ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

TAXONOMIC REVISION, RELATIVE ABUNDANCE, AND ASPECTS OF THE BIOLOGY OF SOME SPECIES OF THE GENUS *GARRA*, HAMILTON 1922 (PISCES: CYPRINIDAE) IN LAKE TANA, ETHIOPIA

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES,

ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF

THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE

IN BIOLOGY

BY

AKEWAKE GEREMEW

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A thesis presented to the School of Graduate Studies,
Addis Ababa University,
In partial fulfillment of the requirement for the Degree of Master of Science in Biology (Fisheries and Aquatic Science)

BY

AKEWAKE GEREMEW

AUGUST 2007

Acknowledgement

This thesis paper would not be complete with out acknowledging the contribution made by a number of people. First, I am very grateful to my research advisors, Drs. Abebe Getahun and Eshete Dejen without whom no last part of this study would get off the ground. Right from its start by suggesting the topic up to providing relevant literatures, and development of thesis write-up, they were absolutely helpful. Especially, Dr. Abebe Getahun was so considerate that he helped me in so many ways including getting additional funds. And of course Dr. Eshete Dejen was very generous in helping me get an easy access to the logistics and other important field matters. In deed, I would be very much indebted to both, for the invaluable contribution they had in this study

My special thanks also goes to the staff members of Bahir Dar Fish and Other Aquatic Life Research Center for making me feel hugely privileged during my 12 month stay there. Especially, I am grateful to Sewmehon Demissie for making the field work easier through her collaboration in the provision of everything for the field. The technical assistants, Biniam and Wondie are highly acknowledged for their fishing efforts and assistance in the tedious lab work. Also the field assistants Gebeyehu, Mulugeta, Hunachew, and the boat drivers Endalamaw, Gebreselassie, and Ayinew, and of course the car driver Habtamu are highly appreciated for the contribution they made during sampling. Belay was such a wonderful friend in my stay in Bahir Dar and I am grateful for his unfailing assistance, especially in the lab and in some part of data analysis (Pasgear). I don't also forget love for birds and their identification he inspired in me. Assefa, Birhan, Mesfin, and Yiftusira were very friendly and fantastic besides their help in the lab work.

My special thanks also go to all members of the JERBE who were in Bahir-Dar in 2006, for their friendly help. Many of them were very helpful in one way or another, but I should mention Dr. Alexander Mironovsky, who spent many hours teaching me on how to collect osteological

morphometric data and discuss the related matter; Dr. Feodor, for helping me in several ways, especially taking the photographs of specimens.

My friend, Mohammed Akmel of Bahir Dar University is highly acknowledged for his encouragement, provision of digital caliper and sampling bottles.

My mother Fatuma Edris and My sister Nebiyat, were the sweetest, I owe you many thanks for your help, support and love during the whole time of my education. Tadesse Taye (Tade), the close friendship “evolved” between us, grown to a brotherhood was more than succeeded. I thank you for everything you have done for me.

I wish to thank also my friends in the Fisheries and Aquatic science stream, especially Zeleke, Lemma and Moges, as they were very helpful in giving comments on this work. We had rewarding interactions for the past three years.

Graduate and Research Program of Addis Ababa University, Systematic Research Fund of American Museum of Natural History and Development Innovation Fund of the Zoological Natural History Museum, AAU through Dr. Abebe Getahun provided financial support. The Amhara Regional Agricultural Research Institute (ARARI) through its wing Bahir-Dar Fish and Other Living Aquatic Research Center provided all finance and logistics for field works.

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List of Abbreviations

AL – Anal fin length

B1 – distance between outer margins of the frontals

B2 – distance between the outer margins of the pterotics

B3 - distance between the outer margins of the sphenotics

BD – Body depth

BL - Basal length of the skull

Cl – Cleithrum

CPD – Caudal peduncle Depth

Cpl – Caudal peduncle length

De – Dentary

DFL – Dorsal fin length

Dw – Disc width

GL – Gut length

HD – Head depth

HL – Head length

Hm - Hyomandibular

HS1 – skull depth at the level of the bend of parasphenoid

HS2 – skull depth at the level of parasphenoid posterior margin

Iop – Interopercle

IOW – Inter orbit width

Mbl – Maxillary barbell length

Mx – Maxilla

OD – Orbit diameter

Op – Opercle

Pecl – Pectoral fin length

PEL – Pelvic fin length

Pha – Pharyngeal bone

Pm - Premaxilla

Pop – Preopercle

Por – Post orbit length

Post gasbladder - Posterior gasbladder length

Prean – Preanal body length

Pred – Predorsal length

Prepec – prepectoral body length

Prepel – Prepelvic body length

Rbl – Rostral barbell length

SNL – Snout length

Vent pos – Vent position

Abstract

Taxonomic revision, relative abundance, reproductive biology, length-weight relation, condition factor and aspects of feeding of Lake Tana *Garra* species were studied from 2187 fish collected during January to December, 2006. Morphological, morphometric and meristic characters were used to revise the taxonomy of the three already described species (*G. tana, G. dembecha* and *G. regressus*) and one different form of *Garra* (small mouth, sm). Cluster and principal component analyses using 23 external and 14 skull bone morphometric measurements revealed that *G. tana* and *G. regressus* are separate dissimilar species from others. *G. dembecha* and *G.* sm showed some similarities, though the few meristic and morphological features were important to differentiate them. The % IRI (Index of Relative Importance) indicated that *G. tana* is abundant in the pelagic sites whereas *G.* sm is abundant in the littoral, and sub littoral sites having the rest of *Garra* species less abundant. Gonado-somatic index (GSI) and % frequency of ripe females were used to determine main breeding season. The main breeding time of *G. regressus* (April-October), *G. tana* (March-July) and *G. dembecha* (May-July) was coincident with the rainy season of the area. *G.* sm was found to breed intensively during the dry season (November-March). *G. tana* is capable of breeding throughout the year, whereas *G. dembecha* breeds only for three months. Extended breeding times were observed in *G.* sm and *G. regressus*. Significant differences were observed between the species for both sexes in the mean size at maturity, except for *G.* sm and *G. dembecha*. Absolute fecundity was found to be related curvilinearly with standard length and linearly with body and gonad weight for *G.* sm, *G. regressus* and *G. tana*. The range of absolute fecundity was (538.9-2968), (606-3397), (1215-1229) and (580.8-1800) for *G. tana*, *G.* sm, *G. dembecha* and *G. regressus*, respectively. The average relative fecundity was 63.3, 77.1, 102.7, and 55.5 for *G. dembecha, G.* sm, *G. tana* and *G. regressus,* respectively. Both relative and absolute fecundity were statistically different ($P< 0.001$) between the species. Egg size frequency distribution revealed that *G. regressus* was found to be multiple spawner, while *G. dembecha; G. tana* and *G.* sm were single spawners. Except for *G. dembecha* and *G. regressus* (Chi-square, $P< 0.05$), the sex ratio in the total catch was not different from 1:1 for the other two species. The relationship between standard length and total weight was curvilinear for all the species, and isometric growth was assumed for all. A significant seasonal fluctuation ($P< 0.0001$) was observed in the condition of all *Garra* species. The better condition of these fishes during late dry and pre-rainy seasons was attributed to the increase in temperature and availability of food. Microscopic examination of gut contents of *G.* sm, *G. tana*

and *G. dembecha* indicated that green, blue-green, diatoms and zooplanktons that are detrital in their origin were dominant.

Key words and phrases: *Condition factor, Food items, Garra, Lake Tana, Length-weight relation, Relative abundance, Reproductive biology, and Taxonomic revision*.

1. INTRODUCTION

In many African countries including Ethiopia human population is increasing considerably with growing nutritional shortage. The diets in such developing countries are not only lacking in quantity, but also in quality of nutrition. Carbohydrates and other bulk foods are often available relatively in abundance, but high protein food is scarce. Selective food production, emphasizing on protein rich foods from cheap sources like fisheries resources, is one possible solution (Holt, 1967). Although Ethiopia has many lakes and streams, which can provide about 51,481 tones of fish per year, the current exploitation is only about 15,389 tones per year (MoA, 2001).

Lake Tana is the largest lake in Ethiopia with a fishery production potential estimated around 15,000 tones (Tesfaye Wudneh, 1998). The lake is situated in the north-western highlands of Ethiopia, 560 km away from Addis Ababa.

Lake Tana contains a fish fauna represented by seven genera, namely *Barbus, Clarias, Garra, Labeobarbus*, *Nemacheilus*, *Oreochromis*, and *Varicorhinus*. The genus *Labeobarbus* which contains 15 hexaploid species of large barbs is regarded as the only known freshwater cyprinid species flock (Nagelkerke, 1997) circumscribed in the same ecosystem. The genus *Barbus* includes three small diploid barbs (Eshete Dejen, 2003), while the genus *Garra* consists of 4 species (Stiassny and Getahun, 2007). The genera *Clarias, Nemacheilus, Oreochromis* and *Varicorhinus* are represented by one species each.

Studies on fishes of Ethiopia in general and that of Lake Tana in particular focused on the description of the diversity, biology, fishery potential of fishes like tilapia, catfish and barbs due to the high commercial value they have. However, studies on small sized fish species which are not currently commercially important never received much attention until Eshete Dejen (2003) studied the biology and fishery potential of small barbs of Lake Tana. Recently, Abebe Getahun (2000)

studied African species of the genus *Garra,* which is another small sized fish, and recognized four species from Lake Tana. *G. tana* (Getahun and Stiassny 2007), *G. regressus* (Getahun and Stiassny 2007), *G. dembecha* (Getahun and Stiassny 2007) and *G. dembeensis* (Rüpell 1836) were described from the lake, in which all except the last were described for the first time and the first two are endemic to the lake. Nagelkerke *et al.* (1994) suggested that it could be a second mini species flock of cyprinids in addition to the *Barbus* species flock. Basically, species flock is regarded as a group of closely related species all circumscribed in the same ecosystem that must have monophyletic origin (Greenwood, 1974). This means that species flocks are results of repeated speciation events from a single ancestral species within a given ecosystem (Kondrashov and Mina, 1986). To fulfill the criteria of species flock in an assemblage, all the members of the flock must have in common shared specialized characters (synapomorphies). However, Abebe Getahun (2000) has doubted the existence of *Garra* species flock based on the phylogenetic tree of *Garra* species in which *G. dembecha* was found to be in a different Sub-clade than the other three sympatric *Garra* species. *G. regressus* was also found to be more closely related to *G. congoensis* (from Zaire) than to the sympatric species of the Lake.

Although some investigations on the karyology of three Ethiopian species (Krysanov and Golubtsov, 1993) and feeding potential based on ecomorphological studies on Lake Tana *Garra* (Driessen, 2002) were reported, no further studies on its biology were conducted. To date, knowledge on distribution, feeding and reproductive strategy is non-existent. It is also not known how many more species of the genus exist in the lake. Abebe Getahun (2000) suggested that there could be more species in this lake than described so far. Therefore, a thorough morphometric analysis of Lake Tana *Garra* species and revision of their taxonomy was needed.

Even though the use of this fish in commercial fisheries has not yet fully developed, there is an indication of its great potential in Lake Tana that it can be used as valuable food fish (Driessen,

2002). Proper management and utilization of this resource requires basic biological knowledge of the fish such as feeding and reproduction. In addition, knowledge of ecological interrelations of the fishes, is crucial for the monitoring and management of the fisheries. Studies in Lake Tana (de Graaf *et al.*, 2000) showed that *Garra* species in the deep part of the lake are among the abundant prey species for large piscivorous barbs especially for those bottom dwelling barbs like *L. gorguarii, L. dainelli* and *L. platydorsus*. Therefore, from ecological point of view the knowledge on the biology of prey species will help for the understanding and proper management of the lake ecosystem.

The aim of the present study is thus, to revise the taxonomy of some species of the genus *Garra* in Lake Tana and to investigate aspects of their biology and abundance in the Bahir Dar gulf of Lake Tana.

General Objective:

- To provide base line biological data useful for rational exploitation, management and conservation of *Garra* stock in Lake Tana.

Specific objectives:

I. To revise the taxonomy of *Garra* species in L. Tana.
II. To investigate the relative abundance of *Garra* species in the different habitats in L. Tana.
III. To study breeding season, size at maturity, fecundity and sex ratio of *Garra* species in L. Tana.
IV. To assess length-weight relationship and condition of *Garra* species in L. Tana.
V. To study the food of *Garra* species in L. Tana.

The results from this study will provide basic information upon which rational exploitation and management of *Garra* fishery can be made.

2. LITERATURE REVIEW

The groups of cyprinid fish species commonly known as stonelapping minnows of the genus *Garra* (Hamilton 1922) are distributed from Borneo, China and Southern Asia through the Middle East, Arabian Peninsula and East Africa to West Africa. To date, close to 78 species have been recognized in the genus (Zhang, 2005), 17 being from Africa (Abebe Getahun, 2000). Most *Garra* species occur in freshwaters, though there appears to be a report on one species from brackish or salt water (*G. tibanica* later synonimized with *G. quadrimaculata*) (Trewavas, 1941). No fossil evidence of *Garra* has so far been found. Although no clear center of origin or route of dispersal for the genus is proposed, a vicariance-dispersal based on recovered phylogeny and the geologic history was suggested by Abebe Getahun (2000). This assumption considers India or coastal Africa as center of origin.

Many authors had catalogued the diversity of the genus on a regional basis until Menon (1964) represented the systematic study of the whole genus. Rüpell in 1836 was the first to describe two species of the genus from Africa. The presence of the genus has been reported from 16 different countries in Africa whose dispersal could be traced back from the coastal areas to the highlands of Ethiopia and to the southern and western parts of Africa (Abebe Getahun, 2000). The Icthyological provinces and sub-provinces in Africa where their presence was reported include Nilo-Sudan, the Upper and Lower Guinea, the Zaire, the Quanza, the East Coast and the Abyssinian provinces.

In Ethiopia where high rates of speciation and diversity is evidenced, their distribution is much pronounced in the north western highland water bodies with Abay and Tekeze basins harboring the highest percentage (75%) of the diversity of the genus (Stiassny and Getahun, 2007). This is consistent with the general pattern of fish species diversity of the country (Abebe Getahun and Stiassny, 1998). *G. aethiopica, G. duobarbis, G. gebaensis, G. ignestii, G. makiensis, G. regressus*,

and *G. tana* were found to be recognized only from Ethiopia. While others *G. blanfordii, G. dembecha, G. dembeensis*, and *G. quadrimaculata* are also found in other African countries.

There is little utility of these fishes in terms of human consumption, which could be due to the small size they have. However, Hora (1956 in Coad, 2006) regarded these fishes as oily fishes, which are eaten in India. Jha, *et al* (2005a) and Jha *et al.* (2005b) mentioned *Garra gotyla gotyla* Gray, 1830 as minor commercial fish. In Ethiopia, Driessen (2002) reported that *Garra* of Lake Tana are used for consumption after sun drying.

Apart from human consumption some species of the genus such as *Garra rufa* Heckel, 1843 also called "doctor fish", were found to have medical importance (in Ichthyotherapy) in which they feed on plaques of skin diseases and have therapeutic effect on the skin disease (Bardakci, *et al.*, 2000). Others like *G. ceylonensis* (Sundrabaranthy *et al.*, 2005) *G. pingi pingi* (Anon, 2007) and *G. cambodgiensis* (Pornsopin *et al*., 2004) are among the recent additions to the aquarium fish trade.

The common food items present in the gut of *Garra* include filamentous algae, diatoms, and detritus (Coad, 2006). These fishes feed on algae, plants, and detritus by scraping from rocks. Driessen (2002) tried to show the potential diet of three lacustrine and one riverine *Garra* of Lake Tana basin. Roberts (1990) also reported *G. allostoma* of Niger basin as an insectivorous species and some other unidentified *Garra* species as plant matter feeder. Most disc-bearing groups of cyprinids, to which *Garra* is a member, have in common a diet which consists of diatoms, filamentous algae and organic detritus (Zhang, 2005). Abebe Getahun (2000) suggested the feeding habit of *Garra* based on their gut length as omnivores (Gut Length, GL 2-3 standard Length, SL), herbivores (GL 3-4 SL) and carnivores (GL 1-2 SL).

In their reproductive habits *Garra* resemble other related cyprinids such as *Labeo* sp. and *Barbus* sp. (De Silva, 1991). Abebe Getahun (2000) remarked that the absence of sexual dimorphism is evident from the African species. In addition, Krysanov and Golubtsov (1993) noted the absence of sexual

dimorphism within karyotypes of three African species (*G. dembeensis, G. makiensis and G. quadrimaculata*). On the contrary, Coad (2006) reported the presence of sexual dimorphism in the Iranian species on the basis of presence of prominent tuberculation in males.

A study on one stream dwelling fish (*G. ceylonensis*) indicated that the fecundity range was found to be between (740-4390), while the mean diameter of ripe eggs measured was 1.27 mm (De Silva, 1991). Furthermore, the report showed the absence of nest building and parental care for such species.

3. Materials and Methods

3.1 Study Area

Lake Tana (12^0 N; 37^0 21' E- approximate center of the Lake) is Ethiopia's largest lake (3150 km^2 or 50% of the lakes area in Ethiopia) (Table 1). It is formed by volcanic blocking of the Blue Nile and is situated in the Northwestern highlands, 560 km north of Addis Ababa, at an altitude of 1830 m (Nagelkerke *et al*., 1994). It is a shallow, oligo-mesotrophic lake fed by seven big perennial rivers: Gilgel Abay (little Blue Nile; the largest), Gelda, Gumara, Rib, Arno-Garno, Megech and Dirma rivers (Fig. 2) with Blue Nile being its only outflow. The age of this lake after its formation is estimated to be some two million years (Mohr, 1962). According to Chorowicz *et al*. (1998), the present form of the lake is due to damming by a 50 km long Quaternary basalt flow, which filled the exit channel of the Blue Nile River. The Lake Tana basin is isolated from the lower parts of the Nile basin by a 40 m high waterfall 30 km downstream from the Blue Nile out flow. The waterfall interestingly not only isolated the Lake Tana basin from the lower Blue Nile basin but also isolated the ichthyofauna. The Lake Tana basin of a catchment area of 16,500 km^2 has a dendritic type of drainage network (Eshete Dejen, 2003).

Table 1. Some physical and chemical characteristics of Lake Tana (From Eshete Dejen, 2003).

Characteristics	Value
Altitude	1830 m
Surface area	3150 km^2
Maximum depth	14 m
Average depth	8.9 m
Conductivity ($\mu S\ cm^{-1}$)	115-147.9
Total dissolved solids ($mg\ l^{-1}$)	148.4-178.1
Temperature (^0C)	20.2-26.9
Turbidity (NTU)	20.2-26.9
pH	6.8-8.3
Chl-a ($\mu g\ l^{-1}$)	3.4-12.9
Oxygen ($mg\ l^{-1}$)	5.9-7.3

The surrounding climatic condition of the lake is characterized by tropical highland climate, with moderate temperature. The major rainy period in the area is between June and October, with peak in August (Eshete Dejen, 2003), although exceptionally minor rainy seasons occur during February and March. The climatic condition is mainly dominated by the dry season (November to May). During the present one year study November to April were considered as dry, although little rains occurred in December, January and April (Fig.1). During the study period the water level of the lake began to rise with the beginning of heavy rains, and it was high between July and October, but low between April and June (Personal observation). The water temperature (2006 data) is moderately warm with a mean of above 20 ^0C all year round.

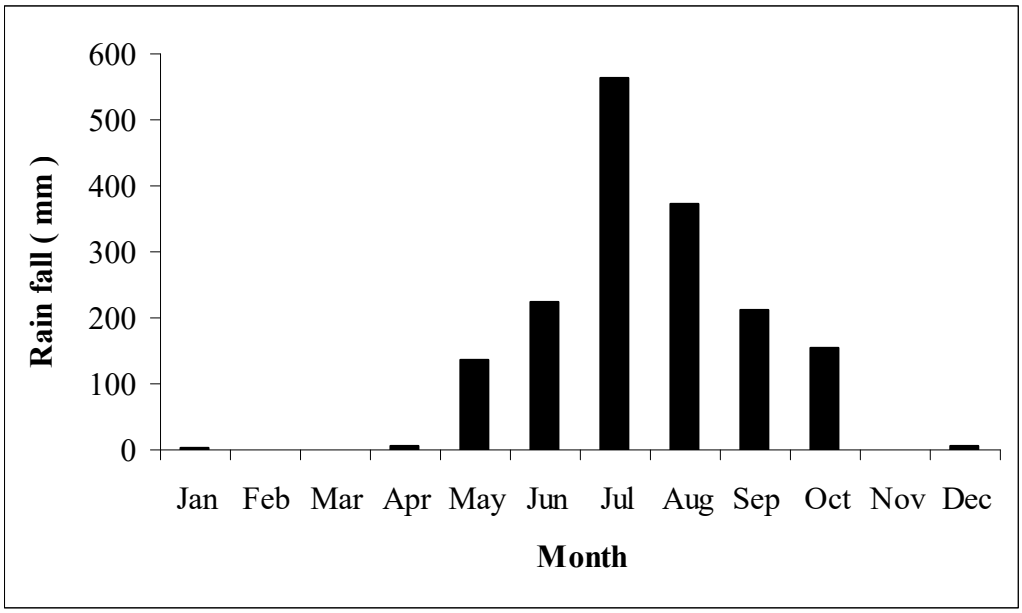


Figure 1. Rainfall (mm) pattern of L. Tana (Bahir-Dar) area for the period January to December 2006 (Data from Ethiopian National Meteorological Agency).

Data from the National Meteorological Agency of Ethiopia show that the mean maximum air temperature was above 23 ^{0}C whereas the mean minimum temperature was below 15 ^{0}C (Fig. 2). Differences between mean maximum and mean minimum air temperature were small during the rainy season. February to April were the hottest months of the year.

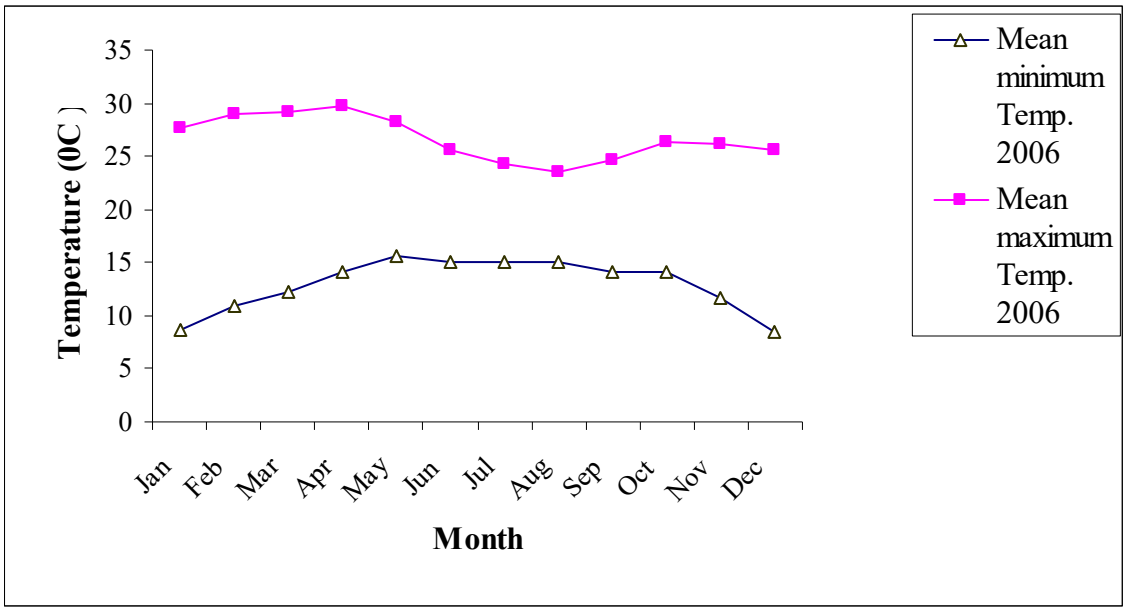


Figure 2. Seasonal variation in mean maximum and minimum air temperature (^{0}C) of L. Tana (Bahir-Dar) area from January to December 2006 (Data from Ethiopian National Meteorological Agency).

Studies on the limnological and phytoplankton aspects of the lake have been made by different authors (eg. Wood and Talling, 1988; Gasse, 1987 in Nagelkerke, 1997; Eshete Dejen, 2003; Ayalew Wondie, 2006). The water chemistry of the lake shows that cations calcium, magnesium, sodium and potassium and anions bicarbonate and carbonate are dominant (Ayalew Wondie, 2006). The most dominant phytoplankton genera of the lake include diatoms *Aulacoseira* sp., *Surirella* sp. and *Synedra* sp. and also the blue-green algae *Microsystis* and *Anabaena* sp. (Wood and Talling, 1988; Ayalew Wondie, 2006). The green algae (chlorophyta), which consists of *Ankistrodesmus*, *Pediastrum*, *Staurastrum*, and *Volvox* are common but less abundant (Gasse, 1987 in Nagelkerke, 1997; Ayalew Wondie, 2006).

The dominant macrophytes include *Typha* sp., *Phragmites* sp., *Cypres* sp., *Scirpus* sp., *Paspalidium* and *Nymphea* sp., which can provide spawning and nursery grounds for fishes (Zenebe Tadesse, 1997).

The zooplankton species found in the lake constitute 13 species (Eshete Dejen *et al*., 2004; Ayalew Wondie, 2006), three copepods, eight cladocerans and two rotifer species (after recent revision by Ayalew Wondie, 2006). The calanoid copepod, *Thermodiaptomous galebi lacustris*, endemic to Lake Tana, dominates the zooplankton community. Of the cyclopoid copepod species, *Thermocyclops ethiopiensis* was the most abundant (Ayalew Wondie, 2006). Generally, the zooplankton community of Lake Tana is regarded as unusual for a tropical lake to have higher proportions of temperate species (i.e. *Daphnia hyalina*, *Ceriodaphnia dubia*) (Eshete Dejen, 2003). This was attributed to be due to the high altitude effect which makes water temperature low for a tropical lake like L. Tana.

Lake Tana fish community, after the latest revision of *Barbus* (Nagelkerke and Sibbing, 2000), is considered as species rich unlike previous reports by Greenwood (1976). The families Balitoridae, Cichlidae and Claridae, are represented by one species each: *Nemacheilus abyssinicus*, *Oreochromis niloticus tana* and *Clarias gariepinus*, respectively. But the largest fish family in the lake is the Cyprinidae, represented by four genera: *Barbus, Garra, Labeobarbus* and *Varicorhinus* (de Graaf, 2003). The genus *Varicorhinus* has only one species in the lake, *V. beso*. The genus *Garra* comprises at least four species which were recently described by Abebe Getahun (2000): *G. tana, G. regressus* (The previous name, *G. microstoma* changed after recent revision in Stiassny and Getahun (2007)), *G. dembecha*, and *G. dembeensis*. The genus *Barbus* in Lake Tana is currently valid for three diploid small barb species: *B. humilis, B. pleurogramma,* and *B. tanapelagius* (Eshete Dejen, 2003). The genus *Labeobarbus*, known as "large barbs" comprises 15 endemic species (Nagelkerke

and Sibbing, 2000), forming the only intact freshwater species flock of large cyprinids known in the world.

Gastropods are common in the littoral habitats and include endemic sub-species *Bellamaya unicolor abyssinica* and *Bulinus* species which are hosts to *Schistosoma haematobium* that causes Bilharzia. Reptiles found include Nile monitor (*Varanus niloticus*), and a python (*Python sebae*). The most common and diverse vertebrate groups in Lake Tana are birds (Pers. Obs.). Piscivorous species include residents such as Little grebe (*Tachybaptus ruficollis*), Great white pelican (*Pelecanus onocrotalus*), Great and Long-tailed cormorants (*Phalacrocorax carbo*, and *P. africanus*), Darter (*Anhinga rufa*), many species of heron, Hammerkop and African fish eagle. Egyptian goose, Spar-winged goose and Pygmy goose are the most conspicuous non-piscivorous aquatic birds. Palearctic migrants to the lake are: Osprey, Great black-headed, Lesser black-headed and Herring gulls, and Whiskered and White-winged black terns (Nagelkerke, 1997). The only mammal observed was Hippopotamus.

3.2. Sampling and measurements

The part of the lake, which this study was conducted mainly comprises the gulf, although four occasional samplings were conducted in the northern part of the Lake at Gorgora site and from the river mouths of Dirma and Megech rivers to check the presence *G. dembeensis*. A few specimens of *Garra* species were also collected from the major feeding rivers of the lake and from their tributaries whenever possible. Basically, the gulf of Lake Tana is a part of the Lake where most studies on fishes were conducted apart to its being an area with highest fish exploitation (Tesfaye Wudneh, 1998).

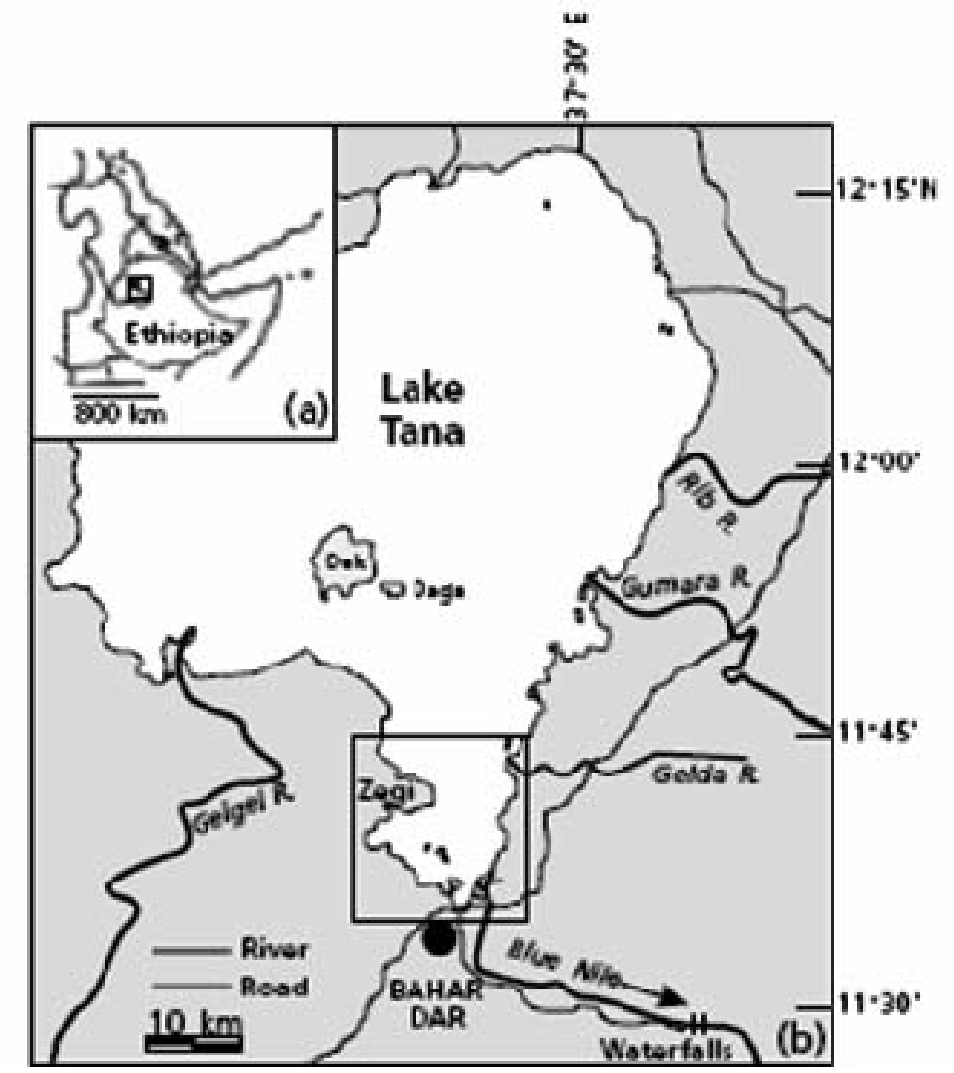


Figure 3. a.) Map of Ethiopia and **b.)** Lake Tana with its major tributary rivers and the out flowing Blue Nile River (Modified after de Graaf, 2003).

Table 2. Description of sampling stations

Stations	Local name	Depth (m)	Sechi-depth range (cm)	Coordinates Lat.	Long.
Littoral 1	Gerima	1.5-3.5	35-100	11^0 36’	37^0 23’
Littoral 2	Air port	1.5-3.8	37-100	11^0 37’	37^0 20’
Sub littoral 1	Debre Mariam	4-7.3	30-60	11^0 37’	37^0 24’
Sub littoral 2	Bahita	4-7.6	30-53	11^0 37’	37^0 21’
Pelagic 1	Kentefami	8-10	30-65	11^0 38’	37^0 23’
Pelagic 2	Kibran-Zegie	8-10	35-70	11^0 39’	37^0 21’

The study was conducted in the southern gulf of Lake Tana in three macro habitats: littoral, sub littoral and pelagic with depths of (0-4 m), (4-8 m) and (8-10 m) respectively (Table 2). From these three macro habitats six sampling stations (Fig. 4) were selected (two stations for each macro habitat).

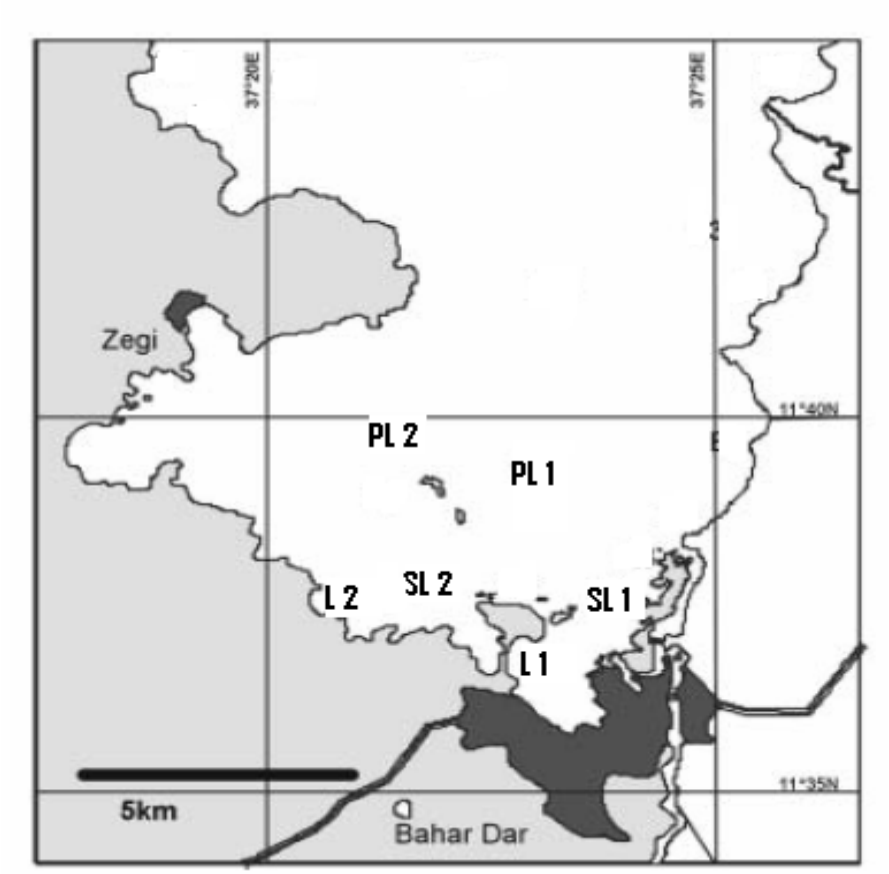


Figure 4. Sampling stations in the Bahir Dar gulf of Lake Tana with three macro-habitats, Littoral (L1 and L2), Sub-littoral (SL 1 and SL 2) and pelagic (PL 1 and PL 2), selected for sampling (Modified after Eshete Dejen, 2003).

Monthly samples were obtained using monofilament gill nets type 'NORDEN' (Lundgrens Company Sweden) of mesh sizes 4, 6, 10, 14 and 15.5 mm bar mesh. Panel length and depth were 12 m and 1.5 m respectively for each net. These were combined with one multi-mesh monofilament gill net of the same type (5, 6.25, 8, 10 and 12.5 mm bar mesh) with 3 x 1.5 m size for single mesh panel. Then the six gill nets were combined as one set.

After capture, fresh fish were measured. Information recorded for each specimen included measurements for standard length to the nearest 0.01 mm, total weight and gonad weight to the

nearest 0.1g. The sex of each specimen was recorded and stage of gonad development was determined.

Measurements of temperature, conductivity, pH, and dissolved oxygen were taken with a portable probe for each sampling occasion. In addition, water transparency (secchi depth) and depth were measured for each sampling time and stations.

3.3. Species identification and measurements for taxonomy

Identification of species was based on the description and key given in Abebe Getahun (2000). Based on these descriptions, differences among *Garra* of Lake Tana, where four forms of *Garra* were reported to be different were treated separately in this study.

External morphological data, morphometric measurements and meristic counts were determined from 40 specimens (10 individuals from each species). Counts and proportional measurements were conducted as in Abebe Getahun (2000) with the addition of the following measurements as given in Zhang and Chen (2002); prepectoral, prepelvic and preanal length. These lengths are the body lengths taken from the snout tip to the origin of pectoral, pelvic and anal fins, respectively. Osteological morphometric data were taken using the methods described in Mina *et al*. (1996). Therefore, cranial bone measurements such as BL, B1, B2, B3, HS1, HS2, Hm, Pm, Pop, Op, Iop, Mx, De, Pha and Cl were taken. Measurements were made using an electronic digital caliper to the nearest 0.01mm.

Sub units of the head are presented as a percentage of head length except for rostral barbel and maxillary barbel lengths which are given as percentages of orbit diameter. Measurement values for gut length expressed in percentages show the measure of standard length as a percentage of gut length. The remaining measurements of body parts including head length are given as a percentage

of the standard length. A total of 23 external morphometric variables were measured and used for Cluster analysis and PCA (Principal Component Analysis). All measurements and counts were made on the left side of fresh specimens. Regarding the bone measurements, all character measurements were stated as a percentage of BL and then the data was log transformed for PCA. Cluster analysis was performed on the ratio-converted measurements with the data set containing no missing values. Euclidean distance between specimens was calculated, and used for cluster analysis by the unweighted pair-group method, using the arithmetic average (UPGMA: Rohlf, 1993). Cluster analysis was done with NTSYS software version 1.80, while the principal component analysis (PCA) was performed on the log-transformed measurements using PAST of version 1.71.

To ease the comparison among species using morphometric ratios and to minimize the impact of ontogenetic and allometric differences adult fishes of narrow size ranges were used.

3. 4. Determination of Relative Abundance

Index of Relative Importance (% IRI) was used to evaluate the relative abundance of *Garra* species at different sampling sites using software "Pasgear 2".

3. 5. Breeding season, sexual maturity, fecundity, egg size determination and sex ratio

Breeding season of *Garra* species was determined from monthly frequency of female fish with ripe gonads (stage IV) and gonadosomatic index (GSI). A five-stage gonad maturity scale for each *Garra* species was determined as in Weyl and Booth (1999) with some modifications (Table 3). GSI was calculated as gonad weight as a percentage of total body weight. The percentage frequency of breeding female fish with ripe gonads and GSI were then plotted by month. The time of the year

when the GSI and frequency were at higher level was considered as the peak breeding season of the fish.

Average size at first sexual maturity ($L_{50\%}$), at which 50% of the fish mature, was determined using the software package called "pasgear 2" (a data base package for experimental or artisanal fishery data from passive gears) for both sexes. Sexual maturity stages in stage III were considered as mature. The percentage of mature fish per length class was calculated and SL_{50} was estimated by fitting a logistic model according to Gunderson *et al.* (1980).

$$P_m = \frac{1}{1 + e^{(-aL+b)}} \cdot 100$$ Where,

P*m* is percent mature (=%Mature) at length L, and a and b are fitted constants.

The relationship between the percentage of mature fish (P_m) per length class and fish length (Standard Length, SL in mm) was described with a logistic curve: a, intercept and b, slope of the curve. From the sigmoid curve $SL_{50\%} = -a/b$ was determined

$$\frac{\ln p_m}{(1-Pm)} = a + bSL_i$$

Table 3. Macroscopic description of various gonadal stages in Lake Tana *Garra* (Modified from Weyl and Booth (1999)).

Stage	Macroscopic appearance
I	Not possible to visibly distinguish sex. Gonad as appears a translucent gelatinous strip.
II	Sex distinguishable. Ovary small band of orange red tissue. Testis discernible as a thin straight band.
III	Ovary increases in size, is flattened dorsoventrally and is orange-red in color. Oocytes visible. Testis increases in size and starts to form lobes and is white in color. Sperm is not extrudable.
IV	Ovary turgid with oocytes and fills the entire abdominal cavity. Oocytes are olive-green to brown in color and loosely attached to ovigerous lamellae. Testis creamy white, showing constrictions. Sperm can be extruded.
V	Ovary flaccid and sac like with few vitellogenic oocytes visible. Testis reduced in size and dirty grey in color.

Fishes in ripe stages were considered for the determination of fecundity and egg size. Fecundity estimation was carried out using the gravimetric method (Bagenal and Braum, 1978) by weighing all the eggs in each of the ovaries from gravid fish species (gonad maturity stage IV ovaries). Samples of eggs were taken from different size classes of fish species on various ovary areas. These eggs were preserved using modified Gilson's fluid (prepared from 100 ml ethanol, 800 ml water, 15 ml HNO_3, 18 ml glacial acetic acid and 20 g mercuric chloride). The ovarian membranes were first

removed mechanically from the preserved ovaries, to count the eggs and to measure ova diameter. After vigorous shaking, two sub samples of 0.5 g of eggs per ovary were counted and the total number of eggs per ovary was estimated by extrapolation. For random measurement of ova diameter, every 0.5 g of eggs counted was poured into a grided Petri dish. The water from the Petri dish was carefully but completely removed without disturbing the egg distribution in the dish. Only those eggs, which touched the grid lines, having a diameter ≥0.75 mm, were measured to the nearest 0.01 mm using an ocular micrometer in a dissecting microscope. Least squares regression was used to find relations between fecundity and standard length, total weight and gonad weight as in Zenebe Tadesse (1997).

Sex ratio (female to male) for each fish species were determined and were tested using Chi-square to determine if it varied from one to one in the total sample as well as seasonally.

3. 6. Length-weight relationship and condition factor

Length-weight relationship for each species was computed using least squares regression analysis (Bagenal and Tesch, 1978): Log TW=Log a +b Log SL, log a, is the intercept and b is the slope of the regression line. Condition factor (well-being) of each fish species were determined by computing Fulton's condition factor as in Bagenal and Tesch (1978), i.e.

$K = \frac{TW100}{SL^3}$ where, K= Fulton condition Factor, TW= Total Weight, SL= Standard Length

Significances of differences in condition factor for each species between sexes, sampling periods and size groups were tested using ANOVA.

3. 7. Feeding Aspects

To study the food items found in the guts of *Garra*, gut was completely removed from the fish and preserved in 4% formalin solution. The compositions of the three evenly divided parts of the gut were determined and get converted into the composition of the whole gut. As digestion was the main problem in determining the items in the gut, gut samples were taken immediately after catch and a thorough identification in the first part of the gut was made. Identification of the gut contents was made using a microscope at high magnifications (100X to 400X) to the lowest possible taxa using descriptions from several sources (e.g. Prescott, 1970; Blomqvist, 1981; Defaye, 1988; Komarek, 1989 and Ayalew Wondie, 2006). Then the relative importance of the food items was determined using one of the numerical methods of analysis- percentage frequency of occurrence (Windell and Bowen, 1978). First, the number of guts in which each of the food items occurred were recorded and the percentage of this were calculated relative to the total number of guts containing food. Then, the proportion of fish in the population ingesting a particular food item was estimated.

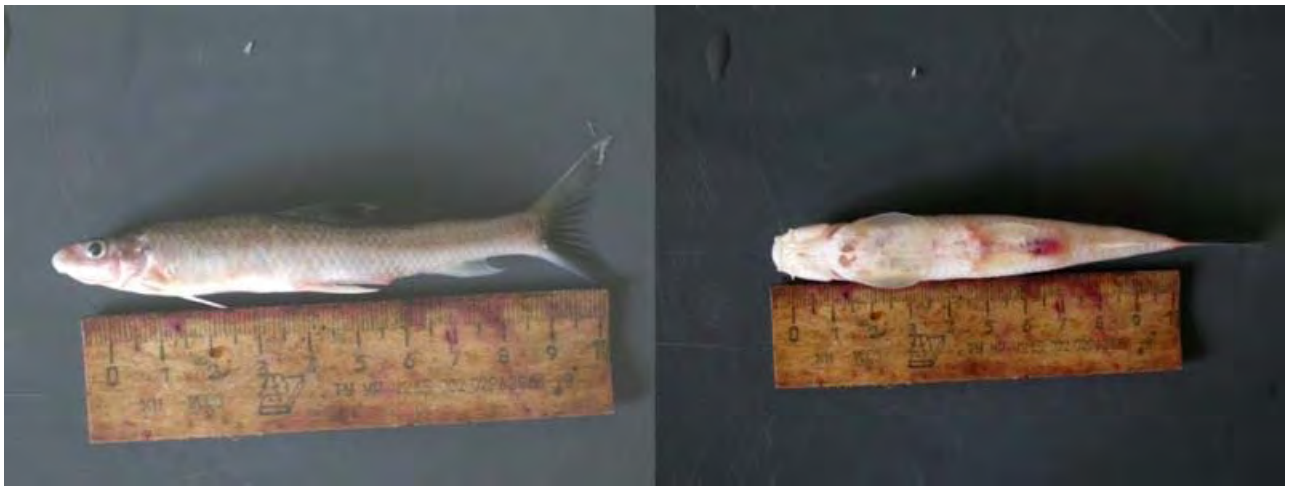
4. Results

4.1. Identification, taxonomic analysis and relative abundance

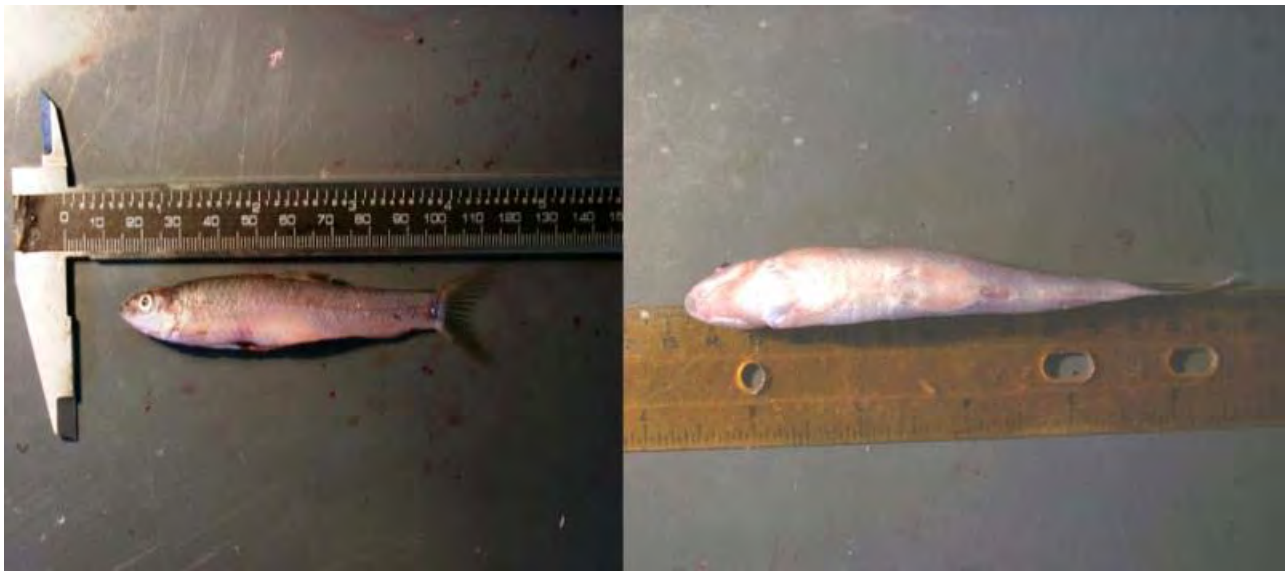
A total of 2187 fishes were caught from the six sampling stations in the lake during January to December 2006. Three species of (*G. tana, G. regressus* and *G. dembecha*) and one different form of *Garra* were considered in this study.

G. tana was distinct and morphologically identified by its brighter creamy white color, wider mouth, narrow and elongated caudal peduncle, and thick and long barbels (Fig. 5). *G. regressus* was identified by its external morphological features such as pointed head, very small mouth with exposed upper jaw, but internally by its very small gut length (Fig. 5). Although both *G. tana* and *G. regressus* were regarded as species with short gut length, the length of the gut for *G. regressus* is relatively much shorter (see Appendix I). *G. dembecha* was identified by its deeper body, short and deep caudal peduncle, darker dorsal and ventral body, and by its very long gut. Despite these identification means to differentiate the *Garra* species, one form of *Garra* was found out to be different from the above mentioned species. So based on the above descriptions and differences observed among L. Tana *Garra* the four forms were treated separately for taxonomic analysis. Furthermore, the position of the new suspected form of *Garra* (Fig. 6) was determined from morphological, meristic, morphometric and other biological characters compared with the other *Garra* species of Lake Tana. Therefore, in this study the one suspected to be new form of *Garra* is designated as 'Small mouth *Garra'* or 'Sm' for convenience.

A.) *Garra dembecha*



B.) *Garra tana*



C.) *Garra regressus*

Figure 5. *Garra* species of L. Tana side and ventral views A.) *Garra dembecha* B.) *Garra tana* C.) *Garra regressus*

4. 1. 1. Taxonomic description of *Garra* sm

G. sm (Fig. 6)

Diagnosis

Garra sm is distinguished from the species of *Garra* in L. Tana by the following combination of characters: yellowish fatty peritoneum (Vs. simply dark in *G. dembecha*), olive to dark greenish dorsal, reddish or yellowish fins (Vs. dark in *G. dembecha*), smaller mouth with undeveloped disc, silvery white or sometimes yellowish white belly (Vs. darker in *G. dembecha*). It has got longer gut (SL 19.9 to 32.5 % GL) than other L. Tana *Garra* (36.68 to 61.89 % in *G. tana*, 59.14 to 78.77% in *G. regressus*) except *G. dembecha* which has much longer gut length (SL 11.5 to 16.7 % GL). 40-41 lateral line scales (Vs. 38-39 in *G. regressus*).

Description

Morphometric and meristic data taken from 10 specimens (94.04-109.66 mm SL) are given in Appendix I. Body elongate, relatively cylindrical anteriorly, dorsal profile slightly convex. Relatively pointed head with weakly flattened dorsum without tubercles on snout. Orbit positioned medially on head. Disc is weakly developed (Type A). Has narrow mouth with well developed rostral cap covering the upper jaw. Two pairs of barbels with rostral barbels longer than maxillary barbels. 40 to 41 lateral line scales. Chest is naked, whereas belly and post pelvic regions are scaled, with some of the belly scales embedded beneath skin.

Dorsal fin having III, seven rays inserted well in advance of pelvic fin; 5.5 scales from lateral line to dorsal fin origin. Pectoral fin has II or III, twelve rays with mildly blunt tips, a length of 15.69-19.19 % SL, and not reaching half way to pelvic fin origin. Pelvic fin pointed, not reaching the anus, shorter than head length and with II, seven or eight rays. Anal fin: origin equidistant between pelvic fin origin and caudal fin base. Vent distant from anal fin (Vent distance 24.2-33.59 %). Caudal fin deeply forked, longest ray greater than twice as long as shortest ray. Gut is moderately long (SL 19.93 to 32.57 % GL). Bilobbed gas bladder has large posterior chamber (23.71-27.4 % SL). Vertebrae 39-40. Pharyngeal teeth in three rows, tooth pattern 2, 3, 5-5, 3, 2.

Figure 6. Side and ventral views of *Garra* sm.

Color pattern

In fresh specimens: dorsal appearance looks dark or dark brown, lighter or even white ventrally and below the lateral line scale row than above. There are prominent black spots at the base of the dorsal fin usually after the fourth ray. Orange, red or dark pigments on both sides of the base of the

operculum. Fins are whitish, yellowish orange or brownish. Sometimes slightly darker pectorals. Dorsal fin membrane darker distally with creamy yellow color.

Coloration in preserved specimens: dorsally brownish up to the lateral line scales, but lighter yellowish or orange below the lateral line and ventrally. A short distinct dark bar spans at the base of the caudal peduncle. Dorsum of head, snout, and most of opercle: dark brown. Lips, barbels, cheeck, the adhesive disc areas, anterior and posterior parts of the orbit, and the opercle membranes are creamy yellow brown. Small black spot just behind opercle, at the first lateral line scale region. Dorsal fin membrane pale cream throughout or sometimes slightly darker distally.

Distribution and habitat

Known only from L. Tana (but not in the feeding rivers). Specimens were collected in both the Southern and Northern part of L. Tana mostly in the littoral and sub littoral areas; however it was also found in the pelagic parts of the lake.

4. 1. 2. Taxonomic analysis

Differences between the mean character values of the four *Garra* forms tested for statistical significance using a Mann-Whitney U-test for two samples is shown in Appendix I.

Among the four *Garra* forms, the morphology of *G. tana* and *G. regressus* (23 parameter values) are most distinct, indicated by the homogeneous clustering of specimens of the two species. The resulting dendrogram is shown in Fig. 7.

Garra sm and *Garra dembecha* also formed a separate homogeneous cluster, but there seems to be a close resemblance in body shape with each other than with the other *Garra* species. However, morphologically they are very distinct by their coloration, which is not included in the cluster analysis (Appendix I).

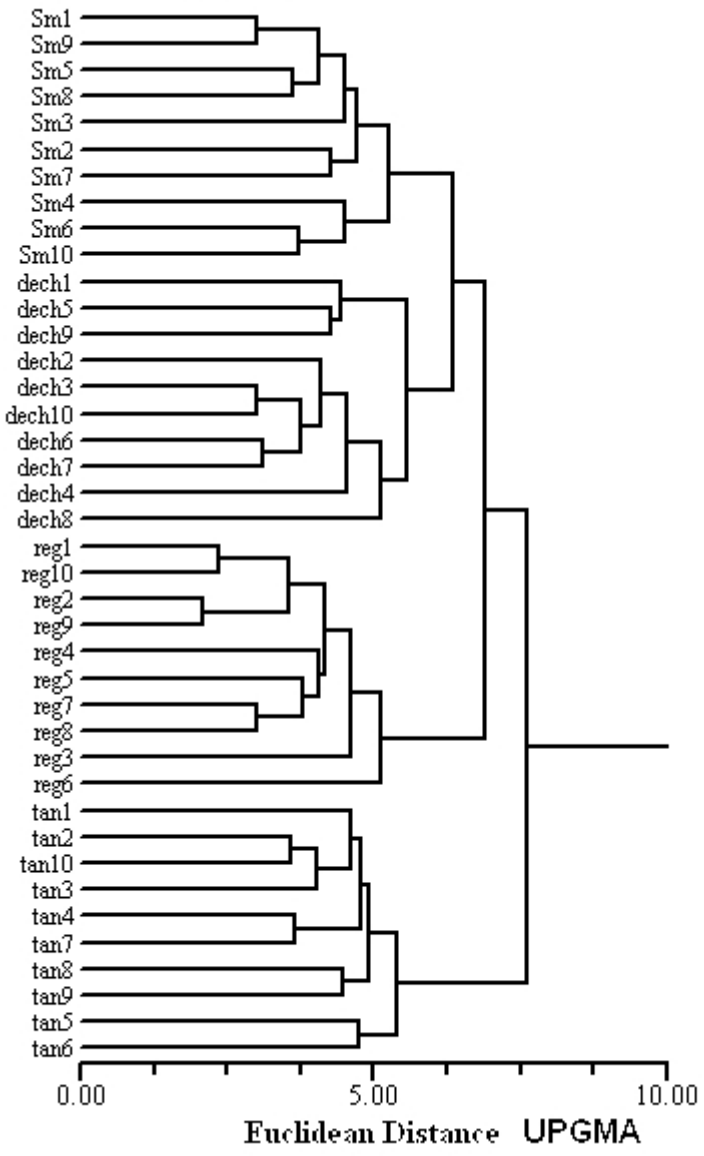


Figure 7. Dendrogram of 40 specimens of the four *Garra* forms, clustered by the unweighted pair-group method, using the arithmetic average (UPGMA: Rohlf 1993). The 23 parameters used are listed in Appendix I. Note that *Garra tana* (tan) and *Garra* regressus (reg) cluster as separate groups with high bootstrap-values, whereas *Garra* sm (sm) and *Garra dembecha* (dech) formed separate cluster groups with low bootstrap-values. Numbers specify the specimens.

The 23 morphometric characters used in the cluster analysis were used in the principal component analysis based on log-transformed data using variance-covariance matrix (Appendix V). PC2 clearly separated specimens of *G. regressus* and *G. tana* from all other species. Though *G.* sm and *G. dembecha* were not separated on this axis, no mix up of specimens was observed.

To verify the importance of different characters in differentiating the four forms of *Garra*, 7 out of the total 23 external morphometric characters namely OD; DW, GL, Rbl, Mbl, posterior gasbladder, and Prepec were found to be indisputably useful in this set of 40 specimens. This was because the characters have higher loadings on the three components of the PCA (Appendix V). These three components accounted 63.4 % of the total variation. It seems that more characters are needed to distinguish *G. dembecha* and *G.* sm, though they formed separate homogenous cluster (Fig. 7). Separately loading the log-transformed values of morphometric measurements of *G.* sm and *G. dembecha* on a PCA scatterplot gave rise to such characters as Mbl, Rbl, OD, and above all GL as most important characters to differentiate the two forms of *Garra*.

The specimens used in PCA of 14 cranial bone characters (Fig. 8) had BL> 15.73 mm which corresponds with SL> 93.18 mm. The main loadings of PC2 (Principal Component 2) were those of the Jaw characters (Pm, Mx, De) and of B1 (Appendix III). This components account for 25.6 % of the total variation. Principal component 2 (PC2), the main shape axis in the analysis, discriminated *G. regressus* and *G. tana*. However, specimens of *G. dembecha* and *G.* sm showed some overlaps.

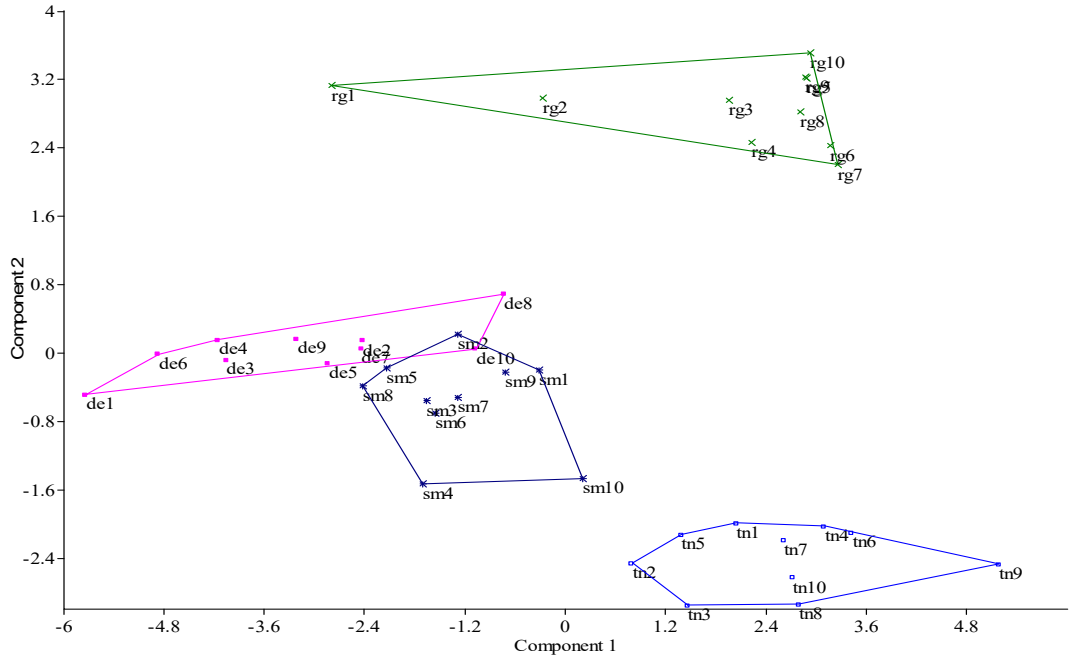


Figure 8. Scatterplot of 40 specimens of the four *Garra* forms based on cranial bone characters on principal component analysis (PCA) using correlation matrix. The specimens are designated as *Garra tana* (tn), *Garra* sm (sm), *Garra regressus* (rg) and *Garra dembecha* (de). Numbers specify the specimens.

4. 1. 3. Taxonomic remarks on *Garra* species of L. Tana

Garra sm differs from other co-existing species in that, it has small mouth (with upper lip covered with rostral cap) and pointed head, but it is different from *G. regressus* in that *G. regressus* has got a very pointed head, very smaller mouth with exposed upper lip and prominent dark predorsal hunch. This species has some what slender body as compared to *G. dembecha* and *G. regressus*, but it is not as slender as *G. tana* and its mouth is not as wide as *G. tana*. It differs from *G. tana* by its color in that *G. tana* is creamy white. But this species is dorsally dark greenish and ventrally brighter starting from below the lateral line. So there exists a distinct color difference below and above the lateral line. It has got also a longer gut than *G. tana* and *G. regressus*. It is different from *G. dembecha* in

that its body is not short and deep, unlike *G. dembecha*. In terms of coloration *G. dembecha* has got darker color and this coloration continues to be indistinct below and above the lateral line. *G. dembecha* is darker ventrally than any one of the Lake Tana *Garra* mentioned above including the new form of *Garra* suspected to be different. There are also belly and post pelvic scales in *G. dembecha* (Fig. 5) which is different from the specimens examined by Stiassny and Getahun (2007). The presence or absence of belly and post pelvic scales as well as higher lateral line scale counts (39-40, versus 37 or 38 in Stiassny and Getahun (2007)) is quite questionable as far as the comparison made between riverine samples of *G. dembecha* in this study is concerned (Appendix II). However, the descriptions given in Stiassny and Getahun (2007) for *G. regressus* and *G. tana* remain in agreement with the present study.

4. 1. 4. Relative abundance and distribution

The species composition of the gillnet catches ranked based on the index of relative importance (% IRI) for different sampling sites is given in Table 4. *G. tana* in the pelagic sites were dominant while the other species have minor contribution in this habitat. It was entirely absent from one of the littoral site and at same time very little contribution was found in the other littoral sites. On the other hand, *G. dembecha* and *Garra* sm were abundant in the littoral sites and then sub littoral sites. The % IRI indicates that the abundance of *G. regressus* was highly appreciated in the sub littoral sites, while it has a very small IRI in the pelagic and littoral sites. The % IRI by species using pooled data indicated that *G.* sm was the most abundant due to the higher values in the littoral and sub littoral sites (Appendix VI)

Except *G. dembecha*, all the lacustrine *Garra* of Lake Tana were absent from the feeding rivers of the lake (Appendix II).

Table 4. The index of relative importance (% **IRI**) for *Garra* species from the six sampling sites in the Gulf of L. Tana calculated using the software "pasgear 2."

	littoral		*sub littoral*		*pelagic*	
Species	***Gerima***	***Air port***	***Bahita***	***D/mariam***	***Entonse/kib.***	***Kibran/Zeg.***
G. dembecha	48.42	11.09	10.65	13.78	0.59	4.74
G. regressus	0.14	3.35	12.89	11.55	1.99	1.96
G. sm	51.42	84.73	60.61	54.90	5.25	7.03
G. tana	0	0.81	15.83	19.76	92.15	90.53

4. 2. Reproductive Biology

No noticeable sexual dimorphism was observed in any of the Lake Tana *Garra* species, except that breeding males of *G. dembecha* had prominent tuberculation at the tip of their snout. This tuberculation was observed only in the breeding months, typically in males but not in females.

4. 2. 1. Breeding season and area

Seasonal variation in the female Gonadosomatic Index (GSI) was evident for *G. tana*. The mean monthly GSI value ranged from 6.59 to 17.94. GSI for this species varied highly significantly between sampling periods (ANOVA, $F= 4.59$, $P< 0.0001$). Higher GSI values were recorded between March and June (Fig. 9A). After June the GSI values progressively dropped and lower values were recorded during January and November. The cycle in GSI was also reflected in the monthly variation in the frequency of females with ripe ovaries (Fig. 10A). Although, female *G. tana* in breeding conditions were caught through out the whole sampling occasion, considerable proportions were found during March to July.

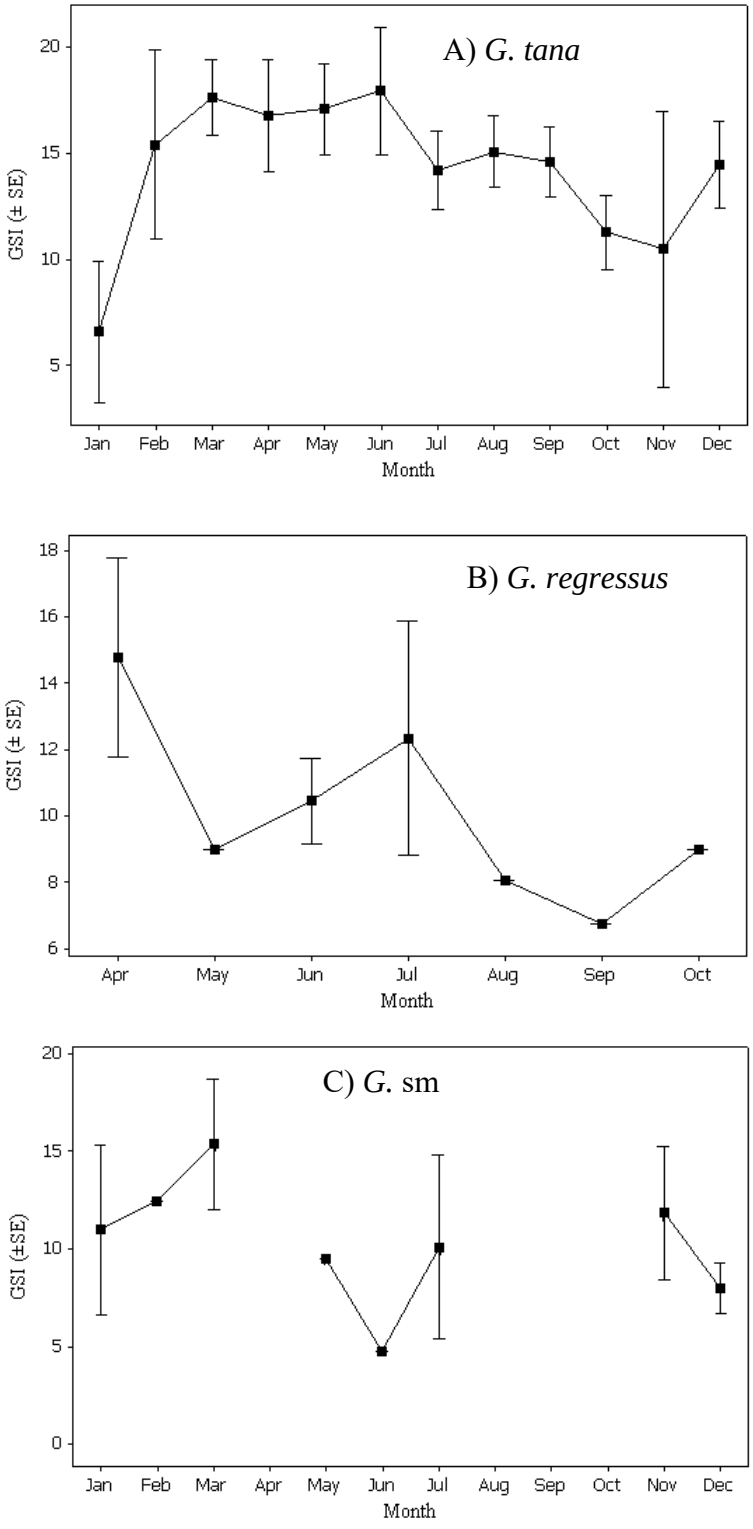


Figure 9. Temporal variation in gonadosomatic index (GSI ±SE) of A.) *Garra tana,* B.) *G. regressus* and C.) *G.* sm from L. Tana determined for females.

Although there was highly insignificant variation in the mean monthly GSI values of female *G. regressus* (ANOVA, F=0.51, P > 0.05), the mean value ranged from 6.76 to 15.48 during April to October. Breeding in this species takes place during the rainy season as seen in Fig. 9B and Fig. 10B, but the initiation of its breeding activity seems to be closely tied to the beginning of the rainy season.

There was a bimodal cycle which female *Garra* sm GSI increased from December peaking in March, also from June peaking in July (Fig. 9C). The mean monthly GSI varied significantly between months (ANOVA, F= 3.31, P< 0.01), where the range was in between 4.78 and 15.39. Higher mean GSI values were recorded in February and March, while lower value was recorded in June. The highest individual values of GSI for this species were recorded in January although very close individual values were recorded in December and March, which coincides with times of higher ripe female frequencies (Fig. 10C). In this species, there were considerable differences between the proportions of females, which were found in breeding conditions at different sampling months. Breeding occurred both in dry and rainy seasons, but the higher proportion of ripe females during the dry season suggests that it is the main breeding season for this species.

Small number of ripe female *Garra dembecha* was caught only in May, June and July (Fig. 10D). For female *G. dembecha* there was no significant variation in the mean GSI values (ANOVA, F= 1.41, P> 0.05) among the three breeding months. The range of mean monthly GSI value was 4.17 to 13.09.

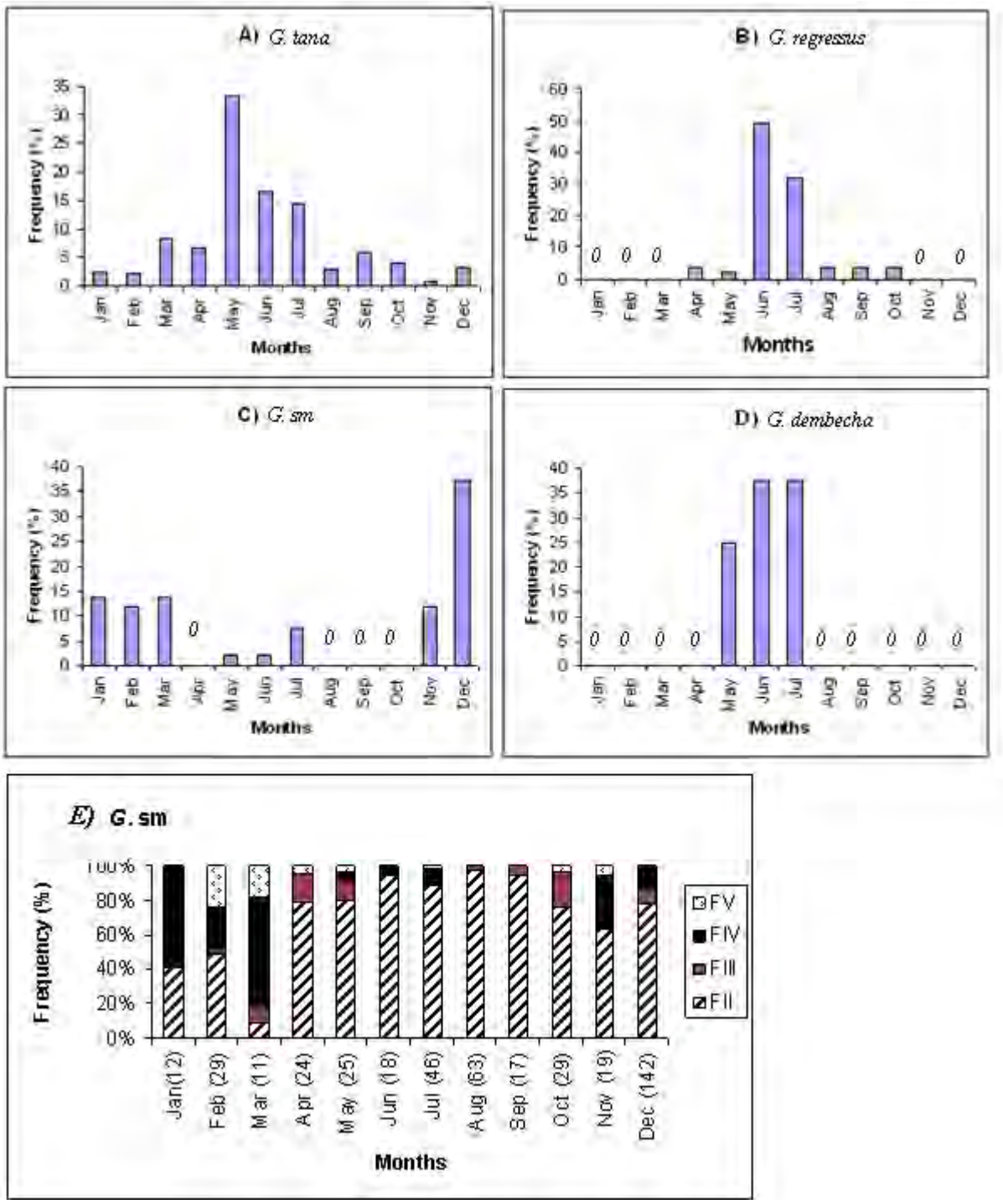


Figure 10. Temporal variation in frequency (%) of ripe female occurrence for A.) *G. tana*, B.) *G. regressus* C.) *G.* sm and D.) *G. dembecha* E) Frequency of females of stages FII to FV for *G.* sm (numbers in parentheses indicate monthly sample sizes) from L. Tana. (Note that the number"0" for some months is to indicate no ripe stages were sampled).

Garra tana has the highest individual GSI (40.45%), measured in June, as well as the maximum mean monthly GSI (17.94%) in the same month (Table 5). Maximum individual and mean monthly GSI (%), as well as the months of such measurements taken for each species of *Garra* is given in Table 5.

Table 5. Species of female Lake Tana *Garra* with max. mean monthly GSI (%) calculated and individual fish with max. GSI (%) measured. N refers to the number of specimens used for calculating max. mean GSI (%).

Species	N	Max. Monthly GSI (%)	Month max. mean GSI (%) calculated	Max individual GSI (%)	Month Max. Individual GSI (%) observed	SL (mm) of individual fish with the max. GSI (%)
Garra tana	25	17.94	June	40.45	June	90.91
Garra regressus	2	14.98	April	19.52	July	111.27
Garra sm	7	15.39	March	16.05	January	101.00
Garra dembecha	1	13.09	July	13.09	July	128.93

Though it was difficult to see the spawning behavior, it is possible to indicate the preferred spawning location from the distribution patterns of stage IV females. For *G. dembecha* the proportion of stage IV females in the littoral and sub-littoral areas were equal (50%, N=8), the pelagic sites being without stage IV females. The proportion of stage IV female *G. regressus* was higher in the sub littoral (78.8%, N=41) than in the other sites. In case of *G.* sm stage IV females were more numerous in the sublittoral sites (43.1%, N=22) as well as in the littoral sites (37.2%,

N=19) than the other sites. For *G. tana*, the proportion of stage IV females in the pelagic area was higher (87%, N=269) than the other sites. *G. tana* is rare in the littoral habitats (Table 4).

4.2.2. Size at maturity ($SL_{50\%}$)

The mean size at first maturity; the standard length at which 50% of the males and females mature, described by the logistic curve is depicted in Fig. 11.

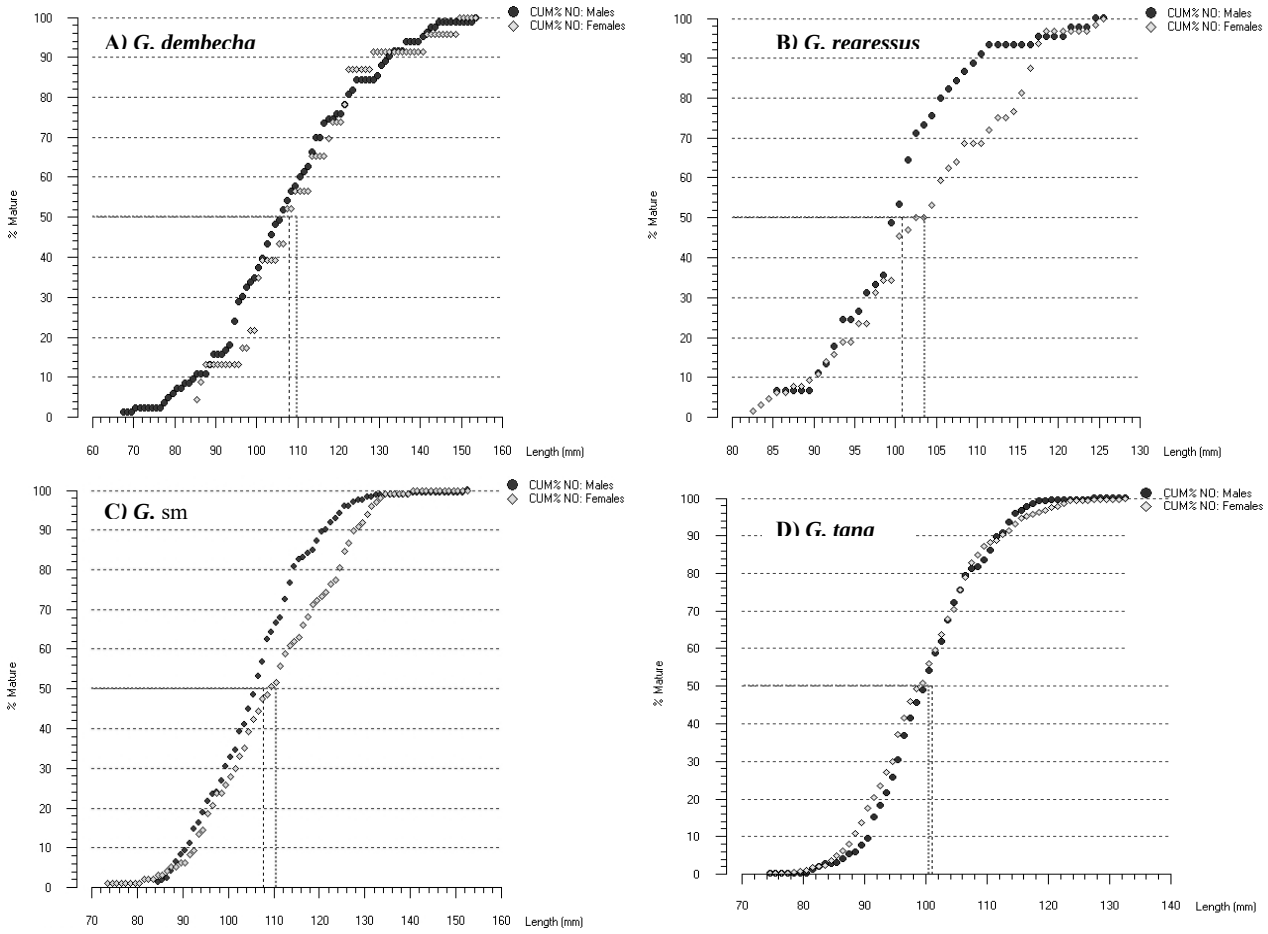


Figure 11. Mean length at first maturity ($SL_{50\%}$) curves for A.) *G. dembecha* B.) *G. regressus*, C.) *G.* sm and D.) *G. tana*

For all species of *Garra* the difference in the mean size at first maturity was significantly different between the species for both males and females, except between *G.* sm and *G. dembecha*. Within a species there was no significant difference between sexes, since the 95% confidence interval overlapped at SL_{50} (Table 6).

Fig. 11 A, B, C and D show the relation between maturity and length for male and female Lake Tana *Garra*. Only individuals in the third or higher stages of gonadal maturity have been considered to be mature.

In *G. dembecha*, it is evident that males start maturing earlier (at 67.89 mm) than females (at 85.03 mm) and that the percentage of mature individuals increases directly with length until, finally, all males and females over 143.06 mm and 147.85 mm, respectively, are mature.

Unlike *G. dembecha*, *G. regressus* females start maturing earlier (at 82.56 mm) than males (at 85.33 mm). All *G. regressus* males and females over the lengths 124.36 mm and 125.06 mm respectively are mature. Males of *G.* sm evidently start maturing at larger length (84.78 mm) than females (73.45 mm), which then the percentage of mature individuals increases with length until, males and females over 131.23 mm and 133.81 mm, respectively, are all mature.

In case of *Garra tana*, both sexes start maturing at approximately the same size (males at 74.45 mm and females at 74.57 mm) in which the percentage of mature individuals increase with length until, all males over 118.16 mm and all females over 123.78 mm are mature.

The 50 % levels in the maturity curves, which may be taken to represent the mean lengths at which maturity is attained, are indicated in Table 6 for both sexes of each species.

Table 6. Mean length at first maturity (SL 50% estimated according to Gunderson *et al.* (1980) *Garra* sm, *G. tana* (tana), *G. regressus* (reg) and *G. dembecha* (dech). Number of specimen (N), Parameter values for b from logistic regression, mean length at maturity (SL 50 in mm, -a/b) and 95 % confidence limit of L 50.

species	sex	N	L50	Lower	Upper	b
sm	M	171	107.67	104.59	108.09	1.66
	F	97	110.44	107.12	112.71	1.63
dech	M	83	107.84	103.83	111.53	1.42
	F	23	109.95	103.48	116.79	1.49
reg	M	45	100.87	98.12	103.10	2.81
	F	64	103.57	101.38	106.57	2.63
tana	M	282	100.50	98.57	101.46	2.3
	F	351	99.99	98.45	100.91	2.24

4. 2. 3. Fecundity

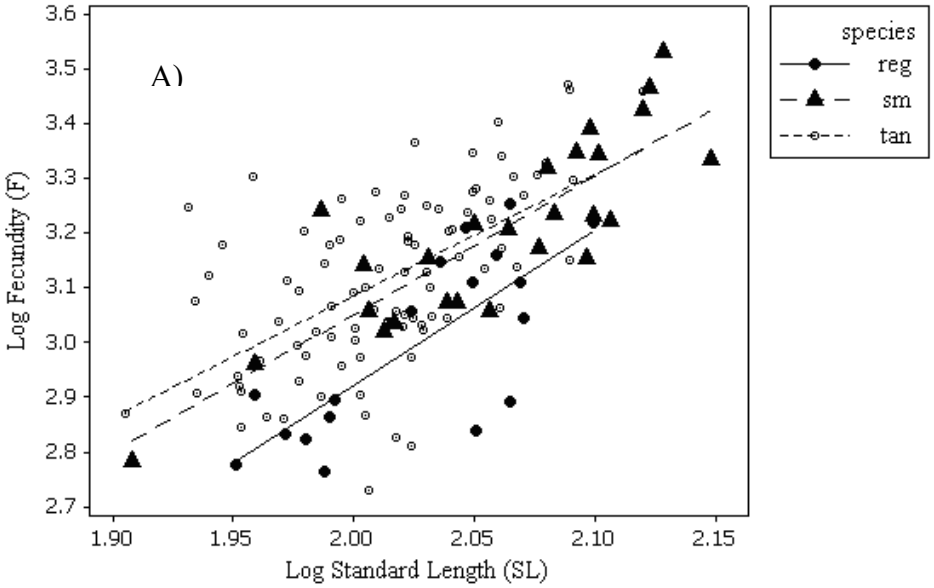
Fecundity of *G. tana* ranged from 538.9 to 2968 eggs for females whose length was between 80.38 and 132 mm with the mean ± SD of 1402.8 ± 525 (n=93). Fecundity was curvilinearly related with SL (Fig. 12A), and linearly related with TW (Fig. 12B) as well as with gonad weight (Fig. 12C). Fecundity of *G.* sm ranged from 606 to 3397 eggs for females whose length was between 81 and 140.84 mm with the mean ± SD of 1703.5 ± 660 n= 26). Fecundity was curvilinearly related with SL (Fig. 12A), and linearly related with TW (Fig. 12B) as well as with gonad weight (Fig. 12C).

Fecundity of *G. regressus* ranged from 580.8 to 1800 eggs for females whose length was between 89.36 to 125.87 mm having mean ± SD of 1060.8 ± 407.4 (n= 18). Like wise fecundity was curvilinearly related with SL (Fig. 12A), and linearly related with TW (Fig. 12B) as well as with gonad weight (Fig. 12C).

Fecundity of *G. dembecha* whose length was between 96.54 to 128.93 mm ranged from 1215 to 1229 with mean ± SD of 1222.2 ± 10.1 (n=3). Due to the smaller number of *G. dembecha* relationships between absolute fecundity and –standard length, -gonad weight and -body weight were not estimated. Absolute fecundity of the four species was statistically different (ANOVA, $F=7.17$, $P< 0.001$).

The average relative fecundity of *G. dembecha*, *G.* sm, *G. tana* and *G. regressus* with mean ± SD was 63.34 ± 27.1, 77.19 ± 17.84, 102.74 ± 32.38 and 55.55 ±19.24, respectively. The relative fecundity of the four species was statistically different (ANOVA, $F= 18.07$, $P< 0.001$).

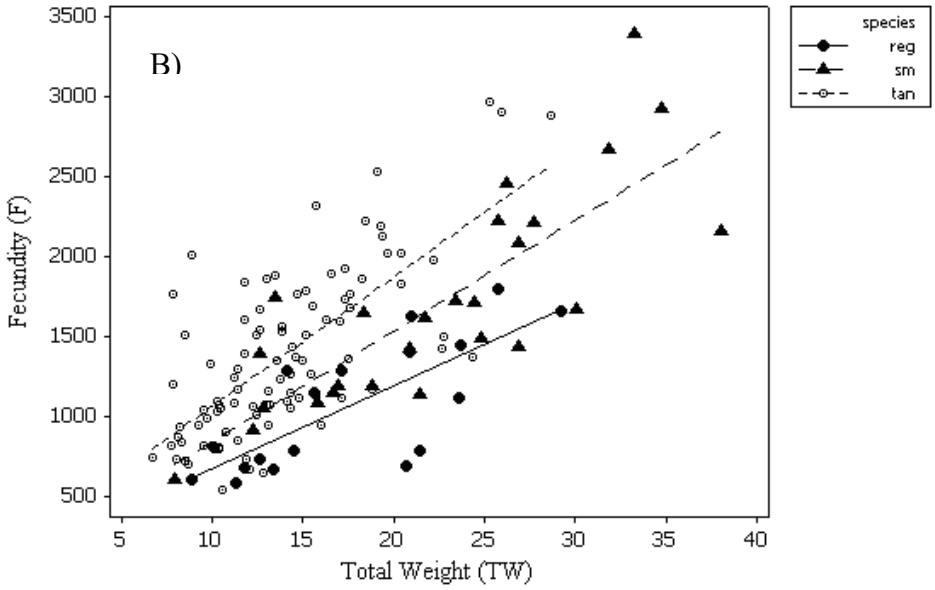
The relative fecundity of *Garra tana* remained more or less the same for all size classes (Table 7). In *Garra* sm, although the relative fecundity showed a drop at higher size class, it remained almost the same for the other size classes. Comparatively speaking, the relative fecundity of *G. regressus* varies for the different size classes.



Garra regressus Log F = - 2.74 + 2.83 Log SL , R^2= 0.5678, P< 0.001 (n=18)

Garra tana Log F = - 1.36 + 2.22 Log SL, R^2= 0.3451, P< 0.001 (n=93)

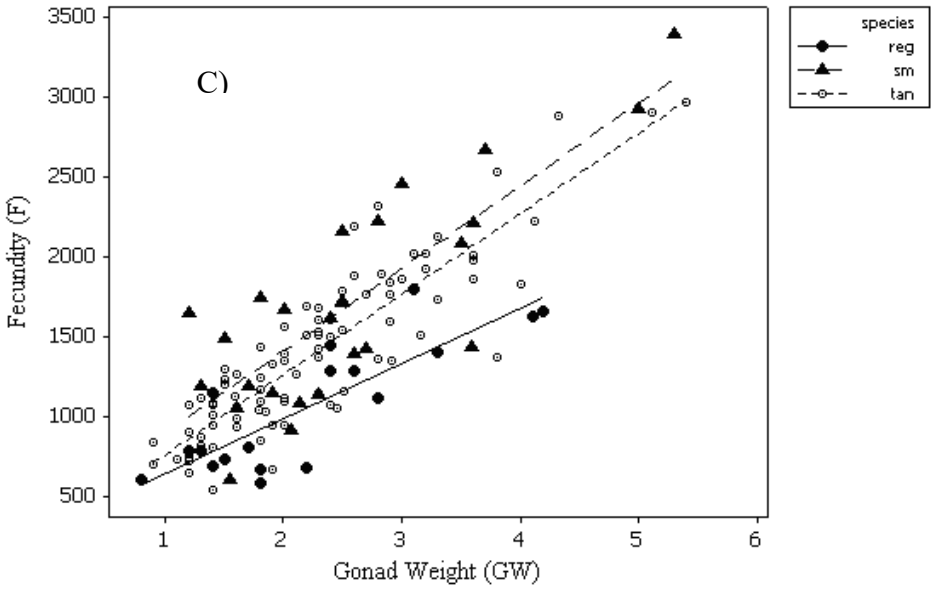
Garra sm Log F = - 1.99 + 2.52 Log SL, R^2= 0.7133, P< 0.001 (n=26)



Garra regressus F= 51.789TW + 152.77, R^2=0.5645, P< 0.001

Garra tana F= 81.236 TW + 248.09, R^2=0.4969, P< 0.001

Garra sm F=69.486 TW + 145.04, R^2=0.6564, P< 0.001



Garra regressus F= 347.7 GW + 288.13, R^2=0.6998, P< 0.001

Garra tana F= 504.77 GW + 251.89, R^2=0.7778, P< 0.001

Garra sm F= 517.57 GW + 375.34, R^2=0.6679, P< 0.001

Figure 12. Absolute fecundity (F) as a function of A) Standard length (SL) B) Total Weight (TW), and C.) Gonad Weight: *G. regressus*= reg, *G.* sm= sm and *G. tana*= tan.

Table 7. Mean absolute and relative fecundity of *G.* sm, *G. tana* and *G. regressus* in relation to their lengths. N= number of specimens in the particular standard length class.

Species	Size class	Absolute fecundity	Relative fecundity	N	mean TW
Garra sm	66.85-81.17	606.1	76.04	1	7.97
	81.18-95.5	914.6	74.66	1	12.25
	95.51-109.83	1683.03	77.07	7	20.79
	109.84-124.16	1857.67	72.96	9	23.02
	124.17-138.49	1733.18	74.18	8	22.53
	138.5-152.82	2162.16	56.89	1	38
Garra tana	79.53-92.66	1407.23	102.58	15	12.63
	92.67-105.8	1404.17	101.24	44	12.66
	105.81-118.94	1419.24	102.64	28	12.69
	118.95-132.08	1538.63	103.24	7	13.28
Garra regressus	87.82-94.94	998.39	60.69	3	16.98
	94.95-102.07	987.51	61.17	4	16.53
	102.08-109.2	1274.9	70.31	2	18.25
	109.21-116.33	1088.08	61.20	6	18.04
	116.34-123.46	1199.16	69.19	2	18.85
	123.47-130.59	1661.6	56.90	1	29.2

4. 2. 4. Egg size

The mean diameter of fully mature ova was calculated by measuring a sub sample of (at least 15) the largest eggs. Thus, the mean diameter of fully mature eggs of *G. dembecha*, *G. regressus*, *G.* sm and *G. tana* was 1.43±0.016 (mean ±SE) (n= 126), 1.81±0.016 (mean±SE) (n= 178), 1.38±0.076 (mean±SE) (n= 163) and 1.22±0.006 (mean±SE) (n= 995), respectively. The egg diameter showed significant variation (T-test, $P< 0.05$) among the four species. The size frequency distribution of

eggs showed unimodality in *Garra* sm, *G. tana* and *G. dembecha* (Fig. 13 a, b and c). In *G. regressus* the ovaries contained two kinds of oocytes, each with its own distinct peak in egg size frequency distribution (Fig. 13d): eggs with yolk (vitellogenic oocytes) and eggs without yolk. Only the vitellogenic eggs were counted to determine fecundity because only these oocytes would be spawned in subsequent peak.

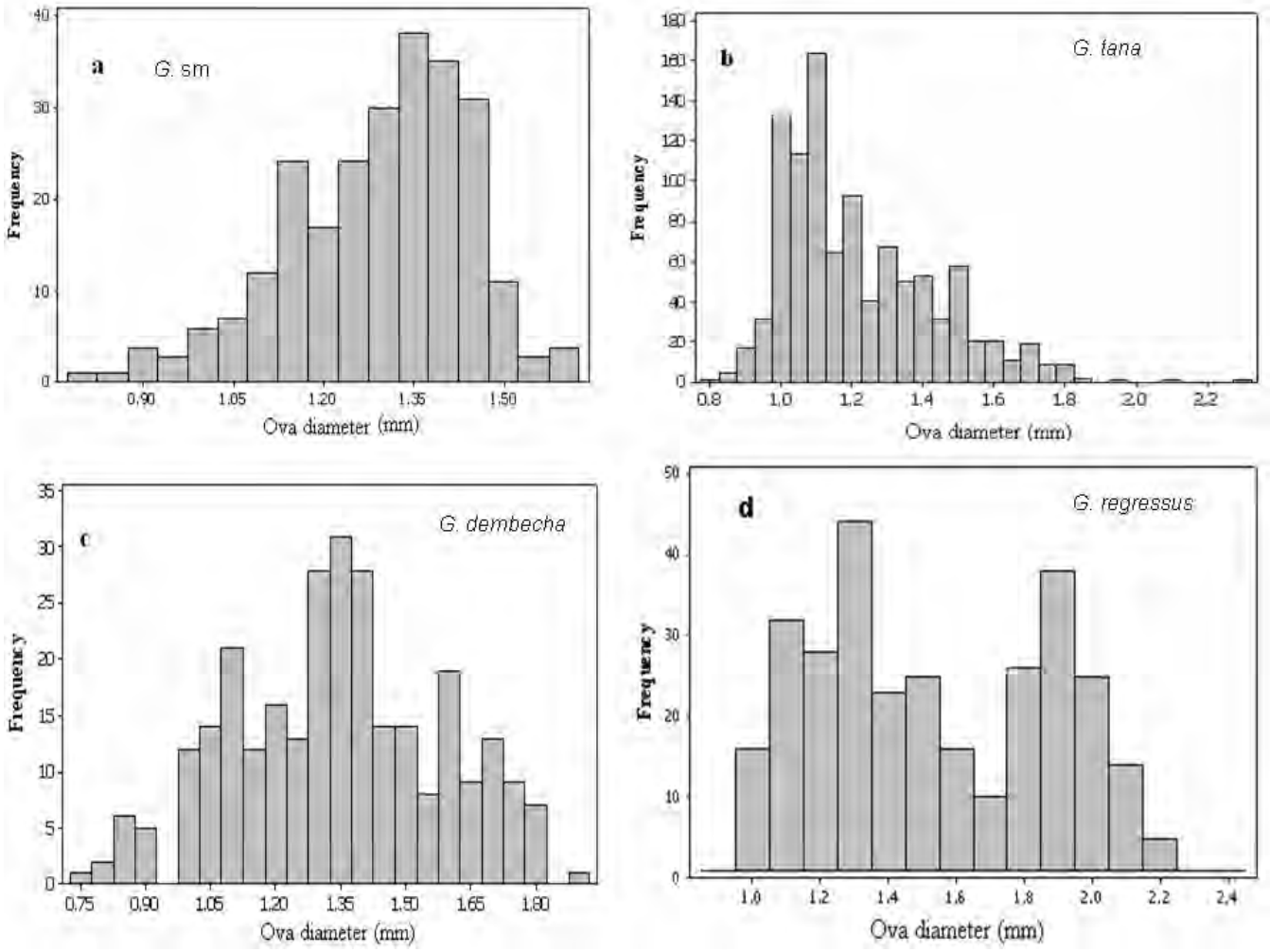


Figure13. Ova diameter frequency histograms of a) *Garra* sm b) *Garra tana* c) *Garra dembecha* d) *Garra regressus*

4. 2. 5. Sex ratio

From a total of 645 *G. tana* individuals examined in 12 sampling occasions, a significant deviation from a 1:1 female: male ratio occurred only during March and April when females were more

numerous and during August when males were numerous. (Table 8). *G. regressus* sex ratio did not differ significantly from 1:1 at any period, except in the total catch the ratio was female-biased (chi-square, $P< 0.05$) (Table 8).

From 859 *G.* sm individuals examined in 12 sampling occasions males were more numerous than females in samples from July, August and October whereas females were more numerous than males in samples from September and December (Table 8). From a total of 299 *G. dembecha* individuals examined in 12 sampling occasions, males were more numerous than females (Chi-Sqr, $P < 0.05$) in the total catch as well as in sample taken in June (Table 8).

Table 8. Number of female and male, and sex ratio (F: M) of Lake Tana *Garra* in monthly samples collected from the Gulf of Lake Tana during the year 2006 (* = significant at 5% level).

	***G.* sm**				***G. tana***				***G. dembecha***				***G. regressus***			
Months	**F**	**M**	**F: M**	**χ^2**	**F**	**M**	**F: M**	**χ^2**	**F**	**M**	**F:M**	**χ^2**	**F**	**M**	**F:M**	**χ^2**
Jan	12	10	1:0.83	0.227	16	25	1:1.56	2	2	1	1:0.5	0.67	2	6	1:3	2.125
Feb	28	21	1:0.75	1.02	14	21	1:1.5	1.428	13	17	1:1.30	0.567	6	1	1:0.16	3.714
Mar	11	11			35	16	1:0.45	7.098*	3	5	1:1.67	0.625	2	2		
Apr	24	23	1:0.96	0.042	21	10	1:0.47	3.935*	7	15	1:2.14	2.954	7	10	1:1.42	0.588
May	25	30	1:1.2	0.472	105	81	1:0.77	3.102	13	16	1:1.23	0.344	2	2		
Jun	18	19	1:1.05	0.054	53	41	1:0.77	1.542	16	36	1:2.25	7.711*	26	15	1:0.57	2.975
Jul	48	87	1:1.81	11.274*	82	62	1:0.75	2.784	3	3			26	14	1:0.54	3.625
Aug	63	91	1:1.44	5.097*	13	33	1:2.54	8.717*	1	5	1:5	2.833	4	3	1:075	0.285
Sep	17	6	1:0.35	5.304*	25	25			3	1	1:0.33	1.25	3	3		
Oct	29	46	1:1.58	3.867*	15	17	1:1.13	0.156	21	26	1:1.24	0.553	5	2	1:0.4	1.428
Nov	19	21	1:1.1	0.125	3	7	1:2.33	1.7	25	24	1:0.96	0.040	0	2		
Dec	144	56	1:0.38	38.725*	16	9	1:0.56	2	23	20	1:0.87	0.232	4	2	1:0.5	0.833
Total	438	421	1:0.96	0.337602	398	347	1:0.87	3.492	130	169	1:1.3	5.090*	87	62	1:0.71	4.201*

4. 3. Length - Weight relationship and condition factor

The length frequency composition and sample size of Lake Tana *Garra* species is presented in Fig. 14. There was statistically significant (P< 0.001) curvilinear relationship between standard length and total weight of *G. dembecha, G. regressus, G. tana and Garra* sm in Lake Tana. The regression equation which was fitted for *G. dembecha* between 51.95 mm and 153 mm SL and 1.6 g – 60.3 g TW, for *G. regressus* fish between 80.69 mm and 130.52 mm SL and 6.5 g – 33.7 g TW, for *G. tana* fish between 40.11 mm and 132 mm SL and 0.5 g – 28.6 g TW and for *Garra sm* fish between 52.52 mm and 152.76 mm SL and 1.5 g – 41.8 g TW was given in Table 9.

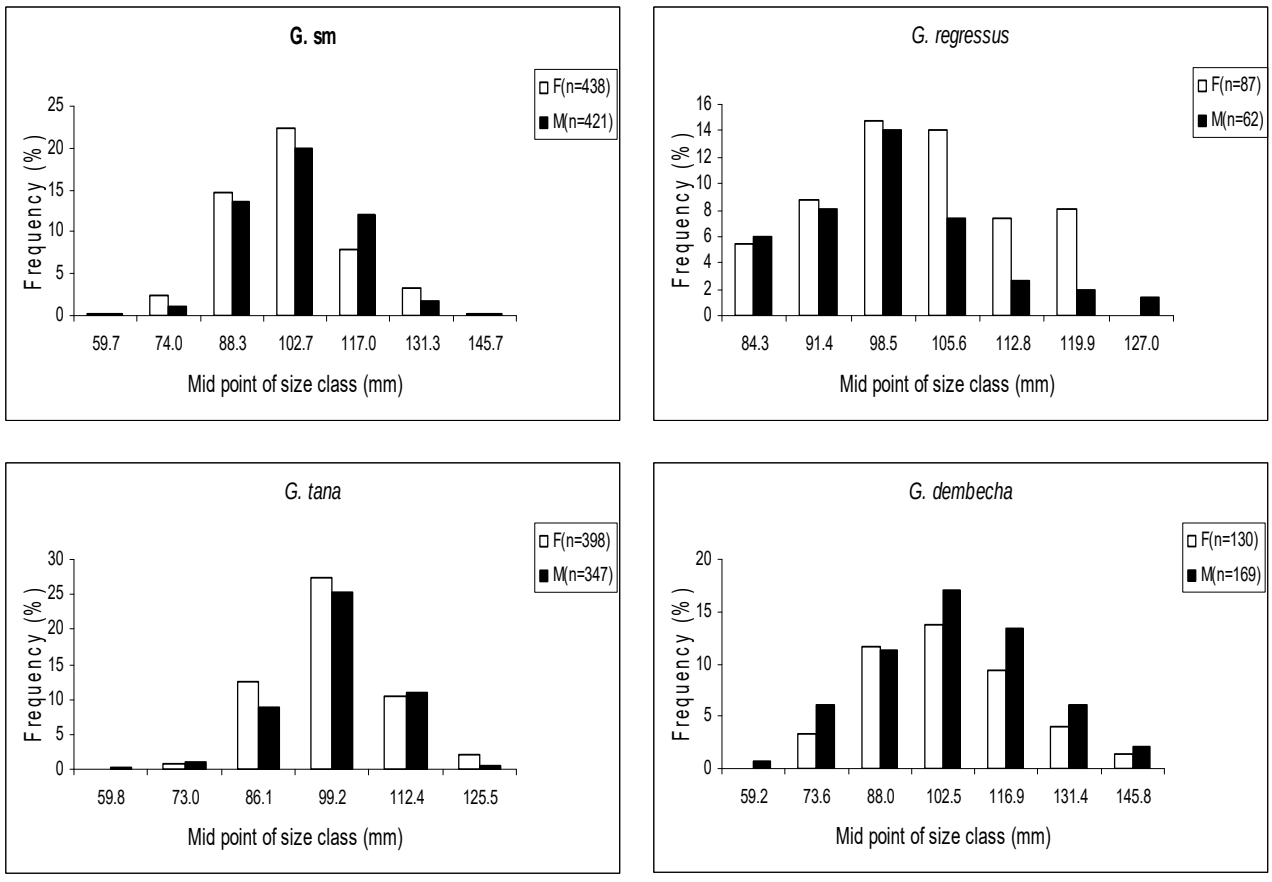


Figure 14. Length-frequency (Standard length in mm) (%) of Lake Tana *Garra* from the total gill net catches.

Table 9. The length-weight regression equations for both males and females and combined sex, the correlation coefficient (r) and the number of specimens (n) of Lake Tana *Garra*.

Species	sex	Regression equation	r	n
Garra dembecha	Male	Log TW = - 5.11 + 3.13 Log SL	0.968	169
	Female	Log TW = - 5.40 + 3.27 Log SL	0.969	130
	combined	Log TW = - 5.18 + 3.16 Log SL	0.968	315
Garra regressus	Male	Log TW = - 5.07 + 3.09 Log SL	0.928	62
	Female	Log TW = - 5.12 + 3.12 Log SL	0.927	87
	combined	Log TW = - 5.08 + 3.10 Log SL	0.92	159
Garra sm	Male	Log TW = - 5.17 + 3.12 Log SL	0.954	421
	Female	Log TW = - 5.13 + 3.10 Log SL	0.945	438
	combined	Log TW = -5.14 + 3.10 Log SL	0.943	938
Garra tana	Male	Log TW = - 5.66 + 3.36 Log SL	0.923	347
	Female	Log TW = - 5.09 + 3.08 Log SL	0.933	398
	Combined	Log TW = - 5.36 + 3.21 Log SL	0.937	773

Mean ± SE Fulton condition factor (FCF), the range of FCF for both sexes of each species and the combined average values are presented in Table 10.

FCF varied highly significantly (ANOVA, $P<0.0001$) between sampling months and between sexes (ANOVA, $P< 0.05$) for all species of *Garra*. However, sex by month interaction for all species of *Garra* was insignificant (ANOVA, $P>0.05$). Thus, temporal variation in FCF for both sexes of each species was similar (Fig. 15).

Generally, lower values of FCF for *G. dembecha* were recorded in August, November and January. Values tended to increase in May, June and July and particularly for males in September (Fig. 15A). In addition, mean FCF in June, which was similar for the sexes, was larger than the rest of the months.

Relatively lower values of FCF for *G. regressus* were recorded in January and February whereas higher values were recorded in May and June for both sexes. But the highest values for males were recorded in November. Mean FCF in August was similar for the sexes (Fig. 15B).

For *G.* sm lower values of FCF were recorded in January and February. Values tended to increase in March and from May to July (Fig. 15C). In addition, mean FCF in March, which was similar for the sexes, was larger than the rest of the months.

G. tana had lower values of FCF recorded in January. Values tended to increase in March, May and June (Fig. 15D). In addition, mean FCF in March and May, which was similar for the sexes, was larger than the rest of the months.

Table 10. Fulton's Condition Factor (FCF ± SE) averages and ranges for both males and females, and combined sex averages of L. Tana *Garra*. (dech= *G. dembecha*, reg= *G. regressus*, sm= *G.* sm, tan= *G. tana*).

species	sex	Average FCF (± SE)	Range	Average FCF (±SE) Combined for sexes
dech	M	1.44 ± 0.016	1.22 ± 0.035 to 1.60 ± 0.025	1.42 ± 0.012
	F	1.39 ± 0.017	1.19 ± 0.034 to 1.61 ± 0.038	
reg	M	1.30 ± 0.02	1.012 ± 0.034 to1.49 ± 0.025	1.33 ± 0.013
	F	1.36 ± 0.019	1.16 ± 0.038 to 1.5 ± 0.033	
sm	M	1.18 ± 0.009	0.93 ± 0.026 to1.395 ± 0.033	1.17 ± 0.006
	F	1.15 ± 0.007	0.9 1± 0.036 to 1.36 ± 0.046	
tan	M	1.14 ± 0.008	0.86 ± 0.018 to 1.25 ± 0.025	1.17 ± 0.005
	F	1.19 ± 0.007	0.91 ± 0.018 to 1.27 ± 0.009	

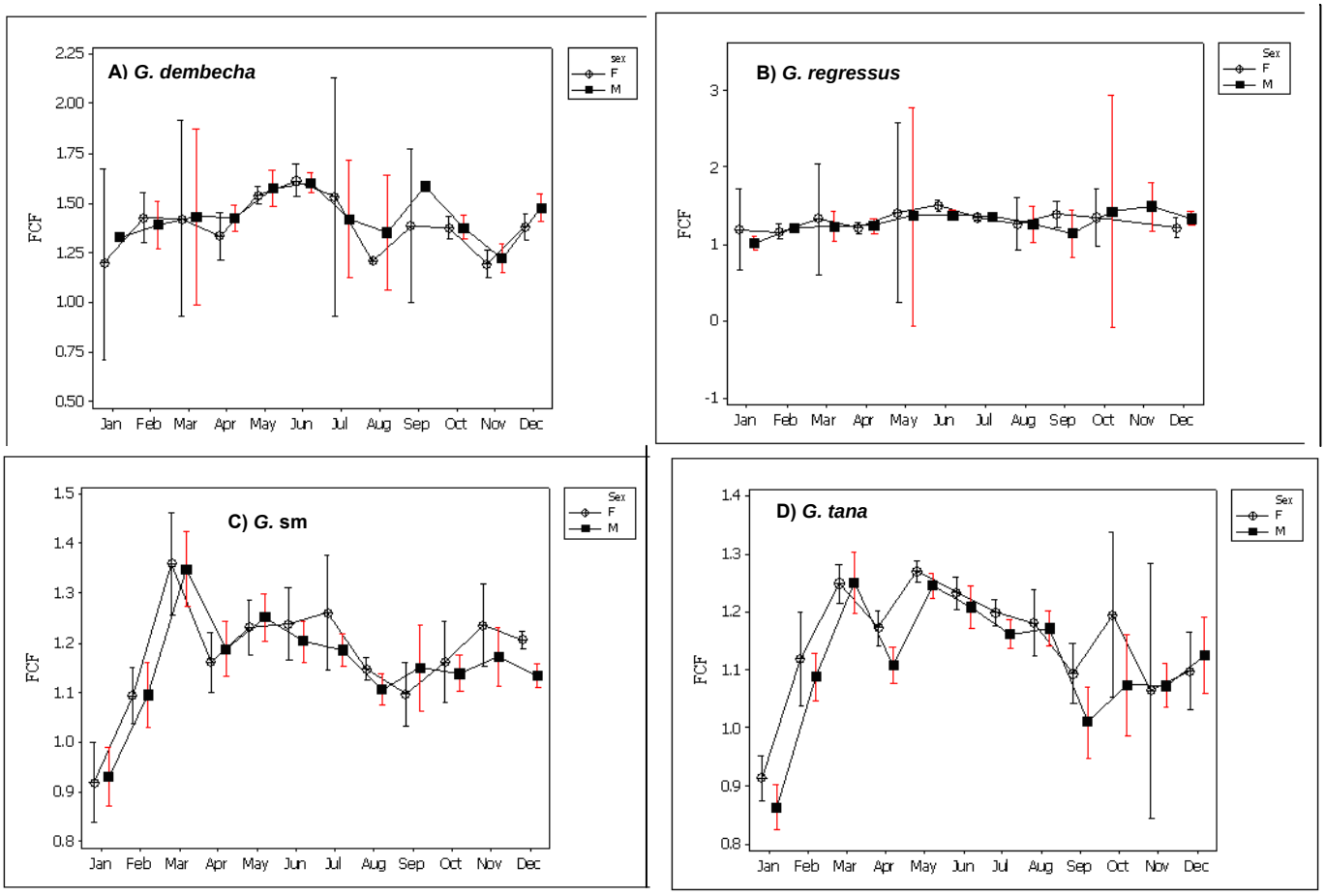


Figure 15. Temporal variation in Fulton condition factor (mean ± SE) of **A.)** *Garra dembecha*, **B.)** *Garra regressus*, **C.)** *Garra* sm and **D.)** *Garra tana* from L. Tana for both sexes.

4. 4. Aspects of feeding

Microscopic examination of gut contents of *G.* sm, *G. tana*, and *G. dembecha* has shown that the diet of the three *Garra* species in L. Tana is composed of phytoplankton-based detritus and silt. A total of 20 genera belonging to the cyanobacteria, diatoms and green algae were identified in the three species of *Garra* (Table 11). The microscopic observation of these items revealed that they were empty indicating their detrital origin. Commonly found cyanobacteria include *Lyngbya* and *Microcystis* species. *Aulacoseira* sp. and *Nitzischia* sp. of Bacillariophyceae were abundant items in all the *Garra* species considered. *Staurastrum* sp. were commonly encountered blue green algae. Although the contribution of animal origin food was small, a large proportion of it has been observed in *G. tana*.

Detritus and mud (silt) constituted the largest proportions of their gut and are responsible for the muddy appearance of the gut contents.

No estimation of gut contents of *G. regressus* was made due to its short and thin gut which made the examination difficult to manage.

Table 11. Food items commonly found in the guts of L. Tana *Garra* species with frequency of occurrence (%) calculated for each items from the total number of guts (n) analyzed for a species**.**

Food items (group/genus)	*G.* sm (n=17)	*G. tana* (n=16)	*G. dembecha* (n=20)
Cyanobacteria			
Lyngbya	52.9	37.5	80
Limnothrix	11.8	12.5	-
Aphanothece	11.8	-	55
Microcystis	47.1	37.5	80
Bacillariophyceae			
Aulacoseira	100.0	100	95
Synedra	11.8	12.5	-
Nitzschia	76.5	37.5	70
Cymbella	29.4	12.5	60
Fragilaria	11.8	-	-
Gomphonema	17.6	-	55
Surirella	47.1	25	65
Pinularia	11.8	25	55
Chlorophta			
Treuberia	52.9	37.5	60
Scenedesmus	11.8	-	-
Pediastrum	29.4	25	75
Staurastrum	76.5	75	75
Chlosterium	11.8	37.5	55
Oocystis	11.8	-	-
Ankistrodesmus	11.8	-	-
Arthrodesmus	-	-	55
Zooplankton			
Branchionus	11.8	-	-
Keratella	58.8	87.5	15
Copepoda	17.6	93.75	60
Nauplii	11.8	37.5	60
Moina	11.8	-	-
Bosmina	82.4	62.5	70
Daphnia	11.8		25
Animal fragment (unidentified)	47.1	62.5	60
Silt (mud)	100.0	100	100
Detritus	100.0	100	100

5. Discussion

5. 1. Taxonomic Analysis

In the present study the morphological variation between L. Tana *Garra* was found to be discontinuous with out any relation to ontogeny and sexual dimorphy. The study further indicated that L. Tana is likely to have at least five forms of *Garra*, which is more than what has been claimed by Stiassny and Getahun (2007). Such high species richness within this genus might not be surprising given the *Labeobarbus* species radiation within this lake.

The results clearly indicated that each form is morphometrically distinct from all others. The dendrograms resulting from the UPGMA using all 23 external morphometric characters (Fig. 7) and using only three best characters (Appendix IV) all clearly differentiated the *Garra* forms. On a PCA using the same 23 characters the presence of overlaps in the main shape axes (PC2 and PC3) for the two *Garra*, *G.* sm and *G. dembecha* seems helpful if more characters are taken. But, characters highlighted (OD, posterior gasbladder and prepectoral fin length) (Appendix V) would have much more importance to differentiate the two, in addition to CPD and GL which showed no overlaps in the range of values (Appendix I). Generally, the best discriminating characters achieving greatest between-groups separation relative to the within-group variation were Cpd, Rbl and GL (Appendix IV). The GL as a character was one of the best single characters used by Abebe Getahun (2000) to separate L. Tana *Garra*.

The differences in the results between the forms of *Garra* using 14 head bone morphometric measurements in an attempt to differentiate them following similar procedures of Mina *et al*. (1996), again resulted in the mix up of some specimens of *G. dembecha* and *G.* sm (Fig. 8).

Within the groupings in all analyses, *G. dembecha* and *G.* sm always demonstrated closest morphological similarity. Despite this, the positions of *G. regressus* and *G. tana* were found to be stable for all the analyses.

The few meristic characters considered in this study are useful to differentiate *G.* sm from the other species of *Garra* in the lake, as long as no overlaps in counts are found. For instance, *G.* sm differs from *G. dembecha* by the higher number of scale rows between lateral line and pelvic fin origin. It has got also higher number of scale rows between lateral line and dorsal fin origin when compared with *G. tana*. Comparing it with *G. regressus*, such characters as simple dorsal fin rays, lateral line scales, scale rows between lateral line and anal fin as well as pelvic fin origins have higher counts in *G.* sm.

Some of the relationships indicated by the present study are in agreement with established opinion. The clear separation of the two species *G. regressus* and *G. tana* unequivocally and consistently demonstrated in all analysis, confirm their species status quo as given in earlier study made by Stiassny and Getahun (2007). In case of *G.* sm the results are ambivalent. The two multivariate techniques showed consistently that *G.* sm and *G. dembecha* were morphologically similar, even got mixed up in some cases; however there were tendencies of dissimilarity.

Despite the good morphological evidences to support the variation between L. Tana *Garra*, lack of any analysis at molecular level hampers the confident proposal of five lacustrine species including *G.* sm in the lake. Recent molecular analysis (Abebe Getahun pers. Com.) of the Lake Tana *Garra* species to establish a relationship with other cyprinids including Asian species showed that they are more closely related to each other than to Asian species and were in a separate cluster. Since this tree never included other African species of the genus, it will be very hard to substantiate monophyletic origin of L. Tana *Garra* species. Conversely, the absence *G.* sm in the analysis hampers the comparison that could be made here.

Basically, morphological traits, which improve individual fitness, are naturally selected through generations and eventually become a species characteristic with a genetic basis (Kramer, 1978). In fact, genetic variability could only be inferred from levels of morphological differences in populations when some form of selection causes the proposed differentiation. Johnson *et al.* (1983) suggested molecular level analysis as more informative than multivariate analysis of morphometric characters. Therefore, this study appears to support this view.

5. 2. Distribution and abundance

The distribution of the four *Garra* forms in L. Tana was inferred from their relative abundance (% IRI) at different sites. *G. tana* is a pelagic form, *G. dembecha* occurs in various lakes and rivers (Abebe Getahun, 2000) (Appendix II) in and out of L. Tana basin having its main distribution in the littoral/sublittoral habitats of L. Tana. Both *G.* sm and *G. regressus* inhabit littoral and sublittoral habitat considerably, although both move frequently in to the open water. In the present study, the sampling conducted in the northern part of L. Tana at different habitats including the river mouths of Dirma and Megech Rivers failed to catch *G. dembeensis* which was previously reported from the shore site at Gorgora by Abebe Getahun (2000). When considering the absence of a species from a particular region it is necessary to bear in mind the possibility that the sampling protocols might be biased against catching that species. In the present study only monofilament gill nets were used when prior studies used active gears such as beach seine (Abebe Getahun pers. Comm.).

The complete absence of lacustrine *Garra*, except *G. dembecha* (Appendix II) from the tributary rivers of L. Tana as well as their capability of breeding within the lake might suggest their greater adaptation to the lacustrine conditions. Thus, the absence of *G.* sm, *G. tana* and *G. regressus* in the rivers comply with the true lacustrine adaptation of these fish species attained through the course of evolution as was put forward in Fernando and Holicik (1982).

5. 3. Reproductive Biology

Based on the results of GSI (Fig. 9) and frequency of females with ripe gonads (Fig. 10), it is possible to suggest that L. Tana *Garra* has seasonal breeding activity. *G. tana* breed intensively during March to August with some breeding activity occurring in other months too. Seasonality in breeding of *G. regressus* and *G. dembecha* was conspicuous from April to October and May to July, respectively.

The intensive breeding activity for the above three species of *Garra* coincides with the major rainy season of the area. Therefore, biotic and abiotic factors that are associated with rainfall seem to be important cues to trigger breeding in these species. Synchronization of sexual maturation and reproduction with rainy season is well documented (Fryer and Iles, 1972; Lowe-McConnell, 1982; Wootton, 1992). For instance, temperature regime (i.e. the decrease in maximum and increase in the minimum air temperature (Fig. 2)) during the rainy season could possibly trigger reproductive activity. Similarly, Elias Dadebo *et al*. (2003) found such temperature regime effect on reproductive rhythm of one Labeine species, *Labeo horie* in L. Chamo. Low daily temperature fluctuations were also reported to accelerate gonadal maturity in warm water dwelling *Garra* species *G. rufa* (Bardakci *et al.,* 2000). In general, temperature plays an important role in governing the reproductive activity of fish (Sundararaj, 1981; Braum, 1978). The association between intensive breeding activity and rainy season has also been reported for other species of the genus *G. gotyla gotyla* (Jha *et al*., 2005b) and other fish species in L. Tana (Zenebe Tadesse, 1997; Tesfaye Wudneh, 1998; de Graaf, 2003; Eshete Dejen, 2003; Wassie Anteneh, 2005), fishes in other lakes in Ethiopia (Demeke Admassu, 1996; Alemayehu Negassa and Abebe Getahun, 2003; Elias Dadebo *et al*., 2003) and elsewhere (Fryer and Iles, 1972; Lowe-McConnell, 1982; Weyl and Booth, 1999).

GSI and frequency of ripe females (Fig. 9 and Fig. 10) indicated that *G.* sm breeds intensively during November to March, having minor breeding activity during May to July. The intensive breeding activity for this species coincides with dry season of the area, unlike the other species of *Garra* in the lake. The divergent pattern of seasonal reproduction in *G.* sm at a cost of high predation pressure by piscivores (Nagelkerke and Sibbing, 1996), limited resources available during the dry season might be a strategy to escape spawning and nursery site competition. Variation in reproductive patterns in fishes in response to factors such as competition for spawning and nursery sites are well documented (Kramer, 1978; Lowe-McConnell, 1987; Wootton, 1992; 1998). In L. Tana, most fish species considered as lacustrine spawner breed during the wet season being ecologically restricted to the littoral zone which is 2 % of the lake area (Zenebe Tadesse, 1997; Nagelkerke and Sibbing, 2000; Eshete Dejen, 2003). Furthermore, from among breeding *Garra* species considered in this study, only *G. tana* were found to be spatially restricted in the offshore areas while others remained restricted mainly to the inshore sites in breeding months. Nevertheless, a more detailed study is required to investigate if competition is an ultimate factor important in governing breeding time in *G.* sm.

In L. Tana, rainy season, occasionally heavy down pours bring water highly turbid with high silt carried to the lake. Such conditions could be a threat to fish species like *Garra* with adhesive, demersal eggs and with no parental care (Growns, 2004). The strategy in this case might be to decrease such threats by breeding outside the rainy season. The same has also been reported for other species of *Garra*, *G. ceylonensis* in Sri Lanka (De Silva, 1991).

This divergent reproductive seasonality of *G.* sm might also be a mechanism for reproductive isolation. Kramer (1978) suggested this as a hypothesis for fish species that are considerably similar in morphology and size.

Although further studies are required, the possible explanations given above for *G.* sm might be important in governing the reproductive seasonality of this species through their effects.

Generally, the study showed the presence of considerable diversity in reproductive periodicity of *Garra* species. The duration of the breeding season ranged from a brief period characteristic of *G. dembecha* in which most of the ripe individuals were found in only three months, through moderately long breeding season of *G.* sm and *G. regressus* to essentially continuous breeding in *G. tana*. Similar patterns of reproductive activity within the same Panamanian stream were found for closely related species of characoids by Kramer (1978). Such differences in reproductive patterning are believed to contribute to patterns of morphological and physiological variations resulting in heritable variation (Reardon and Chapman, 2007).

The difference *G.* sm showed in its breeding time from *G. dembecha* might suggest a reproductive segregation between the two; however they failed to show strong morphological differences.

No spatial differences in distribution between breeding and non-breeding months were observed.

The mean size at sexual maturity estimated in this study was approximately the same for both sexes in all species of *Garra* in L. Tana. Certainly, mean length at maturity (SLm) is determined to predict size-assortative mating as well as management options by restricting mesh sizes to avoid over exploitation, though exploitation is non-existent in this case.

In the present study it was indicated that *G.* sm matures at a smaller size than *G. tana* and *G. regressus* with no overlaps in the 95 % confidence limit of the mean size at maturity. However, it showed overlaps in the confidence limit of the mean values with *G. dembecha*. On the other hand, *G. dembecha* matures at a smaller size than *G. tana*. But *G. regressus* males were found to mature at smaller size than *G. dembecha*, when females of both species showed some overlap in the confidence limits.

Size at maturity vary among closely related species, among populations within species and among individuals within populations; suggesting that they can respond rapidly to natural selection (Stearns, 1992 as cited in Tsikliras and Antonoupoulou, 2006). Length of maturity in many fish species depends on demographic condition and is determined by genes and the environment (Fryer and Iles, 1972; Lowe-McConnell, 1987; Wootton, 1998), but can be influenced by other factors such as long-term fishing pressure, which cannot be the case here.

In the present study the fecundity of *Garra* increased in proportion to length, gonad weight and body weight. The positive correlation of absolute fecundity and body length has been reported for other *Garra* species (e.g. *G. ceylonenesis* in Sri Lanka streams) (De Silva, 1991). The parameter "b" of the relationship of length with fecundity for L. Tana *Garra* is higher than that of *G. ceylonensis* (b=1.22) reported from Sri Lanka (De Silva, 1991). The value of this parameter is in the limit of previously reported values for other fish species (Bagenal, 1978). In many fish species "b" value usually is about 3 when fecundity is related to length and about 1 when related to weight (Bagenal and Braum, 1978). The relatively lower regression coefficient (b=2.22) as well as weaker (r= 0.58) correlation between fecundity and standard length of *G. tana* as compared to *G.* sm and *G. regressus* indicates that fecundity could vary much with in each size class. The higher mean absolute fecundity of *G.* sm, which breeds intensively during the dry season as compared to *G. regressus* and *G. tana*, suggests that the food present during this time might be good to favor for this species to breed.

Because larger females have higher fecundity than smaller females, any comparison of fecundity between populations is confounded by differences in female age and size (Bagenal, 1978). However, this study has shown that at a comparable size class *G.* sm has large number of eggs than *G. tana* and *G. regressus* (Table 7). Lowest fecundity estimates in *G. regressus* reported here

for a comparable size class may be related to the multiple spawning nature of this fish or may be to the larger mean size of its eggs as compared to the other forms of *Garra.* It is evident that smaller sized fishes that have large sized eggs have smaller fecundities and produce multiple clutches of eggs with in a season (Kramer, 1978; Paugy, 2002). Thus, the larger egg size of *G. regressus*, which is unproportional to this smaller sized species, can also be similarly explained.

The high variability in absolute fecundity observed in these species could also be the result of either genetic differences among the females or environmental conditions or a combination of both (Wootton, 1998; Rideout and Morgan, 2007).

The reproductive potential as reflected in the increase in absolute fecundity with length indicates that *Garra* allocates more energy to reproduction as it grows. These are common trade offs in fish between growth and present fecundity (Wootton, 1998). Bagenal (1969) and Paugy (2002) on the other hand, mentioned egg size as a trade off between fecundity and young survival, so that large sized larvae resulting from large egg will have an adaptational advantage. This then might be the reason for lower fecundity observed in *G. regressus,* which has got larger egg size. In *G. tana* the frequency distribution of egg diameters is skewed towards the smaller diameters. Here, therefore, the reverse seems to be the case that, by minimizing egg size they have attained relatively higher fecundity.

The relative fecundity in *Garra* species of L. Tana is low, in comparison with other species of *Garra*; *G. rufa* from Iran streams (mean= 86.84 eggs per gram) (Esmaeili *et al*., 1998), *G. ceylonenesis* in Sri Lanka streams (mean= 866.7 eggs per gram) (De Silva, 1991). However, *G. tana* has comparatively higher relative fecundity (102 eggs per gram) than the other *Garra* species in L. Tana. This might be a strategy for this abundantly found and highly predated (Nagelkerke *et al*., 1995; de Graaf *et al*., 2000) prey species in the deep off shore part of the lake or it might be a

difference in the reproductive investments or genetic variability (Rideout and Morgan, 2007). The effect of predation on one of the most abundant pelagic species in L. Tana, *B. tanapelagius* was revealed in earlier study (Eshete Dejen, 2003), in that this fish showed a larger relative fecundity at smaller length class. The piscivores in L. Tana have their optimum prey size 40-50 mm FL (de Graaf, 2003) that is smaller than the modal length classes of *Garra* species. This then might indicate the less predation pressure on the *Garra* species by the piscivores in the lake. Thus, it is likely that the less variability at different size classes in relative fecundity of L. Tana *Garra* observed might be a different strategy to the one reported in *B. tanapelagius*.

The result of egg size frequency distribution (Fig. 13) in this study shows that *G. dembecha*, *G*. sm and *G. tana* are single spawners in which they spawn once in a breeding season. However, *G. regressus* with extended breeding season showed two distinct peaks in their ova size frequency distribution, which suggests multiple spawning. Species having extended breeding season are usually multiple spawners (King *et al*., 1998 as cited in Eshete Dejen, 2003), in which several clutches of eggs are produced in such species. Basically, multiple spawning helps to reduce competition for nursery and spawning sites, by partitioning their use in time, helps in assuring the survival of some portion of the total spawn to recruitment and provides more adaptability in highly variable environments (Rinchard and Kestemont, 1996; Eshete Dejen, 2003).

The single spawners with one major peak in their egg size frequency among L. Tana *Garra* confirms the statement that benthic species are single spawners because conditions of the environment are usually constant (Bagenal, 1978). Similar spawning conditions were also observed in other species of *Garra* such as *G. ceylonensis* (De Silva, 1991; Sundrabaranthy *et al*., 2005).

Although the frequency distribution of oocyte diameter is an indicator of the nature of spawning in fishes and the presence of more than one group of yolked egg is an accepted criterion that more

than a single spawning takes place (Bagenal, 1978; Blaxter and Hunter, 1982), further histological examination of the gonads of L. Tana *Garra* are required to ensure the single and multiple spawning behavior of the species.

Results of the study showed that, preponderance of male over female was observed in *G. dembecha* while *G. regressus* showed preponderance of females. However, *G.* sm and *G. tana* showed no significant variation in the proportion of females over males from unity. It should be noted that this result doesn't necessarily indicate the sex ratio of the population in the lake. This is because several factors may have an interactive effect as discussed in Demeke Admassu (1994), Zenebe Tadesse (1997) and references there in. Sex based differences in activity associated with breeding behavior might be the reason for sex biased catches in some of the breeding months. For instance, *G. tana* showed preponderance of females in March and April which are the start of peak breeding activity for this fish. On the other hand, males dominated in August, which is after the end of the peak breeding months. In a similar way *G. dembecha* showed dominance of males over females in one of the peak breeding months i.e. June, *G.* sm has shown dominance of females over males in December as well. In *G. regressus,* although not statistically strong to support a deviation from theoretical one-to-one value, females were numerous than males in the catch during the peak breeding months, June and July. So without additional information on the spawning behavior of these species, it would be difficult to eliminate this factor. Since sex reversal was not reported for cyprinids (Devlin and Nagahama, 2002), it will never be the possible factor in this case.

The only exception to have unbalanced sex ratio in most of the non-breeding months was *G.* sm. In July, August and October males were dominant over females, while in September, the opposite became evident. So this probably is attributed to the activity differences between sexes, gear type and sampling site selected as was suggested by Demeke Admassu (1994) for *O. niloticus*.

However, further study is needed to see if these factors are responsible for sex ratio results observed.

The relationship between standard length and total weight of L. Tana *Garra* was highly significant (ANOVA, $p< 0.001$) and curvilinear (Appendix VII). This result conforms to the generalizations made in fish growth (Bagenal and Tesch, 1987). The coefficient of the regression equation calculated in the present study for all L. Tana *Garra* was approximately the same in most cases and was around three as it was expected to be. Therefore, it is possible to say that L. Tana *Garra* shows isometric growth for both sexes, except that males of *G. tana* (b=3.36) and females of *G. dembecha* (b=3.27) tend to show positive allometric growth.

The variation in condition factor of L. Tana *Garra* species between months was statistically significant (ANOVA, $P< 0.0001$). The value of average FCF of *G. tana* and *G.* sm is the same and showed similar pattern of seasonal fluctuations. Generally, L. Tana *Garra* species have relatively good body conditions in the months of March-July than in the other months. Condition of fish can be affected by factors such as environment, food supply, food quality, feeding rate, disease and reproductive activity (Bowen, 1979; Getachew Teferra, 1993). From among the environmental factors temperature seems to be the most important variable. In L. Tana, during the months of March-July the water temperature is much higher than the other months (Eshete Dejen, 2003). So, the better condition of L. Tana *Garra* may be due to the increase in temperature, which possibly increased food consumption and growth.

During the late dry season (March-May), there occurs wind-induced vertical mixing of the lake (Ayalew Wondie, 2006). This mixing, therefore, increases the availability of detritus, epilithic algae and diatoms on which *Garra* species are known to feed. The high temperature coupled with the increase in the availability of food, may account for the better condition of L. Tana *Garra* during this time of the year.

For *G. tana*, *G.* sm, and *G. regressus*, there was a general tendency for their FCF to drop during January and February (Fig. 15), while in March through July months the fishes were in a better condition. It, therefore, appears that a decline in their condition during dry season and its increase during the late dry and pre-rainy season coincides with the primary and secondary productivity regime of L. Tana (Ayalew Wondie, 2006). So it can be generalized that the condition of these species of *Garra* is more likely to be affected by the quality and quantity of food available. However, further studies should be made on the feeding regime of each species of *Garra* in time before any definite generalization.

The low condition factor of *G. dembecha* during the months of November and January as well as in one of the wet season months, August can be attributed to different reasons. For instance, the low condition in August was a phenomenon subsequent to the end of the spawning months (May-July) for this species. However, the low condition in November and January might be related with the poor availability of food and low water temperature of the lake. As it was evident, there is a general reduction in the primary and secondary productivity as well as water temperature of L. Tana (Ayalew Wondie, 2006) during these months, thus making food consumption poor.

5. 4. Aspects of Feeding

The gut content of L. Tana *Garra* is largely composed of detritus, silt and the diatom *Aulacoseira.* The brownish color of their gut contents (Pers. Obs.) might also suggest that these fishes feed more from the bottom surface than from the suspended food. This conforms with the suggestions made about the feeding habit of the fishes based on the position of their mouth (Roberts, 1990; Abebe Getahun, 2000; Zhang, 2005). Furthermore, the appearance of the food items also suggest their detrital origin. This in part supports previous study made on the feeding habits of these species in L. Tana (Driessen, 2002), with a clear reservation on the report made on the presence of

insects in their diet. The presence of insects, however, was reported for another stream dwelling species of the genus, *G. allostoma* (Roberts, 1990). But this is not surprising, as riverine species are more generalist and take advantage of whatever is available (Lowe-McConnell, 1987).

The conformation of the gut contents of the species studied suggests that they are strongly adapted to bottom feeding. Their diets, based on items that are difficult to digest (silt and detritus) (Agastinho and Hahn, 2001) necessitate long intestines so as to maximize the area for absorption. According to Fryer and Iles (1972), the length of the intestine is clearly related to the trophic status of the species, and its length is ordered in the following way: Carnivores< Omnivores< Herbivores< Detritivores. The long gut of *G*. sm and *G. dembecha* which feed largely on detritus and silt as indicated by the muddy color of their gut content can be related to their adaptation for consuming such foods. On the other hand, *G. tana* has shorter intestines than *G*. sm and *G. dembecha*, which are related to a diet based on benthic resources with high nutritional value, as shown by the high occurrences of animal origin food. Abebe Getahun (2000) stated that short intestines indicate a tendency to carnivory in *Garra*.

6. Conclusions and Recommendations

Although the presence of some spawning individuals of *G.* sm at the same time and place with *G. dembecha* might cast doubt on the presence of reproductive segregation, the male tuberculation observed on the snout of *G. dembecha* suggest the existence of recognition of conspecific mating partners through tactile reception. Differences in morphology and in the main breeding times especially, for *G.* sm and *G. dembecha* appear to validate further that they are different species. The absence of any intermediate forms among L. Tana *Garra* might indicate that they are not hybrids. However, further morphological, genetic, and behavioral studies are necessary to rest on the final decision.

The present study provides vital information on size of maturity, main spawning period and breeding place to put in place required information by fisheries managers, although *Garra* are not currently exploited. Thus, the proposed fishery on small barbs in the lake should also consider these small sized fishes, especially in the pelagic habitat as this is shared with *B. tanapelagius*. But prior to any management decision on small meshed fisheries, studies on growth, mortality, biomass and potential yield of *Garra* stock is highly recommended.

Most L. Tana *Garra* species breed during the wet season with a peak in between May-July although some like *G. tana* are capable of breeding throughout the year. While others like *G.* sm breed during the dry season. Therefore, the proposed small-meshed fishery in the pelagic area should consider this peak breeding time so as to minimize the capture of the breeding ones. For other species of *Garra*, distribution pattern indicates that there is an overlap in habitats in the inshore area between *Garra* species and juveniles 'large barbs' as indicated in earlier studies. Thus, further development of a fishery on the inshore dwelling *Garra* should consider at least to the capture of juveniles of 'large barbs' in that area.

L. Tana *Garra* species are regarded as herbivores, feeding on algae, and in some cases zooplankton which have detrital origin. Therefore, a study on the niche occupation along the trophic and spatial dimensions would be important to get the whole picture of trophic resource partitioning or to indicate potential competition for resources among these species.

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8. APPENDICES

Appendix I. Morphometric and meristic data on *Garra* forms of Lake Tana. All measurements and counts agree with Abebe Getahun (2000)'s description. Significant differences (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$) between *G.* sm (sm), *G. regressus* (reg), *G. dembecha* (de) and *G. tana* (tn) are given. These morphometric measurements are used for overall PCA (Appendix V) and cluster analysis (Fig. 7). StDev = standard deviation.

G. sm morphometric characters						sm-tn	sm-de	sm-reg
Variable	n	Mean	StDev	Minimum	Maximum			
As a % of Head Length								
SNL	10	42.97	2.44	39.40	46.71		**	
IOW	10	45.17	2.08	41.77	48.64	***		
Dw	10	32.53	2.40	29.15	37.69	***	***	***
OD	10	23.75	1.50	21.58	26.38		**	
Por	10	41.64	2.94	37.05	46.38			
HD	10	53.49	6.32	45.07	61.68	***		**
As a % of Standard Length								
Pred	10	44.25	0.759	42.81	45.02	**		*
HL	10	19.40	0.566	18.57	20.54	*	***	*
Pecl	10	17.18	1.042	15.69	19.19	**		***
PEL	10	15.78	0.676	14.93	17.10	***		***
BD	10	18.41	1.034	16.82	19.97		***	
AL	10	15.95	0.808	14.77	17.04	*		**
DFL	10	21.78	1.090	20.42	23.23			*
CpL	10	18.53	1.205	16.05	20.5		***	**
Prepec	10	18.22	0.783	16.82	19.52		**	**
Prepel	10	51.78	1.146	49.57	53.24	***	*	**
Prean	10	74.94	0.913	73.84	76.95	***		
post gasblad	10	25.32	1.269	23.71	27.40	***		*
GL	10	24.97	3.50	19.93	32.57	***	***	***
CPD	10	9.556	0.643	8.75	10.44		***	**
vent pos	10	29.19	3.31	24.2	33.59			*
As a % 0f Orbit Diameter								
Rbl	10	68.85	7.60	58.45	79.26	***	**	***
Mbl	10	59.91	6.78	49.06	67.19	**		***

G. sm meristic characters					
Variable	N	Mean	StDev	Minimum	Maximum
Dors. fin rays(simple)	10	3.0	0.0	3.0	3.0

Dors. fin rays (branched)	10	7.0	0.0	7.0	7.0
Anal fin rays(simple)	10	2.2	0.422	2.0	3.0
Anal fin rays(branched)	10	5.7	0.483	5.0	6.0
Pect. fin rays(simple)	10	2.8	0.422	2.0	3.0
Pect. fin rays(branched)	10	12.0	0.0	12.0	12.0
Pelvic fin rays(simple)	10	2.0	0.0	2.0	2.0
Pelvic fin rays (branched)	10	7.1	0.316	7.0	8.0
Lateral line scales	10	40.3	0.483	**40.0**	**41.0**
Scale rows lateral line- dors.	10	5.5	0.0	5.5	5.5
Scale rows lateral line- anal	10	5.25	0.2635	5.0	5.5
Scale rows lateral line- pel	10	5.5	0.0	5.5	5.5
Vertebrae	10	39.3	0.483	**39.0**	**40.0**

Garra regressus meristic characters					
Variables	N	Mean	StDev	Minimum	Maximum
Dors. fin rays (simple)	10	2.0	0.0	2.0	2.0
Dors. fin rays (branched)	10	7.9	0.316	7.0	8.0
Anal fin rays (simple)	10	2.1	0.316	2.0	3.0
Anal fin rays (branched)	10	5.9	0.316	5.0	6.0
Pect. fin rays (simple)	10	3.9	0.316	3.0	4.0
Pect.fin rays (branched)	10	11.1	0.316	11.0	12.0
Pelvic fin rays (simple)	10	2.0	0.0	2.0	2.0
Pelvic fin rays (branched)	10	7.5	0.527	7.0	8.0
Lateral line scales	10	38.8	0.422	38.0	39.0
Scale rows lateral line- dors.	10	5.5	0.0	5.5	5.5
Scale rows lateral line- anal	10	4.4	0.2108	4.0	4.5
Scale rows lateral line- pel	10	4.65	0.2415	4.5	5.0
Vertebrae	10	38.1	0.316	38.0	39.0

G. regressus morphometric characters						reg-tn	reg-de	reg-sm
Variable	n	Mean	StDev	Minimum	Maximum			
As a % of Head Length								

SNL	10	41.559	2.230	36.672	43.768		***	
IOW	10	43.403	1.695	40.817	45.640	**	***	
Dw	10	23.820	2.186	21.432	27.602	***	***	***
OD	10	23.679	1.977	21.314	27.304		*	
Por	10	43.477	1.492	40.822	45.622	**		
HD	10	45.153	1.679	43.270	48.412	*	***	**
As a % of Standard Length								
Pred	10	45.187	0.855	43.615	46.622	***	**	*
HL	10	20.484	0.718	19.586	21.990			*
Pecl	10	19.704	1.379	16.197	21.086		**	***
PEL	10	17.551	1.018	16.443	19.409		*	***
BD	10	19.384	1.358	17.223	20.913	**	*	
AL	10	17.312	0.990	15.908	19.012		**	**
DFL	10	23.011	1.022	21.660	24.693	*	***	*
CpL	10	16.769	0.534	16.065	17.493	**	*	**
Prepec	10	19.751	0.996	18.387	21.418	*		**
Prepel	10	49.851	1.219	48.335	52.038	*	***	**
Prean	10	75.347	0.827	74.213	76.505	***		
post gasblad	10	23.634	1.803	21.259	26.893	***		*
GL	10	66.53	7.32	59.14	78.77	***	***	***
CPD	10	10.502	0.477	9.624	11.406	***	**	**
vent pos	10	26.522	1.325	24.320	28.480		*	*
As a % of Orbit Diameter								
Rbl	10	51.61	4.84	43.61	59.84	***	**	***
Mbl	10	45.614	1.879	40.876	47.963	***	***	***

Garra tana meristic characters					
Variable	N	Mean	StDev	Minimum	Maximum
Dors. fin rays (simple)	10	2.3	0.483	2.0	3.0
Dors. fin rays (branched)	10	7.7	0.483	7.0	8.0
Anal fin rays (simple)	10	2.7	0.483	2.0	3.0
Anal fin rays (branched)	10	5.3	0.483	5.0	6.0
Pect. fin rays (simple)	10	2.5	0.527	2.0	3.0
Pect. fin rays (branched)	10	12.5	0.527	12.0	13.0
Pelvic fin rays (simple)	10	1.7	0.483	1.0	2.0
Pelvic fin rays (branched)	10	7.3	0.483	7.0	8.0
Lateral line	10	39.9	0.316	39.0	40.0
Scale rows lateral line- dors.	10	4.5	0.0	4.50	4.5
Scale rows lateral line- anal	10	4.5	0.0	4.5	4.5

Scale rows lateral line- pel	10	4.4	0.2108	4.0	4.5			
Vertebrae	10	38.6	0.843	37.0	40.0			
G. tana morphometric characters						tn-de	tn-sm	tn-reg
Variable	n	Mean	StDev	Minimum	Maximum			
As a % of Head Length								
SNL	10	43.095	2.979	38.587	46.698	**		
IOW	10	39.455	2.694	34.021	43.611	***	***	**
Dw	10	38.529	2.587	34.426	43.503		***	***
OD	10	23.556	0.925	22.330	25.198	**		
Por	10	40.428	2.103	36.338	42.907			**
HD	10	43.094	2.236	39.242	47.523	***	***	*
As a % of Standard Length								
Pred	10	42.386	1.116	40.331	44.302	**	**	***
HL	10	20.209	0.821	19.066	21.527		*	
Pecl	10	19.056	1.252	17.554	20.979	*	**	
PEL	10	17.496	0.873	16.131	19.210	*	***	
BD	10	17.430	1.319	15.364	19.491	***		**
AL	10	16.829	0.869	15.479	18.475	*	*	
DFL	10	22.096	0.894	20.854	23.998	*		*
CpL	10	18.391	1.224	16.229	20.097	*		**
Prepec	10	18.578	0.981	17.447	20.315	**		*
Prepel	10	48.593	1.176	46.838	50.495	***	***	*
Prean	10	72.987	0.886	71.957	74.957	***	***	***
post gasblad	10	19.853	1.891	18.000	24.397	***	***	***
GL	10	51.12	7.68	36.68	61.89	***	***	***
CPD	10	9.147	0.750	8.090	10.179	***		***
vent pos	10	27.171	2.704	24.080	33.390			
As a % 0f Orbit Diameter								
Rbl	10	95.91	7.43	81.22	106.14	***	***	***
Mbl	10	71.95	10.65	59.57	89.33	**	**	***

Garra dembecha meristic characters					
Variable	N	Mean	StDev	Minimum	Maximum
Dors. fin rays (simple)	10	2.5	0.527	2.0	3.0
Dors. fin rays (branched)	10	7.5	0.527	7.0	8.0
Anal fin rays (simple)	10	2.5	0.527	2.0	3.0
Anal fin rays (branched)	10	5.5	0.527	5.0	6.0
Pect. fin rays (simple)	10	3.5	0.527	3.0	4.0

Pect. fin rays (branched)	10	12.5	0.527	12.0	13.0		
Pelvic fin rays (simple)	10	1.7	0.483	1.0	2.0		
Pelvic fin rays (branched)	10	8.2	0.422	8.0	9.0		
Lateral line	10	39.4	0.516	39.0	40.0		
Scale rows lateral line- dors.	10	5.5	0.0	5.5	5.5		
Scale rows lateral line- anal	10	4.65	0.2415	4.5	5.0		
Scale rows lateral line- pel	10	3.5	0.0	3.5	3.5		
Vertebrae	10	38.3	0.483	38.0	39.0		
G. dembecha morphometric characters						de-tn	de-sm	de-reg
Variable	n	Mean	StDev	Minimum	Maximum			
As a % of Head Length								
SNL	10	46.852	1.880	44.228	50.086	**	**	***
IOW	10	46.851	1.778	43.457	49.774	***		***
Dw	10	38.269	2.681	34.506	43.001		***	***
OD	10	20.807	2.538	17.319	24.564	**	**	*
Por	10	42.621	2.833	38.253	45.507			
HD	10	51.85	3.57	45.38	57.80	***		***
As a % of Standard Length								
Pred	10	44.207	0.594	43.239	44.738	**		**
HL	10	20.944	0.894	20.000	22.628		***	
Pecl	10	17.729	1.146	16.048	19.038	*		**
PEL	10	16.195	1.394	14.938	19.498	*		*
BD	10	21.032	1.345	18.130	22.779	***	***	*
AL	10	16.006	0.583	15.058	16.844	*		**
DFL	10	20.971	0.889	19.118	22.185	*		***
CpL	10	16.044	0.893	14.718	17.358	*	***	*
Prepec	10	20.361	1.560	18.424	24.235	**	**	
Prepel	10	52.933	0.576	51.409	53.497	***	*	***
Prean	10	75.123	0.990	73.881	77.286	***		
post gasblad	10	24.073	2.265	20.521	26.825	***		
GL	10	14.421	1.733	11.517	16.771	***	***	***
CPD	10	11.230	0.223	10.787	11.517	***	***	**
vent pos	10	29.261	2.934	24.850	34.00			*
As a % of Orbit Diameter								
Rbl	10	57.73	3.95	50.21	64.01	***	**	**
Mbl	10	54.85	5.50	49.37	68.36	**		***

Appendix II. *Garra* species collected from the feeding rivers of L. Tana and their tributaries.

Rivers	Locality	coordinates		Date	Habitat	Species
		Lat.	Long.			
Kokga	After the dam	$11^0$20'51.2''	$37^0$08'14.4''	26/606	Pool	*G. dembeensis*
Kokga	After the dam	11^0 20'51.2''	$37^0$08'14.4''	26/606	Rifle	*G. dembecha**
Kiltii	Bridge area	11^0 28'35.1''	$36^0$57'19.1''	26/606	Rifle	*G. dembecha??*
Kiltii	Bridge area	11^0 28' 5.1''	$36^0$57'19.1''	26/606	Rifle	*G. dembecha**
Kiltii	Bridge area	11^0 28'35.1''	$36^0$57'19.1''	26/606	Rifle	*G. ignestii*
Idiyemo	Down the bridge	$11^0$41'31.6''	$37^0$28'12.7''	8/11/06	Rifle	*G. ignestii*
Gelda	Bridge area	$11^0$43'27.7''	$37^0$30'19.4''	7/11/06	Back pool	*G. ignestii*
Gelda	Bridge area	$11^0$43'27.7''	$37^0$30'19.4''	7/11/06	Back pool	*G. ignestii*
Gumara	Wanzaye	$11^0$47'16.2''	$37^0$40'43.0''	8/11/06	Rifle	*G. dembeensis*
Gumera	Maksegnit Town	$12^0$23'27.2''	$37^0$26'56.7''	7/11/06	Small rapids	*G. ignestii*
Gumera	Maksegnit Town	$12^0$23'27.2''	$37^0$26'56.7''	7/11/06	Small rapids	*G. dembecha**
Megech	Up the bridge	$12^0$29'24.7''	$37^0$26'56.7''	6/11/06	Rifle	*G. ignestii*
Megech	Up the bridge	$12^0$29'24.7''	$37^0$26'56.7''	6/11/06	Rifle	*G. dembecha**
Dirma	Kola diba town	$12^0$25'39.4''	$37^0$19'33.7''	6/11/06	Pool	*G. duobarbis*
Dirma	Kola diba town	$12^0$25'39.4''	$37^0$19'33.7''	6/11/06	Pool	*G. dembecha??*
Dirma	Kola diba town	$12^0$25'39.4''	$37^0$19'33.7''	6/11/06	Pool	*G. dembecha**
Dirma	Kola diba town	$12^0$25'39.4''	$37^0$19'33.7''	6/11/06	Rifle	*G. ignestii*

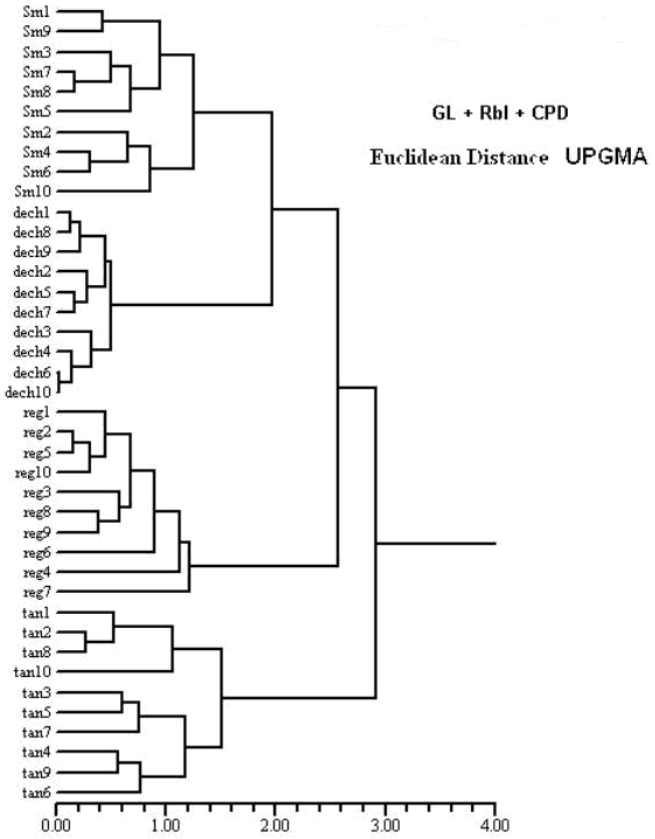
?? = They are similar to the *G. dembecha* of L. Tana in their morphological features.

* = They coincide with the description given in Stiassny and Getahun (2007) in that they lack chest, belly, and post pelvic scales.

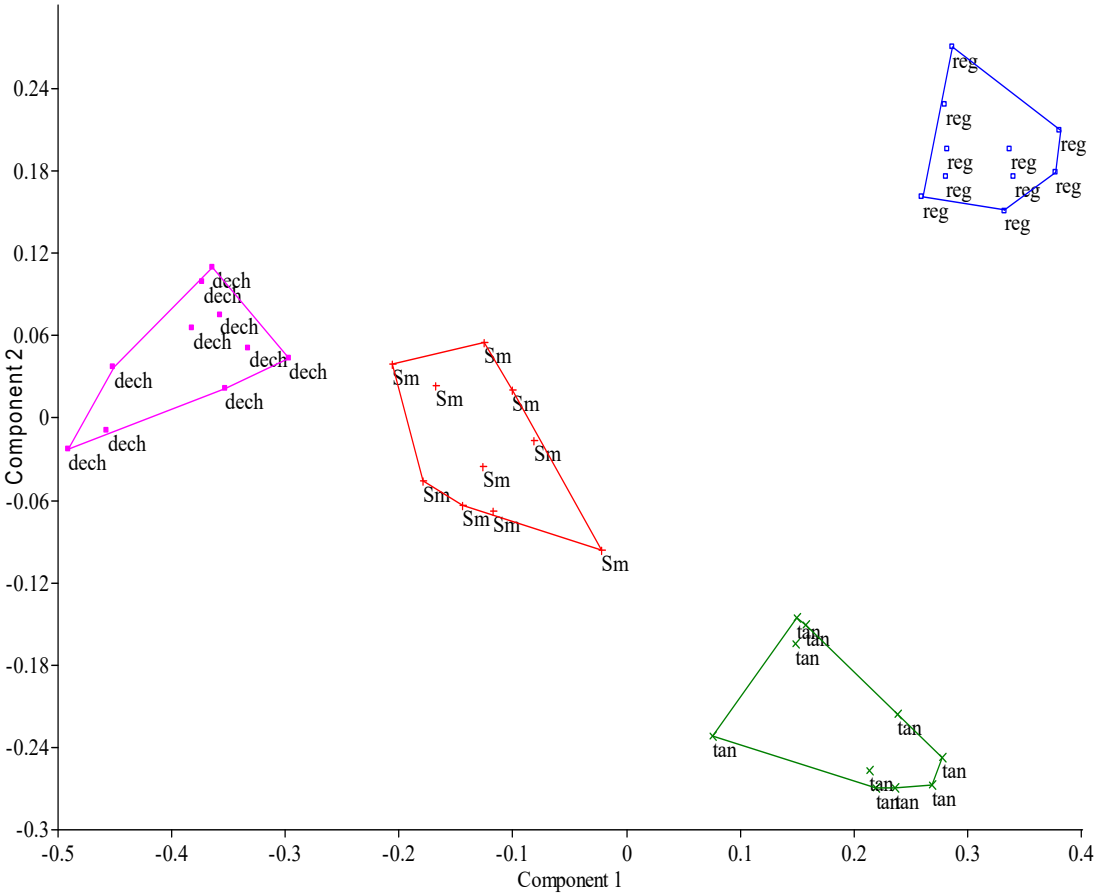
Appendix III. Loadings of 14 skull bone measurements on the two principal components.

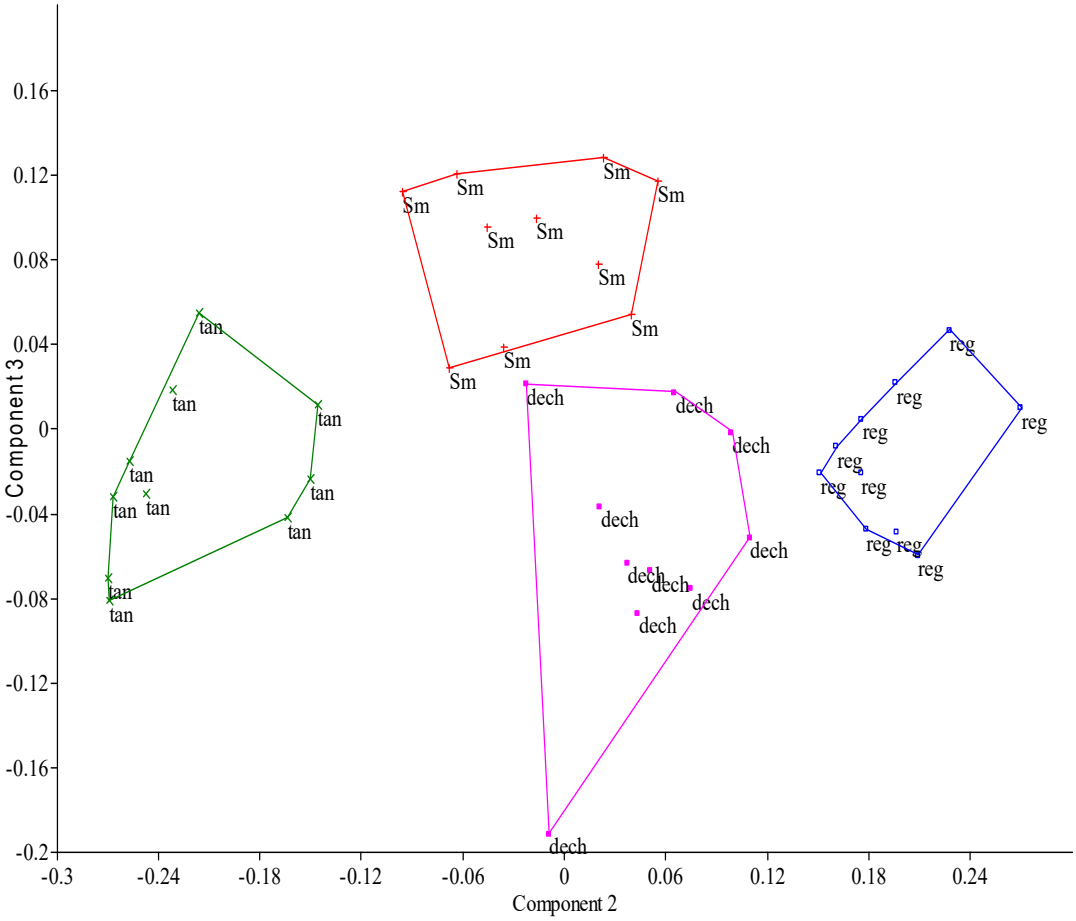
	Principal component loadings	
Characters	PC 1	PC 2
BL	-0.296	0.0319
B3	-0.2919	0.2029
B2	-0.2526	0.2851
B1	-0.253	**0.3254**
HS1	-0.2336	-0.1591
HS2	-0.1263	0.2444
Hm	**-0.3387**	-0.01598
Pm	-0.1337	**-0.4638**
Pop	**-0.3236**	0.148
Op	**-0.3139**	-0.1462
Iop	-0.2856	-0.1708
mx	-0.1394	**-0.4466**
de	-0.1167	**-0.4432**
pha	-0.262	-0.01046
Cl	**-0.3313**	0.04293

Appendix IV. Dendrogram using three best external morphometric characters.



Appendix V. Scatterplot of individuals of *Garra* based on 23 log-transformed external morphological characters using Principal Component Analysis (PCA) with Variance-covariance matrix. The character loadings are on the table below the PCA plots. Specimens designated include: dech (*G. dembecha*), sm (*G.* sm), reg (*G. regressus*) and tan (*G. tana*).

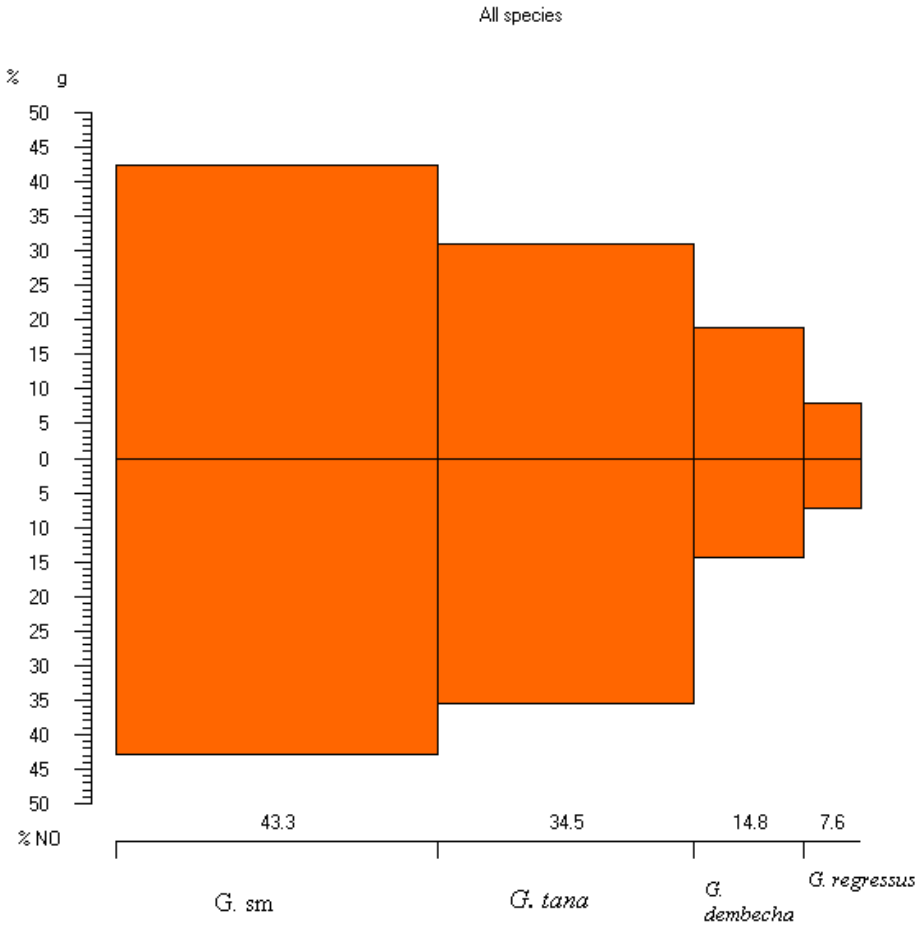




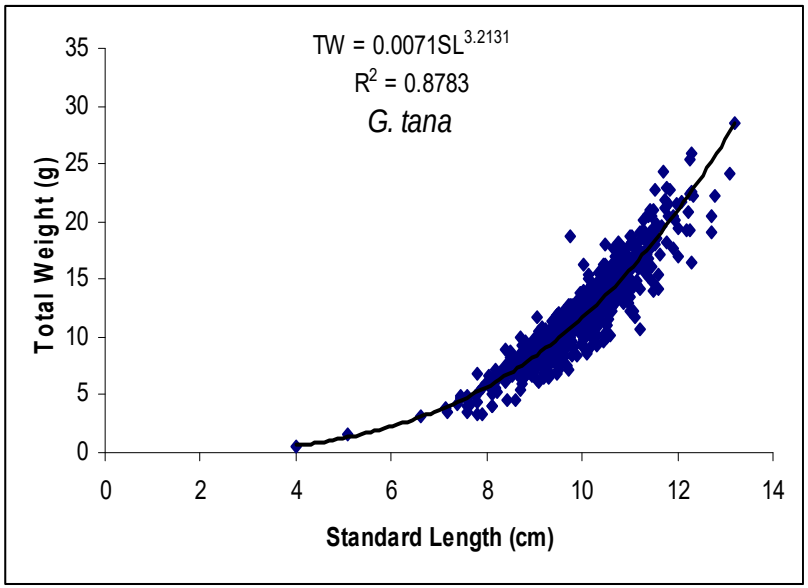
Characters	PC 1	PC 2	PC 3
SL	-0.02079	0.03966	-0.1708
Pred	-0.01153	0.06236	-0.01021
HL	-0.01281	0.01795	-0.286
SNL	-0.05562	-0.02438	-0.2016
OD	0.07271	0.000562	**0.332**
Por	0.000297	0.07372	0.09351
HD	-0.1132	0.04972	0.2811
Pecl	0.05914	0.03365	-0.1723
PEL	0.0668	-0.00331	-0.1441
AL	0.04752	0.03581	-0.043
BD	-0.06087	0.124	-0.2955
DFL	0.0435	0.03628	-0.00089
CpL	0.02883	-0.1194	0.2295
CPD	-0.0632	0.1639	-0.2715
Vent pos	-0.0633	-0.00255	0.2259
Post gasbladder	-0.07808	0.1772	**0.3486**
GL	**0.9502**	0.003113	-0.04042

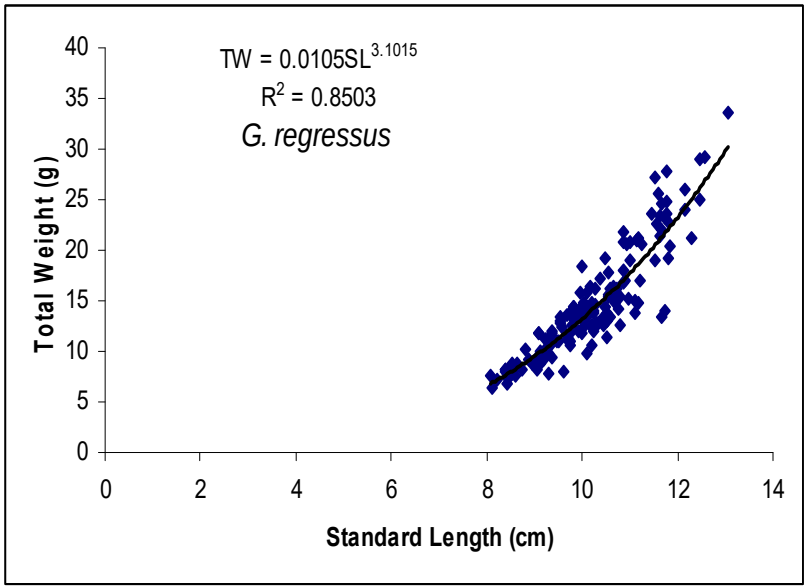
IOW	-0.07986	0.1201	0.1026
Rbl	0.06206	**-0.6698**	0.07233
Mbl	-0.02375	**-0.4806**	0.06281
Dw	-0.1744	**-0.439**	-0.2891
Prepec	-0.01892	0.06719	**-0.3241**
Prepel	-0.05366	0.04164	0.03776
Prean	-0.00849	0.03358	0.01568

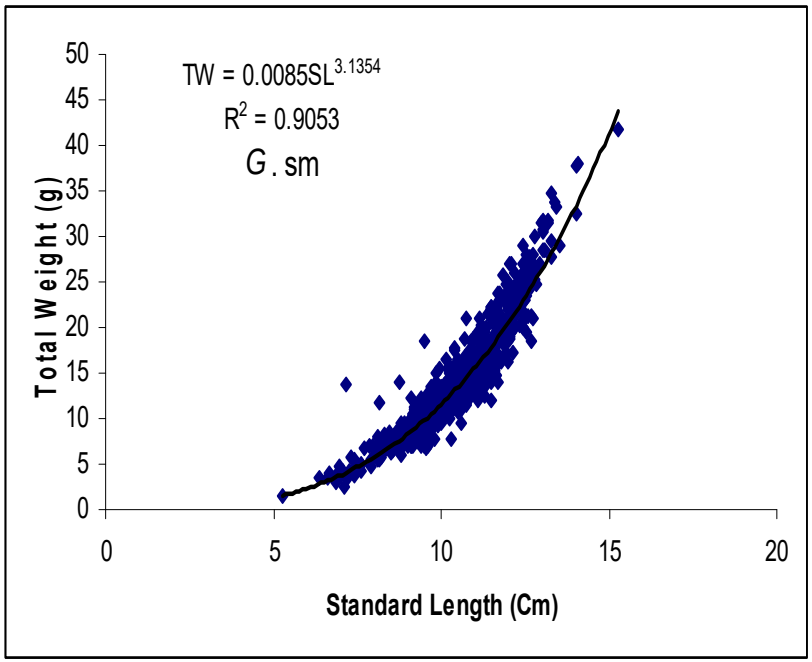
Appendix VI. The IRI of abundance of species in biomass (%g) (the upper part) and in number (%NO) (the lower part) in the year round samples from all sites (pooled).

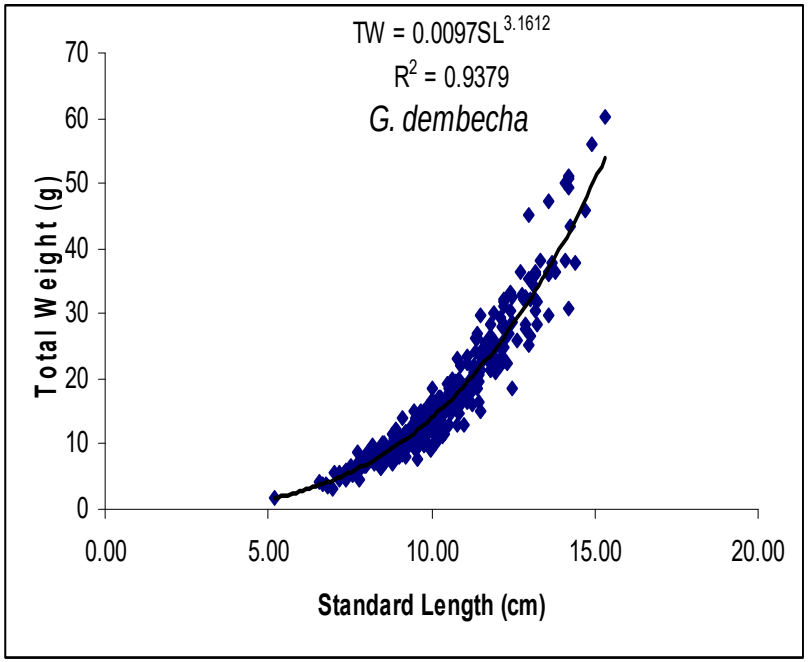


Appendix VII. Graphs of Length-weight relationship of L. Tana *Garra* (*G. dembecha*, *G. regressus*, *G. tana* and *G.* sm).






TW = 0.0085SL3.1354
R2 = 0.9053
G. sm
Total Weight (g)
Standard Length (Cm)
0
5
10
15
20
0
5
10
15
20
25
30
35
40
45
50


TW = 0.0097SL3.1612
R2 = 0.9379
G. dembecha
Total Weight (g)
Standard Length (cm)
0.00
5.00
10.00
15.00
20.00
0
10
20
30
40
50
60
70