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SYSTEMATIC STUDIES OF THE AFRICAN SPECIES OF THE GENUS GARRA (PISCES: CYPRINIDAE)

BY

ABEBE GETAHUN

A dissertation submitted to the Graduate Faculty in Biology in partial fulfillment of
the requirements for the degree of Doctor of Philosophy, the City University of
New York.

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ABSTRACT

SYSTEMATIC STUDIES OF THE AFRICAN SPECIES OF THE GENUS GARRA (PISCES: CYPRINIDAE)

By

Abebe Getahun

Advisor: Dr. Melanie Stiassny

Morphological, morphometric and meristic characters have been used to resolve the taxonomic confusion that exists among the African species of the genus *Garra*. Five species (*G.dembecha, G.duobarbis, G.geba, G.microstoma* and *G.tana*) are described for the first time. Three species (*G.aethiopica, G.blanfordii* and *G.hindii*) are resurrected and two species, *G.trewavasae* and *G.tibanica,* are synonymized with *G.ornata and G.quadrimaculata* respectively. A total of 29 nominal species have so far been described from the Continent and 17 species are, herein, recognized valid. A neotype is designated for one species, *G.dembeensis,* in which the type specimen is lost and the original description and the illustration are found to be inadequate. 6 lectotypes were designated for species previously known from syntypes (*G.aethiopica, G.blanfordii, G.hindii, G.ignestii, G.lancrenonensis* and

G.makiensis)
The monophyly of the sub-family, in which *Garra* is placed- Labeinae, and the interrelationships of the genera within are evaluated. The monophyly of the sub-family is corroborated with four synapomorphies. *Garra* is closely related to the disc bearing genera *Discogobio, Discocheilus* and *Semilabeo.*

Three synapomorphies (the presence of two or more anterior unbranched fin rays, an elongated cleithrum and a wide and short supraethmoid) corroborate the monophyly of the genus *Garra.* But, there is no evidence that suggests the monophyly of the African *Garra.*

The interspecific relationship of *Garra* could not be completely resolved. However, one clade and two sub-clades could be recognized. The clades consist of both African and Asian species.

Species of the genus are found in freshwaters of Africa from Ethiopia in the east to Guinea in the west and Egypt in the north (following the Nile river) to Tanzania in the southeast. Its range is also extended to the Zaire basin and Angolan freshwaters in the southwest. Species richness tends to decrease from east to west. In Ethiopia, where the species richness is highest, 75% of the species are from two northern drainage basins (The Abbay and Tekezze basins). One species (*G.quadrimaculata*) is shared by the Afro-Arabian countries, being found in three African countries (Eritrea, Ethiopia, and Somalia) and in the Arabian Peninsula (e.g. Yemen, Saudi Arabia). An early Paleocene Gondwanic origin of *Garra* is suggested with a Vicariance-Dispersal model.

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others. Ken Lazara has a special place in helping me sort out some of my difficulties in taxonomy.

I am grateful to the photography workshop, AMNH, especially to Denis Finnin in helping me take quality pictures of the many species discussed herein. Angela Clause of the Interdepartmental Laboratory has helped me in making ESM and many of the slides prepared for presentation of this work at different conferences and I am thankful. Prof. Marcus has provided me with a number of softwares and also helped in taking and analyzing the landmark data using geometric morphometric.

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INTRODUCTION

Scientific study of the genus *Garra* began in the early nineteenth century (Buchanan, 1822). Major taxonomic contributions on the Asian species include those of Annandale (1919a, 1919b), Annandale and Hora (1920), and Hora (1921) (mainly on the Indian species), Nichols (1943) and Qingtai & Baoshan (1987) on the Chinese species, Kottelat et al. (1993) on Indonesian species, Kottelat (1998) on Laotian species, Monkolprasit et al. (1997) on Thai species, and Krupp (1983, 1988) and Krupp and Schneider (1989) on species of the Arabian Peninsula. The primary works on African species are those of Rüppell (1836), Boulenger (1901, 1902, 1903, 1905, 1907, 1909 and 1911), and Pellegrin (1905, 1923, 1927, 1935, and 1939). Menon (1964) provides a revision of the genus although African, Chinese and Vietnamese species were poorly represented in that study.

According to Menon (1964) a total of 38 valid species are known. Of these, 8 are from Africa, 6 are from the Middle East, Arabian Peninsula and North-western Asia, while the remaining 24 are from India and South-east Asia. Not included in Menon (1964), or described since, are 3 species (*G.allostoma* Roberts, 1990; *G.congoensis* Poll, 1959 and *G.lancrenonensis* Blache & Miton, 1960) from Africa, a number of species and sub-species (at least 7 species) from the Arabian Peninsula (Krupp, 1983), 1 species from Iran (Coad, 1982), about 6 more species from China (Zhang, E. per. com.), 4 new species from Vietnam (Mai, 1978), and most recently one new species (*G.theunensis*, Kottelat, 1998) from Laos. Thus the number of valid species in the genus, including those described in the present review, is close to 60.

No major biological or ecological studies of the genus have been undertaken (see appendix 1 for review of some of the works).

The genus has a geographic distribution from Borneo, China and Southern Asia through the Middle East, Arabian Peninsula and East Africa to West Africa, thus ranging from about 35°N to about 5°S (Fig.1). With the exception of one species from southern Turkey (Reid, 1996) the genus does not occur in Europe. However, whether or not Southern Turkey should be included in the European realm is questionable. The historical biogeography of Cypriniformes in general and of cyprinids including *Garra* in particular is controversial (see e.g. Nichols 1928, 1930, Darlington 1957, Gery 1969, Roberts 1969, Novacek & Marshall 1976). Howes (1980,1984) considered the present distribution of bariliines, barbines and labeines (including *Garra*) as reflecting a series of vicariant events related to Gondwanian fragmentation. Discussion of historical biogeography is necessarily incomplete due to the rarity of fossil data and paucity of phylogenetic studies. As noted by Greenwood (1983: 183) "Without sound phylogenies even the most carefully contrived scenario-style biogeographical schemes lack credibility, no matter how well substantiated by ecological and physiological data (or surmises) they may appear to be ".

The record for fossil cyprinids in Africa is generally meagre (Cavender, 1991) and no fossil *Garra* have so far been found. African fossils of related genera (*Labeo* and *Barbus*) are known from Tunisia and Kenya (Van Couvering, 1977) dated to about 17 mbp and fossil pharyngeal bones and teeth of *Labeo* have been identified from the Pliocene deposits of Wadi Natrun, Egypt (Greenwood, 1972).

No phylogenetic studies (sensu Hennig, 1966) of the genus have so far been undertaken. Some hypotheses have been suggested by Hora (1920) and Menon (1964). The most notable contribution in terms of a more rigorous phylogenetic approach with sister groups is that of Reid (1978, 1982). According to Reid, *Garra* is included in a Garraini tribe in the subfamily Labeinae. Other members include *Garra*-like cyprinids such as *Semi-labeo*, *Crossocheilus* and *Epalzeorhynchus* (Fig.2). Reid based this grouping on a number of characters, two of which are the presence of a vomero-palatine organ and the presence of a labial fold developed posterior to the lower jaw. However, the presence of these two characters in *Garra* cannot be verified in this work whereas other characters (see details in the monophyly section-part 2 of this thesis) corroborate the grouping of *Garra* in Labeinae and Garraini.

Much confusion persists as far as the taxonomy of the African species is concerned. Rüppell (1836) was the first to describe two species of the genus from Africa. He named his Ethiopian specimens as *Chondrostoma dembeensis* (= *Garra dembeensis*); *Gobio quadrimaculatus* and *Gobio hirticeps* (= *G.quadrimaculata*). There remains confusion surrounding the status of *G.quadrimaculata* in general and this is discussed in more detail in the species account.

Blanford (1870) referred to specimens collected from Ethiopia and Eritrea as *Discognathus lamta*, believing that these specimens did not differ from those from Palestine and Yemen (from where the type specimens were collected). However, specimens of *D.lamta* from the Near East differ from the African specimens. But, as Annandale (1919b) described, *D.lamta* has some relationship to the "specialized" species of Africa. Although what he called specialized is not clear, it may refer to those species of *Garra* having a well-developed disc and a vent far away from the anal fin (e.g. *G.dembeensis* and *G.hindii*). Vinciguerra (1883) reported specimens belonging to "*D.lamta* " and described a new species, *Discognathus chiarinii*, from Lake Arsade (Hora), Ethiopia (synonymized with *G.dembeensis* by Menon (1964)).

Important early studies of the freshwater fish fauna of Africa in general and of the genus *Garra* in particular are those of G.A. Boulenger. Boulenger (1901) described *Discognathus johnstonii* from Lake Victoria and *D.vinciguerrae* from the Nile River. At the same time he renamed specimens collected from Ethiopia and Eritrea as *D.blanfordii* (= *D.lamta* of Blanford, 1870). Later, Menon (1964) synonymized *D. blanfordii* with *D.quadrimaculatus*, and *D.johnstonii* and *D.vinciguerrae* with *G.dembeensis*.

Boulenger (1903) described *D.makiensis* from Maki River, Ethiopia. In the same work he provided an identification key for the six species then known (*D.blanfordii*, *D.dembeensis*, *D.johnstonii*, *D.makiensis*, *D.quadrimaculata* and *D.vinciguerrae*).

Boulenger (1905) described another new species *D.hindii* from the Nyiro River, Kenya. This species which was synonymized with *G.dembeensis* by Menon (1964), is resurrected in this work

Pellegrin (1905) described another new species, *D.rothschildi*, from the Gotta River, Ethiopia. Boulenger (1909) synonymized this species with *D.dembeensis* and also *D.chiarinii* with *D.quadrimaculatus*. Menon (1964) synonymized

D.rothschildii with *G.makiensis*

Nichols and Griscom (1917) described *D.ornatus* from Congo basin. This species is recognized as valid by Menon (1964) and this review. Five nominal species (*D.baudoni, D.occidentalis, D.waterloti, G.waterloti var dageti* and *G.trewavasae*) described later from western and central Africa are junior synonyms of this species. The first four have been synonymized by Menon (1964) and confirmed in this work while the fifth one is synonymized in this review.

Lönnberg and Rendahl (1920) described *D.occidentalis* from Kingoyi, at the watershed between French and Belgian Congo. This species has been synonymized with *G.ornata* by Menon (1964).

Pellegrin (1923) described *D.baudoni from* Gabon. This species has been synonymized with *G.ornata* by Menon (1964). Pellegrin (1927) also described another new species *D.aethiopicus* from Ethiopia. This species was synonymized with *G.quadrimaculata* by Menon (1964) but it is resurrected in this review (see details in the species accounts section).

Gianferrari (1925) described *G.ignesti* from Kahha and Angerab Rivers in Ethiopia. This species remains valid in both Menon (1964) and this review. The same author in 1932 described *D.giarabensis* from some of the specimens he had collected from Eritrea and identified as *D.blanfordii* in 1924. Menon (1964) synonymized this species with *G.dembeensis*. However, the type of this species is deposited in the Milan Museum but Menon (1964) strangely states that it is deposited in Trieste Museum. The present review after examining the type specimen at Milan Museum affirms that this species is a junior synonym of the now valid species *G.blanfordii* not *G.dembeensis*.

Pellegrin (1935) described *D.waterloti* from Guinea. This species was synonymized with *G.ornata* by Menon (1964). Gianferrari (1936) also described a sub-species of *D.blanfordii*, *D.blanfordii cimmaruta* from Adwa, Ethiopia. This sub-species was synonymized with *G.quadrimaculata* by Menon (1964) who, again, incorrectly states that the type specimen is deposited in the Trieste Museum. The type (housed in Milan Museum) has been examined and shown to be a synonymy of *G.blanfordii* (see details in species accounts section)

Trewavas (1941) described *G.tibanica* from Yemen. This species is now synonymized with *G.quadrimaculata* (a problematic species that remained confused for the whole century- see the species account for details). The species has been recorded from three countries in Africa (Ethiopia, Eritrea and Somalia). The materials from Ethiopia and Eritrea have been investigated and their identity confirmed while the whereabouts of the Somalian specimens cannot be determined.

Monod (1950) described *G.trewavasae* from Nigeria and this is recognized here as a junior synonym of *G.ornata*. Monod (1950) also described a sub-species, *G.waterloti dageti* which Menon (1964) correctly synonymized with *G.ornata*.

Menon (1958) described *G.ethelwynnae* from Salamona, Eritrea, a small sized species known only from two specimens. It remains valid.

Poll (1959) described *G.congoensis* from Lower Zaire River system, Congo.

Menon (1964) was not aware of its description and no mention was made of this species in his review. The same is true of *G.lancrenonensis and G.allostoma.*

Blache & Miton (1960) described *G.lancrenonensis* from Central African Republic and Roberts (1990) described *G.allostoma* from Cameroun and both are valid species.

Generally, in previous works, 24 species have been described of which 11 were considered valid (Daget *et al.*, 1984). Many of the species have been synonymized by Menon (1964).

At this point, several questions can be asked about the genus. Is the diversity of the African species under-or over-estimated? Is the genus *Garra* monophyletic? Do the African species of the genus show a close relationship among themselves or are any of the African species closer to Asian species than to other African species? Is there any pattern and explanation in the biogeography of the genus?

To answer the above questions, the present study was designed to:

1. Thoroughly study and resolve taxonomic problems pertaining to the African species of the genus. The main motivations for the taxonomic study are:

   A. Extensive collections and investigations have not been made in Ethiopian freshwaters where the diversity of the African species of the genus was presumed to be high. As is now clear, the species number was underestimated and the taxonomy of most species was inconsistent and confusing. This has also been noted by other scientists working on Lake Tana, Ethiopia (Nagelkerke, 1998).

B. Menon (1964), focused mainly on the Asian species, specifically the Indian ones, to which he had easy access to both field and museum specimens. The African species, in most cases, were not directly investigated and their diagnosis and description was flawed. Many of the inconsistencies are pointed out elsewhere in the text. To mention but a few here, the types of three African species (*G.ignesti, G.giarrabensis and G. blanfordii cimmaruta*) are located at the Milan Museum and have not been investigated since their description (pers.obs. and communication with the curators at Milan Museum), while Menon (1964: 193, 195 and 200) states that these specimens are housed at the Trieste Museum and have been investigated by him. In another instance, the type specimen of *G.dembeensis* was not deposited at the Senckenberg Museum (pers. com. with Uwe Zajonz at the Senckenberg Museum) while Menon (1964: 199) states their presence in this Museum. Clearly the revision of the African species of the genus in Menon's review need to be revisited.

2. See whether or not the genus *Garra* is a monophyletic group.

3. See whether or not the African species of the genus constitute a monophyletic entity within *Garra*.

4. Look at the phylogenetic relationships among the species of the genus with an emphasis on the African species.

5. Look at patterns in the geographic distribution of the genus.

The study is presented as follows:

1. The materials and methods employed during this study are presented in detail.

2. An artificial key of all the African species with their distinguishing characters is constructed. The key is followed by descriptions of the genus and individual species. 5 new species described from Ethiopia are included in this section.

3. Following the descriptions of the species, characters that are important in the taxonomy of the genus are discussed.

4. The phylogenetic position of *Garra* within the sub-family Labeinae is evaluated

5. Monophyly and phylogenetic relationships within the genus is discussed

6. Geographic distribution of the genus is described.

The first three are given in the first part of the thesis while the last three are discussed in the second part of the thesis.

MATERIALS AND METHODS

Specimens were collected from Ethiopian freshwater bodies between 1995 and 1997 using seine net, trawl net and hook and lines. About 109 localities from all the drainage basins of Ethiopia (Fig.3) have been sampled and overall nearly 6000 fish specimens have been collected. A short description of the drainage basins and the fish fauna of Ethiopia is given at the end of this section. Details on the Ethiopian fish fauna and its problems can be found in Getahun and Stiassny (1998). Specimens were fixed in 10% formalin in the field and later transferred to 75% alcohol. This study has benefitted from those field collections since freshly caught specimens have obvious advantages over museum specimens in taxonomic studies:

1. All the natural characters, including colors, can be easily detected and recorded,
2. Series of specimens representing the populations can be examined, and
3. Distortions arising as a result of preservation can be minimized.

About 2000 specimens of *Garra* that have been collected and deposited at the American Museum of Natural History have been studied. About 1000 specimens including all types of all the 24 previously described species from 12 American and European Museums have also been investigated either through direct visit or through loans. A complete list of whole alcohol preserved specimens; cleared and stained materials and radiographs studied are given in appendices 2-4.

External morphological, morphometric and meristic data have mainly been used in species diagnoses. Measurements and counts were made on the left side of the body. Measurements were made using a dial caliper to the nearest 0.1mm. Where possible, 30 specimens representing different size groups were selected and measured. The morphometric data have been converted into percentages with respect to standard length, head length and eye diameter. These data are given as a summary statistics for each species. It has been suggested by some workers (e.g. Packard and Boardman, 1987) that comparing ratios may have problems because of the presence of allometry.

Standard univariate statistics methods (mean, median, range, standard deviation and standard error) have been used to summarize the morphometric data. Multivariate analysis of landmarks has been utilized to investigate shape differences in a pair of species (*G.blanfordii* vs *G.dembecha*) through GRF-ND (Generalized Rotational Fitting in N-Dimensions) and TPS (Thin Plate Spline) programs of Geometric Morphometric (Marcus et al., 1996). Landmarks have been digitized from radiographs of specimens using a digitizing tablet and a software "winwedge". The specimens were alligned using Relative warp (Rohlf and Slice, 1990). The relative warp and partial warp scores were tested for differences using SAS program version 6.12 for Windows 95. Using GLS (Generalized Least Squares) of GRF-ND, size data was processed and shape was regressed on centroid size using TPSREG (Thin-Plate Spline Regression). Ratios (after being corrected for size using standard length) of traditional redundant distance measures (sensu Rohlf and Archie, 1978) were also subjected to Multivariate analysis using SYSTAT.

Osteological investigations were made using specimens cleared and stained following Taylor & Van Dyke (1985). Whenever possible more than one specimen of each species were studied.

To facilitate ready comparisons of the characters with previous reviews of the genus, many of the characters and their definitions follow Menon (1964). An illustration of measurements utilized in this review is given in Fig.4. The definitions are as follows:

A. Measurements

Standard length: a distance from the tip of snout to the caudal base.

Body depth: a distance from dorsum to ventum in front of the dorsal fin.

Head length: a distance from the tip of snout to the posterior bony edge of the operculum.

Head width: a distance through the head, taken at the extreme posterior end of the head between the two opercula.

Head depth: a distance from a point on the occiput (behind the eye) and the isthmus ventrally.

Snout length: a distance between the tip of snout and the anterior rim of the orbit.

Diameter of eye: a distance between the anterior and posterior walls of the bony orbit.

Position of Eye: measuring the distance from the tip of snout to the middle of the eyeball and comparing that to the total length of the head determines position of eye. If the former is half of the length of the head, the position is at the middle. If it is less than half the distance of the head length, then the position is at the anterior part of the head. If it is more than half, then the position is at the posterior part of the head.

Interorbital width: a straight-line distance between the upper rims of the two eyes.

Disc length: a distance between the anterior mid- point and the posterior end of the disc.

Disc width: a distance between the bases of the two maxillary barbels.

Length of fin: a distance from the base of the anterior most ray to the end of the longest ray in the fin.

Width of fin: a distance measured at the widest part of the fin.

Vent position: a distance between the anterior end of anal fin and the vent (given as a percentage of the distance between the anterior ends of the anal and pelvic fins).

Caudal peduncle length: a distance between the posterior end of the anal fin and the postero-ventral end of the caudal peduncle.

Caudal peduncle depth: a distance between the dorsum and ventum of the caudal peduncle at the narrowest part.

Intestine length: the whole intestine was taken out from each specimen, spread to straighten and measured from its anterior tip where it joins the oesophagus to its posterior tip where it joins the vent. Relative intestine length for each fish was determined by dividing the standard length by the length of the intestine. All intestines measured were from adult specimens.

Gas bladder length: the whole gas bladder including the anterior and the posterior parts were measured in alcohol preserved specimens. In some of the cases it is the posterior part that is prominent and measurable. Hence, relative gas bladder length was determined by dividing the standard length by the length of the posterior part.

B. Counts

Lateral line scales: counted from the scale adjacent to the operculum to the caudal base along the lateral line.

Dorsal fin-lateral line scales: diagonal scales from the anterior end of the dorsal fin to the lateral line.

Pelvic fin-lateral line scales: diagonal scales from the anterior end of the pelvic fin to the lateral line.

Anal fin-lateral line scales: diagonal scales from the anterior end of the anal fin to the lateral line.

Predorsal scales: scales from the anterior end of the dorsal fin to the occiput.

Circumpeduncle scales: scales counted around the caudal peduncle at the narrowest part.

Scales between vent and anal fin: The number of scales counted between the posterior end of the vent and the first ray (origin) of anal fin.

Vertebrae: vertebral counts were made from radiographs and cleared and stained specimens. Vertebral counts include the four weberian vertebrae and a single caudal fin vertebra following Skelton (1988) and Tweddle & Skelton (1998).

Gill rakers: number of the outer gill rakers on the lower portion of the outer arch of the left side.

Fin rays were counted from radiographs and cleared and stained specimens, unless these were not available.

C. Morphological Features:

The Suctorial Disc: is an important feature and three types of discs are recognized, types A, B and C depending on their degree of development (Fig.5 A-C). Type A is an inconspicuous disc without free posterior margin. Type C is a developed disc with free posterior margin and Type B is an intermediate with conspicuous disc but indistinct free posterior margin. The disc structure is described in greater detail under character discussion.

Color: descriptions are based on field observations of freshly caught specimens and preserved ones in the case of the Ethiopian species and solely on the preserved specimens in the other cases.

Institutional abbreviations follow Leviton et al. (1985). The following abbreviations are also used: **SL**=standard length; **HL**=Head length: **Max** =Maximum; **Min**=Minimum; **N**=Number of specimens; **SD**=Standard deviation.

A dichotomous artificial key is constructed to identify the African species of the genus. It has no phyletic implication.

Phylogenetic methods:

Alcohol preserved and cleared and stained specimens have been studied (appendices 7 and 8). Osteological and external morphological characters were used to evaluate the generic relationships among labeine genera and the relationships among the species of *Garra*.

Following Platnick (1979) and Stevens (1980) a character is defined as any aspect of the organism being examined while character states are the attributes of that character. Characters were assigned discrete character states in a binary coding scheme. Statements of character condition for the outgroup as well as the ingroup are strictly based on the species examined here.

Drawings were sketched using a Wild TVP microscope with camera lucida attachment. The specimens used in illustrating the work are given in the figure caption.

The methodology used to investigate the relationships is phylogenetic as outlined in Hennig (1966) and later discussed by various authors (e.g. Eldredge and Cracraft, 1980; Madison et al., 1984; Wiley, 1981; Wiley et al., 1991; Watrous and Wheeler, 1981). Unconstrained simultaneous analysis (Nixon and Carpenter, 1993; Kitching et al., 1998) was carried out to find out the most parsimonious distribution of the characters.

The phylogenetic study was done at two levels of universality, at the level of the sub-family Labeinae and at the level of the genus *Garra*.

Exemplars of the genera *Barbus* and *Varicorhinus* were selected as outgroups in the evaluation of the labeine genera investigated. The selection of this outgroup was based on the phylogenetic works of Reid (1978, and Fig.2) in which *Barbus* is considered to be the sister group of the Labeinae. *Varicorhinus* has also been suggested to be closely related to Garraini and particularly to *Garra* (Matthes, 1963), and hence is included as a second outgroup. In the recent work of Howes (1991) *Varicorhinus* is placed with *Barbus* under the barbine lineage.

Ingroup genera for the labeine analysis include *Tylognathus* - Tribe Tylognathini (10 species—Southeast Asia, Banarescu, 1986), *Cirrhinus* – Tribe Labeini (1 species? Southeast Asia, Zhang, 1999), *Osteocheilus* – Tribe Labeini (23 species, Southeast Asia, Karnasuta, 1993), *Labeo* - Tribe Labeini (46 species from Africa, Reid, 1978, the number of Asian species—not known) *Paracrossocheilus* - Tribe Garraini (2 species, Southeast Asia, Banarescu, 1986), *Crossocheilus* – Tribe Garraini (10 species, Southeast Asia, Banarescu, 1986), *Epalzeorhynchos* – Tribe Garraini (5 species, Southeast Asia, Yang and Winterbottom, 1998), *Garra* - Tribe Garraini (ca. 70 species, Africa, Middle east, Arabian Peninsula, India and Southeast Asia, this work), *Discocheilus* - Tribe Garraini (2 species, restricted to Xijiang River, China, Zhang, pers.comm.), *Discogobio*- Tribe Garraini (12 species, Yangtze River and Nanpan-Jiang rivers, China, Zhang, pers.comm.) and *Semilabeo* – Tribe Garraini (2 species, Southeast Asia, Zhang, 1994). The species and number of specimens investigated in this study are given in appendices 7 and 8.

In the investigation of the relationship among species of *Garra*, the genera *Discogobio*, *Discocheilus*, *Semilabeo*, *Crossocheilus*, *Paracrossocheilus* and *Epalzeorhynchos* were used as outgroups. The above genera have been shown to be closely related to *Garra* in this work (Fig.48). *Discogobio*, the sister group, is represented by one specimen of one species. The other genera, except

Epalzeorhynchos, are also poorly represented and their monophyly is not well confirmed, hence the need to use multiple outgroups.

The ingroup includes 24 species of *Garra* of which 3 are with incomplete data. Those with incomplete data are *G.allostoma*, *G.ethelwynnae* and *G.lancrenonensis*. These species are represented by a holotype and a paratype or few paratypes so clearing and staining was not possible and radiographs were found inadequate to resolve many anatomical details. Therefore, they are not included in the analysis. Of the remaining species (Table 40) 14 are African, 2 Middle Eastern and Arabian, 2 Indian and 3 Southeast Asian.

The non-African species were selected based on the following rationales:

1. They represent the full geographical range of the genus
2. They are available for study and
3. Those included in this study represent all the "groups" mentioned in Menon (1964) as evolutionary units in *Garra*.

Computer analyses utilize Hennig86 (Farris, 1988) for parsimony analysis and CLADOS ver. 1.07 (Nixon, 1988) for examination of character distributions and the production of figures. Bremer support (Bremer, 1988, 1994) was employed to test the stability of the clades using PAUP (Swofford, 1993). The rationale behind using this method is that it is based on the original data unlike the other methods (boot-strap and jack-knifing) that rearrange (add or delete) the data. No specific optimization is enforced. However, CLADOS, by default, optimizes characters at polytomies such that independent steps are minimized.

Strict consensus was used to summarize the data from equally parsimonious cladograms. It is preferred since it is compatible with all the cladograms, unlike the Majority-rule consensus that contain those monophyletic groups that appear in a majority of the cladograms.

The Drainage Basins of Ethiopia

Ethiopia has some 7000 km^2 of inland water bodies (Wood and Talling, 1988) contained in about 9 drainage basins (Tedla, 1973, also Fig.3). The drainage pattern is the result of the uplifting during the tertiary period, which created the Rift valley and consequently the two separate highlands (Mohr, 1966).

The northern and central highlands of the country are drained by westward flowing rivers (e.g., the Abbay, Angereb and Tekezze, which form part of the Nile drainage basin) and the eastward flowing rivers draining into the rift valley (e.g. the Katar, Meki and Mojo). Left bank tributaries of the Abbay, the Baro-Akobo and the Ghibe-Omo river systems drain the southwestern part of the highlands.

Mainly the Ghenale and Dawa Rivers drain the southwestern part of the eastern highlands while the southeastern part of the eastern highlands is drained by the headwaters of the Shebelle and Fafan.

Largely the Awash River and its tributaries drain the Ethiopian Rift Valley and Afar lowlands. The Ethiopian Rift valley also contains a number of small endoreic lakes from which the greater part of the country's fish harvest is drawn. The Ethiopian rift lakes include the southern lakes (Chamo and Abaya), the northern lakes (Awassa, Shala, Abiata, Langano, and Ziway) and the saline northern lakes (Afambo, Gamari, Afdera, Asale and part of Abbe). There are also crater lakes such as the high plateau Bishoftu group (Hora, Bishoftu and Arenguade), and Lake Chitu in the rift valley. The Ethiopian highland lakes include Lakes Tana, Hayq, Ardebo and Ashengie. Lakes Garba Guratch and Orgona are high mountain lakes in the Bale region.

The Fish Fauna Of Ethiopia

The freshwater fish fauna of Ethiopia is of particular interest since it contains a mixture of Nilo-Sudanic, East African, and endemic forms (Boulenger, 1905; Nichols and Griscom, 1917; Roberts, 1975; Banarescu, 1995). The Nilo-Sudanic forms are represented by a large number of species found in the Baro-Akobo, Omo-Ghibe and Abay drainage basins (e.g. the genera *Alestes, Bagrus, Barilius, Citharinus, Clarias, Garra, Hydrocynus, Hyperopisus, Labeo, Lates, Malapterurus, Mormyrus, Polypterus* and *Protopterus*).

The southern Rift Valley Lakes (Lakes Chamo and Abaya), and the Shebelle Ghenale basins also have elements of these forms and it is believed that these lakes and river basins had former connections with the upper White Nile (through Lake Rudolf in the former case) as recently as 7500 years ago (Roberts, 1975; McClanahan and Young, 1996). These Nilo-Sudanic forms are believed to reflect past connections of the Nile to Central and West African river systems (Boulenger, 1905; Nichols and Griscom, 1917; Nichols, 1928).

The highland East African forms are found in the Northern Rift Valley lakes (e.g. Awassa, Ziway, Langano), the highland lakes (e.g. Tana, Hayq), and associated river systems, and the Awash drainage basin. These include the genera *Barbus, Clarias, Garra, Oreochromis*, and *Varicorhinus*. They are related to fishes of Eastern and Southern Africa. The major Nilotic groups are rare or absent from the Awash and northern rift valley lakes.

Ethiopian endemics are so far represented by *Danakilia franchettii, Nemacheilus abyssinicus, Garra makiensis, G.ignestii* and a large number of *Barbus* species.

The Species Concept

It is widely believed that there is confusion in the concept of a species and very much so in its recognition (Frost and Hillis, 1990; Frost and Kluge, 1994). The biological species concept (Mayr, 1969) has obvious limitations mainly in the difficulties of determining reproductive compatibility of different populations, not-mentioning its frailty to serve fossil species and uniparentals. Both operationally and theoretically, the phylogenetic species concept seems to be superior over the others, although it may have its own limitations. In this work, the phylogenetic species concept is adopted and morphologically discernible populations are considered valid species. Probably the most fitting definition of species would be that mentioned by Wheeler and Platnick in Mayden and Wood (1995): "The smallest aggregation of populations diagnosable by a unique combination of character states". I am in agreement with the notion that a species may not fulfill the criterion of monophyly since Hennigian monophyly and synapomorphy are for diagnosis of a genus and above.

There exist practical problems in determining autapomorphies for any one species of *Garra*. So, diagnosis of species is usually based on a unique combination of morphological, morphometric and meristic characters, although there exists considerable intraspecific variations in some cases. Whether or not intraspecific variation and populational differences indicate "phenotypic plasticity " and "geographic variation" are difficult to verify. Donoghue (1985) assigns, and de Queiroz and Donoghue (1988, 1990) defend, a "metaspecies" concept for such populations lacking autapomorphies. This concept has been critically reviewed elsewhere (Nixon and Wheeler, 1990) and is not accepted here. The concept and use of "sub-species" has, again, been questioned by many workers including Frost et al., (1992) which I share a similar view.

It is true, however, that rejection of the biological species concept, and a reliance on the phylogenetic species concept and the use of morphometric and meristic characters in determining species may result in an overestimate of the diversity. As discussed in Frost and Hillis (1990), when determining dynamically evolving entities like species, we should be prepared to accept errors of "Type I (recognizing more species than exist), and there is no theoretical or operational advantage in underestimating diversity". Conservation objectives also benefit from exactly identifying existing lineages (if possible) or overestimating them but not otherwise.

ARTIFICIAL KEY TO THE AFRICAN SPECIES OF GARRA

1. Two pairs of barbels--2
   One pair of barbels--
G.duobarbis

2. Disc well developed with free posterior end (see Fig.5C)------------------------3
   Mental disc little or not developed and with no free posterior end (see Fig.5 A & B)--13

3. Chest and belly covered with overlapping scales ----------------------------4
   Chest and belly naked ---5

4. Vent near anal fin (distance from vent to anal fin 8.6-19.1% of the distance between anterior ends of anal and pelvic fins); Position of eye in the middle of the head;
Lateral line scales 34-35. ------*G.quadrimaculata*

   Vent far away from anal fin (distance from vent to anal fin 29.3-30.2% of the distance between anterior ends of anal and pelvic fins); Position of eye at the posterior part of head;
Lateral line scales 40-42. -------*G.hindii*

5. Post-pelvic region naked --6
   Post-pelvic region scaled ---8

6. Full predorsal region scales; White creamy in color; Larger gas bladder, length of gas bladder (posterior part) 21.7-24.4% of standard length----------------
G.blanfordii
   No or 2-3 scales on the predorsal region; Dark black body coloration; Smaller gas bladder, length of gas bladder (posterior part) 20.9-21.6% of standard length)-----7

7. Dorso-ventrally flattened head and body (body depth 14.8-16.8% of standard length); not very well developed disc (Type B disc)----------------------*G.geba*

Dorso-ventrally not flattened (body depth 15.6-23.9% of standard length); Very well developed disc (Type C disc)--------------------------*G.dembeensis*

8. Full predorsal region scales --9
Partial or few predorsal region scales ----------------------------------10

9. Body deep (body depth 29.1-30.9% of standard length); Lower number of scales on the lateral line (29-30); Lower number of vertebrae (27-28)------*G.ethelwynnae*
Body not deep (body depth less than 25% of standard length); Higher number of scales on the lateral line (greater than 34); Higher number of vertebrae (greater than 30)----11

10. Body dorso-ventrally flattened (body depth 10.6-15.0% of standard length); Very well developed disc (Type C); A very small gas bladder, length of gas bladder (posterior part) 3.1-3.8% of standard length.
-----------*G.congoensis*
Body dorso-ventrally not flattened (body depth 15.8-22.3% of standard length); not very well developed disc (Type B) ------------------------------*G.ornata*

11. Vent very near to the anal fin (distance from vent to anal fin 10.3-16.9% of the distance between anterior ends of anal and pelvic fins); Few scales on the belly and chest; Position of eye at the posterior part of head ---------*G.makiensis*
Vent far away from anal fin (distance from vent to anal fin 19.2-29.5% of the distance between anterior ends of anal and pelvic fins); No scales on belly and chest; Position of eye at the anterior part or at the middle of the head ----------12

12. Rostral fold indented; tuberculated snout; Long intestine (more than 5 times the standard length); Eyes at the middle of the head ---------------------*G.ignestii*
Rostral fold not indented; No tubercles on snout; Short intestine (1-2 times the standard length); Eyes at the anterior part of the head-------------*G.aethiopica*

13. Post-pelvic region scaled---14
Post-pelvic region naked---15

14. Rostral fold down grown covering the upper lip---------------------------16

Rostral fold short not covering the upper lip--------------------***G.microstoma***

15. Caudal peduncle thin and elongated (length of caudal peduncle 20.4-22.3% of standard length); Higher number of scales on the lateral line (39-40); Short intestine; (standard length 62.7-79% of length of intestine); Known only from Lake Tana, Ethiopia. ----------------***G.tana***

Caudal peduncle thicker and short (length of caudal peduncle 13.3-20.7% of standard length); Lower number of scales (37-38); long intestine (standard length 40-56% of length of intestine); Known from Eritrea, Ethiopia and Kenya. ---***G.dembecha***

16. Vent very close to the anal fin (distance between vent and anal fin 13.3-17.4% of the distance between the anterior ends of pelvic and anal fins); only known from Chad. ---------------------***G.lancrenonensis***

Vent far away from anal fin (distance between vent and anal fin 28.5-30.6% of the distance between anterior origins of pelvic and anal fins); only known from Cameroun---------------------**G.allostoma**

SPECIES ACCOUNTS

As is obvious from previous discussion, species identification within the genus is problematic and the alpha-level taxonomy is confused. This is especially true for the African species for which the available information is scanty. The confusion may be attributed to individual variability exhibited by many of the species, in for example, scale counts, number of fin rays, and vertebral counts. These are important species level diagnostic characters in many cyprinid genera but seem to have little taxonomic significance in *Garra*.

In this work, one species is synonomized with *G.ornata*; another with *G.quadrimaculata*, three species are resurrected and five new species are described bringing the total described species to 29 and of valid species to 17 (see Table 1). In most cases, a combination of morphological, morphometric and meristic characters have been used to diagnose the species (refer to Table 2 for summary of the unique combination of diagnostic characters). Photographs and sketch drawings of the new species are given. Photographs of representative specimens and sketches of type specimens taken from the original descriptions of the species are also included, (whenever available in the latter case, as some of the original descriptions are without any illustration).

The accounts are arranged in the following sequence:

1. **Synonymy**: As far as possible a full synonymy of each species is presented.

2. **Materials Examined**: All type materials of all species have been examined. The

type materials and the non-type materials are listed in such a way that the museum number is given followed by the standard length in mm and the locality from where the specimens were collected. Whenever available, latitude and longitude data are included.

3. Diagnosis: In most cases a combination of characters is used to diagnose the species. Most important characters in the diagnosis of the species include disc development, position of vent, squamation, size of intestine, gas bladder, and coloration and shape of the body.

4. Description: A more or less uniform format is followed to describe all the species so that easy comparison should be possible. Summaries of morphometric and meristic features used in the description are given in tables for each species.

5. Color: Whenever possible color of freshly caught specimens is described in comparison with the preserved ones. Color of the whole body, the fins and some markings on the body are noted.

6. Geographic distribution: the drainage basin(s) and the country (ies) in which each species is distributed are illustrated by distribution map(s). In the case of the new species the habitat is described together with some environmental data.

7. Remarks: Other important points that are not accomodated in the above sections are included here.

Description of the genus

Garra Buchanan, 1822. Fish. Ganges p.393. (Type, *Cyprinus lamta* Ham. by monotypy and subsequent designation).

The genus is confirmed as monophyletic on the basis of the following three synapomorphies: the presence of 2 prominent anterior unbranched pectoral fin rays, narrow and elongated cleithrum and short and broad ethmoid.

Body elongate and subcylindrical. Mouth transverse, inferior and semi-circular. Upper and lower lips are continuous without any lateral lobes. A suctorial disc present on chin, with free posterior margin in some. Barbels two, four or absent. Paired fins horizontal. Dorsal fin inserted slightly ahead of pelvics. Dorsal fin with 10 to 11 rays (both unbranched and branched) with no spines. Caudal fin slightly emarginate. Anal fins with 8 to 9 rays (both unbranched and branched). Anal base well behind that of dorsal. A proboscis may or may not be present. Lateral line complete and continued to the center of the base of caudal fin. Lateral line below the axis of the body. Pharyngeal teeth are generally in three rows, 2,4,5-5,4,2. Gill openings restricted to sides. Lower jaw sharpened (keratinized) and rough to the touch. Eye situated above the median axis of the body. Tubercles found in both males and females. The vent is variously located, near the anal fin in some species or more distant in others. The ethmoid is wider than long in the dorsal aspect. There are 5 or 6 infraorbital bones. No vomero-palatine organ is present in adults.

Garra aethiopica **(Pellegrin, 1927)**

Fig.6

Discognathus aethiopicus **Pellegrin 1927,** *Bull.Soc.Zool.Fr.*,Paris, **52** pp.231-233. **Eschemeyer, 1998,** *Catalog of fishes*, Vol.1, p.46.

Garra aethiopicus: **Menon, 1964,** *Memoires of the Indian Museum*, Vol.**14**, No.4, p.193 (given as synonym of *G.quadrimaculata*; should have been mentioned as *D.aethiopicus*). **Daget et al., 1984,** *CLOFFA*, Vol.1, p.304 (given as synonym of *G.quadrimaculata*; should have been mentioned as *D.aethiopicus)*. **Fowler, 1976,** *Q.J.Taiwan Mus.*, **29(1-2)**, p.83.

Materials Examined:

Lectotype: MNHN 1927-125; 88.4mm SL, Kabana River, tributary of Awash, in Addis Ababa city at an altitude of 2400m, Ethiopia.

Paralectotype: MNHN 1927.126; 84.4mm SL, same locality as lectotype.

Other Materials: BMNH 1985.7.16.113-117; 63.7-79.7mm SL (5), Abo River near Addis Ababa, Ethiopia (misidentified as *G.dembeensis*). **BMNH 1985.7.16:111-112**; 26.8-1.9mm SL (2), Awash River, Ethiopia (misidentified as *G.dembeensis*). **BMNH 1984.9.7:48**; 44.9mm SL (1), Mojo River, Ethiopia (misidentified as *G.dembeensis*). **AMNH 223672**; 45.4-114.3mm SL (8), Kabana River, Addis Ababa, Ethiopia (9°N and 38°45'E). **AMNH 223649**; 41.1-81.5mm SL (8), Meki River, Near Meki Town, Ethiopia (8°15'N and 38°50'E). **AMNH 223674**; 38.8-78.5 mm SL (17), Akaki River, Near Addis Ababa (9°N and

38°45'E). **AMNH 223676**; 85.8mm SL (1), Mekanisa River, Near Addis Ababa, Ethiopia (9°N and 38°45'E). **AMNH 227315**; 28.8-105.4mm SL (66), Megecha (Gubre) River, In Gubre town, about 10km south of Welkite town on the road to Hosaina, Ethiopia (8°5N and 37°55E); **AMNH 223836**; 21.3-99.1mm SL (86), Awash River, 1 km east of Ginchi town, 80 km from Addis Ababa on the way to Nekempte, Shoa, Ethiopia (9°5N and 38°5E).

Diagnosis:

This species is distinguished from all other African species of the genus by the following combination of characters: It is gray in color, it has an intermediate disc (type B), full scales on predorsal and post-pelvic regions, and no indents on the rostral fold.

Description:

Slender body; body depth 18.9-25.2% of standard length. Length of head 19.8-25.6% of standard length; width of head 63.3-81.0% of length of head; depth of head 58.4-78.0% of length of head. Snout 27.9-42.2% of length of head; no tubercles on snout. Eye located at the anterior part of the head; diameter of eye 15.5-27.2% of length of head; interorbital width 38.6-50.4% of length of head.

Disc is Type B; rostral fold well developed but not indented as opposed to that of *G.dembecha*, *G.ignestii* and *G.makiensis* for example. Papillae restricted to lower lip and peripheral parts of the disc; length of disc 23-37.4% of length of head; width of disc 36.4-55.3% of width of head; length of disc 60.5-97.7% of its own width; two pairs of short barbels; maxillary shorter than rostral barbels; rostral barbels 65.7-107% of the diameter of eye;

33-36 scales on the lateral line; 4.5 scales from lateral line to origin of dorsal; 3.5 scales from lateral line to origin of pelvic and 4-4.5 scales from lateral line to origin of anal fin; dorsal side of the body is completely covered with scales; 12-13 scales on the predorsal region; the post-pelvic region is also scaled; few scales on belly, and chest is naked.

Dorsal fin with 3-4 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 43.3-51.1% of standard length. Pectorals with 4 unbranched and 11 branched rays; length of pectoral 17.9-23.0% of standard length. Anal fin with 3-4 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 6 branched rays; 30-32 vertebrae, a low number compared to generics.

Vent located moderate distance from anal fin (distance from vent to anal fin 19.2-29.5% of the distance between origin of anal and pelvic fins); 2-3 scales between vent and anal fin. Length of caudal peduncle 14.2-18.9% of standard length; depth of caudal peduncle 10.7-12.8% of standard length; 13-16 circumpeduncle scales.

13 gill rakers on the lower part of the outer gill arch. The length of gas bladder (posterior part) 18.3-21.1% of standard length. Intestine is medium in length; 115.8-135.6 mm in absolute length; standard length 47-76% of length of intestine.

Summary of morphometric and meristic features of the species is given in Table 3.

Color:

The body is gray dorsally with a narrow white stripe laterally just below the dorsal fin and a white ventral surface. Prominent black spots at the base of the dorsal fin; they are absent at the anterior part of the fin. A central lining of gray color on the chest, belly and post-pelvic regions.

Geographic distribution:

Found in the Awash drainage basin, Ethiopia (Fig.7).

Remarks:

Menon (1964) had synonomized it wit*h G.quadrimaculat*a. However, *G.quadrimaculata* has a perfected disc. The margin of the rostral fold is not indented in *G.aethiopica* while it is indented in *G.quadrimaculata*. *G.aethiopica* is similar to *G.makiensis* and *G.ignestii* in having a full predorsal scales, and similar number of scales on the lateral line. It differs from both species by its grey color (*G.makiensis* and *G.ignestii* are dark brown to dark black). The length of the intestine is short in *G.aethiopica* (1-2 times the standard length while *G.ignestii* and *G.makiensis* have long intestines (more than 5 times the standard length). The rostral fold in *G.aethiopica* is not pronounced and septated as in the case of the two former species. The position of the eye is infront in *G.aethiopica* while it is behind in *G.makiensis* and in the middle in *G.ignestii*. Scales on the belly are totally absent in *G.ignestii* while there are some scales (non-overlapping) on the belly in *G.aethiopica* and *G.makiensis*.

Garra allostoma Roberts 1990

Fig.8 and 9A

Garra allostoma **Roberts 1990,** *Rev.Hydrobiol.Trop.*, **23(2)**: 161-169.
Eschemeyer, 1998, *Catalogue of fishes*, v. **1**, p.75.

Materials Examined:

Holotype: MNHN 85-93-69-1; 51.8 mm SL (1), Niger basin, Cameroun.

Other Material: CAS 66740; 41.8mm SL (1), R.Menchum, Bamenda highlands, Niger River basin, Cameroun.

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has undeveloped disc (type A), no predorsal scales, few post-pelvic scales, no indents on the margins of the rostral fold, deep caudal peduncle (depth of caudal peduncle 12.3-12.7% of standard length).

Description:

Small fishes (41.8 to 51.8 mm SL). Body not very deep; body depth 20.5-21.7% of standard length. Head shorter but deep; length of head 24.9-25.1% of standard length; width of head 76.7-79.1% of length of head; depth of head 51.2-60.1% of length of head. Snout without tubercles; snout 41.1-44.2% of length of head. Eyes located in the middle of the head; diameter of eye 20.2-24.4% of length of head; interorbital width 34.9-38.8% of length of head.

The disc is poorly developed without free posterior end (type A); no margins on the rostral fold; no papillae on disc; the disc is longer than wide; two pairs of small barbels; rostral barbels are longer than maxillary barbels; rostral barbel length 43% of the diameter of the eye.

36 scales on the lateral line; 4.5 scales from the lateral line to the origin of dorsal fin; 3.5 scales from the lateral line to the origin of pelvic fin; 4 scales from the lateral line to anal fin; no predorsal scales, no scales on chest and belly, only few scales on the post-pelvic region.

Dorsal fin with 3 unbranched and 7 branched rays; distance between anterior origin of dorsal fin and tip of snout 48.3-48.8% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectoral 20.5% of standard length. Anal fin with 3 unbranched and 5 branched rays. Pelvic fin with 2 unbranched and 6 branched rays.

Position of vent far away from anal fin; distance from vent to anal fin 28.5-30.6% of the distance between origins of pelvic and anal fins; 3 scales between vent and anal fin. Length of caudal peduncle 14.9% of standard length; depth of caudal peduncle 12.3-12.7% of standard length; 15-17 circumpeduncle scales.

Summary of morphometric and meristic features of the species is given in Table 4.

Color:

It is creamy in color both dorsally and ventrally, the underside being lighter. There are black spots at the base of the caudal fin and dorsal fin, the latter more prominent.

Geographic distribution:

Reported only from R. Menchum, Niger River basin, Cameroun (Fig.10).

Remarks:

Roberts (1990) reported two rows of pharyngeal teeth for this species. Yet, this cannot be confirmed due to lack of materials for clearing and staining. It is similar to *G.dembecha* in having poorly developed disc and a vent located far away from the anal fin. However, it is different from *G.dembecha* in having no scales on the predorsal region (*G.dembecha* is partially scaled) and in having a non-indented rostral fold. Besides, its small size and creamy color are also distinctive.

Garra blanfordii **(Boulenger 1901)**

Figs.11 and 12A

Discognathus lamta **Blanford 1870,** *Geol.Zool.Abyssin.*,London, p.460. **Vinciguerra 1883,** *Ann.Mus.Stor.nat.Genova*, **18** p.695.

Discognathus blanfordii Boulenger **1901,** *Proc.Zool.Soc.*London, **2** p.160. **Boulenger 1903**, *Proc.Zool.Soc.Lond.*London p.330. **Boulenger 1909,** *Cat.Freshwater Fish Africa*, London, **1**, p.349, fig.263. **Daget et al., 1984,** *CLOFFA*, vol. **1**, p. 304 (as synonym of *G.quadrimaculata*). **Eschemeyer, 1998,** *Catalog of fishes*, vol. **1**, p.238. **Hora 1921,** *Rec.of the Ind.Mus.* Vol. **22. Menon, 1964,** *Memoirs of the Indian Museum*, **14 (4)**: 192-193 (as synonym of *G.quadrimaculata*). **Tedla, 1973,** *Freshwater fishes of Ethiopia*, p.30.

Discognathus vinciguerrae Boulenger **1901,** *Proc.Zool.Soc.Lond.London* p.160. **Boulenger 1907,** *Fish of the Nile*, London, p.185, Pl.31, fig.4. **Boulenger 1909.** *Cat.Freshwater Fish Africa*, London, **1**, p.347, fig.261. **Daget et al., 1984,** *CLOFFA*, vol. **1**, p.304 (as synonym of *G.quadrimaculata*). **Eschmeyer, 1998,** *Catalog of fishes*, vol.**2**, p.1762. **Menon (1964),** *Memoirs of the Indian Musuem*, **14** (4), p.199 (as synonym of *G.quadrimaculata*).

Discognathus giarrabensis Gianferrari **1932.** *Boll.Zool.Napoli, Naples*, 1, p.2. **Daget et al., 1984,** *CLOFFA*, vol. **1**, p. 302 (as synonym of *G.dembeensis)*. **Eschmeyer, 1998,** *Catalog of fishes*, vol. **1**, p.641. **Menon, 1964,** *Memoirs of the*

Indian Museum, vol.14 (4), p.200 (as synonym of *G.dembeensis*).

Discognathus blanfordii cimmaruta **Gianferrari 1936,** *Atti.Soc.Ital.Milano*, Milan, 75, p.295. **Daget et al., 1984,** *CLOFFA*, vol.1, p.304 (as synonym of *G.quadrimaculata*). **Menon, 1964,** *Memoirs of the Indian Museum*, **14(4),** p. 193.

***Garra blanfordii*:** **Fowler, 1976,** *Q.J.Taiwan Mus.*, **29(1-2),** p.83.

Materials Examined:

Lectotype: BMNH 1869-11.4.39; 56.6 mm SL (1), stream at Suru and small pool left at Amba, about twenty-five miles north of Massawa, Eritrea.

Paralectotypes: BMNH 1869.2.8.4-11; 36.2-51.3mm SL (8), Abyssinia. **BMNH 1872.12.18.3**; 41.6mm SL (1), Amba, Abyssinia

Other Materials: BMNH 1907.12.2 1175-9 (type of *D.vinciguerrae*); 35.4mm SL, Near Kermeh, 3rd Cataract (Nile R.), Abyssinia. **MSNM, ex 4290, new 22 (holotype of *D.giarrabensis*)**; 59.2mm SL, Giarraba, Eritrea. **MSNM, ex 4844, new 21 (holotype of *D.blanfordii cimmaruta)***; 72.9mm SL, Gherungura, Adua, Abyssinia. **BMNH 1962.10.31.18-32**; 37.3-76.3mm SL (13), Blue Nile, 25 miles north of Debre Marcos, Ethiopia (misidentified as *G.quadrimaculata*). **BMNH 1962.10.31.1-17**; 37.2-68.9 mm SL (18), Blue Nile, 25 miles north of Debre Marcos (misidentified as *G.quadrimaculata*). **BMNH 1902.12.13.410-419; 46.34**-85.5mm SL (10), Jerrer River, near Harrar, Ethiopia (misidentified as *Discognathus quadrimaculatus*). *BMNH 1903.11.16.15-17*; 26.4-61.7mm SL (3), Gadshimboda

River, Ethiopia (misidentified as *D. quadrimaculatus*). **MNHN 85-93-10-2**; 53.4-68.0mm SL (3), Afrique Orientale. **MNHN 85-93-10-3**; 53.4-67.3mm SL (2), Abyssinia. **MSNM Ex. 4424 New 2108**; 44.4mm SL (1), Abyssinia. **MSNM Ex. 4321 New 20**; 45.6mm SL (1), Massawa, Abyssinia. **AMNH 223686**; 24.4-62.9mm SL (45), Chimuga River, 3 km south of Debremarkos town, Gojam, Ethiopia (37°45E 10°15N). **AMNH 223748**; 27.1-48.5 mm SL (35), Geba River, 2 km south of Hagere Selam town, Tigrai, Ethiopia (13°35N and 39°25E). **AMNH 223832**; 26.9-91.7mm SL (34), Berga River, 2km west of Addis Alem town on the way to Nekempte from Addis Ababa, Shoa, Ethiopia (9°5N and 38°20E). **AMNH 223685**; 26.45-79mm SL (18), Chimuga River, 3 km south of Debremarkos town, Gojam, Ethiopia (10°15'N and 37°45'E).

Diagnosis:

The species can be identified from all other African species of the genus by the following combination of characters: it has a Type C disc, fully scaled predorsal region, no post-pelvic scales, large gas bladder (posterior part of gas bladder 21.7-24.4% of standard length).

Description:

Body depth 20.0-25.1% of standard length. Head shorter; length of head 21.7-27.3% of standard length; width of head 63.8-76.4% of length of head; head depth 58.6-75.2% of length of head. Snout without tubercles; snout 22.2-40.0% of length of head. Eyes located at the anterior portion of the head; diameter of eye 17.6-29.0% of length of head; interorbital width 38.8-52.8% of length of head.

Disc is well developed with free posterior border; the rostral fold is with indented margins; papillae are abundantly found on disc; disc as long as wide or a little wider; length of disc 22.2-41.0% of length of head; width of disc 44.4-65.2% of width of head; length of disc 69.2-96.2% of its own width; two pairs of small barbels; rostral barbels are longer than maxillary barbels; rostral barbels 33-87.5% of diameter of eye.

34-38 scales on the lateral line; 4-4.5 scales from the lateral line to the origin of dorsal fin; 3.5 scales from the lateral line to the origin of pelvic fin; 4.5 scales from the lateral line to the origin of anal fin; predorsal region is fully scaled; belly, chest and post-pelvic regions are naked.

Dorsal fin with 4 unbranched and 7 branched rays; distance between anterior origin of dorsal fin and tip of snout 45.2-53.3% of standard length. Pectoral fin with 5 unbranched and 11 branched rays; length of pectoral 17.0-24.0% of standard length. Anal fin with 4 unbranched and 5 branched rays;

Position of vent a little far away from anal fin; distance from vent to anal fin 20.6-39.5% of the distance between origins of pelvic and anal fins; the area between vent and anal fin is naked. Pelvic fin with 3 unbranched and 7 branched rays. Length of caudal peduncle 15.1-21.6% of standard length; depth of caudal peduncle 10.7-13.9% of standard length; 13-15 circumpeduncle scales.

31-34 vertebrae along the vertebral column. Medium sized intestine; standard length 40-50% of intestine length. Length gas bladder (posterior part) 21.7-24.4%

of standard length. Summary of morphometric and meristic features is given in Table 5.

Color:

The body is creamy in color dorsally and ventrally in both fresh and preserved specimens. The black spots at the base of the dorsal fin not prominent.

Geographic distribution:

Recorded from Ethiopia, Eritrea and Sudan; occurs abundantly in the Abbay drainage basin of Ethiopia (Fig.13 and 30).

Remarks:

Three lots (MNHN 85-93-10-4, MNHN 85-93-10-5 and MNHN 85-93-10-1) at MNHN labelled as *G.blanfordii* do not represent *G. blanfordii*; rather they fit into descriptions of *G.dembeensis*. Menon (1964) synonymized it with *G.quadrimaculata*. However, it differs in its creamy white color, and absence of scales on the chest, belly and post-pelvic regions. Some specimens of *G.dembecha* from the same drainage basin have similar coloration as *G.blanfordii*. However, *G.dembecha* has a vestigial disc and a non-scaled predorsal streak. They show, also, significant shape differences. The shape difference between these two species has been archived and tested using geometric morphometric (see details in Appendix 6). Three nominal species (*Discognathus giarrabensis, D.vinciguerra* and *D.b.cimmaruta*) are synonymized with *G.blanfordii* and comparative data on the synonymes is given in Table 6.

Garra congoensis Poll 1959

Figs.14 and 9B

Garra congoensis Poll **1959,** *Sci.Zool.* v. **71**: 75-174, Pl.16; Poll **and Gosse, 1963,** Annals.Mus.R.Afr.Cent., **116**: 43-111; **Roberts and Stewart, 1976,** *Bull.Mus.Comp.Zool.*, **147(6):** 239-317. **Daget et al.(eds.),1984,** *CLOFFA*, vol.**1**: p.301; **Eschmeyer(ed.), 1998,** *Catalog of fishes*, vol.1, p.406.

Materials Examined:

Holotype: MRAC 103350; 80.5mm SL (1), Regina falls, rapides pres de Kinsuka, Zaire.

Paratypes: MRAC 118291-118295; 32.6-77.7mm SL (4), Stanley Pool, rapides de Kinsuka, Zaire.

Other Materials: CAS 164812; 30.1-40.5mm SL (5), Zaire, Kinshasa, Zaire (Congo) River system, beginnings of rapids near Stanley Pool. **MCZ 50516**; 39.8-64.4mm SL (6), Zaire River mainstream near Inga hydroelectric dam, Zaire (5°3130"S and 13°37'30"E). **MCZ 50128**; 29.1-38.2mm SL (4), Zaire River at Gombe or Ngombe about 20 km West of Kinshasa. Rapids in the mainstream, Zaire. **MCZ 50413**; 71.0mm SL (1), Zaire River mainstream near Isangila, Zaire (5°18'S and 13°36'E). **MRAC 78-006-p-768-777**; 44.1-79.3mm SL (10), Cafunfo, Borio 2, Riv. Cunoga (?), Angola. **SMF 9191**; 56.9mm SL (1), "Kongo", Stanley Pool, Kinshasa (=Leopoldville).

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has a developed disc (type C), full predorsal scales and dorso-ventrally flattened head and body (body depth 10.6-15.0% of standard length).

Description:

Body dorso-ventrally flattened; body depth 10.6-15.0% of standard length. Head also flattened; head depth 35.4-44.6% of head length; length of head 22.2-25.0% of standard length; width of head 63.0-74.4% of length of head. Snout without tubercles; snout 2.0-2.7 in length of head. Eyes located well behind on the head; diameter of eye 20.0-26.3% of length of head; interorbital width 35.2-46.8% of length of head.

Disc is very well developed with free posterior end and ramified papillae; the rostral fold is indented; length of disc 26.4-36.2% of length of head; width of disc 40.3-56.5% of width of head; length of disc 73.7-93.8% of its own width; two pairs of barbels; rostral barbels are longer than maxillary barbels; rostral barbels 35-56 % of eye diameter.

37 scales on the lateral line; 5 scales from lateral line to origin of dorsal fin; 3-3.5 scales from the lateral line to the origin of pelvic fin; 3.5 scales from the lateral line to the origin of anal fin; predorsal region is partially scaled; 7 scales on the predorsal region; chest and belly are naked while the post-pelvic region is scaled.

Dorsal fin with 3 unbranched and 7 branched rays; distance between anterior origin of dorsal fin and tip of snout 44.0-49.5% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectoral 16.8-24.0% of standard length. Anal fin with 3 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 6 branched rays.

Position of vent far away from anal fin; distance from vent to anal fin 33.6-41.5% of the distance between anterior origins of pelvic and anal fins; 4-6 scales between the vent and anal fin. Length of caudal peduncle 12.5-18.0% of standard length; depth of caudal peduncle 7.0-9.0% of standard length; 12 circumpeduncle scales.

Long intestine; standard length 30-35% of length of intestine. Very minute gas bladder; gas bladder (posterior part) 3.1-3.8% of standard length.

Summary of morphometric and meristic features is given in Table 7.

Color:

Ranges from creamy to brown dark dorsally and lighter ventrally. Gray lining on the chest region. The black pigments at the base of dorsal fin not prominent.

Geographic distribution:

Recorded from the Zaire basin, Congo and Angola (Fig15).

Remarks:

It shows similarity with *G.geba* of Ethiopia in being dorso-ventrally depressed. But, *G.geba* has no scales on the predorsal region, post-pelvic region is naked and the position of the eye is on the posterior part of the head. *G.congoensis* is also different from *G.ornata,* which is recorded from similar localities, in having a dorso-ventrally depressed head and body and well-indented rostral fold.

Garra dembecha **spec. nov.**

Figs.16 and 17

Gobio quadrimaculatus **(non-Rüppell, 183*6*):** **Boulenger, 1903,** *Proc.Zool.Soc.Lond.*, p.330. **Boulenger, 1907**, *The fishes of the Nile*, p.186. **Boulenger, 1909,** *Catalogue of the freshwater fishes of Africa*, vol.**1**, p.351;

Discognathus quadrimaculatus **(non-Rüppell, 1836)**: **Boulenger, 1903,** *Proc.Zool.Soc.Lond.*, **2**, p.330. **Boulenger, 1907,** *The fishes of the Nile*, p.186. **Boulenger, 1909,** *Catalogue of the freshwater fishes of Africa*, vol.**1**, p.351.

Crossocheilus quadrimaculatus: **Boulenger, 1902,** *Ann.& Mag.N.H.* **(7)**, p.422. **Boulenger, 1907**, *The fishes of the Nile*, p.186. **Boulenger, 1909,** *Catalogue of the freshwater fishes of Africa*, vol.**1**, p.351.

Materials Examined:

Holotype: AMNH 228483, 78.8mm SL, Bula River, crossing southern part of Dembecha town, Gojam, Ethiopia (10°35'N and 37°30'E). A.Getahun, November 14,1996.

Paratypes: AMNH 223693; 23.5-82.1mm SL (24), locality, collector and date same as holotype.

Other Materials: BMNH 1908.1-20-59-68; 46.0-108.3mm SL (10), Lake Zurui, Kenya (misidentified as *D.quadrimaculatus*). **BMNH 1902.12.13.424-433 / 392-399**; 29.7-86.4mm SL (18), Lake Tana, Ethiopia (misidentified as *D.quadrimaculatus*). **BMNH 1933.9.30.1-3**; 67.1-77.6 mm SL (3), small Abbay River, L.Tsana (misidentified as *D.quadrimaculatus*). **BMNH 1948.1.14.153-156**; 27.3-31.8mm SL (4), Mai Toccor, Eritrea (misidentified as *G.quadrimaculatus*). **BMNH 1908.1.20.69**; 59.6mm SL (1), Akaki River, Ethiopia (misidentified as *G.quadrimaculata*). **BMNH 1937.4.20.14-21**; 52.6-85.5 mm SL (8), Lake Ziway, Ethiopia. (misidentified as *G.quadrimaculata)*. **BMNH 1902.12.13.400-409**; 23.9-95.2 mm SL (10), Chaffe -Donsa high plateau, Abyssinia (misidentified as *G.quadrimaculata*). **BMNH 1903.11.16.13.14**; 45.28-67.3mm SL (2), Suksuk River, Lake Ziway, Ethiopia (misidentified as *D.quadrimaculatus*). **MNHN 85-93-54-7**; 41.9-56.8mm SL (4), Lake Tana, Ethiopia (misidentified as *G.quadrimaculatus*). **MNHN 85-93-54-2**; 36.2-62.1 mm SL (3), Afrique orientale (misidentified as *G.quadrimaculatus*). **MNHN 85.93.54.3**; 22.2-30.6 mm SL (7), Abyssinia (misidentified as *G.quadrimaculatus)*. **MNHN 85-93-54-6**; 18.9mm SL (1), Abyssinia. (misidentified as *G.quadrimaculatus*). **MNHN 85-93-54-1**; 25.5-35.6 mm SL (3), Lake Victoria, Nyanza (misidentified as *G.quadrimaculatus)*. **MNHN 85-93-54-5**; 25.6mm SL (1), Abyssinia (misidentified as *G.quadrimaculatus*). **MHNG 1446.99**; 90.9mm SL (1), affluent of River Athi, env. Nairobi (near Masai Lodge), Kenya (misidentified as *G.dembeensis*). **MHNG 2030.23**; 88.9mm SL (1), Kilimanjaro, Tanzania (incorrectly identified as *G.dembeensis)*. **MSNM 2138 (ex 4322)**; 69.40 mm SL (1), Lake Tana, Bahirdar, Ethiopia (misidentified as *D.quadrimaculatus*). **MSNM 2162 (ex 4314)**; 84.7-129.7 mm SL (6), "Fiume Caha", Gondar, Ethiopia (misidentified as *D.quadrimaculatus*). **AMNH 223702**; 34.0-64.1mm SL (4), Lah River, south of Finote Selam town, Gojam, Ethiopia (10°50'N and 37°15'E). **AMNH 223689**; 100.5 mm SL (1), Gedeb River, about 20 km north of Debremarkos town, Gojam, Ethiopia (10°30'N and 37°40'E). **AMNH 223700**; 55.7-97.3 mm SL (12), Kechen River, 30 km south of Finote Selam town, Gojam, Ethiopia (10°45'N and 37°20'E). **AMNH 223724**; 112.7-124 mm SL (5), Gumara River, northern end of Maksegnit town, about 30 km south of Gondar town, Ethiopia (12°40'N and 37°40' E). **AMNH 223735**; 54.2-64.0 mm SL (3), Dirma River, in Kola Diba town, about 80 km south of Gondar town, on the way to Gorgora, Gondar, Ethiopia (12°25'N and 37°20'E). **AMNH 223796**; 17.9-81.5 mm SL (19), Wenchet creek, on Gondar-Bahirdar road, about 5 km south of Wereta village, Ethiopia (11°45'N and 37°30'E). **AMNH 223805**; 18.4-61.2 mm SL (9), Idiyemo creek, ca 20 km north of Bahir Dar on Gondar road, Ethiopia (11°40'N and 37°30'E). **AMNH 223699**; 58.7-95.1 mm SL (8), Kechen river, about 30 km south of Finote Selam town, Gojam, Ethiopia (10°45'N and 37°20'E). AMNH 223745; 55.4-69.7 mm SL (7), Elala River, crossing northern part of Makale town, Tigrai, Ethiopia (13°30'N and 39°30'E). **AMNH 223677**; 21.9-32.8mm SL (33), Angordgood creek, 4 km northeast of Bahirdar town, Gojam, Ethiopia (11°35'N and 37°30'E). **AMNH 223833**; 31-91.2mm SL (76), Kela River, 1 km east of Welenkomi town, on the way from Addis Ababa to Nekempte, Shoa, Ethiopia (9°5'N and 38°10'E). **AMNH 227303**; 40.9-88.6mm SL (5); Arer River, ca. 30 km northeast of Jima town, on the road to Addis Ababa, Kefa, Ethiopia (7°50'N and 37°10'E). **AMNH 227261**; 40.2-101.6mm SL (42), Dabena River, 2 km southwest of Bedele town, Illubabor, Ethiopia (8°20'N and 36°15'E). **AMNH 223694**; 63.1-84.6mm SL (2), Chereka River, ca. 10 km north of Dembecha town, Gojam, Ethiopia (10°40'N and 37°25'E). **AMNH 223773**; 42.38mm SL (1), Worka River, Wondo Genet, Small stream near the hot spring, Shoa, Ethiopia (7°10'N and 38°40'E). **AMNH 223702**; 33.96-64.1mm SL (4), Lah

River, south of Finote Selam town, Gojam, Ethiopia (10°50'N and 37°15'E). **AMNH 223704**; 40.74-102mm SL (14), Kakist River, near Tilili town, ca. 50 km north of Finote Selam town, Gojam, Ethiopia (10°55'N and 37°5'E).

Diagnosis:

G.dembecha can be distinguished from all other African species of the genus by the following combination of characters: it has undeveloped disc (type A), few predorsal scales, no post-pelvic scales, deep caudal peduncle (depth of caudal peduncle 8.8-12.0% of standard length), elongate intestine (standard length 30-35% of length of intestine), large gas bladder (length of posterior part of bladder 21.7-22.4% of standard length).

Description:

Body relatively depressed; body depth 16.7-23.0% of standard length. Head is also depressed; length of head 19.8-28.2% of standard length; width of head 57.5-80.9% of length of head; depth of head 50.0-65.2% of length of head. Snout without tubercles; snout 25.2-50.0% of length of head. Eye in the middle of the head; diameter of eye 15.8-27.3% of length of head; interorbital width 33.3-49.5% of length of head.

Disc not well developed (type A); it is wider than long; length of disc 21.3-34.7% of length of head; width of disc 33.9-73.7% of width of head; length of disc 55-98.3% of its own width; the rostral fold is well developed with indented margins;

two pairs of barbels; rostral barbels 42-91% in diameter of eye.

37-38 scales on the lateral line system; 5.5 scales from the lateral line to the origin of dorsal fin and 3.5 scales from the lateral line to the origin of pelvic fin; predorsal region partially scaled; belly, chest and post-pelvic region naked.

Dorsal fin with 4 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 45.3-54.4% of standard length. Pectoral fin with 4 unbranched and 12 branched rays; length of pectoral 16.6-22.3% of length of head. Anal fin with 4 unbranched and 5 branched rays. Pelvic fin with 3 unbranched and 7 branched rays.

Vent located far away from anal fin; distance from vent to anal fin 24.3-43.2% of the distance between origins of pelvic and anal fins; 2-3 scales between vent and anal fin. Length of caudal peduncle 13.3-20.7% of standard length; depth of caudal peduncle 8.8-12.0% of standard length; 12-16 circumpeduncle scales.

33-34 vertebrae. Long intestine; standard length 40-56% of length of intestine. Relatively larger gas bladder; gas bladder (posterior part) 21.7-22.4% of standard length.

Summary of morphometric and meristic features is given in Table 8.

Color:

Creamy white to dark brown both dorsally and ventrally with black line streching along the lateral line system on both sides. Black spots and pigments at the base and tip of dorsal fin. The black spots are found at the posterior part of the dorsal fin. Notable black spots behind the operculum on both sides.

Geographic distribution and Habitat:

It is known from three countries in Africa: Eritrea, Ethiopia and Kenya. The type locality, Bula River, is in the Abbay drainage basin, at the southern part of Dembecha town, Gojam, northern Ethiopia. It is an open river with no vegetation and stony bottom. In November at 1:00 pm the pH was measured as 7.6; the water and air temperatures were 75 and 82^{O}F respectively. Its distribution in Ethiopia, Africa and Lake Tana is given in Figs.19, 20 and 21 respectively.

Etymology:

This species is named after Dembecha town, Gojam, Ethiopia. The name Dembecha is a noun in apposition. The Bula River from where the species has been collected crosses the southern part of this town.

Remarks:

This new species includes all those previously known as *G.quadrimaculata (*Non-Rüppell) following the descriptions of Boulenger (1903, 1907, 1909). But, *G.quadrimaculata* (Rüppell 1836) differs considerably from Boulenger's *Discognathus quadrimaculatus*. Some of the prominent differences include: the disc is very well developed (Type C) in *G.quadrimaculata*, but not in this species

(Type A); the scales on the belly and chest are full and overlapping in *G.quadrimaculata*, while there are no chest and belly scales on the new species. Comparative data on *D.quadrimaculatus* sensu Rüppell, 1836 and *D.quadrimaculatus* sensu Boulenger, 1903 is given in Table 9.

Garra dembeensis **(Rüppell, 1836)**

Figs.18 and 12B

***Chondrostoma dembeensis*, Rüppell, 1836,** *Mus. Senckenberg. Abhandl. Beschr. Naturg.* **2(1)** p.16, pl.2, fig.4. (Type locality: "Dembea" Lake at Goraza, Abyssinia, **(Type specimen not available), Eschemeyer, 1998,** *Catalog of fishes*, vol. 1,p.466.

***Gymnostomus dembeensis*: Heckel, 1846,** *Russegger's Reise Egypt.*iii p.329.

Discognathus chiarinii Vinciguerra, **1883,** *Ann.Mus.Genova. Geneva.* **18,** p.696. **Vinciguerra, 1889,** *Ann.Mus.Genova. Geneva*, **29,** p.280; **Boulenger, 1901,** *Proc. Zool.Soc.Lond.,London*, **2,** p.160. **Daget et al., 1984,** *CLOFFA*, vol.1, p.302 (as synonym of *G.dembeensis*). **Eschemeyer, 1998,** *Catalog of fishes*, vol.1, p.362. **Menon, 1964,** *Memoirs of the Indian Museum*, vol. **14(4),** p. 196.

Discognathus johnstonii **Boulenger, 1901,** *Proc. Zool.Soc.Lond.,London*, **2.** p.159. **Boulenger, 1907.** *Fish of the Nile.* p.184, pl.32, fig.2; **Boulenger, 1909,** *Cat. Freshwater Fish Africa. London*, **1,** p.346, fig.260. **Daget et al., 1984,** *CLOFFA.* vol.1, p.302 (as synonym of *G.dembeensis)*. **Eschemeyer, 1998,** *Catalog of fishes*, vol.1, p. 814. **Menon, 1964,** *Memoirs of the Indian Museum.* vol. **14(4),** p. 199-200 (as synonym of *G.dembeensis*).

***Discognathus dembeensis*: Boulenger, 1907,** *Fish Nile.* London, p.181, pl.44, fig.1; **Boulenger, 1909,** *Cat. Freshwater Fish Africa. London*, **1,** p.345, fig.256;

Gianferrari, 1926, *Atti. Soc. Ital. Milano. Milan*, **64**, p.190; **Tedla, 1973,** *Freshwater fishes of Ethiopia*, p.29.

Garra johnstonii: **Greenwood, 1956,** *Uganda J.*, **20(2)**: 129-165.

Garra dembeensis**: Menon, 1964,** *Memoirs of the Ind.Mus.* V.**14 (4)**: 173-260, **Daget et al., 1984,** *CLOFFA*, vol.**1**; **Bishai and Khalil, 1997**, *Freshwater fishes of Egypt*. p.58-59.

Materials Examined:

The holotype is not available at the Senckenberg Museum. The original description is found to be inadequate and a neotype is designated. The proposal for the designation of the neotype is given in appendix 5.

Neotype AMNH 223731; 77.8mm SL (1), Lake Tana at Gorgora, Ethiopia (12^{o}15'N and 37^{o} 20'E), A.Getahun, 18 Nov.1996.

Other Materials: BMNH 1903.8-10: 14-16 (paratypes of *D.chiarinii*); 27.4-29.9mm SL (3), Lake Arsade, "Adda Gallaland", Abyssinia. **BMNH 1901.6.24: 94 (type specimen of *D.johnstonii*)**; 98.4mm SL, Lake Victoria (Victoria Nyanza). **BMNH 1902.12.13.421.423**; 53.0-84.7mm SL (3), Lake Tana, Ethiopia. **BMNH 1908.1.20.50**; 132.9mm SL (1), Didessa River, Western Ethiopia. **BMNH 1937.4.20.24.26**; 95.4-107.9mm SL (3), Ghibe River, southwestern Ethiopia. **BMNH** 1937.13.141; 136.2-137.6mm SL (2), Blue Nile, Ethiopia. **BMNH 1902.11.8.10**; 75.3mm SL (1), Nairobi River, Kilimanjaro at 6500 ft., Kenya.

BMNH 1937.4.20.28; 116.5mm SL (1), Didessa River, western Ethiopia. **BMNH 1937.4.20.27 and 1900.1.20.51.52**; 123.1-146.1mm SL (3), Juju River, Ethiopia. **BMNH 1912.3.22.40-49**; 53.8-84.4mm SL (9), Saya River, Ethiopia. **BMNH 1975.10.7.69-70**; 24.9,58.8mm SL (2), Kikuletwa River entering Nyumba Ya Munga dam, Upper Pangani, Tanzania. **BMNH 1985.7.16:107-110; 22.6-39.8mm** SL (4), Bilate River entering into Lake Abaya, Ethiopia. **BMNH 1981.4.9.363-366**; 52.4mm SL (1), Athi River at Kithimani (Yatta), Kenya. **BMNH 1971.8.12:15-17**; 35.4-38.0mm SL (3), tributary of Sanya-Pangani River, Arush National Park, Tanzania. BMNH 1981.4.9.340; 61.8mm SL (1), Athi River above Lugardo falls, Kenya. **BMNH 1984.9.7:49**; 10.7-41.6mm SL (4), Muger River, Ethiopia. **BMNH 1971.3.22:13-24**; 28.6-35.0mm SL (12), Savo River, Ethiopia. **BMNH 1915.12.2.1**; 47.4mm SL (1), Makindu and Isavo Rivers, Achi system, Kenya. **BMNH 1969.2.11,215-230**; 21.4-53.8mm SL (16), Soni River, trib. of Pangani, Tanzania. **BMNH 1981.4.9:337-339**; 102.1-121.0mm SL (3), Ewsso Nyiro, Kenya. **BMNH 1936.12.22.42-47**; 13.6-69.5mm SL (6), Migaboti River, Athi system. **BMNH 1937.6.4.24-27**; 42.2-54.7mm SL (4), Athi River, Kenya. **BMNH 1971.3.22:25-41**; 36.2-67.1mm SL (17), Tsavo River, Kenya. **BMNH 1908.1.20.53-58**; 93.9-115.5mm SL (6), Sibe River. **BMNH 1908.1.20.45-48;** 121.6-125.5mm SL (4), Sibe River. **MNHN 85-93-18-4; 34.7,74.6mm** SL (2), Tchad. **MNHN 85-93-18-5**; 63.4-86.7mm SL (2), Cameroun. **MNHN 85-93-10-4;** 84.8-100.6mm SL (2), Kabana River, Abyssinia. **MNHN 85-93-10-5**; 30.3-95.3mm SL (22), Ethiopie meridionale. **MNHN 85-93-10-1**; 26.4-30.5mm SL (2), Abyssinia. **MNHN 85-93-27-2**; 74.1mm SL (1), Courema River, Affluent of Awash, Arsi, Ethiopia. **MNHN (Uncatalogued; found with Fermon Yves of** MNHN), 87.7mm SL (1), Lake Victoria, Hippo Island, west side of Mowanza, Tanzania. **MRAC 94-074-p-1111-1120**; 36.7-69.0mm SL (10), Cameroun. **MRAC**

91-051-P-11-15; 29.8-50.2mm SL (10), Kotta creek, Ethiopia (misidentified as *G.quadrimaculata*). **MHNG 2317.81**; 23.3-48.5mm SL (9), Athi River, 14 Fall pres de Thika, Kenya. **MHNG 1446.100**; 72.6mm SL (1), Prov. Simien, Balaghes Valley, Tsion Mariam, 2500m altitude, Ethiopia. **MHNG 1525,58-61**; 48.9-57.6mm SL (4), de l'Quest du lac Chamo, Rift Valley, ambouchure d'un petit affluent, III, Ethiopia. **MHNG 1523.10-12**; 33.4-39.5mm SL (3), Athi River, Falls pres Thika, Kenya. **SMF 1446.100**; 72.9 mm SL (1), Prov. Simien, Balaghes Valley, Tihon Mariam, 2500m altitude, Ethiopia. **SMF 1525.58-61**; 45.0-55.6mm SL (4), de l'quest du lac Chamo, Rift valley, ambouchoure d'un petit affluent, III, Ethiopia. **CAS 63736**; 17.9-51.9mm SL (10), Muheza district, Tanga region, Zigi River at corn mill, in the Usambara mountains, 70 km south east of Amani, Tanzania. **USNM 339720**; 40.9-62.3mm SL (3), Mayo Sabere, a stream draining to Mayo Gashaka, which eventually drains to the River Taraba which joins the River Benue, Nigeria (07°0'20"N and 011°34' 30"E). **USNM 339707**; 31.4-61.8mm SL (3), Hot spring at Matashrip, which eventually drains to the River Taraba which joins the river Benue, Nigeria (07°04'00"N and 011°26'00"E). **USNM 339699**; 16.3-24.3 mm SL (3), Warm spring, tributary of River Jiagum which eventually drains to the River Taraba which joins the River Benue, Nigeria (07°23'40"N and 011°31'50"E). **USNM 338339**; 32.0-50.1mm SL (3), Mayo Dundere, the Upper reaches of the Mayo Gashaka/ Mayo Korngal which eventually drains to the River Taraba which joins the Benue, Nigeria (07°01'50"N and 011°34'00"E). **AMNH 223771 & 223772**; 27.6-99.0mm SL (60), Ardaba River 9 km. north of Arsi Negele on route to Wendo Genet, Shoa, Ethiopia (7°30'N and 38°40'E). **AMNH 223653, 223654 & 223775**; 29.6-71.1mm SL (50), Worka River, Wondo Genet, small stream along the hot spring, Shoa, Ethiopia (7°10'N and 38°40'E). **AMNH 223788**; 58.9mm SL (1), Chufa stream, ca. 4 kilometers south of Abura village, Arsi, Ethiopia (7°55'N and 39°5'E). **AMNH 223657**; 26.7-68.5mm SL (27), Wondo Genet River, crossing southern part of Wondo Genet town, Ethiopia (7°10'N and 38°40'E). **AMNH 223668;** 60.8-70.7mm SL (6), Acamaja River, about 10 km north of Butajira town on the way to Addis Ababa, Ethiopia (8°10'N and 38°35'E). **AMNH 223671**; 32.9-91.1mm SL (29), Lebu River, about 20 km north of Butajira on the way to Addis Ababa, Ethiopia (8°30'N and 38°40'E). **AMNH 223683 &223684;** 27.1-73.1 mm SL (36), Gurunz River, near Debre Libanos, ca. 100 km north of Addis Ababa, Ethiopia (9°40'N and 38° 50'E). **AMNH 223690;** 28.8-62.9 mm SL (3), Gedeb River, ca.20 km north of Debre Markos town, Gojam, Ethiopia (10°30'N and 37°40'E). **AMNH 223665**; 44.7-84.6 mm SL (6), Mesha River, north of Butajira town, Rift Valley, Ethiopia (8°10'N and 38°30'E). **AMNH 223679**; 35.8-75.8mm SL (8), Duberkela River, 70 km north of Addis Ababa, Shoa, Ethiopia (9°30'N and 38°50'E). **AMNH 223782**; 39.5-67.5 mm SL (5), Katar River, ca. 30 km west of Abura village, Arsi, Ethiopia (7°55' N and 39°E). **AMNH 223784**; 23.5-37.9 mm SL (13), Katar River, ca. 30 km west of Abura village, Arsi, Ethiopia (7°55'N and 39°E). **AMNH 223673**; 32.9-70.5 mm SL (17), Akaki River, crossing south-eastern part of Addis Ababa, Addis Ababa, Ethiopia (9°N and 38°45'E). **AMNH 223758**, 22.9-109.6 mm SL (6), Borkena River, at southern end of Kombolcha town, Wollo, Ethiopia (11°10'N and 39°50'E). **AMNH 223705**; 34.5-45.2mm SL (44), Kakist River, near Tillili town ca.50 km north of Finote Selam town, Gojam, Ethiopia (10°55'N and 37°5'E). **AMNH 223650**; 41.6-87.4mm SL (16), Meki River, crossing southern part of Meki town, Rift Valley, Ethiopia (8°15'N and 38°50'E). **AMNH 223663**; 63.5-109mm SL (3), Woja River, ca. 30 km south of Butajira town, Rift valley, Ethiopia (8°5' N and 38°35'E). **AMNH 223681**; 36.0-65.4 mm SL (45), Duberkela River, 70 km north of Addis Ababa, Shoa, Ethiopia (9°30'N and 38°50'E). **AMNH 227265**; 21-

33.7mm SL (15), Dogi River, 2 km west of Kumbabe town on the way to Metu, Illubabor, Ethiopia (8°10'N and 36°50'E). **AMNH 227272**; 30.0-73.6 mm SL (9), Sore River, at the eastern end of Metu town, Illubabor, Ethiopia (8°15'N and 35°40'E). **AMNH 227326**; 99.0mm SL (1), Borkena River, southern end of Kombolcha town, Wollo, Ethiopia (11°10'N and 39°50'E). **AMNH 227296**; 24.5-87.7mm SL (65), Meni River, ca 75 km east of Tepi town on the way to Bonga town, Sueda /Gaweta area, Kefa, Ethiopia (7°10'N and 35°50'E). **AMNH 227275**; 23.1-100.3mm SL (101), Uka River, ca 20 km west of Gore town on the way to Gambella, near Uka town, Illubabor, Ethiopia (8°15'N and 35°10'E). **AMNH 227315**; 28.8-105.4 mm SL (66), Megecha /Gubre River, Gubre town, ca 10 km south of Welkite town, on the way to Hosaina, Shoa, Ethiopia (8°5'N and 37°55'E). **AMNH 223832**; 26.9-91.7mm SL (34), Berga River, 2 km west of Addis Alem town, on the way from Addis Ababa to Nekempte, Shoa , Ethiopia (9°5'N and 38°20'E). **AMNH 227289**; 48.6-116.7 mm SL (9), Yebeg Wuha River (Boko river), at the eastern end of Tepi town, Kefa, Ethiopia (7°10'N and 35°10'E). **AMNH 227303**; 40.9-88.6 mm SL (5), Arer River, ca 30 km northeast of Jima town, on the road to Addis Ababa, Kefa, Ethiopia (7°50'N and 37°10'E). **AMNH 223833**; 31- 91.2 mm SL (76), Kela River, 1 km east of Welenkomi town, on the way from Addis Ababa to Nekempte, Shoa, Ethiopia (9°5'N and 38°10'E). **AMNH 223840**; 27.9-61.8mm SL (4), Melka Gufu River, 50 km east of Bako town, 200 km west of Addis Ababa, travelling from Addis Ababa to Nekempte, Welega, Ethiopia (9°5'N and 37°15'E). **AMNH 223837**; 26.6-101.0mm SL (47), Chole River, near Guder town, at the eastern end of the town, Shoa, Ethiopia (9°N and 37°50'E). **AMNH 227321**; 33.4-113.4mm SL (14), Bilate River, 2 km southwest of Alaba town, Shoa, Ethiopia (7°15'N and 38°5'E). **AMNH 227293**; 17.7-85.4mm SL (15), Minjibat River, ca 30 km east of Tepi town, on the way to Bonga town, Kefa, Ethiopia (7°N and 35°35'E). **AMNH 223838**; 28.2-97.4mm SL (60), Guder River, at the western end of Guder town, Shoa, Ethiopia (9°N and 37°50'E). **AMNH 227248;** 42.2-70.3mm SL (2), Gibe River, western end of Bako town, 255 km west of Addis Ababa on the way to Nekempte, Welega, Ethiopia (9°10'N and 37°5'E). **AMNH 227253;** 70.5-95.9mm SL (3), Loko River, 60 km southwest of Nekempte, near Didessa River, Welega, Ethiopia (8°45'N and 36°25'E). **AMNH 227263**; 51.6-63mm SL (2), Tipecha River, 5 km southwest of Bedele town on the way to Metu, Illubabor, Ethiopia (8°15'N and 36°10'E). **AMNH 227268;** 25.3-58.8mm SL (3), Geyi River, ca. 5 km east of Metu town, Illubabor, Ethiopia (8°20'N and 35°45'E). **AMNH 227260;** 21.3-94.2mm SL (9), Dabena River, 2 km southwest of Bedelle town, Illubabor, Ethiopia (8°20'N and 36°15' E). **AMNH 227274**; 24.3-59mm SL (22), Wangus River, ca 15 km west of Gore town on the way to Gambella, near Uka town, Illubabor, Ethiopia (8°10'N and 35°20'E). **AMNH 227301**; 54.2-79.1mm SL (4); Bulbul River, ca 10 km northeast of Jima town on the way to Addis Ababa, Kefa, Ethiopia (7°45'N and 36°50'E). **AMNH 227298**; 29.4-69.5mm SL (9), Weshi River, ca. 10km southwest of Bonga town, Kefa, Ethiopia (7°20'N and 36°10'E). **AMNH 227287**; 48.3-90.4mm SL (6), Sasa River, 12 km south of Gore town, Illubabor, Ethiopia (8°20'N and 35°35'E). **AMNH 223692**; 29.09-42.9mm SL (6), Bula River, crossing southern part of Dembecha town, Gojam, Ethiopia (10°35'N and 37°30'E). **AMNH 223783**; 37.05-47.2mm SL (11), Katar River, ca. 30 km west of Abura village, Arsi, Ethiopia (7°55'N and 39°E).

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has type C disc, none or 1-2 scales on predorsal region, no post-pelvic scales, small gas bladder (posterior part of gas bladder 20.9-21.6% of standard length).

Description:

Slender body; body depth 15.6-23.9% of standard length. Length of head 19.9-27.1% of standard length; width of head 63.3-84.7% of length of head; head depth 50.0-68.7% of length of head. Snout 33.3-48.1% of length of head. Small circular tubercles infront of the nostrils while there are small tubular tubercles on the lateral sides ventral to the eyes. Eye is located at the middle of the head; diameter of eye 15.7-28.0% of length of head; interorbital width 36.4-48.9% of length of head.

Disc very well developed with free posterior end; rostral fold well developed; margins on rostral fold a little septated; papillae on rostral fold not abundant, but abundant on lower lip and all around the disc; disc a little wider than long; length of disc 19.5-42.1% of length of head; width of disc 36.7-69.2% of width of head; length of disc 60.5-91.7% of its own width; two pairs of barbels; rostral barbels are longer than maxillary barbels; rostral barbels 33-68 % of the diameter of the eye.

36-39 scales on the lateral line; 3.5-5.5 scales from the lateral line to the origin of dorsal fin;3.5-4.5 scales from the lateral line to the origin of pelvic fin; 4 scales from the lateral line to the origin of anal fin; predorsal region is either naked or with few scales (2-3); chest, belly and post-pelvic regions are all naked.

Dorsal fin with 3 (in most) and 4 (in some) unbranched and 7 branched rays;

distance between anterior origin of dorsal fin and tip of snout 44.0-52.1% of standard length. Pectoral fin with 4 unbranched and 12 (in most) and 11 (in some) branched rays; length of pectoral 15.1-23.9% of standard length. Anal fin with 4 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 6 branched rays.

Position of vent far away from the anal fin; distance from vent to anal fin 18.2-38.2% of the distance between origins of pelvic and anal fins; 3-4 scales between vent and anal fin. Length of caudal peduncle 12.7-19.4% of standard length; depth of caudal peduncle 8.3-11.6% of standard length; 12-14 circumpeduncle scales.

33-35 vertebrae. Medium size intestine; standard length 39-42% of intestine length. Length of gas bladder (posterior part) 20.9-21.6% of standard length.

Summary of morphometric and meristic features is given in Table 10.

Color:

It is generally dark brown in color especially on the dorsal side in both live and preserved specimens. Prominent black pigmentation at the base and mid of dorsal fin. Chest with diffused grey color.

Geographic distribution:

It is one of the most widely distributed species of the genus found in 75 % of the localities surveyed in Ethiopia and six other African countries (Figs.19, 20 and 21).

Remarks:

The type specimen of this species is referred to as "not checked " in CLOFFA and "not found" in the recent Catalogue of Fishes by CAS. The type specimen is not available at the Senckenberg Museum. The scientific workers at the Museum have pointed out to me that Rüppell might have not collected the specimens of *G.dembeensis*. The original description and figure of the type specimen is found to be inadequate and a neotype has been designated (see appendix 5). It seems that there has been confusion in differentiating between *G.dembeensis*, *G.johnstonii* and *G.hindii*. *G.johnstonii* is obviously a junior synonym of *G.dembeensis*, but *G.hindii* differs in having its predorsal streak, belly and chest completely scaled. In fact it shares two important meristic and morphometric features with *G.dembeensis*: a higher number of scales on the lateral line and having a vent located far away from the anal fin. Comparative data among the synonyms of *G.dembeensis* is given in Table 11.

Garra duobarbis spec. nov.

Figs. 22 and 23

Materials Examined:

Holotype: AMNH 228484, 66.8mm SL, Dirma river, in Koladiba town about 80 km south of Gondar town, on the way to Gorgora, Gondar, Ethiopia (12°25'N and 37°20'E), A. Getahun, 18 November 1996.

Paratypes: AMNH 223736; 46.1-64.8mm SL (7), same locality and data as the holotype.

Diagnosis:

This species is unique among the African species of the genus in having only a single pair of maxillary barbels.

Description:

Deep-bodied fish; body depth 18.8-24.3% of standard length. Head a little depressed and relatively long; length of head 24.6-28.4% of standard length; width of head 66.8-77.5% of length of head; head depth 51.2-63.9% of length of head; very short snout; snout 30.5-43.1% of head length; no tubercles on the snout. Eyes at the anterior part of the head; diameter of eye 16.6-21.0% of length of head;

interorbital width 38.6-46.3% of length of head.

Disc inconspicous (type A) and the rostral fold is without indents. The rostral barbels are absent while there are two relatively longer maxillary barbels; maxillary barbels 60.3-98.2% of eye diameter.

34-36 scales on the lateral line; 5.5 scales from the lateral line to the origin of dorsal fin; 4.5 scales from the lateral line to the origin of pelvic fin; 5.5 scales from the lateral line to the origin of anal fin; few predorsal scales at the origin of dorsal fin; no scales on belly and chest; post-pelvic region scaled.

Dorsal fin with 4 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 50.6-54.0% of standard length. Pectoral fin with 4 unbranched and 12 branched rays; length of pectoral 12.9-21.4% of length of head. Anal fin with 4 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 6 branched rays.

Position of vent a little far away from anal fin; distance from vent to anal fin 18.8-28.2% of the distance between origins of pelvic and anal fins. Length of caudal peduncle 12.7-16.7% of standard length; width of caudal peduncle 10.6-12.2% of standard length; 14 circumpeduncle scales.

31 vertebrae. The intestine is short; standard length 72-74% of length of intestine. Smaller gas bladder; length of posterior part 15.1-19.6% of standard length.

Summary of morphometric and meristic features is given in Table 12.

Color:

Light black dorsally and very light ventrally; prominent black spots at the base of dorsal fin.

Geographic distribution and Habitat:

This species is known only from the type locality (Fig.24), Dirma River, some 80 km from Gondar town on the way to Gorgora, Ethiopia (12°25'N and 37°20'E). It is a river passing through the town of Koladiba. The fishes were collected some 200 meters west of the bridge on the highway. It is open muddy water with some Eucalyptus trees around. In November at 12:30 pm, the pH was 7.6; the water and air temperature were 75° and 84°F respectively.

Etymology:

The word "duobarbis" denotes the presence of only a pair of barbels in this species.

Garra ethelwynnae **Menon, 1958**

Figs. 25 and 26A

Garra ethelwynnae Menon, **1958,** *Curr.Sci. Bangalore,* **27**: 450-451; **Menon, 1964,** *Memoirs of the Indian Museum,* **14 (4)**: 202-203, fig.7; **Daget et al.,(eds.), 1984,** *CLOFFA*, Vol.**1**: 302-303; **Eschmeyer (ed.), 1998,** *Catalog of fishes*, vol.1,p.546.

Materials Examined:

Holotype: BMNH 1950.5.31.19; 27.8 mm SL (1), Salamona, Eritrea.

Paratype: BMNH 1950.5.31.20; 27.1mm SL (1), Salamona, Eritrea.

Diagnosis:

The species can be distinguished from all other African species of the genus by the following combination of characters: it has a developed disc (type C), full predorsal and post-pelvic scales, smaller number of lateral line scales (29-30), small size (27.1-27.8mm), deep body (body depth 29.1-30.9% of standard length), and vent very close to the anal fin (distance from vent to anal fin 11.9-17.1% of the distance between the origin of pelvic and anal fins).

Description:

It has great body depth; body depth 29.1-30.9% of standard length; relatively larger head; head length 25.8-28.4% of standard length; width of head 75.3-79.1% of head length; head depth 64.9-75.0% of head length. Snout without tubercles; snout 30.5-38.9% of length of head. Eyes located at the middle of the head; diameter of eye 22.2-23.3% of length of head; interorbital width 42.8-47.2% of length of head.

Disc is well developed with free posterior end in that small sized body; disc wider than long; length of disc 19.4-28.6% of length of head; width of disc 29.9-35.1% of width of head; length of disc 70-95.7% of its own width; two pairs of barbels; rostral barbels are longer than maxillary barbels; rostral barbels 67-75 % of the diameter of the eye.

29-30 scales on the lateral line; 4 scales from the lateral line to the origin of dorsal fin; 4 scales from the lateral line to the origin of pelvic fin; 3.5 scales from the lateral line to origin of anal fin; predorsal is fully scaled; chest and belly naked; post-pelvic region scaled.

Dorsal fin with 3 unbranched and 7 branched rays; distance between anterior origin of dorsal fin and tip of snout 50.3-50.5% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectoral 19.0-22.1% of standard length. Anal fin with 3 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 6 branched rays.

Position of vent closer to anal fin; distance from vent to anal fin 11.9-17.1% of the distance between origins of pelvic and anal fins; 1 scale between vent and anal fin. Length of caudal peduncle 12.5-14.0% of standard length; depth of caudal peduncle 11.1-13.2% of standard length. 12 circumpeduncle scales.

Summary of morphometric and meristic characters is given in Table 13.

Color:

It is dark brown with the ventral side of body lighter. There are traces of the dark spots at the base of the dorsal fin in the holotype.

Geographic distribution:

It is known only from the type locality, Salamona, Eritrea (Fig.10).

Remarks:

In the development of the disc and scale coverage, it is similar to *G.aethiopica*, *G.ignestii* and *G.makiensis*. But, its deep body, small number of lateral line scales and the position of the vent differentiates it. It is similar to *G.quadrimaculata* in the position of the vent (being close to the anal fin). However, it differs by having a deep body, fewer numbers of lateral line scales and by having naked chest and belly.

Garra geba spec.nov

Figs. 27 and 28

Materials Examined:

Holotype: AMNH 228485; 86.4mm SL, Geba River, about 2 km south of Hagere Selam town, Tigrai, Ethiopia (13°35'N and 39°25'E). A.Getahun, 22 November 1996.

Paratypes: AMNH 223747; 40.3-62.3mm SL (8), locality, date and collector same as holotype.

Other Materials: AMNH 223745; 55.4-69.6mm SL (7), Elala River, crossing northern part of Makale town, Tigrai, Ethiopia (13°30'N and 39°30'E).

Diagnosis:

The following combination of characters distinguishes *G.geba* from all other African species of the genus: intermediate disc (type B), depressed head and body, no predorsal and post-pelvic scales.

Description:

Depressed body; body depth 14.8-16.8% of standard length; wider head with prominent opercular bones. Length of head 23.2-25.7% of standard length; width of head 61.5-76.1% of length of head; head depth 47.6-59.4% of length of head. Snout 31.6-45.7% of length of head; tubercles are small circular infront of the nostrils while there are also small tubular tubercles beneath the eyes. Position of eye is in the middle of the head; diameter of eye 14.2-23.1% of length of head; interorbital width 34.5-42.5% of length of head.

Disc little developed with a posterior border in adult ones; some papillae on the disc; the rostral fold is with indents; disc is wider than long; length of disc 22.5-27.7% of length of head; width of disc 32.6-50% of width of head; length of disc 66.7-96.4% of its own width; two pairs of barbels; the maxillary longer than the rostral barbels; length of rostral barbels 35-73% of eye diameter.

37-39 scales on the lateral line; 4.5-5.5 scales from the lateral line to the origin of dorsal fin; 2.5-3.5 scales from the lateral line to the origin of pelvic fin; predorsal region, belly, chest and post-pelvic region naked.

Dorsal fin with 4 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 46.9-50.0% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectorals 19.1-22.6% of standard length. Anal fin with 4 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 6 branched rays.

Position of vent far away from anal fin; distance between vent and anal fin 18.4-29.1% of the distance between origins of pelvic and anal fins; 2.5-3 scales between anal fin and vent. Length of caudal peduncle 14.4-19.9% of standard length; width of caudal peduncle 8.3-10.6% of standard length; 10-14 circumpeduncle scales.

Very short intestine; standard length 95-102% of length of intestine. Small gas bladder; length of gas bladder (posterior part) 13.9-16.2% of standard length.

Summary of morphometric and meristic features is given in Table 14.

Color:

Dark brown on the dorsal part and lighter ventrally. In the adult, the base and tip of the dorsal fin has black spots. The middle part of the caudal fin has also these spots. Thin gray lining on the chest

Geographic distribution and Habitat:

The species is only known from the type locality. The type locality (Geba River) is one of the few large rivers in Tigrai province, Ethiopia located some 20 km north west of Makale town, capital of the province and about 2 km south of Hagere Selam town on the way to Tenben and Adwa (Fig.24). The river is with very scarce vegetation, farmlands and barren land all around, degraded as most of the northern rivers are. The fishes were collected at a location about 100 meters east of the bridge (on the highway), an area where the water flows gently and the bottom is muddy and sandy and there is grass along the shores. At 3:15 pm in November, the pH=7.6, the water temperature = 78°F and the air temperature= 87°F.

Etymology:

This species is named after Geba River, from where the species has been collected. The name Geba is a noun in apposition.

Remarks:

Some of the features of this species (absence of scales on the ventral side of body and predorsal region, high number of scales on the lateral line, position of eye) are shared with *G.dembeensis*, but the latter is not as depressed and has a very well developed disc with ramified papillae. On the other hand, the body shape is similar to that of *G.congoensis*. However, besides their disjunct distribution, *G.congoensis* has a very well developed disc, partial scales on the predorsal region, full scale on the post-pelvic region; the position of the eye is well posterior on the head and has lighter coloration.

Garra hindii **(Boulenger 1905)**

Figs. 29 and 26B

Discognathus hindii Boulenger **1905,** *Proc.Zool.Soc.Lond. London,* **1,** p.62, pl.7, fig.1; **Boulenger, 1909,** *Cat.Freshwater Fish Africa,* London, **1,** p.350, fig.264. **Daget et al., 1984,** *CLOFFA,* vol.1, p. 302. **Eschmeyer (ed.), 1998,** *Catalog of fishes,* vol.1, p.733 (as synonym of *G.dembeensis)* (as synonym of *G.dembeensis*). **Menon, 1964,** *Memoirs of the Indian Museum,* vol **14(4),** p.199 (as synonym of *G.dembeensis).*

Garra hindii: **Fowler, 1976,** *Q.J.Taiwan Mus.,* **29 (1-2),** p.84.

Materials Examined:

Lectotype: BMNH 1904.12.23.18, 54.7mm SL, Nyiro river, Kenya.

Paralectotypes: BMNH 1904.12.23.19-37; 38.5-62.4mm SL (19), same locality as lectotype.

Other Materials: BMNH 1937.12.11.6-15; 33.1-64.1mm SL (10), Mbakasi, Athi River (misidentified as *G.dembeensis*); **BMNH 1981.4.9.341-347;** 17.2-55.5mm SL (7), Ragati River at Sagana -Tana system, Kenya (misidentified as *G.dembeensis).* **BMNH 1981.4.9: 367-388;** 22.6-57.5mm SL (18), Ewsso Nyiro River, Kenya (misidentified as *G.dembeensis*). **BMNH 1981.4.9.348-363;** 27.7-61.2 mm SL (16), Ewsso Nyiro River, Kenya (misidentified as *G.dembeensis*). **BMNH 1985.6.26.49;** 55.7mm SL (1), Athi River 26 km S.W. of Nairobi, Kenya (misidentified as *G.dembeensis*). **BMNH 1955.4.7.1-2;** 76.0-85.7 mm SL (2), Ngeng River, Mathew range, Kenya (misidentified as *G.dembeensis*). **BMNH 1919.9.10.213-4**; 54.1-70.7 mm (2), Avakubi River, Ituri, Kenya (misidentified as *Discognathus dembeensis*). **BMNH 1937.6.4.28-35**; 26.4-60.4mm SL (8), Ndulla falls, Thika River, Tana system, Kenya (misidentified as *D. dembeensis*). **BMNH 1966.6.9.1-4**; 43.3-65.4mm SL (4), Owen Falls dam, Uganda (misidentified as *G.dembeensis*). **BMNH 1979.3.5.220-229**; 44.6-53.8mm SL (10), Aquatic import from Kenya (misidentified as *G.dembeensis*). **BMNH 1969.3.24.19-24;** 27.3-74.2mm SL (6), Makania River, Kenya (misidentified as *D.dembeensis*). **BMNH 1902.11.8.8-9**; 59.3-69.7 mm SL (2), Nairobi River, Kilimanjaro at 6500ft., Kenya. **BMNH 1936.2.3.9-11**; 32.8-51.3 mm SL (3), River Taveta, Lumi River, East Africa (misidentified as *G.dembeensis*). **BMNH 1912.11.11.2-8**; 45.1-89.3mm SL (7), Rumiriti, Waso Narok (misidentified as *G.dembeensis)*. **BMNH 1912.3.22.33-39**; 51.1-107.7mm SL (7), Eusso Mara, Kenya (misidentified as *D.dembeensis*). **CAS 52603**; 52.8-59.3mm SL (2), E.Mariana River (Elev.3850 ft.), Isiolo district, Kenya. **CAS 155510**; 55.7-61.9mm SL (2), Sakbayeme River, tributary of Sanga River, Cameroun. **MNHN 85.93.18.2**; 54.3mm SL (1), Congo Belge (misidentified as *D.dembeensis*). **MNHN 85.93.18.1**; 68.9mm SL (1), Congo Belge (misidentified as *G.dembeensis*). **MNHN 85.93.18.3**; 29.3-33.8mm SL (2), Congo Belge (misidentified as *G. dembeensis)*. **MHNG 1523.35-71**; 22.7-76.3mm SL (8), Riv.Ewase Ngiro (Nord) pres Ngobbin, Kenya (misidentified as *G.dembeensis*). **MSNM 23**; 41.6mm SL (1), Nyiro river, 7000ft., Kenya. **MSNM 4320**; 70.6mm SL (1), Saya, Africa (misidentified as *D.dembeensis*).

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has a developed disc (Type C), full scales on the predorsal region, chest, belly and post pelvic region, vent located far away from anal fin (distance from vent to anal fin 29.3-30.2% of the distance between the origins of pelvic and anal fins).

Description:

Body slender; body depth 15.8-19.3% of standard length. Length of head 21.7-25.4% of standard length; width of head 63.2-71.4% of length of head; head depth 52.8-56.3% of head length. Snout is studded with tiny pimples (non-horny) all located anterior to the eye on lateral sides; snout 40.0-45.2% of head length; eye located at the posterior part of the head; diameter of eye 21.6-22.4% of head length; interorbital width 36.3-41.2% of length of head.

Disc is very well developed with free posterior end; papillae all over the disc and the surrounding lips including the rostral fold; disc wider than long; length of disc 25.4-28.7% of length of head; width of disc 43.3-55.1% of width of head; length of disc 75.9-89.7% of its own width; two pairs of barbels; the rostral barbels are longer than the maxillary barbels; the rostral barbels 36-48% of the diameter of the eye.

40-42 scales on the lateral line; 5-5.5 scales from the lateral line to the origin of dorsal fin; 4-4.5 scales from the lateral line to the origin of pelvic fin; 3.5-4 scales from the lateral line to the origin of anal fin; predorsal region fully scaled; belly, chest and post-pelvic regions are scaled.

Dorsal fin with 3 unbranched and 7 branched rays; distance between anterior origin of dorsal fin and tip of snout 46.2-49.1% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectoral 18.7-19.9% of standard length. Anal fin with 3 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 6 branched rays.

Position of vent far away from the anal fin; distance from vent to anal fin 29.3-30.2% of the distance between anterior origins of pelvic and anal fins; 4 scales between the vent and anal fin. Length of caudal peduncle 18.1-18.4% of standard length; depth of caudal peduncle 10.0-10.7% of standard length; 14 circumpeduncle scales.

Short intestine; length of intestine 0.9 in standard length. Small gas bladder; gas bladder (posterior part) 6.3 in standard length.

Summary of morphometric and meristic characters is given in Table 15.

Color:

It is generally brown dorsally and lighter on the ventral side. The black spots at the base of the dorsal fin are prominent.

Geographic distribution:

It is widely distributed in the freshwater bodies of Kenya, although it is also found in other African countries (Fig.30).

Remarks:

G.hindii has been confused with *G.dembeensis*, but the latter does not have scales on the predorsal region, chest, belly and post-pelvic region. The abundance and cover of scales at various parts of the body make it similar to the Afro-Arabian species, *G.quadrimaculata*. But, in *G.quadrimaculata*, the vent is close to the anal fin. And the number of lateral line scale is much higher in *G.hindii* than in *G.quadrimaculata*.

Garra ignestii **(Gianferrari, 1925)**

Figs.31 and 32

Discognathus ignestii **Gianferrari, 1925,** *Atti.Soc.Ital.Milano, Milan*, **64**, p.185. **Eschmeyer, 1998,** *Catalog of fishes*, vol.1, p.759 (year of description incorrectly quoted as 1926).

Garra ignestii: **Menon, 1964,** *Memoirs of the Indian Museum*, v.**14 (4)**: 195-196. **Fowler, 1976,** *Q.J.Taiwan Mus.*, **29(1-2)**, p.85. **Daget et.al., 1984,** *CLOFFA*, **v.1**, p.303.

Materials Examined:

Lectotype: MSNM------- (1), Kahha and Angereb Rivers, Abyssinia.

Paralectotypes: MSNM 24 (Ex.4315); 39.1-89.4mm SL (24), same locality as lectotytpe.

Other Materials Examined: MSNM 2155 (Ex. 4316); 39.4-67.7mm SL (14), Kahha River, Abyssinia. **SMF 1447.1-2**; 80.2-84.5mm SL (2); Tihou Mariam, 2500m, Balaghes valley, Simien province, Ethiopia. **BMNH 1984.9.7: 50-60**; 31.3-83.2 mm SL (11), Tributary of Awash on Dessie road, Ethiopia (misidentified as *G.dembeensis*). **MHNG 1447.1-2**; 79.9-83.4mm SL (2), Balaghes valley, Simien prov., Tihou Mariam (2500 m.), Ethiopia. **MHNG 1525.49-57**; 28.3-80.4mm SL (9), "embouchure d'un petit affluent l'Quest du Lac Chamo", Ethiopia. **AMNH**

223738 and 223739; 45-100.4mm SL (29), Angereb River, 1 km north of Gondar town, Gondar, Ethiopia (12°50'N and 37°35'E). **AMNH 223744 and 223746**; 38.9-80.4mm SL (22), Elala River, crossing northern part of Makale town, Tigrai, Ethiopia (13°30'N and 39°30'E). **AMNH 223749 and 223750**; 27.5-80.5mm SL (12), Kechen Abeba River, ca 20 km south of Lalibela town on the way to Woldiya town, Wollo, Ethiopia (11°55'N and 39°10'E). **AMNH 223752 & 223753**; 19.7-64.8mm SL (12), Tekezze River, ca 50 km south of Lalibela town, Wollo, Ethiopia (11°50' N and 39°15'E). **AMNH 223759**; 45.3-89.3mm SL (7), Borkena River, southern end of Kombolcha town, Ethiopia (11°10'N and 39°50'E). **AMNH 223678 and 223680**; 31.5-77.8mm SL (29), Duberkela River, 70 km north of Addis Ababa, Ethiopia (9°30'N and 38°50'E). **AMNH 223691**; 33.3-69.0mm SL (8), Gedeb River, ca 20 km north of Debremarkos town, Gojam, Ethiopia (10°30'N and 37°40'E). **AMNH 223695 and 223696**; 25-75.5mm SL (15), Chereka River, Ethiopia (10°40'N and 37°25'E). **AMNH 223697 and 223698**; 30.7-70.3 mm SL (9), Kechen River, 30 km south of Finote Selam town, Gojam, Ethiopia (10°45'N and 37°20'E). **AMNH 223701**; 31.8-43.4mm SL (4), Lah River, south of Finote Selam town, Ethiopia (10°50'N and 37°15'E). **AMNH 223709 and 223710**; 42.5-103.1mm SL (4), Muat River, north of Durbete town, Gojam, Ethiopia (11°10'N and 37°E). **AMNH 223712 and 223713**; 32.8-35mm SL (6), Ernu River, near Tara Gedam, ca 100km south of Gondar town, Ethiopia (12°20'N and 37°40'E). **AMNH 223718**; 33.1-49.8mm SL (2), Wenbaha River, ca 80 km south of Gondar town, Ethiopia (12°20'N and 37°40'E). **AMNH 223719**; 25.8-37.8mm SL (5), Garno River, southern end of Enfraz town, ca 50 km south of Gondar town, Ethiopia (12°40'N and 37°40'E). **AMNH 223722, 223723 and 223725**; 29.6-66mm SL (34), Gumara (Maksegnit) River, northern end of Maksegnit town, Ethiopia (12°40'N and 37°40' E). **AMNH 223726**; 32.4-39.2mm SL (3), Megech River, Ethiopia.

AMNH 223742; 24.6-31.5mm SL (3), Zarima River, within Tekezze valley, ca 150 km north of Gondar town, Ethiopia (13°25'N and 37°55'E). **AMNH 223840**; 28.0-61.8mm SL (4), Melka-Gufu River, 50 km east of Bako town, 200 km west of Addis Ababa, travelling from Addis Ababa to Nekempte, Wellega, Ethiopia (9°5'N and 37°15'E). **AMNH 223734 and 223737**; 30.2-5.0mm SL (22); Dirma River, about 80 km south of Gondar on the way to Gorgora, in Koladiba town, Ethiopia (37°20'E and 12°25'N). **AMNH 223791 and 223792**; 20.4-66.9mm SL (53), Angordgood creek 4 km northeast of Bahirdar town, Gojam, Ethiopia (11°35'N and 37°30'E). **AMNH 223800 and 223801**; 18.3-60.1mm SL (53), Gelder River, ca 30 km north of Bahirdar town, Gondar, Ethiopia (11°40'N and 37°30'E). **AMNH 223804**; 30.1-34.2 mm SL (3), Idiyemo creek, ca 20 km north of Bahirdar on Gondar road, Gojam, Ethiopia (11°40'N and 37°30'E).

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has developed disc (Type C), full scales on the predorsal and post-pelvic regions, no scales on chest and belly, vent a little far away from anal fin (distance from vent to anal fin 19.4-25% of the distance between origin of pelvic and anal fins).

Description:

Deep body; body depth 15.3-27.3% of standard length. Short head; length of head 20.3-25.4% of standard length; width of head 57.8-90.2% of length of head; depth of head 52.6-71.9% of length of head. Snout with well-formed horny and smooth tubercles in both females and males; snout 33.0-46.0% of length of head. Position of the eye in the middle of the head; diameter of eye 16.0-27.6% of length of head; interorbital width 37.2-52.0% of length of head.

The rostral fold is indented and the disc is well developed; Length of disc 20.9-33.8% of length of head; width of disc 32.5-63.9% of width of head; length of disc 58.1-88.9% of its own width. Two pairs of barbels; length of rostral barbels 44-116% of eye diameter.

34-36 scales on the lateral line; 4.5 scales above the lateral line to the origin of dorsal fin; 3.5 scales below the lateral line to the origin of pelvic fin; 4.5 scales from the lateral line to the origin of the anal fin; full predorsal scales, post-pelvic region is scaled, but no scales on the belly and chest.

Dorsal fin with 4 to 5 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 30.6-49.0% of standard length. Pectoral fin with 4 unbranched 11 to 12 branched rays; length of pectoral 12.4-23.3% of length of head. Anal fin with 4 unbranched and 5 branched rays; Pelvic fin with 2 unbranched and 7 branched rays.

Position of vent is a little far away from anal fin; distance from vent to anal fin 19.4-25% of the distance between origins of pelvic and anal fins; 2-3 scales between vent and anal fin. Length of caudal peduncle 11.9-20.7% of standard length; depth of caudal peduncle 6.9-13.3% of standard length; 12-14 circumpeduncle scales.

30-32 vertebrae. Long intestine; standard length 18.4-20.8% of length of intestine. Smaller gas bladder; gas bladder (posterior part) 19-30% of standard length.

Summary of morphometric and meristic features is given in Table 16.

Color:

Generally black throughout the dorsal and lateral sides of body; lighter ventrally with grey lining on the chest. Black spots and pigments prominent at the base and mid of dorsal fin and on the caudal fin.

Geographic distribution:

It is found restricted in the freshwater bodies of Northern Ethiopia, Tekezze and Abbay drainage basins (Fig.13).

Remarks:

This species is similar to *G.makiensis* except that there are fewer scales on the belly region; position of the eye is in the middle of the head; vent is not as near to the anal fin as that of *G.makiensis*; the shape of the body is different and has disjunct distribution limited to the northern part of Ethiopia. Menon (1964) noted that the type of this species is deposited in the Trieste Museum and has been investigated. Moreover he states that this species can be distinguished from the "closely related *G.quadrimaculata* by the predorsal streak, the chest, belly and the post-pelvic regions being naked". The type of this species is found in Milan Museum not

Trieste Museum and has never been moved from there and has not been investigated after its description. Data on the type and other materials from Senckenberg and Geneva Museums clearly indicate that this species has scales on the predorsal region and the post-pelvic region, although the chest and belly are naked.

Garra lancrenonensis Blache & Miton, 1960

Fig. 33

Garra lancrenonensis Blache **& Miton, 1960,** *Bulletin du Museum National D'Histoire Naturelle*, Paris, **2**e Serie-Tome **32**-No.**2**, pp.143-153. **Blanc, 1961,** *Bulletin du Museum National d'Histoire Naturelle*, **2**e Serie, Tome **33**, no.**3**, p.265. **Blache et al., 1964**, *Mem.ORSTOM*, **4(2)**: 114, fig.54. **Daget & Durand, 1981,** *Coll.Initiations-Document.Techn. ORSTOM* **45**, p.725. **Daget et al., 1984,** *CLOFFA*, vol.**1**, p.303. **Eschemeyer, 1998**, *Catalog of fishes*, vol. **1**, p. 868.

Materials Examined:

Lectotype: MNHN 1959-227; 26mm SL, " Chutes Lancrenon, bief superieur (Riv.Ngou; affluent de la Riv.Mbere, une des branches du Logone Superieur)", Central African Republic.

Paralectotype: MNHN 1999-1627; 18.3-26mm SL (6), same locality as lectotype.

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has feeble disc (Type A), few scales on the predorsal region and belly and full scales on post-pelvic region, vent very near to the anal fin (distance from vent to anal fin 13.3-17.4% of the distance between origins of pelvic and anal fins).

Description:

Body depth 19.9-23.3% of standard length; length of head 26.8-28.0% of standard length; width of head 62.3-66.1% of length of head; head depth 59.4-60.2% of length of head. The snout is short (snout 26.4-30.4% of length of head); no tubercles on the snout. The position of the eye is in the middle of the head. Diameter of eye 21.7-29.4% of length of head; Inter-orbital width 30.8-36.2% of length of head.

The posterior part of the disc is poorly developed while the rostral fold is distinct with papillae. Length of disc 19.1-23.2% of length of head; width of disc 28.9-34.9% of width of head; length of disc 100% of its own width. Two pairs of barbels; length of rostral barbels 50-67% of diameter of eye.

35-36 scales on the lateral line; 4.5-5.0 scales from origin of dorsal fin to the lateral line; 3.5 scales from origin of pelvic fin to the lateral line; the predorsal region is partially scaled; few scales on the belly and the post-pelvic region is fully scaled.

Dorsal fin with 3 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 45.4-49.5% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectoral 1.2-1.3 in length of head. Anal fin with 3 unbranched and 5 branched rays; pelvic fin with 2 unbranched and 6 branched rays.

The vent is located very close to the anal fin; distance from vent to anal fin 13.3-17.4% of the distance between origins of pelvic and anal fins; 2 scales between vent and anal fin. Length of caudal peduncle 12.1-13.0% of standard length; depth of caudal peduncle 9.3-10.2% of standard length; circum-peduncle scales 12-14.

Summary of morphometric and meristic features of *G. lancrenonensis* is given in Table 17.

Color:

It is white creamy in color both dorsally and ventrally. Black spots at the base of the dorsal fin prominent.

Geographic distribution:

Known only from the type locality, 'Chutes Lancrenon, bief Superior (Riv. Ngou; affluent de la Riv. Mbere, une des branches du Logone Superieur)", Central African Republic (Fig.10).

Remarks:

This species is similar to *G.quadrimaculata* and *G.ethelwynnae* in having a vent located very near to the anal fin. However, the above two species have a Type C disc while *G.lancrenonensis* has a Type A disc. Moreover, the chest of *G.quadrimaculata* is covered with overlapping scales while the chest of *G.lancrenonensis* and *G.ethelwynnae* are naked.

Garra makiensis (Boulenger, 1903)

Figs. 34 and 35A

Discognathus makiensis **Boulenger 1903**, *Proc.Zool.Soc.Lond.*,London, **2** p.330, pl.21, fig.1. **Boulenger, 1905,** *Ann.Mag.nat.Hist.*, **(7)16**, p.43. **Boulenger, 1909,** *Catalogue of the freshwater fishes of Africa*, vol.**1**, p.348, fig.262. **Tedla, 1973,** *Freshwater fishes of Ethiopia*, p.30. **Daget et al., 1984,** *CLOFFA*, vol.**1**, p.303. **Eschemeyer, 1998,** *Catalog of fishes*, vol. **2,** p.1006 and vol.**3**, p.2220 (date incorrectly quoted as 1904).

Discognathus rothschildi Pellegrin, **1905,** *Bull.Mus.Hist.Nat.Paris*, Paris, pp. 291-292. **Boulenger, 1909,** *Catalogue of the freshwater fishes of Africa*, vol **1**, p.345. **Bertin & Esteve,** 1948, *Imp.Nationale*, p.54. **Menon, 1964,** *Memoirs of the Indian Museum*, vol.**14**, no.**4**, p.198 (as synonym of *G.makiensis)*. **Daget et al., 1984,** *CLOFFA*, vol.**1**, p.303 (as synonym of *G. makiensis*). **Eschemeyer, 1998,** *Catalog of fishes*, vol.**2**, p.1474 and vol.**3**, p.2226 (as synonym of *G.makiensis*).

Garra makiensis: **Menon, 1964,** *Memoirs of the Indian Museum*, Vol.**14**, no.**4**, p.198. **Fowler, 1976,** *Q.J.Taiwan Mus.*, **29(1-2)**, p.85. **Daget et al., 1984,** *CLOFFA*, vol.**1**, p.303. **Krysanov & Golubtsov,** 1993, *Journal of Fish Biology*, **42,** 465-467. **Eschmeyer, 1998,** *Catalog of fishes*, vol.**2**, p.1006 (date incorrectly quoted as 1904).

Materials Examined:

Lectotype: BMNH 1905.7.25.87; 69.4mm SL (1), Maki River running into Lake Ziway, Ethiopia.

Paralectotype: BMNH 1905.7.25.88; 48.6mm SL (1), locality same as lectotype.

Other Materials Examined: MNHN 1905-246- 247 (syntypes of *D.rothschildi*); 108.7-135.3 mm SL (2), Gotta River, Awash basin, Ethiopia. **BMNH 1970.10.28.57**; 121.8mm SL (1), Elgo River, Lake Abaya basin, Ethiopia (misidentified as *G.dembeensis*). **BMNH 1968.7.24.49-53**; 37.6-66.6 mm SL (5), Ethiopia N.O.O (undefined acronym) (misidentified as *G.quadrimaculata*). **BMNH 1984.9.7.61-62**; 31.9-56.0mm SL (2), Didessa River, Ethiopia (misidentified as *G.quadrimaculata*). **MRAC 91.051-p-65-74**; 48.9-70.5 mm SL (5), Gota River, Harar province, Ethiopia (misidentified as *G.quadrimaculata*). **AMNH 223774**; 70.2-103.7 mm SL (4), Worka River, Wendo Genet, small stream along hot spring, Ethiopia (7°10'N and 38°40'E). **AMNH 223652**; 30.8-80.9mm SL (3), Worka River, adjacent to the hot spring of the Wabi-Shebelle hotel, Wondo Genet, Ethiopia (7°10'N and 38°40'E). **AMNH 223666**; 32.5-87.5 mm SL (31), Mesha River, north of Butajira town, in the rift valley, Ethiopia (8°10'N and 38°30'E). **AMNH 223669**; 72.5-105.6 mm SL (14), Acamaja River, about 10 km north of Butajira town on the way to Addis Ababa, in the rift valley, Ethiopia (8°20'N and 38°35'E). **AMNH 223656**; 32.3-50.8 mm SL (4), Wondo Genet Rriver, crossing southern part of Wondo Genet town, Ethiopia (7°10'N and 38°40'E). **AMNH 223670**; 56.8-91.7 mm SL (2), Lebu River, about 20 km north of Butajira on the way to Addis Ababa, Ethiopia (8°30' N and 38°40'E). **AMNH 223762**; 42.7-61.9

mm SL (3), Lake Langano, about 150km south of Addis Ababa, Ethiopia (7°35'N and 38°45'E). **AMNH 223763;** 31.2-47.2 mm SL (15), Lake Langano, about 150 km south of Addis Ababa, Ethiopia (7°35'N and 38°45'E). **AMNH 223789**; 26.1-59.3 mm SL (31), Chufa stream, about 4 km south of Abura village, Arsi, Ethiopia (7°55'N and 39°5'E). **AMNH 223770**; 38.7-52.3 mm SL (4), Katar River, about 30 km west of Abura village, Arsi, Ethiopia (7°55'N and 39°E). **AMNH 227289**; 48.6-116.7mm SL (9), Yebeg Wuha River, at the eastern end of Tepi town, Kefa, Ethiopia (7°10'N and 35°10'E). **AMNH 223723**; 72.6-130.8mm SL (14), Errer Gota River, Eastern side of Errer town, pools near main road, Hararge, Ethiopia (09°30'N and 41°15'E). **AMNH 227290;** 25.8-114mm SL(19), Bitin River, 2 km east of Tepi town, on the way to Bonga town, Kefa, Ethiopia (7°10'N and 35°15'E). **AMNH 227296**; 24.5-87.7mm SL (65), Meni River, 75 km east of Tepi town on the way to Bonga town, Sheda /Gawete area, Kefa, South-west of Ethiopia (7°10N and 35 °50E). **AMNH 227275**; 23.1-100.3mm SL (101), Uka River near Uka town about 20 km west of Gore town on the way to Gambella, Illubabor, Ethiopia (8°15'N and 35°10'E). **AMNH 223664**; 45.9-100.8mm SL (3), Mesha River, north of Butajira town, Rift Valley, Ethiopia (8°10'N and 38°30'E). **AMNH 223655**; 51.16-60.4mm SL (3), Wondo Genet River, crossing southern part of Wondo Genet town, Shoa, Ethiopia (7°10'N and 38°40'E).

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has a developed disc (type C), fully scaled on predorsal and post-pelvic regions, few non-overlapping scales on chest and belly, vent close to anal fin (distance between vent and anal fin 10.3-23.3% of the distance between origin of pelvic and anal fins).

Description:

Relatively deep body and curved back (body depth 17.5-27.8% of standard length). Short head; length of head 19.5-26.9% of standard length; width of head 58.7-79.0% of length of head; head depth 54.0-70.0% of length of head. The snout is relatively longer (snout 26.3-50.0% of length of head); tubercles in both male and female specimens. The position of the eye is at the posterior part of the head; diameter of eye 14.6-31.9% of length of head; interorbital width 33.7-44.1% of length of head.

The rostral fold has indented margins; the disc is very well developed with elaborate papillae; it is wider than long; length of disc 16.7-38.3% of length of head; width of disc 35.2-75% of width of head; length of disc 56.4-97.4% of its own width; two pairs of barbels, length of rostral barbel 38-100% of diameter of eye; the maxillary barbels are shorter than the rostral barbels.

35-37 scales on the lateral line; 3.5-4.5 scales from the origin of dorsal fin to the lateral line and 3-4 scales from the origin of pelvic fin to the lateral line; 3.5-4.5 scales from the lateral line to the origin of anal fin; full scales on the predorsal region; few scales on the belly and chest and the post-pelvic region is fully scaled.

Dorsal fin with 4 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 43.6-50.6% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectoral 15.3-24.3% of standard length. Anal fin with 4 unbranched and 5 branched rays. Pelvic fin with 3 unbranched and 7 branched rays.

Position of the vent is close to the anal fin (distance from vent to anal fin 10.3-16.9% of the distance between origins of pelvic and anal fins); 1-2 scales between the vent and the anal fin. Length of caudal peduncle 11.1-20.1% of standard length; depth of caudal peduncle 7.7-13.1% of standard length; 12-15 circumpeduncle scales.

30-32 vertebrae. Long intestine; standard length 15.9-18.1% of length of intestine. Small gas bladder; gas bladder (posterior part) 19-22% of standard length.

Summary of morphometric and meristic features is given in Table 18.

Color:

Dark black dorsally and laterally; with light ventral body with greyish color on the chest. Black pigments on the dorsal and caudal fin. Prominent black spots at the base of dorsal fin.

Geographic distribution:

It is only found in Ethiopia. It has been recorded from the rift valley lake, Lake Langano; rivers that drain into this lake and other rift valley lakes (Lakes Ziway and Abaya); the Awash and Ghibe-Omo basins (Fig.13).

Remarks:

One important character, among others, that differentiate *G.makiensis* from similar species, *G.aethiopica* and *G.ignestii*, is the position of the vent, which is close to anal fin (distance between vent and anal fin 10.3-23.3% of the distance between origins of pelvic and anal fins). It is similar to *G.quadrimaculata* in this character, but differs in the scale cover of the body, especially the chest and belly regions.

Pellegrin (1905) has identified the specimens from Gotta River as *Discognathus rothschildi*. But after examining the types of both *D.rothschildi* from MNHN and *Garra makiensis* from BMNH and collecting specimens from the exact locality, I came to the conclusion, as did Menon (1964), that *D. rothschildi* is a juniour synonym of *G.makiensis*. Data on the type specimens of *D.rothschildii* is given in Table 19.

Garra microstoma spec. nov.

Figs. 36 and 37

Materials Examined:

Holotype: AMNH 228486; 121.8mm SL, Lake Tana, Gerima area, ca. 30 meters off shore (11°35'N and 37°24'E), L.A.J. Nagelkerke, November 1, 1995.

Paratype: AMNH 228487; 94.7mm SL (1), Lake Tana, Gerima, ca 25 meters off shore (11°35'N and 37°24'E), L.A.J. Nagelkerke, November 8, 1995.

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has undeveloped disc (Type A), few scales on the predorsal region and full post-pelvic scales; short rostral fold; pointed head and small mouth in which the upper jaw is exposed (not covered by the rostral fold).

Description:

Body depth 19.8-20.6% of standard length. Head stunted; length of head 19.7-21.0% of standard length; width of head 62.7-71.2% of length of head; head depth 57.5-61.0% of length of head. Snout pointed with some small sized tubercles; snout 38.9-44.7% of length of head. Eye located a little posterior on the head; diameter of eye 16.3-21.7% of length of head; interorbital width 41.0-44.3% of length of head.

Disc inconspicuous without free posterior end; the rostral fold is short leaving the upper jaw exposed, the only African species with such a feature. Two pairs of barbels; the rostral barbels 41-68% of eye diameter.

39 scales on the lateral line; 4-5 scales from the lateral line to the origin of dorsal fin; 3-4 scales from the lateral line to the origin of pelvic fin; few scales on the predorsal region; belly with few scales; chest naked; post-pelvic region scaled.

Dorsal fin with 3 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 44.0-46.3% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectorals 17.5-21.0% of length of head. Anal fin with 3 unbranched and 5 branched rays. Pelvic fin with 2 unbranched and 6 branched rays.

Vent located not very far from anal fin; distance between vent and anal fin 19.3-23.8% of the distance between origins of pelvic and anal fins; 2-4 scales between vent and anal fin. Length of caudal peduncle 18.2-18.9% of standard length; depth of caudal peduncle 9.9-11.1% of standard length; 11-14 circumpeduncle scales.

The intestine is short; standard length 108-116% of length of intestine. Large gas bladder; length of gas bladder (posterior part) 21.7-24.9% of standard length.

Summary of morphometric and meristic features is given in Table 20.

Color:

Dark brown on the dorsal side especially above the lateral line; light brown below the lateral line including the ventral side. Black spots at the base of the dorsal fin; the tip of the dorsal and mid of the caudal fin rays are also with black spots.

Geogarphic distribution and habitat:

It is known only from the type locality, Lake Tana - two specific localities: 25 m from shore of Entos island and 25-30 m from shore at Gerima in papyrus bed in muddy, sandy and rocky bottoms at a depth of 2.5 meters (Fig.21). Trawl net was used to collect the fishes.

Remarks:

All three specimens (one specimen is cleared and stained) were kindly obtained from Leo Nagelkerke and Ferdinand Sibbing of the University of Wageningen, the Netherlands.

Garra ornata (Nichols and Griscom, 1917)

Figs. 38 and 35B

Discognathus ornatus **Nichols and Griscom, 1917,** *Bulletin American Museum of Natural History*, vol.**37**, p.696. **Menon, 1964,** *Memoirs of the Indian Museum*. vol.**14**, no.**4**, p.196. **Daget et al., 1984,** *CLOFFA*, p.303. **Eschemeyer, 1998,** *Catalog of fishes*, vol **2**, p.1252 and vol.**3**, p.2224.

Discognathus dembeensis: **Nichols and Griscom, 1917,** *Bulletin American Museum of Natural History*, vol.**37**, p.695. **Menon, 1964,** *Memoirs of the Indian Museum*, vol.**14**, no.**4**, p.196. **Daget et al., 1984,** *CLOFFA*, p.303.

Discognathus occidentalis **Lonnberg & Rendahl, 1920,** *Ann.Mag.Nat.Hist.,London*, **(9) 6**,p.169. **Menon, 1964,** *Memoirs of the Indian Museum*, vol.**14**, no.**4**, p.196. **Daget et al., 1984,** *CLOFFA*, p.303. **Eschemeyer, 1998,** *Catalog of fishes*, vol.**2**, p.1219 and vol.**3**, p.2223.

Discognathus baudoni **Pellegrin, 1923,** *Bull.Soc.Zool.Fr.* **48,** p.338. (Type locality:"Riviere Loukoula, affluent de la Loeme". **Pellegrin, 1924,** *Bull.Soc.Zool.Fr.*, vol.**49**, p.288. **Pellegrin, 1939,** *Bull.Mus.natn.Hist.nat.,Paris* **(2) 11 (6)**, p.535. **Bertin & Esteve, 1948,** *Imp.Nationale*, p.54. **Monod, 1950,** *Bull.I.F.A.N.*, vol.**12** no.4, p.978, fig.7. **Menon, 1964,** *Memoirs of the Indian Museum*, vol.**14**, no.**4**, p.196. **Daget et al., 1984,** *CLOFFA*, p.303. **Eschemeyer, 1998,** *Catalog of fishes*, vol.**1**, p.205 and vol.**3**, p.2209.

Discognathus waterloti **Pellegrin, 1935,** *Bull.Soc.Zool.Fr.,Paris*, vol.**60**, p.463. **Bertin & Esteve, 1948,** *Imp.Nationale*, p.55. **Menon, 1964,** *Memoirs of the Indian Ocean*, vol.**14**, no.**4**, p.196. **Daget et al., 1984,** *CLOFFA*, vol.**1**, p.303. **Eschemeyer, 1998,** *Catalog of fishes*, vol.**2**, p.1786 and vol.**3**, p.2231.

Garra waterloti: **Monod, 1950,** *Bull.I.F.A.N.*, vol.**12**, no.**4**, p.978, fig.2,5. **Daget, 1954,** *Mem.I.F.A.N.*, vol.**36**, p.184, fig.59. **Daget, 1961,** *Bull.Mus.natn.Hist.nat, Paris*, **(2) 32 (6)**, p.508. **Daget, 1962,** *Mem. I.F.A.N.*, vol.**65**, p.67. **Menon, 1964,** *Memoirs of the Indian Museum*, vol.**14**, no.**4**, p.196 (page number of the reference for the type incorrectly quoted as 276). **Daget & Iltis, 1965,** *Mem.I.F.A.N*, vol.**74**, p.93. **Roberts, 1967,** *J.W.Afr.Sci.Ass.*, vol.**12**, no.**1**, p.12. **Roman, 1972,** *Notes Doc.Voltaiques*, vol.**6**, no.**1**, p.15. **Lowe-McConnell, 1972,** *Keys for the field identification of freshwater fishes likely to occur in or above the new man made lakes, Lake Volta in Ghana and the Kainji Lake on the River Niger in Nigeria*, p.13. **Fowler, 1976,** *Q.J.Taiwan Mus.*, vol.29 no.**1-2**, p.89. **Reid & Sydenham, 1979,** *J.nat.Hist.*, vol.**13**, no.**1**, p.48. **Daget & Durand, 1981,** *Coll.Initiations-Document.Techn.*, vol.45, p.725, fig.42. **Smith, 1983,** *Nigerian Field*, vol.**47**, no.4, p.201.Daget **et al., 1984,** *CLOFFA*, p.303.

Garra waterloti var.dageti **Monod, 1950,** *Bull. I.F.A.N.*, vol.**12**, no.**4**, p.981, fig.3,6.

***Garra waterloti dageti*:** **Daget, 1951,** *Bull. I.F.A.N.*, vol.**13**, no.4, p.1145. **Daget, 1954,** *Mem. I.F.A.N.*, vol.**36**, p.186. **Blanc, 1961,** *Bull.Mus.natn.Hist.nat.,Paris*, **(2) 33 (3)**, p.269. **Kahsbauer, 1962,** *Ann.naturh.Mus.,Wien*, vol.**65**, p.161. **Menon,**

1964, *Memoirs of the Indian Museum,* vol.**14,** no.**4,** p.196 (page number of reference of the type incorrectly quoted as 276). **Fowler, 1976,** *Q.J.Taiwan Mus.*, vol.29, nos.1-2, p.89. **Daget et al., 1984,** *CLOFFA,* p.303. **Eschemeyer, 1998,** *Catalog of fishes*, vol.**1,** p.451 and vol.**3,** p.2212.

Garra ornatus: **Poll, 1957,** *Annls.Mus.r.Congo Belge,* vol.**54,** p.104, fig.170. **Lambert, 1961,** *Annls.Mus.r.Afr.cent.*,vol.**93,** p.20. **Poll & Gosse, 1963,** *Annls Mus.r.Afr. cent.*, vol.**116,** p.76. **Daget et al., 1984,** *CLOFFA,* vol.**1,** p.304.

Garra ornata: **Menon, 1964,** *Memoirs of the Indian Museum*, vol.**14,** no.4, p.196, fig.4. **Fowler, 1976,** *Q.J.Taiwan Mus.*, vol.**29,** nos.**1-2,** p.85. **Daget et al., 1984,** *CLOFFA,* vol.**1,** p.304.

Garra baudoni: **Fowler, 1976,** *Q.J.Taiwan Mus.*, vol.**29,** nos.**1-2,** p.83. **Daget et al., 1984,** *CLOFFA*, vol.**1,** p.304.

Garra occidentalis: **Fowler, 1976,** *Q.J.Taiwan Mus.*, vol.29, nos.**1-2,** p.85. **Daget et al., 1984,** *CLOFFA*, vol.1, p.304.

Garra waterloti waterloti: **Fowler, 1976,** *Q.J.Taiwan Mus.*, vol.**29,** nos.**1-2,** p.89.

Garra trewavasi **Monod, 1950,** *Bull. I.F.A.N.* vol.**12,** no.4, p.979, fig.1,4 and 8. **Blanc, 1961,** *Bull.Mus.natn.Hist.nat.,Paris,* **(2) 33 (3),**p.269. **Kahsbauer, 1962,** *Ann.naturh.Mus.,Wein,* vol.**65,** p.161. **Menon, 1964,** *Memoirs of the Indian Museum,* vol.**14,** no.**4,** p.198, pl.9, fig.1-3. **Daget & Itis, 1965,** *Mem. I.F.A.N.*, vol.74 p.93. **Luyeyi, 1971,** *Homme et Nature I (melange) "Zooleo",* vol.**4,** p.100.

Fowler, 1976, *Q.J.Taiwan Mus.*, vol. **29,** nos.1-2, p.89. **Daget and Durand, 1981,** *Coll. Initiations-Document.Techn.*, vol.45, p.725. **Smith, 1983,** *Nigerian Field*, vol.47, no.4, p.201.

***Garra trewavasae*: Monod, 1951,** *Bull. I.F.A.N.*, vol.13, no.3 p.915. **Reid & Sydenham, 1979,** *J. nat. Hist.*, vol.13, no.1, p.48. **Daget et al., 1984,** *CLOFFA*, vol.1, p.305. **Eschemeyer, 1998,** *Catalog of fishes*, vol.2, p.1692 and vol.3, p.2230 (incorrectly spelled as *trewavasai*).

Materials Examined:

Holotype: AMNH no. 6135; 29.4mm SL, Republic of Congo Orientale, Stanleyville.

Other Materials: BMNH 1922.6.1.2 (holotype of *D.occidentalis*); 47.6mm SL, "Kingoyi, Lower Congo, at the water shed between French and Belgian Congo". **MNHN no.1923-55 (holotype of *D.baudoni*)**; 48.1mm SL, Gabon. **MNHN no.1923-56 (paratype of *D.baudoni*)**; 41.5mm SL (1), from Niari, Kwilu River system. **MNHN no.1935-189 and 190 (syntypes of *D.waterloti*)**; 46.8-55.7mm SL (2), "Banamanan" near Kissidougou, Upper Niger River system, Guinea. **MNHN no.1950-76 (holotype of *D.waterloti var dageti*)**; 40.6mm SL, "Markala", Middle Niger River. **BMNH 1952.12.31.12-17 (paratypes of *D.waterloti var dageti*)**, 24.3-28.2 mm SL (6), "Markala", River Niger, "French Sudan". **MNHN no.1950-75 (holotype of *G.trewavasi*)**; 70.0mm SL, " Luisseau de Bargesh, plateau bautchi", Nigeria. **BMNH no.1950.5.1.265 (paratype of *G.trewavasi*); 53.6mm SL,** Jos plateau, Nigeria. **MNHN 85-93-67-5**; 35.6-75.5mm SL (20), Afrique Noire (labelled as *G.waterloti).* **MNHN 85-93-67-8**; 45.5-86.5mm SL (68), Guinee (labelled as *G.waterloti*). MNHN 85-93-67-7; 16.8-24.8 mm SL (2), Guinee (labelled as *G.waterloti).* **MNHN 85-93-67-3;** 49.31 mm SL (1), Baoule, Soudan (labelled as *G.waterloti).* **MNHN 85-93-67-6;** 17.9-57.0 mm SL (18), Soudan (Labelled as *G.waterloti dageti).* **MNHN 85-93-67-4;** 50.4mm SL (1), Bakoy, Soudan (labelled as *G.waterloti*). **MNHN 85-93-45-1;** 46.0 mm SL (1), Congo Brazzaville (labelled as *G.occidentalis*). **MNHN 85-93-8-2**; 52.5 mm SL (1), Cameroun (labelled as *G.baudoni*). **MNHN 85-93-8-3**; 29.2 mm SL (1), Congo (labelled as *G.baudoni*). **MNHN 85-93-47-1;** 59.5-86.6 mm SL (5), Zaire (labelled as *G.ornata*). **MNHN 85-93-47-3**; 25.4-80.9 mm SL (9), Guinee (labelled as *G.ornata).* **MNHN 85-93-47-2; 23.48-66.04** mm SL (15), Guinee (labelled as *G.ornata).* **MNHN 85-93-64-3**; 36.5-53.2 mm SL (2), Nigeria (labelled as *G.trewavasae*). **MNHN 85-93-64-2;** 23.5-54.0 mm SL (6), Nigeria (labelled as *G. trewavasae*). **MRAC 90-47-p-700;** 47.4 mm SL (1), Chates Wagenias, Kizangani, Zaire (labelled as *G.ornata).* **MRAC 91-068-p-851-860**; 26.6-55.2mm SL (8), Anverba, Affl.Loahoulo, Congo Brazaville (labelled as *G.ornata).* **MHNG 2496.53**; 36.8 mm SL (1), Vallee du Niara, zone forestiere, Congo (labelled as *G.sp.*). **CAS 66741**; 54.1mm SL (1), Niger river, Menchum, Bamenda highlands, Cameroun (labelled as *Garra*).

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has intermmediate disc (type B), few scales on the predorsal region and full scales on the post-pelvic region, and large gas bladder.

Description:

Body depth 15.8-22.3% standard length. Length of head 22.7-28.8% of standard length; width of head 55.7-73.9% of length of head; head depth 44.2-59.2% of length of head. No tubercles on the snout; snout 34.2-44.9% of length of head. Eyes located at the posterior part of the head; diameter of eye 31.4-42.3% of length of head; interorbital width 20.9-28.8% of length of head.

Very well developed disc with free posterior end; the disc is wider than long; length of disc 22.1-34.7% of length of head; width of disc 36.8-55.1% of width of head; length of disc 72.1-92.1% of its own width. Rostral barbels 28-57% of the diameter of the eye.

34-37 scales on the lateral line; 4-5 scales from origin of dorsal fin to the lateral line; 3-4.5 scales from the lateral line to the origin of pelvic fin; 3-3.5 scales from the origin of anal fin to the lateral line; the predorsal region is partially scaled; the belly and chest are naked while the post-pelvic region is scaled.

Dorsal fin with 3 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 45.5-52.2% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectorals 15.4-20.8% of standard length. Anal fin with 3 unbranched and 5 branched rays. Pelvic fin with 2 unbranched and 6 branched rays.

Vent is located far away from the anal fin; distance from vent to anal fin 25.4-

39.1% of the distance between origins of anal and pelvic fins; 3-6 scales between vent and anal fin. Length of caudal peduncle 13.9-17.7% of standard length; depth of caudal peduncle 9.2-10.7% of standard length; 12-14 circumpeduncle scales. Summary of morphometric and meristic features is given in Table 21.

Color:

Brown black to creamy dorsally and lighter on the ventral side. Black spots at the base of the dorsal fin.

Geographic distribution:

It is one of the most wide spread species of the genus comprising many nominal species. Its range extends from Guinea in the west to Congo in the south (reported from Cameroun, Central African republic, Congo, Gabon, Guinea, Nigeria and Zaire) Fig.15.

Remarks:

G.waterloti, especially *G.waterloti dageti*, shows some differences from the other nominal species (e.g. the absence of scales on the predorsal streak in some, the shape of the head being more dorso-ventrally flattened, having narrower caudal peduncle). All the synonyms were done by Menon, (1964) which I agree on, except *G.trewavasi*, which is synonymized in this work. I find no distinctive feature or a combination of features to distinguish this nominal species. Data on the synonyms of *G.ornata* is given in Table 22. The difference of *G.ornata* from *G.congoensis* has been mentioned in the account of the latter species.

Garra quadrimaculata (Rüppell 1836)

Figs. 39 and 40

Gobio quadrimaculatus **Rüppell, 1836,** *Mus.Senckenberg, Abhandl.Beschr.Naturg.* V.**2**, no.**1**, p.22, plate 3, fig.3. **Menon, 1964,** *Memoirs of the Indian Museum,* vol.**14**, no.**4**, p.192. **Daget et al., 1984,** *CLOFFA*, vol.**1**, p.304. **Eschemeyer, 1998,** *Catalog of fishes*, v.**2**, p.1415 and v.**3**, p.2226.

***Discognathus quadrimaculatus*:** **Heckel, 1846,** *Russegger's Reisen in Europe, Asien Und Afrika,* **3**, p.329. **Gianferrari, 1926,** *Atti.Soc.Ital.Milan*, **64**, p.184. **Menon, 1964,** *Memoirs of the Indian Museum,* vol.**14**, no.4, p.192. **Tedla, 1973,** *Freshwater fishes of Ethiopia,* p.31. **Daget et al., 1984**, *CLOFFA,* vol.**1**. p.351. **Bini, 1940,** *Reale accademia d'Italia*, **18**, p.153.

***Barbus quadrimaculatus*:** **Gunther, 1868**, *Cat.Brit.Mus.Fish, London,* **7**, p.98.

***Garra quadrimaculata*:** **Menon, 1964**, *Memoirs of the Indian Museum*, Vol.**14**, no.4, p.192; **Daget et al., 1984**, *CLOFFA*, vol.1, p.304.

Gobio hirticeps **Rüppell, 1836,** *Mus.Senckenberg, Abhandl.Beschr.Naturg*, v.**2**, no.1, p.23, plate 3, fig.4. **Menon, 1964,** *Memoirs of the Indian Museum*, vol.**14**, no.4, p.192; **Daget et al., 1984**, *CLOFFA*, vol.**1**, p.304. **Eschemeyer, 1998,** *Catalog of fishes,* vol.**1**, p.734 and vol.**3**, p.2216.

***Discognathus hirticeps*:** **Heckel, 1846**, *Russegger's Reisen in Europe, Asien Und*

Afrika, 3, p.329. **Menon, 1964,** *Memoirs of the Indian Museum.* vol.14, no.4, p.192. **Daget et al., 1984,** *CLOFFA*, vol.1, p.304.

Discognathus lamta: **Playfair, 1870,** *Proc.Zool.Soc.Lond.*,London, p.85.

Garra tibanica **Trewavas, 1941,** *British Museum (Natural History) expedition to South West Arabia 1937-1938, 3. Freshwater fishes.* London, 1, p. 8. **Menon, 1964,** *Memoirs of the Indian Museum*, Vol.14, no.4, p.191. **Karaman, 1971,** *Mitt.Zool.Mus.,Berl.*, 67, p.234. **Krupp, 1983,** *Fauna Saudi Arabia*, vol.5, p. 607. **Daget et al., 1984,** *CLOFFA*, vol.1, p.304. **Eschemeyer, 1998,** *Catalog of fishes,* vol. 2, p.1677 and vol.3, p.2230.

Garra brittoni **Trewavas, 1941,** *British Museum (Natural History) expedition to South West Arabia 1937-1938, 3, Freshwater fishes,* London, 1, p.11. **Menon, 1964,** *Memoirs of the Indian Museum*, vol.14, no.4. p.192. **Krupp, 1983,** *Fauna Saudi Arabia*, vol.5, p.607. **Daget et al., 1984,** *CLOFFA*, vol.1, p.304. **Eschemeyer, 1998,** *Catalog of fishes,* vol.1, p.285 and vol.3, p.2210.

Materials Examined:

Holotype: SMF no. 5396; 28.9mm SL (1), Abyssinia.

Other Materials: SMF no. 5403 (paralectotype of *Gobio hirticeps*), 39.9mm SL (1), Abyssinia. **BMNH 1940.2.15.2-11 (syntypes of *Garra tibanica*)**; 70.68-97.91mm SL (10), Pond at Usaifira, one mile north of Taizza, Yemen. **BMNH no 1940.8.15.19.2 (type of *Garra brittoni*)**; 100.8mm SL (1), "Migyal al Alaf, a cistern 8 miles south of Sana, Yemen". **BMNH 1951.6.19.1**; 66.5mm SL (1), Adi Ugri, Eritrea. Uncatalogued (Sebeta fish culture center, Ethiopia); 56.75mm SL (1), Ghenale basin, Ethiopia.

Diagnosis:

This species can be distinguished from other African species of the genus by the following combination of characters: it has a developed disc (type C), full scales on the predorsal region, chest, belly and post-pelvic region, vent very near to the anal fin (distance between vent and anal fin 8.6-19.1% of the distance between pelvic and anal fins).

Description:

Depth of body 16.0-20.7% of standard length. Length of head 21.5-22.5% of standard length; width of head 66.8-83.5% of length of head; head depth 58.9-67.5% of length of head. Snout has a peculiar type of tubercles (large and rounded concentrated all around the nostrils in rows on both sides); snout 40.5-42.9% of length of head. Small eye located in the middle of the head; diameter of eye 16.1-19.1% of length of head; interorbital width 42.0-42.3% of length of head.

Disc is well developed with free posterior border and well ramified papillae; length of disc 22.8-26.8% of length of head; width of disc 34.4-47.3% of width of head; disc more wide than long (length of disc 79.4-98.2% of its own width). Length of barbel less than diameter of eye (length of rostral barbel 93.0-94.0% of the diameter of eye).

34 scales on the lateral line; 4.5 scales from lateral line to the origin of dorsal and 3.5 scales from lateral line to the origin of pelvic fin; 3.5-4 scales from the origin of anal fin to the lateral line; the predorsal region is fully scaled; belly, chest and post-pelvic regions are fully scaled.

Dorsal fin with 3 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 47.4-49.7% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectoral 19.0-19.6% of standard length. Anal fin with 3 unbranched and 5 branched rays. Pelvic fin with 2 unbranched and 6 branched rays.

Vent is very close to anal fin; distance from vent to anal fin 8.6-19.1% of the distance between origins of pelvic and anal fins; 2 scales between vent and anal fins. Length of caudal peduncle 17.6-17.9% of standard length; depth of caudal peduncle 10.1-11.3% of standard length; 13 circumpeduncle scales.

The intestine is long; standard length 20.9-24.2% of length of intestine. Large gas bladder (Posterior part) 19-30% of standard length.

Summary of morphometric and meristic features is given in Table 23.

Color:

Black dark to light brown dorsally and creamy ventrally. The black pigments at the base of the dorsal fin, although faded, are present.

Geographic distribution:

It is mainly found in the Arabian Peninsula (i.e.Yemen and Saudi Arabia) while in Africa it has been recorded from southeastern Eritrea, southeastern Ethiopia and Somalia (Fig.30). Specimens from the first two countries have been investigated while the location of specimens from Somalia (mentioned by Menon, 1964) cannot be traced.

Remarks:

G.tibanica Trewavas 1941 is synonymized with *G.quadrimaculata* in this review. These two nominal species have similar diagnostic features. Trewavas is quoted (Menon, 1964: p.193) to have mentioned that *G.tibanica* and *G.quadrimaculata* may be geographical races or sub-species of the same species.

The other confusion regarding *G.quadrimaculata* arose when Boulenger, 1903 described the species as having "a small mental disc, feebly marked and a little longer than broad". This is contrary to the situation in the type specimen of *G.quadrimaculata*. It is clear that Boulenger hasn't investigated the type specimen, but guided by the description of Rueppell and the specimens he received from Ethiopia. Neither Rüppell's original description nor his laterally positioned illustration reveals the condition of the mental disc in this species. Almost all later identifications followed Boulenger's description of *Discognathus quadrimaculatus* assigning the name to those having feebly developed discs (e.g. collections at BMNH, MNHN, MSNM). Data on synonyms of *G.quadrimaculata* is given in

Table 24.

Garra tibanica ghorensis Krupp, 1982 that later in Krupp and Schneider, 1989 was given a species status as *Garra ghorcnsis* and another species (*G.sahilia)* seem to be very similar to *G.quadrimaculata* (types of both species examined). However, further scrutiny of all available specimens of these species may be needed to confirm synonymy.

The closely related African species, especially in having a very posterior vent and full scales on dorsal side is *G.makiensis* (distance from vent to anal fin 6.44-9.69 in the distance between origins of pelvic and anal fins). However, *G.makiensis* has reduced scales on the ventral side of the body, especially on chest and belly.

Garra tana spec. nov.

Figs. 41 and 42

Materials Examined:

Holotype: AMNH 223824; 108.3mm SL, Lake Tana, southern part, Kenbefami, Ethiopia (11°40'N and 37°20'E), M.L.J. Stiassny and A. Getahun, 25 November, 1995.

Paratypes: AMNH 227687; 26.4-102mm SL (8), Lake Tana, northwest from Dek Island, Ethiopia (11°56'N and 37°11'E). **AMNH 227688;** 88.1-94.6mm SL (3), Lake Tana, Kibran shore, Ethiopia (11°39'N and 37°23'E). **AMNH 227689;** 104.4mm SL (1), Lake Tana, Entos Island, ca 25 meters off Entos island, Ethiopia (11°37'N and 37°24'E). **AMNH 227690;** 49.4-100.3mm SL (5), Lake Tana, north of mid-Gulf, Ethiopia (11°46'N and 37°22'E). **AMNH 227691**; 35.5-99.3mm SL (7), Lake Tana, north of mid-gulf, Ethiopia (11°46'N and 37°22'E). **AMNH 227693**; 61.6-100.8mm SL (3), Lake Tana, Bet Menzo island, ca. 500 meters off shore, Ethiopia (11°44'N and 37°25'E). **AMNH 227695;** 89.9-106.5mm SL (3), Lake Tana, Entos island, ca. 25 meters off Entos island, Ethiopia (11°37'N and 37°24'E).

Diagnosis:

This species can be distinguished from all other African species of the genus by the following combination of characters: it has undeveloped disc (type A), few scales on the predorsal region and no post-pelvic scales, narrow caudal peduncle, small sized intestine (standard length 62-79% of length of intestine).

Description:

Body slender; depth of body 13.4-18.8% of standard length. Length of head 18.9-25.6% of standard length; width of head 56.7-66.3% of length of head; head depth 45.2-61.1% of length of head. Longer snout with no tubercles; snout 33.9-44.1% of head length. Eye in the middle of the head; diameter of eye 15.3-27.9% of length of head; interorbital width 29.4-59.4% of length of head.

Disc inconspicous (type A); no free posterior end; rostral fold is well developed covering the upper jaw with indented margins; two pairs of small barbels; the rostral barbels are relatively long; length of rostral barbel 43-127% of eye diameter.

39-40 scales on the lateral line; 4-4.5 scales from the lateral line to the origin of dorsal fin; 3-4 scales from the lateral line to the origin of pelvic fin; 4-4.5 scales from the lateral line to the origin of anal fin; few scales (3-5) on the predorsal region just anterior to the dorsal fin; no scales on the chest and belly as well as the post-pelvic region.

Dorsal fin with 3 unbranched and 7 branched rays; distance between origin of dorsal fin and tip of snout 39.8-50.0% of standard length. Pectoral fin with 4 unbranched and 11 branched rays; length of pectorals 16.6-20.2% of standard length. Anal fin with 3 unbranched and 5 branched rays. Pelvic fin with 2 unbranched and 6 branched rays.

Vent located far away from anal fin; distance from vent to anal fin 17.9-53% of the distance between origins of pelvic and anal fins; 4 scales between vent and anal fin. Elongated and narrow caudal peduncle; length of caudal peduncle 20.4-22.3% of standard length; width of caudal peduncle 7.2-10% of standard length; 12 circumpeduncle scales.

Short intestine; standard length 62-79% of length of intestine. Large and long air bladder; length of air bladder (posterior part) 22.1-25.4% of standard length.

Summary of morphometric and meristic features is given in Table 25.

Color:

Creamy white in color dorsally and ventrally; a little darker above the lateral line; a black marking at the base of the caudal fin; black spots at the base of the dorsal fin. Black spot also on the ventro-posterior edge of the operculum.

Geographic distribution and Habitat:

The species is so far known from the type locality, southern part of Lake Tana, Ethiopia (Fig.21). The fishes were collected from muddy, sandy and rocky bottoms not very far from shores (25 m to 2000m). The water depth ranges from 2 to 14 meters. The fishes were caught by trawl net.

Etymology:

This species is named after Lake Tana from where it has been collected. The name Tana is a noun in apposition.

Remarks:

It has wider mouth and brighter color as compared to the sympatric morphotype *Garra microstoma*. Moreover, unlike the latter species, the upper jaw in *G.tana* is well covered by rostral fold with indented margins. It also differs from the other sympatric species, *G.dembeensis*, by its undeveloped disc (no free posterior end), its creamy white color as well as its narrow and elongated caudal peduncle.

While Dr. Melanie Stiassny and myself collected the holotype in a joint trawl session with Leo Nagelkerke and Ferdinand Sibbing of the Wageningen University, the Netherlands in November 1995, all the paratypes have been kindly donated to the Dept.of Ichthyology, AMNH by the latter in September 1997.

DISCUSSION OF CHARACTERS

What really constitutes a good taxonomic character may depend on the group of organisms investigated and the perception of individual investigators as well. However, a good taxonomic character must be, I think, easily detectable, variable from taxon to taxon and, if possible to verify, genetically determined. Morphological characters are the best candidates for taxonomic work, if they fulfill the latter two criteria. Studying populations in the identification of species has great advantages since the consistency, hence the adaptive value, of characters can easily be evaluated. This review benefits in this respect, for many of the species have been identified from sample sizes adequate to represent the population.

In the following analysis morphological, morphometric and meristic characters are discussed. Ecological roles of many of these characters are assessed. Although emphasis is placed on diagnostic characters, some characters of secondary taxonomic importance are also considered.

Suctorial disc

The disc is a rounded or elliptical structure consisting of a central callous part and a loose membranous flap around it, which is well noted on its lateral and posterior portions. It is believed that this disc serves as a "true sucker" (Hora, 1927) by the creation of a vacuum. The free margins equipped with numerous papillae are also believed to act as a mechanical friction device to prevent the fish from slipping. Whether the disc is an adaptation merely to maintain position in fast flowing waters at bottom habitats or it has other biological roles is open to argument.

The adductor discus suctorius anterior (Matthes, 1963) appears to be the muscle that operates the disc. On contraction, it pulls the fleshy callous upwards, thus creating a strong suction when the disc is pressed against the substrate; it also assists in depressing the mandible, so that the fish can open its mouth even when it is attached to the substrate.

There are significant differences in the development of the disc among the different species of *Garra*. In some the disc is well developed with all the above-mentioned structures, while in others it is weakly developed and there may be only a trace of it evident. The types of disc in the African species of *Garra* can be categorized into the following:

A. **Type A**--- Poorly developed disc with no posterior or lateral free margins (Fig.5A). No or few papillae on the entire surface. African *Garra* species having such a disc include *G.allostoma, G.dembecha, G.duobarbis, G.lancrenonensis, and G.tana and Garra microstoma.* In some of these groups, the disc is so inconspicous that it is difficult to identify the species as members of *Garra*. Much confusion persisted in the past as to whether or not some of them belong to related genera e.g. *Crossocheilus* (Boulenger, 1909).

B. **Type B** -- The disc is conspicous, but the posterior margin is not completely free and is with few and restricted papillae (Fig.5B). Such a disc is characteristic of 3 African species (e.g. *G.aethiopica, G.geba and G.ornata*).

C. **Type C** -- Very well developed disc with extensive lateral and posterior margins and with numerous papillae (Fig.5C). This type of disc is evident in 8 African species (*Garra blanfordii, G. congoensis, G.dembeensis, G.ethelwynnae, G.hindii, G.ignestii, G.makiensis and G.quadrimaculata*). Usually such developed discs are wider than long.

It appears that this interesting structure had received much attention as an important feature in taxonomic, evolutionary and eco-morphological studies. Annandale (1919b) has placed great emphasis on the disc to identify the species of *Garra*. Accordingly, the genus was divided into two sections based on the degree of differentiation of the adhesive disc:

1. "Group of *Discognathus variabilis*" where there is little or no differentiation and
2. "Group of *D.lamta" in* which the disc is relatively large with specialized structures.

Mai (1978) based his identification of some of the Vietnamese *Garra* mainy on the disc character. The disc in the Vietnamese *Garra* shows some diagnostic features like the presence of indents and small lobes at the posterior end.

Menon (1964) is confusing on the issue of the disc. He considers the absence of a conspicuous free posterior end of the disc of some species as a primitive feature taking into consideration especially *G.rossica* and *G.variabilis*. In another instance, he mentions that the development of the disc cannot be taken as a dependable character to distinguish species of the genus and their relationships. Again on page 246 of the same paper, while discussing the evolution of the genus, the development of the disc was taken as a distinguishing feature of the different "complexes and groups".

In an analysis of the disc size between three populations of *Garra rufa* inhabiting different river systems of Israel, Goren (1974) showed that there is no correlation between current speed and sucker size. He further commented that the variability in disc size observed between the different populations is genetically based.

Gatz (1979b), also, showed that current speed is related mainly to body shape, fin size and caudal peduncle depth in different freshwater fishes, although Felley (1984) failed to find significant regression of current speed against any morphological features.

My view herein is in agreement with that of Goren (1974), that the suctorial disc is not necessarily associated to only attaching the fishes to substrata in fast flowing streams and bottom habitat. It may be primarily involved in other biological role and is species specific. Possible evidences are:

1. It has been possible to sample, using seine net, populations of different species of *Garra* that are with and without developed disc from the same site. Other morphological, morphometric and meristic characters judge the difference in the populations.

2. It has been possible to sample populations of *Garra* from relatively stagnant waters of rivers, pools and lakes including Lake Tana and Lake Langano, Ethiopia with developed disc indicative of the fact that the development of the disc is not necessarily related to fast flowing rivers and streams.

3. Correlation study (Table 26) done on 12 species from Ethiopian freshwaters indicate that the two known characters for bottom dwelling: smaller gas bladder and larger and broader pectoral fins, are negatively correlated with each other (Pearson correlation coefficient= -0.563) which is reasonable while neither of them show meaningful correlation with developed disc (correlation coefficient with gas bladder= 0.129 and with pectoral fin width= -0.309) --- this means that with a developed disc there is larger gas bladder and more falcate pectoral fin which is contrary to what is presumed to be the case.

4. Related groups (e.g. *Epalzeorhynchos* sp.) that do not have discs live near the bottom in swiftly flowing streams (Yang and Winterbottom, 1998).

Therefore, I conclude that the disc is not something primarily related to fast flowing streams for resisting strength of current and/or something necessarily related to bottom living. At this stage, although appears speculative, I suggest that the disc is used for and related to feeding. Those species that have well developed disc may be strict scrapers securing their food by attaching themselves to whatever substrata available (e.g. rocks, debris and any other macroflora). This notion is supported by Reid (1978) from aquaria observations: " Specimens of *Garra* which I have kept in aquaria clamp down tightly on hard substrates during the course of a feeding run and it appears that the ventral margin of the rostral fold forms the anterior rim of an adhesive disc." On the other hand, those species without developed disc may be free-swimming filter feeders mainly depending on microfauna and flora. It is also known that a longer intestine is associated with benthic habit (Felley, 1984) and the fact that some of those species with undeveloped disc (e.g. *G.tana* and *G.microstoma*) are with shorter intestines suggested that these species could be free swimming. Their caudal peduncle, which is elongated and relatively thin, suggests the same. Moreover, one of the few African species without developed disc, *G.allostoma*, was also found to have a short intestine feeding on insects (Roberts, 1990). A simple correlation was made among the type of disc (ranking the disc as 1,2,3 corresponding to the types of disc A, B, C), the length of intestine (taking the mean of the percentages of the ratio of stanadard length to intestine length) and the position of the vent (taking the mean of the percentages of the ratio of the distance between the vent and anal fin to the distance between the origins of anal and pelvic fins) of 12 African species. The result (Table 27) indicates that the type of disc is highly correlated (-0.737) to the length of the intestine. The data used for the intestine and the vent is given in Tables 28 and 29 respectively.

The feeding habits of these species should be confirmed, however, by the study of the contents of the intestine and /or direct observation in their habitat.

Barbels

The barbels in *Garra* are simple without any branching. The position of the barbels, as mentioned in Reid (1978), is antero-rostral (i.e. barbels which grow out through and project forward from the rostral fold). According to Raffin-Peyloz (1955, in Reid, 1978) a transverse section of both the rostral and maxillary barbels of a cyprinid show a dermal core occupied by nerve bundles and blood vessels, a middle zone of pigment cells and fibroblasts and a peripheral zone of stratified epithelium. It is, thus, probable that the barbels may have a sensory (gustatory) function (Matthes, 1963) and may also serve as sensory probes when feeding off the substrate (Reid, 1978). Gosline (1973) also confirmed that barbels, especially the maxillary barbels, of many cyprinids are adaptations for bottom feeding and they, also, are one of the keys for the feeding success of cyprinids (Sibbing, 1991).

In most species of *Garra* there are two pairs of barbels. In the Asian species *G.imberba* (South China and Indo-China), there are no barbels at all while *G.rossica* (Afghanistan, E.Persia and Beluchistan), *G.variabilis* (Syria and Iraq) and *G.duobarbis* (a new species from Ethiopia described herein) have only maxillary barbels. *G.cambodgiensis (*previously *G.taeniata)* (Siam and Malaya) and *G.bicornuta* (Mysore) have only rostral barbels. All the African species, except *G.duobarbis*, have two pairs of barbels. The fact that the African species, *G.duobarbis* and the west Asian species, *G.rossica* and *G.variabilis*, have similar pairs of maxillary barbels may have some biogeographic significance.

In related groups, the number of barbels is variable. In *Labeo* the barbels can be two or four; when two, they are always maxillary (Reid, 1985). Similarly, *Crossocheilus* has a pair of rostral barbels while *Epalzeorhynchos* and *Paracrossocheilus* have two pairs of barbels.

Barbels have a considerable history of taxonomic and phyletic significance. Garman (1912) described *G.imberba* under a new sub-genus named *Ageniogarra* distinguished by the absence of barbels. Bleeker (1863 in Hora, 1921) described two sub-genera of *Garra* (i.e. *Garra* and *Discognathus*) distinguishing them merely by the number of barbels, which are four in the former and two in the latter. Fowler (1934) used the length of barbels as one of the important diagnostic features to distinguish *G.spinosa* from *G.cambodgiensis*. Menon (1964) mentioned that the number of barbels as one of the dependable characters in the identification of the species of the genus. Howes (1991), also, stated that the distinction between cyprinines and leuciscines is recognized principally by the presence or absence of barbels.

Controversy in the use of barbels in the taxonomy of cyprinids, especially above the species level, appears in Schmidt (1983). Schmidt (1983), after studying variations in barbels of *Rhiochthys cataractae* (Cyprinidae) in south-eastern New York concluded that barbels are not sound generic characters and should be used with caution at the species level.

Another controversy is in determining whether absence or reduction of barbels in cyprinids is a primitive or derived condition. According to Arai (1982), barbelled cyprinids and those having higher number are more primitive than those lacking or with few numbers. Howes (1991), on the other hand disagrees to the above and believes otherwise "partly on the grounds of commonality (more cyprinid taxa lack barbels than possess them) and partly because those that do have barbels also possess modifications to the nerve course and maxilla which are derived with respect to those taxa lacking barbels".

This review reaffirms that the presence and absence of barbels is not at all trivial in determining taxonomic status, especially at species level. The barbels in *Garra* are consistent in a series of specimens of any one population. The length of the barbels is not size dependent among different species. It has been observed that small sized species such as *G.ethelwynnae* have prominent barbels while large sized species like *G.dembecha* possess small barbels although the length of barbels may show high intraspecific variability. For example, the rostral barbels in *G.aethiopica* and *G.ignesti* vary in length from 35-107 % and 40-116% of the eye diameter respectively.

Skelton (1988) suggested that it is necessary to examine comprehensive geographical and size range series of a species before the taxonomic value of barbels is safely established and each case should be judged on its own merits. This suggestion is commendable.

Tubercles

The snout, in some species of cyprinids, is studded with numerous conical horny tubercles and this structure, according to Wiley and Collette (1970); Collette (1977) and Chen and Arratia (1996), serves the function of recognizing mates and maintaining body contact during spawning. However, Reid (1978, 1985), after investigating *Labeo* species, proposed a hydrodynamic function for these structures. Cambray and Stuart (1985), also, suggest that male barbs in defense of territories use the large head tubercles.

In genera such as *Garra,* tubercles were previously believed to have only been present in males (Krupp, 1982). It is now evident that tubercles are found in both males and females (This work; Krupp, 1983; Cambray and Stuart, 1985 and Skelton, 1988 for *Barbus* species). Even earlier, Wiley and Collette (1970) had studied tuberculate females of *G.gotyla* and *G.cambodgiensis (*formerly *G.taeniata).* However, it is also noted that the males have more breeding (conical tubercles) than the females. On the contrary, Hora (1937) reported that *the* females have horny tubercles while the snout of males is smooth in *G.prashadi.* This observation was also supported by Roberts (1982) in which it was claimed that the most heavily tuberculate individuals tend to be sexually mature females.

Tubercles in the African *Garra* are prominent on the snout except in the case of *G.makiensis* where few round flat tubercles were observed on scales and *G.ornata* in which few tubercles were found on the pectoral fins. In cyprinids, tubercles on the body and fins are reported by Barnard (1943), Cambray and Stuart (1985) and Skelton (1988).

In the African species of *Garra*, the snout of some (e.g. *G.aethiopica, G.allostoma, G.blanfordii,* G.ethelwynae, *G.lancrenonensis*, *G.dembecha* and *G.tan*a) is smooth without any tubercles. *G.dembeensis and G.geba* have small circular tubercles infront of the nostrils while there are small tubular tubercles on the lateral sides ventral to the eyes (Fig.43A). The snout of *G.microstoma* is covered with minute rounded tubercles while *G.duobarbis* has a pattern of small smooth line of tubercles on the upper end of both opercula. *G.quadrimaculata* has a peculiar type (large and rounded) tubercles concentrated all around the nostrils in rows on both sides (Fig. 43B). Tubercles in *G.hindii* are also tiny pimples (non horny) all located anterior to the eye on the lateral sides. *G.ornata* has minute circular tubercles all over the snout and some on the underside of the pectoral fins.

Well-formed horny tubercles are observed in *G.congoensis*, *G.makiensis* and *G.ignesti.* All these species are inhabitants of fast flowing rivers and streams. This may support the suggestion by Reid (1978) that these structures may also serve a hydrodynamic function. Smooth flat circular tubercles (may be sloughed off conical tubercles - sensu Cambray and Stuart, 1985) also exist together with the horny ones. In *G.makiensis* few flat circular tubercles were observed on the scales of two female specimens. Highest development of tubercles is observed in *G.ignestii* (Fig.43C) where the anterior of the snout is studded with large number of horny and smooth tubercles. The tubercles are concentrated on the lateral and dorsal side of the snout in front of the nostrils, but there are few below both eyes and even near the operculum. The dorsal side posterior to the nostrils is devoid of tubercles. In a few specimens examined, it was noted that the females of this species have a pointed snout and a much-reduced number of horny tubercles. The horny tubercles are prominent in the males. This may strengthen the notion suggested by Cambray and Stuart (1985) that males may use these horny tubercles in defense of territories while the report by Hora (1937) and Roberts (1982) -see above, stand against this presumption.

Tubercles are frequently used for taxonomic purposes in cyprinid fishes (Skelton, 1988), and in this review and can also be of significant value in phylogeny.

Intestine

Gut length and pattern of coiling are used as valid systematic characters in many fish groups (Mok, 1977 and Yamaoka, 1985) and also in cyprinids (Kafuku, 1958, 1975 for catastomids and carps; Reid, 1978 for Labeine cyprinids and Skelton, 1988 for red fin minnows). Matthes (1963) examined 2 specimens of *G.dembeensis* and 1 specimen of *G.congoensis* and reported a 4.5 ratio (gut length to standard length) for both species.

There is great variation in the length of the gut among the different species of *Garra*

(Table 28). According to this review the African species can be generally divided into three groups depending on the length of their gut:

1. **Long forms** --Those having long gut (more than 5 times the standard length). Included are *G.congoensis, G.dembecha, G.ignesti, G.makiensis and G.quadrimaculata*

2. **Medium forms**--Those having medium gut (2.5-5 times the standard length). Included are *G.blanfordii,* and *G.dembeensis.*

3. **Short forms**--Those having short gut (1-2 times the standard length). Included are *G.aethiopica, G.duobarbis, G.geba, G. microstoma* and *G.tana.*

The length of the intestine can be used as a taxonomic character to distinguish species in the African *Garra*. For example, in the Lake Tana species the length of the gut is helpful in separating the previously known species (*G.dembeensis* and *G.dembecha --G.quadrimaculata* sensu Boulenger, 1903) from the sympatric new species (*G.tana and G.micrtostoma)*) (Fig.44). But it fails to resolve the two new species although other characters distinguish them very well. In another instance, *G.aethiopica* has been synonymized with *G.quadrimaculata* (Menon, 1964), but they are at opposite ends of the spectrum regarding their gut length.

It is, now, a common knowledge that the length of the gut is related to the feeding habit of the group in question (Nikolsky, 1963; Weatherly, 1972; Ribble and Smith, 1983): those with long guts tend to be herbivorous while those with short guts tend to be carnivorous. So, in the above findings of *Garra*, the first group can be largely herbivores, the second group strictly omnivores depending on balanced diet and the third group can be largely carnivores.

It appears, also, that the length of the intestine is directly related to the position of the vent in *Garra*. In those species where the vent is close to the anal fin, the intestine is longer while in those species where the vent is far away from the anal fin, the intestine is shorter. The fact that herbivory is primitive to carnivory may corroborate the fact that a vent very close to the anal fin is taken as a primitive character by Menon (1964) and Reid (1978).

Unfortunately, I am not able to find out consistent differences in the coiling pattern of the gut among the different species investigated. There is considerable intraspecific variability within the genus.

Gas bladder

In Cyprininae the gas bladder is not enclosed in a bony capsule and is coupled with the inner ear by a chain of ossicles (Ramaswami, 1955). The gas bladder is two chambered, the anterior and posterior chambers being connected by a small duct. A sphincter around the connection allows one chamber to be closed off from the others (Dobbin, 1941). The gas bladder is located between the intestinal tract and the gonad and kidney and is a physostomous type having a connection with the alimentary canal.

There have been some previous studies in *Garra* and related groups regarding the size of the gas bladder in relation to body size. According to Hora (1921) in *Cirrhina* and *Labeo*, the length of gas bladder is contained about 3.3 times in the length of the fish, which is also true for "less modified " species of *Garra*-- *G.adiscus, G.rossicus, G.blanfordii* and *G.rufa* while in *Crossocheilus* it is about 5.3 times in the total length of the fish. The study also shows that the extreme phase of reduction within the genus *Garra* is reached in the Asian species of *G.stenorhynchus, G.arabica, G.gotyla,* and *G.nasuta*, in which the bladder is contained about 15 times in the standard length of the fish.

In this review, 12 species of the genus have been studied and can be divided into two groups with respect to the size of their gas bladder:

1. Those species that have larger gas bladder in which the ratio of standard length to bladder length (posterior part) is less than 5. Included species are *G.aethiopica, G.blanfordii, G.dembecha, G.dembeensis, G.quadrimaculata, G.microstoma and G.tana.* In this group the difference among the species is narrow and the ratio ranges from 4.28 to 4.70. Here the anterior chamber is smaller and the posterior chamber is broad and swollen in the middle while it tapers towards the end (Fig.45A).

2. Those species that have a smaller gas bladder in which the ratio of standard length to bladder length (posterior part) is greater than 5. The species here include *G.congoensis, G.duobarbis, G.geba, G.ignestii* and *G.makiensis*. Considerable reduction is noted in *G.congoensis*, *G.duobarbis*, *G.geba* and *G.makiensis*. The

smallest gas bladder is from *G.congoensis* in which it is 27.9 in standard length. In this species the gas bladder is so small occupying a slight portion of the anterior part of the body cavity. Other characters like the dorso-ventrally flattened head and body as well as the broad pectoral fins also suggest that this species is strictly bottom living. The width of pectoral fin in standard length is 9.9 in *G.geba* while it is 13.1 in *G.ignesti* from the same group and it goes upto 18.8 in *G.tana* from the first group (Table 30). In this group the anterior chamber of the gas bladder is almost inconspicuous and the posterior chamber is thin and almost uniform in thickness (Fig.45B). So it is, I think, permissible to say that these species are either bottom living or living in fast flowing streams.

A correlation study also shows (Table 26) that the gas bladder is negatively correlated (Pearson correlation coefficient = -0.563) to the width of the pectoral fin in all the above species which is reasonable for bottom living animals while the gas bladder has no meaningful relation to the development of the disc (Pearson correlation coefficient = 0.129). For example, *G.geba* has a medium while *G.duobarbis* has a vestigial disc.

Previous study (Gatz, 1979b), also, shows that a small gas bladder is associated with a large pectoral fin area and dorsally displaced eyes. Relative volume of the gas bladder was also assumed to be inversely proportional to the bottom dwelling preference of the fish and negatively correlated with water speed in the habitat of the fish. Hora (1922, 1952), also, reported that the reduction in gas bladder size is directly proportional to the strength of the current of the streams in which *Garra* live.

Squamation

The scales of *Garra* are cycloid type and, as in other cyprinines, it is with basal radii. As is the case in most cyprinids (Lagler, 1947), the focus is sub-basal and the primary radii are developed in posterior field only.

In the African species of *Garra*, the shape of the scales and number of radii are variable intraspecifically and even among different parts of the body of the same fish reducing their value as a good taxonomic character. But, the number of scales on the lateral line and the presence or absence of scales at some parts of the body is more or less consistent and hence their taxonomic value cannot be underestimated. Especially, the presence or absence of scales on the different body parts of *Garra* species appears to be an important feature in the taxonomy of the genus. The presence or absence of scales on the predorsal region (a line from the anterior end of the dorsal fin to the posterior end of the head), chest, belly and post pelvic regions is used to diagnose many of the species.

Predorsal streak scales are found to be full and prominent in 7 species (*G.aethiopica, G.blanfordii, G.ethelwynnae, G.hindii, G.ignestii, G.makiensis, and G.quadrimaculata*), while 5 species (*G.congoensis, G.dembecha, G.lancrenonensis,* and *G.ornata)* have a partially scaled predorsal region and 6 species (*G.allostoma, G.dembeensis, G.geba, G.duobarbis, G. microstoma* and *G.tana*) have no or very few scales (1 or 2) on the predorsal region.

The chest and belly are fully scaled in two species (*G.hindii* and *G.quadrimaculata*). Small area of the belly is scaled in *G.aethiopica,* *G.lancrenonensis*. *G.makiensis*. *G.dembecha* and *G.microstoma)*. All the other African species of the genus have naked chest and belly.

The post-pelvic region is naked in *G.blanfordii*, *G.dembecha*, *G.dembeensis*, *G.geba* and *G.tana*. In all the others the post-pelvic region is scaled. Summary of the squamation pattern in all the African species is given in Table 2.

Generally, it appears that the African species of *Garra* tend to have reduced scale cover as compared to all the investigated species of the Middle East and Asian species of the genus and also the putative sister genera (e.g. *Crossocheilus*, *Epalzeorhynchos*, *Semilabeo*). The only exceptions that lack predorsal scales of the Asian and Middle East *Garra* species, according to Hora (1922), are *G.abhoyai* and *G.rossica*. Those species having full scales on the predorsal region also have their chest, belly and post pelvic region scaled partially or fully. Probably the only exception to this trend is *G.blanfordii* in which the predorsal region scales are full while the chest, belly and the post-pelvic regions are naked.

Scale counts along the lateral line are also worth considering with caution. There is interspecific and intraspecific variation and overlap in the number of scales in the genus. Generally, the range is from 29 to 42. Menon (1964) considers the number of scales along the lateral line as one of the dependable characters, while Annandale (1919b) considers it as one of the variable characters that affords little or no assistance to specific diagnosis. In this review it is used to diagnose some of the species that have extreme low or high number and do not overlap with counts of similar species (judged by other morphological features). For example, lateral line scales have been found to be useful in the diagnosis *of G.ethelwynnae* that has a small count (29-32) and *G.hindii* that has extremely high count (38-42).

The main question here, though difficult to answer, is whether or not the environment influences scale number. Water temperature has been considered as possible explanation to the variation in number of scales in *Garra*. However, Goren (1974) showed, through statistical procedures, that there is no correlation between water temperature and number of scales in *G.rufa* populations and suggested the variations in number to be genetic.

Fins

The genus, like other members of the family Cyprinidae, has the paired fins (pectoral and pelvic), the median fins (dorsal and anal) and the caudal fin. The dorsal fins are a little in advance of the pelvic fins. The caudal fins are forked in which the upper and lower lobes are symmetrical. Hora (1922) reported unequal lobes for hill stream *Garra* species of India, the lower being longer than the upper. This claim cannot be verified in this review. The paired fins are horizontally placed. In flowing water the anterior half of the pectoral fin is held horizontally and along with the body whereas the posterior part of the fin curves sharply upward to the vertical such that its dorsal surface faces the current (Lundberg and Marsh, 1976). There appears to be some correlation between the size of the pectoral fin and the habitat of the fish deduced from the shape of the body. Those species with dorso-ventrally flattened head and body and living on the bottom have wider pectoral and pelvic fins. As previously stated, after studying twelve species of the African *Garra* a negative correlation (Pearson correlation coefficient of -0.563) has been established between the size of gas bladder and the width of pectoral fin.

Those having a smaller gas bladder have also wider pectoral fin and vice versa. There is also a more foreshortening of individual ray segments (length < width) in those species having wider pectoral fins.

The counts of fin rays especially the unbranched rays may vary depending on the method employed. The unbranched rays, some of the anterior ones in particular, are small and inconspicuous and may be undetectable when using whole specimens and radiographs. In those species where a number of specimens were available for investigation (all the Ethiopian species, *G.quadrimaculata, G.ornata and G.congoensis*) cleared and stained specimens were used in determining the number of rays. But, in those species which are represented only by type specimens and/or few other specimens (e.g. *G.ethelwynnae, G.lancrenonensis, G.allostoma*) whole specimens and radiographs have been used. So comparison and assessment of the full spectrum of species has become difficult. Given the above condition, the counts range for the dorsal fin from 3-5 unbranched and 7 branched rays; for the anal fin 3-4 unbranched and 5 branched; for the pectoral fin 4-5 unbranched and 11-12 branched; and for the pelvic fin 2-3 unbranched and 6-7 branched rays.

The African *Garra* species that show consistently high number of fin ray counts in all the fins considered include *G.blanfordii, G.dembecha, G.ignestii* and *G.makiensis* (see tables 3 to 25). There has been previous report by Lundberg and Marsh (1976) that *G.blanfordii* and *G.ornata* are exceptional among the cyprinids in possessing two anterior unbranched pectoral rays and this was considered to be a derived character. I concur with the above view since the presence of one anterior unbranched pectoral fin is the common character in cyprinids. The presence of two unbranched anterior pectoral fin rays is a synapomorphic character that unites all the *Garra* species.

Intraspecific variation was observed in *G.aethiopica, G.dembeensis, G.ignestii* and *G.quadrimaculata* with respect to their dorsal fin; *G.aethiopica* and *G.makiensis* with respect to their anal fin and *G.dembeensis* and *G.ignestii* with respect to their pectoral fins. Unlike previous views (e.g. Menon, 1964) the constancy of most of the counts in most of the species suggest that fin ray counts in *Garra*, if made from cleared and stained specimens, can be used for systematic studies. Gosline (1978) also suggested that it is the stability rather than the variation in unbranched dorsal fin ray counts of cyprinids that seem notable. The form of the last unbranched ray in the dorsal fin has also been reported as to be a useful character in *Barbus* (Boulenger, 1911) and specifically in the Red fin *Barbus* species of South Africa (Skelton, 1988).

Fin length in the different species of *Garra* is overlapping (Tables 31 and 32) and is of little use (if any) for taxonomic purposes in the genus. For example, the mean of the pectoral fin length (Table 32) as percent of standard length in all species of the African *Garra* ranges from 18.4-22.2. The only non-overlapping measures are between *G.hindii* and *G.lancrenonensis* on one hand and between *G.lancrenonensis* and *G.quadrimaculata* on the other. But the number of specimens investigated for *G.hindii, G.lancrenonensis* and *G.quadrimaculata* are 3, 2 and 2 respectively, making this result unreliable for interpretation.

Dorsal fin length indicates two distinct groups, although the distinction is very slight and it is difficult to validate the differences statistically because of the small sample size in some of them. In one group (*G.allostoma, G.ethelwynnae, G.lancrenonensis, G.makiensis* and *G.tana*) the mean length (% standard length) is higher ranging from 23.4-24.7. In the other group consisting of all the rest of the species, the mean length ranges from 18.3 to 23.2. *G.congoensis* (13.5-14.9) and *G.ornata* (14.1-15.1) have a smaller sized anal fin with a very limited overlap with some of the other species. All the other species show considerable overlap.

The pelvic fin size range again overlaps for all of the species (mean range 16.9-21.7% of the standard lengths--Table 32). However, *G.ethelwynnae* (a small sized species) is noted for having large pelvic fins.

Rostral fold

The variations in the structure of the oromandibular region are the basis for identification and monophyly of most labeine genera. For example, *Epalzeorhynchos* is recognized as a distinct and monophyletic genus merely by the presence of a posteriorly free rostral lobe (Yang and Winterbottom, 1998). *Labeo* is known to have an elaborate labial fold which is only conspicuous in the juveniles of Garraini and rudimentary in adults (Reid, 1978). Similarly, the rostral fold (rostral cap sensu Zhang, 1998, Zhang and Chen, 1997, Yang and Winterbottom, 1998) is an important structure in determining taxa.

In Garraini, the rostral fold is thick and downgrown so that it completely overlies the premaxillary bones (Reid, 1978) and the true lips are covered by this structure. In most species of *Garra*, the ventral margin of the rostral fold is indented. The indentation in *Garra* is double invecked (sensu Reid, 1978) and macroscopic granuloid papillae form a band along the invecked margin. Reid suggested that erect rostral lobes could function as hydrodynamic stabilizers.

The extent of growth of the rostral fold and its charcteristic indentation is found to be important in the identification of some species of the African *Garra*. In *G.microstoma*, the rostral fold is short and the lips are exposed. In the majority of the species the rostral fold is indented, while in few species (*G.aethiopica, G.allostoma, G.lancrenonensis* and *G.duobarbis*) the rostral fold is well developed covering the premaxilla, but not indented. The indentation, however, is found to have nothing to do with the development of the disc.

Gill rakers

The gill openings in most species of *Garra* are relatively small. In some species (e.g. *G.geba*) the openings may be wider, but are separated from each other by a considerable distance. This condition may be useful for facilitating suction (Hora, 1922). The gills are feathery with the lamellae possessing parrallel transverse ridges (sensu Matthes, 1963), which are extended distally giving its feathery appearance. The gill rakers, especially in the African species of *Garra*, are placed far apart from each other on the branchial arches.

Although overlapping in most cases, thus lowering its value as a taxonomic character, the two African groups that can be separated based on their number of gill rakers are:

1. Those species having relatively lower number of gill rakers (9-10) (e.g. *G.allostoma, G.blanfordii, G.ethelwynnae and G.quadrimaculata*)

2. Those species that have relatively higher number of gill rakers (12-14) (e.g. *G.congoensis* and *G.geba*). Interestingly, these two species are strictly bottom living species (deduced from their gas bladder size and width of pectoral fins).

The rest have 10 to 12 gill rakers in the lower part of the anterior gill arch.

Previous reports (Matthes. 1963; Menon, 1964) indicate that the number of gill rakers in *Garra* ranges from 9-20. Higher numbers (12-20) were recorded for the Middle East and Asian species (e.g. *Rufa* complex sensu Menon, 1964). The fact that the African species have a lower number of gill rakers as compared to the Asian ones has been reported by Trewavas (1941). In relation to the importance of gill rakers for taxonomic purposes Trewavas (1955) mentioned that gill rakers serve to distinguish *G.rufa* and *Typhlogarra widdowsoni* from the *Garra* of the streams and pools of southwest Arabia. In ecological terms number of gill rakers are usually taken to be inversely correlated with the presence of larger and more benthic prey in the diet (Gatz, 1969b).

Coloration

Although ecological and physiological conditions clearly play a role in the expression of color of fishes, color characteristics are still important in taxonomic studies. However, caution should be taken in investigating long preserved specimens since pigmentation could be affected by preservation. Color can be reliable if color differences are determined from freshly caught specimens in the field or soon there after.

In the case of the African *Garra*, after looking at freshly caught specimens from Ethiopian freshwaters and comparing them with specimens preserved for long periods at different museums, I can say color can be a complementary character in the identification of some of the species of *Garra*. For example, *G.blanfordii* collected several years back and deposited at the British Museum shows similar creamy white coloration as the freshly caught specimens.

Basically, the African *Garra* species show three patterns of body coloration. One species (*G.aethiopica*) shows grey coloration in both fresh and preserved specimens; 5 species (*G.blanfordii*, *G.congoensis*, *G.dembecha*, *G.ornata* and *G.tana*) are light to creamy white while all the rest are brown to dark black.

The presence of black spots at the base of the dorsal fin characterize all the African species, however this character is also shared by the Middle East and Western Asian species. The lateral stripes that are characteristics of some Asian species (e.g. *G.nasuta* from China and Indochina) is absent in the African *Garra*. Nikolski (1963) claimed that species with lateral stripes to be schooling forms, the lateral stripe aiding both in individual orientation and in confusion of predators. A dark lateral band is prominent and distinctive in the Middle East species, *G.lamta* (Trewavas, 1955) while such a prominent lateral band is absent in the African species.

Morphometric and meristic features

Many of the morphometric measurements and meristic counts overlap for the different species, making them serviceable only in the description of the species. So only those measurements that have taxonomic significance are herein analyzed. Some of them (scales, fin ray counts) are mentioned together with their respective morphological features (squamation, fins).

Head and body depth

In *Garra* the body is cylindrical and depth of head and body is highly reduced as compared to putative sister taxa (e.g. *Barbus*, *Epalzeorhynchos*, *Labeo*, *Tylognathus*). The mean value for the African species of *Garra* range from 41.2 to 70.0 for relative head depth and 11.9 to 30 for relative body depth. Relative body depth is the maximum body depth divided by the standard length and relative head depth is the maximum head depth divided by the head length and are both given in percentages here (Table 33). Some species show consistency in their head and body shape and hence these characters are taken as taxonomically important features. For example, *G.congoensis* has a dorso-ventrally flattened head and body and its mean values are exceptionally low (41.2 for head depth and 11.9 for body depth; see table 33). On the other hand, *G.ethelwynnae*, a small species with a maximum standard size of 27.8mm, has exceptionally high mean values (70.0 for head depth and 30.0 for body depth). All the other species have medium values ranging from 52.5 to 67.2 for head depth and 16.0 to 22.8 for body depth. The average of the means is 58.39 for head depth and 20.23 for body depth.

A high relative head and body depths normally are taken to indicate a slow-water habitat preference (Nikolskii, 1933; Gatz, 1979a). On the other hand, depressed head and body is related to bottom habitat and more rapidly flowing waters.

Caudal peduncle

Relative caudal peduncle length is a percentage of the horizontal distance from the posterior end of the anal fin to the ventro-anterior end of the caudal fin divided by the standard length. Relative caudal peduncle depth is a percentage of the distance from dorsum to ventum at the narrowest part of the caudal peduncle divided by the standard length.

An exceptional caudal peduncle length is noted in one species of the African *Garra, G.tana.*

Its average relative caudal peduncle length is 19.2.(Table 34). This slender and elongated caudal peduncle is a diagnostic feature for this species. The caudal peduncle depth of this species is low (mean depth=8.4) as compared with the other species (Table 34). The lowest caudal peduncle depth recorded is from *G.congoensis* having a mean depth of only 8.1. The case of *G.congoensis* seems to be consistent with the eco-morphological interpretation that caudal peduncle depth is reduced in actively swimming forms living in fast waters. The case of *G.tana* is difficult to explain in this perspective. *G.tana* is a lacustrine species without a developed disc. The absence of developed disc, according to the preceeding discussion, is suggestive of free swimming feeding habit. For a free-swimming habit there need to be cylindrical fusiform body that goes together with reduced caudal peduncle depth.

Position of vent

The position of the vent is considered to be one of the important characters to identify some species of the African *Garra*. The position of the vent is determined by taking the percentage of the distance between the vent and the anterior end of the anal fin in the distance between the anterior origins of the anal and pelvic fins. Its taxonomic importance has also been emphasized by Menon (1964).

In most African species the position of vent is distant from the anal fin (Table 29). The exceptional species, in which the vent is located very near to the anal fin are, *G.ethelwynnae* (distance from vent to anal fin 11.9-17.1% of the distance between the anterior origins of anal and pelvic fins), *G.lancrenonensis* (distance from vent to anal fin 13.3-17.4% of the distance between the anterior origins of anal and pelvic fins), *G.makiensis* (distance from vent to anal fin 10.3-16.9% of the distance between the anterior origins of anal and pelvic fins) and *G.quadrimaculata* (distance from vent ot anal fin 8.6-19.1% of the distance between the anterior origins of anal and pelvic fins). As previously discussed, the position of the vent seems to be directly related to the length of the intestine, although the correlation is not strong (Table 27). It appears that those having long intestines have their vent located more closely to the anal fin and vice versa. Menon (1964) and Reid (1978) both considered the condition of having a vent that is close to the anal fin to be primitive which seems to be supported by the length of the intestine and feeding habit (herbivory being ecologically more primitive than carnivory).

Vertebrae

The number of vertebrae in *Garra* appears to be higher as compared to the putative sister genera (e.g.*Epalzeorhynchos* has 27). Two groups in the African species of the genus can be recognized with regard to their number of vertebrae:

1. Those species having lower number of vertebrae (27-28) similar to the sister groups (*G.ethelwynnae* and *G.quadrimaculata*). It should be noted that *G.quadrimaculata* shows other apparently primitive features like scales covering all parts of the body; vent located very close to the anal fin and a very long intestine.

2. Those species having higher number of vertebrae (35-36) like *G.geba*, *G.hindii*, *G.dembecha*, *G.microstoma* and *G.tana*.

All the others have 30 -33 vertebrae.

There seems to be direct correlation between the number of vertebrae and the number of lateral line scales. Those having larger number of scales also do have higher number of vertebrae and viceversa. A little different from this trend is the case of *G.quadrimaculata*. This species has 34-35 scales on the lateral line, but has a lower number of vertebrae (27-28).

PHYLOGENY AND BIOGEOGRAPHY OF *GARRA* AND ITS RELATIONSHIP WITH SISTER GENERA

INTRODUCTION

Currently, there is little evidence that cyprinine subgroups are monophyletic and their phylogeny has yet to be firmly established. However, recent work has contributed to some resolution (Howes, 1980, 1984 on bariliines and neobolines; Skelton, 1980 on *Barbus* and Reid 1978, 1982 and 1985 on labeines). Additional contribution has been made by Zhang (1994) on the Chinese labeines. Karnasuta (1993) reviewed the species of the southeast Asiatic genus *Osteocheilus*. Banarescu (1986) described the species of *Crossocheilus, Epalzeorhynchos* and *Paracrossocheilus* and also formulated some ideas on their relationship. Most recently, Yang and Winterbottom (1998) made a cladistic analysis of the five species of *Epalzeorhynchos (*one of the genera in Labeinae*)*.

Reid (1978, 1985, Fig.2) studied eleven genera in the sub-family Labeinae of which the "*Labeo-bicolor* complex" was later identified as member of *Epalzeorhynchos* (Yang and Winterbottom, 1998). According to Reid, Labeinae is a sub-family of Cyprinidae consisting of three tribes, the Tylognathini, the Labeini and the Garraini. According to him (Fig.2), the Tylognathini consists of the genera *Tylognathus* and *Barbichthyes*; Labeini consists of the genera "*Labeobarbus*", *Cirrhinus*, *Osteocheilus* and *Labeo* while the Garraini consists of *Crossocheilus*, *Epalzeorhynchos*, *Garra* and *Semilabeo*.

All of the genera mentioned by Reid (1978, 1985) except *Barbichthyes* and *Labeobarbus* have been examined and three more genera added. *Barbichthyes* and *Labeobarbus* were not available for study and hence not included. *Discocheilus*, *Discogobio* and *Paracrossocheilus* that have been suggested to be members of Labeinae (Banarescu, 1986; Rainboth, 1991; Zhang et al., 1999) and related to *Garra* and these were included in this work.

Similarly, to date, little work has been done on the phylogeny (sensu Hennig, 1966) of *Garra*. Earlier attempts to study the evolutionary relationships of *Garra* include that of Hora (1920) and Menon (1964). But, these studies were based on assumptions of degree of specialization and/or speculations based on ecological conditions, and lacked critical phylogenetic underpinnings.

Here, the phylogenetic hypothesis of Reid (1978) is evaluated, the assignment of *Garra* to the sub-family Labeinae, the composition of the tribe Garraini and its relation with other disc bearing genera (*Discocheilus*, *Discogobio* and *Semilabeo*) is examined. Monophyly of *Garra* is investigated; the phylogenetic intrarelationships of the genus and its habitat and biogeography is discussed. Based on this study, the classification of the sub-family Labeinae (sensu Reid, 1978) is modified.

This phylogenetic study, thus, attempts to address two levels of universality and each is presented separately. The first part investigates the interrelationship of Labeinae and the second part investigates relationships among *Garra* species. Character description and distribution are presented for each study followed by clade analysis and a concluding remark.

RESULTS OF LABEINE PHYLOGENY

32 characters and 14 taxa (Table 36 and 37) were used in the analysis and a strict consensus was obtained from 4 equally parsimonious trees using algorithms mhennig* (applies branch-swapping to each of the initial trees, retaining no more than one tree for each initial one), mhennig (constructs several trees, each by a single pass, adding the terminals in several different sequences. The shortest trees found are retained) and ie- (implicit enumeration- identifies one tree, certain to be of minimal length) of Hennig86 and heuristic and branch and bound algorithm of PAUP. Clados was used to make the cladogram (illustration) (Fig.48). The consistency index is .76, the retention index is .86 and length of the tree is 42 steps. The strength of the clades is tested by Bremer support using PAUP (Fig.48 in bold numbers).

Description and distribution of the characters

Some of the characters were used both in the analysis of the relationships among the genera in Labeinae as well as the species in *Garra*. Some of the external morphological characters employed have been adequately described in part one of the thesis and hence only the information relevant to the phylogenetic analysis is presented here. The number assigned to the characters here in the description corresponds to the number on the consensus tree recovered from the analysis (Fig.48). In Fig.48 solid black bars denote unique unreversed synapomorphies, dark shaded bars indicate independent origin and light shaded bars indicate reversals.

0. The shape of supraethmoid

Narrow and elongate supraethmoid (character# 0-0; Fig.49a)
Broad and short supraethmoid (character# 0-1; Fig.49b)

The supraethmoid in Labeinae is bordered by the nasals laterally and is firmly sutured to the frontal posteriorly. Anteriorly it is thickened and may bear a notch or a process. In some genera (e.g. *Garra*) both states may be present.

In all genera of Labeinae, except *Garra*, and the outgroup genera the supraethmoid is relatively narrow and elongate which is considered to be the primitive character state. A broad and short supraethmoid bone is characteristic of the genus *Garra* and is interpreted as the derived state. This is one of the characters that support the monophyly of the genus. Howes (1981) proposed that a short and broad supraethmoid as he observed in *Ctenopharyngodon* and *Hypophthalmichthyes* is a plesiomorphic condition in cyprinids on the grounds of widespread occurrence. This may be true in other cyprinid groups. But, in Labeinae and the outgroup genera considered here the widespread condition is a narrow and elongate supraethmoid (see also Ramaswami, 1951 on supraethmoids of *Crossocheilus*, *Garra* and *Gyrinocheilus*) while a broader supraethmoid is restricted to the genus *Garra*.

1. The presence/ absence of antero-lateral concavity on dentary

Absence of antero-lateral concavity on dentary (character# 1-0; Fig.50b)
Presence of antero-lateral concavity on dentary (character# 1-1; Fig.50a)

The morphology of the upper and lower jaw is highly variable within the Cyprinidae. In the outgroup genera, some genera of Labeinae (*Cirrhinus*, *Epalzeorhynchos*, *Labeo*, *Paracrossocheilus*, *Osteocheilus* and *Tylognathus)* and some species of *Garra* (e.g. *G.quadrimaculata*) there is no concavity on the antero-lateral part of the dentary bone. This character is interpreted as the primitive state. Antero-laterally, concavities occur on both sides of the dentary in some genera of Labeinae (*Crossocheilus*, *Discocheilus*, *Discogobio*, *Semilabeo* and in *Garra dembeensis*). This character state is interpreted as the derived condition. It supports the monophyly of the above-mentioned genera. The case of *G.quadrimaculata* is considered to be a reversal to a primitive condition. According to Yang and Winterbottom (1998) one species of *Epalzeorhynchos* (*E.bicornis*), exceptionally, has this concavity on the dentary bone. This may be a secondarily derived condition in *Epalzeorhynchos bicornis*.

2. The presence/ absence of the premaxillary ascending process

Presence of the premaxillary ascending process (character# 2-0, Fig.51c)
Absence or reduction of the premaxillary ascending process (character# 2-1, Fig.51b)

In most genera of Labeinae investigated (*Crossocheilus, Discocheilus, Discogobio), some species of Garra (e.g. G.dembeensis, G.quadrimaculata), Semilabeo*, and *Paracrossocheilus*) and in the outgroup genera the premaxillae bear ascending processes that slope backwards. This condition is interpreted as the primitive state. In *Cirrhinus, Epalzeorhynchos, Labeo, Osteocheilus, Tylognathus* and some species of *Garra* (species not included in this level of analysis) the ascending process is absent. This condition is interpreted as the derived state. The derived character state has apparently evolved independently a number of times in the above genera (Fig.48). According to Yang and Winterbottom (1998) *E.bicornis,* exceptionally, has the ascending process developed.

3. The presence/ absence of a V-shaped gap on the premaxillae

Absence of a V-shaped gap on the premaxillae (character# 3-0; Fig.51b & c)
Presence of a V-shaped gap on the premaxillae (character# 3-1; Fig.51a)

In most genera of Labeinae (*Crossocheilus, Discocheilus, Discogobio, Garra, Labeo, Paracrossocheilus* and *Semilabeo*) and the outgroup genera there is no V-shaped gap at the articulation of the two premaxillae. This character state is interpreted as the plesiomorphic condition. *Cirrhinus, Epalzeorhynchos* and *Osteocheilus* have a V-shaped gap at the articulation of the two premaxillae. This character state is interpreted as derived. It seems most parsimonious that it evolved in the above genera independently (Fig.48).

4. The presence/ absence of concavity at the anterior face of vomer

Presence of concavity at the anterior face of vomer (character# 4-0; Fig.52c)
Absence of concavity at the anterior face of vomer (character# 4-1; Fig.52a and b)

In most Labeinae (*Cirrhinus, Crossocheilus, Discogobio, Garra, Labeo, Paracrossocheilus, Osteocheilus* and *Tylognathus*) including the outgroup genera the anterior face of vomer is deeply concave without a facet. This is interpreted as the primitive state. *Epalzeorhynchos* has a vomer with a well-developed facet, a condition considered to be autapomorphic for this genus. *Discocheilus* and *Semilabeo* lack this concavity and the anterior face of the vomer is straight. This character state supports the monophyly of *Discocheilus* and *Semilabeo*. The absence of concavity is interpreted as the derived character state and may have evolved independently in *Epalzeorhynchos* and in the two disc bearing genera

(*Discocheilus* and *Semilabeo*).

5. The size and shape of maxillae

Narrow and elongated maxillae (character# 5-0; Fig.53b)

Wide and short maxillae (character# 5-1; Fig.53a)

In general, two types of maxillae are recognized in Labeinae and in the outgroup genera. One type is an elongated one and is evident in all the other genera of Labeinae (*Crossocheilus, Discocheilus, Discogobio, Garra, Paracrossocheilus, Semilabeo* and *Tylognathus*). The outgroup genera *Barbus* and *Varicorhinus* have maxillae a little different but more similar in structure to the elongate type. At the level of Labeinae, thus, the elongated type is interpreted as a primitive character state. The other type is wide and short when viewed ventrally and is found in *Epalzeorhynchos, Labeo* and *Osteocheilus*.The derived character state, although homoplasious, supports the clade formed by *Labeo* and *Osteocheilus*, and arose independently in *Epalzeorhynchos* (Fig.48).

6. The infraorbital bones

The infraorbital series consists of thick bony plates (character# 6-0; Fig.54b)

The infraorbital series consists of tubular canal bearing bones (character# 6-1; Fig.54a)

Most of the genera in Labeinae (*Cirrhinus*, *Crossocheilus*, *Discocheilus*, *Discogobio*, *Paracrossocheilus*, *Semilabeo* and *Tylognathus*) and some species of *Garra* including *G.quadrimaculata* have a thick bony plate constituting the infraorbital series and this is interpreted as the primitive condition in Labeinae. The outgroup genera also have this type of plate. *Labeo*, *Osteocheilus* and some species of *Garra* (e.g. *G.dembeensis*) have small bones consisting of largely the canal bearing components. This condition is interpreted as the derived character state. This character state supports, although homoplasious, the monophyly of *Labeo* and *Osteocheilus*. Its appearance in *Garra* is interpreted as a result of independent evolution (Fig.48). At the family level, too, Tretiakov (1946 in Howes, 1980) suggested that those cyprinid genera with the broadest posterior bones are the most primitive.

7. The presence/ absence of postero-dorsal elongation on the lacrimal.

Absence of the postero-dorsal elongation on the lacrimal (character# 7-0; Fig.55a)
Presence of the postero-dorsal elongation on the lacrimal (character# 7-1; Fig.55b & c)

The lacrimal is a prominent bone in the infraorbital series of the labeines. In the outgroup genera, in Labeini (*Cirrhinus*, *Labeo* and *Osteocheilus)* and in Tylognathini (*Tylognathus*) the lacrimal bone is short and broad with no postero-dorsal elongation. This character state is interpreted as primitive. In all the other genera of Labeinae (the Garraini), a postero-dorsal elongation is prominent. This condition is interpreted as the derived state. This character state is one of the character states that support the monophly of the tribe Garraini (*Crossocheilus, Discocheilus, Discogobio, Epalzeorhynchos, Garra, Paracrossocheilus* and *Semilabeo*).

8. Shape of the operculum

Absence of concavity on the operculum (character# 8-0; Fig.56b)
Presence of concavity on the operculum (character# 8-1; Fig.56a)

The size and shape of the opercular bones have been used to define monophyletic groups in Cyprinidae such as the barillines and neobolines (Howes, 1981). In most genera of Labeinae (*Cirrhinus*, *Crossocheilus*, *Discocheilus*, *Discogobio*, *Epalzeorhynchos*, *Paracrossocheilus*, *Semilabeo* and *Tylognathus*), most species of *Garra* (including the two species considered here) and the outgroup genera the dorsal and posterior borders of the operculum are straight and this condition is interpreted as the primitive state. In *Labeo*, *Osteocheilus* and some of the species of *Garra* (in species not considered at this level of analysis), the dorsal and posterior borders of the operculum are concave. This derived state, although homoplasious, supports the clade of *Labeo* and *Osteocheilus*.

9. The shape of the symplectic

The symplectic straight dorsally (character# 9-0; Fig.57a)

The symplectic with some dorsal concavity (character# 9-1; Fig.57b)

While it is true that there is uniformity of the suspensorial elements in Cyprinidae (Howes, 1984) in general, and Labeinae in particular, I find no difference in the quadrate, hyoid arches, palatine, or pterygoids among the different genera of Labeinae investigated. However, variation occurs in the shape of the symplectic. The symplectic in Labeinae is an elongate bone horizontally situated between the metapterygoid and the quadrate overlapping with some portion of the latter. In the outgroup genera, in most genera of Labeinae (*Cirrhinus, Discocheilus, Discogobio, Epalzeorhynchos, Labeo, Paracrossocheilus, Semilabeo, Osteocheilus* and *Tylognathus)* and in some species of *Garra* (e.g. *G.dembeensis, G.quadrimaculata*) the symplectic is straight dorsally. This condition is interpreted as the primitive state. In *Crossocheilus* and in some species of *Garra* (see *Garra* intrarelationships) the symplectic is curved with some dorsal concavity. The fact that the derived character state is evident in *Crossocheilus* and some species of *Garra* indicates a multiple origin for this character state (Fig.48).

10. The number of supraneurals

Supraneurals 4 or more (character# 10-0)

Supraneurals 1 or 2 (character# 10-1)

The variations in development and number of supraneurals in Cyprinidae have been noted by Howes (1978). A higher number (4 or more) of supraneurals is present in most of the labeine genera (*Cirrhinus*, *Crossocheilus*, *Discocheilus*, *Discogobio*, *Epalzeorhynchos*, *Labeo*, *Paracrossocheilus*, *Semilabeo*, *Osteocheilus* and *Tylognathus*), some species of *Garra* (e.g. *G.quadrimaculata*) and in the outgroup genera. This character state is interpreted as primitive. In some of the species of *Garra* (e.g. *G.dembeensis*), there are no or few (1 or 2) supraneurals and this condition is interpreted as the derived state. It has to be noted that primitively in teleosts the supraneurals are numerous (Johnson and Patterson, 1996).

11. The number of rows of pharyngeal teeth

Three rows of pharyngeal teeth (character# 11-0)

Two rows of pharyngeal teeth (character# 11-1)

Pharyngeal teeth are true teeth and are regularly replaced (Matthes, 1963) and can be arranged in one, two, or three rows in cyprinids. Some workers (Chu, 1935 in Eastman and Underhill, 1973; Ramaswami, 1955) maintain that the primitive condition is represented by three rows of teeth. However, Berg (1912 in Vladykov, 1934) proposed that the American cyprinids having one or two rows of teeth are the primitive ones. Neither views are based on Hennigian phylogenetic analysis and do not specify the level of universality at which these conclusions are made. However, the former view is supported here at the level of Labeinae.

The outgroup genera and most genera of Labeinae (*Cirrhinus*, *Crossocheilus*, *Epalzeorhynchos*, *Garra*, *Labeo*, *Osteocheilus* and *Tylognathus*) have three rows of pharyngeal teeth and this character state is interpreted as a primitive condition. In four genera of Labeinae (*Discocheilus*, *Discogobio*, *Paracrossocheilus and Semilabeo)*, there are two rows of teeth. This character state is interpreted as a derived condition supporting the monophyly of the *Discocheilus*, *Discogobio* and *Semilabeo* clade. It has apparently arisen independently in *Paracrossocheilus* (Fig.48).

12. The presence/ absence of bifurcation on the distal face of the leading anal fin pterygiophore

Absence of bifurcation on the distal face of the leading anal fin pterygiophore (character# 12-0; Fig.58b)

Presence of bifurcation on the leading anal fin pterygiophore (character# 12-1; Fig.58a)

In the outgroup genera, the leading anal fin pterygiophore is a straight bone without bifurcation. In all the genera of Labeinae investigated (*Cirrhinus*, *Crossocheilus*, *Discocheilus*, *Discogobio*, *Epalzeorhynchos*, *Garra*, *Labeo*, *Paracrossocheilus*, *Semilabeo*, *Osteocheilus* and *Tylognathus*) the leading anal fin pterygiophore is bifurcated at its distal tip. This character state is interpreted as the derived condition and supports, as a synapomorphic character state, the monophyly of Labeinae.

13. The shape of the leading dorsal fin pterygiophore

Deeply forked leading dorsal fin pterygiophore (character# 13-0; Fig.59b)
Shallowly forked leading dorsal fin pterygiophore (character# 13-1; Fig.59a)

The leading edge of the first dorsal fin pterygiophore in cyprinids is expanded (Howes, 1978). The fork formed by an expansion at the distal end of the pterygiophore is deep in the outgroup genera and all the genera of Labeinae except some species of *Garra* (e.g. *G.dembeensis*). The deeply forked character state is interpreted as the primitive condition while the shallow fork state evident in *G.dembeensis* is interpreted as the derived character state.

14. The presence of pelvic girdle indentation

Pelvic girdle indentation absent (character# 14-0, Fig.60b)
Pelvic girdle indentation present (character# 14-1, Fig.60a)

It has been reported that there is little variation in the pelvic girdle of cyprinids (Howes, 1978). However, some variation among labeines is recorded here. There is no deep indent in most genera of Labeinae (*Cirrhinus*, *Crossocheilus*, *Epalzeorhynchos*, *Labeo*, *Paracrossocheilus*, *Osteocheilus* and *Tylognathus*) and the outgroup genera. This character state is interpreted as the primitive condition.

However, the pelvic girdle has deep indent in the disc bearing genera of Labeinae (*Discocheilus, Discogobio, Garra* and *Semilabeo*). This character state is interpreted as the derived condition and unites the monophyletic clade of the above genera.

15. The number of bifid haemal spines with canal

One (character# 15-0)
Two (character# 15-1)

The preanal caudal centrum with aortic canal in labeines bears one or two (bifid) haemal spine(s). There is only one spine with canal in the outgroup genera and in the other genera of Labeinae (*Cirrhinus, Epalzeorhynchos, Labeo, Paracrossocheilus, Osteocheilus* and *Tylognathus*). This character state is interpreted as the primitive state. There are two branched (bifid) haemal spines with wide aortic canals in some genera of Labeinae (*Crossocheilus, Discocheilus, Discogobio, Garra* and *Semilabeo*). This character state is interpreted as the derived condition. It unites *Crossocheilus* with the disc bearing genera forming a monophyletic clade.

16. The shape of the cleithrum

Cleithrum with broad and short anterior portion (character# 16-0; Fig.61b & c)

Cleithrum with narrow and elongated anterior portion (character# 16-1; Fig.61a)

Regan (1911 in Gosline, 1978) is probably the first to point out that cyprinids of the *Barbus*-group have cleithrum with broad, indented anterior border. Although this condition is recognized to be a characteristic of a wider group of labeines and barbines (Gosline, 1978), the same paper acknowledges the uniqueness of *Garra's* cleithrum. In the outgroup genera and in all the genera of Labeinae except *Garra* the cleithrum is broad and short. This character state is interpreted as the primitive condition. In *Garra*, the cleithrum is narrow and elongated at its anterior portion. This may be associated with a well-developed pectoral fin and girdle, which in turn is presumably associated with bottom living. This condition is interpreted as the derived state and a synapomorphy for *Garra*. This character has to be investigated among specimens of comparable sizes.

17. The presence/ absence of neural process on preural 2 or 3

Absence of process on preural 2 or 3 (character# 17-0; Fig.62b)
Presence of process on preural 2 or 3 (character# 17-1; Fig.62a)

In most cyprinids the common condition is to have one neural spine per caudal centrum. This is the case in the outgroup genera and most of the labeine genera (*Cirrhinus*, *Crossocheilus*, *Discocheilus*, *Discogobio*, *Labeo*, *Paracrossocheilus*, *Semilabeo*, *Osteocheilus*, *Tylognathus* and some species of *Garra* (e.g.*G.quadrimaculata)*). This character state is interpreted as the primitive condition. However, in few species of *Garra* (e.g. *G.dembeensis*) and in *Epalzeorhynchos* there is an additional process at centrum of either preural 2 or 3. This character state is interpreted as the derived state. The occurrence of this derived state in *Epalzeorhynchos* and some species of *Garra* is considered to be of independent origin (Fig.48).

18. The segments of the dorsal fin rays

The dorsal fin ray segments are longer than wide (character# 18-0)

The dorsal fin ray segments are wider than long (character# 18-1)

Fin rays can be important taxonomic and phylogenetic characters if properly utilized. The dorsal fin ray segments, especially the third and fourth branched rays, are longer than wide in most genera of Labeinae (*Cirrhinus*, *Crossocheilus*, *Epalzeorhynchos*, *Paracrossocheilus*, *Labeo*, *Osteocheilus* and *Tylognathus*) and the outgroup genera. Thus, this character state is interpreted as a primitive condition. In the other genera of Labeinae (*Discocheilus*, *Discogobio*, *Garra* and *Semilabeo*) the dorsal fin ray segments are wider than long. This is interpreted as the derived condition. This is one of the three character states that support the monophyly of the above disc bearing Labeinae.

19. The number of unbranched anterior pectoral fin rays

One unbranched pectoral fin ray (character# 19-0)

Two unbranched pectoral fin rays (character# 19-1)

The importance of the unbranched fin rays in taxonomic and phylogenetic studies has been discussed in the first part of the thesis. There is only one unbranched anterior pectoral fin ray in all the genera of Labeinae investigated except *Garra*. This character state is interpreted as the primitive condition. There are two or more unbranched anterior pectoral fin rays in all the *Garra* species investigated. This is interpreted as the derived character state. As far as I know, the presence of two or more unbranched anterior pectoral fin rays have not been so far reported from any genus of Cyprinidae. This is one of the derived characters that support *Garra's* monophyly.

20. The presence/ absence of the suctorial disc

Absence of the suctorial disc (character# 20-0)

Presence of the suctorial disc (character# 20-1)

The suctorial disc is absent in most of the genera of Labeinae (*Cirrhinus*, *Crossocheilus*, *Epalzeorhynchos*, *Labeo*, *Paracrossocheilus*, *Osteocheilus* and *Tylognathus*) and the outgroup genera. This character state is interpreted as the primitive state. It is present in the "disc bearing" genera of Labeinae (*Discocheilus*, *Discogobio, Garra* and *Semilabeo*). Presence of a disc is interpreted as the derived condition and it supports the monophyly of the above disc bearing genera. However, there are considerable differences in the disc type and development within *Garra*, as well as between the disc bearing genera. The stages of disc development in *Garra* have been discussed in the first part of the thesis while the differences *Garra's* disc has from discs of the other genera is summarized in the conclusive remark section of the phylogeny of *Garra*.

21. The position of maxillary barbels

Posteriorly positioned maxillary barbels (character# 21-0)

Anteriorly positioned maxillary barbels (character# 21-1)

The taxonomic and phylogenetic significance and the controversy surrounding barbels have been discussed in part one of the thesis. In the outgroup genera and in all the other genera of Labeinae except *Discocheilus* the maxillary barbels are posteriorly located. This character state is interpreted as the primitive condition. The position of the maxillary barbel shows a distinctly different state in *Discocheilus*. In this genus, the position of the maxillary barbel is anteriorly situated, above the junction of the rostral fold and the lower lip. This character state is interpreted as the derived condition and it is considered to be an autapomorphy for *Discocheilus*. In some genera (e.g. *Tylognathus*) the barbels are absent.

22. The insertion of the anterior barbels

Posteriorly inserted (character# 22-0)

Anteriorly inserted (character# 22-1)

The position of the rostral barbel in all Garraini (a tribe of Labeinae that includes *Crossocheilus*, *Discocheilus*, *Discogobio*, *Epalzeorhynchos*, *Garra*, *Paracrossocheilus* and *Semilabeo*) is at the anterior portion of the rostral fold (or antero-rostral-sensu Reid, 1978). This character state is interpreted as the derived condition. This character supports a monophyletic clade of the Garraini. In *Cirrhinus*, *Labeo*, *Osteocheilus* and the outgroup genera the anterior barbels are located posteriorly (postero-rostral -sensu Reid, 1978). This character state is interpreted as the primitive condition. Barbels are absent in *Tylognathus*.

23. The length of the intestine

Short intestine (length of intestine 1-2 times the standard length) (character# 23-0)

Long intestine (length of intestine greater than 5 times the standard length) (character# 23-1)

A discussion on the intestine, especially with respect to its importance in taxonomy in cyprinids, is given in the first part of the thesis. All genera of Labeinae except some species of *Garra* have longer intestine than those of the outgroup genera. Longer intestine is, thus, interpreted as a derived character state and shorter intestine as a primitive character state. The derived character state is one of the character states that support the monophyly of Labeinae.

24. The presence/ absence of free rostral lobes

Absence of free rostral lobes (character# 24-0)
Presence of free rostral lobes (character# 24-1)

The rostral lobes are flaps of tissue found on both sides of the head anterior to the rostral barbels (see Fig.A17 in Yang and Winterbottom, 1998). Rostral lobes are absent in the outgroup genera and in all genera of Labeinae except *Epalzeorhynchos*. Therefore, this character state is an autapomorphy for *Epalzeorhynchos*. Previously, Banarescu (1986) and Yang and Winterbottom (1998) have also confirmed the monophyly of the genus *Epalzeorhynchos* using this character state.

25. The presence/ absence of Upper Labial fold

Absence of labial fold (character# 25-0)
Presence of labial fold (character# 25-1)

The labial fold is an extended fold of tissue that is a modification or extension of the upper lip (Fig.3 in Reid, 1978). The upper labial fold is absent in the outgroup genera and all genera of Garraini. Its absence is interpreted as the primitive condition. It is present in the genus *Cirrhinus*, *Labeo* and *Osteocheilus* and this is interpreted as the derived character state. This character state supports the monophyly of the tribe Labeini. Reid (1978) considers this character to be present in all Labeinae at least in early life history. However, I have been unable to verify its presence in any labeine genera investigated other than in those cited above.

26. The Presence/ absence of the lower labial fold

Absence of the lower labial fold (character# 26-0)

Presence of the lower labial fold (character# 26-1)

The lower labial fold is illustrated in Reid (1978, Fig.3). In the outgroup genera and in all the genera of Labeinae except *Labeo* and *Osteocheilus* the lower labial fold is absent. This is interpreted as the primitive character state. The lower labial fold is present in the above two genera (*Labeo* and *Osteocheilus)*. This character state is interpreted as derived and supports the monophyly of *Labeo* and *Osteocheilus*.

27. The presence/ absence of rostral fold

Absence or reduction of rostral fold (character# 27-0)

Presence of rostral fold (character# 27-1)

The rostral fold in the outgroup genera is very much reduced while in all genera of Labeinae it is well developed (Fig.5). The condition in the outgroup genera is interpreted as the primitive character state while that found in Labeinae a derived character state. This derived character state is one of the synapomorphies that support the monophyly of Labeinae.

28. The rostral fold continuity with lower lip

Rostral fold separate from lower lip (character# 28-0)

Rostral fold continuous with lower lip (character# 28-1)

In the outgroup genera the rostral fold is very much reduced. *Labeo* has short and thin rostral fold. *Cirrhinus, Osteocheilus* and *Tylognathus* have a rostral fold, but it is not continuous with the lower lip. This is interpreted as the primitive character state. Within Labeinae, those genera grouped under Garraini (*Crossocheilus, Discocheilus, Discogobio, Epalzeorhynchos, Garra, Paracrossocheilus* and *Semilabeo*) have a down grown and thicking of the rostral fold that is continuous with the lower lip (Fig.5). This, presumably derived character state supports the monophyly of the genera grouped under Garraini.

29. The presence/ absence of papillae on rostral fold

Absence of papillae on rostral fold (character# 29-0)

Presence of papillae on rostral fold (character# 29-1)

Papillae (sometimes called unculi-e.g. Roberts, 1982) are minute structures found around the mouth and on rostral folds of most genera of Labeinae. Those found in the rostral fold and lower lips of *Garra* are shown in Figs.63 to 65. Papillae are absent from the rostral folds of *Cirrhinus*, *Labeo*, *Osteocheilus*, *Tylognathus* and the outgroup genera and this condition is considered to be the primitive character state.

The presence of papillae on the rostral fold is considered to be a derived character state and supports the monophyly of some of the genera of Labeinae (those grouped under the tribe Garraini- *Crossocheilus*, *Discocheilus*, *Discogobio*, *Epalzeorhynchos*, *Garra*, *Paracrossocheilus* and *Semilabeo*).

30. The presence/ absence of papillae on lower lip

Absence of papillae on lower lip (character# 30-0)

Presence of papillae on lower lip (character# 30-1)

Similar to character# 28, Papillae are absent from the lower lips of *Cirrhinus*, *Labeo*, *Osteocheilus*, *Tylognathus* and the outgroup genera and this condition is interpreted as the primitive character state.

Papillae are present in the genera of Labeinae that constitute the tribe Garraini and this character state is one of the synapomorphies that support the monophyly of these genera. The papillae are particularly abundant in those disc-bearing genera (*Discocheilus, Discogobio, Garra* and *Semilabeo*) where the lower lip is modified into a suctorial disc.

Roberts (1982), however, reported that he has examined the mouthparts of the Indian *Labeo gonius* and found them extensively covered with "scale-like or leaf-shaped unculi up to 20 µm high". Whether these unculi are similar to the papillae evident in *Garra* and the Garraini is not clear.

31. The position of the mouth

Terminal/ sub-terminal mouth (character# 31-0)
Ventral mouth (character# 31-1)

Position of the mouth is generally a good indication of the habitat where the fish is dwelling and feeding and seems to be a good taxonomic and phylogenetic character. *Barbus* has a terminal mouth that presumably represents the primitive condition. *Varicorhinus* has a sub-terminal mouth that seems to be slight modification of the typical barbine mouth. All genera of Labeinae have a ventrally situated mouth in which it is believed to be an adaptation to bottom living and this character state is interpreted as a derived condition. It is one of the synapomorphies that support the monophyly of Labeinae.

CLADE ANALYSIS

Strength of the support of each clade is tested using Bremer's method by taking extra steps. The number of steps needed to collapse each clade is given in Fig.48.

In the course of this study, the following unique and unreversed synapomorphies confirm the monophyly of Labeinae and *Garra*'s placement within this group.

1.**The dorsal part of the leading anal fin pterygiophore** is deeply bi-furcated (character# 12-1; Fig.58a)

2. **Intestine length** is more than five times the standard length (character# 23-1).

3. **A downgrown or ventrally projecting rostral fold (rostral cap)** is present (character# 27-1; Fig.5 –from the first part of the thesis) that overlies the premaxillary.

4. **Mouth inferior** (character# 30-1).

Reid (1978) suggested 3 more character states as labeine synapomorphies but these cannot be confirmed here. They are:

1. The presence of the vomero-palatine organ.

Efforts to find this character in any stages of *Garra* available here have failed. While, Reid (1985) proposed that the organ regresses in later part of the life of some of the genera of Labeinae including *Garra*. The current study is unable to corroborate this assertion.

2. The presence of the upper and lower labial folds.

The lower lip is prominent in all members of the Labeinae investigated and in *Garra* it is modified with an extension in the form of a disc. However, the upper lip is absent in some genera including *Garra* and highly reduced in some others. The elaboration of the lower and upper lips into folds is clearly evident only in *Cirrhinus*, *Labeo* and *Osteocheilus*. Reid's assertion is that labial folds undergo regression in Garraini. I have been unable to verify this observation and therefore exclude the character as a synapomorphy for Labeinae.

3. The presence of premaxillae that are united in a loose median symphysis.

This character is true for all members of Labeinae investigated but is also found in the outgroup genera making it a plesiomorphic character state and uninformative at the level of the Labeinae.

As indicated in Fig.48, it has not been able to resolve the phylogenetic relationship of Tylognathini with respect to the other two major clades described below:

1. A clade consisting of the genera *Cirrhinus, Labeo* and *Osteocheilus* (tribe Labeini), which is supported by one unique and unreversed synapomorphy; the presence of an upper labial fold (character# 25-1), and by another homoplasious character state, the absence of premaxillae ascending process (character# 2-1). Within the Labeini, *Labeo* and *Osteocheilus* form a sub-clade supported by two unique and unreversed synapomorphic character states: the presence of concavity on the operculum (character# 8-1) and the presence of the lower labial fold (character# 26-1).

2. A second sub-clade (tribe Garraini) consisting of: *Garra, Discogobio, Discocheilus, Semilabeo, Epalzeorhynchos, Crossocheilus* and *Paracrossocheilus* is supported by the following 5 unique and unreversed synapomorphic character states:

a. The presence of postero-lateral elongation of the lacrimal bone (character# 7-1, Fig.55 b & c).

b. The insertion of the first pair of barbels is antero-rostral-sensu Reid (1978) (i.e. barbels that grow out of the down grown rostral fold) (character# 22-1).

c. The rostral fold is thick and down grown (character# 28-1) and continuous with the lower lip.

This is most pronounced in the disc bearing genera (*Garra* Hamilton, 1822, *Discogobio* Lin, 1931, *Discocheilus* Zhang, 1997 (previously *Discolabeo* Chen, 1992) and *Semilabeo* Peters, 1880).

d. Papillae are abundant on the rostral fold (character# 29-1).

e. The lower lip is also studded with papillae (character# 30-1).

Two sub-clades within the Garraini are:

A. An unamed clade consisting of *Crossocheilus, Discogobio, Discocheilus, Garra* and *Semilabeo*. This clade is supported by two unique and unreversed synapomorphic character states:

a. The presence of two branched (bifid) haemal spines with aortic canals at the precaudal vertebrae (character# 15-1).

b. The presence of concavity on the antero-ventral part of the dentary bone (character# 1-1)

B. Another monophyletic group included within the above clade is the disc bearing Garraini (OR Discorostralini - a new term given in reference to the presence of both the rostral fold and the disc) that include *Garra*, *Discogobio* (Fig.66), *Discocheilus* (Fig.67) and *Semilabeo* (Fig.68). A fifth disc-bearing genus, *Placocheilus* with 3 species, is not investigated in this work due to unavailability of material.

The following synapomorphic character states support the monophyletic clade Discorostralini:

a. Presence of ventral disc on lower jaw

The disc is an important taxonomic and phylogenetic character. Its variation and importance is discussed in detail in the first part of the thesis. Considering its importance, previous workers (Chen, 1992, Banarescu, 1986 and Wu et al., 1977 in Zhang, 1994) have suggested the grouping together of these genera now placed under Discorostralini. However, Zhang (1994) tried to show that this grouping based on the presence of disc may be paraphyletic or polyphyletic since some of the disc bearing genera (*Discocheilus* and *Semilabeo*) are more closely related to a non-disc bearing genus *Pseudogyrinocheilus* than they are to the disc bearing genera of *Discogobio* and *Garra*. I haven't been able to investigate *Pseudogyrinocheilus* and therefore cannot fully evaluate his assessment. However, I favor the former scheme because of the additional synapomorphic character states outlined here (see b and c below) that support the close relationship of the disc bearing genera.

It should be noted, however, that the callous structure (or the fleshy pad) of the disc shows some variation in these genera. Greatest development (i.e., the extent the disc is extended posteriorly) is observed in *Garra* followed by *Discogobio, Discocheilus* and *Semilabeo* (in decreasing order)(see Figs.5A-F). The fleshy pad is restricted to the most anterior part of the lower lip in *Discocheilus* and *Semilabeo*.

b. Presence of deep indent at the pelvic girdle (character# 14-1; Fig.60a).

c. Dorsal fin ray segments are wider than long (character# 18-1).

CONCLUDING REMARKS

It has been suggested that *Garra* is "closer" to *Varicorhinus* than it is to *Labeo* and hence it should be placed within the "*Barbus* type" of the African Cyprinidae (Matthes, 1963 p. 32). This opinion was challenged by Reid (1978, 1982). A conclusion supported also by the observation that *Garra* and *Labeo* species have a similar diploid number of chromosomes of $2n=50$ while *Varicorhinus* has $2n=150$ (Paugy et al., 1990 and Golubtsov and Krysanov, 1993 and Krysanov and Golubtsov, 1993). The present study confirms the placement of *Garra* as a labeine cyprinid more closely related to *Labeo* and related groups (as shown in Fig.48) than to the *Barbus-Varicorhinus* (Barbine*)* group.

While some of the synapomorphic character states that support the monophyly of Labeinae mentioned by Reid (1978) cannot be verified, the monophyly and the overall structure of the sub-family are corroborated by the current study. Some modifications are suggested, here, mainly due to the incorporation of additional taxa in the present study. For example, in Reid's (1978) cladogram (Fig.2) *Garra* is placed close to *Semilabeo*. However, the present analysis indicates that *Garra* is more closely related to *Discogobio (*a genus that Reid did not have a chance to investigate*)* than it is to *Semilabeo*, although *Garra* forms a monophyletic group with the three disc bearing genera.

It is also suggested here that *Crossocheilus* and the discorostralini form a monophyletic clade, supported by two synapomorphic character states, and that *Epalzeorhynchos* is an outgroup to this clade. In Reid (1978) *Crossocheilus* and *Epalzeorhynchos* form a monophyletic clade and *Garra* is an outgroup to that clade. However, it should be noted that the "*Labeo-bicolor* complex" of Reid has recently been synonymized with *Epalzeorhynchos* (Yang and Winterbottom, 1998).

In conclusion, it appears that *Garra* (Afro-Asian) are more related to the Asian genera of *Discocheilus*, *Discogobio*, *Semilabeo*, *Crossocheilus*, *Epalzeorhynchos* and *Paracrossocheilus* than to the Afro-Asian genera of *Barbus* and *Labeo*.

RESULTS OF *GARRA* PHYLOGENY

35 characters and 27 taxa (Tables 38 & 39; Table 40 for the ingroup taxa and their geographic distribution; Appendix 7 and 8 for the specimens examined) were employed in the analysis of *Garra* intrarelationships and a strict consensus of length 152, CI=. 28, RI=. 61 was recovered from 10 equally parsimonious trees using the algorithm mhennig* (an algorithm that applies branch swapping to each of the initial trees, retaining no more than one tree for each initial one) of Hennig86 and Clados (for producing the cladograms). *A posteriori* weighing was done to improve the consistency and base groupings on more reliable characters. The characters were weighed using their Rescaled Consistency (consistency times retention indices) from the best fit.

In PAUP (heuristic) 2600 trees were recovered, the shortest tree of which is 177 steps long. The topology of the consensus cladogram recovered using PAUP is the same as that found using Hennig86. Bremer support was searched for all the clades using PAUP (see Fig.69 for the number of steps required to collapse each clade).

While acknowledging that the analysis is preliminary and didn't result in complete resolution, the following clade and two sub-clades are recognized for ease of reference (Fig.69). The clades are selected based on their support by unreversed synapomorphic character states:

1. Clade A---- supported by character# 4, 8, 15, 16 and 20.
2. Sub-clade B---- supported by character# 6, 7, 10, 11, 12, 24, 26 and 29.
3. Sub-clade C---- supported by character# 5 and 9.

Description and distribution of characters

0. The shape of the supraethmoid bone

Supraethmoid long and narrow (character# 0-0; Fig.49a)
Supraethmoid short and broad (character# 0-1; Fig.49b)

In all Labeines, except *Garra,* the supraethmoid is narrow and elongate, and this is interpreted as the primitive character state at the Labeinae level. A broad and short supraethmoid bone is characteristic of the genus *Garra* and is interpreted as the derived state. This character is one of the synapomorphies that support the monophyly of *Garra* as described in the preceding Labeine phylogeny.

1. The shape of the antero-medial part of the Supraethmoid

Antero-medial part of the supraethmoid notched (character# 1-0; Fig.70a)
Antero-medial part of the supraethmoid with process or median elongation (character# 1-1; Fig.70b)

In a few species of *Garra (G.bicornuta, G.blanfordii, G.congoensis, G.microstoma, G.ornata and G.rossica)* and in four genera of the Labeinae investigated (*Crossocheilus, Discocheilus, Discogobio* and *Paracrossocheilus*) the antero-medial part of the supraethmoid is notched. This character state is interpreted as the primitive condition. In *Epalzeorhynchos* and the remaining *Garra* species (*G.aethiopica, G.cambodgiensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.ignestii, G.imberbis, G.lamta, G.makiensis, G.nasuta, G.quadrimaculata, G.rufa* and *G.tana*) the anteromedial part of the supraethmoid has an outgrowth (process). This character state is interpreted as the derived condition. Due to the deteriorated condition of the cleared and stained specimen, this character could not be determined in one of the outgroup genera, *Semilabeo.*

Howes (1980) mentioned that in barbines and labeines, the most derived members of the respective groups possess a medial elongation of the ethmoid block considering this as an adaptation associated with the inferior position of the mouth.

2. The presence/ absence of antero-lateral concavity on dentary

Presence of concavity on dentary (character# 2-0; Fig.50a)

Absence of concavity on dentary (character# 2-1; Fig.50b)

The morphology of the upper and lower jaw is believed to be highly variable in Cyprinidae (Matthes, 1963). Anterolaterally, concavities are present on the dentary in some groups of Labeinae (*Crossocheilus, Discocheilus, Discogobio* and *Semilabeo*) as well as some species of *Garra (G.bicornuta, G.blanfordii, G.cambodgiensis, G.dembeensis, G.geba, G.imberbis, G.lamta, G.makiensis, G.ornata* and *G.rufa*). This character state is interpreted as the primitive condition at the level of *Garra*. However, at the level of Labeinae this character state is the derived condition. In *Epalzeorhynchos* and *Paracrossocheilus* and the remaining *Garra* species *(G.aethiopica, G.dembecha, G.duobarbis, G.hindii, G.ignestii, G.lamta, G.microstoma, G.nasuta, G.quadrimaculata, G.rossica* and *G.tana)* these concavities are absent. This state is interpreted as the derived condition. The character state in *G.congoensis* could not be identified, due to the deteriorated condition of the available cleared and stained material.

3. The presence/ absence of premaxillary ascending process

Presence of a premaxillary ascending process (character# 3-0; Fig.51c)

Absence of a premaxillary ascending process (character# 3-1; Fig.51b)

In most species of *Garra (G.aethiopica, G.cambodgiensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.microstoma, G.ornata* and *G.tana)* and in most other genera of Labeinae (*Crossocheilus, Discocheilus, Discogobio, Paracrossocheilus* and *Semilabeo*) the premaxillae bear anterior ascending processes that slope backwards. This condition is interpreted as primitive. Some species of *Garra* (*G.bicornuta, G.blanfordii, G.ignestii, G.lamta, G.makiensis, G.nasuta* and *G.rufa*) and one outgroup genus *Epalzeorhynchos* lack or have reduced ascending processes. This character state is interpreted as the derived condition. The state in *G.congoensis* cannot be determined, due to the deteriorated condition of the available cleared and stained material.

4. The infraorbital series

Infraorbital series composed of bony plates (character# 4-0; Fig.54b)
Infraorbital series composed of tubular bones (character# 4-1; Fig.54a)

The infra-orbital series in Labeinae are either composed of bony plates below the canal-bearing portion of the bones or are tubular and restricted to the canal bearing part of the bones. In some species of *Garra* (*G.bicornuta, G.blanfordii, G.ignestii, G.makiensis, G.quadrimaculata, G.rossica* and *G.rufa*) and in all the outgroup genera the infraorbital series is with bony plates. This character state is interpreted as the primitive condition.

Tubular bones are found in most of the species of *Garra* (*G.aethiopica, G.cambodgiensis, G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.lamta, G.microstoma, G.nasuta, G.ornata* and *G.tana)*. This character state is interpreted as the derived condition. This is one of the synapomorphies that support the monophyly of a large clade of *Garra* species (Clade A; Fig.69).

Although it was suggested that the most often encountered condition in cyprinids is a reduction of infraorbital ossification (Howes, 1981), broad bony plates are considered to be primitive while tubular canal bearing ones are considered to be derived at this level of universality. This is true at the Labeinae level as well (see previous discussion in character 6). At the family level Tretiakov (1946 in Howes, 1980), also, suggested that those cyprinid genera with the broadest posterior bones are the most primitive.

5. The number of infraorbital series.

Five bones in the infraorbital series (character# 5-0)

Six bones in the infraorbital series (character# 5-1)

The number of bones in the infraorbital series is variable in Labeinae. The infraorbital series, here, includes the lacrimal bone in the count. It was suggested

(Nelson, 1969) that the primitive condition for teleosts is having seven canal bones from the antorbital to the dermosphenotic and reduction of bone and neuromast numbers seems to be a derived condition. However, in Labeinae it appears that reduction of size of bones is a derived condition (previous labeine analysis) while reduction in the number of bones is a plesiomorphic feature. Therefore, the presence of five infraorbital bones in some species of *Garra* (*G.bicornuta, G.blanfordii, G.dembecha, G.ignestii, G.lamta, G.makiensis, G.quadrimaculata, G.rufa* and *G.rossica*) and most of the outgroup genera (*Discocheilus, Discogobio, Epalzeorhynchos, Paracrossocheilus* and *Semilabeo*) is interpreted as the primitive condition.

The presence of six infraorbital bones in some species of *Garra* (*G.aethiopica, G.cambodgiensis, G.congoensis, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.microstoma, G.nasuta, G.ornata* and *G.tana)* and in the outgroup genus *Crossocheilus* is interpreted as the derived character state. This character state supports the monophyly of Sub-clade C and all species of this sub-clade possess thin canal bearing bones and six infraorbital bones.

6. The shape of the postero-dorsal process of the lacrimal bone

Broad postero-dorsal elongation of the lacrimal bone (character# 6-0; Fig.55b)
Narrow and pointed postero-dorsal elongation of the lacrimal bone (character# 6-1; Fig.55c)

The lacrimal is a prominent bone in the infraorbital series of the labeines. In the barbines (*Barbus, Varicorhinus*), Tylognathini (*Tylognathus*) and Labeini (*Cirrhinus*, *Labeo* and *Osteocheilus*), the lacrimal bone is short and broad with no postero-dorsal elongation. In all the other genera of Labeinae (the Garraini) the postero-dorsal elongation is prominent and this character state is interpreted as derived in Labeinae (see description in character# 7 of Labeine phylogeny).

Within *Garra* there is variation in the shape of the elongate lacrimal bone. In some species of *Garra* (*G.bicornuta, G.blanfordii, G.hindii, G.ignestii, G.imberbis, G.lamta, G.makiensis, G.ornata, G.quadrimaculata*, *G.rossica* and *G.rufa)* and some of the outgroup genera (*Discogobio, Epalzeorhynchos, Paracrossocheilus* and *Semilabeo)* the elongation is broad at its posterior end. This character state is interpreted as the primitive condition.

In the remaining species of *Garra (G.aethiopica, G.cambodgiensis, G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.microstoma, G.nasuta* and *G.tana*) and some of the outgroup genera (*Crossocheilus* and *Discocheilus*) the postero-dorsal elongation is narrow and pointed. This character state is interpreted as the derived condition. This character state supports Sub-clade B. However, there are reversals in the clade to the primitive condition (*G.hindii, G.imberbis* and *G.ornata)*.

7. The presence/ absence of concavity on the operculum

Absence of concavity on the operculum (character# 7-0; Fig.56a)

Presence of concavity on the operculum (character# 7-1; Fig.56b)

The shape of the dorsal margin of the opercular bone is variable in *Garra*. In some species (*G.bicornuta*, *G.blanfordii*, *G.dembeensis*, *G.ignestii*, *G.hindii*, *G.lamta*, *G.makiensis*, *G.nasuta*, *G.quadrimaculata*, *G.rossica* and *G.rufa*) and in most of the outgroup genera (*Crossocheilus*, *Discocheilus*, *Discogobio*, *Epalzeorhynchos* and *Paracrossocheilus*) the dorsal and posterior margins of the operculum are straight. This characters state is interpreted as primitive. In the remaining species of *Garra* (*G.aethiopica*, *G.cambodgiensis*, *G.congoensis*, *G.dembecha*, *G.duobarbis*, *G.geba*, *G.imberbis*, *G.lamta*, *G.microstoma* and *G.ornata*) the dorsal and posterior part of the operculum are concave. This character state is interpreted as the derived condition. Reversal to the primitive condition is evident in *G.dembeensis*, *G.hindii* and *G.nasuta*. The state in *Semilabeo* could not be determined.

8. The shape of the symplectic

The symplectic is straight dorsally (character# 8-0; Fig.57a)

The symplectic is dorsally concave (character# 8-1; Fig.57b)

As mentioned in the preceding section on Labeinae, there seems to be uniformity in the suspensorial elements in Labeinae and this is also true for *Garra*. However, the symplectic is a straight bone in some species of *Garra (G.aethiopica, G.bicornuta, G.blanfordii, G.ignestii, G.quadrimaculata, G.rossica* and *G.rufa)* and in all the outgroups except *Crossocheilus*. This character state is interpreted as the primitive condition. The opposing state is with some concavity on the dorsal margin of the bone. This derived character state is found in the remaining species of *Garra* (*G.cambodgiensis*, *G.congoensis*, *G.dembecha*, *G.dembeensis*, *G.duobarbis*, *G.geba*, *G.hindii*, *G.lamta*, *G.makiensis*, *G.microstoma* and *G.tana*) and in *Crossocheilus*. Among the derived species of Clade A, reversal to the primitive state is noted in *G.aethiopica*. The condition in *G.nasuta* and *G.ornata* could not be determined.

9. The shape of the urohyal

Indentation with no posterior tapering (character# 9-0; Fig.71a)

No indentation but presence of sharp tapering posteriorly (character# 9-1; Fig.71b)

Two states of the urohyal are recognized, when viewed dorsally. In one, there is sharp and symmetrical tapering and elongation of the posterior end while in the other there is no sharp tapering at the posterior end and there are indentations at both sides of the posterior end. Moreover, in the latter condition the whole posterior end is asymmetrical.

Some species of *Garra (G.bicornuta, G.blanfordii, G.dembecha, G.hindii, G.ignestii, G.lamta, G.makiensis, G.ornata, G.quadrimaculata, G.rossica* and *G.rufa)* and the outgroup genera *Crossocheilus, Discogobio, Epalzeorhynchos* and *Paracrossocheilus* possess the indented state that is interpreted as primitive. The remaining species of *Garra* (*G.aethiopica, G.cambodgiensis, G.congoensis, G.dembeensis, G.duobarbis, G.geba, G.imberbis, G.microstoma, G.nasuta* and *G.tana)* and one of the outgroup genera *(Discocheilus)* show the tapered character state which is interpreted as the derived condition. The case in *G.hindii* and *G.ornata* is reversal to the primitive condition. The condition in *Semilabeo* could not be determined.

10. The shape of the pharyngeal process

Pharyngeal process broad and short (character# 10-0; Fig.72a)

Pharyngeal process thin, elongate and pointed (character# 10-1; Fig.72b)

The pharyngeal process (=posterior process or posterior shaft e.g., Yang and Winterbottom, 1998)) is believed to be useful indicator of relationships in Cyprinidae (Howes, 1981). Few species of *Garra (G.bicornuta, G.blanfordii, G.ignestii, G.lamta, G.makiensis, G.quadrimaculata, G.rossica* and *G.rufa*) and some of the outgroup genera (*Discogobio, Epalzeorhynchos, Paracrossocheilus* and *Semilabeo)* have a broad and short pharyngeal process. This character state is interpreted as the primitive condition.

In most species of *Garra* (*G.aethiopica, G.cambodgiensis, G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.microstoma, G.ornata, G.nasuta* and *G.tana*) and some of the outgroup genera (*Crossocheilus* and *Discocheilus*) the pharyngeal process is narrow and pointed at its posterior end. This character state is interpreted as the derived condition and it is one of the synapomorphies that support the monophyly of Sub-clade B. It has apparently evolved in *Crossocheilus* and *Discocheilus* independently.

11. The shape of the masticatory plate

Truncate anteriorly (character# 11-0, Fig.72a)
Rounded anteriorly (character# 11-1, Fig.72b)

The masticatory plate is believed to be useful indicator of relationships in Cyprinidae (Howes, 1981). Few species of *Garra (G.bicornuta, G.blanfordii, G.ignestii, G.lamta, G.makiensis, G.quadrimaculata, G.rossica,* and *G.rufa*) and most of the outgroup genera (*Discogobio, Epalzeorhynchos, Paracrossocheilus* and *Semilabeo)* have an anteriorly truncated masticatory plate. This character state is interpreted as the primitive condition.

In most species of *Garra* (*G.aethiopica*, *G.cambodgiensis*, *G.congoensis*, *G.dembecha*, *G.dembeensis*, *G.duobarbis*, *G.geba*, *G.hindii*, *G.imberbis*, *G.microstoma*, *G.ornata*, *G.nasuta* and *G.tana*) and some of the outgroup genera (*Crossocheilus* and *Discocheilus*) the masticatory plate is rounded anteriorly. This is congruent with the preceeding character state and it is one of the synapomorphies that support the monophyly of Sub-clade B. Concurrent with character# 10, it appears to have evolved independently in *Crossocheilus* and *Discocheilus*.

12. The number of supraneurals

Supraneurals 4 or more (character# 12-0)
Supraneurals absent or 1 or 2 (character# 12-1)

Four or more supraneurals are present in some species of *Garra* (*G.geba*, *G.imberbis*, *G.lamta*, *G.makiensis*, *G.nasuta*, *G.quadrimaculata* and *G.rufa*) and in all the outgroup genera. This character state is interpreted as primitive. In the remaining *Garra* species (*G.aethiopica*, *G.bicornuta*, *G.blanfordii*, *G.cambodgiensis*, *G.congoensis*, *G.dembecha*, *G.dembeensis*, *G.duobarbis*, *G.hindii*, *G.ignestii*, *G.microstoma*, *G.ornata*, *G.rossica* and *G.tana*) supraneurals are absent or are few in number. This condition is interpreted as the derived state. This character state is reversed to the primitive condition in *G.imberbis* and *G.nasuta*.

13. The number of rows of pharyngeal teeth

Two rows (character# 13-0)

Three rows (character# 13-1)

There are different opinions (mentioned in the taxonomic discussion and the preceding Labeine phylogeny) as to the primitive/-advanced nature of tooth row number. At the level of Labeinae two rows of teeth were interpreted as derived. However, at the level of *Garra* this may not be true. Most of the outgroup genera (*Discocheilus, Discogobio, Paracrossocheilus* and *Semilabeo*) and a couple of *Garra* species (*G.cambodgiensis* and *G.ornata*) have two pairs of pharyngeal tooth rows. This character state is interpreted as the primitive condition. The remaining species of *Garra* (*G.aethiopica, G.bicornuta, G.blanfordii, G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.ignestii, G.imberbis, G.lamta, G.makiensis, G.microstoma, G.quadrimaculata, G.rossica* and *G.tana*) and two of the outgroup genera (*Crossocheilus* and *Epalzeorhynchos*) have three pairs of tooth rows. This character state is interpreted as the derived condition.

14. The shape of the suture at frontal and parietal

Suture of frontal non-continuous with suture of parietal (character# 14-0, Fig.73a)

Suture of frontal continuous with suture of parietal (character# 14-1, Fig.73b)

In some species of *Garra (G.bicornuta, G.blanfordii, G.congoensis, G.hindii, G.ignestii, G.makiensis, G.quadrimaculata* and *G.rossica*) and the outgroup genera (*Discocheilus, Discogobio, Epalzeorhynchos* and *Semilabeo*) the median sutures of the frontal and parietal are not continuous. This character state is interpreted as the primitive condition. In the remaining species of *Garra (G.aethiopica, G.cambodgiensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.ignestii, G.lamta, G.microstoma, G.nasuta, G.ornata, G.rufa* and *G.tana*) and in the outgroup genera *Crossocheilus* and *Paracrossocheilus* the two sutures are continuous. This character state is interpreted as the derived condition. The condition in *G.congoensis* is apparently reversal to the primitive state.

15. The presence/ absence or reduction of intramuscular bones

More than ten intramuscular bones (character# 15-0)
Less than five or none (character# 15-1)

When present, the intramuscular bones may be of two types: tri-radiate or single rod types (Skelton, 1988). The tri-radiate are mainly evident in the caudal region where they are well developed and ossified. More than ten intramuscular bones are present in some species of *Garra* (*G.bicornuta, G.blanfordii, G.cambodgiensis, G.congoensis, G.ignestii, G.makiensis, G.microstoma, G.nasuta, G.quadrimaculata, G.rossica, G.rufa* and *G.tana*) and all the outgroup genera investigated. This character state is interpreted as the primitive condition. In the remaining species of *Garra* (*G.aethiopica, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.lamta* and *G.ornata*) the intramuscular bones are few in number or completely absent. This character state is interpreted as the derived condition. *G.cambodgiensis, G.congoensis, G.microstoma, G.nasuta* and *G.tana* show a reversal to the primitive condition.

16. The shape of the leading dorsal fin pterygiophore

The proximal face of the first dorsal fin pterygiophore is deeply forked (character# 16-0; Fig.59b)

The proximal face of the first dorsal fin pterygiophore is only superficially forked (character# 16-1; Fig.59a)

The first dorsal fin pterygiophore in cyprinids is expanded (Howes, 1978). The fork, formed by an expansion at the proximal face of the pterygiophore, is deep in some species of *Garra* (*G.bicornuta, G.blanfordii, G.ignestii, G.makiensis, G.microstoma, G.ornata, G.quadrimaculata, G.rossica* and *G.rufa*) and all the outgroup genera investigated. This character state is interpreted as the primitive condition. The remaining *Garra* species (*G.aethiopica, G.cambodgiensis, G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.lamta, G.nasuta*, and *G.tana)* have shallow and superficial forking at the proximal end of the first dorsal fin pterygiophore. This character state is interpreted as the derived condition and supports the monophyly of Clade A. The condition in *G.microstoma* and *G.ornata* is apparently reversed to the primitive condition.

17. The shape of the cleithrum

Cleithrum with broad and short upper limb (character# 17-0; Fig.61b & c)
Cleithrum with narrow and elongated upper limb (character# 17-1; Fig.61a)

Regan (1911 in Gosline, 1978) is probably the first to point out that cyprinids of the *Barbus*-group have cleithra with broad, indented upper limbs. Although this condition is recognized to be a characteristic of a wider group of cyprinids the uniqueness of *Garra's* cleithrum has been acknowledged (Gosline, 1978). In the outgroup genera (*Crossocheilus, Discocheilus, Discogobio, Epalzeorhynchos, Paracrossocheilus* and *Semilabeo*) the cleithrum is broad and short. This character state is interpreted as the primitive condition. In *Garra*, the cleithrum is narrow and elongated along the upper limb. This condition is interpreted as the derived state and an autapomorphy for *Garra*. This character state is one of the character states that support the monophyly of *Garra*. This character has to be investigated among specimens of comparable sizes.

18. The presence/ absence of a neural process on preural 2 or 3.

The absence of a neural process on preural 2 or 3 (character# 18-0; Fig.62b)

The presence of a neural process on preural 2 or 3 (character# 18-1; Fig.62a)

In most Labeinae, the common condition is to have one neural spine per caudal centrum. In most of the outgroup genera (*Crossocheilus*, *Discocheilus*, *Discogobio*, *Paracrossocheilus* and *Semilabeo*) and most of the species of *Garra* (*G.aethiopica*, *G.bicornuta*, *G.cambodgiensis*, *G.congoensis*, *G.duobarbis*, *G.ignestii*, *G.imberbis*, *G.lamta*, *G.makiensis*, *G.microstoma*, *G.nasuta*, *G.ornata*, *G.quadrimaculata*, *G.rossica*, *G.rufa* and *G.tana*) there is a single neural spine per centrum. This condition is interpreted as primitive. However, in a few species of *Garra* (*G.blanfordii*, *G.dembecha* and *G.dembeensis*) and in *Epalzeorhynchos*, there is an additional neural process on preural 2 or 3. This character state is interpreted as the derived condition. It seems that this character evolved in the three species of *Garra* and in *Epalzeorhynchos* independently.

19. The presence/ absence of haemal process at preural 2 or 3

Absence of haemal process at preural 2 or 3 (character# 19-0; Fig.74b)

Presence of haemal process at preural 2 or 3 (character# 19-1; Fig.74a)

The general state observed in all the outgroup genera and most species of *Garra* is to have one haemal spine without a process. This character state is interpreted as the primitive condition. However, in few species of *Garra (G.bicornuta*, *G.blanfordii*, *G.ignestii*, *G.quadrimaculata* and *G.rossica*), there is an additional process, which in some cases is markedly elongated. This character state is interpreted as the derived condition among species of *Garra*.

20. The number of preanal caudal vertebrae

2-4 preanal caudal vertebrae (character# 16-0)
6-12 preanal caudal vertebrae (character# 16-1)

The preanal caudal vertebrae are here defined as the caudal vertebrae counted anteriorly from the insertion of the first anal fin pterygiophore to the first ribbed vertebra. In some species of *Garra* (*G.bicornuta, G.blanfordii, G.ignestii, G.makiensis, G.nasuta, G.quadrimaculata, G.rossica* and *G.rufa)* and in the outgroup genera *Discocheilus, Discogobio* and *Epalzeorhynchos* the number of preanal caudal vertebrae is 2-4. This character state is interpreted as the primitive condition. In the remaining species of *Garra* (*G.aethiopica, G.cambodgiensis, G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.lamta, G.microstoma, G.ornata* and *G.tana*) and two of the outgroup genera *Crossocheilus* and *Paracrossocheilus* the number of preanal caudal vertebrae ranges from 6-12 and this character state is interpreted as the derived condition. This character state supports the monophyly of Clade A. The case of *G.nasuta* is apparently a reversal to the primitive condion.

21. The number of unbranched anterior pectoral fin rays

One unbranched anterior pectoral fin ray (character# 21-0)

Two unbranched anterior pectoral fin rays (character# 21-1)

The importance of unbranched fin rays in taxonomic and phylogenetic studies has been discussed in the first part of the thesis. There is only one unbranched anterior pectoral fin ray in all the genera of Labeinae investigated while there are two unbranched anterior pectoral fin rays in all of the *Garra* species investigated. As far as I know, the presence of two unbranched anterior pectoral fin rays has not been reported in any other genus of Cyprinidae. This is one of the derived characters that support the monophyly of *Garra*.

22. The development of the suctorial disc

Disc well developed (character# 22-0)

Disc reduced or absent (character# 22-1)

The presence of a suctorial disc is evident in four genera of Labeinae investigated– *Discocheilus, Discogobio, Garra* and *Semilabeo*. However, there are differences in disc structure and development both within *Garra* and among these genera. The variability in disc development within *Garra* has been discussed in the first part of the thesis. A disc is prominent in some species of *Garra* (*G.aethiopica, G.bicornuta G.blanfordii, G.cambodgiensis, G.congoensis, G.dembeensis, G.hindii,* *G.ignestii, G.imberbis, G.lamta G.makiensis, G.nasuta, G.ornata, G.quadrimaculata* and *G.rufa*) and in some of the outgroup genera (*Discocheilus, Discogobio* and *Semilabeo*). This condition is interpreted as primitive at the level of *Garra*. In the remaining species of *Garra* (*G.dembecha, G.duobarbis, G.geba, G.microstoma, G.rossica* and *G.tana*) and the outgroup genera (*Crossocheilus, Epalzeorhynchos* and *Paracrossocheilus)* the disc is either rudimentary or it is absent. This character state is interpreted as the derived condition.

23. The presence/ reduction/ absence of barbels

Presence of two pairs of barbels (character# 23-0)
Absence or reduction (one pair) of barbels (character# 23-1)

The taxonomic and phylogenetic significance and the controversy surrounding barbels have been discussed in part one of the thesis. It seems that barbels can be used for both the above purposes if utilized properly.

The presence of two pairs of barbels is a common state in the outgroups of *Garra* and it is also widely distributed among the species of *Garra* and is interpreted as the primitive state while the reduction in barbels (a pair or none) is interpreted as the derived character state. Most of the species of *Garra*, except those mentioned below, and most of the outgroup genera (*Discocheilus, Discogobio, Crossocheilus* and *Epalzeorhynchos)* show the primitive character state in having two pairs of barbels.

The derived state is evident in some species of *Garra (G.bicornuta, G.cambodgiensis, G.duobarbis, G.imberbis* and *G.rossica)* and the outgroup genera *Semilabeo* and *Paracrossocheilus*. It is apparently evolved in the above groups independently.

24. The length of the intestine

Long intestine (> 5 times the standard length) (character# 24-0)
Short intestine (1-2 times the standard length) (character# 24-1)

A discussion on the intestine, especially with respect to its importance in taxonomy of cyprinids, is given in the first part of the thesis. Genera of Labeinae, except some presumably derived species of *Garra*, have longer intestines (length of intestine greater than 5 times the standard length) than those of *Barbus* and *Varicorhinus* (length of intestine 1-2 times the standard length) and longer intestine is taken to be a derived character state at the level of Labeinae while it is a primitive character state at the level of *Garra*. Shorter intestine is interpreted as primitive at the level of Labeinae and derived at the level of *Garra*. Species of *Garra* possessing longer intestines are *G.bicornuta, G.blanfordii, G.congoensis, G.ignestii, G.lamta, G.makiensis, G.quadrimaculata, G.rossica* and *G.rufa*. All the others have relatively shorter intestines (length of intestine not greater than two times the standard length). This character state supports the monophyly of Sub-clade B. The case of *G.congoensis* appears to be reversal to a primitive condition.

25. The presence/ absence of scales in the predorsal region

Full predorsal squamation (character# 25-0)
Few or no predorsal scales (character# 25-1)

Squamation in *Garra* is described in the first part of the thesis. The predorsal scales are full in some species of the African *Garra* (*G.aethiopica, G.blanfordii, G.hindii, G.ignestii, G.makiensis* and *G.quadrimaculata*), in all the species of the other regions investigated (*G.bicornuta, G.cambodgiensis, G.imberbis, G.lamta, G.nasuta, G.rossica* and *G.rufa*) and in all the outgroup genera. This character state is interpreted as primitive. In the remaining African species (*G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.microstoma, G.ornata* and *G.tana*) the scales on the predorsal region are either very reduced or completely absent. This character state is interpreted as the derived condition. It is evident in a clade of three species (*G.congoensis, G.microstoma* and *G.tana*) within sub-clade C, but, seems to have been independently evolved in five other species (*G.dembecha, G.dembeensis, G.duobarbis, G.geba* and *G.ornata*).

26. The number of scales on the lateral line

Less than or equal to 36 scales on the lateral line (character# 26-0)
More than 36 scales on the lateral line (character# 26-1)

In some species of *Garra (G.aethiopica, G.bicornuta, G.blanfordii, G.cambodgiensis, G.duobarbis, G.ignestii, G.lamta, G.makiensis, G.ornata, G.quadrimaculata, G.rossica* and *G.rufa*) and in all the outgroup genera there are 36 or fewer scales on the lateral line. This character state is interpreted as the primitive condition. Species possessing exactly 36 scales are rare, hence the break.

The remaining species of *Garra* (*G.congoensis, G.dembecha, G.dembeensis, G.geba, G.hindii, G.imberbis, G.microstoma, G.nasuta* and *G.tana*) have more than 36 scales on their lateral line. This character state is interpreted as the derived condition. This character state, although homoplasious, is evident in all the species of Sub-clade B. The cases of *G.aethiopica, G.cambodgiensis, G.duobarbis* and *G.ornata* seem to be reversal to the primitive condition.

27. The position of the vent

Vent near the anal fin origin (character# 27-0)
Vent distant from anal fin origin (character# 27-1)

The vent as a taxonomic character has been discussed in the first part of the thesis. Some of the species of *Garra* (*G.makiensis, G.quadrimaculata* and *G.rossica*) and some of the outgroup genera (*Discocheilus, Discogobio, Epalzeorhynchos* and *Semilabeo*) have their vent very close to the anal fin. In these groups the distance between the anal fin and the vent is less than 20% of the distance between the anterior origins of the anal and pelvic fins. This character state is interpreted as the primitive condition. In the remaining *Garra* species and the outgroup genera *Crossocheilus* and *Paracrossocheilus* the vent is relatively distant from the anal fin origin (the distance from the vent to the anal fin is more than 25% of the distance between the anterior origins of the anal and pelvic fins). This character state is interpreted as the derived condition.

28. The presence/ absence of black spots at the base of dorsal fin

Absence of black spots at the base of dorsal fin (character# 28-0)
Presence of black spots at the base of dorsal fin (character# 28-1)

Color variations among *Garra* species does not usually seem to be of phylogenetic significance (detail is given in character discussion section of part one of the thesis). One aspect of coloration that appears to show some significance is the presence of black spots at the base of dorsal fin. These black spots are absent in *G.bicornuta, G.imberbis* and *G.lamta* and all of the outgroup genera. Their absence is interpreted as the primitive condition.

Black spots are present in all other *Garra* species investigated. This character state is interpreted as the derived condition. Although homoplasious, it supports the monophyly of *Garra*. However, it seems to have been reversed in three species of *Garra* in which it is absent.

29. The presence/ absence of chest and abdominal scales

Presence of scales on the chest and abdominal region (character# 29-0)
Absence of scales on the chest and abdominal region (character# 29-1)

In few species of *Garra (G.bicornuta, G.cambodgiensis, G.hindii, G.lamta, G.nasuta, G.quadrimaculata* and *G.rufa*) and in all the outgroup genera the chest and abdomen are covered with overlapping scales. This character state is interpreted as the primitive condition. In the remaining species of *Garra (G.aethiopica, G.blanfordii, G.congoensis, G.dembecha, G.dembeensis, G.duobarbis, G.ignestii, G.imberbis, G.makiensis, G.microstoma, G.ornata, G.rossica* and *G.tana*) the chest and abdomen are not fully scaled or not scaled at all. This character state is interpreted as the derived condition.

30. The presence/ absence of proboscis

Absence of proboscis (character# 30-0)

Presence of proboscis (character# 30-1)

The proboscis is an extension of the snout and may be divided into two or three lobes. In most species of *Garra* and in all the outgroup genera this structure is absent and this is interpreted as the primitive condition. In two species of *Garra* *(G.bicornuta* and *G.nasuta*) the proboscis is evident and this condition is interpreted as the derived state.

31. The presence/ absence of tubercles on snout

Presence of tubercles on snout (character# 31-0)

Absence of tubercles on snout (character# 31-1)

As has been mentioned in the taxonomic section, tubercles may serve a function in mate recognition, maintaining body contact during spawning, defending territories and maintaining buoyancy. Tubercles are present in most species of *Garra* *(G.bicornuta, G.cambodgiensis, G.congoensis, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.ignestii, G.imberbis, G.makiensis, G.microstoma, G.nasuta, G.ornata, G.quadrimaculata* and *G.rufa*) and in some of the outgroup genera (*Discocheilus, Discogobio, Paracrossocheilus* and *Semilabeo*). This character state is interpreted as the primitive condition. Tubercles are absent from the snout of few species of *Garra* (*G.aethiopica, G.blanfordii, G.dembecha, G.lamta, G.rossica* and *G.tana*) and two of the outgroup genera (*Crossocheilus* and *Epalzeorhynchos*). This character state is interpreted as the derived condition.

32. The presence/ absence of body stripes

Absence of body stripes (character# 32-0)

Presence of body stripes (character# 32-1)

Color shows little variability in *Garra* (details discussed in the taxonomic section). According to Nikolski (1963) lateral body stripes are evident in schooling cyprinids, aiding both in individual orientation and in confusion of predators. In all species of *Garra*, except *G.nasuta*, and in all the outgroup genera, lateral body stripes are absent. This character state is interpreted as the primitive condition. The presence of lateral stripes evident only in *G.nasuta* (of the investigated species) is interpreted as the derived character state and an autapomorphy for the species.

33. The size of the gas bladder

Small gas bladder (> 5 times in standard length) (character# 33-0)

Large gas bladder (< 5 times in standard length) (character# 33-1)

The gas bladder in Labeinae is two chambered, the anterior and posterior chambers being connected by a small duct. A small gas bladder is characteristic of some species of *Garra* (*G.congoensis, G.duobarbis, G.geba, G.hindii, G.ignestii,* *G.imberbis, G.lamta, G.makiensis, G.nasuta* and *G.rufa*) and all the outgroup genera. Thus, this character state is interpreted as the primitive condition. In the remaining species of *Garra* (*G.aethiopica, G.bicornuta, G.blanfordii, G.cambodgiensis, G.dembecha, G.dembeensis, G.microstoma, G.quadrimaculata, G.ornata, G.rossica* and *G.tana*) the gas bladder is large and this character state is interpreted as the derived condition.

34. The number of crenulations/ indentations of the rostral fold

Few (less than 15) or not well crenulated (character# 34-0)
Many (more than 18) (character# 34-1)

These are furrows at the ventral margin of the rostral fold. These structures are few and poorly developed in some species of *Garra* (*G.aethiopica, G.blanfordii, G.duobarbis, G.ignestii, G.makiensis, G.quadrimaculata* and *G.rossica*) and in some of the outgroup genera (*Discocheilus, Discogobio, Epalzeorhynchos* and *Semilabeo*). This character state is interpreted as the primitive condition. In most species of *Garra* (*G.bicornuta, G.cambodgiensis, G.congoensis, G.dembecha, G.dembeensis, G.geba, G.hindii, G.imberbis, G.lamta, G.microstoma, G.nasuta, G.ornata, G.rufa* and *G.tana*) and in two of the outgroup genera (*Crossocheilus* and *Paracrossocheilus*) crenulation of the ventral margin is more developed. This character state is interpreted as the derived condition.

CLADE ANALYSIS:

Bremer support (PAUP) was utilized to determine the strength of support of the clades. The number of additional steps required to collapse clades of the cladogram are given in Fig.69 (numbers in bold).

1. *Garra* as a monophyletic group

Monophyly is confirmed by studying all available species of the African *Garra* (three species excluded in the analysis due to lack of material) and representative species of *Garra* of the other regions. The rationales for species selection have been discussed in the materials and methods section.

The following unreversed synapomorphic character states support the monophyly of *Garra*.

1. There are two or more anterior unbranched rays in the pectoral fin in all species of *Garra* examined (character# 21-1) while this character is very simple and easy to verify it is most readily observed in cleared and stained specimens. Noteable exceptions are *G.imberbis* and *G.nasuta* that have asymetrically, one or two unbranched rays on each side.

2. The cleithrum is narrow and elongate in *Garra (*character# 17-1; Fig.61a*)*. Regan (1911 in Gosline, 1978) had previously pointed this out for the first time. This character needs to be considered in relatively comparable sizes.

3. *Garra* has short and broad supraethmoid (character# 0-1; Fig.49a).

Although monophyly of the genus *Garra* is attested to by the above synapomorphic character states, there is no evidence to suggest that the African species constitute a monophyletic entity.

2. Phylogenetic relationships among *Garra* species.

As seen from the cladogram (Fig.69), the genus consists of one large monophyletic clade (Clade A) and two major Sub-clades (Sub-clade B and C) within. There is the presumed primitive paraphyletic grade consisting of the Afro-Arabian species of *G.quadrimaculata*, the East African species of *G.blanfordii*, the Ethiopian species of *G.ignestii* and *G.makiensis*, the Middle East and Western Asian species of *G.bicornuta*, *G.rossica* and *G.rufa*.

The monophyletic species group (Clade A) consisting of the remaining species of *Garra* is supported by the following synapomorphies:

1. The infraorbital series is less bony and consists essentially of only the neural canals especially at the fused third and fourth, and fifth infraorbital bones (character#4-1; Fig.54a).
2. The intramuscular bones are few or none (character# 15-1).
3. The anterior part of the leading dorsal fin pterygiophore is only slightly concave (character # 16-1; Fig.59a).
4. The number of preanal caudal vertebrae (the number of vertebrae anterior to the insertion of the first anal fin pterygiophore to ribbed vertebrae) is 6 or more (character# 20-1).
5. There is concavity at the dorsal and posterior parts of the operculum (character# 7-1; Fig.54b)
6. The pharyngeal process is elongated and pointed posteriorly with a rounded masticatory plate (character#10-1and 11-1, Fig.72b).
7. The intestine is short (less than twice the standard length) (character# 24-1).

The last three derived character states are supporting only Sub-clades B and C.(Fig.69).

One more synapomorphic character state forms another monophyletic clade (sub-clade C) that includes twelve derived species (*G.aethiopica, G.cambodgiensis, G.congoensis, G.dembeensis, G.duobarbis, G.geba, G.hindii, G.imberbis, G.microstoma, G.nasuta, G.ornata* and *G.tana,* see also Fig.69). The number of infraorbital series in the above group is six (character# 5-1). This character is also observed in one of the outgroup genera (*Crossocheilus*) and this is assumed to be as a result of independent evolution.

CONCLUDING REMARKS:

In the course of the present work it has been possible to establish the monophyly of the genus *Garra*. Traditionally, the presence of a suctorial disc was taken as diagnostic character of *Garra*, but a disc is also present in related genera (e.g. *Discocheilus, Discogobio, Placocheilus* and *Semilabeo)* making it a plesiomorphic character state for *Garra*.

However, as has been noted the discs in these genera (Fig.5D-F) display some variation in structure when compared with that of *Garra:*

a. The callus (fleshy pad) of the disc of *Garra* is more posteriorly extended than the callus of the discs of the other genera

b. Uniquely the posterior margin of the disc of *Garra* is rounded while this is not the case in the other genera.

c. Uniquely in *Discogobio,* the central callus is enlarged and surrounded by large papillae (except in its posterior field).

d. Uniquely in *Discocheilus*, the papillae form an indent at the center of the callus and the papillae are bigger and more prominent towards the lower lip, and there are two central lobes overlapping at the point of indentation; there are also two antero-lateral lobes on either side of the disc.

It has proven difficult to completely resolve the phylogenetic relationship among all the species of *Garra* investigated. Because of high levels of homoplasy, cladistic resolution and stability has been reduced. This could have been rectified through increased efforts to locate more differentiating characters. However, this is hampered by the general reduction in variability within the genus, which is a common denominator in Cyprinidae. Coupled with this is the difficulty to acquire adequate and fresh specimens for investigation. This especially refers to the non-Ethiopian species.

In general, it seems that the African species of *Garra* do not show closer relationship to other African species than to their Arabian or Asian counterparts. It also appears that those *Garra* species with less developed discs, reduced coverage of squamation, and reduced or absent barbels are nested within derived clades. Although the presence of the suctorial disc in Labeinae is taken as a derived character state, this does not seem to be the case within *Garra*. So, it may be safe to assume that disc in some *Garra* species is secondarily reduced.

In conclusion, although I have the confidence that the main outlines of relationship among *Garra* endure, I cannot rule out the possibility that an investigation of all the species of *Garra* with the inclusion of additional characters (possibly with the addition of molecular data) may change or modify the scenario.

HABITAT AND NARRATIVE BIOGEOGRAPHY OF GARRA

This title includes three sections:

1. The first section discusses the ecology and habitat of *Garra* species based on information obtained from the field in Ethiopia and through literature review.

2. The second section gives a narration (description) of the geographic distribution of the genus with especial focus on the African species.

3. The third section analyses the evolution and the present day distribution of *Garra* based on the phylogenetic findings and the geological history of the region in which *Garra* is distributed.

1. Habitat

Species of the genus *Garra* inhabit a wide range of substrates (muddy, sandy and rocky bottoms) in streams, rivers, pools and lakes. They are primarily freshwater species; the only brackish water species of the genus so far recorded is *G.quadrimaculata* (previously *G.tibanica*) from Saudi Arabia and Yemen. Some members of the genus like *G.congoensis* and *G.ornata* are specialized for life in very fast flowing turbulent water (Roberts & Stewart, 1976) and also in rocky stretches with rapids and falls (Lowe-McConnell, 1978). Other members of the genus (e.g. *G.barreimiae, G.dunsirei*) are cave dwellers (Banister, 1987) and some individuals of *G.barreimiae* are blind. This species is believed to be rare and threatened (Reid, 1995).

From observations of the Ethiopian species, the genus inhabits a wide range of habitats (Figs.75-81) from degraded to well-protected water systems at altitudes ranging from 1500m to about 3000m above sea level. The most favored habitats are relatively slow moving or stagnant pool edged with long grass or any other emergent flora (e.g. Figs.75B and 80). A water temperature range of 55°F to 90°F and a pH value ranging from 6.1-8.9 have been recorded. They are absent from high altitude (>3000m) cool waters, alkaline and salt waters. The fact that the fishes of this genus can be found in such varied habitats from clear high altitude streams to polluted streams (polluted by human wastes and industrial by-products) suggests a tolerance of a wide spectrum of oxygen concentrations and has low biological oxygen demand. Such resilience to human perturbation and wide distribution qualify this genus for thorough studies in relation to diversity and conservation.

2. Geographic distribution

Geographic distribution of the genus in Africa ranges from about 25°N to 5°S latitude from Ethiopia in the east to Guinea in the west and from Egypt in the north to Tanzania in the south (Fig.1). This area covers the Nilo-Sudan, the Upper and

Lower Guinea, the Zaire, the Quanza, the East Coast and the Abyssinian ichthyological provinces and sub-provinces (Roberts, 1975). The range is more or less congruent to the general pattern of distribution described by Lévêque (1997) that includes the area from the Nile to West Africa and to the Zaire southward ("Type I"). Past interconnections between the different drainage basins of Africa, have been used to explain such a distribution. Disjunct distributions may be attributed to either extinctions OR undiscovered presence so far from those areas. To date the genus has so far been reported from 16 African countries (Table 1). Detailed accounts of the geographic distribution of each species are given in the species account section.

Here, I will make some observations on geographical trends in African *Garra*.

1. The greatest species richness is found in Ethiopia (Fig.82, Tab.1). Richness tends to decrease to the west and to the south of Ethiopian border. This assumes that the central and West African countries are well surveyed for their fish fauna. In West and Central Africa, the genus is relatively abundant in the freshwaters of Cameroun, Congo and Zaire but rarely reaches Angolan waters (as there is a single collection of only 10 specimens of *G.congoensis* from Cafunfo, Borio 2, Angola (MRAC). There are no records of *Garra* in the coastal drainage basins west of Guinea nor in Southern Africa, south of Angola and Lake Victoria, although it is known that some small *Barbus* species (e.g. *Barbus paludinosus*, *B.trimaculatus*

and *B.radiatus*) have wide spread distribution from South Africa through to East Africa (Skelton, et al. 1991).

The wide spread distribution of *G.congoensis*, *G.dembeensis*, *G.hindii* and *G.ornata* in the drainage basins of East, Central and West Africa may suggest an early connection between the Upper Guinean, lower Guinean, Nilo-Sudanian and Zairean provinces as pointed out by Poll (1973) and Roberts (1975). Poll (1973) indicated that the Nilo-Sudanic and the Upper Lualaba basins share certain taxa that are not found in the lower Lualaba or the rest of the Zaire basin. However, Banister and Bailey (1979) indicated that the notion of Poll (1973) has little support, despite the presence of two taxa (*Polypterus senegalus* and *Polypterus bichir*), which are Nilotic elements in the Upper Lualaba.

There are two species recorded from North-eastern Africa (Sudan and Egypt): *Garra blanfordii* (as *Discognathus vinciguerrae*) from Sudan (Sandon, 1950) and *G.dembeensis*-mentioned as a rare species from Egypt (Bishai and Khalil, 1997). Their presence in these Northern African countries is not surprising, as both species are found in abundance in the Abbay drainage basin of Ethiopia, which is a primary feeder of the Nile. OR they represent relicts of a once more widely distributed species. There is no evidence of the presence of *Garra* in the Maghreb ichthyological province west of Egypt although some cyprinids are found in oases of these regions (Lévêque, 1997).

2. In Ethiopia, species richness tends to decrease from north to south (Fig.83). The rivers in the northwestern highlands of Ethiopia have a high diversity of *Garra* while the freshwater bodies in the eastern highlands, the rift valley and the coastal plains are relatively poor. The Abbay and Tekezze basins contain of the highest percentage (75%) with the other drainage basins accounting for only 25% of the Ethiopian species. All the new species described in this study are from these two northern drainage basins.

One species, *G.aethiopica*, is restricted to the Awash darinage basin. The Awash basin has no or little commonality with the Nilo-Sudanic fish fauna.

G.dembecha (*G.quadrimaculata* sensu Boulenger, 1903) and *G.dembeensis* are widespread in almost all drainage basins of the country except the Afar depression. *G.ignestii* and *G.blanfordii* are found in the two northern drainage basins (Tekezze and Abbay). The difference is that *G.blanfordii* extends north to Eritrea and northwest into Sudan, while *G.ignestii* is restricted to the Ethiopian drainage basins. The wide spread distribution of the above two species in the northwestern highlands and their absence in the rift valley and eastern highlands is notable.

Although a few specimens are reported from other drainage basins (Abbay, Awash, Ghibe-Omo and Baro basins) *G.makiensis* is mainly a rift valley species. First described from River Maki, draining into Lake Zwai, it is found abundantly in the rivers and lakes of the rift valley where it is usually found together with *G.dembecha* and *G.dembeensis*.

Lake Tana harbors two new species (*G.tana* and *G.microstoma*) bringing the total found in the lake to four. Prior to this study two species (*G.dembeensis* and *G.dembecha* (*as Discognathus quadrimaculatus*)) had been reported from this lake (Rüppell, 1836; Boulenger, 1903). It seems, then, that another small-scale cyprinid speciation has taken place and/or is in the making in this lake.

Based on the phylogenetic tree (Fig.69), the relationship among *Garra* species of Lake Tana is unresolved except that *G.dembecha* is a sister group of Sub-clade C (the sub-clade in which all the other three *Garra* species of Lake Tana are included). It also appears that *G.microstoma* is more closely related to *G.congoensis* (from Zaire) than it is to the other sympatric *Garra* species of Lake Tana. Therefore, the existence of *Garra*, as a species flock, in Lake Tana is unlikely. The case of the *Barbus* "species flock" has been widely reported by Nagelkerke et al. (1994); Mina et al. (1996); and Nagelkerke & Sibbing (in press).

3. *G.quadrimaculata* (previously known as *G.tibanica*), is the only species found in both Africa and Asia. It is found in the Arabian Peninsula while only few specimens have been collected and identified from southeastern Eritrea, southeastern Ethiopia and Somalia (although I am unable to locate the Somalia specimens reported by Menon (1964) and Krupp (1983), although Krupp doubted

its prior report by Menon). There is an indication in Trewavas (1941) that a collection of unnamed *Garra* in the British Museum from Burao, "British Somaliland" (coll. Crane), belong to the *tibanica-britoni* group (I was not able to locate these collections in the British Museum). Trewavas (1941) further reported that these specimens differ from *G.blanfordii* and "*G.tibanica*" in having rather smaller scales (32-35) in the lateral line, 4 or 4.5 between lateral line and pelvic fin and a somewhat more inferior mouth with greater development of the rostral flap (perhaps indicative of some clinal difference). This review confirms that there are obvious differences between *G.quadrimaculata* (previously *G.tibanica*) and *G.blanfordii*; but, there is no major difference among the specimens identified as *G.tibanica* from the Arabian Peninsula, Eritrea and Ethiopia as far as the key diagnostic characters are concerned. This may be evidence that not all members of a biota need respond to every vicariance event (Platnick and Nelson, 1978). On the other hand, it seems that a number of different species and sub-species from the Arabian Peninsula (e.g. *G.sahilia*, *G.ghorensis*, *G.longipinnis* and several sub-species described by Balletto Spano (1977) but later synonymized with "*G.tibanica*" by Krupp (1983)) show no major difference from *G.quadrimaculata* (previously *G.tibanica*). Similarly, I find no difference between *G.buettikerii* and *G.mamshuka* of Saudi Arabia and *G.barreimae* and *G.barreimae gallagheri* of Oman. Generally, there seems to be confusion among the species of the Arabian Peninsula and a rigorous revision at the species level is much needed. Some of these problems have been pointed out by Krupp (1983).

2. Biogeography

As may be expected, it is difficult to draw conclusion on the historical biogeography of *Garra* for the following reasons:

1. A full species level resolution of the phylogeny of *Garra* was not achieved.
2. The drainage history of the regions in which *Garra* is distributed, especially the Ethiopian region, is poorly known.
3. Comparative phylogenies for co-occuring organisms are not available for consideration of congruent patterns.

Nevertheless, it is evident, from the phylogenetic study, that *Garra* is a monophyletic group and forms a geographically continuous entity. It has also been shown (Fig.72), that the Chinese and Southeast Asian (*G.cambodgiensis, G.imberbis* and *G.nasuta*) as well as *Garra* species from the highlands and interior of Africa (e.g. *G.congoensis, G.duobarbis, G.microstoma, G.ornata* and *G.tana*) form a monophyletic sub-clade. Species found out of the monophyletic group and sub-groups are from the Afro-Arabian coast (*G.quadrimaculata*), coastal Ethiopia (*G.makiensis, G.ignesti,* and *G.blanfordii*) and West-India (*G.rossica* and *G.rufa*).

Although from a different perspective (justification of center of origin), and one lacking a rigorous phylogenetic analysis, Menon (1964) arrived at the conclusion that the "rossica and tibanica complexes" that inhabit the African, Arabian and West-Indian regions form a primitive group within the genus.

According to Darlington (1957), Briggs (1987), Menon (1964), Banarescu (1972, 1995), Southeast Asia is regarded as a center of origin (dispersal center) for the different groups of the Cyprinidae because of the relative diversity of the taxa in these regions. Dispersal of ancestral forms was proposed based on the general argument that the derived forms force ancestral forms into peripheral situations.

According to Hennig's progression rule (1966) and Brundin's (1966, 1972, 1975) new methods of biogeography, it is the ancestral species (or population) that remain at, or near, their site of origin. " A primitive group at least primarily is closer to the area once occupied by the ancestral species than is the comparatively derivative sister group" Brundin (1975).

Since it is not possible to falsify the above two hypotheses, Croizat et al. (1974) and other cladistic biogeographic advocates (Cracraft, 1974 a & b, Nelson and Platnick, 1981, Humphries and Parenti, 1986) rejected or disregarded the concept of center of origin.

Accordingly, no center of origin or route of dispersal for *Garra* is proposed here. Nonetheless, the one-way migration of *Garra* and other cyprinids suggested by Menon (1964), Krupp (1982), and Banarescu (1995) and challenged by Howes

(1980), Kottelat (1989), and Skelton et al. (1991) should be given due consideration and alternative explanations sought.

Possibly a more likely scenario would recognize a Gondwanic evolution and distribution of *Garra* species, with ancestral species inhabiting at least the coastal areas of the Red Sea, the Arabian Peninsula, Middle East and India.

To date there is no fossil *Garra* reported. However some Miocene fossils of *Barbus* and some labeines—e.g. *Labeo* and *Osteocheilus* have been found from Africa and Asia (Cavender, 1991; Vancouvering, 1977).

Based on the recovered phylogeny and the geologic history, the following hypothesis (Vicariance-Dispersal) of *Garra*'s biogeography tentatively is suggested. The dispersal suggested here is essentially vicariance since it is assumed to have occurred before the appearance of a barrier.

The origin of *Garra* can be estimated to the Lower Tertiary or Late Cretaceous, before the separation of India and the Arabian Peninsula from the continental Africa, but after the complete separation of Africa and South America and the separation of Southeast Asia (South Tibet, Burma, Malaya, Sumatra, Borneo) from Australia/New Guinea. Complete separation of Africa and South America is thought to have occurred between 84-106 million years while rifting of Southeast Asia from Australia started in mid to late Jurassic (180-150 Million years)

(Kottelat, 1989). It is probable, thus, that these two events occurred long before the origin of *Garra*, since *Garra* is completely absent from these two continents. However, separation of the Indian continent from Africa and formation of the Red Sea are relatively recent phenomena. India separated from continental Africa in the Late Cretaceous (Briggs, 1987), while the Red Sea is believed to have originated and consequently separated the African continent from the Arabian Peninsula in the early Tertiary sometimes between the Eocene and Oligocene epochs (Getahun, 1998) after the separation of India.

Therefore, *Garra* could have evolved at one point in India or Africa in the late Mesozoic or early Cenozoic before India drifted away from northeastern Africa. And then dispersed covering all the coastal areas of Africa (which includes the present day Arabian Peninsula) and India. Then after, vicariance might have occurred due to the separation of India and formation of the Red Sea. Later on, dispersal progressed both in time and space, thus making *Garra's* dispersal from the coastal areas to the highlands of Ethiopia and the southeastern and western parts of Africa possible. As noted in Lévêque (1997), there must have been interconnection between the different river systems of Africa, especially the Nile and Niger systems that facilitated easy dispersal of the genus. Its absence from other parts of Africa is, I think, further testimony of a relatively recent dispersal phenomenon.

The subsequent speciation and domination by *Garra* of the Southeast Asian and Chinese highlands and some waters of the Middle East could similarly be explained by dispersal after continental India collided with Eurasia during Eocene. High rates of speciation occurred in the highlands of Ethiopia, India, China and Southeast Asia. These areas could be considered as areas of endemism. The fragmentation now observed within Africa and Southeast Asia probably resulted due to hydrographic and climatic changes.

CLASSIFICATION

The classification of Labeinae follows Reid (1978). I accept his proposal of sub-family rank since the group shows a consistent homogeneity and distinct lineage. Minor modification of the sub-family is the division of the tribe Garraini into one monophyletic sub-tribe. The sub-tribe is here named as Discorostralini and consists of those genera that have suctorial discs as a modification of their lower lip (*Discocheilus*, *Discogobio*, *Garra*, *Placocheilus* and *Semilabeo* (*Placocheilus* is only known from the literature)).

Therefore, the place of *Garra* in the hierarchy of the family Cyprinidae would be:

- Family Cyprinidae
- Sub-family Labeinae
    - Tribe Garraini
        - Sub-tribe Discorostralini
            - Genus *Garra*

Table 1. **Valid African species of the genus *Garra*, with synonymy and their geographic distribution.**

VALID SPECIES	SYNONYMY	GEOGRAPHIC DISTRIBUTION
G.aethiopica		Ethiopia
G.allostoma		Cameroun
G.blanfordii	*Discognathus vinciguerrae* *D.giarrabensis* *D.blanfordii cimmaruta*	Eritrea, Ethiopia, Sudan
G.congoensis		Angola, Cameroun, Zaire
G.dembecha		Eritrea, Ethiopia, Kenya, Tanzania
G.dembeensis	*D.chiarinii* *D.johnstonii*	Cameroun, Chad, Egypt, Ethiopia, Kenya, Nigeria Tanzania
G.duobarbis		Ethiopia
G.ethelwynnae		Eritrea
G.gebaensis		Ethiopia
G.hindii		Cameroun, Congo, Kenya, Uganda
G.ignesti		Ethiopia
G.lancrenonensis		Central African Republic (C.A.R)
G.makiensis	*D.rothschildi*	Ethiopia
G.microstoma		Ethiopia
G.ornata	*D.baudoni* *D.occidentalis* *D.trewavasi* *D.waterloti* *G.waterloti dageti*	Cameroun, C.A.R., Congo, Gabon, Guinea, Nigeria, Zaire
G.quadrimaculata	*G.tibanica*	Ethiopia, Eritrea, Somalia
G.tana		Ethiopia

Table 2. **Summary of the diagnostic characters for the African species of *Garra*.**
(* Po-pel = Post-pelvic)

			CHARACTERS		
Species	**Disc**	**Predorsal scales**	**Chest scales**	**Belly scales**	***Po-pel scales**
G.aethiopica	**Type B**	**Full**	**No**	**No**	**Yes**
G.allostoma	**Type A**	**No**	**No**	**No**	**Few**
G.blanfordii	**Type C**	**Full**	**No**	**No**	**No**
G.congoensis	**Type C**	**Full**	**No**	**No**	**Yes**
G.dembecha	**Type A**	**Few**	**No**	**No**	**No**
G.dembeensis	**Type C**	**No**	**No**	**No**	**No**
G.duobarbis	**Type A**	**No**	**No**	**No**	**Yes**
G.ethelwynnae	**Type C**	**Full**	**No**	**No**	**Yes**
G.geba	**Type B**	**No**	**No**	**No**	**No**
G.hindii	**Type C**	**Full**	**Yes**	**Yes**	**Yes**
G.ignestii	**Type C**	**Full**	**No**	**No**	**Yes**
G.lancrenonensis	**Type B**	**Few**	**No**	**Few**	**Yes**
G.makiensis	**Type C**	**Full**	**Few**	**Few**	**Yes**
G.microstoma	**Type A**	**Few**	**No**	**Few**	**Yes**
G.ornata	**Type B**	**Few**	**No**	**No**	**Yes**
G.quadrimaculata	**Type C**	**Full**	**Yes**	**Yes**	**Yes**
G.tana	**Type A**	**Few**	**No**	**No**	**No**

* Po-pel= Post-pelvic

Table 2 continued....

Vent	Intestine	Gas-bladder	Barbels	Bodydepth	Rostral	Caudal ped	Teeth
Med.	Short	Large	4	Deep	No	Wide	3
Far	Long	——	4	Deep	No	Wide	2
Med.	Med.	Large	4	Deep	No	Wide	3
Far	Long	Small	4	Flattened	Yes	Wide	3
Far	Med.	Large	4	Deep	Yes	Wide	3
Far	Med.	Small	4	Deep	Yes	Wide	3
Far	Short	Small	2	Deep	No	Wide	3
Near	——	——	4	Deep	Yes	Wide	—
Med.	Short	Small	4	Flattened	Yes	Wide	3
Far	Short	Small	4	Deep	Yes	Wide	3
Far	Long	Small	4	Deep	Yes	Wide	3
Near	——	——	4	Deep	Yes	Wide	3
Near	Long	Small	4	Deep	Yes	Wide	3
Near	Short	Large	4	Deep	No	Wide	3
Med.	Short	Large	4	Deep	No	Wide	3
Med.	Short	Large	4	Deep	Yes	Wide	3
Med.	Short	Small	4	Deep	No	Narrow	3

Table 3. A. Morphometric and B. Meristic Features of *G.aethiopica*

Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	30	25.2	18.9	22.2	22.3	1.67
Head length	30	25.6	19.8	21.6	21.4	1.15
Predorsal length	30	51.1	43.3	47.3	47.4	1.62
Pectoral fin length	30	23.0	17.9	20.9	21.2	1.35
Caudal peduncle length	30	18.9	14.2	17.3	17.5	1.15
Caudal peduncle depth	30	12.8	10.7	11.7	11.7	0.65
Dorsal fin length	30	22.5	19.6	21.3	20.9	1.15
Anal fin length	30	19.8	16.6	17.9	18.01	0.61
Pelvic fin length	30	19.2	15.5	17.6	17.8	1.05
% Head Length						
Head width	30	81.0	63.3	71.9	71.9	3.79
Head depth	30	78.0	58.4	67.2	66.7	4.00
Snout length	30	42.2	27.9	35.5	35.6	3.85
Orbit diameter	30	27.2	15.5	20.2	11.7	3.04
Interorbital width	30	50.4	38.6	45.0	45.2	3.24
% Orbit Diameter						
Rostral barbel length	30	107.0	65.7	71.9	72.5	17.02
Maxillary barbel length	30	92.5	65.7	80.0	80.2	7.30

B. Meristic Features

Dorsal fin rays	III + 7(20), IV + 7(10)
Anal fin rays	III + 5(15), IV + 5(15)
Pectoral fin rays	IV + 11(30)
Pelvic fin rays	II + 6(30)
Lateral line scales	33 - 36
Caudal peduncle scale rows	13 – 16
Scale rows lateral line-dorsal fin	4.5
Scale rows lateral line-pelvic fin	3.5
Scale rows lateral line-anal fin	3
Predorsal scale rows	15

Table 4. A. Morphometric and B. Meristic Features of *G.allostoma*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	2	21.7	20.5	21.1	21.1	0.887
Head length	2	25.1	24.9	25.0	25.0	0.14
Predorsal length	2	48.8	48.3	48.6	48.6	0.35
Pectoral fin length	2	20.5	20.5	20.5	20.5	0.06
Caudal peduncle length	2	14.9	14.9	14.9	14.9	0.06
Caudal peduncle depth	2	12.7	12.3	12.5	12.5	0.33
Dorsal fin length	2	24.4	23.5	24.0	24.0	0.65
Anal fin length	2	16.2	15.9	16.0	16.0	0.22
Pelvic fin length	2	20.1	19.5	19.7	19.7	0.38
% Head Length						
Head width	2	79.1	76.7	77.9	77.9	1.66
Head depth	2	60.1	51.2	55.6	55.6	6.31
Snout length	2	44.2	41.1	42.6	42.6	2.19
Orbit diameter	2	24.4	20.2	22.3	22.3	3.01
Interorbital width	2	38.8	34.9	36.8	36.8	2.72
Orbit Diameter						
Rostral barbel length	2	44.0	42.0	43.0	43.0	1.41
Maxillary barbel length	2	42.0	40.0	41.0	41.0	1.41

B. Meristic Features

Dorsal fin rays	III + 7(2)
Anal fin rays	III + 5(2)
Pectoral fin rays	IV + 11(2)
Pelvic fin rays	II + 6(2)
Lateral line scales	36
Caudal peduncle scale rows	17
Scale rows lateral line-dorsal fin	4.5
Scale rows lateral line-pelvic fin	3.5
Scale rows lateral line-anal fin	4
Predorsal scale rows	None

Table 5. A. Morphometric and B. Meristic Features of *G.blanfordii*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	30	25.1	20.0	22.8	23.0	1.53
Head length	30	27.3	21.7	23.9	23.8	1.38
Predorsal length	30	53.3	45.2	49.4	49.6	1.99
Pectoral fin length	30	24.0	17.0	19.5	19.4	1.50
Caudal peduncle length	30	21.6	15.1	17.9	18.2	1.57
Caudal peduncle depth	30	13.9	10.7	12.4	12.6	0.83
Dorsal fin length	30	22.6	19.4	20.9	20.8	1.09
Anal fin length	30	18.6	14.7	17.2	17.4	1.10
Pelvic fin length	30	18.8	16.1	17.3	17.4	0.72
% Head Length						
Head width	30	76.4	63.8	70.4	70.9	3.32
Head depth	30	75.2	58.6	67.1	67.3	4.23
Snout length	30	40.0	22.2	32.6	33.4	3.88
Orbit diameter	30	29.0	17.6	21.6	21.3	2.45
Interorbital width	30	52.8	38.8	45.4	45.8	3.15
% Orbit Diameter						
Rostral barbel length	30	87.5	33.0	58.6	61.0	14.66
Maxillary barbel length	30	80.0	30.2	57.3	60.0	14.26

B. Meristic Features

Dorsal fin rays	IV + 7(30)
Anal fin rays	IV + 5(30)
Pectoral fin rays	V + 11(30)
Pelvic fin rays	III + 7(30)
Lateral line scales	34-38
Caudal peduncle scale rows	13-15
Scale rows lateral line-dorsal fin	4 – 4.5
Scale rows lateral line-pelvic fin	3.5
Scale rows lateral line-anal fin	4.5
Predorsal scale rows	14

Table 6. Data on synonyms of *G.blanfordii*

A. MORPHOLOGY	*D.giarrabensis*	*D.b.cimmaruta*	*D.vinciguerrae*
Disc Type	Type C	Type C	Type C
Belly scales	No	No	No
Chest scales	No	No	No
Predorsal scales	Full	Full	Full
Post-pelvic scales Yes	Yes	Yes	
Tubercles	No	No	No
Barbels	4	4	4
Color	Creamy white	Creamy white	Creamy white
Vent Position	Far from anal fin (18.64%)	Far from anal fin (20.8%)	Far from anal fin (22.8%)
B. MORPHOMETRICS			
% Standard length			
Body depth	21.5	19.6	17.8
Head length	22.6	23.0	24.6
Caudal peduncle length	14.5	15.9	14.1
Caudal peduncle depth	12.3	12.8	10.2
Pectoral fin length	19.2	19.9	21.2
% Head length			
Head width	68.2	66.5	57.5
Head depth	61.8	62.2	51.7
Snout length	37.5	33.8	34.5
Eye diameter	15.8	19.9	21.8
Interorbital width	40.5	42.3	35.6

Table 6. continued......

C. MERISTICS

Lateral line scales	35	35	36
Dorsal fin-lateral line	4.5	4.5	4.5
Pelvic fin-lateral line	3.5	3.5	3.5
Circumpeduncle scales	14	14	12

Table 7. A. Morphometric and B. Meristic Features of *G. congoensis*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	10	15.0	10.6	11.9	11.4	1.53
Head length	10	25.0	22.2	23.5	23.4	1.14
Predorsal length	10	49.5	44.0	46.9	47.2	1.50
Pectoral fin length	10	24.0	16.8	20.3	19.9	2.31
Caudal peduncle length	10	18.0	12.5	14.9	15.2	1.57
Caudal peduncle depth	10	9.0	7.0	8.1	8.0	0.64
Dorsal fin length	10	18.9	17.2	18.3	18.4	0.51
Anal fin length	10	14.9	13.5	14.2	14.0	0.57
Pelvic fin length	10	18.7	17.4	18.0	17.9	0.44
% Head Length						
Head width	10	74.4	63.0	69.1	69.6	3.96
Head depth	10	44.6	35.4	41.2	42.0	2.94
Snout length	10	47.4	36.9	42.7	43.0	3.41
Orbit diameter	10	26.3	20.0	23.4	23.3	2.07
Interorbital width	10	46.8	35.2	40.9	42.0	3.37
% Orbit Diameter						
Rostral barbel length	10	56.0	35.0	44.2	42.0	6.11
Maxillary barbel length	10	61.3	43.6	53.0	53.7	6.27

B. Meristic Features

Dorsal fin rays	III + 7(10)
Anal fin rays	III + 5(10)
Pectoral fin rays	IV + 11(10)
Pelvic fin rays	II + 6(10)
Lateral line scales	37
Caudal peduncle scale rows	12
Scale rows lateral line-dorsal fin	5
Scale rows lateral line-pelvic fin	3 – 3.5
Scale rows lateral line-anal fin	3.5
Predorsal scale rows	7

Table 8. A. Morphometric and B. Meristic Features of *G. dembecha* spec. nov.

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	30	23.0	16.7	19.5	19.4	1.85
Head length	30	28.2	19.8	24.7	24.3	1.93
Predorsal length	30	54.4	45.3	50.0	50.0	1.48
Pectoral fin length	30	22.3	16.6	20.1	20.3	1.38
Caudal peduncle length	30	20.7	13.3	16.8	16.6	1.57
Caudal peduncle depth	30	12.0	8.8	10.3	10.3	0.91
Dorsal fin length	30	22.6	19.5	21.0	20.8	0.87
Anal fin length	30	17.0	16.1	16.6	16.6	0.26
Pelvic fin length	30	18.9	16.1	17.6	17.8	0.77
% Head Length						
Head width	30	80.9	57.5	67.2	67.1	5.74
Head depth	30	65.2	50.0	56.9	56.8	3.80
Snout length	30	50.0	25.2	35.5	34.8	6.15
Orbit diameter	30	27.3	15.8	20.7	20.6	3.13
Interorbital width	30	49.5	33.3	39.3	38.9	3.77
% Orbit Diameter						
Rostral barbel length	30	91.0	42.0	60.7	58.5	15.61
Maxillary barbel length	30	86.5	38.0	60.0	56.8	16.10

B. Meristic Features

Dorsal fin rays	IV + 7(30)
Anal fin rays	IV + 5(30)
Pectoral fin rays	IV + 12(30)
Pelvic fin rays	III + 7(30)
Lateral line scales	37-38
Caudal peduncle scale rows	12-16
Scale rows lateral line-dorsal fin	5.5
Scale rows lateral line-pelvic fin	3.5
Scale rows lateral line-anal fin	4.5
Predorsal scale rows	6

Table 9. Comparative data of *Discognathus quadrimaculatus* (Non-Rüppell) (Boulenger, 1903) and *G.quadrimaculata* (Rüppell, 1836) and *G.dembecha* spec.nov.

	D.quadrimaculatus (Rüppell, 1836)	*D.quadrimaculatus* (Boulenger, 1903)	*G.dembecha* (Spec.nov.)
A. MORPHOLOGY			
Disc type	Type C	Type A	Type A
Belly scales	Yes	No	No
Chest scales	Yes	No	No
Predorsal scales	Full	Few	Few
Post-pelvic scales	Yes	Yes	Yes
Tubercles	Yes	No	No
Barbells	4	4	4
Color	Light black	Light black	Light black
Vent position	Near Anal fin (9.7-12.4%)	Far from anal fin (23.4%)	Far from anal fin (24.3-43.2%)
B. MORPHOMETRICS			
% Standard length			
Body depth	16.1-20.7	19.6	16.7-23.0
Head length	21.5-22.6	24.1	19.8-28.2
Caudal peduncle length	17.6-18.0	19.0	13.3-20.7
Caudal peduncle depth	10.1-11.3	10.7	8.8-12.0
Pectoral fin length	19.1-19.6	21.5	16.6-22.3
% Head length			
Head width	66.8-73.6	65.3	57.5-80.9
Head depth	58.9-67.6	59.9	50.0-65.2
Snout length	40.6-42.9	39.5	25.2-50.0
Eye diameter	16.1-19.2	21.0	15.8-27.3
Interorbital width	42.1-42.4	40.7	33.3-49.5

Table 9 continued.....

C. MERISTICS			
Lateral line scales	34-35	38	37-38
Dorsal fin-lateral line	4.5	5.5	5.5
Pelvic fin-lateral line	3.5	3.5	3.5
Circumpeduncle scales	13-14	14	12-16

Table 10. A. Morphometric and B. Meristic Features of *G.dembeensis*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	30	23.9	15.6	20.4	20.5	1.95
Head length	30	27.1	19.9	23.8	23.7	1.62
Predorsal length	30	52.1	44.0	49.3	49.7	1.77
Pectoral fin length	30	23.9	15.1	19.9	20.3	1.96
Caudal peduncle length	30	19.4	12.7	15.6	15.5	1.39
Caudal peduncle depth	30	11.6	8.3	9.9	10.0	0.86
Dorsal fin length	30	23.5	19.9	21.1	20.9	0.97
Anal fin length	30	19.7	17.0	18.3	18.3	0.82
Pelvic fin length	30	20.3	16.6	18.3	18.3	1.09
% Head Length						
Head width	30	84.7	63.3	71.5	70.4	5.53
Head depth	30	68.7	50.0	59.1	58.4	4.26
Snout length	30	48.1	33.3	40.8	41.0	4.39
Orbit diameter	30	28.0	15.7	20.2	19.6	3.04
Interorbital width	30	48.9	36.4	41.5	41.5	2.73
% Orbit Diameter						
Rostral barbel length	30	68.0	33.0	54.3	57.0	10.78
Maxillary barbel length	30	91.0	30.1	51.1	49.6	15.19

B. Meristic Features

Dorsal fin rays	III + 7(20), IV + 7(10)
Anal fin rays	IV + 5(30)
Pectoral fin rays	IV + 11(12) , IV + 12(18)
Pelvic fin rays	II + 6(30)
Lateral line scales	36 – 38
Caudal peduncle scale rows	12-14
Scale rows lateral line-dorsal fin	3.5 – 5.5
Scale rows lateral line-pelvic fin	3.5 –4.5
Scale rows lateral line-anal fin	4
Predorsal scale rows	2 – 3 (14) . None(16)

Table 11. Data on synonyms of *G.dembeensis*

	Discognathus chiarinii	*D.johnstonii*
A. MORPHOLOGY		
Disc type	Type C	Type C
Belly scales	No	No
Chest scales	No	No
Predorsal scales	Few	Few
Post-pelvic scales	No	Yes
Tubercles	No	No
Barbels	4	4
Color	Light black	Dark black
Vent position	Far away from anal fin (37.3%)	Far away from anal fin (26.2%)
B. MORPHOMETRICS		
% Standard length		
Body depth	22.1	23.7
Head length	25.1	20.6
Caudal peduncle length	15.4	15.3
Caudal peduncle depth	11.7	10.7
Pectoral fin length	22.4	15.7
% Head length		
Head width	64.0	71.4
Head depth	65.3	58.6
Snout length	28.0	48.3
Eye diameter	28.0	21.2
Interorbital width	37.3	46.3

Table 11. continued.....

C. MERISTICS		
Lateral line scales	38	39
Dorsal fin-lateral line	4.5	4.5
Pelvic fin-lateral line	3.5	3.5
Circumpeduncle scales	12	13

Table 12. A. Morphometric and B. Meristic Features of *G. duobarbis* spec. nov.

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	10	24.3	18.8	22.4	22.6	1.82
Head length	10	28.4	24.6	25.9	25.7	1.05
Predorsal length	10	54.0	50.6	51.6	51.3	0.97
Pectoral fin length	10	21.4	12.9	18.6	19.4	2.47
Caudal peduncle length	10	16.7	12.7	14.9	15.0	1.43
Caudal peduncle depth	10	12.2	10.6	11.6	11.6	0.47
Dorsal fin length	10	23.9	20.5	21.8	21.7	1.01
Anal fin length	10	18.6	17.4	17.9	17.7	0.42
Pelvic fin length	10	18.3	16.1	17.7	17.8	0.62
% Head Length						
Head width	10	77.5	66.8	72.1	71.7	2.94
Head depth	10	63.9	51.2	55.4	54.8	3.48
Snout length	10	43.1	30.5	37.4	36.8	3.78
Orbit diameter	10	21.0	16.6	18.4	17.9	1.51
Interorbital width	10	46.3	38.6	42.2	41.9	2.54
% Orbit Diameter						
Rostral barbel length	10	No	No	No	No	No
Maxillary barbel length	10	98.2	60.3	88.0	90.7	11.24

B. Meristic Features

Dorsal fin rays	IV + 7(10)
Anal fin rays	IV + 5(10)
Pectoral fin rays	IV + 12(10)
Pelvic fin rays	II + 6(10)
Lateral line scales	34 – 36
Caudal peduncle scale rows	14
Scale rows lateral line-dorsal fin	5.5
Scale rows lateral line-pelvic fin	4.5
Scale rows lateral line-anal fin	5.5
Predorsal scale rows	None

Table 13. A. Morphometric and B. Meristic Features of *G. ethelwynnae*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	2	30.9	29.1	30.0	30.0	1.27
Head length	2	28.4	25.8	27.1	27.1	1.84
Predorsal length	2	50.5	50.3	50.4	50.4	0.14
Pectoral fin length	2	22.1	19.0	20.6	20.6	2.19
Caudal peduncle length	2	14.0	12.5	13.3	13.3	1.06
Caudal peduncle depth	2	13.2	11.1	12.2	12.2	1.49
Dorsal fin length	2	25.1	24.4	24.7	24.7	0.54
Anal fin length	2	19.1	18.7	18.9	18.9	0.32
Pelvic fin length	2	22.3	21.1	21.7	21.7	0.86
% Head Length						
Head width	2	79.1	75.3	77.2	77.2	2.69
Head depth	2	75.0	64.9	70.0	69.9	7.14
Snout length	2	38.9	30.5	34.7	34.7	5.94
Orbit diameter	2	23.3	22.2	22.8	22.8	0.79
Interorbital width	2	47.2	42.8	45.0	45.0	3.11
% Orbit Diameter						
Rostral barbel length	2	75.0	67.0	71.0	71.0	5.66
Maxillary barbel length	2	63.3	56.8	60.0	60.0	4.60

B. Meristic Features

Dorsal fin rays	III + 7(2)
Anal fin rays	III + 5(2)
Pectoral fin rays	IV + 11(2)
Pelvic fin rays	II + 6(2)
Lateral line scales	29 –30
Caudal peduncle scale rows	12
Scale rows lateral line-dorsal fin	4
Scale rows lateral line-pelvic fin	4
Scale rows lateral line-anal fin	3.5
Predorsal scale rows	10

Table 14. A. Morphometric and B. Meristic Features of *G. geba* spec. nov.

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	10	16.8	14.8	16.0	15.9	0.62
Head length	10	25.7	23.2	24.3	24.2	0.83
Predorsal length	10	50.0	46.9	48.5	48.5	0.89
Pectoral fin length	10	22.6	19.1	21.1	21.1	0.92
Caudal peduncle length	10	19.9	14.4	16.9	16.9	1.64
Caudal peduncle depth	10	10.6	8.3	9.6	9.6	0.66
Dorsal fin length	10	22.1	19.4	20.8	21.0	0.98
Anal fin length	10	18.5	12.2	16.4	16.4	1.80
Pelvic fin length	10	17.6	16.2	16.9	16.9	0.57
% Head Length						
Head width	10	76.1	61.5	70.4	70.8	4.10
Head depth	10	59.4	47.6	53.7	52.3	4.01
Snout length	10	45.7	31.6	37.4	36.4	4.22
Orbit diameter	10	23.1	14.2	19.9	20.5	2.50
Interorbital width	10	42.5	34.5	38.7	38.9	2.84
% Orbit Diameter						
Rostral barbel length	10	73.0	35.0	54.8	55.0	11.50
Maxillary barbel length	10	82.8	32.0	57.7	53.4	15.66

B. Meristic Features

Dorsal fin rays	IV + 7(10)
Anal fin rays	IV + 5(10)
Pectoral fin rays	IV + 11(10)
Pelvic fin rays	II + 6(10)
Lateral line scales	37 – 39
Caudal peduncle scale rows	10 – 14
Scale rows lateral line-dorsal fin	4.5 – 5.5
Scale rows lateral line-pelvic fin	2.5 – 3.5
Scale rows lateral line-anal fin	3.5 – 4
Predorsal scale rows	6

Table 15. A. Morphometric and B. Meristic Features of *G.hindii*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	3	19.3	15.8	17.7	17.9	1.76
Head length	3	25.4	21.7	23.3	22.9	1.89
Predorsal length	3	49.1	46.2	47.5	47.2	1.47
Pectoral fin length	3	19.9	18.7	19.5	19.8	0.67
Caudal peduncle length	3	18.4	18.1	18.2	18.2	0.15
Caudal peduncle depth	3	10.7	10.0	10.3	10.3	0.35
Dorsal fin length	3	22.3	21.9	22.1	22.1	0.23
Anal fin length	3	18.1	18.0	18.0	18.0	0.07
Pelvic fin length	3	20.3	19.9	20.1	20.2	0.22
% Head Length						
Head width	3	71.4	63.2	67.7	68.5	4.16
Head depth	3	56.3	52.8	54.1	53.1	1.94
Snout length	3	45.2	40.0	43.1	44.0	2.72
Orbit diameter	3	22.4	21.6	22.1	22.2	0.42
Interorbital width	3	41.2	36.3	38.3	37.6	2.54
% Orbit Diameter						
Rostral barbel length	3	48.0	36.0	43.3	46.0	6.43
Maxillary barbel length	3	59.9	32.1	46.2	46.6	13.9

B. Meristic Features

Dorsal fin rays	III + 7(3)
Anal fin rays	III + 5(3)
Pectoral fin rays	IV + 11(3)
Pelvic fin rays	II + 6(3)
Lateral line scales	40-42
Caudal peduncle scale rows	14
Scale rows lateral line-dorsal fin	5-5.5
Scale rows lateral line-pelvic fin	4-4.5
Scale rows lateral line-anal fin	3.5-4
Predorsal scale rows	9-13

Table 16. A. Morphometric and B. Meristic Features of *G.ignestii*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	30	27.3	15.3	21.6	21.4	2.18
Head length	30	25.4	20.3	23.1	23.2	1.33
Predorsal length	30	49.0	30.6	46.2	47.0	3.21
Pectoral fin length	30	23.3	12.4	20.6	21.2	2.08
Caudal peduncle length	30	20.7	11.9	16.4	16.2	1.78
Caudal peduncle depth	30	13.3	6.9	10.9	11.0	1.28
Dorsal fin length	30	25.3	19.0	21.1	20.6	1.61
Anal fin length	30	19.6	15.4	17.6	17.7	1.09
Pelvic fin length	30	19.7	16.2	17.8	17.8	0.90
% Head Length						
Head width	30	90.2	57.8	71.8	71.0	6.48
Head depth	30	71.9	52.6	61.1	60.5	5.32
Snout length	30	46.0	33.0	40.0	40.3	3.79
Orbit diameter	30	27.6	16.0	20.0	18.9	3.37
Interorbital width	30	52.0	37.2	43.9	43.3	3.36
% Orbit Diameter						
Rostral barbel length	30	116.7	44.0	81.6	84.4	17.78
Maxillary barbel length	30	100.2	38.6	68.4	68.6	16.02

B. Meristic Features

Dorsal fin rays	IV + 7(21) , V + 7(9)
Anal fin rays	IV + 5(30)
Pectoral fin rays	IV + 11(19) , IV + 12(11)
Pelvic fin rays	II + 7(30)
Lateral line scales	34 – 36
Caudal peduncle scale rows	12 – 14
Scale rows lateral line-dorsal fin	4.5
Scale rows lateral line-pelvic fin	3.5
Scale rows lateral line-anal fin	4.5
Predorsal scale rows	10 - 12

Table 17. A. Morphometric and B. Meristic Features of *G.lancrenonensis*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	2	23.3	19.9	21.6	21.6	2.40
Head length	2	28.0	26.8	27.4	27.4	0.85
Predorsal length	2	49.5	45.4	47.5	47.5	2.90
Pectoral fin length	2	23.9	20.5	22.2	22.2	2.40
Caudal peduncle length	2	13.0	12.1	12.6	12.6	0.64
Caudal peduncle depth	2	10.2	9.3	9.8	9.8	0.64
Dorsal fin length	2	24.3	22.5	23.4	23.4	1.31
Anal fin length	2	16.4	16.1	16.3	16.3	0.22
Pelvic fin length	2	17.8	17.3	17.5	17.5	0.40
% Head Length						
Head width	2	66.1	62.3	64.2	64.2	2.69
Head depth	2	60.2	59.4	59.8	59.8	0.57
Snout length	2	30.4	26.4	28.4	28.4	2.83
Orbit diameter	2	29.4	21.7	25.6	25.6	5.45
Interorbital width	2	36.2	30.8	33.5	33.5	3.82
% Orbit Diameter						
Rostral barbel length	2	67.0	50.0	58.5	58.5	12.02
Maxillary barbel length	2	54.0	46.3	50.1	50.1	5.48

B. Meristic Features

Dorsal fin rays	III + 7(2)
Anal fin rays	III + 5(2)
Pectoral fin rays	IV + 11(2)
Pelvic fin rays	II + 6(2)
Lateral line scales	35 – 36
Caudal peduncle scale rows	12 – 14
Scale rows lateral line-dorsal fin	4.5 – 5
Scale rows lateral line-pelvic fin	3.5
Scale rows lateral line-anal fin	3.5
Predorsal scale rows	5

Table 18. A. Morphometric and B. Meristic Features of *G.makiensis*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	30	27.8	17.5	21.7	21.4	2.11
Head length	30	26.9	19.5	22.6	22.6	1.46
Predorsal length	30	50.6	43.6	46.7	46.8	1.74
Pectoral fin length	30	24.3	15.3	20.2	20.2	1.91
Caudal peduncle length	30	20.1	11.1	17.1	17.1	1.85
Caudal peduncle depth	30	13.1	7.7	10.9	10.9	1.04
Dorsal fin length	30	25.6	22.8	24.1	23.9	0.79
Anal fin length	30	19.7	15.9	17.5	17.5	0.91
Pelvic fin length	30	22.7	19.0	20.6	20.4	1.06
% Head Length						
Head width	30	79.0	58.7	70.3	70.7	4.31
Head depth	30	70.0	54.0	62.1	62.8	4.17
Snout length	30	50.0	26.3	41.9	42.2	5.70
Orbit diameter	30	31.9	14.6	21.2	20.8	4.03
Interorbital width	30	50.0	33.7	44.1	44.4	3.64
% Orbit Diameter						
Rostral barbel length	30	100.0	38.0	69.1	69.7	18.21
Maxillary barbel length	30	91.0	35.9	65.2	65.4	17.97

B. Meristic Features

Dorsal fin rays	IV + 7(30)
Anal fin rays	IV + 5(25), IV + 4(5)
Pectoral fin rays	IV + 11(30)
Pelvic fin rays	III + 7(30)
Lateral line scales	35 – 37
Caudal peduncle scale rows	12 – 15
Scale rows lateral line-dorsal fin	3.5 – 4.5
Scale rows lateral line-pelvic fin	3 – 4
Scale rows lateral line-anal fin	3.5 – 4.5
Predorsal scale rows	14 – 15

Table 19. Data on *D.rothscildii* (synonym of *G.makiensis*).

A. MORPHOLOGY

Disc type	Type C
Belly scales	Few
Chest scales	Few
Predorsal scales	Full
Post-pelvic scales	Yes
Tubercles	Yes
Barbels	4
Color	Black
Vent position	Near the anal fin (8.3-14.0%)

B. MORPHOMETRICS

% Standard length

Body depth	20.9-22.2
Head length	19.6-19.9
Caudal peduncle length	17.7-18.6
Caudal peduncle depth	9.7-10.3
Pectoral fin length	18.6-19.7

% Head length

Head width	62.3-67.1
Head depth	57.0-61.6
Snout length	43.4-43.6
Eye diameter	16.6-18.1
Interorbital width	41.5-46.8

Table 19. continued

C. MERISTICS

Lateral line scales	38-39
Dorsal fin-lateral line	4.5
Pelvic fin-lateral line	3.5
Circumpeduncle scales	13

Table 20. A. Morphometric and B. Meristic Features of *G.microstoma*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	3	20.6	19.8	20.1	19.9	0.44
Head length	3	21.0	19.7	20.5	20.9	0.72
Predorsal length	3	46.3	44.0	45.0	44.7	1.18
Pectoral fin length	3	21.0	17.5	19.6	20.2	1.83
Caudal peduncle length	3	18.9	18.2	18.6	18.6	0.35
Caudal peduncle depth	3	11.1	9.9	10.7	11.0	0.67
Dorsal fin length	3	24.1	18.7	20.7	19.5	2.90
Anal fin length	3	18.7	16.8	17.5	16.9	1.08
Pelvic fin length	3	20.8	16.8	19.0	19.5	2.04
% Head Length						
Head width	3	71.2	62.7	66.8	66.6	4.26
Head depth	3	61.0	57.5	59.8	60.8	1.97
Snout length	3	44.7	38.9	41.5	40.8	2.96
Orbit diameter	3	21.7	16.3	19.3	19.9	2.75
Interorbital width	3	44.3	41.0	42.7	42.8	1.65
% Orbit Diameter						
Rostral barbel length	3	66.0	44.0	54.0	52.0	11.14
Maxillary barbel length	3	68.4	35.6	54.0	57.9	16.74

B. Meristic Features

Dorsal fin rays	III + 7(3)
Anal fin rays	III + 5(3)
Pectoral fin rays	IV + 11(3)
Pelvic fin rays	II + 6(3)
Lateral line scales	39
Caudal peduncle scale rows	11 – 14
Scale rows lateral line-dorsal fin	4 – 5
Scale rows lateral line-pelvic fin	3 – 4
Scale rows lateral line-anal fin	4.5
Predorsal scale rows	8 – 9

Table 21. A. Morphometric and B. Meristic Features of *G. ornata*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	10	22.3	15.8	17.8	17.5	1.84
Head length	10	28.8	22.7	24.6	23.9	1.92
Predorsal length	10	52.2	45.5	48.3	48.0	1.84
Pectoral fin length	10	20.8	15.4	18.8	19.3	1.60
Caudal peduncle length	10	17.7	13.9	15.8	16.0	1.19
Caudal peduncle depth	10	10.7	9.2	10.0	10.0	0.52
Dorsal fin length	10	21.4	19.8	20.5	20.6	0.55
Anal fin length	10	15.1	14.1	14.6	14.5	0.42
Pelvic fin length	10	18.5	17.5	18.0	18.0	0.32
% Head Length						
Head width	10	73.9	55.7	66.7	66.9	6.25
Head depth	10	59.2	44.2	52.5	52.3	4.30
Snout length	10	44.9	34.2	40.0	41.3	3.55
Orbit diameter	10	42.3	31.4	37.4	37.4	3.26
Interorbital width	10	28.8	20.9	23.3	22.4	2.50
% Orbit Diameter						
Rostral barbel length	10	57.0	28.0	36.6	32.0	10.77
Maxillary barbel length	10	94.3	33.4	66.8	68.8	18.75

B. Meristic Features

Dorsal fin rays	III + 7(10)
Anal fin rays	III + 5(10)
Pectoral fin rays	IV + 11(10)
Pelvic fin rays	II + 6(10)
Lateral line scales	37
Caudal peduncle scale rows	14
Scale rows lateral line-dorsal fin	5
Scale rows lateral line-pelvic fin	4
Scale rows lateral line-anal fin	3.5
Predorsal scale rows	10

Table 22 Data on synonyms of *G.ornata*

	G.baudoni	*G.occidentalis*	*G.trewavasae*	*G.waterloti*	*G.w.dageti*
A. MORPHOLOGY					
Disc type	Type C	Type C	Type C	Type C	Type C
Belly scales	No	No	No	No	No
Chest scales	No	No	No	No	No
Predorsal scales Few	Few	Few	Few	Few	
Post-pelvic scalesYes	Yes	Yes	Yes	Yes	
Tubercles	No	No	No	No	No
Barbels	4	4	4	4	4
Color	Light black	Creamy white	Light black	Light black	Light black
Vent position	Far away (26.3-26.8 %)	Far away (30.8%)	Far away (21%)	Far away (30.2%)	Far away (30.4%)
B. MORPHOMETRICS					
% Standard length					
Body depth	19.8-22.7	16.4	21.6	15.6-20.5	18.4
Head length	22.8-22.9	23.9	22.6	21.6-22.1	23.1
Caudal peduncle length	15.0-17.1	14.9	13.4	15.6-17.1	13.8
Caudal peduncle depth	11.3-11.6	10.7	11.2	11.3-11.6	9.9
Pectoral fin length	20.0-20.3	18.9	20.1	20.0-20.4	20.2
% Head length					
Head width	70.0-71.6	60.5	67.7	63.4-63.5	66.2
Head depth	50.9-57.9	50.0	58.7	49.6-54.5	56.9
Snout length	36.8-46.4	40.4	40.5	40.7-41.6	40.0
Eye diameter	21.1-22.7	22.8	21.5	19.5-21.8	27.7
Interorbital width	35.8-40.0	31.6	32.9	38.2-41.6	35.1

Table 22. continued.....

C. MERISTICS

Lateral line scales	35-37	35	33	35-36	34
Dorsal fin-lateral line	4.5-5.5	4.5	4.5	4	4
Pelvic fin-lateral line	3.5-4.5	3.5	3.5	3	3
Circumpeduncle scales	12-14	13	13	12	12

Table 23. A. Morphometric and B. Meristic Features of *G.quadrimaculata*

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	2	20.7	16.0	18.4	18.4	3.32
Head length	2	22.5	21.5	22.0	22.0	0.71
Predorsal length	2	49.7	47.4	48.6	48.6	1.63
Pectoral fin length	2	19.6	19.0	19.3	19.3	0.42
Caudal peduncle length	2	17.9	17.6	17.8	17.8	0.21
Caudal peduncle depth	2	11.3	10.1	10.7	10.7	0.85
Dorsal fin length	2	25.9	20.5	23.2	23.2	3.81
Anal fin length	2	18.5	16.5	17.5	17.5	1.39
Pelvic fin length	2	19.3	17.5	18.4	18.4	1.22
% Head Length						
Head width	2	83.5	66.8	75.2	75.2	11.81
Head depth	2	67.5	58.9	63.2	63.2	6.08
Snout length	2	42.9	40.5	41.7	41.7	1.70
Orbit diameter	2	19.1	16.1	17.6	17.6	2.12
Interorbital width	2	42.3	42.0	42.2	42.2	0.21
% Orbit Diameter						
Rostral barbel length	2	94.0	93.0	93.5	93.5	0.71
Maxillary barbel length	2	60.4	60.2	60.3	60.3	0.16

B. Meristic Features

Dorsal fin rays	III + 7(2)
Anal fin rays	III + 5(2)
Pectoral fin rays	IV + 11(2)
Pelvic fin rays	II + 6(2)
Lateral line scales	34
Caudal peduncle scale rows	13
Scale rows lateral line-dorsal fin	4.5
Scale rows lateral line-pelvic fin	3.5
Scale rows lateral line-anal fin	3.5 – 4
Predorsal scale rows	13

Table 24 Data on synonyms of *G.quadrimaculata*

	G.tibanica	*G.brittonii*
A. MORPHOLOGY		
Disc type	Type C	Type C
Belly scales	Yes	Yes
Chest scales	Yes	Yes
Predorsal scales	Full	Full
Post-pelvic scales	Yes	Yes
Tubercles	Yes	Yes
Barbels	4	4
Color	Light black	Light black
Vent position	Near anal fin (12.4%)	Near anal fin (9.7%)
B. MORPHOMETRICS		
% Standard length		
Body depth	20.7	16.1
Head length	22.6	21.5
Caudal peduncle length	17.6	18.0
Caudal peduncle depth	11.3	10.1
Pectoral fin length	19.1	19.6
% Head length		
Head width	73.6	66.8
Head depth	67.6	58.9
Snout length	42.9	40.6
Eye diameter	19.2	16.1
Interorbital width	42.1	42.4

Table 24. continued.......

C. MERISTICS

Lateral line scales	34	35
Dorsal fin-lateral line	4.5	4.5
Pelvic fin-lateral line	3.5	3.5
Circumpeduncle scales	13	14

Table 25. A. Morphometric and B. Meristic Features of *G.tana* spec. nov.

A. Morphometric Features

	N	Max	Min	Mean	Median	SD
% Standard Length						
Body depth	28	18.8	13.4	16.6	17.1	1.47
Head length	28	25.6	18.9	21.5	20.9	1.79
Predorsal length	28	50.0	39.8	43.0	42.0	3.02
Pectoral fin length	28	20.2	16.6	18.4	18.6	1.04
Caudal peduncle length	28	22.3	20.4	19.2	19.4	1.74
Caudal peduncle depth	28	10.0	7.2	8.4	8.2	0.77
Dorsal fin length	28	26.0	22.0	23.6	23.3	1.07
Anal fin length	28	19.3	17.1	18.3	18.2	0.49
Pelvic fin length	28	19.7	16.4	18.0	18.1	0.78
% Head Length						
Head width	28	66.3	56.7	60.5	59.7	2.68
Head depth	28	61.1	45.2	53.1	52.8	3.05
Snout length	28	44.1	33.9	38.4	37.4	3.08
Orbit diameter	28	27.9	15.3	21.5	21.4	3.14
Interorbital width	28	59.4	29.4	36.4	35.3	5.30
% Orbit Diameter						
Rostral barbel length	28	127.0	43.0	81.8	79.5	0.51
Maxillary barbel length	28	102.9	41.0	77.4	79.1	18.07

B. Meristic Features

Dorsal fin rays	III + 7(28)
Anal fin rays	III + 5(28)
Pectoral fin rays	IV + 11(28)
Pelvic fin rays	II + 6(28)
Lateral line scales	39 – 40
Caudal peduncle scale rows	12
Scale rows lateral line-dorsal fin	4 –4.5
Scale rows lateral line-pelvic fin	3 – 4
Scale rows lateral line-anal fin	4 – 4.5
Predorsal scale rows	3 - 5

Table 26. **Pearson Correlation Coefficient Between Gas bladder, Pectoral fin width and Disc development**

	Gas bladder	**Pectoral fin width**	**Disc**
Gas bladder	**1.00**	—	—
Pectoral fin width	**- 0.563**	**1.00**	—
Disc	**0.129**	**- 0.309**	**1.00**

Table 27. Pearson Correlation Coefficient between Disc type, Intestine size and Vent position.

	Disc Type	Intestine ratio of SL	Vent position
Disc Type	1.00	....	....
Intestine ratio of SL	-0.737	1.00	....
Vent position	-0.312	0.293	1.00

Table 28. **Percentages of standard length in length of intestine in some species of the African *Garra*** (N= Number of specimens; R= Range; M= Mean; SD= Standard deviation; SE= Standard error).

SPECIES	N	R	M	SD	SE
G.aethiopica	10	47-76	61.5	8.152	2.578
G.blanfordii	10	40-50	45	3.429	1.084
G.congoensis	5	30-35	31	2.114	0.945
G.dembecha	10	40-56	48	5.180	1.638
G.dembeensis	10	39-42	40.5	0.974	0.308
G.duobarbis	6	72-74	73	0.732	0.299
G.geba	4	95-102	98.5	2.863	1.431
G.ignesti	10	19-30	21.5	3.247	1.027
G.makiensis	10	19-32	20.5	1.009	0.319
G.microstoma	3	108-116	112	4.050	2.338
G.quadrimaculata	10	19-30	24.5	3.506	1.109
G.tana	10	62-79	70.5	5.117	1.618

Table 29. Position of vent (Percentages of distance from vent to anal fin of that between the anterior ends of the pelvic and anal fins) for the African species of *Garra* (N= Num.of specimens; M= Mean; SD= Standard deviation; SE= Standard error).

SPECIES		**POSITION OF VENT**		
	N	**M**	**SD**	**SE**
G. aethiopica	30	20.227	3.312	0.605
G. allostoma	2	29.550	1.485	1.050
G. blanfordii	30	28.460	3.904	0.713
G. congoensis	10	38.736	2.207	0.666
G. dembecha	10	31.987	5.322	0.972
G. dembeensis	30	26.044	4.684	0.828
G. duobarbis	10	22.040	4.002	1.266
G. ethelwynnae	2	14.500	3.677	2.600
G. geba	10	24.600	4.073	1.288
G. hindii	3	29.900	0.520	0.300
G. ignestii	30	18.194	3.242	0.564
G. lancrenonensis	2	15.350	2.899	2.050
G. makiensis	30	13.563	4.550	0.804
G. microstoma	3	21.900	2.330	1.345
G. ornata	10	34.820	4.042	1.278
G. quadrimaculata	4	12.250	4.882	2.441
G. tana	28	27.797	7.027	1.305

Table 30. Ratio (average) of Gas bladder (posterior part) in Standard length AND Pectoral fin width in Standard length of some species of the African *Garra*.

SPECIES		GAS BLADDER			PECTORAL FIN		
	N	M	SD	SE	M	SD	SE
G.aethiopica	10	5.10	0.229	0.072	13.67	0.205	0.065
G.blanfordii	10	4.35	0.172	0.054	16.07	1.238	0.391
G.dembecha	10	4.54	0.057	0.018	11.02	0.454	0.144
G.dembeensis	10	4.70	0.047	0.015	12.71	0.920	0.291
G.duobarbis	6	5.87	0.730	0.298	10.32	0.477	0.195
G.geba	4	6.69	0.416	0.208	9.88	0.785	0.393
G.ignestii	10	5.12	0.221	0.070	13.09	0.694	0.220
G.makiensis	10	5.92	0.312	0.099	10.29	0.979	0.318
G.microstoma	3	4.32	0.300	0.173	16.75	2.845	1.643
G.quadrimaculata	10	4.28	0.149	0.047	12.68	0.901	0.285
G.tana	10	4.53	0.142	0.045	18.82	2.951	0.933

Table 31. Dorsal and Anal Fin lengths given as percentages of the standard length for species of the African *Garra* (N= Numb.of specimens, M= Mean and R=Range)

SPECIES		DORSAL FIN		ANAL FIN	
	N	M	R	M	R
G.aethiopica	30	21.3	19.6-22.5	17.9	16.6-19.8
G.allostoma	2	24.0	23.5-24.5	16.0	15.9-16.2
G.blanfordii	30	20.9	19.4-22.6	17.2	14.7-18.6
G.congoensis	10	18.3	17.2-18.9	14.2	13.5-14.9
G.dembecha	10	21.0	19.5-22.6	16.6	16.1-17.0
G.dembeensis	30	21.1	19.9-23.5	18.3	17.0-19.7
G.duobarbis	10	21.8	20.5-23.9	17.9	17.4-18.6
G.ethelwynnae	2	24.7	24.4-25.1	18.9	18.7-19.1
G.geba	10	20.8	19.4-22.1	16.4	12.2-18.5
G.hindii	3	22.1	21.9-22.3	18.0	18.0-18.1
G.ignestii	30	21.1	19.0-25.3	17.6	15.4-19.6
G.lancrenonensis	2	23.4	22.5-24.3	16.3	16.1-16.4
G.makiensis	30	24.1	22.8-25.6	17.5	15.9-19.7
G.microstoma	3	20.7	18.7-24.1	17.5	16.8-18.7
G.ornata	10	20.5	19.8-21.4	14.6	14.1-15.1
G.quadrimaculata	2	23.2	20.5-25.9	17.5	16.5-18.5
G.tana	28	23.6	22.0-26.0	18.3	17.1-19.3

Table 32.

Pectoral and Pelvic fin lengths given as percentages of standard length for species of the African *Garra* (N= Num.of specimens, M=Mean and R=Range)

SPECIES		PECTORAL FIN		PELVIC FIN	
	N	M	R	M	R
G. aethiopica	30	20.9	17.9-23.0	17.6	15.5-19.2
G. allostoma	2	20.5	20.5	19.7	19.5-20.1
G. blanfordii	30	19.5	17.0-24.0	17.3	16.1-18.8
G. congoensis	10	20.3	16.8-24.0	18.0	17.4-18.7
G. dembecha	10	20.1	16.6-22.3	17.6	16.1-18.9
G. dembeensis	30	19.9	15.1-23.9	18.3	16.6-20.3
G. duobarbis	10	18.6	12.9-21.4	17.7	16.1-18.3
G. ethelwynnae	2	20.6	19.0-22.1	21.7	21.1-22.3
G. geba	10	21.1	19.1-22.6	16.9	16.2-17.6
G. hindii	3	19.5	18.7-19.9	20.1	19.9-20.3
G. ignestii	30	20.6	12.4-23.3	17.8	16.2-19.7
G. lancrenonensis	2	22.2	20.5-23.9	17.5	17.3-17.8
G. makiensis	30	20.2	15.3-24.3	20.6	19.0-22.7
G.microstoma	3	19.6	17.5-21.0	19.0	16.8-20.8
G. ornata	10	18.8	15.4-20.8	18.0	17.5-18.5
G. quadrimaculata	2	19.3	19.0-19.6	18.4	17.3-19.5
G. tana	28	18.4	16.6-20.2	18.0	16.4-19.7

Table 33. Body depth (as % of standard length) and Head depth (as % of head length) for the species of the African *Garra* (N= number of specimens, M= Mean and R=Range).

SPECIES		BODY DEPTH		HEAD DEPTH	
	N	M	R	M	R
G. aethiopica	30	22.2	18.9-25.2	67.2	58.4-78.0
G. allostoma	2	21.1	20.5-21.7	55.6	51.2-60.1
G. blanfordii	30	22.8	20.0-25.1	67.1	58.6-75.2
G. congoensis	10	11.9	10.6-15.0	41.2	35.4-44.6
G. dembecha	10	19.5	16.7-23.0	56.9	50.0-65.2
G. dembeensis	30	20.4	15.6-23.9	59.1	50.0-68.7
G. duobarbis	10	22.4	18.8-24.3	55.4	51.2-63.9
G. ethelwynnae	2	30.0	29.1-30.9	70.0	64.9-75.0
G. geba	10	16.0	14.8-16.8	53.7	47.6-59.4
G. hindii	3	17.7	15.8-19.3	54.1	52.8-56.3
G. ignestii	30	21.6	15.3-27.3	61.1	52.6-71.9
G. lancrenonensis	2	21.6	19.9-23.3	59.8	59.4-60.2
G. makiensis	30	21.7	17.5-27.8	62.1	54.0-70.0
G.microstoma	3	20.1	19.8-20.6	59.8	57.5-61.0
G. ornata	10	17.8	15.8-22.3	52.5	44.2-59.2
G. quadrimaculata	2	18.4	16.0-20.7	63.2	58.9-67.5
G. tana	28	16.6	13.4-18.8	53.1	45.2-61.1

Table 34. Caudal peduncle length and depth (as % of standard length) for species of the African *Garra* (N= Numb.of specimens. M = Mean and R = Range).

SPECIES	**CAUDAL PEDUNCLE LENGTH**			**CAUDAL PEDUNCLE DEPTH**	
	N	**M**	**R**	**M**	**R**
G. aethiopica	30	17.3	14.2-18.9	11.7	10.7-12.8
G. allostoma	2	14.9	14.9	12.5	12.3-12.7
G. blanfordii	30	17.9	15.1-21.6	12.4	10.7-13.9
G. congoensis	10	14.9	12.5-18.0	8.1	7.0-9.0
G. dembecha	10	16.8	13.3-20.7	10.3	8.8-12.0
G. dembeensis	30	15.6	12.7-19.4	9.9	8.3-11.6
G. duobarbis	10	14.9	12.7-16.7	11.6	10.6-12.2
G. ethelwynnae	2	13.3	12.5-14.0	12.2	11.1-13.2
G. geba	10	16.9	14.4-19.9	9.6	8.3-10.6
G. hindii	3	18.2	18.1-18.4	10.3	10.0-10.7
G. ignestii	30	16.4	11.9-20.7	10.9	6.9-13.3
G. lancrenonensis	2	12.6	12.1-13.0	9.8	9.3-10.2
G. makiensis	30	17.1	11.1-20.1	10.9	7.7-13.1
G.microstoma	3	18.6	18.2-18.9	10.7	9.9-11.1
G. ornata	10	15.8	13.9-17.7	10.0	9.2-10.7
G. quadrimaculata	2	17.8	17.6-17.9	10.7	10.1-11.3
G. tana	28	19.2	15.4-22.3	8.4	7.2-10.0

Table 35. Multivariate Analysis of Variance of:

A. Alligned data using land marks for *G.blanfordii* and *G.dembecha* spec.nov. (SAS)

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.23474922	7.4252	18	41	0.0001
Pillai' Trace	0.76525078	7.4252	18	41	0.0001
Hotelling-Lawley Trace	3.25986507	7.4252	18	41	0.0001
Roy's Greatest Root	3.25986507	7.4252	18	41	0.0001

B. Redundant distance measures for *G.blanfordii* and *G.dembecha* spec.nov. (SYSTAT)

Statistic	Value	F	NumDF	DenDF	Prob
Wilks' Lambda	0.244	13.516	11	48	0.000
Pillai Trace	0.756	13.516	11	48	0.000
Hotelling-Lawley Trace	3.098	13.516	11	48	0.000

Table 36

Character States for Labeinae

0. The shape of supraethmoid
1. The presence/ absence of antero-lateral concavity on dentary
2. The presence/ absence of premaxillae ascending process
3. The presence/ absence of V-shaped gap on premaxillae
4. The presence/ absence of concavity at the anterior face of vomer
5. The size and shape of maxillae
6. The infraorbital bones
7. The presence/ absence of postero-dorsal process on lacrimal
8. The presence/ absence of concavity on the operculum
9. The shape of the symplectic
10. The number of supraneurals
11. The number of rows of pharyngeal teeth
12. The presence/ absence of bifurcation on the distal face of the leading anal fin pterygiophore
13. The shape of the leading dorsal fin pterygiophore
14. The presence/ absence of pelvic girdle indentation
15. The number of branched (bifid) haemal spines with canal
16. The shape of cleithrum
17. The presence/ absence of process on preural 2/3
18. The segments of the dorsal fin rays
19. The number of unbranched anterior pectoral fin rays
20. The presence/ absence of suctorial disc
21. The position of the maxillary barbels
22. The insertion of the anterior barbels
23. The length of the intestine
24. The presence/ absence of free rostral lobes

Table 36 continued...

25. The presence/ absence of upper labial fold

26. The presence/ absence of the lower labial fold

27. The presence/ absence of rostral fold

28. Rostral fold continuity with lower lip

29. The presence/ absence of papillae on rostral fold

30. The presence/ absence of papillae on lower lip

31. The position of the mouth

Table 37

Polarity coding for Labeinae

	Characters															
Taxa	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Barbus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Varicorhinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tylognathus	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*
Cirrhinus	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0
Osteocheilus	0	0	1	1	0	1	1	0	1	0	0	0	1	0	0	0
Labeo	0	0	1	0	0	1	1	0	1	0	0	0	1	0	0	0
Epalzeorhynchos	0	0	1	1	1	1	0	1	0	0	0	0	1	0	0	0
Paracrossochei	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0
Crossocheilus	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	1
Discocheilus	0	1	0	0	1	0	0	1	0	0	0	1	1	0	1	1
Discogobio	0	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1
Semilabeo	0	1	0	0	1	0	0	1	0	0	0	1	1	0	1	1
G.dembeensis	1	1	0	0	0	0	1	1	0	0	1	0	1	1	1	1
G.quadrimaculata	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1

Table 37 contd....

	Characters															
Taxa	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
Barbus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Varicorhinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tylognathus	*0*	*0*	*0*	*0*	*0*	*?*	*?*	*1*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*1*
Cirrhinus	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1
Osteocheilus	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	1
Labeo	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	1
Epalzeorhynchos	0	1	0	0	0	0	1	1	1	0	0	1	1	1	1	1
Paracrossochei	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1
Crossocheilus	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1
Discocheilus	0	0	1	0	1	1	1	1	0	0	0	1	1	1	1	1
Discogobio	0	0	1	0	1	0	1	1	0	0	0	1	1	1	1	1
Semilabeo	0	0	1	0	1	0	1	1	0	0	0	1	1	1	1	1
G.dembeensis	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1
G.quadrimaculat	1	0	1	1	1	0	1	1	0	0	0	1	1	1	1	1

Table 38

Character states for *Garra* phylogeny

0. The shape of the supraethmoid bone
1. The shape of the antero-medial part of ethmoid
2. The presence/ absence of concavity on dentary bone
3. The presence/ absence of premaxillae ascending process
4. The infraorbital series
5. The number of infraorbital series
6. The shape of the postero-dorsal elongation of the lacrimal
7. Shape of the operculum
8. The shape of the symplectic
9. The shape of the urohyal
10. The shape of the pharyngeal process
11. The shape of the masticatory plate
12. The number of supraneurals
13. The Number of rows of pharyngeal teeth
14. The shape of the suture at frontal and parietal
15. The Presence/ absence or reduction of intramuscular bones
16. The shape of the leading dorsal fin pterygiophore
17. The shape of cleithrum
18. The presence/ absence of neural process on preural 2/3
19. The presence/ absence of haemal process on preural 2/3
20. The number of preanal caudal vertebrae
21. The number of unbranched anterior pectoral fin rays
22. The suctorial disc development

Table 38 continued....

23. The presence/ reduction/ absence of barbels

24. The length of the intestine

25. The presence/ absence of scales in the predorsal region

26. The number of scales on the lateral line

27. The position of the vent

28. The presence/ absence of black spots at base of dorsal fin

29. The presence/ absence of chest and abdominal scales

30. The presence/absence of proboscis

31. The presence/ absence of tubercles

32. The presence/ absence of body stripes

33. The size of the gas bladder

34. Number of crenulations/ indentations of the rostral fold

Table 39. Polarity Coding For *Garra*

	Characters												
Taxa	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Epalzeorhynchos	0	1	1	1	0	0	0	0	0	0	0	0	0
Paracrossocheilus	0	0	1	0	0	0	0	0	0	0	0	0	0
Crossocheilus	0	0	0	0	0	1	1	0	1	0	1	1	0
Semilabeo	0	?	0	0	?	0	0	?	0	?	0	0	0
Discocheilus	0	0	0	0	0	0	1	0	0	1	1	1	0
Discogobio	0	0	0	0	0	0	0	0	0	0	0	0	0
Garra aethiopica	1	1	1	0	1	1	1	1	0	1	1	1	1
G.blanfordii	1	0	0	1	0	0	0	0	0	0	0	0	1
G.congoensis	1	0	?	?	1	1	1	1	1	1	1	1	1
G.dembecha	1	1	1	0	1	0	1	1	1	0	1	1	1
G.dembeensis	1	1	0	0	1	1	1	0	1	1	1	1	1
G.duobarbis	1	1	1	0	1	1	1	1	1	1	1	1	1
G.geba	1	1	0	0	1	1	1	1	1	1	1	1	0
G.hindii	1	1	1	0	1	1	0	0	1	0	1	1	1
G.ignestii	1	1	1	1	0	0	0	0	0	0	0	0	1
G.makiensis	1	1	0	1	0	0	0	0	0	0	0	0	0
G.microstoma	1	0	1	0	1	1	1	1	1	1	1	1	1
G.ornata	1	0	0	0	1	1	0	1	?	0	1	1	1
G.quadrimaculata	1	1	1	0	0	0	0	0	0	0	0	0	0
G.tana	1	1	1	0	1	1	1	1	1	1	1	1	1
G.rufa	1	1	0	1	0	0	0	0	0	0	0	0	0
G.rossica	1	0	1	0	0	0	0	0	0	0	0	0	1
G.lamta	1	1	0	1	1	0	0	0	1	0	0	0	0
G.bicornuta	1	0	0	1	0	0	0	0	0	0	0	0	1
G.imberbis	1	1	0	0	1	1	0	1	?	1	1	1	0
G.nasuta	1	1	1	1	1	1	1	0	?	1	1	1	0
G.cambodgiensis	1	1	0	0	1	1	1	1	1	1	1	1	1

Table 39 continueed.

Taxa	**Characters** **13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Epalzeorhynchos	1	0	0	0	0	1	0	0
Paracrossocheilus	0	1	0	0	0	0	0	1
Crossocheilus	1	1	0	0	0	0	0	1
Semilabeo	0	0	0	0	0	0	0	0
Discocheilus	0	0	0	0	0	0	0	0
Discogobio	0	0	0	0	0	0	0	0
Garra aethiopica	1	1	1	1	1	0	0	1
G.blanfordii	1	0	0	0	1	1	1	0
G.congoensis	1	0	0	1	1	0	0	1
G.dembecha	1	1	1	1	1	1	0	1
G.dembeensis	1	1	1	1	1	1	0	1
G.duobarbis	1	1	1	1	1	0	0	1
G.geba	1	1	1	1	1	0	0	1
G.hindii	1	0	1	1	1	0	0	1
G.ignestii	1	0	0	0	1	0	1	0
G.makiensis	1	0	0	0	1	0	0	0
G.microstoma	1	1	0	0	1	0	0	1
G.ornata	0	1	1	0	1	0	0	1
G.quadrimaculata	1	0	0	0	1	0	1	0
G.tana	1	1	0	1	1	0	0	1
G.rufa	1	1	0	0	1	0	0	0
G.rossica	1	0	0	0	1	0	1	0
G.lamta	1	1	1	1	1	0	0	1
G.bicornuta	1	0	0	0	1	0	1	0
G.imberbis	1	1	1	1	1	0	0	1
G.nasuta	?	1	0	1	1	0	0	0
G.cambodgiensis	0	1	0	1	1	0	0	1

Table 39 continueed.

Taxa	**Characters**							
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Epalzeorhynchosus	0	0	0	0	0	0	0	0
Paracrossocheilus	0	1	1	0	0	0	1	0
Crossocheilus	0	1	0	0	0	0	1	0
Semilabeo	0	0	1	0	0	1	0	0
Discocheilus	0	0	0	0	0	0	0	0
Discogobio	0	0	0	0	0	0	0	0
Garra aethiopica	1	0	0	1	0	0	1	1
G.blanfordii	1	0	0	0	0	0	1	1
G.congoensis	1	0	0	0	1	1	1	1
G.dembecha	1	1	0	1	1	1	1	1
G.dembeensis	1	0	0	1	1	1	1	1
G.duobarbis	1	1	1	1	1	0	1	1
G.geba	1	1	0	1	1	1	1	1
G.hindii	1	0	0	1	0	1	1	1
G.ignestii	1	0	0	0	0	0	1	1
G.makiensis	1	0	0	0	0	0	0	1
G.microstoma	1	1	0	1	1	1	1	1
G.ornata	1	0	0	1	1	0	1	1
G.quadrimaculata	1	0	0	0	0	0	0	1
G.tana	1	1	0	1	1	1	1	1
G.rufa	1	0	0	0	0	0	1	1
G.rossica	1	1	1	0	0	0	0	1
G.lamta	1	0	0	0	0	0	1	0
G.bicornuta	1	0	1	0	0	0	1	0
G.imberbis	1	0	1	1	0	1	1	0
G.nasuta	1	0	0	1	0	1	1	1
G.cambodgiensis	1	0	1	1	0	0	1	1

Table 39 continueed.			**Characters**			
Taxa	**29**	**30**	**31**	**32**	**33**	**34**
Epalzeorhynchos	0	0	1	0	0	0
Paracrossocheilus	0	0	0	0	0	1
Crossocheilus	0	0	1	0	0	1
Semilabeo	0	0	0	0	0	0
Discocheilus	0	0	0	0	0	0
Discogobio	0	0	0	0	0	0
Garra aethiopica	1	0	1	0	1	0
G.blanfordii	1	0	1	0	1	0
G.congoensis	1	0	0	0	0	1
G.dembecha	1	0	1	0	1	1
G.dembeensis	1	0	0	0	1	1
G.duobarbis	1	0	0	0	0	0
G.geba	1	0	0	0	0	1
G.hindii	0	0	0	0	0	1
G.ignestii	1	0	0	0	0	0
G.makiensis	1	0	0	0	0	0
G.microstoma	1	0	0	0	0	1
G.ornata	1	0	0	0	1	1
G.quadrimaculata	0	0	0	0	1	0
G.tana	1	0	1	0	1	1
G.rufa	0	0	0	0	0	1
G.rossica	1	0	1	0	1	0
G.lamta	0	0	1	0	0	1
G.bicornuta	0	1	0	0	1	1
G.imberbis	1	0	0	0	0	1
G.nasuta	0	1	0	1	0	1
G.cambodgiensis	0	0	0	0	1	1

Table 40. ***Garra*** **species considered for phylogenetic studies and their geographic distribution.**

SPECIES	GEOGRPHIC DISTRIBUTION
G.aethiopica	Africa
G.blanfordii	Africa
G.congoensis	Africa
G.dembecha	Africa
G.dembeensis	Africa
G.duobarbis	Africa
G.geba	Africa
G.hindii	Africa
G.ignestii	frica
G.makiensis	Africa
G.microstoma	Africa
G.ornata	frica
G.quadrimaculata	frica
G.tana	Africa
G.rufa	Middle East
G.rossica	Middle East /Western Asia
G.lamta	India
G.bicornuta	India
G.imberbis	South East Asia/ China
G.nasuta	outh East Asia/ China
G.cambodgiensis	South East Asia

Fig. 1.

Geographic distribution of *Garra* in the world


40
20
0
20
40
40
20
0
20
40

Fig. 2

Relationships among the Labeine cyprinids: (source: Reid, 1978)

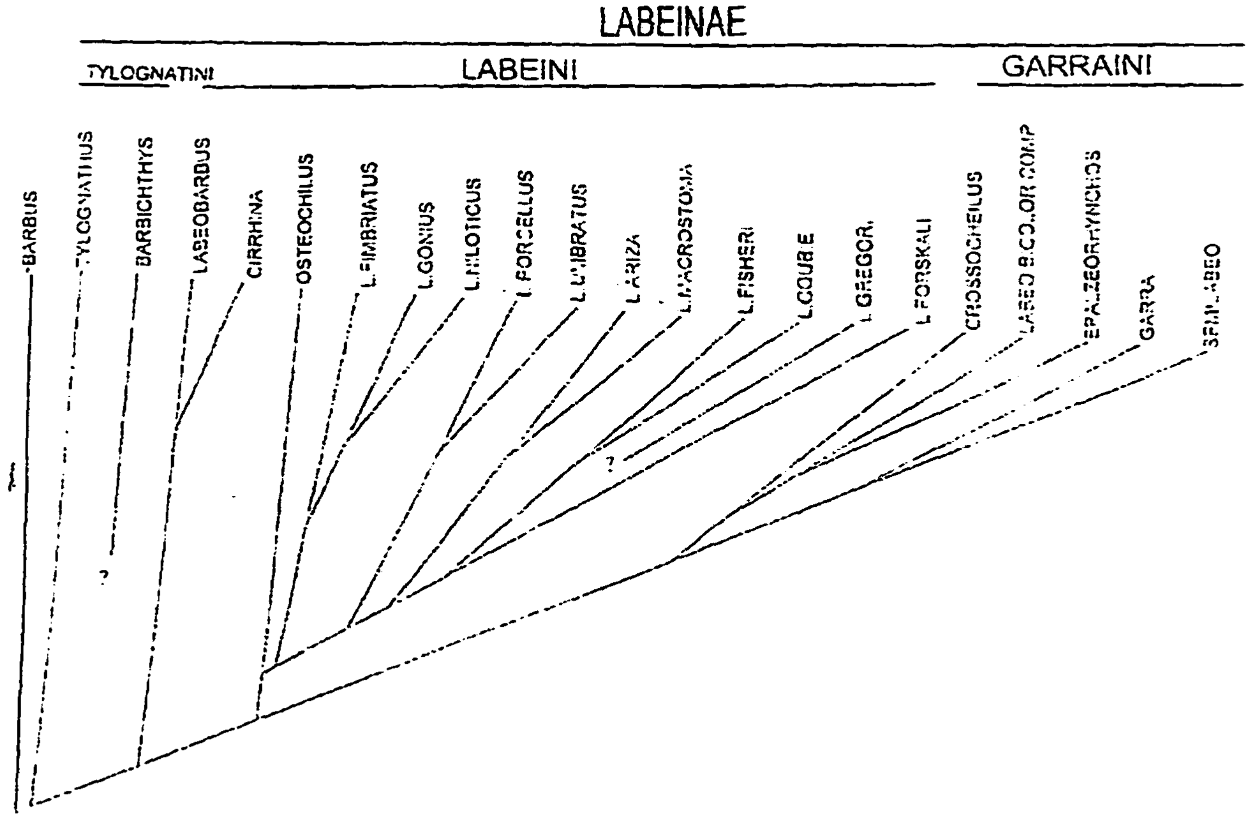

LABEINAE
TYLOGNATINI
LABEINI
GARRAINI
BARBUS
TYLOGNATHUS
BARBICHTHYS
LABEOBARBUS
CIRRHINA
OSTEOCHILUS
L.FIMBRIATUS
L.GONIUS
L.NILOTICUS
L. PORCELLUS
L. UMBRATUS
L. ARIZA
L.MACROSTOMA
L.FISHERI
L.COUBIE
L. GREGORI
L. FORSKALI
CROSSOCHEILUS
LABEO BICOLOR COMP
EPALZEORHYNCHOS
GARRA
SEMILABEO
?
?

Fig. 3.

Drainage Basins of Ethiopia (Stars indicate localities sampled).

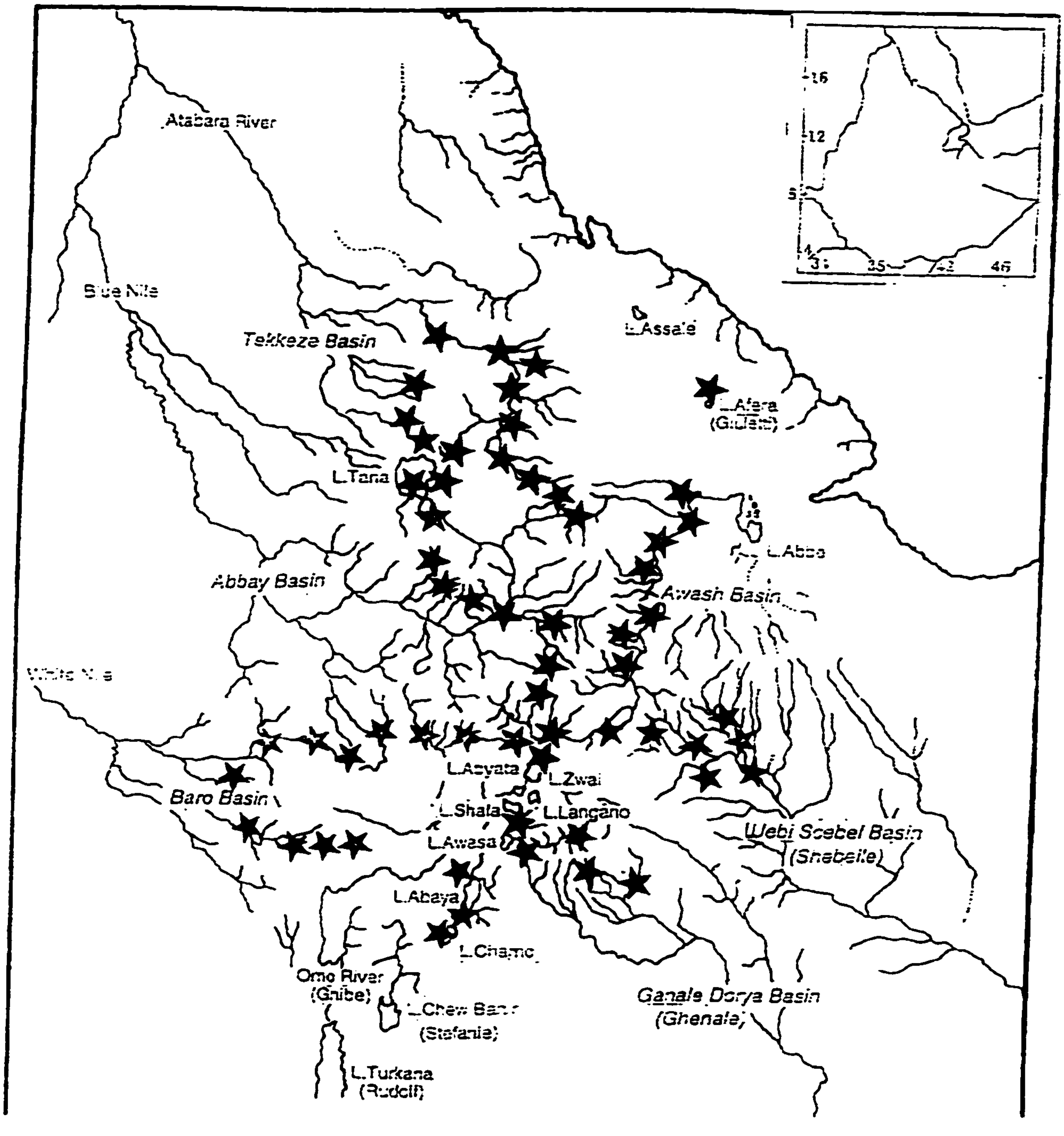

Atabara River
Blue Nile
Tekkeze Basin
L.Assale
L.Afera
(Giulietti)
L.Tana
L.Abbe
Abbay Basin
Awash Basin
White Nile
L.Abyata
L.Zwai
L.Shala
L.Langano
Baro Basin
Webi Scebel Basin
(Shebelle)
L.Awasa
L.Abaya
L.Chamo
Omo River
(Ghibe)
L.Chew Bahir
(Stefanie)
Ganale Dorya Basin
(Ghenale)
L.Turkana
(Rudolf)
16
12
8
4
3
35
42
46

Fig. 4.

Body measurements taken from *Garra*. Abbreviations: **AL**= Anal fin length; **BD**= Body depth; **CPD**= Caudal peduncle depth; **CPL**= Caudal peduncle length; **DFL**= Dorsal fin length; **H**= Head length; **HD**= Head depth; **O**= Orbit diameter; **PECL**= Pectoral fin length; **PEL**= Pelvic fin length; **PO**=Post-orbital length; **PRE D**= Predorsal length; **SL**= Standard length; **SN**= Snout length.

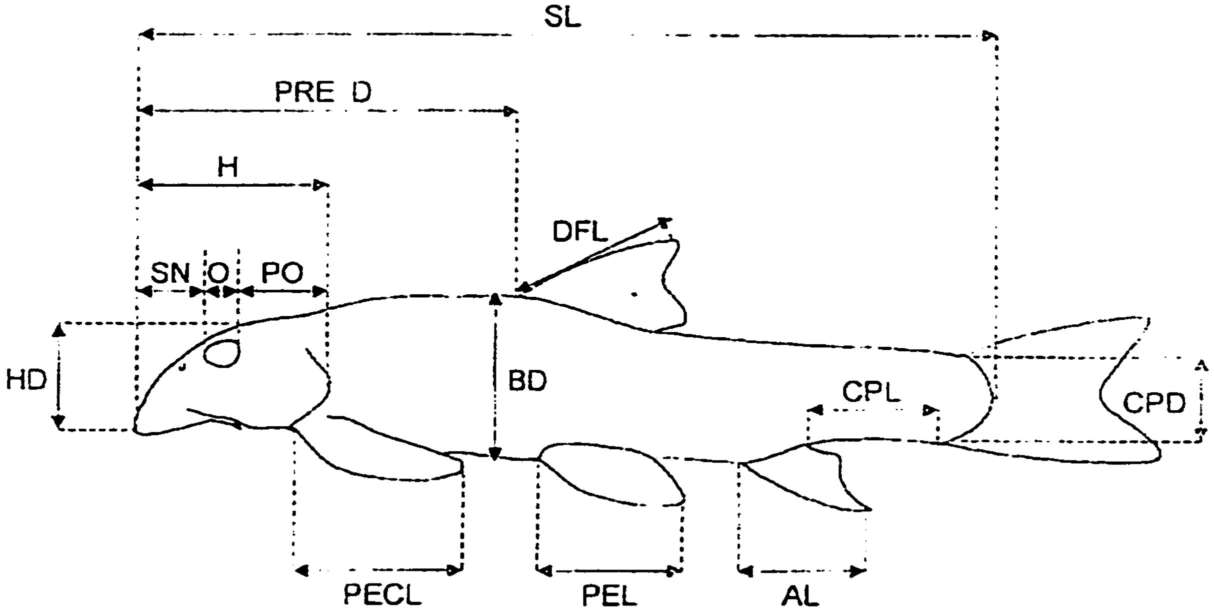

SL
PRE D
H
DFL
SN
O
PO
HD
BD
CPL
CPD
PECL
PEL
AL

Fig. 5.

The suctorial disc structure of **A-C.** *Garra* **D.** *Discocheilus* **E.** *Discogobeo* and **F.** *Semilabeo* (**ALL**= Antero-lateral lobe; **CC**= Central callous structure; **DI**= Disc; **MB**= Maxillary Barbel; **PA**= Papillae; **RB**= Rostral Barbel; **RF**= Rostral fold)

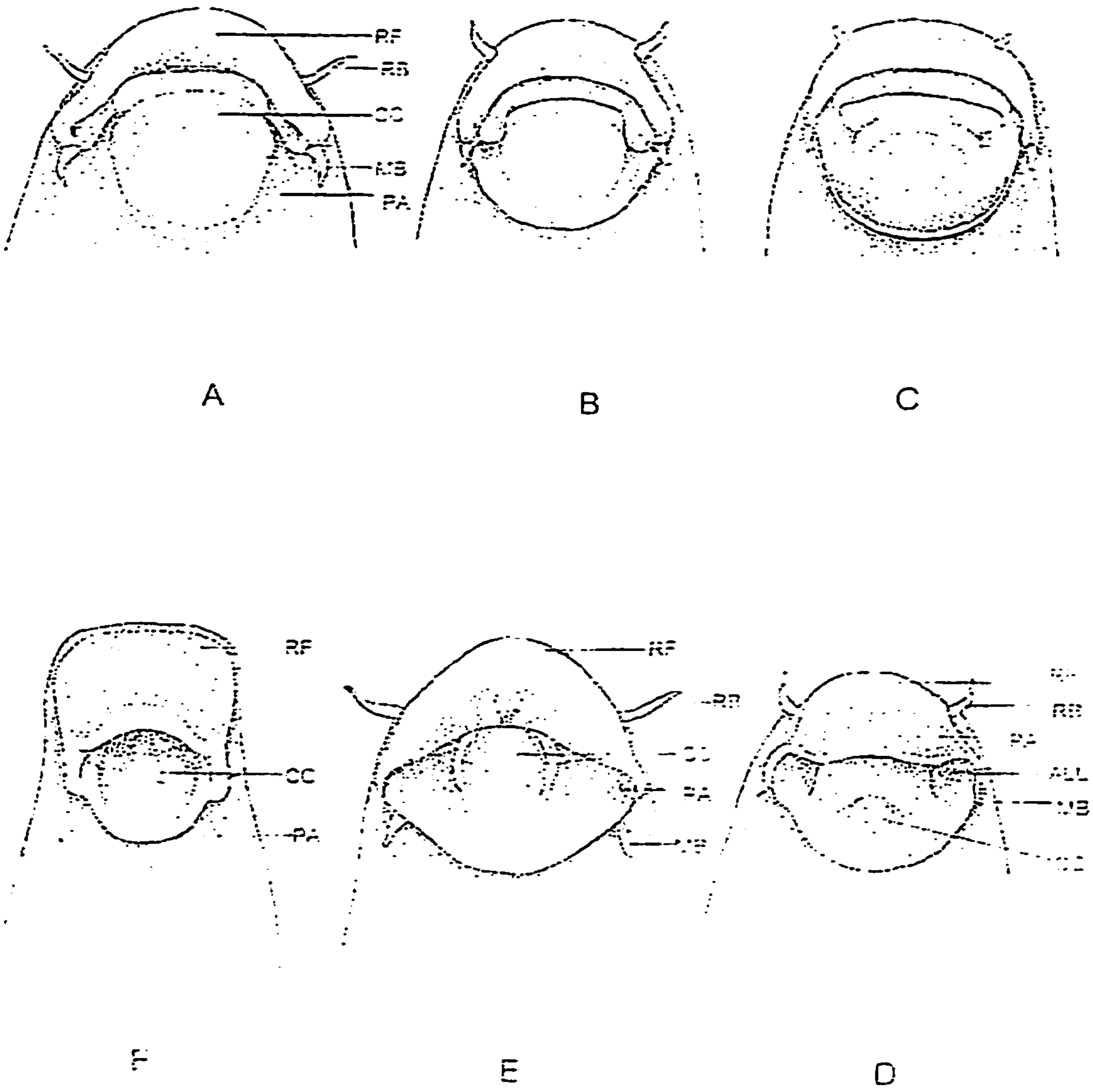
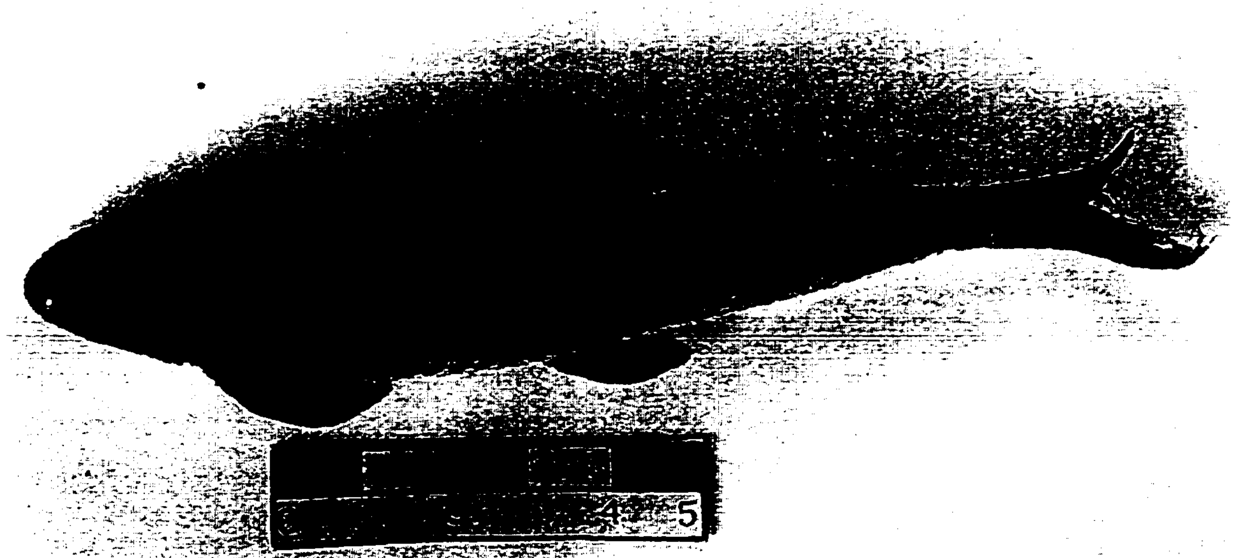

RF
RB
CC
MB
PA
A
B
C
RF
CC
PA
RF
RB
PA
RB
PA
ALL
MB
F
E
D

Fig. 6.

Dorsal and Ventral view of representative specimen of *Garra aethiopica* (AMNH 223672)


4
5

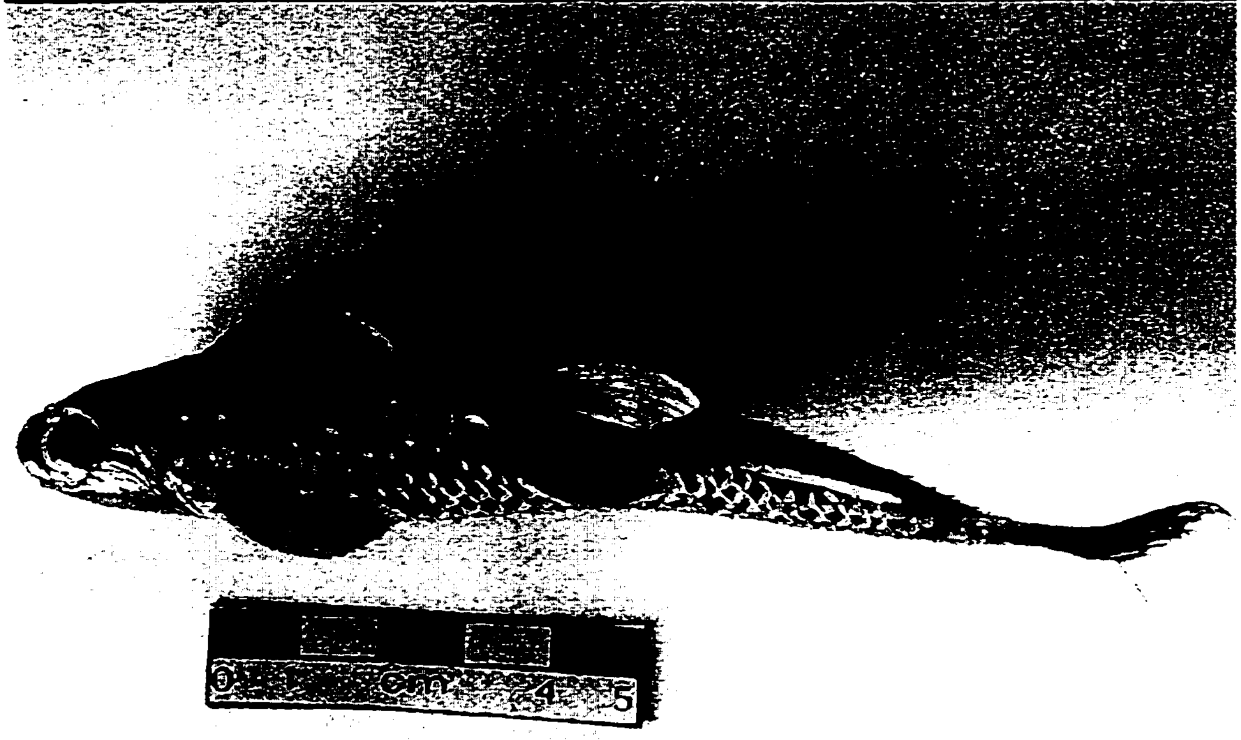
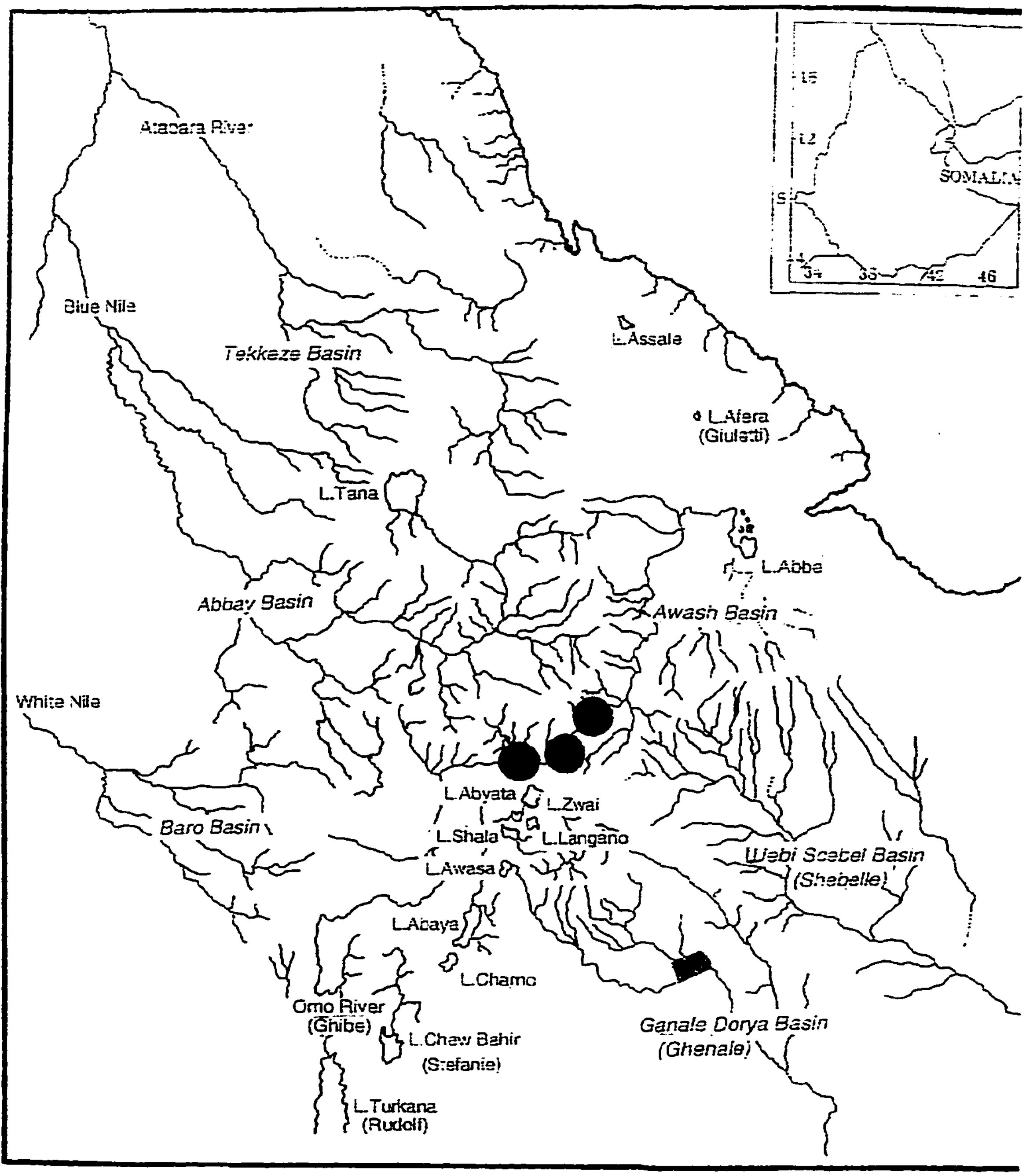

0
cm
4
5

Fig. 7.

Geographic distribution of *Garra aethiopica* and *G.quadrimaculata* in Ethiopian Freshwaters. Based on materials examined and listed in the species accounts section

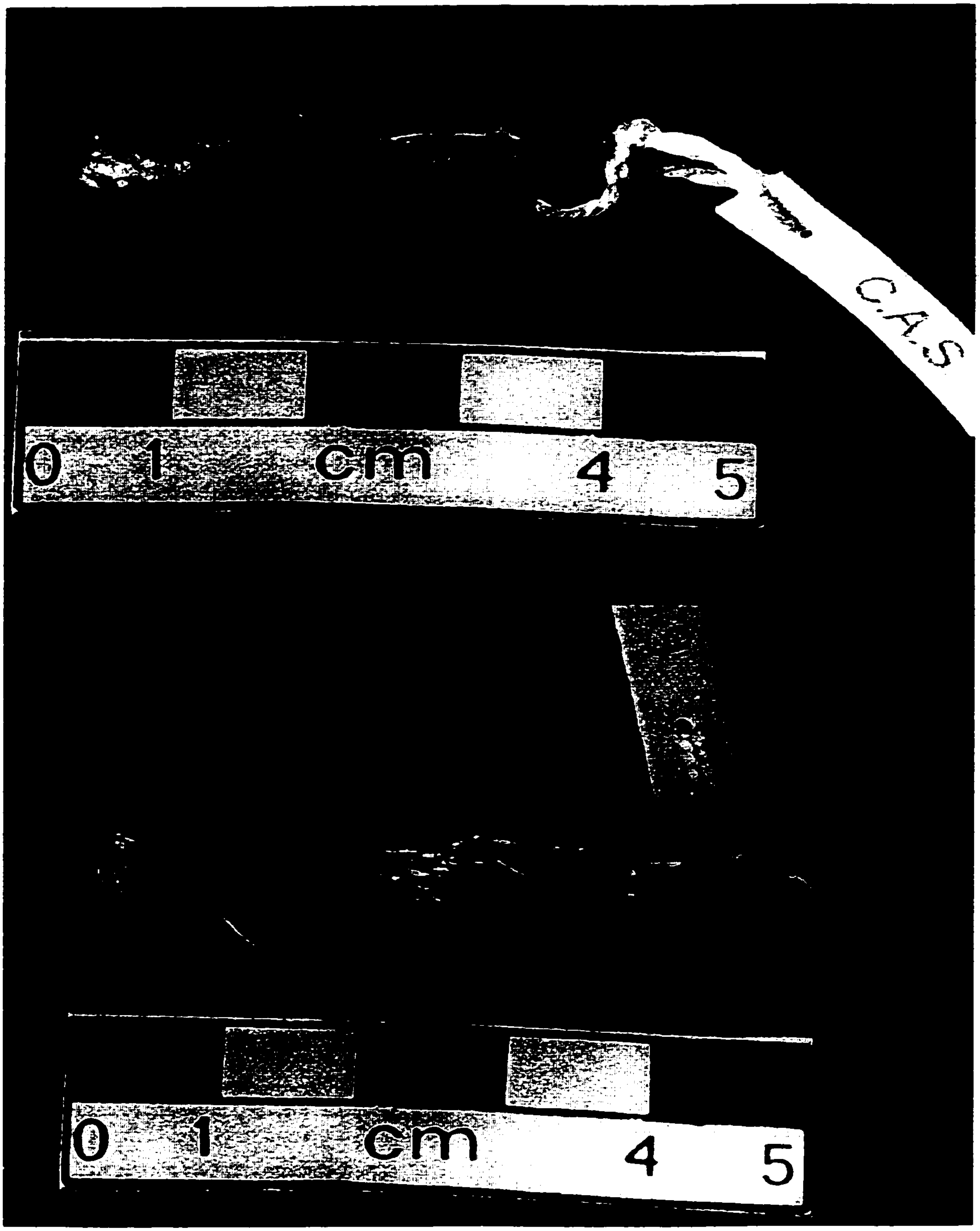


● *G. aethiopica*

■ *G. quadrimaculata*

Fig. 8.

Dorsal and Ventral view of representative specimen of *G.allostoma* (CAS 66740).


C.A.S.
0 1 cm 4 5
0 1 cm 4 5

Fg.9

A. Lateral view, Ventral view and Oromandibular region of the type specimen of *G.allostoma* (Source: Roberts, 1990)

B. Lateral, Ventral and dorsal view of the type specimen of *G.congoensis* (Source: Poll, 1959)

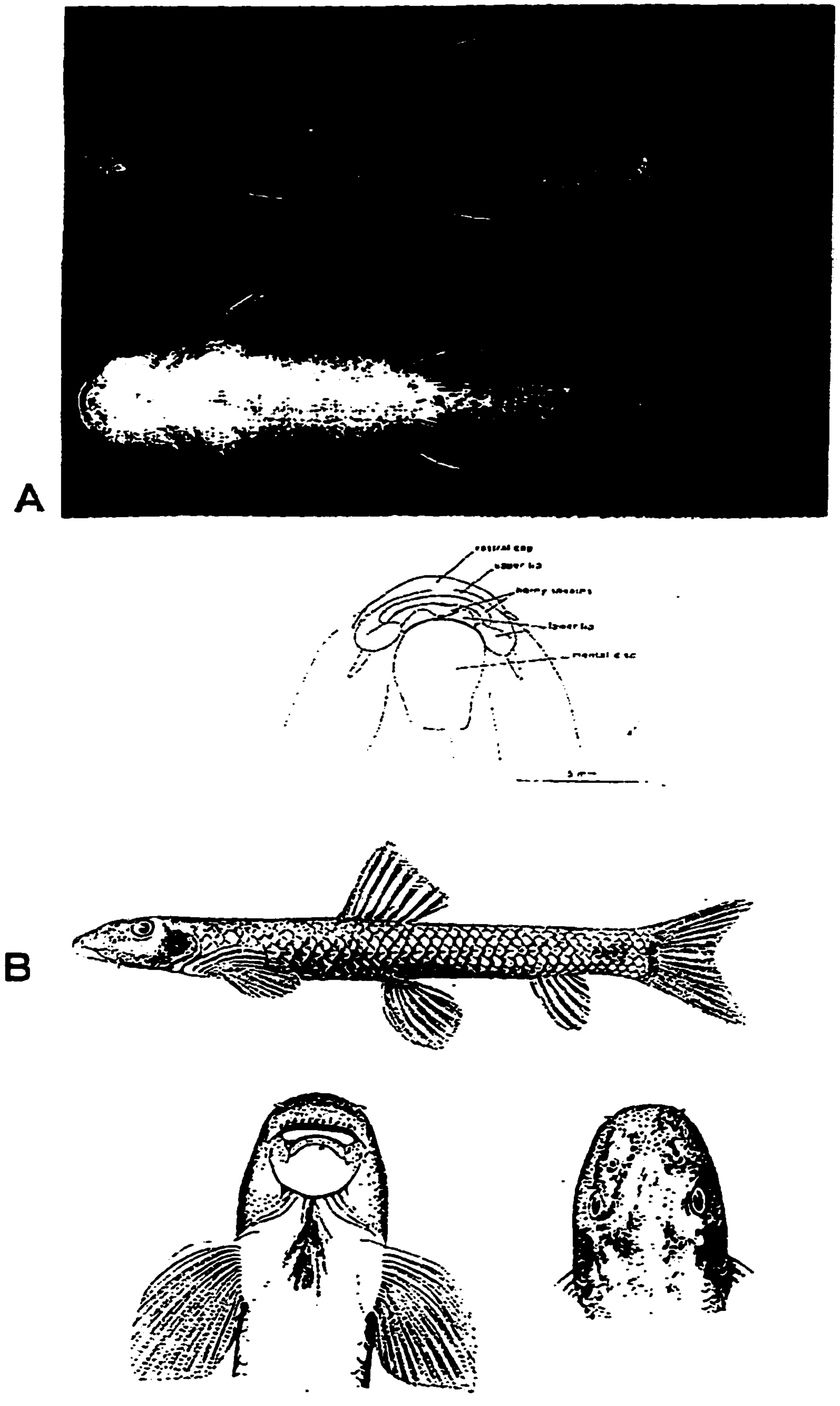
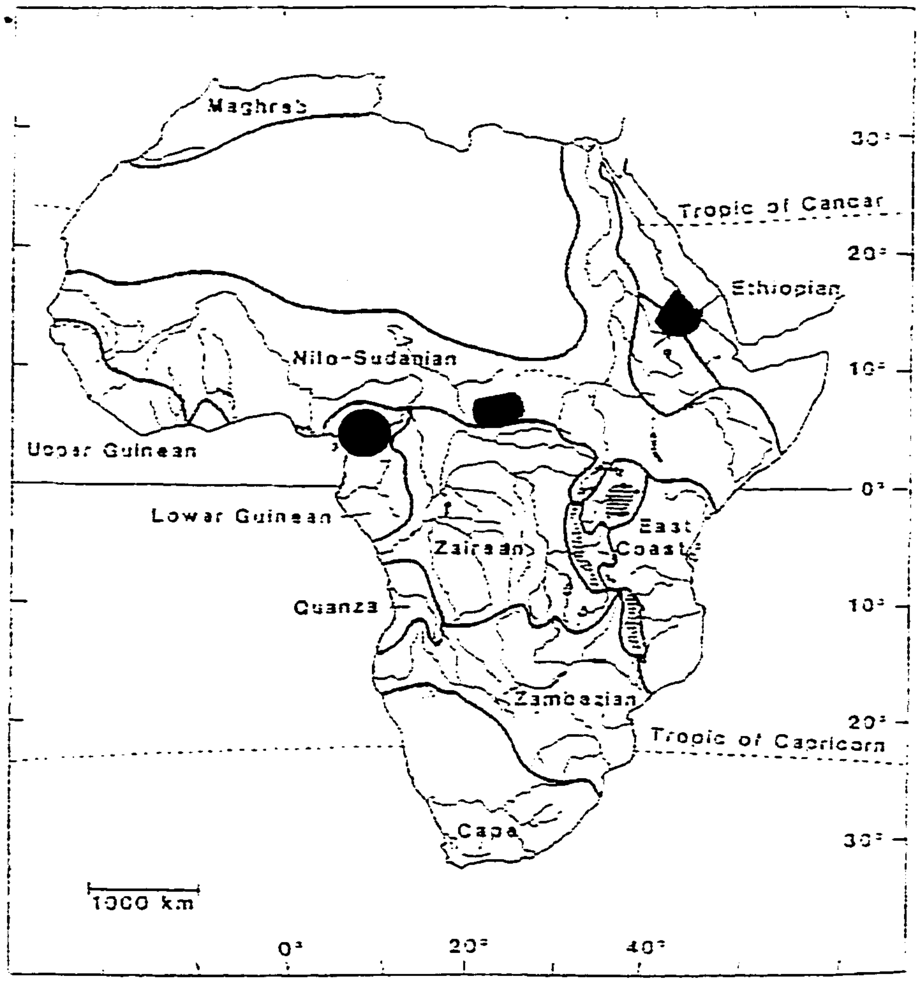

A
rostral cap
upper lip
horny sheaths
lower lip
mental disc
5 mm
B

Fig. 10.

Geographic distribution of *Garra allostoma, G.ethelwynnae and G.lancrenonensis* in Africa (map modified from Skelton et al. 1991). Distribution based on materials examined and listed in the species accounts section.



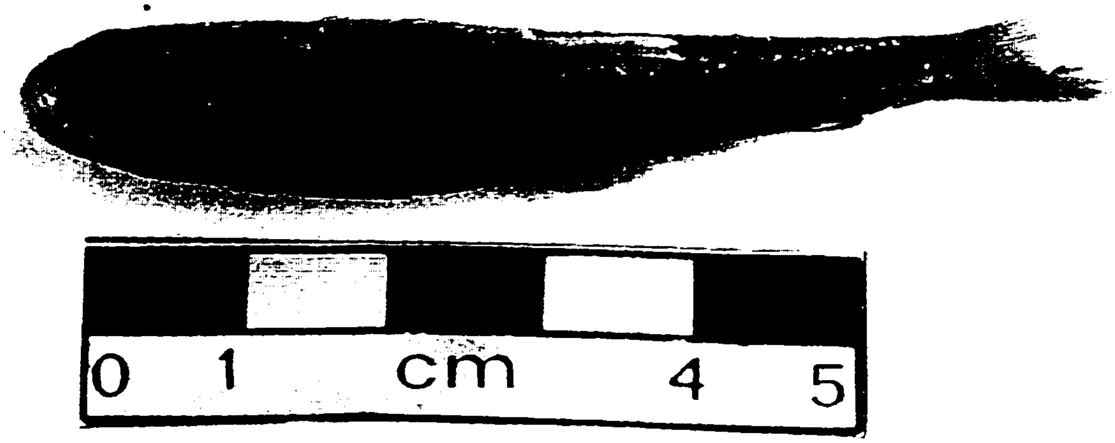
● *G. allostoma*

▬ *G. lancrenonensis*

◆ *G. ethelwynnae*

Fig. 11.

Dorsal and Ventral view of representative specimen of *Garra blanfordii* (AMNH 223686).


0 1 cm 4 5

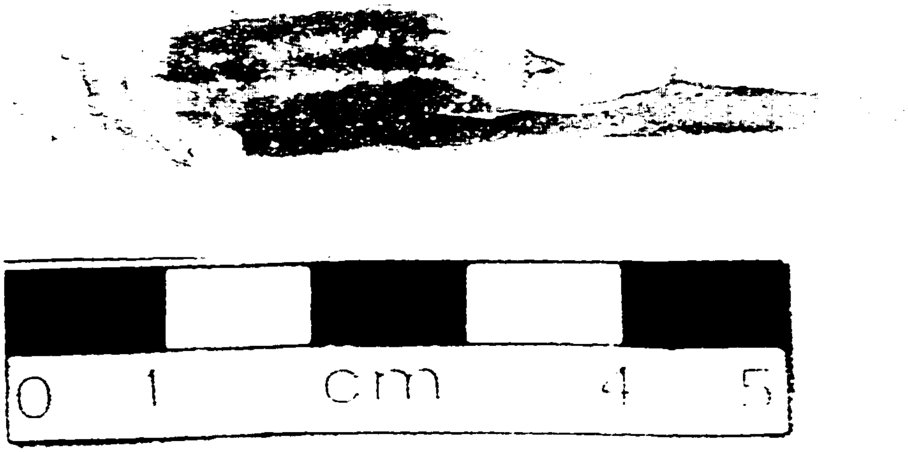
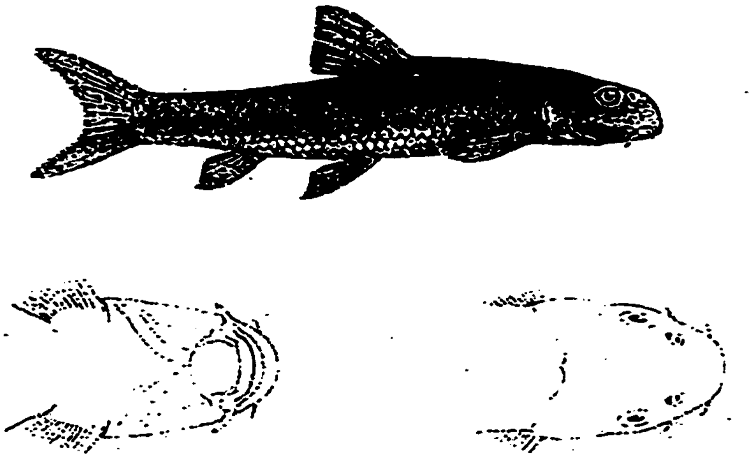

0 1 cm 4 5

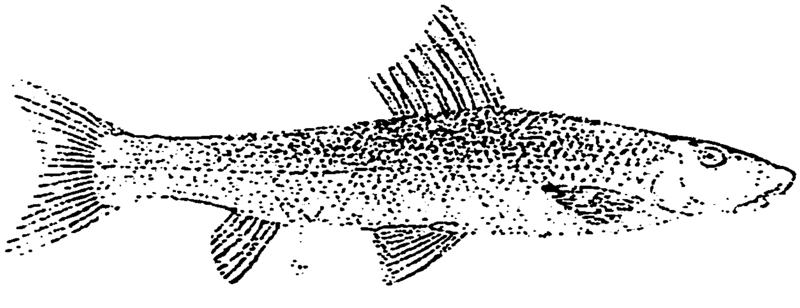
Fig. 12.

A. Lateral, Ventral and Dorsal view of the type specimen of *Garra blanfordii* (Source: Boulenger, 1901).

B. Lateral view of the type specimen of *G.dembeensis* (Source: Rüppell, 1836



A



B

Fig. 13.

Geographic distribution of *Garra blanfordii, G.ignestii and G.makiensis* in Ethiopian Freshwaters Based on materials listed in the species accounts section.

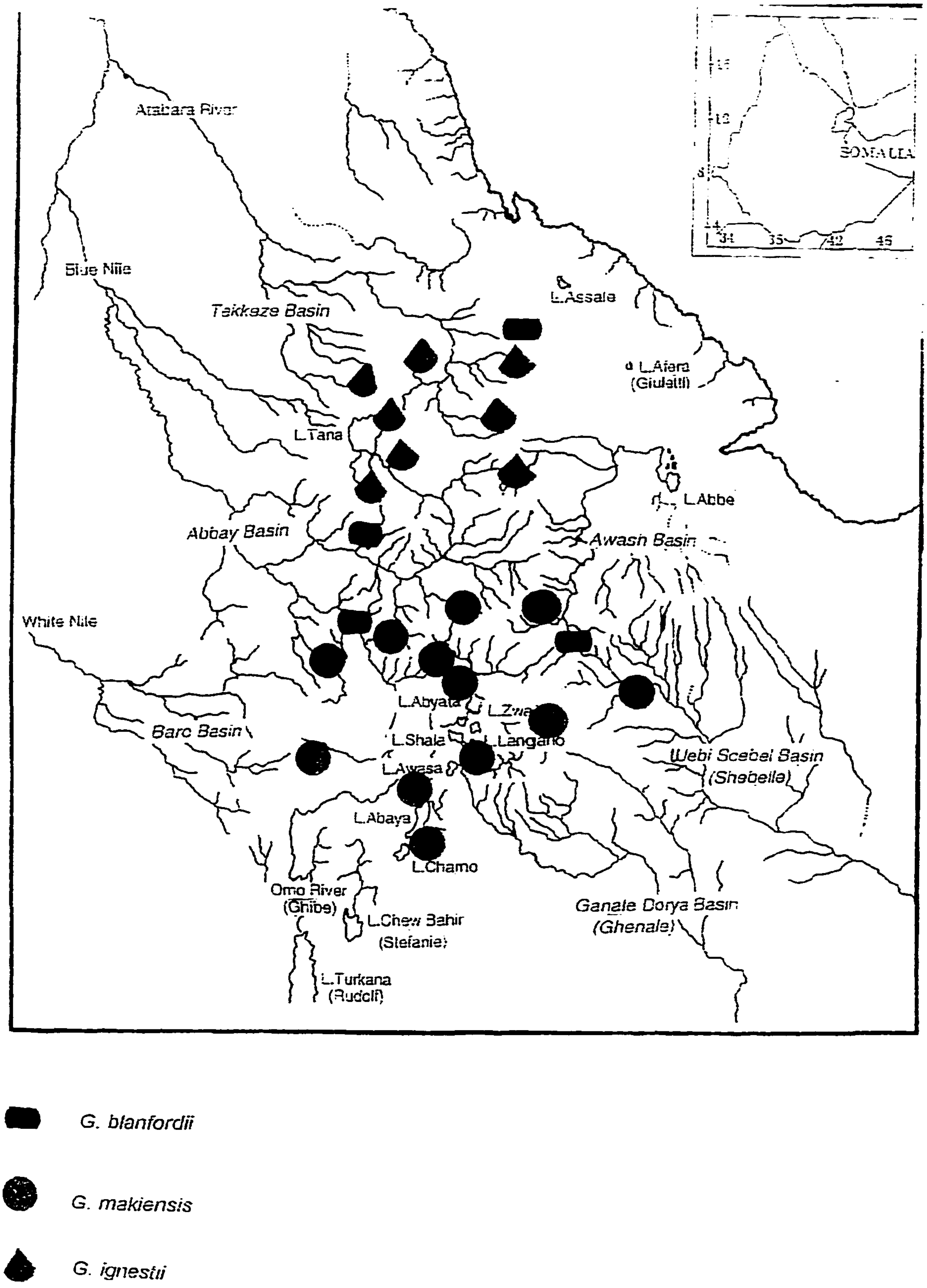

Atbara River
Blue Nile
Takkaze Basin
L.Assale
L.Afara
(Giulatti)
L.Tana
L.Abbe
Abbay Basin
Awash Basin
White Nile
L.Abyata
L.Ziwai
L.Shala
L.Langano
Baro Basin
Webi Scebel Basin
(Shebeille)
L.Awasa
L.Abaya
L.Chamo
Omo River
(Ghibe)
L.Chew Bahir
(Stefanie)
Ganale Dorya Basin
(Ghenale)
L.Turkana
(Rudolf)
SOMALIA
15
12
8
4
34
35
42
45
G. blanfordii
G. makiensis
G. ignestii

Fig. 14.

Dorsal and Ventral view of the holotype of *Garra congoensis* (MRAC 103350).

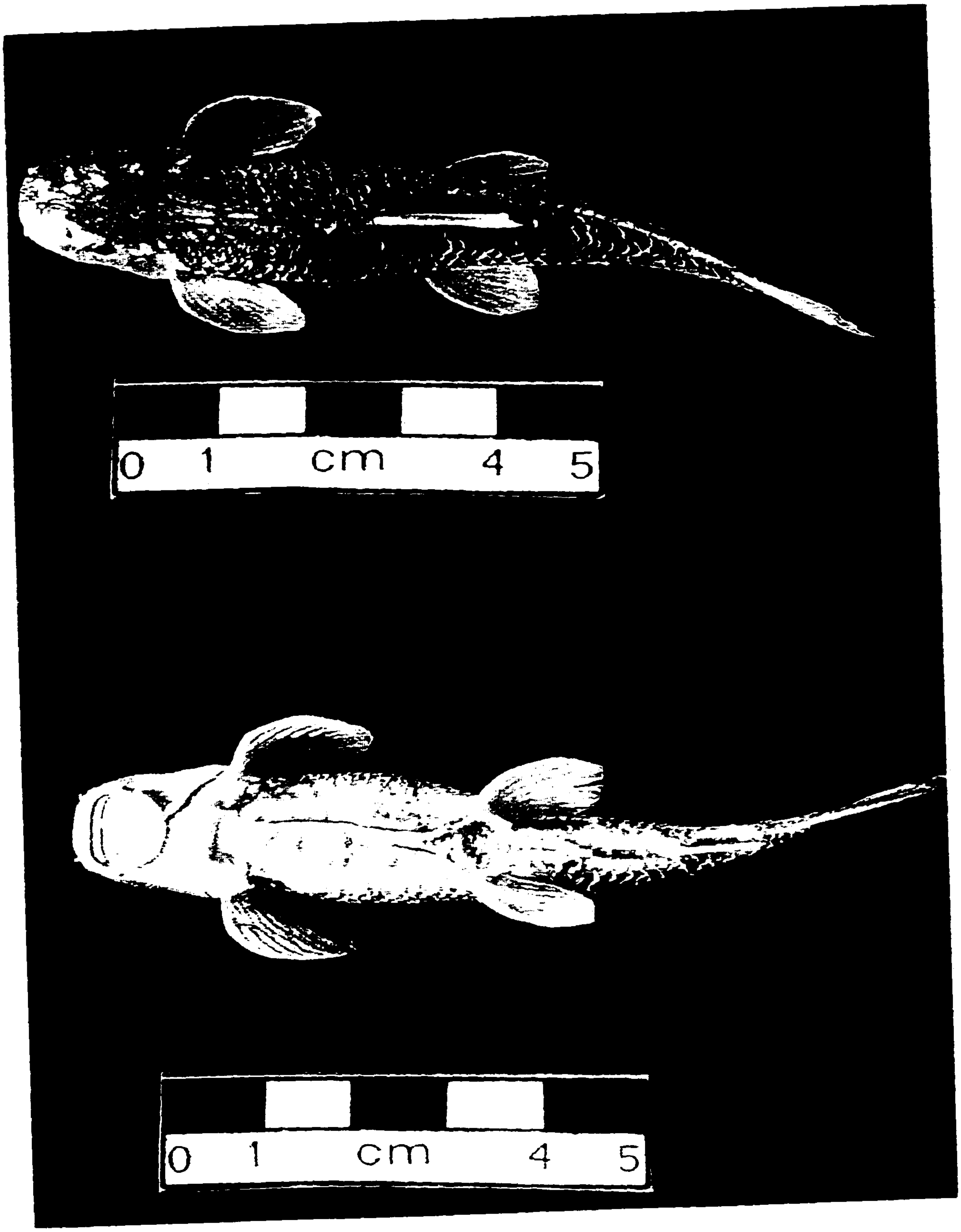

0 1 cm 4 5
0 1 cm 4 5

Fig.15

Geographic distribution of *G.congoensis* and *G.ornata* in Africa (map modified from Skelton et al. 1991). Based on materials examined in the species accounts section.

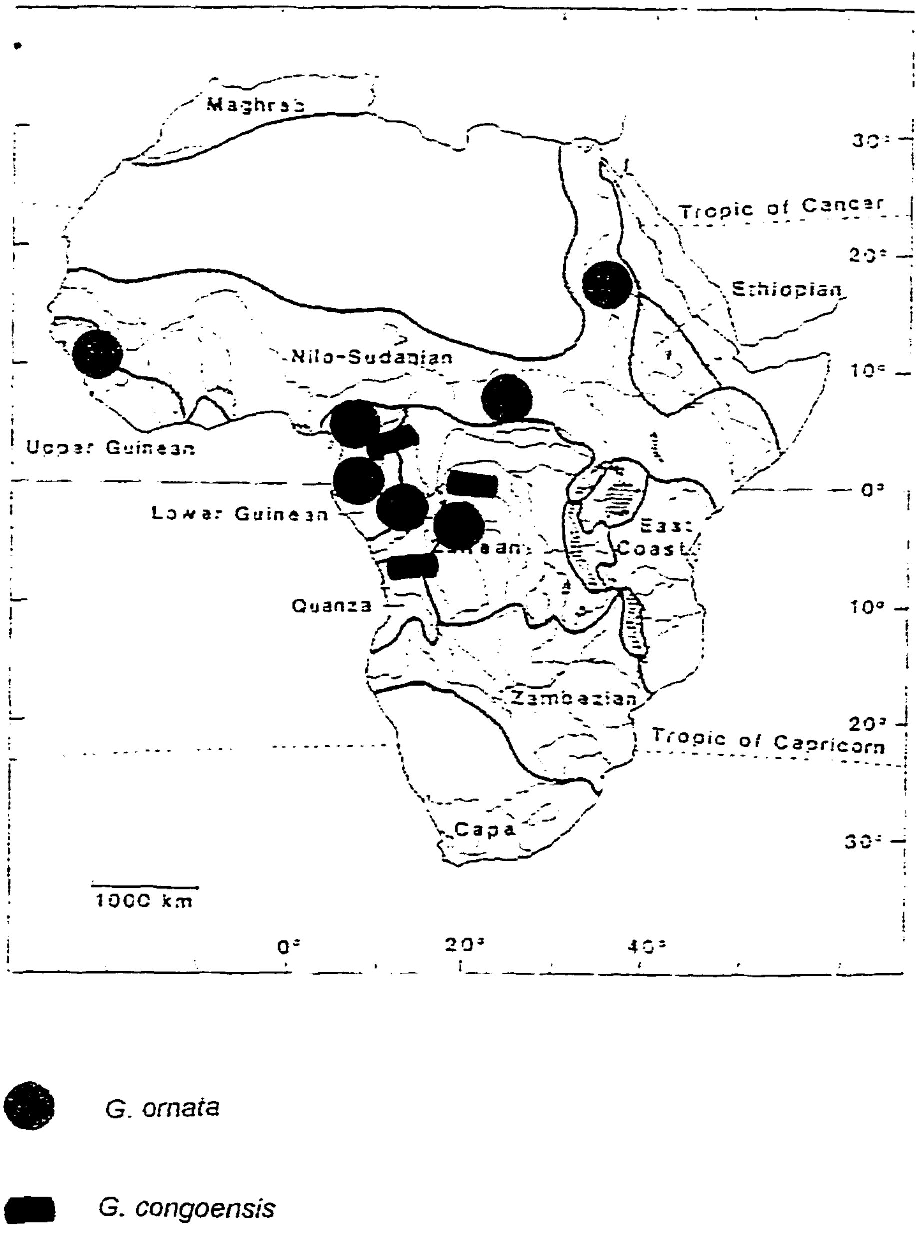

Maghreb
Tropic of Cancer
Ethiopian
Nilo-Sudanian
Upper Guinean
Lower Guinean
ean
East Coast
Quanza
Zambezian
Tropic of Capricorn
Capa
30°
20°
10°
0°
10°
20°
30°
1000 km
0°
20°
40°
● G. ornata
▬ G. congoensis

Fig. 16.

Lateral, Ventral and Dorsal view of *G. dembecha* spec.nov. (AMNH 223693).

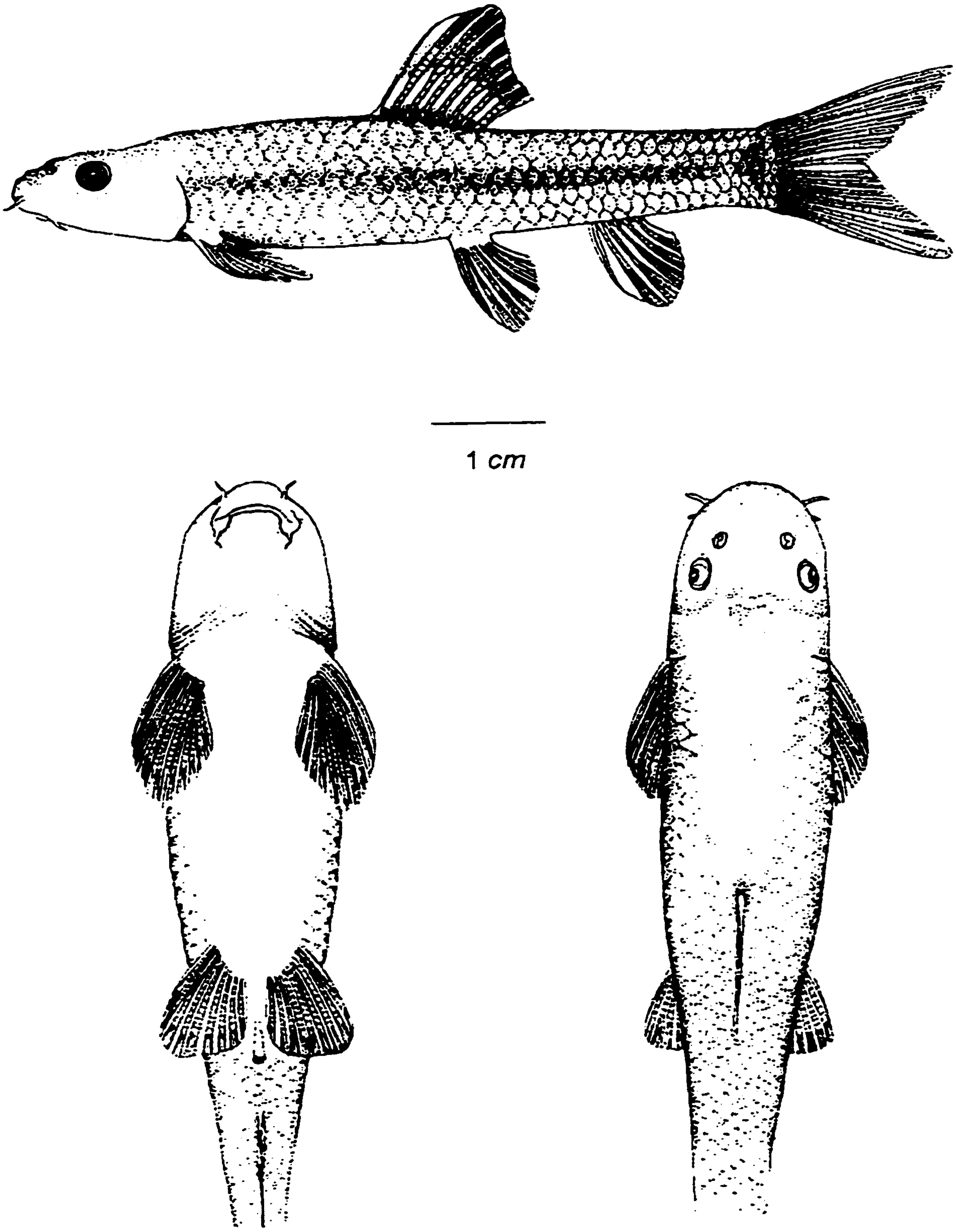
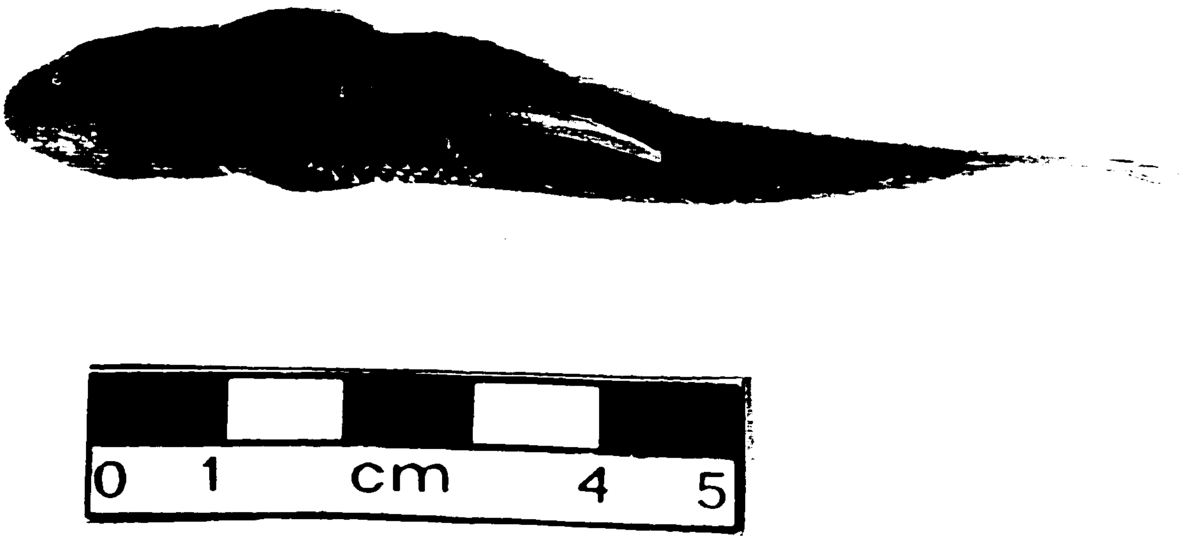

1 cm

Fig. 17.

Dorsal and Ventral view of the holotype of *Garra dembecha* spec.nov. (AMNH 223693).

Fig. 18.

Dorsal and Ventral view of representative specimen of *Garra dembeensis* (AMNH 223731)


0 1 cm 4 5

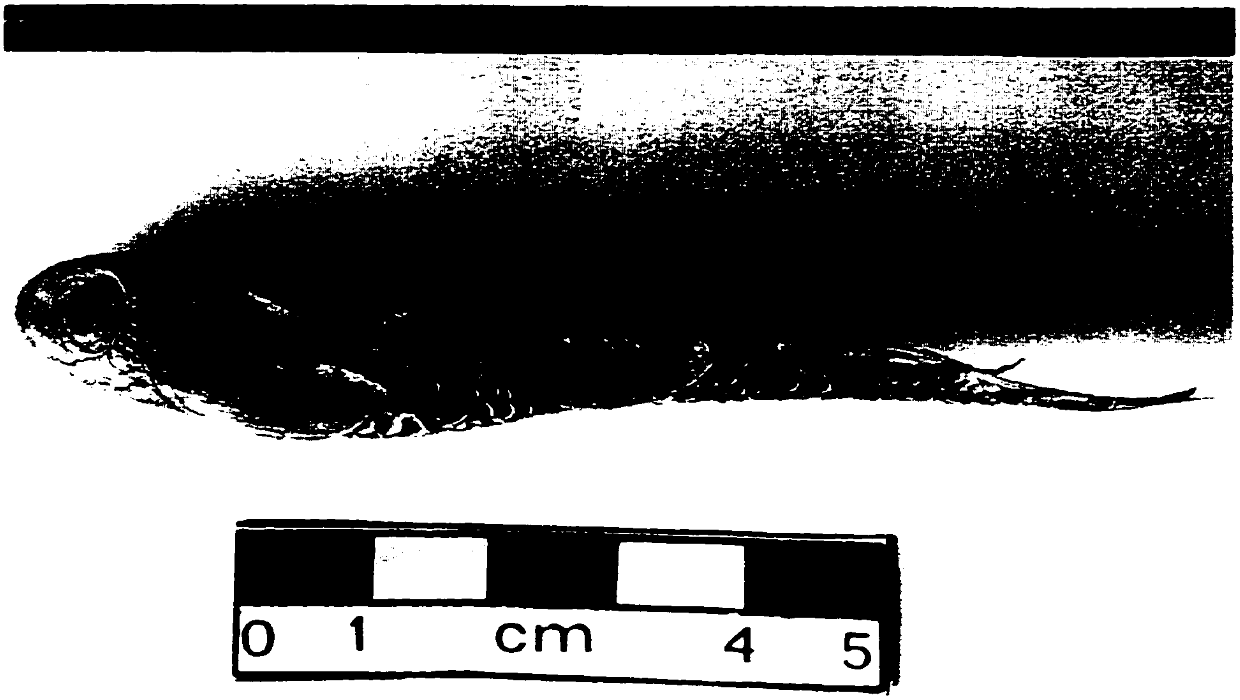

0 1 cm 4 5

Fig. 19.

Geographic distribution of *Garra dembecha* and *G.dembeensis* in Ethiopian Freshwaters (map modified from Skelton et al. 1991). Based on materials listed in the species accounts section.

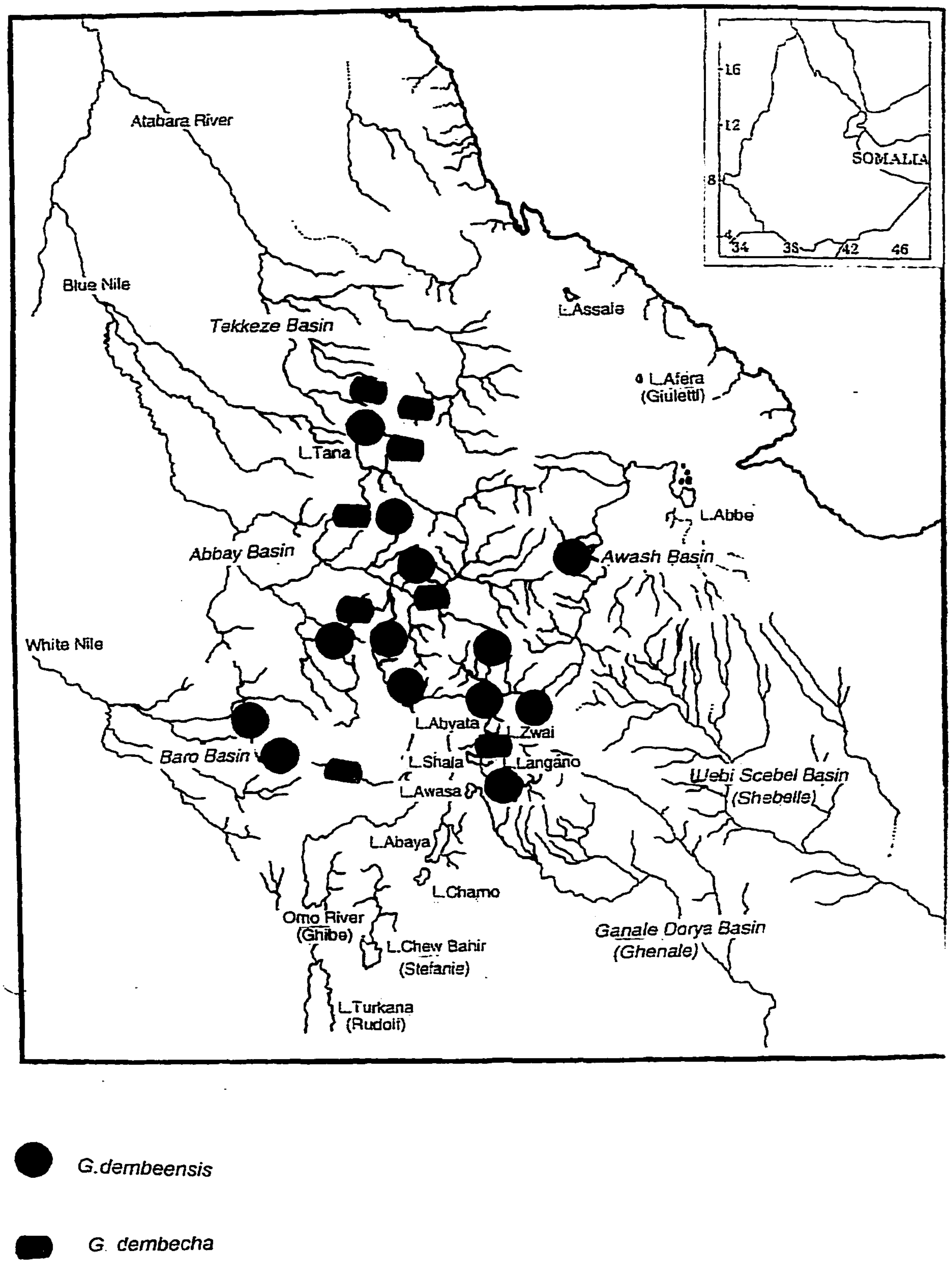
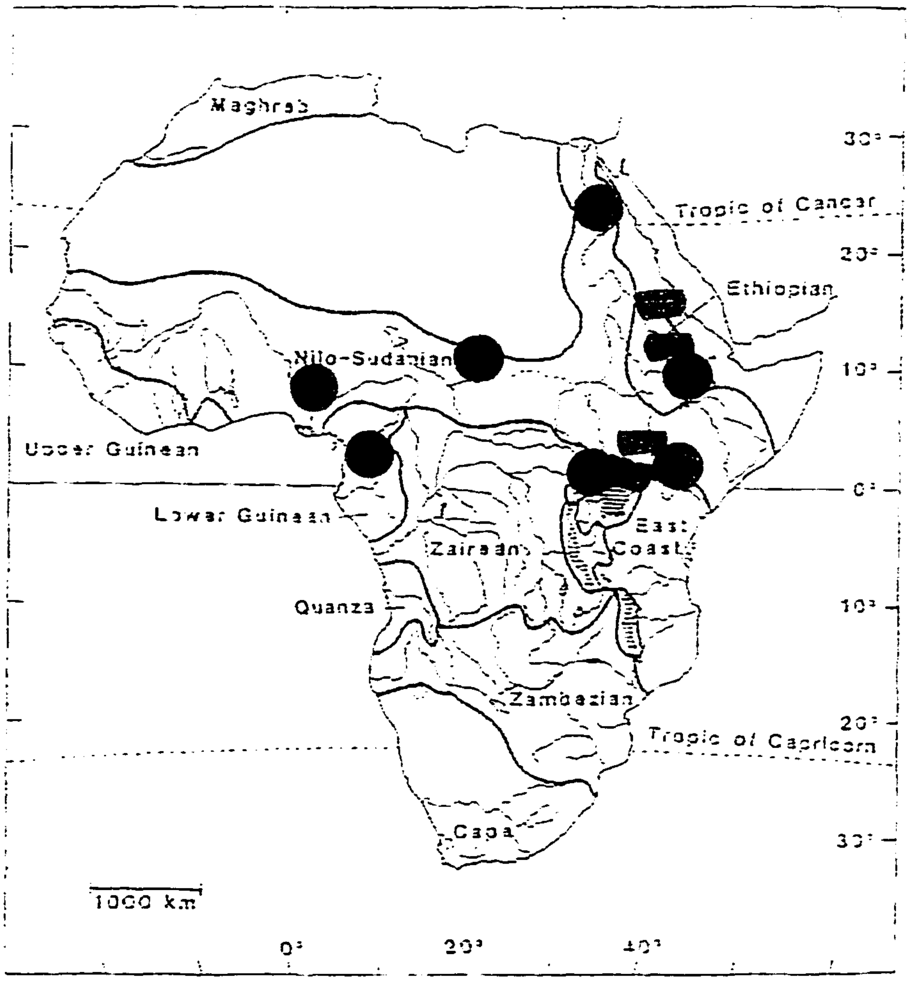

Atabara River
Blue Nile
Tekkeze Basin
L.Assala
L.Afera
(Giulietti)
L.Tana
L.Abbe
Abbay Basin
Awash Basin
White Nile
L.Abyata
L.Zwai
Baro Basin
L.Shala
Langano
Uebi Scebel Basin
(Shebelle)
L.Awasa
L.Abaya
L.Chamo
Omo River
(Ghibe)
L.Chew Bahir
(Stefanie)
Ganale Dorya Basin
(Ghenale)
L.Turkana
(Rudolf)
16
12
8
4
34
38
42
46
SOMALIA
● G.dembeensis
▬ G. dembecha

Fig. 20.

Geographic distribution of *G.dembecha* and *G.dembeensis* in Africa (map modified from Skelton et al. 1991). Based on materials examined in the species accounts section.



● *G.dembeensis*

▨ *G.dembecha*

Fig. 21.

Distribution of *Garra dembecha, G.dembeensis, G.microstoma* and *G.tana* in Lake Tana, Ethiopia (map modified from Nagelkerke, 1998). Based on materials examined in the species accounts section.

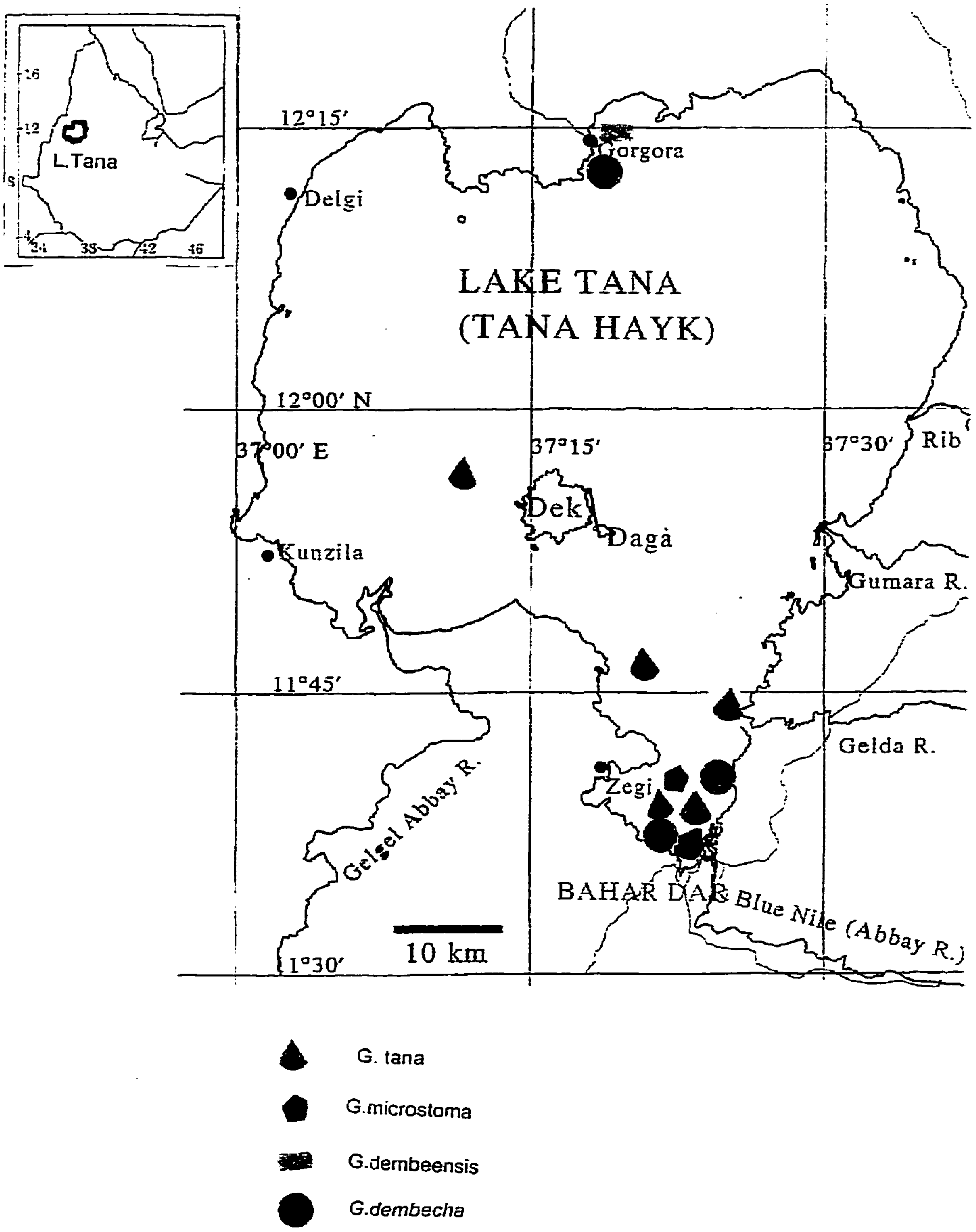

L.Tana
16
12
8
4
34
38
42
46
12°15′
Gorgora
Delgi
LAKE TANA
(TANA HAYK)
12°00′ N
37°00′ E
37°15′
37°30′
Rib
Dek
Dagà
Kunzila
Gumara R.
11°45′
Gelda R.
Zegi
Gelgel Abbay R.
BAHAR DAR
Blue Nile (Abbay R.)
11°30′
10 km
G. tana
G.microstoma
G.dembeensis
G.dembecha

Fig. 22.

Lateral, Ventral and Dorsal view of *G.duobarbis* spec.nov. (AMNH 223736).

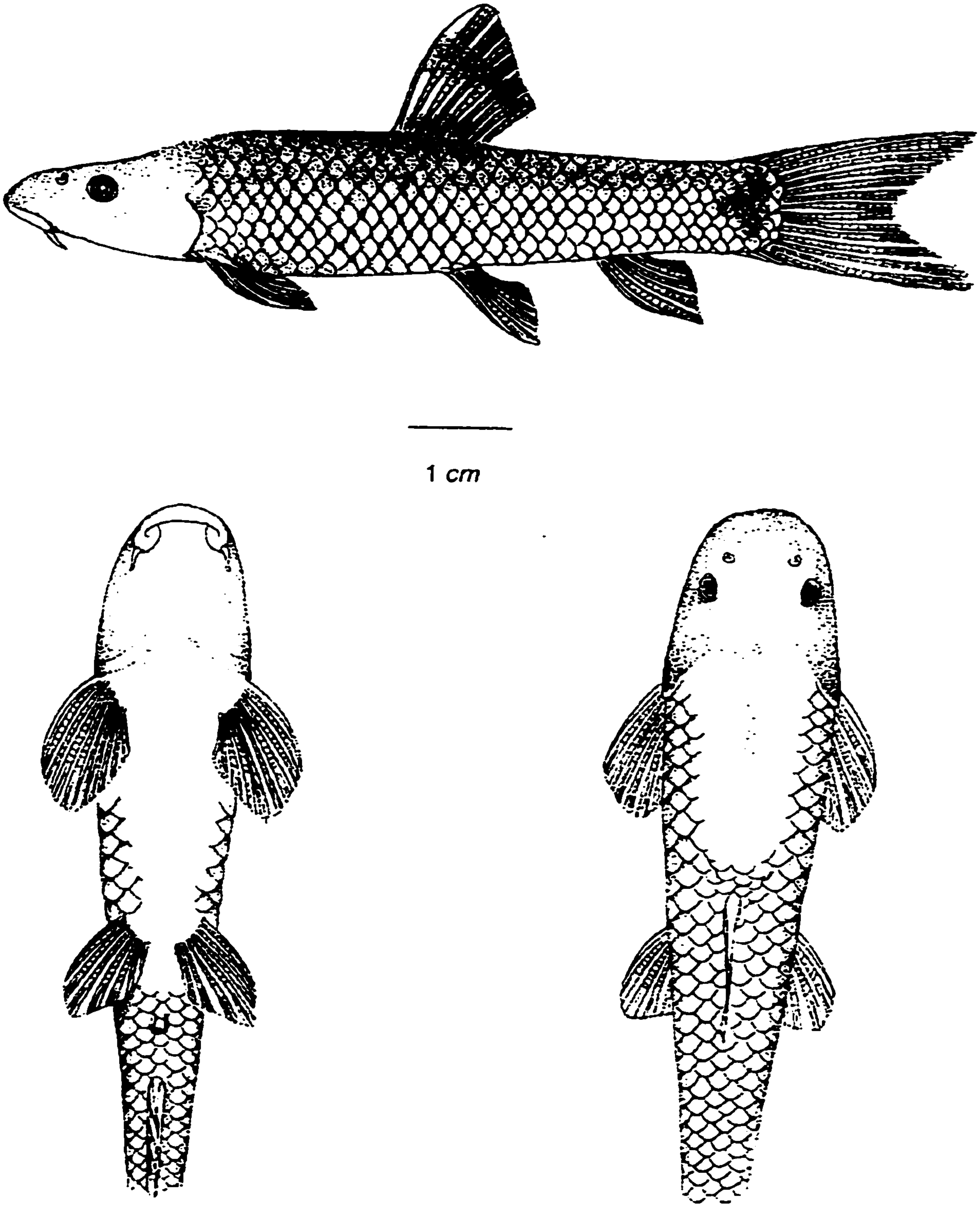
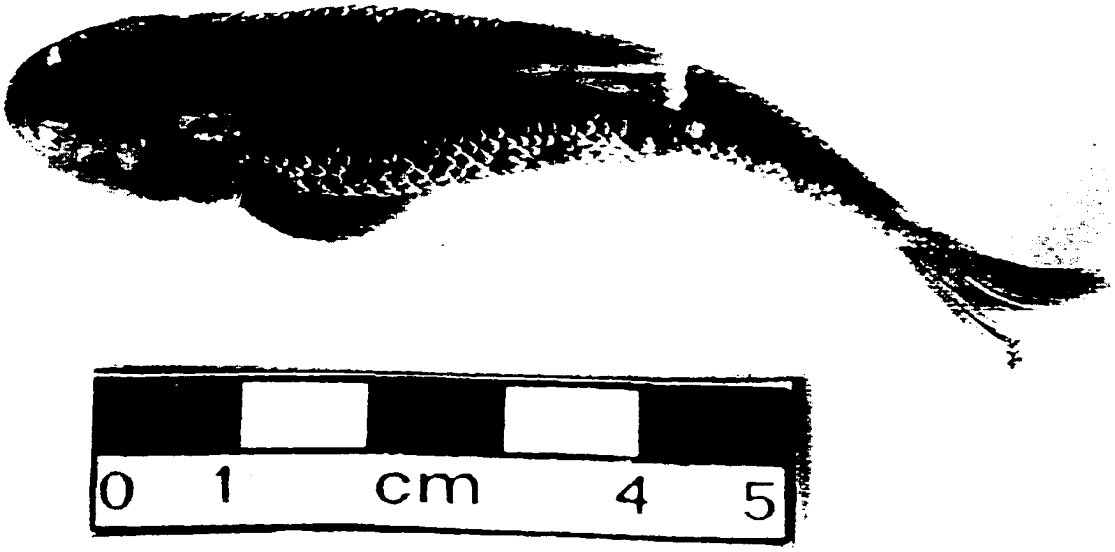

1 cm

Fig. 23.

Dorsal and Ventral view of the holotype of *Garra duobarbis* spec.nov. (AMNH 223736).


0 1 cm 4 5


0 1 cm 4 5

Fig. 24.

Geographic distribution of *Garra duobarbis* and *G.geba* in Ethiopian Freshwaters (based on materials examined in the species accounts section).

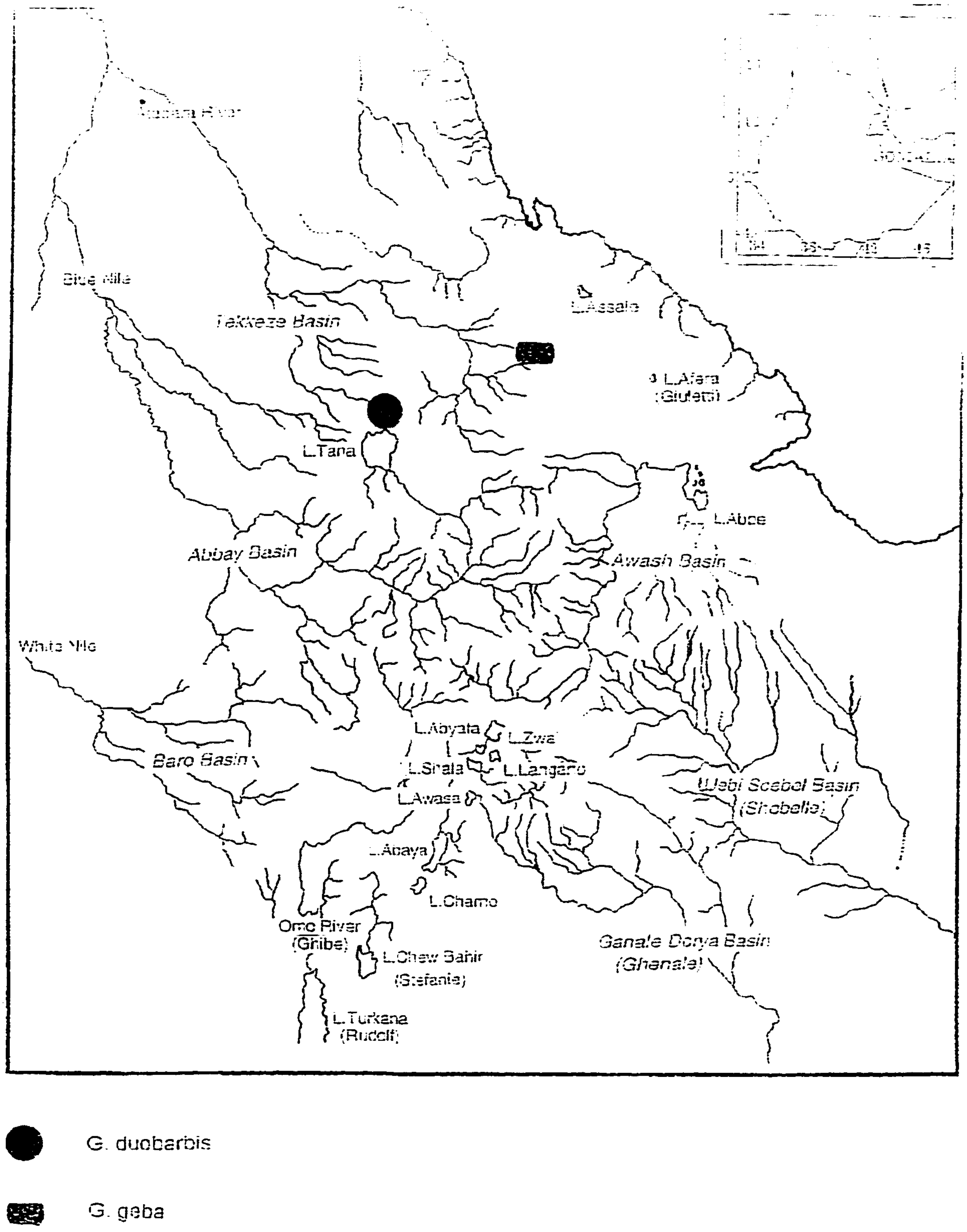

Blue Nile
Tekkeze Basin
L.Assale
L.Afara
(Giulietti)
L.Tana
L.Abbe
Abbay Basin
Awash Basin
White Nile
L.Abyata
L.Zwai
L.Shala
L.Langano
L.Awasa
Baro Basin
Webi Scebel Basin
(Shebelle)
L.Abaya
L.Chamo
Omo River
(Ghibe)
L.Chew Bahir
(Stefanie)
Ganale Dorya Basin
(Ghanale)
L.Turkana
(Rudolf)
● G. duobarbis
▨ G. geba

Fig. 25.

Dorsal and Ventral view of the holotype of *Garra ethelwynnae* (BMNH 1950.5.31.19).

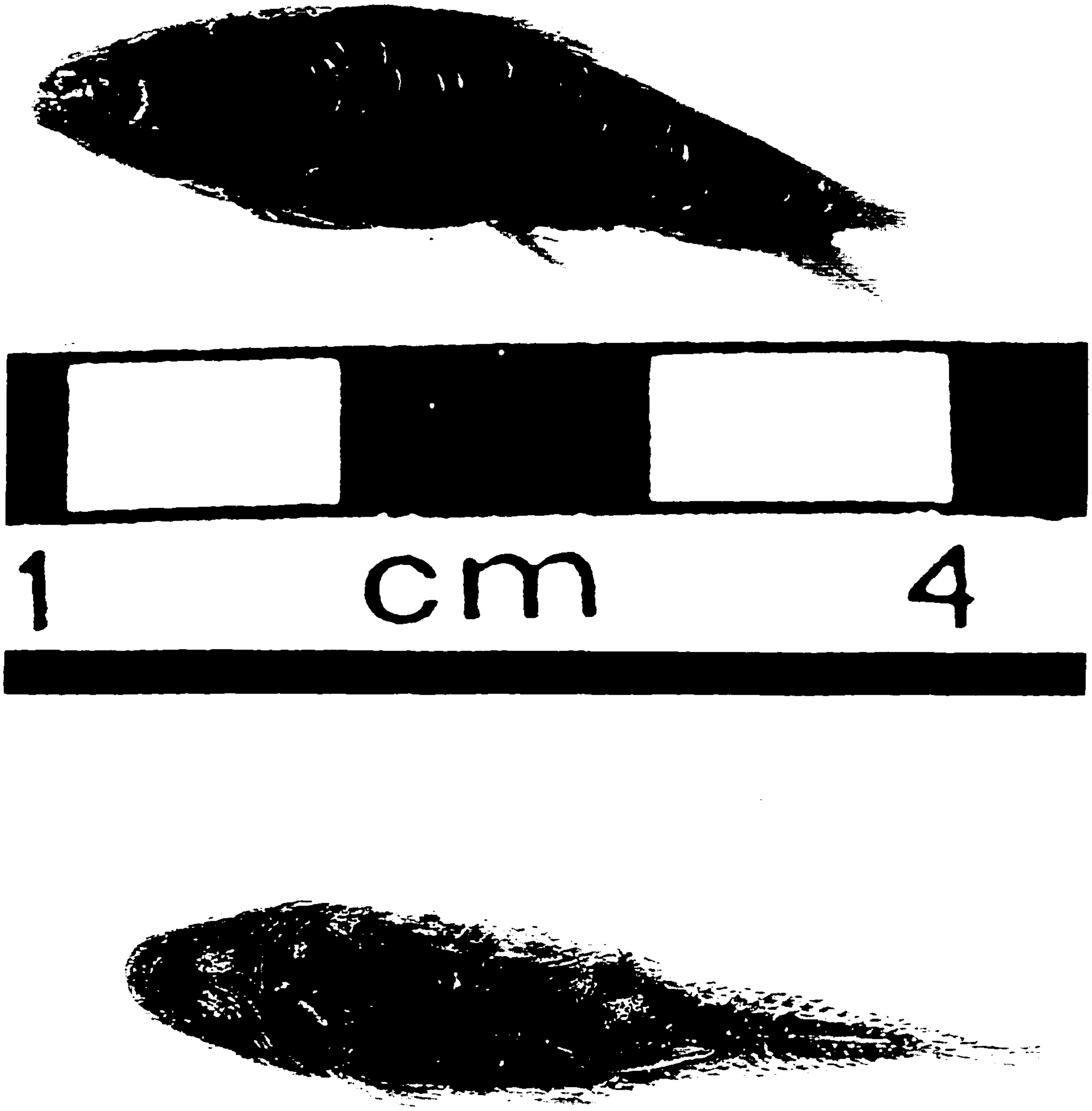
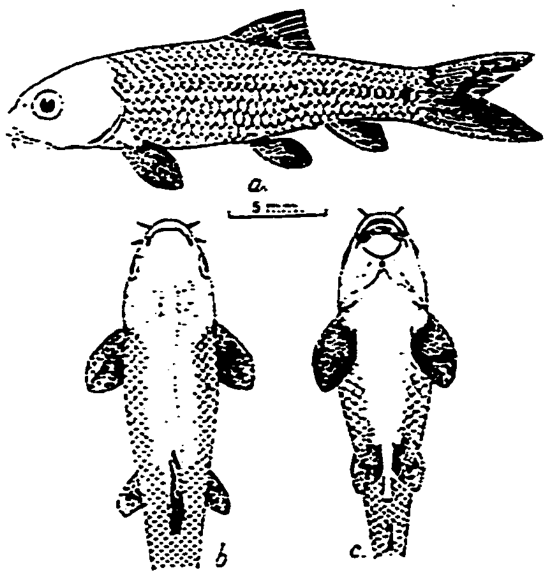

1 cm 4

Fig. 26.

A. Lateral (a), Dorsal (b) and (c) Ventral view of the type specimen of *Garra ethelwynnae.* (Source: Menon, 1958)

B. Lateral, Dorsal and Ventral view of the type specimen of *Garra hindii.* (Source: Boulenger, 1905).

A



B

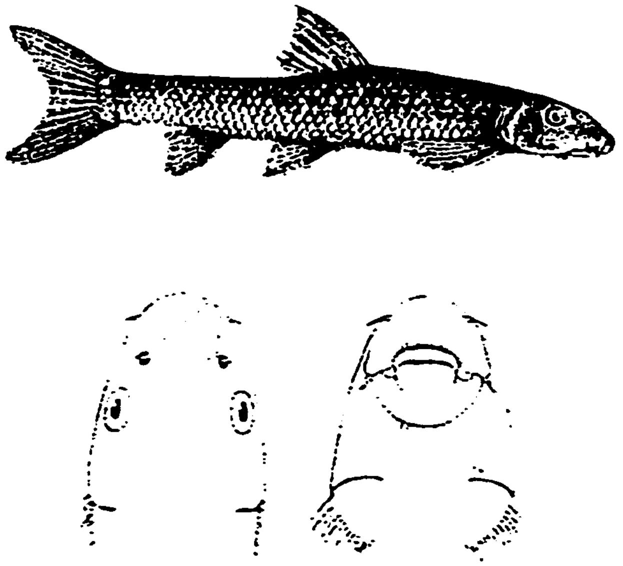


Fig. 27.

Lateral, Ventral and Dorsal view of *Garra geba* spec.nov. (AMNH 223747).

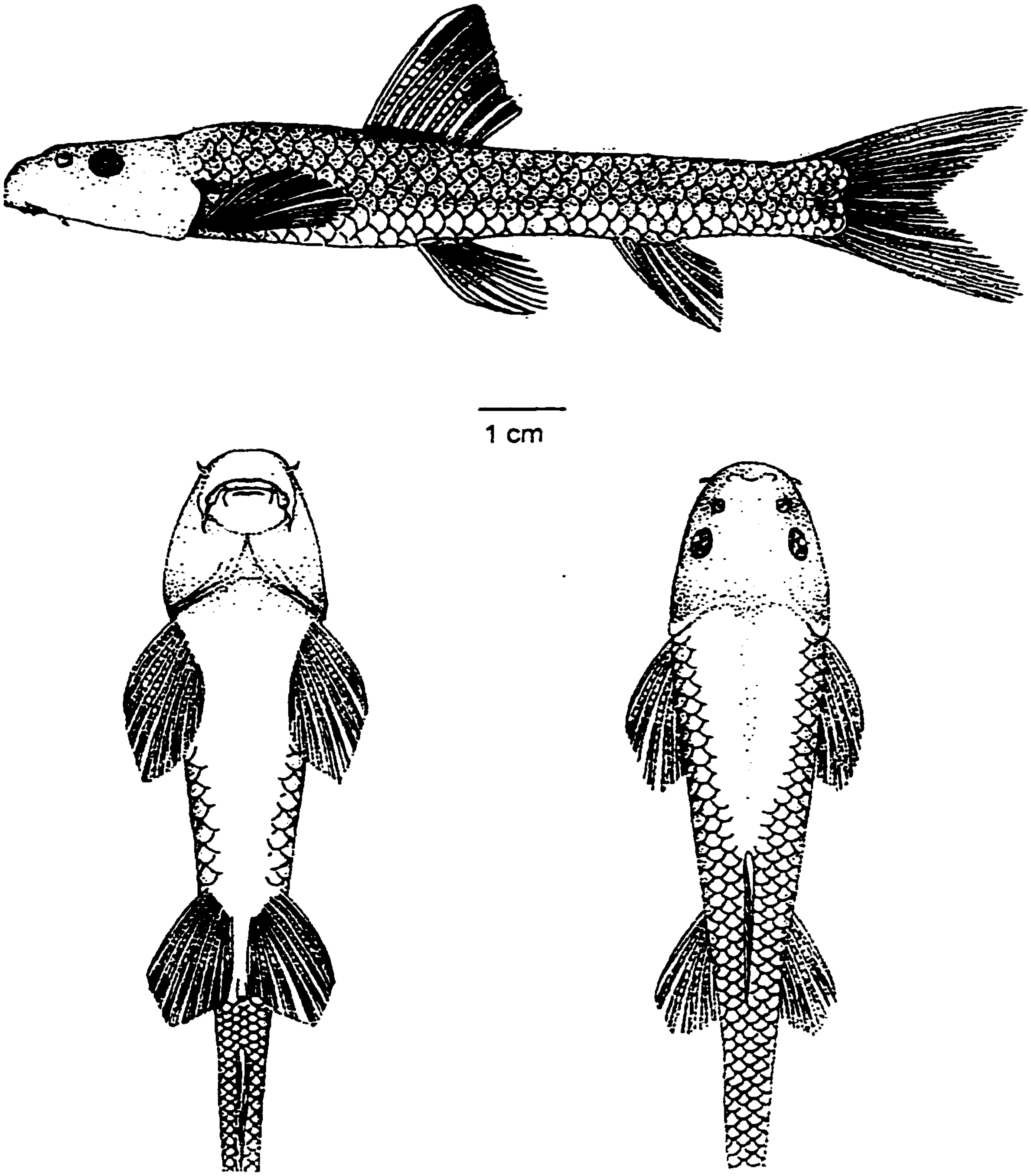
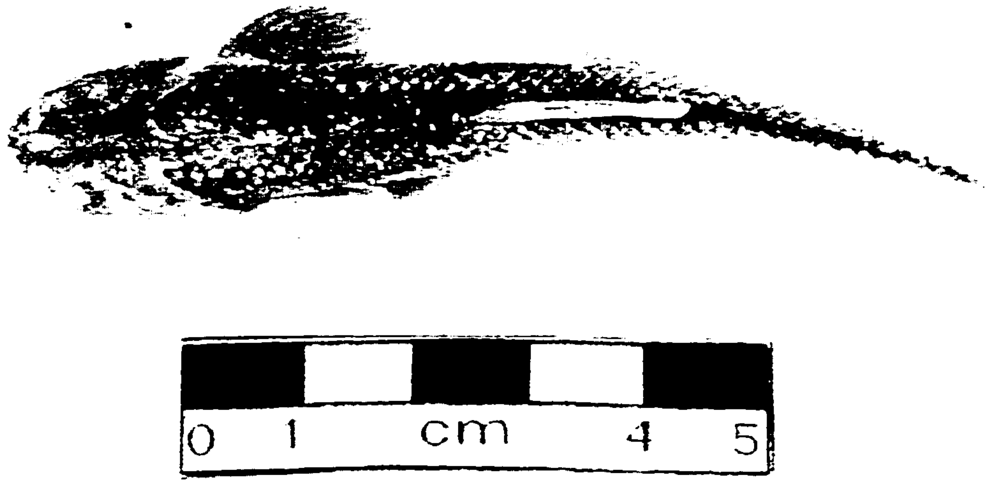

1 cm

Fig. 28.

Dorsal and Ventral view of the holotype of *Garra geba* spec.nov. (AMNH 223747).


0
1
cm
4
5

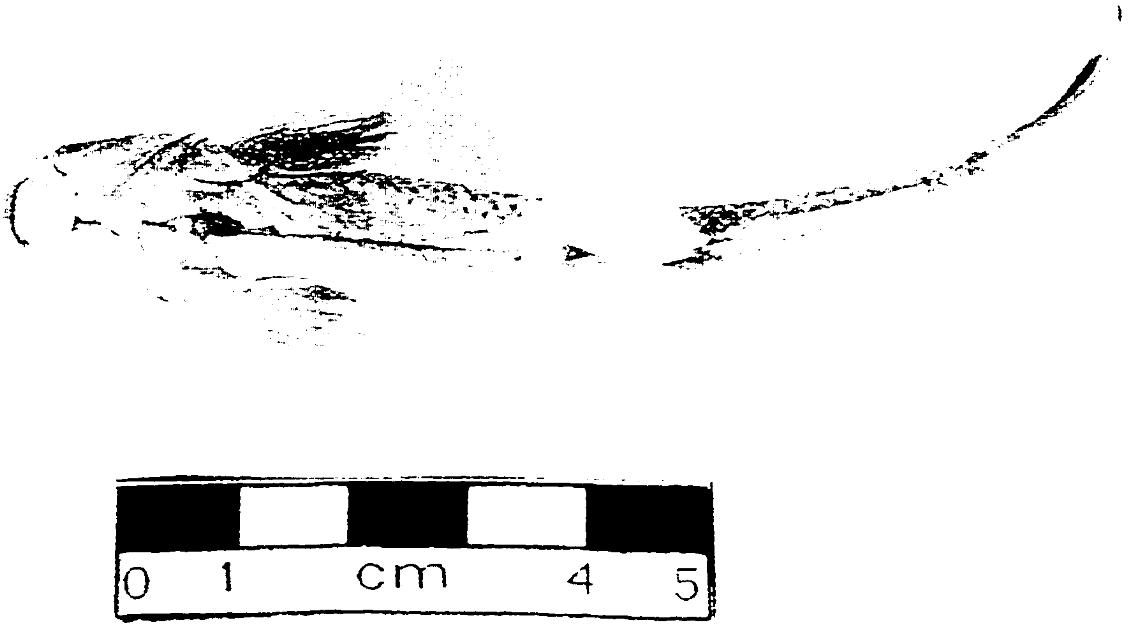
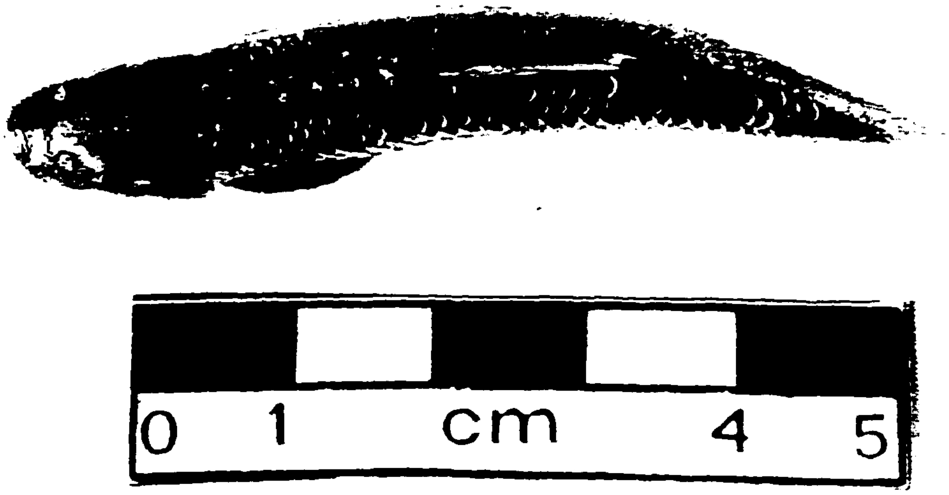

0
1
cm
4
5

Fig. 29.

Dorsal and Ventral view of representative specimen of *G.hindii* (CAS 52603).


0
1
cm
4
5


0
1
cm
4
5

Fig. 30.

Geographic distribution of *G.blanfordii*, *G.hindii* and *G.quadrimaculata* in Africa (map modified from Skelton et al. 1991). Based on materials examined in the species accounts section.

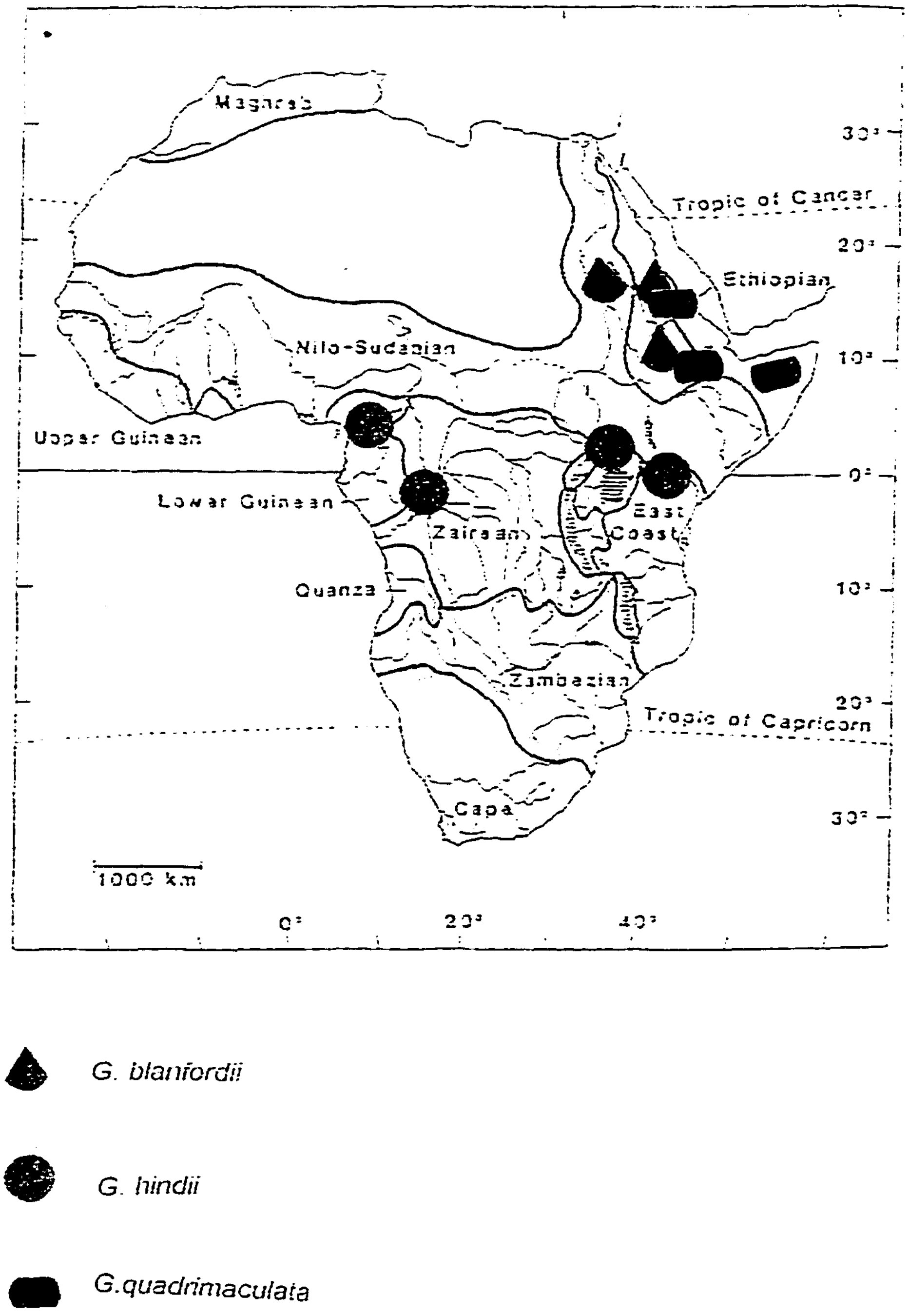
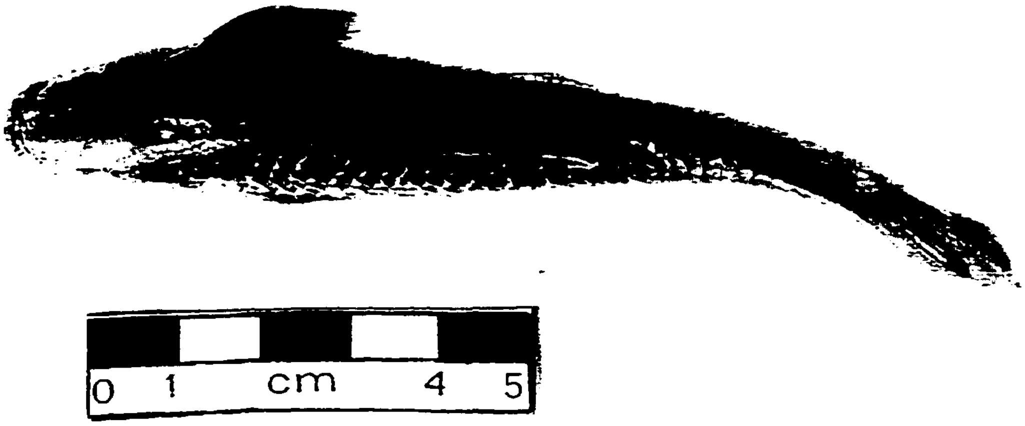

Maghreb
30°
Tropic of Cancer
20°
Ethiopian
Nilo-Sudanian
10°
Upper Guinean
0°
Lower Guinean
East Coast
Zairean
Quanza
10°
Zambezian
20°
Tropic of Capricorn
Cape
30°
1000 km
0°
20°
40°
▲ G. blanfordii
● G. hindii
■ G.quadrimaculata

Fig. 31.

Dorsal and Ventral view of representative specimen of *Garra ignestii* (AMNH 223738).


0 1 cm 4 5


0 1 cm 4 5

Fig. 32.

Ventral and Dorsal view of the anterior section of the type specimen of *Garra ignestii* (Source: Gianferrari, 1925).

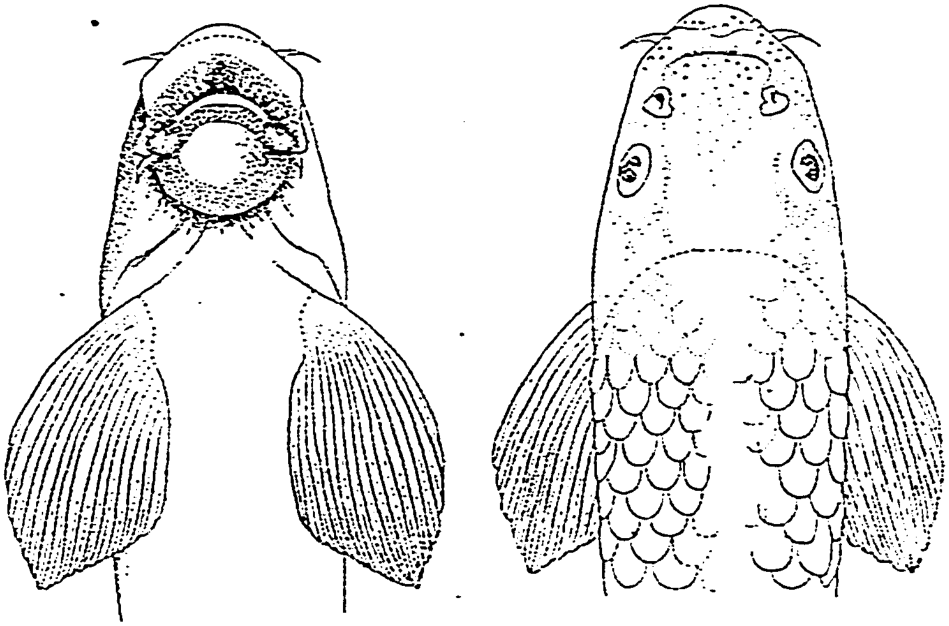


Fig. 33.

Dorsal and ventral view of the type specimen of *Garra lancrenonensis* (MNHN 1959-227).

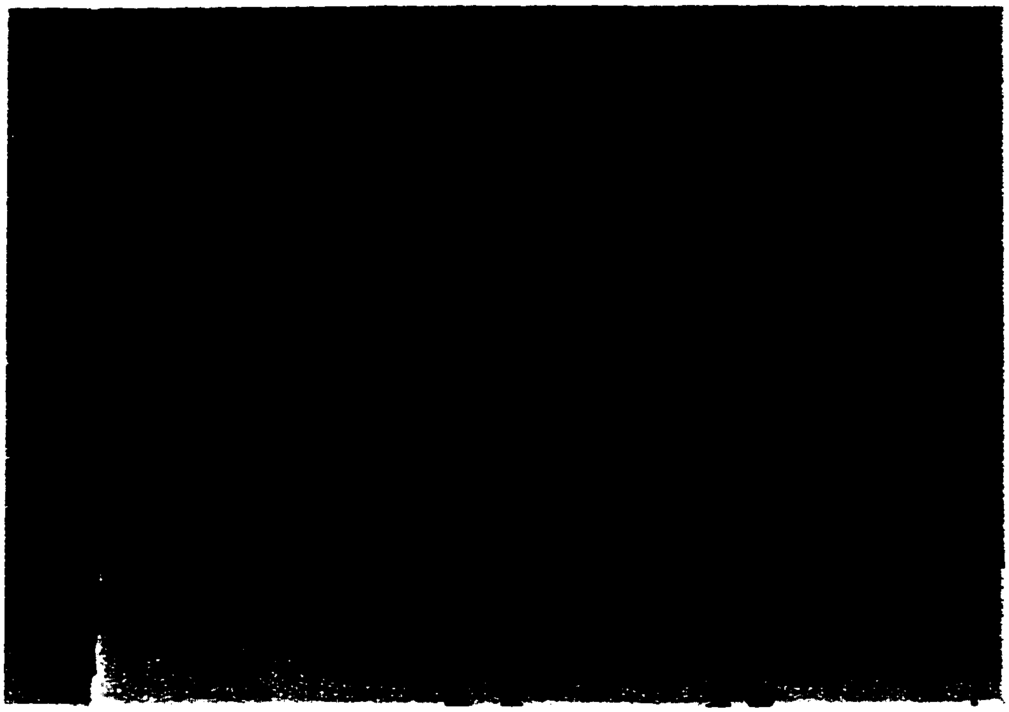
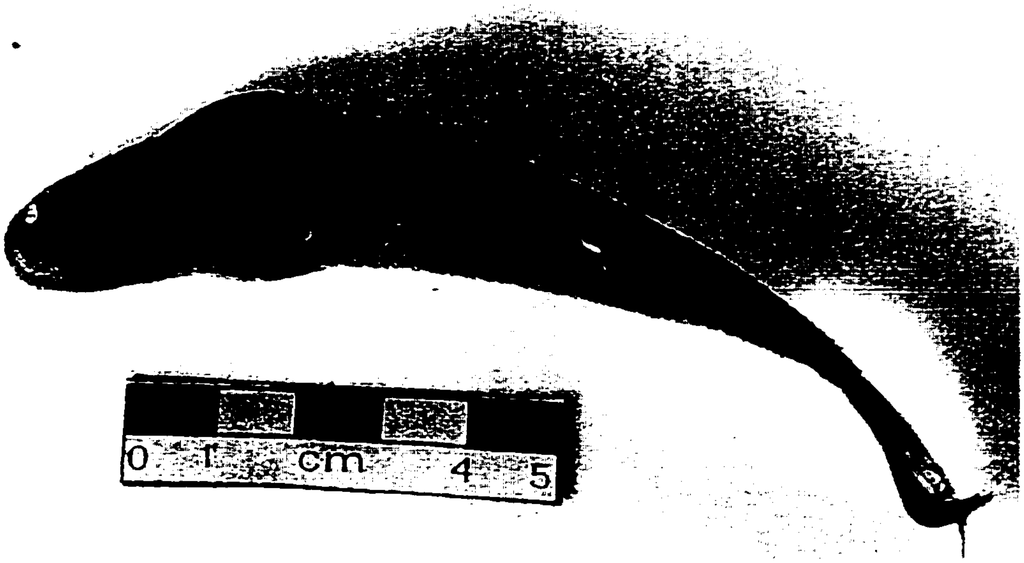


Fig. 34.

Dorsal and Ventral view of a representative specimen of *Garra makiensis* (AMNH 223666).


0 1 cm 4 5

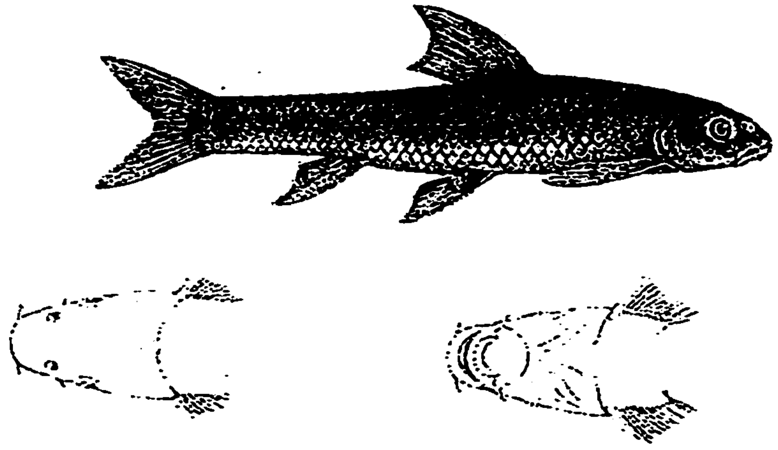

0 1 cm 4 5

Fig. 35.

A. Lateral, Dorsal and Ventral view of the type specimen of *Garra makiensis*. (Source: Boulenger, 1903).

B. Lateral view of the type specimen of *Garra ornata*
(Source: Nichols and Griscom, 1917)

A



B

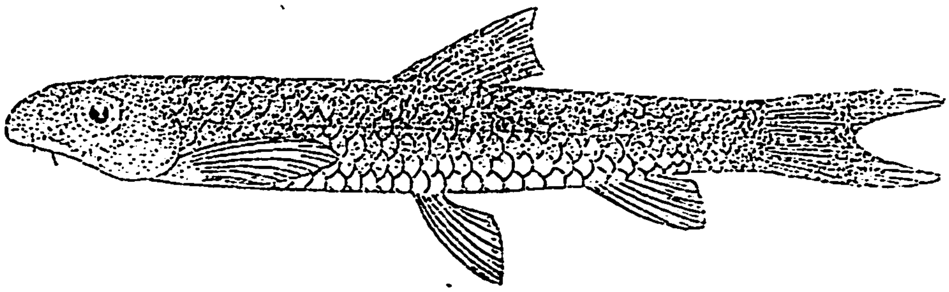


Fig. 36.

Lateral, Ventral and Dorsal view of *Garra microstoma* (AMNH 228486).

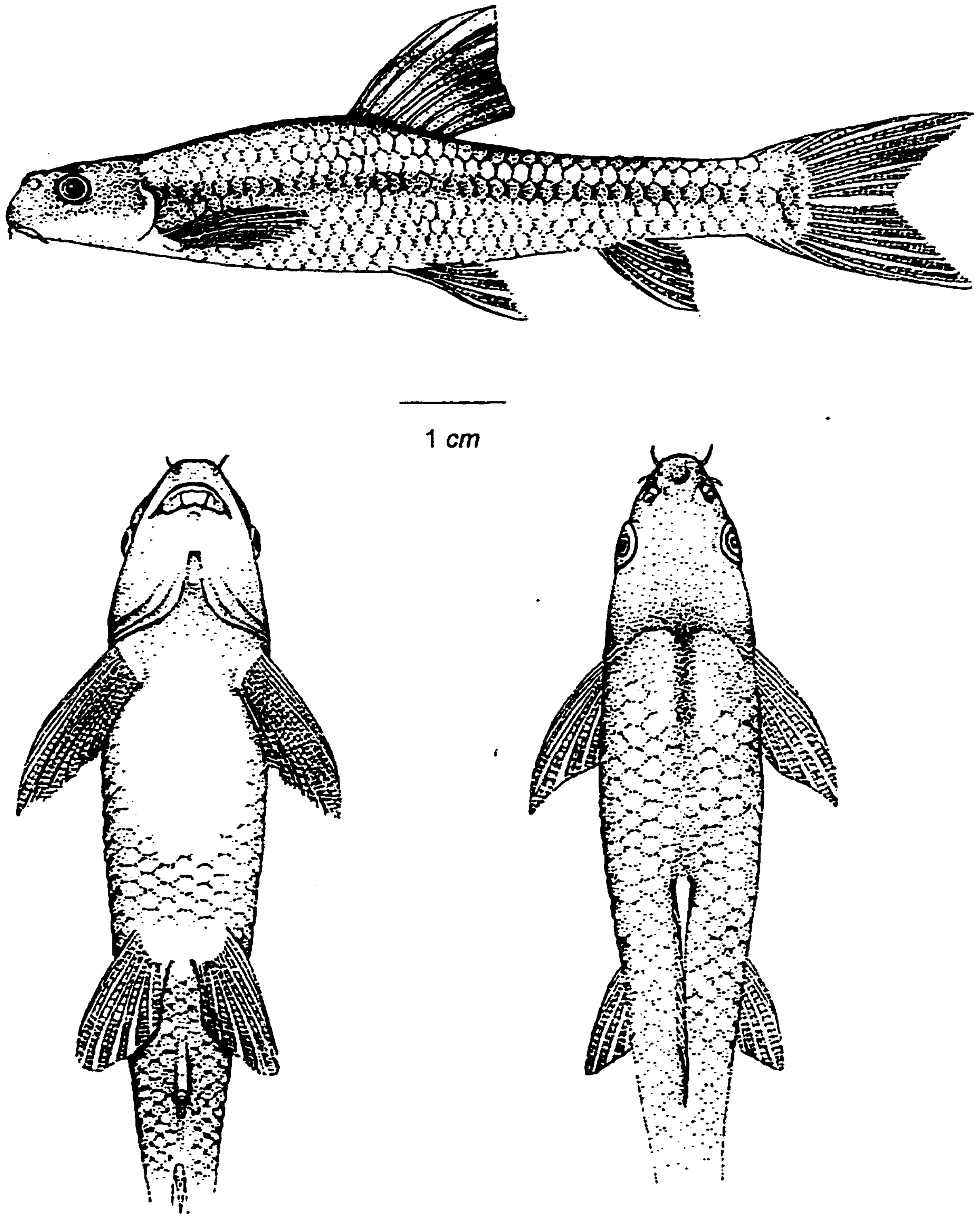

1 cm

Fig. 37.

Dorsal and Ventral view of the holotype of *Garra microstoma* spec.nov.(AMNH 228486)

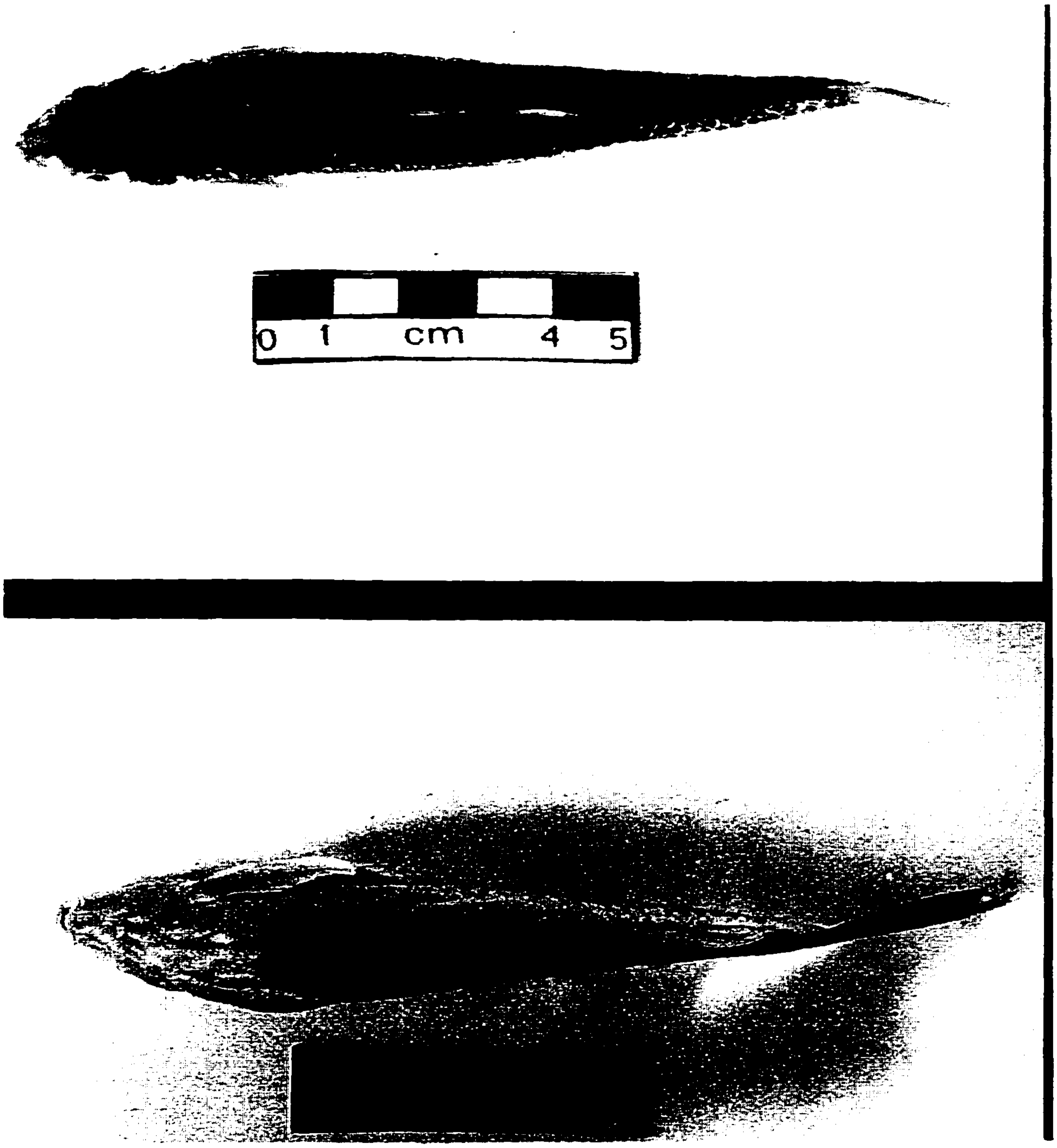
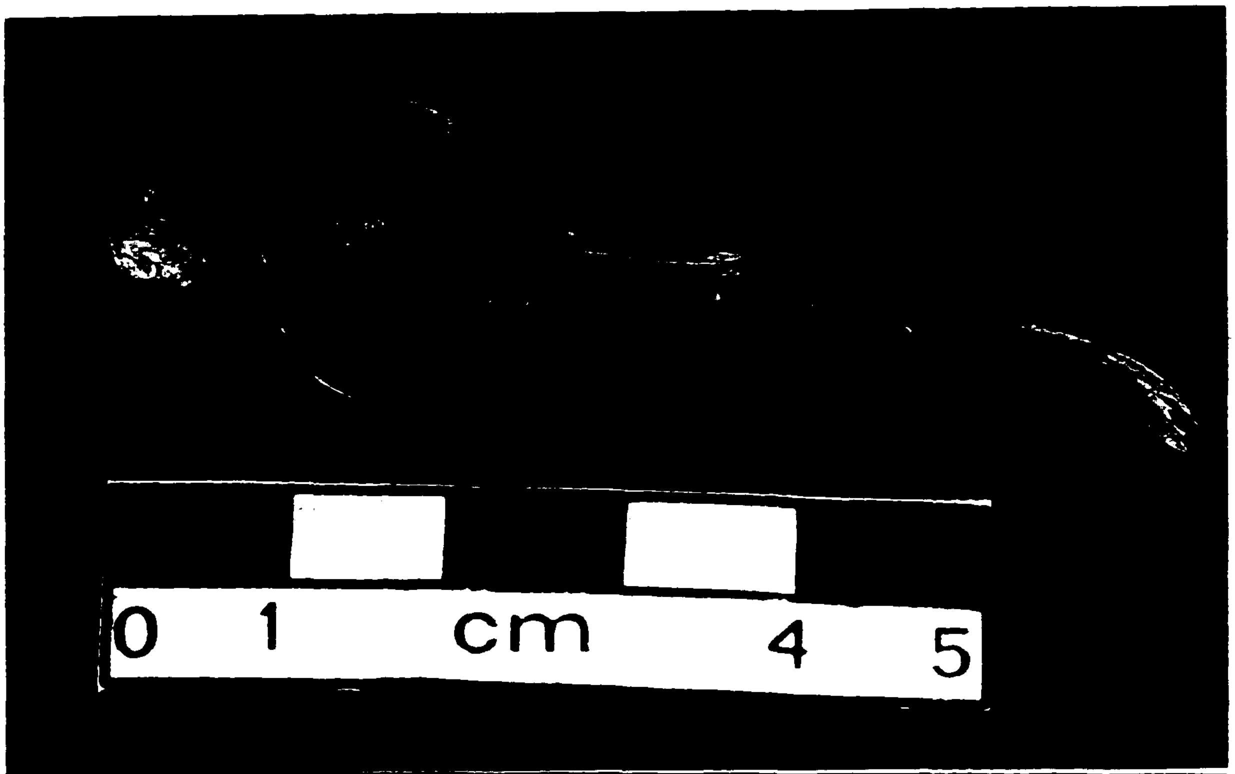

0 1 cm 4 5

Fig. 38.

Dorsal and Ventral view of a representative specimen of *Garra ornata* (MCZ 48319).


0
1
cm
4
5

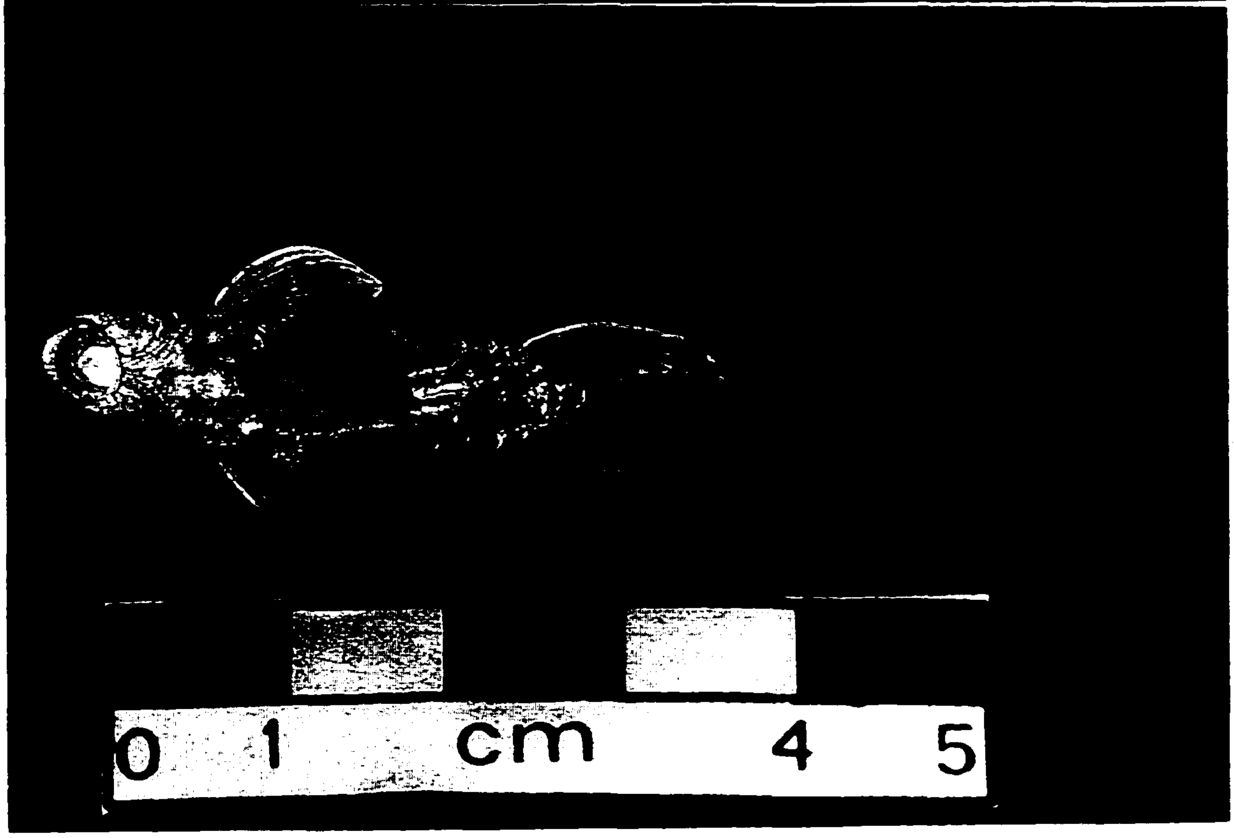
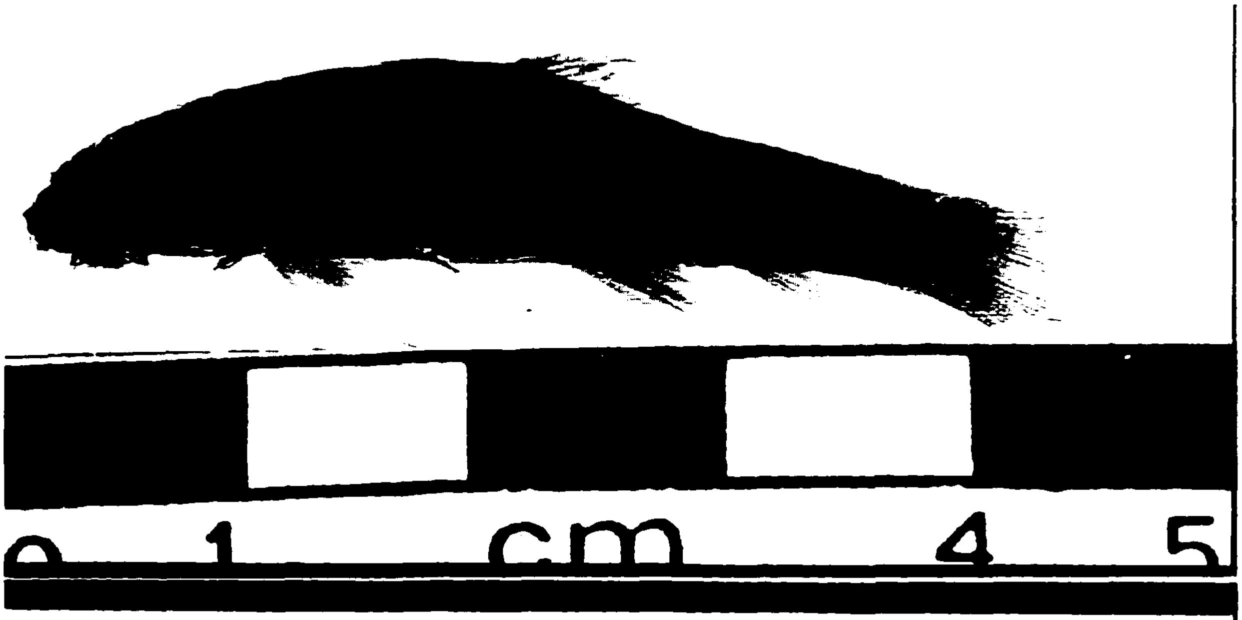

0
1
cm
4
5

Fig. 39.

Dorsal and Ventral view of a representative specimen of *G.quadrimaculata* (AMNH 223724).


0
1
cm
4
5

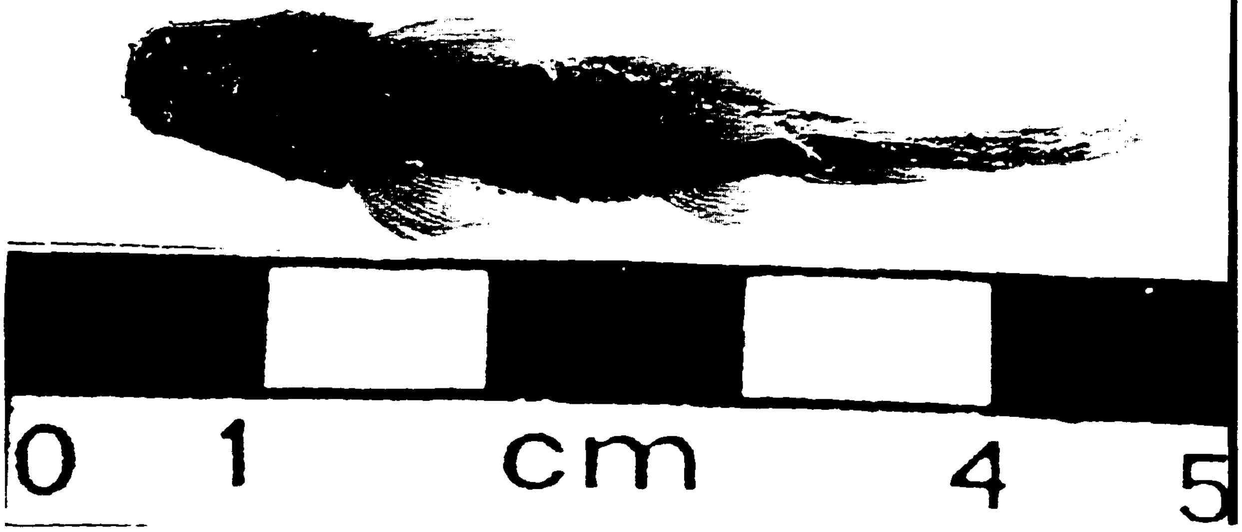

0
1
cm
4
5

Fig. 40.

A. Lateral, dorsal and ventral view of *G.quadrimaculata* (sensu Boulenger, 1903) (Now described as *G.dembecha)*

B. Lateral view of *Gobio quadrimaculatus= Garra quadrimaculata* (Source: Rüppell, 1836)

C. Lateral view of *Gobio hirticeps= Garra quadrimaculata* (Source: Rüppell, 1836)

D. Lateral and ventral view of *G.tibanica* (sensu Trewavas, 1941) (Now synonymized with *G.quadrimaculata*)

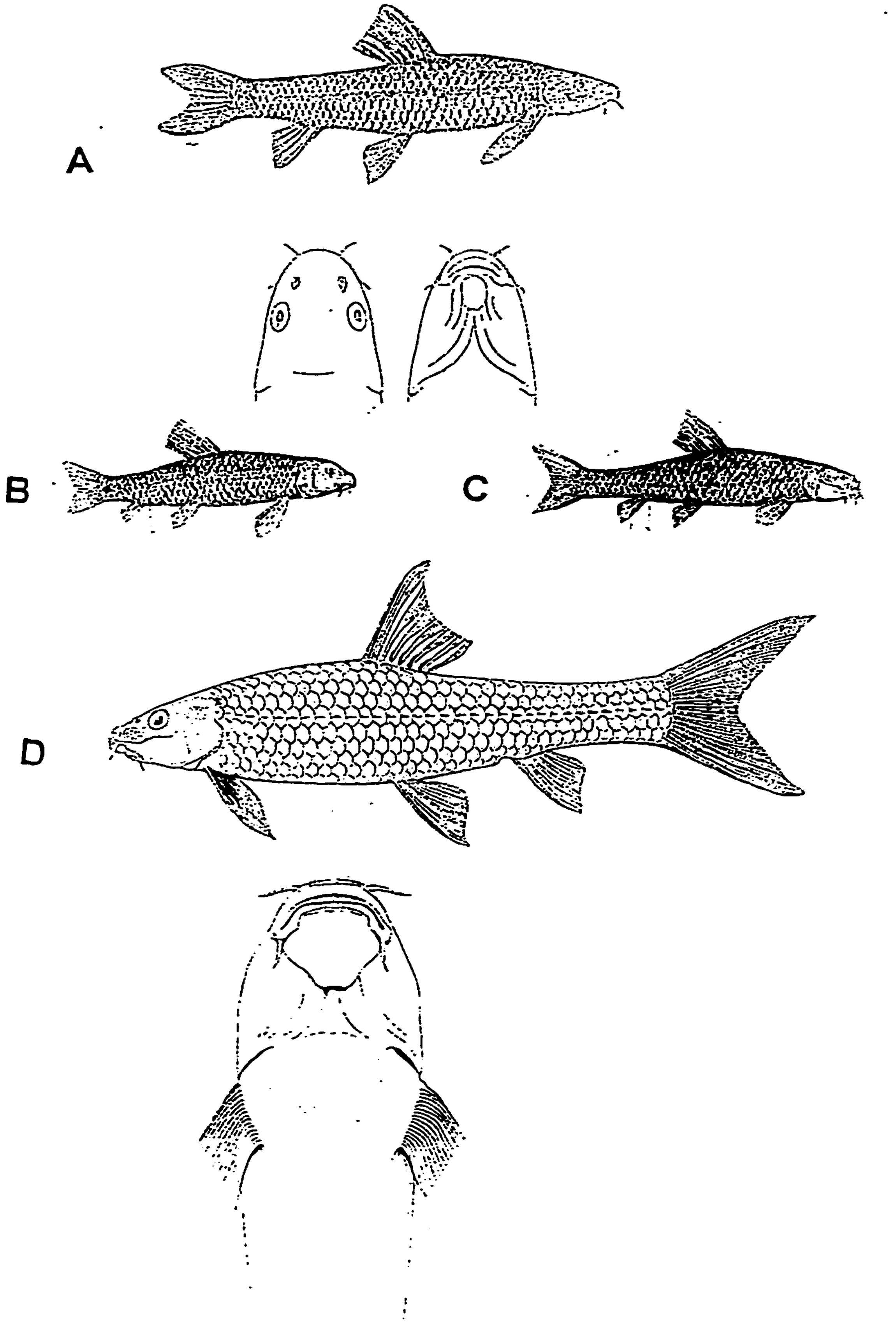

A
B
C
D

Fig. 41.

Lateral, Ventral and Dorsal view of the holotype of *Garra tana* spec.nov. (AMNH 223824)

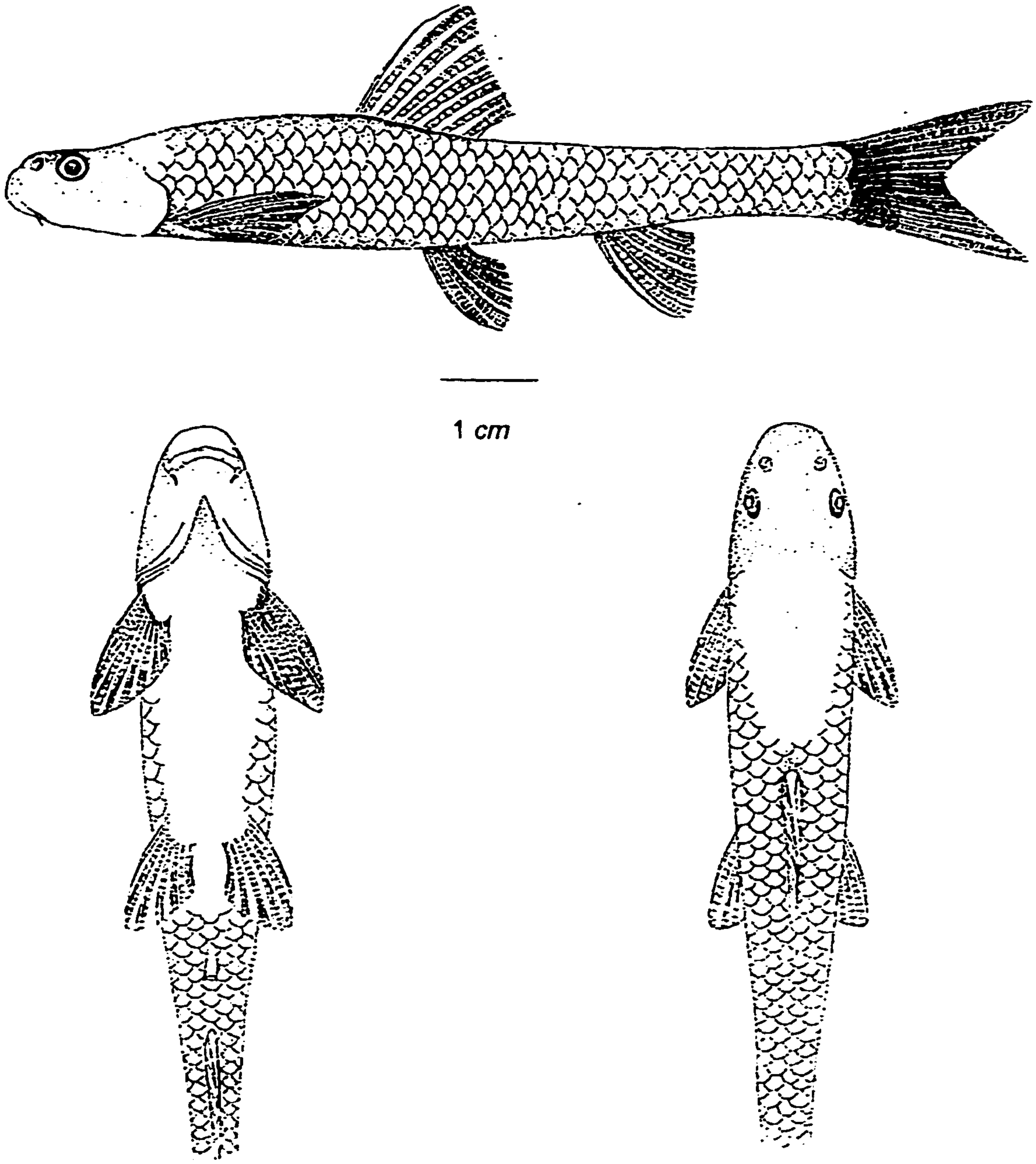
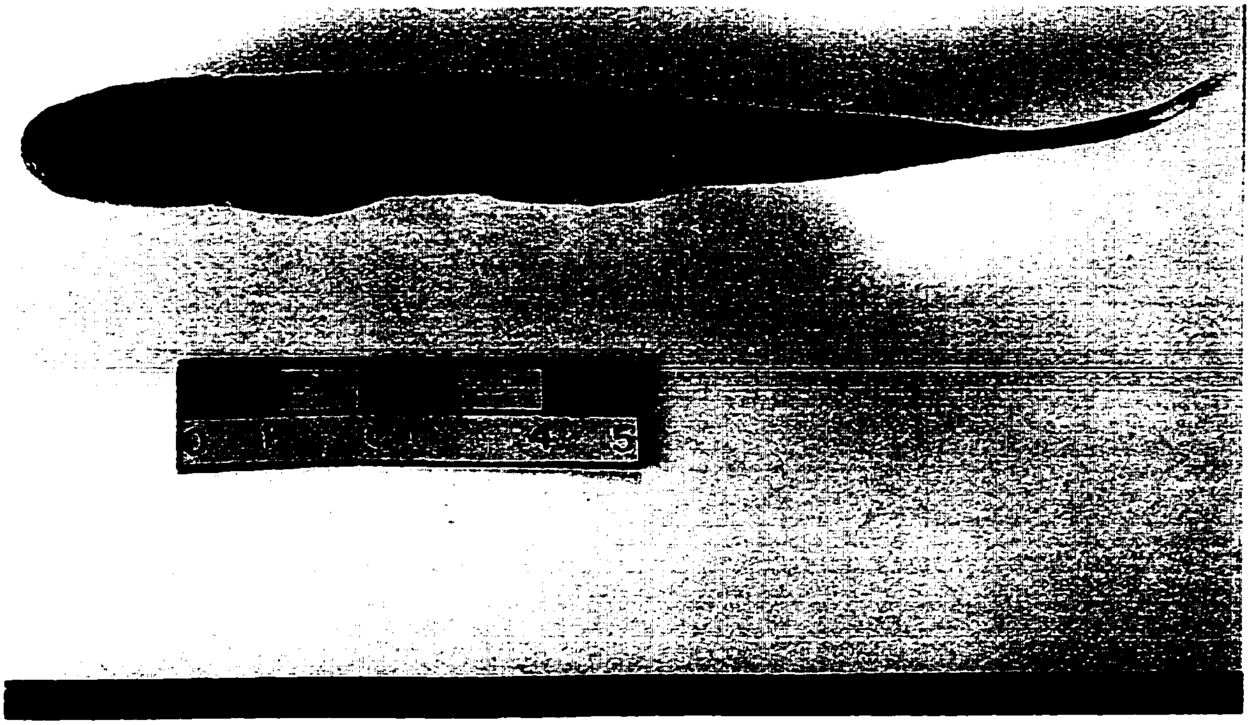

1 cm

Fig. 42.

Dorsal and Ventral view of the holotype of *Garra tana* spec.nov. (AMNH 223824)


0
1
4
5

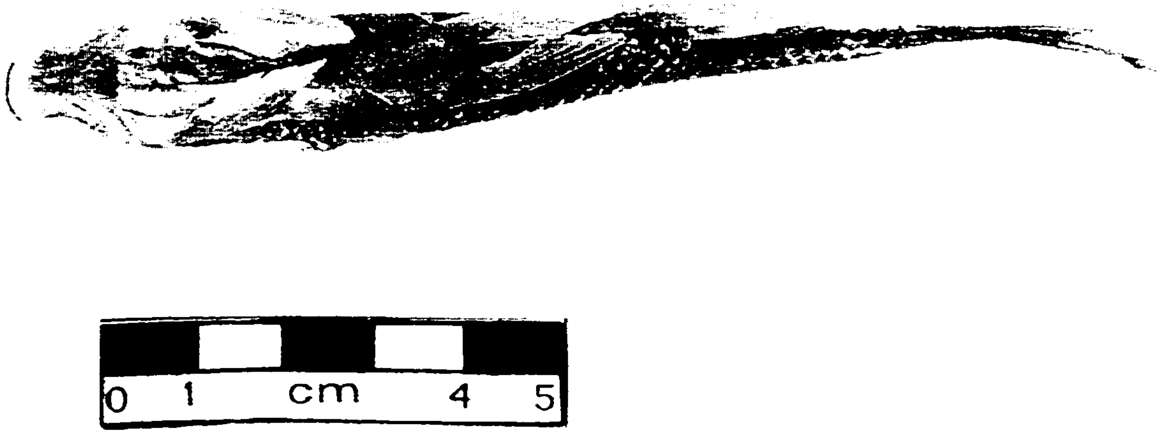

0
1
cm
4
5

Fig. 43.

The different types of tubercles in *Garra*: **A.** *G.quadrimaculata* **B.** *G.ignestii* and **C.** *G.dembeensis.*

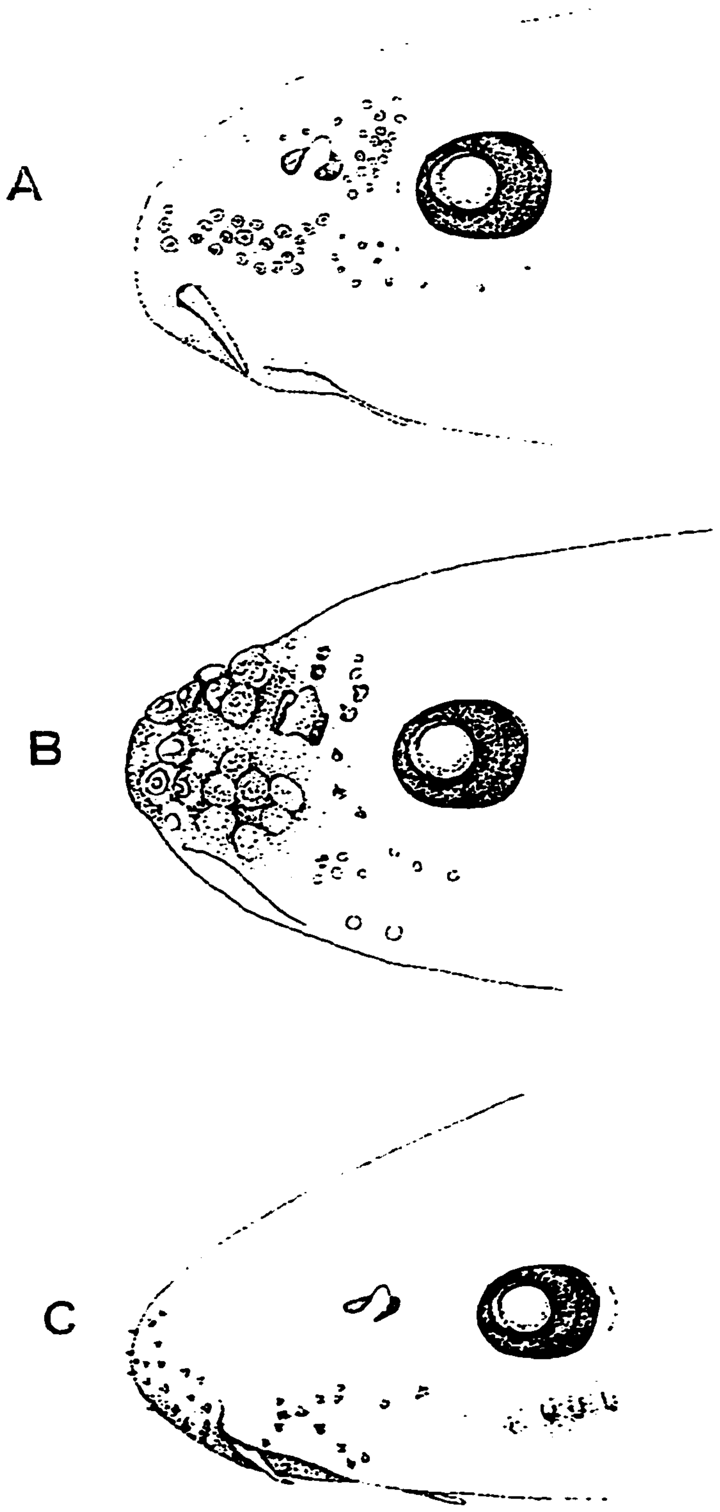

A
B
C

Fig. 44.

Bivariate plot of length of intestine versus standard length in four species of *Garra* (+ = *G.dembecha*; Filled square= *G.dembeensis*; x= *G.tana*; open square= *Garra microstoma*).

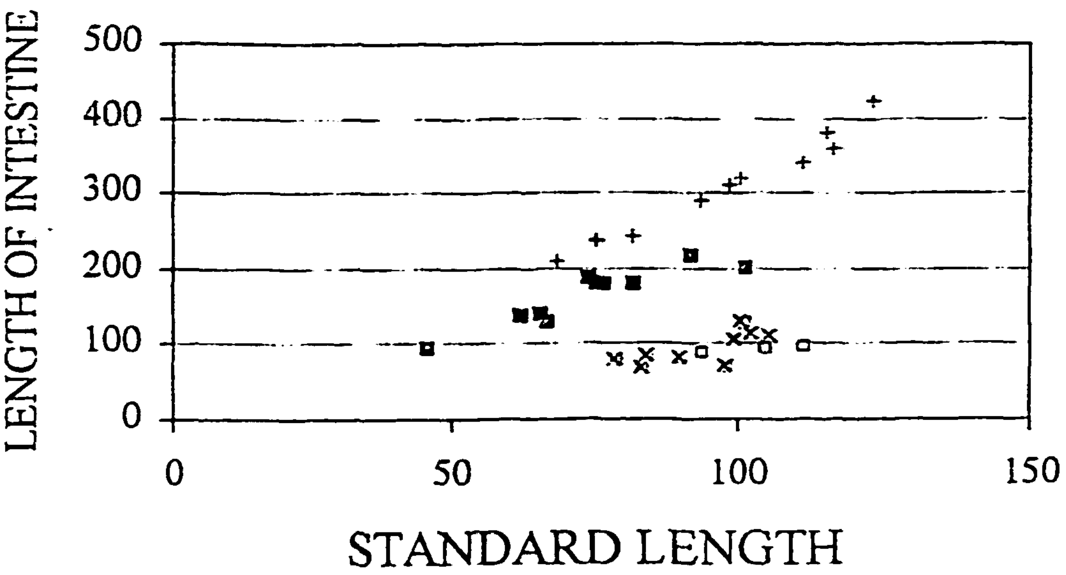
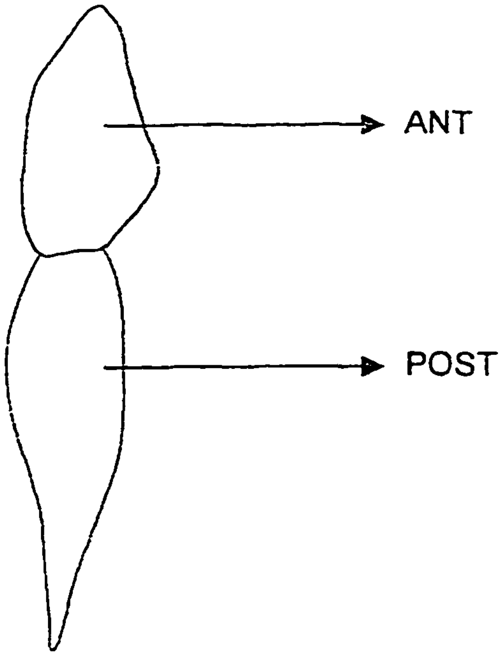

LENGTH OF INTESTINE
500
400
300
200
100
0
0
50
100
150
STANDARD LENGTH

Fig. 45.

The two types of gas bladders in *Garra* : **A.** Anterior chamber smaller and the posterior chamber broad and swollen and **B.** Anterior chamber is inconspicuous and the posterior chamber is thin and uniform.

A



B

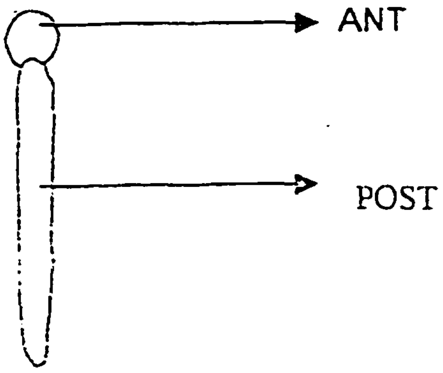


Fig. 46.

Consensus configuration for *G.blanfordii* and *G.dembecha* (numbers indicate the landmarks and the vectors show variations in the position of the landmarks in all the specimens).

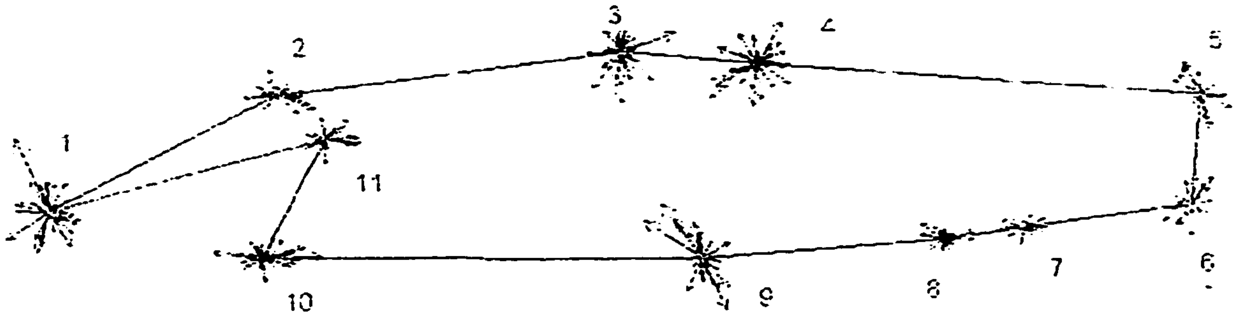

1
2
3
4
5
6
7
8
9
10
11

Fig. 47.

Shape regressed on centroid size for *G.blanfordii* (**A**= small and **B**= large) and *G.dembecha* (**C**=small and **D**=large).

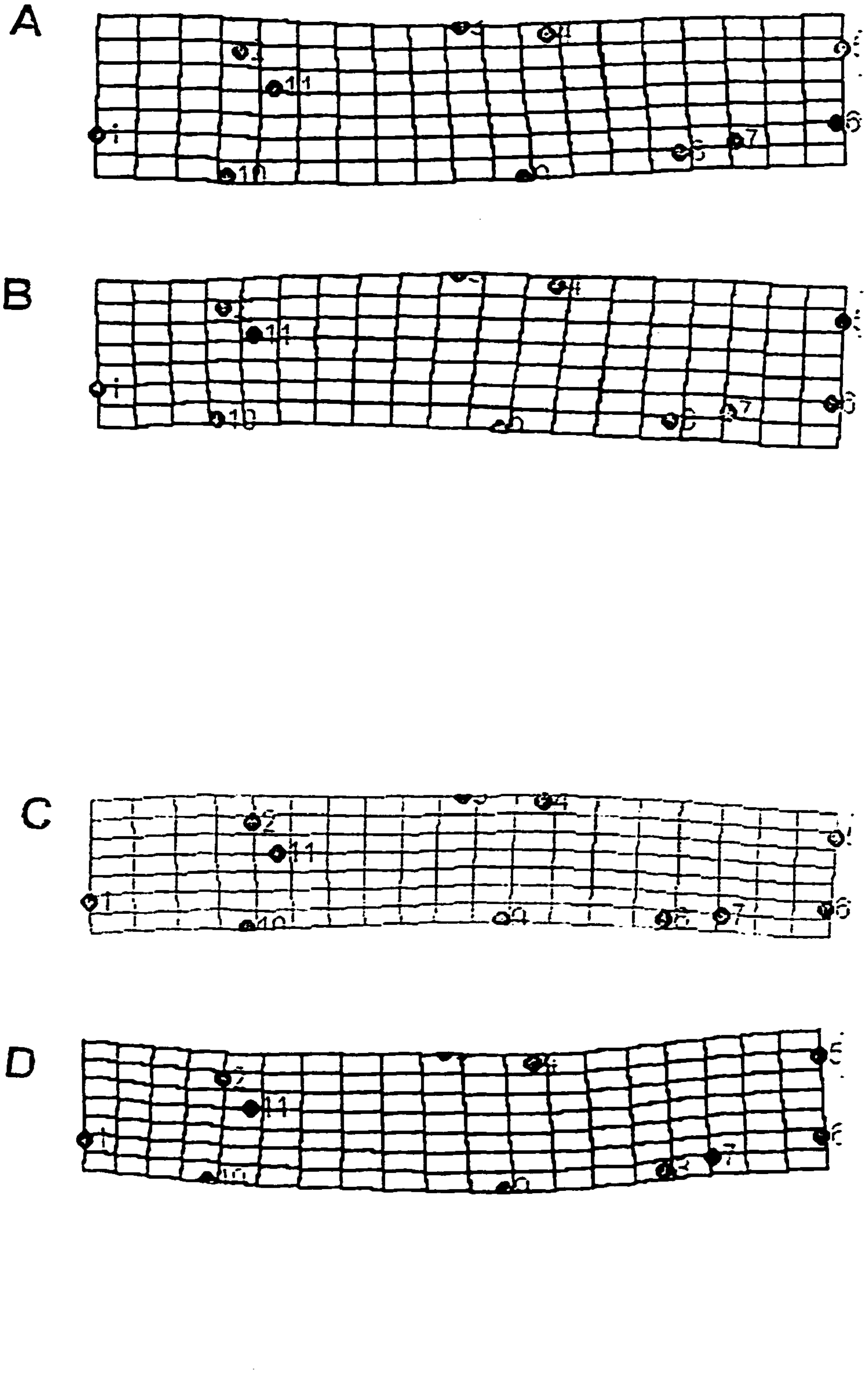

A
B
C
D
1
2
3
4
5
6
7
8
9
10
11

Fig.48

A Cladogram showing relationships among genera of Labeinae

(The dotted hashmarks on the cladogram indicate homoplasy while filled black hashmarks indicate synapomorphy)

(Bold numbers 1,2,3,4 indicate Bremer support for the respective clades)

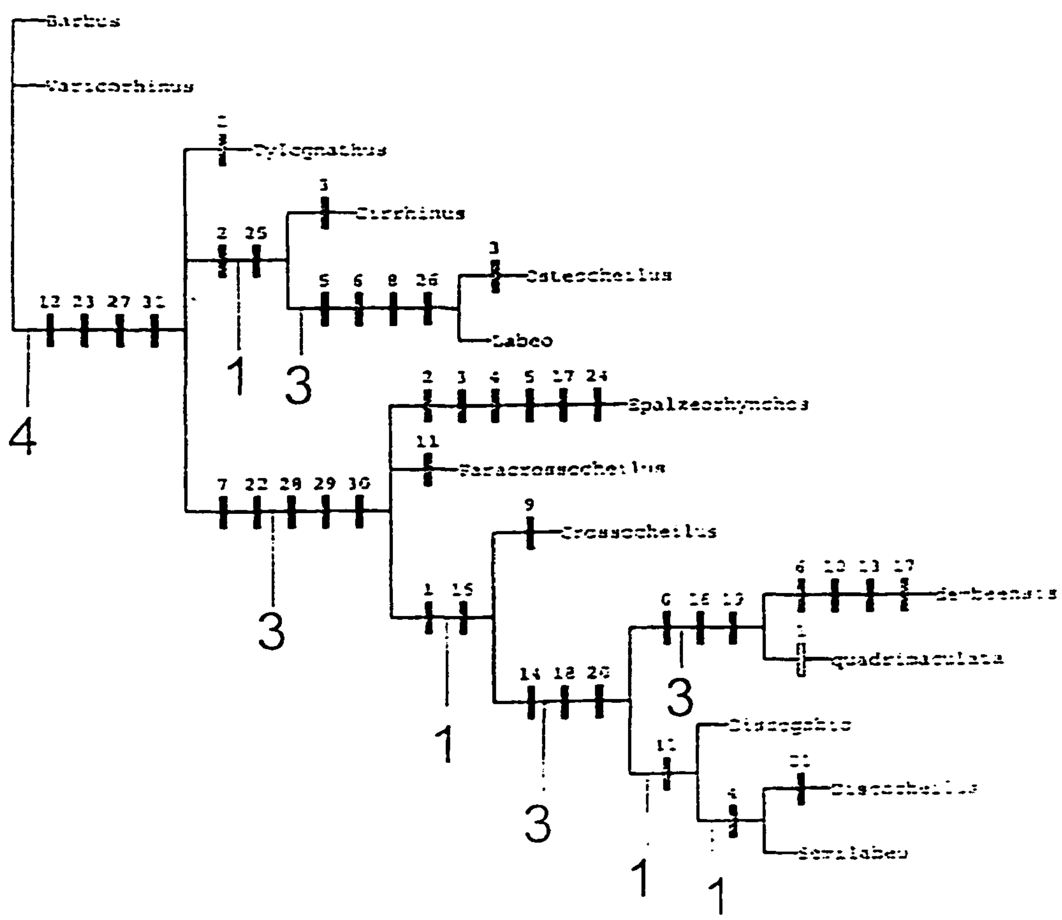
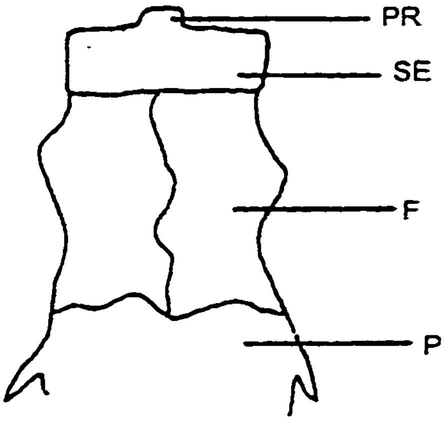
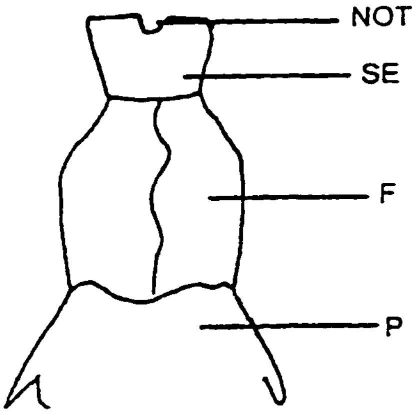

Barbus
Varicorhinus
Tylognathus
3
Cirrhinus
2 25
3
Osteocheilus
5 6 8 26
Labeo
12 23 27 31
1
3
4
2 3 4 5 17 24
Epalzeorhynchos
11
Paracrossocheilus
7 22 28 29 30
3
9
Crossocheilus
1 15
1
6 10 13 17
gerbeensis
6 16 19
quadrimaculata
3
14 18 20
3
Discognathus
Discocheilus
Semilabeo
1
1

Fig.49.

Supraethmoid (dorsal view) of **a.** *Garra makiensis* and **b.** *Crossocheilus latius* (**PR**= Process; **NOT**= Notch **SE**= Supraethmoid; **F**= Frontal; **P**= Parietal)



a



b

Fig.50

Right and left sides of the dentary bone (ventral view) of **a.** *Garra makiensis* and **b.** *Epalzeorhynchos munensis* (CON= Concavity)

a

b

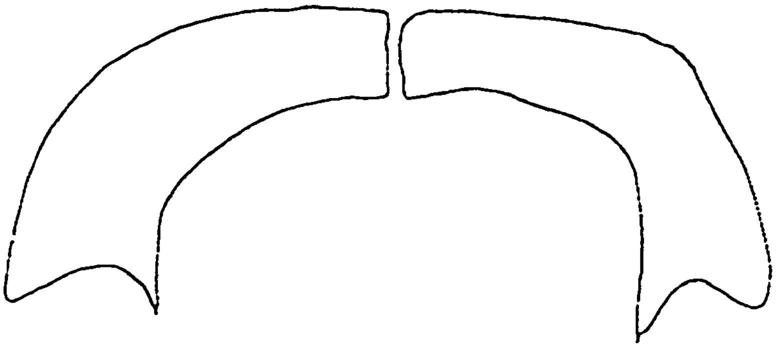
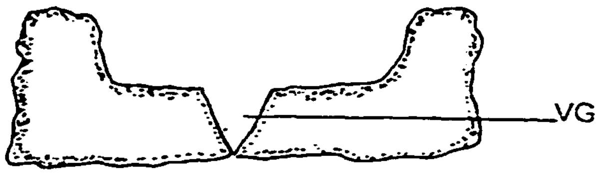
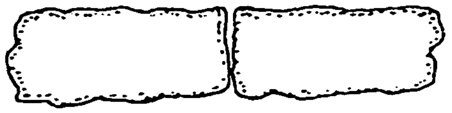


Fig.51

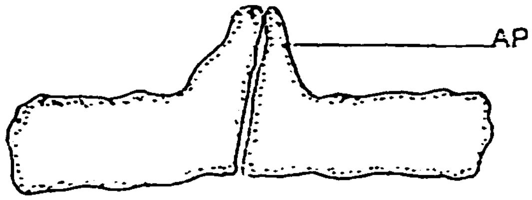
Premaxillae (ventral view) of **a.** *Epalzeorhynchos munensis*
b. *Garra blanfordii* and **c.** *G.duobarbis*
(AP= Ascending process; VG= V-shaped gap)



a



b



c

Fig.52

Vomer (ventral view) of **a.** *Epalzeorhynchos munensis* **b.** *Dischocheilus wui* and **c.** *Garra dembeensis* (**CON**= Concavity; **FAC**= Facet; **VO**= Vomer)

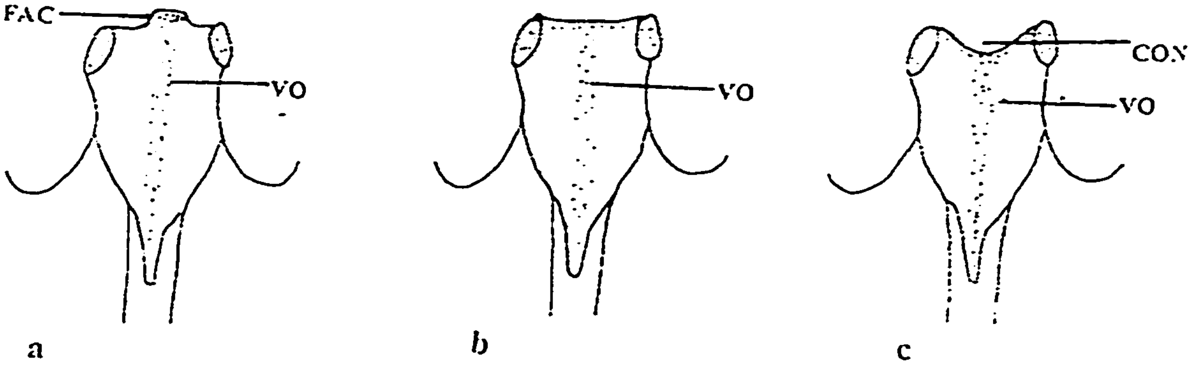
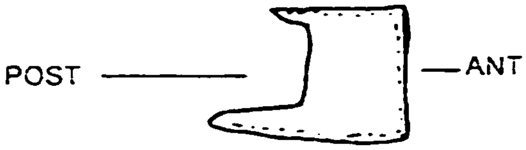

FAC
VO
VO
CON
VO
a
b
c

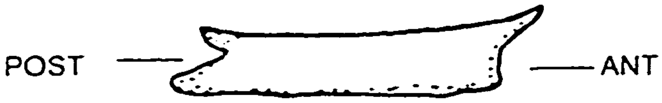
Fig.53

Left maxillae (ventral view) of **a.** *Epalzeorhynchos munensis* and **b.** *Garra makiensis*

(ANT= Anterior; **POST=** Posterior**)**



a



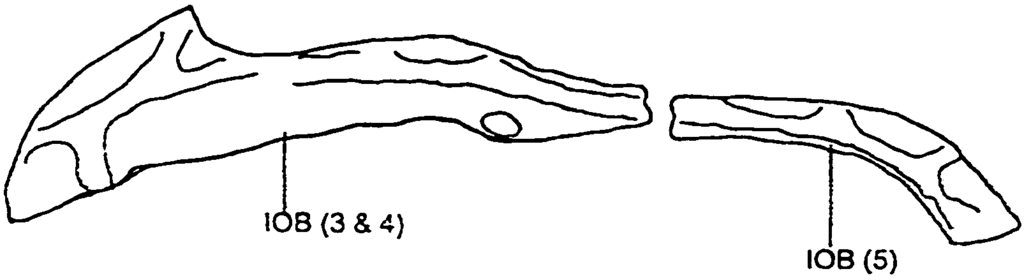
b

Fig.54

Infraorbital bones 3&4 and 5 (lateral view) of **a.** *Garra dembeensis* and **b.** *Discocheilus wui*

(IOB (3 & 4)= Infraorbital bones 3 and 4; **IOB (5)**= Infraorbital bone 5)

a



b

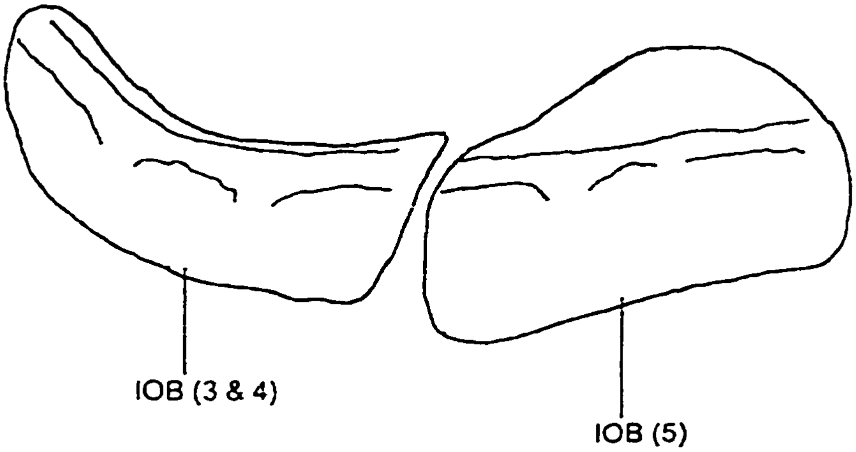
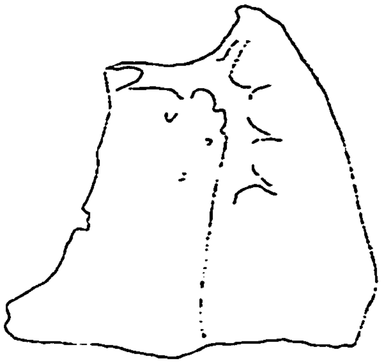
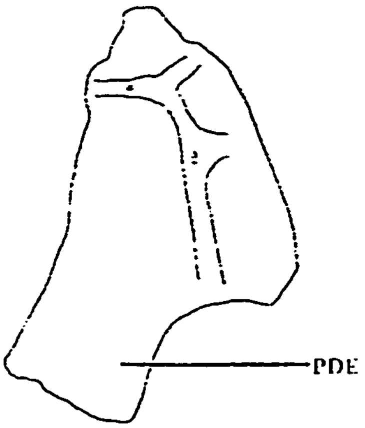


Fig.55

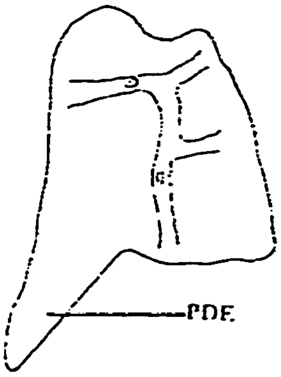
Lacrimal bones (lateral view) of **a.** *Barbus ablabes* **b.** *Epalzeorhynchos munensis* and **c.** *Garra* dembecha
(**PDE**= Postero-dorsal elongation)



a



b

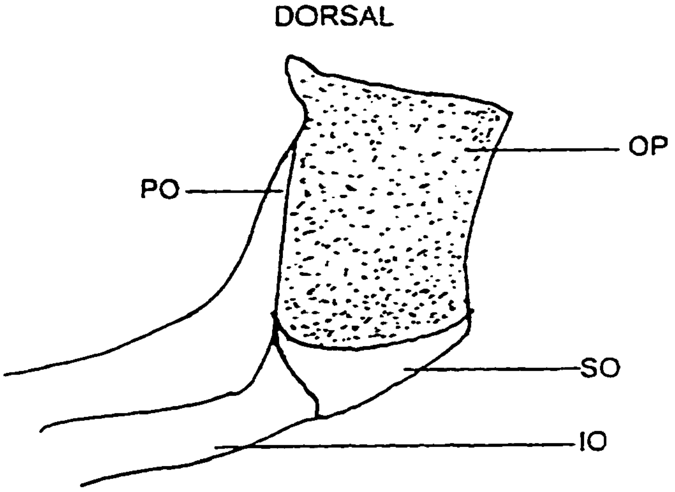


c

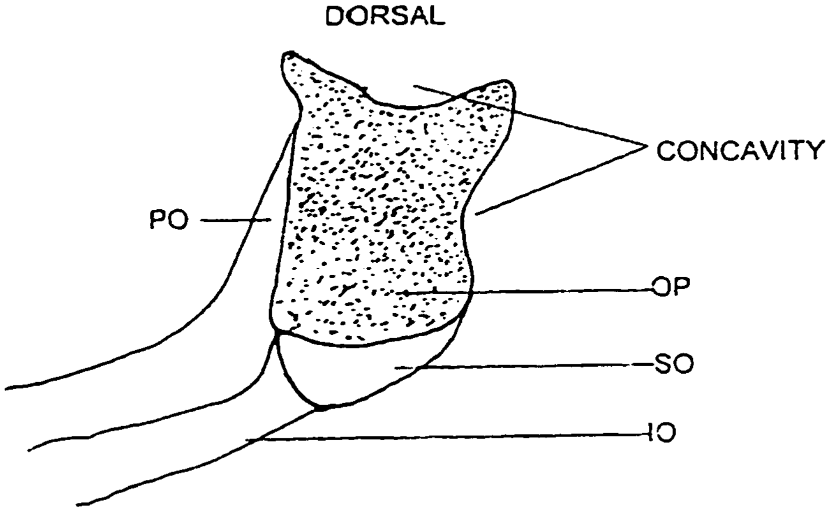
Fig.56

Operculum (left side lateral view) of **a.** *Epalzeorhynchos munensis* and **b.** *Garra tana*

(**IO**= Interopercle; **OP**= Operculum; **PO**= Preopercle; **SO**= Subopercle)



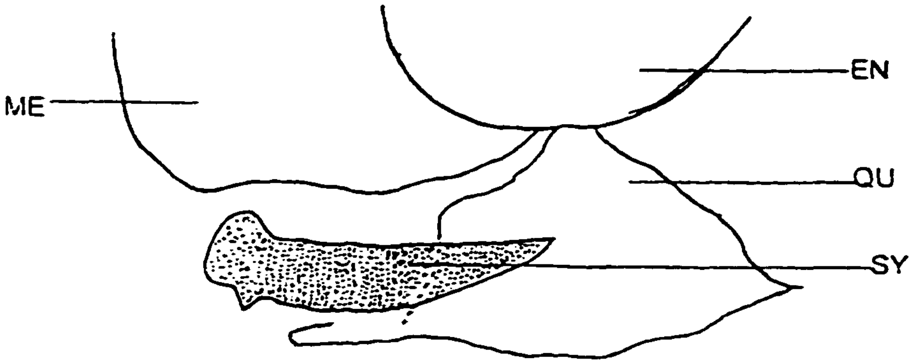
a



b

Fig.57

Left suspensorium (lateral view) of **a.** *Epalzeorhynchos munensis* and **b.** *Garra dembeensis*
(CON= Concavity; EN= Endopterygoid; ME= Metapterygoid; QU= Quadrate; SY= Symplectic)



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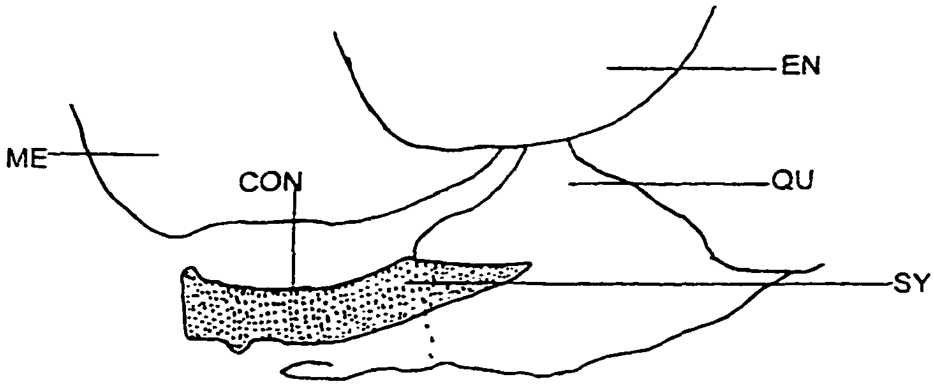
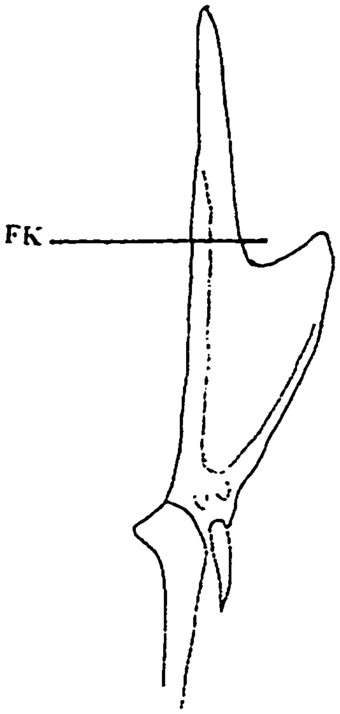


b

Fig.58

Leading anal fin pterygiophore (lateral view) of **a.** *Garra makiensis* and **b.** *Barbus ablabes*
(FK= Fork)

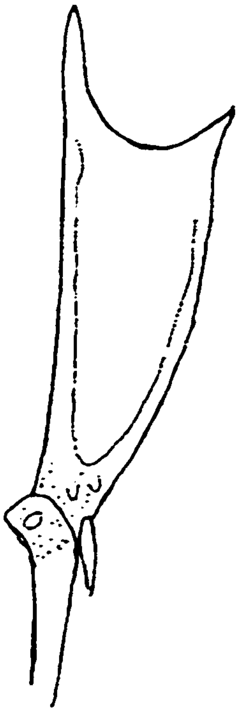


a

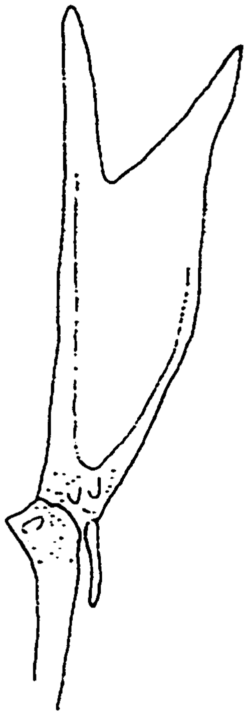
b

Fig.59

Leading dorsal fin pterygiophore (lateral view) of **a.** *Garra dembeensis* and **b.** *Epalzeorhynchos munensis*



a

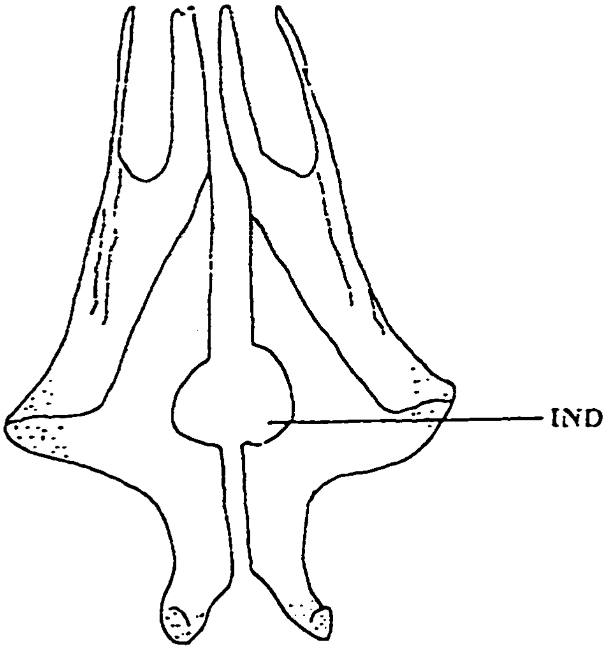


b

Fig.60

Pelvic girdle (ventral view) of **a.** *Discocheilus wui* and **b.** *Epalzeorhynchos munensis*
(**IND**= Indentation)

a



b

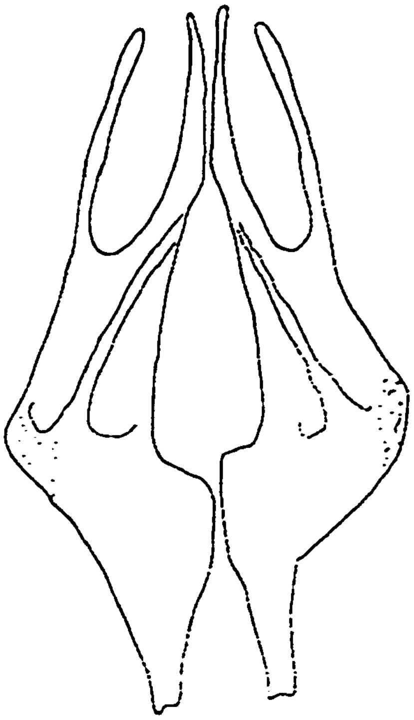
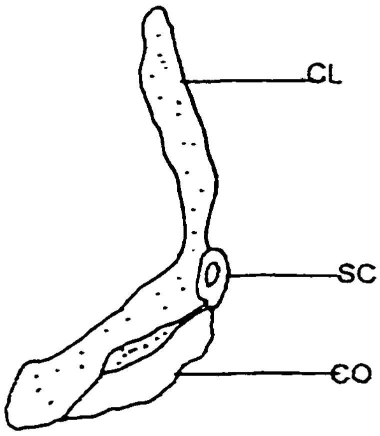
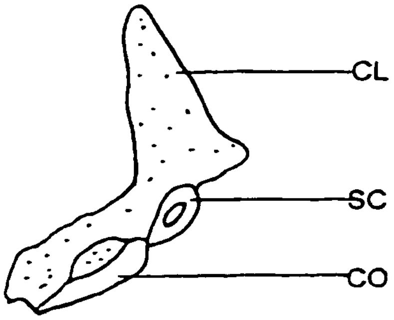


Fig.61

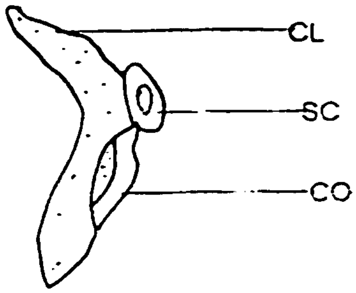
Cleithrum (ventral view) of **a.** *Garra dembeensis* **b.** *Epalzeorhynchos kalopterus* **c.** *Paracrossocheilus acerus*
(CL= Cleithrum; CO= Coracoid; SC= Scapula)



a



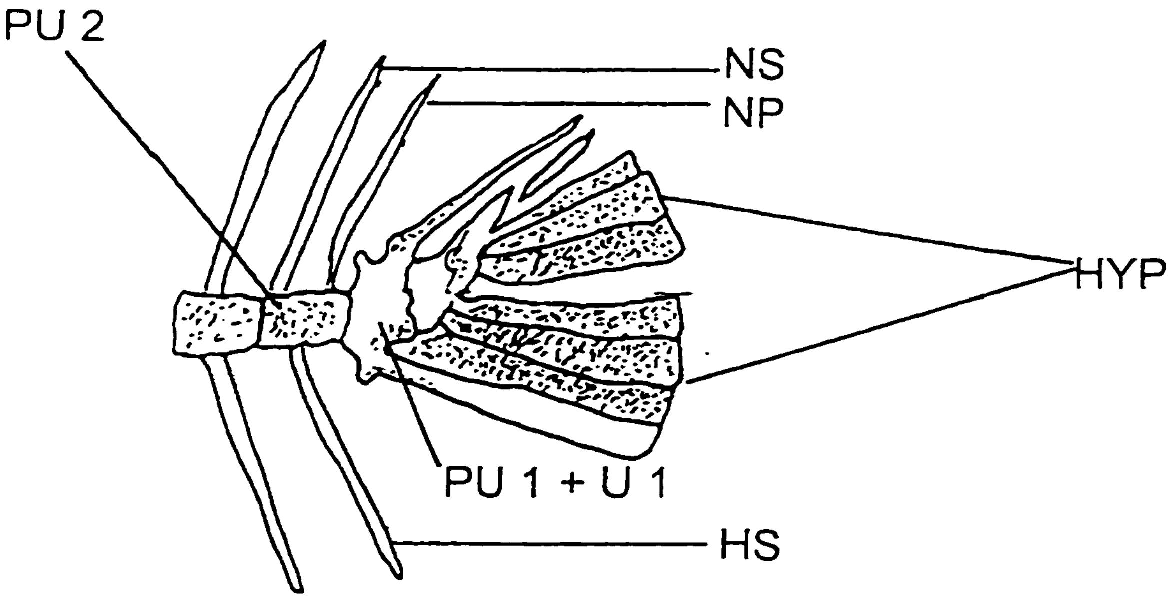
b



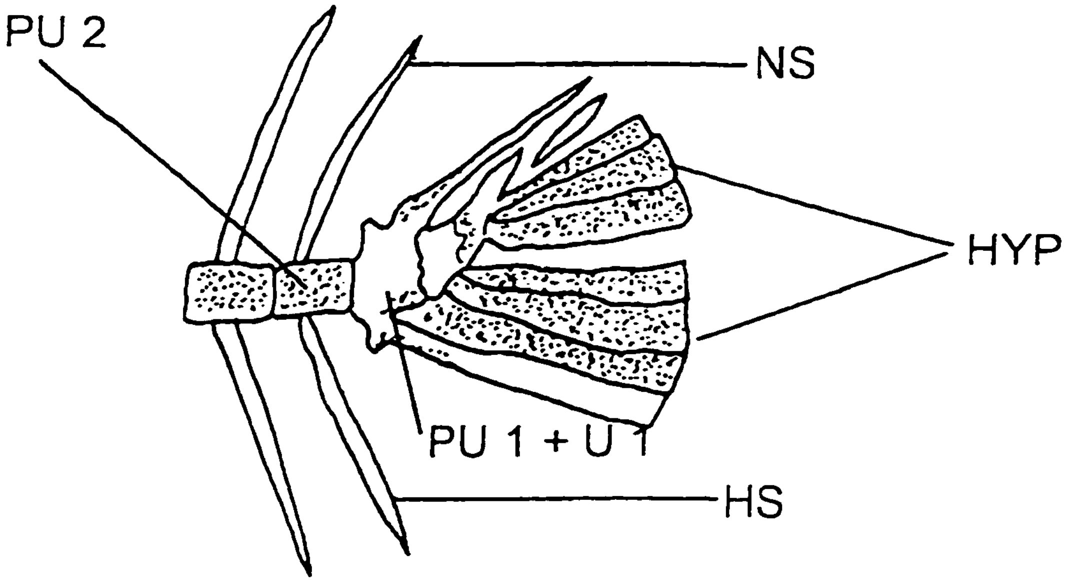
c

Fig.62

Caudal vertebrae (lateral view) of **a.** *Epalzeorhynchos munensis* and **b.** *Discocheilus wui*
(HYP= Hypurals; NP= Neural process; PU1 + U1= Preural and Ural; NS= Neural spine; HS= Haemal spine)



a



b

Fig.63

Mouthparts of *Garra ignestii* (**RF**= Rostral fold; **P**= Papillae; **DI**= Disc)

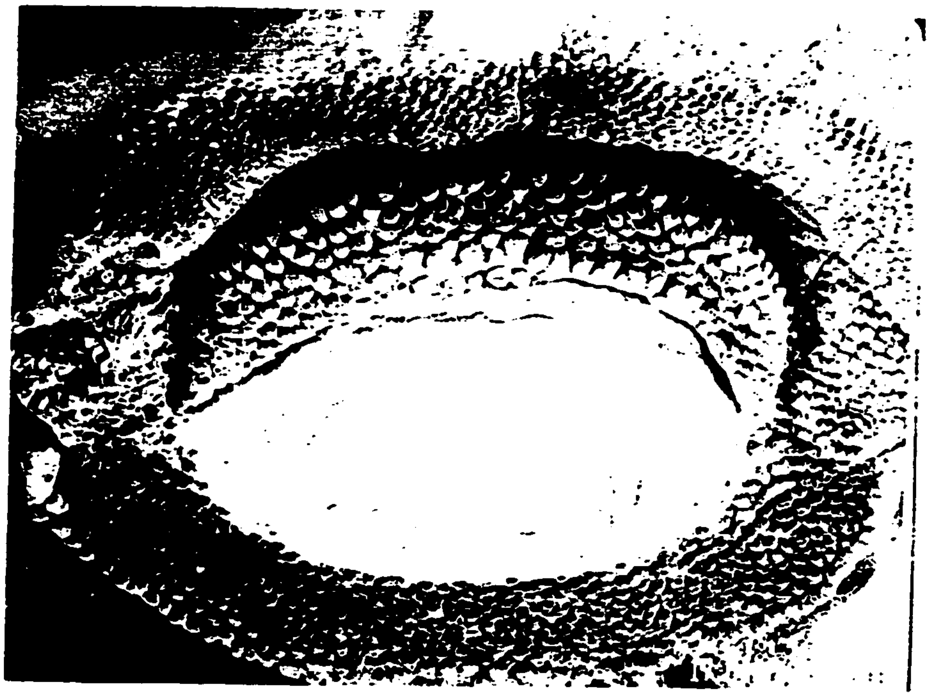


Fig.64

Papillae from mouthparts (upper side of lower lip) of *Garra ignestii*

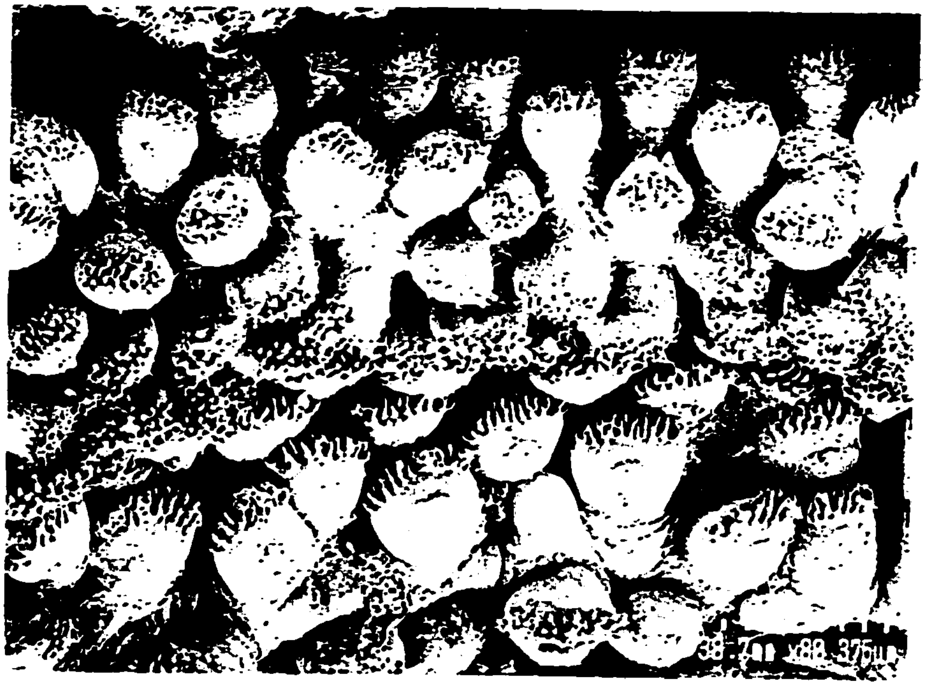

x80 375µm

Fig.65

Papillae from mouthparts (rostral fold) of *Garra ignestii*

Fig.66

Dorsal and ventral view of *Discocheilus wui*


0
1
cm
4
5

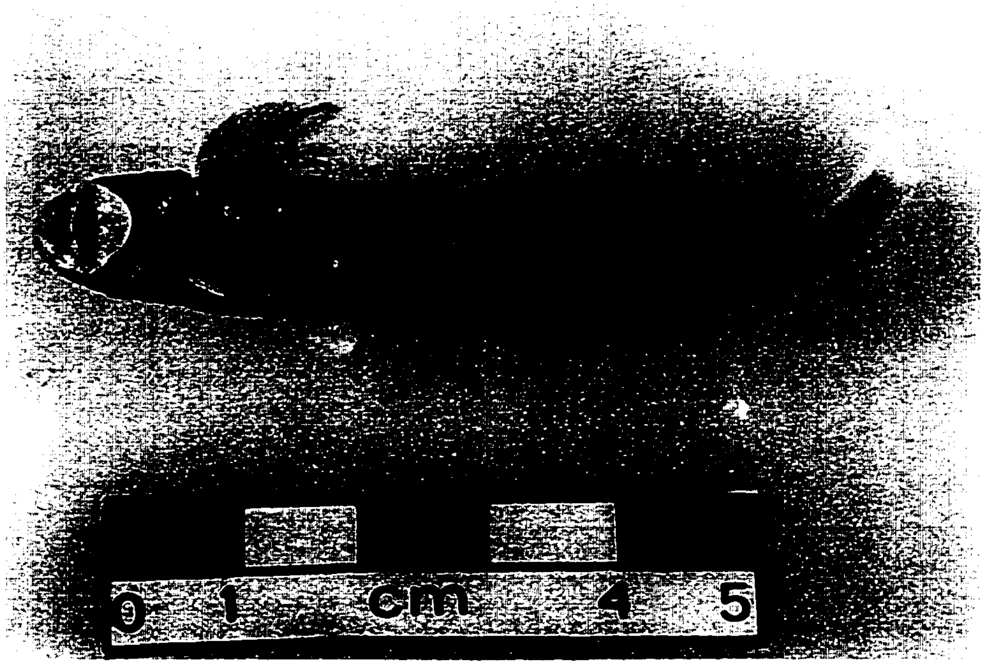
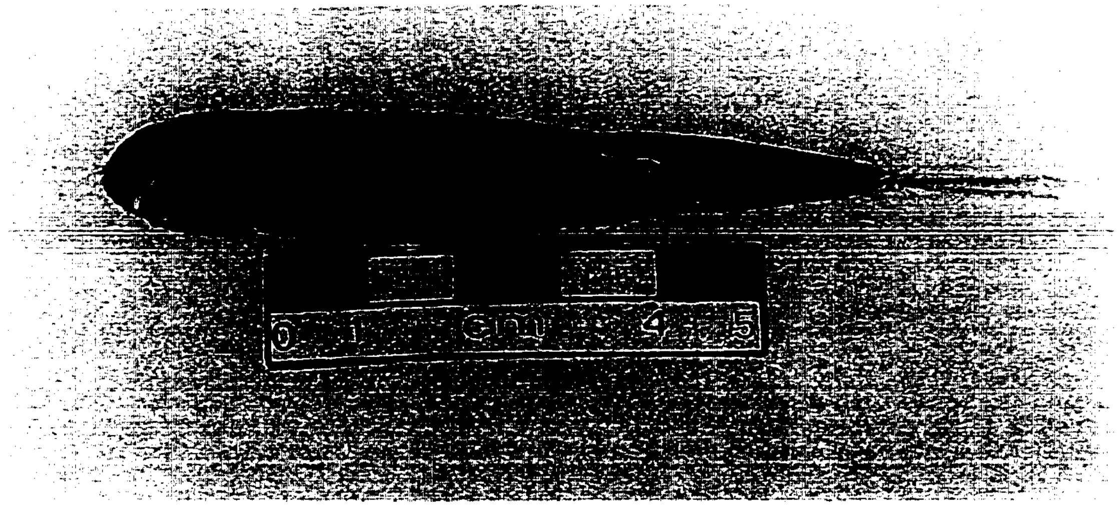

0
1
cm
4
5

Fig.67

Dorsal and ventral view of *Discogobio yunnanensis*


0
1
cm
4
5

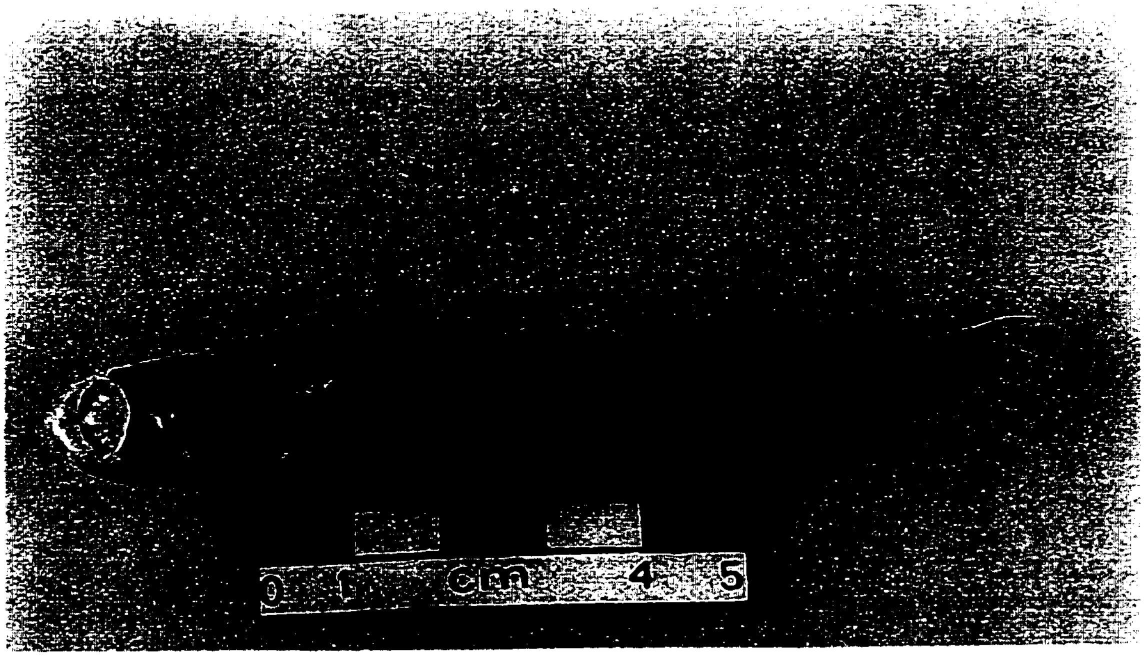
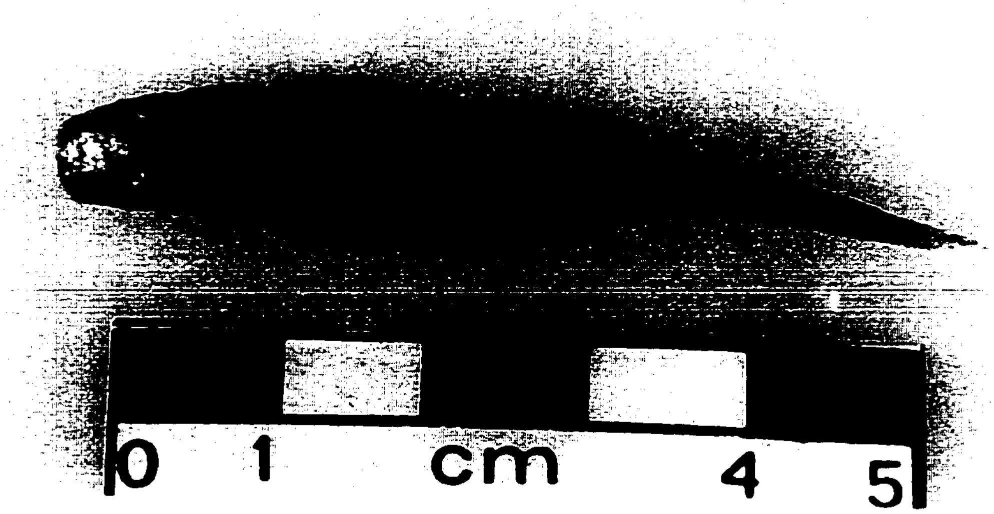

0
1
cm
4
5

Fig.68

Dorsal and ventral view of *Semilabeo procheilus*


0
1
cm
4
5

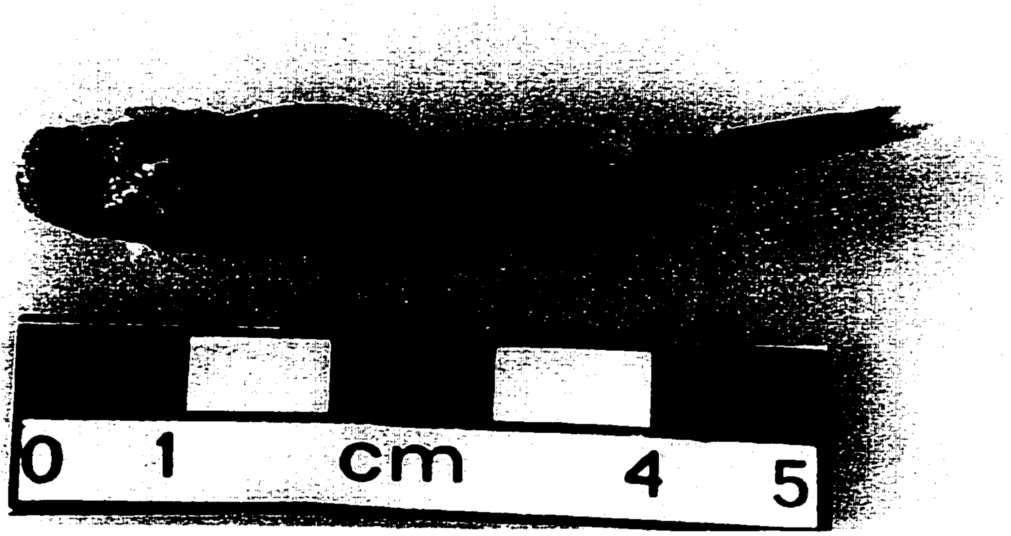

0
1
cm
4
5

Fig.69

A Cladogram showing relationships among *Garra* species

(The dotted hashmarks on the cladogram indicate homoplasy while filled black hashmarks indicate synapomorphy)

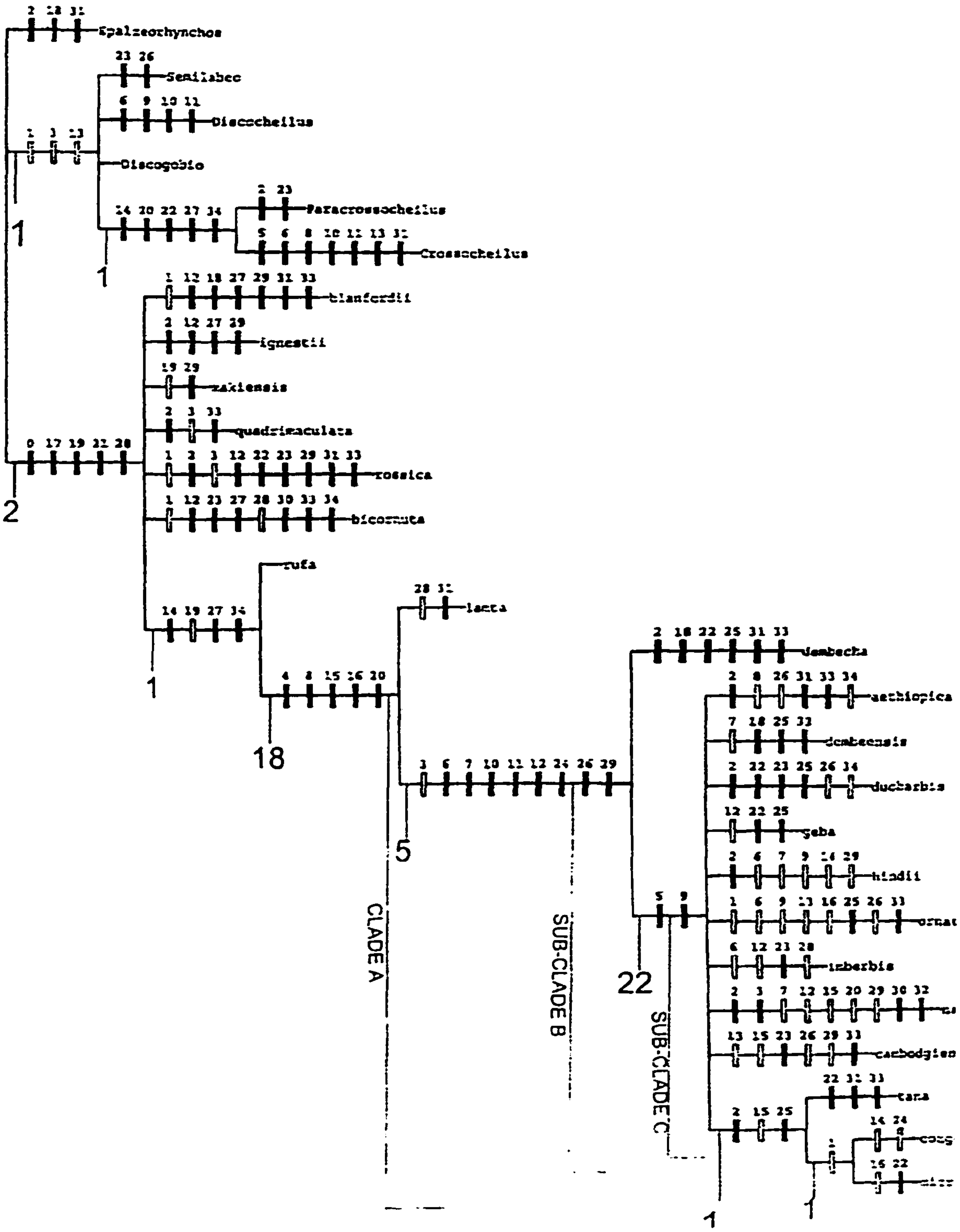
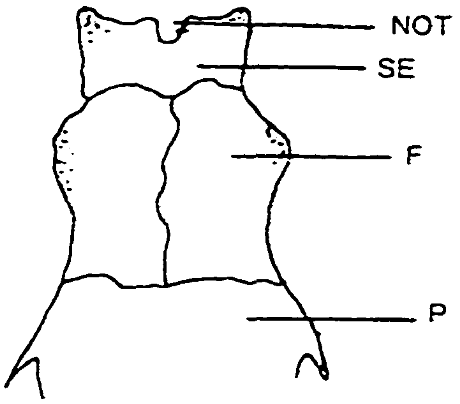
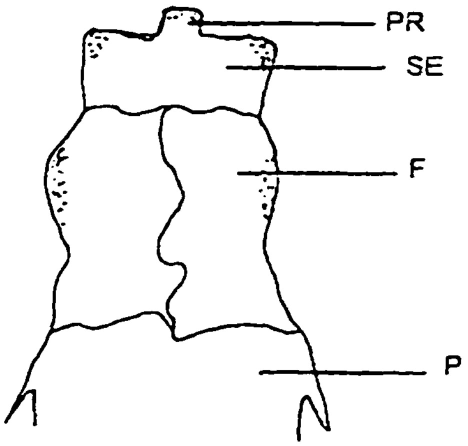

2 18 31
Spalaeorhynchos
23 26
Semilabeo
6 9 10 11
Discocheilus
1 3 13
Discogobio
1
14 20 22 27 34
1
2 23
Paracrossocheilus
5 6 8 10 11 13 31
Crossocheilus
1 12 18 27 29 31 33
blanfordii
2 12 27 29
ignestii
19 29
zakiensis
2 3 33
quadrimaculata
0 17 19 21 28
2
1 2 3 12 22 23 29 31 33
rossica
1 12 23 27 28 30 33 34
bicornuta
rufa
14 19 27 34
1
28 31
laeta
4 8 15 16 20
18
3 6 7 10 11 12 24 26 29
5
CLADE A
SUB-CLADE B
2 18 22 25 31 33
dembecha
2 8 26 31 33 34
aethiopica
7 18 25 33
dembeensis
2 22 23 25 26 34
ducharbis
12 22 25
geba
2 6 7 9 14 29
hindii
5 9
1 6 9 13 16 25 26 33
ornat
6 12 21 28
imberbis
22
2 3 7 12 15 20 29 30 32
13 15 23 26 29 33
cambodgien
SUB-CLADE C
22 31 33
tana
2 15 25
14 24
16 22
1
1

Fig.70.

Antero-medial part of ethmoid (dorsal view) of **a.** *Garra microstoma* and **b.** *Garra dembecha*
(**NOT**= Notched; **SE**= Supraethmoid; **F**= Frontal; **P**= Parietal; **PR**= Process)



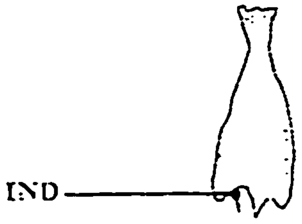
a



b

Fig.71

Urohyal (ventral view) of **a.** *Garra makiensis* and **b.** *Garra duobarbis* (IND= Indentation)

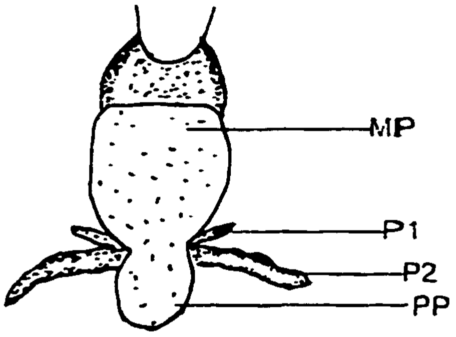


a

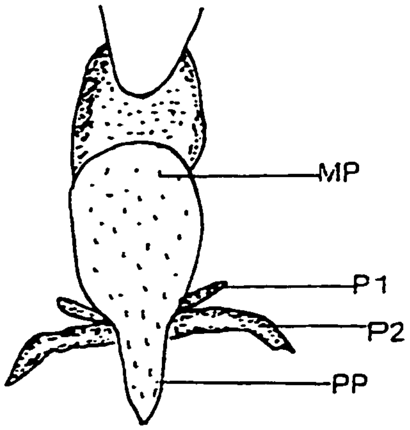
b

Fig.72

Masticatory plate and pharyngeal process (ventral view) of **a**. *Garra rossica* and **b**. *Garra microstoma*
(**MP**= Masticatory plate; **P1**= Process of 1st vertebra; **P2**= Process of 2nd vertebra; **PP**= Pharyngeal process)



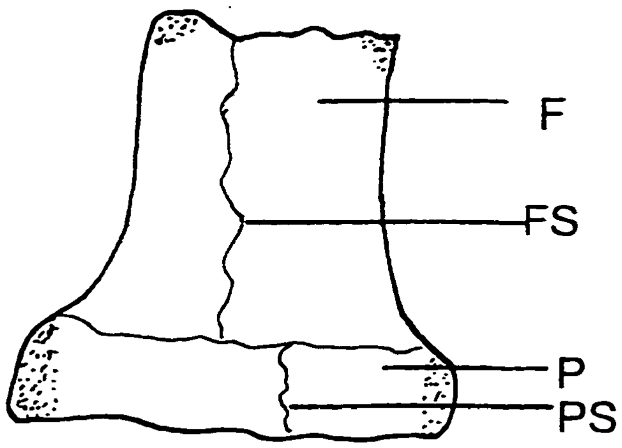
a



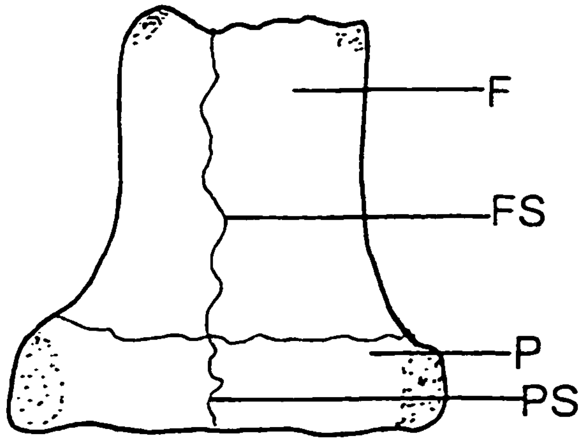
b

Fig.73

Shape of the suture at frontal and parietal (dorsal view) of **a.** *Garra hindii* and **b.** *Garra tana*
(F= Frontal; FS= Frontal Suture; P= Parietal; PS= Parietal suture)



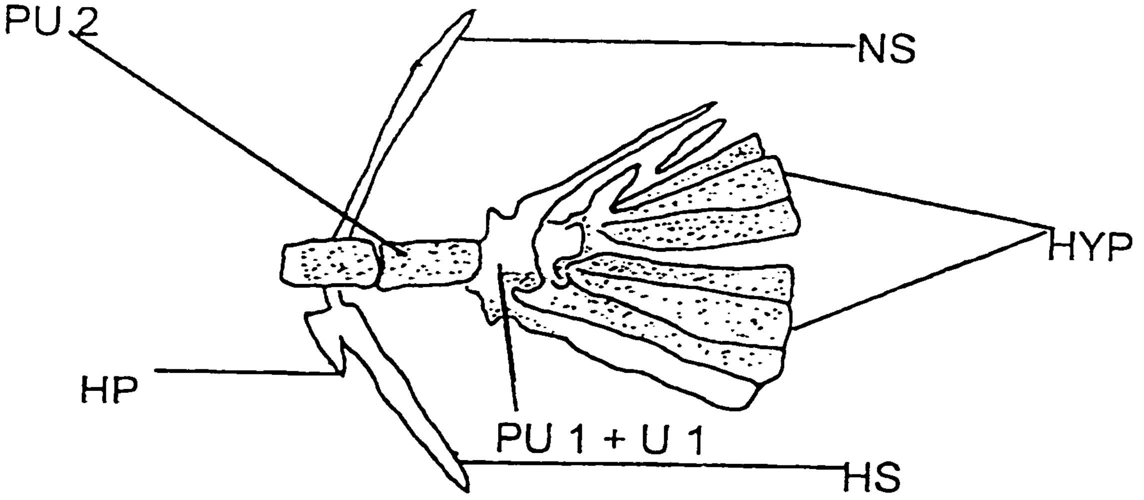
a



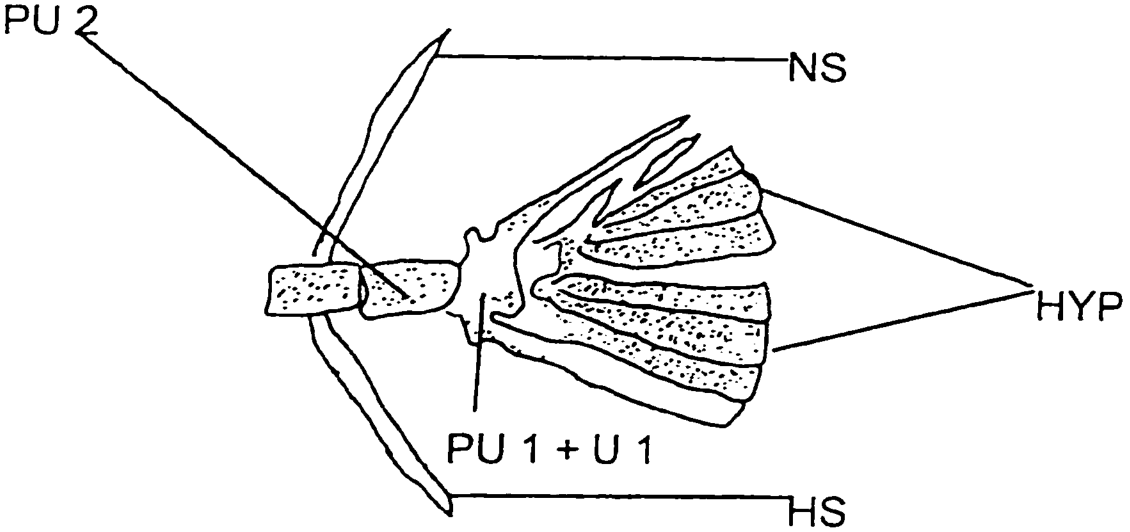
b

Fig.74

Caudal vertebrae (lateral view) of **a.** *Garra ignestii* and **b.** *Garra ornata* (**HYP**= Hypurals; **NS**= Neural spine; **PU1 + U1**= Preural and Ural; **PU2**= Preural2; **HP**= Haemal Process; **HS**= Haemal spine)



a



b

Fig.75

A.

Chimuga River, near Debremarkos town, Abbay drainage basin, Gojam, northern Ethiopia, stony bottom with grassy shores. Found by the highway that goes from Addis Ababa to Gondar. *Garra blanfordii* abundant at this site. Picture taken in November 1996.

B.

Kechen River, between Dembecha and Finote Selam towns, Abbay drainage basin, Gojam, northern Ethiopia. Muddy bottom with grassy shores. Found by the highway that goes from Addis Ababa to Gondar. Large sized *G.dembecha* abundant at this site. Picture taken in November 1996.

B

Fig.76

A.

Wondogenet River, near Wondogenet town, Rift Valley Lakes drainage basin, Southern Ethiopia. Dense vegetation around and stony bottom. People hand washing clothes. *G.makiensis* and *G.dembeensis* were collected from this site. Picture taken in November 1996.

B.

Megecha/ Gubre River, near Gubre town, Awash drainage basin, Gurage zone, central Ethiopia. Muddy water with no vegetation around. Large number of *G.aethiopica* collected from this site. Picture taken in June 1997.

A

B

Fig.77

A.

Akaki River, at the outskirt of Addis Ababa city on the way to Debrezeit, Awash Drainage basin. Some industrial pollution evident. *G.aethiopica* collected from this site. Picture taken in November 1996.

B.

Mekanisa River, at the outskirt of Addis Ababa on the way to Jima, Awash drainage basin. Highly polluted by human activity. One specimen of *G.aethiopica* collected from this site. Picture taken in November 1996.

A

B

Fig.78

A.

Lake Tana at gorgora, Abbay drainage basin, Gondar, Ethiopia. The lake shore at the Gorgora side. *G.dembeensis* collected from this site. Picture taken in November 1996.

B.

Kechen Abeba River, on the way from Woldia town to Lalibela town, Tekezze drainage basin, Wollo, northern Ethiopia. Small River during the dry season. *G.ignestii* collected from this site. Picture taken in November 1996.

B

Fig.79

Outflow of Tipecha River, about 5 km south of Bedele town on the way to Metu, baro drainage basin, southwestern Ethiopia. Well-protected River with dense vegetation. *Garra dembeensis* collected from this site. Picture taken in June 1997.

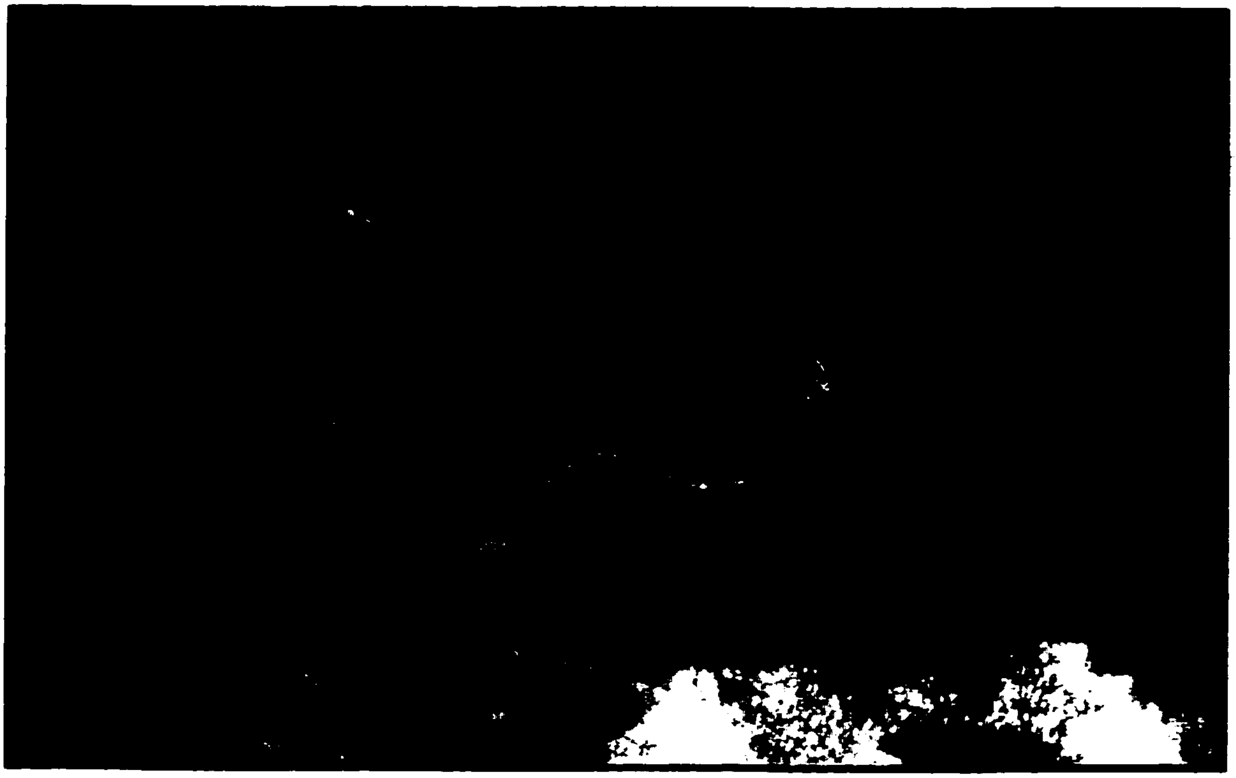


Fig.80

Kakist River, near Tilili town, on the way to Bahirdar town, Abbay drainage basin, northern Ethiopia. Eroded River with no vegetation cover and muddy bottom. *Garra dembeensis* collected from this site. Picture taken in November 1996.

Fig.81

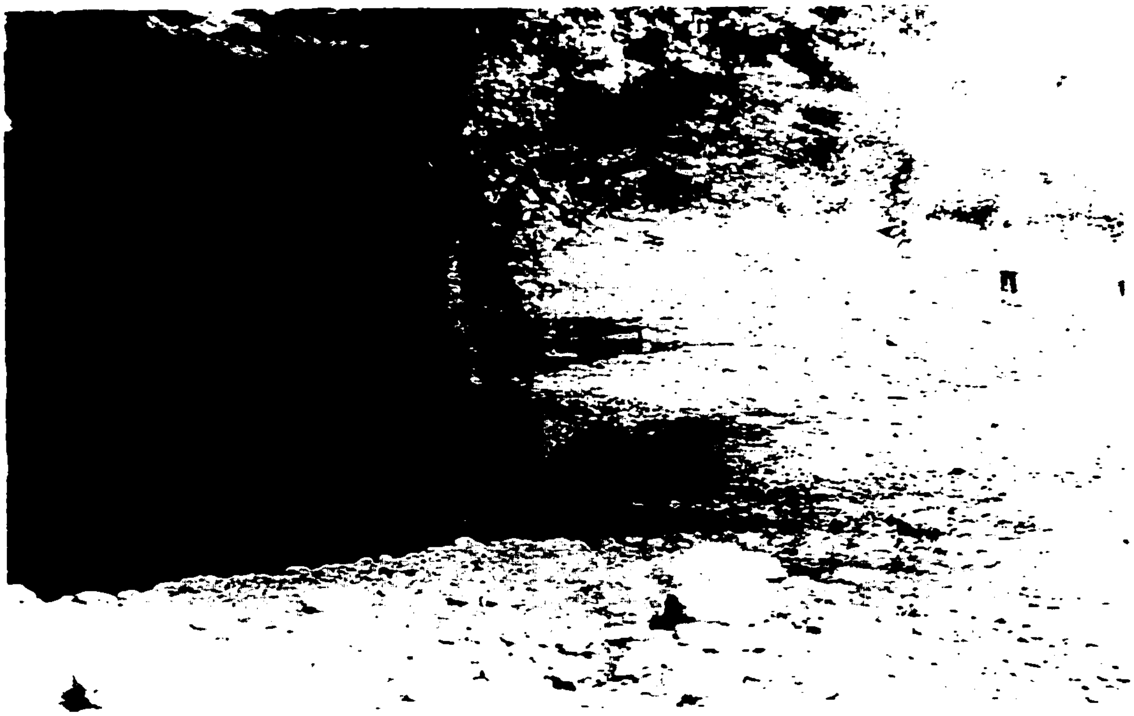
A.

Errer Gota River, some 40 km west of Dire Dawa, Awash drainage basin, Eastern Ethiopia. This is a site at the outskirt of the town of Errer Gota. A small River with some stagnant pools with rocky bottom. Many large specimens of *Garra makiensis* collected at this site. It was from this same site that *Garra rotschildii* (later synonymized with *G.makiensis*) was collected. Picture taken in June 1997.

B.

Borkena River, southern end of Kombolcha town, Awash drainage basin, Wollo, northern Ethiopia. Stony bottom and disturbed by human activity. *Garra dembeensis* collected from this site. Picture taken in November 1996.

A



B

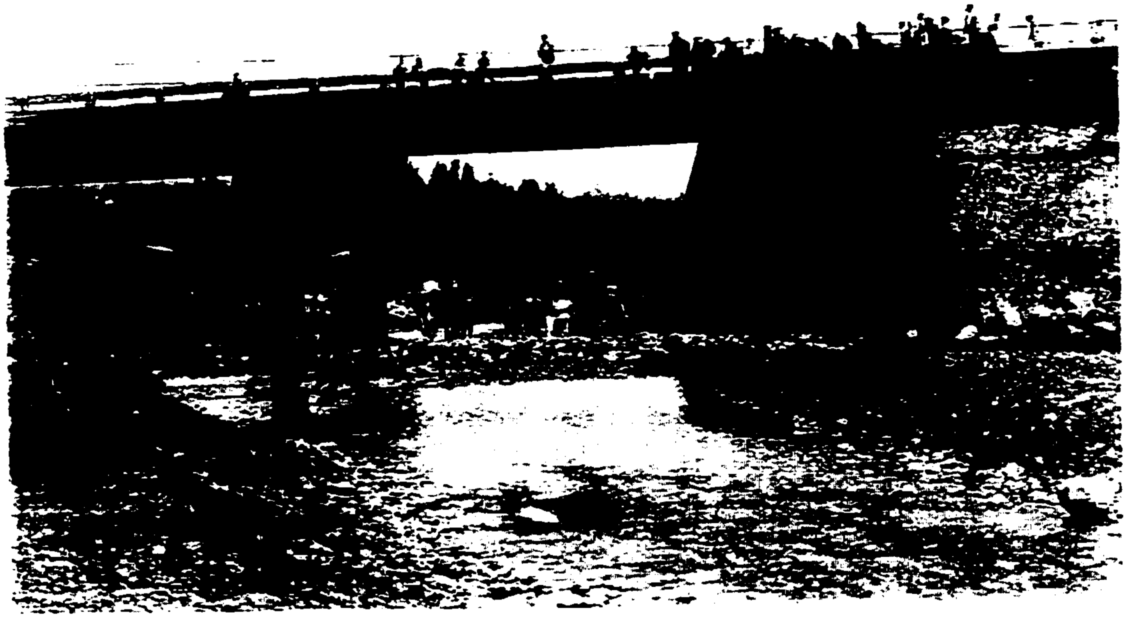


Fig.82

Number of species of *Garra* in African countries

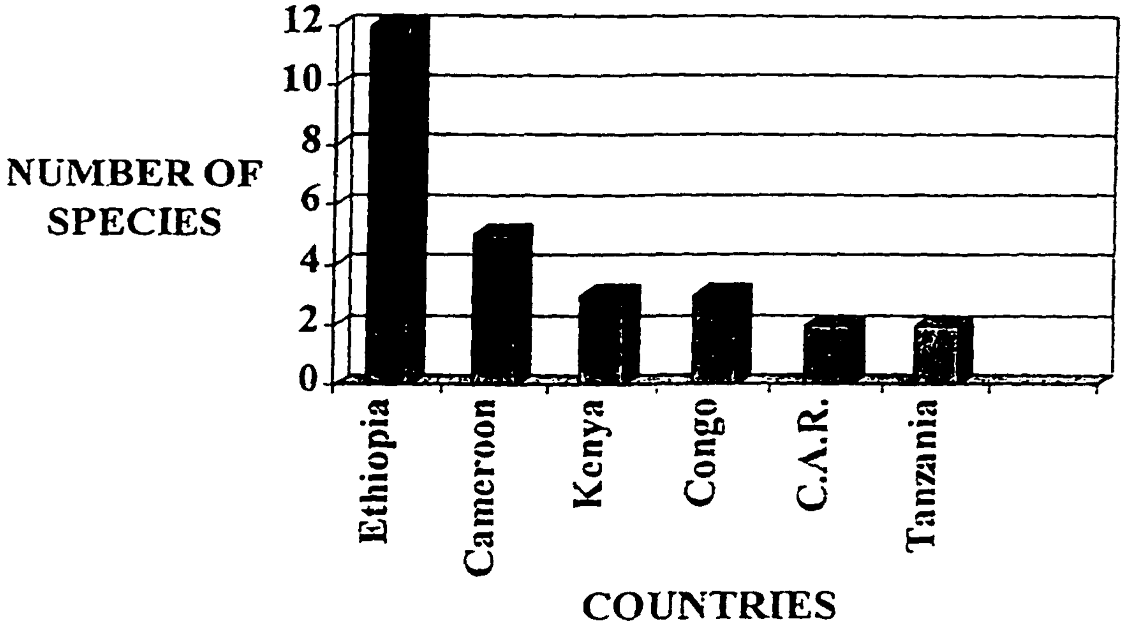
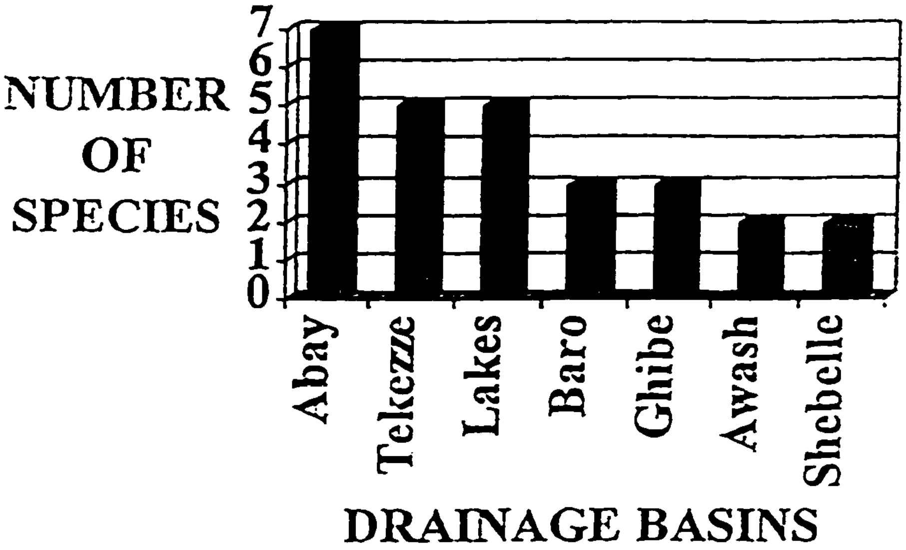

NUMBER OF SPECIES
12
10
8
6
4
2
0
Ethiopia
Cameroon
Kenya
Congo
C.A.R.
Tanzania
COUNTRIES

Fig.83

Number of species of *Garra* in the drainage basins of Ethiopia


NUMBER OF SPECIES
7
6
5
4
3
2
1
0
Abay
Tekezze
Lakes
Baro
Ghibe
Awash
Shebelle
DRAINAGE BASINS

APPENDIX 1.

Biology and ecology of *Garra*

The biology and ecology of the genus is poorly known. Some work is included in Hora (1922 and 1923); in Matthes (1963) regarding feeding and in Krupp (1983) regarding habitat, feeding and reproduction of some species from the Arabian Peninsula. Karyological findings for three African species (*G.dembeensis, G.makiensis* and *G.quadrimaculata*) are presented by Krysanov and Golubtsov (1993), who confirmed that the diploid chromosome number (50) in these African species is no different from their studied counterparts from Asia. Tubercles of two Asian *Garra* species have been studied by Wiley and Collette (1970). Some remarks on the unculi (= horny projections arising from single cells) of *Garra* is mentioned in Roberts (1982). Microanatomy of the gills of *G.lamta* is given in Ojha (1997) and some osteological data are found in Ramaswami (1952, 1955).

a. Feeding

The mouth is inferior and transverse with more or less developed lips. In Labeinae (Reid, 1978) in general there is, during early ontogeny, a ventral shift in the position of the mouth opening. *Garra*, as all cyprinid fishes, possess numerous mucus cells in the bucco-pharyngeal mucosa, as well as developed taste buds, which are believed to be particularly numerous in herbiverous species (Girgis, 1952).

Garra are bottom living omniverous rheophilic scrapers feeding on algae, other phytoplanktons and also small invertebrates. It has been recorded (Jones, 1941 in Reid, 1978) that there is a dietary switch, which includes increasing quantities of algae, particularly unicellular forms during the juvenile phase. According to the classification given by Sibbing (1991) members of the genus *Garra* are of the Biting and Scraping type and the fluted inner margin of the rostral fold suggests a rasping and gripping function (Reid, 1978). Food is scraped off the substrate by the sharp jaw edges and then sucked in through alternating dilation and contraction of the bucco-pharyngeal cavity (Matthes, 1963). According to Matthes (1963), in Cyprinidae in general, the sorting process takes place inside the mouth and anterior pharyngeal cavity, rejected material being spit out through the mouth. This is unlike the situation in other groups of fishes in which unwanted materials are rejected through the gill openings. This contrasts the view of Hora (1923) who mentions that in *Garra* undesirable particles entering the buccal cavity pass through the gill openings

Garra have no stomach and the oesophagus leads directly to the intestine although there is a sphincter separating the two. The length of the intestine differs according to the dominant food type, being longer in those mainly feeding on plant materials. The length of the intestine is an interesting character in *Garra* and shows significant variations among the species (see discussion in the intestine section of character analysis).

b. Reproduction

African species do not show sexual dimorphism and dichromatism. Tubercles have been claimed to be found only in males (Krupp, 1982). According to this report, " the snout of females is pointed while it is more rounded in males. In addition a small bulge at the level of the nostrils is present in males. Horny tubercles are larger and more frequent in males than in females. Furthermore, males have larger dorsal and pectoral fins".

However, Krupp (1983), later, reversed the above view and established the absence of sexual dimorphism and the occurence of tubercles in both males and females of *Garra*. I realized that

even after dissection, only mature females with eggs can be sexed. The absence of sexual dimorphism within karotypes of three African *Garra* species (*G.dembeensis*, *G.makiensis* and *G.quadrimaculata*) has also been noted by Krysanov and Golubtsov (1993) .

During maturity the gonads occupy a large portion (more than 75% in some species) of the body cavity. 400 -1000 eggs have been counted from each individual female. An average of the diameter of the eggs is 1.77 mm. Individuals were found sexually mature at a standard length as low as 70mm. The breeding behaviour of the genus is not known. Migration to rivers during spawning, in the case of lacustrine species, is presumed (Skelton et al., 1991 for related groups).

APPENDIX 2.

Cleared and stained materials examined:

SPECIES	CATALOG NO.	NO. OF SPECIMENS
Garra aethiopica	AMNH 223649	1
	AMNH 223672	1
	AMNH 223674	1
Garra blanfordii	AMNH 223686	3
G.congoensis	MCZ 50516	1
G.dembecha	AMNH 223693	2
G.dembeensis	AMNH 223771	1
	AMNH 223788	1
G.duobarbis	AMNH 223736	2
G.geba	AMNH 223747	4
G.ignestii	AMNH 223800	2
G.imberbis	AMNH (98-025)	1
G.makiensis	AMNH 223774	3
	AMNH 223770	2
	AMNH 223789	1
G.microstoma	AMNH 228487	1
G.nasuta	AMNH (98-024)	2
G.quadrimaculata	BMNH 1940.2.15.2-11	2
G.rossica	AMNH 355335	4
G.tana	AMNH 227687	2
G.cambodgiensis	ANSP 88037	1
G.tibanica	MCZ 61315	1
Crossocheilus latius diplochilus	USNM 271252	2
Discocheilus wui	Unregistered (AMNH)	1
Discogobio yunnanensis	Unregistered (AMNH)	1
Epalzeorhynchus frenatus	AMNH 10202	2
E.kalopterus	ANSP 57531	1
	ANSP 57537	1
E.munensis	AMNH 77916	2
Labeo niloticus	AMNH 9548	1
Paracrossocheilus acerus	AMNH 36375	1
P.vittatus	AMNH 48926	1

APPENDIX 3.

Radiographs examined:

SPECIES	CATALOG NUMBER	NO. OF SPECIMENS
G.aethiopica	AMNH 223649	8
	AMNH 223672	6
	AMNH 223674	15
	AMNH 223676	1
	MNHN 1927-125	1
	MNHN 1927-126	1
G.blanfordii	AMNH 223686	30
G.dembecha	AMNH 223702	27
	AMNH 223689	1
	AMNH 223700	9
	AMNH 223724	2
	AMNH 2223735	3
	AMNH 223796	3
	AMNH 223805	3
G.dembeensis	AMNH 223673	11
	AMNH 223705	12
	AMNH 223758	6
	AMNH 223731	1
	AMNH 223650	6
	AMNH 223663	4
	AMNH 223665	7
	AMNH 223681	7
	AMNH 223782	6
	AMNH 223653	4
	AMNH 223657	4
	AMNH 223668	3
	AMNH 223671	6
	AMNH 223683	5
	AMNH 223690	1
	AMNH 223771	4
	AMNH 223653	5
	AMNH 223788	1
G.duobarbis	AMNH 223736	8
G.ethelwynnae	BMNH 1950.5.31:20	1
	BMNH 1950.5.31:19	1
G.geba	AMNH 223747	10
G.ignestii	AMNH 223738	6
	AMNH 223744	6
	AMNH 223749	6
	AMNH 223752	6
	AMNH 223759	6

G.lancrenonensis	MNHN 1959-227	7
G.makiensis	AMNH 223774	4
	AMNH 223656	4
	AMNH 223666	15
	AMNH 223669	5
	AMNH 223670	2
G.microstoma	AMNH 228486-228487	3
G.quadrimaculata	SMF 5396	1
G.rossica	BMNH 1919.8.16:1	1
G.rothschildi	MNHN 1905-246	1
	MNHN 1905-247	1
G.tana	AMNH 223824	1
	AMNH 227687	8
	AMNH 227688	3
	AMNH 227689	1
	AMNH 227690	5
	AMNH 227691	7
	AMNH 227693	3
	AMNH 227695	3
G.tibanica	BMNH 1940.2.15:2-11	8
G.tibanica ghorensis	SMF 16436	1
G.trewavasae	BMNH 1950.5.1:265	1
G.trewavasai	MNHN 1950-75	1
G. waterloti dageti	BMNH 1952.12.31:12-17	6
	MNHN 1950-76	1
G.w. waterloti	MNHN 1935-189	4
	MNHN 1935-190	2

APPENDIX 4

Alcohol Preserved Specimens Examined (Other than the African *Garra*):

SPECIES	CATALOG NO.	NO. OF SPECIMENS
Garra bicornuta	AMNH 29713	2
G.lamta	AMNH 13950	4
G.nasuta	Unregistered	4
G.orientalis	AMNH 8431	1
G.rossica	AMNH 35533	10
G.rufa rufa	AMNH 40950	4
G.shismatorhyncha	AMNH 8313	1
G.spinosa	ANSP 57410	10
G.taeniata	ANSP 57440	1
G.taeniatops	ANSP 61693	9
Cirrhinus molitorellus	AMNH 37020	2
Crossocheilus latius diplochilus	USNM 271252	6
Discocheilus wui	Unregistered	1
Discogobio yunnanensis	Unregistered	1
Epalzeorhynchus frenatus	ANSP 57531	3
	ANSP 57537	4
Labeo alluadi	ANSP 60372	1
	ANSP 87301	1
L.bicolor	AMNH 59182	9
L.parvus	AMNH 215411	4
Osteocheilus borneensis	AMNH 9492	1
O.vittatus	AMNH 9505	1
Paracrossocheilus acerus	AMNH 36375	1
Semilabeo notabilis	AMNH 12766	1
Tylognathus siamensis	AMNH 36379	2
Varicorhinus ruwenzori	AMNH 71916	2

APPENDIX 5

*Garra dembeensis (*Rüppell, 1836) (Osteichthyes: Cyprinidae): Proposed designation of a neotype.

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Abstract: The purpose of this application is to designate a neotype for *Garra dembeensis* (Rüppell 1836). The type specimen of this species can not be found in Senckenberg Museum. The assumption is that it has never been deposited and the description was based on field observation.

Keywords. Nomenclature; taxonomy; cyprinids; *Garra dembeensis*

1. Rüppell (1836, p.16) described this species as *Chondrostoma dembeensis* from "Dembea" Lake (now Lake Tana), at Goraza, Abyssinia (now Ethiopia). No type specimen of this species has been deposited in the Senckenberg Musuem. This has been confirmed by direct visit and information obtained from the responsible person of the Museum (Uwe Zajonz). According to him, all specimens deposited in the Senckenberg Museum by Rüppell are mentioned in his handwritten notes. And *G.dembeensis* is not one of them. It is, thus, assumed that Rüppell described the species depending on field observation. The description does not explicitly mention some of the distinguishing features of the species (e.g. the type of disc, the extent of the cover of scales). Besides, the illustration given by Rüppell is a lateral view of the species and it doesn't show the development of the disc, nor the scales on chest and belly which are important diagnostic features in *Garra*.

2. Menon (1964, p. 199, 200), without commenting on the absence of the type specimen, synonymized some species (e.g. *Discognathus vinciguerrae* and *D.giarrabensis*) with *G.dembeensis*. These nominal species have considerable differences from *G.dembeensis* and are, rather, junior synonyms of *G.blanfordii* (Getahun, in preparation), which further complicates the proper identification of *G.dembeensis*.

3. *G.dembeensis* is widely distributed in Africa from Ethiopia in the east to Nigeria in the west and Egypt in the northeast to Tanzania in the southeast. In the absence of a type specimen and a figure showing the ventral part of the body, it can easily be confused with some other species from these areas.

4. The neotype was collected from the same locality, Lake Tana, Ethiopia and is described with an illustration showing both the ventral and dorsal features (Getahun, in preparation).

5. The neotype is designated as part of a review work on the taxonomy of the African species of the genus *Garra*.

6. The neotype is deposited at the American Museum of Natural History (AMNH 223731) and can easily be accessed.

The above conditions fulfill all requirements of the International Commission on Zoological Nomenclature (Article 75) for designating a neotype.

7. The International Commission on Zoological Nomenclature is accordingly asked to approve the specimen AMNH 223731 as the neotype of *G.dembeensis*.

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APPENDIX 6

Body Shape Comparison between *G.blanfordii and G.dembecha* spec.nov.

Although attempts to compare shapes (forms) using landmarks (homologous points on the body of animals) started as early as the time of Thompson (1961), major breakthrough especially in the study of biological forms took place after mid -80's (Bookstein, 1982; Strauss and Bookstein, 1982; Bookstein et al., 1985). The study of shape differences in biological forms, Geometric morphometric, is now a rapidly evolving field and a series of recent workshops followed by organized publications (e.g. Rohlf and Bookstein, 1990; Bookstein, 1991; Marcus et al., 1996) has brought it to the attention of many researchers.

Geometric morphometric has obvious advantages over the traditional morphometric measurements. Problems such as focussing on a limited axis (mostly longitudinal), uneven coverage, repeated use of some features, use of external land marks, using too long measurements that have no information on local differences are inherent to the traditional sets of characters. Moreover it is not possible to recover the shape of the original form from the usual data matrices of distance measures (Rohlf and Marcus, 1993). Generally, the geometric method has advantages in that:

1. The difference in shape can be quantified and
2. The difference in shape can be visualized.

Therefore its use in the study of Invertebrates (Stone, 1998) Higher Vertebrates (Corti and Fadda, 1996); Fish Biology (Carpenter, 1996; Corti, et.al., 1996; Loy et al., 1998; Reis,et al., 1998) and Fish Systematics (Schaefer and Provenzano, 1993; Schaefer and Lauder, 1996) has ever been increasing. There have also been attempts (Fink and Zelditch, 1995;

Zelditch, et al., 1995) to use geometric morphometric in phylogenetic studies, but not without controversies
(Pimentel and Riggins, 1987; Crowe, 1994; Bookstein, 1994,1998; Adams and Rosenberg, 1998; Rohlf, 1998; Zelditch et. al., 1998). However, there is no dispute over it being an indespensable tool in delimiting species in alpha taxonomy.

Although morphometric has been employed in a number of cyprinid studies (e.g. Schaefer and Cavender, 1986; Ross and Cavender, 1981; Smith, 1973; Matthews, 1987) the new geometric morphometric method is still awaiting application in cyprinids. Detailed discussion of the application of morphometrics in cyprinid fishes with review of the method is given by Schaefer (1991).

In this work, the new geometric morphometric method is applied to identify shape differences between a pair of supposedly different species showing shape differences.

G.blanfordii Versus G.dembecha

From these two species from the same drainage basin 11 homologous (operational) landmarks (Fig.46) were identified from radiographs of 30 specimens each and the coordinates archived using a digitizing tablet and a software "winwedge". To detect the shape differences of these two species the 11 landmarks of the 60 specimens of the two species were superimposed (sensu Rohlf and Slice, 1990) using relative warp program of Thin Plate Spline and a consensus was found (Fig.46). The trajectories show the variations among the landmarks of the specimens. To take care of the within variation vs the between variation the alligned data was subjected to MANOVA using SAS and a significant difference was obtained (Table 35A). To further confirm this result, redundant distance measures (sensu Rohlf and Archie, 1978) between the landmarks were taken and converted to ratios using standard length inorder to correct for the effects of size and subjected to MANOVA using SYSTAT. A similar result was obtained (Table 35B).

The shape was also regressed on centroid size to visualize the ontogenetic differences using TPSREG following Loy et al. (1996, 1998). TPSREG gives a visual representation of allometry simultaneously for all landmarks. Accordingly, *G.blanfordii* (Fig 47A) generally shows deeper head and body as compared to *G.dembecha* (Fig.47B) in both small and large specimens. It is also evident that they show opposite body shape pattern with increase in size. *G.blanfordii* shows concavity on the dorsal side of body at small size and convexity when grown while the new species shows convexity at small size and concavity at larger size.

APPENDIX 7

ALCOHOL PRESERVED WHOLE SPECIMENS

G.aethiopica	AMNH 223672	9
G.allostoma	CAS 66740	2
G.blanfordii	AMNH 223686	30
G.congoensis	MRAC 118291-118295	4
G.dembecha	AMNH 223693	25
G.dembeensis	AMNH 223730	1
G.duobarbis	AMNH 223736	8
G.ethelwynnae	BMNH 1950.5.31.19	1
G.geba	AMNH 223747	7
G.hindii	CAS 52603	2
	BMNH 1937.12.11.6-15	8
G.ignestii	AMNH 223739	29
G.makiensis	AMNH 223667	3
	AMNH 221323	14
G.microstoma	AMNH 228486, 228487	2
G.ornata	MCZ 48319	1
	AMNH 6135	1
G.quadrimaculata	SMF 5396	1
	SMF 5403	1
	BMNH 1940.2.15.2-11	9
G.tana	AMNH 223824	1
G.bicornuta	AMNH 29713	1
G.nasuta	AMNH 98-024(field number)	4
G.imberbis	AMNH 98-025(field number)	1
G.lamta	AMNH 13950	1
G.rufa	AMNH 40950	3
G.rossica	AMNH 35533	10
G.taeniata	ANSP 88037	15
Barbus bynni	AMNH 215380	5
Cirrhinus molitorellus	AMNH 37020	2
Crossocheilus latius	USNM 275380	4
Discocheilus wui	Uncataloged	1
Discogobio yunnanensis	Uncataloged	1
Eplazeorhynchos frenatus	ANSP 57531	4
	ANSP 57537	4
E.bicolor (Labeo bicolor)	ANSP 60372	1
	ANSP 87301	1
Labeo alluadi	AMNH 215411	3
L.parvus	AMNH 59182	9
Osteocheilus bornensis	AMNH 9492	1

O.vittatus	AMNH 9505	1
Paracrossocheilus acerus	AMNH 36375	1
Semilabeo notabilis	AMNH 12766	1
S.procheilus	USNM 89302	1
Tylognathus siamensis	AMNH 36379	2
Varicorhinus ruwenzorii	AMNH 71916	2

APPENDIX 8

CLEARED AND STAINED MATERIALS

G.aethiopica	AMNH 223672	2
G.blanfordii	AMNH 223686	1
G.congoensis	MCZ 50516	1
G.dembecha	AMNH 223693	2
G.dembeensis	AMNH 223771	7
G.duobarbis	AMNH 223736	2
G.geba	AMNH 223747	3
G.hindii	BMNH 1937.12.11.6-15	2
G.ignestii	AMNH 223800	2
G.makiensis	AMNH 223774	3
G.microstoma	AMNH 228487	1
G.ornata	USNM 338282	2
G.quadrimaculata	BMNH 1940.2.15.2-11	2
G.tana	AMNH 227687	2
G.bicornuta	AMNH 29713	1
G.nasuta	AMNH (98-024-field number)	2
G.imberbis	AMNH (98-025-field number)	1
G.lamta	AMNH 13950	1
G.rufa	AMNH 40950	1
G.rossica	AMNH 355335	3
G.cambodgiensis	ANSP 88037	1
Barbus ablabes	AMNH 32726	3
B.barbus	AMNH 54635	3
B.matsudai	AMNH 11104	5
Cirrhinus chinensis	AMNH 37021	2
Crossocheilus latius	USNM 9548	2
Epalzeorhynchos kalopterus	AMNH 10202	2
E.munensis (Labeo erythrurus)	AMNH 77916	2
Paracrossocheilus acerus	AMNH 36375	1
P.vittatus	AMNH 48926	1
Osteocheilus melanopleurus	AMNH 14574	1
O.salsburyi	AMNH 10624	3
Semilabeo procheilus	USNM 89302	1
Discocheilus wui	Uncataloged (AMNH)	1
Discogobio yunnanensis	Uncataloged (AMNH)	1
Labeo niloticus	AMNH 9548	1
Varicorhinus robustus	AMNH 10691	2
V.tamusiensis	AMNH 11634	2

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