A TAXONOMIC REVISION OF THE SHALLOW-WATER SPECIES OF THE GENERA *LETHRINOPS*, *TRAMITICHROMIS* AND *TAENIOLETHRINOPS* (TELEOSTEI, CICHLIDAE) FROM LAKE MALAWI/NYASA/NIASSA (EAST AFRICA).

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Disclaimer

The statements in this thesis are disclaimed for the purpose of Zoological Nomenclature in accordance with the International Code of Zoological Nomenclature, fourth edition, article 8.3

Abstract

In order for the SADC/GEF Lake Malawi/Nyasa Biodiversity Conservation Project to draw out sound strategic management and conservation recommendations to the riparian countries of Malawi, Mozambique and Tanzania, the need and urgency for revising the taxonomy of some of the scientifically and economically important fish groups was accorded high priority. This study is a contribution towards achieving those goals. It is a taxonomic revision of the shallow-water species of the genera *Taeniolethrinops, Tramitichromis* and *Lethrinops*. These three genera are grouped as *Lethrinops* 'sensu lato' in this thesis, corresponding to the definition of *Lethrinops* prior to the revision by Eccles & Trewavas (1989). All members have a characteristic dentition: the outer teeth in the lower jaw curve inwards posteriorly ending just behind the inner row(s), rather than continuing backwards as a single series, as in most other Malawian haplochromines.

The decision to consider shallow-water *Lethrinops* 'sensu lato' separately from the deep-water ones was not arbitrary, but rather based on available ecological and morphological evidence. Unanticipatedly, on the course of this study, evidence from molecular genetics has helped to strengthen the distinction.

Economically, *Lethrinops* is important for human food and for the aquarium trade.

Lethrinops are precocial fish producing very few young at a time and are consequently unlikely to recover quickly from heavy fishing pressure.

To evolutionary biologists, *Lethrinops* 'sensu lato' is challenging because until now most theories about the evolution of Lake Malawi cichlids have not taken the sand-dwelling fishes fully into consideration. A better knowledge of the distribution patterns of these cichlids, of which *Lethrinops* are the major representatives, can help in explaining the underlying mechanisms of speciation in sand-dwelling cichlids.

Lethrinops 'sensu lato' is taxonomically one of the most complex groups of Lake Malawi/Nyasa haplochromines. The species are closely related and very difficult to differentiate, and the taxonomy is confused and in urgent need of revision. This is more important since taxonomy plays an important role in most of the key criteria of conservation.

The principal objective of this study was to carry out a taxonomic revision of this group and to provide a key to the identification of the species. Further objectives include the mapping of their distribution and analysing their phylogenetic relationships.
Large samples were collected (by trawling, gill netting, beach seining and purchased from local fishermen) from depths less than 20m and from numerous well-defined localities all around the lake. Seventeen type specimens of the 21 described species of the shallow-water *Lethrinops* 'sensu lato' were examined and compared with this recently collected material.

The data of about 500 fish specimens were subjected to principal component analyses (PCA). To further evaluate morphological differences between taxa of comparable size, non- parametric, distribution-free Mann-Whitney U-tests were used.

Within the shallow-water *Lethrinops* 'sensu lato' three genera are recognized which can be separated by characters such as head shape, pharyngeal morphology and dentition, number and shape of gill-rakers, number of the pectoral fin rays and melanin pattern. So far in this study, 28 taxa have been recognized. The overlapping measurements and meristics compound the difficulty inherent in the identification and classification of members of the three genera. The genera *Tramitichromis* and *Taeniolethrinops* are typically shallow- water taxa. Within the genus *Taeniolethrinops* four described species, (*T. cyrtonotus*, *T. furcicauda*, *T. laticeps* and *T. praeorbitalis*) were distinguished. Within the genus *Tramitichromis* nine species were distinguished, five of which are described (*T. brevis*, *T. intermedius*, *T. lituris*, *T. trilineata* and *T. variabilis*); four represent undescribed species and are given a working name (*T.* sp. 'brevis 2', *T.* sp. 'maculae', *T.* sp. 'pharyngeals' and *T.* sp. 'variabilis deep'). For convenience, the shallow water *Lethrinops* 'sensu stricto' were divided into three natural groups, according to shared morphological features.

- The first group is the *lethrinus* group, including three species (*L. lunaris*, *L. leptodon* and *L. lethrinus*) with relatively long snouts and remnants of the horizontal stripes.

- Another group included eight taxa (*L. microstoma*, *L. macrophthalmus*, *L. macrochir*, *L. auritus*, *L. parvidens*, *L.* sp. 'parvidens deep', *L.* 'black dorsal auritus', *L.* sp. 'domira blotch' and *L.* sp. 'turneri') with a relatively short snout and a small mouth set low on the profile. Within this group, special attention has been paid to the confusion involving *L. auritus* and a new species to be described soon, *L.* sp. 'turneri'.
- The last group of *Lethrinops* 'sensu stricto' is ill defined and has an intermediate snout and with a lesser round head. Within this group *L. oculatus*, which was described on the basis of a single specimen, is synonymised with *L. marginatus*. The other valid species of this group are *Lethrinops albus* and *L. furcifer*.

Nearly all species seem to have a lake-wide distribution. All are associated with sandy substrata where they feed mainly on insect larvae and ostracods. Mitochondrial DNA sequence data indicate that *Lethrinops* 'sensu lato' as currently defined is not monophyletic but is paraphyletic or more probably polyphyletic. It is further suggested that the typical *Lethrinops* dentition provides no particular strong evidence for affinity among shallow-water *Lethrinops* s.s., *Tramitichromis* and *Taeniolethrinops*.
The need for management and conservation of this scientifically exciting group of fishes has been pointed out.

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This thesis is dedicated to the cherished memory of my late parents, Peter & Eva.

LIST OF ABBREVIATIONS

The following abbreviations have been used in this thesis (other abbreviations as explained in the text).

BMNH:	British Museum (Natural History), London.
cf:	'confer' (compare).
CLOFFA:	Check-list of Freshwater Fishes of Africa.
DNA:	Deoxyribonucleic acid.
e.g. :	'exempli gratia' (for example).
et al. :	'et alii' (and others)
GEF:	Global Environmental Facility (in this case, of the World Bank).
i.e. :	'id est' (that is)
MRAC	Musee Royal de l'Afrique Centrale, Tervuren, Belgium.
pers. comm. :	personal communication
pers. obs. :	personal observation.
RUSI:	Rhodes University Smith Institute (JLB Smith Institute of Ichthyology, a National Facility of the National Research Foundation, South Africa).
SADC:	Southern African Development Community.
SMRC :	specific mate recognition concept.
SMRS :	specific mate recognition system(s).
s.l. :	'sensu lato' (in the wide sense).
s.s. :	'sensu stricto' (in the strict sense).
viz. :	'videlicet' (namely)
vs:	versus.
ZMB:	Zoologisches Museum der Humboldt-Universität, Berlin.

Chapter 1: Introduction

The present thesis is aimed at providing a detailed morphological study of the shallow-water species of the haplochromine genera *Lethrinops*, *Taeniolethrinops* and *Tramitichromis*, as defined by Eccles & Trewavas (1989). These three genera are collectively referred to as *Lethrinops* 'sensu lato' and correspond to the genus *Lethrinops* as defined by Trewavas (1931). The principal aim is to provide an improved set of species diagnoses and species descriptions. Data on distribution patterns and phylogenetic relationships of the species will supplement these species descriptions.

1.1 Lake Malawi/Nyasa

Lake Malawi, otherwise known as Lake Nyasa in Tanzania and Lago Niassa in Mozambique, is the southern most lake of the Great Rift Valley lakes (Fig. 1.1). In this text the lake will be referred to as Lake Malawi/Nyasa or sometimes just simply 'the lake'. Lake Malawi/Nyasa, the ninth largest in the world and the third largest in Africa, is estimated to be 630 km long, with a surface area of approximately 30800 square km and a maximum width of about 90 km. It is, however, prodigiously deep with a maximum depth of over 700 m and has a shoreline length of some 1500 km (Hutchinson, 1957; Paterson & Kachinjika, 1995). The lake lies between 9^{o} 30'S and 14^{o} 30'S at an average altitude of about 500m above sea level (Eccles, 1974; Eccles, 1984). Areas of greatest depth occur in the northern portion, which is bordered by steep, rocky shores; further south the lake is comparatively shallow and fringed by low-lying land consisting of sandy beaches alternating with areas of water-weed and swamp. The combination of the lake bathymetry and tropical climatic conditions produces thermal stratification of the lake, with the oxic-anoxic boundary layer down to 230-250 m depth (Beauchamp, 1953; Crossley, 1982; Delvaux, 1995). More detailed examination of the water column by Gonfiantini et. al. (1979) described an epilimnion from 0-125 m depth, metalimnion from 125-230 m and hypolimnion below 230 m. It has been shown that the metalimnion-hypolimnion boundary is maintained by a density difference mainly due to higher salinity in the hypoliminion (Paterson & Kachinjika, 1995). Eccles also reports that below 250m, the lake is homothermal at about 22.5°C and anoxic. In the northern part, plant nutrients are limited because of the meromictic character of the lake, but in the shallow south a mixing of nutrients and oxygen occurs throughout the water column, making this an area of high productivity. It is this contrast in environment that results in richer fishing grounds in the south than further north. Table 1.1 below gives a summary of the most important physical and chemical characteristics of the lake.

Table 1.1: Summary of physical and limnological data for Lake Malawi/Nyasa. From Ribbink (1994).

Position	9° 30′-14° 40′S, 33° 50′-33° 36′E
Altitude	474 m above sea level
Maximum depth	756-785m
Mean depth	290-426m
Depth of oxygenated water	170-210m
Volume	8400km^3
Shoreline	1500km
Maximum length	630km
Maximum width	87km
Temperature	Surface 23-29°C, Hypolimnion 22.1-22.5°C
Secchi-disk transparency	12-20m
pH	Surface 7.9-9.1, at 300m 7.8
Conductivity	Surface 215-225µscm^{-1}, at 300m 220-230µscm^{-1}
Primary productivity	252 g cm^{-2}yr^{-1}
Major in-flowing rivers	Nine (9)
Out-flowing river	One (1)
Out flow rate	12km^{3}yr^{-1}
In flow rate	29 km^{3}yr^{-1}
Precipitation	41 km^{3}yr^{-1}
Evaporation	54 km^{3}yr^{-1}
Annual lake fluctuation	0.7-1.8m
Flushing time	750yrs
Residence time	140yrs
Age	1-2myr
Number of lake basins	One (1)
Cool dry period	June - August
Hot dry period	September - November
Wet season	December - May

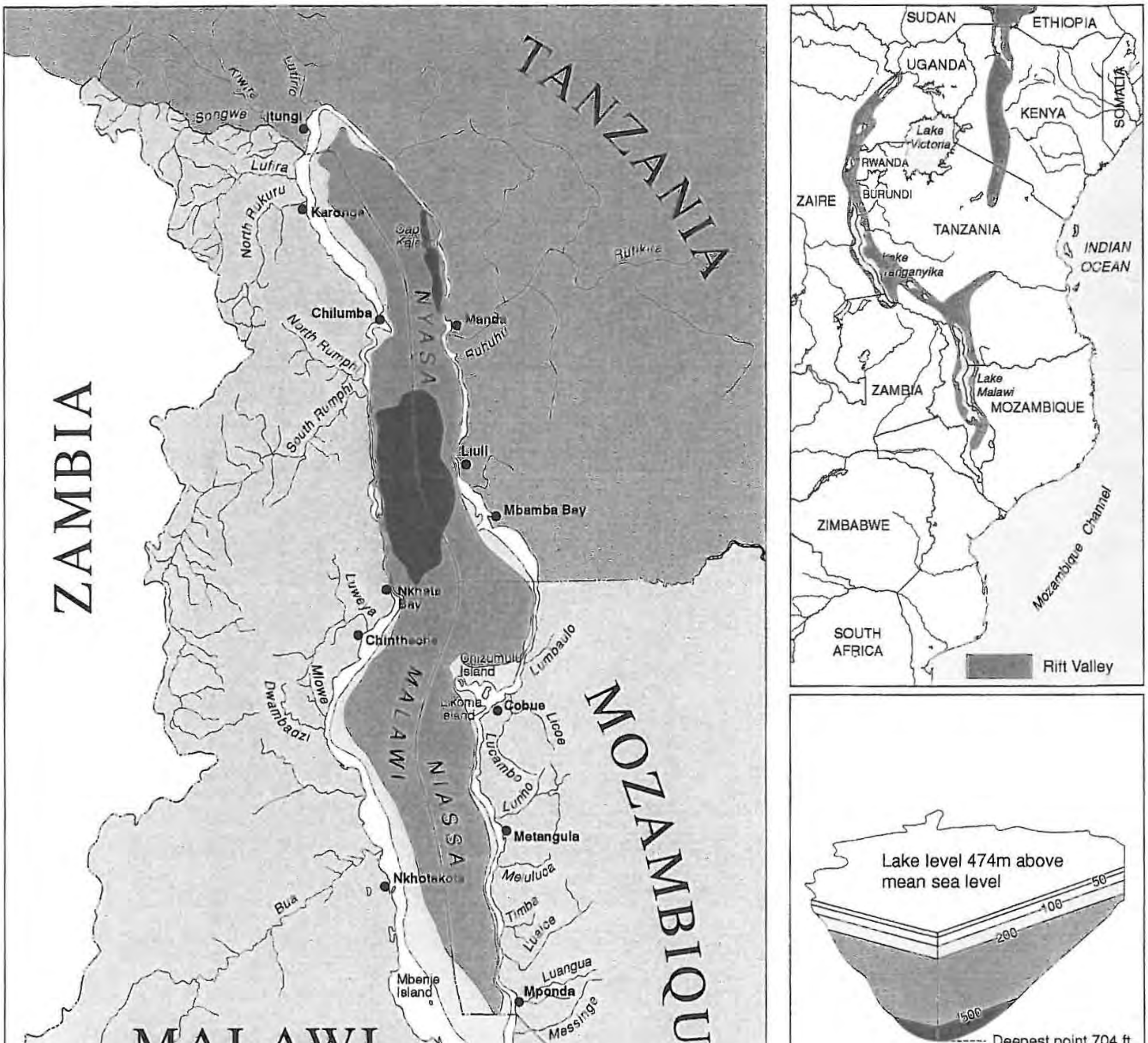


Fig. 1.1. The lake, the catchment and the Rift Valleys.

Because the lake lies in the Rift Valley, much of the shoreline is defined by faults that form steep rocky scarps especially on the eastern side of the lake, but there are also long stretches of sandy beaches and reedy shores. McKaye & Gray (1984) plotted the shoreline types on the western shore of Lake Malawi from the entrance to the Shire river in the south to Karonga in the north, and found that 60.2% was sand, 20.9% vegetation and 18.9% rock, but that these habitats were not distributed uniformly. Many evolutionary scientists postulate that the alternation of sandy or swampy shores with steep rocky coasts has been, and still is, an important factor in the speciation of the Lake Malawi/Nyasa cichlids.

Lake Malawi/Nyasa is an ancient lake, it is estimated to have been formed between one to two million years ago (Banister and Clark, 1980). Some workers, however, suggest that the lake was formed during the Miocene between 2.5 and 5 million years ago (Rosendahl and Livingstone, 1983). Delvaux (1995) reports that the age of formation of this deep water lacustrine system is still controversial, but considers that the Malawi rift basin, hosting the lake, started to develop in late the Miocene (8.6 million years ago), but deep water conditions were acquired only by 4.5 million years ago. The lake then dried out almost completely at the beginning of the Pleistocene (from 1.6 to 1.0 million years ago), as a consequence of stable tectonic conditions and dry climate.

1.2 The fish fauna of Lake Malawi/Nyasa

The ichthyofauna of the lake is marked by a high species richness mainly represented by endemic species of cichlids.

Lake Malawi, with an estimated 700-1000 fish species (Snoeks, 1997 unpublished data), contains the richest community of freshwater fish species in the world. Eleven fish families are represented in the lake, but the family Cichlidae shows the greatest species-richness and with over 99 percent of its species occurring only in Lake Malawi, it has a great degree of endemicity (Table 1.2). These cichlids occupy all the major habitats with communities characterising the sandy, muddy, open-water, vegetated and rocky habitats. This work focuses on fish of the sandy habitat.

Table 1.2: Fish fauna of Lake Malawi/Nyasa; *introduced
Source: Snoeks, unpublished

Family	Number of species in the lake	% endemism
Protopteridae	1	0*
Anguillidae	1	0
Mormyridae	6	0
Characidae	2	0
Cyprinidae	14	64
Bagridae	2	100
Clariidae	15	80
Mochokidae	4	50-100
Aplocheiliidae	1	0
Mastacembelidae	2	100
Cichlidae	600+	99

1.3 The Cichlid Fishes

Before considering the theories put forward to explain the evolution of the Lake Malawi/Nyasa cichlids, it is necessary to establish at the onset exactly what a cichlid is and to see how a member of this family can be recognised and distinguished from members of other families. A formal diagnosis is not called for but it is convenient to list some of the most obvious characteristics of the family. Cichlids are bony, perch-like freshwater fishes whose body is usually bilaterally compressed. They can be distinguished from the other families that comprise the order Perciformes by certain characteristics. There are specialised features that are uniquely shared by cichlids (synapomorphies) and absent in non-cichlids. It is precisely these derived characteristics that are most reasonably interpreted by evolutionary scientists as having been inherited from common ancestors and therefore give cichlids genealogical ties of common ancestry (Stiassny, 1993).

Cichlids and some of their close relatives have two sets of jaws: the oral jaws (the mouth jaws) are specialised in prey capture or food gathering (just like human hands!)

while the second set, the pharyngeal jaws (the throat jaws), are specialised in food processing.

All cichlids, regardless of what they eat, have a fixed pattern of spatial relations between the stomach and the intestine. The cichlid intestine always exits the pouch-like stomach from the left side, and the first intestinal loop always lies on the left side of the fish.

Apart from the above anatomical features there are also behavioural traits that bear testament to their shared evolutionary history common to all cichlids and which are extremely rare in other fish families. This is the behaviour of prolonged parental care, with a major contribution to parenting made by the female fish.

A cichlid is most readily identified by the nostril, the lateral line and the dorsal and anal fins (Fig. 1.3). Unlike most bony fishes which have two pairs of nostrils, in all cichlids there is a single nostril at each side of the head and this feature alone is sufficient to distinguish them from almost all other African freshwater fishes.

All cichlids have an interrupted lateral line system that is divided into upper and lower lines.

All cichlids have a spiny and soft part in both the dorsal and anal fin.

Lastly, it has to be noted that cichlids are mainly freshwater fish, although some can tolerate brackish-water conditions. Many of the characteristics described above are found in other groups of fish too, but most of them are marine fish.

In order to elaborate taxonomic categorisation hierarchy of cichlid classification, a simplified scheme is given in figure 1.2.

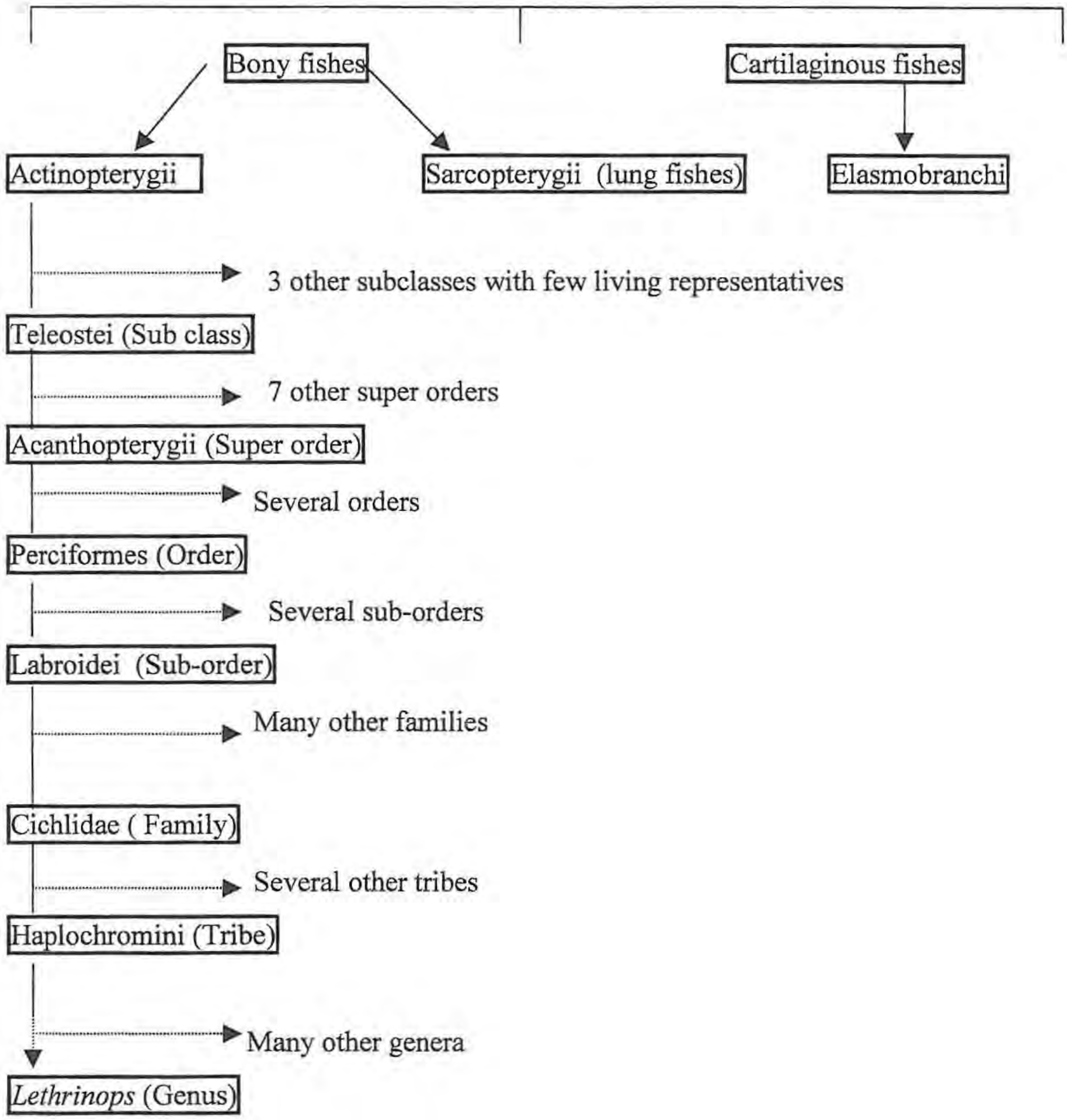


Fig. 1.2. Schematic representation of the hierarchy of cichlid classification (simplified from Nelson, 1994).

Within the order Perciformes, the freshwater family Cichlidae is the biggest group in terms of the number of species.

Cichlids occur naturally in North, South and Central America, Africa, Madagascar, Iran, Syria, the Jordan Valley, south India and Sri Lanka (Lowe-McConnell, 1987). In several regions, cichlids have speciated resulting in richness of species. Nowhere, however, has speciation been as spectacular as in the Great Lakes of Eastern Africa: Lakes Malawi/Nyasa, Tanganyika and Victoria (Fryer & Iles, 1972). The spectacular endemic faunas of these lakes and the importance of their fisheries have stimulated a large amount of ecological research. In addition, the spectacular speciation among cichlid fishes makes these lakes prime sites in the world for the study of speciation and the roles of ecology and behaviour in evolution.

1.4 Lake Malawi/Nyasa cichlids

In Lake Malawi/Nyasa the family Cichlidae is represented by two groups, otherwise referred to as tribes: The tilapiines, of which there are six species namely *Tilapia rendalli*, *Oreochromis squamipinnis*, *O. lidole*, *O. shiranus*, *O. karongae* and *O. saka*; and haplochromines, of which there were thought to be several hundreds (Ribbink *et al.*, 1983; Greenwood, 1991) but recent figures estimate 700-1000 species (Snoeks, unpublished data).

The fact that Lake Malawi/Nyasa contains more species of fish than any other lake in the world is largely due to its wealth of cichlids. All but a few are endemic and until recently it was postulated that most of them have arisen over the past one to two million years ago, possibly from generalised riverine ancestral forms (Oliver, 1984), although there is absolutely no conclusive evidence at present of the number of ancestral forms.

More striking than the number of species present is the fact that most of the cichlid fishes of Lake Malawi/Nyasa are found only in that lake and nowhere else in the world. There are only four cichlids found in Lake Malawi/Nyasa that are not endemic to the catchment: *Serranochromis robustus*, *Oreochromis shiranus*, *Tilapia rendalli* and *Astatotilapia calliptera*. Two further widespread species, *Pseudocrenilabrus philander* and *Tilapia sparrmanii*, are recorded from the lake catchment but are not known to occur in the main lake.

Eccles & Trewavas (1989) defined haplochromine cichlids as maternal mouth-brooding fishes of Africa and Jordan Valley in which the basioccipital bone participates with the parasphenoid bone to form the apophysis for the upper pharyngeal bones. This definition is valid for all haplochromine cichlids of Lake Malawi/Nyasa, which Eccles & Trewavas (op. cit.) conveniently grouped as follows: -

1. *Astatotilapia* → which is represented in the lake only by one species, *A. calliptera*.

2. The 'Mbuna' → these are a group of small to medium sized, mainly lithophilous species that have been divided into ten genera on the basis of different specialisation of the teeth of the jaw.

3. The *Pharyngochromis-Chetia-Serranochromis* group → the majority of haplochromine cichlids of Lake Malawi/Nyasa have affinities to these Zambezian genera.

Oliver (1984), considered the Lake Malawi/Nyasa species to be oligophyletic, with ancestors allied to *Astatotilapia* and to the *Serranochromis-Chetia* group. He thought that the Malawi 'Mbuna' belonged to the *Astatotilapia* group and the other genera, including the *Lethrinops* 'sensu lato', fell into the '*Serranochromis*' assemblage. These views have now been rejected following recent molecular studies (see Meyer, 1990; Moran *et al.*, 1994 and work being presently conducted at the University of Hull, UK). Their results show that the Malawi cichlids comprise six well-differentiated lineages. However, getting more samples from closely related taxa may help in phyletic relationships of the lineages.

As the results stand all of the following are possible:

- The Malawi haplochromines are monophyletic, but *Astatotilapia calliptera* evolved within the lake and later escaped down the Shire/Zambezi to colonise the east flowing rivers of southern Mozambique. There is however, no evidence for this.
- The Malawi haplochromines are 2 separate lineages. One is *Rhamphochromis/Diplotaxodon*, and we don't know the ancestor/sister group to that clade. The other is made up of all the rest, with *A. calliptera* as ancestor/sister group.
- The Malawi haplochromines could be the result of 3, 4, 5, or 6 separate invasions. From personal point of view this is thought to be very unlikely, as all 6 lineages are closely related, and there are quite a lot of morphological similarities between members of separate lineages (e.g. the 2 groups of *Lethrinops*, the 2 *Copadichromis*, see chapter 7 fig. 7.1 for details). It also presupposes that there were sufficiently differentiated ancestral forms to achieve this.

Of the majority of species presently placed in *Lethrinops*, only *L. lethrinus* is found both in the lake and in the rivers (pers. observ.). It is therefore an example of recolonisation of rivers from the lake by cichlids.

The origin of Lake Malawi/Nyasa cichlids, insofar as they colonised the lake, can be considered in light of the zoogeographical affinities of the lake's ichthyofauna with the riverine sister groups in the drainage system. These systems are believed to consist of the upper Zambezi drainage system and the rivers of the East Coast of Africa. Lake Malawi is connected to the Zambezi River via the Shire River and, according to Skelton (1994), the fish share affinities both with the ichthyofauna of the Zambezian ichthyofauna province and of the East Coast ichthyofauna province.

The only plausible possibility is that the ancestors of the endemic cichlids present in Lake Malawi/Nyasa must have been from more than one river system. Once in the lake the cichlids first acquired habitat specificity followed by intra-habitat speciation.

1.5 Taxonomic approaches

Taxonomy deals with the identification and classification of living creatures and with their identification. It is self evident that until it is possible to identify an animal correctly, much of the value of any observation that may be made on it is lost. For instance, it would not only be of little value, but might be positively misleading, if an investigator seeking to develop a fishery were to be unaware that what he regarded as two species of *Oreochromis*, were in fact morphs of one species. Also, a fishery for two species is likely to be mismanaged if they are not recognised as such, and the consequence can be elimination of one of the taxa (Myers et. al., 1997).

In the process of fish identification and classification there are various techniques or approaches in use and the choice depends partly on the particular interest of the one studying the groups. The geographical location of a taxonomist will considerably influence his research strategy. The breadth of taxonomic approaches has room for students with the most diversified interests and talents. His/her natural inclination will lead him/her to select the area, which is most exciting for him/her. What this means is that there is room in taxonomy for biologists of the most diverse interests. Even the mathematically inclined student can make a contribution by applying mathematics to taxonomy. This does not, however, imply that taxonomists are absolutely free to do what they like. Their contribution to science should always follow the stipulated guidelines and rules of taxonomy. The taxonomic techniques in use can employ morphological, anatomical, biochemical/molecular methods. Sometimes a combination of two, three or more techniques is used in trying to make a description of a new species.

In recent years some non-systematists have proposed to abandon most of the morphological taxonomy as "old fashioned" or useless and to concentrate instead on some specialised areas, such as comparative protein chemistry, the taxonomy of behaviour traits, or principles of geographical variation, etc. (Crowson, 1970). Advocates of such specialised approaches forget a number of things: 1) that the various approaches are not mutually exclusive, 2) that in many groups there is still abundant need for the basic morphological alpha-taxonomy. The most important thing is to achieve a practical and widely applicable technique for identification. For Lake Malawi/Nyasa cichlids there is a lot of essential morphological work needed before anyone can sort out how to identify the species in the field.

1.6 Species concepts

> *"The concept of species seems so simple that it always comes as something of a shock to a beginning taxonomist to learn how voluminous and seemingly endless the debate about the species problem has been"* (Mayrs & Ashlock, 1991).

The most perplexing problem facing a taxonomist with cichlid fishes of Lake Malawi/Nyasa is the primary task of defining and delimiting species. The concept of a species as a group of interbreeding natural population which are reproductively isolated from other such groups, as proposed by Mayr (1942, 1969), is almost universally accepted. However, conclusive establishment of specific distinctness based on preserved material alone poses practical problems. The morphological species concept, which is based on the degree of morphological differences, presents a good working hypothesis for a group of fish of which the alpha-taxonomy is poorly known. In fact, in some cases, it may be the only approach relevant and available (Snoeks, 1994). Paterson (1985), rightly pointed out that, " any view of a species must be cast in genetical terms if it is to be useful in understanding the process of evolution, likewise any view of a species must be cast in morphological terms if it is to be useful in the classification and identification process".

When one is sorting specimens from a single locality, it must be remembered that one is potentially dealing with four possibilities as shown below in the discrimination grid for sympatric samples.

Table 1.3: Discrimination grid for sympatric samples.

Morphology & colour	Not reproductively isolated	Reproductively isolated
Identical	1. Same morph of a single species	3. Sibling species
Different	2. Different morph of the same species	4. Different species

Two of these (1 and 4) pose no problems. However, difficulties arise when individuals are morphologically different but belong to the same species (category 2) or are morphologically identical or exceedingly similar yet belong to different biological species (category 3). Many errors in the taxonomic literature (synonyms) are due to the fact that individuals belonging to category 3 are considered to belong to category 1 or that the individuals belonging to category 4 were considered to belong to category 2. Fryer (1959) considered *Pseudotropheus zebra* to show a high degree of polychromatism and he actually believed that *Ps.* sp. 'zebra cobalt' to be conspecific, but Holzberg (1978) found behavioural and ecological differences between blue black/orange blotch (BB/OB) and blue/white (B/W) forms of *Ps. zebra* complex. The results of Holzberg (1978) led to the view of *Ps. zebra* as having two 'sibbling species' (sibbling species are sympatric and sexually isolated populations which show no, or nearly no morphological differences). Schröder (1980) studied the courtship behaviour of the four colour morphs of *Ps. zebra* and reported that the designated BB, OB, B and W, represented two completely separate gene pools (BB/OB and B/W, respectively), between which no gene flow existed. This justified describing the BB/OB and B/W gene pools as different species. Stauffer & Hert (1992) described *Pseudotropheus callainos* as a new species of the *Ps. zebra* complex, distinguishing it from other members of the complex by the blue colours of the males and blue and white colour morphs of the females, and absence of vertical bars.

In cases where recognised species are morphologically distinct, such morphospecies correspond to biological species (Lewis, 1982). But in Lake Malawi, cichlid evolution has taken place rapidly and resulted in the proliferation of a large number of species many of which are highly similar to one another ('sibling species). Although reproductive isolation, without difference in structures visible in preserved material, is common place, the mode of speciation for haplochromine cichlids is sexually driven, whereby species first change on male colour and only later differentiate in morphology. In such a case, the separation of species on morphological grounds alone becomes difficult or sometimes impossible. The task of a taxonomist is to classify and identify groups among populations that are more closely related to each other than to others, and to define and delimit species among them. Ribbink *et. al.* (1983), when confronted with the same problem in Lake Malawi/Nyasa, decided to apply the Specific Mate Recognition System (SMRS) concept described by Paterson (1978) to delimit species. Snoeks (1994) when working on Lake Kivu haplochromine cichlids based his study on a combination of the SMRS concept and morphological species concept. The SMRS concept defines a species as "that most inclusive population of the individual biparental organisms which share a common fertilisation system" (Paterson 1978, 1980, 1985). This concept stresses the importance of mutual recognition among individuals of the same species as partners in reproduction. For sympatric populations, groups that do not recognise each other, and thus do not regularly interbreed, are considered different species, no matter how similar they are to the human eye.

Characters that are important in species recognition are body shape, coloration, melanin pattern, behaviour and microhabitat. If these characters are the same among two geographically isolated populations then Ribbink et al. (op.cit) assumed the two individuals from allopatric populations would recognise each other if they would meet.

Assortative mate choice among anatomically similar but differently coloured forms have been observed in some cichlid species complexes from Lake Victoria (Seehausen 1996). His results support the applicability of the SMRS concept, but caution that species delimitation among allopatric populations should take into account the following two issues:

First, the concept should address the issue of clinal variation (graded changes occurring within the geographical scale of the study). Specific Mate Recognition System characters are more similar for nearby populations than for populations far apart.

Secondly, the concept should employ a maximum of SMRS characters as differences in one character may not be sufficient to separate species within complexes of closely related allopatric populations.

The practical species concept used in this study is based on a combination of the morphological species concept (small but consistent morphometric and meristic differences between samples) and a component of the SMRS concept (the colour pattern of especially sexually active males and melanin pattern of females and immature males). Therefore, a pair of taxa are regarded as different species if they differ in morphometric and meristic characters, body melanin pattern and male breeding coloration.

Taxonomists traditionally base their species decisions on the degree of morphological similarity of the organism before them (Scoble, 1985). This does not mean that species are merely groups of similar organisms delimited for convenience; rather the morphological similarity among organisms is symptomatic of belonging to the same species. In cases where recognised species are morphologically distinct, such morphospecies correspond to valid species.

Live colour alone is not sufficient to delimit species, since various species may have very similar colour patterns, for example, females and immature males of *Taeniolethrinops praeorbitalis* display a bright yellow coloration on the snout and ventral surface. This coloration is displayed also by *Taeniolethrinops furcicauda* and by *Lethrinops macrochir* but the three species can be easily distinguished by their differences in body and head shape and some meristic characters.

Recently, Turner (1999) has urged that the use of male colour as a key component of the definition of sympatric species as admitted by Ribbink *et al.* (1983) is entirely consistent with the idea that reproductive isolation among species is largely due to strong directional selection by female choice for conspicuous male coloration.

Turner's theory (in postulating sympatric speciation) is that many species arise when polymorphism in female preferences leads to divergent selections for two male colour phenotypes, leading to reproductive isolation (Biological Species Concept!). Other changes appear later, including differences in female/juvenile colour. He however admits that if females of a particular species are very unusual in colour, males may evolve to recognise females on the basis of colour.

But why should the importance of male colour be emphasised in the species definition of Lake Malawi/Nyasa cichlids? Personal observation of pre-mating signals indicate that male cichlids send out a combination of signals and colour is just one of them. Turner (op. cit.) clearly and rightly points out that under strong sexual selection by female choice, we would expect to find that males are larger, are more colourful, and have larger fins that allow them to carry out extravagant and energetically expensive courtship rituals in order to 'impress' conspecific females. So it appears that male success is a function of a combination of a number of visual signals. These signals must be visualised by females and appreciated before males are preferentially selected. The male pre-mating reproductive signals may act synergistically or additively.

Most members of *Lethrinops* 'sensu lato' are very difficult to distinguish, particularly if male courtship colour is not known. Among species that display complex courtship behaviour such as the shallow-water sand-dwelling *Lethrinops* from Lake Malawi/Nyasa (pers. observ.), coloration, particularly of breeding males which initiate the mating ritual, plays an important role in species distinction.

1.7 Taxonomy of *Lethrinops* : Historical background

The genus *Lethrinops* was erected by Regan in 1922 by making a distinction between haplochromine cichlids with a pure '*haplochromis*-type' of oral dentition and those that had a '*Lethrinops*-type' dentition. In *Lethrinops*, the outer row of teeth in the lower jaw curves inwards posteriorly ending just behind the inner row(s), not continuing backwards as a single series. The generic name is derived from the marine genus *Lethrinus* to which the type species, *L. lethrinus* is similar. The genus then accommodated four species; *Lethrinops albus*, *L. macrorhynchus*, *L. lethrinus* and *L. leptodon.*

Using material collected from the Tanzanian waters of the lake and deposited at the Berlin Museum, Ahl (1927) described three new species, which he assigned to the genus *Lethrinops*. The three species were *L. argenteus*, *L. marginatus* and *L. fasciatus*.

As a result of examining specimens of Malawian cichlids collected by Dr. Christy in 1925-26 and deposited in the Natural History Museum, London (BMNH), and re-examining the original material of Regan and Ahl, Trewavas (1931) revised the genus and increased the number of species in *Lethrinops* to twenty three.

It was also Trewavas (1931) who expanded the definition of the genus so as to clearly segregate it from *Haplochromis* (Fig. 1.4). "*Lethrinops* are haplochromine cichlids, endemic to the Lake Malawi basin and characterised mainly by the shape of the lower jaw and by the dentition. The lower jaw is narrow at the symphysis; on either side it expands to form a flat, often nearly horizontal surface for the teeth". In the process she included in the genus four species which were previously placed in *Haplochromis*: viz. *Haplochromis brevis*; *H. auritus* (which at that time she synonymised with *H. macrochir*); *H. macrophthalmus* and *H. praeorbitalis*. Of Ahl's three species, she considered *L. argenteus* as a distinct species but closely related to *L. lethrinus* because of its head shape. Trewavas (1931) doubtfully synonymised *L. marginatus* with *L. albus* and confidently referred *L. fasciatus* and *L. macrorhynchus* to *L. praeorbitalis*. New species described by Trewavas (1931) include *L. variabilis*, *L. lituris*, *L. trilineata*, *L. microstoma*, *L. parvidens*, *L. longimanus*, *L. cyrtonotus*, *L. macracanthus*, *L. alta*, *L. oculatus*, *L. furcifer*, *L. furcicauda*, *L. christyi* and *L. laticeps*.

In the 1960's, the Fisheries Research Unit of the Malawi Department of Fisheries established exploratory trawling in Lake Malawi. This was followed by the development of commercial trawling mainly in the south east arm of the lake. Trawling revealed the presence of many new species mainly from the deeper part of the lake and the genus *Lethrinops* gained considerable commercial importance thus also necessitating a taxonomic revision of the group. Two aquarists, Burgess and Axelrod (1973), on the basis of a single specimen described *L. polli*, and on the basis of two specimens described *L. gossei*.

Eccles & Lewis in a series of papers (1977, 1978 & 1979), made group revisions of some species of this genus based mainly on characters such as body and head shape, pharyngeal dentition, and number and form of the gill rakers. They described four new deep-water species, viz. *L. stridei* and *L. microdon*, *L. longipinnis* and *L. mylodon*. The following species were re-described: *L. micrentodon*, *L. argenteus*, *L. lethrinus*, *L. leptodon* [They also discussed the status of *L. lunaris*], *L. parvidens*, *L. auritus*, *L. macrophthalmus*, *L. macrochir*, *L. longimanus* and *L. macracanthus*.

Eccles & Trewavas (1989), in their 'green book' of the haplochromine cichlids of Lake Malawi, have documented major changes in the taxonomy of the genus *Lethrinops*. They removed from *Lethrinops* a group of species with a particular pharyngeal dentition and morphology and placed them in the new genus *Tramitichromis* (Fig 1.5). The remaining species with an oblique dark band were placed in another newly erected genus *Taeniolethrinops*. From then until now the *Lethrinops* species complex has been considered under three genera: *Taeniolethrinops*, *Tramitichromis* and *Lethrinops* 'sensu stricto'. Most of the species formerly contained in *Lethrinops* have been retained in this genus but the following have been reassigned: *L. cyrtonotus*, *L. furcicauda*, *L. laticeps* and *L. praeorbitalis* to *Taeniolethrinops* and *L. brevis*, *L. lituris*, *L. intermedius*, *L. trilineata* and *L. variabilis* to *Tramitichromis*. Eccles & Trewavas rightly noted the close similarity of many of the species of *Lethrinops*, *Tramitichromis* and *Taeniolethrinops*. It is unfortunate that they decided to erect new genera from *Lethrinops* before resolving first the basic issue of whether *Lethrinops* contains several phyletic lines.

Turner (1996), in his book on offshore cichlids, briefly discusses 18 new species of *Lethrinops* mainly from the deeper water of the southern part of the lake. Some, however, are from shallow waters. Although he has classified his species according to melanin patterns, he discusses *Tramitichromis lituris* and *Taeniolethrinops furcicauda* and *T. praeorbitalis* under *Lethrinops*; *Tramitichromis brevis* and *Taeniolethrinops laticeps* under the oblique-striped group dominated by the genus *Mylochromis*; *Lethrinops lethrinus* under the horizontally-striped group mainly of the genus *Protomelas* and *Tramitichromis intermedius* under the spotted group, mainly of the genus *Otopharynx*. This was intended to facilitate rapid field identification and not to indicate theories of phyletic relationship.

The genera *Tramitichromis* and *Taeniolethrinops* are typical shallow-water taxa. The specimens that formed the basis of Trewavas (1931) revision were mainly from shallow waters since at that time deep-water fishing was not established.

Table 1.4: Depth distribution of members of *Lethrinops* 'sensu Eccles & Trewavas 1989'. Data from Fryer 1959; Eccles & Lewis 1977, 1978, 1979; Eccles & Trewavas 1989; Konings 1995 and Turner 1996.

Note: ** = reported depth; *? = depth uncertain but deduced from ecological data.

	Water depth (m)						
Species	5	10	15	20	25	30	>30
Lethrinops lethrinus	**	**	**	**			
Lethrinops leptodon	*?	*?	*?	*?			
Lethrinops lunaris	*?	*?	*?	*?			
Lethrinops argenteus				*?	*?	*?	*?
Lethrinops longipinnis				**	**	**	**
Lethrinops christyi				**	**	**	**
Lethrinops polli							**
Lethrinops altus				**	**	**	**
Lethrinops gossei							**
Lethrinops microdon							**
Lethrinops stridei				**	**	**	**
Lethrinops micrentodon				**	**	**	**
Lethrinops longimanus				**	**	**	**
Lethrinops macracanthus							**
Lethrinops mylodon							**
Lethrinops oculatus	*?	*?	*?	*?			
Lethrinops marginatus	*?	*?	*?	*?			
Lethrinops albus	*?	*?	*?	*?			
Lethrinops furcifer	*?	*?	*?	*?			
Lethrinops auritus	**	**					
Lethrinops microstoma	**	**					
Lethrinops macrochir	**	**	**	**			
Lethrinops parvidens	**	**	**	**	**		
Lethrinops macrophthalmus	*?	*?	*?				

The species of this genus are difficult to differentiate. These cichlids have occupied the largest inshore habitat in the lake i.e. the large stretches of sandy and muddy bottoms. No species of *Lethrinops* 'sensu lato' is known to live exclusively on rocks; most are found off sandy shores but also in the mixed habitat where there is sand in between rocks (intermediate), and most species are distributed within a narrow depth range (Table 1.4). The species that live at greater depth constitute an important part of the catch of commercial trawlers (especially in the south east arm of the lake) and deep-water set gill nets. They have a very distinctive characteristic of deep-dwelling cichlid colouration of black vertical barring on a silvery grey body.

Species that are found in shallow water are regularly caught in beach seines. All members of *Lethrinops* 'sensu lato' have a silvery body when not breeding and all breeding males have a species-specific body, head and fin coloration with distinct egg-spots in their anal fins.

1.8 Rationale and objectives

The decision to study the shallow-water *Lethrinops* 'sensu lato' was based on economic and scientific rationale. My choice of drawing out a limit (20 m depth) for shallow-water *Lethrinops* 'sensu stricto' is based on the information summarised in Table 1.4, while strictly *Taeniolethrinops* and *Tramitichromis* are all shallow-water taxa.

Among the fishes of Lake Malawi/Nyasa, the shallow water benthic haplochromines are important for human food. The human population around Lake Malawi depend on fish as their main source of protein. The ornamental fish trade is a thriving industry and most brightly coloured *Lethrinops* are potential candidate species for sale. From the Tanzanian side there are already reports that seven species of *Lethrinops* 'sensu lato' are being exploited for aquarium purposes (Tomey, 1998).

Anthropogenic influences on and around Lake Malawi are developing fast. Such activities as forest fires, traditional agriculture and indigenous fishing methods pose a great threat to the conservation of the biological diversity of Lake Malawi/Nyasa.

A characteristic of many lacustrine cichlids of Lake Malawi/Nyasa is that they have habitat preferences and tend to be restricted to only those habitats. *Lethrinops* have a remarkable preference for sandy or muddy bottoms from where they feed and breed. Most of the indigenous fishing methods such as beach seining and gillnetting are concentrated in the shallow inshore waters (Fig. 1.6). This fishing practice has its potential dangers because, like most cichlids in Lake Malawi/Nyasa, *Lethrinops* are mouthbrooders; they produce very few young at a time. The advantage of parental care is lost as young are spewed out when brooding females are caught. Nets constantly dragged across the bottom always destroy the spawning platforms. Such

precocial k-selected fish are unlikely to recover quickly from heavy fishing pressure (Ribbink 1990; Lowe-McConnell 1993,1994).
These shallow-water sand-dwelling fish deserve every effort to be conserved and their habitats must be protected because of the vulnerability of this unique and irreplaceable endemic cichlid fauna and in order to safeguard their sustainable utilisation.

The concern about increasing anthropogenic pressure on this freshwater environment necessitated the three countries bordering Lake Malawi/Nyasa to formulate an impressive interdisciplinary research project concerning the biodiversity and conservation of the Lake Malawi/Nyasa aquatic resources. The project, which was funded by the GEF through the World Bank and CIDA, under the umbrella of SADC, had a task of developing a strategy for the scientific base for conservation of the lake resources. But, as "one cannot conserve what one doesn't know", taxonomic studies of major problematic groups was given high priority.

Lethrinops 'sensu lato' is scientifically very challenging to evolutionary biologists because up to now most theories about evolution of Lake Malawi/Nyasa cichlids have not been tested on the sand-dwelling fishes. This is because there is less information on the group on which the theories can be built and tested. Many of the scientifically known sand-dwelling fishes from Lake Malawi/Nyasa have been (re)described on the basis of material collected from a restricted area and their distribution pattern around the lake is not known. A better knowledge of the distribution patterns of these cichlids, of which *Lethrinops* are the major representatives, can help in explaining the underlying mechanisms of speciation among sand-dwelling species.
The genus *Lethrinops* 'sensu lato' is taxonomically one of the most complex groups of Lake Malawi/Nyasa non-mbuna haplochromines. At present, the species level taxonomy of the shallow water *Lethrinops* 'sensu lato' is confused and in urgent need of revision, and this is the subject of the present study.

Objectives of the study

The principal objective of this study is to carry out a taxonomic revision of the shallow-water sand-dwelling *Lethrinops* as defined prior to 1989 when Eccles & Trewavas erected two more genera, (hence the term *Lethrinops* 'sensu lato'), and to provide a key to the identification of the species. Further objectives include the mapping of the distribution patterns and investigations of the phylogenetic relationships of the putative natural groups of *Lethrinops* 'sensu lato'.

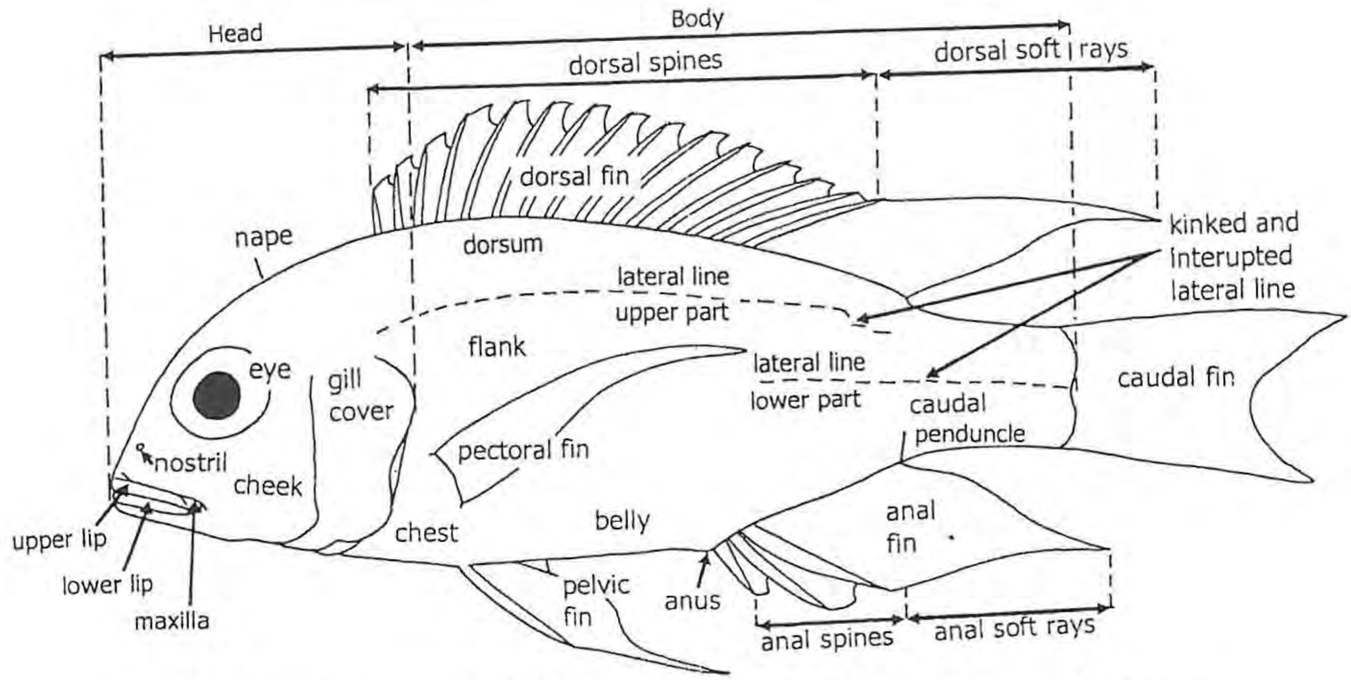


Fig. 1.3. Schematic representation of the more conspicuous main features of a cichlid fish which are used as landmarks in the description of other taxonomically relevant details of the external morphology.

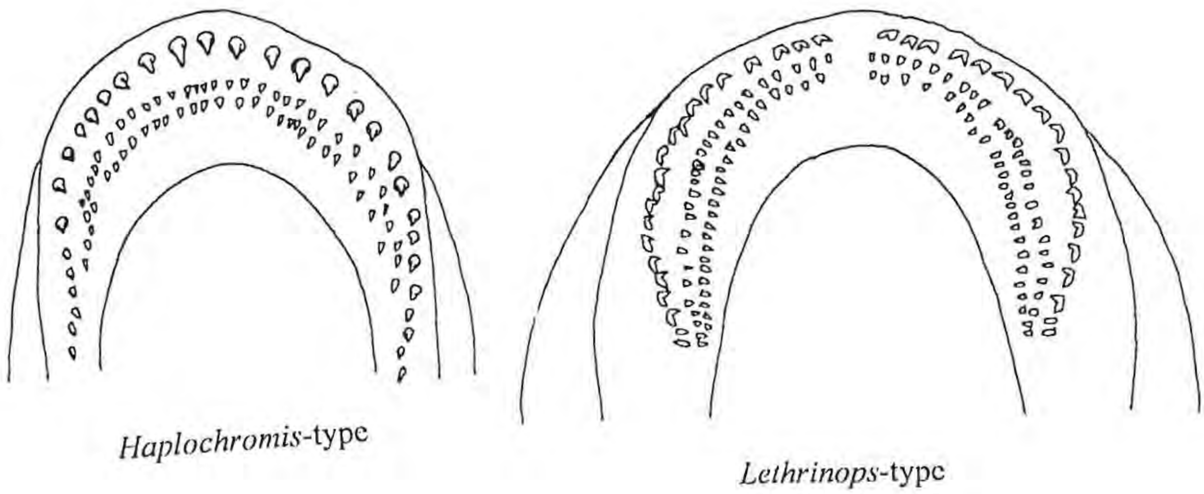


Fig. 1.4. Upper view of lower jaw dental arcades. In typical or *Haplochromis*-type, the outer tooth row continues posteriorly as a single row. In the *Lethrinops*-type the outer row curves inwards posteriorly to end just behind the inner rows.

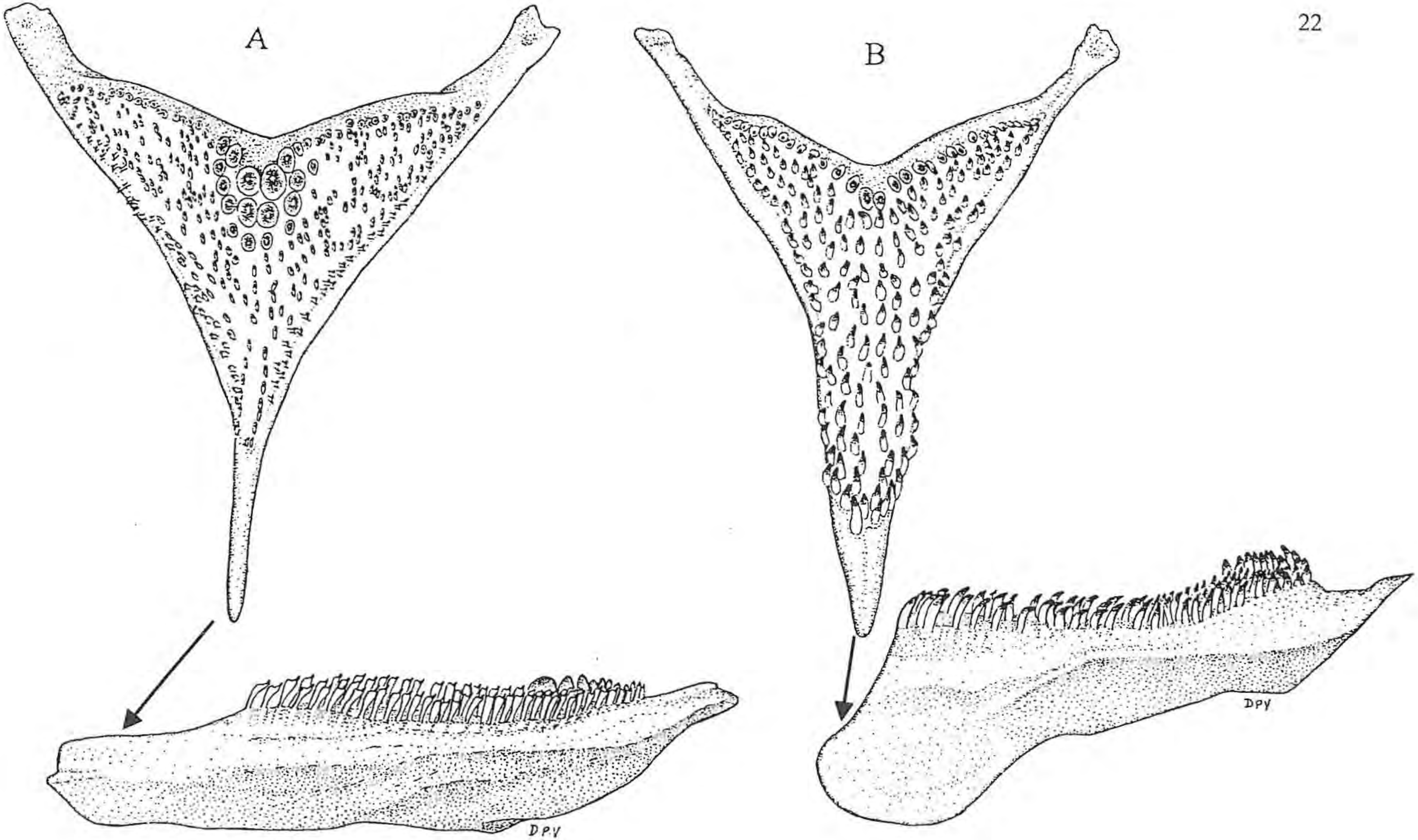


Fig. 1.5. A typical lower pharyngeal bone of: A, *Lethrinops* and *Taeniolethrinops*; B, *Tramitichromis*. Note the keeled and downward anterior blade and the backward directed teeth in the genus *Tramitichromis*, as opposed to unkeeled and straight anterior blade with forward directed or straight teeth in *Lethrinops* and *Taeniolethrinops*.

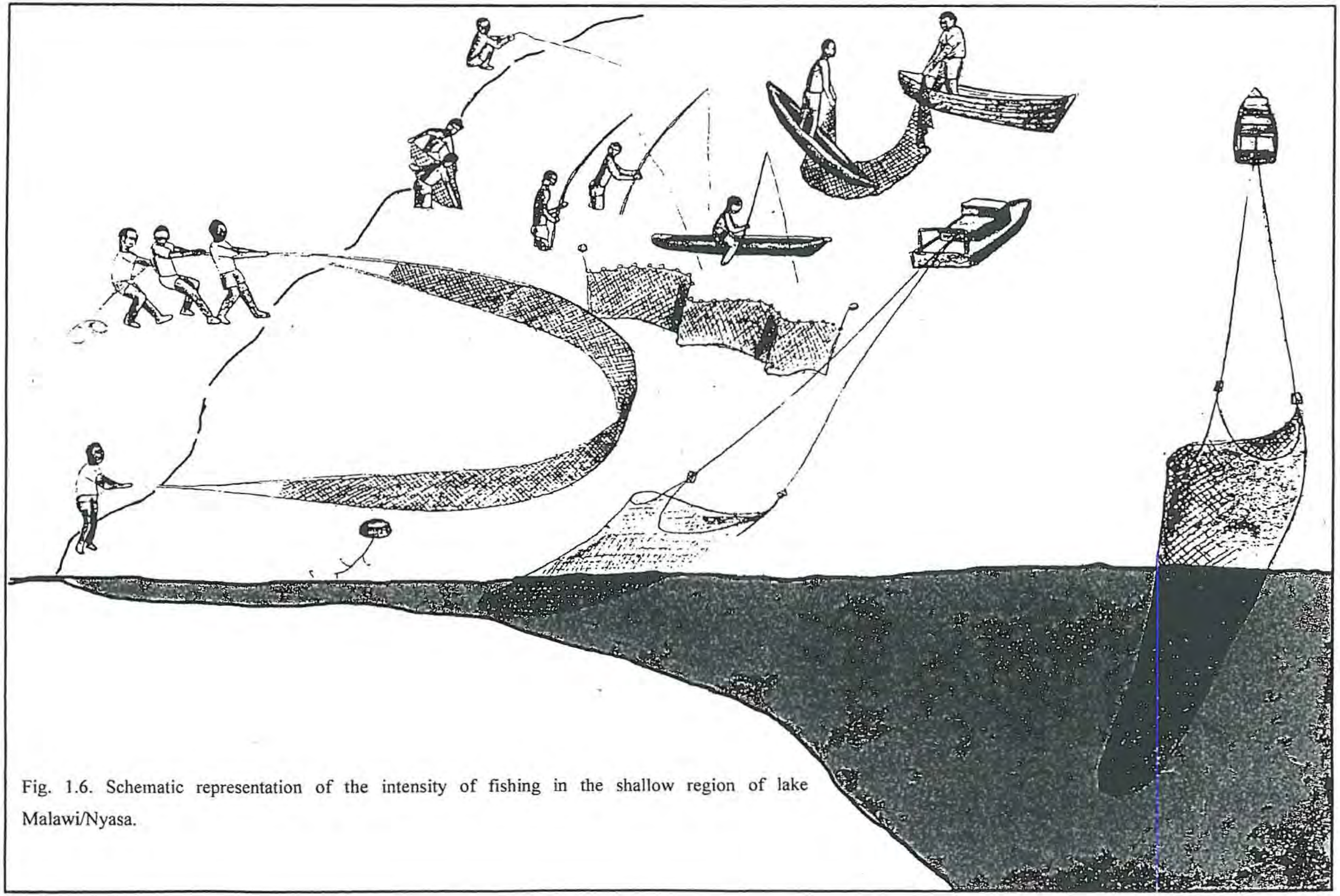


Fig. 1.6. Schematic representation of the intensity of fishing in the shallow region of lake Malawi/Nyasa.

Chapter 2: Material and Methods

The present study is concentrated on shallow-water *Lethrinops* 'sensu lato'. Although fishes were collected from many depths, for the purpose of this study shallow water *Lethrinops* are those caught from a depth of 20 m or less.

About five hundred specimens of the shallow water *Lethrinops* 'sensu lato' were examined and measured for this study. Along with forty-eight *Lethrinops* specimens from the JLB Smith Institute of Ichthyology (RUSI), Grahamstown (South Africa), a large sample of the specimens studied were collected by trawling, gillnetting, beach seining and purchased from local fishermen from localities all around the lake (Fig. 2.1).

Additionally, most types of shallow water *Lethrinops* 'sensu lato' housed in the Natural History Museum (BMNH), London (U.K.) and from the Zoologisches Museum der Humboldt Universität, Berlin (ZMB), (Germany) have been examined and compared with recently collected material. A list of the material examined is given after each species description. For the list of citation in the species descriptions, the work of Daget et al. (1991) was heavily relied on, but more recent publications were also sought out and new ones added to the list.

Furthermore, a representative sample of all the natural groups known was subjected to X-ray photography for vertebrae counts. This work was done at the JLB Smith Institute of Ichthyology, Grahamstown, Republic of South Africa. Fish specimens were radiographed by a Picker Industrial X-ray apparatus and developed on Konica medical X-ray film. The numbers of vertebrae were read from the developed X-film.

The genetic component of this study was done in collaboration with Hull University (Research group of Prof. G. Carvalho). Fin clippings were taken from 350 fish specimens for the molecular analysis in order to complement morphological observations and any relationship among the observed natural groupings.

2.1 Localities sampled

The objective was to sample as many sandy shore beaches as possible throughout the lake. During this study specimens were assembled from 46 localities all around the lake (Fig. 2.1).

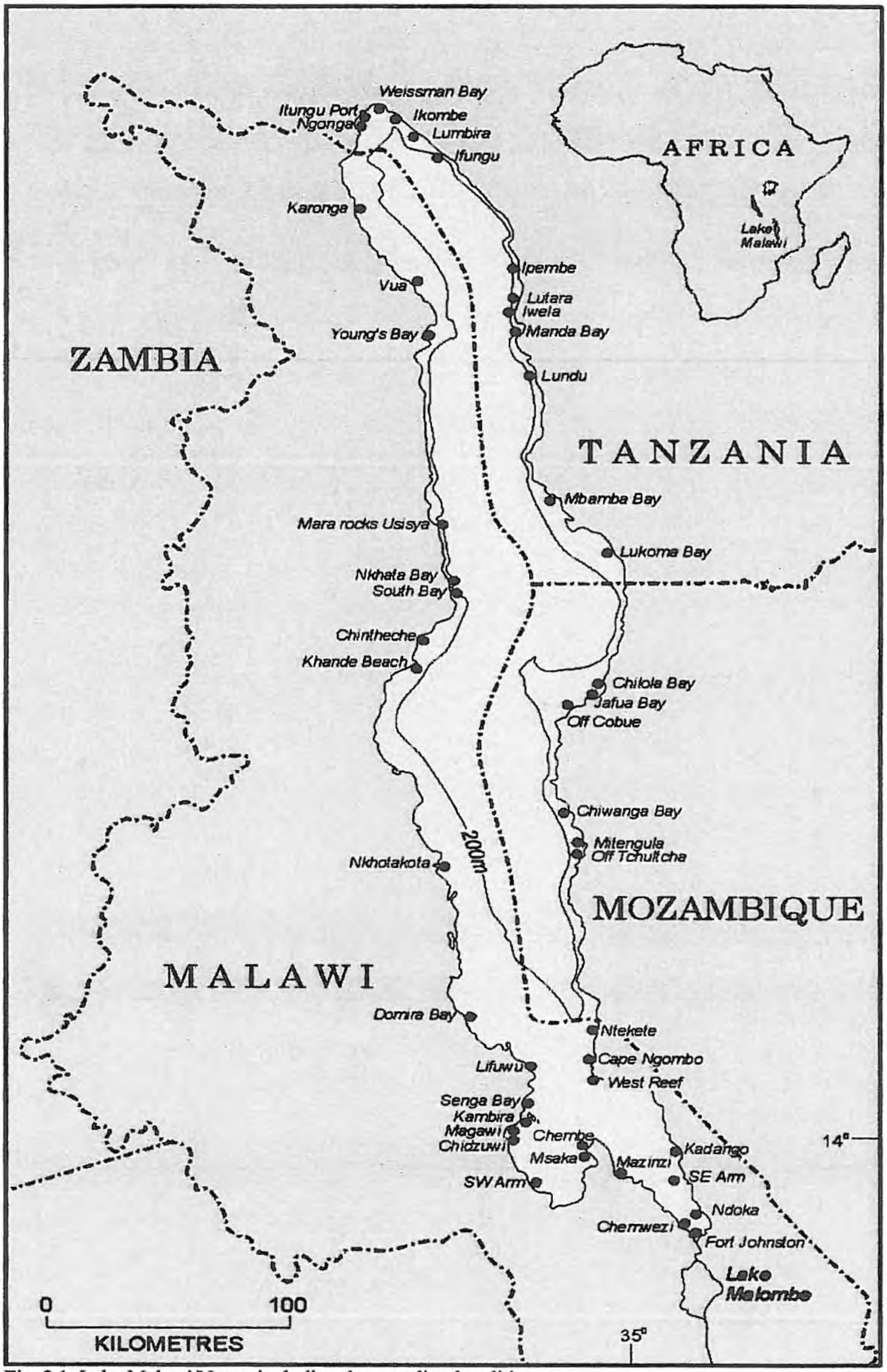


Fig. 2.1. Lake Malawi/Nyasa including the sampling localities.

2.1 Sample and Collection treatment

Fish samples were collected by different methods. Most of the specimens were collected during research cruises by the SADC/GEF Lake Malawi Project research vessel 'RV-Usipa' by trawling and gillnetting in shallow waters (< 20 m) on sandy beaches, or by gillnetting in intermediate habitats during rocky shore cruises. Since the SADC/GEF lake-wide sampling programme was balanced to accommodate other objectives like rocky shore sampling, a dedicated sampling effort had to be done for the collection of fish specimens for this study, using a specially designed 98.82 m beach seine. Sometimes samples were collected opportunistically from local fishermen. In the field, colour pictures, video and colour notes were taken on the spot and the specimens were identified (given a tentative name), labelled (name, location and date) and then fixed in 10% formalin for at least two weeks. Samples for genetic study were however, preserved in 98% ethyl alcohol. In some cases and depending on the time available, the whole fish was preserved in alcohol, but in others, part of the right side pectoral fin was cut off and preserved in vials containing ethyl alcohol. These genetic samples were then sent to the Molecular Ecology and Fisheries Genetics Laboratory, University of Hull, UK and only the results are herein discussed.

At the SADC/GEF Lake Malawi/Nyasa Project laboratory in Senga Bay, Malawi, specimens fixed in formalin for two weeks were rinsed in water for two to three days in order to completely remove the formalin. The fish were then transferred into 70% ethyl alcohol for long-term storage. All the *Lethrinops* collected were identified using the published descriptions (Trewavas, 1931, Eccles & Lewis, 1977; 1978; 1979; Eccles & Trewavas, 1989). All the identified specimens were re-labelled and put into the collection and the information on the label was entered into the SADC/GEF Lake Malawi/Nyasa Project taxonomy database.

2.3 Measurements

Measurements and counts used in this study follow those demonstrated by Barel et al. (1977), Snoeks (1994) and Turner (1996). Their methods of measuring gives more consistent results than the classic procedure whereby length of snout and head are projections and the eye diameter is measured as the ligamentous ring surrounding the eye.

The publication of Barel et al. (1977) should be consulted for all further details on morphological and anatomical terminology and dissections. The small anatomical differences between many Malawian cichlids can be better assessed when the point to point measurements of Barel et al. (1977) are applied. Therefore all measurements were taken from reference point to reference point, i.e. there was no projection onto other planes. Some of the ratios given by Trewavas (1931) and Eccles & Trewavas (1989) cannot therefore be compared directly with the ones given here.

For each specimen, 23 body and head measurements were taken using dial calipers correct to 0.5 mm and 0.1 mm for body and head measurements respectively. Since most aspects of the taxonomic techniques are easier to understand with the aid of figures, I have included schematic representations (Fig. 2.2a-b) of how the measurements have been taken (for head and body only).

Standard length (SL): as defined by Barel *et al.* (1977).

Lachrymal depth (LaCrD) or Preorbital depth: as defined by Barel *et al.* (1977)

Snout length (SnL): as defined by Barel *et al.* (1977).

Lower jaw length (LJL): as defined by Barel *et al.* (1977).

Premaxillary pedicel length (PPL): as defined by Barel *et al.* (1977) and modified by Snoeks (1994).

Cheek depth (ChD): as defined by Barel *et al.* (1977) and modified by Snoeks (1994).

Eye diameter (ED): as defined by Barel *et al.* (1977) and modified by Snoeks (1994).

Interorbital width (IOW): as defined by Barel *et al.* (1977).

Head width (HW): as used by Thys Van den Audenaerde (1964, 1966) and modified by Snoeks (1994).

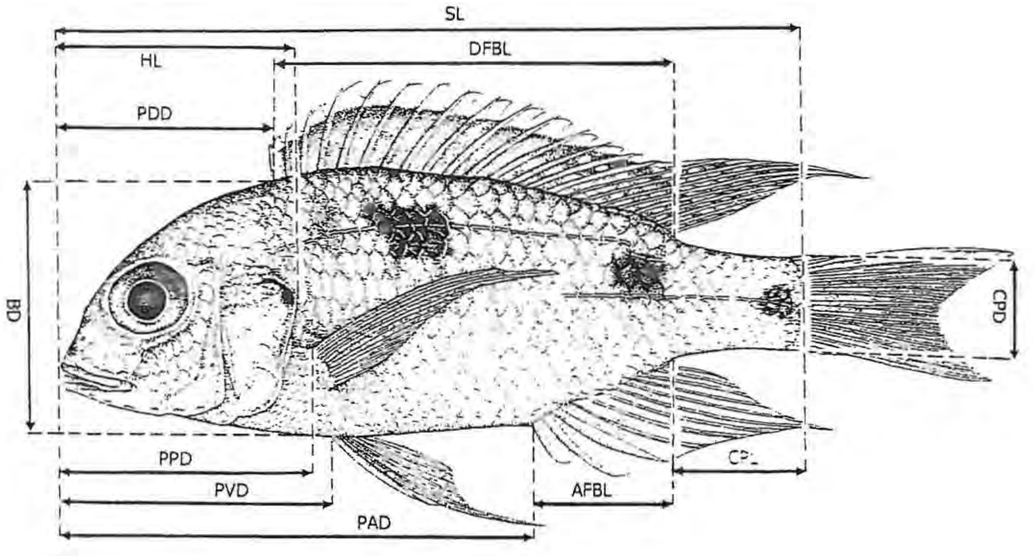
Head length (HL): as defined by Barel *et al.* (1977).

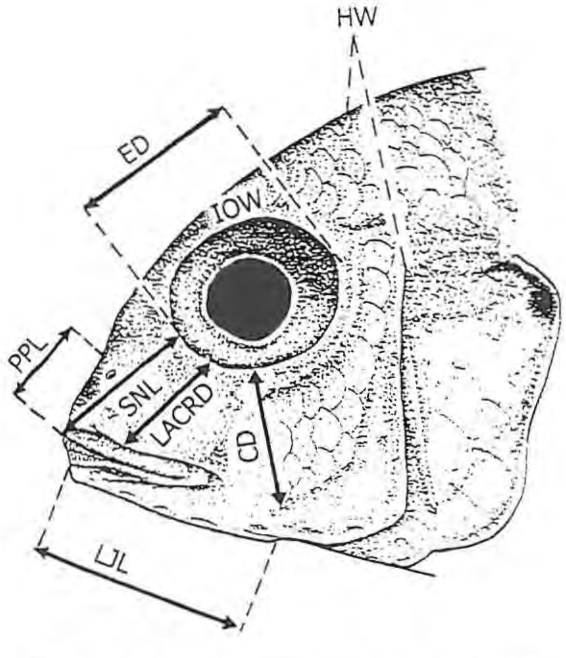
Body depth (BD): as defined by Barel *et al.* (1977).

Dorsal fin base length (DFBL): as defined by Snoeks (1994).

Anal fin base length (AFBL): as defined by Snoeks (1994).

Predorsal distance (PrD): as defined by Snoeks (1994).





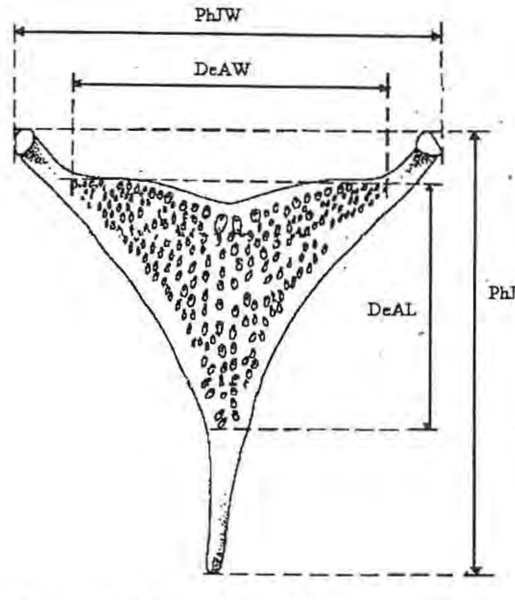


Fig. 2.2a. Schematic representation of the body measurements. The abbreviations correspond to the abbreviations of the measurements as defined in the text. Fig. 2.2b. Schematic representation of the head measurements. The abbreviations correspond to the abbreviations of the measurements as defined in the text.

Fig. 2.2c. Schematic representation of the lower pharyngeal bone measurements. The abbreviations correspond to the abbreviations of the measurements as defined in the text.

Prepectoral distance (PrP): as defined by Snoeks (1994).

Preventral distance (PrV): as defined by Snoeks (1994).

Preanal distance (PrA): as defined by Snoeks (1994).

Caudal peduncle length (CPL): as defined by Barel *et al.* (1977).

Caudal peduncle depth (CPD): as defined by Barel *et al.* (1977).

Lower pharyngeal jaw length (PhJL): as defined by Barel *et al.* (1977) and modified by Snoeks (1994).

Lower pharyngeal jaw width (PhJW): as defined by Barel *et al.* (1977).

Lower pharyngeal jaw dentigerous area length (DeAL): as defined by Barel *et al.* (1977).

Lower pharyngeal jaw dentigerous area width (DeAW): as defined by Barel *et al.* (1977).

For precision and accuracy, pharyngeal jaw measurements and those taken from the head region, except the head length and width, were taken under a binocular microscope. All the measurements were taken from the left side of the fish, which was kept wet to avoid shrinkage due to drying.

Meristics

In addition, 11 meristic counts of scales, fins, gill rakers and dentition were also recorded.

Upper and lower jaw teeth: denotes the number of outer teeth in the oral jaw, all counted according to Snoeks (1994).

Inner tooth rows: the number of tooth rows excluding the outer row of both the upper and lower jaw.

Gill rakers: counted on the outer part of the first gill arch. The number of gill rakers is presented as x/1/y, with x representing the number of gill rakers on the epibranchial, y the number of gill rakers on the ceratobranchial. There is always one gill raker separating the epibranchial from the ceratobranchial.

Dorsal fin formula: number of dorsal fin rays. Spines are indicated as Roman figures, soft rays in Arabic.

Anal fin formula: number of anal fin rays. Spines in Roman figures, soft rays in Arabic.

Pectoral fin formula: number of pectoral fin rays.

Longitudinal scales: correspond to the number of lateral line scales as illustrated on Figure 2.3 and as defined by Barel et al., (1977), Snoeks (1994: Fig. 4.4A).

Lateral line scales: presented as the number of scales on the upper lateral line and the number of scales on the lower lateral line as illustrated on figure 2.3 and as defined by Barel et al., (1977), Snoeks (1994: Fig. 4.4B). In all cases the small-perforated scales on the caudal fin have been excluded.

Transverse line scales: presented as X/Y, with X being the number of scales starting from the dorsal fin origin towards the upper lateral line, counting backwards and ventrally and Y the number of scales starting from the anal fin origin, counting forward and dorsally towards the upper lateral line as illustrated on Figure 2.3 and in Snoeks (1994, Fig. 4.4C &D).

Scales between pectoral and pelvic fin: the number of scales counting from the base of the pectoral fin to the base of pelvic fin as defined by Barel et al., (1977) and as illustrated in figure 2.3 and in Snoeks (1994: Fig.4.4E).

Cheek scales: as defined by Barel et al., (1977) and as illustrated in Figure 2.3 and in Snoeks (1994: Fig. 4.2).

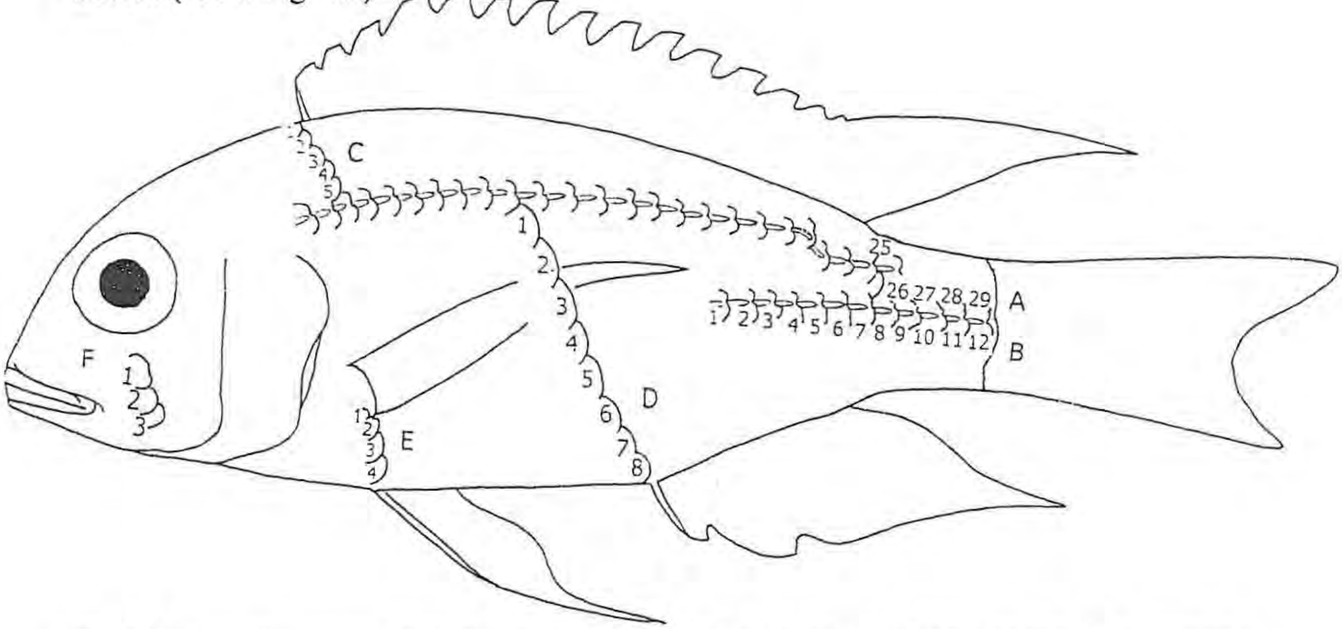


Fig. 2.3. Schematic representation of scale counts in A) longitudinal series at transition zone from upper to lower lateral line, (the thin line traces the passage from the upper to lower lateral line), B) lateral line series at transition zone from upper to lower lateral line (the thin line traces the passage from the upper to lower lateral line), C) transverse series on the upper part of the body, D) transverse series on the lower part of the body, E) scales between pectoral and pelvic fins and F) number of scale rows on the cheek.

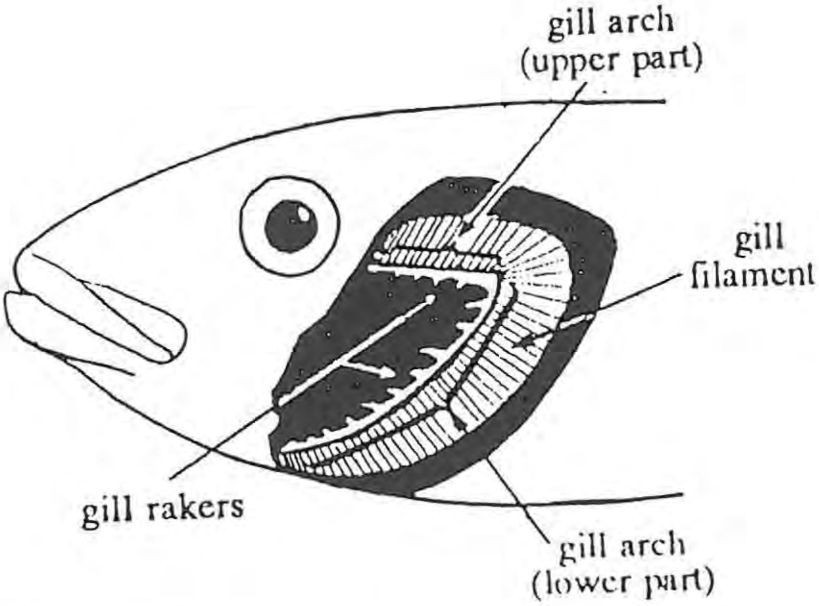


Fig. 2.4 Schematic representation of gill raker counts: Gill rakers are counted on the outer part of the first gill arch. The number of gill rakers is presented as x/1/y, with x representing the number of gill rakers on the ceratobranchial and y representing the number of gill rakers on the epibranchial.

As it is sometimes difficult to decide whether a gill raker is placed right on the transition zone (the angle between the dorsal and ventral part), or either on the ceratobranchial or epibranchial, this meristic has been simplified by always considering the gill raker closest the angle as placed on the angle; hence the 1 separating x and y (Snoeks, 1994).

Qualitative observations

Oral dental arcade: arrangement of teeth in the outer series of the oral jaw. This is most important in distinguishing the members *Lethrinops* 'sensu lato' from all other haplochromine cichlids of Lake Malawi/Nyasa (Fig. 1.3).

Head profile: defines the shape and inclination of the snout (long, short, straight or round).

Premaxillary or maxillary extension: indicated in relation to the position of the nostril and the eye.

Cuspidation: the shape of the teeth for both the outer and inner rows of both upper and lower jaws was recorded as either, uni-, bi- or tricuspid.

Lower pharyngeal jaw shape and dentition: as defined or commented upon by Barel et al., (1977). The shape of the lower jaw and its dentition is an important character for delimiting members of the genus *Tramitichromis* from all other *Lethrinops* 'sensu lato'.

Gill raker shape: noted only for ceratobranchials as either short, long, pointed, flat or thick etc. The shape of gill rakers on the lower arch is distinctive for certain members of the genus *Tramitichromis*.

Melanin patterns and colour descriptions

Six basic melanin patterns are found among haplochromines of Lake Malawi and some of these patterns are unique to the cichlid flock of this lake (Eccles & Trewavas, 1989). The group *Lethrinops* 'sensu lato' contains representatives exhibiting four of these patterns. These are; the 'kirkii' pattern, the transverse pattern, the oblique band or series of spots from nape to middle of caudal base and the three spots or blotches on each side of the body, varying in size and intensity but rather constant in position (Fig. 2.5a-c).

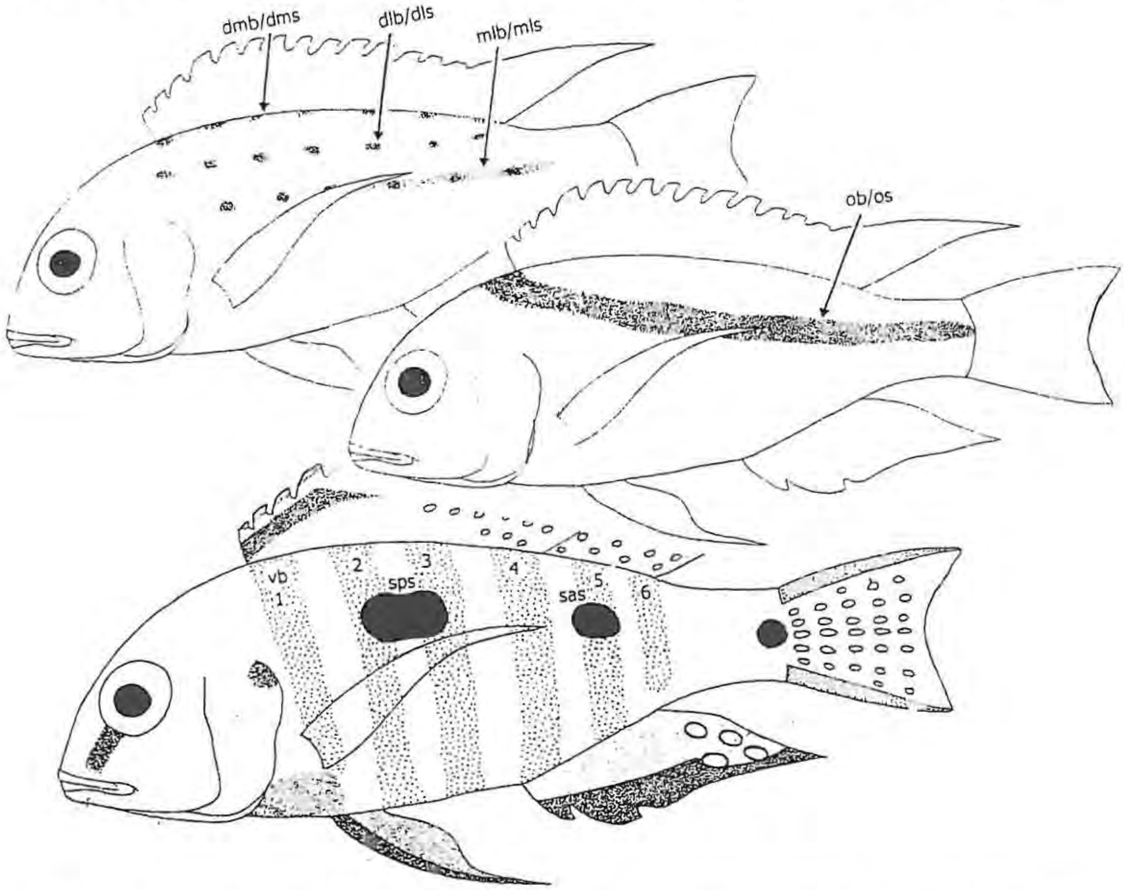


Fig. 2.5a-c Schematic drawing showing the principal melanin pattern represented in members of Lethrinops 'sensu lato' (melanin markings of Lake Malawi cichlids, considered in this study). Abbreviations: dmb/dms = dorsomedial band/ dorsomedial spots, dlb/dls = dorsolateral band/ dorsolateral spots, mlb/mls = midlateral band/ midlateral spots, ob/os = oblique blotch/ oblique stripe. The other abbreviations as indicated in Figure 2.6 (next page).

The spots on the anal fin of breeding or mature males have been referred to as 'egg spots'. These are egg dummies since they mimic the shape of eggs or ocelli and may serve to attract females during spawning; they probably have a reproductive role as specific mate recognising 'signals'.

The colour patterns of fresh and preserved specimens were recorded and photographs were also taken. The principal areas of colour observations are as shown in Figure 2.6. Based on the photographs and field notes, all species were illustrated by the SADC/GEF Lake Malawi Project Scientific Artist, Dave Voorvelt (Plates B-D).

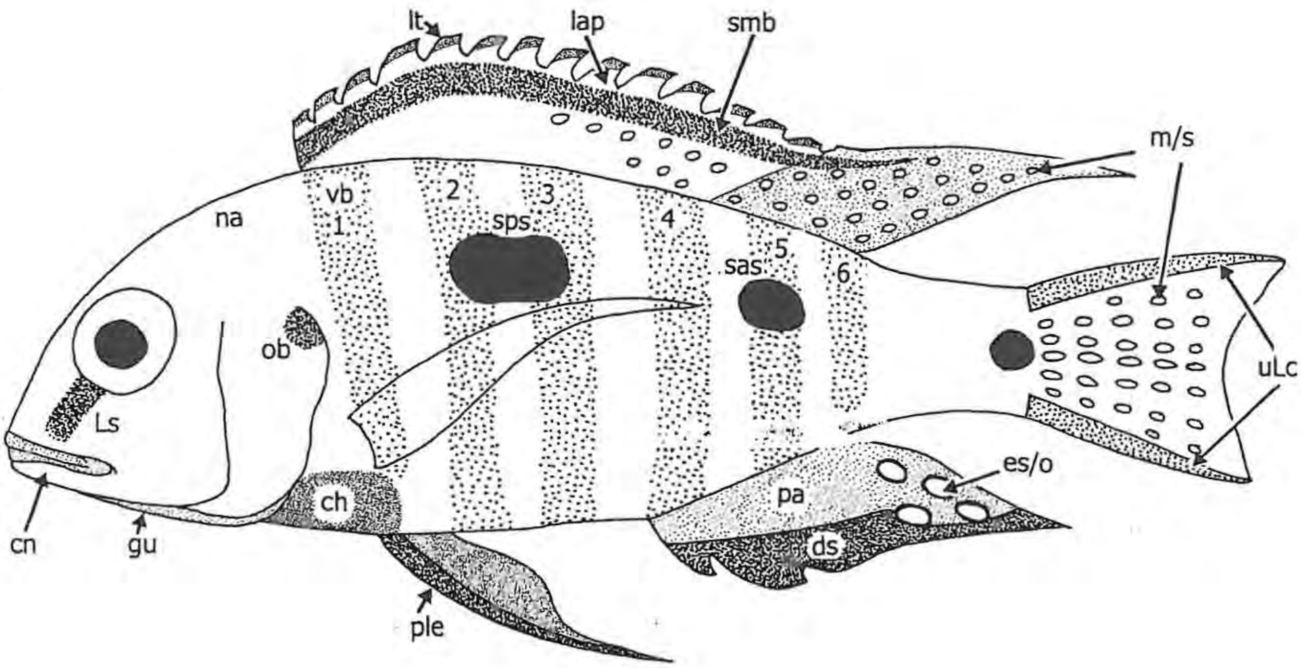


Fig. 2.6. Principal areas of colour observation. On the head region: cn = chin, gu = gular (branchiostegal membrane), Ls = lachrymal stripe (preorbital stripe), na = nape and ob = opercular blotch (spot). The overall body: ch = chest, vb (1-6) = vertical bars, sps = suprapectoral spot (blotch), sas = supra-anal spot, and cd = caudal spot. The belly, flanks and dorsum (refer fig. 1.3) can also be coloured different. For the fins: ple = pelvic leading edge, ds = distal, pa = proximal, es/o = egg spots/ocelli, ulc = upper and lower caudal margin, ms = maculae/striae, smb = submarginal band, lap = lappets and lt = lappet tips.

Data analysis and Statistics

For descriptive purposes, all measurements except standard length are expressed as ratios of a reference length. Most body measurements and head length are expressed as percentages of the standard length. Caudal peduncle depth is expressed also as a percentage of caudal peduncle length. Head measurements are generally expressed as a percentage of head length. Interorbital width is also expressed as a percentage of head width. Lower pharyngeal jaw width is expressed as a percentage of lower pharyngeal jaw length. Lower pharyngeal jaw length and width of dentigerous area are expressed respectively as a percentage of the lower pharyngeal jaw length and width. Dentigerous area length is given as a percentage of dentigerous area width.

For each species, a table is given with the descriptive statistics for all measurements, i.e. the number of the specimens examined, the mean, the standard deviation and the range. For meristics, the number of the specimens examined, the median and range values are given. Where applicable, values for the holotype are given in a separate column.

Univariate as well as multivariate data analyses were used in this study. Since the assumption of a normal distribution (required for certain statistical tests) is not always met by the variables used in this study, non-parametric or distribution-free univariate tests are preferred. Therefore, in this study, the distribution-free, non-parametric Mann-Whitney U-test (two samples) was used to examine intraspecific differences (Sokal & Rohlf, 1981). This test was only performed on samples with specimens belonging to the same length class because the comparison of small-sized samples of specimens of about the same average length and standard deviation is judged to be far more preferable than the comparison of larger unbalanced groups, the results of which would be subject to undesirable allometric effects (Marcus, 1990, Snoeks, 1999). In some cases, this restriction notably reduces the number of specimens that can be compared.
Generally, in African cichlid taxonomy, Principal Component Analysis (PCA) is used to explore the data in a multivariate way, without attributing statistical parameters to the results (Stauffer & Boltz, 1989 and later publications of the same research group; Snoeks, 1999; Hanssens et al., 1999). Morphometrics and meristics are analysed separately. In

this study all data were analysed using Principal Component Analysis (PCA) and where appropriate, the Mann-Whitney U-test, which is a non-parametric distribution-free univariate statistical test was used to establish statistical significance levels. Data for all the specimens measured were analysed at two levels. The first level analysis involved visual inspection and PCA, followed by re-grouping the specimens in their putative natural groups. At the second level each group was analysed separately. The flow chart below summarises these steps.

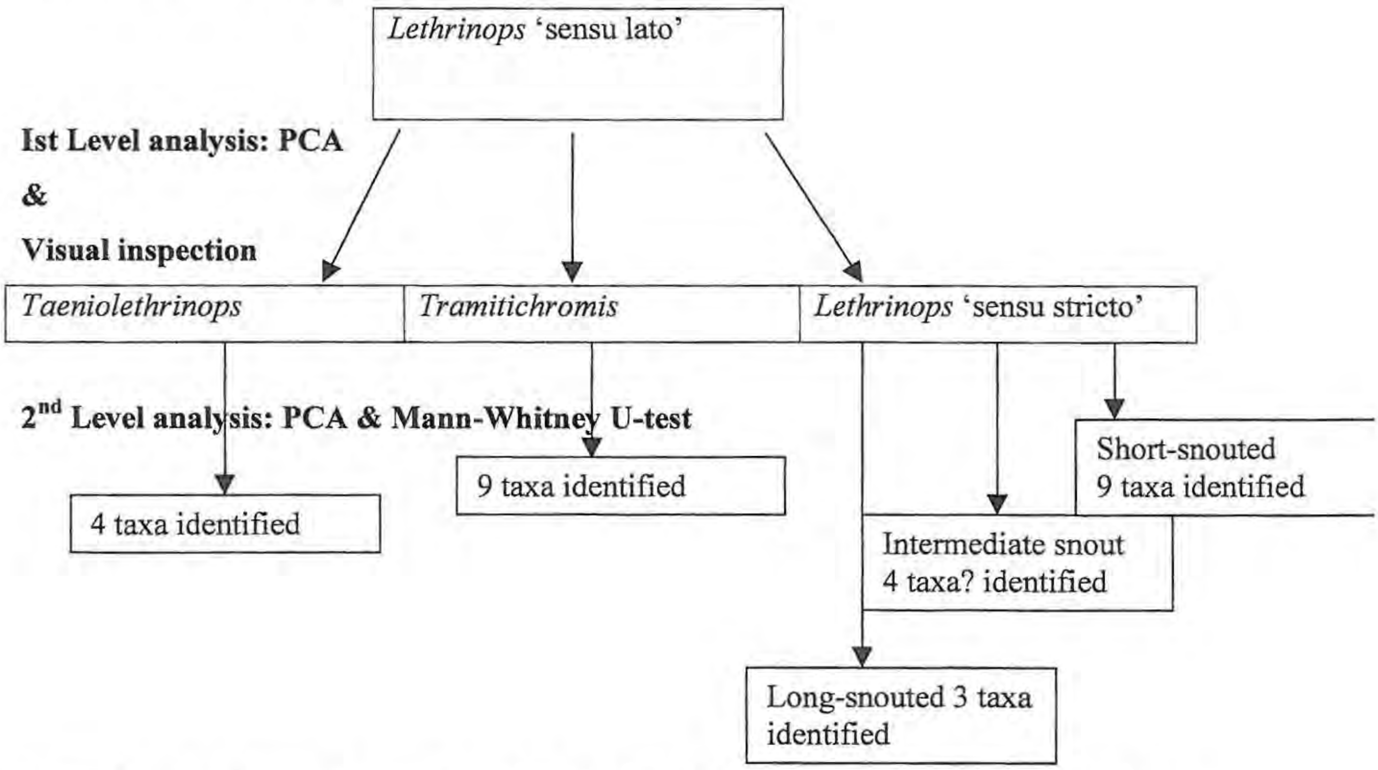


Figure 2.7: Chart showing the approach used in this study for the identification and classification of all members of *Lethrinops* 'sensu lato'. First, a preliminary identification was made to find out to which of the three presumed natural grouping the specimen belongs. Then an analysis of each of the presumed natural groups was done. At all levels of the analysis reference was made to previously published work (Regan, 1922; Ahl, 1927; Trewavas, 1931; Eccles & Lewis, 1977,1978,1979; Eccles & Trewavas 1989; Konings, 1995; Turner, 1996).

Data from about 500 fish specimens were subjected to principal component analysis (PCA) in order to elucidate the structural relationships among the characters/variables.
Prior to PCA, all measurements were log transformed in order to normalise and linearise non-linear relationships among variables, as often produced by growth allometry. Hence,

the first principal component can be regarded as mainly a size factor. All further principal components are interpreted as mainly shape factors. Similar analyses have been done on the untransformed meristics.

For all *Lethrinops* 'sensu lato', a Principal Component Analysis was first done on all measurements and meristics (separately) of the three putative natural groups, *Taeniolethrinops*, *Tramitichromis* and shallow-water *Lethrinops* (sensu Eccles & Trewavas 1989). This was done to identify possible differences among the putative natural groups. Prior to the analysis, a visual inspection of all the readily distinguishable characters was done. When the results of the PCA on measurements was not as informative as the one on meristics, only the latter were presented for the first level analysis (see chapter 3).

The PCA plots were useful as evidence of the investigatory approaches undertaken but no distinctive characteristics was found to support the existing putative natural grouping (Eccles & Trewavas generic classification). Preliminary results on the meristics were found to weakly support the existing genus level grouping. Subsequent PCA's were carried out within each natural group (in this case *Taeniolethrinops*, *Tramitichromis* and shallow-water *Lethrinops* 'sensu stricto') to identify species-level groupings of specimens.
The analyses of each putative natural group are explained in detail in the respective chapters.

Chapter 3: *Lethrinops* 'sensu lato'

Trewavas (1931, 1935) included in *Lethrinops* almost all the species having a characteristic oral dentition [as defined in chapter one]. Eccles & Trewavas (1989) argued that adaptations of feeding apparatus may represent parallelism or congruence and that the presence of melanin patterns which are unique to Lake Malawi/Nyasa cichlid flock may be a more reliable indicator of phylogeny. Nevertheless, in the case of *Lethrinops*, *Taeniolethrinops* and *Tramitichromis* they put more weight on the characteristic dentition than on melanin patterns. They removed from the genus *Lethrinops* (sensu Trewavas 1931, 1935) all those species which had a unique Malawian oblique dark band and erected two new genera, *Taeniolethrinops* (including one species, some specimens of which do not have any oblique band) and *Tramitichromis* (which has a variety of melanin patterns). The 24 species considered under the genus *Lethrinops* by Eccles & Trewavas (1989) and subsequent workers, while sharing the typical *Lethrinops* oral dental arcade, exhibit a variety of melanin patterns. The deep water *Lethrinops* not considered in this study have only vertical bars without any horizontal melanin pattern. They also exhibit a variety of shapes ranging from the long and pointed snouts of the *L. christyi* group to short snouted 'golf heads' of the *L. longimanus* group.

The shallow-water *Lethrinops* 'sensu lato' considered in this study, including several undescribed taxa, exhibit four of the six patterns found in Malawian cichlids. They, however, all share the synapomorph of the characteristic dentition.

Within *Lethrinops* 'sensu lato' are recognized three generic groupings which can be separated on such characters as head shape, pharyngeal morphology and dentition, number and shape of gill-rakers, number of the pectoral fin rays (see 3.1.1) and melanin pattern. When the specimens were grouped into species categories and compared them with previously described species, 28 valid taxa could be recognized. An artificial key to the shallow water (<20m) *Lethrinops* 'sensu lato' has been prepared (Ngatunga & Snoeks 1999). The number of taxa recognized at this moment is as shown below:

Table 3.1. Summary of the recognized taxa within each natural group. * Species presently synonymized.

• *Taeniolethrinops* group	• *Tramitichromis* group
T. furcicauda	*T. brevis, T.* sp. brevis 2
T. laticeps	*T. variabilis, T.* sp. 'variabilis deep'
T. cyrtonotus	*T. trilineata*
T. praeorbitalis	*T. intermedius*
	T. sp. 'pharyngeals'
	T. lituris
	T. sp. 'maculae'

• *Lethrinops* sensu stricto group

Group I	Group II	Group III
L. lethrinus	*L. albus*	*L. parvidens*, *L.* sp. 'parvidens deep'
L. leptodon	*L. marginatus* (=*L. oculatus*)	*L. macrochir*
L. lunaris	*L. furcifer*	*L. macrophthalmus*
		L. auritus
		L. sp. 'turneri'
		L. microstoma
		L. sp. 'black dorsal auritus'
		L. sp. 'domira blotch'

The genera *Tramitichromis* and *Taeniolethrinops* are typical shallow-water taxa. The shallow-water *Lethrinops* 'sensu stricto' were divided into several working groups, according to shared morphological features. One such group is the *lethrinus* group (group I) including three species with relatively long snouts and traces of horizontal melanin pattern. It is relatively easy to separate species within this group. It is confirmed in this study that *L. lunaris* is a valid species and that based on both melanin pattern and morphology, there is only one form of *L. lethrinus*.

Another group included eight taxa with a relatively short snout with a small mouth set low on the profile. Within this group, special attention has been paid to the confusion involving *L. auritus* and *L.* sp. 'turneri'; a new species being described (Ngatunga & Snoeks, in press). *L.* sp. 'domira blotch' could be what Turner (1996) referred to as *L.* sp. 'domira blue'. All measurement and meristics of *L. parvidens* and *L.* sp. 'parvidens deep' completely overlap and further work is required to investigate their differences.

Group 2 of the *Lethrinops* sensu stricto is ill-defined with an intermediate snout. Within this group, *L. oculatus*, which was described on the basis of only a single specimen, has tentatively been placed in synonymy with *L. marginatus*.

The distribution of all taxa from recognised sampled localities has been mapped out. Most species seem to have a lake-wide distribution. Some taxa, however, show a remarkably restricted distribution.

Results of vertebrae counts from X-ray photographs for a representative sample of each natural group show that there is no difference within and between the members of the natural group. This observation is to be expected for most Lake Malawi cichlids, which have speciated very fast.

3.1 Diagnosis

Haplochromine cichlids endemic to the Lake Malawi/Nyasa basin and characterised mainly by dentition. The outer series of teeth in the lower jaw curve inwards posteriorly ending just behind the inner row(s), not continuing backwards as a single series.

3. 2 Analysis

A first PCA was performed on log-transformed measurements for all specimens (n = 420) of the shallow-water *Lethrinops* s.l. measured. The second principal component is mainly defined by the anal fin base length, premaxillary pedicel length, dorsal fin base length, lachrymal depth, snout length and body depth, while the eye diameter contribute most to the third component (Table 3.2). Although there is a large overlap among the three groups of *Lethrinops* s.l., members of *Taeniolethrinops* are mainly on the negative part of second axis and those of *Tramitichromis* aggregate mainly at the centre of the same axis (Fig. 3.1).

A PCA was executed on untransformed meristics (n = 344). The meristics for which insufficient data were available were excluded. The first axis is mainly defined by the number of longitudinal line scales, followed by the number of pectoral fin rays and the number of upper transverse scales. The number of gill rakers (Table 3.3) mainly defines the second axis. Nearly all *Tramitichromis* specimens are in the positive part of the second axis and all *Taeniolethrinops* specimens are on the positive part of the first axis, whereas specimens of *Lethrinops* s.s overlap in both cases (Fig 3.2). The number of ceratobranchial gillrakers plotted against standard length shows that most members of *Tramitichromis* group have a low number of gill rakers (Fig. 3.3). The possible reason for this is given in the chapter on *Tramitichromis*.

A plot of the number of pectoral fin rays against standard length reveals that most members *Taeniolethrinops* have a relatively high number of pectoral fin rays (Fig. 3.4) and the possible reason for that is given in the chapter on *Taeniolethrinops*.

3.3 Artificial key to the genera, as represented in shallow-water

Within *Lethrinops* s.l. are recognised three genera which can be separated on such characters as head shape, pharyngeal morphology and dentition, number and shape of gill-rakers, melanin pattern and number of pectoral fin rays.

A: Anterior blade of lower pharyngeal bone not directed downwards and the toothed area ends in one or two rows anteriorly. Pharyngeal teeth bicuspid with tips of the anterior teeth turned forwards, some taxa have enlarged teeth at the posterior median part of bone. Melanin pattern variable, consisting of vertical bars in most species. In some taxa a dark suprapectoral patch is present with or without a supraanal and caudal spot. Horizontal melanin pattern (when present) consists of mid-lateral, dorso-lateral and dorso-medial series of dark spots or the mid-lateral spots curve up to fuse with the dorsal lateral spots. Snout length either shorter than, equal to, or more than eye diameter. Longitudinal scales 28-35; lower gill raker count 8 to 14**..*Lethrinops* s.s.**

B: Anterior blade of lower pharyngeal bone not directed downwards and the toothed area ends in one or two rows anteriorly. Pharyngeal teeth bicuspid with tips of the anterior teeth turned forwards, no enlarged teeth at the posterior median part of bone.
In all taxa except one, the melanin pattern consists of an oblique dark band from nape to caudal base. Snout length equal to, or more than eye diameter. Longitudinal scales 31-36; lower gill raker counts 9 to 14**..** ***Taeniolethrinops***

C: Anterior blade of lower pharyngeal bone directed downwards and the anterior part of the toothed area is broad, ending in 3 or more tooth rows. Teeth either bicuspid or unicuspid with tips of the anterior teeth turned backwards. Some taxa have enlarged teeth at the posterior median part of bone. Melanin pattern variable consisting of either a complete or incomplete oblique dark band, or lateral dark spots or vertical bars.
Snout equal to (for smaller specimens only) or shorter than diameter of the eye. Longitudinal scales 30-35; lower gill raker counts 5 to 10**.........................** ***Tramitichromis***

Table 3.2: Principal component loadings of the log-transformed variables on the first five axes; all shallow-water *Lethrinops* 'sensu lato' measured (n = 420).

	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.97625	-.155363	-.080707	.065415	.033895
LOGSNL	.97959	-.149424	-.079982	.014776	.022112
LOGLJL	.98273	-.106045	.004441	.036732	.020144
LOGPPL	.96469	-.164472	-.005065	-.127119	-.053106
LOGCHD	.97754	-.109021	-.080777	.044031	.089907
LOGED	.94754	-.048126	.300958	.065203	.059693
LOGIOW	.97900	.047657	.031300	-.111362	-.036484
LOGHW	.98557	.046740	.027773	-.040181	-.020662
LOGHL	.99399	-.073125	.007995	-.013382	-.022927
LOGSL	.99430	.069287	-.010834	.039327	-.013391
LOGBD	.97717	.141324	.000496	-.100962	.006076
LOGDFB	.98230	.156853	-.022754	.028352	.024461
LOGAFB	.96448	.199269	-.064330	.009057	.094185
LOGPRD	.99121	-.065658	-.001711	-.027645	.002260
LOGPRP	.99241	-.055632	.010246	-.013512	-.035921
LOGPRV	.99205	.001117	.010982	-.014263	-.049497
LOGPRA	.99202	.054427	-.004018	.010251	-.027752
LOGCPL	.96779	.091706	-.023843	.174553	-.130842
LOGCPD	.98233	.118337	-.012345	-.036516	.041010
Expl.Var	18.25612	.230634	.117611	.088075	.051796
Prp.Totl	.96085	.012139	.006190	.004636	.002726

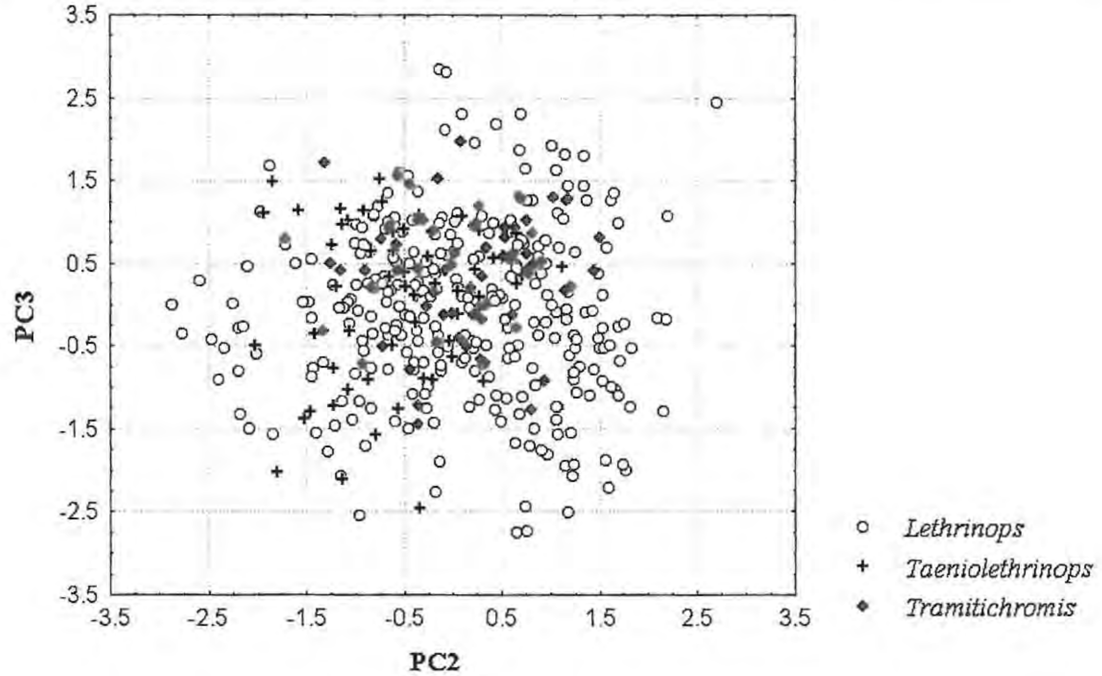


Fig. 3.1: Scatterplot of factor scores on the second and third axis of PCA of log-transformed measurements of all shallow-water *Lethrinops* 'sensu lato' measured (n = 420).

Table 3.3: Principal component loadings of the raw meristics on the first five axes of specimens of shallow-water *Lethrinops* 'sensu lato' (n = 344) examined .

VARIABLE	PC1	PC2	PC3	PC4	PC5
UPPER	.410299	-.490664	-.393783	-.031042	-.274065
LOWER	.351573	-.577619	-.357083	-.019732	-.113605
ROWSUP	.559597	-.242773	.602903	-.328874	-.051427
ROWSLOW	.597959	-.175780	.583882	-.331283	-.149193
GRLOW	-.352201	-.858337	.013774	-.005862	.080958
GRTOTAL	-.335305	-.850711	.051009	-.023611	.109809
DSPINES	-.204741	-.330129	.375534	.655787	-.019800
DSOFT	.554290	.092138	-.384969	-.284593	.474946
ASOFT	.345877	-.176074	-.465645	.160872	.409640
PECTORAL	.670667	.000233	.069299	-.143507	.241300
LATUP	.422152	.096032	.166944	.587340	.098662
LATLOW	.499580	-.137233	.067742	.133548	.141381
LONG	.686572	.057467	.144931	.376691	.208471
TRANSUP	.614831	.097706	-.100327	.160628	-.321896
TRANSLOW	.553052	-.111286	.083231	.099807	.082609
PV	.270023	.060859	-.335606	.193245	-.549447
CHEEK	.530311	-.049990	-.132287	-.103693	-.358168
Expl.Var	4.054908	2.332651	1.701218	1.365933	1.197330
Prp.Totl	.238524	.137215	.100072	.080349	.070431

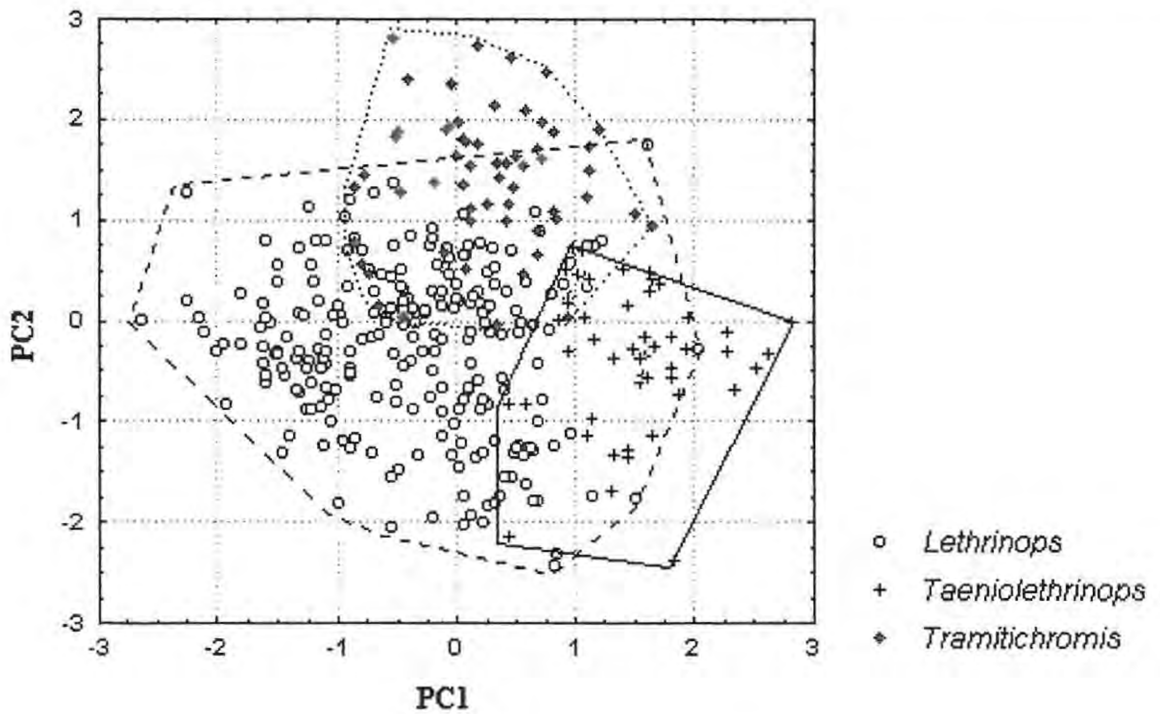


Fig. 3.2: Scatterplot of scores on the first and second axis of a PCA of the raw meristics of specimens of shallow-water *Lethrinops* 'sensu lato' (n = 344) examined.

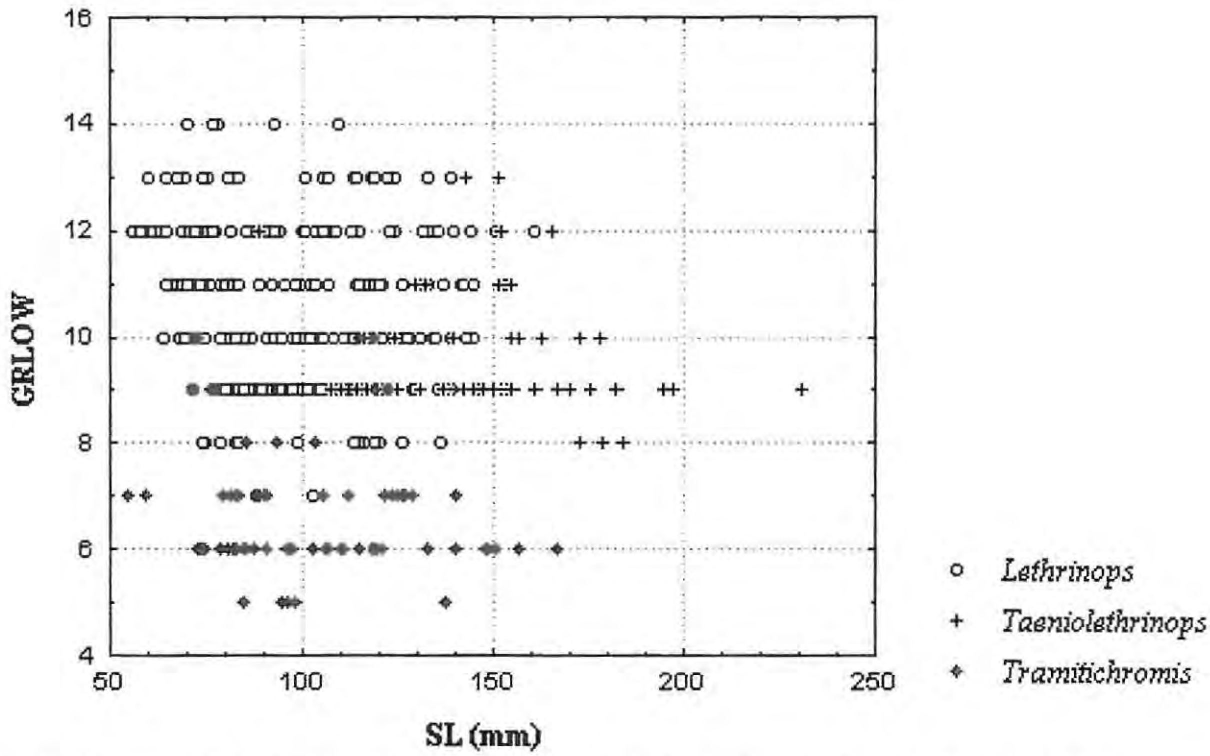


Fig. 3.3: Scatterplot of the number of ceratobranchial gill raker versus standard length for specimens of shallow-water *Lethrinops* 'sensu lato' examined.

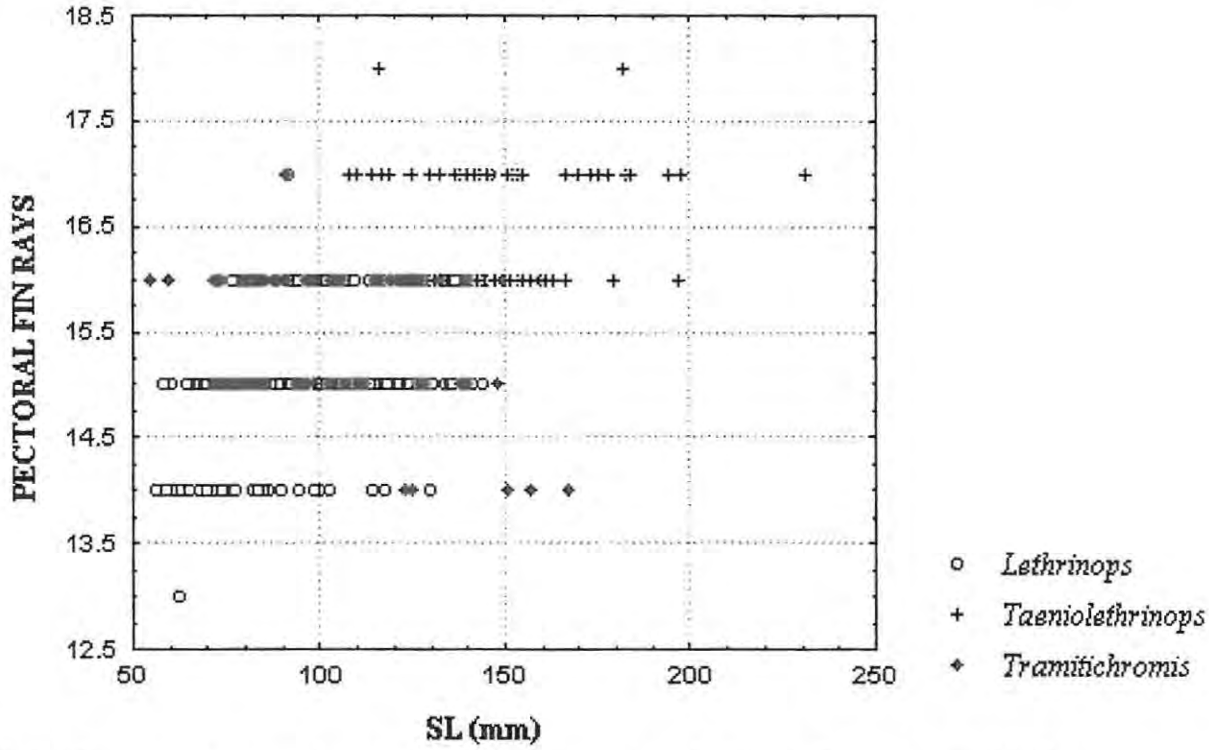


Fig. 3.4: Scatterplot of the number of pectoral fin rays versus standard length for specimens of shallow-water *Lethrinops* 'sensu lato' examined.

Chapter 4: The genus *Taeniolethrinops* Eccles & Trewavas 1989

Taeniolethrinops Eccles & Trewavas, 1989: 261. Type species: *Haplochromis praeorbitalis* Regan, 1922, by original designation.

Etymology

Derived from Greek word 'tainia' which means stripe and "*Lethrinops*", which refers to the oblique band from nape to caudal base (Eccles & Trewavas, 1989) evident in this genus.

4.1 Introduction

Eccles & Trewavas (1989) assigned four members previously in the genus *Lethrinops* to a new genus *Taeniolethrinops*, which is defined mainly by the shared characteristic of an oblique dark band on the body. They designated *T. praeorbitalis* as the type species of the genus. The two syntypes of this species (BMNH 1921.9.6:193-194; male 197.0 mm SL, female 179 mm SL) were examined and measured and no evidence of such a pattern was found. Trewavas (1931) synonymised *Lethrinops macrorhynchus* and *L. fasciatus* with *T. praeorbitalis*. The specimen of *L. macrorhynchus* (BMNH 1897.6.9:256; female cut in two) have a strong dark oblique band but those of *L. fasciatus* (ZMB 32321; female 170.0mm SL, female 197.5 mm SL, female110.0 mm SL; syntypes) do not show any evidence of such an oblique band. However, the overall head and body shape of both specimens resembles that of *T. praeorbitalis*. The other three species *T. laticeps*, *T. furcicauda* and *T. cyrtonotus* all have the characteristic oblique band. The dark oblique band is most prominent in *T. laticeps*. Turner (1996) noted that *T. laticeps* exhibited a prominent oblique band, but in his species, which were mainly collected in the south of the lake, *T. praeorbitalis* and *T. furcicauda* did not. The four species are re-described as forming one group of *Lethrinops* sensu Trewavas 1931 and a key to their identification in the field in given.

4.2 Diagnosis

Haplochromine cichlids endemic to Lake Malawi/Nyasa with a maximum size of 250 mm SL. The teeth in the lower jaw are in 3 to 5 rows, those in the outer series bicuspid anteriorly and unicuspid posteriorly and in the inner series unicuspid and sometimes tricuspid. The outer row curves inward posteriorly to end just behind the inner rows. Anterior blade of lower pharyngeal bone not directed downwards and the toothed area ends in one or two rows anteriorly. Pharyngeal teeth bicuspid with tips of the anterior teeth turned forwards. Snout length equal to, or more than eye diameter. Lower gill raker counts 8 to 13.

In all taxa except one, the melanin pattern consists of an oblique dark band from nape to caudal base. This pattern may be masked by the territorial colour pattern in adult males. Only in *T. praeorbitalis*, non-territorial specimens can be found without the characteristic melanin pattern.

4.3 Analysis

In the results a first Principal Component Analysis on the log-transformed measurements of all specimens of *Taeniolethrinops* measured (n=59), *T. laticeps* and *T. praeorbitalis* are situated mainly on the positive side of the second axis while *T. furcicauda* and *T. cyrtonotus* are almost fully on the negative side of that axis. *Taeniolethrinops laticeps* is, however, separated from *T. praeorbitalis* by the third axis. There is a complete overlap between *T. furcicauda* and *T. cyrtonotus* and some overlap of *T. furcicauda* with *T. laticeps* and slightly with *T. praeorbitalis* as well (Fig. 4.1). The second principal component (PC2) is mainly defined by lachrymal depth, snout length, eye diameter, caudal peduncle length and premaxillary pedicel. Mainly eye diameter, anal fin base length, dorsal fin base length and interorbital width (Table 4.1) define the third principal component (PC3).

Another Principal Component Analysis was executed on untransformed meristics (n=51). The meristics for which insufficient data were available were excluded. *T. cyrtonotus* separates on the negative part of the first axis. This axis is defined by mainly lower gill raker counts on the first gill arch (Table 4.2). This analysis confirms that though *T. cyrtonotus* resembles *T. furcicauda* in measurements, it can be separated clearly on the number of gill rakers (Fig. 4.2).

A separate analysis of *T. praeorbitalis* and *T. laticeps* confirms that they can be separated on eye diameter, snout length, lachrymal depth and interorbital width (Table 4.3, Fig. 4.3).

A final Principal Component Analysis on specimens of *T. laticeps* and *T. furcicauda* resulted in a partial separation of the two species, with *T. laticeps* mainly on the positive side and *T. furcicauda* largely on the negative side of the second principal axis (Fig. 4.4). This axis is mainly defined by caudal peduncle length, anal fin base length, dorsal fin base length, premaxillary pedicel length and interorbital width (Table 4.4). There is, however, considerable overlap which is reduced when the scores on the second axis are plotted against SL (Fig. 4.5).

The eventual differences between *T. praeorbitalis* and *T. laticeps*, *T. praeorbitalis* and *T. furcicauda*, and *T. laticeps* and *T. furcicauda* were further explored using Mann-Whitney U-tests on samples of comparable sizes [*T. praeorbitalis* 148.4 ± 30.9 (110.0-179.0) mm SL (n=7), *T. laticeps* 146.8 ± 20.1 (107.5-178.0) mm SL (n=12) and *T. furcicauda* 141.6 ± 17.6 (117.0-173.0) mm SL (n=22)].

Table 4.5 below summarises the main characters that are significantly different between the three members of *Taeniolethrinops*.

Table 4.5: Synopsis of the significant differences in measurements between *T. praeorbitalis* and *T. laticeps*, *T. praeorbitalis* and *T. furcicauda*, and *T. laticeps* and *T. furcicauda* specimens of comparable sizes (SL p>0.52, see text).

T. praeorbitalis vs *T. laticeps*	*T. praeorbitalis* vs *T. furcicauda*	*T. laticeps* vs *T. furcicauda*
P<0.01	P<0.001	P<0.001
Lachrymal depth % HL	Lachrymal depth % HL	Head length % SL
Head width % HL	Snout length % HL	Predorsal distance % SL
Body depth %HL	Eye diameter % HL	Pre-ventral distance %SL
Pre-ventral distance % SL	Interorbital width % HL	Preanal distance % SL
Eye diameter % HL	Premaxillary pedicel length % HL	Caudal peduncle length %SL
	Head width % HL	Dorsal fin base length % SL
	Predorsal distance % SL	

Table 4.1: Principal component loadings of the log-transformed variables on the first five axes; all *Taeniolethrinops* specimens measured (n = 59).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.96125	.211389	-.070324	-.036451	.068633
LOGSNL	.96359	.225881	-.055846	-.026401	.074601
LOGLJL	.97331	.115438	.046627	-.081005	.059108
LOGPPL	.94947	.175726	.028280	.155502	-.080810
LOGCHD	.97871	.092753	-.070821	-.018977	.063504
LOGED	.88121	-.291367	.337194	-.017547	.129157
LOGIOW	.95854	.042368	.140741	.038082	-.113328
LOGHW	.96427	-.010565	.104875	.076695	-.163541
LOGHL	.98850	.093293	.060150	-.051615	-.021133
LOGSL	.99094	-.067547	-.071053	-.031284	.012390
LOGBD	.97563	-.149526	-.002327	.100197	.021153
LOGDFB	.96615	-.158319	-.156668	.047431	.028435
LOGAFB	.93913	-.162939	-.198788	.130905	.072179
LOGPRD	.98401	.054926	.053847	.046195	.011879
LOGPRP	.97927	.076980	.072063	-.043311	-.009844
LOGPRV	.98655	.037187	.047850	-.086123	.026671
LOGPRA	.98496	-.032386	-.017503	-.075315	-.021035
LOGCPL	.92487	-.217494	-.148880	-.209940	-.140176
LOGCPD	.97598	-.072737	-.081182	.083024	-.013916
Expl.Var	17.68933	.386525	.272738	.141904	.108903
Prp.Totl	.93102	.020343	.014355	.007469	.005732

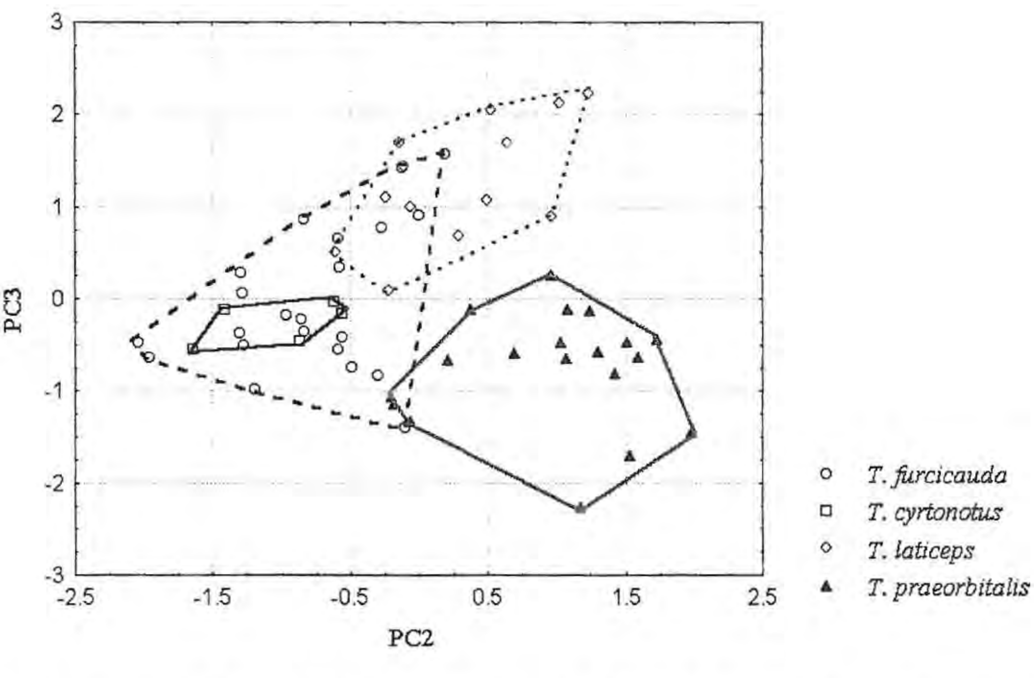


Fig. 4.1: Scatterplot of scores on second and third axis of a PCA of log-transformed measurements of all *Taeniolethrinops* specimens measured (n=59).

Table 4.2: Principal component loadings of the raw meristics on the first five axis of all members of *Taeniolethrinops* examined (n = 51).

VARIABLE	PC1	PC2	PC3	PC4	PC5
UPPER	.619038	.316188	-.084680	-.398722	.195862
LOWER	.522872	.497584	.003798	-.263836	.105317
ROWSUP	.448642	-.061452	.603148	-.135325	-.482175
ROWSLOW	.547172	-.065012	.461536	-.177379	-.454805
GRLOW	.739251	-.288884	-.346190	-.336020	.074937
GRTOTAL	.687521	-.349747	-.293106	-.360733	.079376
DSPINES	-.544183	-.097207	-.243952	-.632450	-.199926
DSOFT	.316191	.358407	.529112	.180805	.469189
ASOFT	-.346598	.636189	-.196593	-.241013	.166657
PECTORAL	-.597579	-.246508	-.090139	-.034175	-.224268
LATUP	-.660643	-.017836	-.014803	-.286064	.181946
LATLOW	.137534	.577993	-.119592	.116688	-.162587
LONG	-.574127	.327317	.220908	-.229829	-.163064
TRANSUP	-.201139	.517017	.277375	-.239418	.102783
TRANSLOW	-.422018	-.154294	.460162	-.306593	.010567
PV	.061096	.408517	-.527380	.223995	-.397172
CHEEK	.144581	.544927	-.149524	.037701	-.388475
Expl.Var	4.077978	2.361227	1.828487	1.364526	1.244353
Prp.Totl	.239881	.138896	.107558	.080266	.073197

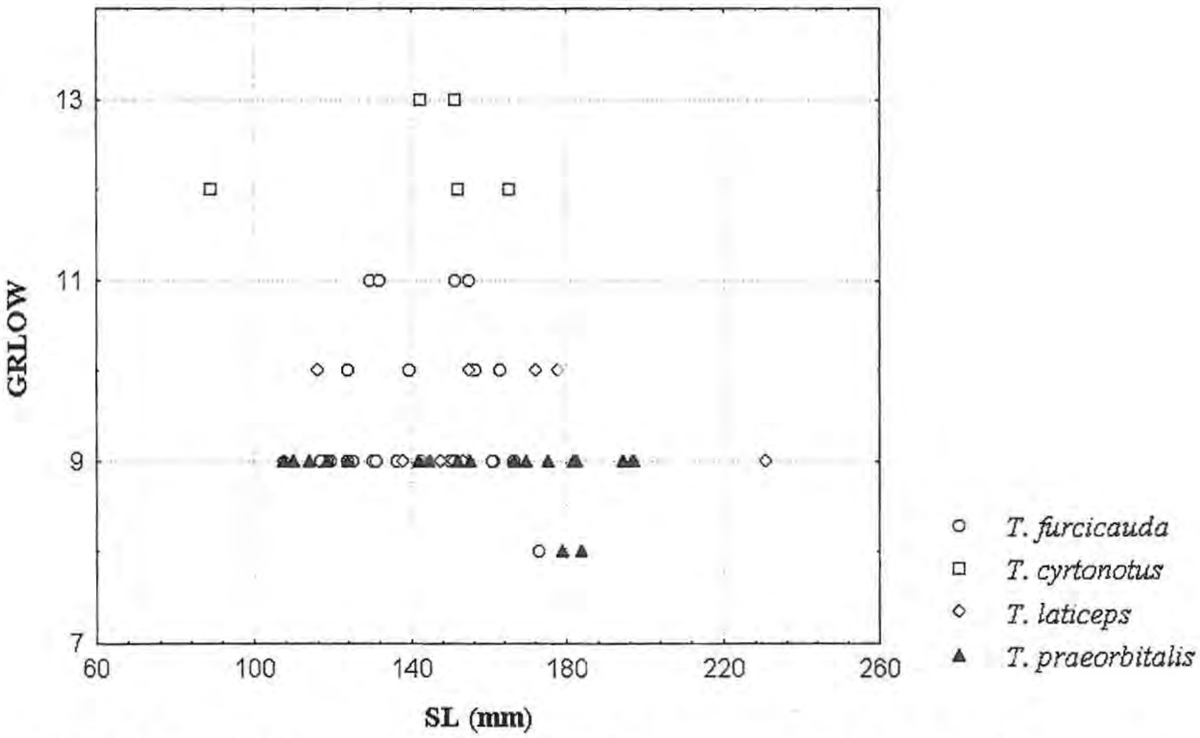


Fig. 4.2: Scatterplot of number of ceratobranchial gill rakers against standard length for the specimens of *Taeniolethrinops* examined (n=51).

Table 4.3: Principal component loadings of log-transformed variables on the first five axes; *T. praeorbitalis* and *T. laticeps* (n = 32).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.97629	-.127170	.087657	.045159	-.061746
LOGSNL	.97903	-.137447	.079469	.070151	-.046366
LOGLJL	.98855	.028051	-.045020	.074675	-.039708
LOGPPL	.96814	.000614	.193177	.014243	.016164
LOGCHD	.98707	-.069382	.040107	.052682	-.051817
LOGED	.87779	.456395	-.084290	.083474	-.063803
LOGIOW	.96855	.121833	.082846	-.133907	.048832
LOGHW	.97020	.111678	.083104	-.048396	.136426
LOGHL	.99628	.007506	.040910	.014799	-.005074
LOGSL	.99432	-.067918	-.046389	-.016298	.009617
LOGBD	.98428	.074370	-.087828	-.078127	-.006556
LOGDFB	.98330	-.105851	-.084951	-.033480	-.030364
LOGAFB	.96497	-.108113	-.090212	-.147460	-.120015
LOGPRD	.99227	.034576	.058638	-.004120	-.024276
LOGPRP	.99064	.017148	.059549	.042060	-.001100
LOGPRV	.99183	.026453	-.046273	.000598	-.004822
LOGPRA	.98772	-.023934	-.054132	-.043612	.067465
LOGCPL	.95571	-.148814	-.168507	.104339	.128620
LOGCPD	.98557	-.045146	-.027129	.009903	.045446
Expl.Var	18.10854	.336316	.143907	.086883	.074814
Prp.Totl	.95308	.017701	.007574	.004573	.003938

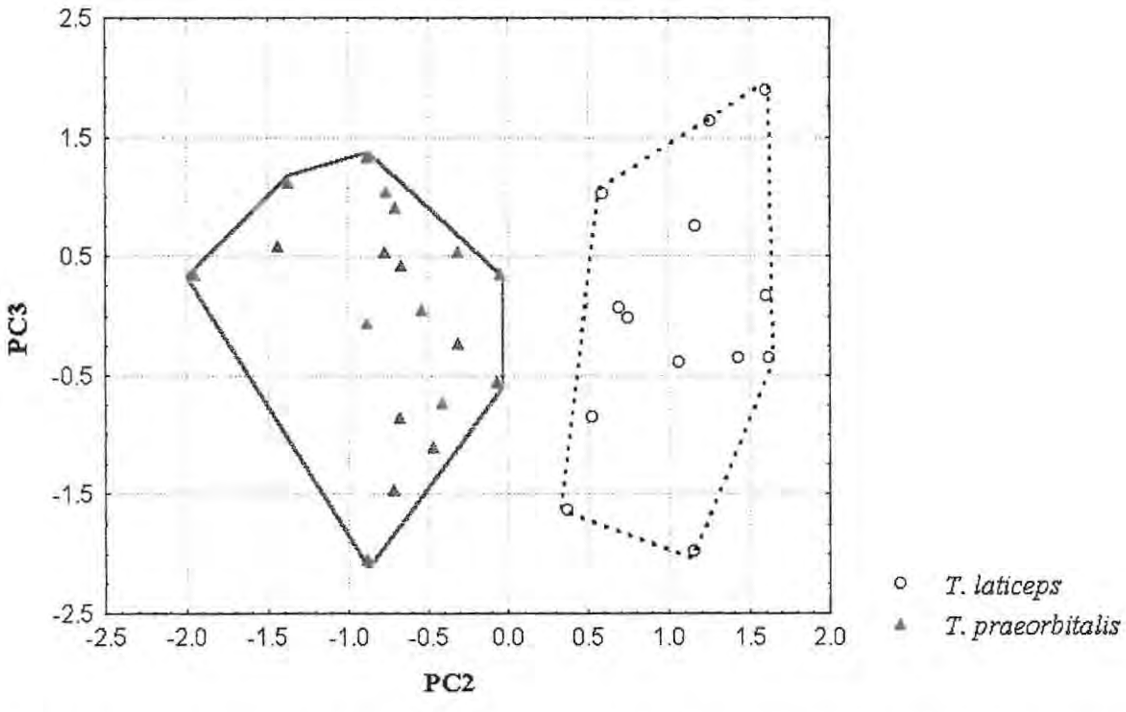


Fig. 4.3: Scatterplot of scores on the second and third axis of a PCA of log-transformed measurements of *T. praeorbitalis* and *T. laticeps* (n = 32).

Table 4.4: Principal component loadings of the log-transformed variables of the first five axes; *T. laticeps* and *T. furcicauda* (n = 35).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.97108	.094943	-.061443	-.055481	-.151916
LOGSNL	.97325	.139484	-.072186	-.027788	-.034110
LOGLJL	.96874	.149975	.040191	.019482	.024487
LOGPPL	.93565	.209840	-.119706	-.142020	.162310
LOGCHD	.97626	-.022474	-.104428	-.045502	-.103402
LOGED	.95433	.109565	.047046	.204923	-.060114
LOGIOW	.95464	.161470	.010002	-.094821	-.148688
LOGHW	.96103	.090625	.015467	-.114629	.026288
LOGHL	.97936	.145974	.084510	-.014392	.000298
LOGSL	.98194	-.157776	.029497	.057323	.014927
LOGBD	.97630	-.108643	-.103592	.091006	.043880
LOGDFB	.94039	-.311122	-.070592	.030646	-.006525
LOGAFB	.89649	-.335453	-.201034	-.077964	.038220
LOGPRD	.98023	.096039	-.030139	.104928	.025588
LOGPRP	.96270	.140192	.126119	-.018854	.113895
LOGPRV	.97765	.072195	.110842	.076118	.047043
LOGPRA	.98449	-.059120	.066691	.046096	.012529
LOGCPL	.86330	-.336828	.342534	-.118072	-.019935
LOGCPD	.97107	-.136745	-.092635	.053481	.018914
Expl.Var	17.46833	.578858	.261989	.145472	.108695
Prp.Totl	.91939	.030466	.013789	.007656	.005721

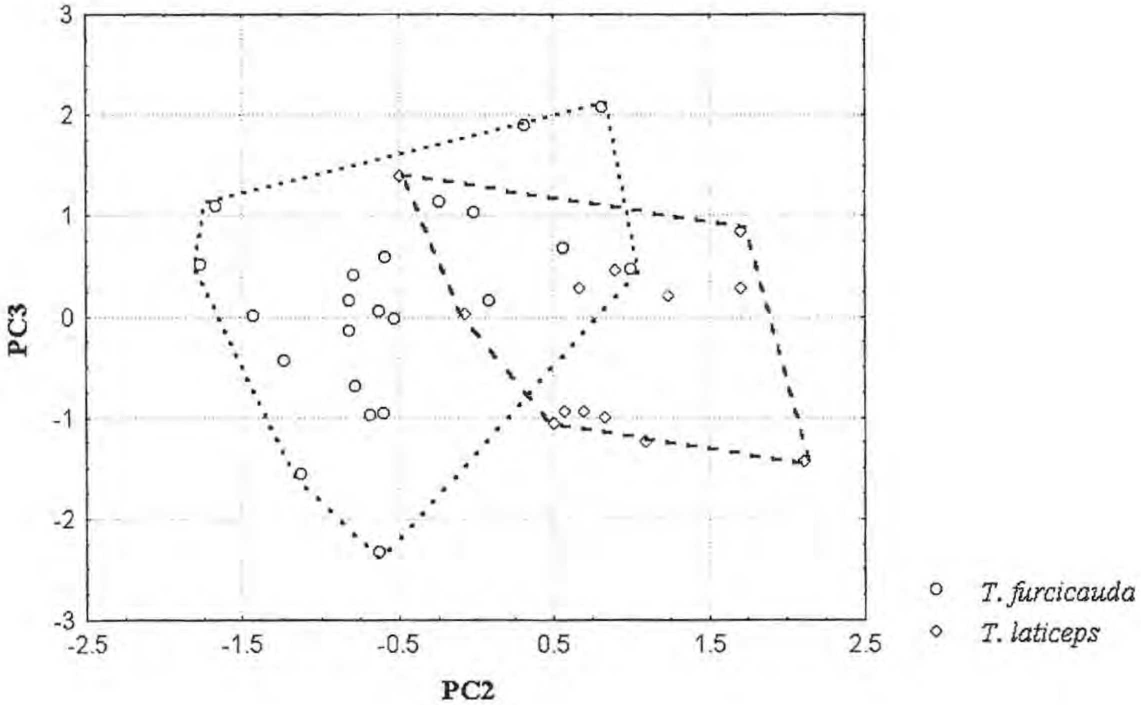


Fig. 4.4: Scatterplot scores on second and third axis of a PCA of log-transformed measurements of *T. laticeps* and *T. furcicauda* (n = 35).

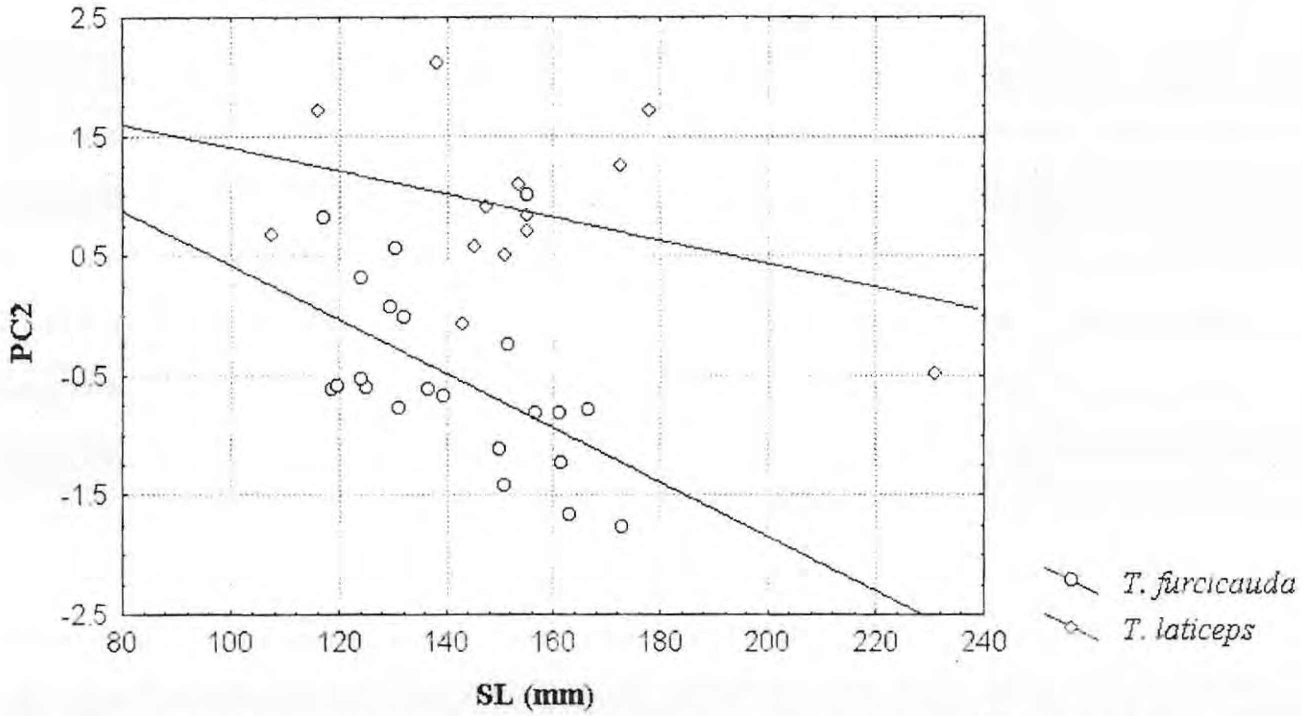


Fig. 4.5: Scatterplot of scores on second axis of a PCA on log-transformed measurements of *T. laticeps* and *T. furcicauda* on standard length; solid lines represent linear fitted functions.

4.4 Artificial key to the species of *Taeniolethrinops*

1a. 12-13 ceratobranchial gill rakers; premaxilla sometimes reaching vertical through the anterior edge of the eye; a complete dark oblique band from nape to caudal peduncle .... ***T. cyrtonotus***

1b. 8-11 ceratobranchial gill rakers; premaxilla extending to between nostril and eye; a complete oblique band from nape to caudal peduncle present in some taxa **2**

2a. Snout short, 31.3-41.1% HL; lachrymal depth 24.4-31.8% HL; premaxillary ending nearer to the eye than nostril; premaxillary pedicel length 21.9-31.4% and eye diameter 28.0-33.2% head length. A complete dark oblique band from nape to caudal peduncle present .... ***T. furcicauda***

2b. Snout long 34.4-47.7% head length; lachrymal depth 26.1-34.8% head length; premaxilla ending just behind the nostril; premaxillary pedicel length 24.1-32.7% and eye diameter 22.7-33.4% head length. A complete dark oblique band from nape to caudal peduncle may be present **3**

3a. Snout 34.4-45.0% head length; lachrymal depth 26.1-32.5% head length; eye diameter 23.8-33.4% head length; interorbital width 21.8- 26.4% head length. A complete dark oblique band from nape to caudal peduncle present.................................. ***T. laticeps***

3b. Snout 40.2-47.7% head length; lachrymal depth 29.3-34.8% head length; eye diameter 22.7-31.0% head length; interorbital width 19.8-24.5% head length. A complete dark oblique band from nape to caudal peduncle may be present in some specimens .... ***T. praeorbitalis***

4.5 *Taeniolethrinops cyrtonotus* (Trewavas, 1931)

Lethrinops cyrtonotus Trewavas, 1931: 145; Jackson, 1961: 585; Jackson et al., 1963: 85.

Lethrinops crytonotus: Ufermann et al., 1987:262.

Taeniolethrinops cyrtonotus: Eccles & Trewavas, 1989: 263, fig. 160.

(Plate 4.1)

Etymology

From Greek, *kyrtos* = "arched" + *notos* = "the back", referring to the marked arched profile of the type specimen (Eccles & Trewavas, 1989).

Diagnosis

Medium-sized species resembling *T. furcicauda* in shape of the snout but differing in the number of the ceratobranchial gill rakers (12-13 against 8-11). Differs from *T. praeorbitalis* and *T. laticeps* in shorter snout and more ceratobranchial gill rakers.

Description

Morphometric and meristic data for *T. cyrtonotus* for the holotype and other specimens examined are summarised in Table 4.6.

Snout with a straight profile but shorter than in *T. praeorbitalis* and *T. laticeps*, 29.8-41.3% HL. Jaws equal anteriorly or lower slightly projecting; premaxilla reaching vertical through the anterior edge of the eye. Oral teeth in the outer row bicuspid anteriorly becoming unicuspid at the posterior end, 70-96 teeth in the outer row of upper jaw and 50-66 in the lower, inner teeth in both jaws unicuspid, 2-4 inner rows in the upper and 4-5 in the lower. Lower pharyngeal bone sub-triangular, teeth all small except for the posterior ones, which are larger, compressed and with anterior cusps, 10-14 along the longest medial series and 32-40 across the posterior margin. Caudal emarginate. A dark band from nape to caudal base on the dorsal profile, distinct in all five specimens examined.

Table 4.6: Morphometric ratios and meristic data for *Taeniolethrinops cyrtonotus*; H is holotype.

	H	Mean	SD	Range	N
Standard length (mm)	89.0	140.0	29.7	89.0-165.5	5
as % head length					
Lachrymal depth	21.9	27.1	3.1	21.9-29.5	5
Snout length	29.8	36.7	4.6	29.8-41.3	5
Lower jaw length	34.3	34.7	0.9	34.2-36.2	5
Premaxillary pedicel length	30.2	30.1	0.7	29.3-31.2	5
Cheek depth	25.1	28.9	2.3	25.1-31.3	5
Eye diameter	34.6	30.6	2.3	28.7-34.6	5
Head width (HW)	44.4	43.1	4.1	40.5-45.5	5
Interorbital width	23.2	23.0	1.1	21.3-24.2	5
as % standard length					
Head length (HL)	35.4	34.2	0.9	33.3-35.4	5
Body depth	39.3	38.2	1.0	37.0-39.3	5
Dorsal fin base length	57.3	54.9	1.6	53.3-57.3	5
Anal fin base length	20.8	19.2	1.2	17.5-20.8	5
Predorsal distance	41.0	37.5	2.0	36.3-41.0	5
Prepectoral distance	35.4	33.8	1.2	32.7-35.4	5
Prepelvic distance	37.6	38.7	1.1	37.3-39.6	5
Pre-anal distance	60.1	64.8	3.0	60.1-67.7	5
Caudal peduncle length (CPL)	19.1	19.3	0.7	18.7-20.1	5
Caudal peduncle depth	13.5	12.4	0.7	11.5-13.5	5

Other					
Interorbital width % HW	52.1	53.5	1.6	52.1-56.2	5
Lower pharyngeal jaw length (PhJL) % HL	30.2	28.4	1.2	27.8-30.2	4
Lower pharyngeal jaw width(PhJW) % PhJL	86.3	87.1	2.4	85.1-90.6	4
Dentigerous area length (DeAL) % PhJL	54.3	55.5	2.3	52.6-57.4	4
Dentigerous area width (DeAW) % PhJW	73.2	75.5	2.2	73.2-77.9	4
Dentigerous area length % DeAW	86.7	84.4	1.9	82.3-86.7	4
Caudal peduncle depth % CPL	70.6	64.1	4.4	60.7-70.6	5

	H	Median	Range	N
Number of teeth upper jaw	71	72	70-96	5
Number of teeth lower jaw	52	52	50-66	5
Inner rows upper jaw	2	4	2-4	5
Inner rows lower jaw	4	4	4-5	5
Gill rakers lower	12	12	12-13	5
Gill rakers total	17	17	16-18	5
Dorsal spines	15	15	15-15	5
Dorsal soft	13	13	10-13	5
Anal soft	10	9	8-10	5
Pectoral fin rays	16	16	16-16	5
Upper lateral line scales	23	24	22-25	5
Lower lateral line scales	16	16	15-17	5
Longitudinal line scales	34	34	31-34	5
Transverse scales above LL	5	5	4-5	5
Transverse scales below LL	9	9	9-9	5
Scales <pectoral-pelvic fin>	6	5	5-6	5
Cheek scales	4	3	3-4	5

Colour pattern

A broad dark band from nape to caudal base, near and parallel to dorsal outline. Specimens examined were all females and were silvery-grey.

Distribution

The type locality is unknown as the collector (Christy) just indicated 'Lake Nyasa'. The other four specimens were collected during the present study, one from Lukoma Bay, in Tanzania and three from Khande in Malawi (Figure 4.6).

Ecology

Probably feeds on small invertebrates found on the sandy substrate, as do the other members of the genus. The fact that this species has a higher number of gill rakers than its congeners suggest a diet of smaller items than that of other members, with a low number of ceratobranchial gill rakers.

Discussion

Eccles &Trewavas (1989) suggested that the holotype might be an aberrant individual of an undescribed species, which they referred to as "*Haplochromis* c.f. balteatus". But this species, they said, had a different dental arcade not typical of *Lethrinops*. The type specimen of *T. cyrtonotus* in the BMNH was examined and measured for this study and it was confirmed that the fish indeed has a *Lethrinops*-type of dentition and a higher number of ceratobranchial gill rakers. Therefore "*Haplochromis* c.f. balteatus" could be something else unrelated to members of the genus *Lethrinops* 'sensu' Trewavas 1931. The individuals assigned to *T. cyrtonotus* in this study were collected in Khande (Malawi) and one in Lukoma Bay (Tanzania). However, they do not have the humped backs evident in the type specimen. They resemble *T. furcicauda* in morphology except for the higher number of gill rakers.

Specimens examined

BMNH 1930.1.31.100; female 89.0 mm SL; 'L. Nyasa'; coll. Christy; holotype

SADC/GEF (28/53/12); female 142.5 mm SL, Lukoma Bay, Tanzania; bottom gill net; 5m depth; 12/10/98. **SADC/GEF (16/2/6)**; female 152.0 mm SL, female 165.5 mm SL, 151.5 mm SL; Khande; bottom trawl at 9-14 m depth; 03/06/97.

4.6 *Taeniolethrinops furcicauda* (Trewavas, 1931)

Lethrinops furcicauda Trewavas, 1931: 149; Jackson, 1961: 587; Jackson et al., 1963: 85; Turner, 1977: 264; Bowmaker et al., 1978:1229; Lewis 1981: 750 tab.1 ; Axelrod et al., 1986: pl.324; Axelrod & Burgess, 1986: 63, photo.; Uffermann et al., 1987: 262.

Taeniolethrinops furcicauda: Eccles & Trewavas, 1989: 261, fig. 159; Konings, 1990:306, photo.; Konings, 1995: 297, photo 3; Turner, 1996:97, photo on page 61.

(Plates 4.2, B1)

Etymology

Named derived from Latin, *furca* = "fork" + *cauda* = "tail" which refer to the deeply forked caudal fin (Eccles & Trewavas, 1989).

Diagnosis

Medium-sized species with a shorter snout than *T. laticeps* and *T. praeorbitalis* (31.3-41.1 vs 34.4-47.7 % HL) of the same size. Resembles *T. cyrtonotus* in snout shape but differs in the number of ceratobranchial gill rakers (8-11 vs 12-13). Oblique band faint or absent.

Description

For descriptive statistics of measurements and meristic data see Table 4.7. Snout with a slightly convex profile 31.3-41.1% in head length; jaws equal anteriorly or lower jaw projecting; maxillary extending to between nostril and eye. Oral teeth in the outer row bicuspid anteriorly becoming unicuspid on the posterior end, with 54-82 and 32-58 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 2-4 rows. Lower pharyngeal bone triangular, teeth 11-13 along the longest medial series and 33-40 across the posterior margin. Caudal fin emarginate. An oblique dark band from nape to base of caudal which, however, may be masked completely by male breeding colours.

Table 4.7: Morphometric ratios and meristic data for *Taeniolethrinops furcicauda*.

	Mean	SD	Range	N
Standard length (mm)	141.6	17.6	117.0-173.0	22

as % head length				
Lachrymal depth	28.0	1.9	24.4-31.8	22
Snout length	37.7	2.7	31.3-41.1	22
Lower jaw length	36.4	1.5	32.1-38.7	22
Premaxillary pedicel length	28.0	2.1	21.9-31.4	22
Cheek depth	30.7	2.3	25.6-35.7	22
Eye diameter	30.2	1.3	28.0-33.2	22
Head width (HW)	43.1	2.4	38.7-47.6	22
Interorbital width	23.3	1.1	21.1-26.2	22
as % standard length				
Head length (HL)	34.8	1.8	32.5-38.5	22
Body depth	36.8	1.4	34.0-39.0	22
Dorsal fin base length	54.4	1.9	50.5-58.0	22
Anal fin base length	19.1	1.2	17.0-21.5	22
Predorsal distance	36.6	1.4	33.5-39	22
Prepectoral distance	34.1	2.2	31.0-38.0	22
Prepelvic distance	39.0	1.6	35.0-41.5	22
Pre-anal distance	65.4	1.6	63.0-68.5	22
Caudal peduncle length (CPL)	19.3	1.1	17.5-21.0	22
Caudal peduncle depth	12.0	0.5	11.0-13.0	22
Other				
Interorbital width % HW	54.0	3.5	47.2-61.9	22
Lower pharyngeal jaw length (PhJL) % HL	28.0	1.5	24.7-30.2	21
Lower pharyngeal jaw width(PhJW) % PhJL	80.4	3.1	74.6-85.9	21
Dentigerous area length (DeAL) % PhJL	59.5	4.4	50.7-66.7	21
Dentigerous area width (DeAW) % PhJW	75.6	4.5	65.6-83.1	21
Dentigerous area length % DeAW	98.1	7.4	85.5-114.1	21
Caudal peduncle depth % CPL	62.5	4.9	52.0-70.8	22

	Median	Range	N
Number of teeth upper jaw	70	54-82	20
Number of teeth lower jaw	46	32-58	20
Inner rows upper jaw	3	2-4	22
Inner rows lower jaw	3	2-4	22
Gill rakers lower	9	8-11	22
Gill rakers total	14	13-17	22
Dorsal spines	15	14-17	22
Dorsal soft	12	11-13	22
Anal soft	10	9-10	22
Pectoral fin rays	16	16-17	22
Upper lateral line scales	25	22-30	22
Lower lateral line scales	16	15-19	22
Longitudinal line scales	34	32-36	22
Transverse scales above LL	5	4-7	22
Transverse scales below LL	9	8-10	22
Scales <pectoral-pelvic fin>	5	4-7	22
Cheek scales	3	3-4	22

Colour pattern

Turner (1996) reports females and immature males as being dark grey dorsally, with silver flanks, marked by seven irregular vertical bars. Three freshly caught male specimens that were purchased from fishermen around Namalenji Island in Senga Bay (Malawi) for this study, had the dorsal and caudal fins dark with grey spots. Lower part of the body, pelvic, anal and especially the lower part of caudal fins was bright yellow. A dark broken band obliquely crosses the upper lateral line and runs from nape to caudal. This band is not as prominent as in *T. laticeps* and in some members of *T. praeorbitalis*. Breeding males have a darker body with yellow iridescence and a blue head, especially the snout. The anal fin of such males is ornamented with several brownish "egg-spots".

Konings (1995, page 298, photo 1) illustrates a species under the name *Taeniolethrinops* sp. 'furcicauda Ntekete'. This fish resembles the fish assigned to *Lethrinops furcifer* in this study because of the short snout, blue head and the orange tinge.

Distribution

Eccles & Trewavas (1989) recorded it at a depth of 5-20 fathoms (9-36m) in their trawl surveys in the southern part of the lake. Turner (1996) reports this species to be sometimes dominant in terms of biomass in samples during the 1992 trawl surveys in the south east arm of the lake and occasionally taken as deep as 55 m. The syntypes examined in the BMNH, were collected from Mwaya in Tanzania, Karonga (northern Malawi) and Fort Maguire in the south. During the SADC/GEF Lake Malawi Project research surveys in the south-west arm of the lake, *T. furcicauda* were found mostly at 10 m and sometimes at 30 m (SADC/GEF Lake Malawi/Nyasa unpublished report). During this study this species were collected mainly from several areas in Malawi but also from Mozambique. This fish has a lake-wide distribution (Fig. 4.6).

Ecology

The stomach contents of five specimens examined by Grant & Turner (unpublished work) were dominated by chironomid larvae and copepods, along with sand detritus, some algal material, other insect larvae and bivalves (Turner, 1996). *Taeniolethrinops furcicauda* has very fine teeth on the pharyngeal bone suggesting that it feeds on a soft benthic diet.

Discussion

The syntypes that have been examined in the BMNH have a characteristic oblique band running parallel with dorsal outline and a clearly forked caudal fin. Konings (1990) illustrates a photograph of a specimen, which resembles those syntypes seen at the BMNH during this study. However, the photograph in Koning, 1995: 298, photo 1 which is claimed to be *T.* sp. 'furcicauda ntekete', is suggested to be conspecific with specimens considered under *L. furcifer* in this study.

The species tentatively assigned to *T. furcicauda* by Turner (1996) showed no oblique band. It is possible that the forms living on shallow muddy substrates do not reveal this characteristic oblique band.

Specimens examined

BMNH 1930.1.31.210; female 151.5mm SL; Mwaya, Tanzania; syntype. **BMNH 1930.1.31.211**; female 155.0mm SL; Bar to Fort Maguire, Malawi; coll. Christy; syntype. **BMNH 1930.1.31.202**; female 156.5mm SL; Karonga, Malawi; coll. Christy; syntype. **SADC/GEF 97/01/10/08-10**; male 130.5mm SL, male 124.0mm SL, male 117.0mm SL; Senga Bay, Malawi; purchase from chirimila fishermen; 14/04/97. **SADC/GEF 97/14/01/21**; female 118.5mm SL; Chembe beach, Malawi; gill net catch from fishermen; 20/05/97. **SADC/GEF 97/16/98/30**; female 161.5mm SL; Senga Bay, Malawi; bottom trawl at 4m depth; 08/06/97. **SADC/GEF 97/16/76/03**; male 139.5mm SL; Domira Bay, Malawi; bottom trawl at 17-23m depth; 07/06/97. **RUSI: 050894**; female 125.0mm SL, female 136.5mm SL; South West Arm of Lake Malawi (14°01′S 34°32′E); 12-19m depth; 24/11/94. **SADC/GEF (33/2/30)**; female 129.5mm SL; Jafua Bay, north of Cobue, Mozambique; bottom trawl; 04/04/98. **SADC/GEF 98/44/01/01-02**; male 173.0mm SL, male 163.0mm SL; Lifuwu, Malawi; purchase from gill net fishermen; 31/07/98. **SADC/GEF 98/42/50/01-03**; female 124.0mm SL, female 131.0mm SL, 119.5mm SL; East shore of northern part of the South East Arm, Malawi; bottom trawl at 10m depth; 02/10/98. **SADC/GEF 98/33/21/26-28**; female 161.0mm SL, female 150.0mm SL, female 151.0mm SL; Chiwanga, Mozambique; bottom set gill nets; 09/04/98. **SADC/GEF 98/33/02/18**; female 132.0mm SL; Jafua Bay, north of Cobue, Mozambique; bottom trawl; 04/04/98. **SADC/GEF 97/21/03/28**; female 166.5mm SL; north end of south west arm and south east arm, a transect trawl from Chipoka to Makanjira, Malawi; 08/10/97

4.7 *Taeniolethrinops laticeps* (Trewavas, 1931)

Lethrinops laticeps Trewavas, 1931: 150; Jackson, 1961: 587 (doubtfully distinct from *L. praeorbitalis*); Jackson *et al*., 1963: 85; Bowmaker et al., 1978: 1229; Ufermann et al., 1987:262.

Taeniolethrinops laticeps: Eccles & Trewavas, 1989: 261, fig. 158 (species distinction with *T. praeorbitalis* doubtful); Konings, 1995: 296 photo 3 (not *T. laticeps*), pg. 298 photo 1 (not *T. laticeps*); Turner, 1996: 133, photo pg. 165.

(Plate 4.3)

Etymology

From Latin, *latus* = "broad" + *caput* = "head" referring to the broad-headed, robust appearance.

Diagnosis

A long-snouted *Taeniolethrinops* with a broad head, ventrally positioned mouth and a prominent black oblique band. It has a longer snout than *T. furcicauda* and *T. cyrtonotus* and can be distinguished from *T. praeorbitalis* by its generally wider interorbital distance and lack of yellow ventral colouration.

Description

Morphometric and meristic data for T. *laticeps* are summarised in Table 4.8.

Snout with a straight profile, 34.4-45.0 % HL. Jaws equal anteriorly or lower slightly projecting; maxillary ending nearer to nostril than to eye. Oral teeth in the outer row bicuspid anteriorly becoming unicuspid at the posterior end, 50-82 teeth in the outer row of upper jaw and 34-60 in the lower, inner teeth in both jaws unicuspid , 2-4 inner rows in the upper and lower. Lower pharyngeal bone triangular, teeth all small, compressed and with anterior cusps, 12-15 along the longest medial series and 34-40 across the posterior margin. 3-5 scales on the cheek; Caudal fin emarginate. A dark oblique band from nape to caudal base, more distinct in immature and female specimens than in breeding males.

Table 4.8: Morphometric ratios and meristic data for *T. laticeps*.

	H	Mean	SD	Range	N
Standard length (mm)	231.0	153.3	30.2	107.5-231.0	13
as % head length					
Lachrymal depth	32.0	29.3	2.0	26.1-32.5	13
Snout length	45.0	40.2	3.0	34.4-45.0	13
Lower jaw length	39.9	37.5	1.3	34.8-39.9	13
Premaxillary pedicel length	30.9	29.6	1.9	24.1-31.6	13
Cheek depth	33.6	30.8	1.6	27.8-33.6	13
Eye diameter	23.8	28.8	2.8	23.8-33.4	13
Head width (HW)	44.2	42.9	1.6	40.7-45.4	13
Interorbital width	26.4	23.7	1.4	21.8-26.4	13
as % standard length					
Head length (HL)	35.7	37.0	1.3	34.3-39.0	13
Body depth	37.7	37.8	1.0	36.0-39.4	13
Dorsal fin base length	54.1	52.6	1.4	50.0-54.6	13
Anal fin base length	18.0	18.4	0.9	16.9-19.9	13
Predorsal distance	39.2	39.8	1.8	37.6-43.0	13
Prepectoral distance	36.6	35.9	1.5	33.6-39.0	13
Prepelvic distance	41.1	41.4	0.9	40.0-42.7	13
Pre-anal distance	65.2	67.1	1.4	65.0-69.5	13
Caudal peduncle length (CPL)	20.1	17.9	1.0	16.6-20.1	13
Caudal peduncle depth	11.9	12.1	0.4	11.5-12.8	13
Other					
Interorbital width % HW	59.7	55.2	3.7	50.5-61.3	13
Lower pharyngeal jaw length (PhJL) % HL	25.7	26.2	1.4	23.5-29.2	12
Lower pharyngeal jaw width(PhJW)%PhJL	85.4	77.7	5.0	68.7-85.4	12

Lower pharyngeal jaw width(PhJW)%PhJL	85.4	77.7	5.0	68.7-85.4	12
Dentigerous area length (DeAL) % PhJL	61.3	60.5	3.8	53.7-64.4	12
Dentigerous area width (DeAW) % PhJW	70.2	76.5	4.4	66.7-80.9	12
Dentigerous area length % DeAW	102.4	102.2	6.7	93.1-115.8	12
Caudal peduncle depth % CPL	59.1	67.9	4.5	59.1-75.0	13

	H	Median	Range	N
Number of teeth upper jaw	60	68	50-82	11
Number of teeth lower jaw	40	46	34-60	11
Inner rows upper jaw	3	3	2-4	13
Inner rows lower jaw	3	3	2-4	13
Gill rakers lower	9	9	9-10	13
Gill rakers total	13	14	13-16	13
Dorsal spines	15	16	15-18	13
Dorsal soft	11	12	10-12	13
Anal soft	9	10	9-10	13
Pectoral fin rays	17	17	16-18	13
Upper lateral line scales	22	27	22-31	13
Lower lateral line scales	16	16	14-18	13
Longitudinal line scales	34	34	34-35	13
Transverse scales above LL	5	5	5-5	13
Transverse scales below LL	9	10	9-10	13
Scales <pectoral-pelvic fin>	9	5	4-9	13
Cheek scales	5	3	3-5	13

Colour pattern

Females and immature males dark grey dorsally, flanks yellowish, belly white. A wide dark band runs obliquely from just anterior to the dorsal fin to caudal peduncle. Often 8-9 vertical bars can be seen under the dorsal fin. Breeding males are generally bluish, especially on the head region. Dorsal fin lappets coppery-tipped.

Distribution

It has a lake-wide distribution (Fig. 4.7) and is found over extensive sandy bottoms as well as in the intermediate habitats. The holotype was collected by Christy at Vua (northern Malawi) and the syntype from Deep Bay (Usisya). Near Magunga village in Tanzania specimens of this species were collected for this study, using a bottom-set gill net at 5.2 m depth on a sandy bottom and some were purchased from fishermen fishing with open water seine nets at 15m depth adjacent and close to Ipembe rocks. At Lukoma Bay (Tanzania) specimens of this species were collected when trawling at a depth of 31-32m, while in Chilola Bay in Mozambique this species was recorded to a depth of 68-78m. They were, however, collected from a much shallower depth in Malawi (9 m).

Ecology

The stomachs of 2 specimens (125, 140 mm SL) are reported to have contained chironomids, large quantities of sand, detritus material and algal remains (Turner, 1996).

Discussion

Eccles & Trewavas (1989) suggested that this species may not be distinct from *T. praeorbitalis*; this view was also shared by Jackson (1961). In this study, the holotype and one paratype of this species have been examined and compared with specimens of *T. praeorbitalis* (striped form). It appears that *T. laticeps* is more robust in appearance than the striped *T. praeorbitalis*. Also, females of *T. laticeps* lack the yellow coloration on the ventral part of the body and fins evident in immature males and females of *T. praeorbitalis*. An illustration of a female fish under the name of *Taeniolethrinops* sp. 'furcicauda ntekete' (Konings, 1991: 50, photo) undoubtedly represent members that are considered to be conspecific with *T. laticeps* in this study. Also, all members of *T. laticeps* have a flat lower jaw, whereas those of *T. praeorbitalis* (striped and unstriped forms) have a shovel-like mouth. This observation is in agreement with Turner (1996), that, indeed *T. laticeps* is a valid species, distinct from *T. praeorbitalis*.

Specimens examined

BMNH 1930.1.31.221; male 231.0 mm SL; Vua, Malawi; coll. Christy; holotype. **BMNH 1930.1.31.222**; female 178.0 mm SL; Deep Bay, Malawi; coll. Christy; paratype. **SADC/GEF 97/01/11/03**; female 145.0 mm SL; Senga Bay, Malawi; purchase from fishermen; 15/04/97. **SADC/GEF 97/21/109/08**; female 147.5 mm SL; bottom trawl transect from Mazinzi to Kadango, South East arm, Malawi;16/11/97. **SADC/GEF 98/45/33/02**; female 138.0 mm SL; bottom set gill net at 5.2 m depth on sandy bottom adjacent and close to Ipembe rocks near Magunga village, Tanzania; 10/11/98. **SADC/GEF 98/45/40/04**; female 116.0 mm SL; bottom set gill nets at 22.5 m depth, Lutara (10°25.8'S 34°33.5'E), Tanzania.11/11/98. **SADC/GEF 98/45/35/03**; male 172.5 mm SL; purchase from fishermen fishing with open water seine nets at 15 m depth close to Ipembe rocks near Magunga village, Tanzania; 10/11/98. **SADC/GEF 98/33/02/40**; female 153.5 mm SL; Jafua Bay, north of Cobue, Mozambique; bottom trawl at 10.8-12.8 m depth; 04/04/98. **SADC/GEF 98/28/44/13-14**; female 143.0 mm SL, female 155.0 mm SL; Lukoma Bay, Tanzania; bottom trawl at 31-32 m depth; 11/01/98. **SADC/GEF 98/33/12/01-02**; female 107.5 mm SL, female 155.0 mm SL; Chilola Bay, Mozambique; bottom trawl at 68-78 m depth; 07/04/98. **SADC/GEF 98/33/04/19**; female 151.0mm SL; Chilola Bay, Mozambique; bottom trawl at 28.5-31.5 m depth; 04/04/98.

4.8 *Taeniolethrinops praeorbitalis* (Regan, 1921)

Tilapia lethrinus (part.), Boulenger, Cat. Afr. Fish. iii. 1915, p.254.

Haplochromis praeorbitalis, Regan, 1922: 717, pl. iii; Uffermann et al., 1987:206.

Lethrinops macrorhynchus, Regan, *tom cit.* p. 720; Trewavas, 1931:151 (synonymy with *L. praeorbitalis*); Uffermann et al., 1987: 263.

Lethrinops praeorbitalis: Trewavas, 1931: 151/ Bertram et al., 1942: 60; Jackson, 1961: 587; Jackson et al., 1963:86; Turner, 1977: 264; Bowmaker et al., 1978: 1229; Galis and Barel, 1980:392; Lewis, 1981: 750, tab. 1; Kocher and McKaye, 1983: 544; Uffermann et al., 1987:264.

Lethrinops furcifer: Mayland, 1982: 175, photo.

Lethrinops fasciatus Ahl, 1927: 61; Trewavas, 1931: 151 (synonymous with *L. praeorbitalis*); Uffermann et al., 1987: 262.

Taeniolethrinops praeorbitalis: Eccles & Trewavas, 1989: 261, fig. 157; Konings, 1991: 30-31, photos; Konings, 1995: 296, photos; Turner, 1996: 76 (*Lethrinops* and allied genera, photos).

(Plates 4.4, A7, A8, B2)

Etymology

The name refers to the elongated snout.

Diagnosis

A member of *Taeniolethrinops* characterised by a long snout and a ventrally placed mouth, a bright yellow ventral colour and sometimes a dark oblique band. It resembles *T. laticeps* in having a long snout 40.2-47.7 % HL and lachrymal depth 29.3-34.8 % HL but differs from it in less interorbital width 19.8-24.5 vs 21.8-26.4 % HL

Description

For descriptive statistics of measurements and meristic data see Table 4.9.

Snout with a straight obliquely descending dorsal profile; 40.2-47.7% in head length; lower jaw projecting; premaxilla ending just behind nostril. Oral teeth in the outer row bicuspid anteriorly becoming unicuspid on the posterior end, with 48-72 and 40-68 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 2-3 rows in upper and 2-4 in lower. Lower pharyngeal bone triangular, teeth 11-14 along the longest medial series and 32-40 across the posterior margin. Caudal fin is emarginate. A dark oblique band from nape along upper lateral line to base of caudal fin which, however, may disappear completely depending on mood.

Table 4.9: Morphometric ratios and meristic data for *T. praeorbitalis*.

	Mean	SD	Range	N
Standard length (mm)	157.5	30.9	107.5-197.5	19
as % head length				
Lachrymal depth	31.4	1.9	28.3-34.8	19
Snout length	43.4	3.1	36.6-47.7	19
Lower jaw length	37.5	1.8	34.2-42.3	19
Premaxillary pedicel length	29.4	1.8	25.7-32.7	19
Cheek depth	31.9	2.4	27.9-37.3	19
Eye diameter	25.9	2.4	22.7-31.0	19
Head width (HW)	40.7	2.1	38.0-45.3	19
Interorbital width	22.4	1.3	19.8-24.5	19
as % standard length				
Head length (HL)	36.0	0.7	34.5-37.4	19
Body depth	35.8	1.4	33.2-39.3	19
Dorsal fin base length	53.0	1.9	49.8-56.7	19
Anal fin base length	18.4	0.9	17.2-20.6	19
Predorsal distance	38.2	1.3	35.7-39.9	19
Prepectoral distance	34.8	1.2	32.1-36.5	19
Prepelvic distance	40.0	0.9	38.3-41.8	19
Pre-anal distance	65.9	2.0	60.0-68.4	19
Caudal peduncle length (CPL)	18.5	1.1	16.6-20.3	19
Caudal peduncle depth	12.0	0.5	11.1-12.9	19

Other				
Interorbital width % HW	55.1	3.8	49.5-58.4	19
Lower pharyngeal jaw length (PhJL) % HL	24.9	1.1	23.5-27.0	16
Lower pharyngeal jaw width(PhJW) % PhJL	79.6	5.3	65.8-89.0	16
Dentigerous area length (DeAL) % PhJL	60.3	3.1	55.6-64.2	16
Dentigerous area width (DeAW) % PhJW	73.6	4.7	63.0-80.4	16
Dentigerous area length % DeAW	103.7	9.7	89.6-122.4	16
Caudal peduncle depth % CPL	64.9	3.8	58.2-74.1	19

	Median	Range	N
Number of teeth upper jaw	62	48-72	15
Number of teeth lower jaw	46	38-68	15
Inner rows upper jaw	3	2-4	18
Inner rows lower jaw	3	2-4	18
Gill rakers lower	9	8-11	19
Gill rakers total	14	12-16	19
Dorsal spines	15	15-16	19
Dorsal soft	12	11-13	19
Anal soft	9	9-11	19
Pectoral fin rays	17	16-18	19
Upper lateral line scales	26	25-28	19
Lower lateral line scales	16	14-18	19
Longitudinal line scales	34	33-35	19
Transverse scales above LL	5	4-6	19
Transverse scales below LL	9	8-11	19
Scales <pectoral-pelvic fin>	5	4-7	19
Cheek scales	3	3-4	19

Colour pattern

The basic body coloration of juveniles, females and sub-adult males is silvery-grey with yellow iridescence. The snout, lower head area and chest are of intensive yellow in some individuals. The yellow coloration frequently extends to the pelvic and anal fin. Breeding males are dark-greenish to bluish all over. Some specimens have a dark band.

Distribution

According to Eccles & Trewavas (1989) *T. praeorbitalis* is common in the southern part of the lake and is caught at Mbenji Island as well. During this study specimens of *T. praeorbitalis* were collected from 15 localities around the lake (Fig. 4.7). This species has, therefore, a lake-wide distribution. Jackson (1961) and Eccles & Trewavas (1989) report that this fish extends to a depth of 50 m. However, during sandy shore cruises carried out by the SADC/GEF Lake Malawi Project between 1997-1999, specimens of *T. praeorbitalis* were recorded only up to a sampling depth of 18-25 m and surveys carried out in the south west arm of the lake encountered this fish at 10 m and 30 m but it was never common at any depth (SADC/GEF Lake Malawi/Nyasa unpublished report).

Ecology

Large cichlid, which can reach 250 mm SL. Feeds predominantly on insect larvae which they dig out from the sandy substrate (Eccles & Trewavas, 1989; Spreinat, 1996). The shovel-like mouth and the higher number of fin pectoral rays enables this fish to plunge deep into the substrate to search for food (Konings, 1995). Since *T. praeorbitalis* is a large cichlid, its continuous digging effort creates a lot of stirred-up material. Some sand-welling cichlids (e.g. *Cyrtocara moori, Fossorochromis rostratus*) are attracted to stirred-up material and usually follow *T. praeorbitalis* also searching the ploughed sand for exposed invertebrates (Konings, 1991; Spreinat, 1995). When surveying the south-west arm of the lake, the SADC/GEF Lake Malawi/Nyasa Project recorded a size range of 75 to 195 mm SL for this fish. From the stomachs of 13 specimens examined, chironomid larvae were dominant followed by copepods, but sand, detritus and other unidentified benthic invertebrates were also recorded.

Discussion

Regan (1922) based the original description of this species on two specimens collected by Wood (210 and 240 mm total length). There is no mention of the dark oblique band in this description. The types indeed do not have such a band (pers. observ.).

The type of *Lethrinops macrorhynchus*, which has been considered as a junior synonym of *T. praeorbitalis* have been examined together with three types of *Lethrinops fasciatus*, another species synonymised with *T. praeorbitalis* and the two syntypes of *T. praeorbitalis*, and compared them with freshly collected specimens. The type of *T. macrorhynchus* has a dark oblique band/stripe from the nape to caudal base, but for the types of *T. fasciatus*, only one specimen had a stripe which was however not so prominent. It was necessary to find out whether the striped and non-striped *T. praeorbitalis* were the same. On the basis of the PCA on head and body measurements and counts, no distinctive morphological character was found that could be used to delimit the striped form from the non-striped form. *Taeniolethrinops macrorhynchus*, when analysed together with specimens of *T. laticeps* and *T. praeorbitalis* for head measurements only, falls within the range of *T. praeorbitalis* and not *T. laticeps*.

Many small specimens collected from both the Malawian and Tanzanian side of the lake do not show the oblique band. This suggests that *T. praeorbitalis*, as known at present, exists in two colour patterns. However, future investigations with genetic studies might prove that they are actually different. At present, it may be safe to assume that *T. praeorbitalis* is polymorphic in colour.

T. praeorbitalis generally has 8-9 gill rakers on the lower part of the gill arch, one aberrant specimen had 11 gill rakers on one side, 9 on the other. Thus the recorded natural variation in ceratobranchials for this species is between 8 and 11.

Specimens examined

ZMB 32321; female 170.0 mm SL, female 197.5 mm SL, female110.0 mm SL; Nyassa see bei Langenburg (Lumbira); coll. Fulleborni; 3 of 8 syntypes of *L. fasciatus*.

BMNH 1921.9.6:193-194; male 197.0 mm SL, female 179 mm SL; 'Lake Nyasa' coll. Wood. Syntypes of *H. praeorbitalis*. **BMNH 1897.6.9:256**; female cut in two; type of *L. macrorhynchus*. **SADC/GEF (20/31/28)**: male 175.5 mm SL; Nkhotakota, Malawi; trawl bottom at 7-9 m depth; 22/09/97. **SADC/GEF 97/16/02/10**; male 124.0 mm SL; Khande, Malawi; bottom trawl, 18-25 m depth; 03/06/97. **SADC/GEF 97/21/03/28**; female 194.5 mm SL female 184 mm SL; north end of south west arm and south east arm, a transect trawl from Chipoka to Makanjira, Malawi; 08/10/97. **SADC/GEF 98/28/115/19-20**; female 114.0 mm SL, female 166.5 mm SL; Weissman Bay, Tanzania; bottom set gill nets; 7-8 m depth; 14/01/98. **SADC/GEF 97/21/21/17**; unsexed 183.0 mm SL; a transect trawl from Mazinzi to Kadonga; 11/10/97. **SADC/GEF 98/33/2/11-12**; female 152.0 mm SL, female 142.0 mm SL; Jafua Bay, north of Cobue, Mozambique; bottom trawl at 10.8-12.8m depth; 04/04/98. **SADC/GEF 98/33/21/22-25**; female 107.5 mm SL, female 118.5 mm SL, female 145.0 mm SL, female 155.5 mm SL; Chiwanga, Mozambique; bottom set gill nets; 09/04/98. **SADC/GEF 98/28/89/04**; male 182.0 mm SL; Manda, Tanzania; 31/01/98.

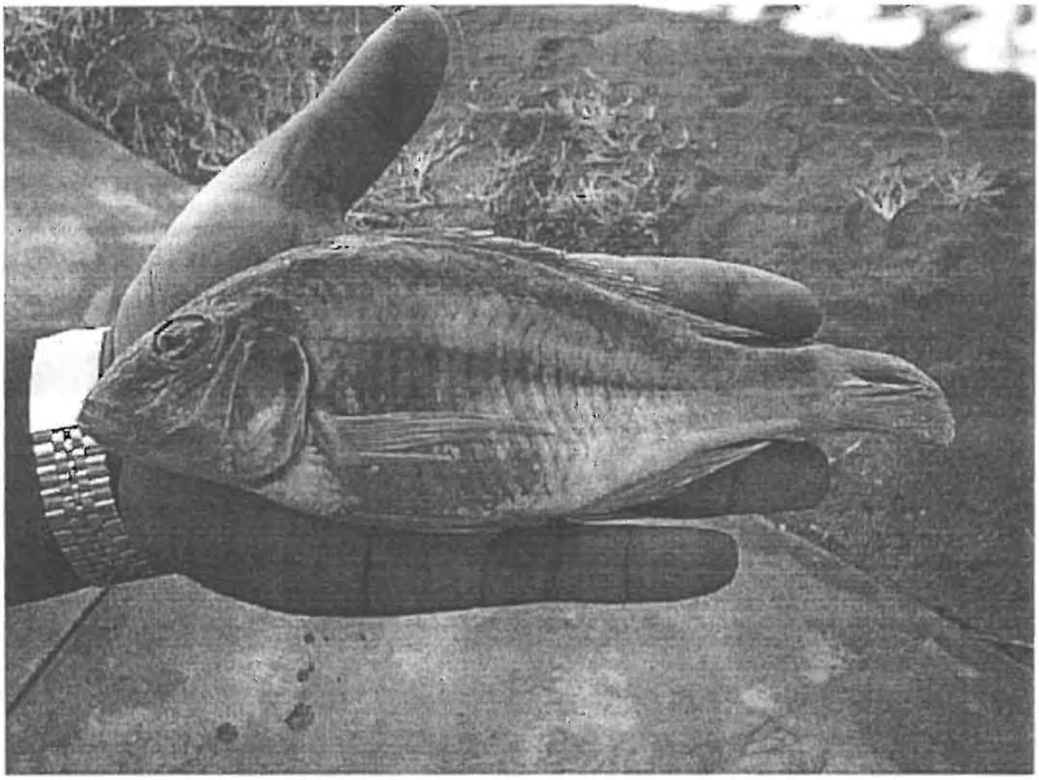


PLATE 4.1: *Taeniolethrinops cyrtonotus*

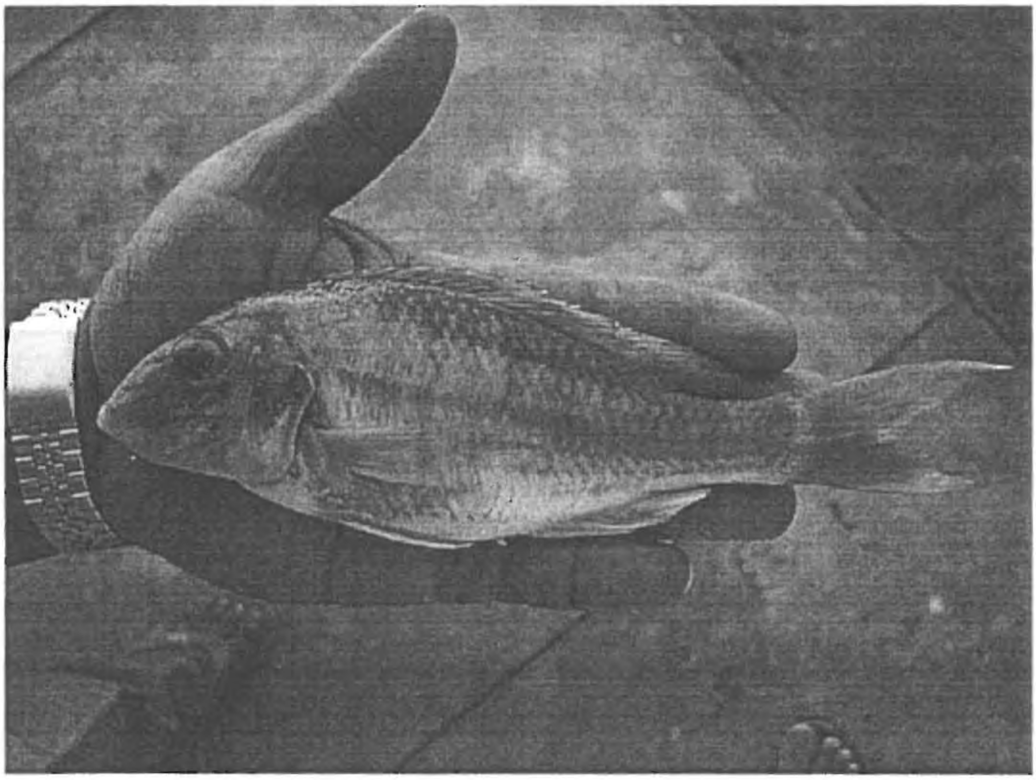


PLATE 4.2: *Taeniolethrinops furcicauda*

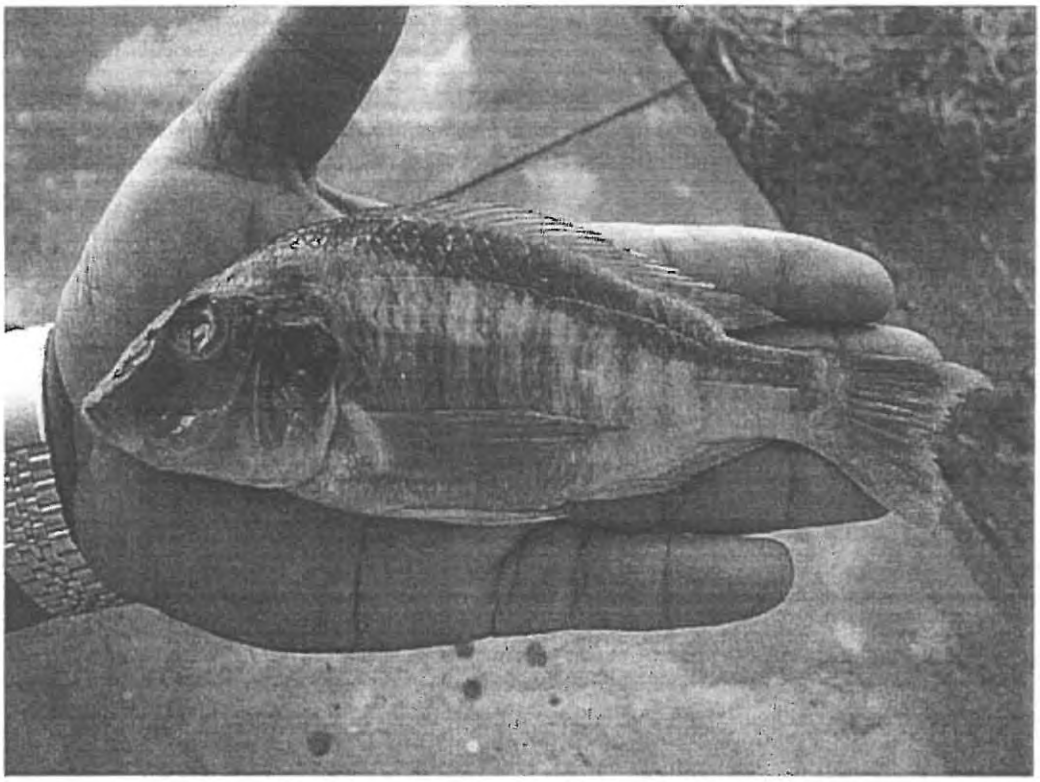


PLATE 4.3: *Taeniolethrinops laticeps*

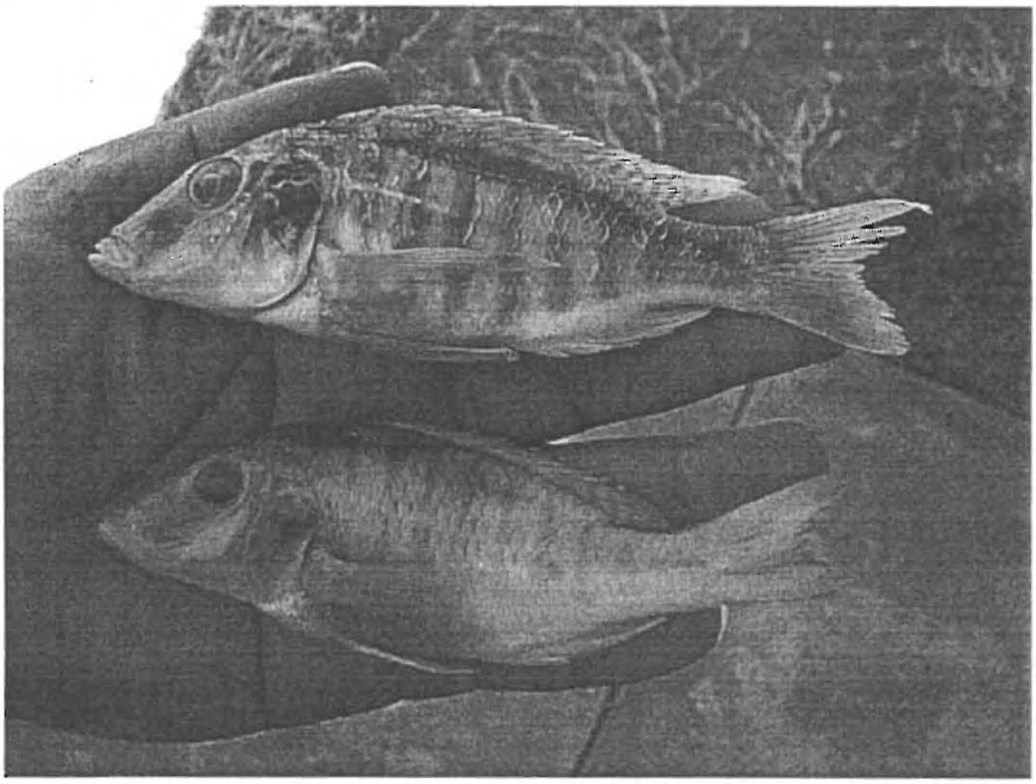


PLATE 4.4: *Taeniolethrinops praeorbitalis*

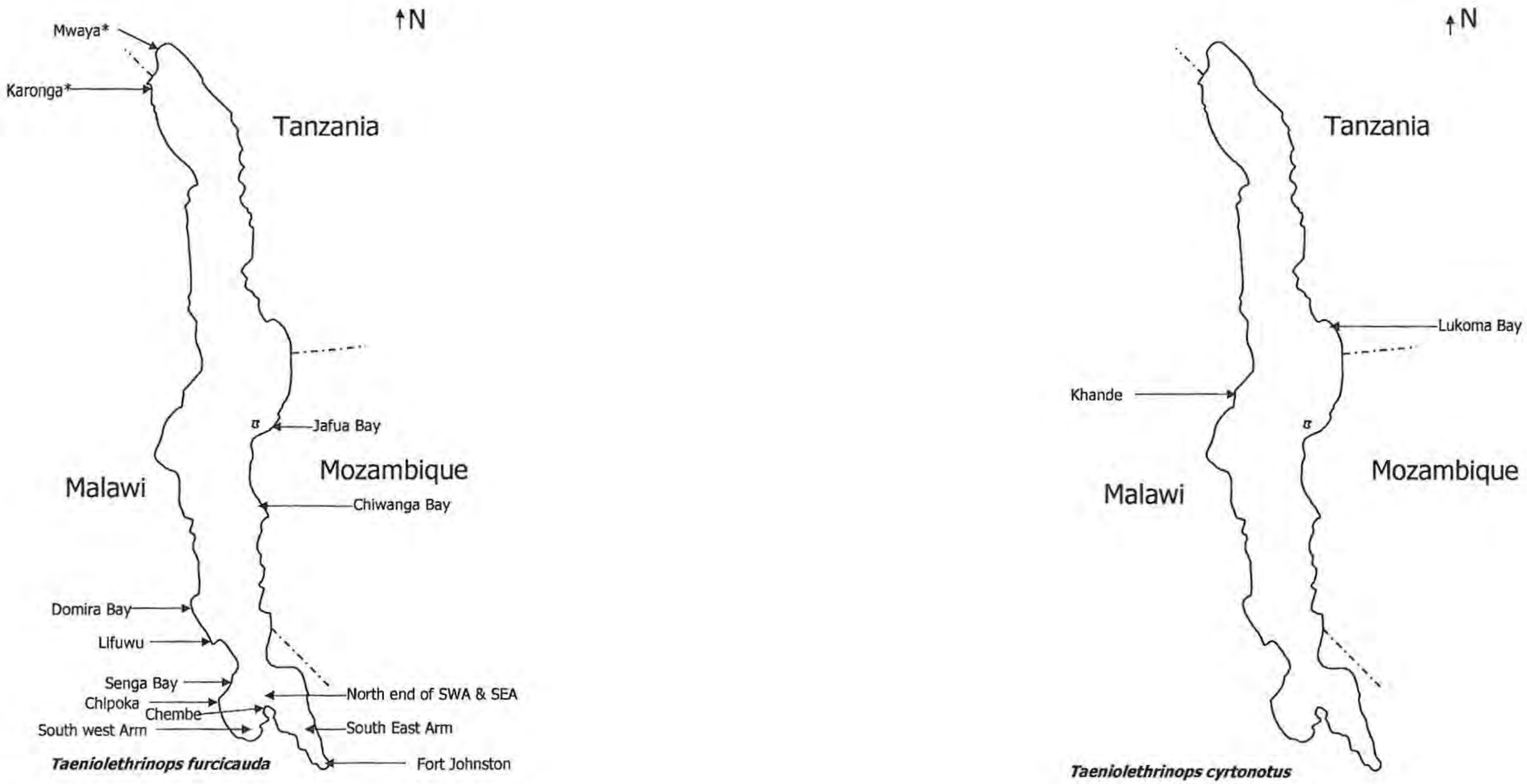


Fig. 4.6: Localities where *Taeniolethrinops furcicauda* and *T. cyrtonotus* have been collected during this study; * denotes type localities.

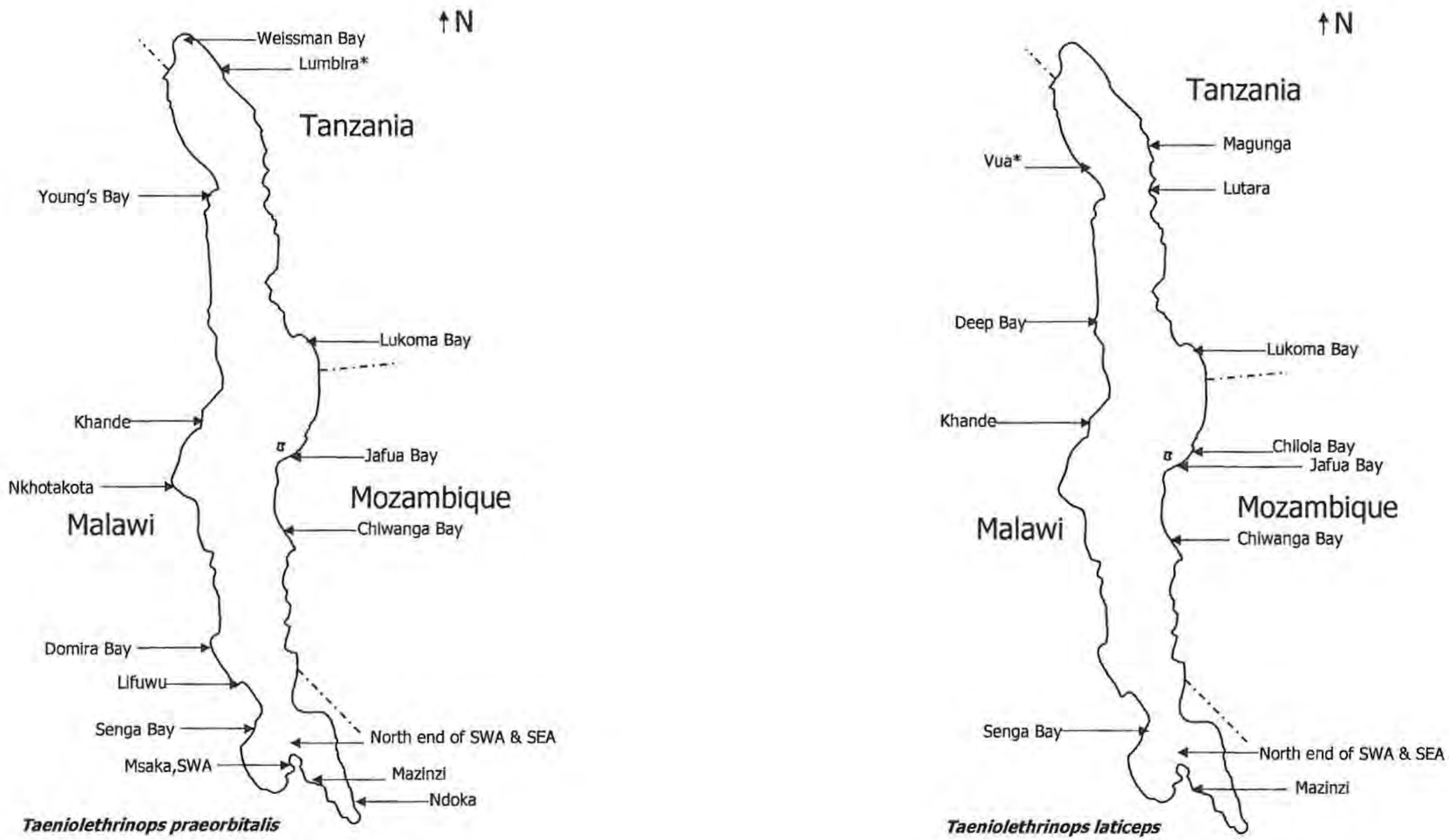


Fig. 4.7: Localities where *Taeniolethrinops praeorbitalis* and *T. laticeps* have been collected during this study; * denotes type localities.

Chapter 5: The genus *Tramitichromis* Eccles & Trewavas 1989

Tramitichromis Eccles & Trewavas, 1989: 256. Type species: *Tilapia brevis* Boulenger, 1908, by original designation.

Etymology

According to Eccles & Trewavas (1989) the generic name is derived from Latin '*trames*' which means a byway and adding '*chromis*'. It refers to the departure of the lower pharyngeal jaws from the usual range of structure.

5.1 Introduction

The genus *Tramitichromis* is characterised by the peculiar shape of the lower pharyngeal bone. The teeth on this bone are all slender and long; those situated at the front are longer, an unusual feature. These long anterior teeth are further characterised by their long tips, which are bent backwards. In all other species of *Lethrinops* 'sensu lato' the front teeth are small and their tips pointed forward. Another feature of *Tramitichromis* is the downward projecting anterior blade of the pharyngeal bone. The upper edge of this blade runs horizontally in most cichlids, but in *Tramitichromis* it is downward inclined forming a keel-like shape.

The lower gill-rakers are squat and strong. In some members of *Tramitichromis* the first two rakers are usually no more than small knobs on the gill arch. The central three to five rakers on the lower arch are much larger. Most individuals are found in the intermediate habitat; that is in the sandy bottom between rocks. During this study, most specimens of *Tramitichromis* were collected when gillnetting on intermediate habitats, but some were obtained from extensive sandy beaches. Intermediate habitats usually have coarse sand particles and the skeletal features of *Tramitichromis* may have evolved as an adaptation to feeding on food items that are found in this habitat. Konings (1995) argued that the strength of the rakers is probably needed to withstand the abrasive action of heavy sandy particles, hence the characteristic form and number of ceratobranchial gill rakers (few and broad). Nine taxa have been recognised in this study. Five have been previously described as valid species: *T. brevis*, *T. variabilis*, *T. trilineata*, *T. lituris* and *T. intermedius*. Four are probably new species, and a preliminary description is given here in this work. They are however, only referred to by their working names (cheironyms) as: *Tramitichromis* sp. 'pharyngeals', *T.* sp. '*variabilis* deep', *T.* sp. '*brevis* 2' and *T.* sp. 'maculae'. The later three appeared to represent rare species, although their similarity to better known species and scarcity of material means that their status as new species is uncertain at this stage. The nine taxa, while sharing the characteristic unusual pharyngeal bone shape and dentition, exhibit a variety of melanin patterns ranging from a diagonal band, through oblique spots to only having vertical bars. *Tramitichromis brevis* has a characteristic diagonal band as in the genus *Mylochromis* and some members of the genus *Taeniolethrinops* but differ from *Mylochromis* species in oral dental arcade and from *Taeniolethrinops* species in head shape. Turner (1996), in a pragmatic approach to classify the Lake Malawi/Nyasa cichlids according to their melanin pattern, discussed *T. brevis* under the genus *Mylochromis* and other oblique-striped species and *T. intermedius* under the genus *Otopharynx* and other spotted species. Konings (1995) discusses and illustrates a number of specimens under *Tramitichromis* but some of them are misidentified. For example, figures 3 and 4 on page 288 are definitely not *T. brevis*. Of the nine taxa mentioned and discussed below, only *T. intermedius* has bicuspid anterior pharyngeal teeth, with tips straight and not turned backward, and the blade less prominently inclined ventrally. This characteristic is shared with some members of the short-snouted *Lethrinops* 'sensu stricto'.

5.2 Diagnosis

Anterior blade of lower pharyngeal bones directed downwards and anterior part of the toothed area is broad, ending in 3 or more tooth rows. Lower pharyngeal jaw teeth either bicuspid or unicuspid with tips of anterior teeth turned backwards in all species except one. Melanin pattern variable consisting of either a complete or incomplete oblique dark band or lateral dark spots or vertical bars. Snout equal to or shorter than diameter of the eye. Lower gill raker counts 5 to 10.

5.3 Analysis

A first Principal Component Analysis on measurements for all the nine taxa of this genus (n=70) was not very informative. However, *Tramitichromis brevis*, *T.* sp. '*brevis* 2', *T.*

trilineata and *T.* sp. '*variabilis* deep' are mainly on the positive part of the third axis. This axis is defined mainly by the eye diameter and by premaxillary pedicel length (Table 5.1). *Tramitichromis variabilis* and *T.* sp. 'maculae' are on the negative part of the same axis. *Tramitichromis intermedius*, *T.* sp. 'pharyngeals' and *T. lituris* are scattered on the positive and negative parts of the third axis (Fig. 5.1).

Repeating the analysis, but using only meristics and excluding specimens with insufficient data (n = 58), the highest factor loadings on the first principal component are for the number of inner teeth rows on the lower jaw and the gill raker counts on the ceratobranchial gill arch (Table 5.2). A plot of the first axis against standard length shows *T. intermedius* to be on the positive part of the first axis (Fig. 5.2). Another plot of the number of ceratobranchial gill rakers against standard length reveals that *T. intermedius* is the only member in the genus *Tramitichromis* with a high number of gill rakers of 8-10 against 5-7 in the rest of similar size (Fig. 5.3).

A Principal Component Analysis on the remaining eight taxa (n=59) including measurements for the lower pharyngeal bone, shows the highest loadings on the second axis are for the pharyngeal jaw dentigerous area width (DEAW), pharyngeal jaw width (PHJW), pharyngeal jaw length (PHJL) and eye diameter and on the third axis for the pharyngeal jaw dentigerous area width and the anal fin base length (table 5.3). *Tramitichromis* sp. 'pharyngeals' is separated on the positive part of the second axis and the negative part of the third axis (Fig. 5.4).

In a further PCA on the measurements of the seven remaining members excluding *T.* sp. 'pharyngeals' (n=53), *T. trilineata* is on the positive side of the third axis clearly separated from the rest. The third axis is defined mainly by anal fin base length and by body depth (Table 5.4, Fig. 5.5).

Of the remaining six members of *Tramitichromis*, *T. brevis* and *T.* sp. '*brevis* 2' have a different plesiomorphic melanin pattern from the rest. This consists of a complete dark oblique band from nape to caudal peduncle. Therefore *T. brevis* and *T.* sp. '*brevis* 2' are analysed separately from the other four taxa.

The analysis of *T. brevis* and *T.* sp. '*brevis* 2'(n=21), shows the highest loadings on the second axis to be due to the eye diameter and the lower jaw length and on the third axis due to the anal fin base length (Table 5.5). A plot of the second axis against standard length shows a clear separation of the two taxa (Fig. 5.6).

The last principal component analysis for this group is done on the four remaining members, *T. lituris*, *T. variabilis*, *T.* sp. '*variabilis* deep' and *T.* sp. 'maculae. The highest loadings on the second axis are on the caudal peduncle length, lower jaw length and cheek depth and on the third axis the highest loading is on the premaxillary pedicel length and eye diameter (Table 5.6). A scatter plot of the second against the third axis indicates a separation of *T. variabilis* on the negative parts of both axes (Fig. 5.7). There is, however, an overlap between the three taxa excluding, *T.* sp. 'maculae'. Of these four members of *Tramitichromis*, *T.* sp. 'maculae' is the only member with a highly maculated caudal and dorsal fin, small eye (diameter ≤ 29.8 % in head length) and longer snout (snout length ≥ 38.4 % in head length).

The eventual differences between *T. lituris* and *T. variabilis* were explored using a Mann-Whitney U-test on samples of comparable sizes [*T. lituris* 123.2±7.3 (110.0-140.0) mm SL (n=11) and *T. variabilis* 127.1± 8.1 (105.5-150.5) mm SL (n=10)]

Table 5.7 below summarises the main characters that are significantly different between the two members of *Tramitichromis*.

Table 5.7: Synopsis of the significant differences in measurements between *T. lituris* and *T. variabilis* on samples of comparable sizes (p=0.57) [*T. lituris* 123.2±7.3 (110.0-140.0) mm SL (n=11) and *T. variabilis* 127.1± 19.0 (105.5-150.5) mm SL (n=10)]. In the third column is stated which species has the larger value for each of the characters.

Lachrymal depth % HL	P<0.05	*T. lituris* > *T. variabilis*
Lower jaw length % HL	P<0.05	*T. lituris* > *T. variabilis*
Cheek depth % HL	P<0.05	*T. lituris* > *T. variabilis*
Dorsal fin base length % SL	P<0.05	*T. lituris* > *T. variabilis*
Predorsal distance % SL	P<0.01	*T. lituris* > *T. variabilis*
Preanal distance % SL	P<0.05	*T. lituris* < *T. variabilis*

Tramitichromis sp. 'variabilis deep' can be distinguished from *T. lituris* and from *T. variabilis* by having a slightly deeper body.

Table 5.1: Principal component loadings of the log-transformed variables on the first five axes; all nine taxa of the genus *Tramitichromis* measured (n = 70).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.98747	-.107182	.048590	-.027312	.013930
LOGSNL	.98708	-.113391	-.001187	.022356	.041410
LOGLJL	.98488	-.074389	.033990	.009190	.068159
LOGPPL	.97341	-.130797	.078046	.008811	-.154008
LOGCHD	.98689	-.046833	.022173	-.079452	.064934
LOGED	.95676	.167840	.226648	.046540	.022163
LOGIOW	.98144	.030550	-.018077	.098030	-.061293
LOGHW	.98616	.003374	.038767	.010355	-.008216
LOGHL	.99662	-.024258	.009109	.023662	.023341
LOGSL	.99514	.053109	-.040116	-.033562	.015375
LOGBD	.98877	.046829	-.050958	.031082	-.050122
LOGDFB	.99276	.076244	-.034721	-.009797	-.000218
LOGAFB	.97849	.097975	-.109612	-.010697	-.031293
LOGPRD	.99084	-.053143	-.024986	.041988	.032483
LOGPRP	.99176	-.033395	-.021342	.032688	.030344
LOGPRV	.99494	.015357	-.019943	.024386	.002251
LOGPRA	.99222	.059637	-.040576	-.014305	.027254
LOGCPL	.97288	.032053	.015104	-.211444	-.044457
LOGCPD	.98627	.004338	-.102600	.036126	.004711
Expl.Var	18.45521	.108088	.094688	.072111	.047800
Prp.Totl	.97133	.005689	.004984	.003795	.002516

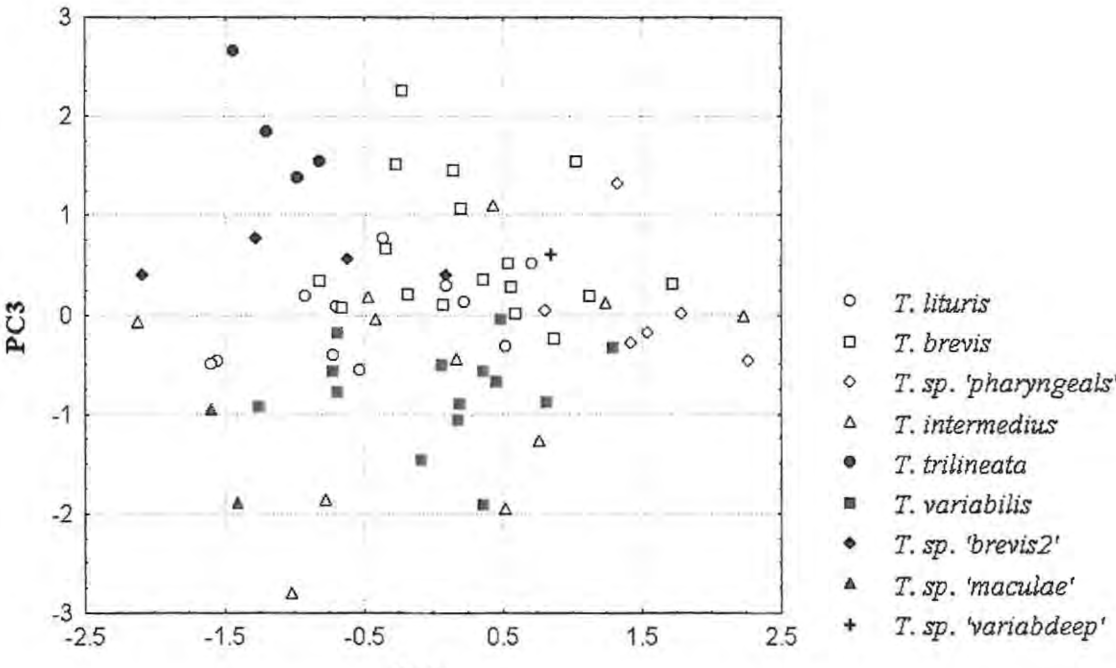


Fig. 5.1: Scatterplot of factor scores on the second and third axis of PCA of log-transformed variables of all members of the genus *Tramitichromis* measured (n = 70).

Table 5.2: Principal component loadings of the untransformed meristics on the five axes of specimens of the genus *Tramitichromis* examined (n = 58).

VARIABLE	PC1	PC2	PC3	PC4	PC5
UPPER	-.258938	-.312867	.485113	-.408614	.055259
LOWER	-.269818	-.024136	.503391	-.365044	-.149020
ROWSUP	-.649785	.214783	.419962	.413554	-.219924
ROWSLOW	-.747359	.080522	.435058	.234490	-.078575
GRLOW	.723702	.305935	.504912	-.228190	.030870
GRTOTAL	.676481	.336921	.550519	-.211582	.031838
DSPINES	.341665	.585547	-.019792	.431327	.151382
DSOFT	-.457909	-.149964	-.203540	-.636280	-.123688
ASOFT	.031648	.123886	-.331044	-.084041	-.533821
PECTORAL	.243220	.236584	-.444931	-.376034	-.294009
LATUP	-.172564	.504219	-.171056	-.005959	-.474087
LATLOW	-.227570	.635144	.227214	-.150271	.334813
LONG	-.151949	.680732	-.358654	-.006259	.000353
TRANSUP	-.350172	.420095	-.238668	-.068224	.400154
TRANSLOW	-.300507	.632979	.113668	-.402219	-.006023
PV	-.179231	-.116721	-.367010	-.231693	.662137
CHEEK	-.207751	.076621	-.030777	.092084	.192232
Expl.Var	2.881427	2.512548	2.176806	1.613683	1.463784
Prp.Totl	.169496	.147797	.128047	.094923	.086105

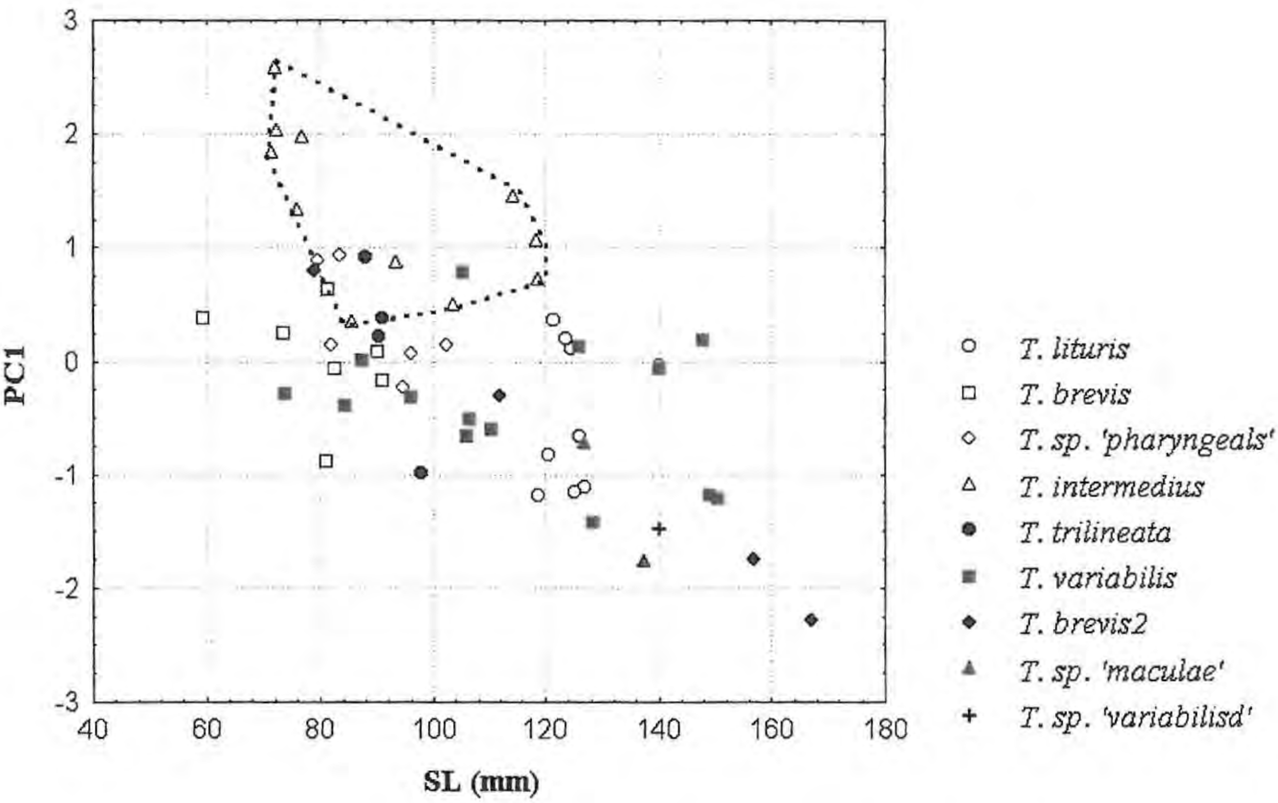


Fig. 5.2: Scatterplot of scores on the first axis of a PCA of the untransformed meristics against standard length for specimens of the genus *Tramitichromis* examined (n = 58).

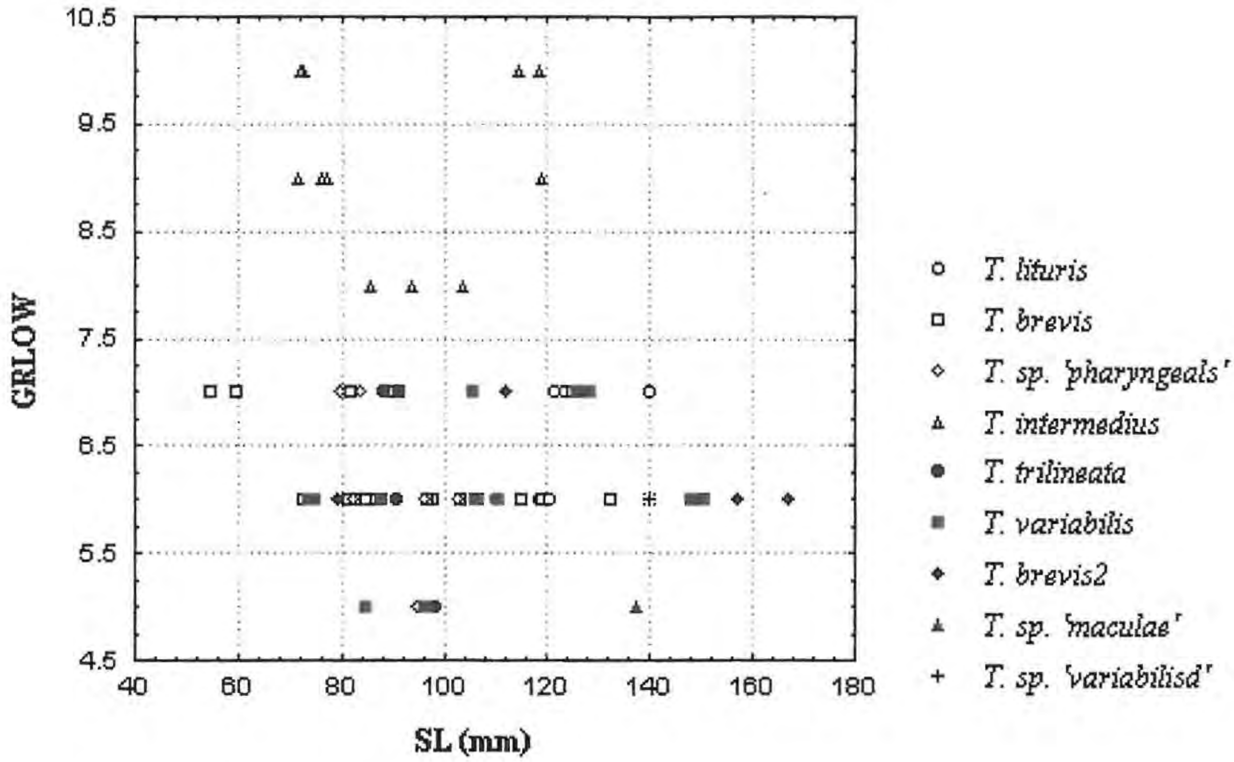


Fig. 5.3: Scatterplot of the number of ceratobranchial gill rakers versus standard length for specimens of the genus *Tramitichromis* examined.

Table 5.3: Principal component loadings of the log-transformed measurements on the first five axes; members of the genus Tramitichromis excluding *T. intermedius* (n = 59).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.98386	-.099510	.099325	-.018533	-.045309
LOGSNL	.98606	-.083009	.083484	.015758	-.061601
LOGLJL	.98332	-.044665	.087642	-.013251	-.000667
LOGPPL	.97356	-.093436	.062554	.055812	-.079937
LOGCHD	.98368	-.061799	.022013	-.070818	-.080983
LOGED	.96277	.165987	.019341	.122114	-.067987
LOGIOW	.97911	-.052012	-.005872	.103412	.093001
LOGHW	.98852	-.023745	.018796	.002381	.031357
LOGHL	.99628	-.031571	.033306	.020897	-.018165
LOGSL	.99409	-.041499	-.066154	-.031799	.007895
LOGBD	.98337	-.076279	-.096046	.053948	.043266
LOGDFB	.99106	-.024384	-.085857	-.002872	.037057
LOGAFB	.97678	-.051679	-.149207	-.016869	.030935
LOGPRD	.98787	-.097692	.021401	.041054	-.022640
LOGPRP	.99325	-.026388	.040332	.009561	.005283
LOGPRV	.99328	-.046155	-.018667	.025852	.017210
LOGPRA	.99316	-.033374	-.064205	-.011782	-.000366
LOGCPL	.96764	-.045112	-.040554	-.215232	-.022824
LOGCPD	.98128	-.114096	-.075122	.017701	.046658
LOGPHJL	.96115	.196551	.128693	-.008081	.020111
LOGPHJW	.95027	.249892	-.092709	-.017092	-.028423
LOGDEAL	.95495	.147954	.176981	-.066487	.138190
LOGDEAW	.92887	.325165	-.100020	.001411	-.043038
Expl.Var	22.00576	.331199	.154347	.093162	.063341
Prp.Totl	.95677	.014400	.006711	.004051	.002754

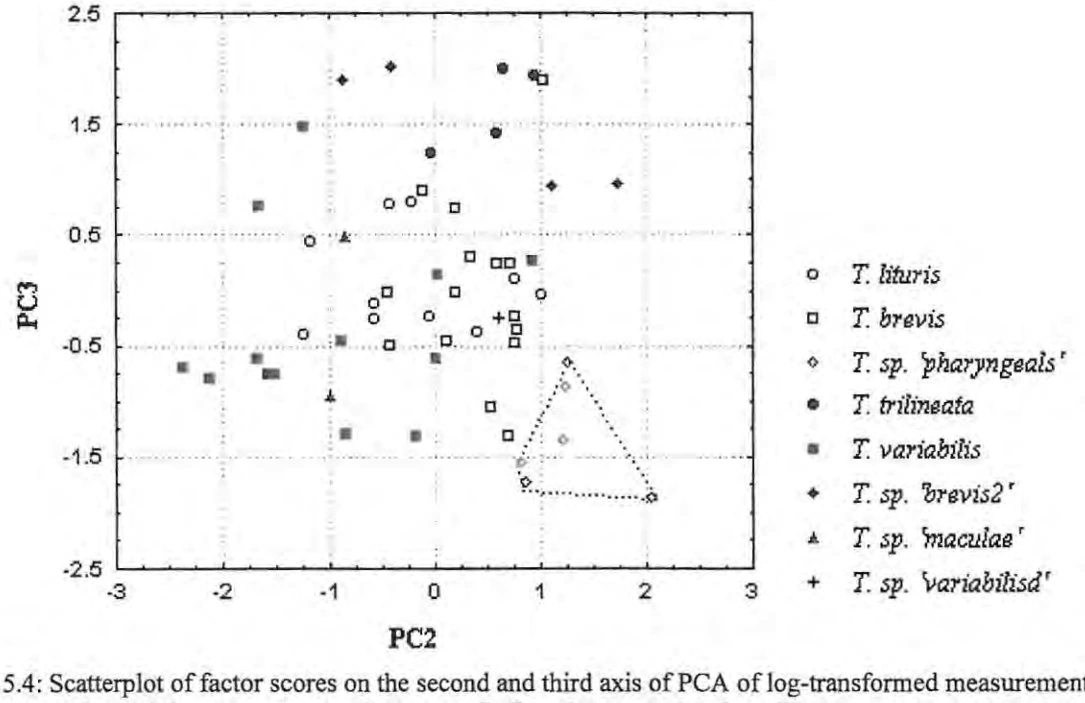


Fig. 5.4: Scatterplot of factor scores on the second and third axis of PCA of log-transformed measurements for the members of the genus *Tramitichromis* excluding *T. intermedius* (n = 59).

Table 5.4: Principal component loadings of log-transformed variables on the first five axes; members of the genus *Tramitichromis* excluding *T. intermedius* and *T.* sp. 'pharyngeals' (n = 53).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.99116	.022560	.091526	.002471	-.013971
LOGSNL	.99231	.006634	.076464	-.022680	.019222
LOGLJL	.98380	-.005200	.097454	-.056145	-.083662
LOGPPL	.98034	.019525	.059825	-.107282	.134284
LOGCHD	.98516	.040323	.094624	.049763	-.034415
LOGED	.95913	-.266047	.010446	.078534	.037114
LOGIOW	.98098	-.064492	-.106257	-.042611	-.059868
LOGHW	.98701	-.018748	.008377	-.033191	-.066548
LOGHL	.99723	-.019197	.032800	-.019296	.006616
LOGSL	.99667	.027604	-.027001	.035655	.010651
LOGBD	.98737	.013044	-.111000	-.016146	-.010652
LOGDFB	.99358	.002695	-.068900	.046224	-.017586
LOGAFB	.98186	.052329	-.116791	.003143	.071205
LOGPRD	.99198	.014689	.020162	-.037131	.000483
LOGPRP	.99380	-.003674	.031760	-.034931	-.002435
LOGPRV	.99491	-.005295	-.017756	-.030402	.010275
LOGPRA	.99472	.000646	-.029452	.037387	.014190
LOGCPL	.97376	.103184	.041971	.173962	.019126
LOGCPD	.98777	.073067	-.088007	-.023774	-.032397
Expl.Var	18.51179	.098169	.092341	.066543	.043549
Prp.Totl	.97430	.005167	.004860	.003502	.002292

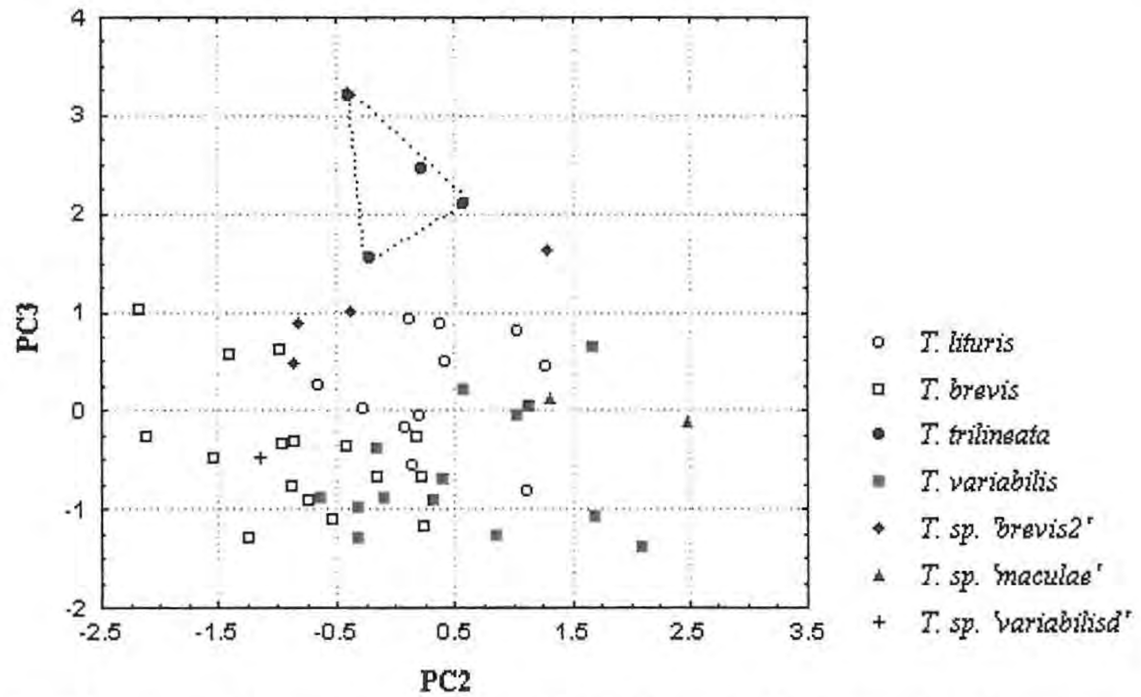


Fig. 5.5: Scatterplot of factor scores on the second and third axis of PCA of log-transformed measurements for members of the genus *Tramitichromis* excluding *T. intermedius* and *T.* sp. 'pharyngeals' (n = 53).

Table 5.5: Principal component loadings of the log-transformed variables on the first five axes; for *T. brevis* and *T.* sp. 'brevis 2' (n = 21).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.99454	-.060365	-.039302	.026261	-.011338
LOGSNL	.99278	-.055131	-.031989	.074439	-.030568
LOGLJL	.98661	-.114096	.031015	.005310	.063647
LOGPPL	.98577	-.103532	.017129	.058670	-.033101
LOGCHD	.99257	.016779	-.014159	.050872	-.075298
LOGED	.98019	.126445	-.095603	.097767	.039018
LOGIOW	.98411	.009176	-.090444	-.040209	.128284
LOGHW	.98720	-.074387	-.028322	-.084788	.018657
LOGHL	.99827	-.027048	-.006819	-.006815	-.025753
LOGSL	.99741	.038122	.004079	-.030353	-.037872
LOGBD	.99296	.049698	.016202	-.000945	-.027775
LOGDFB	.99380	.083746	-.017564	-.048686	-.015809
LOGAFB	.98080	.048640	.136259	.071080	.089964
LOGPRD	.99632	-.006848	-.004607	.024536	-.003375
LOGPRP	.99659	-.068246	.013290	-.022135	-.008309
LOGPRV	.99797	-.015435	-.011903	-.023187	-.005548
LOGPRA	.99499	.058196	-.019189	-.039581	-.052548
LOGCPL	.98693	.058130	.115933	-.020808	-.009932
LOGCPD	.99107	.037198	.026688	-.089589	.001102
Expl.Var	18.66384	.079434	.056207	.050700	.044391
Prp.Totl	.98231	.004181	.002958	.002668	.002336

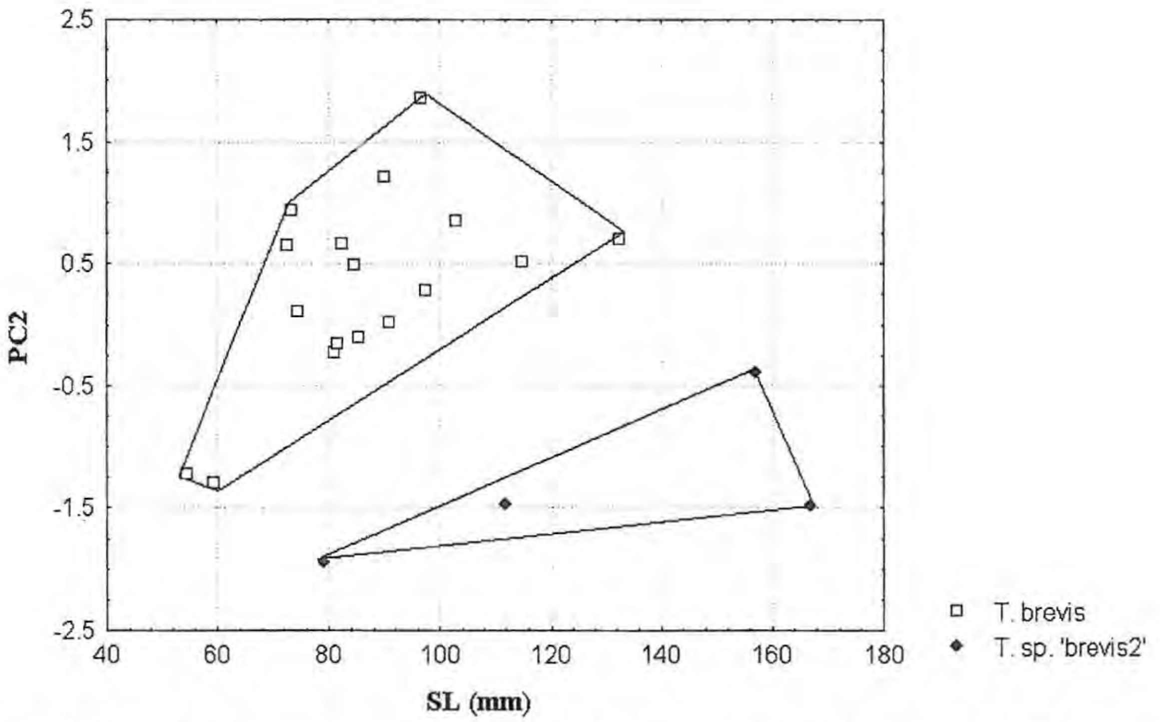


Fig. 5.6: Scatterplot of scores on the second axis of a PCA of log-transformed measurements against standard length for *T. brevis* and *T.* sp. 'brevis 2' (n = 21).

Table 5.6: Principal component loadings of log-transformed variables on the first five axes of *T. lituris*, *T. variabilis*, *T.* sp. 'variabilis deep' and *T.* sp. 'maculae' (n = 26).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.98576	.077847	.008067	.032436	.011210
LOGSNL	.98994	.069260	-.028254	-.008712	.031830
LOGLJL	.97662	.140354	.107628	.025546	.044631
LOGPPL	.96442	.137299	-.146246	.061945	-.095050
LOGCHD	.97310	.122018	.123749	.029094	.047277
LOGED	.96352	-.106332	.176424	-.006985	-.162400
LOGIOW	.97734	-.076466	.072692	.001070	.018567
LOGHW	.97809	-.021013	.052575	-.122822	.050201
LOGHL	.99519	.029836	.005286	-.008435	-.010693
LOGSL	.99324	-.064241	-.060766	.027741	-.008682
LOGBD	.97777	-.075595	-.039550	-.131644	.027738
LOGDFB	.98975	-.067958	.041046	-.006540	-.045722
LOGAFB	.98543	-.066107	-.083077	-.013171	-.059841
LOGPRD	.98028	.137429	-.008513	.059393	-.057685
LOGPRP	.98736	.002553	-.016069	-.026239	.034861
LOGPRV	.98727	-.025800	-.100237	-.029491	.011153
LOGPRA	.98954	-.076143	-.082540	-.017664	-.011131
LOGCPL	.95442	-.182040	.000215	.205866	.098602
LOGCPD	.98404	.042650	-.017559	-.064763	.074319
Expl.Var	18.27536	.161925	.119693	.091959	.070306
Prp.Totl	.96186	.008522	.006300	.004840	.003700

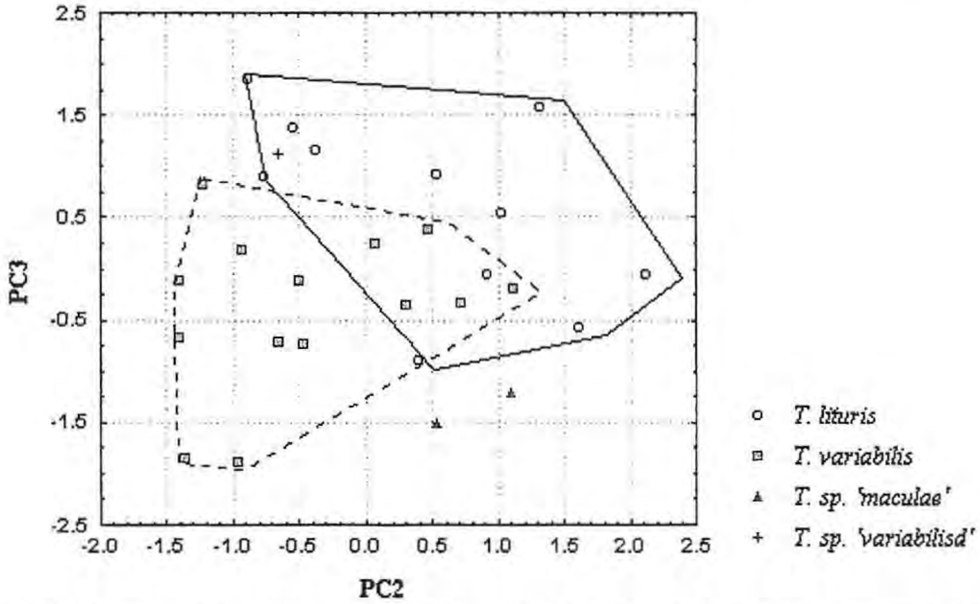


Fig. 5.7: Scatterplot of factor scores on the second and third axis of PCA of log-transformed measurements of *T. lituris*, *T. variabilis*, *T.* sp. 'variabilis deep' and *T.* sp. 'maculae' (n = 26).

5.4 Artificial key to the species

1a. 8-10 ceratobranchial gill rakers; principal melanin pattern consisting of a supra-pectoral patch, supraanal and sometimes caudal spot. Anterior teeth on the lower pharyngeal jaw have tips turned forward .... ***T. intermedius***

1b. 5-7 ceratobranchial gill rakers; melanin pattern consist of either vertical bars, a dark oblique band, a series of oblique spots from nape to caudal or a dark supra-pectoral patch. Anterior teeth on the lower pharyngeal jaw turned backward **2**

2a. No oblique band or series of spots; pharyngeal jaw width 89.0-100.0% pharyngeal jaw length; enlarged pharyngeal teeth.. ***T.* sp. 'pharyngeals'**

2b. A dark oblique band, a series of oblique or horizontal spots from nape to caudal peduncle, or a darker patch on the dorsum present; pharyngeal jaw width 73.0-95.7% pharyngeal jaw length; enlarged pharyngeal teeth in some specimens of >140.0 mm SL **3**

3a. A dark complete oblique band from nape to caudal peduncle present.......................... **4**

3b. A dark complete oblique band from nape to caudal peduncle absent........................... **5**

4a. Eye diameter 34.1-43.1% HL.. ***T. brevis***

4b. Eye diameter 28.7-36.4 % HL.. ***T.* sp. '*brevis* 2'**

5a. Principal melanin pattern consisting of a series of spots along the dorsal and dorso-lateral and mid-lateral; body depth 33.3-36.7 % SL; anal fin base length 17.0-19.9 % SL; eye diameter 36.2-38.3 % HL .... ***T. trilineata***

5b. Principal melanin pattern consisting of a series of oblique spots or supra-pectoral patch. Body depth 35.1-42.1 % SL; anal fin base 18.9-21.9 % SL; eye diameter 28.8-37.8 % HL **6**

6a. Eye small 28.8-29.8 % HL; snout length 38.4-38.9 % HL; dorsal and caudal fins highly maculated .... ***T.* sp. 'maculae'**

6b. Eye diameter 29.8-37.8 % HL; snout length 30.0-38.4 % HL; dorsal and caudal fins not maculated **7**

7a. Lachrymal depth 19.6-27.3 % HL; a series of spots forming an oblique row from nape to caudal base **8**

7b. Lachrymal depth 25.3-28.0 % HL; a dark suprapectoral patch below the dorsal fin formed by thickening of the 3rd-5th vertical bars .... ***T. lituris***

8a. Body depth less than 41.7 % SL .... ***T. variabilis***

8b. Body depth more than 41.7 % SL .... ***T.* sp. '*variabilis* deep'**

5.5 *Tramitichromis intermedius* (Trewavas, 1935)

Lethrinops intermedia Trewavas, 1935: 109, fig 11; Jackson, 1961: 585; Jackson et al., 1963: 86; Bowmaker et al., 1978:1229; Ufermann et al.,1987:262.

Tramitichromis intermedius Eccles & Trewavas, 1989: 259 fig 156; Konings, 1995:277, fig. 5; Turner,1996: 152, photo page 168.

(Plate 5.1)

Etymology

The species name is derived from the Latin *intermedius* probably referring to the intermediate position of this species between the members of *Lethrinops* 'sensu stricto' and those of *Tramitichromis*. In the original description of (Trewavas, 1935) it was indicated that some morphological features indicate relationship with *L. brevis* while others placed it near *L. argenteus* and *L. lethrinus*.

Diagnosis

It is the only member of *Tramitichromis* with the pharyngeal jaw dentition and morphology intermediate between the genera *Lethrinops* 'sensu stricto' and *Tramitichromis*. Distinguished from all members of the genus *Tramitichromis* and other short snouted species of the *Lethrinops* group except *L. auritus* by the presence of three dark spots in the body: the supra-pectoral, supra-anal and caudal spots. Differs from most other 3-spotted species from Lake Malawi/Nyasa in the shape of the first lower gill-raker (broad and flat) and *Lethrinops*-type dentition and from *L. auritus* in lower gill-raker counts and shape. Has fewer gill rakers (8-10) than most of the *Lethrinops* except *L. parvidens* from which it differs by its spotted melanin pattern. Can be easily differentiated from all other member of the genus *Tramitichromis* by the body spots, greater number of ceratobranchial gill rakers. *Tramitichromis* sp. 'pharyngeal' is the only other species of the genus with enlarged median pharyngeal teeth.

Description

For descriptive statistics of measurements and meristic data see Table 5.8. Snout with a slightly convex profile shorter than eye diameter 31.2±1.8 (28.6-33.9) vs 35.9±1.9 (33.2-

39.2) % in head length; jaws equal anteriorly; maxillary extending to vertical from the anterior edge of eye or sometimes below the eye. Oral teeth in the outer row mainly bicuspid becoming unicuspid posteriorly, with 52-71 and 32-54) teeth in the outer row of upper and lower jaw respectively; inner teeth on both jaws tricuspid and few unicuspid and in 1 row on the upper and 1-2 rows on the lower. Lower pharyngeal bone with a group of enlarged teeth at the postero-median area, teeth 10-13 along the longest medial series and 20-46 across the posterior margin. The teeth at the anterior end are in two rows.

Table 5.8 Morphometric ratios and meristic data for *Tramitichromis intermedius*

	Mean	SD	Range	N
Standard length (mm)	91.2	19.5	71.50-119.0	11
as % head length				
Lachrymal depth	21.2	3.1	17.1-24.8	11
Snout length	31.2	1.8	28.6-33.9	11
Lower jaw length	35.1	2.3	31.7-38.3	11
Premaxillary pedicel length	23.9	2.5	20.4-28.6	11
Cheek depth	27.0	2.7	23.7-30.4	11
Eye diameter	35.9	1.9	33.2-39.2	11
Head width (HW)	46.0	2.8	40.4-51.0	11
Interorbital width	22.6	1.6	20.8-26.5	11
as % standard length				
Head length (HL)	33.5	0.8	31.9-34.3	11
Body depth	36.5	1.4	34.5-38.6	11
Dorsal fin base length	54.6	1.5	51.7-57.0	11
Anal fin base length	19.9	0.8	18.7-21.7	11
Predorsal distance	36.3	1.6	32.3-37.9	11
Prepectoral distance	33.5	1.4	31.7-36.4	11
Prepelvic distance	37.6	0.5	36.7-38.4	11

Pre-anal distance	65.5	1.8	62.2-68.4	11
Caudal peduncle length (CPL)	18.6	1.4	16.9-21.3	11
Caudal peduncle depth	12.3	0.5	11.3-13.3	11
Other				
Interorbital width % HW	49.2	3.5	43.2-55.3	11
Lower pharyngeal jaw length (PhJL) % HL	31.2	2.0	28.6-34.2	11
Lower pharyngeal jaw width(PhJW) % PhJL	85.5	4.4	79.3-93.1	11
Dentigerous area length (DeAL) % PhJL	64.9	4.4	58.6-72.2	11
Dentigerous area width (DeAW) % PhJW	79.8	2.2	76.7-83.6	11
Dentigerous area length % DeAW	95.2	5.3	89.7-107.5	11
Caudal peduncle depth % CPL	66.5	6.9	54.6-73.2	11

	Median	Range	N
Number of teeth upper jaw	64	52-71	11
Number of teeth lower jaw	40	32-54	11
Inner rows upper jaw	1	1-1	11
Inner rows lower jaw	1	1-2	11
Gill rakers lower	9	8-10	11
Gill rakers total	14	11-15	11
Dorsal spines	15	14-16	11
Dorsal soft	10	10-12	11
Anal soft	9	9-9	11
Pectoral fin rays	15	15-16	11
Upper lateral line scales	25	23-29	11
Lower lateral line scales	15	14-17	11
Longitudinal line scales	32	32-34	11
Transverse scales above LL	5	4-5	11
Transverse scales below LL	9	9-10	11
Scales <pectoral-pelvic fin>	5	4-6	11

Cheek scales	3	2-3	11

Colour pattern: Dark grey dorsally, paler ventrally with two dark blotches on flanks. Ripe male blue with orange spots on dorsal and anal fins. Pelvic orange brown with white anterior edge. Dorsal fin margin white with red-tipped lappets. Branchiostegal membrane and chest red or sometimes orange. Dark flank spot sometimes visible.

Distribution:

Konings (1995) states that this species has a lake-wide distribution. During my study this species was collected from the northern tip of the lake (Weissman Bay) and from the southern part of the lake (fig. 5.8).

Ecology:

Konings (1995) reports that this species feeds on insect larvae and soft-bodied invertebrates.

Discussion

Trewavas (1935) states that the short snout, few gill rakers and short pharyngeal blade in *L. intermedius* indicate a relationship with *L. brevis*, but the structure of the pharyngeal teeth places it in the other group of the genus where its affinities are with *L. argenteus* and *L. lethrinus*. In erecting the genus *Tramitichromis* (which includes *T. brevis*), Eccles & Trewavas (1989) put much emphasis on the special morphology of the pharyngeal apparatus. They removed *L. intermedius* from *Lethrinops* and placed it in *Tramitichromis* on account of its pharyngeal bone structure. Konings (1990) re-assigned this species to *Trematocranus*, on the basis of its colour pattern and enlarged sensory pits (which are not evident in the specimens examined for this study). Subsequently, Konings (1995) treated it under *Tramitichromis* with reservations. *Tramitichromis intermedius* shows a well-developed melanin pattern of large lateral spots, a short snout, and short pharyngeal blade with a slight keel. It shares most of these features with *L. auritus*, *L. parvidens* and *L.* sp. 'turneri'. Within *Tramitichromis* it is the only described species with anterior pharyngeal teeth with forward turned major cusps. It therefore appears to be intermediate between the *parvidens-auritus*-'turneri' group and the other *Tramitichromis* species.

Specimens examined

SADC/GEF (21/21/28); unsexed 103.5 mm SL; South East Arm, a trawl transect from Mazinzi to Kadango, Malawi; 11/10/97. **SADC/GEF 97/14/09/02**; male 85.5 mm SL; Chembe, South West Arm of lake Malawi, purchased from rod and line fishermen; 20/05/97. **SADC/GEF (CR 44)**; female 76.0 mm SL, male 71.5 mm SL, male 72.5 mm SL, male 77.0 mm SL; Chidzuwi/Nkama, (near river Linthipe), 13°52'S 34°35'E, Malawi; beach seine at 2.3 m depth; 15/10/98. **SADC/GEF 97/21/21/51**; unsexed 93.5 mm SL; South East Arm, a trawl transect from Mazinzi to Kadango, Malawi; 11/10/97.

5.6 *Tramitichromis* sp. 'pharyngeals'

(Plate 5.2)

Etymology

Cheironym referring to the enlarged postero-medial teeth of the lower pharyngeal bone.

Diagnosis

Small to medium-sized *Tramitichromis* distinguished from all members of the genus except *T. intermedius* and larger individuals of *T. variabilis* in having enlarged teeth on the central part of the lower pharyngeal bone. Differ from *T. intermedius* in the absence of any body spots and fewer ceratobranchial gill rakers (5-7 versus 8-10). Differs from *T. variabilis* in lack of oblique series of spots on the body.

Description

For descriptive statistics of measurements and meristic data see Table 5.9. Snout shorter than eye diameter [28.7±1.6 (26.0-29.8) Vs 39.4±1.6 (37.3-41.5)% HL]; jaws equal anteriorly; maxillary extending to below the eye. Oral teeth in the outer row mainly bicuspid, with 60-73 and 34-51 teeth in the outer row of upper and lower jaw respectively; inner teeth bicuspid becoming unicuspid posteriorly on the upper, and tricuspid and unicuspid on the lower jaw. Lower pharyngeal bone with many enlarged flattened postero-median teeth, 9-13 teeth along the longest medial series and 20-33 across the posterior margin, anterior teeth with tips turned backwards. The lower pharyngeal bone is robust like that of a snail crusher with length almost equal to its width. Gill rakers are short and dumpy anteriorly, caudal forked.

Table 5.9: Morphometric ratios and meristic data for *Tramitichromis* sp. 'pharyngeals'

	Mean	SD	Range	N
Standard length (mm)	89.7	9.3	79.5-102.5	6
as % head length				
Lachrymal depth	20.5	1.4	18.9-22.4	6

Snout length	28.7	1.6	26.0-29.8	6
Lower jaw length	35.7	1.4	34.0-36.9	6
Premaxillary pedicel length	24.7	1.6	22.4-26.8	6
Cheek depth	27.9	1.5	26.4-29.7	6
Eye diameter	39.4	1.6	37.3-41.5	6
Head width (HW)	48.2	1.9	44.8-50.0	6
Interorbital width	22.4	1.0	20.9-23.7	6
as % standard length				
Head length (HL)	31.7	0.8	30.7-32.7	6
Body depth	36.4	0.9	34.6-37.0	6
Dorsal fin base length	55.4	1.5	52.8-57.1	6
Anal fin base length	20.1	1.0	18.8-21.5	6
Predorsal distance	34.2	0.7	33.3-35.1	6
Prepectoral distance	31.6	1.2	30.2-32.9	6
Prepelvic distance	37.0	1.0	35.5-38.3	6
Pre-anal distance	64.3	1.2	63.0-65.9	6
Caudal peduncle length (CPL)	19.2	1.0	17.6-20.4	6
Caudal peduncle depth	11.8	0.6	11.0-12.6	6
Other				
Interorbital width % HW	46.6	1.7	44.8-48.8	6
Lower pharyngeal jaw length (PhJL) % HL	28.9	1.4	27.6-31.4	6
Lower pharyngeal jaw width(PhJW) % PhJL	95.2	4.4	89.0-100.0	6
Dentigerous area length (DeAL) % PhJL	70.1	4.8	63.7-76.7	6
Dentigerous area width (DeAW) % PhJW	77.2	2.3	74.7-80.0	6
Dentigerous area length % DeAW	95.4	3.2	93.4-101.8	6
Caudal peduncle depth % CPL	61.6	4.6	57.9-69.4	6

	Median	Range	N
Number of teeth upper jaw	68	60-73	6
Number of teeth lower jaw	41.5	34-51	6
Inner rows upper jaw	1	1-1	6
Inner rows lower jaw	1	1-1	6
Gill rakers lower	6	5-7	6
Gill rakers total	10	9-11	6
Dorsal spines	15	15-16	6
Dorsal soft	11	10-11	6
Anal soft	9	9-10	6
Pectoral fin rays	15	15-15	6
Upper lateral line scales	25.5	22-26	6
Lower lateral line scales	14.5	12-17	6
Longitudinal line scales	33	32-33	6
Transverse scales above LL	5	4-5	6
Transverse scales below LL	8.5	8-9	6
Scales <pectoral-pelvic fin>	6	4-8	6
Cheek scales	3	3-3	6

Colour pattern

Dorsal fin dark grey with a white submarginal band and yellow-tipped lappets. White spots on the dorsal fin membrane especially the soft dorsal. Breeding males are deep blue with golden hue. The gular (branchiostegal membrane) is red. Anal fin with yellow egg-spots and caudal fin bluish with yellow maculae.

Distribution

All specimens examined are from the southern part of the lake, Senga Bay (Malawi), and the South East Arm (Fig. 5.8). It occurred in very shallow waters (1.5-5.9 m depth).

Ecology

Tramitichromis sp. 'pharyngeals' is probably an inhabitant of open-sand bottoms and does not seem to prefer intermediate habitats. From the shape and dentition of the lower pharyngeal apparatus, this fish could be dining on a similar diet to *T. intermedius*.

Discussion

The SADC/GEF Lake Malawi/Nyasa taxonomy team, during one of the sandy cruises, collected from the same shallow trawl (Mazinzi to Kadango at 5.9 - 6.3 m depth), specimens which were immediately recognised as different members of the genus *Tramitichromis*. The specimens were temporarily given working names and later confirmed in the laboratory as: *Tramitichromis intermedius* (*T.* sp. 'double spot steep head'), *Tramitichromis trilineata* (*T.* sp. 'steep snout blue head females'), *Tramitichromis variabilis* (*T.* sp. 'blue round head'), *Tramitichromis lituris* (*T.* sp. 'spot red lappets'). In addition specimens of undescribed member of the genus were collected. They were distinct from the rest by having a robust lower pharyngeal apparatus reminiscent of a molluscivore. These were referred to as *Tramitichromis* sp. 'pharyngeals'. Specimens with similar pharyngeal morphology were later recorded from a beach seine catch (2 m depth) around Senga Bay. The specimens were darker on the dorsum just below the spinous dorsal fin like *T. lituris* but differed in having a larger eye and in the form of the lower pharyngeal bone and its dentition. No member of *Tramitichromis* previously documented has this unusual pharyngeal shape and dentition and it is therefore regarded in this study as an undescribed member of this genus. Konings (1995:288, photo 2) reports an undescribed species which he refers to as, *Tramitichromis* sp. 'variabilis red flush' from Kambiri point, Malawi. The specimens illustrated resemble the mature male specimens of T. sp. 'pharyngeals', and they are probably conspecific.

Specimens examined

SADC/GEF (CR25/38); unsexed 79.5 mm SL; Senga Bay, Malawi; beach seine at 2 m depth; 27/11/97. **SADC/GEF (21/21/38** two specimens), **(21/21/27)**; unsexed 82.0 mm SL, unsexed 83.0 mm SL, unsexed 94.5 mm SL, unsexed 96.0 mm SL; South East Arm, a trawl transect from Mazinzi to Kadango, Malawi; depth 5.9 m; 11/10/97. **SADC/GEF 98/01/42/02**; male 102.5 mm SL; Senga Bay, Malawi; purchased from fishermen fishing beach seine for 'kambuzi' at 1.5 m depth; 05/02/98

5.7 *Tramitichromis brevis* (Boulenger, 1908)

Tilapia brevis, Boulenger, Cat. Afr. Fish. iii. p. 262, fig. 177 (1915).

Haplochromis brevis, Regan, Proc. Zool. Soc. 1921, p. 709; Ufermann et al; 1987: 186

Lethrinops brevis, Trewavas 1931: 140, fig. 3b, 4b; Fryer, 1959: 195, Fryer & Iles, 1972: 80; Bowmaker et al., 1978: 1229; Mayland, 1978: 246; Galis & Barel, 1980: 392; Mayland, 1982: 238; Steack, 1983: 237, photo120; Ufermann et al., 1987: 262.

Tramitichromis brevis, Eccles & Trewavas, 1989: 256, fig.150, 151; Konings, 1995: 288, photo 3 & 4; Turner, 1996:135.

(Plates 5.3, 5.4)

Etymology

The species name *brevis* is derived from the Latin adjective of *brevis* for 'short', most probably referring to the short head and snout.

Diagnosis

Recognized as a member of the genus *Tramitichromis* by the pharyngeal jaw dentition and morphology. Differs from all other members of *Tramitichromis* except *T.* sp. '*brevis* 2'in having a prominent oblique dark band from nape to base of caudal fin. Differ from *T.* sp. '*brevis* 2' of the similar size category by the possession of a larger eye. Eye diameter 39.0±2.4 (34.1-43.1) % HL. Anterior teeth of the lower pharyngeal bone are narrow and cylindrical with ends curved backwards.

Description

For descriptive statistics of measurements and meristic data see Table 5.10.

Snout short with a decurved profile 30.5±2.8 (26.7-35.1) % HL; jaws equal anteriorly or lower jaw slightly shorter; maxillary extending to below the eye. Oral teeth in the outer row mainly bicuspid, with 51-76 and 33-48 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws tricuspid and unicuspid and in 1-2 rows. Lower pharyngeal bone deeply notched behind with the dentigerous area blunt in front and in four rows and anterior blade short and 'keeled'; teeth 12-16 along the longest medial series and 32-39 across the posterior margin. The two most anterior gill rakers are short and cushion-like, caudal forked.

Table 5.10: Morphometric ratios and meristic data for *Tramitichromis brevis*

	Mean	SD	Range	N
Standard length (mm)	86.8	19.0	54.5-132.5	17
as % head length				
Lachrymal depth	21.7	2.2	18.3-26.0	17
Snout length	30.5	2.8	26.7-35.1	17
Lower jaw length	34.6	2.4	30.3-39.3	17
Premaxillary pedicel length	25.7	1.2	23.7-27.9	17
Cheek depth	26.2	2.6	21.4-30.7	17
Eye diameter	39.0	2.4	34.1-43.1	17
Head width (HW)	46.7	2.0	44.1-50.0	17
Interorbital width	23.2	1.6	20.8-26.4	17
as % standard length				
Head length (HL)	33.9	1.0	31.7-35.8	17
Body depth	38.2	1.5	35.0-40.8	17
Dorsal fin base length	55.7	1.1	53.7-57.2	17
Anal fin base length	19.6	1.2	17.2-21.8	17
Predorsal distance	37.2	1.3	35.2-39.4	17
Prepectoral distance	33.5	1.2	32.1-36.7	17
Prepelvic distance	38.5	1.1	36.7-41.3	17
Pre-anal distance	64.9	1.2	62.2-66.7	17
Caudal peduncle length (CPL)	18.6	0.9	17.0-19.7	17
Caudal peduncle depth	12.7	0.5	12.1-13.8	17
Other				
Interorbital width % HW	49.9	4.4	43.5-60.0	17

Lower pharyngeal jaw length (PhJL) % HL	28.7	1.5	26.7-32.4	15
Lower pharyngeal jaw width(PhJW)%PhJL	84.6	6.8	73.0-95.5	15
Dentigerous area length (DeAL) % PhJL	67.7	3.7	58.5-71.9	15
Dentigerous area width (DeAW) % PhJW	79.2	5.0	72.9-90.0	15
Dentigerous area length % DeAW	101.7	8.2	87.9-113.9	15
Caudal peduncle depth % CPL	68.4	3.7	62.9-75.9	17

	Median	Range	N
Number of teeth upper jaw	60	51-76	7
Number of teeth lower jaw	40	33-48	7
Inner rows upper jaw	2	1-2	17
Inner rows lower jaw	2	1-2	17
Gill rakers lower	6	6-7	17
Gill rakers total	10	10-11	17
Dorsal spines	15	14-16	17
Dorsal soft	12	11-12	17
Anal soft	9	9-10	17
Pectoral fin rays	16	15-16	17
Upper lateral line scales	26	21-27	17
Lower lateral line scales	15	13-17	17
Longitudinal line scales	32	30-34	17
Transverse scales above LL	5	4-6	17
Transverse scales below LL	9	8-9	17
Scales <pectoral-pelvic fin>	5	4-6	17
Cheek scales	3	2-4	17

Colour pattern

Konings (1990, 1995) observed that females and immature males are silvery grey with a conspicuous black oblique bar. Ripe males are blue, with numerous orange spots and stripes in the dorsal and caudal fins. Anal fin darker with several large yellow-orange egg-spots and a white margin. Pelvics dark with white leading edge. Dorsal fin with white margin and orange lappets. Branchiostegal membranes and chest orange.

Distribution

Mainly found in intermediate habitats. During this study most individuals were caught when gill nets were set in sand near rocks. *Tramitichromis brevis* was not recorded when trawling large stretches of sandy beaches. It has a lake-wide distribution (Fig. 5.9).

Ecology

According to Fryer (1959) and Eccles & Trewavas (1989) this fish feeds on chironomids. Konings (1995) reports that males of *T. brevis* build small sand-castle nests near rocks. This may be the reason why this fish was recorded mainly during the SADC/GEF Lake Malawi Project rocky shore cruises.

Discussion

Tramitichromis brevis resembles most members of *Taeniolethrinops* in having a dark oblique band near and roughly parallel to the dorsal outline from the nape to the base of the caudal fin. Unlike all members of *Taeniolethrinops* this fish has a short snout, which is shorter than the eye diameter. Konings (1995) rightly noted that *T. brevis* can easily be recognised by its small adult size and by the prominent diagonal stripe on the flanks, however, the specimens on his photographs (Konings 1995:288, photo 3 & 4) from Chizumulu Island do not exhibit the prominent oblique stripe. The oblique striped pattern is apparently not found in any cichlid except the endemic haplochromines of Lake Malawi/Nyasa (Eccles & Trewavas, 1989). In the lake, this pattern is associated with a number of very different taxa, which Eccles & Trewavas (1989) placed into a variety of genera. For ease of field identification, Turner (1996) reports this fish under a chapter heading "*Mylochromis* and other oblique-striped species".

Specimens examined

BMNH 1908.10.27.103-104; unsexed 59.5 mm SL, unsexed 54.5 mm SL; 'Lake Nyasa'; coll. Capt. E.L. Rhodes. Syntypes. **SADC/GEF (24/100/19)**; female 73.5 mm SL; near

Chindunga rocks in the South West Arm of Lake Malawi; bottom set gill net at 5.3 m depth; 18/11/97. **RUSI: 032973**; male 132.5 mm SL, female 115.0 mm SL, female 103.0 mm SL, unsexed 96.5 mm SL, male 97.5 mm SL, Florence Bay, south of Chilumba, Malawi; coll. Malawi Fisheries Department; 17/11/72. **RUSI: 032961**; unsexed 72.5 mm SL, unsexed 84.5 mm SL, unsexed 82.5 mm SL, female 85.5 mm SL, female 74.5 mm SL; Chambe 1, Malawi, Lake Malawi fishing station 2; coll. Malawi Fisheries Department; 07/03/72. **SADC/GEF 98/45/07/10**; unsexed 81.0 mm SL; Mbamba Bay (Ngukyo) Island, Tanzania; bottom set gill nets at 20.5-22 m depth; 06/11/98. **SADC/GEF (45/46/23)**; female 81.5 mm SL; Lundu (at the Lundu port), Tanzania; bottom set gill nets at 4.7-5 m depth, 12/11/98. **SADC/GEF 97/20/55/18-19**; unsexed 91.0 mm SL, unsexed 90.0 mm SL; Young's Bay (just south of Chilumba), Malawi; bottom set gill nets at 9.7-14.0 m depth; 26/09/97.

5.8 *Tramitichromis* sp. '*brevis* 2'

(Plate 5.5)

Etymology

The working name refers to its close resemblance to *T. brevis*.

Diagnosis

A medium to large member of the genus *Tramitichromis* (maximum recorded size 167 mm SL) which differs from all other members considered under this genus except *T. brevis* in the presence of an oblique band from nape to caudal fin base. Distinguished from similar sized *T. brevis* by having longer lower jaw [39.3±1.8 (37.7-41.6) vs 34.6±2.4 (30.3-39.3) % HL] and smaller eye [31.9±3.4 (28.7-36.4) vs 39.0±2.4 (34.1-43.1) % HL].

Description

For descriptive statistics of measurements and meristic data see Table 5.11. Snout with a slightly convex profile and of a length equal to or greater than eye diameter [34.9±3.6 (30.9-38.0) % HL]; jaws equal anteriorly or lower jaw slightly shorter than upper; maxillary extending to vertical from the anterior edge of eye. Oral teeth in the outer row mainly unicuspid; a few are however weakly bicuspid and with tips directed posteriorly; 42-68 and 28-48 teeth in the outer row of upper and lower jaw respectively; inner teeth on both jaws unicuspid and in 1-3 and 1-5 rows in upper and lower jaw respectively. Lower pharyngeal bone with some of the postero-median teeth enlarged and flatted at the top, teeth 13-17 along the longest medial series and 18-38 across the posterior margin; caudal forked.

Table 5.11: Morphometric ratios and meristic data for *Tramitichromis* sp. '*brevis* 2'

	Mean	SD	Range	N
Standard length (mm)	128.8	40.9	79.0-167.0	4
as % head length				

Lachrymal depth (LacrD)	25.8	2.6	22.5-28.3	4
Snout length (SnL)	34.9	3.6	30.9-38.0	4
Lower jaw length (LJL)	39.3	1.8	37.7-41.6	4
Premaxillary pedicel length (PPL)	26.5	0.9	25.2-27.0	4
Cheek depth (ChD)	29.5	2.9	26.5-32.6	4
Eye diameter (ED)	31.9	3.4	28.7-36.4	4
Head width (HW)	47.0	1.2	45.5-48.1	4
Interorbital width (IOW)	23.3	2.5	19.6-25.0	4
as % standard length				
Head length (HL)	34.5	0.2	34.4-34.8	4
Body depth (BD)	38.0	0.7	37.1-38.5	4
Dorsal fin base length (DFB)	54.7	2.5	51.9-58.0	4
Anal fin base length (AFB)	19.3	1.3	17.4-20.4	4
Predorsal distance (PrD)	37.3	1.5	35.3-38.6	4
Prepectoral distance (PrP)	34.6	0.6	34.1-35.4	4
Prepelvic distance (PrV)	39.5	0.5	39.2-40.1	4
Pre-anal distance (PrA)	64.8	1.5	63.8-67.0	4
Caudal peduncle length (CPL)	18.4	0.9	17.4-19.6	4
Caudal peduncle depth (CPD)	12.1	0.4	11.8-12.7	4
Other				
Interorbital width % HW	49.5	4.4	43.2-52.8	4
Lower pharyngeal jaw length (PhJL) % HL	28.9	1.6	27.8-31.3	4
Lower pharyngeal jaw width(PhJW) % PhJL	80.1	3.5	76.6-84.8	4
Dentigerous area length (DeAL) % PhJL	73.6	2.4	71.0-76.6	4
Dentigerous area width (DeAW) % PhJW	74.0	4.4	69.8-79.7	4
Dentigerous area length % DeAW	124.5	8.1	120.0-136.7	4
Caudal peduncle depth % CPL	65.8	2.3	63.8-69.0	4

	Median	Range	N
Number of teeth upper jaw	64.5	42-68	4
Number of teeth lower jaw	41.5	28-48	4
Inner rows upper jaw	2	1-3	4
Inner rows lower jaw	2	1-5	4
Gill rakers lower	6	6-7	4
Gill rakers total	11	10-11	4
Dorsal spines	15	15-15	4
Dorsal soft	11.5	11-12	4
Anal soft	9	9-9	4
Pectoral fin rays	14.5	14-16	4
Upper lateral line scales	26	24-27	4
Lower lateral line scales	14.5	13-16	4
Longitudinal line scales	32.5	31-33	4
Transverse scales above LL	5	5-6	4
Transverse scales below LL	9.5	9-10	4
Scales <pectoral-pelvic fin>	5.5	5-6	4
Cheek scales	3	3-3	4

Colour pattern

Live coloration unknown. Preserved specimens are dark grey dorsally and white ventrally. Paired fins are hyaline, anal fin dark proximally and white distally. Dorsal fin with dark spots and caudal fin with dark striae.

Distribution

Material examined during this study was collected from the SE and SW Arms of Lake Malawi/Nyasa as well as from the central part of the lake on the Mozambique shore (Fig. 5.10). This fish was sometimes collected together and in the same place with *T.* bre*vis*. Just like the closely resembling *T. brevis*, this species probably also has a lake-wide distribution and lives mainly in intermediate habitats.

Ecology

The stomach contents revealed a diet of mainly chironomid larva and pupae with a lot of sand always present.

Discussion

The specimens were first identified as *Tramitichromis variabilis*, but were later found not to possess either of the two documented melanin patterns of *T. variabilis*. Instead of an oblique series of spots, these specimens have an oblique stripe like in *T. brevis*, but unlike *T. brevis* the stripe or band is not as prominent, the lower jaw is longer and the eye smaller. It was not possible to examine the types of *T. variabilis*, and the syntypes of *T. brevis* that are in BMNH are small specimens but the oblique band is obvious. Until it is possible to see all the types of *T. variabilis*, T. sp. '*brevis* 2 is tentatively regarded as another undescribed member of the genus that requires more investigation.

Specimens examined

SADC/GEF 98/33/02/20; male 149.0 mm SL; Jafua Bay (north of Cobue), Mozambique; bottom trawl at 10.8-12.8 m depth; 04/04/98. **SADC/GEF (24/28/06)**; male 112.0 mm SL; West reef (South East Arm of Lake Malawi), Malawi; bottom set gill nets at 4.3-4.9m depth; 12/11/97. **SADC/GEF 97/14/06/45**; unsexed 79.0 mm SL; Chembe beach, Malawi; purchase from chirimila fishermen; 20.05/97. **SADC/GEF 98/33/02/16**; male 167.0 mm SL; Jafua Bay (north of Cobue), Mozambique; bottom trawl at 10.8-12.8 m depth; 04/04/98.

5.9 *Tramitichromis trilineata* (Trewavas, 1931)

Lethrinops trilineata Trewavas, 1931: 141; Jackson, 1961: 585; Jackson et al., 1963: 84; Bowmaker et al., 1978:1229; Ufermann et al., 1987: 264.

Tramitichromis trilineata, Eccles & Trewavas, 1989: 258, fig. 155; Konings, 1995: 287, photo 3.

(Plate 5.6)

Etymology

The species name is derived from the Latin *tres* meaning three and *lineatus*, which means with lines, in reference to the body melanin pattern.

Diagnosis

A species of *Tramitichromis* diagnosed by the series of spots along the dorsal fin base and dorso-lateral and mid-lateral spots, all parallel with the body axis. Differs from *Tramitichromis* sp. 'maculae' in a larger eye [36.9±1.0 (36.2-38.3) vs 29.3±0.7 (28.8-29.8) % HL].

Description

For descriptive statistics of measurements and meristic data see Table 5.12.

Snout with a slightly convex profile and shorter than diameter of the eye 32.39±1.1 (31.9-34.0) vs 36.9±1.0 (36.2-38.3) % HL; jaws equal anteriorly; maxillary extending to below the eye. Oral teeth in the outer row mainly bicuspid, with 58-64 and 39-56 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws tricuspid and in 1 and 2 rows in the upper and lower jaws respectively. Lower pharyngeal bone with an anterior blade short and keeled, and with tips of teeth at the anterior end turned backwards, all teeth simple, 11-13 teeth along the longest medial series and 33-40 across the posterior margin. Caudal fin forked.

Table 5.12: Morphometric ratios and meristic data for *Tramitichromis trilineata*.

	Mean	SD	Range	N
Standard length (mm)	91.9	4.3	88.0-98.0	4

as % head length				
Lachrymal depth	24.3	0.1	24.1-24.4	4
Snout length	32.9	1.1	31.9-34.0	4
Lower jaw length	35.9	1.2	34.9-37.5	4
Premaxillary pedicel length	25.9	0.8	25.3-27.1	4
Cheek depth	29.4	0.4	29.0-29.8	4
Eye diameter	36.9	1.0	36.2-38.3	4
Head width (HW)	46.8	1.1	45.3-47.7	4
Interorbital width	20.5	1.1	19.7-22.2	4
as % standard length				
Head length (HL)	34.3	0.9	33.2-35.4	4
Body depth	35.3	1.3	33.5-36.7	4
Dorsal fin base length	54.1	1.1	52.8-55.5	4
Anal fin base length	18.0	0.9	17.0-18.8	4
Predorsal distance	36.1	1.0	34.7-36.9	4
Prepectoral distance	34.2	1.0	33.2-35.4	4
Prepelvic distance	37.9	0.7	37.4-38.8	4
Pre-anal distance	65.0	1.0	63.6-65.9	4
Caudal peduncle length (CPL)	20.8	0.8	19.9-21.5	4
Caudal peduncle depth	12.0	0.4	11.4-12.2	4
Other				
Interorbital width % HW	43.9	2.2	41.3-46.5	4
Lower pharyngeal jaw length (PhJL) % HL	29.8	0.8	28.6-30.3	4
Lower pharyngeal jaw width(PhJW) % PhJL	78.2	2.6	75.8-80.6	4
Dentigerous area length (DeAL) % PhJL	69.0	2.3	65.9-71.0	4
Dentigerous area width (DeAW) % PhJW	80.2	2.5	77.3-83.3	4
Dentigerous area length % DeAW	110.2	5.4	103.4-115.3	4
Caudal peduncle depth % CPL	57.5	2.7	55.6-61.5	4

	Median	Range	N
Number of teeth upper jaw	60	58-64	4
Number of teeth lower jaw	39.5	39-56	4
Inner rows upper jaw	1	1-1	4
Inner rows lower jaw	2	2-2	4
Gill rakers lower	6.5	5-7	4
Gill rakers total	10.5	9-12	4
Dorsal spines	14.5	14-15	4
Dorsal soft	11	10-12	4
Anal soft	9	8-9	4
Pectoral fin rays	16	15-16	4
Upper lateral line scales	23	22-25	4
Lower lateral line scales	14.5	14-15	4
Longitudinal line scales	32.5	32-33	4
Transverse scales above LL	4	4-5	4
Transverse scales below LL	8	8-9	4
Scales <pectoral-pelvic fin>	5.5	5-6	4
Cheek scales	3	3-3	4

Colour pattern

Females are silvery with a greenish-yellow tinge dorsally and white ventrally. Paired fins hyaline, anal hyaline with small yellow spots. Dorsal greyish with yellow submarginal band becoming clear on the trailing end. Caudal fin grey with the lower caudal margin yellow. According to Konings (1995), breeding males are greyish blue on the dorsum and whitish ventrally, the body with a yellow iridescence. Head is completely blue on the upper part and yellow on the underside including the gular and the chest. Paired fins hyaline with yellow tinge. Anal fin is dark distally and hyaline proximally with a few (5-6) large yellow 'egg-spots'. Caudal and dorsal fins with yellow spots.

Distribution

So far specimens of *T. trilineata* have only been collected from the South East Arm of Lake Malawi and from Lake Malombe (fig. 5.9).

Ecology

It is a species of shallow soft bottoms. Stomach contents reveal that it feeds on insect larvae like the other members of the genus.

Discussion

The type locality is indicated in CLOFFA 4 (Daget et.al. 1991) just as, "Lake Nyasa" based on the original description in which no details on the collecting locality were given. However, the holotype is indicated by same authors to have come from Monkey Bay. There was no opportunity to examine the specimen because it was on loan. Trewavas (1931) based her description of the species on a single specimen. She distinguished the specimen from *L. microstoma* by the longer lower jaw and by the coloration. She pointed out that the specimen resembles *T. lituris* in the number of gill-rakers (9) and in pharyngeal jaw shape and dentition, and also *T. variabilis* in coloration. The specimen illustrated by Eccles & Trewavas (1989) does not have oblique spots like *T. variabilis*, but rather has three series of spots running along the body axis and parallel to each other. They report specimens from Mazinzi near Monkey Bay when trawling at a depth of 10 fathoms (18m), which they doubtfully refer to this species. Konings (1995: 287, photo 3) depicts *T. trilineata*, although he admits not having examined other specimens of *T. trilineata*. In this study, specimens with the characteristic pattern reported by Konings (1995) have been identified as *T. trilineata*. These specimens, however, differ from the single specimen of Trewavas (op. cit.) in the number of lower gill-rakers (5-7 vs 9) and this is attributed to natural variation since all other characters are the same.

Specimens examined

SADC/GEF (21/21/37); unsexed 90.5 mm SL, unsexed 91.0 mm SL; SADC/GEF (21/21/25); unsexed 88.0 mm SL; **SADC/GEF (21/21/34)**; unsexed 98.0 mm SL; South East Arm, a trawl transect from Mazinzi to Kadango, Malawi; 11/10/97. **SADC/GEF**

98/48/02/01; female 74.0 mm SL; Mvera beach Lake Malombe, purchase from fishermen; 22/11/98.

5.10 *Tramitichromis* sp. 'maculae'

Etymology

The name refers to the highly maculated caudal fin and the trailing end of the dorsal fin which are the main characteristic for distinguishing this taxon from *T. variabilis*.

Diagnosis

A medium-sized *Tramitichromis* similar to *T. variabilis* from which it differs in its relatively smaller eye [29.3±0.7 (28.8-29.8) vs 33.5±2.3 (29.8-37.8) % HL] and male breeding pattern whereby the caudal fin and the trailing end of the dorsal fin is highly maculated with yellow spots/maculae.

Description

For descriptive statistics of measurements and meristic data see Table 5.13.

Snout with a slightly convex profile longer than diameter of the eye 38.6±0.4 (38.4-38.9) vs 29.3±0.7 (28.8-29.8) % HL; jaws equal anteriorly or lower jaw slightly shorter; maxillary extending to vertical from the anterior edge of eye. Oral teeth in the outer row mainly unicuspid with a few bicuspid, with 56 or 66 and 44 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 3 or 4 rows. Lower pharyngeal bone with an anterior blade short and keeled, and with tips of teeth at the anterior end turned backwards, teeth simple except for those on the central part which are slightly enlarged but not flattened, 14 teeth along the longest medial series and 24 or 30 across the posterior margin. Caudal fin forked and highly maculated with yellow maculae.

Table 5.13: Morphometric ratios and meristic data for *Tramitichromis* sp. 'maculae'

	Mean	SD	Range	N
Standard length (mm)	132.3	7.4	127.0-137.5	2
as % head length				
Lachrymal depth	27.1	0.8	26.5-27.6	2

Snout length	38.6	0.4	38.4-38.9	2
Lower jaw length	37.6	0.2	37.4-37.8	2
Premaxillary pedicel length	28.4	0.7	27.9-28.8	2
Cheek depth	31.1	1.8	29.8-32.4	2
Eye diameter	29.3	0.7	28.8-29.8	2
Head width (HW)	46.3	0.3	46.1-46.5	2
Interorbital width	24.2	0.1	24.2-24.3	2
as % standard length				
Head length (HL)	33.1	1.1	32.4-33.9	2
Body depth	39.3	0.1	39.3-39.4	2
Dorsal fin base length	54.5	1.5	53.5-55.5	2
Anal fin base length	19.9	0.3	19.6-20.1	2
Predorsal distance	36.3	0.4	36.0-36.6	2
Prepectoral distance	33.3	0.8	32.7-33.9	2
Prepelvic distance	38.8	0.3	38.5-39.0	2
Pre-anal distance	65.0	0.4	64.7-65.4	2
Caudal peduncle length (CPL)	19.6	1.0	18.9-20.4	2
Caudal peduncle depth	12.7	0.1	12.6-12.7	2
Other				
Interorbital width % HW	52.3	0.5	52.0-52.7	2
Lower pharyngeal jaw length (PhJL) % HL	26.4	1.1	25.6-27.2	2
Lower pharyngeal jaw width(PhJW) % PhJL	82.8	8.2	76.9-88.6	2
Dentigerous area length (DeAL) % PhJL	70.6	0.5	70.2-70.9	2
Dentigerous area width (DeAW) % PhJW	80.7	2.1	79.2-82.2	2
Dentigerous area length % DeAW	106.1	8.6	100.0-112.2	2
Caudal peduncle depth % CPL	64.6	3.0	62.5-66.7	2

	Median	Range	N
Number of teeth upper jaw	61	56-66	2
Number of teeth lower jaw	44	44	2
Inner rows upper jaw	3.5	3-4	2
Inner rows lower jaw	3.5	3-4	2
Gill rakers lower	6	5-7	2
Gill rakers total	10	9-11	2
Dorsal spines	15	15-15	2
Dorsal soft	10.5	10-11	2
Anal soft	9	9-9	2
Pectoral fin rays	15	15-15	2
Upper lateral line scales	25.5	25-26	2
Lower lateral line scales	15.5	14-17	2
Longitudinal line scales	32	31-33	2
Transverse scales above LL	5	5-5	2
Transverse scales below LL	9	9-9	2
Scales <pectoral-pelvic fin>	4	4-4	2
Cheek scales	3	3-3	2

Colour pattern

The colour of the two preserved males was silver-grey with a yellow hue; anal fin dark with a yellow tinge distally; caudal and dorsal fin with yellow maculae; pelvic dark with yellow iridescence.

Distribution

Both specimens were collected by bottom trawling at a depth between 10.8 and 12.8 m at Jafua Bay, north of Cobue on the Mozambican shore (Fig. 5.10).

Ecology

Probably feeds on the same diet as *T. variabilis* and *T.* sp. '*variabilis* deep' as the oral dentition and the pharyngeal mill of these three taxa is quite similar.

Discussion

The two specimens considered here as probably new species of the genus *Tramitichromis*, were all collected from the Mozambican shore. The specimens were first identified as *T. brevis* but on close examination they were found to resemble *T. variabilis* more than *T. brevis*. They differ from *T. 'variabilis* deep' in body depth, body depth is the same as *T. variabilis*. The smaller eye differentiates both from *T. variabilis* and *T. brevis* but not *T.* sp. 'brevis 2' from which it only differs in having a highly maculated caudal fin. Although this taxa was poorly represented in the collections for this study, which renders reliable identification difficult, it is suggested to be considered as separate in anticipation that similar individuals may be spotted in future work.

Specimens examined

SADC/GEF 98/33/02/45, **SADC/GEF 98/33/02/47**; male 137.5 mm SL, male 127.0 mm SL; Jafua Bay (north of Cobue), Mozambique; bottom trawl at 10.8-12.8 m depth; 04/04/98.

5.11 *Tramitichromis* variabilis (Trewavas, 1931)

Lethrinops variabilis Trewavas, 1931: 139, fig. 2, 3a, 4a; Jackson, 1961:585; Blanc, 1962: 216; Jackson *et al.*, 1963:264.

Tramitichromis variabilis Eccles & Trewavas, 1989: 257, fig. 152, 153; Konings, 1995: 288, fig. 1 & 2; Turner, 1996:96.

(Plate 5.7)

Etymology

The species name is derived from the Latin adjective *variabilis* which means variable, referring to the variable body melanin pattern.

Diagnosis

Recognised as a member of the genus *Tramitichromis* by the lower pharyngeal bone shape and dentition. Distinguished from all other members except *T.* sp. 'variabilis deep' by the presence of a series of spots from nape to base of caudal fin. Differ significantly ($p<0.05$) from *T. lituris* in lachrymal depth, lower jaw length, cheek depth, dorsal fin base length, predorsal distance and preanal distance. The lower pharyngeal bone is also characteristic. The anterior blade is projected downward at an angle more than 50° to the horizontal plane, in all other members of *Tramitichromis* the projection is always less than 45°.

Description

Morphometric and meristic data for *T. variabilis* for all specimens examined are summarised in Table 5.14.

Snout with a round profile equal to or shorter than eye diameter [34.0±2.8 (28.9-38.4) vs 33.5±2.3 (29.8-37.8)% in head length]. Jaws equal anteriorly; maxillary reaching vertical from the anterior edge of the eye. Oral teeth in the outer row mainly unicuspid with a few bicuspid on the anterior part, 47-86 teeth in the outer row of upper jaw and 34-54 in the lower, inner teeth in both jaws mainly unicuspid with a few tricuspid, 1-4 inner rows in the upper and lower jaws. Lower pharyngeal bone deeply notched posteriorly, dentigerous area broadly blunt anteriorly; teeth ending in 3-5 rows and with the blade short and deflected downwards forming a keel. In exceptionally large specimens a few teeth at the central part of the bone slightly enlarged and robust. Teeth on the posterior end are bicuspid and with anterior cusps straight while those on the anterior end are unicuspid with the tip turned backwards. 11-16 teeth along the longest medial series and 28-34 across the posterior margin. Caudal fin slightly emarginate. Principal melanin pattern of a series of oblique spots from nape to the base of caudal fin.

Table 5.14: Morphometric ratios and meristic data for *Tramitichromis variabilis*

	Mean	SD	Range	N
Standard length (mm)	115.2	25.5	74-150.5	14
as % head length				
Lachrymal depth	24.4	2.1	19.6-27.3	14
Snout length	34.0	2.8	28.9-38.4	14
Lower jaw length	35.5	1.2	33.6-38.0	14
Premaxillary pedicel length	26.1	1.9	23.1-29.3	14
Cheek depth	29.4	1.6	26.2-31.7	14
Eye diameter	33.5	2.3	29.8-37.8	14
Head width (HW)	46.7	1.6	44.3-50.0	14
Interorbital width	23.9	1.4	22.0-26.4	14
as % standard length				
Head length (HL)	32.7	1.1	31.3-35.1	14
Body depth	38.0	1.9	35.1-41.7	14
Dorsal fin base length	55.5	1.2	53.2-57.6	14
Anal fin base length	20.1	0.6	18.9-21.3	14
Predorsal distance	35.9	1.6	33.3-39.2	14
Prepectoral distance	32.6	1.4	30.7-35.8	14
Prepelvic distance	37.2	1.1	36.1-39.9	14
Pre-anal distance	64.3	1.1	62.8-66.7	14
Caudal peduncle length (CPL)	19.0	0.7	17.9-20.3	14

Caudal peduncle length (CPL)	19.0	0.7	17.9-20.3	14
Caudal peduncle depth	12.4	0.5	11.4-13.0	14
Other				
Interorbital width % HW	51.2	3.6	44.4-56.3	14
Lower pharyngeal jaw length (PhJL) % HL	26.3	2.4	23.3-31.2	13
Lower pharyngeal jaw width(PhJW) % PhJL	84.5	6.2	76.5-95.2	13
Dentigerous area length (DeAL) % PhJL	71.9	5.3	62.6-82.5	13
Dentigerous area width (DeAW) % PhJW	75.7	5.3	66.7-85.5	13
Dentigerous area length % DeAW	113.1	8.8	93.5-132.0	13
Caudal peduncle depth % CPL	65.4	4.1	58.2-71.7	14

	Median	Range	N
Number of teeth upper jaw	56.5	47-86	14
Number of teeth lower jaw	39	34-54	14
Inner rows upper jaw	2	1-4	14
Inner rows lower jaw	2	1-4	14
Gill rakers lower	6	5-7	14
Gill rakers total	10	9-11	14
Dorsal spines	15	15-17	14
Dorsal soft	11	10-12	14
Anal soft	9	9-10	14
Pectoral fin rays	16	14-16	14
Upper lateral line scales	25.5	23-27	14
Lower lateral line scales	15	14-18	14
Longitudinal line scales	33	32-35	14
Transverse scales above LL	5	4-6	14
Transverse scales below LL	9	9-10	14
Scales <pectoral-pelvic fin>	5	3-7	14
Cheek scales	3	2-3	14

Colour pattern

Preserved colour of adult males: anal fin dark, dorsal fin dark with long trailing end and white lappets, pelvic fins dark and long.

Distribution

Tramitichromis variabilis has a lake-wide distribution. Specimens examined were collected from locations as far apart as Itungi port on the Tanzanian shore and Jafua Bay in Mozambique waters (Fig. 5.9). The species was also recorded from Lake Malombe.

Ecology

It has a preference for soft-bottom habitats where it feeds on worms and other soft invertebrates that live on the sediment on the substrate (Konings, 1995; pers. obs.).

Discussion

The last taxonomic study on this species was by Trewavas (1931). Based on the body melanin pattern she reported two colour morphs, which she assigned to this species. The first colour pattern consists of a series of spots running obliquely from the nape to the caudal base. The second consists of a series of spots at the base of the dorsal fin, a parallel streak above or crossing the upper lateral line below the spinous dorsal, and a third along the lower lateral line running forward to the head and ending below some part of the spinous dorsal. The latter pattern, could be a 'weak' version of the "the kirkii" pattern common among many cichlids of Lake Malawi/Nyasa. Konings (1995:287) assigned individuals with such a pattern to *T. trilineata* and this assignment is found to be agreeable. Presently all specimens with such a pattern are regarded as *T. trilineata*.

Individuals with the former (oblique series of spots) pattern are poorly defined and may represent a complex of related species. Eccles & Trewavas (1989) report that the types of *T. variabilis* have a melanin pattern, which consists of a partial oblique band or series of spots. All specimens with such a pattern have assigned to the *T. variabilis* complex. Two specimens in Konings (1995: 288, photo 1 & 2) appear to belong to this complex, one (photo 1) obviously resembles the specimens assigned to *T. variabilis* in this study. The other (photo 2) appears to be a specimen tentatively assigned to the undescribed *T.* sp.

'pharyngeals'. The *T. variabilis* complex presently comprises of three taxa, viz., *T. variabilis*, *T.* sp. '*variabilis* deep' and *T.* sp. 'maculae'.

Specimens examined

SADC/GEF 98/33/02/09-01; male 110.5 mm SL, male 148.0 mm SL; Jafua Bay (north of Cobue), Mozambique; bottom trawl at 10.8-12.8 m depth; 04/04/98. **SADC/GEF 98/46/01/01**; female 106.0 mm SL Itungi port (Weissman Bay), Tanzania; beach seine; 06/07/98. **SADC/GEF 98/46/01/38-40**; unsexed 87.5 mm SL, unsexed 84.5 mm SL, unsexed 96.0 mm SL Itungi port (Weissman Bay), Tanzania; beach seine; 08/07/98. **SADC/GEF 97/27/06/18-19**; unsexed 105.5 mm SL; unsexed 106.5 mm SL; Itungi port (Weissman Bay), Tanzania; beach seine; 20/12/97. **SADC/GEF 98/33/02/43-44**, **SADC/GEF 98/33/02/46**, **SADC/GEF 98/33/02/48**; male 150.5 mm SL, male 128.5 mm SL, male 126.0 mm SL, male 140.0 mm SL; Jafua Bay (north of Cobue), Mozambique; bottom trawl at 10.8-12.8 m depth; 04/04/98. **SADC/GEF 98/48/02/01**; female 74.0 mm SL, Mvera beach in Lake Malombe, purchased from fish market; 22/11/98.

5.12 *Tramitichromis* sp. 'variabilis deep'

Etymology

This species is very similar to *T. variabilis* except for the deeper body, hence the name '*variabilis* deep'.

Diagnosis

A *Tramitichromis* that is reminiscent of *T. variabilis* except for the body depth which is over 41.7 % SL and for the head width which is over 50 % HL. It also differs in breeding colours, as the preserved specimen is yellowish unlike those of *T. variabilis*, which are dark grey.

Description

The description given below is based on a single specimen, 140 mm SL collected from Jafua Bay on the Mozambican shores of the lake.

Morphometric and meristic data for the specimen of *T.* sp. 'variabilis deep' examined are summarised in Table 5.15.

Snout with a round profile longer than eye diameter. Jaws equal anteriorly; maxillary reaching vertical from the anterior edge of the eye or nearly so. Oral teeth in the outer row bicuspid, 58 teeth in the outer row of upper jaw and 42 in the lower, inner teeth in both jaws tricuspid, 3 inner rows in the upper and lower jaws. Lower pharyngeal bone notched posteriorly, dentigerous area broadly blunt anteriorly and with the blade short and deflected downwards forming a keel. A few teeth at the central part of the bone slightly larger but not flat. Teeth on the posterior end are bicuspid and with anterior cusps straight while those on the anterior end are unicuspid with the tip turned backwards. 13 along the longest medial series and 25 across the posterior margin. Caudal slightly emarginate. Principal melanin pattern of a series of oblique spots from nape to the base of caudal fin.

Table 5.15: Morphometric ratios and meristic data for *Tramitichromis* sp. 'variabilis deep'

	Mean	SD	Range	N
Standard length (mm)	140.0			1
as % head length				
Lachrymal depth	25.8			1
Snout length	36.7			1
Lower jaw length	36.5			1
Premaxillary pedicel length	26.7			1
Cheek depth	31.3			1
Eye diameter	32.4			1
Head width (HW)	50.5			1
Interorbital width	24.3			1
as % standard length				
Head length (HL)	34.6			1
Body depth	42.1			1
Dorsal fin base length	58.6			1
Anal fin base length	21.4			1
Predorsal distance	35.7			1
Prepectoral distance	34.3			1
Prepelvic distance	38.6			1
Preanal distance	64.6			1
Caudal peduncle length (CPL)	19.6			1
Caudal peduncle depth	12.9			1
Other				
Interorbital width % HW	48.2			1
Lower pharyngeal jaw length (PhJL) % HL	26.8			1
Lower pharyngeal jaw width(PhJW) % PhJL	85.4			1
Dentigerous area length (DeAL) % PhJL	76.9			1

Dentigerous area width (DeAW) % PhJW	78.4		1
Dentigerous area length % DeAW	114.9		1
Caudal peduncle depth % CPL	65.5		1

	Median	Range	N
Number of teeth upper jaw	58		1
Number of teeth lower jaw	42		1
Inner rows upper jaw	3		1
Inner rows lower jaw	3		1
Gill rakers lower	6		1
Gill rakers total	10		1
Dorsal spines	15		1
Dorsal soft	11		1
Anal soft	9		1
Pectoral fin rays	15		1
Upper lateral line scales	26		1
Lower lateral line scales	17		1
Longitudinal line scales	33		1
Transverse scales above LL	5		1
Transverse scales below LL	10		1
Scales <pectoral-pelvic fin>	6		1
Cheek scales	3		1

Colour pattern

Live coloration not recorded but the preserved specimen is grey with a yellow tinge, especially in the head region. A faint oblique band is easily visible on the body below the dorsal fin.

Distribution

A single specimen identified as belonging to this taxon was collected during the normal SADC/GEF Lake Malawi Project scientific cruises from Jafua Bay (north of Cobue), Mozambique (Fig. 5.10). It is assumed that the fish can be found in similar habitats elsewhere in the lake.

Ecology

The stomach contained the remains of chironomid larvae, sand and detritus material. It is therefore a benthic feeder.

Discussion

A single specimen was found among those originally identified as *T. variabilis*. This specimen was different from all the specimens identified as *T. variabilis* on account of the body depth. The body depth of this specimen fell out of range of the fourteen specimens of T. variabilis examined. The specimens also had a yellow iridescence especially on the head. Konings (1995: 289' photo 7) reported on a fish from Senga Bay, Malawi under the pseudonym *T.* sp.' " lituris yellow" which is similar to this fish and is considered here as undescribed.

Specimens examined

SADC/GEF 98/33/02/19; male 140.0 mm SL; Jafua Bay (north of Cobue), Mozambique; bottom trawl at 10.8-12.8 m depth; 04/04/98.

5.13 *Tramitichromis lituris (Trewavas* 1931*)*

Lethrinops lituris Trewavas, 1931:139; Blanc, 1962: 216; Ufermann et al., 1987:363.

Lethrinops liturus Jackson, 1961: 585; Jackson et al., 1963:84; Bowmaker et al., 1978:1229.

Tramitichromis lituris Eccles & Trewavas, 1989: 258, fig. 154; Konings, 1995: 289, fig. 5 & 6; Turner, 1996:96, photo page 60.

(Plate 5.8)

Etymology

The species name is derived from the Latin *litura* (noun) for an irregular, blurred spot, blotch or marking, referring to the indefinite patch on the upper lateral line below the spinous dorsal.

Diagnosis

A species of *Tramitichromis* diagnosed by a dark supra-pectoral patch below the dorsal fin formed by thickening of the 3^{rd}-5^{th} vertical bars.

Description

Morphometric and meristic data for *T. lituris* for all specimens examined are summarised in Table 5.16.

Snout with a round profile as long as or longer than eye diameter [35.4±1.8 (33.3-37.6) Vs 32.7±1.6 (31.1-35.1)% in head length]. Jaws equal anteriorly; maxillary reaching vertical from the anterior edge of the eye. Oral teeth in the outer row weakly bicuspid otherwise mostly unicuspid, 56-76 teeth in the outer row of upper jaw and 38-54 in the lower, inner teeth in both jaws unicuspid, 1-3 inner rows in the upper and 2-3 in the lower. Lower pharyngeal bone slightly notched posteriorly with dentigerous area less blunt than those of *T. brevis* and *T. variabilis*, anterior teeth are cylindrical and larger than the median teeth with tips turned backwards, anterior blade rather short and keeled. 12-16 teeth along the longest medial series and 36-42 across the posterior margin. Caudal slightly forked. Principal melanin pattern of indistinct suprapectoral patch on the upper lateral line below the spinous dorsal.

Table 5.16: Morphometric ratios and meristic data for *Tramitichromis lituris*

	Mean	SD	Range	N
Standard length (mm)	123.2	7.3	110-140	11
as % head length				
Lachrymal depth	26.5	0.8	25.3-28.0	11
Snout length	35.4	1.8	33.3-37.6	11
Lower jaw length	37.1	1.3	34.5-38.9	11
Premaxillary pedicel length	26.7	1.5	25.1-30.1	11
Cheek depth	31.6	1.8	28.2-34.0	11
Eye diameter	32.7	1.6	31.1-35.1	11
Head width (HW)	46.8	2.0	42.9-49.4	11
Interorbital width	24.0	1.5	22.1-26.3	11
as % standard length				
Head length (HL)	33.4	0.9	31.5-34.6	11
Body depth	37.9	1.0	36.1-40.0	11
Dorsal fin base length	57.0	1.3	54.5-59.1	11
Anal fin base length	19.9	0.5	19.1-20.6	11
Predorsal distance	37.6	1.2	35.7-39.9	11
Prepectoral distance	33.1	1.2	31.2-35.0	11
Prepelvic distance	37.7	1.3	36.2-40.2	11
Pre-anal distance	63.3	1.0	61.4-64.6	11
Caudal peduncle length (CPL)	19.4	1.2	17.9-21.4	11
Caudal peduncle depth	12.6	0.5	11.8-13.4	11

Other				
Interorbital width % HW	51.3	3.4	47.0-58.2	11
Lower pharyngeal jaw length (PhJL) % HL	28.2	1.7	25.4-31.1	10
Lower pharyngeal jaw width(PhJW) % PhJL	82.4	4.2	76.3-90.0	10
Dentigerous area length (DeAL) % PhJL	67.7	5.1	60.0-75.0	10
Dentigerous area width (DeAW) % PhJW	74.9	5.0	65.6-83.3	10
Dentigerous area length % DeAW	110.1	9.2	98.6-127.1	10
Caudal peduncle depth % CPL	65.2	5.3	55.3-71.1	11

	Median	Range	N
Number of teeth upper jaw	64	56-76	9
Number of teeth lower jaw	40	38-54	9
Inner rows upper jaw	2	1-3	10
Inner rows lower jaw	2	2-3	10
Gill rakers lower	7	6-7	11
Gill rakers total	11	10-11	11
Dorsal spines	15	15-16	11
Dorsal soft	11	10-12	11
Anal soft	9	9-10	11
Pectoral fin rays	16	14-16	11
Upper lateral line scales	25	23-27	11
Lower lateral line scales	16	14-18	11
Longitudinal line scales	33	31-35	11
Transverse scales above LL	5	5-6	11
Transverse scales below LL	9	8-10	11
Scales <pectoral-pelvic fin>	6	5-7	11
Cheek scales	3	2-4	11

Colour pattern

Females and immature males silvery with a brownish yellow cast and faint vertical bars, with a faint blotch formed by fusion of 3 bars (Turner, 1996). According to observations made in this study, the 3^{rd} to 5^{th} bar fuse to form an often oblong blotch which, however, may be difficult to detect in breeding males. Breeding males are blue with the body shining metallic orange; the dorsal fin with orange spots and the caudal fin with orange maculae. The dorsal fin has bluish white lappets, which are tipped orange. Anal fin with numerous large orange 'egg-spots'; pelvic fins are dark with bluish cast proximally and bluish white distally.

Distribution

The five syntypes examined were collected by Christy; three from somewhere around Karonga, the bordering district of Malawi and Tanzania, one from Mwaya on the northern tip of the lake within Tanzanian waters and the other one from between Bar and Fort Maguire (Malawi) in the south east part of the lake. The two specimens examined at the JLB Smith Institute of Ichthyology were collected by the Malawi Fisheries Department around the Monkey Bay area. The rest of the specimens were collected by the author at Itungi port (close to Mwaya) on the Tanzanian shore. Probably *T. lituris* has a lake-wide distribution (Fig. 5.8).

Ecology

Data from four specimens examined show that it is a benthic feeder. Stomach contents were dominated by chironomid larvae, sand, detritus and some algal material.

Discussion

Trewavas (1931) described this species on the basis of forty-seven specimens having a total length ranging from 88 to 168 mm. All the syntypes examined and measured at the BMNH for this study, except the smallest (83.0mm SL), have the characteristic dark oblong patch below the spinous dorsal. As all other features of the small specimen correspond to those of the larger specimens, it is assumed that the patch might have bleached with time. Eccles & Trewavas (1989) report that *T. lituris* was abundant at 9 m just north of the 'narrowest part of the lake' which probably means somewhere near Lifuwu, Salima (Malawi). This is an area of extensive soft bottom, a likely habitat for *T. lituris*. The species that they illustrate seems to be conspecific with those identified as *T. lituris* in this study and those of Konings (1995: 289, photo 5 & 6). Turner (1996: 96, photo page 60) reports *T. lituris* from the South East Arm of the lake. However, none of the syntypes examined during this study correspond to these specimens and therefore they probably are not the true *T. lituris*.

Specimens examined

BMNH 1930.1.31.21-23; male125.0mm SL, male 110.0 mm SL, male 83.0 mm SL; Karonga, Malawi; coll. Christy. Syntypes. **BMNH 1930.1.31.181**; male 126.0 mm SL; Mwaya, Tanzania; coll: Christy; syntype. **BMNH 1930.1.31.45**; female 123.5 mm SL; Bar to Fort Maguire, Malawi; coll. Christy. Syntype. **RUSI: 015509**; male 120.5 mm SL, female 119.0 mm SL; Monkey Bay, Malawi; coll. Malawi Fisheries Department 07/12/73. **SADC/GEF 98/46/03/03**; male 140.5 mm SL; Itungi port, Tanzania; Beach seine at 3 m depth; 08/07/98. **SADC/GEF 97/27/07/03-05**; female 124.5 mm SL, male 121.5 mm SL, male 127.5 mm SL; Itungi port (Weissman Bay), Tanzania; beach seine; 20/12/97.

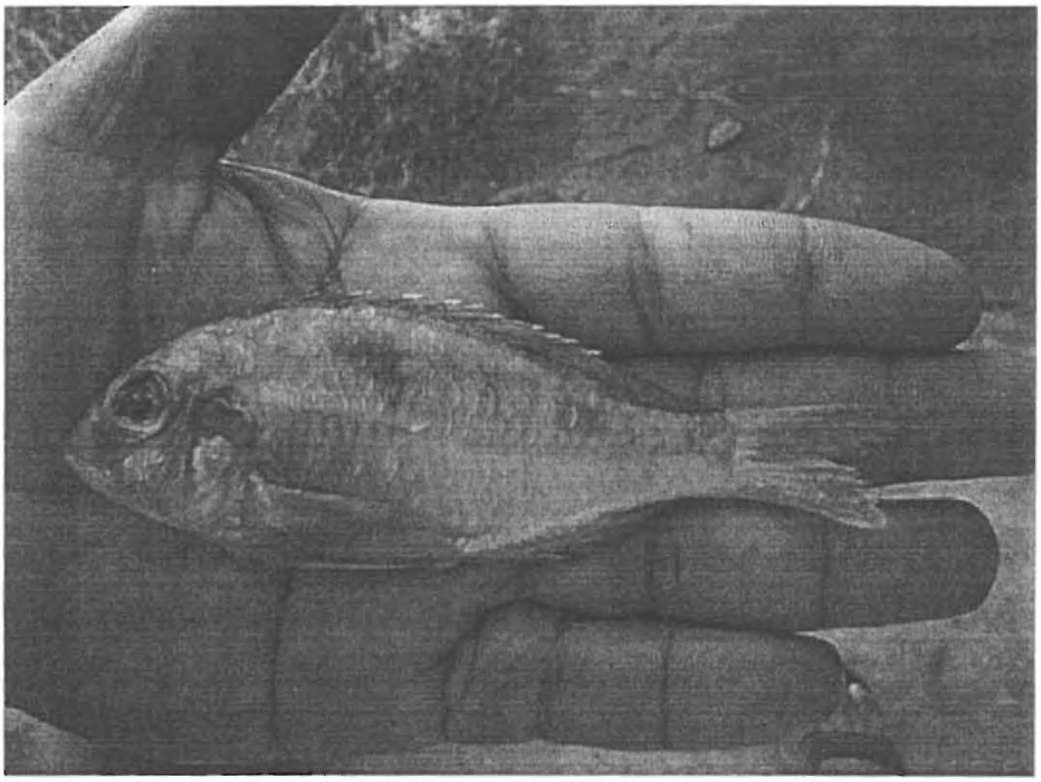


PLATE 5.1: *Tramitichromis intermedius*

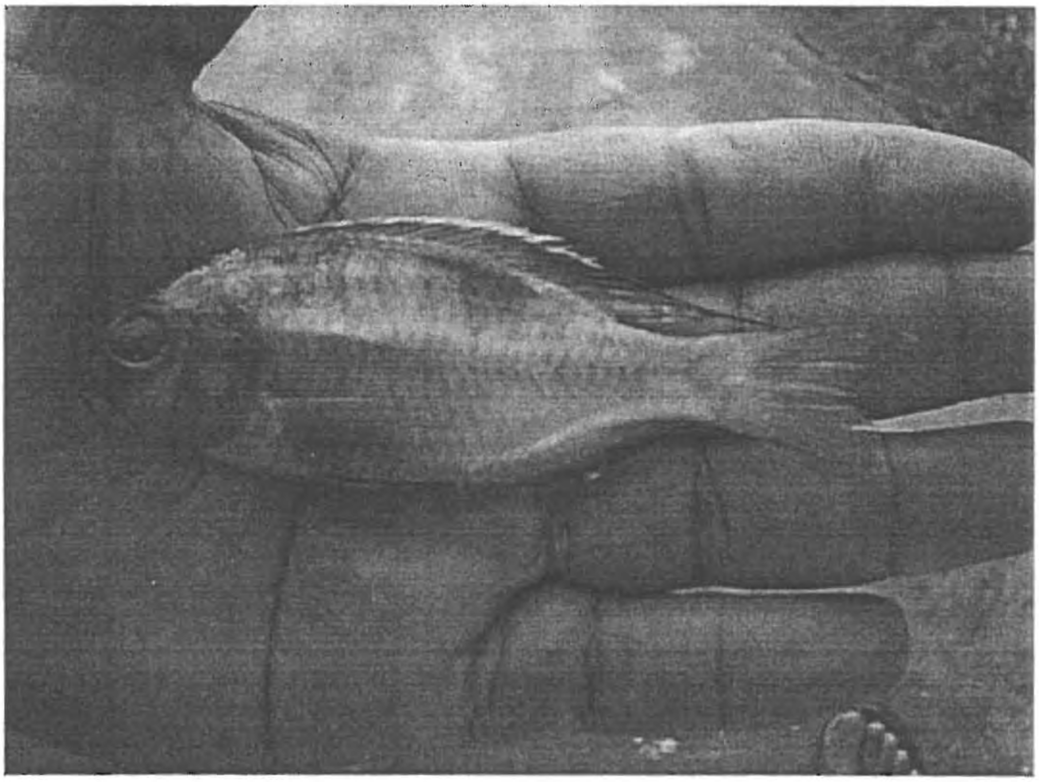


PLATE 5.2: *Tramitichromis* sp. 'pharyngeals'

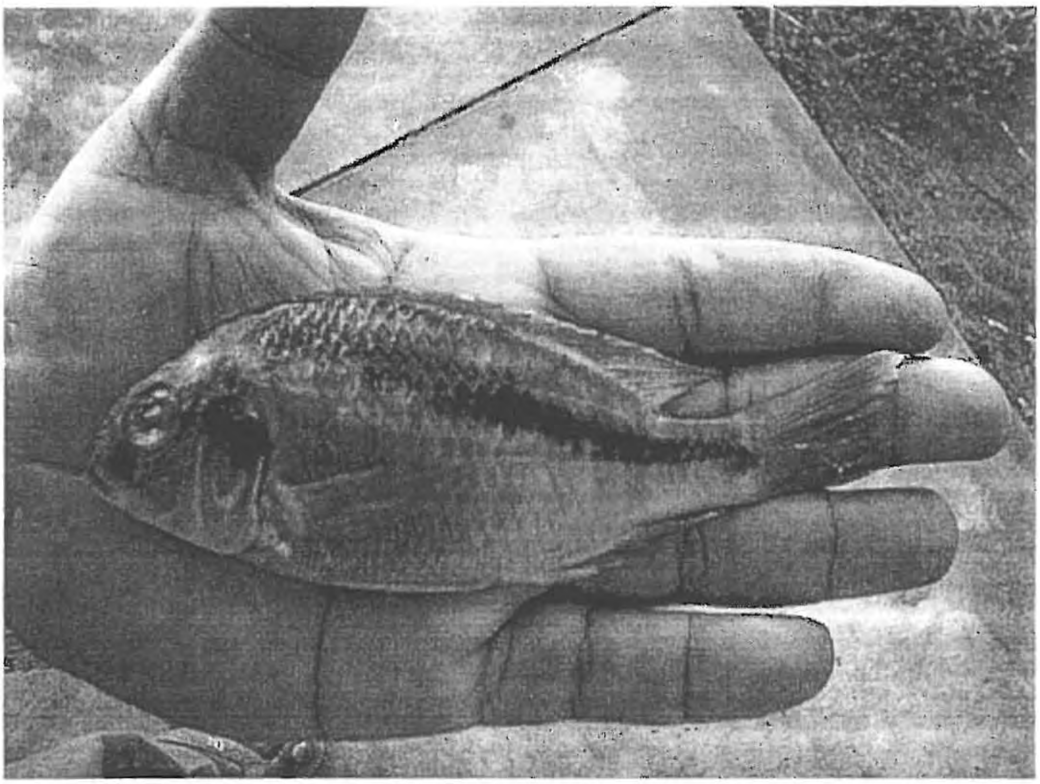


PLATE 5.3: *Tramitichromis brevis* (Tanzania)

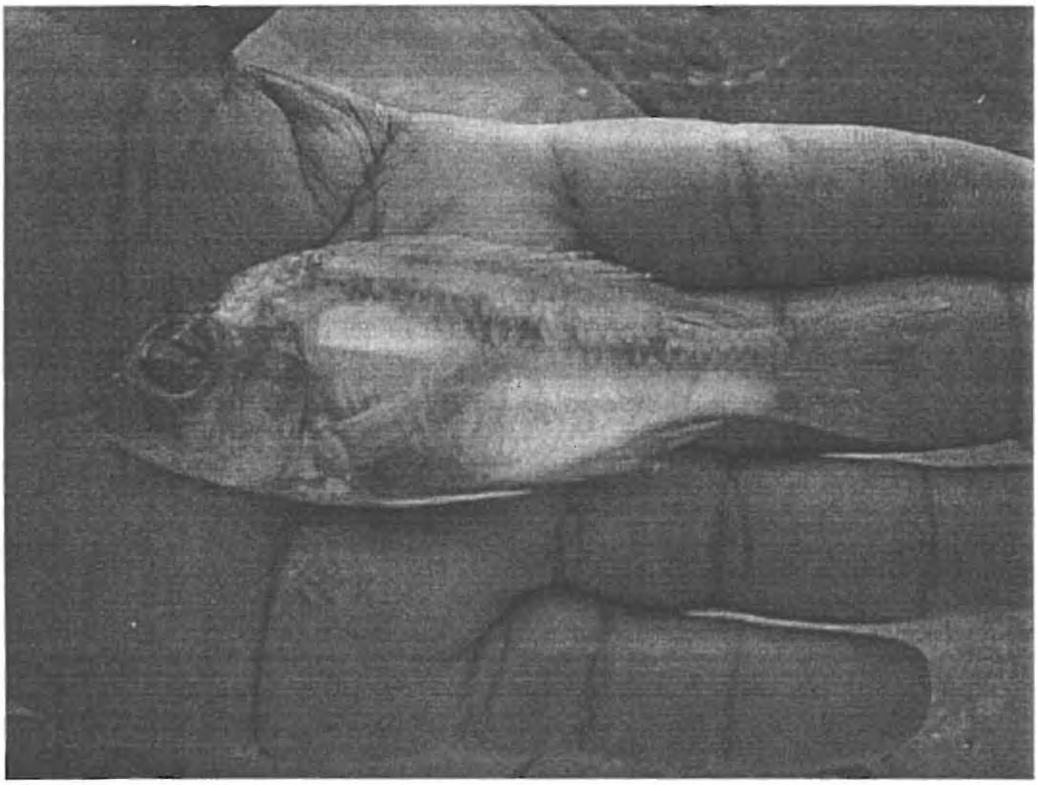


PLATE 5.4: *Tramitichromis brevis* (Malawi)

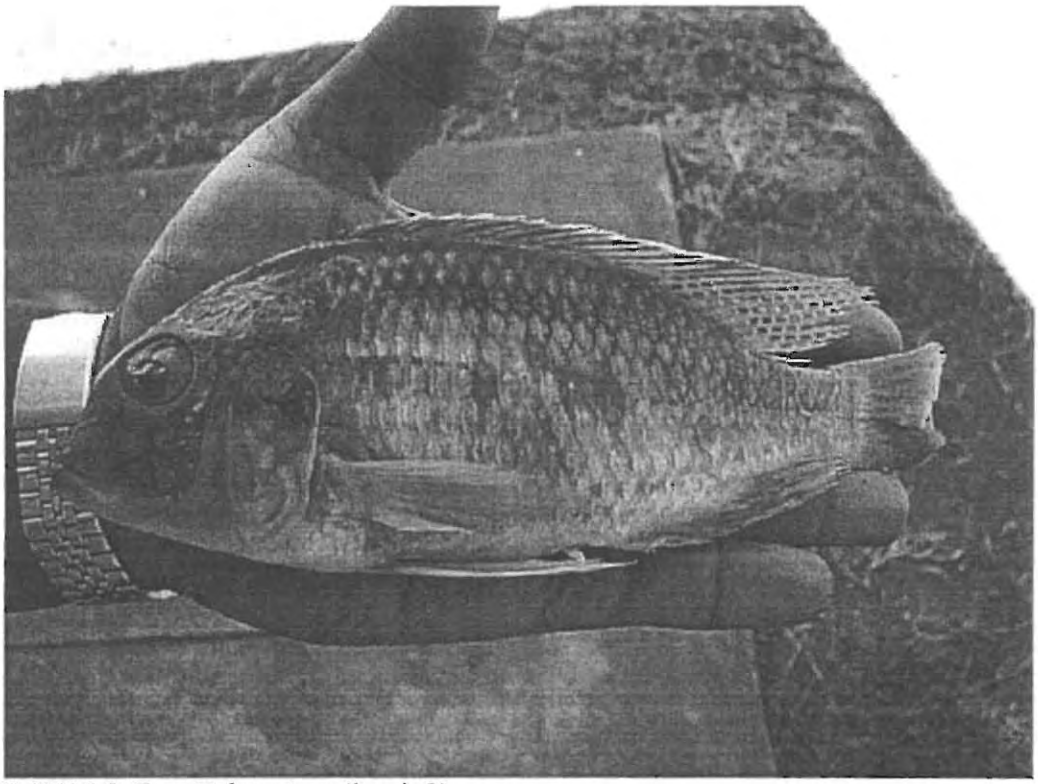


PLATE 5.5: *Tramitichromis* sp. 'brevis 2'

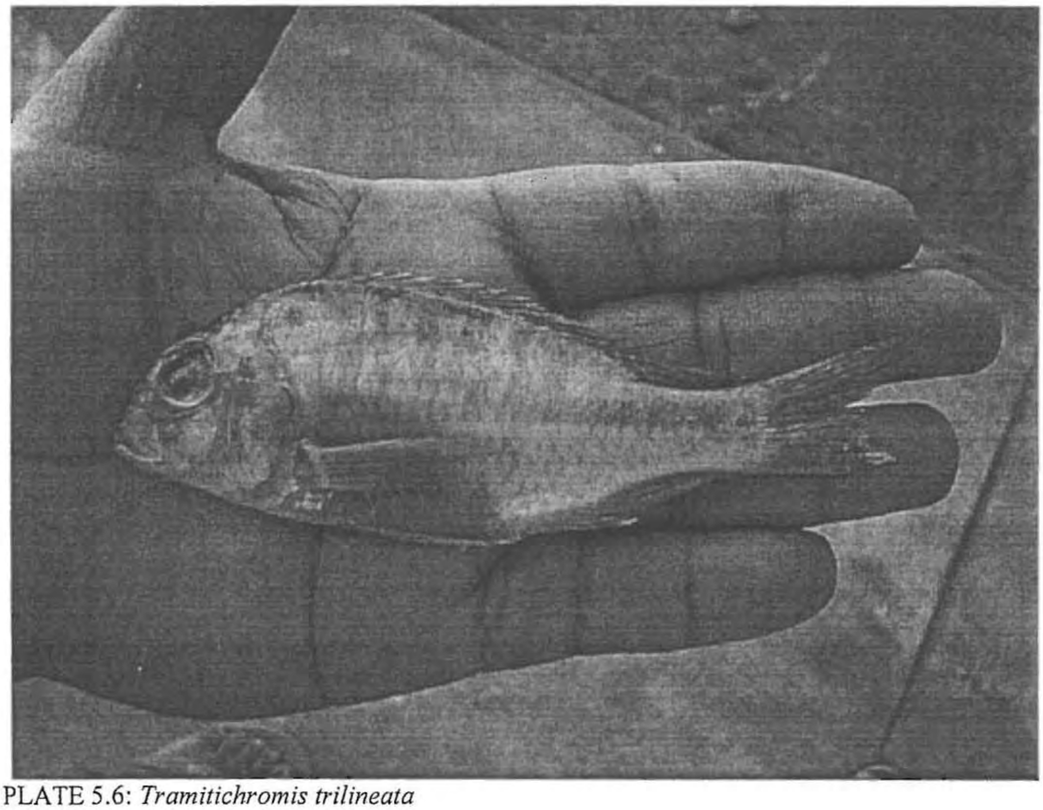


PLATE 5.6: *Tramitichromis trilineata*

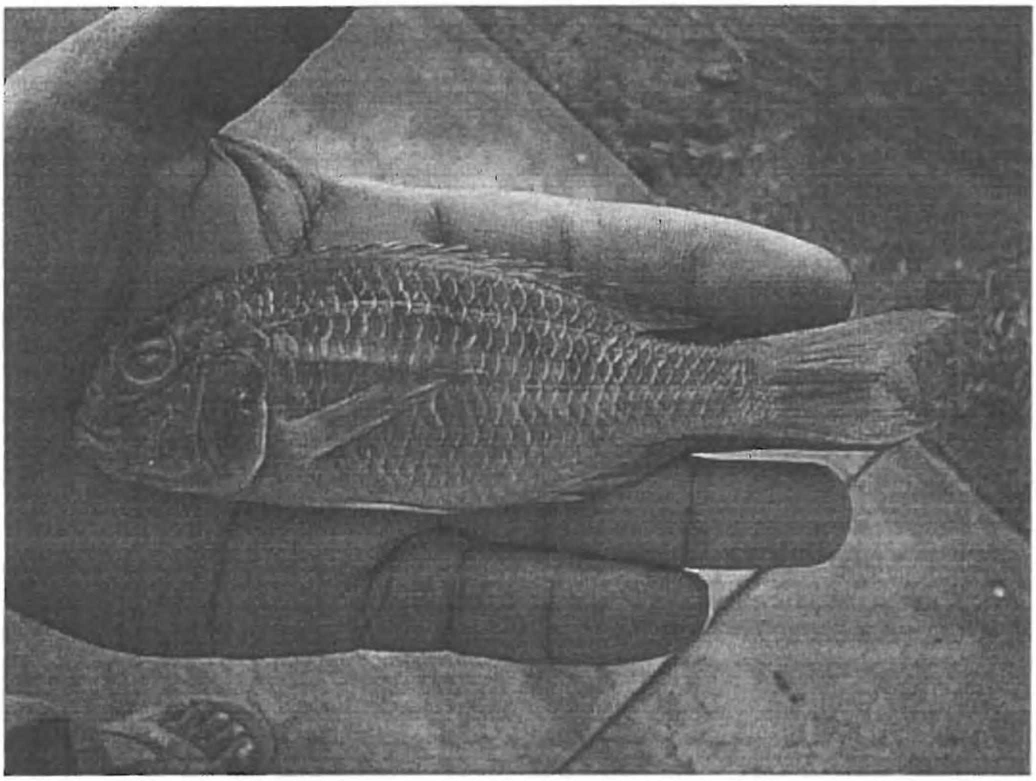


PLATE 5.7: *Tramitichromis variabilis*

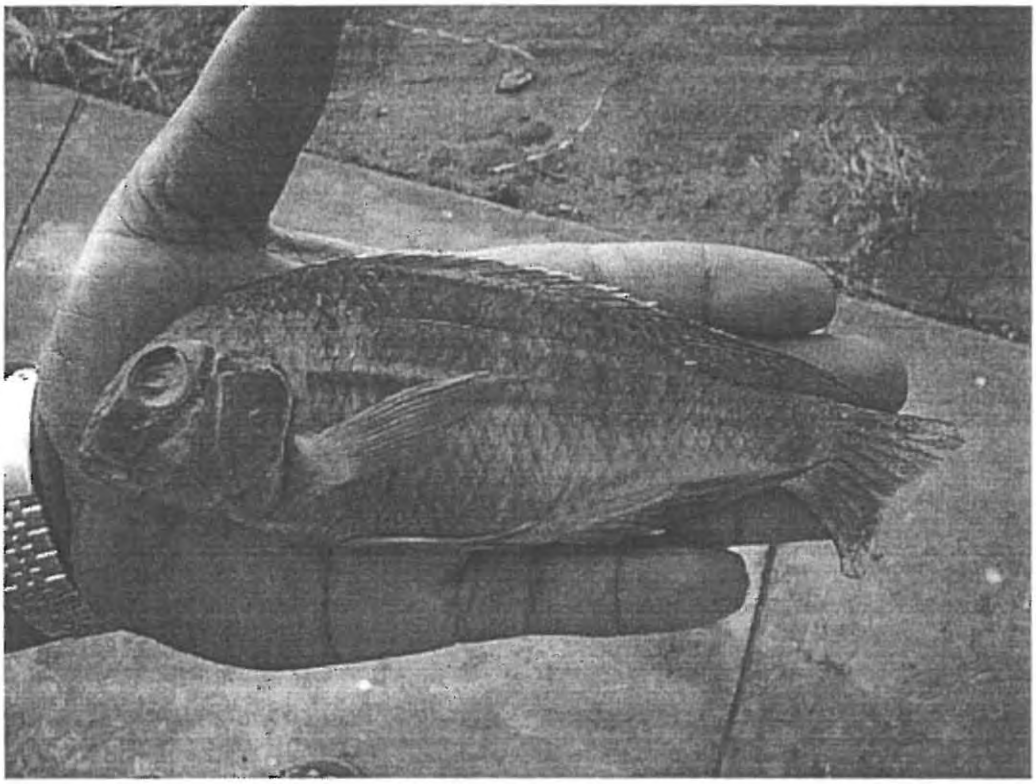


PLATE 5.8: *Tramitichromis lituris*

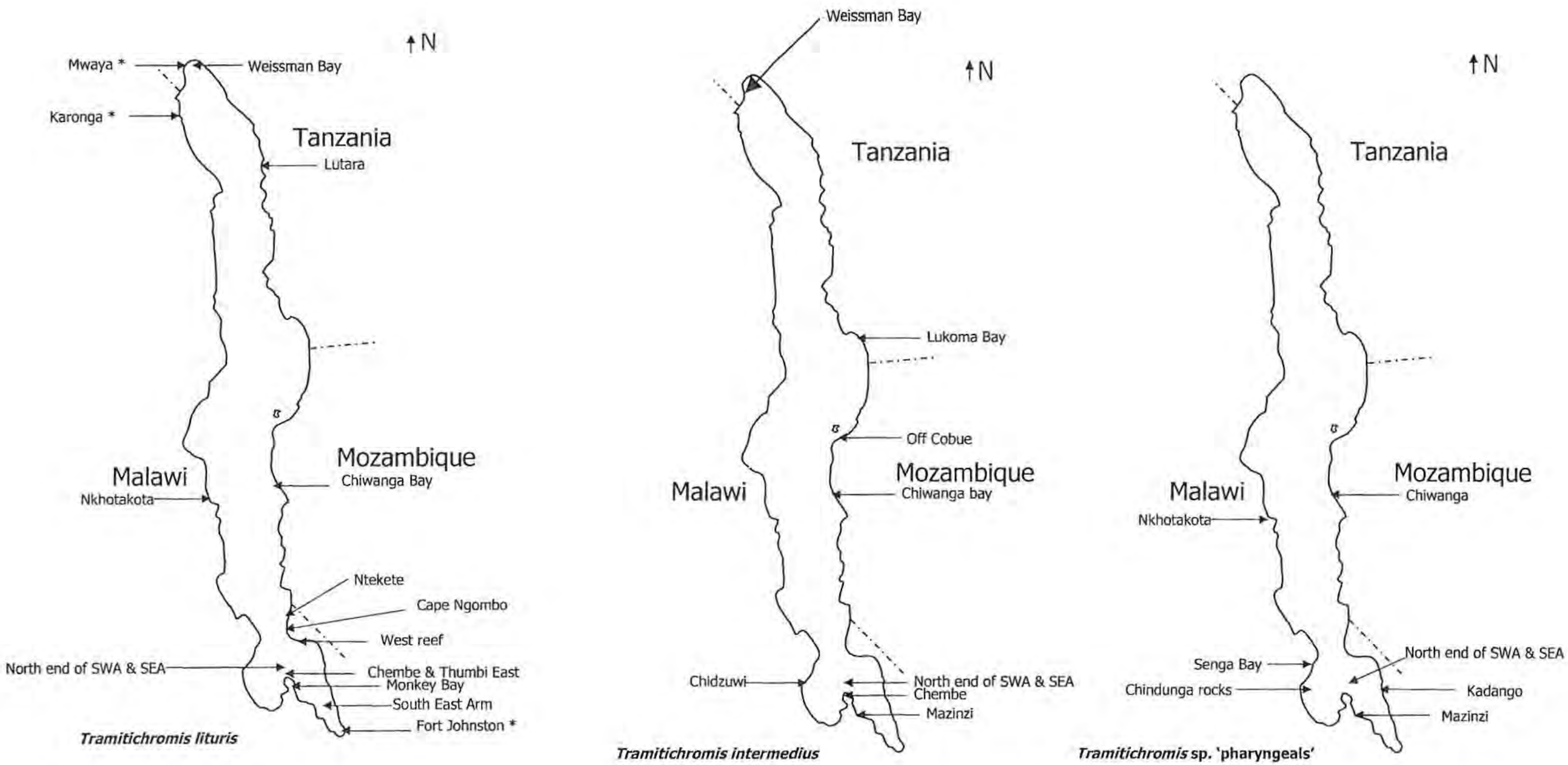


Fig. 5.8: Localities where *Tramitichromis lituris*, *T. intermedius* and *T.* sp. 'pharyngeals' have been collected during this study; * type localities.

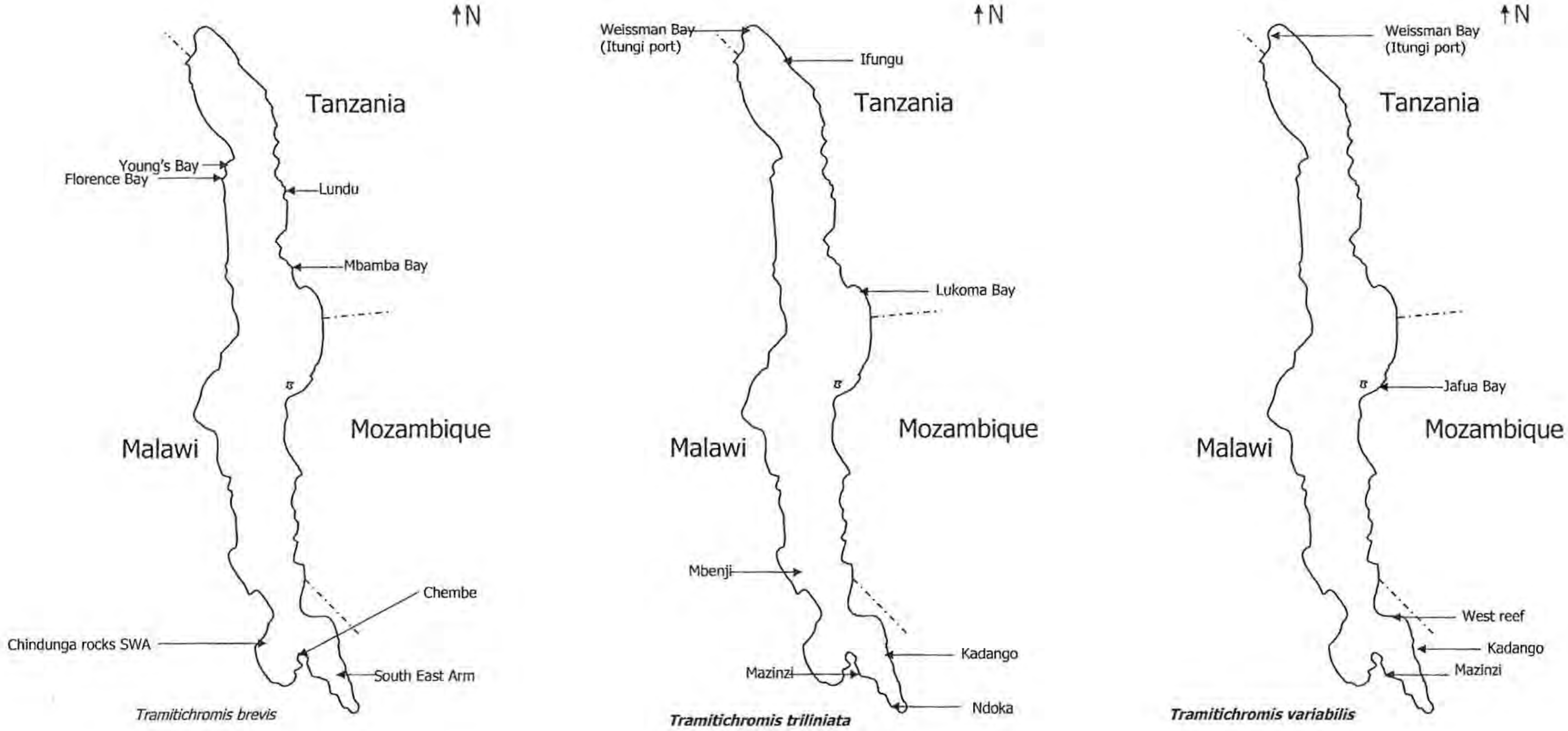


Fig. 5.9: Localities where *Tramitichromis brevis*, *T. trilineata* and *T. variabilis* have been collected during this study.

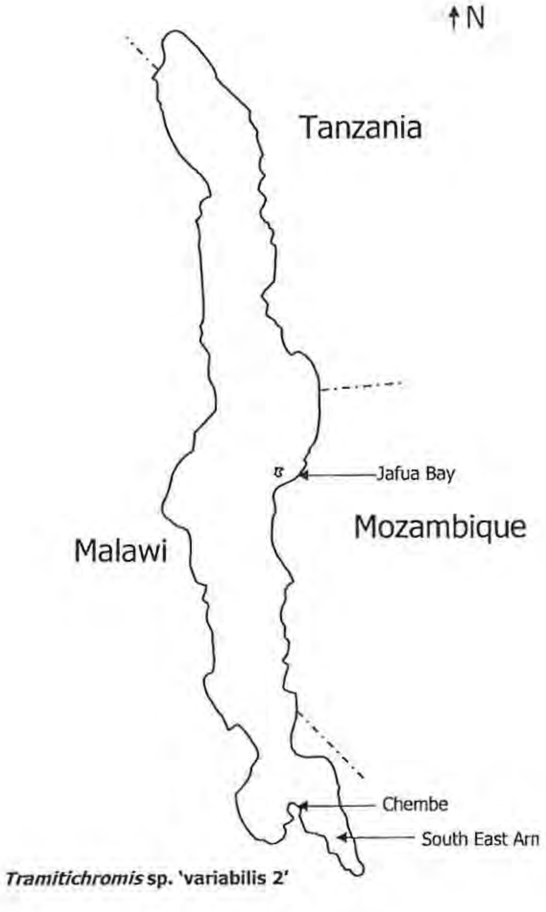


Fig. 5.10: Localities where *Tramitichromis* sp. 'brevis 2', *T*. sp. 'variabilis deep' and *T*. sp. 'maculae have been collected during this study.

Chapter 6: Shallow-water *Lethrinops* 'sensu stricto' (Regan, 1922)

Lethrinops Regan, 1922:719 Type species: *Chromis lethrinus* Günther, 1893, by original designation; Trewavas, 1931 (synopsis of the genus); Eccles & Lewis, 1977, 1978,1979 (partial revisions of the genus); Greenwood, 1983; Eccles & Lewis, 1989:120, 15 illustrations; Konings, 1995: 282, 34 photographs; Turner, 1996: 76, 159 & 201, 39 photographs (mainly from deep water).

Etymology

The name is derived from the name of a marine fish genus, *Lethrinus* which is similar in appearance to the type species + "ops" derived from Greek "opsis" = "appearance".

6.1 Introduction

After having split the genus *Lethrinops* as defined by Trewavas (1931) (= *Lethrinops* 'sensu lato') in three genera *Lethrinops*, *Taeniolethrinops* and *Tramitichromis*, Eccles & Trewavas (1989) pointed out the possibility that the newly defined *Lethrinops* (= 'sensu stricto') may be polyphyletic. Molecular studies show clearly that the shallow water *Lethrinops* 'sensu stricto' together with those of the genera *Taeniolethrinops* and *Tramitichromis*, fall within one distinct clade/lineage while the deep-water *Lethrinops* fall into another, separate clade/lineage (Moran et al., 1994; Hauser et. al., 1999). From the results of these molecùlar studies it is suggested that deep water Lethrinops should be put into a different genus. In this chapter, three groups of shallow-water *Lethrinops* 'sensu stricto' are examined and their component members described and re-described.

The first group consists of three species: *Lethrinops lunaris*, *L. leptodon* and *L. lethrinus*. They are all characterised by the possession of long, straight and gently sloping snouts. It has been possible to examine and measure the types of *L. lunaris* and *L. leptodon* and compare them with recently collected specimens. It was not possible in this study to examine the types of *L. lethrinus* because they were on loan from the BMNH.

The second group comprises of taxa, which possess short and convex snouts (the 'golf heads'), with the maxillary extension reaching directly below the eye. Five of these are already described and they are therefore re-described in this study. The status of the remaining four, which are probably new species, is discussed. Those described (or re-described) are: *L. auritus*, *L. macrochir*, *L. macrophthalmus*, *L. microstoma* and *L. parvidens*. The undescribed members are only referred to by their cheironym and include: *Lethrinops* sp. 'turneri', *L.* sp. 'domira blotch' *L.* sp. 'parvidens deep' and *L.* sp. 'black dorsal auritus'. The types of *L. auritus*, *L. macrochir*, *L. macrophthalmus*, *L. microstoma* and *L. parvidens* have been examined, measured and compared with recently collected material. All except *L. microstoma* have a group of more or less enlarged teeth in the postero-medial area of the lower pharyngeal bone.

The last group is ill-defined and consists of species with an intermediate snout and all have small teeth in the postero-medial area of the lower pharyngeal bone. The members of this group are *Lethrinops albus*, *L. furcifer*, *L. marginatus* and *L. oculatus*, which is tentatively put in synonymy with *L. marginatus*.

The diagnostic features of *Lethrinops* 'sensu stricto' are given below and each group is quantitatively analysed separately to delimit the specific taxonomic category. An artificial key, which can assist in the identification, is provided, followed by the description and information on the distribution of each taxon.

6.2 Diagnosis

This diagnosis applies only to the shallow-water species. At present many deep-water species are also placed in the genus *Lethrinops*. However molecular results indicate that the deep-water species may have to be accommodated in a separate genus (see chapter 7). Oral teeth in the outer row of lower jaw curve inward posteriorly to end just behind the inner row(s). Anterior blade of lower pharyngeal bone not directed downwards and the toothed area ends in one row anteriorly. Teeth bicuspid with tips of the anterior teeth turned forwards.

Melanin pattern variable, consisting of vertical bars in most species. In some taxa, a dark supra-pectoral patch is present with or without a supra-anal and caudal spot. Horizontal melanin pattern when present consist of mid-lateral, dorso-lateral and dorso-medial series of dark spots or the mid-lateral spots curve up to fuse with the dorsal lateral spots. Snout length either shorter than, equal to, or more than the eye diameter. Lower gill raker count 8 to 14.

6.3 Analysis

For the purpose of this analysis *Lethrinops* 'sensu stricto' was divided into 3 working groups.

- The *lethrinus* group, including three species with relatively long snouts and a mix of horizontal and vertical melanin pattern. All three have been formally described but their actual status has always been doubtful.
- Another group including nine taxa with relatively short snout and mouth set low on the profile. Most members have small adult size. Only five have been formally described, four are probably new to science.
- The last group of the shallow water *Lethrinops* 'sensu stricto' is actually ill-defined, members have an intermediate snout and have not been revised since the original descriptions.

Principal Component Analysis was first performed on all members of the long snouted *Lethrinops* sensu stricto group (n=79). Table 6.1 shows the principal component loadings of the log-transformed variables on the first five axes. The premaxillary pedicel length followed by the anal-fin base length, the caudal peduncle depth and the dorsal fin base length mainly defines the second axis. The third axis is mainly defined by the eye diameter. On the X-Y scatter plot of factor scores on the second and third principal axis (Fig. 6.1), *L. lunaris* is situated on the positive part of the second axes with an overlap with the other taxa. When the second axis is now plotted against standard length the overlapping is much reduced (Fig. 6.2).

An analysis was also performed on meristics for all specimens of this group examined (n=60). The first axis is mainly defined by the number of gill rakers, the dorsal soft fin rays and anal soft fin rays. The second axis is mainly defined by number of dorsal spines whereas the third axis defined by number of scales between pectoral and pelvic fins (Table 6.2).

When scores on the first and second axes are plotted against each other, the scatter plot shows there is a clear separation of *L. lunaris* in the positive part of the first axis (Fig.

6.3). A scatter plot of the first axis against standard length clearly shows the separation of *L. lunaris* from the other two taxa (Fig. 6.4).

Following the results of the first analysis on log-transformed measurements, another analysis was performed on measurements excluding *L. lunaris* and analysing only the remaining two taxa (*L. leptodon* and *L. lethrinus*, n=55). This analysis is not informative (Fig. 6.5). When the same analysis is repeated on raw meristics (n = 44), the first axis is mainly defined by the number of teeth in the outer row of the upper and lower jaw, the number of gill rakers, the number of dorsal spines and the number of longitudinal scales (Table 6.3). The second axis is mainly defined by the number of scales between the pectoral and pelvic fins and the number of cheek scales. A plot of the scores of the first and second axes (Fig. 6.6) puts *L. lethrinus* fully on the positive part of the first axis whereas *L. leptodon* is mainly on the negative side of the same axis.
The eventual differences in measurements between *L. leptodon* and *L. lethrinus* was explored further through Mann-Whitney U test on samples of comparable sizes [*L. lethrinus* 111.4 ± 16.5(91.5-143.0) mm SL (n=12) and *L. leptodon* 122.5 ± 13.3 (89.5-143.0) mm SL (n=29)]. The results revealed significant difference in seven characters (Table 6.4). When the same test was performed on meristics, the number of ceratobranchial and total gill raker counts were found to differ significantly between *L. leptodon* and *L. lethrinus*. There was also a significant difference in the dorsal spines and longitudinal scales.

Table 6.4: Synopsis of the significant differences in measurements and meristics between *L. lethrinus* and *L. leptodon* of similar size distribution [*L. lethrinus* 111.4 ± 16.5 (91.5-143.0) mm SL (n=12) and L. *leptodon* 122.5 ± 13.3 (89.5-143.0) mm SL (n=29)]. In the third column is stated which species has the larger value for each of the characters.

Head length %SL	P < 0.01	*L. lethrinus* > *L. leptodon*
Prepectoral distance %SL	P < 0.01	*L. lethrinus* > *L. leptodon*
Pre-ventral distance %SL	P < 0.01	*L. lethrinus* > *L. leptodon*
Cheek depth %HL	P < 0.01	*L. lethrinus* < *L. leptodon*
Dorsal fin base %SL	P < 0.05	*L. lethrinus* < *L. leptodon*
Anal fin base %SL	P < 0.05	*L. lethrinus* < *L. leptodon*
Predorsal distance % SL	P < 0.05	*L. lethrinus* > *L. leptodon*
GRLOW	P < 0.0001	*L. lethrinus* < *L. leptodon*
GRTOTAL	P < 0.0001	*L. lethrinus* < *L. leptodon*
DSPINES	P < 0.0001	*L. lethrinus* < *L. leptodon*
Teeth Upper	P < 0.001	*L. lethrinus* < *L. leptodon*
Teeth lower	P < 0.001	*L. lethrinus* < *L. leptodon*
LONG scales	P < 0.001	*L. lethrinus* < *L. leptodon*

A Principal Component Analysis was performed on all the nine taxa of the shallow water *Lethrinops* with a short snout and small mouth set low on the profile (n=126). The results of the factor scores show that the second axis is mainly defined by the caudal peduncle length, followed by premaxillary pedicel length, anal fin base length and dorsal fin base length (Table: 6.5). The third axis is mainly defined by the eye diameter. On the X-Y scatter plot of factor scores on second and third principal axes, *L.* sp. 'turneri', *L.* sp. 'domira blotch', *L.* sp. 'parvidens deep' and *L. macrophthalmus* are mainly situated on the positive part of the second axis where as *L. auritus* and *L.* sp. 'black dorsal auritus' are mainly on the negative part of the same axis. *Lethrinops macrochir*, *L. auritus* and *L.* sp. 'turneri' are on the positive side of the third axis while *L.* sp. 'black dorsal auritus' and *L. macrophthalmus* are completely on the negative side of the third axis (Fig. 6.7). When the respective axes are plotted against standard length, the indication of separation becomes evident such as for example between *L.* sp 'tuneri', *L. macrophthalmus* and *L.* sp. 'domira blotch' versus *L. auritus* and *L.* sp. 'black dorsal auritus' on the second axis (Fig. 6.8) and *L. macrophthalmus* and *L.* sp. 'black dorsal auritus' versus *L.* sp. 'turneri', *L.* sp. 'domira blotch and *L. auritus* on the third axis (Fig.6.9). A similar analysis on meristics for all the nine taxa (n=116) is less informative (Fig. 6.10). However, one can observe *L.* parvidens, *L.* sp. 'parvidens deep' and *L.* sp. domira blotch' in the right lower corner. A scatter plot of gill rakers versus standard length (Fig. 6.11) better illustrates this. The two subgroups were then analysed separately.

Principal Component Analysis was first performed on all specimens (n=95) of the short snouted *Lethrinops* with a relatively high number of gill rakers. The second axis is mainly defined by caudal peduncle length, premaxillary pedicel length and dorsal fin base length and the third axis by caudal peduncle length and eye diameter (Table 6.6). Again *L.* sp. 'turneri', *L. microstoma* and *L. macrophthalmus* are separated mainly on the positive part of the second axis while *L. auritus* and *L.* sp. 'black dorsal auritus' are all on the negative part of the same axis. *Lethrinops auritus* and *L.* sp. 'turneri' are mainly on the positive part of the third axis and separate from *L.* sp. 'black dorsal auritus' and *L. macrophthalmus* which are situated fully on the negative part of the third axis (Fig. 6.12).

A further Principal Component Analysis, excluding *L. macrophthalmus* separates *L.* sp. 'black dorsal auritus' and *L. microstoma* from the other taxa on the negative part of the third axis (Fig. 6.13) and these are separated from each other by the second axis. *Lethrinops* sp. 'turneri' is fully on the positive part of the second axis and when the scores of this axis are plotted against standard length the separation becomes clearer (Fig. 6.14). The second axis is defined mainly by premaxillary pedicel length, dorsal fin base length, caudal peduncle length, anal fin base length and lower jaw length, while the third axis is mainly defined by body depth and pre-ventral distance (Table 6.7).

A Principal Component Analysis was then performed on the log-transformed measurements and the raw meristics of *L. microstoma* and *L.* sp. 'black dorsal auritus' in order to further separate these two taxa. The analysis of the measurement was less informative than the meristics, which clearly differentiated the two species (Fig. 6.15).

Table 6.8 below shows the synopsis of the characters that can be used to distinguish between *L.* sp. 'black dorsal auritus' and *L. microstoma.*

Table 6.8: Synopsis of the distinctive characters (measurements and meristics) for *L. microstoma* and *L.* sp. 'black dorsal auritus'.

Character	*L. microstoma* (n=14)	*L.* sp. 'black dorsal auritus' (n=7)
PV	5-8	3
TRANSUP	4-6	3-4
CHEEK	3	2
ED % HL	32.9-37.8	38.0-41.6 (n=7)

Further elaboration by Mann –Whitney U test to test for significant differences could not be done because the samples were not of a similar size class.

A Principal Component Analysis was performed on the remaining species with the high number of gill rakers, *L. auritus* and *L. macrochir*. Results of principal component analysis on the log-transformed measurements were not informative, but PCA on the meristics completely separated the two species on the first axis. Since the two species have a large difference in standard length, a plot of the first axis on standard length is more realistic (Fig. 6.16). Table 6.9 show characters that mainly defines the first axis and many of these are size related.

A further analysis by Mann-Whitney U tests could not be performed because of the lack of similar size classes.

Another Principal Component Analysis was performed on the three taxa with a low number of gill rakers, *L. parvidens*, *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch' (n=33). On an X-Y plot of second and third axes, *L.* sp. 'domira blotch' is situated on the far positive side of the second axis (Fig. 6.17). Eye diameter, caudal peduncle length, anal fin base length and premaxillary pedicel length define this axis (Table 6.10). The separation becomes clearer if the second axis is plotted against standard length (Fig: 6.18). PCA results for the raw meristics are given on Table 6.11. When scores of the first axis are plotted against the second axis, *L.* sp. 'parvidens deep' is mainly on the positive side of the first axis while *L. parvidens* and *L.* sp. 'domira blotch' are on the negative part of the same axis (Fig. 6.19). Figure 6.20 is a re-plot of the first axis against standard length since meristics defining the first axis can be strongly influenced by size.

A PCA of specimens of *L. parvidens* and *L.* sp. 'parvidens deep' on measurements was not informative. A similar analysis on raw meristics produced results which are suspected to give a strong allometric influence (Fig. 6.21 & Fig. 6.22).

Lethrinops parvidens and *L.* sp. 'parvidens deep' fail to separate on either measurements or meristics.

The last group to analyse is the group with the intermediate snouts and fine teeth on the lower pharyngeal jaw. This is the group of *L. furcifer*, *L. albus*, *L. marginatus* and *L. oculatus*.

The results of the Principal Component Analysis (n=73) show that the second principal axis is mainly defined by eye diameter, lower jaw length and anal fin base length, the third axis is defined by premaxillary pedicel length, cheek depth and caudal peduncle length (Table 6.12). On an X-Y scatter plot of factor scores on the second axis versus the standard length, *L. furcifer* separate from the others (Fig. 6.23) and on the third axis versus standard length, *L. albus* separates from *L. marginatus* and *L. oculatus* (Fig. 6.24). *Lethrinops oculatus* clusters better with *L. marginatus* than with *L. albus*, therefore a final PCA of *L. marginatus* with *L. albus* was carried out. The results were not informative, but *L. oculatus* was still found to cluster with *L. marginatus*.

Table 6.1: Principal component loadings of the log-transformed variables on the first five axes of specimens of *L. lunaris, L. lethrinus* and *L. leptodon* (n = 79).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.96871	-.122719	-.104705	-.052423	.126762
LOGSNL	.97189	-.129761	-.127731	.003699	.052711
LOGLJL	.96365	-.068400	.032405	.140389	-.009460
LOGPPL	.87776	-.410033	-.011264	-.174818	-.112301
LOGCHD	.97015	-.045923	-.082077	-.077980	.135734
LOGED	.91261	-.166692	.354269	.039554	.082005
LOGIOW	.96458	.101047	-.041221	.090719	-.118835
LOGHW	.97417	.041903	-.059377	.123622	.022330
LOGHL	.98684	-.122024	-.026832	.054790	-.027415
LOGSL	.98909	.100318	.031138	-.068851	-.015827
LOGBD	.97417	.124924	-.027422	.102406	.018641
LOGDFB	.97243	.196791	.021480	-.068795	.014623
LOGAFB	.93327	.267702	.070409	-.138757	.016925
LOGPRD	.98555	-.088578	-.038672	.020357	.024272
LOGPRP	.98059	-.114266	.009080	.058922	-.071070
LOGPRV	.98305	-.041163	-.004082	.071401	-.042452
LOGPRA	.98791	.066945	.021904	-.057389	.000813
LOGCPL	.94920	.144962	.015159	-.090704	-.133012
LOGCPD	.95862	.233226	-.009242	.002498	.028690
Expl.Var	17.64845	.500003	.176174	.146917	.099125
Prp.Totl	.92887	.026316	.009272	.007732	.005217

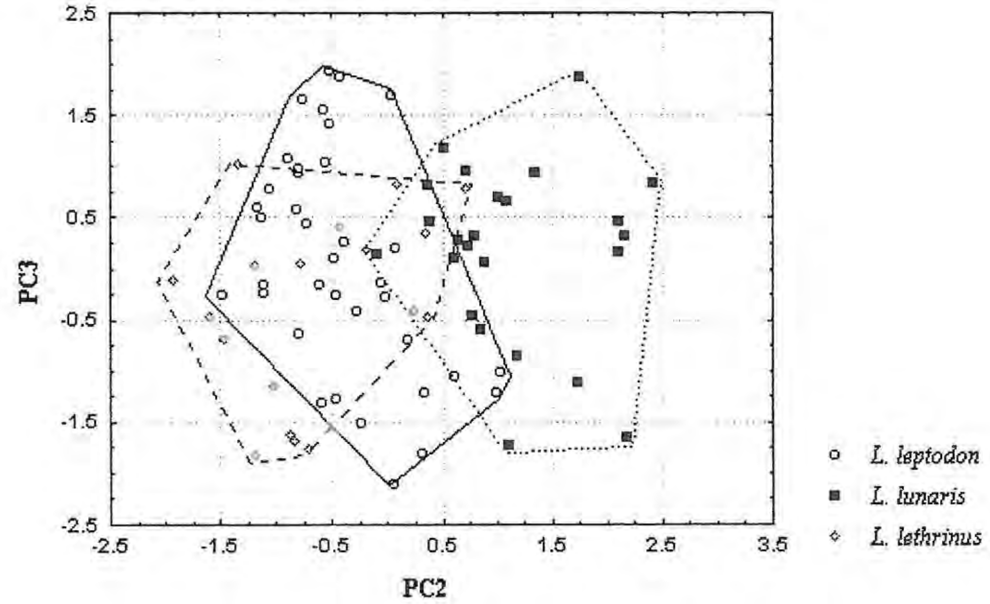


Fig. 6.1: Scatterplot of scores on the second and third axis of PCA of log-transformed measurements for specimens of *L. lunaris, L. lethrinus* and *L. leptodon* (n = 79).

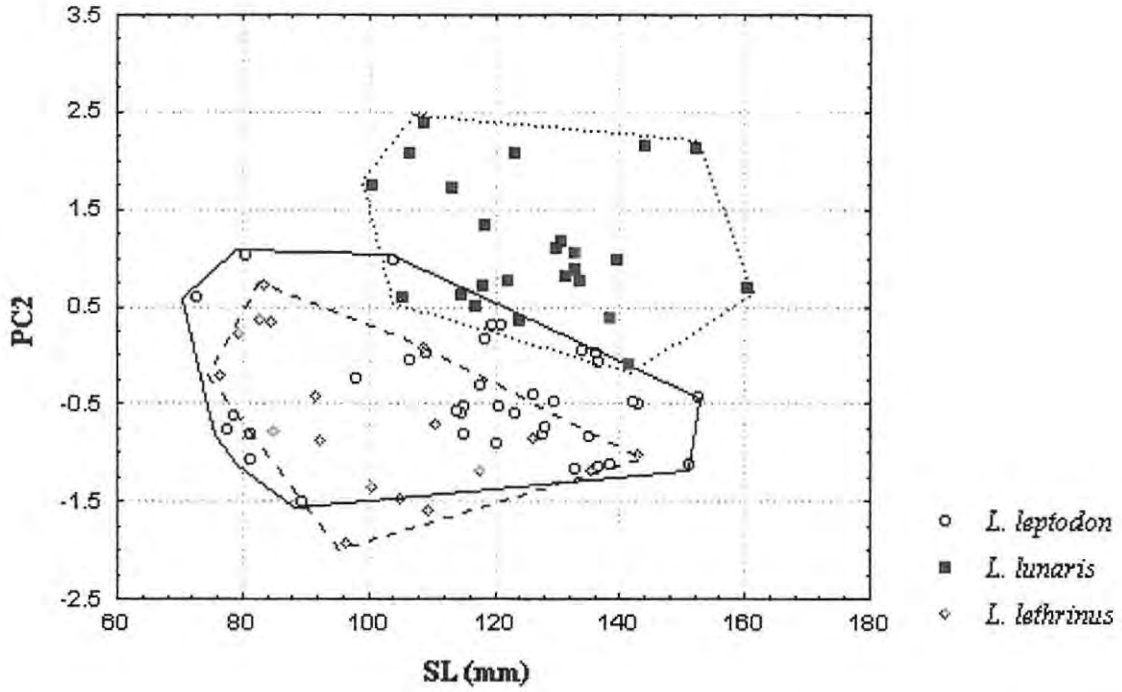


Fig. 6.2: Scatterplot of scores on the second axis against standard length for specimens of *L. lunaris*, *L. lethrinus* and *L. leptodon* (n = 79).

Table 6.2: Principal component loadings of untransformed meristics on the first five axes of examined specimens of *L. lunaris*, *L. lethrinus* and *L. leptodon* (n=60).

VARIABLE	PC1	PC2	PC3	PC4	PC5
UPPER	.328377	-.490565	-.466745	.466949	-.112887
LOWER	.623780	-.533569	-.234322	.224490	-.111627
ROWSUP	-.667028	-.528826	.013910	.180920	.062080
ROWSLOW	-.692004	-.495146	-.085031	.060122	.027041
GRLOW	.854103	-.053651	-.058067	.037919	.027607
GRTOTAL	.857865	-.064685	-.126501	.003703	.081118
DSPINES	.143988	-.700854	.111469	-.154335	.359081
DSOFT	.805107	.453269	-.048670	.110348	-.053626
ASOFT	.743870	.197793	-.170719	-.193497	.184170
PECTORAL	.081430	.029374	-.013569	.669876	-.539549
LATUP	.111545	-.443734	-.142180	-.327064	-.340434
LATLOW	.304891	-.331814	.291629	-.361150	-.341069
LONG	.492186	-.449237	-.060766	-.371871	.079412
TRANSUP	-.314344	.191790	-.547682	-.090608	.278357
TRANSLOW	.211059	-.117357	.080558	.497127	.663226
PV	-.155305	.038624	-.841201	-.211560	-.042646
CHEEK	-.298108	.170615	-.658369	-.065360	-.053124
Expl.Var	4.719050	2.383845	1.900149	1.508469	1.254500
Prp.Totl	.277591	.140226	.111773	.088733	.073794

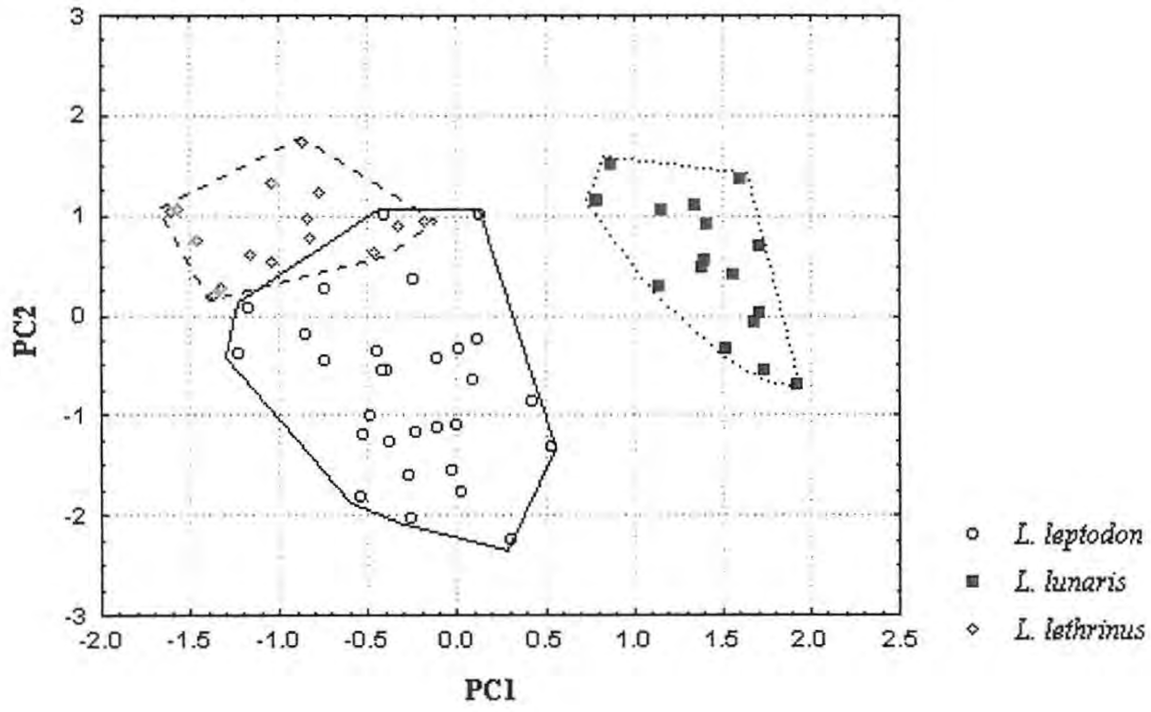


Fig. 6.3: Scatterplot of scores on the first and second axis of a PCA of the raw meristics of specimens of *L. lunaris*, *L. lethrinus* and *L. leptodon* (n=60).

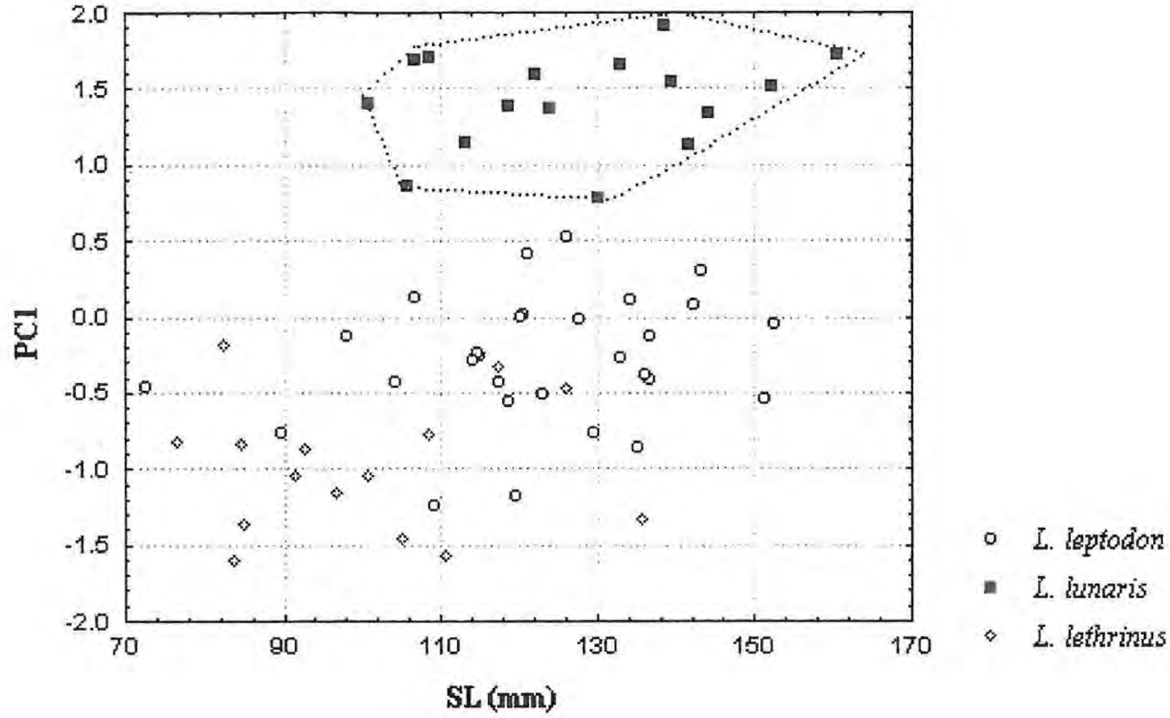


Fig. 6.4: Scatterplot of scores on the first axis of a PCA of raw meristics against standard length for specimens of *L. lethrinus*, *L. leptodon* and *L. lunaris* (n = 60).

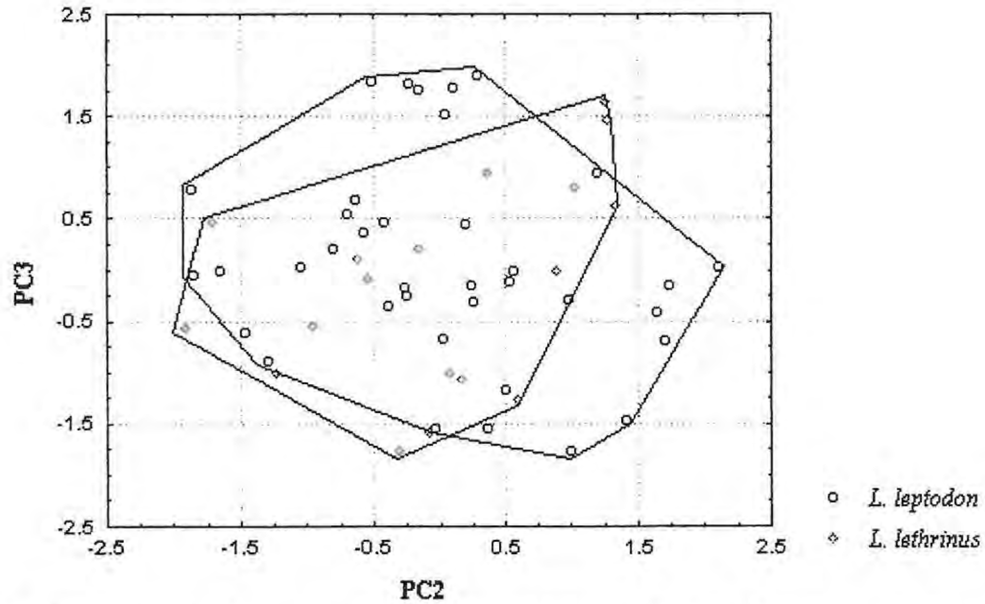


Fig. 6.5: Scatterplot of scores on the second and third axis of a PCA of log-transformed measurements for specimens of *L. lethrinus* and *L. leptodon* (n = 55).

Table 6.3: Principal component loadings of the raw meristics on the first five axes of specimens of *L. lethrinus* and *L. leptodon* (n = 44).

VARIABLE	PC1	PC2	PC3	PC4	PC5
UPPER	-.606341	-.208488	-.479429	-.133740	-.278982
LOWER	-.809947	-.223832	-.138534	-.268618	-.205247
ROWSUP	-.448474	-.404248	-.317877	-.008800	.179433
ROWSLOW	-.537647	-.080616	-.326666	.157514	.276166
GRLOW	-.726011	.180072	.083522	.460483	-.102193
GRTOTAL	-.768439	.289041	.095982	.410142	-.019707
DSPINES	-.703285	-.056960	.340469	-.005441	.392466
DSOFT	.186331	.079432	.186135	.485430	-.720309
ASOFT	-.196451	.442499	.323214	.165806	-.216751
PECTORAL	.018362	-.301024	-.554228	.167255	-.510695
LATUP	-.248608	.263975	-.152438	-.781672	-.259582
LATLOW	-.329095	-.006748	.414131	-.274319	-.091293
LONG	-.613644	.289546	.291177	-.189093	-.149576
TRANSUP	.155334	.578733	-.237828	.040037	.199932
TRANSLOW	-.170748	-.263631	-.164704	.415514	.271931
PV	-.130185	.777409	-.284256	-.117315	.026543
CHEEK	.103936	.629979	-.571298	.150148	.131921
Expl.Var	3.827411	2.234666	1.805588	1.718910	1.450033
Prp.Totl	.225142	.131451	.106211	.101112	.085296

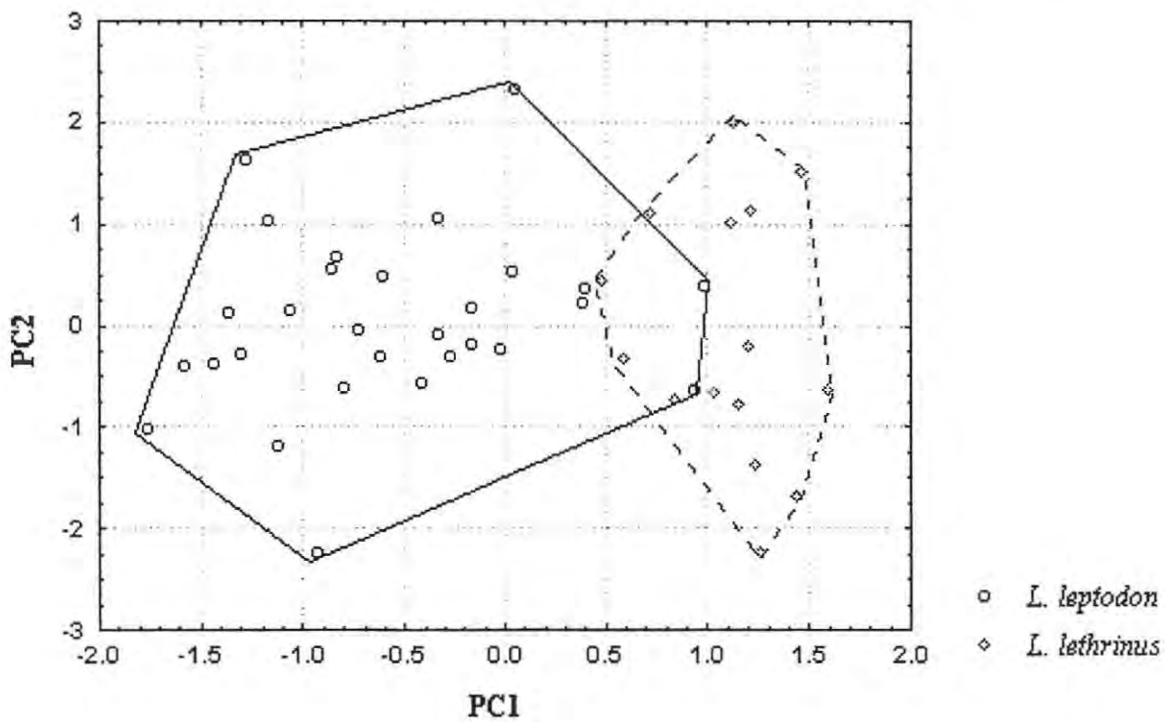


Fig. 6.6: Scatterplot of scores on the first and second axis of a PCA of raw meristics of specimens of *L. lethrinus* and *L. leptodon* (n = 44).

Table 6.5: Principal component loadings of the log-transformed measurements on the first five axes; all taxa of the short-snouted shallow-water *Lethrinops* 'sensu stricto'(n = 128).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.98023	-.040892	.026310	.119566	-.006045
LOGSNL	.97541	-.088094	.061450	.134214	-.006868
LOGLJL	.97355	-.098118	-.045891	-.100863	.028984
LOGPPL	.94619	-.245780	.039299	-.052854	-.146364
LOGCHD	.97867	-.060691	.101542	-.005366	-.000958
LOGED	.95741	-.130132	-.211859	-.041908	.104165
LOGIOW	.97609	-.009791	.055308	-.029984	-.034719
LOGHW	.98345	.019942	-.018387	-.071140	.001537
LOGHL	.99295	-.072821	-.015395	.022534	.016749
LOGSL	.99223	.095394	-.026423	.034803	.014360
LOGBD	.97430	.080383	.109867	-.138559	-.012595
LOGDFB	.98005	.160513	.015890	-.001761	.021871
LOGAFB	.96592	.166334	.084729	.006644	.034315
LOGPRD	.98599	-.084123	.003643	.028550	.004214
LOGPRP	.98963	-.057712	-.024902	.010851	-.007759
LOGPRV	.98544	.008077	-.045662	.073795	-.000696
LOGPRA	.98980	.055784	-.016211	.036562	.030833
LOGCPL	.94199	.236806	-.153238	.000972	-.161548
LOGCPD	.97638	.064726	.054090	-.031361	.111802
Expl.Var	18.10593	.248726	.116537	.082686	.076333
Prp.Totl	.95294	.013091	.006134	.004352	.004018

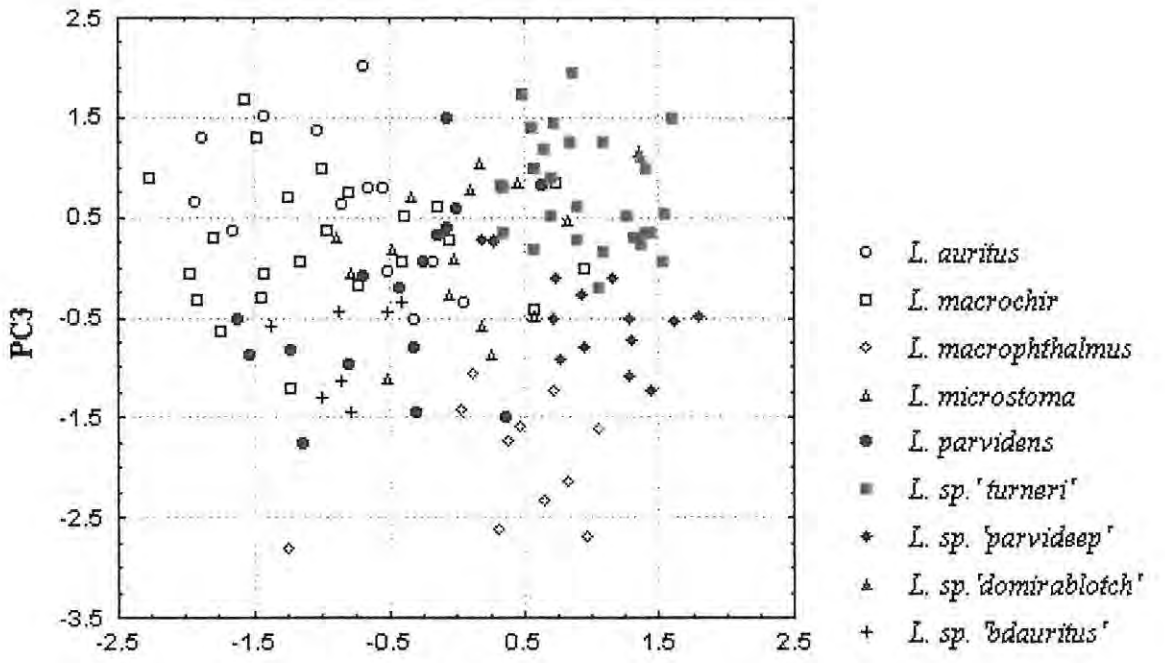


Fig. 6.7: Scatterplot of factor scores on the second and third axis of PCA of log-transformed measurements for all taxa of the short-snouted shallow-water *Lethrinops* s. s (n = 128).

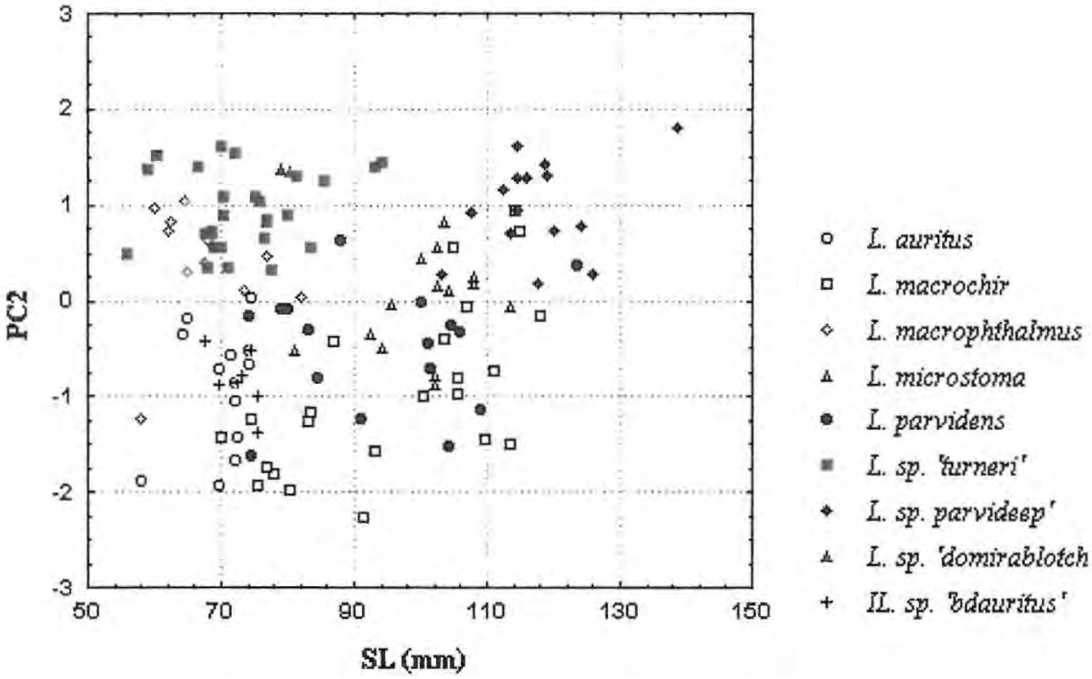


Fig. 6.8: Scatterplot of scores on the second axis of a PCA of log-transformed measurements against standard length for all members of the short-snouted shallow-water *Lethrinops* (n = 128).

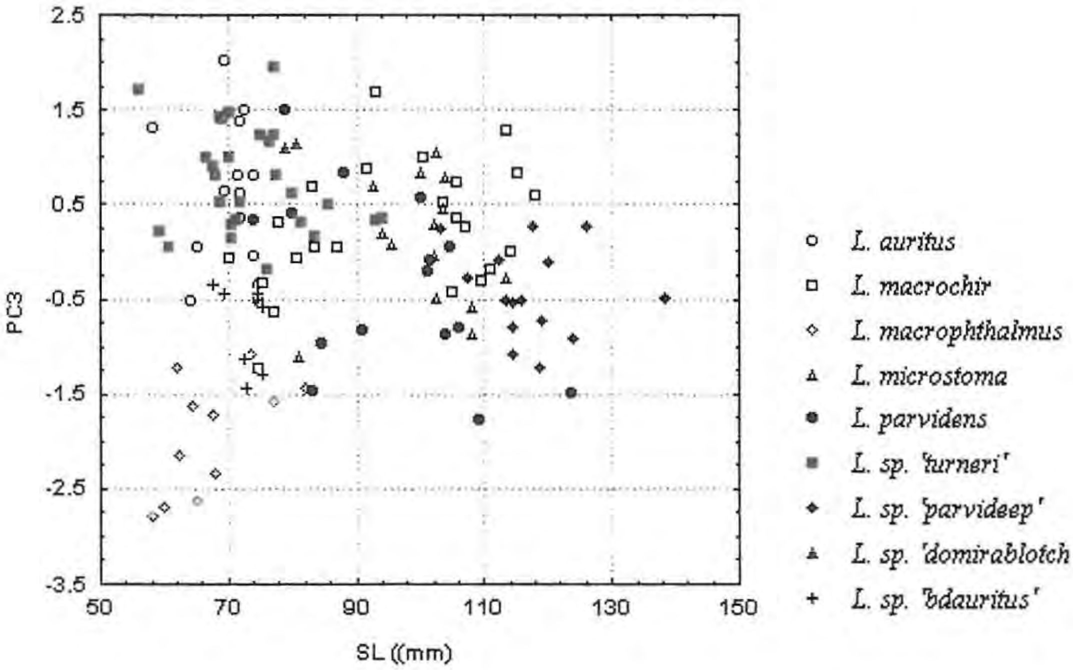


Figure 6.9: Scatterplot of scores on the third axis of a PCA of log-transformed measurements against standard length for all members of the short-snouted shallow-water *Lethrinops* (n = 128).

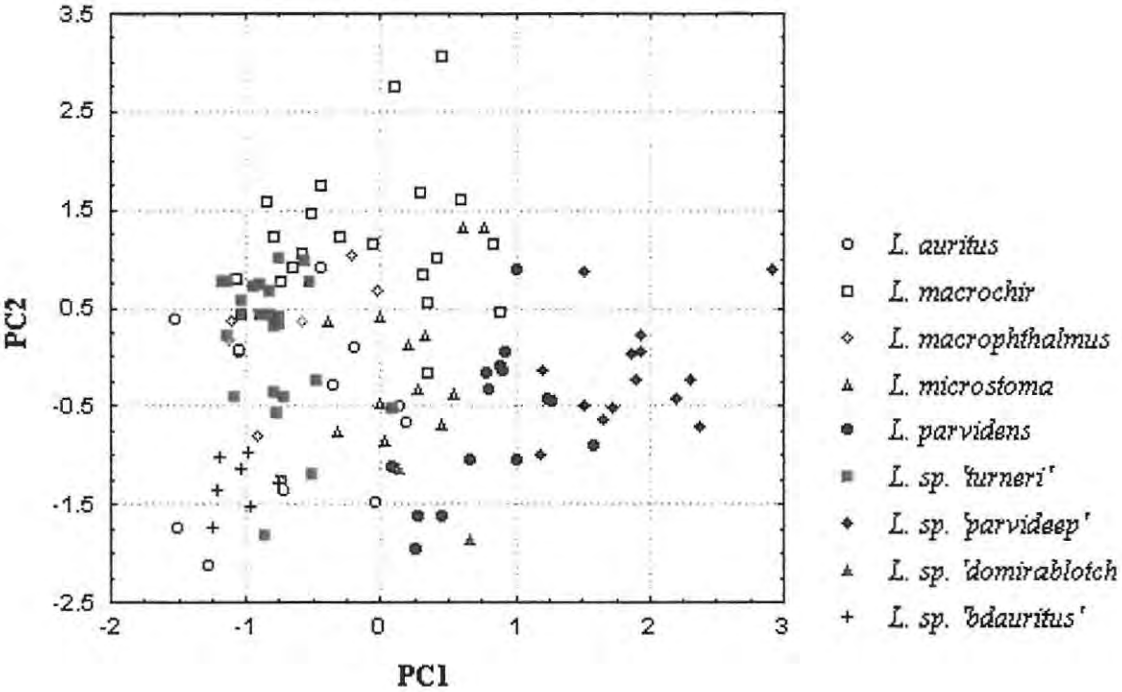


Fig. 6.10: Scatterplot of scores on the first and second axis of a PCA of raw meristics for all taxa of the short-snouted shallow-water *Lethrinops* s.s

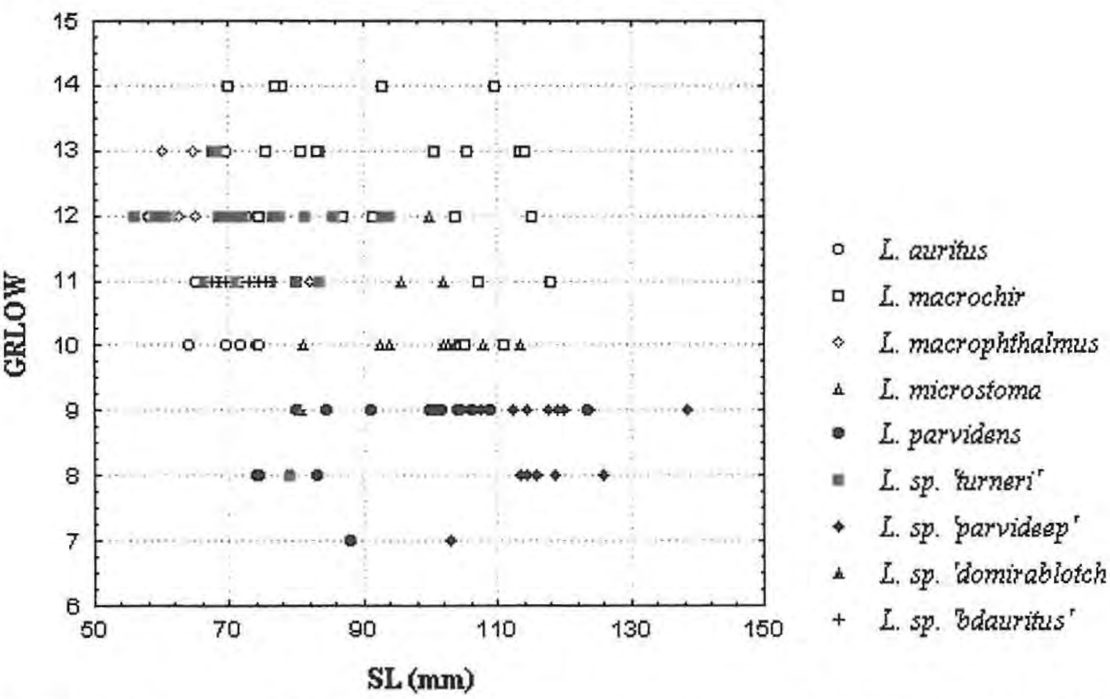


Fig. 6.11: Scatterplot of the number of ceratobranchial gill rakers against standard length for all taxa of the short-snouted shallow-water *Lethrinops* s.s

Table 6.6: Principal component loadings of the log-transformed variables on the first five axes; specimens of the short- snouted shallow-water *Lethrinops* with a relatively high number of gill rakers (n = 95).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.98097	-.032175	-.011235	-.072439	.062370
LOGSNL	.96975	-.133577	.034655	-.115221	.032408
LOGLJL	.96453	-.152050	.014982	.147469	.036440
LOGPPL	.95639	-.207890	-.020520	.055524	-.087964
LOGCHD	.97438	-.073855	.125640	.057267	.053873
LOGED	.95207	-.139508	-.201436	-.001325	-.062876
LOGIOW	.97393	.029479	.063087	-.005810	.092159
LOGHW	.97649	.018256	-.005386	.113230	.078015
LOGHL	.99059	-.092861	-.009503	-.019892	.023571
LOGSL	.99109	.100648	-.034863	-.045281	.000880
LOGBD	.96790	.114331	.138471	.112804	-.086171
LOGDFB	.97361	.197097	.010370	-.033392	-.030391
LOGAFB	.96129	.158051	.113507	-.060866	.037522
LOGPRD	.98328	-.092653	.020203	-.042665	.037491
LOGPRP	.98798	-.064141	-.034434	-.004687	-.020528
LOGPRV	.97925	.006659	-.072149	-.104754	-.020881
LOGPRA	.98659	.068581	-.029910	-.060754	-.031685
LOGCPL	.92871	.251787	-.216764	.101582	.034598
LOGCPD	.97378	.050348	.104870	-.011103	-.150445
Expl.Var	17.96403	.290364	.161493	.106429	.072852
Prp.Totl	.94548	.015282	.008500	.005602	.003834

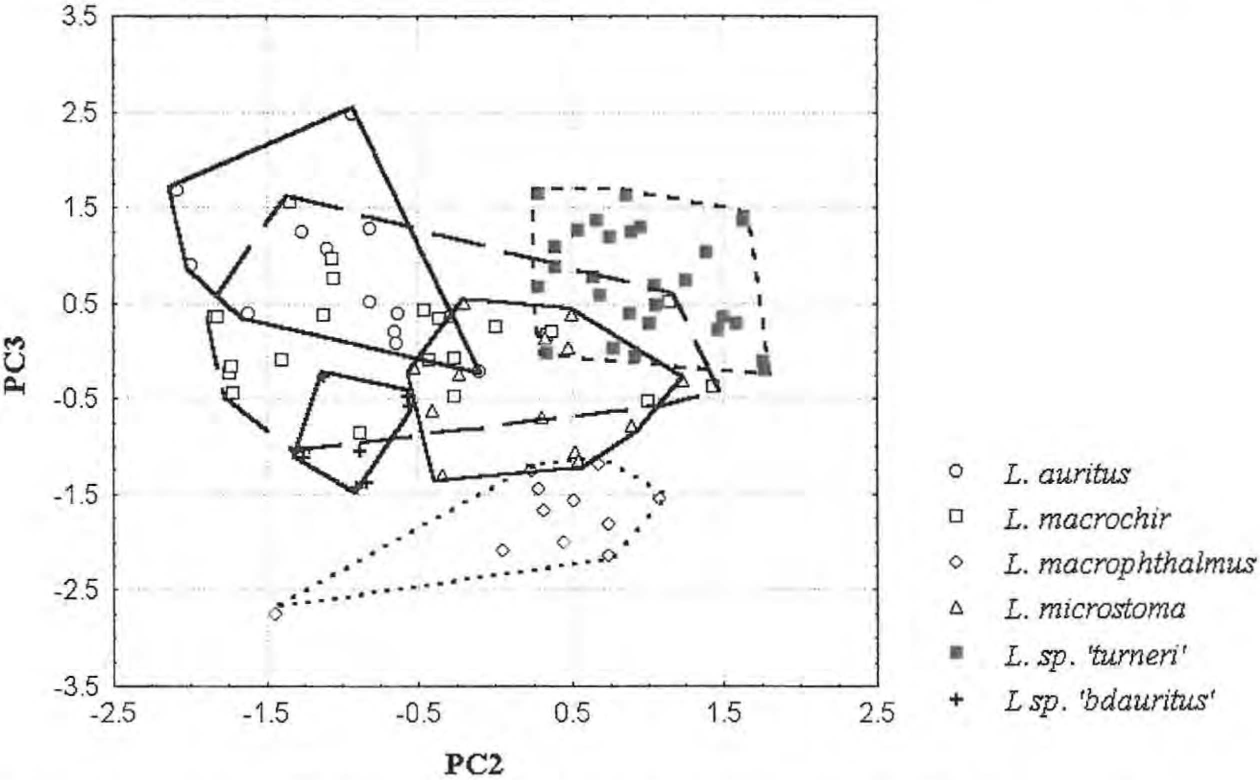


Fig. 6.12: Scatterplot of factor scores on the second and third axis of a PCA of log-transformed variables for specimens of the short- snouted shallow-water *Lethrinops* with a relatively high number of gill rakers (n = 95).

Table 6.7: Principal component loadings of log-transformed measurements on the first five axes; *L. auritus*, *L. macrochir*, *L. microstoma*, *L.* sp. 'turner' and *L.* sp. 'black dorsal auritus' (n = 84).

VARIABLE	PC1	PC	PC3	PC4	PC5
LOGLACRD	.97822	-.030716	-.078237	.062095	.005704
LOGSNL	.97375	-.117561	-.069794	.033530	.032056
LOGLJL	.96007	-.168393	.132254	.039830	.034119
LOGPPL	.95146	-.228579	.040268	-.087011	.096066
LOGCHD	.97561	-.086276	.110921	.054240	.044114
LOGED	.95868	-.158776	-.100812	-.069558	-.119872
LOGIOW	.97359	.042304	.018013	.092830	-.040716
LOGHW	.97819	.005831	.104808	.083988	-.046646
LOGHL	.98998	-.099906	-.022557	.019216	-.033284
LOGSL	.99029	.106845	-.058774	-.001875	.007056
LOGBD	.96304	.135189	.189108	-.086244	-.005635
LOGDFB	.96987	.216004	-.015664	-.027363	-.019216
LOGAFB	.96031	.187336	.016417	.088436	-.085298
LOGPRD	.98159	-.098005	-.037721	.043273	.008098
LOGPRP	.98703	-.070375	-.019020	-.025677	-.020222
LOGPRV	.97685	.005496	-.142252	-.030662	.026707
LOGPRA	.98484	.078752	-.064949	-.038912	-.006845
LOGCPL	.94986	.214433	-.051243	.007024	.179225
LOGCPD	.97193	.067635	.054342	-.160136	-.050869
Expl.Var	17.96755	.322617	.135938	.084649	.076380
Prp.Totl	.94566	.016980	.007155	.004455	.004020

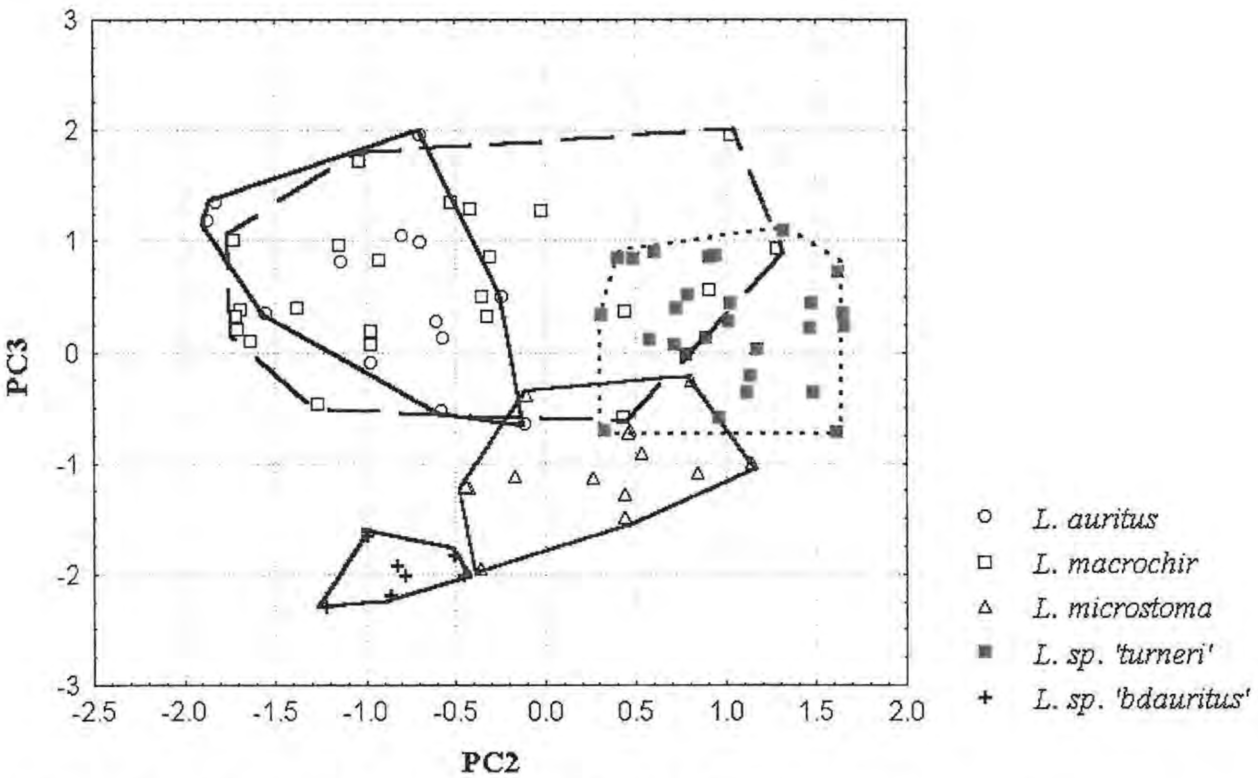


Fig. 6.13: Scatterplot of factor scores on the second and third axis of a PCA of log-transformed measurements; *L. auritus*, *L. macrochir*, *L. microstoma*, *L.* sp. 'turner' and *L.* sp. 'black dorsal auritus' (n = 84).

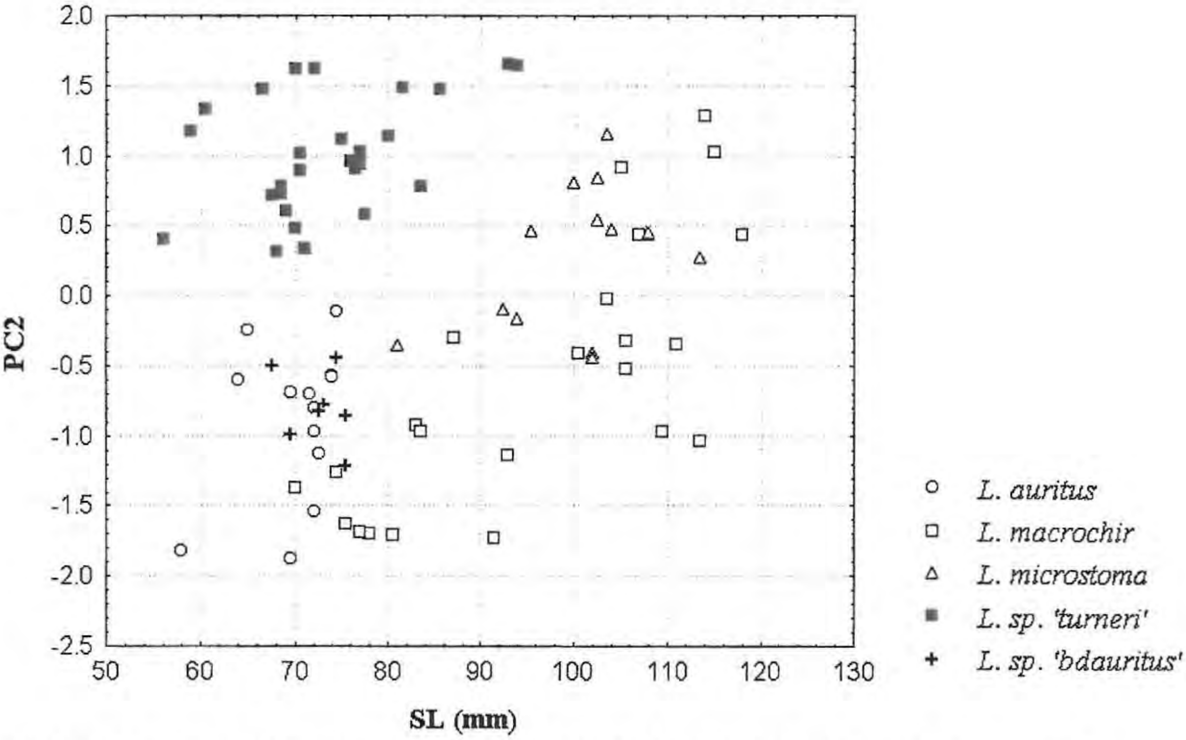


Fig. 6.14: Scatterplot of factor scores on the second axis of a PCA of log-transformed measurements against standard length of *L. auritus*, *L. macrochir*, *L. microstoma*, *L.* sp. 'turneri' and *L.* sp. 'bdauritus' (n = 84).

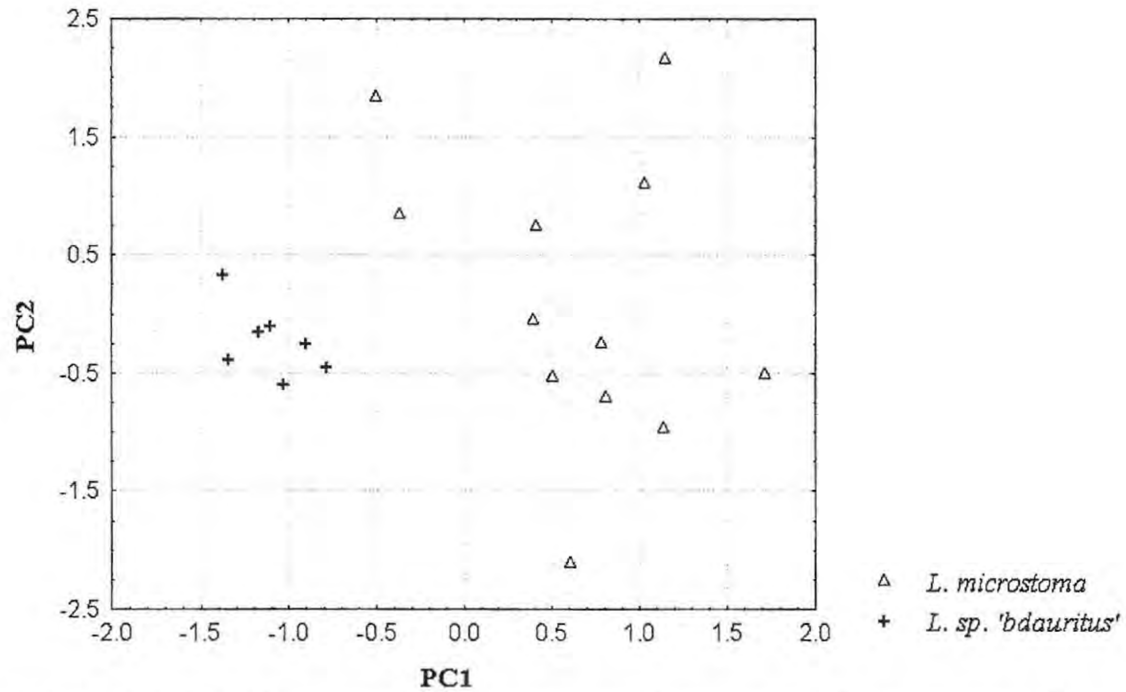


Fig. 6.15: Scatterplot of factor scores on the first and second axis of a PCA of the raw meristics for specimens of *L. microstoma* and *L.* sp. 'black dorsal auritus'.

Table 6.9: Principal component loadings of untransformed meristics on the first five axes for specimens of *L. auritus* and *L. macrochir* (n = 33).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOWER	.622247	.054534	.337831	-.026346	.466354
ROWSUP	.577973	.540119	-.110271	.459204	-.060994
ROWSLOW	.536456	.432301	-.365218	.417519	-.120457
GRLOW	.500375	.447953	.532451	-.395002	-.137075
GRTOTAL	.500595	.470161	.460060	-.435589	-.175045
DSPINES	.670970	.301479	-.061520	.379680	.117116
DSOFT	.099866	-.385369	.369125	.366723	-.561589
ASOFT	-.068338	-.382287	.628479	.432785	.333232
PECTORAL	.216489	-.015798	.724033	.391203	.067199
LATUP	.601909	-.279330	-.508759	-.065862	-.249955
LATLOW	.682112	-.018265	-.310168	-.103114	.018110
LONG	.628858	-.392157	-.194705	.196211	-.201124
TRANSUP	.605439	-.399025	.172364	-.307784	.079547
TRANSLOW	.559668	-.291299	.326730	-.161666	-.502327
PV	.031582	-.805890	-.007314	.042527	-.046625
CHEEK	.694313	-.094075	-.161855	-.089812	.317549
Expl.Var	4.771556	2.673283	2.392514	1.552147	1.340299
Prp.Totl	.280680	.157252	.140736	.091303	.078841

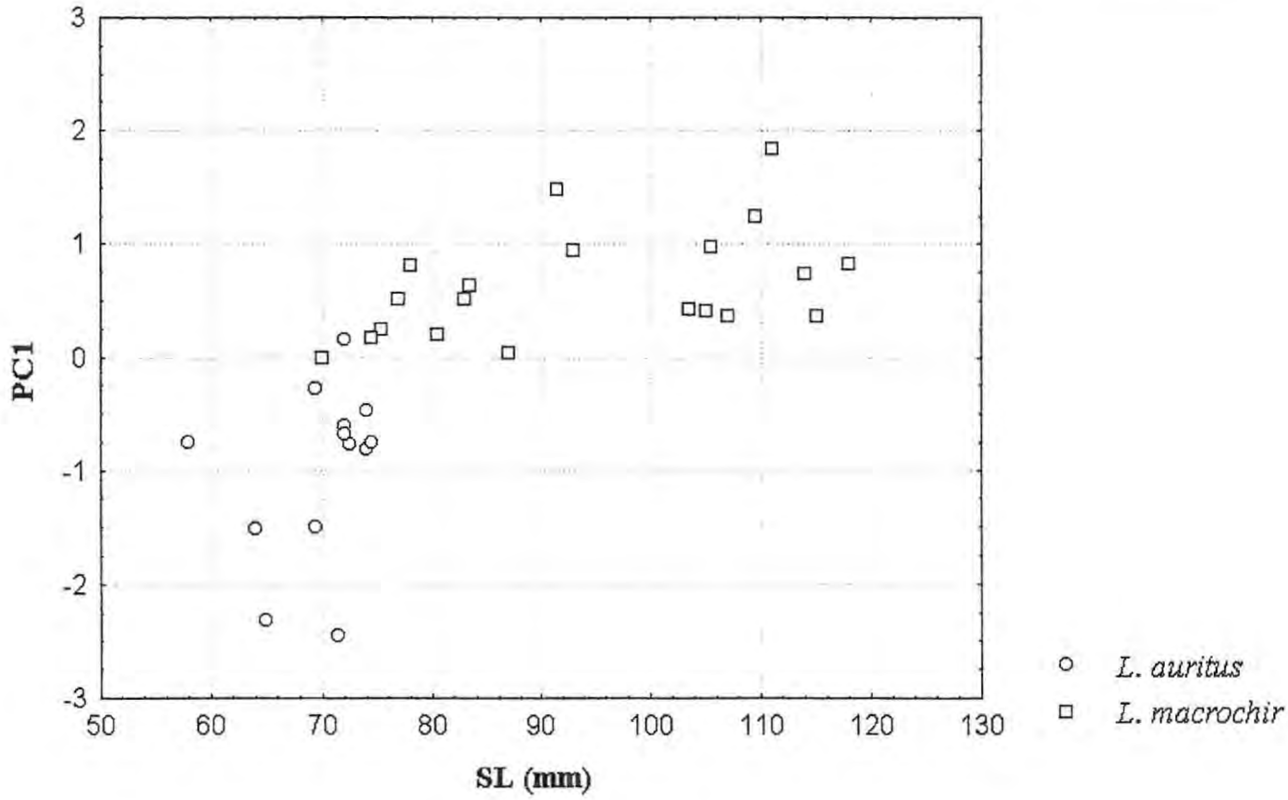


Fig. 6.16: Scatterplot of factor scores on the second axis of a PCA of the raw meristics against standard length for specimens of *L. auritus* and *L. macrochir*.

Table 6.10: Principal component loadings of the log-transformed variables on the first five axes; *L. parvidens*, *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch' (n = 33).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.95594	.017269	.234439	-.105083	.085765
LOGSNL	.97024	.121370	.164548	-.034452	-.000450
LOGLJL	.97490	-.114780	-.045712	-.000726	-.015738
LOGPPL	.93015	-.240725	.093454	.156496	.179267
LOGCHD	.97207	.005132	.070101	-.162632	-.012874
LOGED	.91905	-.334873	-.143774	-.058575	-.066076
LOGIOW	.96621	-.102864	.062399	.100997	-.060173
LOGHW	.98827	-.005676	-.063229	.052147	.006585
LOGHL	.99194	-.063841	.029268	.000138	-.034833
LOGSL	.98954	.091805	-.059646	-.023706	.001937
LOGBD	.97932	.043333	-.061916	.099023	.024015
LOGDFB	.97827	.120509	-.091264	-.004478	.088741
LOGAFB	.94291	.242265	-.095437	.114133	.058036
LOGPRD	.97892	-.119266	.036176	.041399	-.082995
LOGPRP	.98386	-.027990	.038865	-.013046	-.091310
LOGPRV	.98992	.007674	-.018223	-.010186	-.040796
LOGPRA	.98917	.029954	-.045393	-.097489	.022908
LOGCPL	.93795	.251726	.047452	.091524	-.137948
LOGCPD	.95874	.066747	-.151508	-.137767	.081044
Expl.Var	17.82248	.380313	.182441	.141783	.103986
Prp.Totl	.93803	.020016	.009602	.007462	.005473

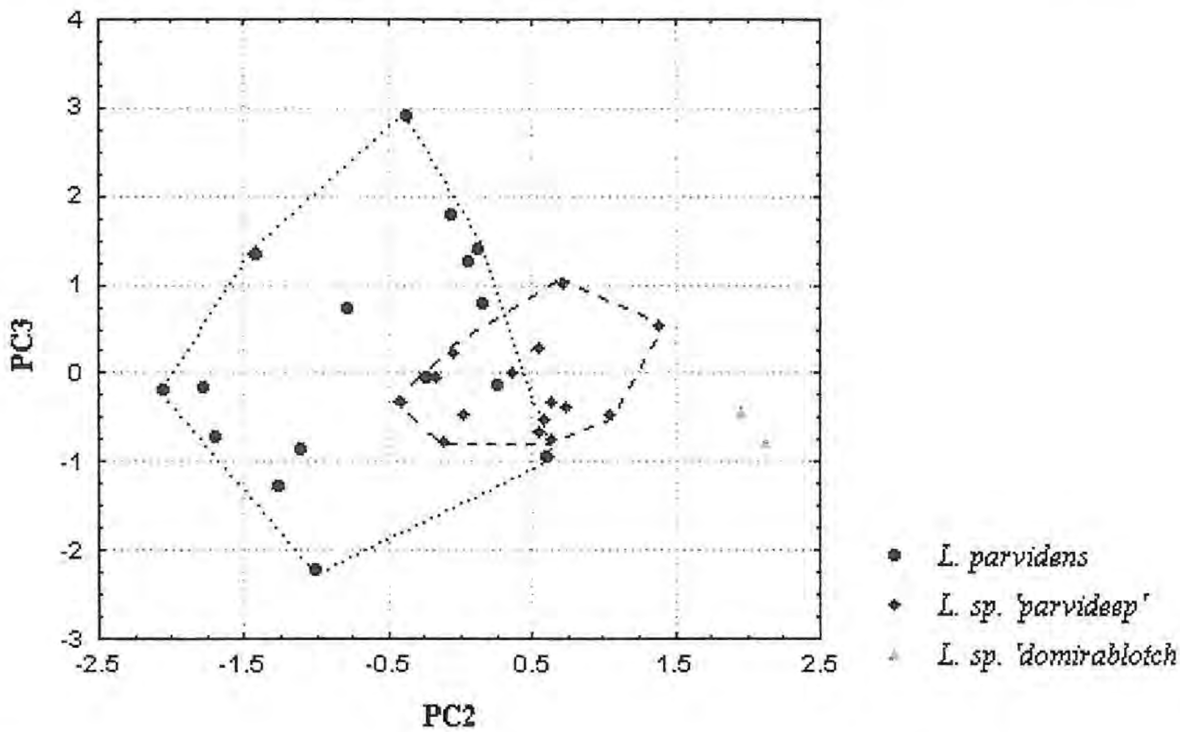


Fig. 6.17: Scatterplot of factor scores on the second and third axis of PCA of log-transformed measurements for specimens of *L. parvidens*, *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch'.

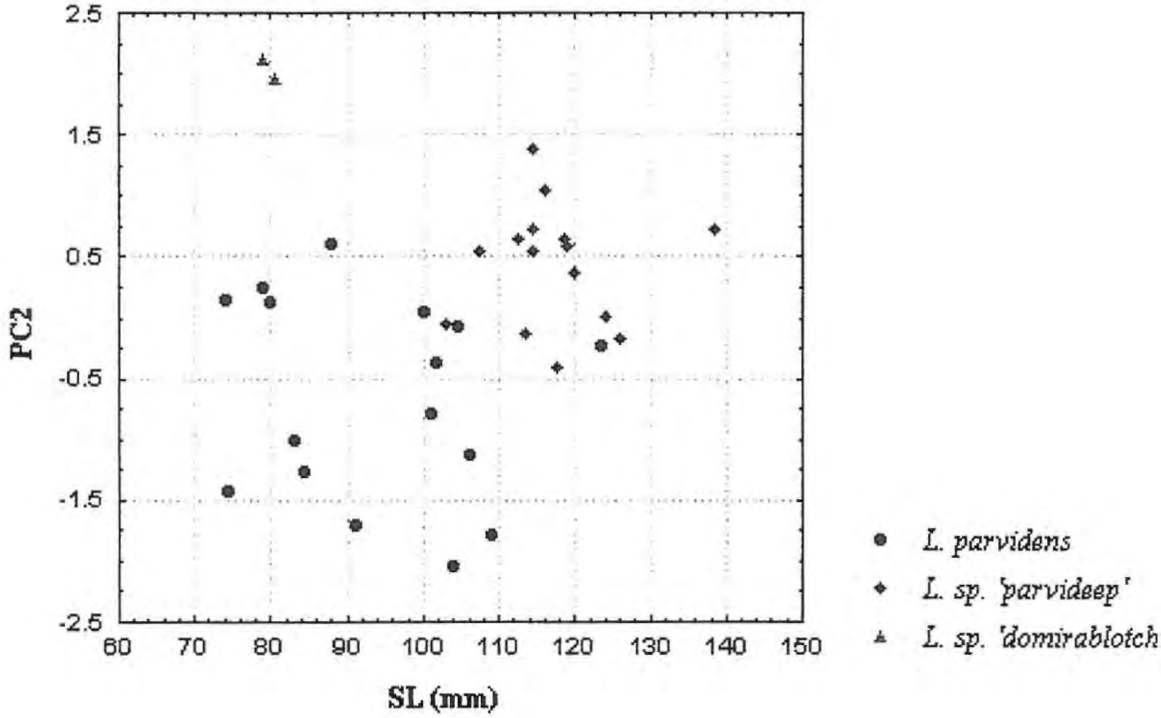


Fig. 6.18: Scatterplot of factor scores on the second axis of PCA of log-transformed measurements against standard length for specimens of *L. parvidens*, *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch'.

Table 6.11: Principal component loadings of the untransformed meristics on the first five axes; *L. parvidens*, *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch' (n = 31).

VARIABLE	PC1	PC2	PC3	PC4	PC5
UPPER	.811598	.053671	.118289	.184768	.158871
LOWER	.677993	-.148027	.058023	.416013	.212446
ROWSUP	.176581	.028270	-.662016	.073089	-.317962
ROWSLOW	.264395	-.226382	-.226728	.298729	-.671757
GRLOW	-.234392	-.488607	.647687	.133406	.022981
GRTOTAL	-.559079	-.317742	.605453	-.029573	-.251835
DSPINES	-.329232	-.736817	-.321961	.140342	-.026088
DSOFT	.357690	.213669	.133021	-.754259	.182202
ASOFT	.530692	-.143455	.295657	.156402	-.063921
PECTORAL	-.345656	-.573476	.120092	-.310600	-.252496
LATUP	.380461	-.703492	-.183269	-.276922	-.086567
LATLOW	-.008742	-.599006	.115850	.169155	.361399
LONG	.596453	-.488289	-.119892	.050764	.362365
TRANSUP	.680856	-.289931	-.194659	-.229906	-.018916
TRANSLOW	.733529	-.146338	.131439	-.317015	-.133888
PV	.564210	.353737	.412471	.312366	-.181281
CHEEK	.581764	.063956	.358373	-.161816	-.461380
Expl.Var	4.383404	2.681374	1.931404	1.414983	1.321827
Prp.Totl	.257847	.157728	.113612	.083234	.077755

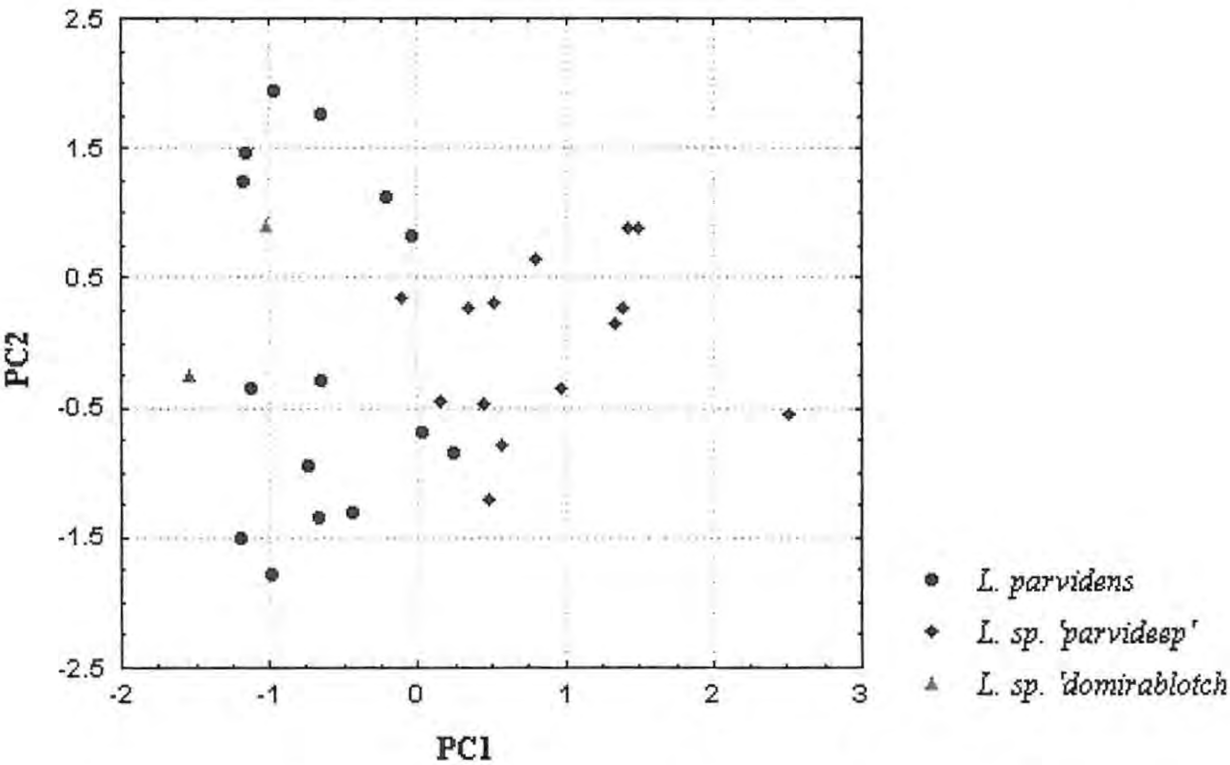


Fig. 6.19: Scatterplot of factor scores on the first and second axis of a PCA of the raw meristics for specimens of *L. parvidens*, *L.* sp. 'parvidens and *L.* sp. 'domira blotch'.

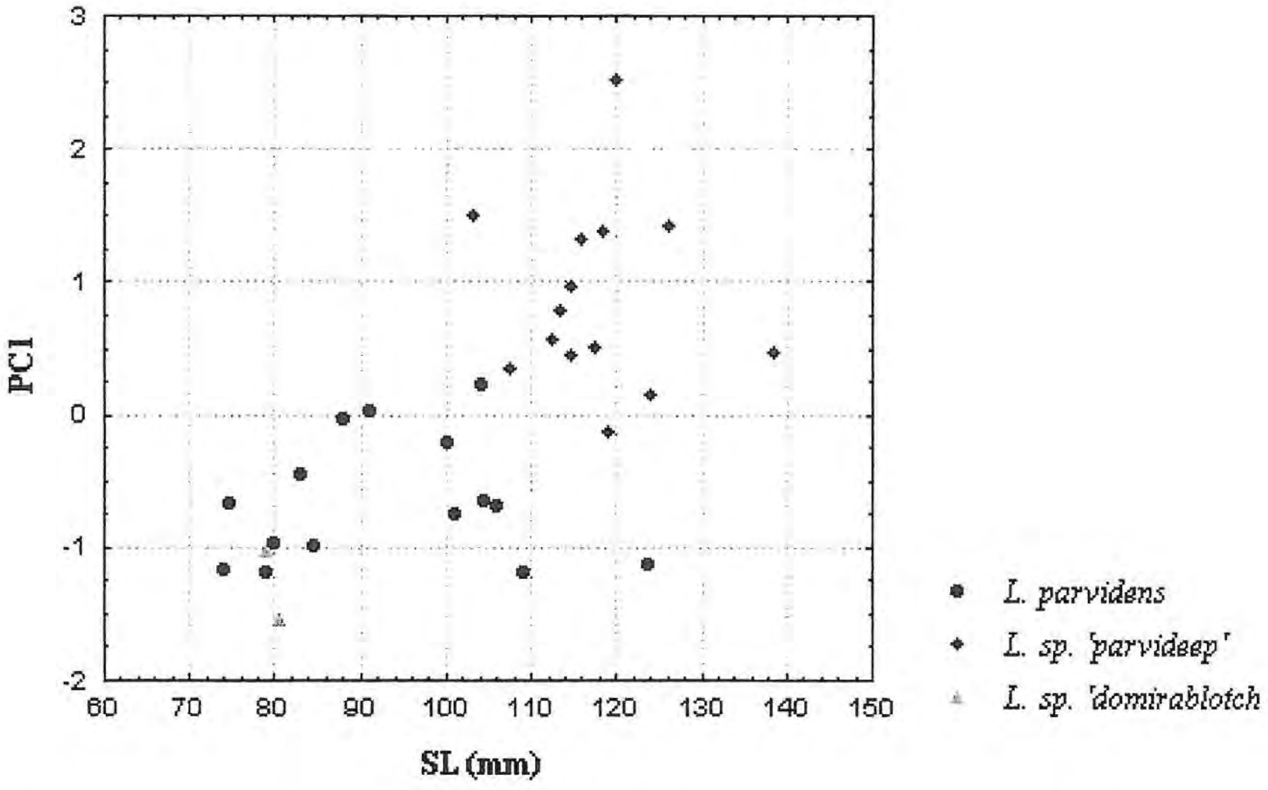


Fig. 6.20: Scatterplot of factor scores on the first axis of a PCA of the raw meristics against standard length for specimens of *L. parvidens*, *L.* sp. 'parvidens and *L.* sp. 'domira blotch'.

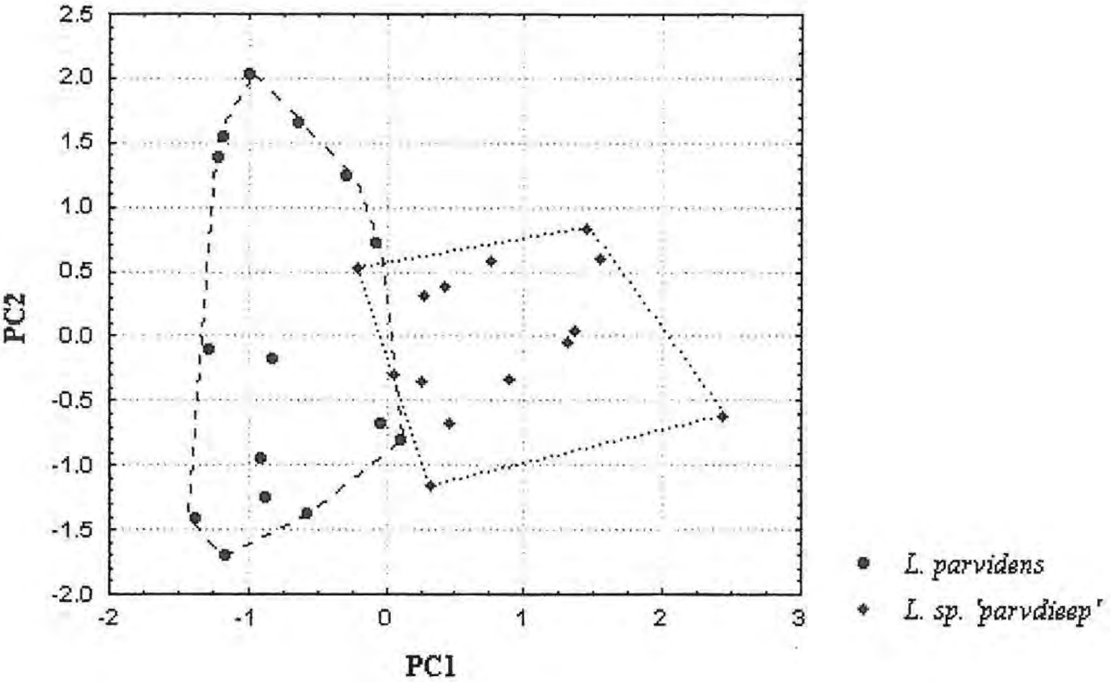


Fig. 6.21: Scatterplot of factor score on the first and second axis of a PCA of the raw meristics for specimens of *L. parvidens* and *L.* sp. 'parvidens deep'.

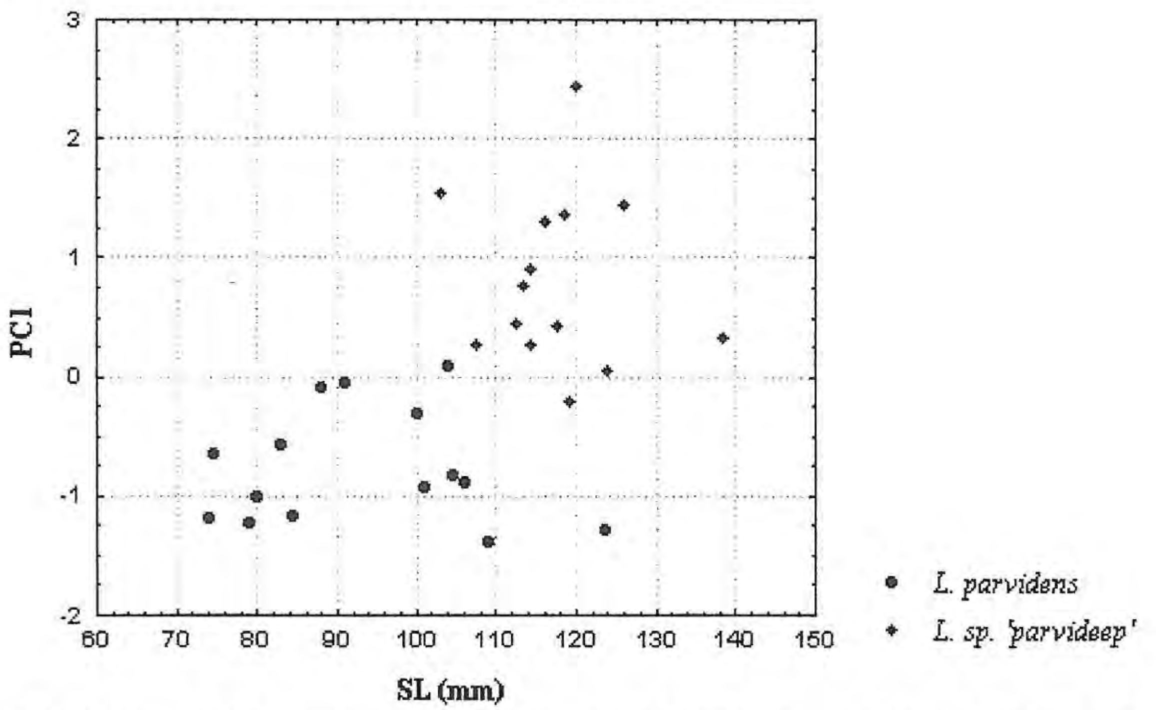


Fig. 6.22: Scatterplot of factor score on the first axis of a PCA of the raw meristics against standard length for specimens of *L. parvidens* and *L.* sp. 'parvidens deep'.

Table 6.12: Principal component loadings of log-transformed variables on the first five axes; all specimens of *L. furcifer*, *L. albus*, *L. marginatus* and *L. oculatus* measured (n = 73).

VARIABLE	PC1	PC2	PC3	PC4	PC5
LOGLACRD	.94265	-.118800	-.058928	.201461	.113751
LOGSNL	.96155	-.052616	-.105655	.075785	-.121456
LOGLJL	.95893	-.157782	.001520	.004766	.007491
LOGPPL	.92793	.045113	-.266691	-.118696	.204068
LOGCHD	.93993	-.106908	-.176129	.139080	-.106409
LOGED	.85126	-.472904	.120337	-.174172	.014833
LOGIOW	.95211	.084677	-.042121	-.140815	-.105909
LOGHW	.97555	.069313	.011569	-.043661	-.059012
LOGHL	.98330	-.006405	-.001721	-.044345	.009721
LOGSL	.98739	.069012	.080656	-.007464	.041776
LOGBD	.97415	.109523	.033398	-.050144	-.004789
LOGDFB	.98019	.068585	.114952	.010971	.029619
LOGAFB	.95906	.141064	.123757	.029267	.025829
LOGPRD	.97505	-.043656	-.085830	.012782	-.051416
LOGPRP	.98290	.035838	.005868	-.039365	-.051470
LOGPRV	.97905	.101088	-.010480	-.024825	-.041389
LOGPRA	.97285	.151832	.051857	-.019292	.022299
LOGCPL	.94203	-.053432	.151683	.184197	.043765
LOGCPD	.98466	.067817	.048825	-.006315	.037769
Expl.Var	17.51017	.376172	.204917	.174039	.109885
Prp.Totl	.92159	.019799	.010785	.009160	.005783

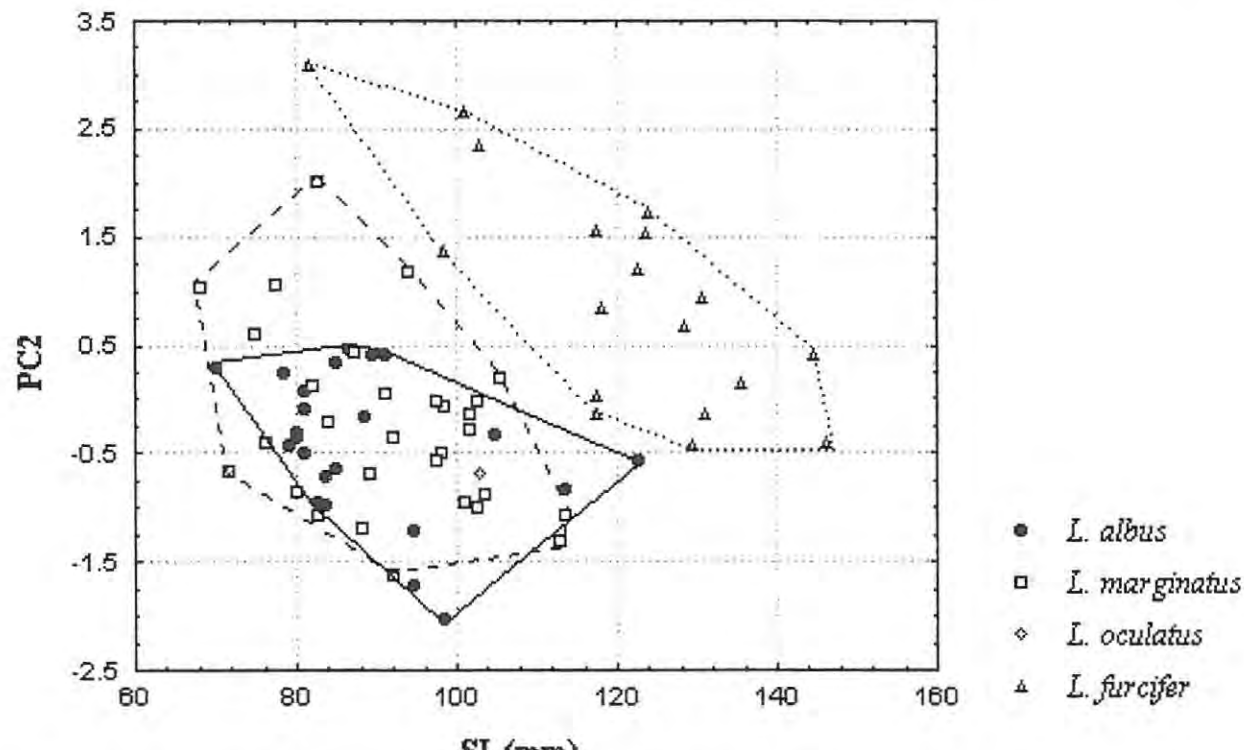


Fig. 6.23: Scatterplot of factor scores on the second axis of a PCA of log-transformed measurements against standard length for specimens of *L. furcifer*, *L. albus*, *L. marginatus* and *L. oculatus* (n= 73).

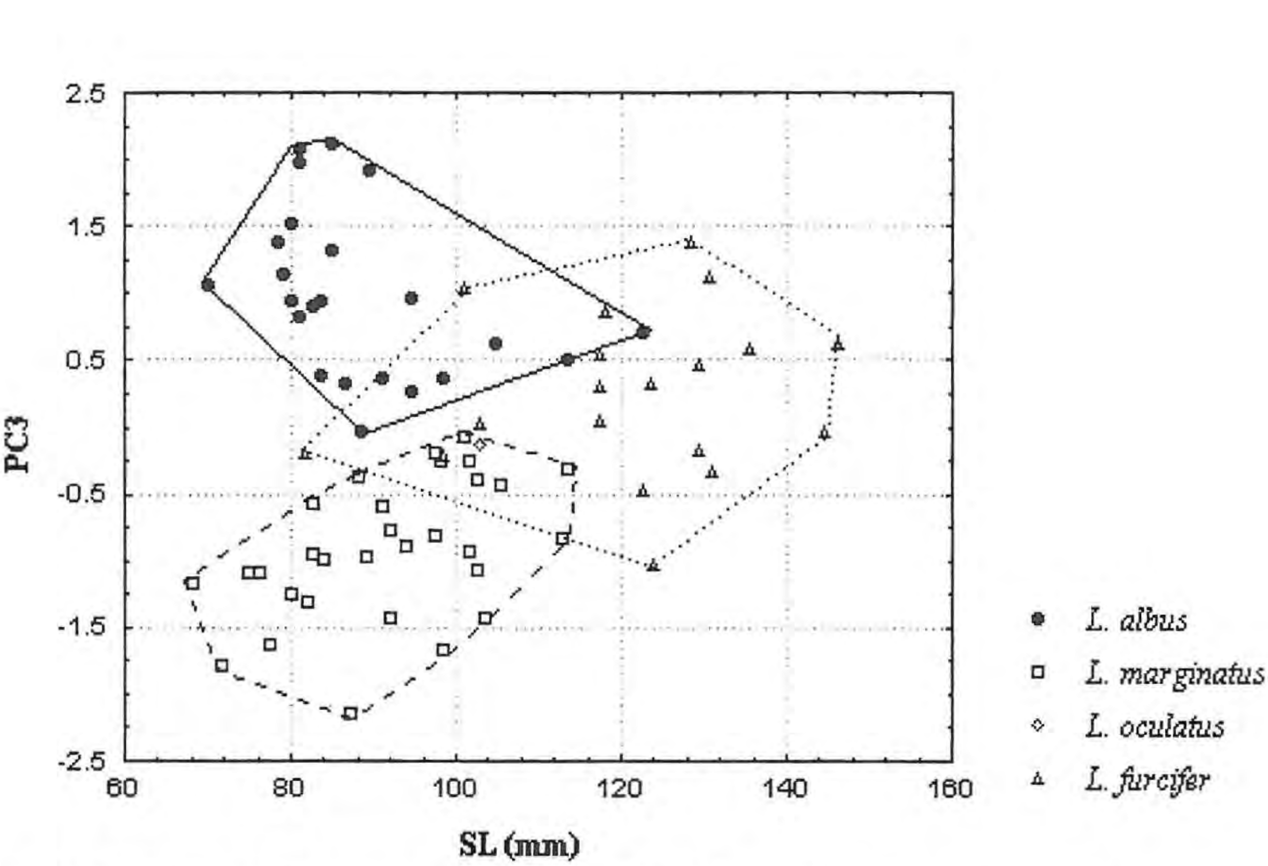


Fig. 6.24: Scatterplot of factor scores on the third axis of a PCA of log-transformed measurements against standard length for specimens of *L. furcifer*, *L. albus*, *L. marginatus* and *L. oculatus* (n= 73).

6.4 Artificial key to the species

1a. Snout long, steeply sloping, mouth wedge shaped; principal melanin pattern on body consisting of variable horizontal components **2**

1b. Snout short or moderately long; principal melanin pattern consisting mainly of vertical bars; some taxa have a suprapectoral patch or suprapectoral, supraanal and caudal spots **4**

2a. Melanin pattern consisting of a dark elongated suprapectoral spot on the lateral line between the 4^{th} and 12^{th} dorsal spine; caudal fin crescentric; 11-13 ceratobranchial gill rakers; 11-13 dorsal soft rays; lower oral teeth in 2 rows; head length 29.9-34.2 % SL .... ***L. lunaris***

2b. Melanin pattern with horizontal dorso-lateral, dorso-medial and mid-lateral bands or mid-lateral band fused with dorso-medial band; 8-11 ceratobranchial gill rakers; 9-11 dorsal soft rays; lower oral teeth in 3-4 rows; head length 32.9-38.9% SL **3**

3a. Horizontal melanin pattern when not masked by male breeding colours, consisting of mid-lateral, dorsal-lateral and sometimes dorso-medial series of dark spots; 8-10 (mostly 9) ceratobranchial gill rakers; cheek depth 23.1-33.1% HL; head length 34.1-38.9% SL .... ***L. lethrinus***

3b. Mid-lateral spots curve up to fuse with the dorsal lateral spots. 8-11 (mostly 10) ceratobranchial gill rakers; cheek depth 26.3-36.7% HL; head length 33.0-36.6% SL .... ***L. leptodon***

4a. Short snout; small mouth set low on profile. All members of this group have a group of more or less enlarged teeth on the medio-posterior area of the lower pharyngeal jaw .. **5**

4b. Snout intermediate; mouth not set low on profile; no enlarged pharyngeal jaw teeth **12**

5a. 10-14 ceratobranchial gill rakers; pharyngeal teeth either simple and fine or enlarged 6

5b. 7-9 ceratobranchial gill rakers; postero-medial teeth of the lower pharyngeal jaw enlarged 11

6a. Pharyngeal jaw teeth all fine; width of lower pharyngeal jaw 92.1%-109.0% length of the jaw; all breeding males with pink gular .... ***L. microstoma***

6b. Pharyngeal jaw teeth enlarged; width of lower pharyngeal jaw 81.0%-102.9% length of the jaw; breeding males differently coloured, without orange gular 7

7a. Eye diameter 38.9-44.9% head length; caudal peduncle 20.6-22.5% standard length ... . ***L. macrophthalmus***

7b. Eye diameter 34.7-41.9% head length; caudal peduncle 16.7-20.5% standard length 8

8a. Head length 28.8-32.9% standard length; principal melanin pattern consist only of vertical bars 9

8b. Head length 32.0-36.6% standard length; some members have dark spots on the body 10

9a. Body depth 33.9-41.6%, anal fin base 19.4-22.2% standard length; snout length 22.8-30.5%; premaxillary pedicel length 19.4-27.4%, eye diameter 34.7-42.7%, head width 44.0-52.9% and interorbital width 20.5-28.2% head length; sexually mature territorial males have a distinctive orange-brown coloration on the upper part of the head................ .... ***L. sp. 'turneri'***

9b. Body depth 33.1-35.3%, anal fin base 17.9-20.5% standard length; snout length 27.8-30.2%; premaxillary pedicel length 21.8-28.2%, eye diameter 38.0-41.7%, head width 42.9-45.8% and interorbital width 20.8-23.0% head length; sexually mature territorial males are deep blue with an overall orange iridescence, dark orange on the upper part of the head and a black trailing soft dorsal fin .... ***L.* sp. 'black dorsal auritus'**

10a. Principal melanin pattern of suprapectoral, supraanal and caudal spots, obvious in freshly caught specimens. Premaxillary pedicel length 21.8-27.2% head length; eye diameter 36.4-41.9% head length; 10-12 ceratobranchial gill rakers. Ventral part of head and body grey with blue iridescence.. ***L. auritus***

10b. Principal melanin pattern with vertical bars. Premaxillary pedicel length 25.5-32.0% HL; eye diameter 31.9-39.6% HL; 12-14 ceratobranchial gill rakers. Ventral part of head and body yellow... ***L. macrochir***

11a. A suprapectoral patch/spot present. Head length 29.2-30.4% standard length; premaxillary pedicel length 18.8-23.8% head length........................ ***L.* sp. 'domira blotch'**

11b. Only vertical bars present. Head length 31.3-34.9% standard length; premaxillary pedicel length 21.6-27.7% head length.............. ***L. parvidens*** and ***L.* sp. 'parvidens deep'**

12a. A dark suprapectoral patch on the upper lateral line, sometimes extending posteriorly but not reaching the caudal peduncle. Eye diameter 28.2-36.1% head length; anal fin base 18.7-22.3% standard length; 31-34 longitudinal scales; 14-16 dorsal spines.. .... ***L. furcifer***

12b. Depending on reproductive mood only traces of vertical bars visible, or upper lateral line darker in some males. Eye diameter 31.0-43.1% head length; anal fin base length 16.1-21.4% standard length; 28-34 longitudinal scales; 15-17 dorsal spines.................. **13**

13a Premaxillary pedicel length 21.6-28.3% head length; predorsal distance 35.1-39.0% standard length; caudal peduncle length 17.5-21.1% standard length .... ***L. marginatus* (including *L. oculatus*)**

13b Premaxillary pedicel length 19.1-25.6% head length; predorsal distance 32.4-37.1% standard length; caudal peduncle length 18.5-22.8% standard length .... ***L. albus***

6.5 *Lethrinops lunaris* Trewavas, 1931

Lethrinops leptodon (part) Regan, 1922: 721.

Lethrinops lunaris Trewavas, 1931: 148; Jackson, 1961:586; Jackson et al., 1963: 85; Bowmaker et al., 1978: 1229; Eccles & Lewis, 1978: 10; Ufermann et al., 1987: 263; Eccles & Trewavas, 1989: 123.

(Plates 6.1, A3 & B6)

Etymology

From Latin, *luna* = "the moon", referring to the crescentric caudal fin.

Diagnosis

A moderately sized species attaining a maximum standard length of 160 mm. Distinguished from all the long-snouted *Lethrinops* by a dark oblong supra-pectoral spot on the upper lateral line below the 4th and 12th dorsal spine; caudal fin crescentric; 11-13 ceratobranchials, lower oral teeth in 2 rows and a smaller head length 29.9-34.2% SL.

Description

For descriptive statistics of measurements and meristic data see Table 6.13.

Snout elongate with a slightly sloping profile 31.7-44.0 (38.2.±2.8)% in head length. Body fairly deep 33.9-40.2 (7.2±1.8)% in standard length and jaws equal anteriorly; maxillary extending to nearly vertical from the anterior edge of eye. Oral teeth in the outer row mostly bicuspid although a few on the posterior end are unicuspid, with 66-103 and 50-70 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws tricuspid with a few unicuspid and only one inner row. Lower pharyngeal bone sub-triangular with fine teeth, teeth 11-13 along the longest medial series and 34-across the posterior margin. Caudal fin is crescentric (= moon shaped). A dark oblong supra pectoral spot covering 6 pored scales below the 4th and 12th dorsal fin spines. The spot appears as a fusion of the 3rd to 5th vertical bars.

Table 6.13: Morphometric ratios and meristic data for *Lethrinops lunaris*.

	Mean	SD	Range	N
Standard length (mm)	126.6	15.1	100.5-160.5	24
as % head length				
Lachrymal depth	27.8	2.0	22.9-31.5	24
Snout length	38.2	2.8	31.7-44.0	24
Lower jaw length	38.0	1.7	35.1-40.3	24
Premaxillary pedicel length	26.2	2.8	20.6-30.6	24
Cheek depth	33.3	2	26.3-36.5	24
Eye diameter	31.2	2	27.2-35.6	24
Head width (HW)	45.4	1.9	41.6-48.9	24
Interorbital width	23.5	1.3	21.0-25.4	24
as % standard length				
Head length	32.3	1.0	29.9-34.2	24
Body depth	37.2	1.8	33.9-40.2	24
Dorsal fin base length	57.1	1.2	54.8-59.3	24
Anal fin base length	21.0	1.1	18.6-24.0	24
Predorsal distance	35.6	1.6	33.2-39.3	24
Prepectoral distance	32.0	1.0	30.6-33.8	24
Prepelvic distance	36.7	1.2	34.0-38.7	24
Pre-anal distance	63.9	1.1	62.1-66.5	24
Caudal peduncle length (CPL)	19.1	0.8	17.9-21.3	24
Caudal peduncle depth	12.6	0.5	11.6-13.4	24
Other				
Interorbital width % HW	51.9	3.3	45.4-57.4	24
Lower pharyngeal jaw length (PhJL) % HL	31.6	1.4	29.6-35.7	20
Lower pharyngeal jaw width(PhJW) % PhJL	82.1	4.3	70.0-88.0	20

Dentigerous area length % PhJL	57.3	4.3	46.2-64.4	20
Dentigerous area width (DeAW) % PhJW	79.1	2.4	74.5-82.7	20
Dentigerous area length % DeAW	88.4	6.1	72.3-98.8	20
Caudal peduncle depth % CPL	65.7	3.8	58.9-75.0	24

	Median	Range	N
Number of teeth upper jaw	78	66-103	16
Number of teeth lower jaw	59.5	50-70	16
Inner rows upper jaw	1	1-1	23
Inner rows lower jaw	1	1-1	23
Gill rakers lower	12	11-13	24
Gill rakers total	17	15-18	24
Dorsal spines	15	15-16	24
Dorsal soft	12	11-13	24
Anal soft	10	9-10	24
Pectoral fin rays	16	15-16	24
Upper lateral line scales	24	22-28	24
Lower lateral line scales	16	14-19	24
Longitudinal line scales	33	31-34	24
Transverse scales above LL	5	4-6	24
Transverse scales below LL	9	8-11	24
Scales <pectoral-pelvic fin>	5	4-8	24
Cheek scales	3	2-4	24

Colour pattern

Body generally grey, and darker below the spinous dorsal base. There are 7-8 faint wide vertical bars. The 3^{rd} to 5^{th} fuse on the upper lateral line to form an oblong supra-pectoral spot, which sometimes can be masked by male breeding colour Fins grey with orange spots. Breeding males are greenish blue with orange iridescence; dorsal fin lappets white with orange tips.

Distribution

Figure 6.25 shows sites where *Lethrinops lunaris* has been recorded during this study. This fish may have a lake wide-distribution although in this study it was only recorded in the southern half of the lake.

Ecology

Probably feeds on insect larvae, crustaceans and zooplankton (Konings, 1995). Based on the fine shape of the pharyngeal teeth and relatively higher number of gill rakers than the other members of this sub-group, *L. lunaris* may be preferring small soft-bottom organisms.

Discussion

Lethrinops lunaris is strictly a shallow-water haplochromine cichlid and belongs to a group of shallow water *Lethrinops* 'sensu stricto' characterised by a long snout and by the presence of remnants of horizontal plesiomorphic body melanin pattern.

This group is part of the second group revised by Eccles & Lewis (1978) excluding the deep-water dwelling *L. argenteus* and *L. longipinnis*.

Trewavas (1931) based her description of *L. lunaris* on the specimens collected by the naturalist Rodney Carrington Wood (1920) and five other specimens collected by Dr. Cuthbert Christy (1925-1926) and concluded that *L. lunaris* is different from *L. leptodon* by the more deeply emarginate caudal fin and slightly narrower lachrymal depth. Eccles & Lewis (1978), while discussing the status of *L. lunaris*, argued that the degree of emargination of the caudal fin and lachrymal depth are rather variable characters. They therefore cautioned that the differences noted by Trewavas were not sufficient to justify specific segregation. However, they pointed out the consistent difference in head shape and pharyngeal dentition between Wood's specimen and Christys' specimens. Their conclusion was that *L. lunaris* should stand to incorporate only the Wood's specimen. The Wood's specimen collected from an unknown locality and the specimens of Christy collected between the present Mangochi and Makanjila in the south east arm of Lake Malawi have been examined and re-measured in this study and compared with recently collected specimens from Khande, Lifuwu and Domira Bay. Based on the head shape, oral and pharyngeal jaw dentition and melanin pattern, it is concluded that *L. lunaris* is indeed a separate and valid species. So the differences observed by Eccles & Lewis (1978) are within the total variability.

Specimens examined

BMNH 1921.9.6:208; female 133.5 mm SL; 'Lake Nyasa'; coll. Wood; syntype

BMNH 1931.1.31:157-161; female 105.5 mm SL, male 114.5 mm SL, female 117.0 mm SL, female 130.5mm SL, male 141.5 mm SL; Fort Johnston to Fort Maguire; coll. Christy. Syntypes. **SADC/GEF 97/16/03/08**; female 124.0 mm SL; Khande, Malawi; trawled at 18-25 m depth; 03/06/97. **SADC/GEF 97/16/02/01-09**; male 144.0 mm SL, female 123.0 mm SL; Khande, Malawi; trawled at 9-14 m depth; 03/06/97. **SADC/GEF 97/16/61/23-26**; female 113.0 mm SL, female 100.5 mm SL, female 106.5 mm SL, female 108.5mm SL; Domira Bay, Malawi; bottom gill net set at 3 m depth; 05/06/97.

SADC/GEF 98/44/03/08; female 130.0 mm SL; Lifuwu, Malawi; beach seine; 19/08/98.

SADC/GEF 98/44/03/04-05; female 118.0 mm SL, female 133.0 mm SL; Lifuwu, Malawi; beach seine; 19/08/98. **SADC/GEF 98/44/03/09**; female 131.5 mm SL; Lifuwu, Malawi; beach seine; 19/08/98. **SADC/GEF 98/44/01/01-04**; female 133.0 mm SL, female 138.5 mm SL, female 118.5 mm SL, female 139.5 mm SL; Lifuwu, Malawi; gill nets; 17/08/98. **SADC/GEF 97/01/29/34-35**; female 152.0 mm SL, female 160.5 mm SL, female 122.0 mm SL; Lifuwu, Malawi; purchase from fishermen; 29/07/97.

6.6 *Lethrinops lethrinus* (Günther, 1893)

Chromis lethrinus, Günther, Proc. Zool. Soc. 1893, p. 622, pl. iv A; Ufermann et al., 1987:76

Tilapia lethrinus (part.), Boulenger, 1898: 4; Boulenger: 1899:129; Pellegrin, 1904: 337; Boulenger, 1905: 57; Boulenger, 1915, Cat. Afr. Fish. iii. p. 254, fig. 171.

Lethrinops lethrinus, Regan, Proc. Zool. Soc. 1922, p.720; Trewavas, 1931:146; Bertram et al., 1942: 116; Jackson, 1961:586; Jackson et al., 1963:85; Bowmaker et al., 1978: 1229; Eccles & Lewis, 1978:6 fig. 5; Loiselle, 1979: 46 phot.; Greenwood, 1983: 279, fig. 15-16; Axelrod & Burgess, 1986: 187, phot.; Axelrod et al., 1986: pl. 323; Ufermann et al., 1987: 262; Eccles & Trewavas 1989: 122, fig. 55; Konings, 1995: 286, photo 1; Turner, 1996: 201, photo pg. 176.

Lethrinops lethrinops : Ribbink & Hill, 1979: 510, fig. 2.

(Plates 6.2 & A2)

Etymology

The species name is derived from a marine fish genus of which this fish resembles.

Diagnosis

A long-snouted shallow water *Lethrinops* 'sensu stricto' with a distinctive horizontal melanin pattern of mid-lateral, dorso-lateral and dorso-medial stripes (the 'kirkii' pattern). Distinguished from both *L. lunaris* and *L. leptodon* in having a slightly longer head; 34.1-38.9 % SL vs 29.9-34.2 % SL in *L. lunaris* and 33.0-36.6 % SL in *L. leptodon*. *Lethrinops lethrinus* also has a low number of ceratobranchial gill rakers (8-10 vs 11-13) and slightly fewer dorsal soft rays than *L. lunaris*.

Description

For descriptive statistics of measurements and meristic data see Table 6.14.

Body relatively deep, snout straight and steeply sloping 30.7-41 (36.6±3.5)% head length; mouth terminal with the lower jaw protruding slightly. Maxillary extension is between nostril and anterior part of the eye.

Oral teeth in the outer row bicuspid anteriorly becoming unicuspid on the posterior end, with 58-78 and 32-46 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 1-2 rows. Lower pharyngeal bone sub-triangular, teeth 10-13 along the longest medial series and 30-40 across the posterior margin. Caudal emarginate.

Table 6.14: Morphometric ratios and meristic data for *Lethrinops lethrinus*.

	Mean	SD	Range	N
Standard length (mm)	101.6	19.6	76.5-143.0	18
as % head length				
Lachrymal depth	25.8	2.6	22.1-30.4	18
Snout length	36.6	3.5	30.7-41.2	18
Lower jaw length	37.2	2.5	29.2-40.7	18
Premaxillary pedicel length	27.4	1.9	24.1-30.3	18
Cheek depth	29.3	3.0	23.1-33.1	18
Eye diameter	31.5	3.1	26.2-35.8	18
Head width	43.3	1.8	40.7-47.4	18
Interorbital width	20.8	1.6	18.3-23.1	18
as % standard length				
Head length (HL)	36.5	1.3	34.1-38.9	18
Body depth	37.4	1.3	34.9-38.9	18
Dorsal fin base length	53.7	1.5	50.8-56.5	18
Anal fin base length	18.9	1.2	16.6-21.3	18
Predorsal distance	39.1	1.3	36.1-41.6	18
Prepectoral distance	35.9	1.5	32.9-38.4	18
Prepelvic distance	39.9	1.7	36.0-42.7	18
Pre-anal distance	64.8	1.3	62.7-67.1	18
Caudal peduncle length (CPL)	19.4	1.0	17.7-21.2	18

Caudal peduncle depth	11.9	0.4	11.1-12.6	18
Other				
Interorbital width % HW	48.1	4.1	41.3-55.6	18
Lower pharyngeal jaw length (PhJL) % HL	28.6	1.5	25.9-30.8	18
Lower pharyngeal jaw width(PhJW) % PhJL	79.3	8.3	67.8-100.0	18
Dentigerous area length (DeAL) % PhJL	66.7	6.5	56.7-83.1	18
Dentigerous area width (DeAW) % PhJW	82.4	7.2	70.7-102.5	18
Dentigerous area length % DeAW	103.0	9.9	87.2-119.5	18
Caudal peduncle depth % CPL	61.4	4.0	54.3-69.2	18

	Median	Range	N
Number of teeth upper jaw	66	58-78	15
Number of teeth lower jaw	40	32-46	15
Inner rows upper jaw	2	1-2	18
Inner rows lower jaw	2	1-3	18
Gill rakers lower	9	8-10	18
Gill rakers total	13	12-15	18
Dorsal spines	15	14-16	18
Dorsal soft	11	10-11	18
Anal soft	9	8-10	18
Pectoral fin rays	16	14-16	18
Upper lateral line scales	23	20-26	18
Lower lateral line scales	15	13-17	18
Longitudinal line scales	31.5	30-34	18
Transverse scales above LL	5	4-6	18
Transverse scales below LL	9	8-10	18
Scales <pectoral-pelvic fin>	5	4-6	18
Cheek scales	3	3-5	18

Colour pattern:

Females and non-breeding males silvery with a series of horizontal stripes, the upper usually manifested as a series of spots ('the kirkii' pattern). Dorsal fin margin white with red-tipped lappets. Ripe males are turquoise-green with numerous orange spots on dorsal and caudal fins.

Distribution

Eccles and Trewavas (1989) state that *Lethrinops lethrinus* is widespread in the southern part of the lake and in rivers. Indeed most of the specimens examined for this study were obtained from the southern part of the lake, from rivers flowing into the lake (Figure 6.25) and some from Lake Malombe, but some were also from as far north as Nkhata Bay. It seems to prefer shallow, muddy areas.

Ecology:

Konings (1990) reports that this species feeds on small benthic invertebrates. Turner (1996) found stomachs of two specimens from the south east arm of the lake to contain mainly chironomid larvae, but also copepods, diatoms, and detritus. Twenty stomachs of specimens from various parts of the lake analysed for food items also confirmed that chironomid larvae and zooplankton copepods are the main food of *L. lethrinus*.

Discussion

Trewavas (1931) noted that there is some variation in the body melanin pattern amongst the type materials of *L. lethrinus* and concluded that the differences were dependent upon sex and state of maturity. Eccles & Lewis (1978) believe that these differences were geographical. Specimens from Lake Malombe, from the south east arm, from Nkhata Bay and from two rivers (Bua and Kiwiya) flowing into Lake Malawi have been examined in this study. It is stared with conviction that only one pattern can be found in *L. lethrinus*: the 'B pattern ('the kirkii') of Trewavas (1931). Turner (1996) pointed out that *L. lethrinus* may be unrelated to the majority of the species presently placed in *Lethrinops*. Therefore, in his classification of Lake Malawi/Nyasa cichlids he discusses *L. lethrinus* together with species of the genus *Protomelas* and other horizontally striped species.

The other pattern which Trewavas (1931) refers to as the modified version of the 'B pattern' where the mid-lateral stripe curves up to fuse with the dorso-lateral oblong spot, is only present in *L. leptodon.* It is suspected that both Trewavas (1931) and Eccles & Lewis (1978) were dealing with a mixture of *L. lethrinus* and *L. leptodon.* Therefore, in this study, all specimens with a 'modified B pattern' have been removed from *L. lethrinus* and assigned to *L. leptodon.*

Specimens examined

RUSI: 050974; male 143.0 mm SL, female 97.5mm SL, female 117.5 mm SL; South East Arm (Lake Malawi), 14° 12'S 34°11'E; depth 12-20m; 27/11/94. **RUSI: 052148**; female 79.5 mm SL; Monkey bay, Malawi; 22/05/73. **RUSI: 015508**; unsexed 110.5 mm SL, female 109.5 mm SL, female 91.5 mm SL; Foo 1, Malawi; 17/01/1973. **SADC/GEF (24/89/12);** male 126.0 mm SL; Chemwezi Island, South East Arm, Malawi; 15/11/97.

SADC/GEF 97/21/73/23; female 82.5 mm SL, female 76.5 mm SL; Mazinzi, South East Arm, Malawi; 12/10/97. **SADC/GEF (21/79/10)**; female 96.5 mm SL, male 135.0 mm SL; trawl transect from Ndoka to Chemwezi, South East Arm, Malawi; 13/10/97.

SADC/GEF 97/21/77/14; female 105.0 mm SL; trawl transect from Ndoka to Chemwezi, South East Arm, Malawi; 12/10/97. **MFRU (no number)**; female 108.5 mm SL; Nkhata Bay, Malawi; seine in the south of the Bay; 15/3/63. **MFRU (no number)**; female 100.5 mm SL; 'Lake Malawi (L. Nyasa basin); trawled in 5-6 m; 01/08/72. **MFRU (no number)**; unsexed 83.5 mm SL; Lake Malawi affluent rivers, Bua river; coll. Tweddle & Willoughly; 14/10/76. **MFRU (no number)**; unsexed 84.5 mm SL; Lake Malawi affluent rivers, Kawiya river, obtained by electro-fishing; 13/10/76. **SADC/GEF 97/21/19/74**; unsexed 85.0 mm SL; trawl transect from Mazinzi to Kadonga, South East Arm, Malawi; 11/10/97.

6.7 *Lethrinops leptodon* Regan, 1921

Lethrinops leptodon (part) Regan, 1921: 721; Trewavas, 1931: 147; Jackson, 1961: 586; Jackson et al., 1963; Bowmaker et al., 1978: 1229; Eccles and Lewis, 1978: 8, fig. 6; Ufermann et al., 1987: 262.

Lethrinops leptodon: Eccles & Trewavas, 1989: 122, fig. 56.

(Plates 6.3 & A1)

Etymology

Noun in apposition, from Greek *leptos* = "weak" + *odous* = "tooth", referring to the weak dentition (Eccles & Trewavas, 1989).

Diagnosis

A long-snouted shallow-water *Lethrinops 'sensu stricto'* with a distinctive horizontal melanin pattern whereby the mid-lateral stripe curves up to fuse with the dorsal-lateral elongated spot.

L. leptodon is distinguished from *L. lethrinus* by the shorter head (33.0-36.6% standard length); the cheek deeper (26.3-36.7% head length); higher number of ceratobranchials (8-12, median 11) and by the body melanin pattern. Maxillary extension not reaching vertical from the anterior edge of the eye; teeth in 3 or 4 species. Posterio-median teeth in the lower pharyngeal jaw enlarged and slightly flattened.

Description

A moderate-sized species attaining a standard length of 153mm. For descriptive statistics of measurements and meristic data see Table 6.15.

Snout moderately long with a steeply sloping profile 30.0-43.3 (37.7±3.5)% in head length; jaws equal anteriorly or lower jaw projecting; maxillary extending to between nostril and eye. Oral teeth in the outer row bicuspid anteriorly becoming unicuspid on the posterior end, with 40-106 and 35-66 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 1-3 rows. Lower pharyngeal bone triangular, teeth 11-14 along the longest medial series and 32-42 across the posterior margin. Caudal fin slightly forked.

Table 6.15: Morphometric ratios and meristic data for *Lethrinops leptodon*.

	Mean	SD	Range	N
Standard length (mm)	116.9	21.8	72.5-152.5	37
as % head length				
Lachrymal depth	27.8	2.3	23.5-33.8	37
Snout length	37.7	3.5	30.0-43.3	37
Lower jaw length	37.2	2.3	32.3-42.3	37
Premaxillary pedicel length	28.5	2.5	23.2-32.9	37
Cheek depth	32.3	2.5	26.3-36.7	37
Eye diameter	31.6	2.8	28.2-39.6	37
Head width (HW)	43.9	2.4	38.3-51.0	37
Interorbital width	21.6	1.7	17.9-23.8	37
as % standard length				
Head length (HL)	34.7	0.8	33.0-36.6	37
Body depth	37.1	2.7	30.3-43.1	37
Dorsal fin base length	54.5	1.7	50.0-58.7	37
Anal fin base length	19.5	1.1	17.8-21.9	37
Predorsal distance	38.3	1.4	35.2-41.3	37
Prepectoral distance	34.3	1.2	32.2-36.4	37
Prepelvic distance	38.5	1.7	34.6-41.9	37
Pre-anal distance	65.1	1.4	61.9-68.0	37
Caudal peduncle length (CPL)	18.6	1.1	16.6-20.7	37
Caudal peduncle depth	12.1	0.7	10.8-13.3	37
Other				
Interorbital width % HW	49.3	4.8	41.5-61.1	37

Lower pharyngeal jaw length (PhJL)%HL	29.8	1.9	24.4-33.4	36
Lower pharyngeal jaw width(PhJW)%PhJL	81.7	5.5	70.7-100.0	36
Dentigerous area length (DeAL) % PhJL	60.0	3.9	51.2-67.7	36
Dentigerous area width (DeAW) % PhJW	75.8	3.7	64.7-84.2	36
Dentigerous area length % DeAW	97.2	7.4	81.5-113.6	36
Caudal peduncle depth % CPL	65.0	5.4	56.5-75	37

Meristics

	Median	Range	N
Number of teeth upper jaw	80	40-106	29
Number of teeth lower jaw	54	35-66	30
Inner rows upper jaw	2	1-3	36
Inner rows lower jaw	2	1-4	36
Gill rakers lower	11	8-12	37
Gill rakers total	15	13-16	37
Dorsal spines	16	15-17	37
Dorsal soft	10	9-11	37
Anal soft	9	8-10	37
Pectoral fin rays	16	14-16	37
Upper lateral line scales	25	20-28	37
Lower lateral line scales	16	14-18	37
Longitudinal line scales	32	31-34	37
Transverse scales above LL	5	4-6	37
Transverse scales below LL	9	7-10	37
Scales <pectoral-pelvic fin>	5	4-6	37
Cheek scales	3	2-4	37

Colour pattern

According to Eccles & Lewis (1978), live females are silvery-olive, head light olive with a golden sheen; dorsal and anal fins hyaline with orange brown spots; dorsal lappets orange. Such colouration was also recorded from beach seine specimens collected around Senga Bay. A distinct dark patch on the upper lateral line beneath the dorsal spine, which sometimes fuses with the mid-lateral stripe. Breeding male are blue-green with yellow iridescence, masking any underlying plesiomorphic melanin pattern. In poorly preserved specimens and in fish kept out of water for some time the only remaining pattern is a dark patch below the spinous dorsal.

Distribution

Wood collected the types examined in the BMNH from an unspecified locality. Eccles & Lewis (1978) obtained specimens from beach seine catches near Chintheche (11° 50'S 34° 11'E) on the western shore of Lake Malawi. Eccles & Lewis (1978) did not record any *L. leptodon* from the well-sampled south east and south west arms of Lake Malawi. Probably this could have been either an artefact of their sampling regime or they might have identified *L. leptodon* specimens as *L. lethrinus*. The five RUSI specimens examined for this study at the JLB Smith Institute of Ichthyology were collected by Dr. P. Greenwood in 1994 from the south east arm of Lake Malawi (14°10'S 34° 38'E) at a depth of 7m. Figure 6.25 shows the sites where *L. leptodon* has been recorded during this study. It is likely that *L. leptodon* has a lake wide-distribution.

Ecology

L. leptodon "prefers" sandy-muddy bottoms, but unlike *L. lethrinus* it has not been recorded in rivers. Examination of the gut contents of twenty-three specimens of *L. leptodon* revealed food items similar to *L. lethrinus*, a diet that consisted mainly of chironomid larvae.

Discussion

All the features that Konings (1995: 293-4) discusses of being of *L. oculatus* actually apply to the specimens collected and identified with certainty as *L. leptodon* in this study.

The only *L. oculatus* used in Trewavas (1931) description and housed in BMNH has been examined; none of its features correspond to those reported by Konings (op.cit.). *Lethrinops leptodon* is very common in beach seine catches especially around Senga Bay and Lifuwu. Its wedge-shaped mouth is characteristic, as is the dark oblong spot formed by the overlapping of two dark diagonal bands.

Specimens examined

BMNH 1921.9.6:204-207; unsexed 115.0 mm SL, male 151.0 mm SL, male 129.0 mm SL, male 142.0 mm SL; 'Lake Nyasa'; Coll. Wood; syntypes. **RUSI: 050909**; female 80.5 mm SL, male 104.0 mm SL, female 119.5 mm SL, male 109.0 mm SL; South West Arm (Malawi) 14° 10'S 34° 38'E; depth 7 m; 24.11.1994. **SADC/GEF 97/01/05/06**; female 115.0 mm SL; Senga Bay (in front of SADC/GEF Project office), Malawi; purchased from fishermen; 06/02/97. **SADC/GEF 96/02/01/01-02**; m 135.0 mm SL; Senga Bay, Malawi; purchased from fishermen; 10/09/96. **SADC/GEF 96/02/01/30-33**; female 80.5 mm SL, female 78.5 mm SL, male 81.0 mm SL, female 77.5 mm SL; Senga Bay, Malawi; purchased from fishermen; 10/09/96. **SADC/GEF 97/01/08/01-04**; male 134.0 mm SL, male 136.0 mm SL, male 123.0 mm SL, male 120.5 mm SL; Senga Bay (just off Namalenji Island), Malawi; purchased from fishermen; 26/02/97. **SADC/GEF 97/01/10/07**, male 114.0 mm SL, **97/01/10/10**, male 118.5 mm SL; Senga Bay (near Nguwo cottage), Malawi; purchase from beach seine fishermen; 14/04/97.

SADC/GEF 96/02/01/01; male 106.0 mm SL; Senga Bay, Malawi; purchase from fishermen. **SADC/GEF 97/16/62/40**, male 72.5 mm SL, 97/16/62/41, female 98.0 mm SL, 97/16/62/42, female121.0 mm SL; Domira Bay, Malawi; beach seine fishermen; 05/06/97. **SADC/GEF (CR44/1** two specimens); male 114.5 mm SL, male 136.5 mm SL, Lifuwu, Malawi; gill net; 4 m depth. **SADC/GEF 98/44/03/01**; male 128.0 mm SL; Senga Bay (in front of SADC/GEF office), Malawi; beach seine fishing; 19/8/98. **SADC/GEF 98/44/02/01**; male 138.5 mm SL; Senga Bay (in front of SADC/GEF office), Malawi; beach seine fishing; 19/8/98. **SADC/GEF 97/20/01/80**; male 126.0 mm SL; Senga Bay, Malawi; bottom trawl at depth of 2.2-14 m; 21/09/97. **SADC/GEF 98/28/60/01**; male 136.5 mm SL; Lukoma Bay (just south of Mbamba Bay), Tanzania; purchase from hand liners at depth of 11 m; 12/01/98. **SADC/GEF 97/14/6/46**; male 89.5

mm SL; Chembe beach, Malawi; purchase from fishermen. **SADC/GEF 97/01/30/01-05**; male 120.0 mm SL, male 127.5 mm SL, male 152.5 mm SL, male 133.0 mm SL, male 143.0 mm SL; Kambiri, (Malawi); purchase from beach seine fishermen; 31/10/97.

6.8 *Lethrinops microstoma* Trewavas, 1931

Lethrinops microstoma Trewavas, 1931: 141, fig. 5d; Jackson, 1961: 585; Blanc, 1962: 216; Jackson et al., 1963: 84; Bowmaker et al., 1978:1229; Ufermann et al., 1987: 263; Eccles & Trewavas, 1989: 134, fig. 66. Konings, 1995:285, photo 2.

(Plates 6.4, A5-6, B5, C1 & C4-6)

Etymology

Noun in apposition, from Greek *mikros* which means 'small' and *stoma* which means 'mouth'. Referring to the characteristic small mouth.

Diagnosis

A small to medium-sized *Lethrinops* with snout equal to or shorter than eye diameter. Belongs to a group of the short-snouted shallow-water *Lethrinops* 'sensu lato' with 10-14 ceratobranchial gill rakers. Distinguished from all members of the short-snouted *Lethrinops* by the shape of the lower pharyngeal bone, which is unusually slender, deeply notched behind and with numerous all-fine teeth. Width of the pharyngeal jaw is 92.1-109.0 % PhJL against 81.0-102.9 % PhJL. All sexually mature territorial males have a distinctive pink gular/throat.

Description

For descriptive statistics of measurements and meristic data see Table 6.16.

Snout with a slightly convex profile 31.3-41.1% in head length; jaws equal anteriorly or lower jaw projecting; maxillary extending to vertical from the anterior edge of eye. Oral teeth in the outer row mainly bicuspid, with 50-86 and 32-52 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws tricuspid and in 1-2 rows. Lower pharyngeal bone deeply notched behind with the 'horns' well spread, teeth 11-13 along the longest medial series and 33-40 across the posterior margin. Caudal fin forked.

Table 6.16: Morphometric ratios and meristic data for *Lethrinops microstoma*.

	Mean	SD	Range	N
Standard length (mm)	100.6	8.0	81.0-113.5	14
as % head length				
Lachrymal depth	23.0	1.4	20.3-25.3	14
Snout length	31.4	2.6	25.9-35.7	14
Lower jaw length	32.7	1.7	29.7-35.1	14
Premaxillary pedicel length	25.4	1.8	23.6-29.1	14
Cheek depth	26.1	1.7	21.5-28.8	14
Eye diameter	35.3	1.6	32.9-37.8	14
Head width (HW)	46.9	2.0	44.8-51.6	14
Interorbital width	24.1	1.2	22.6-26.1	14
as % standard length				
Head length (HL)	32.9	0.9	31.3-34.8	14
Body depth	36.5	1.4	34.0-38.4	14
Dorsal fin base length	55.9	1.0	54.3-57.6	14
Anal fin base length	20.2	0.7	18.5-21.0	14
Predorsal distance	36.2	0.8	35.1-37.6	14
Prepectoral distance	32.8	1.5	30.8-35.3	14
Prepelvic distance	38.2	1.1	36.6-39.7	14
Pre-anal distance	65.2	1.3	62.3-67.0	14
Caudal peduncle length (CPL)	18.7	1.0	17.2-20.5	14
Caudal peduncle depth	12.1	0.7	10.6-13.6	14
Other				
Interorbital width % HW	51.3	3.1	45.9-56.7	14
Lower pharyngeal jaw length (PhJL) % HL	27.8	1.5	25.0-30.0	13
Lower pharyngeal jaw width(PhJW) % PhJL	98.5	5.4	90.1-109.4	12
Dentigerous area length (DeAL) % PhJL	57.9	6.2	46.4-70.6	13

Dentigerous area width (DeAW) % PhJW	78.3	3.4	73.0-84.2	12
Dentigerous area length % DeAW	75.0	8.0	61.6-89.2	12
Caudal peduncle depth % CPL	64.9	5.1	58.5-78.8	14

	Median	Range	N
Number of teeth upper jaw	63.5	50-86	12
Number of teeth lower jaw	46	32-52	12
Inner rows upper jaw	1	1-2	14
Inner rows lower jaw	1	1-2	14
Gill rakers lower	10	10-12	14
Gill rakers total	14.5	14-18	14
Dorsal spines	16	15-17	14
Dorsal soft	11	10-12	14
Anal soft	9	8-10	14
Pectoral fin rays	15	14-15	14
Upper lateral line scales	23	20-26	14
Lower lateral line scales	14	13-16	14
Longitudinal line scales	32	29-33	14
Transverse scales above LL	5	4-6	14
Transverse scales below LL	9	8-10	14
Scales <pectoral-pelvic fin>	5	5-8	14
Cheek scales	3	2-3	14

Colour pattern

Eccles & Trewavas (1989) give a detailed account of the coloration of *L. microstoma* and Konings (1995) provides a photographic illustration of a male from Ntekete, Malawi. The most distinctive coloration is that exhibited by sexually mature and territorial males. The gular and branchiostegal membrane are bright orange to orange-brown (see Plate A6). Dorsal lappets of both males and females are tipped vermilion or red. In this study, colour illustrations have been provided for specimens of *L. microstoma* from different parts of the lake (see plate B5, C4-C6).

Distribution

Three of the syntypes examined at the BMNH were collected at Karonga, Malawi and four at Vua, also from the northern part of the lake. The other specimens of this species that were collected were mainly from Senga Bay and Kambiri in the south (fig. 6.26), all from relatively shallow waters. It is agreed with Konings' (1995) observation that this species has a lake-wide distribution.

Ecology

The stomach contents of *L. microstoma* have not been examined in this study, but according to Konings (1995), it feeds predominantly on zooplankton and other invertebrates found above the sand.

Discussion

Lethrinops microstoma can be easily identified by its lower pharyngeal bone, which is unusually slender, deeply forked behind and lacks enlarged teeth on the surface. Also, the bright orange colour of the gular and branchiostegal membrane of breeding males is another additional character for the identification of this short-snouted species. Konings (1995) reports that this fish sometimes feeds in the water column, unlike most shallow-water *Lethrinops*. He also observed *L. microstoma* gathering at places where plankton is abundant. It is interesting to note such a feeding behaviour atypical of shallow-water sand-dwelling *Lethrinops*. It is clear that the characteristic lower pharyngeal bone, shape and dentition found in this species is instrumental in processing the food items taken through this particular feeding behaviour.

Specimens examined

BMNH 1930.1.31.58-60; female 102.0 mm SL, male 108.0 mm SL, male 113.5 mm SL; Karonga, Malawi; coll. Christy; syntypes. **BMNH 1930.1.31.72-75**; male 92.5 mm SL, male 102.0 mm SL, male 103.5mm SL, male 104.0 mm SL; Vua, Malawi; coll. Christy.

Syntypes. **SADC/GEF 98/01/38/01-02**; female102.5 mm SL, female100.0 mm SL; Senga Bay, Malawi; purchase from rod and line fishermen; 02/02/98. **SADC/GEF 97/01/24/01, 97/01/24/03**; female 94.0 mm SL, unsexed 81.0 mm SL; Senga Bay, Malawi; purchase from beach seine fishermen; 14/05/97. **SADC/GEF 98/44/39/01-02**; male 102.5 mm SL, male 108.0 mm SL; Kambiri, Malawi; gill net set at 3 m depth. 29/11/98. **SADC/GEF 98/01/47/01**; male 95.5 mm SL; Senga Bay, Malawi; purchase from chirimila fishermen; 02/08/98.

6.9 *Lethrinops* sp. 'black dorsal auritus'

(Plate C2)

Etymology

A working name referring to the characteristic trailing end of the soft dorsal fin more distinctive in sexually mature males which is black or dark. Also females have a black submarginal band in the dorsal fin.

Diagnosis

A small *Lethrinops* with a snout shorter than the eye diameter. Differs from all other short-snouted members of the shallow-water *Lethrinops* with a high number of ceratobranchial gill rakers and enlarged postero-median pharyngeal teeth except *L. macrophthalmus* and *L.* sp. 'tuneri' in the shorter head (31.7-32.9 % SL vs 32.0-36.6 % SL) and different male breeding coloration. Differ from *L. macrophthalmus* in a relatively smaller eye (ED 38.0-41.7 vs 38.9-44.9 % HL) and shorter caudal peduncle (18.0-19.3 vs 20.6-22.5 % SL) and from *L.* sp. 'turneri' mainly in head width (42.9-45.8 vs 44.0-52.9 % HL). Sexually mature territorial males are deep blue on snouts with an overall orange iridescence on body becoming deeper orange on nape and a black trailing soft dorsal fin. Differs from *L. parvidens*, *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch' by a higher ceratobranchial a count (11 against 7-9 gill rakers).

Description

For descriptive statistics of measurements and meristic data see Table 6.17. Snout with a slightly round profile 27.8-30.2 (28.9±0.9)% in head length; jaws equal anteriorly; maxillary reaching level of front of the eye orbit. Oral teeth in the outer row completely bicuspid, with 48-58 and 40-46 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws completely tricuspid and in 1 row. Lower pharyngeal bone triangular, with a group of 6-9 postero-median teeth enlarged, 11-12 teeth along the longest medial series and 34-39 teeth across the posterior margin. Caudal fin emarginate.

Table 6.17: Morphometric ratios and meristic data for *Lethrinops* sp. 'black dorsal auritus'

	Mean	SD	Range	N
Standard length (mm)	72.6	3.1	67.5-75.5	7
as % head length				
Lachrymal depth	18.1	0.6	17.3-19.2	7
Snout length	28.9	0.9	27.8-30.2	7
Lower jaw length	32.9	1.6	30.6-34.7	7
Premaxillary pedicel length	24.7	2.5	21.8-28.2	7
Cheek depth	21.9	1.0	20.4-23.3	7
Eye diameter	39.8	1.6	38.0-41.7	7
Head width (HW)	44.5	1.1	42.9-45.8	7
Interorbital width	21.5	0.9	20.8-23.0	7
as % standard length				
Head length (HL)	32.5	0.4	31.7-32.9	7
Body depth	34.1	0.7	33.1-35.3	7
Dorsal fin base length	54.5	1.4	51.7-55.6	7
Anal fin base length	19.3	1.1	17.9-20.5	7
Predorsal distance	35.5	1.2	34.2-37.1	7
Prepectoral distance	33.1	0.8	31.9-34.2	7
Prepelvic distance	39.9	1.4	37.0-41.1	7
Pre-anal distance	65.7	1.3	64.2-67.6	7
Caudal peduncle length (CPL)	18.7	0.5	18.0-19.3	7
Caudal peduncle depth	12.2	0.3	11.9-12.6	7
Other				
Interorbital width % HW	48.3	1.8	46.4-50.5	7
Lower pharyngeal jaw length (PhJL) % HL	28.3	0.9	26.5-29.1	7
Lower pharyngeal jaw width(PhJW) % PhJL	94.0	5.0	87.5-100.0	7
Dentigerous area length (DeAL) % PhJL	63.2	3.0	59.4-67.7	7

Dentigerous area width (DeAW) % PhJW	80.4	3.6	76.1-86.2	7
Dentigerous area length % DeAW	83.8	2.4	80.9-88.0	7
Caudal peduncle depth % CPL	65.3	2.0	62.1-68.0	7

	Median	Range	N
Number of teeth upper jaw	56	48-58	7
Number of teeth lower jaw	40	40-46	7
Inner rows upper jaw	1	1-1	7
Inner rows lower jaw	1	1-1	7
Gill rakers lower	11	11-11	7
Gill rakers total	16	16-16	7
Dorsal spines	16	15-16	7
Dorsal soft	11	10-11	7
Anal soft	9	9-9	7
Pectoral fin rays	14	14-15	7
Upper lateral line scales	25	23-25	7
Lower lateral line scales	14	11-14	7
Longitudinal line scales	32	32-33	7
Transverse scales above LL	3	3-4	7
Transverse scales below LL	8	8-8	7
Scales <pectoral-pelvic fin>	4	4-4	7
Cheek scales	2	2-2	7

Colour pattern

Females and immature males silvery with a sandy cast and yellow iridescence. A black submarginal band on the dorsal fin is characteristic in both sexes. The band becomes wider on the trailing end of the fin. Dorsal fin lappets are orange. Eight faint vertical bars can be seen on the body below the dorsal fin of females and non-breeding males. Sexually mature territorial males have deep blue on snouts with an overall orange iridescence on the body becoming deeper orange on the nape. Caudal fin dusky with orange maculae/striae. Dorsal fin dusky with orange spots especially in the soft-rayed part. Anal fin dark distally and dusky proximally with seven orange anal spots. The leading edge/anterior border of the pelvic fins is also darker.

Distribution

All specimens used in this study were obtained by beach seining at a depth of 2 m at Sanga beach, 25 km north of Chintheche, Malawi (fig. 6.28). This area has an extensive shallow sandy beach. Konings (1995) illustrates species that he observed in Chembe Beach in the southern part of Lake Malawi/Nyasa and in Selewa, south of Chilumba, Malawi. All these fish resemble *L.* sp. 'black dorsal auritus'. It is possible that future work may reveal the lake-wide distribution of this undescribed species.

Ecology

Lethrinops sp. 'black dorsal auritus' was taken together with *L. auritus* in the same haul at Sanga. This is an indication that they may have the same ecological requirements. A few stomachs examined showed a diet consisting mainly of chironomid larvae with occasional copepods.

Discussion

These specimens have been compared with the other members of the short-snouted *Lethrinops* that have a characteristic orange nape but none of them resemble them. At the same locality (Sanga beach), and even in the same beach seine haul, specimens identified as *L. auritus*, by the presence of the distinct spots on the body were collected. Konings (1995: pg. 290-291, photo 1-7) gives photographic illustrations of small *Lethrinops* of the *L. auritus* 'species group'. All of them have a characteristic golden or yellow nape, but none of them is a true *L. auritus*.

Lethrinops sp. 'black dorsal auritus' is very similar to some members of *L. auritus* 'sensu Konings' species complex. These fish therefore represent yet another undescribed member of the shallow-water short-snouted *Lethrinops* group complex.

Specimens examined

SADC/GEF (47/1/11); male 74.5 mm SL, male 73.0 mm SL, female 67.5 mm SL, female 72.5 mm SL, female 69.5 mm SL, female 75.5 mm SL, female 75.5 mm SL; Sanga beach, 25 km north of Chintheche, Malawi; beach seine catch; 23/07/98.

6.10 *Lethrinops macrophthalmus* (Boulenger, 1908)

Tilapia macrophthalma (part.), Boulenger, 1908: 242: Boulenger, 1915:Cat. Afr. Fish. iii. p. 261, fig. 176; Ufermann et al., 1987: 384

Haplochromis macrophthalmus, Regan, Proc. Zool. Soc. 1921, p. 714; Ufermann *et al.*, 1987:197.

Lethrinops macrophthalmus, Trewavas, 1931: 143; Jackson, 1961: 586; Jackson *et al.*, 1963: 85; Bowmaker et al., 1978: 1229; Eccles & Lewis,1979:3, fig.2; Eccles & Trewavas, 1989: 137, fig. 69.

(Plate 6.5)

Etymology

Noun in apposition, from Greek *makros* = "large" + *ophthalmos* = "eye", referring to the large eye (Eccles & Trewavas, 1989).

Diagnosis

A small-sized shallow-water *Lethrinops*. Belongs to a group characterised by the possession of a short snout, small mouth and a group of enlarged teeth on the central part of the lower pharyngeal jaw. Differs from *L. parvidens*, *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch' in the higher number of gill rakers on the first ceratobranchial (11-13 against 7-9), and differs from the rest of the group in larger eye and different male breeding colours.

Description

For descriptive statistics of measurements and meristic data see Table 6.18.

Snout shorter than eye diameter [20.0-28.6 (24.1±2.7)% against 38.9-44.9 (41.2±1.8)% head length respectively]; jaws equal anteriorly; maxillary extending to slightly below the eye. Mouth small, set low on profile; oral teeth in the outer row bicuspid, with 48-62 and 36-50 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws tricuspid and in 1-2 rows. Lower pharyngeal bone triangular, teeth 10-13 along the longest medial series and 36-42 across the posterior margin. Caudal fin emarginate. 8-9 vertical bars below the dorsal fin.

Table 6.18: Morphometric ratios and meristic data for *Lethrinops macrophthalmus*.

	Mean	SD	Range	N
Standard length (mm)	67.3	7.4	58.0-82.0	11
as % head length				
Lachrymal depth	17.4	1.5	15.1-20.8	11
Snout length	24.1	2.7	20.0-28.6	11
Lower jaw length	34.0	1.6	31.6-37.3	11
Premaxillary pedicel length	23.3	2.3	19.5-28.2	11
Cheek depth	20.8	2.1	17.3-23.9	11
Eye diameter	41.2	1.8	38.9-44.9	11
Head width (HW)	50.2	1.8	48.7-54.1	11
Interorbital width	21.6	1.6	19.1-24.2	11
as % standard length				
Head length (HL)	31.4	0.8	30.2-33.1	11
Body depth	35.5	1.7	32.8-39.0	11
Dorsal fin base length	55.3	1.5	53.7-58.3	11
Anal fin base length	19.2	1.1	17.2-21.3	11
Predorsal distance	33.7	1.2	32.4-36.6	11
Prepectoral distance	32.1	0.9	30.7-33.5	11
Prepelvic distance	36.2	1.4	33.1-38.4	11
Pre-anal distance	63.9	1.4	61.5-65.8	11
Caudal peduncle length (CPL)	21.4	0.8	20.6-22.5	11
Caudal peduncle depth	11.8	0.5	11.1-12.8	11
Other				
Interorbital width % HW	43.0	3.1	38.0-48.8	11

Lower pharyngeal jaw length (PhJL) % HL	31.5	2.5	27.0-37.3	11
Lower pharyngeal jaw width(PhJW) % PhJL	94.9	5.2	84.2-100.0	11
Dentigerous area length (DeAL) % PhJL	62.7	5.4	54.7-70.6	11
Dentigerous area width (DeAW) % PhJW	83.5	2.9	78.5-87.5	11
Dentigerous area length % DeAW	79.1	4.8	71.4-87.8	11
Caudal peduncle depth % CPL	55.2	3.0	51.7-61.8	11

	Median	Range	N
Number of teeth upper jaw	52.5	48-62	10
Number of teeth lower jaw	37.5	36-50	10
Inner rows upper jaw	1	1-2	11
Inner rows lower jaw	2	1-2	11
Gill rakers lower	12	11-13	11
Gill rakers total	17	16-18	11
Dorsal spines	16	16-17	11
Dorsal soft	10	9-11	11
Anal soft	9	8-10	11
Pectoral fin rays	14	13-15	11
Upper lateral line scales	25.5	25-26	6
Lower lateral line scales	14.5	13-15	6
Longitudinal line scales	33	32-33	6
Transverse scales above LL	5	4-5	6
Transverse scales below LL	8	8-9	6
Scales <pectoral-pelvic fin>	7	5-8	7
Cheek scales	3	2-3	9

Colour pattern

Freshly caught females and non-breeding males are silvery with a brownish appearance dorsally. Generally, the body scales shine yellow and the ventral part of the body is whitish. The upper part of the head is grey while the ventral part is white. Dorsal fin greyish with yellow spots on membrane, lappets white with orange tips. Judging from the colour of preserved specimens, breeding males are probably blue black in appearance (see Plate 6.5).

Distribution

The type examined at BMNH was collected from an unknown location, with the label only given as, 'locality: Lake Nyasa'. Of the five specimens examined from the JLB Smith Institute of ichthyology, one was from Nkhotakota (Malawi) and the other four from the South West Arm of Lake Malawi/Nyasa. During this study additional material was collected from Nkhotakota and some from Lifuwu and Senga Bay (Fig. 6.26).

Ecology

According to Eccles & Lewis (1979) the diet of *L. macrophthalmus* consists of chironomid larvae, ostracods and copepods, but also occasionally dining on cladocera and larger insects. In this study, this fish was collected up to a depth a depth of 14m; it is therefore a fish of relatively shallow waters and soft bottoms. Eccles & Trewavas (1989) state that *L. macrophthalmus* apparently is an inhabitant of sheltered shallow waters with *Vallisneria* vegetation.

Discussion

The type of *L. macrophthalmus* is a small specimen with most of its body scales missing. The large eye is however very characteristic and it was possible to compare it with other specimens collected at Nkhotakota. One specimen (RUSI 8321) used by Eccles & Lewis (1979) in the re-description of this species was examined and confirmed that it is indeed conspecific with specimens collected in this study. There is no doubt that the specimen illustrated by Konings (1995: 292, fig 1) is similar to *L. macrophthalmus*.

Specimens examined

BMNH 1908.10.27.96; immature 58.0 mm SL; 'Lake Nyasa'; coll. Capt. E.L. Rhodes; paralectotype. **RUSI: 8321**; unsexed 82.0 mm SL; North East of old jetty in Nkhotakota, Malawi; bottom trawl at unknown depth; 03/05/78. **RUSI: 050926**; male 60.0 mm SL, unsexed 64.5 mm SL, unsexed 62.5 mm SL, male 62.0 mm SL; South West Arm of Lake

Malawi (13°55'S 34°33'E); bottom trawl at 9-13 m depth; 25/11/94. **SADC/GEF 97/01/29/07**; male 68.0 mm SL; Lifuwu, Malawi; purchase from beach seine fishermen; 29/07/97. **SADC/GEF (20/01/53)**; male 67.5 mm SL, male 65.0 mm SL; Senga Bay, Malawi; bottom trawl at 14 m depth; 21/09/97. **SADC/GEF (20/31/04)**; unsexed 73.5 mm SL, unsexed 77.0 mm SL; Nkhotakota, Malawi; bottom trawl at 7-9 m depth; 22/09/97.

Lethrinops sp. 'turneri'

Lethrinops 'pink head' Turner, 1996: 93, photo p. 59.

(Plates 6.6, A4)

Etymology. Named after Professor George Turner who has worked extensively on the fishes and fisheries of Lakes Malawi/Nyasa and Malombe and who was the first to report this species from the two lakes.

Diagnosis.

Lethrinops sp. 'turneri' belongs to a group of shallow-water *Lethrinops* characterised by short snouts, small adult size and, in most members, the possession of a few enlarged teeth at the posterior median part of the lower pharyngeal bone. Within the shallow-water *Lethrinops*, *L.* sp. 'turneri' can be distinguished mainly by the colour pattern of adult males, which have the nape and the upper part of the head distinctively orange-brown coloured. *Lethrinops* sp. 'turneri' resembles *L. auritus* and *L. macrophthalmus* in small adult size and, together with *L. macrochir*, in the deep body and a terminal mouth set low on the profile. It can be distinguished from *L. auritus* by its shorter head [31.1 ± 1.0 (29.0 - 32.6) Vs 33.7 ± 1.0 (32.2 – 35.3)% SL] and predorsal distance [33.9 ± 1.5 (30.4-36.9) Vs 37.6 ± 1.6(33.6 – 39.6)% SL]; from *L. macrophthalmus* by its smaller eye [37.1 ± 1.5 (34.7 – 40.0) Vs 40.7 ± 1.8 (38.6 – 44.9)% HL]; from *L. macrochir* by the shorter premaxillary pedicel length [23.3 ± 2.0 (18.8 – 27.4) Vs 29.2 ± 2.2 (25.5 – 32.0)% HL] and from *L. parvidens* by the higher number of ceratobranchial gill rakers (11-13 Vs 7-10).

Description. Morphometric and meristic data for *L.* sp. 'turneri' are summarised in Table 6.19. Body moderately compressed with an average depth of 38.6% in standard length. Snout considerably shorter than eye diameter 27.2 ± 2.2 (23.3 – 31.1) Vs 37.2 ± 1.5 (34.7 – 40.0) % in head length.

Jaws isognathous, maxillary extending to nearly vertical from the anterior edge of the eye, teeth in the outer rows mostly bicuspid but those in the upper rows become unicuspid posteriorly. Two inner rows of tricuspid teeth in both jaws.

Lower pharyngeal bone is sub triangular and almost equilateral, teeth well spaced with 11-13 teeth along the longest medial series and 38-44 across the posterior margin which are also larger. A few teeth at the posterior medial area enlarged.

Gill rakers are short with inner crenellations. Caudal fin slightly forked and with lobes of equal length.

The vertebral column has a total of 29-30 vertebrae comprising of 13-14 abdominal and 15-16 caudal vertebrae.

Table 6.19. Morphometric ratios and meristics for *Lethrinops* sp. 'turneri'. Summary values include holotype (H).

	H	Mean	SD	Range	N
Standard length (mm)	77.0	73.5	9.1	56.0-94.0	27
as % head length					
Lachrymal depth	18.0	18.6	1.6	15.6-22.9	27
Snout length	30.2	26.6	2.1	22.8-30.5	27
Lower jaw length	33.1	34.0	2.0	30.4-37.6	27
Premaxillary pedicel length	24.5	23.2	2.0	19.4-27.4	27
Cheek depth	26.5	23.4	2.0	19.4-28.0	27
Eye diameter	34.7	37.6	2.0	34.7-42.9	27
Head width (HW)	46.9	48.3	1.7	44.0-52.9	27
Interorbital width	20.8	23.4	1.7	20.5-28.2	27
as % standard length					
Head length (HL)	31.8	31.0	1.0	28.8-32.6	27
Body depth	41.6	38.7	1.5	33.9-41.6	27
Dorsal fin base length	58.4	57.3	1.3	54.2-59.1	27
Anal fin base length	21.4	20.9	0.9	19.4-22.2	27
Predorsal distance	35.1	34.1	1.3	31.4-36.9	27
Prepectoral distance	33.8	31.5	1.2	29.3-33.8	27

Prepelvic distance	37.7	36.3	1.3	33.1-38.0	27
Pre-anal distance	65.6	64.9	2.0	60.1-67.7	27
Caudal peduncle length (CPL)	19.5	19.6	0.9	17.4-21.5	27
Caudal peduncle depth	13.6	12.6	0.5	11.1-13.6	27
Other					
Interorbital width % HW	44.3	48.5	3.4	42.9-57.3	27
Lower pharyngeal jaw length (PhJL) % HL	31.0	30.9	1.7	27.1-34.4	26
Lower pharyngeal jaw width(PhJW) % PhJL	96.1	96.5	4.1	86.8-102.9	26
Dentigerous area length (DeAL) % PhJL	67.1	62.0	4.5	51.3-70.0	26
Dentigerous area width (DeAW) % PhJW	76.7	81.1	3.5	72.3-87.9	26
Dentigerous area length % DeAW	91.1	79.4	6.5	67.2-95.5	26
Caudal peduncle depth % CPL	70.0	64.4	4.2	55.3-74.1	26
Meristics	H	Median		Range	N
Number of teeth upper jaw	63	62		50-71	26
Number of teeth lower jaw	51	42		37-51	26
Inner rows upper jaw	2	2		1-2	26
Inner rows lower jaw	2	2		1-2	27
Gill rakers lower	12	11		11-13	27
Gill rakers total	18	17		16-18	27
Dorsal spines	16	16		14-17	27
Dorsal soft	10	10		10-12	27
Anal soft	9	9		8-10	27
Pectoral fin rays	15	15		14-16	27
Upper lateral line scales	23	24		21-27	26
Lower lateral line scales	13	14		13-16	26
Longitudinal line scales	32	32		30-33	26
Transverse scales above LL	5	4		4-6	26
Transverse scales below LL	9	9		8-9	26
Scales <pectoral-pelvic fin>	7	5		3-7	26
Cheek scales	2	2		2-3	27

Colour pattern

The body is ginger-grey with an orange iridescence. Ripe males with bright blue snout and pale blue opercula. The upper part of the head and the nape are orange-brown. Dorsal fins creamy-grey with orange spots, a dark submarginal band extending and widening posteriorly, lappets whitish with orange tips. Caudal fin dark with orange spots and stripes. Anal fin darker distally with orange margin, about seven egg-spots clearly visible. Turner (1996) reported that females and immature males are silvery. There are 8-9 thin dark vertical bars below the dorsal fin.

Distribution. The species is abundant in Lake Malombe but also recorded off Fowo and Namiasi in the southern part of Lake Malawi (Turner 1996). During this study, specimens of *L.* sp. 'turneri' were collected from Lake Malombe, the southern part of the Lake Malawi (South East & South West Arms) and in Domira Bay, (Fig. 6.27) and from very shallow depths (2-15 m).

Ecology

They are fish of small adult size (max. 120 mm TL) with size at maturity sometimes less than 60 mm TL. Females produce approximately 30 eggs per batch (data from dissection of ovaries: Turner, 1996). The major food items recorded from stomachs of 5 specimens from Lake Malombe were chironomids, copepods, chaoborus larvae, ostracods, nematodes and diatoms. Algal remains, detritus and sand were found in all stomachs (Msukwa, per.com.). So they are predominantly bottom-feeding carnivores. This observation agrees with those reported by Turner (1996).

Discussion:

Turner (1996) noted that at least one specimen used in the description of *L. auritus* by Eccles & Lewis (1979) and deposited in the Monkey Bay field museum has a gill raker form identical to the species he called *L.* sp. 'pink head'. I have examined and measured this and other specimens (deposited in the Monkey Bay field museum and in the JLB Smith Institute of Ichthyology collection) and have confirmed they belong to the new species, *L.* sp. 'turneri', which is clearly distinct from *L. auritus*. The two specimens

(RUSI 08317/1-2) included in *L. auritus* by Eccles & Lewis (1979) are included in L. sp. 'turneri'. Seven specimens collected by Greenwood from the south east arm of Lake Malawi/Nyasa on 28/11/94 and deposited in the JLB Smith Institute of Ichthyology (RUSI 050983/1-7) as *Lethrinops* cf. auritus, also belong to this species. Konings (1995: pg. 290-291, photo 1-7) gives photographic illustrations of small *Lethrinops* of the *L. auritus* 'species group'. All of them have a characteristic golden or yellow nape, but none of them is a true *L. auritus*.

Placidochromis longimanus is reported to have similar meristics and morphometerics to *L.* sp. 'turneri' (Turner 1996). However, on examining specimens of *P. longimanus*, they do not have *Lethrinops*-type dentition and therefore cannot be included in the genus *Lethrinops* as it is currently defined.

Specimens examined:

RUSI: 050983; male 81.5 mm SL, unsexed 85.5 mm SL, male 94.0mm SL, male 93.0 mm SL, male 83.5 mm SL, male 76.5 mm SL, male 77.5 mm SL; South East Arm of Lake Malawi (14°20'S 35°16'E); 15 m depth; 28/11/94. **RUSI 08317/ 1-2**, male 59.0 mm SL, female 60.5 mm SL, Monkey Bay beach, Malawi; seine net. **SADC/GEF 97/16/61/16-17**; female 76.0 mm SL, female 75.0 mm SL; Domira Bay, Malawi; gill nets set at 3 m depth; 05/06/97. **SADC/GEF (CR48**, specimen 01-06); male 77.0 mm SL, male 70.0 mm SL, male 70.0 mm SL, unsexed 72.0 mm SL, male 68.5 mm SL, male 70.5 mm SL; Mvera, Lake Malombe, Malawi; seine nets; 22/11/98. **SADC/GEF (CR48, specimen 07-13)**; unsexed 77.0 mm SL, unsexed 66.5 mm SL, male 80.0 mm SL, male 70.5 mm SL, male 69.0 mm SL, male 71.0 mm SL, male 68.5 mm SL; Lake Malombe, purchase from Ulongwe market, Malawi; 21/11/98. **SADC/GEF 99/44/55/03**; female 67.5 mm SL, female 68.0 mm SL; Mgawi/Nsala, 13°51'S 34°35'E, Malawi; beach seine catch; 08/02/99. **SADC/GEF 97/24/53/163**; unsexed 56.0 mm SL; Thumbi East Island, South East Arm at the entrance to Monkey Bay; gill net at 2-2.8 m depth; 14/11/97.

6.12 *Lethrinops auritus* (Regan, 1922)

Haplochromis aurita Regan, 1922: 699, fig. 14; Ufermann et al., 1987: 184

Lethrinops aurita (part), Trewavas, 1931: 144; Jackson, 1961: 586; Jackson *et al.*, 1963:85.

Lethrinops auritus Bowmaker et al., 1978: 1229; Eccles & Lewis 1979:5, fig. 3; Lewis, 1980: 36; Staeck, 1983: 236, photo. 119; Axelrod et al., 1986: pl. 324; Ufermann et al., 1987: 262.

Lethrinops auritus: Holtje, 1988: 72, phot. (non *L. auritus*); Eccles & Trewavas, 1989: 133, fig. 65; Konings, 1995: 290, phot.1, 3 & 4(non *L. auritus*). Turner, 1996:91.

(Plates 6.7, D3, D4 & D6)

Etymology

Adjective, from the Latin *auratus* = "golden" (Eccles & Trewavas, 1989)

Diagnosis

Lethrinops auritus belongs to a group of shallow water *Lethrinops* characterised by short snouts, small adult size and, in most members, the possession of a few enlarged teeth at the posterior median part of the lower pharyngeal bone. Within this group, *L. auritus* can be distinguished mainly by the body melanin pattern of freshly caught individuals, which consist of a supra-pectoral, supra-anal and caudal spot. Differs from *L.* sp. 'domira blotch' in higher number of ceratobranchial gill rakers (10-12 vs 8-9) and in longer head [33.7±1.0 (32.2-35.3) vs 29.8±0.8 (29.2-30.4) % SL]. Can easily be distinguished from *L.* sp. 'turneri and *L.* sp. 'black dorsal auritus' not only on body melanin, but also in head length. For *L. auritus*, head length 33.7±1.0 (32.2-35.3) % SL against 31.0±1.0 (28.8-32.6) and 32.5±0.4 (31.7-32.9) % SL for *L.* sp. 'turneri and *L.* sp. 'black dorsal auritus' respectively. It is also distinct from *L. macrochir* by lacking the yellow coloration on the head and by relatively smaller number of ceratobranchial gill rakers (10-12 vs 12-14).

Description

Morphometric and meristic data for *L. auritus* for the holotype and other specimens examined are summarised in Table 6.20.

Snout with a convex profile shorter than eye diameter [27.8±2.4 (24.1-31.3) Vs 37.7±1.1 (36.4-39.5) % in head length]. Jaws equal anteriorly; maxillary reaching vertical from the anterior edge of the eye or slightly below the eye. Oral teeth in the outer row bicuspid, 42-78 teeth in the outer row of upper jaw and 30-48 in the lower jaw, inner teeth in both jaws tricuspid, 1-2 inner rows in the upper and lower jaws. Lower pharyngeal bone sub-triangular, a few teeth at the central part of the bone slightly enlarged, teeth compressed and with anterior cusps straight, 10-14 along the longest medial series and 32-40 across the posterior margin. Caudal emarginate. Principal melanin pattern consist of supra-pectoral, supra-anal and caudal spots.

Table 6.20: Morphometric ratios and meristics for *Lethrinops auritus*. Summary values include holotype (H).

	H	Mean	SD	Range	N
Standard length (mm)	64.0	69.9	4.8	58.0-74.5	13
as % head length					
Lachrymal depth	14.8	18.1	1.7	14.8-21.7	13
Snout length	24.3	27.8	2.4	24.1-31.3	13
Lower jaw length	36.7	35.4	1.5	33.2-37.5	13
Premaxillary pedicel length	21.4	24.1	2.1	21.3-27.2	13
Cheek depth	22.4	24.5	1.7	21.2-26.4	13
Eye diameter	39.5	37.7	1.1	36.4-39.5	13
Head width (HW)	47.6	47.7	2.6	44.0-53.2	13
Interorbital width	22.4	22.8	1.5	21.0-25.7	13
as % standard length					
Head length (HL)	32.8	33.7	1.0	32.2-35.3	13
Body depth	35.2	37.8	2.2	33.6-41.0	13
Dorsal fin base length	53.1	54.7	0.8	53.1-55.9	13
Anal fin base length	21.1	20.8	0.9	18.8-21.7	13

Predorsal distance	36.7	37.9	1.1	35.4-39.6	13
Prepectoral distance	31.3	33.0	1.2	31.3-35.4	13
Prepelvic distance	36.7	36.4	1.5	33.6-39.6	13
Pre-anal distance	60.9	63.9	1.6	60.9-66.7	13
Caudal peduncle length (CPL)	19.5	19.0	0.8	17.3-20.1	13
Caudal peduncle depth	11.7	12.6	0.7	11.4-13.8	13
Other					
Interorbital width % HW	47.0	47.8	3.9	43.3-56.4	13
Lower pharyngeal jaw length (PhJL) % HL	-	33.5	1.7	31.7-37.6	10
Lower pharyngeal jaw width(PhJW) % PhJL	-	87.8	4.9	82.9-97.5	10
Dentigerous area length (DeAL) % PhJL	-	67.8	3.5	63.8-74.3	10
Dentigerous area width (DeAW) % PhJW	-	80.4	4.6	72.9-87.9	10
Dentigerous area length % DeAW	-	96.5	7.9	86.3-113.7	10
Caudal peduncle depth % CPL	60.0	66.4	5.2	58.6-76.2	13
Meristics	H	Median		Range	N
Number of teeth upper jaw	60	59		42-78	13
Number of teeth lower jaw	42	40		30-48	13
Inner rows upper jaw	1	1		1-2	13
Inner rows lower jaw	1	2		1-2	13
Gill rakers lower	10	11		10-13	13
Gill rakers total	15	16		14-18	13
Dorsal spines	15	15		15-16	13
Dorsal soft	11	10		9-11	13
Anal soft	10	9		9-10	13
Pectoral fin rays	15	15		14-15	13
Upper lateral line scales	22	23		20-27	13
Lower lateral line scales	11	13		11-16	13
Longitudinal line scales	30	31		28-32	13
Transverse scales above LL	5	4		3-5	13
Transverse scales below LL	8	8		8-9	13

Scales <pectoral-pelvic fin>	6	5	4-6	13
Cheek scales	3	3	2-3	13

Colour pattern

Both freshly caught females and non-breeding males are silvery with 7-8 vertical bars below dorsal fin and characteristic body markings which consist of supra-pectoral, supra-anal and caudal spots. The caudal and supra-anal spots, however, fade very quickly after death.

Distribution

Lethrinops auritus was taken with beach seine from very shallow waters on soft sandy bottoms. In the extreme north it was taken from a pure muddy substrate. Its distribution over the lake is as shown in Figure 6.27.

Ecology

The gut content of those specimens examined consisted mainly of chironomid larvae, copepods and nematodes but also diatoms, sand, detritus and mites.

Discussion

In *L. auritus* and most short-snouted species the maxillary is extending to below the eye. Regan (1922) in his synopsis of the Nyassa species of *Haplochromis* considered *H. auritus* (= *L. auritus*) as spotted with outer teeth tricuspid, lower jaw not projecting and differing from all such forms in maxillary extension except for *H. macrochir* which he noted had a different coloration (silvery with faint dark vertical bars). Therefore in the original description of *L. auritus*, the dark spot on the lateral line below the spinous dorsal, is clearly indicated. It is unfortunate therefore that Trewavas (1931) put *L. macrochir* in synonymy with *L. auritus* without taking this character into account.

Eccles & Lewis (1979) resurrected the specific status of *L. auritus* and re-described it together with the other short snouted *Lethrinops* namely *L. macrochir*, *L. macrophthalmus* and *L. parvidens*. They diagnosed *L. auritus* as having no enlarged pharyngeal teeth and with 12 to 13 gill rakers on the lower arch. They claimed that *L. auritus* differs from *L. macrochir* in the relatively smaller head, shallow body, shorter premaxillary pedicel and the larger eye and squat form of gill rakers; from *L. macrophthalmus* and *L. parvidens* in the absence of enlarged postero- medial pharyngeal teeth; from *L. parvidens* in higher number of gill rakers. In this study, the only consistent differences between *L. auritus* and *L. macrochir* is in their adult size, melanin pattern and coloration of immature males and females and coloration of the breeding males.

Lethrinops auritus is a small fish hardly reaching 75mm SL with three clear spots on the supra-pectoral supra-anal and caudal spot. The last two spots fade very quickly after the death of the fish and if not fixed immediately, only the supra-pectoral spot remains visible. *Lethrinops macrochir*, on the other hand, is a medium sized fish attaining with a recorded standard length of 118mm and with a distinctive yellow coloration on the lower part of the head and gular region. Breeding males are bluish with yellow body iridescence like *L. auritus* but unlike the latter, the dorsal fin margins of *L. macrochir* are bright yellow.

Specimens examined

BMNH 1921.9.6.133; male 64.0 mm SL; 'Lake Nyasa'; coll. Wood; holotype.
SADC/GEF (27/4/12); male 69.5 mm SL, male 65.0 mm SL, male 72.0 mm SL, male 58.0 mm SL, male 69.5 mm SL, male 72.5 mm SL, male 72.0 mm SL; Mwaya (near the mouth of river Mbaka), Tanzania; beach seine at 2 m depth; 18/12/97. **SADC/GEF 98/01/37/01**; male 71.5 mm SL; Senga Bay, Malawi; purchase from beach seine fishermen; 29/01/98. **SADC/GEF 98/47/01/01**; male 74.0 mm SL, male 72.0 mm SL; Chintheche, (in-front of Zambani lodge), Malawi; beach seine catch; 22/07/98. **SADC/GEF 99/44/55/01-02**; male 74.0 mm SL, male 74.5 mm SL; Mgawi/Nsala, 13°51'S 34°35'E, Malawi; beach seine catch; 08/02/99.

6.13 *Lethrinops macrochir* (Regan, 1922)

Haplochromis macrochir Regan, 1922: 712, fig. 24; Trewavas, 1931: 144 (synonymy with *Lethrinops aurita*); Ufermann *et al.*, 1987: 197.

Lethrinops aurita (part), Trewavas, 1931: 144; Jackson, 1961:586; Jackson *et al.*, 1963:85; Bowmaker, et al., 1978:1229; Axelrod & Burgess, 1983: 186 (photo).

Lethrinops macrochir, Eccles and Lewis, 1979: 7, fig 4 (rehabilitation of *L. macrochir*); Ufermann *et al.*, 1987: 263; Eccles & Trewavas, 1989:135, fig. 67; Konings, 1995: 293, photo 6; Turner, 1996: 91, photo pg. 59

(Plate 6.8)

Etymology

Noun in apposition, from Greek "makros" = "large" + "cheir" = "hand", referring to the long pectoral fins (Eccles & Trewavas, 1989).

Diagnosis

A medium-sized species attaining a standard length of about 120mm. Differs from all other members of the shallow water short-snouted *Lethrinops* in the bright yellow coloration of the lower part of the head and gular region. Differs from *L. macrophthalmus* in smaller eye [36.3±2.3 (31.9-39.6) vs 41.2±1.8 (38.9-44.9)% head length] and deeper body [40.5±1.7 (37.2-44.3) vs 35.5±1.7 (32.8-39.0)% standard length]. Only distinguished from *L. auritus* by the absence of the supra-pectoral, supra-anal and caudal spots and the yellow ventral surface.

Description

Morphometric and meristic data for *L. macrochir* for the holotype and other specimens examined are summarised in Table 6.21.

Body depth 40.5±1.7 (37.2-44.3) % SL. Snout with a slightly convex profile equal to or shorter than eye diameter [30.1±1.8 (26.0-35.8) vs 36.3±2.3 (31.9-39.6)]% HL. Jaws equal anteriorly; maxillary reaching vertical from the anterior edge of the eye. Oral teeth in the outer row bicuspid, 54-90 teeth in the outer row of upper jaw and 34-58 in the lower, inner teeth in both jaws tricuspid , 1-3 inner rows in the upper and lower jaws. Lower pharyngeal bone sub-triangular, with a group of 12 to 20 teeth at the posterio-medial area enlarged, anterior teeth compressed, with anterior cusps, and with ends turned forward or straight. There are 10-14 teeth along the longest medial series and 31-42 across the posterior margin. Caudal fin emarginate. Principal melanin pattern consists of only vertical bars, 8-9 of which are below dorsal fin.

Table 6.21. Morphometric ratios and meristics for *Lethrinops macrochir*. Summary values include lectotype (L).

	L	Mean	SD	Range	N
Standard length (mm)	109.5	95.7	15.5	70.0-118.0	23
as % head length					
Lachrymal depth	21.8	21.1	1.8	17.4-25.5	23
Snout length	32.1	30.1	2.6	26.0-35.8	23
Lower jaw length	35.5	36.1	1.8	31.9-39.7	23
Premaxillary pedicel length	31.8	28.4	1.9	25.5-32.0	23
Cheek depth	27.6	27.0	2.6	21.2-32.0	23
Eye diameter	34.7	36.3	2.3	31.9-39.6	23
Head width (HW)	44.7	47.5	2.9	43.3-55.4	23
Interorbital width	22.4	22.7	1.5	19.2-25.4	23
as % standard length					
Head length (HL)	34.7	34.1	1.4	32.0-36.6	23
Body depth	41.1	40.5	1.7	37.2-44.3	23
Dorsal fin base length	54.8	55.8	2.4	51.7-61.0	23
Anal fin base length	18.7	20.3	0.9	18.7-21.9	23
Predorsal distance	39.7	37.1	1.8	33.3-41.0	23
Prepectoral distance	33.8	34.4	1.7	31.9-38.3	23
Prepelvic distance	39.7	38.8	1.7	36.7-44.8	23
Pre-anal distance	65.8	65.7	2.1	63.5-71.6	23
Caudal peduncle length (CPL)	19.2	18.7	1.1	16.7-20.2	23
Caudal peduncle depth	12.8	12.8	0.5	11.5-13.8	23

Other					
Interorbital width % HW	50.0	47.8	3.4	40.0-53.9	23
Lower pharyngeal jaw length (PhJL) % HL	29.7	31.1	1.6	27.9-33.9	22
Lower pharyngeal jaw width(PhJW) % PhJL	88.5	89.6	4.8	81.3-101.1	22
Dentigerous area length (DeAL) % PhJL	60.2	58.8	3.8	50.5-66.0	22
Dentigerous area width (DeAW) % PhJW	76.0	77.5	3.6	72.1-86.3	22
Dentigerous area length % DeAW	89.5	84.9	6.8	73.4-100.0	22
Caudal peduncle depth % CPL	64.3	68.8	5.2	60.9-80.6	23
Meristics	L	Median		Range	N
Number of teeth upper jaw	90	68		54-90	20
Number of teeth lower jaw	49	46		34-58	20
Inner rows upper jaw	1	2		1-3	22
Inner rows lower jaw	2	2		1-3	22
Gill rakers lower	14	13		10-14	23
Gill rakers total	18	17		14-19	23
Dorsal spines	16	16		14-17	23
Dorsal soft	10	10		9-10	23
Anal soft	9	9		9-10	23
Pectoral fin rays	15	15		15-16	23
Upper lateral line scales	25	25		22-28	23
Lower lateral line scales	14	15		13-17	23
Longitudinal line scales	31	32		30-33	23
Transverse scales above LL	6	5		4-6	23
Transverse scales below LL	9	9		8-10	23
Scales <pectoral-pelvic fin>	5	5		4-8	23
Cheek scales	4	3		3-4	23

Colour pattern

Freshly caught females and non-breeding males are silvery with yellow head and ventral region. Body silvery with yellow lustre; 8-9 faint vertical bars below dorsal fin. Dorsal fin pale grey with yellow spots on membranes. Lappets tipped orange. Sexually mature and breeding males are blue-green with the dorsal fin margin bright yellow orange. Anal fin dark proximally with creamy 'egg spots' and bright red distally.

Distribution

Eccles & Lewis (1979) report a depth range of 9-18m. Specimens examined from the RUSI collections were trawled from a depth range of 15-27m. During this study, some specimens were collected from a depth range of 3-15m, mainly from the southern part of the lake. During the SADC/GEF Lake Malawi/Nyasa Project research surveys, *L. macrochir* was caught only at 10 m. Figure 6.26 shows localities were specimens used in this study have been collected. The types are from unknown localities.

Ecology

According to Eccles & Lewis (1979), the diet of *L. macrochir* consist of benthic invertebrates, especially chironomids. Turner (1996) also reported stomach contents of chironomids as well as diatoms and detritus.

Discussion

During this study no measurement or meristic character could be found which could easily distinguish specimens of *L. macrochir* from those of *L. auritus*. Based on a similar observation, Trewavas (1931) considered this species to be conspecific with *L. auritus* but Eccles & Lewis (1979) disagreed, pointing out that *L. auritus* has a smaller size at maturity. Based on the basic melanin pattern and general body coloration of females and non-breeding males of *Lethrinops auritus* and *L. macrochir*, it is strongly believed from this work, that the two are distinct species. There is no difficulty in distinguishing these species in practice, as even very small immature *L. macrochir* display a bright yellow ventral surface, including the pelvic and anal fins (see plate on p.59 of Turner 1996); live specimens of *L. auritus* on the other hand, show clear body spots.

Specimens examined

BMNH 1921.9.6.186-187; male 105.5mm SL, male 109.5mm SL; 'Lake Nyasa'; coll. Wood; Lectotype and paralectotype respectively. **RUSI: 050978**; female 113.5mm SL; South East Arm of Lake Malawi (14°20'S 35°16'E); bottom trawl at 15m depth; 28.11.94. **RUSI: 050980**; male 103.5 mm SL, male 87.0 mm SL, male 114.0 mm SL, male 115.0 mm SL; South East Arm of Lake Malawi (14°20'S 35°16'E); bottom trawl at 15 m depth; 28.11.94. **RUSI: 8323**; male 100.5 mm SL; Lake Malawi (14°06'S 34°35'E) – White House, Malawi; bottom trawl at 18-27 m depth; 20/07/91. **RUSI: 8322**; male 105.5 mm SL; Mazinzi Bay (14°06'S 34°56'E); bottom trawl in 22-27 m depth off Kanjedza island; 15/06/77. **SADC/GEF 96/02/03/64**; male 110.5 mm SL; Senga Bay, Malawi; purchase from fishermen; 13/09/69. **SADC/GEF 96/01/01/17**; male 91.5 mm SL; Senga Bay, Malawi; purchase from fishermen; 22/07/96. **SADC/GEF 97/01/21/15-16**; female 80.5 mm SL, female 77.0 mm SL; Senga Bay, Malawi; purchase from fishermen; 12/05/97. **SADC/GEF 97/16/61/20**; female 83.5 mm SL; Domira Bay, Malawi; bottom set gill nets at 3 m depth; 05/06/97. **SADC/GEF 98/34/01/01-03**; female 118.0 mm SL, female 107 mm SL, female 109.0 mm SL; Leopard Bay, Malawi; bottom trawl at 12.5-14 m depth; 23/04/98. **SADC/GEF 99/01/50/08-13**; female 93.0 mm SL, female 74.5 mm SL, male 75.5 mm SL, unsexed 70.0 mm SL, female 78.0 mm SL, female 83.0 mm SL; Senga Bay, Malawi; purchase from fishermen; 16/04/99.

6.14 *Lethrinops* sp. 'domira blotch'

(Plate 6.9)

Etymology

A working name referring to the locality at which the specimens were collected and the supra pectoral spot evident in members of this taxa.

Diagnosis

A small relatively deep-bodied shallow water *Lethrinops* distinguished from all other members of the short-snouted *Lethrinops* by the low number of ceratobranchial gill rakers and the presence of 1-2 dark blotches on flanks and caudal peduncle. *Lethrinops* sp. 'domira blotch' differs from all other short-snouted shallow-water *Lethrinops* except *L. parvidens* and *L.* sp. 'parvidens deep' in lower number of ceratobranchial gill rakers (8-9 as opposed to 10-14) and from *L. parvidens* and *L.* sp. 'parvidens deep' in the presence of a suprapectoral blotch and caudal spot and in shorter head [29.8±0.8 (29.2-30.4) vs 33.9±0.9 (31.6-34.9) and 32.3±0.7 (31.3-33.9) % SL].

Description

For descriptive statistics of measurements and meristic data see Table 6.22.

Snout with a slightly convex profile shorter than diameter of the eye [30.1±1.3 (29.2-31.1) vs 36.0±0.8 (35.4-36.6) % in head length; jaws equal anteriorly; maxillary extending to vertical to the anterior part of the eye. Oral teeth in the outer row bicuspid in lower jaw but upper bicuspid anteriorly becoming unicuspid on the posterior end, with 60 and 41-42 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in one row. Lower pharyngeal bone triangular, 10 teeth along the longest medial series and 33-37 across the posterior margin. Caudal fin emarginate. A dark patch/spot on the dorsum below the spinous dorsal formed by thickening of 3^{rd} to 5^{th} vertical bar and a caudal spot is present.

Table 6.22: Morphometric ratios and meristic data for *Lethrinops* sp. 'domira blotch'.

	Mean	SD	Range	N
Standard length (mm)	78.8	1.1	79.0-80.5	2
as % head length				
Lachrymal depth	21.7	0.6	21.3-22.1	2
Snout length	30.1	1.3	29.2-31.1	2
Lower jaw length	33.5	2.6	31.7-35.3	2
Premaxillary pedicel length	21.3	3.6	18.8-23.8	2
Cheek depth	27.4	0.4	27.1-27.7	2
Eye diameter	36.0	0.8	35.4-36.6	2
Head width (HW)	48.4	0.7	47.9-48.9	2
Interorbital width	20.9	1.8	19.6-22.1	2
as % standard length				
Head length (HL)	29.8	0.8	29.2-30.4	2
Body depth	33.9	0.4	33.5-34.2	2
Dorsal fin base length	57.0	1.0	56.3-57.8	2
Anal fin base length	20.1	0.6	19.6-20.5	2
Predorsal distance	31.0	0.9	30.4-31.6	2
Prepectoral distance	31.0	0.0	31.0-31.1	2
Prepelvic distance	36.1	0.0	36.0-36.1	2
Pre-anal distance	63.6	1.3	62.7-64.6	2
Caudal peduncle length (CPL)	18.5	1.1	17.7-19.3	2
Caudal peduncle depth	13.5	0.3	13.3-13.7	2
Other				
Interorbital width % HW	43.0	3.1	40.9-45.2	2
Lower pharyngeal jaw length (PhJL) % HL	29.9	0.2	29.8-30.0	2
Lower pharyngeal jaw width(PhJW) % PhJL	88.1	6.7	83.3-92.9	2
Dentigerous area length (DeAL) % PhJL	65.5	2.3	63.9-67.1	2

Dentigerous area width (DeAW) % PhJW	83.2	0.2	83.1-83.3	2
Dentigerous area length % DeAW	89.5	3.5	87.0-92.0	2
Caudal peduncle depth % CPL	73.0	2.9	71.0-75.0	2

	Median	Range	N
Number of teeth upper jaw	60	60-60	2
Number of teeth lower jaw	41	41-42	2
Inner rows upper jaw	1	1-1	2
Inner rows lower jaw	1	1-1	2
Gill rakers lower	9	8-9	2
Gill rakers total	13	12-13	2
Dorsal spines	16	15-16	2
Dorsal soft	12	11-12	2
Anal soft	9	9-9	2
Pectoral fin rays	16	15-16	2
Upper lateral line scales	26	25-26	2
Lower lateral line scales	15	14-15	2
Longitudinal line scales	33	32-33	2
Transverse scales above LL	4	4-4	2
Transverse scales below LL	8	8-8	2
Scales <pectoral-pelvic fin>	4	4-4	2
Cheek scales	3	2-3	2

Colour pattern

Both specimens collected from Domira Bay were females. They were silvery with 7-8 faint vertical bars under the dorsal fin. A large supra-pectoral blotch, and a smaller spot on the caudal end of the caudal peduncle were easily visible. There is no supra-anal spot.

Distribution

All specimens were collected at Domira Bay (Malawi) (Fig.6.28).

Ecology

The two members of this taxon were obtained from gill nets set at a depth of 3m on a soft sandy substratum. The stomach contents of the two fish were not analysed for diet.

Discussion

This species was first identified in the field as *L. parvidens* based on the shape and dentition of the pharyngeal apparatus and the number of ceratobranchial gill rakers. In body shape and colour pattern this fish resembles members of the genus *Otopharynx* more than *Lethrinops* species, but the shape of the lower jaw and dentition is of the characteristic '*Lethrinops*'-type. Turner (1996) collected a few specimens from a depth of 55m off Domira Bay, which had similar colour pattern but different gill raker number (10-12) and referred to them as *Lethrinops* sp. 'Domira blue'. These do not appear to belong to *L.* sp. 'domira blotch' but probably represent a different deep-water species.

Specimens examined

SADC/GEF 97/16/61/18-19; unsexed 80.5 mm SL, female 79.0 mm SL; Domira Bay, Malawi; gill nets set at 3 m depth; 05/06/97.

6.15 *Lethrinops parvidens* Trewavas, 1931

Lethrinops parvidens Trewavas, 1931:141; Jackson, 1961: 585; Jackson et al., 1963:84; Turner, 1977a: 233; Turner, 1977b: 264: Tweddle & Turner, 1977: 388, fig. 4, 9-10, tab. 1-3; Bowmaker *et al.*, 1978: 1229, Eccles & Lewis 1979: 1, fig.1; Lewis 1981: 750, tab. 1: Mayland, 1982: 173; Axelrod & Burgess, 1986: 186, phot.; Axelrod et al., 1986: pl. 323; Ufermann et al., 1987: 264; Eccles & Lewis, 1989: 136, fig. 68; Konings, 1995: 295; Turner, 1996: 94

(Plates 6.10 & B4)

Etymology

Noun in apposition, from Latin *parvus* which means 'small' and *dens* which means 'tooth'. It refers to the small and weak oral dentition.

Diagnosis

A small to medium-sized shallow-water short-snouted *Lethrinops* distinguished from all such other members except *L.* sp. 'parvidens deep' and *L.* sp. 'domira blotch' by the lower number of ceratobranchial gill rakers. Differ from *L.* sp. 'domira blotch' in lacking the blotch and from *L.* sp. 'parvidens deep' in smaller adult size and in shape of caudal fin which is not 'moon shaped'.

Description

For descriptive statistics of measurements and meristic data see Table 6.23. Snout with a slightly convex profile equal to or shorter than eye diameter [29.2±2.4 (25.2-34.1) vs 37.5±2.6 (32.7-42.6)% in head length]. Jaws equal anteriorly; maxillary ending vertical with the anterior edge of the eye not extending to below eye. Oral teeth in the outer row bicuspid anteriorly but in upper jaw the teeth become unicuspid posteriorly, with 58-76 and 23-48 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 1-2 rows. Lower pharyngeal sub-triangular, acute anterior with long anterior blade, a few teeth at the posterior median are enlarged and blunt, other teeth compressed with an anterior cusp and with ends turned forward, a few anterior sometimes with ends turned backwards as in members of *Tramitichromis*. There are teeth 10-13 along the longest medial series and 34-38 across the posterior margin. Caudal deeply forked. Body melanin pattern consist of only traces of wide dark vertical bars 7-8 of which are below the dorsal fin.

Table 6.23: Morphometric ratios and meristic data for *Lethrinops parvidens*.

	Mean	SD	Range	N
Standard length (mm)	94.0	14.3	74.0-123.5	16
as % head length				
Lachrymal depth	21.6	1.8	18.2-25.0	16
Snout length	29.2	2.4	25.2-34.1	16
Lower jaw length	35.1	2.3	30.2-39.2	16
Premaxillary pedicel length	24.9	1.2	22.8-27.0	16
Cheek depth	26.8	2.4	23.0-31.3	16
Eye diameter	37.5	2.6	32.7-42.6	16
Head width (HW)	46.9	1.7	44.3-50.0	16
Interorbital width	22.6	0.8	21.5-24.2	16
as % standard length				
Head length (HL)	33.3	0.9	31.6-34.9	16
Body depth	37.1	1.6	34.8-39.2	16
Dorsal fin base length	55.8	1.7	52.8-59.5	16
Anal fin base length	19.7	1.1	18.3-22.2	16
Predorsal distance	36.3	1.6	33.2-39.0	16
Prepectoral distance	33.0	1.1	31.3-35.3	16
Prepelvic distance	37.8	1.2	35.8-40.0	16
Pre-anal distance	65.0	1.2	62.8-66.5	16
Caudal peduncle length (CPL)	18.5	1.2	16.4-20.9	16
Caudal peduncle depth (CPD)	12.8	0.7	11.5-13.9	16
Other				

Interorbital width % HW	48.3	2.4	43.7-51.6	16
Lower pharyngeal jaw length (PhJL) % HL	28.8	1.4	27.2-31.0	15
Lower pharyngeal jaw width(PhJW) % PhJL	87.2	5.7	76.9-98.6	15
Dentigerous area length (DeAL) % PhJL	63.1	4.5	53.3-69.9	15
Dentigerous area width (DeAW) % PhJW	77.4	4.7	64.9-83.3	15
Dentigerous area length % DeAW	94.1	8.5	81.0-110.0	15
Caudal peduncle depth % CPL	69.0	5.6	60.6-78.1	16

	Median	Range	N
Number of teeth upper jaw	64	58-76	15
Number of teeth lower jaw	40	23-48	15
Inner rows upper jaw	1	1-2	16
Inner rows lower jaw	1	1-2	16
Gill rakers lower	8	7-9	16
Gill rakers total	13	12-14	16
Dorsal spines	16	14-17	16
Dorsal soft	11	10-12	16
Anal soft	9	9-10	16
Pectoral fin rays	15	15-16	16
Upper lateral line scales	24	22-30	16
Lower lateral line scales	15.5	12-19	16
Longitudinal line scales	32	31-34	16
Transverse scales above LL	5	4-5	16
Transverse scales below LL	9	6-9	16
Scales <pectoral-pelvic fin>	5	4-8	16
Cheek scales	3	3-4	16

Colour pattern

Seven female specimens which were all caught at a depth of 22.2-31.5m in an intermediate habitat around Mara rocks (Usisya, Malawi), all had an overall silvery coloration with orange iridescence on head region and the dorsum shines pinkish when freshly caught. After preservation these specimens remained only silvery, with 7-8 dark vertical bars below the dorsal fin.

Distribution

The syntypes examined were all from the eastern shore of the South East Arm of Lake Malawi, the collecting locality is stated as from Fort Johnston to Fort Maguire. Specimens of *Lethrinops parvidens* have been collected from localities indicated in Figure 6.27. According to Eccles & Lewis (1979) this species has also been collected from Metangula (Mozambique coast) and from all around the South East Arm and northwards to Nkhata Bay. It may be quite likely that this fish has a lake-wide distribution.

Ecology

Eccles & Lewis (1979) noted that *Lethrinops parvidens* is very abundant in depths of 9-36m (5-20 fathoms). During this study, specimens were collected from a depth of 3-31.5 m, mainly from intermediate habitats, where sand is close to rocks. *Lethrinops parvidens* may have an ecological requirement similar to most species of *Tramitichromis*. The most predominant food item reported from the gut of this fish is chironomid larvae, together with diatoms (Eccles & Lewis, 1979). Copepods were also frequently taken. Eccles & Lewis (1979) also observed that in one specimen the major component of the gut contents was the small bivalved mollusc, *Pisidium*. In view of possible misidentification, it is hard to evaluate distribution and ecological information given by Eccles & Lewis (1979).

Discussion

This species was described by Trewavas (1931) based on a sample which Turner (1996) believe is not conspecific. The exact collecting locality is unknown (given only as from "Fort Johnston to Fort Maguire"). Four of the six syntypes at the BMNH (two were on loan) were examined for this study: two have an indefinite dark patch on the upper lateral line below the spinous dorsal and another one below the soft dorsal. They are all males and this difference has been tentatively attributed to natural variation.

This species was redescribed by Eccles & Lewis (1979). They also included more than one species in their redescription. For example, specimens deposited at the JLB Smith Institute of Ichthyology (RUSI 08320, RUSI 32044 and RUSI 050902) are definitely not the same species. The shape of the lower pharyngeal jaw and dentition suggest that specimen number RUSI 050902 is actually a *Tramitichromis* (probably what has been called *T.* sp. 'pharyngeals' in this work). Specimen number RUSI 08320 has a large mouth unlike most of the *L. parvidens* specimens examined. It is similar in shape to *L. macrochir*, but distinct from it in low number of gill rakers. The samples were collected just outside Monkey Bay at 14^0 04′S 34^0 56′E. This point on the bathymetric map of Lake Malawi/Nyasa falls in waters of a depth of more than 80m. The specimens therefore probably represent another undescribed species from the deeper waters.

Turner (1996) illustrates an average looking *Lethrinops* species under the name of *Lethrinops* cf. *parvidens* with 8-11 gill rakers. He does not discuss the lower pharyngeal bone morphology and dentition. On the basis of the photographs it is difficult to identify this species. It is suspected to represent yet another of member of the *L. parvidens* complex from deeper waters.

It can be stated with confidence, however, that *Lethrinops* cf. *parvidens* illustrated by Konings (1995, pg. 294, photo by Dr. George Turner) is close and similar to the specimens collected elsewhere from the lake and positively identified as *L. parvidens* in this study.

Specimens examined

BMNH 1930.1.31.64-67; unsexed 74.5 mm SL, male 80.0 mm SL, female 101.5 mm SL, male 100.0 mm SL; Fort Johnston to Fort Maguire, Malawi; coll. Christy; syntypes.

SADC/GEF (27/2/9); unsexed 74.0 mm SL, female 88.0 mm SL, unsexed 79.0 mm SL; Ngonga (between Songwe and Kiwira rivers), Tanzania; beach seine catch; 16/12/97.

SADC/GEF 96/02/03/68; female 123.0 mm SL; Senga Bay, Malawi; purchase from fishermen; 13/09/96. **SADC/GEF 97/01/10/12**; male 104.5 mm SL; Senga Bay near

Nguwo cottage, Malawi; purchase from beach seine fishermen; 14/04/97. **SADC/GEF 99/54/11/01-05**; female 109.0 mm SL, female 106.0 mm SL, female 101.0 mm SL, female 84.5 mm SL, female 83.0 mm SL; near Mara rocks in Usisya, Malawi; bottom set gill nets at 30.4-31.5m depth; 24/02/99. **SADC/GEF 99/54/08/07-08**; female 91.0mm SL, female 104.0mm SL; near Mara rocks in Usisya, Malawi; bottom set gill nets at 22.2-22.6m depth; 24/02/99.

6.16 *Lethrinops* sp. 'parvidens deep'

(Plate 6.11)

Etymology

The working name refers to a described species *L. parvidens* to which it resembles except for its larger size and deep-bodied appearance.

Diagnosis

A medium-sized shallow-water short-snouted *Lethrinops* distinguished from all such other members except *L. parvidens* and L. sp. 'domira blotch' by the lower number of ceratobranchial gill rakers (7-9 vs 10-14). Differs from *L. parvidens* in the shape of the caudal fin being rather crescentic and in having 9 thin and faint vertical bars as opposed to 7-8 wide dark bars, and from *L.* sp. 'domira blotch' in the absence of any other body markings apart from the vertical bars.

Description

For descriptive statistics of measurements and meristic data see Table 6.24.

Snout with a slightly convex profile equal to or shorter than eye diameter [32.3±1.5 (29.3-35.3) vs 34.8±1.2 (32.8-37.2)% in head length]. Jaws equal anteriorly; maxillary ending vertical with the anterior edge of the eye not extending to below eye. Oral teeth in the outer row bicuspid anteriorly but in upper jaw the teeth become unicuspid posteriorly, with 64-82 and 42-66 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 1-2 rows. Lower pharyngeal sub-triangular, acute anterior with long anterior blade, a few teeth at the posterior median are enlarged and blunt, other teeth compressed with an anterior cusp and with ends turned forward, a few anterior teeth sometimes with ends turned backwards as in members of *Tramitichromis*. There are 10-15 teeth along the longest medial series and 32-38 across the posterior margin. Caudal fin crescentrically emarginate. Body melanin pattern consists of only traces of thin dark vertical bars, 9 of which are below the dorsal fin.

Table 6.24: Morphometric ratios and meristic data for *Lethrinops* sp. 'parvidens deep'.

	Mean	SD	Range	N
Standard length (mm)	117.3	8.2	103-138.5	15
as % head length				
Lachrymal depth	22.6	1.6	20.0-26.3	15
Snout length	32.3	1.5	29.3-35.3	15
Lower jaw length	36.3	1.7	32.9-39.4	15
Premaxillary pedicel length	24.2	1.8	21.6-27.7	15
Cheek depth	28.1	1.3	24.7-29.6	15
Eye diameter	34.8	1.2	32.8-37.2	15
Head width (HW)	47.9	1.2	45.2-49.3	15
Interorbital width	23.1	1.1	20.5-24.7	15
as % standard length				
Head length (HL)	32.3	0.7	31.3-33.9	15
Body depth	38.1	1.4	35.8-40.5	15
Dorsal fin base length	56.4	1.3	53.9-58.7	15
Anal fin base length	20.8	0.9	18.9-21.8	15
Predorsal distance	35.0	1.2	33.2-37.1	15
Prepectoral distance	31.9	1.3	29.8-34.0	15
Prepelvic distance	37.5	0.9	35.8-38.7	15
Pre-anal distance	64.4	2.1	59.1-67.2	15
Caudal peduncle length (CPL)	19.5	1.2	17.5-21.4	15
Caudal peduncle depth	12.7	0.5	11.8-14.0	15
Other				
Interorbital width % HW	48.3	2.6	42.9-52.4	15
Lower pharyngeal jaw length (PhJL) % HL	30.3	1.1	28.2-31.3	13
Lower pharyngeal jaw width(PhJW) % PhJL	83.8	3.6	78.1-89.8	13
Dentigerous area length (DeAL) % PhJL	65.8	4.4	56.8-72.9	13

Dentigerous area width (DeAW) % PhJW	80.2	3.1	75.3-86.0	13
Dentigerous area length % DeAW	98.1	5.5	85.1-104.0	13
Caudal peduncle depth % CPL	62.4	5.6	57.4-78.6	15

	Median	Range	N
Number of teeth upper jaw	78.5	64-82	14
Number of teeth lower jaw	49	42-66	14
Inner rows upper jaw	1	1-2	15
Inner rows lower jaw	1	1-2	15
Gill rakers lower	8	7-9	15
Gill rakers total	12	11-13	15
Dorsal spines	15	15-16	15
Dorsal soft	12	10-13	15
Anal soft	10	9-11	15
Pectoral fin rays	15	15-16	15
Upper lateral line scales	27	25-29	15
Lower lateral line scales	16	14-17	15
Longitudinal line scales	34	32-34	15
Transverse scales above LL	5	4-6	15
Transverse scales below LL	9	9-11	15
Scales <pectoral-pelvic fin>	6	6-9	15
Cheek scales	3	3-4	15

Colour pattern

Live coloration was not recorded as specimens were identified after preservation. Preserved specimens are silvery with traces of thin vertical bars. Preserved males have anal fins darker distally with 9-10 large spots proximally.

Distribution

This fish has been collected from the South East Arm of Lake Malawi/Nyasa (Chiponda) and as far north as Khande in the central part of the lake (Fig. 6.28). It has been found in depths from 15-25m. *Lethrinops* sp. 'parvidens deep' has been caught in locations as far apart as Khande, north of Nkhata Bay, Domira Bay and the southern part of the lake. It indeed has a lake-wide distribution. This fish was not collected during rocky shore cruises. They therefore prefer open and extensive sandy habitats and live nowhere near rocks.

Ecology

From the shape and dentition of the pharyngeal apparatus it can be deduced that members of this taxa may feed on benthic invertebrates especially chironomids and also diatoms and copepods, as do the closely related *L. parvidens*.

Discussion

The information on species distribution suggest that, unlike *L. parvidens*, *L.* sp. 'parvidens deep' occurs mainly in extensive sandy habitat and does not prefer intermediate habitats. It is this habitat preference together with the few distinct characters mentioned above, that has led to this being considered as a separate and distinct taxon, different from the described *Lethrinops parvidens*. However future studies based on other methods are required to ascertain the status of these taxa.

Specimens examined

RUSI: 32044; male 111.0mm SL, male 120.0mm SL, male 118.5mm SL, male 107.5mm SL, male 103.0mm SL, male 114.5mm SL; Chiponda 3, Malawi; depth unknown; 16/01/73.

SADC/GEF 97/16/76/04-08, 97/16/76/10; female 113.5mm SL, male 114.5mm SL, female 114.5mm SL, female 124.0mm SL, female 112.5mm SL, female 138.5mm SL; Domira Bay, Malawi; bottom trawl at 17-23m depth; 07/06/97. **SADC/GEF 97/16/03/09**; female 126.0mm SL; Khande, Malawi; bottom trawl at 18-25m depth; 03/06/97. **SADC/GEF 97/16/76/01, 97/16/76/09**; female 119.0mm SL, female 117.0mm SL; Domira Bay, Malawi; bottom trawl at 17-23m depth; 07/06/97.

6.17 *Lethrinops furcifer* Trewavas, 1931

Lethrinops furcifer Trewavas, 1931: 149; Fryer,1959: 159, figs. 68-71; Jackson, 1961: 987; Blanc, 1962: 215; Jackson et al., 1963: 85; Fryer & Iles, 1972: 78, fig.; Turner, 1977b: 264; Bowmaker et al., 1978: 1229; Mayland, 1978: 246; Lewis, 1981: 750, tab. 1; Mayland, 1982: 175, fig.; Axelrod & Burgess, 1986: 59, phot.; Ufermann et al., 1987: 262; Eccles & Trewavas, 1989: 132, fig. 64; Konings, 1995: 287; Turner,1996: 95.

(Plates 6.12, B7 & B8)

Etymology

Noun in apposition, from Latin *furca* = "fork" + *ferre* = "to bear", referring to the deeply forked caudal fin.

Diagnosis

A medium to large shallow-water *Lethrinops* of the intermediate snout group and without any enlarged teeth on the central part of the lower pharyngeal jaw. Differs from all other member of this group in having a dark supra-pectoral patch on the upper lateral line, sometimes extending posteriorly but not reaching the caudal peduncle and in males in breeding 'dress'. Also, the eye is relatively smaller when compared to the other two members [31.2±2.1 (28.2-36.1) vs 36.4±2.7 (32.1-43.1) and 38.3±2.3 (32.9-42.4)% head length for *L. marginatus* and *L. albus* respectively].

Description

For descriptive statistics of measurements and meristic data see Table 6.25.

Snout with a round profile a little longer than eye diameter [33.8±1.8 (31.0-37.1) vs 31.2±2.1 (28-36.1)% in head length]. Jaws equal anteriorly; maxillary just reaching vertical from anterior edge of the eye. Oral teeth in the outer row bicuspid anteriorly becoming unicuspid on the posterior end, with 57-80 and 32-54 teeth in the outer row of upper and lower jaw respectively, inner teeth on both jaws unicuspid and in 1-2 rows. Lower pharyngeal bone triangular and moderately notched behind with all teeth small, compressed and with anterior cusp, anterior teeth have straight tips or slightly turned backwards, 10-15 teeth along the longest medial series and 36-54 across the posterior margin. Caudal fin forked. A dark supra-pectoral patch on the upper lateral line, sometimes extending posteriorly but not reaching the caudal peduncle.

Table 6.25: Morphometric ratios and meristic data for *Lethrinops furcifer*.

	Mean	SD	Range	N
Standard length (mm)	121.0	16.0	81.5-146.0	19
as % head length				
Lachrymal depth	24.1	3.5	17.9-31.1	19
Snout length	33.8	1.8	31.0-37.1	19
Lower jaw length	35.8	2.2	31.3-39.5	19
Premaxillary pedicel length	25.4	1.4	23.2-28.1	19
Cheek depth	29.1	2.9	23.8-34.1	19
Eye diameter	31.2	2.1	28.2-36.1	19
Head width (HW)	47.2	2.4	42.7-52.0	19
Interorbital width	22.8	1.8	20.5-25.9	19
as % standard length				
Head length (HL)	31.7	1.6	28.7-35.0	19
Body depth	36.6	1.9	34.3-40.6	19
Dorsal fin base length	56.6	2.5	52.2-61.4	19
Anal fin base length	20.4	1.1	18.7-22.3	19
Predorsal distance	33.5	1.7	30.6-36.7	19
Prepectoral distance	32.0	1.7	28.4-34.7	19
Prepelvic distance	37.5	1.7	34.6-41.1	19
Pre-anal distance	65.3	1.9	62.3-68.8	19
Caudal peduncle length (CPL)	18.6	1.0	16.9-20.4	19
Caudal peduncle depth	12.2	0.3	11.4-12.9	19

Other				
Interorbital width % HW	48.4	2.8	43.5-53.1	19
Lower pharyngeal jaw length (PhJL) % HL	28.8	1.7	26.1-31.5	15
Lower pharyngeal jaw width(PhJW) % PhJL	87.4	8.0	67.4-102.7	15
Dentigerous area length (DeAL) % PhJL	65.2	6.4	55.8-77.5	15
Dentigerous area width (DeAW) % PhJW	80.0	4.1	74.8-90.8	15
Dentigerous area length % DeAW	94.2	13.6	72.1-126.6	15
Caudal peduncle depth % CPL	66.0	4.3	60.4-72.7	19

	Median	Range	N
Number of teeth upper jaw	69	57-80	14
Number of teeth lower jaw	47	32-54	14
Inner rows upper jaw	1	1-2	19
Inner rows lower jaw	1	1-2	19
Gill rakers lower	9	9-13	19
Gill rakers total	14	13-20	19
Dorsal spines	15	14-16	19
Dorsal soft	12	10-13	19
Anal soft	10	8-11	19
Pectoral fin rays	15	14-16	19
Upper lateral line scales	24	22-28	17
Lower lateral line scales	15	12-18	17
Longitudinal line scales	33	31-34	17
Transverse scales above LL	5	4-6	15
Transverse scales below LL	9	8-10	15
Scales <pectoral-pelvic fin>	6	4-8	15
Cheek scales	3	2-4	19

Colour pattern

Females are silvery and non-breeding males are silvery with a yellowish hue. Breeding males are blue with an orange iridescence. The head, including the operculum of such territorial males, is dark blue or metallic blue. Dorsal fin bluish with orange spots on membranes especially on the soft-rayed part. Caudal fin bluish ornamented with orange maculae/striae on membranes. Anal fin bluish with numerous small orange spots. Pelvics pale bluish. About seven vertical bars below the dorsal fin, the 2^{nd} to 4^{th} of which fuse on the upper lateral line below the spinous dorsal to form an oblong supra-pectoral spot.

Distribution

The syntypes examined at the BMNH were collected at Karonga (Malawi) and at Itungi Port area (Tanzania). One specimen examined at the Monkey Bay Fisheries Research Unit, was beach-seined at Mayoka beach near Nkhata Bay (Malawi). During this study, this fish was collected from locations as far apart as Senga Bay and Domira Bay (Malawi) and at Ikombe on the Tanzanian shores. *Lethrinops furcifer* therefore, has a lake-wide distribution (Fig. 6.29)

Ecology

Lethrinops furcifer occurs in areas of pure sand and feeds on soft invertebrates such as chironomid larvae (Fryer, 1959). But as far as I know, no specimens were preserved to verify the identity of the species concerned. This fish was very common at Ikombe beach, on the Tanzanian shores, where the largest specimen collected from a depth of 3m was 131mm standard length.

Discussion

Lethrinops furcifer has not been studied since the work of Trewavas (1931). It was originally described from 12 specimens and according to CLOFFA 4 (Daget et al., 1991), no holotype is designated. Eccles & Trewavas (1989) report *L. furcifer* to be common on exposed sandy beaches in Nkhata Bay area, but not well known from the southern part of the lake. They, however, claim that it was common in one station of 9m during a trawling survey, but decline to name the station. They also give a drawing of what appears to be a mature male and it is indicated as a lectotype. A registration number of the specimen is, however, not given. Five of the syntypes at the BMNH collected from Itungi port on the Tanzanian shores and from Karonga (Malawi) have been examined in this study and have been compared with specimens collected from various other locations of the lake and this has led to the conclusion that they are indeed conspecific. Fryer (1959: 195, fig. 68-71) reports that *L. furcifer* is the commonest species on sandy shores in the north of the lake and that it feeds on chironomids. The shape of gill rakers illustrated resembles that of *L. furcifer* examined for this study, but the feeding behaviour stated is typical of many *Lethrinops* species and not characteristic of only *L. furcifer*. Fryer (1959) and Fryer & Iles (1972: 79, fig. 101) report the existence of yet another undescribed species which is similar to *L. furcifer* and can only be distinguished from it by its higher gill raker count (16-17) and finer pharyngeal teeth. During this study a shallow-water *Lethrinops* with such a high number of gill rakers has not been encountered. This is either a misidentification or members of one of the deep water *Lethrinops* species. Possibly, what is being referred to is *Lethrinops micrentodon*. Konings (1995) gives a list of commonly seen *Lethrinops* and states that *L. furcifer* is the largest of them reaching a maximum total length of 200mm. But the specimen he illustrates (page 286 fig. 2 *L. furcifer*, male at Kambiri point, Malawi) does not seem to be conspecific with the *L. furcifer* collected and compared with the types during this study. From the shape of the mouth and horizontal melanin obscured by male breeding colours, it is suspected to be *Tramitichromis trilineata* male in breeding colour. Turner (1996: 95, photo pg. 59) discusses what he refers to as *Lethrinops* cf. *furcifer* and reports that the specimens illustrated by Konings (1991 & 1995) as *Taeniolethrinops furcicauda* may be conspecific with his *L.* cf. *furcifer*. From the shape of the head and from the position of the maxillary extension, none of these is conspecific with the types seen during this study. Spreinat (1995) illustrates a *Lethrinops* 'sensu lato' from the Tanzanian part of the lake which he calls *Taeniolethrinops* 'Black Fin' found at Ikombe, Nkanda, Lupingu, Pombo reef and Undu point; but he further states that the body shape is similar to *L. furcifer*. Similar fish were collected from Ikombe during this study and positively identified them as *Lethrinops furcifer* (Plates B7).

Specimens examined

BMNH 1930. 1.31:187-189; female 129.5mm SL, male 144.5mm SL, female 146.0mm SL; Karonga, Malawi; coll. Christyi; syntypes. **BMNH 1930**. 1.31:190-191; male 123.5mm SL, male 122.5mm SL; Between Mwaya and Mbasi river mouths, Tanzania; coll. Christyi; syntypes. **MFRU (no number)**; male 135.5mm SL; Nkhata Bay, Malawi; seine at Mayoka beach, 21/01/58. **RUSI: 015541**; female 118.0mm SL, female 117.5mm SL, female 130.5mm SL, female 128.5mm SL; Domira Bay, Malawi; 20/12/69. **SADC/GEF 97/23/2/18**; male 129.5mm SL; Ikombe north of Alt Langenburg, Tanzania; gill net bottom 3m; 15/08/97. **SADC/GEF 97/23/2/4**; male 98.5mm SL; Ikombe north of Alt Langenburg, Tanzania; gill net bottom 3m; 15/08/97. **SADC/GEF 97/23/2/2**; male 131.0mm SL; Ikombe north of Alt Langenburg, Tanzania; gill net bottom 3m; 15/08/97. **SADC/GEF 97/23/2/1**; male 117.5mm SL; Ikombe north of Alt Langenburg, Tanzania; gill net bottom 3m; 15/08/97. **SADC/GEF 97/23/3/1**; male 101.0mm SL; Ikombe north of Alt Langenburg, Tanzania; gill net bottom 3m; 16/08/97. **SADC/GEF 97/23/3/2**; male 103.0mm SL; Ikombe north of Alt Langenburg, Tanzania; gill net bottom 3m; 16/08/97. **SADC/GEF 96/02/03/59**; female 117.5mm SL; Senga Bay, Malawi; Purchase from fishermen; 12/09/96. **SADC/GEF 97/01/10/18**; female 101.5mm SL; Senga Bay, Malawi; purchase from fishermen; 14/04/97. **SADC/GEF 97/16/03/02**; female 124.0mm SL; Khande, Malawi; trawl bottom at 18-25m depth; 03/06/97.

6.18 *Lethrinops marginatus* Ahl, 1927

Lethrinops marginatus Ahl, 1927, Sitzüngsber. Ges. naturf. Fr. Berl. p. 61; Trewavas, 1931: 148 (synonymy with *L. alba*); Ufermann et al., 1987: 263; Eccles & Trewavas, 1989: 130 (rehabilitation of *L. marginatus*).

Lethrinops alba (part) Trewavas, 1931:148

Lethrinops oculata, Trewavas, 1931: 148; Eccles & Trewavas, 1989: 130.

Lethrinops cf. *marginatus*, Konings, 1995:292, photo 3

(Plates 6.13, C3, C7 & D7)

Etymology

Adjective (Latin : *marginatus*, -a, um = bordered).

Diagnosis

A small to medium-sized shallow-water *Lethrinops* of the intermediate snout and with simple teeth on lower pharyngeal bone. Differs from all such members except *L. albus* in the absence of any other body markings except vertical bars and from *L. albus* in the longer premaxillary pedicel and relatively shorter caudal peduncle and also in male breeding coloration. Also gill rakers of *L. marginatus* are finger-like and slender, unlike those of *L. albus* which are short and fleshy. Males have a red flush/blotch above the pectoral fin base near the operculum, which is very distinctive in sexually mature and territorial males.

Description

Morphometric and meristic data for *L. marginatus*, for the holotype and other specimens examined are summarised in Table 6.26.

Snout with a slightly declivitous profile which is equal to or less than eye diameter [32.8±2.3 (26.3-36.1) vs 36.4±2.7 (32.1-43.1)% in head length]. Jaws equal anteriorly or lower jaw slightly projecting; maxillary reaching not far short of vertical from the anterior edge of the eye (but never below the eye). Oral teeth in the outer row bicuspid anteriorly becoming unicuspid at the posterior end, 40-80 teeth in the outer row of upper jaw and 32-59 in the lower jaw, inner teeth in both jaws unicuspid and few tricuspid, 1-2 inner rows in the upper and lower jaw. Lower pharyngeal bone triangular and moderately notched behind with all teeth small, compressed and with anterior cusp, anterior teeth have straight tips or turned forwards, 12-14 teeth along the longest medial series and 37-44 across the posterior margin. Caudal emarginate. Body melanin pattern consists of only traces of vertical bars or sometimes some males may be darker on the anterior part of the upper lateral line.

Table 6.26: Morphometric ratios and meristics for *Lethrinops marginatus*. Summary values include holotype (H).

	H	Mean	SD	Range	N
Standard length (mm)	102.5	91.6	11.9	68.0-113.5	30
as % head length					
Lachrymal depth	25.6	24.3	1.6	20.4-27.3	30
Snout length	33.2	32.8	2.3	26.3-36.1	30
Lower jaw length	35.5	36.9	1.6	34.3-40.9	30
Premaxillary pedicel length	26.2	25.9	1.8	21.6-28.8	30
Cheek depth	25.6	29.0	2.5	24.1-34.5	30
Eye diameter	32.1	36.4	2.7	32.1-43.1	30
Head width (HW)	45.1	44.8	1.9	42.0-49.3	30
Interorbital width	21.4	21.4	1.3	18.8-25.0	30
as % standard length					
Head length (HL)	34.6	33.5	1.2	31.4-35.8	30
Body depth	36.1	34.7	2.4	27.2-38.1	30
Dorsal fin base length	53.7	54.3	2.4	48.1-59.3	30
Anal fin base length	18.5	19.1	1.4	16.1-21.3	30
Predorsal distance	37.6	36.7	1.2	34.5-39.0	30
Prepectoral distance	32.7	33.4	1.0	30.3-34.8	30
Prepelvic distance	37.1	37.4	1.1	35.6-39.8	30
Pre-anal distance	65.9	63.3	1.8	60.2-67.6	30
Caudal peduncle length (CPL)	20.0	19.7	1.1	17.5-21.3	30

Caudal peduncle depth	12.2	12.0	0.6	10.3-13.1	30
Other					
Interorbital width % HW	47.5	47.0	3.0	42.9-55.2	30
Lower pharyngeal jaw length (PhJL) % HL	27.9	30.9	1.9	27.9-35.2	29
Lower pharyngeal jaw width(PhJW) %PhJL	79.8	79.3	4.4	68.5-88.8	29
Dentigerous area length (DeAL) % PhJL	56.6	61.1	3.5	55.8-68.4	29
Dentigerous area width (DeAW) % PhJW	79.7	78.5	3.7	71.4-90.6	29
Dentigerous area length % DeAW	88.9	98.4	6.9	83.3-115.5	29
Caudal peduncle depth % CPL	61.0	61.2	3.1	55.6-67.9	30
Meristics	H	Median		Range	N
Number of teeth upper jaw	-	65		40-80	27
Number of teeth lower jaw	-	45		32-59	27
Inner rows upper jaw	1	1		1-2	30
Inner rows lower jaw	1	1		1-2	30
Gill rakers lower	10	10		9-11	30
Gill rakers total	14	14		13-16	30
Dorsal spines	16	16		15-17	30
Dorsal soft	11	11		9-13	30
Anal soft	9	9		9-10	30
Pectoral fin rays	16	15		14-16	30
Upper lateral line scales	24	24		20-27	30
Lower lateral line scales	13	15		13-18	30
Longitudinal line scales	32	32		28-33	30
Transverse scales above LL	5	5		4-6	30
Transverse scales below LL	8	8		7-10	30
Scales <pectoral-pelvic fin>	6	5		3-7	30
Cheek scales	2	3		2-4	30

Colour pattern

Females and non-breeding males are silvery, darker on the dorsum than the ventral part. Pectoral fin pale yellow; pelvic white; upper part of the caudal fin and rayed part of dorsal fin with white spots and the lower caudal margin is yellowish. Breeding males grey blue with the body generally shining yellow with a distinctive red flush above pectoral fin. The head is dusky-blue becoming deep blue on the ventral part, including the gular. Dorsal fin grey with a creamy-white submarginal band and the lappets tipped red, the soft-rayed part has red maculae or spots. Caudal fin dressed with red maculae/striae. Anal fins grey with large pale orange spots. Pelvics are grey distally. About 7 vertical bars below the dorsal fin.

Distribution

The holotype was collected from Alt Langenburg (presently called Lumbira, on the Tanzanian shores). Other specimens have been collected from Micuio on the Mozambique coast, Cape Ngombo and Senga bay in Malawi and between Kiwira and Songwe rivers in Tanzania as well as from Ikombe north of Alt Langenburg (Fig. 6.29). This fish therefore has a wide distribution around the lake.

Ecology

All specimens were collected by beach-seine from a depth of not more than 7m, indicating that *L. marginatus* prefers very shallow waters. Stomach content analysis revealed a diet of mainly benthic invertebrates with chironomid larvae dominating.

Discussion

Ahl (1927) described *L. marginatus* from material collected from the Tanzanian shore of the lake. Trewavas (1931), when making the first revision of the genus *Lethrinops* 'sensu lato', doubtfully considered *L. marginatus* a synonym of *L. albus*. In her synopsis she reports that *L. albus* is occasionally darker on the upper lateral line. Such an observation does refer to members of *L. marginatus*, as all specimens of *L. albus* examined during this study do not have such a marking. Eccles & Trewavas (1989) subsequently resurrected the status of *L. marginatus*, pointing out the characteristic long slender gill rakers, with crenellations on the inner surface as opposed to short gill rakers found in specimens of *L. albus*. Konings (1995: 292, fig. 2) illustrates a specimen from Senga Bay referring to it as *L.* cf. *marginatus*. Similar specimens were collected from Senga Bay and from the northern part of the lake and compared with the holotype from Berlin museum. It is with confidence that they are conspecific.

Specimens examined

ZMB 23478; unsexed 102.5mm SL; Nyassa b. Langenburg (Lumbira), Tanzania; holotype. **BMNH 1930.1.31.162**; male 103.0mm SL; Fort Johnston to Fort Maguire, Malawi. (Formally a holotype of *L. oculata*). **SADC/GEF 97/16/98/07-09**; female 94.0mm SL, female 101.5mm SL, female 87.0mm SL; Senga Bay, Malawi; bottom trawl at 5m depth; 08/06/97. **SADC/GEF (25/38)**; female 76.0mm SL; Senga Bay, Malawi; beach seine at depth 5m; 27/11/97. **SADC/GEF 97/01/20/05-06**; female 91.0mm SL, female 97.5mm SL; Senga Bay, Malawi; purchase from fishermen; 11/05/97. **SADC/GEF (27/2/1)**; male 113.0mm SL; Ngonga (between Songwe and Kiwira rivers), Tanzania; beach seine at 4m depth;16/12/97. **SADC/GEF (27/2/6)**; male 102.5mm SL, male 113.5mm SL, male103.5mm SL; Ngonga (between Songwe and Kiwira rivers), Tanzania; beach seine at 4m depth;16/12/97. **SADC/GEF (Cr23/4)**; male 98.5mm SL; Ikombe north of Alt Langenburg, Tanzania; 16/08/97. **SADC/GEF 96/01/01/19-20**; unsexed 75.0mm SL, unsexed 71.0mm SL; Senga Bay, Malawi; purchase from fishermen; 22/07/96. **SADC/GEF 96/02/01/29**; male 82.0mm SL; Senga Bay, Malawi; purchase from fishermen; 10/09/96. **SADC/GEF 96/01/01/18**; unsexed 68.0mm SL; Senga Bay, Malawi; purchase from fishermen; 22/07/96. **SADC/GEF 96/02/03/62**; male 91.5mm SL; Senga Bay, Malawi; purchase from fishermen; 12/09/96. **SADC/GEF 96/02/01/05**; male 81.5mm SL; Senga Bay, Malawi; purchase from fishermen; 10/09/96.
SADC/GEF (no number); male 79.5mm SL, female 84.0mm SL, female 82.5mm SL; Senga Bay, Malawi; purchase from fishermen; 03/10/96. **SADC/GEF 97/01/10/06**; male 98.0mm SL; Senga Bay, Malawi; purchase from fishermen; 14/04/97. **SADC/GEF 97/01/24/02**; female 92.0mm SL; Senga Bay, Malawi; purchase from fishermen; 14/05/97. **SADC/GEF (24/35/5)**; male 120.5mm SL; Cape Ngombo, Malawi; gill net at 4.8m depth; 13/11/97. **SADC/GEF 98/01/42/3**; unsexed 97.5mm SL; Senga Bay,

Malawi; purchase from fishermen; 05/02/98. **SADC/GEF 99/44/59/01-04**; male 101mm SL, male 101.5mm SL, male 89.0mm SL, male 88.0mm SL, male 79.0mm SL; Senga Bay, Malawi; beach seine; 20/02/99. **SADC/GEF 99/75/03/01**; male 113.5mm SL; Micuio, Mozambique; beach seine at 7m depth; 29/03/99.

6.19 *Lethrinops albus* Regan, 1922

Tilapia macrophthalmus (part) Boulenger, 1915): 261.

Lethrinops albus Regan, 1922: 719; Eccles & Trewavas, 1989: 132, fig. 63.

Lethrinops alba (part) Trewavas, 1931: 148, fig. 5c

Lethrinops alba: Jackson, 1961:587; Jackson et al., 1963: 85; Bowmaker et al., 1978: 1229; Galis & Barel, 1980:392; Ufermann et al., 1987:261

(Plates 6.14, D1, D2, D5)

Etymology

Adjective from the Latin *albus* = "white", referring to the pale coloration of the preserved specimen.

Diagnosis

A medium-sized shallow-water *Lethrinops* of the intermediate snout and with simple teeth on lower pharyngeal bone. Differs from all such members except *L. marginatus* in the absence of any other body markings except vertical bars and the occasionally darker appearance on the upper lateral line, and from *L. marginatus* in the shorter premaxillary pedicel and relatively longer caudal peduncle and also in male breeding coloration.

Description

Morphometric and meristic data for *L. albus*, for the holotype and other specimens examined are summarised in Table 6.27.

Snout with a slightly convex equal to or less than eye diameter [31.5±3.5 (25.9-36.9) vs 38.3±2.3 (32.9-42.4)% in head length]. Jaws equal anteriorly; maxillary reaching not far short of vertical from the anterior edge of the eye (but never below the eye). Oral teeth in the outer row bicuspid anteriorly becoming unicuspid at the posterior end, 40-79 teeth in the outer row of upper jaw and 24-60 in the lower, inner teeth in both jaws unicuspid and few teeth tricuspid, 1-2 inner rows in the upper and lower jaw. Lower pharyngeal bone triangular and moderately notched behind with all teeth small, compressed and with anterior cusp, anterior teeth have straight tips or turned forwards, 11-14 teeth along the longest medial series and 34-45 across the posterior margin. Caudal fin emarginate. Body melanin pattern consists of only traces of vertical bars.

Table 6.27: Morphometric ratios and meristics for *Lethrinops albus*. Summary values include holotype (H).

	H	Mean	SD	Range	N
Standard length (mm)	78.5	88.4	12.0	70-122.5	23
as % head length					
Lachrymal depth	23.4	23.6	1.3	21.1-26.0	23
Snout length	27.5	31.6	3.4	25.9-36.9	23
Lower jaw length	37.7	37.5	1.8	33.4-40.8	23
Premaxillary pedicel length	21.1	22.0	2.1	19.1-27.0	23
Cheek depth	21.1	27.0	3.4	20.8-31.2	23
Eye diameter	38.5	38.3	2.3	32.9-42.4	23
Head width (HW)	45.3	45.0	2.9	35.8-50.0	23
Interorbital width	17.7	20.3	1.8	17.4-24.2	23
as % standard length					
Head length (HL)	33.8	32.7	1.4	29.4-34.4	23
Body depth	33.8	33.1	2.0	29.1-36.5	23
Dorsal fin base length	54.8	54.4	1.8	50.3-57.0	23
Anal fin base length	19.1	19.1	0.9	17.6-21.2	23
Predorsal distance	34.4	35.0	1.3	32.4-37.1	23
Prepectoral distance	32.5	32.7	1.4	30.2-35.8	23
Prepelvic distance	37.6	36.3	1.9	30.9-39.2	23
Pre-anal distance	61.1	63.3	1.6	59.8-65.3	23
Caudal peduncle length (CPL)	18.5	20.4	1.2	18.5-22.8	23
Caudal peduncle depth	12.1	11.8	0.4	11.0-12.4	23
Other					
Interorbital width % HW	39.2	45.6	3.9	39.2-52.6	23
Lower pharyngeal jaw length (PhJL) % HL	28.7	30.7	2.4	25.4-37.3	20
Lower pharyngeal jaw width(PhJW) % PhJL	90.8	82.3	6.4	73.2-94.3	20
Dentigerous area length (DeAL) % PhJL	61.8	59.9	4.3	52.9-65.6	20

Dentigerous area width (DeAW) % PhJW	76.8	77.9	4.3	66.7-84.8	20
Dentigerous area length % DeAW	88.7	93.8	7.1	73.4-103.3	20
Caudal peduncle depth % CPL	65.5	58.0	3.6	51.4-65.5	23
Meristics	H	Median		Range	N
Number of teeth upper jaw	-	62		40-79	21
Number of teeth lower jaw	-	46		24-60	21
Inner rows upper jaw	-	1		1-2	21
Inner rows lower jaw	-	2		1-2	21
Gill rakers lower	10	9		9-12	23
Gill rakers total	15	14		13-17	23
Dorsal spines	16	16		15-17	23
Dorsal soft	11	11		9-13	23
Anal soft	9	9		9-10	23
Pectoral fin rays	16	15		14-16	23
Upper lateral line scales	22	24		21-26	23
Lower lateral line scales	12	15		12-18	23
Longitudinal line scales	30	32		29-34	23
Transverse scales above LL	5	5		4-5	23
Transverse scales below LL	8	8		6-9	23
Scales <pectoral-pelvic fin>	6	4		3-6	23
Cheek scales	3	3		2-4	23

Colour pattern

Females are silvery with a yellowish tinge dorsally but whitish ventrally. Non-breeding males are less pale ventrally. Dorsal fin hyaline with white spots. Caudal fin margin tipped red. Anal fin hyaline with small yellow spots. Pelvic fins and pectoral fin white.

Breeding males are generally 'dressed' blue green head and body with yellow iridescence, the throat/gular is yellow and chest part pale-grey with yellow tinge. Dorsal fin grey and shining yellow with a creamy-white submarginal band with lappet tipped red, the soft dorsal is also spotted red. Caudal fin is bluish ornamented with red maculae/striae making the whole fin looking mainly red. Anal fin dark with small pale orange spots. Pelvics dusky distally. About 8 vertical bars below dorsal fin but do not reach the dorsal fin base.

Distribution

The holotype was collected from an unspecified locality between Kondowe and Karonga in the northern part of Lake Malawi/Nyasa. All the specimens examined in this study were collected from the southern part of the lake as indicated in Figure 6.29.

Ecology

The few stomachs examined showed a diet of mainly chironomids, diatoms, copepods and there were always particles of sand. All the specimens collected by beach-seine and those purchased from local fishermen were from a depth of between 2-5m. No specimens were recorded from a depth of more than 5m, clearly showing that *L. albus* is indeed a fish of very shallow waters and thus quite vulnerable to the beach-seining practices common in most beaches around the lake, especially in Malawi.

Discussion

Lethrinops albus is among the four species that were originally accommodated in the genus *Lethrinops* (Regan, 1922). Trewavas (1931), when first revising the genus, included in her redescription of this species some of Boulenger's (1908) *Tilapia macrophthalma* specimens and doubtfully included Ahl's (1927) *Lethrinops marginatus*. Since then this species has not been studied. Konings (1995), when discussing the genus *Lethrinops*, reports *L. albus* under the group of 'small *Lethrinops*' and gives a photographic illustration of a male and female from Khande island (Malawi). The shape is similar to the specimens identified as *L. albus* in this study, but the male coloration provokes hesitant disbelief rather than a firm conviction. The coloration on the caudal and dorsal fins is different from the specimens examined in this study.

Specimens examined

BMNH 1897.6.9.270; unsexed 78.5mm SL; Kondowe to Karonga, Malawi; holotype (also *Chromis johnstoni, Tilapia macrophthalmus*). **SADC/GEF (no number L11-L13)**; unsexed 80.0mm SL, female 80.5mm SL, female 81.0mm SL; Senga Bay, Malawi; purchase from fishermen; 03/10/96. **SADC/GEF (no number L36-L40)**; male 86.0mm SL, male 85.0mm SL, male 79.5mm SL, 83.5mm SL, 91.0mm SL; Senga Bay, Malawi; purchase from fishermen; 03/10/96. **SADC/GEF 97/01/06/01-02**; female 88.5mm SL, male 81.0mm SL; Senga Bay purchase from fishermen; 10/02/97. **SADC/GEF (no number L43)**; male 83.5mm SL; Senga Bay, Malawi; purchase from fishermen; 03/10/96. **SADC/GEF (no number L46, L48)**; female 80.0mm SL, unsexed 70.0mm SL; Senga Bay, Malawi; purchase from fishermen; 03/10/96. **SADC/GEF (no number L64)**; male 85.0mm SL; Senga Bay, Malawi; purchase from fishermen; 03/10/96. **SADC/GEF 97/01/10/02-05**; male 94.5mm SL, male 82.5mm SL, female 89.5mm SL, male 98.5mm SL; Senga Bay, Malawi; Beach seine; 14/04/97. **SADC/GEF (no number L95)**; male 105.0mm SL; Kambiri, Malawi; purchase from fishermen; 08/06/97.

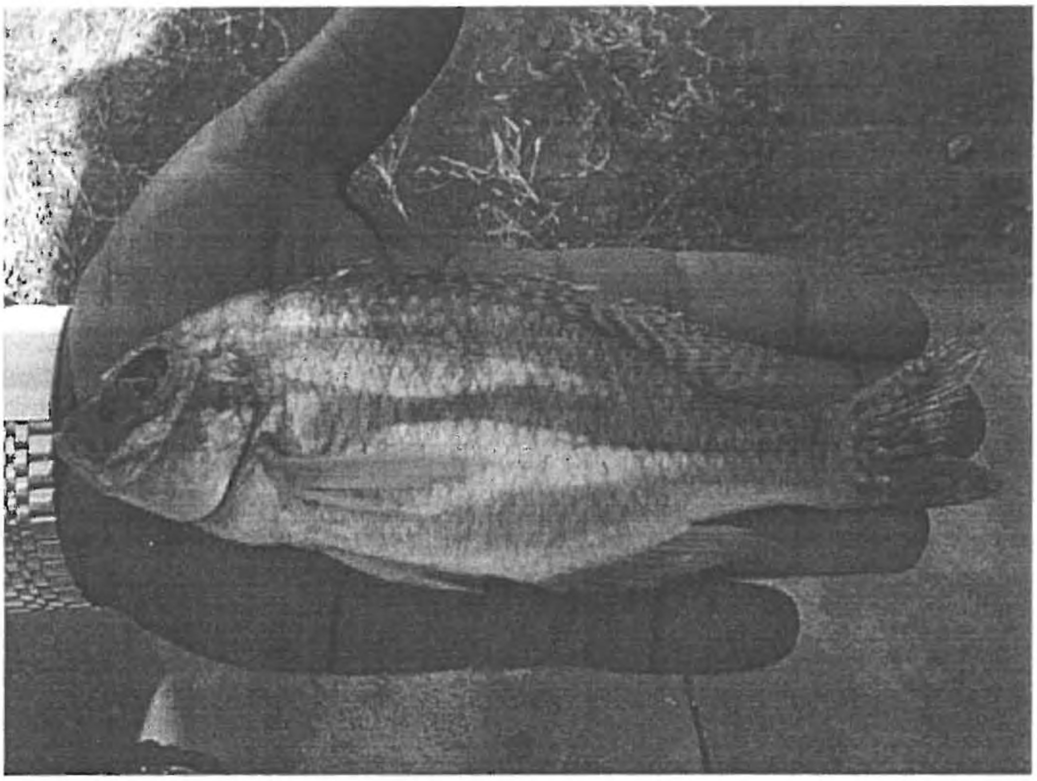


PLATE 6.1: *Lethrinops lunaris*

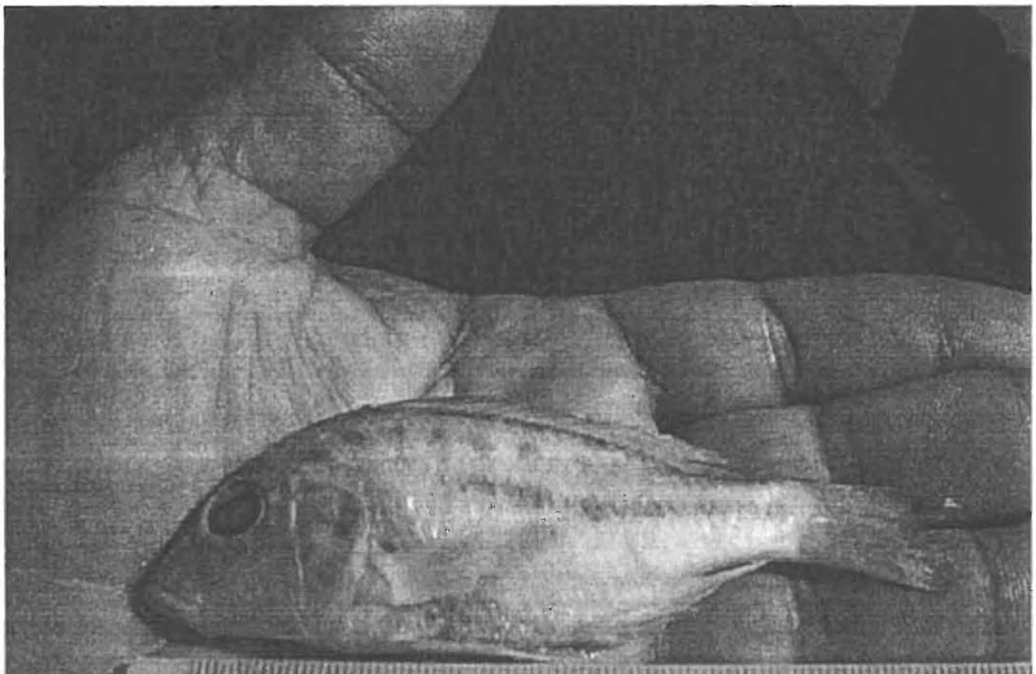


PLATE 6.2: *Lethrinops lethrinus*

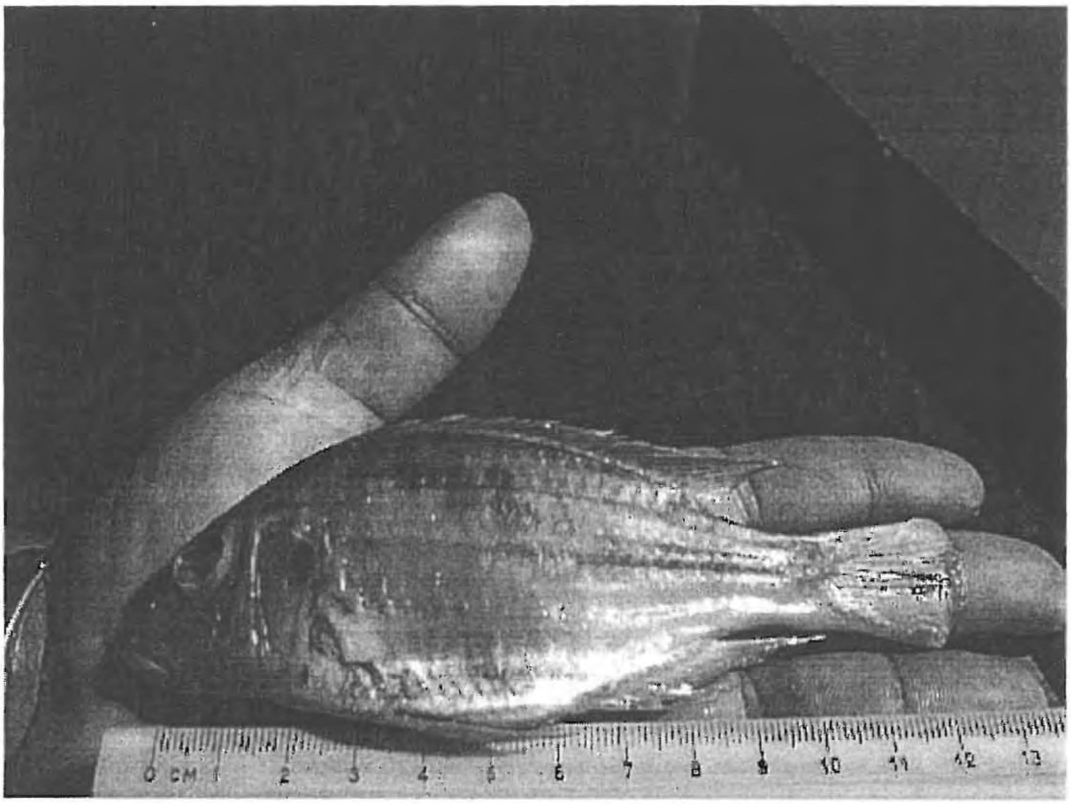


PLATE 6.3 : *Lethrinops leptodon*

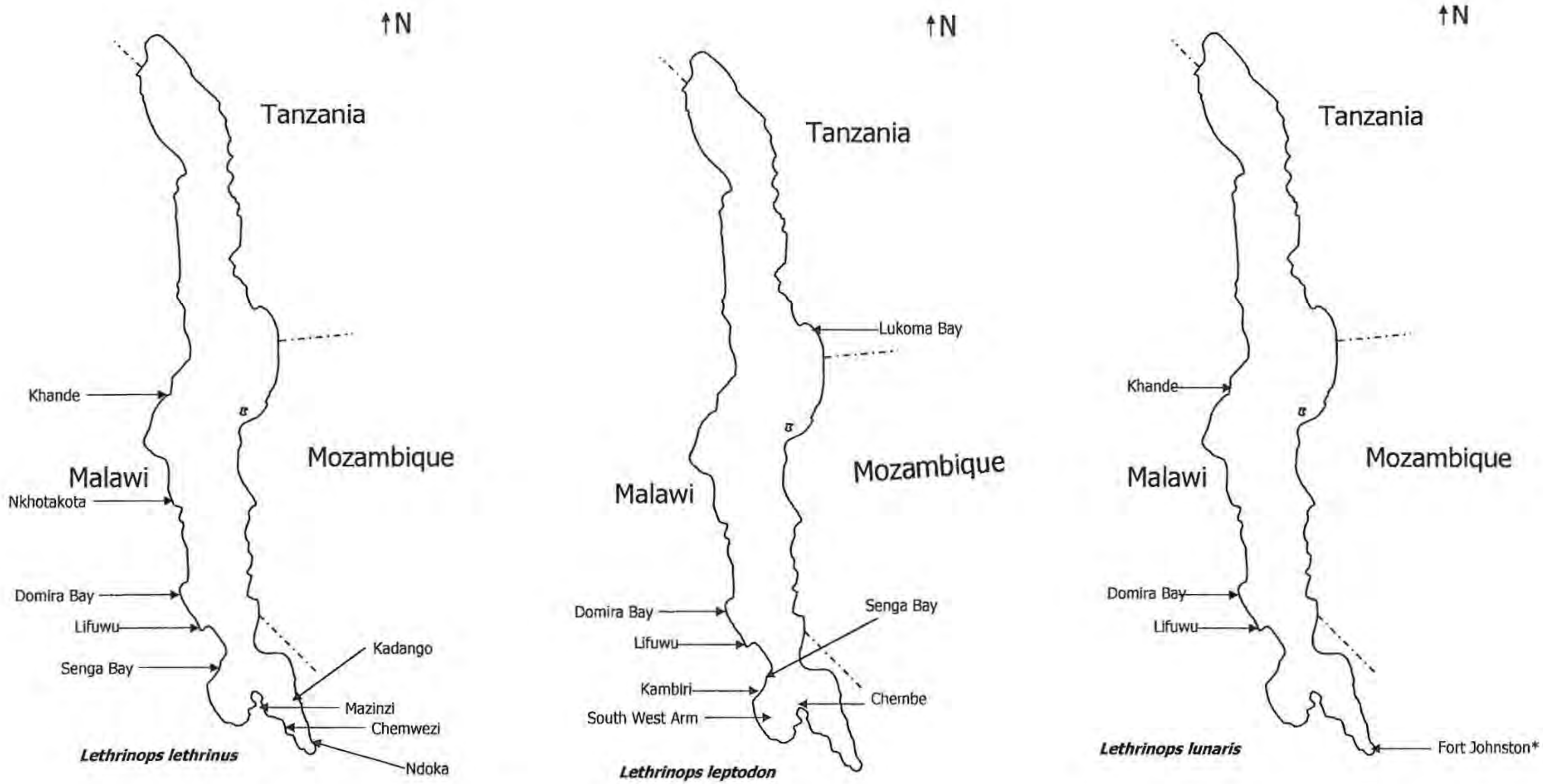


Fig. 6.25: Localities where *Lethrinops lethrinus*, *L. leptodon* and *L. lunaris* have been collected during this study; *denotes type localities.

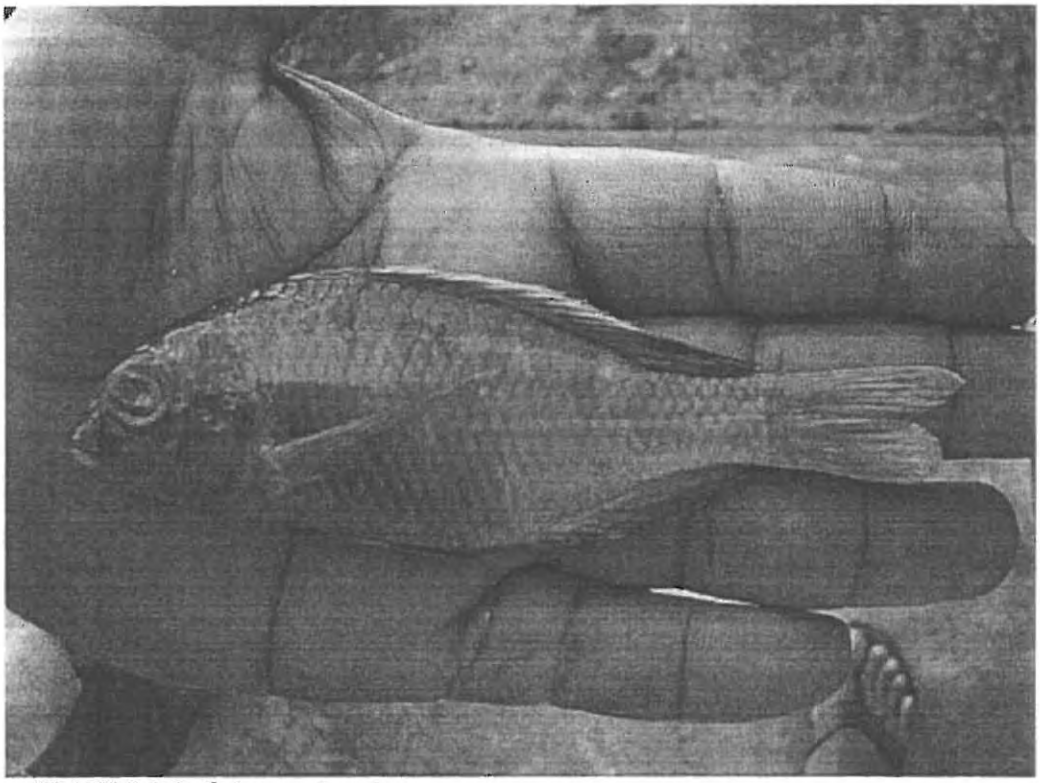


PLATE 6.4: *Lethrinops microstoma*

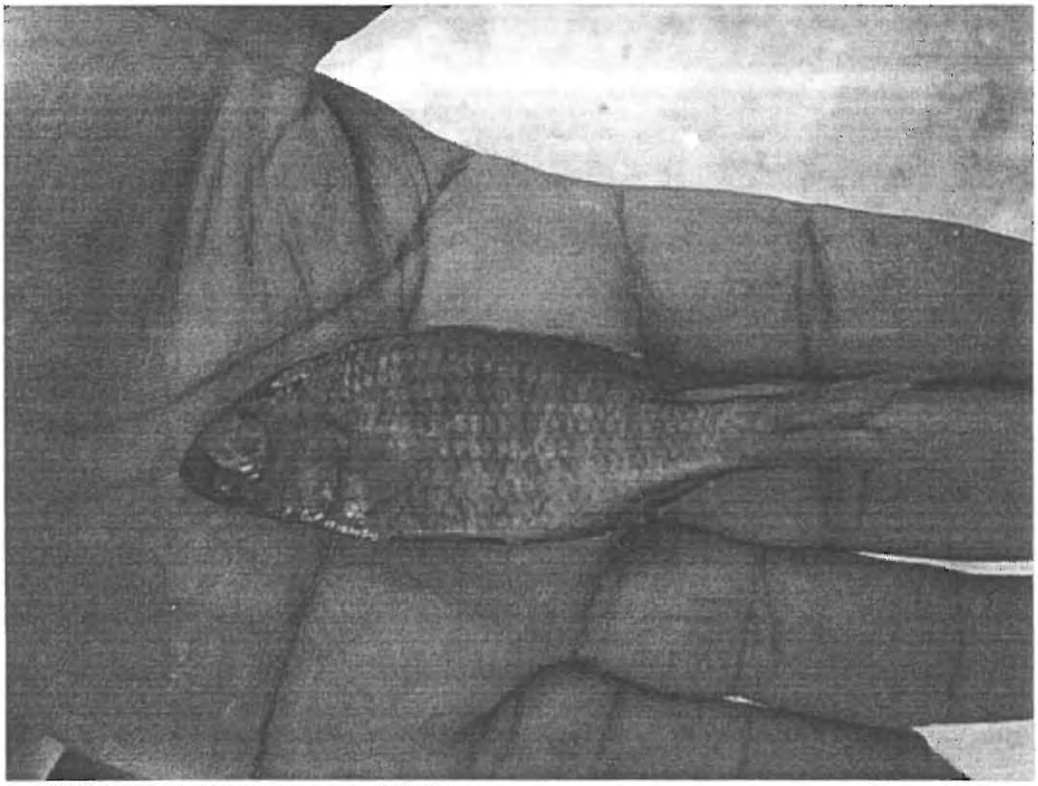


PLATE 6.5: *Lethrinops macrophthalmus*

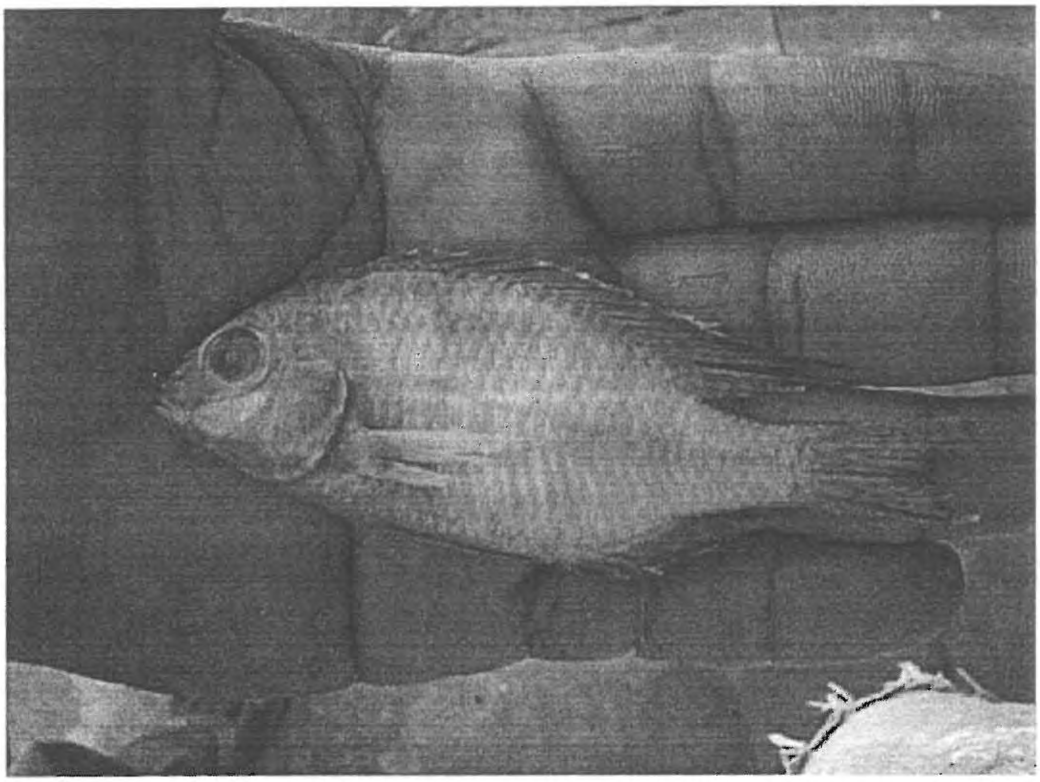


PLATE 6.6: *Lethrinops* sp. 'turneri'

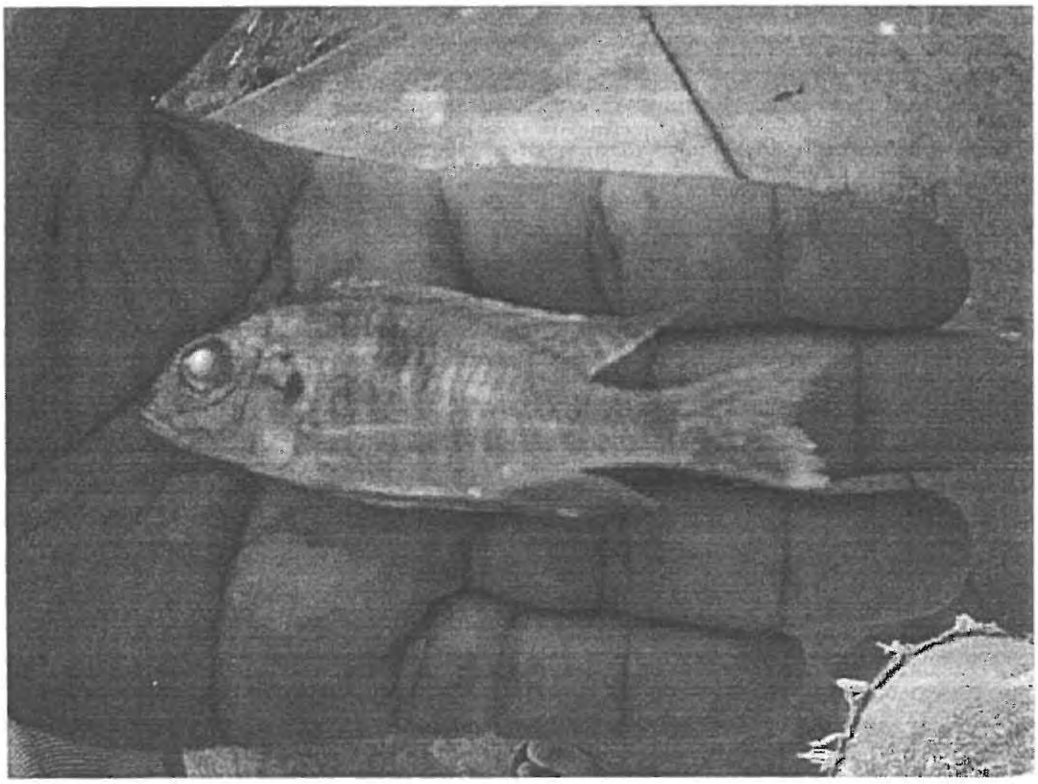


PLATE 6.7: *Lethrinops auritus*

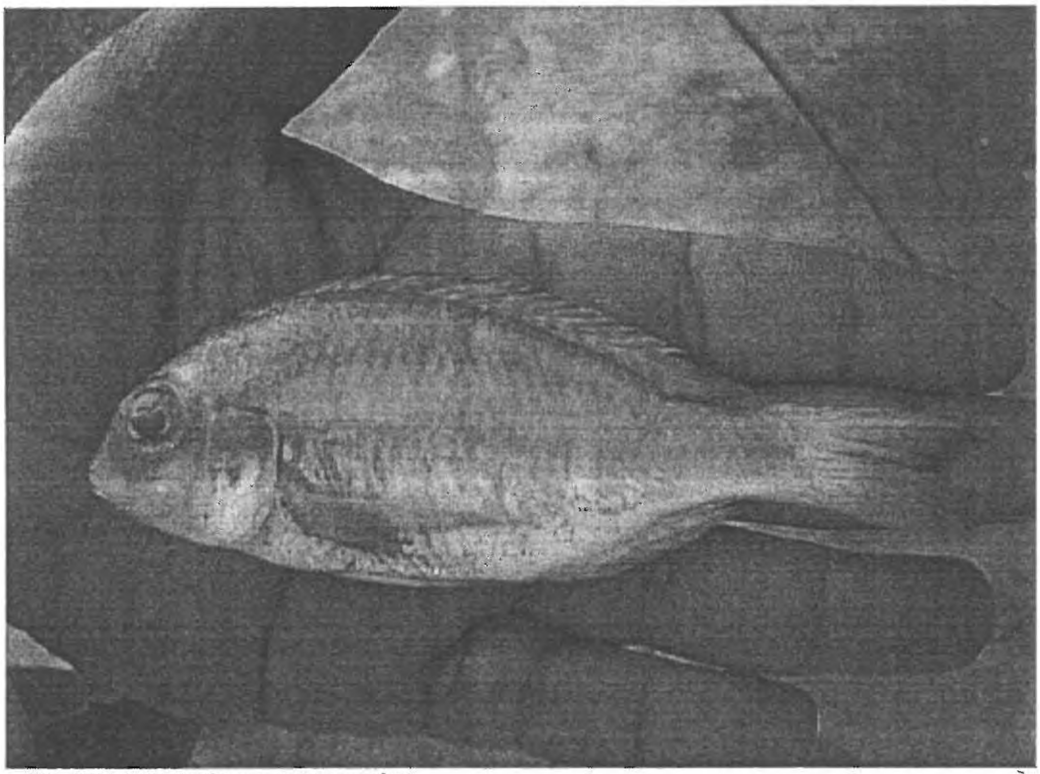


PLATE 6.8: *Lethrinops macrochir*

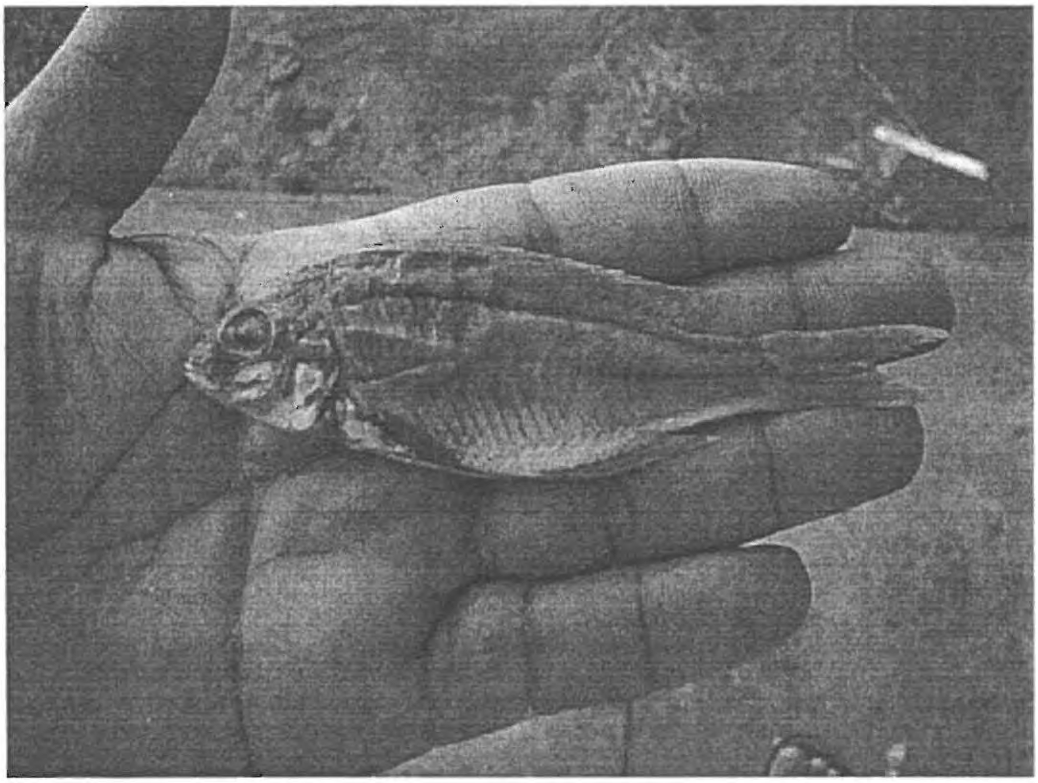


PLATE 6.9: *Lethrinops* sp. 'domira blotched'

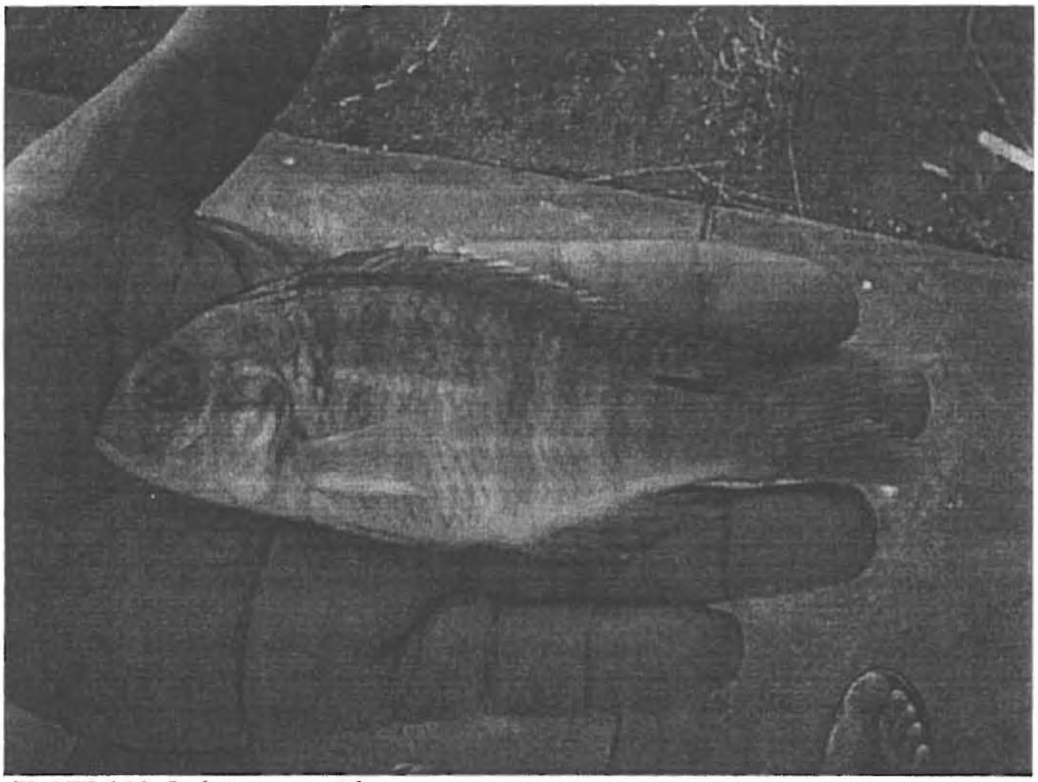


PLATE 6.10: *Lethrinops parvidens*

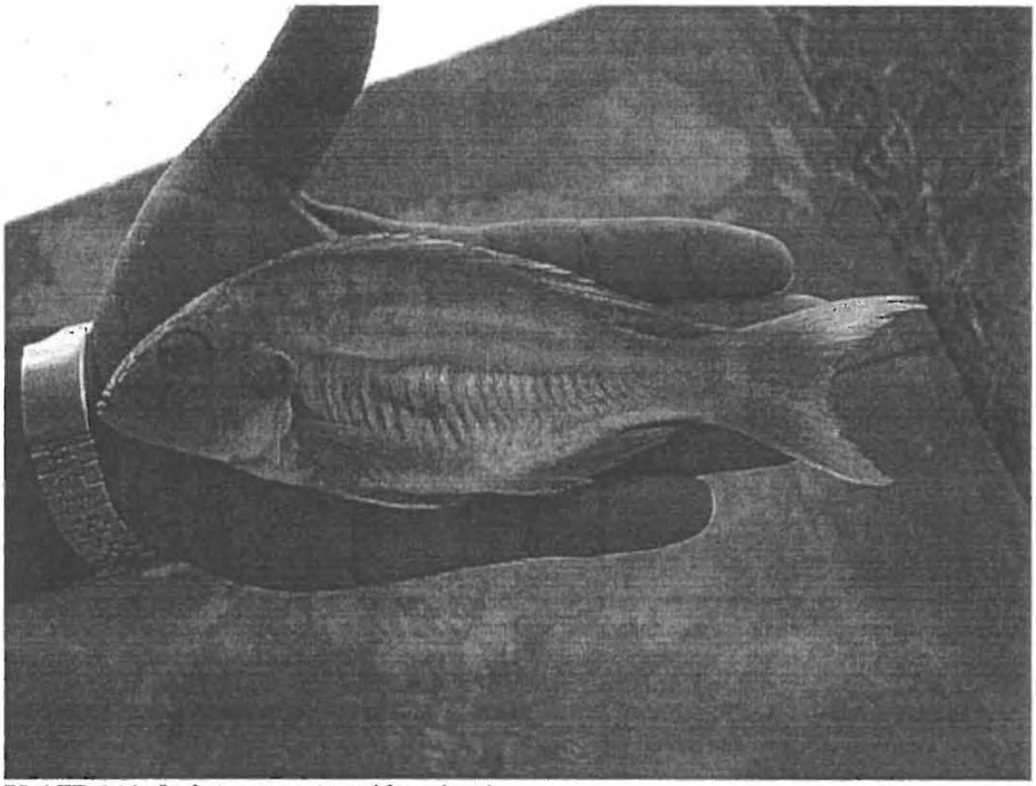


PLATE 6.11: *Lethrinops* sp. 'parvidens deep'

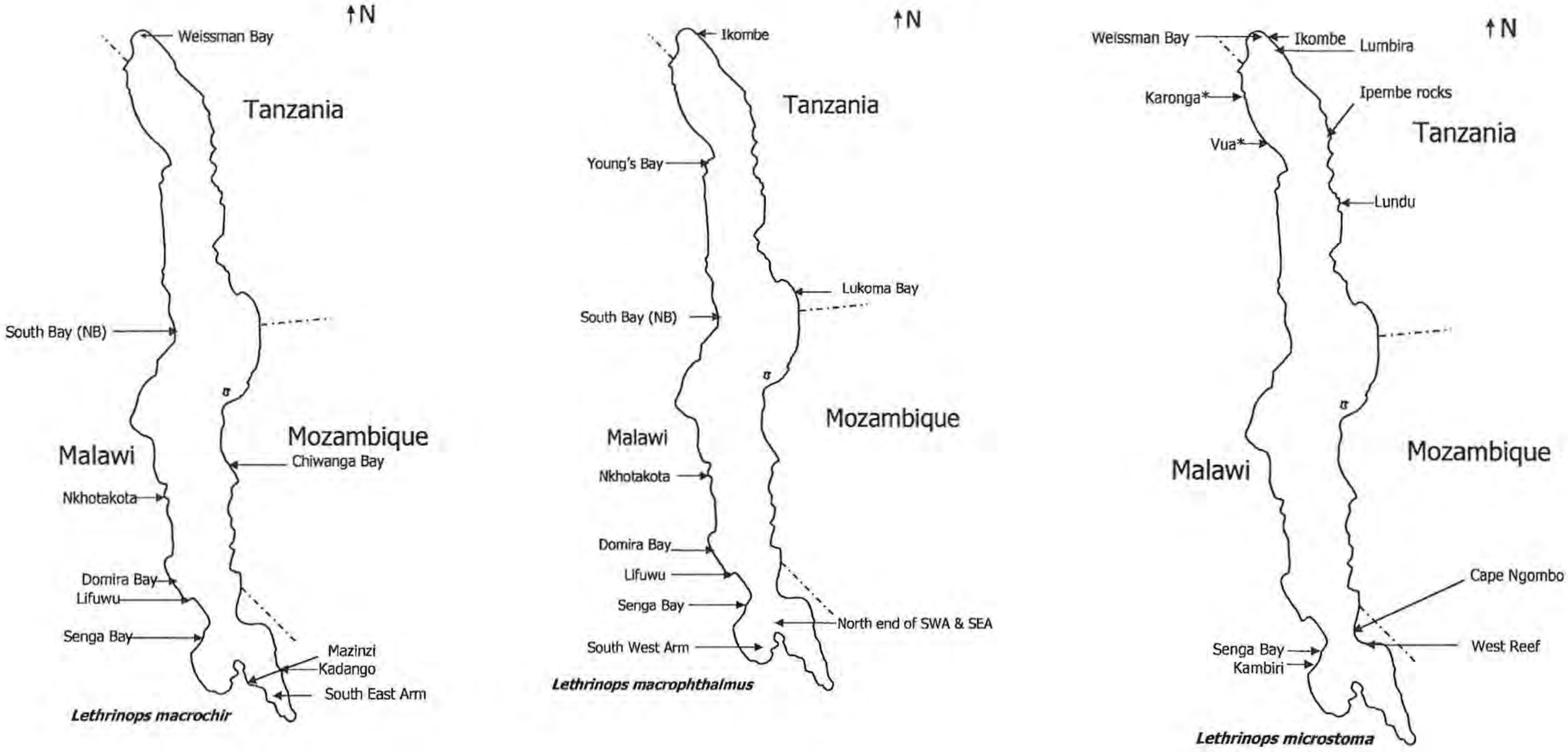


Fig. 6.26: Localities where *Lethrinops macrochir*, *L. macrophthalmus* and *L. microstoma* have been collected during this study; * type localities.

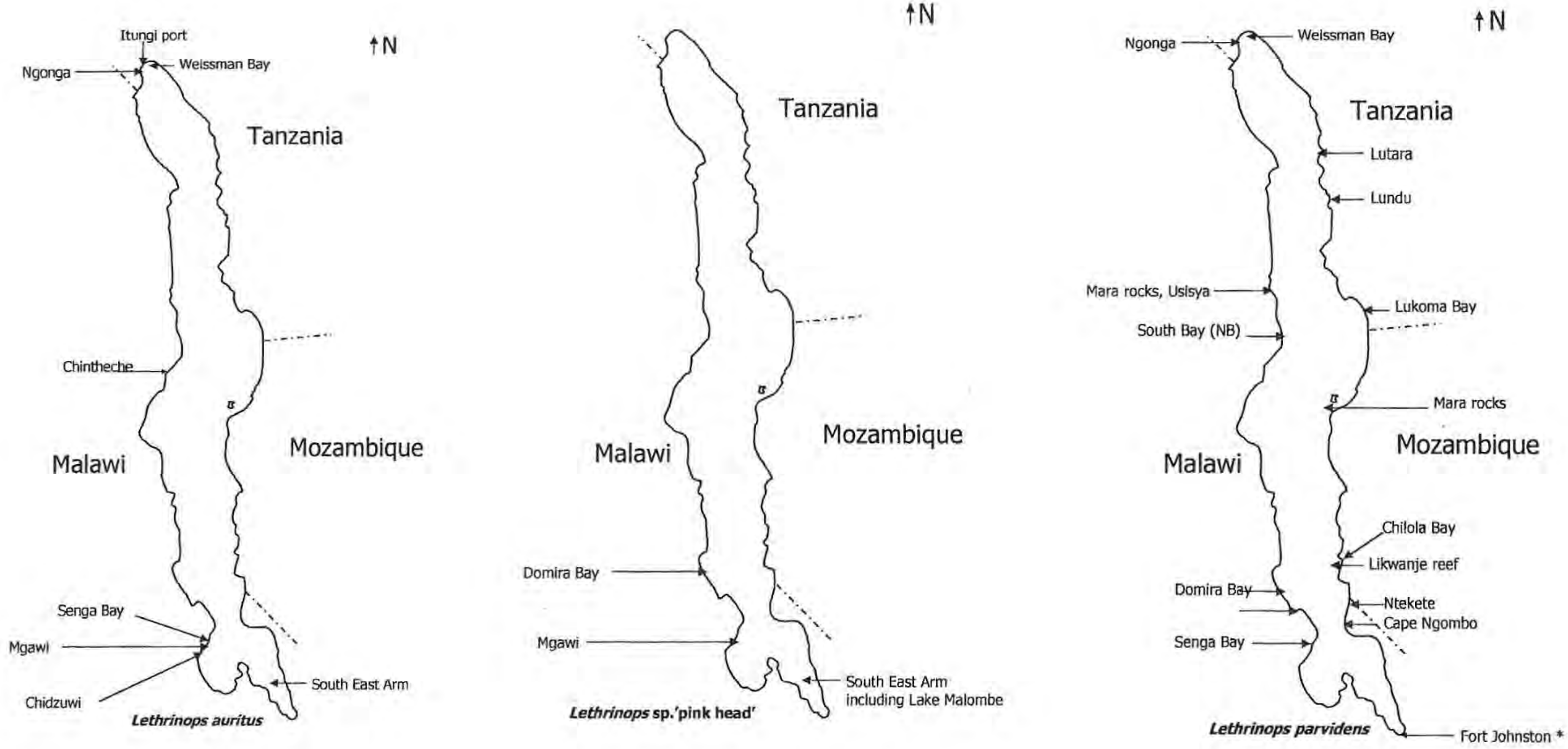


Figure 6.27: Localities where *Lethrinops auritus*, *L.* sp. 'turneri' and *L. parvidens* have been collected during this study; *denotes type localities.

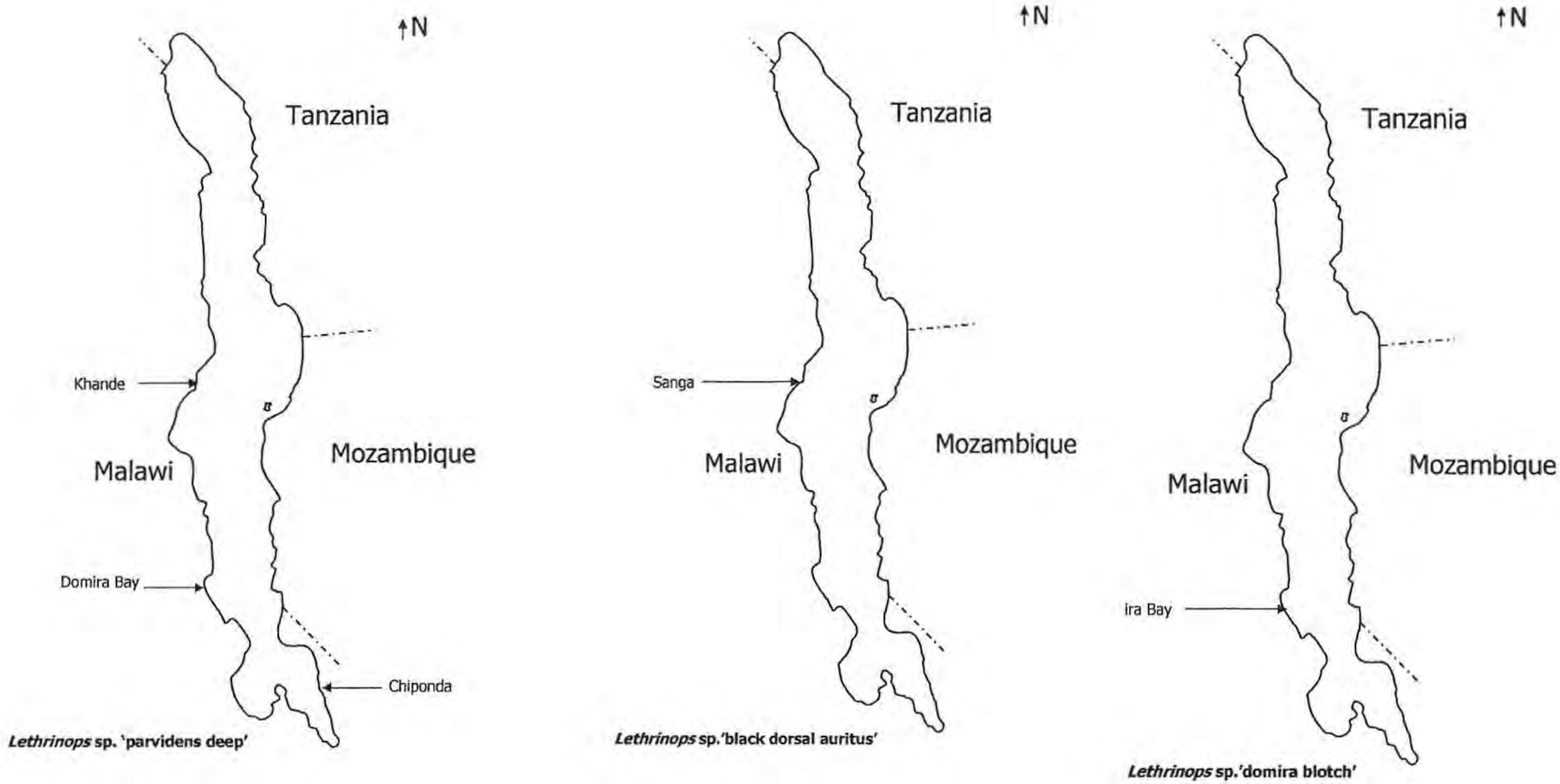


Figure 6.28: Localities where *Lethrinops* sp. 'parvidens deep', *Lethrinops* sp. 'black dorsal auritus' and *L.* sp. domira blotch' have been collected during this study.

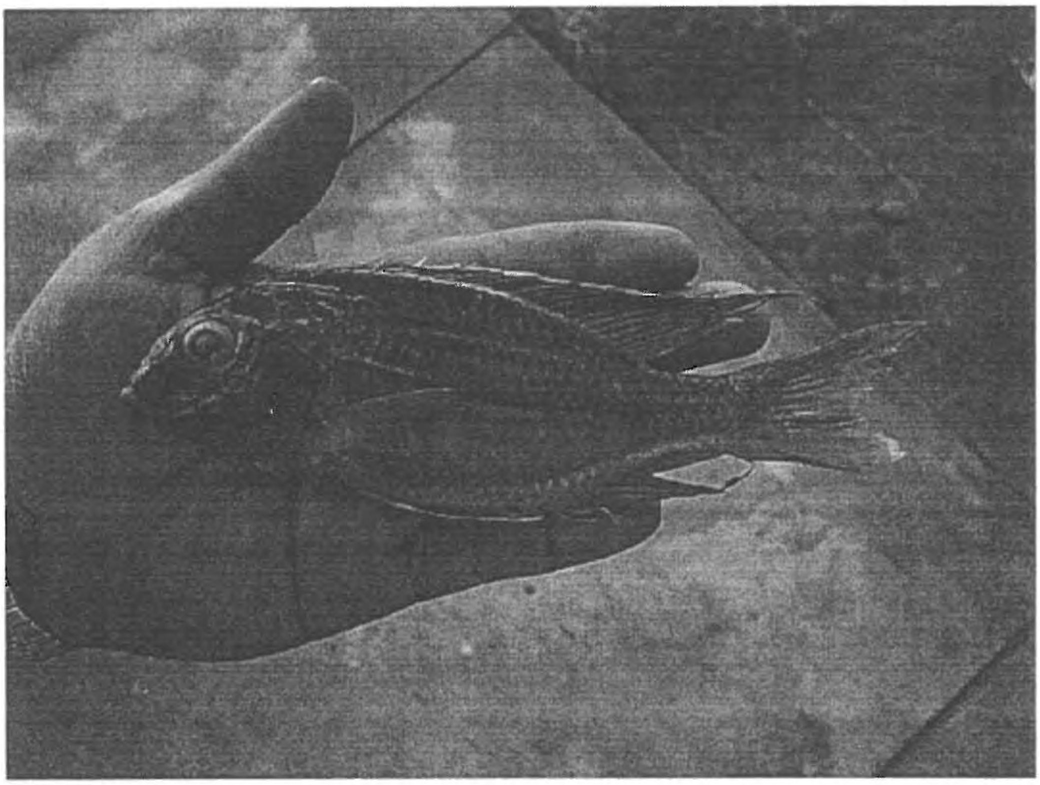


PLATE 6.12: *Lethrinops furcifer*

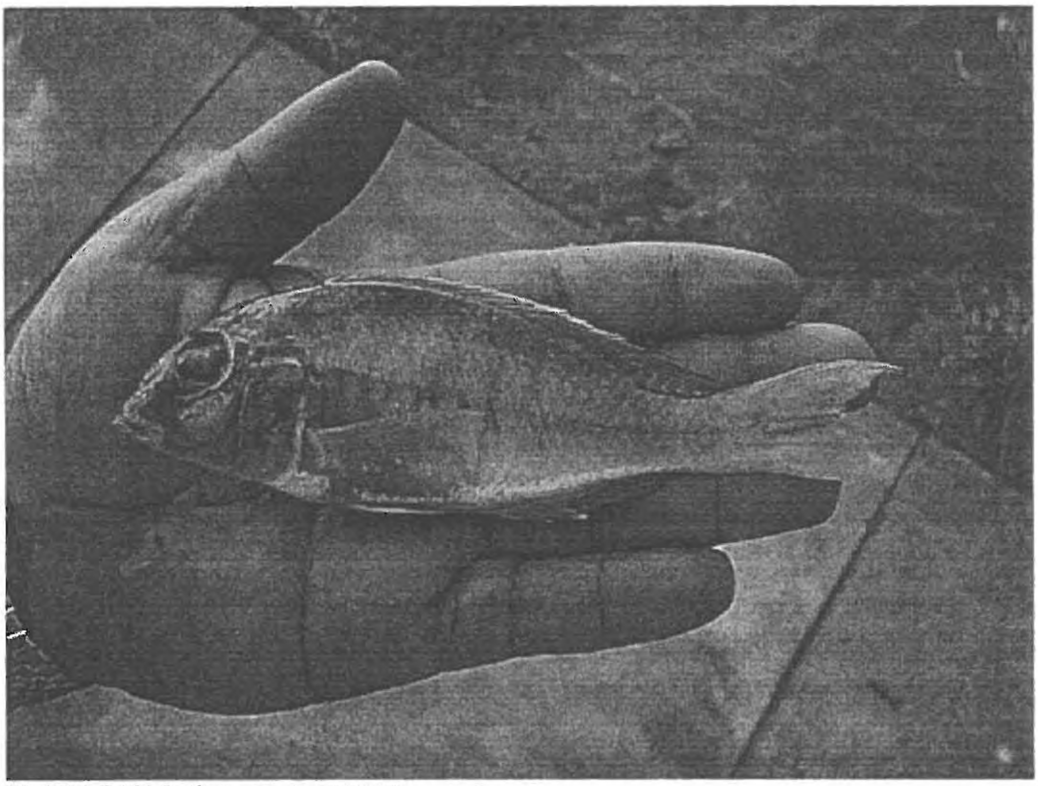


PLATE 6.13: *Lethrinops marginatus*

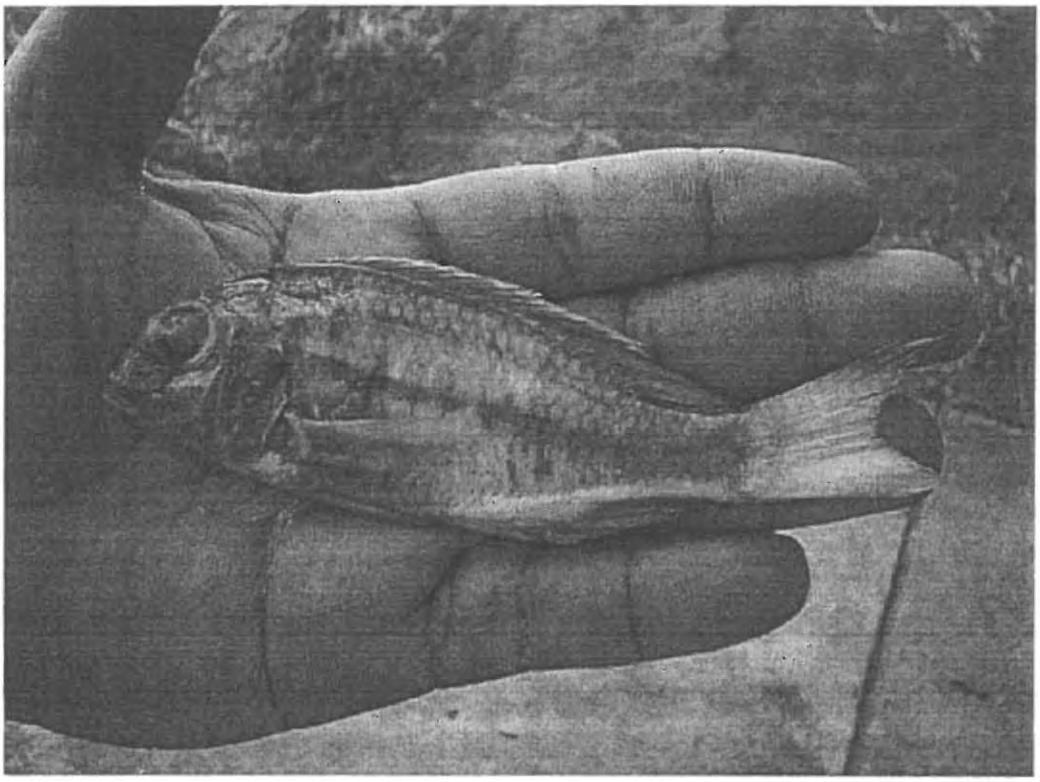


PLATE 6.14: *Lethrinops albus*

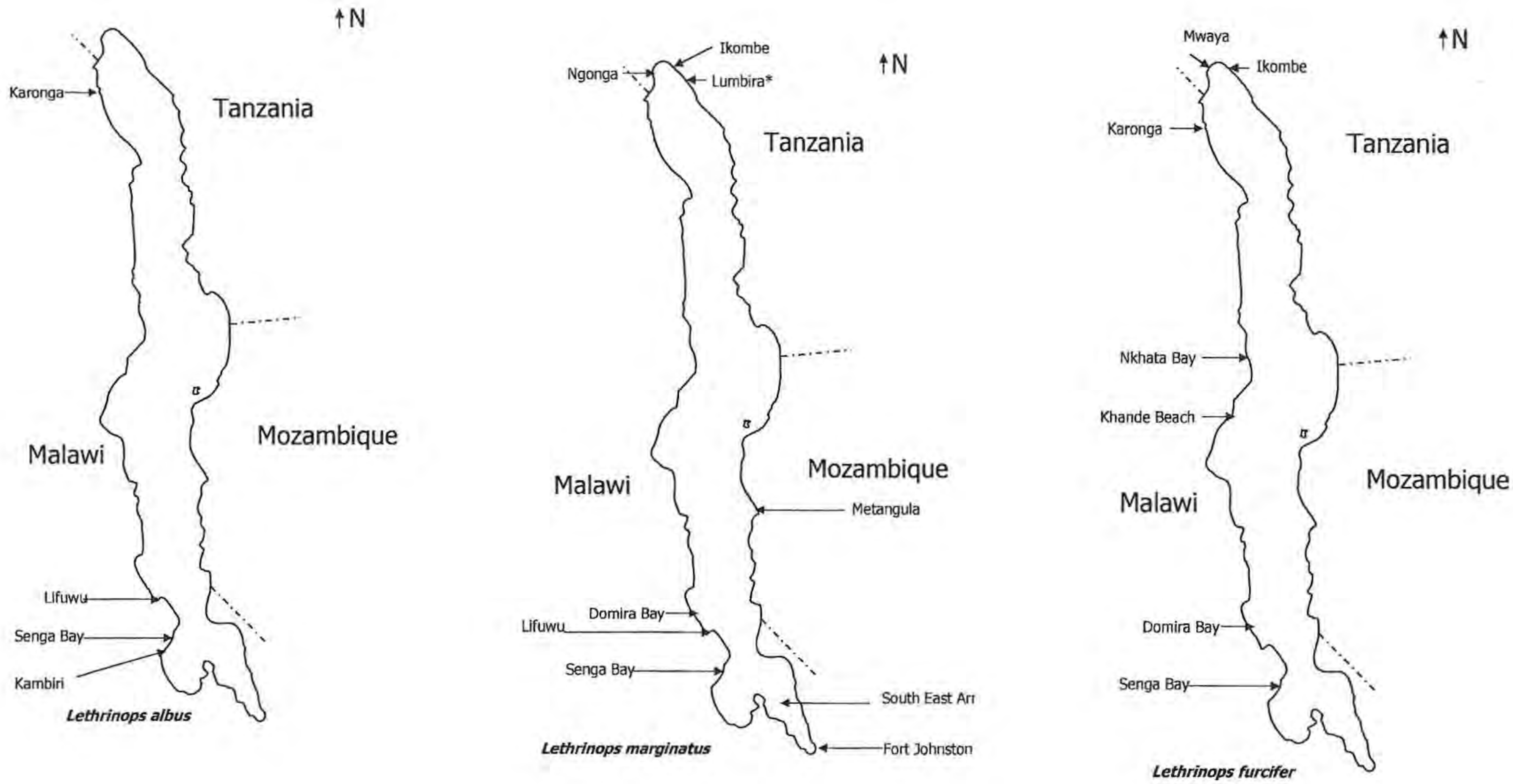


Fig. 6.29: Localities where *Lethrinops albus*, *L. marginatus* and *L. furcifer* have been collected during this study * denotes type localities.

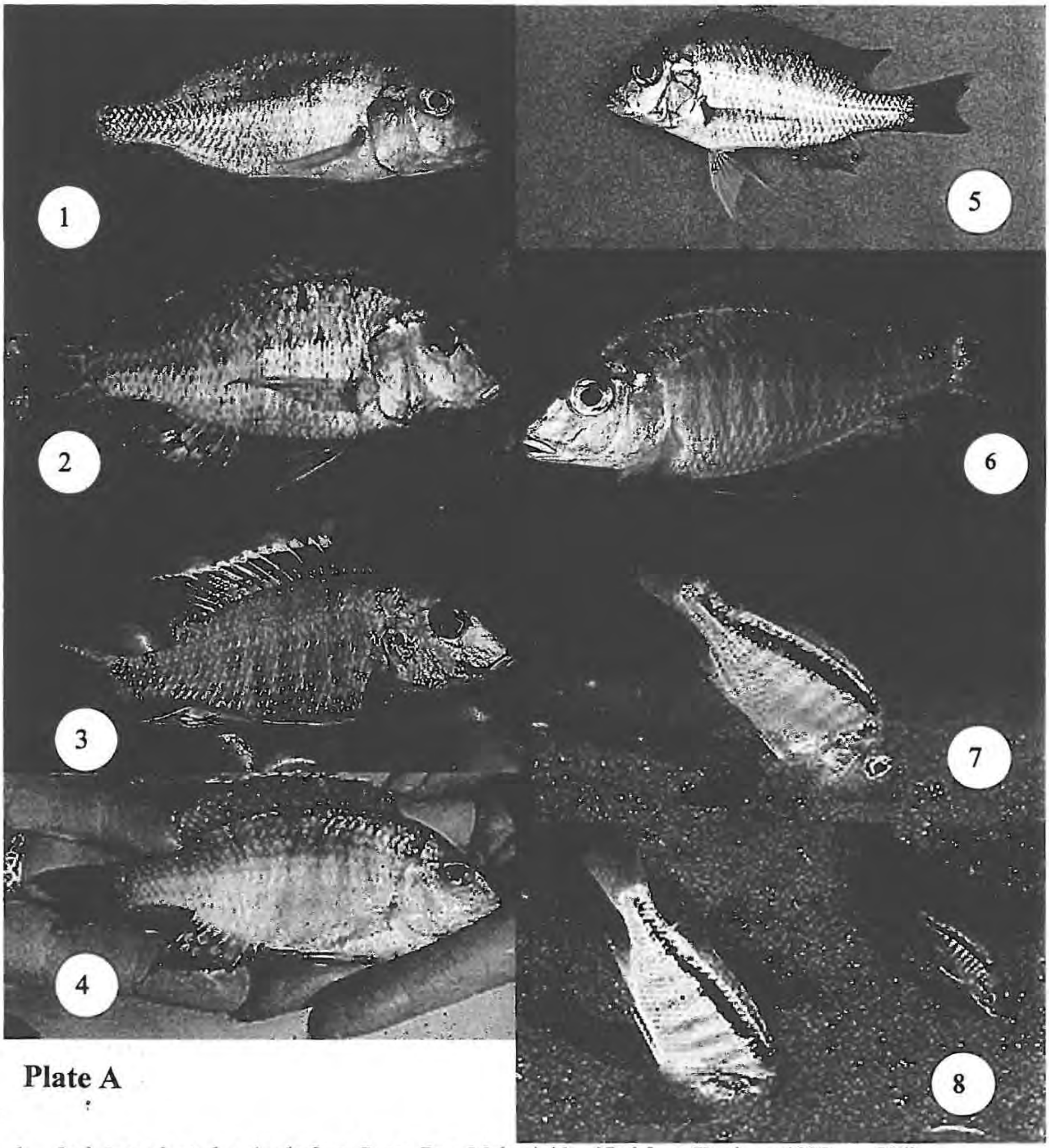


Plate A

1. *Lethrinops leptodon*, (male from Senga Bay, Malawi, identified from Konings, 1995, pg. 294).
2. *Lethrinops lethrinus*, (male from South-East Arm, Turner, 1996, pg. 176).
3. *Lethrinops lunaris*, (male from Senga Bay, Malawi, identified from Konings, 1995, pg.294).
4. *Lethrinops* sp. 'turneri', (male from South-East Arm, from Turner, 1996, pg. 59).
5. *Lethrinops microstoma*, (non-breeding male, from Senga Bay, Malawi).
6. *Lethrinops microstoma*, (male from Ntekete, Malawi, note the distinctive pink gular/throat, Konings, 1995, pg.285).
7. *Taeniolethrinops praeorbitalis* striped-type, (probably female from Lupingu, Tanzania).
8. *Taeniolethrinops praeorbitalis* striped-type, (probably female) and a sub-adult *T. laticeps*, (from Lupingu, Tanzania, Spreinat, 1995, pg. 93).

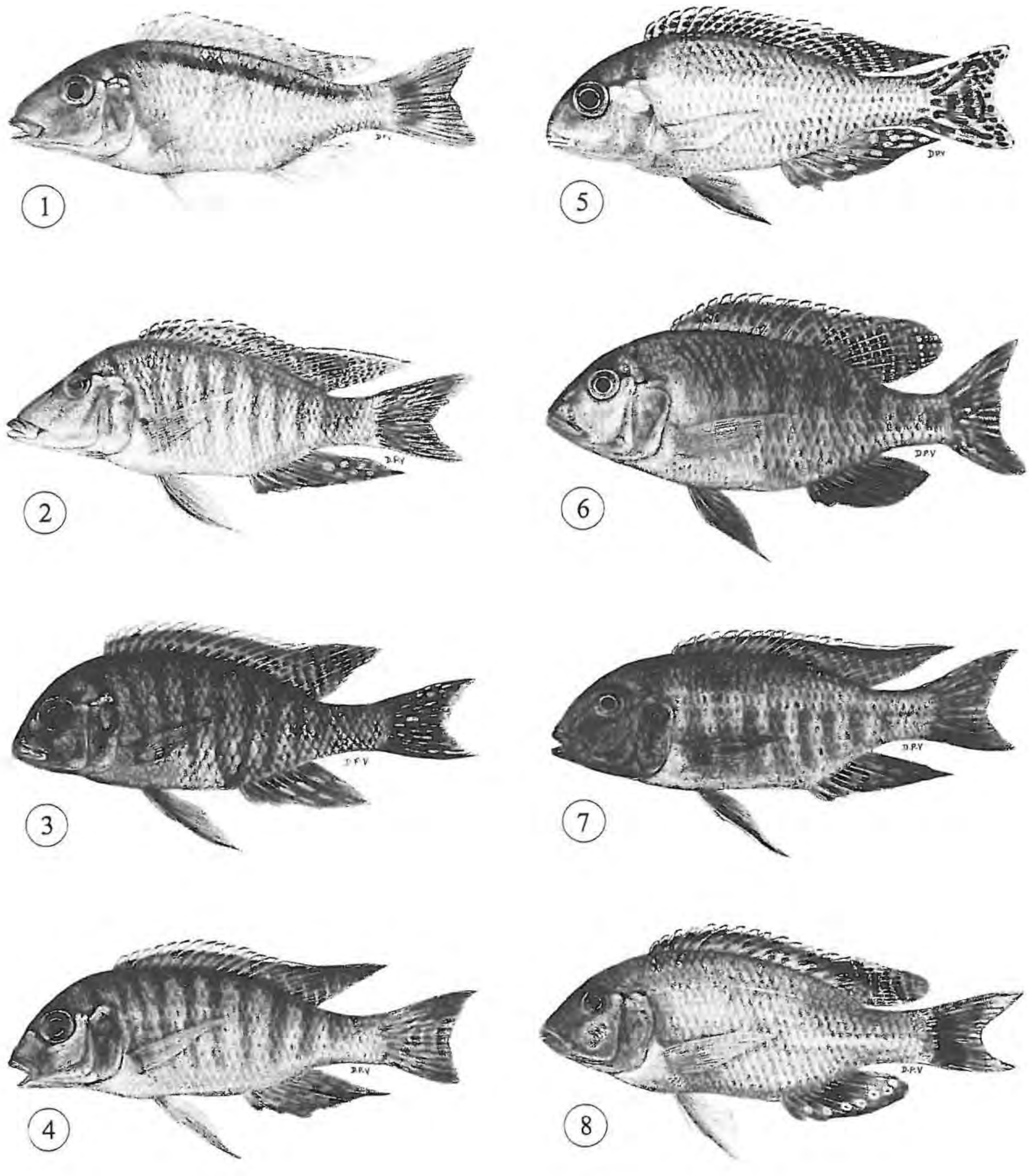


Plate B

1. *Taeniolethrinops furcicauda*, (female from, Chintheche, Malawi)
2. *Taeniolethrinops praeorbitalis* (male from Itungi, Tanzania)
3. *Tramitichromis* sp. 'pharyngeals' (male from Nkhota kota, Malawi)
4. *Lethrinops parvidens* (male from Chintheche, Malawi)
5. *Lethrinops microstoma* (male from Ngonga, Tanzania)
6. *Lethrinops lunaris* (male from Khande, Malawi)
7. *Lethrinops furcifer* (male from Ikombe, Tanzania)
8. *Lethrinops furcifer* (male from Chintheche, Malawi)

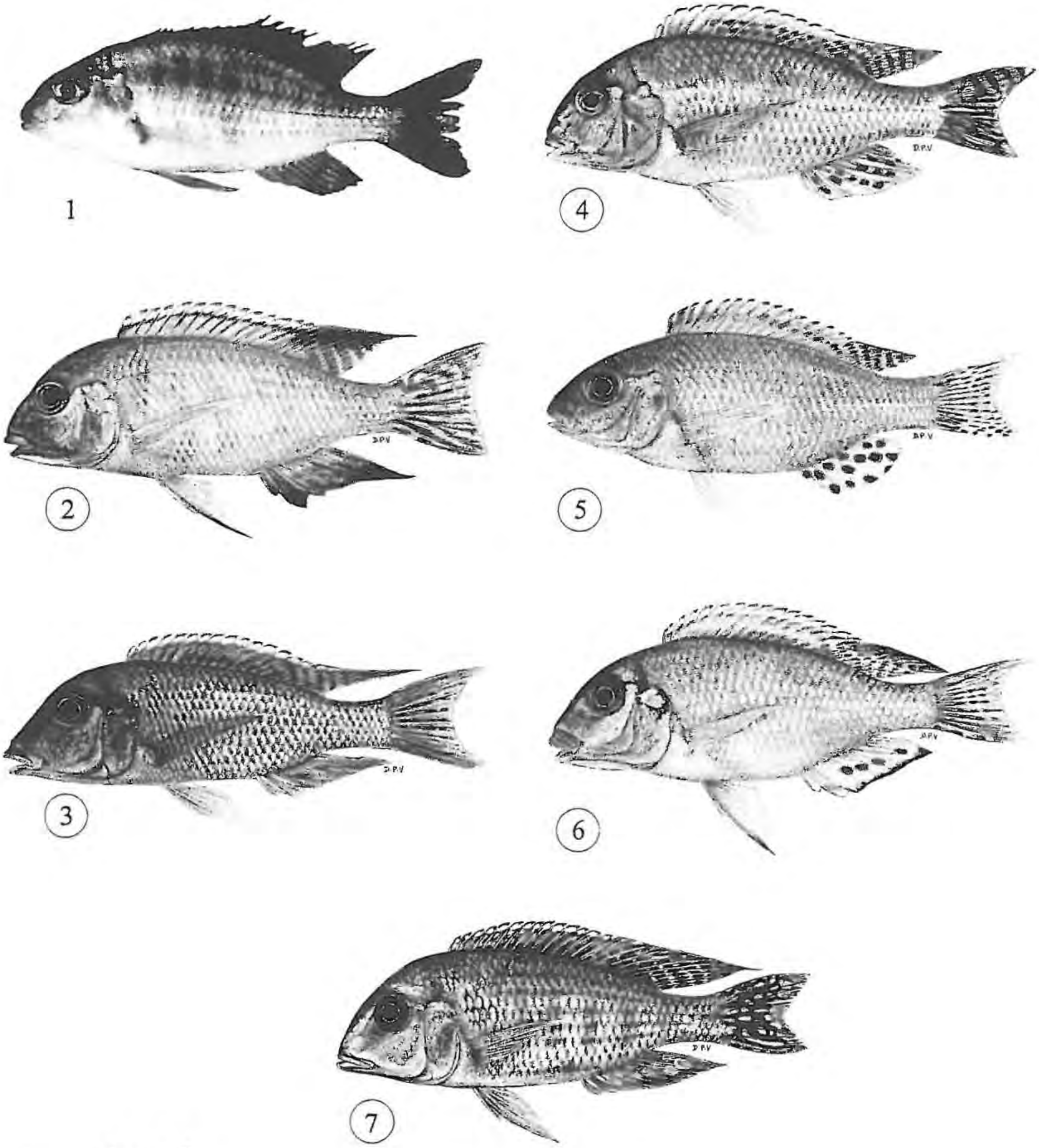


Plate C

1. *Lethrinops microstoma* (female from Senga Bay, Malawi)
2. *Lethrinops* sp. 'black dorsal auritus' (male from Sanga beach, Malawi)
3. *Lethrinops marginatus* (male from Chintheche, Malawi)
4. *Lethrinops microstoma* (male from Senga Bay, Malawi)
5. *Lethrinops microstoma* (male from Chintheche, Malawi)
6. *Lethrinops microstoma* (male from Chintheche, Malawi)
7. *Lethrinops marginatus* (male from Senga Bay, Malawi)

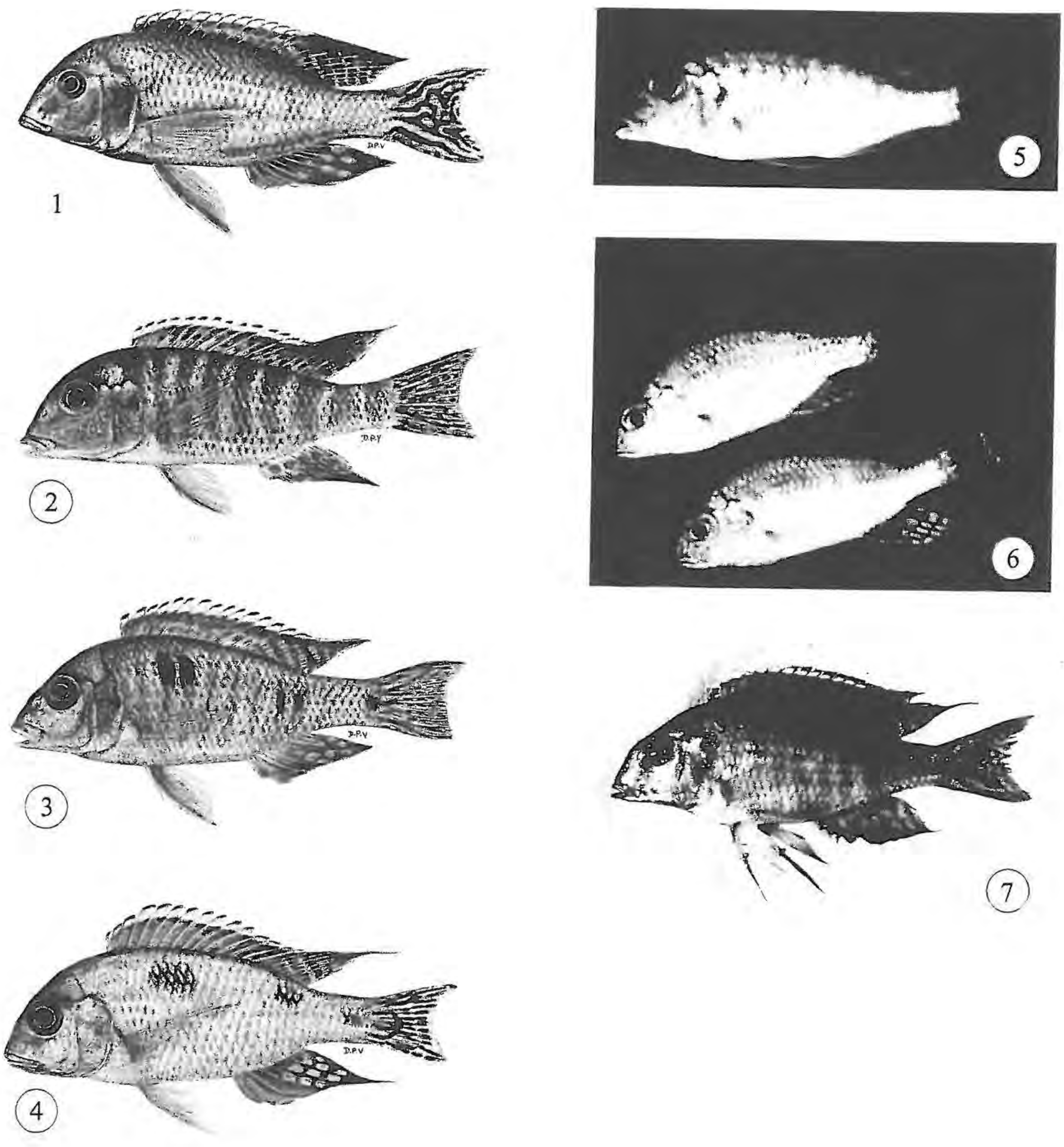


Plate D

1. *Lethrinops albus* (male from Ngonga, Tanzania)
2. *Lethrinops albus* (male from Chintheche, Malawi)
3. *Lethrinops auritus* (male from Chintheche, Malawi)
4. *Lethrinops auritus* (male from Senga Bay, Malawi)
5. *Lethrinops albus* (female from Ngonga, Tanzania)
6. *Lethrinops auritus* (male from Ngonga, Tanzania)
7. *Lethrinops marginatus* (male from Senga Bay, Malawi

Chapter 7. General discussion

7.1. Molecular phylogeny of shallow-water *Lethrinops* 'sensu lato'

Attempts to reconstruct the phylogenetic relationships of the Lake Malawi/Nyasa haplochromine cichlids have for long been confounded by two major obstacles. First, there is the paucity of information (morphological, osteological, etc.) of characters and character states and secondly, the occurrence of parallelism, which made it difficult to ascertain if the shared traits are actually synapomorphic (Eccles & Trewavas, 1989). Thirdly, there is also the problem of the large numbers of closely related taxa which are very difficult to distinguish.

When confronted with these problems, Eccles & Trewavas (1989) based their taxonomic classification of the Malawian haplochromine cichlids mainly on body melanin pattern, morphology of the oral and the pharyngeal jaws and dentition. They revised the genus *Lethrinops* 'sensu lato' and described two new genera: *Taeniolethrinops* and *Tramitichromis*. All three genera share the typical *Lethrinops* dentition, but in their generic classification, Eccles & Trewavas (1989) also gave a considerable phylogenetic weight to the melanin pattern.

Recent developments in molecular genetics have revolutionised phylogenetics and have cast doubt on some theories that were forwarded to explain the descent of Malawian haplochromine cichlids. Moran et al. (1994), using restriction enzyme analysis of mitochondrial DNA (mtDNA), assayed 40 species of Lake Malawi/Nyasa haplochromines and also included two species from Lake Tanganyika as outgroups. Six distinctive lineage groups were distinguished; two of which were major clades represented by a large number of species. The other four were each represented by a single species and regarded as either oligotypic lineages, non-endemics or outgroups. Interestingly, one of the two major clades was composed of the shallow-water, rock-dwelling mbuna species together with morphologically different deep-water species, whereas the other included a diverse array of shallow-water sand-dwelling species. In the context of the genus *Lethrinops*, their findings revealed that deep-water *Lethrinops* (represented by *L. gossei*) are closely related to Mbuna. These findings sparked some hesitant disbelief among some ichthyologists. Morphologically, the deep-water cichlids are very different from the shallow-water, mostly lithophilic, Mbuna.

The SADC/GEF and DFID projects on Lake Malawi/Nyasa contracted scientists from the Molecular Ecology and Fisheries Genetics Laboratory, Department of Biological Sciences, University of Hull (UK). They performed mtDNA sequence analyses on a range of specimens and, elaborating on the results of Moran et al. (1994), found a fascinating pattern, the results of which are discussed by Hauser et al. (1999). Basically, the Malawi cichlid flock comprises 6 closely related lineages: (A) *Rhamphochromis*, (B) *Diplotaxodon/Pallidochromis*, (C) *Copadichromis virginalis*, (D) *Astatotilapia calliptera*, (E) Mbuna, *Aulonocara*, Alticorpus, deep-water *Lethrinops* and (F) the rest of the sand-dwelling cichlids such as *Otopharynx*, *Mylochromis*, *Protomelas*, *Nimbochromis*, *Ctenopharyx*, *Dimidiochromis*, *Cyrtocara*, *Exochromis* *Sciaenochromis*, Stigmatochromis, *Champsochromis*, *Buccochromis* and the remaining of *Copadichromis* and *Lethrinops* (Fig. 7.1, see also fig. 3 in Hauser et al. (1999)). Based on the work done at Hull it became more than convincing that there are only six lineages within the Malawian haplochromines. The task was now to decide which species belong to which of the six groups. When 18 species of the *Lethrinops* 'sensu lato' were included, they were put into two clearly distinct clades (Fig. 7.2, see also fig. 4 in Hauser et. al. (1999)).

In the Mbuna clade (E) were found all the deep-water *Lethrinops*: *Lethrinops altus*, *Lethrinops* sp. 'oliveri', *Lethrinops* sp. 'deepwater albus', *Lethrinops longipinnis*, *Lethrinops microdon*, *Lethrinops gossei*, *Lethrinops polli*, *Lethrinops longimanus* and *Lethrinops* cf. *parvidens*. In clade F (the rest) were present the shallow-water *Lethrinops* 'sensu lato' represented by the following members: *Taeniolethrinops praeorbitalis*, *Taeniolethrinops laticeps* and *Taeniolethrinops furcicauda*, *Tramitichromis variabilis*, *Tramitichromis brevis* and *Tramitichromis lituris* and *Lethrinops furcifer*, *Lethrinops marginatus* and *Lethrinops albus*. All the shallow-water samples were collected from the Tanzanian shore.

It is quite evident from the dendrogram presented that mtDNA sequence data are not able to resolve the full *Lethrinops* 'sensu lato' phylogeny, though a deep split within this group is demonstrated. Fascinatingly, all specimens of each putative species should cluster together, but they do not. This suggests that speciation is occurring more rapidly than alleles fixation. Another possibility is that the genetic differentiation is very recent.

It is not possible to reliably reconstruct the sequence of branching among the six major lineages, or to reliably resolve relationships between species belonging to these groups. The lineages seem to represent the initial burst of radiation in the lake. The six clades were very consistently found by all possible phylogenetic algorithms and with 2 separate mtDNA regions (ND2 and D-loop: Idid, pers. comm.)

Most likely, *Lethrinops* 'sensu lato', as currently defined, is not monophyletic but is paraphyletic or more probably polyphyletic. From the dendrogram it is also not possible to confirm the monophyly of *Taeniolethrinops*, *Tramitichromis* and shallow-water *Lethrinops* s.s. This indicates clearly that the typical *Lethrinops* dentition has either arisen more than once, or only once and subsequently was lost in many taxa. According to these molecular results, the special *Lethrinops* dentition provides no particularly strong evidence for affinity among shallow-water *Lethrinops* s.s., *Tramitichromis* and *Taeniolethrinops*.

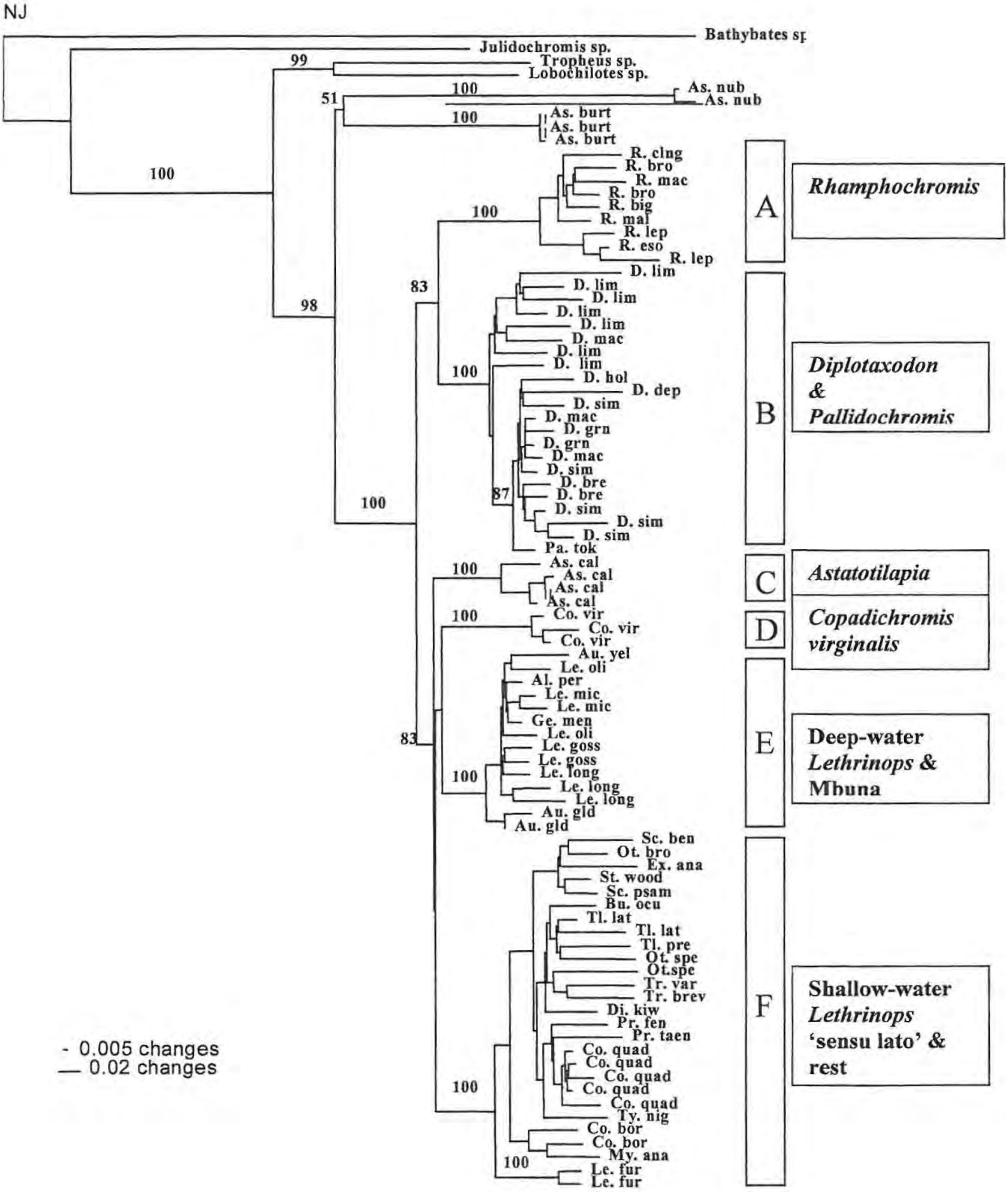


Figure 7.1. Neighbour-Joining dendrogram (Tamura- Nei) with 1000 bootstrap replicates (From Hauser et.al 1999).

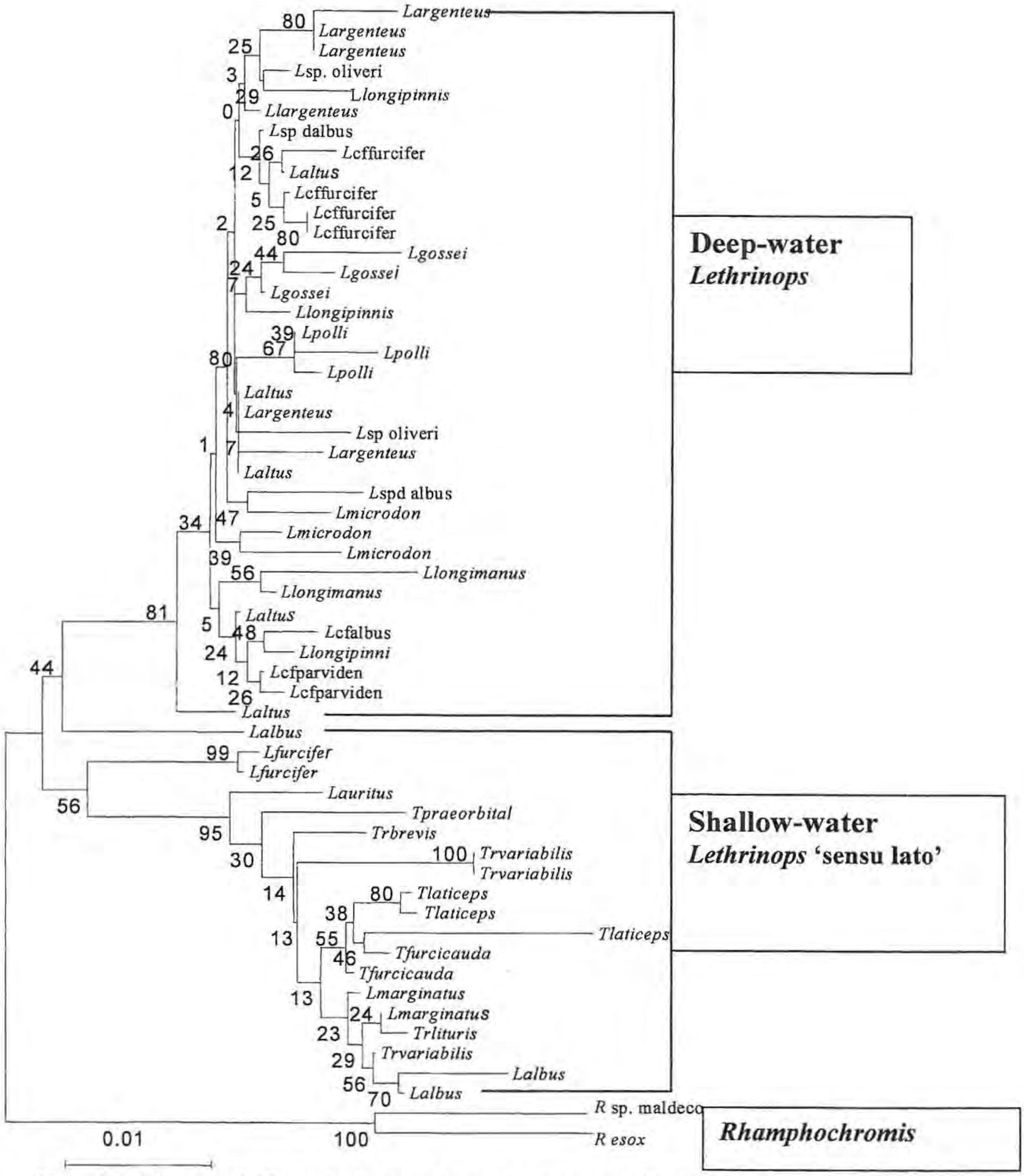


Figure 7.2: Nearest neighbour dendrogram based on sequences of *Lethrinops* 'sensu lato'

7.2. The complexity of *Lethrinops* taxonomy

Many earlier descriptions of *Lethrinops* 'sensu lato' species have been based on small samples collected from imprecisely defined localities, and few characters have been used to differentiate the taxa. Several shallow-water species were reviewed by Eccles & Lewis (1978, 1979) including additional specimens from more precise localities within the Malawian part of the lake.

In the present work, revision of shallow-water *Lethrinops* 'sensu lato' has been based mainly on newly collected specimens from several localities all around the lake. Both the generic and the species descriptions have been enlarged upon. Attempts have been made to synthesize more of the various conclusions of previous workers as well as to provide distribution records of the species. The decision to consider the shallow-water *Lethrinops* as being different from the deep-water ones was not arbitrary. First, there is ecological evidence that the two groups occupy different depth ranges (Table 1.4). Secondly, morphologically the two groups have different melanin patterns. In the course of this study it has further been shown that the two form different phylogenetic lineages (Fig. 7.1 & Fig. 7.2). Therefore, for the first time a clear distinction has been drawn between shallow-water and deep-water *Lethrinops* based on ecological, morphological and molecular evidence (Table 7.1).

Table7:1 Distinctions between deep-water and shallow-water *Lethrinops* 'sensu stricto'

Group/Demarcation	Ecological	Morphological	Molecular phylogenetic
Deep-water ***Lethrinops***	All species found at depths in excess of 20m	Predominant body melanin pattern (if any) vertical bars. Lower gill rakers 9-30	Form a clade with mbuna, *Aulonocara* and *Alticorpus*
Shallow-water ***Lethrinops***	All species found at depths of 20m or less, although the range of a few extend to deeper waters	Predominant body melanin pattern (if any) can be vertical, horizontal or oblique stripes or an oblique row of spots or a mixture of any two. Lower gill rakers 5-14	Form part of a diverse clade that includes most other sand-dwelling cichlids.

Rather than entering deep into the never-ending debate on species concepts or proposing yet another concept, a pragmatic approach has been opted for. The work presented in this thesis uses (largely) morphological information to estimate genetical species status of the taxa under study, that is, the study is using morphological evidence to estimate the 'biological' species status of the taxa understudy. However also the information on colour pattern of other males, females and juveniles has been taken into account, complemented with information on the distribution and habitat range.

This study has once more elucidated the difficulty inherent in the taxonomy of the Lake Malawi/Nyasa cichlid fishes, due to the presence of closely related species complexes, which are difficult to distinguish using morphological characters.

Using Principal Component Analyses (PCA) and Mann-Whitney U tests on morphometric and meristic data, it has been possible to detect differences among the taxa investigated. Sometimes the differences were clear-cut, but in other cases differentiation was very difficult. The lack of enough specimens in some taxa also created such difficulties.

In addition to the clear-cut species with large samples sizes, some taxa with very small sample sizes that do not fit well in any of the described species, were distinguished. These could have been put at the end in a separate chapter as "specimens of uncertain status," but have instead been presented with full species descriptions and included in the key as it is thought that they may represent valid species which are presently poorly represented in the collections. Some of these taxa may represent very rare species.

Traditionally, a revision of a group of fishes is concluded with a key for the identification of species. However, the explosive speciation that has taken place amongst the cichlid species of Lake Malawi/Nyasa has resulted in the proliferation of reproductively isolated, but morphologically similar species, which are extremely difficult to separate on anatomical and morphological grounds alone. Barel et al. (1977) discussed the impossibility of constructing a simple identification key for the Lake Victoria cichlids, and noted that hardly ever does one morphological character serve to identify closely related species and that it is not exceptional for all morphometric and meristic feature to overlap. Eccles & Lewis (1977) found individual variation was such that no single character could be used to distinguish with certainty all specimens of *Lethrinops stridei* from *L. microdon* and *L. micrentodon* and only by examining a combination of number of features in conjunction could a reliable identification be made. Lewis (1982), when confronted with the problem of morphometric overlap in the genus *Labidochromis*, decided to use colour patterns of live adult males. Such an approach cannot be fully applied in this study because of the manner in which data were collected precluded observations of sexually active live males. The use of male colour patterns for the construction of species identification keys involves underwater observations and laboratory studies on live fish. Such colour descriptions may be of less use for fisheries field identification purposes in the absence of true territorial male colour patterns.

Instead of presenting unwieldy keys, after use of which one inevitably has to check the species description, Snoeks (1994) opted for identification guide-lines for the Lake Kivu haplochromines based on which species correspond to which easy to determine morphological feature. He however, strongly recommended the inexperienced researcher to compare the identification against the individual diagnosis and description of the species.

All the *Lethrinops* species examined display considerable variation in almost every character measured. Although there are significant differences in the means of proportional measurements and counts between some species, the overlap is such that these meristic values are often of little use for the identification of a single specimen or small sample. This lack of clear-cut morphological distinction makes an attempt to construct a morphological key for this group notoriously difficult.

The conclusion that the species described above are valid was based on consideration of a number of factors. These included differences in morphological features, meristics, particularly of the gill rakers and the dentition, but also such qualitative characters as body, head and snout shape, markings in the body and fins and male breeding coloration.

The artificial key produced from this study of *Lethrinops* 'sensu lato' is based on the most complete information currently available and requires field practice and some prior knowledge of these fishes. This is certainly not surprising as in fact it is very rare to find a key to the species in studies on African lacustrine cichlids, which works effectively, except for a few groups (Greenwood, 1973). This is because of the large amount of inter-specific overlap.

A summary discussion of each taxonomic category is given hereunder but also refer to the full description of each species group for additional details.

7.2.1. The genus *Taeniolethrinops*:

Four distinct species within the genus *Taeniolethrinops* have been distinguished with the following observations:

T. cyrtonotus: Only the number of gill rakers can be used distinguish *T. cyrtonotus* from *T. furcicauda*. There is a complete overlap with *T. furcicauda* on measurements. One hypothesis could be that *T. cyrtonotus* specimens are just *T. furcicauda* with a high number of gill rakers. If this hypothesis is true and *T. cyrtonotus* were to be included in *T. furcicauda*, then the range in gill raker counts of this species would be very large compared to all other species. When specimens of *T. cyrtonotus* (except the type) and *T. furcicauda* are laid side by side it is hardly possible to notice any difference on general body morphology except for the slightly deeper bodied appearance of *T. cyrtonotus*. Unfortunately, none of the specimens assigned to *T. cyrtonotus* in this study, have the humped backs evident in the type. Possibly the type is a deformed or aberrant individual which is conspecific to the normal specimens which have been assigned to this species on the basis of similar gill raker counts.

Taeniolethrinops praeorbitalis: Failure to detect any morphological differences between the striped and unstriped forms of *T. praeorbitalis* may be taken as supporting evidence, that *T. praeorbitalis* is polymorphic in colour. The striped morphs (including the types of *T. macrorhynchus*) are morphologically different from *T. laticeps*, which makes field identification difficult.

The focus for future work should then be to examine whether the two forms (striped and unstriped) interbreed successfully in their natural habitat. Work on molecular genetics may help in resolving this element of uncertainty.

7.2.2. The genus *Tramitichromis*:

Accurate field identification of most members of this group without recourse to the oral and pharyngeal teeth shape and morphology, is often impossible. Most members of the genus *Tramitichromis* have a 'golf-shaped' head profile, short snouts and variable melanin patterns. In this morphological appearance they resemble members of the short-snouted *Lethrinops* 'sensu stricto.' This work has demonstrated the difficulty inherent in distinguishing the different taxa using morphological characteristics alone. *Tramitichromis brevis* can easily be identified by the presence of the oblique band and head shape. For ease of field identification, Turner (1996) discussed this species in his chapter together with '*Mylochromis* and other oblique-striped species'. Similarly, he put *T. intermedius* under the chapter heading '*Otopharynx* and other spotted species'. The status of *T. intermedius* is somewhat problematic which has led previous workers to consider this species under three different genera; *Lethrinops* (Trewavas, 1931), *Tramitichromis* (Eccles & Trewavas, 1989; Konings, 1995 with reservations) and *Trematocranus* (Konings, 1990). The specimens that have been assigned to *T. intermedius* in this study, do not have the enlarged sensory pits Konings (1990) assumed to be characteristic for *Trematocranus*. Clearly, *T. intermedius* has a pure *Lethrinops* dentition, but, within this group appears to be intermediate in morphology between the *parvidens-auritus*-'turneri' group of *Lethrinops* 'sensu stricto' and *Tramitichromis*. This species is therefore discussed here under the genus *Tramitichromis*.

A rare taxon referred to here as *T.* sp. 'brevis 2' closely resembles *T. brevis* in morphology. Two other newly found taxa are *T.* sp. 'variabilis deep' and *T.* sp. 'maculae'. Unfortunately, because of the manner in which these specimens were collected, information on live colours is lacking. Future work should focus mainly on the Mozambican coast from where most of the 'odd-looking' specimens were collected and take into account the male breeding colour patterns.

7.2.3. The shallow-water *Lethrinops* s.s

Morphologically, and for ease of field identification, the shallow-water *Lethrinops* 'sensu stricto' have been split up into three working groups. These do not however, reflect any phyletic relationship for members of each group.

The three species considered under the long-snouted shallow-water *Lethrinops* 'sensu stricto' can easily be distinguished among themselves and from members of the other two groups. Previous reports (Eccles & Lewis, 1978; Eccles & Trewavas, 1989) have in some cases doubted the specific status of some of the members of this group. The descriptions given in this study should help to resolve the taxonomic status of *L. lethrinus*, *L. leptodon* and *L. lunaris*.

Two of the nine taxa conveniently grouped under the short-snouted shallow-water *Lethrinops* 'sensu stricto' pose taxonomic uncertainties. These are *L.* sp 'parvidens deep' and *L.* sp. 'domira blotch'. The former because only large-sized specimen were available for analysis, and the latter because only two specimens were recorded. Principal Component Analysis on log-transformed measurements and raw meristics failed to bring up distinctive characters to separate *L. parvidens* from *L.* sp. 'parvidens deep' with confidence. It is only hoped that further work on live fish will help to resolve the true status regarding the two taxa. The short-snouted group comprises *L. microstoma*, *L.* sp. 'turneri', *L. auritus*, *L.* sp. 'black dorsal auritus', *L. macrochir*, *L. macrophthalmus*, *L.* sp. 'domira blotch' and the *L. parvidens*-group, which may require some experience to identify correctly.

In the last group, with members having intermediate snouts and fine teeth on the lower pharyngeal jaw, the type of *L. oculatus* and the only specimen used in the original description, has been synonymised with *L. marginatus*. This decision was prompted by the lack of freshly caught specimens that could fit the original description and the high morphological overlap with specimens of *L. marginatus*. It is relatively easy to identify *L. furcifer* but it requires a bit of taxonomic instinct to identify females and non-breeding males of *L. albus* from those of *L. marginatus* in the field.

7.3. Feeding Ecology:

Generally, there is no difference in the food items taken by the different taxa reported here, with the exception of *L. microstoma* which has been noted to have a preference for copepods, while all other shallow-water *Lethrinops* 'sensu lato' feed predominantly on chironomid larvae (Table 7.2). Stomach content analyses revealed varying proportions of benthic invertebrates: chironomid larvae, ostracods, copepods, oligochaetes and diatoms.

The majority of the shallow-water *Lethrinops* 'sensu lato' share the same depth distribution and are nearly all benthic feeders (sifting sand for edibles).

It is unexpected in ecology that closely related species would occupy essentially the same habitat, at the same time and stage in their life history and take the same food. The ecological similarity shown by the various species discussed here is unlikely to represent a contradiction of Gause's Exclusion Hypothesis (Gause, 1934), but rather that insufficient is known about the ecology and life-history of this group. Further ecological work is recommended, especially as these are such important fish commercially.

Table 7. 2: The maximum depth recorded (all taken to zero depth); main diet (co = copepods, ch = chironomid larvae, inv = invertebrate larvae, ch? = probably chironomids) and geographical distribution (N = north S = south, C = central) for the shallow-water *Lethrinops* 'sensu lato'.

Species	**Depth (m)**	**Diet**	**Distribution**
	0 50 100		
Taeniolethrinops cyrtonotus		inv.?	C
Taeniolethrinops furcicauda		ch	S, C, N
Taeniolethrinops laticeps		ch	S, C, N
Taeniolethrinops praeorbitalis		ch	S, C, N
Tramitichromis intermedius		ch	S, C, N
Tramitichromis sp. 'pharyngeals'		ch?	S, C
Tramitichromis brevis		ch	S, C, N
Tramitichromis sp. '*brevis* 2'		ch	S,C
Tramitichromis trilineata		ch	S, C, N
Tramitichromis sp. 'maculae'		ch?	C
Tramitichromis lituris		ch	S, C, N
Tramitichromis variabilis		ch	S, C, N
Tramitichromis sp. 'var. deep'		ch,	C
Lethrinops lunaris		ch	S, C
Lethrinops lethrinus		ch	S, C
Lethrinops leptodon		ch	S, C
Lethrinops microstoma		co	S, C, N
Lethrinops macrophthalmus		ch	S, C, N
Lethrinops sp. 'turneri'		ch	S
Lethrinops sp. 'bdauritus'		ch	C
Lethrinops auritus		ch	S, C, N
Lethrinops macrochir		ch	S, C, N
Lethrinops sp. 'domira blotch'		?	S
Lethrinops parvidens		ch	S, C, N
Lethrinops sp. 'parvidens deep'		ch	S, C
Lethrinops furcifer		ch	S, C, N
Lethrinops marginatus		ch	S, C, N
Lethrinops albus		ch	S, C, N
	0 50 100		

7.4. Colouration and colour polymorphism

The number of colour plates presented in this thesis, while not fully representative of all the shallow-water *Lethrinops* 'sensu lato', at least show a few of the many taxa studied and give some insight into the colourful beauty displayed and hence the potentiality of the group as aquarium candidates.

The present study reveals that *Lethrinops* conspecifics from different areas, and especially the males in different reproductive states, usually differ slightly in colour.

It has been observed in *Lethrinops* that closely related species have very different nuptial colour patterns. It seems possible that certain colour marks of males may activate some females of the same species more than of others. It is important to emphasize that in all the shallow-water *Lethrinops* sexually active and territorial males develop a species-specific colour pattern. That being the case, species need not differ in characters, other than male colours (which can only be seen in breeding seasons!). Thus failure by some workers, for example, to find ways of differentiating females, juveniles and non-breeding males may not be due to incompetence as taxonomists, but instead due to high resemblance of species that are almost identical in those stages.

Two colour morphs of *T. praeorbitalis* have been recognized in this study, the striped and unstriped morphs. Specimens of the two forms are present both in the northern and in the southern part of the lake. No other differences, except for the differences in melanin pattern were observed. It is suggested that, this observation point to the possible presence of polychromatism in *T. praeorbitalis*.

7.5. Distribution

Based on data from fisheries trawl surveys in the southern part of Lake Malawi, Lewis (1981) observed that many species of cichlid that occur in Lake Malawi's sub-littoral zone, do not occur in catches made from depths greater than 20 m and vice versa. With very few exceptions, most species of shallow-water *Lethrinops* 'sensu lato' have clearly defined depth ranges. Some species are restricted to very shallow waters and do not occur at a depth of more than 10 m. This category includes species like *L. lethrinus*, *L. auritus*, *L. microstoma*, *L.* sp. 'turneri', *L. albus*, *L. marginatus* and most *Tramitichromis* spp. except *T. brevis*. Others such as *Taeniolethrinops furcicauda*, *T. cyrtonotus*, *T.*

praeorbitalis, *L. lunaris* *L. furcifer* *L. macrochir*, *L. macrophthalmus*, *T. brevis* and *L* . sp. 'parvidens deep' have been collected to a depth of 25 m. A few species have a considerable depth range: *L. parvidens* has been recorded to a depth of 32 m while *T. laticeps* has been collected from depths between 5.2 m to 78 m (in Tanzania *T. laticeps* was collected from 5.2 m, 15 m, 22.5m and 31-32 m whereas in Mozambican waters it was collected from 10.8-12.8 m, 28.5-31.5 m and 68-78m). Table 7.2 gives a summary of the depth distribution for the shallow-water *Lethrinops* 'sensu stricto'. Only the maximum depth is given, as it is uncertain what the minimum depth for each species is, all have been taken to zero depth. Further ecological analyses are needed to determine more precisely the full depth range for each species.

With very few exceptions (Table 7.2), preliminary results of geographical distribution for most taxa considered in this work indicate a lake-wide distribution. The distribution records presented are by no means complete. This is inevitable in any study which attempts to survey so many species in a large and complex habitat like Lake Malawi/Nyasa.

7.6. Conservation

The uniqueness of Lake Malawi/Nyasa ichthyofauna has been pointed out in the introductory chapter of this thesis. To understand the value of the ichthyodiversity of this lake is a prerequisite for any conservation and management plan. Snoeks (1999) has highlighted the special characters of the fauna of this lake with some figures as summarised below:

- The estimated total number of fish species in Lake Malawi/Nyasa is the highest in the world.
- The number of species described at present is about 350.
- Lake Malawi/Nyasa holds the world record in having the highest number of undescribed fish species.
- As it is with the other East African Great Lakes, the major part of the fish fauna consists of only one family of perch-like fishes, the Cichlidae (accounting for over 90 % of the fish species). Nearly all of these are endemic to the lake basin, i.e. they do not live anywhere else.

Since the lake has an ichthyofauna that is unique in many aspects, the scientific emphasis of the GEF project on Lake Malawi/Nyasa was placed on an assessment of biodiversity of the lake in order to conserve it. And because the unit of biodiversity is the taxon (Eldredge, 1992; Forey et al. 1994), the management and conservation of the cichlid fauna of Lake Malawi/Nyasa requires, among other things, a sound background knowledge of the taxonomy of the group. Or in other words: one cannot protect what one does not know (Snoeks, 1999). This study therefore, is directly linked to and contributes to the overall goals of the SADC/GEF Lake Malawi/Nyasa Biodiversity Conservation Project.

For Lake Malawi/Nyasa with its largely unknown ichthyobiology, one cannot appreciate the importance of taxonomic studies until she/he is subjected to sorting thousands of fishes from all parts the lake and identifying them and this is exactly what this study is about.

This work, therefore, represents a major step on the long road towards resolving the systematic confusion of *Taeniolethrinops*, *Tramitichromis* and *Lethrinops* 'sensu stricto', since sound taxonomic and genetic data together with distribution patterns (biogeography), provide valuable tools for the conservation scenarios.

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