FISH ECOLOGY REPORT

LAKE MALAWI/NYASA/NIASSA BIODIVERSITY CONSERVATION PROJECT

Edited by Fabrice Duponchelle & Anthony J. Ribbink

SADC
Southern African
Development Community

GEF
Global Environmental
Facility

Illustrations by Dave Voorvelt

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Edited by

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Acknowledgements

(F. Duponchelle)

This report covers the work of the Ecology team of the SADC/GEF, Lake Malawi/Nyasa Biodiversity Conservation Project for the period from June 1998 to the end of the Project in July 1999. Given the late start of this part of the ecology work and the time constraints before the end of the project, the success of the several research programs undertaken by the Ecology team is indebted to many people for their support and assistance.

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General introduction

General introduction

Lake Malawi/Niassa/Nyasa is the southern most of the East African Rift Lakes, lying from 9°30'S to 14°30'S between three riparian countries: Malawi, Tanzania and Mozambique (**Figure 1**). It is one of the oldest (many million years, Lowe-McConnell et al. 1994, Konings 1995, Stiassny & Meyer 1999) and largest lakes of the world. Its mean area (29 000 km², Bootsma & Hecky 1993) makes it the 9th largest lake in the world and 3rd largest lake of Africa after the lakes Victoria and Tanganyika (Lowe-McConnell 1993, Ribbink 1994, Konings 1995). Lake Malawi is located 472 m above the sea level, its maximum depth is 785 m and averaged about 292 m (Bootsma & Hecky 1993). An important characteristic is that more than 80% of the lake is deeper than 200m (Thompson et al. 1996), depth under which it is permanently stratified and anoxic (Eccles 1974, Lowe-McConnell 1993). This basically means that the living space available for the fish and the other components of the food chains is only about 20% of the lake volume. About one third of Lake Malawi's shoreline is steep and rocky whereas two thirds are gently sloping sandy beaches or swampy river estuaries (Lowe-McConnell 1994, Lowe-McConnell et al. 1994). One of the main distinctive features of the lake is its exceptional water clarity, upon which the entire ecosystem is highly dependent (Bootsma & Hecky 1993, Hecky & Bootsma 1999).

However, the most well known characteristic of the lake is its exceptional fish richness. It harbours greatest fish species richness than any other lake in the world (Fryer & Iles 1972, Ribbink 1988, Turner 1996). It is currently estimated that between 500 and 1000 different fish species are present in the lake (Konings 1995, van Oppen et al. 1998), although only about a third are presently described or merely catalogued by a cheironym (Ribbink et al. 1983). All these fishes, apart from 44 species belonging to nine other families (Ribbink et al. 1983, Ribbink 1988), belong to a single family, the Cichlidae. With the exception of chambo (*Oreochromis spp*.), all cichlids are closely related species, possibly descended from a single common ancestor (Meyer 1993, Meyer et al. 1990, Moran et al. 1994, Stiassny & Meyer 1999). This tremendous cichlid fish diversity, known as a "species flock" (or a complex of species flocks, Greenwood 1984), has evolved in a very short evolutionary time period, some of which may have been within the last 200 to 300 years for some species (Owen et al. 1990). More than 99% of these cichlid fish species are endemic of Lake Malawi (Ribbink 1991, Turner 1996), which means that they can't be found anywhere else in the world. Moreover, there is also a high degree of intra-lacustrine endemicity, many species belonging only to particular islands or stretches of shore within the lake (Ribbink & Eccles 1988, Eccles & Trewavas 1989, Ribbink 1991). These peculiarities of the lake fishes have led to develop a great interest from the scientific community, challenged by the understanding of what constitutes the most striking example of rapid vertebrate radiation known at this day (Turner 1998).

Importance of the lake and its fragility

Lake Malawi/Niassa/Nyasa is the fourth largest freshwater body in the world and constitutes an inestimable resource in this semi-arid region (Hecky & Bootsma 1999). It

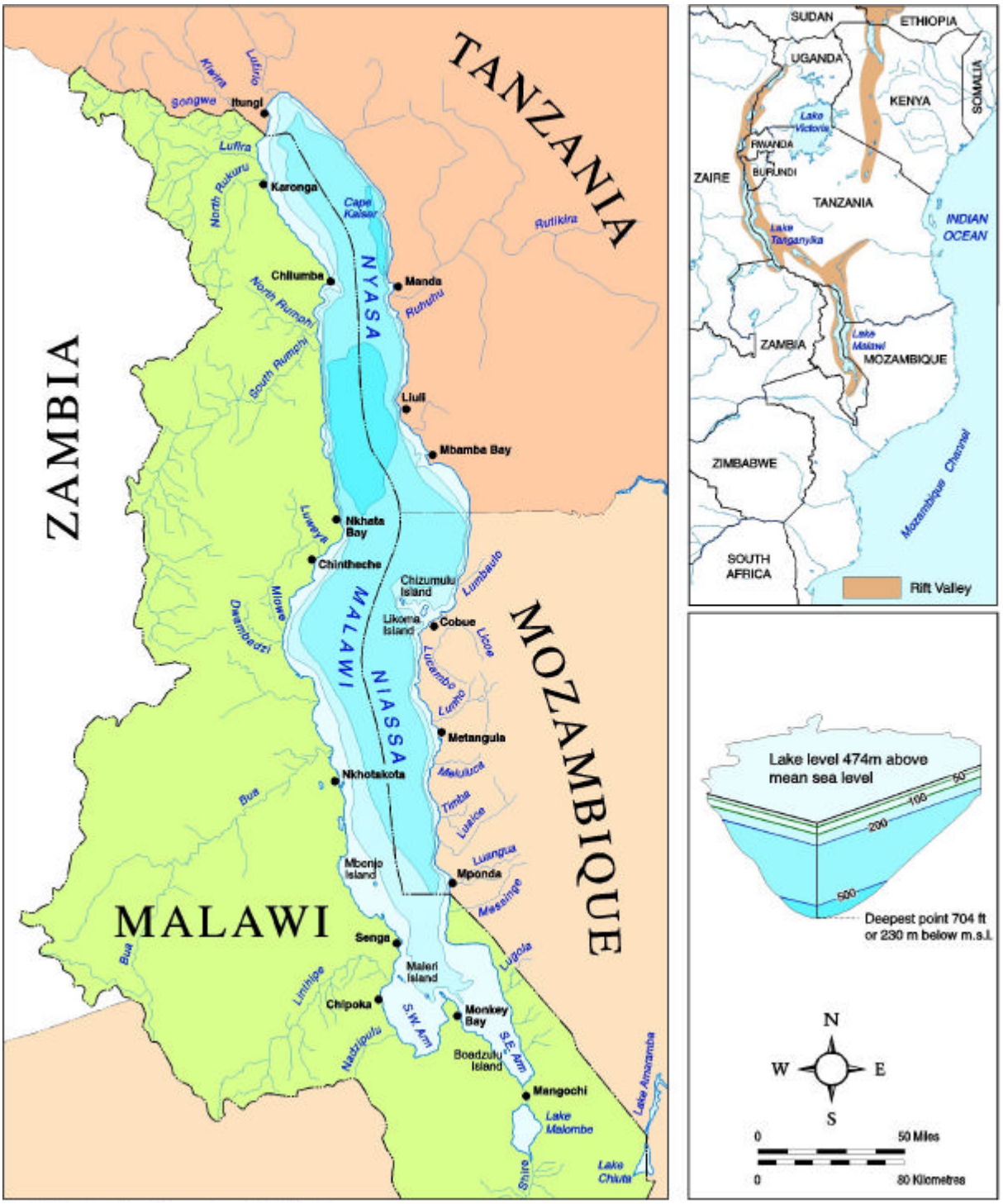

Figure 1. Lake Malawi, its catchment and the Rift valleys.

provides water for drinking, irrigation and domestic uses for people living on the lakeshores, but also fish. The value of the lake fishes does not lie only in their scientific interest, but also in their primordial nutritional status. In the Malawian part at least, they sustain vitally important fisheries that provide 75% of the animal protein consumed by people and work for an estimated 35,000 fishermen and presumably as many as 2,000,000 people through associated activities (Mkoko 1992, cited by Ribbink 1994 and Turner 1994b). Although the fish constitute, with the water itself, the most important resource of the lake and the main concern at this day, they are part of a complex ecosystem which needs to be preserved as a whole if it is to be used in a sustainable way. As mentioned previously, the fish and the other components of the food chains rely heavily on the water quality of the lake. The physical characteristics (depth, small outflow, long flushing time) of Lake Malawi/Niassa/Nyasa and their implications for pollution retention and ecosystem fragility have been discussed in detail by Bootsma & Hecky (1993). While its great depth allows the various pollutants to go undetected for many years, its low flushing rate makes the elimination process very long (several centuries) once thresholds are reached. The water quality has been a major issue of the SADC/GEF Project, which has provided a sound scientific knowledge about the lake limnology (see Bootsma & Hecky 1999 for review). Though the lake is still in rather pristine condition, the first signs of changes have already been observed, for the phytoplankton species characteristic of eutrophic systems, which were formerly rare are now becoming progressively dominant (Hecky et al. 1999).

Main threats to the fish diversity

Malawi is a weakly industrialised country in which most of the people live directly upon natural resources through agriculture, fisheries and associated activities. The demographic context, with one of the highest population density of Africa and an annual increase well over 3% (Ferguson et al. 1993, Kalipeni 1996), leads to a steadily increasing human pressure on the limited natural resources of the country. Two mains threats to the fish communities can be distinguished and both are related to changes in the use of natural resources.

1) - Fishing activities are the more direct human influences on fish communities. In absence of alternative employment, the rapidly growing human population exerts an increasing fish demand, which entails an increased pressure on the already overexploited stocks (Turner 1995). Despite their huge economical and scientific interests, very little is known about Lake Malawi cichlid fishes. As emphasised previously, about only one third of the fish are described or catalogued, and new species are discovered regularly. Paradoxically, the most studied fish are the colourful rock-dwelling haplochromines, which are almost not exploited, except for the ornamental trade (Turner 1994b, 1995). The fish exploited for food purposes are those that inhabit the shallow and deep sandy shores. They sustain a highly diversified traditional fishery and a localised commercial mechanised fishery that have greatly expended over the past 20 years (Tweddle & Magasa 1989) and, which are according to the most resent assessments, already fully or over-exploited (Turner et al. 1995, Turner 1995). It has been stressed that mechanised fisheries might be incompatible with the continued existence of the highly diverse cichlid communities and that maximising the fish yield would lead to a decline in the number of endemic species in the exploited area (Turner 1977b, Turner 1995). Fisheries scientists have already shown the critical effects of over exploitation, such as the reduction in population size, the modification of size structure and some local extinction of the larger cichlid species (Turner 1977a, 1977b, Turner 1995, Turner et al. 1995). However, while it is believed that cichlid populations are likely to slowly recover from overexploitation given their life-history characteristics (Ribbink 1987), it has also been

suggested that cichlid fisheries were more resilient than previously thought (Tweddle & Magasa 1989). As pointed out by Turner (1994b), "it is essential to distinguish between the resilience of a multi-species fish stock and the vulnerability of individual species". The fishery's resilience might be achieved through the unnoticed disappearance of several species. Given the importance of fish for people nutrition, there is an urgent need for an appropriate fisheries management regulations. However, beside the huge number of species exploited, the extent of the shore line, the great variety of fishing techniques in use and their poorly known selectivity, effective fisheries management is currently hampered by the lack of knowledge about the fish taxonomy and life-histories. Taxonomy and systematic, which deal with species determination and description, provide species inventories and geographical distribution of ichthyofauna that are basic information for any management and conservation purposes. On the other hand, fisheries management relies on mathematics models to predict the evolution of stocks. These models are heavily dependent upon population parameters, such as breeding season, age and size at maturity, fecundity, growth and mortality rates, which are currently missing (Lowe-McConnell et al. 1994, Worthington & Lowe-McConnell 1994, Turner 1995). If exploited stocks are to be managed properly, the gaps in understanding have to be filled so that outstanding information is gathered.
An other interesting question is: are the species which decline or disappear from trawl catches actually endangered? Most target fish of trawl fisheries are sandy bottom species for which belonging to specific areas of the lake and degree of stenotopy are poorly known. They also occur in other areas and/or depth of the lake where the localised mechanised fisheries do no longer occur (Banda & Tómasson 1996, Tómasson & Banda 1996). Their relative disappearance from fisheries catches in a particular area might then not be a real threat to Biodiversity. However, our present state of knowledge miss some very important information concerning the notion of “population” for the exploited species. For example, the same species in two distant parts of the lake could belong to different populations, presenting life history and/or genetic variations. They might also present morphological differences. In such a case the disappearance of one of these populations would be much more critical as it would lead to a lost of diversity. As most of the mechanised fisheries occurs in the southern part of the lake, studies aiming to determine the population status of the exploited species should be carried out in order to assess the potentiality of re-colonisation from less exploited parts of the lake.

2) – Together with fishing, agriculture is the most important human activity in Malawi. The steadily increasing human populations and the degradation of lands in the river catchments, such as deforestation, burning of vegetation, destruction of wet lands on the river banks for agricultural purposes and the cultivation of marginal areas, are cause of major concern. All these activities, by removing the vegetation cover, weaken the soil, which is carried away with its nutrients directly in the rivers by the rains and ultimately arrive in the lake. Another source of nutrients and pollution are the industrial sewage. The land clearance burning is also suspected to strongly participate to the atmospheric phosphorus deposition in the lake. The limnology team of the SADC/GEF Project have identified the increasing load of sediments and nutrients received by the lake from rivers and atmosphere as the main threat to the water quality (Bootsma & Hecky 1999). The consequences of a sediment/nutrient enrichment of the lake on the water quality have been experienced in the Laurentian Great Lakes or Lake Victoria and reviewed in Bootsma & Hecky (1993). Among the main effects of increased sediment and nutrient loads on aquatic communities (see Patterson & Makin 1998 for review), the reduction of available living space as the oxic/anoxic boundary moves up (Bootsma & Hecky 1993), the reduction of light penetration affecting photosynthetic rates or sexual mate choice (Seehausen et al. 1997), the reduction of habitat complexity and destruction of

spawning grounds are of direct importance for fish (Waters 1995, Evans *et al*. 1996, Lévêque 1997). For instance, over-fishing and siltation resulting from deforestation have strongly diminished the abundance of potadromous fish species in Lake Malawi/Niassa/Nyasa (Tweddle 1992). In Lake Tanganyika, species richness of fish was found much lower at sites with high sedimentation than at less disturbed sites (Cohen et al. 1993a). Similar observation were reported for Lake Victoria, where increased turbidity was recognised partly responsible for the decline in cichlid diversity (Seehausen et al. 1997).

Research program undertaken

In June 1998, a new "senior Ecologist was appointed, in replacement of the former one, by the SADC/GEF Lake Malawi Biodiversity Conservation Project, which closing date was the 31/07/1999. Taking into account the main threats to the fish communities and the fact that a single annual cycle was left before the end of the project, we decided to focus our researches on the following particular aspects:

- Provide the fisheries managers with the maximum information about the life histories (breeding season, age and size at maturity, fecundity, growth and mortality rates, diet) of the main demersal cichlid species, and the temporal patterns of their distribution, abundance and diversity. These research actions are detailed in Chapters 1 to 4.
- As emphasised previously, for the conservation of biodiversity as well as for the fisheries management, it is crucial to known whether a species is represented by a single population widespread all over the lake, or by different populations (or stocks) with distinctive morphometric, genetic and life history characteristics. A complementary study has then been undertaken in collaboration with the taxonomists of the project, to compare the morphometrics, the genetics (microsatellites) and the life history traits of two species in four different locations between the SWA and Nkhata Bay. This part is detailed in Chapter 5.
- Assess the potential influence of suspended sediments on the distribution, abundance, diversity and some life-history characteristics of the rocky shore cichlid fishes (Chapter 6).

Chapter 1:

Temporal trends of trawl catches in the North of the South West Arm, Lake Malawi

Chapter 1: Temporal trends of trawl catches in the North of the South West Arm, Lake Malawi

F. Duponchelle, A.J. Ribbink, A. Msukwa, J. Mafuka & D. Mandere

Introduction

Since the closing of trawling activities between Domira Bay and Nkhotakota in 1993, the trawl fisheries occur only in the SE and SW Arms of the lake (Tweddle & Magasa 1989, Banda et al. 1996, Banda & Tómasson 1996). During the last two decades, a number of reports and observations have pointed out the dangers of the current overexploitation of fish communities by trawling that has already led to drastic changes in size structures of the exploited stocks and to decreasing catches in the southern part of the lake (Turner 1977a, 1977b, Turner 1995, Turner et al. 1995, Banda et al. 1996). However, the SEA, which hold most of the commercial trawling, has received much more attention than the SWA, where only one pair-trawler operates in the shallower zone (Tómasson & Banda 1996, A. Bulirani, pers. com.). While numerous studies have been carried out to improve knowledge of species distribution and abundance for a better management of mechanised fisheries (review by Tweddle 1991), none had focused on the seasonal or temporal trends of catches in the SWA until the recent two year survey with three months sampling intervals carried out by Tómasson & Banda (1996). As the trawler operating in the SWA fish only in the shallow waters of the southern part of the arm and given that traditional fisheries are mostly confined to shallow and inshore areas (Banda & Tómasson 1996, Tómasson & Banda 1996), the offshore part of the northern SWA can therefore be considered as almost unexploited, except for occasional surveys by the Ndunduma (A. Bulirani, pers. com.). Therefore, the north of the SWA appeared to be the ideal area to conduct a program designed to assess the temporal trends of the distribution, diversity, abundance and the life histories of the most important fish species caught by trawling. The unexploited aspect of the fish stocks was particularly favourable for the estimation of growth and natural mortality of the major species needed for fisheries management (Turner 1995). The following chapter deals with the temporal patterns of monthly trawl catches at exactly the same sites and depths in the north of the SWA over a complete annual cycle.

Material and methods

Trawl surveys

The project's research vessel, R/V USIPA, was used for the surveys except for the months of July and August 1998, when the R/V NDUNDUMA was used. The NDUNDUMA, which belongs to the Fisheries Department, is a 17.5 m long trawler propelled by a 380 HP engine. R/V USIPA is a 15 m steel catamaran powered by twin 135 HP engines. The bottom trawl was approximately 40 m foot rope and 35 mm stretched cod end mesh. Morgère semi oval doors of 135kg each spread the trawl. Actual opening of the trawl was observed using

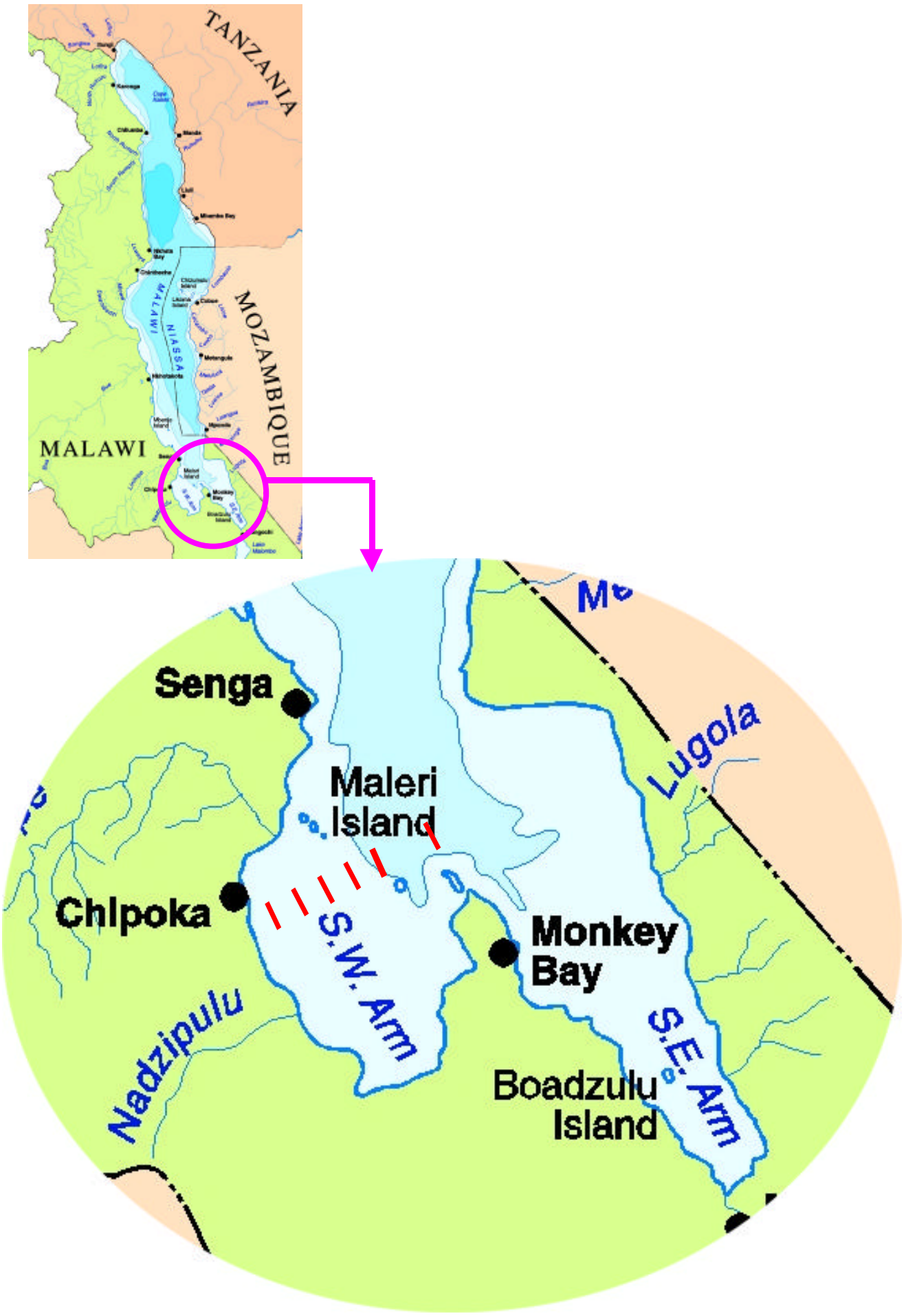

Figure C1. The southern part of the Lake Malawi/Nyasa showing the South West Arm (SWA) and the South East Arm (SEA). The bars represent the monthly sample sites at 10, 30, 50, 75, 100 and 125m depths.

the Scanmar height sensor, CT 150, and displayed on Scanmar's color graphic monitor. The trawl opening varied between 4.1 and 4.3 m.
Each tow was for a duration of 20 minutes at a speed of ± 4630m/h (2.5 knots, range 2.3-2.7). On average the distance covered by each tow was 1543m. Swept area varied between 175,279.49 m³ at 10m depth to 277,868.04 m³ at 125m depth (Capt. M. Day 1999).

Each month from June 1998 to May 1999, one tow was done at 10, 30, 50, 75, 100 and 125 m depth on approximately always the same sites along a line between Chipoka and Lukoloma (Figure C1). The exact positions of every tow are given in Appendix 1. Owing to ship availability, no sample was collected in September 1998.

Species identification

This is of common knowledge, species identification in Lake Malawi is a real problem (Lewis 1982, Tómasson and Banda 1996, Turner 1995, 1996). Despite the very useful book of Turner (1996), fish identification remains extremely difficult on the field for many taxa. Moreover, as the identification problems are size-related, the small species (*Aulonocara spp*., *Nyassachromis spp*., and some *Placidochromis spp*. for examples) are more likely to lead to inconsistencies.

However, we had to work along with these problems and, as this program was aimed to provide the fisheries department with the basic life histories of the most commonly trawled species, it was decided that if mistakes were to occur, they had to be consistent with the Fisheries Department's mistakes. For this reason, Davis Mandere, Research Assistant and "field identifier" at the Malawi Fisheries Department, did all the fish identifications on board. During the first two cruises (June and July 1998), Mark Hanssens, support taxonomist on the SADC/GEF Project assisted him in species identification in order to ensure the consistency of names used by the Fisheries Department and the SADC/GEF Project. George Turner was present for the August 1998 cruise and reported some inaccuracies concerning *Rhamphochromis spp*. *Diplotaxodon spp*. and small species groups such *Aulonocara spp*. It is believed that inaccuracies concerning the *Diplotaxodon spp*. encountered in the fished area (*limnothrissa, macrops, apogon, argenteus, greenwoodii* and *brevimaxillaris*) were solved during that cruise, at least for the common species (*limnothrissa, macrops, apogon, argenteus*).

As our study mainly focused on cichlids, the catfishes were separated into three groups, *Bathyclarias spp*., *Bagrus meridionalis* and *Synodontis njassae*. No attempt was made to identify the species constituting the *Bathyclarias spp*. flock, which were lumped together into one group. *Clarias gariepinus*, rarely caught, was grouped within the Bathyclarias spp. complex. Despite the growing assumption that *Synodontis njassae* would be constituted by more than one species, no formal evidence has yet been provided and *Synodontis* were considered as a single species over their full depth range.

Owing to the difficulty of identifying them accurately, *Oreochromis spp*. were lumped into one group, as were the *Rhamphochromis spp*.

For the groups of small species such as *Aulonocara spp*., *Nyassachromis spp*., which species were not accurately identified, only the following species were recorded individually: *Aulonocara 'blue orange', A. 'minutus', A. 'cf. macrochir', A. 'rostratum deep', Nyassachromis argyrosoma*.

It was suggested (J. Snoeks, pers. com.) that what we called *Nyassachromis argyrosoma* was probably a complex of different *Nyassachromis spp*., as these species are very difficult to identify and poorly known. However, for no particular anomaly appeared from data analysis, we kept considering it as a single species.
Otopharynx argyrosma was also recorded as a single species, but it became evident while analysing the data (length-weight or fecundity-weight relationships) that more than one species were included under this name.

As a rule, to avoid confusion given the rhythm imposed by sorting fish on board and to ensure the consistency of the name attributed to a given species, Davis Mandere was asked to consistently allocate a particular species the name he was used to, even when we knew the name had changed (or was wrong). The proper name was subsequently entered in the database. This was the case for the following species for instance:

- *Stigmatochromis guttatus* was identified as *'woodi deep'* on board.
- *Sciaenochromis benthicola* was recorded as *'spilostichus'* on board

What we thought was *Lethrinops 'longipinnis orange head*' turned out to be *Lethrinops argenteus* (Snoeks, pers. com.). Actually, the characteristic *L. longipinnis* whose breeding male has a blue head and a dark striped body (see illustration p. 58 in Turner 1996) was never found in our fishing area in the SWA. Some males were found sometimes with a darker dress, but never with a blue head. The species we identified as *L. 'longipinnis orange head'* is illustrated p. 57 (top right picture) in Turner's book (1996) as *L. longipinnis* Domira Bay. The taxonomy team of the project has found that *L. longipinnis* was a complex of different species (Snoeks, pers. com.), and that *Lethrinops 'longipinnis orange* head' was definitely *Lethrinops argenteus* (Ahl 1927). In our case 99% of the specimen were found at depth between 10 and 50m, and seldom below. This tends to confirm that *'orange head'* differs from *longipinnis*, which is supposed to frequently occur at greater depths (Turner 1996).

The spelling of species names used was that given in Turner (1996).

Catch analysis

For each tow, the catfishes *Bathyclarias spp*. and *Bagrus meridionalis* were separated from the main catch, counted and weighed. The rest of the catch was then randomly distributed in 50 kg boxes and the weight recorded. The total catch weight (kg) was recorded as the sum of *Bathyclarias spp*., *Bagrus meridionalis* and the remaining catch.

A 50 kg filled box was taken as a representative sample of the whole catch and analysed. Large and medium sized fish were sorted out of this sample with rare species and classified according to their taxonomic status. The weight of the remaining "small fish" (< 5-8 cm TL) from the catch was weighed and a random sub-sample of about 3 kg was removed from the sample and placed in the deep freeze for later examination. When the large, medium and rare species were processed, the sub-sample of small fishes was processed following the same protocol.

For each species, the number of specimens and their total weight was recorded to the nearest g. The standard length (SL) of each specimen was recorded to the nearest mm for analysis of length frequencies. When the number of specimens for a given species was too large, a sub-sample (which proportion in weight of the main sample was recorded) comprising at least 100 specimens was taken. This procedure was mainly used for the large males schools of identical size.

Nine target species were selected according to their relative abundance, depth distribution and basic ecological characteristics (benthic or pelagic habits, broad trophic category) (Tómasson & Banda 1996, Turner 1996). These were *Lethrinops gossei* Burgess & Axelrod, *Lethrinops argenteus* Ahl (= *L. 'longipinnis orange head'*), *Diplotaxodon limnothrissa* Turner, *Diplotaxodon macrops* Turner & Stauffer, *Copadichromis virginalis* Iles, *Mylochromis anaphyrmus* Burgess & Axelrod, *Alticorpus mentale* Stauffer & McKaye, *Alticorpus macrocleithrum* Stauffer & McKaye and *Taeniolethrinops praeorbitalis* Regan.
For these species, all the females from each haul were preserved in formalin for later examination.

Environmental data

After each tow, a CTD cast and a grab sample were taken in the middle of the transect. Both CTD and the benthic grab were lowered using the hydrographic winch of the R/V USIPA. The CTD casts recorded, every 2 seconds during the way down and the way up, measures of the following parameters: depth (m), temperature (ºC), oxygen concentration ($mg.l^{-1}$), conductivity ($mS.cm^{-1}$), water clarity (% transmission), fluorescence (arbitrary unit).

Grab samples

After each trawl a sample of bottom sediments was taken in the middle of the trawl transect by using a 24 cm benthic grab sampler lowered on the hydrographic winch. The grab digs about 10 cm into the sediment in such a way that the upper layers form more of the sample than the lower layers. It therefore gives qualitative rather than quantitative information. Each sediment sample was placed in a bucket. A sub-sample was taken, placed in 250 ml plastic bottle and deep frozen for later determination of sediment particle size. In March, April and May 1999, after the sub-sample was removed, the remaining part of the sediment sample was fixed in formalin (10%) for later extraction of benthic organisms for stable isotope studies.

Determination of sediment particle size:

The deep frozen sub-sample was mixed by hand after de-freezing and a sub-sample of 200 cc was placed in a 1 liter measuring cylinder toped up to 1000 cc with water. The cylinder was then inverted and shaken several times to suspend the sediment in the water. The sediment was then passed through a series of sieves (2 mm, 1mm, 500 µm, 250 µm, 125 µm, 63 µm) starting at the largest aperture. The volume of sediment retained in each sieve was determined using a measuring cylinder filed with water. Size class boundaries were as follows: > 256 mm = boulders, 64-256 mm = cobbles, 4-64 mm = pebbles, 2-4 mm granules, 1-2 mm = very coarse sand, 500 µm-1 mm = coarse sand, 63 µm-500 µm = fine sand, < 63 µm = silt and clay (mud). According to the proportions of the different components, the sample was then roughly categorized as "very coarse sand" (> 1 mm), "medium sand" (250 µm-1 mm), "very fine sand" (63 µm-250 µm) and "mud"(<63µm).

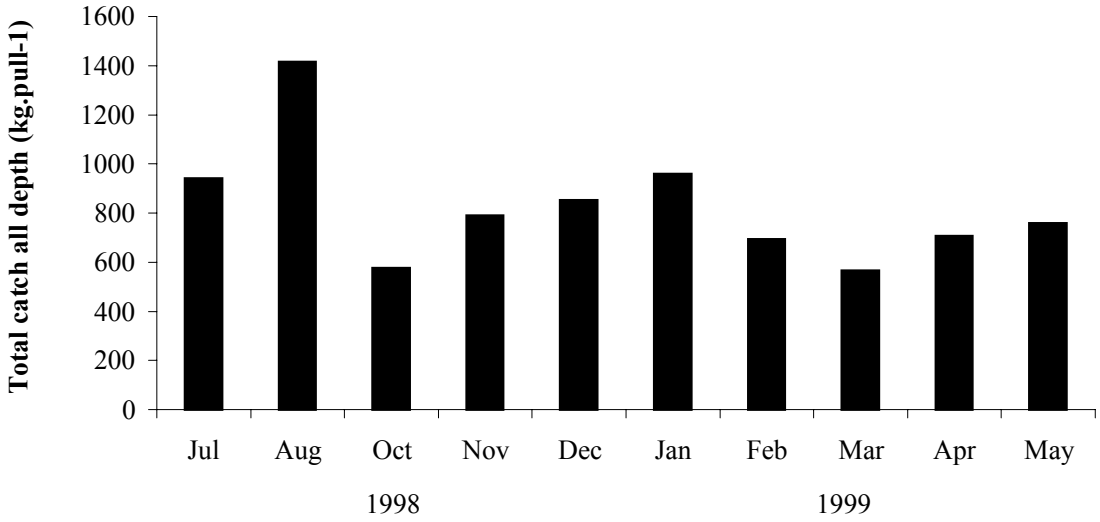

Figure C2. Total catches all depths pooled over the full sampling period (July 1998-May1999).

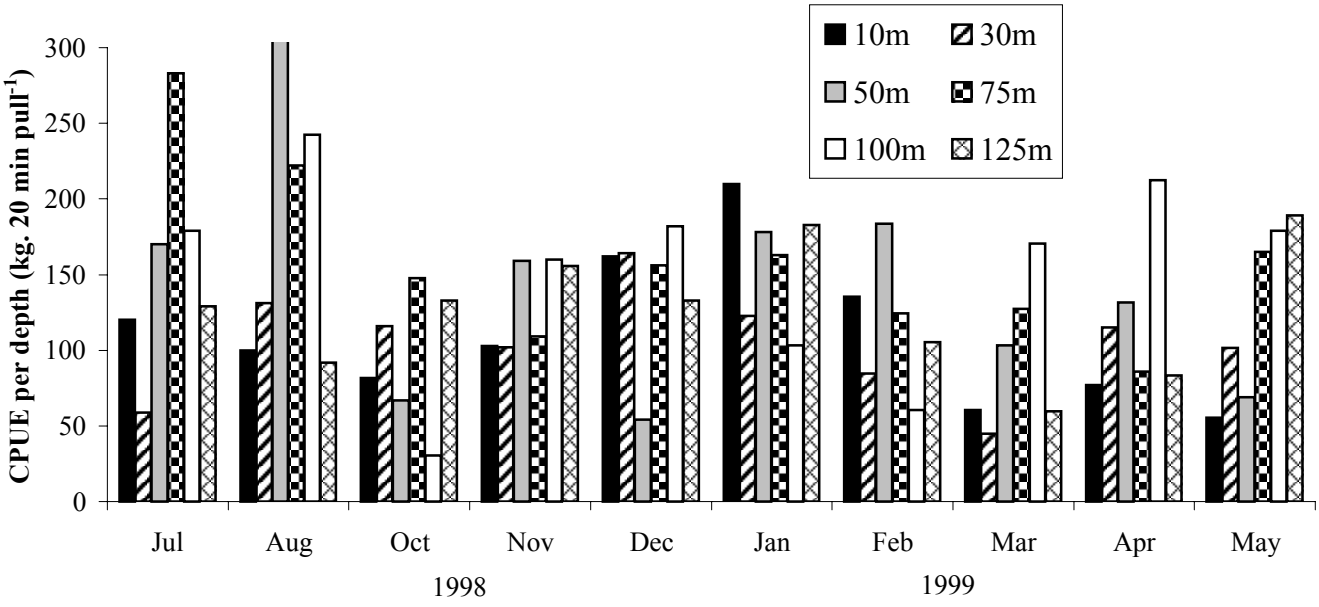

Figure C3. CPUE per depth over the full sampling period (July 1998-May1999).

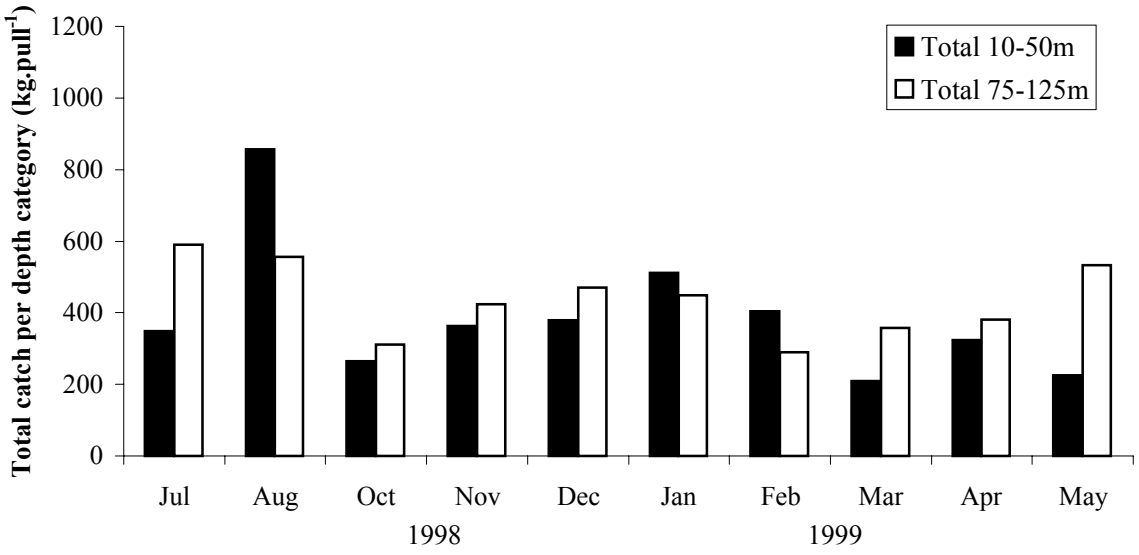

Figure C4. Total catch per depth category over the full sampling period (July 1998-May1999).

Results

Catches per month

Owing to non uniformity between the record sheets of June and the other months, the data for June 98 were not included in the analyses. The results presented below concern the period from July 1998 to May 1999.

The total catches per months all depths pooled fluctuated from about 600 kg for six 20 min pulls, to about 1000 kg (Figure C2). The high value recorded in August 1998 was due to an exceptional catch of *Bathyclarias spp*. at 50 m: 42 specimens giving a total of 400 kg, with a total catch of 626 kg (Figure C3). Individual catches fluctuated between 30.5 kg at 100 m in October and 283 kg at 75 m in July, excluding the 626 kg recorded in August (Figure C3). Temporal fluctuation was observed in the catches, the lowest were recorded in October 1998 and March 1999 and the highest in July-August 1998 and January 1999 (Figure C2). This temporal fluctuation was also observed for each depth (Figure C3) and when depths were pooled per category (Figure C4). With the exceptions of July-August 1998 and May 1999, the catches in the shallows and the in the deep waters were very similar (Figure C4).

Catches per depth

The mean CPUE per depth, all months pooled (Figure C5a) showed that the highest catches were recorded at 50 m and the lowest at 30 m. Catches were generally higher in the deep zone (50 to 125m) than in the shallows (10 to 30m). Almost the same results were obtained when the exceptional catch of *Bathyclarias* spp. in August 1998 was removed, except that the highest catches were recorded at 75m (Figure C5b). However, no significant difference of catch among depths was found in either cases, respectively with (Kruskal-Wallis one-way ANOVA on ranks H=8.33, 5 df, p=0.139) or without the August *Bathyclarias spp.* catch (one-way ANOVA F=1.845, 5 df, p=0.118).

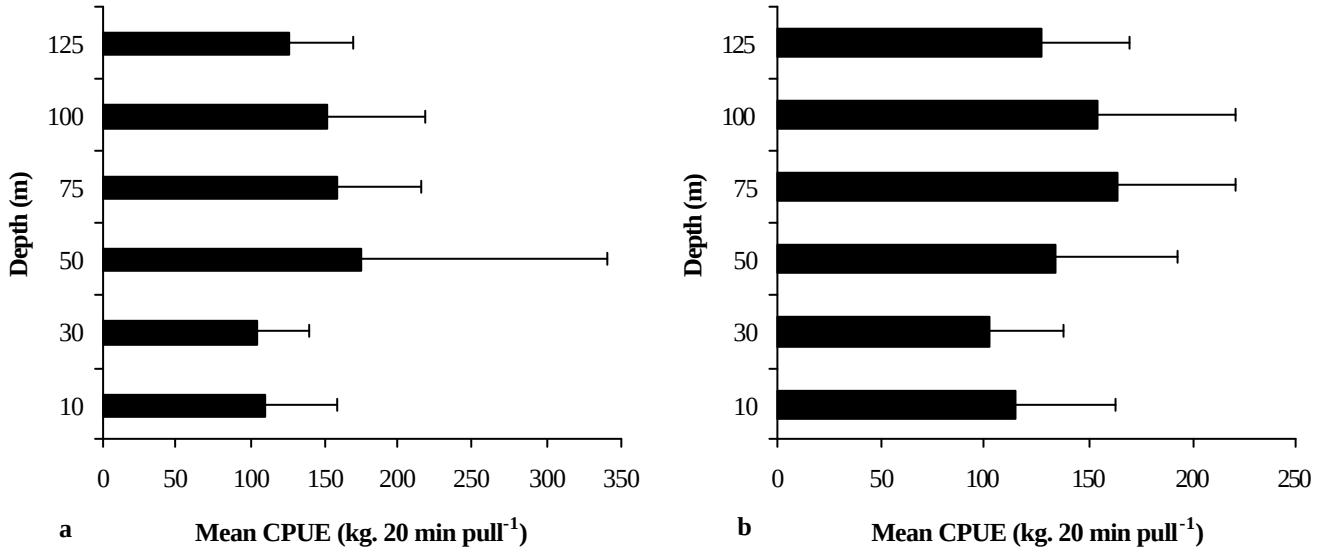

Figure C5. Mean CPUE (kg / 20 min pull) per depth (± standard deviation) over the full sampling period in the SWA (July-98 to May 99) (a) and with the exceptional *Bathyclarias spp*. catch removed (b), see text.

Table C1. Proportion in weight of the main demersal species trawled at 10m depth in the SWA (catfishes species in italic).

Species name	Jul-98	Aug-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Mean
Aulonocara blue orange	-	0,8	2,4	0,4	11,7	9,3	3,1	0,7	0,1	-	**2,8**
Bagrus meridionalis	*7,5*	-	*12,9*	*4,0*	*5,1*	*6,5*	*14,2*	*9,1*	*3,6*	*2,4*	***6,5***
Bathyclarias spp.	*0,6*	-	*5,0*	*5,8*	*10,1*	*10,3*	*17,6*	*8,6*	*4,2*	*6,1*	***6,8***
Buccochromis lepturus	8,7	3,0	7,2	1,1	0,1	-	0,0	3,0	10,0	11,4	**4,4**
Buccochromis nototaenia	2,1	0,4	1,0	0,1	0,5	0,6	0,0	0,6	1,6	-	**0,7**
Chilotilapia rhoadesi	4,2	2,4	1,1	2,0	0,6	0,3	0,2	2,0	0,2	0,8	**1,4**
Copadichromis quadrimaculatus	0,2	-	6,5	0,1	0,0		0,1	0,4	1,6	0,3	**1,0**
Copadichromis virginalis	-	1,2	-	-	0,2	0,2	2,3	-	-	-	**0,4**
Ctenopharynx nitidus	-	-	0,8	0,1	0,3	0,0	0,1	0,1	0,2	0,4	**0,2**
Lethrinops altus	-	-	-	0,4	0,4	0,0	0,1	-	-	-	**0,1**
Lethrinops furcifer	-	-	5,9	0,2	0,1	0,5	0,1	-	-	-	**0,7**
Lethrinops argenteus	16,2	3,5	3,5	24,3	32,5	21,3	10,5	7,5	7,0	5,8	**13,2**
Lethrinops macrochir	-	0,2	-	0,1	0,4	1,3	10,3	-	0,0	-	**1,2**
Mylochromis anaphyrmus	3,4	1,3	5,9	6,8	0,5	2,3	2,4	5,1	3,7	7,4	**3,9**
Mylochromis melanonotus	-	0,6	0,5	-	0,5	-	-	-	-	0,3	**0,2**
Mylochromis spilostichus	2,4	0,1	-	0,1	-	-	0,2	0,6	0,2	0,8	**0,4**
Nyassachromis argyrosoma	-	-	38,4	32,5	20,2	5,7	11,9	53,6	38,5	30,5	**23,1**
Oreochromis spp.	17,7	56,6	0,3	-	12,3	31,9	16,9	-	5,4	6,3	**14,7**
Otopharynx cf productus	0,4	0,2	1,7	0,1	-	0,1	1,0	1,2	0,1	1,8	**0,7**
Otopharynx decorus	-	1,8	0,4	0,2	0,2	-	0,1	-	0,1	-	**0,3**
Placidochromis suboccularis	-	-	-	0,1	0,0	-	0,0	0,1	-	0,1	**0,0**
Pseudotropheus livingstoni	-	-	2,4	0,6	0,0	-	0,0	2,7	2,0	5,9	**1,4**
Synodontis njassae	*0,9*	*1,0*	-	*15,8*	*0,7*	*0,6*	*0,1*	*0,5*	*0,2*	*0,3*	***2,0***
Taeniolethrinops furcicauda	0,6	0,2	2,0	0,2	0,1	-	0,9	1,3	3,2	7,5	**1,6**
Taeniolethrinops praeorbitalis	-	2,6	0,2	-	-	1,5	1,4	-	-	-	**0,6**
Trematocranus placodon	2,4	2,1	-	0,1	0,5	0,3	1,4	-	-	-	**0,7**
Total	**67,5**	**77,9**	**98,1**	**95,1**	**96,9**	**92,7**	**94,8**	**97,2**	**82,0**	**88,0**	**89,1**

Table C2. Proportion in weight of the main demersal species trawled at 30m depth in the SWA (catfishes species in italic).

Species name	Jul-98	Aug-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Mean
Aulonocara blue orange	-	19,0	-	3,4	0,2	4,4	3,1	-	0,1	10,0	**4,0**
Aulonocara macrochir	-	-	0,1	0,1	0,3	0,2	-	0,1	-	0,0	**0,1**
Bagrus meridionalis	*5,3*	*5,5*	*5,8*	*8,1*	*4,2*	*22,6*	*14,2*	*6,1*	*7,1*	*1,4*	***8,0***
Bathyclarias spp.	*12,4*	*5,5*	*5,8*	*4,3*	*8,3*	*7,7*	*17,6*	-	*4,0*	*2,6*	***6,8***
Buccochromis lepturus	2,0	1,0	-	-	-	-	0,0	1,0	-	1,4	**0,5**
Buccochromis nototaenia	3,3	2,6	1,8	1,7	0,8	2,4	0,0	1,7	1,3	1,6	**1,7**
Chilotilapia rhoadesi	10,7	0,4	1,0	0,4	-	0,3	0,2	0,2	0,1	0,7	**1,4**
Copadichromis quadrimaculatus	3,7	11,8	0,5	0,8	-	2,6	0,1	0,1	0,3	-	**2,0**
Copadichromis virginalis	1,2	21,2	0,4	1,9	67,7	1,6	2,3	-	-	0,0	**9,6**
Lethrinops altus	-	-	0,2	2,7	0,5	1,9	0,1	17,7	1,7	0,3	**2,5**
Lethrinops longimanus	0,4	-	-	1,2	-	0,2	-	0,2	-	-	**0,2**
Lethrinops argenteus	28,5	15,8	13,3	21,7	6,5	17,0	10,5	17,6	26,8	27,2	**18,5**
Lethrinops matumba	-	-	0,4	1,0	0,2	1,6	-	2,9	0,1	0,5	**0,7**
Mylochromis anaphyrmus	20,6	3,0	5,1	11,2	1,9	6,7	2,4	4,5	6,3	4,2	**6,6**
Mylochromis spilostichus	-	0,8	-	0,5	-	-	0,2	0,5	0,5	1,2	**0,4**
Nyassachromis argyrosoma	-	-	37,9	15,2	3,1	23,2	11,9	34,3	44,1	34,8	**20,5**
Oreochromis spp.	-	7,2	-	-	-	0,3	16,9	-	-	0,7	**2,5**
Otopharynx argyrosoma	1,6	1,3	-	0,2	3,6	4,4	-	1,8	-	-	**1,3**
Otopharynx speciosus	0,2	-	-	0,0	0,2	0,3	-	0,2	1,4	1,2	**0,3**
Placidochromis long	-	-	-	1,5	-	0,1	-	0,6	-	0,7	**0,3**
Rhamphochromis spp.	2,5	1,3	0,5	11,8	0,7	0,1	0,2	2,8	2,5	1,7	**2,4**
Synodontis njassae	*0,5*	*0,3*	*23,3*	*9,4*	*1,4*	*0,7*	*0,1*	*3,1*	*3,4*	*3,1*	***4,5***
Taeniolethrinops laticeps	0,1	0,2	-	-	0,2	0,3	-	-	-	0,5	**0,1**
Taeniolethrinops praeorbitalis	0,8	0,4	0,2	0,1	-	0,5	1,4	-	0,1	0,1	**0,4**
Total	**93,7**	**97,3**	**96,4**	**97,2**	**99,7**	**99,0**	**81,1**	**95,3**	**99,5**	**94,0**	**95,3**

Proportions of cichlids and catfishes

The proportion of cichlids and catfishes (*Bagrus meridionalis*, *Bathyclarias spp*. and *Synodontis njassae*) in the catches at each month are presented in the Figures C6a and C6b, in number and weight respectively. The catfishes constituted regularly between 2 and 9% of the catches in number from July to December 1998 and less than 0.5% between January and May 1999 (Figure C6a). On the other hand, catfishes represented consistently 8 to 25% of the catches in weight during the whole sampling period (Figure C6b).

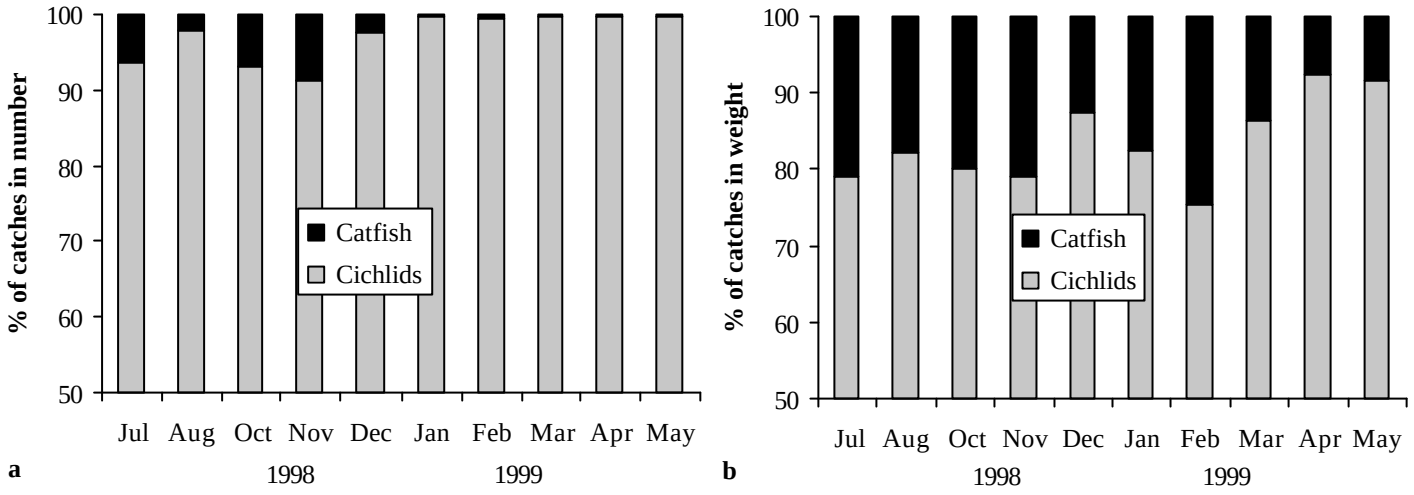

Figure C6. Proportions of cichlids and catfishes in the catches over the sampling period (July-98 to May-99), in number (a) and weight (b).

The proportion of catfishes per depth varied from 2% at 75 and 100 m to 5% at 125 m, in number (Figure C7a) and from 15.3% at 10 m to 22% at 100 m, in weight (Figure C7b). The proportion in weight of catfishes was not significantly different among depth (F=0.445, p=0.815).

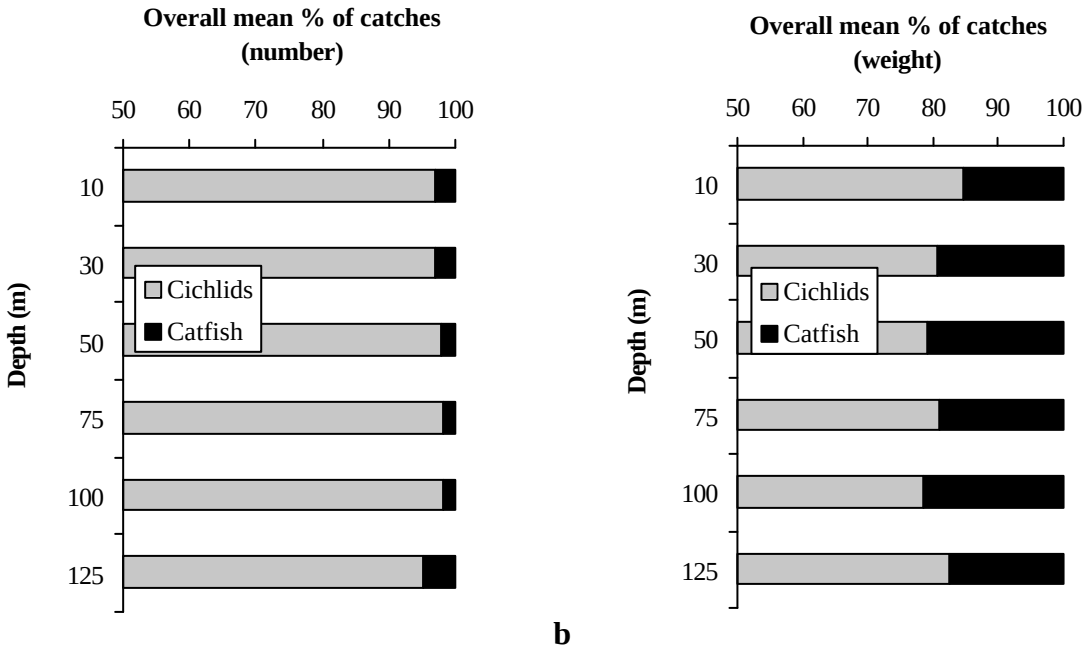

Figure C7. Proportions of cichlids and catfishes in the catches per depth all months pooled, in number (a) and weight (b).

Table C3. Proportion in weight of the main demersal species trawled at 50m depth in the SWA (catfishes species in italic).

Species name	Jul-98	Aug-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Mean
Alticorpus mentale	0,3	-	-	-	0,8	0,9	0,5	0,7	0,7	0,1	**0,4**
Aulonocara blue orange	-	0,2	-	-	-	0,5	0,6	-	-	0,0	**0,1**
Aulonocara macrochir	0,1	0,4	1,1	1,0	1,7	1,3	0,1	1,2	2,6	0,2	**1,0**
Bagrus meridionalis	*6,7*	*1,3*	*3,7*	*11,5*	*7,0*	*13,8*	*19,2*	*14,6*	*5,5*	*4,9*	***8,8***
Bathyclarias spp.	*11,9*	*41,4*	*4,4*	*8,5*	-	*3,1*	*10,9*	*1,9*	*0,0*	*4,2*	***8,6***
Copadichromis quadrimaculatus	-	0,8	1,4	0,4	-	0,2	0,2	0,3	0,1	-	**0,3**
Copadichromis virginalis	50,4	1,0	1,8	47,7	53,8	27,9	33,1	10,5	22,2	44,2	**29,2**
Diplotaxodon argenteus	0,2	-	0,9	-	-	0,5	-	1,8	0,5	1,7	**0,6**
Diplotaxodon limnothrissa	1,3	0,1	0,5	-	0,3	5,1	0,1	28,1	2,1	0,9	**3,8**
Docimodus johnstoni	0,1	0,2	-	-	-	0,1	-	-	-	0,3	**0,1**
Hemitaeniochromis insignis	-	-	0,1	-	-	-	-	0,1	0,0	0,0	**0,0**
Lethrinops altus	0,3	0,8	0,7	0,5	0,5	1,9	0,6	0,6	2,3	-	**0,8**
Lethrinops longimanus	1,1	4,5	0,0	3,0	0,4	0,4	6,7	0,4	0,4	0,1	**1,7**
Lethrinops argenteus	13,7	17,5	32,0	15,7	23,0	10,2	9,7	19,9	38,4	9,4	**18,9**
Lethrinops minutus	-	1,1	6,3	-	-	4,3	0,9	1,1	0,5	4,3	**1,8**
Lethrinops parvidens	-	-	-	-	0,0	-	0,1	0,1	0,2	-	**0,0**
Mylochromis anaphyrmus	0,8	1,4	1,7	0,3	0,7	0,5	0,6	0,5	0,8	0,4	**0,8**
Mylochromis spilostichus	-	7,3	-	-	-	-	0,6	0,1	0,4	0,9	**0,9**
Otopharynx speciosus	0,3	1,3	0,2	0,2	0,5	0,6	1,1	0,7	0,1	0,5	**0,5**
Placidochromis long	-	-	2,6	1,5	3,9	1,3	0,6	0,2	0,1	5,3	**1,6**
Rhamphochromis spp.	2,9	2,8	20,0	0,8	3,7	2,5	2,1	1,8	0,9	15,0	**5,3**
Sciaenochromis benthicola	0,7	0,5	0,8	0,3	0,0	3,4	5,1	0,6	0,9	0,6	**1,3**
Synodontis njassae	*6,7*	*3,5*	*1,3*	*3,2*	*3,6*	*4,3*	*2,5*	*3,7*	*3,5*	*3,6*	***3,6***
Trematocranus brevirostris	-	-	16,7	1,6	0,0	2,3	3,5	10,1	14,5	1,4	**5,0**
Total	**97,5**	**86,1**	**96,3**	**95,9**	**99,9**	**85,2**	**98,8**	**99,0**	**96,7**	**98,1**	**95,4**

Table C4. Proportion in weight of the main demersal species trawled at 75m depth in the SWA (catfishes species in italic).

Species name	Jul-98	Aug-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Mean
Alticorpus spp.	0,6	-	-	-	2,2	2,1	0,3	-	-	-	**0,5**
Alticorpus geoffreyi	20,1	20,4	9,0	4,7	8,0	1,1	2,2	4,2	6,3	12,2	**8,8**
Alticorpus macrocleithrum	1,1	1,3	0,1	-	-	-	-	-	-	0,1	**0,3**
Alticorpus mentale	3,5	4,4	4,8	11,6	18,7	2,0	16,1	4,5	3,5	4,2	**7,3**
Alticorpus pectinatum	0,8	0,3	0,6	0,1	1,5	1,2	5,0	3,8	1,8	2,2	**1,7**
Aulonocara minutus	0,7	0,9	0,5	-	0,9	0,2	0,3	1,4	0,3	1,8	**0,7**
Aulonocara rostratum	-	-	2,0	-	-	0,1	0,2	1,9	0,8	0,9	**0,6**
Bagrus meridionalis	*9,3*	*8,8*	*8,6*	*3,1*	*3,3*	*6,5*	*11,0*	*2,4*	*5,3*	*1,6*	***6,0***
Bathyclarias spp.	*17,6*	*8,8*	*24,9*	*6,1*	*0,7*	*15,0*	*11,7*	*4,0*	*2,1*	*9,7*	***10,1***
Diplotaxodon apogon	-	1,9	0,3	-	8,4	9,2	5,6	2,2	1,9	0,5	**3,0**
Diplotaxodon argenteus	1,0	0,8	1,9	1,8	3,0	5,6	3,6	3,7	3,5	1,7	**2,6**
Diplotaxodon macrops	2,3	3,6	-	-	0,5	13,6	4,7	9,1	3,9	2,3	**4,0**
Diplotaxodon limnothrissa	3,7	2,9	12,9	2,0	0,7	1,5	8,4	4,1	19,4	21,3	**7,7**
Lethrinops deep water albus	0,2	1,2	0,1	31,3	0,1	-	-	-	-	-	**3,3**
Lethrinops gossei	16,2	14,4	9,2	1,9	16,1	17,1	17,3	29,5	41,4	17,3	**18,0**
Lethrinops oliveri	2,7	19,4	7,2	9,8	12,9	13,5	5,3	13,7	3,2	8,9	**9,7**
Lethrinops polli	5,4	5,8	2,3	0,5	1,4	1,2	2,1	4,2	0,5	6,8	**3,0**
Pallidochromis tokolosh	1,3	1,3	0,4	-	1,3	1,7	1,0	0,2	0,1	0,7	**0,8**
Rhamphochromis spp.	0,7	0,9	8,6	7,6	2,2	1,4	0,0	0,9	0,2	0,8	**2,3**
Sciaenochromis alhi	-	-	0,2	0,0	0,2	0,1	0,2	-	-	0,9	**0,2**
Sciaenochromis benthicola	0,1	0,1	-	2,0	7,1	0,3	-	0,3	0,0	0,2	**1,0**
Synodontis njassae	*8,9*	*0,3*	*0,6*	*0,8*	*1,7*	*2,0*	*2,3*	*6,3*	*3,7*	*1,8*	***2,8***
Total	**96,0**	**97,5**	**94,2**	**83,4**	**91,0**	**95,4**	**97,4**	**96,4**	**98,0**	**95,9**	**94,5**

Catch composition

Fishes representing the major part of the catches at each month are presented in Tables C1 to C6 for the depths of 10m, 30m, 50m, 75m, 100m and 125m respectively. Although cyprinids and mormyrids were sometimes caught, their occurrence was so rare and their contribution to the catches so weak that they were negligible. Therefore, catches were assumed to be constituted only of cichlids and catfishes.

The catfish species (*Bathyclarias spp.*, *Bagrus meridionalis* and *Synodontis njassae*) were consistently amongst the most important species (in weight) at each depth, averaging 15.3% at 10m, 19.3% at 30m, 21% at 50m, 18.9% at 75m, 21.6% at 100m and 17.6% at 125m. Owing to their large sizes, the *Bathyclarias spp*. and the *Bagrus meridionalis* were much less important in number as illustrated in Figures C8a and C8b respectively.

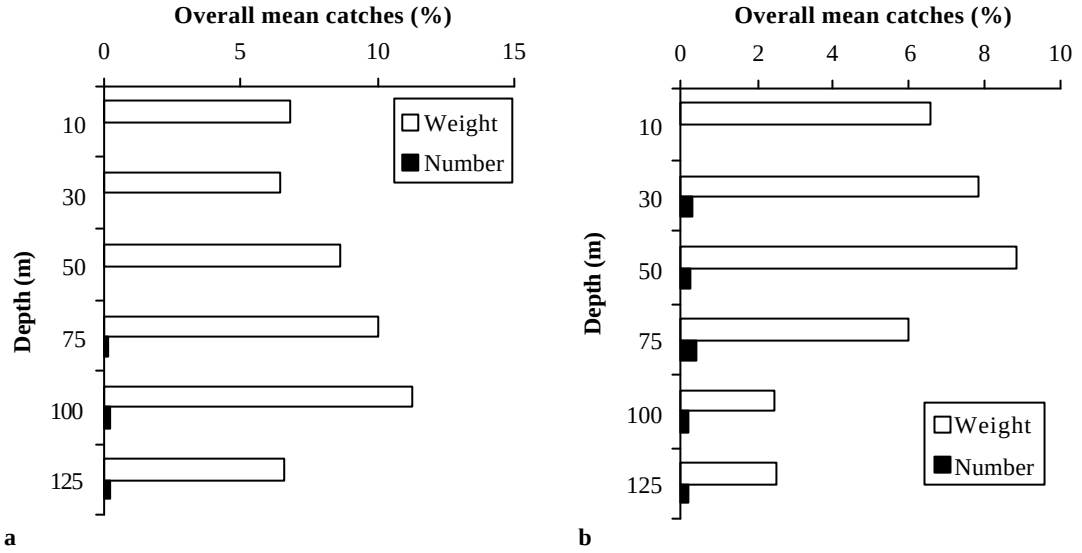

Figure C8. Overall mean catches (in proportion of weight and number) per depth for *Bathyclarias spp*. (a) and *Bagrus meridionalis* (b) from July 98 to May 99.

B. meridionalis was proportionally more abundant in the shallow waters (10 to 50m) while *Bathyclarias spp*. was better represented in the deep waters (75 to 125m).

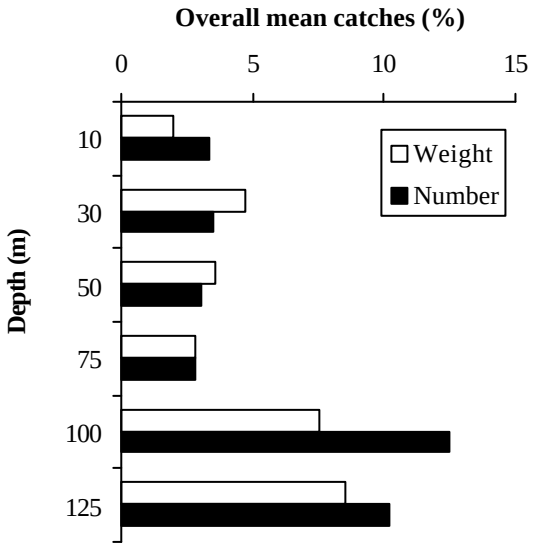

Figure C9. Overall mean catches (in proportion of weight and number) per depth for *Synodontis njassae* from July 98 to May 99.

Table C5. Proportion in weight of the main demersal species trawled at 100m depth in the SWA (catfishes species in italic).

Species name	Jul-98	Aug-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Mean
Alticorpus geoffreyi	2,6	2,4	2,1	3,4	1,8	1,4	3,4	0,9	2,1	1,0	**2,1**
Alticorpus macrocleithrum	3,9	2,8	-	1,2	1,6	1,0	0,9	0,5	0,1	0,2	**1,2**
Alticorpus mentale	21,7	15,0	1,9	9,6	4,1	8,4	21,1	6,7	25,1	6,9	**12,1**
Alticorpus pectinatum	2,6	0,2	0,4	5,7	1,2	0,6	2,6	0,6	1,1	1,1	**1,6**
Aulonocara long	-	0,1	-	-	0,1	-	0,0	0,0	0,0	0,1	**0,0**
Aulonocara minutus	0,8	1,0	0,2	0,8	0,2	0,0	0,8	0,1	0,4	0,2	**0,5**
Aulonocara rostratum	-	-	-	-	-	-	0,4	0,2	0,0	0,0	**0,1**
Bagrus meridionalis	*2,8*	*6,6*	*0,1*	*2,4*	*0,5*	*0,6*	*0,6*	*10,3*	*0,7*	*0,3*	***2,5***
Bathyclarias spp.	*6,9*	*9,4*	-	*15,0*	*10,1*	*5,5*	*25,6*	*20,0*	*10,1*	*10,0*	***11,3***
Diplotaxodon apogon	-	2,2	3,1	17,7	4,3	1,8	0,1	0,7	0,3	0,9	**3,1**
Diplotaxodon argenteus	0,7	-	14,9	5,0	3,7	0,7	0,0	0,9	1,0	1,2	**2,8**
Diplotaxodon macrops	0,3	6,9	2,4	2,5	25,0	21,5	1,2	18,3	5,8	20,2	**10,4**
Diplotaxodon limnothrissa	0,1	-	52,8	3,6	5,9	2,6	1,5	1,1	0,8	28,5	**9,7**
Lethrinops deep water altus	5,9	5,8	1,4	6,1	-	1,2	0,3	0,1	6,2	2,9	**3,0**
Lethrinops gossei	34,4	21,7	2,4	9,6	21,5	28,2	23,4	20,1	35,2	20,6	**21,7**
Lethrinops oliveri	4,9	17,4	2,8	4,4	4,6	3,5	0,3	0,4	-	1,8	**4,0**
Lethrinops polli	0,1	0,9	0,2	3,2	-	1,2	0,2	0,2	0,5	0,1	**0,7**
Pallidochromis tokolosh	0,1	-	0,1	0,6	0,1	0,0	-	0,0	1,4	0,4	**0,3**
Placidochromis "flatjaws"	0,4	-	-	-	5,7	0,1	0,1	0,0	0,5	-	**0,7**
Placidochromis platyrhynchos	1,8	1,2	0,1	-	1,3	0,3	0,2	0,0	0,3	0,1	**0,5**
Synodontis njassae	*5,4*	*0,5*	*1,9*	*3,2*	*1,7*	*20,9*	*13,0*	*18,3*	*7,2*	*3,3*	***7,6***
Total	**95,4**	**94,3**	**86,7**	**94,0**	**93,6**	**99,5**	**95,8**	**99,5**	**99,0**	**99,8**	**95,8**

Table C6. Proportion in weight of the main demersal species trawled at 125m depth in the SWA (catfishes species in italic).

Species name	Jul-98	Aug-98	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Mean
Alticorpus spp.	0,1	-	-	-	0,9	1,9	1,8	2,5	0,5	1,6	**0,9**
Alticorpus geoffreyi	1,6	1,0	2,2	3,8	18,7	3,1	5,0	3,8	2,9	2,0	**4,4**
Alticorpus macrocleithrum	-	0,1	-	0,2	2,1	0,2	0,1	-	-	-	**0,3**
Alticorpus mentale	19,6	15,8	15,8	2,1	15,1	3,7	5,4	9,3	5,0	7,1	**9,9**
Alticorpus pectinatum	0,1	-	0,3	4,5	4,7	-	0,2	0,9	1,8	-	**1,3**
Aulonocara long	-	-	0,6	-	-	0,0	0,1	0,3	0,1	0,3	**0,1**
Aulonocara minutus	-	0,2	1,4	1,4	1,9	1,1	0,6	8,2	1,0	0,7	**1,7**
Aulonocara rostratum	-	-	0,5	-	-	0,1	0,5	0,4	-	0,7	**0,2**
Bagrus meridionalis	*2,4*	*6,3*	*2,4*	*1,1*	*0,3*	*7,0*	*2,0*	*1,0*	*0,2*	*2,6*	***2,5***
Bathyclarias spp.	*15,1*	*6,3*	*2,4*	*2,7*	*13,5*	*7,3*	*8,5*	*3,6*	*2,7*	*4,0*	***6,6***
Diplotaxodon apogon	-	12,5	3,1	4,0	1,8	1,7	1,2	1,6	5,4	1,9	**3,3**
Diplotaxodon argenteus	0,2	0,2	3,8	1,0	1,2	1,5	1,8	0,2	3,1	2,6	**1,6**
Diplotaxodon macrops	0,7	7,5	7,8	10,9	-	15,2	17,2	6,2	24,3	27,6	**11,8**
Diplotaxodon brevimaxillaris	-	-	0,5	0,5	0,3	0,5	0,3	-	-	1,4	**0,3**
Diplotaxodon limnothrissa	0,1	0,2	0,7	1,0	0,1	0,9	0,6	0,8	3,3	9,4	**1,7**
Hemitaeniochromis insignis	-	-	0,2	-	-	0,3	-	0,1	0,1	0,1	**0,1**
Lethrinops deep water albus	5,1	0,3	4,1	0,2	0,1	0,8	-	-	-	0,1	**1,1**
Lethrinops deep water altus	9,1	6,6	6,5	4,4	2,1	2,6	6,0	4,2	6,0	5,4	**5,3**
Lethrinops gossei	15,4	21,4	10,5	33,4	12,0	37,2	31,2	31,4	33,8	20,1	**24,6**
Lethrinops oliveri	3,5	3,6	2,7	2,8	5,1	1,7	0,8	8,6	-	0,7	**3,0**
Lethrinops polli	0,2	-	0,1	0,7	0,2	-	0,2	-	-	-	**0,1**
Pallidochromis tokolosh	1,0	3,0	3,5	0,3	1,3	2,9	2,8	0,4	1,4	2,6	**1,9**
Placidochromis "flatjaws"	-	-	-	-	0,3	0,0	0,5	3,3	0,3	-	**0,4**
Placidochromis platyrhynchos	1,9	10,6	4,9	0,6	1,4	2,0	3,3	6,5	1,8	2,1	**3,5**
Synodontis njassae	*12,8*	*1,0*	*16,4*	*20,2*	*3,1*	*6,0*	*8,5*	*6,0*	*5,9*	*5,1*	***8,5***
Total	**88,9**	**96,7**	**90,5**	**95,8**	**85,9**	**97,8**	**98,5**	**99,2**	**99,5**	**98,0**	**95,1**

The smaller *S. njassae* was more evenly represented in number and weight and appeared more abundant in the very deep zone (100-125m, Figure C9).

A minimum of 145 (see Appendix 2) to at least 170 different species were caught during the sampling year from June 1998 to May 1999 (taking into account the several species lumped together under their generic names, such as the *Aulonocara spp*., the *Bathyclarias spp*., the *Copadichromis spp*., the *Lethrinops spp*., the *Mylochromis spp*., the *Nyassachromis spp*., the *Oreochromis s*pp., the *Otopharynx spp*., the *Placidochromis spp*., the *Rhamphochromis spp.*, the *Sciaenochromis spp.*). However, despite this high number of sampled species, relatively few cichlid species accounted for more than 50% of the catches in weight at all depths, respectively 51% at 10m (*Lethrinops argenteus*, *Nyassachromis argyrosoma* and *Oreochromis spp*. Table C1), 55.2% at 30m (*Copadichromis virginalis*, *L. argenteus Mylochromis anaphyrmus* and *N. argyrosoma* Table C2), 56.9% at 50m (*C. virginalis*, *Diplotaxodon limnothrissa*, *L. argenteus*, and *Trematocranus brevirostris* Table C3), 55.5% at 75m (*Alticorpus geoffreyi*, *Alticorpus mentale*, *Diplotaxodon macrops*, *D. limnothrissa*, *Lethrinops gossei* and *Lethrinops oliveri* Table C4), 53.9% at 100m (*A. mentale*, *D. macrops*, *D. limnothrissa*, *L. gossei* Table C5) and 51.6% at 125m (*A. mentale*, *D. macrops*, *Lethrinops "deep water altus"* and *L. gossei* Table C6). Some of these species were dominant over two to three depths, such as *L. argenteus*, *C. virginalis* and *N. argyrosoma* in the shallows (10 to 50m), *A. mentale*, *D. macrops*, *D. limnothrissa* and *L. gossei* in the deeper waters (75 to 125m).
Added to the proportion of catfishes at each depths, about 10 fish species only accounted for 70 to 80% of the catches in weight over the sampling period.
A clear change in species composition appeared after 50 m, the "shallow" water species being encountered down to 50m whereas the characteristic "deep" water species appeared from 75 m downwards (Tables C1 to C6).

The results of catch per unit effort (kg / 20 min pull) for each species according to depth are summarised in Appendix 3. The total number of species caught over the sampling period decreased with increasing depth from 80 species at 10 m to 48 at 125 m (Appendix 3). Again, these values are underestimated owing to the several species lumped together under their generic names. Unlike the three catfish species, which were consistently caught at any depth, very few cichlid species had depth distribution covering all the sampled depths (Appendix 3). Only 12 out of the 133 cichlid species or species groups listed in Appendix 3 covered all (or at least 5 of) the sampled depths. Most of the others were restricted to three or four depths and some species were confined to one or two depths only.

Discussion

During the whole sampling period (June 1998 to May 1999), no other trawlers were encountered in the sampled area, roughly from Chipoka to Lukoloma (Figure C1). The trawlers in activity in the SWA occur in the southern part of the arm and only the Ndunduma can occasionally trawl in the north of the SWA (A. Bulirani, pers. com.). Therefore, it can be considered that our sampled area is almost not commercially exploited by trawlers. We recorded the highest catches at 75 and 100 m, and the catches were higher at 125 m than at 10 and 30 m, whereas the CPUE is supposed to be higher in the shallow zone (Turner 1977a, Tómasson & Banda 1996). This is likely to be a consequence of the light exploitation of the deep zone by commercial fisheries whereas the shallow zone is heavily exploited by artisanal fishermen in the studied area.

Temporal fluctuations of the total catches per month (all depths pooled) were observed. But the same temporal patterns were also observed at each depth and when depths were pooled per category, suggesting that the representativeness of our sampling was good, despite a potential inter-haul variability. Tweddle & Magasa (1989) also reported seasonal

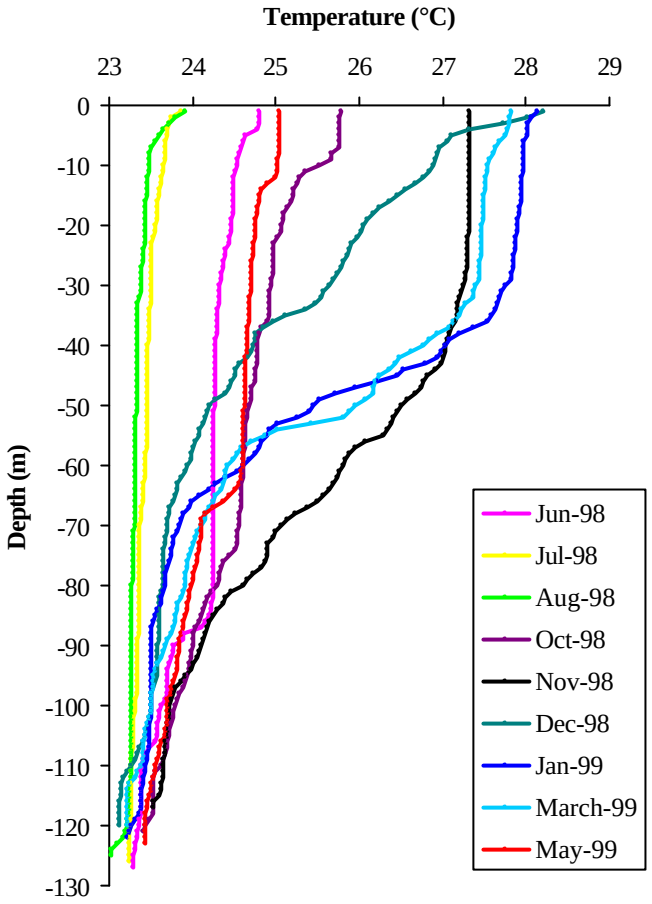

Figure C10. Seasonal progression of temperature profile according to depth off Cap Maclear, SWA.

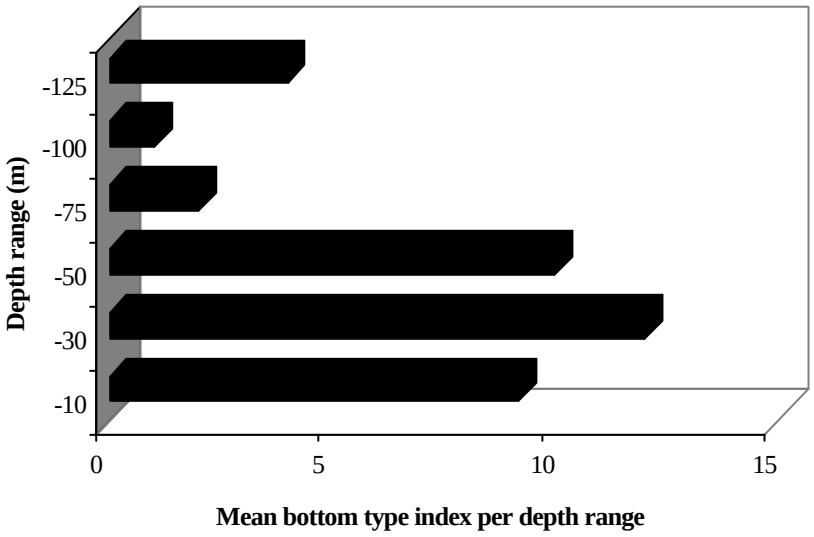

Figure C11. Modification of bottom type with depth in the SWA. Each bottom type category was given an arbitrary value for graphic representation: 15 for "very coarse sand", 10 for "medium sand", 5 for "very fine sand" and 0 for "mud". The values are the means over five months (June to December 1998).

trends in the catch rates in the SEA with usually a peak in August and September, which is supported by our results.

The catches were dominated by cichlids both in number and weight. However, the catfishes, represented by only 3 genera (*Bathyclarias*, *Bagrus* and *Synodontis*) of which two have a single species (*Bagrus meridionalis* and *Synodontis njassae*), consistently constituted a significant part of the catches. Owing to their large size (for *Bathyclarias spp*. and *Bagrus meridionalis* at least), their contribution to the catches was much more important when referred to their biomass than to their number. They consistently represented between 10 and 25% of the catches. Tómasson & Banda (1996) found that in the SWA *B. meridionalis* was more abundant in the deep waters (50 to 100 m) but bigger in the shallows (0 to 50 m). During our sampling period and in the sampled area, which was restricted to the north of the SWA, *B. meridionalis* was more abundant between 10 and 50 m, as observed by Turner (1977), and large specimens were evenly distributed according to depth. *Bathyclarias spp*. tended to be better represented in the deep waters from 50 m downwards whereas their maximum catch was observed at 40-60 m by Turner (1977). As pointed out by Tómasson & Banda (1996), *Synodontis njassae* was common at all depths and displayed an increasing occurrence and abundance with depth, becoming much more abundant in the very deep zone (100 and 125 m). Although specimens from 50 to 200 mm (standard length) were recorded, most individuals caught were of uniform size, between 90 and 110 mm SL, which corresponded to previous observations of 12 to 14 cm TL (Tómasson & Banda 1996).

When adjusted to a 30 min pull and per depth category, the CPUE per species (Appendix 3) were not always consistent with those reported by Tómasson & Banda (1996). Details will be given in Chapter 2.

A marked change in species composition was reported to occur around 50 m in the SWA (Tómasson & Banda 1996). It was hypothesised to be related to the position of the thermocline or the substrate type. This spectacular shift in species composition between 50 and 75 m was also observed in our study. However, the position of the thermocline does not seem to be the best explanation to that pattern for it fluctuates significantly with season (Figure C10), whereas the species distribution pattern is stable (Tables C1 to C6). As most of the exploited species are demersal fish and therefore closely related to the bottom, the sediment quality might constitute a better explanation. The grab sample analyses revealed a gradient in bottom type composition from the shallows to the deep waters. The bottom types can roughly be categorised as "very coarse sand", "medium sand", "very fine sand" and "mud". Each of these categories were attributed arbitrary values, respectively 15, 10, 5 and 0 for the sake of graphic representation. The results of grab sample analyses over several months are summarised in Figure C11. A clear change in bottom composition from coarse and medium sand to very fine sand and mud appears after 50m and is likely to influence the species composition pattern according to depth.

A notable observation was that throughout the year, the bulk of the catches was constituted by a few common cichlid and catfish species. At any given depth, despite the large number of species regularly recorded, 60 to 80% of the catches was made of no more than ten species including the three catfishes. And about twenty species only accounted for 90 to 95% of the catches at each depth, with some species being dominant in two or three of the sampled depths. This indicates that the largest part of the species caught is relatively rare or at least infrequent. For the rarer ones, the occurrence in the catches might be incidental to unusual movements out of their habitat, which would expose them to the trawl. Another potential explanation might be that we did sample only a restricted amount of different habitats, though this hypothesis is very unlikely given the surface covered by a 20 min pull. Hence, for the majority of the infrequent species it probably means that they do exist in small population number and/or have patchy distributions either because of their high specialisation to specific type of habitats or because of the narrowness of their trophic niche. In any case, these species are likely to be the first endangered by intensive exploitation.

The decreasing number of species caught with increasing depth reported by previous authors (Turner 1977a, Tómasson & Banda 1996) was also observed in our study (Appendix 3). The generally accepted statement that demersal cichlids usually have restricted depth distributions (Eccles & Trewavas 1989, Banda & Tómasson 1996, Tómasson & Banda 1996, Turner 1996) was also supported by our results. Another well-known trend is the decreasing occurrence of large cichlid species with depth (Turner 1977a). We observed that even though there was a higher number of large species in the shallows (*Buccochromis spp.*, *Taeniolethrinops spp.*, *Serranochromis robustus*…), their occurrence was weak, except for the *Oreochromis spp.*, and catches were dominated by small species such as *Aulonocara spp.*, *Nyassachromis spp.* or *Copadichromis virginalis* and a few larger species such as *Lethrinops argenteus* and *Mylochromis anaphyrmus* (Tables C1 and C2). On the other hand, the dominant species of the deep zone were rather large fish such as *Lethrinops gossei,* the *Alticorpus spp.* and *mentale* particularly, the *Diplotaxodon spp.* (Tables C4 to C6). The decreased occurrence of large and medium species in the catches reported by Turner (1977b) and Turner et al. (1995) probably also affected the shallow waters of the SWA. However, an interesting proportion of large species remains in the almost unexploited deep zone. Given that over the year the highest catches were recorded from 50 m downwards, where the dominant species are relatively large, any expansion of trawl fisheries in the southern part of the Lake should take place in the deep zone shared by the SE and SW arms. This supports the position of Banda et al. (1996) against FAO's (1993) recommendation that no expansion of the trawl fishery should take place in the deeper zone of the SEA.

Chapter 2:

Depth distribution and breeding patterns of the demersal species most commonly caught by trawling in the South West Arm of Lake Malawi

Chapter 2: Depth distribution and breeding patterns of the demersal species most commonly caught by trawling in the South West Arm of Lake Malawi

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Introduction

Given the tremendous diversity of Malawi cichlids, very few studies have been carried out on their breeding biology so far. Earlier studies focused on some species in the north (Jackson et al. 1963) and central part of the lake (zooplanctivorous *Utaka*: Iles 1960, 1971). A comprehensive work highlighted the reproductive seasonality of ten rock frequenting species (Marsh et al. 1986). A recent survey of the pelagic zone provided information about the breeding of *Copadichromis quadrimaculatus*, *Diplotaxodon limnothrissa* and *'big eye'* and *Rhamphochromis longiceps* (Thompson et al. 1996). Despite the fact they hold an economically important commercial fishery, very few species apart from *chambo* (Lowe 1953, McKaye & Stauffer 1988, Turner et al. 1991) have been studied in the south of the lake, where the commercial fisheries take place. Maturity and fecundity were estimated for *Copadichromis* ("*Haplochromis*") *mloto, Lethrinops parvidens* , *L. longipinnis*, *Mylochromis* ("*Haplochromis*") *anaphyrmus* and *Otopharynx* ("*Haplochromis*") *intermedius* (Tweddle & Turner 1977), while breeding season and maturity were detailed for three *Lethrinops* species, *microdon*, *'species A'* and *gossei* by Lewis & Tweddle (1990). McKaye (1983) reported marked seasonal variations in nest numbers for *Cyrtocara eucinostomus*.

Although the information is incomplete for some species, our study describes the breeding biology of about 40 of the most important trawled species in the SWA.

It is important to remember that the sampling period was June 1998 to May 1999. However, all the information related to catches are based on the period from July 1998 to May 1999 for the reasons explained in the previous chapter. Owing to inter species variability of occurrence in the catches and therefore to sample size, the results presented in this chapter will be of irregular quality, the information being complete and reliable for some species and more indicative for the rarer ones. For the reader's convenience, information about the species is delivered per genera, which are ordered alphabetically. For each species, whenever possible, the following information is displayed: size range (SL), depth distribution, occurrence and abundance over the full sampling period, breeding season, age and size at maturity, fecundity and egg size.

For the breeding season, priority will always be given to the females pattern. Most of the time in cichlids, males are sexually active for longer periods than females; a way to always be 'ready' probably. As a consequence, determination of the breeding season is more accurate when based upon female data. However, when the sample sizes are not optimum for females, information about males may be useful. On the other hand, as most Malawi cichlids form breeding leks to attract females (Konings 1995, Turner 1996), priority will be given to ripe males distribution for estimation of spawning depth. The weight of individuals was not taken on board, but only in the lab on ripe females, except for the nine target species (*Alticorpus macrocleithrum*, *Alticorpus mentale*, *Copadichromis virginalis*, *Diplotaxodon limnothrissa*, *Diplotaxodon macrops*, *Lethrinops argenteus*, *Lethrinops gossei*, *Mylochromis anaphyrmus* and *Taeniolethrinops praeorbitalis*), for which all the females were weighed. Most of the

length-weight relationships are then based on data for ripe females, which explain their low sample size sometimes.

Material and methods

All the fish analysed were collected during the monthly trawl catches in the north of the South West Arm (see Chapter 1 for details).

The comparisons of CPUE per depth for each species with those reported in Tómasson & Banda (1996) are based on the values given in Appendix 3, but pooled per depth category (shallow zone = 0-50 m, deep zone = 51-100 m, very deep zone = >100 m) and reported to 30 min pulls (instead of 20 min in our case) to be comparable with Tómasson & Banda (1996) values.

The maturity stage of female gonads was macroscopically determined using the slightly modified scale of Legendre & Ecoutin (1989) (Duponchelle 1997).

Stage 1: immature. The gonad looks like two short transparent cylinders. No oocytes are visible to the naked eyes. As a comparison, immature testicle is much longer and thinner, like two long tinny silver filaments.

Stage 2: beginning maturation. The ovaries are slightly larger and little whitish oocytes and apparent.

Stage 3: maturing. The ovaries continue to grow in length and thickness and are full of yellowish oocytes in early vitellogenesis.

Stage 4: final maturation. The ovaries occupy a large part of the abdominal cavity and are full of large uniform sized oocytes in late vitellogenesis.

Stage 5: ripe. Ovulation occurred, oocytes can be expelled by a gentle pressure on the abdomen. This stage is ephemera.

Stage 6: spent. The ovaries look like large bloody empty bags with remaining large sized atretic follicles. Small whitish oocytes are visible.

Stage 6-2: resting. The general aspect of the gonad recall a stage 2, but the ovarian wall is thicker, the gonad is larger, often reddish with an aspect of empty bag. This stage is distinctive of resting females, which have spawned during the past breeding season.

Stage 6-3: recovering post-spawning females. The general aspect of the gonad is like a stage 3 but with empty rooms, remaining large-sized atretic follicles and the blood vessels are still well apparent. This stage is characteristic of post-spawning females initiating another cycle of vitellogenesis.

Males were only recorded as being either in "breeding colour" or not.

For each species, all the stage 4 and 5 females were preserved in 10 % formalin for later examination.

Nine target species were selected according to their relative abundance, depth distribution and basic ecological characteristics (benthic or pellagic habits, broad trophic category) (Tómasson and Banda 1996, Turner 1996). These were *Lethrinops gossei* Burgess & Axelrod, *Lethrinops argenteus* Ahl (= *L. longipinnis 'orange head'*), *Diplotaxodon limnothrissa* Turner, *Diplotaxodon macrops* Turner & Stauffer, *Copadichromis virginalis* Iles, *Mylochromis anaphyrmus* Burgess & Axelrod, *Alticorpus mentale* Stauffer & McKaye, *Alticorpus macrocleithrum* Stauffer & McKaye and *Taeniolethrinops praeorbitalis* Regan.

For these species, all the females from each haul were preserved in formalin for later examination.

All fish preserved in formalin were measured (SL) to the nearest mm and weighed to the nearest 0.1 g. Their maturity stage was determined and the gonads in stage 4 were weighed for Gonado-Somatic Index (GSI) calculation (gonad weight/total body weight × 100) then preserved in 5% formalin for fecundity and mean oocyte weight calculation.

The breeding season was determined from the monthly proportions (in %) of the different stages of sexual maturation (Legendre & Ecoutin 1989, Duponchelle et al. 1999). In order to eliminate the small immature females, which would give a biased weight to the immature stages (1 and 2), and to define more precisely the spawning season, only females which size was greater than or equal to the size at first sexual maturity were considered in analysis.

The average size at first maturation (L_{50}) is defined as the standard length at which 50% of the females are at an advanced stage of the first sexual cycle during the breeding season. In practice, this is the size at which 50% of the females have reached the stage 3 of the maturity scale (Legendre & Ecoutin 1996, Duponchelle & Panfili 1998). For the estimation of L_{50}, only the fish sampled during the height of the breeding season were considered.
Age at maturity was calculated from the Von Bertalanffy Growth Curve (VBGC) equation:

$$L_t = L\infty\ (1-\exp\ (-K\ (t-t_0)) \qquad (2)$$

Where L_t is the mean length at age t, $L\infty$ is the asymptotic length K the growth coefficient and t_0 the size at age 0. This equation can be written:

$$t = (-\ln\ (1-\ (L_t\ /\ L\infty))\ /\ K) + t_0$$

Replacing L_t by the mean size at maturity (L_{50}), age at maturity (A_{50}) is then:

$$A_{50} = (-\ln\ (1-\ (L_{50}\ /\ L\infty))\ /\ K) + t_0$$

$L\infty$ and K were obtained from length frequency distribution analysis and are provided in the Chapter "Growth" for twenty three of the species. The size at age 0 was considered null.

Fecundity is defined here as the number of oocytes to be released at the next spawn, and correspond to the absolute fecundity. It is estimated, from gonads in the final maturation stage (stage 4), by the number of oocytes belonging to the largest diameter modal group. This oocyte group is clearly separated from the rest of the oocytes to the naked eye and corresponds approximately to oocytes that are going to be released (Duponchelle 1997, Duponchelle *et al*. 2000).

Oocyte weight measurements were all carried out on samples preserved in 5% formalin. The average oocyte weight per female, was determined by weighing 50 oocytes (Peters 1963) belonging to those considered for fecundity estimates.

In order to compare mean oocyte weight and diameter among the different species, the measurements need to be made on oocytes in a similar vitellogenic stage, then on oocytes whose growth is completed. A simplified version of the method applied by Duponchelle (1997) was used to determine the GSI threshold above which the oocyte weight do no longer increase significantly. For each species, the individual oocyte weights were plotted against the GSI. The GSI corresponded to the beginning of the asymptotic part of the curve was visually determined and the fish whose GSI was inferior to the defined GSI were removed. The final GSI threshold was reached when no correlation subsisted between the mean oocyte weight and the GSI.

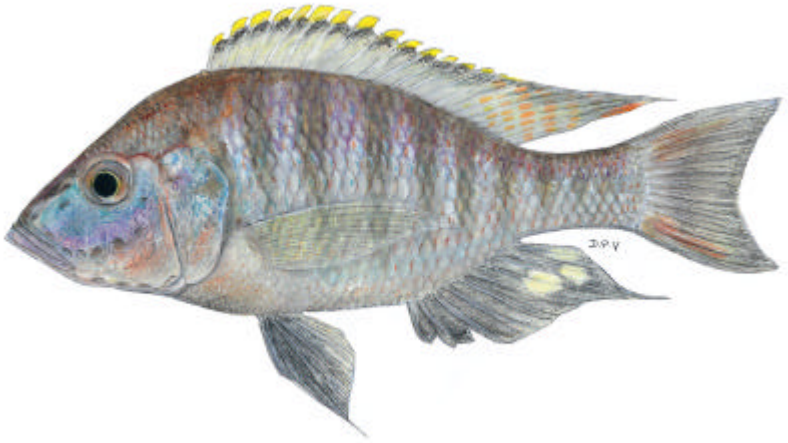


Plate 1. *Alticorpus 'geoffreyi'* (by Dave Voorvelt).

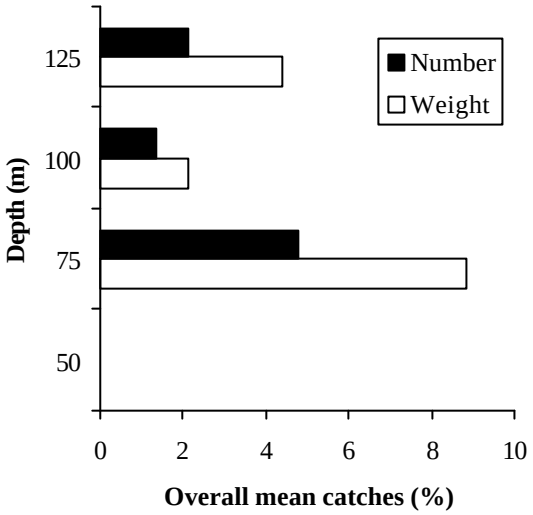


Figure 2-1. Mean occurrence and abundance in the catches per depth of *Alticorpus 'geoffreyi'* in the SWA between July 1998 and May 1999.

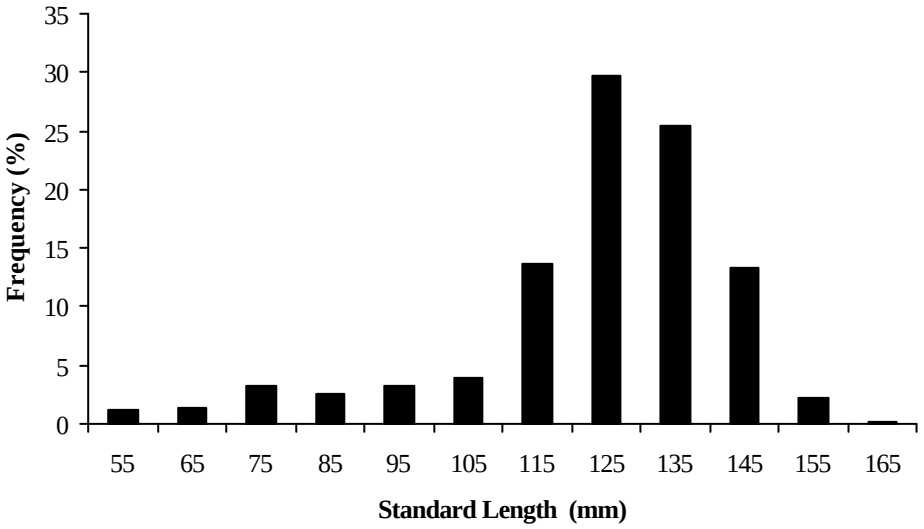


Figure 2-2. Size range and frequencies of *Alticorpus 'geoffreyi'* caught in the SWA between July 1998 and May 1999.

Results

Alticorpus spp.

Alticorpus 'geoffreyi' **(Plate 1)**

721 females and 845 males were analysed. *A. 'geoffreyi'* is a deep water species rarely encountered at 50m. In our sampling it was most abundant at 75m and still well represented at 125m. (Figure 2-1). It constituted in average between 2 and 9% of the catches in weight and between 1 and 5% in number, depending upon depth, but was more abundant at 75 m. The mean CPUE per depth category was 0.3 kg for the shallow zone, 37.4 in the deep zone, and 9.1 in the very deep zone, which differed markedly with the values reported by Tómasson & Banda (1996) for the shallow (9.3 kg) and deep (11.4 kg) zones, but matched in the very deep zone (9.0 kg). They also observed *A. 'geoffreyi'* from 20 m depth downwards in the SWA, whereas we never encountered it before 50 m. This might explain the difference in CPUE in the shallow zone. Specimens caught ranged between 55 and 165 mm with a mode from 110 to 150 mm (Figure 2-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

The breeding season for females occurred from March to October with a maximum activity between May and August (Figure 2-3a). The proportion of males in breeding colour was much higher than the proportion of ripe females, but basically confirmed the position of the breeding season (Figure 2-3b). Ripe females were mostly found at 75 and 100 m whereas males in breeding colour were much more abundant at 75m, suggesting that breeding could occur around 75 m depth (Table 2-1). The size at maturity of female was about 90mm (Figure 2-4) and was reached at 14 months old.

Table 2-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Alticorpus geoffreyi* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
50 m	0.5	0	0	0.5	
75 m	54.1	38.7	40.2	84.4	78.8
100 m	13.5	42.7	16.7	3.9	15.2
125 m	31.9	18.6	43.1	11.2	6

The length-weight and fecundity-weight relationships are given in Figure 2-5 and 2-6, respectively. Fecundity ranged from 86 to 231 for females weighing between 33 and 94 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3.7% (Figure 2-7) and the mean oocyte weight was 17.70 mg (± 2.48 SD, N= 26).

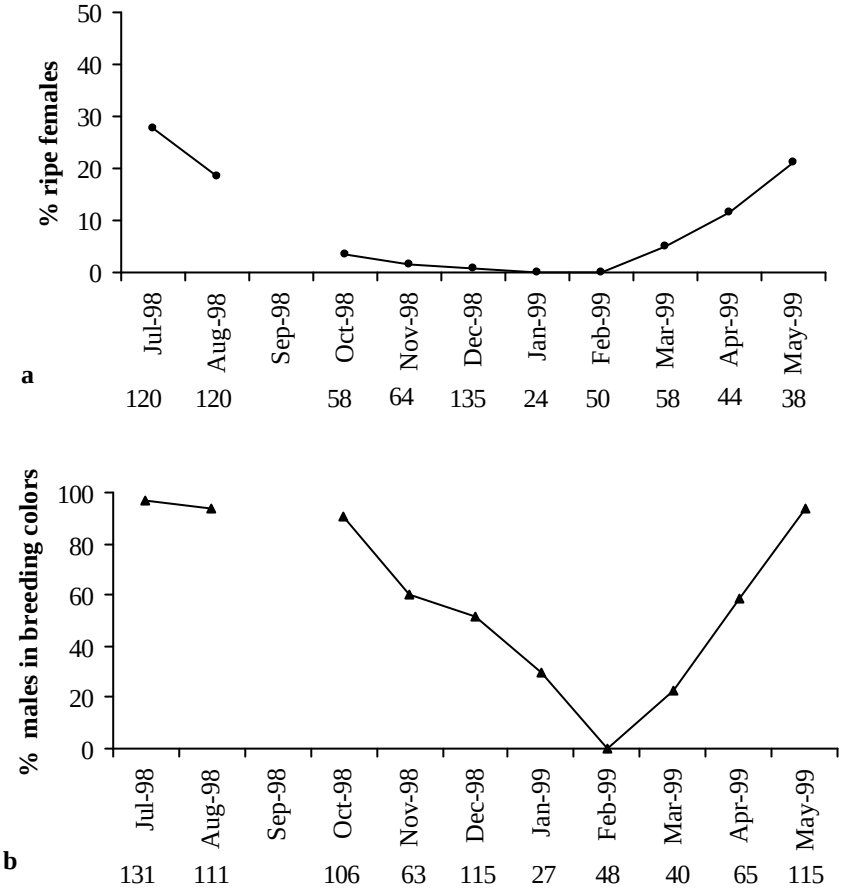


Figure 2-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Alticorpus 'geoffreyi'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

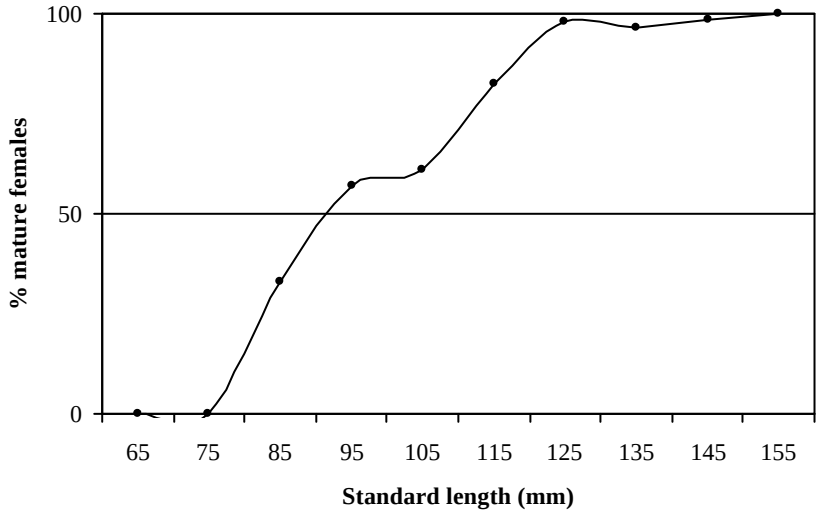


Figure 2-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Alticorpus 'geoffreyi'* in the SWA.

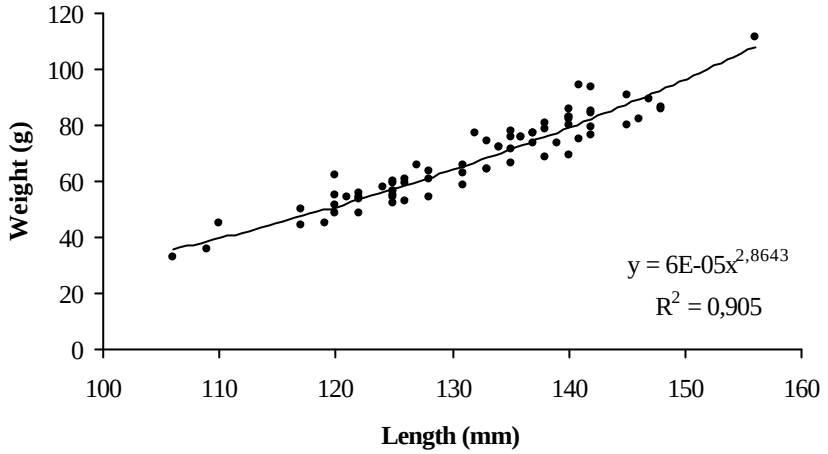


Figure 2-5. Length-weight relationship for *Alticorpus geoffreyi* females in the SWA. (R^2 = determination coefficient).

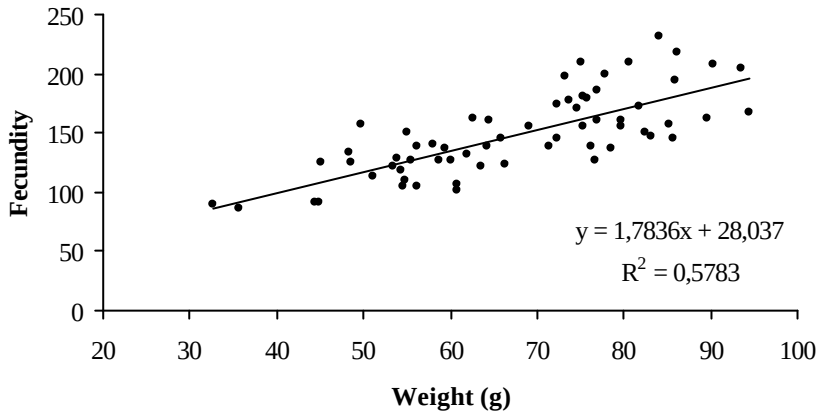


Figure 2-6. Fecundity-weight relationship for *Alticorpus geoffreyi* females in the SWA. (R^2 = determination coefficient).

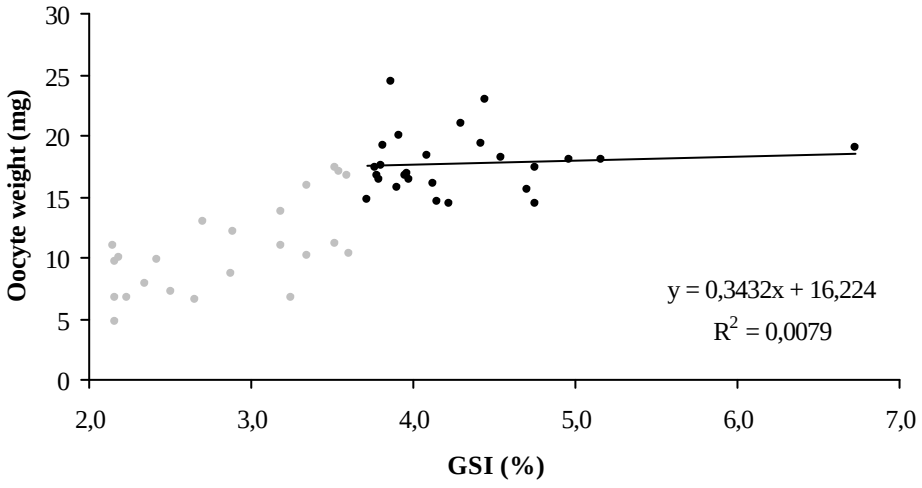


Figure 2-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Alticorpus geoffreyi*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3.7 %. (R^2 = determination coefficient)

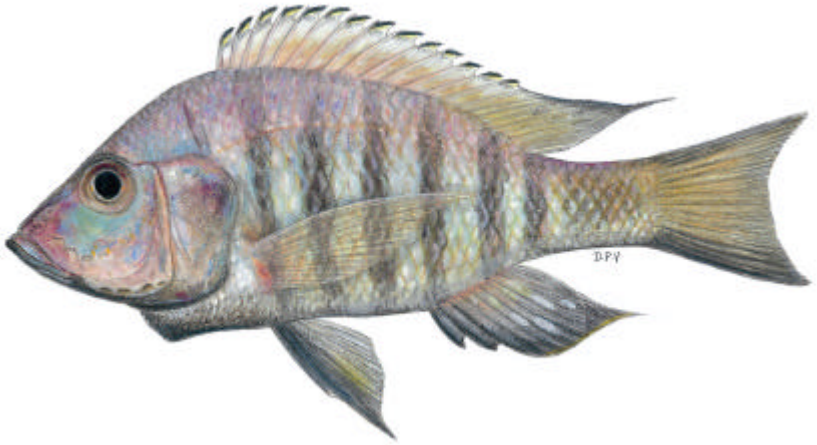


Plate 2. *Alticorpus macrocleithrum* (by Dave Voorvelt).

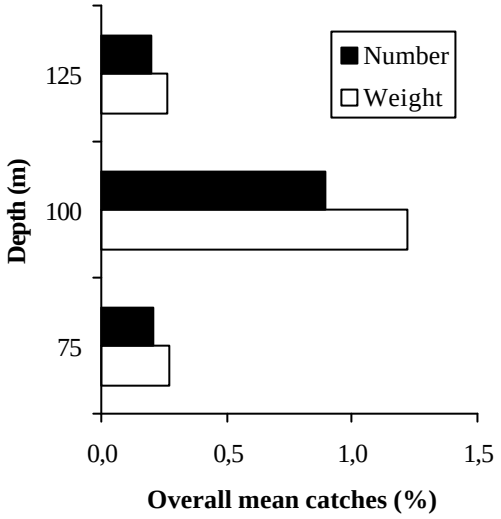


Figure 3-1. Mean occurrence and abundance in the catches per depth of *Alticorpus macrocleithrum* in the SWA between July 1998 and May 1999.

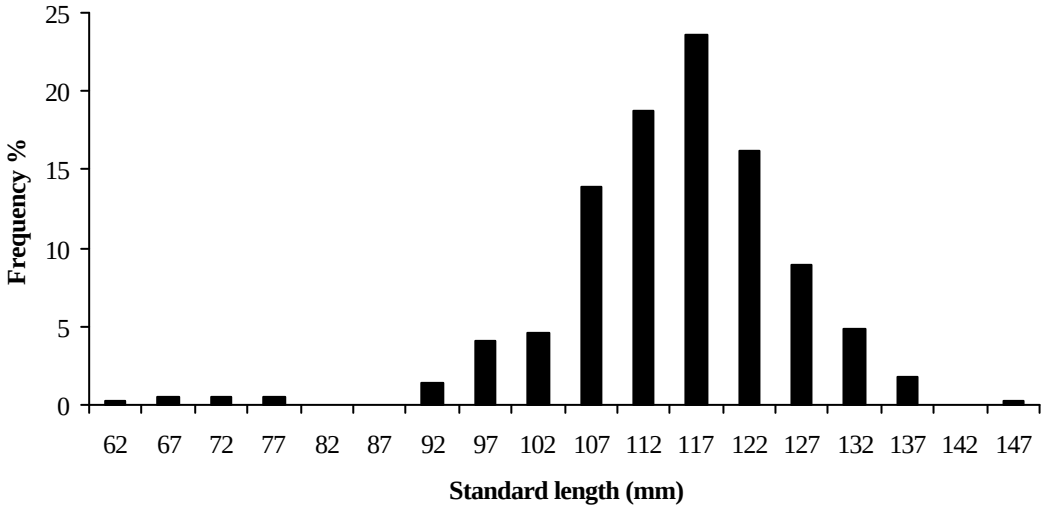


Figure 3-2. Size range and frequencies of *Alticorpus macrocleithrum* caught in the SWA between July 1998 and May 1999.

Alticorpus macrocleithrum (Stauffer & McKaye) (Plate 2)

317 females and 153 males were analysed. *A. macrocleithrum* is a deep water species encountered between 75 m and 125 m, but more abundant at 100 m (Figure 3-1). It is not an abundant species, always constituting less than 1.5% of the catches both in weight and number. The mean CPUE per depth category was 5.1 kg in the deep zone and 0.6 kg in the very deep zone, which is about twice the values reported in Tómasson & Banda (1996) for the deep zone (2.7 kg), but 8 times less in the very deep zone (5 kg). As for *A. 'geoffreyi'*, the depth distribution we found was more restricted than that observed by Tómasson & Banda (1996), who found *A. macrocleithrum* from 40 m downwards. Specimens caught ranged between 60 and 148 mm with a mode from 105 to 130 mm (Figure 3-2). The sex ratio observed over the full sampling period was F/M 0.7/0.3.

Owing to weak sample number at some months both for females and males, the breeding season is difficult to determine with certainty (Figure 3-3a and b). It seemed from female data (Figure 3-3a) that breeding season occurred between April and August. Despite high fluctuations from 0 to 100% due to very low sample size at some months (June, October, April and May), the data for males supported by correct sample size tended to confirm that breeding season. However, the low sample size for females in September–October and in March do not allow us to exclude the possibility that breeding season might be a bit protracted, beginning a bit earlier and finishing a bit later than observed on those graphs (March to September ?). All the breeding females, nearly all (97%) the males in breeding colour (Table 3-1) were found are 100 m, suggesting that spawning might occur at that depth. Maturity was reached early in their second year at 18 months old at a mean size of 100 mm for females (Figure 3-4). However, size at maturity has to be determined at the height of the breeding season to be accurate but owing to the low sample size we had to consider every data available. As a consequence, it is likely that L_{50} was overestimated.

Table 3-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Alticorpus macrocleithrum* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	29.7				
100 m	64.4	100	83.3	96.6	88
125 m	5.9		16.7	3.4	12

The length-weight and fecundity-weight relationships are given in Figure 3-5 and 3-6, respectively. Fecundity ranged from 96 to 304 for females weighing between 26 and 76 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 4.5% (Figure 3-7) and the mean oocyte weight was 12.73 mg (± 2.6 SD, N= 24).

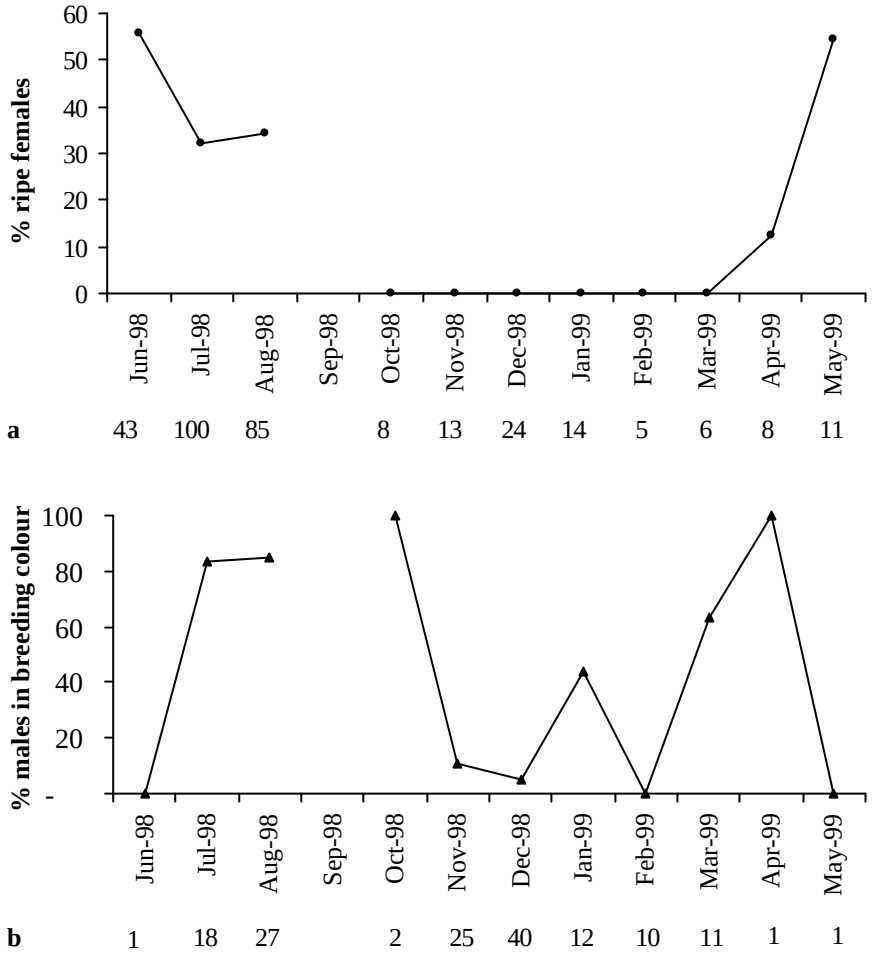


Figure 3-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Alticorpus macrocleithrum* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

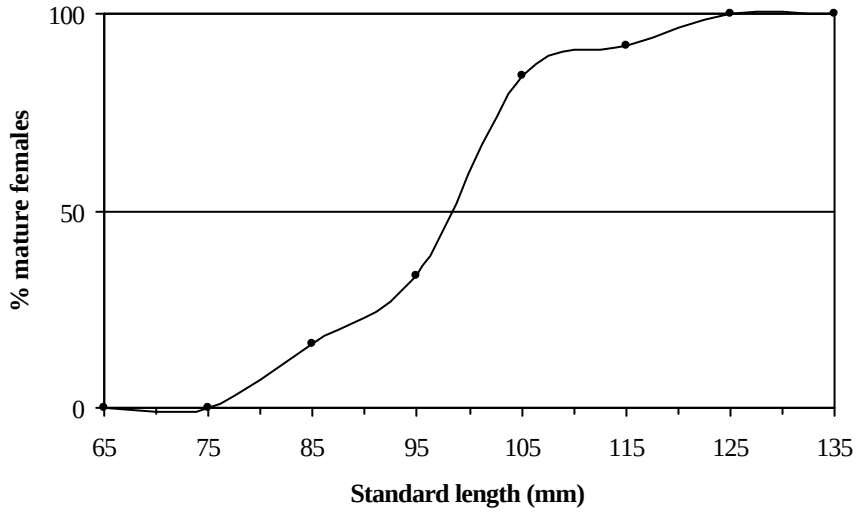


Figure 3-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Alticorpus macrocleithrum* in the SWA.

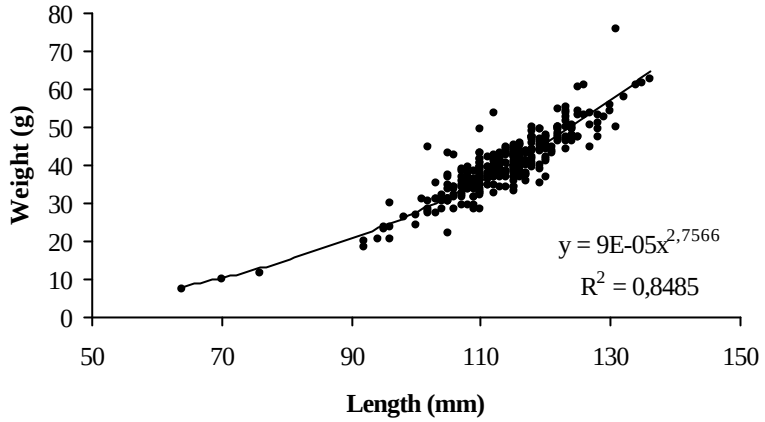


Figure 3-5. Length-weight relationship for *Alticorpus macrocleithrum* females in the SWA. (R^2 = determination coefficient).

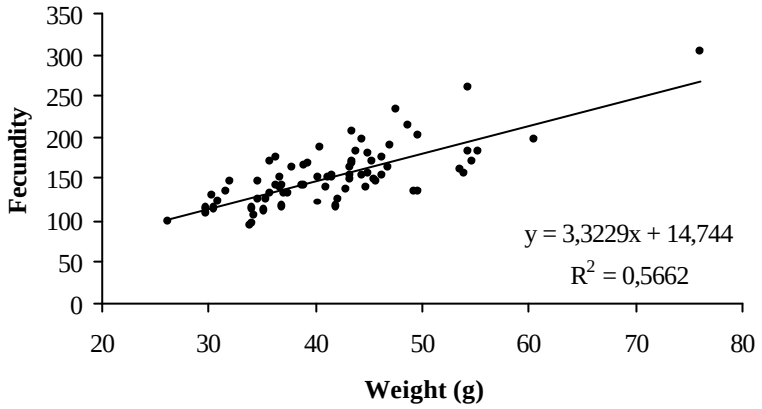


Figure 3-6. Fecundity-weight relationship for *Alticorpus macrocleithrum* females in the SWA. (R^2 = determination coefficient).

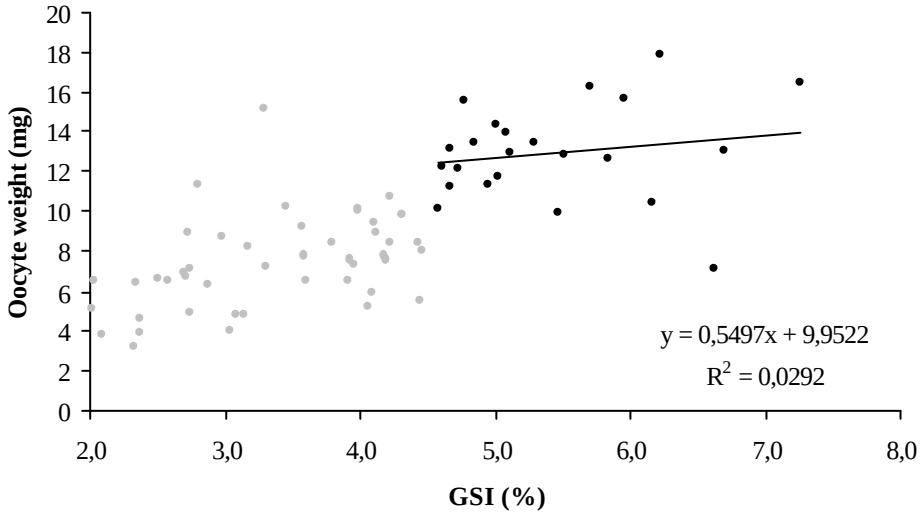


Figure 3-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Alticorpus macrocleithrum*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 4.5%. (R^2 = determination coefficient)

Plate 3. *Alticorpus mentale* (by Dave Voorvelt).

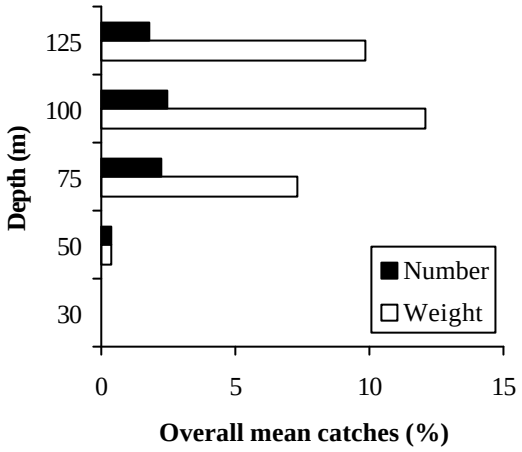


Figure 4-1. Mean occurrence and abundance in the catches per depth of *Alticorpus mentale* in the SWA between July 1998 and May 1999.

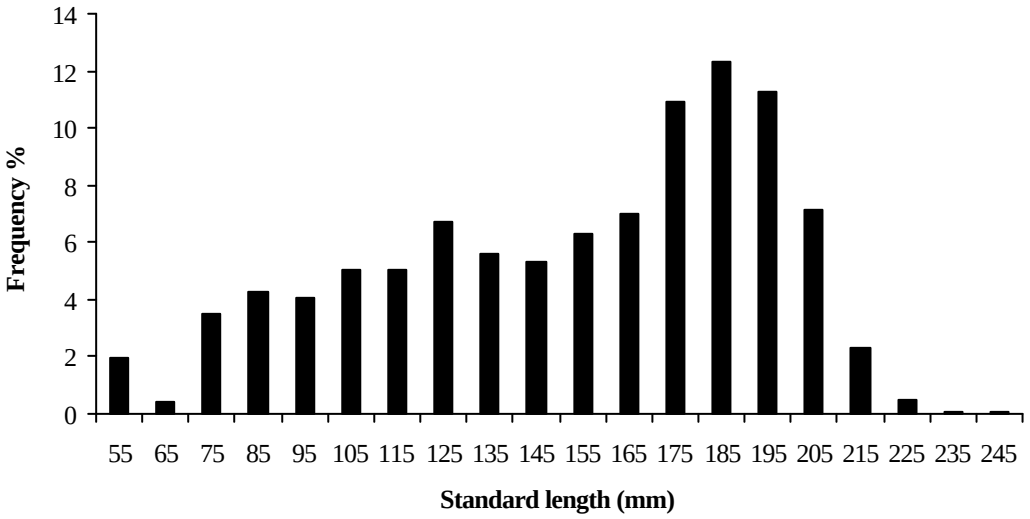


Figure 4-2. Size range and frequencies of *Alticorpus mentale* caught in the SWA between July 1998 and May 1999.

Alticorpus mentale (Stauffer & McKaye) (Plate 3)

1011 females and 959 males were analysed. *A. mentale* is a deep water species that can be encountered from 30 m but becomes abundant from 75 m downwards (Figure 4-1). It is an abundant fish always constituting between 7 and 13% of the catches in weight and a bit less in number (about 3%) due to its large size. The mean CPUE per depth category was 1.1 kg in the shallow zone, 51.1 kg in the deep zone and 20.1 kg in the very deep zone, which is about twice as much as reported in Tómasson & Banda (1996) for the deep and very deep zones (11.4 and 12.7 kg, respectively), but 2 times less in the shallow zone (2.3 kg). The depth distribution we found corresponded with that observed by Tómasson & Banda (1996). Specimens caught ranged between 53 and 245 mm (Figure 4-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Unlike *A. 'geoffreyi'* and *A. macrocleithrum*, *A. mentale* breeds throughout the year with a peak in November and another one in January-February and a marked decrease of activity in December and May (Figure 4-3a). Males in breeding colour were also found at each month even thought peaks of activity did not necessarily match those of females (Figure 4-3b). It is interesting to note that the period from November to March is the period when *Aulonocara 'minutus'*, frequently found as the dominant prey items in *A. mentale* stomach contents (see Chapter "Diet"), was most abundant in the catches. Ripe females were more abundant at 75 and 100 m whereas males in breeding colour were preferentially found at 100 m and 125 m in a lesser extent (Table 4-1). Immature individuals were mostly found at 75 m but were reasonably abundant at 100 and 125 m. *A. mentale* seems able to spawn at any depth between 75 and 125 m. Maturity was reached early in their second year at 16 months old at a mean size of 160 mm for females (Figure 4-4).

Table 4-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Alticorpus mentale* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
30 m	0.2	0	0	0	0
50 m	1	0	2.6	0.5	4.7
75 m	39	41.8	4.3	9.4	54.3
100 m	26.9	44.5	25	68.5	19.6
125 m	32.8	13.6	29.1	21.6	21.5

The length-weight and fecundity-weight relationships are given in Figure 4-5 and 4-6, respectively. Fecundity ranged from 92 to 356 for females weighing between 49 and 307 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 4-7) and the mean oocyte weight was 24.36 mg (± 4.18 SD, N= 31).

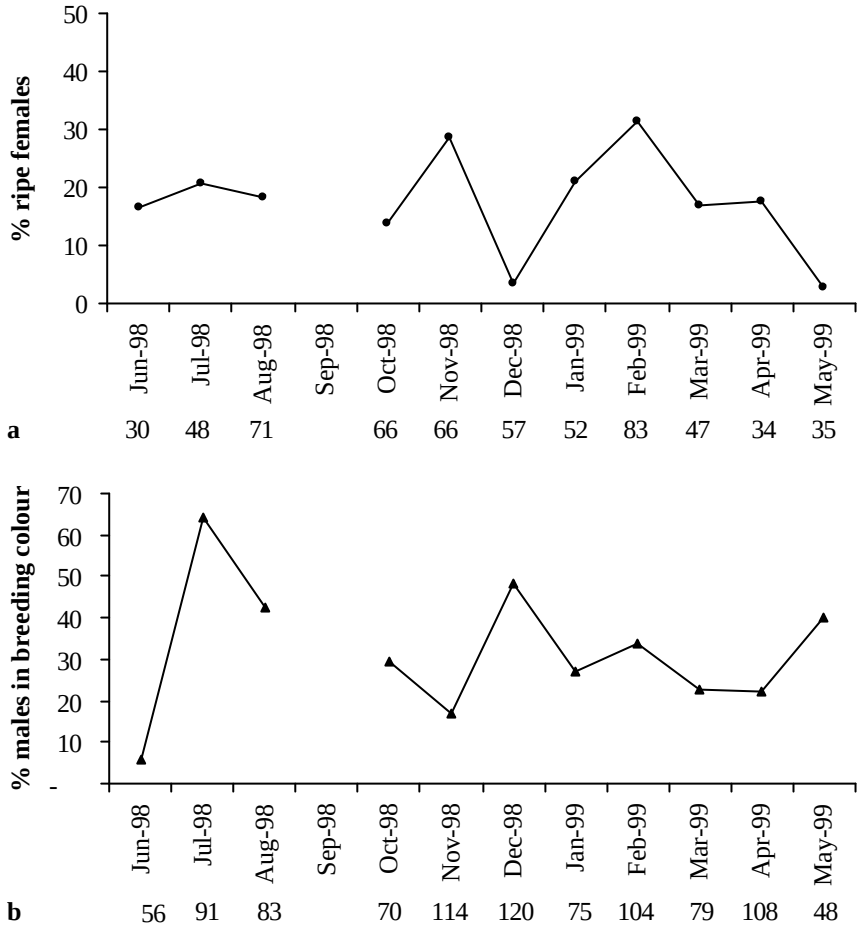


Figure 4-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Alticorpus mentale* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

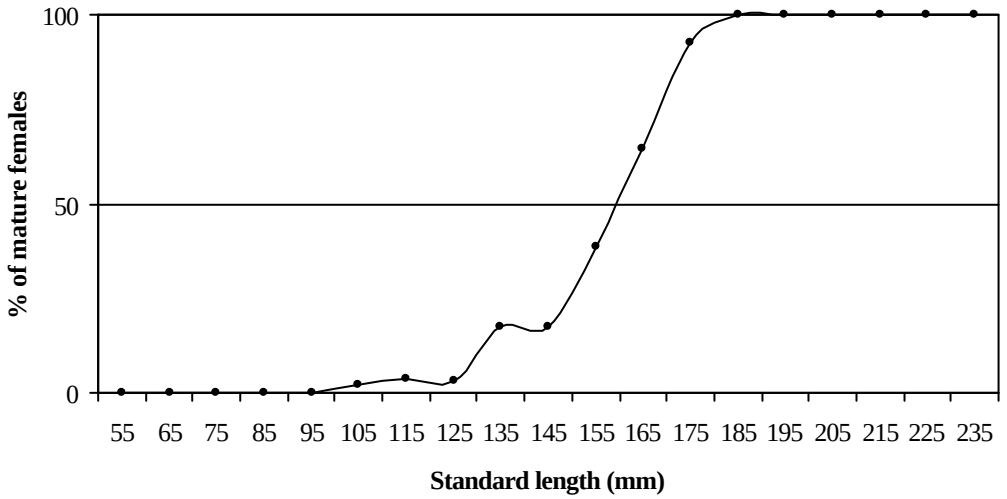


Figure 4-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Alticorpus mentale* in the SWA.

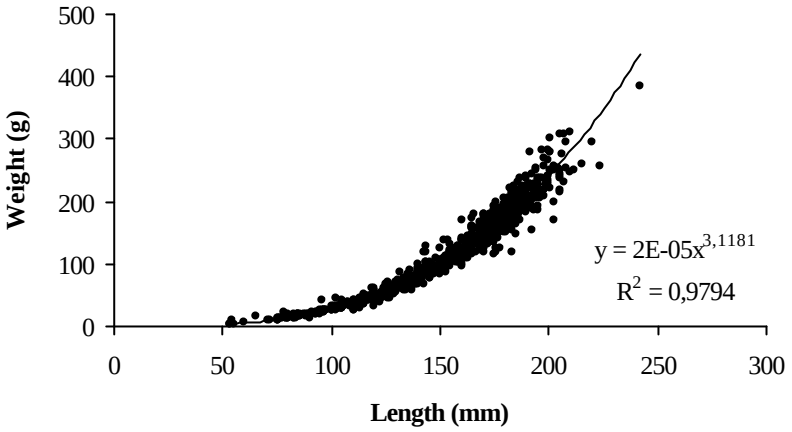


Figure 4-5. Length-weight relationship for *Alticorpus mentale* females in the SWA. (R^2 = determination coefficient).

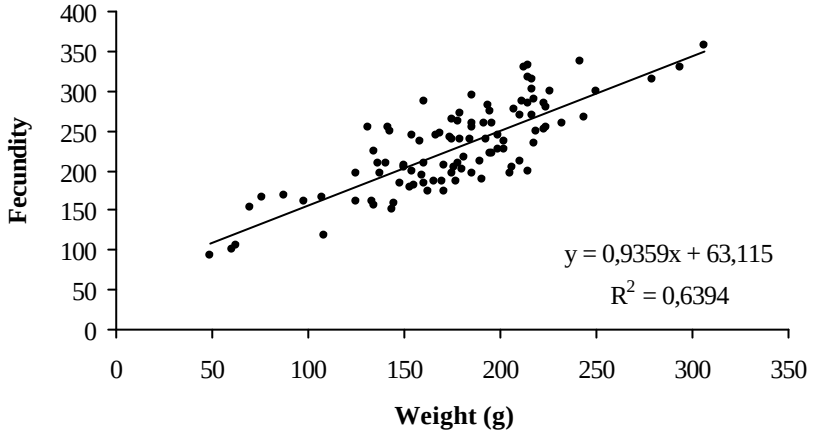


Figure 4-6. Fecundity-weight relationship for *Alticorpus mentale* females in the SWA. (R^2 = determination coefficient).

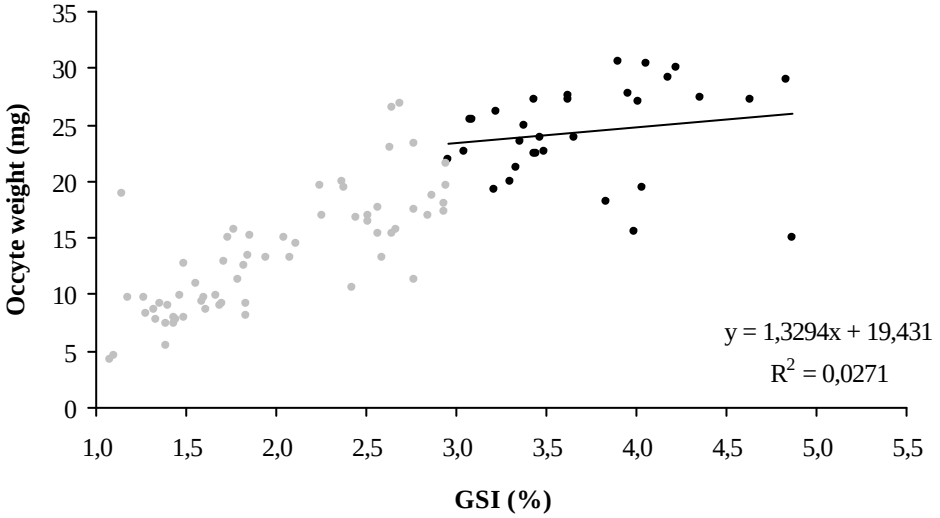


Figure 4-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Alticorpus mentale*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient)

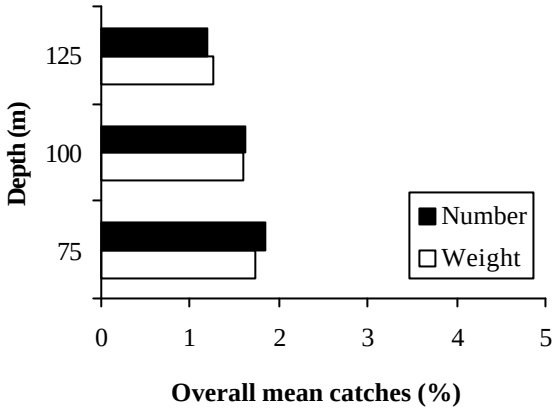


Figure 5-1. Mean occurrence and abundance in the catches per depth of *Alticorpus pectinatum* in the SWA between July 1998 and May 1999.

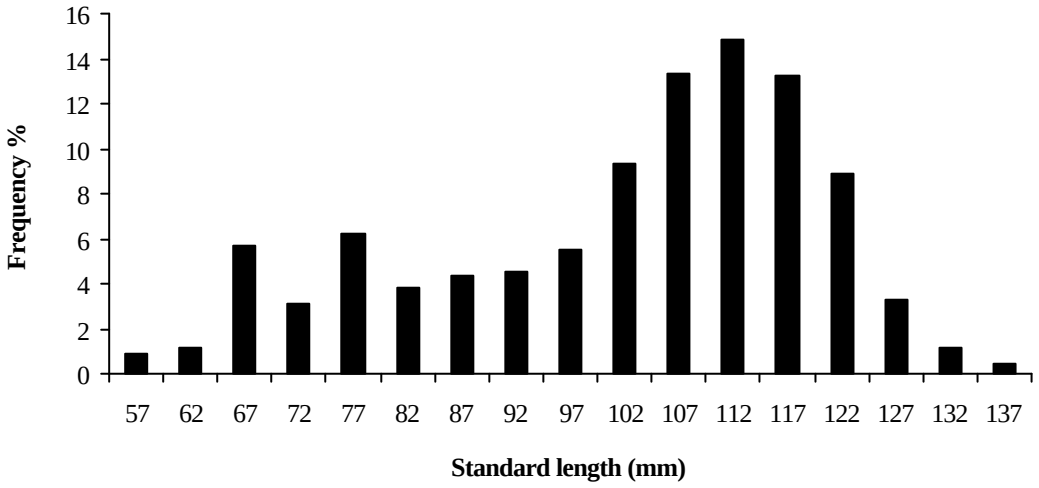


Figure 5-2. Size range and frequencies of *Alticorpus pectinatum* caught in the SWA between July 1998 and May 1999.

Alticorpus pectinatum (Stauffer & McKaye)

259 females and 375 males were analysed. *A. pectinatum* is a deep water fish evenly distributed between 75 m and 125 m (Figure 5-1). It is not an abundant species, always constituting between 1 and 2% of the catches both in weight and number. The mean CPUE per depth category was 8.4 kg in the deep zone and 2.6 kg in the very deep zone, which is about twice as much as the values reported in Tómasson & Banda (1996) for the deep zone (3.8 kg), but about 4 times less in the very deep zone (8.9 kg). As for *A. 'geoffreyi'* and *A. macrocleithrum*, the depth distribution we found was more restricted than that observed by Tómasson & Banda (1996), who found *A. pectinatum* from 45 m downwards. Specimens caught ranged between 55 and 140 mm with a mode from 100 to 125 mm (Figure 5-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

The breeding season occurred from November to May with an increased activity in January-February (Figure 5-3a). The monthly progression of males in breeding colour indicated the same pattern and suggested that breeding season could be protracted, occurring also in June, when all the males (43) were in breeding colour (Figure 5-3b). About three quarter of the breeding females were found at 100 m and the other quarter at 75 m, whereas males in breeding colour and immature individuals were more evenly distributed at 75 and 100 m (Table 5-1). Spawning might occur mostly at 100 m although males and immature distribution does not confirm it firmly. Maturity was reached early in their second year at 12 months old at a mean size of 70 mm for females (Figure 5-4).

Table 5-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Alticorpus pectinatum* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	37.6	24.1	53.3	47	42.3
100 m	40.2	72.4	19.2	30.5	50
125 m	22.3	3.4	27.5	22.5	7.7

The length-weight and fecundity-weight relationships are given in Figure 5-5 and 5-6, respectively. Fecundity ranged from 38 to 181 for females weighing between 7 and 44 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 4% (Figure 5-7) and the mean oocyte weight was 15.29 mg (± 2.8 SD, N= 3).

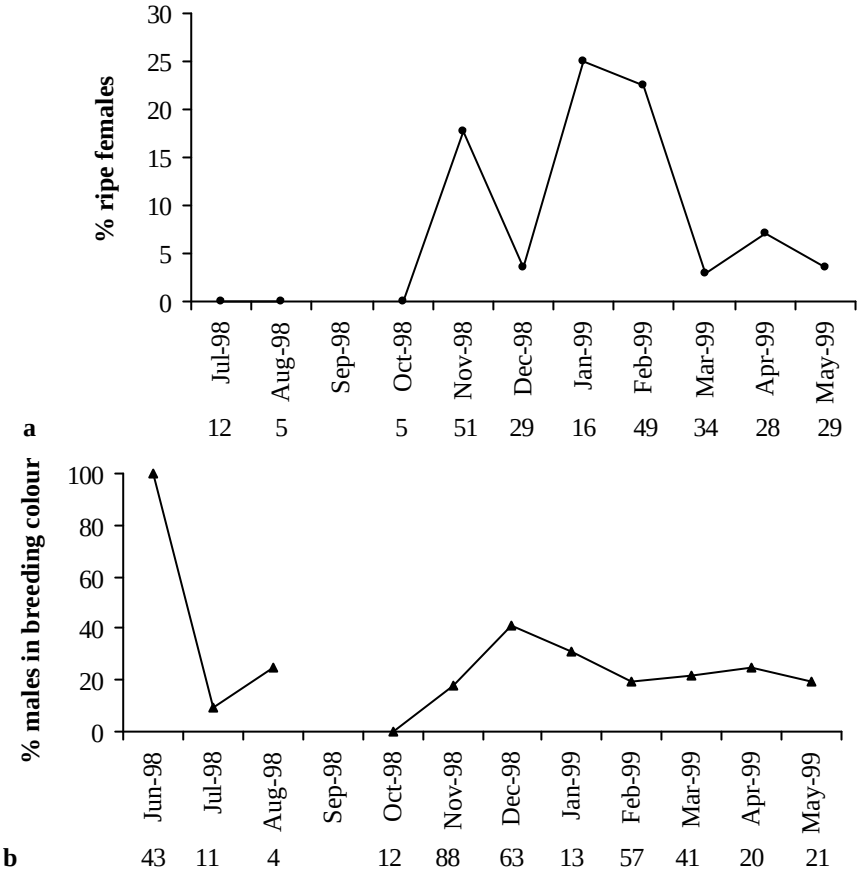


Figure 5-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Alticorpus pectinatum* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

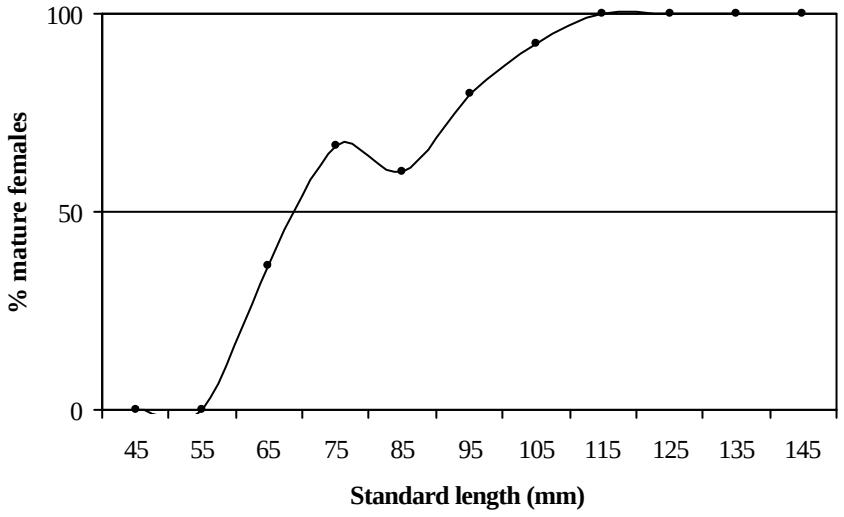


Figure 5-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Alticorpus pectinatum* in the SWA.

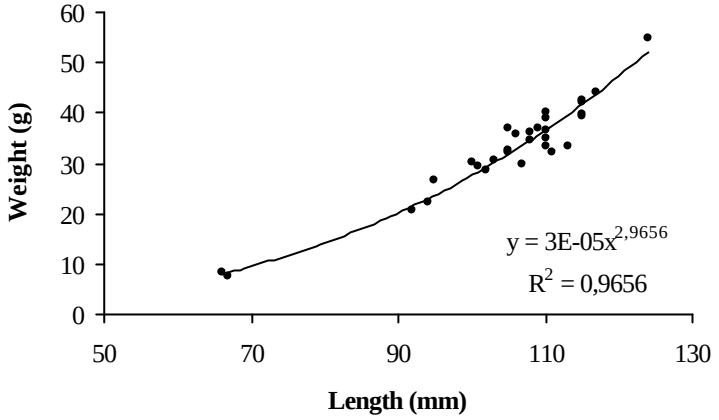


Figure 5-5. Length-weight relationship for *Alticorpus pectinatum* females in the SWA. (R^2 = determination coefficient).

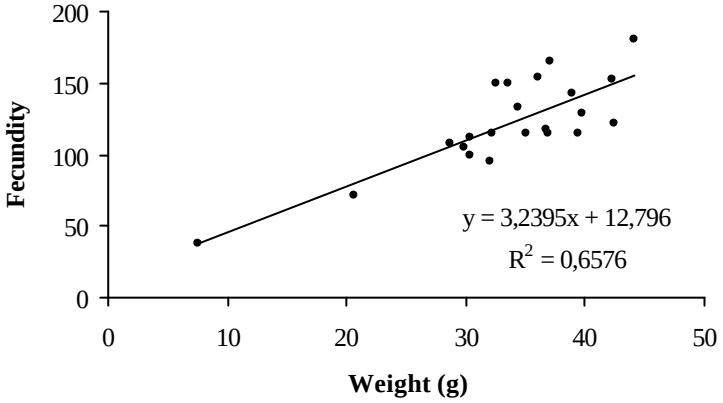


Figure 5-6. Fecundity-weight relationship for *Alticorpus pectinatum* females in the SWA. (R^2 = determination coefficient).

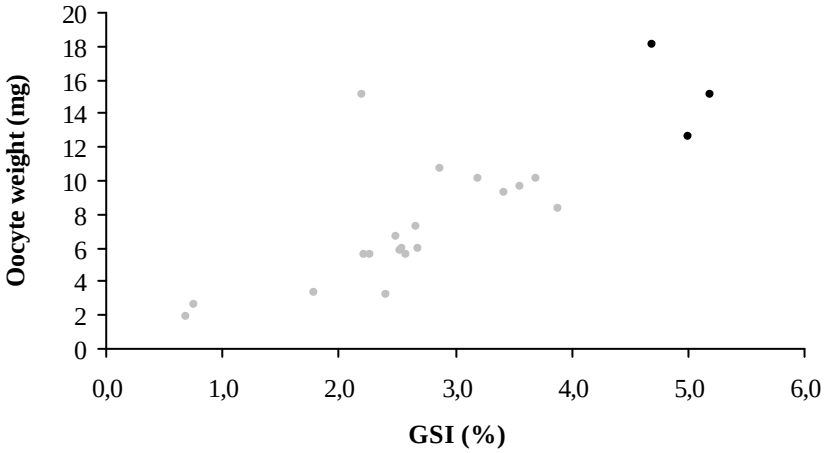


Figure 5-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Alticorpus pectinatum*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 4%. (R^2 = determination coefficient)

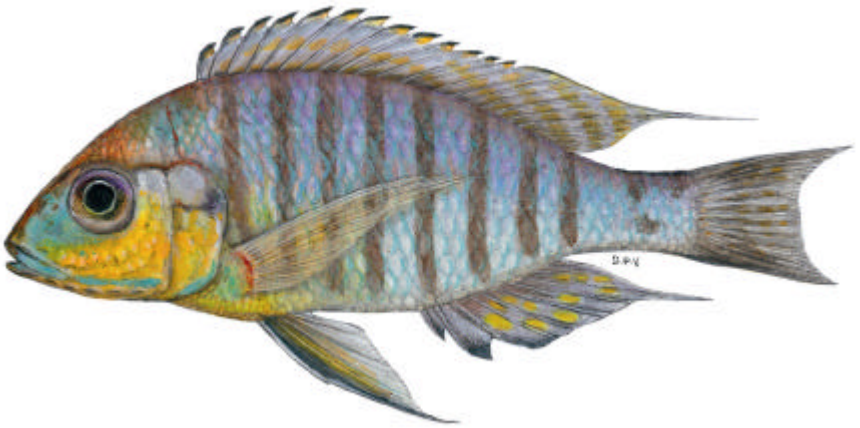


Plate 4. *Aulonocara 'blue orange'* (by Dave Voorvelt).

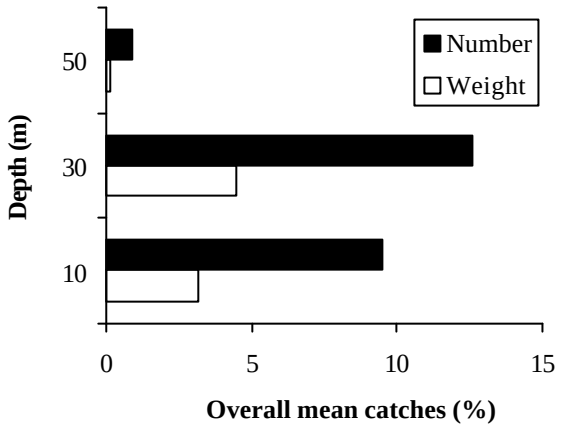


Figure 6-1. Mean occurrence and abundance in the catches per depth of *Aulonocara 'blue orange'* in the SWA between July 1998 and May 1999.

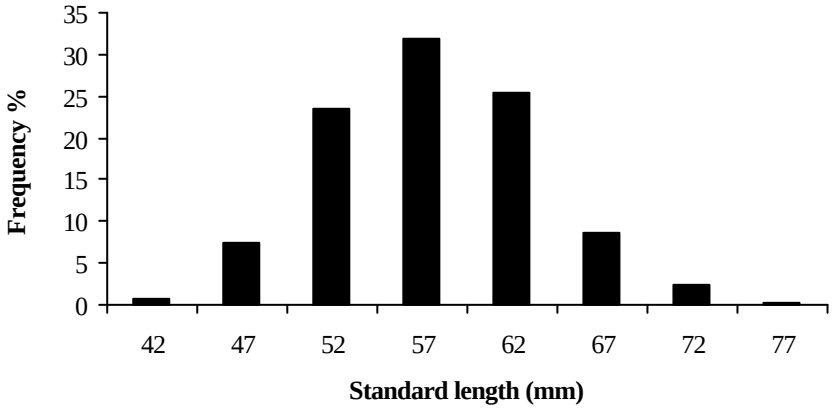


Figure 6-2. Size range and frequencies of *Aulonocara 'blue orange'* caught in the SWA between July 1998 and May 1999.

Aulonocara spp.

Aulonocara 'blue orange' **(Plate 4)**

244 females and 485 males were analysed. *A. 'blue orange'* is a small fish encountered in shallow water between 10 and 50 m but only abundant at 10 and 30 m, where it constituted 9.5 and 12.6% of the catches in number, respectively and 3.2 and 4.5% in weight (Figure 6-1). It was found only once at 75 m in November 98. The mean CPUE per depth category was higher (17.6 kg in the shallow zone) than that reported in Tómasson & Banda (1996). The depth distribution was much more restricted in our case than the 10 to 130 m depth range they reported. Specimens caught ranged between 40 and 80 mm with a mode from 50 to 65 mm (Figure 6-2). The sex ratio observed over the full sampling period was F/M 0.3/0.7.

Owing to identification uncertainty, data from June and July 1998 were not included in the analyses. The breeding season seemed to occur between July-August and February (Figure 6-3a and b). However, due to the very low sample size in March and April and the high percentage of males in breeding colour in April and May, it can't be excluded that *A. 'blue orange*' might breed throughout the year. More than three quarter of the ripe females were sampled at 10 m and the other quarter at 30 m (Table 6-1). Males in breeding colour were evenly distributed between 10 and 30 m and most of the immature individuals were found at 30 m. If *A. 'blue orange*' does spawn at a precise depth, it does not reflect clearly in breeding males and immature distribution. However, the results suggest that spawning would occur around 10 m. Maturity was reached in their first year at 9 months old at a mean size of 48 mm for females (Figure 6-4).

Table 6-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Aulonocara 'blue orange'* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	47.3	76	60.9	45.5	34.2
30 m	47.9	24	36.6	48.5	61.8
50 m	4.8	0	2.6	6.1	3.9

The length-weight and fecundity-weight relationships are given in Figure 6-5 and 6-6, respectively. Fecundity ranged from 9 to 41 for females weighing between 2 and 7g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 2.5% (Figure 6-7) and the mean oocyte weight was 4.46 mg (± 0.89 SD, N= 16).

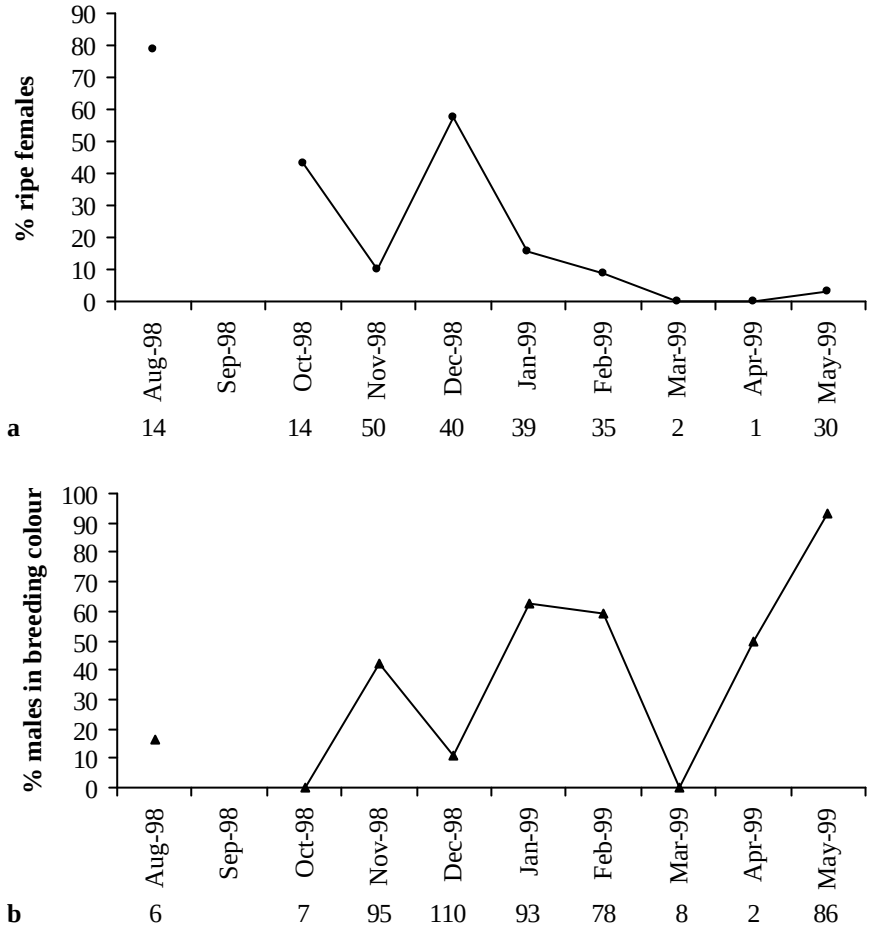


Figure 6-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Aulonocara 'blue orange'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

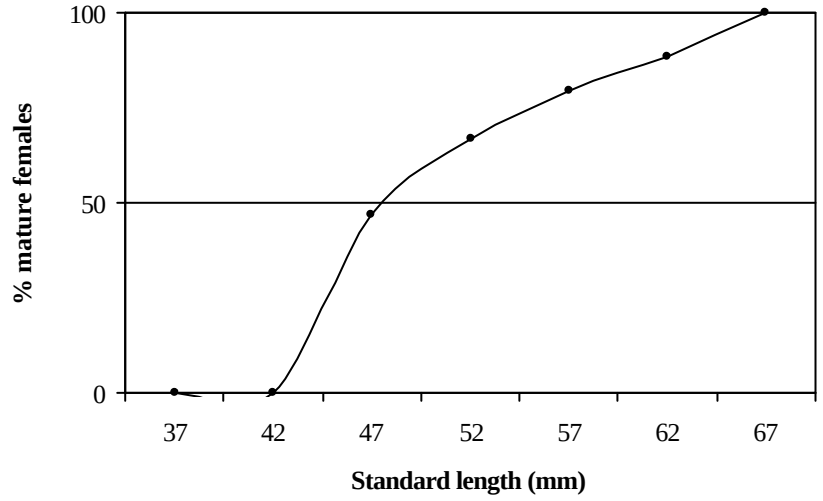


Figure 6-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Aulonocara 'blue orange'* in the SWA.

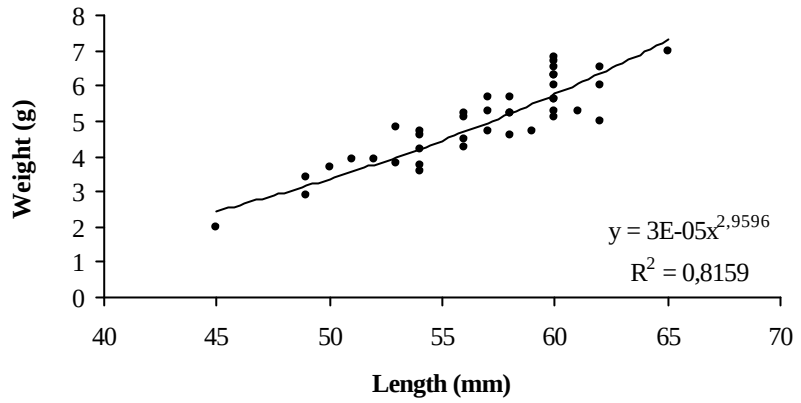


Figure 6-5. Length-weight relationship for *Aulonocara 'blue orange'* females in the SWA. (R^2 = determination coefficient).

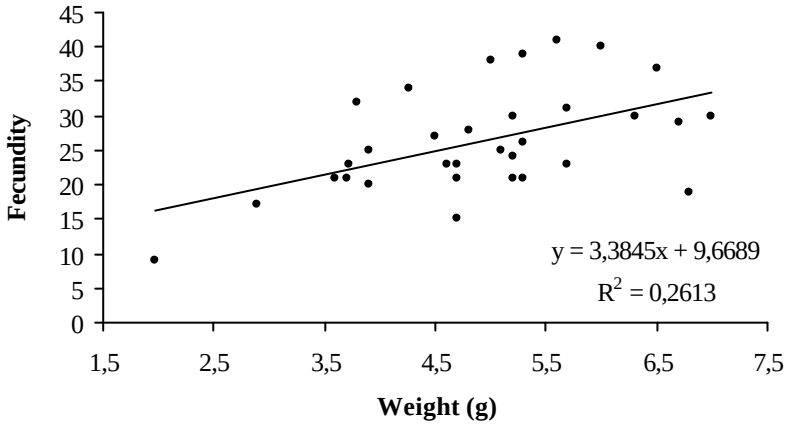


Figure 6-6. Fecundity-weight relationship for *Aulonocara 'blue orange'* females in the SWA. (R^2 = determination coefficient).

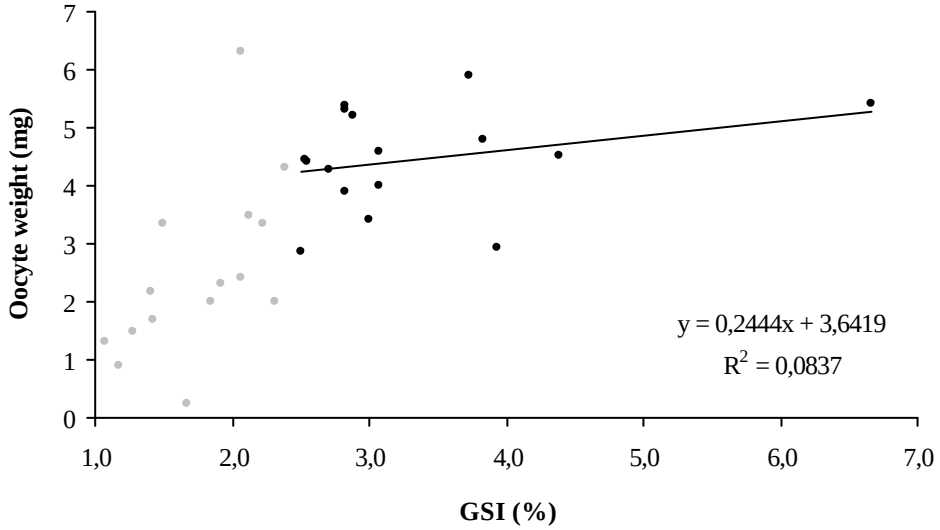


Figure 6-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Aulonocara 'blue orange'*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 2.5%. (R^2 = determination coefficient).

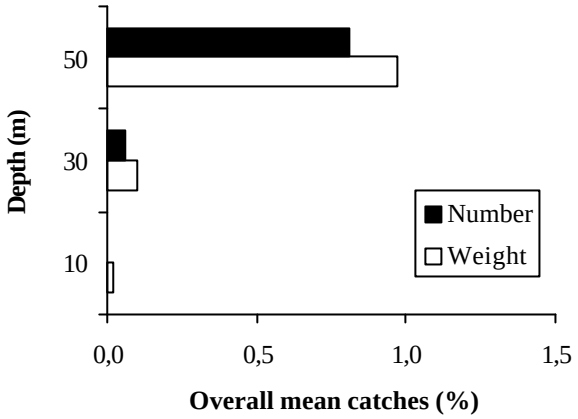


Figure 7-1. Mean occurrence and abundance in the catches per depth of *Aulonocara 'cf. macrochir'* in the SWA between July 1998 and May 1999.

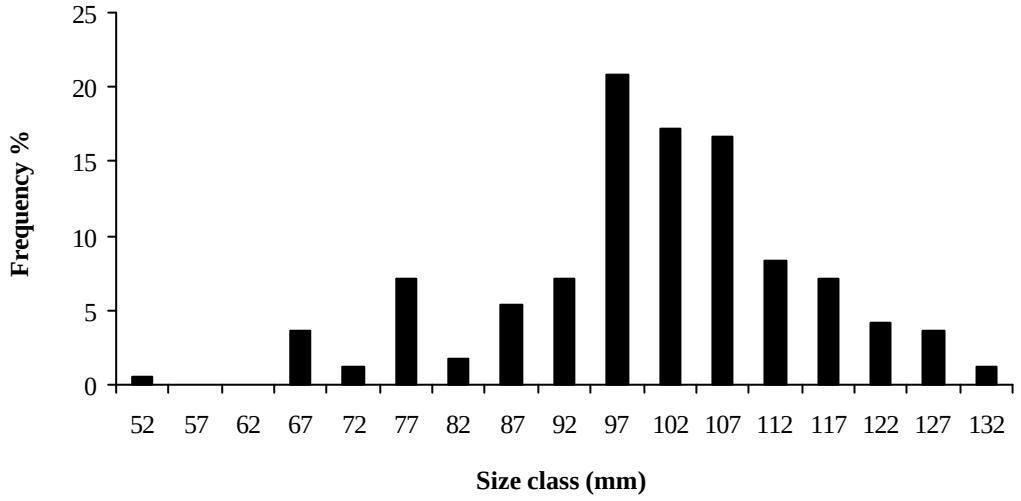


Figure 7-2. Size range and frequencies of *Aulonocara 'cf. macrochir'* caught in the SWA between July 1998 and May 1999.

Aulonocara 'cf. macrochir'

74 females and 90 males were analysed. *A. 'cf. macrochir'* was a relatively rare fish encountered from 10 m to 50 m but more abundant at 50 m where it constituted 1% and 0.8% of the catches in weight and number, respectively (Figure 7-1). The mean CPUE per depth category (2.7 kg in the shallow zone) matched that reported in Tómasson & Banda (1996). The depth distribution was much more restricted in our case than the 8 to 150 m depth range that they reported. Specimens caught ranged between 50 and 135 mm with a mode from 95 to 110 mm (Figure 7-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

As *A. 'cf. macrochir'* is a relatively rare species, the following information about life history traits is based on low sample size and can not be considered as very reliable but rather as indicative. A breeding activity was observed from August to October and from December to March (Figure 7-3a and b). Taking into account the sparse information available about both females and males, it can be hypothesised that this species might breed most of the year, with reduced activity in June and July. As most specimens were caught at 50 m the percentages of ripe females (62.5%), males in breeding colour (100%) and immature individuals (87%) at this depth suggested that spawning probably occurs at 50 m. Maturity was reached at about 100 mm for females (Figure 7-4). Again, owing to low sample size, L_{50} was probably overestimated and is likely to be closer to 90 mm.

The length-weight and fecundity-weight relationships are given in Figure 7-5 and 7-6, respectively. Fecundity ranged from 50 to 134 for females weighing between 16 and 60 g. No relationship was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was impossible to assess due to the low sample size. However, as no relationship was found between oocyte weight and GSI from the data available (Figure 7-7), the mean oocyte weight was estimated from all the available data and was 4.82 mg (± 1.13 SD, N= 8).

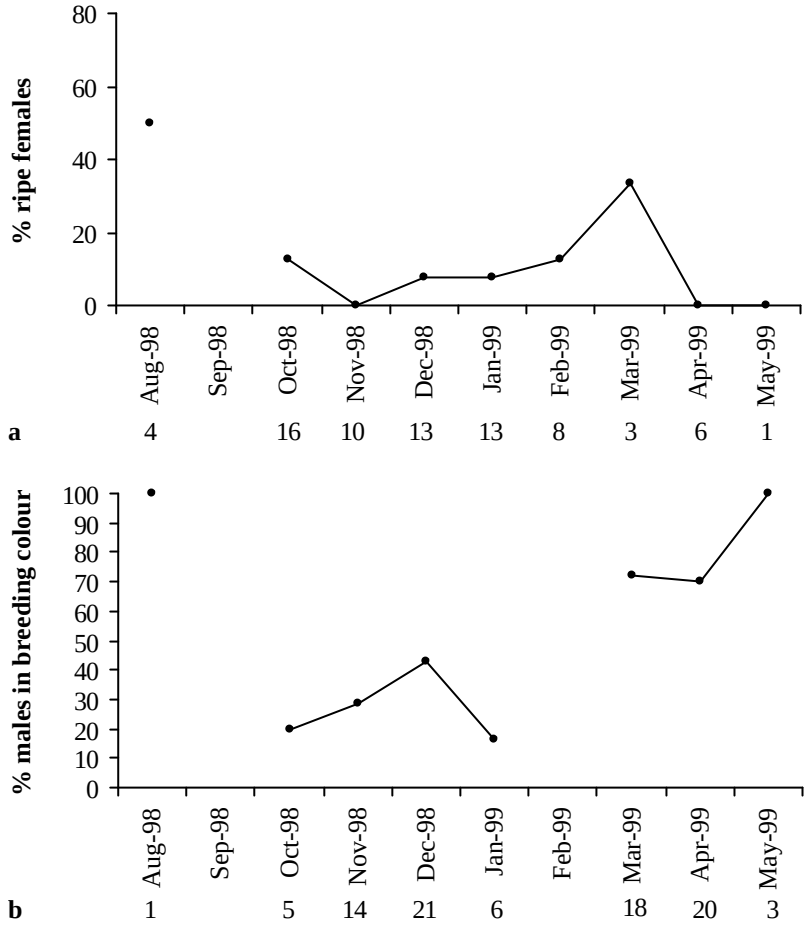


Figure 7-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Aulonocara 'cf. macrochir'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

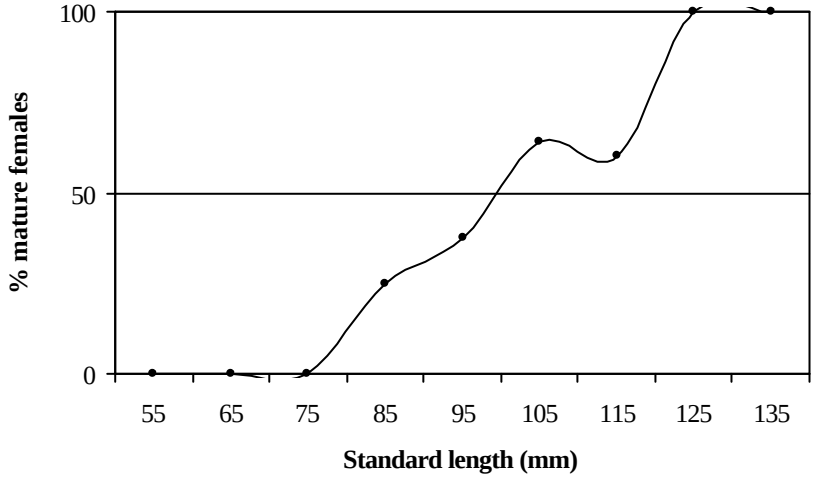


Figure 7-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Aulonocara 'cf. macrochir'* in the SWA.

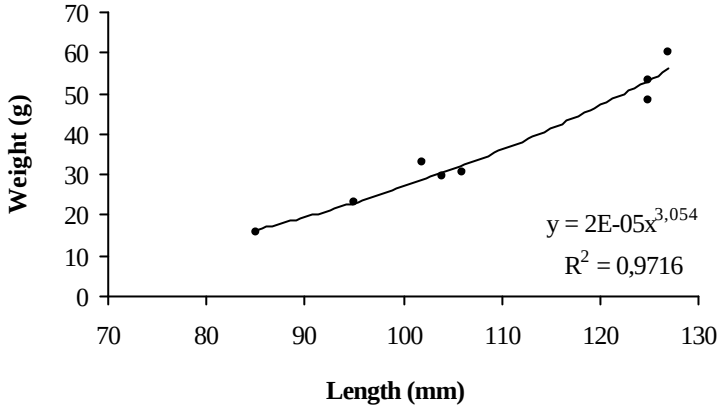


Figure 7-5. Length-weight relationship for *Aulonocara 'cf. macrochir'* females in the SWA. (R^2 = determination coefficient).

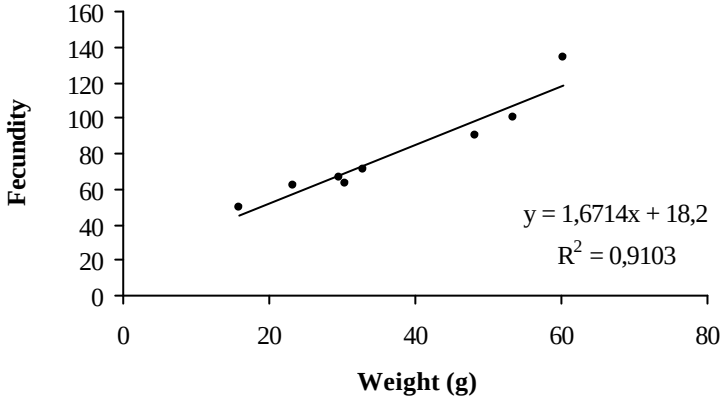


Figure 7-6. Fecundity-weight relationship for *Aulonocara 'cf. macrochir'* females in the SWA. (R^2 = determination coefficient).

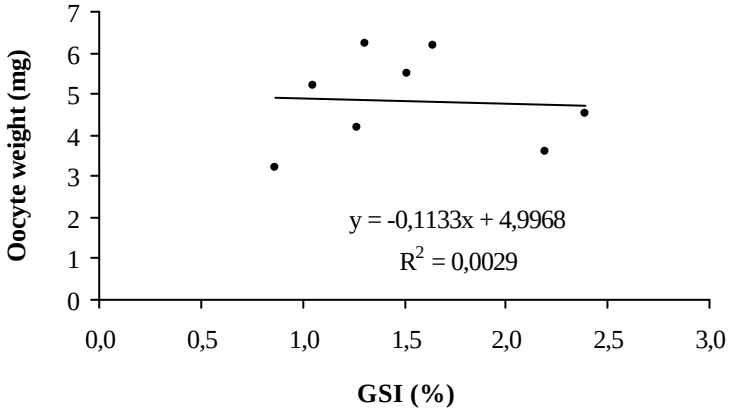


Figure 7-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Aulonocara 'cf. macrochir'*. (R^2 = determination coefficient).

Plate 5. *Aulonocara 'minutus'* (by Dave Voorvelt).

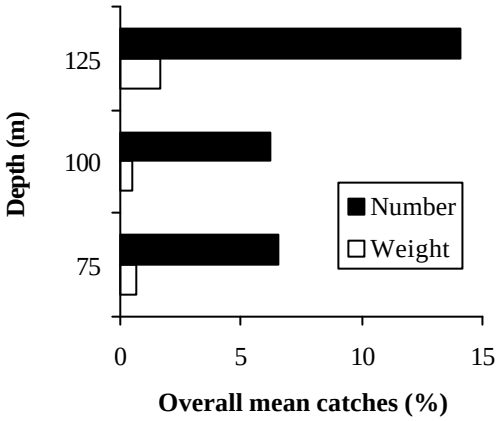


Figure 8-1. Mean occurrence and abundance in the catches per depth of *Aulonocara 'minutus'* in the SWA between July 1998 and May 1999.

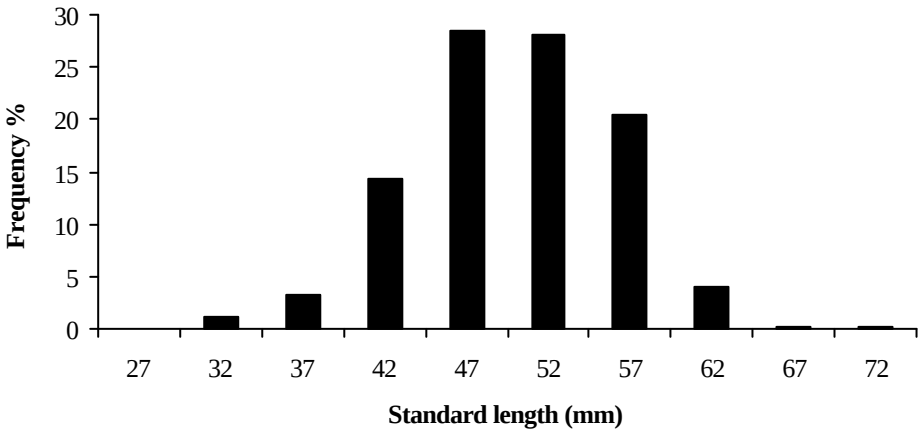


Figure 8-2. Size range and frequencies of *Aulonocara 'minutus'* caught in the SWA between July 1998 and May 1999.

Aulonocara 'minutus' **(Plate 5)**

573 females and 781 males were analysed. *A. 'minutus'* is a deep water fish caught from 75 to 125 m depth (Figure 8-1). It was much more abundant at 125 m, where it constituted up to 14% of the catches in number and only 1.7% in weight owing to its very small size. *A. 'minutus'* is one of the smallest demersal species of Lake Malawi. Specimens collected ranged between 25 and 75 mm with a mode from 40 to 60 mm (Figure 8-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6. The mean CPUE per depth category was 3.5 kg in the deep zone and 2.6 kg in the very deep zone, which is about two times less than the values reported in Tómasson & Banda (1996) for the deep zone (7.3 kg), and about 4 times less in the very deep zone (11.3 kg). As for *A. 'cf. macrochir'* and *A. 'blue orange'*, the depth distribution we found was much more restricted than that observed by Tómasson & Banda (1996), who found *A. 'minutus'* from 10 to 130 m.

Unlike *A. 'cf. macrochir'* and *A. 'blue orange'*, *A. 'minutus'* was found to breed throughout the year with an increased activity in June and February (Figure 8-3a and b). About 50% of non breeding females and males as well as immature individuals were found at 125 m, the other half being evenly distributed between 75 and 100m (Table 8-1). On the other hand, about 50% of the ripe females and males in breeding colour were caught at 100 m, whereas the other half were evenly distributed at 75 and 125. This suggested that spawning might occur at 100 m. Maturity was reached in their first year at 7 months at a mean size of 42 mm for females (Figure 8-4).

Table 8-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Aulonocara 'minutus'* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	24.2	18.7	15.7	20.9	18.1
100 m	27.7	53.8	28.6	48.1	32.2
125 m	48.1	27.5	55.7	31	49.7

The length-weight and fecundity-weight relationships are given in Figure 8-5 and 8-6, respectively. Fecundity ranged from 50 to 134 for females weighing between 16 and 60 g and was not significantly correlated to female body weight ($r = 0.26$). No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 2% (Figure 8-7) and the mean oocyte weight was 3.82 mg (± 1.13 SD, N= 29).

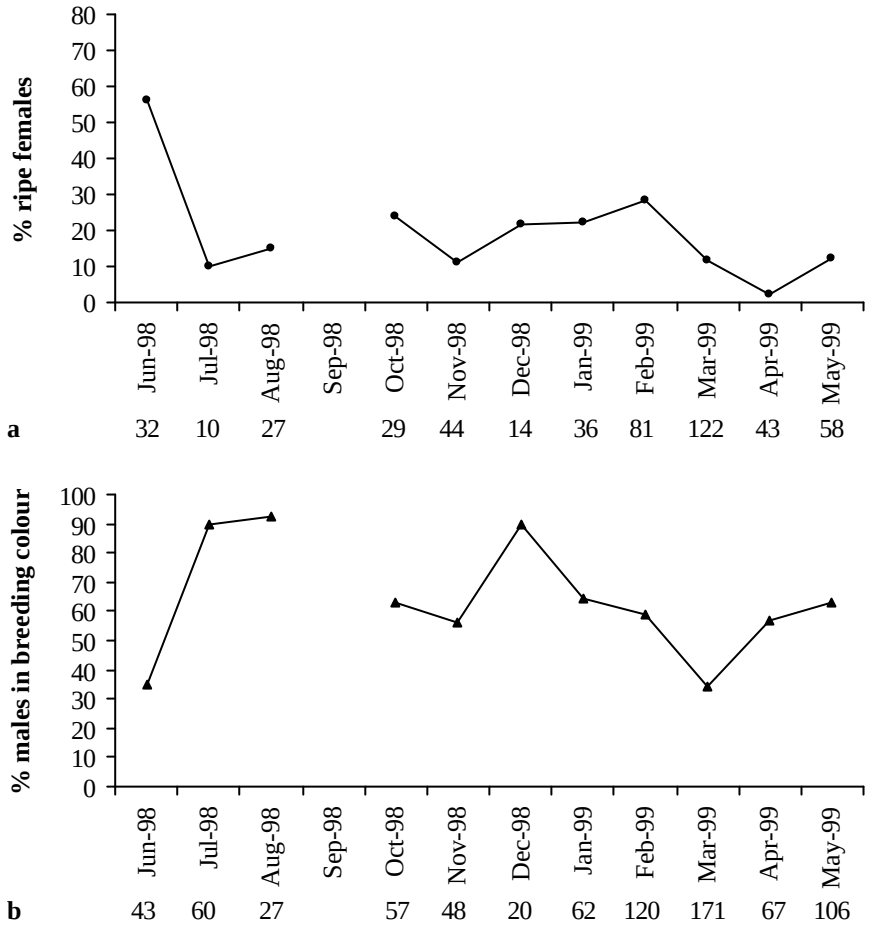


Figure 8-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Aulonocara 'minutus'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

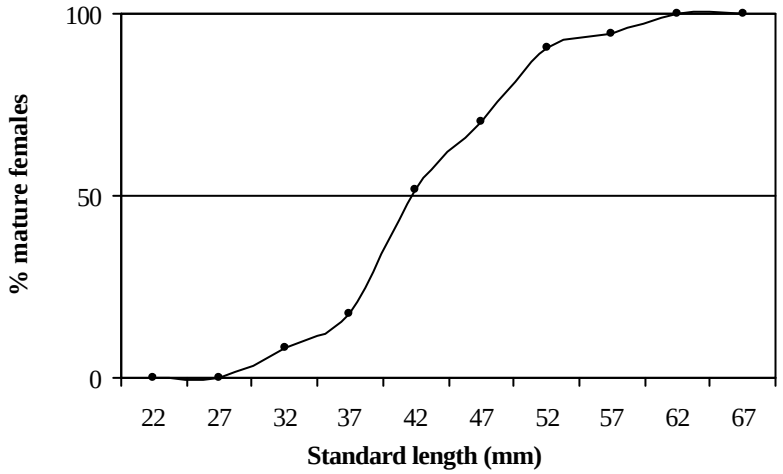


Figure 8-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Aulonocara 'minutus'* in the SWA.

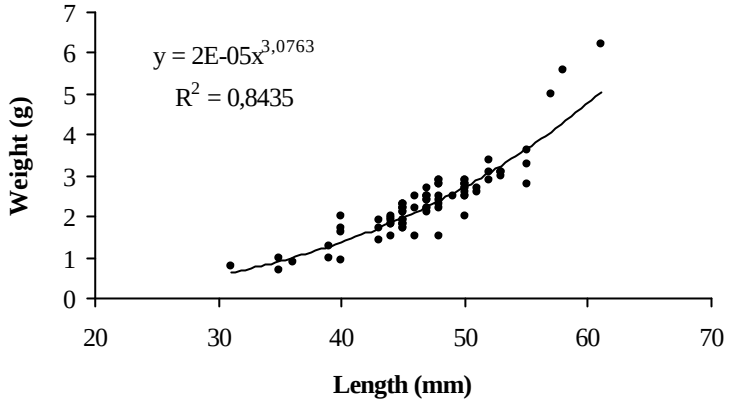


Figure 8-5. Length-weight relationship for *Aulonocara 'minutus'* females in the SWA. (R^2 = determination coefficient).

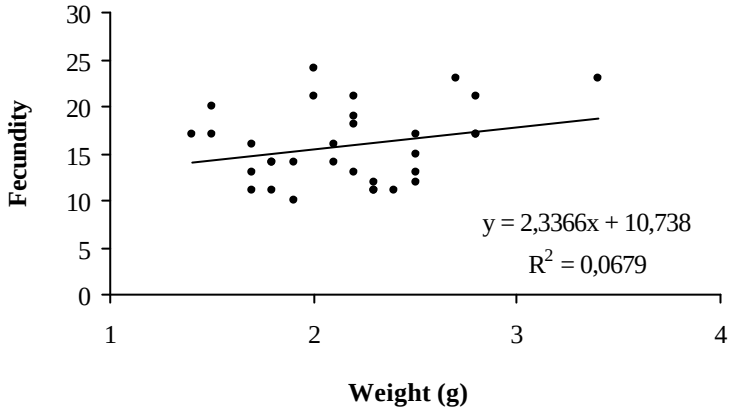


Figure 8-6. Fecundity-weight relationship for *Aulonocara 'minutus'* females in the SWA. (R^2 = determination coefficient).

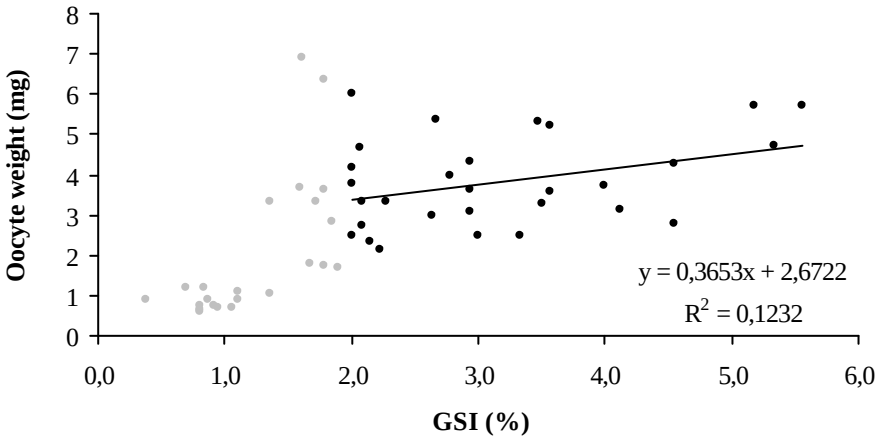


Figure 8-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Aulonocara 'minutus'*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 2%. (R^2 = determination coefficient).

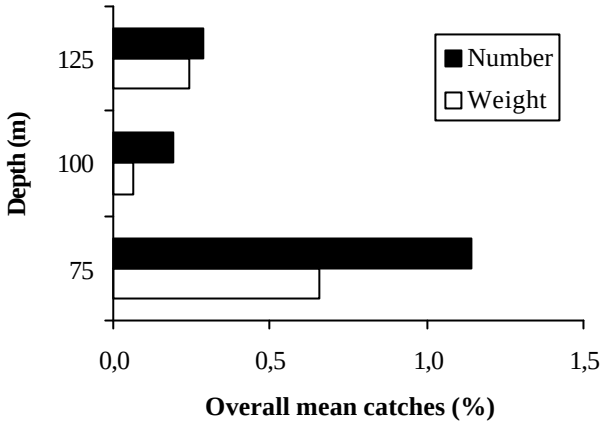


Figure 9-1. Mean occurrence and abundance in the catches per depth of *Aulonocara 'rostratum deep'* in the SWA between July 1998 and May 1999.

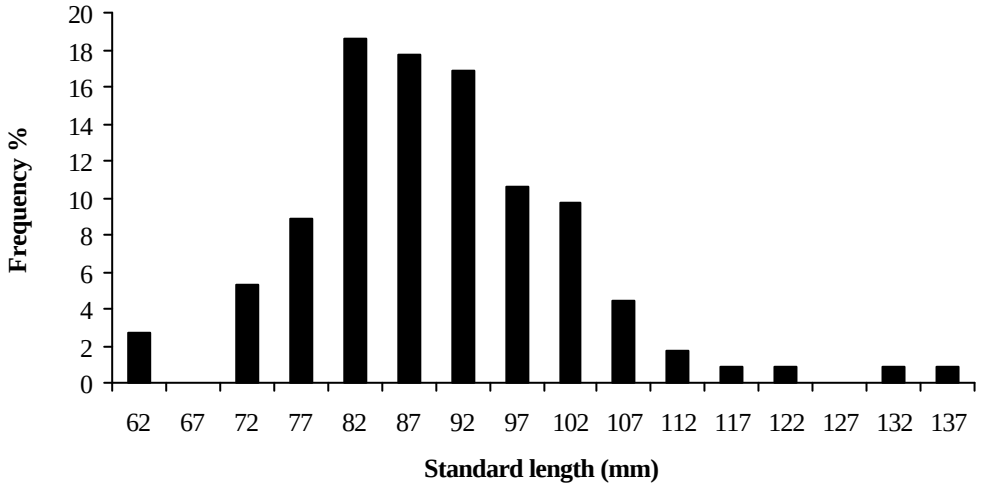


Figure 9-2. Size range and frequencies of *Aulonocara 'rostratum deep'* caught in the SWA between July 1998 and May 1999.

Aulonocara 'rostratum deep'

56 females and 57 males were analysed. *A. 'rostratum deep'* is a relatively rare fish found from 75 to 125 m depth but more frequent at 125 m (Figure 9-1). The mean CPUE per depth category was 1.7 kg in the deep zone and 0.5 kg in the very deep zone, which is about ten times less than the values reported in Tómasson & Banda (1996) for the deep zone (5.1 kg), and more than twenty times less in the very deep zone (13.2 kg). As for *A. 'cf. macrochir'* and *A. 'blue orange'* and A. *'minutus'*, the depth distribution we found was much more restricted than that observed by Tómasson & Banda (1996), who found *A. 'rostratum deep'* from 30 to 130 m. Specimens caught ranged between 60 and 140 mm with a mode from 80 to 105 mm (Figure 9-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

As *A. 'rostratum deep'* is a rare species, the following information about life history traits is based on low sample size and can not be considered as very reliable but rather as indicative. A breeding activity was observed in October, March and May (Figure 9-3a and b). From the few data available, ripe females and males in breeding colour were evenly distributed among depths. Maturity was reached at about 75 mm (Figure 9-4).

The length-weight and fecundity-weight relationships are given in Figure 9-5 and 9-6, respectively. Fecundity ranged from 41 to 167 for females weighing between 14 and 69 g. The mean oocyte weight was impossible to assess from the few data available on this species.

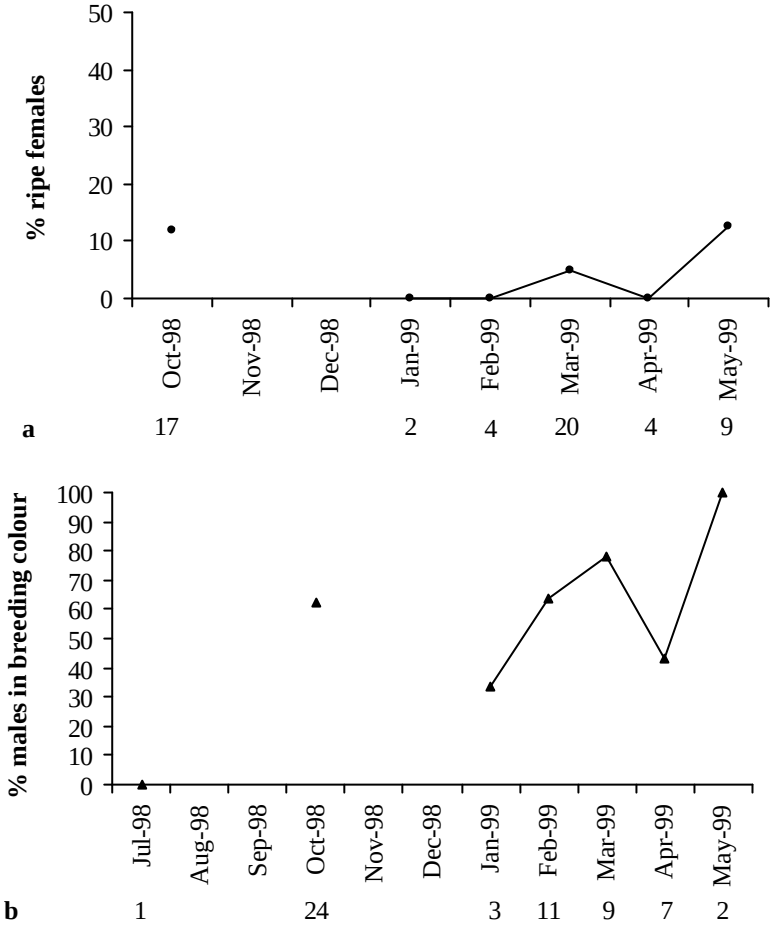


Figure 9-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Aulonocara 'rostratum deep'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

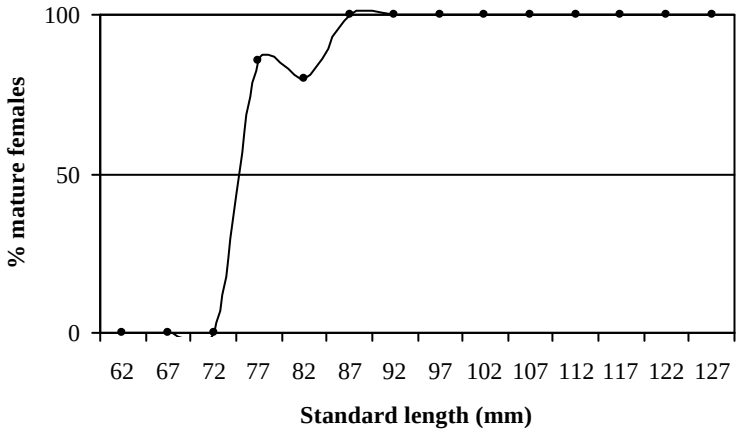


Figure 9-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Aulonocara 'rostratum deep'* in the SWA.

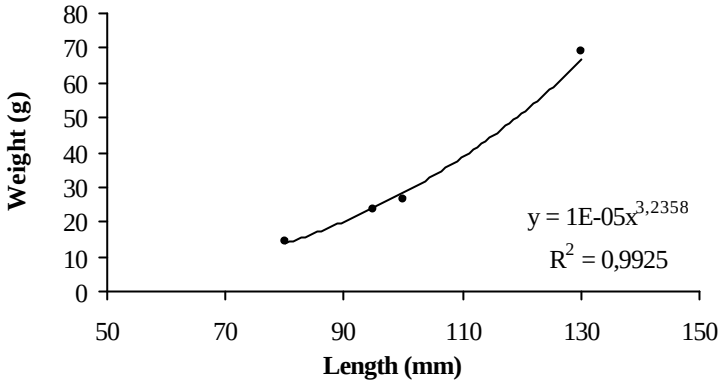


Figure 9-5. Length-weight relationship for *Aulonocara 'rostratum deep'* females in the SWA. (R^2 = determination coefficient).

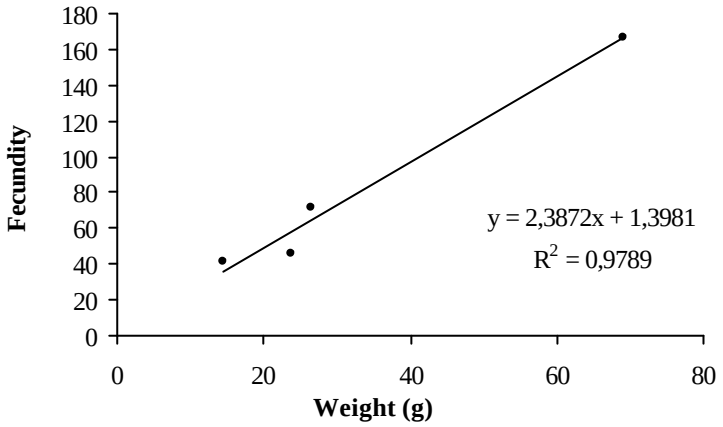


Figure 9-6. Fecundity-weight relationship for *Aulonocara 'rostratum deep'* females in the SWA. (R^2 = determination coefficient).

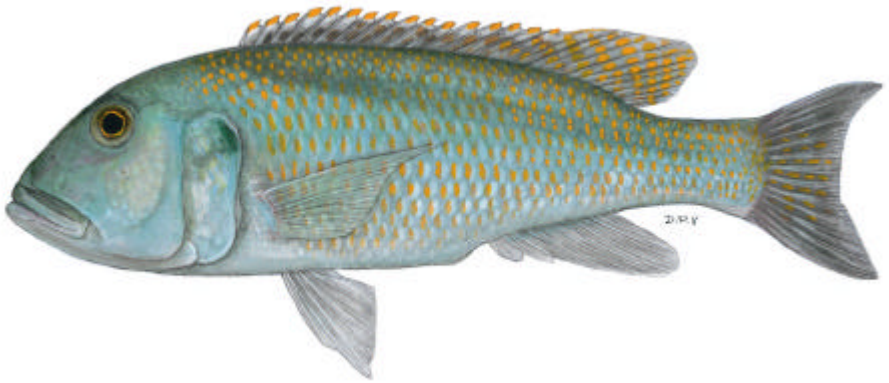


Plate 6. *Buccochromis lepturus* (by Dave Voorvelt).

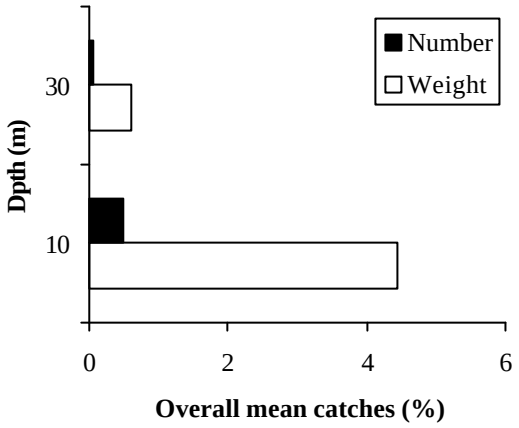


Figure 10-1. Mean occurrence and abundance in the catches per depth of *Buccochromis lepturus* in the SWA between July 1998 and May 1999.

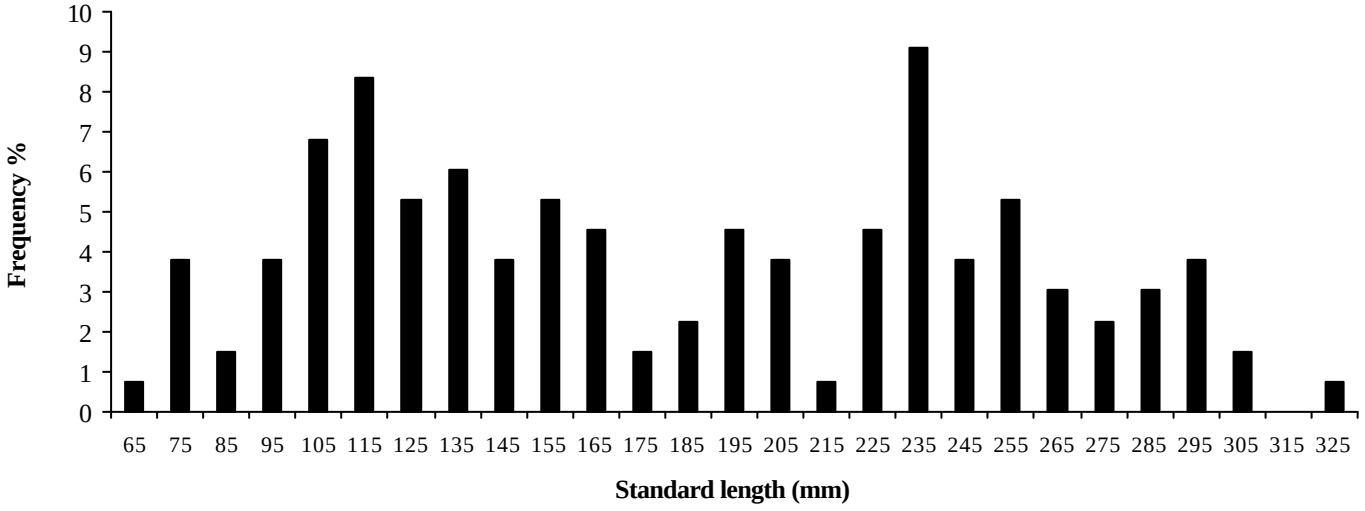


Figure 10-2. Size range and frequencies of *Buccochromis lepturus* caught in the SWA between July 1998 and May 1999.

Buccochromis spp.

***Buccochromis lepturus* (Regan) (Plate 6)**

74 females and 58 males were analysed. *B. lepturus* is a large shallow water fish essentially encountered at 10 m, where it constituted 4.5% of the catches in weight but only 0.5% in number owing to its large size (Figure 10-1). It was also found sometimes at 30 m. The mean CPUE per depth category was 6.5 kg in the shallow zone, which approximately matched the values reported in Tómasson & Banda (1996) (7.4 kg). The depth distribution observed in our study was more restricted than that of Tómasson & Banda (1996), who found *B. lepturus* down to 50m. Specimens caught ranged between 60 and 330 mm (Figure 10-2). The sex ratio observed over the full sampling period was F/M 0.6/0.4.

B. lepturus being an abundant species, the number of specimen caught at each sampling session was very low, which severely hampered the precise determination of breeding season and other life history traits. From the few data available, it seems that breeding season might occur between March-April and August (Figure 10-3a and b). The few ripe females or males in breeding colour were mostly found at 10 m, suggesting a rather shallow spawning. Maturity was reached at about 160 mm for females (Figure 10-4).

The length-weight and fecundity-weight relationships are given in Figure 10-5 and 10-6, respectively. Fecundity ranged from 267 to 627 for females weighing between 294 and 588 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was difficult to assess due to low sample size but was tentatively fixed at about 2% (Figure 10-7). The mean oocyte weight was 19.99 mg (± 1.88 SD, N= 4).

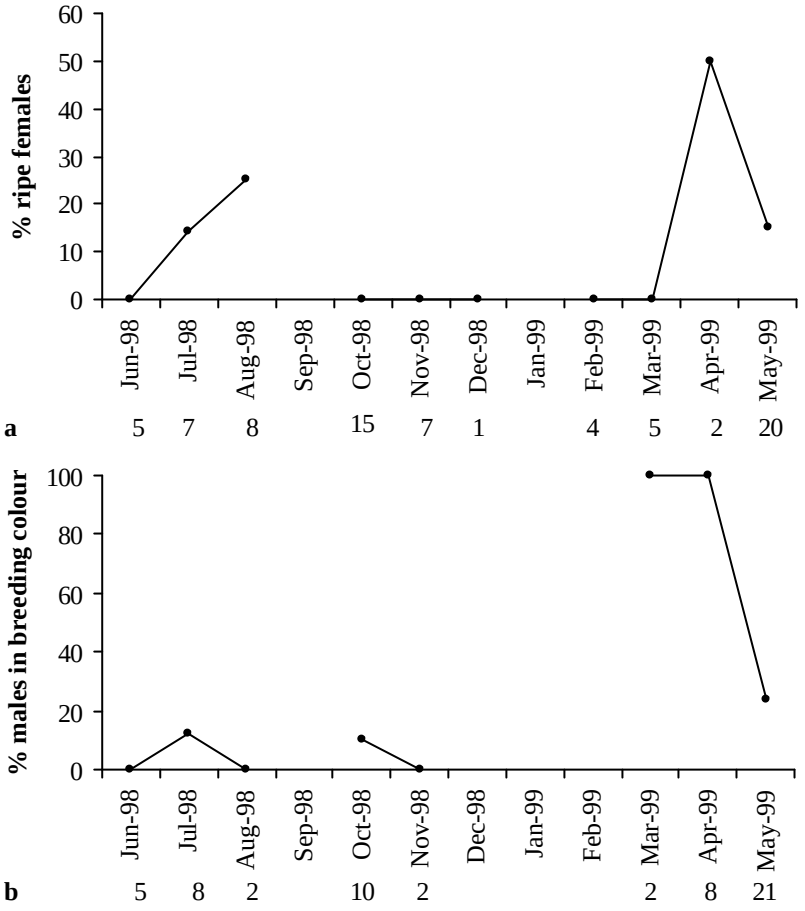


Figure 10-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Buccochromis lepturus* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

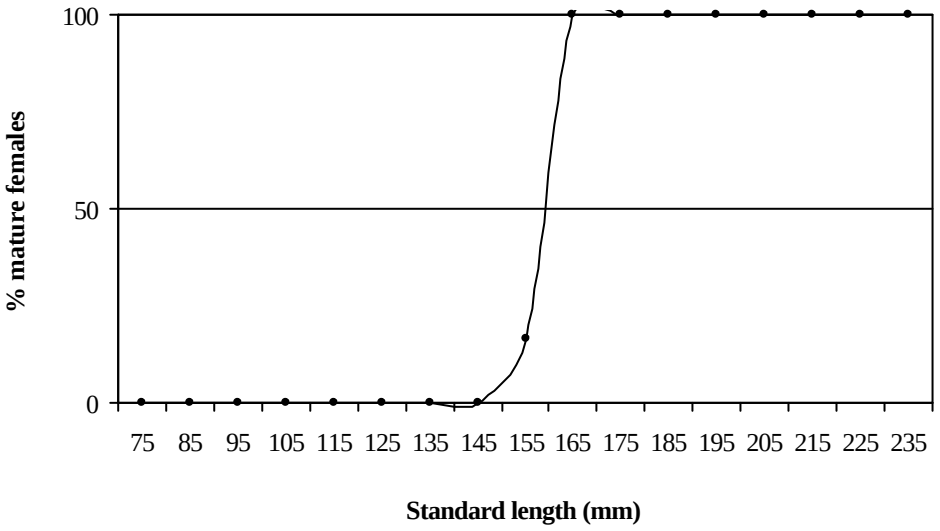


Figure 10-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Buccochromis lepturus* in the SWA.

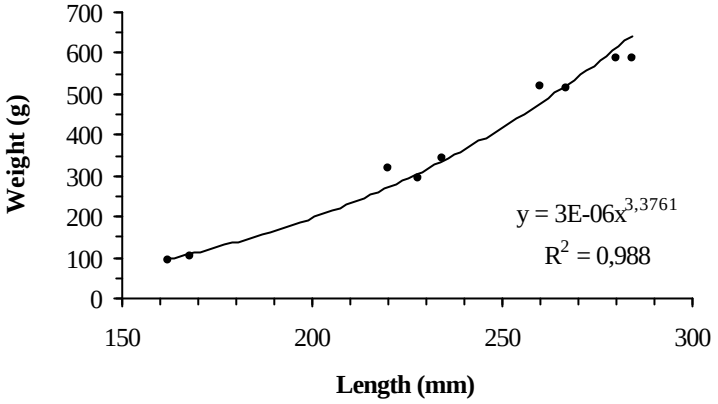


Figure 10-5. Length-weight relationship for *Buccochromis lepturus* females in the SWA. (R^2 = determination coefficient).

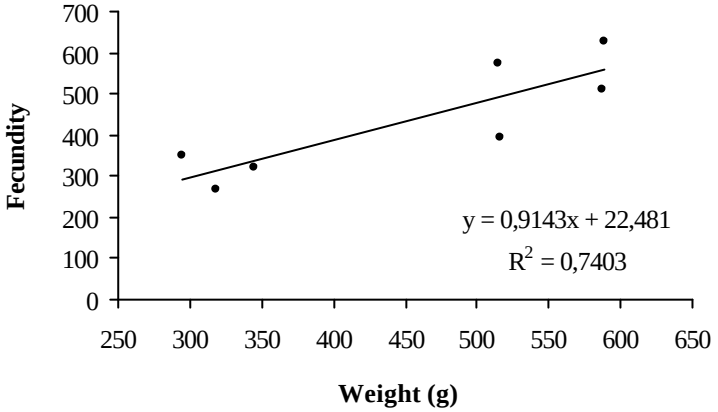


Figure 10-6. Fecundity-weight relationship for *Buccochromis lepturus* females in the SWA. (R^2 = determination coefficient).

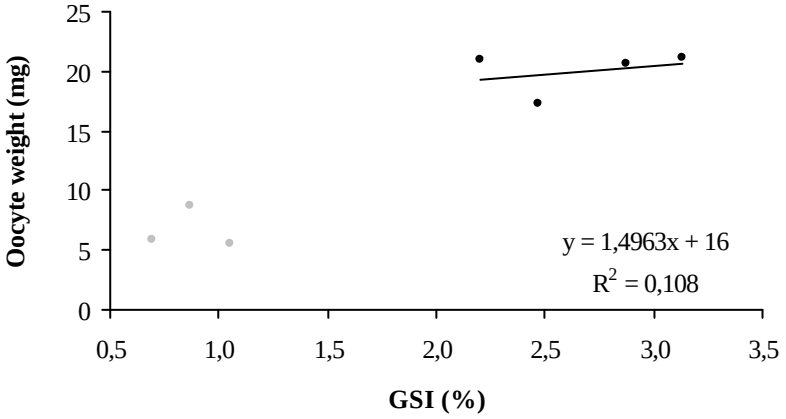


Figure 10-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Buccochromis lepturus*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 2%. (R^2 = determination coefficient).

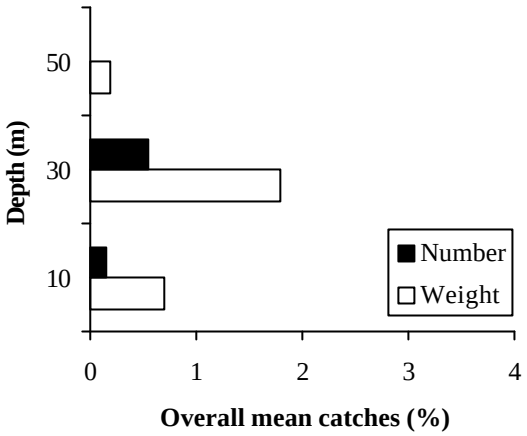


Figure 11-1. Mean occurrence and abundance in the catches per depth of *Buccochromis nototaenia* in the SWA between July 1998 and May 1999.

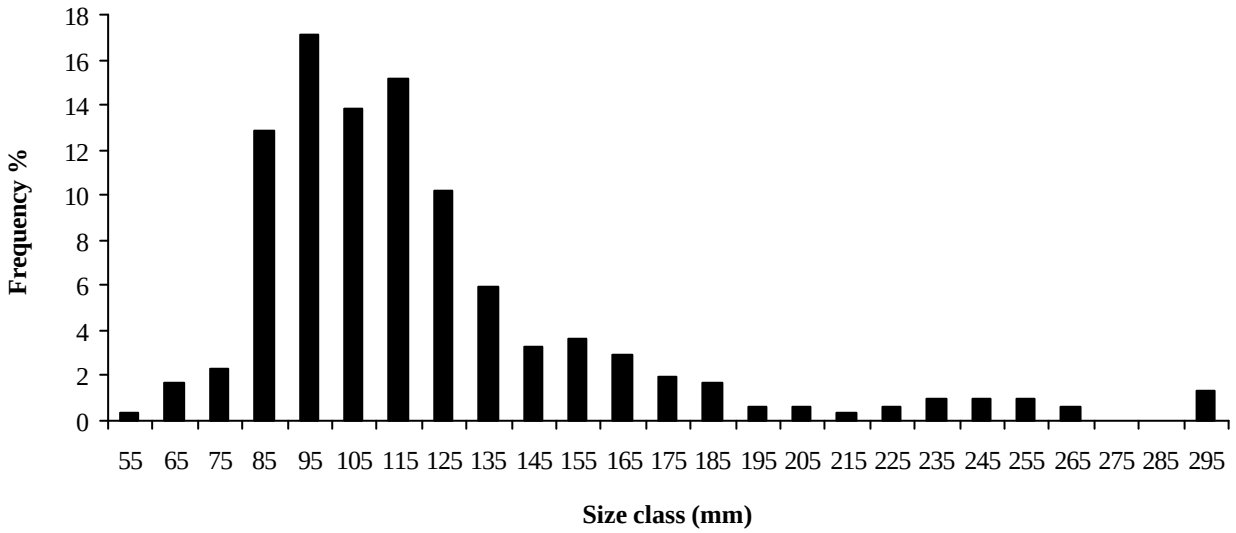


Figure 11-2. Size range and frequencies of *Buccochromis nototaenia* caught in the SWA between July 1998 and May 1999.

Buccochromis nototaenia (Boulenger)

122 females and 182 males were analysed. *B. nototaenia* is a large shallow water fish found between 10 and 50 m (Figure 11-1). It was more frequently encountered at 30 m, where it constituted about 2% of the catches in weight and 0.5% in number. The mean CPUE per depth category was 5.1 kg in the shallow zone, which was a bit more than the value reported in Tómasson & Banda (1996) (3.9 kg). The depth distribution observed in our study matched that of Tómasson & Banda (1996). Specimens caught ranged between 50 and 300 mm (Figure 11-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

As for *B. lepturus*, the low sample size hampered the precise determination of breeding season and other life history traits. All that can be said from females (Figure 11-3a) and males (Figure 11-3b) data is that we observed a breeding activity in April, July and August. However, it seems a weird behaviour for a Malawi cichlid to start breeding for one month then stop for two months and beginning again for two others months. Although there was no data to support it, it can be hypothesised that breeding season might occur between April and August as for *B. lepturus*. About 70% of the ripe females and males in breeding colour and 84% of the immature individuals were sampled at 30 m, suggesting that spawning could occur at this depth (Table 11-1). The plot of the percentage of ripe females against standard length did not give a proper sigmoïd curve (Figure 11-4). Size at maturity has to be determined at the height of the breeding season to be accurate but owing to the low sample size we had to consider all data available. As a consequence, females caught outside the breeding season were included in the analyses, even large resting females, which may explain the shape of the upper part of the curve. Nevertheless, small sized females are more informative than large ones and the size range between 100 mm and 130 mm was supported by the higher sample size (55 females), giving a relative "power" to this part of the curve. From the data available it can be estimated that maturity was reached around 115 mm for females. Maturity appears at a smaller size than anticipated given the large maximum observed length for this species and compared to *B. lepturus*.

Table 11-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Buccochromis nototaenia* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	20.9	28.6	17.6	16.7	14.6
30 m	79.1	71.4	80	66.7	84.4
50 m			2.4	16.7	1

The length-weight and fecundity-weight relationships are given in Figure 11-5 and 11-6, respectively. Fecundity ranged from 100 to 315 for females weighing between 40 and 250 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was difficult to assess due to low sample size but was tentatively fixed at about 2% (Figure 11-7). The mean oocyte weight was 11.70 mg (± 3.63 SD, N= 3).

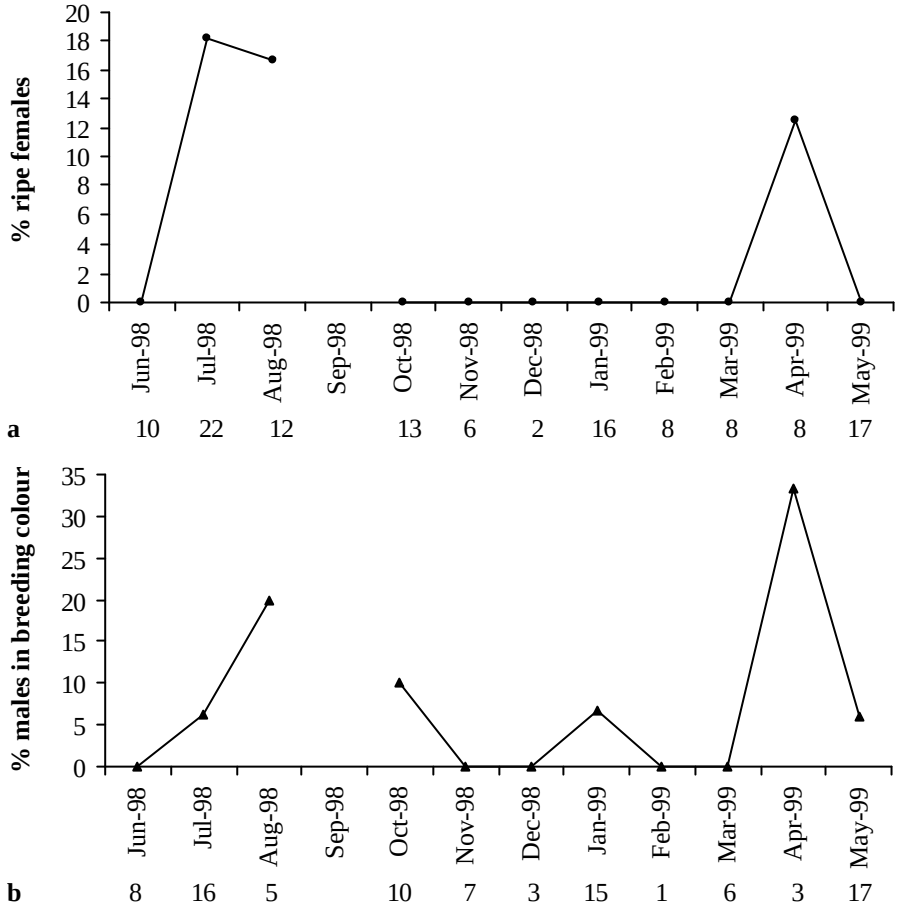


Figure 11-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Buccochromis nototaenia* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

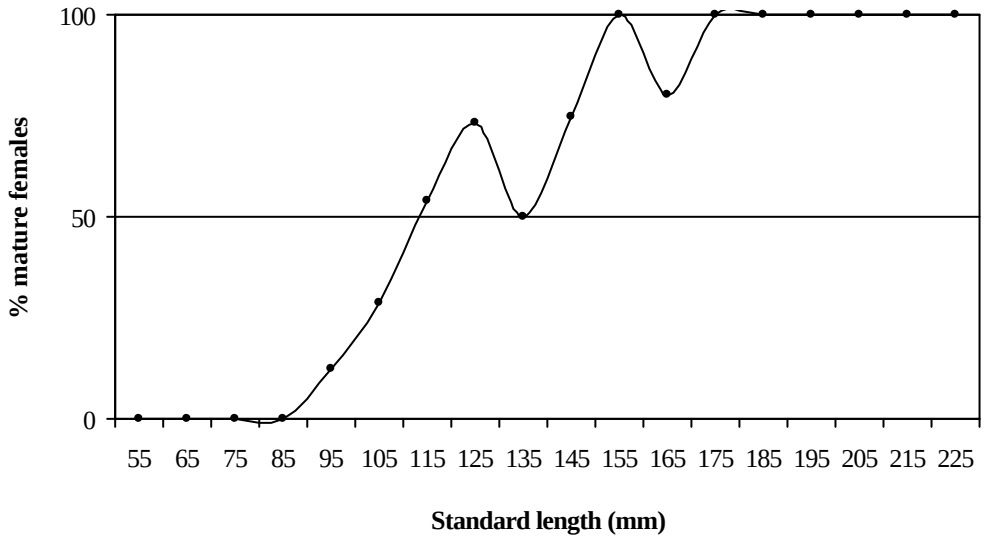


Figure 11-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Buccochromis nototaenia* in the SWA.

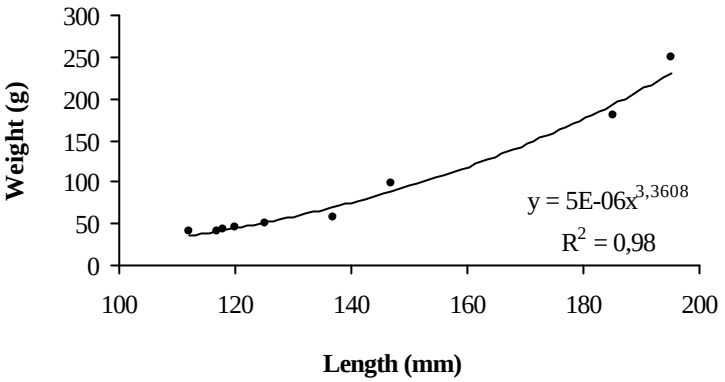


Figure 11-5. Length-weight relationship for *Buccochromis nototaenia* females in the SWA. (R^2 = determination coefficient).

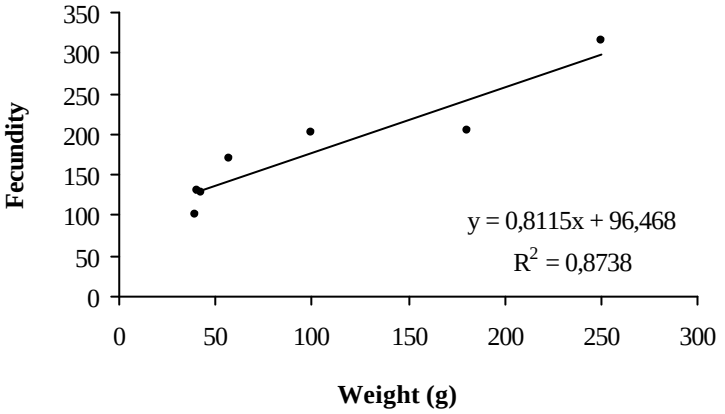


Figure 11-6. Fecundity-weight relationship for *Buccochromis nototaenia* females in the SWA. (R^2 = determination coefficient).

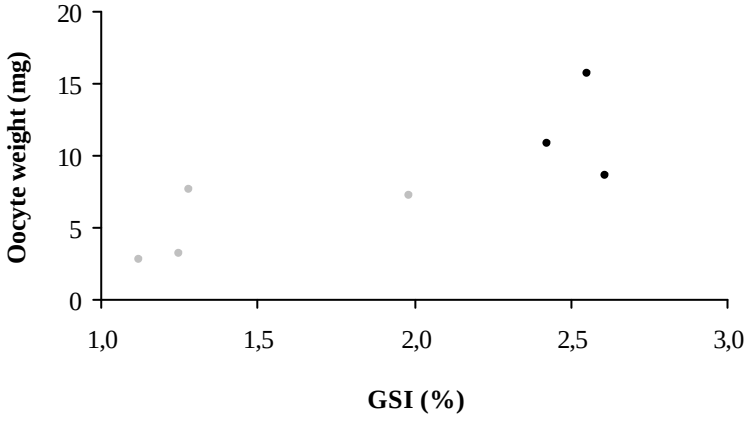


Figure 11-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Buccochromis nototaenia*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 2%. (R^2 = determination coefficient).

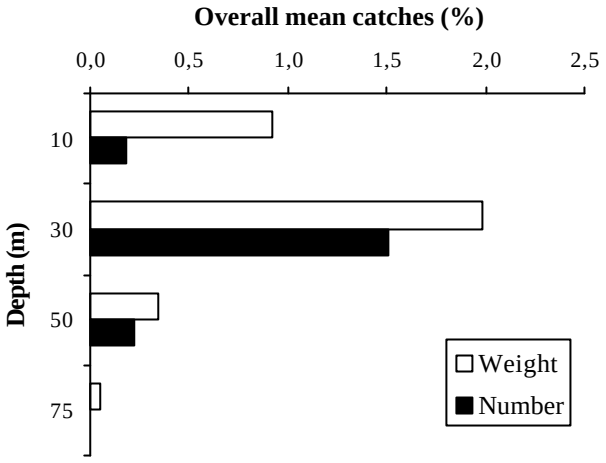


Figure 12-1. Mean occurrence and abundance in the catches per depth of *Copadichromis quadrimaculatus* in the SWA between July 1998 and May 1999.

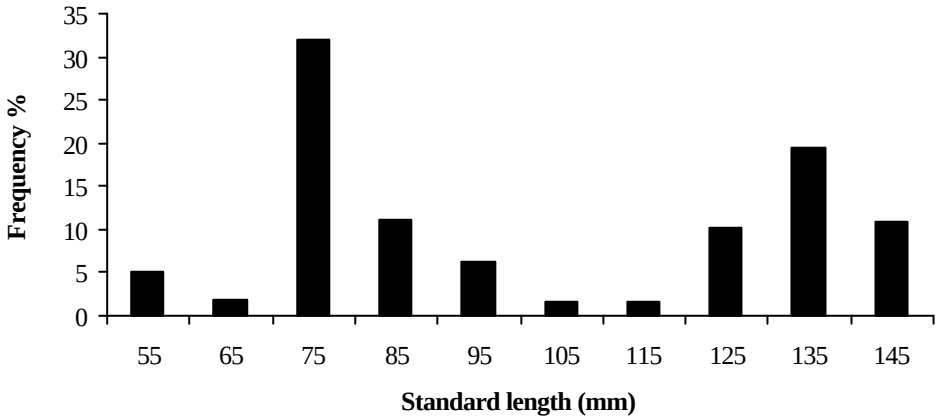


Figure 12-2. Size range and frequencies of *Copadichromis quadrimaculatus* caught in the SWA between July 1998 and May 1999.

Copadichromis spp.

***Copadichromis quadrimaculatus* (Regan)**

132 females and 214 males were analysed. *C. quadrimaculatus* was caught from 10 to 75 m but occurred more frequently at 30 m, where it constituted 2% and 1.5% of the catches, in weight and number, respectively (Figure 12-1). The mean CPUE per depth category was 6.9 kg in the shallow zone and 0.15 kg in the deep zone, which was about three times less than the value reported in Tómasson & Banda (1996) for the shallow zone (3.9 kg). The depth distribution observed in our study was much more restricted than that of Tómasson & Banda (1996), who reported *C. quadrimaculatus* from 8 to 135 m. Specimens caught ranged between 50 and 150 mm (Figure 12-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

The low sample size hampered the precise determination of breeding season and other life history traits. From data available about females (Figure 13-3a) and males (Figure 12-3b), it can be estimated that breeding season occurs from April to October. Taking into account the very low sample size of females in February-March and data from males, breeding season might actually start in February-March. This corresponds quite well with the % of active females observed in open waters during the SADC/ODA Project (Thompson et al. 1995, 1996). Most ripe females, males in breeding colour and immature individuals were found at 30 m, suggesting that spawning could occur at this depth (Table 12-1). The percentage of mature females (stage 3 and above) per size class is presented in Figure 12-4. No female was caught in the size range where maturity occurred. The 50% of mature females observed in the size range 80-90 mm was based on 2 females only and is probably overestimated. However, the second part of the curve from 120 mm upwards was based on consistent sample size and it can be reasonably estimated that maturity was reached around 100 mm, which was much less than the 15 cm TL (about 120 mm SL) reported for the same species in the open waters (Thompson et al. 1995, 1996). This corresponded to a mean age at maturity of 20 months.

Table 12-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Buccochromis nototaenia* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	29.3	20	2	37.6	1.4
30	52.4	50	75.5	57	76.8
50 m	14.6	25	22.4	5.5	21.7
75 m	3.7	5			

The length-weight and fecundity-weight relationships are given in Figure 12-5 and 12-6, respectively. Fecundity ranged from 15 to 62 for females weighing between 53 and 75 g. Using the length-weight and fecundity weight relationships, and assuming a 2 to 3 cm difference between standard and total length for a size range of 17 to 20 cm TL, the mean fecundity (50 eggs for females between 17 and 20cm TL) found by Thompson et al. (1996) corresponded with the fecundity we got for females of similar size. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight

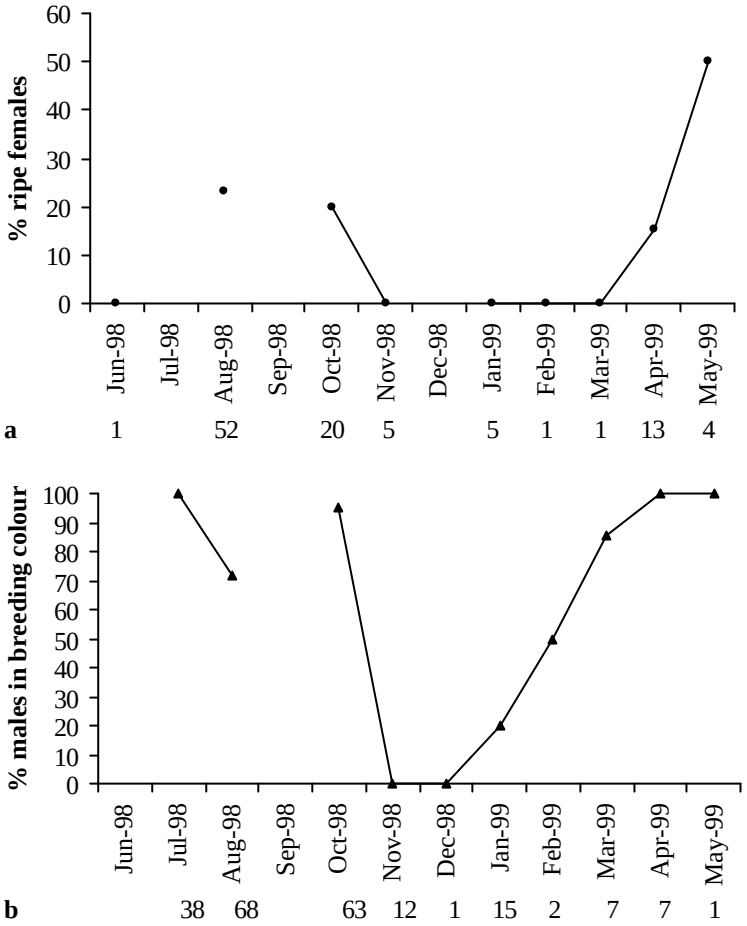


Figure 12-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Copadichromis quadrimaculatus* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

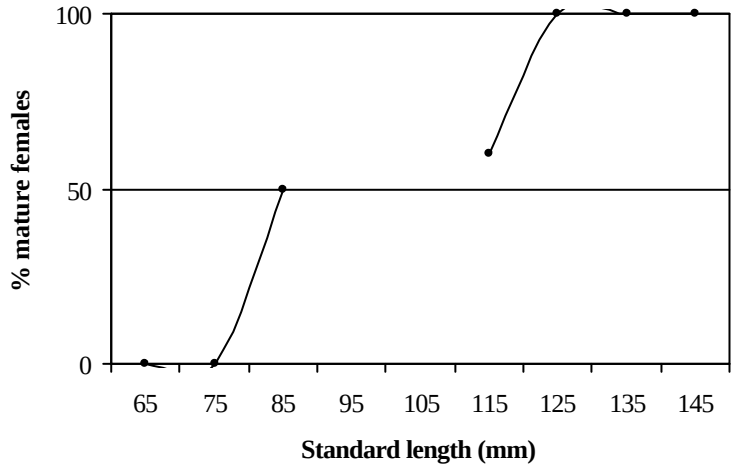


Figure 12-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Copadichromis quadrimaculatus* in the SWA.

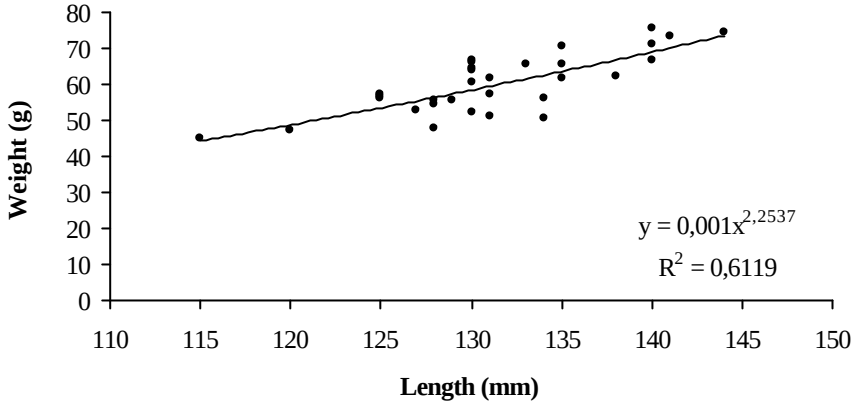


Figure 12-5. Length-weight relationship for *Copadichromis quadrimaculatus* females in the SWA. (R^2 = determination coefficient).

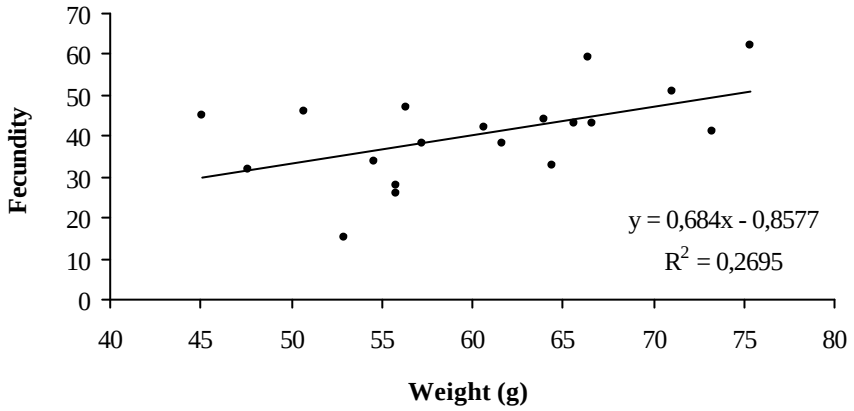


Figure 12-6. Fecundity-weight relationship for *Copadichromis quadrimaculatus* females in the SWA. (R^2 = determination coefficient).

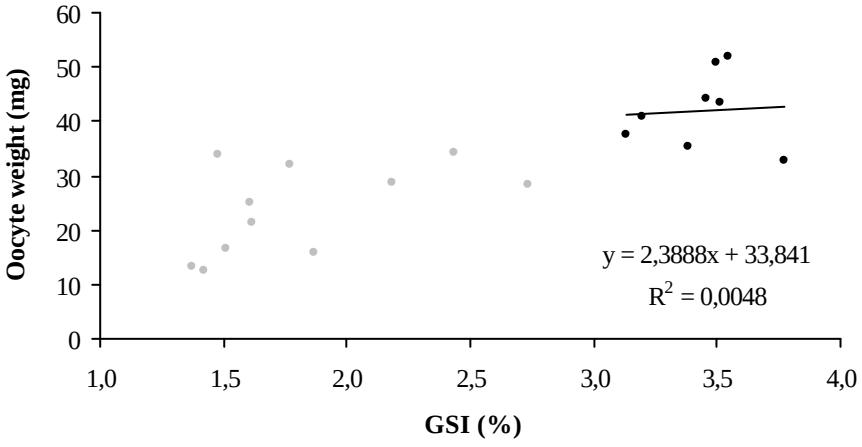


Figure 12-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Copadichromis quadrimaculatus*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

Plate 7. *Copadichromis virginalis* (by Dave Voorvelt).

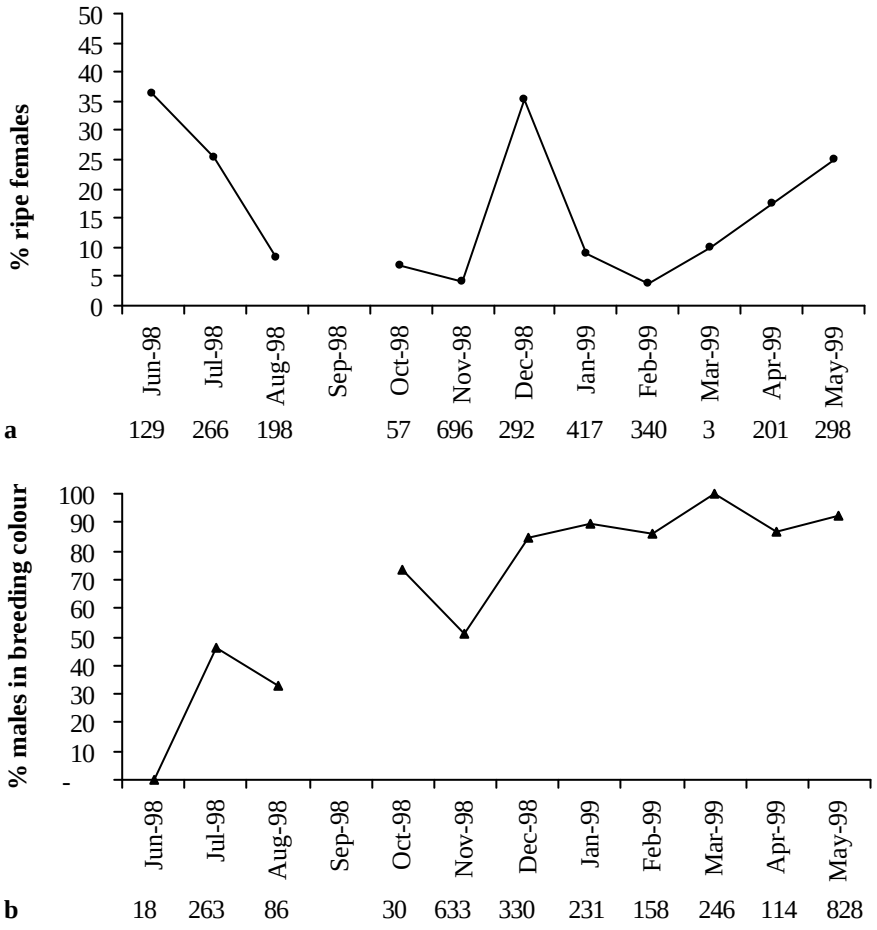


Figure 13-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Copadichromis virginalis* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

did no longer increase significantly was 3% (Figure 12-7). The mean oocyte weight was 42.05 mg (± 6.96 SD, N= 8).

Copadichromis virginalis (Iles) (Plate 7)

2886 females and 3052 males were analysed. *C. virginalis* was encountered from 10 m to 50 m and rarely at 100 m (Figure 13-1).

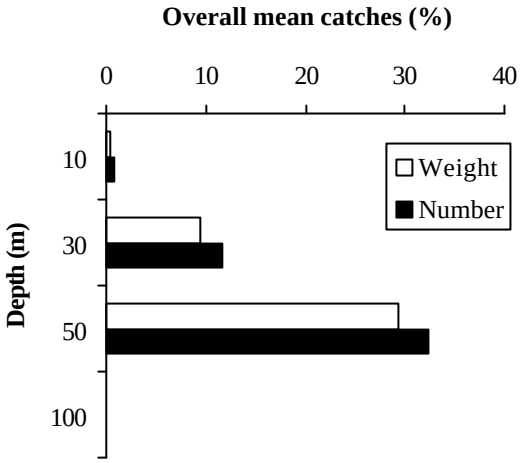


Figure 13-1. Mean occurrence and abundance in the catches per depth of *Copadichromis virginalis* in the SWA between July 1998 and May 1999.

It was one of the most abundant species in shallow water, where it constituted about 10% and 30% (both in weight and number) of the catches at 30 and 50 m, respectively. The mean CPUE per depth category was 97.7 kg in the shallow zone and 0.15 kg in the deep zone, which matched the value reported in Tómasson & Banda (1996) for the shallow zone (108.8 kg). As for *C. quadrimaculatus* the depth distribution observed in our study was a bit more restricted than that of Tómasson & Banda (1996), who reported *C. virginalis* from 8 to 120 m. Specimens caught ranged between 45 and 125 mm (Figure 13-2).

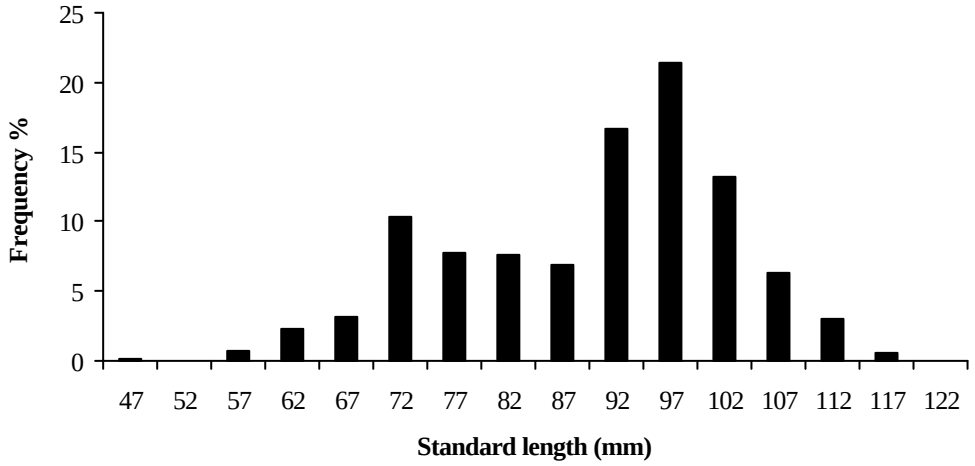


Figure 13-2. Size range and frequencies of *Copadichromis virginalis* caught in the SWA between July 1998 and May 1999.

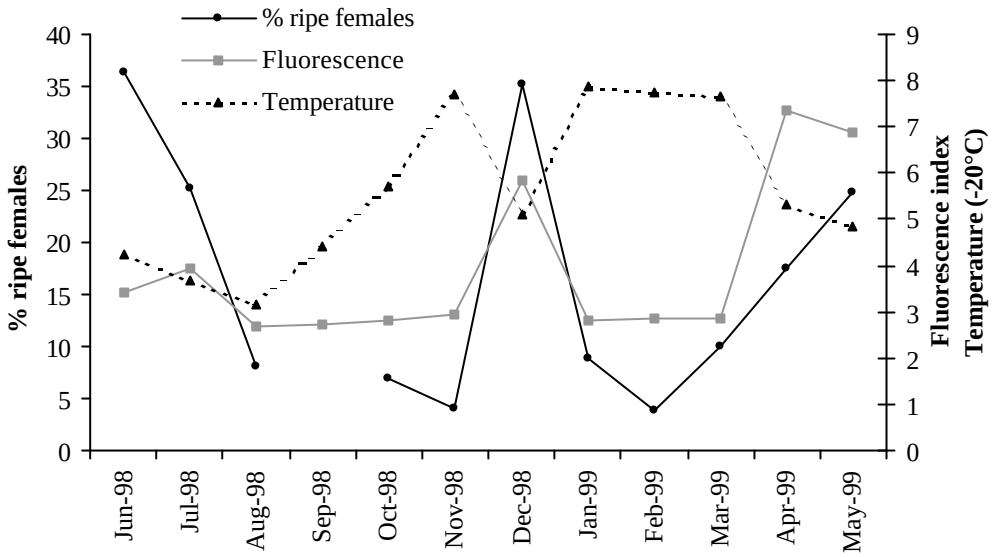


Figure 13-4. Monthly percentage of ripe females in relation with temperature (= temperature minus 20°C to fit the axis scale) and fluorescence, used as an index of chlorophyll a concentration.

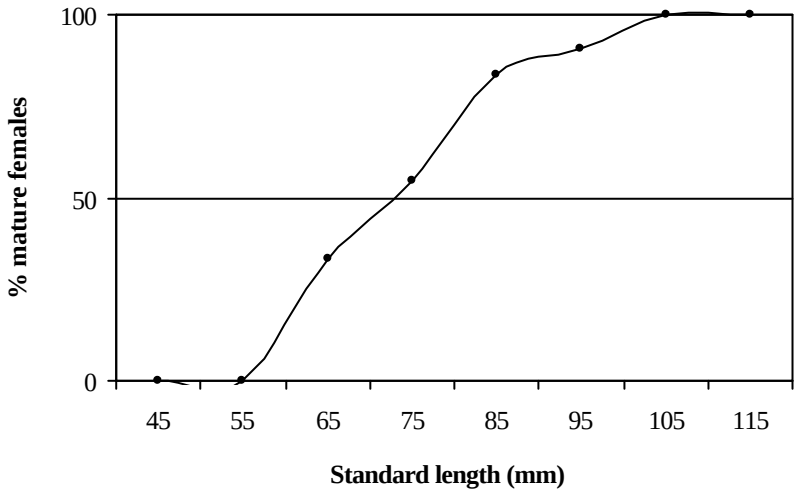


Figure 13-5. Percentage of mature females (stage 3 and above) per size class (standard length) for *Copadichromis virginalis* in the SWA.

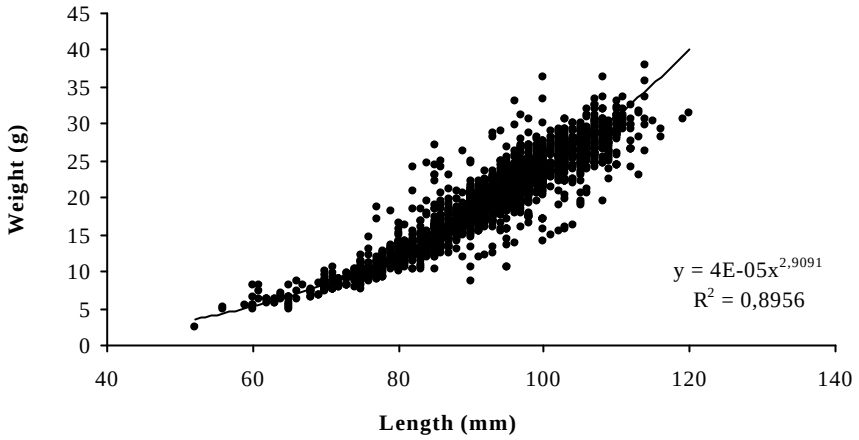


Figure 13-6. Length-weight relationship for *Copadichromis virginalis* females in the SWA. (R^2 = determination coefficient).

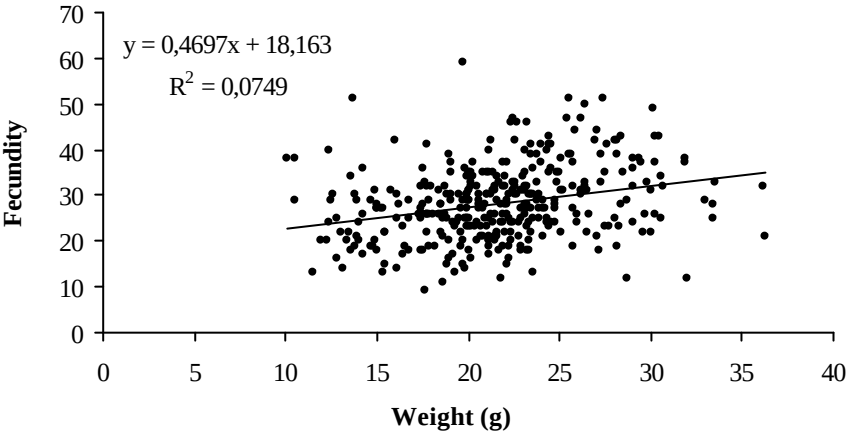


Figure 13-7. Fecundity-weight relationship for *Copadichromis virginalis* females in the SWA. (R^2 = determination coefficient).

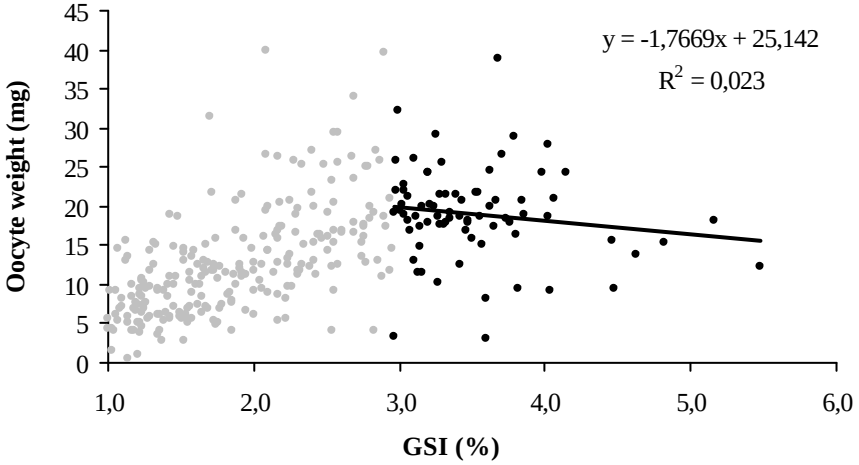


Figure 13-8. Relationship between oocyte weight and gonado-somatic index (GSI) for *Copadichromis virginalis*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

The sex ratio observed over the full sampling period was F/M 0.5/0.5.

C. virginalis was found to breed throughout the year (Figure 13-3a and b) with two peaks of activity, a punctual one in December and another one from May to July (Figure 13-3a). This figure markedly differed from Iles's (1971) observations who reported a very restricted breeding season (March to May) in the region of Nkata Bay. The percentage of ripe females seemed inversely related to water temperature (Figure 13-4), being higher during the cold water season (windy season) from April-May to August, and directly related to the chlorophyll a concentration. As *C. virginalis* is a zooplankton feeder (Iles 1960, 1971, Turner 1996, present study see chapter "Diet"), most of the sexual activity occurred during windy season when the water column was mixed up and the rich cold upwelling increased the phytoplankton production and consequently the zooplankton abundance. The punctual peak of sexual activity observed in December 1998 corresponded with a drop of temperature of about 3°C, an associated increased concentration in chlorophyll a and then an increased zooplankton availability. More than 70% of the ripe females and males in breeding colour were found at 50 m (Table 13-1) and the rest at 30 m, suggesting that spawning could occur mostly at 50 m and in a lesser extent at 30 m. Maturity was reached in their first year at 12 months old at a mean size of 75 mm for females (Figure 13-5).

Table 13-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Copadichromis virginalis* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	0.3	0.5	1.7	0.3	4.8
30	17.8	26.2	24.8	7.7	25.2
50 m	81.9	73.1	73.3	92	69.4
100 m	0	0.2	0.1	0	0.6

The length-weight and fecundity-weight relationships are given in Figure 13-6 and 13-7, respectively. Fecundity ranged from 9 to 59 for females weighing between 10 and 36 g and was not correlated to body weight. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 13-8). The mean oocyte weight was 18.93 mg (± 5.90 SD, N= 76).

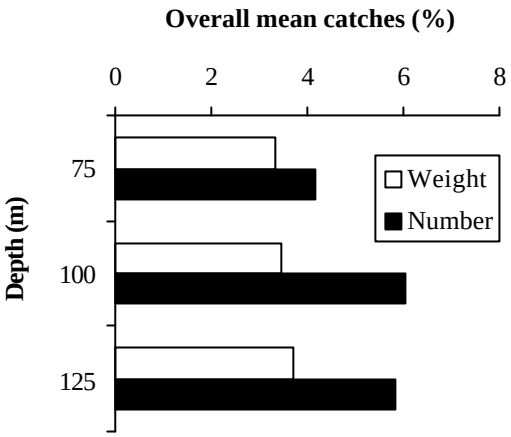


Figure 14-1. Mean occurrence and abundance in the catches per depth of *Diplotaxodon apogon* in the SWA between July 1998 and May 1999.

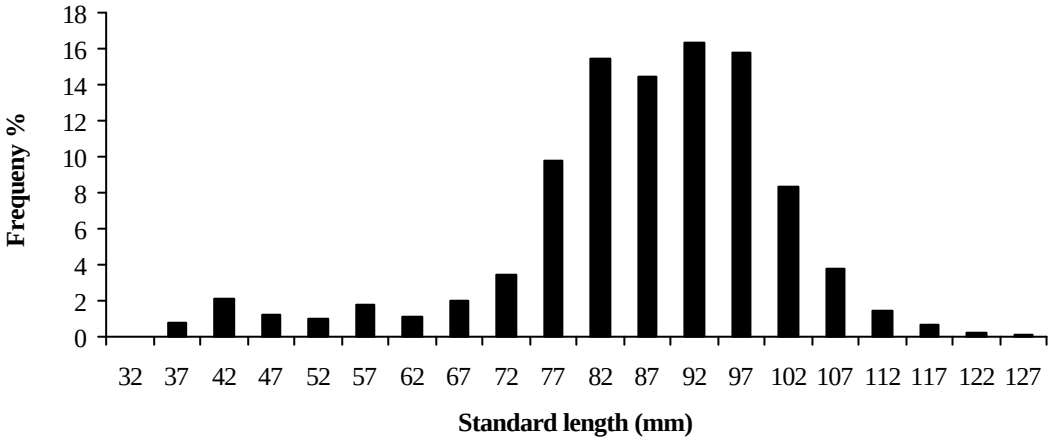


Figure 14-2. Size range and frequencies of *Diplotaxodon apogon* caught in the SWA between July 1998 and May 1999.

Diplotaxodon and Pallidochromis spp.

Pallidochromis tokolosh (Turner) is the only species of this genus. Despite its anatomical distinctness that separates it from Diplotaxodon, recent molecular evidence suggested that this species is a member of the *Diplotaxodon* clade (Turner et al. 1999). It will then be presented together with the *Diplotaxodon spp*..

***Diplotaxodon apogon* (Turner & Stauffer)**

616 females and 729 males were analysed. *D. apogon* was found from 75 to 125 m, where it constituted between 3 and 4% of the catches in weight and 4 to 6% in number (Figure 14-1). The mean CPUE per depth category was 15.6 kg in the deep zone and 6 kg in the very deep zone. There was no record for this species in Tómasson & Banda (1996). Specimens caught ranged between 33 and 130 mm with a mode from 75 to 105 mm (Figure 14-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Breeding activity was detected in August 98 and from November 98 to April 99 for females (Figure 14-3a) whereas more than 60% of males in breeding colour were found at every sampled month (Figure 14-3b). Despite the very high percentage of males in breeding colour throughout the year, female data suggested a bimodal breeding season with a major peak from November to March and a smaller one around August. More than 60% of the ripe females were found at 100m (Table 14-1). More than 80 % of the males in breeding colour were evenly distributed at 75 and 125 m, but aggregations of such breeding males (50 to 90 individuals) were found at all three depths. No particular indication about spawning depth was drawn from these results. Maturity was reached in their second year at 21 months old at a mean size of 88 mm for females (Figure 14-4).

Table 14-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Diplotaxodon apogon* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	27.4	14.1	5.8	40.3	13.3
100 m	43.3	62.5	79.5	16.1	53.4
125 m	29.3	23.4	14.7	43.6	33.3

The length-weight and fecundity-weight relationships are given in Figure 14-5 and 14-6, respectively. Fecundity ranged from 9 to 34 for females weighing between 16 and 39 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 2.7% (Figure 14-7). The mean oocyte weight was 46.04 mg (± 5.99 SD, N= 22).

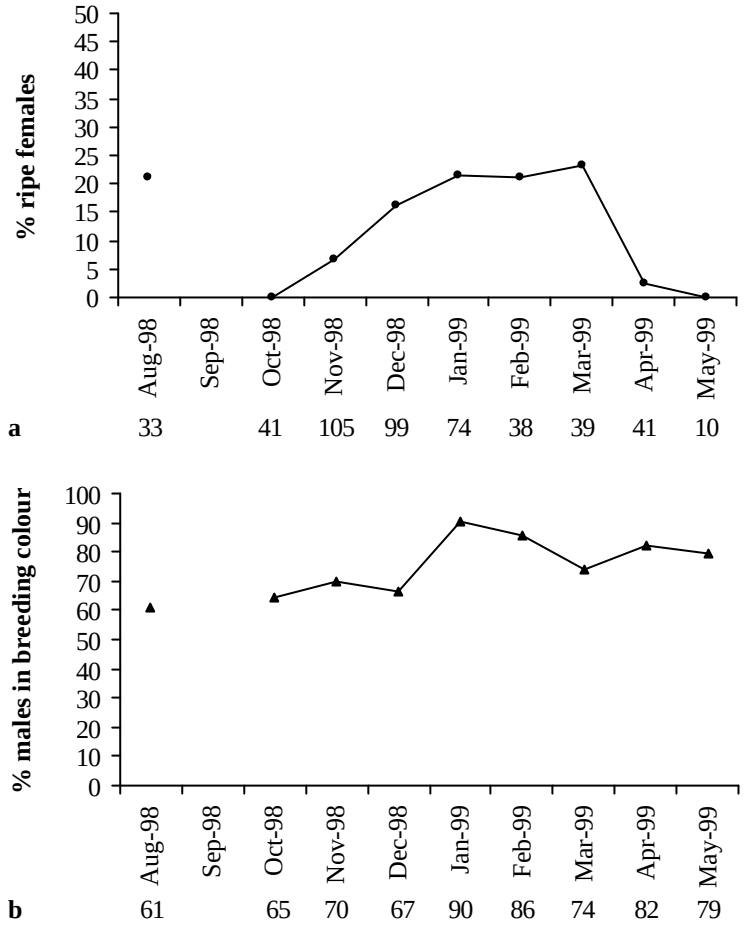


Figure 14-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Diplotaxodon apogon* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

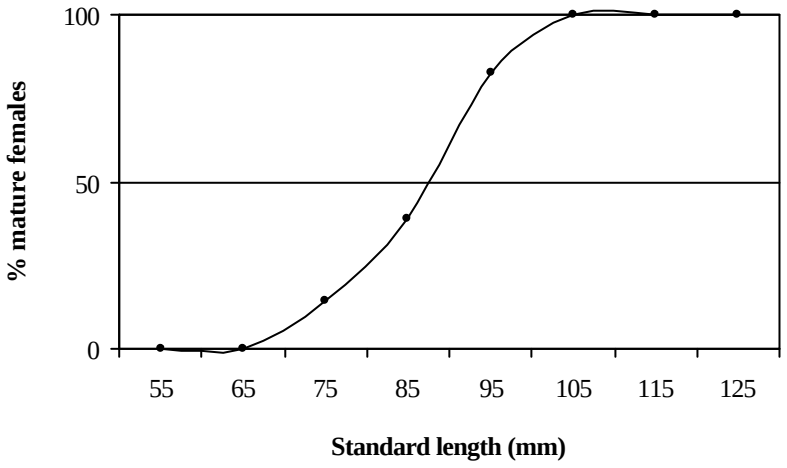


Figure 14-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Diplotaxodon apogon* in the SWA.

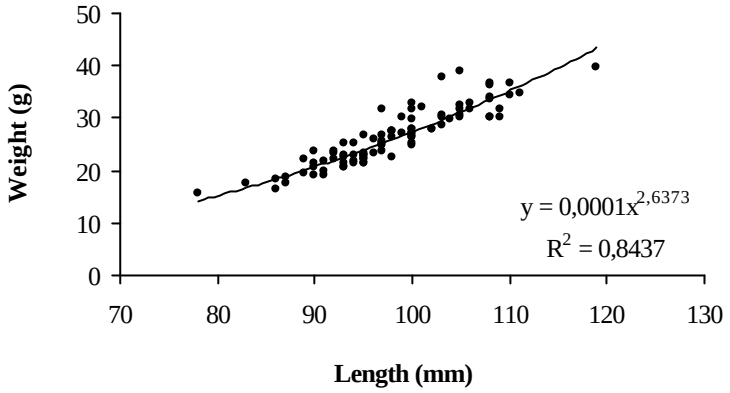


Figure 14-5. Length-weight relationship for *Diplotaxodon apogon* females in the SWA. (R^2 = determination coefficient).

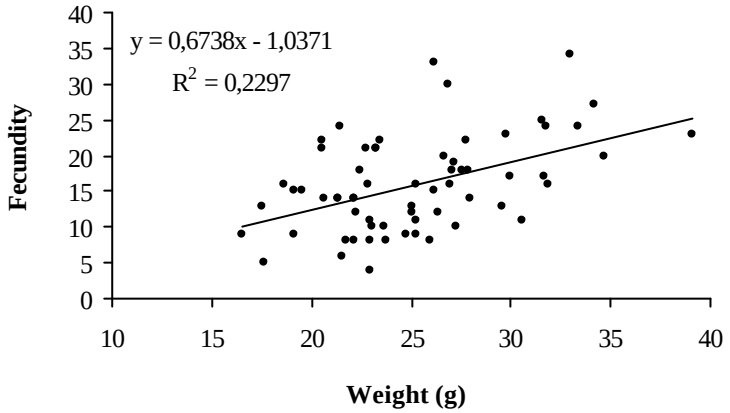


Figure 14-6. Fecundity-weight relationship for *Diplotaxodon apogon* females in the SWA. (R^2 = determination coefficient).

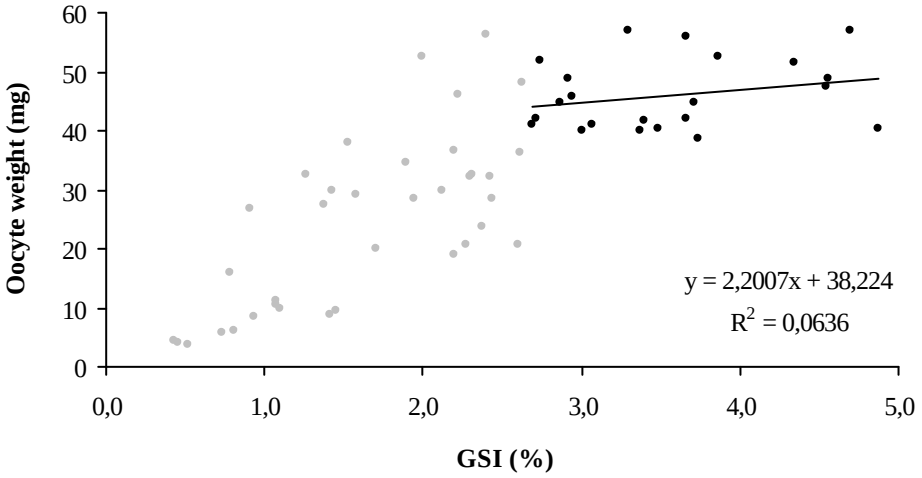


Figure 14-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Diplotaxodon apogon*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 2.7%. (R^2 = determination coefficient).

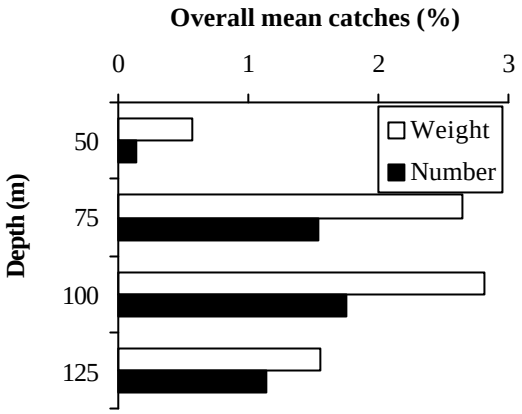


Figure 15-1. Mean occurrence and abundance in the catches per depth of *Diplotaxodon argenteus* in the SWA between July 1998 and May 1999.

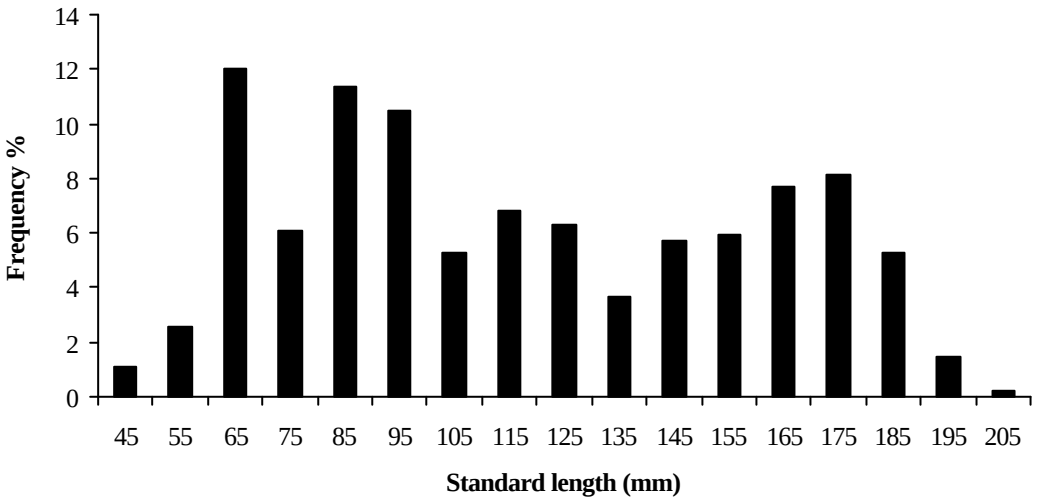


Figure 15-2. Size range and frequencies of *Diplotaxodon argenteus* caught in the SWA between July 1998 and May 1999.

Diplotaxodon argenteus (Trewavas)

278 females and 343 males were analysed. D. argenteus was found between 50 and 125 m but became more frequent from 75 m downwards, where it constituted between about 1 and 2% of the catches in number and 1.5 and 3% in weight (Figure 15-1). The mean CPUE per depth category was 1.5 kg in the shallow zone, 11 kg in the deep zone and 3.3 kg in the very deep zone, which matched the values reported in Tómasson & Banda (1996) for the shallows (1.2 kg) but was about three times more for the deep (3 kg) and very deep zones (1.3 kg). Specimens caught ranged between 48 and 206 mm (Figure 15-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

Owing to irregularity in the catches of this species and low sample size of individuals above the size at maturity, precise determination of breeding season was not possible. Breeding females were found in October-November 98 and from February to May 99 (Figure 15-3a). More than 30% of males in breeding colour were found all year long excluding June 98 were only one individual was caught (Figure 15-3b). Considering the high percentages of breeding males and the extremely low sample size for females from June to September, it is likely that *D. argenteus* breed most of the year with a possible cessation in December-January. Ripe females were relatively evenly distributed between 75 and 125 m, whereas more than 60% of males in breeding colour were caught at 75 m, suggesting that spawning could mainly occur at 75 m (Table 15-1). Maturity was reached in their second year at 20 months old at a mean size of 140 mm for females (Figure 15-4).

Table 15-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Diplotaxodon argenteus* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
50 m	35.3	11.1	2.1	0.6	1
75 m	11.2	22.2	35.4	61.7	29.5
100 m	38.8	33.3	29.6	16.2	33.4
125 m	14.7	33.3	32.8	21.4	36

The length-weight and fecundity-weight relationships are given in Figure 15-5 and 15-6, respectively. Fecundity ranged from 25 to 53 for females weighing between 55 and 139 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 15-7). The mean oocyte weight was 73.03 mg (± 7.98 SD, N= 3).

Diplotaxodon limnothrissa (Turner) (Plate 8)

1462 females and 2723 males were analysed. *D. limnothrissa* was common from 50 to 125 m and was occasionally encountered at 10 m depth (Figure 16-1), which corresponds to the depth distribution reported by Thompson et al. (1996) and Tómasson & Banda (1996). It was a dominant species in the catches at 50, 75 and 100 m, where it constituted (in number and weight, respectively) 6.2 and 3.8%, 8.3 and 7.7% and 11.7 and 9.7% of the catches, respectively. The mean CPUE per depth category was 14.7 kg in the shallow zone, 34.1 kg in

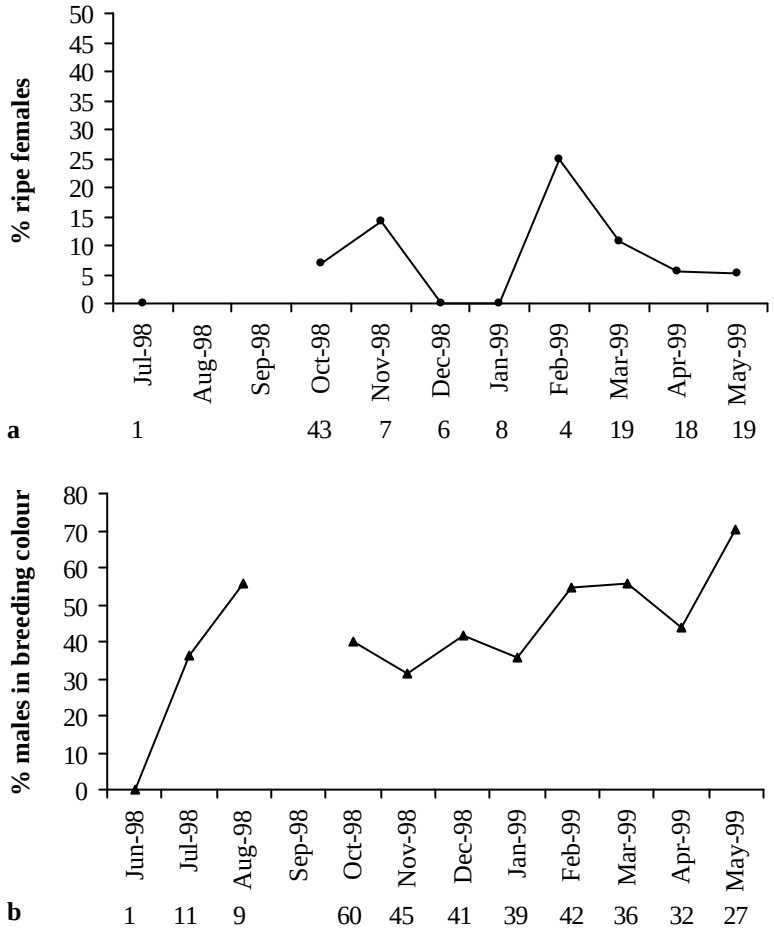


Figure 15-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Diplotaxodon argenteus* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

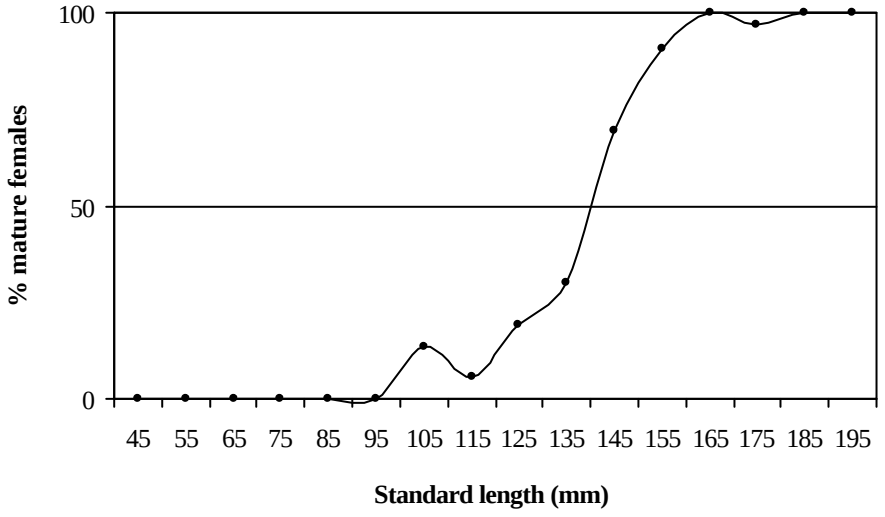


Figure 15-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Diplotaxodon argenteus* in the SWA.

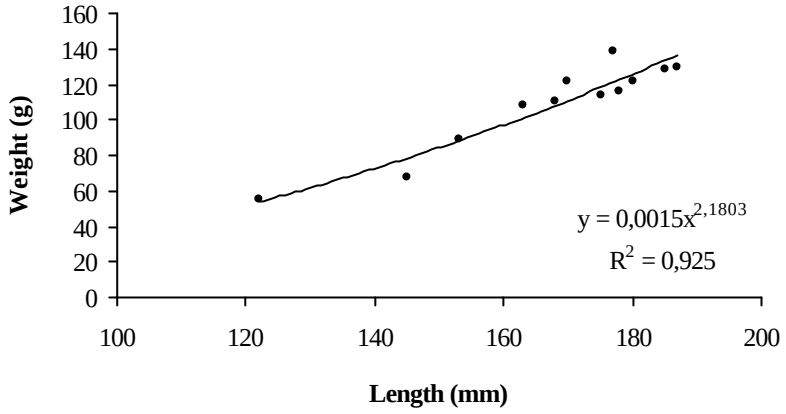


Figure 15-5. Length-weight relationship for *Diplotaxodon argenteus* females in the SWA. (R^2 = determination coefficient).

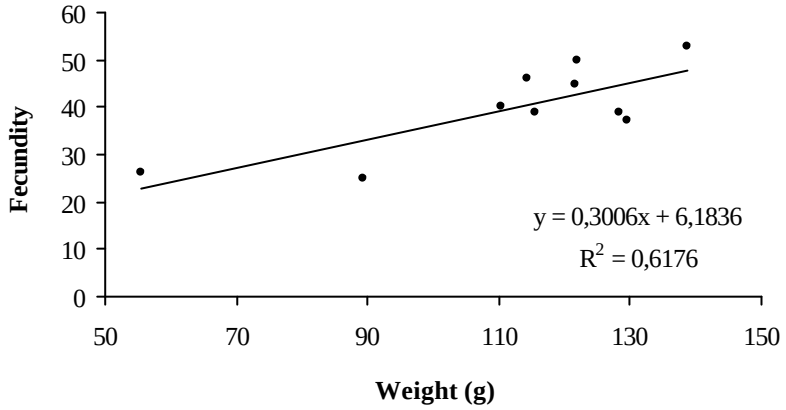


Figure 15-6. Fecundity-weight relationship for *Diplotaxodon argenteus* females in the SWA. (R^2 = determination coefficient).

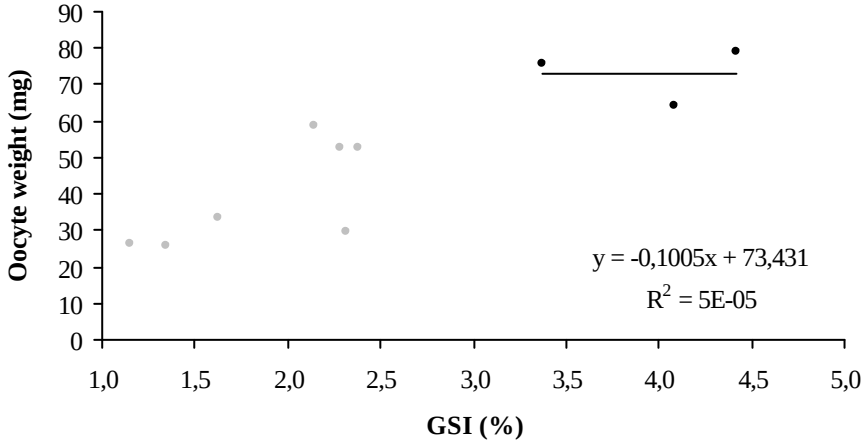


Figure 15-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Diplotaxodon argenteus*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 2.7%. (R^2 = determination coefficient).

Plate 8. *Diplotaxodon limnothrissa* (by Dave Voorvelt).

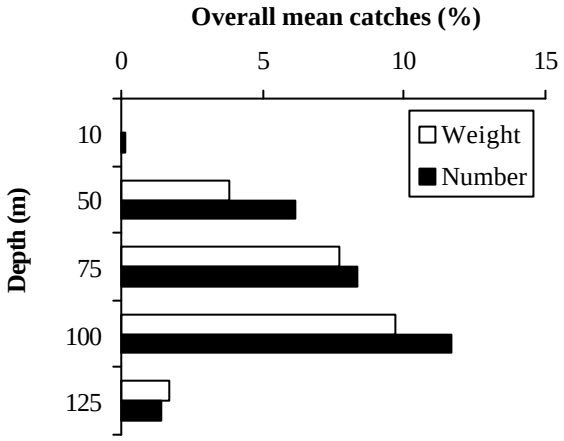


Figure 16-1. Mean occurrence and abundance in the catches per depth of *Diplotaxodon limnothrissa* in the SWA between July 1998 and May 1999.

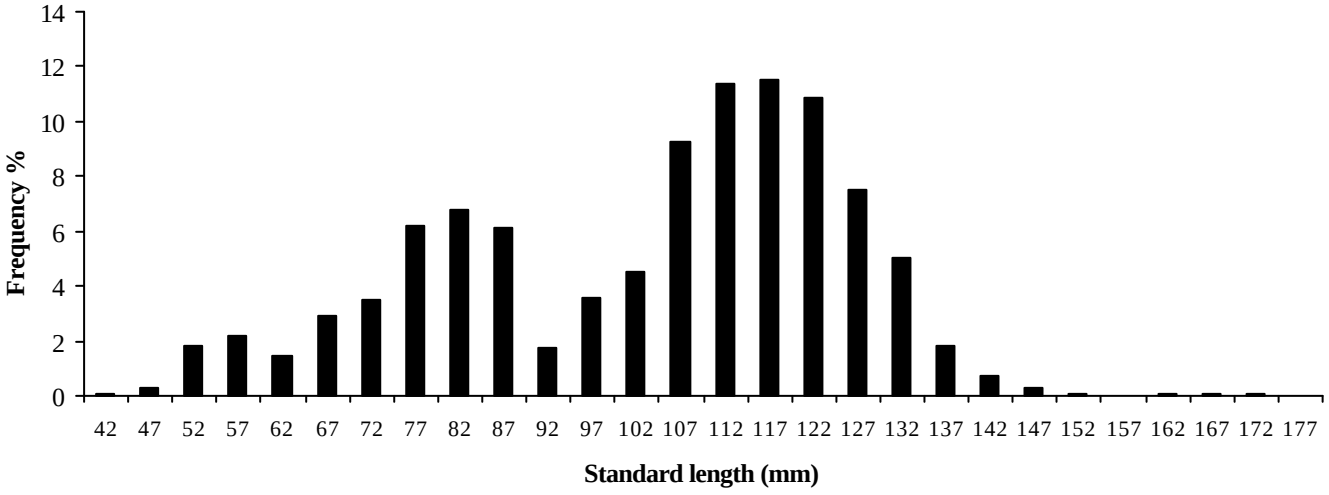


Figure 16-2. Size range and frequencies of *Diplotaxodon limnothrissa* caught in the SWA between July 1998 and May 1999.

the deep zone and 4.1 kg in the very deep zone, which approximately matched the values reported in Tómasson & Banda (1996) for the deep (36 kg) and very deep zones (7.1 kg) but was about twice as much for the shallows (6.7 kg). Specimen caught ranged between 40 and 175 mm (Figure 16-2). The sex ratio that was observed over the full sampling period was F/M 0.3/0.7.

Breeding season for females in the SWA occurred from March to August with a peak between April and June (Figure 16-3a) whereas males in breeding colour were caught throughout the year except in June (Figure 16-3b). These results being based upon pretty consistent sample size, the reason for the lack of fitting between females and males results is too be found elsewhere. Ripe females of the same species were found almost all year with a peak in March-April from offshore fishing locations and with a peak in May-June from inshore fishing location in the SEA (Thompson et al. 1996). Ripe females and males were also recorded from all over the Lake at any time of the year (Turner 1994a, Robinson R. L. pers. com.). Recent molecular analyses have shown that *D. limnothrissa* was constituted of a single wide spread population all over the Lake (Turner et al. 1999). This implies no breeding isolation from any part of the Lake and then large scale migrations of individuals. It is therefore likely that the breeding season we observed in the SWA between June 98 and May 99 was only a fixed and reductive picture of what happens at the Lake scale. Taking into account all the available information, it is probable that *D. limnothrissa* breeds all year long, but with seasonal geographical peak of activity, which would explain our observed pattern. Ripe females and males in breeding colour were found from 50 to 125 m with a higher frequency at 125 m for females and at 75 m for males (Table 16-1). It was previously thought that *D. limnothrissa* was not forming demersal spawning arenas because aggregation of breeding males had never been observed (Turner 1994a, Thompson et al. 1996). This was used to emphasised that some of the pelagic cichlid species might be able to spawn independently of the bottom of the lake (Thompson et al. 1996), as already observed for *Copadichromis* ("*Haplochromis*") *chrysonotus* (Eccles & Lewis 1981). However, large aggregations of males in breeding colours (more than 300 specimens) were found at 75 and 100 m in the SWA in April and May 99, suggesting that spawning probably occur close to the bottom at these depths. As already reported by Turner (1994a, 1996), *D. limnothrissa* females were observed to moothbrood young to large sizes, up to 23 mm SL. Maturity was reached early in their second year at 16 months old at a mean size of 105 mm for females (Figure 16-4), a size a bit smaller than the 14 cm TL (about 113 mm SL) reported by Thompson et al. (1996).

Table 16-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Diplotaxodon limnothrissa* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	0.2	0	0.4	0	0.7
50 m	14.4	25.7	18.5	4.1	34.7
75 m	39.6	11	31.5	53.4	34.4
100 m	35.4	17.8	41	31.2	27
125 m	10.4	45.5	8.5	11.3	3.3

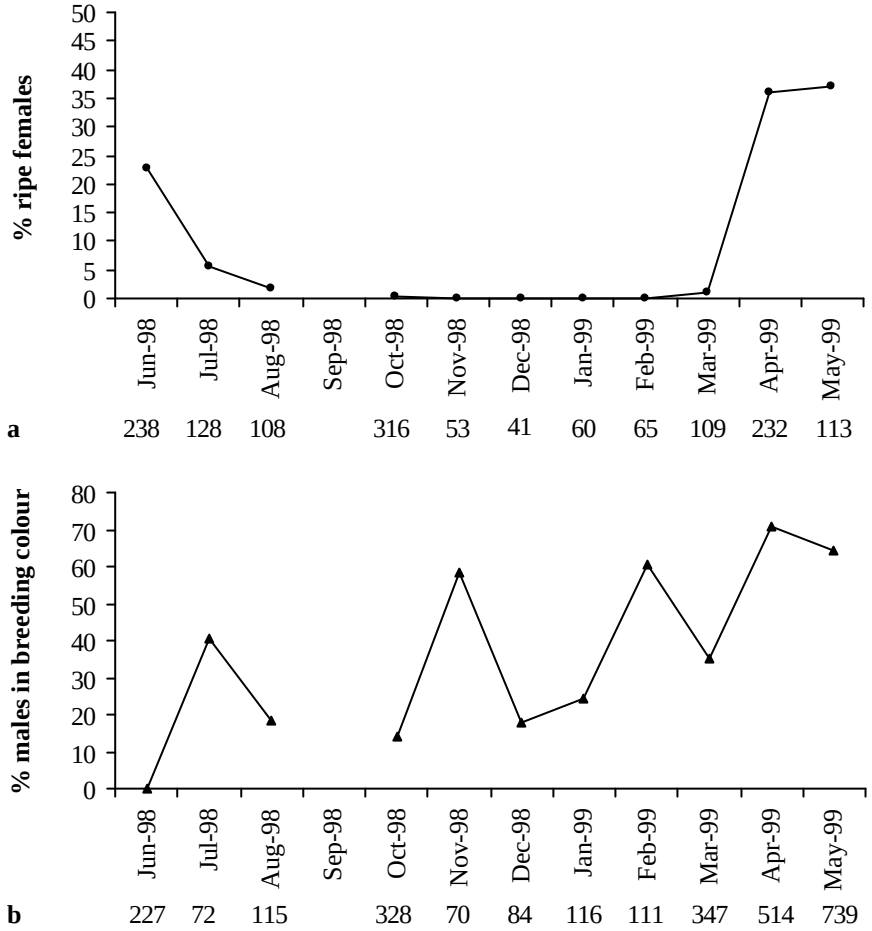


Figure 16-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Diplotaxodon limnothrissa* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

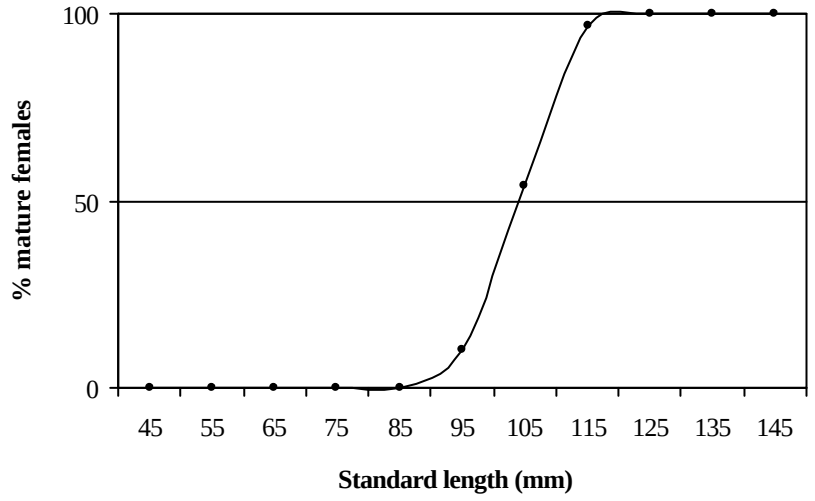


Figure 16-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Diplotaxodon limnothrissa* in the SWA.

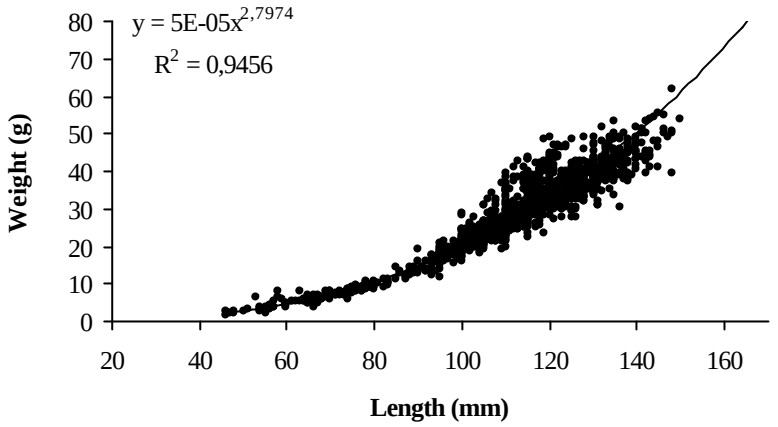


Figure 16-5. Length-weight relationship for *Diplotaxodon limnothrissa* females in the SWA. (R^2 = determination coefficient).

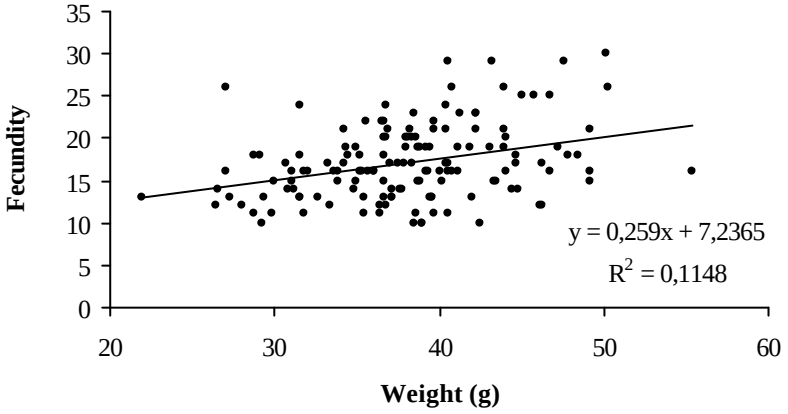


Figure 16-6. Fecundity-weight relationship for *Diplotaxodon limnothrissa* females in the SWA. (R^2 = determination coefficient).

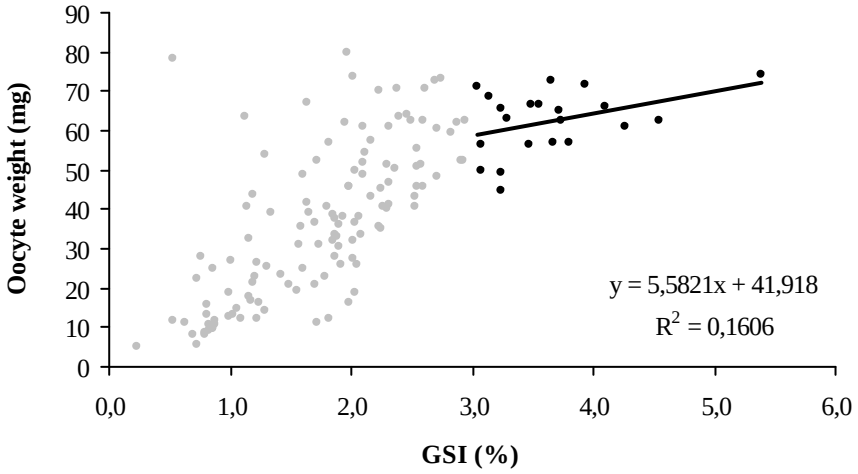


Figure 16-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Diplotaxodon limnothrissa*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

Plate 9. *Diplotaxodon macrops* (by Dave Voorvelt).

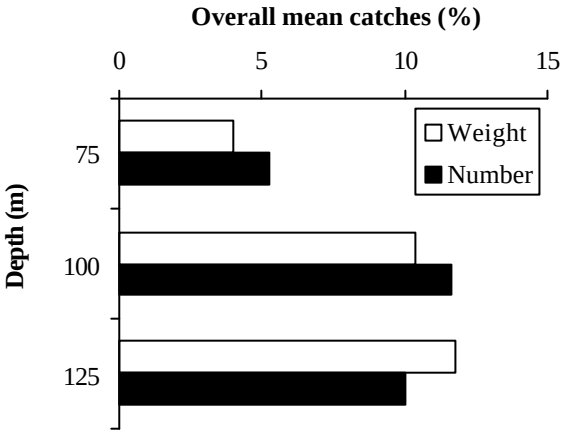


Figure 17-1. Mean occurrence and abundance in the catches per depth of *Diplotaxodon macrops* in the SWA between July 1998 and May 1999.

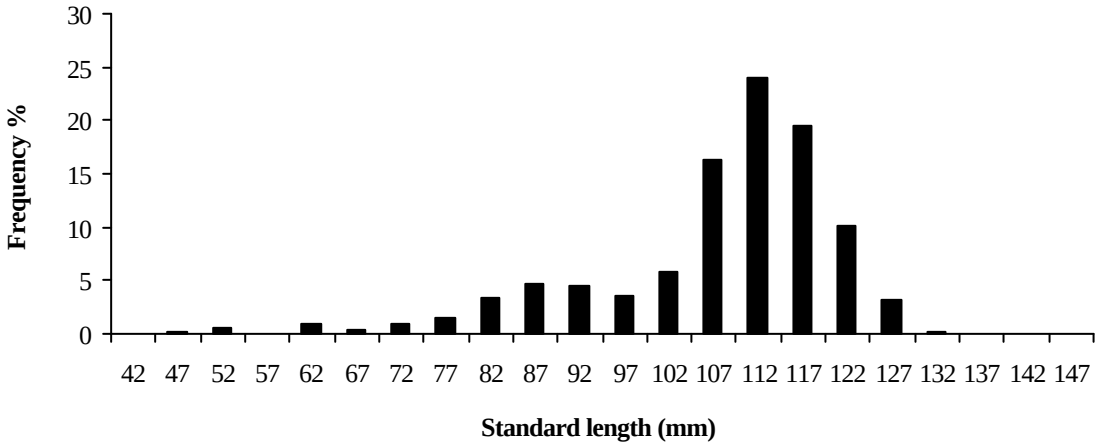


Figure 17-2. Size range and frequencies of *Diplotaxodon macrops* caught in the SWA between July 1998 and May 1999.

The length-weight and fecundity-weight relationships are given in Figure 16-5 and 16-6, respectively. Fecundity ranged from 10 to 30 for females weighing between 22 and 55 g and was not correlated to body weight. The fecundity range we found corresponded with the average fecundity of 15 eggs observed by Thompson et al. (1996) for females of 14-18 cm TL. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 16-7). The mean oocyte weight was 62.30 mg (± 7.93 SD, N= 21).

Diplotaxodon macrops (Turner & Stauffer) (Plate 9)

1664 females and 2919 males were analysed. *D. macrops* was caught from 75 to 125 m (Figure 17-1). It was a dominant species in the catches at 75 100 and 125 m, where it constituted (in number and weight, respectively) 5.3 and 4%, 11.6 and 10.4% and 10 and 11.8% of the catches, respectively. The mean CPUE per depth category was 39.3 kg in the deep zone and 24 kg in the very deep zone. There was no record for this species in Tómasson & Banda (1996). Specimens caught ranged between 40 and 135 mm (Figure 17-2). A single individual measuring 150 mm was caught, which was probably a specimen of the resembling *D. 'offshore'* that grows larger (Robinson R. L., pers. com.). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

Ripe females (Figure 17-3a) and males (Figure 17-3b) were found throughout the year with a decline between October and December and a peak of activity from February to April. Most ripe females and males in breeding colour were found at 100 and 125 m (Table 17-1). All the large aggregations of breeding males (between 100 and 400 specimens) observed in August 98, January, February, March , April and May 99, were caught at 100 and 125 m, suggesting that spawning probably occurs at these depths. The mean size at maturity for females was about 98 mm (Figure 17-4), which corresponded to a mean age at maturity of 20 months.

Table 17-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Diplotaxodon macrops* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	11.9	5.1	24.9	11.5	33.2
100 m	52.1	49.1	47.8	30.4	46.5
125 m	36.1	45.8	27.3	58	20.3

The length-weight and fecundity-weight relationships are given in Figure 17-5 and 17-6, respectively. Fecundity ranged from 10 to 37 for females weighing between 20.6 and 51 g and was not correlated to body weight. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 17-7). The mean oocyte weight was 56.04 mg (± 9.4 SD, N= 46).

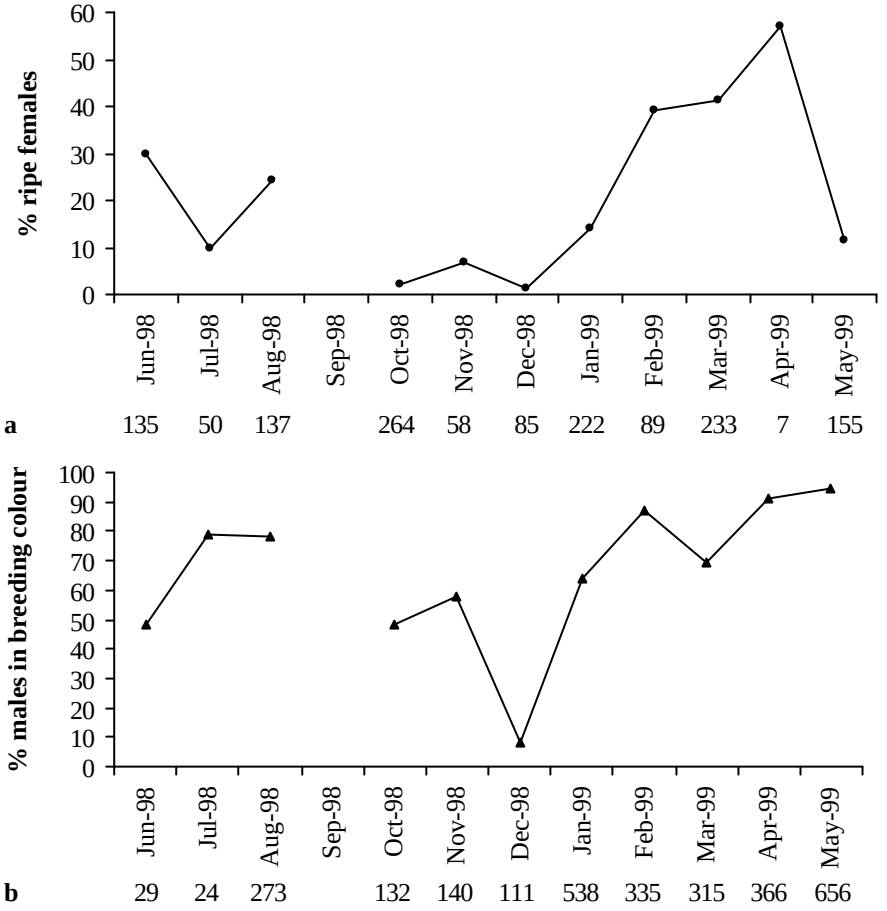


Figure 17-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Diplotaxodon macrops* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

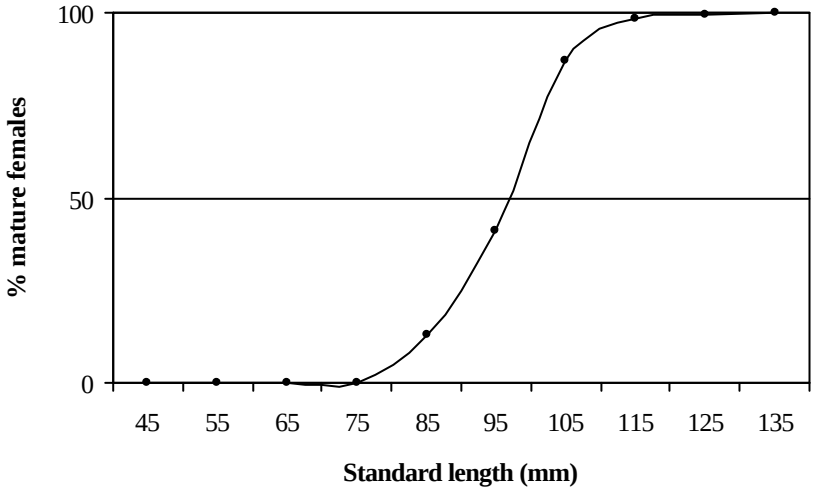


Figure 17-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Diplotaxodon macrops* in the SWA.

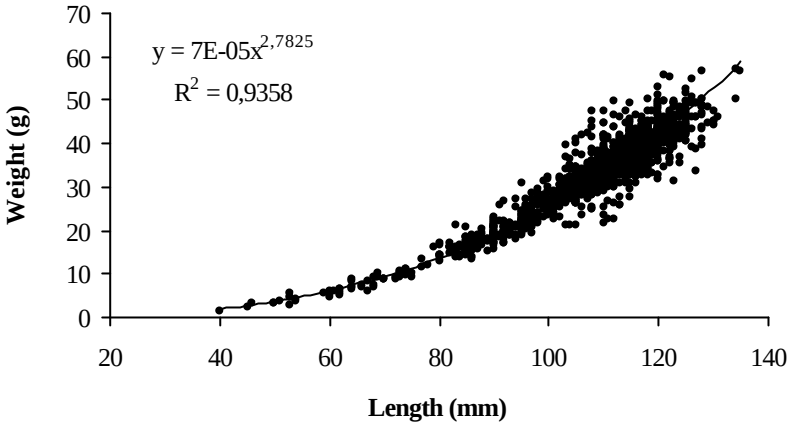


Figure 17-5. Length-weight relationship for *Diplotaxodon macrops* females in the SWA. (R^2 = determination coefficient).

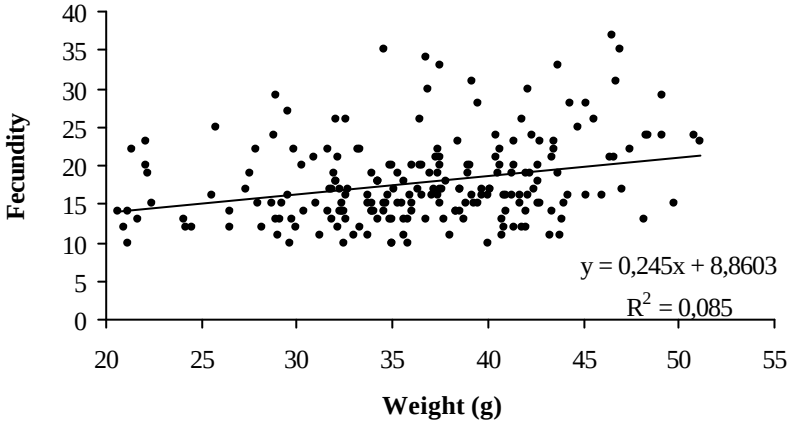


Figure 17-6. Fecundity-weight relationship for *Diplotaxodon macrops* females in the SWA. (R^2 = determination coefficient).

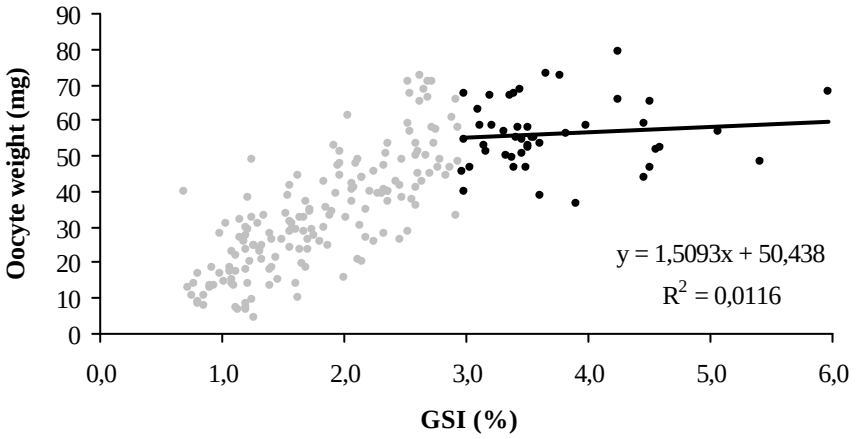


Figure 17-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Diplotaxodon macrops*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

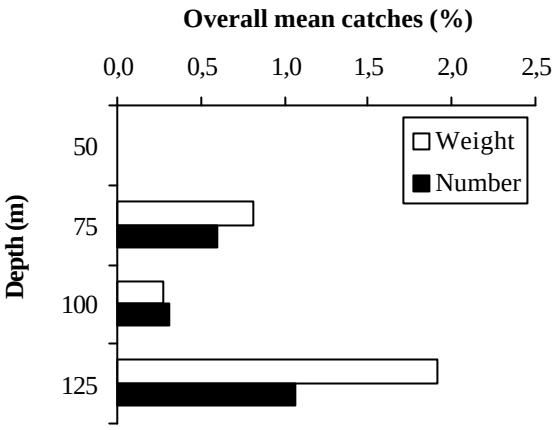


Figure 18-1. Mean occurrence and abundance in the catches per depth of *Pallidochromis tokolosh* in the SWA between July 1998 and May 1999.

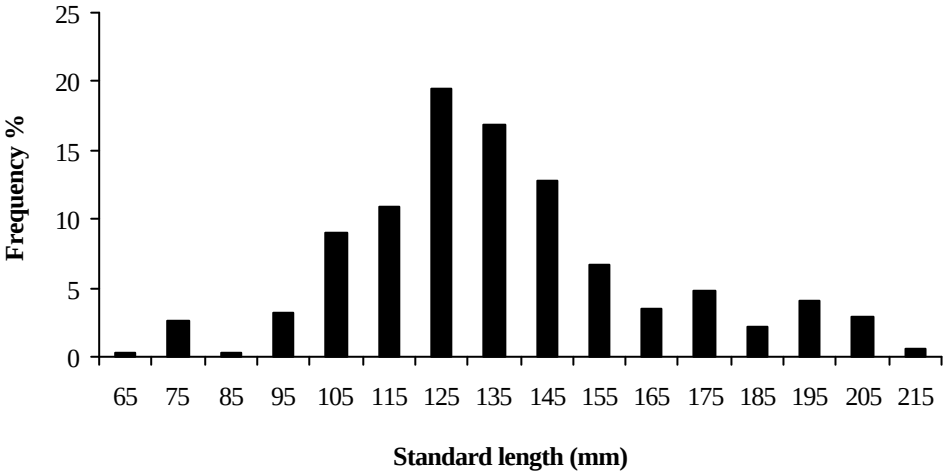


Figure 18-2. Size range and frequencies of *Pallidochromis tokolosh* caught in the SWA between July 1998 and May 1999.

Pallidochromis tokolosh (Turner)

210 females and 134 males were analysed. *P. tokolosh* was common from 75 to 125 m and was occasionally caught at 50 m (Figure 18-1). It was more frequent at 125 m, where it constituted 1.1 and 1.9% of the catches in number and weight, respectively. The mean CPUE per depth category was 0.15 kg in the shallows, 3.6 kg in the deep zone and 4.4 kg in the very deep zone, which matched the values reported by Tómasson & Banda (1996) for the shallow and deep zone but was more than twice as much for the very deep zone (1.8 kg). Specimens caught ranged between 62 and 213 mm with a mode from 100 to 160 mm (Figure 18-2). The sex ratio observed over the full sampling period was F/M 0.6/0.4.

P. tokolosh is not an abundant fish and low sample size at some months hampered the correct determination of breeding season. Next, we never observed any particular breeding dress for males and therefore the percentage of males in breeding colour was impossible to assess. From the data available, it seemed that the breeding season would occur between October and February (Figure 18-3). The depth distribution of ripe females (Table 18-1) reflected the relative abundance per depth with 67% at 125 m and 30% at 75 m. No particular indication about spawning depth was drawn from these results. Maturity was reached early in their second year at 16 months old at a mean size of 135 mm for females (Figure 18-4).

Table 18-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Pallidochromis tokolosh* in the SWA. Sample size between bracket.

Depth	Non ripe females (70)	Ripe females (27)	Immature Specimens (185)
50 m	0	3.7	0
75 m	22.9	29.6	44.3
100 m	10	0	18.4
125 m	67.1	66.7	37.3

The length-weight and fecundity-weight relationships are presented in Figure 18-5 and 18-6, respectively. Fecundity ranged from 13 to 87 for females weighing between 36 and 143 g. No relation was found between oocyte weight and body weight. The largest and heaviest oocytes of all cichlid species studied were produced by *P. tokolosh*, the record being 85 mg. The GSI threshold above which the oocyte weight did no longer increase significantly was not determined owing to low sample size of high GSI (Figure 18-7). Nevertheless, assuming a 3% threshold as for the other species of the *Diplotaxodon* clade, the mean oocyte weight was 70.49 mg (± 12.53 SD, N= 3).

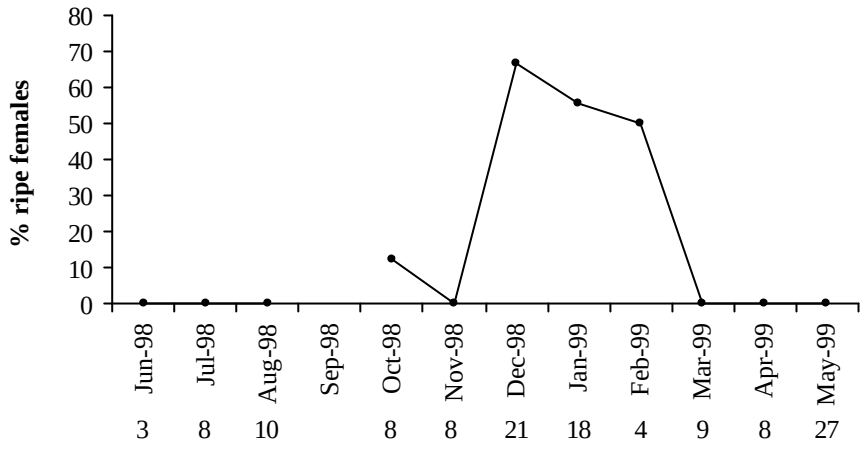


Figure 18-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females *Pallidochromis tokolosh* in the SWA The values below the x-axis are the effective (number of females which size was above the size at maturity) for each month.

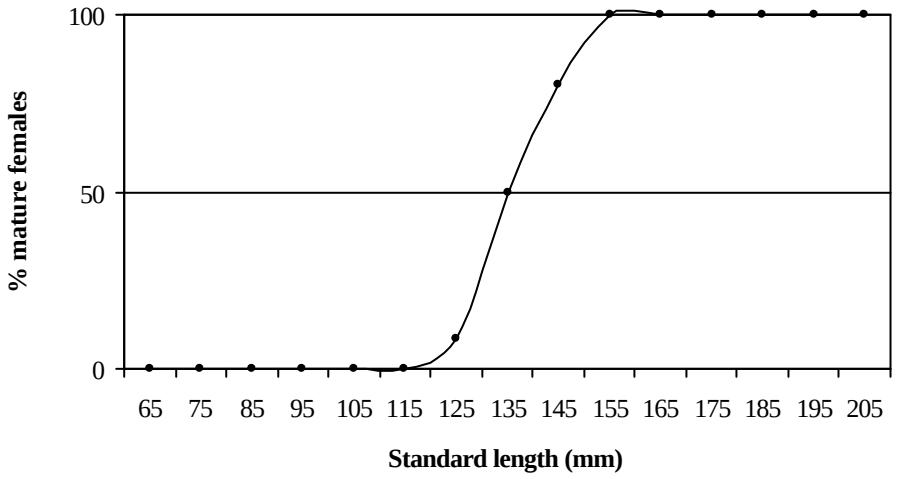


Figure 18-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Pallidochromis tokolosh* in the SWA.

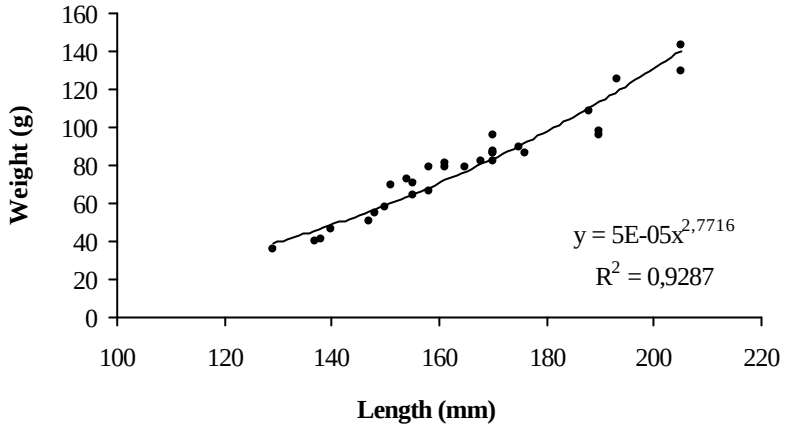


Figure 18-5. Length-weight relationship for *Pallidochromis tokolosh* females in the SWA. (R^2 = determination coefficient).

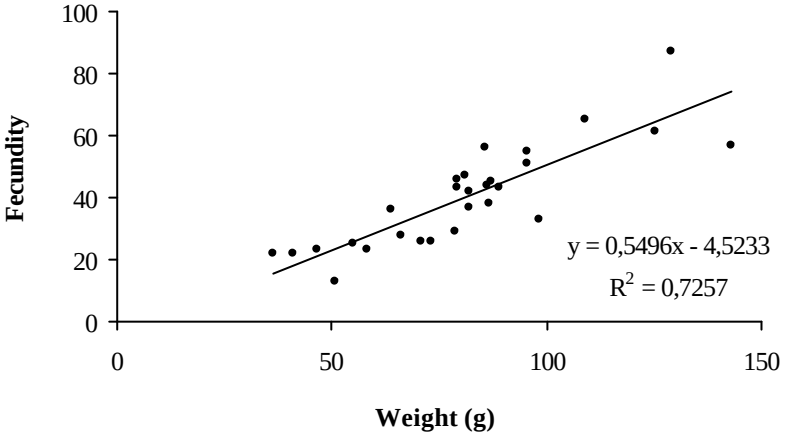


Figure 18-6. Fecundity-weight relationship for *Pallidochromis tokolosh* females in the SWA. (R^2 = determination coefficient).

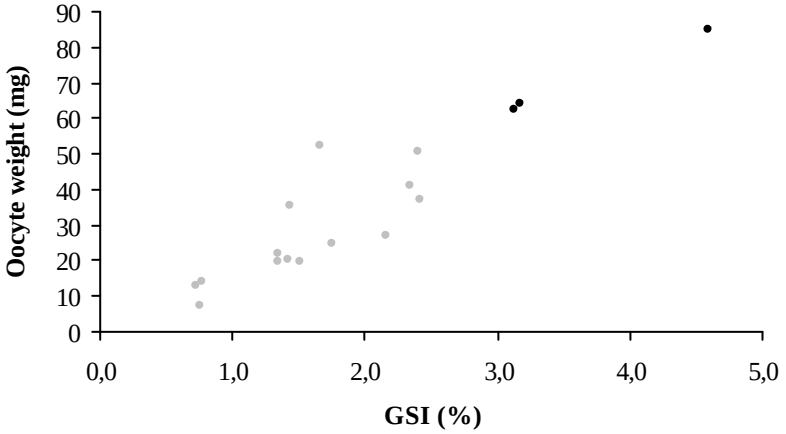


Figure 18-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Pallidochromis tokolosh*. Oocytes from females whose GSI was below (in grey) and above (in black) 3%.

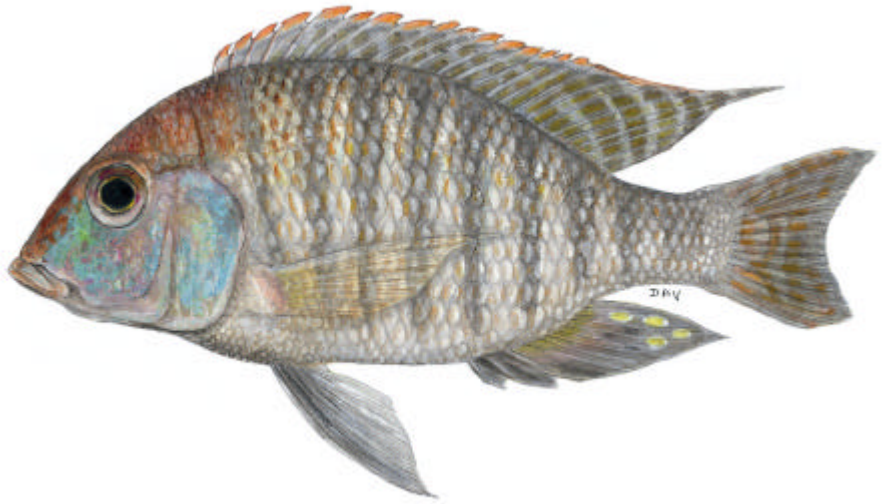


Plate 10. *Lethrinops argenteus* (by Dave Voorvelt).

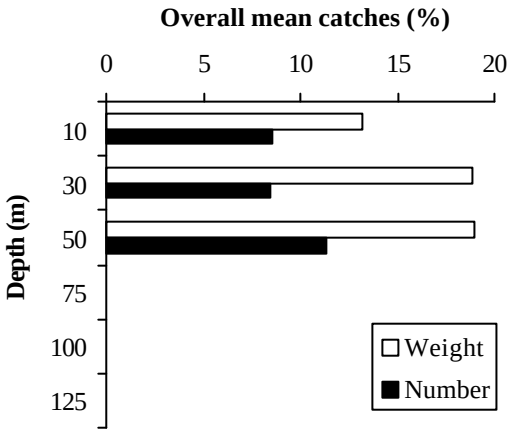


Figure 19-1. Mean occurrence and abundance in the catches per depth of *Lethrinops argenteus* in the SWA between July 1998 and May 1999.

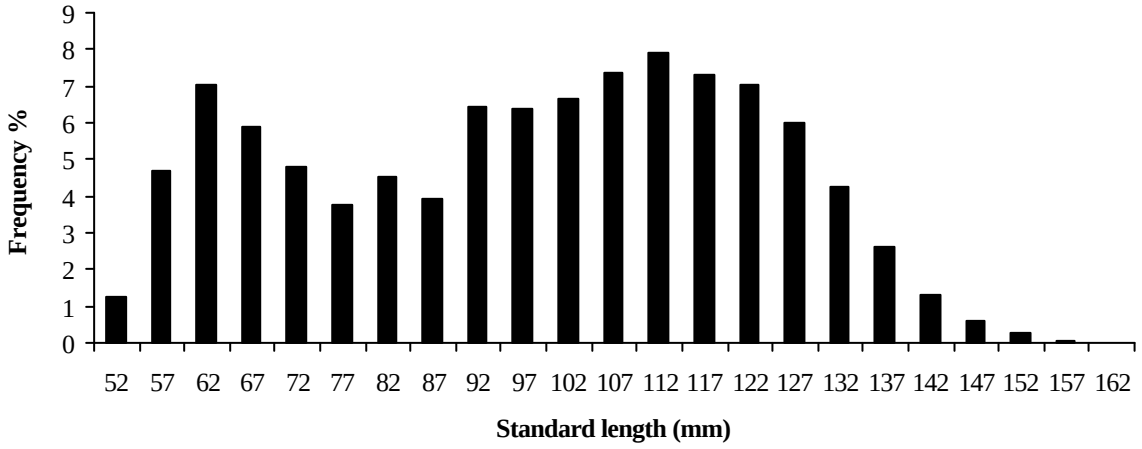


Figure 19-2. Size range and frequencies of *Lethrinops argenteus* caught in the SWA between July 1998 and May 1999.

Lethrinops spp.

Lethrinops argenteus (Ahl) (Plate 10)

3176 females and 2424 males were analysed. *L. argenteus* was caught from 10 to 125 m (Figure 19-1). It was abundant only between 10 and 50 m where it was a dominant species in the catches, constituting between 9 and 11% of the catches in number and between 13 and 19% in weight. The mean CPUE per depth category was 127.4 kg in the shallows, 0.15 and 0.3 kg in the deep and very deep zones, respectively. No reference was made to this species in Tómasson & Banda (1996), who probably included this species in the *L. longipinnis* group. Specimens caught ranged between 50 and 165 mm (Figure 19-2). The sex ratio observed over the full sampling period was F/M 0.6/0.4.

Ripe females (Figure 19-3a) and males (Figure 19-3b) of *L. argenteus* were found throughout the year with steady decline from March to June and in October and peaks of activity in August 98 and between December and February 99. 70% of males in breeding colour and 43% of ripe females were caught at 30 m (Table 19-1). Aggregations of breeding males, although small (between 30 and 80 individuals) compared to those observed for *Diplotaxodon spp*., were always found at 30 m suggesting that spawning could occur at this depth. The mean size at maturity for females was about 108 mm (Figure 19-4), which corresponded to a mean age at maturity of 12 months.

Table 19-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Lethrinops argenteus* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	17.4	26.2	31.2	22.6	23.1
30 m	35.8	41.1	43.1	70.2	27.3
50 m	46.5	32.3	25.5	6.7	49.5
75 m	0.1	0	0.2	0.2	0.2
100 m	0	0.4	0	0	0
125 m	0.2	0	0.1	0.3	0

The length-weight and fecundity-weight relationships are presented in Figure 19-5 and 19-6, respectively. Fecundity ranged from 43 to 218 for females weighing between 12.5 and 103 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 4% (Figure 19-7). The mean oocyte weight was 20.09 mg (± 4.17 SD, N= 28).

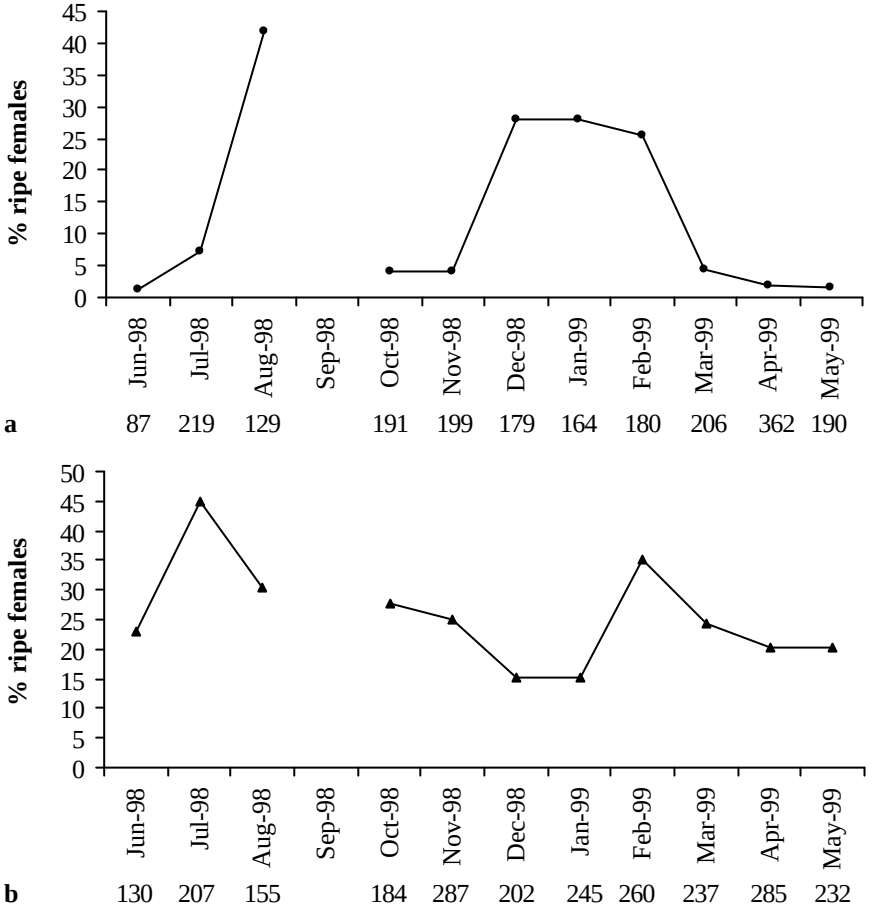


Figure 19-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Lethrinops argenteus* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

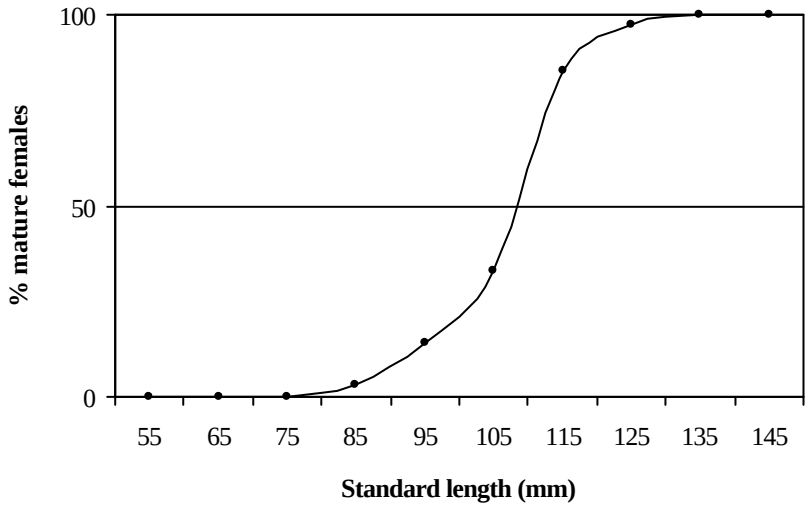


Figure 19-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Lethrinops argenteus* in the SWA.

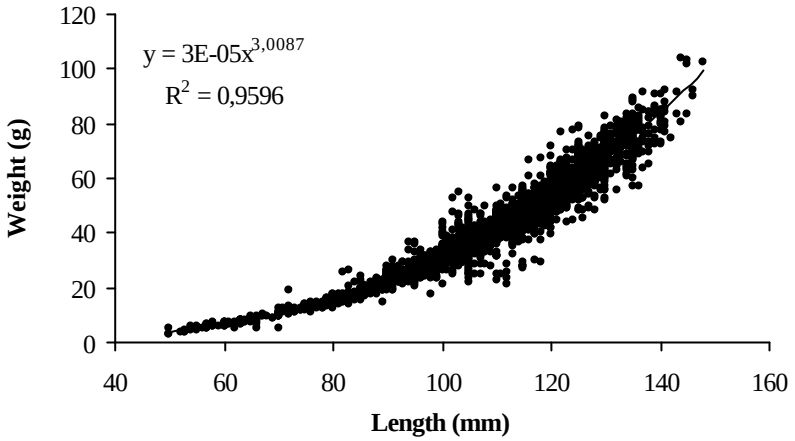


Figure 19-5. Length-weight relationship for *Lethrinops argenteus* females in the SWA. (R^2 = determination coefficient).

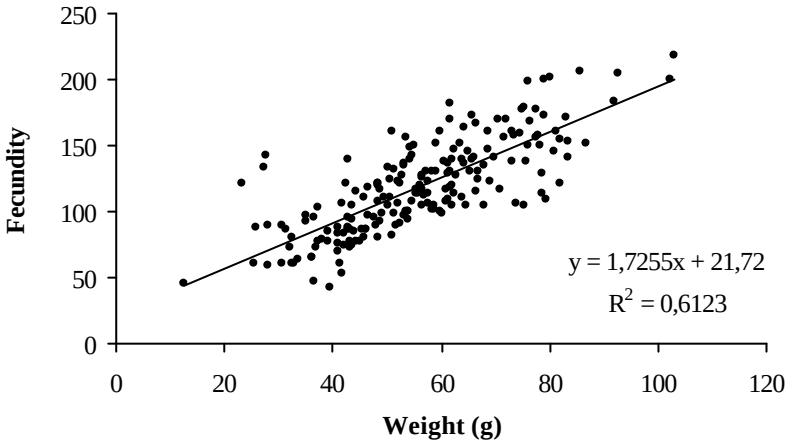


Figure 19-6. Fecundity-weight relationship for *Lethrinops argenteus* females in the SWA. (R^2 = determination coefficient).

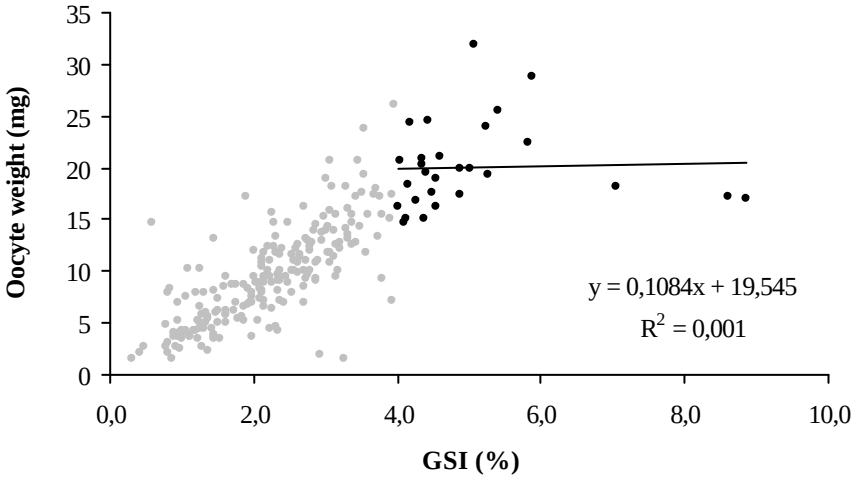


Figure 19-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Lethrinops argenteus* Oocytes from females whose GSI was below (in grey) and above (in black with regression) 4%. (R^2 = determination coefficient).

Plate 11. *Lethrinops 'deep water albus'* (by Dave Voorvelt).

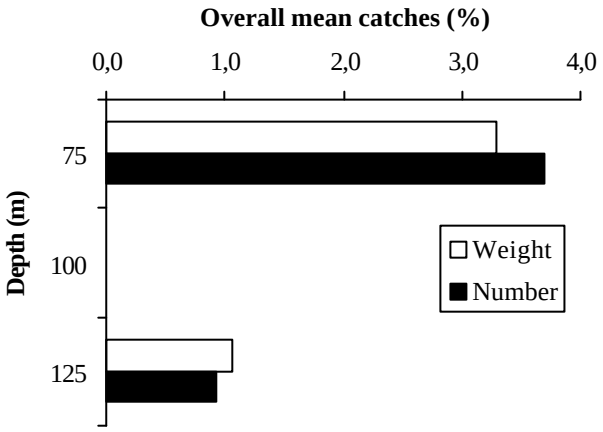


Figure 20-1. Mean occurrence and abundance in the catches per depth of *Lethrinops 'deep water albus'* in the SWA between July 1998 and May 1999.

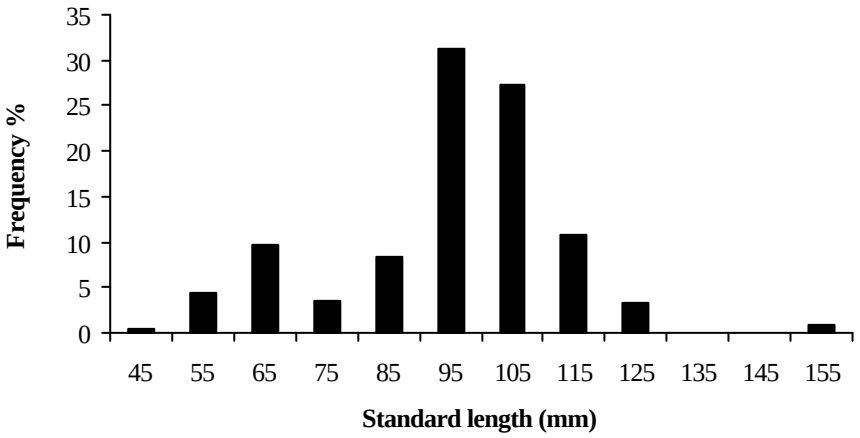


Figure 20-2. Size range and frequencies of *Lethrinops 'deep water albus'* caught in the SWA between July 1998 and May 1999.

Lethrinops 'deep water albus' **(Plate 11)**

303 females and 171 males were analysed. *L. 'deep water albus*' was caught from 75 to 125 m, though rarely at 100 m (Figure 20-1). It was not an abundant fish, always constituting less than 1% of the catches and often completely absent from the sampled part of the SWA. The 3.3 and 3.7% of the catches respectively in weight and number, observed at 75 m were due to an exceptional catch in November 98, during which *L. 'deep water albus*' made up to 31 and 33% of the catch in weight and number. However, *L. 'deep water albus*' was very abundant off Domira Bay and off Leopard Bay, being the dominant species in catches of 400 to 600 kg between 75 and 125 m. This species seemed to be dominant in the deep water catches when *Lethrinops gossei* was absent or rare. *L. 'deep water albus*' was often very abundant in the catches in these areas when we were targeting for *L. gossei*, and one or the other was dominant but never both of them at the same time. As a matter of fact, during the exceptional catch of *L. 'deep water albus*' at 75 m in the SWA in November 98, only 38 specimens of *L. gossei* were caught. As *L. gossei* was a consistently dominant species in the deep zone of the SWA (see further), it might explain why *L. 'deep water albus*' was rare. Specimens caught ranged between 40 and 160 mm (Figure 20-2). The sex ratio observed over the full sampling period was F/M 0.6/0.4.

Owing to irregularity in the catches of this species and low sample size for most of the months, precise determination of breeding season was not possible and. Ripe females were found from June to August 98 and in November and January 98 (Figure 20-3a) whereas males in breeding colour were found at each sampling date, including in May (Figure 20-3b). Size at maturity was estimated at about 82 mm for females and was probably slightly overestimated as this estimation was not done during the height of the breeding season but with all the data available for females (Figure 20-4).

The length-weight and fecundity-weight relationships are presented in Figure 20-5 and 20-6, respectively. Fecundity ranged from 65 to 151 for females weighing between 19 and 42 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was not determine precisely owing to low sample size, but was estimated at 4% (Figure 20-7). The mean oocyte weight was 10.27 mg (± 0.89 SD, N= 3).

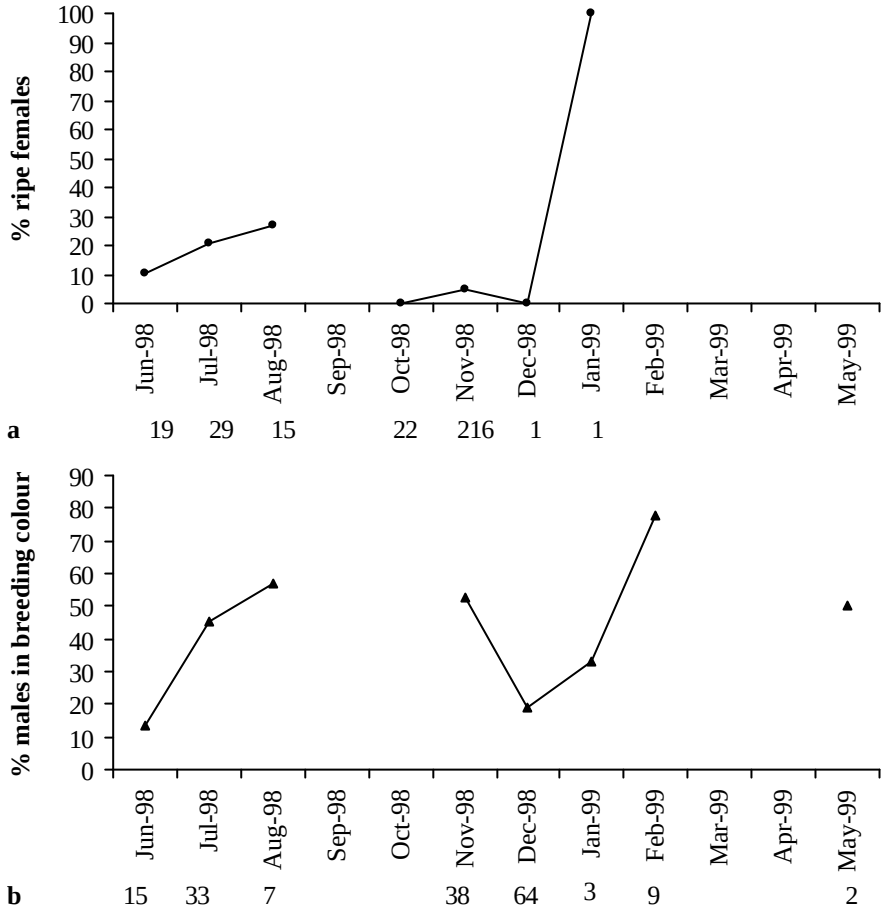


Figure 20-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Lethrinops 'deep water albus'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

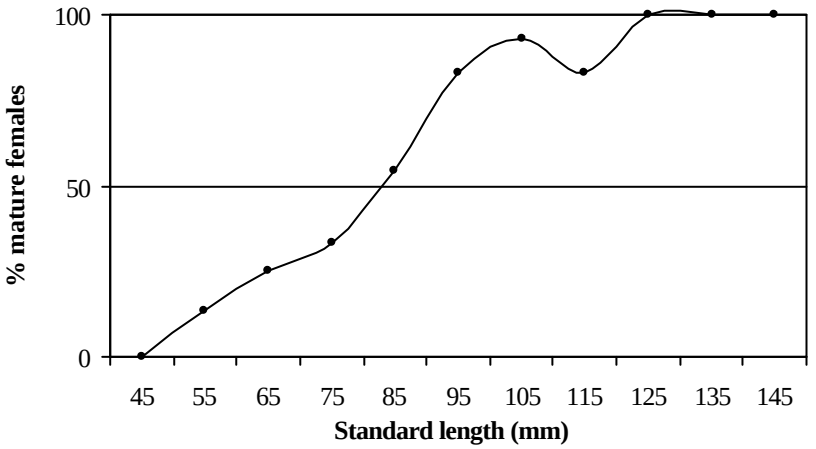


Figure 20-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Lethrinops 'deep water albus'* in the SWA.

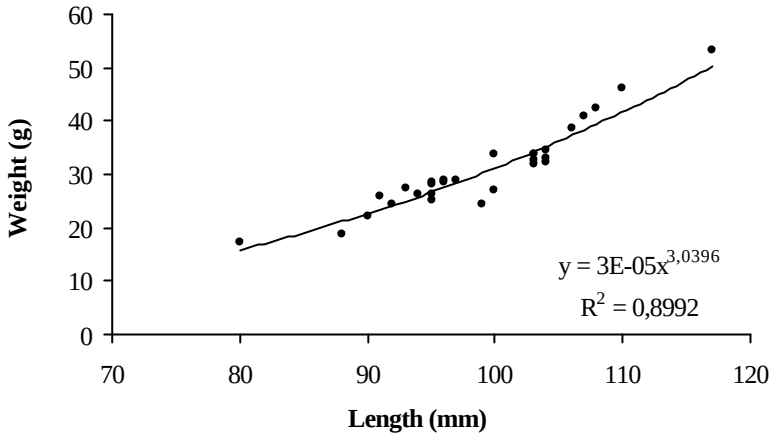


Figure 20-5. Length-weight relationship for *Lethrinops 'deep water albus'* females in the SWA. (R^2 = determination coefficient).

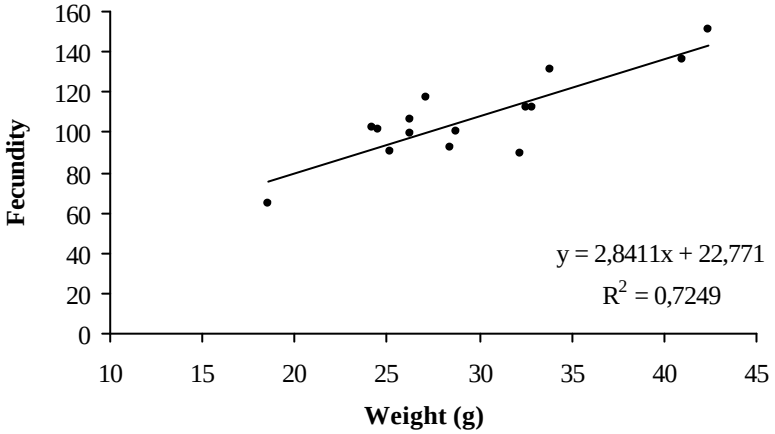


Figure 20-6. Fecundity-weight relationship for *Lethrinops 'deep water albus'* females in the SWA. (R^2 = determination coefficient).

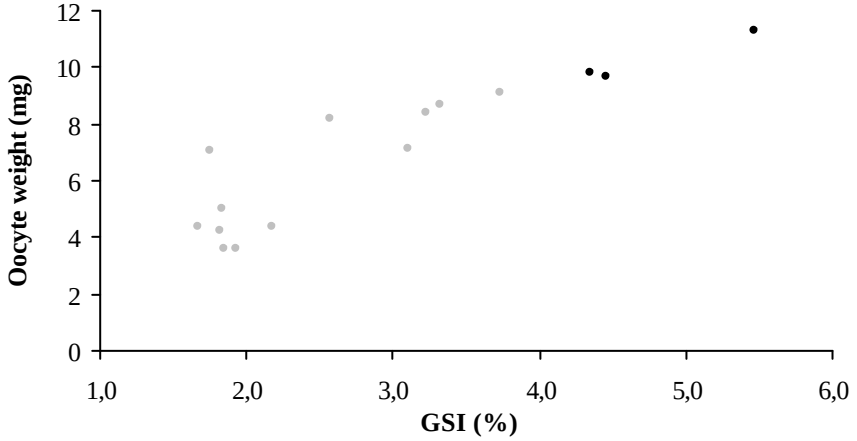


Figure 20-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Lethrinops 'deep water albus'* Oocytes from females whose GSI was below (in grey) and above (in black with regression) 4%. (R^2 = determination coefficient).

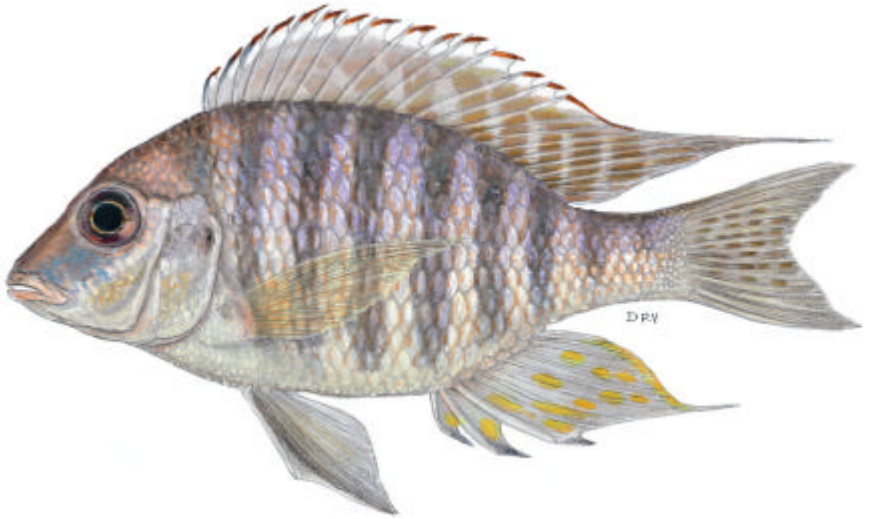


Plate 12. *Lethrinops 'deep water altus'* (by Dave Voorvelt).

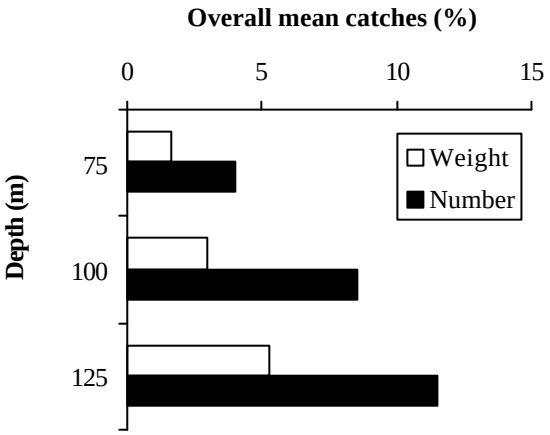


Figure 21-1. Mean occurrence and abundance in the catches per depth of *Lethrinops 'deep water altus'* in the SWA between July 1998 and May 1999.

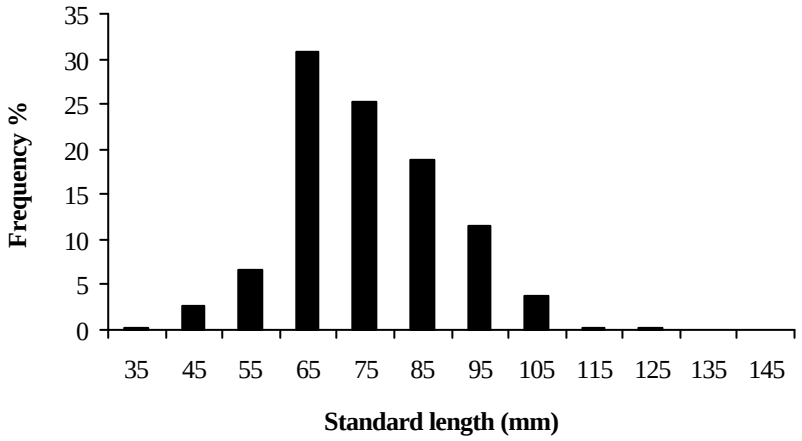


Figure 21-2. Size range and frequencies of *Lethrinops 'deep water altus'* caught in the SWA between July 1998 and May 1999.

Lethrinops 'deep water altus' **(Plate 12)**

625 females and 885 males were analysed. *L. 'deep water altus*' was an abundant species of the deep and very deep zones, increasing in occurrence and biomass with depth from 75 to 125 m to reach 5.3 and 11.5% of the catches in weight and number, respectively (Figure 21-1). The mean CPUE per depth category was 8.6 and 3.3 kg in the deep and very deep zones, respectively. No reference was made to this species in Tómasson & Banda (1996). Specimens caught ranged between 35 and 130 mm with a mode from 60 to 100 mm (Figure 21-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

Breeding season occurred between December and August-September with a peak of activity from February to June and a cessation in October-November confirmed by the lower percentage of active males during this period (Figure 21-3a and b). Ripe females and immature individuals were evenly distributed between 75 and 125 m, whereas about 60% of the males in breeding colour were caught at 125 m, suggesting that spawning could occur mostly at this depth (Table 21-1). The mean size at maturity for females was about 60 mm (Figure 21-4), which corresponded to a mean age at maturity of 11 months.

Table 21-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Lethrinops 'deep water altus*' in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	14.2	29.5	12.6	11.5	23.5
100 m	46.2	34.7	37.1	31.3	37.3
125 m	39.7	35.8	50.3	57.2	39.2

The length-weight and fecundity-weight relationships are presented in Figure 21-5 and 21-6, respectively. Fecundity ranged from 10 to 84 for females weighing between 5 and 19 g and was not correlated with body weight. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 21-7). The mean oocyte weight was 8.08 mg (± 2.32 SD, N= 34).

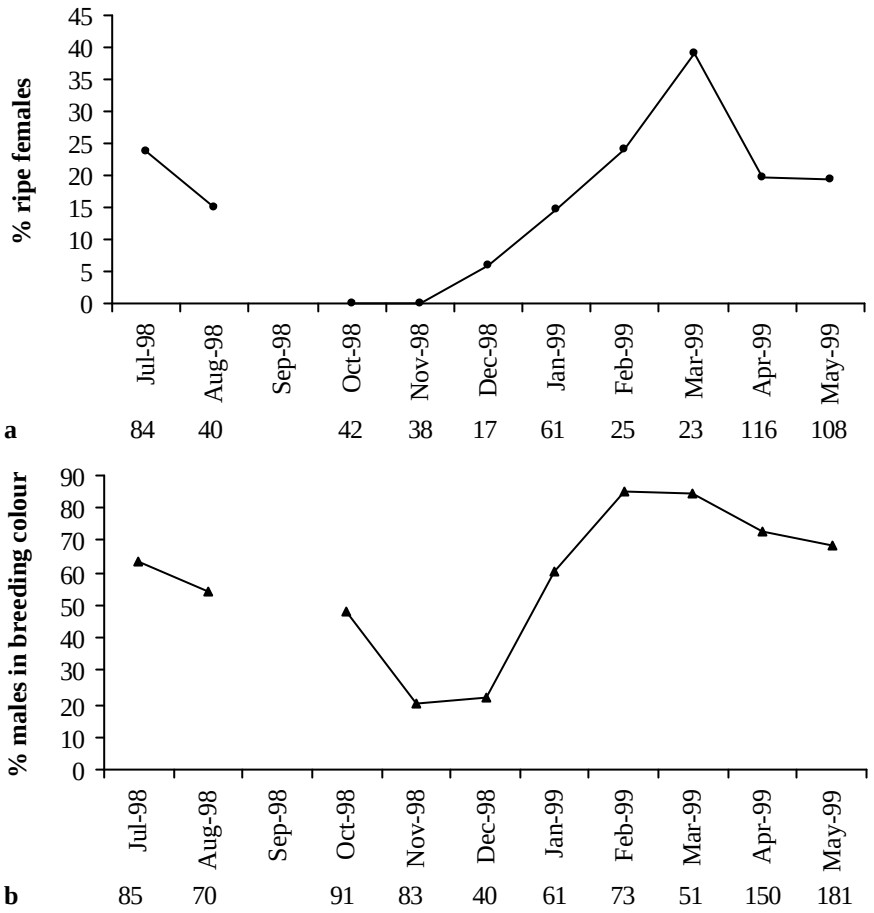


Figure 21-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Lethrinops 'deep water altus'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

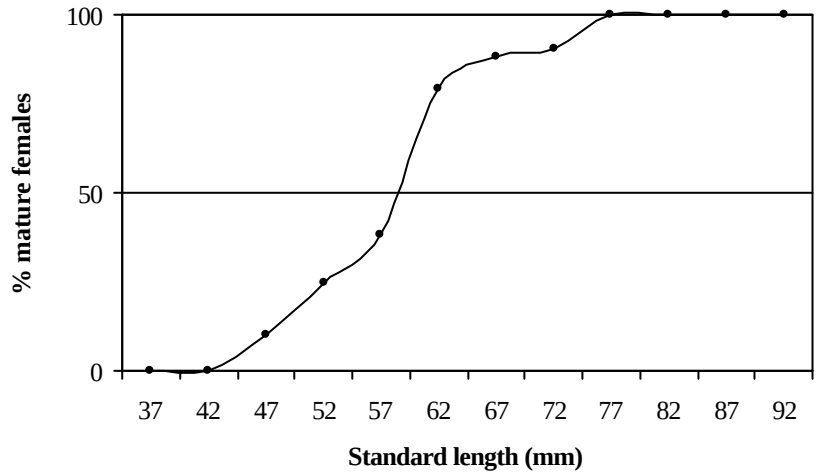


Figure 21-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Lethrinops 'deep water altus'* in the SWA.

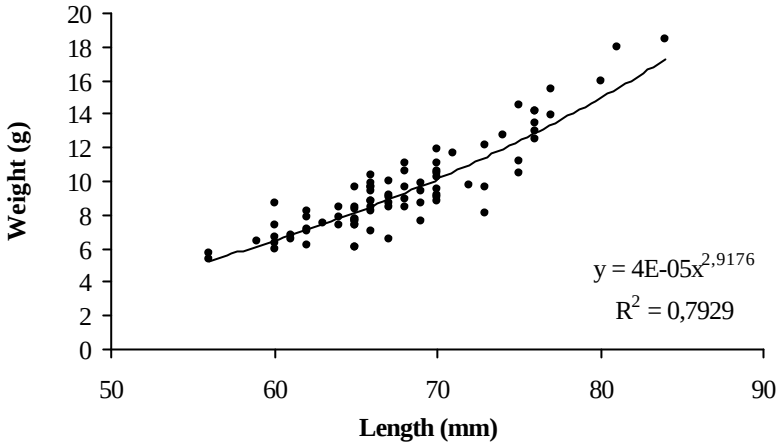


Figure 21-5. Length-weight relationship for *Lethrinops 'deep water altus'* females in the SWA. (R^2 = determination coefficient).

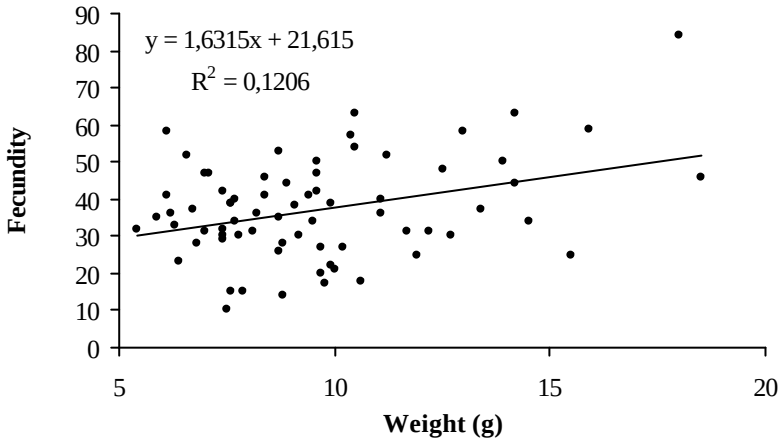


Figure 21-6. Fecundity-weight relationship for *Lethrinops 'deep water altus'* females in the SWA. (R^2 = determination coefficient).

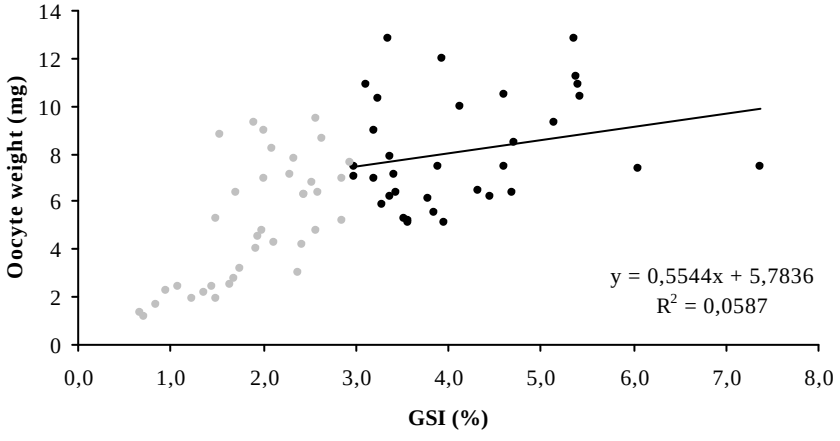


Figure 21-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Lethrinops 'deep water altus'* Oocytes from females whose GSI was below (in grey) and above (in black with regression) 4%. (R^2 = determination coefficient).

Plate 13. Lethrinops gossei (by Dave Voorvelt).

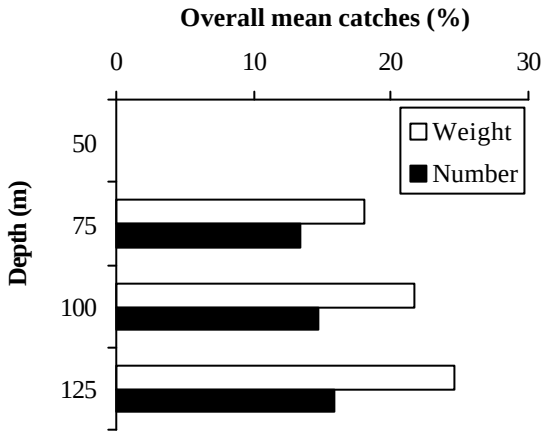


Figure 22-1. Mean occurrence and abundance in the catches per depth of *Lethrinops gossei* in the SWA between July 1998 and May 1999.

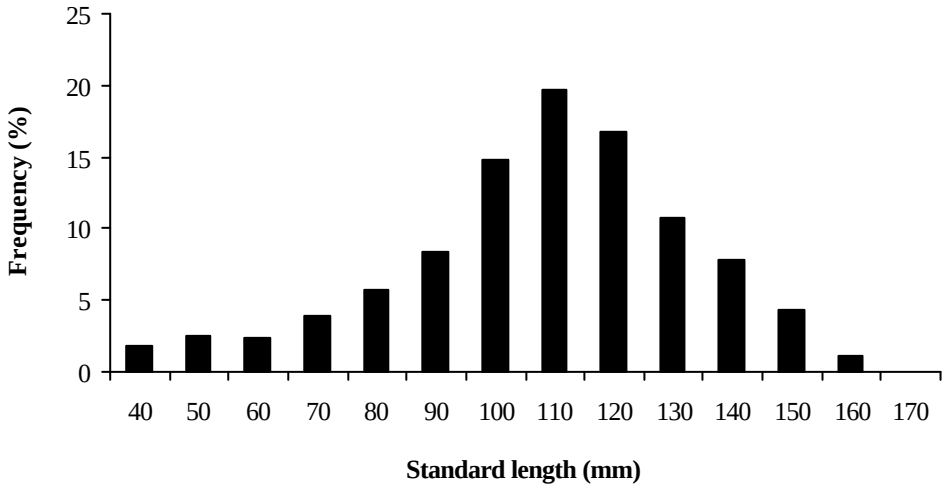


Figure 22-2. Size range and frequencies of *Lethrinops gossei* caught in the SWA between July 1998 and May 1999.

Lethrinops gossei (Burgess & Axelrod) (Plate 13)

3513 females and 3425 males were analysed. *L. gossei* was caught from 50 to 125 m, becoming very abundant form 75 m downwards (Figure 22-1). It was a dominant species of the deep and very deep zones, where it constituted between 13 and 16% of the catches in number and between 18 and 25% in weight. The mean CPUE per depth category was 0.3, 108 and 51.6 kg for the shallow, deep and very deep zones, respectively. Except for the very deep zone, this was very different from the values reported in Tómasson & Banda (1996), who caught much more *L. gossei* per time unit in the shallows (21.6 kg) and about two times less in the deep zone (61.9 kg). Specimens caught ranged between 35 and 170 mm with a mode from 95 to 135 mm (Figure 22-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Breeding season occurred between November and August with a peak of activity from January to March-April and a stop in September-October (Figure 22-3a). It was one of the rare species for which the profile of the percentage of ripe males followed exactly the female's one (Figure 22-3b). The breeding season we observed corresponded relatively well to that found by Lewis & Tweddle (1990), who reported a decline in October-November and a peak in March for the period 1983-85. Ripe females and males were evenly distributed between 75 and 125 m (Table 22-1), as were the aggregations of males in breeding colour (between 100 and 200 specimens), suggesting that spawning probably takes place at all three depths. The mean size at maturity for females was about 92 mm (Figure 22-4), which is much less than the 147 mm TL estimated by Lewis & Tweddle (1990). This corresponded to a mean age at maturity of 11 months.

Table 22-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Lethrinops gossei* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
50 m	0	0	0.1	0.1	0.2
75 m	33.5	42.1	28	27.8	44
100 m	26.9	36.8	39.3	37.8	36.4
125 m	39.6	21.1	32.6	34.3	19.4

The length-weight and fecundity-weight relationships are presented in Figure 22-5 and 22-6, respectively. Fecundity ranged from 23 to 234 for females weighing between 10 and 109 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 4% (Figure 22-7). The mean oocyte weight was 21.34 mg (± 4.34 SD, N= 190). A GSI of 12.4% was recorded for a *L. gossei* female (Figure 22-7), which was the highest GSI calculated on any cichlid species during the course of this study.

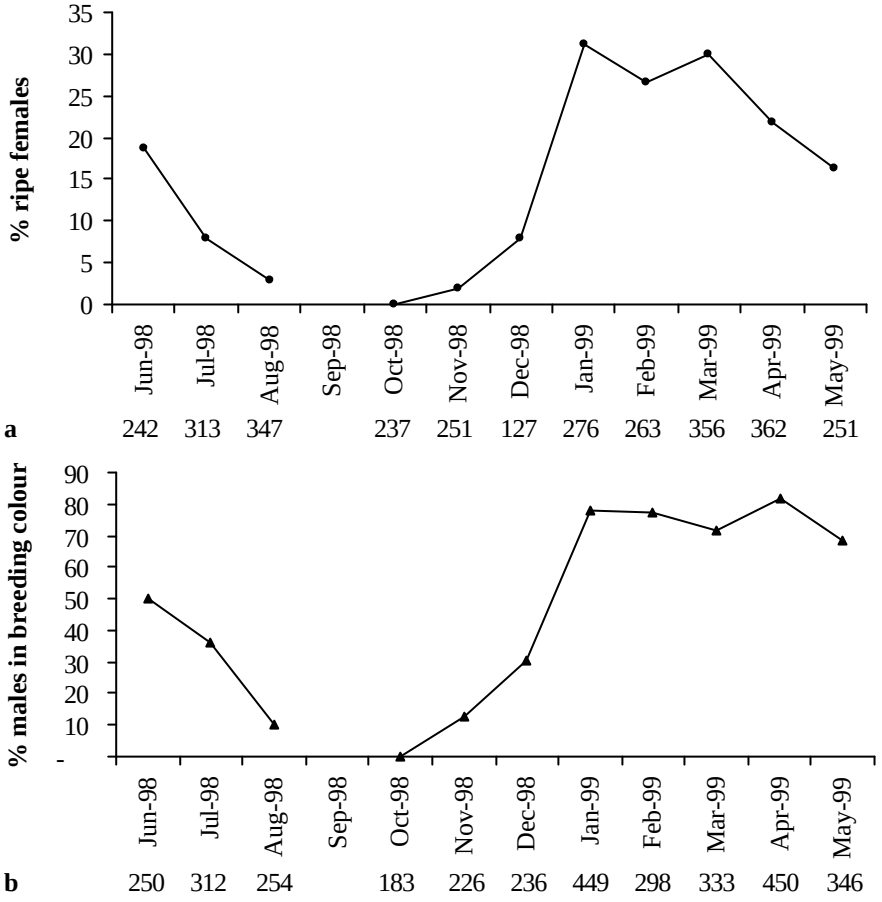


Figure 22-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Lethrinops gossei* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

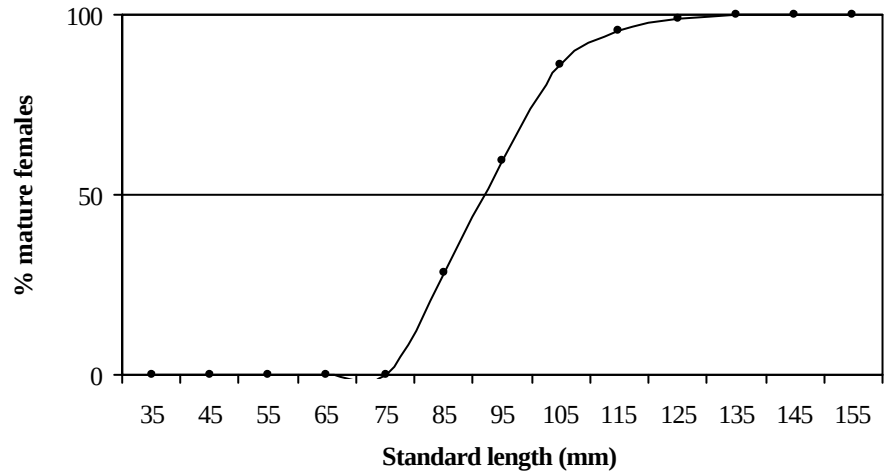


Figure 22-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Lethrinops gossei* in the SWA.

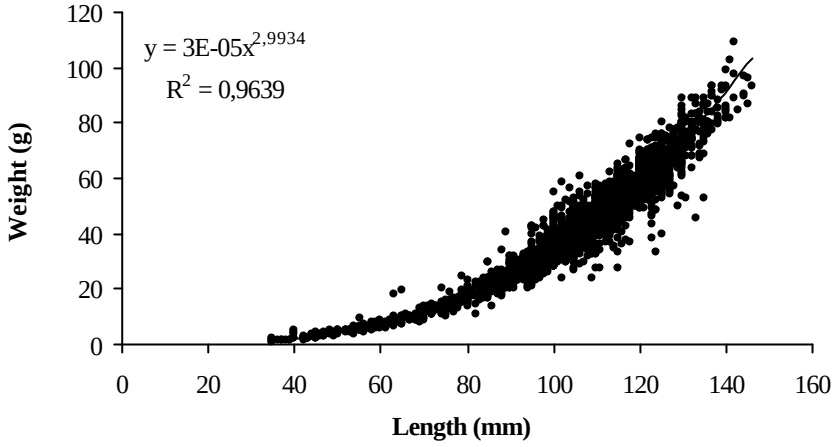


Figure 22-5. Length-weight relationship for *Lethrinops gossei* females in the SWA. (R^2 = determination coefficient).

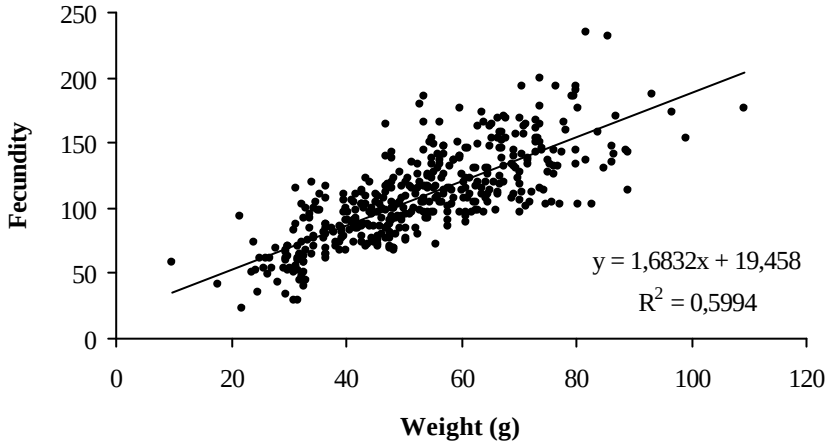


Figure 22-6. Fecundity-weight relationship for *Lethrinops gossei* females in the SWA. (R^2 = determination coefficient).

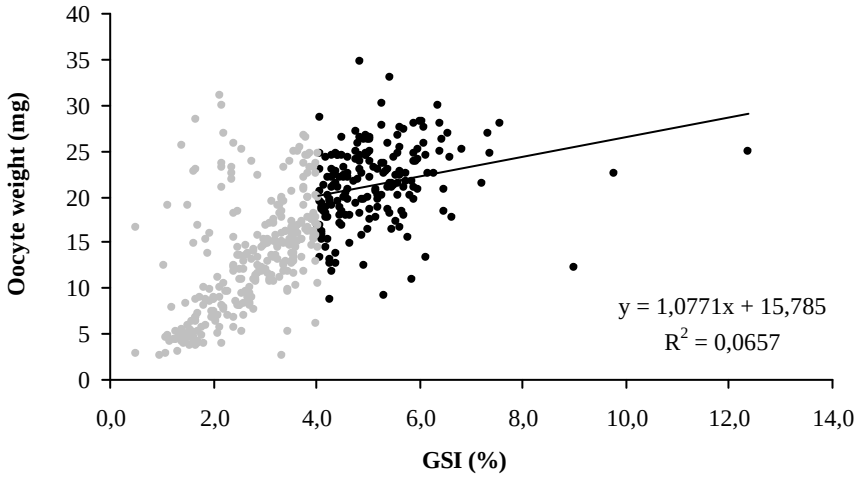


Figure 22-7. Relationship between oocyte weight and gonado-somatic index (GSI) for Lethrinops gossei. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 4%. (R^2 = determination coefficient).

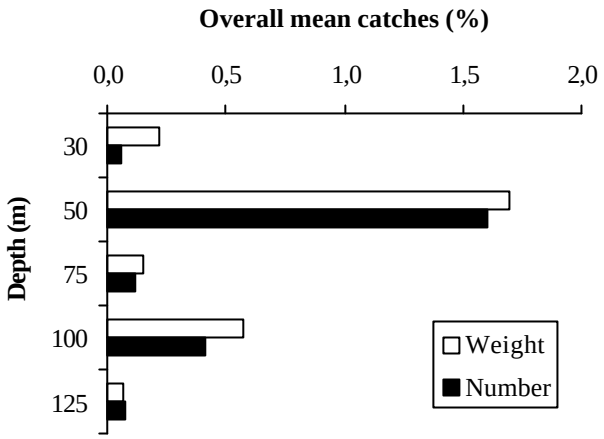


Figure 23-1. Mean occurrence and abundance in the catches per depth of *Lethrinops longimanus* in the SWA between July 1998 and May 1999.

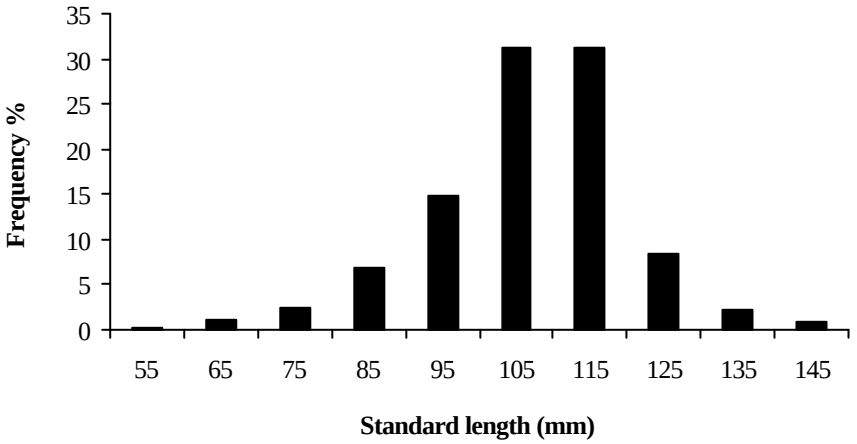


Figure 23-2. Size range and frequencies of *Lethrinops longimanus* caught in the SWA between July 1998 and May 1999.

Lethrinops longimanus (Trewavas)

210 females and 154 males were analysed. *L. longimanus* was caught from 30 to 125 m (Figure 23-1). It was a relatively rare fish averaging less than 1% of the catches at all depths except at 50 m where it made up to 1.6 and 1.7% in number and weight, respectively. The mean CPUE per depth category 11.7, 2 and 0.15 kg for the shallow, deep and very deep zones, respectively, were much lower than those reported by Tómasson & Banda (1996) (18.9, 23.1 and 3.7 kg, respectively). Specimens caught ranged between 56 and 147 mm with a mode from 100 to 120 mm (Figure 23-2). The sex ratio observed over the full sampling period was F/M 0.6/0.4.

Owing to low sample size at some months and bw number of ripe females caught, determination of precise breeding season was impossible. What can be said from the few data available is that breeding probably did not take place during the period from November to February when sample size were correct (Figure 23-3a). The only significant proportion of ripe females was found in August 98, and taking into account the data for males (Figure 23-3b), it might be hypothesised that breeding season occur from May-June to August-September. All the ripe females and 70% of the ripe males were found at 50m, suggesting that spawning might occur at this depth. However, most specimens of *L. longimanus* were caught at 50 m and this trend might reflect nothing more than the depth of occurrence. The mean size at maturity for females was about 107 mm, which was probably overestimated given that this estimation was done with all the data available for females, including females caught outside the breeding season (Figure 23-4). This corresponded to a mean age at maturity of 18 months, hence also probably overestimated.

Owing to the very narrow size range of females measured, it was impossible to assess the length-weight relationship. The fecundity-weight relationship is presented in Figure 23-5. Fecundity ranged from 57 to 99 for females weighing between 35 and 47 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was estimated at about 4% (Figure 23-6). The mean oocyte weight was 14.88 mg (± 1.97 SD, N= 4).

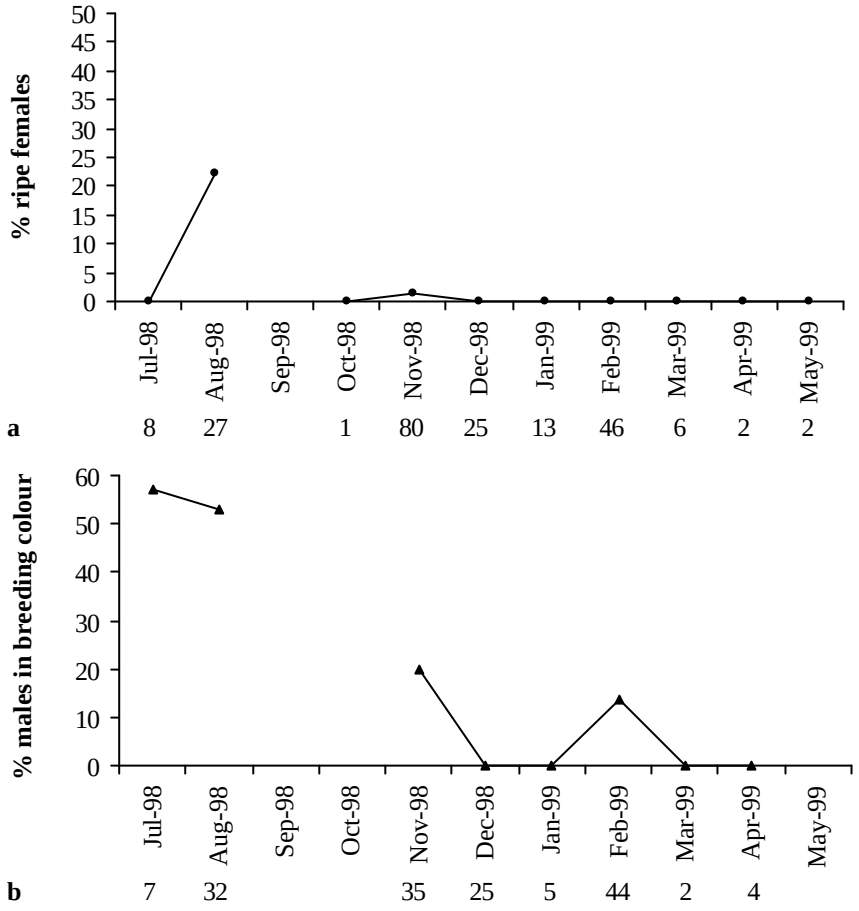


Figure 23-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Lethrinops longimanus* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

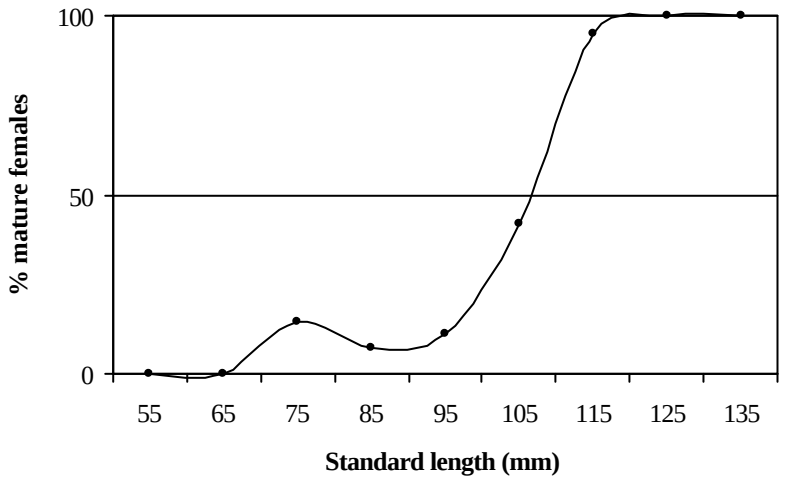


Figure 23-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Lethrinops longimanus* in the SWA.

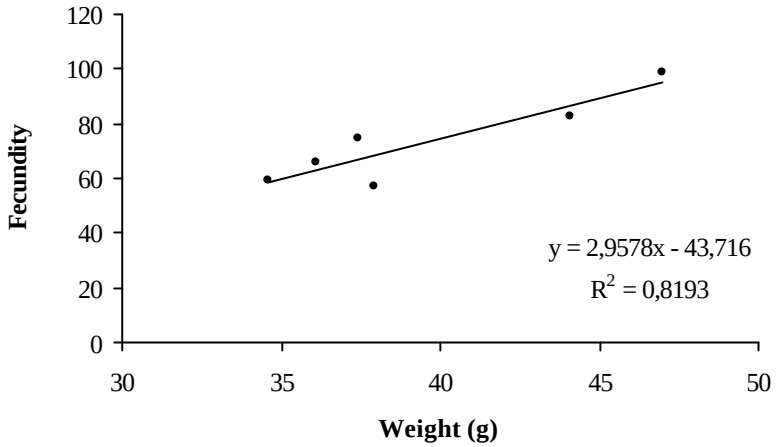


Figure 23-5. Fecundity-weight relationship for *Lethrinops longimanus* females in the SWA. (R^2 = determination coefficient).

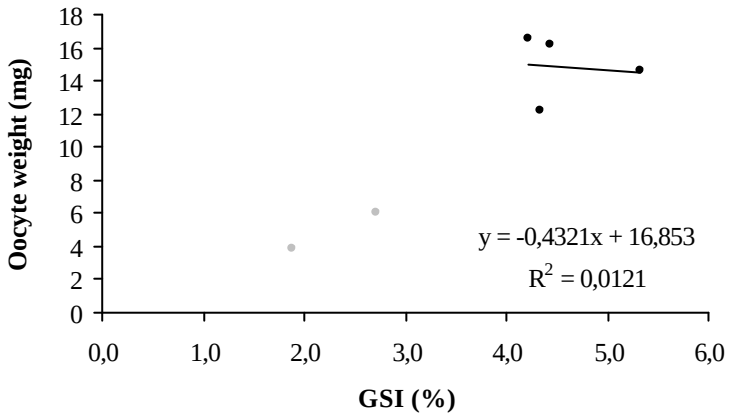


Figure 23-6. Relationship between oocyte weight and gonado-somatic index (GSI) for *Lethrinops longimanus*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 4%. (R^2 = determination coefficient).

Lethrinops macrochir (Regan)

L. macrochir is a rare species caught only at 10 m. It was usually absent from the catches, except for November to February and once in August. 42 females and 89 males were analysed, giving a sex ratio of F/M 0.3/0.7. Specimens caught ranged from 59 to 150 mm (**Figure 24-1**).

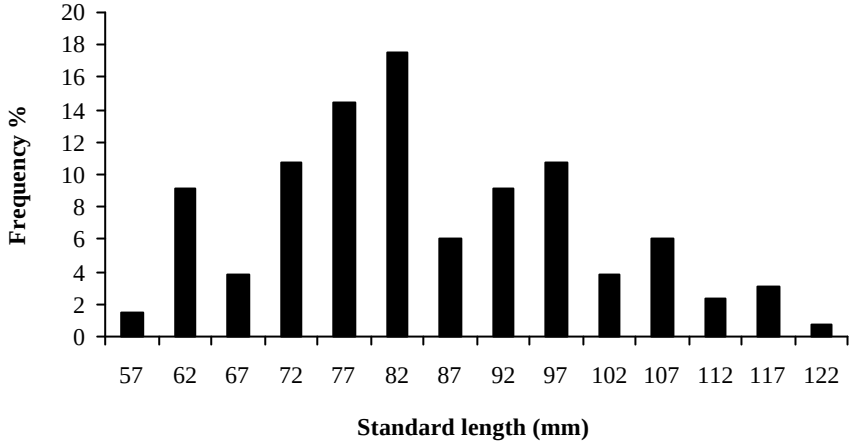


Figure 24-1. Size range and frequencies of *Lethrinops macrochir* caught in the SWA between July 1998 and May 1999.

Among the rare species, *L. macrochir* was one for which we caught some ripe females, allowing an estimation of the fecundity-weight relationship (**Figure 24-2**) and oocyte weight (for females whose GSI was above 4%, which is the maximum encountered for the genus): 11.87 mg (± 0.97 SD, N= 2).

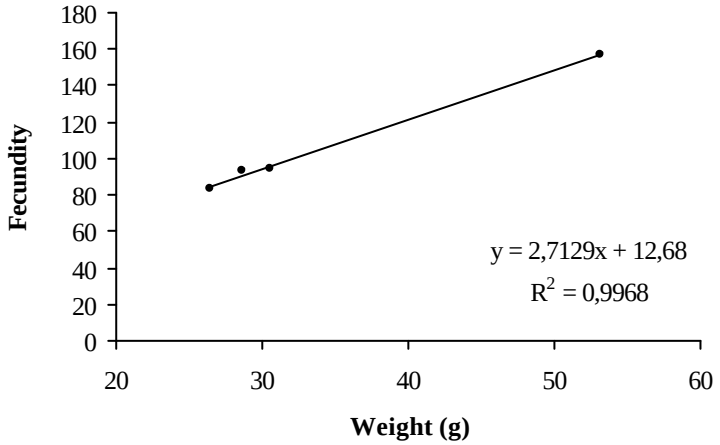


Figure 24-2. Fecundity-weight relationship for *Lethrinops macrochir* females in the SWA. (R^2 = determination coefficient).

Plate 14. *Lethrinops 'oliveri'* (by Dave Voorvelt).

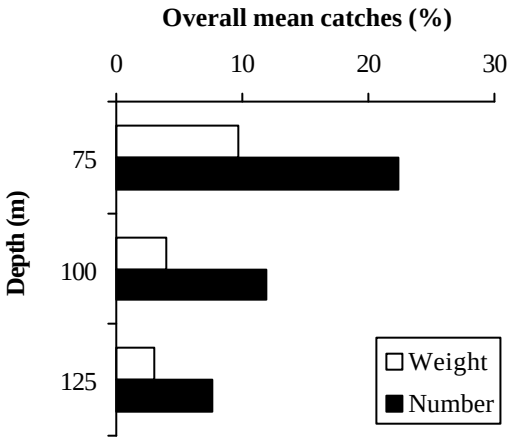


Figure 25-1. Mean occurrence and abundance in the catches per depth of *Lethrinops 'oliveri'* in the SWA between July 1998 and May 1999.

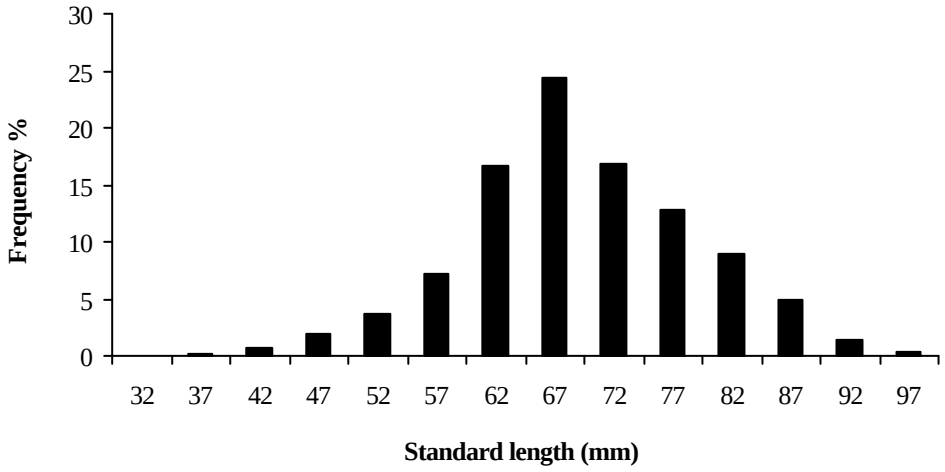


Figure 25-2. Size range and frequencies of *Lethrinops 'oliveri'* caught in the SWA between July 1998 and May 1999.

Lethrinops 'oliveri' (Plate 14)

875 females and 1017 males were analysed. *L. 'oliveri'* was caught between 75 and 125 m, with a decreasing occurrence and biomass with depth (Figure 25-1). It was a dominant species of the deep and very deep zones, constituting between 3 and 10% of the catches in number and between 8 and 22% in weight. The mean CPUE per depth category, 39.8 and 5.4 kg for the deep and very deep zones, respectively, matched the value reported by Tómasson & Banda (1996) for the deep zone (36.7 kg), but was about three times less for the very deep zone (16.7 kg). The depth distribution observed in our study was more restricted than that of Tómasson & Banda (1996), who reported *L. 'oliveri'* from 20 to 150 m. Specimens caught ranged between 33 and 98 mm (Figure 25-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Breeding occurred throughout the year with a trough from October to December and a peak of activity from February to April (Figure 25-3a). As for *L. gossei*, the profile of the percentage of ripe males followed exactly the female's one (Figure 25-3b). Ripe females and males were most abundant at 75 m, suggesting that spawning could occur mainly at this depth (Table 25-1). The mean size at maturity for females was about 60 mm (Figure 25-4), which corresponded to a mean age at maturity of 11 months.

Table 25-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Lethrinops 'oliveri'* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	45.3	46.5	37.2	67.7	43.5
100 m	38.3	31.6	38.1	27.3	36.6
125 m	16.3	21.9	24.7	5.1	19.9

The length-weight and fecundity-weight relationships are presented in Figure 25-5 and 25-6, respectively. Fecundity ranged from 19 to 81 for females weighing between 4 and 16 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 25-7). The mean oocyte weight was 7.21 mg (± 1.61 SD, N= 45).

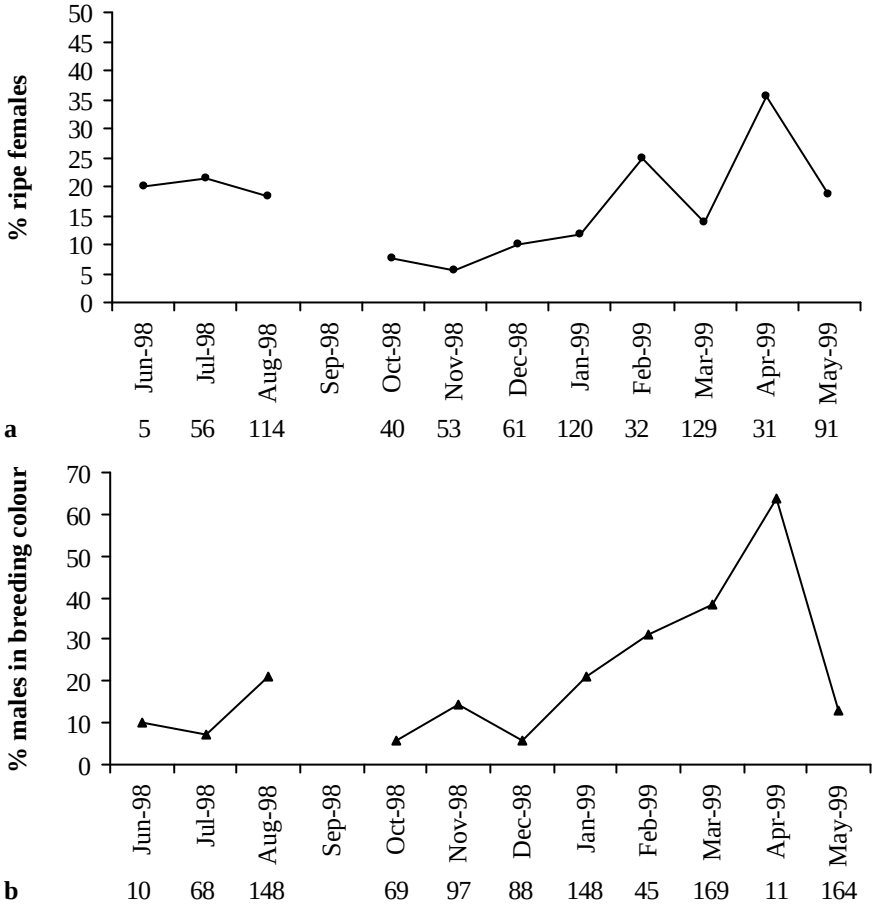


Figure 25-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Lethrinops 'oliveri'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

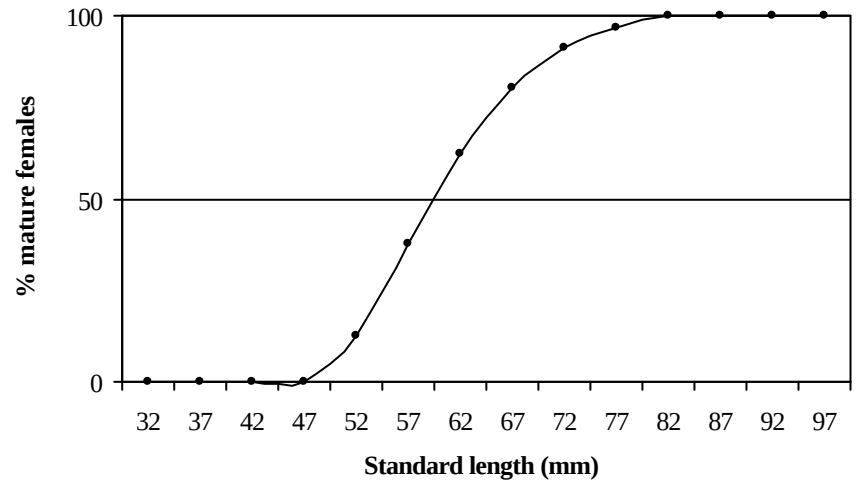


Figure 25-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Lethrinops 'oliveri'* in the SWA.

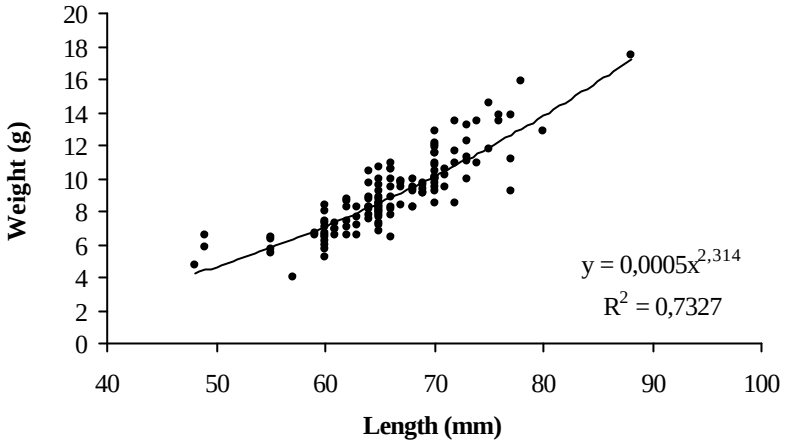


Figure 25-5. Length-weight relationship for *Lethrinops 'oliveri'* females in the SWA. (R^2 = determination coefficient).

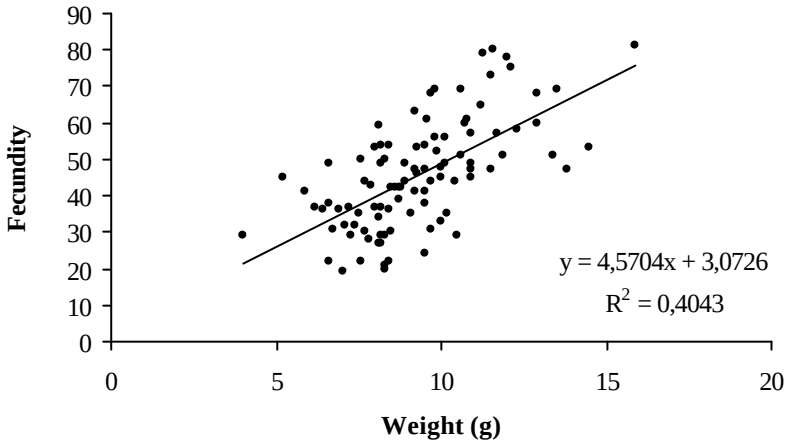


Figure 25-6. Fecundity-weight relationship for *Lethrinops 'oliveri'* females in the SWA. (R^2 = determination coefficient).

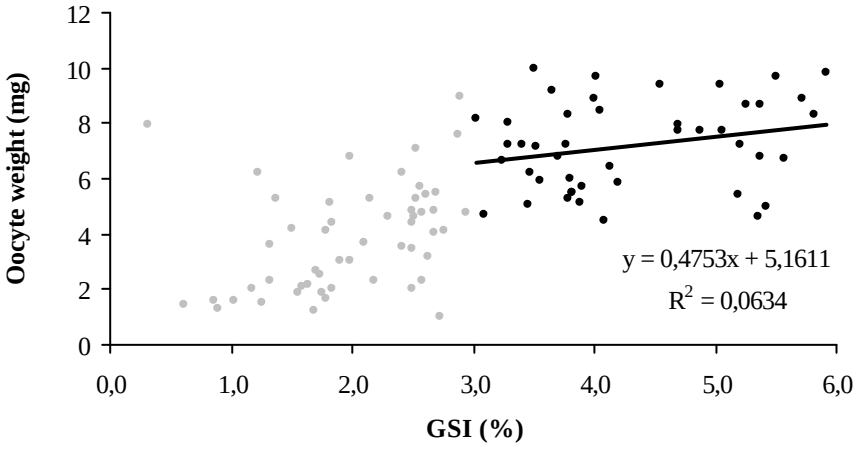


Figure 25-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Lethrinops 'oliveri'*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

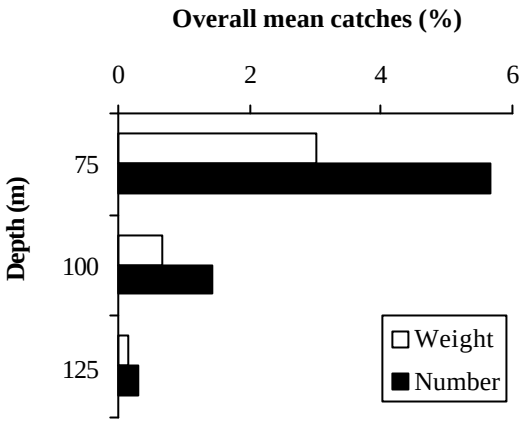


Figure 26-1. Mean occurrence and abundance in the catches per depth of *Lethrinops polli* in the SWA between July 1998 and May 1999.

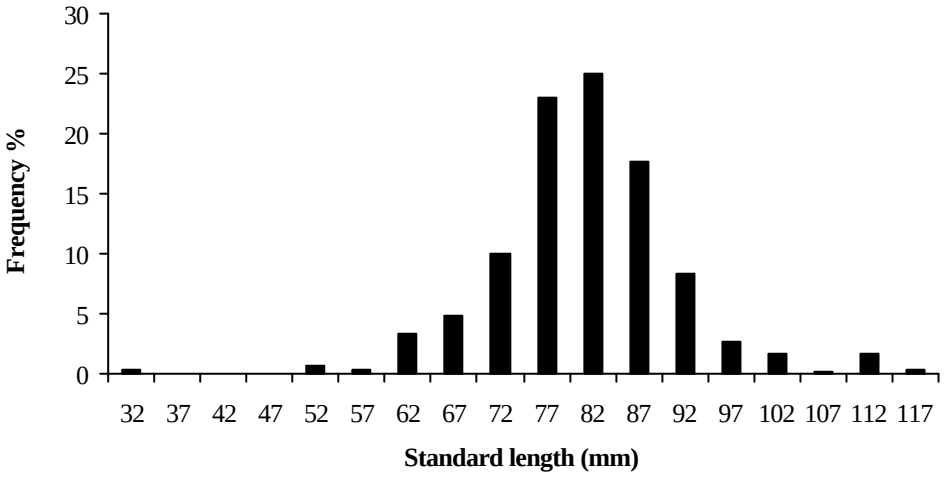


Figure 26-2. Size range and frequencies of *Lethrinops polli* caught in the SWA between July 1998 and May 1999.

Lethrinops polli (Burgess & Axelrod)

229 females and 198 males were analysed. *L. polli* was caught between 75 and 125 m, with a decreasing occurrence and biomass with depth (Figure 26-1). It was caught regularly in the deep and very deep zones, constituting between 0.1 and 3% of the catches in weight and between 0.3 and 5.6% in number. The mean CPUE per depth category, 12.3 and 0.3 kg for the deep and very deep zones, respectively, was about four times as much as the value reported by Tómasson & Banda (1996) for the deep zone (3 kg), and about seven times less for the very deep zone (2.2 kg). As for *L. 'oliveri'*, the depth distribution observed in our study was more restricted than that of Tómasson & Banda (1996), who reported *L. polli* from 10 to 140 m. Specimens caught ranged between 30 and 120 mm (Figure 26-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Breeding season occurred from May to August-September, with an isolated activity in December, in the middle of the resting period (Figure 26-3a). As for *L. gossei* and *L. 'oliveri'*, the profile of the percentage of ripe males followed exactly the female's one (Figure 26-3b). Ripe females and males were clearly most abundant at 75 m, suggesting that spawning could occur mainly at this depth (Table 26-1). The mean size at maturity for females was about 65 mm (Figure 26-4), which corresponded to a mean age at maturity of 10 months.

Table 26-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Lethrinops polli* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	68.9	76.3	50.4	85.5	83.3
100 m	28.9	21.1	41.1	10.1	5.6
125 m	2.1	2.6	8.5	4.3	11.1

The length-weight and fecundity-weight relationships are presented in Figure 26-5 and 26-6, respectively. Fecundity ranged from 11 to 89 for females weighing between 9 and 35 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 26-7). The mean oocyte weight was 12.26 mg (± 2.16 SD, N= 18).

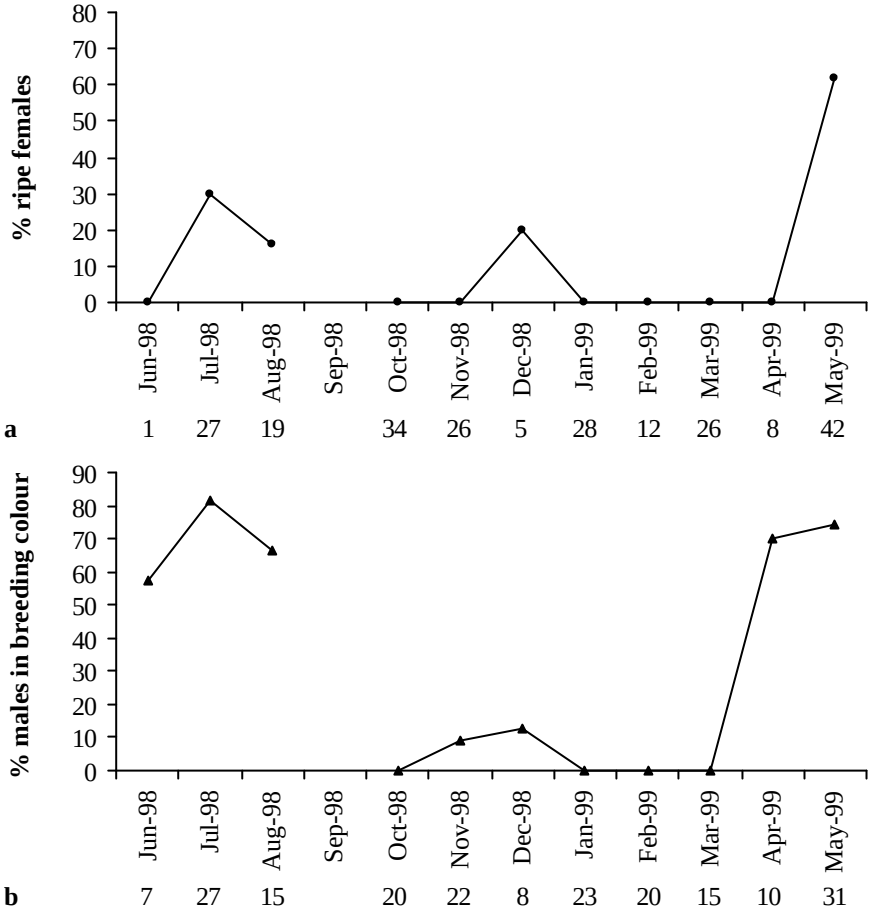


Figure 26-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Lethrinops polli* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

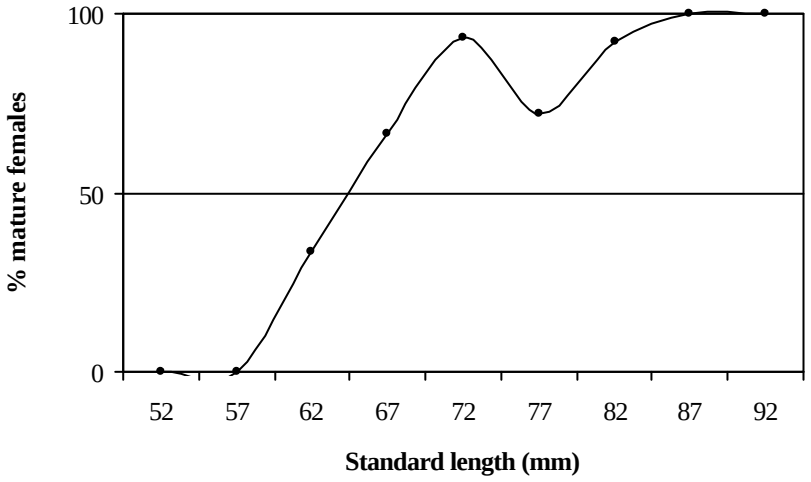


Figure 26-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Lethrinops polli* in the SWA.

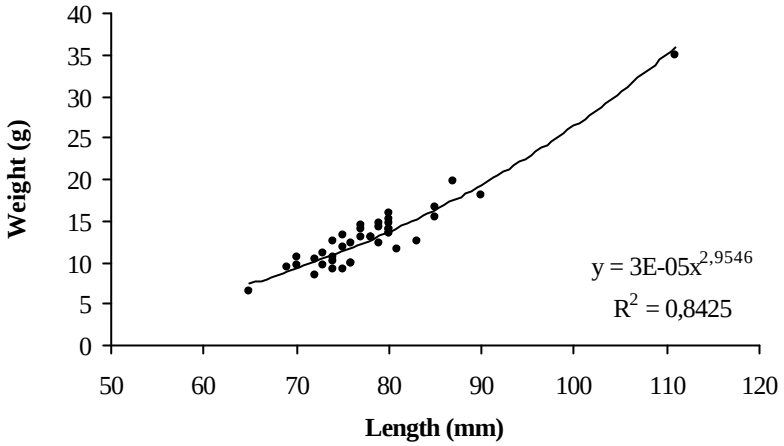


Figure 26-5. Length-weight relationship for *Lethrinops polli* females in the SWA. (R^2 = determination coefficient).

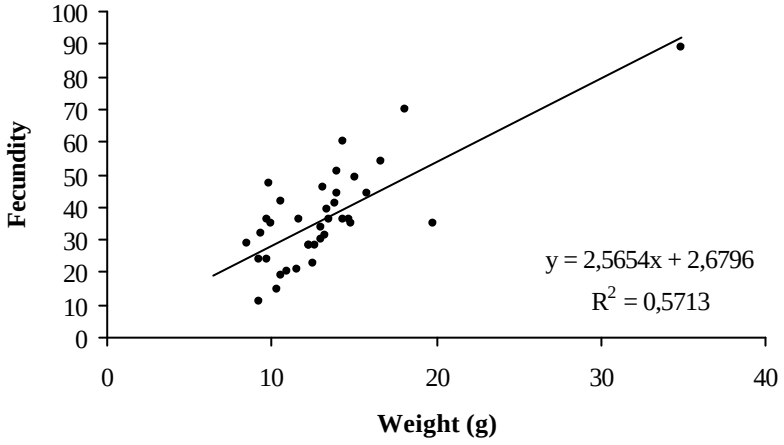


Figure 26-6. Fecundity-weight relationship for *Lethrinops polli* females in the SWA. (R^2 = determination coefficient).

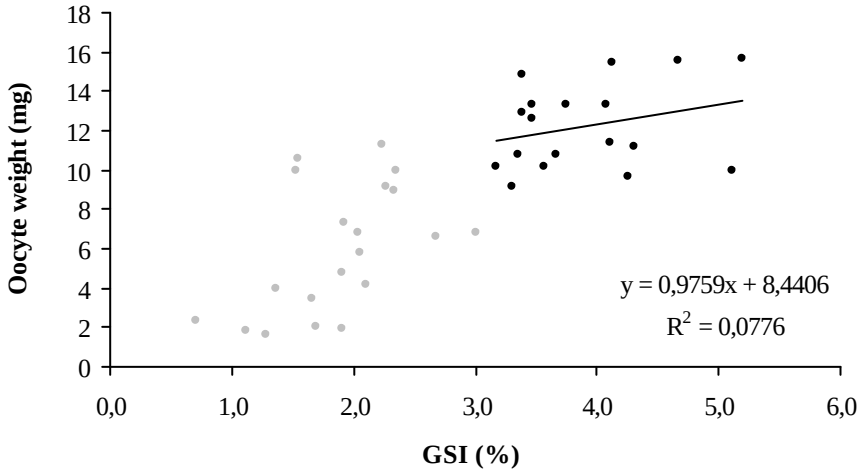


Figure 26-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Lethrinops polli.* Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

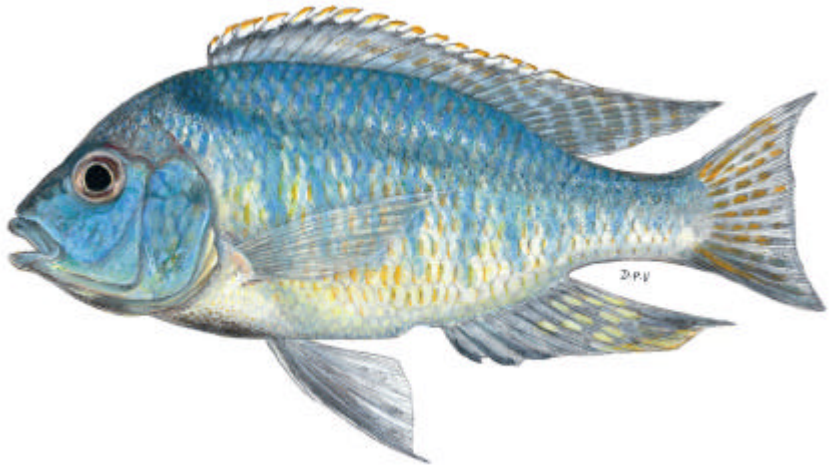


Plate 15. Mylochromis anaphyrmus (by Dave Voorvelt).

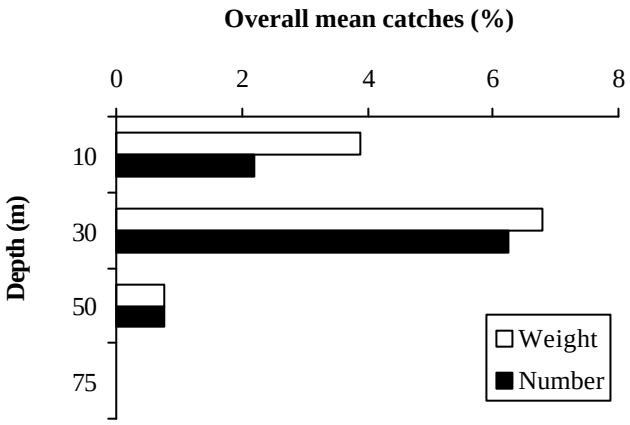


Figure 27-1. Mean occurrence and abundance in the catches per depth of *Mylochromis anaphyrmus* in the SWA between July 1998 and May 1999.

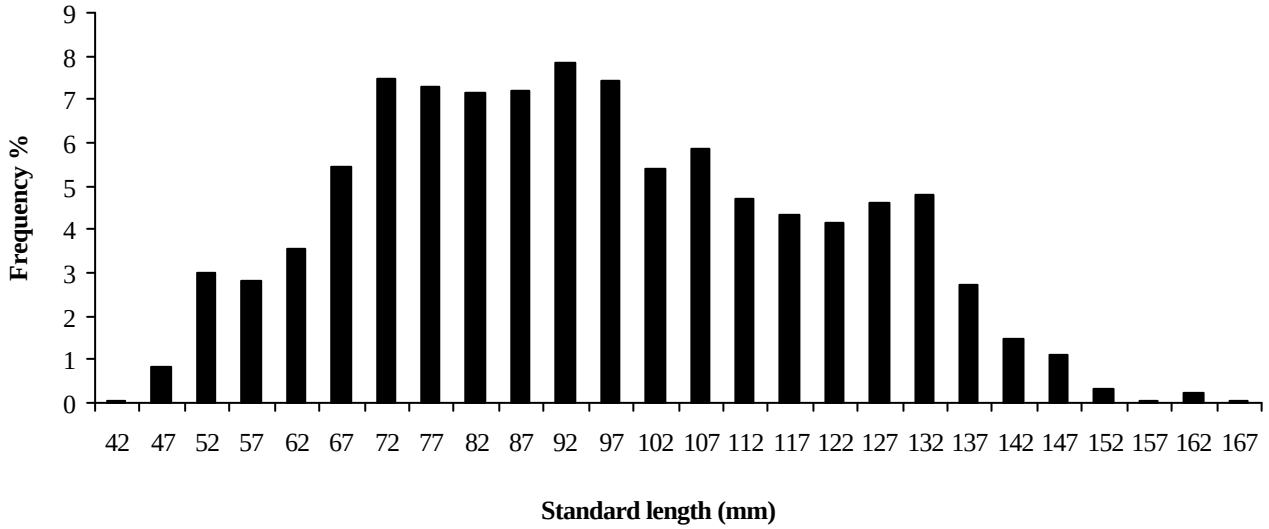


Figure 27-2. Size range and frequencies of *Mylochromis anaphyrmus* caught in the SWA between July 1998 and May 1999.

Mylochromis spp.

Mylochromis anaphyrmus (Burgess & Axelrod) (Plate 15)

1375 females and 1058 males were analysed. *M. anaphyrmus* was caught from 10 to 75 m, but mostly abundant at 10 and 30 m (Figure 27-1). Actually, a single specimen was caught at 75 m. It was a very common species in the shallow zone, constituting between 4 and 7% of the catches in weight and between 2 and 6% in number. The mean CPUE per depth category, 23.3 kg for the shallows, was more than twice as much as the value found by Tómasson & Banda (1996) (9.8 kg). The depth distribution they reported was very similar to the one we observed. Specimens caught ranged between 40 and 164 mm (Figure 27-2). The sex ratio observed over the full sampling period was F/M 0.6/0.4.

The breeding season was from January to October, with a peak between March and June, a steady decline in November, and ceasing in December (Figure 27-3a), even though occurrence of males in breeding colour was more erratic (Figure 27-3b). Ripe males and immature individuals were evenly distributed between 10 and 30 m (Table 27-1). However, as more than three quarters of the ripe females were found at 30 m, spawning probably occurs at 30 m. Maturity was reached early in their second year at 17 months old, at a mean size of 105 mm for females (Figure 27-4), which was less than the 160 mm TL (about 130 mm SL) and 3 years old reported by Tweddle & Turner (1977).

Table 27-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Mylochromis anaphyrmus* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	25.8	11.4	35.6	48.9	39.4
30 m	64.2	76.2	60.9	46.7	56.6
50 m	10	12.4	3.5	4.4	4.1

The length-weight and fecundity-weight relationships are presented in Figure 27-5 and 27-6, respectively. Fecundity ranged from 58 to 236 for females weighing between 21 and 98 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 27-7). The mean oocyte weight was 11.13 mg (± 1.93 SD, N= 21).

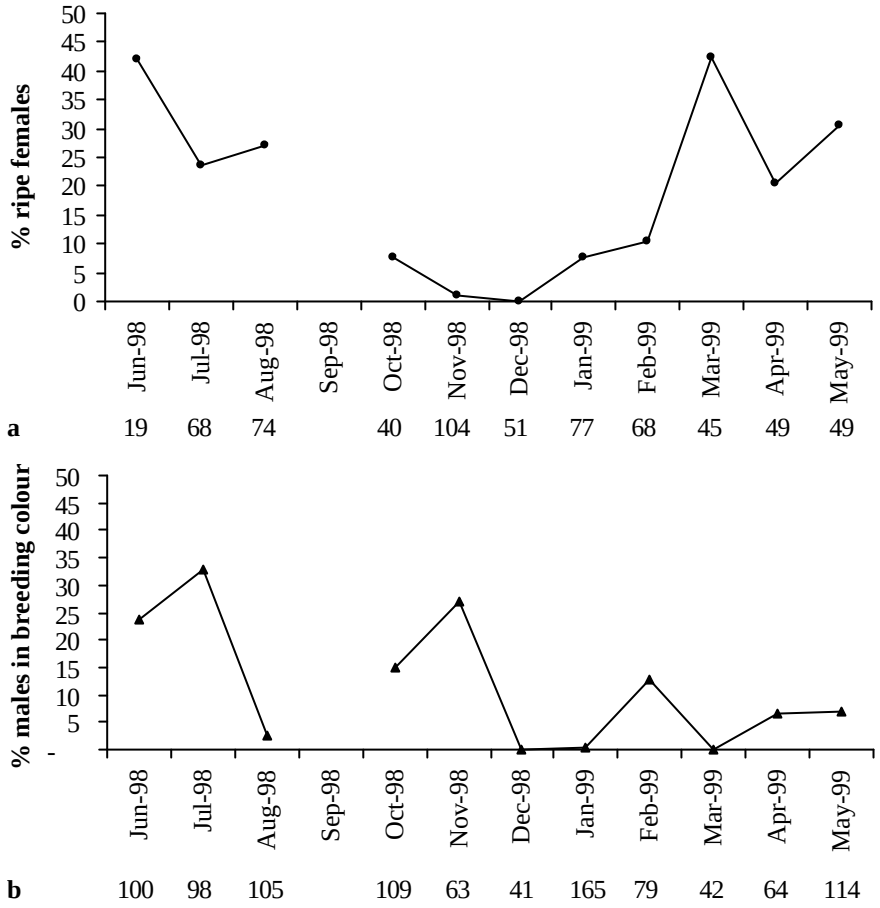


Figure 27-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Mylochromis anaphyrmus* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

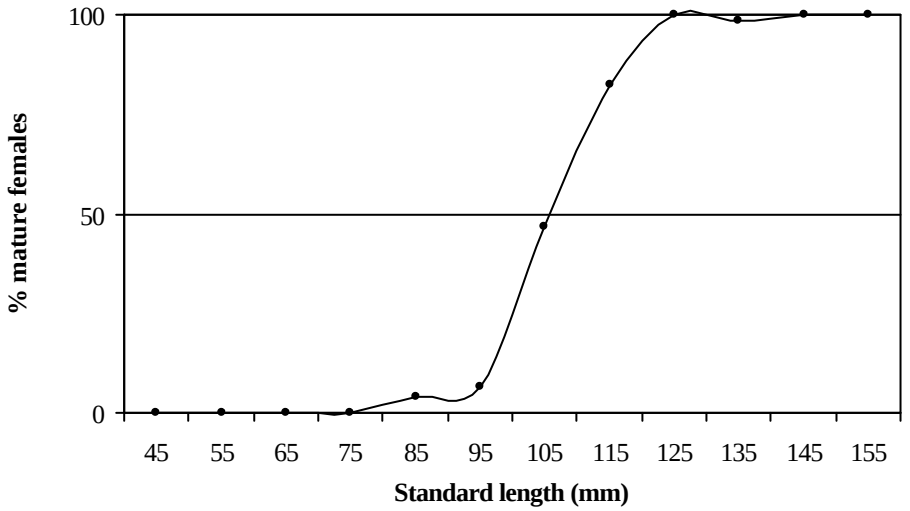


Figure 27-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Mylochromis anaphyrmus* in the SWA.

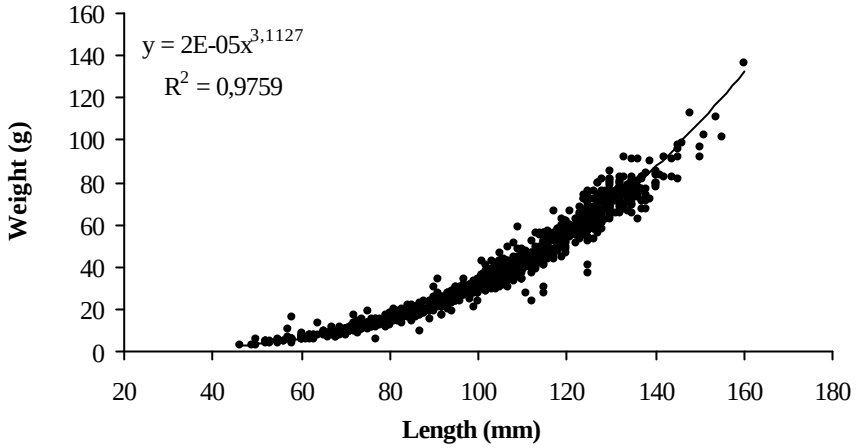


Figure 27-5. Length-weight relationship for *Mylochromis anaphyrmus* females in the SWA. (R^2 = determination coefficient).

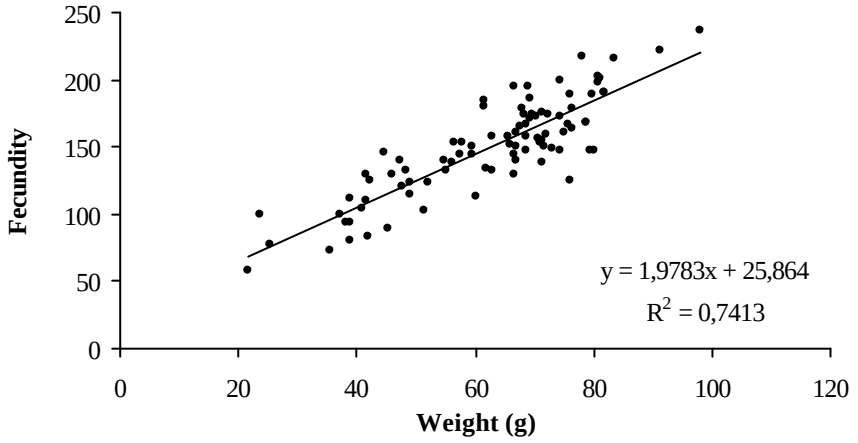


Figure 27-6. Fecundity-weight relationship for *Mylochromis anaphyrmus* females in the SWA. (R^2 = determination coefficient).

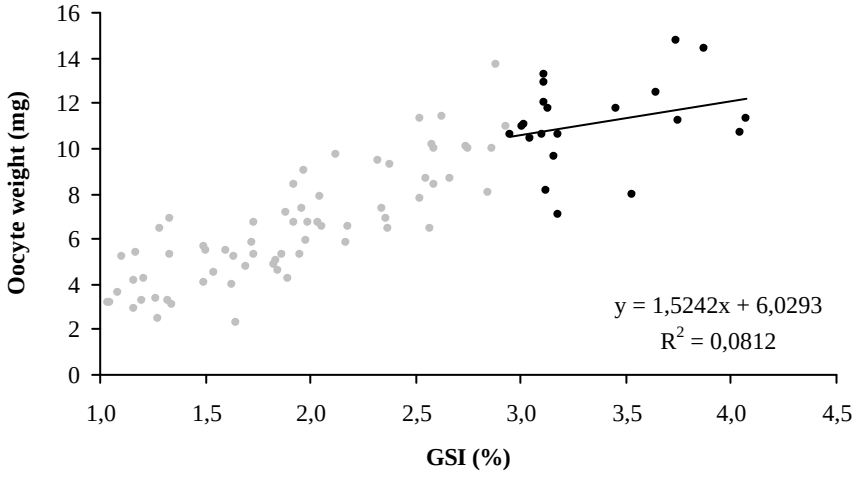


Figure 27-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Mylochromis anaphyrmus*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

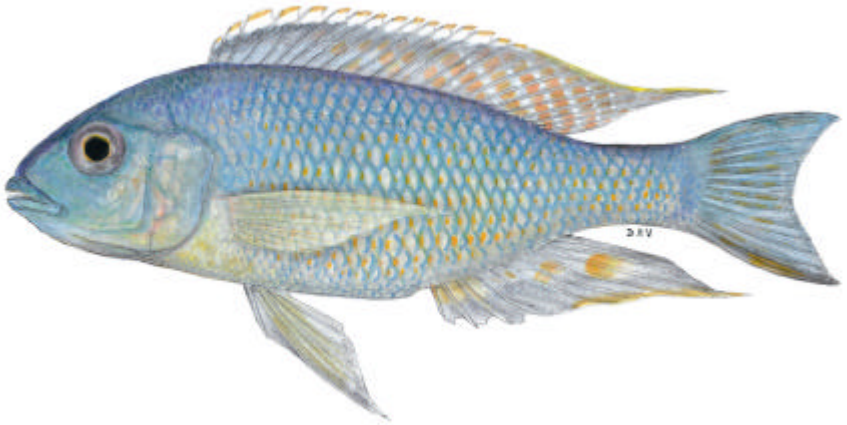


Plate 16. *Nyassachromis 'argyrosoma'* (by Dave Voorvelt).

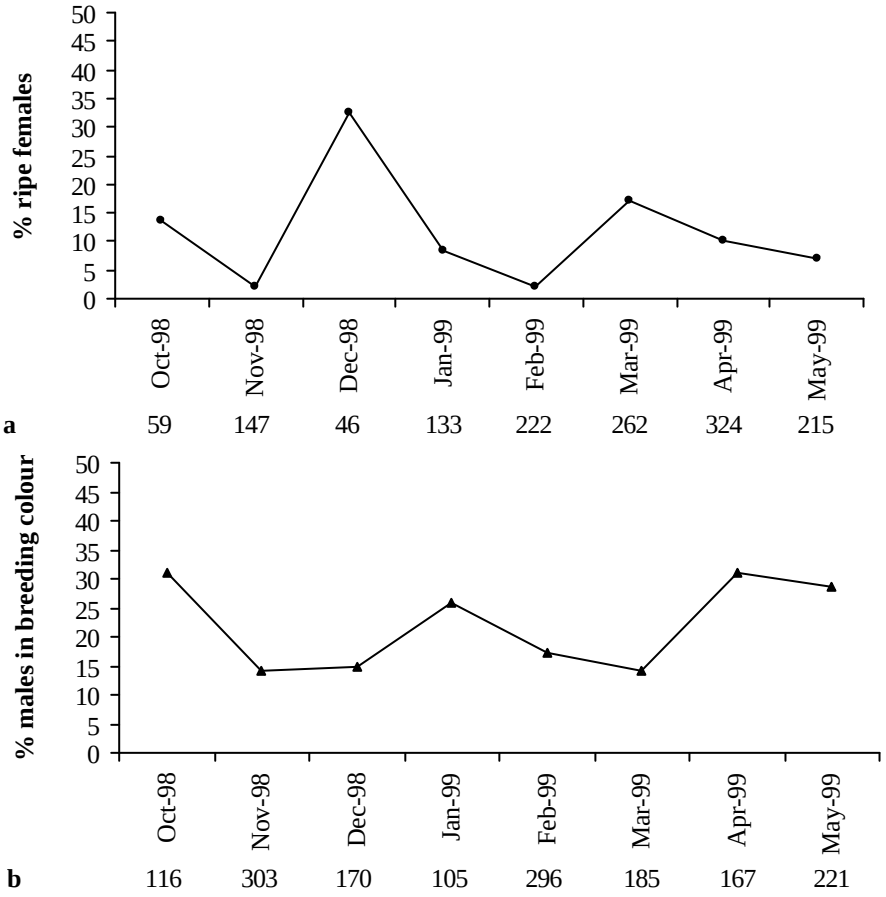


Figure 28-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Nyassachromis 'argyrosoma'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

Nyassachromis spp.

Nyassachromis 'argyrosoma' (Plate 16)

1440 females and 1563 males were analysed. *N. 'argyrosoma'* is a small species caught from 10 to 50 m, but was most abundant at 10 and 30 m (Figure 28-1).

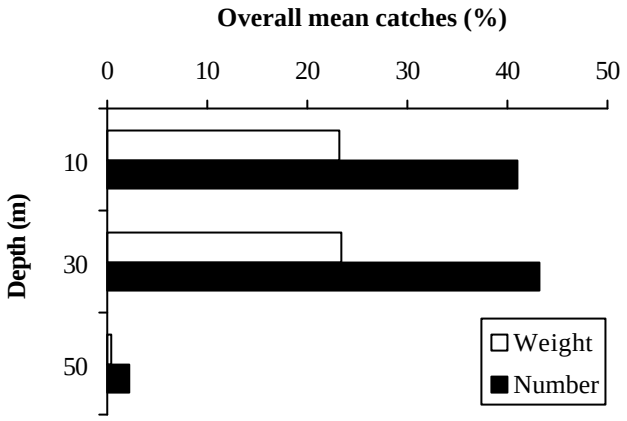


Figure 28-1. Mean occurrence and abundance in the catches per depth of *Nyassachromis 'argyrosoma'* in the SWA between July 1998 and May 1999.

With *Aulonocara 'blue orange'* and *Copadichromis virginalis*, *N. 'argyrosoma'* was a numerically dominant species in the shallow zone, constituting about 23% of the catches in weight, and 41 and 43% in number at 10 and 30 m, respectively. The mean CPUE per depth category was 91.8 kg for the shallows. No reference to this species (under this name at least) was made in Tómasson & Banda (1996). Specimens caught ranged between 38 and 97 mm (Figure 28-2).

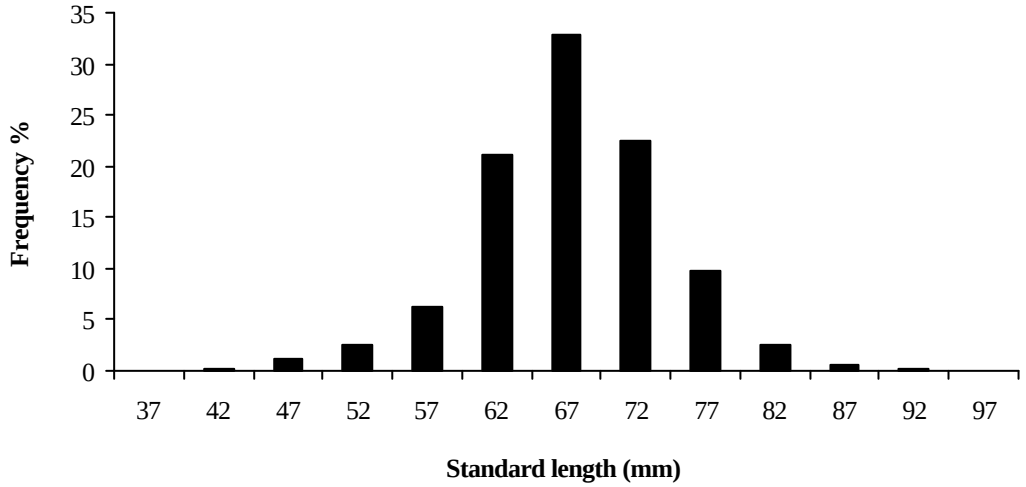


Figure 28-2. Size range and frequencies of *Nyassachromis 'argyrosoma'* caught in the SWA between July 1998 and May 1999.

The sex ratio observed over the full sampling period was F/M 0.5/0.5.

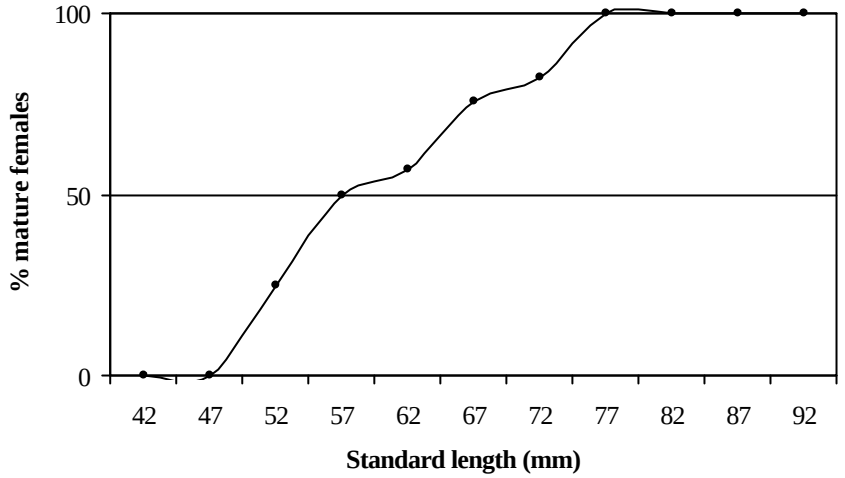


Figure 28-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Nyassachromis 'argyrosoma'* in the SWA.

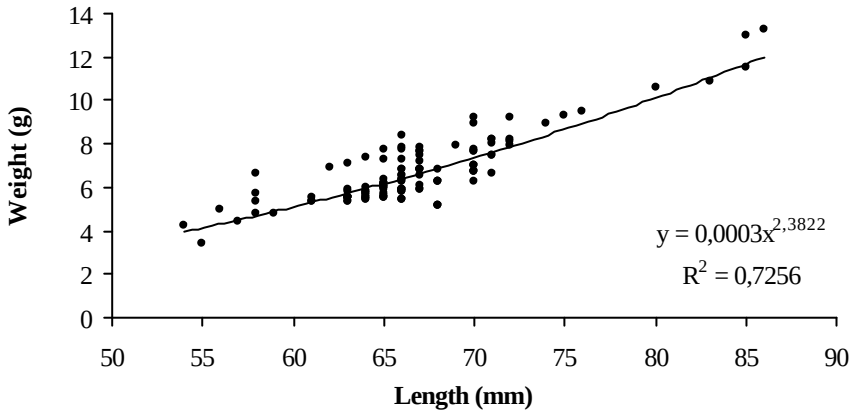


Figure 28-5. Length-weight relationship for *Nyassachromis 'argyrosoma'* females in the SWA. (R^2 = determination coefficient).

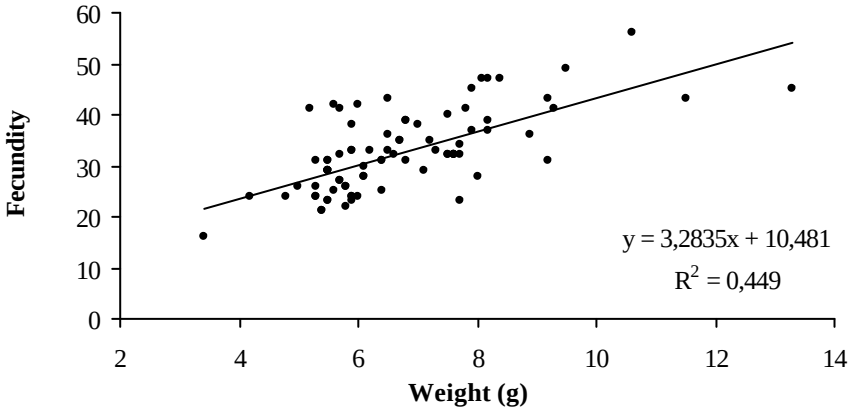


Figure 28-6. Fecundity-weight relationship for *Nyassachromis 'argyrosoma'* females in the SWA. (R^2 = determination coefficient).

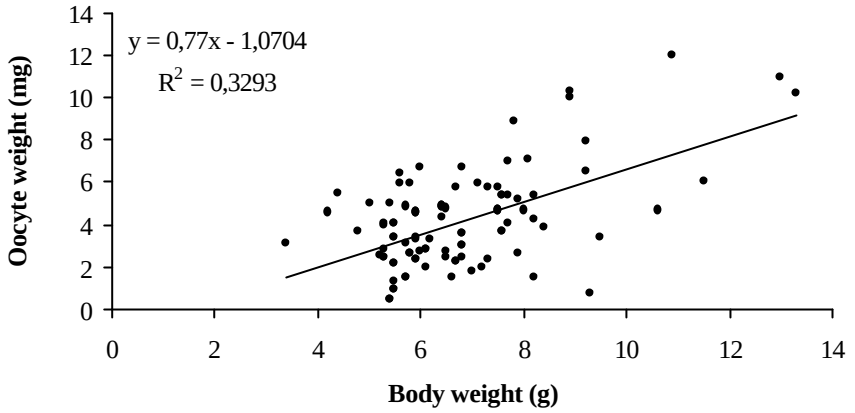


Figure 28-7. Relationship between oocyte weight and body weight for *Nyassachromis 'argyrosoma'* females in the SWA. (R^2 = determination coefficient).

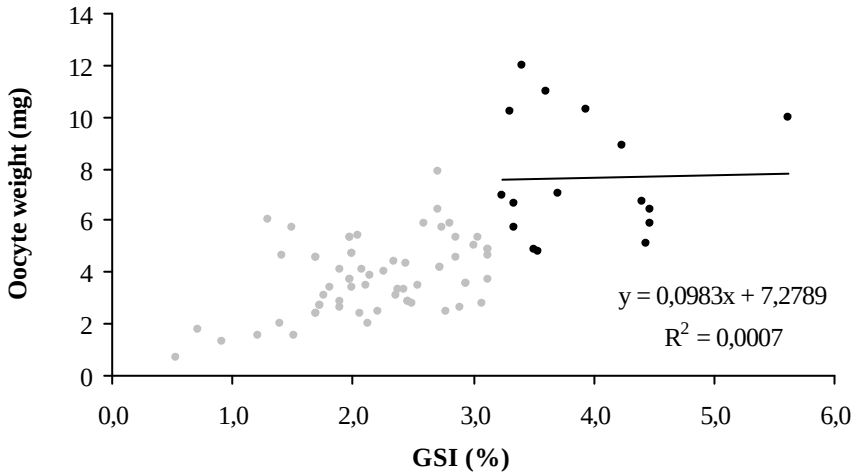


Figure 28-8. Relationship between oocyte weight and gonado-somatic index (GSI) for *Nyassachromis 'argyrosoma'*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3.2%. (R^2 = determination coefficient).

Ripe females (Figure 28-3a) and males (Figure 28-3b) were found at all the sampled months, with peaks in December and March and decreased activity in November and February. Owing to inconsistencies in species identification during the first three months of sampling, data were removed from analyses. However, it is likely that breading occurred all year long. Three quarters of the ripe females and more than half the ripe males were found at 10 m, the rest were at 30 m (Table 28-1), suggesting that spawning probably occurs between 10 and 30 m and mostly at 10 m. As most immature individuals were caught at 30 and 50 m, it appears that after being released, juveniles migrate into deeper waters. The mean size at maturity was about 57 mm for females (Figure 28-4), which corresponded to a mean age at maturity of 10 months. The upper part of the sigmoïd curve does reach 100% after various steps, which is unexpected for an abundant species. Even though we had to take into account data from months outside the peaks of breeding activity to increase the sample size in each size class, an alternative explanation can not be excluded for this species. The taxonomy of the *Nyassachromis spp.* complex is one of the most difficult and despite the particular attention given to this species on board, specimen of an other larger species might have been included, which would explain the significant occurrence of immature specimens above the mean size at maturity.

Table 28-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Nyassachromis 'argyrosoma'* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
10 m	48.9	74.1	47.3	57.6	16.5
30 m	51.1	25.9	45.8	30	31.7
50 m	0	0	6.9	12.4	51.8

The length-weight and fecundity-weight relationships are presented in Figure 28-5 and 28-6, respectively. Fecundity ranged from 16 to 56 for females weighing between 3 and 13 g. A positive correlation was found between oocyte weight and body weight (Figure 28-7). This is the only species for which a relationship between oocyte weight and body weight was found and it might be due to identification inaccuracies. The GSI threshold above which the oocyte weight did no longer increase significantly was 3.2% (Figure 28-8). The mean oocyte weight was 7.66 mg (± 2.36 SD, N= 16). The standard deviation was very high for such a low mean oocyte weight, which was probably due to the fact that oocyte weight was correlated with body weight.

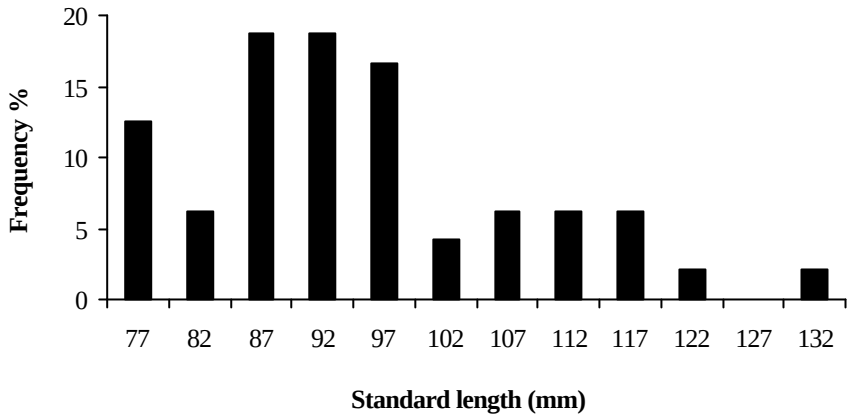


Figure 29-1. Size range and frequencies of *Otopharynx 'productus'* caught in the SWA between July 1998 and May 1999.

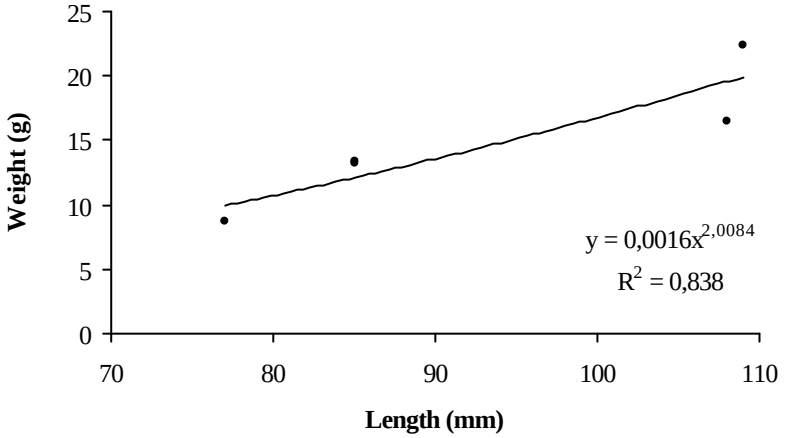


Figure 29-2. Length-weight relationship for *Otopharynx 'productus'* females in the SWA. (R^2 = determination coefficient).

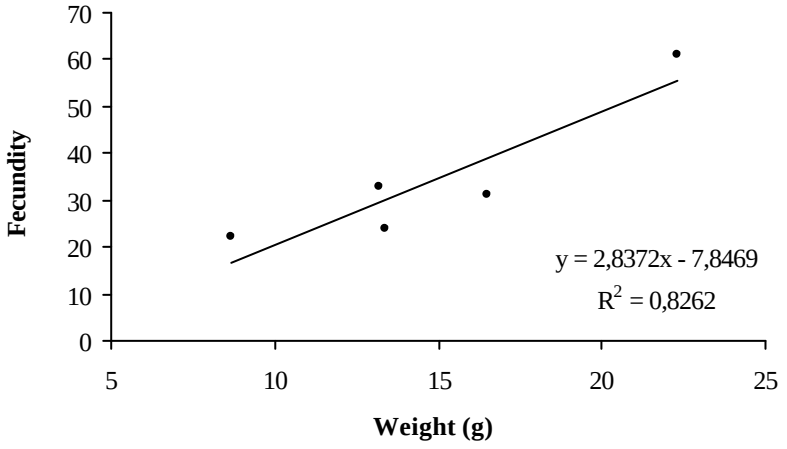


Figure 29-3. Fecundity-weight relationship for *Otopharynx 'productus'* females in the SWA. (R^2 = determination coefficient).

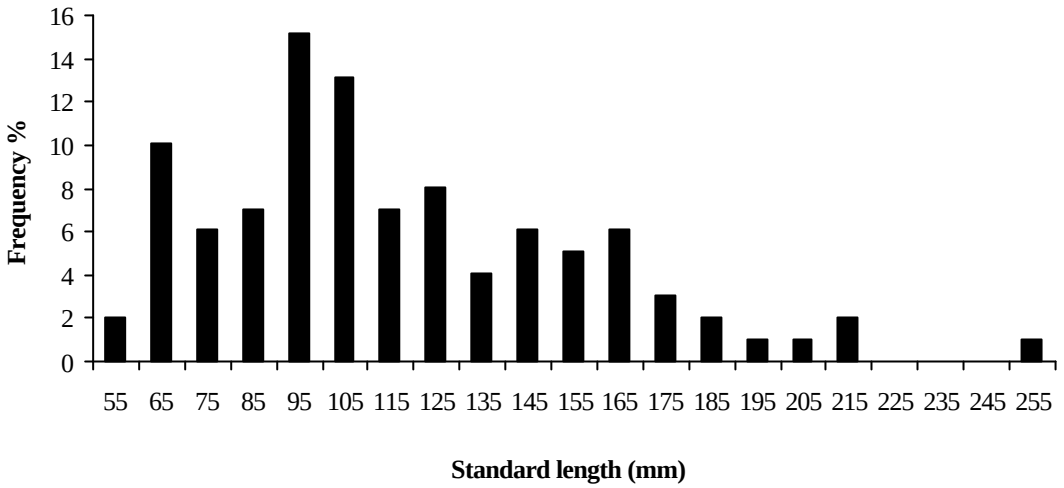


Figure 30-1. Size range and frequencies of *Otopharynx speciosus* caught in the SWA between July 1998 and May 1999.

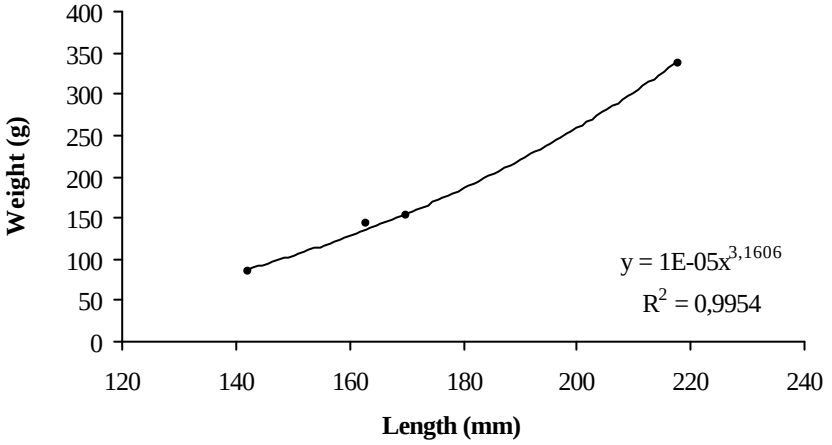


Figure 30-2. Length-weight relationship for *Otopharynx speciosus* females in the SWA. (R^2 = determination coefficient).

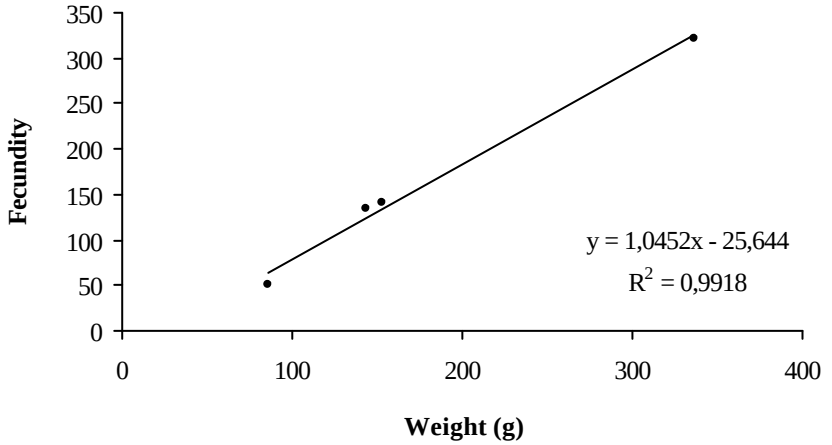


Figure 30-3. Fecundity-weight relationship for *Otopharynx speciosus* females in the SWA. (R^2 = determination coefficient).

Otopharynx spp.

Otopharynx 'productus'

O. 'productus' is a rare species encountered at 10 and 30 m. 27 females and 20 males were analysed, giving a sex ratio of F/M 0.6/0.4. Specimens caught ranged between 75 and 134 mm (Figure 29-1). Among the rare species, *O. 'productus*' was one for which we caught some ripe females, allowing an estimation of the length-weight (Figure 29-2) and fecundity-weight relationships (Figure 29-3). Fecundity ranged between 22 and 61 for females weighing between 9 and 22 g. The mean oocyte weight was impossible to assess from the few data available, but the largest oocytes weighed averaged 14.2 mg for a GSI of 2.8%.

Otopharynx speciosus (Trewavas)

Like *O. 'productus*', *O. speciosus* is not an abundant species and was essentially caught between 30 and 75 m. 61 females and 38 males were analysed, giving a sex ratio of F/M 0.6/0.4. Specimens caught ranged between 55 and 260 mm (Figure 30-1). Among the rare species, *O. 'productus*' was also one for which we caught some ripe females, allowing an estimation of the length-weight (Figure 30-2) and fecundity-weight relationships (Figure 30-3). Fecundity ranged between 51 and 322 for females weighing between 85 and 337 g. The mean oocyte weight was impossible to assess from the few data available, but the largest oocytes weighed averaged 25 mg for a GSI of 2.9%.

Placidochromis spp.

Placidochromis 'long'

111 females and 180 males were analysed. *P. 'long'* is a small species caught from 10 to 50 m, with an increasing occurrence and biomass with depth (Figure 31-1).

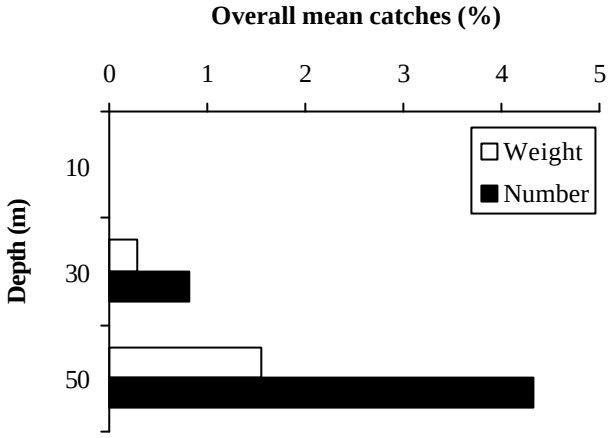


Figure 31-1. Mean occurrence and abundance in the catches per depth of *Placidochromis 'long'* in the SWA between July 1998 and May 1999.

It was most common at 50 m, where it constituted 1.6 and 4.3% of the catches in weight and number, respectively. The mean CPUE per depth category was 3.2 kg for the shallows. No reference to this species (under this name at least) was made in Tómasson & Banda (1996). Specimens caught ranged between 47 and 77 mm (Figure 31-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

Owing to low sample size or absence of data for some months, the precise determination of breeding season and size at maturity was not possible. Ripe females (Figure 31-3a) and males (Figure 31-3b) were found only in October and in April-May and breeding season might occur from April-May to October.

The length-weight and fecundity-weight relationships are presented in Figure 31-4 and 31-5, respectively. Fecundity ranged from 17 to 38 for females weighing between 4.7 and 6.7 g. No relationship was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight no longer increased significantly was estimated at 2% (Figure 31-6). The mean oocyte weight was 4.36 mg (± 1.30 SD, N= 10).

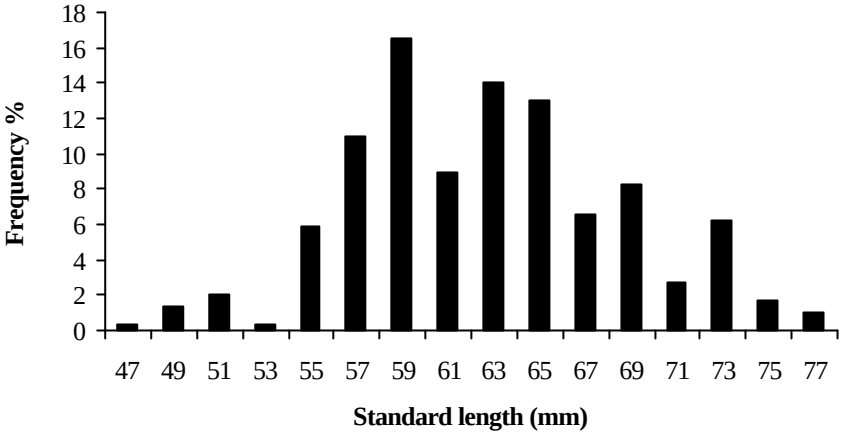


Figure 31-2. Size range and frequencies of *Placidochromis 'long'* caught in the SWA between July 1998 and May 1999.

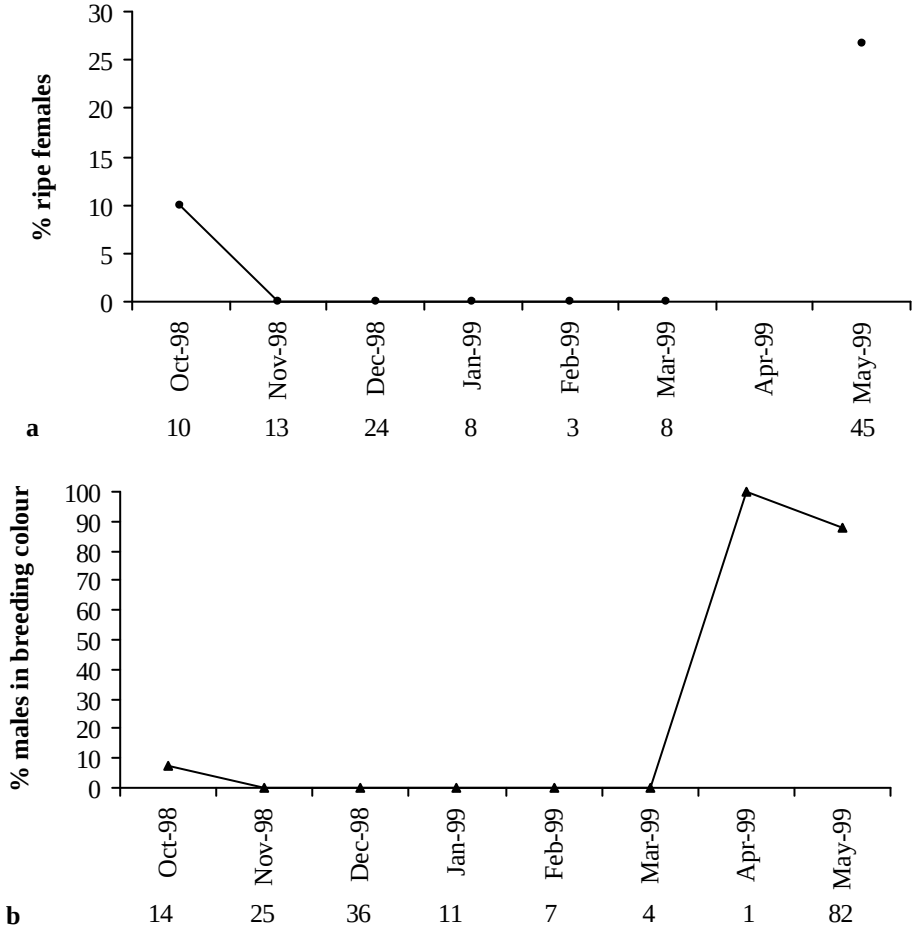


Figure 31-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Placidochromis 'long'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

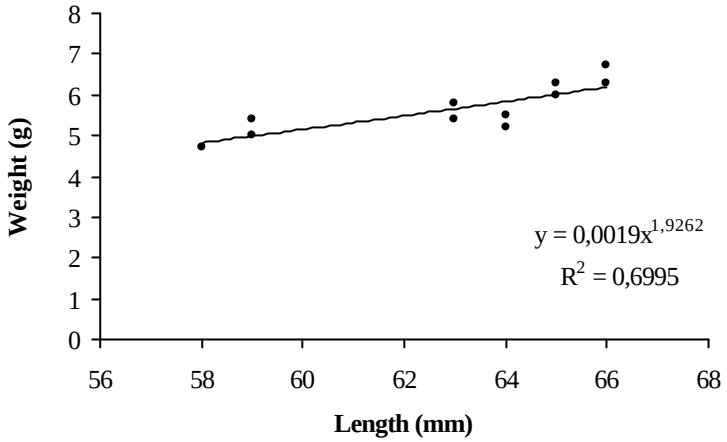


Figure 31-4. Length-weight relationship for *Placidochromis 'long'* females in the SWA. (R^2 = determination coefficient).

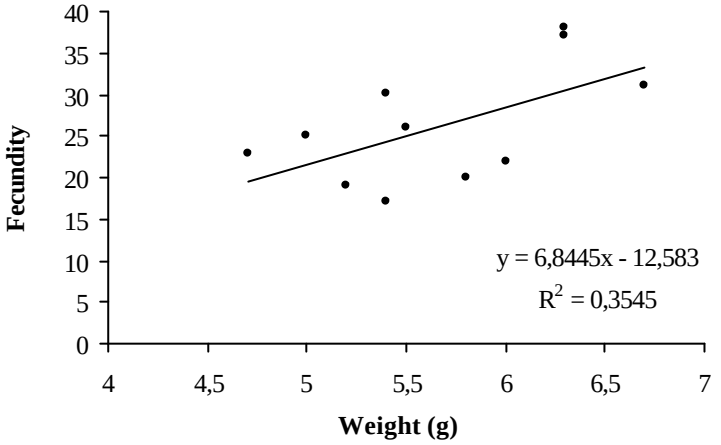


Figure 31-5. Fecundity-weight relationship for *Placidochromis 'long'* females in the SWA. (R^2 = determination coefficient).

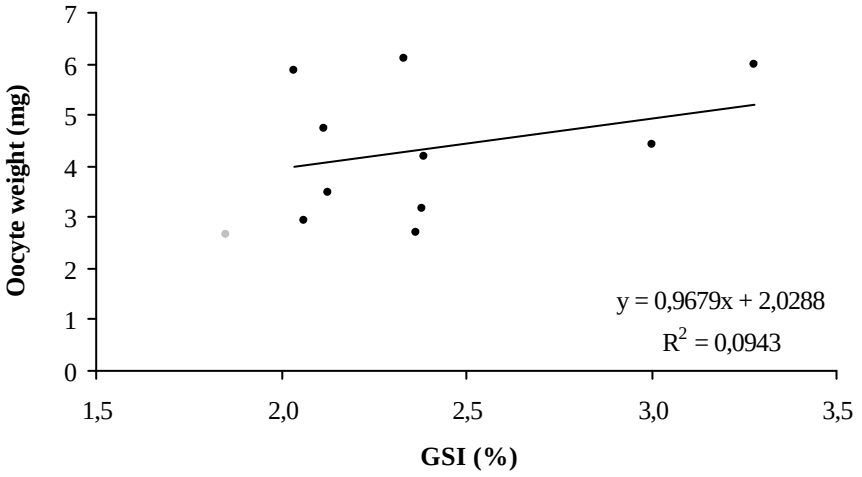


Figure 31-6. Relationship between oocyte weight and gonado-somatic index (GSI) for *Placidochromis 'long'*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3.2%. (R^2 = determination coefficient).

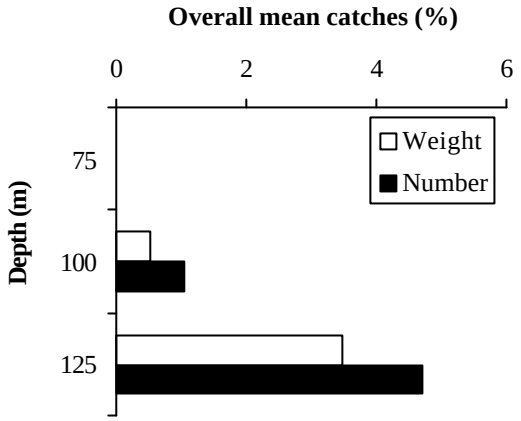


Figure 32-1. Mean occurrence and abundance in the catches per depth of *Placidochromis 'platyrhynchos'* in the SWA between July 1998 and May 1999.

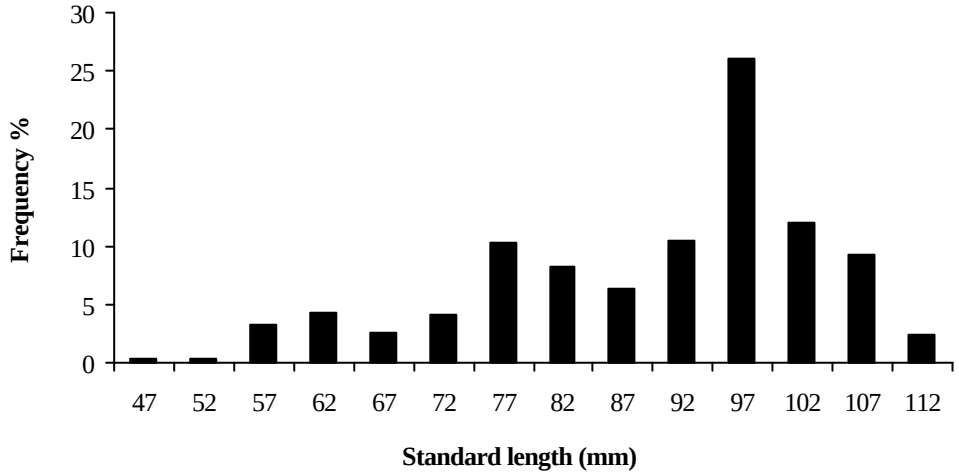


Figure 32-2. Size range and frequencies of *Placidochromis 'platyrhynchos'* caught in the SWA between July 1998 and May 1999.

Placidochromis 'platyrhynchos'

263 females and 225 males were analysed. *P. 'platyrhynchos'* is a relatively small species caught from 75 to 125 m, with an increasing occurrence and biomass with depth (Figure 32-1). It was a very common species at 125 m, where it constituted 3.5 and 4.7% of the catches in weight and number, respectively. The mean CPUE per depth category was 1.7 kg for the deep zone and 6.2 kg for the very deep zone, which matched with the value reported by Tómasson & Banda (1996) for the deep zone (1.4 kg) and was more than twice as much for the very deep zone (2.8 kg). Specimens caught ranged between 46 and 115 mm (Figure 32-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Ripe females were found from July to August and from December to May (Figure 32-3a). Considering the very low sample size for June, it can be estimated than breeding season occurred from December to October, with a peak from January to May and a cessation in November. This pattern was confirmed by males data, excluding the months with very low sample size such as August and November (Figure 32-3b). Nearly all the ripe females and males and the immature individuals were caught at 125 m, suggesting that spawning could take place at this depth (Table 32-1). The mean size at maturity was about 80 mm (Figure 32-4), which was probably overestimated given that this estimation was with all the data available to increase the sample size, including data outside the breeding season. This corresponded to a mean age at maturity of 12 months.

Table 32-1. Percentage of ripe females (stages 4 and 5), males in breeding colour and immature individuals (whose size is below the size at maturity) per depth for *Placidochromis 'platyrhynchos'* in the SWA.

Depth	Non ripe females	Ripe females	Males not in breeding colour	Males in breeding colour	Immature specimens
75 m	0	0	1.2	0	0
100 m	23.4	7.5	28.2	1.4	16.7
125 m	76.6	92.5	70.6	98.6	83.3

The length-weight and fecundity-weight relationships are presented in Figure 32-5 and 32-6, respectively. Fecundity ranged from 23 to 93 for females weighing between 9 and 31 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3.5% (Figure 32-7). The mean oocyte weight was 13.83 mg (± 1.88 SD, N= 24).

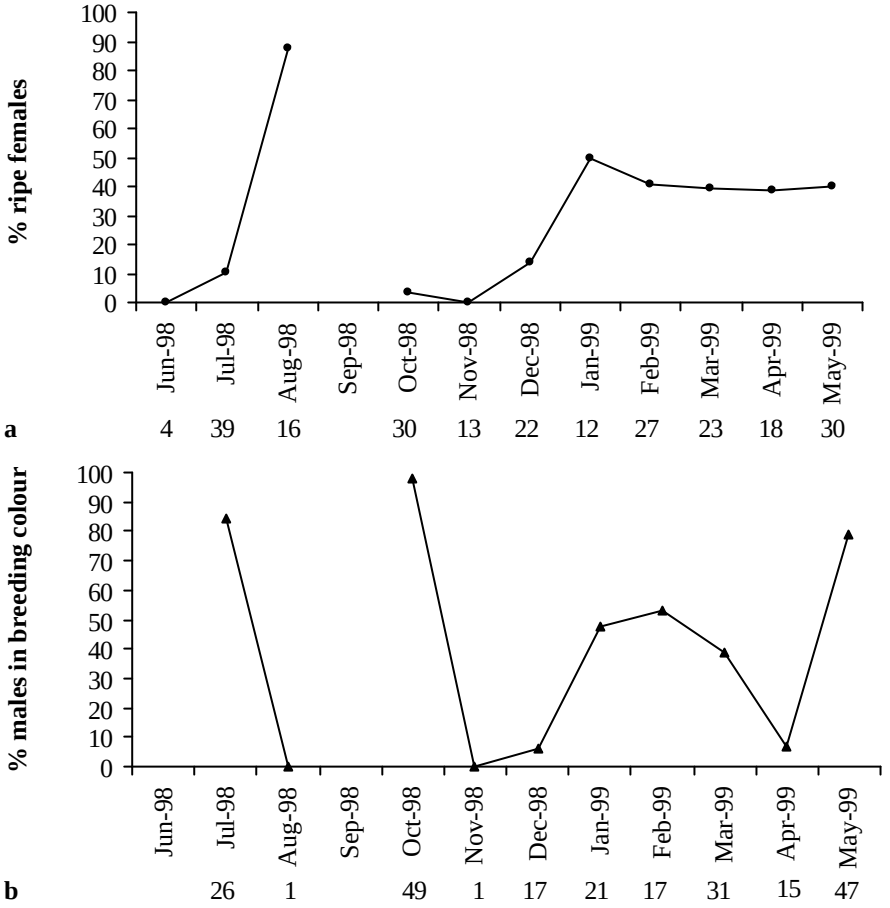


Figure 32-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Placidochromis 'platyrhynchos'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

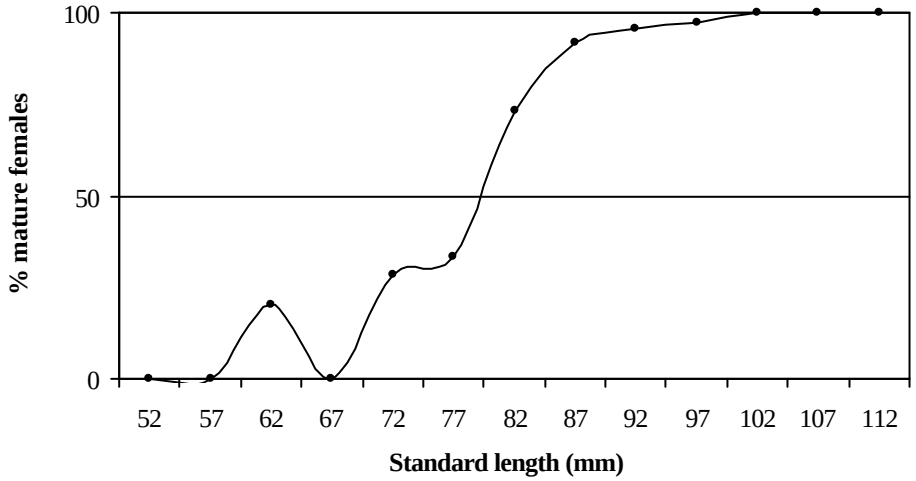


Figure 32-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Placidochromis 'platyrhynchos'* in the SWA.

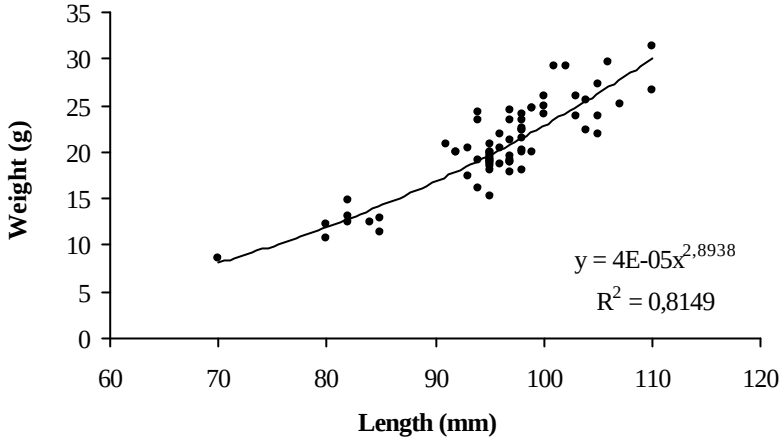


Figure 32-5. Length-weight relationship for *Placidochromis 'platyrhynchos'* females in the SWA. (R^2 = determination coefficient).

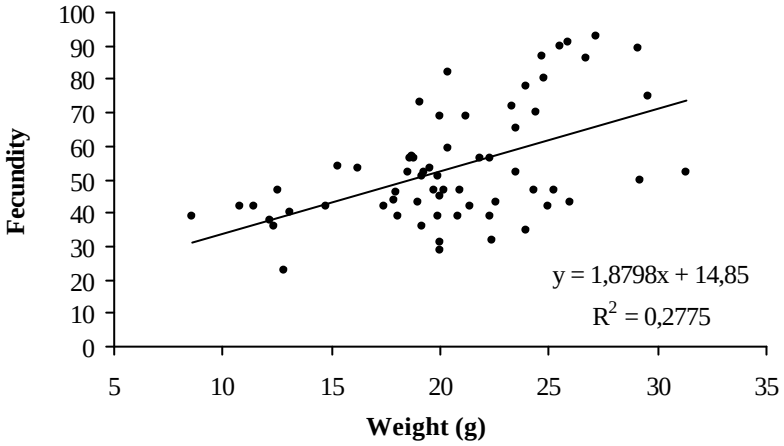


Figure 32-6. Fecundity-weight relationship for *Placidochromis 'platyrhynchos'* females in the SWA. (R^2 = determination coefficient).

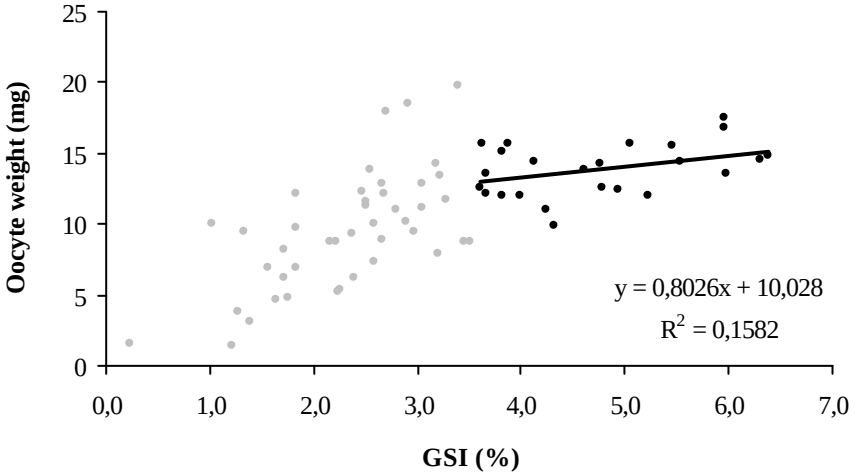


Figure 32-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Placidochromis 'platyrhynchos'*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3.5%. (R^2 = determination coefficient).

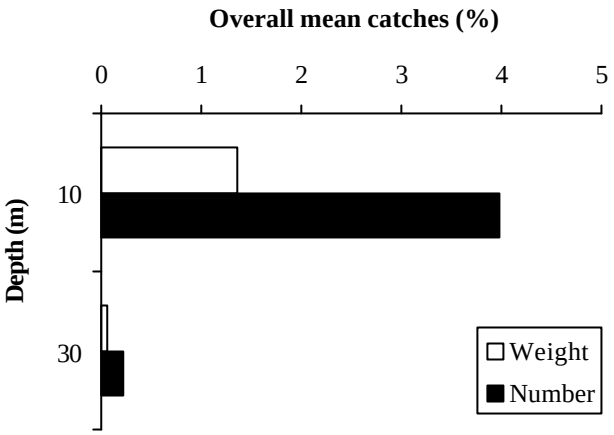


Figure 33-1. Mean occurrence and abundance in the catches per depth of *Pseudotropheus livingstonii* in the SWA between July 1998 and May 1999.

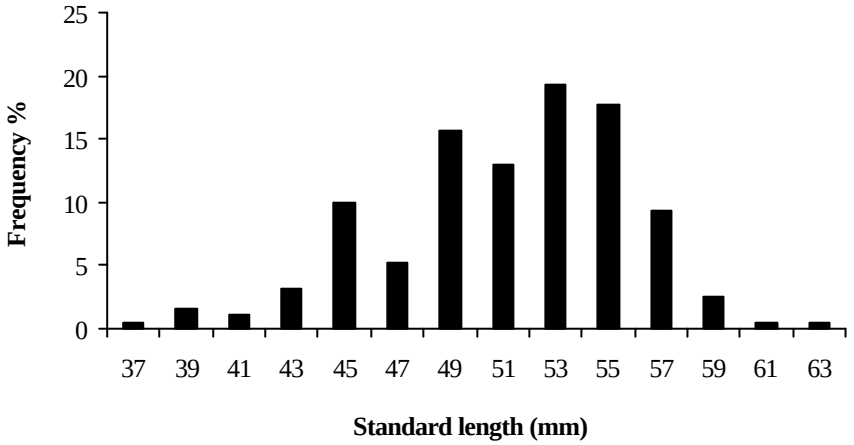


Figure 33-2. Size range and frequencies of *Pseudotropheus livingstonii* caught in the SWA between July 1998 and May 1999.

Pseudotropheus spp.

***Pseudotropheus livingstonii* (Boulenger)**

68 females and 124 males were analysed. *Ps. livingstonii* is a small species principally caught at 10 and sometimes at 30 m (Figure 33-1). It constituted 1.4 and 4% of the catches in weight and number, respectively. The mean CPUE per depth category was 1.8 kg for the shallow zone, which was about five times less than the value reported by Tómasson & Banda (1996) (9.8 kg). Specimens caught ranged between 37 and 63 mm (Figure 33-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

As *Ps. Livingstonii* was sometimes relatively abundant and sometimes absent from the catches for a few months, precise determination of the breeding season was impossible. Each time it was present in the catches (October, November, March, April, May), ripe females were found (Figure 33-3a), which was not always the case for males in breeding colour (Figure 33-3b). Maturity was reached at about 37 mm for females (Figure 33-4).

The length-weight and fecundity-weight relationships are presented in Figure 33-5 and 33-6, respectively. Fecundity ranged from 15 to 33 for females weighing between 3 and 5 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was estimated at about 2% (Figure 33-7). The mean oocyte weight was 5.45 mg (± 0.59 SD, N= 7).

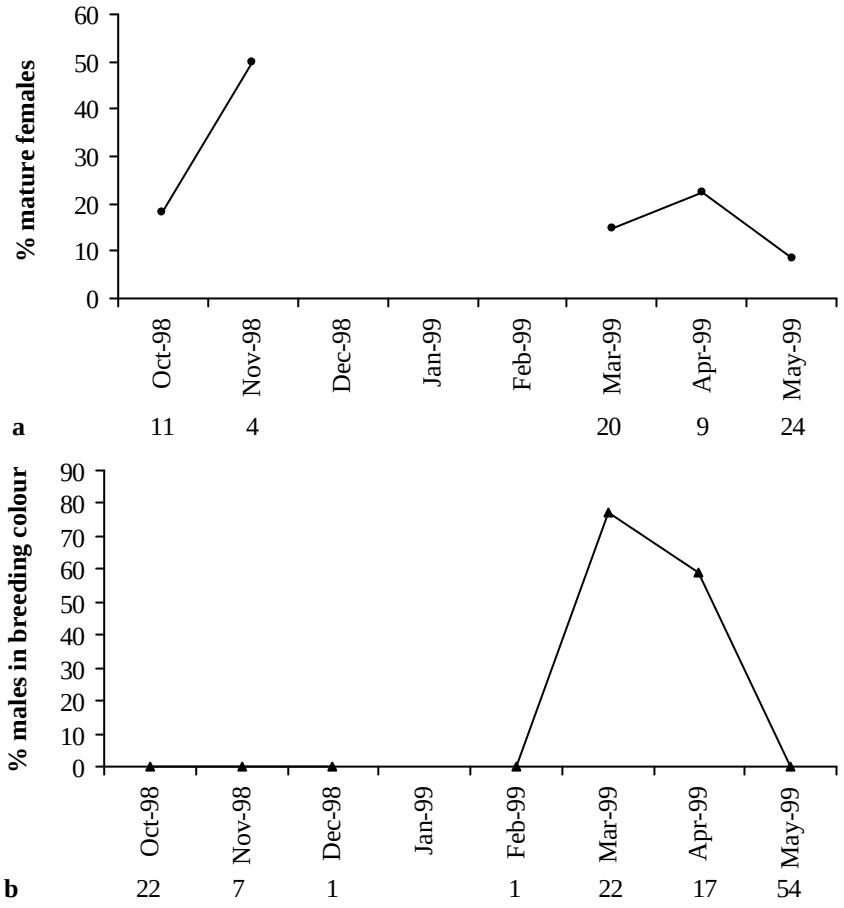


Figure 33-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Pseudotropheus livingstonii* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

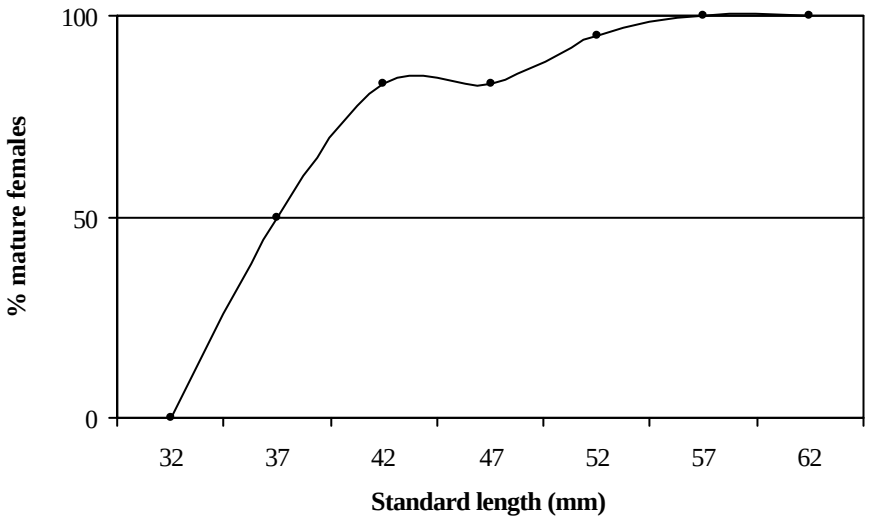


Figure 33-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Pseudotropheus livingstonii* in the SWA.

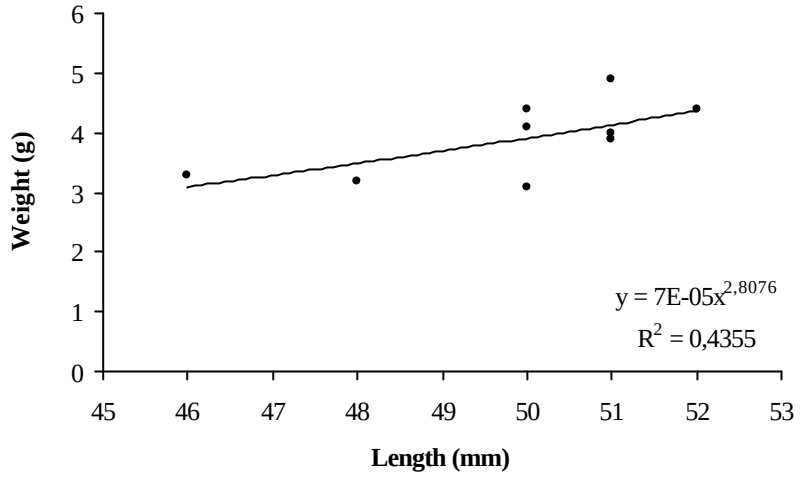


Figure 33-5. Length-weight relationship for *Pseudotropheus livingstonii* females in the SWA. (R^2 = determination coefficient).

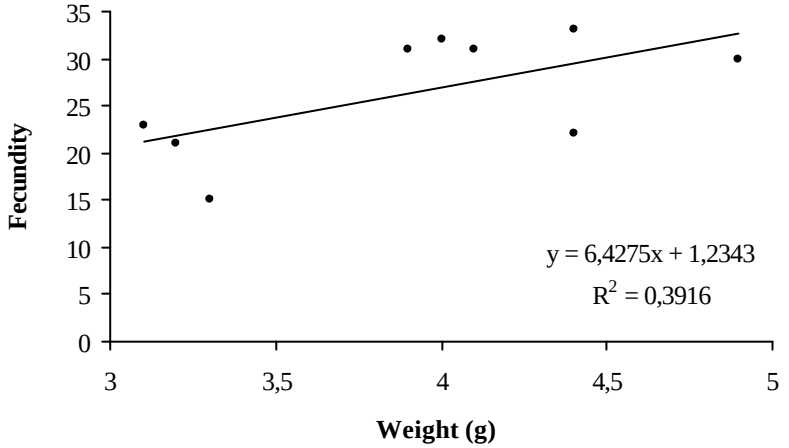


Figure 33-6. Fecundity-weight relationship for *Pseudotropheus livingstonii* females in the SWA. (R^2 = determination coefficient).

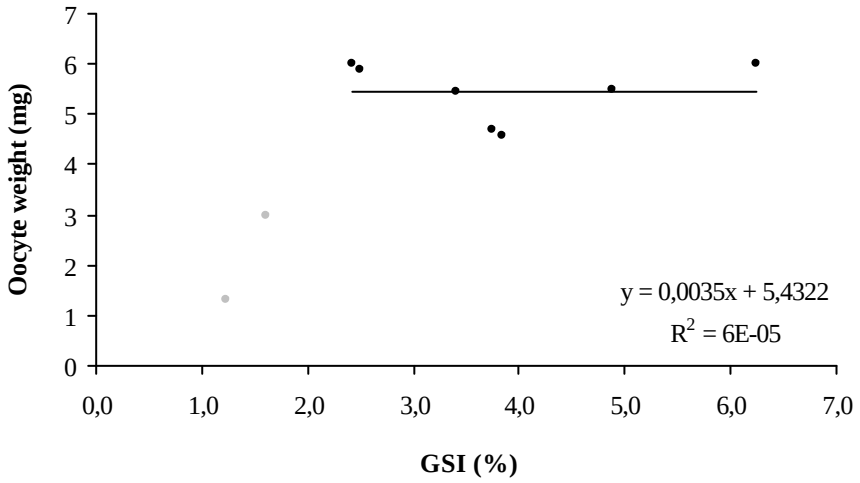


Figure 33-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Pseudotropheus livingstonii*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 2%. (R^2 = determination coefficient).

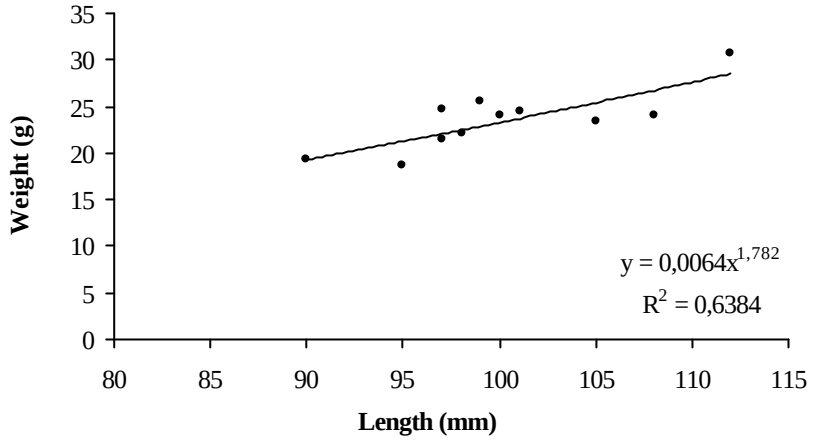


Figure 34-3. Length-weight relationship for *Sciaenochromis ahli* females in the SWA. (R^2 = determination coefficient).

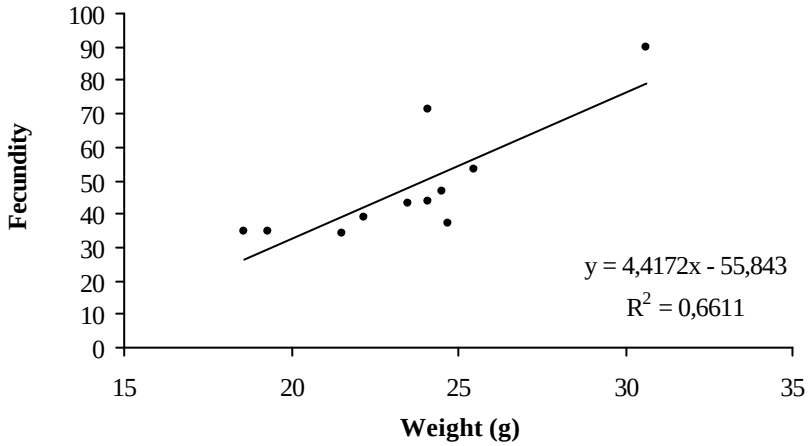


Figure 34-4. Fecundity-weight relationship for *Sciaenochromis ahli* females in the SWA. (R^2 = determination coefficient).

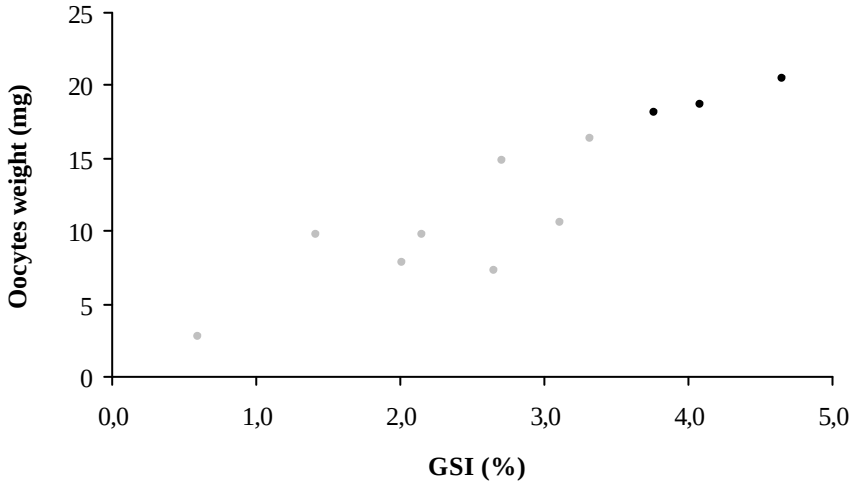


Figure 34-5. Relationship between oocyte weight and gonado-somatic index (GSI) for *Sciaenochromis ahli*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3.5%. (R^2 = determination coefficient).

Sciaenochromis spp.

***Sciaenochromis ahli* (Trewavas)**

38 females and 37 males were analysed. *S. ahli* is a relatively small species encountered at every depth from 10 to 125 m but never numerous in any of them. The mean CPUE per depth category was 0.9, 0.8 and 0.3 kg for the shallow, deep and very deep zones, respectively. No reference to this species (under this name at least) was made in Tómasson & Banda (1996). Specimens caught ranged between 62 and 124 mm (Figure 34-1).

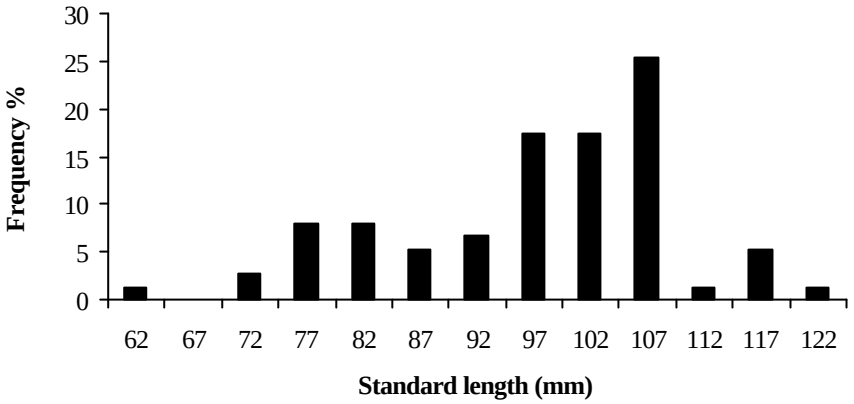


Figure 34-1. Size range and frequencies of *Sciaenochromis ahli* caught in the SWA between July 1998 and May 1999.

The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Owing to low sample size or absence of data for some months, the precise determination of breeding season and size at maturity was not possible. Ripe females were found at each sampling date except when sample size were almost null (March and April) (Figure 34-2). Only three males in breeding colour were found, in November and May, all at 75 m. Breeding season could then occur at least from October to May.

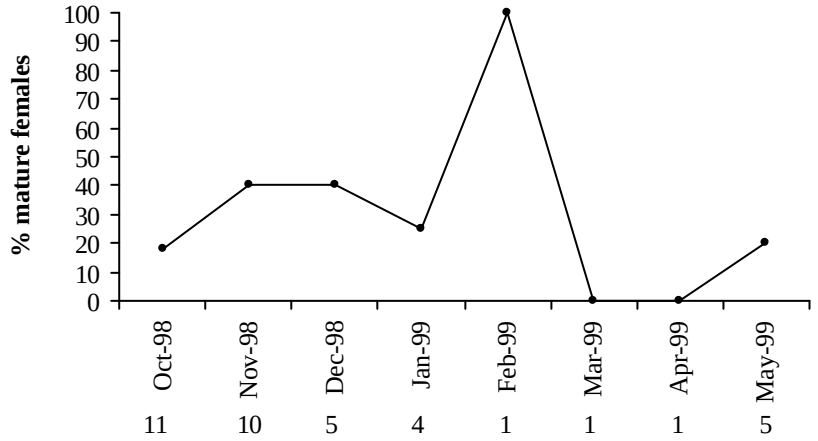


Figure 34-2. Seasonal progression of the percentage of ripe (stages 4 and 5) females *Sciaenochromis ahli* in the SWA The values below the x-axis are the sample size for each month.

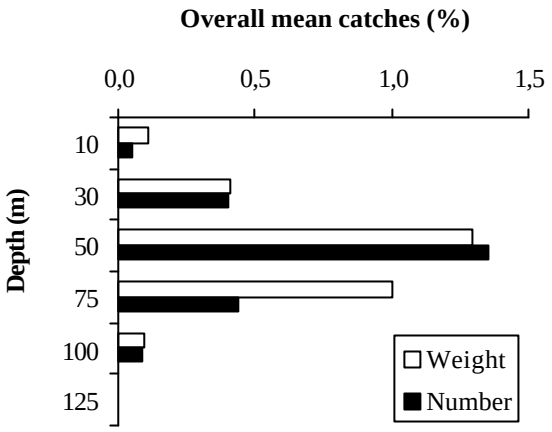


Figure 35-1. Mean occurrence and abundance in the catches per depth of *Sciaenochromis benthicola* in the SWA between July 1998 and May 1999.

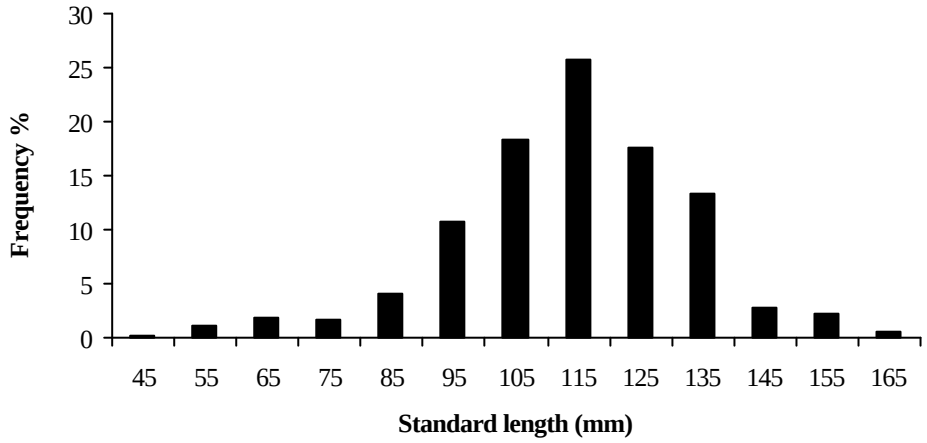


Figure 35-2. Size range and frequencies of *Sciaenochromis benthicola* caught in the SWA between July 1998 and May 1999.

The length-weight and fecundity-weight relationships are presented in Figure 34-3 and 34-4, respectively. Fecundity ranged from 35 to 90 for females weighing between 19 and 31 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was impossible to assess because of low sample size. However, despite the fact that oocyte weight apparently still increased with GSI above 3.5% (Figure 34-5), the mean oocyte weight was estimated from the three females whose GSI was above 3.5%, and was 19.11 mg (± 1.25 SD, N= 3).

Sciaenochromis benthicola (Konings)

188 females and 182 males were analysed. *S. benthicola* was encountered at every depth from 10 to 125 m but was more frequent at 50 and 75 m, where it constituted 1 to 1.3% of the catches in weight and 0.4 to 1.4% in number, respectively (Figure 35-1). The mean CPUE per depth category was 5.6, 2.4 kg and almost nothing for the shallow, deep and very deep zones, respectively. No reference to this species (under this name at least) was made in Tómasson & Banda (1996). Specimens caught ranged between 48 and 168 mm (Figure 35-2). The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Owing to low sample size or absence of data for some months, the precise determination of breeding season was not possible. Ripe females were found in June, August and from November to February, with peaks in August and December (Figure 35-3a). Data for males gave approximately the same pattern except for the period from June to August, when no ripe males were found (Figure 35-3b). 100% of the ripe females and 91% of the males in breeding colour were found at 50 and 75 m, suggesting that spawning could occur at these depths. The mean size at maturity was about 100 mm for females (Figure 35-4). Size at maturity has to be determined at the height of the breeding season to be accurate, but owing to the low sample size we had to consider every data available. As a consequence, females caught outside the peak of breeding season were included in the analyses, even large resting females, which explains the shape of the upper part of the curve.

The length-weight and fecundity-weight relationships are presented in Figure 35-5 and 35-6, respectively. Fecundity ranged from 32 to 99 for females weighing between 26 and 69 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight no longer increased significantly was 3% (Figure 35-7). The mean oocyte weight was 27.31 mg (± 4.12 SD, N= 13).

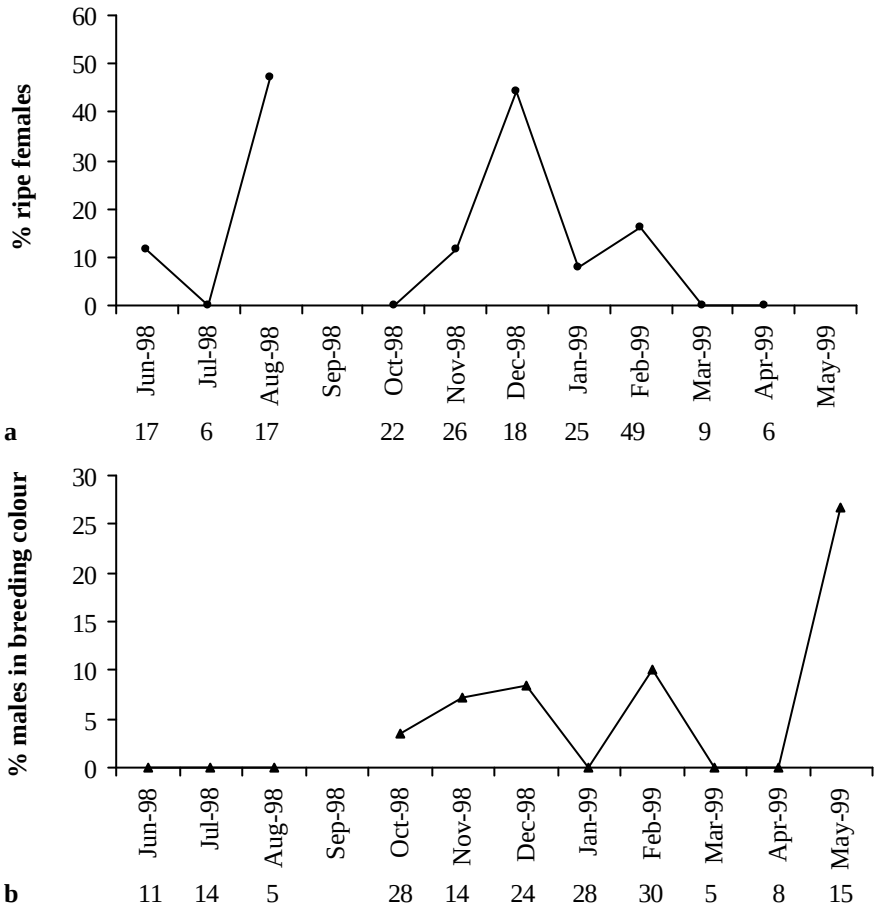


Figure 35-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Sciaenochromis benthicola* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

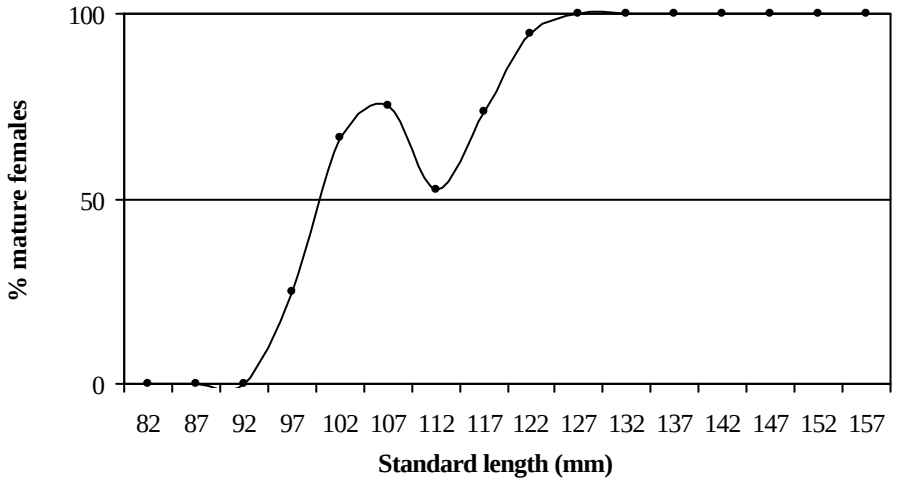


Figure 35-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Sciaenochromis benthicola* in the SWA.

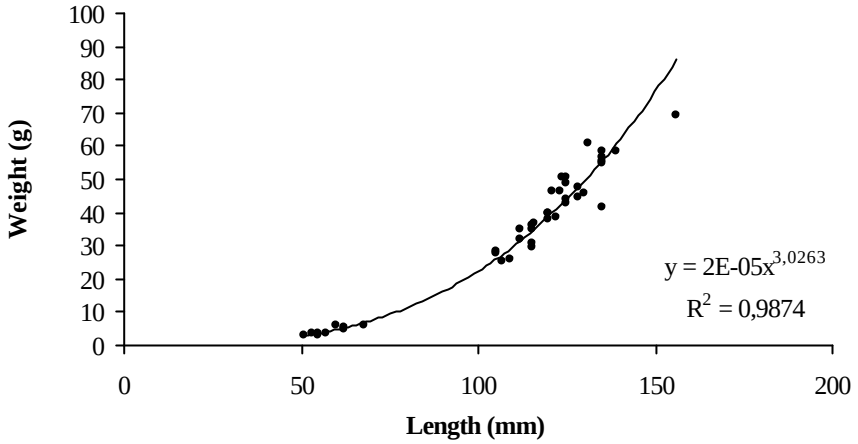


Figure 35-5. Length-weight relationship for *Sciaenochromis benthicola* females in the SWA. (R^2 = determination coefficient).

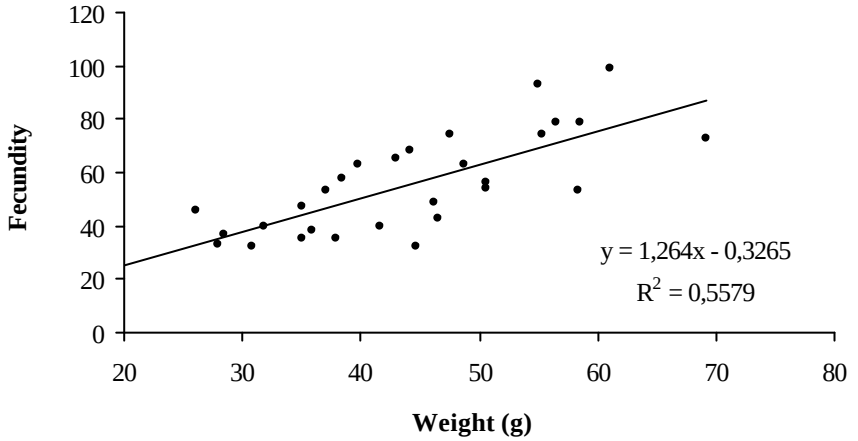


Figure 35-6. Fecundity-weight relationship for *Sciaenochromis benthicola* females in the SWA. (R^2 = determination coefficient).

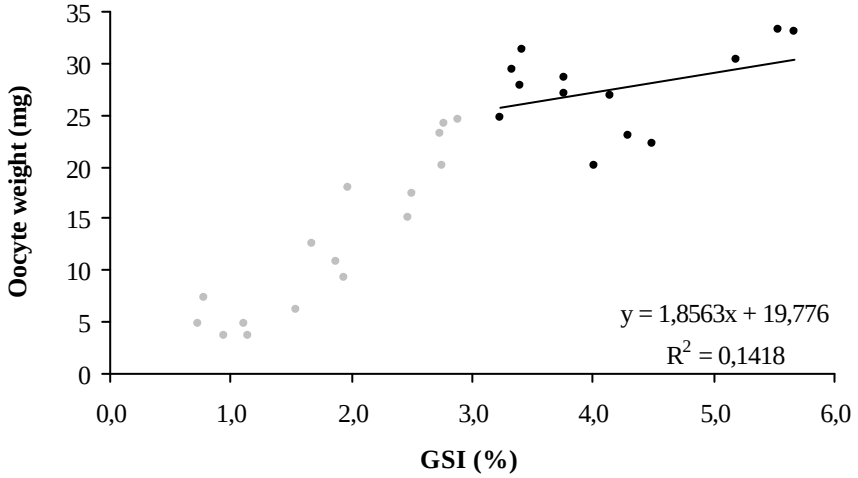


Figure 35-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Sciaenochromis benthicola*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

Stigmatochromis spp.

Stigmatochromis 'guttatus'

62 females and 22 males were analysed. *S. 'guttatus'* was encountered at every depth from 10 to 125 m but was never abundant in any of them although it occurred more frequently at 50 and 75 m. Specimens caught ranged between 64 and 147 mm (Figure 36-1). The sex ratio observed over the full sampling period was F/M 0.7/0.3.

Owing to low sample size or absence of data for some months, the precise determination of breeding season was not possible. Ripe females were found from October to December, in February and in April-May (Figure 36-2). The six males in breeding colour we found were caught at 50 m in March. The mean size at maturity was about 100 mm for females (Figure 36-3), which was probably overestimated as this estimation was not done during the height of the breeding season but with all the data available for females, to increase the sample size.

The length-weight and fecundity-weight relationships are presented in Figure 36-4 and 36-5, respectively. Fecundity ranged from 21 to 64 for females weighing between 20 and 46 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was 3% (Figure 36-6). The mean oocyte weight was 29.09 mg (± 2.97 SD, N= 4).

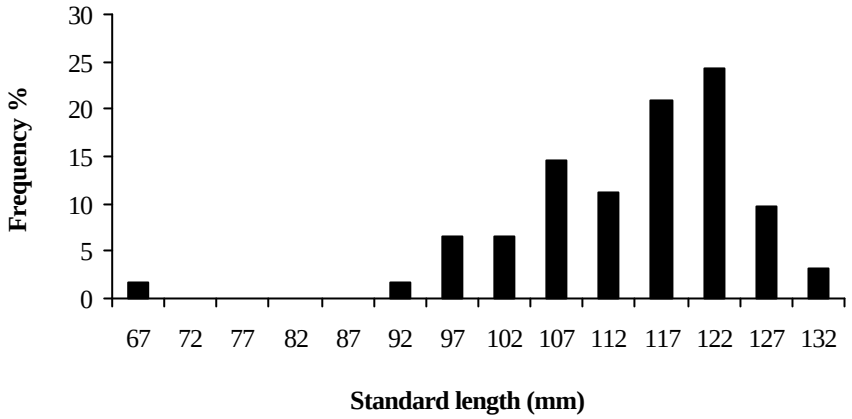


Figure 36-1. Size range and frequencies of *Stigmatochromis 'guttatus'* caught in the SWA between July 1998 and May 1999.

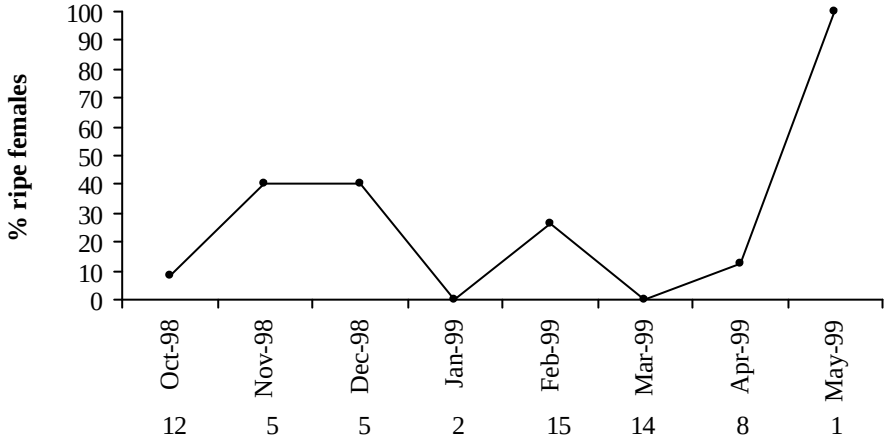


Figure 36-2. Seasonal progression of the percentage of ripe (stages 4 and 5) females *Stigmatochromis 'guttatus'* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

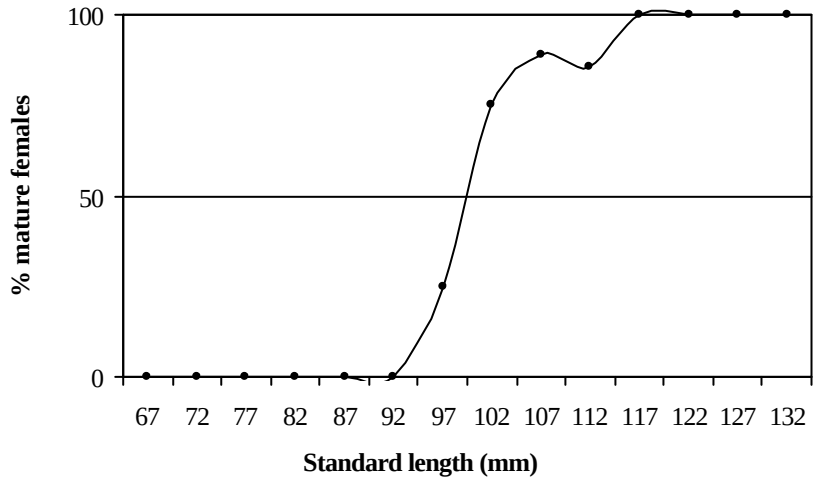


Figure 36-3. Percentage of mature females (stage 3 and above) per size class (standard length) for *Stigmatochromis 'guttatus'* in the SWA.

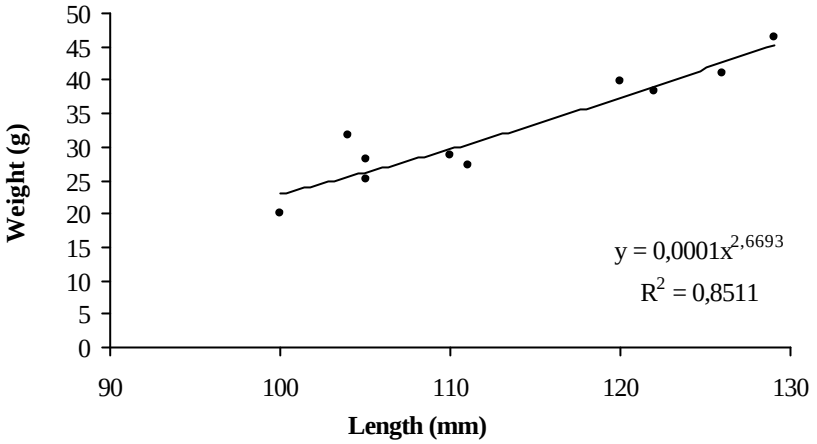


Figure 36-4. Length-weight relationship for *Stigmatochromis 'guttatus'* females in the SWA. (R^2 = determination coefficient).

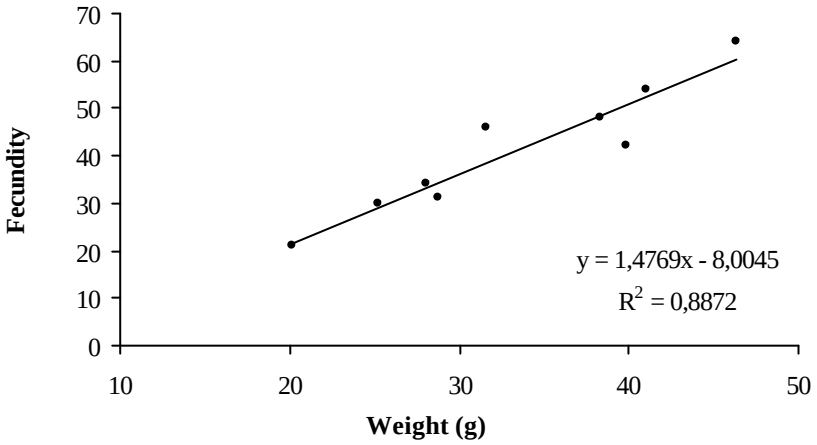


Figure 36-5. Fecundity-weight relationship for *Stigmatochromis 'guttatus'* females in the SWA. (R^2 = determination coefficient).

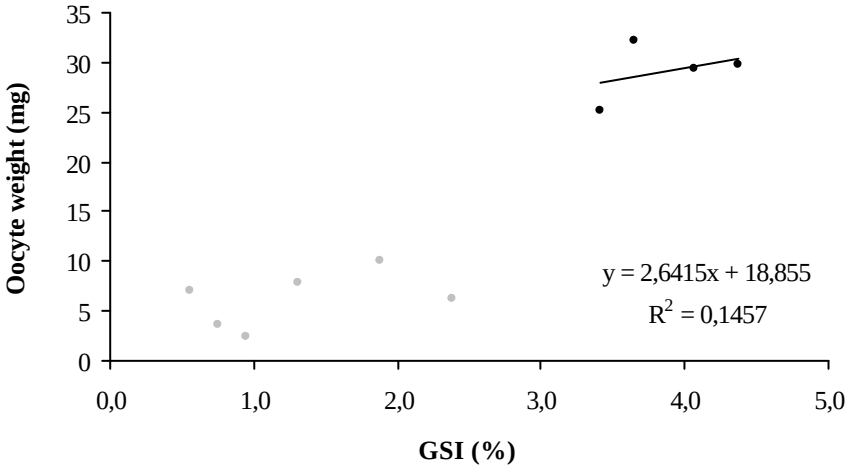


Figure 36-6. Relationship between oocyte weight and gonado-somatic index (GSI) for *Stigmatochromis 'guttatus'*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

Taeniolethrinops spp.

Taeniolethrinops furcicauda (Trewavas) (Plate 17)

135 females and 88 males were analysed. *T. furcicauda* was mostly encountered at 10 m where it made up to 1.2 and 1.6% of the catches in number and weight, respectively. It was also found sometimes at 30 m. Specimens caught ranged between 65 and 178 mm (Figure 37-1).

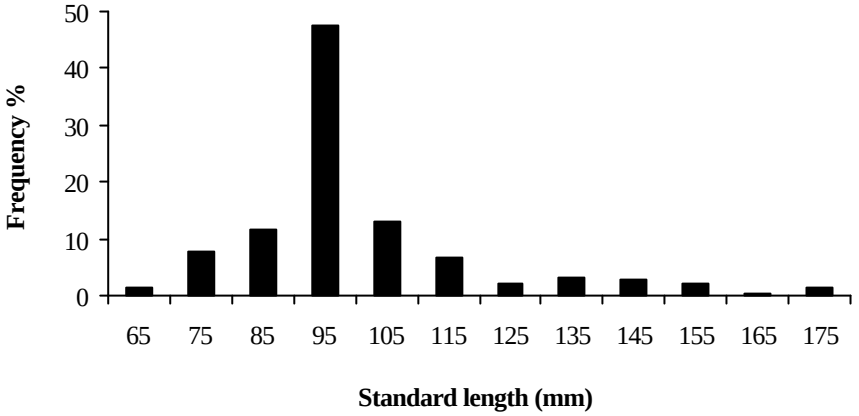


Figure 37-1. Size range and frequencies of *Taeniolethrinops furcicauda* caught in the SWA between July 1998 and May 1999.

The sex ratio observed over the full sampling period was F/M 0.6/0.4.

Owing to low sample size or absence of data for some months, the precise determination of breeding season was not possible. Ripe females were only found in July (Figure 37-2), as was the single male in breeding colour caught. The mean size at maturity was about 130 mm for females (Figure 37-3), which was probably overestimated as this estimation was not done during the height of the breeding season but with all the data available for females, to increase the sample size.

The length-weight relationship is not given because of the too narrow size range of females measured. The fecundity-weight relationship is presented in Figure 37-4. Fecundity ranged from 138 to 219 for females weighing between 88 and 109 g and was not correlated to body weight. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was difficult to assess owing to low sample size. However, as the oocyte weight did no longer increase above a GSI of 1.5% (Figure 37-5), the mean oocyte weight was estimated (probably underestimated) at 10.13 mg (± 0.83 SD, N= 3).

Plate 17. *Taeniolethrinops furcicauda* (by Dave Voorvelt).

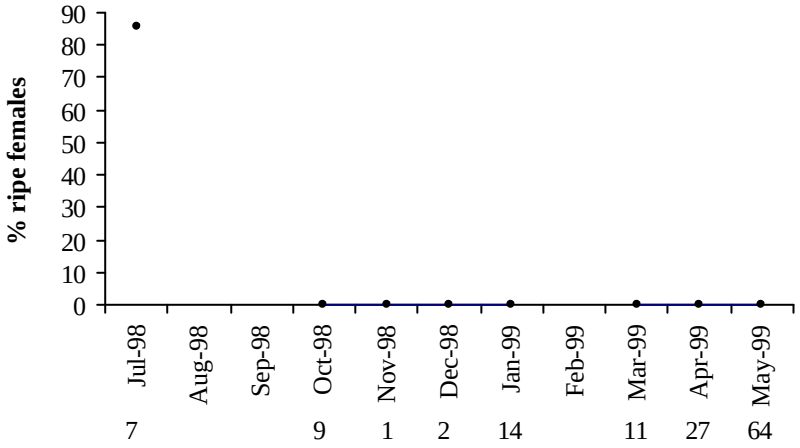


Figure 37-2. Seasonal progression of the percentage of ripe (stages 4 and 5) females *Taeniolethrinops furcicauda* in the SWA The values below the x-axis are the effective for each month.

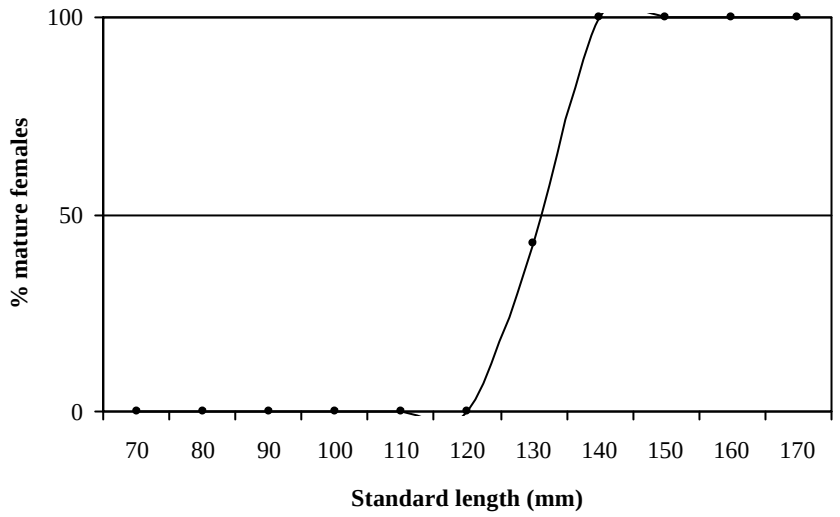


Figure 37-3. Percentage of mature females (stage 3 and above) per size class (standard length) for *Taeniolethrinops furcicauda* in the SWA.

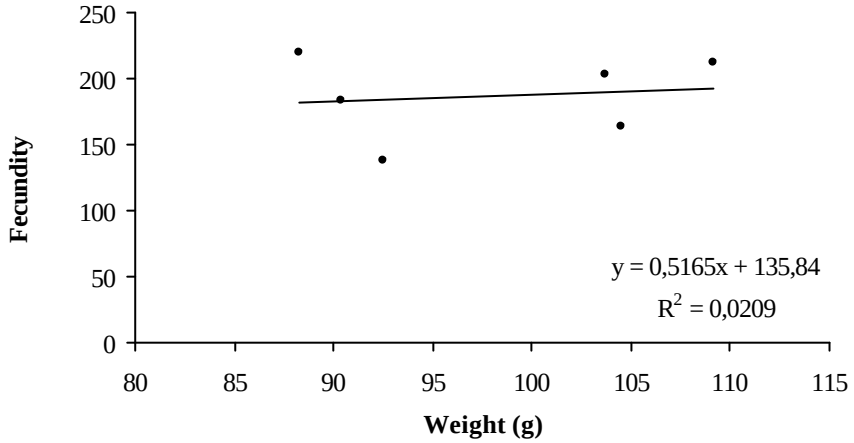


Figure 37-4. Fecundity-weight relationship for *Taeniolethrinops furcicauda* females in the SWA. (R^2 = determination coefficient).

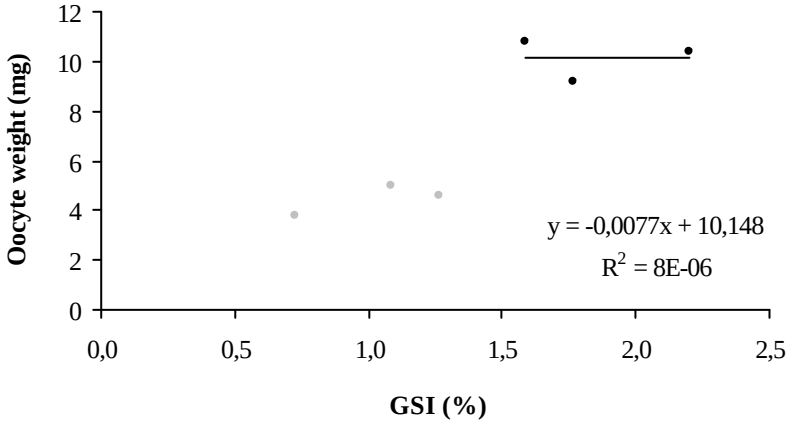


Figure 37-5. Relationship between oocyte weight and gonado-somatic index (GSI) for *Taeniolethrinops furcicauda*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 1.5%. (R^2 = determination coefficient).

Taeniolethrinops praeorbitalis (Regan) (Plate 18)

85 females and 78 males were analysed. *T. praeorbitalis* was encountered at 10 m and 30 m, but was never frequent at any depth. Specimens caught ranged between 71 and 199 mm (Figure 38-1).

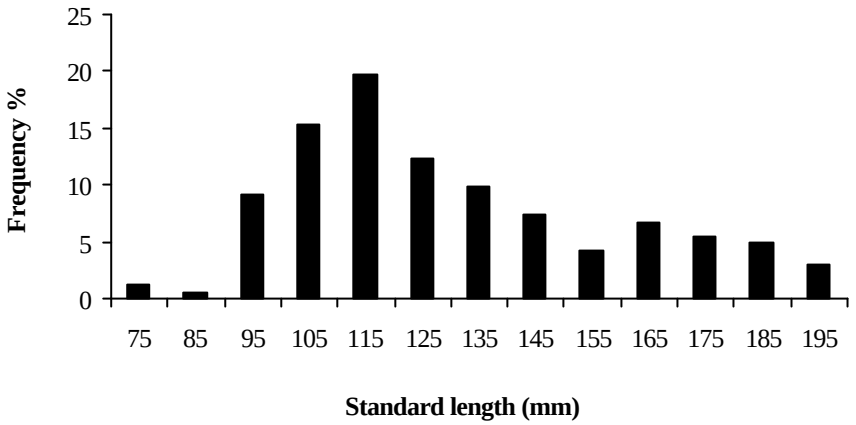


Figure 38-1. Size range and frequencies of *Taeniolethrinops praeorbitalis* caught in the SWA between July 1998 and May 1999.

The sex ratio observed over the full sampling period was F/M 0.5/0.5.

Owing to low sample size or absence of data for some months, the precise determination of breeding season was not possible. Ripe females were only found in August, and no male in breeding colour was ever caught. The mean size at maturity was about 155 mm for females (Figure 38-2), which was probably overestimated as this estimation was not done during the height of the breeding season but with all the data available for females, to increase the sample size. The first inflexion of the lower part of the curve came from the August data and it is likely that the mean size at maturity would rather be around 130 mm.

The length-weight and fecundity-weight relationships are presented in Figure 38-3 and 38-4, respectively. Fecundity ranged from 193 to 250 for females weighing between 135 and 184 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was estimated from the few data available at about 3% (Figure 38-5) and the mean oocyte weight was 25.73 mg (± 2.02 SD, N= 3).

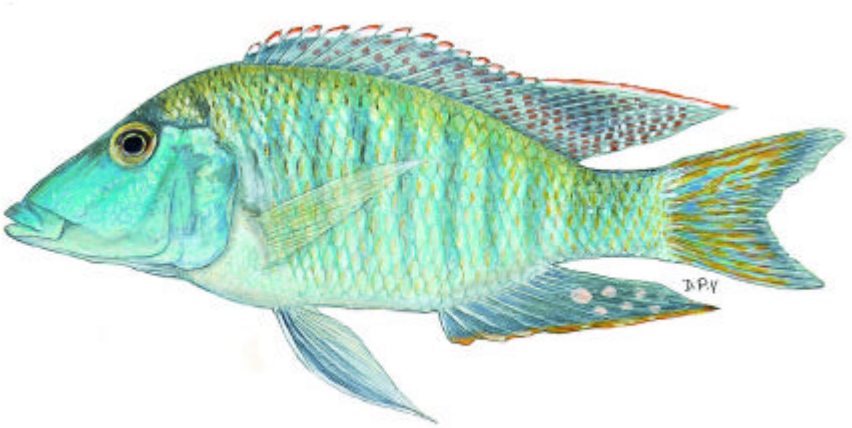


Plate 18. *Taeniolethrinops praeorbitalis* (by Dave Voorvelt).

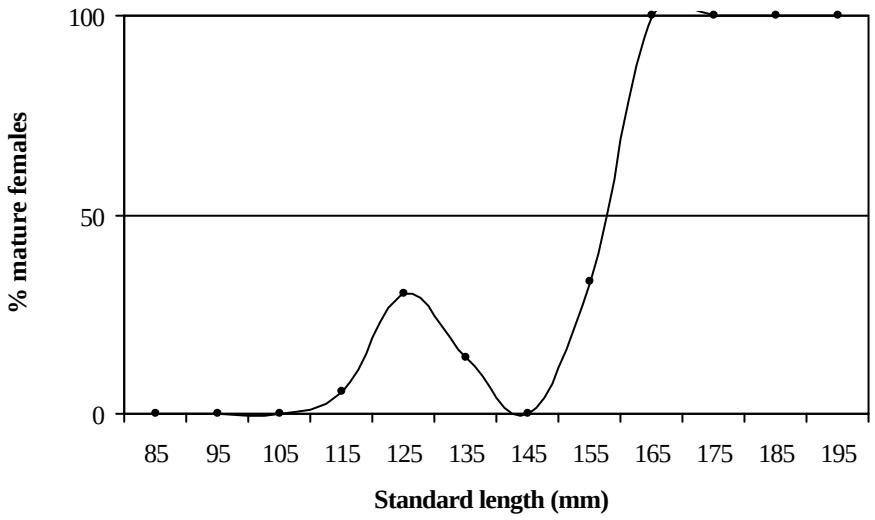


Figure 38-2. Percentage of mature females (stage 3 and above) per size class (standard length) for *Taeniolethrinops praeorbitalis* in the SWA.

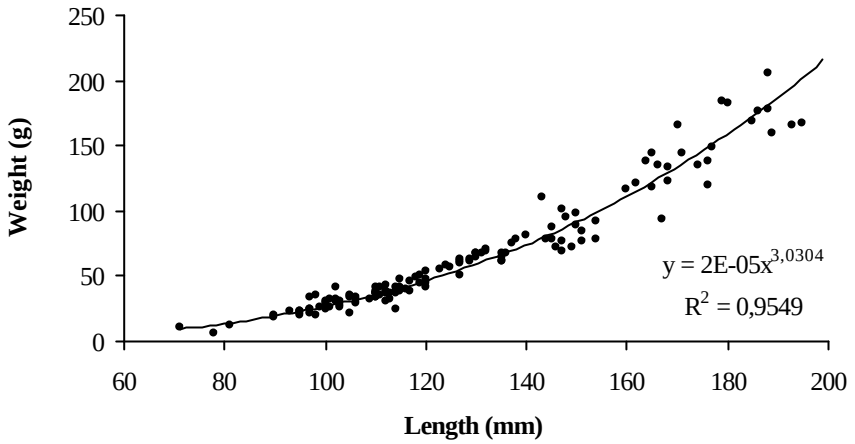


Figure 38-3. Length-weight relationship for *Taeniolethrinops praeorbitalis* females in the SWA. (R^2 = determination coefficient).

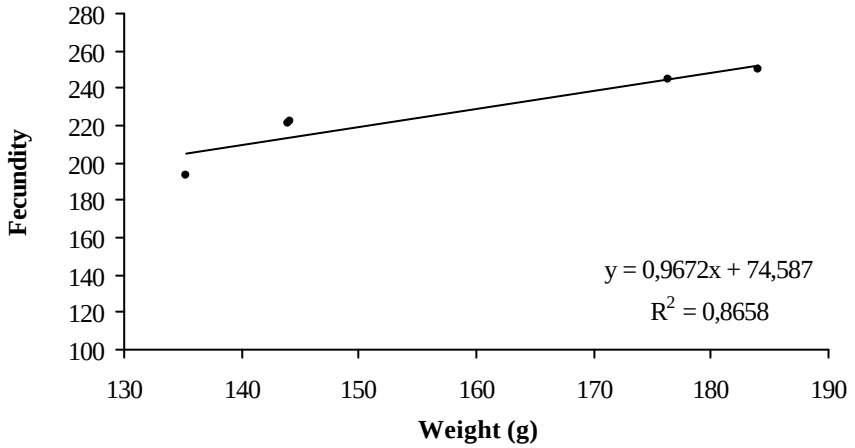


Figure 38-4. Fecundity-weight relationship for *Taeniolethrinops praeorbitalis* females in the SWA. (R^2 = determination coefficient).

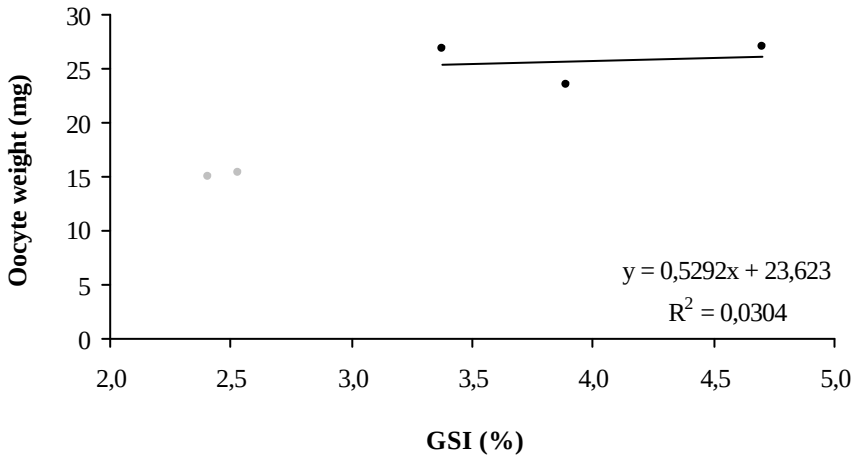


Figure 38-5. Relationship between oocyte weight and gonado-somatic index (GSI) for *Taeniolethrinops praeorbitalis*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

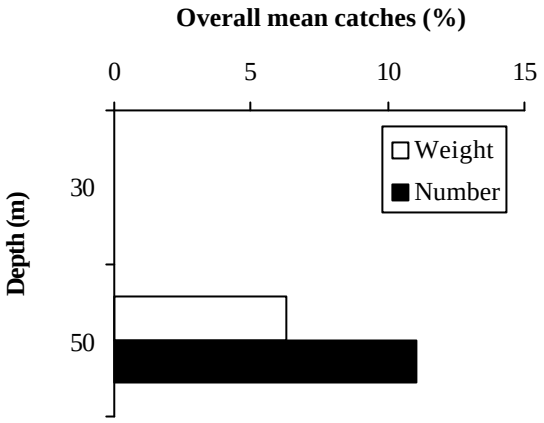


Figure 39-1. Mean occurrence and abundance in the catches per depth of *Trematocranus brevirostris* in the SWA between July 1998 and May 1999.

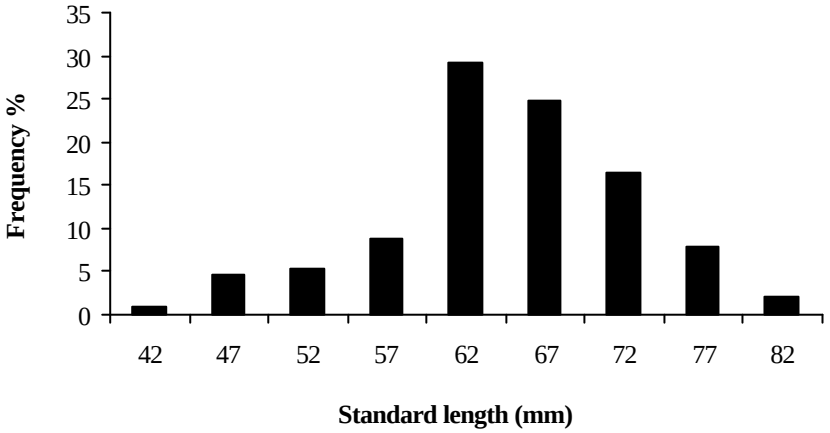


Figure 39-2. Size range and frequencies of *Trematocranus brevirostris* caught in the SWA between July 1998 and May 1999.

Trematocranus spp.

***Trematocranus brevirostris* (Trewavas)**

162 females and 249 males were analysed. *T. brevirostris* is a small species encountered at 30 and 50 m but mostly present at 50 m where it made up to 6.3 and 11.1% of the catches in weight and number, respectively (Figure 39-1). The mean CPUE per depth category was 9.9 kg for the shallows. No reference to this species (under this name at least) was made in Tómasson & Banda (1996). Specimens caught ranged between 40 and 85 mm (Figure 39-2). The sex ratio observed over the full sampling period was F/M 0.4/0.6.

Owing to low sample size or absence of data for some months, the precise determination of breeding season was not possible. The monthly progression of ripe females (Figure 39-3a) and males (Figure 39-3b) were very similar, indicating a breeding activity from January to May, and in October, with a peak in March-April. According to the percentages of ripe females and males in May and October, it is likely that some breeding also activity occur between May and October. As almost all the specimens of *T. brevirostris* were caught at 50 m, spawning probably takes place at this depth. Maturity was reached in their first year at 11 months old at a mean size of 50 mm for females (Figure 39-4). Size at maturity has to be determined at the height of the breeding season to be accurate, but owing to the low sample size we had to consider every data available. As a consequence, females caught outside the peak of breeding season were included in the analyse, even large resting females, which explain the shape of the upper part of the curve.

The length-weight and fecundity-weight relationships are presented in Figure 39-5 and 39-6, respectively. Fecundity ranged from 13 to 47 for females weighing between 4 and 13 g and was not correlated to body weight. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was estimated from the few data available at about 3% (Figure 39-7) and the mean oocyte weight was 6.70 mg (± 1.12 SD, N= 12).

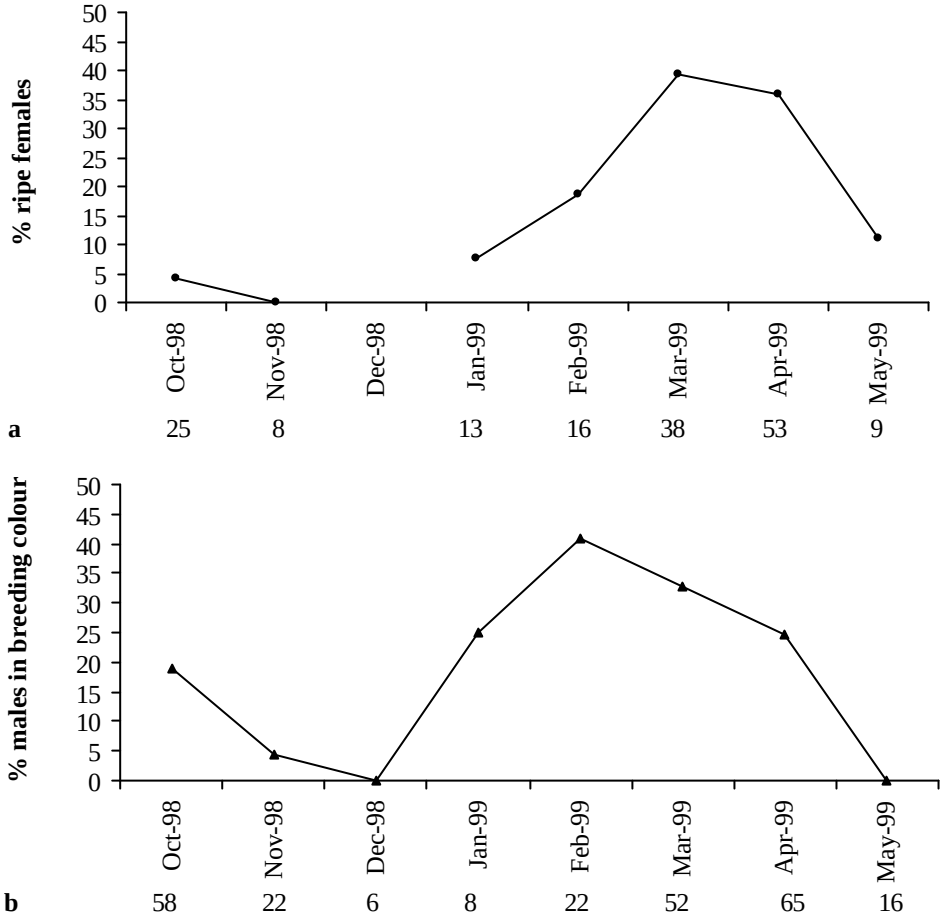


Figure 39-3. Seasonal progression of the percentage of ripe (stages 4 and 5) females (a) and males (b) *Trematocranus brevirostris* in the SWA The values below the x-axis are the effective (number of male or females which size was above the size at maturity) for each month.

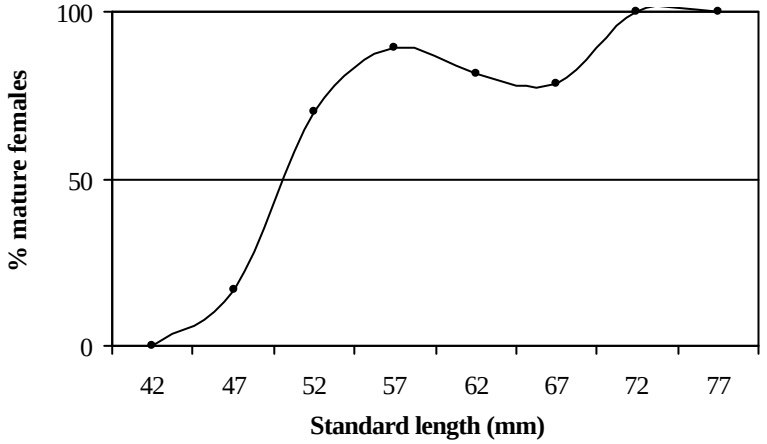


Figure 39-4. Percentage of mature females (stage 3 and above) per size class (standard length) for *Trematocranus brevirostris* in the SWA.

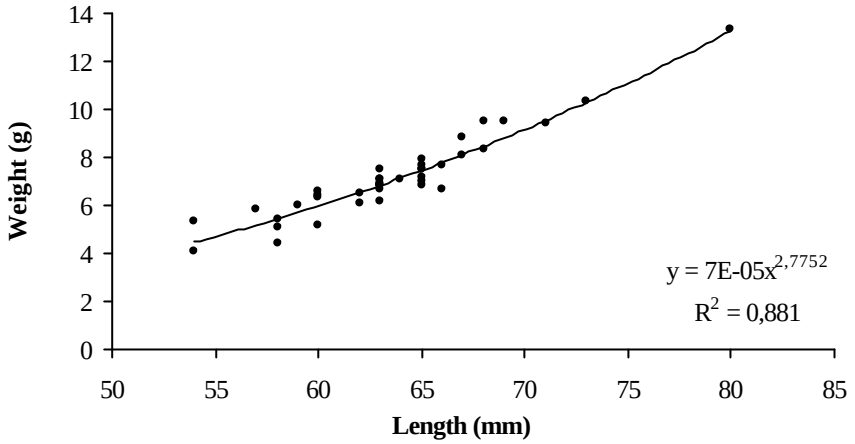


Figure 39-5. Length-weight relationship for *Trematocranus brevirostris* females in the SWA. (R^2 = determination coefficient).

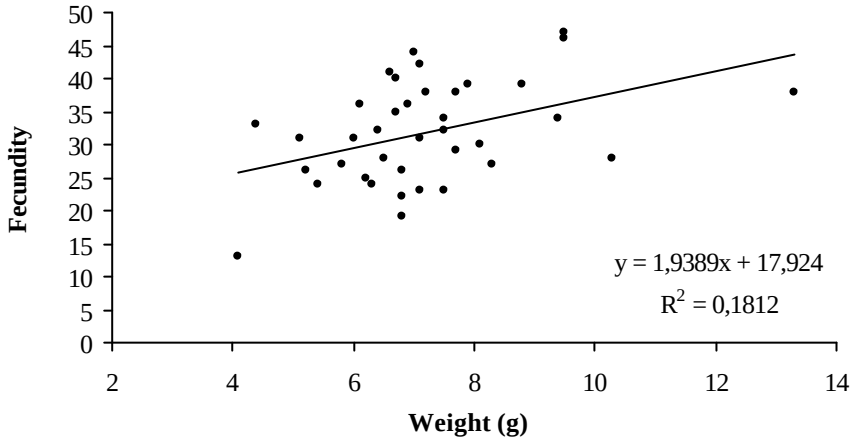


Figure 39-6. Fecundity-weight relationship for *Trematocranus brevirostris* females in the SWA. (R^2 = determination coefficient).

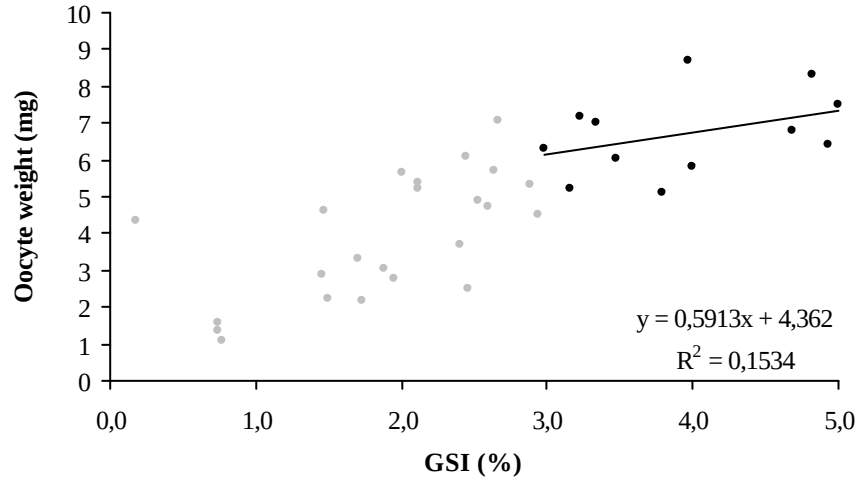


Figure 39-7. Relationship between oocyte weight and gonado-somatic index (GSI) for *Trematocranus brevirostris*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

Trematocranus placodon (Regan) (Plate 19)

34 females and 17 males were analysed. *T. placodon* is a common but not abundant species only encountered at 10 m. The mean CPUE per depth category was about 2 kg for the shallows, which was about three times less than the value reported (5.8 kg) by Tómasson & Banda (1996). Specimens caught ranged between 90 and 160 mm (Figure 40-1).

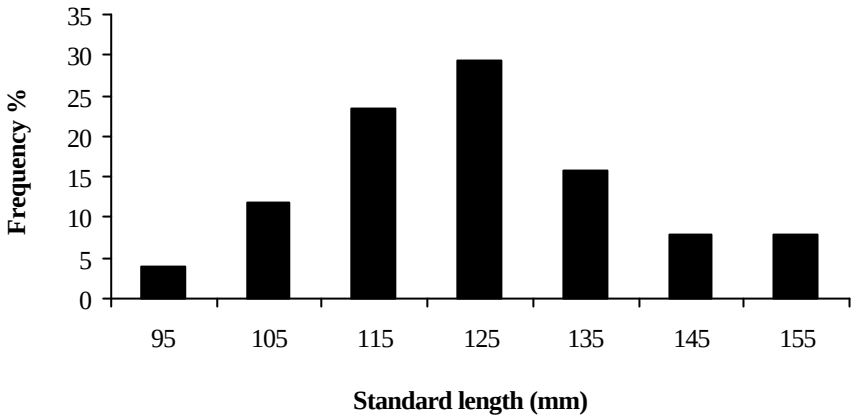


Figure 40-1. Size range and frequencies of *Trematocranus placodon* caught in the SWA between July 1998 and May 1999.

The sex ratio observed over the full sampling period was F/M 0.7/0.3.

Owing to low sample size or absence of data for some months, the precise determination of breeding season was not possible. Ripe females were found from June too August and in January-February (Figure 40-2). Only three males in breeding colour were caught, in July 98. The mean size at maturity was about 105 mm for females (Figure 40-3), which was probably overestimated as this estimation was not done during the height of the breeding season but with all the data available for females, to increase the sample size.

The length-weight and fecundity-weight relationships are presented in Figure 40-4 and 40-5, respectively. Fecundity ranged from 76 to 178 for females weighing between 41 and 91 g. No relation was found between oocyte weight and body weight. The GSI threshold above which the oocyte weight did no longer increase significantly was estimated from the few data available at about 2.5% (Figure 40-6) and the mean oocyte weight was 12.83 mg (± 1.15 SD, N= 5).

Plate 19. *Trematocranus placodon* (by Dave Voorvelt).

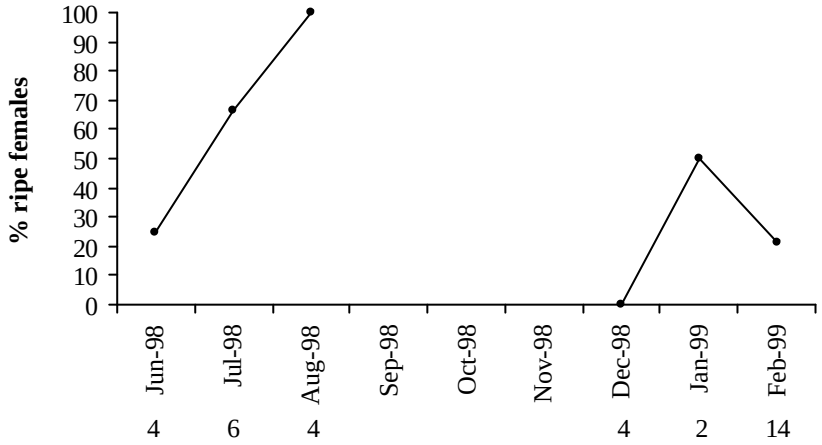


Figure 40-2. Seasonal progression of the percentage of ripe (stages 4 and 5) females *Trematocranus placodon* in the SWA The values below the x-axis are the effective for each month.

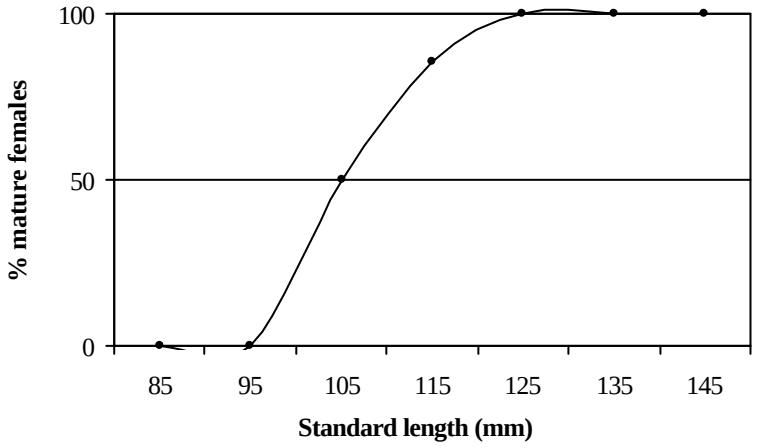


Figure 40-3. Percentage of mature females (stage 3 and above) per size class (standard length) for *Trematocranus placodon* in the SWA.

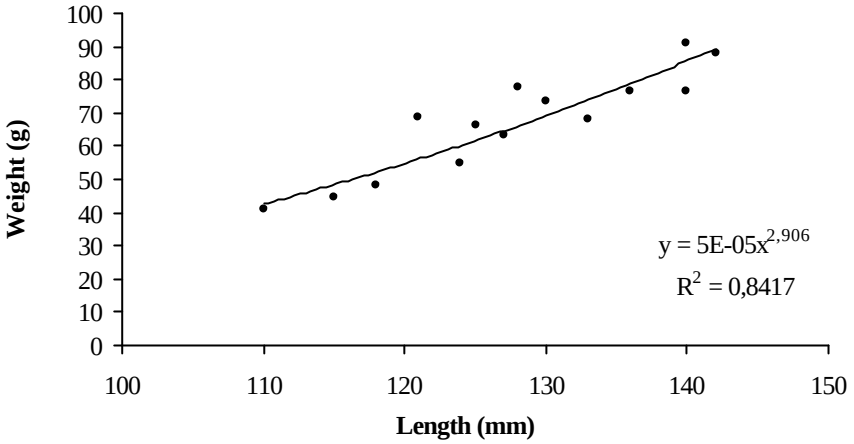


Figure 40-4. Length-weight relationship for *Trematocranus placodon* females in the SWA. (R^2 = determination coefficient).

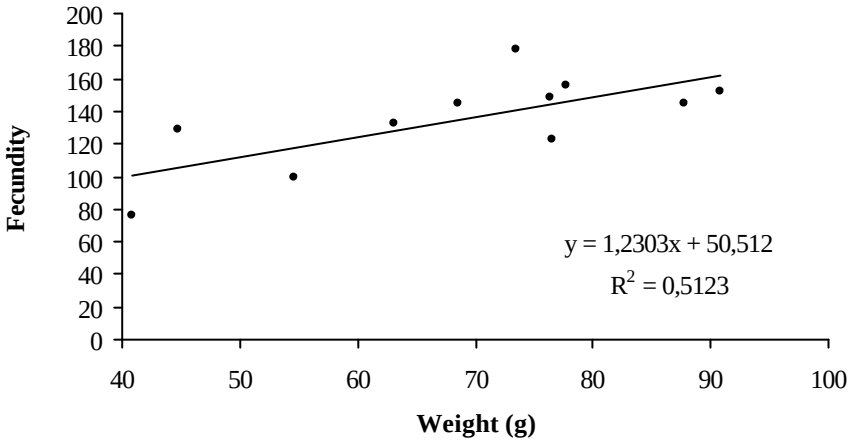


Figure 40-5. Fecundity-weight relationship for *Trematocranus placodon* females in the SWA. (R^2 = determination coefficient).

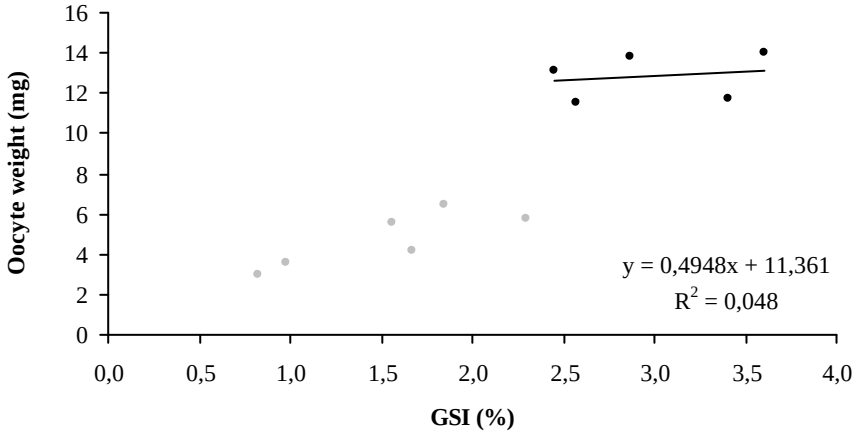


Figure 40-6. Relationship between oocyte weight and gonado-somatic index (GSI) for *Trematocranus placodon*. Oocytes from females whose GSI was below (in grey) and above (in black with regression) 3%. (R^2 = determination coefficient).

Table 41. Peak of breeding activity of species per depth category. X = data supported by good sample size, x = data supported by low sample size. "Intermediate" means common in both deep and shallow zone.

Depth category	Species	1998 Jun	Jul	Aug	Oct	Nov	Dec	1999 Jan	Feb	Mar	Apr	May
Deep water (75-125m)	*A. 'geoffreyi'*	X	X	X								X
	A. macrocleithrum	***x***	X	X								x
	A. mentale					X		X	X			
	A. pectinatum							X	X			
	Au. minutus	X							X			
	D. apogon			X				X	X	X		
	D. macrops								X	X	X	
	P. tokolosh						X	X	X			
	L. 'deep water altus'	X							X	X	X	X
	L. gossei							X	X	X	X	
	L. 'oliveri'								X	X	X	
	L. polli											X
	Pl. 'platyrhynchos'			x				X	X	X	X	X
Intermed-iate	*D. limnothrissa*	X									X	X
	C. quadrimaculatus			x								
	C. virginalis	X	X									X
	L. longimanus			x								
	Sc. ahli				X	X						
	Sc. Benthicola			X			X					
Shallow water (10-50m)	*Au. 'blue orange'*			X	X		X					
	L. argenteus			X			X	X	X			
	M. anaphyrmus	X								X	X	X
	N. 'argyrosoma'						X			X		
	Pl. 'long'											x
	T. furcicauda		x									
	T. praeorbitalis			x								
	Tr. brevirostris									X	X	

Discussion

Depth distribution and mean CPUE for the major species were compared with those found by Tómasson & Banda (1996) in the SWA. Several of the species we regularly caught were absent of Tómasson & Banda (1996) survey of the SWA, and the other way round. This is likely due to identification differences between the two studies, some species being either lumped together under their generic names or accurately identified. Also, the smaller area covered might explain the absence of some species in our survey. However, global trends in CPUE were similar for both studies and the observed differences may lies in the fact that Tómasson & Banda covered the entire SWA whereas our work focused on the northern part of it.

Breeding species were found throughout the year at any depth. Some species were capable of breeding throughout the year (as already reported by Marsh et al. 1986, Lewis & Tweddle 1990, Thompson et al. 1996) with marked seasonal variations in the proportions of ripe individuals, whereas others appeared to have distinct breeding season (as the *Oreochromis spp*., Lowe-McConnell 1987 or members of the *Utaka* group, Iles 1960, 1971, Jackson et al. 1963), generally over 6 months long. Again, these patterns were independent from the depth distribution of the species. An interesting hypothesis linking the length of the breeding season to the fecundity of the species was proposed by Marsh et al. (1986): the lower the fecundity the longer the breeding season. If this hypothesis seemed to fit for the *mbuna*, it does however not hold for the demersal cichlids. Indeed, species such as *Lethrinops argenteus*, or *L. oliveri*, which had continuous breeding season also presented amongst the highest relative fecundity (2162 eggs.kg^{-1}, 4931 eggs.kg^{-1}, respectively) whereas species such as *Diplotaxodon apogon* with definite breeding season had amongst the lowest relative fecundity (632 eggs.kg^{-1}). Apart from a single species, *Copadichromis virginalis*, whose peaks of breeding activity were clearly related to plankton abundance, the breeding cycle of the other species was not directly related to any of the monitored environmental factors (temperature, oxygen concentration, photoperiod, algal abundance, conductivity). No particular breeding distribution pattern was found among the several species studied, when they were grouped per trophic category, per genera or per depth category. Even when focusing on the peaks of breeding activity per depth category (Table 41), no marked structure appeared. The peaks of breeding activity were evenly distributed over the year for the shallow water species. The only slight remarkable trend was that the highest concentration of breeding peaks occurred from January to May for the deep water species whereas no peak was recorded from January to March for the species with "intermediate" depth distribution. The period from December to April is the time of the year when the lake is most strongly stratified, the thermocline being around 40-50 m (Eccles 1974, see Figure 11 previous chapter). It also corresponds to the period of lowest phytoplankton and zooplankton abundance (Irvine 1995). However, most of the studied species are supposed to be benthic invertebrates feeders and the observed breeding patterns might be related to the relative abundance of their main food sources, as seems to be the rule for *mbuna* (Marsh et al. 1986). The seasonal progression of benthic invertebrate abundance and biomass, which is currently under study in the European Union Project: "The trophic ecology of the demersal fish community of Lake Malawi/Niasa", might shed a new light on the determinism of the observed breeding patterns. On the other hand, the reason for this apparent time sharing could lie in Fryer & Iles (1972) hypothesis of self-controlled population densities (population homeostasis) achieved through sharing of spawning territories. Lowe-McConnell (1979) also suggested that for tropical fishes asynchronous breeding could be a good way of maximising resource use for species with similar requirements. However, given the good correspondence between food availability and

Table 42. Ratio of length at maturity (L_{50}) to maximum observed length (MOL) for several cichlids species caught by trawling in the South West Arm of Lake Malawi between June 1998 and May 1999. The lengths are standard lengths. In italic are values for which determination of L_{50} was uncertain owing to low effective.

Species	MOL (mm)	L_{50} (mm)	Ratio
A. 'geoffreyi'	165	90	0.55
A. macrocleithrum	*148*	*100*	*0.68*
A. mentale	245	160	0.65
A. pectinatum	140	70	0.5
Au. 'blue orange'	78	48	0.62
Au. 'cf macrochir'	*134*	*100*	*0.75*
Au. 'minutus'	72	42	0.58
Au. 'rostratum deep'	140	75	0.54
B. lepturus	326	160	0.49
B. nototaenia	*300*	*115*	*0.38*
C. quadrimaculatus	*150*	*100*	*0.67*
C. virginalis	123	75	0.61
D. apogon	130	88	0.68
D. argenteus	206	140	0.68
D. limnothrissa	175	105	0.6
D. macrops	135	98	0.73
P. tokolosh	213	135	0.63
L. argenteus	165	108	0.65
L. 'deep water albus'	160	82	0.51
L. 'deep water altus'	130	60	0.46
L. gossei	170	92	0.54
L. longimanus	*147*	*107*	*0.73*
L. 'oliveri'	98	60	0.61
L. polli	120	65	0.54
M. anaphyrmus	164	105	0.64
N. 'argyrosoma'	97	57	0.59
Pl. 'platyrhynchos'	*115*	*80*	*0.69*
Ps. livingstonii	63	37	0.59
Sc. benthicola	168	100	0.60
St. 'guttatus'	147	100	0.68
T. furcicauda	178	130	0.73
T. praeorbitalis	199	130	0.65
Tr. brevirostris	85	50	0.59
Tr. placodon	160	105	0.66

breeding patterns for rock-dwelling species and *C. virginalis*, this is likely to be also the case for demersal species. For every species, more males than females in breeding condition were caught at any time of the year. This was also observed by Lewis & Tweddle (1990) on the three studied *Lethrinops spp*. Although not demonstrated for every species, the general trend of Malawi cichlids males to form breeding aggregations is likely to account for this difference, breeding males being more vulnerable to trawling when they form leks (Fryer 1972, 1984).

Among the species for which we determined the size at maturity, a few had already been studied: *Diplotaxodon limnothrissa* (Thompson et al. 1996), *Lethrinops gossei* (Lewis & Tweddle (1990), *Mylochromis anaphyrmus* (Tweddle & Turner 1977). The size at maturity we got for *L. gossei* and *M. anaphyrmus* were much smaller than those reported by Lewis & Tweddle and Tweddle & Turner. Size at maturity may vary among successive years for a same population under environmental variation (Duponchelle & Panfili 1998), or over longer time periods under fishing pressure (Stewart 1988, Lowe-McConnell 1982, Trewavas 1983). The observed differences in size at maturity could thus lie in the distant time period and geographical area between the studies. However, the method they both used overestimated the L_{50}. The average size at first maturation (L_{50}) is defined as the length at which 50% of the females are mature during the breeding season. Tweddle & Turner and Lewis & Tweddle considered the "length at the percentage point which is one-half of the maximum percentage of mature fish found in any length group", that is the highest point on the sigmoid curve. But as they considered in fact ripe fish as being mature, and that there is always only a fraction of the population in a "ripe" state, they consistently overestimated the L_{50}. That's the reason why their sigmoid never reached 100%. Iles (1971) stated that the ratio of length at maturity to asymptotic length for cichlids was characteristically a little above 0.7. The ratios found by Tweddle & Turner (1977) tended to confirm that mean value. However, as they overestimated the L_{50}, the ratios they found were also overestimated. In our study, the asymptotic length was not calculated for all the species (see Chapter "Growth"), thus the maximum observed length, considered to be close to the asymptotic length, was used to calculate the ratio (Table 42). Ratios ranged between 0.38 and 0.75 with an averaged value of 0.61. As the L_{50} for some species were probably overestimated due to low sample size (in italic in Table 42) and considering that the maximum observed length is usually smaller than the theoretic asymptotic length, the average ratio is likely to be a little below 0.6. In the case of *Lethrinops 'deep water altus'*, the ratio value of 0.46 might have been underestimated. Indeed, this low value might lie in misidentification of the largest specimens (up to 130 mm), as Turner (1996) reported a maximum size of 10 cm TL for this species. It is interesting to note that some genera present ratio values that tend to be close to 0.7 (e.g. *Diplotaxodon spp.*, *Copadichromis spp*.) whereas others show values closer to 0.5 such as the *Buccochromis* and *Lethrinops spp*..

Despite the importance of this population parameter in fisheries management, age at maturity had only been estimated on a few species so far: *Lethrinops longipinnis*, *L. parvidens*, *Mylochromis* ("*Haplochromis*") *anaphyrmus*, *Copadichromis* ("*Haplochromis*") *mloto* (Tweddle & Turner 1977). These species were believed to reach maturity at the end of their third year except *C. mloto*, which matured at the end of its second year. *M. anaphyrmus* was the only common species between Tweddle & Turner study and ours. We found *M. anaphyrmus* was reaching maturity early in its second year at 18 months old. The growth parameters determined by Tweddle & Turner (1977), K=0.671 and $L\infty$=196 mm TL, being very similar to ours: K=0.62 and $L\infty$=180 mm SL (see Chapter "Growth"), the two fold difference in age at maturity observed between the two studies (which took place in the same area) lies mainly in the overestimation of size at maturity by the method used in Tweddle & Turner (1977). Assuming the same mean size at maturity of 160 mm TL (about 130 mm SL in our case), they would mature early in their third year (25 months) as well. It is very likely that

this overestimation of age and size at maturity hold as well for the others species they studied. Growth and age at maturity were also estimated for *C.* ("*Haplochromis*") *virginalis* and *C.* ("*Haplochromis*") *quadrimaculatus* by Iles (1971). They were both reaching maturity at three years old whereas we found they matured in their first and second year at 12 and 20 months for *C. virginalis* and *C. quadrimaculatus*, respectively. Despite slight differences in growth parameters, the differences between the two sets of estimations lies in the fact that determination of the size at maturity was based on ripe females in Iles's study (Iles 1971, Jackson et al. 1963), which leads to an overestimation of L_{50}. Indeed, the size at maturity they determined represented 88 and 84 % of the maximum theoretical length (asymptotic length) for *C. virginalis* and *C. quadrimaculatus*, respectively. It is assumed that in unexploited stocks, which is certainly not the case for members of the Utaka group, the oldest fish reach only about 95% of their asymptotic length (review in Pauly 1980). This means that in Iles's case, they would breed for the first time close to their maximum size, which only few fish reach. Also, assuming the mean maturity length ratio Iles (1971) considered as the rule for cichlids (0.7), age at maturity would have been 1.6 and 2.0 years old for its populations of *C. virginalis* and *C. quadrimaculatus*, respectively, which would place them in the range of age at maturity we observed. The 22 species for which we determined A_{50} reached maturity before the end of their second year or during their first year for the smallest species (*Au. 'Blue orange'*, *Au. 'minutus'*, *N. 'argyrosoma'*…). It is more conceivable that highly exploited species with such low fecundity as the Lake Malawi cichlids, mature early in their life (around one year old) rather than in the last part of their lives (more than three years old). Indeed, very few species grew older than four years (see Chapter "Growth", see also the abacus of longevity versus mean maximum length drawn out of 111 species of African freshwater fishes by de Merona 1983). Next, as only a very small fraction of a fish population reach the asymptotic length, which is usually slightly higher than the maximum observed length, this means that very few fish indeed would reach maturity and would therefore reproduce to ensure the replenishment of populations or the species survival. This clearly appears when looking at the proportion of fish reaching the size at maturity on the length frequency distributions presented in Iles (1971). Species with such a life history strategy would have unlikely survive about thirty years of intense exploitation by fisheries, which systematically remove the large specimens of fish populations (Turner 1977b, Turner 1995, Turner et al. 1995).

It is a well known characteristic of Lake Malawi cichlids, they usually produce few but large eggs (see for review Fryer & Iles 1972, Konings 1995, Turner 1996). The forty species studied perfectly fitted into this trend. However, as already mentioned above, distinct reproductive strategies are distinguished among species and genera: species of the *Diplotaxodon* clade (sensu Turner et al. 1999) and *Rhamphochromis spp.* (pers. obs.) clearly presented the lowest relative fecundities and the largest eggs of all species. Although in a lesser extent, *C. quadrimaculatus* also presented low fecundity and large eggs. On the other hand, for a same body weight *Lethrinops*, *Alticorpus* or *Mylochromis* species produced much smaller but more numerous eggs. It appears that the species having a more pelagic life style such as the *Diplotaxodon spp.*, *Rhamphochromis spp.* (Allison et al. 1996, Thompson et al. 1995, 1996, Turner et al. 1999), or *C. quadrimaculatus* (Allison et al. 1996, Thompson et al. 1995, 1996) are characterised by reduced fecundity, very large eggs and delayed maturity (*Diplotaxodon* and *Copadichromis spp.* had the highest Lmax to L_{50} ratios). This reproductive strategy, which enable females to moothbrood young to very large sizes (observed for *D. limnothrissa* Turner 1994a, 1996, this study), is likely to be an adaptation to the pelagic environment. Egg size is an essential parameter of fish reproductive strategy for it conditions the ability to use a large array of food sources, to avoid predators and to survive unfavourable

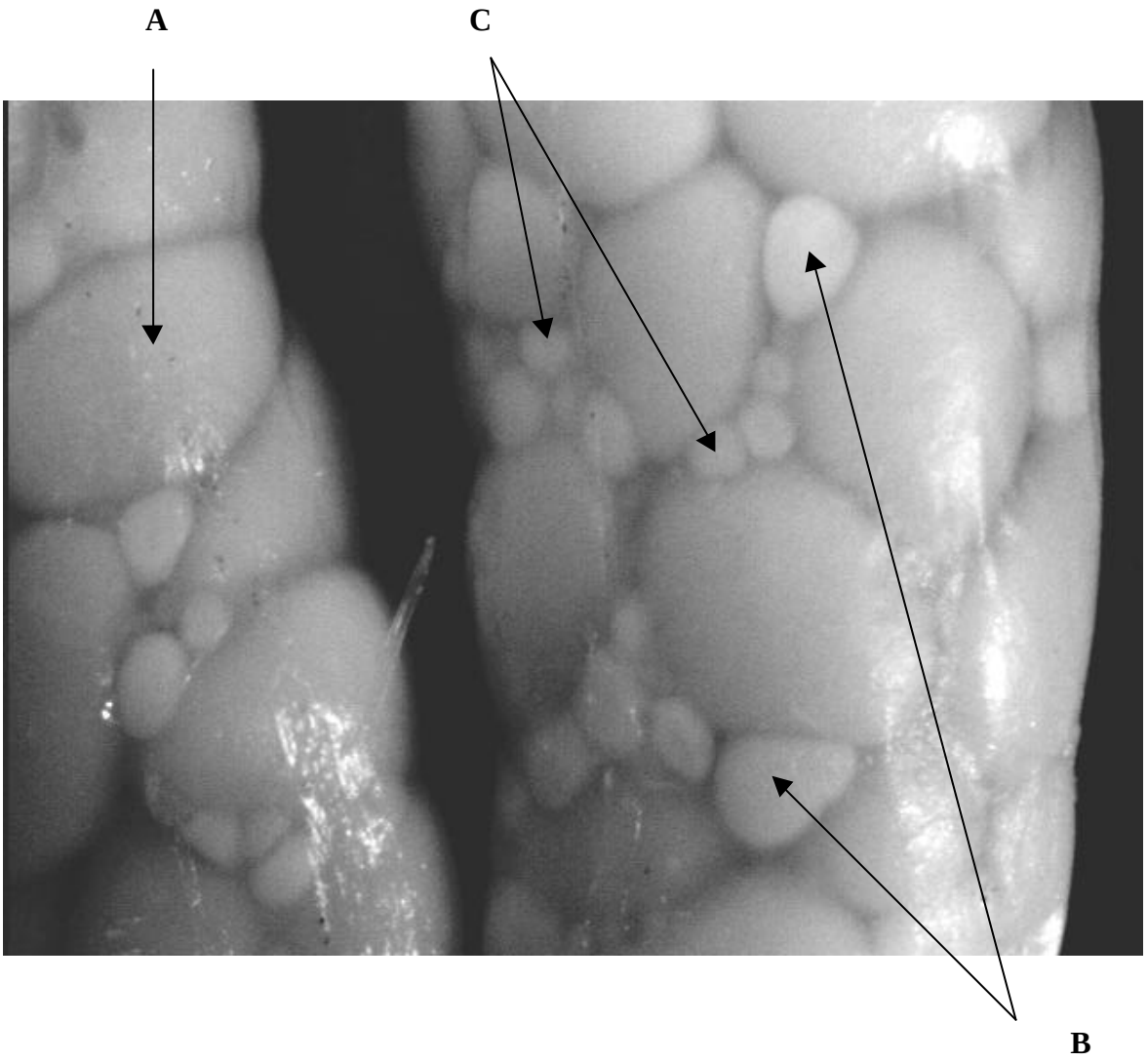


Plate 20. Gonad of a ripe Lethrinops longimanus female with at least three batches of oocytes. A = oocytes in late vitellogenesis that will be laid at the next spawn. B = second batch of developing vitellogenic oocytes (characteristic of a stage 3). C = third batch of oocytes in early development (characteristic of a stage 2).

environmental conditions (Bagenal 1969, 1978, Ware 1977, Mann & Mills 1979, Reznick, 1982, Marsh 1986, Sargent et al. 1987, Wootton 1990, Cambray & Bruton 1994, Wootton 1994). An inverse relationship links the egg size and the fecundity in most fish species (Mann & Mills 1979, Albaret 1982, Stearns 1983, Duarte & Alcaraz 1989, Elgar 1990) and in cichlids particularly (Peters 1963, De Silva 1986, Legendre & Ecoutin 1989, 1996, Duponchelle et al. 2000, this study). According to the energetic cost of gamete production, food is probably one of the most important environmental factors involved in the regulation of fecundity (Wooton & Evans 1976, Wooton 1979). Therefore, food availability being relatively poor in the pelagic zone, a logical strategy to improve both parents and offspring's fitness is to produce fewer eggs but of larger size and to moothbrood young to large size to enhance their survival. Indeed, the larger the fry when released by the female the more effective they will be in utilising the scarce food resources of the open waters. If this hypothesis is true, the cichlid reproductive strategy to adapt to pelagic environment would differ markedly from the strategy of most other pelagic fish families, which generally produce large numbers of small eggs (reviews by Duarte & Alcaraz 1989, Elgar 1990), including the freshwater pelagic cyprinids *Engraulicypris sardella* in Lake Malawi (Jackson et al. 1963) and *Rastrineobola argentea* in Lake Victoria (review in Witte & van Densen 1995), or the clupeids *Stolothrissa tanganicae* and *Limnothrissa miodon* in Lake Tanganyika (reviews by Coulter 1991, Marshall 1993, and Patterson & Makin 1998).

As pointed out by Fryer & Iles (1972), to know how many eggs each female produces at each brood is important but how many times a year that number is produced is even more essential for fisheries management. Determining the number of times a female can spawn during a breeding season is a difficult task in natural environments, particularly for the demersal Malawi cichlids. Cichlids are known world-wide for their capacity to have multiple spawning events during the same breeding season when environmental conditions are favourable (Lowe 1955, Trewavas 1983 for review, James & Bruton 1992). However, based on the observation of only one batch of eggs at a time in ovaries of ripe female cichlids in Lake Malawi, it was assumed that a same female was able to spawn only once per breeding season (Lowe 1955, Iles 1971, Tweddle and Turner 1977). Having analysed tens of thousands demersal cichlids pertaining to at least 170 species (Appendix 1) during the course of this study, three sets of evidence have emerged to suggest that annual multiple spawning is likely. The evidence is presented below:

(1) - For most of the studied species it was observed but not recorded that more than one batch of eggs were in the ovaries of ripe females. An example is given on Plate 20, which presents the ovaries of a ripe *Lethrinops longimanus* female. A minimum of three batches of developing oocytes are clearly visible: the batch that will be released soon (A), a second batch that already undertook vitellogenesis (B), and a third one of smaller oocytes in early development (C). To verify the observation, and taking the opportunity of a fishing cruise with the RV Ndunduma in the SWA in July 1999, a special survey was organised in order to check the existence of more than one batch of oocyte in cichlids ripe gonads. All the females found with ripe gonads had two and sometimes three batches of oocytes. The sample included the following species: *Alticorpus 'geoffreyi'*, *A. macrocleithrum*, *A. mentale*, *A. pectinatum*, *Aulonocara 'blue orange'*, *Copadichromis virginalis*, *Diplotaxodon greenwoodi*, *Hemitaeniochromis insignis*, *Lethrinops longimanus*, *L. gossei*, *L. 'oliveri'*, *L. polli*, *Mylochromis anaphyrmus*, *Otopharynx speciosus*, *O. brooksi* and *Sciaenochromis 'guttatus'*.

(2) - The gonad maturity stage 6-3 (see Material and methods) was frequently observed for all the studied species. This stage is characteristic of post-spawning females initiating another cycle of vitellogenesis.

(3) - Moothbrooding females of many species were often found with developing ovaries (stages 6-3 or 3).

These three sets of evidence strongly suggest that each female probably spawns more than once during the breeding season, for haplochromine cichlids at least. Indeed, it would be very poor energetic strategy for a female to initiate another vitellogenesis cycle if the developed oocytes were not to be laid. In such a stable environment as Lake Malawi, it is very unlikely that environmental conditions become so unfavourable that a female would resorb her eggs during the few weeks needed to complete a vetillogenesis cycle (four to five weeks in cichlids, Fishelson 1966, Gauthier et al. 1996, Tacon et al. 1996). Furthermore, although extensive breeding season does not mean that individual fish breed continuously, most of the studied species have breeding seasons lasting more than six months, and several showed continuous breeding seasons. It appears very reasonable in these conditions that individual fish, known to breed repeatedly in aquarium, may then reproduce more than once, as do cichlids everywhere else (reviews by Fryer & Iles 1972, Trewavas 1983, Lowe-McConnell 1987).

Although this study presents the most comprehensive work on Lake Malawi cichlids life histories, it is based on a one year survey only. As inter annual variability of reproductive characteristics can be important in African cichlids (Duponchelle & Panfili 1998, Duponchelle et al. 1999, 2000), the described breeding patterns might not represent a permanent situation but rather a situation representative of the prevalent environmental conditions. However, Lake Malawi is a stable environment where important environmental perturbations are unlikely. The likeliest unexpected fluctuations are in resource availability, which might modify the intensity of breeding activity rather than its periodicity (Duponchelle et al. 1999). Furthermore, the breeding season observed for *C.* ("*Haplochromis*") *virginalis* and *C.* ("*Haplochromis*") *quadrimaculatus* were the same over a period of five years (Iles 1971) and Lewis & Tweddle (1990) reported very similar trends in breeding seasonality among the three years of their study, which suggested little or no inter annual variability of breeding patterns.

Chapter 3:

Growth patterns of some of the most important demersal fish species caught by trawling in the South West Arm of Lake Malawi

Chapter 3: Growth patterns of some of the most important demersal fish species caught by trawling in the South West Arm of Lake Malawi

F. Duponchelle, A.J. Ribbink, A. Msukwa, J. Mafuka & D. Mandere

Introduction

Several methods exist to assess fish growth parameters, such as analysis of periodic marks on opercular bones, scales, vertebrae or otoliths, individual tagging or analysis of length frequency distributions (review by Casselman 1987, de Merona et al. 1988, Wootton 1990, King 1995). Among these methods, analysis of the modal progression of length frequency distributions (Ricker 1975) has been commonly used for African freshwater fishes despite its potential biases in tropical conditions, where lack of seasonality, long spawning periods, non-year events giving rise to variations in growth and survival rates (hence to age and size modes) may lead to erroneously interpret size modes as differing in age by units of year. Indeed, tropical species often have extended breeding seasons during which multiple broods are produced and several cohorts (a cohort is a group of fish born at the same time) are likely to be encountered. In these conditions following year classes is often difficult and hamper precise interpretation of length progression series (Fryer & Iles 1972, Casselman 1987, Lowe-McConnell 1987, de Merona et al. 1988, King 1995). As just seen in the previous chapter, most of the studied species have extended breeding seasons. However, when reasonably accurate information on the species biology is available, such as the breeding season and the maximum length, it is still possible to obtain correct estimates of growth using modal length progression analysis. For most of the species studied below, more than one cohort per year was identifiable and different sets of K and L_∞ provided reasonable fit of the length frequency distributions. In every case, we retained the set of parameters that best corresponded with the breeding patterns observed for the species (ie. which estimated date of birth best corresponded with breeding peaks) and that best described the distributions (ie. which went through the largest number of large modes). Also, as an extensive sampling was done monthly over a complete annual cycle, always on the same sites, it was assumed that for most species the maximum observed length was close to the asymptotic length (L_∞), which participated in selecting the best set of parameters. This was particularly true for the small abundant species, for which we fixed L∞ within a few millimetres from the maximum observed length. This process also permitted to diminish the tendency of ELEFAN method to underestimate K and overestimate L∞ (Moreau et al. 1995).

Despite the 35 mm cod end mesh size, the length frequency distributions were influenced either by the trawl selectivity or the absence of the juveniles from trawled areas. Indeed; juveniles of species were seldom caught before 50 mm and were usually accessible to the trawl gear between 60 and 90 mm depending on species and shapes. Consequently, adults were better represented in the catches than juveniles and length frequency distributions below the size of full selection were not adequate for mortality estimates. Whenever one or more suitable distributions were available, mortality estimates were based only on them. But in most of the cases, they were based on all the distributions. This must be kept in mind even

though mortality estimates often appeared reasonable. FiSAT allows correction of the bias due to fishing gear's selectivity, which often leads to a better estimation of the growth parameters (Moreau et al. 1995, Gayanilo et al. 1996). This correction was tried for every species and never lead to better estimations (according to the "goodness of fit" index of the ELEFAN routine, see Gayanilo & Pauly 1997). The weight given to small length systematically flattened out the rest of the distribution and the resulting fits were bad. All the estimations were therefore based on non corrected data. However, for every species except the small ones for which it was not necessary, the smoothing of the data by calculating the running averages over three length bins (5 mm for most of the species and 10 mm for large and not abundant species) helped to track the progression of modes.
All the lengths are standard lengths.

Material and methods

All the fish analysed were collected during the monthly trawl catches in the north of the South West Arm (see Chapter 1 for details).

The following equation was used to convert total lengths (TL) from literature into standard length (SL):

$$SL = 0.785\ TL + 3.477 \quad (1)$$

This equation was calculated from Table G1.

Table G1. Growth estimates (mm in TL) of Lake Malawi cichlids species given by Iles (1971) and Tweddle & Turner (1977) and the same growth estimates expressed in SL by de Merona et al. (1988).

Species	$L\infty$ (TL)	K	References	$L\infty$ (SL)	References
H. anaphyrmus	196	0,671	Tweddle & Turner (1977)	157	De Merona et al. (1988)
H. intermedius	229	0,571	Tweddle & Turner (1977)	184	De Merona et al. (1988)
H. virginalis	121	0,778	Iles (1971)	99	De Merona et al. (1988)
H. quadrimaculatus	190	0,65	Iles (1971)	153	De Merona et al. (1988)
H. pleurostigmoides	144	0,764	Iles (1971)	116	De Merona et al. (1988)
L. parvidens	208	0,487	Tweddle & Turner (1977)	166	De Merona et al. (1988)
L. longipinnis	202	0,571	Tweddle & Turner (1977)	162	De Merona et al. (1988)

Growth was estimated from the modal progressions of length frequency distributions of species at every sampled month. The growth parameters were calculated by the Von Bertalanffy Growth Curve (VBGC) equation (equation 2) fitted by the electronic length frequency analysis (ELEFAN) method (Pauly 1987) using the FAO-ICLARM Package FiSAT (Gayanilo et al. 1996, Gayanilo & Pauly 1997).

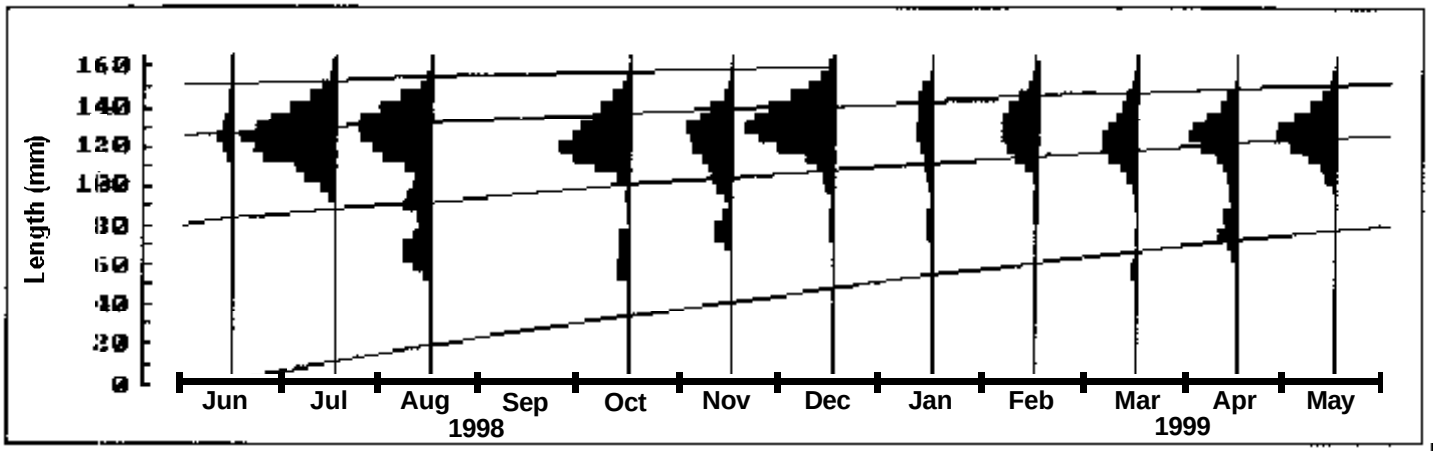
$$L_t = L_\infty (1-\exp (-K (t-t_0)) \qquad (2)$$

Where L_t is the mean length at age t, L_∞ is the asymptotic length, K the growth coefficient and t_0 the size at age 0.

Among the several growth models available (VBGC, Richards, Gompertz, logistic, quadratic, exponential, ect. see Schnute 1981 for review), the VBGC model was retained for the following reasons: 1)- for African fish species the VBGC usually provides a good fit of the data (de Merona et al. 1988, Moreau et al. 1995). 2)- it proves useful for comparative purposes as it has been largely utilised for African freshwater species and cichlids particularly, for which synthesis are available (de Merona et al. 1983, 1988, Moreau et al. 1995). The ELEFAN method, used by Moreau et al. (1995) on 57 stocks of African freshwater species was also utilised in this study for comparative purposes.

Mortality estimates were obtained as described in Moreau et al. (1991) and Moreau & Nyakageni (1992) for Lake Tanganyika fishes. Total mortality (Z) was estimated by the method of the length-converted catch curves (LCC) (Pauly 1983). This method consists in pooling all the distributions while keeping their relative importance to obtain a single frequency distribution. This decreases part of the sampling biases. Total mortality is then calculated on the descending part of this single global distribution. But Z is determined in a given age/size range and the estimation makes sense only within this range. Natural mortality (M) was evaluated using Pauly's equation (Pauly 1980) based on $L\infty$, K and the mean annual environmental temperature of the species concerned. For each species, the mean annual temperature used for natural mortality estimates corresponds to the mean annual temperature at the depth to which the species was more abundant (see Chapter "Breeding and depth distribution"). Fishing mortality (F) was calculated as F = Z-M. All these methods were provided by the FiSAT package, including the estimation of the probability of capture.

The mean size at first capture by the trawl (Lc = length at which 50% of the fish entering the trawl are retained by the gear) was calculated for each species from the length-converted catch curves using FiSAT (Gayanilo & Pauly 1997).



FigureG1-1.Lengthfrequencyplotsfor *A.'geoffreyi'* intheSWAofLakeMalawi.

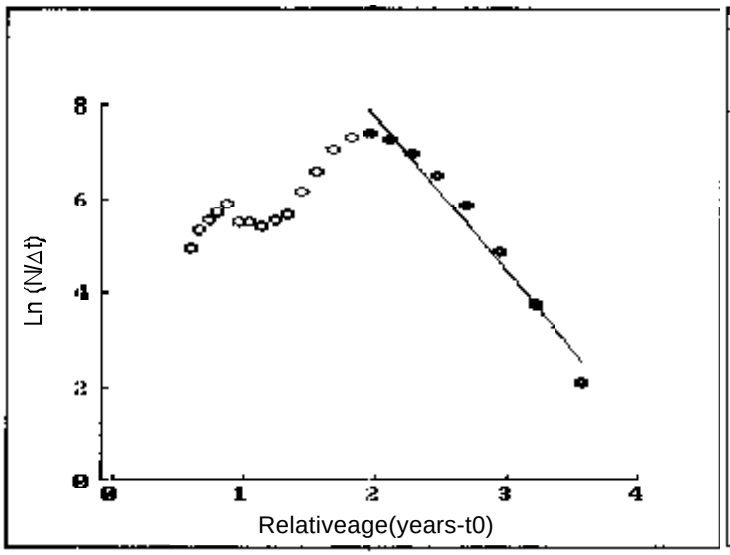
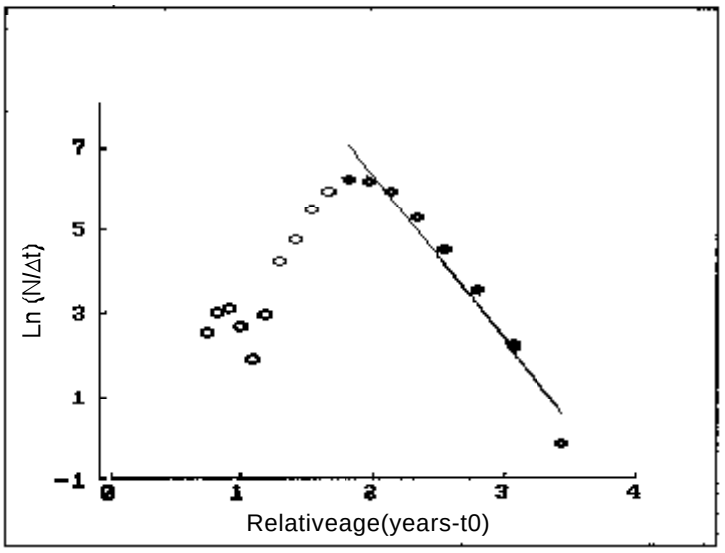
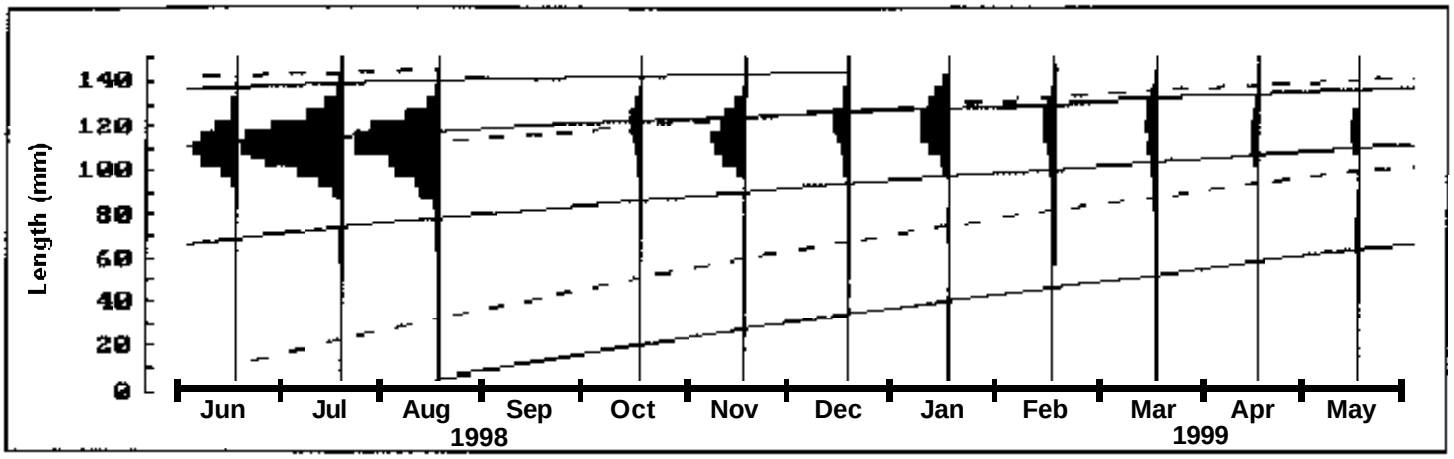


Figure G1-2. Length converted catch curve for *A. 'geoffreyi'*.



FigureG2-2.Lengthconvertedcatchcurvefor *A.macrocleithrum.*



FigureG2-1.Lengthfrequencyplotsfor *A.macrocleithrum* intheSWAofLakeMalawi.

Results

Alticorpus spp.

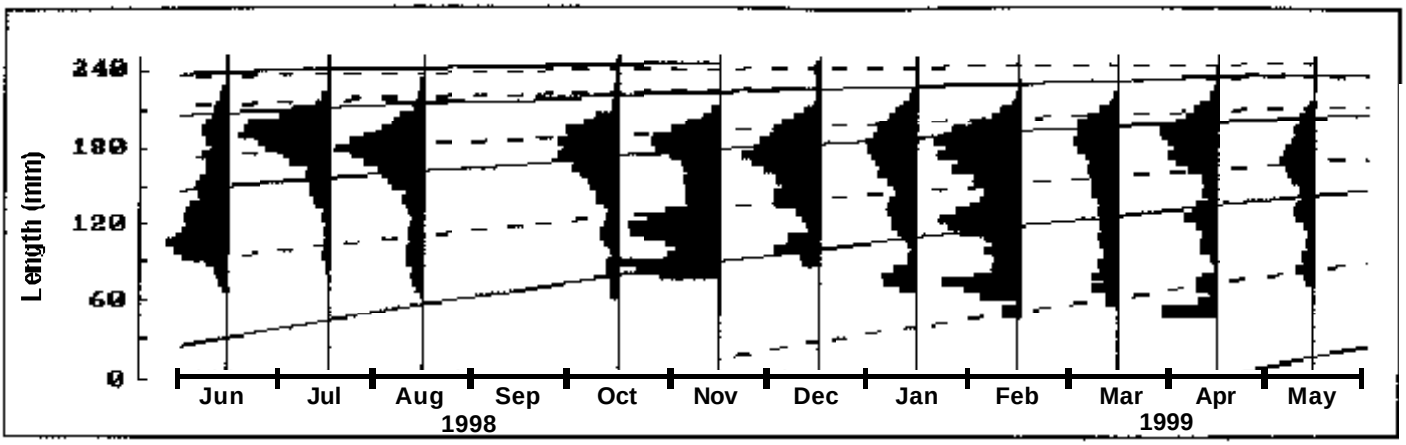
Alticorpus 'geoffreyi'

The length frequency distributions, based on 1721 fish are presented in Figure G1-1. Three year classes were identified by the model with L_∞=181 mm and K=0.6. The calculated date of birth (June) corresponded to the middle of the observed breeding peak.
Assuming a mean environmental temperature of 24°C and taking into account all the distributions, the mortality estimates were: Z=3.29, M=1.37 and F=1.92 for the age range showed in Figure G1-2. Given that the length frequency distributions were not adequate, it is likely that mortality was overestimated, particularly for a deep water species subjected to little if any exploitation in this part of the lake. The selectivity of the 35 mm cod end trawl net for this species was 120 mm.

Alticorpus macrocleithrum

A. macrocleithrum was not an abundant fish and only 437 specimens were measured over the sampling period. The length frequency distributions are presented in Figure G2-1. Two sets of growth estimates, correctly fitting the distributions and giving birth dates consistent with breeding observation were obtained: L_∞ = 166, K = 0.92 (dashed line) and L_∞ = 166, K = 0.6 (solid line). The calculated date of birth, May-June for the first set and July-August for the second corresponded to the middle of the observed breeding peak. Given the low number of individuals of the length frequency distributions, particularly in the small sizes (little peaks between 60 and 80 mm were all based on one or two fish only), it was difficult to decide for one or the other set of parameters.
Assuming a mean environmental temperature of 24°C corresponding to the depth distribution of *A. macrocleithrum* (75 to 125 m) and taking into account all the distributions, the mortality estimates were: Z=6.04, M=1.86 and F=4.18 with L_∞=166, K=0.92 and Z=3.94, M=1.40 and F=2.54 with L_∞=166, K=0.6. The mean size at first capture by the 35 mm cod end trawl net for this species was 106 mm with both sets of parameters. In both cases, mortality estimates were high partly because the shapes of distributions were not adapted to calculate mortality parameters. However, the second set of mortality estimates, though overestimated, appeared more realistic, particularly for a deep water species subjected to little if any exploitation. Furthermore, with K=0.92, fish would reach their maximum size and die at the end of their second year, which appears too fast for a fish of this size compared to others related species.

For these reasons, the set of parameters L_∞ = 166 and K = 0.6 was chosen for the calculation of age at maturity and mortality estimates (Z=3.94, M=1.40 and F=2.54 for the age range showed in Figure G2-2).



FigureG3-1.Lengthfrequencyplotsfor *A.mentale* intheSWAofLakeMalawi.

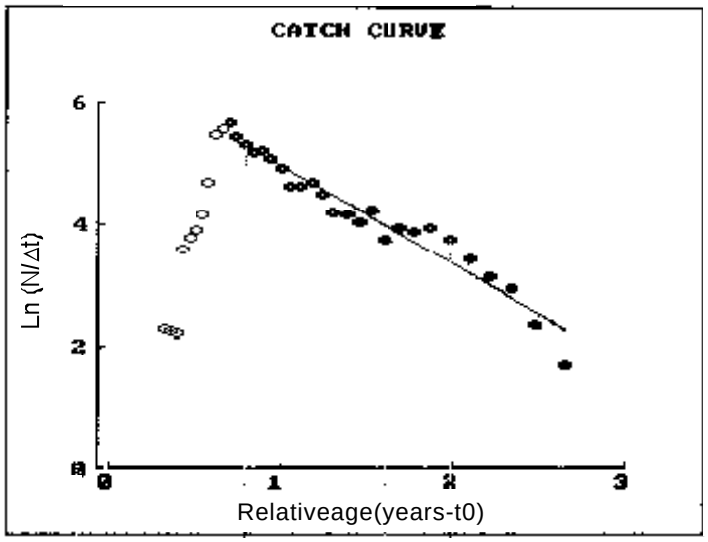


Figure G3-2. Length converted catch curve for *A. mentale*.

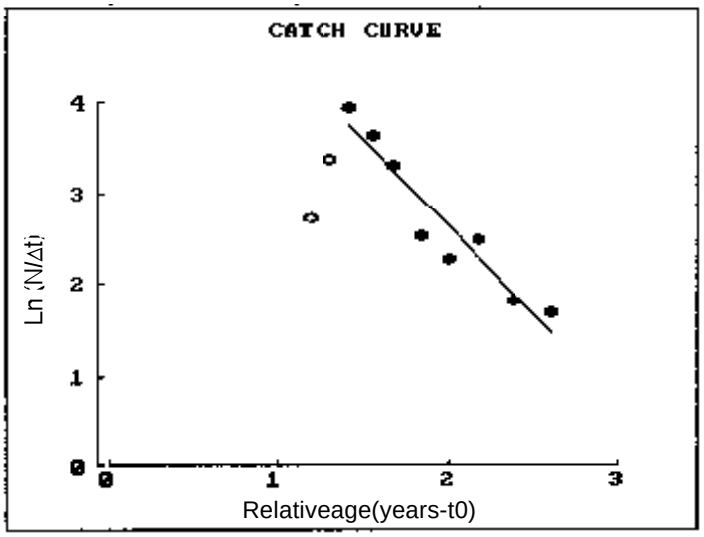
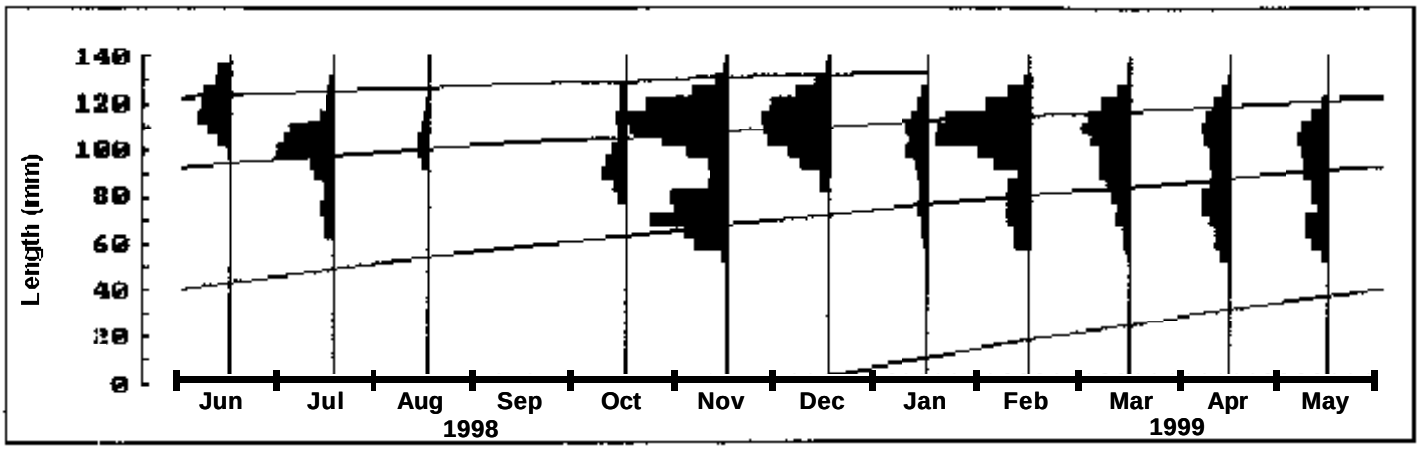


Figure G4-2.Lengthconvertedcatchcurvefor *A.pectinatum*.



FigureG4-1.Lengthfrequencyplotsfor *A.pectinatum* intheSWAofLakeMalawi.

Alticorpus mentale

The length frequency distributions, based on 2150 fish are presented in Figure G3-1. Two year classes were identified by the software, with L_∞=266 mm and K=0.7 (solid line). The calculated date of birth, April corresponded with a period of intense breeding activity.

Assuming a mean environmental temperature of 24°C corresponding to the depth distribution of *A. mentale* (75 to 125 m) and considering only the June distribution, the mortality estimates were: Z=1.63, M=1.36 and F=0.27 for the age range showed in Figure G3-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 91 mm.

Another set of parameters provided a good fit of the distributions: L∞=256 mm and K=0.68 (dashed line). The birth date, October-November also matched a period of intense breeding activity. However, the corresponding fit was going through a smaller number of large peaks than the first set of parameters, which was therefore considered better.

Alticorpus pectinatum

The length frequency distributions, based on 942 fish are presented in Figure G4-1. Three year classes were identified by the software with L_∞=160 mm and K=0.58. The calculated date of birth, December corresponded with a period of intense breeding activity.

Assuming a mean environmental temperature of 24°C corresponding to the depth distribution of *A. pectinatum* (75 to 125 m) and considering only the October distribution, the mortality estimates were: Z=1.90, M=1.39 and F=0.51 for the age range showed in Figure G4-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 84 mm.

Aulonocara spp.

Aulonocara 'blue orange'

The length frequency distributions, based on 7793 fish are presented in Figure G5-1. *Au. 'blue orange'* is a small species and juveniles were not caught by the net. Consequently a single year class was identified by the software with L_∞=80 mm and K=1.21. The calculated date of birth, December-January corresponded with a peak of breeding activity.

Assuming a mean environmental temperature of 26°C corresponding to the depth distribution of *Au. 'blue orange'* (10 to 30 m) and considering all the distributions, the mortality estimates were: Z=4.67, M=2.83 and F=1.84 for the age range showed in Figure G5-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 51 mm. Although *Au. 'blue orange'* is a short lived fast growing species with a high natural mortality (M), the estimated total mortality was probably overestimated owing to the shape of length distributions.

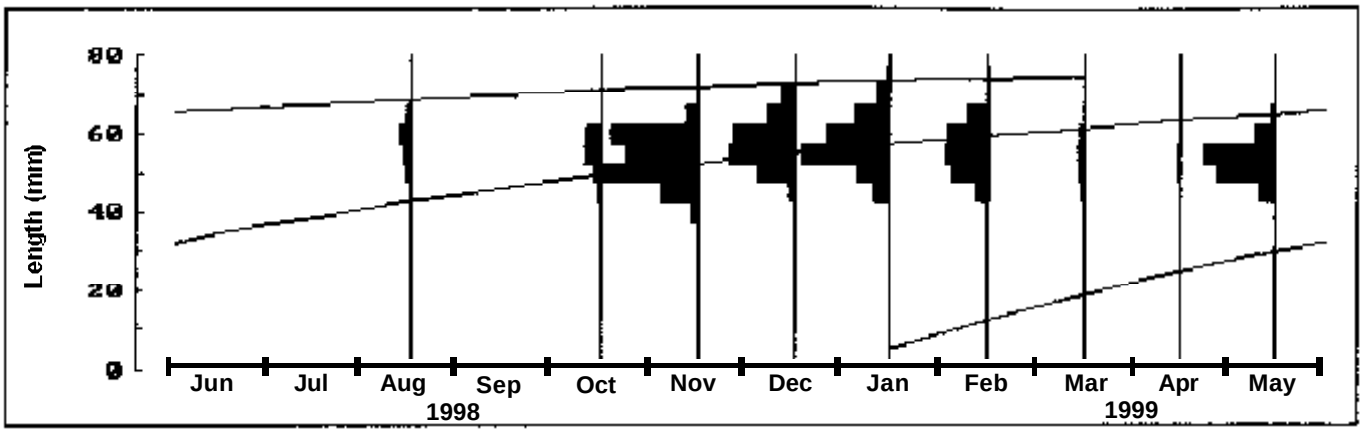


Figure G5-1. Length frequency plots for *Au. 'blueorange'* in the SW A of Lake Malawi.

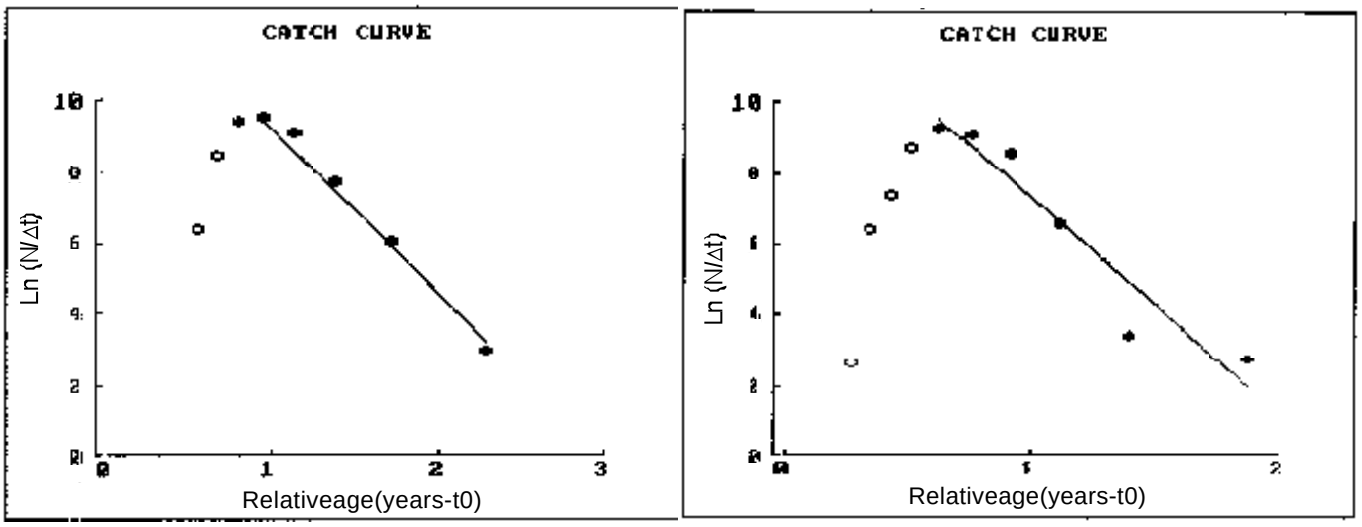


Figure G5-2. Length converted catch curve for *Au. 'blue orange'*.

Figure G6-2. Length converted catch curve for *Au. 'minutus'*.

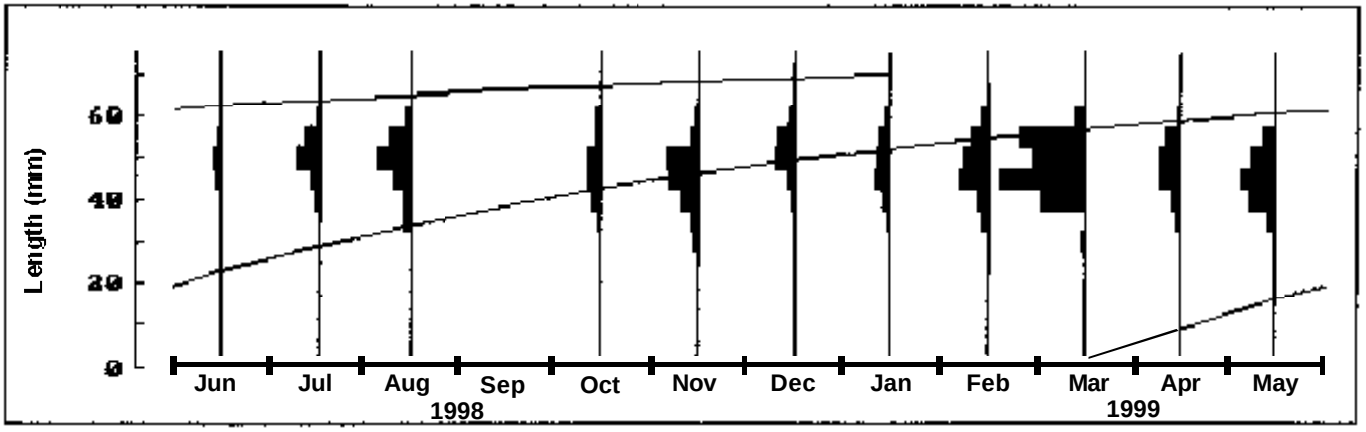


Figure G6-1. Length frequency plots for *Au. 'minutus'* in the SW A of Lake Malawi.

Aulonocara 'minutus'

The length frequency distributions, based on 4539 fish are presented in Figure G6-1. *Au. 'minutus'* is also a small species and juveniles were not caught by the net. Consequently a single year class was identified by the software with L_∞=75 mm and K=1.44. The calculated date of birth, March corresponded with a period of intense breeding activity.
Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *Au. 'minutus'* (75 to 125 m) and considering all the distributions, the mortality estimates were: Z=6.07, M=3.08 and F=2.99 for the age range showed in Figure G6-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 41 mm. Although *Au. 'minutus'* is a short lived fast growing species with a high natural mortality rate (M), mortality estimates were probably overestimated owing to the shape of length distributions. Indeed, fishing mortality is likely to be close to zero in this deep part of the lake where almost no trawling activity takes place.

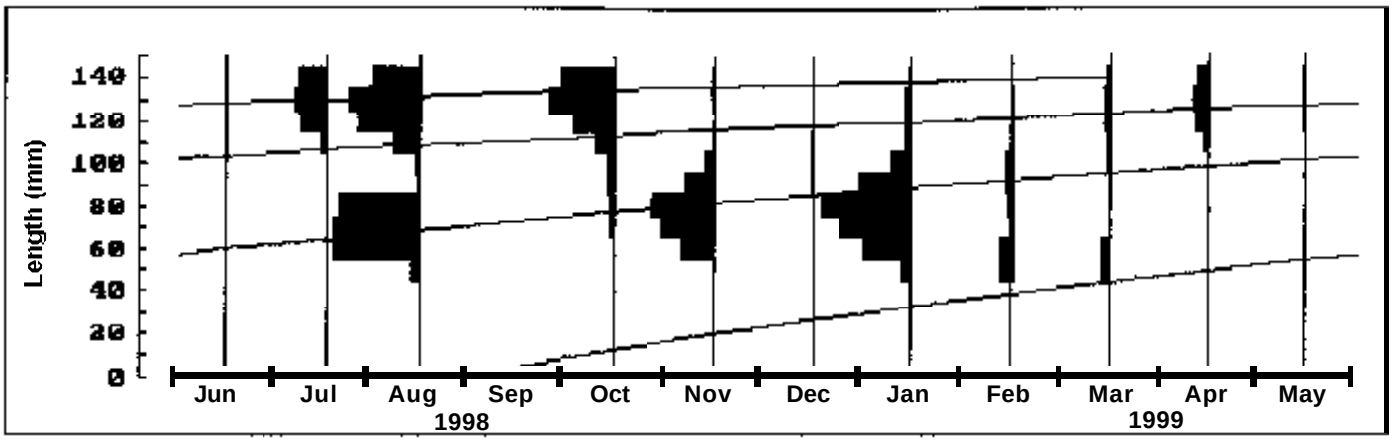
Copadichromis spp.

Copadichromis quadrimaculatus

C. quadrimaculatus was a relatively rare fish and only 631 specimens were measured over the sampling period. The length frequency distributions are presented in Figure G7-1. Despite the low sample size, a reasonably good growth estimation was obtained with L_∞=160 mm and K=0.58. The calculated date of birth, September corresponded with a period of breeding activity.
Assuming a mean environmental temperature of 25°C corresponding to the depth distribution of *C. quadrimaculatus* (10 to 75 m) and considering only the November and January distributions, the mortality estimates were: Z=1.95, M=1.41 and F=0.54 for the age range showed in Figure G7-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 59 mm.

Copadichromis virginalis

The length frequency distributions, based on 11982 fish are presented in Figure G8-1. Two year classes were identified by the software with L_∞=130 mm and K=0.84. The calculated date of birth, May corresponded to the middle of the main peak of breeding activity.
Assuming a mean environmental temperature of 25.5°C corresponding to the depth distribution of *C. virginalis* (10 to 50 m) and considering only the April distribution, the mortality estimates were: Z=3.55, M=1.93 and F=1.62 for the age range showed in Figure G8-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 72 mm.



FigureG7-1.Lengthfrequencyplotsfor *C.quadrimaculatus* intheSWAofLakeMalawi.

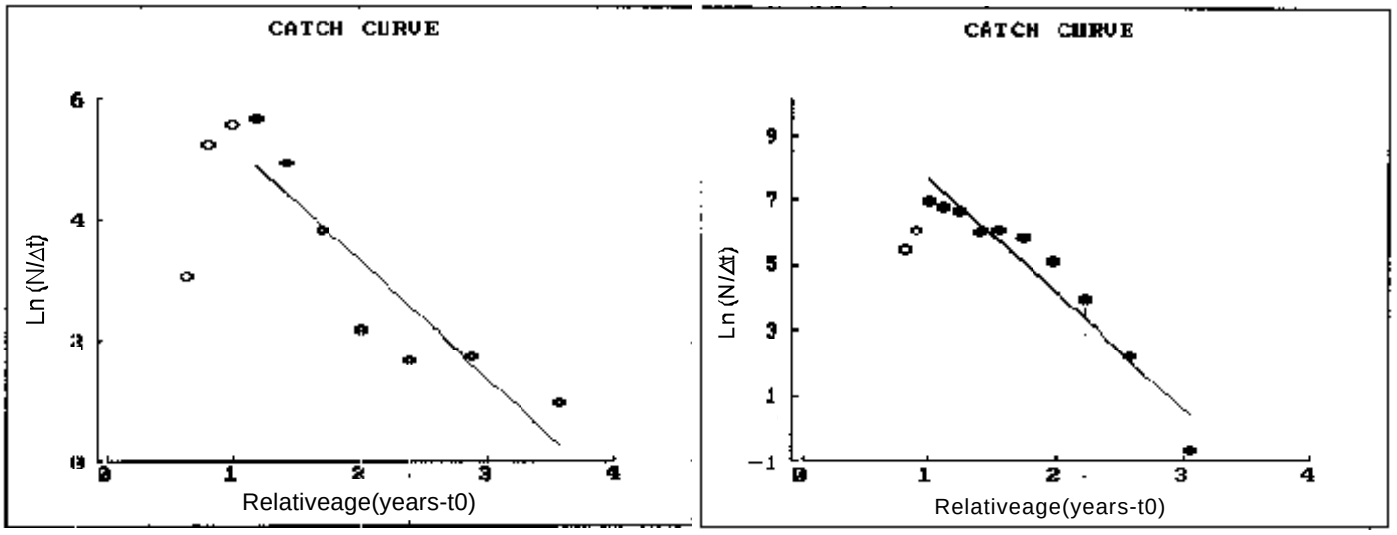
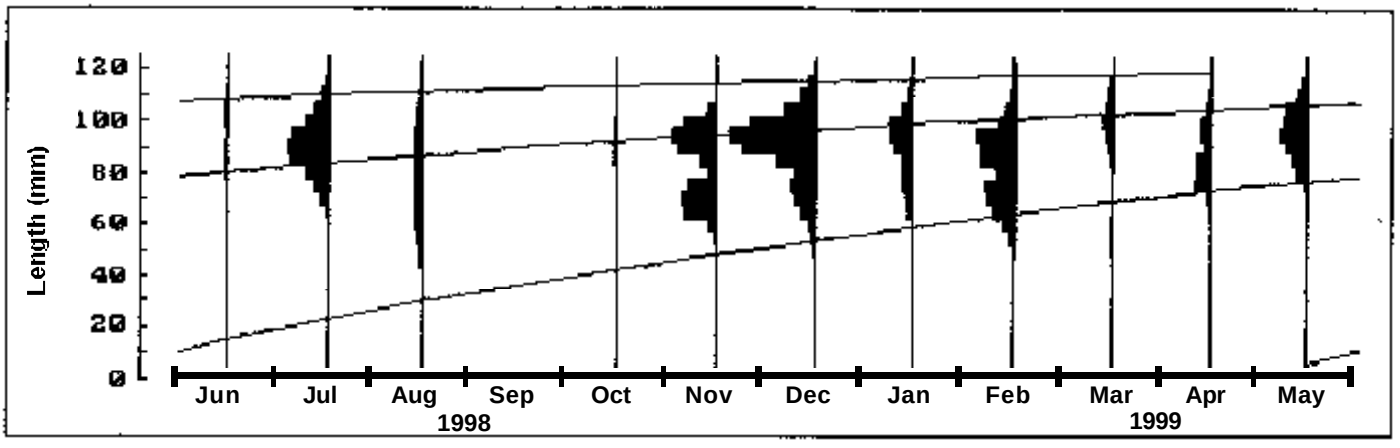
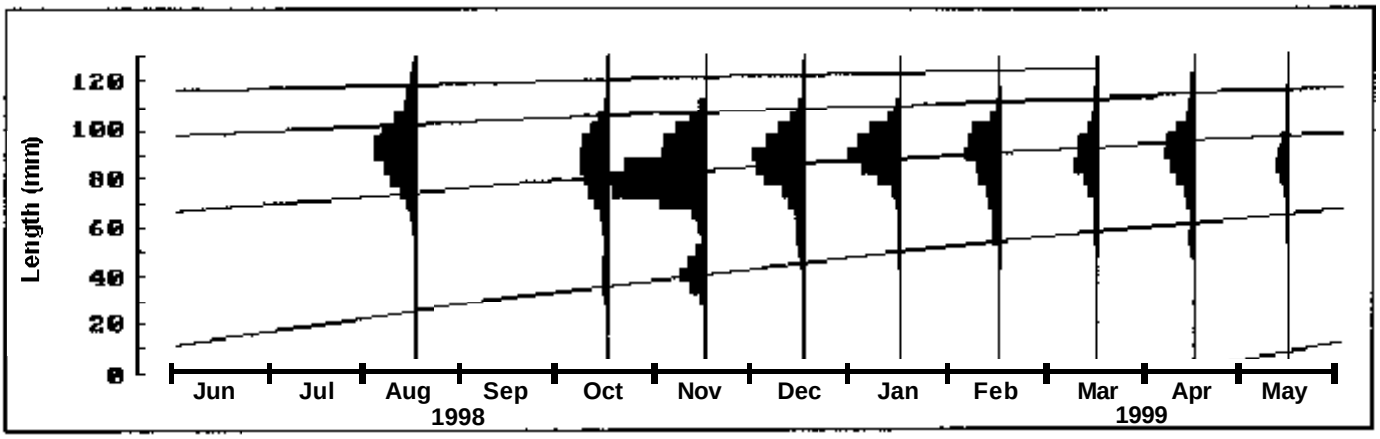


Figure G7-2. Length converted catch curve for *C. quadrimaculatus*. FigureG8-2.Lengthconvertedcatchcurvefor *C.virginalis* .



FigureG8-1.Lengthfrequencyplotsfor *C.virginalis* intheSWAofLakeMalawi.



FigureG9-1.Lengthfrequencyplotsfor *D.apogon* intheSWAofLakeMalawi.

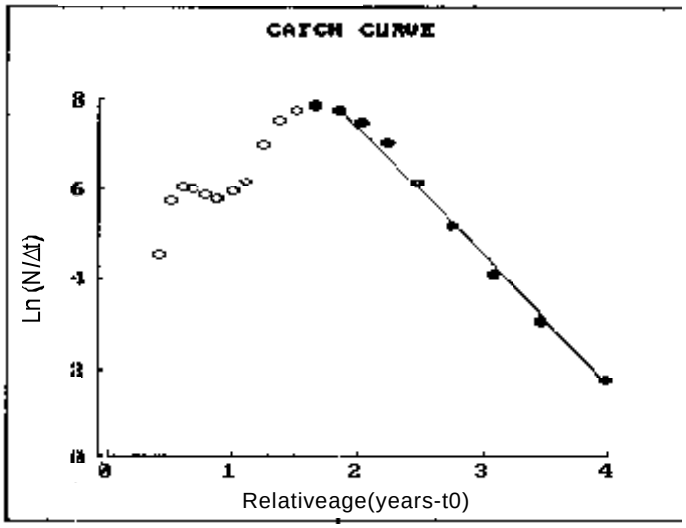
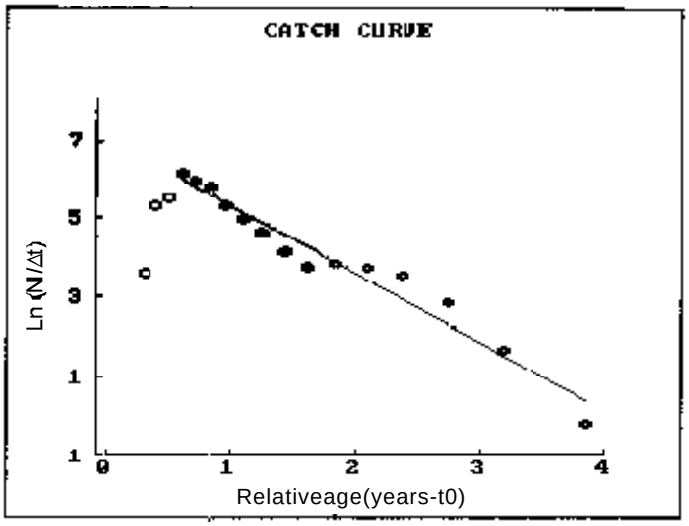
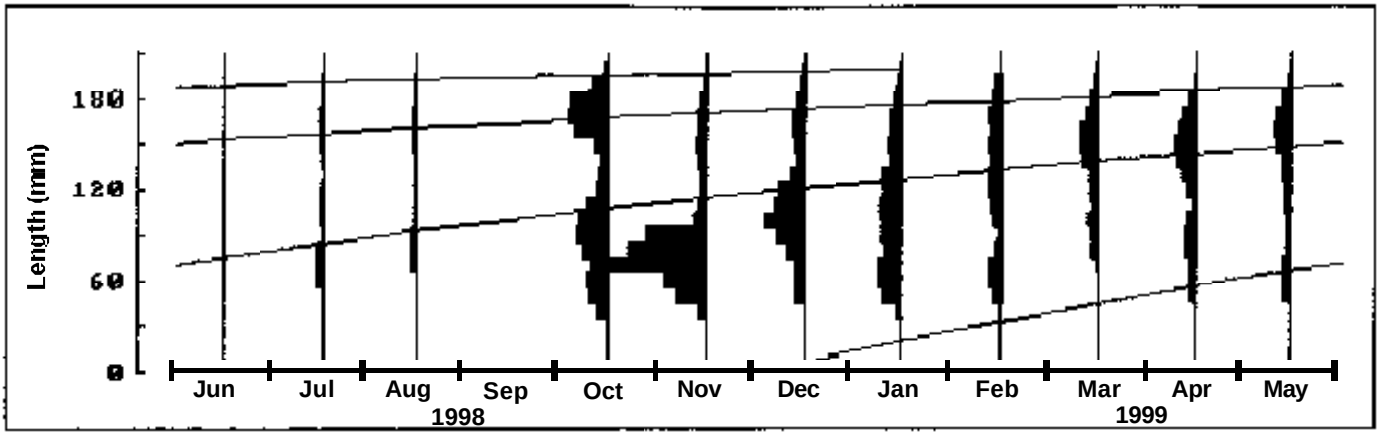


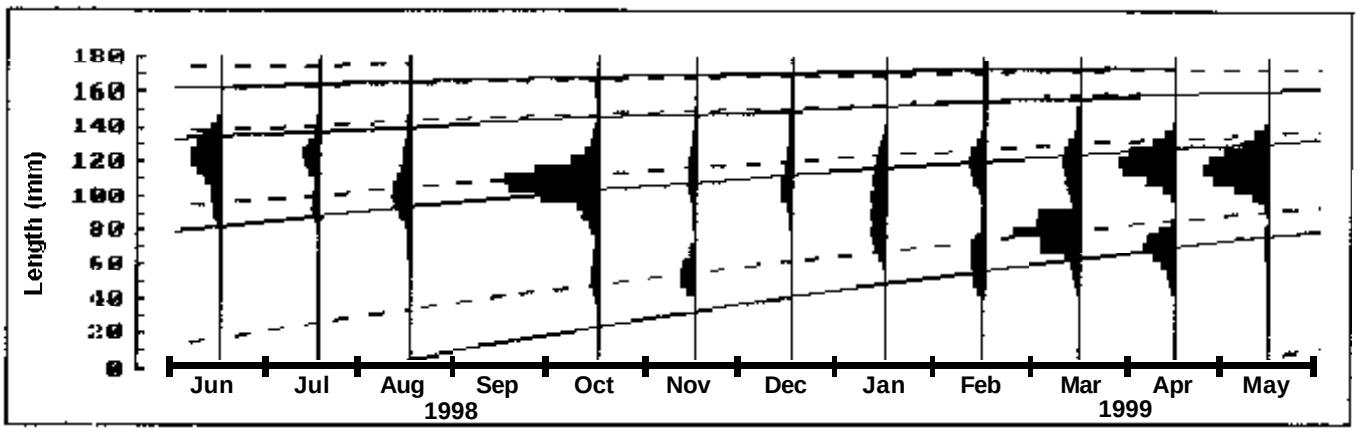
Figure G9-2. Length converted catch curve for *D. apogon*.



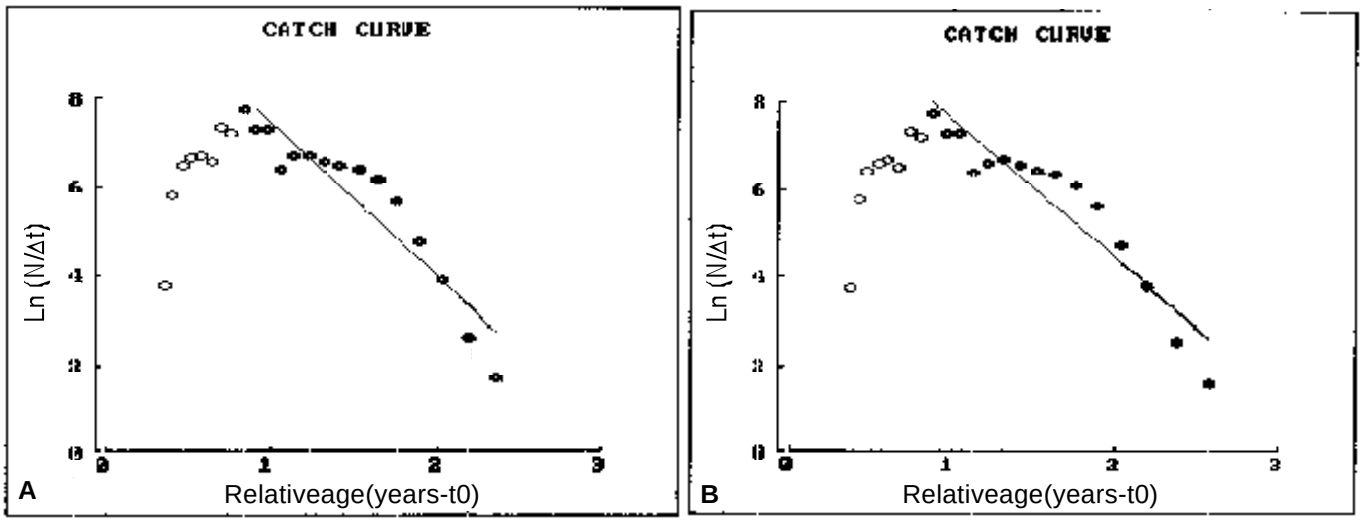
FigureG10-2.Lengthconvertedcatchcurvefor *D.argenteus*.



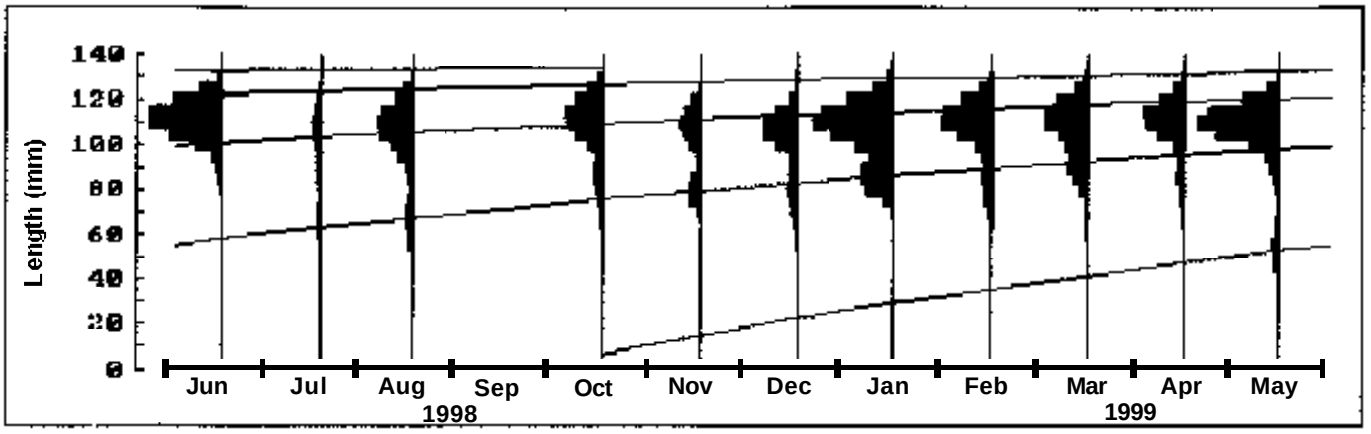
FigureG10-1.Lengthfrequencyplotsfor *D.argenteus* intheSWAofLakeMalawi.



FigureG11-1.Lengthfrequencyplotsfor *D.limnothrissa* intheSWAofLakeMalawi.



Figures G11-2. Length converted catch curves for *D. limnothrissa*.



FigureG12-1.Lengthfrequencyplotsfor *D.macrops* intheSWAofLakeMalawi.

Diplotaxodon and Pallidochromis spp.

Diplotaxodon apogon

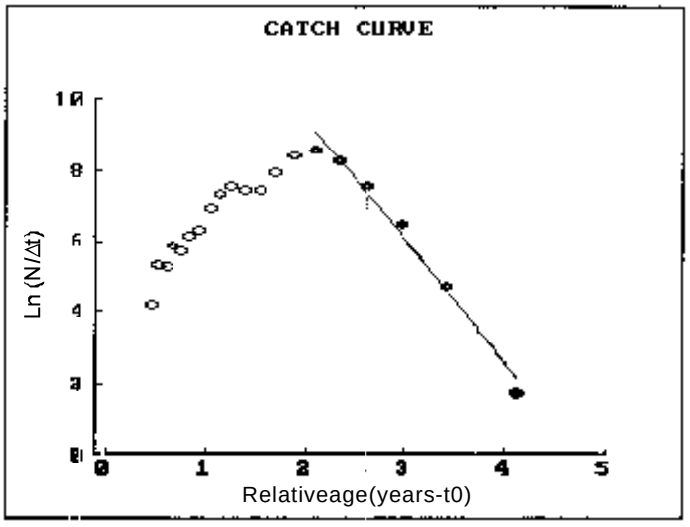
The length frequency distributions, based on 2754 fish are presented in Figure G9-1. Three year classes were identified by the software with L_∞=140 mm and K=0.56. The calculated date of birth, April corresponded to the end of the main peak of breeding activity.
Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *D. apogon* (75 to 125 m) and considering all the distributions, the mortality estimates were: Z=2.86, M=1.39 and F=1.47 for the age range showed in Figure G9-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 80 mm.

Diplotaxodon argenteus

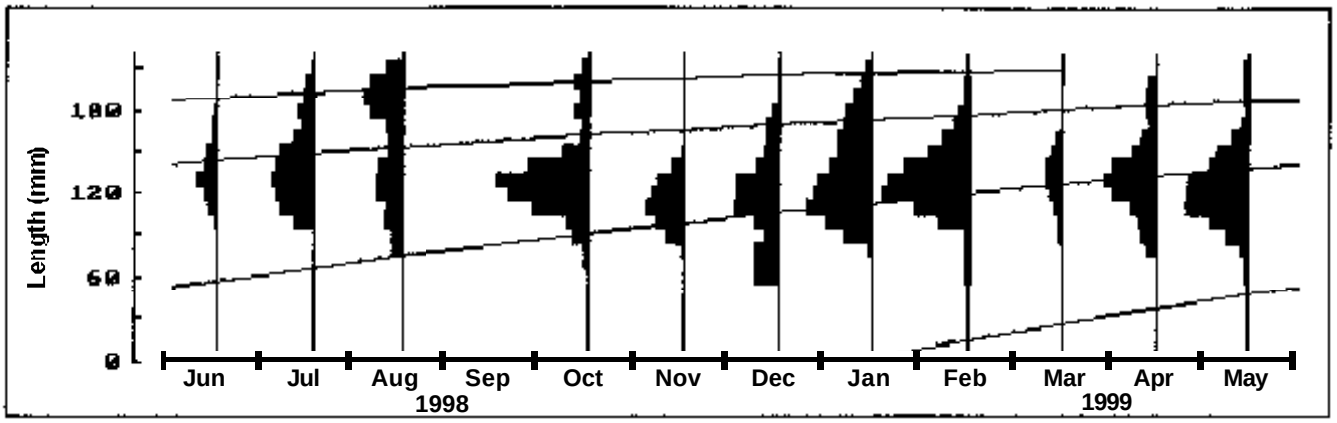
The length frequency distributions, based on 908 fish are presented in Figure G10-1. Two sets of parameters gave good fit of the distribution, each of them fitting three year classes. With the first set, L_∞=219 mm and K=0.78 (solid line), the date of birth was December. Assuming a mean environmental temperature of 24°C corresponding to the depth distribution of *D. argenteus* (50 to 125 m) and considering the November and December distributions only, the mortality estimates were: Z=2.19, M=1.54 and F=0.65 for the age range 0.8 to 3 years. With the second set of parameters, L_∞=220 mm and K=0.62 (dashed line), the date of birth was April and the mortality estimates were: Z=1.74, M=1.33 and F=0.41 for the age range 0.8 to 4 years.
The mean size at first capture by the 35 mm cod end trawl net for this species was 57 mm with both sets of parameters.
Both fits were good, however, the dashed line went better through the middle of the major peaks whereas the solid line went often through the end of the peaks (ex. October or December). Next, a birth in April, during the major breeding season appeared more reasonable than a birth in December after a little isolated breeding peak based on low sample size. Furthermore, mortality estimates and life span (Figure G10-2) obtained with the second set of parameters (L_∞=220 mm, K=0.62, dashed line), also appeared more reasonable for a deep water species subjected to little if any exploitation.
Consequently, the following parameters were considered to better represent the data and were used for the calculation of age at maturity: L_∞=220 mm, K=0.62, Z=1.74, M=1.33 and F=0.41.

Diplotaxodon limnothrissa

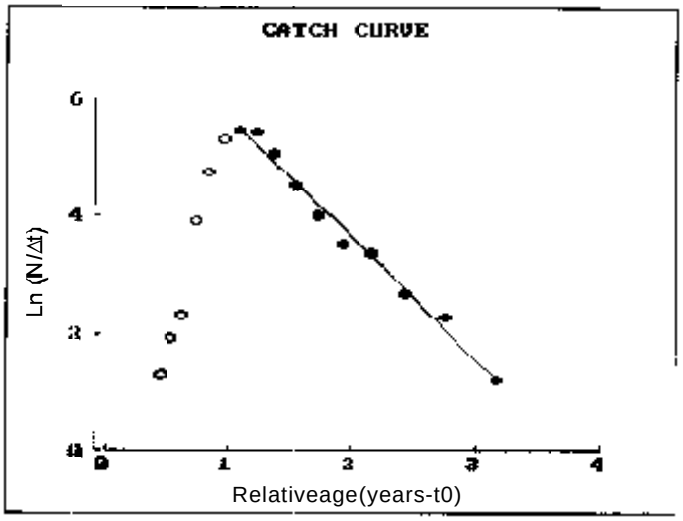
The length frequency distributions, based on 5823 fish are presented in Figure G11-1. Three year classes were identified by the software (solid line), with L_∞=192 mm, K=0.64. The calculated date of birth, July-August corresponded to the last two months of the breeding season.
Assuming a mean environmental temperature of 24°C corresponding to the depth distribution of *D. limnothrissa* (50 to 125 m) and considering only the August, November and March distributions, the mortality estimates were: Z=3.48, M=1.41 and F=2.07 for the age range showed in Figure G11-2A. Given that the length frequency distributions were not adequate, it is likely that mortality estimates were overestimated, particularly for a deep water species



FigureG12-2.Lengthconvertedcatchcurvefor *D.macrops.*



FigureG13-1.Lengthfrequencyplotsfor *P.tokolosh* intheSWAofLakeMalawi.



FigureG13-2.Lengthconvertedcatchcurvefor *P. tokolosh*.

subjected to little if any exploitation in this part of the lake. The mean size at first capture by the 35 mm cod end trawl net for this species was 77 mm.
More than one cohort per year class were present. The major peak in March appeared to be from the same year class that the lower peaks fitted by the solid lined model in February and April. The best estimation fitting that cohort (dashed line) was obtained with L_{∞}=188 mm, K=0.62. The calculated date of birth, May corresponded to the first two months of the breeding season. Mortality estimates were: Z=3.22, M=1.39 and F=1.83 for the age range showed in Figure G11-2B. The selectivity of the 10 mm cod end trawl net with this set of parameters was 74 mm.

These two estimations, one taking into account the cohort born in the beginning of the breeding season, the other considering the cohort born at the end of the breeding season were very similar and gave very close growth and mortality estimates. The cohort born at the beginning of the breeding season (dashed line) had a slightly slower growth leading to an age at maturity of 16 months old whereas the cohort born at the end of the breeding season (solid line) reached maturity at 15 months old.

Diplotaxodon macrops

The length frequency distributions, based on 5778 fish are presented in Figure G12-1. Three year classes were identified by the software with L_{∞}=143 mm, K=0.7. The calculated date of birth, September-October corresponded to the last months of the second peak of breeding activity. No correct fit gave a birth in the major breeding peak (January-May).
Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *D. macrops* (75 to 125 m) and considering all the distributions, the mortality estimates were: Z=3.12, M=1.6 and F=1.52 for the age range showed in Figure G12-2. Given that the length frequency distributions were not adequate, it is likely that mortality estimates were overestimated, particularly for a deep water species subjected to little if any exploitation in this part of the lake. The mean size at first capture by the 35 mm cod end trawl net for this species was 106 mm, which also appeared overestimated.

Pallidochromis tokolosh

P. tokolosh was not an abundant fish and only 375 specimens were measured over the sampling period. The length frequency distributions are presented in Figure G13-1. Despite the low sample size, a reasonably good growth estimation was obtained with L_{∞}=244 mm, K=0.62. The calculated date of birth, January corresponded to the middle of the observed breeding season.
Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *P. tokolosh* (75 to 125 m) and considering the June, July, October, January and February distributions, the mortality estimates were: Z=2.06, M=1.28 and F=0.78 for the age range showed in Figure G13-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 106 mm, which appeared overestimated though it translated the length distributions.

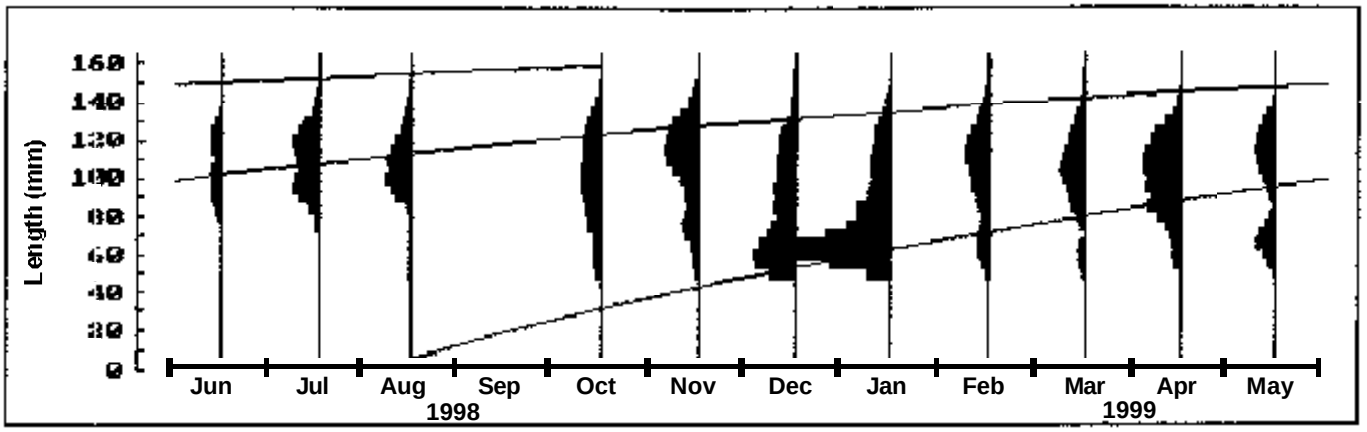


Figure G14-1.Lengthfrequencyplotsfor *L.argenteus* intheSWAofLakeMalawi.

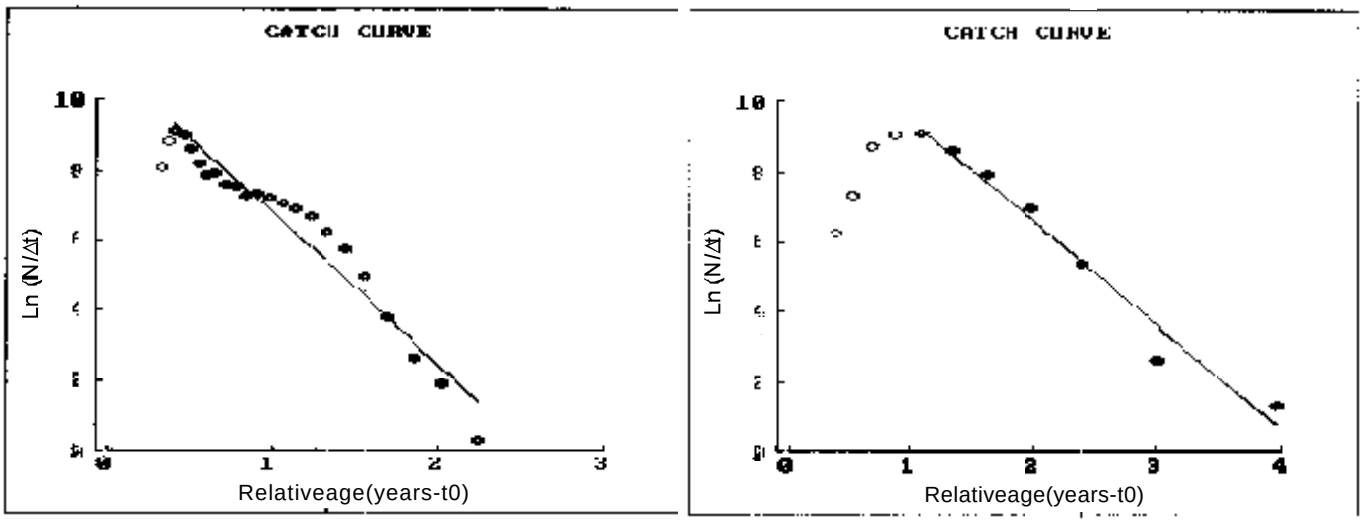
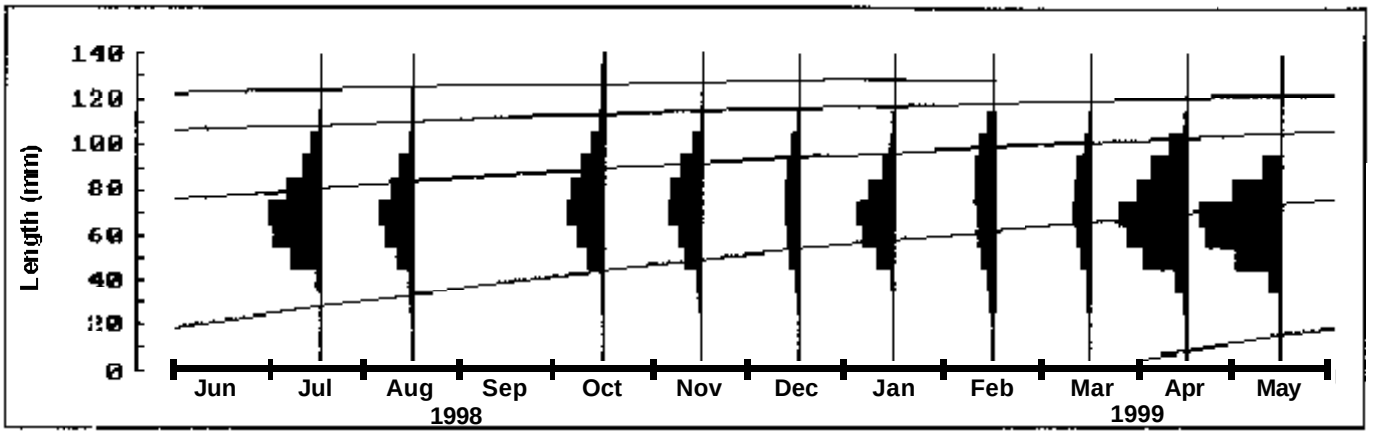


Figure G14-2. Length converted catch curve for *L. argenteus*. FigureG15-2.Lengthconvertedcatchcurvefor *L.'dwaltus'*.



FigureG15-1.Lengthfrequencyplotsfor *L.'dwaltus'* intheSWAofLakeMalawi.

Lethrinops spp.

Lethrinops argenteus

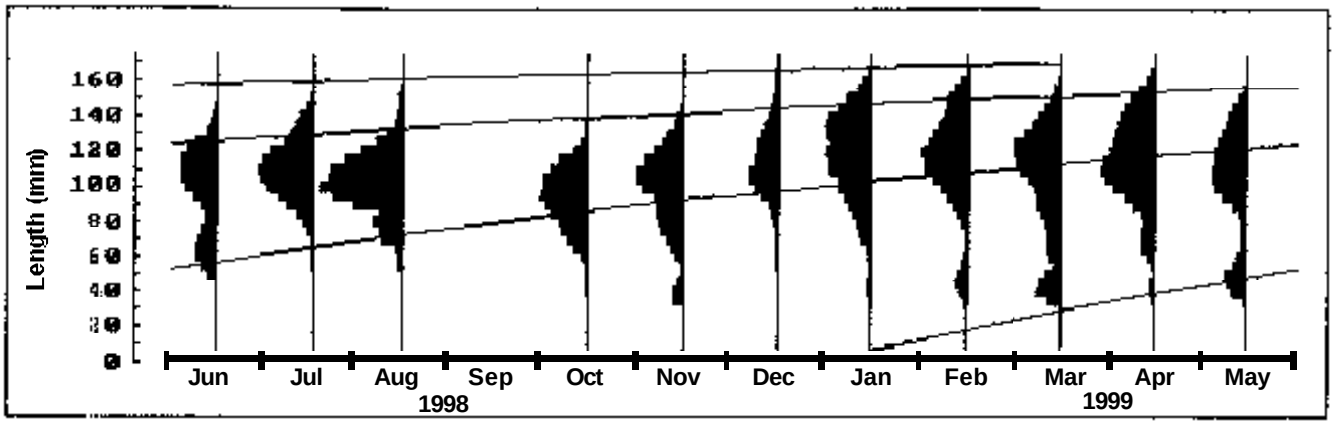
The length frequency distributions, based on 9225 fish are presented in Figure G14-1. Two year classes were identified by the software with L_{∞}=182 mm, K=0.94. The calculated date of birth, August corresponded to a major peak of breeding activity.
Assuming a mean environmental temperature of 25°C corresponding to the depth distribution of *L. argenteus* (10 to 50 m) and considering only the December and January distributions, the mortality estimates were: Z=4.38, M=1.87 and F=2.51 for the age range showed in Figure G14-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 55 mm.

Lethrinops 'deep water altus'

The length frequency distributions, based on 1510 fish are presented in Figure G15-1. Despite the relative homogeneity of length distribution among successive months, it was possible to fit a VBGC, which gave reasonable estimates with L_{∞}=142 mm, K=0.62. The calculated date of birth, March corresponded to the main peak of sexual activity.
Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *L. 'deep water altus'* (75 to 125 m) and considering only the December and January distributions, the mortality estimates were: Z=2.94, M=1.48 and F=1.46 for the age range showed in Figure G15-2. As the deep zone in this part of the lake is almost not exploited, it is very likely that mortality were overestimated owing to the under-representation of juveniles in the length distributions. The mean size at first capture by the 35 mm cod end trawl net for this species was 58 mm.

Lethrinops gossei

The length frequency distributions, based on 8072 fish are presented in Figure G16-1. The best combination was obtained with L_{∞}=185 mm, K=0.78. The calculated date of birth, March corresponded to the peak of breeding activity.
Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *L. gossei* (75 to 125 m) and considering all the distributions, the mortality estimates were: Z=3.48, M=1.60 and F=1.88 for the age range showed in Figure G16-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 99 mm. Again, as the deep zone in this part of the lake is hardly exploited, it is very likely that mortality was overestimated owing to the inadequate length distributions.



FigureG16-1.Lengthfrequencyplotsfor *L.gossei* intheSWAofLakeMalawi.

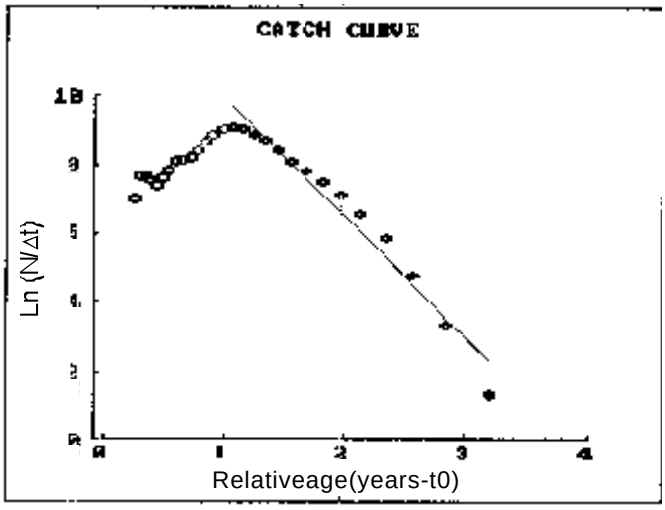
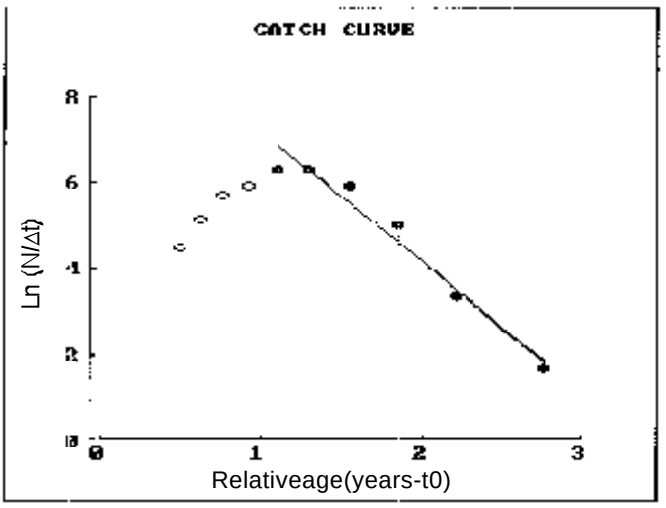
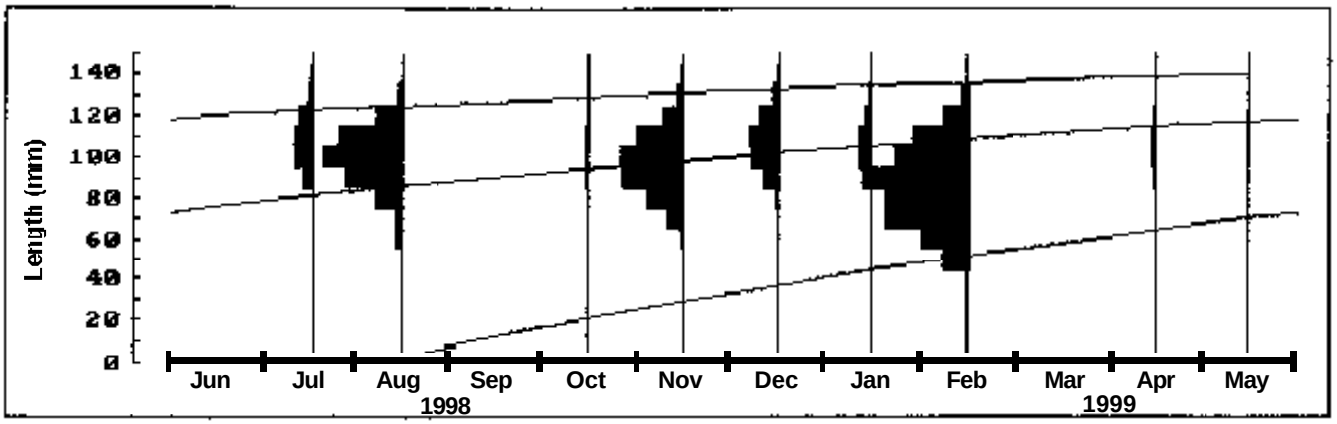


Figure G16-2. Length converted catch curve for *L. gossei*.



FigureG17-2.Lengthconvertedcatchcurvefor *L.longimanus*.



FigureG17-1.Lengthfrequencyplotsfor *L.longimanus* intheSWAofLakeMalawi.

Lethrinops longimanus

L. longimanus was not an abundant fish and only 553 specimens were measured over the sampling period. The length frequency distributions are presented in Figure G17-1. Despite the low sample size and the lack of clear progression in length modes, a reasonable growth estimation was obtained with L_{∞}=160 mm, K=0.75. As it was impossible to determine the precise breeding season for this species, it was difficult to assess the quality of the calculated date of birth, August. However, it occurred at the period when most breeding activity was observed.

Assuming a mean environmental temperature of 25°C corresponding to the depth distribution of *L. longimanus* (30 to 125 m) and considering all the distributions, the mortality estimates were: Z=3.00, M=1.67 and F=1.33 for the age range showed in Figure G17-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 82 mm.

Despite the poor appropriateness of the data set to this kind of study, the estimates were in agreement with the values obtained for other *Lethrinops* species of comparable size.

Lethrinops 'oliveri'

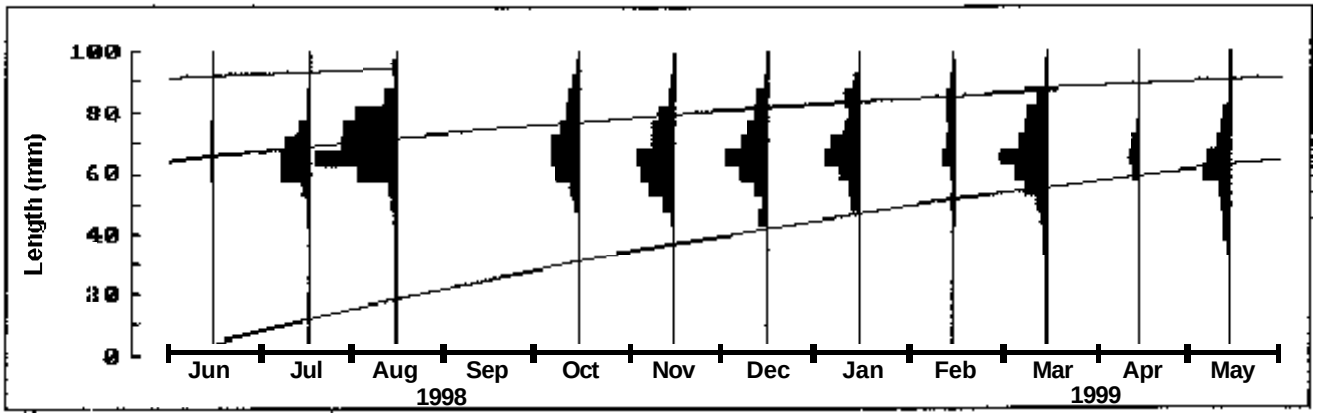
The length frequency distributions, based on 9020 fish are presented in Figure G18-1. As for the other small species a relative homogeneity of length distribution among successive months was observed. However, it was possible to fit a VBGC, which gave reasonable estimates with L_{∞}=110 mm, K=0.88. The calculated date of birth, June corresponded to the middle of the main breeding season.

Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *L. 'oliveri'* (75 to 125 m) and considering all the distributions, the mortality estimates were: Z=4.31, M=2.0 and F=2.31 for the age range showed in Figure G18-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 60 mm. Again, as the deep zone in this part of the lake is lightly exploited, it is very likely that mortality was overestimated owing to the non adequate length distributions.

Lethrinops polli

The length frequency distributions, based on 1681 fish are presented in Figure G19-1. The best estimation was obtained with L_{∞}=134 mm, K=0.78. The calculated date of birth, August-September corresponded to the end of the main observed breeding season.

Assuming a mean environmental temperature of 24°C corresponding to the depth distribution of *L. polli* (75 to 125 m) and considering only the July, August and May distributions, the mortality estimates were: Z=3.43, M=1.77 and F=1.66 for the age range showed in Figure G19-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 71 mm. Again, as the deep zone in this part of the lake is almost not exploited, it is very likely that mortality was overestimated owing to the non adequate length distributions.



FigureG18-1.Lengthfrequencyplotsfor *L.'oliveri'* intheSWAofLakeMalawi.

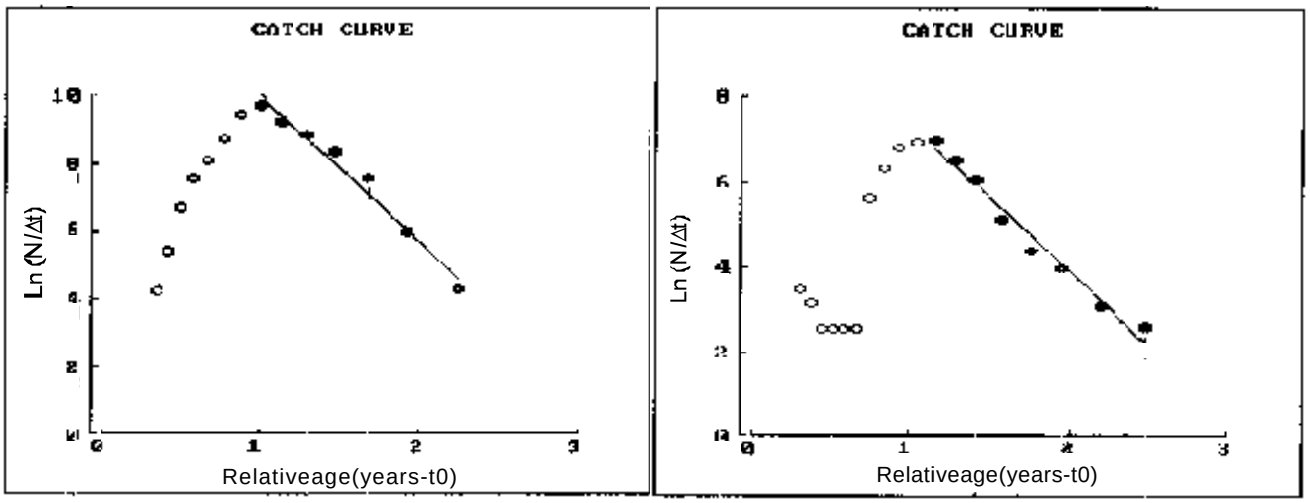
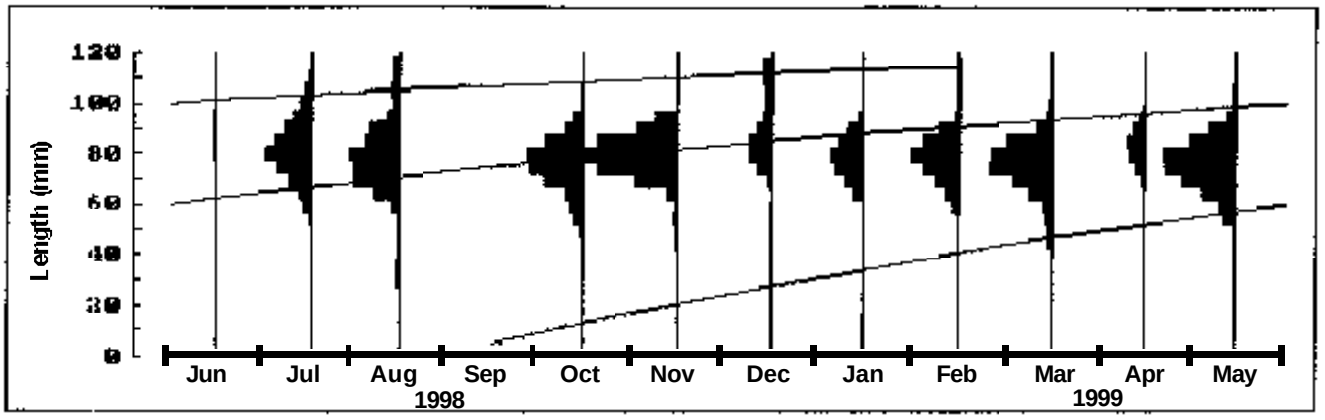
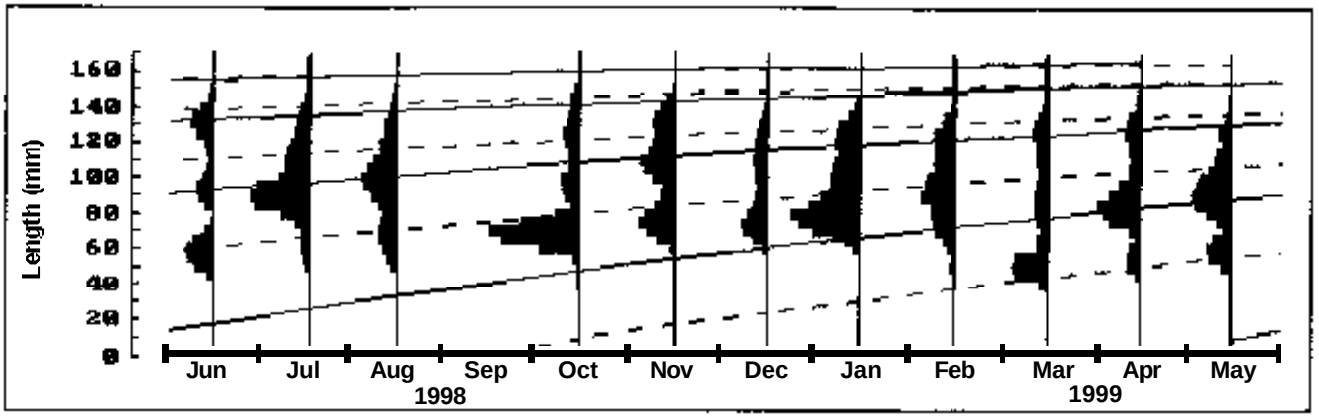


Figure G18-2. Length converted catch curve for *L. 'oliveri'*.

Figure G19-2.Lengthconvertedcatchcurvefor *L.polli*.



FigureG19-1.Lengthfrequencyplotsfor *L.polli* intheSWAofLakeMalawi.



FigureG20-1.Lengthfrequencyplotsfor *M.anaphyrmus* intheSWAofLakeMalawi.

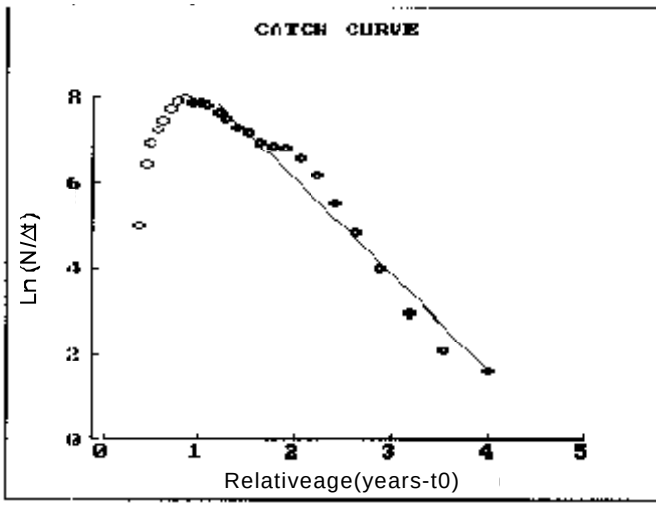
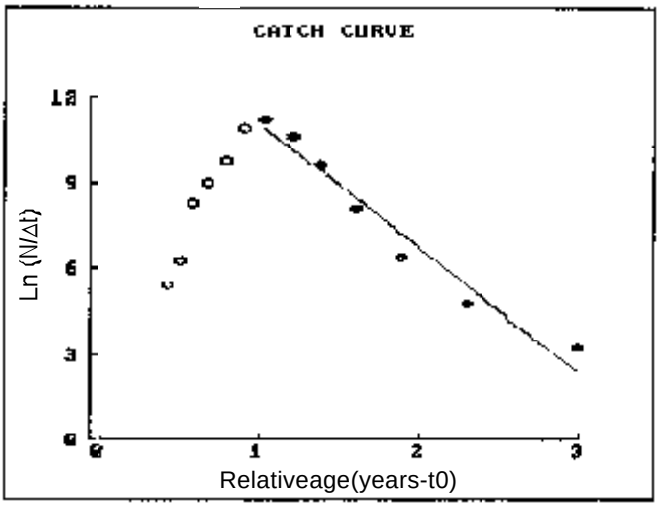
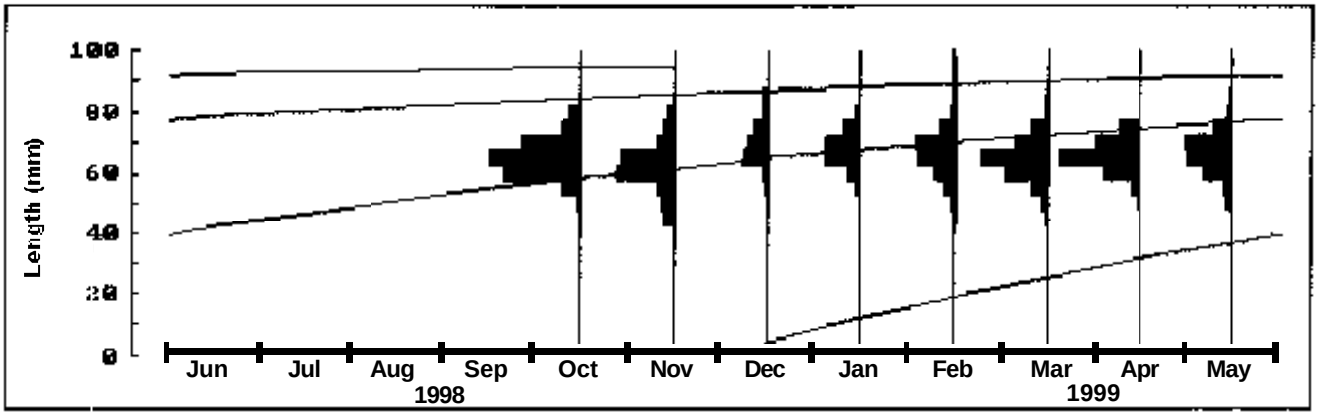


Figure G20-2. Length converted catch curve for *M. anaphyrmus.*



FigureG21-2.Lengthconvertedcatchcurvefor *N.'argyrosoma'.*



FigureG21-1.Lengthfrequencyplotsfor *N.'argyrosoma'* intheSWAofLakeMalawi.

Mylochromis spp.

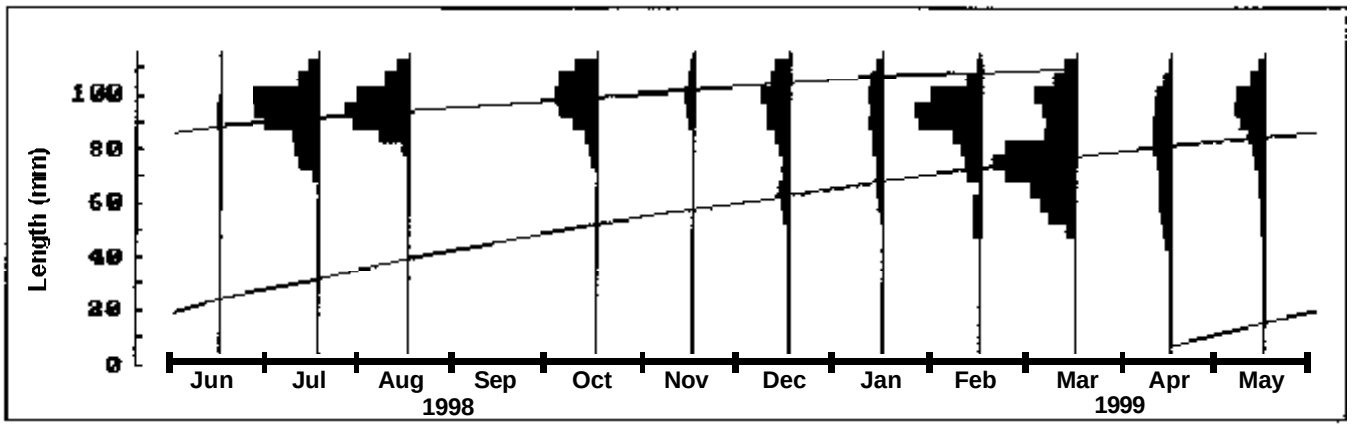
Mylochromis anaphyrmus

The length frequency distributions, based on 3007 fish are presented in Figure G20-1. Three year classes were identified by the software (solid line), with L_{∞}=180 mm, K=0.62. The calculated date of birth, May corresponded to the main peak of breeding activity.
More than one cohort per year class was present. The peaks of small sizes in March, April and May appeared to be from the same year class that the upper peaks fitted by the solid lined model in April and May. The best estimation fitting that cohort (dashed line) was obtained with L_{∞}=179 mm, K=0.52. The calculated date of birth, September corresponded to the last two months of the breeding season.
However, the estimation taking into account the cohort born in the middle of the breeding season (solid line) fitted the distributions best and was selected for the calculations of mortality. Assuming a mean environmental temperature of 26°C corresponding to the depth distribution of *M. anaphyrmus* (10 to 50 m) and considering all the distributions, the mortality estimates were: Z=2.22, M=1.46 and F=0.76 for the age range showed in Figure G20-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 72 mm.

Nyassachromis spp.

Nyassachromis 'argyrosoma'

The length frequency distributions, based on 34235 fish are presented in Figure G21-1. As for the other small species a relative homogeneity of length distribution among successive months was observed. However, it was possible to fit a VBGC, which gave reasonable estimates with L_{∞}=100 mm, K=1. The calculated date of birth, December corresponded to the major peak of breeding activity.
Assuming a mean environmental temperature of 26°C corresponding to the depth distribution of *N. 'argyrosoma'* (10 to 30 m) and considering all the distributions, the mortality estimates were: Z=4.38, M=2.34 and F=2.04 for the age range showed in Figure G21-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 59 mm. Again, it is very likely that mortality was overestimated owing to the inadequate length distributions.



FigureG22-1.Lengthfrequencyplotsfor *Pl.'platyrhynchos'* intheSWAofLakeMalawi.

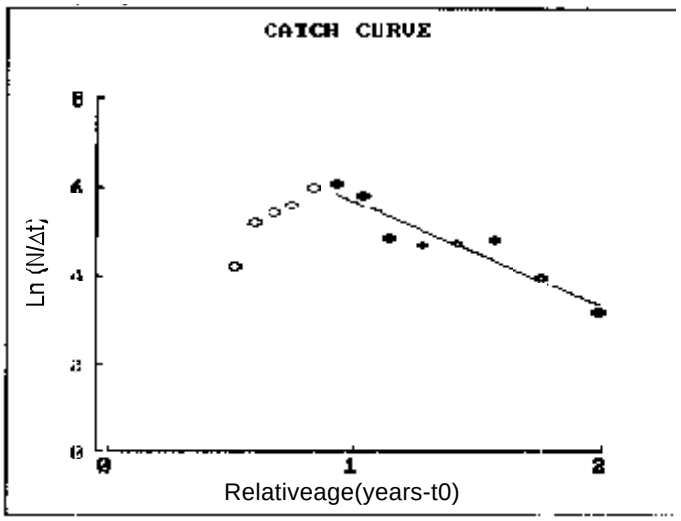
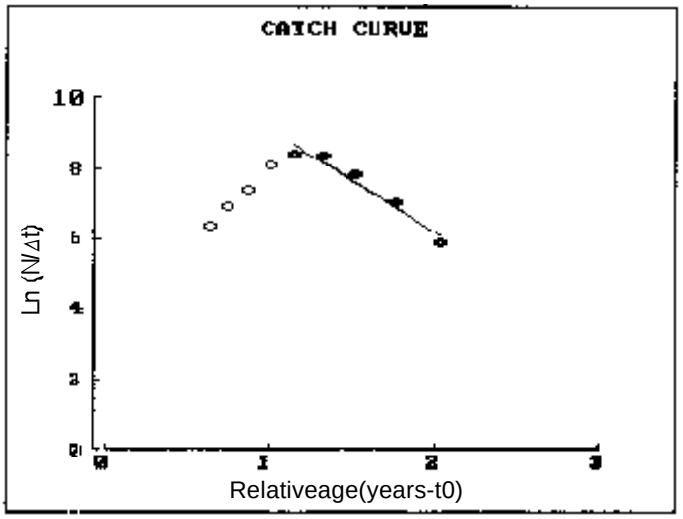
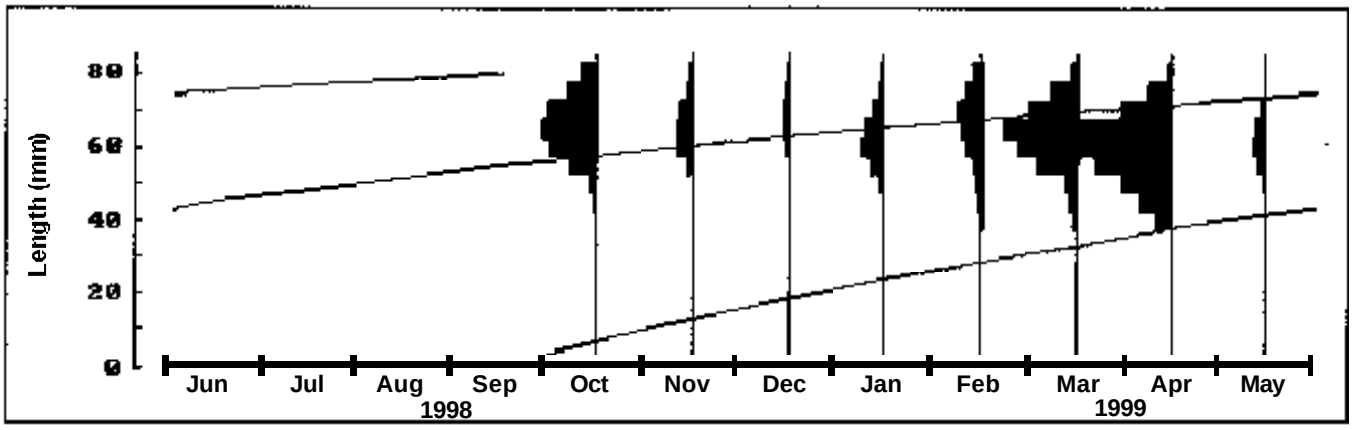


Figure G22-2. Length converted catch curve for *Pl. 'platyrhynchos'*.



FigureG23-2.Lengthconvertedcatchcurvefor *T.brevirostris*.



FigureG23-1.Lengthfrequencyplotsfor *T.brevirostris* intheSWAofLakeMalawi.

Placidochromis spp.

Placidochromis 'platyrhynchos'

The length frequency distributions, based on 1053 fish are presented in Figure G22-1. The best estimation, fitting two year classes, was obtained with L_{∞}=132 mm, K=0.9. The calculated date of birth, April corresponded to the middle of the main observed breeding season.

Assuming a mean environmental temperature of 23.5°C corresponding to the depth distribution of *P. 'platyrhynchos'* (75 to 125 m) and considering only the March distribution, the mortality estimates were: Z=2.43, M=1.93 and F=0.5 for the age range showed in Figure G22-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 64 mm.

Trematocranus spp.

Trematocranus brevirostris

The length frequency distributions, based on 3371 fish are presented in Figure G23-1. As for the other small species a relative homogeneity of length distribution among successive months was observed. However, it was possible to fit a VBGC, which gave reasonable estimates with L_{∞}=100 mm, K=0.79. The calculated date of birth, September seemed to correspond with a period of breeding activity.

Assuming a mean environmental temperature of 25°C corresponding to the depth distribution of *T. brevirostris* (around 50 m) and considering all the distributions, the mortality estimates were: Z=2.99, M=1.97 and F=1.02 for the age range showed in Figure G23-2. The mean size at first capture by the 35 mm cod end trawl net for this species was 55 mm.

Table G2. Growth parameters for 23 cichlid species from the SWA of Lake Malawi. L_∞ and K are the parameters of the Von Bertalanffy growth curve equation (VBGC). The TMM (mean maximum observed length) is the average length of the ten largest fish caught (de Merona 1983, Moreau & Nyakageni 1992). K' and L_∞' are rapid growth estimates calculated as follows: L_∞' = 1,248 TMM, K' = 153 / L_∞' (de Merona 1983). ΔG: growth difference at 2 years old obtained by fitting the VBCG with both sets of estimates (L_∞', K' and L_∞, K). Values indicate the magnitude of growth overestimation by the rapid growth estimation model.

	L_∞ (mm)	K (year^{-1})	TMM (mm)	L_∞' (mm)	K' (year^{-1})	DG (mm)
A. 'geoffreyi'	181	0,6	158,2	197	0,77	29
A. macrocleithrum	166	0,6	138,1	172	0,89	27
A. mentale	266	0,7	229	286	0,54	-13
A. pectinatum	160	0,58	134,5	168	0,91	31
Au. 'blue orange'	80	1,21	72,6	91	1,69	15
Au. 'minutus'	75	1,44	67,4	84	1,82	11
C. quadrimaculatus	160	0,58	147,5	184	0,83	39
C. virginalis	130	0,84	120,4	150	1,02	25
D. apogon	140	0,56	123,1	154	1,00	38
D. argenteus	220	0,62	197	246	0,62	19
D. limnothrissa	188	0,62	167,9	210	0,73	27
D. macrops	143	0,7	131,2	164	0,93	31
P. tokolosh	244	0,62	205,6	257	0,60	5
L. argenteus	182	0,94	156,5	195	0,78	0
L. 'deep water altus'	142	0,62	115	144	1,07	26
L. gossei	185	0,78	164,4	205	0,75	13
L. longimanus	160	0,75	136,5	170	0,90	18
L. 'oliveri'	110	0,88	96,3	120	1,27	20
L. polli	134	0,78	110,5	138	1,11	17
M. anaphyrmus	180	0,62	159	198	0,77	28
N. 'argyrosoma'	100	1	93,7	117	1,31	22
Pl. 'platyrhynchos'	132	0,9	114	142	1,08	16
Tr. Brevirostris	100	0,79	80,9	101	1,52	17

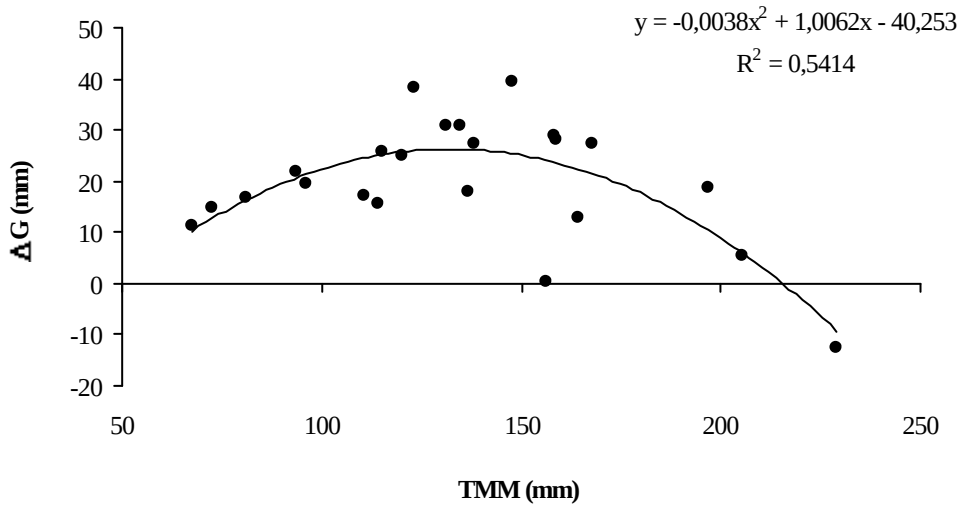


Figure G27. Distribution of G in relation with mean maximum observed length (TMM).

Discussion

As expected from the extended breeding seasons displayed by the studied species, more than one cohort per year class was usually present in the length frequency distributions. Knowledge about the species biology significantly helped us choosing among the various sets of growth parameters that correctly fitted the distributions. In particular, for a similar "quality of distribution's fitting", we always selected the set of parameters that gave a birth date consistent with the breeding season observed for the species (see previous Chapter). For this, we considered that the potential bias associated with the assumption that growth curve parameters applied right to zero, and not merely to the smallest sampled sizes (between 45 and 60 mm depending on species) was negligible. Although the breeding seasonality of species was studied over a single annual cycle, previous investigations over more than one annual cycle have suggested little or no inter annual variability of breeding patterns (Iles 1971, Tweddle & Turner 1977). Also, we decided to keep the asymptotic length ($L\infty$) within a controlled ranged. The trawl, with its 35 mm cod end mesh size is a non species-selective gear, catching fish from about 50 mm (see the estimated length at first capture for the studied species) to more than 300 mm (ex. *Buccochromis spp*.). Large and fast predatory species such as *Rhamphochromis spp*. were also caught, sometimes to sizes up to 500 mm. As a consequence and given the large numbers of specimens caught for most of the species, we considered that the maximum observed lengths were likely to be close to the asymptotic lengths, for the sampled area. Therefore, $L\infty$ was intentionally kept within a range of 1 to 2 cm above the maximum observed length for the medium and large species, and within a few millimetres above for the smallest species (*Au. 'blue orange'*, *Au. 'minutus'*, *N. 'argyrosoma'*, *T. brevirostris*).

Growth factor (K) values ranged from 0.56 to 1.44, averaging 0.77 (Table G2). As expected given the inverse relationship between $L\infty$ and K (de Merona et al. 1988), the smallest species (L_∞ < 100 mm) had the highest K, ranging from 0.79 to 1.44 with an average value of 1.11. However, the largest species (*A. mentale, P. tokolosh* and *D. argenteus*) did not have the lowest K. Medium sized species did have them. For comparative purposes, growth estimates of individual species were fitted by the VBGC equation and grouped per genera or size classes (Figure G24). The VBGC have been fitted up to the maximum observed length (MOL) of species. Within a single genus, species with comparable lengths had slight growth differences, though usually not higher than 1 cm at 2 years old as illustrated by *A. macrocleithrum* and *A. pectinatum* (Figure G24a), *D. apogon* and *D. macrops* (Figure G24b), *L. argenteus* and *L. gossei* (Figure G24c) or *Au. 'blue orange'* and *Au. 'minutus'* (Figure G24d). Growth performances of species within genera, as expressed by length at age, were proportional to their maximum length for *Alticorpus*, *Diplotaxodon* and *Lethrinops spp*., with the exception of *L. 'deep water altus'* having a slower growth than the smaller *L. polli.* Between genera comparison for species of similar lengths showed that *Lethrinops spp*. had better growth than *Alticorpus* and *Diplotaxodon spp*. (see *L. argenteus* and *gossei* versus *A. 'geoffreyi'* and *D. limnothrissa*). *Lethrinops* versus *Copadichromis spp*. comparisons were less clear as the similarly sized *C. virginalis* and *L. polli* had equivalent growths whereas *C. quadrimaculatus* had a slower growth than *L. longimanus*. *A. pectinatum* and *C. quadrimaculatus* had the same growth estimates and logically presented exactly the same growth curves, as did *A. 'geoffreyi'* and *M. anaphyrmus* (Figure G24a). Apart from *L. 'deep water altus'*, which growth was intermediate to those of *D. macrops* and *D. apogon*, *Lethrinops* species tended to have better growths than species of others genera with similar sizes.

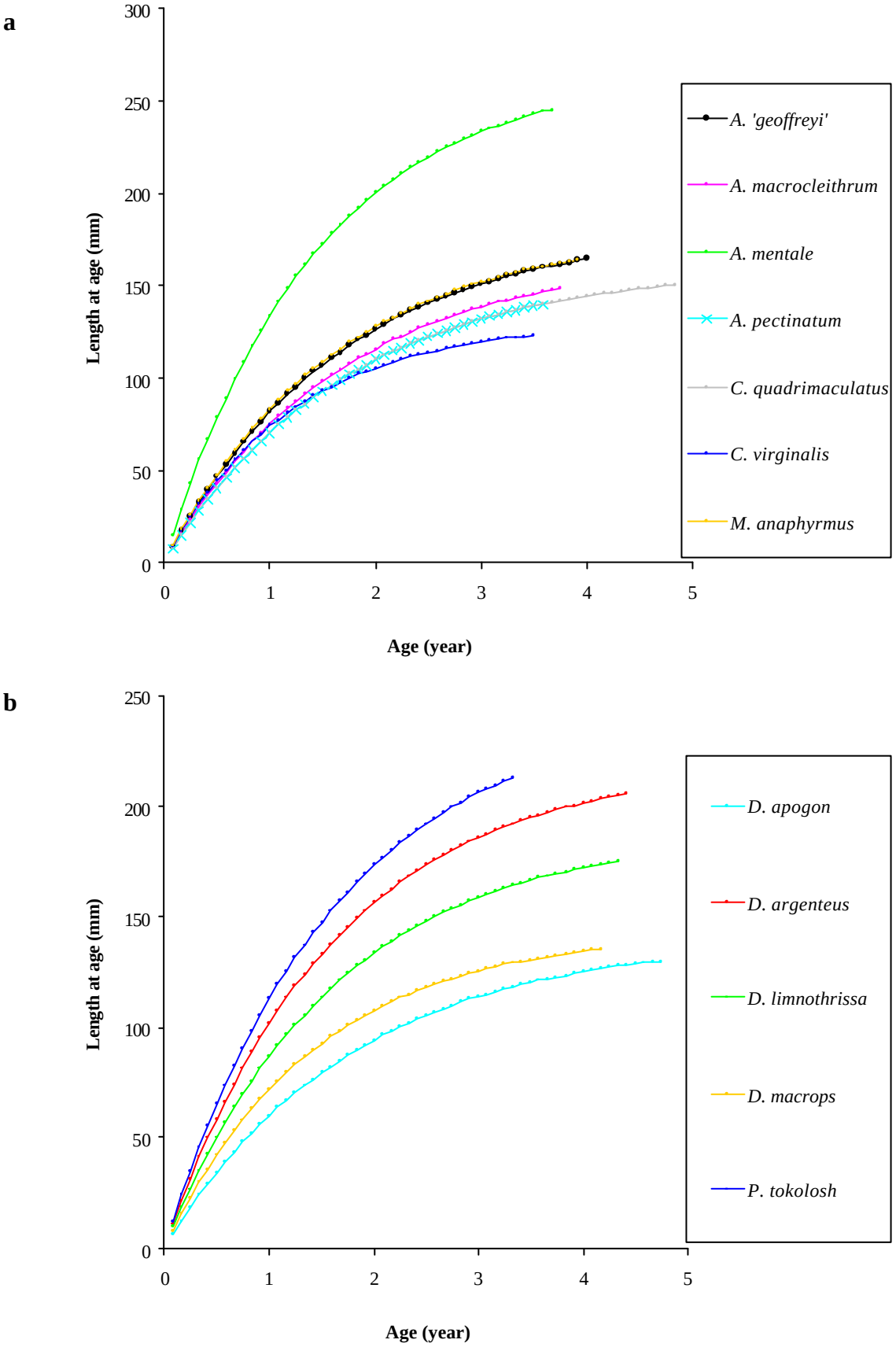
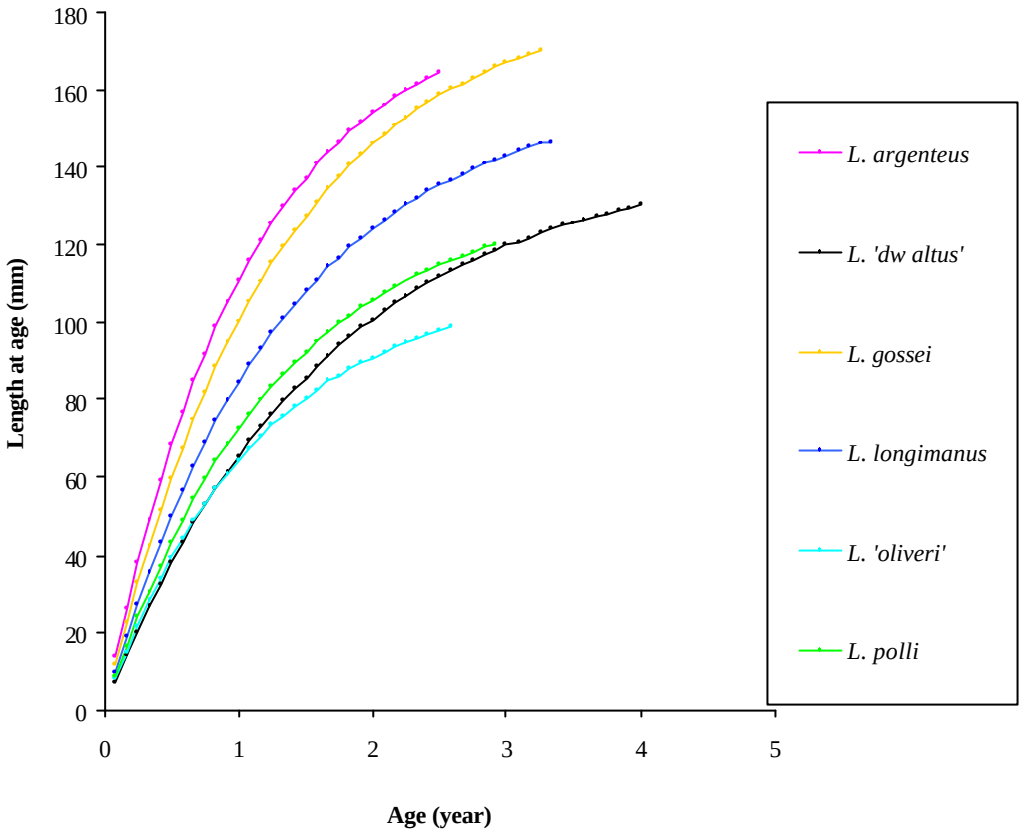


Figure G24. Von Bertalanffy growth curves for cichlid species caught by trawling in the SWA of Lake Malawi between June 1998 and May 1999. a: *Alticorpus, Copadichromis* & *Mylochromis spp*., b: *Diplotaxodon* & *Pallidochromis spp*..

c



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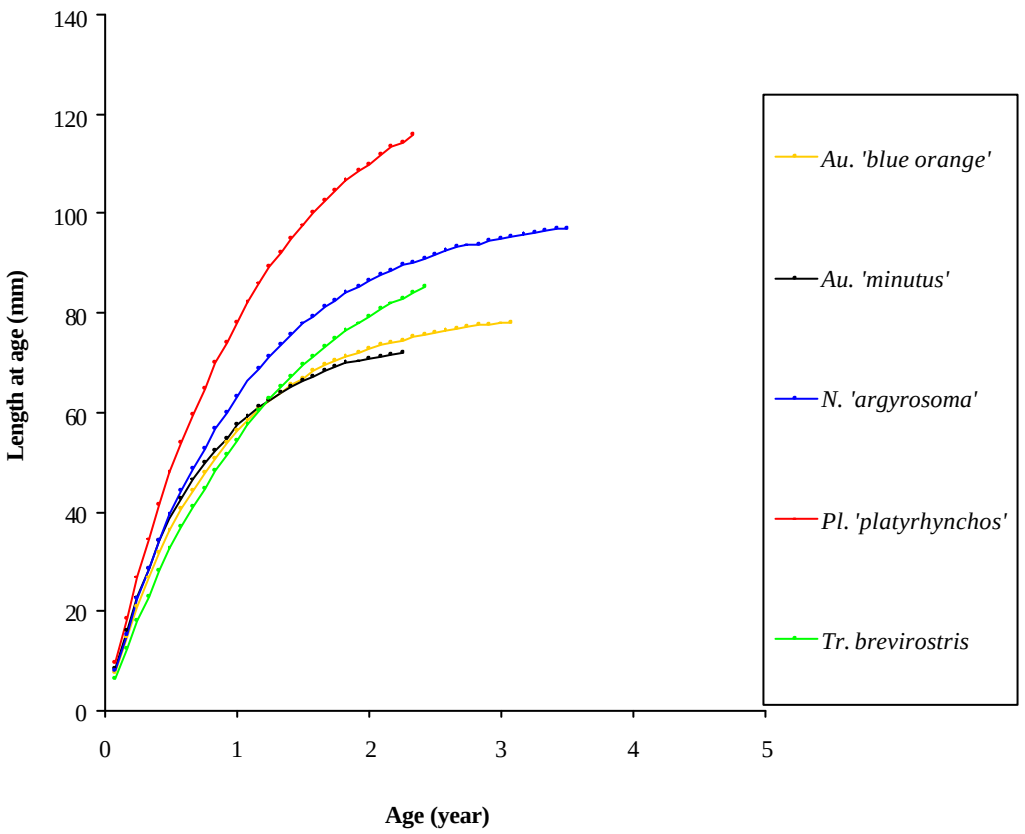

Figure G24. Von Bertalanffy growth curves for cichlid species caught by trawling in the SWA of Lake Malawi between June 1998 and May 1999. c: *Lethrinops spp*., d: miscellaneous small species.

For a same population, values of L∞ and K can significantly vary from one cohort to another (Craig 1978). Examples of multiple cohorts within a same year class were given by *A. mentale*, *D. limnothrissa* and *M. anaphyrmus*, though they appeared for most of the medium and large species. For these three species, growth estimates of the two cohorts resulted in different growth performances (Figure G25).

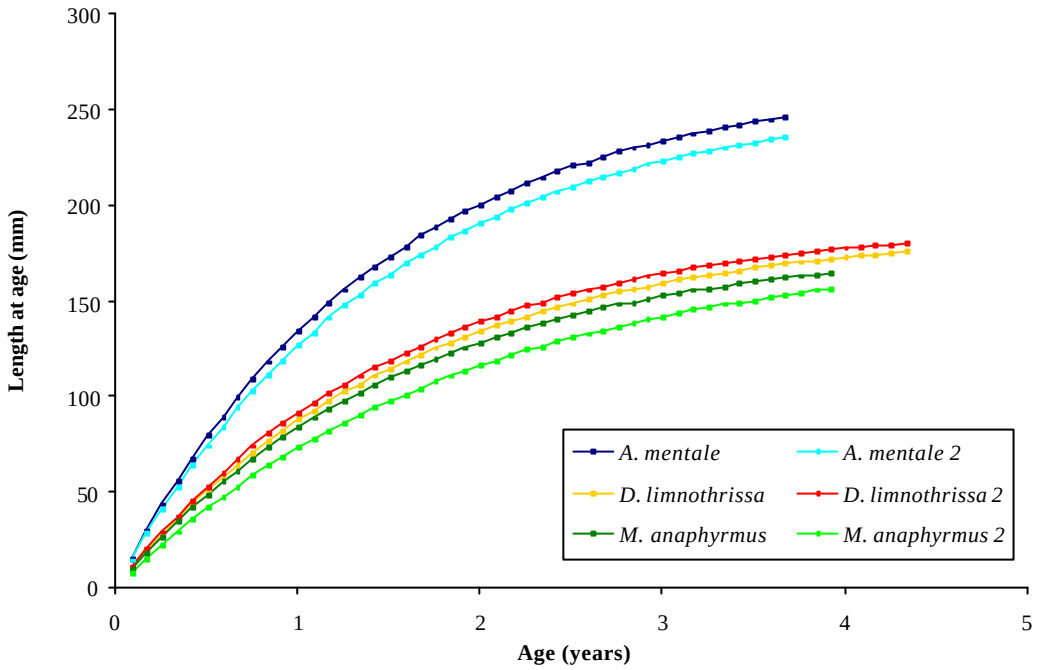

Figure G25. Von Bertalanffy growth curves illustrating differences among cohorts for three species caught by trawling in the SWA of Lake Malawi between June 1998 and May 1999. *Alticorpus mentale* = cohort born in April (L_∞ = 266, K = 0.7), *A. mentale* 2 = cohort born in October-November (L_∞ = 256, K = 0.68). *Diplotaxodon limnothrissa* = cohort born in May (L_∞ = 188, K = 0.62), *D. limnothrissa* 2 = cohort born in July-August (L_∞ = 192, K = 0.64). *Mylochromis anaphyrmus* = cohort born in May (L_∞ = 180, K = 0.62), *M. anaphyrmus* 2 = cohort born in September (L_∞ = 179, K = 0.52).

For *A. mentale*, the cohort born in April had a length of 200 mm at 2 years old against 190 mm for the cohort born in October-November (5.5 % difference). For *D. limnothrissa* the respective lengths at 2 years old were 134 mm for the cohort born in May and 139 mm for the cohort born in July-August (4% difference). The largest length difference at 2 years old (10.4%) was observed for *M. anaphyrmus*: 128 mm and 116 mm for the cohorts born in May and September, respectively. These growth differences appeared after only a few months and were already marked at one year old. This means that for fish of a same population, growth depends upon the period of birth, thus of the prevailing environmental conditions. The most important environmental parameters influencing growth are temperature, oxygen and food availability (Pauly 1980, Caulton 1982, Pitcher & Hart 1982, Wootton 1990). For the deep water species (*A. mentale*, *D. limnothrissa*) temperature variations over the year (less than two degrees, Figure G26a) were unlikely to influence growth. In the depth distribution of *M. anaphyrmus*, temperature variations were more important (between 4 and 5°C). However, during the period separating the two cohorts (May with best growth and September) temperature were at their minimum and increased from August until the next cold season (May to August). Temperature is therefore unlikely to account for the observed growth

differences. The opposite pattern is observed for oxygen (Figure G26b) with higher seasonal fluctuations in the deep waters (about 5 mg.l^{-1}) than in the shallows (less than 2 mg.l^{-1}). In the deep zone, oxygen concentration increased from February to August and then decreased from September to January. For *A. mentale* (which presented the highest growth difference in the deep zone), the cohort with the slowest growth (born in October-November) faced a two fold decrease in oxygen concentration during its first three months. In December and January D.O. got down to 1.5 mg.l^{-1}, which represented about 17% saturation at 23°C and 100 m depth. It has been shown that growth of tilapia, which are well known to tolerate very low D.O., is reduced below 25% saturation (review by Chervinski 1982). Exposition to such low D.O. during at least two months might partly account for the observed growth difference between the cohorts. However both cohorts encountered periods of low oxygen concentration during their first six months and growth differences between cohorts were also observed for species which did not face low D.O. (*M. anaphyrmus*). Variations in food availability appears a more plausible explanation though little is known about seasonal variations of food availability for these three species with marked different feeding regimes: piscivorous, zooplanktivorous and malacophageous for *A. mentale*, *D. limnothrissa* and *M. anaphyrmus*, respectively (see chapter "Diet"). Nevertheless, whatever caused these growth differences among cohorts, it is striking that differences remained over time. Indeed, compensatory growth is well documented in fish and cichlids (review in Weatherley & Gill 1987, Melard et al. 1997). In Malawi cichlids for which fasting periods imposed by mouthbrooding are frequent, genuine capacities to buffer these periods are expected and probably exist (see Chapter 6).

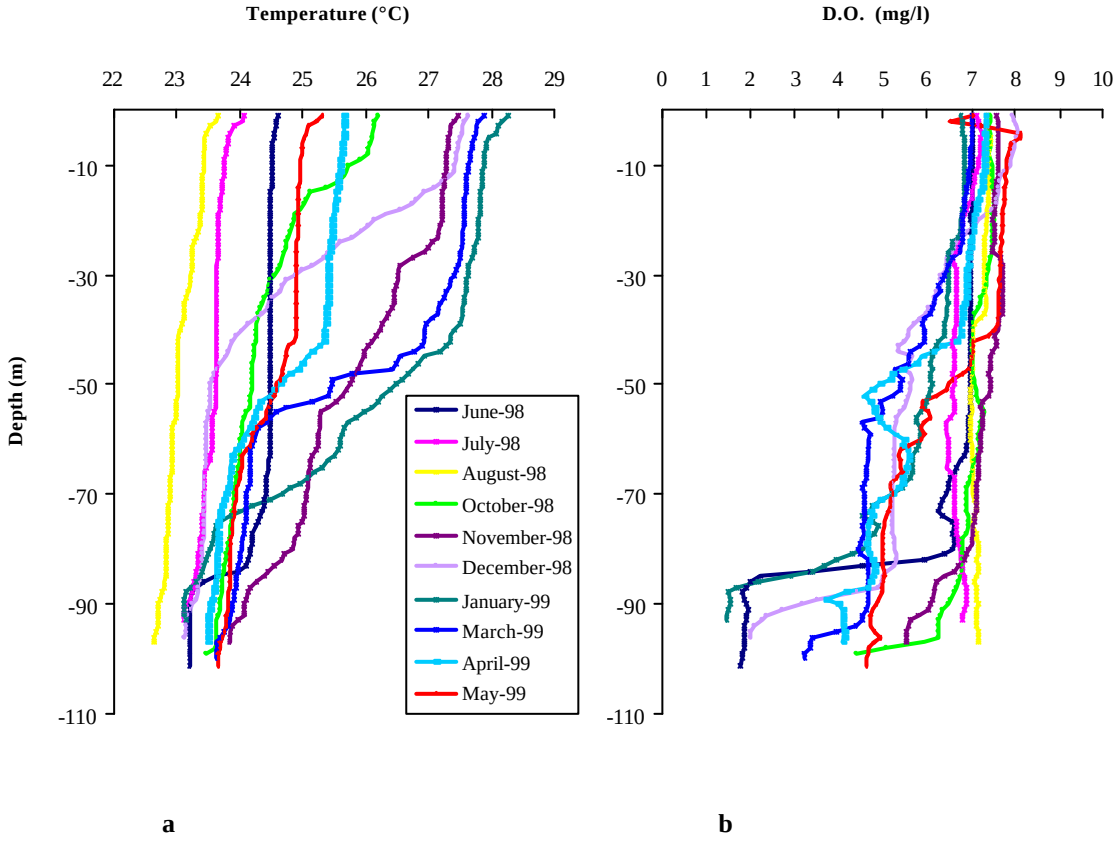

Figure G26. Seasonal variations of thermocline (a) and oxycline (b) at our 100 m transect in the SWA, Lake Malawi.

Equations allowing rapid estimation of Von Bertalanffy growth parameters were proposed for African freshwater fishes (de Merona 1983). These equations, based on 111 species, were:

$L_\infty' = 1.248\ TMM$ and $K' = 153 / L\infty'$

TMM being the mean maximum length, usually calculated as the mean length of the ten largest specimen caught (Moreau & Nyakageni 1992). K' and L_∞' were calculated for our species and compared with K and L∞ obtained from length progression analysis (Table G2). Rapid estimates of asymptotic length (L_∞') were always higher than the corresponding L∞, except for *L. 'deep water altus'*, *L. polli* and *Tr. brevirostris* for which values were close. The same trend was observed with rapid estimates of the growth factor (K'), generally much higher than the K obtained from length frequencies. However, for the five largest and fastest growing species (*A. mentale*, *D. argenteus*, *P. tokolosh*, *L. argenteus* and *L. gossei*), rapid estimates were equal or lower than the observed K. The lack of fitting between the rapid growth estimates model and the estimates resulting from length progression analysis may lie in the fact that only half of the 111 species on which the model is based were cichlids, and most of them were tilapiine cichlids (de Merona 1983, de Merona et al. 1988). Only 9 species out of 111 were haplochromine cichlids. Next, the aim to this rapid growth estimates model was to provide a quick and reasonably reliable way to assess growth in absence of suitable data for other methods, not to replace them. The rapid growth estimation model does not seem well adapted to haplochromine cichlids, for which it tends to overestimate growth by an average value of 20 mm (ΔG) at 2 years old. However, the overestimation tended to be lower for small and large species than for medium sized ones (Figure G27).

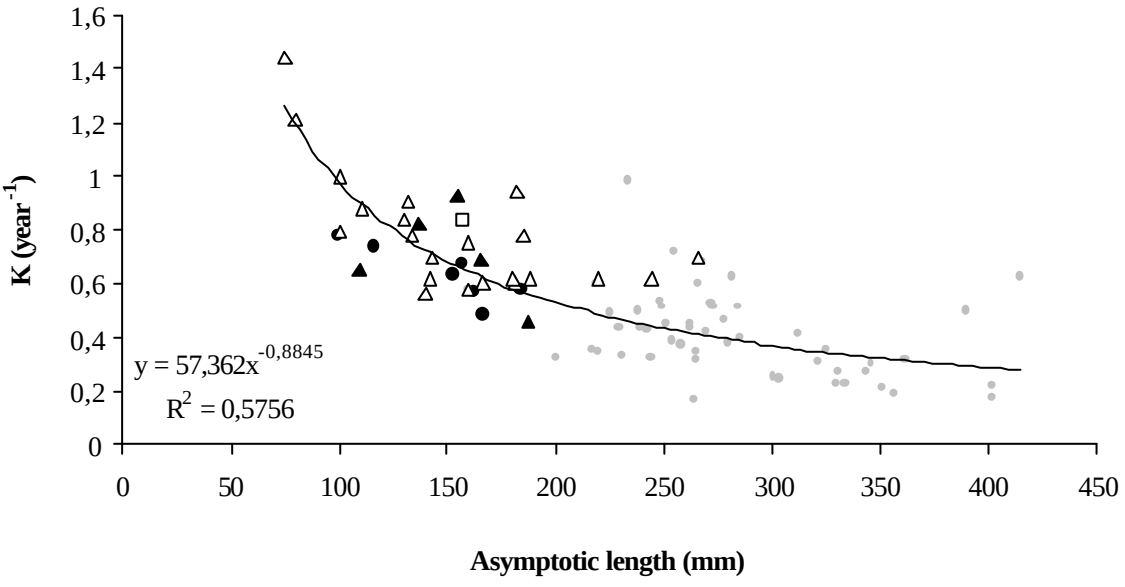

Figure G28. Relationship between K and L_∞ for 87 species of African cichlids. Grey spots = data from de Merona 1983, de Merona et al. (1988). Black spots = data from Iles (1971) and Tweddle & Turner (1977) for Malawi haplochromine cichlids, adjusted in SL by de Merona et al. (1988). Black triangles = data from Iles (1971) and Tweddle & Turner (1977) for Malawi haplochromine cichlids recalculated using ELEFAN by Moreau et al. (1995) and adjusted in SL using equation (1) (see Material and Methods). White square = *Diplotaxodon limnothrissa* from Thompson et al. (1995) adjusted in SL using equation (1). White triangles = data from this study.

Growth data available for 86 African cichlid species from Iles (1971), Tweddle & Turner (1977), de Merona (1983), de Merona et al. (1988), Moreau et al. (1995), and this study, were used to produce a general relationship between K and $L\infty$ and to check how our estimates were fitting in it (Figure G28). Our estimates were within the range of reported values for other African cichlids and Malawian haplochromines and set new references for small species with asymptotic length below 100 mm. Out of the 23 species we studied, four had already been studied for growth parameters: *Copadichromis quadrimaculatus*, *C. virginalis* (Iles 1971, recalculated by Moreau et al. 1995), *Diplotaxodon limnothrissa* (Thompson et al. 1995) and *Mylochromis anaphyrmus* (Tweddle & Turner 1997, recalculated by Moreau et al. 1995). As growth estimates can vary from one cohort to another within a same population (Craig 1978, de Merona 1983 for review, this study), comparing our results with growth estimates obtained 20 to 30 years ago (Iles 1971, Tweddle & Turner 1977) in different geographic areas may appear useless. However, despite the time and distance separating the estimations, growth differences for a same species at 2 years old (calculated using equation 2) were within the range of the differences we found among cohorts of a same species, though growth performances were always better with our estimates. More striking were the differences of longevity we found compared to Iles's (1971) and Tweddle & Turner's (1977), who reported 5 to 6 years life span. As illustrated on Figure G24, the species were not growing older than 4.5 to 5 years, and most of them no older than 4 years. Similar life span were found by Moreau et al. (1995) from Iles's (1971) and Tweddle &Turner's (1977) data reanalysed using FiSAT package. Haplochromines and non tilapiine cichlids from other lakes also lived between 2 and 4.5 years (Moreau et al. 1995), which tends to confirm shorter life span than previously thought for non tilapiine cichlids. Attempts to determine accurately mortality rates were often not successful. Indeed, though within the range of mortality values reported for Malawi cichlids (Tweddle & Turner 1977, Moreau et al. 1995), mortality rates often appeared overestimated. Given the low fishing exploitation in the sampled area, reasonable estimates of instantaneous mortality rate (Z), particularly for the deep water species, should have been close to natural mortality estimates (M), which usually seemed reasonable. This was seldom the case. The reason mainly lie in the fact that length distributions were biased by lack or under-representation of smaller individuals. However, this is a common problem in Lake Malawi and even though juveniles were caught by fishing gears, it would be of little help considering the identification problems that would result. Consequently, though mortality rates were probably overestimated, they remain a useful basis for fisheries and trophic modelling.

Chapter 4:

Temporal diet patterns of some Lake Malawi demersal fish species as revealed by stomach contents and stable isotope analysis

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Introduction

Cichlids have evolved an astonishing diversity of feeding adaptations and behaviours that enable them to utilise virtually any kind of food, from phytoplankton, epilithic and epiphytic algae, plants, detritus, zooplankton, molluscs, insects, benthic invertebrates, fish eggs, larvae, eyes, and scales, to whole fish (reviews in Fryer & Iles 1972, Ribbink 1990, Yamaoka 1991). The role of the feeding apparatus and trophic specialisations in the adaptive radiation of African cichlids has often been discussed (Fryer & Iles 1972, Liem 1980, 1991, McKaye & Marsh 1983, Ribbink et al. 1983, Reinthal 1990, Ribbink 1990, Yamaoka 1991). The understanding of how such rich and diverse fish communities with apparently similar food requirements can coexist still challenges ecologists. In Lake Malawi, since Fryer's (1959) suggestion that the mbuna community was violating the Gaussian principle of competitive exclusion, several studies have provided evidences that food partitioning may reduce interspecific competition and allow coexistence among rock-dwelling cichlids fishes (McKaye & Marsh 1983, Marsh & Ribbink 1985, Reinthal 1990, Bootsma et al. 1996, Genner et al. 1999a, 1999b, 1999c). Similar conclusions have resulted from research in Lake Tanganyika (Sturmbauer et al. 1992) and Victoria (Bouton et al. 1997). However, while diet, feeding behaviour and trophic specialisations have been, and still are, intensely studied in Malawian rock-dwelling species, very little is known of the divers offshore (sensu Turner 1996) cichlid communities. Apart from the zooplanktivorous utaka group (*Copadichromis spp*.) (Fryer & Iles 1972), the chambo (*Oreochromis spp*., Turner et al. 1991b) and the pelagic species, whose feeding ecology was recently thoroughly studied (Allison et al. 1996, Ngatunga & Allison 1996), the only information available on the diet of offshore fishes comes from Eccles & Trewavas (1989) and Turner (1996). These studies resulted in useful now insights into fish feeding habits, but they were limited by the relatively small numbers of observations and the limited time span over which fish stomach contents were monitored. The currently running European Union Project: "The trophic ecology of the demersal fish community of lake Malawi/Niassa", partly aimed at filling this gap, will improve our knowledge. However, the seasonal variability of fish diet is not a priority of the EU Project. The temporal aspect of demersal fish diets was investigated in the context of a general program designed to assess the seasonal progression of distribution, abundance and diversity of the fish species exploited by demersal trawling and to determine their main life history characteristics. Such a study had been considered when the new "Ecology program" had started in June 1998, but had been cancelled because the research actions already undergone were too time and people-consuming to allow the addition of another program. However, when a new staff member detached from the World University Service of Canada (WUSC) joined the ecology team of the project in October 1998, the study was reconsidered and initiated in November 1998. However, since the program ended in June 1999, an entire annual

cycle could not be studied. We decided to determine the diet and its potential seasonal variability for the nine target species retained for the life history study (*Lethrinops gossei, Lethrinops argenteus = L. longipinnis 'orange head', Diplotaxodon limnothrissa, Diplotaxodon macrops, Copadichromis virginalis, Mylochromis anaphyrmus, Alticorpus mentale, Alticorpus macrocleithrum* and *Taeniolethrinops praeorbitalis*) with both monthly stomach content and stable isotope analysis. Whereas stomach content analysis provides insight into the ingested food items over a short time period, stable isotope signatures represent a spatio-temporal integration of the assimilated food over long time periods varying from months to years depending on fish growth rates (Peterson & Fry 1987, Hesslein et al. 1991, 1993, Bootsma et al. 1996, Gannes et al. 1997, Gorokhova & Hansson 1999, Fry et al. 1999). Stable isotope analysis is particularly useful for deep-water species that often have inverted stomachs when retrieved from trawls.

Material and methods

Stomach content analysis

Seasonal variability of diet was estimated over 8 months for the nine target species. Fish were collected from the monthly trawl survey in the north of the South West Arm (SWA). Every month from November 1998 to May 1999, 20 specimens of each species were sampled from the main catch as soon as the total catch weight was estimated. 15% formalin was injected in the abdominal cavity of each fish to ensure the preservation of food items and the fish were fixed in 10% formalin for later examination. A frequently encountered problem when trawling below 50m depth is that the stomachs are often burst out of the fish mouths during hauling. For *Alticorpus mentale*, whose stomachs were almost systematically empty, every specimen from the whole catch was checked for intact stomachs. Even apparently intact stomachs often contained only very little amounts of remaining food items.

When enough intact stomachs were available, 5 specimens of each species were analysed each month for diet composition. For the sake of data compatibility, the method used was the modified version of the "point method" (Hynes 1950) selected by the ongoing EU Project: "The trophic ecology of the demersal fish community of lake Malawi/Niassa" (Darwall, 1999). The weight of the stomach plus content and the stomach minus content were determined to the nearest 0.001g. Total weight of stomach contents was calculated as the difference between the two weights. The stomach content was then examined under binocular microscope (10X to 40X magnification). All identifiable items were grouped into separate piles and allocated one of the following value: 16, 8, 4, 2, 1, or P (if present but in negligible amounts). The most abundant items were allocated a 16 and the others items were allocated a 16, 8, 4, 2, 1 or P depending upon their abundance relative to the most abundant item. All the small items unidentifiable under the binocular were pooled under a pile of "Small Unidentified" and allocated a value according to their relative proportion of the total stomach content. The pile of small unidentified items was then mixed with a small quantity of water (approximately 4× volume of the pile) and agitated thoroughly to break up any compacted lump. The sample was then left to settle out and the excess water removed. The remaining solution was homogeneously mixed and a small quantity (approx. 0.1 ml) was poured onto a slide under a slip cover. The slide was marked into quarters to define 4 sub-samples. The whole slide was then analysed under 40X to 400X magnification to identify the full range of food items. Each sub-sample was analysed under 40X magnification and each item was allocated a number of points as described above. When the four sub-samples were quite variable, the process was repeated with a second slide to get a total of eight estimates. The

composition of the small unidentified pile was then converted in percentage composition of each of its constituents and expressed as a percentage of the total stomach content. The percentage composition was calculated for each item as its own points value divided by the combined total of points for all items combined, multiplied by 100. In order to avoid giving too much weight to stomachs with only very little content, for every month each diet item value was weighted by the total weight of the stomachs analysed for that given month (W. Darwall, pers. com.).
Items which made up less than 2% of the diet each were lumped together and referred to as "others". Non identifiable materials were recorded as "No ID".

Stable isotope analysis

Fish samples for stable isotope analysis were collected by trawling during the January 1999 cruise. About six specimens of each of the nine target species, three small and three large whenever possible, were collected. Only dorsal muscle tissue was analysed. The potential food sources were collected during the April 1999 cruise. Benthic invertebrates and gastropods were sorted out from grab samples at 10, 30, 50, 75, 100 and 125 m depth. Sediment samples were taken from the upper layer of grab samples at every depth. Zooplankton and mayfly larvae were collected by 125 m vertical tows with a 50 µm mesh zooplankton net.

Stable isotope analyses were carried out at the Environmental Isotope Laboratory at the University of Waterloo, Canada. Samples were run for Nitrogen and Carbon analysis on an Isochrome Continuous Flow Stable Isotope Mass Spectrometer (Micromass) coupled to a Carlo Erba Elemental Analyzer (CHNS-O EA1108). Results were corrected to Nitrogen standards IAEA-N1 and IAEA-N2 (both Ammonium Sulphate) and Carbon standards IAEA-CH6 (sugar), EIL-72 (cellulose) and EIL-32 (graphite). EIL-70b, a lipid extracted/ball-milled fish material, is often used as a monitoring standard – ('EIL' denotes Internal Standards with values calculated using International Standards). The error for clean ball-milled standard material is +/- 0.2‰ for Carbon and +/- 0.3‰ for Nitrogen. This error can be expected to increase depending on the homogeneity, type and amount of sample used in analysis. A truer representation of sample reproducibility can be gained through sample repeats. Standards are placed throughout each run at a range of weights to allow for an additional linearity correction, when necessary, due to machine fluctuations or samples of varying signal peak areas. Nitrogen and Carbon concentrations are calculated based on Carlo Erba Elemental Standards B2005, B2035 and B2036 with an error of +/- 1%.

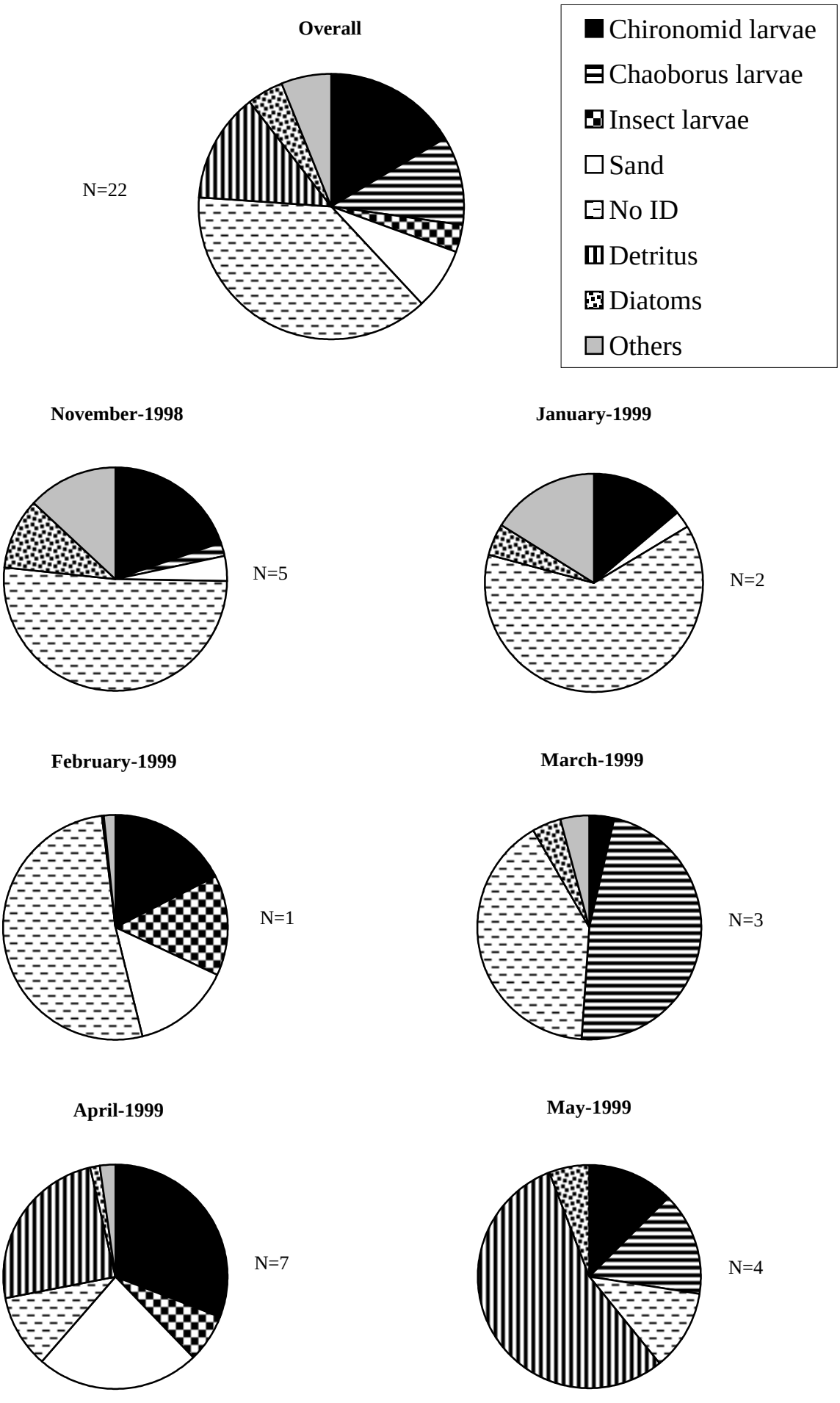

Figure D1. Overall and monthly diet composition (% wet weight) of *Alticorpus macrocleithrum* . See text for details on "Others" items.

Results and Discussion

Stomach content analysis

Alticorpus macrocleithrum

A. macrocleithrum is a deep water species found between 75 and 125 m. As for most of the deep water species, stomachs were very often inverted during trawl hauling. Only 22 specimens with remaining items in their stomachs were caught between November 1998 and May 1999. Weight of stomach contents averaged 31.2 mg and ranged from 6.4 to 96.8 mg for fishes of 103 to 137 mm SL (31-67 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D1.
As inferred from its anatomy by Stauffer & McKaye (1985), *A. macrocleithrum* appears to be a benthic invertebrate feeder. About 51% of the diet was not identifiable though, recorded either as detritus or "no id". The other 49% were constituted of chironomid larvae, *Chaoborus* larvae, insect larvae, diatoms, sand and other items (fish scales, adult insects, cladocerans, copepods, gastropods, oligochetes, macrophytes and other algae). The most important food items were chironomid larvae, present at every sampled date and lake fly (*Chaoborus*) larvae, though they were found only in March and May. Owing to its short gut and deep water existence, Stauffer & McKaye suggested *A. macrocleithrum* was not feeding on algae or phytoplankton. However, at every month except in February (0.3%), diatoms constituted between 1.4 and 10.5% of the diet. Diatoms might be ingested incidentally with sediment and sand while digging to catch the invertebrates. However, diatoms accounted for 10.5 of the diet in November, when only a small quantity of sand had been ingested (compared to February and April) and for 4.1% in March where almost no sand was ingested. Next the proportion of diatoms ingested appeared too high to be incidental.
Although the high proportion of detritus and unidentified materials at every month tended to screen the potential seasonal patterns, some food items occurred in the diet only at some months (ex. *Chaoborus* and insect larvae) suggesting *A. macrocleithrum* feeds opportunistically upon these items when available, either because they were the most abundant items at the moment or because they are preferred items.

Alticorpus mentale

A. mentale is also a deep water species mostly abundant between 75 and 125 m. As stomachs were almost always empty, every specimen from the whole catch was checked for intact stomach. Despite this effort, only 14 specimens had remaining items in their stomachs during the period from November 1998 to May 1999. Weight of stomachs contents averaged 1374.8 mg and ranged from 10.2 to 6549.2 mg for fishes of 110 to 245 mm SL (25-279 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D2.
As expected from its morphology, *A. mentale* is a piscivore. At any sampled date except December when 47% of the stomach content was unidentifiable, more than 75% of its diet consisted of adult cichlid fishes, often *Aulonocara minutus*. Other items were cichlid fry, scales, eggs, chironomid larvae, *Chaoborus* larvae, insect pupae, crustacean zooplankton, nematodes, sand, macrophytes and other algae. A significant amount of diatoms was recorded only once from a single large specimen (245 mm SL) in December, in which they made up to 19.7% of the stomach contents. No seasonal pattern was observed during the sampling period. An interesting observation, not apparent on the figures, was that of five relatively small

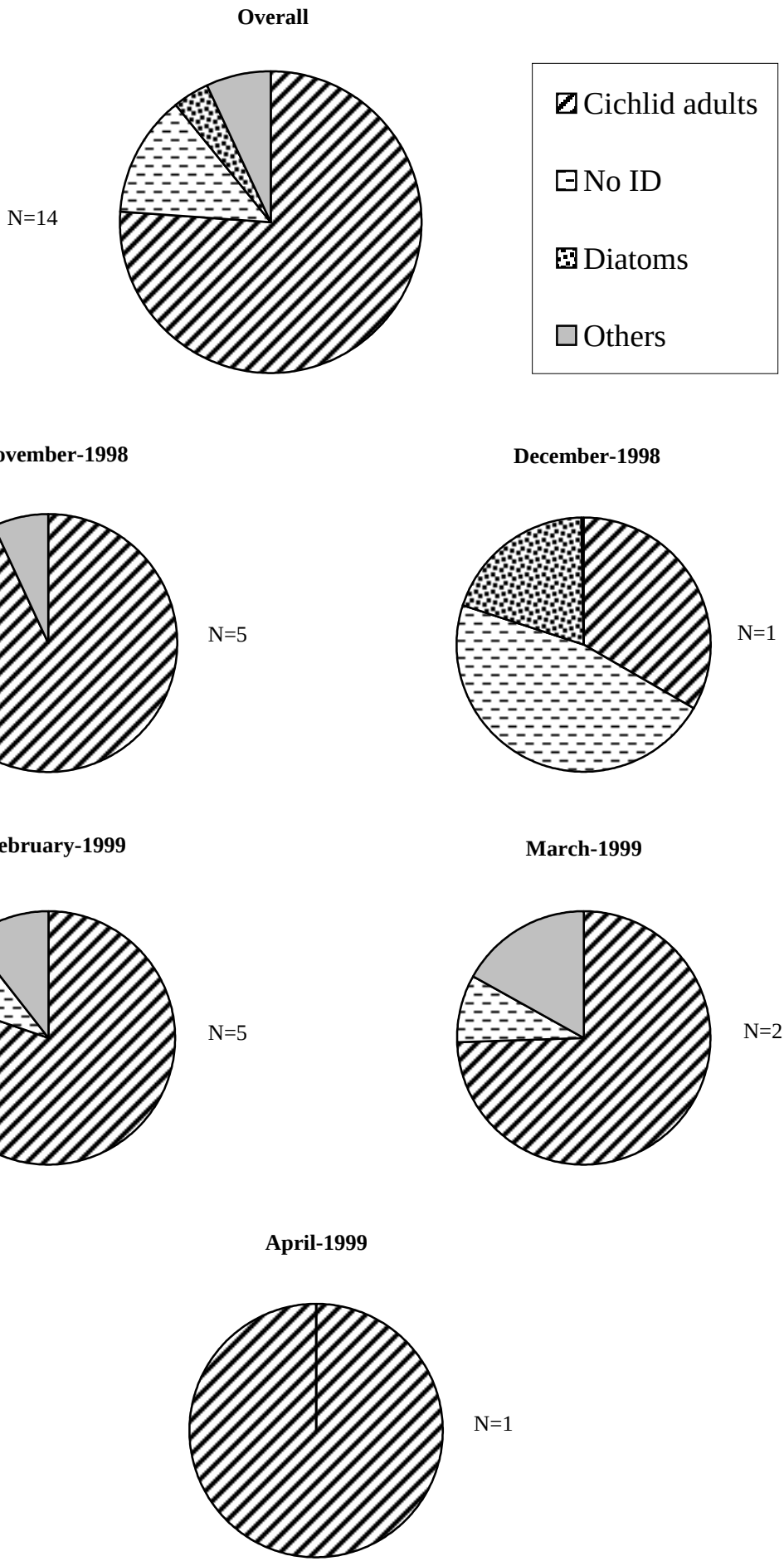

Figure D2. Overall and monthly diet composition (% wet weight) of *Alticorpus mentale* . See text for details on "Others" items.

individuals measuring between 110 and 117 mm, four fed principally (61 to 84% of the diet) on zooplankton (mostly copepods), and the fifth one fed on fish (94%). This pattern was not represented in the figures because the stomach content of these four small specimens were too light to account for a significant part of the weighted monthly mean diet.

Copadichromis virginalis

C. virginalis mainly occurs at depths between 30 and 50 m in the north of the SWA. Inverted stomachs were not a problem and 30 specimens were analysed between November 1998 and May 1999. Weight of stomachs contents averaged 68.7 mg and ranged from 18 to 190 mg for fishes of 70 to 115 mm SL (8-37 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D3.
C. virginalis is known as a member of the zooplanktivorous *utaka* group (Iles 1971, Fryer & Iles 1972, Turner 1996). Indeed, more than 95% of the diet was made of zooplankton, mainly copepods. It was only in this species that significant amount of cladocerans were found. No seasonal pattern was observed, crustacean zooplankton constituting more than 95% of the diet at any sampled date except December 1998, when the "others" components of the diet accounted for 17%. Other items were fish scales, chironomid larvae, *Chaoborus* adults and larvae, insects adults and larvae, nematodes, macrophytes, other algae and detritus. No particular trend relative to size was observed.

Diplotaxodon limnothrissa

D. limnothrissa was found at depths from 50 to 125 m, but was mostly abundant between 75 and 100 m. Despite their deep water existence, stomachs were not always inverted after hauling and 31 specimens were analysed. Weight of stomachs contents averaged 66 mg and ranged from 8 to 272mg for fishes of 101 to 145 mm SL (20-48 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D4.
Turner (1994) described *D. limnothrissa* as a zooplankton feeder, with specimens above 12 mm SL feeding mainly on copepods and small specimens of 3 mm feeding on chaoborid larvae and copepods. Allison et al. (1996) reported a mixed diet composed of crustacean zooplankton, *Chaoborus* larvae, *Engraulicypris sardella* (*usipa*) larvae and occasionally phytoplankton. Our observations support the statement of a mixed diet: 71% of the diet was made of copepods, *Chaoborus* larvae, adult insects and *usipa* larvae. The remaining part of the diet was composed of unidentified material, detritus and "others" items (cichlid fry, scales, fish eggs, chironomid larvae, cladocerans, bivalves, sand, diatoms and other algae). Unlike for *A. mentale* and *C. virginalis*, diet composition strongly varied among months, being either dominated by copepods in November 1998, April and May 1999, by *usipa* larvae in January 1999 or *Chaoborus* larvae in March 1999. As for *A. macrocleithrum*, Chaoborus larvae were almost exclusively present in the diet in March and May 1999 (also some in February). *D. limnothrissa* appears to feed opportunistically on a few preferred food items depending upon their availability. No particular trend relative to size was observed in the narrow size range studied.

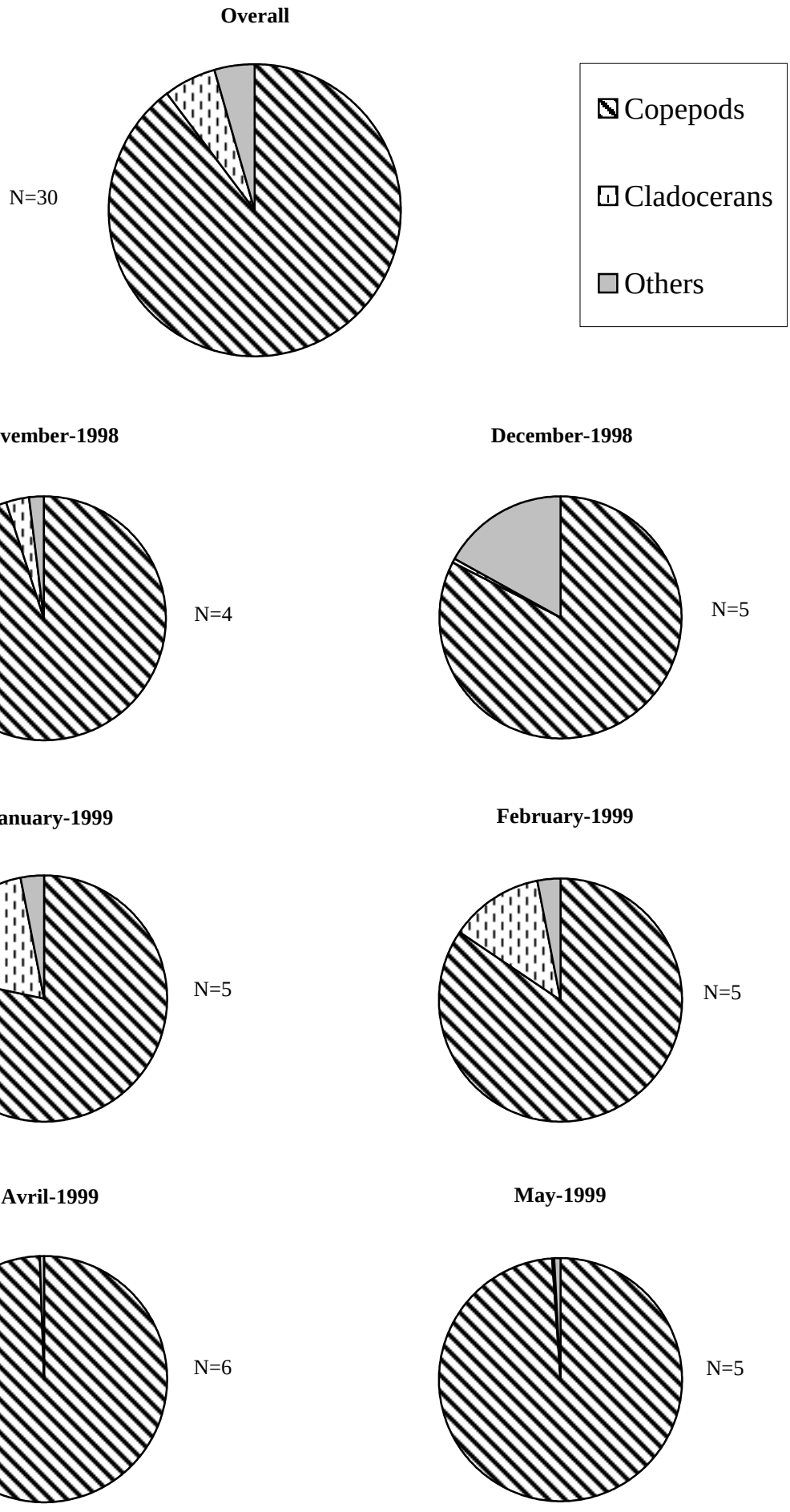

Figure D3. Overall and monthly diet composition (% wet weight) of *Copadichromis virginalis* . See text for details on "Others" items.

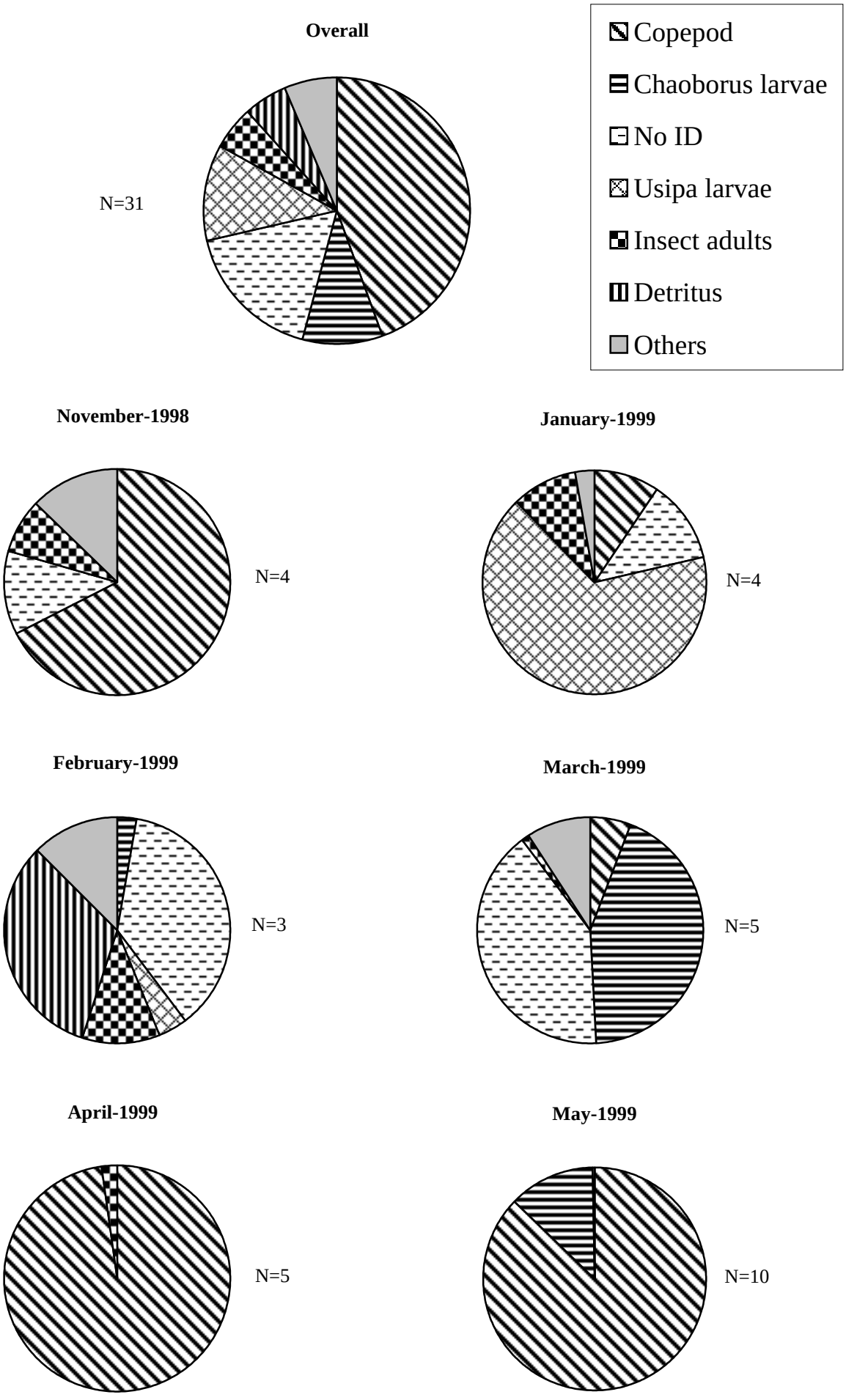

Figure D4. Overall and monthly diet composition (% wet weight) of *Diplotaxodon limnothrissa* . See text for details on "Others" items.

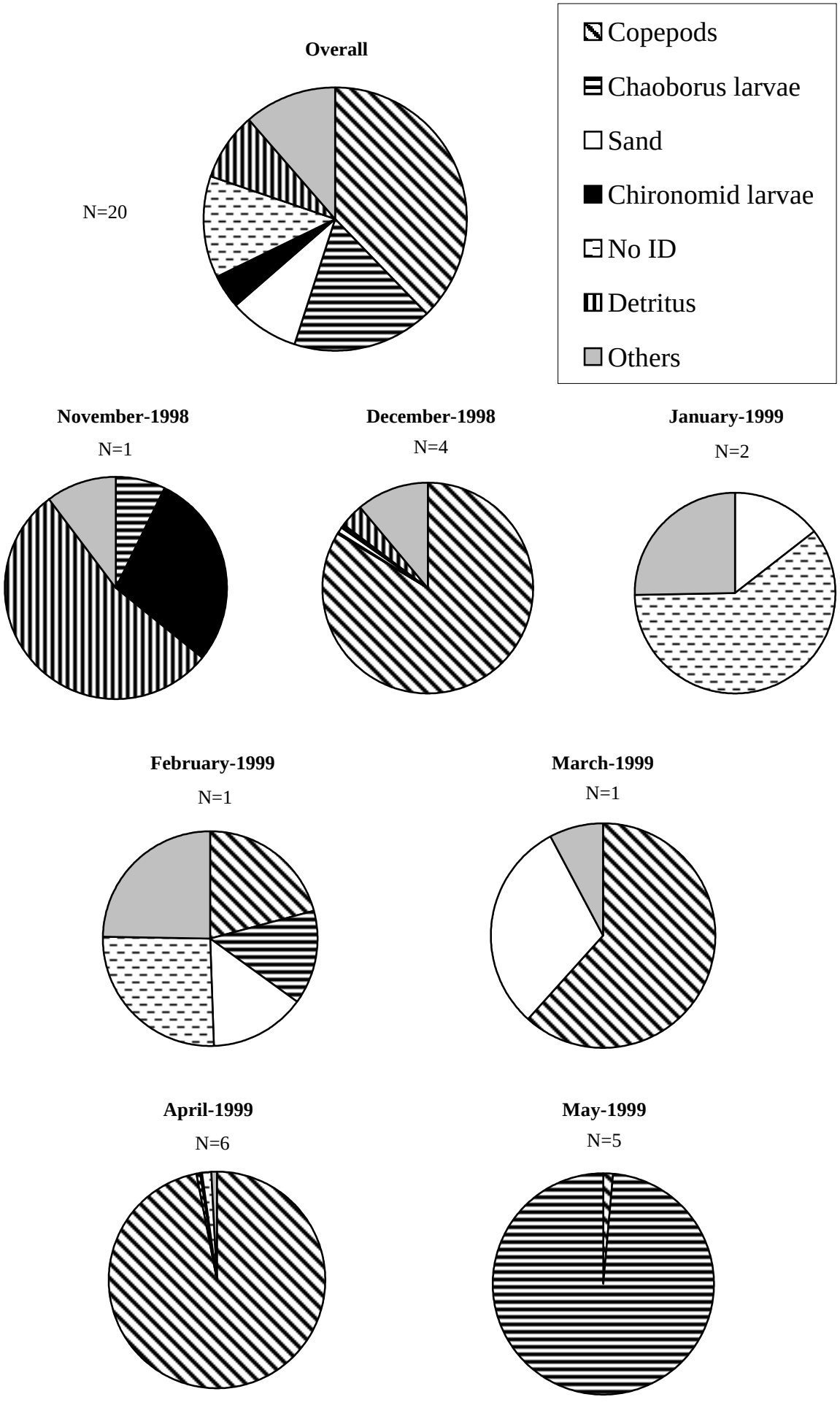

Figure D5. Overall and monthly diet composition (% wet weight) of *Diplotaxodon macrops* . See text for details on "Others" items.

Diplotaxodon macrops

D. macrops is a deep water species found from 75 to 125 m. Stomachs with remaining items were not as frequent as for D. limnothrissa and only 20 specimens were analysed between November 1998 and May 1999. Weight of stomachs contents averaged 61.2 mg and ranged from 5.4 to 157.4 mg for fishes of 85 to 118 mm SL (17-42 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D5.

Turner (1996) stated D. macrops was zooplanktivorous. Our results tend to support this statement as 55% of the diet was made of copepods and *Chaoborus* larvae. The remaining part of the diet was constituted of chironomid larvae, sand, detritus non identified material and other items (scales, adult insects, cladocerans, macrophytes, diatoms and other algae). It is important to notice that at months when more than only one or two specimens were examined, zooplankton accounted for 84 to 99% of the diet (December 1998, April and May 1999). Chironomid larvae constituted a significant part of the diet only once in November 1998, with a single fish examined. Chaoborus larvae were dominant items in February and May 1999. Like for *D. limnothrissa*, diet composition strongly varied among months for D. macrops, which seemed to switch opportunistically on some preferred items according to their relative availability. No particular trend relative to size was observed over the size range examined.

Diet composition of *D. macrops* was globally similar to that of *D. limnothrissa*, copepods and Chaoborus larvae accounting for most of their diet. However, their feeding strategy appeared slightly different as benthic invertebrates and important amount of sand were regularly found in *D. macrops* diet, suggesting a digging activity not observed in *D. limnothrissa*.

Lethrinops argenteus

L. argenteus (='*longipinnis orange head*') mainly occurs at depth between 10 and 30 m. The stomachs of 34 specimens were examined during the period from November 1998 to May 1999. Weight of stomachs contents averaged 54.2 mg and ranged from 6 to 197 mg for fishes of 92 to 142 mm SL (37-87 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D6.

Diet composition of *L. argenteus* was almost identical from one month to another, being essentially constituted of chironomid larvae (49 to 82%), sand, detritus, non identified material and other items (scales, fish eggs, insects adults, larvae and pupae, crustacean zooplankton, nematods, gastropods, bivalvs, macrophytes, diatoms and other algae). Given the nature of the main food item and the presence of large amounts of sand at each month, this species seems to be a benthic invertebrate feeder specialised on chironomid larvae.

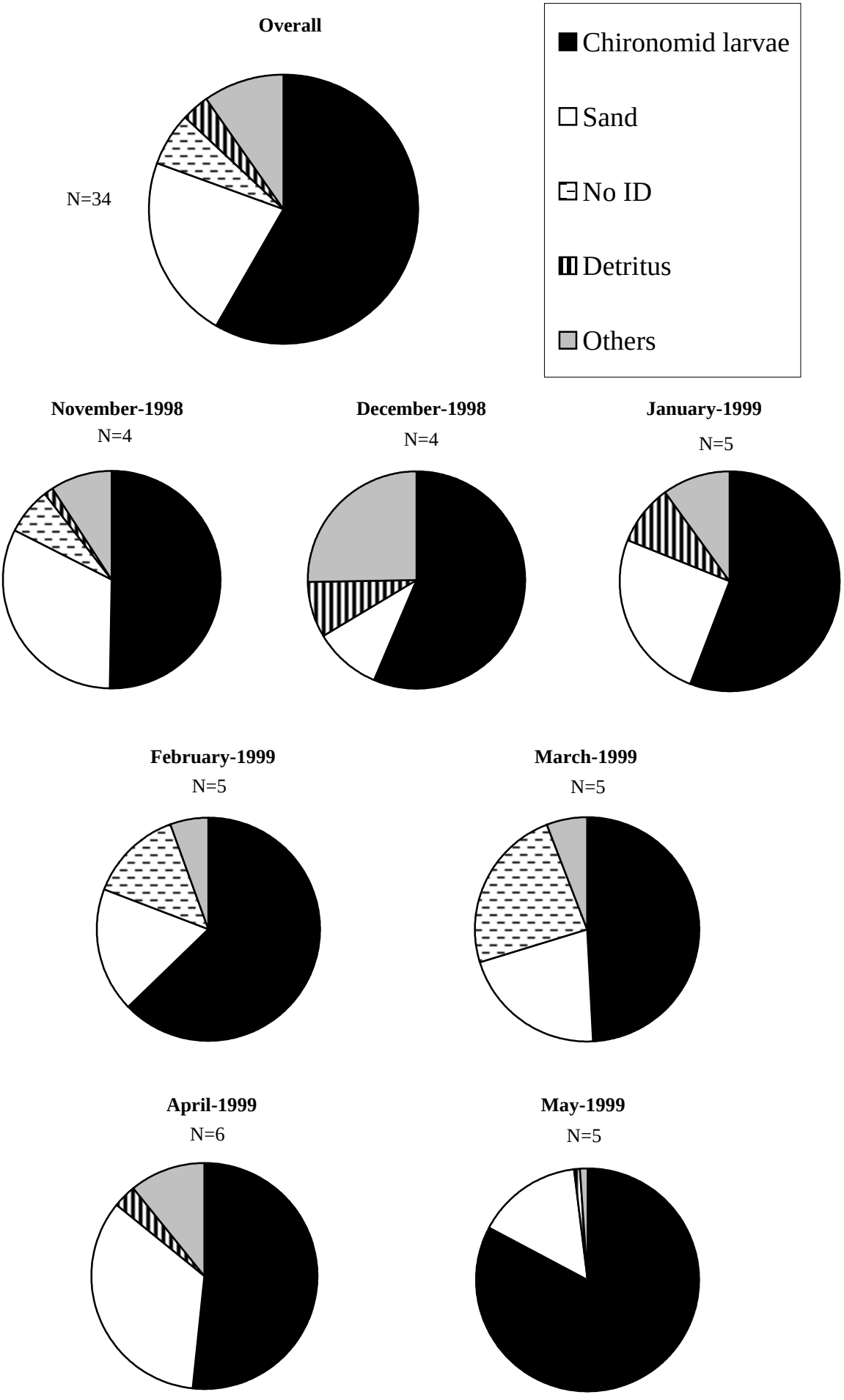

Figure D6. Overall and monthly diet composition (% wet weight) of *Lethrinops argenteus* . See text for details on "Others" items.

Lethrinops gossei

L. gossei is a deep water species mainly caught from 75 to 125 m depth. Despite is deep water existence, stomachs not inverted were found though they were seldom full. The stomachs of 21 specimens were examined between November 1998 and May 1999. Weight of stomachs contents averaged 72.7 mg and ranged from 5 to 210 mg for fishes of 101 to 155 mm SL (33-118 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D7.
Turner (1996) stated this species fed on benthic arthropods. Our results rather indicated a mixed diet constituted of benthic invertebrates and zooplankton. Over the sampling period, dominant food items were *Chaoborus* larvae, chironomid larvae, diatoms and copepods, making up to 76% all together. The remaining part of the diet was made of unidentified material, detritus and other items (scales, insects adults, larvae and pupae, nematodes, macrophytes and other algae). Diet composition was highly variable from one month to another, being dominated by diatoms in December 1998 and January 1999, by chironomid larvae in April 1999 and by *Chaoborus* larvae in March and May 1999. Diatoms might appear to be ingested incidentally, but as only a very small amount of sand was found in the stomachs and given the large amounts of diatoms found, the hypothesis of accidental ingestion is unlikely. No particular trend relative to size was observed. *L. gossei* appeared to switch opportunistically on a few preferred food items according to their availability.

Mylochromis anaphyrmus

M. anaphyrmus frequents the shallow waters between 10 and 50 m depth. The stomachs of 36 specimens were examined between November 1998 and May 1999. Weight of stomachs contents averaged 45.6 mg and ranged from 8 to 290 mg for fishes of 84 to 151 mm SL (16-125 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D8.
This species is known as a gastropod feeder (McKaye et al. 1986, Eccles & Trewavas 1989, Konings 1995, Turner 1996, Msukwa & Ribbink 1997), although copepods, chironomids, algal remains and arthropod material are sometimes found (Turner 1996). Most of the specimens we examined had lots of snail remains in their guts. However, what is presented here is only the stomach content analysis. Gastropods made up to an averaged 16% (4-44%) of the stomach content only. Chironomid larvae accounted for 41%, adult insects for 10% and crustacean zooplankton for 5%. The remaining part of stomach content was made of sand, non identified material and other items (scales, chironomid pupae, *Chaoborus* larvae, insect pupae and larvae, nematodes, bivalves, macrophytes, diatoms and other algae). Dominant components of stomach contents were the same from one month to another, but the relative proportion of these items slightly varied among months. No particular trend relative to size was observed except that individuals below 100 mm SL tended to have higher proportions of chironomid larvae in their stomachs; more than 99% for the two smallest specimens (80 and 84 mm).

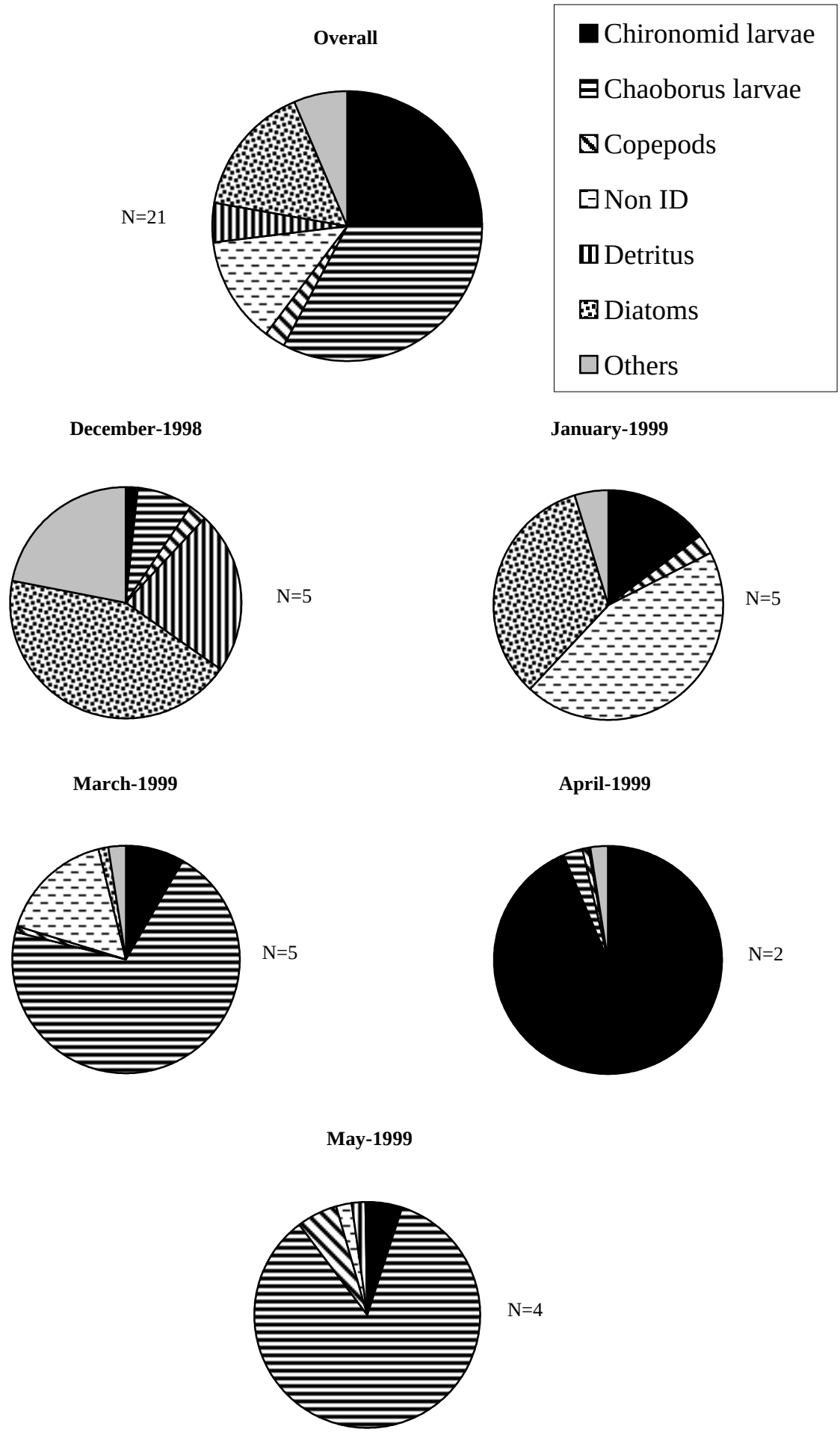

Figure D7. Overall and monthly diet composition (% wet weight) of *Lethrinops gossei* . See text for details on "Others" items.

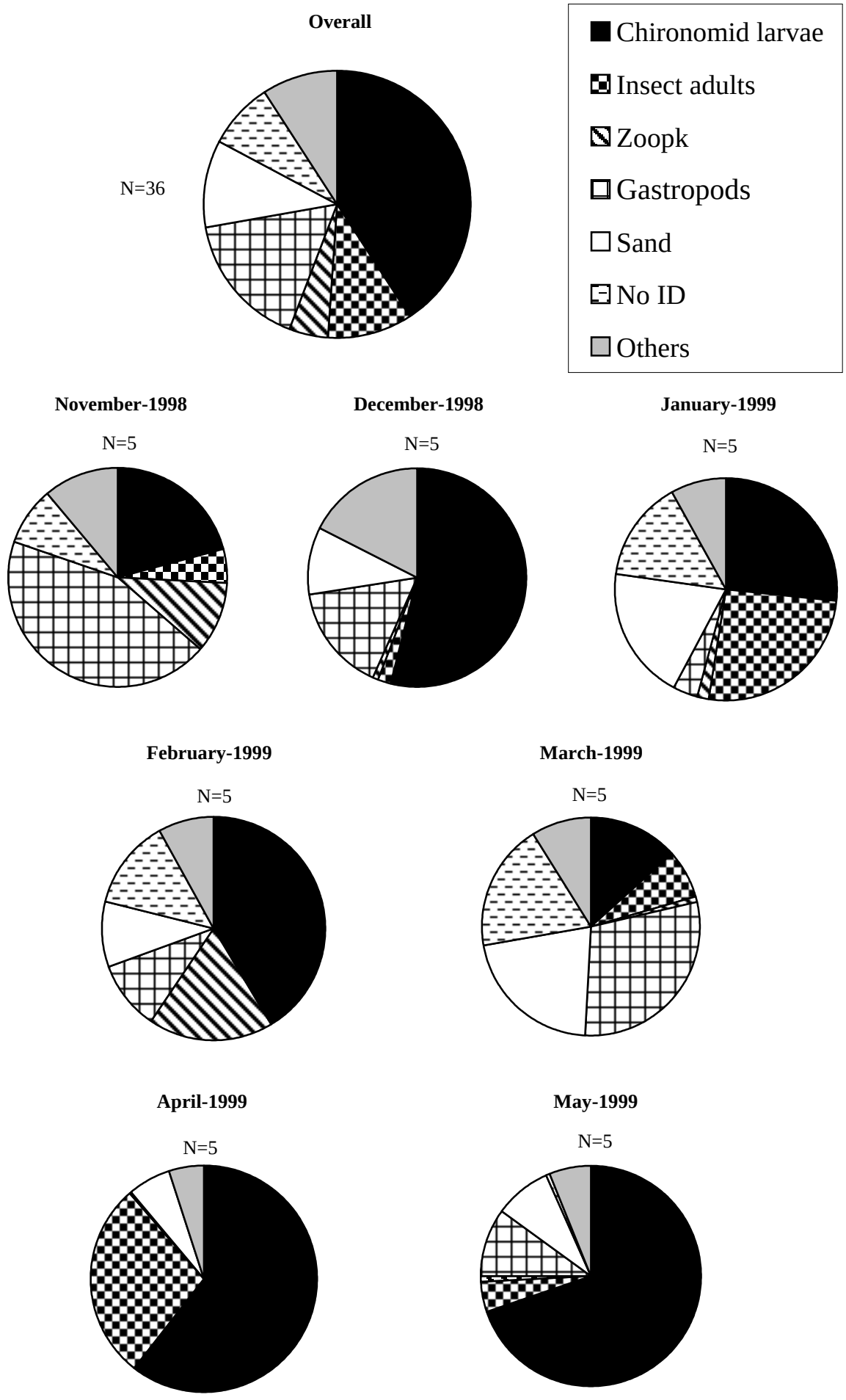

Figure D8. Overall and monthly diet composition (% wet weight) of *Mylochromis anaphyrmus* . See text for details on "Others" items.

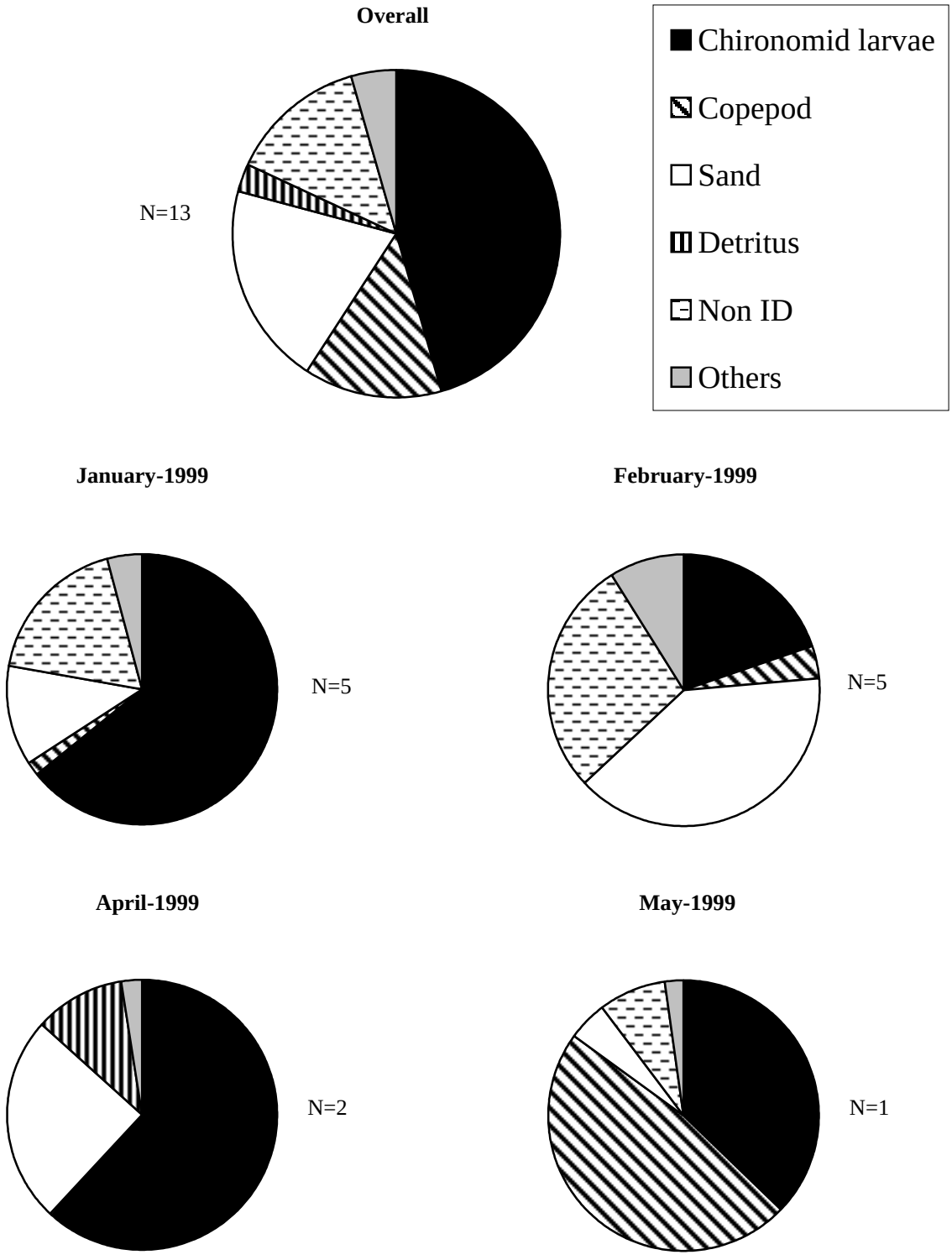

Figure D9. Overall and monthly diet composition (% wet weight) of *Taeniolethrinops praeorbitalis* See text for details on "Others" items.

Taeniolethrinops praeorbitalis

T. praeorbitalis is a shallow water species encountered from 10 to 30 m depth. The stomachs of 13 specimens were examined between November 1998 and May 1999. Weight of stomachs contents averaged 49.3 mg and ranged from 5 to 142 mg for fishes of 97 to 193 mm SL (24-166 g). Diet composition (as percentage of the wet weight) at each sampled month and all months pooled are presented in Figure D9.
This species is known to feed primarily on chironomid larvae (Fryer 1959, Eccles & Trewavas 1989, Turner 1996). However, specimens examined by Fryer (1959) were sometimes full of nematodes. Jackson (cited by Turner 1996) reported T. praeorbitalis fed mostly on *Chaoborus* larvae. Konings (1995) stated its main food is insect larvae. Detritus, diatoms and sand were also reported to occur in its diet (Turner 1996). The 13 specimens we examined fed largely on chironomid larvae, which averaged 46% of the diet. Copepods accounted for 13%, though they had been abundant in one specimen only in May 1999. The remaining components of the diet were large amounts of sand, detritus, non identified materials and other items (scales, insect adults and pupae, nematodes, macrophytes, cladocerans, diatoms and other algae). Apart from the one specimen with lots of copepods in May, no temporal variability in diet composition was noticed, the only variation being the relative proportions of chironomids and sand between months. The small specimens (90-130 mm SL) analysed tended to have a smaller proportion of chironomid larvae in their stomachs and larger proportions of copepods and plant material than large individuals (165-195 mm).

With the exception of a few species, which actually feed upon fish (*A. mentale, D. limnothrissa*…), the presence of fish scales in almost every stomach analysed, regardless of species, probably represents an artefact caused by the piling up of fishes during the trawl hauling. Indeed, at every haul, medium and large fish, including non piscivorous species, had small fish stuck in their mouths.

Stable isotopes analysis

As already emphasised by Bootsma et al. (1996), the use of both $\delta^{13}C$ and $\delta^{15}N$ signatures is very useful in separating fish with identical $\delta^{13}C$ signals but different feeding habits. Without the $\delta^{15}N$ signatures, it would have been impossible to distinguish between species such as *C. virginalis*, small *D. limnothrissa, L. gossei* and large *A. mentale* for example, which all have very different feeding regimes: zooplankton feeders, benthic invertebrate feeder and piscivore.
Except for *M. anaphyrmus*, there was significant intra-specific variability of both $\delta^{13}C$ and $\delta^{15}N$ for all species (Figure D10). This was particularly striking for *A. mentale*, which covered a $\delta^{13}C$ range of $4‰$ and about $2.5‰$ in $\delta^{15}N$. For most of the species, this variability was mainly explained by size differences among individuals, as illustrated by the circles and written sizes on Figure D10. In general, smaller specimens had a lower $\delta^{15}N$ signature than larger ones, indicating they were on a lower trophic level. Intra-specific variations of $\delta^{13}C$ also showed small specimens fed on different items than large ones. As a consequence, small and large specimens of the species *A. mentale, C. virginalis, D. limnothrissa* and *T. praeorbitalis*, were subsequently separated in the analysis.

The average isotopic composition of the nine target species and their potential food sources are presented on Figure D11. Owing to low sample size for most of the food sources, samples were analysed for $\delta^{13}C$ only and few $\delta^{15}N$ signatures are available. Adult mayfly

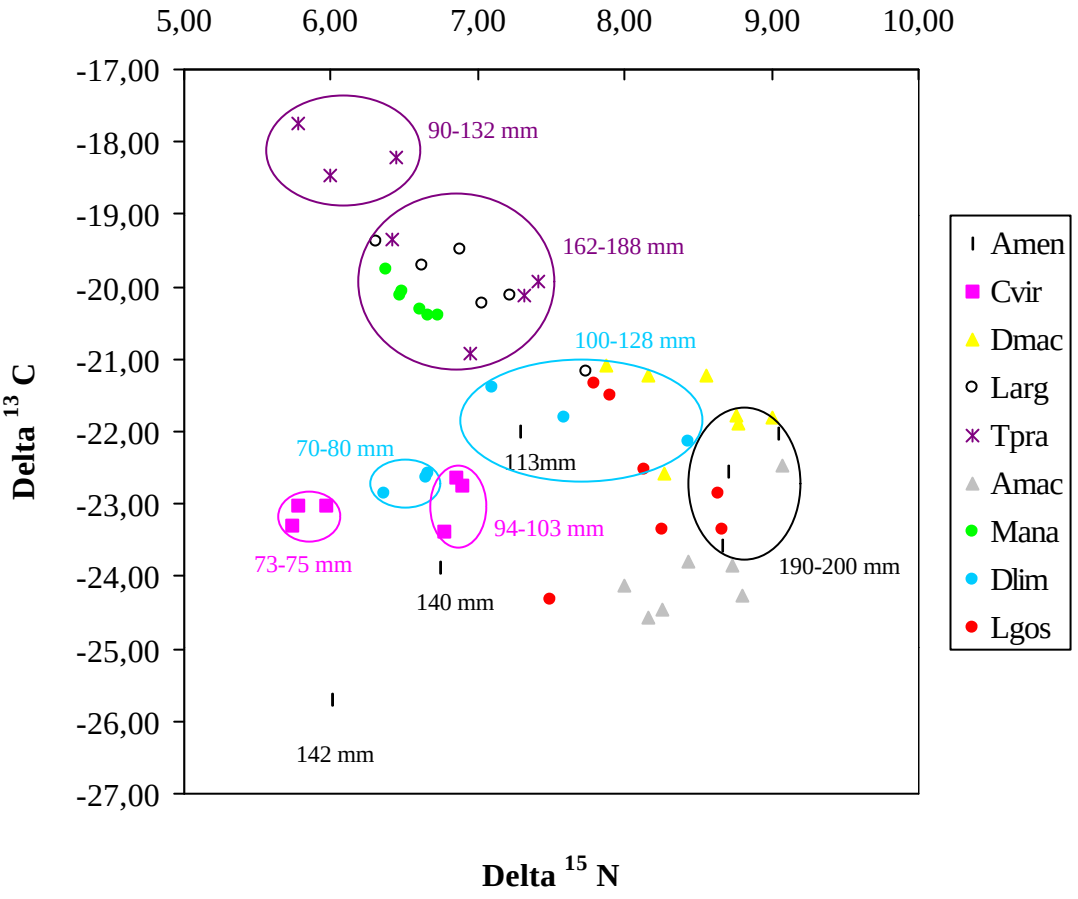

Figure D10. Individual isotopic composition of some demersal cichlid fish species in South West Arm of Lake Malawi. Amac = *Alticorpus macrocleithrum*, Amen = *Alticorpus mentale*, Cvir = *Copadichromis virginalis*, Dlim = *Diplotaxodon limnothrissa*, Dmac = *Diplotaxodon macrops*, Larg = *Lethrinops argenteus*, Lgos = *Lethrinops gossei*, Mana = *Mylochromis anaphyrmus*, Tpra = *Taeniolethrinops praeorbitalis*. Numbers represent the standard length or standard length ranges of specimens.

isotopic composition is not displayed on this figure because they can not be a significant food sources for these fish owing to their high mean $\delta^{15}N$ signatures: 7.82. The nine fish species displayed a $\delta^{15}N$ range of just over 3‰, which corresponds approximately to one trophic level (3 to 5‰ Peterson & Fry 1987, Hesslein et al. 1991, Bootsma et al. 1996). For most of the nine fish species, stable isotope results were consistent with stomach content analysis.

A. macrocleithrum had the second highest $\delta^{15}N$ signature (8.49), just below that of the piscivorous *A. mentale*. It was found to have a mixed diet composed mainly of benthic invertebrates, chaoborid larvae and unidentified material. Zooplankton and oligochaetes were also regularly found in its stomachs. The isotopic composition of this fish was consistent with these observations as it was intermediate between the lightest $\delta^{13}C$ signatures (zooplankton *Diaphanosoma excisum, Tropodiaptomus cunningtoni* and Oligochaetes at 100 m) and the heavier *Chaoborus* larvae, average zooplankton and sediment between 75 and 125 m (Figure D11).

The large specimens (190-200 mm SL) of *A. mentale* had the highest $\delta^{15}N$ signature, as expected from its almost strictly piscivorous habits (Figure D11). The smaller specimens (113-142 mm) had a lighter $\delta^{15}N$ and lighter $\delta^{13}C$ composition. Stomach contents of all the small specimens analysed contained over 60% zooplankton, except for one individual who had fed on fish (95%). Carbon isotopic composition of small *A. mentale* matched these observations, being intermediate between the different zooplankton species.

C. virginalis had amongst the lowest $\delta^{15}N$ in muscle. Stomach content analysis revealed this species feeds almost exclusively on zooplankton, which was supported by its isotopic composition, right in the range of the different zooplankton species (Figure D11). The $\delta^{15}N$ difference observed between small and large specimen is likely due to a selective predation upon different zooplankton species. Large specimens of *C. virginalis* probably feed more upon larger predatory zooplankton species than small ones.

Large *D. limnothrissa* specimens (100-128 mm SL) had a higher average $\delta^{15}N$ signature (7.71) than the small specimens (70-80 mm) (6.56), indicating they relied on food sources of a slightly higher trophic level (Figure D11). Temporal trends of stomach content analysis revealed a mixed diet composed of zooplankton, Chaoborus larvae, usipa and adult insects. This is supported by its $\delta^{13}C$ signature, which is slightly above those of zooplankton species, Chaoborid larvae, mixed adult insects and below the signature of some insect species such as Eatonica shoutedini (Ephemeroptera). It must be stressed that the Coleoptera can not account for an important part of *D. limnothrissa* diet because their mean $\delta^{15}N$ signature is only about 1‰ lighter.

D. macrops mean $\delta^{15}N$ signature (8.49) places this species on top of the represented trophic level with *A. mentale* and *A. macrocleithrum* (Figure D11). As for *D. limnothrissa*, stomach content analysis revealed a mixed diet in which crustacean zooplankton and Chaoborus larvae accounted for more than 50%. Its mean $\delta^{13}C$ isotopic signature supported these results. It was about 2‰ above the main zooplankton and chaoborid larvae signatures, indicating that this species relies also on heavier ^{13}C sources. Adults insects such as Coleoptera, which indeed have heavier ^{13}C signals, were often found in stomachs.

L. argenteus and *T. praeorbitalis* had almost exactly the same isotopic composition (Figure D11) and the heaviest $\delta^{13}C$ signature after the small specimens of *T. praeorbitalis*. Monthly stomach analysis for both species showed very similar diet composition mainly made of chironomid larvae, sand, detritus and other items. However, *L. argenteus* and *T. praeorbitalis* $\delta^{13}C$ signatures were heavier than expected if they were relying only upon chironomid larvae at 10, 30 and 50m (which is the depth distribution of these species in the sampled area, except for *T. praeorbitalis* only found at 10 and 30 m). As these species are

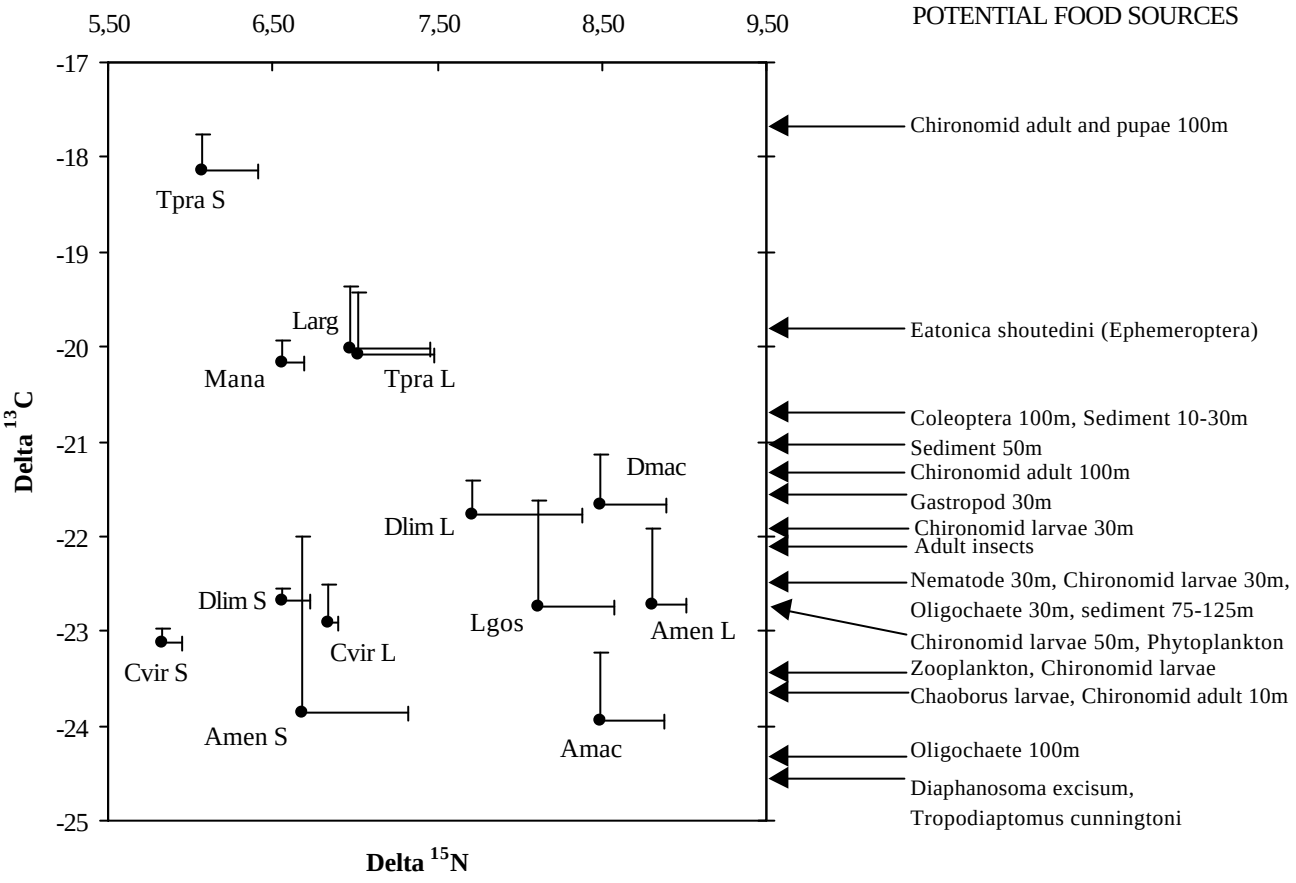

Figure D11. Mean isotopic composition (± standard deviation) of some demersal cichlid fish species and their potential food sources in South West Arm of Lake Malawi. Amac = *Alticorpus macrocleithrum*, Amen = *Alticorpus mentale*, Cvir = *Copadichromis virginalis*, Dlim = *Diplotaxodon limnothrissa*, Dmac = *Diplotaxodon macrops*, Larg = *Lethrinops argenteus*, Lgos = *Lethrinops gossei*, Mana = *Mylochromis anaphyrmus*, Tpra = *Taeniolethrinops praeorbitalis*. S and L refer to small and large specimens of a given species, respectively. The numbers correspond to the depth at which the samples were collected. Adult insects refer to the averaged $\delta^{13}C$ values of Hemiptera, Ephemeroptera and Corixidae. Zooplankton refers to the averaged $\delta^{13}C$ values of various crustacean copepod species (*Diaptomus vraepelini*, *D. dimixtus*, *Mesocyclops neglectus*, *M. leukarti*).

bottom feeders ingesting large amounts of sand, they probably also have other food sources with heavier carbon signals like periphyton (Bootsma et al. 1996) or other plant material, which were indeed regularly found in stomachs.

As observed in stomach content analysis, small specimens (90-130 mm SL) of *T. praeorbitalis* tended to have a different diet composition than large individuals (160-195 mm), which was reflected in their isotopic composition. Small individuals had heavier $\delta^{13}C$ and lighter $\delta^{15}N$ signals. Stomach analysis revealed that apart from chironomid larvae, zooplankton and plant material were important components of their diet. However, as the zooplankton has a lighter ^{13}C signal than chironomid larvae found in shallow water, it can not account for the heavier ^{13}C signature of small *T. praeorbitalis* compared to large ones. Oligochaetes, which are difficult to identify in stomachs when digested, have been found to account for more than 50% of *T. praeorbitalis* diet (W. Darwall, pers. com.) and might have constituted an important part of the unidentified material in our analysis. Unfortunately, we did not get enough oligochaetes at 10 m, where all the *T. praeorbitalis* analysed for isotopic composition were caught, to analyse them for isotopic composition. Nevertheless, given the large difference in $\delta^{13}C$ signal between oligochaetes at 100 m and 30 m (Figure D11), oligochaetes are likely to have a heavier ^{13}C signature in the shallow waters, but probably not heavy enough to actually account for a large part of *T. praeorbitalis* isotopic composition. The sand-digging habits of this species suggests that it may rely on vegetal materials (periphyton debris) with heavier ^{13}C signals found in sediment. The higher $\delta^{13}C$ and lower $\delta^{15}N$ suggest that small *T. praeorbitalis* may rely even more than adults on benthic algae, and may occupy a shallower habitat.

The deep water *L. gossei* had an average $\delta^{15}N$ signature among the highest (8.12) (Figure D11). Its diet composition as revealed by stomach contents varied much from one month to another, the main food items being *Chaoborus* larvae, chironomid larvae, diatoms, crustacean zooplankton and other less important items. Its $\delta^{13}C$ signature, about $1‰$ above that of *Chaoborus* larvae and zooplankton, might indicate that this species mainly relies on these food sources. However, as we do not have carbon signals of chironomid larvae in deep waters nor of diatoms, their potential importance in *L. gossei* diet can not be excluded.

M. anaphyrmus is commonly referred to as a gastropod-eater and most of the specimens examined had lots of snail remains in their guts. However, gastropods represented only a small fraction (16%) of the stomach contents in which chironomid larvae accounted for 41%, adult insect 10% and zooplankton 5%. Despite the weak occurrence of gastropods in stomach contents, *M. anaphyrmus* ^{13}C average signature (–20.17) was consistent with a diet mostly based on gastropods, for which the average signature at 30 m (most common depth of the species in the sampled area) was –22.02 (Figure D11). Usually a food source is on average $1‰$ heavier in ^{13}C than its consumer. The 2% found here might be explained by a preference for particular gastropod species with slightly lighter signatures or by feeding partly at shallower depths, where gastropods can be expected to have heavier signals (Bootsma et al. 1996).

Conclusions

Despite the high variability of stomach fullness encountered during this study, particularly for the deep water species, a good correspondence between the results of stomach content and stable isotope analysis was observed for most of the nine fish species. Stable isotope results proved very useful in clarifying the observed patterns. Species with the narrower feeding regime such as *A. mentale* or *C. virginalis* had an isotopic composition exactly matching the stomach content observations. For *M. anaphyrmus*, despite the

dominance of other food items in the stomachs at every sampled months, the isotopic composition confirmed the previously reported snail diet of the species (McKaye et al. 1986, Eccles & Trewavas 1989, Konings 1995, Turner 1996, Msukwa & Ribbink 1997). Stomach content analysis indicated regular temporal trends of diet composition for both *L. argenteus* and *T. praeorbitalis*, mainly dominated by chironomid larvae. However, stable isotope analysis revealed that the apparently secondary vegetal food items were playing an important role in the diet of these species, particularly for the small specimens of *T. praeorbitalis.* Isotopic composition clearly illustrated the diet separation among these demersal fish: on one hand there is the pelagic phytoplankton food chain, centered on $-23°/_{oo}$ with at least two trophic levels and intermediate feeding levels and on the other hand there is an ascending line towards heavier carbon source, which is most likely a periphyton-based food web represented by *T. praeorbitalis.* The ascending line to heavier carbon and lighter nitrogen likely represents mixed feeding on the periphyton-based source and the phytoplankton-based source, though there was no piscivore specialising on *T. praeorbitalis* in our collection. This is interesting in that it does indicate that benthic algal production is contributing to energy flow of the demersal fishes even well away from shore.

Species with a complex feeding regime such as *A. macrocleithrum*, *D. limnothrissa*, *D. macrops* and *L. gossei* showed important temporal variations in diet composition. These variations, which at first look appeared to be of opportunistic nature, are likely to be influenced by seasonal trends in food availability. Indeed, these four species fed upon *Chaoborus* larvae when available. For each of these species, *Chaoborus* larvae were dominant items in their stomachs at exactly the same months, March and May, and only at these months. This strongly suggests that the observed opportunistic feeding regimes were related to the seasonal and/or temporal fluctuations of their preferred food sources availability.

These results emphasise the complementary nature of stomach content and stable isotope approaches in the study of feeding habits and trophic patterns of complex fish communities. There appears to be a heavy reliance by most demersal fish on benthic organisms as a food source and little complete dietary overlap, supporting the belief that these fish must partition their resources in order to coexist (Bootsma et al. 1996, Turner 1996). If the habitat was to become more homogeneous (as a result of increased sedimentation, reduced water clarity, etc.), it can be expected that benthic organisms will be affected and that the potential for competitive exclusion will increase.

Chapter 5:

Morphometric, genetic and ecological comparison of two important demersal species along a gradient from the South West Arm to Nkhata Bay

Chapter 5: Morphometric, genetic and ecological comparison of two important demersal species along a gradient from the South West Arm to Nkhata Bay

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Introduction

The state of the demersal trawling fisheries in Lake Malawi has been monitored since the development of this industry in 1968 (Tweddle & Magasa 1989). Various authors have reported the consequences of trawling activities on fish communities, such as the profound size structure modifications, the decreased occurrence of some species and the disappearance of some others in the SEA, and drew the attention to the associated dangers for biodiversity conservation (Turner 1977a, 1977b, Turner 1995, Turner et al. 1995). However, demersal trawling only occurs in a restricted area in the southern part of the lake, representing less than five percent of its total surface. A recent report from the Fisheries Department revealed that most of the exploited species in the SE and SW Arms also occur in the non exploited trawling grounds between Dormira Bay and Nkhata Bay (Banda & Tómasson 1996, Tómasson & Banda 1996). When considering both fisheries management and biodiversity conservation issues, a logical question arises: are the species that have disappeared from the catches in the SEA really endangered if they also occur in other areas of the Lake? Although some of these species are supposed to occur only in restricted parts of the lake (Turner 1996), their degree of stenotopy is unknown and a decreasing stock might be repopulated from other geographical areas. However, a single species present in geographically distant parts of the lake might be composed of a single widespread population, or of different populations (or "stocks" in fisheries language). For the conservation of biodiversity as well as for the fisheries management, it appears crucial to know whether a species is represented by a single population distributed all over the lake, or by different populations with distinctive morphometric, genetic and life-history characteristics. If the threatened species of the southern arms were to be composed of a single widespread population, their disappearance from the exploited trawling areas would not represent an irreversible threat for the biodiversity. On the other hand, if they were distinct populations with different morphometric, genetic and life-history characteristics, their disappearance would lead to an irreversible loss of biodiversity. The starting hypothesis for this study is that shallow-water species have more chances to encounter physical barriers to their movements and therefore are more likely to be structured in distinct populations than deep-water species. A study was undertaken in collaboration with the taxonomists of the project, to compare the morphometrics, the genetics and some life-history traits of two species (a shallow-water and a deep-water species) from four different locations between the SWA and Nkhata Bay (Figure P1). This would allow us to assess whether they are part of a single widespread population or of distinct populations and consequently whether eventual differences are related to geographical distance and depth.

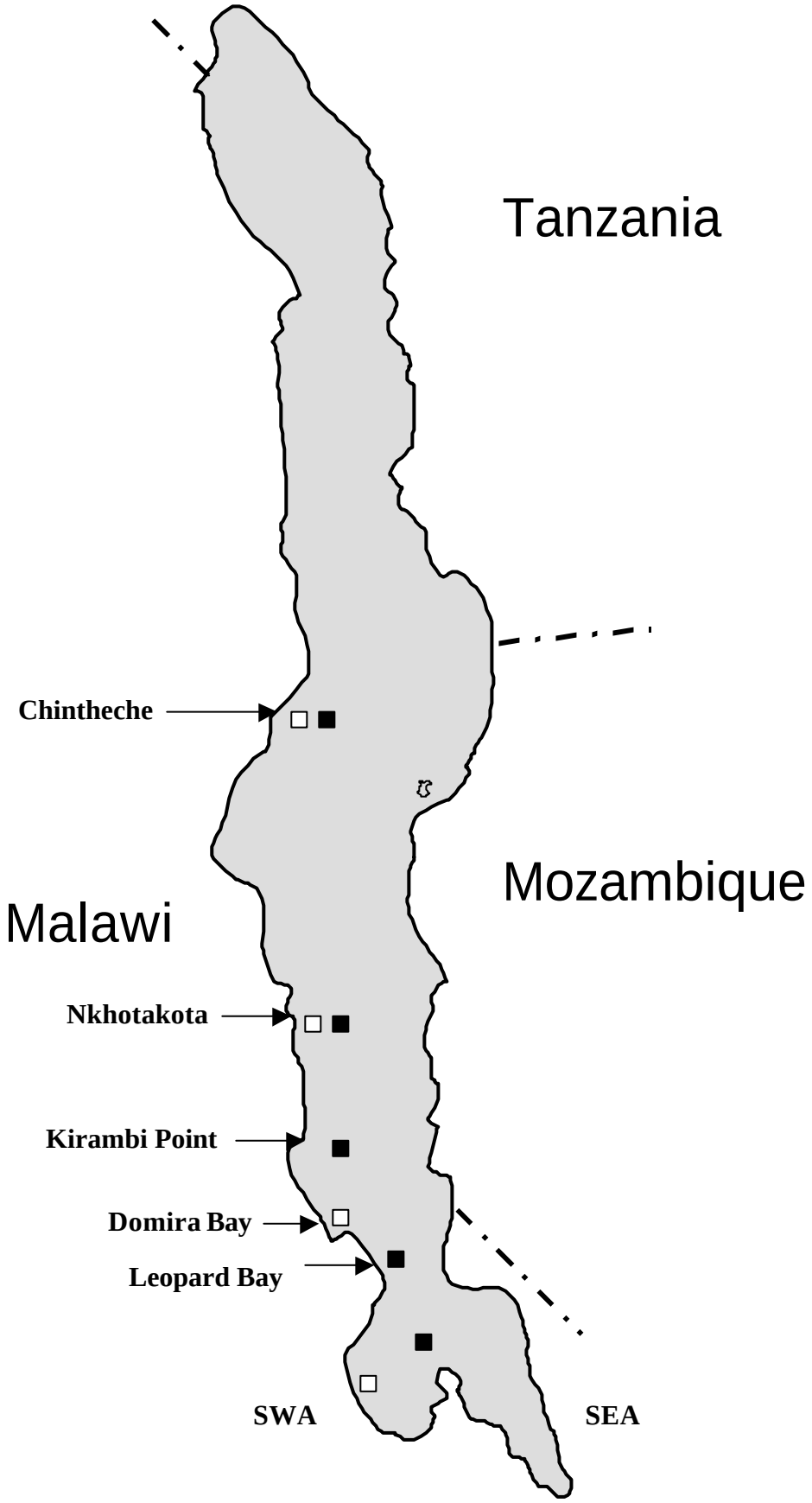


Figure P1. Map of Lake Malawi showing the sampling sites for *Mylochromis anaphyrmus* (white squares) and *Lethrinops gossei* (black squares) populations comparison.

Material and Methods

The shallow-water species, *Mylochromis anaphyrmus*, was sampled in the north of the SWA (where the monthly survey was done), Dormira Bay, Nkhotakota and Chinteche in February 1999. *M. anaphyrmus* was chosen for this study as a representative of the shallow water demersal community. It was one of the target species for the life-history studies within the project. Reasons for this choice are the fact that this species is relatively easily to identify, and common within its distribution range. Eccles & Trewavas (1989) reported that *M. anaphyrmus* is very common over sandy substrates, in waters of 15 to 35 meters depth in the southern part of the lake. They added that it was also reported from Nkhotakota. Konings (1995) stated that *M. anaphyrmus* is endemic to the southern and western parts of the lake. Turner (1996) reported that this species was present in 42 out of 57 experimental trawl catches between 18 and 72 m depth in the South-East Arm where it is often one of the most abundant species. Banda & Tómasson (1996) reported it in the SW and SE Arms as well as from Domira Bay to Nkhata Bay.
The deep-water species, *Lethrinops gossei* was chosen for the same reasons. It is an abundant species in deep water and was one of the target species for life-history studies within the project.. Eccles & Trewavas (1989) reported that it dominates the benthic community at depths of 92-130 m in the SEA. Turner (1996) stated it was one of the dominant species at depths of 90 m or more in the SEA. He also reported what appeared to be a female *L. gossei* caught off Karonga, in the far north of the lake. Banda & Tómasson (1996) reported it in the SW and SE Arms as well as from Domira Bay to Nkhata Bay. It was sampled during the same February 1999 cruise in the north of the SWA, where the monthly survey was done, off Leopard Bay, off Kiramby Point, in Nkhotakota and Chinteche (Figure P1).

It was planned that at each location, 30 specimens of each species were to be collected for morphometric analyses, 75 to 100 specimens for genetics and 100 to 200 specimens for life history traits analysis. *L. gossei* proved to be rare in Chinteche area between Bandawe Point and Sanga Point so that only 35 specimens were caught as a whole.

Morphometric analysis

At the time we were writing this report, the morphometric analysis of *L. gossei* was not yet finished so that only the analysis for *M. anaphyrmus* will be presented here.
Ideally, for each locality 15 specimens of each sex, all of similar size, should have been preserved. For some localities this could not be done. Hence, the results and analyses are based on a lower number of specimens. No female specimens were preserved from Nkhotakota. On all specimens 23 measurements and 17 counts were taken following Snoeks (1994). Two techniques were used to explore and analyse the metric data: Principal Component Analysis (PCA) on the log-transformed measurements and Mann-Whitney U-Tests on the relative measurements (percentages).
List of abbreviations used:
LacD : lachrymal depth ; SnL : snout length ; LJL : lower jaw length ; ChD : cheek depth ; EyeD : eye diameter ; IOW : interorbital width ; HW : head width ; HL : head length ; SL : standard length ; BD : body depth ; DFB : dorsal fin base ; AFB : anal fin base ; PrD : predorsal distance ; PrP : prepectoral distance ; PrV : preventral distance ; PrA : preanal distance ; CPL caudal peduncle length ; CPD caudal peduncle depth ; PhJL : pharyngeal jaw length ; PhJW : pharyngeal jaw width ; DeArL ; dentigerous area length (pharyngeal jaw) ; DeArW : dentigerous area width ; UJT : number of outer teeth in the upper oral jaw ; LJT : number of outer teeth in the lower oral jaw.

Genetic analysis

Microsatellites variability for the two species has been investigated using primers already defined by Rico *et al.* (1993,1996) and Zardoya *et al.* (1996). These primers have been already tested across a panel of very diverse fish species and successfully amplified in non-source species due to a high level of conservation of the flanking regions of these microsatellites. Eight different loci have been tried (Table P1). Numerous amplification conditions were used for each pair of primers with variations in the concentration of $MgCl_2$ and of the annealing temperature.

For locus GMO 2 we always observed two bands of respectively 250 and 290 bp in both species. Locus GMO 132 gave also two bands of 50 and 300 bp. At loci GMO 145 and CIER 51, we did not obtain any band. A 310 bp band was observed for *M. anaphyrmus* at locus CIER 62 and a 250 bp band for both species at locus TMO M25.

Only locus TMO M5 and TMO M 27 gave, for both species, bands varying in size from 300 to 400 bp for TMO M5 and from 230 to 250 bp for TMO M27.

PCR conditions were as follows: DNA was amplified (94°C 60 s, 48°C 60s, 72°C 60s) for 35 cycles in 20 µl volumes (1 x polymerase buffer, 1.5 mM $MgCl_2$, 0.4 mM of each dNTP, 75 ng of each primer, and 1 unit of Taq Promega).

The genetic population structure has been statistically described using Wright (1969) "F statistics" indices with Weir & Cokerham (1984) formulas. Fis measure the deficit of heterozygous due to non-random mating in a (sub)population while Fst measure the loss of heterozygosity due to the subdivision of the sample in two or more populations.

Isolation by distance was tested using Mantel's test (Mantel 1967). Mantel's test consists of a comparison of two matrices (here Fst versus geographical distances). This test determines if there is a correlation between the two matrices. The Mantel coefficient Z is calculated from the real data and then the data are permuted to obtain pseudo matrices and the corresponding pseudo Z' values. The various Z' values obtained are compared to the Z values. If Z is statistically different of all Z', then the two matrices are correlated.

All coefficient and statistical analysis have been done using GENETIX programme (Belkir et al. 1996)

Life history traits analysis

For both species, length-weight relationships, percentage of ripe females, and fecundity were compared between populations. As it needs to be estimated during the peak of the breeding season, which may vary at each site, size at maturity was not compared between populations. Determination of life history traits was done as described in Chapter 2.

Comparison of the percentage of ripe females between populations was carried out using a Kruskal-Wallis one way ANOVA on ranks (Sherrer 1984).

As for most of the fish species, length-weight relationship among populations of the two species were characterised by the following equation: $W = a.L^b$. Direct comparison of populations using the maximum likelihood method (Tomassone et al. 1993) was not possible because regression residuals increased with length. Length and weights were then logarithmically transformed (ln), which lead to a linear relationship between length and weight. Therefore, estimation of differences between populations was investigated by comparing regression lines between length and weight. The regressions were compared by an analysis of covariance (Scherrer 1984) followed by a 2×2 comparison method. First, slopes were compared, and populations whose slopes were not significantly different were then

compared for intercepts. As the type I error increases when more than two populations are compared pairwise (Scherrer 1984), a probability α' was calculated so that the overall α (α = 0.05 in our case) was maintained over the k(k-1)/2 comparisons. The new α' was calculated by the following formula: $\alpha' = 1-(1-\alpha)^{2/(k(k-1))}$.
Rather than comparing regressions between fecundity and body weight over a narrow weight range, we compared relative fecundity (fecundity per kg of body weight). Over the weight ranges studied, no correlation was found between relative fecundity and body weight, as it may happen in cichlids (Legendre 1992). Relative fecundity was compared using one way ANOVA followed by Tukey's all pairwise multiple comparison test (Scherrer 1984).

Table P1. Microsatellites loci and primers tested.

Locus	Primers	references
GMO 2	F ccctcagattcaaatgaagga	Rico *et al*., 1993
	R gtgtgagatgactgtgtcg	Rico *et al*., 1996
GMO 132	F ggaacccattggattcaggc	
	R cgaaaggacgagccaataac	
GMO 145	F gcattgtaggaacaacaattaac	
	R gtgcatgtgctcattatagc	
CIER 51	F gccaaaacactgacgaggtga	
	R tttgcgcaagcttcaggatga	
CIER 62	F ggtgctgtcacttttggccac	
	R aactctgctggtcgccactcc	
TMO M5	F gctcaatattctcagctgacgca	Zardoya *et al*., 1996
	R aga aca gcg ctg gct atg aaa agg t	
TMO M25	F ctgcagtggcacatcaagaatgagcagcggt	
	R caagaacctttcaagtcattttg	
TMO M27	F aggcaggcaattaccttgatgtt	
	R tactaactctgaaagaacctgtgat	

Results and Discussion

Morphometric analysis

Principal Component Analysis.

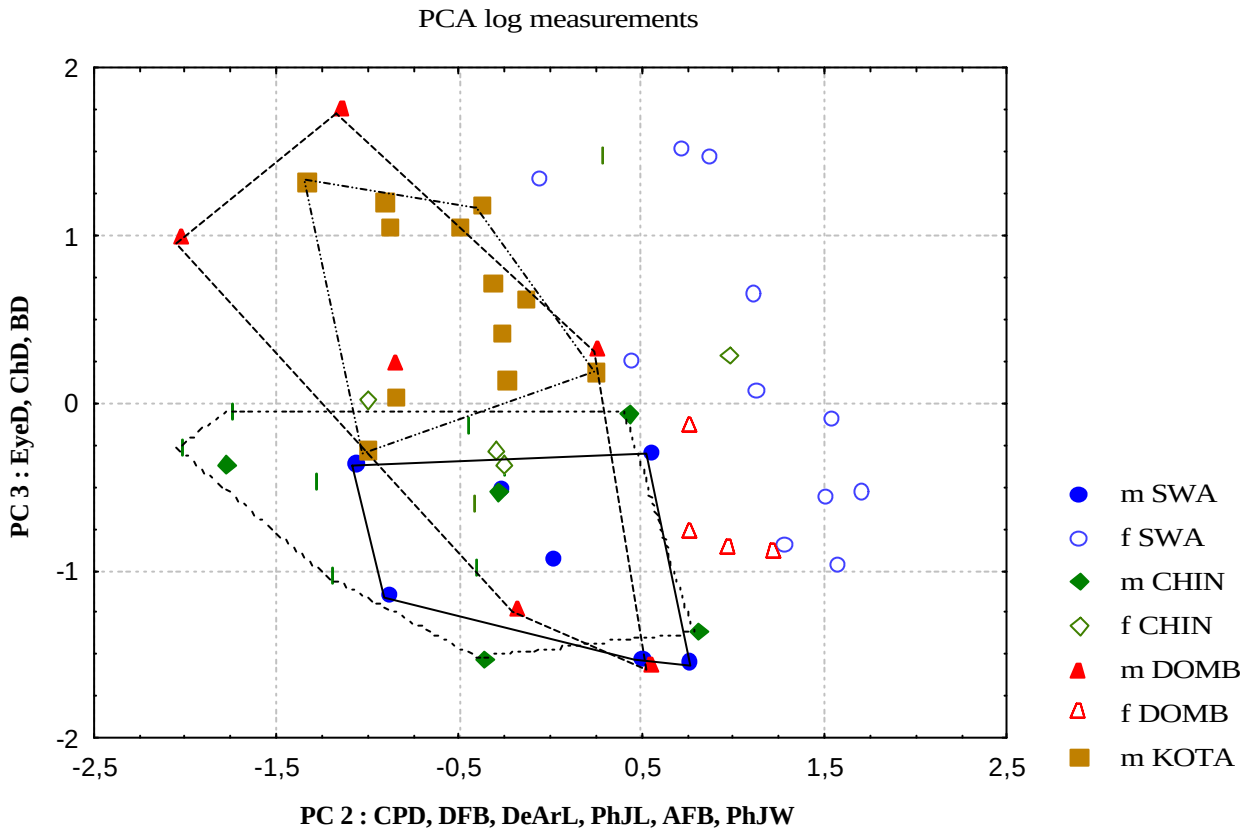


Figure P2. PCA of the log-transformed measurements, all specimens included (n=60).

A first PCA (Figure P2) on all specimens showed that morphological differences between males and females are generally larger than the differences observed between the populations. Male and female specimens are partly separated on PC2; female specimens are shifted towards the positive, male specimens towards the negative side of PC2. Polygons are drawn for the males only. All further analyses were therefore based on either males or females alone.

In this plot SWA and CHIN males are relatively well separated on PC3 from the KOTA males. The DOMB males overlap with all other populations on PC3. This result is surprising since the South West Arm and Chinteche are the most distant localities sampled and we would have expected differences to be most prominent between these two populations. The third component is mainly defined by eye diameter and cheek depth (both measurements are obviously strongly correlated). This surprising result is probably due to the fact that all specimens were included in this analysis. The larger morphological differences that are found between sexes are mixed and analysed together with the inter population morphological differences and may therefore 'blur' the latter ones. Therefore another PCA was done,

including only male specimens (Figure P3). The plot of the specimens on the second and third principal component shows a large overlap between almost all populations. Some distinction appears between the SWA and KOTA males on PC2. The SWA males are mainly on the positive part of PC2, the KOTA males are shifted towards the negative part of PC2.

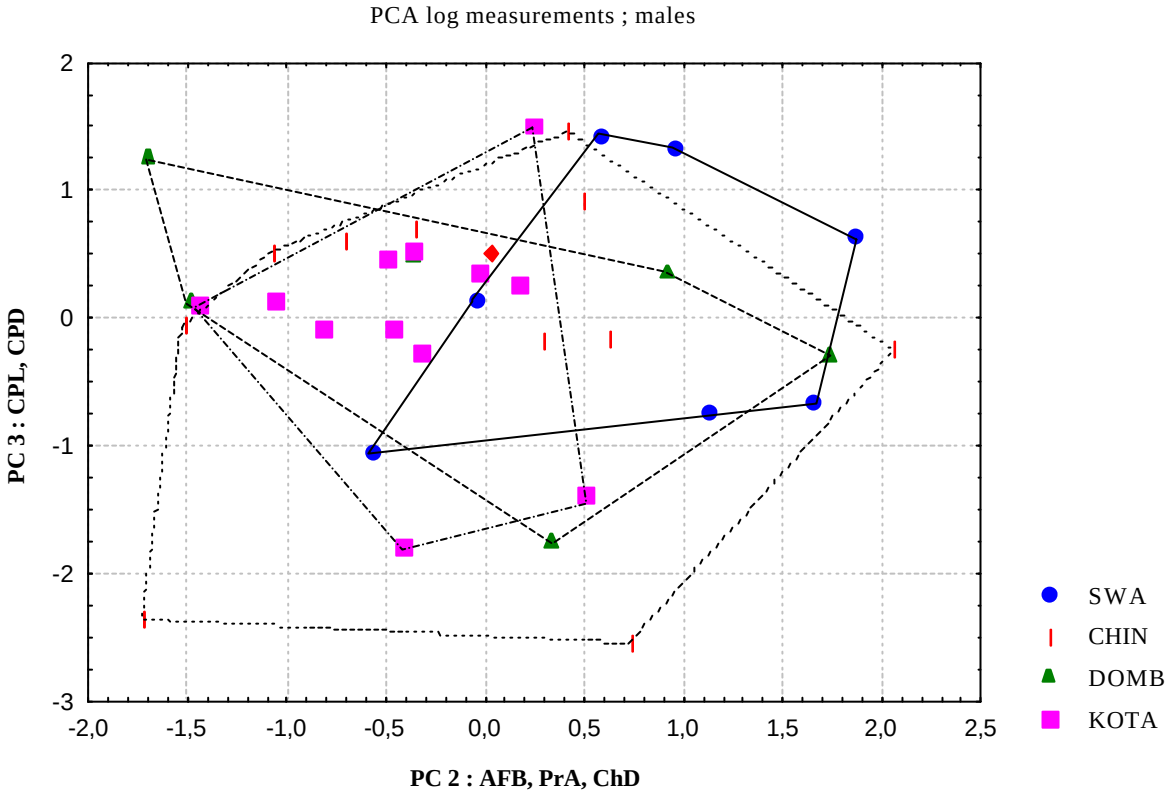


Figure P3. PCA of the log-transformed measurements, male specimens (n=37).

The factor loadings from this analysis indicated that the third component was almost entirely defined by a single character, the caudal peduncle length. After verification of the measurements, it appeared that one of the males collected in Chinteche was aberrant for this character. However, the measurement was checked and found to be correct. Consequently, the third principal component is unreliable to distinguish the populations (Figure P3).

We therefore added another plot using the second and fourth principal component (Figure P4). On PC4, the CHIN males are relatively well separated from the males of the other populations. One CHIN specimen was aberrant and scored high on PC4 (Figure P4: specimen marked with arrow). This was again the same aberrant male with the high CPL value.

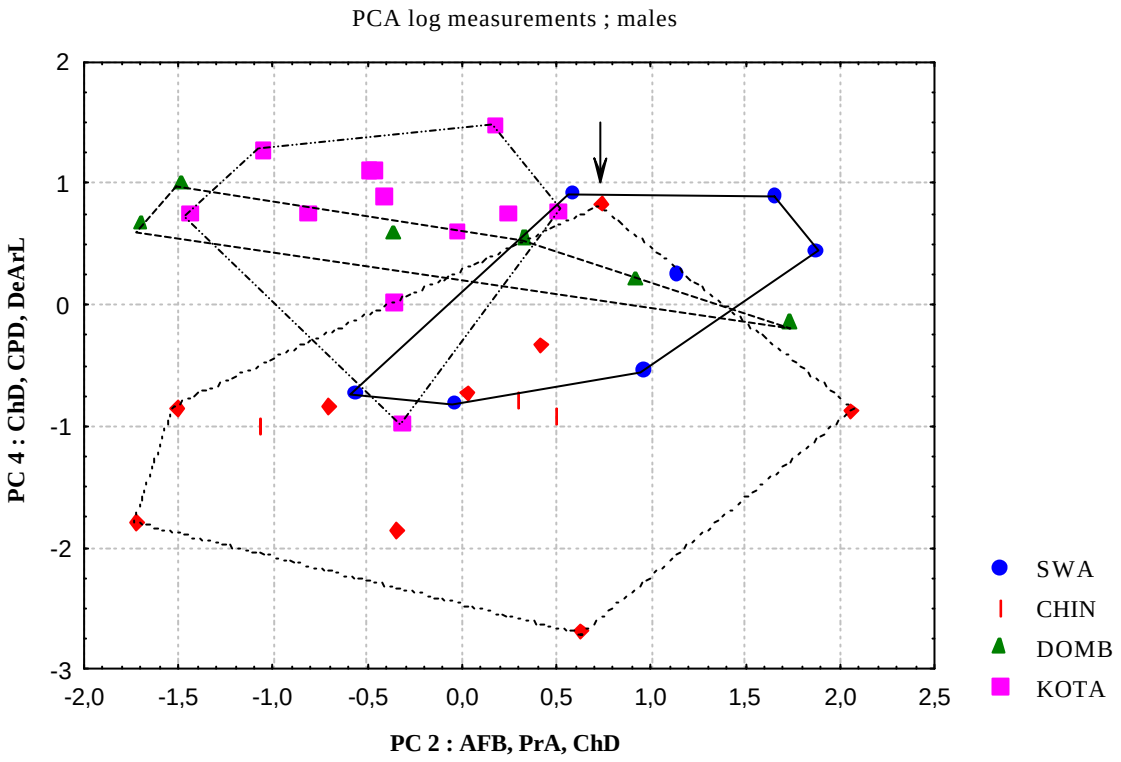


Figure P4. PCA of the log-transformed measurements, male specimens (n=37).

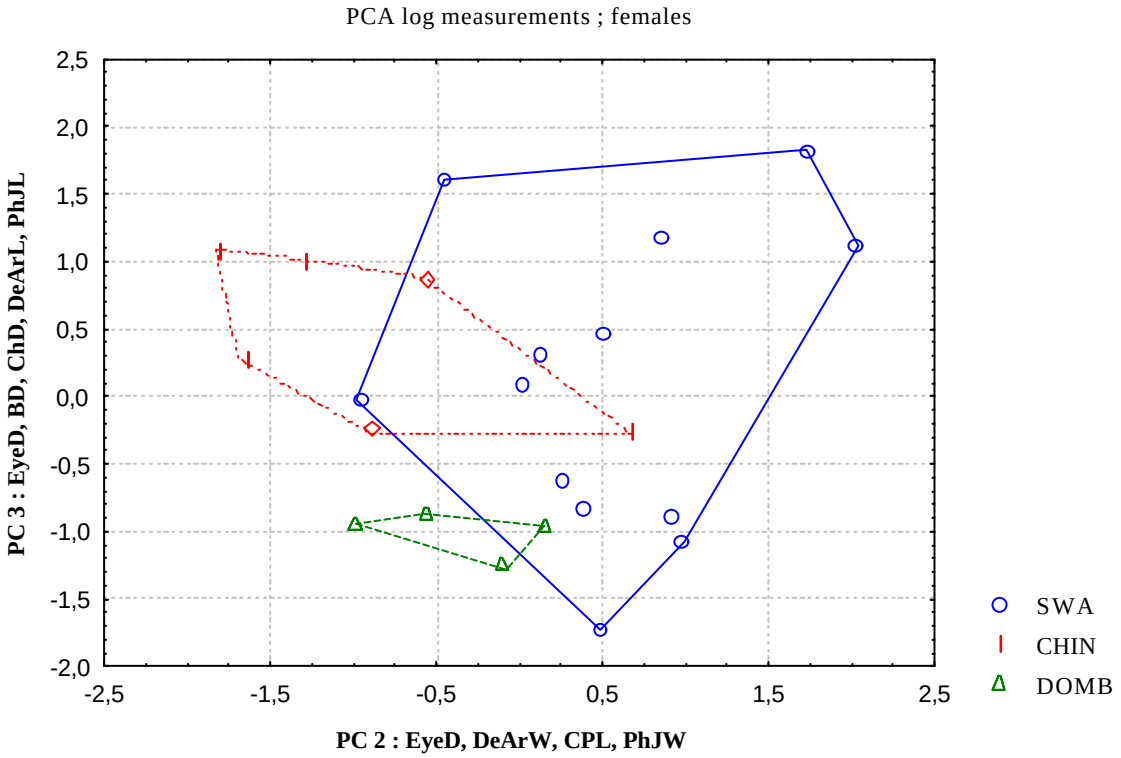


Figure P5. PCA of the log-transformed measurements, female specimens (n=23).

A PCA on the log-transformed measurements for the female specimens was done as well (Figure P5). Here we see that the SWA population is morphologically more diverse than

the other two (there are obviously more observations from the SWA which explains part of the higher variability) and overlaps with both other populations. On PC3 the CHIN females are neatly separated from the DOMB females. Factor loadings on PC3 indicate that they mainly differ in eye diameter and body depth.

Further PC analyses were made to compare all populations two-by-two. These analyses did not show clear or better results than the previous PC analyses. Large overlaps were observed for almost all PCA analyses when only two populations were included.

Mann-Whitney U-Test.

The Mann-Whitney U-test was used to analyse morphological differences between all populations. Data used for these analyses are the relative measurements (percentages).
We used only specimens of the same sex for these tests. To avoid allometric inferences, specimens were selected on the basis of their standard length for each test between two populations, so that the p-value for the standard length was close to 0.5 or larger. So, for each test a different subset of specimens was used, and in most cases not all specimens from a given locality were included in the analyses. A first test was done including male specimens from all populations.

Table P2 gives an overview of the results of the analysis between all four populations.

Table P2. Comparison of all four populations using the Mann-Whitney U-Test. Above diagonal the number of characters for which significant differences were found, p values as follows : * indicates p < 0,05; ** p < 0.005; *** p < 0.0005. Below diagonal p value for SL and number of specimens from each population used for the comparison. Characters for which significant differences were found are given and discussed in the text.

	SWA	DOMB	KOTA	CHIN
SWA		2 *	3 * 1 **	4 * 3 **
DOMB	p=0.52 for SL n SWA 19 n DOMB 10		1 * 1 **	3 * 1 **
KOTA	p=0.86 for SL n SWA 9 n KOTA 9	p=0.56 for SL n DOMB 8 n KOTA 9		1 ** 1 ***
CHIN	p=0.46 for SL n SWA 18 n CHIN 16	p=0.93 n DOMB 6 n CHIN 12	p=0.52 n KOTA 10 n CHIN 14	

The number of characters that differ between populations increases with increasing distance between the populations. In addition, the morphological differences found between populations become more significant with increasing distance.

The characters that were found to be significantly different between the four populations are:

SWA-DOMB.	* : EyeD/HL and DeArW/PhJW
SWA-KOTA.	* : HL/SL, PrD/SL and DeArW/PhJW
	** : PhJL/HL.
SWA-CHIN.	* : LacD/HL, SnL/HL, LJL/HL and CPD/SL
	** : HL/SL, PrD/SL and PhJL/HL
DOMB-KOTA.	* : EyeD/HL
	** : DeArW/PhJW
DOMB-CHIN.	* : LJL/HL, ChD/HL, IOW/HL and DeArW/PhJW
KOTA-CHIN.	** : LacD/HL
	*** : ChD/HL

The table and short overview show that all populations differ from each other for at least two characters. Some populations differ in a particular character from all or most other populations. For the dentigerous area width of the pharyngeal jaw the SWA population is significantly different from the DOMB and KOTA populations but not from the CHIN population. Moreover, for this character the DOMB population differs from all other populations. For the eye diameter a significant difference was observed between the DOMB population and the SWA and KOTA, but again not when compared to the CHIN population. The CHIN population is furthermore significantly different from the SWA and KOTA populations but not from the DOMB Population for the lachrymal depth. No consistent differences were found between the Nkhotakota population and the three other populations.

Differences between females from three populations were analysed as well. Unfortunately three out of four female specimens from the DOMB population were significantly larger than the females from the SWA and CHIN populations. So, no comparison between DOMB and the two other could be made. As a result, only the SWA and CHIN populations could be compared. Seven SWA and five CHIN female specimens were used in the analysis, the p value for SL was 0.68. We found only two significant differences ($p<0.05$ but >0.005) for the ChD/HL and DeArL/PhJL.

Meristics

For only three characters (the number of outer teeth in the oral jaws and the number of dorsal fin spines) significant differences were found between the populations.
Plots of the number of outer teeth in the upper and lower oral jaws are given. Specimens are categorised by locality and sex. Polygons are only given for male specimens (Figures P6 and P7).
Both graphs show that female specimens cannot be reliably distinguished on the basis of this character. The SWA females overlap with all other populations for the number of outer teeth both in upper and lower jaws. The only difference was noted for the outer teeth in the upper jaw, the female DOMB specimens have a higher number than the female CHIN specimens (52-58 vs 43-52).

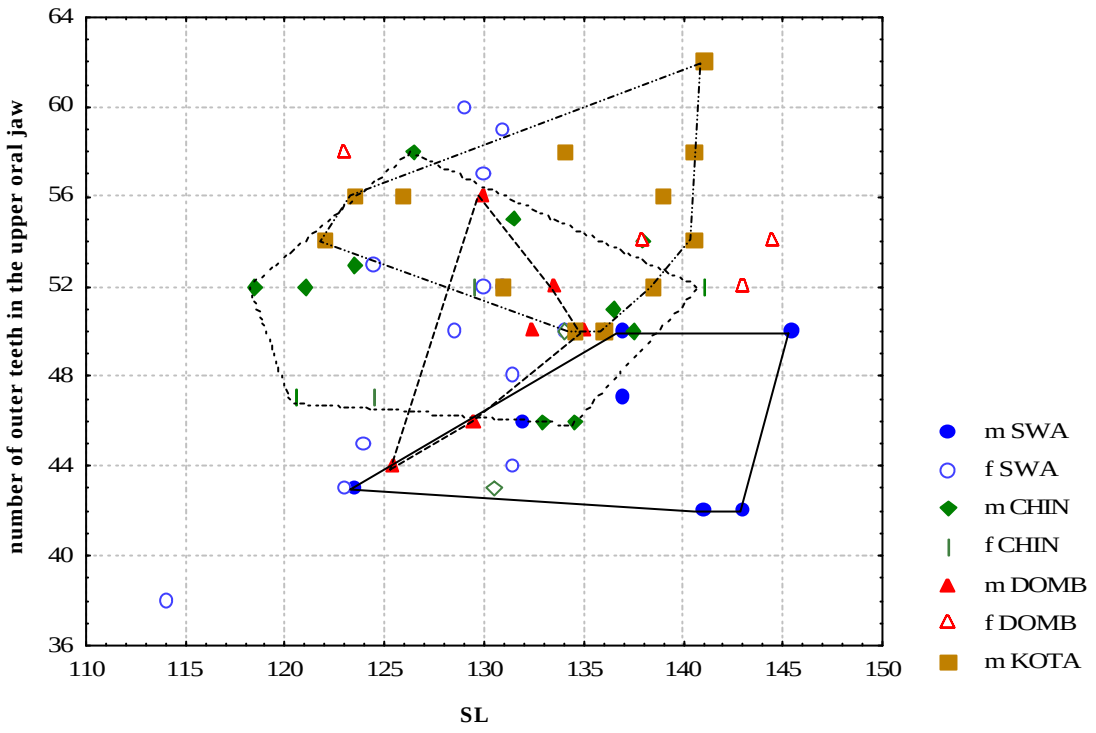


Figure P6. Plot of the number of outer teeth in the upper oral jaw vs SL, male specimens marked with polygons (n=60).

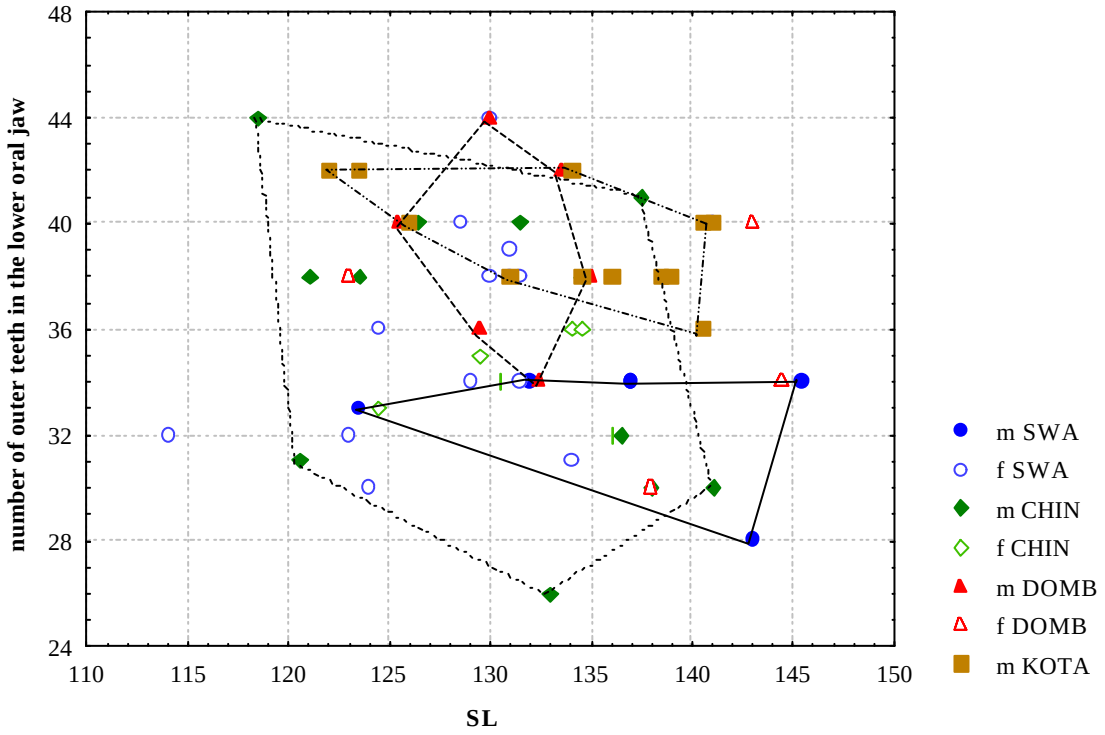


Figure P7. Plot of the number of outer teeth in the lower oral jaw vs SL, male specimens marked with polygons (n=60).

For the male specimens, the differences on teeth number are clearer. The SWA males are clearly different from the KOTA males, in having a lower number of outer teeth (42-50 vs 50-62 UJT and 28-40 vs 36-42 LJT respectively). For the outer teeth number in the upper oral jaw, the range of both other populations (DOMB and CHIN) is intermediate. For the outer teeth number in the lower jaw, the DOMB population has a relatively large range that overlaps completely with the KOTA population and is different from the SWA population. The CHIN males have the largest range and overlap with all other populations.

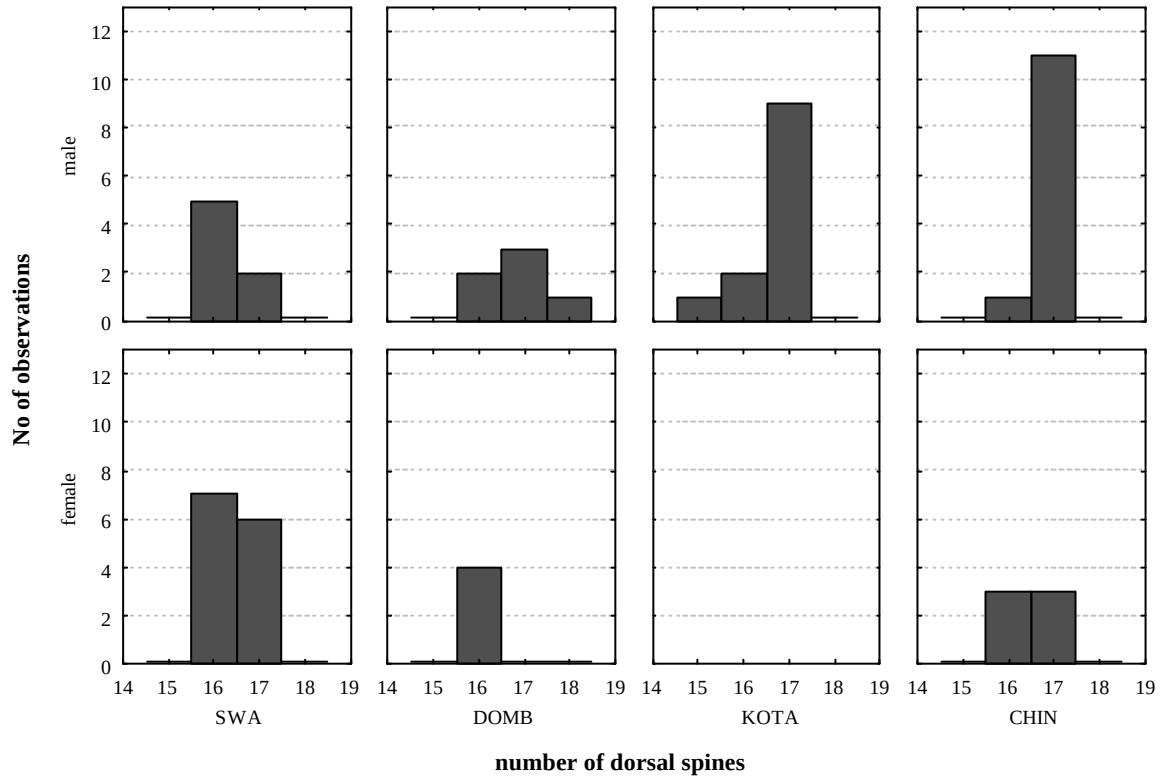


Figure P8. Histogram with the number of dorsal spines, categorised by sex and locality. (n=60).

The histogram of the number of dorsal fin spines (Figure P8) shows that in males there was a slight increase in spine number along the south-north axis. This pattern was not visible in females. In the SWA population, the modal number of dorsal spines is 16 for males (about 2/3 16, 1/3 17); for the DOMB males both numbers are about equal; for the KOTA and particularly the CHIN males the majority have 17 dorsal fin spines.

These results show the presence of small but significant morphological differences between all *M. anaphyrmus* populations examined. The amount of difference is clearly linked to geographical distance.

Table P3. Allelic frequencies observed in the four populations of *M. anaphyrmus*: South West Arm (SW), Domira Bay (DO), Nkhotakota (NK) and Chinteche (CH).

	SW	DO	NK	CH
Locus TMO M5				
(N)	21	15	14	4
295	0.00	0.00	0.00	0.25
313	0.05	0.00	0.00	0.00
315	0.00	0.13	0.00	0.00
317	0.02	0.10	0.00	0.00
321	0.05	0.00	0.04	0.00
323	0.43	0.20	0.00	0.00
327	0.00	0.03	0.00	0.50
329	0.12	0.03	0.04	0.25
331	0.00	0.13	0.14	0.00
333	0.00	0.03	0.21	0.00
335	0.17	0.07	0.29	0.00
337	0.02	0.17	0.21	0.00
339	0.00	0.00	0.07	0.00
353	0.02	0.00	0.00	0.00
361	0.05	0.00	0.00	0.00
363	0.00	0.07	0.00	0.00
365	0.02	0.00	0.00	0.00
367	0.02	0.00	0.00	0.00
369	0.02	0.03	0.00	0.00
H	0.79	0.90	0.83	0.71
H obs.	0.48	0.67	0.50	0.50
Locus TMO M27				
(N)	17	30	15	21
236	0.00	0.02	0.00	0.05
238	0.74	0.55	0.87	0.45
240	0.00	0.08	0.03	0.05
242	0.26	0.23	0.10	0.45
244	0.00	0.12	0.00	0.00
H	0.40	0.63	0.25	0.60
H obs.	0.29	0.60	0.13	0.67
H obs.	0.39	0.63	0.32	0.58
A	7.00	8.00	5.00	3.50

Genetic analysis

Allelic frequencies obtained are summarised in Table P3 and P4 for *Mylochromis anaphyrmus* and *Lethrinops gossei,* respectively.

Mylochromis anaphyrmus

Four populations were investigated: South West Arm (SWA), Domira Bay (DOMB), Nkhotakota (KOTA) and Chinteche (CHIN). 19 alleles were observed at locus TMO M5 and 5 at locus TMO M27. Fis and Fst values are summarised in Table P5 and Table P6, respectively.

Table P5. Fis Values in *M. anaphyrmus* populations for both TMO M5 and TMO M27 loci. Statistically significant values are underlined.

Locus	TMO M5	TMO M27
South West Arm	0.3976	0.2727
Domira Bay	0.2689	0.0526
Nkhotokota	0.4052	0.4667
Chinteche	0.323	-0.1133

At locus TMO M5, three out of four Fis values were statistically significant indicating that there was an excess of homozygous. Only the Chinteche sample did not exhibit such homozygous excess but it was likely due to the low sample size (4). No significant values have been observed for locus TMO M27.

Table P6. Fst Values in *M. anaphyrmus* populations for all loci combined, TMO M5 alone and TMO M27 alone. Statistically significant values are underlined.

All loci	DOMB	KOTA	CHIN
SWA	0.038	0.1057	0.1563
DOMB	_	0.0639	0.0968
KOTA		_	0.2018
Locus TMO M5	**DOMB**	**KOTA**	**CHIN**
SWA	0.047	0.1348	0.1984
DOMB	_	0.0453	0.1341
KOTA		_	0.1851
Locus TMO M27	**DOMB**	**KOTA**	**CHIN**
SWA	0.035	0.0257	0.0824
DOMB	_	0.0947	0.0378
KOTA		_	0.2304

Table P4. Allelic frequencies observed in the five populations of *L. gossei*: South West Arm (SW), Leopard Bay (LB), Kiramby Point (KP), Nkhotakota (NK) and Chinteche (CH).

	SW	LB	KP	NK	CH
Locus TMO M5					
(N)	17	19	2	11	3
237	0.00	0.00	0.00	0.05	0.00
293	0.00	0.00	0.00	0.14	0.00
299	0.00	0.00	0.00	0.18	0.00
317	0.00	0.03	0.00	0.00	0.00
319	0.00	0.03	0.00	0.00	0.00
321	0.00	0.00	0.00	0.23	0.00
323	0.00	0.00	0.50	0.00	0.00
325	0.00	0.05	0.00	0.00	0.50
327	0.09	0.05	0.25	0.05	0.00
329	0.03	0.00	0.00	0.00	0.00
331	0.06	0.18	0.25	0.00	0.00
333	0.03	0.00	0.00	0.00	0.00
335	0.12	0.16	0.00	0.00	0.17
337	0.09	0.00	0.00	0.00	0.00
339	0.03	0.13	0.00	0.00	0.33
341	0.09	0.03	0.00	0.00	0.00
343	0.03	0.05	0.00	0.00	0.00
345	0.06	0.08	0.00	0.00	0.00
347	0.03	0.00	0.00	0.00	0.00
349	0.00	0.03	0.00	0.00	0.00
351	0.00	0.03	0.00	0.00	0.00
353	0.00	0.05	0.00	0.00	0.00
355	0.12	0.00	0.00	0.23	0.00
357	0.06	0.03	0.00	0.00	0.00
359	0.00	0.03	0.00	0.00	0.00
361	0.00	0.00	0.00	0.14	0.00
365	0.03	0.03	0.00	0.00	0.00
369	0.12	0.00	0.00	0.00	0.00
373	0.00	0.03	0.00	0.00	0.00
379	0.03	0.00	0.00	0.00	0.00
H	0.94	0.92	0.83	0.86	0.73
Hobs.	0.88	0.63	0.50	0.64	0.33
Locus TMO M27					
(N)	27	29	24	27	6
219	0.04	0.00	0.00	0.00	0.00
225	0.02	0.00	0.00	0.00	0.00
229	0.00	0.00	0.04	0.00	0.00
232	0.00	0.02	0.00	0.00	0.00
236	0.00	0.00	0.08	0.04	0.00
238	0.78	0.86	0.56	0.81	0.83
240	0.02	0.05	0.00	0.00	0.00
242	0.15	0.07	0.29	0.15	0.17
244	0.00	0.00	0.02	0.00	0.00
Hn.b.	0.38	0.25	0.60	0.32	0.30
Hobs.	0.26	0.24	0.54	0.22	0.33
Hobs	0.57	0.44	0.52	0.43	0.33
A	10.5	10.5	4.0	5.0	2.5

When using the two loci, all the populations were differentiated with statistically significant Fst values. All the populations but one were differentiated with locus TMO M5 alone and all but two with locus TMO M27 alone.

Mantel test (using Fst and geographical distances matrices) obtained with locus TMO M5 indicated a positive correlation between Fst and the geographical distances between populations (no Z' value superior to Z) (Table P7).

Table P7. Mantel matrices for Fst values (upper matrices) using all loci, TMO M5 alone or TMO M27 alone, and for geographical distances between *M. anaphyrmus* populations (lower matrices)

All loci	SWA	DOMB	KOTA	CHIN
SWA		0.038	0.1057	0.1563
DOMB	60	_	0.0639	0.0968
KOTA	135	75	_	0.2018
CHIN	275	215	140	_
Z=226.81, 24 permutations, 5 values ≥ Z				

Locus TMO M5	SWA	DOMB	KOTA	CHIN
SWA		0.047	0.1348	0.1984
DOMB	60	_	0.0453	0.1341
KOTA	135	75	_	0.1851
CHIN	275	215	140	_
Z=267.44, 24 permutations, 0 values ≥ Z				

Locus TMO M27	SWA	DOMB	KOTA	CHIN
SWA		0.035	0.0257	0.0824
DOMB	60	_	0.0947	0.0378
KOTA	135	75	_	0.2304
CHIN	275	215	140	_
Z=151.43, 24 permutations, 16 values ≥ Z				

Lethrinops gossei

Five populations were investigated: South West Arm (SWA), Leopard Bay (LB) Kiramby Point (KP), Nkhotakota (KOTA) and Chinteche (CHIN). 30 alleles have been observed at locus TMO M5 and 9 at locus TMO M27.
Fis and Fst values are summarised in Table P8 and Table P9, respectively.

Table P8. Fis Values in *L. gossei* populations for both TMO M5 and TMO M27 loci. Statistically significant values are underlined.

Locus	TMO M5	TMO M27
South West Arm	0.0698	0.318
Leopard Bay	0.3229	0.0485
Kiramby Point	NA	0.120
Nkhotokota	0.2708	0.3067
Chinteche	NA	-0.1111

Significant Fis values were observed at Leopard Bay and Nkhotakota for locus TMO M5 and at South West Arm for locus TMO M27.

Table P9. Fst values in *L. gossei* populations for all loci, TMO M5 alone and TMO M27 alone. Statistically significant values are underlined.

All loci	LB	KP	KOTA	CHIN
SWA	0.0092	0.0485	0.0403	0.0595
LB	_	0.0514	0.0727	0.0175
KP		_	0.0886	0.07133
KOTA		_		0.1080
Locus TMO M5	LB	KP	KOTA	CHIN
SWA	0.0108	0.0462	0.0608	0.0999
LB	_	0.0061	0.0932	0.0294
KP			0.0983	0.0938
KOTA			_	0.1584
Locus TMO M27	LB	KP	KOTA	CHIN
SWA	0.0046	0.0540	-0.0178	-0.0600
LB	_	0.1404	0.0012	-0.0263
KP		_	0.0693	0.0321
KOTA			_	-0.0636

Fst values were statistically significant between KOTA and SWA, KOTA and LB and between SWA and CHIN, mainly due to locus TMO M5.

All Mantel tests did not indicate any correlation between Fst and geographical distances matrices for *L. gossei* populations (Table P10**)**.

Table P10. Mantel matrices for Fst values (upper matrices) using all loci, TMO M5 alone or TMO M27 alone, and for geographical distances between *L. gossei* populations (lower matrices).

All locus	SWA	LB	KP	KOTA	CHIN
SWA	_	0.009	0.049	0.040	0.060
LB	31	_	0.051	0.073	0.018
KP	63	32	_	0.089	0.071
KOTA	123	92	60	_	0108
CHIN	243	212	180	120	_
Z =131.82, 120 permutations, 75 values ≥ Z					

Locus TMO M5	SWA	LB	KP	KOTA	CHIN
SWA	_	0.011	0.046	0.061	0.100
LB	31	_	0.006	0.093	0.029
KP	63	32	_	0.098	0.094
KOTA	123	92	60	_	0.158
CHIN	243	212	180	120	_
Z =183.51, 120 permutations, 39 values ≥ Z					

Locus TMO M27	SWA	LB	KP	KOTA	CHIN
SWA	_	0.005	0.054	-0.018	-0.060
LB	31	_	0.140	0.001	-0.026
KP	63	32	_	0.069	0.032
KOTA	123	92	60	_	-0.064
CHIN	243	212	180	120	_
Z =-23.82, 120 permutations, 117 values ≥ Z					

Despite the high number of specimens analysed at each location for each species, some populations are represented by a very low number of specimens due to technical problems. Both loci are polymorph and it is evident that the polymorphism of low sampled populations is underestimated (for every locus and species, the number of alleles increases with the sample size). Nevertheless, these data can be analysed keeping in mind that the results only indicate tendencies and have to be confirmed with more specimens and even more loci.

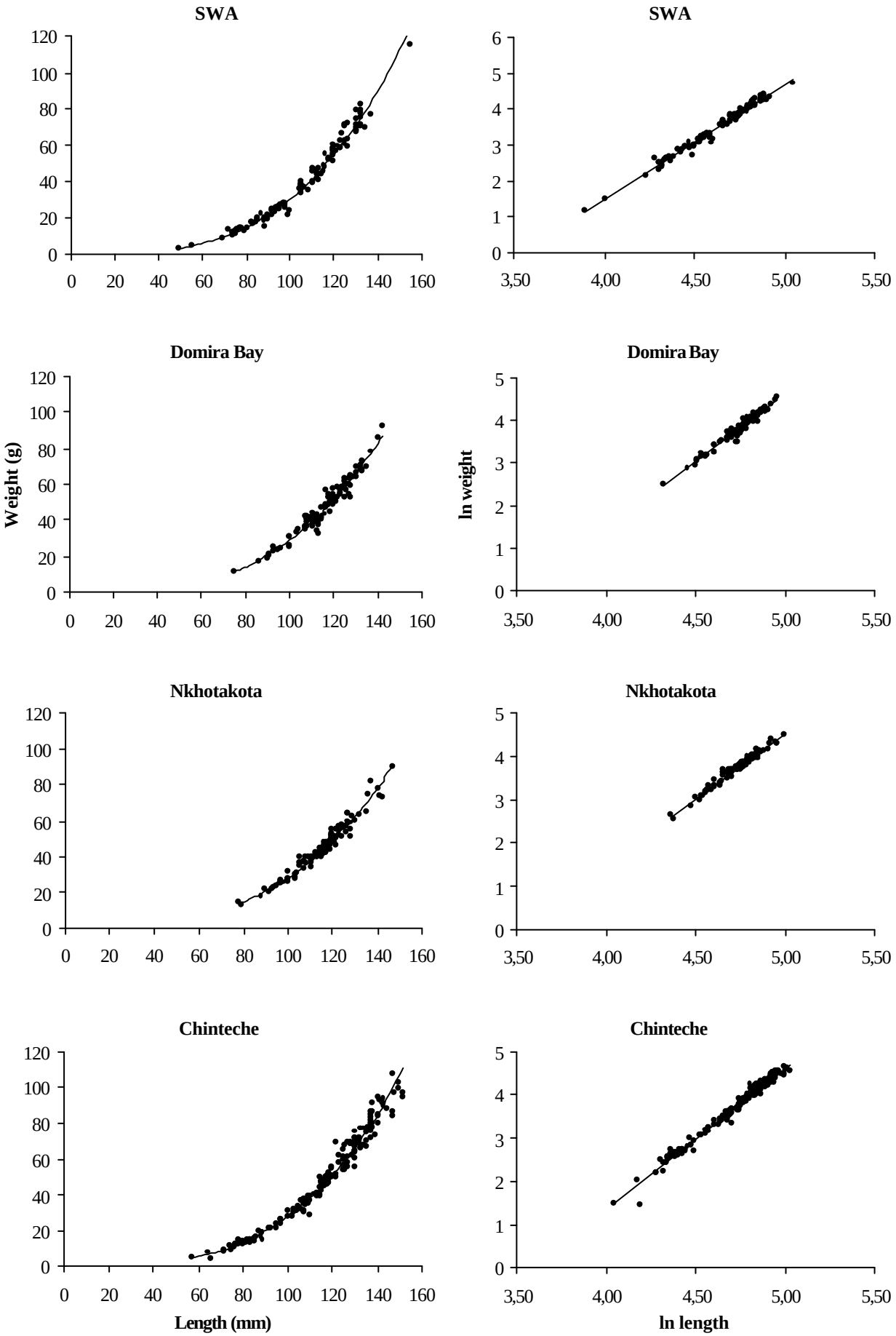


Figure P9. Length-weight relationships for *Mylochromis anaphyrmus* females at four locations in Lake Malawi.

In both species we found some significant Fis values. It is very likely that, to some extent, a non-random mating exists. Under the neutral model, heterozygous deficits are expected either when there is a mixture of different reproductive units inside a sample ("classical" Wahlund effect) or when there is family structuring or inbreeding within this sample. Typically when two or more populations are mixed in a sample, linkage desequilibrium (non randomly association between alleles of different loci) is observed as well as heterozygous deficits. Linkage desequilibrium can also be caused by random drift in small size population or by strong selection, two hypotheses that can be rejected here. For both species and loci, no linkage desequilibrium has been detected, hence local inbreeding might explain the observed results.
We also have to pay attention to possible null alleles, which can create artificial heterozygous deficits: in this case also, no linkage desequilibrium was observed.
Statistically significant Fst values were observed in both species for both loci and populations of *M. anaphyrmus* were more differentiated than those of *L. gossei.* It is then possible that the different populations of both species are genetically differentiated.
The results of the Mantel test indicated a correlation between Fst values and the geographical distances between all pairs of populations in *M. anaphyrmus*. This could correspond to an isolation by distance model, a model in which populations exchange few migrants, mainly with close populations.

Life history traits analysis

Mylochromis anaphyrmus:

At every sample site, fish were collected in February 99, which corresponded with the beginning of the breeding season in the SWA. The timing of breeding season for the species is unknown in Domira Bay, Nkhotakota and Chinteche. However, the percentages of ripe females were not significantly different among sites (One way ANOVA on ranks Kruskal-Wallis, H=2.916, 3 df, p=0.405): 6% in SWA, 4% in Domira Bay, 9% in Nkhotakota and 6% in Chinteche.

Length-weight relationships at each location are given in Table P11. Comparison of length-weight relationships after Log transformation (Figure P9) revealed significant differences among populations ($F_{3,535}$=6.145, p<0.0001). Multiple comparison procedure indicated that every population differed from the others, either by slope or intercept differences, except Domira Bay and Chinteche (Table P12).

Table P11. Comparison of *Mylochromis anaphyrmus* populations. Total number of fish (N), length (L)_weight (W) relationships, determination coefficient (R^2), number of fish used for fecundity calculation (n), mean relative fecundity (MRF) ± SEM.

Location	N	Relationships	R^2	n	MRF
SWA	126	$W = 0.00001 \times L^{3.2353}$ $\ln(W) = 3.2373 \times \ln(L) - 11.4997$	0.984	7	2391 ± 94
Domira Bay	107	$W = 0.00001 \times L^{3.1446}$ $\ln(W) = 3.1446 \times \ln(L) - 11.1180$	0.957	3	3469 ± 273
Nkhotakota	122	$W = 0.00003 \times L^{3.0204}$ $\ln(W) = 3.0204 \times \ln(L) - 10.5690$	0.971	11	2494 ± 121
Chinteche	185	$W = 0.000007 \times L^{3.2946}$ $\ln(W) = 3.2946 \times \ln(L) - 11.8430$	0.984	11	2281 ± 77

Table P12. Comparison of length-weight relationships (ln transformed) among populations of *Mylochromis anaphyrmus*. ns : non significant, *: significant slope differences ($p<0.05$), #: significant intercept differences ($p<0.05$).

	Domira Bay	Nkhotakota	Chinteche
SWA	#	*	#
Domira Bay		#	ns
Nkhotakota			*

Relative fecundity (Table P11) was also significantly different among populations ($F=9.88$, $p<0.001$), though only the Domira Bay population differed from all the others (Table P13). Despite the low number of observations for the Domira Bay population, all three fish were above 3000 eggs per kg, which only one female reached in all the other populations pooled.

Table P13. Comparison of relative fecundity among populations of *Mylochromis anaphyrmus*. ns : non significant, *: significant differences ($p<0.05$).

	Domira Bay	Nkhotakota	Chinteche
SWA	*	ns	ns
Domira Bay		*	*
Nkhotakota			ns

Lethrinops gossei:

As for *M. anaphyrmus*, fish from every location were collected in February 1999, which corresponded to the peak of breeding activity for this species in the SWA. The percentage of ripe females differed significantly among populations ($H=66.866$, 4 df, $p<0.001$): 24% in SWA, 0% in Leopard Bay, 12% at Kiramby Point, 10% in Nkhotakota and 31% in Chinteche. SWA population differed from all the other populations except Chinteche, and Leopard Bay differed from all the others as well (Table P14). The absence of significant differences between the Chinteche population and the others is caused by the low number of fish analysed for Chinteche (13).

Table P14. Comparison of percentages of ripe females among populations of *Lethrinops gossei*. ns : non significant, *: significant differences ($p<0.05$).

	Leopard Bay	Kiramby Point	Nkhotakota	Chinteche
SWA	*	*	*	ns
Leopard Bay		*	*	*
Kiramby Point			ns	ns
Nkhotakota				ns

Length-weight relationships at each location are given in Table P15.

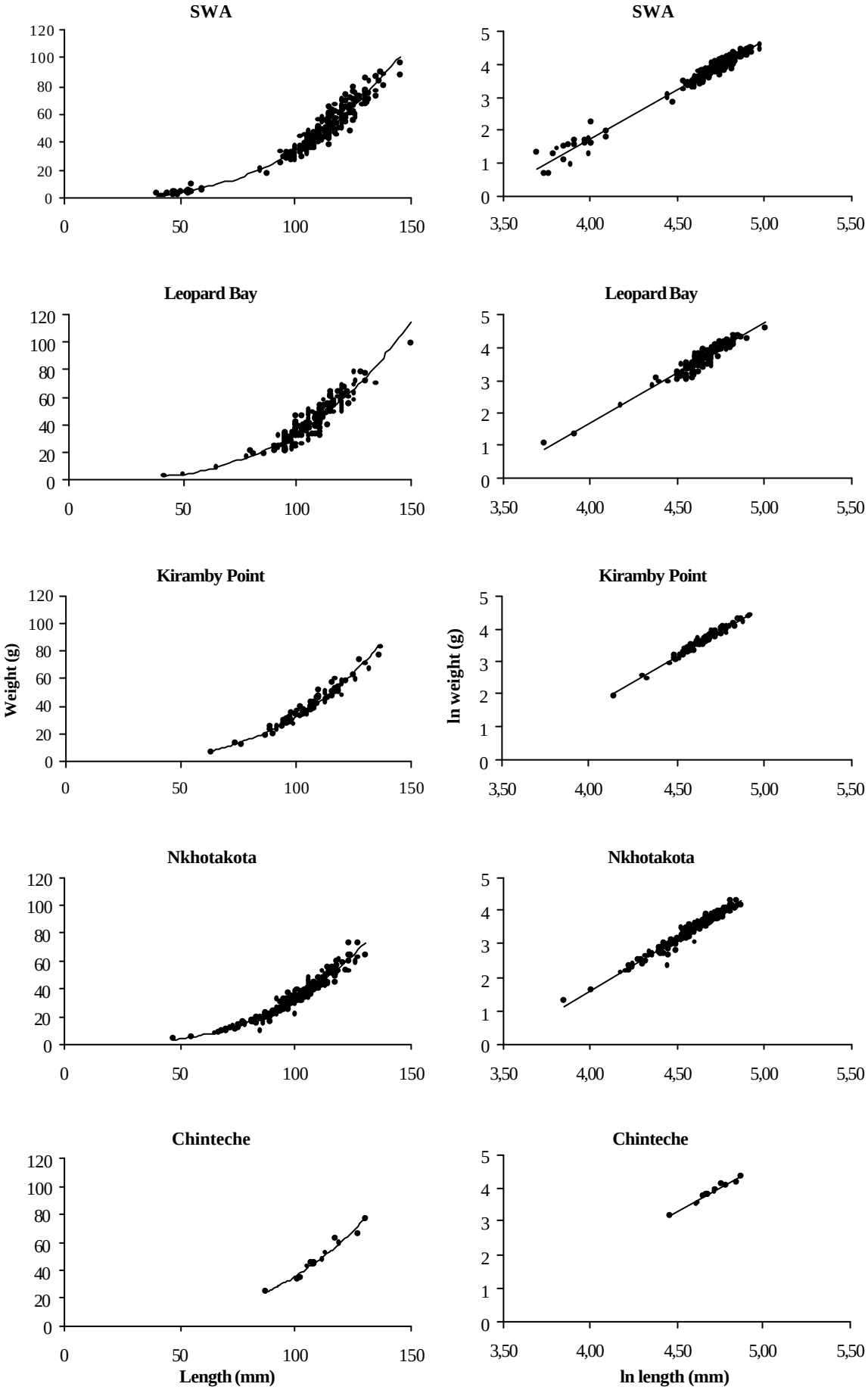


Figure P10. Length-weight relationships for *Lethrinops gossei* females at five locations in Lake Malawi.

Table P15. Comparison of *Lethrinops gossei* populations. Total number of fish (N), length (L)_weight (W) relationships, determination coefficient (R^2), number of fish used for fecundity calculation (n), mean relative fecundity (MRF) ± SEM.

Location	N	Relationships	R^2	n	MRF
SWA	287	$W = 0.00004 \times L^{2.9598}$ $\ln(W) = 2.9598 \times \ln(L) - 10.107$	0.971	67	1999 ± 46
Leopard Bay	192	$W = 0.00003 \times L^{3.0107}$ $\ln(W) = 3.0441 \times \ln(L) - 10.502$	0.866	0	
Kiramby Point	89	$W = 0.00002 \times L^{3.0749}$ $\ln(W) = 3.0749 \times \ln(L) - 10.687$	0.960	11	2204 ± 103
Nkhotakota	281	$W = 0.00002 \times L^{3.1267}$ $\ln(W) = 3.1267 \times \ln(L) - 10.933$	0.959	27	2054 ± 57
Chinteche	13	$W = 0.00005 \times L^{2.9097}$ $\ln(W) = 2.9097 \times \ln(L) - 9.8257$	0.967	4	1823 ± 85

Comparison of length-weight relationships after Log transformation (Figure P10) revealed significant differences among populations ($F_{4,857}$=2.505, p=0.041) even when Chinteche was removed from analysis ($F_{3,845}$=3.291, p=0.02). Multiple comparison procedure showed either slope or intercept differences between SWA and Kiramby Point, SWA and Nkhotakota, Leopard bay and Nkhotakota, Kiramby Point and Chinteche, Nkhotakota and Chinteche (Table P16).

Table P16. Comparison of length-weight relationships (ln transformed) among populations of *Lethrinops gossei*. ns : non significant, *: significant slope differences (p<0.05), #: significant intercept differences (p<0.05).

	Leopard Bay	Kiramby Point	Nkhotakota	Chinteche
SWA	ns	#	*	ns
Leopard Bay		ns	#	ns
Kiramby Point			ns	#
Nkhotakota				#

The number of eggs per kg body weight (relative fecundity Table P15) produced by females did not differ among populations for *L. gossei* (F=1.589, p=0.196).

Except for the percentage of ripe females, which differed significantly among *L. gossei* populations only, differences among populations were more intense (see significance levels of statistic tests) and more numerous for *M. anaphyrmus* than for *L. gossei.* Indeed, there was no fecundity difference among populations for *L. gossei*, and the significance level for length-weight relationships differences was just below 5% (p=0.041) while it was highly significant between *M. anaphyrmus* populations (p<0.0001). The intensity of ecological differences among populations seemed higher for *M. anaphyrmus* than for *L. gossei.* Unlike for morphometric and genetic analysis, differences of life history traits among populations were apparently not related to geographical distance.

Conclusions

Owing to technical problems in the genetic analysis resulting in a low sample number and time constraints preventing the analysis of morphometric data in time for *L. gossei*, the results of this study are not as complete and elaborated as we wished they would be, and further analysis are still needed. However, despite these hitches, the innovative combination of the genetic, morphometric and ecological approaches proved very complementary and informative. All three approaches resulted in matching results and strong tendencies can already be drawn.

For *M. anaphyrmus*, highly significant genetic, morphometric and ecological differences were found among the four populations analysed. Morphometric and genetic differences were linked to geographical distance between the populations.

For *L. gossei*, genetic and ecological differences were also observed among the populations studied, although these differences were less significant and abundant than for *M. anaphyrmus*. Also, the observed differences were not related to geographic isolation.

These results indicate that, from the South West Arm to Nkhata Bay, both *M. anaphyrmus* and *L. gossei* are not constituted of one large uniform stock but of several distinct populations separated by restricted gene flow, which should be considered as different stocks for fisheries management. They also suggest that, as expected, the degree of population differentiation was stronger (highest) for the shallow water species (*M. anaphyrmus*) than for the deep water one (*L. gossei*), which encounter much less physical barriers to its movements and therefore to the gene flows among individuals from distant geographic areas. This hypothesis is supported by the recent demonstration that no genetic difference were found among any of the populations of *Diplotaxodon limnothrissa* (Turner et al. 1999), which as a pelagic species (Allison et al. 1996, Thompson et al. 1996, Turner et al. 1999) does not encounter any barrier to its movements.

Chapter 6:

The potential influence of fluvial sediments on rock-dwelling fish communities

Chapter 6: The potential influence of fluvial sediments on rock-dwelling fish communities

F. Duponchelle, A.J. Ribbink, A. Msukwa, J. Mafuka & D. Mandere

Introduction

In Malawi, the increasing demographic pressure (Ferguson et al. 1993, Kalipeni 1996) has recently accelerated the unsustainable land use practices around the lakeshore and its catchments. As a result of deforestation, burning of vegetation, destruction of wet lands in the catchments for agricultural purposes and the cultivation of marginal areas such as steep slopes of hills (Mkanda 1999), massive quantities of sediment eroded from clear-cut watersheds are discharged in the rivers and eventually in the lake (Bootsma & Hecky 1993). The negative impact of excess sedimentation and water turbidity on the diversity and ecology of aquatic communities has been reported for other Great Lakes (Waters 1995, Evans et al. 1996) and Lake Tanganyika particularly (review by Patterson & Makin 1998). In Lake Tanganyika, species richness of crustacean ostracodes was found much lower at highly disturbed sites than at less disturbed sites, reductions ranging from 40 to 62%. The same pattern, though not statistically tested, was observed for fish, with reductions in species richness ranging from 35 to 65% at highly disturbed sites (Cohen et al. 1993a, Cohen et al. 1996). Lower fish diversity was also reported in areas that have become turbid as a result of recent eutrophication in Lake Victoria, where increased turbidity was recognised to be partly responsible for the decline in cichlid diversity (Seehausen et al. 1997). In Lake Malawi, the impact of sediment discharge is not yet permanent and remains associated to the rainy season. However, intensification of unsustainable land use practices increases the sediment loads and is cause of major concern (Bootsma & Hecky 1993). The limnology team of the SADC/GEF Project identified the steadily increasing sediment and nutrient loads arriving both from rivers and atmosphere as the main threat to the water quality and therefore to the stability of the lake ecosystem as a whole (Bootsma & Hecky 1999). As an example, within three days following a strong rain event in February 1998, the Linthipe River, located in the highly populated southern part of the lake, delivered about 700 000 tonnes of suspended sediment to Lake Malawi (McCullough 1999). Much of the suspended river load is made of sand and coarse silt which settled out quickly (McCullough 1999). Despite the rapid deposition of most of these sediments, from January to March-April, a sediment plume settles more or less permanently, depending on wind and currents, around the Maleri Islands in front of the river mouth. Among the potential effects of increased sediment loads on aquatic communities (listed in Patterson & Makin 1998), the reduction of light penetration affecting photosynthetic rates or sexual mate choice (Seehausen et al. 1997), the reduction of habitat complexity and destruction of spawning grounds are of direct importance for fish (Waters 1995, Evans *et al*. 1996, Lévêque 1997). As an example, over-fishing and siltation resulting from deforestation have strongly diminished the abundance of potadromous fish species in Lake Malawi (Tweddle 1992, Turner 1994b). For the littoral rocky shore, which food web is based on benthic algae growing on rocks (Worthington & Lowe-McConnell 1994), the blanketing of benthic algae by deposited sediments primarily affects the specialised aufwuchs eaters (Patterson & Makin 1998). Lake Malawi rock-dwelling *mbuna*, whose communities directly rely on the algal carpet covering the rocks (Fryer 1959, Ribbink et al. 1983, Marsh & Ribbink 1986, Reinthal 1990) and whose mobility and migration capacity are very restricted (Ribbink et al. 1983, McElroy & Kornfield

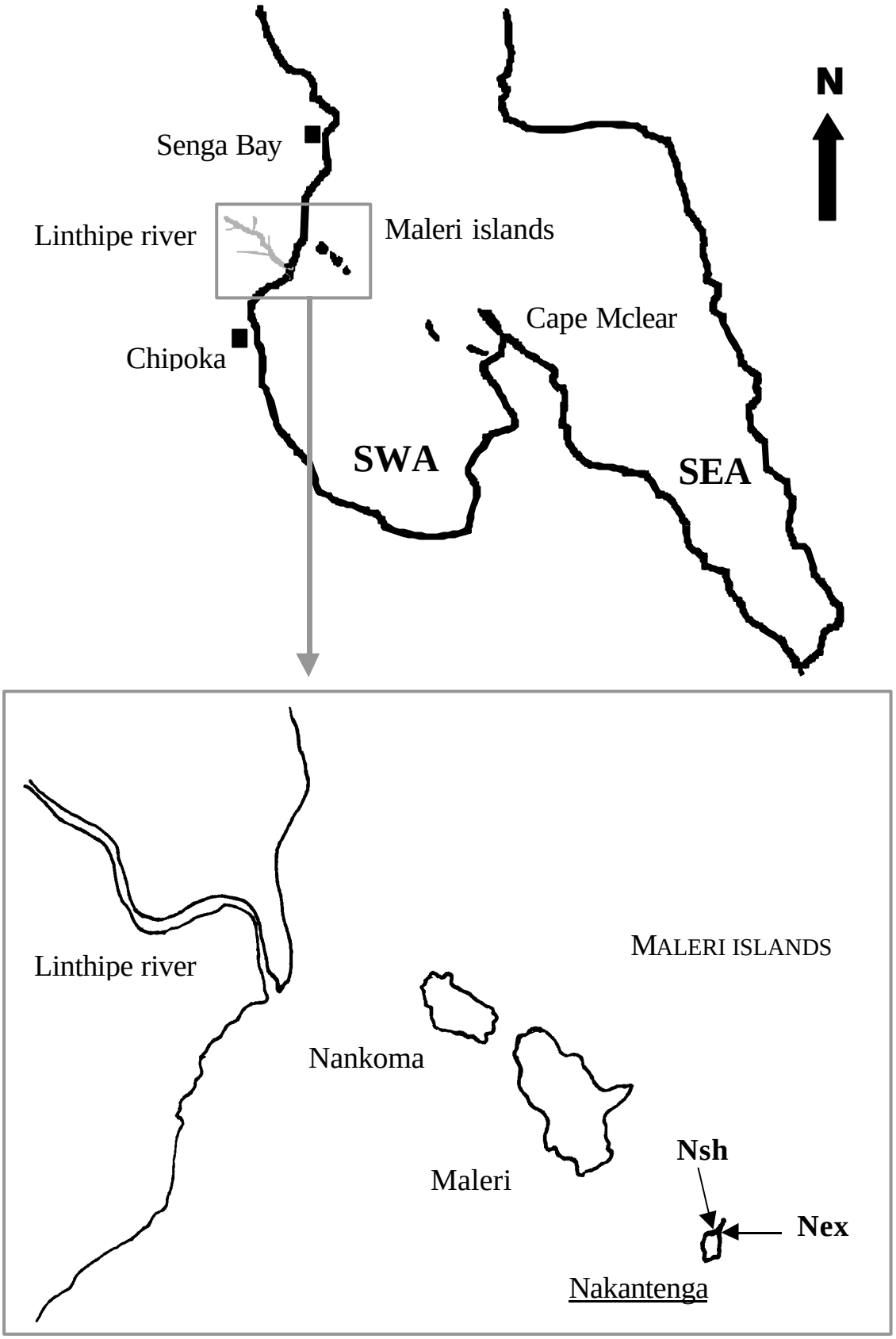


Figure S1. Southern Lake Malawi, with a detail of the Linthipe river delta and the Maleri islands. Arrows indicate the two sampling sites on Nakantenga island, Nsheltered (Nsh) and Nexposed (Nex). Detailed region redrawn from P. Cooley (1999).

1990, Van Oppen et al. 1997) should therefore be directly impacted by the increasing sediment discharges. Ribbink et al (1983) found a mantle of mud was deposited by plumes on the rocks of the Maleri Islands and postulated that it would affect the fishes access to benthic algae. Occasional observations of fish migrations from deep water to the shallows in the rocky shores of the Maleri Islands when the sediment plume was settled were reported (H. Bootsma, pers. com.). During the plume influence, the light penetration is greatly reduced and affects the benthic algal productivity on which most of the *mbuna* depend. Higgins et al. (1999) indicated how this would cause the fish to move upwards to the shallows to compensate for the shortage of food in the deeper waters. The present study, carried out in collaboration with the limnology team of the project, was designed to test for that hypothesis and to monitor the potential influence of suspended sediments on the diversity, abundance, condition and some life history traits of rock-dwelling fish communities.

Material and methods

The rainy season in the Lake Malawi/Nyasa basin usually starts in November and ends in March (Eccles 1974, Ribbink 1994). In order to assess the potential influence of suspended sediment on rock-dwelling fish communities, we decided to sample during undisturbed condition (i.e. before the rains), during the disturbed situation (i.e. the rainy season) and after a few months of recovered undisturbed situation (i.e. after the end of rains). Hence, from October 1998 to May 1999, 2 sites impacted by fluvial sediments and 2 control sites were sampled monthly.

The impacted sites were located on Nakantenga Island (Figure S1), off the Linthipe river mouth. The Linthipe is the largest river of the southern part of the lake and its catchment is one of the most densely populated around the lake (Mkanda 1999, Kingdon et al. 1999, Bootsma & Hecky 1999). The Linthipe catchment has been selected as a model for the study of land use, soil erosion and sedimentation in Lake Malawi watershed (Mkanda F.X. PhD thesis in prep., McCullough G., PhD thesis in prep.). Two sites were sampled on Nakantenga Island:

- a sheltered bay (Nsh) located on the northern shore of the island and protected from the south-easterly trade wind (*Mwera*), mainly blowing from June to September, by a natural rock barrier,
- an exposed bay (Nex) located on the other side of the rock barrier, hence submitted to the trade wind.

The control sites were located in a sediment free area, in Thumbi West Island at Cape Maclear (Figure S2). T13 is a little protected bay on the north side of the island, whereas T8 is a non protected rocky area on the northeast side of the island.

Fish species were named according to Ribbink et al. (1983). Every month from October 98 to April 99, the following sampling was carried out at each site:

- Fish diversity and abundance were estimated using underwater visual censuses at 10 m, 6 m and 2 m depth, following the protocol described in Ribbink et al. (1983). Transects were demarcated by two 6 mm diameter nylon cords, 25 m in length, held 2 m apart by a galvanised pipe at each end so that an area of 50 m² was sampled. At each site and depth, the 4 corners of the 50 m² areas were permanently marked to ensure that the censuses were done exactly at the same place every month. Fishes within the demarcated areas were counted after waiting at least 3 min for them to recover from any diver disturbance. For most species, sexually active males, in breeding dress and apparently defending territories, were counted. For each species, the number of individuals was the mean number of two consecutive censuses along the transect.

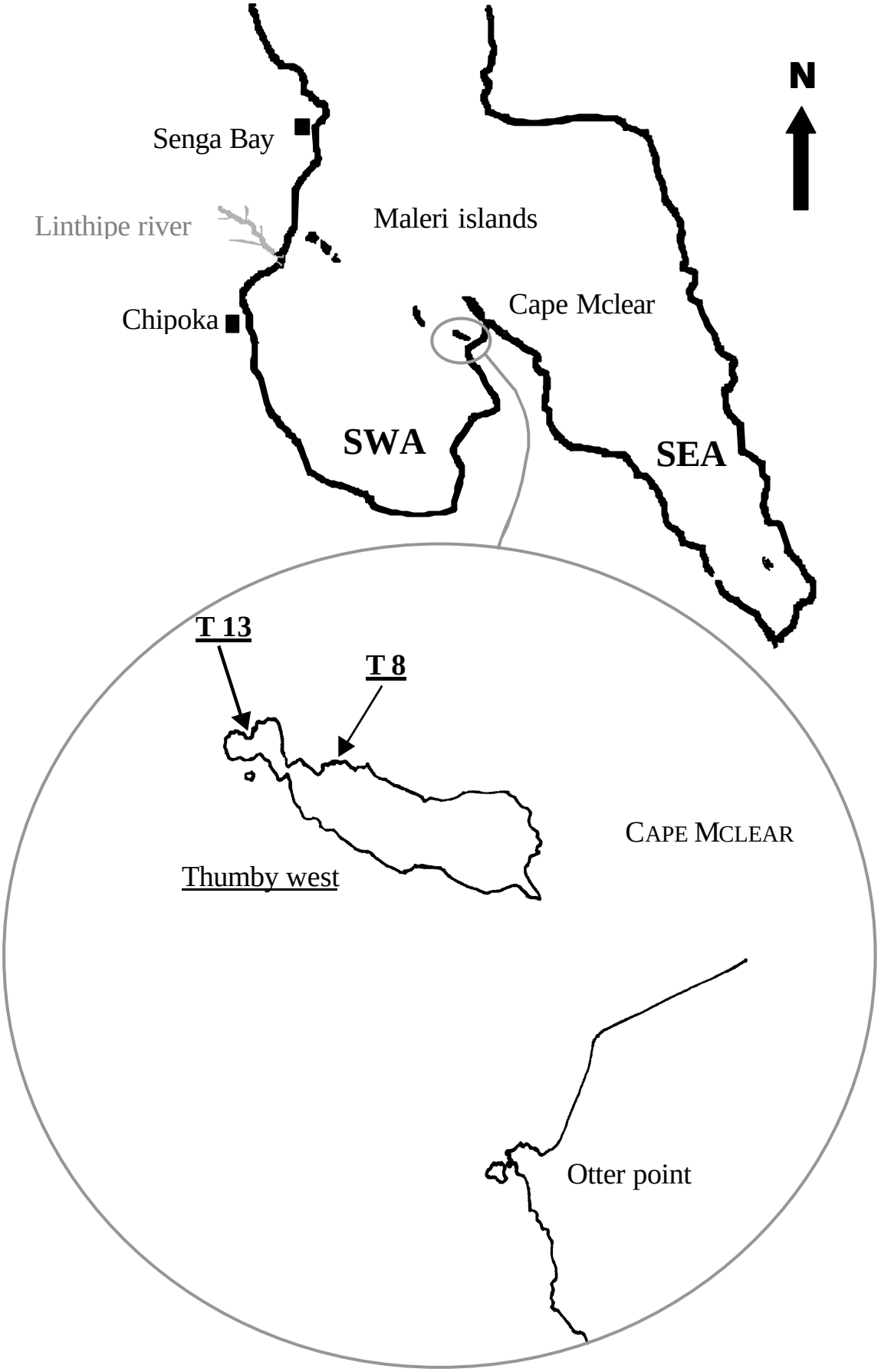


Figure S2. Southern Lake Malawi, with a detail of Cape Mclear showing the sampling sites on Thumby west island, T13 and T8. Detailed region redrawn from P. Cooley (1999).

Owing to the very bad visibility conditions at both sites in Nakantenga island in February and March 1999 (Secchi disk measurements < 2 m), visual censuses were not possible. Owing to technical problems, none of the sites was sampled in November 1998, and Thumbi sites were not sampled in October.

- At each site and depth, a 30 m length × 1.5 m height monofilament nylon gill net, constituted of three 10 m panels of 0.5, 1 and 1.5 inch mesh size, was set for two hours. Gill nets were carefully set apart from the areas used for visual censuses. The depth at the beginning and the end of setting was checked with a manual depth sounder (Echotest, Plastimo) and verified with scuba shortly after. After two hours, the fish were removed from the net, sorted to species, labelled and placed in 10% formalin for later examination. Gill nets were found to fluctuate too much in their catches to be used for diversity and abundance estimations. Indeed, parts of the net were sometimes torn by rocks either during setting or hauling, which modified the catch per unit effort (CPUE). Some fish species tended to follow the diver during the checking of the net depth, entangling themselves more than without the diver's disturbance, which also modified the CPUE. Therefore, gill nets were not used to estimate fish diversity and abundance. They were used only to assess the potential modification of life history traits during the plume, such as variations in the % of ripe females, in the condition factor, the fecundity and the egg size.

Both visual censuses and gill net samplings were always done in the morning between 8.00 and 12.00 to avoid potential diel fluctuations in fish distribution and abundance.

- Concurrently, benthic algae samples were collected by scraping at the same depths on top of flat horizontal rocks, to monitor the benthic algae biomass. Algae samples were processed by the limnology team of the project. The scrapings were collected using a thick-walled acrylic tube with an inside diameter of 4.5 cm². The base of the tube was fitted with a neoprene skirt to ensure a good seal with the rock. A plunger fitted with a stiff wire brush within the tube was used to scrape the algae off of the rock. After scraping, the sample was drawn into a syringe that was attached near the base of the scraping tube via a small tube. After collection, the sample was poured into a bottle and diluted to 250 ml. After thoroughly mixing, a subsample of this was filtered on a Whatman glass fibre GF/F filter (nominal pore size = 0.7 µm). The filter was placed in a mixture of methanol and acetone for at least 24 hours to extract algal pigments, after which chlorophyll *a* was measured on a Turner fluorometer. Based on the volume of extract, the filtration volume, and the area of rock that was scraped, the final measured volumetric chlorophyll *a* concentration was converted to an areal measurement of µg/cm². Samples were usually collected in triplicate.
- Secchi disk measurements were also carried out to monitor the water transparency.

All fish preserved in formalin were measured (SL) to the nearest 1 mm and weighed to the nearest 0.1 g. Their maturity stage was determined and the gonads in stage 4 were weighed for Gonado-Somatic Index (GSI) calculation (gonad weight/total body weight × 100) then preserved in 5% formalin for fecundity and mean oocyte weight calculation.

The maturity stage of female gonads was macroscopically determined using the slightly modified scale of Legendre & Ecoutin (1989) (Duponchelle 1997).

Stage 1: immature. The gonad looks like two short transparent cylinders. No oocytes are visible to the naked eyes. As a comparison, immature testicle is much longer and thinner, like two long tinny silver filaments.

Stage 2: beginning maturation. The ovaries are slightly larger and little whitish oocytes and apparent.

Stage 3: maturing. The ovaries continue to grow in length and thickness and are full of yellowish oocytes in early vitellogenesis.

Stage 4: final maturation. The ovaries occupy a large part of the abdominal cavity and are full of large uniform sized oocytes in late vitellogenesis.

Stage 5: ripe. Ovulation occurred, oocytes can be expelled by a gentle pressure on the abdomen. This stage is ephemera.
Stage 6: spent. The ovaries look like large bloody empty bags with remaining large sized atretic follicles. Small whitish oocytes are visible.
Stage 6-2: resting. The general aspect of the gonad recall a stage 2, but the ovarian wall is thicker, the gonad is larger, often reddish with an aspect of empty bag. This stage is distinctive of resting females, which have spawned during the past breeding season.
Stage 6-3: recovering post-spawning females. The general aspect of the gonad is like a stage 3 but with empty rooms, remaining large-sized atretic follicles and the blood vessels are still well apparent. This stage is characteristic of post-spawning females initiating another cycle of vitellogenesis.
Males were only recorded as being either in "breeding colour" or not.

The average size at first maturation (L_{50}) is defined as the standard length at which 50% of the females are at an advanced stage of the first sexual cycle during the breeding season. In practice, this is the size at which 50% of the females have reached the stage 3 of the maturity scale (Legendre & Ecoutin 1996, Duponchelle & Panfili 1998). For the estimation of L_{50}, only the fish sampled during the height of the breeding season were considered.

Fecundity is defined here as the number of oocytes to be released at the next spawn, and correspond to the absolute fecundity. It is estimated, from gonads in the final maturation stage (stage 4), by the number of oocytes belonging to the largest diameter modal group. This oocyte group is clearly separated from the rest of the oocytes to the naked eye and corresponds approximately to oocytes that are going to be released (Duponchelle 1997, Duponchelle *et al*. 2000).

Oocyte weight measurements were all carried out on samples preserved in 5% formalin. The average oocyte weight per female, was determined by weighing 50 oocytes (Peters 1963) belonging to those considered for fecundity estimates.

In order to compare mean oocyte weight and diameter among the different species, the measurements need to be made on oocytes in a similar vitellogenic stage, then on oocytes whose growth is completed. A simplified version of the method applied by Duponchelle (1997) was used to determine the GSI threshold above which the oocyte weight do no longer increase significantly. For each species, the individual oocyte weights were plotted against the GSI. The GSI corresponded to the beginning of the asymptotic part of the curve was visually determined and the fish whose GSI was inferior to the defined GSI were removed. The final GSI threshold was reached when no correlation subsisted between the mean oocyte weight and the GSI.

The Fulton's condition factor was calculated as $CF = 100\,000 \times W/L^3$, where W is the wet weight and L the standard length (Anderson & Gutreuter 1983). Given the well known trend of CF to increase with the length of fish (Anderson & Gutreuter 1983), the absence of relationship between length and CF over the size range sampled was checked for every species using Pearson correlation.

Statistics

Comparisons of among months diversity and abundance of fish species were performed with one way repeated measures ANOVA using SigmaStat software (Jandel Scientific).

The temporal variation of the condition factor for every species was assessed using univariate general linear model with month, site and sex as factors and CF as the dependant

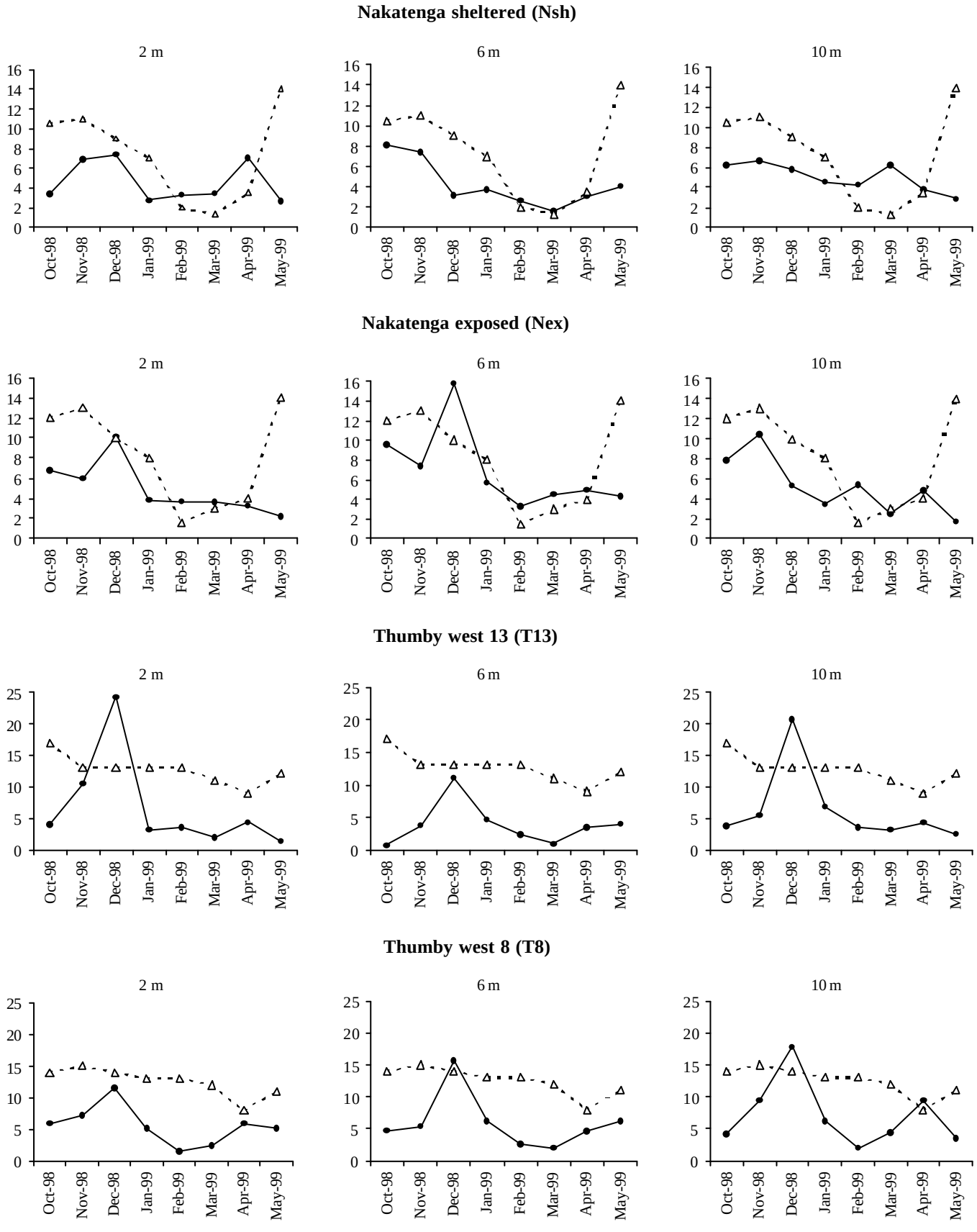


Figure S4. Monthly progression of benthic chlorophyll a biomass (µg/cm²) (black dots) and of light penetration estimated by Secchi disk measurements (m) (white triangles) at 2 m, 6 m and 10 m depth at each sampled site, from October 1998 to May 1999. Note the different y axis scale between Nakantenga and Thumby sites. Algae sampling was done on top of flat horizontal rocks using a scrapper. Values are averages of three replicates.

variable, using SPSS software. Given the low sample number at some sites for some species, the significance level for interaction between factors was fixed at 1%.

Results

Although rainfall patterns might be slightly different in Cape Maclear and Maleri Islands than in Senga bay, rains effectively started at the end of November 1998 (the 23rd) and stopped the 11th of April 1999 at Senga Bay station (Figure S3). Despite an effective start of the rainy season in late November, the Linthipe river discharge really began in January to reach a peak in March (Figure S3). As the sediment plume is linked to the river discharge rather than to the rains directly, therefore the period under consideration when referring herein to the rainy season is "January to May".

In February and March 1999, visibility was so poor in Nakantenga sites that visual censuses were impossible to carry out. However, while one of the two divers was scraping for benthic algae samples, the other diver was doing fish observations. Although this required to be less than 50 cm away from the fish and that it was often impossible to identify the species, behavioural observations were still possible. Fish were virtually immobile with fins held erect a they do at night. They stayed in or very close to the entrance to their hideaways among the rocks, or rested on the rocks. There was virtually no feeding, territorial or courtship behaviour.

Chlorophyll a biomass

Mean monthly benthic chlorophyll a biomass for each depth and site are presented in Figure S4. A similar temporal trend was evident at almost all sites and depths, suggesting that these data, though collected only once per month, represented real monthly trends. A chlorophyll peak was observed in December 1998 at every depth in Thumbi West sites, possibly due to an increased nutrient availability resulting from land runoff (H. Bootsma, pers. com.). Another smaller peak was observed in April-May, but apart from these peaks, chlorophyll concentration was rather similar between the dry and rainy seasons. At Nakantenga sites, there was also a slight increase in chlorophyll in December, though not apparent at all depths, but it was followed by chlorophyll concentrations that were lower than before the rainy season. This suggests a greater impact of siltation and reduced light penetration at Nakantenga. However, changes in chlorophyll concentration at the impacted sites (Nsh and Nex) were less important than expected. Indeed, from January-February to May 1999, the thickness of sediment (up to 2 cm sometimes) covering the rocks observed while diving at all depths (and especially at 6 and 10 m) should have almost completely prevent photosynthesis, even when the plume was temporary out of the island. Furthermore light penetration was severely diminished when the plume was settled, with Secchi disk measurements inferior to 4 m from February to April (Figure S4). Concern that benthic chlorophyll a concentration did not change as much as expected between the dry and the rainy season at Nakantenga matched observations on previous years at the nearby Maleri Island by the project's limnology team. The explanation probably lies in the phytoplankton production in the first few metres that had settled and mixed with the sediment (H. Bootsma, pers. com.). The question is whether this type of algae is still useful to the fish as a food source?

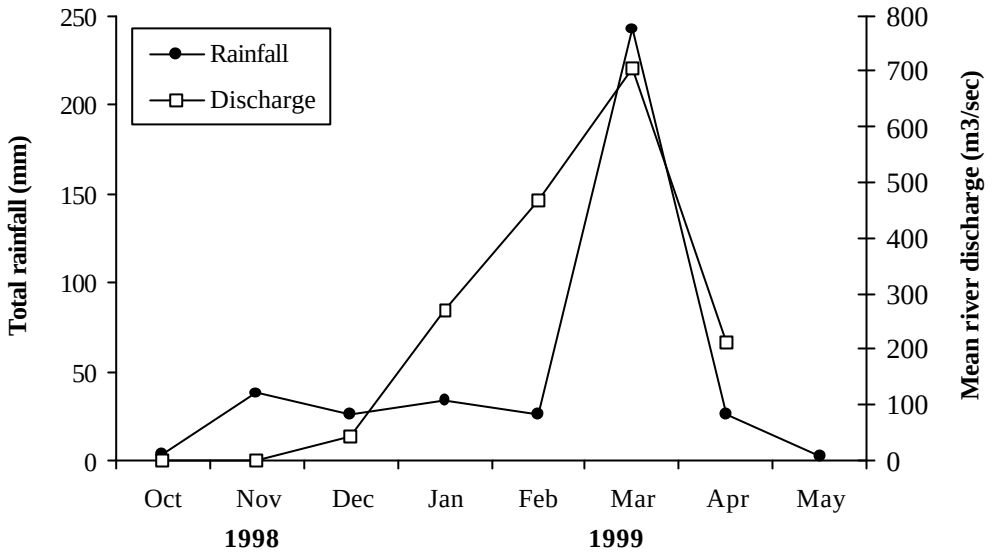


Figure S3. Total rainfall at Senga Bay station and mean Linthipe river discharge from October 1998 to April 1999.

Table S1b. Visual censuses at 2 m, 6 m and 10 m depth at Nakantenga exposed (Nex) site.

Month	**Oct-98**			**Dec-98**			**Jan-99**			**Apr-99**			**May-99**		
Species name **Depth (m)**	**2**	**6**	**10**	**2**	**6**	**10**	**2**	**6**	**10**	**2**	**6**	**10**	**2**	**6**	**10**
Pseudotropheus zebra red dorsal	2	6	68	0	11	77	2	10	39	2	8	38	3	9	11
Pseudotropheus zebra yellow throat	15	8	0	13	6	0	19	6	0	18	4	0	17	7	0
Pseudotropheus zebra black dorsal	0	2	3	0	0	1	0	0	3	0	2	3	0	3	3
Pseudotropheus barlowi	0	9	3	0	11	1	0	4	1	0	9	1	0	6	3
Pseudotropheus tropheops lilac maleri	4	2	0	4	1	0	4	1	0	8	1	0	5	1	0
Pseudotropheus tropheops maleri blue	4	0	0	2	0	0	1	0	0	1	0	0	2	0	0
Pseudotropheus tropheops orange chest	10	1	2	6	2	1	7	1	0	1	1	0	6	0	0
Pseudotropheus williamsi	2	0	0	1	0	0	1	0	0	1	0	0	2	0	0
Pseudotropheus elongatus brown	0	0	0	0	0	7	0	1	7	0	1	2	0	0	1
Pseudotropheus aggressive yellow head	11	19	0	24	44	0	0	50	1	35	44	5	60	35	6
Pseudotropheus aggressive blue	4	0	0	6	0	0	10	0	0	8	0	0	9	0	0
Pseudotropheus aggressive zebra	15	0	0	6	1	0	30	4	0	4	1	0	5	0	0
Pseudotropheus burrower	0	21	7	0	11	10	1	12	12	4	10	0	0	15	10
Melanochromis auratus	2	3	2	3	2	1	2	8	8	8	2	1	5	2	0
Melanochromis vermivorous	0	0	0	0	4	0	1	7	0	0	1	0	0	0	0
Melanochromis melanopterus	3	5	3	0	0	0	0	0	1	1	0	3	0	2	1
Melanochromis crabro	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Petrotilapia yellow chin	4	0	0	4	0	0	2	0	0	3	0	0	2	0	0
Petrotilapia genalutea	2	0	0	3	0	0	2	1	0	2	0	0	2	0	0
Petrotilapia fuscous	5	3	9	5	4	5	2	3	9	2	3	4	2	4	1
Labidochromis vellicans	0	0	0	2	1	0	4	4	0	3	2	0	1	2	0
Labidochromis pallidus	2	3	5	3	2	3	3	3	3	4	2	0	3	1	1
Labeotropheus fuelleborni	6	0	2	6	2	2	5	1	0	8	0	5	9	0	0
Labeotropheus trewavasae	1	0	1	2	1	0	0	0	1	0	0	0	0	1	0
Genyochromis mento	0	2	1	0	0	1	1	1	1	0	1	0	0	1	0
Aulonocara gold	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2
Protomelas taeniolatus	2	1	4	0	0	2	0	0	3	0	3	5	0	0	0
Territorial Total	**94**	**85**	**110**	**90**	**104**	**111**	**97**	**117**	**91**	**113**	**95**	**67**	**133**	**89**	**39**

Visual censuses

It should be kept in mind that censuses were done exactly at the same place within each site. Variations in relative abundance of species were observed among months along the rainy season. At Nakantenga sheltered (Nsh) site (Table S1a), *Ps. zebra 'red dorsal'* tended to be more abundant at 6 m and especially at 10 m during the rainy season. *Ps. zebra 'black dorsal*' was also more abundant at 6 m during the rainy season. The same increasing trends at 10 m were noticed for *Ps. elongatus 'brown'* and *Petrotilapia fuscous*, whereas *Ps. barlowi* abundance decreased at 10 m. *Ps. 'aggressive yellow head'* tended to be more abundant at 2 m but less at 6 and 10 m during the rainy months. However, diversity and abundance variations of species among months were not significant at any depth (one way repeated measures ANOVA, F=0.7 p=0.593 for 2m, F=0.653 p=0.626 for 6 m and F=0.697 p= 0.597 for 10 m depth).

Table S1a. Visual censuses at 2 m, 6 m and 10 m depth at Nakantenga sheltered (Nsh) site.

Month	Oct-98			Dec-98			Jan-99			Apr-99			May-99		
Species name **Depth (m)**	**2**	**6**	**10**	**2**	**6**	**10**	**2**	**6**	**10**	**2**	**6**	**10**	**2**	**6**	**10**
Pseudotropheus zebra 'red dorsal'	2	10	8	0	5	3	1	20	4	2	20	38	1	8	18
Pseudotropheus zebra 'yellow throat'	8	0	0	14	0	0	15	0	0	22	0	0	13	0	0
Pseudotropheus zebra 'black dorsal'	2	2	3	0	1	4	0	3	5	0	7	3	0	5	4
Pseudotropheus barlowi	0	6	2	0	5	4	0	4	2	0	5	1	0	5	0
Pseudotropheus tropheops 'lilac maleri'	7	0	0	3	1	0	4	1	0	3	0	0	3	0	0
Pseudotropheus tropheops 'orange chest'	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0
Pseudotropheus williamsi	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Pseudotropheus elongatus 'brown'	1	1	0	2	0	0	0	6	1	1	1	2	0	4	5
Pseudotropheus 'aggressive yellow head'	3	31	11	0	22	9	3	9	7	5	8	0	8	15	0
Pseudotropheus 'aggressive zebra'	21	0	0	34	0	0	36	1	0	26	0	0	38	0	0
Pseudotropheus burrower	10	15	14	5	18	7	6	23	13	6	16	5	4	16	10
Melanochromis auratus	3	2	1	2	0	0	2	2	2	2	1	1	1	3	3
Melanochromis vermivorous	0	0	0	4	0	0	3	3	0	2	1	0	1	0	0
Melanochromis melanopterus	2	2	2	0	0	0	1	1	0	0	0	2	1	0	2
Petrotilapia 'yellow chin'	0	0	0	1	0	0	1	0	0	1	0	0	3	0	0
Petrotilapia genalutea	0	0	0	1	0	0	1	0	0	3	0	0	3	0	0
Petrotilapia 'fuscous'	0	2	2	2	0	0	1	3	1	1	2	4	1	4	10
Labidochromis vellicans	0	0	0	3	0	0	3	0	0	3	0	0	2	2	1
Labidochromis pallidus	3	3	3	3	0	0	4	2	1	5	1	5	4	3	4
Labeotropheus fuelleborni	1	0	0	1	0	0	1	0	0	3	0	0	1	0	0
Labeotropheus trewavasae	1	1	0	1	0	0	0	1	0	1	0	0	0	1	0
Genyochromis mento	1	1	0	2	0	0	1	0	0	1	1	0	1	2	0
Aulonocara 'gold'	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Protomelas taeniolatus	0	0	3	0	0	0	0	0	0	0	7	5	0	0	0
Territorial Total	**66**	**76**	**49**	**78**	**52**	**27**	**84**	**79**	**37**	**88**	**71**	**66**	**85**	**71**	**57**

At Nakantenga exposed (Nex) site (Table S1b), *Ps. zebra 'red dorsal'* showed an opposite trend, being less abundant at 10 m during the rainy season, like *Ps. tropheops 'orange chest'* and *Petrotilapia fuscous*, which was also less abundant at 2 m. *Labeotropheus fuelleborni* and *Melanochromis auratus* tended to be more abundant at 2 m during the rainy months. *Ps. 'aggressive yellow head'* abundance tended to increase at every depth during the rainy season.

Table S2b. Visual censuses at 2 m, 6 m and 10 m depth at Thumby west T8 site.

Species name / Month / Depth (m)	Dec-98			Jan-99			Feb-99			Mar-99			Apr-99			May-99		
	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10
Pseudotropheus zebra	16	1	2	12	15	4	19	14	4	16	12	4	9	6	2	13	12	3
Pseudotropheus zebra callainos	24	9	0	1	1	0	24	1	0	18	1	0	20	0	0	15	1	0
Pseudotropheus aurora	0	0	2	9	8	2	0	11	3	0	12	3	0	8	2	0	10	3
Pseudotropheus heteropictus	0	0	9	0	0	12	0	0	13	0	1	15	0	2	14	0	1	15
Pseudotropheus livingstonii	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotropheus tropheops lilac	0	2	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0
Pseudotropheus tropheops red cheek	13	14	0	2	3	0	12	1	0	16	2	0	14	2	0	11	1	0
Pseudotropheus tropheops orange chest	9	6	8	14	16	6	13	15	11	8	13	12	7	16	14	12	13	10
Pseudotropheus tropheops intermediate	0	0	6	6	6	8	1	10	8	0	9	8	0	11	9	0	10	9
Pseudotropheus tropheops gracilior	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotropheus williamsi	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotropheus elongatus brown	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotropheus elongatus slab	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0
Pseudotropheus aggressive brown	18	0	0	0	0	0	17	0	0	21	0	0	16	0	0	15	0	0
Pseudotropheus tiny	0	0	4	0	0	1	0	0	4	0	0	5	0	0	5	0	0	5
Melanochromis auratus	1	0	3	0	1	1	2	3	2	3	1	2	1	2	2	2	1	1
Melanochromis melanopterus	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Melanochromis vermivorous	8	0	0	0	0	0	10	0	0	8	0	0	11	0	0	10	0	0
Melanochromis joanjohnsonae	5	0	0	0	0	0	3	0	0	3	0	0	4	0	0	3	0	0
Melanochromis crabro	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petrotilapia mumbo blue	2	0	0	0	0	0	3	0	0	3	0	0	3	0	0	4	0	0
Petrotilapia genalutea	3	6	0	0	0	0	2	0	0	3	0	0	6	0	0	2	0	0
Petrotilapia nigra	1	0	0	6	4	3	2	8	1	1	5	1	2	7	2	1	3	1
Labidochromis vellicans	0	0	0	0	1	0	5	0	0	3	1	0	4	2	0	3	0	0
Labidochromis freibergi	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labidochromis gigas	0	0	3	2	3	2	2	3	4	0	3	4	0	2	3	1	6	3
Labidochromis blue bar	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cynotilapia afra	13	1	21	19	26	26	26	26	24	20	24	26	8	5	6	28	28	21
Labeotropheus fuelleborni	10	1	0	1	2	0	13	0	0	11	2	0	16	1	0	16	0	0
Labeotropheus trewavasae	0	0	0	1	1	0	1	0	0	2	1	0	1	1	0	0	1	0
Genyochromis mento	0	2	0	0	0	0	2	1	1	1	1	1	1	1	1	1	1	1
Aulonocara blue	0	1	0	2	0	1	0	2	5	0	1	3	0	1	3	0	2	3
Protomelas taeniolatus	0	65	0	1	2	1	0	3	0	0	3	1	0	2	1	0	0	1
Territorial Total	**123**	**205**	**59**	**77**	**90**	**69**	**158**	**99**	**80**	**138**	**92**	**86**	**124**	**69**	**64**	**137**	**91**	**76**

Again, the observed variations in species diversity and abundance were not significant at any depth (one way repeated measures ANOVA, F=0.453 p=0.770 for 2m, F=0.816 p=0.518 for 6 m and F=1.220 p= 0.307 for 10 m depth).

At Thumbi West T13 site (Table S2a), some species tended to be more abundant during the rainy season at 2 m (*Ps. callainos, Melanochromis vermivorus, Labidochromis vellicans, L. fuelleborni*), 6 m (*L. fuelleborni*) and 10 m (*Ps. tropheops 'orange chest'*). *Ps. tropheops 'intermediate'* was less abundant at 6 m during the rainy months. However, these species diversity and abundance variations among months were not significant at any depth (one way repeated measures ANOVA, F=1.301 p= 0.265 for 2m, F=0.757 p=0.582 for 6 m and F=0.833 p=0.527 for 10 m depth).

Table S2a. Visual censuses at 2 m, 6 m and 10 m depth at Thumbi west T13 site.

Species name / Month / Depth (m)	Dec-98			Jan-99			Feb-99			Mar-99			Apr-99			May-99		
	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10	2	6	10
Pseudotropheus zebra	12	30	37	21	27	28	16	31	21	24	38	33	16	36	26	20	35	38
Pseudotropheus zebra callainos	35	20	3	33	27	4	41	17	1	57	25	3	54	24	0	46	15	2
Pseudotropheus aurora	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudotropheus heteropictus	0	2	2	0	0	2	0	0	1	0	0	3	0	0	2	0	0	2
Pseudotropheus tropheops lilac	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0
Pseudotropheus tropheops red cheek	4	4	0	4	7	1	4	5	0	6	7	0	4	4	0	3	4	0
Pseudotropheus tropheops orange chest	2	6	8	5	13	8	3	16	9	5	13	10	4	17	12	4	11	13
Pseudotropheus tropheops intermediate	0	9	5	0	3	10	0	4	8	0	2	8	0	2	7	0	1	7
Pseudotropheus elongatus brown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pseudotropheus elongatus slab	0	0	0	0	1	1	0	1	3	0	2	3	0	1	3	0	1	1
Pseudotropheus aggressive blue	10	0	0	6	0	0	6	0	0	6	0	0	6	0	0	5	0	0
Pseudotropheus aggressive brown	32	0	0	19	0	0	26	0	0	19	0	0	23	0	0	22	0	0
Pseudotropheus tiny	0	3	2	0	0	2	0	0	4	0	1	3	0	0	6	0	0	4
Melanochromis auratus	2	2	3	3	2	2	0	1	2	1	2	1	2	2	3	2	3	3
Melanochromis melanopterus	2	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melanochromis chipokae	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Melanochromis vermivorous	8	2	0	14	3	0	21	1	0	10	3	2	12	2	1	16	4	1
Melanochromis parallelus	3	2	1	2	3	2	3	2	3	2	0	1	2	3	1	2	1	2
Melanochromis joanjohnsonae	6	0	0	4	1	0	6	0	0	2	0	0	5	0	0	5	0	0
Petrotilapia mumbo blue	1	0	0	1	0	0	1	0	0	1	0	0	2	0	0	1	0	0
Petrotilapia tridentiger	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Petrotilapia genalutea	2	0	0	4	0	0	1	0	0	1	0	0	2	0	0	1	0	0
Petrotilapia nigra	1	1	2	0	3	3	1	6	2	1	2	2	0	4	3	0	4	2
Labidochromis vellicans	1	2	1	4	4	4	2	4	1	5	3	0	7	2	0	5	3	1
Cynotilapia afra	1	9	0	5	5	0	3	5	0	4	6	0	5	6	0	10	7	0
Labeotropheus fuelleborni	2	4	0	8	18	0	16	13	0	11	15	0	21	18	0	14	11	0
Labeotropheus trewavasae	1	2	1	1	2	3	2	4	2	1	3	4	2	3	6	2	4	4
Genyochromis mento	0	0	2	0	0	0	1	1	1	1	1	0	2	1	3	1	2	1
Aulonocara blue	0	3	0	0	0	2	0	1	1	0	0	1	0	0	1	0	0	2
Protomelas taeniolatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Territorial Total	**126**	**103**	**71**	**134**	**119**	**72**	**155**	**112**	**60**	**158**	**123**	**74**	**171**	**125**	**74**	**162**	**106**	**84**

At Thumbi West T8 site (Table S2b), *Ps. callainos* and *Ps. tropheops 'red cheek'* were found less abundant at 6 m during the rainy season. The opposite tendency was observed at 2 m for *Labidochromis vellicans* and *L. fuelleborni*, and at 6 m for *Ps. aurora* and *Ps. tropheops*

'orange chest' . This last species was also more abundant at 10 m. As for T13 site, species diversity and abundance variations among months were not significant at any depth at T8 (one way repeated measures ANOVA, F=1.958 p= 0.086 for 2m, F=1.175 p=0.322 for 6 m and F=1.262 p=0.282 for 10 m depth).

Life history traits and condition

Life history traits such as fecundity, egg size and size at maturity require large fish samples to be determined. Between months comparisons within each site were not possible owing to insufficient sample numbers. As a consequence, they were compared only for the few species abundant enough and represented at both Nakantenga and Thumbi sites. Also owing to sample number, Nex and Nsh sites were pooled as were T13 and T8, for the Nakantenga versus Thumbi west comparisons of life history traits among populations.
Potential condition variations were investigated for every species abundant enough at every sampled months.

Species present at both Nakantenga and Thumbi west sites

To be accurate, length at maturity has to be determined at the height of the breeding season. Determination of the breeding season was not possible as we did not sample during a complete annual cycle. However, most of the *mbuna*, including the two species below, breed throughout the year with a peak in August to October and one in February to March (Marsh et al. 1986). Our sampling period from October 1998 to May 1999, included part of the first breeding peak and completely the second one. Therefore, length at maturity were estimated from the complete sampling period.

Labeotropheus fuelleborni

The size at maturity of *L. fuelleborni* was slightly higher at Nakantenga (66 mm) than at Thumbi west (62 mm) (Figure S5).

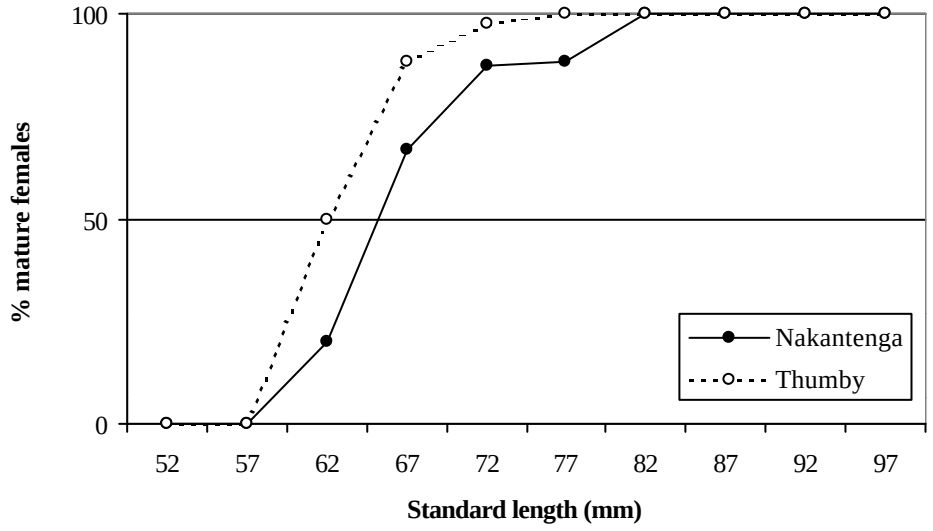


Figure S5. Mean length at first sexual maturity for *Labeotropheus fuelleborni* at Nakantenga and Thumbi west sites.

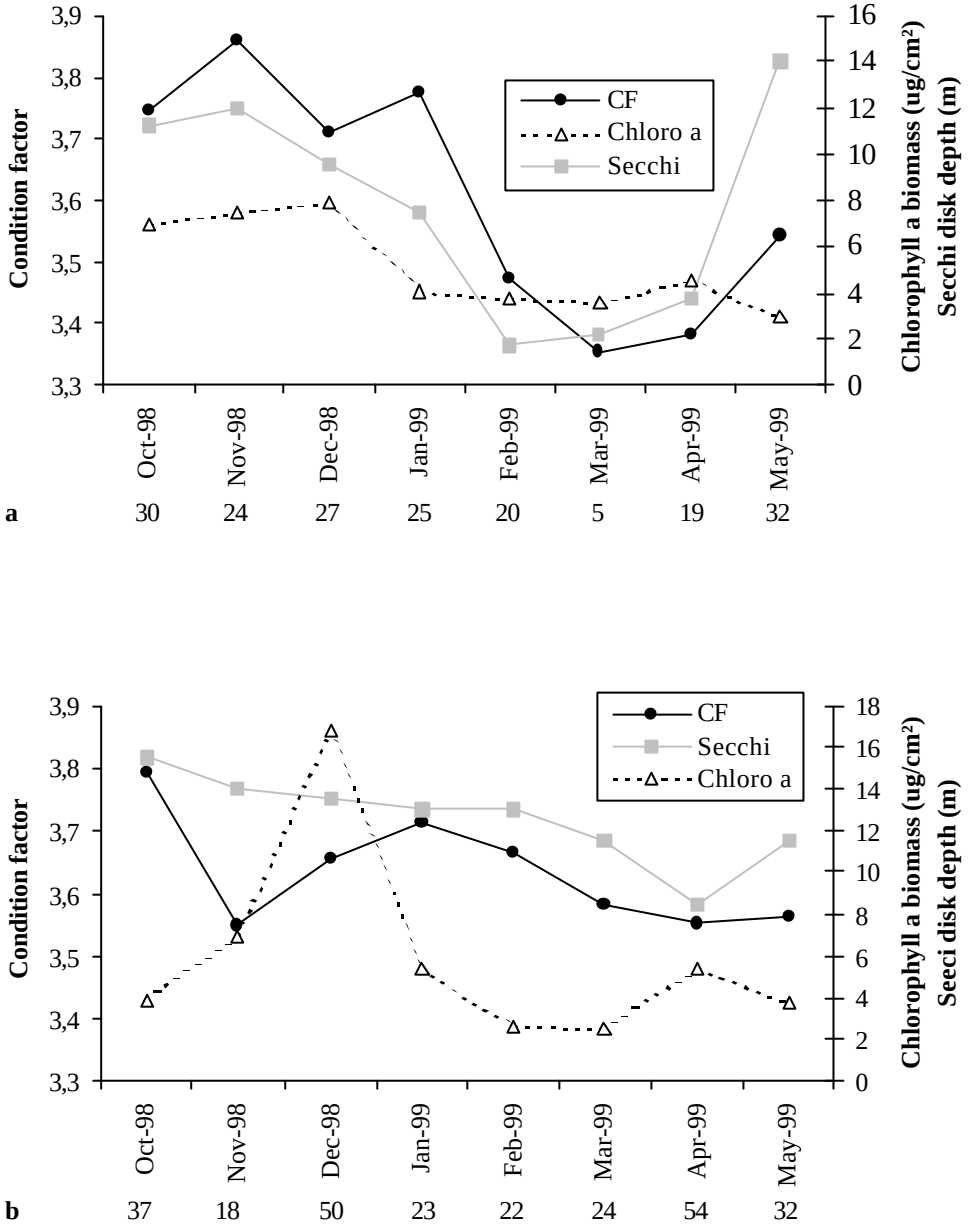


Figure S6. Monthly progression of *Labeotropheus fuelleborni* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga sites (a) and Thumby west sites (b). Numbers below the months are the corresponding sample numbers.

As the relative fecundity was not correlated to the body weight for *L. fuelleborni* at either sites (Pearson correlation r=-0.225, p=0.506 and r=-0.298, p=0.140 for Nakantenga and Thumbi populations, respectively), comparison of fecundity were done on relative fecundity. There was no significant difference (Mann-Whitney rank sum test: T= 221, p=0.702) of relative fecundity between the populations of Nakantenga (N=11, mean relative fecundity=1725 ± 405 SD) and Thumbi west (N=26, mean relative fecundity=1675 ± 252 SD).

The GSI threshold above which oocyte weight did no longer increase significantly was 3.8% for *L. fuelleborni*. At Nakantenga sites, only two females had a GSI superior to 3.8%, giving a mean oocyte weight of 31.9 mg ± 2.69. At Thumbi west sites, 4 females had a GSI superior to 3.8%, giving a mean oocyte weight of 29.5 mg ± 5.21. Owing to the low sample number at Nakantenga, statistical comparison was not possible, but the weak difference was likely to be insignificant.

Analysis of monthly progression of mean condition factor (CF) were carried out separately at Nakantenga and Thumbi sites.

At Nakantenga, no correlation was observed between CF and length of fish (Pearson correlation p>0.05), allowing to test for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. The monthly progression of the mean condition factor, secchi disk measurements and benthic chlorophyll a biomass are presented in Figure S6a. The significant factors were month ($F_{7,156}$=4.673, p<0.0001) and site ($F_{1,156}$=4.565, p=0.034). There was no interaction between factors. An all pairwise Tukey's multiple comparison test was then performed to identify differences among months and the results are presented in Table S3.

Table S3. Differences of mean condition factor among months for *Labeotropheus fuelleborni* at Nakantenga sites. * = significant difference (p<0.05).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------				*		*	
November-98		----------			*	*	*	*
December-98			----------				*	
January-99				----------	*		*	
February-99					----------			
March-99						----------		
April-99							----------	
May-99								----------

Homogeneous subsets were October, November, December and January versus February, March, April and May. The mean condition factor was significantly lower during the period from February-99 to May-99 than during the period from October-98 to January-99 ($F_{1,180}$=42.657, p<0.0001), indicating a significant effect of rainy season on condition factor. Despite their similar monthly progression (Figure S6a), there was no significant correlation between the mean CF and Secchi disk measurements (Pearson correlation p>0.05). Also, no correlation was observed between the mean CF and the chlorophyll a biomass.

At Thumbi west, no correlation was observed between CF and length of fish (Pearson correlation p>0.05), allowing to search for between months, sites and sex differences. None of the factor had a significant effect on the mean condition factor, indicating that the rainy season did not significantly influence the condition of *L. fuelleborni* at Thumbi west. The monthly progression of the mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass are presented in Figure S6b. No significant correlation was found between the mean CF, Secchi disk measurements and the chlorophyll a biomass (Pearson correlation p>0.05).

Pseudotropheus tropheops 'orange chest'

The mean size at maturity of *Ps. tropheops 'orange chest'* was the same (65 mm) in Nakantenga and Thumbi west sites (Figure S7).

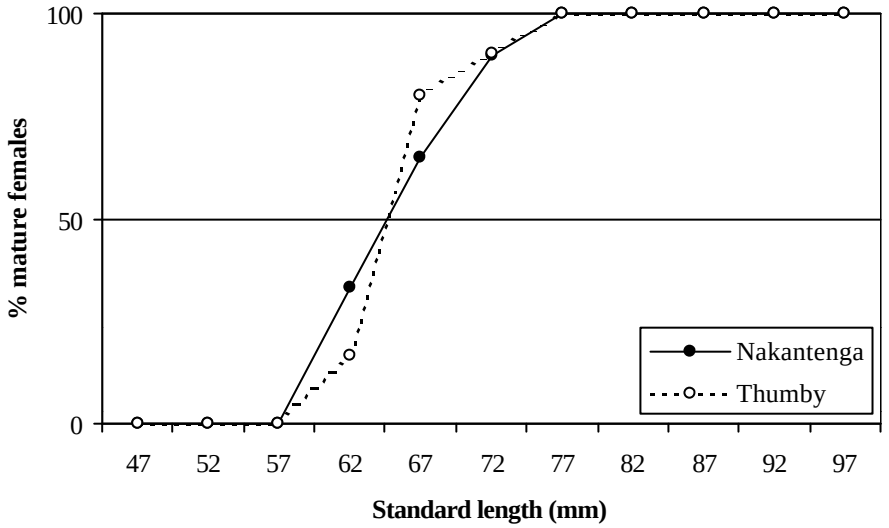


Figure S7. Mean length at first sexual maturity for *Pseudotropheus tropheops 'orange chest'* at Nakantenga and Thumbi west sites.

As the relative fecundity was not correlated to the body weight for *Ps. tropheops 'orange chest'* at either sites (Pearson correlation r=-0.21, p=0.489 and r=-0.28, p=0.134 for Nakantenga and Thumbi populations, respectively), comparisons of fecundity were done on relative fecundity. There was no significant difference (t-test: t= 1.889, 4 df, p=0.066) of relative fecundity between the populations of Nakantenga (N=13, mean relative fecundity=2451 ± 495 SD) and Thumbi west (N=30, mean relative fecundity=2183 ± 395 SD).

The GSI threshold above which oocyte weight did no longer increase significantly was 4% for *Ps. tropheops 'orange chest'*. At Nakantenga sites, 7 females had a GSI superior to 4%, giving a mean oocyte weight of 17.7 mg ± 2.73. At Thumbi west sites, 9 females had a GSI superior to 4%, giving a mean oocyte weight of 17.4 mg ± 2.68. The difference in oocyte weight between the females of two sites was not significant (t-test t=-0.534, 14 df, p=0.602).

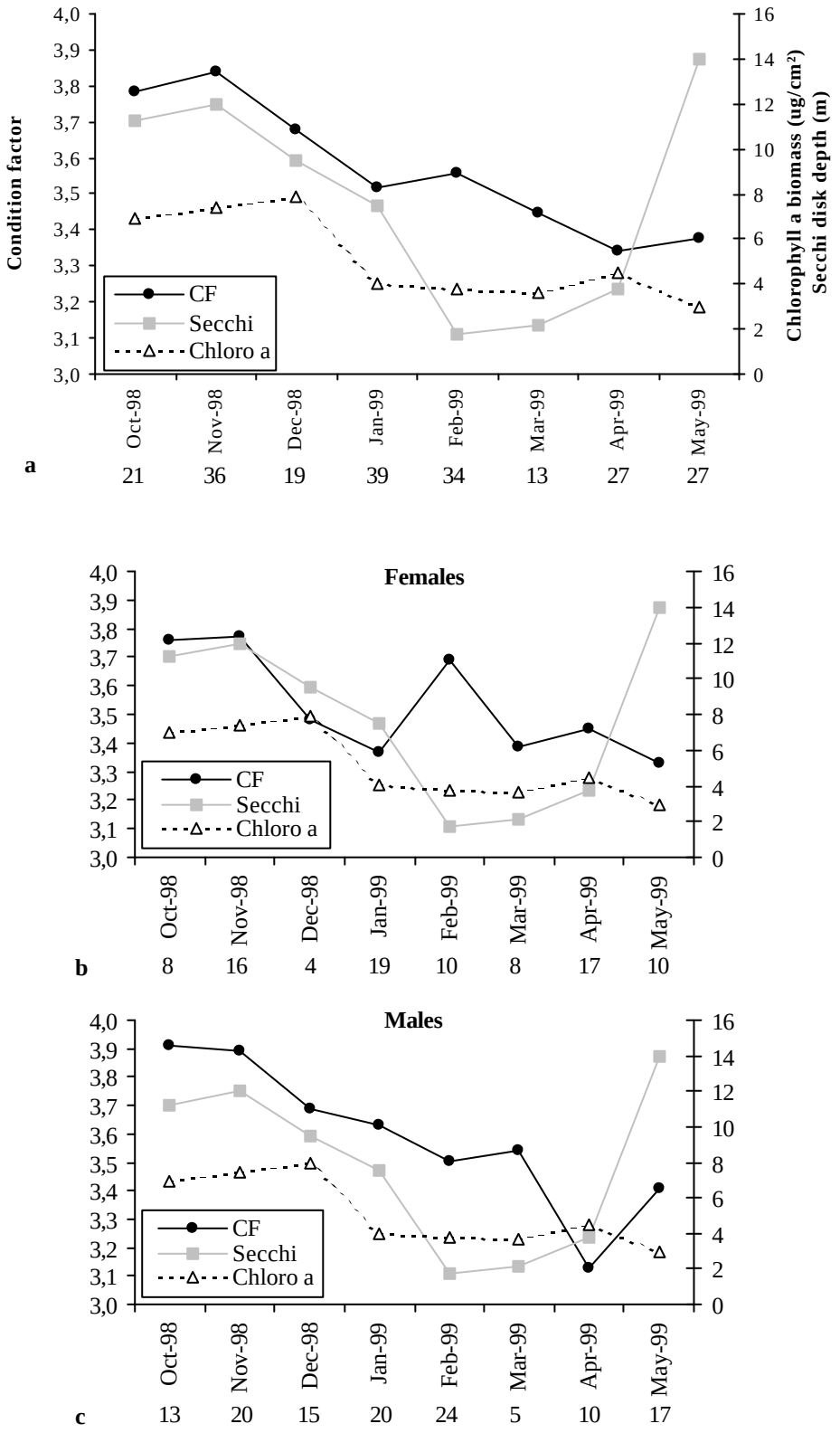


Figure S8. Monthly progression of *Pseudotropheus tropheops 'orange chest'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga sites for females and males pooled (a), females only (b) and males only (c). Numbers below the months are the corresponding sample numbers.

Analysis of monthly progression of condition factor (CF) were carried out separately at Nakantenga and Thumbi sites.

Nakantenga: The monthly progression of the mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass are presented in Figure S8a. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. The only significant factors was month ($F_{7,189}=8.533$, $p<0.0001$) but the interaction between month and sex was significant ($p=0.004$). Therefore, females and males had to be separated for analysis (Figure S8b and c). No significant correlation was found between the mean CF, Secchi disk measurements and the chlorophyll a biomass for females (Pearson correlation $p>0.05$). Despite their similar monthly progression (Figure S8c), there was no significant correlation between the mean CF and Secchi disk measurements for males. Mean CF and chlorophyll a biomass were not correlated either.
Once separated, both females and males showed significant differences of mean condition factor among months ($F_{7,79}=3.061$, $p=0.007$ for females and $F_{7,110}=9.409$, $p<0.0001$ for males). Results of all pairwise Tukey's multiple comparison test are presented in Table S4.

Table S4. Differences of mean condition factor among months for *Pseudotropheus tropheops 'orange chest'* females (*) and males (#) at Nakantenga sites (above the diagonal), and females and males pooled (*) at Thumbi west sites (below the diagonal). *, # = significant difference ($p<0.05$).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------			*	#		#	* #
November-98		----------		*	#	*	* #	* #
December-98			----------				#	
January-99		*		----------			#	
February-99		*	*	*	----------		#	
March-99		*	*	*		----------		
April-99		*	*	*	*	*	----------	
May-99		*	*	*	*			----------

The mean condition factor showed a clear tendency to decrease during the rainy season for males (Figure S8c). As CF in February differed from October-November but also from April, February was excluded from the analysis for between season comparison. The mean CF was significantly lower during the period from March-99 to May-99 than during the period from October-98 to January-99 ($F_{1,98}=35.305$, $p<0.0001$), indicating a significant effect of rainy season on condition factor. The same tendency was observed for females (Figure S8b) despite a sudden increase in February. However, as the mean CF in January significantly differed from that of October and November (Table S4), the same months grouping could not be done for females. The statistical comparison were carried out according to the following "season" grouping: October-December versus January-May and the difference was significant ($F_{1,90}=20.438$, $p<0.0001$).

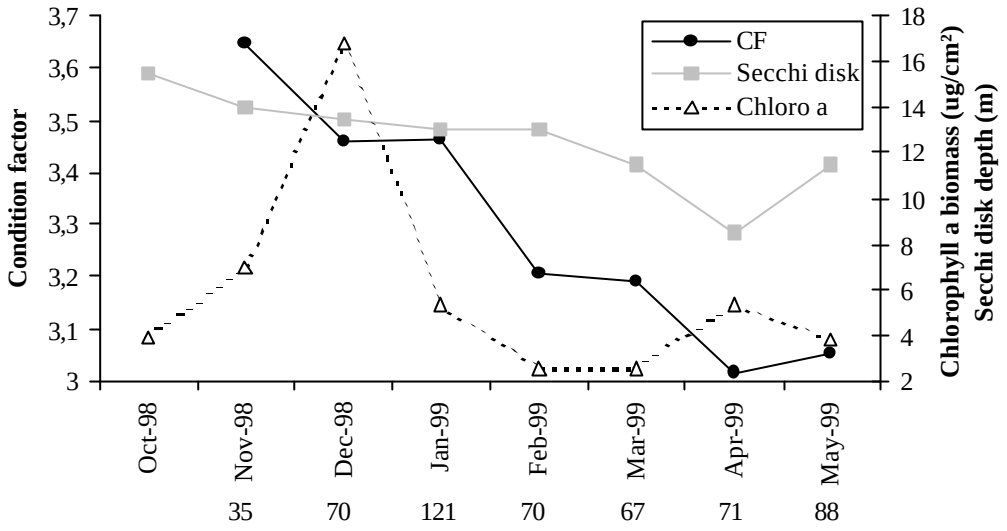


Figure S9. Monthly progression of *Pseudotropheus tropheops 'orange chest'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Thumby west sites. Numbers below the months are the corresponding sample numbers.

At Thumbi west, no correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to search for between months, sites and sex differences. The only factor with a significant effect was month ($F_{7,496}=24.801$, $p<0.0001$). Unlike for Nakantenga, there was no interaction between factors. Surprisingly, as Thumbi west was the control site, the mean condition factor strongly decreased from October to May (Figure S9) and differences among months were almost all significant (Table S4). The mean CF was significantly correlated to the Secchi disk measurements (Pearson correlation $r=0.84$, $p=0.018$), but not to the chlorophyll a biomass.

Species present only at Nakantenga sites

Pseudotropheus zebra 'red dorsal'

The monthly progression of *Ps. zebra 'red dorsal'* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Nakantenga sites are presented in Figure S10a. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. All three factors had a significant effect and interactions existed between all of them. Therefore, sites and sex had to be separated in analysis to test for between months differences.
At Nakantenga sheltered site (Nsh), there were significant monthly differences of CF for both females (Figure S10b, $F_{7,499}=22.978$, $p<0.0001$) and males (Figure S10c, $F_{7,1248}=28.919$, $p<0.0001$). Results of all pairwise Tukey's multiple comparison test are presented in Table S5.

Table S5. Differences of mean condition factor among months for *Pseudotropheus zebra 'red dorsal'* females (*) and males (#) at Nakantenga sheltered site (above the diagonal), and females (*) and males (#) at Nakantenga exposed site (below the diagonal). *, # = significant difference ($p<0.05$).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------						* #	* #
November-98	*	----------				#	* #	* #
December-98		*	----------			#	* #	* #
January-99	*			----------		#	* #	* #
February-99					----------		* #	* #
March-99	*					----------		
April-99	#	* #		* #	#	* #	----------	
May-99		*		*		*	#	----------

For both females and males, homogeneous months subsets were October-February versus March-May (Figure S10a and b and Table S5). Using these subsets, CF was significantly lower in March-May than in October-February for both females ($F_{1,505}=139.718$, $p<0.0001$) and males ($F_{1,1254}=192.879$, $p<0.0001$). Hence, for *Ps. zebra 'red dorsal'*, the effect of season on CF appeared later than for *L. fuelleborni* and *Ps. tropheops 'orange chest'*. The mean CF was correlated neither with the Secchi disk measurements, nor the chlorophyll a biomass (Pearson correlation $p>0.05$).

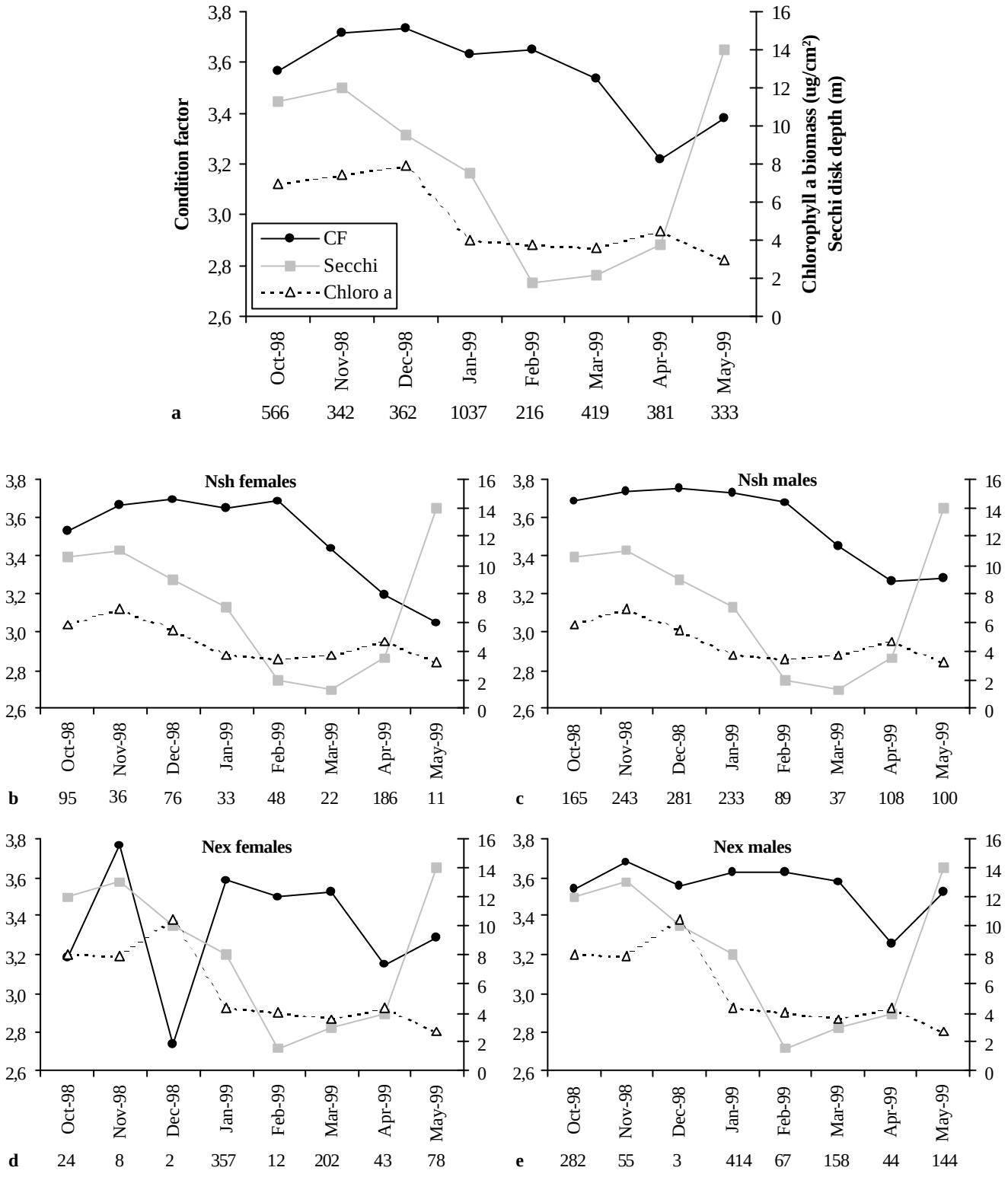


Figure S10. Monthly progression of *Pseudotropheus zebra 'red dorsal'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga for both sites, females and males pooled (a), at Nakantenga sheltered (Nsh) for females only (b), males only (c) and at Nakantenga exposed (Nex) for females only (d), males only (e). Numbers below the months are the corresponding sample numbers.

At Nakantenga exposed site (Nex), there were also significant monthly differences of CF for both females (Figure S10d, $F_{7,718}$=13.742, p<0.0001) and males (Figure S10e, $F_{7,1159}$=6.652, p<0.0001). Results of all pairwise Tukey's multiple comparison test are presented in Table S5. Unlike at Nsh site, there was no clear pattern of seasonal variation in CF for both females and males. The mean CF was quite constant from one month to another for males apart from a drop in April (Figure S10e), while it strongly fluctuated for females (Figure S10d). Note that the very low mean CF value in December for females might be due to the very low sample number. The mean CF was correlated neither with the Secchi disk measurements, nor the chlorophyll a biomass (Pearson correlation p>0.05).

Pseudotropheus zebra 'yellow throat'

The monthly progression of *Ps. zebra 'yellow throat'* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Nakantenga sites are presented in Figure S11. No correlation was observed between CF and length of fish (Pearson correlation p>0.05), allowing to search for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. The only factor with a significant effect was month ($F_{7,220}$=2.126, p=0.042), indicating that CF differed among months. There was no interaction between factors. Results of all pairwise Tukey's multiple comparison test are presented in Table S6.

Table S6. Differences of mean condition factor among months for *Pseudotropheus zebra 'yellow throat'* (above the diagonal) and *Pseudotropheus zebra 'black dorsal'* (below the diagonal) at Nakantenga sites. * = significant difference (p<0.05).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------							
November-98	*	----------			*		*	*
December-98			----------	*	*	*	*	*
January-99				----------				
February-99					----------			
March-99	*	*	*	*	*	----------		
April-99		*	*				----------	
May-99	*	*	*	*	*			----------

Homogeneous months subsets were October-December versus January-May (Figure S11 and Table S6). Using these subsets, CF was significantly lower in January-May than in October-December ($F_{1,243}$=42.980, p<0.0001). Whereas the effect of season on CF appeared late in the rainy season (March) for Ps. zebra 'red dorsal', it was noticed as soon as January for Ps. zebra 'yellow throat'. The mean CF was significantly correlated to the chlorophyll a biomass (Pearson correlation r=0.943, p=0.0005) but not with the Secchi disk measurements.

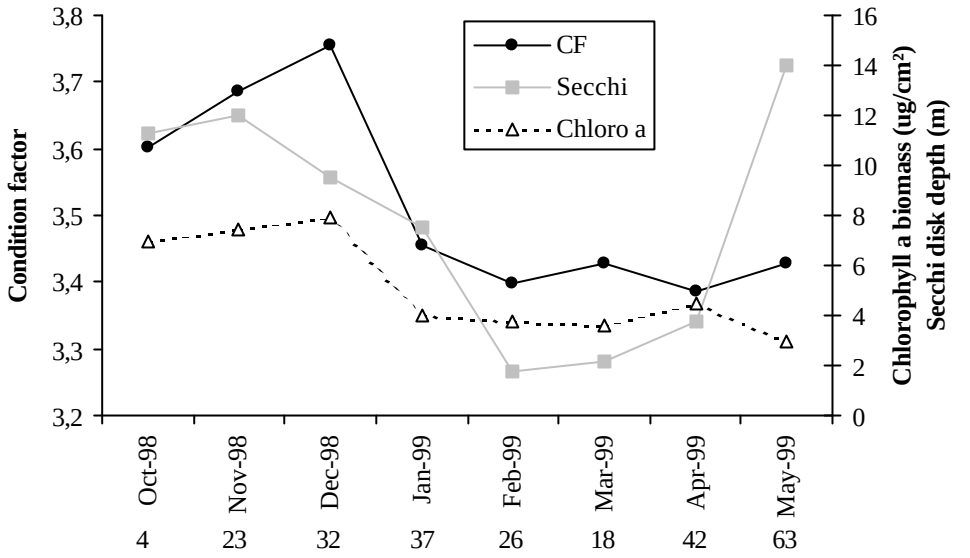


Figure S11. Monthly progression of *Pseudotropheus zebra 'yellow throat'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga for both sites. Numbers below the months are the corresponding sample numbers.

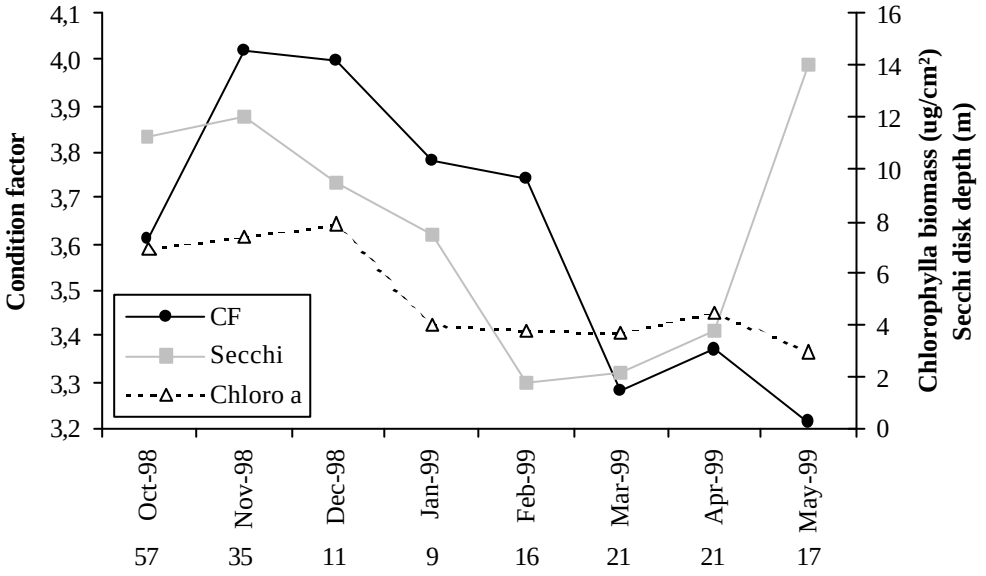


Figure S12. Monthly progression of *Pseudotropheus zebra 'black dorsal'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga for both sites. Numbers below the months are the corresponding sample numbers.

Pseudotropheus zebra 'black dorsal'

The monthly progression of *Ps. zebra 'black dorsal'* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Nakantenga sites are presented in Figure S12. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. The only factor with a significant effect was month ($F_{7,157}=6.220$, $p<0.0001$), indicating that CF differed among months. There was no interaction between factors. Results of all pairwise Tukey's multiple comparison test are presented in Table S6. Homogeneous months subsets were October-February versus March-May (Figure S12 and Table S6). Using these subsets, CF was significantly lower in March-May than in October- February ($F_{1,185}=50.056$, $p<0.0001$). As for *Ps. zebra 'red dorsal'*, *Ps. zebra 'black dorsal'* influence of season on CF appeared late in the rainy season. The mean CF was significantly correlated to the chlorophyll a biomass (Pearson correlation $r=0.744$, $p=0.034$) but not with the Secchi disk measurements.

Petrotilapia 'fuscous'

The monthly progression of *P. 'fuscous'* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Nakantenga sites are presented in Figure S13. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. The only factor with a significant effect was month ($F_{7,150}=10.609$, $p<0.0001$), indicating that CF differed among months. There was no interaction between factors. Results of all pairwise Tukey's multiple comparison test are presented in Table S7.

Table S7. Differences of mean condition factor among months for *Petrotilapia fuscous'* (above the diagonal) and *Pseudotropheus barlowi* (below the diagonal) at Nakantenga sites. * = significant difference ($p<0.05$).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------		*		*	*	*	*
November-98		----------	*		*	*	*	*
December-98			----------					
January-99				----------			*	*
February-99					----------			
March-99						----------		
April-99	*	*		*	*	*	----------	
May-99	*	*		*	*	*		----------

The difference in mean CF between December and October-November might be a artefact due to the low sample number. Therefore, despite this difference, December was considered as part of the October-January group. Homogeneous months subsets were then October- January,

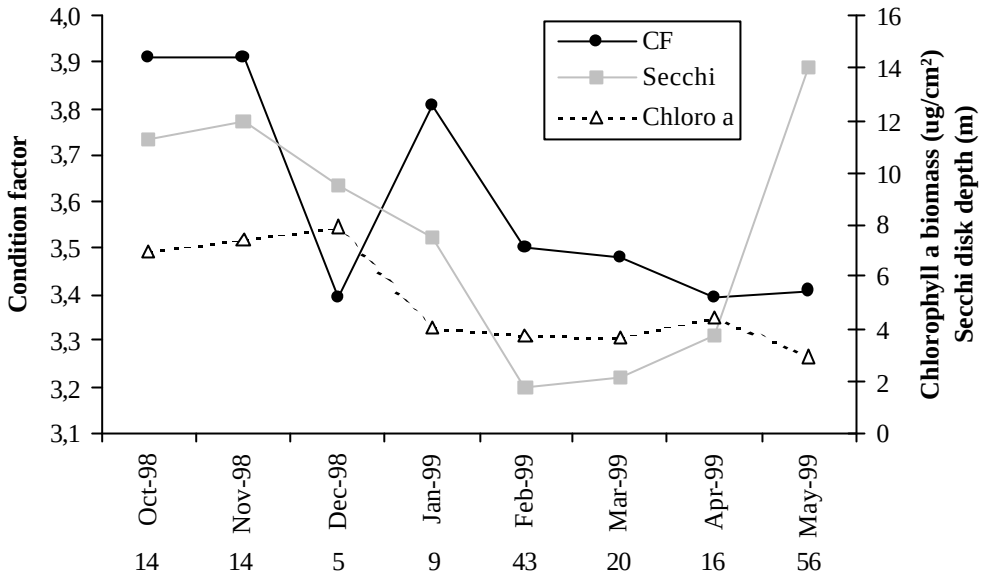


Figure S13. Monthly progression of *Petrotilapia fuscous'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga for both sites. Numbers below the months are the corresponding sample numbers.

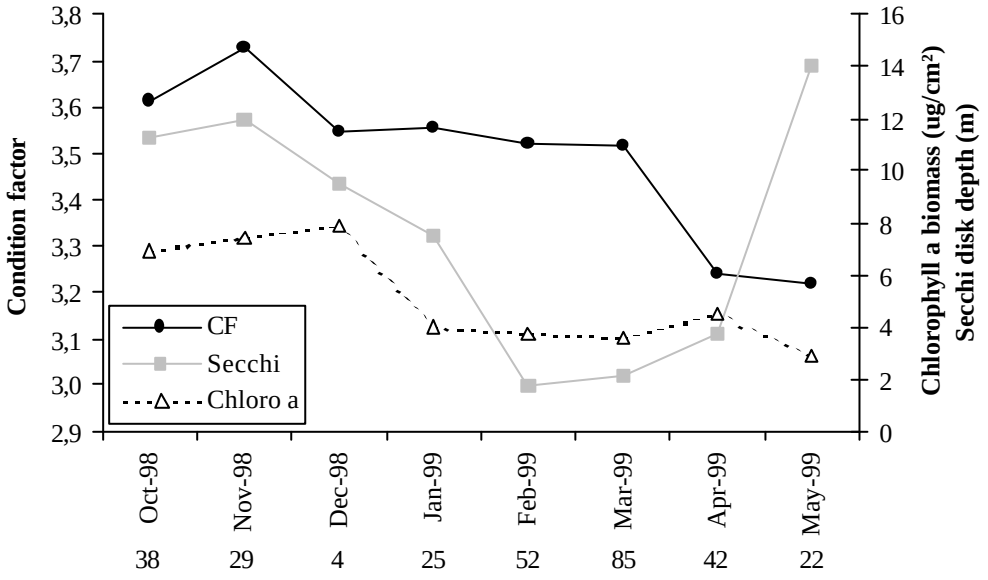


Figure S14. Monthly progression of *Pseudotropheus barlowi* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga for both sites. Numbers below the months are the corresponding sample numbers.

versus February-May (Figure S13 and Table S7). Using these subsets, CF was significantly lower in February -May than in October- January ($F_{1,175}$=46.847, p<0.0001). Month grouping according to CF temporal variations was the same as for *L. fuelleborni* and *Ps. tropheops 'orange chest'*. The mean CF was correlated neither with the Secchi disk measurements, nor the chlorophyll a biomass (Pearson correlation p>0.05).

Pseudotropheus barlowi

The monthly progression of *Ps. barlowi* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Nakantenga sites are presented in Figure S14. No correlation was observed between CF and length of fish (Pearson correlation p>0.05), allowing to test for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. The only factor with a significant effect was month ($F_{7,271}$=7.967, p<0.0001), indicating that CF differed among months. There was no interaction between factors. Results of all pairwise Tukey's multiple comparison test are presented in Table S7. Homogeneous months subsets were October-March versus April-May (Figure S14**,** Table S7). Using these subsets, CF was significantly lower during the period April-May than the period October-March ($F_{1,295}$=48.287, p<0.0001). The mean CF was correlated neither with the Secchi disk measurements, nor the chlorophyll a biomass (Pearson correlation p>0.05).

Pseudotropheus williamsi

The monthly progression of *Ps. williamsi* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Nakantenga sites are presented in Figure S15. No correlation was observed between CF and length of fish (Pearson correlation p>0.05), allowing to test for between months (October to May), sites (Nex and Nsh) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. The only factor with a significant effect was month ($F_{7,171}$=3.594, p=0.002), indicating that CF differed among months. There was no interaction between factors. Results of all pairwise Tukey's multiple comparison test are presented in Table S8.

Table S8. Differences of mean condition factor among months for *Pseudotropheus williamsi* at Nakantenga sites. * = significant difference (p<0.05).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------							
November-98		----------						
December-98			----------					
January-99				----------				
February-99					----------		*	
March-99						----------	*	
April-99							----------	*
May-99								----------

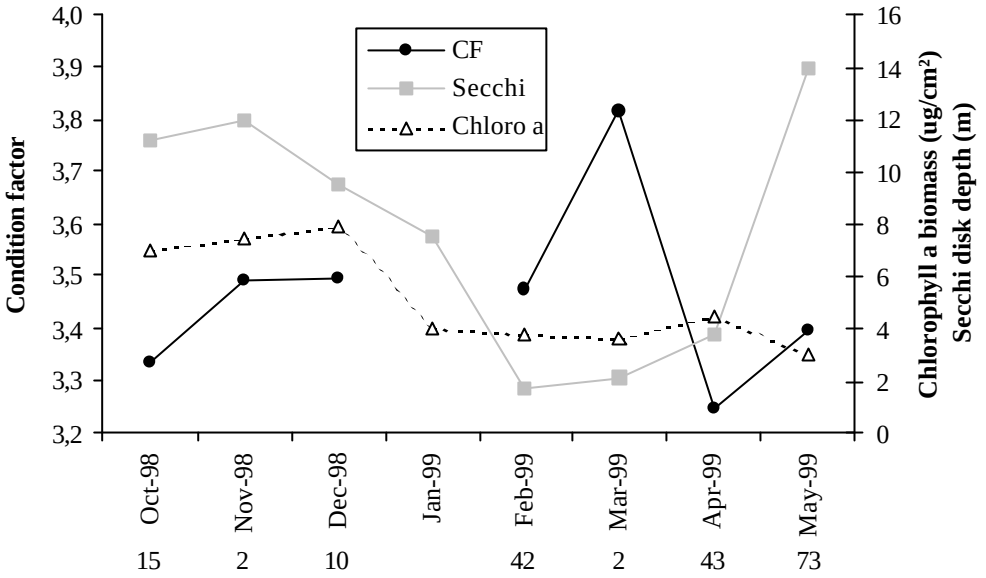


Figure S15. Monthly progression of *Pseudotropheus williamsi* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga for both sites. Numbers below the months are the corresponding sample numbers.

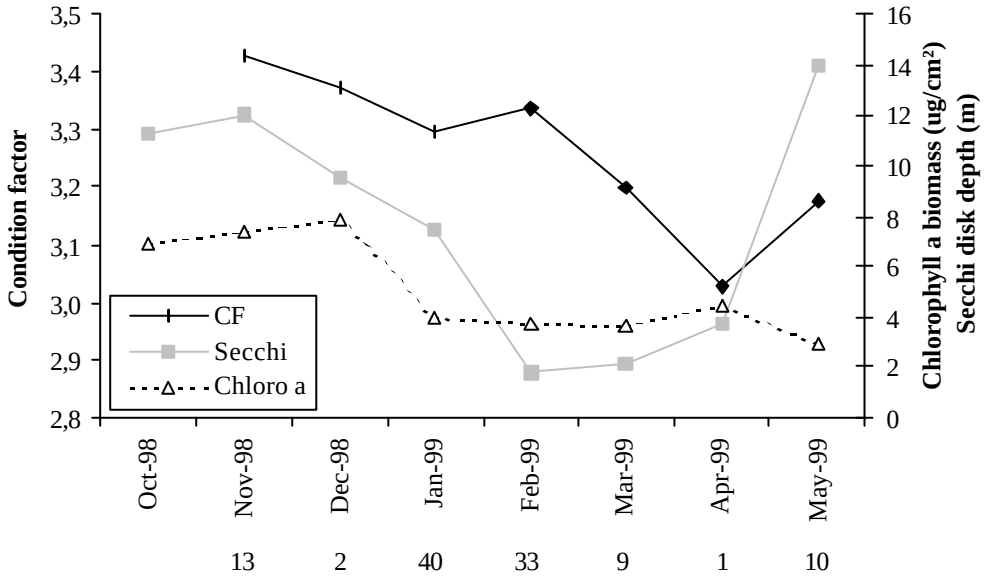


Figure S16. Monthly progression of *Pseudotropheus 'aggressive zebra'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Nakantenga for both sites. Numbers below the months are the corresponding sample numbers.

The only month differing from the others was April, when mean condition factor was slightly lower. However, the temporal variations of the mean CF did not show any clear seasonal pattern (Figure S15) and season did not seem to have a marked effect on CF for this species. The mean CF was correlated neither with the Secchi disk measurements, nor the chlorophyll a biomass (Pearson correlation $p>0.05$).

Pseudotropheus 'aggressive zebra'

The monthly progression of *Ps. 'aggressive zebra'* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Nakantenga sites are presented in Figure S16. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months, sites and sex differences using a general linear model with month, site and sex as factors and CF as dependant variable. Despite the fact that the mean condition factor tended to decrease along the rainy season from November to May, none of the factors had a significant effect indicating that the observed differences were not significant. The mean CF was correlated neither with the Secchi disk measurements, nor the chlorophyll a biomass (Pearson correlation $p>0.05$).

Species present only at Thumbi west sites

Pseudotropheus zebra

The monthly progression of *Ps. zebra 'red dorsal'* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Thumbi west sites are presented in Figure S17a. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months (October to May), sites (T13 and T13) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. All three factors had a significant effect and interactions existed between month and site, and between month and sex. Therefore, sites and sex had to be separated in analysis to test for monthly differences.
At Thumbi T13, there were significant monthly differences of CF for both females (Figure S17b, $F_{7,283}=3.96$, $p<0.0001$) and males (Figure S17c, $F_{7,654}=2.381$, $p=0.021$). Results of all pairwise Tukey's multiple comparison test are presented in Table S9.

Table S9. Differences of mean condition factor among months for *Pseudotropheus zebra* females (*) and males (#) at Thumbi T13 site (above the diagonal), and females (*) and males (#) at Thumbi T8 site (below the diagonal). *, # = significant difference ($p<0.05$).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------	*						
November-98		----------	*				#	
December-98			----------	*	*			
January-99	#			----------				
February-99	#				----------			
March-99	* #	*		* #	* #	----------		
April-99	* #	* #		* #	* #		----------	
May-99	* #	#		* #	* #			----------

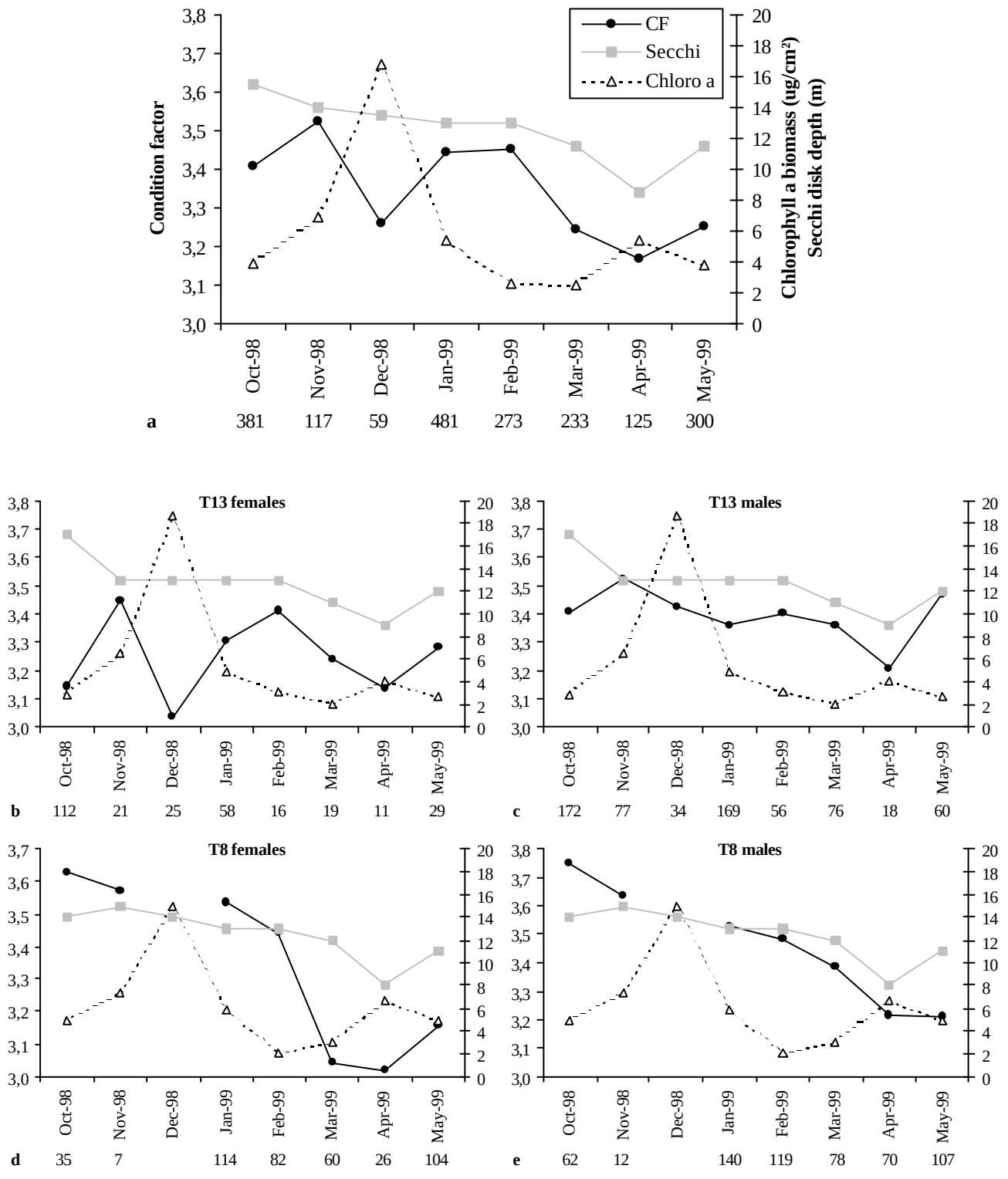


Figure S17. Monthly progression of *Pseudotropheus zebra* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Thumby west for both sites, females and males pooled (a), at Thumby T13 for females only (b), males only (c) and at Thumby T8 for females only (d), males only (e). Numbers below the months are the corresponding sample numbers.

Despite some significant differences among months, there was no evidence of seasonal effect on CF for females (Figure S17b), and only a slight decreasing trend for males (Figure S17c). The mean CF was correlated neither with the Secchi disk measurements, nor with the chlorophyll a biomass (Pearson correlation $p>0.05$) for both females and males.

At Thumbi T8, there were significant monthly differences of CF for both females (Figure S17d, $F_{7,421}=21.746$, $p<0.0001$) and males (Figure S17e, $F_{7,581}=18.289$, $p<0.0001$). Results of all pairwise Tukey's multiple comparison test are presented in Table S9. A clear decreasing pattern of mean CF along the rainy season was observed for both females (Figure S17d) and males (Figure S17e) and the following month subsets emerged: October-February versus March-May. Using these subsets, CF was significantly lower during the period March-May than during the period October-February for both females ($F_{1,426}=119.450$, $p<0.0001$) and males ($F_{1,586}=86.061$, $p<0.0001$). The mean CF was significantly correlated to the Secchi disk measurements for both females ($r=0.843$, $p=0.017$) and males ($r=0.842$, $p=0.017$), but not with the chlorophyll a biomass.

Pseudotropheus tropheops 'red cheek'

The monthly progression of *Ps. tropheops 'red cheek'* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Thumbi west sites are presented in Figure S18. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months (October to May), sites (T13 and T8) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. Both month ($F_{7,165}=6.651$, $p<0.0001$) and sex ($F_{1,165}=9.534$, $p=0.002$) had a significant effect on the mean condition factor. There was no interaction among factors. Results of all pairwise Tukey's multiple comparison test for months are presented in Table S10.

Table S10. Differences of mean condition factor among months for *Pseudotropheus tropheops 'red cheek'* (above the diagonal) and *Pseudotropheus callainos* (below the diagonal) at Thumbi west sites. *, # = significant difference ($p<0.05$).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------		*		*		*	*
November-98		----------					*	*
December-98			----------					
January-99	*			----------			*	*
February-99	*				----------			
March-99	*					----------	*	*
April-99	*			*			----------	
May-99	*			*				----------

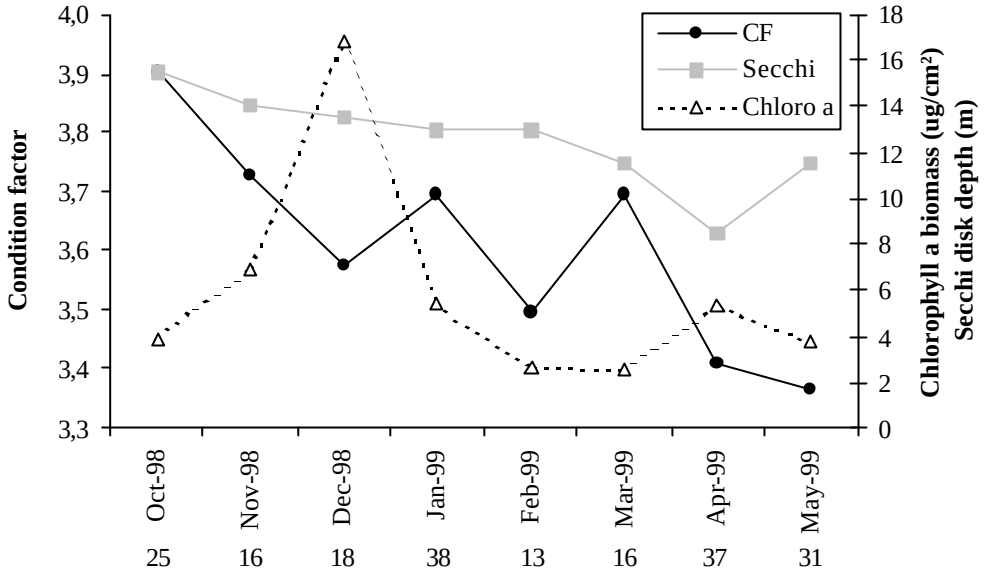


Figure S18. Monthly progression of *Pseudotropheus tropheops 'red cheek'* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Thumby west for both sites. Numbers below the months are the corresponding sample numbers.

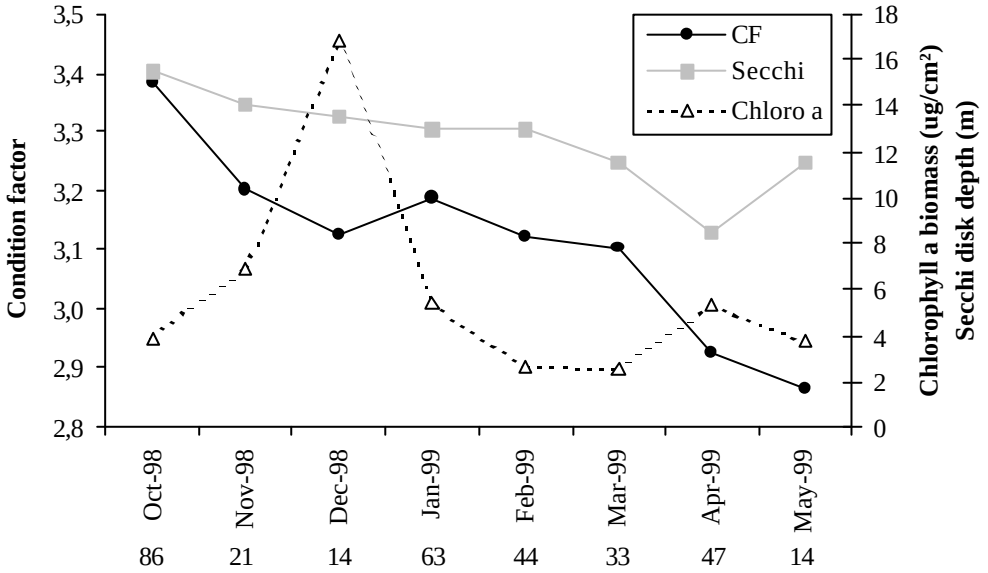


Figure S19. Monthly progression of *Pseudotropheus callainos* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Thumby west for both sites. Numbers below the months are the corresponding sample numbers.

Despite the clear tendency of mean CF to decrease along the rainy season (Figure S18), it was not possible to group months (i.e. October-January versus February-May) owing to the significant difference between March and April and May (Table S10). However, separating April-May from the other months, the mean CF was significantly lower in April-May ($F_{1,192}$=37.886, p<0.0001). The mean CF was significantly correlated to the Secchi disk measurements (r=0.768, p=0.026), but not with the chlorophyll a biomass.

Pseudotropheus callainos

The monthly progression of *Ps. callainos* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Thumbi west sites are presented in Figure S19. No correlation was observed between CF and length of fish (Pearson correlation p>0.05), allowing to test for between months (October to May), sites (T13 and T8) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. Month had a significant effect ($F_{7,294}$=4.050, p<0.0001), indicating that the mean CF differed among months. There was no interaction among factors. Results of all pairwise Tukey's multiple comparison test for months are presented in Table S10. Statistical results exactly translated the trend observed on Figure S19, where the mean condition factor steadily decreased from October to December, was relatively constant from December to March then decreased again in April and May. The mean CF was significantly correlated to the Secchi disk measurements (r=0.870, p=0.005), but not with the chlorophyll a biomass.

Pseudotropheus aurora

The monthly progression of *Ps. aurora* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Thumbi west sites are presented in Figure S20. No correlation was observed between CF and length of fish (Pearson correlation p>0.05), allowing to test for between months (October to May), sites (T13 and T8) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. Month had a significant effect ($F_{7,270}$=11.242, p<0.0001), indicating that the mean CF differed among months. There was no interaction among factors. Results of all pairwise Tukey's multiple comparison test for months are presented in Table S11.

Table S11. Differences of mean condition factor among months for *Pseudotropheus aurora* at Thumbi west sites. *, # = significant difference (p<0.05).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
October-98	----------	*			*	*	*	*
November-98		----------	*	*	*	*	*	*
December-98			----------		*		*	
January-99				----------	*	*	*	*
February-99					----------		*	
March-99						----------	*	
April-99							----------	*
May-99								----------

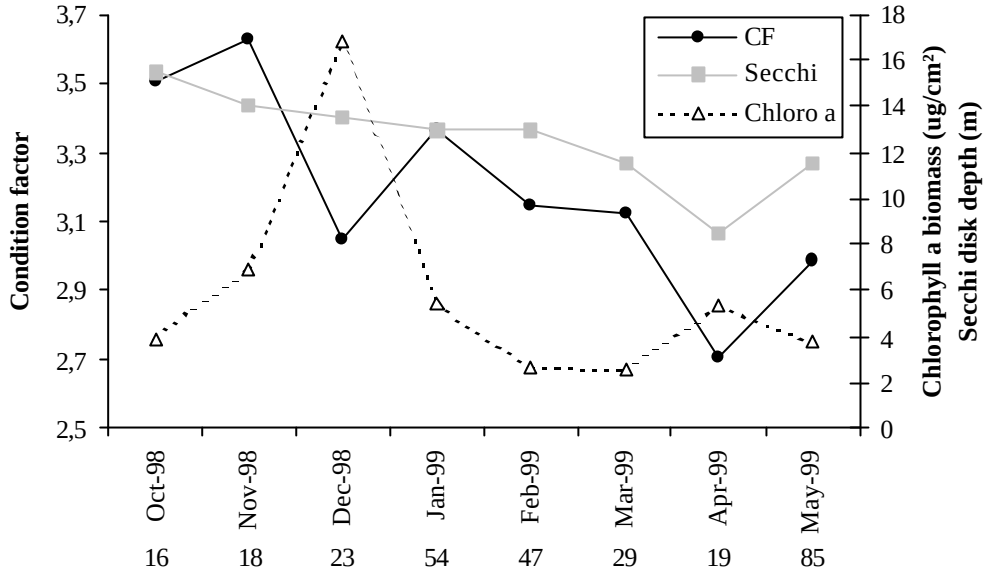


Figure S20. Monthly progression of *Pseudotropheus aurora* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Thumby west for both sites. Numbers below the months are the corresponding sample numbers.

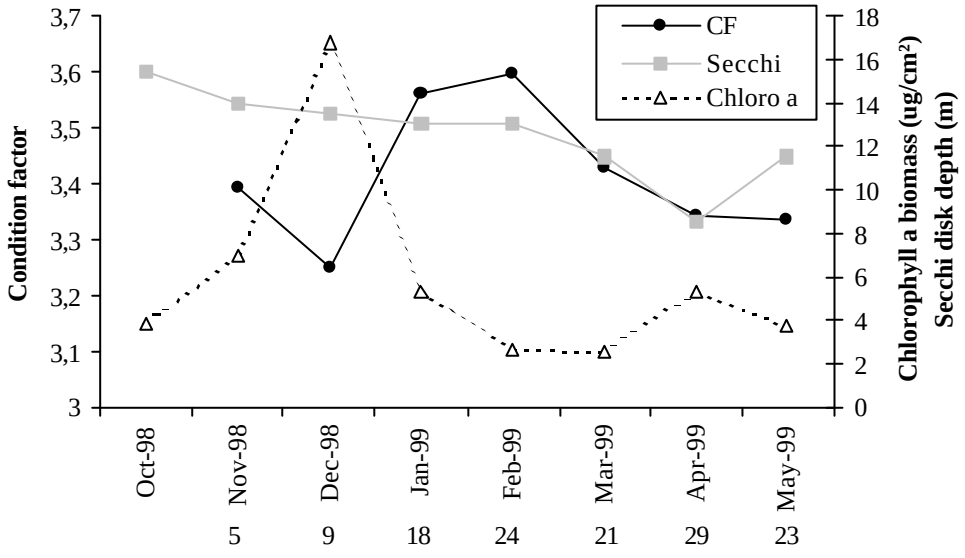


Figure S21. Monthly progression of *Petrotilapia nigra* mean condition factor, Secchi disk measurements (m) and benthic chlorophyll a biomass (µg/cm²) at Thumby west for both sites. Numbers below the months are the corresponding sample numbers.

A similar pattern as that of *Ps. callainos* was observed for *Ps. aurora*, with the mean condition factor decreasing from November to December, a plateau phase from December to March and then another decrease in April-May (Figure S20). During what we called the plateau phase, a sharp increase of the mean CF arose in January as for most of the species at Thumbi sites, though in a lesser extent. Statistical results confirmed that most of the observed differences were significant. The mean CF was significantly correlated to the Secchi disk measurements ($r=0.829$, $p=0.011$), but not with the chlorophyll a biomass.

Petrotilapia nigra

The monthly progression of *P. nigra* mean condition factor, Secchi disk measurements and benthic chlorophyll a biomass at Thumbi west sites are presented in Figure S21. No correlation was observed between CF and length of fish (Pearson correlation $p>0.05$), allowing to test for between months (October to May), sites (T13 and T8) and sex (females and males) differences using a general linear model with month, site and sex as factors and CF as dependant variable. None of the factors had a significant effect on mean condition factor, which translated the absence of seasonal effect on CF (Figure S21). The mean CF was correlated neither with the Secchi disk measurements nor the chlorophyll a biomass.

Discussion

Parallel to this study of rocky shore fish communities (September 1998 to April 1999), the impact of suspended sediments on the abundance and species richness of near-shore sandy fishes was investigated along a sedimentation gradient from Linthipe river mouth to 35 km northwards, during the course of a Master's degree (Sululu 2000). In Lake Tanganyika, Cohen et al. (1993a) compared the biodiversity and abundance of ostracods, diatoms and fish species in sites permanently characterised by diverse degrees of sedimentation disturbances, but for which no baseline data were available to assess the state of species communities before the apparition of the permanent disturbance. The originality of both Sululu's and ours studies, compared to that of Cohen et al. (1993a), lies in that we investigated the short term effects of a temporary sediment disturbance on sites for which pre-disturbance state was (previously) assessed.

In Lake Tanganyika, sites highly impacted by sedimentation had a lower species richness and species abundance than non impacted sites, and sites characterised by an intermediate disturbance had intermediate species richness and abundance (Cohen et al. 1993a). In Lake Malawi, significant variations in the abundance and species richness of sand-dwelling fish were observed before and during the sedimentation period at the station closest to the Linthipe river mouth in gillnet catches, but not in beach seine catches (Sululu 2000). However, over all the stations sampled by beach seine, the mean abundance of cichlids rose during the rainy season, while species richness declined (Sululu 2000). Some fluctuations in the relative abundance of rock-dwelling species were observed among months at both Nakantenga and Thumbi sites. However, these variations were not significant. Thumbi west sites housed a slightly higher number of species than Nakantenga sites and on both islands exposed sites were richer than protected ones: 24, 27, 30 and 33 species for Nsh, Nex, T13 and T8 respectively. However, within each site, the number of species did not changed along the rainy season, thus during the disturbance period.

Close to the Linthipe river mouth, both species richness and abundance of sand-dwelling fishes showed overall significant negative correlation with the concentration of suspended sediments (Sululu 2000). The concentration of suspended sediment was assessed by Secchi disk measurements in our case. Correlation between species richness or abundance and

concentration of suspended sediment was not investigated as species richness and abundance did not differ significantly. On the other hand, a striking pattern appeared when looking at the relationship between the fishes mean condition factor and the Secchi disk measurements or the mean chlorophyll a biomass. Despite often similar monthly progression, there was very few significant correlation between the species mean CF and these two parameters. However, at Nakantenga, the mean CF of species, when significant, was always positively correlated to the chlorophyll a biomass (r=0.744, p=0.034 for *Ps. zebra 'black dorsal'* and r=0.943, p=0.0005 for *Ps. zebra 'yellow throat'*), whereas it was always correlated with the Secchi disk depth when significant at Thumbi West (r=0.829, p=0.011 for *Ps. aurora*; r=0.870, p=0.005 for *Ps. callainos*; r=0.768, p=0.026 for *Ps. tropheops 'red cheek'*; r=0.843, p=0.017 for females, r=0.842, p=0.017 for males *Ps. zebra* at T8). Chlorophyll a biomass was found to fluctuate very little in Thumbi West sites (Figure S4) apart from a temporary large peak resulting from land runoff. On the other hand, water clarity (assessed by Secchi disk measurements) decreased slightly but steadily from October to April-May (Figure S4). A decreased visibility might interfere with plankton foraging for the partly plankton feeding species of the *Ps. zebra* complex and account for a decreased condition. But it is more difficult to explain the influence of a slightly decreased water clarity on a preferentially aufwush feeder like *Ps. tropheops 'red cheek'*, especially if the effect of water transparency does not affect algae biomass. Suspended particles, though not as abundant as at Nakantenga, might decrease the nutritional value of the benthic detritus and algae (Cohen et al. 1993b), accounting for the observed decreased condition of fish species. Next, if a slight decline of water clarity affects the fish condition, why for none of the species (not even species of the *Ps. zebra* complex) the CF was correlated to Secchi disk measurements at Nakantenga where the visibility strongly decreased? A likely explanation is that unlike the monthly mean chlorophyll biomass, which probably reflected real monthly trends (see results), monthly Secchi disk measurements, taken once a month, may not represent monthly trends at Nakantenga, but rather transient trends. Indeed, even though the island was most of the time surrounded by "cloudy waters" from February to April-May, the dense sediment plume resulting in very poor visibility was going back and forth according to wind and current direction. Given the observed steady sediment deposition on rocks from February to April-May at Nakantenga, and the subsequent decline of algal biomass, it appears logical that fish condition was rather correlated to algae biomass, even if this correlation was significant for a few species only.

At Thumbi West sites, an sudden increase of the mean condition factor was observed for all the species in January. As this increase occurred for every species, it is likely to be a consequence of the algae biomass peak recorded in December at every site in Thumbi Island.

The influence of suspended sediment on life history characteristics could only be assessed on two species present at both islands and abundant enough at both of them. For both species (*L. fuelleborni* and *Ps. tropheops 'orange chest'*) no significant difference of size at maturity, fecundity or oocyte weight was observed between the site highly impacted by fluvial sediment (Nakantenga) and the control site (Thumbi West).

The mean condition factor showed a clear decreasing trend along the rainy season (i.e. during the sediment plume's influence) for every species but one at Nakantenga sites. More surprising was the same tendency, though in a lesser extent, observed at Thumbi West sites, which were supposed to be the sediment free or control sites. Although the sediment plume was seen once surrounding Mumbo Island off Cape Maclear, it never reached Thumbi West. Also there is no major river at Cape Maclear and despite deforestation problems on the steep slopes of the Nankumba peninsula resulting in some silt deposition on the rocky shores (Bootsma 1992), Thumbi West is by far less impacted by sedimentation than Nakantenga.

Table S12. Homogeneous months grouping for between-season comparison of mean condition factor per species at Nakantenga. White bars, mean CF does not differ from the dry season mean value. Black bars, mean CF significantly lower than the dry season mean value. Absence of bars means that season had no effect on the CF.

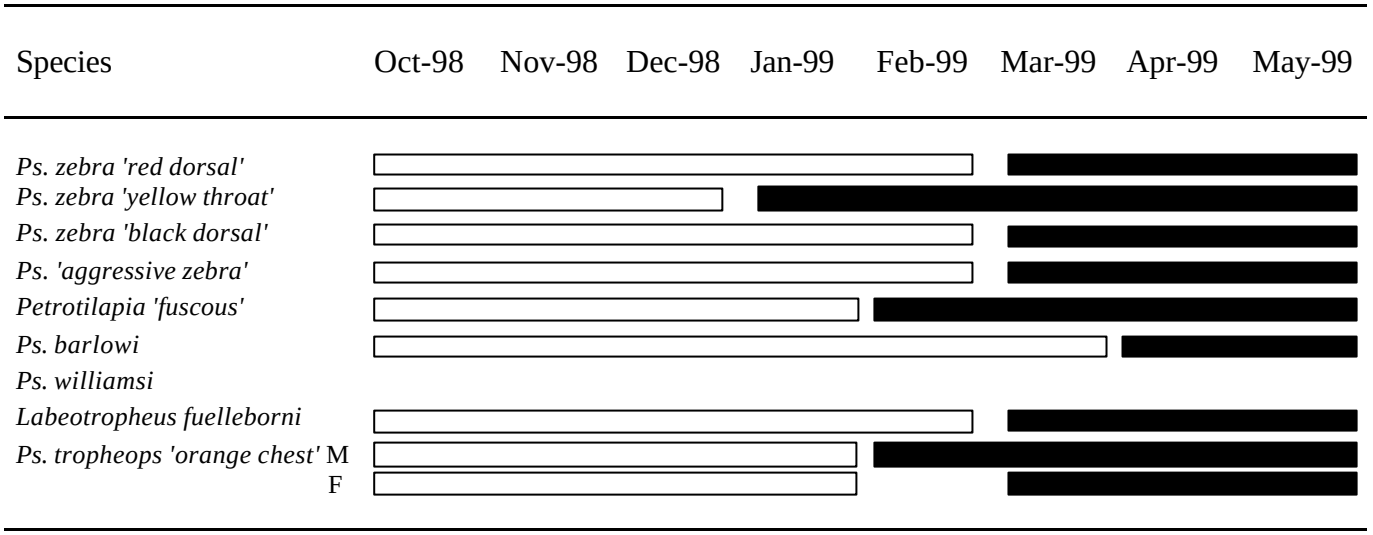
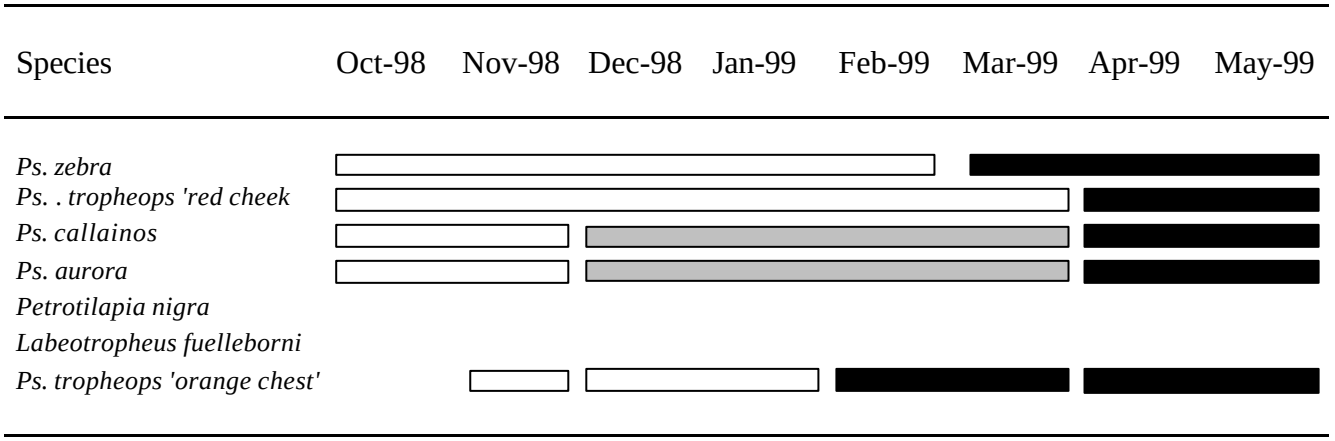


Table S13. Homogeneous months grouping for between-season comparison of mean condition factor per species at Thumby west. White bars: mean CF does not differ from the dry season mean value. Black bars: mean CF significantly lower than the dry season mean value. Grey bars: intermediate state. Absence of bars means that season had no effect on the CF.



Benthic algal biomass and water clarity measurements along the course of this study clearly supported this statement. However, Thumbi West might possibly not be considered as a real sediment free site, which would account for the observed results.
The decrease of mean condition factor along the rainy season did not start at the same time for every species at Nakantenga (Table S12). Depending on species, the date at which the mean CF started to significantly decrease varied from January to April, but for most of them it started in March (50%) and February (25%), which was the period when the Linthipe river discharge was maximum (Figure S3), the water clarity the worst and the algae biomass the lowest (Figure S4). A similar tendency was observed at Thumbi West site (Table S13), but the difference in CF appeared more progressively to become really significant later in the season for most of the species. It is interesting to note that for most of the species at Thumbi West, the lowest CF were recorded in April-May, when algae biomass and water clarity had already started to increase (Figure S4).
The influence of season on the mean CF was also observed to vary between sites at each island. At Nsh, for *Ps. zebra 'red dorsal'* season had the same significant effect on CF for both females and males whereas no effect was detected at Nex for either sex. At Thumbi West T8, for *Ps. zebra*, season had the same significant effect on CF for both females and males whereas no effect was detected at site T13 for either sex. Interestingly, these species are ecological equivalent on the two islands and were the two most abundant species.

The hypothesis that during the sediment plume, the fish would move upwards from the deep waters to the shallows to compensate for the shortage of food availability in the deeper waters, was not verified during this study. At Nsh site, only one species was found more abundant at 2 m during the rainy season. Two species were more abundant at 6 m and 3 at 10 m, whereas only 2 species were less abundant at 10 m and one at 6 m. At Nex site, three species were found less abundant at 10 m and one at 6 m during the rainy season, whereas at each depth one species was found more abundant. At Thumbi West sites, only three species were less abundant at 6 m during the rainy season, whereas two were more abundant at 10 m, three at 6 m and six at 2 m. Furthermore, none of these trends were significant. However, it is likely that the monthly sampling frequency was not adequate to reveal such a phenomenon, which is probably rather transient. Indeed, during one sampling at Nakantenga exposed site in February 1999, we experienced an exceptional event. A dense sediment plume was settled around the island, water visibility being less than 2 m at the surface (Secchi disk depth: 1.5 m), when a narrow band (about 20 m width) of clearer water drifted towards our site. We quickly equipped ourselves with scuba gears and slates, and jumped down the water to observe the fishes behaviour during that event. Before the arrival of the clearer water band, fishes were moving only very little, staying within a 50 cm radius from their hiding hole, some of them not moving at all, behaving as if it were night. When the clearer water band reached the site, within seconds all the fishes gathered in the water column near the surface in a huge crowd cropping frenetically upon plankton. A few minutes later, the clear water was gone and the fishes almost instantaneously returned down to their respective hiding holes, as if nothing had happened and it were night again (Ribbink & Duponchelle, unpublished data). This quick observation might actually be what happens when the wind and currents drive the plume away from the island. Opportunistic behaviour and ability to food switching of *mbuna* are well documented (Fryer & Iles 1972, McKaye & Marsh 1983, Ribbink et al. 1983, Reinthal 1990). Our hypothesis is that during darkness resulting from the dense plume's presence, *mbuna* would spend very little energy in territorial and sexual activity given the poor visibility and in feeding upon scarce and/or blanketed benthic material with diminished nutritional value. Instead of that, they would keep resting, expensing only limited amounts of

energy, awaiting for improved environmental conditions. As soon as visibility improves, they all move in the water column towards the shallows, feeding upon the large amounts of plankton flourishing from the nutrients associated with suspended particles, making up for the food deprivation endured or building up reserves. This strategy would allow the highly stenotopic *mbuna* to pass through the still-temporary disturbance occasioned by the suspended sediment. It would explain why, unlike the easily-moving sand-dwelling species, no significant variations in species richness or abundance were observed and why only a decreased body condition was recorded for *mbuna*. The stable isotope samples taken during this study but unfortunately not available at the moment might shed some light and support or reject that hypothesis.

This study is considered as preliminary. A clear decreased in body condition was observed for almost every species during the period of the sediment plume's influence. However, our results also suggest that a sampling design with much shorter sampling intervals is necessary to better understand the dynamics of rock-dwelling fish reaction to suspended sediment disturbance. A regular stomach content analysis before and during the sedimentation period would help testing our hypothesis. Multivariate analysis of the data, which would help clarifying the observed trends, was not possible given the time constraint over this report, but will be carried out ultimately. Despite the seasonal and temporary effects of suspended sediment, still restricted to the rainy season, impacts have already been detected on sandy (Sululu 2000) and rocky fish communities. Given the increase of anthropogenic activities that lead to habitat degradation and increased erosion around the Lake shore and the steadily increasing human population, this impact is very likely to considerably worsen in the coming years.

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Appendixes

Appendix 1. Date, GPS positioning and depth of each trawl transect (TBM), CTD cast (CTD) and Grab sample (GRB) in the SWA between June 1998 and May 1999.

Cruise	Sample	Gear	Date	Time	Time	Latitude (deg)	Latitude (min)	Latitude (deg)	Latitude (min)	Longitude (deg)	Longitude (min)	Longitude (deg)	Longitude (min)	Bottom depth
				Setting	Hauling	Setting	Setting	Hauling	Hauling	Setting	Setting	Hauling	Hauling	
38	1	TBM	15/6/98	09:30	09:50	14	0,557	14	1,37	34	35,564	34	35,482	50,5
38	2	GRB	15/6/98	10:23		14	0,83			34	35,607			51
38	3	CTD	15/6/98	10:31		14	0,843			34	35,57			50,8
38	4	TBM	15/6/98	15:45	16:05	13	52,755	13	51,744	34	51,067	34	50,806	128
38	5	GRB	15/6/98	16:46		13	52,121			34	50,938			131
38	6	CTD	15/6/98	17:02		13	52,06			34	50,999			132
38	7	TBM	16/6/98	06:58	07:18	13	57,321	13	56,63	34	43,992	34	43,46	105
38	8	CTD	16/6/98	11:00		13	57,031			34	43,84			105
38	9	GRB	16/6/98	11:12		13	56,9			34	43,813			105
38	10	TBM	16/6/98	13:08	13:32	14	2,061	14	1,02	34	33,966	34	33,84	25,6
38	11	CTD	16/6/98	14:10		14	1,576			34	33,876			31
38	12	GRB	16/6/98	14:17		14	1,639			34	33,807			30,4
38	13	TBM	17/6/98	07:19	07:39	14	0,1	13	59,388	34	37,47	34	36,997	77,6
38	14	CTD	17/6/98	11:30		13	59,905			34	37,393			77
38	15	GRB	17/6/98	11:41		13	59,822			34	37,378			76,9
38	16	TBM	17/6/98	12:37	12:57	14	1,952	14	2,729	34	32,815	34	32,86	10,9
38	17	CTD	17/6/98	13:30		14	2,1			34	32,787			10,7
38	18	GRB	17/6/98	13:40		14	2,095			34	32,757			10,1
39	1	TBM	9/7/98	11:15	11:35	14	1,07	14	2,01	34	33,86	34	33,92	29,8
39	2	GRB	9/7/98	12:00		14	1,53			34	34,05			32,5
39	3	TBM	9/7/98	14:42	15:02	13	32,7	13	51,7	34	51,23	34	50,9	127
39	4	GRB	9/7/98	15:32		13	52,21			34	50,93			130
39	5	TBM	10/7/98	08:16	08:36	13	57,26	13	56,54	34	43,95	34	43,5	103
39	6	GRB	10/7/98	09:05		13	56,97			34	43,73			103
39	7	TBM	10/7/98	11:22	11:42	13	59,35	14	0,29	34	36,97	34	37,67	71,5
39	8	GRB	10/7/98	12:45		13	59,7			34	37,25			74
39	9	CTD	10/7/98	12:15		13	59,78			34	37,28			74
39	10	TBM	10/7/98	14:48	15:08	14	0,34	14	1,56	34	35,61	34	35,46	50
39	11	CTD	10/7/98	15:35		14	0,91			34	35,52			14
39	12	GRB	10/7/98	15:45		14	0,86			34	35,53			49
39	13	CTD	10/7/98			14	1,57			34	33,95			31
39	14	CTD	10/7/98	17:30		13	56,92			34	43,74			10,3
39	16	TBM	11/7/98	11:38	11:58	14	1,77	14	2,71	34	32,83	34	33,01	9
39	17	GRB	11/7/98	12:16		14	2,35			34	32,94			10,3
40	1	TBM	12/8/98	09:43	10:03	14	87	14	203	34	3379	34	3398	29,4
40	2	CTD	12/8/98	10:33		14	150			34	3404			32,1
40	3	GRB	12/8/98	10:40		14	145			34	3403			31,5
40	4	TBM	12/8/98	12:59	13:19	13	5750	13	5650	34	4411	34	4350	103
40	5	CTD	12/8/98	13:49		13	5697			34	4376			103
40	6	GRB	12/8/98	13:56		13	5679			34	4376			103
40	7	TBM	12/8/98	15:31	15:21	13	5290	13	5186	34	5122	34	5091	126

Cruise	Sample	Gear	Date	Time	Time	Latitude (deg)	Latitude (min)	Latitude (deg)	Latitude (min)	Longitude (deg)	Longitude (min)	Longitude (deg)	Longitude (min)	Bottom depth
				Setting	Hauling	Setting	Setting	Hauling	Hauling	Setting	Setting	Hauling	Hauling	
40	8	CTD	12/8/98	16:27		13	5217			34	5100			130
40	9	GRB	12/8/98	16:36		13	5212			34	5106			129
40	10	TBM	13/8/98	09:00	09:20	14	18	13	5925	34	3762	34	3685	70
40	11	CTD	13/8/98	09:45		13	5987			34	3735			74
40	12	GRB	13/8/98	09:56		13	5976			34	3734			74
40	13	TBM	13/8/98	11:52	12:12	14	32	14	147	34	3560	34	3551	50
40	14	CTD	13/8/98	12:35		14	88			35	3556			49
40	15	GRB	13/8/98	12:42		14	86			34	3558			49
40	16	TBM	13/8/98	15:11	15:31	14	194	14	304	34	3287	34	3303	10
40	17	CTD	13/8/98	15:55		14	248			34	3288			10
40	18	GRB	13/8/98	16:02		14	247			34	3289			10
43	1	TBM	7/10/98	08:04	08:24	14	0,936	14	1,87	34	32,981	34	33,104	11,3
43	2	CTD	7/10/98	08:48		14	1,822			34	33,092			12,9
43	3	GRB	7/10/98	08:56		14	1,813			34	33,078			12,8
43	4	TBM	7/10/98	10:11	10:31	14	1,366	14	2,238	34	33,874	34	33,736	30,8
43	5	CTD	7/10/98	11:11		14	1,361			34	33,823			29,8
43	6	GRB	7/10/98	11:17		14	1,337			34	33,74			29,7
43	7	TBM	7/10/98	13:45	14:10	14	0,257	14	1,054	34	35,097	34	36,085	43
43	8	CTD	7/10/98	14:50		14	0,741			34	35,773			52,6
43	9	GRB	7/10/98	14:57		14	0,691			34	35,791			52,8
43	10	TBM	7/10/98	15:20	15:40	14	0,603	14	0,349	34	34,325	34	34,088	37
43	11	TBM	8/10/98	06:41	07:01	13	53,379	13	52,737	34	51,465	34	51,692	125
43	12	CTD	8/10/98	07:44		13	52,805			34	51,851			124
43	13	GRB	8/10/98	07:57		13	52,836			34	51,908			124
43	14	TBM	8/10/98	10:23	10:43	13	56,913	13	57,902	34	43,256	34	43,211	103
43	15	TBM	8/10/98	11:22	11:42	13	57,953	13	57,103	34	43,196	34	42,692	99
43	16	CTD	8/10/98	12:49		13	57,529			34	42,968			100
43	17	GRB	8/10/98	12:59		13	57,514			34	42,997			99
43	18	TBM	8/10/98	14:22	14:43	14	0,08	13	59,241	34	37,935	34	37,365	78
43	19	CTD	8/10/98	15:24		13	59,274			34	37,32			75
43	20	GRB	8/10/98	15:26		13	59,258			34	37,342			75,1
49	1	TBM	24/11/98	12:15	12:39	14	0,816	14	2,015	34	33,28	34	33,101	12
49	2	CTD	24/11/98	13:16		14	1,883			34	33,113			13,3
49	3	GRB	24/11/98	13:22		14	1,836			34	33,067			12,1
49	4	GRB	24/11/98	13:35		14	1,764			34	33,055			11,5
49	5	GRB	24/11/98	13:38		14	1,729			34	33,044			11,5
49	6	GRB	24/11/98	13:40		14	1,714			34	33,048			11,5
49	7	GRB	24/11/98	13:42		14	1,706			34	33,035			11,4
49	8	TBM	24/11/98	15:43	16:03	14	1,497	14	2,424	34	34,012	34	34,131	31,9
49	9	CTD	24/11/98	16:38		14	1,772			34	34,11			32,5
49	10	GRB	24/11/98	16:48		14	1,691			34	34,087			32,9
49	11	GRB	24/11/98	16:55		14	1,678			34	34,055			32,5
49	12	GRB	24/11/98	17:00		14	1,652			34	34,028			32,4

Cruise	Sample	Gear	Date	Time	Time	Latitude (deg)	Latitude (min)	Latitude (deg)	Latitude (min)	Longitude (deg)	Longitude (min)	Longitude (deg)	Longitude (min)	Bottom depth
				Setting	Hauling	Setting	Setting	Hauling	Hauling	Setting	Setting	Hauling	Hauling	
49	13	GRB	24/11/98	17:04		14	1,633			34	34,022			32,3
49	14	GRB	24/11/98	17:07		14	1,629			34	34,015			32,2
49	15	TBM	25/11/98	06:50	07:11	13	54,576	13	53,607	34	50,421	34	50,081	120
49	16	CTD	25/11/98	07:57		13	53,848			34	50,151			122
49	17	GRB	25/11/98	08:10		13	53,966			34	50,091			121
49	18	GRB	25/11/98	08:21		13	53,107			34	50,053			120
49	19	GRB	25/11/98	08:32		13	54,157			34	50,043			120
49	20	GRB	25/11/98	08:39		13	54,196			34	50,029			120
49	21	GRB	25/11/98	08:46		13	54,257			34	50,014			120
49	32	TBM	26/11/98	09:47	10:09	13	56,718	13	57,521	34	42,626	34	43,056	99
49	33	CTD	26/11/98	10:55		13	57,154			34	43,123			100
49	34	GRB	26/11/98	11:05		13	57,254			34	43,247			101
49	35	GRB	26/11/98	11:13		13	57,311			34	43,33			101
49	36	GRB	26/11/98	11:28		13	57,442			34	43,426			101
49	37	GRB	26/11/98	11:39		13	57,549			34	43,538			101
49	38	GRB	26/11/98	11:45		13	57,553			34	43,579			101
49	39	TBM	26/11/98	13:45	14:07	13	59,547	14	0,487	34	37,449	34	37,308	75
49	40	CTD	26/11/98	14:52		14	0,129			34	37,254			74
49	41	GRB	26/11/98	15:00		14	0,149			34	37,164			72
49	42	GRB	26/11/98	15:07		14	0,125			34	37,15			72
49	43	GRB	26/11/98	15:11		14	0,077			34	37,176			72
49	44	GRB	26/11/98	15:19		14	0,095			34	37,202			72
49	45	GRB	26/11/98	15:24		14	0,082			34	37,217			72
49	46	TBM	26/11/98	15:54	16:14	14	0,269	14	0,031	34	35,827	34	35,489	53
49	47	CTD	26/11/98	16:47		14	0,706			34	35,548			49
49	48	GRB	26/11/98	16:51		14	0,724			34	35,524			49
51	1	TBM	15/12/98	08:00	08:20	14	1,776	14	2,645	34	33,236	34	33,383	14
51	2	CTD	15/12/98	08:50		14	2,042			34	33,286			14
51	3	GRB	15/12/98	08:56		14	1,979			34	33,263			14
51	4	TBM	15/12/98	10:45	11:05	13	57,484	13	56,129	34	43,095	34	43,246	100
51	5	CTD	15/12/98	11:46		13	57,025			34	43,228			103
51	6	GRB	15/12/98	11:58		13	56,894			34	43,192			104
51	7	TBM	15/12/98	14:15	14:35	13	53,256	13	52	34	50,123	34	50,183	125
51	8	CTD	15/12/98	15:21		13	52,9			34	50,26			126
51	9	GRB	15/12/98	15:36		13	52,983			34	50,346			126
51	10	TBM	16/12/98	05:50	06:10	14	0,125	13	59,455	34	39,117	34	38,533	80
51	11	CTD	16/12/98	06:57		13	59,911			34	38,873			80
51	12	GRB	16/12/98	07:00		13	59,91			34	38,867			80
51	13	TBM	16/12/98	09:42	10:02	14	0,734	14	1,32	34	35,882	34	35,188	53
51	14	CTD	16/12/98	10:34		14	0,807			34	35,369			49
51	15	GRB	16/12/98	10:40		14	0,866			34	35,348			49
51	16	TBM	16/12/98	12:16	12:36	14	1,198	14	1,532	34	34,105	34	34,511	31
51	17	CTD	16/12/98	14:06		14	1,199			34	34,049			31

Cruise	Sample	Gear	Date	Time Setting	Time Hauling	Latitude (deg) Setting	Latitude (min) Setting	Latitude (deg) Hauling	Latitude (min) Hauling	Longitude (deg) Setting	Longitude (min) Setting	Longitude (deg) Hauling	Longitude (min) Hauling	Bottom depth
51	18	GRB	16/12/98	14:12		14	1,233			34	33,911			31
52	1	TBM	27/1/99	08:07	08:27	14	1,705	14	2,534	34	33,153	34	33,271	14
52	2	ZOO	27/1/99	09:02		14	1,952			34	33,136			13
52	3	GRB	27/1/99	09:07		14	2,014			34	33,132			13
52	4	GRB	27/1/99	09:17		14	2,014			34	33,132			13
52	5	GRB	27/1/99	09:20		14	2,014			34	33,132			13
52	6	GRB	27/1/99	09:25		14	2,014			34	33,132			13
52	7	GRB	27/1/99	09:30		14	2,014			34	33,132			13
52	8	GRB	27/1/99	09:35		14	2,014			34	33,132			13
52	9	CTD	27/1/99	09:40		14	2,014			34	33,132			13
52	10	TBM	27/1/99	11:34	11:54	13	58,042	13	57,306	34	43,25	34	43,763	100
52	11	CTD	27/1/99	12:50		13	57,644			34	43,538			101
52	12	ZOO	27/1/99	12:59		13	57,567			34	43,494			100
52	13	GRB	27/1/99	13:15		13	57,524			34	43,454			101
52	14	GRB	27/1/99	13:24		13	57,504			34	43,392			101
52	15	GRB	27/1/99	13:32		13	57,496			34	43,338			101
52	16	GRB	27/1/99	13:39		13	57,469			34	43,293			101
52	17	GRB	27/1/99	13:46		13	57,47			34	43,295			101
52	18	GRB	27/1/99	13:51		13	57,486			34	43,191			101
52	19	TBM	27/1/99	15:26	15:46	13	52,658	13	51,835	34	50,347	34	50,4	127
52	20	CTD	27/1/99	16:31		13	52,235			34	50,324			128
52	21	ZOO	27/1/99	16:48		13	52,202			34	50,284			129
52	22	GRB	27/1/99	17:01		13	52,171			34	50,211			129
52	23	GRB	27/1/99	17:14		13	52,216			34	50,158			128
52	24	GRB	27/1/99	17:25		13	52,176			34	50,168			128
52	25	GRB	27/1/99	17:32		13	52,156			34	50,155			128
52	26	GRB	27/1/99	17:36		13	52,208			34	50,09			128
52	27	GRB	27/1/99	17:42		13	52,205			34	50,053			128
52	28	TBM	28/1/99	06:36	06:56	13	59,906	13	59,247	34	37,979	34	37,503	77
52	29	CTD	28/1/99	07:36		13	59,615			34	37,781			78
52	30	ZOO	28/1/99	07:44		13	59,721			34	37,87			77
52	31	GRB	28/1/99	08:02		13	59,719			34	37,807			77
52	32	GRB	28/1/99	08:07		13	59,754			34	37,801			77
52	33	GRB	28/1/99	08:14		13	59,752			34	37,782			77
52	34	GRB	28/1/99	08:20		13	59,752			33	37,73			77
52	35	GRB	28/1/99	08:27		13	59,702			33	37,69			77
52	36	TBM	28/1/99	09:22	09:42	14	1,896	14	0,895	34	34,055	34	33,851	31
52	37	CTD	28/1/99	10:20		14	1,495			34	34,113			33
52	38	ZOO	28/1/99	10:29		14	1,398			34	34,044			32
52	39	GRB	28/1/99	10:37		14	1,317			34	34,054			32
52	40	GRB	28/1/99	10:41		14	1,308			34	34,057			32
52	41	GRB	28/1/99	10:45		14	1,284			34	34,281			31
52	42	GRB	28/1/99	10:48		14	1,269			34	34,033			31

Cruise	Sample	Gear	Date	Time	Time	Latitude (deg)	Latitude (min)	Latitude (deg)	Latitude (min)	Longitude (deg)	Longitude (min)	Longitude (deg)	Longitude (min)	Bottom depth
				Setting	Hauling	Setting	Setting	Hauling	Hauling	Setting	Setting	Hauling	Hauling	
52	43	GRB	28/1/99	10:51		14	1,245			34	34,042			31
52	44	GRB	28/1/99	10:54		14	1,224			34	34,009			31
52	45	TBM	28/1/99	12:00	12:20	14	0,218	14	1,153	34	35,531	34	35,807	48
52	46	CTD	28/1/99	12:59		14	0,931			34	35,607			49
52	47	ZOO	28/1/99	13:07		14	0,891			34	35,527			49
52	48	GRB	28/1/99	13:17		14	0,881			34	35,393			49
52	49	GRB	28/1/99	13:23		14	0,878			34	35,342			49
52	50	GRB	28/1/99	13:28		14	0,87			34	35,263			49
52	51	GRB	28/1/99	13:31		14	0,858			34	35,244			47
52	52	GRB	28/1/99	13:34		14	0,86			34	35,202			47
52	53	GRB	28/1/99	13:38		14	0,865			34	35,2			47
52	54	GRB	28/1/99	14:38		13	58,95			34	36,8			53
52	55	GRB	28/1/99	14:48		13	55,957			34	36,649			52
53	1	TBM	16/2/99	08:46	09:06	14	2,878	14	2,184	34	33,415	34	32,954	13
53	2	CTD	16/2/99	09:44		14	2,604			34	32,221			13
53	3	GRB	16/2/99	09:48		14	2,604			34	32,221			13
53	4	GRB	16/2/99	09:51		14	2,604			34	32,221			13
53	5	GRB	16/2/99	09:53		14	2,604			34	32,221			13
53	6	GRB	16/2/99	09:57		14	2,604			34	32,221			13
53	7	GRB	16/2/99	09:59		14	2,604			34	32,221			13
53	8	TBM	16/2/99	11:46	12:06	14	2,162	14	1,321	34	34,101	34	33,982	29
53	9	CTD	16/2/99	12:59		14	1,69			34	33,942			32
53	10	GRB	16/2/99	13:07		14	1,602			34	33,953			32
53	11	GRB	16/2/99	13:12		14	1,617			34	34,039			32
53	12	GRB	16/2/99	13:14		14	1,575			34	34,045			32
53	13	GRB	16/2/99	13:17		14	1,595			34	33,999			32
53	14	GRB	16/2/99	13:21		14	1,554			34	33,987			32
53	15	TBM	16/2/99	13:59	14:19	14	1,427	14	0,579	34	35,341	34	35,344	49
53	16	CTD	16/2/99	14:53		14	1,096			34	35,38			48
53	17	GRB	16/2/99	14:58		14	1,091			34	35,323			48
53	18	TBM	17/2/99	06:27	06:47	13	54,036	13	53,341	34	51,227	34	51,394	122
53	19	CTD	17/2/99	07:35		13	53,536			34	51,284			124
53	20	GRB	17/2/99	07:43		13	53,579			34	51,177			124
53	21	GRB	17/2/99	07:58		13	53,577			34	51,153			124
53	22	GRB	17/2/99	08:07		13	53,581			34	51,09			124
53	23	GRB	17/2/99	08:16		13	53,621			34	51,021			124
53	25	TBM	17/2/99	09:59	10:19	13	57,167	13	56,289	34	43,671	34	43,253	101
53	26	CTD	17/2/99	11:01		13	56,577			34	43,462			104
53	27	GRB	17/2/99	11:10		13	56,562			34	43,459			104
53	28	TBM	17/2/99	12:25	12:45	13	59,345	14	0,196	34	37,522	34	37,422	76
53	29	CTD	17/2/99	13:28		13	59,812			34	37,468			75
53	30	GRB	17/2/99	13:35		13	59,762			34	37,425			75
53	31	GRB	17/2/99	13:42		13	59,714			34	37,413			75

Cruise	Sample	Gear	Date	Time Setting	Time Hauling	Latitude (deg) Setting	Latitude (min) Setting	Latitude (deg) Hauling	Latitude (min) Hauling	Longitude (deg) Setting	Longitude (min) Setting	Longitude (deg) Hauling	Longitude (min) Hauling	Bottom depth
53	32	GRB	17/2/99	13:46		13	59,681			34	37,383			75
53	33	GRB	17/2/99	13:52		13	59,647			34	37,383			75
53	34	GRB	17/2/99	13:58		13	59,668			34	37,383			75
53	35	TBM	17/2/99	18:38	18:58	13	38,993	13	38,013	34	40,343	34	40,219	126
55	1	TBM	19/3/99	10:45	11:05	14	0,416	14	1,148	34	33,158	34	33,159	16
55	2	CTD	19/3/99	11:37		14	0,922			34	33,138			17
55	3	GRB	19/3/99	11:41		14	0,861			34	33,068			15,7
55	4	GRB	19/3/99	11:44		14	0,84			34	33,081			15,5
55	5	TBM	19/3/99	13:36	13:56	13	57,936	13	57,112	34	43,265	34	43,549	101
55	6	CTD	19/3/99	14:30		13	57,088			34	43,264			102
55	7	GRB	19/3/99	14:43		13	57,119			34	43,159			102
55	8	GRB	19/3/99	14:50		13	57,138			34	43,11			102
55	9	TBM	19/3/99	16:22	16:42	13	53,576	13	52,972	34	49,441	34	49,692	122
55	10	CTD	19/3/99	17:28		13	53,378			34	49,582			122
55	11	GRB	19/3/99	17:40		13	53,489			34	49,52			122
55	12	GRB	19/3/99	17:46		13	53,57			34	49,508			122
55	13	TBM	20/3/99	05:55	06:15	14	0,494	13	59,743	34	38,168	34	37,736	79
55	14	CTD	20/3/99	06:50		13	59,797			34	37,541			79
55	15	GRB	20/3/99	07:03		13	59,8			34	37,433			78
55	16	GRB	20/3/99	07:09		13	59,87			34	37,523			78,5
55	17	TBM	20/3/99	08:31	08:51	14	1,119	14	0,246	34	35,708	34	35,555	51,1
55	18	CTD	20/3/99	09:25		14	0,755			34	35,623			50,1
55	19	GRB	20/3/99	09:32		14	0,686			34	35,576			50
55	20	GRB	20/3/99	09:35		14	0,658			34	35,573			49,7
55	21	TBM	20/3/99	11:37	11:57	14	2,193	14	1,455	34	34,066	34	33,821	27,8
55	22	CTD	20/3/99	12:38		14	1,658			34	33,862			30,3
55	23	GRB	20/3/99	12:42		14	1,648			34	33,804			29,8
55	24	GRB	20/3/99	12:47		14	1,648			34	33,794			29,8
57	1	TBM	14/4/99	09:00	09:20	14	0,589	14	1,372	34	33,157	34	33,062	19
57	2	CTD	14/4/99	09:55		14	1,258			34	33,072			11
57	3	GRB	14/4/99	09:59		14	1,258			34	33,072			11
57	4	GRB	14/4/99	10:03		14	1,258			34	33,072			11
57	5	GRB	14/4/99	10:06		14	1,258			34	33,072			11
57	6	GRB	14/4/99	10:09		14	1,258			34	33,072			11
57	7	GRB	14/4/99	10:12		14	1,258			34	33,072			11
57	8	GRB	14/4/99	10:15		14	1,258			34	33,072			11
57	9	TBM	14/4/99	11:32	11:52	14	0,29	13	59,505	34	37,584	34	37,536	77
57	10	CTD	14/4/99	12:25		13	59,451			34	37,481			76
57	11	GRB	14/4/99	12:37		13	59,376			34	37,367			76
57	12	GRB	14/4/99	12:45		13	59,357			34	37,311			75
57	13	GRB	14/4/99	12:51		13	59,321			34	37,269			75
57	14	GRB	14/4/99	12:56		13	59,273			34	37,228			75
57	15	GRB	14/4/99	13:01		13	59,227			34	37,177			75

Cruise	Sample	Gear	Date	Time Setting	Time Hauling	Latitude (deg) Setting	Latitude (min) Setting	Latitude (deg) Hauling	Latitude (min) Hauling	Longitude (deg) Setting	Longitude (min) Setting	Longitude (deg) Hauling	Longitude (min) Hauling	Bottom depth
57	16	GRB	14/4/99	13:09		13	59,145			34	37,115			74
57	17	TBM	14/4/99	14:20	14:40	14	0,835	14	0,087	34	35,732	34	35,643	52
57	18	CTD	14/4/99	15:10		14	0,404			34	35,59			51
57	19	GRB	14/4/99	15:16		14	0,291			34	35,474			50
57	20	GRB	14/4/99	15:20		14	0,276			34	35,455			49
57	21	TBM	15/4/99	06:10	06:30	13	53,878	13	53,063	34	50,216	34	50,084	122
57	22	TBM	15/4/99	09:30	09:50	13	57,584	13	56,776	34	43,46	34	43,555	102
57	23	CTD	15/4/99	10:34		13	57,11			34	43,608			104
57	24	GRB	15/4/99	10:40		13	57,104			34	43,617			104
57	25	GRB	15/4/99	10:51		13	57,051			34	43,676			104
57	26	TBM	15/4/99	12:45	13:05	14	1,934	14	1,116	34	33,983	34	33,593	32
57	27	CTD	15/4/99	13:40		14	1,068			34	33,639			29
57	28	GRB	15/4/99	13:43		14	1,068			34	33,639			29
57	29	GRB	15/4/99	13:46		14	1,068			34	33,639			29
57	30	GRB	15/4/99	13:52		14	1,068			34	33,639			29
57	31	GRB	15/4/99	13:55		14	1,068			34	33,639			29
57	32	GRB	15/4/99	14:00		14	1,068			34	33,639			29
57	33	GRB	15/4/99	14:03		14	1,068			34	33,639			29
58	1	TBM	20/5/99	07:38	07:59	14	0,135	14	0,973	34	33,096	34	33,056	14
58	2	CTD	20/5/99	08:25		14	0,545			34	33,001			13
58	3	GRB	20/5/99	08:29		14	0,545			34	33,002			13
58	4	GRB	20/5/99	08:38		14	0,545			34	33,002			13
58	5	GRB	20/5/99	08:40		14	0,545			34	33,002			13
58	6	GRB	20/5/99	08:45		14	0,545			34	33,002			13
58	7	GRB	20/5/99	08:47		14	0,545			34	33,002			13
58	8	TBM	20/5/99	10:03	10:23	14	0,5	14	1,443	34	35,674	34	35,719	51
58	9	CTD	20/5/99	10:49		14	1,007			34	35,468			51
58	10	GRB	20/5/99	10:58		14	0,865			34	35,418			51
58	11	TBM	20/5/99	12:52	13:12	13	57,24	13	56,471	34	43,255	34	43,66	102
58	12	CTD	20/5/99	13:50		13	56,908			34	43,591			105
58	13	GRB	20/5/99	14:00		13	56,895			34	43,675			106
58	14	TBM	20/5/99	15:26	15:46	13	53,242	13	52,565	34	51,348	34	51,762	127
58	15	CTD	20/5/99	16:28		13	52,742			34	51,764			125
58	16	GRB	20/5/99	16:42		13	52,702			34	51,861			124
58	17	GRB	20/5/99	16:53		13	52,698			34	51,938			124
58	18	GRB	20/5/99	17:03		13	52,741			34	52,014			123
58	19	GRB	20/5/99	17:26		13	52,675			34	52,163			122
58	20	TBM	21/5/99	06:07	06:27	14	0,117	13	59,401	34	37,765	34	37,342	78
58	21	CTD	21/5/99	07:00		13	59,391			34	37,454			76
58	22	GRB	21/5/99	07:08		13	59,288			34	37,478			77
58	23	GRB	21/5/99	07:15		13	59,232			34	37,466			77
58	24	GRB	21/5/99	07:21		13	59,223			34	37,449			77
58	25	GRB	21/5/99	07:27		13	59,176			34	37,404			76

Cruise	Sample	Gear	Date	Time	Time	Latitude (deg)	Latitude (min)	Latitude (deg)	Latitude (min)	Longitude (deg)	Longitude (min)	Longitude (deg)	Longitude (min)	Bottom depth
				Setting	Hauling	Setting	Setting	Hauling	Hauling	Setting	Setting	Hauling	Hauling	
58	26	GRB	21/5/99	07:33		13	59,176			34	37,381			76
58	27	TBM	21/5/99	08:29	08:49	14	1,707	14	0,901	34	34,036	34	33,537	33
58	28	CTD	21/5/99	09:19		14	0,983			34	33,663			30
58	29	GRB	21/5/99	09:25		14	0,967			34	33,642			30
58	30	GRB	21/5/99	09:28		14	0,923			34	33,731			30
58	31	GRB	21/5/99	09:31		14	0,875			34	33,72			29
58	32	GRB	21/5/99	09:34		14	0,86			34	33,783			29
58	33	GRB	21/5/99	09:42		14	0,851			34	33,794			29

Appendix 2. List of fish species caught by trawling in the SWA.

Alticorpus 'geoffreyi'
Alticorpus macrocleithrum
Alticorpus mentale
Alticorpus pectinatum
Alticorpus spp.
Aristochromis christyi
Aulonocara 'blue orange'
Aulonocara 'copper'
Aulonocara guentheri
Aulonocara 'long'
Aulonocara 'cf. macrochir'
Aulonocara 'minutus'
Aulonocara rostratum
Aulonocara 'rostratum deep'
Aulonocara spp.
Bagrus meridionalis
Barbus eurystomus
Barbus johnstonii
Barbus litamba
Bathyclarias spp.
Buccochromis lepturus
Buccochromis nototaenia
Buccochromis rhoadesi
Buccochromis 'small'
Caprichromis liemi
Champsochromis caeruleus
Chilotilapia rhoadesi
Copadichromis inornatus
Copadichromis quadrimaculatus
Copadichromis trimaculatus
Copadichromis virginalis
Copadichromis spp.
Corematodus taeniatus
Ctenopharynx nitidus
Ctenopharynx pictus
Dimidiochromis sp.
Diplotaxodon apogon
Diplotaxodon argenteus
Diplotaxodon macrops
Diplotaxodon 'brevimaxillaris'
Diplotaxodon greenwoodi
Diplotaxodon limnothrissa
Diplotaxodon 'similis'
Diplotaxodon spp.
Docimodus johnstonii
Engraulicypris sardella
Exochochromis anagenis
Haplochromis 'sp.'
Hemitaeniochromis 'insignis'
Hemitaeniochromis urotaenia
Hemitilapia oxyrhynchus
Lethrinops albus
Lethrinops altus
Lethrinops argenteus
Lethrinops 'blue orange'
Lethrinops 'cf. auritus'
Lethrinops christyi
Lethrinops dark
Lethrinops 'deep water albus'
Lethrinops 'deep water altus'
Lethrinops 'cf. furcifer'
Lethrinops gossei
Lethrinops 'grey'
Lethrinops lethrinus
Lethrinops longimanus
Lethrinops longipinnis
Lethrinops macrochir
Lethrinops 'macrostoma'
Lethrinops 'matumbae'
Lethrinops microdon
Lethrinops 'minutus'
Lethrinops mylodon
Lethrinops 'oliveri'
Lethrinops 'cf. parvidens'
Lethrinops 'pink head'
Lethrinops polli
Lethrinops stridei
Lethrinops 'yellow chin'
Lethrinops spp.
Mormyrus longirostris
Mylochromis anaphyrmus
Mylochromis formosus
Mylochromis gracilis
Mylochromis melanonotus
Mylochromis sphaerodon
Mylochromis spilostichus
Mylochromis 'torpedo'
Mylochromis spp.
Nevochromis chrysogaster
Nimbochromis livingstonii
Nimbochromis polystigma
Nimbochromis venustus
Nyassachromis argyrosoma
Nyassachromis eucynostomus
Nyassachromis spp.
Opsaridium microcephallus
Opsaridium microlepis
Oreochromis spp.
Otopharynx argyrosoma
Otopharynx auromarginatus
Otopharynx brooksi
Otopharynx 'productus'
Otopharynx decorus
Otopharynx speciosus
Otopharynx spp.
Pallidochromis tokolosh
Placidochromis 'acuticeps'
Placidochromis "flatjaws"
Placidochromis 'hennydaviesae III'
Placidochromis 'hennydaviesae IV'
Placidochromis johnstonii
Placidochromis long
Placidochromis 'macrognathus'
Placidochromis 'platyrhynchos'
Placidochromis 'cf. subocularis'
Placidochromis spp.
Protomelas triaenodon
Protomelas spilopterus
Pseudotropheus elegans
Pseudotropheus lanisticola
Pseudotropheus livingstonii
Pseudotropheus spp.
Rhamphochromis spp.
Sciaenochromis alhi
Sciaenochromis benthicola
Sciaenochromis psammophilus
Sciaenochromis spp.
Serranochromis robustus
Stigmatochromis pholidophorus
Stigmatochromis woodi
Stigmatochromis 'guttatus'
Synodontis njassae
Taeniochromis holotaenia
Taeniolethrinops furcicauda
Taeniolethrinops laticeps
Taeniolethrinops praeorbitalis
Tramitichromis lituris
Trematocranus brevirostris
Trematocranus macrostoma
Trematocranus placodon
Unknown spp.

Appendix 3. Mean CPUE (kg / 20min pull) per depth for each species over the sampling period (July-1998 to May-1999).

Species	10m	30m	50m	75m	100m	125m
Alticorpus spp.	-	0,2	0,1	1,0	0,9	1,2
Alticorpus 'geoffreyi'	-	-	0,3	21,4	3,5	6,1
Alticorpus macrocleithrum	-	-	-	0,9	2,5	0,4
Alticorpus mentale	-	0,0	0,7	12,2	21,9	13,4
Alticorpus pectinatum	-	-	-	2,8	2,8	1,7
Aristochromis christyi	0,1	0,0	-	-	-	-
Aulonocara 'cf. macrochir'	0,0	0,1	1,7	-	-	-
Aulonocara spp.	0,2	-	0,2	0,5	0,0	1,1
Aulonocara 'blue orange'	5,6	5,6	0,5	-	-	-
Aulonocara 'copper'	-	-	-	0,4	-	-
Aulonocara guentheri	0,9	0,1	-	-	-	-
Aulonocara 'long'	0,0	-	0,0	0,2	0,1	0,2
Aulonocara 'minutus'	-	-	-	1,4	0,9	1,7
Aulonocara rostratum	0,0	-	-	-	-	-
Aulonocara 'rostratum deep'	-	-	0,1	1,0	0,1	0,3
Bagrus meridionalis	9,6	12,9	17,8	13,0	5,6	4,3
Barbus eurystomus	0,0	0,1	-	-	-	-
Barbus johnstonii	-	0,2	-	-	-	-
Barbus litamba	-	-	0,1	-	-	-
Bathyclarias spp.	11,3	10,4	49,8	23,1	19,7	9,3
Buccochromis lepturus	3,7	0,6	-	-	-	-
Buccochromis nototaenia	1,0	2,3	0,1	-	-	-
Buccochromis rhoadesi	0,5	0,1	-	-	-	-
Buccochromis 'small'	0,0	-	-	-	-	-
Caprichromis liemi	-	0,0	0,0	-	-	-
Champsochromis caeruleus	0,1	0,1	-	-	-	-
Chilotilapia rhoadesi	1,4	1,1	-	-	-	-
Copadichromis inornatus	0,1	-	-	-	-	-
Copadichromis quadrimaculatus	0,9	2,6	1,1	0,1	-	-
Copadichromis spp.	0,1	0,0	-	-	-	-
Copadichromis trimaculatus	-	-	-	-	-	0,0
Copadichromis virginalis	0,7	16,7	47,7	-	0,1	-
Corematodus taeniatus	0,0	0,0	0,0	0,0	-	-
Ctenopharynx nitidus	0,2	0,1	-	-	-	-
Ctenopharynx pictus	-	-	0,1	-	-	-
Dimidiochromis sp.	0,0	-	-	-	-	-
Diplotaxodon apogon	-	-	-	5,0	5,4	4,0
Diplotaxodon argenteus	-	-	1,0	4,4	2,9	2,2
Diplotaxodon spp.	-	-	-	0,3	0,5	0,5
Diplotaxodon 'brevimaxillaris'	-	-	0,0	0,1	0,2	0,6
Diplotaxodon greenwoodi	-	-	-	0,1	0,3	0,2
Diplotaxodon limnothrissa	0,1	-	9,7	13,4	9,3	2,7
Diplotaxodon macrops	-	-	-	7,3	18,9	16,0
Diplotaxodon 'similis'	-	-	-	0,0	-	0,1
Docimodus johnstonii	0,1	0,0	0,3	-	-	-
Engraulicypris sardella	0,0	0,0	-	0,0	0,0	-
Exochromis anagenis	-	-	0,0	-	-	-
Haplochromis 'sp.'	-	-	0,0	-	-	-
Hemitaeniochromis 'insignis'	-	-	0,0	0,1	0,0	0,1
Hemitaeniochromis urotaenia	0,1	-	0,0	-	-	-
Hemitilapia oxyrhynchus	-	-	-	-	-	-
Lethrinops christyi	0,3	0,0	1,0	-	-	-
Lethrinops 'matumbae'	-	1,0	0,0	-	-	-
Lethrinops 'deep water albus'	-	-	1,4	3,5	0,0	4,8

Species	10m	30m	50m	75m	100m	125m
Lethrinops albus	-	-	0,2	0,0	-	0,6
Lethrinops altus	0,2	2,6	2,1	1,8	1,4	4,6
Lethrinops spp.	1,0	0,1	2,0	0,5	0,1	0,4
Lethrinops 'blue orange'	-	0,6	-	-	-	-
Lethrinops 'cf. auritus'	0,0	-	-	-	-	-
Lethrinops dark	2,6	0,3	4,1	0,3	0,3	1,5
Lethrinops 'deep water altus'	-	-	-	1,0	4,7	2,2
Lethrinops 'cf. furcifer'	1,1	0,1	-	-	-	-
Lethrinops gossei	-	-	0,2	32,0	40,0	34,4
Lethrinops 'grey'	-	-	-	-	1,0	-
Lethrinops lethrinus	0,2	-	-	-	-	-
Lethrinops longimanus	-	0,5	7,3	0,2	1,1	0,1
Lethrinops argenteus	20,3	23,9	40,7	0,1	0,0	0,2
Lethrinops macrochir	3,5	-	-	-	-	-
Lethrinops 'macrostoma'	-	-	-	0,0	-	-
Lethrinops microdon	1,0	-	0,1	0,0	0,0	-
Lethrinops 'minutus'	0,0	-	3,5	-	-	-
Lethrinops mylodon	-	0,2	0,1	-	0,2	-
Lethrinops 'oliveri'	-	-	-	18,2	8,3	3,6
Lethrinops 'cf. parvidens'	0,4	0,0	0,1	-	-	-
Lethrinops 'pink head'	0,2	-	-	-	-	-
Lethrinops polli	-	-	-	7,0	1,2	0,2
Lethrinops stridei	-	-	-	-	0,0	-
Lethrinops 'yellow chin'	-	-	0,9	-	-	-
Mormyrus longirostris	-	-	-	-	-	0,1
Mylochromis anaphyrmus	4,6	8,6	2,3	0,0	-	-
Mylochromis formosus	0,1	0,1	0,2	-	-	-
Mylochromis gracilis	-	0,2	0,2	0,5	-	-
Mylochromis spp.	0,2	0,1	-	-	-	-
Mylochromis melanonotus	0,3	0,2	-	-	-	-
Mylochromis sphaerodon	0,0	0,0	-	-	-	-
Mylochromis spilostichus	0,4	0,5	7,4	-	-	-
Mylochromis 'torpedo'	0,0	-	-	-	-	-
Nevochromis chrysogaster	0,0	-	-	-	-	-
Nimbochromis livingstonii	0,1	0,0	0,2	0,1	-	-
Nimbochromis venustus	0,0	-	-	-	-	-
Nyassachromis argyrosoma	28,6	31,7	0,9	-	-	-
Nyassachromis spp.	0,5	0,3	-	-	-	-
Nyassachromis eucynostomus	0,5	0,1	-	-	-	-
Nimbochromis polystigma	0,0	-	-	-	-	-
Opsaridium microcephallus	-	0,0	-	-	-	-
Opsaridium microlepis	-	0,0	0,7	0,2	-	-
Oreochromis spp.	27,7	1,1	7,8	0,1	-	-
Otopharynx argyrosoma	2,2	2,2	0,1	-	-	-
Otopharynx auromarginatus	-	-	-	-	-	-
Otopharynx brooksi	-	-	-	0,5	0,0	0,0
Otopharynx 'productus'	0,7	0,0	-	-	-	-
Otopharynx decorus	0,4	0,4	-	-	-	-
Otopharynx spp.	0,2	-	-	-	-	0,0
Otopharynx speciosus	-	0,8	2,1	0,1	-	-
Pallidochromis tokolosh	-	-	0,1	1,8	0,6	2,9
Placidochromis 'acuticeps'	-	-	-	-	-	0,1
Placidochromis "flatjaws"	-	-	-	0,0	1,3	0,3
Placidochromis spp.	-	-	0,0	0,3	0,0	-
Placidochromis 'macrognathus'	-	0,0	0,0	0,0	0,0	0,1
Placidochromis 'hennydaviesae III'	-	-	-	-	-	0,1
Placidochromis 'hennydaviesae IV'	-	-	-	-	-	0,1
Placidochromis johnstonii	-	0,0	-	-	-	-

Species	10m	30m	50m	75m	100m	125m
Placidochromis 'long'	-	0,4	1,7	-	-	-
Placidochromis 'platyrhynchos'	-	-	-	0,0	1,1	4,1
Placidochromis 'cf. subocularis'	0,1	0,0	-	-	-	-
Protomelas spilopterus	0,0	0,0	-	-	-	-
Protomelas triaenodon	0,0	-	-	-	-	-
Pseudotropheus elegans	0,1	0,1	-	-	-	-
Pseudotropheus lanisticola	-	-	-	-	-	-
Pseudotropheus livingstonii	1,1	0,1	-	-	-	-
Pseudotropheus spp.	-	0,0	-	-	-	-
Rhamphochromis spp.	0,6	3,9	8,5	4,2	0,7	0,6
Sciaenochromis spp.	0,1	0,0	0,0	-	-	-
Sciaenochromis alhi	0,4	0,1	0,1	0,3	0,2	0,2
Sciaenochromis benthicola	0,1	0,5	3,1	1,4	0,2	0,0
Sciaenochromis psammophilus	-	-	-	0,1	-	-
Serranochromis robustus	0,1	-	-	-	-	-
Stigmatochromis pholidophorus	0,0	-	-	-	-	-
Stigmatochromis woodi	0,0	0,0	0,1	0,0	-	0,0
Stigmatochromis 'guttatus'	0,0	-	0,5	0,3	0,0	0,0
Synodontis njassae	2,5	7,2	8,8	6,4	11,8	11,7
Taeniochromis holotaenia	0,0	0,0	-	-	-	-
Taeniolethrinops furcicauda	1,3	0,0	-	-	-	-
Taeniolethrinops laticeps	-	0,2	-	-	-	-
Taeniolethrinops praeorbitalis	1,1	0,3	-	-	-	-
Tramitichromis lituris	0,8	-	-	-	-	-
Trematocranus brevirostris	-	0,0	6,6	-	-	-
Trematocranus macrostoma	0,0	-	-	-	-	-
Trematocranus placodon	1,3	-	-	-	-	-
Minimum number of species per depth	**80**	**71**	**66**	**58**	**47**	**48**