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

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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

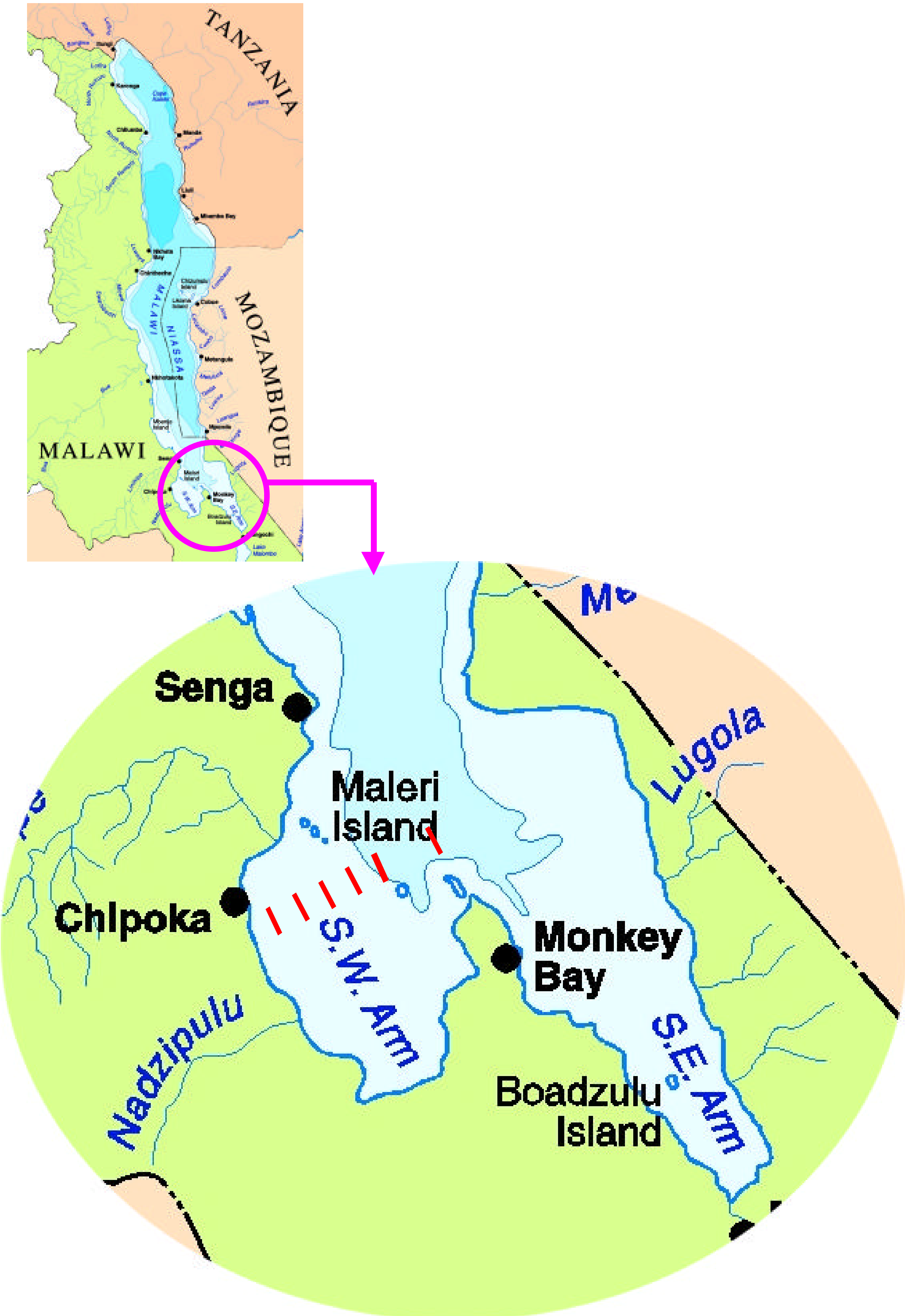

Figure C1. The southern part of the Lake Malawi/Nyasa showing the South West Arm (SWA) and the South East Arm (SEA). The bars represent the monthly sample sites at 10, 30, 50, 75, 100 and 125m depths.

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 m^3 at 10m depth to 277,868.04 m^3 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 (°C), oxygen concentration (mg.l^{-1}), conductivity (mS.cm^{-1}), water clarity (% transmission), fluorescence (arbitrary unit).

<u>Grab samples</u>

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.

<u>Determination of sediment particle size:</u>

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).

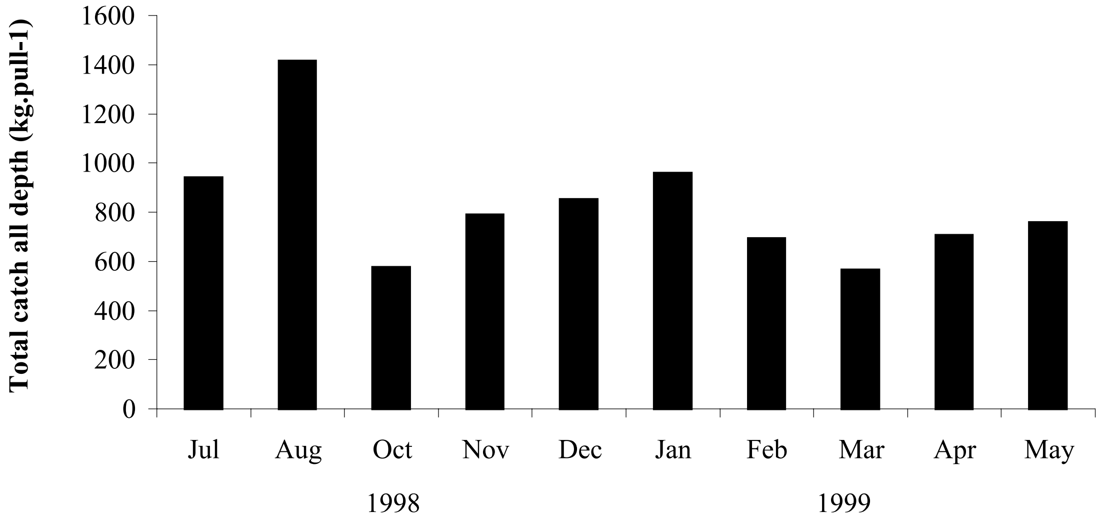

Figure C2. Total catches all depths pooled over the full sampling period (July 1998-May1999).

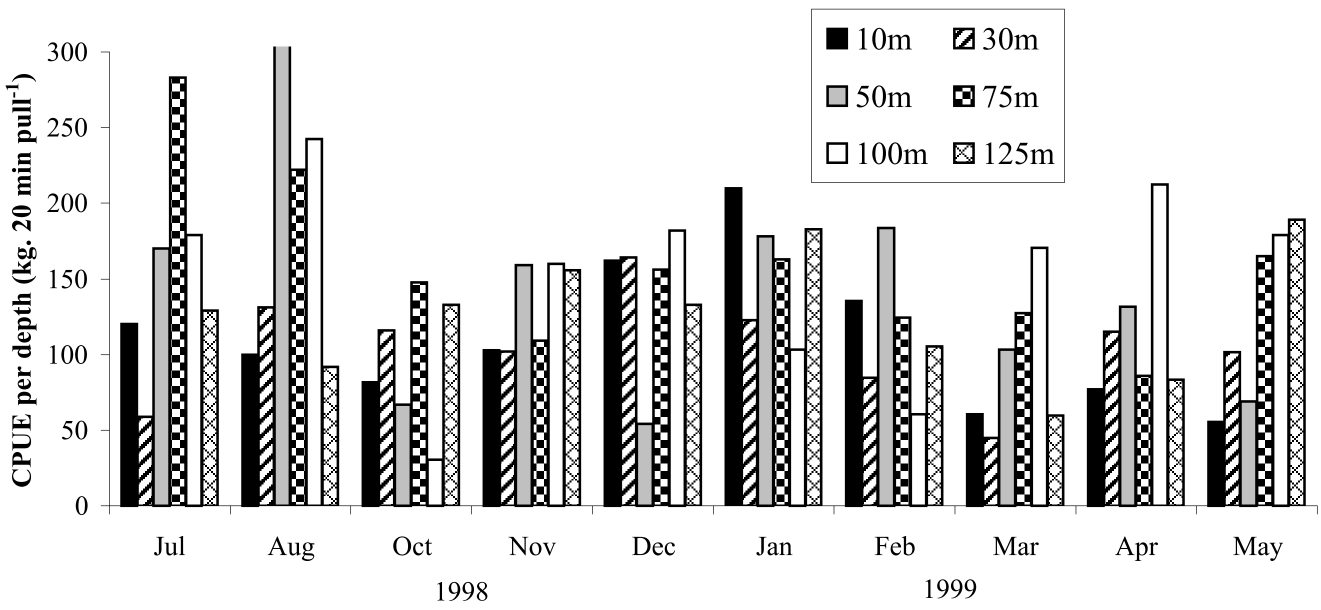

Figure C3. CPUE per depth over the full sampling period (July 1998-May1999).

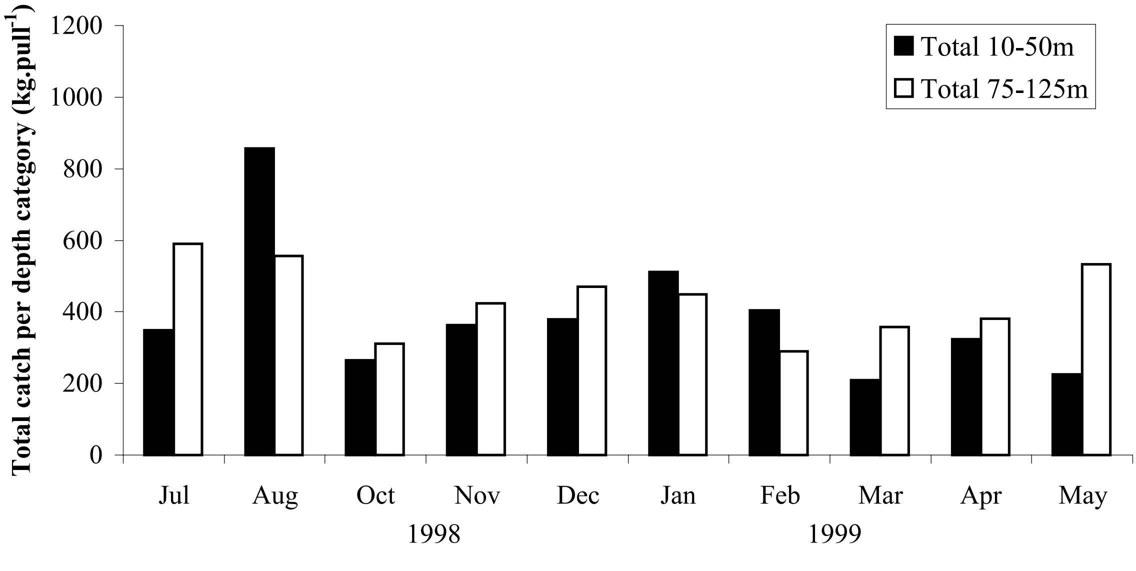

Figure C4. Total catch per depth category over the full sampling period (July 1998-May1999).

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).

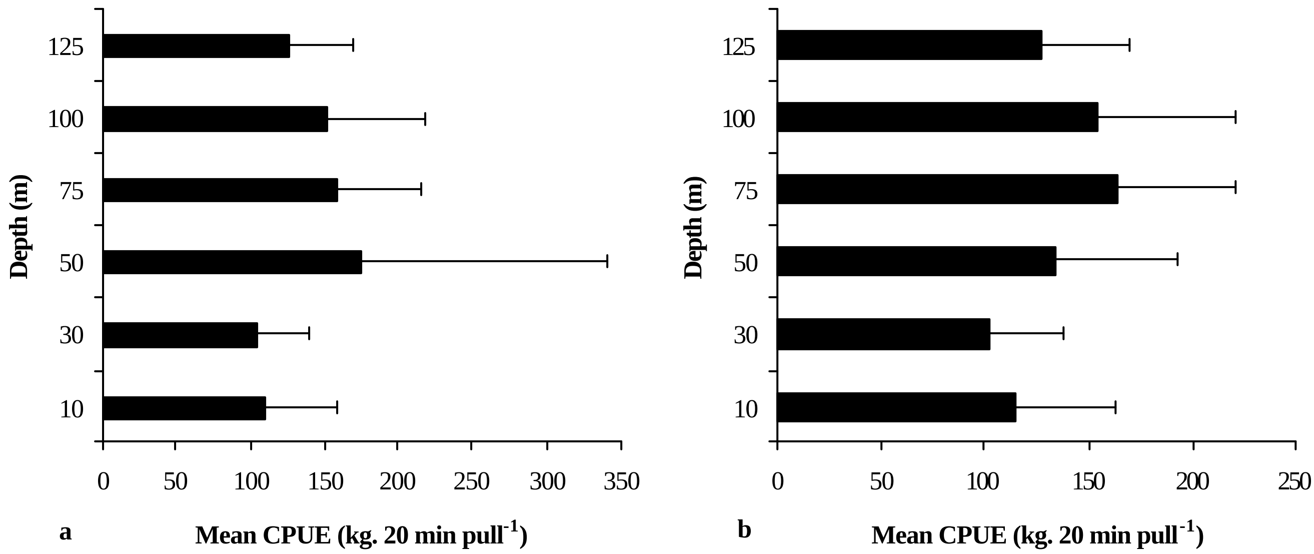

Figure C5. Mean CPUE (kg / 20 min pull) per depth (± standard deviation) over the full sampling period in the SWA (July-98 to May 99) (a) and with the exceptional *Bathyclarias spp*. catch removed (b), see text.

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).

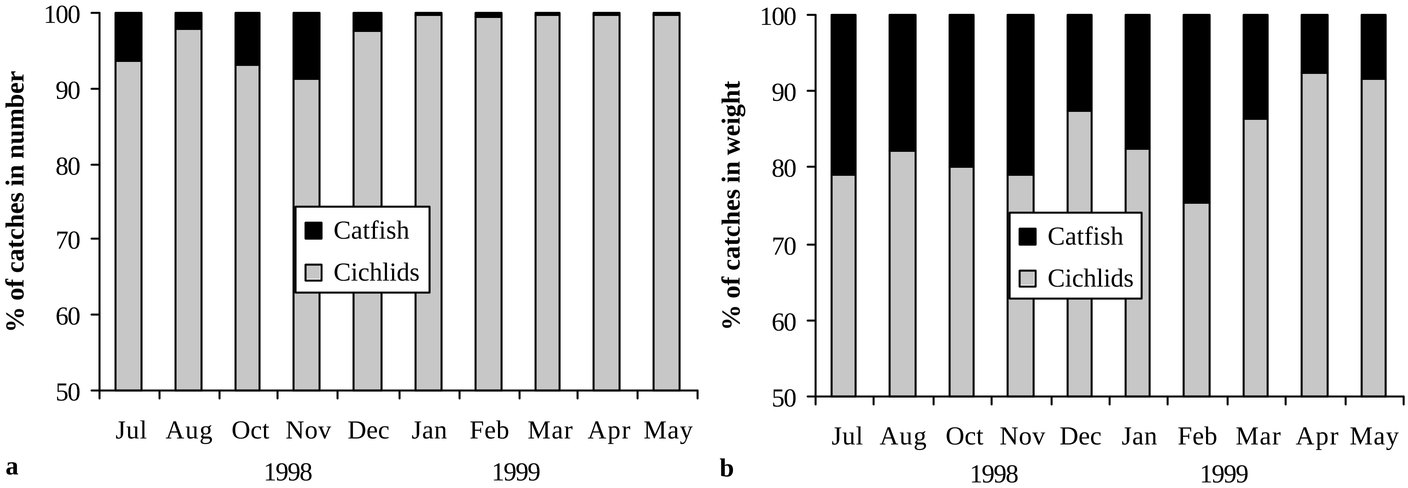

Figure C6. Proportions of cichlids and catfishes in the catches over the sampling period (July-98 to May-99), in number (a) and weight (b).

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).

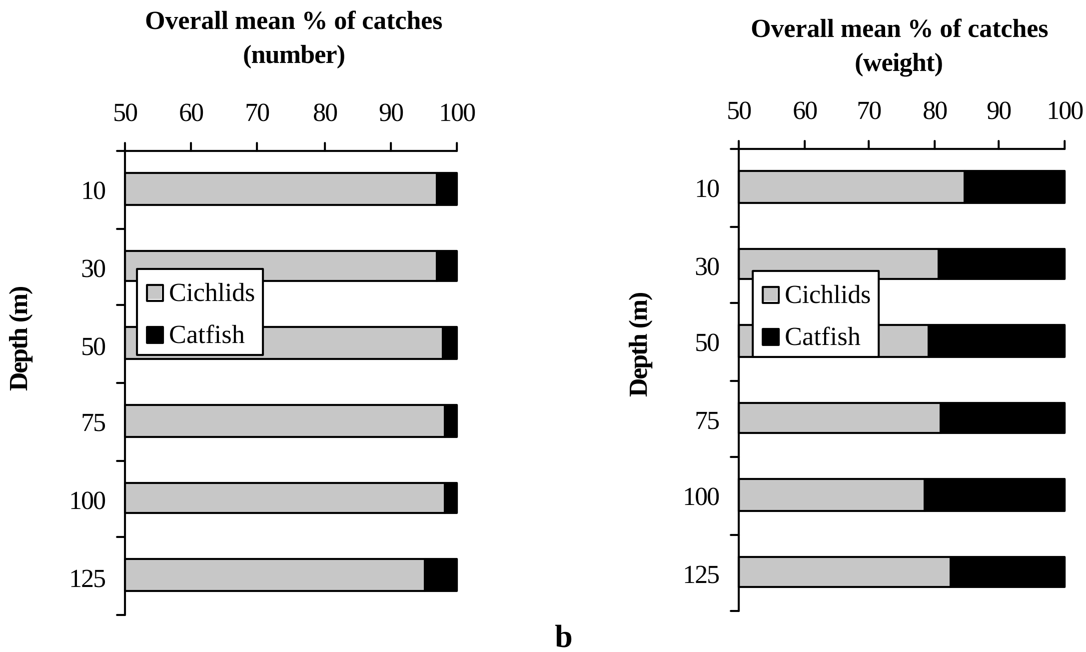

Figure C7. Proportions of cichlids and catfishes in the catches per depth all months pooled, in number (a) and weight (b).

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.

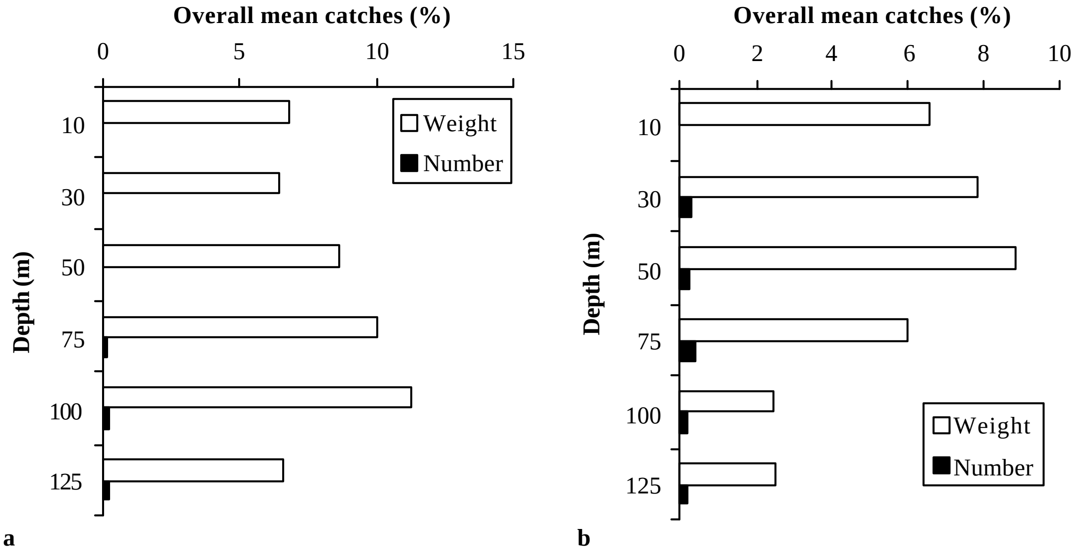

Figure C8. Overall mean catches (in proportion of weight and number) per depth for *Bathyclarias spp*. (a) and *Bagrus meridionalis* (b) from July 98 to May 99.

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).

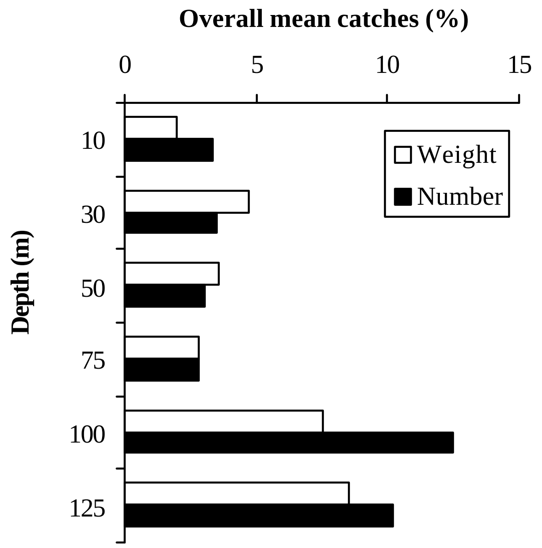

Figure C9. Overall mean catches (in proportion of weight and number) per depth for *Synodontis njassae* from July 98 to May 99.

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

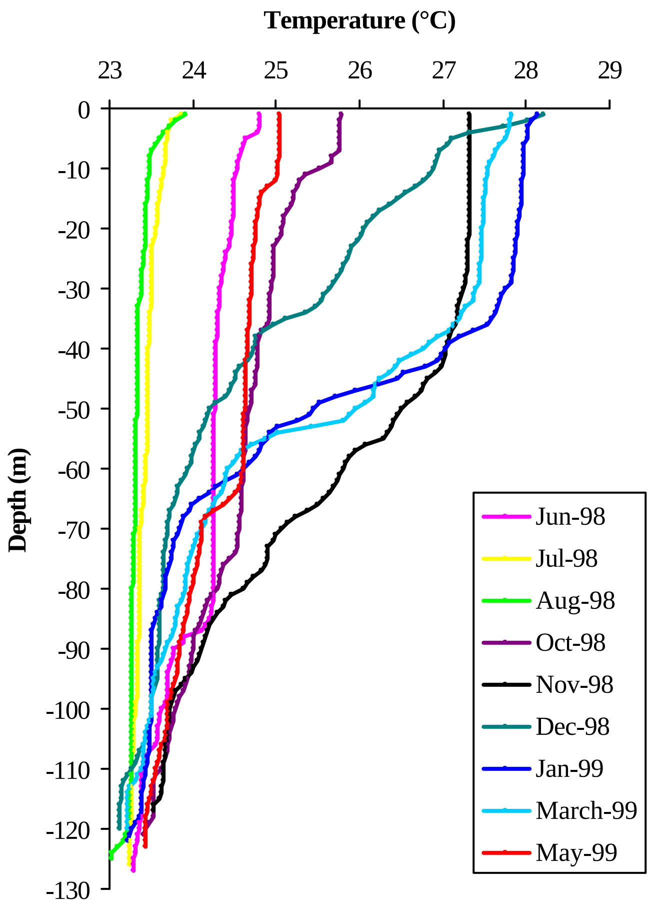

Figure C10. Seasonal progression of temperature profile according to depth off Cap Maclear, SWA.

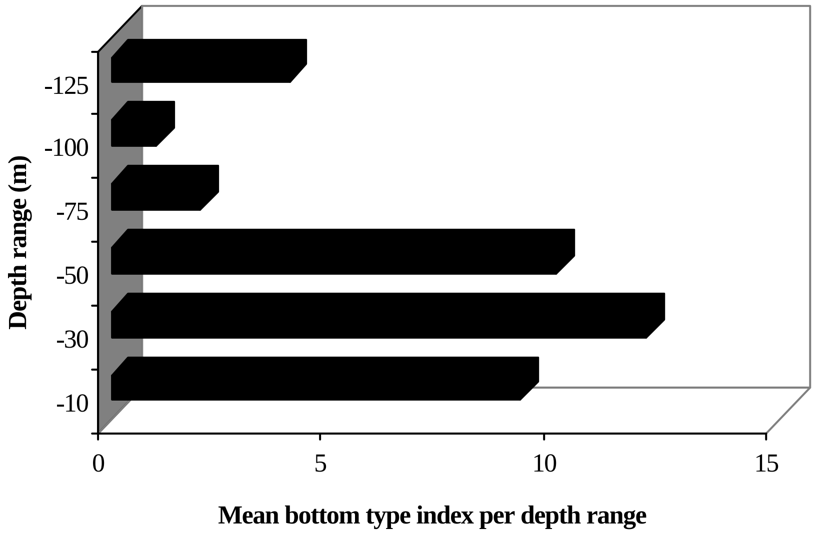

Figure C11. Modification of bottom type with depth in the SWA. Each bottom type category was given an arbitrary value for graphic representation: 15 for "very coarse sand", 10 for "medium sand", 5 for "very fine sand" and 0 for "mud". The values are the means over five months (June to December 1998).

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.