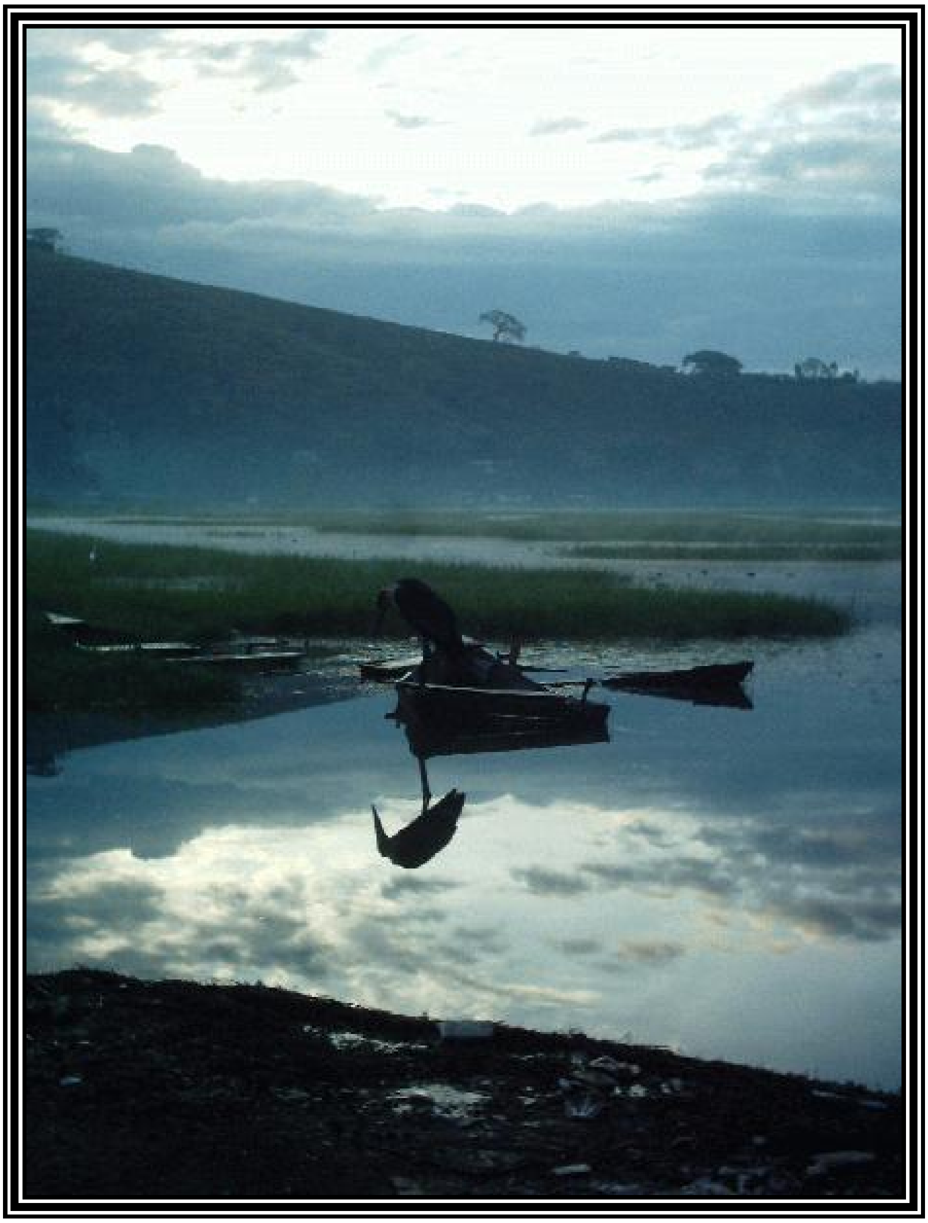
THE FISHERIES IN LAKE AWASSA, ETHIOPIA; ESTIMATION OF ANNUAL YIELD



MSc thesis
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2004

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Abstract

A number of different assumptions of species composition and annual yields of fish in Ethiopian freshwater lakes exist in available published literature. The fisheries have been characterized as overexploitations, but little is known about the actual effects the current landings have on the stocks. Therefore the landings by the fishermen at the most important local fish market at Lake Awassa recorded by counting number of boats and random sampling of catches, in three periods from February 2003 to February 2004. Experimental gill netting was conducted to obtain samples from the populations in order to analyze size structure related to maturation, especially within the tilapia species *Oreochromis niloticus*. Landings were entirely dominated by one species, *O niloticus,* with a consistent increase in landings during the dry season. Landings were estimated to 576 – 741 metric tons year $^{-1}$ of *O. niloticus*, 18 – 58 tons year $^{-1}$, of *Clarias gariepinus,* and 2 - 13 tons year $^{-1}$ of *Barbus* spp. The individual length of *O. niloticus* in the catches is >180 mm. The length at first maturity seems to have decreased with 20 – 50 mm during a relatively short period of time, probably due to a higher fishing pressure. The two other species (*C. gariepinus* and *Barbus* spp) seems to be little affected by the fishing pressure.

Sammendrag

Det eksisterer en rekke forskjellige antagelser om artsammensetningen og årlig avkastning av fisk i Etiopiske innsjøer i tilgjengelig publisert litteratur. Fiskeriene har vært karakterisert som overutnyttelse, men den faktiske effekten de nåværende fangstene har på fiskebestandene vet man lite om. Derfor ble fangstene til fiskerne på det viktigste lokale fiskemarkedet i Awassasjøen registrert ved å telle antall båter observert og tilfeldige prøver av fangstene i tre perioder fra februar 2003 til februar 2004. Et prøvefiske ble utført for skaffe prøver av bestandene for å analysere lengdestruktur relatert til kjønnsmodning, spesielt innenfor en tilapia art, *Oreochromis niloticus*. Fangstene var fullstendig dominert av en art, *O niloticus,* med en konsis økning i fangstene i tørketiden. Fangstene ble estimert til 576 – 741 tonn år $^{-1}$ av *O. niloticus*, 18 – 58 tonn år $^{-1}$ av *Clarias gariepinus,* og 2 - 13 tonn år $^{-1}$ av *Barbus* spp. Den individuelle lengden i fangstene av *O. niloticus* er >180 mm. Lengden ved første gangs kjønnsmodning ser ut til å ha avtatt med mellom 20 og 50 mm i løpet av en relativ kort periode, sannsynligvis på grunn av et høyere fisketrykk. De to andre artene (*C. gariepinus* and *Barbus* spp) ser ut til å være lite påvirket av fisket.

1. Introduction

Ethiopia is classified as being among the least developed countries in the world. The annual population growth rate is 2.9 % (Breuil 1995). Until recently Ethiopia had a solid fish potential estimated at over 80 000 t/year, of which about 50 000 tons per year came from marine waters (Breuil 1995). The contribution of fisheries to GDP is very small, and would remain so even if the maximum economic yields were actually extracted (Breuil 1995). Ethiopia is a developing country with sparse industrial and other major human activities demanding a big scale usage of the water resources (Zinabu et al 2002). The pressure from different human activities on the limited freshwater resources is increasing. Due to traditions, Ethiopian freshwater fish resources have been utilized at very small scales. The commercial fisheries as present today began at a very small scale, and during the last decades they have developed to cover most of the countries freshwater systems (Reintjens & Wudneh 1998). The importance of today's fisheries is difficult to evaluate because most of the fish is being distributed trough the local community at remote areas (Reintjens & Wudneh 1998). However, in Lake Awassa fish stocks are reported to show signs of over fishing. The landings was estimated to an average of 910 tons per year during 1991 – 1996, but dropped with nearly 50% in 1995 and 1996, and recovered somewhat in 1996/97(Reintjens & Wudneh1998).

In 1996/1997, the total number of fishermen in Ethiopia was believed to be more than 3000, and their total landings was estimated to 10400 tons from lakes Abaya, Awassa, Chamo, Langano, Tana, Ziway and Koka reservoir (fig 1) (Reintjens and Wudneh 1998). The national average fish consumption is the lowest in Africa, and fish eating habits have been mainly influenced by the Orthodox Church which encourages the eating of fish during the fasting (Breuil 1995). The development of the fisheries has considerably benefited from external assistance. Non Governmental Organizations such as the Interchurch Foundation Ethiopia and the Interchurch Organization for Development Cooperation have been active all over the country. The EU has been the biggest donor: In the 80`s, a first phase of the Lake Fisheries Development Project (LFDP) covered some of the rift valley lakes. It lead to the introduction of improved fishing technologies and made surveys of the fish stocks on two lakes (Ziway and Abaya), while phase two started in 1992 and concentrated on the rift valley lakes and Lake Tana (Reintjens et al 1998). Between 1992 and 1997, total landings increased by 220% (from 3250 to 10400 tons). Several of the stocks shows signs of over fishing (Reintjens & Wudneh 1998) and for some of the stocks, like the Nile perch (*Lates niloticus*) stock in Lake Chamo, the yields have collapsed (Reintjens et al 1998). Some part of the increase in landings is only apparent as production data until the end of 1993 represent landings recorded by fisheries officers. For instance the official figures for the landings from Lake Awassa in 1992 and 1993 were 300 and 415 tons while a "back-of-the-envelope-calculation" based on the records of catch per fishermen and the number of fishermen give estimates of 940 and 860 tons instead (Reintjens & Wudneh

1998). Estimates of the potential yield have been calculated from different empirical methods on individual lakes (surface area, mean depth and conductivity). According to the methods used, differences are large and conservative estimates of potential yield ranges from 30 000 to 40 000 tons year $^{-1}$ for the main Ethiopian water bodies (Breuil 1995).
Latest available estimates in published literature of safe production levels based on stock assessment studies are relatively less optimistic (about 8300 tons), but does not include the fishery for common carp in Koka dam (Reintjens & Wudneh 1998), or that a pelagic fishery with landings of about 10 000 tons could eventually be developed in Lake Tana (Reintjens et al 1998).

Published records on landings from African lakes are sparse available in general, and from Ethiopian lakes records are scanty in particular. Among the given estimates available, few distinguish between the species composition in the landings and among the given estimates the variation is large. The relative distribution among species is also given in weight, and does not consider the relative large species-specific difference in size among them.

Since the available landing estimates are highly various, and the latest and most accurate estimates from Lake Awassa in Ethiopia were characterized as ”back-of-the-envelope-calculations”, my study aims to estimate the size of the current landings in this lake. The region is characterized by two distinct seasons per year. Sampling was therefore conducted twice in the dry season and once in the rainy season to estimate the landings in both seasons, and to get a total estimate for a whole year.
To examine which proportions of the fish stocks were affected by the fishery (i.e. which length classes the landings consisted off), length distribution in the landings as well as in experimental gill net catches were recorded.

2. Study area

2.1 Lake Awassa

Lake Awassa (Lat: 6^0 33'-7^0 33' N; Long: 38^0 22' – 38^0 29' E) is located at an altitude of 1680 m in the Ethiopian rift valley (fig 1).
The region is characterized by a dry sub humid climate, with monthly mean minimum air temperature between 7.0 ^{0}C and 13.7 ^{0}C and maximum air temperature between 23.0 ^{0}C and 32 ^{0}C. Surface water temperature of the lake ranged from 17.8 ^{0}C to 25.2 ^{0}C in 1987/1988 (Admassu & Casselman 2000).
The position of the inter-tropical- convergence zone (ITCZ), which is a low-pressure area of convergence between tropical easterlies and equatorial westerlies, over Ethiopia, was advanced as a major explanation for the seasonal distribution of rainfall. In general this means that there is a humid regime prevails

towards Equator and dry conditions prevail north of the ITCZ. The Rift Valley climate is generally characterized by a four-month dry season (November-February) and an eight-month rainy season (March-October) (Gamachu 1977, cited by Tudorancea et al. 1999). Rainfall is subject to important variability according to altitude. In general, the plateaus over 2 500 m receive 1 400 - 1 800 mm year $^{-1}$, mid-altitude regions (600 - 2 500 m) receive 1 000-1 400 mm year $^{-1}$, and coastal lowlands get less than 200 mm year $^{-1}$ (Breuil 1995)

Lake Awassa lacks any obvious outlet, but is fed by a small river, the Tikur Weha. There is a regular annual fluctuation in water level. In the dry season the water level decreases with more than 1 m compared to rainy season levels (Admassu & Casselman 2000) (fig 2). The lake water level also fluctuates considerably over the years in response to variations in rainfall and evaporation. Due to the fluctuations, the maximum depth and surface area varies. It was assessed by Zinabu et al. (2002) that the water level of Lake Awassa has been either maintained or increased (despite the drought), presumably due to seepage-in of dilute subterranean water and/ or surface inflow. According to Kebede et al. (1994) the surface area is 90 km^2, the max depth is 22 m, the mean depth is 11 m, and the catchment area 1250 km^2.
Lake Awassa and most of the nearby lakes are by any means salt and rich in nutrients (Kebede et al. 1994). However, compared with other rift valley lakes, Lake Awassa is relatively dilute. As an example, the nearby Lake Chitu and Lake Abijata (fig 1) have conductivities of 49100 μS cm $^{-1}$ and 28130 μS cm $^{-1}$ respectively. Especially saline is Lake Chitu with a salt-concentration of 44.9 g l $^{-1}$ (Kebede et al 1994).

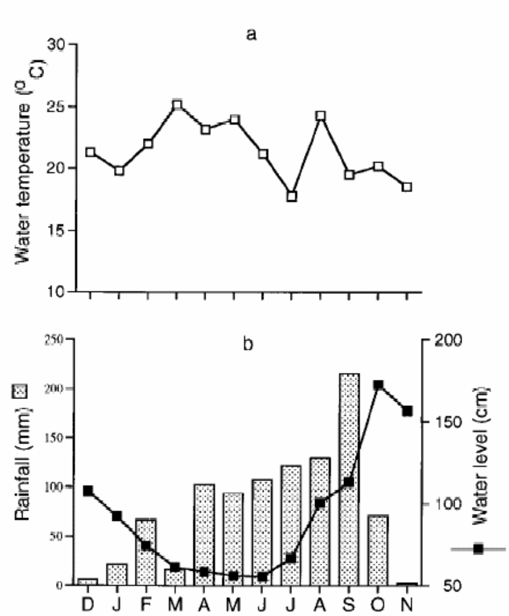


Figure 2 Surface water temperatures of Lake Awassa (a) and monthly total rainfall for the region and water level of the lake (b) between December, 1987 and November, 1988 (From Admassu & Casselman, 2000).

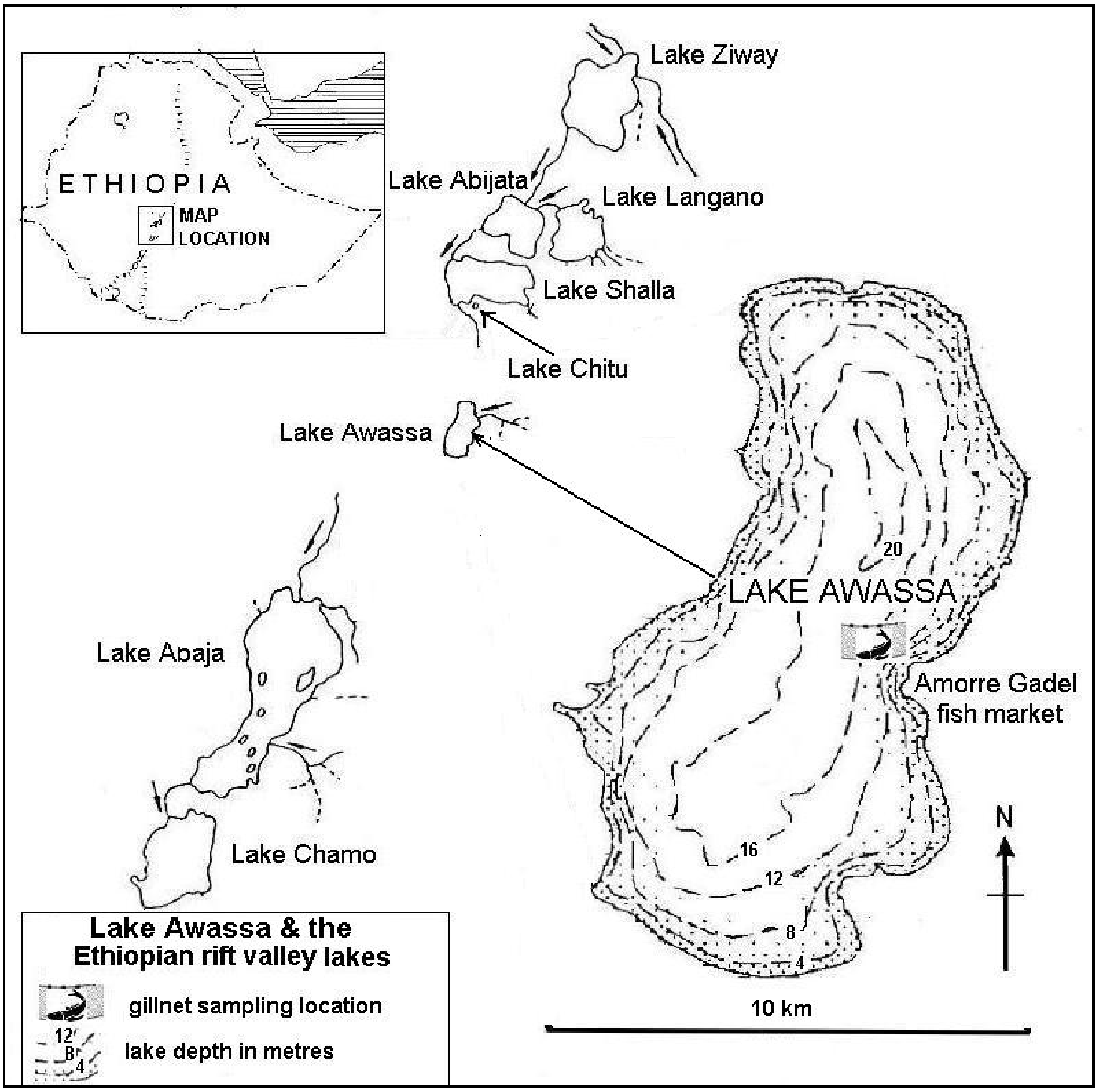


Figure 1 Depth map of Lake Awassa and its geographical position among the other rift valley lakes in Ethiopia.

Nitrate appears to be the nutrient that limits the phytoplankton production in Lake Awassa. A stable stratification was found to develop during January to May followed by a complete mixing in May due to cooling and an influx of cold rain water (Kebede & Belay 1994). The concentration of phosphates was found to increase with mixing and/or rainfall resulting in an increase in phytoplankton biomass during the periods December to January and June to July. Anoxic conditions at the deepest part of the lake can occur when the lake become thermal stratified (Kebede & Belay 1994).

A considerable was found decrease in conductivity and ionic concentrations when comparing data from the 1960s and 1980s with data from 1999 - 2000. The conductivity sank from 1176 $\mu S\ cm^{-1}$ in 1961 to 846 $\mu S\ cm^{-1}$ in 1999 - 2000. A consistent decrease in chlorophyll a values has also been noticeable in Lake Awassa during the 1990`s compared to values recorded during 1980 - 1986. These decreases are believed to be due to the increased water level mentioned above (Zinabu et al 2002).

2.2 Phyto- and zooplankton

The dominant phytoplankton species are *Lynbya nyassae, Botryococcus braunii* and *Microcystis* spp. (Kebede & Belay 1994). The dominant zooplankton species are *Mesocyclops aequatorialis, Thermocyclops consimilis, Diaphanosomsa excium*, and typical cosmopolitan species of *Brachionus* and *Keratella* (Mengistou & Fernando 1991, Mengistou et al. 1991). The littoral is covered by an extensive belt of submerged and emergent rooted vegetation that provides spawning and nursery grounds for *O. niloticus*. The shallow area between 0.5 and 1 m depth is covered by *Potamogeton schweifurtii* and the water lily *Nymphaea coruela*. Further offshore down to 3 – 4 m depth is a sub zone dominated by the emergent plant *Paspalidium geminatium* (Tudorancea et al. 1988) (fig 3).

Figure 3 Littoral area in Lake Awassa covered with vegetation. The fish market Amorre Gadel is located at the sandy white “beach” on the promontory in the upper left of the picture

2.3 The fish community

The fish community in Lake Awassa consists of minimum six species. The species collected in this study was Nile tilapia (*Oreochromis niloticus niloticus* Linnaeus, 1758) (fig 4), North African catfish (*Clarias gariepinus* Burchell 1882) (fig 4) and Straightfin barb (*Barbus paludinosus* Peters 1852) (fig 5).

Figure 4 Left photo *Oreochromis niloticus* (160 mm TL) and right photo *Clarias gariepinus* (480 mm TL)

The species mentioned above are determined to species level in Lake Awassa. For the *Barbus* spp (fig 6) and the *Garra* spp (fig 5) this is still left to be determined. The *Garra* spp found in this study was very low in numbers, with maximum size 123 mm (TL), while *B. paludinosus* was found in considerable amounts, with maximum size 160 mm (unpublished data). Another relatively small species (max-size = 45 mm TL); Black lampeye (*Aplocheilichthys antinorii*, Vinciguerra 1883) has been demonstrated in the lake by others (Harrison 1985).

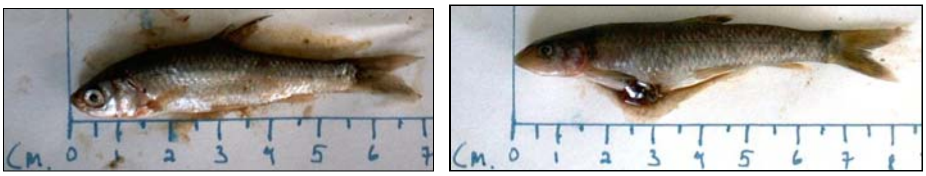


Figure 5 Left photo *Barbus paludinosus* (70 mm TL) and right photo Garra spp (85 mm TL).

There are no publications available neither on *Garra* spp, *B. paludinosus* nor *A. antinorii* from Lake Awassa or any of the other lakes in Ethiopia. Another ongoing study will illuminate some of the aspects regarding this species (Zerihun Desta pers. comm.).

Figure 6 Large piscivorous Barbus spp, 610 mm (left photo) and smaller omnivorous Barbus spp, 250 mm (right photo)

2.4 The fish market, Amorre Gadel

There are currently two landing sites for fish at Lake Awassa. One of them, Amorre Gadel (see figure 7) is located close to Awassa city, and is the largest by number of boat present on a daily basis. The other landing site is located in a rural area and is not that persistent. There are not that many boats there and the fishermen do not use it on a daily basis as they tend to sell their fish elsewhere around the lake depending on distance from their fishing grounds and the price achieved elsewhere. However, during the fasting periods of the Orthodox Church followers (March/April, early half of August) (Dadebo 2000), price for fish more than doubles at Amorre gadel, and most of the boats go there to achieve the highest price available. This demand and offer mechanism totally determines the price for fish: At Amorre gadel the price for one “big” tilapia increases from 0.5 birr to 1.0 birr (0.06 to 0.12 US$) during the fasting periods (The fishermen divide the fish in groups of either “small”, “big” or “very big” before it is sold). This sudden doubling in price shows a similar drop immediately after the fasting period.

The boats arrives at the marked from 06.00 – 08.00 in the morning, and dependent on the catches and the demand for fish, the marked period is over within 4 – 6 hours.

The vessels used by the fishermen are exactly similar wooden boats operated by oars (fig 7). Some of the fishermen have their fishing grounds on the opposite side of the lake and travels considerable distance to deliver their daily catch (fig 1 & 3). There are two fishermen in each boat operating their own set of gill nets. One of them has the front, while the other has the hindmost part of the boat as his place of work.

Figure 7 Amorre gadel fish marked, Awassa, Ethiopia.

The relative value of the fish sold at Amorre gadel is only a part of the “economy” such markets produces in developing countries. Besides the fishermen and the merchandisers there are more people (fig 7) depending on the daily landings of fish from Lake Awassa than there are fishermen: In 2000 the UNICEF report “Children working on the streets of Ethiopia” estimated the number of children working as assistants to the fishermen of Lake Awassa to be about 360. Another study conducted to determine the presence of fish tape worm and other helminthic parasites (Yared et al. 2001) took samples from 150 male children less than 15 years of age involved in fishing and fish processing activity. Most of the children were aged 10-15 years (55.3%) and the remaining (44.7%) were between 5-9 years. Many of these children get their daily protein needs covered by eating raw fish directly from the fish boats (figure 7). As an effect of eating raw fish the overall prevalence rate of intestinal helminthic infection amongst these children was 92.7 % (Yared et al 2001).

3. Methods and materials

3.1 Landing estimates

To estimate the total catch of fish taken by the commercial fisheries in Lake Awassa, I used a method for roving creel survey with no uniform probability sampling as described by Malvestuto et al. (1978) which was modified to the conditions found in Lake Awassa. The method was originally designed to conduct creel surveys to estimate fishing success, total effort and thus total harvest using a method of stratified random sampling, but the procedure appears to be readily adaptable to a wide variety of field situations and has applications in both access point and roving creel surveys (Malvestuto et al. 1978).
Between 4 February 2003 and 5 February 2004 I registered the number of fish boat $^{-1}$ and the number of boats at Amorre Gadel at three occasions. The dry season was sampled in February/March 2003 and January /February 2004, while the rainy season was sampled in August/September 2003. The number of boats present at the fish market in the sampling periods is given in table 1.
Number of boats operating on Lake Awassa varies through the year, due to incidental maintenance and replacement of the boats which are easily wrecked (fig 8).

Table 1 Number of boats sampled and number of boats observed at Amorre Gadel 04.02.03 – 05.02.04. * = Christian Orthodox fasting period.

Date	Number of boats in sample	Number of boats observed
04.02.03	5	77
08.02.03	4	68
10.02.03	3	75
15.02.03	4	73
20.02.03	6	71
05.03.03	5	104*
11.03.03	3	108*
17.08.03	8	80
18.08.03	8	85
19.08.03	8	83
21.08.03	8	86
22.08.03	8	85
23.08.03	9	68
24.08.03	8	70
25.08.03	10	74
26.08.03	9	70
27.08.03	8	73
28.08.03	10	74
29.08.03	9	76
22.01.04	8	72
23.01.04	7	64
24.01.04	7	71
27.01.04	6	85
02.02.04	8	71
03.02.04	8	79
04.02.04	7	74
05.02.04	8	76

To get access to register the fish before it was sold, one of the fishermen was hired to communicate with the others, since they speak several different languages. When prices are high, and demand for fish even higher the fishermen would rather sell the fish than letting us count it, so without assistance the sampling would have been impossible. The boats in the samples were randomly chosen when they arrived to the shore to sell their daily catch. The number of fish boat $^{-1}$ was recorded immediately after the fish was released from the gill nets, and the number of boats observed was recorded after the fish was sold while the fishermen's assistants were preparing the gill nets for the next setting. Totally we counted 19124 fish (table 2).
To estimate the length distribution of the fish in the landings we registered the length of the fish from 27 boats during the first sampling period. The lengths was determined in mm from 3365 *O. niloticus,* 74 *C. gariepinus* and 7 *Barbus* spp in this period, while lengths from 20 *Barbus* spp was determined in August 2003.

Table 2 Number of boats sampled and number of fish in the samples.

Period	Number of boats sampled	Number of *O. niloticus*	Number of *C. gariepinus*	Number of *Barbus* spp
Dry season (03)	30	3797	85	7
Rainy season (03)	104	8619	189	42
Dry season (04)	59	6253	95	37
Total	193	18669	369	86

Since the children working as assistants for the fishermen started straightening the gill nets immediately after the fishermen had released the fish, it was not possible to visually count the gill nets as I was occupied with counting the number of fish boat $^{-1}$ before it was sold.

Length weight relationships for all species included in the commercial fisheries were obtained by regression analysis of length and weight. The regression equations were thereafter used to calculate the weight in the landings. Regression analysis was conducted on 381 *O. niloticus* from the experimental gillnetting and 16 *O. niloticus* from the fish market, 90 *Barbus* spp from the experimental gillnetting and 20 *Barbus* spp from the fish market and 12 *C. gariepinus* from the experimental gillnetting.

There is a distinct dry and rainy season in the Ethiopian rift valley. Naturally the length of these seasons varies through time, but generally the rainy season lasts for about 8 months and the dry season for 4 months (see chapter 3). Hence, the rainy season was set to 245 days and the dry season was set to 120 days in this study.

3.2 Experimental fishing

To obtain essential information like length at first maturity in the fish stocks, a simultaneous experimental gillnet sampling was conducted with monthly intervals at 3 fixed localities in each habitat of the lake during 5 months (February to June 2003). Experimental monofilament nylon gill nets with mesh sizes (from not to not): 52mm, 42mm, 39mm, 37mm, 35mm, 32mm, 31mm, 29mm, 27mm, 26mm, 24mm, 21mm, 20mm, 19.5mm, 16mm, 13mm, 12.5mm, 10mm, 8mm, 6mm, 6.25mm and 5mm was set in the littoral zone (2 – 3m), pelagic zone (1 – 7m) and profundal zone (7 - 13m) of Lake Awassa.

A total of 730 *O. niloticus* 14 *C. gariepinus* and 315 *Barbus* spp were collected during five months of experimental gillnetting. Out of these we registered sexual maturity from 461 *O. niloticus*, 14 *C. gariepinus* and 215 *Barbus* spp. Total length (TL) was measured from the tip of the snout to the end of the tail fin in

natural position. Total weight (TW) was taken using an electronic scale for fish less than 500 g. A spring balancet was used for fish more than 500 g.
The sex and maturity stage of each fish was determined by a visual examination of the gonads and by using a five-point maturity scale (Dadebo et al 2003). According to this maturity-scale the fish was categorized as immature (I), recovering spent or developing virgin (II), ripening (III), ripe (IV) or spent (V). Length at first maturity was defined as the length at which 50 % of the individuals reach maturity (Dadebo et al. 2003). Fish in stadium III, IV and V was considered mature. Length at first maturity was determined from the percentage of mature fish that were grouped into 10 mm length classes.

Figure 8 Fish boat with gill nets on the after-deck ready to leave for the fish grounds of Lake Awassa. Wrecked and partly sunken boats set out of fish utilization are visible in the background.

3.3 Data analysis

The software Minitab 13.1 for Windows was used for statistical analysis, while data analysis and figures was made with Microsoft office Excel 2003.

4. Results

4.1 Number of fish boats in Lake Awassa

The increasing demand for fish during the fasting periods, followed by an increase in number of boats present at the fish marked, as described in chapter 3.4, was corresponding the sampling. The number of boats observed suddenly increased from an average of 73 day $^{-1}$ in February up to108 day $^{-1}$ in the beginning of the long fasting period in March. During the short fasting period in August the increase is not that obvious, but still present (table 1).

4.2 Species composition in the landings

The relative distributions amongst the species in the fishermen's landings during the sampling periods were consistent through the periods, *O. niloticus* was dominating the fisheries, contributing with more than 97 % by number of the total yield, during all the periods' sampled (table 3). For all seasons together the proportion was less than 2 % of *C. gariepinus* and less than 0.5 % of *Barbus* of the total (table3).

Table 3 Number (n) and frequency (%) of the different species in the fishermen's landings during the three seasons sampled at the fish market.

	Dry season 03		Rainy season 03		Dry season 04	
Species	n	%	n	%	n	%
O. niloticus	3797	97.6	8619	97.4	6253	97.9
C. gariepinus	85	2.2	189	2.1	95	1.5
Barbus spp	7	0.2	42	0.5	37	0.6

4.3 Number of fish boat $^{-1}$

A general increase in the mean number of fish boat $^{-1}$ was found in the dry seasons compared with the rainy season. The increase was most pronounced for *O. niloticus*, where the mean increased from 82 to 112 boat $^{-1}$ (table 4).
A smaller increase was also present for the other two species contributing to the fisheries, indicating a difference in catchability between the two dominating seasons for these species. The mean number day $^{-1}$ of fish boat $^{-1}$ and the estimated 95 % confidence intervals for all species in the sample are given in table 4.

Table 4 Mean numbers of fish boat $^{-1}$ day $^{-1}$, and 95% confidence intervals, in the rainy season 2003 and in the dry seasons 2003/2004. (P = 0.000)

	Rainy season		Dry season	
Species	Mean boat $^{-1}$	95% CI	Mean boat $^{-1}$	95% CI
O. niloticus	82.9	74.2 - 91.6	112.9	98.7 - 127.1
C. gariepinus	1.8	1.0 - 2.6	2.0	1.0 - 3.1
Barbus spp	0.4	0.1 - 0.7	0.5	0.2 - 0.8

4.4 Length and weight in the landings

The spread in length-interval was relatively less in extent for *O. niloticus* than it was for the other two species (table 5). The mean length and the estimated mean weight calculated by regression analysis, and the 95 % confidence intervals for length and weight are given in table 5.

Table 5 Number of fish in sample, mean length, mean weight and 95% confidence intervals for the species in the landings (P = 0.000, P* = 0.192, due to few number of *Barbus* spp in sample).

Species	n	Mean length (mm)	95% C.I.	Mean weight (g)	95% C.I.
O. niloticus	3365	217	216-218	184	182-187
C. gariepinus	74	411	399-423	503	463-544
Barbus spp	33	338*	314-360*	388*	312-476*

Figure 9 Landing of *O. niloticus* at the fish market.

4.5 Landing estimates of *O. niloticus*

In the rainy season, the number of *O. niloticus* boat $^{-1}$ ranged from 18 to 230 (fig 10A). The mean number was 82.9 boat $^{-1}$, and in this season the landings day $^{-1}$ were estimated to 74.2 – 91.6 *O. niloticus* boat $^{-1}$ (table 4).

During the dry seasons the number of *O. niloticus* boat $^{-1}$ ranged from 20 to 454 (fig 10B). The mean number boat $^{-1}$ was 112.9, and in this season the landings day $^{-1}$ were estimated to 98.7 – 127.1 *O. niloticus* boat $^{-1}$ (table 4).

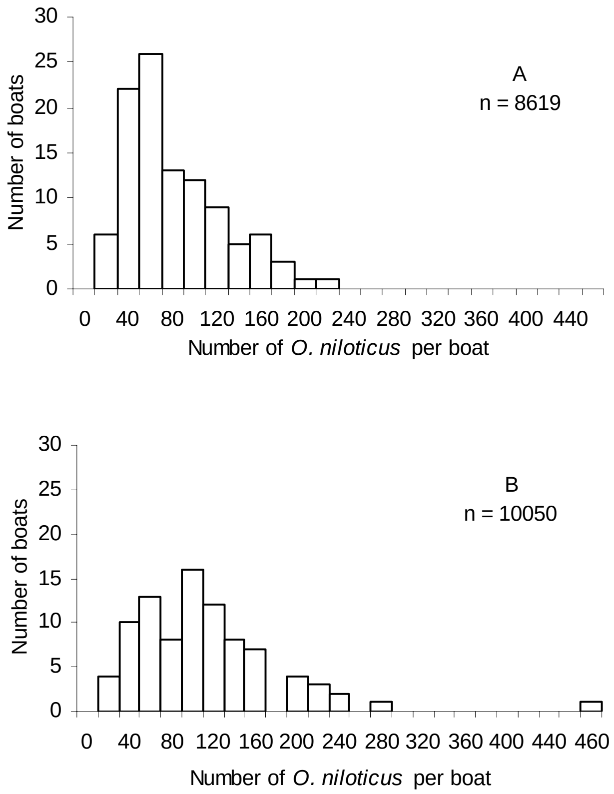
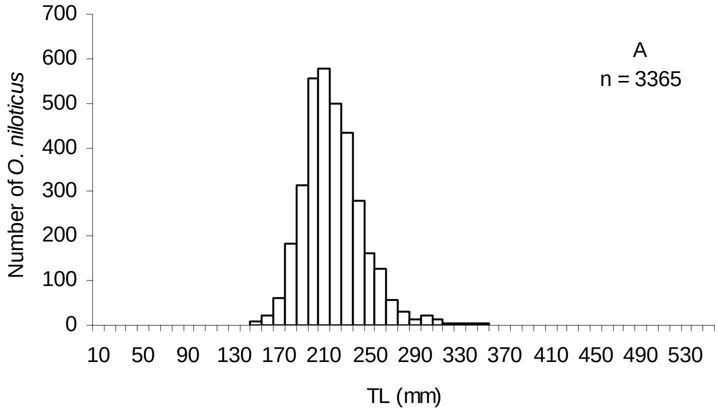


Figure 10 Number of *O. niloticus* boat $^{-1}$ in the rainy season (A) and the dry seasons (B).

The *O. niloticus* found in the fishermen's landings was in the length-interval 130 - 370 mm (fig 11A) while the mean length was 217 mm (table 5).

A regression equation fitted for *O. niloticus* between 43 and 340 mm (TL) and between 1 and 680 g (TW); **log(TW) = -5.00651 + 3.11231 log(TL)**, ($p = 0.000$, $r^2 = 0.99$, $n = 3365$) describes a curvilinear relation between length and weight (fig 11B).



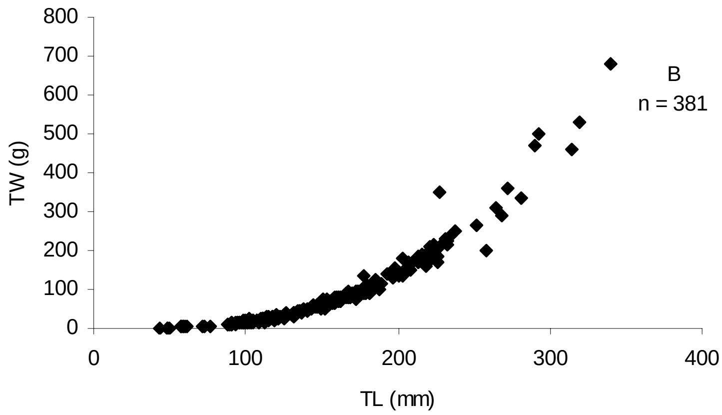


Figure 11 Length distributions in the fishermen's landings (A) and length-weight relationship (B) of *O. niloticus*.

Landings day $^{-1}$ were estimated to 13.6 – 17.2 kg boat $^{-1}$ in the rainy season and to 18.0 – 23.8 kg boat $^{-1}$ in the dry season. The mean landings day $^{-1}$ increased from 15.3 kg boat $^{-1}$ in the rainy season to 20.9 kg boat $^{-1}$ in the dry season.

This represents 348.6 - 441.2 tons in the rainy season and 227.2 - 300.1 tons in the dry season. Mean annual yield was estimated to 656.9 tons. For *O. niloticus* annual yield was estimated to 575.7 - 741.3 tons.

4.6 Landing estimates of *C. gariepinus*

In the rainy season majority of boats did not have any *C. gariepinus* in the landings, but I found a relatively large number in some of the boats (fig 12A). The mean number boat $^{-1}$ was 1.8, and in this season the landings day $^{-1}$ were estimated to 1.0 – 2.6 *C. gariepinus* boat $^{-1}$ (table 4).

During the dry seasons the number of *C. gariepinus* boat $^{-1}$ was still low, but one of the boats had 36 *C. gariepinus* in the landing (fig 12B).
The mean number boat $^{-1}$ was 2.0, and in this season the landing day $^{-1}$ were estimated to 1 – 3.1 *C. gariepinus* boat $^{-1}$ (table 4).

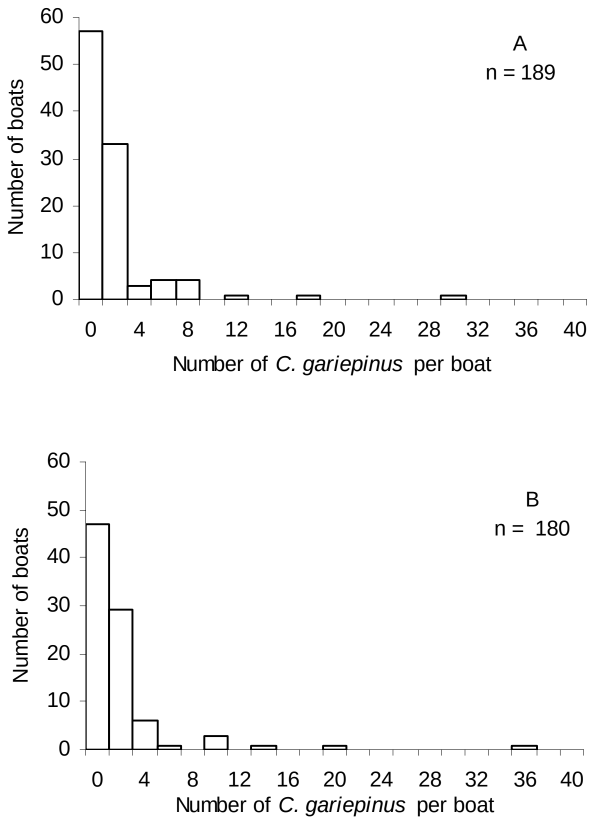
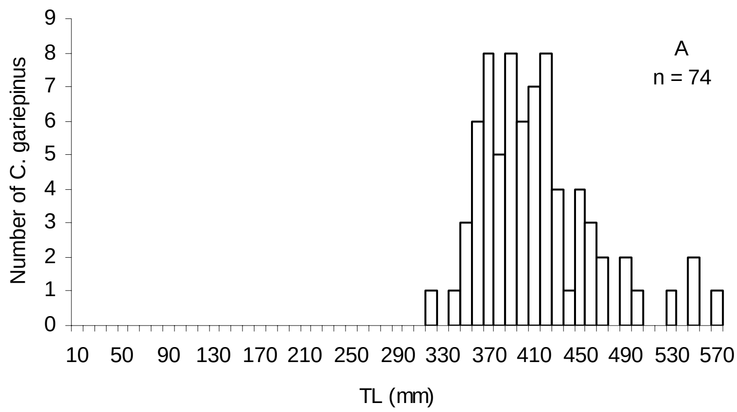


Figure 12 Number of *C. gariepinus* boat $^{-1}$ in the rain season (A) and in the dry seasons (B).

The *C. gariepinus* in the fishermen's landings was in the length-interval 320 - 570 mm (fig 13A) while the mean length was 411 mm (table 5).

A regression equation fitted for *C. gariepinus* between 268 and 542 mm (TL) and between 130 and 1250 g (TW); **log (TW) = -4.80763 + 2.87240 log (TL)**, (p = 0.000, r^2 = 0.98, n = 74) describes a curvilinear relation between length and weight (fig 13B).



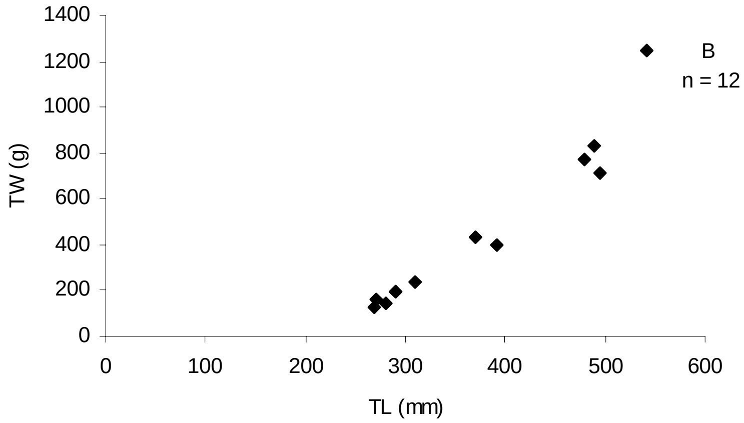


Figure 13 Length distribution in the fishermen's landing (A) and length-weight relationship (B) of *C. gariepinus*.

Landings day $^{-1}$ were estimated to 0.48 – 1.42 kg boat $^{-1}$ in the rainy season and to 0.5 - 1.7 kg boat $^{-1}$ in the dry season. The mean landings day $^{-1}$ increased from 0.9 kg boat $^{-1}$ in the rainy season to 1.0 kg boat $^{-1}$ in the dry season.

This represents 12.27 - 36.58 tons in the rainy season and 5.78 - 21.01 tons in the dry season. Mean annual yield was estimated to 35.76 tons. For *C. gariepinus* the landings were estimated to range between 18.05 and 57.59 tons year $^{-1}$.

4.7 Landing estimates of *Barbus* spp

In the rainy season I only found 42 *Barbus* spp in the fishermen's landings (table 3). The mean number boat $^{-1}$ was 0.4, and in this season the landings day $^{-1}$ were estimated to 0.1 – 0.7 *Barbus* spp boat $^{-1}$ (table 4).

During the dry seasons I found 10 *Barbus* spp in one of the boats while most of the fishermen did not have any *Barbus* spp in their catch (fig 14B).
The mean number boat $^{-1}$ was 0.49, and in this season the landings day $^{-1}$ were estimated to 0.2 - 0.8 *Barbus* spp. boat $^{-1}$ (table 4).

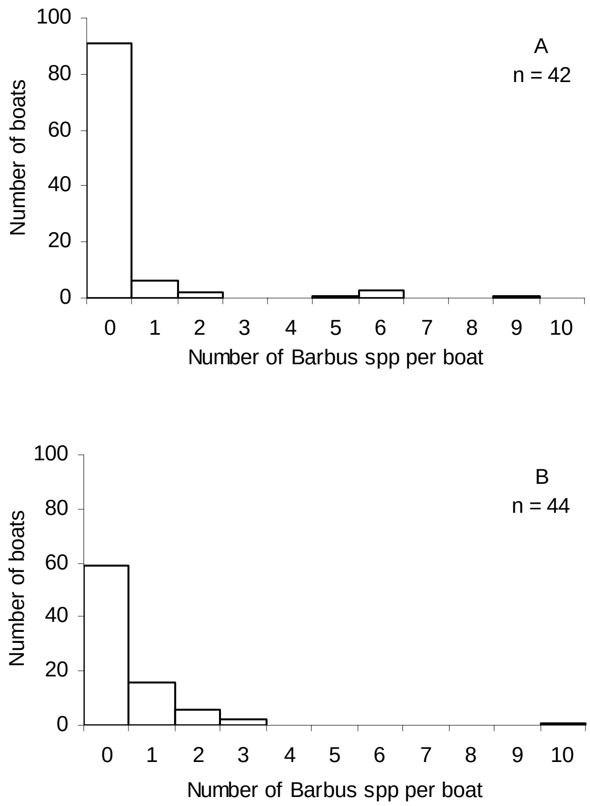


Figure 14 Number of *Barbus* spp boat $^{-1}$ in the rainy season (A) and in the dry seasons (B).

The *Barbus* spp in the fishermen's landings was in the length-interval 230 – 510 mm (fig 15A), while mean length was 338 mm.

A regression equation fitted for *Barbus* spp between 102 and 510 mm (TL) and between 135 and 1600 g (TW); **log (TW) = -5.19721 + 3.07988 log (TL)**, (P = 0.000, r^2 = 0.99, n = 33) describes a curvilinear relation between length and weight (fig 15B).

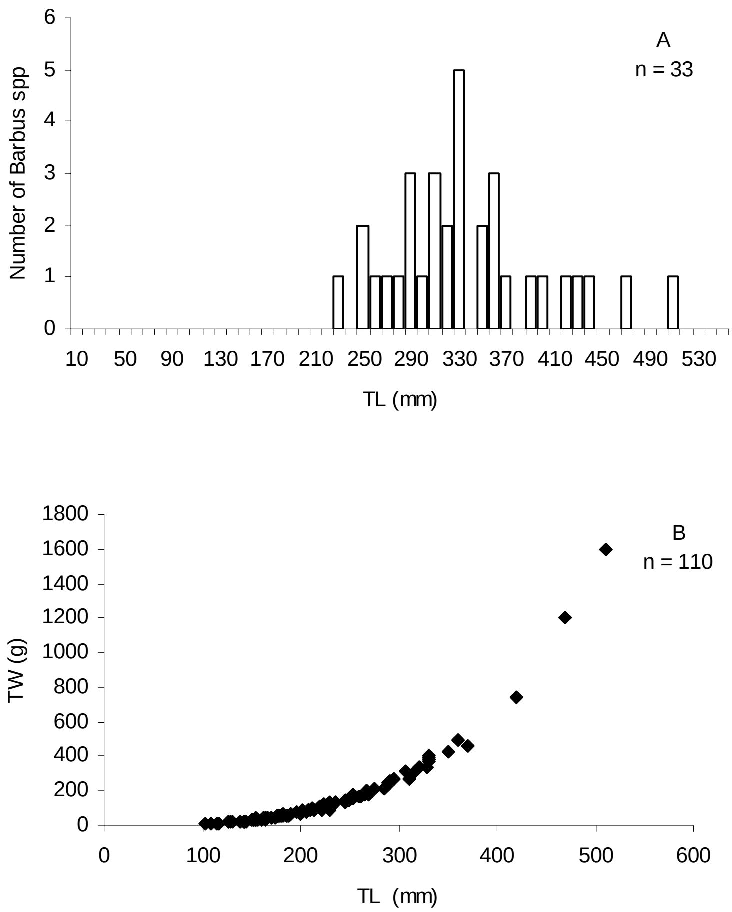


Figure 15 Length distributions in the landings (A), and length-weight relationship (B) of *Barbus* spp.

Landings day $^{-1}$ were estimated to 0.04 – 0.3 kg boat $^{-1}$ in the rainy season and to 0.07 – 0.3 kg boat $^{-1}$ in the dry season. The mean landings day $^{-1}$ increased from 0.16 kg boat $^{-1}$ in the rainy season to 0.19 kg boat $^{-1}$ in the dry season.

This represents 1.0 - 8.2 tons in the rainy season and 0.9 - 4.5 tons in the dry season. Mean annual yield was estimated to 6.51 tons. For *Barbus* spp the landings were estimated to range between 2.0 and 12.7 tons year $^{-1}$.

4.8 Length at first maturity and recruitment to the fisheries

O. niloticus

From a total 461 O. niloticus examined, 201 (43.6 %) were males and 260 (56.4 %) were females. The average length at which 50 % of the males attained first maturity was 178 mm (fig 16), while the length at which 50 % of the females reached sexual maturity was 141 mm (fig 17). The smallest mature male was 90 mm (fig 16), while the smallest mature female was 100 mm (fig17).

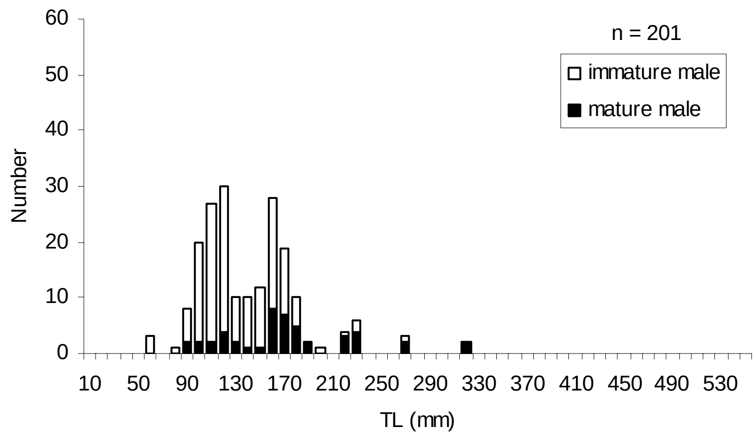


Figure 16 Length distribution and sexual maturation of male *O. niloticus*.

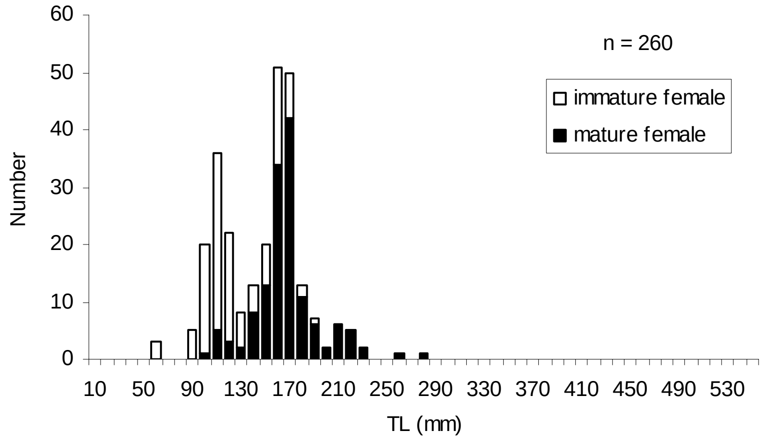


Figure 17 Length distribution and sexual maturation of female *O. niloticus*.

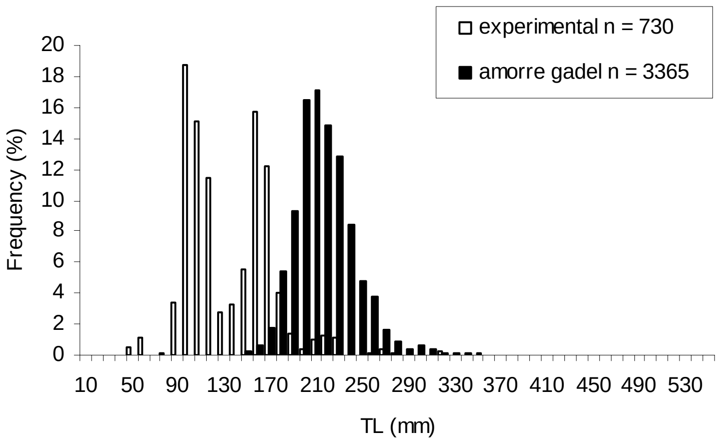


Figure 18 Frequency (%) of length classes of *O. niloticus* collected during five months of experimental gillnetting, and frequency of length classes collected at Amorre gadel fish market .

When *O niloticus* reach about 130 mm it starts contributing to the commercial fisheries and when it exceeds 180 mm the majority of specimen seems to be taken by the commercial fisheries (fig 18).
Before reaching catchable size, the majority of *O. niloticus* seems to participate once to the recruitment of its species. However a few specimens seem to breed more than once (fig 16, 17 & 18).

C. gariepinus

Only 14 *C. gariepinus* was collected during 5 months of experimental gillnet fishing, which illustrates the later elaborated low catchability of this species by gillnets. Due to few numbers of *C. gariepinus* in the sample it was not possible to determine length at first maturity for this species.

***Barbus* spp**

From a total 215 *Barbus* spp examined 160 (74.4 %) were males and 55 (25.6 %) were females. Out of the 215 *Barbus* spp 109 were mature males (fig 19), whereas only 5 were mature females (fig 20). The average length at which 50 % of the male’s attained maturity was 169 mm (fig 19). Due to the length of the fish in the sample it was not possible to determine when the females attained maturity (fig 20). The smallest mature male was 100 mm (fig 19) and the smallest mature female was 160 mm (fig 20).

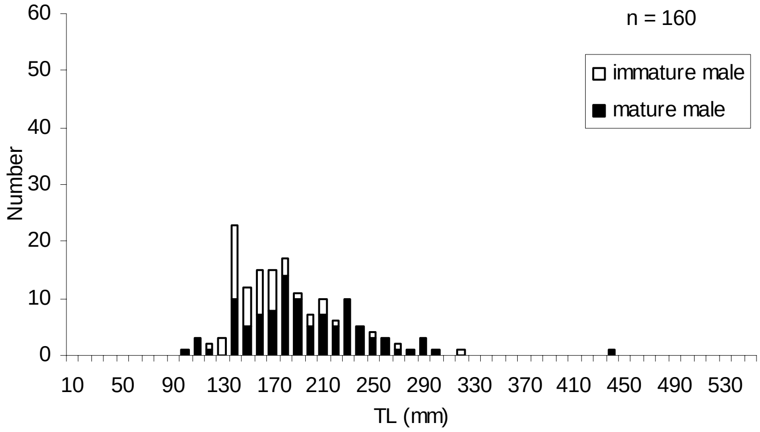


Figure 19 Length distributions and sexual maturation of male *Barbus* spp

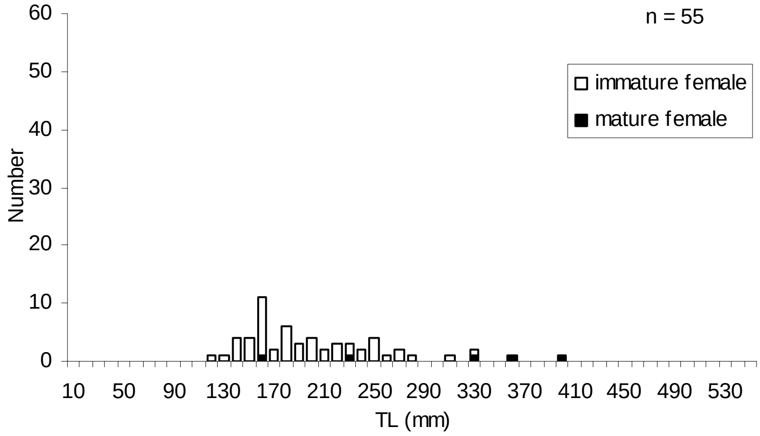


Figure 20 Length distributions and sexual maturation of female *Barbus* spp

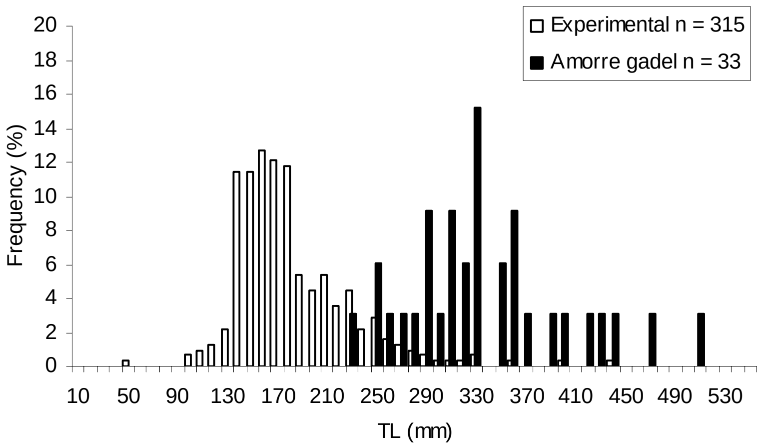


Figure 21 Frequency (%) of length classes of *Barbus* spp collected during five months of experimental gillnetting and frequency of length classes collected at Amorre Gadel fish market.

The majority of the *Barbus* spp stock is not affected by the fishery since most of the specimens are below catchable size (fig 21). When Barbus reach about 200 mm it's recruited the commercial fisheries. When length of this *Barbus* spp. exceeds about 250 mm the majority seems to be taken by the fisheries (fig 21).

5. Discussion

5.1 Landing estimates

In this study the fish landings were estimated to 576 - 741 tons *O. niloticus*, 18 - 58 tons *C. gariepinus,* and 2 - 13 tons *Barbus* spp. During all three sampling periods a consistent trend in the species composition in the landings of Lake Awassa was found. *O. niloticus* was totally dominating in the fish landings, and its relative share was 97.6%, 97.4% and 97.9% by number in the dry season 2003, rainy season 2003 and dry season 2004, respectively. Due to the limited contribution by *C. gariepinus* and *Barbus* spp to the fisheries in Lake Awassa, *O. niloticus* is given special attention in the following discussion.

Safe level production target for all species contributing to the fisheries in Lake Awassa, based on stock assessment studies, was estimated to 5.4 tons per km^2, and represents the second largest safe level production target among all Ethiopian lakes (Reintjens & Wudneh 1998). Only the most nutrient rich (Kebede et al. 1994) Lake Chamo has a larger safe level production target (6.1 tons per km^2) (Reintjens et al. 1998). However, Lake Chamo has a much more diverse natural piscifauna than that of Lake Awassa, containing 12 species (Admassu & Ahlgren 2000). Since the landings of Nile perch collapsed in Lake Chamo due to overfishing in 1995, a large increase in *Labeo* landings has developed, and the latest landing estimates was 2500 tons (Reintjens et al. 1998). The most similar lake, when evaluating fisheries production in Ethiopia to the conditions in Lake Awassa, is Lake Ziway. In this lake fisheries mainly consists of *O. niloticus* (90 %, Abebe & Getachew 1987) and the safe target production was estimated to 5 tons km^2 year $^{-1}$ (Reintjens et al. 1998). In Lake Awassa, the yields of *O. niloticus* was estimated to 460 tons in 1996/1997, while the safe production level for this species was estimated to 440 tons year $^{-1}$ (Reintjens & Wudneh 1998). Other landingestimates of *O. niloticus* from Lake Awassa are not available in published literature.

In this study the annual mean contribution by weight from the different species was estimated to 657 (94 %) tons *O. niloticus,* 36 tons (5,1 %) *C. gariepinus* and 7 tons (0.9 %) *Barbus* spp
Published estimates of the contribution by weight from *O. niloticus* to the total Ethiopian yields are highly variable. The estimates are ranging from 80 % (Tudorancea et al. 1999) to 60 % (Reintjens & Wudneh. 1998). Similarly, estimates on the contribution by weight of *O. niloticus* to the total yield from Lake

Awassa are given a wide range of estimates. Dadebo (2000) estimated the catch of *O. niloticus* to 90 % of the total, while Yosef & Casselman (1995), cited by Admassu (1996), estimated the contribution to be about 85% of the total. The contribution has also been estimated to be as low as 60–80 % (Getachew. 1987). Different published empirical potential production estimates are also varying. Breuil (1995) estimated the potential production from Lake Awassa to 660 tons year $^{-1}$ based on mean depth. But others have empirically estimated the potential production as high as 1100 tons year $^{-1}$ (LFDP 1994b, cited by Reintjens & Wudneh. 1998)

Possible sources for miscalculation and the accuracy of the estimates presented in this study are elaborated below.

The presented estimates assumes that the number of boats is fixed and constant trough the year (the number of boats operating in the lake was set to 105) while the number may vary through the year.
According to the local representative from the Ministry of Agriculture (MOA) in Awassa, the total number of boats operating on the lake varies, but through the sampling period it was assumed to be about 105 (Awoke Kuisa, pers. comm.). Thus, judging from the procured information from the local representative from MOA, and that the observations of boats (table 1) at three occasions during one year were corresponding the offer and demand mechanism described in chapter 2.4, the number of boats operating the lake seems relatively constant. And, since the maximum number of boats observed when the demand for fish at Amorre Gadel was at the highest (108, table 1), the given estimate of 105 boats appears close to the actual number of boats present trough the sampling periods in 2003 and early 2004.

Due to the general and particular to the present demand for proteins in Ethiopia, one can assume that all available boats are fishing on a daily basis: If the fishermen do not sell their fish, it is consumed by the local community. Likewise, one can assume that all available gillnets are used regularly, regardless of alterations in number of boats: If one of the boats is wrecked, gillnets from this boat are used by the other boats.

However, since the sampling was conducted during three different occasions through a year, an eventual change in effort and/or catch per unit effort (CPUE) would have less significant impact on the landing estimates than if the sampling were conducted once, within a short period of time.

In Lake Awassa, a main peak in breeding of *O. niloticus* occurred during January-March, and a secondary peak occurred during July-September (Admassu 1996, Tudorancea et al. 1988). Thus, the sampling at Amorre gadel was conducted during the most active breeding season of *O. niloticus* at two occasions (04.02.03-11.03.03 and 22.01.04-05.02.04), and once during the second most active breeding season (17.08.03-29.08.03). Since gillnets are set close to the littoral zone, nearby the spawning areas of *O. niloticus* (Tudorancea et al. 1988), it is possible that the landing estimate for this species is in the upper level of its actual range.

The relatively small spread in length distribution of *O. niloticus* in the landings would have given a correspondingly low spread in landing estimates if the variation in number of *O. niloticus* registered boat $^{-1}$ was equally low. However, the variation in number of *O. niloticus* boat $^{-1}$, especially during the dry seasons, was relatively large. Hence, the extent of the landing estimate, especially that for the dry season, is relatively wide.
The large spread in length of *C. gariepinus* in the landings, and the low number in sample, together with large variation in number of *C. gariepinus* boat $^{-1}$ gives a huge spread in the landing estimate for this species.
Very low number and large variation in length in the sample size of *Barbus* spp, together with a relatively large variation in number of *Barbus* spp boat $^{-1}$ gives a correspondingly large spread in the estimated yield of this species.

Hence, further employment of the given estimates should consider the above discussion.

5.2 Dry season versus rainy season landings

A pronounced increase in dry season landings was found for *O. niloticus,* with the daily mean of 15.3 kg boat $^{-1}$in the rainy season increased to 20.9 kg boat $^{-1}$ in the dry season.
Seasonal variations in landings of *O. niloticus* are normally attributed to spawning movements (Lowe-McConnell 1958, 1979., cited by Kolding, 1993).

The annual decrease in water level during the dry season are obviously leading to an increase in catchability of all species present in Lake Awassa, since the same number of gill nets are fishing when the spawning populations are concentrated in a smaller volume of water.

The increase in dry season landings for *O. niloticus* is also coincident with an increase in phytoplankton biomass in Lake Awassa. Particularly does the *Botryococcus braunii* biomass show a large increase in the dry season (Kebede & Belay. 1994), Since *B. braunii* was found to be the most utilized pray by *O. niloticus* in Lake Awassa (Getachew & Fernando. 1989), a connection between annual fluctuations in phytoplankton biomass and increased catchability due to increased feeding movement is a possibility.

However, the in general the commercial fishery utilizes the relatively large and mature sizes of *O. niloticus* present in the lake. Since the females mouth-brood the eggs and juveniles, whereas the males, in addition to fertilizing several

females, are engaged in building and guarding spawning sites (Fryer & Iles, 1972, cited by Tudorancea et al. 1988), the relatively larger and mature fish are prevented from increased feeding movement in the breeding season.
Hence, spawning movements points out to be the most important cue to increased dry season catchability of *O. niloticus* in Lake Awassa.

For *C. gariepinus* and *Barbus* spp the increase found in the dry season landings was relatively less pronounced. The mean weight day $^{-1}$ increased from 0.9 to 1.0 kg boat $^{-1}$ for *C. gariepinus* and from 0.16 to 0.19 kg boat $^{-1}$ for *Barbus* spp.
The catchability of *C. gariepinus* seems be most accidental due to the morphology of this species. Long barbells (see fig 4) on the snout seem to prevent entanglement in gill nets. The estimated contribution to the fisheries from this species is very low compared to reports of large quanta's caught by long-line in the fasting periods: Dadebo (2000) estimated that the contribution of *C. gariepinus* rises up to 20 % of the total harvest during these periods. This indicates a considerable *C. gariepinus* stock practically unaffected by gill net fishing. Hence the small increase found in the dry season for this species might just as well be a coincidence. However, both juvenile and adult *C. gariepinus* was found to be piscivorous in feeding habits (81.7% and 86.8% of the food by volume respectively), and *O. niloticus* was the most utilized prey (71.05% and 77.5% for juveniles and adults respectively) (Dadebo, 2000).
In the absence of other specialized piscivores, the larger *Barbus* spp appears piscivorous, and *O. niloticus* appeared the most common fish ingested by this species. The relative contribution of fish in the diet of *Barbus* spp was also found to increase in the dry season (Admassu & Dadebo, 1997). Hence, increased feeding movements might explain the increase in dry season landings for these species.

5.3 Effects of the fisheries on fish the stocks

Judging from the above cited report of landings by long-line fishing, the present *C. gariepinus* stock is relatively large. The five months of experimental fishing also discloses a considerable *Barbus* spp stock. However, the sampling at the fish market shows that these stocks are literally unaffected by the gillnet fishery. The *Barbus* spp found in the landings seems to be the piscivores part of the population who switches from omnivorous feeding habits when reaching more than 320 mm (Admassu & Casselman, 1997).

In this study *O. niloticus* was found to attain first maturity at an average length of 178 mm for males and at 141 mm for females. Admassu (1994) reported that 50 % of the individuals in Lake Awassa attained sexual maturity at 198 mm for males and 188 mm for females (Golubtsov et al. 2002). This is a decrease of 20 mm for males and almost 50 mm for females within a relatively short period of time.

. There is a large variation in length at first maturity in different stocks of *O. niloticus* within the Ethiopian rift valley lakes. In Lake Chamo 50 % of both sexes was mature at about 420 mm (Teferi et al. 2001), while the average maturity size in Lake Ziway was estimated to be between 190 and 200 mm (Abebe & Getachew, 1992). Lowe-McConnell (1958, 1982) cited by Kolding (1993) studied 8 different populations of *O. niloticus* in East African waters and found two with median maturation size of 280 mm, one of 270 mm and the rest smaller (down to 140mm). It is well known that *O. niloticus* has a remarkable plasticity in maturation sizes and the phenomenon of "dwarfing" or "stunting" represent one of the major constrains in commercial cultivation of tilapia (Kolding 1993). Under natural conditions stunting, in general, seems particularly associated with droughts in shallow lakes, or when isolated from the main water in pools and lagoons (Lowe-McConnell 1958, Fryer & Iles 1972 cited by Kolding 1993). Kolding (1993) reported a dramatic reduction in length at maturity within a relative short period of time in Ferguson's Gulf in Lake Turkana, Kenya. He found that the median size at maturity decreased by 130 mm over 29 years due to size specific mortality rates caused by long-time fluctuations in water and dissolved oxygen levels. A detailed examination of the population dynamics and life-history styles of *O. niloticus* is available in his work (Kolding 1993).

The plasticity of this species and its ability to rapid adjustment to its present environment as discussed above seems to explain the decrease in length at first maturity found in Lake Awassa. The low variation in length distribution in the *O. niloticus* landings strongly indicates a uniform mesh size in gillnets distributed among the fishermen. When *O. niloticus* exceeds about 180 mm in length, mortality rates due to the fishery pressure are relatively much larger than they are for specimens less than 180 mm. Hence, the reduction in length at first maturity is most likely an adaptation to the size specific mortality rates determined by the mesh size in the fishermen's gillnets.
.
The *O. niloticus* stock in Lake Awassa is under pressure at all stadiums in life history. Not only are mortality rates for the larger specimen's high due to fishing. Mortality rates in juveniles due predation seems to be considerable due to the above cited rates of piscivorous found in the *C. gariepinus* and *Barbus* spp stocks. *Barbus* spp between 205 and 320 mm was considered omnivorous, and insects (mainly Chironomids) were the most important food for this species in Lake Awassa (Admassu & Dadebo, 1997). Juvenile *O. niloticus* in Lake Awassa was also found to be omnivorous in feeding habits, and Chironomidae larvae and some adult insects represented the bulk of the diet as a percentage of food by volume in the juveniles less than 25 – 30 mm SL (Tudorancea et al. 1988). Hence, there is also a considerable intraspesific competition between juvenile *O. niloticus* and the considerable *Barbus* spp stock demonstrated by the experimental fishing.

5.4 Management

Ethiopia has no effective fisheries legislation (Reintjens et al. 1998). Most notable is the lack of legal provisions to monitor fishing activities through fisheries regulations and the lack of a clearly designated enforcement agency. However, general principles as well as a set of uncoordinated fishery regulatory practices do exist (Breuil, 1995). Fisheries legislation for Ethiopia was drafted by FAO in 1983. This draft included decrees for fisheries management, development and fisheries regulations. Unfortunately, this draft which was then thought suitable has never been followed up by the responsible authorities (Breuil 1995). In the absence of fisheries legislation, the authority empowered with the leading institutional responsibility is not clearly established. Hence, economical considerations for the most valuable species, *O. niloticus* seem to determine the management strategies in Lake Awassa. However the fish community consists of minimum six species. The experimental gillnetting indicated relatively large stocks of both *Barbus* spp and *B. paludinosus* in the lake. The *C. gariepinus* stock is probably considerable (Dadebo 2000) and a large stock of *A. antinorii* is utilizing the shallowest part of the littoral zone (Dadebo pers. comm.). The *Garra* spp found in this study are possibly the native algae feeder Dembea stone lapper (*Garra dembeensis,* Rüppell 1836) which has been frequently demonstrated in a number of the nearby rivers (Anon 2002). However this species was only found in very small amounts in Lake Awassa (Unpublished data).

5.5 Conclusion and recommendations

The landing estimates presented in this study seems close to the safe production target estimated for Lake Awassa. Whether the current size of the landings is due to a reduction in effort or in CPUE is not clear in the available published literature, but if this is a consequence of the latter, management strategies seems improper.

The present gillnet fisheries in Lake Awassa are highly selective, and the landings are totally dominated by one of the species, *O. niloticus*. The present findings of a decrease in length at first maturity bear witness of a stock adapted to the sudden increase in mortality when length exceeds 180 mm. When fish gets sexually mature, it starts converting the nutrient assimilated to produce sexual organs at the expense of growth. Hence a earlier sexual maturation at relatively shorter lengths leads to a corresponding decrease in production of valuable proteins for human consumption.

The current social and economic environment present, with high population growth rates and sparse job opportunities, not only in the Lake Awassa region, but through all Ethiopia, tend to lead rapidly to overfishing (Reintjens et al 1998). In the absence of clearly defined fisheries legislation, and in the newly adopted economic political environment due to the replacement of the central planned economy with a market-based economy, fisheries management seems to be determined by economical considerations.

As a result of over fishing, not only less food is being provided to the community, but also the cost of fishing is higher than it could be

.

A long term study of this kind, with regular and more frequent sampling intervals, to monitor the catch per boat, and the changes in catch over time, may form the basis for future managements of the fish stocks in Lake Awassa

Acknowledgements

I thank Z. Desta for his help in data collection and the staff members at Faculty of Natural Science, Debub University for their collaboration during the sampling in Ethiopia, and R. Borgstrøm for critical comments on various stages in this work.

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