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The Extent of Immature Fish Harvesting by the Commercial Fishery in Lake Hawassa, Ethiopia

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ABSTRACT

The sustainability of a given fishery is a function of the number of sexually matured fish present in water. If there is intensive immature fishing, the population of fish reaching the stage of recruitment will decrease, which in turn results in lower yield and biomass. The present study was conducted to estimate the extent of immature fish harvesting by the commercial fishery of Lake Hawassa. Random samples of 962 *Oreochromis niloticus* and 672 *Clarias gariepinus* were taken from the fishermen's catch for two weeks from May 15 to 30, 2011, which was peak spawning season for both fish species. The maturity of the sampled fish was determined by visual examination of developmental stages of gonads based on their size, structure and the space they occupy in the body cavity of fish. Lengths at first sexual maturity of male and female *C.gariepinus* were55.9cm and 54.8cm, respectively and that of male and female *O.niloticus* were 20.8cm and 20.3cm, respectively. There was heavy immature fishing of *C.gariepinus* as high as 77.6% but immature fish harvesting was slight for *O.niloticus* (23.0%). Thus immature fishing of *C.gariepinus* should be stopped as soon as possible since only one fifth of the population has the chance to breed and replenish the stock before it is caught. Widening the currently used mesh size from 8cm to 10cm is recommended to avoid immature fishing.

Keywords: Immature fishing, Length at first maturity, *Oreochromis niloticus, Clarias gariepinus,* Lake Hawassa, Ethiopia.

1. INTRODUCTION

The number of young fish recruited every year in a given water body is a function of the number of eggs spawned. This is directly related to the biomass of sexually mature fish present. If there are no breeding fish, there cannot be any recruitment. The number of fish attaining recruitment will increase, when there is abundant sexually mature fish in the water (LFDP, 1997). When the immature fish move into the areas where fishing is actually carried out, they can be captured if inappropriate fishing gear is used, resulting in a reduction of sexually mature fish biomass present in a water body. If this biomass drops to too low levels, recruitment will start to decrease. This in turn results in lower yield and biomass, leading to over exploitation of the fish stock (Sparre and Venema, 1992). Thus, application of mesh size and hook size limitation is very important to avoid capturing individuals of target species in their immature stages. The close association between effort and length of fish implies that fishery can be managed entirely on the basis of control of length both in terms of the assessment of the status of the fishery and through promotion of mesh size restriction, though it has limitations in multispecies fisheries (FAO, 1997).

Capture of large quantities of small and immature fish is a general problem, common to many fisheries, threatening the integrity of fish stock and thus seriously undermining the sustainability of fisheries (Ohwayo and Balirwa, 2004). For instance, the haddock *Melanogrammus aeglefinus* has been heavily exploited in the commercial fisheries of the northwest Atlantic. Catches of haddock from the St. Pierre Bank off Newfoundland declined from 58,000 tons in 1955, to around 6,000 tons in 1957 and further reductions to less than 1,000 tones in the 1970s (Templeman and Bishop, 1979). Biological data collected between 1948–51 and 1969–75 showed a decline in the mean age at 50% maturity from 4.6 to 3.3 years in males and from 5.9 to 4.3 years in females (Templeman and Bishop, 1979). Beacham (1983) pointed out that this decline occurred over a period of both increasing and decreasing growth rates, so that the change in age at maturity is not simply related to changes in growth rate due to the compensatory effect of reduced biomass. In addition, immature fishing by trawl nets along Mangalore Malpe coast of Karnataka, south west India, decreased the yield by 20% in 2006 (Dineshbabu and Radhakrishnan, 2009).

In the case of Lake Hawassa, gillnets are the main fishing gears, though long lines are used to catch *C. gariepinus*. The minimum stretched mesh size of gill nets was set to be 8cm by LFDP (1997). However, the appropriateness of this fishing gear (whether it catches immature fish or not) have not yet been studied. In addition to this, long lines are used for *C. gariepinus* fishing but hook size has not been strictly set. In such a situation, catching immature fish is an unavoidable phenomenon (FAO, 1984). Therefore, this study was conducted to assess the extent of immature fish exploitation on the two commercially important fish species i.e., the Nile tilapia (*O. niloticus*) and the African catfish (*C. gariepinus*) in Lake Hawassa.

2. MATERIALS AND METHODS

2.1. Description of the study area

Lake Hawassa is located at the west of Hawassa city, between 6°33’-7°33’N and 38°22’-38°29’E, with an altitude of 1,680 m (Fig 1). It has an area of 90 km^2 and an average depth of

11m (Elias Dadebo, 2000; Yosef Tekle-Giorgis, 2002). The lake is the smallest of the Ethiopian rift valley lakes and its main inflow is River Tikur Wuha that drains the swampy wetland called Shallo. The lake has no visible surface outlet (Elias Dadebo, 2000).

The fish species found in Lake Hawassa are the Nile tilapia (*Oreochromis niloticus* L, 1758), the African catfish (*Clarias gariepinus* Burchell, 1822), the African big b*arb (Labeobarbus intermedius,* Rüppel 1836*)*, the straight fin barb (*Barbus paludinosis* Peters*, 1852)*, the black lampeye *(Aplocheilichthys antinorii* Vinciguerra, 1883) and the stone lapping minnow *(Gara quadrimaculata* Rüppel, *1835)* (Elias Dadebo, 2000). Commercially important species are *O.niloticus, C.gariepinus* and *L.intermedius* (LFDP, 1996), whereas the other three minnow fish species are not fished due to their small size. *O. niloticus* constitutes about 90% of the total production, while *C. gariepinus* and *L. intermedius* contribute only about 7-8% and 2-3%, respectively. However, the contribution of *C.gariepinus* rises up to 20% of the total landing during the fasting periods (March to April and early half of August) of the Orthodox Church followers (Elias Dadebo, 2000). *O.niloticus* and *L.intermedius* are caught exclusively by gill nets while *C.gariepinus* is caught by both gill nets and long lines. Since *L.intermedius* was not available in the fish market during the sampling period, it was not included in this study. The common landing site and fish market of Lake Hawassa fishery is "Amora Gedel" (Fig 1) but illegal fishermen also land their catches at other shores of the lake.

2.2. Sampling and data collection

For biological data collection, random samples of 962 *O.niloticus* and 672 *C.gariepinus* were taken from the fishermen's catch for two weeks from May 15 to 30, 2011, which was peak spawning season for both fish species (Demeke Admassu, 1994; Elias Dadebo, 2000; Yosef Tekle-Giorgis, 2002). Total length was measured to the nearest mm and total weight to the nearest gm. Then each fish was dissected to determine sex and maturity by visual examination of the gonads using a five point maturity scale. The maturity stage of each fish was described based on the size, shape, color, texture, and the space the gonads occupy in the body cavity of fish (Omotosho, 1993). Accordingly, fish were categorized as immature (I), recovering spent or developing virgin (II), ripening (III), ripe (IV) and spent (V). All fish with gonad maturity stage of I and II were considered as immature fish, whereas those with maturity stages of III and above were considered as mature (Omotosho, 1993; Tesfaye Wudneh, 1998).

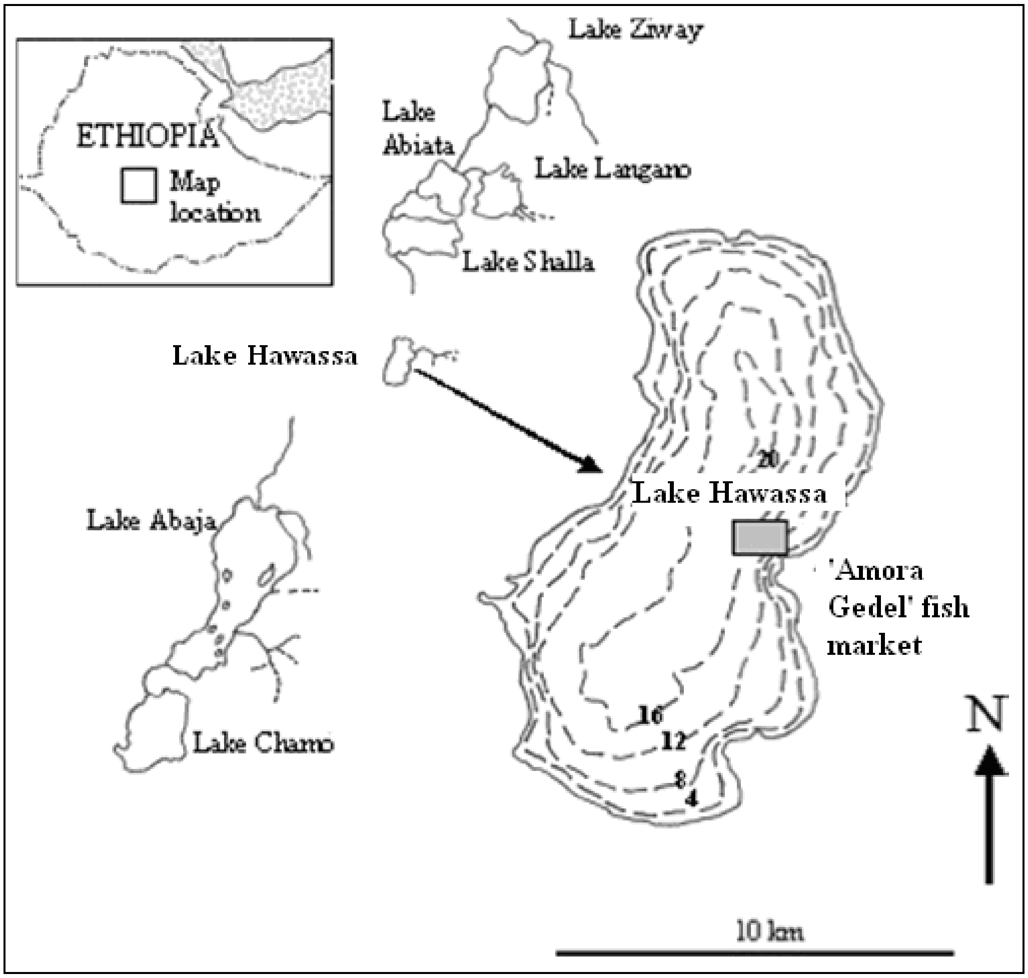

Figure 1. The location of Lake Hawassa in the Ethiopian Rift Valley, and its bathymetric map; the rectangle indicates the sampling site (Zerihun Desta et al., 2006).

The length measurements were then categorized into length intervals (i.e., 2 cm for *O.niloticus* and 5 cm for *C.gariepinus*) and the proportion of mature fish per length class was calculated. Based on this, the average length at which 50% of the fish had mature gonads (L_{50}) was estimated for the two species using a logistic relationship established between the proportion of mature fish per length class (PM) and fish length (King, 1995). The following equation was used:

$$PM_i = \frac{1}{1 + \exp - (a + b * L_i)}$$

Where, PM_i = the proportion of mature fish in the i^{th} length group
Li = midpoint of the i^{th} length group (cm);
a and b are the intercept and the slope of the relationship

Parameter estimates for the above relationship were obtained by fitting a logistic regression using a non-linear curve fitting procedure. The average length at which 50% of the fish possessed mature gonads was estimated by dividing the intercept (a) by the slope of the above relationship and it is considered as the length of first sexual maturity (Ni and Sandeman, 1984; Omotosho, 1993). The percentages of fish caught by fishermen below the length of first maturity were calculated for *O. niloticus* and *C. gariepinus* separately and the information was used to evaluate the extent of immature fish exploitation by the commercial fishery.

2.3. Data analysis

Various descriptive statistical procedures (mean, standard error, percentages, etc.) were used to summarize the data using Excel (version 2007) and SPSS (version 19.0) statistical packages. In addition to this, non linear regression procedure of SPSS was used to fit the logistic regression relationship between proportion of mature fish and fish length.

3. RESULTS

3.1 The extent of immature *C.gariepinus* exploitation

The percentages of male and female *C.gariepinus* having gonad stages III, IV and V (mature fish) were plotted against total length. Accordingly, the average length at which 50% of the fish reached maturity for the first time (L_{50}) was 55.9cm and 54.8cm for males and females, respectively (Fig 2). Table 1 gives parameter estimates for the regression fit and the lower and upper 95% confidence intervals for lengths at first maturity (L_{50}) of male (51.8cm and 59.8cm, respectively) and female (52.9cm and 56.2cm, respectively) *C.gariepinus* were narrow. This indicates that the L_{50} estimates for male (55.9cm) and female (54.8cm) *C.gariepinus* are reasonable estimates. Similarly, the value R^2 (coefficient of determination) is 0.98 for the respective fit indicating that the fitting was dependable and that the estimated maturity parameters are 98% valid (Table 1).

As shown in table 2, out of the total 672 *C.gariepinus* that were randomly sampled from the fishermen's catch, 77.6% were below 55cm, which are below length at first sexual maturity (i.e., immature fish), indicating the presence of heavy immature fish exploitation of this fish species. Thus, only 22.4% of *C.gariepinus* caught by fishermen had attained maturity and were able to reproduce at least once before they were caught. This implies that only one fifth (22.4%) of the

C.gariepinus population has the opportunity to reproduce and replenish the stock and the rest 77.6% are taken out before breeding and replacing themselves.

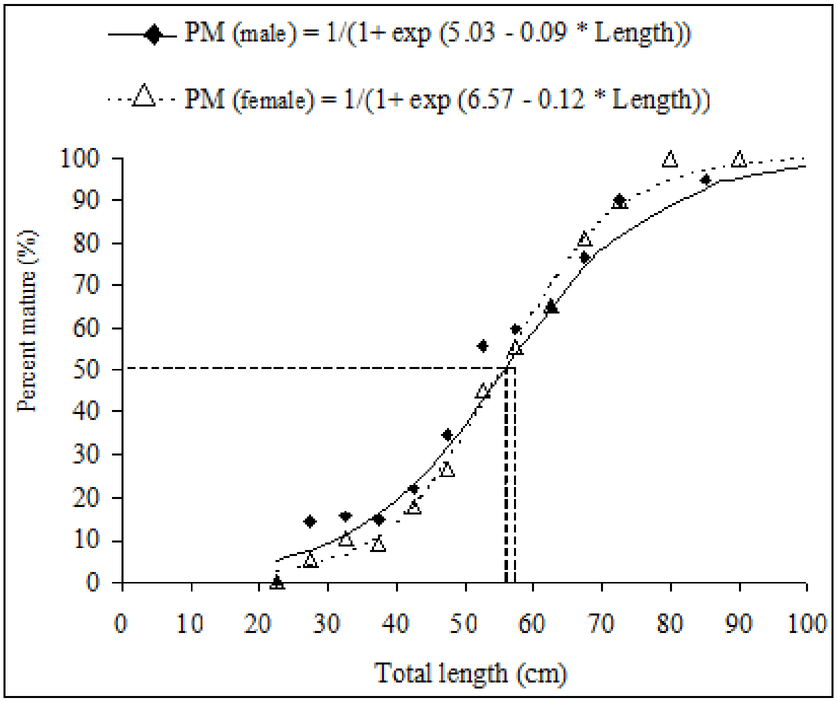

Figure 2. The relationship between percentages of male (diamond) and female (triangles) *C.gariepinus* with mature gonads and total length.

***Note**: the logistic curve that gives the expected proportion of maturity (PM) at each length is shown for male (solid curve) and female (dashed curve) fish with their equation. Dotted line indicates the length at which 50% of the fish possess mature gonad (average lengths at first maturity).*

Table 1. Maturity parameter estimates for *C. gariepinus*.

Maturity parameters	***Values***	***Standard Error***	***95% confidence interval (CI)***	
			Lower 95% (CI)	***Upper 95% (CI)***
Male *C. gariepinus*				
• a	5.03	0.4	4.14	5.92
• b	0.09	0.01	0.08	0.099
• L_{50} (cm)	55.9		51.8	59.8
• R^2	0.98			
Female *C. gariepinus*				
• a	6.57	0.3396	5.82	7.3
• b	0.12	0.0061	0.11	0.13
• L_{50} (cm)	54.8		52.9	56.2
• R^2	0.98			

Table 2. Proportion of *C. gariepinus* caught in each length group out of the total 672 randomly sampled fish from the fishermen's catch.

Length group (cm)	***No. of fish sampled***	***Percentage of fish sampled (%)***	
20 - 25	4	**0.6**	
25 - 30	33	**4.9**	
30 - 35	136	**20.2**	
35 - 40	190	**28.3**	**77.6 %**
40 - 45	79	**11.8**	
45 - 50	41	**6.1**	
50 - 55	38	**5.7**	
55 - 60	35	5.2	
60 - 65	34	5.1	
65 -70	38	5.7	
70 - 75	20	3.0	
75 - 80	8	1.2	
80 - 85	7	1.0	
85 - 100	9	1.3	
Total sampled	**672**	**100.0**	

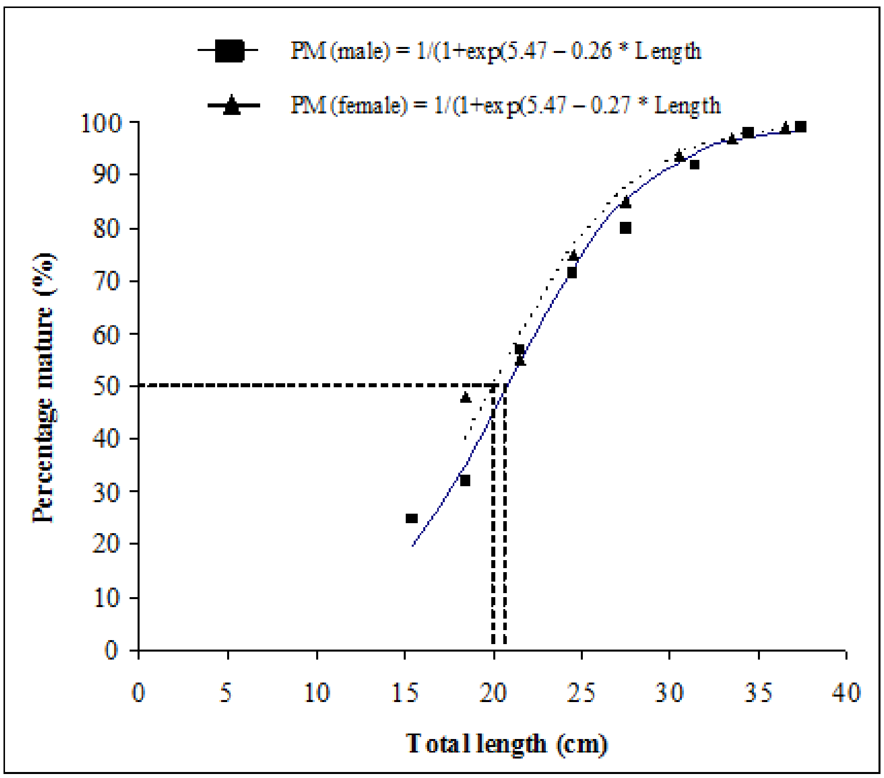

Figure 3. The relationship between percentages of male (squares) and female (triangles) *O.niloticus* with mature gonads and total length.

Note: *The logistic curve that gives the expected proportion of maturity (PM) at each length is shown for male (solid curve) and female (dashed curve) fish with their equations. Dotted line indicates the length at which 50% of the fish possess mature gonad (average lengths at first maturity).*

3.2 The extent of immature *O.niloticus* exploitation

The relationship between the proportion of mature fish and total length of *O.niloticus* was determined based on empirical data collected from fishermen (Fig 3). The average length at which 50% of *O.niloticus* reached maturity (length at first sexual maturity, L_{50}) was found to be 20.3cm and 20.8cm for female and male *O.niloticus*, respectively (Fig 3). As shown in table 3, the lower and upper 95% confidence intervals for length at first maturity (L_{50}) of male (20.1cm and 21.5cm, respectively) and female (20.0cm and 20.6cm, respectively) *O.niloticus* were narrow. This shows that the L_{50} estimates for male (20.8cm) and female (20.3cm) *O.niloticus* are close approximation to the reality. Similarly, the value of R^2 (0.97) indicates that the estimated parameters can be trusted with 97% probability.

As shown in table 4, about 23.0% of *O.niloticus* caught in Lake Hawassa by fishermen were below the length of first sexual maturity (21cm), indicating the presence of some level of immature fish exploitation of this fish species. Amongst these, 18.1% were between the size range of 19-21cm, and only 4.9% were below 19cm (Table 4). This shows that fishermen's nets were fairly wide to allow escape of *O.niloticus* below 19cm but not wide enough to avoid catching *O.niloticus* between the length intervals 19-21cm, which are unfortunately immature fish. Hence, 21cm should be the cut off size not to catch *O.niloticus* below this length at a commercial scale so as to protect the fish population. Thus, fishermen net should be widened to allow escape of 19-21cm *O.niloticus.*

Table 3. Maturity parameter estimates for *O. niloticus.*

Maturity parameters	*Values*	*Standard Error*	*95% confidence interval (CI)*	
			Lower 95% (CI)	*Upper 95% (CI)*
Male *O. niloticus*				
• a	5.47	0.42	4.23	5.92
• b	0.263	0.02	0.21	0.275
• L50 (cm)	20.8		20.1	21.5
• R^2	0.97			
Female *O. niloticus*				
• a	5.47	0.40	5.80	6.31
• b	0.27	0.01	0.29	0.306
• L50 (cm)	20.3		20.0	20.6
• R^2	0.97			

Table 4. Number and proportion of *O.niloticus* sampled in each length group out of 962 randomly taken fish from the fishermen's catch.

Length group (cm)	***No. of fish sampled***	***Percentage of fish sampled (%)***	
13-15	2	0.21	
15-17	4	0.42	
17-19	41	4.26	22.97%
19-21	174	18.09	
21-23	269	27.96	
23-25	175	18.19	
25-27	127	13.20	
27-29	79	8.21	
29-31	52	5.41	
31-33	25	2.6	
33-35	6	0.62	
35-37	6	0.62	
37-39	2	0.21	
Total sampled	**962**	**100**	

4. DISCUSSION

To maintain sustainable fisheries, fish should be exposed to fishing gears after attainment of length of first sexual maturity. Thus, length at first maturity of fish is considered as a minimum harvestable size of a given fish species (FAO, 1984). In the present study the average length at first sexual maturity for female *C.gariepinus* was 54.8cm, which is very close to the 56.0 cm reported by Yosef Tekle-Giorgis (2002) for the same species in Lake Hawassa. However, the length at first maturity of male *C.gariepinus* documented in this study (55.9cm) is longer than that reported by Yosef Tekle-Giorgis (2002) as 41cm. The present length at first sexual maturity recorded for both sexes of *C.gariepinus* in Lake Hawassa was longer than the value reported by Tesfaye Wudneh (1998) in Lake Tana as 30.5cm and 36.0cm for male and female *C.gariepinus*, respectively. However, the values recorded for Lake Hawassa were smaller than that reported by Yosef Tekle-Giorgis (2002) in Lake Chamo i.e., 59.0 and 64.0cm for male and female *C.gariepinus*, respectively. These differences may be related to growth rate differences among the different *C.gariepinus* stocks in the respective lakes.

Based on the present findings, *C.gariepinus* below 55cm (length at first sexual maturity) should not be caught if sustainable fishery is to be maintained. Unfortunately, very high proportions of *C.gariepinus* caught (77.8%) were below 55cm (immature) (Table 2) as *C.gariepinus* starting from 22cm are vulnerable to the mesh of the gill nets used by fishermen in Lake Hawassa. This is because of incidental capture of *C.gariepinus* by gill nets set to capture *O.niloticus*. The mesh size of gill nets currently used by fishermen in Lake Hawassa for *O.niloticus* fishing (8cm) is too narrow for *C.gariepinus* resulting in immature fish harvest. Contrary to Lake Hawassa, in Lake Chamo the fishermen use nets with wider meshes (i.e., 12-14cm) and thus *C.gariepinus* below length at first sexual maturity (i.e. 65cm) are rarely seen in the commercial catches (Yosef Tekle-Giorgis, 2002).

The other cause for heavy immature fishing of *C.gariepinus* could be due to the use of long line for this fish species at the vegetated shore areas where juvenile fish grow (personal observation). The size selectivity of long lines is limited (Ralston, 1982; Bertrand, 1988) and thus use of this poor size selective fishing gear in areas where immature fish are abundant (shore area) enhances immature fishing (Bertrand, 1988).

Apart from this, fishermen's knowledge on the length at first sexual maturity is very limited. Based on a survey done at Hawassa, very few fishermen (1.3%) know the correct length at first sexual maturity of *C.gariepinus* and *O.niloticus*. 50.6% of the fishermen did not know whether the *C.gariepinus* they catch is mature or immature. This coupled with the view of fishermen that fish is 'inexhaustible' resource, can be dangerous to the sustainable use of the fish resource.

In the case of *O.niloticus*, its average lengths at first sexual maturity for female (20.3cm) and male fish (20.8cm) in Lake Hawassa are slightly larger than those reported by other investigators in Ethiopia. For instance, the average length at first sexual maturity of female *O.niloticus* in Lakes Hawassa was 18cm (Demeke Admassu, 1994) and that of the same species in Lake Tana was 18.5cm (Tesfaye Wudneh, 1998). Comparing the present finding with that of the work of Demeke Admassu (1994), the increase in length at first maturity of *O.niloticus* from 18cm to 20cm could be due to a decrease in fishing pressure, as the present level of fishing pressure expanded on Lake Hawassa is lower than the fishing efforts expanded in the early 1990's. It is known that fishing pressure and length at first sexual maturity are inversely related. As fishing mortality increases, fish populations respond to the new environmental circumstances by changing their life history pattern in order to compensate for the losses imposed by fishing activity (Kolding et al., 1992; Wootton, 1998).

The heavy immature fishing of *C.gariepinus*; and the slight immature fishing of *O.niloticus* can be reduced by widening the currently used mesh size to get proper *C.gariepinus* harvest. Tesfaye

Wudneh (1998) set a relationship between best mesh size (BMS mm stretched mesh) and total length (TL mm) for *C.gariepinus* to be:

$$BMS = 0.113 \times TL + 41$$

Inserting the total length at first maturity (55cm = 550mm) in place of TL in this formula gives the best mesh size (BMS) or appropriate mesh size for *C.gariepinus* harvest as 103.15mm =10.3cm. Accordingly, the minimum mesh size of gillnets in Lake Hawassa should be 10cm. The optimum catch size of *O.niloticus* for a 10cm mesh size is 25cm (Tesfaye Wudneh, 1998), which is larger by 4cm than the minimum harvestable size i.e. length at first maturity of *O.niloticus* in Lake Hawassa (21cm). This helps to protect the fish stock since there is massive illegal fishing (high fishing pressure) on the lake. However, fishermen may be reluctant to this new mesh size restriction as the 10cm mesh does not allow them to harvest *O.niloticus* as before. Accordingly, the management bodies should conduct extensive awareness creation work among fishermen as well as there may be a need for provision of some incentive to fishermen who implement proper fishing regulations.

5. ACKNOWLEDGEMENTS

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