THE EXTENT OF FISH HARVEST ON THE COMMERCIAL FISHERY OF LAKE HAWASSA, ETHIOPIA

Tesfaye Muluye[1],*, Girma Tilahun[1] and Yosef Tekle-Giorgis[2]

[1]Department of Biology, Haramaya University, P. O. Box 138, Dire dawa, Ethiopia. E-mail: abitytesfa@gmail.com

[1]Department of Biology, Hawassa University, P.O. Box 5, Hawassa, Ethiopia

[2]Department of Animal and Range Sciences, Hawassa University, P. O. Box 336, Hawassa, Ethiopia*Author to whom all correspondence should be addressed

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ABSTRACT

The sustainability of a given fishery is a function of the number of sexually matured fish present. If there is intensive immature fishing, the number of fish reaching at stage of recruitment will decrease, which in turn results in lower yields and biomass. This study was conducted to estimate the extent of immature fishing on the commercial fishery of Lake Hawassa. A random of 962 Oreochromis niloticus and 672 Clarias gariepinus were sampled from the fishermen catch for two weeks from May 15 to 30/2011 which was peak spawning season for both O. niloticus and C. gariepinus. The maturity of the sampled fish was determined by visual examination of developmental stages of gonads based on their sizes and the space they occupy in the body cavity of fish. Results showed that there was heavy immature fishing as high as 77.8% in C. gariepinus, however, slight immature fishing (22.7%) was documented for O. niloticus. Lengths at first sexual maturity of male and female C. gariepinus were 55.4 cm and 53.3 cm, respectively and, 20 cm and 20.8 cm for female and male O. niloticus, respectively. 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 minimum mesh size from 8 cm to 10 cm is recommended to avoid immature fishing.

Keywords: C. gariepinus, Immature fishing, Length at first maturity, O. niloticus.

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Introduction

The number of young fish recruiting 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 reaching at stage of recruitment will increase, when there are more and more sexually mature fish (LFDP, 1997). When the immature fish move into the areas where fishing is actually carried out, they can be captured with inappropriate fishing gears, resulting in a reduction of the sexually mature fish biomass present in a water body. If this biomass drops to low levels, recruitment will start to decrease. This in turn results in lower yields and biomass, leading to over exploitation of the fish stock (Sparre and Vanema, 1992).

Thus, applications of mesh size limitations are very important to avoid capturing fish species in their immature stages. The close association between effort and length of the 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 limitations 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 demersal fisheries of the northwest Atlantic. Catches of haddock from the St. Pierre Bank off Newfoundland declined from 58,000 tonnes in 1955, to around 6,000 tonnes in 1957 and further reductions to less than 1,000 tonnes in the 1970s (Templeman and Bishop, 1979a). Biological data collected between 1948-51 and 1969-75 show 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, 1979a). Beacham (1983b) has 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, the immature fishing by trawl nets along Mangalore Malp coast of Karnataka, South West India, have decreased the yield by 20% in 2006 (Dineshbabu and Radhakrishnan, 2009).

In the case of Lake Hawassa, gill nets are the main fishing gears, though long lines are also used. The minimum stretched mesh size of gill nets was set to be 8 cm by LFDP (1997). However, the appropriateness of this fishing gear (whether it catches immature fish or not) have not yet been studied. Generally, mesh size recommendation is based on L_{50} and other detailed studies. In addition to this, long lines are used for *C. gariepinus* fishing which are not size selective gears. In such a situation, catching immature fish is unavoidable phenomena (FAO, 1984). Thus, it appears important to assess the extent of immature fishing in the lake. Accordingly, this study has made a survey on the extent of immature fish exploitation on the two commercially important fish species i.e. Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) in Lake Hawassa.

Objectives of the study

General objective

- The main objective of this study is to assess the extent of immature fish harvest on the commercial fishery of Lake Hawassa.

Specific objectives

- To assess the extent of immature fish harvest on Nile tilapia (*Oreochromis niloticus*) in Lake Hawassa
- To assess the extent of immature fish harvest on African catfish (*Clarias gariepinus*) in Lake Hawassa
- To determine the lengths at first maturity of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) in Lake Hawassa

Materials and Methods

Description of the study area

The lake is found to the west of Hawassa town and has an area of 90 km^2 and average depth of 11 m and lies between 6°33'-7°33' N and 38°22'-39°29' E, with an altitude of 1680 m (Elias Dadebo, 2000; Yosef Tekle-Giorgis, 2002) (Fig. 1). 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, but has no obvious surface outlet (Elias Dadebo, 2000).

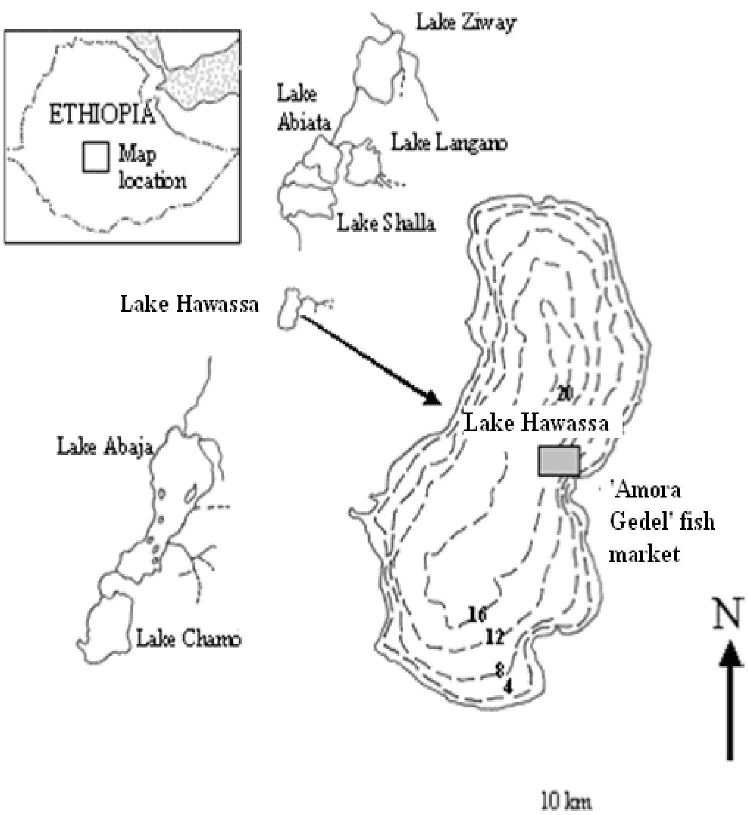

Fig.1. The location of Lake Hawassa in Ethiopian Rift Valley, and its bathymetric map; the rectangle indicates the sampling site (after Zerihun Desta *et al*., 2006).

The fish species found in Lake Hawassa are: *O. niloticus*, *C. gariepinus*, *B. intermedius* (African big barb, small barb (*Barbus paludinosus*), the cyprinid (*Garra quadrimaculata*), and the cyprinodont (*Aplocheilichthyes antinorii*) (Golubstov, Dgebuadze and Mina, 2002). The three fish species which are commercially important to the lake are *O*. *niloticus*, *C*. *gariepinus* and *B*. *intermedius* (LFDP, 1996). Of these, *O*. *niloticus* constitutes about 90% of the total production, while *C*. *gariepinus* and *B*. *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 *B*. *intermedius* are caught exclusively by gill nets while *C*. *gariepinus* is caught by both gill nets and long lines. Since *B*. *intermedius* was not available in the fish market during the sampling period, it was not included. The common landing site and fish market of Lake Hawassa fishery is “Amora Gedel” (Fig. 2), but illegal fishermen also land their catches at other shores of the lake.

Sampling and data collection

For biological data collection, 962 *O. niloticus* and 672 *C. gariepinus* were randomly sampled from the fishermen catch (Demeke Admassu, 1994; Elias Dadebo, 2000; Yosef Tekle-Giorgis, 2002). Total length was measured to the nearest millimeter. Then each fish was dissected to determine sex and maturity stages of each fish by visual examination of the gonads using a five point maturity scales. This maturity scale describes the developmental stages of gonads based on their size, shape, color, texture, and the space they occupy in the body cavity of fish (Holden and Raitt, 1974). Based on this maturity scales, 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 (Tesfaye Wudneh, 1998; Holden and Raitt, 1974).

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 mature (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).

$PM=1/ (1+\exp [-r (L-L_m)])$

Where, r is the slope of the curve and L_m is the mean length at sexual maturity or the length which corresponds to a proportion of 0.5 (or 50 per cent) in reproductive condition.

The above parameter estimates were obtained by fitting a logistic regression using a non-linear curve fitting procedure. The average length, at which 50% of the fish mature, was considered as the length of first sexual maturity (Holden and Raitt, 1974). The percentages of fish caught by the 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 fishing by the commercial fishery.

Data analysis

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Various descriptive statistical procedures (mean, standard error, percentages, etc.) were used to summarize the data using Excel (version 2007) and SPSS (version 15.0) 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.

Results

The extent of immature fishing activity in *C. gariepinus*

The percentages of male and female *C. gariepinus* having gonad stages three, four and five (mature fish) were plotted against length data (Fig. 2). The average length at which 50% of the fish reached maturity for the first time (L_{50}) was 53.5 cm and 55.4 cm for male and female *C. gariepinus*, respectively (Fig. 4).

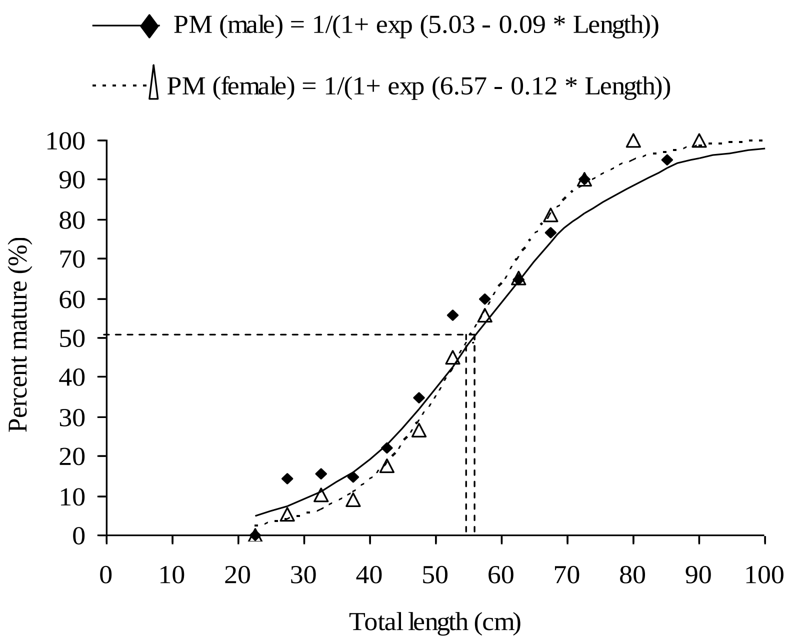

Fig. 2. The relationship between percentages of male (squares) and female (triangles) *C. gariepinus* with mature gonads and total length. Note that the logistic curve that gives the expected proportion of maturity (PM) at each length is shown for male (solid line) and female (dashed line) fish with their equation. Dotted line indicates the length at which 50% of the fish possess mature gonads (average lengths at first maturity).

As shown in Table 1 the lower and upper 95% confidence intervals for lengths at first maturity (L_{50}) of male (53.4 cm and 53.6 cm, respectively) and female (55.36 cm and 55.47 cm, respectively). *C. gariepinus* was found to be very narrow. This shows that the L_{50} estimates for male (53.5 cm) and female (55.4 cm) *C. gariepinus* are good estimates. Similarly, the values and standard errors of 'a' (y intercept) and 'b' (slope of the graph) together with R^2 values of the graph are shown in Table 1.

Table 1. Maturity parameters 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	0.11
• L_{50} (cm)	53.5		53.4	53.6
• R^2	0.98			
Female *C. gariepinus*				
• a	6.57	0.3396	5.8187	7.3135
• b	0.12	0.0061	0.1051	0.1318
• L_{50} (cm)	55.4		55.3605	55.473
• R^2	0.98			

As shown in Table 2, out of the total 672 *C*. *gariepinus* randomly sampled from the fishermen catch, 77.8% were below 55 cm, which are below length at first sexual maturity, (i.e., immature fish), indicating the presence of heavy immature fishing in this fish species.

Thus only 22.2% of *C*. *gariepinus* caught by the fishermen had attained maturity and were able to reproduce at list once before they were caught. This implies that only one-fifth (22.2%) of the *C*. *gariepinus* population has the opportunity to reproduce and replenish the stock and the rest 77.8% are taken out before breeding and replacing themselves.

Table 2. Proportion of catfish caught in each length group out of the total 672 randomly sampled fish from the fishermen catch.

Length group (cm)	**No. of fish sampled**	**Percentage of fish sampled (%)**	
20 -25	4	0.6	**77.8 %** (20–45 cm)
25 - 30	33	4.9	
30 - 35	136	20.2	
35 - 40	190	28.3	
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	

The extent of immature fishing activity in *O. niloticus*

Fig. 3 below shows the relationship between the proportion of mature fish and total length of *O. niloticus* determined based on empirical data collected from the fishermen. The average length at which 50% of *O. niloticus* reached maturity (L_{50}), length at first sexual maturity, was found to be 20 cm and 20.8 cm for female and male *O. niloticus*, respectively (Fig. 3).

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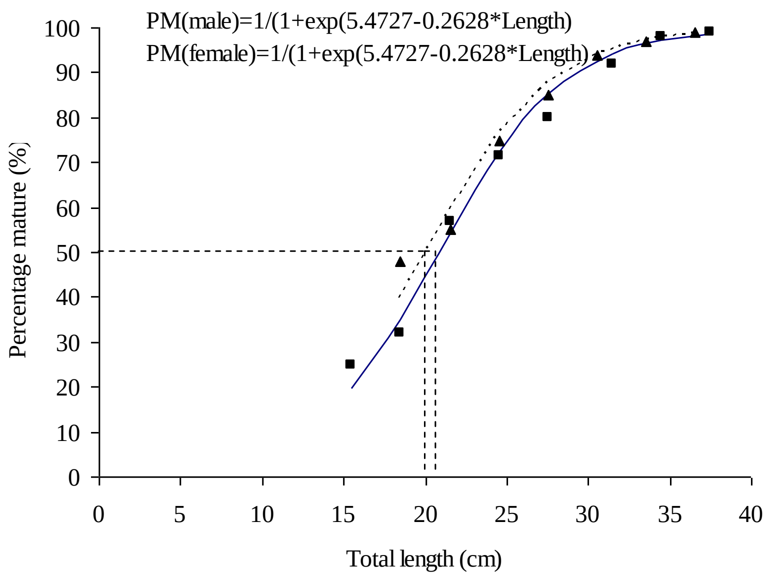

Fig. 3. The relationship between percentages of male (squares) and female (triangles) *O. niloticus* with mature gonads and total length. Note that the logistic curve that gives the expected proportion of maturity (PM) at each length is shown for male (solid line) and female (dashed line) fish with their equations. Dotted line indicate the length at which 50% of the fish possess mature gonad (average lengths at first maturity.

As shown in Table 3, the lower and upper 95% confidence intervals for lengths at first maturity (L_{50}) of male (20.6 cm and 21 cm, respectively) and female (19.8 cm and 20.2 cm, respectively) *O. niloticus* was found to be very narrow. This shows that the L_{50} estimates for male (20.8 cm) and female (20 cm) *O. niloticus* are good estimates. Similarly, the values and standard errors of 'a' (y intercept) and 'b' (slope) together with R^2 values of the relationship are shown in Table 3.

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

			95% confidence interval (CI)	
Maturity parameters	**Values**	**Standard error**	**Lower 95% (CI)**	**Upper 95% (CI)**
Male *O. niloticus*				
• a	5.47	0.42	4.23	5.92
• b	0.26	0.02	0.18	0.11
• L_{50} (cm)	20.8		20.6	21
• R^2	0.97			
Female *O. niloticus*				
• a	5.47	0.4000	5.8187	7.3135
• b	0.26	0.0100	0.1051	0.1318
• L_{50} (cm)	20.0		19.8	20.2
• R^2	0.97			

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As shown by Table 4, about 22.7% of *O*. *niloticus* caught by the fishermen were below the length at first sexual maturity (21 cm) (i.e., immature fish), indicating the presence of some level of immature fishing in this fish species. Among these, 18% were between the size range of 19-21 cm, and only 4.7% were below 19 cm (Table 4).

This shows that fishermen nets are fairly wide to allow escape of *O*. *niloticus* below 19 cm but they were not wide enough to avoid catching *O*. *niloticus* between the length intervals 19-21 cm, which are unfortunately immature fish. Thus 21 cm 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 19-21 cm *O*. *niloticus*.

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

Length group (cm)	**No. of fish sampled**	**Percentage of fish sampled (%)**	
13-15	2	0.02	
15-17	4	0.42	22.7 %
17-19	41	4.26	
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	

Discussion

To maintain sustainable fisheries, fish should be exposed to fishing gears after the 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 55.4 cm, which is very close to the 56.0 cm reported by Yosef Tekle-Giorgis (2002). However, the male *C*. *gariepinus* length at first maturity documented in this study (53.4 cm) is longer than that reported by Yosef Tekle-Giorgis (2002) i.e., 41 cm. The present length at first sexual maturity recorded for both sexes of *C*. *gariepinus* in Lake Hawassa was longer than that reported by Tesfaye Wudneh (1998) in Lake Tana i.e., 30.5 cm and 36 cm 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 and 64 cm for male and female *C*. *gariepinus*, respectively. These differences may be because of growth rate differences among the different *C*. *gariepinus* stocks in the respective lakes.

Based on the present findings, *C*. *gariepinus* below 55 cm (length at first sexual maturity) should not be caught if sustainable fishery is to be maintained. Unfortunately, very high proportions of the fish caught (77.8%) were below 55 cm (immature) and starting from 22 cm and above were vulnerable to the gill nets of fishermen. This is because of incidental capture of *C*. *gariepinus* by gill nets set to capture *O*. *niloticus*. The mesh size of gill nets for *O*. *niloticus* fishing (8 to 10 cm) is too narrow for *C*. *gariepinus* of 22 cm and above length, (since the total length of *C*. *gariepinus* is quite larger than that of *O*. *niloticus*), resulting in immature *C*. *gariepinus* harvest. As opposed to Lake Hawassa, in Lake Chamo the fishermen use nets with wider meshes (i.e., 12-14 cm) and thus *C*. *gariepinus* below length at first sexual maturity i.e., 65 cm, are rarely seen in the commercial catches (Yosef Tekle-Giorgis, 2002).

The other cause for heavy immature fishing in *C*. *gariepinus* could be due to the long (hook) and line fishing of this fish species on the closed areas where the juvenile fish grows (Sparre and Vanema, 1992). The size selectivity of long lines is proved to be limited by a number of researchers (Ralston, 1982; Bertrand, 1988). Use of this poor size selective fishing gear on areas where immature fish are abundant (closed area) enhances immature fishing (Bertrand, 1988).

Apart from this, fishermen knowledge on the length at first sexual maturity is very limited. Only very few of the fishermen (1.3%) know the correct length at first sexual maturity of *C*. *gariepinus*. This explains why most fishermen had no idea whether the fish they exploit is mature or not (i.e., 50.6% of them did not know whether the *C*. *gariepinus* they catch is mature or immature). This coupled with view of fishermen that fish is ‘inexhaustible’ resource, can be dangerous to the sustainable use of the fish resource.

When coming to the case of *O*. *niloticus*, its average lengths at first sexual maturity for female (20 cm) and male (20.8 cm) in Lake Hawassa are larger than those reported by other investigators in Ethiopia for which data are available. For instance, the average length at first sexual maturity of female *O*. *niloticus* in Lakes Hawassa and Tana were 18.8 and 18.1, respectively (Demeke Admassu, 1994; Tesfaye Wudneh, 1998). The increase in length at first maturity from 18 cm to 21 cm could be due to a decrease in fishing pressure, since 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, 1992; Wootton, 1998). However, since stock assessment research has not been conducted, the status of stock cannot be predicted with certainty.

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Heavy immature fishing in *C*. *gariepinus* and a slight immature fishing in *O*. *niloticus*, can be reduced by widening the currently used mesh size to get proper *C*. *gariepinus* harvest. Tesfaye Wudneh (1998) has set relationship between best mesh size (BMS mm stretched mesh) and total length (TL mm) for *C*. *gariepinus* to be: BMS = 0.113×TL + 41. Replacing the total length at first maturity (55 cm = 550 mm) in place of TL in this formula gives the best mesh (BMS) or appropriate mesh size for *C*. *gariepinus* harvest. Thus:

BMS = 0.113×TL + 41

BMS = 0.113×550 mm + 41

BMS =103.15mm =10.3 cm

Thus, the minimum mesh size of gillnets in lake Hawassa should be 10 cm. A 10 cm mesh size catches 25 cm *O. niloticus* (Tesfaye Wudneh, 1998) which is larger by 4 cm than the minimum harvestable size i.e. length at first maturity (21 cm). 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 a 10 cm mesh does not allow them to harvest *O. niloticus* as before. Since the majority of fishermen accepted the current use of mesh size as ‘appropriate’, introducing new mesh size restriction may need high effort from the management bodies.

Conclusion and Recommendation

There is intensive immature fishing of *C*. *gariepinus* in which 77.8% of the fish caught are immature and only 22.2% are mature. This shows that only 22.2% of the population has the chance to breed and replenish the stock before it is caught This in return severely damages the population of *C*. *gariepinus* since only one-fifth of the population is breeding. Thus immature fishing of *C*. *gariepinus* should be stopped at as soon as possible. In the case of *O*. *niloticus*, there is also immature fish harvesting as 22.7% (about one-fifth) of the population captured is below the size of first sexual maturity. This is mainly because the mesh size of gill nets used is not wide enough to release *O*. *niloticus* 19-21cm size group.

Thus the currently used minimum mesh size restriction of gill nets i.e., 8 cm should be widened to10 cm to avoid immature fishing (especially, *C*. *gariepinus* immature fishing). The current fisheries managers should give high emphasis for the implementation of this new mesh size restriction. To do this, fisheries managers need to create a commitment among the fishermen through educational discussions first, and continue strong supervision for its implementation.

The weed belts surrounding the lake are breeding and nursery areas for fish. Therefore in order to avoid immature fishing and enhance recruitment, fishing (including long lines) should be strictly forbidden in these areas. In addition to this the period of time for the closed season should be lengthened a month on May.

Acknowledgements

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