Sustainable systems

The impact of gillnet selectivity on immature Nile tilapia (*Oreochromis niloticus* L.) (Pisces: Cichlidae) in Lake Hawassa, Ethiopia

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ABSTRACT

The impact of gillnet selectivity on immature Nile tilapia (Oreochromis niloticus L.) in Lake Hawassa was studied based on length distribution of 10,274 fish samples obtained from the landings of the fishermen from March-May 2012. The aim of the study was to know the effect of the mesh size used by the fishermen on immature fish before they reach their spawning size. The mean length of the fish caught was 22.6 ±0.2 cm. The sizes at first maturity (Lm50) of 1,141 male and1,447 female O. niloticus were determined using logistic curve and found to be 16.8 cm and 19.8 cm TL, respectively. In order to find the girth circumference of the fish at a given length, linear regression line was fitted by using the total length (TL) as abscissa and the girth circumference (GC) as ordinate of 366 fish samples. The relationship was described by the formula: GC = 0.749TL – 0.054, r2 = 0.987. Since the GC is twice the length of the mesh size of the gillnet used in capturing the fish, it is possible to calculate the minimum mesh size that should be used to capture fish at its size of Lm50. Accordingly 7.5 cm stretched mesh size was found to be the minimum mesh size of the gillnet that should be used in tilapia fishery in Lake Hawassa. This mesh size is slightly lower than the mesh size used to capture the mean length of 22.6 cm TL which is 8.4 cm stretched mesh size. The current mesh size used in the lake is slightly higher than the minimum mesh size used to capture tilapia at its Lm50 but care should be taken not to lower the mesh size any further otherwise immature fish will be affected by the fishery. The current fishing activity captures about 20% of fish that are below the Lm50. This information is vital for management purpose that intends to minimize the impact of the gillnet selectivity on immature tilapia in Lake Hawassa.

Keywords: gill net selectivity, length at first maturity, mesh size, Oreochromis niloticus, Lake Hawassa (Awassa)

1. Introduction

The Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758), is a widely distributed fish species in tropical and subtropical Africa, including the Volta, Gambia, Senegal, Niger River, and the Nile River basin. It is native to Lakes Chad, Tanganyika, Albert, Edward, and Kivu (Shipton et al., 2004; Njir et al., 2004).

Ethiopia boasts a relatively large area of inland water bodies with diverse aquatic ecosystems, holding scientific interest and economic importance. Among the economically and ecologically significant fish species, *O. niloticus* stands out as the most important fish in the country's fisheries production, especially in the traditional fishery of Lake Hawassa (Alemayehu Negassa and Prabu, 2008; Yirgaw Teferi et al., 2000; Elias Dadebo, 2000).

In Ethiopia, *O. niloticus* is widely distributed in various inland water bodies, including lakes, rivers, reservoirs, and swamps. It is the most exploited and commercially important species, contributing significantly to the nation's total landings and particularly dominating the catch in Lake Hawassa, where it constitutes 93.0% of the landings (LFDP, 1997; Demeke Admassu, 1998; Bjorkli, 2004). Recent estimates indicate annual landings of tilapia ranging from 575.7 to 741.3 tons (Bjorkli, 2004).

The gill net is the most common fishing gear employed in tilapia fisheries across Ethiopia, known for its high selectivity. Understanding the selectivity of fishing gear is crucial for effective fish stock management. Gill net selectivity is influenced by various factors, including mesh size, body shape, fish size, netting twine thickness and flexibility, and twine visibility (Hamley, 1975). Among these, mesh size is deemed the most significant factor affecting gill net selectivity (von Brandt, 1975). Consequently, studies on selectivity often focus on the impact of mesh size on size selectivity (Fabi et al., 2002; Stergou and Erzini, 2002; Park et al., 2004; Askey et al., 2007; Karabulak and Erk, 2008; Ayaz et al., 2009).

In recent times, there has been growing concern that the reduction in gill net mesh size might be affecting juvenile *O. niloticus* in Lake Hawassa before reaching sexual maturity. Analyzing the body length distribution of fish caught in different gill net mesh sizes provides a straightforward way to assess and compare the selectivity of these mesh sizes. For effective management, this length distribution is compared with the length at first maturity to determine if a significant proportion of the stock is being caught before reaching reproductive age. This study aims to investigate the impact of gill net mesh selectivity on immature *O. niloticus* in Lake Hawassa.

2. Materials and Methods

2.1. Study Area

Lake Hawassa (6º 33' - 7 º 33' N and 38 º 22' - 38 º 29' E) is situated at an altitude of 1,680 m in the central part of the Ethiopian Rift Valley, approximately 275 km south of the capital, Addis Ababa (Fig. 1). Covering a surface area of 90 km2, a catchment area of 1,250 km2, a maximum depth of 22 m, and a mean depth of 11 m, Lake Hawassa plays a significant role in the region's ecology and economy (Elias Dadebo, 2000). The area experiences a dry, sub-humid climate with a mean annual rainfall of 1,154 mm over the long eight rainy months (March to October). According to Zinabu GebreMariam (1988), the lake undergoes mixing during the primary rainy months (June and July) and in December. The annual potential evapo-transpiration ranges from 1,100 to 1,250 mm. Lake Hawassa has a slightly alkaline pH range of 8.3-9.1 and a conductivity range of 780-965 µScm-1 (Zinabu Genremariam 1988). It is a topographically closed basin with no known outflow, primarily fed by a small river named Tikur-Wuha originating from Shallow Swamp and the rivers (streams) on the north and west caldera walls, which are ephemeral.

The littoral area of Lake Hawassa comprises emergent and submergent macrophytes (Zerihun Desta, 2008; Fig. 2). This area supports diverse invertebrate benthic communities, waterfowls, the Nile monitored lizard (*Varanus niloticus*), otter (*Lutra lutra*), and hippopotamus (*Hippopotamus amphibious*) (Zerihun Desta, 2008). The lake is home to six fish species, namely *O. niloticus, Clarias gariepinus, Labeobarbus intermidius, Barbus* *paludinosus, Aplochelichthys antinorii, and Garra quadrimaculata* (Elias, 2000). The last three species are not commercially fished due to their small size.

size.

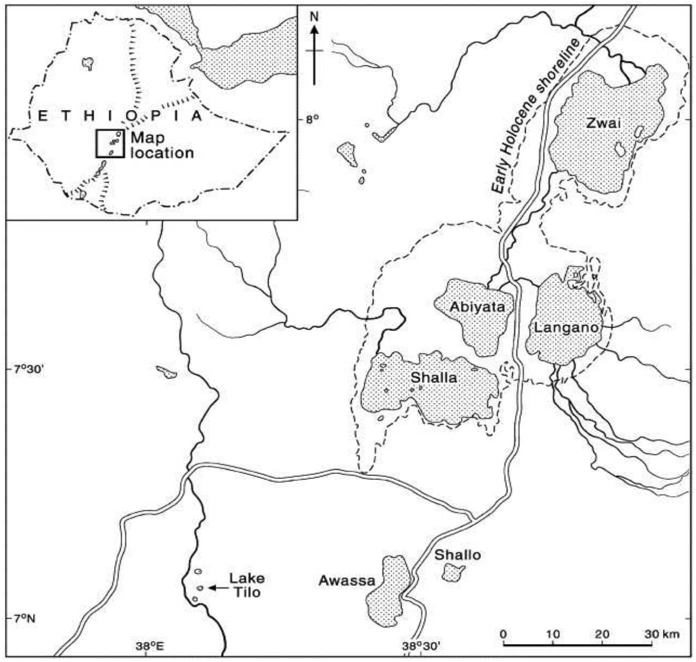

Fig. 1. Lake Hawassa (previously Awassa) in relation to other central Rift Valley Lakes of Ethiopia (Lamb *et al*. 2011)

2.2. Fish Sampling and Measurements

A total of 10,242 fish samples were procured from landings at Amora Gedel fish market. The total length (TL) of all fish samples was measured to the nearest millimeter. Length measurements were obtained from 48 randomly selected boats, with girth circumference measured at the deepest part of the body to the nearest millimeter. The gillnet mesh size was measured to the nearest millimeter, with five measurements taken from each net and averaged to determine the mean mesh size. The mesh sizes of all gillnets from the selected boats were measured to establish the range of mesh sizes utilized by the fishermen.

2.3. Sexual Maturity Stages

The maturity stage of each gonad was assessed using a five-point maturity scale (Holden and Raitt, 1974). The maturity scale categorizes gonad maturity into stages: immature (I), recovering spent or developing virgin (II), ripening (III), ripe (IV), and spent (V).

2.4. Size at First Maturity

The percentage of male and female *O. niloticus* with gonad stages three, four, and five in different length groups was plotted against length for each sex. The length at which 50% of the fish are mature (*Lm50*) was determined based on the relationship between the percentages of mature fish at different size classes, using the logistic function (SPSS Program). This parameter serves as an important indicator of the size at first maturity for the studied population.

Fig. 2. Lake Hawassa as seen from the western side of Mount Tabor (Bjørkli, 2004).

3. Results and discussion

3.1. Mean length of fish captured

The mean length of fish was calculated from 10,274 fish samples obtained from the landings of the fishermen from March- May 2012. The mean length of the fish caught was

22.6 ±0.2 cm. The majority of fish caught were between the length of 20- 24 cm TL (Fig. 3).

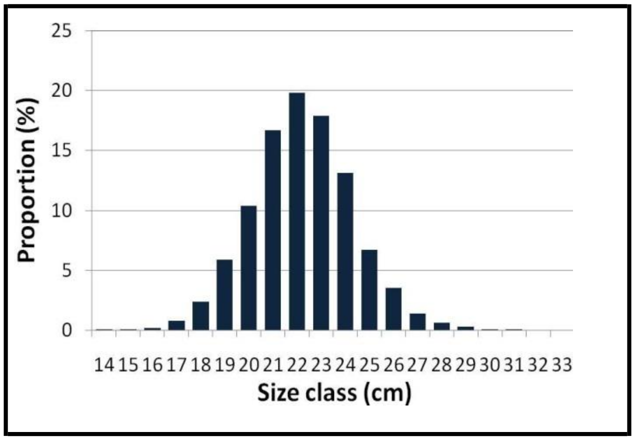

Fig. 3. Size distribution of 10,242 *O. niloticus* caught using the commercial gill nets (80-120 mm stretched mesh size)

3.2. Size at First Maturity

The length at first maturity (*Lm50*) for both female and male *O. niloticus* (Fig. 4) was estimated to be 16.8 cm and 20.0 cm, respectively. The smallest female fish found in breeding condition measured 13.9 cm TL, while the smallest male fish found in breeding condition measured 17.0 cm TL. Various authors have reported different sizes at first maturity for *O. niloticus* in various water bodies across Africa (Yirga et al., 2001; Nijiru et al., 2006; Demeke Admassu, 1994; LFDP, 1997). Notably, except in Lake Koka, the size at first maturity of *O. niloticus* is considerably higher in other lakes compared to Lake Hawassa (Table 1). This discrepancy could be attributed to the intense fishing activity in Lake Hawassa relative to the other lakes. High fishing activity tends to decrease the size at first maturity of fish, as a compensatory response to the losses incurred through fishing pressure (Wootton, 1998).

In *O. niloticus*, males exhibit faster growth than females. Consequently, adult males are larger than conspecific females of the same age in the population. Due to this phenomenon, management practices in Lake Hawassa should take into account the *Lm50* of males to determine the minimum allowable size for fish in order to sustain the population.

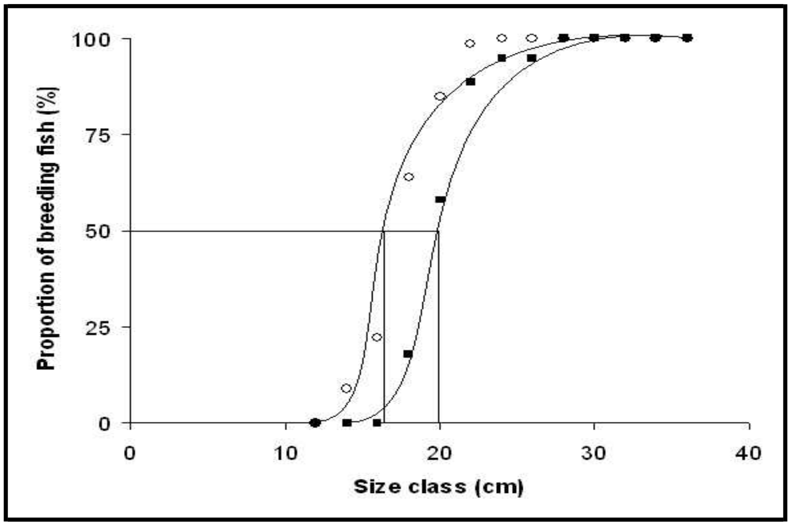

Fig. 4. Size at first maturity of the Nile tilapia *O. niloticus* from Lake Hawassa (○- females, ■- males

4. Impact of Fishing Activity on Population Dynamics

In the past, the population of *O. niloticus* in Lake Hawassa faced severe challenges due to unrestricted access to fishing activities by anyone interested. There were no controls on the number of fishermen, boats, and nets, leading to over-exploitation and a decline in the size of the captured fish. To enhance catch probability, fishermen lowered the mesh size of their nets.

Recently, the Fisheries Section of the Ministry of Agriculture, in collaboration with other concerned bodies, introduced legislation to regulate fishing activities (LFDP, 1997). The legislation set specific limits, including a maximum of 750 nets, a minimum stretched mesh size of 8.0 cm, a minimum twine thickness of 210/2, a maximum gill net length of 70 m, and a maximum height of 2.5 m (LFDP, 1996).

5. Relationship Between Total Length and Girth Circumference

To determine the girth circumference (*GC*) of fish at a given length, a linear regression line was fitted using total length (*TL*) as the abscissa and girth circumference (*GC*) as the ordinate for 366 fish samples. A highly significant positive linear relationship was observed between total length and girth circumference of *O. niloticus* in Lake Hawassa, described by the formula: GC = 0.749TL – 0.054, with an r^2 value of 0.987 (Fig. 5). Since *GC* is twice the length of the mesh size of the gillnet used for capture, it is possible to calculate the minimum mesh size required to capture fish at its size of *Lm50*. Accordingly, a 7.5 cm stretched mesh size was identified as the minimum mesh size for gillnets in tilapia fishery in Lake Hawassa. This mesh size is slightly smaller than the mesh size used to capture the mean length of 22.6 cm TL, which is 8.4 cm stretched mesh size.

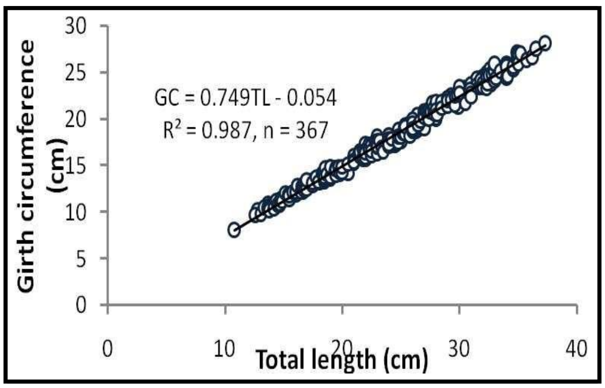

Fig. 5. The relationship between total length and girth circumference of 376 *O. niloticus* in Lake Hawassa

3.4. Current Mesh Sizes Used by Fishermen

Mesh size measurements from 194 gill nets in Lake Hawassa indicated a range of 7-12 cm stretched mesh, with an average of 9.2 cm (Table 2). Only 5.2% of these nets were found to have mesh sizes below the legally established minimum of 8.0 cm. Since each gill net had five mesh size measurements taken, a total of 970 measurements were analyzed. The current mesh size used is slightly larger than the minimum required to capture tilapia at its *Lm50* (7.5 cm). However, caution is advised against further reducing the mesh size, as it may adversely affect immature fish.

Presently, the fishing activity captures approximately 20% of fish below the *Lm50*. To protect the breeding population, it is recommended to prohibit fishing in the shallow littoral areas, which serve as breeding and nursery grounds for *O. niloticus*. Considering the biannual breeding activity of *O. niloticus* in Lake Hawassa (March-May and September-October), fishing activities should be banned in these areas during these periods.

Conclusion and Recommendations

The study determined that the average size at first maturity (*Lm50*) for females and males was 16.8 cm TL and 20.0 cm TL, respectively. The relationship between TL and GC suggested a minimum mesh size of 7.5 cm for gillnets. The average mesh size used by fishermen in Lake Hawassa was 9.2 cm, slightly exceeding the legally permitted 8.0 cm. This suggests that the gill net fishery, under the current management scheme, is relatively safe, with the average caught fish size (22.6 cm) being higher than the species' size at first maturity (20.0 cm).

Analysis of length distribution revealed that 9.4% of caught fish were smaller than the size at first maturity. Additionally, 5.2% of the total mesh size measurements were below 8.0 cm. While the general mesh size used in Lake Hawassa appears satisfactory, it is recommended that fishermen refrain from using gill nets with a mesh size lower than 8.0 cm. Acknowledgments were given to Dr. Yosef Tekle-Giorgis for providing data, as well as to individuals and organizations that assisted in data collection. Financial support was provided by NORAD.

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