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# GILLNET SELECTIVITY OF LAKE TANA PISCIVOROUS FISH: *LABEOBARBUS MEGASTOMA*

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**ABSTRACT:** Gillnet selectivity parameters and its impacts on the population of the Lake Tana *Labeobarbus megastoma*, were estimated from fishery-independent catches in multi-panel gillnets with stretched mesh sizes ranging from 60 to 140 mm. Selectivity on *L. megastoma* was assessed using the PASGEAR software. Five different functional models; normal location, normal scale, gamma, log-normal and bi-modal were used to fit the selectivity curves to the catch data. It was shown that the bi-modal function was the best fit to the data. For the bi-modal selectivity curves, the optimum lengths (100% retention probability) for the 60, 80, 100, 120 and 140 mm mesh sizes were 24.18 cm, 32.24 cm, 40.3 cm, 48.36 cm and 56.42 cm, respectively. Considering the size at first maturity ($L_{50\%}$), 100 mm mesh size was found to be the most adequate mesh for exploiting the minimum allowable landing size (35 cm).

**Key words/phrases**: Bi-modal, *Labeobarbus*, Lake Tana, Selectivity.

## INTRODUCTION

*Labeobarbus megastoma* is one of the eight piscivorous fish species, which together with thirteen other species, compose the endemic hexaploid ‘large barb’ species flock of Lake Tana. It is the sixth most important fish species (IRI=3.7%) with regard to numbers in the pooled catches data of the exploratory fishing program conducted by the Bahir Dar Fisheries and Other Aquatic Life Research Centre between 1995 and 2007 (Unpublished data). It has been subjected to overfishing because *L. megastoma*, was relatively abundant in the river mouths throughout the year, masking possible aggregations of these species in the river mouths during the peak spawning months (de Graaf *et al*., 2005). In 1999, *L. megastoma* contributed 29% of the total catch (n=76) in Dukolit during 2-15 September (de Graaf *et al*., 2005).

Their aggregations at the river mouth during spawning migrations makes them vulnerable to overfishing, because their exploitation can, in extreme cases, lead to a dramatic decrease in the number of recruits. Moreover, at present there is no limitation on the number and type of gillnets used.

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Gillnets are widely used in artisanal fisheries in developing countries because they are efficient, relatively inexpensive and capable of catching higher amount of commercially valuable species than other fishermen gears (Valdéz-Pizzini *et al*., 1992). The same is true for the Lake Tana fisheries (Pers. Obs.).

Gillnet selectivity studies are frequently used to estimate the abundance and size structure of fish populations, particularly where trawls cannot be used (e.g., Hansson and Rudstam, 1995). Due to the lack of nonselective gears, it is necessary to use several gillnets of differing mesh sizes simultaneously to estimate selectivity.

Various indirect methods are used for estimating selectivity of gillnets. Most studies on selectivity are based on Baranov's "Principle of Geometrical Similarity", which states that selection depends on the geometry of the fish and the meshes (Baranov, 1948). Thus, it is assumed that is the same for any combination of fish length and mesh size for which ratio is constant and that all the mesh sizes will be equally efficient. However, this principle does not hold true if the catch processes (gilling, entangling, wedging) are varying (Hovgärd, 1996; Hovgärd and Lassen, 2000).

Although gillnets are one of the most commonly used fishing gear for Lake Tana *L. megastoma*, the impact they have on the selectivity of the target population is unknown. The analysis of the selectivity of this type of gear will provide biological fishery information for the management and development of the Lake Tana fishery.

Gillnet selectivity studies of Lake Tana *L. megastoma* fish species previously have been done by de Graaf *et al*. (2003) together with all *Labeobarbus* fish species on the southern gulf of Bahir Dar and the mouths of the four permanent contributing rivers. But no detail information is available for the whole lake system of the *L. megastoma* fish species. So the objective of this study was to measure the *L. megastoma* selectivity of gillnets used in the exploratory fishery program of Lake Tana. A secondary objective was to investigate the effect of the small mesh gillnets on the length at first capture of *L. megastoma*, *vis-a-vis* the effect on rejuvenation and the economic survival of the fishermen with a view to proffering appropriate management strategy for the fishery.

## MATERIALS AND METHODS

Data to estimate selectivity of gillnets to *L. megastoma* in Lake Tana were obtained from a fishery independent sampling program of the Bahir Dar Fisheries and Other Aquatic Life Research Centre (BFALRC) in which the author was a participant. Exploratory fishing was conducted at six sites in the northern and southern (Bahir Dar Gulf) parts of the lake. Each of the six sites, whose coordinates are given in Table 1, was further sub-divided into three sub-sites which were identified as 'river mouth', 'macrophyte cover' and 'open water'. Fish samples were caught monthly during February 2000 through to December 2004 and bimonthly during January 2005 through to December 2006.

Table 1. The coordinates (corner points) of the six sampling stations on Lake Tana.

| **Station name** | **Coordinates** | |
|---|---|---|
| | **North** | **East** |
| Gerima | 11°37'02" | 37°23'05" |
| Zegie | 11°42'06" | 37°23'09" |
| Abbay | 11°51'05" | 37°08'01" |
| Dirma | 12°15'44.8" | 37°18'43.4" |
| Gedamat | 12°12'52.2" | 37°17'35.3" |
| Sekela | 12°13'20.9" | 37°18'47.7" |

The sampling gear used was a 250 m long and 3 m deep gillnet panel consisting of five individual gillnets having stretched mesh size (mm) 60, 80 (that are currently used by local fishermen), 100, 120 and 140, respectively. Each gillnet was 50 m long and 3 m deep, and made of PA multifilament twines (210 D/18). In addition, each gillnet had a hanging ratio of 0.50. The five gillnets were randomly connected end-to-end, and the resulting 250 m long panel was set around sunset and retrieved at dawn. Thus, the average soaking time was 12 hrs throughout the sampling period. During the whole study period, almost similar fishing conditions and operations were maintained. The fishing gear currently used by local fishermen are almost similar to ones used in this study and is the same mesh size used by commercial fishermen. All gillnets were made with the same materials and standard by Lake Tana No.1 Fish Supply Association.

Upon retrieval of the sampling gear, fish caught in the five gillnets were collected separately in five labeled boxes and transported to the laboratory. In the laboratory, several variables were measured on each specimen, of which fork length (FL) is relevant for this study. FL was measured to the nearest 1 cm. In addition, the sex and the gonadal maturity stage of each fish were also determined by inspecting the gonads using Holden and Raitt (1979) five-stage gonad maturity key. Stages 1 to 5 represent gonad states as immature, maturing (or recovering), ripening, ripe (running) and spent, respectively. Maturity data were used to estimate length of 50% maturity ($L_{50}$) as shown below. Data on FL from the whole sampling period were grouped into length classes each with a class width of 1 cm, and frequencies recorded. Thus, a table of length-frequencies was prepared showing the number of *L. megastoma* of length 'FL' caught by a gillnet of mesh size 'm' (m being 60 mm, 80 mm, 100 mm, 120 mm and 140 mm).

Gillnet selectivity was estimated from the length-frequency data using PASGEAR II software (version 2.3 October 2007) (Kolding, 1999), which is available at http://www.cdcf.no/data/pasgear. The software is a customized database package intended for experimental fishery data from passive gears, and based on the general statistical model (SELECT) described by Millar (1992), its specific application for gillnets and hooks are described by Millar and Holst (1997), and Millar and Fryer (1999). The length-frequency data were analyzed using five models of selection curves in PASGEAR before identifying the model that best fits the data. The five models were normal location, normal scale, gamma, log-normal and bi-modal models whose descriptions are available in the aforementioned literature (e.g., Millar and Holst, 1997; Millar and Fryer, 1999). Thus, all the models assume that fish length of maximum retention (mean length or modal length) is proportional to mesh size. The normal location and normal scale models yield symmetrical selection curves, but the former assumes that spread (standard deviation) is fixed across mesh size whereas in the normal scale model, both modal length and spread increase with mesh size, i.e., principle of geometric similarity (Baranov, 1948). The log-normal, gamma, and bi-modal models yield asymmetrical (skewed) selection curves in which spread may be proportional to mesh size.

Whether a model fits observed length-frequency data, i.e., goodness of fit, was evaluated by comparing model deviance with the number of degrees of freedom (df) within a model. Generally, for a model to be a good fit, its deviance should not be much larger than its df (Park *et al*., 2004). However, it is even more desirable for the deviance to be smaller than df for a model to be a best fitting one. Accordingly, the goodness of fit of the five models to length-frequency data of *L. megastoma* was evaluated based on deviance and df obtained from PASGEAR and the best fitting model.

$L_{50}$ was estimated for males and females *L. megastoma* from Lake Tana according to Gunderson *et al*. (1980). Thus, percentage of mature fish per length class was calculated and $L_{50}$ was estimated by fitting a logistic model with the formula below using PASGEAR.

$$P_m = \frac{1}{1+e^{(-aL+b)}} * 100$$

Where $P_m$ is percent mature (=%mature) at length L, and a and b are fitted constants. The relationship between the percentage of mature fish ($P_m$) per length class and fish length (Fork Length, FL in cm) was described with a logistic curve: a, intercept and b, slope of the curve. From the sigmoid curve $FL_{50\%}=-a/b$ was determined.

$$\frac{lnP_m}{(1-P_m)} = a + bFL_i$$

## RESULTS

A total number of 828 *L. megastoma*, ranging from 13.5–73.3 cm (fork length: FL) were collected in the present study. The standard deviation for optimum catch length ranged between 3.7 and 8.2 cm. The length-frequency distributions caught in five different meshes of gillnets are presented in Fig. 1.

The highest number of catch (75.6%) was obtained in the smallest mesh size of net and the number of individuals caught during the fishing period decreased with the increase of mesh size. The average proportions in terms of numbers for the nets of 60, 80, 100, 120 and 140 mm meshes were 32.7%, 43.8%, 16.7%, 4.9% and 1.8%, respectively. The mean length of captured fish was 27.3 cm for 60 mm mesh size, 32.3 cm for 80 mm mesh size, 38.0 cm for 100 mm mesh size, 45.8 cm for 120 mm mesh size, and 47.7 cm for 140 mm mesh size. The mean length of fish is almost linearly proportional to the increasing mesh size as may be seen from the observed and fitted catch curves (Fig. 2).

All gillnets are selective in a certain range. The range of selectivity of gillnets increased with increasing mesh size. Gillnet selectivity on *L. megastoma* was assessed using the SELECT method implemented in the PASGEAR software.

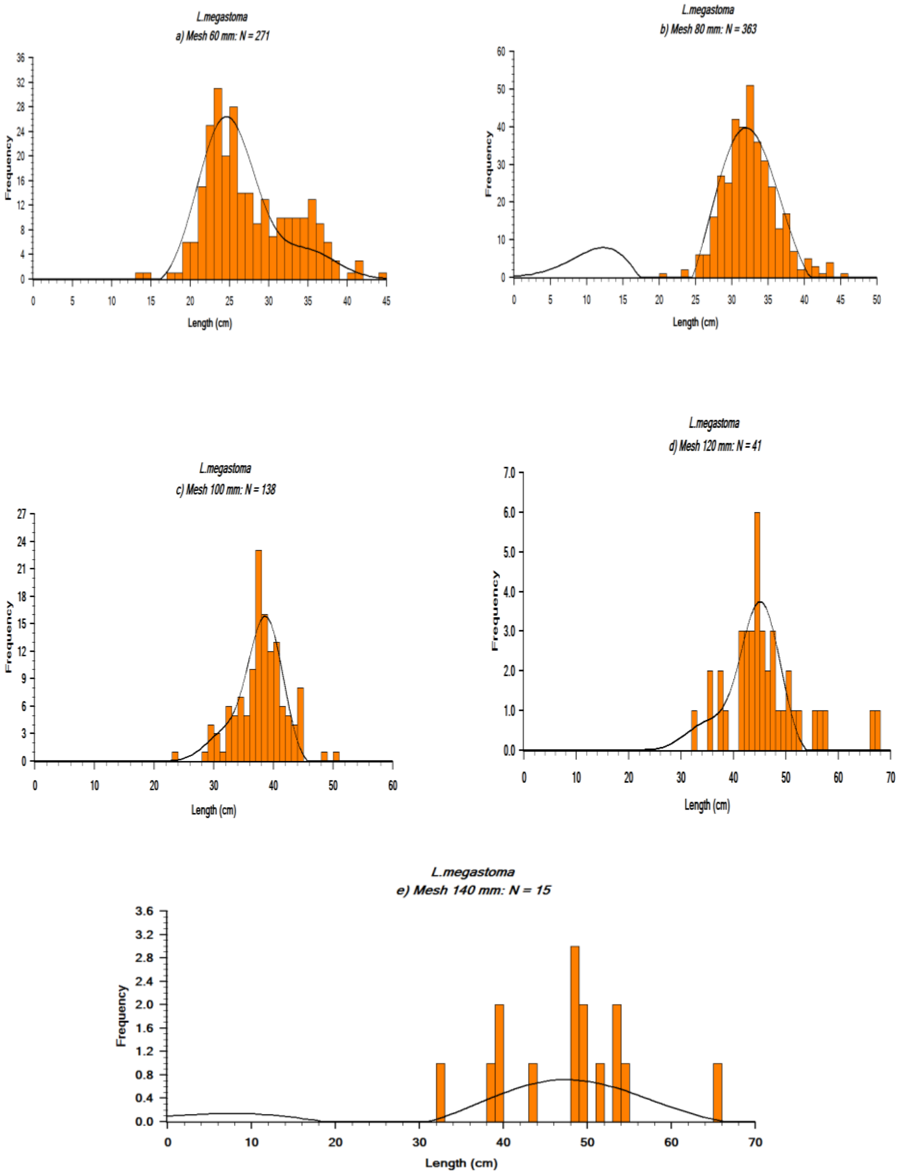


Fig. 1. Histogram of length-frequency distributions of *Labeobarbus megastoma* and fixed catch curve (line) using data obtained by gillnets of (a) 60 mm, (b) 80 mm, (c) 100 mm, (d) 120 mm and, (e) 140 mm mesh sizes in Lake Tana (N=number of fish caught).

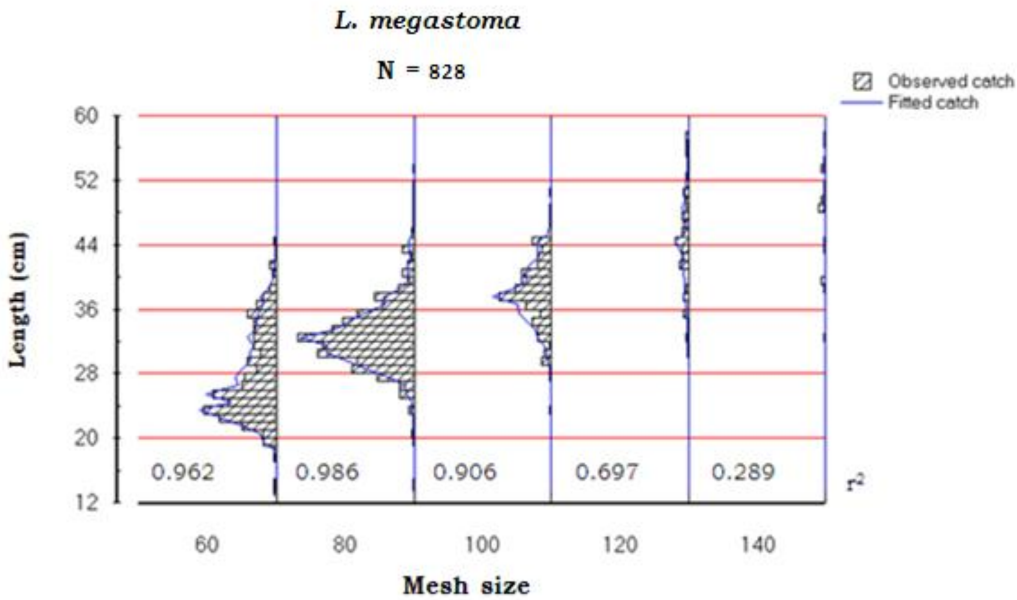


Fig. 2. Length distribution histogram of observed catch data and calculated regression (equation line) of mean size at capture of *L. megastoma* caught with different mesh sizes (stretched mesh 60, 80, 100, 120, 140 mm). N=Total number of fish included into regression analysis.

The parameters of the different models fitted as well as the deviance, which is the likelihood ratio goodness of fit statistic, and the corresponding degrees of freedom for the best five different functional models; normal location, normal scale, gamma, log-normal and bi-modal are presented in Table 2.

Table 2. Fitted parameters and deviances for the fit (d.f. is degrees of freedom).

| **Model** | **Parameters** | **Model d.f deviance** | **$r^2$** | **Goodness of fit (*p value*)** |
|---|---|---|---|---|
| Bi-modal | $(K_1, K_2, K_3, K_4, W)$=(0.40,0.04,0.55, 0.11, 0.287) | 89.79 | 0.97 | 0.66 |
| Normal location | $(K_1, \sigma)$=(0.421, 6.041) | 217.64 | 0.87 | 0.0 |
| Normal scale | $(k_1, K_2)$=(0.449, 0.074) | 279.42 | 0.80 | 0.0 |
| Log-normal | $(\mu_1, \sigma)$=(3.279, 0.171) | 199.95 | 0.87 | 0.0 |
| Gamma | $(K, \alpha)$=(0.013, 35.721) | 220.50 | 0.85 | 0.0 |

The bi-modal model had the lowest deviance value, indicating the best fit for *L. megastoma* species. In general, the deviances of the best models were in all cases equal or marginally better under the assumption of equal fishing powers proportional to mesh size for fish caught with gillnet of SELECT model. The common mesh selection parameter $k_1$ relating the modal length to the mesh size was found to be 0.40. On the basis of this parameter, the corresponding model lengths for 60, 80, 100, 120 and 140 mm meshes were calculated to be 24.18 cm, 32.24 cm, 40.3 cm, 48.36 cm and 56.42 cm, respectively. Selectivity curves based on bi-modal for the different mesh sizes are shown in Fig. 3.

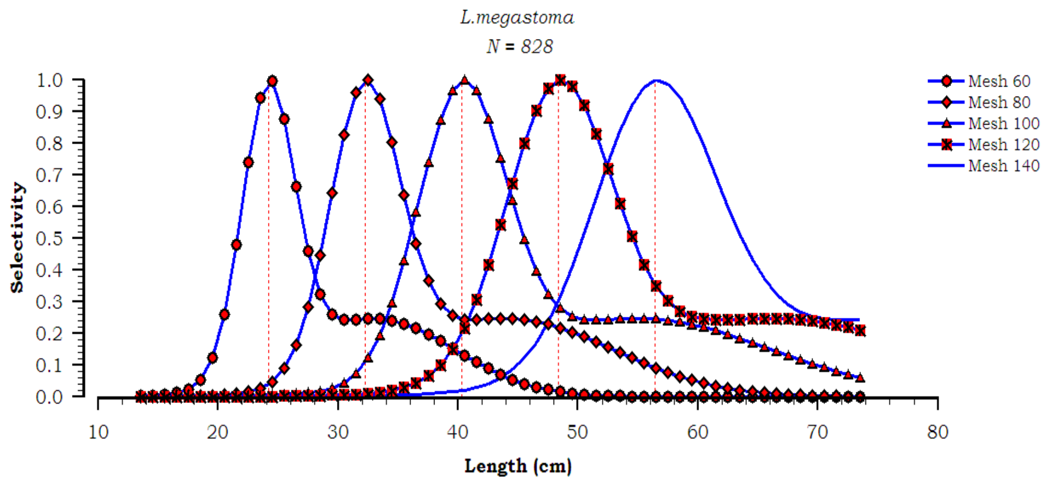


Fig. 3. Gillnet selection curves for *L. megastoma* caught with different mesh sizes (stretched mesh 60, 80, 100, 120, 140 mm). N=total number of fish caught.

Length-frequency distributions of the sampled *L. megastoma* were also examined in terms of skewness, which is available in the PASGEAR. Distributions were approximately normal for mesh sizes 80 mm. The length-frequency distribution was positively skewed for 60, 100 and 120 mm meshes, and negatively skewed for the larger mesh panels (140 mm). The magnitude of the skewness decreases with increasing mesh size (Fig. 1).

The length at first maturity ($L_{50\%}$) was observed by the experimental nets of mesh size 60, 80, 100, 120 and 140 mm were 33.31 for female and 31.07 for male *L. megastoma* (Fig. 4).

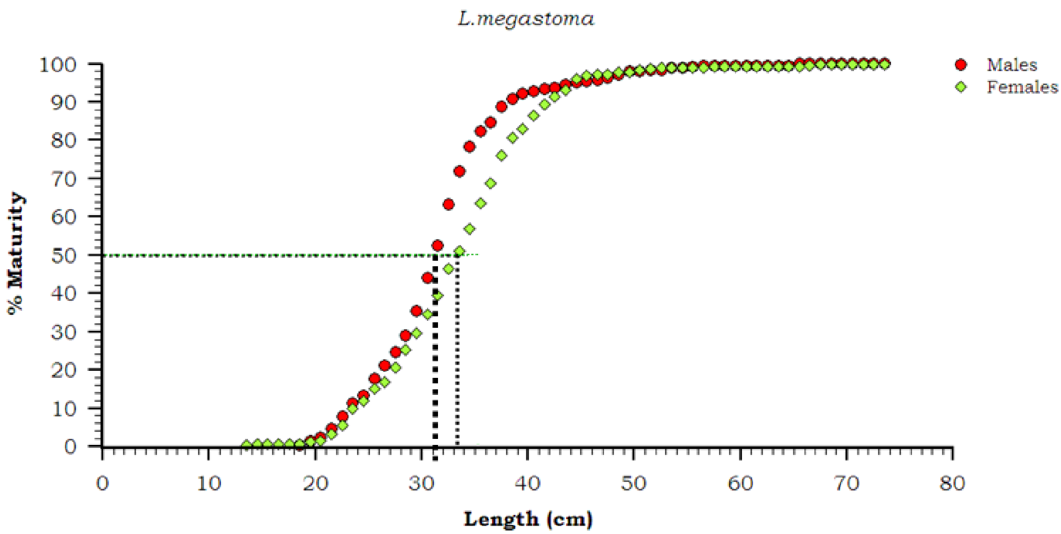


Fig. 4. Length at first maturity ($L_{50}$) curves for male and female *L. megastoma*.

## DISCUSSION

In the present study, the bi-modal (bi-normal) was found to best represent the selectivity curve of gillnet for the *L. megastoma*. According to Dos Santos *et al*. (2003) and Erzini *et al*. (2003), the lowest deviance value corresponds to the best fitting. This is in agreement with this findings where bi-modal had lowest deviance among the rest five model (bi-modal < log-normal < normal location < gamma < normal scale).

As generally stated in many studies (Dos Santos *et al*., 2003; Erzini *et al*., 2003; Dinçer and Bahar, 2008), bi-modal curves may produce better fit than unimodal models for several fish species. This may be attributed to the fact that in gillnets some part of the catch is due to entangling rather than being wedged or gilled (Sbrana *et al*., 2007; Carol and Garcia-Berthou, 2007).

The main idea behind the fishery regulations is to permit adults to contribute to recruit before being caught. de Graaf *et al*. (2003) have reported that length at first maturity for female *L. megastoma* is 36.1 cm and that of male is 26.5 cm, respectively, whereas in this study, female scored 33.31 cm and male 31.07 cm, respectively. The difference might be due to fishing gear variation combination of trawl and gillnet versus gillnet only and fishing site variation of southern gulf and tributary rivers with that of whole lake. Procedure of gonad developmental stage (1–7) of De Silva *et al*. (1985) with that of Holden and Raitt’s (1979) five-stage gonad maturity may also cause difference. Almost no catch smaller than length at first maturity was observed by the experimental nets of mesh size 120 and 140 mm.

The ratio of fish below $L_{50\%}$ (<31.07 cm) captured by 60, 80, 100, 120 and 140 mm meshes were 78.9%, 62.2%, 12.9%, 2.5% and 7.1%, respectively. However, more than 50% of the catch in 60 and 80 mm mesh were undersized individuals below length at first maturity. On the other hand, the ratios of undersized individuals that were taken by 100, 120 and 140 mm mesh size were below 15%, 5% and 10%, respectively.

For management purposes, 100, 120 and 140 mm mesh sizes were found to be in agreement with the actual length at first maturity ($L_{50\%}$). There is no minimum mesh size established for *L. megastoma* in Lake Tana fishery regulations. According to this study, the most recommended mesh size would be 100 mm, even though this net catches less fish than 80 mm net, assuring more protection for the juveniles. Previously, de Graaf *et al*. (2003) reported that 100 mm stretched mesh is adequate but the difference is that the commercial fishermen used 100 mm stretched mesh size gillnet and in the study sites were restricted to northern gulf of L. Tana. In the current study, the fishermen used 80 mm net and our sampling area encompassed almost all parts of the lake, so the 100 mm mesh of gillnet recommendation as a minimum mesh size for *L. megastoma* fisheries in L. Tana is appropriate. It will give an opportunity for fish to spawn, at least once, before being exploited.

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