Journal of Agricultural Science and Technology A 4 (2014) 135-140
Earlier title: Journal of Agricultural Science and Technology, ISSN 1939-1250

Gillnet Selectivity and Length at Maturity of Nile Tilapia (*Oreochromis niloticus* L.) in a Tropical Reservoir (Amerti: Ethiopia)

Mathewos Hailu
Ziway Fisheries Resources Research Center, Ziway 229, Ethiopia

Received: November 20, 2013 / Published: February 20, 2014.

Abstract: The selectivity of gillnets for *Oreochromis niloticus* in Amerti reservoir (9°63′ N, 37°23′ E) was determined from gillnets with four mesh sizes (60, 80, 100 and 120 mm). Four selectivity models (a normal model assuming fixed spread, a normal model assuming that spread is proportional to mesh size, a lognormal model and a gamma model) were fitted to the data by using the share each length's catch total (SELECT) method. A total of 657 specimens of *Oreochromis niloticus* were caught (12.0-35.5 cm total length, T_L). The sizes at first sexual maturity were 21.5 cm T_L and 18.9 cm T_L, respectively, for male and female *Oreochromis niloticus*. The lognormal selectivity curve provided the best fit to the data according to model deviance estimates with optimum selectivity of 16.66, 22.26, 27.78 and 33.38 cm T_L for the 60, 80, 100 and 120 mm mesh sizes, respectively.

Key words: Gillnet, mesh selectivity, Nile tilapia, SELECT.

1. Introduction

Oreochromis niloticus (Nile tilapia) is native fish species of East African lakes [1]. The species has been introduced to many parts of the world and has adapted to wide range of environmental variables [2]. Adaptation of Nile tilapia to various environments is due to its ability to both protracted spawning period and variability in length at first maturity in response to environmental and fisheries related stress [3-5].

Nile tilapia is one of the most important commercial fish species in Ethiopia [6]. Regardless of the adaptability and tolerance to various environmental and anthropogenic impacts, high demand for Nile tilapia in Ethiopia has led to the decline of fish stocks in some Ethiopian lakes and reservoirs [7]. The decline of *Oreochromis niloticus* is aggravated due to lack of regulations on fishing effort, minimum landing size and minimum mesh size of gillnets.

Managing fisheries requires a combination of limits on area, time, gear, size, species and effort [6]. Fishing gears greatly influence the size frequency of targeted species [8, 9], and understanding the reproductive biology and selectivity of the fishing gears in a particular environment is important for managing a targeted species.

Due to the size-selective nature of gillnets which are widely used by fisheries that target *Oreochromis niloticus*, mesh size regulations can be an effective tool for managing the size composition of catches [10]. The share each length's catch total (SELECT) model is considered to be the most robust indirect method to estimate gear selectivity [10, 11]. The method is widely used to obtain selectivity of various fishing gears [12].

Recently (February, 2013), regional proclamation has been ratified on fish resource conservation, food

Corresponding author: Mathewos Hailu, assistant researcher, research field: aquatic ecology. E-mail: lemathewos@gmail.com.

safety and aquaculture. This document puts considerable emphasis on regulation, permits and the role of the fishery inspector. Thus, this study aimed at identifying size at first maturity and selectivity of gillnets for Nile tilapia.

2. Materials and Methods

2.1 Sampling

The study was conducted in Amerti reservoir (9°63′ N, 37°23′ E), which is located at an altitude of 2,243 m absl. Gillnet surveys were carried out monthly between August 2011 and June 2012 using multifilament gillnet fleets comprising 60, 80, 100 and 120 mm stretched mesh size made from 210 D/3 twine. The panel length of each mesh size was 25 m with 3 m depth. Immediately after capture, the total length (T_L) and total weight (T_W) were measured and weighted to the nearest 1 mm and 0.1 g, respectively. Fish were then dissected, sexed and the gonads were assigned a stage of maturity according to Ref. [13].

2.2 Data Analysis

Sex ratio was computed and chi-square (χ^2) test was used to determine if it varied from the null hypothesis 1:1 [14]. The length-weight relationship was determined by using nonlinear least-squares regression (SPSS, 2011).

Gill net selectivity was estimated by using SELECT method [15]. The SELECT method applies maximum likelihood which estimates selectivity parameters from a general log-linear model [16]. The expected catch (V) of *Oreochromis niloticus* of length class i in gillnet j is described by:

$$V_{ij} = P_j \lambda_i r_j \quad (1)$$

where, P_j is the relative fishing intensity of gillnet j; λ_i is the abundance of *Oreochromis niloticus* in length class i; r_j is the selection curve for each gillnet j.

Relative fishing intensity represents fishing effort and fishing intensity combined and is the conditional probability that a fish contacted gillnet panel j with the assumption that it made single contact with the entire combined gillnet panel [12]. The normal, gamma and lognormal models (Table 1) observe geometric similarity (mean (μ_j) and spread (σ_j) proportional to mesh size) whereas the normal model with fixed spread is not geometrically similar (mean (μ_j) and spread (σ_j) equal across mesh sizes).

Catch data from Amerti reservoir were pooled by mesh size into 1 cm length classes, and the midpoint of each size class was used to estimate a selectivity curve for each mesh size. The four gillnet selectivity models (normal location, normal scale, gamma and log-normal) were fitted to the data by using the “gillnet functions” package in R statistical software [16, 17]. For each model, the data were fitted under the assumptions of equal effort and proportional effort to the size of the mesh. Goodness of fit statistics in the form of model deviance was used to choose the best model.

The mean length of fish at first maturity (L_{50}) was determined using the method described in Ref. [18]. The method fits the percentages of mature fish that were grouped in 1 cm length classes to the logistic equation:

$$P_L = (\exp(\alpha + \beta L))/(1 + \exp(\alpha + \beta L)) \quad (2)$$

where, P_L is proportion of mature fish at length L, L is total length (cm) and α (the intercept) and β (the slope) of least-squares estimates.

3. Results

A total of 657 *Oreochromis niloticus* specimens, comprising 398 males and 259 females were captured during the sampling period. The sex ratio was biased to males (χ^2 = 22.47, P < 0.0001). The T_L of the specimens ranged from 12.0 cm to 35.5 cm (Fig. 1) with a corresponding weight of 56.9-1,535.8 g. The length-weight relationships were curvilinear and statistically significant with $W = 0.016L_T^{3.034}$, $R^2 = 0.98$.

Average length (± SD) of *Oreochromis niloticus* captured by the gill nets with 60, 80, 100 and 120 mm mesh size were 16.3 ± 1.5, 22.5 ± 2.8, 24.8 ± 1.8 and

Table 1 Selectivitycurves for normal, gamma and lognormal models used to estimate gillnet selectivity for *Oreochromis niloticus.*

Model	Selection curve	Modal length
Normal (fixed spread)	$\exp\left[-\frac{(l_j - k \cdot m_i)^2}{2\sigma^2}\right]$	$k \cdot m_i$
Normal	$\exp\left[-\frac{(l_j - k_1 \cdot m_i)^2}{2k_2^2 \cdot m_i^2}\right]$	$k \cdot m_i$
Gamma	$\frac{m_i}{l_j m_1}.\exp\left\{\mu - \frac{\sigma^2}{2} - \frac{\left[\log(l_j) - \mu - \log({}^{m_i}/_{m_1})^2\right]}{2\sigma^2}\right\}$	$(\alpha - 1)km_i$
Lognormal	$\left[\frac{l_j}{(\alpha - 1)km_i}\right]^{\alpha-1}.\exp\left(\alpha - 1 - \frac{l_j}{km_i}\right)$	$\exp(\mu - \sigma^2)\left(\frac{m_j}{m_1}\right)$

where, l_j is the midpoint of length class j; m_i is the mesh size for panel i (i = 1-4 panels).

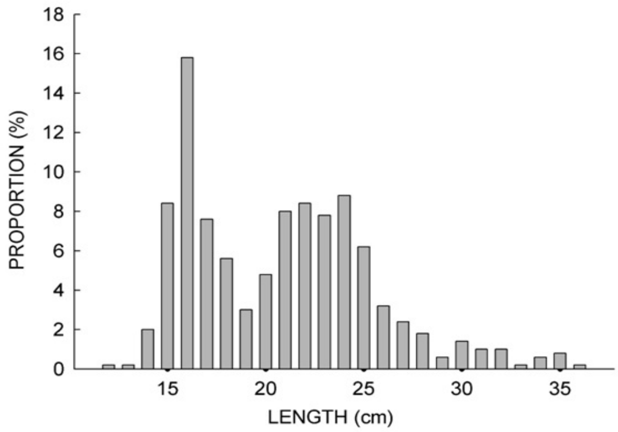

Fig. 1 Length frequency distribution of captured *Oreochromis niloticus* in Amerti reservoir.

30.3 ± 4.4 cm, respectively (Fig. 2). The size at first sexual maturity (L_{50}) for male *Oreochromis niloticus* was 21.5 cm T_L while the females attained L_{50} at 18.9 cm T_L (Fig. 3). The smallest female found with ripe gonads was 14.9 cm T_L. Majority of the individuals (99.5%) captured by 60 mm mesh size were below L_{50} (Fig. 2). There was a general increase in the mean size of *Oreochromis niloticus* with increasing mesh size.

There is no significant difference among the modes (i.e., lengths at maximum selectivity) estimated for each mesh size across all models (Fig. 4). However, the lognormal models with effort either equal or proportional to mesh size had identical and the lowest model deviance (Table 2) among the four models fitted using the SELECT method. The parameters and model variance of the selectivity curves of the normal scale, normal location, log normal and gamma models are shown in Table 2. The modes of the lognormal selection curves was found at 16.66, 22.26, 27.78 and 33.38 cm T_L for the 60, 80, 100 and 120 mm mesh sizes, respectively (Fig. 4).

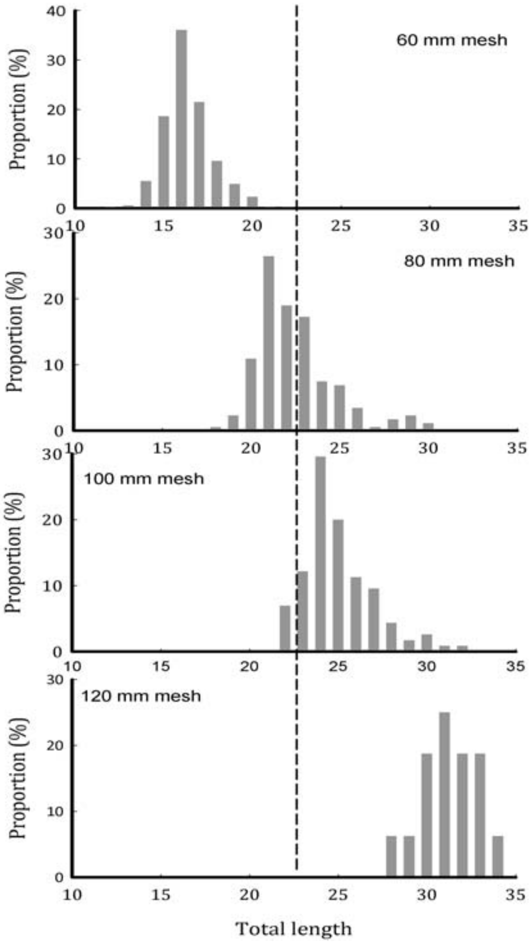

Fig. 2 Proportion of *Oreochromis niloticus* captured by (60-120 mm) mesh sizes gillnet. Dotted line indicates size at first maturity.

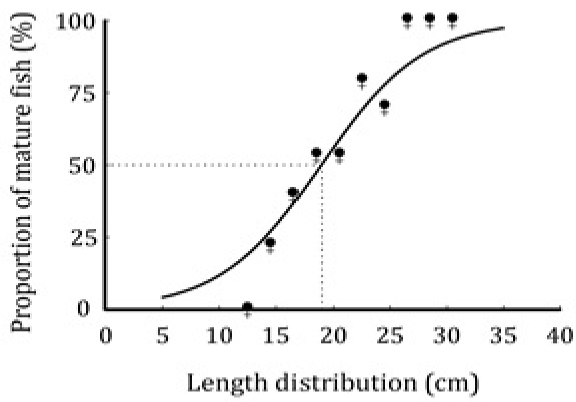

Fig. 3 Length at first maturity of female *Oreochromis niloticus* in Amerti reservoir.

4. Discussion

For Amerti reservoir, the catch was biased towards males in the current study (1.54:1). Slight variation in sex ratio of wild population is a typical phenomenon among Tilapias [4, 19] which might be attributable to differential migration of sexes [20].

The size at first maturity for *Oreochromis niloticus* is variable and broad in range in several East African lakes and reservoirs, ranging from 13 cm, Lake Tanganyika [21] to 42 cm, Lake Chamo [22]. Size at maturity in *Oreochromis niloticus* is inversely related

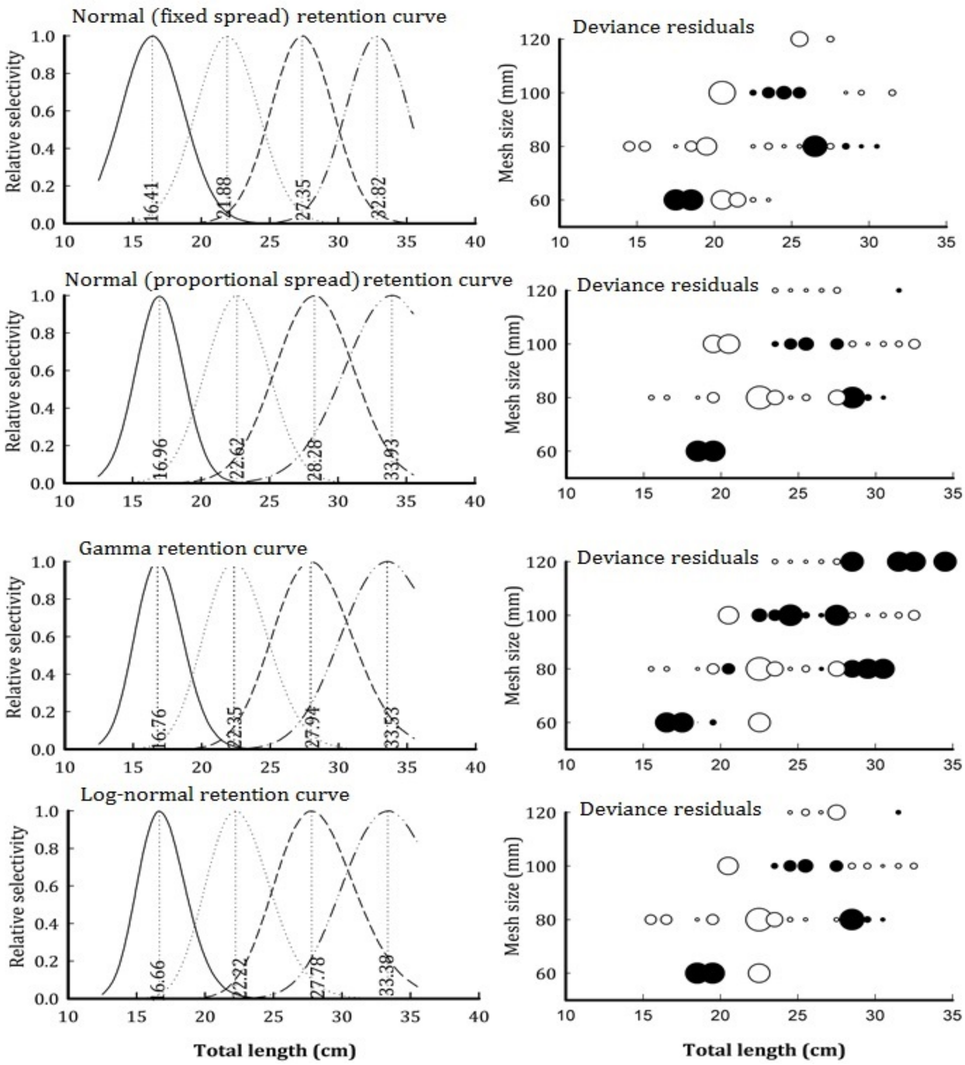

Fig. 4 Gillnet selectivity curves and residuals estimated for *Oreochromis niloticus* in Amerti reservoir for the 60-120 mm mesh sizes.

The plots on the left are the estimated gillnet selectivity curves while the plots on the right show the residuals of the models. Filled circles represent positive residuals and open circles represent negative residuals. The area of the circle is proportional to the square of the residual.

Table 2 Results of the models fit using the SELECT method for gillnet selectivity estimation, *Oreochromis niloticus* in Amerti reservoir.

Model	Equal fishing power		Fishing power α mesh size	
	Parameters	Deviance	Parameters	Deviance
Normal (fixed spread) (k, σ)	(0.274, 2.812)	105.08	(0.28, 2.29)	109.47
Normal (k_1, k_2)	(0.28, 0.0002)	98.45	(0.29, 0.0008)	98.60
Gamma (α, k)	(93.53, 0.003)	86.88	(95.4, 0.003)	86.88
Lognormal (m_1, σ)	(2.82, 0.104)	82.45	(2.84, 0.104)	82.45

to growth, and thereby is influenced by ecological habitat [23] and fishing pressure [3-5]. The latter could be ruled out for Amerti reservoir as there is no well-established fishing in the reservoir.

The model deviances obtained under the two assumptions about fishing power were essentially equal, and residual plots (not shown) were nearly identical. The ratio of model deviance to degrees of freedom was slightly higher than 1 (1.2), indicating slight over dispersion of the data. This result indicates that Nile tilapia may not have behaved independently violating the first assumption of independent catches. However, over dispersion does not necessarily affect parameter estimation [11, 12].

Deviance plot showed a similar degree of bias towards all models except the gamma model which showed the highest number of positive residuals for the higher length classes (22-34 cm T_L) in mesh sizes 80, 100 and 120 mm (Fig. 4). The plot indicated that more of the larger individuals were caught in these mesh groups than predicted by the models. The 80 mm mesh sizes caught fewer of the smallest *Oreochromis niloticus* than predicted by the lognormal model. The smallest mesh size (60 mm) panel caught more smaller (< 20 cm T_L) *Oreochromis niloticus* than predicted (Fig. 4).

In general, the gillnet with mesh size 80 mm most efficiently selects individuals about 17-30 cm in length, and the selection has a sharp peak in about 22 cm length class. Length at first maturity has a great importance in the determination of optimum mesh size [24]. The estimated lengths for females and males of *Oreochromis niloticus* in this study were 18.9 cm T_L and 21.5 cm T_L, respectively. Fishing gear restriction is a preferable way of management than closure in small scale artisanal fisheries [9] as it does not threaten the livelihoods of fishers which depend only in fisheries. Thus, the legal minimum size for *Oreochromis niloticus* should be 21 cm which can be achieved if the minimum mesh size is established at 80 mm.

Acknowledgments

The author’s sincere gratitude goes to the technical staff of Ziway Fisheries Resources Research Center, particularly Mr Getachew Senbete, Mitiku Bonxa and Dawit Imiru for their assistance during the fieldwork. The study was financed by the Oromia Agricultural Research Institute (OARI).

References

[1] E. Trewavas, Tilapiine Fishes of the Genera *Sarotherodon*, *Oreochromis* and *Danakilia*, British Natural History Museum, London, 1983, p. 583.

[2] R.L. Welcome, International introductions of inland aquatic species, FAO Fish Tech Pap 294, 1988, p. 318.

[3] J. Chervinski, Environmental physiology of tilapias, in: The Biology and Culture of Tilapias, 1982, pp. 119-128.

[4] M. Njiru, J.E. Ojuok, J.B. Okeyo-Owuor, M. Muchiri, M.J. Ntiba, I.G. Cowx, Some biological aspects and life history strategies of Nile tilapia *Oreochromis niloticus* (L.) in Lake Victoria, Kenya, Afr. J. Ecol. 44 (2006) 30-37.

[5] J.E. Ojuok, M. Njiru, M.J. Ntiba, K.M. Mavuti, The effect of overfishing on the life-history strategies of Nile tilapia, *Oreochromis Niloticus* (L.) in the Nyanza Gulf of Lake Victoria, Kenya, Aquat. Ecosyst. Health Manag. 10 (2007) 443-448.

[6] D. Admaasu, Maturity, fecundity, brood-size and sex ratio of tilapia (*Oreochromis niloticus*) in Lake Awassa (Ethiopian Rift Valley), Hydrobiologia 337 (1996) 77-83.

[7] D. Reyntjens, T. Wudneh, Fisheries management: A review of the current status and research needs in Ethiopia, SINET: Ethiop. J. Sci. 21 (1988) 231-266.

[8] A.K. Morison, Input and output controls in fisheries management: A plea for more consistency in fisheries management, Fish. Manag. Ecol. 11 (2004) 411-413.

[9] T.R. McClanahan, J. Maina, J. Davies, Perceptions of resource users and managers towards fisheries management options in Kenyan coral reefs, Fish. Manag. Ecol. 12 (2005) 105-112.

[10] R.B. McAuley, C.A. Simpfendorfer, I.W. Wright, Gillnet mesh selectivity of the sandbar shark (*Carcharhinus Plumbeus*): Implications for fisheries management, ICES J. Mar. Sci. 64 (2007) 1702-1709.

[11] R.B. Millar, R.J. Fryer, Estimating the size-selection curves of towed gears, traps, nets and hooks, Rev. Fish Biol. Fish. 9 (1999) 89-116.

[12] I.E. Baremore, D.M. Bethea, K.I. Andrews, Gillnet selectivity for juvenile blacktip sharks (*Carcharhinus Limbatus*), Fishery Bulletin 110 (2012) 230-241.

[13] T.B. Bagenal, E. Braum, Eggs and early life history, in: Methods for Assessment of Fish Production in Freshwaters, IBP Handbook No. 3, 1968, pp. 165-201.

[14] J.H. Zar, Biostatistical Analysis, Prentice-Hall, New Jersey, 1999, p. 620.

[15] B.M. Russell, H. Rene, Estimation of gillnet and hook selectivity using log-linear models, ICES J. Mar. Sci. 54 (1997) 471-477.

[16] R.B. Millar, R code for fitting select models to gillnet data, http://www.stat.auckland.ac.nz/~millar/selectware/R/gillnets/ (accessed Aug. 10, 2013).

[17] R Development Core Team, A programming environment for data analysis and graphics, http://www.R-project.org (accessed Aug. 10, 2013).

[18] T.W. Echeverria, Thirty-four species of California rockfishes: Maturity and seasonality of reproduction, U.S. Fish. Bull. 85 (1987) 229-250.

[19] C.N.J. Luís, D.C. Edmir, Reproduction, food dynamics and exploitation level of *Oreochromis niloticus* (Perciformes: Cichlidae) from artisanal fisheries in Barra Bonita Reservoir, Brazil, Rev. Biol. Trop. 60 (2012) 721-734.

[20] J.N. Rinne, B. Wanjala, Observations on movement patterns of *Tilapia* spp. in Nyanza Gulf, Lake Victoria, East Africa, J. Fish Biol. 20 (1982) 317-322.

[21] N. Mulimbwa, O. Sarvala, M. van der Knaap, The effect of intensive fishing on two cichlids (*Oreochromis niloticus* and *Astatotilapia burtoni*) in Nyangara wetland at the north end of Lake Tanganyika (D. R. Congo) with fishery management implications, Aquat. Ecosyst. Health Manag. 13 (2010) 11-19.

[22] Y. Teferi, D. Admaasu, S. Mengistou, Breeding season maturation and fecundity of *Oreochromis niloticus* L. (Pisces: Cichilidae) in Lake Chamo, Ethiopia, SINET: Ethiop. J. Sci. 24 (2001) 255-264.

[23] R.H. Lowe-McConnell, Tilapias in fish communities, in: The Biology and Culture of Tilapias, Manila, Philippines: ICLARM Conference Proceedings, 1982, pp. 309-316.

[24] E.O. Caner, B.K. Volkan, M. Mavruk, A. Erhan, Spawning, maturity length and size selectivity for pikeperch (*Sander lucioperca*) in Seyhan Dam Lake, J. Vet. Anim. Sci. Adv. 10 (2011) 545-551.