Growth and population parameters of Nile tilapia, Oreochromis niloticus (L.) in the open waters of Lake Victoria, Kenya

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Growth and population parameters of Nile tilapia, *Oreochromis niloticus* (L.) in the open waters of Lake Victoria, Kenya

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Abstract

The Nile tilapia (*Oreochromis niloticus*) was introduced into Lake Victoria in the early 1950s and 1960s and has since become the dominant tilapiine in the lake. This study investigated the growth and population parameters of *O. niloticus* in Lake Victoria on the basis of length–frequency data collected during the period June 2014 and June 2015. The asymptotic length (L_∞) had a mean (±SE) value of 46.24 ± 0.04 cm TL, growth curvature (K) of 0.69 ± 0.25 year^{-1}, total mortality (Z) of 2.18 ± 0.80 year^{-1}, a natural mortality (M) of 1.14 ± 0.28 year^{-1}, a fishing mortality (F) of 1.05 ± 0.53 year^{-1}, an exploitation rate (E) of 0.46 ± 0.08, a growth performance index ($\varnothing$) of 3.14 ± 0.17 and a length at first capture (L_{C50}) of 20.31 ± 0.40 cm TL. Comparing the results of this study with previous studies indicates the parameters K, Z and M have increased, whereas $\varnothing$, F, E and L_{C50} have decreased. Changes in these parameters could be attributed to the existing high fishing capacity, and changing lake conditions. Thus, management measures should include continued restriction on illegal fishing methods and gears, such as the use of undersized gillnets (<5 in. mesh size) and beach seines. More attention also should be directed to the implementation of measures to control pollution of the lake from its various sources.

Key words

growth, mortality, Nile tilapia.

INTRODUCTION

The Nile tilapia (*Oreochromis niloticus)* is among the exotic species introduced into Lake Victoria in the early 1950s and 1960s to increase exploitable fish stocks, thereby reducing fishing pressure on the two native species (*O. esculentus* (Graham); *O. variabilis* (Boulenger)) (Welcomme 1967; Ogutu-Ohwayo 1990). Nile tilapia now dominates, whereas most of the other tilapiines are rarely caught in the lake. The increase in *O. niloticus* is attributed to overfishing of endemic tilapiines, reducing competition. The very diverse diet of *O. niloticus,* which includes insects, algae, fish, molluscs and detritus (Njiru *et al.* 2004), probably gave the species a higher survival rate in the changing Lake Victoria ecosystem. The dominance of *O. niloticus* over other tilapiines in the lake is attributed to several factors, including high fecundity and fast growth rates. The fish also can survive a wide range of pH values and can resist low dissolved oxygen concentrations, according to Balirwa (1998). Nile tilapia is now the commercially most important tilapiine, and the third most important fishery in Lake Victoria, after Nile perch (*Lates niloticus* (L.)) and a native cyprinid (*Rastrineobola argentea* (Pellegrin)) (Cowx *et al.* 2003; Njiru *et al.* 2005). According to Njiru *et al.* (2008), nutrient inputs into the lake have resulted in increased eutrophication and algal blooms in Lake Victoria. The resulting deteriorated water quality has actually led to the dominance of the phytoplankton community in the lake by blue-green algae, which offer a poor quality of food and include toxic groups (Lung'ayia *et al.* 2000). The observed ecological changes that have taken place in Lake Victoria over the years, together with the pressures from intensive fishing, are hypothesized to have influenced the population parameters of various fish species in the lake. Thus, this study was undertaken to determine the growth and

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population parameters of *O. niloticus* in the Kenyan part of Lake Victoria, using length–frequency data.

MATERIALS AND METHODS

Lake Victoria, with an area of 68 800 km, is the second largest freshwater lake in the world, being shared by Kenya, Uganda and Tanzania in the ratios of 6%, 45% and 49% of the surface area, respectively (Johnson *et al.* 2000). It stretches 412 km from north to south between 0°30′N and 3°12′S, and 355 km from west to east between 31°37′ and 34°53′E. It lies across the equator at an altitude of 1135 m above sea level. Nyanza Gulf is a large inlet from Lake Victoria that extends into Kenya, being comparatively shallow, with a maximum and average depth of 68 and 6 m, respectively. The Gulf constitutes the major portion of the Kenyan part of Lake Victoria. This study was conducted within two stations in the Kenyan waters of Lake Victoria (GPS location of Gul Kamin Ougo: 0°12′33.8″S 34°11′06.8″E; Honge: 0°02′37″S, 34°00′48.6″E). The fishery at Gul Kamin Ougo (5–7 m depth) covers the nearshore, while Honge (16–25 m) covers the deep waters.

Sampling and data analysis

Samples (2058) of *O. niloticus* obtained from commercial catches between June 2014 and June 2015 were analysed. The samples were representative of fish stocks from the nearshore and deeper waters. The fish were measured in the field (total length, TL) to the nearest centimetre (cm). Data analysis was based on length–frequency distribution analysis. The Electronic Length Frequency Analysis (ELEFAN I in FAO ICLRAM Stock Assessment Tool (FISAT)) (Pauly 1987; Gayanilo *et al.* 1996) was used to estimate population parameters. Estimates of the growth parameters were based on the von Bertalanffy growth formula (VBGF), which is expressed as follows:

$$L_t = L_\infty(1 - \exp(-K(t - t0))) \quad (1)$$

where L_t = predicted length at age t; L_∞ = asymptotic length; K = growth curvature; t_o = age the fish would have been at zero length.

The total mortality (Z) was estimated using a length-converted catch curve. The coefficient of natural mortality (M) was estimated with K (year^{-1}), L_∞ (cm) and T (mean annual water temperature of 24°C), following Pauly' s empirical formula (Pauly 1980), as follows:

$$Ln(M) = -0.0152 - 0.279\ln(L_\infty) + 0.6543\ln(K) + 0.463\ln(T) \quad (2)$$

The fishing mortality (F) was computed from the relationship:

$$F = Z - M \quad (3)$$

The exploitation rate (E) was calculated from the relationship:

$$E = \frac{F}{Z} = \frac{F}{F + M} \quad (4)$$

The growth performance index (∅) was computed, according to Pauly and Munro (1984), as follows:

$$\text{Ø} = Ln(K) + 2(L\infty) \quad (5)$$

The probability of capture was obtained from the backward extrapolation of the length-converted catch curve, according to Pauly *et al.* (1984).

RESULTS

Growth parameters

The growth parameters of *O. niloticus* are presented in Table 1. The mean (±SE) of L_∞, K and ∅ was 46.24 ± 0.04, 0.69 ± 0.25 and 3.14 ± 0.17, respectively.

Population parameters

Values of total mortality (Z), natural mortality (M), fishing mortality (F) coefficients and exploitation rates (E) from a length-converted catch curve are presented in Figure 1a, b. The mean (±SE) values of Z, M, F and E were 2.18 ± 0.80, 1.14 ± 0.28, 1.05 ± 0.53 and 0.46 ± 0.08, respectively.

Probability of capture

The estimated lengths at first capture (L_{C50}) were 20.70 cm TL at Gul Kamin Ougo and 19.91 cm TL at Honge (Figure 2a,b, respectively). The mean (±SE) value of L_{C50} was 20.31 ± 0.40 cm.

DISCUSSION

The changes in growth and population parameters of *O. niloticus* in Lake Victoria between 1985 and 2015 are presented in Table 2.

Comparing the findings of the present study with the recent study by Njiru (2003) in Lake Victoria, it was found that the parameters K, Z and M have increased, whereas ∅, F, E and L_{C50} have decreased. The observed decline in fishing mortality (F) could be attributed to the deliberate monitoring, control and surveillance (MCS) effort to manage the fishing capacity of Lake Victoria. Although seemingly insignificant, the Lake Victoria Frame Survey reported the number of fishing boats in the Kenyan sector decreased from 13 717 in 2012 to 13 550 in 2014, and the gillnets

Table 1. Growth parameters of *O. niloticus*

Stations	GPS locations	L_∞ (cm)	K (year^{-1})	(∅)
Gul Kamin Ougo	0°12′33.8″S, 34°11′06.8″E	46.28	0.93	3.30
Honge	0°02′37″S, 34°00′48.6″E	46.20	0.44	2.97
Mean ± SE		46.24 ± 0.04	0.69 ± 0.25	3.14 ± 0.17

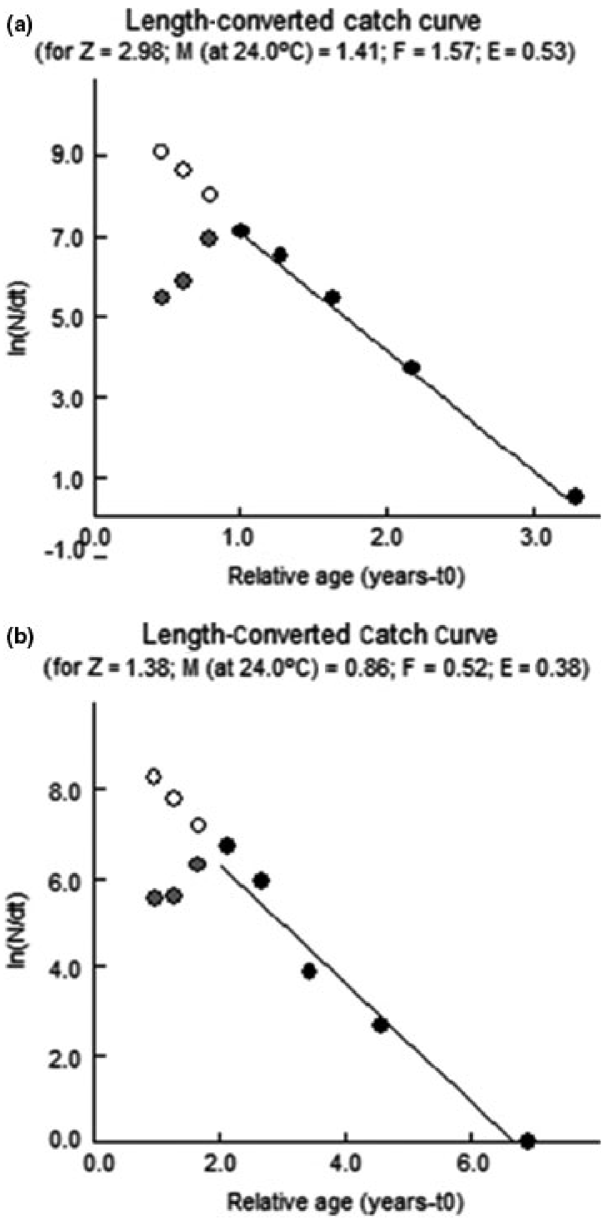

Fig. 1. (a, b) Values of total mortality (*Z*), natural mortality (*M*), fishing mortality (*F*) coefficients and exploitation rates (*E*) from length-converted catch curve.

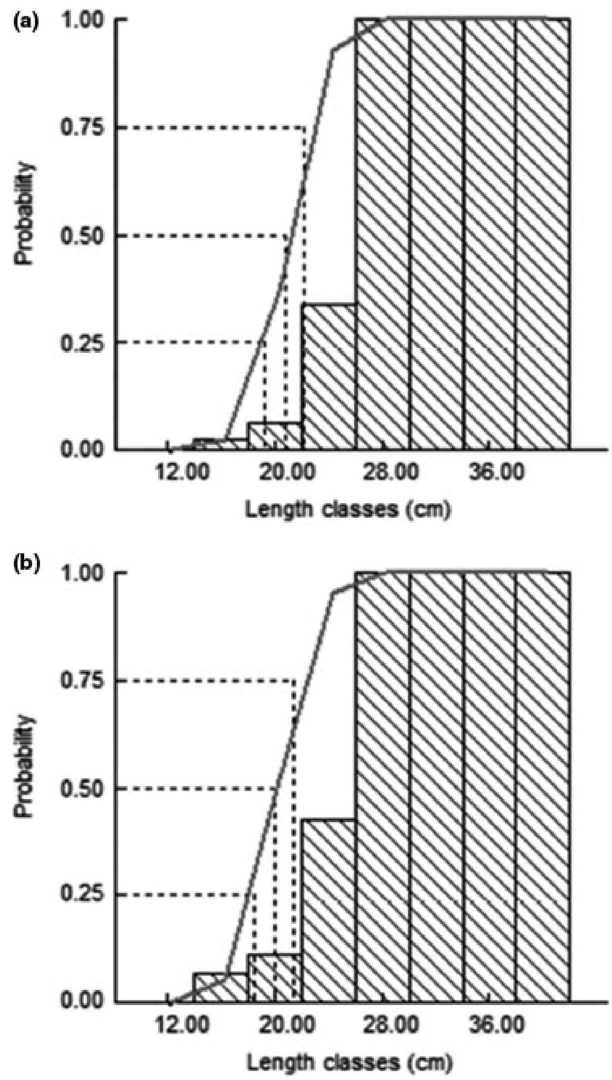

Fig. 2. (a, b) Estimated lengths at first capture (L_{C50}) for Gul Kamin Ougo and Honge, respectively.

decreased from 207 950 to 188 984, while the fishers slightly increased from 40 078 to 40 133 during the same period.

The natural fish mortality is attributable to factors not associated with fishing, such as predation, competition, cannibalism, diseases, spawning stress, starvation and pollution stress. The higher natural mortality (*M*) reported in the present study could be attributed to a faster growth rate (K), and possibly adaptive tactics to maximize survival and reproductive success (Njiru *et al.* 2006). According to Zhang and Megrey (2006), the

Table 2. Changes in growth and population parameters of *O. niloticus* in Lake Victoria, 1985–2015

L_∞	K	(∅)	Z	M	F	E	L_{C50}	Period	Source
64.60	0.25	3.03	0.82	0.54	0.28	0.34	–	1985–1986	Getabu (1992)
63.10	0.35	3.16	1.71	0.72	0.99	0.58	–	1989–1990	Dache (1994)
58.78	0.59	3.36	2.16	1.12	1.12	0.52	28.54	1998–2000	Njiru (2003)
46.24	0.69	3.14	2.18	1.14	1.05	0.46	20.31	2014–2015	Present study

growth and mortality may be correlated in an empirically useful way; that is, fast-growing fish tend to have higher mortality rates, as K is linked to the longevity of the fish which, in turn, is related to mortality. Zhang and Megrey (2006) further generalized that a long-lived fish approaches its limiting size relatively slowly, whereas short-lived fish grow rapidly. Thus, fish species with high K values usually have high M values, and vice versa. Thus, a slow-growing species cannot bear a high natural mortality; if it did, it would never reach maturity and ultimately go extinct. The high fishing mortality (F) (0.46 year^{-1}) reported in the present study could be linked with the reduced asymptotic length (L_∞), and a faster growth rate (K), of *O. niloticus* in the lake. As ∅ is determined by K and L_∞, an increased K and reduced L_∞ therefore result in a high ∅ value.

The water quality in the Lake Victoria ecosystem has been rapidly deteriorating due to pollution and increased disturbances in its catchments (Sitoki *et al.* 2010). The impacts have been the dominance of the phytoplankton community in the lake by blue-green algae. Blue-green algae represent a poor-quality food and include toxic algal groups (Lung'ayia *et al.* 2000). In response to this effect, *O. niloticus* is able to actively select for the rare diatoms and green algae, even when blue greens are the more abundant species (Njiru *et al.* 2005). The shift in the food of *O. niloticus* in Lake Victoria from herbivorous towards an insectivorous diet (Njiru *et al.* 2004) could also contribute to a high growth rate (K). Nutrient inputs into the lake have resulted in increased eutrophication and algal blooms in Lake Victoria, as reported by Njiru *et al.* (2008). Deteriorated water quality and increased anoxia have caused the displacement and decline of some fish species. *O. niloticus*, however, has a higher tolerance to low oxygen concentrations and excluded Nile perch under the water hyacinth, where the dissolved oxygen concentrations in the water column can go as low as 0.001 mg L^{-1} (Njiru *et al.* 2002). Njiru (2003) reported Nile tilapia in Lake Victoria growing to a maximum length of 60 cm TL, which could probably have reduced predation by Nile perch. The length at first capture (L_{C50}) for *O. niloticus* reported in the present study is lower than its length at first maturity (L_{M50}) in the Kenyan waters of Lake Victoria (Njiru *et al.* 2006). This implies the fishing gears are catching high proportions of immature fish. The use of illegal fishing gears is still rampant in the lake, despite MCS efforts. A total of 75 205 undersized gillnet (<5 in. mesh size) and 856 beach seines were reported in the Kenyan sector during the 2014 Frame Survey.

CONCLUSION

Oreochromis niloticus in Lake Victoria has attained a better growth performance, despite the existing high fishing capacity and changing lake conditions. Thus, management measures should include continued restriction on illegal fishing methods and gears, such as the use of undersized gillnets (<5 in. mesh size) and beach seines. More attention also should be directed to the implementation of measures that control pollution of the lake from its various sources.

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