Some aspects of Nile tilapia *Oreochromis niloticus (L.)* population characteristics in Lake Victoria, Kenya.

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Abstract

Length frequency data collected from commercial landings were used to estimate growth parameters, mortality (Z, F, M), growth performance index (ϕ') and exploitation rate (E) in *O. niloticus* from the Nyanza Gulf of Lake Victoria, Kenya. The asymptotic length (L_∞) had mean (±S.D) of 58.78 ± 2.42 cm TL, K of 0.59 ± 0.05 yr^{-1}, Z of 2.16 ± 0.40 yr^{-1}, M of 1.00 ± 0.06 yr^{-1}, F of 1.12 ± 0.34 yr^{-1}, E of 0.51 ± 0.06 and ϕ' of 3.31 ± 0.04. Fifty percentage (L_{50}) entry into the fishery had a mean (±S.D) of 26.18 ± 12.50 cm TL.

A comparison with previous studies in the gulf indicates that *O. niloticus* is now caught at a lower mean size, K, Z, M, F, have increased and the fish is maturing earlier. These changes may point to a population under stress, but still the fish exhibits high growth performance (ϕ') and grows to a large size and if well manage high production can be attained. The study showed that the major threat to the *Oreochromis* fishery is overexploitation caused by use of illegal fishing methods leading to capture of immature fish and breeding fish.

The remedial measures to sustain the fishery include imposing ban on illegal fishing methods, limiting entry to the fishery, encouraging alternative livelihood and involvement of the community in fisheries management.

Key words: growth, mortality, recruitment, selection

Introduction

The Nile tilapia, *Oreochromis niloticus* (L.), which was introduced in Lake Victoria in 1950s, is the third commercially important fish after introduced Nile Perch, *Lates niloticus* (L.) and endemic pelagic cyprinid *Rastrineobola argentea* (Pellegrin) (Witte and Densen 1995; Othina and Tweddle 1999). Increase in *O. niloticus* is attributed to over fishing of endemic tilapiines thus reducing competition while swamps clearance could have increased it spawning areas (Welcomme 1967). The *O. niloticus* can also survive a wide range of pH, resists low levels of dissolved oxygen and feeds on a variety of food items (Balirwa 1998; Njiru 1999).

In Kenya waters of Lake Victoria *O. niloticus* is slow growing and majority of the fish caught is below the recommended 5 inches mesh size (Getabu 1994). Studies further show that the fishery is operating beyond maximum sustainable yield, indicating overfishing. This study was designed to study population parameters of *O. niloticus* using length frequency data in different locations in Nyanza Gulf of Lake Victoria, Kenya. The results are compared with previous studies to offer management strategies for the fishery.

Materials and methods
Study area
The Nyanza Gulf constitutes the major portion of Kenyan part of Lake Victoria, with an area of 1920 km^2, a length of 60 km and a width varying from 6 and 30 km (Fig 1). The gulf is shallow with a mean depth of 6 m and lies at an altitude of 1134 m above sea level. A description of the gulf is given by Okach and Dadzie (1988).

Sampling
Monthly length frequency data on *O. niloticus* were collected from July 1998 to December 2000 from commercial catches at five landing sites in the Nyanza Gulf of Lake Victoria (Fig. 1). The samples were representative of the stock from the outer, mid, and inner Gulf, *viz,* Dunga, Kendu Bay, Asembo Bay, Homa Bay and Luanda Gembe. Approximately two hundred specimens were randomly selected from commercial catches every month at each station and measured (total length (TL), nearest cm). The surface temperature was recorded for each station every month to determine the natural mortality coefficient.

Data analysis was based on length frequency distribution analysis. The Eletron Length Frequency Analysis (ELEFAN I and II) computer programs incorporated in FAO-ICLRAM Stock Assessment Tool (FISAT) (Pauly 1987; Gayanilo et al. 1996) were used to estimate population parameters. Data for each landing site was merged into a single file thus constituting a single ''artificial year''. The estimate of the growth parameters were based on the Von Bertalanffy growth formula (VBGF) expressed by the form:

$$L_t = L_\infty \, (1\text{-}exp \, (\text{-}K*(t\text{-} t_o)))$$

Where, L_t is the predicted length at age t, L_∞ is the asymptotic length, K is a growth constant, t_o is the age the fish would have been at zero length.

Preliminary estimation of L_∞ was done by the Powell-Wetherall method and FISAT was further used to improve the quality of L_∞ and K (Pauly 1980). Total mortality (Z) was estimated using a length-converted catch curve. Natural mortality (M) was estimated from equation of Pauly (1980). This method consists of a plot of the natural logarithm of the number of fish in various age groups against their corresponding age. A regression analysis is done on the descending right hand arm of the catch curve, and Z estimated as the negative slope. The coefficient of natural mortality (M) was estimated following Pauly's empirical formula (Pauly 1980), linking natural mortality with the von Bertalanffy parameters, K (yr^{-1}), L_∞ (cm) and the mean annual temperature (T ^{o}C) of the water in which the fish stock lives (in this case 25 ^{o}C): i.e.,

$log_{10}(M) = \text{-}0.0152\text{-}0.279* \, log_{10} \, L_\infty + 0.6543 \, log_{10} \, K + 0.463 \, log_{10} \, T$

The fishing mortality (F) was computed from the relationship $F = Z-M$, while the exploitation rate (E) was calculated from the relationship $E = F/Z = F/(F + M)$. The growth performance index (ø) was computed according to Pauly and Munro (1984):

$$\text{ø} = log_{10} K + 2\ log_{10} L_{\infty},$$

where, K is the growth constant (yr^{-1}) and L_{∞} is the asymptotic length.

Gear selection was estimated by backward extrapolation of the catch curve, thus estimating the number of juveniles, which ought to have caught had it not been for incomplete selection and recruitment. To obtain probabilities of capture, the number of fish in each length class caught were divided by the expected numbers (Pauly et al. 1984). A plot for probability of capture by length was obtained from the backward extrapolation of the right, descending arm of a catch-curve, and calculating the number of fish that would have been caught had it not been for selection and incomplete recruitment. Recruitment pattern was obtained by projection of length axis of the available length-frequency data.

Table 1. Asymptotic length (L_{∞}), growth curvature (K), and growth performance index (ø) of *O. niloticus* artisanal catches from Nyanza Gulf, Lake Victoria, Kenya.

	Powell Wetherall L_{∞}(cm)	ELEFAN L_{∞}(cm)	K (yr^{-1})	(ø)
Dunga	56.07	57.00	0.56	3.26
Kendu Bay	58.83	58.00	0.55	3.27
Asembo Bay	58.59	59.80	0.59	3.32
Homa Bay	57.31	56.60	0.68	3.34
Luanda Gembe	60.86	62.50	0.58	3.36
Mean ± SD	58.33±1.79	58.78±2.42	0.59±0.05	3.31±0.04

Table 2 Total mortality (Z), Natural mortality (M), fishing mortality (F) coefficient, and exploitation rate (E) of *O. niloticus* artisanal fishery from Nyanza Gulf of Lake Victoria.

Station	Z	M (yr^{1})	F (yr^{1})	E
Dunga	2.06	0.97	1.09	0.53
Kendu Bay	1.77	0.95	0.82	0.46
Asembo Bay	1.03	0.99	1.03	0.51
Homa Bay	2.81	1.10	1.71	0.61
Luanda Gembe	1.93	1.10	1.71	0.61
Mean±SD	1.92±0.64	1.00±0.06	1.12±0.34	0.52±0.06

Results

The mean (± SD) L_∞ was 58.33 ± 1.79 cm TL and 58.78 ± 2.42 cm TL for Powell-Wetherall and FISAT methods respectively (Table 1). Luanda Gembe (62.50 cm) had the highest L_∞ and Homa Bay (56.60 cm) the lowest. The growth coefficient (K) had mean (± SD) of 0.59 ± 0.05 yr^{-1} with Homa Bay (0.68 yr^{-1}) and Kendu Bay (0.55 yr^{-1}) with the highest and the lowest respectively (Table 1). Values of K and L_∞ used for subsequent analysis. The growth performance index (ø) had mean (± SD) of 3.31± 0.04, with Luanda Gembe (3.36) achieving the highest and Dunga (3.26) the lowest (Table 1). The estimated total mortality coefficient (Z) had mean (± SD) 1.92 ± 0.64 yr^{-1}, natural mortality coefficient (M) at 1.00 ±0.06 yr^{-1}, fishing morality coefficient (F) at 1.12±0.34 and exploitation rate (E) at 0.52 ± 0.06 (Table 2). Mean (± SD) entry to the fishery at L_{25}, L_{50}, L_{75} was 20.96 ± 15.75, 26.18 ± 12.50, 28.54 ± 12.19 cm TL respectively (Table 3).

Discussion

Previous studies shows that L_∞ of *O. niloticus* has decreased from 64.6 cm TL in 1985/1986 to 56.7 cm TL 1998/2000, K increased from 0.25 yr-1 to 0.59 yr^{-1}, while ø has increased from 3.02 t0 3.27 at the same time (Table 4). The magnitude of ø is determined by K and L_∞, with and increase in K and reduction in L_∞ results in high ø. Diet type, exploitation, genetic make up may determine growth potential of a species (Ssentonga and Welcomme, 1985). The food types and their digestibility have been found to determine the difference growth patterns of Nile tilapia in natural waters. Bowen (1982) indicated that tilapia consumes food material of high calorific value, which are suitable for growth. In Lake Victoria, *O. niloticus* has shifted its feeding from herbivorous towards an insectivorous diet (Njiru 1999), and this could be contributing to high growth rate (K) and thus ø. Use of illegal fishing methods may lead to over exploitation and thus a reduction of the average size of fish caught and a faster growth rate. The fishing mortality (F) had a mean (±SD) of 1.25 ± 0.34, which is higher than previously reported in the lake. Over exploitation in Lake Victoria has also been documented by Ssentongo and Welcomme 1985; Othina and Tweddle 1999). Overexploitation results in reduction of average size of fish in a stock and a faster growth rate (Sparre and Venema 1998). The Kenyan portion of Lake Victoria constitutes only 6% of the entire lake, but it has the highest concentration of boats (8000) and fishers (30 000). The fishery is open access and there is no limit to the number of boats and gears used. The recommended gill mesh size for *O. niloticus* fishery of 5 inches, but 2-3 inches are commonly encountered. Destructive beach seines and trawling, although ban in the lake are still operational. At Homa Bay, with the highest Z, F, K and E, landings were by beach and mosquito seines.

Table 3 Nile tilapia probability of capture and sizes at which 25, 50 and 75% of the encountered fish were retained and optimum (L_{opt}) sizes, which would be realised in a location.

Station	L_{opt} (cm)	L_{25}(cm)	L_{50}(cm)	L_{75}(cm)
Dunga	35.80	38.21	40.19	36.16
Kendu Bay	32.35	35.74	38.30	36.81
Asembo Bay	28.74	31.45	31.31	38.35
Kendu Bay	32.35	35.74	38.30	36.81
Luanda Gembe	2.74	12.24	15.38	40.13
Mean±SD	20.96±15.75	26.18±12.50	28.54±12.19	37.64±1.61

Natural mortality has increased from 0.54 yr^{-1} in 1985/1986 to 1.00 yr^{-1} on 1998/2000 (Table). Faster growing fish have higher natural mortalities (Sparre and Venema 1998), and the warmer the ambient temperature the higher the natural mortality. Nile tilapia K has increased together with temperature (from 23 ^{0}C (Crul 1995) to 25 ^{0}C), and these could be contributing to the increased mortality.

The length at first capture (Lc$_{50}$) for *O. niloticus* with present commercial catch gears varied from 13.25 cm TL at Homa Bay to 38.21 cm TL at Dunga. In Kenyan waters of the lake, the smallest ripe *O. niloticus* male was 26.2 cm TL and female 23. 3 cm TL, fifty percent maturity for males was at 30 cm TL and females 33 cm TL (Ojuok 1999). Therefore, the present commercial gears in Kenyan waters of Lake Victoria are catching high proportions of immature *O. niloticus*. There has also been a reduction in the size at first maturity since the early 1990s when *O. niloticus* was maturing at an average length of 35 cm TL in Kenyan waters (Getabu 1992). This earlier maturation of tilapia could be a tactic to maximize reproductive success possibly linked to population response to over fishing.

Table 4. Growth parameters and growth performance of Oreochromis niloticus from Nyanza Gulf of Lake Victoria, Kenya.

L_∞(cm)	K(yr^{-1})	Φ	Z	M	F	E	Data collection	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	1998-2000	Present study

Continued use of mesh size smaller than recommended and the destruction of breeding grounds through the application of illegal fishing gears may lead to a further reduction of the size of *O. niloticus* at first capture. The fishers in turn will further reduce their mesh size and resort to illegal fishing methods to target the smaller fishes. This will result in a long-term decline of the size and catches of the species. However, even under these
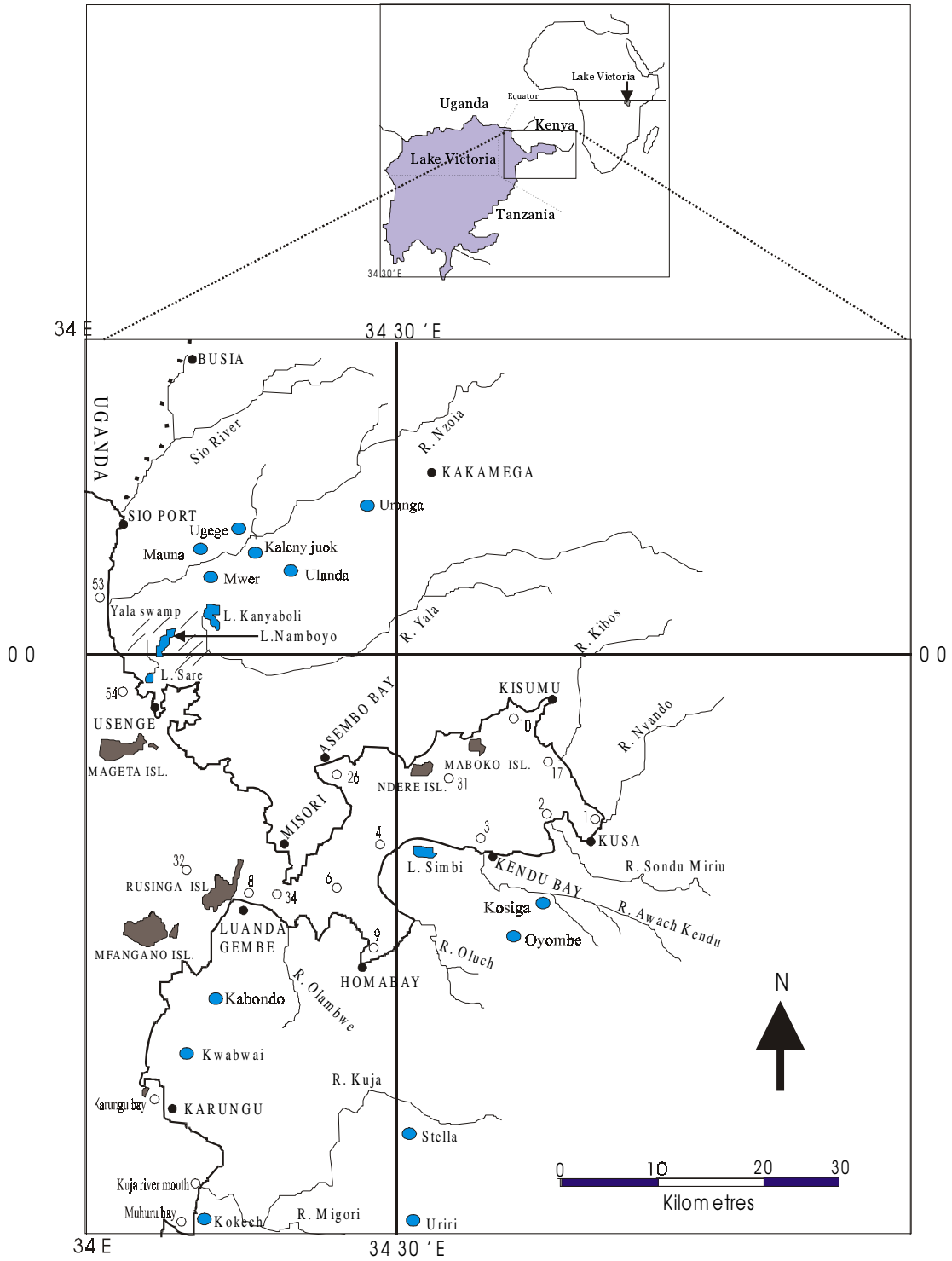
Fig. 1: Map of Nyanza Gulf, Lake Victoria showing sampling stations.

stressful conditions, *O. niloticus* shows a high growth performance index, attaining large sizes and if well managed, production could be increased. Higher production would provide more protein and income to people living around the lake and who depend so much on fishing because farming is not developed due to poor soils and unpredictable rains.

To sustain the fishery imposing the existing ban on beach seining, use of illegal mesh sizes and other destructive fishing methods need to the urgently addressed by the authorities concerned. The entry to the fishery, which is now open, should be limited and in addition to the registration of boats, licensing of nets should be introduced to help in monitoring the effort exerted on the fishery. Fishers should be provided with cold storage to avoid wastage and the landed fish should be sold through co-operative societies to improve returns. Law enforcers should increase their efforts and political interference in the running of the fishing industry should be reduced. Alternative sources of livelihood, such as aquaculture and farming, should be encouraged to reduce pressured on the fishery.

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