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Outa N. Otieno
Department of Biological Sciences, Egerton University, P.O. Box 536-20115, Egerton, Kenya.

N. Kitaka
Department of Biological Sciences, Egerton University, P.O. Box 536-20115, Egerton, Kenya.

J.M. Njiru
Department of Fisheries and Aquatic Sciences, University of Eldoret, P.O. Box 1125-30100, Eldoret, Kenya.

Correspondence:
Outa N. Otieno
Department of Biological Sciences, Egerton University, P.O. Box 536-20115, Egerton, Kenya
Email: nichouta@gmail.com
Tel: +254 723 052 865

Length-weight relationship, condition factor, length at first maturity and sex ratio of Nile tilapia, *Oreochromis niloticus* in Lake Naivasha, Kenya

Outa N. Otieno, N. Kitaka, J.M. Njiru

Abstract
Fish samples (541) were collected every two weeks from different parts of Lake Naivasha using gill nets (50 mm to 150 mm mesh size) and beach seines (< 10 mm) between November 2013 and February 2014.The main focus of the study was on sex ratio, length-weight relationship and body condition of Nile tilapia. Results revealed that there were more males sampled with a sex ratio of male to female of 2:1. A comparison of the length-weight relationship for males and females showed that most of the fish had negative allometric growth (b <3) with males from Oserian and Hippo sampling stations point showing isometric growth (b =3). Length at first fish maturity of male and female fish obtained during this study was 17.7 cm TL and 18.0 cm TL respectively. The results from this study showed that fish in the lake are in good condition with condition factor value above 1.

Keywords: Length-weight, condition, sex ratio, maturity, Naivasha, Nile tilapia.

1. Introduction
Nile tilapia (*Oreochromis niloticus*) is of great commercial importance often forming the basis of commercial fisheries in many African lakes [4]. This species was introduced in Lake Naivasha around 1967 but disappeared in 1971 and the reasons for the disappearance are not clear to date [8]. The fish was then reintroduced by the Government in 2011 under the Economic Stimulus Program (ESP). Nile tilapia is still not the commercially most important fish in Lake Naivasha, three years after reintroduction since the common carp (*Cyprinus carpio*) which is more of an invasive species is still present in large populations (Njiru *et al*., 2008). Nile tilapia is the most desired fish species by the local community among the commercially exploited fish species in the lake. This is because it has fewer bones in its flesh compared to *C. carpio*.

Length-weight relationship gives the condition and growth patterns of fish. It provides important information concerning the structure and function of fish populations [9]. In sampling programs, it is usually easier to measure length only (e.g., because of the motion of the boat especially when the waves are strong). The length-weight relationships of a particular species allow the inter-conversion of these parameters. Fish are said to be growing isometrically if the length increases with equal proportion to body weight for constant specific gravity [16, 18] while allometric growth is assumed when the increase in any of the parameters (length or weight) is unproportional to the other. It is therefore possible to estimate the weight or length of fish from either of each parameter that is available from a formula that takes into account the growth pattern (whether isometric or allometric).

Condition factor refers to the well-being of the fish in question and by extension its health status [3]. It is therefore an index reflecting interactions between biotic and abiotic factors to the physiological condition of fish. Condition factor is estimated by comparing individual fish weight of a given length to a standard weight. It is assumed that heavier fish reflect a healthier physiological state. It is an important concept in fisheries management and can be used to assess the health and potential of any fishery to support the fishing pressure. This simple approach and interpretation can therefore aid in development of intervention measures which can easily be implemented by fishery managers especially with respect to maintaining a healthy fish population through controlling of the fishing effort.

Proper estimation of size at first maturity (L_{M50} - length at which 50% of the fish are mature) is very useful for fish stock management. This information is crucial in formulation of management options especially in the choice of gear to be used in capture fisheries. It can guide the managers in setting mesh sizes that will target mature fish which have contributed to the next generation giving juvenile fish time to grow and mature [11]. The recognition of maturity status of fish is based on visual and subjective descriptions of ovaries and testes at different maturation stages. The main focus of this paper is to assess the length-weight, condition factor, sex ratio and length at first maturity of *O. niloticus* in Lake Naivasha since its reintroduction into the lake in 2011.

2. Methods

2.1 Study Area

Lake Naivasha lies in latitude of 0° 46' 10" (0.7694), longitude of 36° 20' 25" (36.3403) and altitude 1890 m, within the Eastern Rift Valley. It is the second-largest freshwater lake in Kenya after the Kenya portion of Lake Victoria [13]. It has a surface area of 139 km² and an average depth of 3.35 m, with the deepest area being 7m [8] though these values vary with extreme conditions.

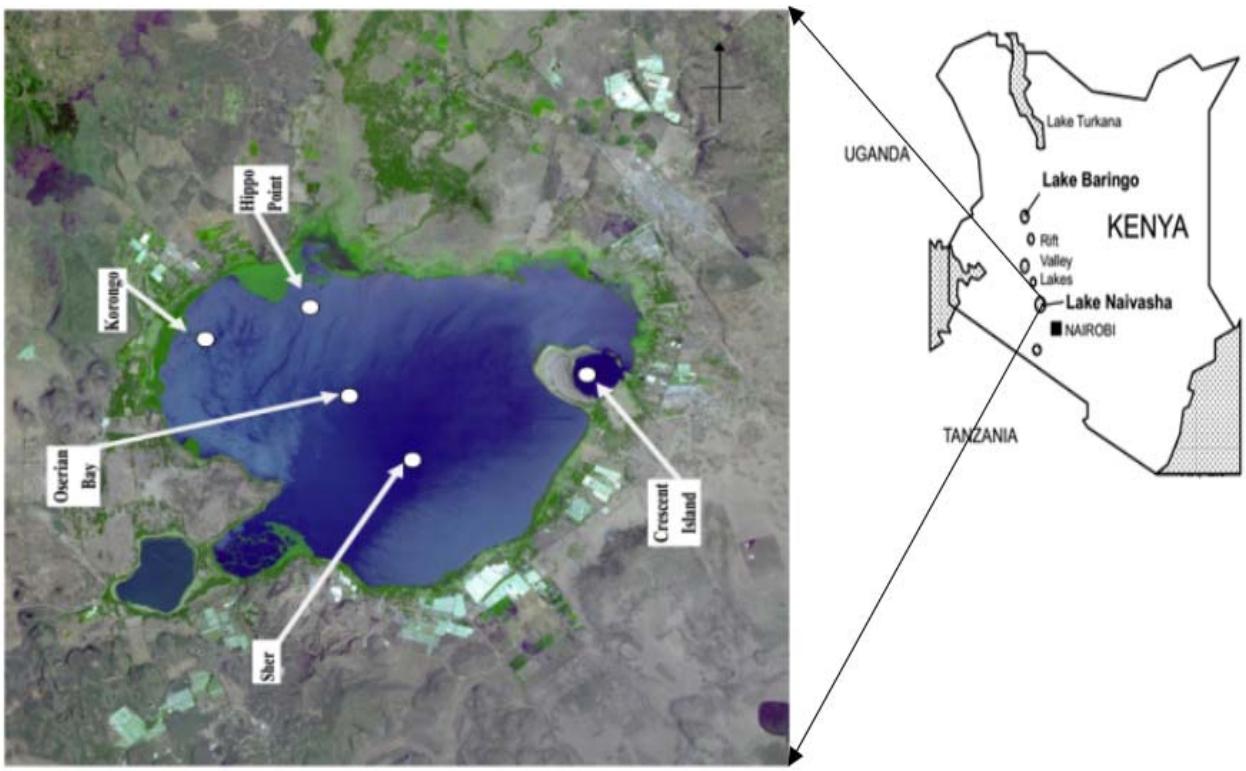

Fig 1: Map of Lake Naivasha showing sampling sites (Edited from Google Maps and Hickley *et al*., 2008)

2.2 Sample collection and analysis

Fish samples were collected weekly between November 2013 and February 2014 using gill nets with head rope 50 m and coded mesh size 150 mm, 125 mm, 100 mm, 75 mm and 50 mm from five sampling stations. The sampling sites were (Korongo, Hippo point, Oserian, Sher Bay and Crescent Island). Korongo and Hippo point stations are near the shore and characterized by water hyacinth (*Eichhornia crassipes*) and papyrus (*Cyperus papyrus*) vegetation comprising of muddy substrate, decayed plant materials and silt. The average depths of the stations are 1.6 m and 2.1 m respectively. Oserian Bay, Sher Bay and Crescent Island Crater Lake are situated in the open waters and are characterized by occasional invasion by the floating mats of *Eichhornia crassipes* and detached *Cyperus papyrus* especially during strong winds at high water levels. The average depths in these stations are 3.7 m, 3.5 m and 4.9 m respectively. The substrate is mainly silt and sand.

The range of 50 mm to 150 mm in mesh size gave room to sample fish of varied size classes (Taylor *et al*., 2011). Mosquito nets were also used to catch smaller fish that could not be caught by 50 mm net.

The nets were set at the sampling sites for four hours before retrieving. Immediately after retrieving, each fish was weighed (g) to the nearest 0.1 grams using an electronic weighing scale (Digitron T745) and the total length measured to the nearest centimeter using a measuring board. The fish were dissected and sex of each fish determined according to Witte and Van Densen (1995).

The weight-length relationship was calculated using Wooton (1990) [21] formula below;

$$W = aTL^b$$

Where, W is the body weight of fish in gram, TL the total length in centimeters, a, the intercept and b the slope of the regression line.

Relative condition factor (Kn) was estimated using the equation below by (LeCren, 1951);

$$Kn = \frac{W}{aTL^b}$$

Where, Kn is the condition factor, W is the body weight of fish in gram, TL the total length in centimeters, a, the intercept and b the slope of the regression line The sex ratio, expressed as male: female, was analyzed separately for every sampling site, and in 1 cm length classes, with deviations from the 1:1 null hypothesis tested with the use of chi-square test. Fish in maturity stages I, II, III was considered immature, while those in stages IV-VI was considered mature for the purpose of calculating the size at first maturity (Lm_{50}) by fitting frequency data of mature individuals by length class to a logistic curve using the least-square method [17].

3. Results

3.1 Length-weight relationship

Male fish from Oserian and Hippo point showed isometric growth with values of regression slope b being 3.0 and 3.0 respectively (b=3) as shown in Figures 2 a and b.

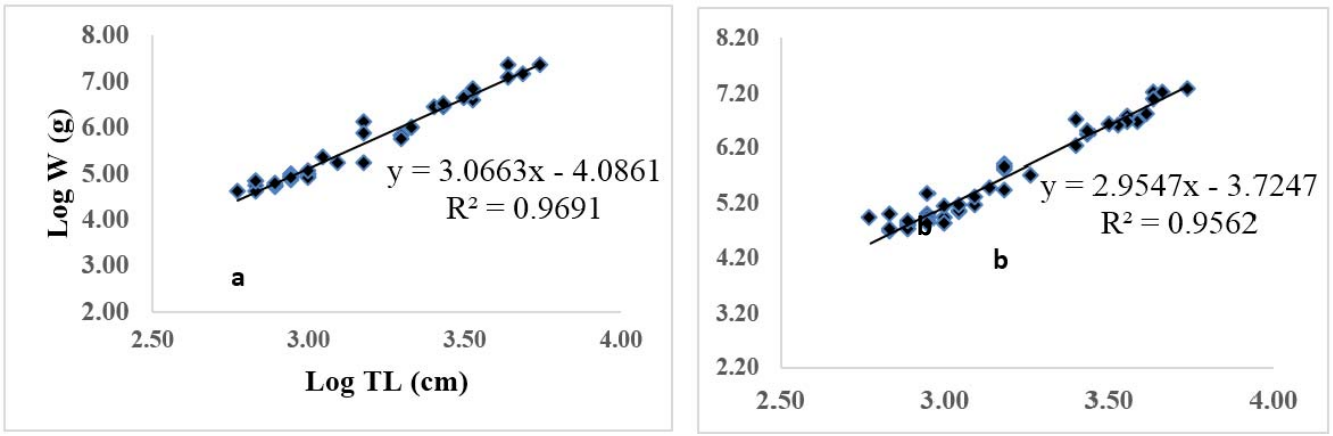

Fig 2: Log length-Log weight relationship of male *O. niloticus* at Oserian (a) and Hippo point (b)

Fish from (Sher Bay, Korongo and Crescent) showed negative allometric growth pattern recording values of b<3. However, when all the sexes were combined from all the sites, none obeyed the cube law. The LWR equations for fish from all the sampling points are summerised in Table 1 below.

Table 1: Length- weight relationships for *O. niloticus* from various sampling stations in Lake Naivasha

Sampling station	Length- weight relationship equation
Korongo	$Log_{10}W$= -0.064+1.512$Log_{10}TL$
Oserian	$Log_{10}W$= -0.147+1.559$Log_{10}TL$
Crescent Island	$Log_{10}W$= -0.705+1.678$Log_{10}TL$
Hippo point	$Log_{10}W$= -0.235+1.613$Log_{10}TL$
Sher Bay	$Log_{10}W$= -0.682+2.012$Log_{10}TL$
Whole lake	$Log_{10}W$= -0.64+2.312$Log_{10}TL$

3.2 Condition factor

The values of condition factor recorded for all the fish were higher than 1 as presented in Table 4.4. This shows that the fish are in very good condition. The highest value (2.63) was recorded for female fish in the whole lake (whole sample) while the lowest value (1.97) was recorded for male fish from Crescent Island. Oserian.

Table 2: Relative condition factor of *O. niloticus* in the various sampling stations in Lake Naivasha

	Whole lake	Oserian	Hippo point	Korongo	Cresent Island	Sher Bay
Male	2.38	2.09	2.13	2.07	1.97	2.00
Female	2.63	2.14	2.18	2.04	2.11	2.02
All fish	2.46	2.12	2.16	2.06	2.04	2.01

3.3 Sex ratio

The fish sample was dominated by male fish in all the sites as shown in Table 3. The sex ratio were greater than 1 in all the sampling stations. Crescent Island recorded the highest value (2.71) while Korongo recorded the lowest ratio of 1.79 (See Table 3). The Chi-square test however showed no significant difference between the sexes (P > 0.05).

Table 3: Numbers and sex ratios of fish in the various sampling sites and in the whole lake

Site	Sher Bay	Oserian	Hippo point	Korongo	Crescent Island	Whole lake
Male	47	46	46	43	76	258
Female	21	23	19	24	28	115
Sex ratios	2.24	2.00	2.42	1.79	2.71	2.24

Length at first maturity for male and female first was assessed separately and results presented in Figure 3 below. The smallest mature male and female fish recorded were 20 (TL) cm and 22 (TL) cm respectively. The length at first maturity (L_{M50}= LM_{75}-LM_{25}) for male and female fish was 17.7 cm TL and 18.0 cm TL respectively. Chi- square test showed no significant difference in the values of L_{M50} for male and female fish ($P>0.05$).

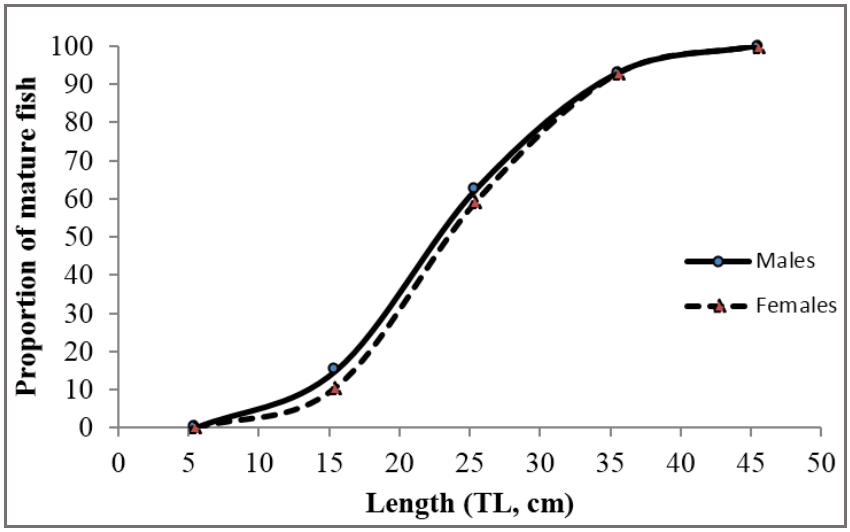

Fig 3: Length at first maturity of male and female *O. niloticus* in Lake Naivasha

4. Discussion

4.1 Length- weight relationship

The results of the length- weight relationship showed that fish from most of the sites did not obey cube law which assumes that the regression slope *b*= 3. Most of the fish showed allometric growth (*b*<3) except for male fish from Oserian and Hippo point that showed isometric growth (*b*=3) therefore obeying cube law (Taylor *et al*., 2011). This (*b*<3) could mean that large fish had more elongated body shape or smaller fish were in better nutritional condition at the time of sampling [7]. These results agree with several studies in other systems that have recorded allometric growth in Nile tilapia. Offem and Omoniyi (2007) [15] for example recorded 2.19 for *O. niloticus* in Nigerian dams. The negative allometry in the length-weight relationship of fish in the whole lake was an indication that the population of the species in these zones had heterogeneous groups with body weights varying differently with the cube of total length. On the other hand isometric growth shown by males of the same species in Oserian and Hippo point (*b*= 3.1 and *b*=3.0) was an indication that these zones have homogenous groups in their populations. It could also be as a result of the water quality parameters especially in Oserian that had high oxygen levels.

4.2 Condition factor

Fish in Lake Naivasha showed good condition with values above 1. This could be due to abundance of food within the lake as this has been shown to improve the condition of fish. The good condition could be due to the better water quality parameters (physico-chemical parameters) which are within the tolerable range for Nile tilapia (temperature between 22.0-22.5, oxygen between 4.5 mg/l to 6.8 mg/l and pH between 7.1 and 7.7). Ighwela and Ahmed, (2011) recorded values higher than 1 for intensively fed Nile tilapia in aquaculture ponds in the USA. They recorded higher values for females than for males under the same feeding programme which agrees with results of this study which has recorded higher values for male and female fish in most of the sites. However, [16] recorded values below 1 for Nile tilapia in polyculture ponds in Nigeria. They attributed the poor condition factor to inadequate food and overcrowding within the ponds. Bwanika *et al*., (2004) [5] recorded values between 1.5 and 1.8 in Lake Nyamusingiri and Lake Kyasanduka in Uganda. The condition factor of *O. niloticus* has been recorded to be around 1 in normally growing fish and increases when sexual maturation approaches [16]. However, it can be lower or higher than this depending on the conditions within the habitat particularly availability of food.

4.3 Sex ratio

The sample was dominated by male fish in all the sampling sites. This could be attributed to the fact that male fish tends to be more aggressive and territorial compared to female ones. This agrees with results obtained by [2] who compared the

aggressive behaviour of the two sexes of *O. niloticus*. This behaviour makes male fish more vulnerable to getting entangled in the nets. The dominance of males in the sample was probably because once fertilization of the eggs was completed; the males possibly emigrate from spawning areas towards feeding grounds located in shallow part while the females move towards submerged vegetation and rocky areas for incubation of the eggs hence providing protection of offspring in these quite hidden areas where they cannot easily caught. During the incubation period, feeding and movement is minimized by the female fish making them more unlikely to be caught during sampling hence the low numbers of females obtained during this study. This agrees with results reported by Offem and Omoniyi, (2007) [15] who also recorded a male dominated population with male to female ratio of 2:1 on Cross river, Nigeria. These results compare with those recorded by Njiru *et al*., (2006) who recorded a male dominated population with a sex ratio being significantly different from 1:1 in the Kenyan portion of Lake Victoria.

4.4 Length at first maturity *(L_{m50})*

The smallest mature male and female fish in the sample were 20 cm TL and 22 cm TL respectively. These results differ slightly from those recorded by Njiru *et al*., (2006) who recorded 21 cm TL and 22.7 cm TL for male and female fish respectively in Lake Victoria. The early maturity could be a survival tactic to cope with the stresses like high fishing pressure and challenges posed by the common carp which destroys breeding nests made by *O. niloticus* as they feed at the lake bottom. Balirwa, (1998) reported that Nile tilapia in Lake Victoria shows signs of maturity at 25 cm TL which is higher than that reported in this study. In the current study, the length at first maturity was 17.7 cm TL for male and 18.0 cm TL for female fish. The values obtained in this study are lower than the 34.56 cm TL and 30.81 cm TL for males and females respectively reported by Njiru *et al.*, (2006) [14] for *O. niloticus* in Lake Victoria. Duponchelle and Legendre, (2000) recorded much lower value of L_{M50} of 11.3 cm TL and 9.9 cm TL for male and female fish respectively in Lake Ayame (Ivory Coast). Bwanika *et al.*, (2004) [5] suggested that Nile tilapia delays maturation when living in large lakes but breeds at younger ages when in smaller lakes and ponds. They attributed this to the small size of the river which during dry seasons had water only in small pools (habitat shrinking) that could lead to competition, lower amounts of dissolved oxygen and other factors that stress the fish. Lake Naivasha being a small lake could experience more abrupt changes in the physic-chemical parameters compared to larger lakes like Lake Victoria. This could stress the fish leading to early maturity. This shows that *O. niloticus* can adopt *r* strategy by maturing faster in order to take advantage of the short lived resources brought about by the floods onto the floodplains as hypothesized for other floodplain organisms in the 'Extension of the Flood Pulse Concept' [20].

4.5 Conclusions and recommendations

Since these results showed that the Lake Naivasha fish stock is dominated by males it is important to carry out more studies especially on reproduction and fecundity of *O. niloticus* to establish whether the fish population can reproduce at a rate that would ensure population sustainability to support the community dependent upon it for their livelihood. It would also be important to further study sex ratio with a focus on the behavior of female *O. niloticus* fish to ascertain whether they were fewer in the population or female fish in the population could not be caught during sampling due to the behavioral differences between the two sexes.

5. Acknowledgement

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