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Length–weight relationship and condition factor of *Clarias gariepinus* in Lake Naivasha, Kenya

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Abstract
Length–weight relationship and condition factor of 139 specimens of *Clarias gariepinus* in Lake Naivasha were investigated monthly, from experimental surveys, for a period of 6 months (October 2014 to April 2015). Samples for this study were collected by gill netting at Oserian bay and Crescent Lake. The parameters *a* and *b* of the length-weight relationship were estimated using the formula $W= aL^b$ while the condition factor was calculated from the equation $K = W100/ L^3$. The *b* values in the relationship were; males (3.157), females (3.302) and both sexes combined (3.232), all exhibiting positive allometric growth hence obeying the cube law. The mean condition factor (K) of the specimen produced male, female and combined sex values of 0.5771, 0.5284 and 0.5527 respectively, an indication of the unhealthy status of the population with less tissue energy reserves, depressed reproductive potential and low survival. The determination of *b* and *k* of introduced fish species in an aquatic system is useful in assessing the well-being, growth performance and feed utilization in natural systems.

Keywords: *Clarias gariepinus*, cube law, allometry, condition factor.

1. Introduction
The African catfish, *Clarias gariepinus*, is a non native fish species in Lake Naivasha and was first sighted by Kenya Marine and Fisheries Research Institute (KMFRI) researchers in 2012 during their regular monthly fish stock assessment. In other natural water bodies, catfish is an economically important food fish [1]. *C. gariepinus* exhibits many qualities which makes it suitable to adapt to the environmental conditions of Lake Naivasha. These include its rapid growth, hardiness, high disease resistance, high yield potential, high fecundity, air-breathing characteristics and good market potentials [2, 3]. The aforementioned facts necessitate a search for reliable information on the length-weight and condition factor of *C. gariepinus* in Lake Naivasha.

The length-weight relationship (LWR) is a useful tool in fishery assessment, which helps in predicting weight from length required in yield assessment [4] and in the calculation of biomass [5]. In sampling programs, it is usually easier to measure length only while weight cannot be measured simply. The LWR of a particular species allows the inter-conversion of these parameters. Also, morphometric comparisons can be made between species and populations [6]. Furthermore, the LWR allows fish condition to be estimated. The relationship between the length (*L*) and weight (*W*) of a fish is usually expressed by the equation $W = aL^b$. Where *a* is the intercept and *b* is the allometry coefficient. Values of the exponent *b* provide information on fish growth. When $b = 3$, increase in weight is isometric. When the value of *b* is other than 3, weight increase is allometric (positive if $b > 3$, negative if $b < 3$). This is a useful tool that provides important information concerning the structure and function of fish populations [7].

The condition factor is an index reflecting interactions between biotic and abiotic factors in the physiological condition of fish. It shows the population's welfare during the various stages of the life cycle [8]. The analysis of fish condition has become a standard practice in the management of fish populations, as a measure of both individual and cohort (e.g., age or size group) fitness or well-being. Condition factor has been generically described as the well-being or robustness of an individual fish [8] and has typically been estimated by comparing individual fish weight of a given length to a standard weight. Condition factor has also been estimated by directly measuring physiological parameters related to the energy stores such as tissue lipid content and reproductive status [9].

Measurements of condition factor are generally intended to act as indicators of tissue energy reserves, with the expectation that a fish in relatively good condition should demonstrate higher growth rates, greater reproductive potential and higher survival than a lower conditioned counterpart, given comparable environmental conditions [10]. As a result, numerous studies have investigated the relationship between measures of fish condition and parameters such as population structure, growth, fecundity, life history adaptations, environmental conditions or management actions such as stocking [8]. Fish condition may be used to characterize components of the environment in which the fish exists (e.g., habitat, prey availability, competition). Measures of fish condition are of value to fisheries managers who must assess population status, impacts of management actions, and anthropogenic influences on the resource they are managing [11]. A critical component in interpreting fish condition data in a useful and applicable way is to apply the correct statistical methodologies when collecting and analyzing the data. The condition factor usually increases when sexual maturation approaches [11]. Values of condition indices vary among individuals, and may vary annually within individuals. Changes in environmental factors, such as temperature, may affect condition factor by influencing fish behaviour and metabolism, as well as food availability. In extreme cases, low condition can induce reproductive failure and lead to skipped spawning seasons [12].

The aim of this study was to provide information on the length–weight relationship and condition factor of *C. gariepinus*, a new fish species, never been studied before in Lake Naivasha. In addition to increasing knowledge on the species in the lake, as it is non-native to Lake Naivasha, these data allowed comparison with values for the fish in Lake Baringo and other natural ranges in Africa.

2. Materials and methods

2.1 Study area

This study was done on Lake Naivasha. It is a shallow freshwater body, situated in the eastern rift valley of Kenya (0° 46'S, and 36° 20'E) at an altitude of about 1890 m above sea level [14]. It covers a surface area varying between 120 Km^2 and 160 Km^2 depending on the dry and wet seasons, respectively [13]. The lake's mean depth varies between 4 m and 6 m [14]. Two sampling stations which were used in the study are indicated in Figure 1

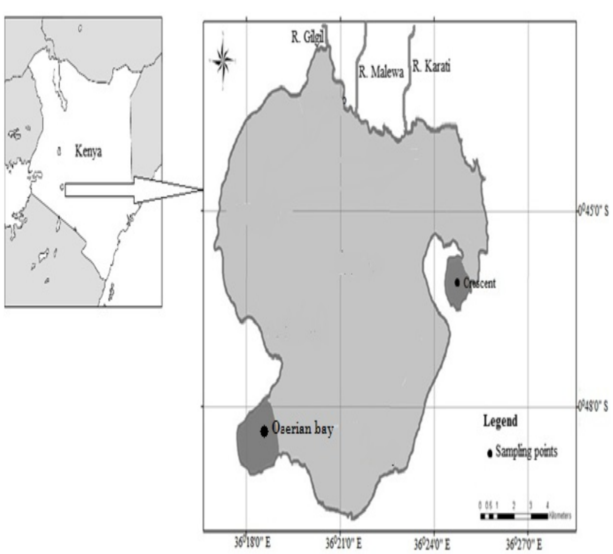


Fig 1: Map of sampling site[s in Lake Naivasha

2.2. Sample collection and analysis

Sampling comprised setting of gill nets of mesh size 35–70 mm at dusk, with lifting after approximately 10 h fishing. Following prompt removal from the net, fish were identified, length and weight of individual fish were measured *in situ* and recorded. The total length (TL in cm) (i.e. from snout to the end of the caudal fin) of each fish was measured using a meter rule. Weight of each fish was measured using the Digitron T745 weighing balance. The length-weight relationship was calculated using the formula by Wooton [15].

$$W = aL^b$$

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

Relative condition factor (Kn) was estimated following Le Cren [16]:

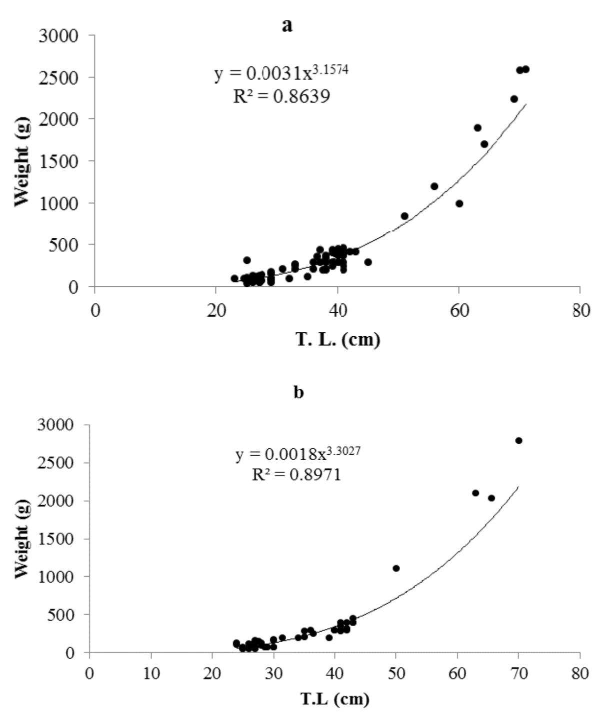
$$Kn = \frac{W \times 100}{L^3}$$

Where Kn is the condition factor, W is the body weight of fish in grams, *L* the total length in centimeters.

3. Results

3.1 Length-weight relationships

A total of 139 fish were measured. Total length ranged from 23 to 71 cm and weight from 50 to 2785 g. The total length - total weight relationships were separately evaluated for all individuals and grouped by sex (females and males). The equations for the sexes are given in table 2. Figure 2 shows the length-weight relationship of male, female and both sexes combined of *C. gariepinus*. When sexes were seperated, male (Fig. 2a) and female (Fig. 2b) *C. gariepinus* had different allometry coefficient values of 3.157 and 3.302 respectively. This indicated that both had positive allometric growth. The regression slope, *b*, when both sexes are combined (Fig. 2c) was 3.232, which is aslo higher than the allometry coefficient value of 3. This indicates that the fish had positive allometric growth.



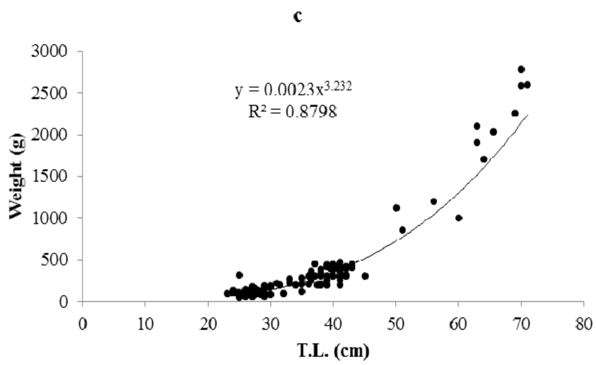


Fig 2: L-W relationship of male (a), female (b) and both sexes (c) of *C. gariepinus* in Lake Naivasha

3.2 Fish condition factor

The length frequency and weight distribution of the combined sexes are presented in figure 3. In the combined fish samples, the 26 - 30 cm total length group had the largest number caught with a total of 52 samples and a mean weight of 102.1 g. The least number of 1 fish sample was recorded in the 46-50, 51-55 and 71-75 cm size groups, with a mean weight of 1155, 855 and 2600 g respectively. There was no particular consistency in the condition factor values. However, class intervals from 61 to 75 exhibited the highest values. The highest mean K value of 0.89 was recorded in size category 46-50 cm while the lowest mean K value, 0.49, was in size category 41-45 cm. The K values for male samples were generally higher than those of the females. The mean K values for male, female and combined sexes were 0.58, 0.53 and 0.55 respectively (Fig. 4).

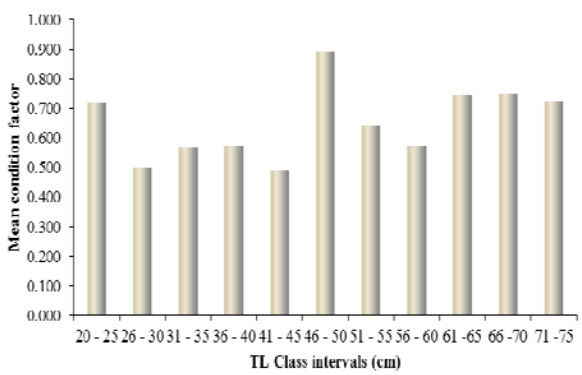


Fig 3: Mean condition factors of *C. gariepinus* per TL class intervals in Lake Naivasha

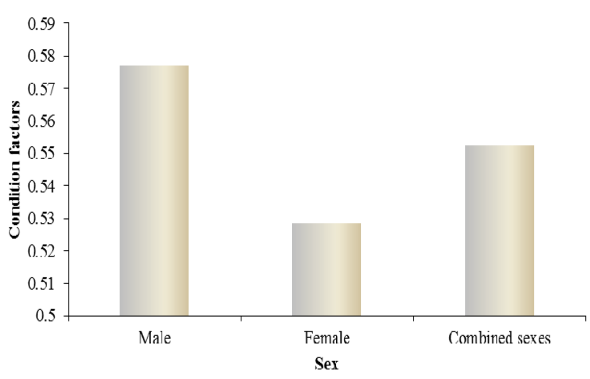


Fig 4: Mean condition factors of male, female and combined sexes of *C. gariepinus* in Lake Naivasha

4. Discussion

Length-weight relationship gives the condition and growth patterns of fish. It provides important information concerning the structure and function of fish populations [17]. The length-weight determination of *C. gariepinus* in Lake Naivasha was considered to be of significant interest. Apart from assisting in the prediction of the average weight of this fish at a given length, it was also used to assess the well-being of the catfish population in the lake. The length-weight data obtained from this study showed different values for the males, females and combined sexes. The males had an equation of $W=0.003L^{3.157}$, females $W=0.001L^{3.302}$ and when both sexes were combined the equation was $W=0.002L^{3.232}$. These equations obtained from the data of this study indicated a positive allometric growth for the *C. gariepinus* in Lake Naivasha. Fish undergoing positive allometric growth is an indication of stoutness of the body with increase in length. *C. gariepinus* are relatively new fish species in Lake Naivasha and these results therefore indicate a positive adaption by the fish to the lake. There was no marked differences in *a* and *b* values of *C. gariepinus* in lakes Naivasha, Baringo and populations elsewhere A length-weight relationship study by Britton and Harper [18] on different fish species of Lake Baringo showed that when both sexes of *C. gariepinus* were combined, the *a* and *b* values were 0.0032 and 3.214 signifying a positive allometric growth which are similar to results from this study. *C. gariepinus* in the study by Britton and Harper [18] had a length range of 16.5 to 44.3cm and an r^2 value of 0.97. A similar study of *C. gariepinus* by Torres [19] in Lake Kariba had results of positive allometric growth of the fish. *a* and *b* values were 0.011 and 3.013 respectively. However, an assessment of the *C. gariepinus* by Kolding [20] at Bangweulu swamps in Zambia found the *a* and *b* values of to be 0.008 and 2.983 respectively, indicating a negative allometric growth, a slight deviation from this study.

Fish body condition is known to vary seasonally depending on changes in gonadal development, food availability, and other environmental factors [21]. No great variation in relative condition factor (K) was observed for *C. gariepinus* throughout the sampling period. However, it was observed that mean condition factor for *C. gariepinus* were of values of < 1 which indicated that *C. gariepinus* are generally not doing well in the Lake. The condition factors of combined sexes of *C. gariepinus* (K= 0.55) in Lake Naivasha is lower than the value (K= 1.06) reported for *C. gariepinus* in Lake Baringo by Kembenya [22]. This may be due to reduced availability of food and prey item. Mean condition factor (K) recorded in this study for males fish species were higher (fig. 4) indicating that males were in good condition, and their general well-being was better than the females fish species examined. The reason for this observation could be due to the fact that females expended a lot of metabolic energy that could have been used for body building, in egg laying and care of young ones. It was observed in this study that condition factor (K) values were high in the larger fishes and it decreased in the small sized fishes. This suggests that the larger sized fishes are better adapted to the ecological status of Lake Naivasha. The ranges of condition factor obtained in this study were similar those values from the Niger Delta for some catfishes have been generally low. A range of 0.77 – 0.81 was reported for *Chrysichthys filamentosus* in Oguta lake [23]. Also, a range of 0.49-1.8 was recorded in a similar population in Andoni River [24].

5. Conclusion and recommendations

The length-weight relationships of samples indicated that the population of *C. gariepinus* studied had a good growth ratio. The growth of *C. gariepinus* in Lake Naivasha obeyed the cube law of growth as all of the fish showed allometric growth (b <3). The size distribution of the population studied indicates a population which has potential for growth. The condition factor values (K) obtained for the fish population showed that the population was not in good condition, an indication of the unhealthy status of the population with less tissue energy reserves, depressed reproductive potential and low survival. It is equally an indication of the inability of study environment's ability to sustain the population of *C. gariepinus*

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