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International Journal of Current Research
Vol. 6, Issue, 09, pp.8286-8292, September, 2014

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF COMMON CARP, *CYPRINUS CARPIO* IN LAKE NAIVASHA, KENYA

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ARTICLE INFO

Article History:
Received 15th June, 2014
Received in revised form
22nd July, 2014
Accepted 31st August, 2014
Published online 18th September, 2014

Key words:
Length-weight relationship,
Condition factor,
Length at first maturity,
Cyprinus carpio.

ABSTRACT

This study aimed at determining the length-weight relationship (LWR), condition factor (K) and length at first maturity of common carp (*Cyprinus carpio*) in Lake Naivasha, Kenya. The fish were sampled monthly using a gill net of mesh size between 1.5 to 5 inches. The lake was accessed using an engine boat from November 2013 to February 2014. A total of 520 fish of *C. carpio* were sampled. Total length and weight of the fish were measured using measuring board (0.1cm) and digital weighing balance (0.1g) respectively. There was a significant difference of Length-weight relationships between males and females ($p < 0.05$) with 'r' values of 0.82 and 0.72 for males and females respectively. The growth exponent ('b' values) of the length weight relationship for the fish was 2.3 for males, indicating isometric growth and 1.9 for females, suggesting allometric growth. The condition factor was 1.23 ± 0.21 and 1.05 ± 0.13 for males and females respectively, indicating a good condition for *C. carpio* of Lake Naivasha. The lower condition factor for females suggest that females were already spent during the period of sampling. The estimated length at first maturity for *C. carpio* was found to be 47cm (Total Length).

INTRODUCTION

Lake Naivasha has been a habitat for single fish species, the endemic *Aplocheilichthys antinori*, which was last recorded in 1962 (Elder *et al*., 1971). Since 1925, various fish introductions have been made, with varying success histories (Litterick *et al*., 1979; Muchiri and Hickley, 1991). Today, a wider variety of fish species including *Oreochromis niloticus, Oreochromis leucostictus*, *Tilapia zillii*, *Micropterus salmoides* (large mouth black bass) *Cyprinus carpio* (common carp), *Procambarus clarkii* (Crayfish) and Mirror carp, longfin barb *Barbus paludinosus* (Boulenger) coexist in the lake (Elder *et al*., 1971; Siddiqui, 1977; Hickley *et al*., 2000; Hickley *et al*., 2004; Ojuok *et al.,* 2007; Aloo *et al*, 2013). *C. carpio* is the most dominant fish species in lake Naivasha and despite being native to Asia, *C. carpio* is commercially cultured in many parts of the world including Australia, South America and central and Eastern Europe. This is due to its fast growth rate, easy cultivation and high feed efficiency ratio (Lowe *et al*., 2000). The *C. carpio* is hardy and thrives in turbid waters (Kottelat, 2007).Today, China accounts for the largest commercial production of *C. carpio*, with approximately 70% of total global production (FAO, 2006). The fisheries of *C. carpio* in Lake Naivasha increased from 0.9 tons (< 1%) in 2002 to 133.4 tons (95 %) in 2006, making it the most important commercial fish in Lake Naivasha (Mageria *et al*., 2006). Biologically, the wild *C. carpio* are slimmer with body length about four times the body height, having red flesh with a forward-protruding mouth. The average length and weight of *C. carpio* is about 40 - 80 cm and 2-14 kg respectively (Billard, 1995). The *C. carpio* has a diversified diet feeding on a variety of food items, which include plant materials and detritus (Njiru *et al*., 2007).

The length-weight relationship is an important tool in fish biology, physiology and ecology. This relationship serves the purposes of determining the type of the mathematical relationship between two variables so that if one variable is known the other could be computed (Mir *et al*., 2012, Sarkar *et al.,* 2013). A part from giving information on the condition and growth patterns of fish, changes in length-weight relationship can indicate the age and year-classes of fishes (Bagenal and Tesch, 1978; Thomas *et al*., 2003). These studies are also widely used for conversion of the growth-in-length

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equation to growth-in-weight for use in stock assessment models, estimation of the mortality rate and estimation of biomass from length observations (Weatherley and Gill, 1987; Wootton, 1990; Moutopoulos and Stergiou, 2002). According to Bayhan (2008), the data on length and weight can also be used to compare fish life history between regions in species and populations. The relationship between length (L) and weight (W) typically takes the allometric form: $W = aL^b$, or in the linear form: Log W=Log a + b Log L, where 'a' and 'b' are constants estimated by regression analysis. If fish retains the same shape, it grows isometrically and the length exponent "b" has the value b = 3.0 (Wootton, 1990). The b values above 3 indicates positive allometric growth, where fish becomes heavier for its length while b values below 3 means that the fish becomes lighter for its length therefore negative allometric growth. (Ratnakala *et al*., 2013)

The length-weight relationship provides an opportunity to calculate an index commonly used by fisheries biologists to compare the "well-being" of a fish (Ibrahim *et al*; 1980, Sani *et al.*, 2010; Sarkar *et al.,* 2013). This index is called condition factor (K) and is computed using the formula ($K = 100 X W/L^3$). Fish with a high value of K are heavy for their length, while fish with a low K value are lighter (Ibrahim *et al*., 1980). Fish condition, which is defined as the robustness or wellbeing of an individual fish (Le Cren 1951; Bulow *et al*., 1981; Blackwell *et al*., 2000), is an essential component of fishery biology used to assess the general health of populations (Gulland 1983; Sparre *et al*., 1989, Froese, 2006). The condition factor K also gives information when comparing two populations living in certain feeding, density, and climatic conditions; when determining the period of gonadal maturation; and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Weatherley, 1972, Anibeze, 2000; Sarkar *et al.,* 2013). Since the fish condition can vary within and among populations, it is therefore critical to identify environmental predictors of this variation to optimize fishery production.

Length at first maturity is defined as the length at which 50% of the individuals of a given sex are considered to be reproductively mature (Karna, 2011). Usually it is based on females through visual and subjective descriptions of macroscopic aspects of ovaries and testes at different maturation stages (Gerritsen *et al*., 2003; Karna 2012) and is estimated by fitting a logistic curve to the relationships between proportions of weight and length (Tokai and Mitsuhashi, 1998; Goncalves and Erzini, 2000; Dadebo *et al*., 2003; Lewis and Fontoura, 2005;Gerritsen *et al*., 2003). It is abbreviated as L_{50} and it is also referred to as length at sexual maturity. Length at first maturity (LM_{50}) is estimated according to the general model proposed by Binohlan and Froese (2009): $L_{50} = 10 - 0.1189 + 0.9157 * \text{Log} (L_{max})$, where L_{50} is the size at first maturity and L_{max} is the maximum recorded size of a species. Despite being one of the most commercially exploited fish species in Lake Naivasha, there are no previous reports and information concerning the Length Weight Relationship and condition factor of *C. carpio* is available in the lake. Further Fish Base database (Froese and Pauly 2012) shows no record of LWR, condition factor and length at first maturity of the *C. carpio* in Lake Naivasha. Therefore this current study provides baseline information of *C. carpio* in tropical lakes on LWR, condition factor and length at first maturity in Lake Naivasha.

MATERIALS AND METHODS

Study area

Lake Naivasha is a shallow freshwater lake (mean depth 6m), approximately 160 km^2 in area, situated in the Eastern Rift valley region in Kenya. The Lake Naivasha lies between 0° 40′S and 0° 50′S and 36° 15′E and 36° 25′E in a closed basin at an altitude of 1,890 m above sea level. The lake, whose volume is approximately 6.8×10^8 m^3, receives 90 % of its water from the perennial River Malewa. The lake has an area of 15,600 ha (including islands) and a catchment area of 2,378 km^2. The lake has ground water seepage along the north and northeast shores, which is responsible for up to 16% of the total influx (Harper and Mavuti, 2004). The lake was randomly subdivided into 4 parts, where samplings were done (Figure 1).

Sample collection and data analysis

During the study (November 2013 to February 2014), a total of 520 fishes were sampled from the lake using a multifilament gill net of mesh size ranging from 1.5 to 5 inches. The fishes were transferred to the laboratory in Kenya Marine and Fisheries Institute, Naivasha station for further analysis. The total length and weight of individual fish were taken using a measuring board (0.1 cm) and digital weighing balance (0.1g) respectively. The weight was taken after blot drying the fish to avoid errors in weight measurements. The Length-weight relationship was expressed by the equation: $W = aL^b$, Where 'b' is an exponent with a value demonstrating fish normal growth dimensions. The Linear transformation was made using natural logarithm at the observed lengths and weights according to Zar (1974) as follows:

$$\textbf{Log W = b log L + log a}$$

Where
W = the weight of the fish in grams,
L = the total length of the fish in centimeters
a = exponent describing of the rate of change of weight with length
b = weight at unit length
The condition factor was calculated using the formula**:**

$$\mathbf{K = 100\ W/ L^b}$$

Where
W = the weight of the fish in grams
L = the total length of the fish in centimeters
b = the value obtained from the length-weight equation.
Further, the monthly relative condition factor (K_n) of the fish samples was calculated according to Le Cren (1951). This K_n value can also be used to compare conditions between species, though in this study, it was used to compare the condition of *C. carpio* within its size classes of total length.

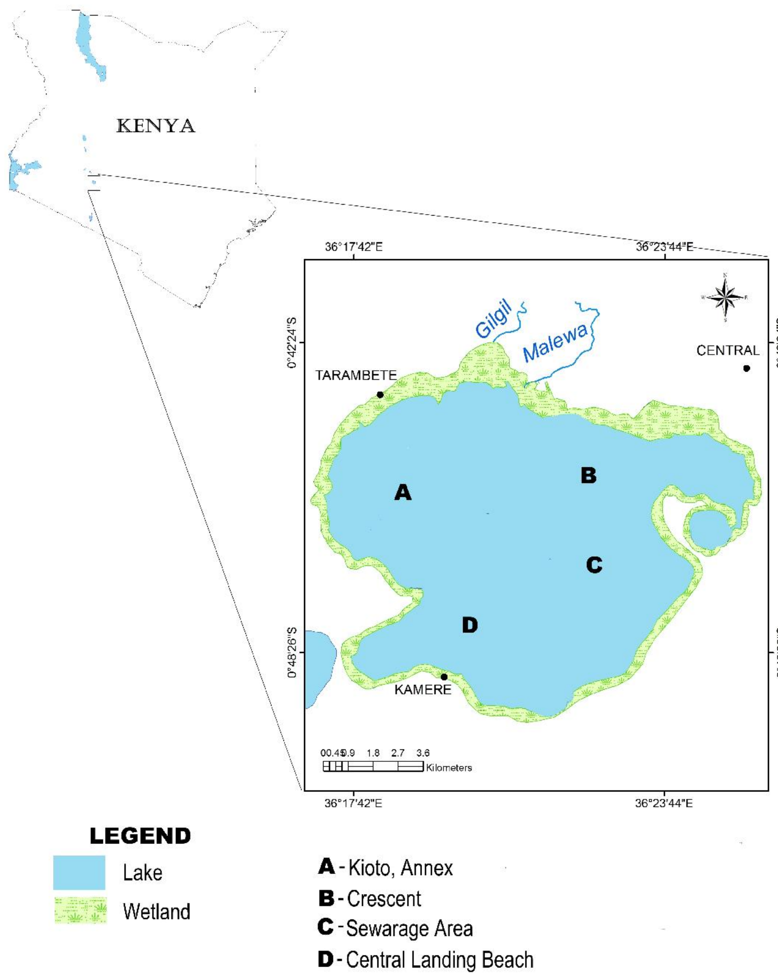


Fig. 1. Lake Naivasha map showing the four sampling sites

K_n= W/ W

Where:
W = the weight of the fish in grams
W = aL^b
b = the value obtained from the equation 1
Finally, length at first maturity (L_{50}) was estimated according to the general model proposed by Binohlan and Froese (2009): $L_{50} = 10 - 0.1189 + 0.9157 * \text{Log}(L_{max})$, where L_{50} is the size at first maturity and L_{max} is the maximum recorded size of a species.

RESULTS

Length-weight relationships

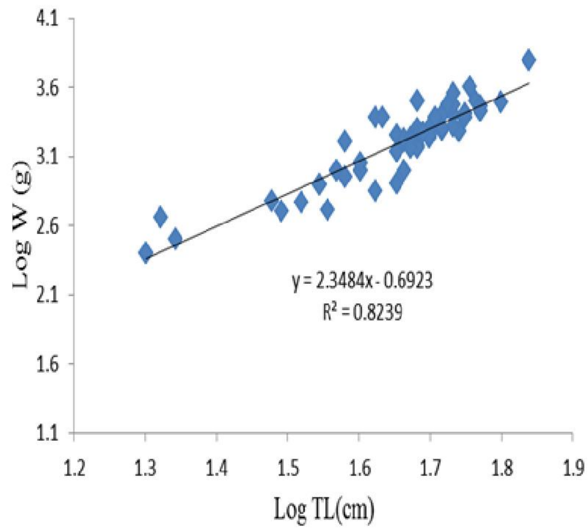
The results of the length-weight analyses of 322 males and 198 females are presented in Table 1 and Figure 2a and b. Length-weight relationships equations obtained for males and females were Log W= 0.6923 + 2.3484Log L (n = 322) and Log W = 0.9712+1.9455Log L (n = 198) respectively. There was a significant difference of Length-weight relationships between males and females ($p < 0.05$) with 'r' values of 0.82 and 0.72 for males and females respectively. The growth exponent ('b' values) of the length weight relationship for the fish was 2.3 for males, indicating isometric growth and 1.9 for females, suggesting negative allometric growth.

Table 1. Estimated parameters of the length-weight relationships for male and female *C. carpio* in Lake Naivasha

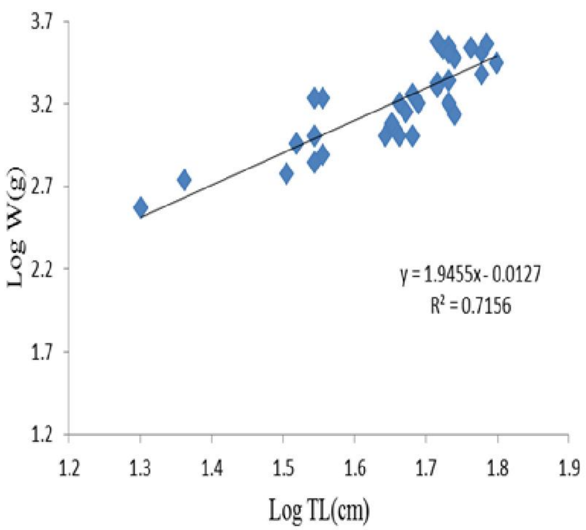
Sex	N	Length range (cm)	a	b	r
Males	322	20-89	0.6923	2.3484	0.8239
Females	198	20-69	0.9712	1.9455	0.7156

The ranges of condition factor (K) calculated for male and females *C. carpio* varied from 0.61 -2.15 ± 0.02 and 0.55 – 1.79 ± 0.02 respectively (Figure 3).

The variations in condition factor with size for males and females are shown in Tables 2 and 3 respectively. The results showed that bigger sizes of male and female fish (31 – 60 cm) had higher K factor and are in better condition than smaller sizes. The computed exponent describing the rate of change of weight with length 'a' was 0.2 and 1.0 for male and female respectively. There was significant difference between the K factor of males and females (P <0.05)



(a)



(b)

Fig. 2. Length-weight relationship of male (a) and female (b) *C. carpio.*

Table 2. Mean condition factor (K) in relation to size for male *C. carpio*

Length group (cm)	Number of Specimens	Range of K-factor	Mean of K-Factor
11-20	30	0.61-1.32	0.53 ± 0.01
21-30	58	0.66-1.38	0.96 ± 0.10
31-40	75	1.21-2.11	1.57 ± 0.12
41-50	129	1.47-2.14	1.84 ± 0.14
51-60	30	2.11-2.15	2.08 ± 0.21
61-70	0	-	-

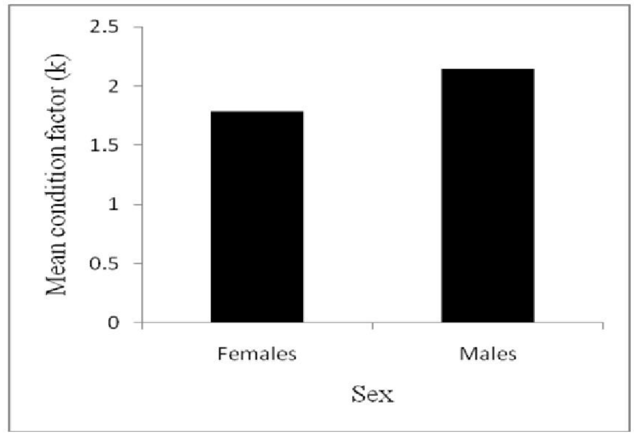


Fig. 3.Variation in condition factor of male and female *C. carpio.*

Table 3. Mean condition factor (K) in relation to size for female *C. carpio*

Length Group (Cm)	Number of Specimens	Range of K-Factor	Mean of K-Factor
11.0-20	0	-	-
21 - 30	0	-	-
31 - 40	31	0.54-1.02	0.79 ± 0.10
41 - 50	45	0.60-1.08	0.79 ± 0.10
51-60	97	0.81-1.73	1.14 ± 0.23
61-70	25	1.66-1.79	1.61 ± 0.17

The results of length at first maturity (L_{M50}) analyses of 322 males and 198 females are presented in Figure 4. The estimated length at first maturity was 47cm total length (TL) for the species.

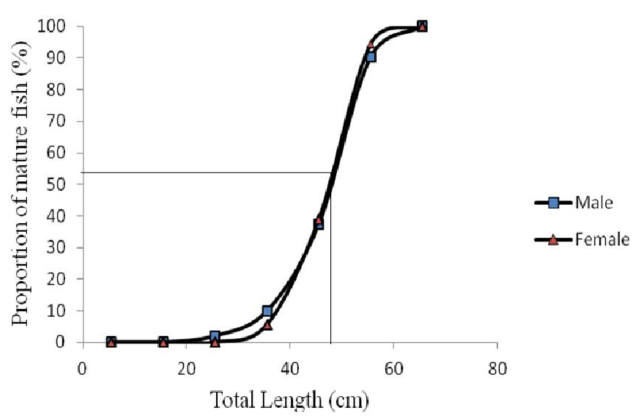


Fig. 4. Estimated proportion of mature *C. carpio.*

DISCUSSION

The higher correlation coefficient (r) for LWR for *C. carpio* indicates that length increases with increasing weight. This observation corresponds to earlier studies involving *Hemichromis bimaculatus*, *Sarotherodon melanotheron* and *Chromidotilapia guentheri* species from Eleiyele Lake, South western Nigeria according to Ayoade and Ikulala (2007). The value of 'b' (growth exponent) for male *C. carpio* (2.3) is within the accepted limits of 2 and 4 and suggests isometric growth for the males (Tesch, 1971; Ayoade and Ikulala, 2007) while the lower 'b' value (1.9) of females indicates negative allometric growth (Tesch, 1971; Ayoade and Ikulala, 2007). According to Gerritsen *et al*. (2003), the variations in 'b' values between males and females may depend on various factors such as number of specimen examined, and the sampling season. However the change of *b* values may also depend primarily on the shape and fatness of the species as well as physical factors such as temperature, salinity, food, sex and stage of maturity (Pauly, 1984; Sparre, and Venema, 1992; Wooten, 1998; Sarkar *et al.,* 2013). Equally, LWR in fish is affected by gonad maturity, sex, diet, stomach fullness, health, and preservation techniques as well as season and habitat (Cox and Hinch, 1997).

The condition factor of both males and females was greater than 1 at size range of 31- 60cm. This shows that the fish is above average condition in the lake (Wade 1992). However, there is a significant difference between the K factor of the male and female ($P < 0.05$). The lower K for the females could be attributed to low gonad maturity since sampling was done on rainy season when the fish are not likely to spawn. This observation is similar to that of Da Costa and Araujo, (2003) who suggested that during such periods, a larger part of the energy is allocated for growth and emptying of ovaries leading to relatively lower condition factor. Further, the difference of the K values between males and females may be attributed to metabolic strain during maturation or spawning as well as changes in feeding activity. Similar condition was observed in several species of fish by earlier studies (Dhanze *et al.*, 2005; Barua *et al*., 1988; Gupta, 1988; Jhingran, 1972). Smallest mature male and female fish were 30 cm and 45cm respectively. Length at first maturity ($L_{M50)}$ of *C. carpio* indicated that at 47cm and over, most of the female fish were reproductive. However, males are slightly larger in size at maturity than females. This is due to environmental conditions which induce phenotypic flexibility in fishes resulting to changes in size at maturity (Wertheimer *et al*., 2004).

Conclusion and recommendation

This research work provides information on the length-weight relationships, condition factor and the length at first maturity of *C. carpio* in Lake Naivasha. The results obtained in the study indicate negative allometric growth for females and isometric growth for male *C. carpio.* The results on condition factor of both males and females are greater than 1 at size range of 31-60 cm in the lake. This indicates that most fish in the lake are heavy for their respective lengths therefore their robustness is at best. However significant difference between the condition factor of the male and female *C. carpio* indicates that there is need for critical studies for identification of environmental predictors of this variation to optimize fishery production. Length at first maturity (L_{M50}) of *C. carpio* indicates that at lengths above 47cm, most females are reproductive. The study recommends further LWR analysis for both dry and wet seasons including water quality parameter analysis.

Acknowledgement

Finally the authors wish to thank the Kenya Agricultural Productivity and Agribusiness Program (KAPAP) Competitive Grant System (KAPAP-CGS) under the Aquaculture Value Chain Component "Commercializing aquaculture production through sustainable technologies and market linkages" for funding this research work.

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