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Understanding selected growth aspects in Redbelly Tilapia, *Coptodon zilli* (Gervais) and Largemouth Bass, *Micropterus salmoides* (Lacepède) in Lake Naivasha, Kenya; Fisheries Management Perspective

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Abstract

Coptodon zilli and *Micropterus salmoides* were introduced into Lake Naivasha in 1929 and 1959, to boost the fisheries and for recreational fishing respectively. The population of the two fish species in the lake has been declining making it necessary to assess selected growth aspects to inform management and policy making for recovery and establishment of their populations. Length-weight relationship, condition factor, sex ratio and length at first maturity of the fish were studied from October 2016 to November 2018. A total of 303 fish samples; 193 *C. zilli* and 110 *M. salmoides* were studied. Results showed that *C. zilli* and *M. salmoides* had an allometry coefficient value of 2.9 and 3.1 and condition factor (K) value of 1.77 and 1.39 respectively. The sex ratios (male: female) of *C. zilli* and *M. salmoides* were 1.1:1 and 1.3: 1 respectively. The shortest total length for mature *C. zilli* and *M. salmoides* recorded were 12 cm and 26.5 cm while 21.8 cm and 51 cm were for the longest respectively. The fish exhibited allometric growth pattern. They were also found to be in good condition with K factor above 1. It was concluded that the fish are generally in a good condition though the early maturity for *C. zilli* could be a sign of either environmental or fishing pressure. Domination of the species by males is a case for concern since it presents uncertainty on the future of the fisheries. Restocking of Lake Naivasha with the two fish species should be considered.

Keywords: *Coptodon zilli; Tilapia zilli; Micropterus salmoides;* Lake Naivasha

1. INTRODUCTION

The Redbelly tilapia *Coptodon zilli* (Gervais), formerly *Tilapia zilli* is widely distributed in Africa and was introduced in Lake Naivasha in 1959 [1]. The introduction of *C. zilli* into Lake Naivasha was motivated by the need to provide an alternative cheap source of protein [1]. The fish prefers shallow marginal waters in all stages of growth and development [1]. The piscivorous largemouth bass, *Micropterus salmoides* (Lacepède) is native to North America where it inhabits rocky areas in both rivers and shallow lakes [2] and the fish was introduced into Lake Naivasha in 1929 and later in 1946 for sport fishing [3,4,5]. Before the accidental introduction of *Cyprinus carpio* (Linnaeus) in 1997 and the re-introduction of *Oreochromis niloticus* (Linnaeus) in 2011 by the Government of Kenya, Lake Naivasha fishery was being dominated by *C. zilli*, *M. salmoides* and *Oreochromis leucostictus* [6, 7, 8].

It has been observed with interest that the numbers of *C. zilli* and *M. salmoides* in Lake Naivasha have been declining over the years, as indicated by data from field studies and commercial catch records for different locations in the lake over years [9]. Presently, the two fish species have been reported to show habitat preference in their distribution with *C. zilli* occurring in large numbers in sections of the Oserian Bay [9]. On the other hand, *M. salmoides* has preference for rocky habitats of Crescent Island Lake and Hippo Point (KMFRI unpublished data). The habitats at Oserian Bay, Crescent Lake and Hippo Point are fish breeding areas and have very low wave action.

As a result of the decline in the populations of the two fish species, it is necessary to assess various aspects of their growth such as length-weight relationship, condition factor, sex ratio and length at first maturity. Previous studies on Lake Naivasha have focused on various aspects of growth and reproduction of *O. niloticus* and *C. carpio* [1, 7, 8, 10]. There still exists a gap on growth aspects for *C. zilli* and *M. salmoides.*

Length-weight relationship is an important tool in fishery assessment since it helps in predicting length from weight required in yield assessment [11] and in the calculation of fish biomass [12]. It also provides important information regarding the function and structure of various fish populations [13]. Fish condition factor, length at first maturity and sex ratio are also important concepts in fisheries management. Condition factor and length at first maturity can be used to assess the health and potential of any fishery to

support the fishing pressure. The condition factor provides information on the general well-being of a fish and its health condition within a mixed population with other fish species. The length at which 50% of the fish are mature, also known as length at first maturity, is very useful in fish stock management [14]. Information on length at first maturity is crucial in formulation of management options especially in the choice of gear to be used in capture fisheries. Fisheries managers can use it as a guide in setting mesh sizes that will target only the mature and ageing fish while giving juvenile fish time to grow to maturity [14]. Sex ratio is important in determining population viability since it shows the dominance of a particular sex. A population dominated by male fish is more unpredictable than one dominated by female fish [15]. It is also an important factor in determining the balance of the males and females in the habitat. These three growth parameters of the two fish species were investigated in order to understand the general characteristics of the population of the species within the lake in light of the intense human activities and pressures within the lake.

The main aim of this research was to assess the growth parameters of the two fish species. This included determination of the length-weight relationship, condition factor, sex ratio and length at first maturity of the fish for use in management and policy making. It will eventually aid in curbing the decline and enhancing recovery and establishment of their populations within the lake.

2. MATERIALS AND METHODS

Study area

Lake Naivasha is a shallow freshwater lake in the eastern arm of the Great Rift Valley in Kenya on 0° 45' S; 36° 26' E. It is on an altitude of 1890 m above sea level and has a surface area of approximately 139 km^2 [16]. It has an average depth of 3.35 m with the deepest area being 7 m [17] though these values vary with change in rainfall patterns. The lake was declared a Ramsar site in 1995 due to its unique flora and fauna [18]. It is the major source of fish for the surrounding community and the excess is transported to other towns including Nairobi. The lake also provides fresh water for the numerous horticultural industries in the area. Apart from transient streams, the lake is fed by the perennial Malewa and Gilgil rivers with the former being the main one [18].

Sampling and data analysis

Gill nets of variable mesh size ranging from 2.5 – 6 inches were used to collect *M. salmoides* and *C. zilli* samples in Lake Naivasha from October 2014 to November 2016. Collected fish samples were identified and classified by species. Sexual maturity status was assigned as stage I–VI according to Witte and Densen [19]. Fish in maturity stages I, II, III were considered immature, while those in stages IV-VI were considered mature. Length and weight of individual fish were measured and recorded. The total length (TL) in cm 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 top weighing balance. The length-weight relationship was calculated using the formula by Wooton [20]:

$$W = aTL^b \qquad Eq.\ 1$$

Where W is the total body weight of fish in grams, TL is the total length in centimeters, *a*, the intercept and *b* the slope of the regression line. Condition factor (K) was estimated following Le Cren [21]:

$$K = \frac{W}{L^b} \qquad Eq.\ 2$$

Where K is the condition factor, W is the total body weight of fish in grams, L the total length in centimeters and *b* is the regression slope.

Sex ratio was determined for mature fish i.e. only those fish whose gonads were identifiable as male and female. Maturity status for each sample of fish was assigned as stage I–VI according to Witte and Van Densen [19]. Fish gonads in stages I, II, III were considered immature, while those in stages IV-VI were considered mature. Only the mature fish gonads were used for the purpose of calculating the size at first maturity

(Lm50) by fitting frequency data of mature individuals by length class to a logistic curve using the least-square method [22].

3. RESULTS

Length-weight relationship was calculated for a total of 303 fish made up of 193 *C. zilli* and 110 *M. salmoides*. The total length of *C. zilli* ranged from 11 to 21.8 cm and their weight from 11 to 195 g while *M. salmoides* ranged from 18.6 to 51 cm in total length and 85 to 2120 g in total weight. Length-weight relationships were evaluated separately for the two fish species and the regression equations derived (Fig. 1). Results showed that *C. zilli* and *M. salmoides* had an allometry coefficient value of 2.9 and 3.1 respectively, an indication of negative allometric growth in *C. zilli* and positive growth in *M. salmoides.* Both fish species did not obey the Cube Law which assumes that the regression slope *b* is equal to 3. *C. zilli* had a negative allometric growth ($b<3$) while *M. salmoides* had a positive allometric growth ($b>3$).

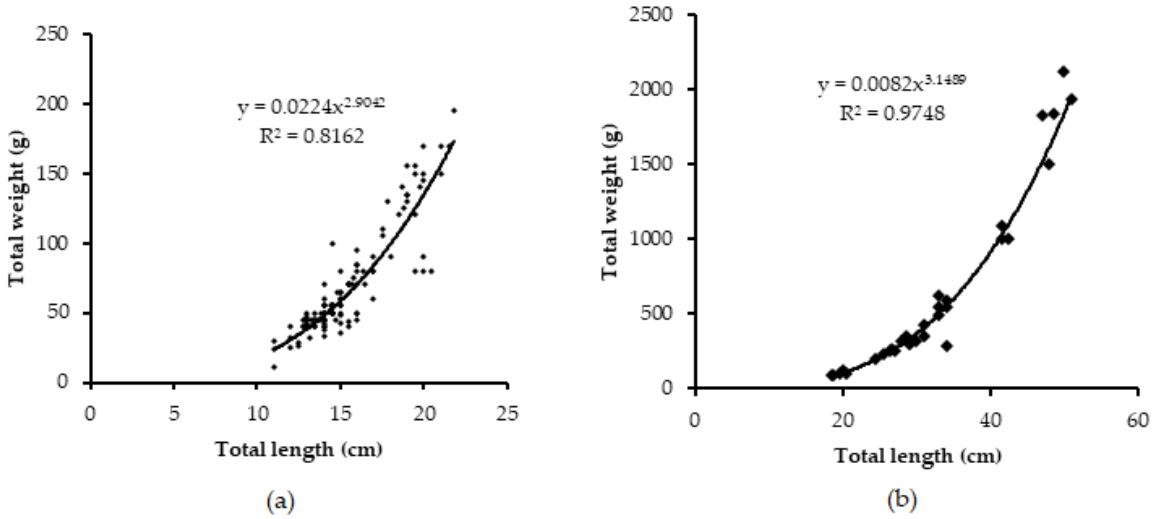

Figure 1. Length-weight relationship of (a) *C. zilli* and (b) *M. salmoides* in Lake Naivasha

Condition factor (K) of the two species was 1.77 and 1.39 for *C. zilli* and *M. salmoides* respectively (Fig. 2). The K values for both fish species were greater than 1 meaning their bodies were in good condition.

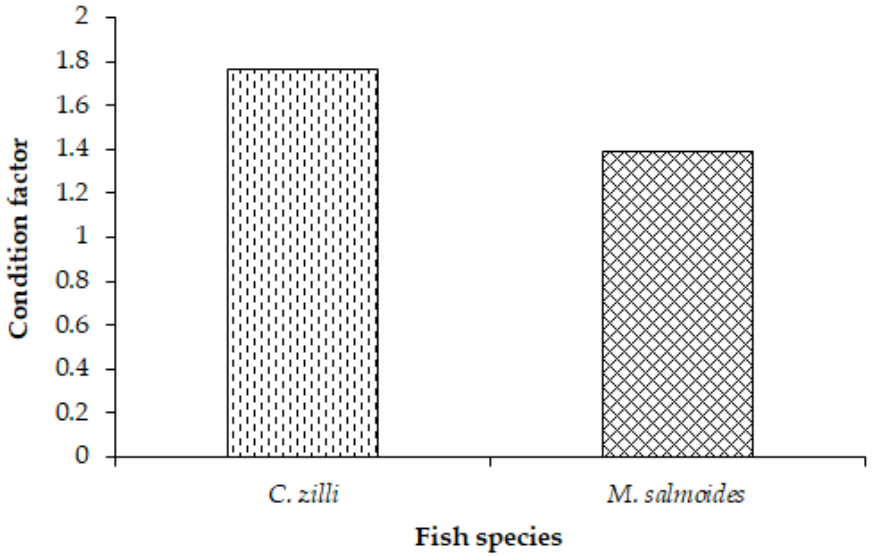

Figure 2. Condition factor of *C. zilli* and *M. salmoides* in Lake Naivasha

Samples of *C. zilli* were found to have a male: female percentage composition of 52%:48% leading to a male: female sex ratio of 1.1:1 respectively. Similarly, *M. salmoides* had a male: female sex ration of 1.3:1 making up a percentage composition of 57% and 43% respectively (Fig. 3).

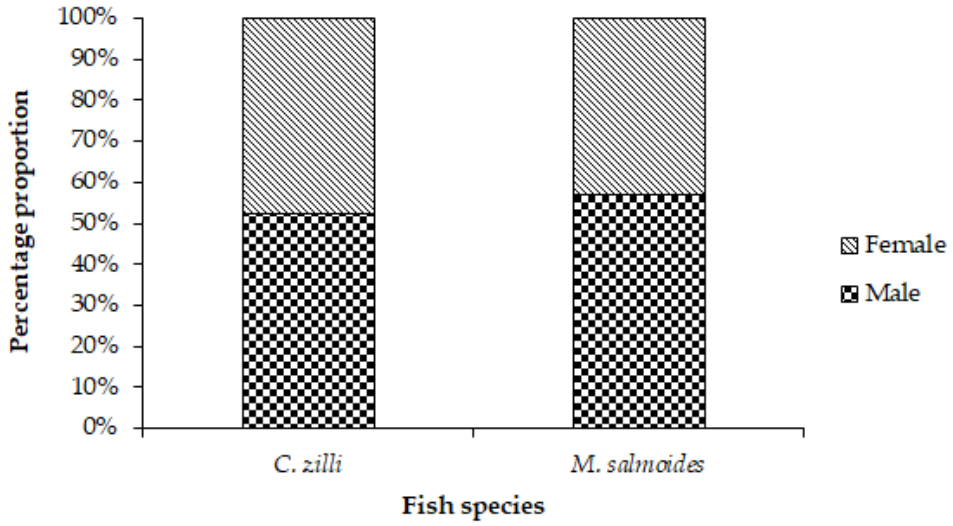

Figure 3. Percentage composition of each sex of *C. zilli* and *M. salmoides* in Lake Naivasha

Length at first maturity was assessed separately for the mature *C. zilli* and *M. salmoides* and results presented in Figure 4. The shortest total length for mature *C. zilli* and *M. salmoides* recorded were 12cm and 26.5 cm while 21.8 and 51 cm were for the longest respectively. The length at fist maturity for *C. zilli* and *M. salmoides* was 13.5 cm TL and 32.6 cm TL respectively.

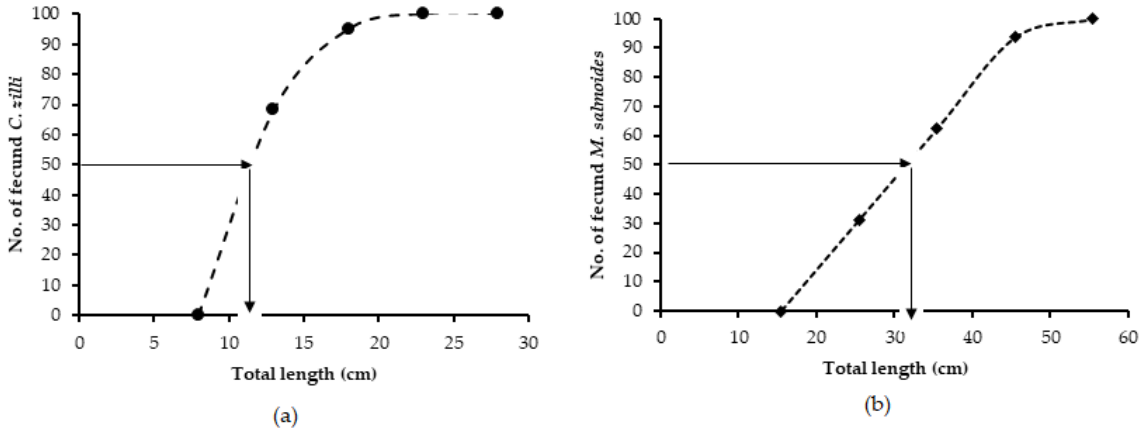

Figure 4. Length at first maturity (LM_{50}) of (a) *C. zilli* and (b) *M. salmoides* in Lake Naivasha

4. DISCUSSION

The results of this research point to the fact that the two fish species are in a generally good condition, exhibiting allometric growth and the population is dominated by male fish. Fish with values of *b* being less than 3 could mean that large fish had more elongated body shape. It could also be an indication that the smaller fish were in better nutritional condition at the time of sampling. Fish with *b* values greater than 3 could be therefore be a result of poor nutritional condition and compressed body structure [23]. Differences in *b* values is mostly as a result of either one or a combination of factors such as the duration of sample collection, differences in the number of specimens examined, location and season effects and distinctions in the observed length ranges of the specimens caught [24]. However, the change of *b* values is greatly dependent on the shape and fatness of the species. Additionally, physical, chemical and biological factors such as temperature, salinity, food, sex and stage of maturity can also have an effect on the *b* values [22, 25].

Both *C. zilli* and *M. salmoides* in Lake Naivasha had K values of greater than 1, an indication of general well-being and stable physiological status of the fish in the lake. This

could be due to abundance of food within the lake [8] as this has been shown to improve the condition of fish [7, 8]. The greater than 1 values for condition factor of the fish could also be due to the water quality parameters of Lake Naivasha which are within the tolerable range for both fish species [4]. The physico-chemical parameters being cited were from a comprehensive study by the author on the water quality of Lake Naivasha during similar period as the current study [11]. The study on water quality of Lake Naivasha noted relative stability in all water physicochemical parameters in the lake with an exception of pH values which were slightly higher compared to those observed in previous study [11]. Condition factor is also known to fluctuate with the reproductive cycle of the fish and tends to increase on the onset of reproduction [7, 8].

Sex ratio in fish varies considerably from one species to another but in majority of the species; it is close to 1:1 [26]. A study by Bal and Rao [27] noted that any deviation from this ratio is an indication of dominance of one sex over the other, which is caused by the differential behavior of the sexes. In both *C. zilli* and *M. salmoides* in Lake Naivasha, the males were found to be the dominant sex. Another factor that could explain the dominance of males in the two fish species is that dominance by males in the African lakes is common within the cichlid populations because of the higher growth rate they exhibit compared to the females [28]. A fish population dominated by males presents uncertainty in the future of the fisheries and could be a great hindrance to recruitment. This is because the contribution to the next generation is by the female members of the population.

Length at first maturity (LM_{50}) shows that length at which 50% of the fish in the population are mature. A low LM_{50} value depicts fish under pressure from either overfishing or human activities or other ecological and environmental factors [29]. It is a manifestation of the fish adjusting to the pressure and compensating for it by maturing and reproducing early. Nile tilapia for example has been seen to mature at lower lengths in more stressful water bodies compared to those with less stressor. In Lake Naivasha for example it was observed to mature at 18 cm compared to 21 cm in Lake Victoria [15]. The early maturity exhibited by *C. zilli* in Lake Naivasha could be a pointer to pressures within the lake environment such as continued increase fishing effort and use of gillnets with mesh size smaller than the recommended five inches [29]. It could also be as result

of competition from other species like the recently introduced Nile tilapia which is known to be very aggressive and strong competitor in novel environments [29]. The fish *M. salmoides* in Lake Naivasha has however shown no signs of early maturity and could be as a result of proper adaptation to the conditions of the lake. It could also be as a result of lack of competition in feeding since the fish is currently the only carnivore in the lake. The other fish species in Lake Naivasha are either planktivores or omnivores. This may have resulted in *M. salmoides* creating its own niche in the lake.

5. CONCLUSION

The two fish species are in a good condition, an indication of general well-being and stable physiological status of the fish. The length-weight relationships shows that the population of both fish species are within the recommended growth ratio. Domination of the sexes by males, although a common feature in African lakes, is a case for concern since it presents and uncertainty on the future of the fisheries. The low population of the two fish species could be due to other factors such as overfishing or using the wrong gear size for fishing while the early maturity of both fish species should be subjected to further studies. Additionally, investigations should be centered on breeding and population dynamics. Finally, restocking of Lake Naivasha with the two fish species should be considered and proper fishing enforced. Any gear likely to remove fingerlings should be banned.

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