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Some biological aspects of straightfin barb, *Enteromius paludinosus* (Peters 1852) during the rainy season in Lake Naivasha, Kenya

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ABSTRACT

This paper focused on determining the sub lethal effects of reported pollutants in Lake Naivasha, Kenya using the straightfin barb (*Enteromius paludinosus*), a decade after the existing baseline study. The specific objectives included determining the length–weight relationship (LWR), condition factor (K) and the sex ratio, of the migratory *E. paludinosus*. A total of 1279 straightfin barb were collected from the mouth of River Malewa, a major source of water for Lake Naivasha using seine nets of mesh size 1.2 mm in the month of November 2017. The fish were caught and transported to the laboratory, then killed humanely by cervical dislocation and thereafter their lengths (cm) and weights (g) determined followed by their dissection to examine the gonads. The length–weight relationship was determined using the formula $W = aTL^b$. The condition factor (K) was determined using the formula $K = 100\,W/\,L^b$. A student's *t*-test was used to test the significant differences in the weight and length of both sexes. The sex ratio, expressed as male: female was calculated by dividing the number of females by that of the males. The equations obtained for the LWR of the combined sexes, males and females of *E. paludinosus* were, Log $W = 3.23$ Log L + Log 0.1073, Log $W = 2.83$ Log L + Log 0.1500 and Log $W = 2.87$ Log L + Log 0.1522 respectively. The mean condition factor of the combined sex, males and females of *E. paludinosus* were; 0.5897, 0.5729 and 0.5981 respectively. The sex ratio of the fish was 1: 1.981 (males: females). The results showed that *E. paludinosus* in Lake Naivasha are not in a good condition, $k < 1$. The findings of this study may be attributed to the state of the lake due to the reported pollution increase and ecological changes by recent studies.

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Introduction

Lake Naivasha is one of the most valued resources in the Rift Valley. It is a Ramsar site since 1995, a wetland of international importance [24]. There have been numerous studies in the Lake focusing on different aspects: fish species composition [2,40], ecology [14,17], pollution [18,22,34], fish biology [15,33], fish parasitology [1,35,38] among others. For instance, a study by Hickley et al. [16] in Lake Naivasha found the following fish species at that time: common carp (*Cyprinus carpio*),

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the blue-spotted tilapia (*Oreochromis leucostictus*), largemouth bass *(Micropterus salmoides*), redbelly tilapia (*Tilapia zillii*) and straightfin barb (*E. paludinosus*).

A number of investigations on heavy metals and other trace elements have also been carried out in the lake [29,31]. Jimoh et al. [18] identified the source of pollutants into the lake as the flower farms on the catchment which find their way into the lake through River Malewa among others such as the runoff from town center. Mutia et al. [29] reported an increase in levels of heavy metals such as Lead (Pb), Copper (Cu) and Cadmium (Cd), while Kitaka et al. [22] reported an increase in nutrient levels such as Phosphorous, thus, affecting the quality of the lake. This has consequently stimulated investigations on the health status of the biota including fish and whether or not they get affected by the changes in the quality of the environment that they live in. This is typically done by determining the LWR and condition factor [5,20,36].

LWR is a vital aspect in fishery assessment that aids in the estimatation of weight from length needed in the computation of biomass and in fish harvest assessment [11]. For example, a study by Britton and Harper [5] on LWR of five species which were then found in Lake Naivasha, indicated that fish had a good growth ratio. Several fish species from Lake Naivasha have depicted differences in sex ratios [27,28,36,39]. Different fish species have different sexes dominating in the population. For example, studies on *E. paludinosus* by Mutia [27] and Mutia et al. [28] revealed female population to be dominating as opposed to fish species like for instance *O. leucostictus* and *O. niloticus* having males dominating their population ([39] and [36]) respectively.

E. paludinosus came into view in Lake Naivasha in the 1920s and 1982 [16]. Even though it is not common in the fish markets, it is used as a source of protein by the people who live around the lake [2]. Several studies have been conducted on different aspects of this fish species in Lake Naivasha. For example, on fish parasites [6], spawning seasons in the lake [28] as well as on the LWR [5] and sex ratio [27,28]. However, all these earlier studies were carried out more than a decade ago. A lot of changes have occurred in the lake (increased pollution, rise of heavy metal levels, fish species composition and changes in water levels as well as the ecology of the lake among others) which may have impacted on this fish species. The main focus of this study was to establish sub lethal effects through assessing the length–weight relationship, condition factor and sex ratio of *E. paludinosus* in Lake Naivasha.

Materials and methods

Study area

Sampling was done in the month of November 2017 in Lake Naivasha. The description of the study site has been vastly done by Gaudet and Melack [12], Kitaka et al. [22], Odongo et al. [32] among many others. Lake Naivasha was declared a Ramsar site in 1995 in recognition of its global importance to wildlife [24] particularly with more than 400 species of water birds. This study was conducted at the mouth of River Malewa (0.714622°S 36.362709°E) as indicated in Fig. 1.

Sample collection and analysis

Fish samples were collected using seine nets of mesh size 1.2 mm from the mouth of River Malewa. The fish were caught then placed into the aerated water tanks. Thereafter, they were transported alive in the tanks to a research laboratory at the Biological Sciences Department, Egerton University. In the laboratory, the fish were killed humanely by cervical dislocation. This was then followed by measurements of the total lengths (TL) in cm using a measuring board. The weight of the fish was then measured in g using an electronic weighing scale, (ED 4202S, Sartorius AG, Germany). The fish were then dissected following the standard procedures according to Florio et al. [9] and the gonads examined. A guideline by Keys [21] was used to calculate the length–weight relationship as follows;

$$W = aTL^b$$

where

W = the weight of fish in grams
TL = the total length in centimeters
a = the intercept
b = the slope of the regression line.

A linear transformation was made using natural logarithm at the observed lengths and weights according to Keys [21] as follows:

$$\text{Log } W = b \text{ Log } L + \text{Log } a$$

The condition factor (K) was determined using the formula by Le Cren [23] as follows:

$$K = 100\, W/\, L^b$$

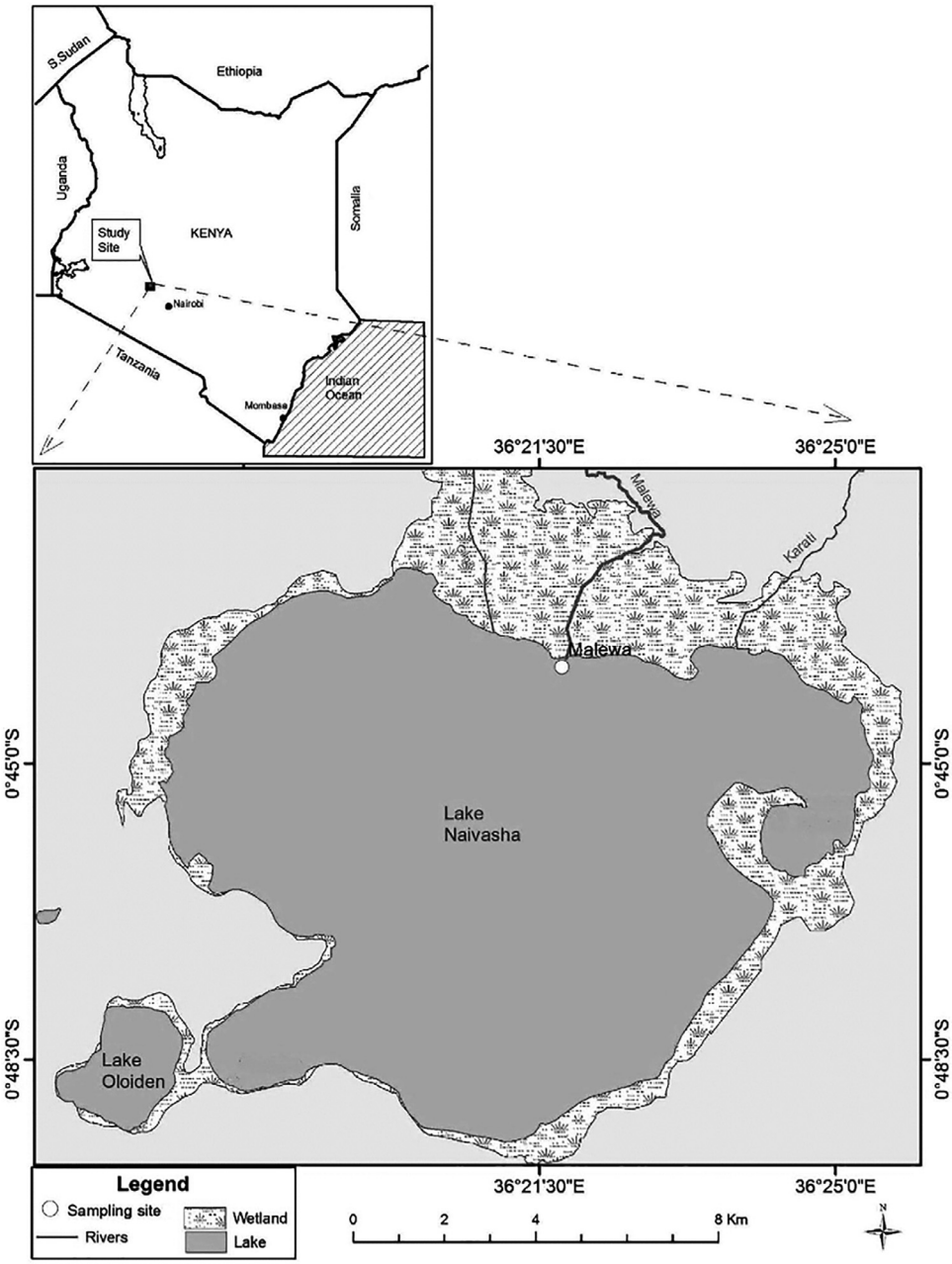

Fig. 1. A map of Lake Naivasha showing the sampling site.

Statistical tests

A student's *t*-test was used to test the significant differences in the weight and length of both sexes from the data obtained from this study, after log transformation. The sex ratio, expressed as male: female was calculated by dividing the number of females by that of the males and null hypothesis tested with the use of chi-square test.

Results

Length–weight relationships

A total of 1279 fish were measured. Total length ranged from 6 to 11.1 cm and weight from 1.86 to 13.84 g. The mean length was 8.4840 with a standard deviation of 1.0240 while that of the weight was 6.2011 with a standard deviation of

Table 1
Length–weight relationship of *E. paludinosus*.

Sex	*n*	Length range (cm)	*a*	*b*	r^2	*p*
Both sexes	1279	6 - 11.1	0.1073	3.23 P	0.923	<0.05
Male	429	6 - 9.7	0.1500	2.83 N	0.746	<0.05
Female	850	6.5 - 11.1	0.1522	2.87 N	0.816	<0.05

n, sample size; P, positive allometry; N, negative allometry: r^2, coefficient of determination: p, probability.

2.3357. The length–weight relationships were determined separately for all individuals and categorized by sex (males and females) and are presented in both Table 1 and Figs. 2a–c.

Condition factor

The mean condition factor and the standard errors were 0.5897 ± 0.002, 0.5981 ± 0.002 and 0.5729 ± 0.003 for both sexes combined, the females and males respectively. This is illustrated in Fig. 3.

Sex ratio

Out of the total number of the fish samples, female fish dominated (850) while the males were 429. The sex ratio was calculated by dividing the number of female fish by that of the males. The sex ratio was greater than 1 which was 1: 1.981 (males: females). The Chi-square test showed a significant difference between the sexes ($P < 0.05$).

Discussion

Length–weight relationship

The length–weight relationships were significant ($P < 0.05$), with values of $r^2 > 0.70$. The expression was log-transformed as suggested by Keys [21]. The equation of both sexes combined was $W = 0.1073\ L^{3.23}$, indicating a positive allometric growth. The equation for males was $W = 0.1500\ L^{2.83}$ and females, $W = 0.1522\ L^{2.87}$, both indicating a negative allometric growth. This result signified a positive allometric growth and is different from that of Britton and Harper [5] who reported that when both sexes of *E. paludinosus* were combined, a and b values were 0.0173 and 2.904 indicating an isometric growth. This could be due to the temporal variation because it is more than a decade ago and some ecological aspects of the lake such as water quality changes, pollution levels as well as the ecology of the lake as a whole were different. In a related study by Giannetto et al. [13] on *Barbus pergamonensis*, from the Aegean region in Turkey recorded a similar observation to that of this study reporting a positive allometric growth of 3.129. Similar results were recorded by Marčeta [25] on *B. balcanicus* from Slovenia whereby a positive allometric growth with a b value of 3.0493 was obtained. However, Bibak et al. [4] and Dan-kishiya [8] recorded a negative allometric growth for the *B. grypus* (from Dalaki River in Iran) and *B. occidentalis* (from Lower Usuma Reservoir in Nigeria) with b values of 2.93 and 2.11 respectively.

According to Pervin and Mortuza [37], high b values show a general state of great demand of food as well as the gonad content of the fish. Thus, a remarkable increase in weight is reached upon the consumption of the foods which aid them in growth and energy gain [19]. However, b values could vary due to factors like growth period, sex, gonad development and the contents of the stomach [37]. Moreover, b values depend considerably on conditions such as environmental settings, biological, geographical, seasonality as well as other factors including sampling [10].

Condition factor

The condition factor (K) of both males and females *E. paludinosus* in this study was less than 1 thus indicating that this fish species is in a very poor condition. According to Barnham and Baxter [3], a K value that is approximately 1.40 indicates a good and well-proportioned fish while that of 1.20 indicates a fish of moderate condition. A K value of 1.00 on the other hand shows that the condition of the fish is poor. There was a significant difference between the K factor of the males and females ($P < 0.05$). Mean condition factor (K) recorded in this study for female fish species was slightly higher ($K = 0.5981$) than that for the males (0.5729) indicating that females were in a slightly better condition than the males fish species examined. The poor condition of *E. paludinosus* as indicated by the very low K values could be as a result of the sub lethal effects of pollution in the lake as reported in the studies by Ochieng et al. [31], Mutia et al. [29], Otachi et al. [35], among many others. Heavy metals such as Lead (Pb), Copper (Cu) and Cadmium (Cd) were found to be among the pollutants in Lake Naivasha with their source identified as the flower farms [29]. Other heavy metals reported in the lake are such as Cobalt (Co), Chromium (Cr), Stannum (Sn) and Zinc (Zn) [31]. Furthermore, Otachi et al. [35] reported levels of Cd, Pb, Cu, Zn, Stromium (Sr), Rubidium (Rb) and Molybdenum (Mo) from the sediment samples of Lake Naivasha. These pollutants have sparked changes in the lake through contamination thus affecting the biota, *E. paludinosus* included as shown by the

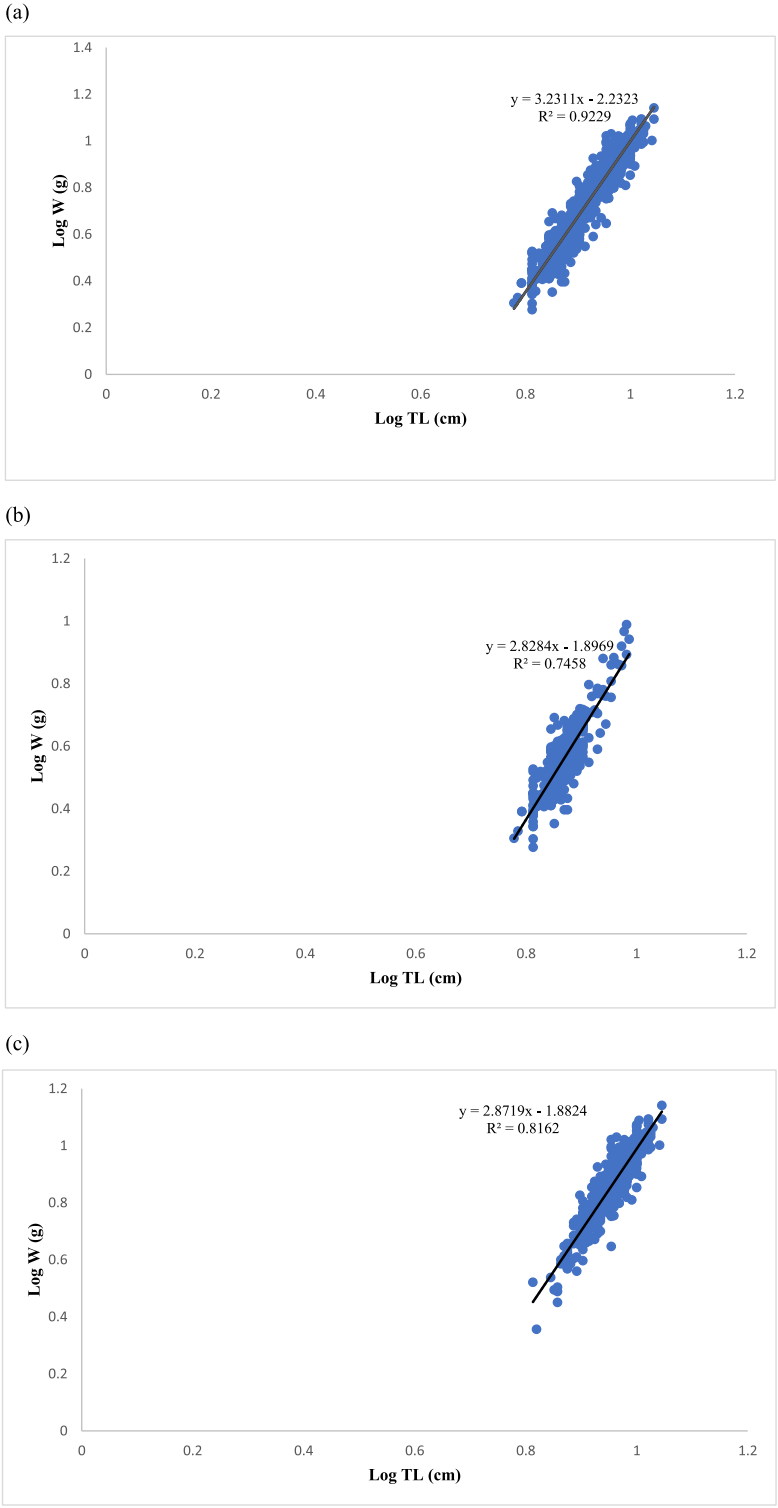

Fig. 2. (a). Length–weight relationship of both sexes of *E. paludinosus*. (b). Length–weight relationship of male *E. paludinosus*. (c). Length–weight relationship of female *E. paludinosus*.

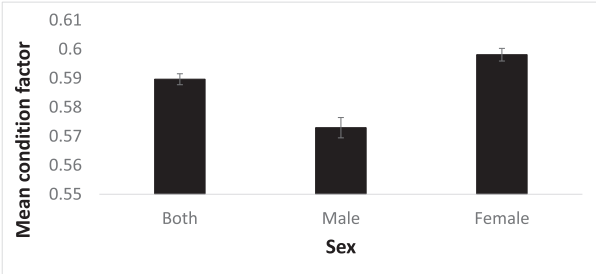

Fig. 3. Mean condition factors of combined sexes, male and female *E. paludinosus* in Lake Naivasha.

low K values in this study. Some of the toxic effects of heavy metals in aquatic organisms reported include bioaccumulation in various organs, tissue damage, disruption in growth and reproduction and induction and synthesis of metallothionein [7]. There is hardly any information on the condition factor of *E. paludinosus* from Lake Naivasha as the baseline study by Britton and Harper, [5] only provided data on the LWR of the fish.

Sex ratio

The sampled fish was dominated by female fish with a sex ratio of 1: 1.981. This finding was slightly different from that of Mutia et al. [28] in Lake Naivasha where the females were 877 and males 550 with a sex ratio of 1:1.6 although it agreed with that females were more than males. This therefore showed that there has not been any difference in the female dominance even though there is an eleven-year difference from the time the baseline study was conducted. The significant difference in sex ratio could be as a result of a number of factors. There could be behavioral variances between the sexes that might have made females more susceptible during fishing hence trapped in the active gear such as seine nets that were used to catch the fish in this study. Another possibility for the significant difference in sex ratio is the migratory patterns between the males and females that might differ depending on the seasons [26]. Other possible determining factors could be the difference in growth rate between the sexes whereby females attain larger body size than their male counterparts, as well food supply where females dominate when there is plenty of food [30]. It was also evident that the sampled *E. paludinosus* were migrating upstream for spawning at the time of sampling. This is because the morphologically ripe gonads were present in the fish all through the dissection procedure.

Conclusion

The length–weight relationships of samples indicated that the population of *E. paludinosus* studied had a good growth ratio. Both sexes combined produced a $b > 3$ which indicated a positive allometric growth while that of the males and females separated produced a b value of ($b < 3$) indicating a negative allometric growth. The population was not in good condition as the condition factor values (K) obtained for the fish population revealed. This is a clear indication of the unhealthy status of this species of fish population with a probability of depressed procreative potential. The sex ratio revealed that the female *E. paludinosus* were more than the males.

Declaration of Competing Interest

None.

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