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Original Research Article

Condition Factor, Length-Weight Relationship and Sexual Maturity Stages of *Labeobarbus tanensis* in River Kathita of the Upper Tana River Basin of MT. Kenya

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Abstract: Information on health of fish populations and sexual maturity is useful in formulating fisheries management regulations. There is little such information on fish species of upper Tana River basin of Mt. Kenya. Therefore, a study was conducted to estimate condition factor, length-weight relationship, sexual maturity and length at 50% maturity of *Labeobarbus tanensis* during March - August 2020. Fish were caught in River Kathita and in adjacent four dams on upper Tana River using electrofishing equipment and gillnets respectively. Specimen of *L. tanensis* were sorted from the catch and lengths measured to the nearest 0.1 cm TL using a measuring board and weights to the nearest gram using a weighing balance. Specimens were dissected to reveal gonads which were further dissected to evaluate the sexual maturity stages of eggs on a 1 to 6 scale (Witte & Vandensen, 1995). Estimated condition factor was greater than 1 indicating that the fish populations were healthy. Smallest mature male and female were 12.0 and 12.89 cm TL respectively. Length at 50% maturity for males and females were 13.9 and 14.9 cm TL respectively. Over 90% of mature fish were caught in Kathita River and few in dams. Length-weight relationship for both sexes are as follows: Females: Log W = 3.154 log TL - 2.104; R2 = 0.958. Males: log W = 3.184 log TL - 2.125; R2=0.960. Information obtained will be useful in formulating mesh-size regulations for sustainable exploitation of the fish.

Keywords: Condition factor, sexual maturity, L_{m50}, length-weight relationship, *Labeobarbus tanensis*, Total length, Standard length.

1.0 INTRODUCTION

Fisheries management and research uses biometric relationships for transformation of data collected in the field into applicable indices (Patiyal, Lal, Punia, Singh, & Mir, 2013). Length-weight relationship (LWR) of fishes are vital in fish biology and fisheries as they allow the estimate of the average weight of the fish of a given length group by establishing a mathematical relation between them (Mir *et al.*, 2012). The LWR can be used as a character for the differentiation of taxonomic units and the association alterations with the different developmental events in life such as metamorphosis, growth and onset of maturity just like any other morphometric characters (Patiyal *et al.*, 2013). In addition, LWR can also be used in setting yield equations for estimating the number of fish landed and comparing the population in space and time (Singh *et al.*, 2011). Fulton's condition factor (K) is extensively used in fisheries and fish biology studies. This factor is calculated from the association between the weight of a fish and its length, with the intention of describing the "condition" of that individual fish (Froese, 2006). Diverse values in K of a fish shows the state of sexual maturity, the degree of food sources obtainability, age and sex of some species (Patiyal *et al.*, 2013). These associations are also vital component of FishBase (Froese and Pauly, 2012). Besides this, the data on length and weight can also deliver vital clues on climate and environmental changes, and change in anthropogenic activities (Sani *et al.*, 2010).

Labeobarbus tanensis (Günther 1894) is one of the ray-finned fishes and belongs to the family cyprinidae (Froese & Pauly, 2021). This group of fishes

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is widely distributed worldwide. The family constitutes some farmed fishes such as *Cyprinus carpio* (Linnaeus, 1758) and *Labeo rohita* (Hamiliton, 1822) (Patiyal *et al*., 2013). Recent researches on a group of similar species such as *C. carpio* in Europe and *L. rohita* in india as *L. tanesnsis* has been conducted (Patiyal et al., 2013). Mol. Jaiswar et al., (2019) carried out a study on length-weight relationship and condition factor of five species of the genus Labeo (Family: Cyprinidae) namely *L. rohita* (Hamiliton, 1822), *L. Calbasu* (Hamiliton, 1822), *L. bata* (Hamiliton, 1822), *L. dyocheilus* (McClelland, 1839) and *L. porcellus* (H *calbasu, bata, rohita, dyocheilus and porcellus*) in Cauvery River, Peninsular in India. The parameter b of length-weight relationship ranged from 3.286 (*L. dyocheilus*) to 2.615 (*L. bata*). All the labeo species had a condition factor of greater than 1 revealing that they were in healthy conditions (Migiro *et al*., 2014).

In Africa, it's native to Tanzania, Kenya and Burundi and endemic to Ethiopia (Froese & Pauly, 2021). In Kenya, the fish is native to R. Tana, Nero-Narok basin, Athi and Ewaso Nyiro River (Froese & Pauly, 2021). Studies by Sunda, 2018 on a similar species, *Labeobarbus altianalis* inhabiting the Kuja River in L. Victoria basin revealed a parameter b of length-weight relationship of 3.01. In another study of *Labeobarbus intermedius* in L. Baringo revealed parameter b of length-weight relationship of 3.049 whereas De Vos, 1990 estimated b of 3.02 of *Labeo gregorii* in R. Tana and 3.15 of *L. altianalis* of L. Victoria.

L. tanensis is among 8 species of the same genera which closely resemble one another (Mann, 1969). It is considered to be synonymous to *Labeobarbus oxhyrhyncus* (Günther 1894), belonging to the group of barbus family constituting of about 16 species whose taxonomy is incomplete (Mann, 1969). Out of these, eight are members of the *Barbus tanensis* complex, large bodied and of commercial value (Mann, 1969). These 8 species are taxonomically very close and are difficult to identify from one another (Mann, 1969). They are mainly distributed in upper Tana basin but are absent from the lower reaches (Mann, 1969).

L. tanensis is the main fish species caught in the upper Tana basin by fishermen using hand lines, traps, seine nets and gillnets (Kinyua, (pers.com). It supports the subsistence of the communities by providing high quality protein thus contributing to the food security (Mann, 1969). For this reason, it is locally known as 'ngoko' meaning chicken (Kinyua, (pers.com). Together with other 8 species, their biology is poorly documented (Campbell *et al*., 1980). It's fishery in the past was poorly developed because the communities in the upper Tana basin did not know the nutritional and economic value of the fish resources (Mann, 1969). *Barbus tanensis* is omnivorous and potamodromous as it migrates upstream to reproduce in the fast flowing tributaries during the rainy season (Mann, 1969). All earlier studies on the fishes of River Tana basin were conducted by researchers from the East African freshwater fisheries research organization from early 1900 up to early 1970s (Jumbe *et al*., 1997; Dadzie *et al*., 1979; Dadziel & Odero, 1989; Boulenger, 1909 and Dadzie, 1985). These studies mainly emphasized on the taxonomy, distribution and general few feeding ecology of fish (Campbell *et al*., 1980). There were few attempts to assess the fishery potential of the river especially at the lower reaches (Mann 1967 and 1969; Van Someren 1952; (Campbell *et al*., 1980) and Copley 1941 and 1958).

Due to poor communication network, existence of crocodiles, hippos and tribal feuds occasioned by scarcity of natural resources like water and grasslands, it has been difficult to conduct in-depth studies on fish biology and fishery potential of Tana River (Campbell *et al*., 1980). Few studies have been conducted on population dynamics, reproduction, ecological physiology and systematics (Campbell *et al*., 1980).

The ecological and commercial significance of the commercial fish species of R. Kathita and the associated dams of R. Tana can't be underrated. The age and growth of young-of-the year of some exploited fish population are essential input for rational management decisions for both capture fisheries and aquaculture (Migiro *et al*., 2014). However, information on LWR, condition factor and sex maturity stages for most exploited fish species are scarce. This study therefore was focused on the condition factor, length-weight relationships and sexual maturity stages of *L. tanensis* in upper Tana river basin.

2.0 METHODOLOGY

2.1 Study area

The study area constituted of the upper Tana river basin of Mt. Kenya region, an area of high altitude ranging from 472 (Kathita-Tana rivers confluence – S7) to 1982 meters above sea level respectively at the Mung'enya reservoir (S2). The area experiences a semi-temperate climate with day time temperatures ranging from 29°C - 40°C (Recha *et al*., 2017). This section of Mt Kenya region has many sources of tributaries such as Kathita River which eventually converge to form River Tana. The upper part of the study area containing three sampling stations, S1 and S2 at Mung'enya run and reservoir respectively and S3 at Kaguu bridge station (just below Meru town) on the River Kathita, is located in the cold region of Mt Kenya where temperatures are mostly below 20°C. Four other stations lie on the lower Kathita River at Matangige village (S4), Kathita-Gakuuru rivers confluence (S5), Mwerera village (S6) and at Kathita-Tana confluence (S7). A further four sampling stations namely: Masinga (S8), Kamburu (S9), Kindaruma (S10) and Kiambere (S11) like the former four are situated in a warmer region in an area containing a series of dams on the upper Tana River. The region receives an annual bimodal rainfall pattern from March to May, and from October to December ranging from 500-800mm (Recha *et al*., 2017).

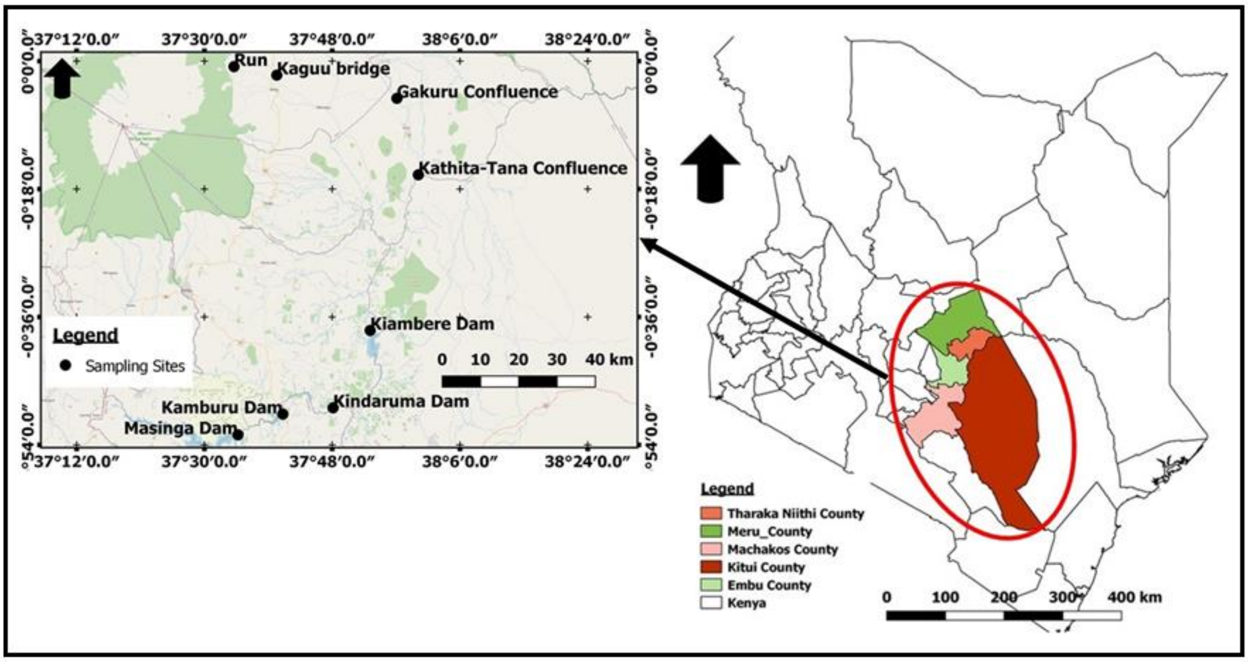

Figure 1: Showing sites sampled in Mt. Kenya region ecosystems

Both natural and planted vegetation is present. It consists of trees like: Mulberry fig (Ficus sycomorus L.), Tamarind (*Tamaridus indica* L.1753), Mexican-white cedar *(Cupressus lusitanica* Mill.), Patula pine *(Pinus patula* Schiede ex schltdl. & Cham), African baobab (*Adansonia digitate* L.), Natal fig (*Ficus natalensis* Hochst), Neem tree (*Azadirachta indica* A. Juss., 1830) and Mango tree *(Mangifera indica* L.) (Quattrocchi, 2012), grass and shrubs. Currently, there is continuous reduction of forest cover due to huge demand of high quality timber from the region. Farming, livestock keeping, fishing and apiculture are the main economic activities in the area. Crops grown include: Tea, vegetables, coffee, pyrethrum, bananas, maize, peas, cowpeas, millet, sorghum, groundnuts and green grams.

2.2 Research design

The study mainly involved field work whereby sampling was conducted once monthly from March to August 2020 to collect data for use in estimating condition factor, length weight-relationship and staging sexual maturity of *L. tanensis*. There were eleven sampling sites, of which seven were of River Kathita and four in the dams with each dam having one sampling station.

The positions of sampling sites and their altitude were recorded using Geographical positioning system (Garmin Ltd) and are presented in Table 1.

Table 1: GPS positions of sampling sites in the upper Tana River basin

No.	Station	Altitude m (a.s.l)	Longitudes	Latitudes
S1.	Mung'enya – Run	1941	37.56936	0.01297
S2.	Mung'enya – Pool	1982	37.56947	0.01294
S3.	Kaguu bridge	1448	37.66994	0.03290
S4	Matangige village	701	37.95131	0.08782
S5.	K-G confluence	701	37.95209	0.08734
S6.	Mwerera village	484	38.00243	0.26590
S7.	K-T confluence	472	38.00236	0.26668
S8.	Kamburu dam	1016	37.6679	0.8291
S9.	Kiambere dam	706	37.4846	0.4838
S10.	Kindaruma dam	789	37.4846	0.4838
S11.	Masinga dam	1062	37.3540	0.5321

The most upstream sampling point was at Mung'enya reservoir on River Kathita tributary while the rest of sampling sites were along the river profile with the last one situated in Kiambere dam on the River Tana downstream.

2.3 Data collection and analysis procedures

Fishing was conducted once every month at each sampling site using electrofishing equipment (Samus 1000 and a battery of 12 volts producing a current of 75A) for a period of one hour. Data on fish catch rates per hour, total body lengths and weights and sexual maturity stages were recorded. The lengths and weights were measured using a measuring board to the nearest 0.1 cm TL and to 0.01 g using an electronic top pan weighing balance, Asca, Cm-12.

2.4 Condition factor

The condition factor expresses the health or well-being (Mir *et al*., 2012) of fish, based on the assumption that heavier fish of a given length are in better condition. The coefficient of condition, K was calculated using Fulton (1904):

$K = (100 \times W)/L^3$

Where W is body weight (W) in grams and L is the total body length (TL) in cm. All the statistical analysis was done using Excel 2016.

2.5 Length-Weight relationship

The relationship between length and weight of fish was analyzed by measuring length and weight of fish specimens collected from study area. The statistical relationship between these parameters of fishes were established by using the parabolic equation by Froese (2006).

$W = aL^b$

Where, W = weight of fish in grams, L =length of fish in mm, a = constant and b = an exponential expressing relationship between length-weight.

The relationship ($W = a\ L^b$) when converted into the logarithmic form gives a straight line relationship graphically:

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

Where b represents the slope of the line, Log a is a constant.

2.6 Sexual maturity stages

Knowing the sexual maturity status of a fish population helps to understand the size at which a fish can be recruited into a fishery. This helps in formulation of appropriate fisheries regulation.

In the field, the fish caught were categorized into males and females and dissected using a dissection kit to reveal the gonads. The gonads were further dissected to enhance the identification of sexual maturity stage of each fish. Identification of stages was conducted using a six-point key described in Witte and Vandensen 1995. Stages 1 to 3 indicated immature fish while stage 4 indicated mature, stage 5 - ripe and running, and stage 6 - spent gonads respectively. The size of smallest mature fish was recorded.

3.0 RESULTS

3.1 Condition Factor

A total of 153 fish constituting of 89 males and 64 females were analyzed for condition factor. The size range for males ranged from 10.5 to 33.0 cm TL with a mean of 16.24 ± 0.41 cm TL. Their condition factor ranged from 0.93 to 1.82 with a mean of 1.2 ± 0.02. The size range for females ranged from 12.0 to 32.0 cm TL with a mean of 18.30 ± 0.64 cm TL. Their condition factor ranged from 0.92 to 1.9 with a mean of 1.2 ± 0.02.

3.2 Length-weight relationship

The linear regression equations are given in Fig 2. A total of 148 specimens of *L. tanensis* constituting of 83 males and 65 females were analyzed for length-weight relationship. Their sex ratio i.e. females: males was 1:1.4.

The size range of female analyzed was 12.0 - 32.0 cm TL, with a mean length of 18.43 ± 0.66 cm TL while the size range of males analyzed was 10.5 - 27.5 cm TL with a mean length of 16.5 ± 0.44 cm TL.

The weight-length relationship for males and females were estimated according to the following models Froese (2006).

Females: Log W = 3.154 log TL - 2.104; R2 = 0.958.

Males: log W = 3.184 log TL - 2.125; R2=0.960.

The regression analysis of body weights on body lengths for both female and male fish are given in Figure 2 and 3.

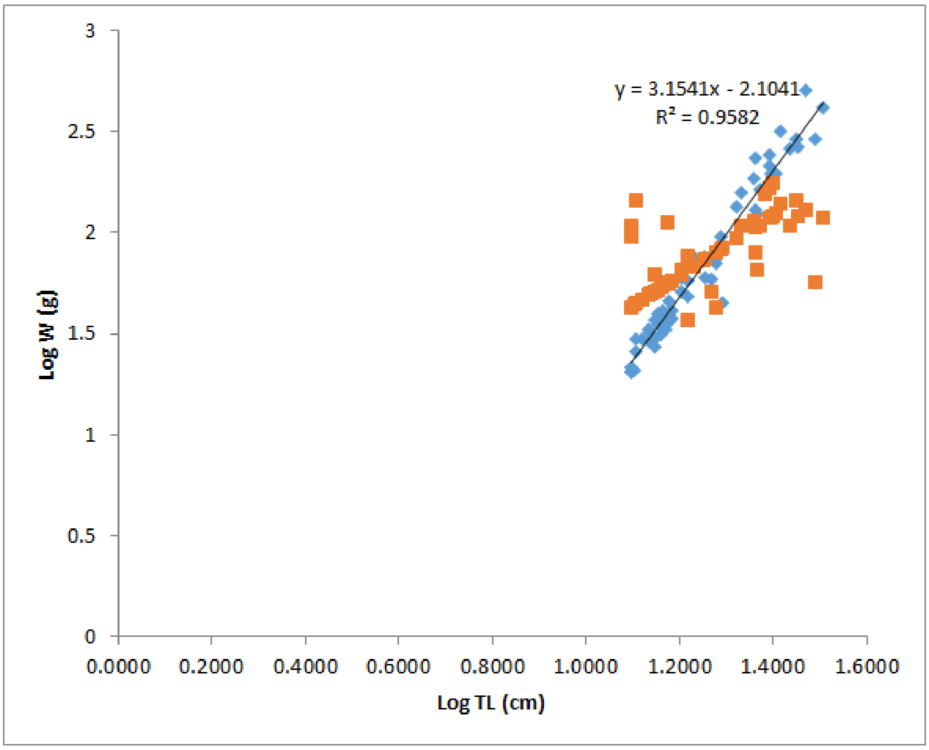

Figure 2: Length weight relationship of female *L. tanensis* of the upper Tana River basin, Mt. Kenya region

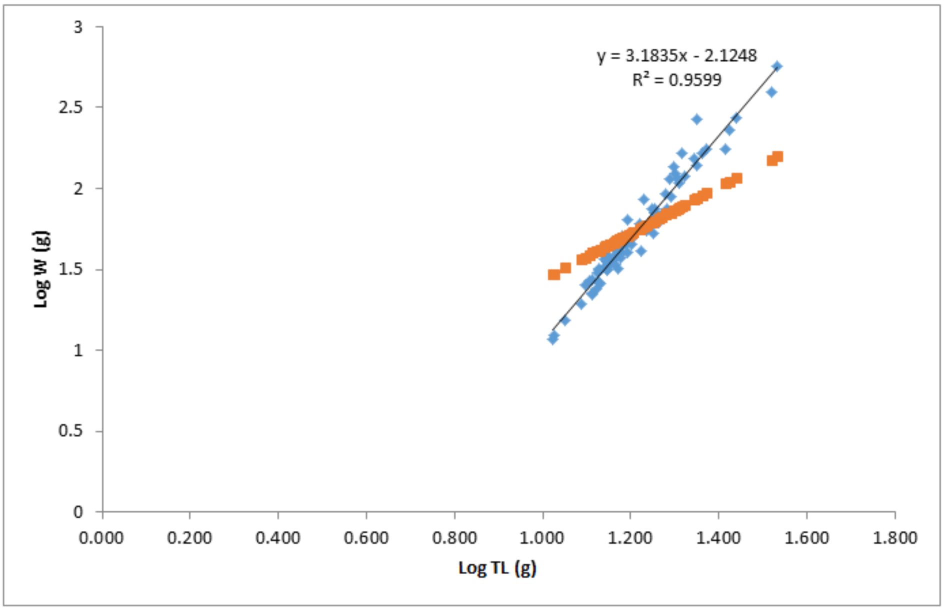

Figure 3: Length-weight relationship of female *L. tanensis* of the upper Tana River basin, Mt. Kenya region

The total length coefficient in both cases was approximately 3, that is, 3.154 for females and 3.184 for males showing that the fish has an isometric mode of growth, that is, during growth, weight and length of fish grow proportionately.

3.3 Sexual maturity stages

Analysis of the distribution of the sexual maturity stages showed that most mature fish were found in the rivers and the tributaries – Kathita River while few were found in dams (Table 2). The sampling site with most mature fish were S7, S5 and S4. All the three stations were distributed along the river Kathita up to station 7 which is at its confluence with the main Tana River. The majority of the fish in column 1 were immature and could not be sexed nor identified to species level because of the high similarity to other *Labeo spp.* in the Tana river basin.

Table 2: Distribution of mature and immature *L. tanensis* among sampling sites in the upper Tana basin (S1-S11)

Sampling site	Total No. of fish	No. of immature males	No. of immature females	No. of mature males.	No. of mature females	Total mature fish.
S1	0	0	0	0	0	0
S2	0	0	0	0	0	0
S3	0	0	0	0	0	0
S4	36	15	12	8	1	9
S5	69	25	25	16	3	19
S6	24	14	5	2	3	5
S7	35	5	10	14	6	20
S8	0	0	0	0	0	0
S9	6	0	2	3	1	4
S10	4	2	2	0	0	0
S11	1	0	1	0	0	0

A total of 177 fish comprising of 73 females and 104 males were analyzed for sexual maturity stages. The male size range was 10.5 - 27.5 cm TL with a mean size of 16.615 ± 0.41 cm TL.

The distribution of sexual maturity stages of 2 - 6 for both males and females are presented in the Tables 3 and 4.

Table 3: Distribution of sexual maturity stages of male *L. tanensis*

Maturity Stage	Range	Mean	Frequency	% Frequency	% Cumulative Frequency
2	12.0-13.0	12.89	15	30%	30%
3	13.0-15.6.0	14.78	5	10%	40%
4	11.0-15.0	13.83	7	14%	54%
5	15.0-23.0	17.16	11	22%	76%
6	14.5-34.0	20	12	24%	100%

The mean length of the smallest male mature fish was 12.89 cm while the length at 50% maturity for the male was 13.8 cm (Figure 4).

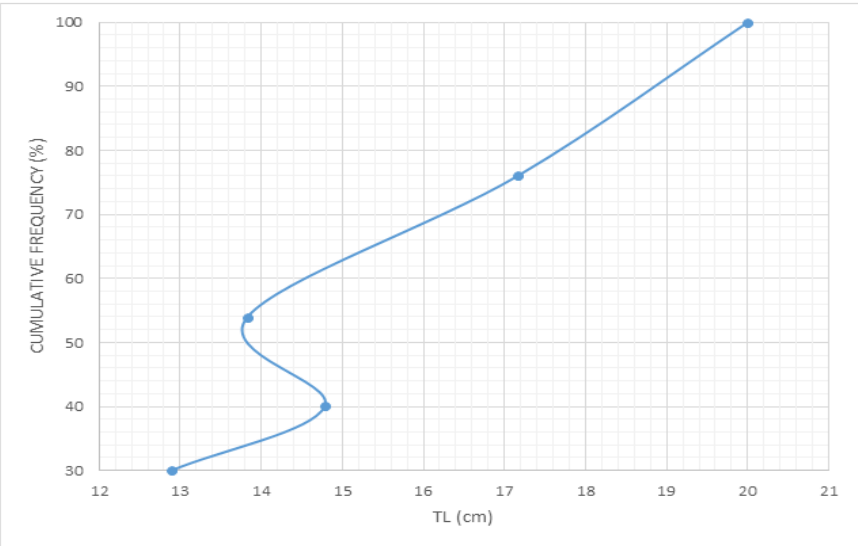

Figure 4: Length at 50% maturity (L_{m50}) of *L. tanensis* in upper Tana basin, Mt. Kenya region

The female size range analyzed for sexual maturity stages was 12.0 - 32.0 cm TL with a mean of 18.427 ± 0.65 cm TL. The size of the smallest mature female was 12.0 cm TL (Table 3).

Table 4: Distribution of sexual maturity stages of female *L. tanensis*

Maturity Stage	Range	Mean	Frequency	% Frequency	% Cumulative Frequency
2	10-15.0	13.6	9	39.1%	39.1%
3	15-20.0	16.5	5	21.7%	60.8%
4	20-25.0	22.58	4	17.4%	78.2%
5	25-27.0	21.2	3	13.0%	91.2%
6	27-31.0	27.8	2	8.7%	100%

The length at 50% maturity was 14.9 cm TL (Figure 5). The analysis showed that females mature at a larger size than male meaning that when females mature, they find males which are ready to fertilize their eggs. This ensures that all eggs are fertilized.

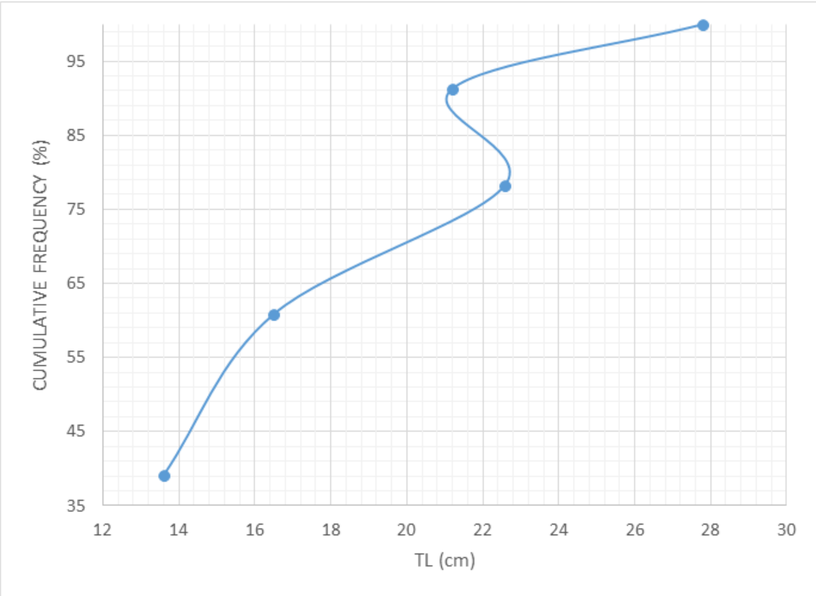

Figure 5: Length at 50% maturity (L_{m50}) of *L. tanensis* in upper Tana basin, Mt. Kenya region

4.0 DISCUSSION

The condition factor (K) of *L. tanensis* was greater than 1.0 suggesting that its population in upper Tana River basin are healthy. High condition factor values indicate favorable environmental conditions while low values indicate less favorable environmental conditions (Moradinasab *et al*., 2012). Other studies have found K values greater than 1 in freshwater species (Migiro *et al*., 2014).

The healthy conditions of River Kathita and upper Tana basin is probably due to less perturbation by anthropogenic activities. This is evidenced by the good water quality in the rivers and streams of the study area hence the good environment quality supports the wellbeing of fish in the study area.

Table 5 shows a comparison of the condition factor and length-weight relationship of Labeobarbus and Labeo fish species from different geographical areas. It shows the condition factor of *L. tanensis* falls within the range 1.001 – 1.4 of estimated condition factors of the fishes indicated. It can also be noted that the species compared in the table achieve different maximum lengths (range) in their life time. Therefore, the condition factor does not seem to be affected by the maximum size the fish attains. Condition factors of other species indicated could not be found in the literature.

Table 5: Comparison of the condition factor and length-weight relationship of fish from different geographical areas

Geographical area (sampling location)	Name of species	Condition factor	Length-Weight relationships. a b R^2			Ref
L. Baringo –Kenya	*Labeobarbus intermedius*	1.4	0.0147	3.049	0.960	Lévêque, C. and J. Daget, 1984.
R. Tana- Kenya	*Labeobarbus tanensis*	-	0.000	-	-	
L. Victoria	*Labeobarbus altianalis*	-	0.01000	3.159	0.97	De Vos L, 1990
Cauvery River, India	*L. calbasu*	1.019±0.023	0.0086	3.069	0.97	Mol.Jaiswa *et al.*, 2019
Cauvery River, India	*L. bata*	1.001±0.011	0.0254	2.615	0.87	Mol.Jaiswa *et al.*, 2019
Cauvery River, India	*L. rohita*	1.013±0.021	0.0164	2.908	0.95	Mol.Jaiswa *et al.*, 2019
Cauvery River, India	*L. dyocheilus*	1.005±0.023	0.0039	3.286	0.99	Mol.Jaiswa *et al.*, 2019
Cauvery River, India	*L. porcellus*	1.003	0.0379	2.628	0.70	Mol.Jaiswa *et al.*, 2019
Tana River- Kenya	*L. gregorii*	-	0.00977	3.02	-	De Vos L, 1990
L. Baringo- Kenya	*L. cylindricus*	-	0.0105	3.010	0.960	Reid, 1985
L. Turkana-Kenya	*L. horie*	-	0.00692	3.07	-	Lévêque, C. and J. Daget, 1984.
L. Vitoria-Tanzania	*L. Victorianus*	-	0.00570	3.340	-	Reid, 1985

The length-weight relationship is a vital aspect for the evaluation of fish biology (Akintola *et al*., 2010). The growth constant (b value) of 3 illustrates an isometric growth dimension of the fish (Yongo *et al*., 2016). The b value (3.15 and 3.18) estimated in Fig 2 and 3 respectively demonstrates an isometric growth dimension with no significant difference ($p>0.05$) from the value of 3. The coefficient of determination (r^2 = 0.96) indicated a strong positive correlation ($p < 0.05$) between weight and length of the *L. tanensis* in the Kathita River and the associated dams of R. Tana. Similarly, the b value (slope of the regression) of the length-weight relationship depicted in table 5 does not seem to vary much. It ranges from 2.615 to 3.340 and that of *L. tanensis* falls well within this range. Difference in b values can be probably due to the combination of one or more factors: Number of specimens examined, area / seasonal effect, habitat, degree of stomach fullness, gonadal maturity, sex, health and general fish condition and preservation technique (Migiro *et al*., 2014).

This study further showed that mature *L. tanensis* preferred the riverine environment to the dams of the Tana River. The fact that most of them were found on the confluence of the Tana and Kathita Rivers and also within the latter river meant that the fish were on their upstream migration to their preferred breeding sites in the tributaries of the upper Tana basin (Mann, 1969). This is supported by the fact that only four mature fish specimen (7.02%) were found in dams compared to 92.98 % in the riverine habitats.

The size range of *L. tanensis* caught fall slightly short of the maximum size 40.0 cm TL the species attain in its life time (Froese & Pauly 2021). This shows that there isn’t much fishing pressure on the species. The length at 50% maturity estimated in this study will go a long way in assisting the formulation of management regulation that can prevent the overfishing of *L. tanensis* and related species in the upper Tana River basin. Therefore, only nets that can capture *L. tanensis* of above 15 cm can be allowed for fishing in the upper Tana basin.

The observation that females mature at a larger size than males could be an adaptation that sees to it that by the time females mature, they find that males are already mature to fertilize their eggs. This ensures successful fertilization of all eggs laid by fish and prevention of egg mortality.

5.0 CONCLUSION AND RECOMMENDATIONS

The wellbeing of *L. tanensis* populations in the upper Tana River is good, their condition factor being greater than 1. Based on the maximum sizes of the fish caught of 33cm TL and the maximum lengths, the species attains in its lifetime of 40.0 cm TL, the species appears to be lightly fished. Its stocks can therefore be well managed now that the sizes of the smallest fish and the size at 50% maturity are known. The fish is the main one being exploited and the most abundant in the upper Tana basin.

There is need to conduct more research on other biological aspects such as eggs and larval survival in its breeding and nursery grounds and its stock parameters to assist in formulating mesh size regulations that can bring about sustainable exploitations of the species.

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