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Growth, mortality and exploitation rate of Barbus altianalis of River Kuja, Lake Victoria Basin, Kenya.

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ABSTRACT

Barbus altianalis is a potamodromous fish that is important for both food and sports fishing. In Kenya, *B. altianalis* is restricted to the Lake Victoria and its drainage basin. River Kuja is one of the major tributaries draining into Lake Victoria, and limited research has been carried out to pertain the *B. altianalis* species. There is a history of the decline in *B. altianalis* abundance and distribution in the Lake Victoria basin. This fish, formerly widely distributed in the Lake and the rivers draining into it, is nowadays mainly confined to the rivers. The analysis was carried out using FiSAT software to assess the condition of the *B. altianalis* populations such as growth, mortality and exploitation rate. Fish samples were collected from October 2016 to July 2017 using electrofishing equipment from the Kuja River. Length and weight of individual fish were measured, and the total numbers were counted at four different sampling points along the river. Length-frequency data were used to estimate the growth parameters K, L_∞ and Z/K using the Powel Wetheral method in the FiSAT software. The asymptotic length, (L_∞) and the ratio of the total mortality rate (Z) to the growth constant (K), were estimated to be 54.05 cm TL and 1.717 respectively. The curvature parameter K was estimated as 1.47 yr^{-1}, Z was 2.52 yr^{-1},and the growth performance index was found to be 3.63. The exploitation, natural and fishing mortalities rates were estimated to be 0.32, 1.71 yr^{-1} and 0.81 yr^{-1} respectively. By assessing the asymptotic length calculated, mortalities estimated and exploitation rate found, it is evident that River Kuja has *B. altianalis* populations. Out of 1239 individuals, 78.05 % were sexually immature, this, therefore, indicates that sustainable management measures be put in place to conserve the young *B. altianalis* populations.

INTRODUCTION

Barbus altianalis (Boulenger 1900) is a ray-finned fish from the Cyprinidae family and an important fish for both food and sports fishing (Chemoiwa et al. 2017). It inhabits inshore waters, including fast-flowing waters and feeds on algae, insect and mollusk (Ombogo 2012). It is a stomachless riverine fish with a maximum recorded total length of 90 cm (Ondhoro et al. 2016). In Kenya, *B. altianalis* is restricted to the Lake Victoria and its drainage basin. Lake Victoria is one of African's most important sources of inland fishery production and has nine major affluent river basins (River Sio, Nzoia, Yala, Nyando, Sondu-Miriu, Awach, Kuja, Mara, and Kagera). *B. altianalis* is a potamodromous fish that migrates upstream to spawn (Ntakimazi 2006), and its population has drastically declined in the Lake fishery (Ondhoro et al. 2016). Its common name in dholuo is Fwani (Obiero et al. 2012).

B. altianalis is listed in the International Union for Conservation of Nature (IUCN) red list of threatened species due to the decline of its native population (Ntakimazi 2006). The fish faces anthropogenic threats such as unsustainable farming methods, domestic and industrial pollution (Chemoiwa et al. 2013) which have led to eutrophication and loss of fish migratory routes (Geelhand et al. 2016).

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Lake Victoria supported multiple of species but is currently dominated by *R. argentea, Lates niloticus* and *Oreochromis niloticus* (Njiru et al. 2010). Lake Victoria had 14 *Barbus* species that were known to be in existence (Balirwa 1984) and out of the 14 species; *B. altianalis* grows to a larger size with the largest individual caught reported to be 90 cm total length. The management system continues to focus on the commercial species that dominate the lake catches while the high-value native species mainly *Barbus altianalis,* are getting extinct. This is designated by the low catch rates in the Lakes Victoria which have reduced from 0.5 to 0.2 kg/hr (Chande & Mhitu 2005; Ntakimazi 2006) in the 1970s and recorded to have further declined to 0.06 kg/hr in Lake Victoria by Chande and Mhitu (2005).

B. altianalis was one of the native fish species in the affluent rivers of Lake Victoria (Chemoiwa et al. 2013) in the 1950s and 1960s (Corbet 1961). However, overfishing has caused a reduction in the riverine species from annual catches of 2500 tonnes in the 1950s to 108 tonnes in the 1980s and 1990s (Ochumba and Manyala 1992). Recent studies by Ojwang et al. (2007) show that *B. altianalis* have stationary populations concentrated at the river mouths of the Lake Victoria Basin. Further studies by Chemoiwa et al. 2017 indicate that *B. altianalis* is not purely a potamodromous fish but also has permanent river-dwelling populations.

River systems are known to have rich and diverse fish communities (Obiero et al. 2012) which form an important resource for fisheries and aesthetic values. Unfortunately, fish in rivers are less studied compared to those in lakes and reservoirs (Welcomme and Merona). Chemoiwa et al. (2013) observed that cyprinids, particularly *Barbus* species are the most successful in colonizing the affluent rivers of Lake Victoria and are little studied (Ombogo 2012).

The introduction of more efficient gillnets and unregulated fisheries have negatively impacted on the riverine spawning fish stocks (Taabu 2004; Njiru et al. 2010). Intensive fishing using monofilament nylon gillnets has over time removed large sized fish from riverine stocks, only allowing smaller sized fish to access most of the upstream riverine habitats (Obiero et al. 2012).

The purpose of this study was to assess the stocks of *B. altianalis* in the River Kuja, to obtain information on the population dynamics such as; growth, mortality and exploitation rates which are essential inputs in models used for fisheries management and conservation.

MATERIALS AND METHODS

Study area

River Kuja (Fig. 1) extends from a longitude of 34^0 7'60''E to a latitude of 00^0 55'60''S. It has a length of 149 km with an area of 6900 km^2 and with an average discharge of 58 m^3/s. The region has an altitude ranging from 1100-2050m above sea level. It originates from the highlands of Kiabonyoru in Nyamira county passing through the heart of Gucha district running West through Migori town where it is joined by tributaries then into Lake Victoria Kenya.

It drains through an agricultural area that supports crops such as coffee, tea, maize sugarcane. The river is also used for the Lower Kuja Irrigation project. Four sampling points were selected along the river representing the upstream (Kegati station), midstream (Kanga station) and along the downstream (Gogo falls dam station and Wath Ong'er station)

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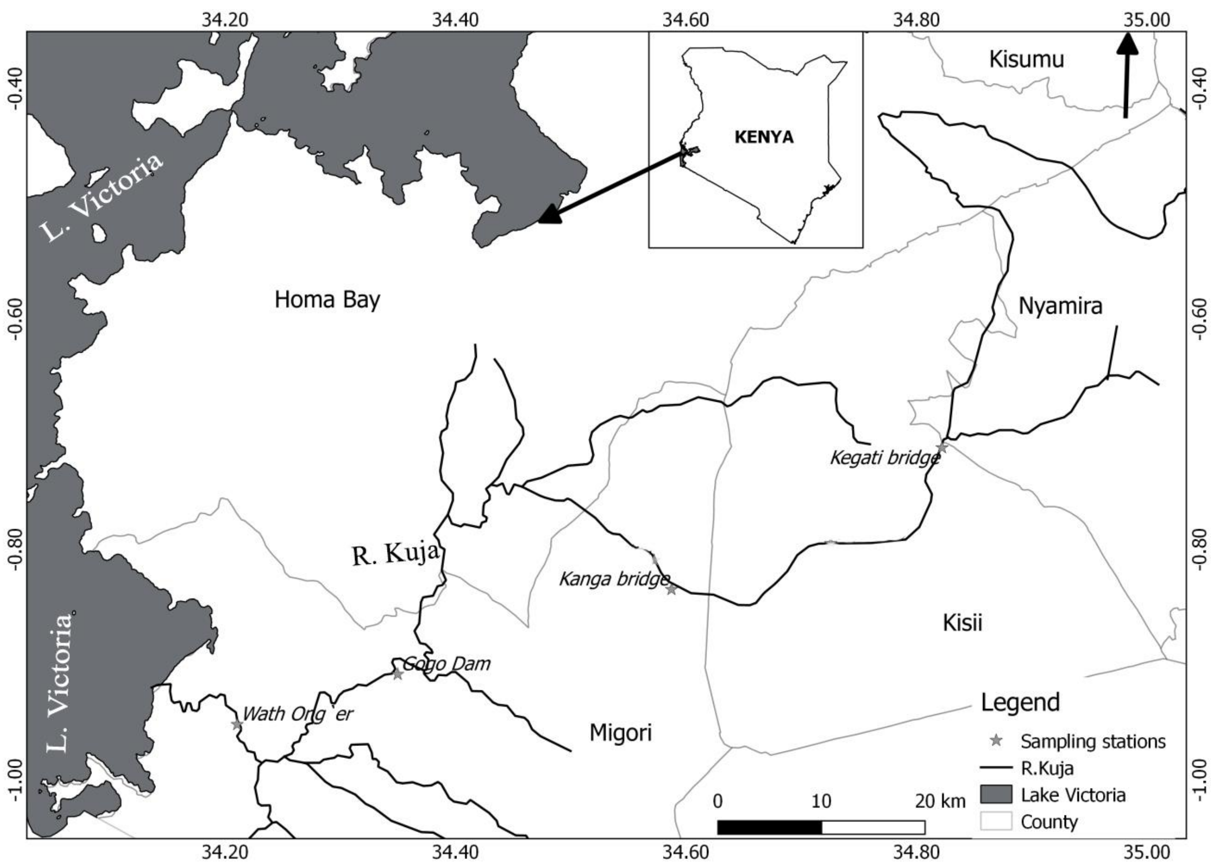

Figure 1: River Kuja with the sampling stations.

Collection of samples

Length-frequency data on *B. altianalis* were collected using electrofishing equipment once a month from four different sampling sites (Fig. 1) for a period of ten months (October 2016 to July 2017). All fish were measured to the nearest centimeter total length (TL) and focal length (FL) with a fish measuring board and weighed to the nearest 0.1 g using digital weighing scale (model salter XL, precision 0.01-10 kg). The fish were separated into males and females to obtain sex ratio. The fish were dissected for sexual maturity examination. The gonads were categorized according to the developmental stages for the species as described by Rutaisire and Booth 2005.

Growth, mortality and exploitation rate

Monthly length-frequency distributions of male and female *B. altianalis* were analyzed using the FAO- ICLARM Fish Stock Assessment Tools (FiSAT) computer program. The Powel Wetherall method in the FiSAT program was used to plot L_i against L_i - L'_i from which L_∞ and Z/K are estimated:

$$L\infty = \frac{a}{-b} \qquad \text{Wetherall et al. (1987)}$$

$$\frac{Z}{K} = \frac{1+b}{-b}$$

Total mortality Z was estimated using the following formulae as per Sparre et al. (1989) in the FiSAT program:

$$Z = K(L\infty - L)/(L - L')$$

where L_∞ and K are parameters of the von Bertalanffy Growth Function (VBGF).

L = Mean length

L_∞ = Asymptotic length/ mean length of the old fish

K = Growth coefficient/ curvature parameter/ how fast the fish approaches their asymptotic length.

The growth constant K was estimated using Ebert's 1973 method in the FiSAT program:

$$K = \ln L_\infty{}^D - L_2{}^D / L_\infty{}^D - L_1{}^D .1/(t_1 - t_2)^D \qquad \text{(Vakily et al. 1986)}$$

Where L_1 and L_2 are the mean lengths at times t_1 and t_2 when length-frequency samples were taken and D, the surface parameter.

Natural mortality (M) was estimated using the empirical relationship in the FiSAT program: (Pauly 1980)

$$Log_{10}M = -0.0066 - 0.279 Log_{10}L_\infty + 0.6543 Log_{10}K + 0.4634\, Log_{10}T$$

Where, M is the natural mortality, L_∞ the asymptotic length, K the growth coefficient of the VBGF and T the mean annual habitat water temperature in ^{0}C.

Once Z and M were obtained, fishing mortality (F) was estimated using the relationship:

$$F = Z - M$$

Where, Z is the total mortality and M, natural mortality.

The exploitation level (E) was estimated using the formulae $E = F/Z$ developed by Gulland (1971).

Growth performance index

The growth performance index was computed according to Moreau et al. 1986: $\emptyset' = Log10K + 2Log10L_\infty$

Length-weight relationship

The relationship between the length (L) and weight (W) of the fish was expressed by the following equation (Eagderi and Radkhah 2015):

Where, W - weight (g), L - total length (cm), a – coefficient related to body form, b – exponential expressing the relationship between length and weight.

$$W = aL^b$$

The linear transformation was performed using natural logarithm at the observed lengths and weights and the following $\text{Log}\, W = \text{Log}\, a + b\, \text{Log}\, L$ was applied (Ricker 1975). T-test was done to calculate the deviation of the allometric coefficient b from the theoretical value of isometric growth (b=3). All tests of significance were at α=0.05. For statistical differences, data were analyzed using computer software SPSS version 23.0.

RESULT

Length frequency

The data presented (Fig. 2) was used for the estimation of the growth parameters and the total mortality rate. The 1239 *B. altianalis* caught from R. Kuja demonstrated a size distribution that ranged from 3 to 53 cm TL with a mean length of 11.05±1.89 cm TL (Fig. 2). The general length-frequency distribution displayed a modal length class of 4.1 – 6.0 cm TL. Most of the fish in the distribution were immature and had not attained recruitment age.

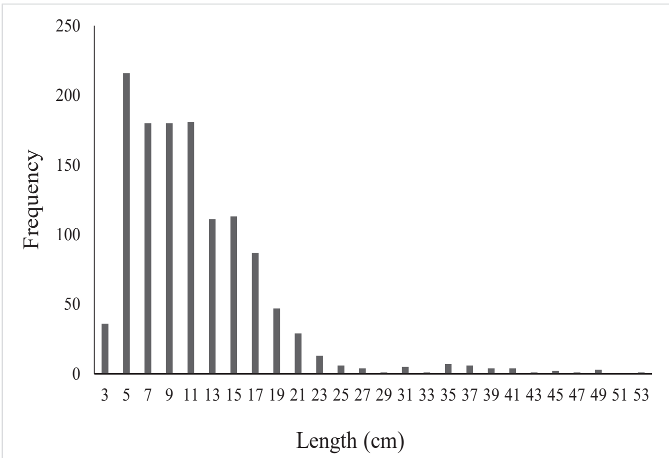

Figure 2: Length frequency distribution of *B. altianalis* from River Kuja.

Length weight relationship

Relationship between body weight and total length of *B. altianalis* was described by the equation: W = - 2.0597$TL^{3.01}$ (r^2 = 0.97) (Fig. 3). The power of the equation (b = 3.01) shows isometric growth exhibited by *B. altianalis* from R. Kuja with no significant difference (p>0.05) with the value of 3. The regression coefficient (r) of the equation (0.97) indicated a strong positive correlation (p < 0.05) between weight and length of the *B. altianalis* in the Kuja River. The regression coefficients of Kegati bridge, Kanga bridge, Gogo and Wath Ong'er are 3.02, 3.10, 3.08 and 3.12 respectively (Table 1).

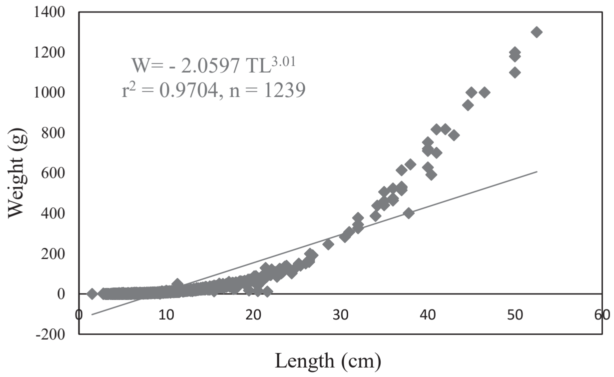

Figure 3: Length weight relationship of *B. altianalis* of River Kuja.

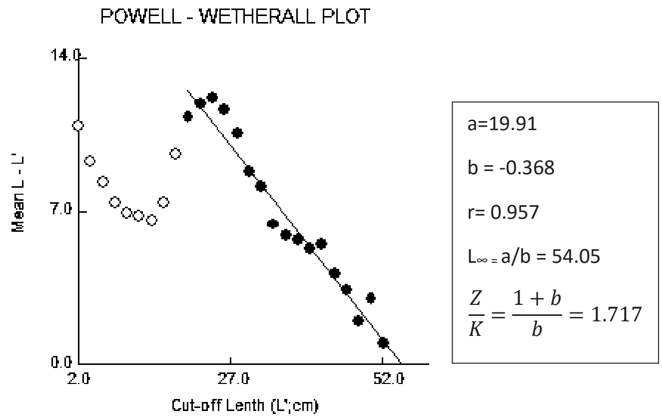

Figure 6: L infinity and the ratio of total mortality to the asymptotic length.

Mean Length distribution and number of fish per station

The mean length distribution (Fig. 4) shows the different mean lengths at different sampling station along the river. Gogo falls dam station recorded the highest mean length of 20.1 cm while Wath Ong'er station had the lowest mean length of 8.2 cm. Kanga bridge station had the highest numbers of *B. altianalis* (Fig. 5).

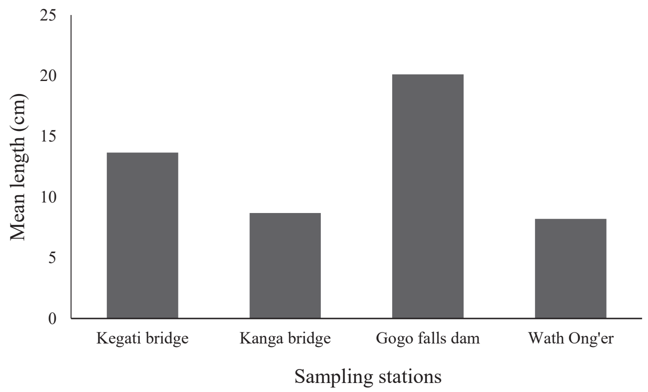

Figure 4: Mean length (TL) of *B. altianalis* from the sampling stations along R. Kuja.

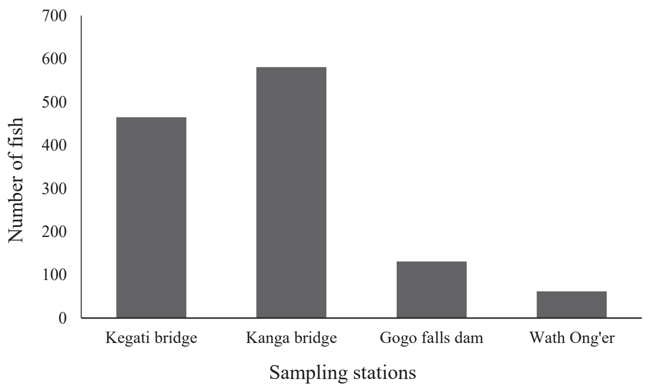

Figure 5: Number of *B. altianalis* from the sampling stations along R. Kuja.

Growth, mortality and exploitation rate

Powel Wetheral modified version in FiSAT (Pauly, 1986) was used to estimated L_∞ and Z/K (Fig. 6). The values of L_∞ and Z/K were 54.05 cm TL as 1.717 respectively. The growth constant K was estimated using the Ebert's (1973) method and found to be 1.47 yr $^{-1}$.

Total mortality Z was calculated from the values of Z/K and K and found to be 2.52 yr^{-1}.The growth performance index ($\emptyset' = Log10K + 2Log10L_\infty$)= 3.63. The natural and fishing mortalities were estimated to be 1.71 yr^{-1} and 0.81 yr^{-1} respectively. The exploitation rate was found to be 0.32.

Recruitment pattern

The recruitment pattern displays two cohorts revealing that the fish recruits twice a year in the 3rd and 7th month respectively (Fig. 7).

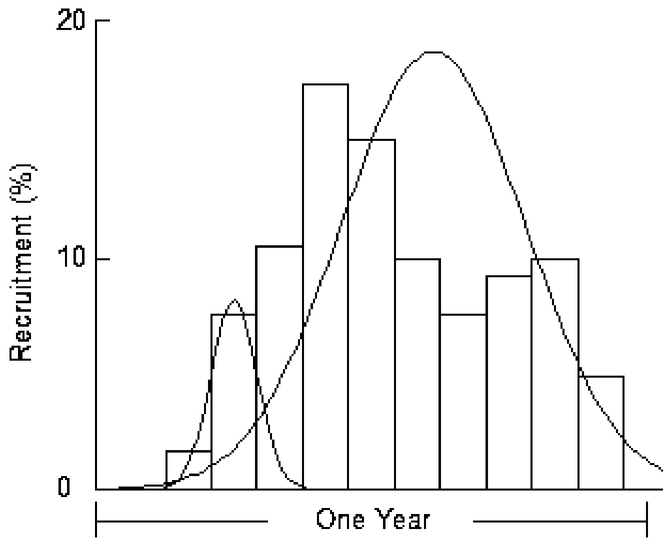

Figure 7: Recruitment pattern of *Barbus altianalis* of River Kuja.

Sex

The ratio of females to males was 1:1.34 and a chi-square test indicated no significant difference (p >0.05) from 1:1 sex ratio. The minimum mature size for males and females was 15cm and 16.5 cm respectively. From the fish samples collected, 21.95 % were mature, and 78.05 % were immature. The males dominated the mature samples accounting 79.78%.

DISCUSSION

Knowledge of various population parameters like asymptotic length (L_∞), growth coefficient (K), mortality (natural and fishing) rate and exploitation level (E) is necessary for planning and management of fisheries resources (Amin et al. 2009). *B. altianalis* sampled from R. Kuja demonstrated a size distribution that ranged from 3 to 53 cm TL with a mean length of 11.05±1.89 cm TL (Fig. 2). The maximum observed total length (53 cm TL) was smaller than the recorded maximum length (90 cm) (Ondhoro et al. 2016). The fish had a mean length of 11cm TL (Fig. 2) which reveals immaturity for the larger population in R. Kuja. The finding is supported by Buonerba (2010) who realized that juveniles were more dominant in the riverine conditions.

The length-weight relationship is an important aspect of the assessment 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 (3.01) estimated in Fig. 3 demonstrates an isometric growth dimension with no significant difference ($p>0.05$) from the value of 3. The coefficient of determination (r^2 = 0.97) indicated a strong positive correlation ($p < 0.05$) between weight and length of the *B. altianalis* in the Kuja River. The regression coefficients of Kegati bridge, Kanga bridge, Gogo and Wath Ong'er are 3.02, 3.10, 3.08 and 3.12 respectively (Table 1). *B. altianalis* from Kegati Bridge displayed an isometric growth while those from Kanga, Gogo and Wath Ong'er stations displayed a positive allometric growth. The results concur with a study conducted on *B. altianalis* by Ondhoro et al. (2016) which revealed a regression coefficient of 3.27 (positive allometric growth) from River Nile, Lake Edward and Kazinga Channel in Uganda.

The mean length observed ranged between 8cm TL and 20cm TL from the four sampling stations (Fig. 4). This indicated the presence of higher number of small immature fish in the three stations with a mean length of less than 15cm TL. According to Buonerba (2010), juveniles are more dominant in the riverine conditions, while the adults inhabit both riverine and lacustrine habitats. This was evident from the stations sampled along the river.

Kenya Electricity Generating Company has placed a power station at Gogo falls along R. Kuja. Gogo falls dam station had the highest fish mean length of 20.1 cm TL while Wath Ong'er the smallest of 8.2 cm TL (Fig. 5). Gogo station has a fall and a dam; this could be acting as a block to the potamodrous fish that migrate upstream to spawn. This could also be the reason as to why we found larger sizes compared to other stations. The dam acts as a barrier to the *B. altianalis* which is a potamodromous fish. It blocks the brood stock from getting to their spawning grounds in the breeding season, causing a substantial letdown of recruitment and eventual extinction of the stock beyond the dam (Marmulla 2001). The blockage may have contributed to the larger sizes found compared to other stations.

The asymptotic length, (L_∞) and the ratio of the total mortality rate (Z) to the growth constant (K), were estimated to be 54.05 cm and 1.717 respectively (Fig. 6). The curvature parameter (K) which is how fast the fish approaches the asymptotic length was 1.47 yr^{-1}. The growth parameter shows that *B. altianalis* of R. Kuja grows unrestrainedly.

The total mortality Z was 2.52 yr^{-1} and the growth performance index ($\text{Ø}'$ = Log 10 K + 2 log 10 L_∞) = 3.63. The total mortality rate Z = 2.52 yr^{-1} is high due to fishing, blocking of migratory patterns, pollution, turbidity caused by siltation through agriculture (Obiero et al. 2012). The high growth performance index exhibited by *B. altianalis* in River Kuja could be attributed to overfishing (Ondhoro et al. 2016) which reduces the size of fish and in turn increases growth rate (Garcia 1986). The average size of the fish is therefore attained much faster, leading to an increase in the growth constant (K). An increase in K increase the growth performance index (Getabu 1992)

Total, natural and fishing mortalities were estimated to be 2.52 yr^{-1}, 1.71 yr^{-1}, 0.81 yr^{-1} respectively. The natural mortality was greater than the fishing mortality. This could be due to pollution and other anthropogenic activities (Obiero et al. 2012). The lower fishing mortality may be caused by the presence of relatively small size fish that cannot be exploited owing to the restriction on the immature fishing stock. Overfishing (Njiru et al. 2010) has led to depletion of large-sized fish. This has resulted in reduced fishing mortality since the large fishable part of the stock is depleted, and only small sizes remain that is not preferable to fishers. The exploitation rate was estimated to be low (0.32) due to the same reason of immature fish dominating the *B. altianalis* stock of R. Kuja.

The *B. altianalis* fish recruits twice a year being the 3rd and 7th month (Fig. 7). This shows that the fish can grow to a reproductive size and contribute to the adult stock, and thus available fingerlings throughout the year. It is evident that the *B. altianalis* in R. Kuja is not stocked but the fish recruits itself in the population. The ratio of females to males was 1:1.34, this shows that there were more males than females which can be attributed to the fact that the fish is potamodromous and highly seasonal.

The results indicated the presence of *B. altianalis* in the Kuja River although 79.8% constitute fish that are sexually immature. The asymptotic length shows that the fish can grow to a larger size if it is well conserved. The knowledge gained will be useful for management purposes since it acts as an input for formulating the models used for sustainable management.

CONCLUSION

The results indicate the presence of *B. altianalis* in the Kuja River although 79.8% constitute fish that are sexually immature. The asymptotic length shows that the fish can grow to a larger size if it is well conserved. The curvature parameter (K) and the growth performance index indicate that the fish grows faster which could help promote the riverine fisheries. The knowledge gained will be useful for management purposes since it acts as inputs for formulating the models used for sustainable management. The management will ensure the growth of the immature fish and conserve the *B. altianalis* populations of River Kuja.

Table 1: Number of fish, mean lengths, mean weight, regression constant, regression coefficient and correlation coefficient of the sampled stations.

Station	Number of fish	Mean Length	Mean Weight	Regression constant (a)	Regression coefficient (b)	Correlation coefficient (r)
Kegati bridge	465	13.66±7.09	51.07±153.30	-2.09	3.02	0.99
Kanga bridge	581	8.68±4.37	11.33±20.12	-2.16	3.10	0.97
Gogo falls dam	131	20.10±12.85	196.27±291.56	-2.15	3.08	0.98
Wath Ong'er	62	8.20±3.53	7.96±10.64	-2.19	3.12	0.95
All 4 stations	1239	10.71±6.56	31.07±107.76	-2.06	3.01	0.97

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