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RESEARCH NOTE

Some biological aspects of the Silurid Catfish, *Bagrus docmak* (Forksskal, 1775) in Lake Victoria, Kenya

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Abstract

Bagrus docmak is indigenous to Lake Victoria, being an important source of economic livelihoods to communities around the lake. Although its stocks in the lake are facing intense fishing, predation and ecological changes, data on its biological aspects are scanty, being the basis for the current study. Fish samples for the present study were collected using gillnets of 10- and 50-mm mesh sizes. The length and weight of individual fish caught were measured in the field, while stomachs were preserved in 5% formalin and taken to the laboratory for gut content analysis. The overall sex ratio (male: female) was 1.0:1.26, and did not deviate significantly from 1:1. The lengths of the fish ranged from 12.0 to 55.0 cm TL and the weights ranged between 20.0 and 1650.0 g, with a mean length and weight of 32.7 cm TL and 351.2 g, respectively. The fish were in a good condition with mean condition factors (K) of 1.0, 1.01 and 0.97 for all fish, females and males, respectively. The fish exhibited a negative allometric growth pattern, with a length–weight relationship slope (*b*) of 2.90, 2.94 and 2.94 for all fish, females, and males, respectively. Stomach analyses revealed an ontogenetic diet shift, where juveniles of less than 30 cm TL feeding exclusively on *Caridina nilotica*. With increasing size, the fish ingested insects and other fish species, including barbus, bivalves, haplochromines, crabs and detritus in variable quantities. The results of the present study provide useful information on the biological aspects of *B. docmak* useful for its management and comprehensive stock assessment when required. It also provides insights into the feeding ecology of this fish in view of the changing Lake Victoria ecosystem. Accurate Knowledge regarding its food requirements can inform feed formulation for its successful culture.

KEYWORDS
catfishes, condition factor, food and feeding, length–weight, sex ratio

1 | INTRODUCTION

Bagrus docmak is a relatively large catfish found in freshwater habitats in Africa (Ogari & Asila, 1992). It inhabits lakes, swamps and rivers in both shallow and deep waters associated with rocky bottoms and coarse substrates (Lock, 1982). *Bagrus docmak* is an indigenous piscivorous fish native to Lakes Victoria, Albert, Edward and George and the Nile and Kagera Rivers in Uganda (Ogari & Asila, 1992; Ogutu-Ohwayo, 1990). It is an important source of economic livelihoods to communities located around Lake Victoria. Additionally, *B. docmak* is a species of high aquaculture potential largely because of its attractive attributes that include size, taste, flesh quality and overall commercial importance (Mwanja et al., 2014). Being a carnivorous fish, it can also be used in polyculture with Nile tilapia

(*Oreochromis niloticus*) as a measure to check the latter's populations in culture systems (Mwanja et al., 2014).

Catches of *B. docmak* in Lake Victoria have strongly declined after the upsurge of Nile perch (*Lates niloticus*) (Balirwa et al., 2003; Yongo et al., 2017) and concomitant ecological changes, with *B. docmak* currently restricted to refugia in rocky habitats and mouths of large rivers. Predation by, and competition with *L. niloticus* for haplochromines as food, might have played a role in their decline (Balirwa et al., 2003; Ogutu-Ohwayo, 1990). Before the introduction of exotic species, Lake Victoria contained a multispecies fishery comprising more than 500 endemic fish species, dominated primarily by the tilapiines *Oreochromis esculentus* and *Oreochromis variabilis* and haplochromine cichlids (Ogutu-Ohwayo, 1990). Other important species included *Rastrineobola argentea*, *Protopterus aethiopicus*, *Bagrus docmak*, *Clarias gariepinus*, *Schilbe intermedius* and species of the genera *Synodontis* and of the family Mormyridae. Many of these native species suffered severe declines because of predation by *Lates niloticus*, hybridization and competition with *O. niloticus*, and increased fishing pressure (Njiru et al., 2005; Yongo et al., 2018). Consequently, the lake's ecosystem has been severely affected by human activities and environmental changes, including the introduction of exotic species, invasion of water hyacinth, climate change, overexploitation, pollution and eutrophication (Yongo et al., 2021).

Studies on length–weight relationships and condition factors are well-documented for some freshwater fishes in Lake Victoria (Njiru et al., 2006; Yongo et al., 2019). There are, however, limited studies on the length–weight relationship and condition factor of *B. docmak* in the lake. The Condition factor is a quantitative parameter of the state of the well-being of the fish that determines its present and future success by its influence on growth, reproduction, and survival (LeCren, 1951). The food and feeding habits of *Bagrus* species in Lake Victoria have been studied by other researchers (Ogari & Asila, 1992; Seegers, 2008). Understanding the feeding habit of fish is very useful in guiding the formulation of artificial diets for its culture. Fish exploit food items based on adaptations, including their mouth, gill rakers, dentitions and gut systems related to feeding. Previous Lake Victoria studies have reported invertebrates as the principal food source for *B. docmak* during their juvenile stages, while the adult fish are primarily piscivorous feeding on haplochromines (Seegers, 2008), which have since declined in the lake. In fact, ecological changes in Lake Victoria has altered the feeding habits of various species, including *L. niloticus* (Agembe et al., 2018), *O. niloticus* (Njiru et al., 2004) and *Rastrineobola argentea* (Yongo, Manyala, Njiru, et al., 2016). These possible changes could also have altered the feeding habits and biological attributes of *B. docmak* in the lake. However, relevant data are sparse for this fish. Thus, the present study investigated the length–weight relationship, condition factor, sex ratio and feeding of *Bagrus docmak* in order to gain a better understanding of its biology and feeding ecology in light of the changing Lake Victoria ecosystem, which is necessary for effective management purposes.

2 | MATERIALS AND METHODS

2.1 | Sample collection and analyses

The experimental survey was conducted using a canoe outfitted with an outboard engine. Fishing was conducted every 3 months between September 2015 and July 2016 from areas located at 34°13′ and 34°52′E and 0°4′ and 0°32′S, representing the Kenyan waters of Lake Victoria (Figure 1). Fish specimens were caught using multifilament gillnets (50-mm mesh size; 10 mm wings and codend). The nets were set overnight at 19:00 hours and retrieved at 06:30 hours the following day. Immediately after their capture, the fish were sorted for *B. docmak* (127) specimens. The total length (0.1 cm) and weight (0.1g) of each fish were measured in the field using a measuring board and a balance, respectively. The fish were then dissected and sex was determined by macroscopic examination of the gonads according to the procedure of Bagenal and Tesch (1978). Each fish stomach was given an index of fullness from 0 to 20 in the field, using the point method of Hyslop (1980). An empty stomach scored 0 points, while stomachs that were quarter, half, three-quarters and completely full scored 5, 10, 15 and 20 points, respectively.

Non-empty stomachs were preserved in 5% formalin and transported to the Kenya Marine and Fisheries Research Institute laboratory in Kisumu (Kenya) for gut content analysis. In the laboratory, food items were emptied into a petri dish and examined with a dissecting binocular microscope (×50). Food items were sorted into categories and identified. Each category was assigned a number of points proportional to the estimated contribution. The percentage frequency of occurrence was calculated as numbers of stomach with particular food items, expressed as percentages. The gut contents were assessed separately for different length class categories (<30; 31–35; 36–40; 41–45; 46–50; 51–55 cm TL) to compare the contribution of food items in each length class. The formula of LeCren (1951) was used to estimate the relationship between the weight of the fish and its total length, as $W = a \times \mathrm{TL}^b$, using the linear regression of the log-transformed equation:

$$\mathrm{Log}\, W = \mathrm{Log}a + b\mathrm{Log}\,\mathrm{TL} \tag{1}$$

The parameters a = *intercept of length–weight relationship*; and b = slope of length–weight relationship.

The relative condition factor was calculated according to the method of LeCren (1951), as follows:

$$\mathrm{Kn} = \frac{W}{\left(a \times \mathrm{TL}^b\right)}, \tag{2}$$

where *Kn* = relative condition factor; *W* = weight of the fish (g); and TL = total length of the fish (cm). The terms *a* = intercept and *b* = slope are constants of the regression equation.

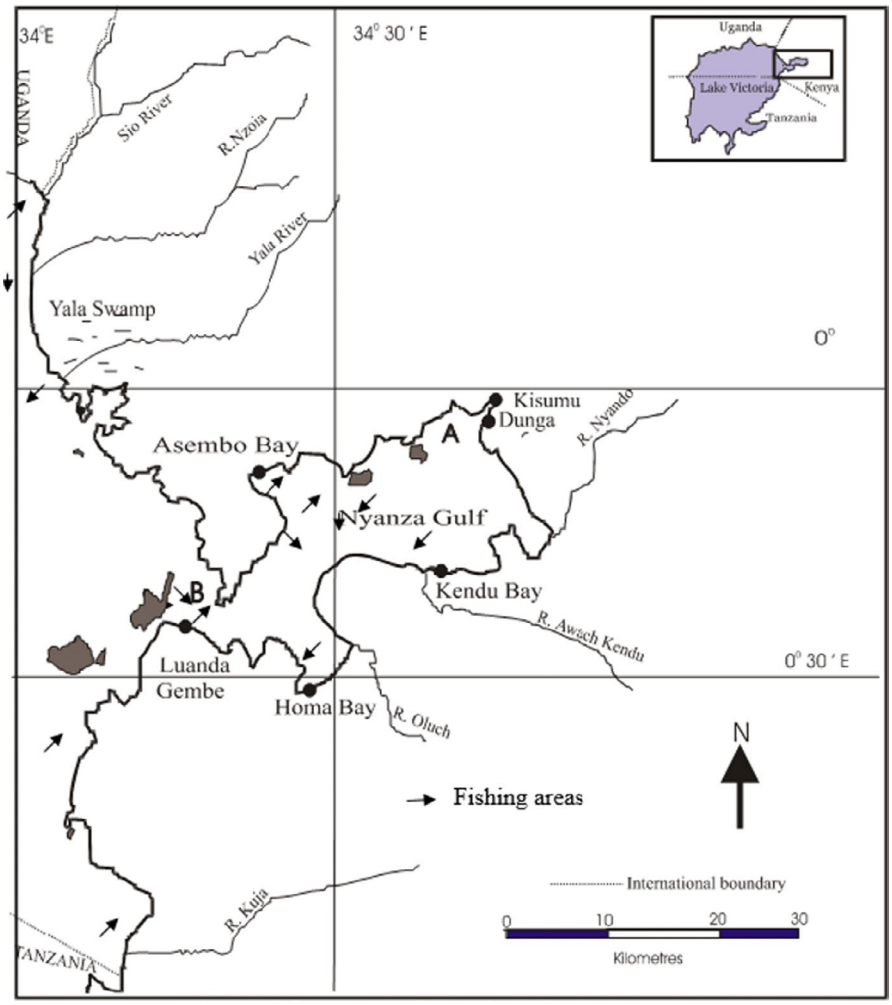

FIGURE 1 Map of Lake Victoria, Kenya showing sampling areas

TABLE 1 Relative condition factor of *Bagrus docmak* from Lake Victoria in relation to size classes

TL	*n*	Mean	SE	95% CI
<30	42	1.009	0.038	(0.821, 1.113)
31–35	23	0.966	0.043	(0.872, 1.075)
36–40	19	0.969	0.029	(0.875, 1.026)
41–45	10	0.981	0.019	(0.951, 1.010)
46–50	17	1.062	0.068	(0.950, 1.186)
51–55	16	1.071	0.068	(0.947, 1.223)
Total	127	1.000	0.019	(0.889, 1.072)

2.2 | Statistical analysis

All data were analysed using IBM SPSS statistics 21. The level of significance for all the analyses was α = 0.05. Chi-square (χ^2) was used to compare the sex ratio data of the fish population to the hypothetical distribution of 1:1, whereas a *t*-test was used to test for variations in mean total length and body weight between female and male fish. Kruskal-Wallis was used to test for differences in the condition factor in relation to the sex and size classes of the fish. Linear regression analysis was used to predict the weight from the total length. A student *t*-test comparison was performed to verify if the regression slope (*b*) was statistically significantly different from the length–weight predictions assigned for isometric growth (*b* = 3). While a statistically significant difference of *b* from 3 implies an allometric growth either positive or negative ($p < .05$), an isometric growth was assigned when *b* was not statistically different from 3 ($p > .05$). The coefficient of determination (R^2) was used as a measure of the quality of the linear regression predictions, with a value close to 1 implying a better model.

3 | RESULTS

The overall male: female sex ratio was 1.0:1.26, not deviating significantly from the hypothetical distribution of 1:1 (χ^2 = 1.27, p = 0.26). The length of the fish ranged from 12.0 to 55.0 cm TL, and the weight between 20.0 and 1650.0 g, with mean (±SE) lengths and weights of 32.7 ± 1.1 cm TL and 351.2 ± 32.3 g, respectively. The mean length was 33.6 ± 1.3 cm for females and 33.0 ± 1.8 cm for males, whereas females and males had mean weights of 359.6 ± 38.9 and 363.6 ± 56.2 g, respectively. There was no significant difference in the mean length (*t*-test, t = 0.30, p = .765) or weight (t = 0.06, p = .954) between males and females. The mean condition factor was

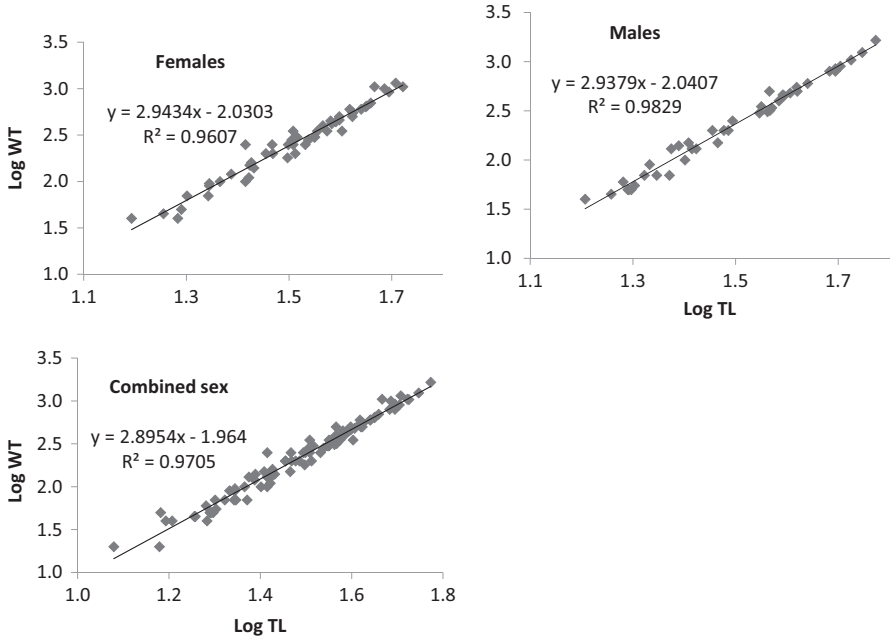

FIGURE 2 Log TL (total length)-Log WT (weight) relationship of *Bagrus docmak* from Lake Victoria, Kenya

0.97, 1.01 and 1.00 for male, female and combined sexes, respectively. The condition factor was not significantly different between males and females (Kruskal-Wallis test, $H = 2.21$, $p = .137$). Similarly, there was no significant variation in the condition factor in relation to the fish size classes ($H = 2.54$, $p = .771$; Table 1). The slope (b) of the length–weight relationship was 2.94, 2.94 and 2.90 for females, males and combined sexes, respectively (Figure 2). The fish exhibited an overall negative allometric growth pattern ($b < 3$, t-test, $p < 0.05$). Analysis of the stomach fullness revealed most stomachs (44.6%) were ¼ full, while 29.7% were empty (Figure 3a). The non-empty guts contained a variety of food items, with shrimps (*Caridina nilotica*), insects and fish remains each contributing the highest (21%) proportions (Figure 3b). The relationship between stomach fullness and size class indicated that most stomachs in each size class were ¼ full, with empty stomachs notably decreasing with increasing fish size (Figure 4). Gut content analysis indicated that fish of <30 cm TL fed exclusively on *Caridina nilotica*. Otherwise, with increased size, the fish ingested insects and other fish, such as barbus, bivalve, haplochromines, crabs and detritus in variable quantities (Figure 5).

4 | DISCUSSION

The results of the present study revealed that no sex dimorphism exists in *Bagrus docmak*, and that the sex ratio do not deviate significantly from the hypothetical 1:1 ratio. The fish appeared to be in good condition and the condition factor did not differ by sex or size of the fish. However, the fish exhibited a negative allometric growth pattern. In terms of its feeding ecology, *B. docmak* exhibited an ontogenetic diet shift, wherein juveniles fed exclusively on *Caridina nilotica*, while the adults fed on insects and other fish. The results of the present study also were compared with those of previous studies on *B. docmak* and were discussed in relation to the ecological conditions, being discussed in the context of the variations in the sex ratio, length–weight relationship, condition factor, feeding and feeding habits.

4.1 | Sex ratio

The sex ratio of 1.0:1.26 (male: female) for *B. docmak* in the present study were comparable with the findings of Anja et al., (2009) (sex ratio = 1.0:1.07), Ikongbeh et al., (2012) (sex ratio = 1.0:1.08) for *B. docmak* collected from Lake Chamo (Ethiopia) and Lake Akata (Nigeria), respectively. Similar sex ratio findings have also been observed in other related catfish by Mutethya et al., (2020) for *Schilbe intermedius* (sex ratio = 1.0:1.23), and Yongo and Wairimu (2018) for *Synodontis victoriae* (sex ratio = 1.0:2.70) from the Nyanza Gulf of Lake Victoria (Kenya). In contrast, Aruho et al., (2013) reported a relatively low sex ratio of 1.0:0.96 for *B. docmak* from the Victoria Nile compared with the present study. Interestingly, none of the above-noted studies detected any significant differences in the sex ratios. Thus, it appears that the catfish tended to exhibit nearly equal populations of males and females, in contrast to cyprinids, for which the male populations dominated (Njiru et al., 2006; Yongo et al., 2018). Several other studies reported that the sex ratio of the fish populations can vary on the basis of location between a predominance of males to females (Arthington & Milton, 1986; Bruton & Boltt, 1975; Waithaka et al., 2020; Yongo, Manyala, Kito, et al., 2016). Russell et al., (2012), for example, reported that sex ratio of *Oreochromis mossambicus* populations sampled from northern Australia were biased towards a predominance of females. According to these authors, the general bias towards females was a potential mechanism to produce more offspring in situations wherein the populations are under some stress, and as a result, are allocations of resources to increase biomass.

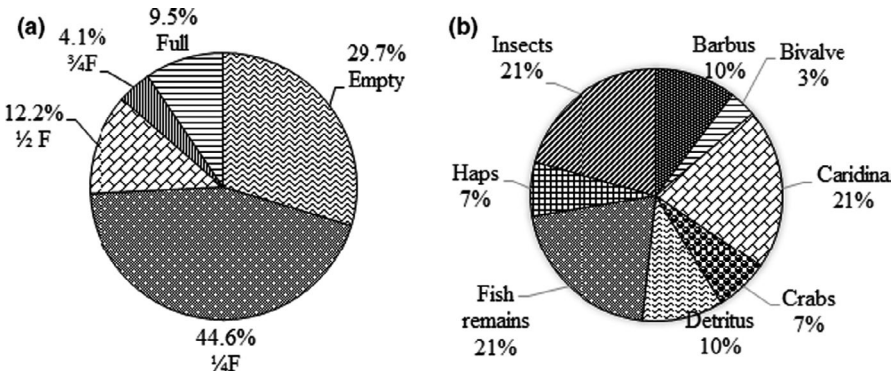

FIGURE 3 (a) Stomach fullness. (b) Diet composition of *Bagrus docmak* from Lake Victoria, Kenya

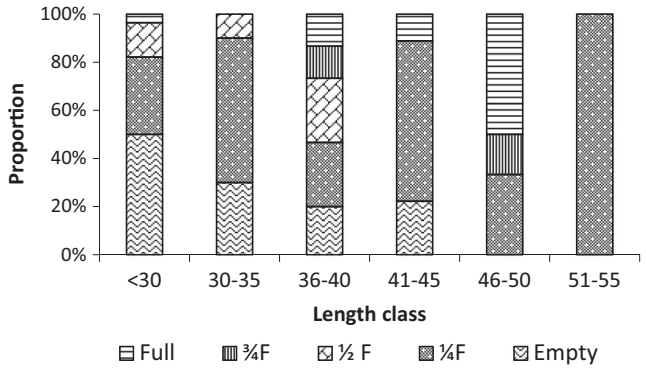

FIGURE 4 Stomach fullness in relation to size classes of *Bagrus docmak* from Lake Victoria, Kenya

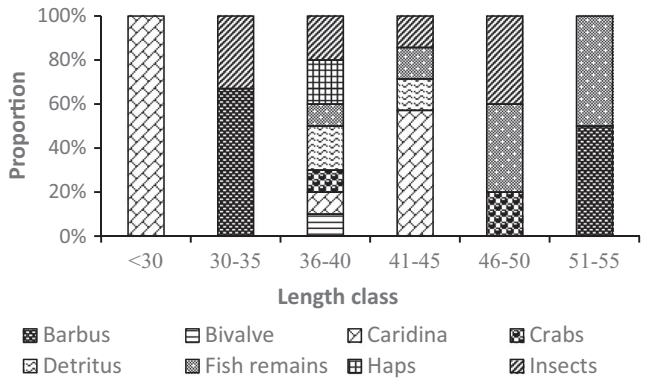

FIGURE 5 Percentage contribution of different food items consumed at different size classes of *Bagrus docmak* from Lake Victoria, Kenya

4.2 | Length–weight relationship

Parameters, such as the length–weight relationship and condition factor are important for studying the biology of fishes (Lizama et al., 2002; Mutethya et al., 2020; Yongo et al., 2017). They can be used to predict the weight of fish from length measurements obtained from stock assessments (Pauly, 1993). The length–weight relationships and condition factor are also important parameters for assessing the health condition of fish (Mortuza & Al-Misned, 2013; Nehemia et al., 2012). Accordingly, length–weight relationships have been emphasized in many studies, providing information about the growth patterns, general health, habitat conditions and life history as well as the morphological characteristics of the fish (Froese, 2006; Yongo, Olukoye, et al., 2019). The fish can exhibit either isometric, negative allometric, or positive allometric growth patterns. Isometric growth is associated with no change in body shape as the fish grow. Negative allometric growth means the fish becomes more slender with increasing length, while positive allometric growth implies the fish becomes relatively stouter or deeper bodied as it grows (Riedel et al., 2007).

The negative allometric growth pattern (b = 2.90) observed in the present study suggests that *B. docmak* exhibits a relatively slow growth rate and tend to be slender. The high coefficient of determination values (0.97) obtained in assessing the length–weight relationships indicates a good prediction of a linear regression for *B. docmak*. Comparing the results of the present study with those of previous studies indicated that some of these results are in agreement with other regional and international findings on length-weight relationships while others are not. As an example, in terms of agreement, Ikongbeh et al., (2012) reported a negative allometric growth for *B. docmak* from Lake Akata (b = 2.79), while Yongo & Wairimu (2020) reported a negative allometry for the catfish *S. victoriae* from Lake Victoria (b = 2.91). However, the negative allometric growth reported for *B. docmak* (b = 2.90) in the present study did not agree with the positive allometric growth for *Bagrus bayad* (b = 3.1) and isometric growth for *B. docmak* (b = 3.05) reported by El-Drawany and Elnagar (2015) from the Muess Channel in Egypt.

Furthermore, the results of the present study were not comparable with the findings of Anja et al., (2009) who reported a positive allometric growth for *B. docmak* (b = 3.24) from Lake Chamo or Keyombe et al., (2015) who also found a positive allometric growth for *Clarias gariepinus* (b = 3.23) from Lake Naivasha (Kenya). Similarly, the positive allometric growth pattern reported by Mutethya, Okoth, et al., (2020) for *S. intermedius* (b = 3.30) from Lake Victoria was not in agreement with the findings of the present study. According to Yilmaz et al., (2012) and Ali et al., (2016), fish might show different growth patterns attributable to water quality, food availability, habitat conditions, season and life stages. Furthermore, variations in fish growth patterns could also be related to the condition of the species itself, its phenotype, specific geographic location, and therefore, its

environment (Tsoumani et al., 2006). However, because these factors were not specifically considered in the present study, it was not possible to clarify which factors among those described above influenced these study results. It should also be noted that the growth process can differ in the same fish species on the basis of dwelling diverse locations influenced by numerous biotic and abiotic factors.

4.3 | Condition factor

The condition factor (K) which represents the degree of well-being of the fish in their habitat is expressed by the 'coefficient of condition', also known as length–weight factor. It is a measure of various ecological and biological factors, such as degree of fitness, gonad development and the suitability of the environment with respect to the feeding conditions (Mortuza & Al-Misned, 2013; Yongo, Manyala, Njiru, et al., 2016). When the condition factor K value is equal to or greater than one, it means the fish have attained a better condition (LeCren, 1951). Based on this criterion, *B. docmak* fish sampled from Lake Victoria during the present study were in a good condition, with a mean K value of 1.0. These results were comparable with the findings of Mutethya, Okoth, et al., (2020) for *S. intermedius* (K = 1.00), and Yongo and Wairimu (2018) for *S. victoriae* (K = 1.01) from the Nyanza Gulf of Lake Victoria (Kenya). However, the K results for *B. docmak* in the present study were not in agreement with the results of Ikongbeh et al., (2012), who reported a K value of 1.62 for the same species from Lake Akata. The results also were not in agreement with the findings of Anja et al., (2009) for *B. docmak* (K = 0.4–0.5) and Keyombe et al., (2015) for *C. gariepinus* (K = 0.55) from lakes Chamo and Naivasha, respectively. The condition factor of fish can vary on the basis of the species type, prevailing environmental conditions, and food availability in their occupied habitats (Okach and Dadzie 1988; Wanyanga et al., 2016). The condition factor of fish can also be affected by season, reproductive cycles and water quality parameters (Khallaf et al., 2003), which were not considered in the present study.

4.4 | Food and feeding habits

The diet composition of *B. docmak* in the present study varied with fish size, with juveniles <30 cm TL feeding exclusively on *Caridina nilotica*, while the adult fish ingested various food items, including insects, barbus, bivalve, haplochromines, crabs and detritus. However, Okach and Dadzie (1988) reported that adult *B. docmak* collected from the Nyanza Gulf of Lake Victoria fed mostly on fish-haplochromis spp. and *Engraulicypris argenteus* (Pelligrin), whereas the juveniles preferred aquatic benthic invertebrates, such as *Phyllogomphus aethiops*, *Phanostoma senegalense*, *Chironomus* spp., *Caridina nilotica* and *Chaoborus* spp. among others. Juvenile *B. docmak* (<40 cm FL) in Lake Chamo (Ethiopia) ingested more insects, while adult fish were largely piscivores with fish constituting 98% of their diet by weight (Anja & Mengistou, 2001). A comprehensive review by Yongo et al., (2019) on the food and feeding habits of various *Synodontis* catfishes in African fresh waters also reported a similar ontogenetic diet shift. Bagrus species are predatory bottom-dwellers, feeding predominantly on invertebrates when young and shifting to a piscivorous feeding habit when they become adults (Chilvers & Gee, 1974). Ontogenetic changes in fish diet are influenced by the development of fish morphological and physiological features associated with its growth (Agembe et al., 2018; Njiru et al., 2004; Yongo, Manyala, Njiru, et al., 2016). The present study provides information on the biological aspects of *B. docmak* useful for its management as well as insight regarding the feeding ecology of *B. docmak* in regard to the changing Lake Victoria ecosystem. Knowledge of its food requirements can inform feed formulation for its successful culture and further studies on the reproduction and life history strategies of *B. docmak* are warranted.

CONFLICT OF INTEREST

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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