Journal of Fisheries
Volume 11 Issue 1 April 2023
Peer Reviewed | Open Access

eISSN 2311-3111
pISSN 2311-729X

DOI: https://doi.org/10.17017/j.fish.431

Original Article

Length-weight relationships and condition factors of mono- and mixed-sex Nile tilapia (*Oreochromis niloticus*) in open water cage culture system

Sanzib Kumar Barman[1,2] • Bhupal Ronjon Das[2] • Mrityunjoy Kunda[2] • Sabuj Kanti Mazumder[3] • Md. Jasim Uddin[4] • Partho Protim Barman[5]

[1] *Department of Fishery Resources Conservation and Management, Faculty of Fisheries and Ocean Sciences, Khulna Agricultural University, Khulna 9100, Bangladesh*
[2] *Department of Aquatic Resource Management, Faculty of Fisheries, Sylhet Agricultural University, Sylhet 3100, Bangladesh*
[3] *Department of Genetics and Fish Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh*
[4] *Department of Fisheries Management, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh*
[5] *Department of Coastal and Marine Fisheries, Sylhet Agricultural University, Sylhet 3100, Bangladesh*

Sanzib Kumar Barman and Bhupal Ronjon Das have equally contributed to this work.

Correspondence
Dr. Sabuj Kanti Mazumder; Dept. of Genetics and Fish Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh
sabugfb@bsmrau.edu.bd

Manuscript history
Received 21 April 2022 | Accepted 29 November 2022 | Published online 1 March 2023

Citation
Barman SK, Das BR, Kunda M, Mazumder SK, Uddin MJ, Barman PP (2023) Length-weight relationships and condition factors of mono- and mixed-sex Nile tilapia (*Oreochromis niloticus*) in open water cage culture system. Journal of Fisheries 11(1): 111204. DOI: 10.17017/j.fish.431

Abstract
The current study compared the length-weight relationships and condition factors in mono- and mixed-sex Nile tilapia (*Oreochromis niloticus*). The trial lasted for 91 days and included two treatments with five replications for each, all with the same stocking density. During the study period, 20 randomly selected fish individuals were measured and recorded from each cage every two weeks. The observed growth trend was allometric, with no significant difference in the mean exponential values (b), 2.696 and 2.65 for mono and mixed-sex tilapia respectively. There was a significant difference in final weight gain between monosex (171.58±7.39 g) and mixed-sex (149.09±4.14 g) tilapia. There was no significant difference in final length between monosex (19.80±0.42 cm) and mixed-sex (19.80±0.42 cm) tilapia. Moreover, the mean correlation coefficient (r^2) of both groups was positive. The Fulton condition factor (K) also varies from 0.700 to 1.000 (monosex) and 1.000 to 1.010 (mixed-sex). The relative condition factor (K_n) for monosex and mixed-sex tilapia ranged from 1.96 to 2.222 and 2.092 to 2.35 respectively, indicated good aquaculture conditions. The present findings will attract fish farmers to mixed-sex tilapia culture by allowing them to lessen hormone administration and expected to boost national fish production through open water cage aquaculture.

Keywords: Fulton condition factor; length-weight relationship; open water cage culture; *Oreochromis niloticus*; relative condition factor

1 | INTRODUCTION

The Nile Tilapia (*Oreochromis niloticus*) is considered one of the utmost popular freshwater fish species in the global aquaculture, as a source of animal protein and socio-economic benefit (Chakraborty *et al.* 2011; Islam *et al.* 2015). It possesses diversified characteristics, including its fast growth performance with high valued fillets (Thongprajukaew *et al.* 2017), a wide range of environmental and induced handling stress tolerance ability (Ogello *et al.* 2017), disease resistance and omnivorous feeding behaviours (Vasconcelos *et al.* 2018) and an excellent consumer acceptance benefits (Githukia *et al.* 2015) to make it suitable for aquaculture globally. Therefore, *O. niloticus* was introduced in Bangladesh from Thailand by UNICEF in 1974 by considering its high yielding performance and significant role as animal protein source. However, the Genetically Improved Farmed Tilapia (GIFT) of *O. niloticus* was introduced by Bangladesh Fisheries Research Institute (BFRI) in 1993 (Githukia *et al.* 2015; Kunda *et al.* 2021). It has become the most widely farmed variety with its commercially available local strains.

Moreover, the GIFT *O. niloticus* can perform well on inexpensive feed and fertiliser with a wide range of waters and cages (Chakraborty *et al.* 2011). Over reproducing ability results stunted growth and unmarketable harvesting size of the mixed Nile tilapia. In contrast, mono-sex male Nile tilapia produce higher yield (Githukia *et al.* 2015).

Because of the increased fish production, cage culture is considered one of the most important technologies, which has been already established effectively in Asia, Europe and America (Moniruzzaman *et al.* 2015). After introduction in the late 1800s, this technique has been practicing in both freshwater and marine waters of different Southeast Asian countries including open sea, lakes, estuaries, tanks, ponds and rivers (Balcázar *et al.* 2006). However, the aquaculture structures are still concerted mostly in pond culture practices in Bangladesh (Balcázar *et al.* 2006; Ridha 2011). Thus, the cage culture in open water bodies like river could provide an opportunity for increasing fish production. Considering this practical point of view, the current study of the cage culture system was conducted in Kura River of Sylhet district, Bangladesh. Kura River is considered a diversified source of fish due to its unique inter-connectivity between the river Surma upstream and the river Kushiyara downstream (Barman *et al.* 2021). The fish production of this inter-connected river contributes to the livelihood of more than 3000 households of the surrounding area and thus, to the national economy (Barman *et al.* 2021). However, Kura River may offer an incredible choice for the tilapia cage culture system considering its well-meaning role as a valuable animal protein.

In the cage culture system, length-weight relationship (LWR) and condition factor analysis are essential in knowing the growth pattern, age structure, recruitment, mortality and overall well-being of cultured fish species (Das *et al.* 2018; Bhat *et al.* 2022). It is essential to study the LWR to compare the intensification of mono-sex and mixed-sex tilapia culture and production in the open water cage aquaculture system. However, very little work has been done on the stocking density, production performance and economic benefits of Nile tilapia cage culture (Siddik *et al.* 2014; Kunda *et al.* 2021), but no published work has been found on the LWR of Nile tilapia in an open water cage culture in Bangladesh. Thus, this was the first work aimed to investigate a comparative study on the LWR of the Nile tilapia in an open water cage culture system in Kura River of Bangladesh.

2 | METHODOLOGY

2.1 Study area and experimental fish

The cage aquaculture study was conducted in Kura River at Golapganj Upazila (located between 24°41′ and 24°55′N and between 91°55′ and 92°06′E) of Sylhet district, Bangladesh. The Nile tilapia fish fry was produced and reared in the Reliance Hatchery, Trishal, Mymensingh, Bangladesh. A total of 1200 (including 600 mono-sex and 600 mixed-sex) experimental fingerlings were released into the cage culture system. The length and weight of fingerlings were recorded before introduction. Fingerlings were transported using water-filled oxygenated polythene bags to ensure maximum survivability and minimum stress.

2.2 Construction and installation of cages

Cages were made by 0.8 cm meshed tire cord nylon net and fixed with $1m^3$ (1m × 1m × 1m) PVC pipe frame tied with nylon twine. Empty capped plastic galon of five litre fixed with a bamboo frame (five cages in each frame) to keep it floating. Each cage was tied to bamboo poles. Cages were settled into the water with bamboo poles one week prior to stocking of tilapia fingerlings. The cages were equipped with covers to prevent losses of floating feeds escaping from the cages by the natural flow of water. All the cages were placed in Kura River at an ideal location to allow sufficient water current and easy access for management and were separated from each other as well as the bottom substrate by 15 cm distance to optimise water quality. There was a small window on the top of every cage to facilitate feeding as well as sampling and harvesting of fish.

2.3 Experimental design, feeding strategy and sampling

A total of 10 cages were randomly stocked, each with 120 fingerlings. Five cages were stocked with mono-sex and the other five stocked with mixed-sex tilapia respectively. The same sizes (about 6 cm) tilapia fingerlings were stocked, all cages were made by 0.8 cm meshed tire cord nylon net and fixed with $1m^3$ (1m × 1m × 1m) PVC pipe frame tied with nylon twine. The experiment was conducted based on two treatments (T_1 and T_2), each with five replications (R_1 – R_5) for mono-sex and mixed-sex tilapia respectively. Fish individuals were fed commercial feed (floating feed) containing 30% protein content starting the next day (day 2) after stocking of fingerlings at 10% of body weight and gradually reduced to 3% of the body weight at the end at 91-day. Feeding rates were adjusted after every seven days depending on mean body weight of fish. The upper aperture was used to distribute feeds over the cages. The daily feed rations were divided into two equal portions for each cage and were fed in the morning (0900 hrs) and afternoon (1600 hrs) respectively. However, all cages were cleaned every 15 days. Cleaning was done by removing of aquatic weeds as well as other unwanted aquatic materials attached to the cages, specially the cage nets and frame. However, in some cases the debris of waste feeds were also cleaned.

Sampling for the length and weight measurements was conducted on fortnightly basis after stocking. The samplings progressed gradually, started on 16 Sep 2016 followed by samplings on 1 Oct, 16 Oct, 1 Nov, 16 Nov and 1 Dec of 2016. However, experimental fish were mopped on a filter paper before being weighed to remove excess water from the body and to ensure accuracy of the measurement. Weight and length were measured using a sensitive weighing balance (Digital scale model AFD (Ek-300i, USA), to the nearest 0.001 g, and a measuring scale respectively. The total length was measured as the distance from the snout to the tip of the caudal fin; whereas the caudal length was excluded during the measurement of the standard length. Sampling was done by randomly collecting 20 individuals from each of the cages, i.e., 100 mono-sex and 100 mixed-sex tilapia. Sampled individuals were released back to the respective cages after measurements.

2.4 Measurement of length-weight relationship (LWR)

The LWR was calculated using the modified equation of Froese (2006), as follows: $W = a\ L^b$; where W indicates the weight of fish (g), L specifies the length of fish (cm), a is the intercept of the regression and b is an exponential (b = 3 means isometric weight gain; b = other than 3 means allometric weight gain, where $b > 3$ and $b < 3$ indicate positive and negative allometric growth respectively. Additionally, the relationship between weight and total length (TL) and standard length (SL) were calculated using the equations $W = a\ TL^b$ and $W = a\ SL^b$ respectively measured the weight and standard length. Moreover, a power curve of best fit to the dataset was drawn through values representing the body weight for the range of arbitrarily chosen values of different lengths. A smooth line was drawn through the points of the power curve, which describes the relationship between length and weight.

2.5 Condition factor

The Fulton's condition factor (K) was calculated for each fish individual following Fulton (1904): $K = 100\ W/L^3$. While relative condition factor (K_n) was calculated following Le Cren (1951): $K_n = W(a\ L^b)^{-1}$. Here, W is the body weight (g), L is the total length (cm), a is the intercept, b is the slope and 100 is a factor to bring the value of K near unity.

2.6 Data analysis

Determination of a and b values was performed using non-linear regression. The curve fitting was carried out using chi-square (χ^2) methods using Levenberg-Marquardt and Simplex algorithms readily developed in Microcal Origin™ (version 9.0) computer software. The measurement of model fit was evaluated by the coefficient of determination (r^2). Additionally, a two-factor factorial model was used to compare the condition factors between the two treatments. All results were expressed as mean ± SE.

3 | RESULTS

3.1 Total length and bodyweight relationship

The results of LWR showed a significantly ($p < 0.05$) negative allometric growth both in mono-sex tilapia and mixed-sex tilapia respectively (Figure 1). Therefore, the results of the first sampling ($BW = 0.021\ TL^{2.96}$, $r^2 = 0.9007$, $\chi^2 = 5.281$ for T_1 and $BW = 0.03\ TL^{2.85}$, $r^2 = 0.92$, $\chi^2 = 2.99$ for T_2) also showed no significant difference between two treatments (Figure 1a). These results indicated similar growth patterns in terms of increasing total length between both treatments, which had also been observed at the end (i.e. sixth sampling; Figure 1f) of the experiment ($BW = 0.24\ TL^{2.21}$, $r^2 = 0.70$, $\chi^2 = 351.14$ for T_1 and $BW = 0.24\ TL^{2.85}$, $r^2 = 0.87$, $\chi^2 = 202.69$) for ???. Also, the mean value of b (2.696) for the mono-sex population is very near the mean value (2.65) for the mixed-sex tilapia population which indicated better growth but in a similar allometric pattern.

Therefore, the results of the LWR considering the final weight gain showed a significant difference ($p < 0.05$) between the treatments. However, no significant ($p > 0.05$) weight gain was observed until the 75th day of the experimental period. However, the values of the coefficient of determination (r^2) indicated strong and highly significant ($p < 0.05$) relationships between the total length and body weight for both mono- and mixed-sex tilapia. The mean value of r^2 for both mono-sex (0.86) and mixed-sex (0.67) tilapia revealed a highly positive and significant ($p < 0.05$) relationship between total length and weight (Table 1).

3.2 Standard length and body-weight relationship

The results of LWR showed a significantly ($p < 0.05$) negative allometric growth both in mono-sex and mixed-sex tilapia (Figure 2). However, the second sampling of T_2

treatment exceptionally showed slightly positive allometric growth (BW = 0.03 $SL^{3.03}$, r^2 = 0.87, χ^2 = 20.27) in terms of increasing length. However, the r^2 value was close to 1 in both T_1 and T_2 groups, which indicated a positive relationship between standard length and weight of fish in open water aquaculture (Table 2).

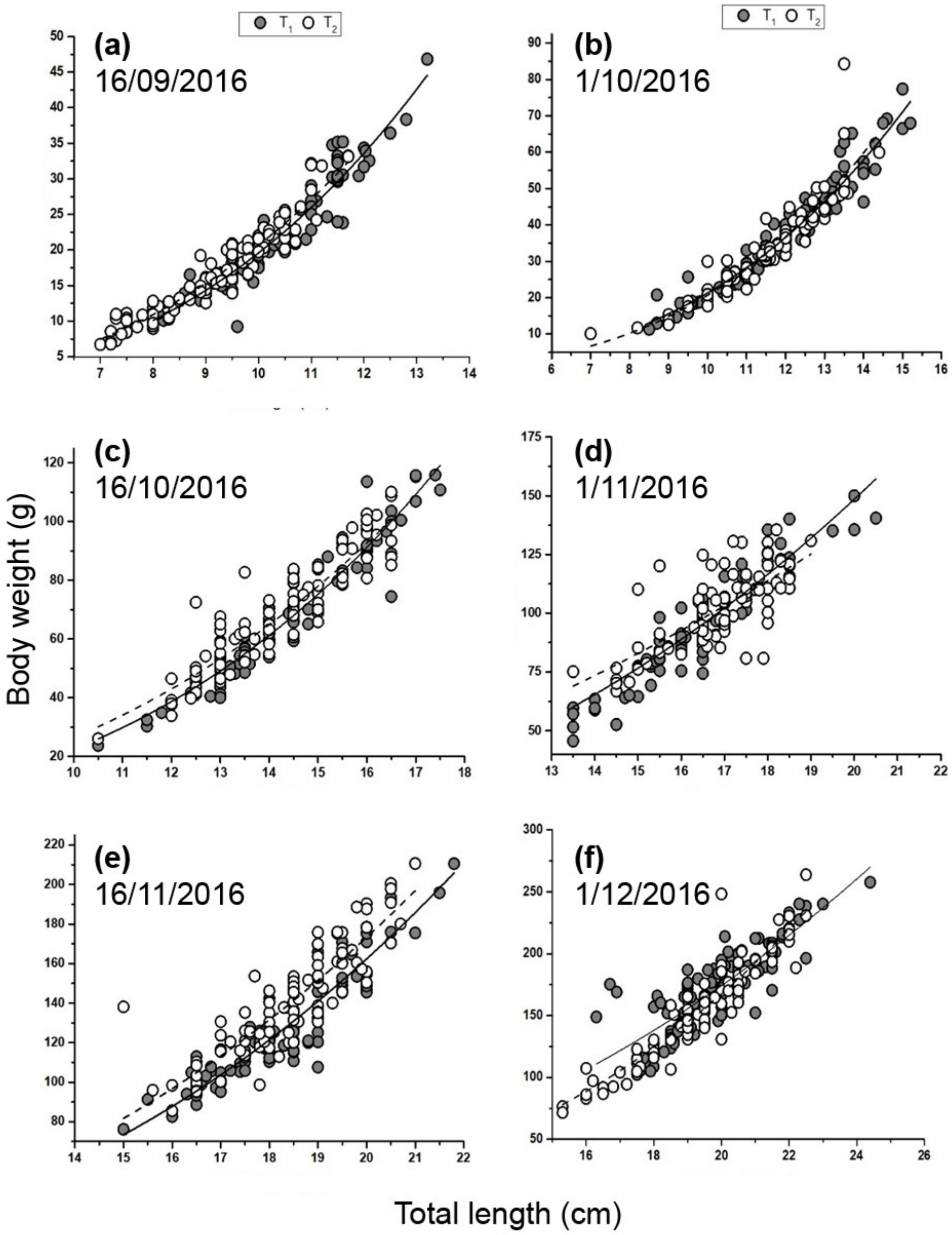

FIGURE 1 Relationship between total length and body weight of mono and mixed-sex tilapia. The solid line represented mono-sex (T_1) nonlinear fit and the dashed line represented mixed-sex (T_2) nonlinear fit, whereas solid and open circles were represented individual fish samples. a – f represent date-wise length-weight relationship of mono-sex (T_1) and mixed-sex (T_2) tilapia.

TABLE 1 Relationship between total length and body weight of mono-sex and mixed-sex tilapia.

Sampling dates	χ^2		r^2		*a* ± SE		*b* ± SE		BW	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
16.09.2016	5.28	2.99	0.90	0.92	0.02± 0.01	0.03± 0.01	2.96 ± 0.10	2.85 ± 0.09	0.021 × $TL^{2.96}$	0.03 × $TL^{2.85}$
01.10.2016	13.61	20.27	0.93	0.87	0.02 ± 0.01	0.01 ± 0.01	2.97 ± 0.09	3.17 ± 0.14	0.02 × $TL^{2.97}$	0.01 × $TL^{3.17}$
16.10.2016	37.47	54.40	0.92	0.09	0.02 ± 0.01	0.06 ± 0.02	2.98 ± 0.09	2.67 ± 0.12	0.02 × $TL^{2.98}$	0.06 × $TL^{2.67}$
01.11.2016	68.12	115.34	0.85	0.53	15.15 ± 0.05	0.74 ± 0.36	2.30 ± 0.10	1.74 ± 0.17	15.15 × $TL^{2.30}$	0.74 × $TL^{1.74}$
16.11.2016	111.32	175.01	0.86	0.76	0.04 ± 0.01	0.07 ± 0.03	2.76 ± 0.11	2.61 ± 0.15	0.04 × $TL^{2.76}$	0.07 × $TL^{2.61}$
01.12.2016	351.14	202.69	0.70	0.87	0.24 ± 0.10	0.03 ± 0.01	2.21 ± 0.15	2.85 ± 0.12	0.24 × $TL^{2.21}$	0.24 × $TL^{2.85}$

T_1, mono-sex tilapia group; T_2, mixed-sex tilapia group, χ^2, chi square result; r^2, coefficient determination; *a* and *b*, parameters of length-weight relationship; BW, body weight; TL, total length; SE, standard error.

A significant (p < 0.05) result was observed for final weight gain between the T_1 and T_2 treatment groups, in which mono-sex tilapia (T_1) showed comparatively higher weight gain (171.58 ± 7.39 g) than mixed-sex (T_2) tilapia (149.09 ± 4.14 g). However, no significant differences was observed in weight until the 75-day of the culture period. Thus, the relationship between the standard length and body weight of the Nile tilapia revealed an allometric growth pattern.

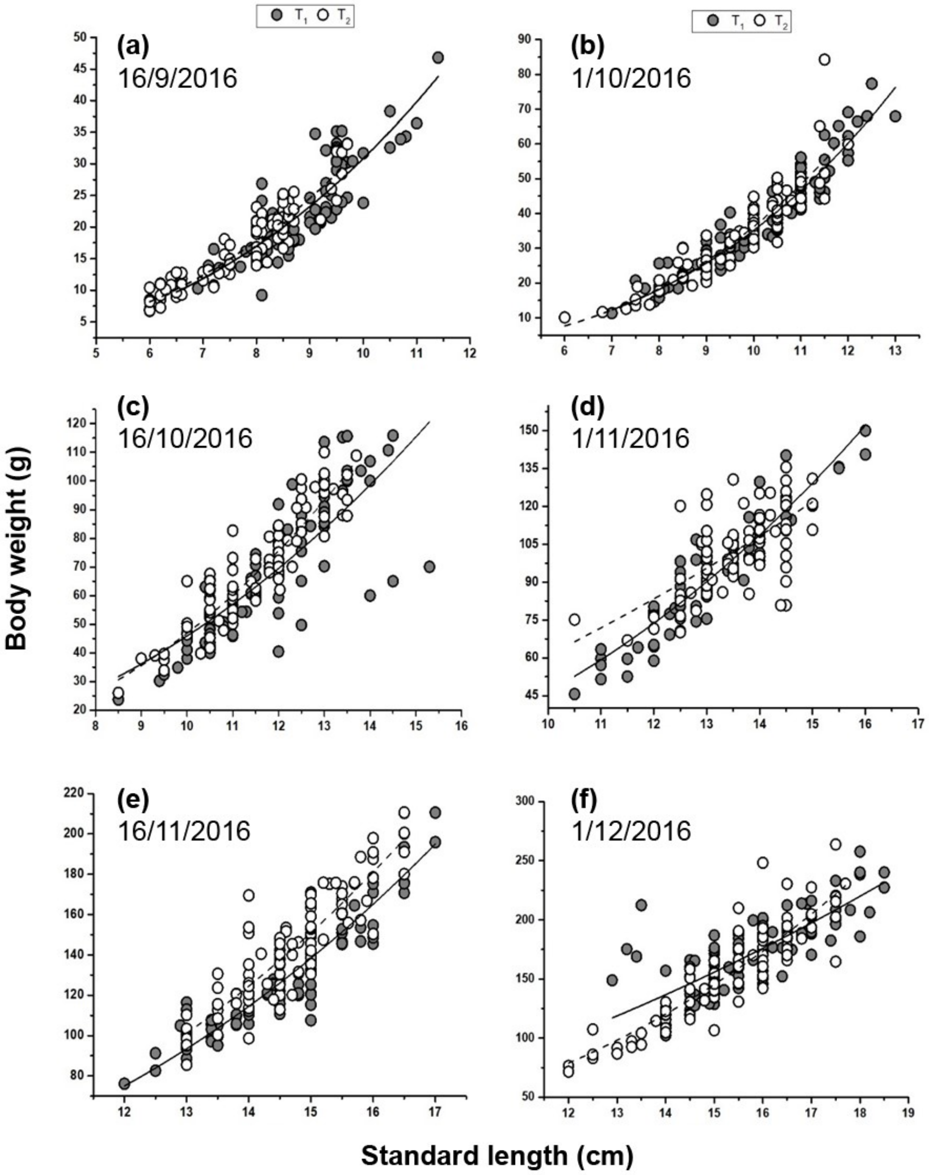

FIGURE 2 Relationship between standard length and body weight of mono- and mixed-sex tilapia. The solid line represented mono-sex (T_1) nonlinear fit, and the dashed line represented mixed-sex (T_2) nonlinear fit, whereas solid and open circles were represented individual fish samples. a – f represent date-wise length-weight relationship of mono-sex (T_1) and mixed-sex (T_2) tilapia.

TABLE 2 Relationship between standard length and body weight of mono- and mixed-sex tilapia.

Sampling dates	χ^2		r^2		a ± SE		b ± SE		BW	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
16.09.2016	12.18	4.92	0.77	0.87	0.07± 0.02	0.06± 0.02	2.68± 0.14	2.71± 0.12	$0.07 \times SL^{2.68}$	$0.06 \times SL^{2.71}$
01.10.2016	19.30	23.26	0.91	0.85	0.04± 0.01	0.03± 0.01	2.95± 0.11	3.03± 0.15	$0.04 \times SL^{2.95}$	$0.03 \times SL^{3.03}$
16.10.2016	163.82	59.04	0.66	0.84	0.24± 0.11	0.11± 0.04	2.27± 0.17	2.62± 0.12	$0.24 \times SL^{2.27}$	$0.11 \times SL^{2.62}$
01.11.2016	58.18	139.90	0.87	0.44	0.14± 0.04	1.22± 0.65	2.52± 0.10	1.70± 2.0	$0.14 \times SL^{2.52}$	$1.22 \times SL^{1.70}$
16.11.2016	177.53	15.38	0.85	0.81	0.08± 0.03	0.08± 0.03	2.74± 0.12	2.81± 0.14	$0.08 \times SL^{2.47}$	$0.08 \times SL^{2.81}$
01.12.2016	459.02	293.91	0.60	0.81	0.92± 0.39	0.09± 0.04	1.89± 0.15	2.74± 0.15	$0.92 \times SL^{1.89}$	$0.09 \times SL^{2.47}$

T_1, mono-sex tilapia group; T_2, mixed-sex tilapia group, χ^2, chi square result; r^2, coefficient determination; a and b, parameters of length-weight relationship; BW, body weight; TL, total length; SE, standard error.

3.3 Condition factors

The range of Fulton condition factor (*K*) was recorded from 1.960 ± 0.20 to 2.222 ± 0.19 for mono-sex tilapia and 2.098 ± 0.23 to 2.350 ± 0.29 for mixed-sex tilapia (Figure 3). Additionally, the range of relative condition factor (K_n) was recorded from 0.700 ± 0.06 to 1.002 ± 0.08 for mono-sex tilapia and 1.000 ± 0.12 to 1.010 ± 0.13 for mixed-sex tilapia (Figure 4).

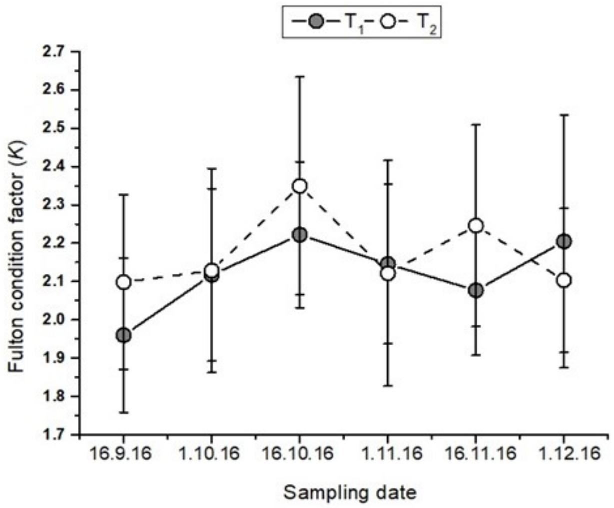

FIGURE 3 Mean Fulton condition factor at six different sampling dates. The solid line represents mono-sex tilapia and the dashed line represents mixed-sex tilapia. Solid and open circles represent mean values for mono- and mixed-sex tilapia groups respectively. Solid bar denotes a variant of condition factor values.

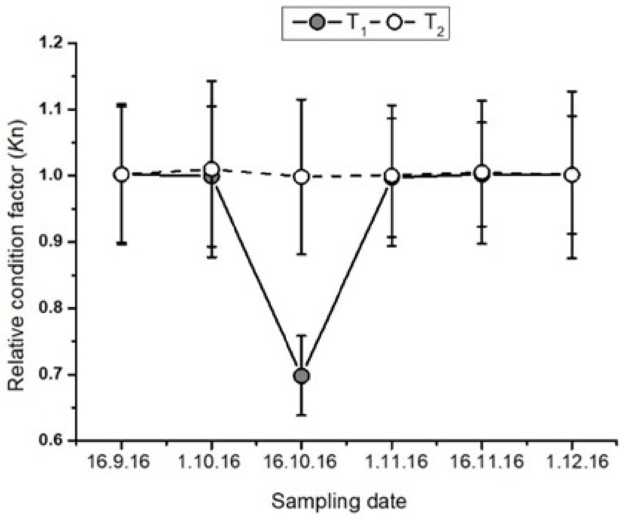

FIGURE 4 Mean relative condition factor at six different sampling dates. The solid line represents mono-sex, and the dashed line represents mixed-sex tilapia. Solid and open circles represent mean values for mono- and mixed-sex tilapia groups respectively. Solid bar denotes a variant of condition factor values.

The values of the condition factors (*K* and K_n) of mono- and mixed-sex tilapia groups are presented in Table 3. The results of *K* and K_n revealed a good condition for both mono- and mixed-sex tilapia groups (Table 3).

TABLE 3 Values of the two condition factors for mono-sex (T_1) and mixed-sex (T_2) tilapia groups.

Sampling dates	Group	Status of wellbeing	
		K ± SE	K_n ± SE
16/9/2016	T_1	1.960 ± 0.20^G	1.001 ± 0.10^G
	T_2	2.098 ± 0.23^G	1.001 ± 0.11^G
1/10/2016	T_1	2.118 ± 0.23^G	1.000 ± 0.11^G
	T_2	2.129 ± 0.27^G	1.010 ± 0.13^G
16/10/2016	T_1	2.222 ± 0.19^G	0.700 ± 0.06^B
	T_2	2.350 ± 0.29^G	1.000 ± 0.12^G
1/11/2016	T_1	2.146 ± 0.21^G	1.000 ± 0.09^G
	T_2	2.120 ± 0.29^G	1.000 ± 0.11^G
16/11/2016	T_1	2.077 ± 0.17^G	1.002 ± 0.08^G
	T_2	2.246 ± 0.26^G	1.005 ± 0.11^G
1/12/2016	T_1	2.205 ± 0.33^G	1.001 ± 0.13^G
	T_2	2.103 ± 0.19^G	1.001 ± 0.09^G

G represents good health condition.

4 | DISCUSSION

Any fishery must be managed effectively and this requires a thorough understanding of demographic factors like the link between length and weight (Dan-Kishiya 2013). The LWRs of this study revealed an allometric growth pattern for both mono-sex and mixed-sex Nile tilapia- similar to the study conducted in Ebonyi River (Ude *et al.* 2011). The *b* values in LWRs, that determines the growth pattern of the experimental species, indicated a negative allometric growth pattern in the present study. The negative allometric growth refers to the comparatively faster increase in length than body weight. The different water quality parameters (e.g. water temperature, dissolved oxygen) and the health condition are only a few of the variables that determine the growth rate of fishes like tilapia and might be responsible for the observed allometric growth (Islam *et al.* 2016; Aktar *et al.* 2020; Kunda *et al.* 2021; Bhuyain *et al.* 2022). Additionally, the negative allometric growth pattern of tilapia with *b* values ranging between 1.4 and 2.3 has been reported elsewhere (Dan-Kishiya 2013) that also supports our findings. However, this research reported a strong correlation between the length and weight of mono-sex tilapia.

The final average weight gain was significantly higher in mono-sex tilapia than mixed-sex tilapia. However, no significant difference was observed in weight gain until the 75th day of experiment. It is possible that the methyl testosterone hormone utilised for sex reversal had a positive impact on mono-sex tilapia growth. According to research, *O. niloticus* responds favourably to this hormone as a growth inducer (Kuwaye *et al.* 1993). However, no significant difference was observed between treatment groups at the end of the study. These results harmonise with the findings of Siddik *et al.* (2014) who stated a final weight gain of 141.45 ± 2.54 g and 107.60 ± 2.02 g in male mono-sex and mixed-sex *O. niloticus*. Comparatively faster growth in male mono-sex tilapia in this study is in-line with the findings of Chakraborty *et al.* (2011). However, a study by Deb *et al.* (2020) also reported no significant difference in the length-weight relationship between mono-sex and mixed-sex tilapia until 72nd days of the culture period due to hormonal impacts on growth, corroborative to our research findings.

Fish wellbeing can be evaluated using the condition factor, which indicates the strength and wellbeing of fish in their range of habitats (Ridha 2011). The findings of our research for *K* values were higher when compared to a study based in Koka Reservoir in Ethiopia (Asmamaw *et al.* 2019), which might be due to differences in culture conditions and geographical location. They also reported a better culture condition for male mono-sex culture than mixed-sex tilapia with *K* values of more than 2, whereas *K* values of less than 1.8 indicated poor culture conditions (Crab *et al.* 2009), which also support the present findings as well. These differences may be due to females' spawning conditions in mixed-sex tilapia culture conditions.

Moreover, the condition factor is also helpful for monitoring the feeding intensity, age and growth rates in fish (Ighwela *et al.* 2011). However, the range of relative condition factor was similar in both mono-sex and mixed-sex tilapia populations, indicating good health condition and well-being for the fishes. Moreover, the experimental cages of our study were equipped with covers to prevent losses of floating feeds escaping from the cages by the natural flow of water.

5 | CONCLUSION

This study concluded that there were no significant differences in the length-weight relationship between mono- and mixed-sex tilapia in cage culture systems from an open water body until 75-day of experimental period. However, the final weight gain changed significantly after 91 days of experimental duration. The results also showed a similar allometric growth pattern in both tilapia groups, even though comparatively higher growth was obtained in mixed-sex tilapia group. These findings suggested that mixed-sex *O. niloticus* will permit fish farmers to accomplish more body weight of fish within the short and similar culture duration to mono-sex tilapia. Therefore, farmers will be made aware of the mixed-sex tilapia culture, which will contribute more to the total fish production.

CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTION

SKB and BRD participated in the study design, carried out the experimental setup, data collection, writing manuscript, editing and review. SKM contributed to the study's design coordination, performed the statistical analysis, review and supervised the work. MK, MJU and PPB participated in the design, coordination, writing and editing manuscript. All authors read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

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

REFERENCES

Aktar MJ, Islam MJ, Barman SK, Kunda M (2020) Assessment of fish biodiversity in the Teesta River of Banladesh. Journal of Sylhet Agricultural University 7(2): 95–114.

Asmamaw B, Beyene B, Tessema M, Assefa A (2019) Length-weight relationships and condition factor of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae) in Koka Reservoir, Ethiopia. International Journal of Fisheries and Aquatic Research 4: 47–51.

Balcázar JL, Aguirre A, Gómez G, Paredes W (2006) Culture of hybrid red tilapia (*Oreochromis mossambicus* × *Oreochromis niloticus*) in marine cages: effects of stocking density on survival and growth. University of Zaragoza, Zaragoza, Spain.

Barman SK, Kunda M, Mazumder SK, Nahiduzzaman M, Barman PP, Das SK (2021) Fish-diversity in the Kura River of Bangladesh: patterns and threats. Malayasian Applied Biology 50: 1–14.

Bhat AA, Arafat MY, Parveen M, Bakhtiyar Y (2022) Comparative account on the length-weight and length-length relationships and condition factor of six cyprinid fishes from Dal Lake, Kashmir. Journal of Fisheries 10(3): 103202.

Bhuyain ASMSR, Barman SK, Hossain MM, Khan MMH, Mim KK, Mazumder SK (2022) Seasonal dynamics of heavy metal concentrations in water and fish from Hakaluki Haor of Bangladesh. Conservation 2(3): 473–484.

Chakraborty SB, Mazumdar D, Chatterji U, Banerjee S (2011) Growth of mixed-sex and monosex Nile tilapia in different culture systems. Turkish Journal of Fisheries and Aquatic Sciences 11: 133–140.

Crab R, Kochva M, Verstraete W, Avnimelech Y (2009) Bio-flocs technology application in over-wintering of tilapia. Aquacultural Engineering 40: 105–112.

Dan-Kishiya AS (2013) Length-weight relationship and condition factor of five fish species from a tropical water supply reservoir in Abuja, Nigeria. American Journal of Research Communication 1: 175–187.

Das UN, Jana P, Pahari T, Roy A, Dhara K (2018) Comparative study on growth performance and economics between GIFT and local varieties of *Oreochromis niloticus* (Linnaeus, 1758) reared in pond culture systems. International Journal of Pure & Applied Bioscience 6: 603–610.

Deb AR, Kunda M, Marine SS, Islam MJ (2020) Study on production performance and economic benefits between mixed-sex and mono-sex tilapia (*Oreochromis niloticus*). Journal of Fisheries and Aquaculture Research 5: 61–70.

Froese R (2006) Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology 22(4): 241–253.

Fulton TW (1904) The rate of growth of fishes. Twentysecond Annual Report, Part III. Fishes Board of Scotland, Edinburgh. pp. 141–241.

Githukia CM, Ogello EO, Kembenya EM, Achieng AO, Obiero KO, Munguti JM (2015) Comparative growth performance of male monosex and mixed sex Nile tilapia (*Oreochromis niloticus* L.) reared in earthen ponds. Croatian Journal of Fisheries 73: 20–25.

Ighwela KA, Ahmed A Bin, Abol-Munaf AB (2011) Condition factor as an indicator of growth and feeding intensity of Nile tilapia fingerlings (*Oreochromis niloticus*) feed on different levels of maltose. American-Eurasian Journal of Agricultural and Environmental Science 11: 559–563.

Islam MA, Islam MJ, Arefin S, Rashid A, Barman SK (2016) Factors affecting the fisheries biodiversity of Ratargul Swamp Forest of Sylhet district, Bangladesh. IOSR Journal of Environmental Science, Toxicology and Food Technology 10(1): 60–65.

Islam MA, Islam MJ, Barman SK, Morshed F, Marine SS (2015) Study on present status of fish biodiversity in wetlands of Sylhet district, Bangladesh. Agriculture, Forestry and Fisheries 4: 296–299.

Kunda M, Pandit D, Harun-Al-Rashid A (2021) Optimization of stocking density for mono-sex Nile tilapia (*Oreochromis niloticus*) production in riverine cage culture in Bangladesh. Heliyon 7(11): e08334.

Kuwaye TT, Okimoto DK, Shimoda SK, Howerton RD, Lin HR, ... Grau EG (1993) Effect of 17α-methyltestosterone on the growth of the euryhaline tilapia, *Oreochromis mossambicus*, in fresh water and in sea water. Aquaculture 113(1-2): 137–152.

Le Cren ED (1951) The length-weight relationship and seasonal cycle in gonad weights and condition in the perch (*Perca fluviatilis*). The Journal of Animal Ecology 20(2): 201–219.

Moniruzzaman M, Uddin KB, Basak S, Mahmud Y, Zaher M, Bai SC (2015) Effects of stocking density on growth, body composition, yield and economic returns of monosex tilapia (*Oreochromis niloticus* L.) under cage culture system in Kaptai Lake of Bangladesh. Journal of Aquaculture Research and Development 6(8): 1.

Ogello EO, Kembenya EM, Githukia CM, Aera CN, Munguti JM, Nyamweya CS (2017) Substitution of fish meal with sunflower seed meal in diets for Nile tilapia (*Oreochromis niloticus* L.) reared in earthen ponds. Journal of Applied Aquaculture 29(1): 81–99.

Ridha MT (2011) Evaluation of monosex culture of GIFT and non-improved strains of Nile tilapia *Oreochromis niloticus* in recirculating tanks. International Aquatic Research (Islamic Azad University, Tonekabon Branch) 3(3): 189–195.

Siddik MAB, Nahar A, Ahamed F, Hossain MY (2014) Overwintering growth performance of mixed-Sex and mono-sex Nile tilapia *Oreochromis niloticus* in the Northeastern Bangladesh. Croatian Journal of Fisheries 72: 70–76.

Thongprajukaew K, Kovitvadhi S, Kovitvadhi U, Preprame P (2017) Effects of feeding frequency on growth performance and digestive enzyme activity of sex-reversed Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758). Agriculture and Natural Resources 51(4): 292–298.

Ude EF, Ugwu LLC, Mgbenka BO, Nwani CD (2011) Evaluation of length-weight relationship of fish species of Ebonyi River, Nigeria. Nigerian Journal of Fisheries 8(1): 136–144.

Vasconcelos FR, Menezes RF, Attayde LJ (2018) Effects of the Nile tilapia (*Oreochromis niloticus* L.) on the plankton community of a tropical reservoir during and after an algal bloom. Hydrobiologia 817: 393–401.

SK Barman https://orcid.org/0000-0002-9011-1067
M Kunda https://orcid.org/0000-0002-7325-5851
SK Mazumder https://orcid.org/0000-0002-3604-2363
MJ Uddin https://orcid.org/0000-0001-7878-814X
PP Barman https://orcid.org/0000-0002-3468-1292