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Original Article

Length-length, length-weight relationship and condition factor of an ecological invader, *Cyprinus carpio* (Linneaus, 1758) from Manasbal Lake of Kashmir Himalaya, India

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Abstract
The common carp *Cyprinus carpio* is a well-known invasive species. A total of 472 specimens of *C. carpio* (8.6–35 cm, 10.5–1000 g) were collected from Manasbal Lake of Kashmir Himalaya for this study between March 2018 and February 2020. A strong correlation between the respective parameters of length-length and length-weight with r and R^2 values approaching to 1 in both. The regression analysis indicated negative allometric growth for both sexes. For female, b value ranged from 2.04 (in spring) to 2.80 (in summer) whereas for male, it varied from 1.99 (in spring) to 2.99 (in summer). The value of Fulton's (K) and relative (K_n) condition factors were greater than 1 in every season for both sexes which indicated that *C. carpio* population in the Manasbal Lake is in a good health condition and the water quality parameters along with other respective factors are favourable for successful thriving of this fish in the lake. The present study will be helpful to develop future strategies in terms of sustainable management of invasive *C. carpio* in the Manasbal Lake and similar water bodies.

Keywords: Allometric growth; biological invasion; common carp; correlation coefficient; coefficient of determination; management

1 | INTRODUCTION

The common carp *Cyprinus carpio* is the native species to Eastern Europe and Central Asia (Lever 1996), but commonly found in aquatic habitats from Europe to Asia and America to Australia as a result of successful invasion (FAO 2002; Koehn 2004; Galib and Mohsin 2011). Due to its fast-growing capability as well as adaptability to establish itself in any kind of environment, *C. carpio* is designated as an invasive species posing a great threat to native diversity (Zambrano *et al.* 2006; Weber and Brown 2009; Khan *et al.* 2016). Despite its invasive nature, the fish possess good nutritional value and acts as an important backbone of economy in many areas (Galib and Mohsin 2011; Mohsin *et al.* 2012). Therefore, it is necessary to manage this resource in a sustainable way. Study of fish population dynamics is one such aspect by which assessment of a fish stock is done in order to form management strategies (Bonfill 2005). Length-length and length-weight relationship form very important parameters which can be useful in understanding different factors affecting a given population. Length-length relationship finds its use mainly in studies of comparative growth

in a fish population which is necessary for framing management policies (Alam *et al.* 2012; Mousavi-Sabet *et al.* 2013). Length-weight relationship (LWR) forms an important aspect to know biological, physiological and ecological parameters and above all the life history pattern of a fish population (Aera *et al.* 2014). The LWR is a mathematical model equation which enables calculation of unknown variable among the two variables (Mir *et al.* 2012). There are many more important parameters which can be obtained through the analysis of LWR, as the general condition of a fish population, pattern of its growth, age as well as year class structure etc. (Moutopoulos and Stergiou 2002; Thomas *et al.* 2003; Froese 2006; Mekonnen *et al.* 2018). The important yield of LWR is the index of well-being i.e. the condition factor which governs the overall robustness of the fish samples and also the general health condition of a given fish population (Gulland 1983; Blackwell *et al.* 2000). Variation in the values of condition factor can also be useful in the study of seasonal changes occurring in the fishes along with rate of change of feeding potential and thus can be used to optimise the fishery production (Anibeze 2000; Sarkar *et al.* 2013).

Though most of the studies on LLR and LWR have been carried out for indigenous *Schizothorax* species and some aspect of length-weight relationship of *C. carpio* in different lentic and lotic water bodies of the Kashmir Himalaya (e.g. Shafi *et al.* 2012; Arafat and Bakhtiyar 2018, 2020; Wani *et al.* 2020), but the information regarding the LLR and different condition factors of invasive *C. carpio* in water bodies especially in Manasbal Lake of Kashmir Himalaya is scarce. Keeping in view the invasive nature of *C. carpio*, the present study was undertaken, so that it could serve as a baseline data for fishery biologists to frame proper management policies for such invasive fish species especially in the Manasbal Lake of Kashmir Himalaya.

2 | METHODOLOGY

2.1 Study area

The Manasbal Lake is located in the Ganderbal district, 30 km to the North of main Srinagar city (Figure 1) with geographical coordinates of 34°14′ – 34°15′N and 74°39′ – 74°41′E and an altitude of 1584 ma.s.l (Shafi *et al.* 2012; Naik *et al.* 2015). The main source of water of this lake is a large number of springs present within the lake at the bottom as well as in the surrounding areas. *Cyprinus carpio* was transported to Indian waters from Sri Lanka in 1939 as a part of game fishery and in Kashmir it was introduced in Dal and Manasbal lakes in 1956 from where it got spread to almost all the water bodies of the valley and due to its invasive nature resulting in decline of local Schizothoracine fish population (Foetdar and Qadri 1974; Qurashi *et al.* 2017).

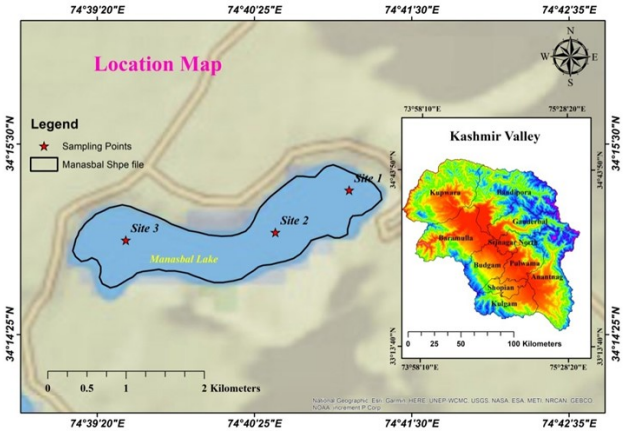

FIGURE 1 Map showing the location of Manasbal Lake and sampling sites.

2.2 Sample collection

Fish specimens were collected on the monthly basis for a period of two years from March 2018 to February 2020. A total of 472 fish specimens of *C. carpio* were collected (234 male and 238 females) from three sampling sites (Site 1–3, Figure 1) with the help of expert fishermen using cast net of mesh size 1.5 to 3 inches. Fishes were transported to Fish Biology and Limnology Research Laboratory, Department of Zoology, University of Kashmir for measurement of their total length (TL), standard length (SL) and fork length (FL) and total weight (TW) after wiping off moisture from the samples. The representative specimens of different lengths were fixed in 10% buffered formalin before long term preservation in 10% ethanol.

2.3 Estimation of Length-length relationship (LLR), length-weight relationship (LWR) and condition factors (K, K_n)

The TL, SL and FL of individual fish was measured with the help of a digital Vernier calliper (Aerospace, China; to the nearest 0.1 cm) right from the tip of snout up to the end of longest ray of caudal fin and TW was taken using a digital weighing balance (Kerro BL50001, India; to the nearest 0.1 g).

The LWR was estimated by the log transformation of regression equation,

$W = a L^b$ (Zar 1984) as; $\text{Log } W = b \text{ Log } L + \text{Log } a$ (Ricker 1975).

Where, W = total weight of fish in g; L = total length of fish in cm; a = intercept of the regression curve; and b = regression coefficient / growth coefficient.

The condition of the fish was calculated seasonally using the Fulton's condition factor equation as;

$K = (W / L^3) \times 100$ (Le Cren 1951; Froese 2006)

While the relative condition factor (K_n) was calculated using equation;

$Kn = W/aL^b$ (Le Cren 1951)

Where, K = Fulton's condition factor; K_n = Relative condition factor; W = total weight of fish in g; L = total length of fish cm; a = exponent describing the rate of change of weight with length; and b = growth coefficient.

The linear regression equations between the parameters TL vs FL, TL vs SL, and FL vs SL, was obtained by taking the overall length, standard length, and fork length respectively.

2.4 Data analysis

The statistical analysis was performed using computer package MS Excel-2016 and SPSS version 20. ANOVA was used to get the significant and non-significant difference among the values of growth coefficient and condition factor.

3 | RESULTS

The statistical parameters for LLR are presented in Table 1 for four representative seasons. The relationship between TL, SL and FL for both sexes of *C. carpio* were established and the value of coefficient of determination (R^2) was found close to 1. The study revealed that all the LLR parameters were highly significant ($p < 0.01$) and also the values of coefficient of correlation were approaching to 1 in all the specimens.

The statistical parameters for LWR of *C. carpio* including the regression equation, regression parameters a and b, 95 % confidence limits of a and b and the coefficient of determination (R^2) is depicted in Table 2. The values of b were found to be minimum in spring for both males and females (1.99 and 2.04) and maximum in summer (2.99 and 2.80) for both the sexes. Further the R^2 value was found to be high during all seasons with values ranging from 0.7 to 0.9 showing a high significance ($p < 0.01$) for all the related parameters.

TABLE 1 Length-length parameters of *Cyprinus carpio* in Manasbal Lake.

Seasons	Sex	Number	Equation	*a*	*b*	*r*
Spring	Female	68	TL = a+bSL	0.179	0.927	0.98
			FL = a+b SL	0.089	0.959	0.98
			TL = a+bFL	0.112	0.951	0.99
	Male	68	TL = a+bSL	0.151	0.960	0.98
			FL = a+b SL	0.073	0.980	0.99
			TL = a+bFL	0.085	0.974	0.98
Summer	Female	64	TL = a+bSL	0.126	0.972	0.99
			FL = a+b SL	0.028	1.063	0.97
			TL = a+bFL	0.214	0.863	0.97
	Male	63	TL = a+bSL	0.194	0.916	0.99
			FL = a+b SL	0.100	0.956	0.99
			TL = a+bFL	0.100	0.955	0.99
Autumn	Female	62	TL = a+bSL	0.188	0.921	0.99
			FL = a+b SL	0.083	0.971	0.99
			TL = a+bFL	0.113	0.944	0.99
	Male	48	TL = a+bSL	0.239	0.881	0.97
			FL = a+b SL	0.181	0.889	0.97
			TL = a+b FL	0.075	0.976	0.99
Winter	Female	44	TL = a+bSL	0.212	0.901	0.97
			FL = a+b SL	0.073	0.978	0.99
			TL = a+bFL	0.152	0.915	0.97
	Male	55	TL = a+bSL	0.189	0.924	0.88
			FL = a+b SL	0.149	0.917	0.98
			TL = a+bFL	0.014	1.028	0.92

TL, total length; FL, fork length; SL, standard length; *a*, intercept; *b*, slope; *r*, coefficient of correlation

The seasonal variation in K and K_n of *C. carpio* is depicted in Table 3 and Figure 2. The values of both K and K_n were found to be greater than 1 in all the seasons indicating that the fish was in a good condition. The value of K was found to be maximum (1.54 ± 0.48 for males and 1.49 ± 0.428 for females) during spring and minimum (1.34 ± 0.17 for males and 1.35 ± 0.24 for females) during autumn (Table 3). Similarly, for K_n the maximum value (5.20 ± 1.22 for males and 4.58 ± 1.05 for females) was found during spring and minimum value (1.96 ± 0.71 for males and 2.32 ± 0.82 for females) during summer. Both condition factors showed a decreasing trend from spring to summer and after that it again started increasing (Figure 2).

TABLE 2 Length-weight relationship parameters of *Cyprinus carpio* in Manasbal Lake.

Season	Sex	Length range (cm)	Weight range (g)	Regression equation	*a*	95% CI of *a*	*b*	95% CI of *b*	R^2
Spring	Male	12 – 28.5	25.6 – 383	Log W = 1.990Log L – 0.574	0.563	0.4 – 0.8	1.99	1.7 – 2.3	0.754
	Female	12 – 25.4	25.6 – 195	Log W = 2.042Log L – 0.653	0.52	0.4 – 0.7	2.04	1.8 – 2.3	0.811
Summer	Males	8.6 – 27.0	10.5 – 258	Log W= 2.998Log L - 1.867	0.155	0.1 – 0.2	3.00	2.7 – 3.3	0.882
	Female	9.4 – 27.0	12.2 – 229.3	Log W = 2.796Log L - 1.610	0.2	0.2 – 0.3	2.8	2.6 – 3.0	0.918
Autumn	Male	12.0 – 29.5	28.9 – 365.0	Log W = 2.751Log L - 1.559	0.21	0.2 – 0.3	2.751	2.6 – 3.0	0.941
	Female	13.0 – 31.0	20.3 – 441	Log W = 2.653Log L - 1.428	0.24	0.1 – 0.4	2.653	2.2 – 3.1	0.714
Winter	Male	12.5 – 28.0	33.0 – 289	Log W = 2.230Log L - 0.891	0.41	0.3 – 0.6	2.23	1.9 – 2.6	0.758
	Female	14.5 – 35.0	34.5 – 1000	Log W = 2.787Log L - 1.598	0.202	0.1 – 0.3	2.78	2.5 – 3.1	0.914

a, intercept; *b*, slope; R^2, coefficient of determination; CI, confidence limits.

TABLE 3 Seasonal variation in condition factors of *Cyprinus carpio* in Manasbal Lake.

Season	Sex	Fulton's condition factor (*K*)			Relative condition factor (K_n)		
		Min	Max	Mean ± SD	Min	Max	Mean ± SD
Spring	Males	0.66	2.73	1.54 ± 0.48	2.86	9.49	5.20 ± 1.22
	Females	0.66	3.09	1.49 ± 0.43	2.52	7.02	4.58 ± 1.05
Summer	Males	0.53	1.80	1.38 ± 0.26	0.45	3.72	1.96 ± 0.71
	Females	0.42	1.82	1.39 ± 0.23	0.65	3.98	2.32 ± 0.82
Autumn	Males	1.08	1.78	1.34 ± 0.17	1.16	4.74	2.51 ± 0.64
	Females	0.14	1.82	1.35 ± 0.24	1.44	5.21	3.01 ± 0.86
Winter	Males	0.51	2.56	1.34 ± 0.31	2.47	6.29	3.99 ± 0.82
	Females	0.93	2.33	1.40 ± 0.30	1.56	5.67	2.81 ± 0.91

Min, minimum; max, maximum; SD, standard deviation

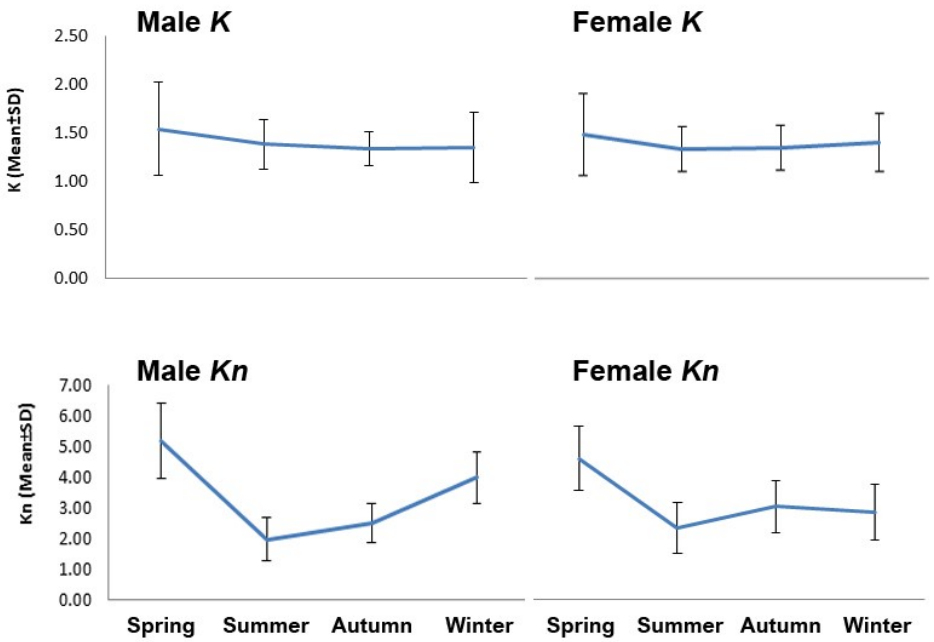

FIGURE 2 Seasonal variation in Fulton's condition factor (*K*, upper panel) relative condition factor (K_n, lower pannel) of males and females of *Cyprinus carpio* in Manasbal Lake.

4 | DISCUSSION

Length-length and length-weight relationship are important parameters in fish biology as both the relationships yield necessary information about the general condition, comparative growth patterns of fish as well as the trend followed by the fish population during its development (Le Cren 1951; Ricker 1975; Moutopoulos and Stergiou 2002). In fish biology such relationships are often used during inter conversion of length and weight data to yield the important characters like growth and condition of a fish (Le Cren 1951; Froese 2006; King 2007). Further the length-weight data can be used to estimate fish bio-

mass, changes in the life history patterns, analyse the population stock and the fish condition factor (Petrakis and Stergiou 1995; Moutopoulos and Stergiou 2002). Keeping in view the importance of the length-length and length- weight relationship in determining the biological aspects of a fish population this study was carried out to have a detailed knowledge of the same. In our study of LWR the correlation coefficient (*r*) was found to be high (0.9) indicating that *C. carpio* in Manasbal Lake is showing a linear increase in both length and weight during its growth. Our studies are in conformity with the findings of Ayoade and Ikulala (2007) and Aera *et al.* (2014). The ideal value of growth constant *b* is reported to be equal to 3 and if the value lies below 3 it is the representative of negative allometric growth and if it is greater than 3 it represents positive allometric growth (Srissuwantach *et al.* 1980; Jensen 1996). According to Ricker (1975) the optimal value of the growth coefficient *b* is 3, while Froese (2006) states that the ideal range of *b* value is 2.5 to 4, which is supported by many workers (Aera *et al.* 2014; Hamid *et al.* 2015). As our study was based on seasonal variation, it was reported that both males and females showed minimum *b* value (1.99 and 2.04) in spring which can be attributed to different factors like spawning pressure, less feed intake due to mature gonads and also physical factors like low temperature etc. thus showing a negative allometric growth during the spring. Our results are in conformity with the studies carried out by several others (e.g. Ayoade and Ikulala 2007; Sarkar *et al.* 2013; Shukla and Mishra 2017). The maximum *b* value was obtained in summer for both males and females (2.99 and 2.8) indicating negative allometric growth for both sexes. The findings are in accordance with others (e.g. Cox and Hinch 1997; Saylar and Benzer 2014; Kindong *et al.* 2018). The slight difference in b values of males and females may be attributed to the facts of numeral variation in fish specimens examined as well as general morphology and physiology of the fishes (Gerritsen *et al.* 2003).

In the study of LLR, the values were found to be highly significant ($p < 0.01$) and highly correlated with both coefficient of determination (R^2) and coefficient of correlation (*r*) values, both near to 1. Similar results were also reported by Mousavi-Sabet *et al.* (2013) for *Hemiculter leucisculus*.

Condition factor is the representative of degree of well-being of a fish population (Froese 2006; Rodriguez *et al.* 2017), and reflects the general physiological status of a fish which involves the affecting factors like availability of food, phase of gonad maturation and also the environmental variables (Nikolsky 1969). Thus, the condition factor is a well-known parameter regulating the health of fish species (Froese 2006), and it is known to be determined by a number of factors including the start of the maturation process, sex, spawning period, and environmental pressures such as pollution (Hoda 1987; Al-Daham and Wahab 1991; Doddamani *et al.* 2001; Devi *et al.* 2008). The values of *K* and K_n recorded during the present study were found to be greater than 1 in all the seasons both for males and females, which revealed that both sexes are growing in an ideal condition. In addition, no significant difference in *K* and K_n values between males and females was recorded. The maximum mean values of *K* in males and females was reported in spring (1.54 and 1.48 respectively) and minimum in autumn (1.34 and 1.35 respectively). Similarly, for K_n, the maximum mean values for both males and females were reported in spring (5.20 and 4.58 respectively) and minimum in summer (1.96 and 2.32 respectively). The increased value of condition factors during spring may be attributed to matured condition of gonads and preparation for spawning. After spawning or breeding season the condition factors go on decreasing because of spawning stress, as spawning is an energy demanding and stressful period that also affects immune functions (Kortet *et al.* 2003). Bagenal and Tsech (1978) put forth a hypothesis that heavier fish of a given length shows better condition. Another researcher established the criteria of analysing condition factor for Salmonid fish as, *K* = 0.80 (extremely poor), 1 (poor), 1.20 (fair), 1.40 (good) and 1.60 (excellent) (Barnham and Baxter 2003). Similarly, as per Morton and Routledge (2006) the fish condition criteria follows, *K* = 0.8 – 1.0 (very bad), 1.0 – 1.2 (bad), 1.2 – 1.4 (balanced), 1.4 – 1.6 (good) and ≥ 1.6 (very good). Applying these criteria to our study it was found that both males and females were in good condition which may be due to availability of abundant feed sources, less competition and better habitat conditions. Our results are supported by those of Gayanilo and Pauly (1997), Schneider (2000), Saliu (2001), Ahmed *et al.* (2013) and Syed *et al.* (2020).

5 | CONCLUSIONS

As plenty of research work has already proven that *C. carpio* is an invasive species affecting local fauna worldwide due to its characteristic features of rapid growth, numerous feeding options, and high fecundity rates, this study was undertaken to highlight some of the characteristic aspects of the same as length-length, length-weight relationship and condition factor from the Manasbal Lake. This study was done on purpose keeping in view the importance of the parameters in providing basic information about the well-being and growth condition of the fish. The study revealed that the fishes in the said lake are in a good condition indicating that the lake is very friendly to the survival of this specie in turn causing a great threat to native biodiversity.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

SA study design, field sampling, sample analysis and manuscript preparation; **MP** helped with the statistical analysis and manuscript preparation; **YB** research supervision, sample analysis and manuscript preparation.

DATA AVAILABILITY STATEMENT

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

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