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LENGTH-WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR OF GOLDEN MAHSEER (*TOR PUTITORA*) UNDER POND-REARED CONDITION IN SOUTHERN FOOTHILLS OF BHUTAN

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ABSTRACT: A study was conducted with the objective to establish the first ever length-weight relationship and evaluate the physical robustness of the endangered Golden Mahseer (*Tor putitora* Hamilton 1822) in Bhutan. The study samples were from populations reared in fertilized earthen ponds at National Research and Development Centre for Aquaculture (NRDCA), Gelephu. Data on total length and total weight of 120 juvenile and adult specimens of fish were collected in November, 2017. To enable simple linear regression analysis for estimating the coefficient of total length in describing total weight, the linear growth model ($ln\ W = ln\ a + b.\ ln\ L$) was used. An indicator of physical robustness was estimated using Le Cren's formula for relative condition factor (Kn) ($Kn = \frac{W}{\hat{W}}$). Length-weight relationships and relative condition factors were estimated separately for two different groups of juveniles, adult males, adult females and pooled data. The relationships between total weight and total length across groups and for the pooled data were highly significant at 99% significance level. The length-weight relationships and relative condition factors (mean values) were: ln W= -2.581+1.749 ln L and 1.044 for 9-month-old juveniles; ln W= -4.062+2.782 ln L and 1.025 for 13-month-old juveniles; ln W= -4.385+2.946 ln L and 1.066 for adult males; ln W= -5.420+3.195 ln L and 1.113 for adult females; and ln W=-3.979+2.822 ln L and 1.064 for pooled data.

Keywords: Golden Mahseer; length-weight relationship; pond; relative condition factor.

1. INTRODUCTION

Golden Mahseer (*Tor putitora* Hamilton 1822) is a freshwater fish belonging to the family Cyprinidae. It is reported to grow to a maximum size of 2.75 m length and 54 kg weight (wikipedia). Also, commonly called as the Putitor Mahseer and Himalayan Mahseer, the Golden Mahseer is an excellent game-fish, actively sought by recreational fishing enthusiasts for its remarkable fighting ability. It is also a prized food-fish. It is found in the waters of the Himalaya and south Asia, in countries like India, Nepal, Pakistan, Bhutan and Myanmar. The International Union for Conservation of Nature (IUCN) evaluates Golden Mahseer as an endangered fish. IUCN reports that the wild population of this fish has already declined by 50% and that it may decline further by even up to 80% as a result of habitat destruction and reproductive cycle disruptions caused by anthropogenic activities such as hydroelectric

power dam construction. There is an urgent need to initiate efforts to conserve Golden Mahseer to prevent it from becoming extinct in several locations across the range of its distribution (IUCN 2013).

Golden Mahseer occurs in several water bodies in Bhutan. It is generally considered to be the most important fish species of the country's aquatic ichthyofauna, outclassing all other fish species in terms of appearance and size. Major rivers like *Punatshangchhu* and *Mangdechhu* have traditionally been considered safe haven for Golden Mahseer. However, in recent years, with hydropower facilities being constructed on these rivers, it is believed that the fish's traditional routes for spawning migration therein and breeding and nursing grounds upstream have been undermined significantly.

This paper examines the Length-Weight Relationship (LWR) and relative condition factor of Golden Mahseer reared with daily supplementary feeding at 2% of total stock weight in fertilized earthen ponds at the NRDCA, Gelephu, Bhutan. LWR is an important biometric indicator that has gainful uses in fisheries management and research. It quantifies the relationship between the weight and length of fish and can therefore be used to estimate the weight of a fish corresponding to its length. For example, the length observations from underwater visual census methods can be converted into weight estimates for biomass estimation (Froese 1998). LWR also enables the measurement of the variation from the expected weight for length of individual fish or groups of fish as an indication of fatness, general wellbeing, gonadal development etc. (Le Cren 1951). LWR also has other important applications, such as to set yield equations (Beverton and Holt 1957). Several past studies have described the LWRs and the general wellbeing of Golden Mahseer from different waters (Islam et al. 2002; Johal et al. 2005; Atkore et al. 2007; Gandotri et al. 2008; Patiyal et al. 2013; Rawal et al. 2013; Ali et al. 2014; Khajuria et al. 2014; Naeem et al. 2014).

Relative condition factor is a robust indicator of the general wellbeing (condition) of fish. the relative condition factor enables distinguishing between and measuring separately the influences on condition of length and other factors such as environment, food supply and degree of parasitization (Le Cren 1951).

However, to date, no such studies have ever been conducted on Golden Mahseer occurring in the waters of Bhutan. The present study is the first ever analysis of LWR and relative condition factor of Golden Mahseer in Bhutan.

2. MATERIALS AND METHOD

2.1 Study site and samples

The study was conducted at NDRCA (26º52'7.68" N and 9º29'45.25"), Gelephu, Bhutan. The total length to the nearest centimeter (cm) and total weight to the nearest gram (g) of 120 Golden Mahseer were measured with a Vernier caliper and a high-precision digital weighing balance, respectively, in November, 2017. The study sample comprised 30 adult males, 30 adult females, 30 9-month-old and 30 13-month-old juveniles. The adult fish were collected from *Mangdechhu* in 2014 while the juveniles were the offspring of these adults produced at NRDCA. The fish were fed supplementary diet on a daily basis.

2.2 Computation of LWR and Relative condition factor (Kn)

To establish LWR, separately for adult males, adult females, 9-month-old juveniles and 13-month-old juveniles and for pooled data, the allometric growth model was used was: $W = aL^b$, where W= weight, L= length, a= constant and b= exponent (Le Cren 1951).

The allometric growth equation was log-transformed using natural logarithm to derive the linear equation model: $ln\ W = ln\ a + b.\ ln\ L$ (a and b were estimated by least square method).

To estimate the Relative Condition Factor (Kn), group-wise and for pooled data as with the LWR, Le Cren's relative condition factor was computed with the following equation. Relative condition factors (Kn) of individual fishes within the context of the groups they belong and in the context of the pooled data were calculated using their observed lengths and corresponding LWR equations.

$Kn = \frac{W}{\hat{W}}$ (where W= observed weight and $\hat{W}$= standard weight calculated using the estimated LWR).

The dataset was analyzed with the statistical software Stata Version 13.

3. RESULTS AND DISCUSSION

3.1 LWR

Table 1 presents the total length and total weight for groups and pooled data. While the smallest fish recorded during the study was 2.3 cm long and 0.32 g heavy, the largest recorded was 68.3 cm long and 3760 g heavy. The curvilinear relation between the total weight (TW) and total length (TL) is presented in Figure 1. The linear relationship between log-transformed total weight (lnTW) and log-transformed total length (lnTL) is presented in Figure 2. Figure 3 presents the scatterplot of the residuals from regressing lnTW on lnTL against lnTL, which showed no visible pattern to how the

Table 1: Total Length and Total Weight of sample groups.

Sample group	Total Length (cm)			
	Min	Max	Mean	SD[β]
9-month-old juveniles	2.30	05.20	03.52	00.62
13-month-old juveniles	12.10	27.0	19.52	03.71
Adult males	41.00	54.60	48.30	3.336
Adult females	48.30	68.30	56.75	04.76
Pooled data (N=120)	2.30	68.30	32.04	21.85

[β]Standard Deviation

residual varied with lnTL, thus, indicating that the model used in this study was correct.

The results of regressing lnTW on lnTL separately for adult males, adult females, 9-month-old juveniles and 13-month-old juveniles, and for pooled data are presented in Table 2. The mathematical forms of group-wise and pooled data LWRs, derived using the estimates for *a* and *b* are presented in Table 3.

Across groups and for the pooled data, the total length of Golden Mahseer was highly significant in explaining the variances in its weight. Except in the case of 9-month-old juveniles, the value of *b* for all other groups was within 2.5 to 4, thus, conforming to the observations of Hile and Martin (as cited in Le Cren 1951). The value of *b* was close to 3 for adult males and females, 13-month-old juveniles and the pooled data suggests that Golden Mahseer at NRDCA grows isometrically (where *b*=3) and equally in all directions as per Spencer's Cube law (as cited in Froese 2006). Our findings agree with those reported by several authors (Islam et al. 2002; Johal et al. 2005; Gandotra et al. 2008; Rawal et al. 2013; Ali et al. 2014; Khajuria et al. 2014). However, for the 9-month-old juveniles sample, *b* was estimated to be 1.749, which is outside the range observed by Hile and Martin (as cited in Le Cren 1951). This is consistent with the findings reported for Golden Mahseer juveniles in India (Atkore et al. 2007; Khajuria et al. 2014). A negative allometric growth of 0^+ year old Golden Mahseer was reported by Gandotra et al. (2008). In this study, the negative allometric growth observed for juveniles could be explained from two fronts. The negative allometric growth is probably due to the fish's natural growth pattern where weight does not increase as much as length. It could also be due to unsatisfactory growth of fish, resulting from inadequate food, parasitic infection, disease and unsuitable environmental conditions or a combination of these factors.

3.2 Relative Condition Factor (Kn)

The means of Kn for different groups of Golden Mahseer are presented in Table 4. The Mean Kn values were 1.066, 1.113, 1.044, 1.025 and 1.064 for adult males, adult females, 9-month-old juveniles, 13-month-old juveniles and pooled data, respectively, which indicates that on average, Golden Mahseer at NRDCA are in good physical condition. The supplementary diet provided to fish on a daily basis assured an environment with abundant food supply, which is reflected by proper growth and gain in physical mass of fish. Further, because the fish population was reared in confinement, its movement was substantially restricted, which may have enabled it to accumulate additional physical mass, compared to a population of comparable attributes in the wild where movement is not restricted and the fish has to spend a considerable amount of energy on foraging. The Golden Mahseer's satisfactory physical condition at NRDCA may partly be attributed to the water being maintained at optimum quality in terms of content of dissolved oxygen, pH, alkalinity, carbon dioxide, etc., and the fish being protected from undue stress from illegal fishing activities and other factors that routinely disturb the comparable populations in the wild.

For the 9-month-old juveniles, the Kn value of 1.044 indicated a negative allometric growth pattern, which could possibly be due to natural growth pattern. The Kn values of this study are similar to those reported by Islam et al. (2002) for pond-reared Golden Mahseer.

4. CONCLUSION

This study established separately the first ever LWRs for adult males, adult females, two independent groups of juveniles and pooled sample of the endangered Golden Mahseer in Bhutan. In spite of the samples being derived from pond-reared populations, the findings of this study should serve as baseline for further similar studies in the country, particularly for Golden Mahseer populations in *Mangdechhu* river basin.

The physically robust population of Golden Mahseer should enable its use as benchmarks in assessing the robustness of cultivated and wild populations of Golden Mahseer.

However, the sample size in this study is rather small and it may not have represented the population adequately. Therefore, further studies for similar groups of Golden Mahseer with larger sample sizes and randomized sampling procedures are recommended for comparison with the findings of the present study.

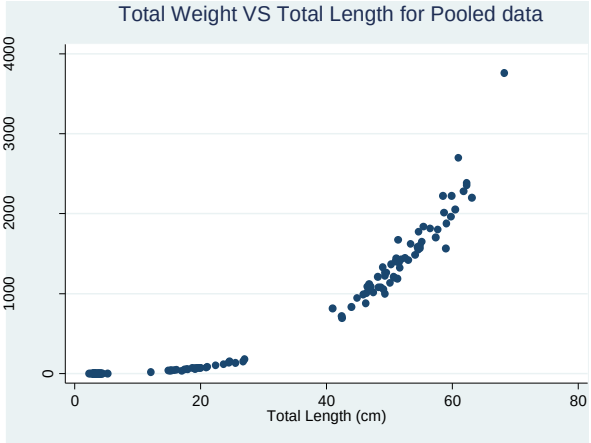

Figure 1: Scatterplot for pooled data of natural log of total weight against log of total length.

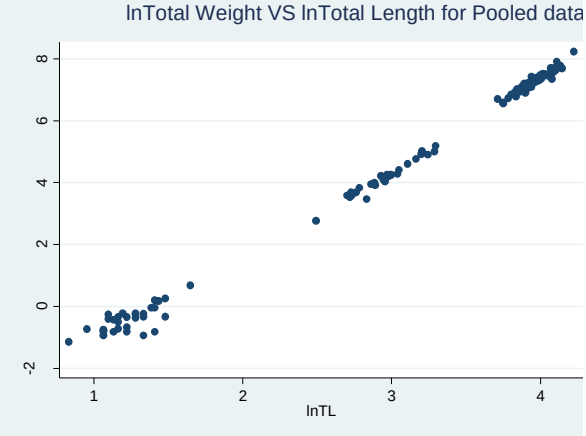

Figure 2: Scatterplot for pooled data of total weight against total length.

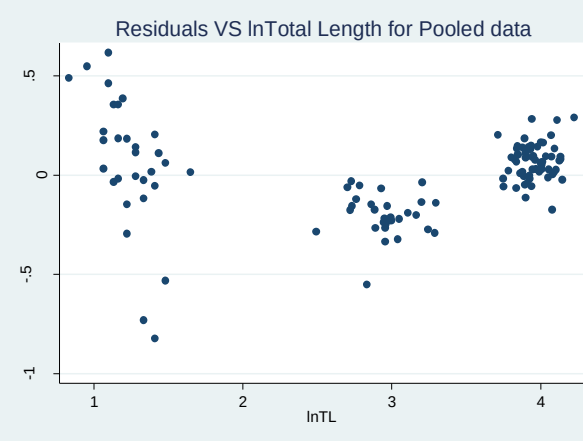

Figure 3: Scatterplot for pooled data of residuals against natural log of total length.

Table 2: Coefficient estimates from regressing natural log of Total Weight on natural log of Total Length

Sample Group	Constant	ln (Total Length)	R^2
9-month-old juveniles	-2.581*** (0.378)	1.749*** (0.301)	0.545
13-month-old juveniles	-4.062*** (0.312)	2.782*** (0.105)	0.961
Adult males	-4.385*** (0.911)	2.946*** (0.235)	0.848
Adult females	-5.420*** (0.820)	3.195*** (0.203)	0.898
Pooled data (N=120)	-3.979*** (0.057)	2.822*** (0.017)	0.995

Standard errors are reported in parentheses.
***p≤0.001.

Table 3: Length-Weight relationships derived using coefficient estimates from regressing natural log of Total Weight on natural log of Total Length

Sample Group	Regression Equation (ln W=ln a +b. ln L)	Allometric Growth Equation ($W = aL^b$)
Adult males	lnW=-4.385+2.946 lnL	$W=0.012\ L^{2.94}$
Adult females	lnW=-420+3.195 lnL	$W=0.004\ L^{3.20}$
9-month-old juveniles	lnW=-2.581+1.749 lnL	$W=0.075\ L^{1.75}$
13-month-old juveniles	lnW=-4.062+2.782 lnL	$W=0.017\ L^{2.78}$
Pooled data	lnW=-3.979 +2.822 lnL	$W=0.018\ L^{2.822}$

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Table 4: Descriptive statistics of group-wise and pooled relative condition factors.

Group	n	Relative Condition Factor (Kn)			
		Min.	Max.	Mean	SD[β]
1. Adult males	30	0.878	1.299	1.066	0.093
2. Adult females	30	0.859	1.332	1.113	0.100
3. 9-month-old juveniles	30	0.497	1.502	1.044	0.260
4. 13-month-old juveniles	30	0.714	1.215	1.025	0.104
Pooled data	120	0.455	1.926	1.064	0.228

[β]Standard Deviation

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