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Pre- and post-spawning condition descriptors for the Indian major carp, *Cirrhinus mrigala*

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Popularly known as mrigal, *Cirrhinus mrigala* (Hamilton 1822) is one of the important aquaculture species in India. Besides catla (*Gibelion catla*) and rohu (*Labeo rohita*), mrigal belongs to the group of carps collectively known as the Indian major carps (IMC). Mrigal production was 5.7% (of 3.59 million metric tonnes) during 2017 (FAO 2019) in India. In most commercial carp hatcheries, the three IMC species are spawned simultaneously during the monsoon season. Much is known about the growth and/or grow out performance of mrigal under various aquaculture production systems. Little is known about the GSI (gonadosomatic index) and the sex-specific pre- and post-spawning length-weight relationships (LWRs) and/or weight-weight relationships (WWRs) of the species from commercial hatcheries, which were investigated in the present study.

The study was conducted at the Dhom Fish Seed Production Center of Government of Maharashtra, India during July, 2019. The IMC species, *Cirrhinus mrigala* (Hamilton 1822) was maintained in the broodstock ponds at the hatchery site alongside other IMCs namely catla (*Gibelion catla*) and rohu (*Labeo rohita*). The brood fish were fed with a diet prepared with combination of groundnut oil cake and rice bran in 7:3 proportion fortified with 2% vitamin mineral mixture and fed at 3-4% of body weight two times a day (Aga *et al*. 2017). Given the general difficulties associated with repetitive sampling of fish from the large broodstock ponds (~ 2000 m^2), the weight-length sampling was conducted while the selected brood fish were introduced into the circular spawning pool individually (from the hapa confinement within the pool) and prior to the fish being administered the hormonal preparations. In one set for induced spawning, a total of 25.753 kg mrigal female fish were used. A commercial preparation of inducing hormones SPAWN PRO (Salmon gonadotropin releasing hormone analogue and domperidone) was used as an inducing agent. Male and female fish were given single injection of spawn-pro at the rate of 0.1 to 0.2 ml per kg and at the rate of 0.3 to 0.4 ml per kg weight, respectively. Total length (TL) was recorded to the nearest centimeter and body weight (BW) to the nearest gram for each individual male and female specimen using standard methods. Mean differences in the pre- and post-spawning BW (body weight) were treated as the effective reproductive output or the GSI (gonadosomatic index, %). Data on 18 randomly sampled male-female pairs each, were obtained during the pre- and post-spawning sampling phases covering two spawning cycles.

Data were analyzed for differences in the mean length-weight of the pre- and post-spawning fishes using a paired t-test. The LWRs and WWRs were computed and statistically compared for differences in their slopes. Ordinary least square (OLS) regression was conducted to compute the LWRs/WWRs; standard major axis (SMA) regressions were performed for understanding the BW–BW and TL–TL relations assessed separately for the males and females in their pre- and post-spawning phases. Statistical significance was concluded at $\alpha = 0.05$.

Sampled males and females ranged from 42–55 cm and 39–54 cm in TL and from 0.83–1.46 kg and 0.52–1.35 kg BW, respectively. In one set, for induced spawning, a total of 25.753 kg rohu fish was used. Spawning took place 8 to 10 h after injection. In induced spawning, using inducing agent Ovaprim (Rokade *et al.* 2006) had reported similar duration for spawning. Total eggs produced were 28,92,551. Relative fecundity was found to be 1, 12,319 eggs per kg weight of fish. Fertilization rate for mrigala fish was found to be 84.66%. This data is similar to the relative fecundity and fertilization in mrigal and other carps (Rokade *et al.* 2006, Iqbal and Kausar 2009). Descriptive statistics [(mean, min, max, standard error of mean (S.E.), and the coefficient of variation (C.V.)] for the length-weight data have been given in Table 1. Differences in BW (and TL) of the pre-spawning (initial) and post-spawning (final) males and females have been outlined (Table 2).

These differences also indicate the effective reproductive output, i.e. reduction in BW due to spawning or GSI for the two sexes. Accordingly, the maximum post-spawning

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Table 1. Mean total length (TL, cm) and body weight (BW, g) of initial (pre-spawning) and final (post-spawning) stage *Cirrhinus mrigala* (n = 18)

Parameter	Pre-spawning				Post-spawning			
	Male		Female		Male		Female	
	TL	BW	TL	BW	TL	BW	TL	BW
Mean	46	1.10	44	1.02	47	0.99	44	0.81
S.E.	0.57	0.03	0.72	0.03	0.80	0.03	0.82	0.04
Min	42	0.90	39	0.83	42	0.83	41	0.52
Max	53	1.46	53	1.32	55	1.31	54	1.35
C.V.	5.23	13.22	6.94	13.74	7.27	11.76	7.92	22.72

Table 2. Initial (pre-spawning) and final (post-spawning) length-weight differences in *Cirrhinus mrigala* (paired *t*-Test) and GSI (or reproductive output)

Parameter	Gender	Initial	Final	Absolute difference *(4 – 3)*	p-value	Reproductive output		
						g	g/Kg	GSI
1	*2*	*3*	*4*	*5*	*6*	7	8	9
TL (cm)	Male	46	47	1	0.3282		–	
	Female	44	44	0	1.0000		–	
BW (g)	Male	1.10	0.99	0.11	0.0208	115	105	10.5
	Female	1.02	0.81	0.21	0.0052	208	204	20.4

weight reduction was recorded in the females (20.4%) as compared to males (10.5%). While, both sexes displayed a significant reduction in their post-spawning weight based on the t-test ($p < 0.05$), the pre- and post-spawning lengths were found to be identical ($p > 0.05$) (Table 2). As expected, the pre- versus post-spawning LWRs and the LLRs did not differ significantly for males and females ($p > 0.05$); the WWRs returned significant results in the pre- and post-spawning females ($p < 0.05$) (Table 3).

The present study was undertaken to understand the pre- and post-spawning changes occurring in the body weight, the LWRs and the WWRs in the males and females of *Cirrhinus mrigala* maintained as brood stock in a typical IMC hatchery. Although, mrigal attains maturity at about 35 cm TL or roughly at about 1 kg BW (Hanumantharao 1971), brood stock with higher BWs are preferred in most hatcheries across India. The mean pre-spawning male-female weights in the present study were 1.46 ±0.03 and 1.32 ±0.03 kg, respectively based on a sample size of 18 pairs. Instead of computing the GSI in the conventional manner via dissecting the individual fishes, the per cent reduction in the mean BW of the post-spawning individuals was treated as the GSI in the present case. Accordingly, an effective GSI of 10.5% and 20.4% was recorded respectively for the males and females. While the male GSI in mrigal has not been reliably defined, two records on female GSI were found with almost matching values of 20.67% (Prasad *et al.* 2018) and 16.45% (Iqbal and Kausar 2009). Given the large reduction in the pre- to post-spawning weights, the mean BWs differed significantly for both sexes based on paired t-test ($p < 0.05$). However, and entirely as expected, the mean pre- and post-spawning TL returned identical means for both males and females ($p > 0.05$) indicating that the sampling protocol adopted in the study was appropriate.

The OLS regression revealed no differences in the slopes '*b*' and/or the intercepts '*a*' of the pre- and post-spawning male-female LWRs ($p > 0.05$). However, a unique phenomenon was observed of the opposing trends in the slope '*b*' of the males and females LWRs. In males,

Table 3. Length-weight, weight-weight, and length-length relationships of pre- and post-spawning *Cirrhinus mrigala* (n = 18)

Gender	Status	*a* (95% CI)	*b* (95% CI)	Slopes *b1* = *b2* (p-value)
		Ordinary Least Square (OLS) regression		
Male	Pre	-3.422 (-4.057; -2.228)	2.0831 (1.359; 2.463)	> 0.05
	Post	-1.3801 (-1.995; -0.5047)	0.8210 (0.3047; 1.192)	
Female	Pre	-2.6533 (-3.378; -1.844)	1.6186 (1.127; 2.064)	> 0.05
	Post	-4.2546 (-5.272; -2.27)	2.5297 (1.315; 3.142)	
		Standard Major Axis (SMA) regression: Weight-weight		
Male	Pre vs. Post	0.0246 (-0.0121; 0.1112)	-0.8793 (-3.073; -0.383)	0.613
Female	Pre vs. Post	-0.0889 (-0.133; -0.0438)	-1.6151 (-2.353; -0.3509)	0.040
		Standard Major Axis (SMA) regression: Length-length		
Male	Pre vs. Post	4.0179 (1.834; 10.41)	-1.4134 (-5.269; -0.0966)	0.177
Female	Pre vs. Post	3.4888 (1.154; 4.76)	-1.1235 (-1.895; 0.2999)	0.639

'*b*' decreased from 2.0831 to 0.821, while it increased in females from 1.6186 to 2.5297 post-spawning. This could partly be explained such that the smaller males were found to be in a better 'condition' than the larger ones with a reverse situation in case of females (Froese 2006). In a similar manner, the larger females were in a relatively better condition given their higher GSI or fecundity as compared to smaller and/or lighter females. This observation is entirely true given: (a) the linear relationship of fecundity to weight in females, and (b) the large or voluminous nature of ovaries (as compared to the testes) in the mature or ripe females. There is a caveat, however, on the observed changes in the slope as follows. Unlike the conventional LWRs, which are obtained based on length-weight data covering the maximum size range of a species, the present LWRs were generated using only the mature individuals belonging to a narrow size range of 39–55 cm (TL) and 0.52–1.46 kg (BW). The proposed LWRs, therefore, should not be treated as the conventional LWRs. Nonetheless, they serve the intended purpose here in this study.

The unique observations on the prevalence of inverse trends in the male and female LWR slopes need further validation using higher number of data points on the same species and/or other IMC or cyprinid species maintained in commercial hatcheries for breeding purpose. Also, the possibility of the observed trends being an artifact of random selection cannot be ruled out. It is a fact that the commercial IMC hatcheries in India generally resort to simultaneous spawning of the three IMCs namely catla, rohu, and mrigal at any given instance. Thus, tagging of individual spawners is not commonly practiced (besides tagging being highly stressful). Therefore, randomly selected (i.e. different males and female pairs) were used for observing the pre- and post-spawning differences, especially in BW. Such an artifact, if one actually exists, can be eliminated by conducting pair-wise separate spawning trials using fixed pair(s). However, the aim of the present study was to capture the actual differences as encountered during routine hatchery operations (as opposed to the differences that may occur under planned or experimental studies).

SMA (standard major axis) regression was used to test the classical pre- and post- spawning changes in the weight (and length) of mrigal. SMA assumes both the 'x' and 'y' variables (pre- and post-spawning weights and/or lengths in this study) to be independent of each other and thus offers the most appropriate comparisons (besides the paired *t*-Test) in the defined situation. The post-spawning weight reduction of 20.4% in females constituted as a significant difference as compared to the pre-spawning BW with a negative slope of b = -1.6151 ($p < 0.05$). BW reduction of 10.5% (b = -0.8793) in the males was found to be insufficient to statistically significant ($p > 0.05$). High CV in the weight measurements to a tune of about 12–23%, also could lead to statistically inconclusive differences for such (random) comparisons. However, the paired t-test has already confirmed significant weight reduction in the pre- and post-spawning males too ($p < 0.05$). Again, as expected, the pre- and post-spawning SMA regressions returned identical trends in both the male and female LLRs ($p > 0.05$). All the length-length comparisons conducted in the study using the paired *t*-Test, and the OLS and SMA regressions invariably returned identical initial and final profiles ($p > 0.05$). These results have significance with respect to the sampling protocol followed. In a way, the results validate that the random sampling that was presently resorted to was truly scientific and absolutely random. This could be evidenced from the similar length-length-based statistical profiles, which have served their sole purpose of internal validation in the study.

Overall, and as expected, it can be concluded that the Indian major carp *Cirrhinus mrigala* undergoes significant post-spawning weight reductions under commercial hatchery conditions and under the stimulus of induced breeding. The extent of this reduction observed is the GSI of the species, which for the males and females was 10.5% and 20.4%, respectively. To our knowledge, this is the first instance where the GSI of an IMC has been investigated and reported from the broodstock used at a commercial circular hatchery. Observed reverse trends in the LWR slopes in the pre- and post-spawning males and females demand further investigations.

SUMMARY

Mrigal or *Cirrhinus mrigala* (Hamilton 1822) is one of the important aquaculture species in India. During 2017, mrigal contributed 5.7% to the aquaculture production of India. The present study was undertaken to describe the hatchery-level pre- and post-spawning condition, i.e. weight changes in the length-weight relationships (LWRs) and the weight-weight relationships (WWRs) associated with the two phases for the mrigal males and females used as broodstock from a commercial IMC hatchery. For the 18 pairs of individuals sampled, the TL (total length) ranged from 42–55 cm and 39–54 cm, and the BW (body weight) from 0.83–1.46 kg and 0.52–1.35 kg respectively for males and females. The GSI was recorded at 10.5% for males and 20.4% for females. The pre- and post-spawning weights differed significantly in both sexes based on paired t-test. Trends in the LWR and weight-weight slopes have been discussed in the article.

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