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Comparative study on seasonal change in physiological conditions in two different age groups of male Amur common carp (*Cyprinus carpio haematopterus*)

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Abstract
Physiological condition factors were measured in two different age groups male Amur common carp of during summer, autumn, winter and spring seasons in order to understand the relationship associated with their reproduction stages. Fulton's condition factor (K), somatic condition factor (Ks), hepatosomatic indices (HSI) and gonadosomatic indices (GSI) of male fishes were measured. Significant differences (p<0.05) were observed for both age groups in relation to age, seasons and interaction (age and seasons) for GSI, HSI, K and Ks level. Levels of GSI, HSI, K and Ks were higher in 2+ year's age group male as compared to 1+ year's age group in all four seasons. Pearson's correlations (p<0.01) showed a significant positive correlation of GSI with K and Ks and also between K and Ks. A significant negative correlation was observed between HSI with GSI and Ks. The physiological indices observed in 1+ and 2+ year's age Amur common carp indicated the presence of developed/mature gonads throughout the year with two major peaks – one in spring and other in the summer season. Higher age groups (2+ years) had higher index value, which signified their higher reproductive potential than younger (1+ year) age group.

Keywords: Amur common carp, physiological indices, seasonal

Introduction
Common carp (*Cyprinus carpio*, Linnaeus, 1758) is one of the oldest domesticated and mostly widely cultured fish species in the world FIGIS, 2011) [11] belonging to the Cyprinidae family and considered as the largest family freshwater fishes. The erstwhile amur wild carp is an ancient form that originated from the Asian carp centre (Amur-China type of wild carp, *Cyprinus carpio haematopterus*) and spread to the water bodies of Western Asia. The relevance of physiological studies relies on the influence of body conditions on the performance of the organism with species having a relatively healthier physiological condition being considered to have improved fitness for activities such as reproduction, migration etc (Brosset *et al.*, 2015a & b) [4, 5]. There are numbers of simple condition-based indices for assessing physiological conditions of an organism which are relatively easy to use requiring minimal training and usually cost effective thus making it more attractive to the monitoring agencies and widely used in fisheries management. These indices tend to be relatively insensitive to short-term (i.e., acute) changes in environmental conditions making it favourable tool for seasonal based studies. Considering the physiological, sex, age group and seasonal changes associated with the pre- and post-reproduction, the following study was undertaken on Amur common carp during four different seasons.

Material and Methods
Experimental fish were collected and segregated from hatchery breed Amur common carp from experimental fish pond and held in two separate groups designated as Pond A (for 1+ year's old group) and Pond B (for 2+ years' old groups) in two earthen pond. The fishes were fed once daily @ 3% body weight with supplementary pelleted diet containing 25% protein till July after which 1:1 ratio soya bran and mustard oil cake at the same ratio due to shortage of pelleted feeds. The experimental site is located in Tarai region of Shivalik range of the Himalayas having sub-tropical climatic condition characterized by very hot, humid and dry summer and very cold winter. The monsoon period falls between mid of June till the end of September. Clove oil (Velisek *et al.*, 2005) [31] was used to anaesthetise prior to experimental procedure.

Condition factor

Comparing the relative length and weight of an individual or groups can provide the information on general well-being and change associated with the reproduction and gonad development of the species. Fulton's condition factor (K) (Fulton, 1904) [12] and somatic condition factor (Ks) of male fishes were calculated from the individual fishes as follows:

$$\text{Condition Factor (K)} = \frac{\text{Weight (g)}}{\text{Length (g)}^3} \times 100$$

$$\text{Somatic Condition Factor (Ks)} = \frac{\text{Body Weight (g)} - \text{Gonad Weight (g)}}{\text{Lenght}^3\ \text{(cm)}} \times 100$$

The factor 100 is used to bring K and Ks value close to unity.

Organosomatic indices

Liver, gonads and the viscera of the individual male were removed and weighed to the nearest measurement. The hepatosomatic indices (HSI) gonadosomatic indices (GSI) were expressed as below:

$$\text{HSI} = \frac{\text{Wt. of liver (g)}}{\text{Total body wt. (g)}} \times 100$$

$$\text{GSI} = \frac{\text{Wt. of the gonad (g)}}{\text{Total body wt. (g)}} \times 100$$

Result and Discussion

Table 1: Physiological Indices of 1+ and 2+ Year's old Male Amur Common Carp

Age Groups	Indices	Summer	Autumn	Spring	Winter
2+	GSI	12.53±0.78	6.36±0.24	8.11±0.76	15.24±1.09
	HSI	1.18±0.09	1.67±0.11	1.26±0.07	0.91±0.15
	K	1.75±0.06	1.58±0.03	1.66±0.03	1.82±0.01
	Ks	1.53±0.07	1.48±0.03	1.52±0.03	1.54±0.02
1+	GSI	5.45±0.23	2.73±0.25	4.09±0.21	12.25±0.58
	HSI	1.73±0.08	1.84±0.17	1.29±0.14	1.12±0.08
	K	1.53±0.08	1.29±0.04	1.41±0.04	1.73±0.07
	Ks	1.44±0.07	1.25±0.04	1.35±0.04	1.52±0.06

[Data are given as mean±SEM (n=5)]

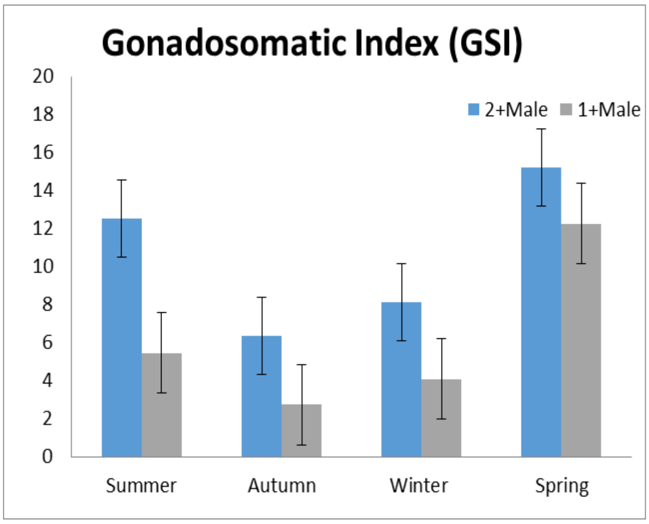

Fig 1: GSI of 2+ and 1+ years old

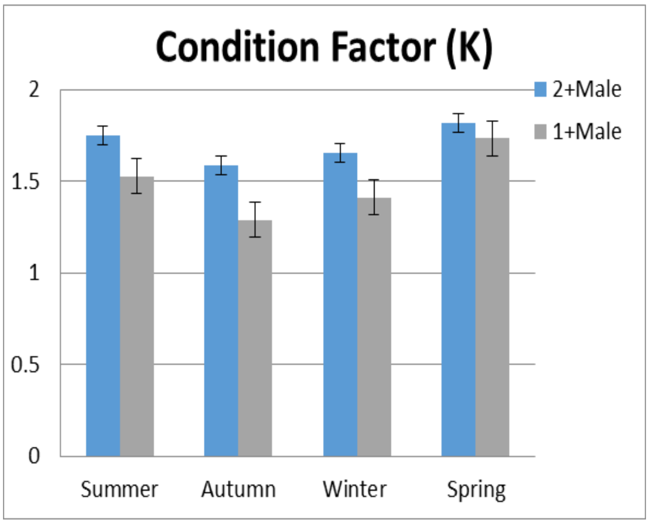

Fig 3: K value of 2+ and 1+ years old

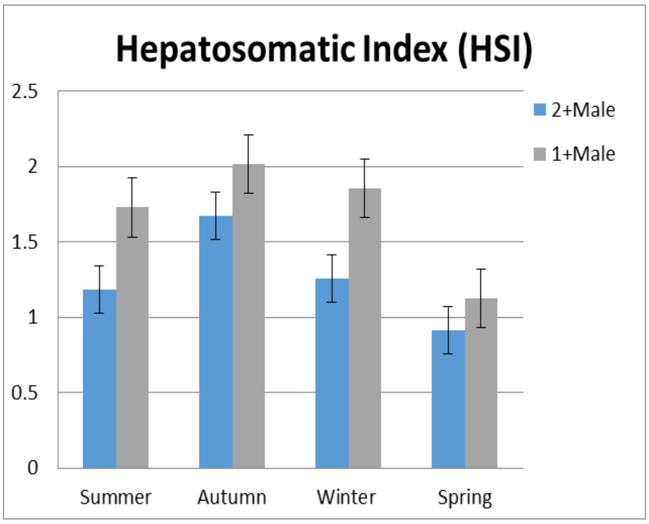

Fig 2: HSI of 2+ and 1+ years old

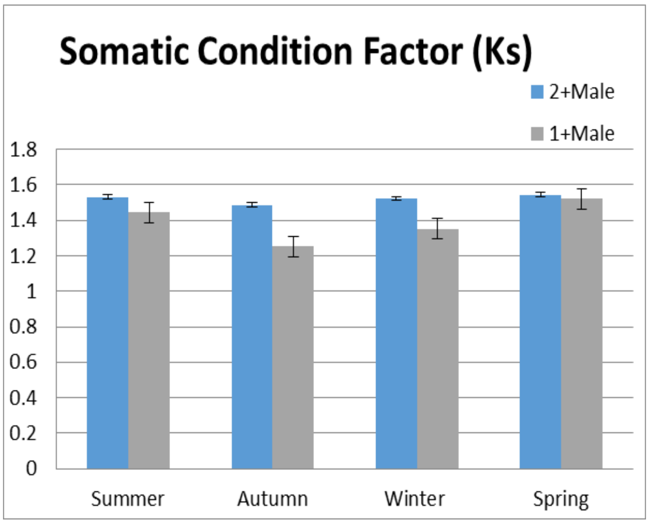

Fig 4: Ks value of 2+ and 1+ years old

Observations on physiological indices (GSI, HSI, K and Ks) of 1+ and 2+ year's male age groups in four different seasons are shown in Table 1. Observations on GSI, K and Ks in both age groups showed similar trend with highest level in spring season, which decreased in summer and reached to the lowest level in autumn with slight recovery in winter season. Hepatosomatic index in both age groups showed highest level in autumn season, which decreased in winter and reached to the lowest level in spring followed by slight increase in summer season. Significant differences ($p<0.05$) were observed for both age groups of Amur common carp in relation to age, seasons and interaction (age and seasons) for GSI, HSI, K and Ks level. Levels of GSI, HSI, K and Ks were higher in 2+ year's age group as compared to 1+ year's age group in all four seasons. Pearson's correlations ($p<0.01$) showed significant positive correlation of GSI with K and Ks and also between K and Ks. Significant negative correlation were observed between HSI with GSI and Ks.

In the present study, GSI level in both 1+ and 2+ year's age groups of Amur common carp was high throughout the study period but showed significant seasonal variations with high level in spring followed by summer season. This indicates that gonads in Amur common carp remained active throughout the year with major peak in spring season coinciding with the main spawning season. Next minor peak in summer/monsoon signifies the low spawning activity level during that period. Abassi *et al*., (2011) [1] reported high level of GSI during the month of May and another highest level during mid-August month that suggested about multiple spawning behaviour of *Cyprinus carpio* dependent upon environmental factors. Seasonal changes in GSI level in relation to reproductive activities have been reported in *Sciaenops ocellatus* (Craig *et al.,* 2000) [7], *Tinca tinca* (Pinillos *et al.,* 2003) [20], Japanese Dace-*Tribolodon hakonensis* (Ma *et al.,* 2005) [18], spotted murrel-*Channa punctatus* (Basak *et al.,* 2016) [2] and *Capoeta trutta* (Eroğlu and Şen, 2017) [10]. Inverse correlation between GSI and HSI are indicative of role of liver in gonadal development and energy mobilisation for the same. Role of liver in energy mobilization from liver and other energy reserves for gonadal development resulting in lowering of HSI have been reported in *Heteropneustes fossilis* (Singh and Singh, 1979) [24], *Cirrhinus mrigala* (Singh and Singh, 1984) [27], *Pagrus auratus* (Scott and Pankhurst, 1992) [22], *Clarias batrachus* (Singh and Singh, 1983; Hussain and Singh, 2004) [26, 13], *Notopterus notopterus* (Sudarshan and Kulkarni, 2013) [29], *Mystus vittatus* (Sreevalli and Sudha, 2014) [28] *Cyprinus carpio carpio* (Vazirzadeh *et al.,* 2014) [30] and *Tilapia mossambica* (Satheesh and Kulkarni, 2016) [21].

Seasonal variations of HSI levels in both 1+ and 2+ year's age group observed during the present study showed higher HSI level in 1+ year as compared to 2+ year's age group, which might be due to proportionate transfer and mobilisation of more energy for reproductive processes in 2+ year's age group, as indicated by higher GSI level. The relationship between HSI and energy reserves is seasonal and highly variable depending on feeding, growth period and reproductive activity as reported in three-spined stickleback (Chellappa *et al.,* 1995) [6], brown bullheads (Yang and Baumann, 2006) [33], *Cyprinus carpio* (Desai and Singh, 2009) and whitefish (*Coregonus muksun* and *Coregonus lavaretus*) (Borvinskaya *et al.*, 2016) [3].

Observations on K levels in both age groups showed seasonal variations with 2+ years having higher level than 1+ year's age group. This might be an indication of better overall health conditions in older groups with better physiological performances like reproduction as the species ages. An increase in K level from pre-spawning phase to gonadal maturation and decline after post-spawning have been reported in *Notopterus notopterus* by Shankar and Kulkarni (2014) [23]. For mature fish declined in the K level may be correlated with gonadal development and spawning behaviour, since substantial amount of energy gets invested during the reproductive period of fish life cycle (Jobling, 1995) [14]. Changes in the K level have been reported in different fishes in relation to their reproductive cycle - *Monopterus cuchia* (Narejo *et al.,* 2002) [19]. Other factors like seasonal factor - *Acrossochilus haxagonolepis* (Dasgupta, 1988) [8], physico-chemical factors - *Daysciaena albida* (Cuv.) and *Gerres filamentosus* (Cuv.), age - *Labeo dussumieri* (Kurup and Samuel, 1987; Kurup, 1990) [17, 16], physiological status - Carangid *Alepes para* (Kalita and Jayabalan, 1997) [15] etc have also been reported to influence the K value. The somatic condition factor (Ks) in the present study the pattern similar to K level in both 1+ and 2+ year's age groups of Amur common carp. Seasonal variations in Ks level during breeding season due to changes in the gonadal maturity were reported in *Gastersteus aculatus* (Wootton *et al*., 1978) [32]. Seasonal changes in K and Ks value due gonadal maturity and reproductive cycle was observed in *Channa punctatus* (Singh, 2010) [25]. Satheesh and Kulkarni (2016) [21] which were attributed to extensive use of energy in reproductive activities and reduced feeding activity as the main cause for the decline of Ks value during off seasons (autumn and winter) in *Tilapia mossambica*.

Physiological indices in 1+ and 2+ year's old Amur common carp showed similar trend in different seasons. Levels of GSI, K and Ks were recorded at highest level in spring season, which decreased in summer and reached to the lowest level in autumn with slight recovery in winter season. Hepatosomatic index showed highest level in autumn season, which decreased in winter and reached to the lowest level in spring followed by slight increase in summer season. Levels of GSI, HSI, K and Ks were higher in 2+ year's age group as compared to 1+ year's age group in all four seasons. Pearson's correlations showed significant positive correlation of GSI with K and Ks and also between K and Ks while HSI exhibited negative correlation with GSI and Ks. The physiological indices observed in 1+ and 2+ year's age Amur common carp indicated presence of developed/mature gonads throughout the year with two major peaks – one in spring and other in summer season. Higher age groups (2+ years) had higher index value, which signified their higher reproductive potential than younger (1+ year) age group.

Conclusion

Based on the physiological indices spring season was found to be most potent period for reproduction seed production of Amur common carp, in the Tarai region of Uttarakhand. This study might be helpful in formulating for future research programmes towards achieving off season breeding and seed production of Amur common carp. Seasonal changes in physiological along with the hormones and biochemical parameters were found to have profound effect on the scale of success of reproduction of Amur common carp, *Cyprinus carpio haematopterus,* during spring and summer seasons and 2+ year's age group showed better reproductive potential.

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