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Assessment of fecundity, gonadosomatic index and hepatosomatic index of snow trout, *Schizothorax plagiostomus* in river Lidder, from Kashmir Himalaya, India

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Abstract
The present study was carried out to assess fecundity (F), gonadosomatic index (GSI) and hepatosomatic index (HSI) of snow trout, *Schizothorax plagiostomus* in river Lidder originating from Kashmir Himalaya of District Anantnag, India. The fish samples used in the present study was within the range of 25.5cm to 40.33cm in total length and weight ranging from 250g to 580g and the sampling duration was from July, 2013 to June, 2014. For the estimation of fecundity, 40 mature female specimens were selected. The mean value of fecundity was (12964.62 ± 7385.54) with a mean total length of (34.48cm ± 4.69) and mean body weight (372.48g ± 173.82). The maximum fecundity 32136.06 was calculated for a fish measuring 39cm in total length, 540g in weight, while minimum fecundity 4110 was observed in fish having a total length of 27.5cm and weight 280g. The relative fecundity to weight ranged from 9.696 for a fish with total length 30cm and weight 230g to 56.704 for a fish with total length 38cm and weight 460g.The relative fecundity to length ranged from 64.52 for a fish with total length 30cm and weight 230g to 824 for a fish with total length 39cm and weight 540g. The mean GSI value of female fish fluctuated between minimum 1.059 ± 0.62 in August to maximum 14.95 ± 2.69 in May, while the GSI values of male fish also fluctuated with minimum 4.131 ± 0.47 to maximum 14.837± 2.97 in July and March, respectively. Similarly the HSI values of both male and female fish also produced variable results with respect to different months where minimum HSI value 0.622 ± 0.002 was reported in the month of May and maximum value 2.436 ± 0.594 was observed in male fish during the month of November. While the female fish showed its minimum HSI (1.027 ± 0.131) in the month of May and reached its maximum (2.163 ± 0.285) in November. The statistical relationship of fecundity with other parameters such as total length (TL), total weight (TW), ovary length (OL) and ovary weight (OW) were calculated. The relationships were found to be highly significant ($p<0.05$) between fecundity and fish length (r=0.835, $p<0.05$), fecundity and fish weight (r=0.803, $p<0.05$), fecundity and ovary weight (r=0.796, $p<0.05$) and fecundity and ovary length (r=0.836, $p<0.05$), respectively.

Keywords: *Schizothorax plagiostomus*, fecundity, gonadosomatic index, hepatosomatic index

1. Introduction

The fishes belonging to the genus *Schizothorax* and other carps are common in river and lakes of Kashmir and serves as important food item of human population of the region. The Lidder River as a whole as well as its tributaries and distributaries harbour a number of fish species which include exotic trout and indigenous spps. Such as *Schizothorax plagiostomus*, *S. labiatus, S. esocinus, Crossocheilus diplochilus, Glyptosternon reticulum* and *Triplophysa kashmirensis* etc. Among *Schizothorax* species, *S. plagiostomus* is one of the most dominant fish followed by *S. labiatus* and *S. esocinus* (Bhat *et al*., 2010) [7]. This species is commonly known as 'Khont' and is considered as highly valued table fish in Kashmir region, because of its taste and nutritional values due to which it is also preferred over exotic trout and is one of the most commercially important food fish species of Kashmir Himalaya. Therefore, knowledge regarding the reproductive biology of this species becomes essential for its culture, management and production point of view. The reproductive potential i.e. fecundity is an important biological parameter that plays a significant role in evaluating the commercial potentials of fish stocks (Gomez-Marquez, 2003) [12].

Study on the reproductive potential of fish is one of the most important biological parameters for fish population estimation based on fecundity of the fish or total egg production (Mekkawy and Hassan, 2011) [19]. Fecundity is an Important parameter in fishes for determining the reproductive potential of fish species (Zin *et al*., 2011) [32]. Also a thorough knowledge on the fecundity of the fish is essential for evaluating the commercial potentialities, stock study, life history, particular culture and the management of fishery (Lagler *et al*., 1956; Zin *et al*., 2011) [16, 32]. Generally fish fecundity is species specific and varies from one species to another (Alam and Pathak, 2010) [2]. Fecundity along with other indices such as gonadosomatic index (GSI) and hepatosomatic index (HSI) are used to access the reproductive condition of a fish.

Monthly variations in GSI provide the reasonable indicator of reproductive seasonality of fish. The seasonal timing of reproduction, spawning time is often identified from changes in the GSI which determines the reproductive season of the fish (Arruda *et al*., 1993) [4]. The liver is a key organ in fish for production of vitellogenin, which is a yolk precursor and play a significant role for the development of eggs. Hence, study of hepatosomatic index (HSI) is also important because it describes the status of energy stored in fish and is thus good indicator of recent feeding activity of the fish (Tyler and Dunns, 1976) [29].

Except for a few preliminary reports on reproductive biology of *Schizothorax* species (Sunder and Subla, 1984, Gandotra *et al.,* 2009, Bhat, 2012, Shafi *et al.,* 2013) [28, 10, 7, 26], no work has so far been carried out on the reproductive biology of *S. plagiostomus*, which is the most important and dominant food fish species in river Lidder of Kashmir Himalayas. Keeping in view the important contribution of *S. plagiostomus* as food fish, the present investigation was carried out to assess its reproductive biology for the better conservation and management of this species.

2. Material and methods

2.1 Study Site and fish collection

Lidder is an important tributary of river Jhelum and is formed by the confluence of the East and West Lidder at Pahalgam which is a world famous tourist resort. The former originates from the high altitude glacier fed Lake Sheshnag and the later from the Tarsar and Kolahai glacier. *S. plagiostomus* specimens used in the present study were taken from the river Lidder, which lies to the North of district Anantnag, Jammu and Kashmir, India in the central Himalayan mountain range with the geographical coordinates of 33°04ˊ - 34˚15ˊ N latitude and 75°05′- 75°32′E.

2.2 Collection and Identification of Specimens

A total of 200 specimens of *S. plagiostomus* were collected and studied during the entire period. The method for identification of fish was used as described earlier by (Day, 1876 and Kullander *et al*., 1999) [9, 15]. The duration of the study period was from July, 2013 to June, 2014.

2.3 Measurements

The total length of the fishes was measured to the nearest 0.01cm and weight was taken on digital balance (Shimadzu UX320G) with 0.01g accuracy. Subsequently, the fishes were dissected to obtain their gonads and liver. The gonads were carefully removed and the moisture was thoroughly wiped with the help of the blotting paper. Total length and weight of the gonads were recorded and then fixed in 5% formalin solution for at least 24 hours to bring hardness of eggs to make it much easier to separate the eggs from the walls of ovary.

2.4 Fecundity (F)

In the present study the sub-sample method was applied to estimate the fecundity of *S. plagiostomus*. Fully mature fish, collected just before spawning, was considered for fecundity study. The fish was dissected and exposed with the help of sterile blade. The undisturbed mass of ovary was taken out in intact form and weighed accurately. Three different sections, each of 1 gm in weight was taken from the anterior, middle and posterior regions of ovary, respectively. Sections were weighed on digital balance. Ova from these three small sections of ovary were separated by teasing and counted. As it was over, the individual number of these sections was added and made a sum total of it. Then the fecundity of the collected specimen was calculated according to (Yelden and Avsar, 2000) [31].

$$F = \frac{\text{Ovary weight} \times \text{number of eggs in the sub sample}}{\text{Sub sample weight}}$$

2.5 Gonadosomatic Index (GSI)

Live ripe female and male specimens were collected from the source. The weight and total body length was recorded. The samples were dissected and finally the ripe ovaries and testes were exposed and were taken out carefully in intact form. Weight of gonads was taken and finally GSI value of the specimen was calculated. The GSI was calculated to know the maturity in order to determine the breeding cycle of the fish. This was done as percentage of the gonad weight (GW) in terms of body weight (BW) of the fish (Afonso-Dias *et al*., 2005) [1].

$$GSI = \frac{GW}{BW} \times 100$$

Where GW and BW are gonad weight and total weight in both sexes, respectively.

2.6 Hepatosomatic index (HSI)

Hepatosomatic index (HSI) was calculated to examine monthly variations in feeding intensity and to correlate these variations with breeding cycles. The HSI was calculated according to the method of (Rajaguru, 1999) [22] by determining the weight of hepatopancreas as a percentage of the total live weight of the fish.

$$HSI = \frac{LW}{BW} \times 100$$

Where LW and BW are liver weight and total weight in both sexes, respectively

3. Results

3.1 Fecundity (F)

The results over the one year study on the assessment of fecundity (F), gonadosomatic index (GSI), and hepatosomatic index (HSI) of snow trout*, S. Plagiostomus* obtained from river Lidder is presented in Table I, 2 and 3. In the present study the fecundity was found to be maximum (32136.06) in the month of May with a fish having total length of 39 cm and weight 540 g. While the minimum fecundity (4110) was recorded with a fish of total length 27.5 cm and body weight 280 g. Overall the mean value of fecundity was recorded 12964.62 ± 7385.54 with a mean total length of 34.48 ± 4.69 cm and mean body weight 372.48 ± 173.82 g, respectively.

The relative fecundity to weight ranged from 9.696 for a fish with total length 30cm and weight 230g to 56.704 for a fish with total length 38cm and weight 460g.The relative fecundity to length ranged from 64.52 for a fish with total length 30cm and weight 230g to 824 for a fish with total length 39cm and weight 540g.The study revealed that the relationship between fecundity and total length (TL), total weight (TW), ovary length (OL), and ovary weight (OW) of *S. plagiostomus* from river Lidder were found to be highly significant (P<0.05).

3.2 Fecundity in relation to different parameters

The scatter diagram (Fig.1) revealed a linear relationship between fecundity and fish length and the coefficient of correlation was found to be significant (P<0.05; r=0.835). The relationship between fecundity (F) and total length (TL) is expressed by the mathematical equation:

F = - 32353 +1314 TL (r= 0.835; P<0.05)

Similarly, the fecundity and fish weight also produce a highly significant relationship (P<0.05; r=0.80) among each other (Fig. 2).These relationships also suggests that, in fishes of the same weight, the heavier the gonads, the greater would be the fecundity and the relationship is expressed as:

F = 263 +34.1 FW (r=0.80; P<0.05)

The fecundity gradually increases with the increase in the weight of ovaries (Fig. 3). A highly significant (P<0.05) relationship was found between the two parameters which are expressed by the equation:

F = 2545 +422 (r =0.796; P<0.05)

With the increase in length of ovaries (Fig. 4) a significant (P<0.05) linear relationship was observed between the fecundity and ovary length and the relationship is expressed with the equation:

F = -14050 +2025 (OL) (r=0.836; P<0.05)

Table 1: Monthly variation of mean absolute fecundity and mean relative fecundity with other means of body parameters for gravid females *Schizothorax plagiostomus.*

Months	Avg. body wt.(g)	Range	Avg. body length (cm)	Range	Avg. Ovary wt. in (gm)	Avg. Ovary Length (cm)	Range	Sample size	Mean absolute fecundity ±SD	Mean relative Fecundity to weight.	Mean relative Fecundity to length.
July	300	200-340	30.33	20-30	10.1	10.2	-	5	-	-	-
Aug	330	250-400	33.8	28-36	19.63	11.86	9014.4 – 10921	6	10006.91± 683.61	29.081	312.1303
Sep	337.33	202-460	34.16	30-38	19.78	12.33	3573.92 – 26084	5	13074.92± 11657.87	33.9096	367.372
Oct	329.8	195-794	32.4	29.3-42	17.01	11.318	1890.72 - 25121.4	5	9417.57±9 189.27	26.6131	265.933
Nov	408.2	260-672	37.4	34-42	26.2	13.88	7384 – 25400	5	16403.66± 6716.835	29.5072	430.602
Dec	487	228-1030	38.5	33-47	27.42	15.45	9406.9 - 27155.58	4	16141.575 ±7862.92	38.5402	403.7507
Jan	310	280-350	30.5	27.5-35	16.4	13.06	4110 – 13115	3	9845.733± 4983	24.898	317.8237
Feb	317.5	285-350	30.75	27.5-34	16.7	11.905	8631 – 10421	3	9526±4852	36.883	316.3985
March	428.5	395-462	37.5	35-40	27.815	15.55	16212 – 18540	3	17376±116 4	40.586	463.35
April	345	330-360	36.5	36-37	25.1	14.5	9208 - 15415	3	12311.5±4 389.01	32.473	336.195
May	363.6	230-690	36.7	30-43	48.22	15.66	8950 - 32136.06	5	18826.61± 9851.81	34.890	496.316
June	322.5	250-395	32.15	29.3-35	19.32	13.9	9980 – 10421	3	10200.5±3 11.83	33.475	319.176

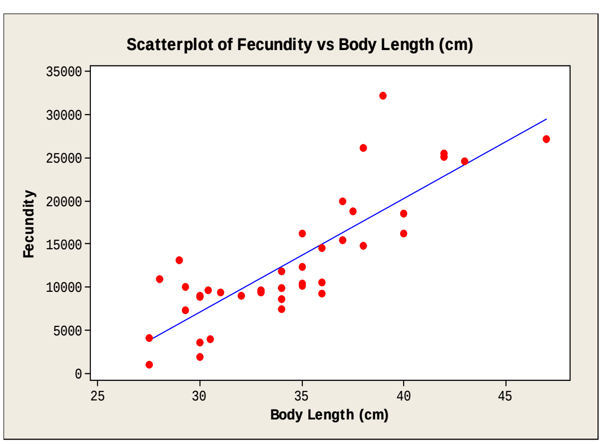

Fig 1: Relationship between body length and fecundity in *S. plagiostomus*

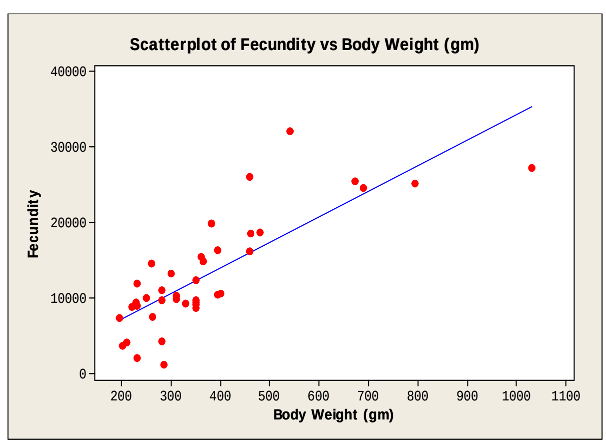

Fig 2: Relationship between body weight and fecundity in *S. plagiostomus*

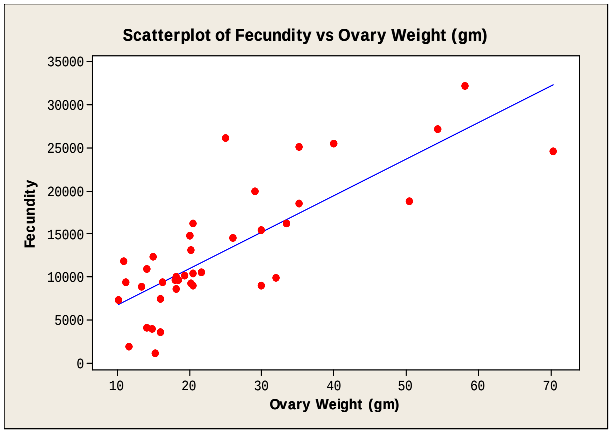

Fig 3: Relationship between ovary weight and fecundity in *S. plagiostomus*

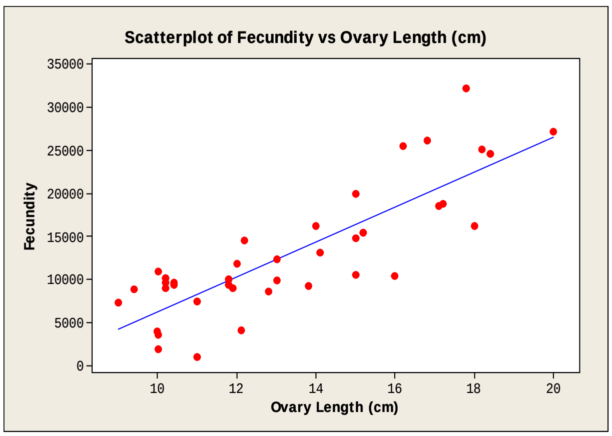

Fig 4: Relationship between ovary length and fecundity in *S. plagiostomus*

3.3 Gonadosomatic index (GSI)

The mean GSI of male fish varied from minimum (4.131 ± 0.47) in July to maximum (14.837 ± 2.97) in March (Table 2). The mean GSI of the female fish also fluctuated between minimum (1.059 ± 0.62) in August to maximum (14.95±2.69) in May (Table 3). This suggests that in the month of May *S. Plagiostomus* reached its peak breeding period. While during the same month majority of the males were found in oozing condition, swollen and white in colour. Although in majority of male fish the GSI was recorded highest in the month of March which could suggests the peak breeding season, and then it gradually decreased and attained its lowest value in July. However some male fish also showed its peak during the month of April. While in the month of June and July GSI decreased due to oozing of milt and finally the spent testes were found at the end of July. A female exhibit comparatively higher GSI values as compared to the male fish which is evident from the calculated GSI where the maximum GSI (14.95 ± 2.69) was recorded in the month of May and all the fishes were found in mature stage. The GSI decreased in the month of June which can be attributed to spawning season of fish as some fishes were found in oozing condition. After that value of GSI gradually decreased and reached its minimum values in the month of August which indicate the spent phase of this fish.

3.4 Hepatosomatic index (HSI)

In the present study the mean HSI of male fish fluctuated from minimum (0.622±0.002) in the month of May to maximum (2.436±0.594) in November (Table 2). The mean HSI of female fish fluctuated from minimum (1.027±0.131) in May to maximum (2.163±0.285) in November (Table 3). The variations in hepatosomatic index have observed on monthly basis as well as seasonal basis depending upon the breeding season as well as the availability of food. The present study shows a high hepatic activity during November (preparatory period) while low hepatic activity during spawning season March- April (Fig. 5).

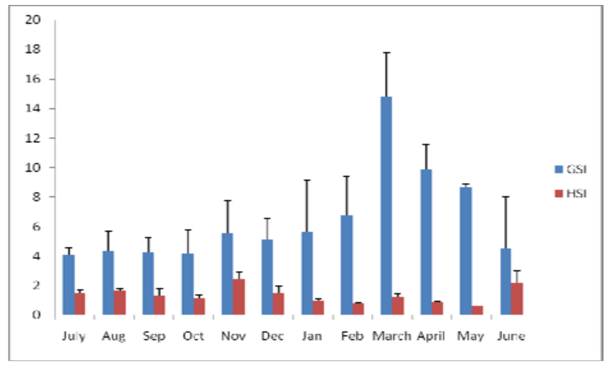

Fig. 5: Depicts the monthly fluctuation in the gonadsomatic index and hepatosomatic index in *S. plagiostomus* male

Table 2: Month wise mean values of gonadosomatic and hepatosomatic indicies of *S. plagiostomus* male from July 2013 – June 2014

Month	GSI ±SD	HSI ±SD
July	4.131±0.47	1.520±0.21
Aug	4.377±1.31	1.689±0.12
Sep	4.242±1.05	1.326±0.45
Oct	4.152±1.62	1.111±0.24
Nov	5.611±2.16	2.436±0.5
Dec	5.154±1.42	1.505±0.43
Jan	5.693±3.44	0.986±0.08
Feb	6.799±2.58	0.822±0.04
March	14.837±2.97	1.236±0.23
April	9.87±1.66	0.861±0.06
May	8.667±0.18	0.622±0.002
June	4.545±3.49	2.176±0.83

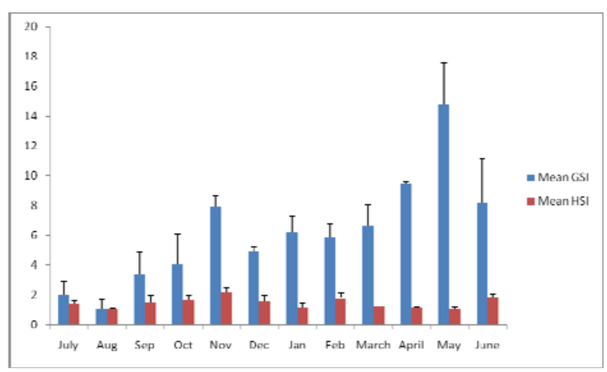

Fig 6: Monthly fluctuation in the gonadosomatic index and hepatosomatic index in *S. plagiostomus* female

Table 3: Month wise mean values of gonadosomatic and hepatosomatic indicies of *S. plagiostomus* female from July 2013 – June 2014

Month	Mean GSI ±SD	Mean HSI ±SD
July	1.984±0.87	1.389±0.21
Aug	1.059±0.62	1.051±0.05
Sep	3.395±1.52	1.519±0.41
Oct	4.065±1.99	1.677±0.31
Nov	7.914±0.76	2.163±0.28
Dec	4.947±0.24	1.587±0.36
Jan	6.197±1.08	1.143±0.24
Feb	5.814±0.95	1.589±0.31
March	6.648±1.37	1.203±0.01
April	9.47±0.15	1.127±0.04
May	14.95±2.69	1.027±0.13
June	8.158±2.96	1.838±0.22

4. Discussion

Fully mature fish, collected just before spawning, was considered for fecundity studies. In fisheries science, several methods have been applied to estimate fecundity (Arnold *et al.,* 1997; Irwin and Murdoch *et al*., 1991) [3, 13]. The two most common methods still in use to count fish eggs involved soak the ovaries in Gilson’s fluid and counting a sub-sample of the eggs (Volumetric method) on the basis of certain volume (Simpson, 1951) [27] or certain weight (Gravimetric method) (Bagenal and Braum, 1978) [5]. The present study reveals that the maximum fecundity was 32136.06 for a fish measuring 39 cm in total length (540 g in weight) and minimum fecundity 4110 was observed in fish having a total length of 27.5 cm (weight 280 g). This study revealed that larger fish were more fecund than smaller fish. Similar results were also reported in the past on the other fish species such as *Tachysurus tenuispinis* (Dan, 1977) [8], *Labeo rohita* (Alam and Pathak, 2010) [2], *Liza parsia* (Rheman *et al*., 2002) [24] and *Lates calcalifer* (Ratnalka *et al.,* 2013) [23]. Variation in the fecundity among the fishes of the same as well as different species is very common depending upon the various factors such as size of the fish, age and condition of the fish, and also depends upon the space and food intake by the fish. Bagenal (1967) [6] has reported that length and weight are reliable indicators of the capacity of egg production; hence the fecundity increases with the increase of the fish in size and weight. This condition is also found in the present work, in which the number of eggs increases with an increase of length and weight of fish. During the present study relationship of fecundity with total length, total weight, ovary length and ovary weight were found to be significant which are in accordance with the findings of Sarker *et al*., (2002) [25] who reported an increase in fecundity with the increase in size, weight and gonad weight in case of *Mystus gulio*. Body weight is a more reliable indicator of the fish egg production capacity than body length (Wootton, 1973) [30]. In the present study a linear significant relationship among various body parameters were reported in *S. plagiostomus*, which also coincide with the results on other fish species such as *Liza parsia* (Rheman *et al*., 2002) [24], *Periophthalmus papilio* (Lawson, 2011) [17] and *Pellonula Leonensis* (Kingdom and Allison, 2011) [14].

In *S. plagiostomus* the GSI was observed to vary with season. A gradual and distinct development of gonad was seen to begin from January, and reaching its peaks during March, in male and during May in female. Thereafter, GSI declines abruptly in both male and female fish. GSI indicates gonadal development and maturity of fish which increases with the maturation of the fish and declines abruptly thereafter (Parameswarn *et al*., 1974; Rheman *et al.,* 2002) [24]. Yeldan and Avsar (2000) [31] have also reported that GSI is widely used especially for the bony fishes in order to examine the spawning period because its value is directly related to the development of the gonad. In the present study, GSI showed higher value during the period from October - May with the highest value noticed in May (14.837±2.698) and declined between July-September, there seems to be the resting period from July – September. After that the gonads increase in weight with some acceleration around November. In a similar study, the spawning period of *Cynoglossus arel* and *Cynoglossus lida* were prolonged, lasting for 10 months and spawning peak for *Cynoglossus arel and Cynoglossus lida* was recorded in January and September, respectively (Ghaffari *et al.,* 2011) [11]. Alfonso-Dias *et al*., (2005) [1] while studying reproductive aspect of *Microchirus azevia*, reported that GSI value were higher between January and May and decreased between June and August, which almost coincides with the results of present study. The higher GSI values recorded during the present study were in the month of March and May, which shows peak breeding season with lower values of HSI in the same months. In case of both the sexes it was observed, when the HSI values were at its minimal, the GSI values were highest and this condition suggests the point that the liver has a weight loss during reproduction which may indicate the mobilization of hepatic reserve for gonads maturation (Zin *et al*., 2011) [32] and therefore the same period might be the pre-spawning period of this fish. HSI is associated with liver energetic reserves and metabolic activity (Lenhardt *et al.,* 2009) [18]. The variation in HSI of *S. plagiostomus* during the present study clearly indicate in both male and female fish (Fig. 5. and Fig. 6), respectively. The mean HSI of male fish fluctuated from minimum (0.622 ± 0.002) in the month of May to maximum (2.436 ± 0.594) in November, while the mean HSI of female fish fluctuated from minimum (1.027 ± 0.131) in May to maximum (2.163 ± 0.285) in November. Therefore, the present study shows a high hepatic activity during November (preparatory period) while low hepatic activity during spawning season i.e. March-April in *S. plagiostomus*. Moreover, the differences in HSI that were found in the present study were probably caused due to the variation in the availability of diet in the natural conditions that varied throughout the year.

The study concluded that significant changes exist in HSI and GSI among different months throughout the year must be kept in mind when using these parameters as biomarkers for better understanding of its life cycle, including the sensitivity of different phase of pollution.

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