

## BREEDING ASSESSMENT OF *SCHIZOTHORAX PLAGIOSTOMUS* IN RIVER INDUS, DISTRICT KOHISTAN, NORTHERN PAKISTAN

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### ABSTRACT

In this study, the relationship of total body length (TBL) and total body weight (TBW), Fulton's condition factor (FCF), gonado somatic index (GSI) and absolute fecundity were determined in snow trout (*Schizothorax plagiostomus*) from river Indus at district Kohistan, Northern Pakistan. A total of 540 matured specimens (male=277, female= 263) were collected between January and December 2016 by using a gill net. A curvilinear relationship of fecundity and GSI with TBL and TBW were investigated by the quadratic model fit. The study revealed the fact that *S. plagiostomus* spawned twice in a year, during spring and autumn. The growth coefficient *b* value and mean condition factor were estimated at 3.42 and 1.75 in both sexes respectively. The GSI in males and females was found 4.4% and 10.96% respectively. In females mean absolute fecundity was 4578.16 eggs. The present study has significance in providing baseline information for the management and conservation of this species of economic importance through captivity breeding.

## 1. INTRODUCTION

Pakistan is blessed with a diversity of natural water resources in the form of rivers, streams, lakes, and springs (Soomro *et al.* 2011), fed mainly by largest mass and collection of glaciers in north comprising of Karakorum range and Himalaya (Hayat *et al.* 2019). Indus is the major river of Pakistan with a total length of 3058 Km, originating in the Mansorawar Lake in Tibet and draining an area of 963,480 Km<sup>2</sup> before it falls into the Arabian Sea (Sehgal, 1988). Indus River and its tributaries are the major sources for the largest irrigation network of Pakistan which serves forty-two million acres of cultivated land (Ahmad *et al.* 2007). Tarbela dam and six barrages (Jinnah, Chasma, Taunsa, Guddu, Sukkur, and Kotri) are also constructed by the flowing water of the Indus River (Muhammad *et al.* 2017).

Almost one hundred eighty species of fishes have been reported from different parts of the Indus River and its tributaries in Pakistan which further endorse the concern of researchers on the fish fauna of this river (Mirza & Mirza 2014). Many ichthyologists have investigated the fish fauna of river Indus and its tributaries, (Jayaram, 1981; Talwar & Jhingran, 1991; Rafique, 2000; Iqbal *et al.* 2013). However, a brief description is still needed as several serious threats due to the climate change and hydal power projects are critical. Meristic and morphometric analysis constitute an important tool to differentiate closely related organisms. Length weight relationship (LWRs) and relative condition factor (K) are very important tools in the fisheries sciences since it provides valuable information about the growth, fitness, and maturation of the target fish.

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Like any other morphometric character, the length-weight relationship can be used as a character for the differentiation of taxonomic units and the relationship changes with various developmental events in life such as metamorphosis, growth and the onset of maturity (Negi & Nautiyal, 2002). This length weight relationship is helpful for estimating the wellbeing of a fish and can be used in studies of gonad development, rate of feeding, metamorphosis, maturity, and condition (Le Cren, 1951). The spawning season has a temporal scale, with most fishes exhibiting one or two spawning seasons in a year. Reproduction has key components of gonadal development (maturity stages), gonadosomatic index (GSI) and fecundity, which are vital demographic characteristics essential to an understanding of a species' life history (Hussain et al. 2018). *S. sinuatus*, *S. plagiostomus* and *S. richardsoni* had exhibited intermittent spawning from July to January (Badola & Singh, 1984). *S. plagiostomus* spawns twice a year (March to April and September to October) and becomes sexually mature at 18-24 cm total length both in a natural and artificial environment (Jan et al. 2016).

Fecundity is known to vary within species with latitude and location and with spawning time (Hussain et al. 2018). Along with these, the Condition factor (CF) is also a useful index for the monitoring of feeding intensity, age and growth rates in fish (Goel et al. 2011). Condition factors can be used an indicator of relative health (Brown and Murphy, 1991). Previously the reproductive behavior in fishes has shown a strong relationship with total body length (TBL), total body weight (TBW), gonad weight, gonad length, ovary length and ovary weight (Sehgal, 1988), fecundity with TBL and TBW, and GSI (Amtyaz et al. 2013) and hepatosomatic index in *S. plagiostomus* has been examined (Jan & Ahmed, 2016).

Several studies have been done to explore the fish species composition and distribution of the ichthyofauna in the River Indus. However, the reproductive information of *S. plagiostomus* inhabiting River Indus is meager. For the same purpose, the present study sort to investigate the breeding behavior, seasonal variations, correlation of total body length (TBL) with total body weight (TBW), gonado-somatic index (GSI) and absolute fecundity ( $F_{ab}$ ) of *S. plagiostomus*, along river Indus and its tributaries in Kohistan district of northern Pakistan. The study would be useful in understanding the relationship of fecundity with various parameters in the target fish for its seed

production in captivity. Captivity breeding will facilitate the stocking process of this economically important fish species into natural water resources for the purpose of its conservation.

## 2. MATERIALS AND METHODS

The present study was conducted in Kohistan District of Khyber Pakhtunkhwa (KP), northern Pakistan, situated between 34° 54' and 35° 52' north latitudes and 72° 43' and 73° 57' east longitudes, covering an area of 7492 (Jayaram, 1981). A total of 540 fish samples (45 specimens each month) were collected from Jalkot, Palas, Keyal, Barseen, Kandia and Darel streams along River Indus as described in table 1. The coordinates for the collection site were extracted from google earth PRO (version 7.3) and the site map was constructed in ArcGIS software version 10.3.1 (Figure 1).

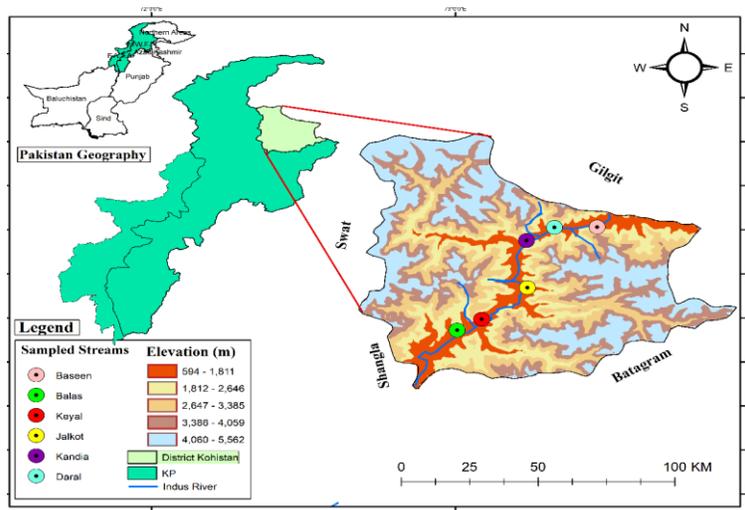


Figure 1. Sampling sites at different streams along River Indus in Indus Kohistan, KP, Pakistan.

Gill nets of 1, 1.5, 2, 2.5 and 3cm stretched bar mesh having a length of 25 feet and depth of 6 feet were used for fish sampling. Fish samples were identified by using the previously described keys (Jayaram, 1981; Kullander et al. 1999).

The total body length (TBL) in centimeter and total body weight (TBW) in gram of each specimen were recorded using line gauge and balancer respectively. Each specimen was dissected carefully, and the gonads were separated for the weight and length measurement. The maturity stages were also identified by using a seven-point maturity scale as described by (Muhammad et al.

2017) as described in table 1, followed by preservation in 5% formalin solution.

The relationship between TBL and TBW of each male and female *S. plagiostomus* was calculated by using the equation (Bagenal & Tesch, 1978).

$$W = aTL^b$$

where W is the total body weight and TL is the total body length, a and b are the intercept and slope of the regression line, respectively.

The Fulton's Condition Factor was also calculated by using the following equation (Bagenal and Tesch, 1978).

$$FCF (K - value) = \frac{TBW}{TBL^3} \times 100$$

where FCF is a Fulton's condition factor.

During this study, the monthly GSI of *S. plagiostomus* was calculated to determine its period and frequency of spawning round the year (Bariche, 2017).

$$GSI(\%) = \frac{Gonad\ Weight}{TBW}$$

where GSI denotes for gonado somatic index and TBW is total body weight.

The fecundity was calculated by using a total of 263 ovaries extracted from female *S. plagiostomus*. Gravid females were easily recognized from enlarge abdomen, after careful dissection each lobe of the matured ovaries were cut down into three sections (anterior, middle and posterior) and preserved in Gilson's fluid in order to loosen ova from the ovarian wall.

Following the same method, the two lobes of ovaries were dried up with blotting paper and weighed. Then 0.01g of each ovary was taken separately from the anterior, middle and posterior parts of each lobe. The matured ova were easily identified and distinguished from their reddish color. Only the number of ripe oocytes in 0.01 g (reddish in color) were counted with the help of the magnifying lens and then multiplied by the total weight of the ovary.

The gravimetric method was applied to determine the total fecundity of gravid fish (Yeldan & Avşar, 2000).

$$F_a = \frac{Gonad\ weight\ (g) \times no\ of\ oocytes\ in\ sub - sample}{Sub - sample\ weight\ (g)}$$

$$F_a = \frac{F1 + F2 + F3}{3}$$

where  $F_a$  is the absolute fecundity and  $F_1$ ,  $F_2$  and  $F_3$  are the fecundity count in the sub-sections

### Statistical analysis

The recorded observations were entered into the Microsoft Excel sheet (version 2013) and each variable was assorted. Furthermore, the statistical analysis was performed by transferring the excel sheet to the SPSS version 21 for the chi-square test considered <0.05 a constant significant value. A curvilinear quadratic regression analysis was used for the estimation of the regression curve between TBL correlated with TBW and each with GSI.

### 3. RESULTS AND DISCUSSION

A total of 540 *S. plagiostomus* each 277 (51%) males and 263 (49%) females were examined in this study. The collection of *S. plagiostomus* was also recorded such as 94 (17%) were collected in each Palas, Keyal, Barseen and Kandia streams followed by 86 (16%) and 82 (15%) from Jalkot and Darel stream respectively as described in table 2. A high significant difference was observed in the distribution of male and female *S. plagiostomus* along collection sites (<0.0001).

A maximum of seven maturity stages in the gonads of *S. plagiostomus* were identified i.e., Stage-I immature, stage-II unambiguous sex, stage-III developing, stage-IV maturing, stage- V mature, stage-VI running, and stage-VII spent as described in table 1 (Nagelkerke, 1997).

A synchronized breeding condition with slight variations in the maturity stages of male *S. plagiostomus* was observed figure 2a. As compared to females the gonad developing stage in males started a bit earlier from late July. In August the developing gonads illustrated slight reddish color followed by lobed and white color gonads in late August in both sexes however the developing stage extends to early September in males (Autumn spawning). The maturity of gonads begins in September ranged till November followed by lobed and white gonads (maturing stage IV) in January and February (Spring spawning).

Stages I, II and III were also found missing during the same breeding season where both gonads were recorded in stage IV directly during January. In line with the literature reviewed, the present study has confirmed that *S. plagostomus* spawn twice a year, March, and April. The spent stage was quite extended in males compared to females during the month of May (Figure 2).

The scatter plot of the curvilinear relationship between TBL and TBW in both males and females was calculated. The quadratic curve shows the initial slight increase of TBW in response to TBL in both male and female *S. plagostomus* however it increases exponentially when the total body length exceeds 30 cm. The overall model of weight-length relationship was highly significant with  $R^2$  value of 0.902 for male and 0.900 for female *S. plagostomus* (Figure 3 A-B).

To calculate the condition factor K-value, the month-wise line graph for both male and female *S. plagostomus* was plotted. During the present study length weight relationship and condition factor of *S. plagostomus* showed some variation throughout the year. In male *S. plagostomus* the highest mean K-value of 1.99 was recorded during June while the lowest K-value of 1.52 and 1.47 were recorded during February and January respectively (Figure 4). The variation in the K-value was less significant (0.046) for male *S. plagostomus*. In female *S. plagostomus* the highest mean K-value of 1.98 was observed during July and November whereas the lowest K-value of 1.41 was recorded during February. The variations were significant for female *S. plagostomus*.

The mean GSI calculated for male *S. plagostomus* during spring and autumn breeding cycles was 17.84 and 15.41 respectively. Similarly, the mean GSI estimated for female *S. plagostomus* following the same breeding cycles was 17.77 and 16.06 respectively (Figure 5).

The monthly regression analysis record of total body length (TBL) correlated with GSI shows the highly significant effect of TBL on GSI in male *S. plagostomus* (0.0001). The scatter plot shows an early increase of GSI between 20 cm to 25 cm of TBL, however, a rapid decline was observed in the GSI of male *S. plagostomus* when body length has increased as shown in figure 6A. An initial increase of GSI in response to TBL increase up to 25 cm followed by the rapid decline in GSI against TBL

increase was recorded among female *S. plagostomus*. The declining pattern of GSI versus TBL is evident in the scatter plot as shown in figure 6B.

The initial increase of GSI among male *S. plagostomus* weighing up to 250 g of TBW, however, it was significantly decreased when body weight increased. The minimum GSI was observed in individuals around 1250 g of total body weight. The minimum GSI was recorded in female *S. plagostomus* having TBL between 40 cm to 45 cm. Female *S. plagostomus* gain maximum GSI at 250 g of total body weight. The minimum GSI was recorded in specimens having TBW of 1250 g as shown in figure 7.

The effect of TBL on absolute fecundity was significant in individuals having a TBL between 20 cm and 25 cm. The scatter plot shows an initial increase of absolute fecundity in specimens having 25 cm of TBL and then a declining pattern of absolute fecundity. The minimum absolute fecundity was recorded in individual fish specimens having TBL around 45 cm (Figure 8A).

The regression analysis shows the initial increase of absolute fecundity in individuals weighing between 250 g and 500 g of TBW and then a rapid decline when TBW increases. The minimum absolute fecundity was estimated in individual specimens weighing between 750 g and 1000 g above which a slight increase in the absolute fecundity was observed in individuals at 1250 g of TBW (Figure 8B).

A total of 263 female *S. plagostomus* having 20.5 cm to 43.8 cm matured female fish were used to estimate fecundity. The estimated fecundity during the present study was ranged from 659.89 to 20474.96 eggs  $\text{Kg}^{-1}$ . The maximum mean absolute fecundity of 14079.92 ( $\pm 648.93$ ) eggs  $\text{Kg}^{-1}$  were estimated during November with a mean TBL of 27.5 cm and mean TBW of 406 g whereas the minimum mean absolute fecundity of 2046.93 ( $\pm 288.66$ ) eggs  $\text{Kg}^{-1}$  were recorded during February in fish having mean TBL 32.7 cm and mean TBW of 484 g (Figure 9).

Studies on the reproductive behavior of fishes involve morphometry (TBL and TBW), fecundity estimation, reproductive season cycle, spawning behavior and spawning fraction which contributes a greater value in quantifying the reproductive capacity of fish species. The absolute health of fishes is based on the TBL, TBW, and gonadal weight which enhances the fecundity quality of

fishes in addition to the maturational cycle and monthly variation in GSI provided a good indication of the development of gonads (Akhtar *et al.* 2016). The economically important fish species need special concerns over the reproductive strategies, seasonal fecundity rate and determination of physical growth.

Fish fauna are the economically important sector which plays a vital role in the economy of Pakistan (Shah *et al.* 2018). Among these the *S. plagiostomus* are also important and mostly confined to the northern Himalaya region (Jan *et al.* 2016). Various studies have confirmed the existence of *S. plagiostomus* in different regions of KP (Khatak *et al.* 2015). In present study a total of 540 comprising of 277 (%) male and 263 (%) female *S. plagiostomus* were collected from various streams of District Kohistan and their physical morphometry (TBL and TBW) were correlated with the GSI and fecundity rate. The K-value and maturity stages throughout the year were also estimated.

Almost synchronized period of spawning was observed for both male and female *S. plagiostomus* during spring (February to April) and autumn seasons (September to November). Various reports confirmed that *S. plagiostomus* spawn two time each year (Singh & Sharma, 2016), while contrary to that Akhtar *et al.* showed that *S. plagiostomus* spawn once annually (Akhtar *et al.* 2016). In this study it was observed that *S. plagiostomus* spawn in both spring and Autumn season, and their gonads developing stages includes seven stages of maturity in both sexes of *S. plagiostomus* including Stage-I immature, stage-II unambiguous sex, stage-III developing, stage-IV maturing, stage-V mature, stage-VI running, and stage-VII spent. Similar reports were also provided by (Negi & Nautiyal, 2002). However, there are six stages of maturity in *Schizothorax richardsonii* (Agarwal *et al.* 2018), five maturity stages in *Schizothorax niger* and *Schizothorax esocinus* (Raina, 1976). The International Council for Exploration of the Seas has recognized seven maturity stages for fish in temperate waters (Qadri *et al.* 2019).

Month wise variation showed immaturity of gonads in June while maturity was noticed two times each in September to November and February to April. The structural changes were observed in July and August which were not observed in Autumn breeding cycle and the matured gonads were followed by a spent stage in

May. Similar consequences were showed by Munro, (1990). The sudden increase in water temperature during May seems to inhibit the breeding response where gonads were observed totally in spent condition. Exteroceptive factors such as water temperature, food availability, and duration of photoperiod were positively correlated with the spawning behavior of *S. richardsonii* (Negi & Nautiyal, 2002).

The statistical analysis between TBL and TBW has a diverse application in fisheries sciences which is very useful for the evaluation of condition factor in fishes. The quadratic curve shows an initial slight increase of TBW in response to TBL in both male and female *S. plagiostomus* showing R<sup>2</sup> value of 0.900 and 0.900 respectively. The exponential increases in the growth were observed by increases in the total length. Similarly, the TBL and TBW was ranged from 9.6 cm to 52 cm and 7 to 948 g respectively with the maximum growth with respect to total length was found 0.908 (Bhat *et al.* 2010), 0.992 (Jan *et al.* 2016), and linear regression 0.92 and non-linear 0.95 in *Schizothorax richardsonii*. Thus, in length weight relationship of Snow trout, weight increases in length throughout its life.

The slope coefficient b<sub>2</sub> for TBL correlated with TBW in males and females are within the range of 0.825 to 3.138 and 1.15 to 2.68 respectively. The highest b<sub>2</sub> value in males *S. plagiostomus* indicates the rapid weight gain in males than females. The slight difference of minimum TBL in male shows that it gains maturity a bit earlier than female owing to the consequences of (Jan *et al.* 2014; Khan *et al.* 2018), and contrary to the findings of (Dar *et al.* 2012). The slope value of regression line less than 3 has also been reported in *Cyprinus carpio communis* and *Ctenopharyngodon idella* (Dhanze & Dhanse, 1997).

The CF in both male and female *S. plagiostomus* shows variations in different months. The highest K-value of  $1.99 \pm 0.13$  for male *S. plagiostomus* was noticed in the month of June while for females it was  $1.98 \pm 0.12$  in July and  $1.98 \pm 0.09$  in November. The K-value recorded for both sex of *S. plagiostomus* during the present study is slightly higher when compared to the K-values recorded for *S. plagiostomus* by (Jan *et al.* 2014). from Lidder River Kashmir. Maximum K value found in the month of September (1.05) and least in July (1.03) (Kumar *et al.* 2014). The average CF for *S. richardsonii* was found 0.73 (Goel *et al.* 2011). The seasonal variation in CF seems to

be attributed to high feeding activity, fat deposition and gonadal development as a preparation for coming breeding season. Maguire & Mace (1993) reported that increase in K-values indicates the accumulation of fat and sometimes it reflects the gonadal development. CF revealed that the fluctuations in K values can be attributed to the spawning cycle as well as feeding intensity.

The present study revealed the fact that all male and female *S. plagiostomus* gain maximum GSI at 25 cm of total body length. The smaller fish specimens have greater GSI when compared to larger ones. In both male and female *S. plagiostomus* the GSI was found to decrease curve-linearly with the increase in TBL and TBW. A linear relationship between these variables were observed by (Bahuguna & Khatri, 2009) and (Muhammad and Pathak, 2010). Monthly variations in GSI index provided a very good indication of gonads development round the year. The suddenly decreased in the GSI were indicating the post-spawning season of *S. plagiostomus*. Stage-wise calculation of GSI in the present study revealed that highest GSI were observed in ripe stages (Stage-V and VI) while the lowest values were recorded in spent (stage-VII), immature (Stage-I) and maturing (stage-II), respectively.

Fecundity of *S. plagiostomus* calculated in the present study, did not show allometric pattern of growth with TBL and TBW which is contradictory to the findings of (Goel et al. 2011) and (Soomro et al. 2011). In this study, the fecundity was at the peak in fishes of 20 cm to 25 cm in TBL and 250 g and 500 g TBW. Generally, all teleost fishes have a linear relationship of fecundity with TBW and ovary weight, however Bagenal, (1957) reported a non-linear relationship of these parameters. The number of ova varied from 3437 to 34800 for a fish varied in TBL 26.2 to 45.3 cm and TBW 176.5 g to 1150 g. The regression equation was found to be linear for both TBL ( $r = 0.96$ ) and TBW ( $r = 0.961$ ). In *S. plagiostomus* the fecundity was ranged from  $1695 \pm 524.44$  to  $3297 \pm 282.99$  eggs with TBL  $22.52 \pm 2.84$  to  $27.90 \pm 1.88$  cm and TBW  $172.33 \pm 10.9$  to  $240.9 \pm 7.59$  g [4]. Similarly, the Study determined that fecundity of *S. plagiostomus* ranged from  $1695 \pm 524.44$  and  $3,297 \pm 282.99$  on the average length of fish ranging  $22.52 \pm 2.8$  to  $27.90 \pm 1.8$  cm and average fish weight ranging  $172.3 \pm 10.9$  to  $240.9 \pm 7.5$  g (Akhtar et al. 2016).

In the present study the highest absolute fecundity of  $8504.59 \pm 614.62$  ( $2386.67$ - $13610.19$ ) was recorded in the month of April during spring cycle in gravid specimen having total body length of 29.24 (13.80-52) cm. During autumn the mean absolute fecundity of  $14079.92 \pm 648.93$  and range ( $9998.88$ - $20474.96$ ) was recorded in the gravid specimens having total body length of 27.5 (21.5-39.5) cm in the month of November. Same relationship between absolute fecundity and TBL in *S. phulo* were reported by (Pishka et al. 1997). It was also observed that gravid females were more fecund in November than April. The mean value of fecundity was estimated as 14599 eggs with a mean TBL (34.340 cm) and a mean TBW (440.60 g). This seasonal variability may be due to changes in food availability and the resulting scope of individual fish to allocate energy either to reproduction or to somatic growth and maintenance. Similar seasonal changes were observed in the gonads of *S. richardsonii* (Qadri et al. 2013).

#### 4. CONCLUSION

Being economically important species in the county, conservation, and management of *S. plagiostomus* are necessary in the river Indus, especially during its breeding season. The results of the study provide important insights about the fecundity and reproductive parameters that will be helpful to conserve this species through breeding in captivity and then seed stocking into the natural water resources.

#### 5. CONFLICT OF INTEREST

All authors have declared that there is no conflict of interest regarding this publication.

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Table 1. Locality wise distribution of Male and Female *S. platiostomus*.

Locality/Stream	Total %	Male Frequency %	Female Frequency %	Cumulative %
Jalkot	86 (16)	52 (60)	34 (40)	16
Palas	94 (17)	41 (43)	53 (57)	33
Keyal	94 (17)	56 (60)	38 (40)	51
Barseen	94 (17)	48 (51)	46 (49)	68
Kandia	90 (17)	38 (42)	52 (58)	84
Darel	82 (15)	42 (51)	40 (49)	100
Total	540 (100)	277 (51)	263 (49)	100

Table 2. Locality wise distribution of male and female *S. plagiostomus*

Locality (Streams)	Total (%)	Male frequency (%)	Female frequency (%)	Cumulative %	P value
Jalkot	86 (16)	52 (60)	34 (40)	16	
Palas	94 (17)	41 (43)	53 (57)	33	
Keyal	94 (17)	56 (60)	38 (40)	51	
Barseen	94 (17)	48 (51)	46 (49)	68	<0.0001
Kandia	90 (17)	38 (42)	52 (58)	84	
Darel	82 (15)	42 (51)	40 (49)	100	
Total	540 (100)	277 (51)	263 (49)	100	

Table 1. Gonad maturation stages for cyprinids (Nagelkerke, 1997).

Gonad Stages	Male	Female
I	Immature, indistinguishable male from female, gonads are a pair of elongated transparent strings running along the body cavity.	Immature, indistinguishable male from female, gonads are a pair of elongated transparent strings running along the body cavity.
II	Unambiguously male. Testes verysmall, tube shaped white-reddish andnon-lobed.	Unambiguously female. Ovaries verysmall, tube shaped white-reddish and invisible eggs.
III	Testes larger and white reddish incolor. Lobed up to some extent and starting flattened to sideways.	Ovaries larger and white reddish in color. Starting flattened to sideways. Eggs very small.
IV	Large testes white in color, lobed andflattened to sideways	Large Ovaries, flattened to sideways and covering body cavity wall. Eggs yellowish.
V	Large whitish testes, sperm run outwhen testes cutoff.	Large and full ovary and completely covering the body cavity. Eggs yellowish and run out when ovaries cut.
VI	Running, large white testes	Running, eggs yellow and extruded out through stripping.
VII	Spent, testes became empty, wrinkled, and reddish in color.	Spent, ovaries wrinkled reddish in color which contain few yellow eggs.

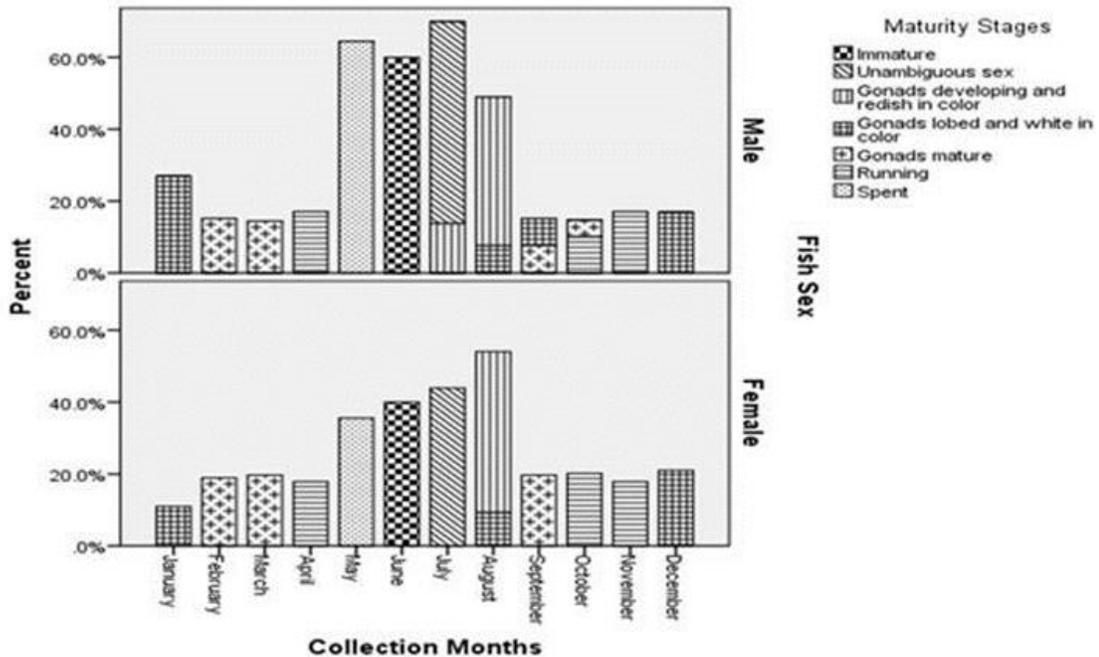


Figure 2. Variations in the maturity stages of male and female *S. plagiostomus*

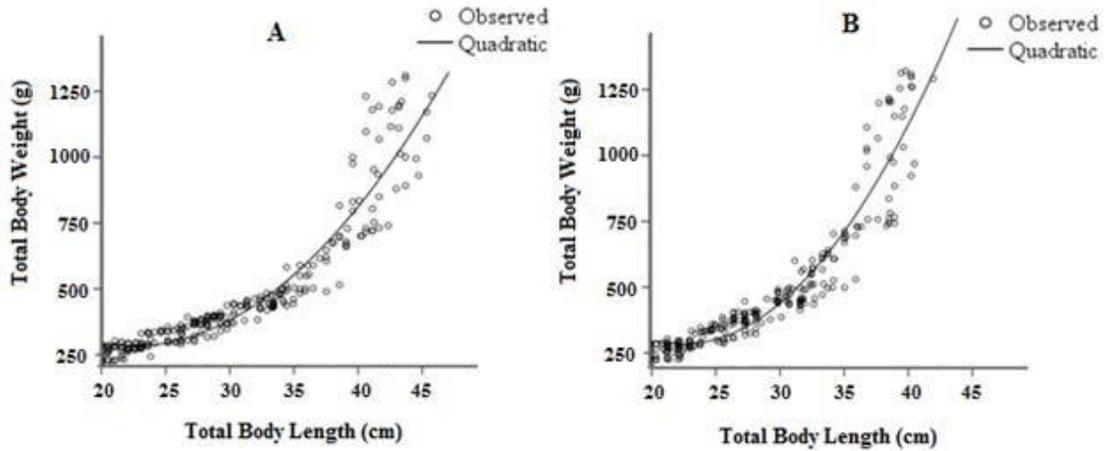


Figure 3. Scatter plot of the curvilinear relationship between TBL and TBW in both male (A) and female (B) *S. plagiostomus*.

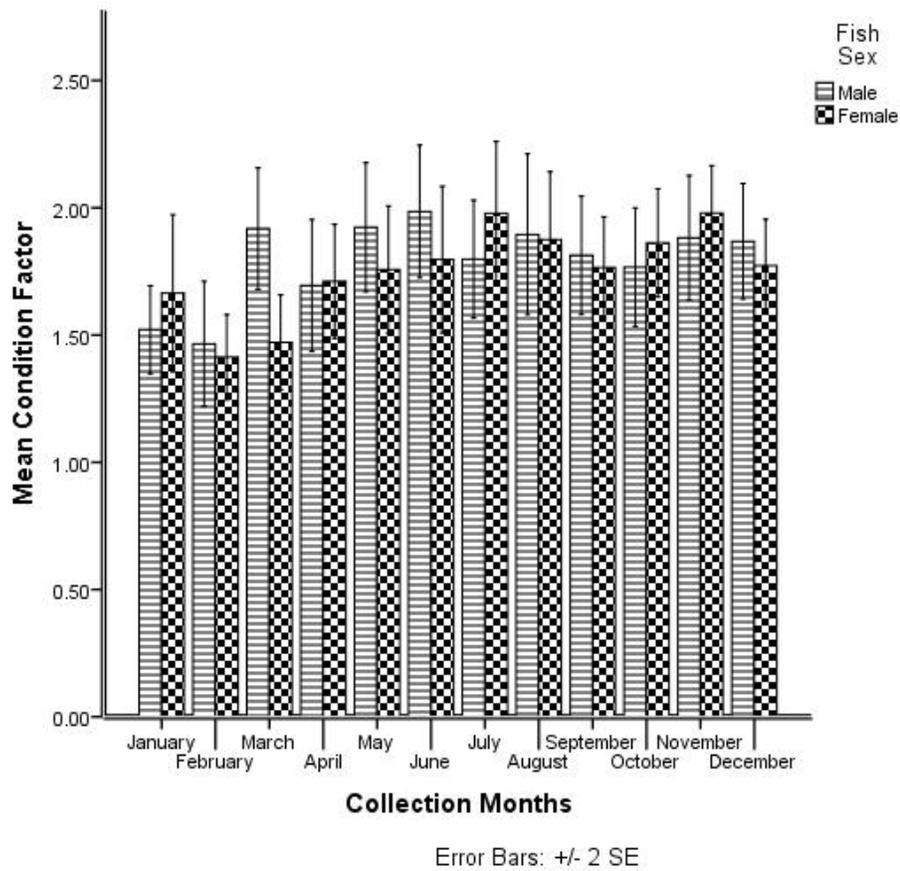


Figure 4. Bar graph showing monthly variation in the mean Condition Factor (K) with standard error bars, of male and female *S. plagiostomus* caught from river Indus in northern Pakistan during 2016.

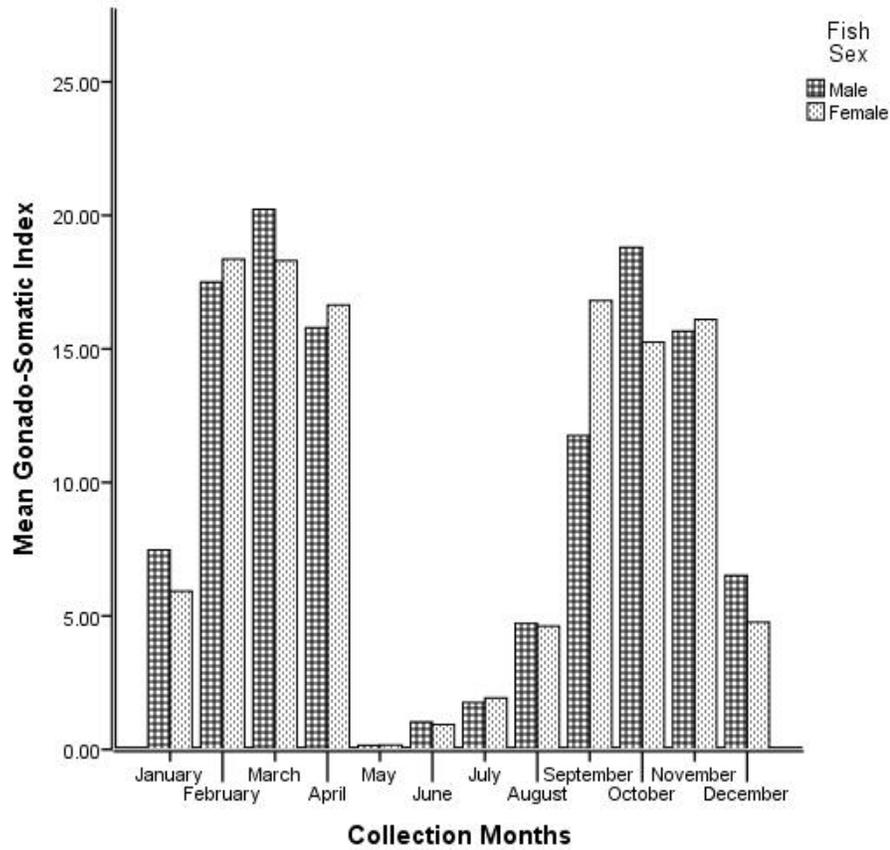


Figure 5. Bar graph showing monthly variation in the mean GSI of male and female *S. plagiostomus* caught from river Indus in northern Pakistan during 2016.

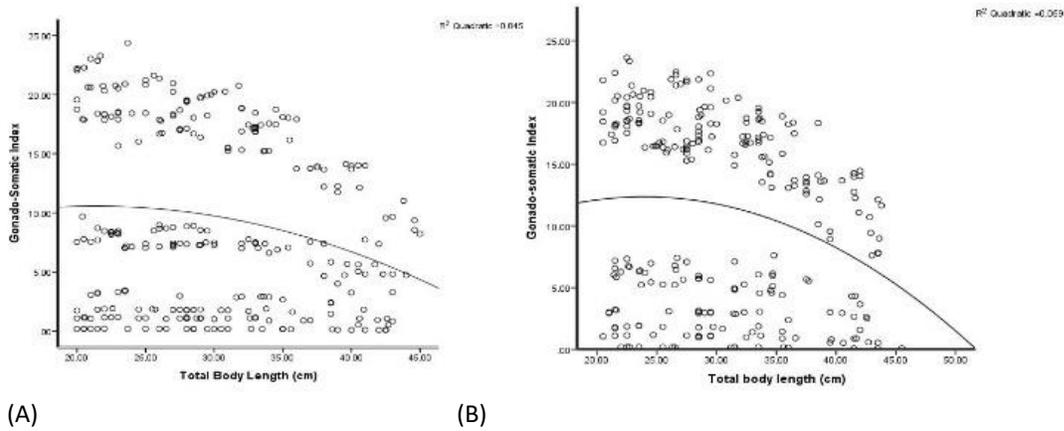


Figure 6. Scatter plot showing curvilinear relationship negative (quadratic model fit) between total body length TL (cm) and GSI of male *S. plagiostomus* (A) and female *S. plagiostomus* (B) caught from river Indus in northern Pakistan during 2016.

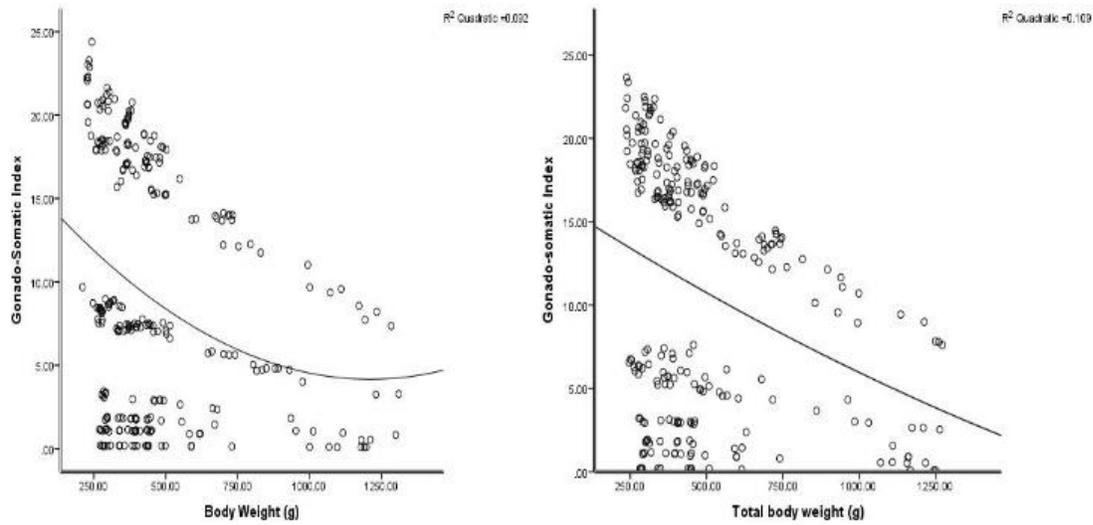


Figure 7. Scatter plot showing curvilinear relationship negative (quadratic model fit) between total body Weight (g) and GSI of male *S. plagiostomus* (A) and female *S. plagiostomus* (B) caught from river Indus in northern Pakistan during 2016.

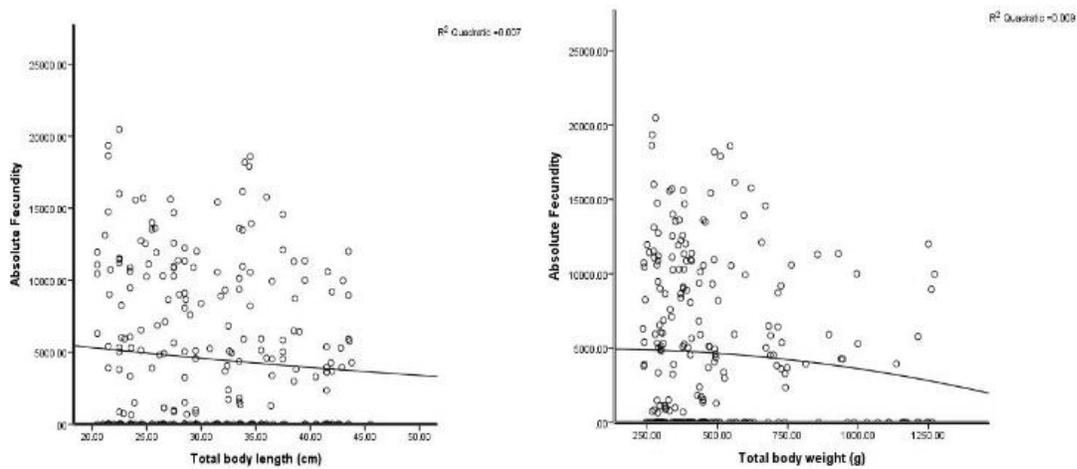


Figure 8. Scatter plot showing curvilinear relationship negative (quadratic model fit) total body length TL (cm) vs fecundity (A) and total body Weight (g) vs fecundity (B) in female *S. plagiostomus* caught from river Indus in northern Pakistan during 2016.

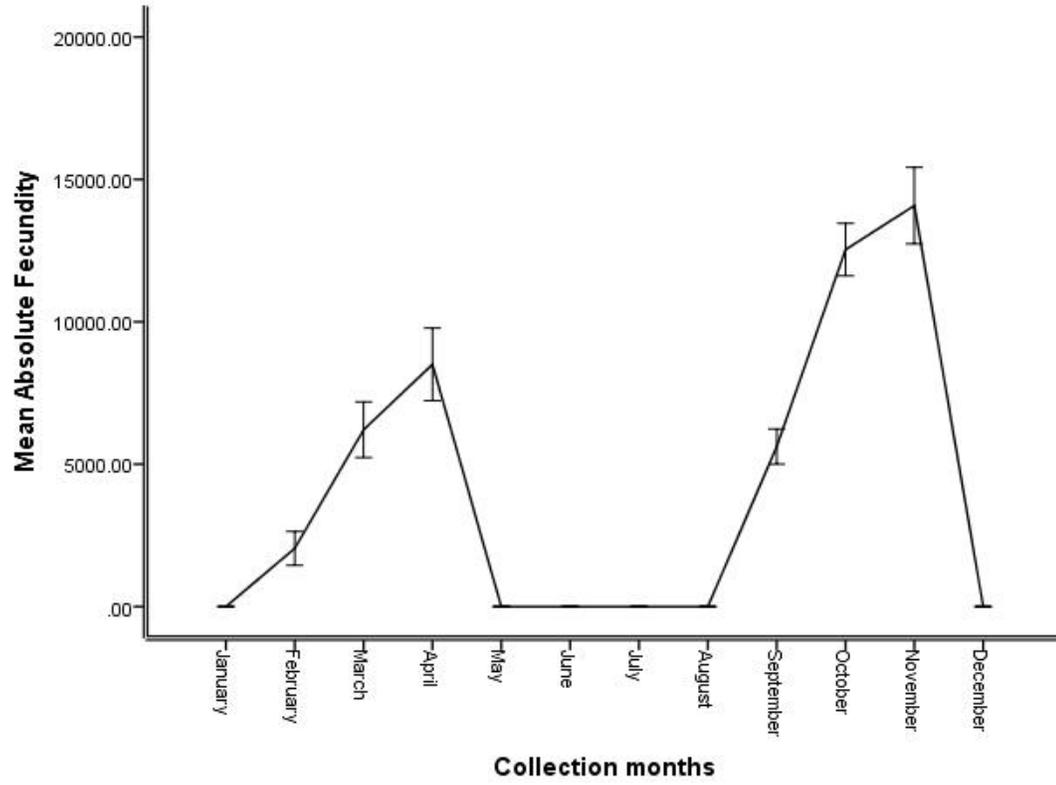


Figure 9. Line graph showing monthly variations in the mean absolute fecundity with standard error bars of female *S. plagiostomus*.