# REPRODUCTIVE BIOLOGY OF TAPPER TAIL ANCHOVY *COILIA RAMCARATI* ALONG THE COAST OF CHITTAGONG

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## Abstract

**A total of 754 male and 893 female samples of *Coilia ramcarati* (Hamilton 1822) were collected from commercial catches during the period from January 2010 to December 2010 from the coastal waters of Chittagong and Cox's Bazar to study the reproduction of this species. The sex ratio disproportion between the 2 sexes (♂♂ 0.84:1.00 ♀♀) showed a dominance of females over the males. Well marked sexual dimorphism is observed; the gametes develop in the gonads of separate fish and fertilization is external in the water. Both male and female gonads undergo marked cyclic morphological changes before reaching full maturity and becoming ripe, as represented through the gonadosomatic index (GSI), hepatosomatic index, and Fulton's Condition Factor values. The marked increase in the GSI demonstrated a prolonged spawning season extending from March to August. The fecundity of *Coilia ramcarati* in the present study ranged from 3129 to 16578 eggs with the mean of 7632.13 ± 3169.17. Linear positive relationships of fecundity with total length, body weight, gonad weight, and ova diameter were observed.**

**Keywords: Sex ratio, maturation, spawning, fecundity.**

## Introduction

Reproduction and recruitment are 2 of the major events in the life history of a species (King, 1995). A full understanding of the reproductive biology is important in fisheries research, stock assessment, stock discrimination, and management of a population (Offem *et al*., 2008; He *et al*., 2011; Tsikliras *et al*., 2013). Sex ratio constitutes basic information required for the estimation of the potential for successful reproduction and stock assessment in fish populations both in nature and in artificial breeding grounds (Nabi, 1994; Vicentini and Araujo, 2003). Gonad development indicates the status of maturation of a particular fish and is essential for estimation of fecundity and spawning seasons (Bagenal and Braum, 1978; West, 1990; Weddle and Burr, 1991; Nabi, 1994). The gonadosomatic index (GSI) is a good indicator of gonadal development and the spawning season (Dadzie and Wangila, 1980; West 1990). Ova-diameter represents the time of spawning and the spawning periodicity of fish (Hickling and Rutenberg, 1936).

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The hepatosomatic index (HSI) gives an idea about maturation and the feeding intensity status, whether the food reserves in the liver are affected during the process of yolk formation or not. The Fulton's Conditions Factor (K) in relation to length and weight indicates the degree of well being and fitness in numerical terms at different maturation stages and spawning periods (Oso *et al*., 2011). Knowledge on fecundity and breeding strategy is necessary to evaluate the reproductive potential of the spawning stock of individual fish species leading to management of the fisheries (Das, 1977; Khan *et al*., 2002; Murua *et al*., 2003). *Coilia ramcarati* is one of the most abundant species accounting for 6.86-20.80% of the total fish catch in the Matla River estuarine system of Sundarban (Mukherjee *et al*., 2012) and 0.12-2.25% of the artisanal fishery of Bangladesh (Nabi 2007). It is eaten either fresh or dried, is a delicacy in some coastal countries including Bangladesh, and is higher priced than other members of its genus (Parvez and Nabi, 2014). Fisheries management requires that the reproductive capacity of a stock is sustained above a threshold level that is sufficient to ensure that a high level of egg production is maintained and that recruitment is not jeopardised (Goodyear 1993, Mace and Sissenwine 1993, Mace 2001). Knowledge of the spawning season along with fishing locations is instrumental in establishing regulations to protect heavily exploited species (Rosenberg *et al*., 2000). For successful management and exploitation of a certain fishery, a study on its reproductive biology is an urgent task. Conservation and management measures require information on the fundamental biology of *C ramcarati* and its habitat. Hence the present study is designed to understand the reproductive biology of *C. ramcarati*.

## Materials and Methods

### Data Collection

A total of 754 male and 893 female fish samples were collected from commercial catches harvested by the estuarine set bag net fishery of Bangladesh from coastal waters of Chittagong during the period from January 2010 to December 2010. The collected specimens were brought to the laboratory for analysis. After washing, the specimens were dissected out on a tray. The fish were sexed after dissecting out the gonads. The gonads and liver from each fish were separated carefully and allowed to harden for several days by dipping these in 10 % neutrally buffered formalin. Data recorded for each specimen included measurements for total length (TL), body weight (BW), gonad weight (GW), and liver weight (LW) to the nearest 0.01 cm and 0.0001 g. Each testis, ovary, and liver was weighed with an electronic balance. The ova diameters of each ovary were measured to the nearest 0.0001 mm by means of an ocular micrometer under the magnification of a compound microscope.

### Sex Ratio

Sex ratio was determined for all fish pooled by the month and length classes. The differences in sex ratio were analyzed and tested for significant deviation from the expected 1:1 ratio by using a chi-square (c2) goodness of fit test at 95% significance level (Zar, 1999). This test was applied for both the month and length classes.

### Maturation and Spawning

The annual cyclic changes (pre-spawning, spawning, and post spawning periods) were determined critically after assessing the GSI, HSI, and K values month-wise, all year round. Stages of maturity were determined from the weight, color, shape, and transparency of the gonads' ova diameters and consistency of the ovary. The GSI values were also taken into consideration in this regard. The GSI of the gonads of each fish were calculated using the formula, $GSI = \frac{\text{Gonadal weight}}{\text{Total weight}} \times 100$ (King, 1995). The HSI was calculated by the formula, $HSI = \frac{\text{Weight of liver}}{\text{Gutted weight of body}} \times 100$ (El-Boray, 2004), and the condition factor K was calculated by the formula, $K = \frac{\text{Body weigh t - Gonad weight}}{(\text{Length})^3} \times 100$ (Kader, 1984).

### Fecundity

The gravimetric methods of McGregor (1922) and Laglar (1956) were followed for the fecundity estimation. Six cross-sections, each weighing approximately 0.05 g to 0.10 g, were removed along with the accompanying membranes from the anterior, middle, and posterior region of the 2 lobes of the ovaries of each fish (Nabi *et al*., 2014). The total number of eggs for each fish was calculated from the sample mean and the total weight of the ovary. All fecundities presented here are the total number of eggs in both the ovaries, as followed by Healy and Nicol (1975). However, the individual egg counts for each lobe (left and right) were also calculated (Nabi *et al*., 2014). In order to determine the relationship between: fecundity (F)-total length (TL), F = a + bTL; fecundity (F)-body weight (BW), F = a + bBW; fecundity (F)-gonad weight (GW), F = a + bGW ; and fecundity (F)-ova diameter (OD), F = a + bOD, the correlation of the coefficients (r) were calculated and the regression lines were derived following the least square method (LeCren, 1951; Hartman and Conkle, 1960, Gupta, 2000; Nabi *et al*., 2014). For all the arithmetical relationship, the significance of 'r' was tested by the t-test at 5% level of significance. The value of 't' was calculated using the formula, $t = \frac{r\sqrt{(n-2)}}{\sqrt{(1-r^2)}}$ with (n-2) degrees of freedom (Gupta, 2000; Nabi *et al*., 2014).

## Results and Discussion

### Sex Ratio

The final analysis showed that the sex ratio of male to female was (♂♂ 0.84:1.00 ♀♀). The monthly distribution of the two sexes in the collected samples (Figure 1) were tested by $\chi^2$ test and the calculated value was found to be $\chi^2_{cal}$=10.67, which was lower than the tabulated $\chi^2$ value ($\chi^2_{tab}$=35.17) at 95% significance level. No significant difference between male and female is observed when compared within months. The length class-wise distribution of male and female (Figure 2) was also tested by $\chi^2$ tests and the calculated value was found to be 109.44, which was greater than the tabulated $\chi^2$ value ($\chi^2_{tab}$=54.57) at 95% significance level. Significant differences in the number of males and females in different length classes are observed.

The disproportionate occurrence in the number of the two sexes of *C. ramcarati* disagrees with the universal hypothesis that the males and females of any environment should be 1.00:1.00. However, this universal hypothesis is not expected for the maximum of organisms as the difference in male and female depends on the surrounding ecological environment. Both Gadgil (1967) and Fernandez and Devaraj (1996) reported that males outnumbered females in the population of *C. dussumieri* in the vicinity of Bombay waters on the northwest coast of India. But in the present investigation, females were found to be dominant

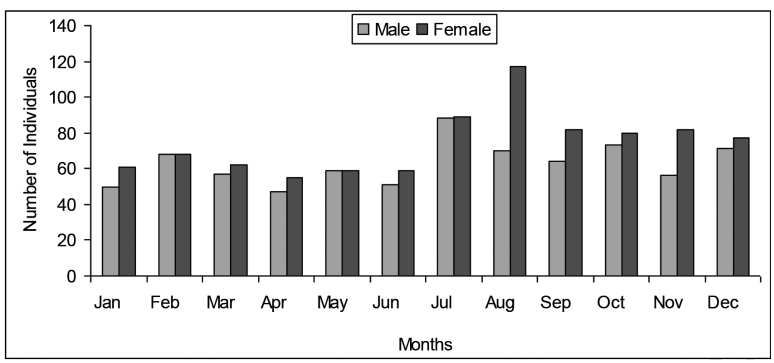


**Figure 1. Distribution of males and females in different months**

over the males, which agrees with the report of David (1954), Ravish (1962), Gupta (1968), Nabi (1994), Yigin and Ismen (2013), and Rajesh *et al*. (2014) for different species. The dominance of the females over the males during the spawning period may be due to the requirements of a higher number of females for successful mating.

## Maturation and Spawning

The *C. ramcarati* show well marked sexual dimorphism; the gametes (the sperms and the eggs) develop in separate gonads (testes and ovary), and fertilization is external in the water. *C. ramcarati* exhibits a seasonal cycle in the production of gametes. Both male and female gonads undergo marked cyclic morphological changes before reaching full maturity and becoming ripe which is represented by their GSI, HSI, and K values.

## Gonadosomatic Index (GSI)

The average value of the GSI shows an obvious change during the period studied. The gonad weight ranged from 0.0001 to 0.1813 g in the male and 0.0005 g to 0.6621 g in the female. The monthly changes of the GSI values of *C. ramcarati* males and females are shown in Figure 3. There were very small values (0.0760 in males and 0.1242 in females) at the beginning of the year that represent the pre-spawning period. Then they sharply increase to reach the peak in April (0.2980 in males and 6.3270 in females) indicating the spawning period. After the spawning period the GSI values gradually

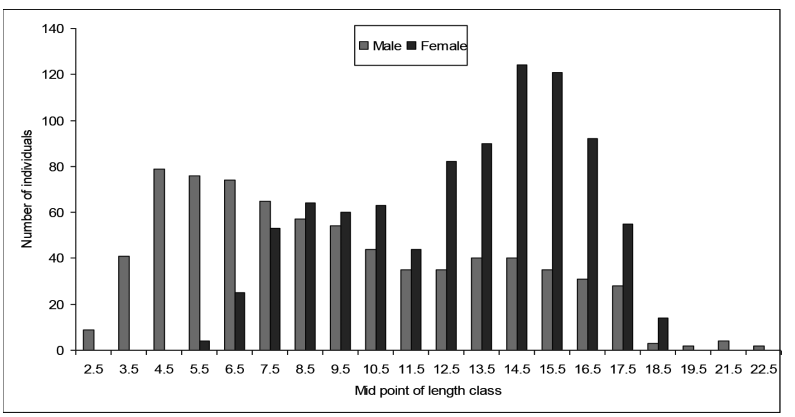


**Figure 2. Distribution of males and females in different length classes**

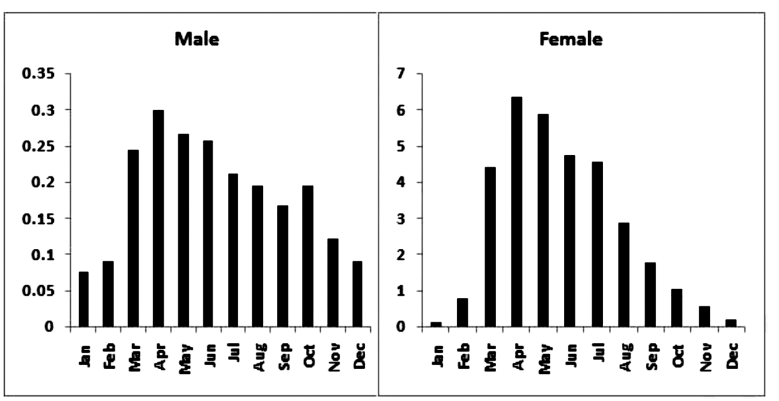


**Figure 3. Monthly average GSI values of males and females**

decrease.

**Hepatosomatic Index (HSI)**

The monthly average HSI value of the male *C. ramcarati* increases from January and continues to reach a peak in April (0.4854). Then it falls in May (0.3495) and remains nearly constant up to July. After that it smoothly increases to reach the second peak in October (0.5903) but then it sharply decreases up to December (Figure 4). But in the case of the female, the HSI decreases from the beginning of the year and continues into the spawning period (March-July). After that, it begins to increase and remains on the increase up to the next cycle.

**Condition Factor (K)**

The average value of K for the male *C. ramcarati* roughly increases from January to reach its apex in April (0.9368) and remains almost constant up to July. After a sudden fall in August (0.9019), it jumps to climb to its second peak (0.9328) in the next month. Then it gradually descends until November and again rises in December (Figure 5). In the case of the female, an increased K value was observed at the beginning of the year (Figure 5). Then it decreased in the early spawning period (March-April). Again the value of K gradually increases from the late spawning period (May-July) to the early post-spawning period and reaches the

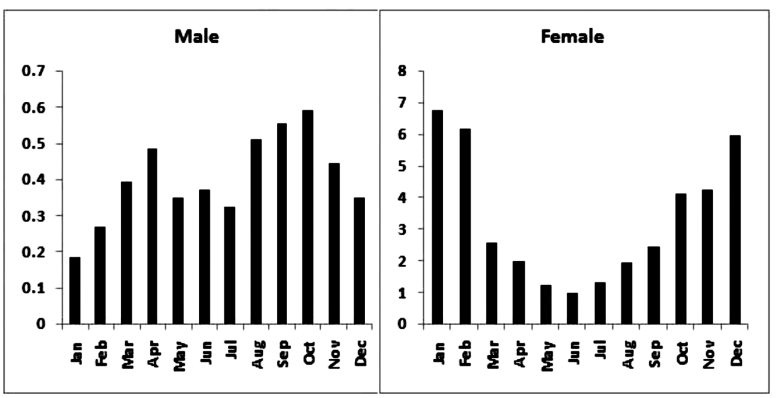


**Figure 4. Monthly HSI values of males and females**

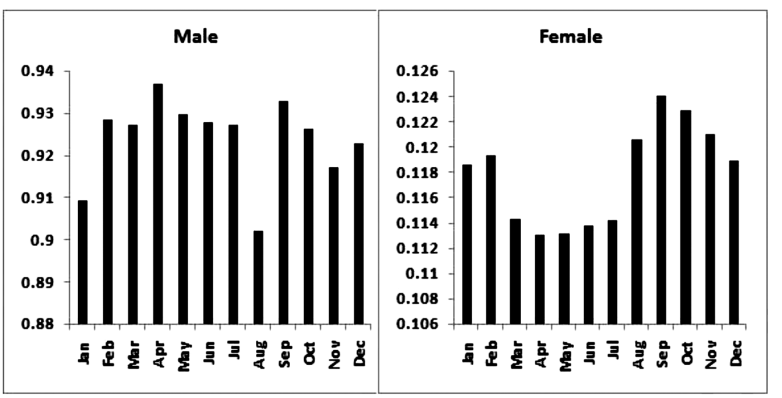


**Figure 5. Monthly average K values of males and females**

apex in September (0.1240). Then it decreases gradually in the late post-spawning period (October-December).

**Testis Development and Maturity Stages**

The gonad weight ranged from 0.0001 to 0.1813 g in the male. Based on the color and macroscopic observation, testis development was divided into 3 stages. At the **immature** stage, the testis was thicker, thread-like in structure and the color was pale-yellow. However, at the **maturing** stage, the testes had rapidly increased in size. During the **mature** stage, the testes had become larger than in the maturing stage.

**Ovary Development and Maturity Stages**

The mean weight of the ovary was 0.16±0.11 and the range varied between 0.0096 and 0.5768 g. The average weight of the right ovary (0.0845 ± 0.0533 g) was significantly higher ($p > 0.05$) than the weight (0.747± 0.0534) of the left ovary. The classification of the ovary of the female *C. ramcarati* into various stages was done on the basis of macroscopic observations such as gonad appearance and color. On the basis of morphological features such as shape, color of the ovary, GSI values, and ova diameters, 5 maturity stages can be recognized for female *C. ramcarati*. The stages of the ovaries of the female *C. ramcarati* are: Stage-I (Immature), in which the ovaries were very small, thin, thread-like, translucent, and with inconspicuous vascularisation. The ovaries occupied only a small part of the body cavity and the ova were not visible to the naked eye. The colors of the ovaries were pale or dirty white. The tiny, transparent immature ova diameters varied from 0.1584 mm to 0.3172 mm and their GSI ranged from 0.0378 to 1.0760. Immature females were found all round the year even in the spawning period. Stage-II (Developing), in which the ovaries became slightly larger, thicker, opaque, and somewhat longer than the immature ovaries. The colors of the ovaries become whitish to light yellowish. The diameters of the maturing ova varied between 0.3172 mm to 0.5297 mm and their GSI ranged from 1.0760 to 2.5207. Stage-III (Mature), in which the ovaries were yellowish to yellow white in colour and larger in shape. The ova were firmly attached to the ovarian tissue and each other. The diameters of the ova ranged from 0.5297 mm to 0.7765 mm and their GSI varied from 2.5207 to 6.3714. Stage-IV (Spawning), in which the ovaries were yellowish to dark yellowish and the ova were not firmly attached with ovarian tissue. The diameters of the ova ranged from 0.7765 mm to 0.9825 mm and their GSI varied from 4.8462 to 11.1002. Stage-V (Spent), in which the empty ovarian bags with very small white eggs (granule like) were present. The diameters of the ova varied from 0.1957 mm to 0.2495 mm and their GSI varied from 1.0972 to 1.2503.

**Spawning Period**

The GSI is a good indicator of the gonadal development and maturity of the fish which increases with sexual maturity and declines after spawning (King, 1995; Soyinka, 2014). The annual cyclic changes in the gonad weight, liver weight, and condition factor were found and these have been assessed in relation to the 3 major arbitrary periods. During January-February, the gonads attain full maturity (pre-spawning period). After that, in March-July, the expulsion of the gametes from the body into the surrounding water results in fertilization (spawning period), and after spawning a new crop of germ cells is formed (post-spawning period) which gradually mature during the rest of the year to become ready for the next season. In the present investigation the marked increase in the GSI demonstrated a prolonged spawning season of *C. ramcarati*. Parvez and Nabi (2015) reported continuous recruitment of the fish in almost every month from the same region. He *et al*. (2011) also demonstrated a prolonged spawning season of *C. mystus* in the same months in the Yangtze estuary in China. Li *et al*. (2007) reported that *C. ectenes* females started spawning in May in the lower reach of the Yangtze River. Continuous spawning over the entire year with a peak in the pre-monsoon months (March to May) was also reported for *C. dussumieri* from Indian waters (Fernandez and Devaraj, 1996). The results agree with the reports of Fulton (1898), Htun-Han (1978), Nash (1982), and Kader (1984) on the ovarian weights of different species of fish.

The former two researchers attributed it to the uptake of fluid by the fully ripe oocytes (Stage-IV). This stage immediately precedes ovulation, as spent fish (Stage-V) are found after this period. This also agrees with the reports of Htun-Han (1978), Nash (1982), and Kader (1984) on *Limanda limanda, Lesueurigobius friesii,* and *Gobioides rubicundus,* respectively. The testes maintain a heavier weight during late March to October and these eight months may be considered to be the spawning period of the male *C. ramcarati*. January to February is the pre-spawning period both for the male and female *C. ramcarati*. The gonads, both the testes and ovaries, appear to have a relatively long inactive or resting phase, after which they grow and develop (King, 1995). The liver index (HSI) remained relatively high and nearly constant for both males and females throughout the maturation period until the beginning of the spawning. This indicates that the reserves in the liver are not seriously depleted during the process of yolk formation. It was found that the fish continued feeding during the period of maturation. This is probably the reason why the HSI remains high during the pre-spawning and early spawning period. This agrees with the reports of Peters (1868) and Day (1870) on *Apocryptes variegatus* and *A. cantories,* respectively. During the spawning season many fish stop feeding and live on their reserve food materials (Lagler, 1956). In the present investigation, this type of phenomenon was also observed especially in the case of the male *C. ramcarati* as the HSI value fell in the mid-spawning period. The liver weight in *C. ramcarati* fell immediately after spawning, probably due to fasting and heavy movement in the spawning season, and this agrees with the reports of Peters (1868) and Day (1870) which showed that, in *A. variegatus* and *A. cantories*, respectively, the liver index was lower in the post-spawning period. The condition factor K remained relatively high and nearly constant for both males and females during the pre-spawning period. A considerably higher condition factor K of the female *C. ramcarati* was found in the pre-spawning months and a fall in the condition factor during the late spawning period agrees with the report of Aziz (1993) on *Sillago domina;* she explained that the latter may be due to gonadal increase during that period. The considerably higher condition factor K during the post-spawning and pre-pawning periods in the male *C. ramcarati* agrees with the report of Day (1870) on the higher condition factor of *A. cantories* during the same period.

**Fecundity**

The fecundity of *C. ramcarati* in the present study ranged from 3129 to 16578 eggs with the mean fecundity of 7632.13 ± 3169.17. The minimum fecundity (3129) was found in a fish having a total length of 9.80 cm, body weight of 3.58 g, and ovary weight of 0.0347 g. While the maximum fecundity (16678) was observed in a fish with a total length of 12.50 cm,

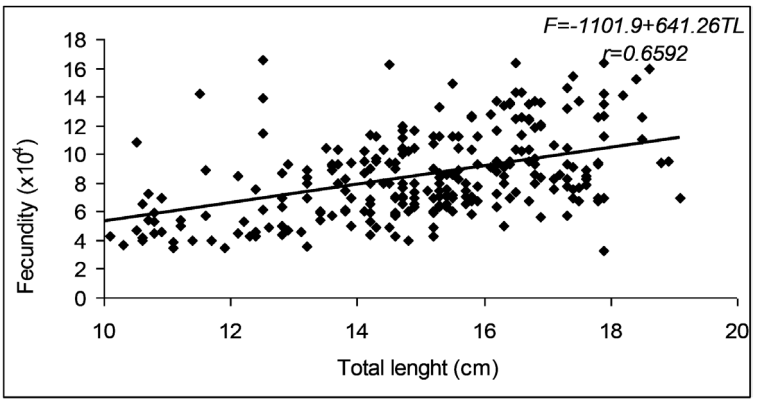


**Figure 6. Relationship between fecundity (F) and total length (TL)**

body weight 6.18 g, and gonad weight of 0.1736 g. Linear and positive relationships were found between the total length and fecundity (Figure 6), body weight and fecundity (Figure 7), gonad weight and fecundity (Figure 8), and ova diameters and fecundity (Figure 9), as shown in Table 1.

The range of fecundity (3129 to 16578) and the average number of eggs of *C. ramcarati* (7632.13± 3169.17) found in the present study indicates that the fish is poorly fecund for its size. This conclusion agrees with the results of Varghese (1976) for the same species from the Hooghly estuary. Varghese (1976) found that the fecundity of *C. ramcarati* ranged between 1939 and 15528, which result is more or less similar to the present study (3129 to 16578). The fecundity of *C. dussumieri* was found to vary from 1200 to 4200 (Gadgil, 1967) and 1000 to 5000 (Fernandez and Devaraj, 1996) in Bombay waters of India. In the case of *C. mystus,* absolute fecundity was found ranging between 2816 and 22813 in the coastal waters of Zhoushan (Xu and Zhou, 2005) and between 3093 and 36786 in the Yangtze estuary, China (He *et al*., 2011).

The number of eggs or fecundity varies from species to species, as well as within the same species, due to different factors such as age, size, body and gonad weight, and the ecological condition of the water body (Saifullah *et al*., 2004). However, this slight difference in fecundity may be racial (Gupta, 1970) or may be due to differences in the time of spawning (Healy and Nicol, 1975) and maturation stages (Kader, 1984). The variation in fecundity is very common in fish and has been reported by many researchers (Bagenal, 1971, 1978; Nikolsky,

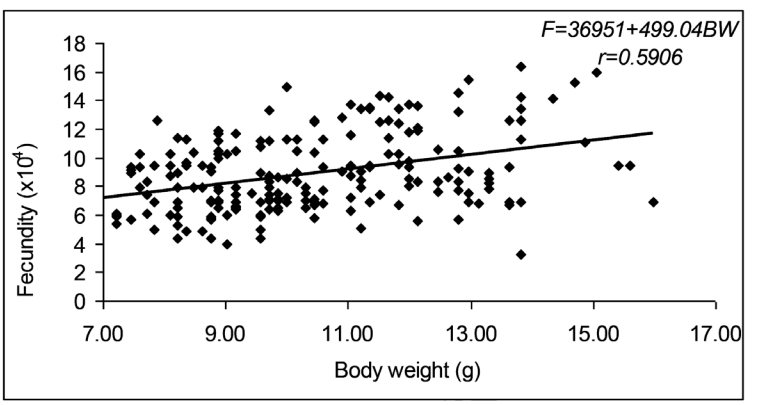


**Figure 7. Relationship between fecundity (F) and body weight (BW)**

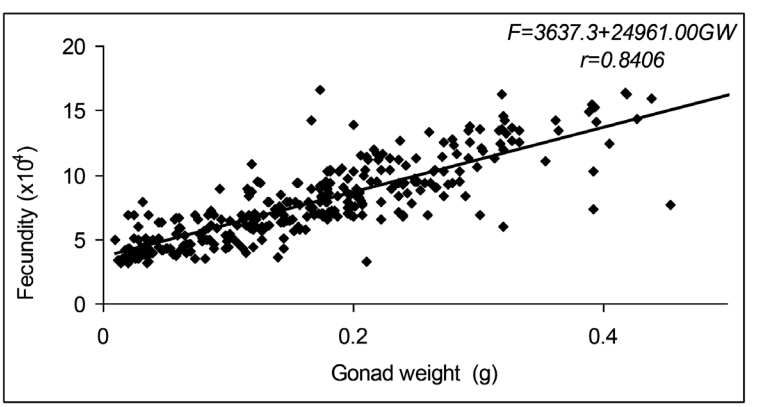


**Figure 8. Relationship between fecundity (F) and gonad weight (GW)**

1963, 1969). Numerous factors like different stocks of fish (Farran, 1938), nutritional status (Scott, 1961), racial characteristics (Bagenal, 1966), time of sampling and maturation stage (Healy, 1971), and changes in environmental parameters (Bagenal, 1978) have so far been reported to affect the fecundity both within the species and between fish populations. Variation in the fecundity of the fish in the same length class was found in this study which indicates that the fecundity of a fish does not solely depend on its length. This comment agrees with the findings of Islam and Talbot (1968) on *H. ilisha*, Kader (1984) on *G. rubicundus*, Aziz (1993) on *S. domina*, and Nabi (1994) on *Polynemus paradiseus*. Observed linear positive relationships of fecundity with total length, body weight, gonad weight, and ova diameters agree with the findings of Varghese (1976) for the same species from the Hooghly estuary, India. Similar results were also obtained by (Bagenal,1966), Grant (1972), Shafi and Mustafa (1976), Shafi *et al.* (1979), Kader *et al.* (1982), Nargis *et al.* (1983), and Nabi (1994) for different fish species. A much closer relationship of fecundity with gonad weight was observed when a comparative study of the correlation of coefficients between fecundity and other body parameters was done which pointed towards the conclusion that the fecundity increases more with the increase of gonad weight than with other parameters. Varghese (1976) and Rao and Rao (2007) also made the same comment for *C. ramcarati* and *Glossogobius giuris* from the Hooghly estuary and Bisakhapatnam River estuary, India.

## Conclusions

In the present investigation, a prolonged spawning season of *C. ramcarati* was found. The range of fecundity and the average number of eggs indicates that the fish has low fecundity like some other species of its genus. The relationships between fecundity and length of

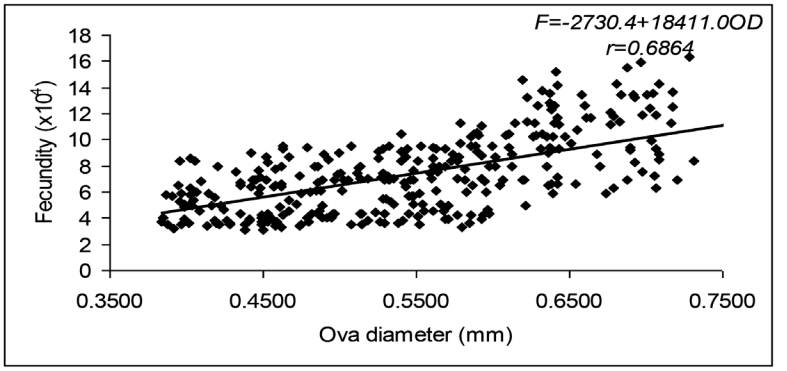


**Figure 9. Relationship between fecundity (F) and ova diameters (OD)**

**Table 1. Estimated relationship between fecundity (F) and other body parameters**

| Parameters | Equation | Value of 'r' | Value of 't' | Value of 't0.05' |
|---|---|---|---|---|
| Total length (TL) | $F = -1101.9 + 641.26TL$ | 0.6592* | 0.6592 | 1.645 |
| Body weight (BW) | $F = 36951 + 499.04BW$ | 0.5906* | 0.5906 | 1.645 |
| Gonad weight (GW) | $F = 3637.3 + 24961.0GW$ | 0.8406* | 0.8406 | 1.645 |
| Ova diameter (OD) | $F = -2730.4 + 18411.0OD$ | 0.6864* | 0.6864 | 1.645 |

**significant correlation*

fish, fecundity and body weight of fish, and fecundity and gonad weight were found to be linear indicating that the fecundity generally increased with an increasing length, weight, and ovary weight. The annual reproductive cycle and spawning season information obtained in the present study could be a help in taking appropriate measures to manage the fishery in view of the dwindling resources due to over-exploitation. Also, these findings will increase the life history data available for the fish.

## Acknowledgements

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## References

Aziz, F.B. (1993). Studies on the biology of whiting *Sillago domina* Cuv and Val.1828 from the landing centers and markets of Chittagong. [M.Sc. Thesis], Institute of Marine Sciences, University of Chittagong.

Bagenal, T.B. (1978). Methods for Assessment for Fish Production in Freshwaters. (3rd edition). Blackwell Scientific Publication, Oxford, UK, 365p.

Bagenal, T.B. (1966). The ecological and geographical aspects of the fecundity of plaice. J. Marine Biol., 46:161-186.

Bagenal, T.B. (1971). The inter-relationship of the size of fish eggs, the data of spawning and the production cycle. J. Fish Biol., 3:207-219.

Bagenal, T.B. and Braum, E. (1978). Eggs and early life history. In: Fish Production in Fresh Waters. Bagenal, T.B., (ed.). Blackwell Scientific Publications, Oxford, UK, p. 165-201.

Dadzie, S. and Wangila, B.C.C. (1980). Reproductive biology, length-weight relationship and relative condition of pond raised *Tilapia zilli* (Gervais). J. Fish Biol., 17:243-253.

David, A. (1954). A preliminary survey of the fish and fisheries of a five mile stretch of the Hooghly river near Barracpore. Indian J. Fish., 1:231-250.

Day, F. (1870). On the fishes of the Andaman Islands. P. Zool. Soc. London, 1870(3):677-705.

Das, H.P. (1977). The fecundity of gray mullet *Mugil cephalas* L. along the Goa coast. Mahasagar Bulletin of the National Institute of Oceanography, 10 (1-2):79-82.

El-Boray, K.F. (2004). Reproductive biology and histological characters of male *Rhabdosargus haffara* (Teleostei; Sparidae) from Suez Bay, Red Sea. Egyptian J. Aquatic Research, 30(B): 226-233.

Farran, G.P. (1938). On the size and number of ova of Irish coast herring. J. du Conseil Int. pour l'Exploration de la Mer, 13(1):91-100.

Fernandez, I. and Devaraj, M. (1996). Dynamics of the gold-spotted grenadier anchovy (*Coilia dussumieri*) stock along the north-west coast of India. Indian J. Fish., 43(1):27-38.

Fulton, T.W. (1898). On the growth and maturation of the ovarian eggs of teleostean. Annual Report of the Fishery Board of Scotland, 16:88-124.

Gadgil, M. (1967). On some aspects of the biology of *Coilia dussumieri* (Cuv. and Val.). J. Bombay Natural History Society, 64(1):55-69.

Goodyear, C.P. (1993). Spawning stock biomass per recruit in fisheries management. Foundation and current use. Can. Spec. Publ. Fish. Aquat. Sci., 120:67-81.

Grant, C.J. (1972). The biology of the soldier fish, *Gymnopistes marmoratus* (Pisces: Scorpaenidae). Aust. J. Mar. Fresh. Res., 23:151-163.

Gupta, M.V. (1968). Observations on the fecundity of *Polynemus paradiseus* Linn. from the Hooghly estuarine system. Proceedings of the National Institute of Sciences of India, 34(6):330-345.

Gupta, M.V. (1970). Racial analysis of *Polynemus Paradiseus* Linnaeus. J. Inland Fish. Society India, 11:55-59.

Gupta, S.P. (2000). Statistical Methods.Sultan Chand and Sons, New Delhi, India, 1436p.

Hartman, W.L. and Conkle, C.Y. (1960). Fecundity of red salmon at Brooks and Karluk Lakes, Alaska. US Fish and Wildlife Service Fishery Bulletin, 180:53-60.

He, W., Li, Y.X., Liu, M., Radhakrishnan, K.V., Li, Z.J., Murphy, B.R., and Xie, S.G. (2011). Reproductive biology of *Coilia mystus* (Linnaeus) from the Yangtze Estuary, China: responses to overexploitation. J. Appl. Ichthyol., 27(5):1197-1202.

Healy, M.C. (1971). Gonad development and fecundity of the sand goby, *Gobius minutus* Pallas. T. Am. Fish. Soc., 100:520-526.

Healy, M.C. and Nicol, C.W. (1975). Fecundity comparisons for various stocks of lake white fish, *Coregonus clupeaformes*. J. Fish. Res. Board Can., 32(3):404-407.

Hickling, C.F. and Rutenberg, E. (1936). The ovary as an indicator of the spawning period of fishes. J. Mar. Biol. Assoc. UK., 21:311-17.

Htun-Han, M. (1978). The reproductive biology of the dab, *Limanda limanda* (L.) in the North Sea: seasonal changes in the ovary. J. Fish Biol.,

13:351-359.

Islam, B.W. and Talbot, G.B. (1968). Fluvial migration spawning and fecundity of the Indus River hilsa, *Hilsa ilisa*. T. Am. Fish. Soc., 1:350-355.

Kader, M.A., Hossain, M.A., and Mohi, S.A. (1982). The fecundity of *Lepturacanthus savala* James. J. Asiatic Society of Bangladesh, Science, 8(1):53-57.

Kader, M.A. (1984). Studies on *Gobioides rubicundus* (Hamilton-Buchanan) from the Karnafully estuary. [Ph. D. thesis]. University of Chittagong, Chittagong, Bangladesh, 107p.

Khan, M.S.A., Alam, M.J., Rheman, S., and Rahman, M.M. (2002). Study on the fecundity and GSI of brackishwater catfish *Plotosus canius* (Hamilton-Buchanan). J. Biol. Sci., 2(4):232-234.

King, M. (1995). Fisheries. Biology, Assessment and Management. 1st ed. Fishing News Books, Ltd., Chichester, UK, 341p.

Laglar, K.F. (1956). Freshwater Fishery Biology. 2nd ed. W.C. Brown and Co., Dubuque, IA, USA, 421p.

LeCren E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in perch (*Perca fluviatilis*). J. Anim. Ecol., 20:201-219.

Li, Y., Xie, S., Li, Z., Gong, W., and He, W. (2007). Gonad development of an anadromous fish *Coilia ectenes* (Engraulidae) in lower reach of Yangtze River, China. Fisheries Sci., 73:1224-1230.

Mace, P.M. and Sissenwine, M.P. (1993). How much spawning per recruit is enough? In: Risk Evaluation and Biological Reference Points for Fisheries Management. Smith, S.J., Hunt, J.J., and Rivard, D. (eds).National Research Council of Canada, NRC Research Press, Ottawa, ON, Canada, p. 101-118.

Mace, P.M. (2001). A new role for MSY in single-species and ecosystem approaches to fisheries stock assessment and management. Fish Fish., 2:2-32.

McGregor, E.A. (1922). Observations on the egg yield of Klamath River king salmon. Calif. Fish Game, 8:160-164.

Murua, H., Kraus, G., Saborido-Rey, F., Witthames, P.R., Thorsen, A., and Junquera, S. (2003). Procedures to estimate fecundity of marine fish species in relation to their reproductive strategy. J. Northwest Atlantic Fish. Sci., 33:33-54.

Mukherjee, S., Chaudhuri, A., Kundu, N., Mitra, S., and Homechaudhuri, S. (2012). Comprehensive analysis of fish assemblages in relation to seasonal environmental variables in an estuarine river of Indian Sundarbans. Estuar. Coast., 36:192-202.

Nabi, M.R.U. (1994). On the study of the thread fin *Polinemous paradiscus* from the landing centers and local market of Chittagong. [MSc. thesis]. Institute of Marine Sciences, University of Chittagong, Chittagong, Bangladesh, 67p.

Nabi, M.R.U. (2007). Management of estuarine set bag net fishery of Bangladesh: application of traditional scientific methods, sustainable livelihoods approach and local indigenous knowledge. [Ph.D. thesis], Borneo Marine Research Institute, Malaysian University of Sabah, 109p.

Nabi, M.R.U. and Ullah, M.H. (2012). Effects of set bag net fisheries on the shallow coastal ecosystem of the Bay of Bengal. Ocean Coast. Manage., 67:75-86.

Nargis, A., Hossain, M.A., and Kashem, M.A. (1983). On the food, feeding, fecundity and sex ratio of *Anabus testudineus* (Bloch). Proceedings of the 4th National Conference of the Zoological Society of Pakistan: Section IV, p. 23-24.

Nash, R.D.M. (1982). The biology of Fries' goby, *Lesueurigobius friesii* (Malm), in the Firth of Clyde, Scotland and comparison with other stocks. J. Fish Biol., 21:69-85.

Nikolsky, G.V. (1969). Theory of Fish Population Dynamics as the Biological Background for Rational Exploitation and Management of Fishery Resources. Oliver and Boyd, Edinburgh, UK, 323p.

Nikolsky, G.V. (1963). The Ecology of Fishes. Academic Press, London, UK, 352 pp.

Offem, B.O., Ayotunde, E.O., and Ikpi, G.U. (2008). Dynamics in the reproductive biology of *Heterobranchus longifilis* Val, (Pisces: 1840) in the inland wetlands of Cross River, Nigeria. Research J. Fish. Hydro., 3(1):22-31.

Oso, J.A., Idowu, E.O., Fagbuaro, O., Olaniran, T.S., and Ayorinde, B.E. (2011). Fecundity, condition factor and Gonado-Somatic Index of Hepsetus odoe (African pike) in a tropical reservoir, Southwest Nigeria. World Journal of Fish and Marine Sciences, 3 (2):112-116.Parvez, M.S. and Nabi, M.R.U. (2014). Morphometric and meristic analysis of *Coilia ramcarati* (Hamilton, 1822) for racial investigation from Chittagong and Cox's Bazar coasts. J. Bangladesh Academy Sci., 38(1):71-74.

Parvez, M.S. and Nabi, M.R.U. (2015). Population dynamics of *Coilia ramcarati* from the estuarine set bag net fishery of Bangladesh. Walailak J. Sci. Technol., 12(6):539-552.

Peters, W.C.H. (1868). Allocation to Calamiana and redescription of the fish species *Apocryptes variegates* and *Vaimosa mindora* (Gobioidei: Gobiidae: Gobionellinae) with description of a new species. Monatsberichte der Konigllich Preussischen Akademie Wissenschaften Berlin, 1868:254-281.

Rajesh, M., Rajesh, K.M., and Panda, K. (2014). Reproductive biology of mullet, *Valamugil buchanani* from Mulky estuary off Arabian Sea, Dakshina Kannada, India. Indian J. Anim. Res., 48(4):336 -343. Rao, P.S. and Rao, L.M. (2007).

Sex ratio, fecundity, maturity and spawning details of *Glossogobius giuris* (Hamilton) from Gosthani estuary near Visakhapatnam. IUP J. Life Sci., 1(1):16-29.

Ravish, C. (1962). A preliminary account of the distribution and abundance of fish larvae in the Hooghly estuary. Indian J. Fish., 9A(1):48-70.

Rosenberg, A., Bigford, T.E., Leathery, S., Hill, R.L., and Bickers, K. (2000). Ecosystem approaches to fishery management through essential fish habitat. B. Mar. Sci., 66:535-542.

Saifullah, A.S.M., Rahman, M.S., and Khan, Y.S.A. (2004). Fecundity of *Hilsa ilisha* (Hamilton, 1822) from the Bay of Bengal. Pakistan J. Biol. Sci., 7(8):1394-1398.

Scott, D.P. (1961). Effects of food quantity on the fecundity of rainbow trout, *Salmo gairdneri*. J. Fish. Research Board Canada, 19:715-731.

Shafi, M. and Mustafa, G. (1976). Observation on the same aspects of the biology of the climbing perch *Anabus testudineus* (Bloch). Bangl. J. Zoo., 4:21-28.

Shafi, M., Quddus, M.M.A., and Chakrabarti, S. (1979). Food and feeding habits, spawning and fecundity of spotted mackerel. Bangl. J. Agric., 4(1):47-56.

Soyinka, O.O. (2014). Observations on the sex ratio, fecundity, egg size and gonadosomatic index of grey mullet, *Mugil cephalus* from high brackish tropical lagoon. J. Fish. Aquatic Sci., 9(6):455-462.

Tsikliras, A.C., Stergiou, K.I., and Froese, R. (2013). Editorial note on reproductive biology of fishes. Acta Ichthyol. Piscat., 43(1):1-5.

Varghese, T.J. (1976). Studies on the fecundity of *Coilia ramcarati* (Ham.-Buch.). P. Indian A.S.-Plant Sc., 83(2):47-54.

Vicentini, R.N. and Araujo, F.G. (2003). Sex ratio and size structure of *Micropogonias furnieri* (Desmarest, 1823) (Perciformes, Sciaenidae) in Sepetiba Bay, Rio de Janeiro, Brazil. Braz. J. Biol., 3:559-566.

Weddle, G.K. and Burr, B.M. (1991). Fecundity and dynamics of multiple spawning in darters: an in-stream study of *Etheostoma rafinesquei*. Copeia, 1991:419-433.

West, G. (1990). Methods of assessing ovarian development in fishes: a review. Aust. J. Mar. Fresh. Res., 41:199-222.

Xu, K. and Zhou, Y. (2005). The Individual Fecundity of *Coilia mystus* (Linnaeus) in the coastal waters of Zhoushan. Marine Fisheries Research Institute of Zhejiang Province, Zhoushan, 316100, China. http://www.cnki.cn. Accessed date: February 26, 2015.

Yigin, C.C. and Ismen, A. (2013). Reproductive biology of spiny dogfish *Squalus acanthias*, in the North Aegean Sea. Turk. J. Fish. Aquat. Sc., 13:169-177.

Zar, J.H. (1999). Biostatistical Analysis. 4th edition. Prentice Hall, Upper Saddle River, NJ, USA, 662p.