2016

# Biology and Stock Assessment of the Threatened Fish Puntius Ticto (Hamilton, 1822) (Cyprinidae) in the Gorai River, Southwestern Bangladesh

Islam, Md. Shafiqul

University of Rajshahi

# BIOLOGY AND STOCK ASSESSMENT OF THE THREATENED FISH *PUNTIUS TICTO* (HAMILTON, 1822) (CYPRINIDAE) IN THE GORAI RIVER, SOUTHWESTERN BANGLADESH

(Presently it is named as *Pethia ticto*)

***A THESIS SUBMITTED TO***
***THE UNIVERSITY OF RAJSHAHI, RAJSHAHI, BANGLADESH***
***FOR THE DEGREE OF***
***DOCTOR OF PHILOSOPHY (Ph.D)***

SUBMITTED BY

**Md. Shafiqul Islam**
**Roll No.: 10604**
**Registration No.: 0015**
**Session: 2010-2011**

***May, 2016***

***Department of Fisheries***
***Faculty of Agriculture***
***University of Rajshahi***
***Rajshahi 6205, Bangladesh***

W. mv‡jnv †Rmwgb
c‡dmi
wdkvixR wefvM
ivRkvnx wekwe`¨vjq
ivRkvnx-6205
evsjv‡`k|

Dr. Saleha Jasmine
Professor
Department of Fisheries
University of Rajshahi
Rajshahi-6205
Bangladesh

# Certificate

*This is to certify that, the thesis entitled "**Biology and stock assessment of the threatened fish Puntius ticto (Hamilton, 1822) (Cyprinidae) in the Gorai River, southwestern Bangladesh**" has been prepared by Md. Shafiqul Islam (Roll No. 10604 and Reg. No. 0015) under my supervision for submission to the Department of Fisheries, University of Rajshahi, Bangladesh, for the Degree of Doctor of Philosophy. All the data presented in this thesis are based on his own observation and no part of this work has been previously published or submitted for any other degree.*

**Supervisor**

11.5.16

**(Dr. Saleha Jasmine)**
**Professor**
**Department of Fisheries**
**University of Rajshahi**
**Rajshahi 6205, Bangladesh**

# DECLARATION

I hereby declare that the whole work submitted as a thesis entitled **''Biology and stock assessment of the threatened fish *Puntius ticto* (Hamilton, 1822) (Cyprinidae) in the Gorai River, southwestern Bangladesh''** to the department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi 6205, Bangladesh for the Degree of Doctor of Philosophy is the result of my own investigation which has been carried out under the supervision of Dr. Saleha Jasmine, Professor, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi 6205, Bangladesh. I further declare that this thesis has not been submitted elsewhere for any other degree.

Md. Shafiqul Islam
Researcher

Dedicated

To My

Beloved

Parents

# Acknowledgement

*All the admiration, praise and extolments go to Almighty Allah, the most merciful, who has enabled the author to submit this thesis.*

*The author extremely pleased in expressing his high indebtedness, heartiest profound, deepest sense of respect, gratitude and best regards to his supervisor Dr. Saleha Jasmine, Professor, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi, Bangladesh, for her kind and constant supervision and advice during the research work and successful completion of the thesis.*

*The author likes to extend his cordial gratefulness and appreciation to Dr. Md. Yeamin Hossain, Associate Professor, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi, Bangladesh, for providing analytical support, design and guideline to write this thesis.*

*The author wishes to express his deepest sense of gratitude and sincere devotion to Dr. M. Afzal Hussain, Professor and Chairman, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi, Bangladesh, for providing all laboratory facilities and encouragement during this research work.*

*The author is grateful to Dr. Md. Abdul Wahab, Dr. Joarder Faruque Ahmed, Professor, Faculty of Fisheries Management, Bangladesh Agricultural University, Mymensingh, Bangladesh; Dr. Md. Akhtar Hossain, Professor, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi, Bangladesh, Dr. Md. Abu Sayed Jewel, Associate Professor, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Rajshahi, Bangladesh, and Md. Mosaddequr Rahman, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima 890-0056, Japan, for their encouragement and valuable suggestion throughout the study period.*

*The author also takes this opportunity to express his gratefulness to Md. Alomgir Hossen and Md. Nasir Uddin Pramanik, Masters Students for their kind help during the laboratory work.*

*The author also likes to express his gratitude to the fishers of Gorai River, Kushtia, for their co-operation during sampling.*

*Finally, the author is ever grateful to his beloved parents, wife and son for their moral support, constant blessing, good advice and encouragement during the research work.*

***The Author***

# Abstract

The present study describes the fisheries biology including length-weight relationships (LWRs), condition factor (Fulton's, $K_F$), pre-predator status (based on relative weight, $W_R$), reproductive biology (size at first sexual maturity, spawning season and fecundity), growth parameters (asymptotic length, growth co-efficient, age at zero length) and stock status (fishing mortality, natural mortality, total mortality, exploitation rate) of the threatened fish *Puntius ticto* (Hamilton, 1822) from the Gorai River, southwestern Bangladesh. A sum of 1200 individuals of *P. ticto* was sampled during July 2010 to June 2011 using cast net, square lift net and conical trap. Here, the total length (TL) was ranged from 2.77-7.48 cm for male and 2.66-8.00 cm for female. The body weight (BW) ranged from 0.42-6.6 g for male and 0.23-8.94 for female *P. ticto*. The *b* values of LWRs ranged from 2.63 to 3.62 for males and 3.04 to 3.76 for females and the overall *b* values of LWRs indicated negative allometric growth (< 3.00) in both males and females. The $K_F$ was higher in January for both genders suggesting that the fish was in good condition in that month. Also, the $W_R$ was higher in the month of December-March for male and January-March for female populations of *P. ticto* indicating that, in these months the predator was in lower and prey was in higher amount. Also, the mean $W_R$ was significantly different from 100 for both sexes suggesting the habitat was not in balance condition with lower prey-higher predator. On the basis of gonadosomatic index (GSI) the first sexual maturity was 4.2 cm in TL for male and 4.7 cm in TL for female *P. ticto*. The higher GSI were found during the month of April-September, which indicates the spawning season of *P. ticto* in the Gorai River and peak values of GSI were found in the month of June-July, which point out peak spawning season. Also, when temperature increases above $30^{o}$C and rainfall starts, then the *P. ticto* began to spawn. There is a significant correlation between temperature, rainfall and the spawning season. During the study, lowest fecundity was 2021 and highest fecundity was 8623 with mean value of 4600±2037. The length-frequency distribution indicated that male *P. ticto* were first recruited in the month of September and female *P. ticto* were first recruited in the month of August. Estimated growth equations showed $TL_\infty$ in male is 10.26 cm, and in female is 10.55 cm but female grew faster than male. The growth co-efficient was 1.16 year$^{-1}$ for male and 1.30 year$^{-1}$ for female. Also, age at $t_o$ was calculated as 0.006 for males and 0.007 for females. The growth performance index for males and females *P. ticto* was 1.80 and 2.16, respectively and longevity was 2.6 year for males and 2.30 year for females. The calculated natural mortality was 1.66 year$^{-1}$ for males and 2.74 year$^{-1}$ for females; and fishing mortality was recorded as 2.01 year$^{-1}$ and 4.40 year$^{-1}$ for males and females respectively. In addition, the total mortality was 2.67 and 7.14 year$^{-1}$ for male and female populations of *P. ticto.* From the estimates fishing and total mortalities, the exploitation rate was calculated as 0.58 or 58% for male and 0.62 or % for female. Therefore, the findings of this study would be very effective for sustainable management and conservation for the stock of *P. ticto* in the Gorai River and surrounding ecosystems.

# CONTENT

**Acknowledgement**…………………………………………………………….……. **I**

**Abstract**…………………………………………………………………….……..**II**

**CHAPTER 1: GENERAL INTRODUCTION**…….............................**01-08**

**1.1. Fisheries and Bangladesh**…………………………………………………**01-03**

**1.2. Short Profile of *Puntius ticto***…………………………….…………………...**03-04**

**1.3. Common Names**……………………………………………………..…...**04**

**1.4. Synonyms**……………………………...…………………………..…**05**

**1.5. Distribution**……………………………...……………………..……..**05**

**1.6. Abundance**……………………………………………………………….**05**

**1.7. Conservation status**…………………………..……………………..…**05-06**

**1.8. Morphology**……………………………………………………….……..…**06**

**1.9. Fin formula**………………………………………………………..………...**06**

**1.10. Maximum length and weight**……………………………….…………...…**06**

**1.11. Habitat**……………………………………………………………….…..…**06**

**1.12. Ecology**…………………………………….…………………………**06**

**1.13. Breeding time**…………………………………….……………….…..**07**

**1.14. Food and feeding**……………………………………..……………....**07**

**1.15. Threats**………………………………………………………………..**07**

**1.16. Overall objectives**……………………………….…………….…..**07**

**1.17. Specific Objectives**…………………………………………………...…**08**

**CHAPTER 2: REVIEW OF LITERATURE**……….....................**09-30**

CHAPTER 3: ……………………………………………………………......27-78

STUDY 1……………………………………………………………...........31-49

1.1. Introduction ..……………………………….……………………….31-32

1.2. Materials and methods…………………………………………..…......32-35

1.3. Results………………………………………………………………...…35-46

1.4. Discussion……………………………………………………………..47-49

1.5. Conclusion………………………………………..………..………...…49

STUDY 2………………………………………….....………………...50-58

2.1. Introduction……………………………………………………………..50

2.2. Materials and methods……………………………..………………………51

2.3. Results………………………………………………………………...52-56

2.4. Discussion………………………………………………………………57-58

2.5. Conclusion……………………………………………………..…………...58

STUDY 3…………………………………………………………….… 59-74

3.1. Introduction…………………………………………...…………59-60

3.2. Materials and method……………………………………………………60-63

3.3. Results………………………………………………….………………63-71

3.3.1. Size at sexual maturity……………………………...…………..63-65

3.3.2. Spawning season…………………………………………….…….66

3.3.3. Relationship of spawning season and climate change (temperature and rainfall)……………….……………………….…66-68

3.3.4. Fecundity…………………………………………………….…….69-71

3.4. Discussion…………………………………………………………….…72-73

3.5. Conclusion……………………………………………………………..…..74

STUDY 4…………………………………………………………….…75-87

4.1. Introduction…………………………………………………….…75-76

4.2. Materials and Methods……………………….……………….…..76-79

4.2.1. Length based growth analysis…………………...…………………76-78

4.2.2. Growth performance indices ……………………….………………78

4.2.3. Longevity……………………………………………………..78-79

4.3. Results……………………………………………………………79-85

4.3.1. Length frequency distribution………………………..................79-81

4.3.2. Growth parameters based on length……………………….…82-84

4.3.3. Growth performance indices and longevity…………………..…85

4.4. Discussion………………………………………...……………86-87

4.5. Conclusion…………………………………………………………87

STUDY 5…………………………..……………………………88-95

5.1. Introduction……………………………………..………..…………88

5.2. Materials and Methods…………………………..…….........89-90

5.2.1. Estimation of mortality and exploitation rate………...……….……89-90

5.3. Results…………………………………………………….……..90-93

5.4. Discussion…………………………………………….….………93-94

5.5. Conclusion……………………………………………………....….95

CHAPTER 4: GENERAL DISCUSSION……………...………...96-100

CHAPTER 5: SUMMARY AND CONCLUSION……………..01-105

CHAPTER 6: REFERENCES……………………………………106-125

# LIST OF TABLE


| Table No. | Title | Page No. |
|---|---|---|
| Table 1 | Common names and country list of *Puntius ticto* | 04 |
| Table 2 | List of some synonyms and their status with validity | 05 |
| Table 3 | Descriptive statistics on the total length (cm) and weight (g) measurements of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 36 |
| Table 4 | Descriptive statistics on the total length (cm) and weight (g) measurements of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 37 |
| Table 5 | Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 38 |
| Table 6 | Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 39 |
| Table 7 | Fulton′s condition factor, $K_F = 100 \times (BW/TL^3)$ of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 44 |
| Table 8 | Fulton′s condition factor, $K_F = 100 \times (BW/TL^3)$ of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 45 |

| | | |
|---|---|---|
| Table 9 | Descriptive statistics on the relative weight ($W_R$) of male *Puntius ticto* (Hamilton, 1822) in the Gorai River, southwestern Bangladesh | 53 |
| Table 10 | Descriptive statistics on the relative weight ($W_R$) of male *Puntius ticto* (Hamilton, 1822) in the Gorai River, southwestern Bangladesh | 54 |
| Table 11 | Fecundity (average number of eggs) in various length classes of *Puntius ticto* (Hamilton, 1822), in the Gorai River, from July 2010 to June 2011 | 69 |
| Table 12 | Fecundity (average number of eggs) in various body weight classes of *Puntius ticto* (Hamilton, 1822), in the Gorai River, from July 2010 to June 2011 | 69 |

# LIST OF FIGURES


| Figure No. | Title | Page No. |
| --- | --- | --- |
| Figure 1 | The generalised ln-ln relationships between total length (TL) and body weight (BW) of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 40 |
| Figure 2 | Relationships between total length (TL) and body weight (BW) of the male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 40 |
| Figure 3 | The generalised ln-ln relationships between total length (TL) and body weight (BW) of the female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 41 |
| Figure 4 | Relationships between total length (TL) and body weight (BW) of the female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 41 |
| Figure 5 | Monthly variations of *b* values for male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 42 |
| Figure 6 | Monthly variations of b values for female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh | 43 |

| | | |
|---|---|---|
| **Figure 7** | **Monthly variations of the Fulton′s condition factor ($K_F$) of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh** | **46** |
| **Figure 8** | **Monthly variations of the Fulton′s condition factor ($K_F$) of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh** | **46** |
| **Figure 9** | **Monthly variations of relative weight ($W_R$) for male *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh** | **55** |
| **Figure 10** | **Monthly variations of relative weight ($W_R$) for female *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh** | **55** |
| **Figure 11** | **Relationships between total length and relative weight for male *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh** | **56** |
| **Figure 12** | **Relationships between total length and relative weight for female *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh** | **56** |
| **Figure 13** | **Showing the GSI based first sexual maturity of male *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **64** |
| **Figure 14** | **Showing the GSI based first sexual maturity of female *Puntius ticto* from the Gorai River, southwestern** | **24** |

| | | |
|---|---|---|
| | **Bangladesh during July 2010 to June 2011** | |
| **Figure 15** | **Showing the spawning season of male *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **67** |
| **Figure 16** | **Showing the spawning season of female *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **67** |
| **Figure 17** | **Monthly changes of temperature in the region of Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **68** |
| **Figure 18** | **Monthly changes of rainfall in the region of Gorai River southwestern Bangladesh during July 2010 to June 2011** | **68** |
| **Figure 19** | **Relationships between total length and fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **70** |
| **Figure 20** | **Relationships between ln total length and ln fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **70** |
| **Figure 21** | **Relationships between body weight and fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **71** |
| **Figure 22** | **Relationships between ln body weight and ln fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011** | **71** |
| **Figure 23** | **Length-frequency distribution of male *Puntius ticto* in the Gorai River southwestern Bangladesh from July** | **80** |

| | | |
|---|---|---|
| | **2010 to June 2011** | |
| **Figure 24** | **Length-frequency distribution of female *Puntius ticto* in the Gorai River southwestern Bangladesh from July 2010 to June 2011** | **81** |
| **Figure 25** | **A Powel-Wetherall plot for the male *Puntius ticto*. Solid black symbols are used in the regression which provides asymptotic TL of 10.12 cm and Z/K of 4.61** | **83** |
| **Figure 26** | **von Bertalanffy growth curve ($TL_\infty$ =10.26 cm, K =1.16 year $^{-1}$, C = 0, winter point (WP) = 0) of male *Puntius ticto* as superimposed on the restructured total length-frequency histogram** | **83** |
| **Figure 27** | **A Powel-Wetherall plot for the female *Puntius ticto*. Solid black symbols are used in the regression which provides asymptotic TL of 10.30 cm and Z/K of 3.72** | **84** |
| **Figure 28** | **von Bertalanffy growth curve ($TL_\infty$ =10.55 cm, K =1.30 year $^{-1}$, C = 0, winter point (WP) = 0) of female *Puntius ticto* as superimposed on the restructured total length-frequency histogram** | **84** |
| **Figure 29** | **Growth performance index for ($TL_\infty$ =10.26 cm, K =1.16 year $^{-1}$, C = 0, winter point (WP) = 0) of male *Puntius ticto*** | **85** |
| **Figure 30** | **Growth performance index ($TL_\infty$ =10.55 cm, K =1.3 year-1, C = 0, winter point (WP) = 0) of female *Puntius ticto*** | **85** |

| | | |
|---|---|---|
| **Figure 31** | **Length-converted catch curve for male *Puntius ticto*. Data included in the regression are shown as black solid points** | **91** |
| **Figure 32** | **Length-converted catch curve for female *Puntius ticto*. Data included in the regression are shown as black solid points** | **91** |
| **Figure 33** | **Relative yield per recruit and biomass per recruit of male *Puntius ticto* in the Gorai River, southwestern Bangladesh** | **92** |
| **Figure 34** | **Relative yield per recruit and biomass per recruit of female *Puntius ticto* in the Gorai River, southwestern Bangladesh** | **93** |

# LIST OF PLATE


| Plates No. | Title | Page No. |
|---|---|---|
| Plate 1 | Photos of *Puntius ticto* | 04 |
| Plate 2 | Map showing the study site (Original source: www.google.com; Accessed on 20 December 2014) | 33 |
| Plate 3 | Collection of samples using cast net (above photo) and measurement of length (below left) and weight (below right) | 34 |
| Plate 4 | Collection of gonad of *Puntius ticto* | 61 |
| Plate 5 | Measurement and weighting of gonad of *Puntius ticto* | 61 |
| Plate 6 | Counting of eggs of *Puntius ticto* | 62 |

# GENERAL INTRODUCTION

## 1.1. Fisheries and Bangladesh

Bangladesh is a low-lying riverine country in South Asia located between latitude $20^0 34'$ and $26^0 38'$N and longitude $88^0 41'$ and $92^0 41'$ E. Bangladesh is exclusively gifted with extremely rich and extensive inland and marine water resources which mainly include floodplains, rivers, estuaries, coastal belt and vast sea waters. Along with potential resources, Bangladesh is also rich in the diversity of various fish species and other important aquatic species. Hence it is ranked third in aquatic biodiversity in Asia behind China and India with approximately 300 species of fresh and brackish water species (Hussain and Mazid, 2001). Fish and fisheries have been an integral part of the life of the people of Bangladesh and play a major role in employment, nutrition, foreign exchange earnings and other aspect of the economy (Alam and Thomson, 2001). However, the rich fish diversity of this country is now under threat due to cover exploitation, habitat loss, ecological changes to fish habitat and some other divergent reasons; thus 54 freshwater fish species has been categorized as threaten to extinction in Bangladesh (IUCN Bangladesh, 2000).

Bangladesh being a riverine country the main source of protein in our diet is fish. In our country about 60% of animal protein comes from fish and it contributes in 3.69% G.D.P (DoF, 2015). Presently fish protein is said to be healthier and cholesterol free and the adults are advised to take much fish than meat because it contains all the essential amino acids in about right proportion and so called as "Complete protein". Small indigenous fish species are more nutritious. According to (Ross et al., 2003), the small indigenous fish species (SIS), which are defined as species attaining a maximum length of 5-25 cm contribute considerably to total fish intake. These are important target species for small scale fishermen in Bangladesh, who use a variety of traditional fishing gears (Craig et al., 2004; Kibria and Ahmed, 2005). These small indigenous fishes are major source of animal protein and micronutrients in the diet of the rural small-scale farmer's family of Bangladesh (Alim et al., 2004). These small indigenous fish species of Bangladesh has a high nutritional value in terms of protein, micronutrient, vitamins and minerals not commonly available in other foods (Ross et al., 2003). These are important source of essential micro and macro nutrient in human body. It contains 72% water, 19% protein, 80% fat, 0.15% calcium 0.25% phosphorus and 0.10% vitamin. The liver fat contain vitamin-A and D which is important for our bone, skin and eye and also plays a significant role in the elimination of malnutrition in Bangladesh.

Fish is a natural complement to rice in the national diet; giving rise to the adage Maache-Bhate Bangali ("a Bengali is made of fish and rice") fish alone supplies about 60% of animal protein intake in Bangladesh (Ahmed et al., 1997). There are 260 indigenous freshwater bony fish species, suitable for human consumption, belonging to 145 genera and 55 families, constitute a very rich aquatic bio-diversity in Bangladesh (Craig et al., 2004). Among these species, over 150 species have been considered as small indigenous species (SIS) (Amin et al., 2009). The small indigenous fish species (SIS) are defined as species attaining a maximum length of 5-25 cm contribute considerably to total fish intake (Ross et al., 2003). Small indigenous fish species have been considered as an excellent source of essential macro and micro-nutrients which can play an important role in the elimination of malnutrition problem in Bangladesh (Thilsted et al., 1997). Rural people of many South Asian countries including Bangladesh, consume 56-73 species of SIS among which Punti (*Puntius ticto* Hamilton*)*, mola (*Amblypharyngodon mola*, Hamilton), chela (*Chela cachius*, Hamilton), and Tengra (*Mystus cavasius*) are most commonly preferred (Ahmed et al., 2010).

## 1.2. Short Profile of *Puntius ticto*

The small fish *Puntius ticto* (Hamilton, 1822) (Cypriniformes: Cyprinidae) now it is *Pethia ticto* (Pethiyagoda et al., 2012), is a fresh- and brackish-water, subtropical species which is commonly known as "ticto" or "two-spot" barb. This fish is also known as *tit punti* in Bangladesh, *pothia* in India, *poti* in Nepal, and thith pethiya in Sri-Lanka (Froese and Pauly 2015). It is a most popular aquarium fish among barb species in Bangladesh and other Asian countries (Froese and Pauly, 2015). Previously abundant in the rivers, creeks, canals, reservoirs, lakes, swampland (*beels*, *haors,* and *baors*) and ponds of Bangladesh (ICUN Bangladesh, 2000), India, and Sri-Lanka (Froese and Pauly 2015), but the populations have seriously declined to the verge of extinction due to over exploitation and various ecological changes in its natural habitats (Mijkherjee et al., 2002). Due to destruction of the natural habitat and other factors, population of this species is declining rapidly (Hossain et al., 2012a).

## Systematic position:

Plate 1: Photos of *Puntius ticto*

Phylum: Chordata

Class: Actinopterygii

Order: Cypriniformes

Family:

Cyprinidae

Genus: *Puntius*

Species: *Puntius ticto*

New name: *Pethia ticto*

## 1.3. Common Names

Tit punti in Bangladesh (Rahman, 1989), Tetputi and pothia in India (Froese and Pauly, 2015), Poti and Titepothi in Nepal (Froese and Pauly, 2015), Thith pethiya in Sri Lanka (Pethiyagoda, 1991).

Table 1. Common names and country list of *Puntius ticto*

| Common Name | Country | Language |
|---|---|---|
| Ticto barb | Global | English |
| Two spot barb | USA | English |
| Ticto barb | India | English |
| Toplet Burbe | Denmark | Danish |
| Zweipunk barbe | Germany | German |
| Two spotted barb | Bangladesh | English |
| Poti | Nepal | Nepali |
| Tit punti | Bangladesh | Bengali |
| Tic-tac-toe barb | Srilanka | English |

## 1.4. Synonyms

**Table 2. List of some synonym and their status with validity**

| Synonym | Status | Validity |
|---|---|---|
| *Pethia ticto* (Hamilton 1822) | New combination | Yes |
| *Cyprinus ticto* (Hamilton 1822) | Original | No |
| *Systomus ticto* (Hamilton 1822) | New combination | No |

## 1.5. Distribution

This fish is widely distributed through the Indian subcontinent, including Bangladesh, India, Nepal, Pakistan, Sri-Lanka, Myanmar and Thailand (Talwar and Jhingran, 1991). It also occurs in the upper Mekong, Salween, Irrawaddy, Mekong and upper Chao Phraya basins (Kottelat, 1985).

## 1.6. Abundance

This fish was previously abundant in the rivers, creeks, canals, reservoirs, lakes, swamplands (beels, haors and baors) and ponds of Bangladesh (IUCN Bangladesh, 2000), India and Sri-Lanka (Froese and Pauly, 2015), but the populations have seriously declined to the verge of extinction (Hossain et al., 2014).

## 1.7. Conservation status

Vulnerable in Bangladesh (IUCN Bangladesh, 2000); lower risk near threatened in India (Balasundaram et al., 2000; Sarkar et al., 2010); threatened in Sri-Lanka (IUCN Sri-Lanka, 2000); least concern on the global IUCN Red List of Threatened Species (Dahanukar, 2010). *P. ticto* is declining rapidly due to heavy fishing pressure and a number of studies have been conducted on *P. ticto*, includeing conservational status (IUCN Bangladesh, 2000), population traits (Archarya and

Iftekhar, 2000; Chandrashekha-riah et al., 2000) and biology (Hossain, 2010a; Hossain et al., 2009a; 2012b).

## 1.8. Morphology

Mouth is small and its position is terminal. Barbels are absent, color is silvery. Two black spots found on the lateral line which in incomplete. Depth of body less than one-third of the standard length (Rahman, 1989). It grows to a maximum length of 11.8 cm (Banik and Saha, 2012).

## 1.9. Fin formula

D. 11 (3/8); $P_1$. 13-15; $P_2$. 9; A. 7- 8 (2- 3/8). (Rahman, 1989) D iii-iv/8; A ii-iii/5; P.i/12-14; V.i/8 (Talwar and Jhingran, 1991).

## 1.10. Maximum length and weight

It grows to a maximum total length of 11.8 cm and weight 60 g (Banik and Saha, 2012).

## 1.11. Habitat

Ticto barb inhabits standing and running waters, usually in ponds and rivers with mostly muddy bottoms in Bangladesh and world-wide water bodies (Froese and Pauly, 2015).

## 1.12. Ecology

Ticto barb inhabits still shallow, marginal waters of tanks and rivers, mostly with muddy bottoms. It feeds on crustaceans, insects, plankton, plants and other benthic invertebrates (Bisht and Das, 1981).

## 1.13. Breeding time

It has extended period of breeding which lasts from April to June (Villif and Jorgensen, 1993).

## 1.14. Food and feeding

It feeds on crustaceans, insects, plankton, plants and other benthic invertebrates (Bisht and Das, 1981).

## 1.15. Threats

The populations have seriously declined due to over-exploitation and various ecological changes in its natural habitats (Hossain et al., 2014).

## 1.16. Overall objectives

The overall objective of this study is to describe the biological aspects and stock assessment of *P. ticto* from the Gorai River, southwestern Bangladesh.

## 1.17. Specific Objectives

The specific objectives of this study are:

(i) To estimate length-weight relationships and condition factor of the threatened fish species *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh.

(ii) To calculate pre-predator status of the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh.

(iii) To estimate reproductive Biology of the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh.

(iv) To determine growth parameters of the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh.

(v) To assess the stock status of the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh.

# REVIEW OF LITERATURE

Literature on the biology of small indigenous fish species in Bangladesh is scare. A very few sound works on the aspects of the fisheries biology especially on sex ratio, length frequency distribution, length-weight relationships, length-length relationships and condition factors of *Puntius ticto* are available in the Indian sub-continent. It is very indispensable to review the earlier studies or research works related to the planned study before conducting a study or experiment. The scopes and objectives of the present study related to literature are discussed below:

**Abowei et al. (2009)** described the length-weight relationship and condition factor of five fish species from Nkoro River in the Niger delta region of Nigeria was studied for twelve months using data obtained from fishers. All species studied exhibited isometric growth (*b* =3) except *S. maderensis* and *C. senegalensis* with (*b*), 3.6 and 3.5 respectively that exhibited positive allometric growth. The condition factor ranged from 0.917 (*I. Africana*) to 0.985 (*C. senegalensis*). There was difference in the condition factors for the combined fish species and the monthly factor for each fish species studied: *E. fimbrata* (0.85±0.015), *I. Africana* (0.96±0.061), *S. maderensis* (0.87±0.072), *A. mola*, with an average value of 3.098. The LWRs indicated a negative allometric growth in *M. aculeatus* and a positive allometric growth for the remaining species. All LLRs presented in this study were highly significant ($P < 0.001$), with most of the coefficient of determination values being >0.9; one exception was *A. mola* ($r^2$ =0.868 for SL *vs.* FL).described the length-weight relationship and condition factor of five fish species form Nkoro

River in the Niger delta region of Nigeria, the condition factor ranged from 0.917 (*I. Africana*) to 0.985 (*C. senegalensis*). There was difference in the condition factors for the combined fish species and the monthly factor for each fish species studied: *E. fimbrata* (0.85±0.015), *I. Africana* (0.96±0.061), *S. maderensis* (0.87±0.072), and *E. senegalensis* (0.62±0.011), while *C. senegalensis* was 1.10±0.042. All species studied were in good condition (k≠0.5).

**Agboola and Anetekhai (2008)** established the length-weight relationships for 35 fish species from the Badagry creek, Lagos, Nigeria and found the values of the parameter '*b*' are within the range of 2.5-3.5.

**Aguirre et al. (2008)** calculated the length-weight relationship of 21 species of fish from a coastal lagoon in the southwestern Gulf of California and found no differences between sexes in any species. The slope (*b*) showed values between 2.5 and 3.5.

**Ahmed et al. (2012)** described the length–weight relationship (LWR), length–length relationship (LLR) and the condition of the silver hatchet Chela, *Chela cachius* (Hamilton, 1822) from the Old Brahmaputra River in Bangladesh. In this study, 12 monthly samples total 2400 specimens (1172 male; 1228 female) collected from November 2004 to October 2005 were used to conduct this study. For each individual, the total length (TL), fork length (FL) and standard length (SL) as well as body weight (BW) were measured. The overall sex ratio showed no significant difference from the expected value of 1:1 and the analysis of covariance (ANCOVA) revealed no significant difference between LWRs of male and female for the pooled data over a year. Parameters of LWRs of combined gender varied monthly with high coefficients of determination ($r^2 > 0.751$; $P < 0.001$). All the LLRs (SL *vs*. FL, FL *vs*. TL and SL *vs*. TL) exhibited strong correlations ($r^2 >$ 0.886; $P < 0.001$) and ANCOVA analyses further indicated that LLRs did not differ between males and females. The relative-condition factors with regard to both months and SLs varied in all gender groups. Females maintained similar mean condition throughout life and showed more plumpness than both males and combined genders in all months. Finally, the results should be useful for the sustainable management of this minnow species in Old Brahmaputra River and adjacent water-bodies.

**Bobori et al. (2010)** studied length-weight (L-W) relationships for 17 fish species (one hybrid included) from three natural, eutrophic lakes in Greece. The calculated values (mean ±S E) of the exponent *b* ranged from 2.117 ± 0.119 to 3550 ± 0.104 (global mean ± SE: 3.044 ± 0.066), with 87% of the observed *b* values of the species / lake combinations lying within the expected range of 2.5-3.5.

**Dulcic and Glamuzina (2006)** observed the length-weight relationship for fish species from three eastern Adriatic estuarine systems. The values of the parameter '*b*' mostly remained within the expected range of 2.5-3.5 that indicate isometric growth.

**Esmaeili and Ebrahimi (2006)** studied the length-weight relationships of 24 freshwater fish species of Iran and found significant length-weight relationship with high correlation coefficient for all species. The value of the parameter '*b*' varied between 2.881 and 3.545.

**Froese (2006)** presented a historical review, a meta-analysis, and recommendations for users about weight-length relationships, condition factors and relative weight equations. The historical review traces the development of the respective concepts. The meta-analysis explores 3929 weight-length relationships of the type $W= a*L^b$ for 1773 species of fishes. It shows that 82% of the variance in a plot of log an over *b* can be explained by allometric versus isometric growth patterns and by different body shapes of the respective species. Across species median *b* = 3.03 is significantly larger than 3.0, thus indication a tendency towards slightly positive-allometric growth (increase in relative body thickness or plumpness) in most fishes. The expected range of $2.5 < b < 3.5$ is confirmed. Mean estimates of *b* outside this range are often based on only one or two weight-length relationships per species. However, true cases of strong allometric growth do exist and three examples are given. Within species, a plot of log *a vs. b* can be used to detect outliers in weight-length relationships. An equation to calculate mean condition factors from weight-length relationships is given as $K_{mean} = 100a\ L^{b-3}$ . Relative weight $W_{rm} = 100W/ (a_m L^{bm})$ can be used for comparing the condition of individuals across populations, where $a_m$ is the geometric mean of a and $b_m$ is the mean of *b* across all available weight-length relationships for a given species. Twelve recommendations for proper use and presentation of weight-length relationships, condition factors and relative weight are given.

**Gandotra et al. (2009)** studied on 600 specimens (ranging from 2.9 cm to 13 cm of Total Length and 1.03 g to 19 g body weight), describe length weight relationship and condition factor in different age groups of *Aspidoparia morar* from river Tawi and its tributaries (in India). The value of correlation coefficient indicated a high degree of correlation between length and weight in all the age groups. It was 0.988 in O+ age group, 0.956 in 1+age group, 0.960 in 2+age groups and 0.971 in 3+age group. The condition factor (K) was found to decrease with advancing age viz. 1.057, 0.882, 0.875 and 0.87 in 0+, 1+, 2+, & 3+ age groups respectively.

**Ghailen et al. (2011)** studied some biological parameters of the little tuna *Euthynnus alletteratus* (Rafinesque, 1810) in the Tunisian waters. Between January 2008 and December 2009, 592 specimens of Scombrid fish species *Euthynnus alletteratus* (Rafinesque, 1810) were captured in the coastal areas of Tunisian waters. Sex-ratio was 57.77% of females. They were found to outnumber males during all year except in June and July. The calculated length-weight relationships were $Wt = 0.0329FL^{2.8101}$ for females, $Wt = 0.0368FL^{2.7832}$, for $Wt = 0.0349FL^{2.7962}$ for pooled data.

**Gupta et al. (2011)** described the condition factor, length-weight and length-length relationships for an endangered freshwater fish species *Ompok pabda* (Hamilton) of the family Siluridae from the River Gomti in Northern India. The values of regression parameter *b* ranged from 2.81 to 3.32 ($r^2 > 0.90$). During the pre-monsoon, the allometric coefficient *b* of the LWR was close to isometric value ($b$ = 3.08), although it suggested negative allometric growth in monsoon periods while positive growth in post-monsoon. The condition factor values ranged from 0.672 to 0.744. Results of the present study could be useful to help in conservation and sustainable fisheries management of this endangered species.

**Haniffa et al. (2006)** studied the length-weight relationships of 1940 spotted murrel, *Channa punctata* (Bloch, 1793), collected in the Tamirabarani, Siruvani, Vellar and Cauvery rivers of Western Ghats, Tamil Nadu, India in the years 2001 through 2003. Results of that study showed that there was no significant difference ($P > 0.005$) in the length-weight relationship as a function of sex in the Siruvani, Vellaru and Cauvery populations, whereas there is a significant difference between males and females in the Tamirabarani population, indication non-homogeneity of these relationships.

**Heydarnejad (2009)** studied the length-weight relationships (LWR) are calculated for six freshwater fish species collected during 2006 and 2007 in Iran. The values of the exponent bin the LWR ($W=a*L^b$) vary between 2.985 and 3.543. The LWR with high correlation coefficient ($r^2$) is significant for all the species.

**Hile (1936)** studied on the age and growth of cisco *Leucicthyes artedi* le Suercur in the lake of north eastern highland and observed that the value of the regression coefficient “n” usually lies between 2.5 and 4.0 and for ideal fish maintain the shape n=3. The values of regression coefficient for male (2.941), female (3.008) and combined sexes (2.984).

**Hossain (2010a)** described the length-weight (LWR) and length-length (LLR) relationships, as well as the condition factors of the three important Schibid catfishes from the Padma River, northwestern Bangladesh, namely *Ailia coila* (Hamilton, 1822), *Eutropiichthys vacha* (Hamilton, 1822), and *Neotropius atherinoides* (Bloch, 1794). A total of 347 specimens were caught using traditional fishing gears from March 2006 to February 2007. For each individual, the total (TL), fork (FL) and standard (SL) lengths were measured using digital slide calipers. Individual body weight (BW) was also taken through a digital balance.

The coefficient *b* of the LWR was close to the isometric value ($b \approx 3.000$) in *A. coila*, although it suggested negative allometric growth in *E. vacha* ($b \approx 2.980$) and *N. atherinoides* ($b \approx 2.900$). The results also indicated that the LLRs were highly correlated ($r^2 > 0.914$; $P < 0.01$). The equations of the condition factors for each species were best expressed by $K = 100\times(BW/(TL^{3.000})$ for *A. coila*, $K = 100 \times$ $(BW/(TL^{3.000})$ for *E. vacha*, and $Kn = BW/[(0.095\times TL^{2.899}]$ and $K = 100 \times (BW/(TL^{3.000})$ for *N. atherinoides*. This study presents for the first time results on the total length-body weight relationships and on the condition factors of these catfishes from Padma River, northwestern Bangladesh.

**Hossain (2010b)** described the length-weight (LWR) and length-length (LLR) relationships of four cyprinid important small indigenous fish species (SIS) from the Padma River, Bangladesh. A total of 914 specimens were caught by traditional fishing gear from March 2006 to February 2007. Length (cm) and body weight (g) for each specimen was taken by a digital slide caliper and balance, respectively. The allometric coefficient *b* was close to isometric value (≈3.000) in *Aspidoparia morar* and *Puntius ticto*, although it suggested positive allometric growth in *Amblypharyngodon mola* and *Lepidocephalus guntea*. The results further indicated that LLRs were highly correlated ($r^2 > 0.932$; $P < 0.001$).

**Hossain et al. (2006a)** studied the condition factor for the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. They found the Fulton′s condition factor (*K*) ranged from 0.972 to 3.188 in males (n =1407) and from 1.564 to 3.186 in females (n =1031). There were no significant differences in *K* between months ($P > 0.05$). The average *K* in females (*K* = 2.316) was significantly higher than in males (*K* =2.196). In females, the lowest mean *K* was found in April (*K* = 1.621) and the highest in August (*K* =3.186); in males, the lowest mean *K* was found in April (*K* = 0.972) and was highest in August (*K* =3.188). The *Km* tends to be lower, between 5.5 and 7.0 cm SL in females and >7.0 cm SL males, indicating that these size classes were in the worst condition. The higher condition (*Km*) values of males coincide with the size class of lower condition of the females (5.0– 7.0 cm SL); moreover, specimens >7.0 cm SL display an upward trend in females (i.e. better condition) whilst a downward trend in males (i.e. worst condition).

**Hossain et al. (2006b)** described the annual conditions as well as the length-weight (LWR) and length-length relationships (LLR) of the Asian striped cat fish, *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae), an important fishery in the Mathavanga River (SW) Bangladesh. A total amount of 2438 specimens (3.60-9.60 cm standard length) used in this study was caught with traditional fishing gear from January to December 2004. Overall, the allometric co-efficient b of the LWR was close to the iso-metric value (*b*=3.058), although it suggested negative allometric growth for males (*b*=2.959) whilst positive allometric growth for females (*b* =3.314). The result further indicated that, the LLRs were highly correlated ($r^2$ > 0.989, $P < 0.001$). The monthly gonadosomatic index showed that the reproductive period of *M. vittatus* began in April and ended in August when the highest values of the Fulton′s condition factor (K) indicated their recovery.

**Hossain et al. (2008)** described some biological parameters, including sex ratio, length-frequency distributions, size at sexual maturity, fecundity as well as length-weight (LWR) and length-length (LLR) relationship of 135 specimens of the Ganges River sprat *Corica soborna* (Hamilton, 1822) (Clupeidae), an important target species for small scale fisheries in the Mthabhanga River in Bangladesh. The sex-ratio showed no significant differences from expected value of 1:1 ($\chi 2$=0.07, $P > 0.05$). The allometric coefficient *b* values of the LWR indicated isometric growth (*b*~3.0) for both males and females (2.946 and 2.968, respectively). The LLR analysis between TL and fork length (FL) showed a highly significant correlation in both sexes ($r^2 > 0.911$, $P > 0.001$).

**Hossain et al. (2009a)** described the length-weight (LWR) and morphometric relationships of 266 specimens of the tank goby *Glossogobius giuris* (Hamilton, 1822) (Perciformes: Gobiidae), and important small indigenous fish species in the Ganges, northwestern Bangladesh. The allometric coefficient *b* of the LWR for the combined sexes was close to the isometric value ($b$ = 3.068 for TL and $b$ = 3.089 for SL, standard length), but with a slight negative allometric growth for males ($b$ = 2.954 for TL, $b$ = 2.953 for SL) and a slight positive allometric growth for females ($b$ = 3.293 for TL, $b$ = 3.166 for SL). The results further indicated that morphometric relationships were highly correlated ($r^2 > 0.712$; $P < 0.001$).

**Hossain et al. (2009b)** studied the length-weight (LWR) and length-length (LLR) relationships for ten small indigenous fish species (SIS) from the lower part of the Ganges, Bangladesh, namely *Ailia coila, Amblypharyngodon mola, Aspidoparia morar, Clupisoma atherinoides, Eutropiichthyes vacha, Glossogobius giuris, Gudusia chapra, Lepidoceephallus guntea, Mystus vittatus and Puntius ticto.* A total of 2142 specimens representing 10 species of 5 families used for this study were caught by traditional fishing gear from March 2006 to February 2007. Standard length (SL), total length (TL), and fork length (FL) for each specimen were measured by digital slide calipers and each body weight was taken by a digital balance. The allometric coefficient b of the LWR was close to the isometric value ($b$ = 3.001) in *G. giuris*, although it suggested negative allometric growth in *A. coila, A. morar, C. atherinoides, E. vacha* and *Puntius ticto* whilst positive allometric growth in rest of the species. The results further indicated that the LLRs were highly correlated ($r^2 > 0.890$; $P < 0.01$).

**Hossain et al. (2009c)** described the length-weight (LWR) and morphometric relationships of the tank goby *Glossogobius giuris* (Hamilton, 1822) (Perciformes: Gobiidae), an important small indigenous fish species in the Ganges, northwestern Bangladesh. A total of 266 specimens, 11.30-23.60 cm in total length (TL), were caught using traditional fishing gear from March 2006 to February 2007. The allometric coefficient $b$ of the LWR for the combined sexes was close to the isometric value ($b$ = 3.068 for TL and $b$ = 3.089 for SL, standard length), but with a slight negative allometric growth for males ($b$ = 2.954 for TL, $b$ = 2.953 for SL) and a slight positive allometric growth for females ($b$ = 3.293 for TL, $b$ = 3.166 for SL). The results further indicated that morphometric relationships were highly correlated ($r^2 > 0.712$; $P < 0.001$). To the best of our knowledge, this study presented the first reference on LWR and morphometric relationships for *G. giuris* from Bangladeshi waters. These results will be useful for fishery managers to impose adequate regulations for sustainable *G. giuris* fishery management not only in the Ganges of Bangladesh but also in neighbouring countries.

**Hossain et al. (2012a)** described the size at first sexual maturity, length-weight relationships (LWR) in relation to size at first sexual maturity, and Fulton's condition factor ($K_F$) of *Eutropiichthys vacha* in the Ganges River, northwestern Bangladesh during January, April and July to December 2010. The analysis of covariance (ANCOVA) revealed significant differences in slope and intercept between early and late phases for males (F=4.532, $P < 0.001$) and females (F=21.984, $P < 0.001$). The $K_F$ was not significantly correlated with TL for males ($r_s$= 0.052; $P$ = 0.378), but highly correlated for females ($r_s$= -0.165; $P$ = 0.005).

**Hossain et al. (2012b)** described the length–weight relationships (LWRs) and length–length relationships (LLRs) of five threatened fishes from the Jamuna River, a distributary of the Brahmaputra River in northern Bangladesh namely *Ailiichthys punctata* (Day, 1871), *Botia lohachata* (Chaudhuri 1912), *Chanda nama* (Hamilton 1822), *Laubuca laubuca* (Hamilton 1822) and *Mystus cavasius* (Hamilton 1822). A total of 919 specimens from five species in five families used for this study were caught by traditional fishing gear, March 2010 through February 2011. The allometric coefficient ($b$) of the LWRs indicated negative allometric growth in *A. punctata*, *B. lohachata*, and *C. nama* ($b < 3.00$), but positive allometric growth in *L. laubuca* and *M. cavasius* ($b > 3.00$). Furthermore, the LLRs were highly correlated ($r^2 > 0.978$; $P < 0.001$). This study presents the first reference on LWRs and LLRs for these threatened species in Bangladesh. The results would be useful for sustainable management and conservation of the limited stocks in the Brahmaputra River ecosystem.

**Hossain et al. (2012c)** described the length-weight relationships (LWR), length-length relationship (LLR) of five threatened fish from the Jamuna river a distributaries of the Brahmaputra river in Northern Bangladesh namely *Ailichthys punctata* (Day, 1871), *Botia lohachata* (Chaudhuri, 1912), *Chanda nama* (Hamilton, 1822), *Laubuca laubuca* (Hamilton, 1822) and *Mystus cavasius* (Hamilton, 1822). A total of 919 specimens from five species in five families used for this study were caught by traditional fishing gear, March 2010 through February 2011. The allometric coefficient (*b*) of the LWRs were indicated negative allometric growth in *A. punctata*, *B. lohachata*, *C. nama* ($b$ < 3.00), but positive allometric growth in *L. laubuca* and *M. cavasius* ($b$ > 3.00). Furthermore, the LLRs are highly correlated ($r^2$ = 0978; $P$ <.001). This study presents the first references on LWRs and LLLRs for these threatened species in Bangladesh. The results would be useful for sustainable management and conservation of the limited stocks in the Brahmaputra river ecosystem.

**Hossain et al. (2012d)** described the condition- (Fulton′s and Relative weight) and form-factor ($a_{3.0}$) of the five threatened fishes from the Jamuna River, a distributary of the Brahmaputra River in northern Bangladesh. A total of 919 specimens from five species in five families used for this study were caught by traditional fishing gear during March 2010 through February 2011. For each individual, the total (TL), fork (FL) and standard (SL) length were measured by digital slide calipers while individual body weight (BW) was measured using a digital balance. The Fulton′s condition factor ($K_F$) showed significant variations ($P$ < 0.01) among species, with best performance by *B. lohachata* (1.49±0.20) followed by *C. nama* (1.41±0.19), *M. cavasius* (0.79±0.14), *L. laubuca* (0.78±0.09) and *A. punctata* (0.71±0.12). The calculated minimum and maximum relative weight ($W_R$) was 53.14 for *C. nama* and 167.88 for *A. punctata*, respectively. However, the estimated relative weight

($W_R$) was close to 100 for all populations ($P$ > 0.05) indicating a balanced habitat with food availability relative to the presence of predators. The calculated minimum and maximum form factor ($a_{3.0}$) was 0.0062 for *A. punctata* and 0.0158 for *B. lohachata*, respectively. To the best of our knowledge, this study presents the first reference on $K_F$, $W_R$ and $a_{3.0}$ factors for these threatened species in Bangladesh. The results would be useful for sustainable management and conservation of the limited stocks in the Brahmaputra River ecosystem.

**Hossain et al. (2012e)** described the size at first sexual maturity, fecundity, length–weight (LWRs) and length–length relationships (LLRs) of the pool barb, *Puntius sophore*, using data obtained from different geographical locations in Bangladesh. A total of 905 specimens were caught by traditional fishing gear from March 2010 to February 2011. Additionally, a total of 121 females were collected from a commercial catch of the Padma River during June–July 2011 to estimate size at first maturity and to determine fecundity. Total length (TL), fork length (FL) and standard length (SL) were measured with digital slide calipers. Individual body weights (BW) were determined for all specimens, and gonad weights (GW) from 121 females were weighed to an accuracy of 0.001 g. The female gonadosomatic index (GSI) was calculated as [GSI (%) = (GW ⁄ BW)* 100]. Female size at first maturity was estimated using GSI and TL as indicators, and estimated as 5.00 cm TL in the Padma River. Specimens larger than 5.00 cm TL were used to determine fecundity. Mean total fecundity was 5300 ± 2700, ranging from 1580 to 16590. A positive exponential correlation was recorded between total fecundity and total length ($r^2$ = 0.421). Relative fecundity ranged from 466 to 4036 (mean 1100 ± 580) in the Padma River. The LWR of pooled data for sexes combined was estimated as

BW = 0.0155 TL 2.98 as ANCOVA revealed no significant differences in LWRs between rivers ($P$ > 0.05). All LLRs were highly correlated ($r^2$ > 0.983; $P$ < 0.001), and ANCOVA analyses further indicated that LLRs did not differ between rivers ($P$ > 0.05). These results will help in further studies on the population assessment of the species.

**Hossain et al. (2012f)** described the first at sexual maturity, fecundity, length-weight (LWR) and length-length relationships (LLR) of the pool barb (*Puntius sophore*) using data obtained from different geo-graphical locations in Bangladesh. A total of 905 specimens were caught by traditional fishing gear from March 2010 to February 2011. Additionally a total of 121 females were collected from a commercial catch of the Padma river during June-July 2011 to estimate size at first sexual maturity and to determine fecundity. Total length (TL), fork length (FL) and standard length (SL) were measured with digital slide calipers. Individuals body weight (BW) were determined for all specimens and gonad weight (GW) from 121 females weighted to an accuracy of 0.001 g. The female gonadosomatic index (GSI) was calculated as [GSI (%)=( GW/BW)* 100] Female size at first maturity was estimated using GSI and TL as indicators and estimated as 5.00 cm TL in the Padma river. Specimens larger than 5.00 cm TL were used to determine fecundity. Mean total fecundity was 5300±2700 ranging from 1580 to 165900. A positive exponential correlation was recorded between total fecundity and total length ($r^2$ = 0.421). Relative fecundity ranged from 466 to 4036 (mean 1100±580) in the Padma river. The LWR of pooled data for sexes combined was estimated as BW=0.0155 and TL=2.98 as ANOVA revealed no significant differences in between LWR river ($P$ > 0.05). All LLRs are highly correlated ($r^2$ = 0.983; $P$ < 0.001) and ANOVA analyses further indicated that LLRs did not differ between rivers ($P > 0.05$). The result will help in further studies on the population assessment of the species.

**Hossain et al. (2014)** furnished the length-weight relationships (LWRs), length-length relationships (LLRs) and form factor ($a_{3.0}$) of these three threatened fishes from the Ganges River, northwestern Bangladesh. A total of 773 specimens from three species under two families used for this study were caught by traditional fishing gear between April 2011 and March 2012. The analysis of covariance (ANCOVA) revealed significant differences between the sexes in LWRs for *L. boga* ($P < 0.001$), but not with rest of the species ($P > 0.05$). Furthermore, the LLRs were highly correlated ($r^2 > 0.983$; $P < 0.001$), and ANCOVA analyses additionally indicated that LLRs did not differ between sexes ($P > 0.05$). The calculated form factor ($a_{3.0}$) was 0.0111, 0.0159 and 0.0129 for *L. boga*, *N. nandus* and *P. ticto*, respectively. This study presents the first reference on LWRs, LLRs and form factor for these threatened species in Bangladesh. The results would be useful for further studies on the population assessment and sustainable conservation of the limited stocks in the Ganges River ecosystem.

**Iqbal and Suzuki (2009)** studied the condition factor, length-weight (LWR) and length-length relationships (LLR) of 1121 specimens (511 males; 620 females) of *G. equulus* for the first time. The overall allometric coefficient b of LWR was close to the isometric values ($b = 3.088$). Fulton′s condition factor showed high values at the beginning of the spawning season (June-September) and lies in peak at two months later from the spawning season.

**Khan et al. (2011)** described the length-weight relationship of two commercially important freshwater fish species of India viz., *Channa marulius* and *Heteropneustes fossilis* collected from the Ganga River, during the period January 2009- December 2010. Regression parameter *b* for *Channa marulius* and *Heteropneustes fossilis* was 3.0 ($r^2 > 0.97$) and 3.14 ($r^2 > 0.98$), respectively.

**Manorama and Ramanujam (2011)** studied length-weight relationship (LWR) of *Puntius shalynius* in Meghalaya, India. The samples for the study were collected from Umiam River. The value of the exponent '*b*' in the LWR was less than 3, with 0.885 for males and 1.616 in females. This shows that the species exhibit allometric growth pattern. There was no difference in LWR between sexes and seasons.

**Martin (1949)** studied on the mechanics of environmental control of body form in fishes and reported that the value of the regression coefficient "n" usually lies between 2.5 and 4.0 and for ideal fish maintain the shape n=3. The values of regression coefficient for male (2.941), female (3.008) and combined sexes (2.984).

**Mazlan et al. (2012)** reported the regression of coefficient b of *A. duodecimalis* was 2.75=0.13 (x=0.352; $r$ = 0.953) for seagrass habitat and 3.81±0.33 (x=0.033; $r$ = 0.695) for mangrove habitat. The atherinids of seagrass habitat displayed a negative allometric growth pattern ($b$ < 3.0) in comparison with the mangrove habitat displayed a positive allometric growth pattern ($b$ > 3.0).

**Metin et al. (2006)** studied 1527 specimens of poor cod, *Trisopterus minutes,* collected by trawl fishing between April 2001 and March 2002 from the Izmir Bay (Middle Aegean Sea). Of the sampled population 53% were males and 41% females (sex ratio female: male = 1: 1.3). Length-weight relationships were determined for males, females and combined sexes as W= $0.007L^{3.16,}$ W = $0.009L^{3.04}$ and W= $0.007L^{3.14}$ respectively.

**Morey et al. (2003)** presented the weight-length relationships (WLRs) for 103 fish species inhabiting littoral to lower slope habitats of the Balearic Islands and Iberian coast (western Mediterranean). Samples were collected using seven types of fishing gear and at depths ranging from 0.5 to 1713m. Captures were made between the years 1991 and 2001. The *b* values in the WLR, $W = a*L^b$ varied between 2.072 and 3.847 and showed a mean value of 3.03 (S.E. = ±0.03). Whenever possible, the *b* values for the species obtained both in this study and some of the previously reported in the Mediterranean Sea were compared, showing the existence of spatial variation whose causes are discussed.

**Muralidharan et al. (2011)** described the length-weight relationships of 1007 individuals of fishes belonging to 14 species representing two orders, four families and ten genera. The *b* values ranged from 2.91 for *Pangasius pangasius* to 3.20 for *Cirrhinus reba*. Parameter *b* for almost all species reported here was equal to 3. The *a* values for the species studied ranged from 0.002 to 0.027 for *Mystus armatus* and *Puntius sarana*, respectively. Samples collected during this study had species of varied size and form. There was a correlation between the shape and form and the *a* values noted, with the shape and body form varying from elongate (*Ompak bimaculatus*) to short and deep bodied (*Catla catla*). Six of the species collected were juveniles; hence the length–weight relationships of these species refer to juveniles. However, the observed condition $b = 3$ shows that the smaller specimens have the same form and condition as the large specimens. Length-weight relationships for five species (*Barbodes carnaticus*, *Cirrhinus reba*, *Tor khudree*, *Mystus armatus* and *Mystus cavasius*) were not available in Fishbase.

**Rahman et al. (2012)** described the length-frequency distributions, length-weight (LWR), length-length relationship (LWR), condition- and form-factor of *Puntius sophore* wild populations from the Chalan *beel*, northcentral Bangladesh. Sampling was done using traditional fishing gears during March 2010 to February 2011. For each individual, the total length (TL), fork length (FL) and standard length (SL) were measured by digital slide calipers. Individual body weight (BW) was also taken by a digital balance. A total of 185 specimens ranging from 3.62-9.02 cm TL (total length) and 0.70-13.20 g BW (body weight) were analyzed in this study. The length-frequency distribution showed that the 6-7 cm TL size group was numerically dominant and constituted 43% of the total population. The coefficient $b$ of the LWR indicated positive allometric growth ($b < 3.00$) for *P. sophore* in the Chalan *beel*. The results also indicated that the LWRs were highly correlated ($r^2 >$ 0.945). The calculated Fulton′s condition factor ($K$) values ranged from 0.69-2.35, with a mean value 1.64±0.30. The relative weight ($W_r$) was not significantly different from 100 for ($P$=0.074), indicating the balance habitat with food availability relative to the presence of predators for *P. sophore*. The estimated values of form factor ($a_{3.0}$) were as 0.0138, 0.0345 and 0.0435 for TL, FL and SL of *P. sophore*. These results will be useful for fishery biologists and conservationists to suggest adequate regulations for sustainable fishery management and conservation its numerous stocks in the region.

**Ross et al. (2003)** stated that the small indigenous fish species (SIS), which are defined as species attaining a maximum length of 5-25 cm contribute considerably to total fish intake.

**Salam et al. (2005)** studied the weight length and condition factor relationship of a fresh water wild *Puntius chola* from Islamabad, Pakistan. They studied fifty two fresh Water wild *Puntius chola* of variable sizes. The growth in weight was almost proportional to the cube of its length. The value of the slope $b$ = 2.80 which coincides with the slope of that of an ideal fish. Condition factor remains fairly constant in measuring length or weight. Regression parameters were found to be highly significant.

**Sani et al. (2010)** studied the length-weight relationships (LWRs) of 588 fish covering eight families, 13 genera and 14 species *(Notopterus notopterus, Gudusia chapra, Labeo calbasu, Puntius sarana, Cirrhinus mrigala, Ompok bimaculatus, Mystus tengara, Mystus cavasius, Sperata aor, Sperata seenghala, Eutropiichthys vacha, Wallago attu, Rhinomugil corsula, and Mastacembelus armatus)* captured in the Betwa River (tributary of the Yamuna River) and Gomti River (tributary of the Ganga River) from December 2007 to January 2009. The $b$ values varied between 2.4 (*M. armatus*) and 3.52 (*P. sarana*), with the mean $b$ = 2.96 at $P < 0.001$ for all species. The observations are significant for conservation and management because the Betwa River has been approved under India's first interlinking plan with the Ken River, and no length-weight data had thus far been reported for the Gomti River. The objective was to evaluate the LWRs of these two unstudied rivers for fisheries management.

**Santic et al. (2006)** studied the seasonal changes in length-weight relationships (LWRs), gonadosomatic index (GSI and condition factor of Mediterranean horse mackerel, *Trachurus mediterraneus* (Steindachner, 1868). Ranging from 14.8 to 39.1 cm total length (TL), a total of 1245 specimens (605 males and 640 females) were collected in the eastern Adriatic Sea. Samples were taken at monthly intervals (January-December 2003) using bottom trawls. The *b* values of LWRs ($W=a*L^b$) varied during the year with season and condition. Including specimens collected in all seasons, the *b* values showed that shape as they gained weight. The GSI reached maximum values in June and a minimum in December.

**Solomon et al. (2011)** presented fundamental information on the reproductive biology of *Puntius denisonii,* an endemic and threatened aquarium fish of the Western Ghats Hotspot. Results are base on the observations from three river systems, Chandragiri, Valapattannam and Chaliyar. Sex ratio deviated significantly from 1:1 and was skewed in favour of males.

**Soomro et al. (2007)** described the length-weight (LWR) and length-length (LLR) relationships of 281 specimen of a freshwater fish *Eutropiichthyes vacha* (Hamilton, 1822) from Indus River, Sindh, Pakistan during the month from February 2005 to January 2006. The values for allometric coefficient *b* of the LWR were close to isometric value for male ($b$ =3.159) and combined values for both sexes ($b$ = 3.053). However, it suggested negative allometric growth for females ($b$ = 2.973). Results for LLRs indicated that these are highly correlated ($r^2$ >0.9), $P <$ 0.0001.

**Tareque et al. (2009)** estimated length-weight relationship (LWR), condition factor (K), relative condition factor (Kn), fecundity and egg diameter of *Puntius sophore* (Hamilton) from 120 individuals collected from the Mouri river of Khulna district, Bangladesh during 7th August to 25th October 2006. The total length (TL) ranged from 4.9 cm (body weight, W=1.47 g) to 9.20 cm (W=12.84 g) for male and 6.8 cm (W=5.08 g) to 9.9 cm (W=14.25 g) for female. The logarithmic relationships of $L_T$-W and $L_s$-W were strongly positive as estimated, $r^2$=0.93 and $r^2$=0.92. The mean K and Kn were 15.03+2.20 and 1.07+0.40 respectively. The relationships of $L_T$-K and $L_T$-Kn were insignificant ($r^2$ = 0.00 and $r^2$ = 0.126). The mean bilobed gonad weight ($W_G$) was 1.36+0.438 g. The mean ova diameter was 6.5+0.51µm, 6.5±0.68 µm and 6.31±0.56 µm at the anterior, center and posterior portion of both lobes respectively. The fecundity of F of *P. sophore* varied from 743 to 4013 ($L_T$:7.0-9.9 cm; W:5.3-14.3 g). $L_T$ and W-F relationships were positive but weak. $W_G$-F relationship was positively strong. GSI of *P. sophore* was 15.25±3.80 in August.

**Wambiji et al. (2008)** recorded a total of 64, 260 and 736 specimens of *Siganus stellatus, S. canaliculatus and S. sutor* were recorded, with mean ± standard error for total length (TL) as 16.0 ± 0.6cm, 22.5± 0.3cm and 26.5 ± 0.2cm with corresponding wet body weights (B $W_s$ ) of 71.28 ± 8.53g, 158.58 ± 6.45 and 258.80 ± 4.30g, respectively. TL-BW relationships were best expressed by $\log_{10}$ BW = 2.597$\log_{10}$ TL-1.356 for *S. stellatus*, $\log_{10}$ BW = 2.800$\log_{10}$ TL-1.635 for *S. canaliculatus* and $\log_{10}$ BW = 2.716$\log_{10}$ TL-1.484 for *S. sutor* with relative condition factors expressed by Kn=BW/[(4.4×$10^{-2}$ ) ($TL^{2.597}$ )], Kn = BW/

[($2.32\times10^{-2}$ ) ($TL^{2.716}$ )] for the three species respectively. TL and BW were significantly correlated with Kn and K.

**Xue et al. (2011)** estimated length-weight relationships (LWRs) for 31 fish species caught by bottom trawl surveys in Jiaozhou Bay on the west coast of the south Yellow sea. This study presents the first reference on LWRs for 15 of these species and new records of maximum total length for two species. Most of the *b* values fell within the expected range of 2.5-3.5. The mean value of *b* was 3.094-0.064 (95% CL), which was significantly larger than 3.0, indicating a slight but significant tendency towards positive allometric growth in most fishes.

**Yilmaz et al. (2010)** described the length-weight (LWR) and length-length relationships of 170 individuals of *Capoeta sieboldii* from Hirfanli Dam Lake, Turkey. Condition factor (k) was also calculated per fork length class of females and males. LWRs of females and males were not statistically different with and within season. LWRs indicated isometric growth in both sexes. The slopes of LWRs were 3.171 for females and 2.980 for males. All correlations among fork length, total length, and standard length were highly significant ($P < 0.001$, $r^2 >$ 0.92). The values of K ranged from 1.21 to 1.43 for females and from 1.12 to 1.36 for males.

**Yousaf et al. (2009)** studied the length-weight parameters of *Wallago attu* and *Sperata sarwari* from the Indus River, southern Punjab, Pakistan with W=0.001698 $L^{3.27}$ for *W. attu* and W= 001698 $L^{3.28}$ for *S. sarwari*. The values of the slope b are significantly higher than *b*= 3.0, which shows that the weight grows more rapidly as compared to the cube of the length. Thus it was concluded that body proportions changed as fish grew in size.

# STUDY: 1

## Estimation of Length-weight relationships and condition factor of the threatened fish species *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh

### 1.1. Introduction

The relationship between length and weight (LWR) are useful parameters for assessing the well-being of the individuals and for determining possible differences among different stocks of the same species (King, 1996). Information on length-weight relationships (LWRs) of a fish species in a given geographic region is helpful in fisheries and environmental monitoring programs (Froese, 2006; Hossain et al., 2012a). The LWRs are used to estimate body weight using length measurements and are very crucial for comparing the life histories of fishes among different geographic locations (Hossain et al., 2013, 2015), also helpful for conservation and stock assessment (Hossain et al., 2009b, 2012b; Ahmed et al., 2012). Fish can attain isometric growth, negative allometric growth or positive allometric growth pattern. Isometric growth is associated with no change of body shape as an organism or fish grows. Negative allometric growth implies the fish becomes more slender as it increase in weight while positive allometric growth implies the fish becomes relatively stouter or deeper-bodied as it increases in length (Riedel et al., 2007).

The condition factor shows the degree of well being of the fish in their natural habitat. This factor is a measure of various ecological and biological factors such as degree of fitness, gonad development and the suitability of the environment with regard to the feeding condition (Mac Gregoer, 1959). In addition, condition factor is a quantitative parameter of the state of well-being of the fish that will determine present and future population success by its influence on growth, reproduction and survival (Richter, 2007). Moreover the condition factor (Fulton′s, $K_F$) is important biological parameters for fishes, from which the condition of health of stocks can be deduced (Bagenal and Tesch, 1978). The principle objectives are to find out the growth pattern of *Puntius ticto* through LWRs and their monthly variations. Also to estimate the condition of fish health and habitat.

## 1.2. Materials and methods

The present study was conducted in the Gorai (a tributary of the Padma) River, southwestern Bangladesh. Monthly samples were collected randomly during daytime from fishermen’s catch landed at different points near Boro Bazar ghat and Horipur ghat in Kustia town, southwestern Bangladesh from July 2010 to June 2011. This fish were usually caught by means of the traditional fishing gears such as cast net (*jhaki jal*), square lift net (*tar jal*), and conical trap (*dughair*). Samples were immediately preserved with ice in site. The specimens were then transferred to the Department of Fisheries, University of Rajshahi (Bangladesh), where all morphometric and meristic characteristics were examined according to Talwar and Jhingran (1991) and fixed with 10% formalin in the laboratory.

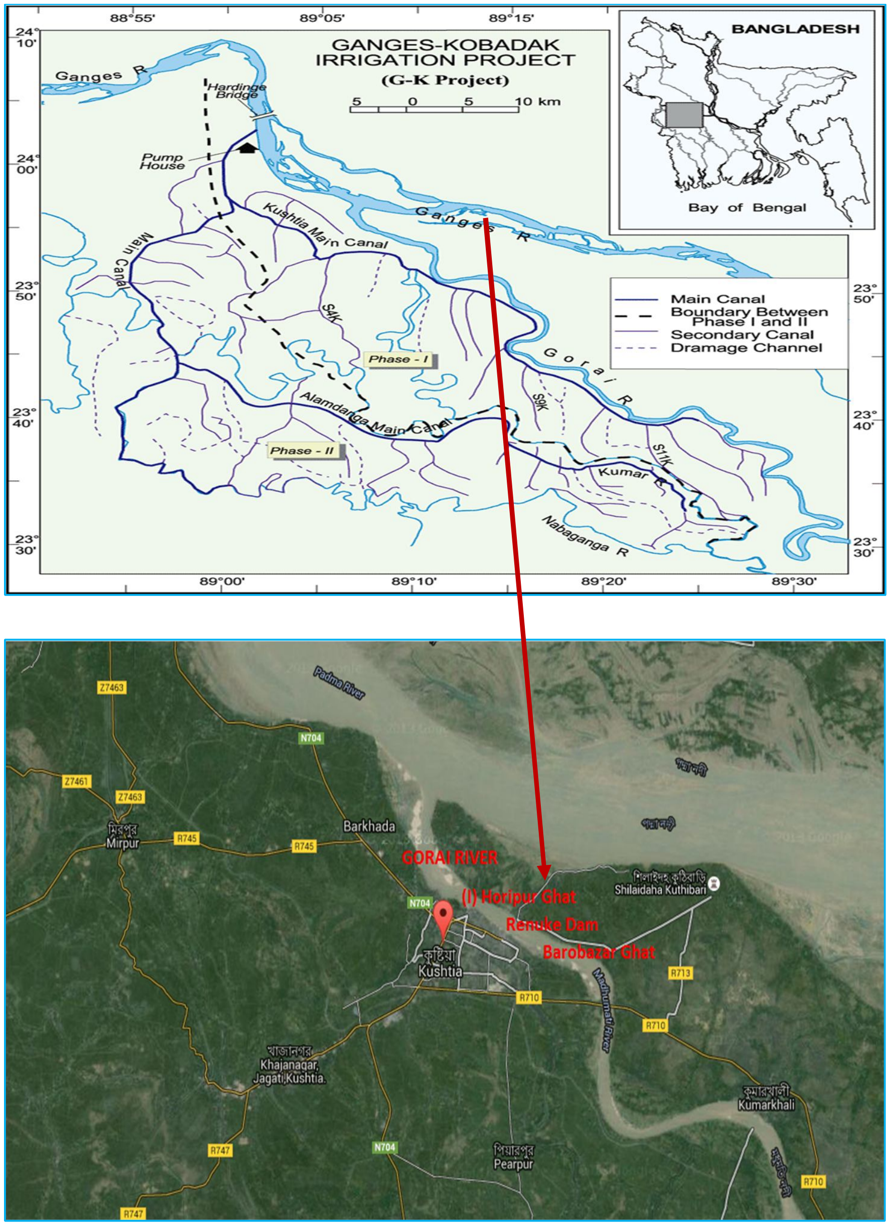


Plate 2. Map showing the study site (Original source: www.google.com; Accessed on 20 December 2014).

For each individual, total length (TL) was measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS; Mitutoyo Corporation, Tokyo, Japan), and whole body weight (BW) was taken on a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy.


Plate 3. Collection of samples using cast net (above photo) and measurement of length (below left) and weight (below right).

The LWR was calculated using the expression: $W= a*L^b$, where the $W$ is the body weight (BW g) and $L$ the total length (TL cm). Parameters $a$ and $b$ were estimated by linear regression analysis based on natural logarithms: $\ln (W) = \ln (a) + b \ln (L)$. Additionally, 95% confidence limits of $a$ and $b$, and the coefficient of determination $r^2$ were estimated. According to Froese (2006), all extreme outliers were excluded from the analyses. A t-test was applied to determine significant differences from the isometric value of $b = 3$ (Sokal and Rohlf, 1987). The Fulton′s condition factor ($K_F$) was calculated using the equation given by Fulton (1904) as $K_F = 100 \times (W/L^3)$, where $W$ is the body weight (BW in g), and $L$ the total length (TL in cm). The scale factor of 100 was used to bring the $K_F$ close to the unit factor (Hossain et al., 2012b).

## 1.3. Results

The descriptive statistics for monthly length and weight measurements, sample sizes ($n$), regression parameters and 95% confidence intervals for $a$ and $b$ of the LWR, and coefficients of determination ($r^2$) of *P. tcto* in the Gorai River are illustrated in Table 3, 4, 5 and 6 respectively and Figure 1, 2, 3 and 4.

Table 3. Descriptive statistics on the total length (cm) and weight (g) measurements of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh

| Sampling date | Sex | n | Total length (cm) | | | | Body weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Mean ± SD** | **95% CL** | **Min** | **Max** | **Mean ± SD** | **95% CL** |
| July 2010 | M | 32 | 5.56 | 6.26 | 5.67±0.43 | 5.52-5.83 | 1.18 | 3.13 | 2.26±0.53 | 2.07-2.45 |
| August | M | 39 | 4.09 | 6.08 | 5.02±0.59 | 4.83-5.21 | 0.89 | 3.55 | 1.86±0.75 | 1.61-2.10 |
| September | M | 34 | 3.99 | 5.74 | 4.65±0.36 | 4.52-4.77 | 0.75 | 2.44 | 1.32±0.32 | 1.21-1..43 |
| October | M | 49 | 3.82 | 5.85 | 4.66±0.44 | 4.54-4.79 | 0.85 | 2.73 | 1.46±0.43 | 1.34-1.58 |
| November | M | 28 | 4.84 | 7.48 | 6.27±0.58 | 6.04-6.49 | 1.49 | 4.60 | 2.84±0.73 | 2.56-3.12 |
| December | M | 38 | 3.73 | 6.92 | 4.99±0.77 | 4.74-5.24 | 0.66 | 4.48 | 1.78±0.95 | 1.46-2.09 |
| January 2011 | M | 43 | 3.24 | 6.37 | 4.61±0.84 | 4.35-4.87 | 0.43 | 4.16 | 1.63±1.01 | 1.32-1.94 |
| February | M | 35 | 3.91 | 6.53 | 5.32±0.60 | 5.11-5.52 | 0.92 | 4.00 | 2.30±0.84 | 2.02-2.59 |
| March | M | 34 | 3.98 | 7.22 | 5.16±0.63 | 4.94-5.37 | 0.95 | 6.60 | 2.39±1.14 | 2.00-2.79 |
| April | M | 41 | 2.77 | 5.30 | 3.91±0.71 | 3.64-4.17 | 0.42 | 5.27 | 2.22±1.37 | 1.72-2.73 |
| May | M | 34 | 4.15 | 5.58 | 4.61±0.36 | 4.49-4.74 | 0.90 | 3.24 | 1.54±0.52 | 1.35-1.72 |
| June | M | 47 | 4.28 | 5.65 | 4.76±0.32 | 4.67-4.86 | 1.15 | 2.76 | 1.61±0.39 | 1.49-1.72 |

n, sample size; Min, minimum, Max, maximum, M, male; SD, standard deviation; CL, confidence limit of mean

Table 4. Descriptive statistics on the total length (cm) and weight (g) measurements of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh

| Sampling date | Sex | n | Total length (cm) | | | | Body weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Mean ± SD** | **95% CL** | **Min** | **Max** | **Mean ± SD** | **95% CL** |
| July 2010 | F | 68 | 4.26 | 6.65 | 5.59±0.56 | 5.45-5.73 | 1.01 | 3.62 | 2.22±0.71 | 2.04-2.39 |
| August | F | 61 | 3.80 | 6.38 | 5.25±0.56 | 5.10-5.39 | 0.69 | 4.20 | 2.14±0.79 | 1.94-2.35 |
| September | F | 66 | 3.30 | 6.07 | 4.61±0.52 | 4.48-4.74 | 0.30 | 3.88 | 1.33±0.57 | 1.19-1.47 |
| October | F | 51 | 3.47 | 5.70 | 4.52±0.52 | 4.37-4.67 | 0.53 | 2.89 | 1.33±0.48 | 1.19-1.46 |
| November | F | 72 | 5.68 | 7.74 | 6.79±0.43 | 6.69-6.89 | 1.96 | 5.36 | 3.73±0.76 | 3.56-3.91 |
| December | F | 62 | 3.80 | 7.21 | 5.40±1.06 | 5.13-5.67 | 0.70 | 5.40 | 2.44±0.14 | 2.08-2.79 |
| January 2011 | F | 57 | 2.66 | 8.00 | 4.88±1.06 | 4.60-5.16 | 0.23 | 8.94 | 2.07±1.53 | 1.66-2.47 |
| February | F | 65 | 3.96 | 7.36 | 5.38±0.70 | 5.21-5.55 | 0.92 | 5.76 | 2.40±1.06 | 2.13-2.66 |
| March | F | 66 | 3.98 | 7.36 | 5.02±0.58 | 4.88-5.16 | 1.01 | 7.29 | 2.22±1.02 | 1.97-2.47 |
| April | F | 59 | 2.59 | 5.63 | 4.06±0.69 | 3.88-4.24 | 0.60 | 6.78 | 2.53±1.39 | 2.17-2.89 |
| May | F | 66 | 4.15 | 5.86 | 4.77±0.45 | 4.66-4.88 | 0.88 | 3.58 | 1.74±0.63 | 1.59-1.90 |
| June | F | 53 | 4.03 | 5.35 | 4.71±0.31 | 4.63-4.80 | 0.98 | 2.42 | 1.57±0.34 | 1.48-1.66 |

n, sample size; Min, minimum, Max, maximum, F, female; SD, standard deviation; CL, confidence limit of mean

Table 5. Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh

| **Sampling date** | **Sex** | **n** | **Intercept** | | **Slope** | | $r^2$ |
|---|---|---|---|---|---|---|---|
| | | | ***a*** | **95% CL of *a*** | ***b*** | **95% CL of *b*** | |
| July 2010 | M | 32 | 0.0121 | 0.0061 to 0.0239 | 3.00 | 2.61 -3.394 | 0.891 |
| August | M | 39 | 0.0077 | 0.0070 to 0.0169 | 3.15 | 2.88 – 3.43 | 0.936 |
| September | M | 34 | 0.0110 | 0.0061 to 0.0198 | 3.10 | 2.72 – 3.49 | 0.895 |
| October | M | 49 | 0.0176 | 0.0120 to 0.0259 | 2.85 | 2.60 – 3.10 | 0.910 |
| November | M | 28 | 0.0225 | 0.0117 to 0.0429 | 2.63 | 2.27 – 2.98 | 0.900 |
| December | M | 38 | 0.0112 | 0.0076 to 0.0167 | 3.10 | 2.85 – 3.35 | 0.948 |
| January 2011 | M | 43 | 0.0066 | 0.0044 to 0.0099 | 3.50 | 3.24 – 3.77 | 0.945 |
| February | M | 35 | 0.0122 | 0.0064 to 0.0234 | 3.11 | 2.72 – 3.49 | 0.889 |
| March | M | 34 | 0.0069 | 0.0033 to 0.0146 | 3.52 | 3.07 – 3.98 | 0.886 |
| April | M | 41 | 0.0148 | 0.0103 to 0.0213 | 3.58 | 3.31 – 3.84 | 0.964 |
| May | M | 34 | 0.0059 | 0.0024 to 0.0141 | 3.62 | 3.05 – 3.95 | 0.837 |
| June | M | 47 | 0.0096 | 0.0064 to 0.0143 | 3.27 | 3.01 – 3.53 | 0.835 |

n, sample size; *a, b* are LWRs parameters; M, male; CL, confidence limit of mean; $r^2$, coefficient of correlation

Table 6. Descriptive statistics and estimated parameters of the length-weight relationships ($BW = a \times TL^b$) of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh

| **Sampling date** | **Sex** | **n** | **Intercept** | | **Slope** | | $r^2$ |
|---|---|---|---|---|---|---|---|
| | | | ***a*** | **95% CL of *a*** | ***b*** | **95% CL of *b*** | |
| July 2010 | F | 68 | 0.0079 | 0.0057 to 0.0109 | 3.25 | 3.07 – 3.44 | 0.949 |
| August | F | 61 | 0.0077 | 0.0049 to 0.0119 | 3.37 | 3.10 – 3.64 | 0.936 |
| September | F | 66 | 0.0040 | 0.0029 to 0.0055 | 3.76 | 3.54 – 3.97 | 0.951 |
| October | F | 51 | 0.0111 | 0.0086 to 0.0146 | 3.14 | 2.96 – 3.31 | 0.963 |
| November | F | 72 | 0.0110 | 0.0061 to 0.0199 | 3.04 | 2.73 – 3.34 | 0.845 |
| December | F | 62 | 0.0118 | 0.0094 to 0.0147 | 3.09 | 2.96 – 3.23 | 0.973 |
| January 2011 | F | 57 | 0.0119 | 0.0086 to 0.0164 | 3.16 | 2.95 – 3.36 | 0.945 |
| February | F | 65 | 0.0125 | 0.0085 to 0.0182 | 3.09 | 2.86 – 3.32 | 0.939 |
| March | F | 66 | 0.0092 | 0.0051 to 0.0165 | 3.36 | 3.00 – 3.72 | 0.843 |
| April | F | 59 | 0.0165 | 0.0128 to 0.0214 | 3.50 | 3.32 – 3.69 | 0.962 |
| May | F | 66 | 0.0080 | 0.0053 to 0.0121 | 3.42 | 3.16 – 3.69 | 0.912 |
| June | F | 53 | 0.0107 | 0.0072 to 0.0160 | 3.21 | 2.95 – 3.47 | 0.924 |

n, sample size; *a*, *b* are LWRs parameters; F, female; CL, confidence limit of mean; $r^2$, coefficient of correlation

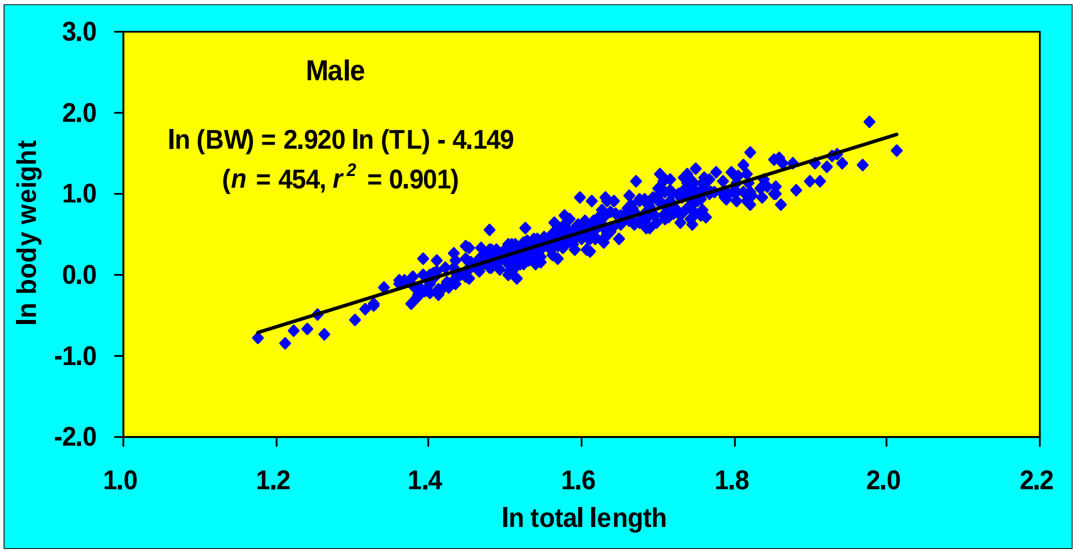


Figure 1. The generalised ln-ln relationships between total length (TL) and body weight (BW) of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

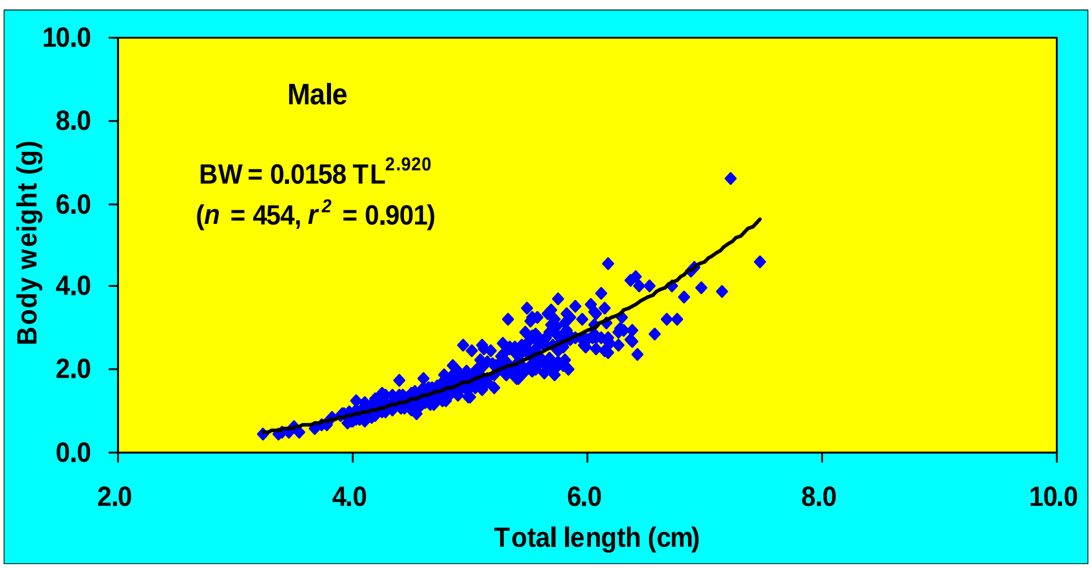


Figure 2. Relationships between total length (TL) and body weight (BW) of the male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

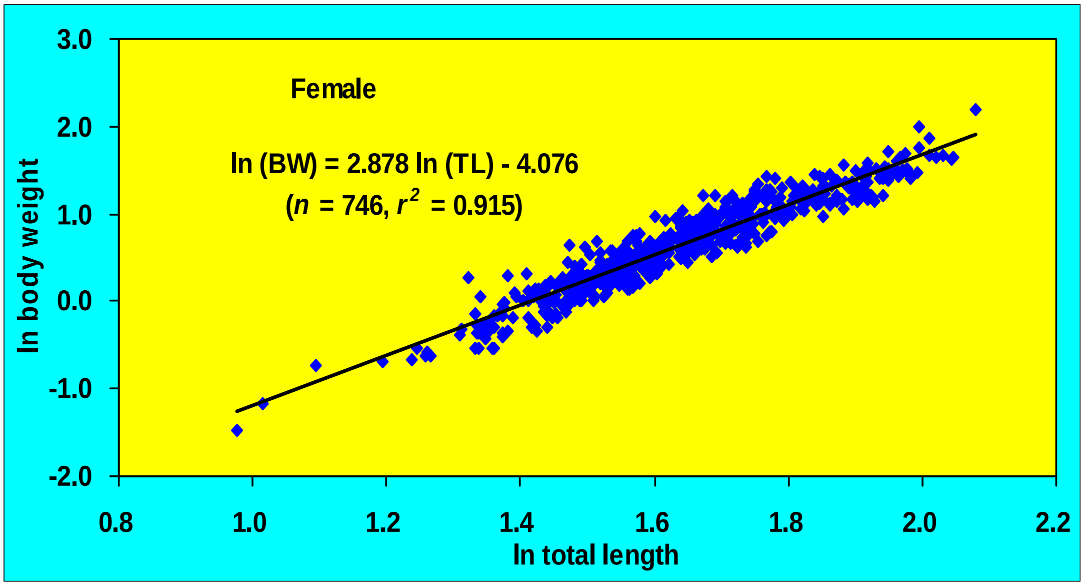


Figure 3. The generalised ln-ln relationships between total length (TL) and body weight (BW) of the female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

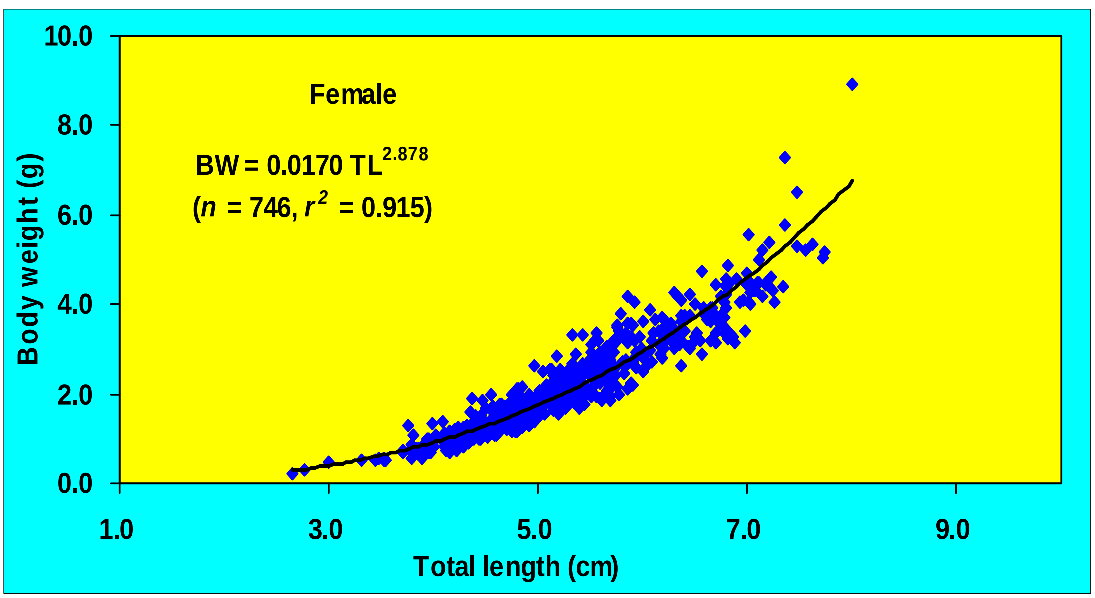


Figure 4. Relationships between total length (TL) and body weight (BW) of the female *Puntius ticto in* the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

The allometric coefficient (*b*) of males indicated positive allometric growth in the month of August to September and December to June ($b > 3.0$), isometric growth was found in the month of July ($b = 3.0$), but negative allometric growth in October to December ($b < 3.0$). In addition, females indicated positive allometric growth in all the months ($b > 3.0$). Monthly variations of *b* values for male and female *P. ticto* have been shown in figure 5 and 6. However there was no significant differences in the overall intercepts (F = 0.461, df = 1197, $P = 0.498$) and slopes (F = 0.659, df = 1196, $P = 0.417$) between the sexes of *P. ticto* in the Gorai River.

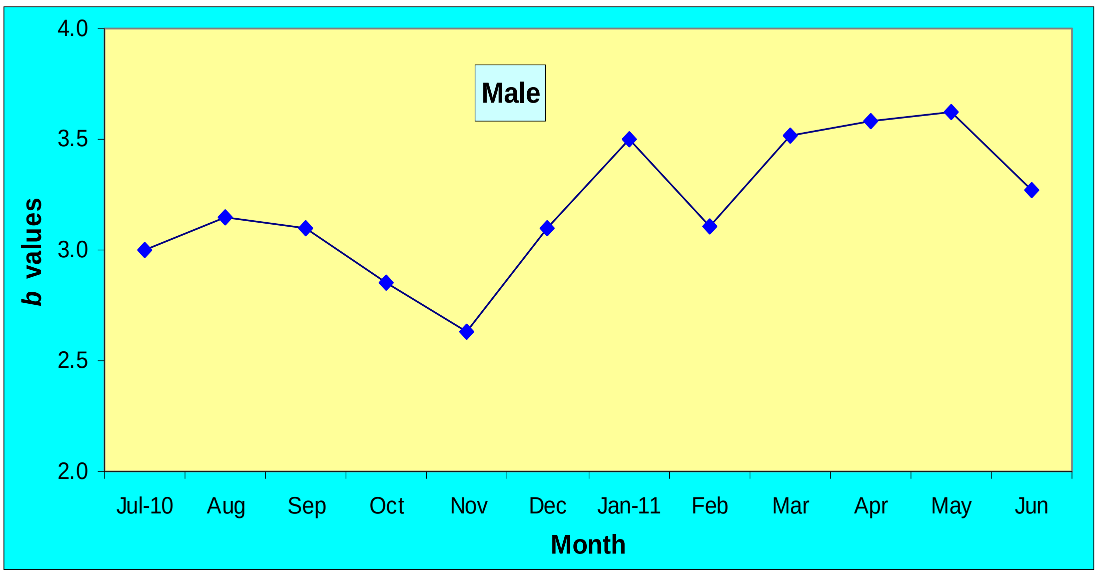


Figure 5. Monthly variations of *b* values for male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

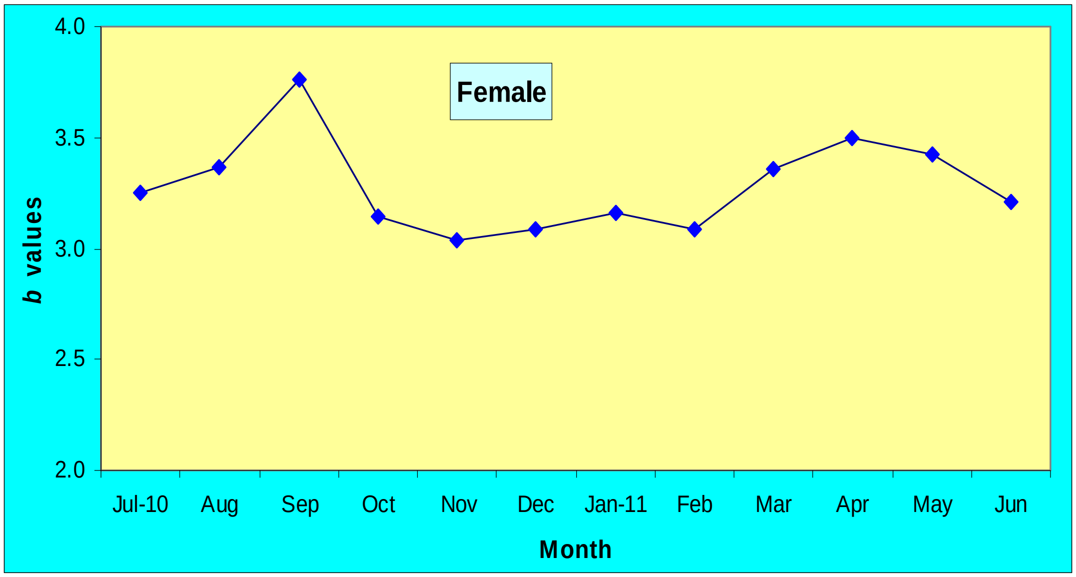


Figure 6. Monthly variations of *b* values for female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

The Fulton′s condition factor for the male of two-spot barb ranged from 1.14±0.10 in November to 1.64±0.25 in March. In case of female, Fulton′s condition factor varied from 1.18±0.10 in November to 1.66±0.27 in March. Nonetheless, the Mann-Whitney *U*-test showed no significant differences in the Fulton′s condition factors between males and females of the *P. ticto* in the Gorai river (Two tailed, $P = 0.809$). The Fulton′s condition factor for male and female, minimum and maximum values, Mean±SD and 95% confidence level are shown in Table 7, 8 and figure 7, 8.

Table 7. Fulton′s condition factor, $K_F = 100 \times (BW/TL^3)$ of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

| **Sampling date** | **Sex** | **n** | **Fulton′s condition factor ($K_F$)** | | | |
|---|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Mean±SD** | **95% CL** |
| July 2010 | M | 32 | 1.00 | 1.39 | 1.22±0.10 | 1.18-1.25 |
| August | M | 39 | 0.81 | 1.70 | 1.40±0.14 | 1.35-1.44 |
| September | M | 34 | 1.11 | 1.50 | 1.30±0.11 | 1.26-1.33 |
| October | M | 49 | 1.19 | 1.75 | 1.41±0.11 | 1.37-1.44 |
| November | M | 28 | 0.90 | 1.32 | 1.14±0.10 | 1.10-1.18 |
| December | M | 38 | 1.06 | 1.89 | 1.32±0.15 | 1.27-1.37 |
| January 2011 | M | 43 | 1.14 | 2.14 | 1.44±0.26 | 1.36-1.52 |
| February | M | 35 | 1.10 | 1.84 | 1.47±0.19 | 1.41-1.54 |
| March | M | 34 | 1.01 | 2.11 | 1.64±0.25 | 1.55-1.73 |
| April | M | 41 | 1.36 | 1.51 | 1.44±0.04 | 1.42-1.45 |
| May | M | 34 | 1.12 | 1.92 | 1.52±0.19 | 1.45-1.59 |
| June | M | 47 | 1.30 | 1.62 | 1.46±0.09 | 1.44-1.49 |

n, sample size; M, male; Min, minimum; Max, maximum; SD, standard deviation; CL, confidence limit for mean values

Table 8. Fulton′s condition factor, $K_F = 100 \times (BW/TL^3)$ of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

| **Sampling date** | **Sex** | **n** | **Fulton′s condition factor ($K_F$)** | | | |
|---|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Mean±SD** | **95% CL** |
| July 2010 | F | 68 | 1.01 | 1.40 | 1.22±0.10 | 1.20-1.25 |
| August | F | 61 | 1.12 | 1.71 | 1.42±0.17 | 1.38-1.46 |
| September | F | 66 | 0.83 | 1.73 | 1.27±0.16 | 1.23-1.31 |
| October | F | 51 | 1.18 | 1.58 | 1.38±0.10 | 1.35-1.41 |
| November | F | 72 | 0.96 | 1.37 | 1.18±0.10 | 1.16-1.20 |
| December | F | 62 | 1.06 | 1.60 | 1.38±0.14 | 1.34-1.41 |
| January 2011 | F | 57 | 0.98 | 2.48 | 1.53±0.27 | 1.46-1.60 |
| February | F | 65 | 1.11 | 1.92 | 1.46±0.17 | 1.42-1.50 |
| March | F | 66 | 1.10 | 2.20 | 1.66±0.27 | 1.59-1.73 |
| April | F | 59 | 1.38 | 1.52 | 1.44±0.03 | 1.43-1.45 |
| May | F | 66 | 1.19 | 1.86 | 1.55±0.16 | 1.51-1.59 |
| June | F | 53 | 1.26 | 1.64 | 1.48±0.09 | 1.45-1.50 |

n, sample size; Min, minimum; Max, maximum; F, female; SD, standard deviation; CL, confidence limit for mean values

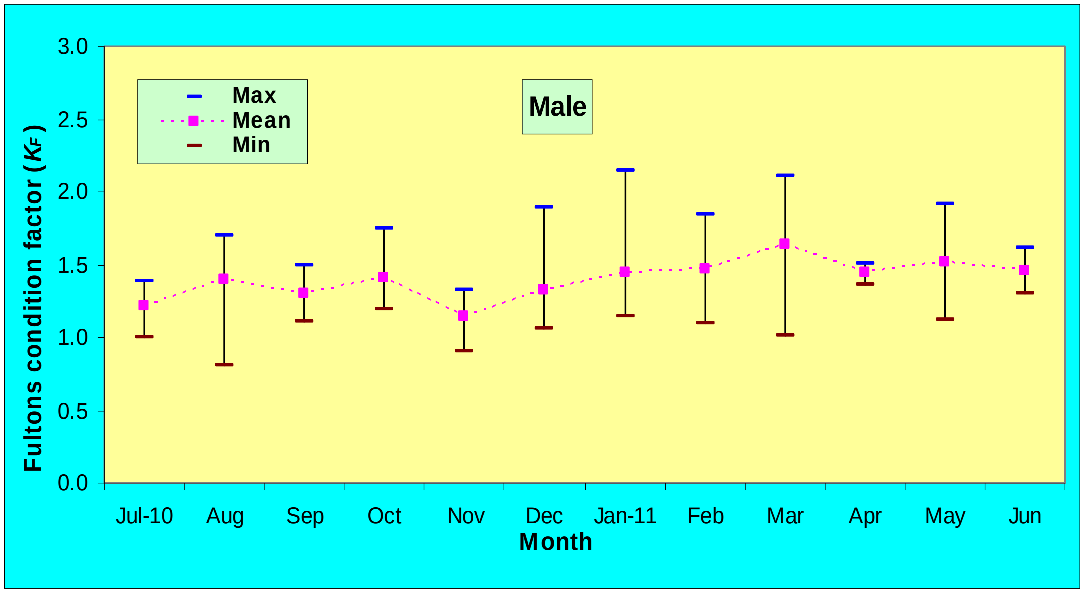


Figure 7. Monthly variations of the Fulton′s condition factor ($K_F$) of male *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

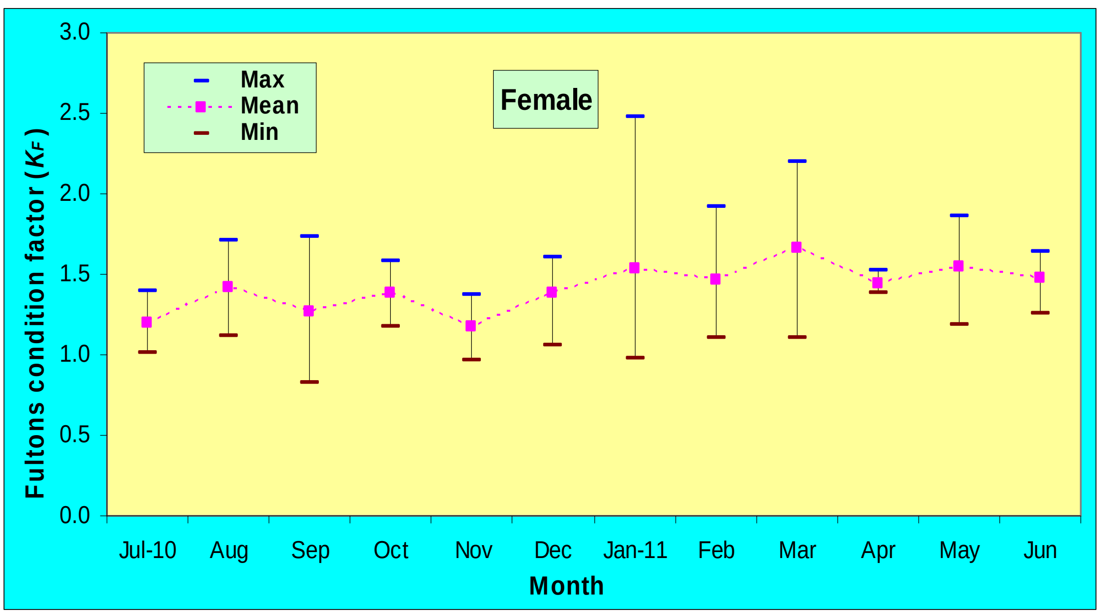


Figure 8. Monthly variations of the Fulton′s condition factor ($K_F$) of female *Puntius ticto* in the Gorai (a tributary of the Padma) River, southwestern Bangladesh.

## 1.4. Discussion

The present study used a large number of individuals with different body sizes captured by some traditional fishing gears. The total length (TL) was ranged from 2.77-7.48 cm for male and 2.66-8.00 cm for female. However, it was not possible to catch fishes smaller than 2.77 cm TL and larger than 8.00 cm in TL. The absence of smaller and larger sized fishes was associated with the selectivity of the fishing gear rather than their absence in the study area. However, Hossain et al. (2012c) reported the maximum SL for *P. ticto* from the Ganges River, northwestern Bangladesh as 8.60 cm, whereas Banik and Saha (2012) recorded the maximum length of this fish from India as 11.8 cm TL.

The parameter *b* values vary between 2 and 4, however, values ranging from 2.5 to 3.5 are more common (Carlander, 1969; Froese, 2006). In general and despite the many variations in fish forms between species, *b* is close to 3, indicating that fish grow isometrically; values significantly different from 3.0 indicate allometric growth (Tesch, 1971). In the current study, *b* values were within the limits (2 and 4) reported by Tesch (1971) for most fishes. In the present study, the regression parameter *b* of the LWRs ranged from 2.63 to 3.62 for males and 3.04 to 3.76 for females. The overall *b* for the LWR indicated negative allometric growth ($< 3.00$) in both males and females which is accordance with the result of Hossain et al. (2009a), who reported the *b* value for *P. ticto* as 2.92 in the Padma River, northwestern Bangladesh. Isometric growth indicates that the body increases in all dimensions in the same proportion to growth, whereas negative allometry indicates that the body becomes more rotund as it increases in length, and negative allometry indicates a slimmer body (Jobling, 2008). However, the length-weight relationship in fishes can be affected by several factors including habitat, area, seasonal effect, degree of stomach fullness, gonad maturity, sex, health, preservation techniques and differences in the observed length ranges of the specimen caught (Tesch, 1971), all of which were not accounted in the present study. In addition, growth increment, differences in age and stage of maturity, food, as well as environmental conditions such as temperature, salinity and seasonality can also affect the value of *b* for the same species (Weatherley and Gill, 1987).

Froese (2006) stated that the regression parameter *a* of the length-weight relationship is an indicator of the body shape of fishes and that there is clear increase in the *a* value from eel-like to short-deep. In this study most *a* values have been estimated as smaller than 0.01. Therefore most of the species could be classified as relatively elongated, which is expected of the fishes inhabiting river ecosystems (Birecikligil and Çiçek, 2011). However, Hossain et al. (2009a) reported the *a* value for the two-spot barb as 0.035. Nonetheless, Mbaru et al. (2010) reported that the regression parameters, particularly *a*, may vary daily, seasonally, and / or between habitats, unlike the parameter *b*, which does not vary significantly throughout the year.

Condition factor is one of the standard practices in fisheries which is used as a indicator of the variability attributable to growth coefficient. It expresses the condition of a fish such as the degree of wellbeing, relative robustness or fatness in numerical terms. The condition of a fish reflects physical and biological circumstances and fluctuates by interaction among feeding conditions, parasitic infections and physiological factors (Le Cren, 1551). The Fulton′s condition factor ($K_F$) is an index reflecting interactions between biotic and abiotic factors in the physiological condition of the fishes. It shows the well-being of the population during various life cycle stages (Angelescu et al., 1958). When condition factor value is higher it means that the fish has attained a better condition. The condition factor of fish can be affected by a number of factors such as stress, sex, season, availability of feeds, and other water quality parameters (Khallaf et al., 2003). The Fulton′s condition factor of *P. ticto* was higher in January for both genders suggesting in that month the fish was in good condition. However, no references dealing with the condition factors on the two-spot barb are available in the Gorai River, preventing the comparison with present result.

## 1.5. Conclusion

This study presents the length-weight relationships and condition factor (Fulton′s condition factor) of *P. ticto* from the Gorai River, southwestern Bangladesh. This study shows that the overall *b* values of LWR indicated negative allometric growth for both males and females and the highest value of condition indicates the fish was in good condition in the month of January. The findings of this study could contribute to the management of this fish species and also awaken an interest in the study of other native fish species that play an important role in the riverine ecosystems.

# STUDY:2

## Estimation of prey-predator status of the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh

### 2.1. Introduction

Understand of prey-predator interactions can advance the scientific basis for fisheries management. Prey-predator interactions have the potential to help in managing the size distributions of predators and prey in fish communities. Growth rate may affect fish condition as measured by relative weight. Information on relative weight is needed to know on how quickly relative weight changes in response to changes in growth rate or food consumption. The status of prey-predator can be determined through relative weight ($W_R$). Relative weight can be used to estimate the condition of fish health (Rypel and Richter, 2008). According to Porath and Peters (1997) the $W_R$ influenced the prey availability in a population. There is a significant correlation between relative weight, prey and predator availability (Kohler and Kelly, 1991). The values of $W_R$ falling below 100 for an individual or population recommend problems such as low prey accessibility or high predator density; whereas values above 100 indicates a prey surplus or low predator density (Rypel and Richter, 2008). Therefore, the objectives of this study is to focus on the prey-predator status of *Puntius ticto* in the Gorai River, southwestern Bangladesh.

## 2.2. Materials and methods

The present study was conducted in the Gorai (a tributary of the Padma) River, southwestern Bangladesh. Monthly samples were collected randomly during daytime from fishermen′s catch landed at different points near Boro Bazar ghat and Horipur ghat in Kustia town, southwestern Bangladesh from July 2010 to June 2011. This fish were usually caught by means of the traditional fishing gears such as cast net (*jhaki jal*), square lift net (*tar jal*), and conical trap (*dughair*) (see plate 3). Samples were immediately preserved with ice in site. The specimens were then transferred to the Department of Fisheries, University of Rajshahi (Bangladesh) and fixed with 10% formalin in the laboratory.

For each individual, total length (TL) was measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS; Mitutoyo Corporation, Tokyo, Japan), and whole body weight (BW) was taken on a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy. The $W_R$ was calculated by the equation given by Froese (2006), as: $W_R = (W/W_S) \times 100$, where $W$ is the weight of a particular individual and $W_S$ is the predicted standard weight for the same individual as calculated by $W_S = a{*}L^b$, where $a$ and $b$ values were obtained from the relationships between TL and BW.

Statistical analyses were performed using Graph Pad Prism 6.5 software (GraphPad Software, Inc., San Diego, CA). The Wilcoxon signed rank test was used to compare the mean relative weight ($W_R$) with 100. The Spearman rank correlation test was used to analyze the relationship between the TL *vs.* $W_R$. All statistical analyses were considered significant level at 5% ($P < 0.05$).

## 2.3. Results

A sum of 1200 individuals of *P. ticto* was sampled during the study from the Gorai River. Monthly changes of relative weight ($W_R$) are given in Table 9 and 10. The minimum and maximum values of $W_R$ were 62.03 and 149.36 in the month of January for male populations of *P. ticto* (Figure 9). Also the minimum and maximum values of $W_R$ were 66.76 and 1760.25 in the month of January for female of *P. ticto* in the Gorai River, respectively (Figure 10). According to Shapiro-Wilk normality test the $W_R$ for male and female populations of *P. ticto* did not pass the normality ($P < 0.001$). The Mann Whitney U-test indicate there was no significant difference in $W_R$ for male and female populations of *P. ticto* in the Gorai River ecosystem ($P = 0.486$, U = 165294). Spearman rank correlation test revealed that, there was no significant correlation between TL *vs.* $W_R$ for male and female inhabitants of *P. ticto* ($r_s$=-0.0048, $P = 0.918$ for male and $r_s$=0.0314, $P = 0.392$ for female). Wilcoxon signed rank test indicate the mean $W_R$ was not significantly different from 100 for male ($P = 0.208$) and female ($P = 0.626$) population of *P. ticto* in the Gorai River (Figure 11 and 12).

Table 9. Descriptive statistics on the relative weight ($W_R$) of male *Puntius ticto* (Hamilton, 1822) in the Gorai River, southwestern Bangladesh

| **Sampling date** | **Sex** | **n** | **Relative weight ($W_R$)** | | | |
|---|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Mean ± SD** | **95% of CL** |
| July 2010 | M | 32 | 82.36 | 114.84 | 100.75±8.17 | 97.81-103.70 |
| August | M | 39 | 80.88 | 119.41 | 100.80±9.46 | 97.74-103.87 |
| September | M | 34 | 86.81 | 117.06 | 100.99±8.18 | 98.14-103.85 |
| October | M | 49 | 84.97 | 123.01 | 100.64±8.03 | 98.34-102.95 |
| November | M | 28 | 79.32 | 118.73 | 99.30±8.24 | 96.11-102.49 |
| December | M | 38 | 80.93 | 146.67 | 100.64±11.57 | 96.84-104.45 |
| January 2011 | M | 43 | 62.03 | 149.36 | 102.33±16.28 | 97.32-107.34 |
| February | M | 35 | 75.24 | 125.28 | 100.41±12.69 | 96.05-104.77 |
| March | M | 34 | 66.58 | 137.10 | 101.41±15.00 | 96.18-106.65 |
| April | M | 41 | 92.99 | 125.34 | 100.79±6.09 | 98.87-102.72 |
| May | M | 34 | 74.51 | 125.34 | 101.51±11.94 | 97.35-105.68 |
| June | M | 47 | 88.93 | 110.35 | 100.03±5.60 | 98.40-101.68 |

n, sample size; M, male; Min, minimum; Max, maximum; $W_R$, relative weight; SD, standard deviation; CL, confidence limit

Table 10. Descriptive statistics on the relative weight ($W_R$) of female *Puntius ticto* (Hamilton, 1822) in the Gorai River, southwestern Bangladesh

| **Sampling date** | **Sex** | **n** | **Relative weight ($W_R$)** | | | |
|---|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Mean ± SD** | **95% of CL** |
| July 2010 | F | 68 | 83.03 | 115.37 | 100.64±7.89 | 98.73-102.56 |
| August | F | 61 | 76.56 | 116.92 | 99.92±10.94 | 97.11-102.72 |
| September | F | 66 | 82.19 | 118.98 | 99.84±9.67 | 97.47-102.22 |
| October | F | 51 | 84.77 | 117.34 | 99.66±7.22 | 97.63-101.69 |
| November | F | 72 | 82.23 | 117.86 | 101.20±8.38 | 99.23-103.16 |
| December | F | 62 | 78.10 | 118.85 | 100.38±10.10 | 97.81-102.94 |
| January 2011 | F | 57 | 66.76 | 170.25 | 101.08±18.01 | 96.31-105.86 |
| February | F | 65 | 76.47 | 132.29 | 100.24±11.47 | 97.40-103.08 |
| March | F | 66 | 69.15 | 141.32 | 101.10±16.36 | 97.08-105.12 |
| April | F | 59 | 93.62 | 112.65 | 99.46±4.90 | 98.18-100.73 |
| May | F | 66 | 80.44 | 123.70 | 100.52±9.72 | 98.13-102.91 |
| June | F | 53 | 87.01 | 113.10 | 99.83±6.03 | 98.17-101.50 |

n, sample size; F, female; Min, minimum; Max, maximum; $W_R$, relative weight; SD, standard deviation; CL, confidence limit

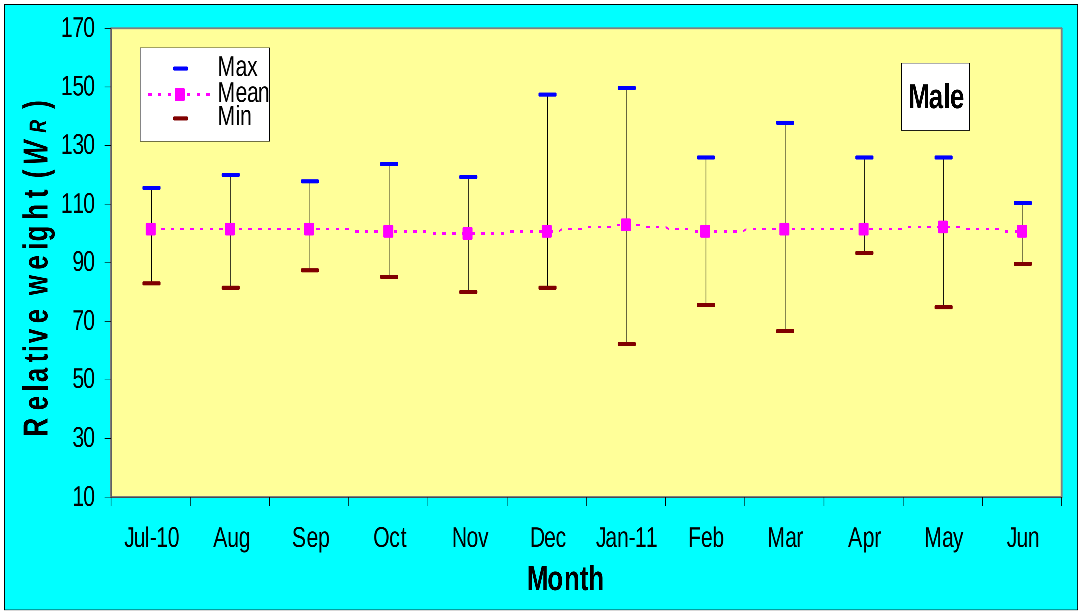


Figure 9. Monthly variations of relative weight ($W_R$) for male *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh.

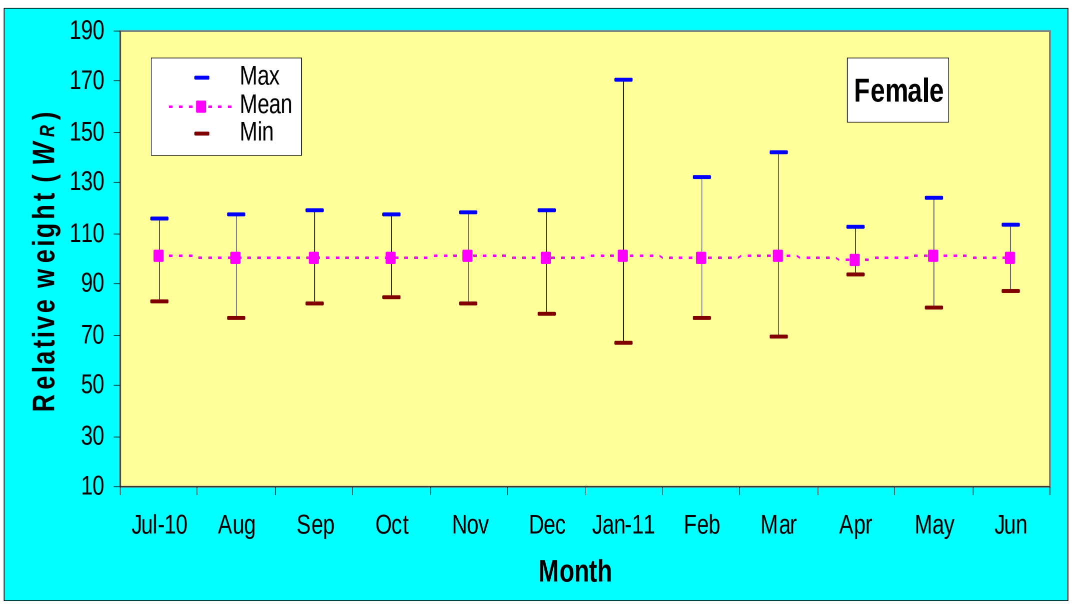


Figure 10. Monthly variations of relative weight ($W_R$) for female *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh.

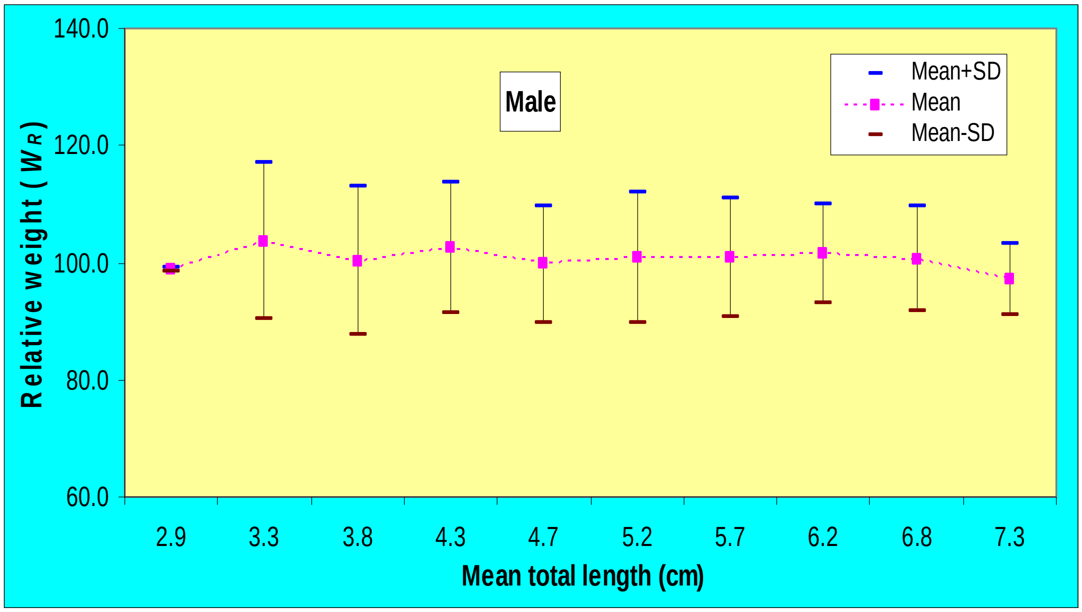


Figure 11. Relationships between total length and relative weight for male *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh.

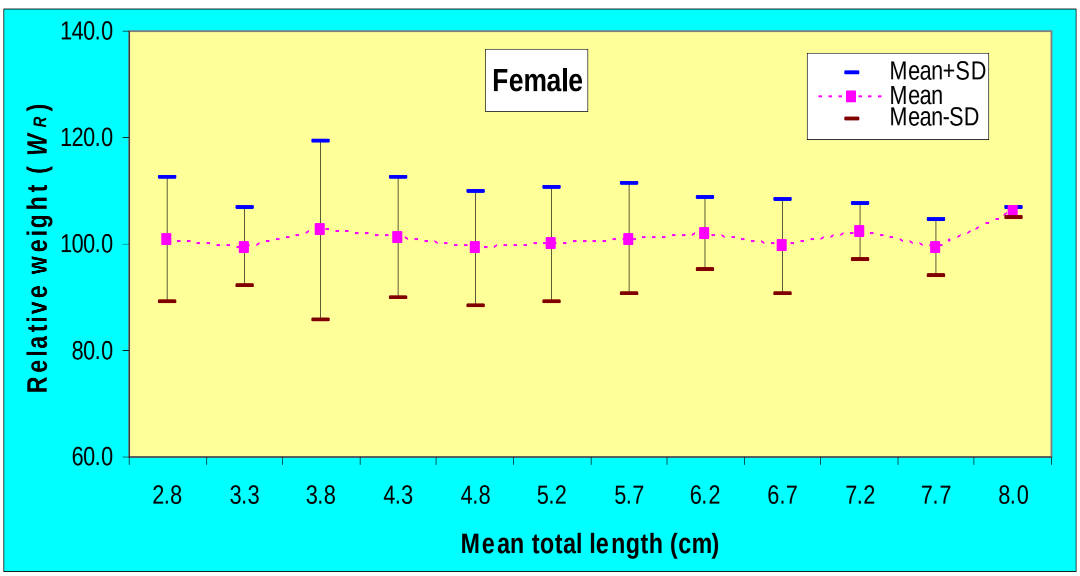


Figure 12. Relationships between total length and relative weight for female *Puntius ticto* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh.

## 2.4. Discussion

Relative weight is the most popular index to assess the status of fish in a habitat (Froese, 2006). Prey-predator status of a water body affects the fisheries community and the recruitment pattern (Shulman and Ogden, 1987). The $W_R$ declining below 100 for a population indicate lower prey or high predator density; whereas values above 100 indicate a prey surplus or lower predator. In our study the mean $W_R$ was significantly different from 100 for male and female populations of *P. ticto* indicating the habitat was not in balance condition with lower prey-high predator.

The $W_R$ was higher in the month of December-March for male and January-March for female populations of *P. ticto* that represent in these month the predator was in lower amount and prey was in higher amount in the Gorai River ecosystem. Also in the month of January the $W_R$ was very low for both male and female population of *P. ticto* that indicates in the January the predator was in higher amount and it may be due to the spatial distribution of fishes and climatic condition. The $W_R$ of fishes may also be affected by physiological and behavioral aspects of fishes (Davis, 2000).

Recently a number studies have espoused the use of $W_R$ for assisting in the management and conservation of nongame fishes, particularly those that are threatened or endangered (Bister et al. 2000; Didenko et al., 2004). In addition this result expresses that, the TL and $W_R$ was not significantly correlated for both male and female sexes in the study area, suggesting unavailability of food relative to the presence of predators that may be indicative of good water quality. This is the first study on prey-predator relationships for *P. ticto* in the Gorai River, southwestern Bangladesh. There is no available literature or references dealing with the prey-predator relationship for this species prevent the comparison with our findings.

## 2.5. Conclusion

The above study provides information on prey-predator status of the threatened fish *P. ticto* from the Gorai River, southwestern Bangladesh. It indicates the ecosystem of Gorai River was in balance condition with the balance ratio of prey-predator. The abundance of prey and predator may vary due to spatial and temporal variations. These results may provide baseline for further study and would be helpful to sustainable management of *P. ticto* in the Gorai River or surrounding ecosystems.

# STUDY:3

## Estimation of reproductive biology of the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh

### 3.1. Introduction

Determining the size at first sexual maturity in fish is important for distinguishing (i) different populations within species and (ii) temporal changes in length at first maturity from fisheries pressure or for other reasons (Templeman, 1987). In addition, maturation size is of special interest in fisheries management and is widely used as an indicator of minimum-permissible capture size (Lucifora et al., 1999).

The term fecundity refers the egg laying capacity of a fish or the number of ripe eggs produced by a fish in a single spawning season (Jan et al., 2014). Knowledge about fish fecundity is essential for evaluating the potential of stocks, life histories, practical culture, and actual management of the fishery (Lagler, 1956). Such assessments are of paramount importance in fisheries management for estimating the number of offspring produced in a season and the reproductive capacity of species (Qasim and Qayyum, 1963). The reproductive potential, i.e., fecundity is an assessment of fecundity to understand the recovery ability of fish populations (Lagler 1956; Nikolskii 1969; Tracey et al., 2007). The fecundity and its relation to female size make it possible to estimate the potential of egg output (Chondar, 1977).

The timing and location of spawning are integral components of the adaptation of marine fish life cycles to their environments. Maintenance of a population depends on successful recruitment of young fish to nursery areas and from nursery areas back to the parent population. The choice of spawning time and location is important, as these are likely to have evolved to optimize either the transport of planktonic stages to the nursery areas, or the conditions experienced by the young fish along the way, or both. In highly reproductive systems, spawning location and timing may have been selected based on the necessity of avoiding excessive transport (i.e. currents that carry them past or away from the nurseries) and the need for retention in areas conducive to survival (Hinckley et al., 2001). Therefore, the objective of this study is to determine the sexual maturity, spawning season and fecundity of *Puntius ticto* from the Gorai River.

## 3.2. Materials and method

The present study was conducted in the Gorai (a tributary of the Padma) River, southwestern Bangladesh. Monthly samples were collected randomly during daytime from fishermen's catch landed at different points near Boro Bazar ghat and Horipur ghat in Kustia town, southwestern Bangladesh from July 2010 to June 2011. This fish were usually caught by means of the traditional fishing gears such as cast net (*jhaki jal*), square lift net (*tar jal*), and conical trap (*dughair*) (see plate 3) Samples were immediately preserved with ice in site. The specimens were then transferred to the Department of Fisheries, University of Rajshahi (Bangladesh) and fixed with 10% formalin in the laboratory.

For each individual, total length (TL) was measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS; Mitutoyo Corporation, Tokyo, Japan), and whole body weight (BW) and whole gonads were removed from each male and female fish and weighed (GW) was taken on a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy.

Plate 4. Collection of gonad of *Puntius ticto.*


Plate 5. Measurement and weighting of gonad of *Puntius ticto*.

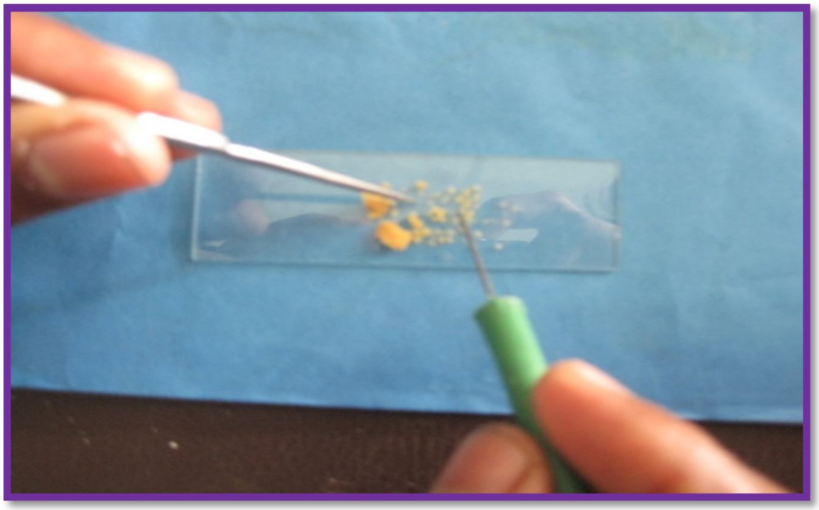

Plate 6. Counting of eggs of *Puntius ticto*.

The size at first sexual maturity ($L_m$) of this species in the Gorai River was calculated using the equation, log ($L_m$) = -0.1189 + 0.9157* log (Lmax), by Binohlan and Froese (2009) for male and female separately. The gonadosomatic index (GSI) was calculated by the equation, GSI (%) = (GW ⁄BW) × 100. The monthly changes of GSI (%) were also used for estimation of spawning and peak spawning season of *P. ticto* in the Gorai River. The size at first sexual maturity of females was estimated by the relationship between the gonadosomatic index and total length.

The specimen larger (≥ 4.00 cm in TL) than the first size at sexual maturity was used for the estimation of fecundity during this study. For this estimation, the ovaries were weighed; three sub-samples were taken from the front, mid and rear sections of each ovary and weighed. The total number of eggs in each sub-sample of ovary was calculated. This value should be proportional to the total ovary weight such that the number of eggs ($F_1$) for the sub-sample was estimated using the equation, $F_1$ = (gonad weight · number of eggs in the sub-sample) ⁄ sub-sample weight (Yeldan and Avsar, 2000). Later, by taking the mean number of three sub-sample fecundities ($F_1$, $F_2$, $F_3$), the individual fecundity for each female fish was calculated [$F_T = (F_1 + F_2 + F_3) / 3$]. The relationships between fecundity and some morphometric measurements were determined by relating total fecundity (Fe) data to total length (TL) and total weight (BW) using the following formulae:

$$\ln F_T = \ln m + (n \times \ln TL); \; F_e = m \times TL^n$$

$$\ln F_T = \ln m + (n \times \ln BW); \; F_e = m \times BW^n$$

where, m and n are constant parameters in the linear regression analysis. Also the spawning season based on the monthly variations gonadosomatic index were determined. All statistical analyses were considered significant level at 5% ($P < 0.05$).

## 3.3. Results:

### 3.3.1. Size at sexual maturity

A total of 1200 (male = 454, female = 746) individuals of *P. ticto* were sampled during the study. The results showed that the TL was ranged from 2.77-7.48 cm for male and 2.66-8.00 cm for female. The BW ranged from 0.42-6.6 g for male and 0.23-8.94 for female *P. ticto*. The lowest value of gonadal weight was 0.001 in January and 0.04 in June and July for male *P. ticto*. On the other hand for female *P. ticto* the lowest value of gonadal weight was in January as 0.005 g and highest value was in June as 2.42 g. The relationship between TL and GSI of male and female *P. ticto* are shown in figure 13 and 14.

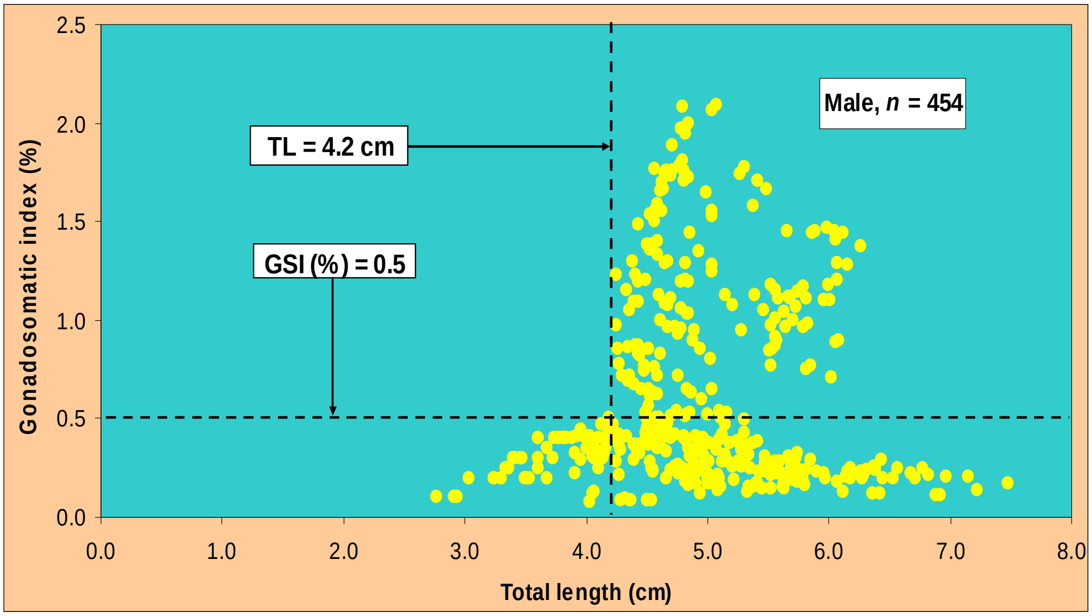


Figure 13. Showing the GSI based first sexual maturity of male *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

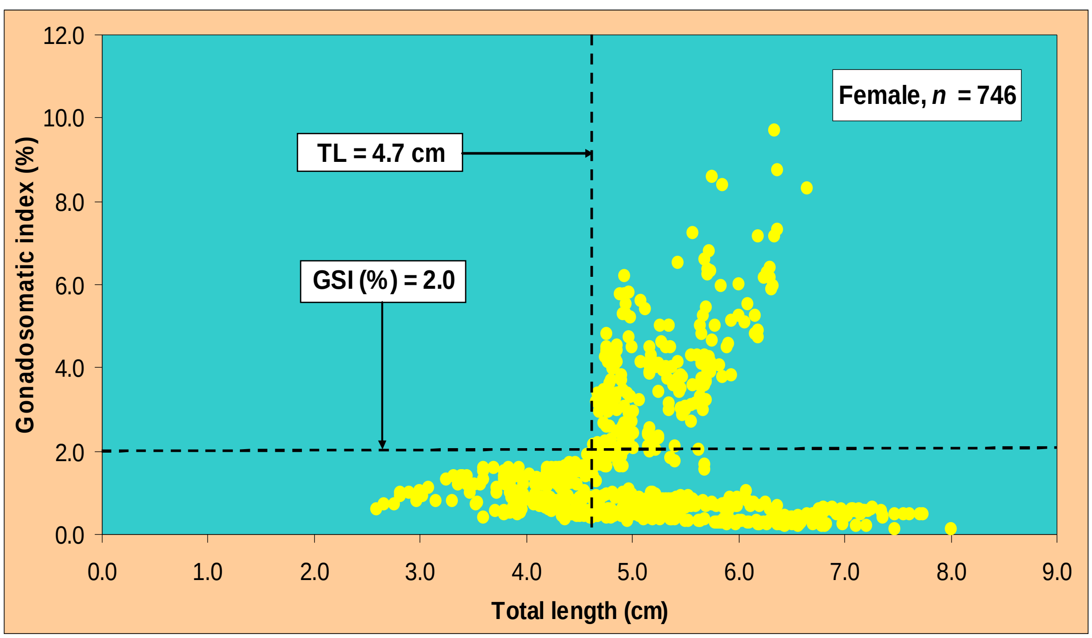


Figure 14. Showing the GSI based first sexual maturity of female *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

The GSI of male smaller than 4.0 cm TL was low (<0.4). Most of the females with >4.5 cm TL recorded calculated GSI of > 1.5. The highest recorded GSI in male *P. ticto* was 2.08 in June 2010. The GSI rose sharply at around 4.2 cm TL. High GSI (>0.5) was only recorded in males with TL >4.2 cm TL. Therefore, the size at first sexual maturity was considered to be 4.2 cm TL and individuals with a ≥0.5% could be roughly defined as mature male *P. ticto* in the Gorai River, southern Bangladesh. Spearman′s rank correlation test showed a significant correlation between GSI and TL for males larger than 4.2 cm TL ($r_s$=-0.285, $P < 0.001$).

The GSI of female smaller than 4.2 cm TL was low (<1.8). Most of the females with >5.0 cm TL recorded calculated GSI of > 6.0. The highest recorded GSI in female *P. ticto* was 9.4 in June 2010. The GSI rose sharply at around 4.7 cm TL. Higher GSI (>2.0) was only recorded in females with TL >4.7 cm TL. Therefore, the size at first sexual maturity was considered to be 4.7 cm TL and individuals with a ≥2.0% could be roughly defined as mature female *P. ticto* in the Gorai River, southern Bangladesh. Spearman′s rank correlation test showed a significant correlation between GSI and TL for females larger than 4.7 cm TL ($r_s$=-0.365, $P < 0.001$).

Also on the basis of maximum length the first sexual maturity was 4.8 cm in TL (95% CL=3.9-4.9) for male and 5.1 cm in TL (95% CL=4.2-6.3) for female *P. ticto* in the Gorai River, southwestern Bangladesh.

### 3.3.2. Spawning season

The monthly changes of GSI for male and female *P. ticto* was shown in Figure 15 and 16. The GSI values were low (< 0.5) during the October 2010 to March 2011 for male fishes. In addition, the lower values of GSI (<2.0%) for female *P. ticto* was in October 2010 to March 2011. However, the higher GSI (>0.50% for males >2.0% for females) were found during the month of April to September, which indicated the spawning season for *P. ticto* in the Gorai River. In addition, peak values of GSI were found in the month of June-July, which was the peak spawning season for this species.

### 3.3.3. Relationship of spawning season and climate change (temperature and rainfall)

When temperature increases above $30^{o}$ C then the spawning season start and it continues to September (Figure 17). There is significant correlation found for temperature and GSI (spearman rank correlation test, $r_s$=0.823, $P$=0.002 for male and $r_s$ =0.774, $P$=0.004 for female).

In the study, it was found that when rainfall starts the *P. ticto* also begins their spawning period (from April to September) shown in figure 18. There is significant correlation exists with rainfall and GSI (spearman rank correlation test, $r_s$=0.840, $P$=0.001 for male and $r_s$ =0.840, $P$ = 0.002 for female).

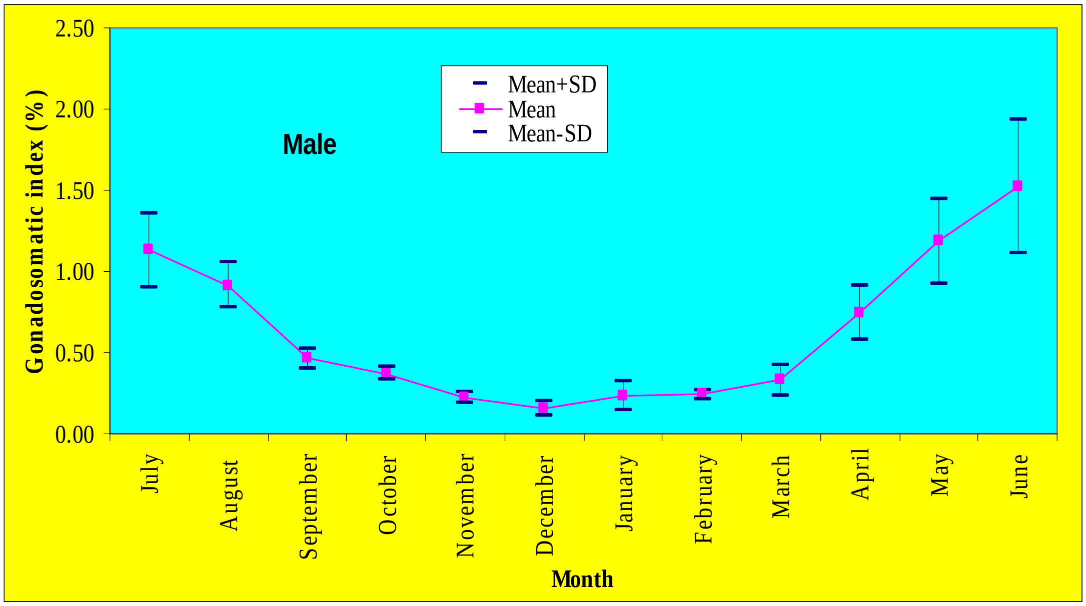


Figure 15. Showing the spawning season of male *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

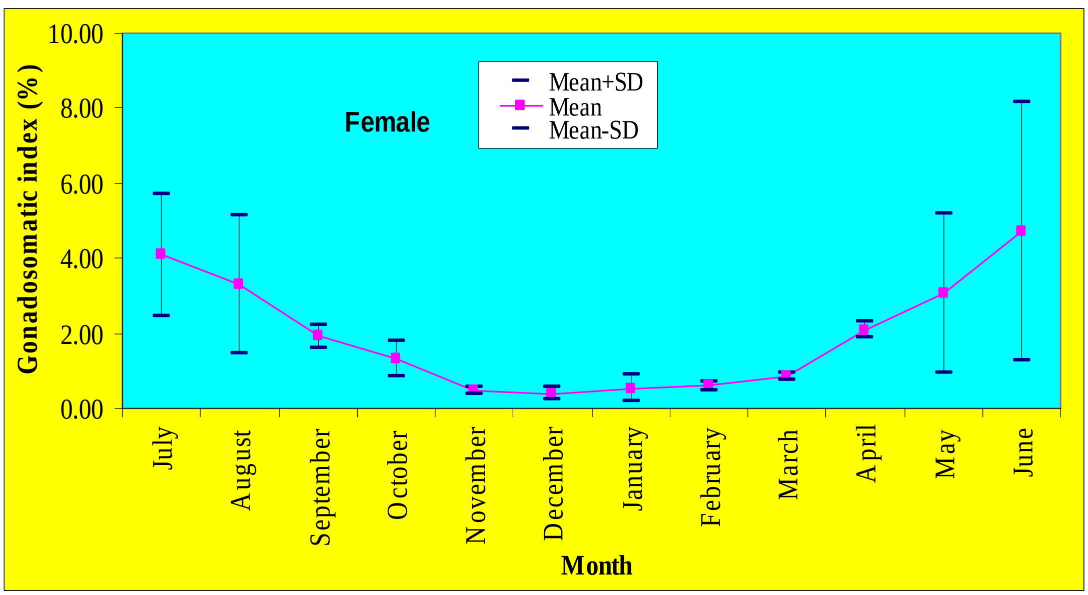


Figure 16. Showing the spawning season of female *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

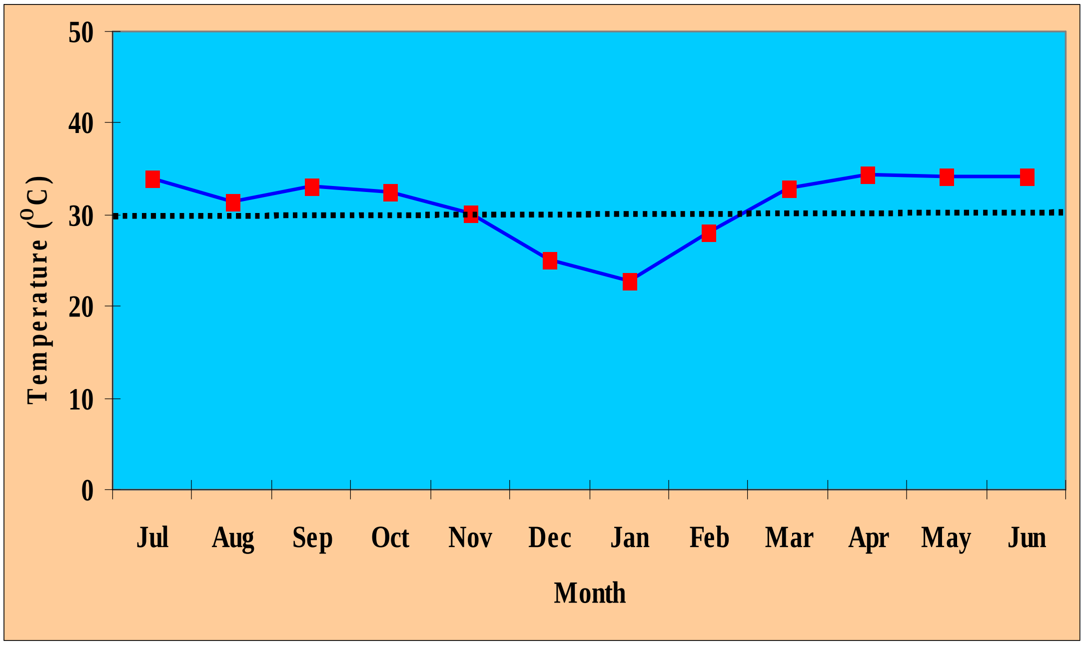


Figure 17. Monthly changes of temperature in the region of Gorai River, southwestern Bangladesh during July 2010 to June 2011.

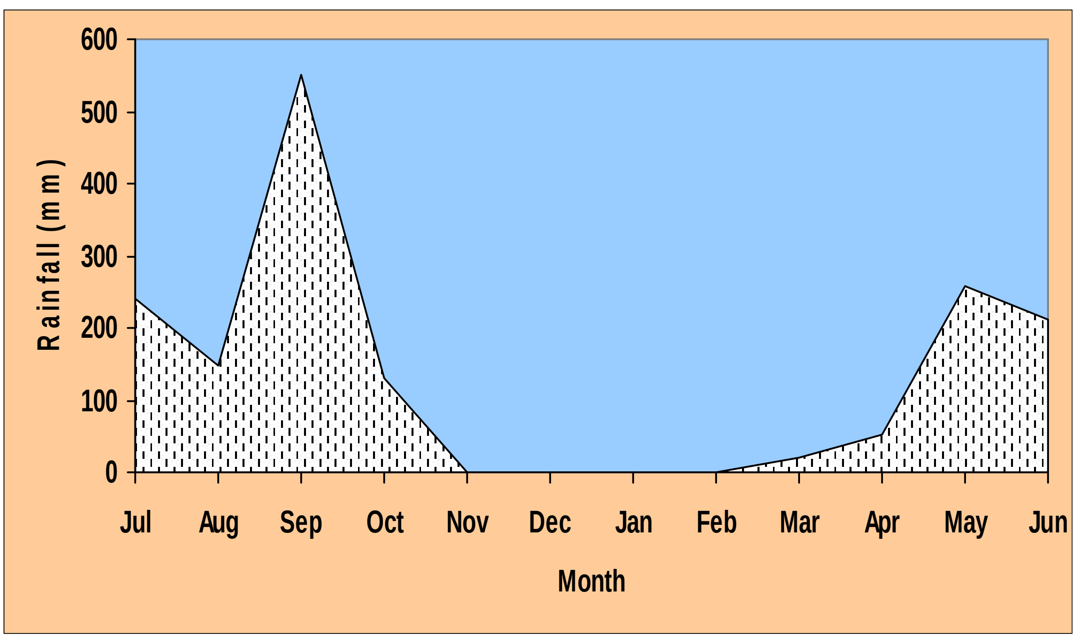


Figure 18. Monthly changes of rainfall in the region of Gorai River southwestern Bangladesh during July 2010 to June 2011.

### 3.3.4. Fecundity

A total of 104 mature females were collected. The lowest fecundity was 2021 and highest fecundity was 8623 with mean value of 4600±2037. Total fecundity (number of eggs per ovary) at different total length and body weight of *P. ticto* is given in table 11 and 12 respectively.

Table 11. Fecundity (average number of eggs) in various length classes of *Puntius ticto* (Hamilton, 1822), in the Gorai River, from July 2010 to June 2011

| **TL class cm** | **Mean TL** | **No. of fish examined** | **No. of eggs per TL class** | | |
|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Average** |
| 4.00-4.99 | 4.5 | 22 | 2021 | 2811 | 2356 |
| 5.00-5.99 | 5.5 | 34 | 2425 | 4560 | 3448 |
| 6.00-6.99 | 6.5 | 28 | 3983 | 6250 | 5434 |
| 7.00-7.99 | 7.5 | 12 | 6689 | 8258 | 7442 |
| 8.00-8.99 | 8.5 | 8 | 8350 | 8623 | 8490 |

TL, total length; Min, minimum; Max, maximum

Table 12. Fecundity (average number of eggs) in various body weight classes of *Puntius ticto* (Hamilton, 1822), in the Gorai River, from July 2010 to June 2011

| **BW of fish (g)** | **Mean BW (g)** | **No. of fish examined** | **No. of eggs per BW class** | | |
|---|---|---|---|---|---|
| | | | **Min** | **Max** | **Average** |
| 1.50-3.49 | 2.5 | 42 | 2021 | 3698 | 2698 |
| 3.50-4.49 | 4.0 | 22 | 3522 | 5048 | 4173 |
| 4.50-5.49 | 5.0 | 10 | 5216 | 5867 | 5564 |
| 5.50-6.49 | 6.0 | 8 | 5745 | 6158 | 5995 |
| 6.50-7.49 | 7.0 | 4 | 6250 | 6689 | 6670 |
| 7.50-8.49 | 8.0 | 8 | 6870 | 8057 | 7427 |
| 8.50-9.49 | 9.0 | 8 | 8258 | 8536 | 8399 |
| 9.50-10.49 | 10.0 | 2 | 8610 | 8623 | 8617 |

BW, body weight; Min, minimum; Max, maximum

Also the relationships between total length *vs.* fecundity are shown in figure 19 and 20. Analysis of regression showed that there was a significant relationship between the total length and fecundity (TL *vs.* $F_T$ and ln TL *vs.* Ln $F_T$) with $r^2$=0.962 ($P$ < 0.001). The results indicated that the number of eggs per female increased with increasing the total length.

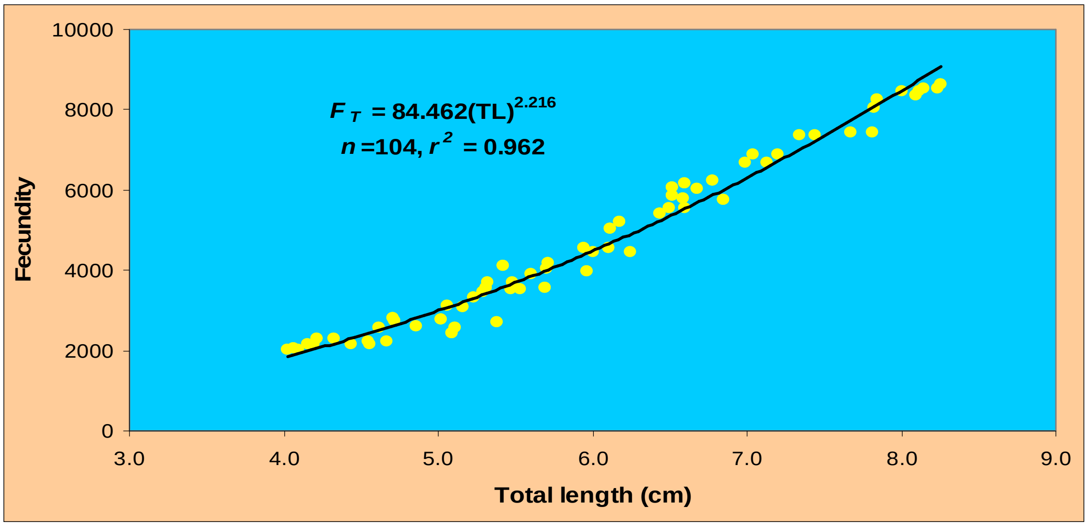


Figure 19. Relationships between total length and fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

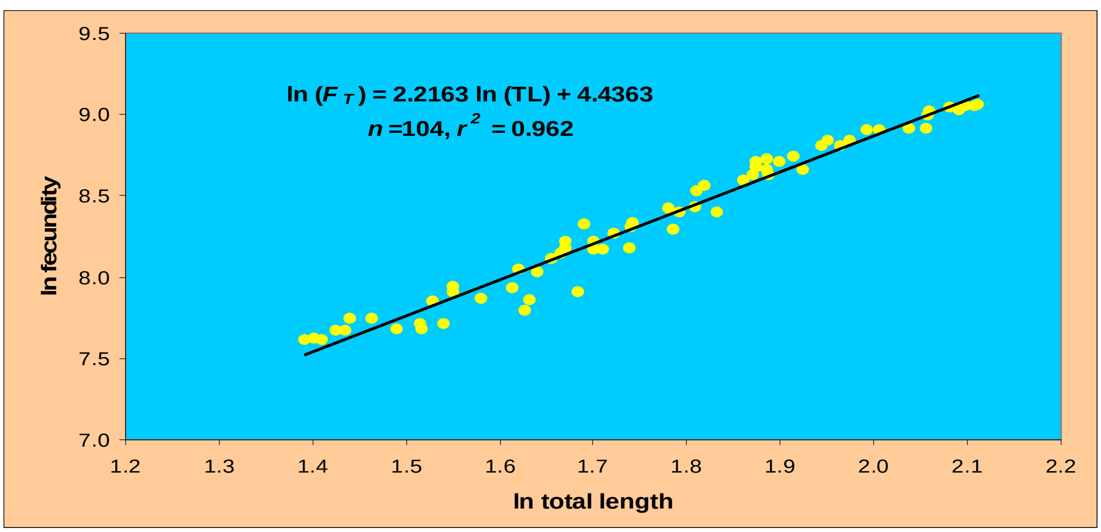


Figure 20. Relationships between ln total length and ln fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

Furthermore, the relationships between body weight and fecundity are shown in figure 21and 22. Analysis of regression showed that there was a significant relationship between the fecundity and body weight (BW *vs.* $F_T$, and ln BW *vs.* ln $F_T$) with $r^2 = 0.970$ ($P < 0.001$). The results indicated that the number of eggs per female increased with increasing the body weight.

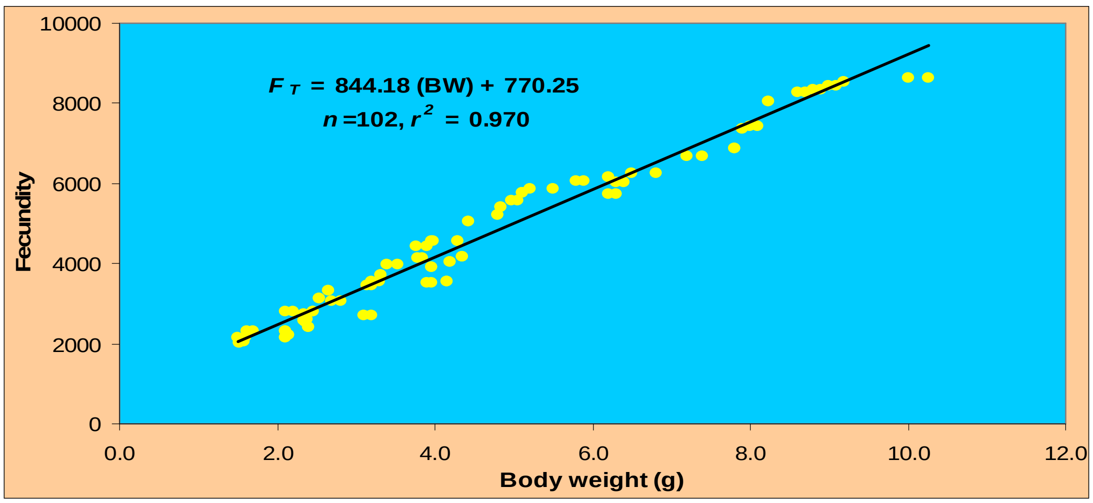


Figure 21. Relationships between body weight and fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

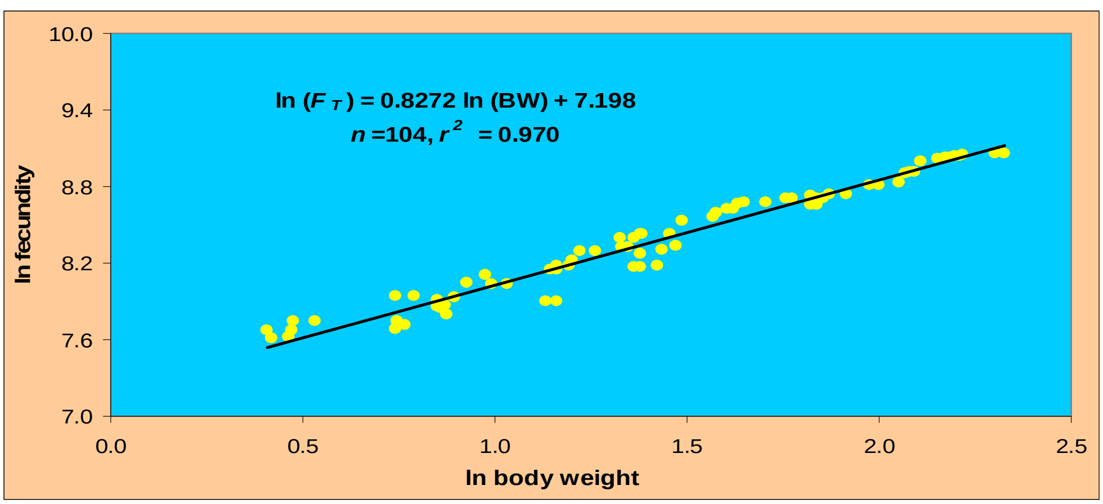


Figure 22. Relationships between ln body weight and ln fecundity of *Puntius ticto* from the Gorai River, southwestern Bangladesh during July 2010 to June 2011.

## 3.4. Discussion

Information on size at first sexual maturity of *P. ticto* from plots of percentage occurrence of mature fishes against length class (King, 2007) can be obtained from the resulting of logistic equation (Halls et al., 1999; Halls, 2005). Several studies have reported low accuracy in the estimation of size at sexual maturity of fishes using this logistic equation (Ohtomi et al., 2003; Hossain and Ohtomi, 2010). However, the present study is the first attempt to determine the size at first maturity for *P. ticto* from the Gorai River based on TL *vs.* GSI relationships. On the basis of GSI the first sexual maturity was 4.2 cm in TL for male and 4.7 cm in TL for female *P. ticto*. Moreover, based on the maximum length the first sexual maturity was 4.8 cm in TL for male and 5.1 cm in TL for female populations of *P. ticto* in the Gorai River, southwestern Bangladesh. The first sexual maturity may vary in different geographic locations due to differences in sample sizes, shrinkage in body size of the formalin preserved specimens, environmental factors, particularly water temperature, population densities, and food availability. Only few studies on first sexual maturity for different species were done by Hossain et al. (2010, 2012a, b). But there are no studies on this species; which restrains to compare with the present findings.

However, the highest values of GSI were found during the month of April to September, which indicated the spawning season for *P. ticto* in the Gorai River. In addition, peak values of GSI were found in the month of June-July, which was the peak spawning season for this species. Spawning season is very important to know the spawning time and the migration of fishes for spawning purposes (Wilding et al., 2000).

Spawning activities are often related to climatic conditions like rainfall (Wilding et al., 2000). In our study, when temperature increases above $30^{o}$ C and rainfall starts then the *P. ticto* also began to breed. There is a significant correlation among temperature, rainfall and the spawning season. Due to lack of available literature it was not possible to compare with the present result.

The knowledge of fecundity is an important aspect in stock size assessment, stock discrimination (Holden and Raitt, 1974) and rational utilization of stock (Morales, 1991) and in explaining the variation of population as well as to make efforts for increasing the amount of fish yield. Studies on fecundity are very effective for fishery resources management and conservation (Marshall et al., 2003). In this present study, lowest fecundity was 2021 and highest fecundity was 8623 with mean value of 4600±2037. Whereas, Banik and Saha (2012) has got the fecundity for *P. ticto* as 4374-10804 and Hossain et al. (2012c) has found 1611-4130 from the Ganges River. Also, there was a significant relationship between the total length *vs.* fecundity and body weight *vs.* fecundity for *P. ticto* in the Gorai River, southwestern Bangladesh. Positive relationships between fecundity *vs.* total length, body weight, ovary length and ovary weight have been reported in a number of fishes (Khan and Jhingran, 1975; Hossain et al., 2010; Jan et al., 2014) and this support to the present study. In the present study fecundity increases with the increase of length and body weight and it was similar with Jan et al. (2014) who were studied *Schizothorax plagiostomus* fish species in river Jhelum, Kashmir. However, fecundity of fishes varies especially due to environmental factors including temperature and foods, and biological factors such as age, size, body and gonadal weight (Lagler, 1956).

## 3.5. Conclusion

This study provides valuable information on first sexual maturity, spawning season and peak spawning season, relationships of climate change with spawning season and fecundity of *P. ticto* in the Gorai River eco-system. Basis of GSI the first sexual maturity was 4.2 cm in TL for male and 4.7 cm in TL for female *P. ticto.* Spawning season was ranged from April to September and the fecundity was varied from 2021 to 8623. The present findings would be very helpful for sustainable management and conservation of *P. ticto* in the Gorai River and neighboring ecosystem.

# STUDY:4

## Estimation of growth parameters of the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh

### 4.1. Introduction

Age and growth is a vital component for understanding the ecology and life history of any fish- and shell-fish species (Hossain and Ohtomi, 2010; Ahmed et al., 2012). Precise age determinations provide essential life-history information and are imperative for unfolding a species' population dynamics (Ahamed et al., 2012). A fundamental knowledge of fish age characteristics is necessary for stock assessments and to develop management or conservation plans (Ahmed et al., 2007). Age studies can furnish basic data of stock age structure, age at first maturity, spawning frequency, individual and stock responses to changes in the habitat, recruitment success, determination of population changes due to fishing rates etc.

In Bangladesh, inland fish- and shell-fish have been inadequately studied and very little known about their biology, including most of the commercially important species (Hossain et al., 2008; 2012b). Moreover, there is an urgent need to manage and regulate the small-scale inland capture fishery in the region and this requires basic population dynamics information for the target species (Santos et al, 2011). Although, Mustafa and de Graaf (2008) studied growth parameters of this species in Dikshi beel of Pabna and Shapla beel of B. Baria District but there is a notable short of information available on the growth rates and life spans of *Puntius* *ticto*. Therefore, the objective of this study is to determine the length frequency distribution, growth patterns, growth performance index and longevity of *P. ticto* from the Gorai River, southwestern Bangladesh.

## 4.2. Materials and Methods

The present study was conducted in the Gorai (a tributary of the Padma) River, southwestern Bangladesh. Monthly samples were collected randomly during daytime from fishermen's catch landed at different points near Boro Bazar ghat and Horipur ghat in Kustia town, southwestern Bangladesh from July 2010 to June 2011. This fish were usually caught by means of the traditional fishing gears such as cast net (*jhaki jal*), square lift net (*tar jal*), and conical trap (*dughair*) (see plate 3). Samples were immediately preserved with ice in site. The specimens were then transferred to the Department of Fisheries, University of Rajshahi (Bangladesh) and fixed with 10% formalin in the laboratory.

For each individual, total length (TL) was measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS; Mitutoyo Corporation, Tokyo, Japan), and whole body weight (BW) and whole gonads were removed from each male and female fish and weighed (GW) was taken on a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy.

### 4.2.1. Length based growth analysis

In order to avoid potential bias introduced by small size samples, only samples with a high number of observations for *P. ticto* are included in this analysis. In the multiple samples method, the length-frequency distributions (LFDs) from samples collected at different times were arranged sequentially one after one according to the sampling dates and the modes of a single cohort were traced as they progress along the length axis. The ages of mode of a single cohort or all cohorts were assessed from the spawning date (e.g., Hossain and Ohtomi, 2010). The growth, therefore, were estimated using monthly length-frequency data. Total length frequency distributions by sex for *P. ticto* with 1 cm interval were constructed for each sample. A file of time series of length-frequency data with constant class size was required. Data analysis was conducted with the most recent version of FiSAT II (Gayanilo and Pauly, 1997) statistical software. The method used to estimate the parameters was electronic length frequency analysis (ELEFAN) and has the following steps (Pauly et al., 1980). Initially, frequencies over a time scale were plotted to analyze visually for modal changes. In the absence of apparent modal changes to the time series of length frequencies, only $L_\infty$ parameters were computed. Powell-Wetherall plot is used to estimate the value of $L_\infty$ and Z/K independently which is important for direct fitting of length-frequency data (Wetherall, 1986). The value of $L_\infty$ and Z/K were estimated by pooling a series of length-frequency data composed at small time intervals. Input parameter graphical identification of smallest length fully recruited by the gear (L', or cut-off length) has a function of the form: (L-L') = a + b * L', where L is the mean length of all fish equal to, or longer than, length L', which becomes a series of lower limits for the length intervals of fully vulnerable fish. The regression line in the Wetherall plot is fitted through all data representing the fully exploited part of the sample, often from one length-interval to the right of the highest mode in the length-frequency data. From the regression line, the value of Z/K was estimated from the slope, *b*, as:

Z/K = - (1+*b*) /*b*. In addition, preliminary K values were estimated using the optimization procedures of ELEFAN II and Shepherd routines (Scan of K values, in FiSAT software). Using the input data from length frequencies and ELEFAN I program, asymptotic length ($L\infty$) and growth coefficient ($K$) were estimated for both males and females. To find the best growth curve passing through the maximum number of peaks, different starting samples and starting lengths were subjected to the goodness-of-fit tests by assessing the ratio ESP/ASP (*Rn*), where ESP is the explained sum of peaks and ASP is the available sum of peaks in the length frequencies. Input data were separated by sex and the values of *K* and L∞ were estimated for each sex by the von Bertalanffy growth equation:

$L_t = L_\infty [1-\exp\{-K(t-t_o)\}]$ (von Bertalanffy, 1938)

Where, $L_t$ is the TL (cm) at age t (month), $L_\infty$ is the asymptotic TL (cm), K is the growth coefficient (year-1), and $t_o$ is the hypothetical age when the TL would be zero. The $t_o$ was estimated by employing the equation of Pauly (1980):

$\text{Log}(-t_o) = -0.3922 - 0.2752 \text{ Log } L_\infty - 1.038 \text{ Log } K$

### 4.2.2. Growth performance indices

The estimated values of $L_\infty$ and K for *M. armatus* and *O. pabda* were used for comparison of growth performance indices (Ø') between sexes using the equation by Pauly and Munro (1984): $Ø' = \log_{10} K + 2\log_{10} L_\infty$.

### 4.2.3. Longevity

From the parameters of $L_\infty$ and K of the von Bertalanffy growth equation, the potential longevity of *P. ticto* was calculated using the formula of Pauly and Munro (1984): Tmax = 3/K. Additionally, Taylor (1958) defined longevity (A) as the time required to attain 95% of the $L_\infty$ with the following equation: $A_{95\%} = t_o + \log_e (1-0.95)/K$. This equation might be used to determine longevity based on 99% of $L_\infty$ by substituting 0.99 for 0.95 in the equation (Taylor, 1958). All statistical analyses were considered significant level at 5% ($P < 0.05$).

## 4.3. Results

### 4.3.1. Length frequency distribution

Length-frequency distribution of male *P. ticto* shows that, the populations were first recruited in the month of September and for female the populations were first recruited on the month of August (Figure 23 and 24).

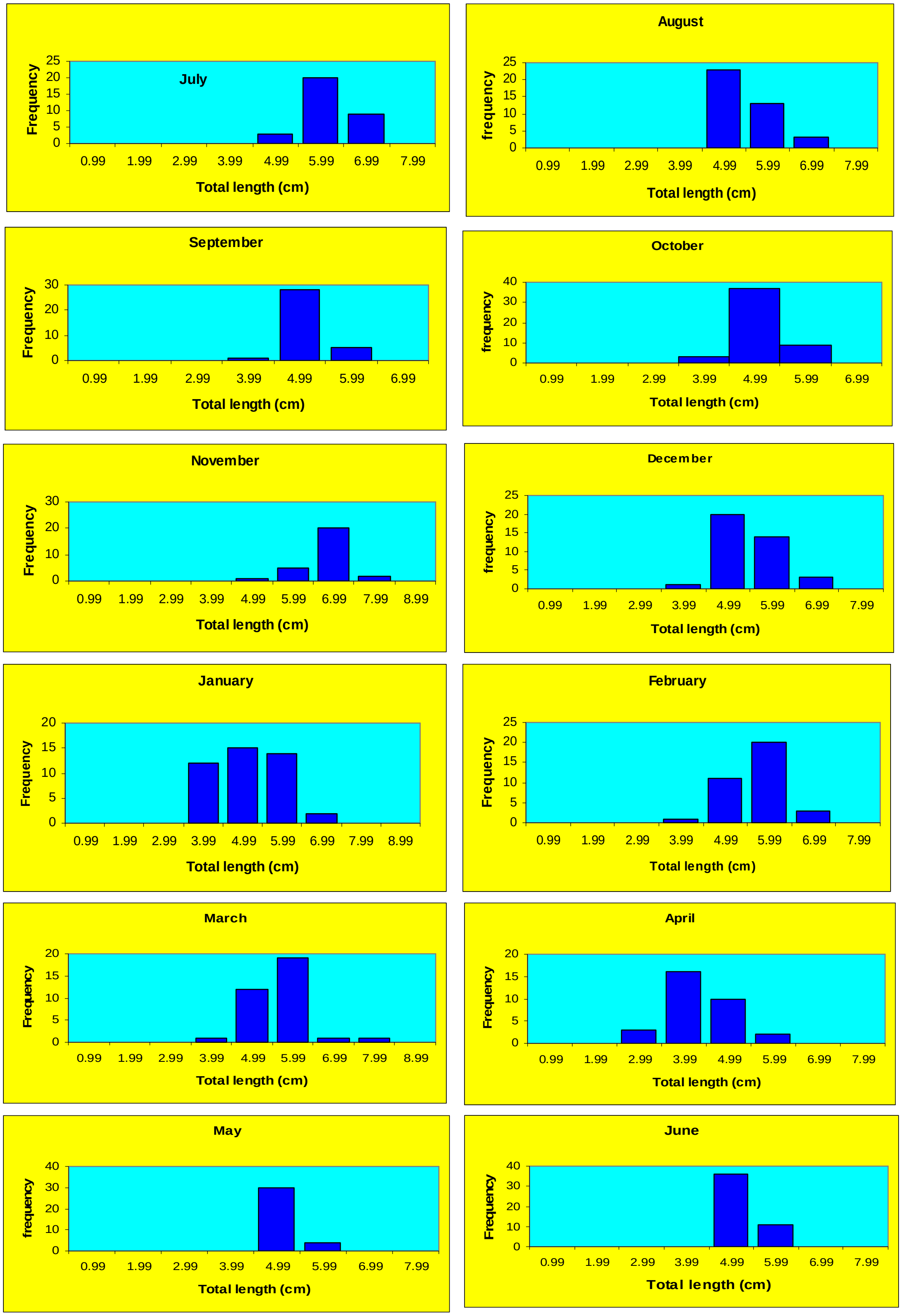


Figure 23. Length-frequency distribution of male *Puntius ticto* in the Gorai River southwestern Bangladesh from July 2010 to June 2011.

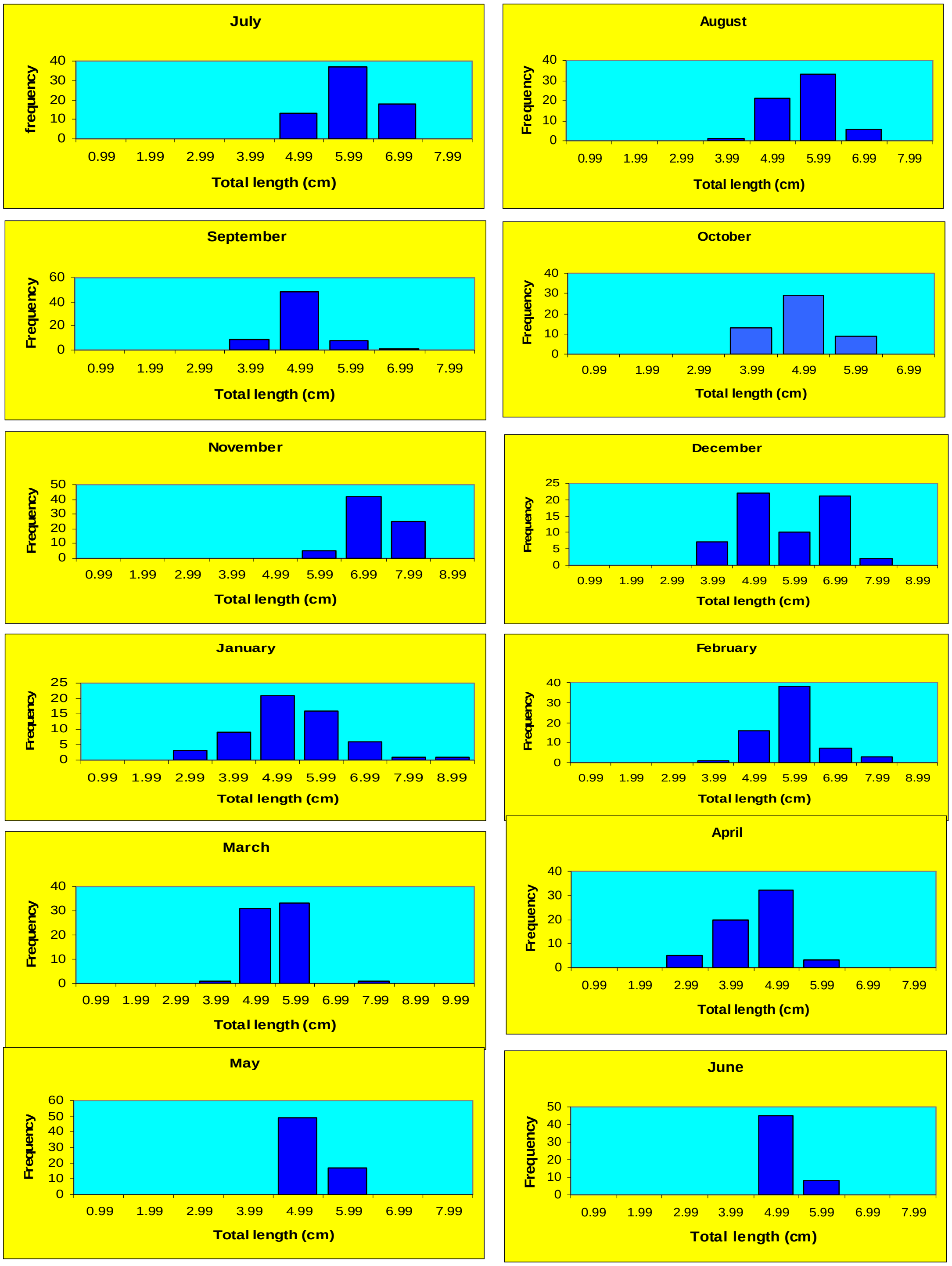


Figure 24. Length-frequency distribution of female *Puntius ticto* in the Gorai River southwestern Bangladesh from July 2010 to June 2011.

### 4.3.2. Growth parameters based on length

Since at least a regular cohort over the time of sampling period in either male or female population could not be traced in this study, therefore, growth parameters analyses were done by the direct fit of ELEFAN I incorporated in FiSAT tool. The analysis of the pooled length-frequency data of male *P. ticto* by the Powell-Wetherall procedure gave an initial TL∞ value of 10.12 cm and Z/K of 4.61 (Figure 25). Using $TL_\infty$ = 10.12 cm as a seed value in the K-Scan, the ELEFAN I analysis yielded to optimized and von Bertalanffy growth curve with the following parameters: $TL_\infty$ = 10.26 cm, k = 1.16 $year^{-1}$, C = 0 and WP = 0. The computed growth curve using these parameters is shown over the restructured TL distribution in Figure 26. The growth curve showed no seasonal oscillation in growth. The observed maximum TL was 7.48 cm and the predicted maximum TL was 10.26 cm. It was assumed in the growth analysis that the value of the third parameter of the von Bertalanffy growth function $t_o$ be zero (Pauly and David, 1981). On the other hand, the analysis of the pooled length–frequency data of female *P. ticto* by the Powell-Wetherall procedure gave an initial $TL_\infty$ value of 10.30 cm and Z/K of 3.72 (Figure 27). Using $TL_\infty$ = 10.30 cm as a seed value in the K-Scan, the ELEFAN I analysis yielded to optimized and von Bertalanffy growth curve with the following parameters: $TL_\infty$ = 10.55 cm, k = 1.30 per year, C = 0 and WP = 0. Figure 28 showed the von Bertalanffy growth curve of female as superimposed on the restructured total length-frequency histogram. The curve revealed no seasonal oscillation in growth. The observed maximum TL was 8.00 cm and the predicted maximum TL was 10.55 cm. In addition, the $t_o$ was calculated as -0.006 for males and -0.007 for females using the equation of Pauly (1980).

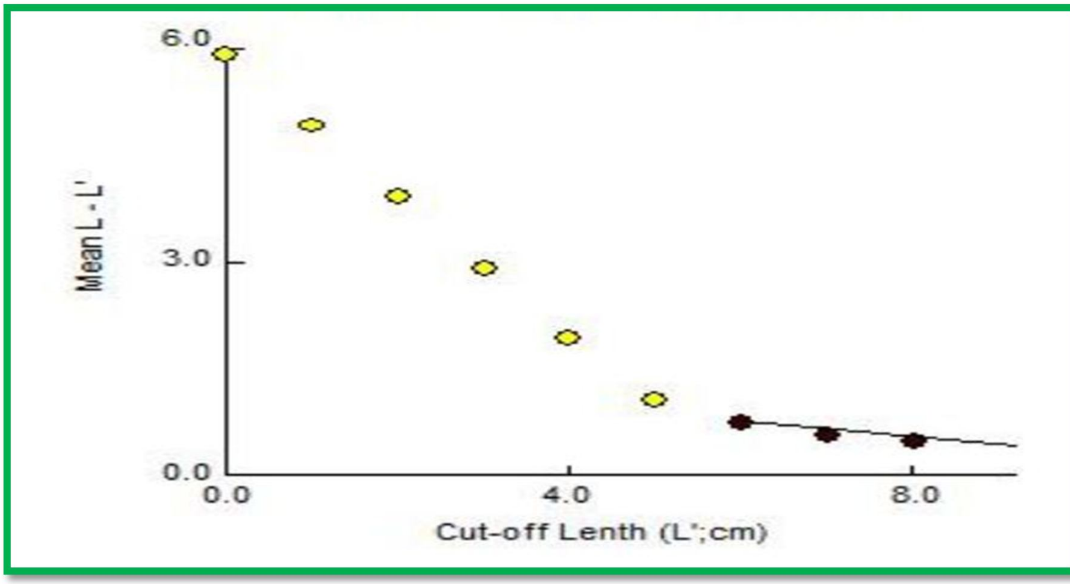


Figure 25. A Powel-Wetherall plot for the male *Puntius ticto*. Solid black symbols are used in the regression which provides asymptotic TL of 10.12 cm and Z/K of 4.61.

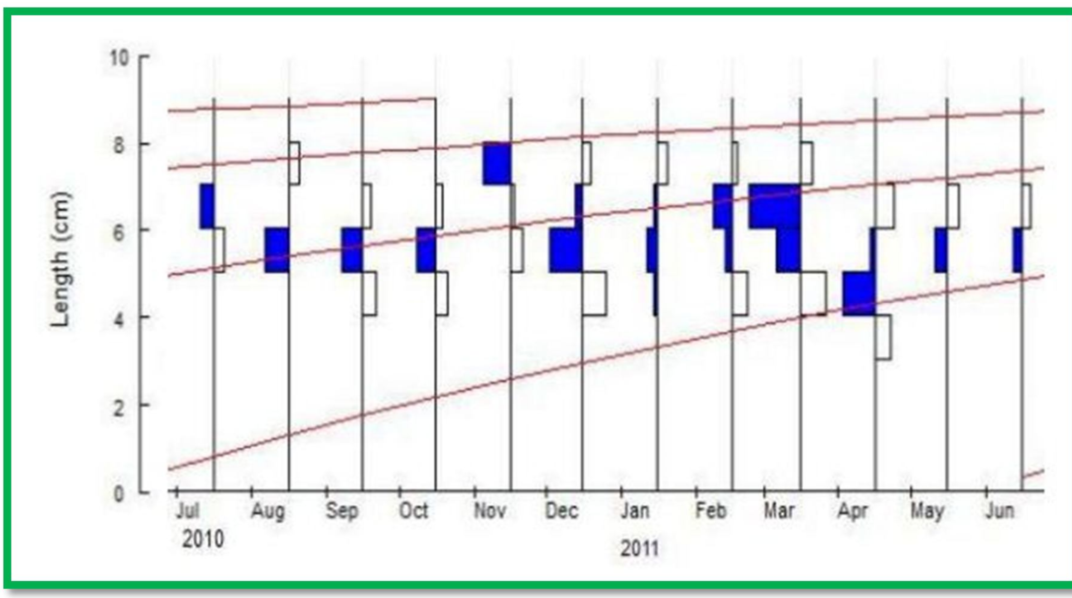


Figure 26. von Bertalanffy growth curve ($TL_{\infty}$ =10.26 cm, K =1.16 year$^{-1}$, C = 0, winter point (WP) = 0) of male *Puntius ticto* as superimposed on the restructured total length-frequency histogram.

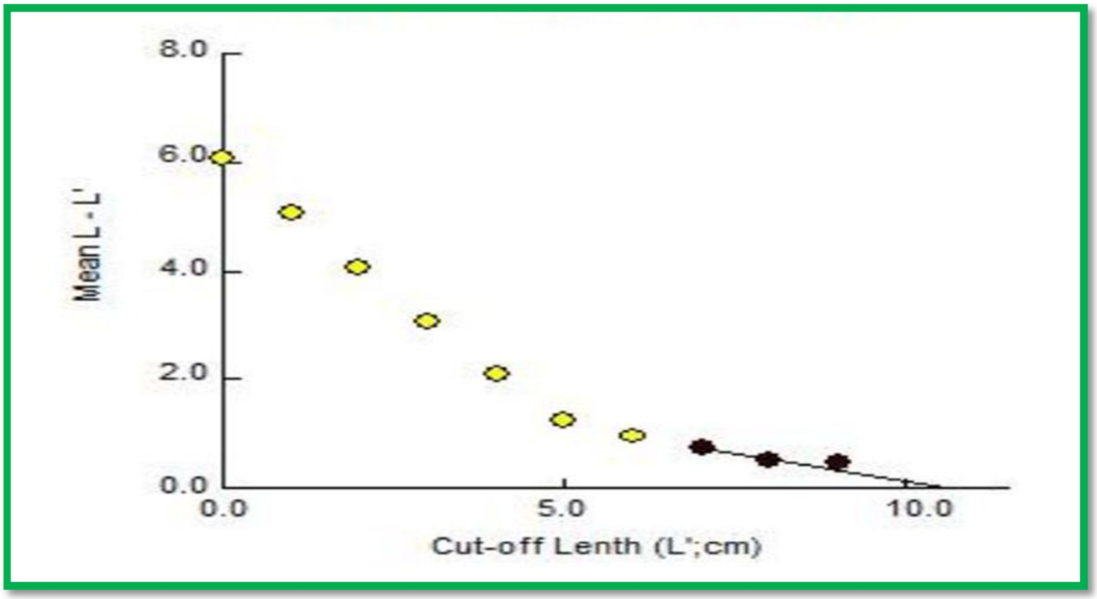


Figure 27. A Powel-Wetherall plot for the female *Puntius ticto*. Solid black symbols are used in the regression which provides asymptotic TL of 10.30 cm and Z/K of 3.72.

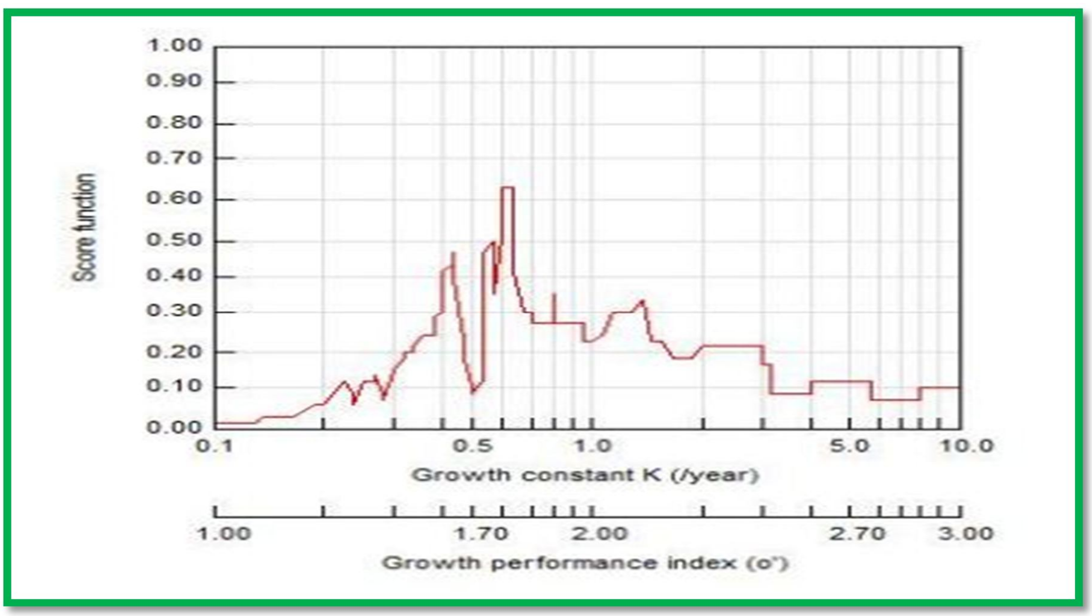


Figure 28. von Bertalanffy growth curve ($TL_{\infty}$ =10.55 cm, k =1.30 year $^{-1}$, C = 0, winter point (WP) = 0) of female *Puntius ticto* as superimposed on the restructured total length-frequency histogram.

### 4.3.3. Growth performance indices and longevity

The calculated growth performance index for males and females *P. ticto* was 1.80 and 2.16 respectively. Growth performance index or male and female *P. ticto* are shown in figure 29 and 30. That means growth performance was higher in females than males. Furthermore the longevity was 2.6 year for males and 2.30 year for females.

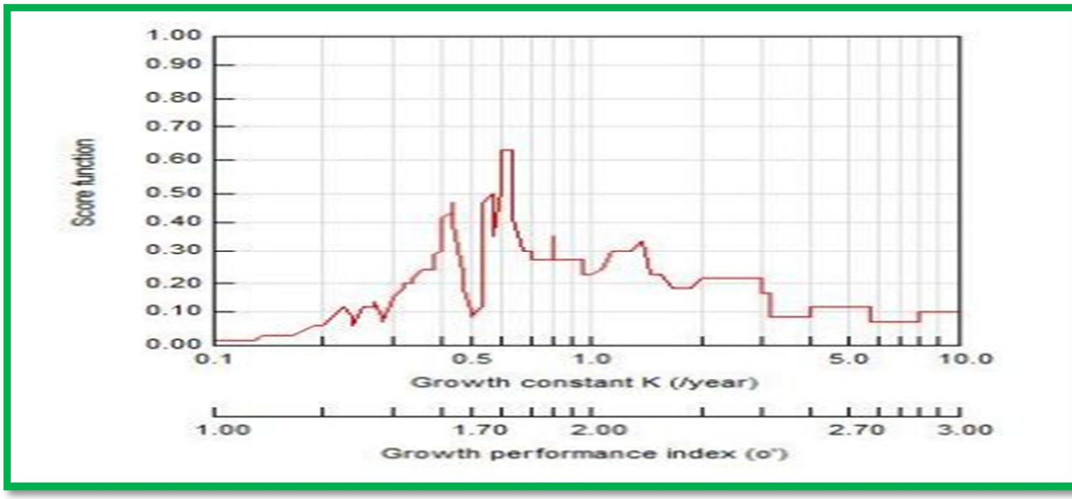


Figure 29. Growth performance index for ($TL_\infty$ =10.26 cm, k =1.16 year $^{-1}$, C = 0, winter point (WP) = 0) of male *Puntius ticto.*

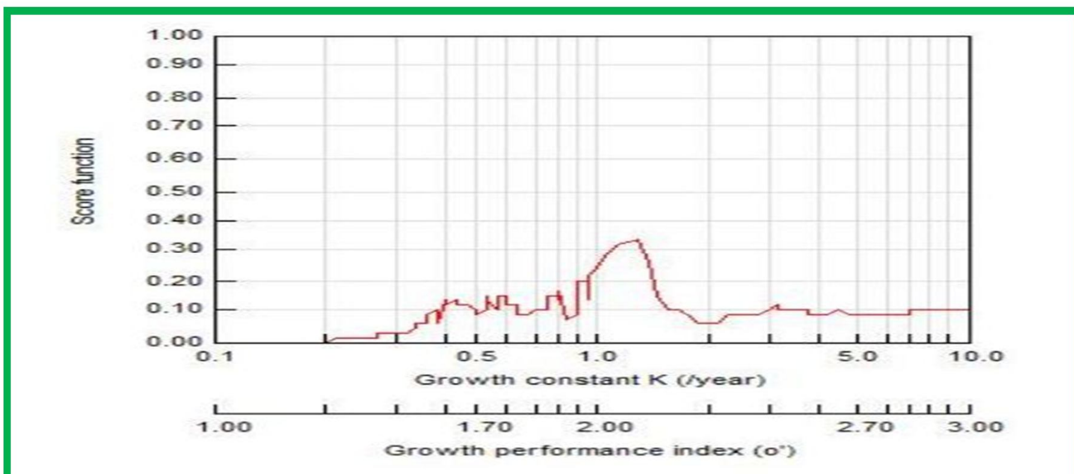


Figure 30. Growth performance index ($TL_\infty$ =10.55 cm, k =1.30 year-$^{1}$, C = 0, winter point (WP) = 0) of female *Puntius ticto.*

## 4.4. Discussion

The length-frequency distribution indicated that male *P. ticto* were first recruited in the month of September and for female *P. ticto* were first recruited in the month of August. The estimation of growth of fish can be done by length-frequency analyses, mark-recapture experiments, and growth checks of hard parts like scales, otoliths, and vertebrae (King, 2007). The development of computer software for the analysis of length-frequency data has resulted in a rapid increase in the use of this technique. Additionally, due to the lack of well defined characteristics formed in hard parts that indicate age, the age and growth of natural *P. ticto* populations were estimated by identifying successive age groups from the modes of length frequency distributions.

For the ticto barb, *P. ticto*, however, study on age and growth by any standard methods were not present in Bangladesh particularly. In the present study, we assembled a large number of specimens of *P. ticto* from the Gorai River. This in turn, allowed us to get frequency distributions of both sexes that used to estimate age and growth of this species.

The current study adopted von Bertalanffy growth equation for male and female as the appropriate equation for *P. ticto* in Gorai River of Bangladesh. The von Bertalanffy growth curves were fitted to length at age data of male and female separately and ELEFAN I method provided the values of growth parameters by direct fitting of standard length-frequency data. By using these parameters the relationship between age and standard length were established.

Among the models examined, the von Bertalanffy model was the finest articulated for expression of growth of *P. ticto*. According to Soriano et al. (1992), fishery biologist frequently used this model, and it is a good descriptor of fish growth patterns. Although our estimated growth equations showed a similar $TL_\infty$ in males (10.26 cm), and in females (10.55 cm) but female grew faster than male in the early stages of life cycle. For accurately measure productiveness at the population level, fish growth and condition are, thus, vital factors.

However, Hossain et al. (2012c) reported the maximum SL for *P. ticto* from the Ganges River, northwestern Bangladesh as 8.60 cm, whereas Banik and Saha (2012) recorded the maximum length of this fish from India as 11.8 cm TL, which is in agreement with the present study. Fluctuations in environmental factors such as water temperature may affect fish growth by affecting fish behavior and metabolism as well as food availability would be the reasons to create these differences.

Also the growth performance index for males and females *P. ticto* was 1.80 and 2.16 respectively and longevity was 2.6 for males and 2.30 year for females. Due to lack of available study it restrains to compare with this present study.

## 4.5. Conclusion

This study reported the growth parameters including maximum estimated total length, growth performance index and longevity of the threatened fish *P. ticto* from the Gorai River, southwestern Bangladesh. It would be very helpful for sustainable management and conservation of this species in the Gorai River ecosystem.

# STUDY:5

## Assessment of the status of stock for the threatened fish *Puntius ticto* (Cyprinidae) (Hamilton, 1822) in the Gorai River, southwestern Bangladesh

### 5.1. Introduction

Stock assessment involves the use of various statistical and mathematical calculations to make quantitative predictions about the reactions of fish populations to alternative management choices. It is widely accepted that the fundamental purpose of fisheries management is to ensure sustainable production over time from fish stocks, preferably through regulatory and enhancement actions that promote economic and social well-being of the fishermen and industries that use the production.

These stock assessment combined using simple or complex mathematical models to derive best estimates of vital statistics such as historical and recent trends in the number and biomass of the resource, recruitment levels (number of small fish entering the fishery each year), and the fishing mortality rate or the fraction of the stock alive at the beginning of the year that are killed by fishing, commonly referred to as the exploitation rate (NRC, 1998a, b). The objectives of this study are to describe the mortality (fishing mortality, natural mortality and total mortality) and exploitation rate of *Puntius ticto* from the Gorai River, southwestern Bangladesh.

## 5.2. Materials and Methods

The present study was conducted in the Gorai (a tributary of the Padma) River, southwestern Bangladesh. Monthly samples were collected randomly during daytime from fishermen's catch landed at different points near Boro Bazar ghat and Horipur ghat in Kustia town, southwestern Bangladesh from July 2010 to June 2011. This fish were usually caught by means of the traditional fishing gears such as cast net (*jhaki jal*), square lift net (*tar jal*), and conical trap (*dughair*) (see plate 3). Samples were immediately preserved with ice in site. The specimens were then transferred to the Department of Fisheries, University of Rajshahi (Bangladesh) and fixed with 10% formalin in the laboratory.

For each individual, total length (TL) was measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS; Mitutoyo Corporation, Tokyo, Japan), and whole body weight (BW) and whole gonads were removed from each male and female fish and weighed (GW) was taken on a digital balance (Shimadzu, EB-430DW; Shimadzu Seisakusho, Tokyo, Japan) with 0.01 g accuracy.

### 5.2.1. Estimation of mortality and exploitation rate:

Once growth parameters are obtained, the instantaneous rate of total mortality (Z) for *P. ticto* were estimated by the length converted catch curve method (Pauly, 1983) which is given as $\ln (Nt/\Delta t) = a + b*t$ ; where, N is the number of individuals of relative age (t), and Δt is time needed for the species through a length class. The slope *b* of the curve with its sign changed gives an estimate of Z (King, 2007).

The instantaneous rate of natural mortality (M) of *P. ticto* was estimated using the empirical formula of Pauly (1980) given as:

$$\text{Log}_{10} M = -0.0152 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where, M is the natural mortality, L∞ the asymptotic length, K refers to the growth coefficient of the von Bertalanffy equation and T is the average annual environmental temperature ($^{O}$C) in which the stocks live.

The fishing mortality (F) of *M. armatus* and *O. pabda* were estimated by subtracting the natural mortality (M) from the total mortality (Z): F = Z – F.

The exploitation rate (E) of *P. ticto* were calculated as the proportion of the fishing mortality relative to total mortality (Gulland, 1965): E = F / Z = F / (F + M).

## 5.3. Results

The value of total mortality estimated from the slope of the length-converted catch curve for both male and female *P. ticto* are shown in Figures 31and 32**.** The length converted catch curve analysis estimated the instantaneous rate of total mortality *Z* = 2.67 year$^{-1}$ for males and 7.14 year$^{-1}$ for females. The calculated values of the instantaneous rates of natural mortality were *M* = 1.66 year$^{-1}$ for males and 2.74 year$^{-1}$ for females. Thus, the fishing mortality (*F*) was recorded as 2.01 year$^{-1}$ and 4.40 year$^{-1}$ for males and females respectively.

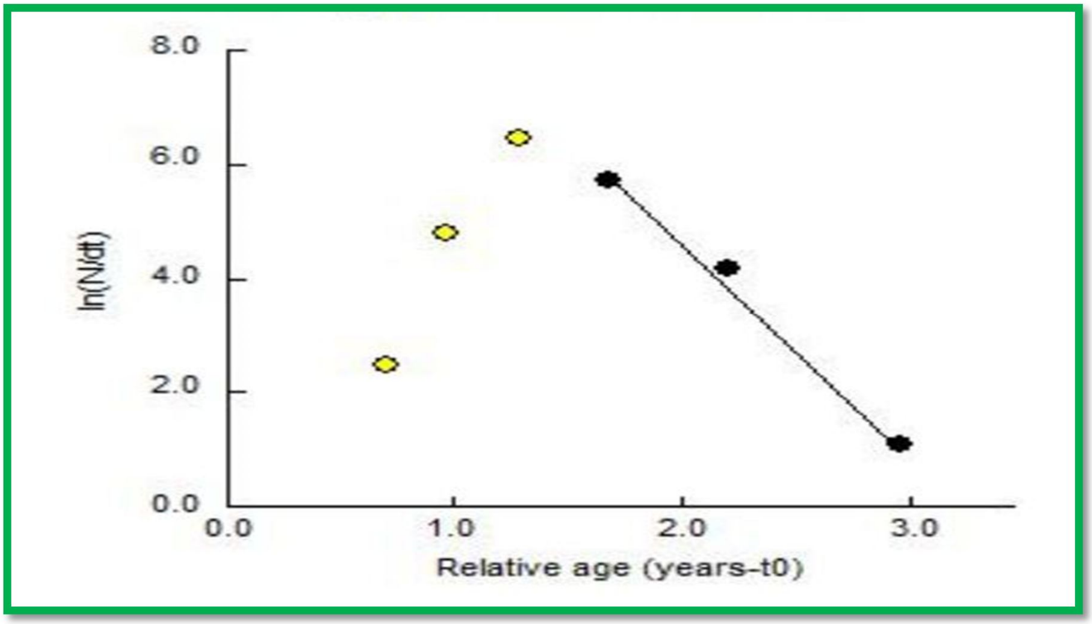


Figure 31. Length-converted catch curve for male *Puntius ticto*. Data included in the regression are shown as black solid points.

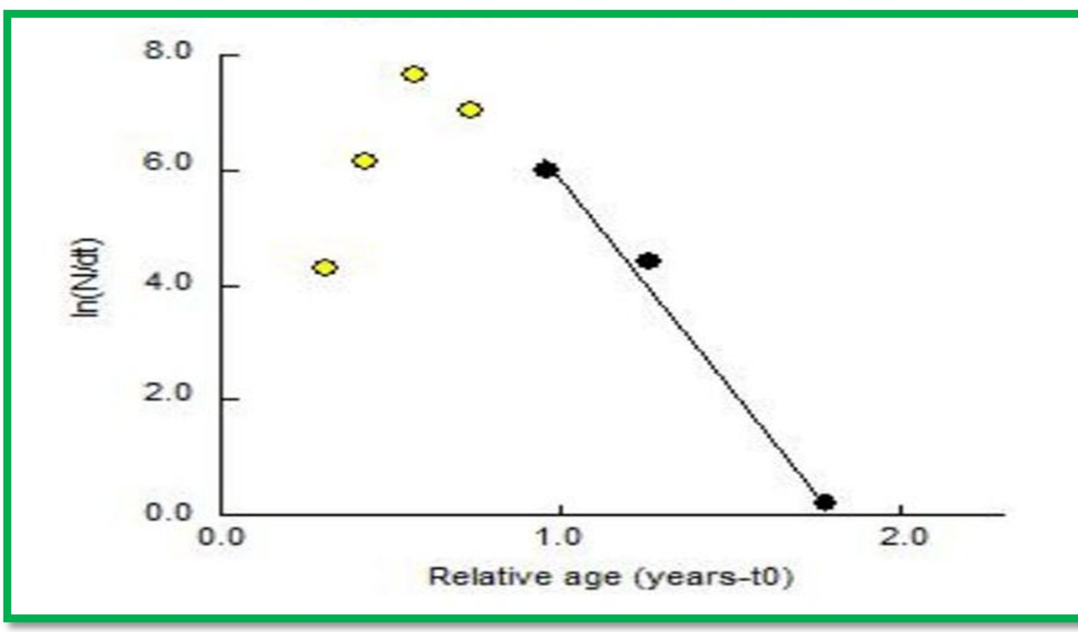


Figure 32. Length-converted catch curve for female *Puntius ticto.* Data included in the regression are shown as black solid points.

From the estimates of the instantaneous of fishing and total mortalities, the exploitation rate was calculated as *E* = 0.58 or 58% for male and 0.62 or % for female. But we have found maximum exploitation rate would be 0.57 or 57% for male and 0.54 or 54% for female. The exploitation rates for male and female *P. ticto* are shown in figure 33 and 34.

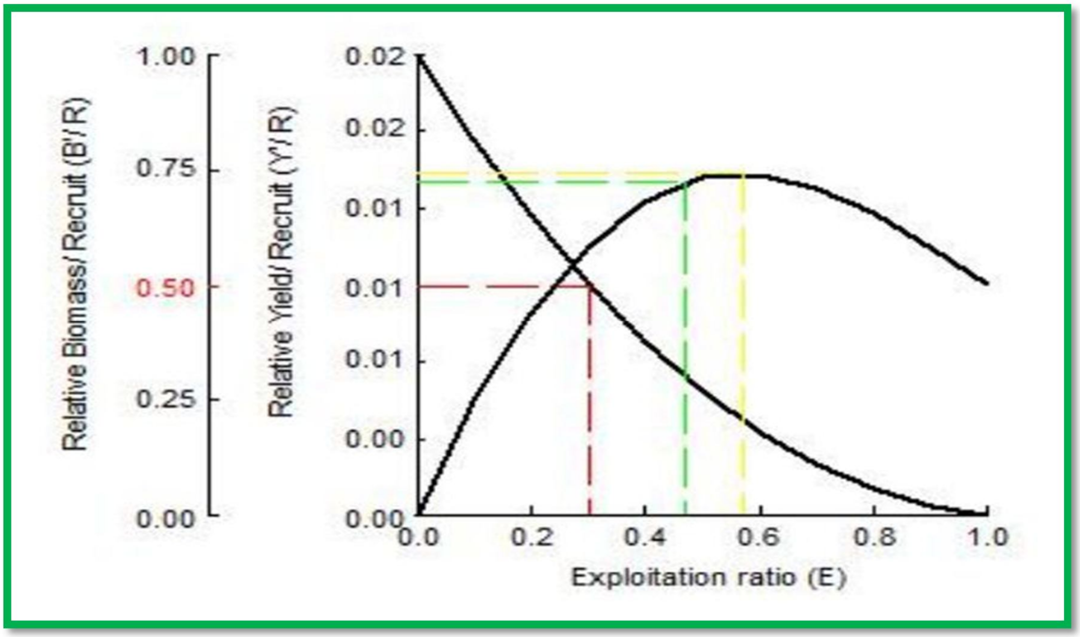


Figure 33. Relative yield per recruit and biomass per recruit of male *Puntius ticto* in the Gorai River, southwestern Bangladesh.

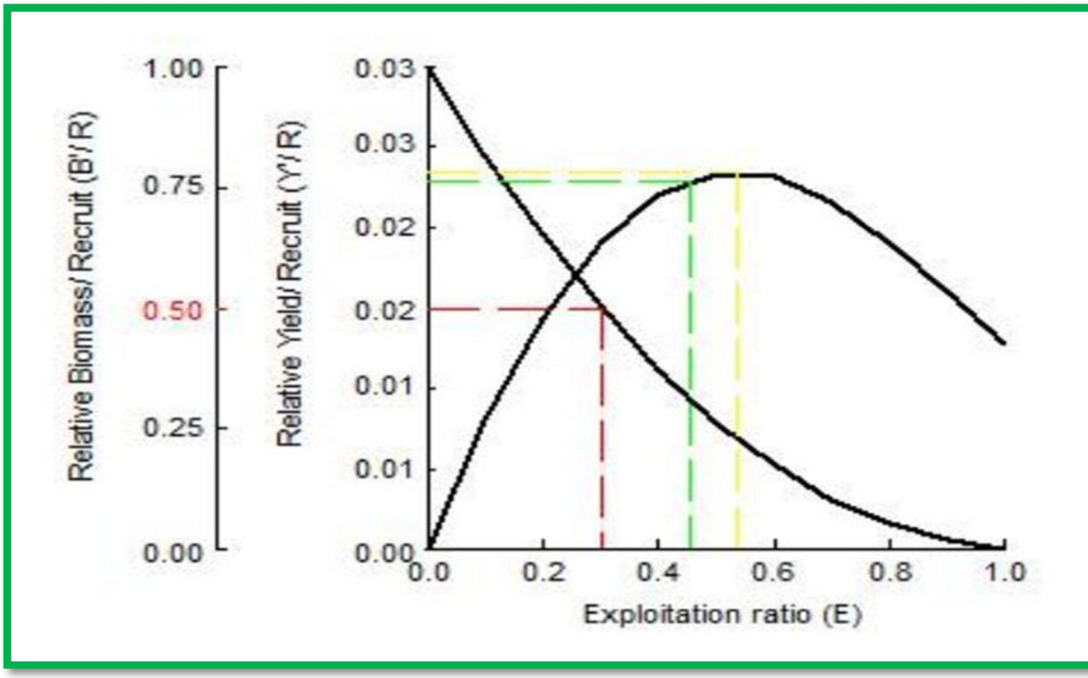


Figure 34. Relative yield per recruit and biomass per recruit of female *Puntius ticto* in the Gorai River, southwestern Bangladesh.

## 5.4. Discussion

Stock assessments provide fisheries managers with the information that is used in the regulation of a fish stock and also describe the past and current status of a fish stock. The natural mortality is one of the most significant quantities in fisheries stock assessment and management. The magnitude of natural mortality relates openly to the productivity of the stock, the yields that can be obtained, optimal exploitation rates, management quantities, and reference points. Fishing mortality is a parameter used in fisheries population dynamics to account for the loss of fish in a fish stock through death. During the study calculated values of the instantaneous rates of natural mortality were 1.66 $year^{-1}$ for males and 2.74 $year^{-1}$ for females and the fishing mortality was recorded as 2.01 $year^{-1}$ and 4.40 $year^{-1}$ for males and females respectively, in the Gorai River, southwestern Bangladesh. Thus the estimated instantaneous rate of total mortality was 2.67 $year^{-1}$ for males and 7.14 $year^{-1}$ for females. Here, it was found that both natural mortality and fishing mortality was higher in females than males. This may be due to the larger body sizes of female population, high sensitivity to microbial disease and gear selectivity.

Exploitation rate, applied on a fish stock, is the proportion of the numbers or biomass removed by fishing. From the estimates of the instantaneous of fishing and total mortalities, the exploitation rate was calculated as 0.58 or 58% for male and 0.62 or % for female. But we have found maximum exploitation rate as 0.57 or 57% for male and 0.54 or 54% for female and maximum exploitation rate was near similar for male *P. ticto*, but under fishing was found for female population of *P. ticto* and for this exploitation rate can be increased as 8% for female population of this species in the Gorai River ecosystem. This is the first study on these above aspects and due to lack of available study; it was not possible to compare with the present findings.

## 5.5. Conclusion

This study point out the stock assessment including natural mortality, fishing mortality, total mortality and exploitation rate of the threatened fish *P. ticto* from the Gorai River, southwestern Bangladesh. Through the stock assessment, it is easy to determine the mortality (both fishing mortality and natural mortality), and the exploitation rate of fishes in a water body. In our study it was found that mortality rate was higher in female than male and the female populations of *P. ticto* were in under fishing. The results of this study would be very effective for proper management fish stock and to introduce appropriate fishing regulations for better management.

# GENERAL DISCUSSION

This is the first study which provides all the life history parameters except food and feeding habit. The *b* values of LWRs may vary between 2 and 4, however, values ranging from 2.5 to 3.5 are more common (Carlander, 1969; Froese, 2006). In the present study, *b* values were within the limits (2 and 4) reported by Tesch (1971) for most fishes. In this study, the regression parameter *b* of the LWRs ranged from 2.63 to 3.62 for males and 3.04 to 3.76 for females. The overall *b* for the LWR indicated negative allometric growth (< 3.00) in both males and females which is accordance with the result of Hossain et al. (2009a), who reported the *b* value for *P. ticto* as 2.92 in the Padma River, northwestern Bangladesh. Isometric growth indicates that the body increases in all dimensions in the same proportion to growth, whereas negative allometry indicates that the body becomes more rotund as it increases in length, and negative allometry indicates a slimmer body (Jobling, 2008). However, the length-weight relationship in fishes can be affected by several factors i. e., habitat, area, seasonal effect, degree of stomach fullness, gonad maturity, sex, health, preservation techniques and differences in the observed length ranges of the specimen caught (Tesch, 1971), all of which were excluded in the present study.

According to Froese (2006), the regression parameter *a* of length weight relationship is an indicator of the body shape of fishes. In this study, most *a* values have been estimated as smaller than 0.01. Therefore, most of the species could be classified as relatively elongated, which is expected of the fishes inhabiting river ecosystems (Birecikligil and Çiçek, 2011). However, Hossain et al. (2009a) reported the *a* value for the two-spot barb as 0.035. Nonetheless, Mbaru et al. (2010) reported that the regression parameters, particularly *a*, may vary daily, seasonally, and / or between habitats.

The Fulton′s condition factor ($K_F$) is an index reflecting interactions between biotic and abiotic factors in the physiological condition of the fishes. It shows the well-being of the population during various life cycle stages (Angelescu et al., 1958). The Fulton′s condition factor of *P. ticto* was higher in January for both genders suggesting in that month the fish was in good condition. However, no references dealing with the condition factors on the two-spot barb are available in the Gorai River, preventing the comparison with present result.

The relative weight ($W_R$) is the most popular index to assess the status of fish in a habitat (Froese, 2006). The $W_R$ declining below 100 for a population indicate lower prey or high predator density; whereas values above 100 indicate a prey surplus or lower predator. In the present study the mean $W_R$ was significantly different from 100 for male and female populations of *P. ticto* indicating the habitat was not in balance condition with lower prey and high predator. The $W_R$ was higher in the month of December-March for male and January-March for female populations of *P. ticto* indicating that, in these months the predator was in lower and prey was in higher amount in the Gorai River ecosystem. In addition this result expresses that, the TL and $W_R$ was not significantly correlated for both male and female sexes in the study area. This is the first study on prey-predator relationships for *P. ticto* in the Ganges River, southwestern Bangladesh. There is no available literature or references dealing with the prey-predator relationship for this species prevent the comparison with our findings.

On the basis of gonadosomatic index (GSI) the first sexual maturity was 4.2 cm in TL for male and 4.7 cm in TL for female *P. ticto*. Moreover, based on the maximum length the first sexual maturity was 4.8 cm in TL for male and 5.1 cm in TL for female populations of *P. ticto* in the Gorai River, southwestern Bangladesh. Very few studies on sexual maturity for different species were conducted by Hossain et al. (2010, 2012a, b). But there are no studies on this species; which restrains to compare with the present findings. However, the higher GSI were found during the month of April-September, which indicated the spawning season for *P. ticto* in the Gorai River. In addition, peak values of GSI were found in the month of June-July, which was the peak spawning season for this species.

Also when temperature increases above $30^{o}$ C and rainfall starts then the *P. ticto* also began to breed. There is a significant correlation among temperature, rainfall and the spawning season. In the present study, lowest fecundity was 2021 and highest fecundity was 8623 with mean value of 4600±2037. Whereas, Banik and Saha (2012) has estimated the fecundity for *P. ticto* as 4374-10804 and Hossain et al. (2012c) has found 1611-4130 from the Ganges River. Also, there was a significant relationship between the total length *vs.* fecundity and body weight *vs.* fecundity for *P. ticto* in the Gorai River ecosystem.

Based on length-frequency distribution (LFDs) pattern the male *P. ticto* were first recruited in the month of September and for female *P. ticto* were first recruited on the month of August. The estimation of growth of fish can be done by length-frequency analyses, mark-recapture method, and growth checks of hard parts like scales, otoliths, and vertebrae (King, 2007). Additionally, due to the lack of well defined characteristics formed in hard parts that indicate age, the age and growth of natural *P. ticto* populations were estimated by identifying successive age groups from the modes of length frequency distributions.

For the ticto barb, *P. ticto*, however, study on age and growth by any standard methods were not present in Bangladesh. In the present study, we assembled a large number of specimens of *P. ticto* from the Gorai River. The current study adopted von Bertalanffy growth equation for male and female as the appropriate equation for *P. ticto* in Old Brahmaputra River of Bangladesh. According to Soriano et al. (1992), fishery biologist frequently used this model, and it is a good descriptor of fish growth patterns. The estimated growth equations showed a similar $TL_{\infty}$ in males (10.26 cm), and in females (10.55 cm) but female grew faster than male in the early stages of life cycle. For accurately measure productiveness at the population level, fish growth and condition are, thus, vital factors.

Fluctuations in environmental factors such as water temperature may affect fish growth by affecting fish behaviour and metabolism as well as food availability. Also the growth performance index for males and females *P. ticto* was 1.80 and 2.16 respectively and longevity was 2.6 for males and 2.30 year for females.

During the study the total mortality for *P. ticto* was 2.67 and 7.14 $year^{-1}$ for male and female populations respectively, in the Gorai River southwestern Bangladesh. Also, it was found that both natural mortality and fishing mortality was higher in females than males. Estimated exploitation rate and maximum exploitation rate was near similar for male *P. ticto*, but exploitation rate can be increased as 8% for female population of this species in the Gorai River ecosystem.

This is the first study on these above aspects and due to lack of available literature; it was not possible to compare with the present findings. The results of this present study may provide baseline for further study and would be helpful for sustainable management and conservation of *P. ticto* in the Gorai River and surrounding ecosystem.

# SUMMARY AND CONCLUSION

The small indigenous species *Puntius ticto (*Hamilton, 1822) now it is *Pethia ticto*, is a fresh- and brackish-water fish of the family Cyprinidae. It is commonly used as food fish and aquarium fish in Bangladesh and other Asian countries. The objectives of this study is to describes the length-weight relationships (LWRs), condition factors (Fulton′s, $K_F$), pre-predator relationships (based on relative weight, $W_R$), reproductive biology, growth parameters and stock assessment of the threatened fish *P. ticto* (Hamilton, 1822) from the Gorai River, southwestern Bangladesh. A sum of 1200 individuals of *P. ticto* was sampled during July 2010 to June 2011 using different types of traditional fishing gears including- cast net, square lift net and conical trap.

A total of 1200 (male = 454, female = 746) individuals of *P. ticto* were sampled during the study. The results showed that the total length (TL) was ranged from 2.77-7.48 cm for male and 2.66-8.00 cm for female. The body weight (BW) ranged from 0.42-6.6 g for male and 0.23-8.94 for female *P. ticto*. For LWRs, the allometric coefficient (*b*) of males indicated positive allometric growth in the month of August to September and December to June ($b > 3.0$), isometric growth was found in the month of July ($b = 3.0$), but negative allometric growth in October to December ($b < 3.0$). In addition, females indicated positive allometric growth in all the months ($b > 3.0$). However there was no significant differences in the overall intercepts (F = 0.461, df = 1197, $P = 0.498$) and slopes (F = 0.659, df = 1196, $P$ = 0.417) between the sexes of *P. ticto* in the Gorai River. The $K_F$ for the male of two-spot barb ranged from 1.14±0.10 in November to 1.64±0.25 in March. In case of female, $K_F$ varied from 1.18±0.10 in November to 1.66±0.27 in March. Nonetheless, the Mann-Whitney *U*-test showed no significant differences in the $K_F$ between males and females ($P = 0.809$).

The minimum and maximum values of $W_R$ were 62.03 and 149.36 in the month of January for male populations of *P. ticto*. Also, the minimum and maximum values of $W_R$ were 66.76 and 1760.25 in the month of January for female of *P. ticto* in the Gorai River. According to Shapiro-Wilk normality test the $W_R$ for male and female populations of *P. ticto* did not pass the normality ($P < 0.001$). Wilcoxon signed rank test indicate the mean $W_R$ was not significantly different from 100 for male ($P = 0.208$) and female ($P = 0.626$) population of *P. ticto* in the Gorai River.

The lowest value of gonadal weight was 0.001 in January and 0.04 in June and July for male *P. ticto*. On the other hand for female *P. ticto* the lowest value of gonadal weight was in January as 0.005 g and highest value was in June as 2.42 g.

The GSI of male smaller than 4.0 cm TL was low (<0.4). Most of the females with >4.5 cm TL recorded calculated GSI of > 1.5. The highest recorded GSI in male *P. ticto* was 2.08 in June 2010. The GSI rose sharply at around 4.2 cm TL. High GSI (>0.5) was only recorded in males with TL >4.2 cm TL. Therefore, the size at first sexual maturity was considered to be 4.2 cm TL and individuals with a ≥0.5% could be roughly defined as mature male *P. ticto* in the Gorai River, southern Bangladesh. Spearman′s rank correlation test showed a significant correlation between GSI and TL for males larger than 4.2 cm TL ($r_s$=-0.285, $P <$ 0.001). The GSI of female smaller than 4.2 cm TL was low (<1.8). Most of the females with >5.0 cm TL recorded calculated GSI of > 6.0. The highest recorded GSI in female *P. ticto* was 9.4 in June 2010. The GSI rose sharply at around 4.7 cm TL. Higher GSI (>2.0) was only recorded in females with TL >4.7 cm TL. Therefore, the size at first sexual maturity was considered to be 4.7 cm TL and individuals with a ≥2.0% could be roughly defined as mature female *P. ticto* in the Gorai River, southern Bangladesh. Spearman′s rank correlation test showed a significant correlation between GSI and TL for females larger than 4.7 cm TL ($r_s$=-0.365, $P < 0.001$). Also on the basis of maximum length the first sexual maturity was 4.8 cm in TL (95% CL=3.9-4.9) for male and 5.1 cm in TL (95% CL=4.2-6.3) for female *P. ticto* in the Gorai River, southwestern Bangladesh. GSI values were low (< 0.5) during the October 2010 to March 2011 for male fishes. In addition, the lower values of GSI (<2.0%) for female *P. ticto* was in October 2010 to March 2011. However, the higher GSI (>0.50% for males >2.0% for females) were found during the month of April to September, which indicated the spawning season for *P. ticto* in the Gorai River. In addition, peak values of GSI were found in the month of June-July, which was the peak spawning season for this species. When temperature increases above $30^{o}$ C then the spawning season start and it continues to September. There is a significant correlation between temperature and GSI (spearman rank correlation test, $r_s$=0.823, $P$=0.002 for male and $r_s$ =0.774, $P$=0.004 for female). In the study, it was found that when rainfall starts the *P. ticto* also begins their spawning period (from April to September). There is significant correlation exists with rainfall and GSI (spearman rank correlation test, $r_s$=0.840, $P$=0.001 for male and $r_s$ =0.840, $P$ = 0.002 for female). A total of 104 mature females were collected. The lowest fecundity was 2021 and highest fecundity was

8623 with mean value of 4600±2037. Analysis of regression showed that there was a significant relationship between the total length and fecundity ($r^2 = 0.962$, $P < 0.001$). Also, there was a significant relationship between the fecundity and body ($r^2 = 0.970$, $P < 0.001$).

Length-frequency distribution of male *P. ticto* shows that, the populations were first recruited in the month of September and for female the populations were first recruited on the month of August. The observed maximum TL was 7.48 cm and the predicted maximum TL was 10.26 cm for male *P. ticto* and the observed maximum TL was 8.00 cm and the predicted maximum TL was 10.55 cm for female populations of *P. ticto* in the Gorai River ecosystem. The curve revealed no seasonal oscillation in growth. The calculated growth performance index for males and females *P. ticto* was 1.80 and 2.16 respectively. That means growth performance was higher in females than males. Furthermore, the longevity was 2.6 year for males and 2.30 year for females.

The length converted catch curve analysis estimated the instantaneous rate of total mortality $Z$ = 2.67 year$^{-1}$ for males and 7.14 year$^{-1}$ for females. The calculated values of the instantaneous rates of natural mortality were $M$ = 1.66 year$^{-1}$ for males and 2.74 year$^{-1}$ for females. Thus, the fishing mortality ($F$) was recorded as 2.01 year$^{-1}$ and 4.40 year$^{-1}$ for males and females respectively. From the estimates of the instantaneous of fishing and total mortalities, the exploitation rate was calculated as $E$ = 0.58 or 58% for male and 0.62 or % for female.

The present study provides the complete description on length-weight relationships, condition factors, pre-predator relationships, reproductive biology, growth parameters and stock assessment of the threatened fish *P. ticto* from the Gorai River, southwestern Bangladesh. The findings of this study would be an effective tool for fishery managers, fish biologists and conservationists to initiate early management strategies and regulations for the sustainable conservation of the remaining stocks of this species in the Gorai River and contiguous ecosystems.

# REFERENCES


Abowei, J. F. N., Davis, O. A., Eli, A. A., 2009: Study of the Length-Weight Relationship and Condition Factor of Five Fish Species from Nkoro River, Niger Delta, Nigeria. *Journal of Biological Sciences*, **1:** 94-98.

Agboola, J. I., Anetekhai, M. A., 2008: Length-weight relationships of some fresh and brackish water fishes in Badagry creeck, Nigeria. *Journal of Applied Ichthyology*, **24:** 623-625.

Aguirre, H., Amezcua F., Madria-Vera, J., Soto C., 2008: Length-weight relationship for 21 fish species from a coastal lagoon in the siouthwestern Gulf of California. *Journal of Applied Ichthyology*, **24:** 91-92.

Ahmed, M., Capistrano, A. D., Hossain, M., 1997: Experience of partnership models for the co-management of Bangladesh fisheries. *Fisheries Management and Ecology*, **4:** 233-248.

Ahmed, S. A. S., Bart, A. N., Yi, Y., Rakocy, J. E., Diana, J. S., 2010: The effect of the introduction of Nile Tilapia (*Orechromis niloticus*, L.) on small indigenous fish species (mola, *Amblypharyngodon mola*, Hamilton; chela, *Chela cachius*, Hamilton; punti, *Puntius sophore*, Hamilton). *Aquqculture Research*, **41:** 904-912.

Ahmed, Z. F., Hossain, M. Y., Ohtomi, J., 2012: Condition, length-weight and length-length relationships of the silver hatchet Chela, *Chela cachius* (Hamilton, 1822) in the old Brahmaputra River of Bangladesh. *Journal of Freshwater Ecology*, **27:**123-130.

Alam, M. F., Thomson, K. J., 2001: Current constraints and future possibilities for Bangladesh fisheries. *Food policy,* **26:** 297-313.

Alim, M. A., Wahab, M. A., Milstein, A., 2004: Effects of Adding Different Proportions of the Small Fish Punti (*Puntius sophore*) and Mola (*Amblypharyngodon mola*) to a Polyculture of Large Carp. *Aquaculture Research,* **35:** 124–133.

Amin, A. K. M. R., Parvez, I., Zaman, M. B., Amin, H. A., 2009: Study of the Present Status of Endangered Small Indigenous Species (SI) of Fish in the Natural Waters of the North-West Part of *Bangladesh. Journal of Environmental Science & Natural Resources,* **2:** 163-168.

Angelescu, V., Gneri, F. S., Nani, A., 1958: La merluza del mar argentine (biologia e taxonomia). Secr. Mar. Serv. Hidrog. Nav. Publico, H1004: pp. 1–224.

Archarya, P., Iftekhar, M. B., 2000: Freshwater Ichthyofauna of Maharashtra State. p. 136-144. In: Ponniah, A.G.; Gopalakrishnan, A., (eds.). Endemic Fish Diversity of Western Ghats. NBFGR-NATP Publication. National Bureau of Fish Genetic Resources, Lucknow, U.P., India. **1**, pp. 347.

Bagenal, T. B., Tesch, F. W., 1978: Age and growth. In Methods for Assessment of Fish Production in Fresh Waters, 3rd ed., edited by T. Bagenal. IBP Handbook No.3, Blackwell Science Publications, Oxford. pp. 101-136.

Balasundaram, C., Arumugam, R., Murugan, P. B., 2000: Fish diversity of Kolli hills, Western Ghats, Salem district, Tamil Nadu. Zoos' Print Journal, **16:** 403-406.

Banik, S., Saha, S., 2012: *Puntius ticto* (Hamilton, 1822) of Tripura, India: reproductive physiology and biology. *Journal of Environment*, **1:** 136-141.

Binohlan, C., Froese, R., 2009: Empirical equations for estimating maximum length from length at first maturity. *Journal of Applied Ichthyology*, **25:** 611-613.

Birecikligil, S., Çiçek, E., 2011: Length-weight relationships for 16 freshwater fishes caught in tributaries of Euphrates and Orontes rivers in Gaziantep (southeastern Anatolia, Turkey). *Journal of Applied Ichthyology*, **27:** 1131–1132.

Bisht, R. S., Das, S. M., 1981: Observations on aquatic insects as food of fishes and the predatory action of some aquatic insects on fish and fish food. *Journal of Inland Fisheries Society India*, 13: 80-86.

Bister, T. J., Willis, D. W., Brown, M. L., Jordan, S. M., Neumann, R. M., Quist, M. C., Guy, C. S., 2000: Proposed standard weight (*Ws*) equations and standard length categories for 18 warm-water nongame and riverine fih species. *North American Journal of Fisheries Management*, **20:** 570-574.

Bobori, D. C., Moutopoulos, D. K., Bekri, M., Salvarina, I., Munoz, A. I. P., 2010: Length-weight relationships of freshwater fish species caught in three Greek lakes. *Journal of Biological Research*, **14:** 219-224.

Carlander, K. D., 1969: Handbook of freshwater fishery biology, vol.1. The Iowa State University Press, Ames, IA, pp. 752.

Chandrashekhariah, H. N., Rahman, M. F., Raghavan, S. L., 2000: Status of fish fauna in Karnataka. p. 98-135. In: Endemic fish diversity of Western Ghats. edited by Ponniah, A. G., Gopalakrishnan, A. NBFGR-NATP Publication. National Bureau of Fish Genetic Resources, Lucknow, U.P., India.

Chondar, S. L., 1977: Fecundity and its role in racial studies of *Gudusia chapra* (Pisces: Clupeidae). *The Proceedings of the Indian Academy of Sciences,* **86:** 245-254.

Craig, J. F., Halls, A. S., Barr, J. J. F., Bean. C. W., 2004: The Bangladesh floodplain fisheries. *Fisheries Research*, **66:** 271-286.

Dahanukar, N., 2010: *Puntius ticto.* The IUCN Red List of Threatened Species. Version 2014.1. <www.iucnredlist. org>. Downloaded on 11 Jamuary 2016.

Davis, M. W., 2000: Key principles for understanding fish bycatch and discard mortality. *Canadian journal of Fisheries and Aquatic Sciences,* **59:** 1834-1843.

Didenko, A.V., Bonar, S. A., Matter, W. J., 2004: Standard weight (Ws) equations for four rare desert fishes. *North American Journal of Fisheries Management,* **24:** 697-703.

DoF (Department of Fisheries)., 2015: National Fish Week Compendium 2015. Department of Fisheries, Bangladesh, p. 130.

Dulčić, J., Glamuzina, B., 2006: Length–weight relationships for selected fish species from three eastern Adriatic estuarine systems (Croatia). *Journal of Applied Ichthyology*, **22:** 254-256.

Esmaeili, H. R., Ebrahimi, M., 2006: Length–weight relationships of some freshwater fishes of Iran. *Journal of Applied Ichthyology,* **22:** 328-329.

Froese, R., 2006: Cube law, condition factor and weight length relationship: history meta-analysis and recommendations. *Journal Applied Ichthyology,* **22:** 241-253.

Froese, R., Pauly, D. (Eds.)., 2015: Fishbase 2015. World Wide Web electronic publication. Available at:http://www.fishbase.org; (accessed on 26 December 2015).

Gandotra, V., Singhal, A., Bedi, P., 2009: "Identifying Security Requirements Hybrid Technique", Fourth International Conference on Software Engineering Advances (ICSEA'09), Portugal, pp. 407-412.

Gayanilo, F. C., Pauly, D., 1997: FAO-ICLARM fish stock assessment (FiSAT) reference manual. FAO Computerized Information Series (Fisheries*)*, **8:**2.

Ghailen, H., Hattour, A., Allaya, H., Jarboui, O., Boouain, A., 2011: Some biological parameters of the little tuna *Thynnus alletteratus* (Rafinesque, 1810) in Tunisian waters. *Cahiers de Biologie Marine,* **52:** 33-40.

Gulland, J. A., 1965: Estimation of mortality rates. In: Annex to Arctic Fisheries Working Group Report ICES C.M./1965/D:3 (Mimeo) (Reprinted as In: Cushing, P.H. (Ed). Key Papers on Fish Populations. IRL Press, Oxford, pp. 231–241.

Gupta, B. K., Sarkar, U. K., Bhardwaj, S. K., Pa. A., 2011: Condition factor, length-weight and length-length relationships of an endangered fish *Ompok* *pabda* (Hamilton 1822) (Siluriformes: Siluridae) from the River Gomti, a tributary of the River Ganga, India. *Journal of Applied Ichthyology,* **27:** 962-964.

Halls, A. S., 2005: The use of sluice gates for stock enhancement and diversification of livelihoods (R8210). Fisheries Assessment Report. MRAG, London, p. 75 (Available at: http:// www.fmsp.org.uk/Documents/r8210/r8210_3.pdf).

Halls, A. S., Hoggarth, D. D., Debnath, D., 1999: Impacts of hydraulic engineering on the dynamics and production potential of flood plain fish populations in Bangladesh. *Fisheries Management and Ecology,* **6:** 261–285.

Haniffa, M. A., Nagarajan, M., Gopalakrishnan, A., 2006: Length-weight relationships of *Channa punctata* (Bloch, 1793) from Western Ghats rivers of Tamil Nadu. *Journal of Applied Ichthyology*, **22:** 308-309.

Heydarnejad, M. S., 2009: Length-weight relationships for six freshwater fish species in Iran. *Chinese Journal of Oceanology and Limnology*, **27:** 61-62.

Hile, R., 1936: *Age and growth of the cisco, Leucichthys artedi (Le Sueur), in the lakes of the northeastern highlands, Wisconsin*. US Government Printing Office.

Hinckley, S., Hermann, A. J., Mier, K. L., Megrey, B. A., 2001: Importance of spawning location and timing to successful transport to nursery areas: a simulation study of Gulf of Alaska walleye pollock. *ICES Journal of Marine Science: Journal du Conseil*, **58:** 1042-1052.

Holden, M. J., Raitt, D. F. S., 1974: Manual of fiheries science part 2: methods of resource investiatin and applicatin. *FAO Fish Technical Paper 115 Rev,* **1:** 1–214.

Hossain, M. Y., 2010a: Length-Weight, Length-Length Relationships and Condition Factors of Three Schibid Catfishes from the Padma River, Northwestern Bangladesh. *Asian Fisheries Science*, **23:** 329-339.

Hossain, M. Y., 2010b: Morphometric Relationships of Length-Weight and Length-Length of Four Cyprinid Small Indigenous Fish Species from the Padma River (NW Bangladesh). *Turkish Journal of Fisheries and Aquatic Sciences*, **10:** 131-134.

Hossain, M. Y., Ahmed, Z. F., Islam, A. B. M. S., Jasmine, S., Ohtomi, J., 2010: Gonadosomatic index-based size at first sexual maturity and fecundity indices of the Indian River shad *Gudusia chapra* (Clupeidae) in the Ganges River (NW Bangladesh). *Journal of Applied Ichthyology,* **26:** 550-553.

Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Islam, A. K. M. R., Jasmine, S., Oscoz, J., Miranda, R., Ohtomi, J., 2006b: Length-weight and length-length relationships of some small indigenous fish species from the Mathabhanga River, southwestern Bangladesh. *Journal of Applied Ichthyology,* **22:** 301-303.

Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Jasmine, S., Oscoz, J., Miranda, R., Ohtomi, J., 2006a: Condition, length–weight and length–length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes:

Bagridae) in the Mathabhanga River, southwestern Bangladesh. *Journal of Applied Ichthyology*, **22:** 304–307.

Hossain, M. Y., Jasmine, S., Ibrahim, A. H. M., Ahmed, Z. F., Rahman, M. M., Ohtomi, J., 2009a: Length–weight and length–length relationships of 10 small fish species from the Ganges, Bangladesh. *Journal of Applied Ichthyology*, **25:** 117–119.

Hossain, M. Y., Jewel, M. A. S., Nahar, L., Rahman M. M., Naif, A., Ohtomi, J., 2012a: Gonadosomatic index-based size at first sexual maturity of the catfish *Eutropiichthys vacha* (Hamilton, 1822) in the Ganges River, North-western Bangladesh. *Journal of Applied Ichthyology*, **28:** 601–605.

Hossain, M. Y., Khatun, M. M., Jasmine, S., Rahman, M. M., Jahan, S., Jewel, M. A. S., Ohtomi, J., 2013: Life-history Traits of the Threatened Freshwater Fish *Cirrhinus reba* (Hamilton 1822) (Cypriniformes: Cyprinidae) in the Ganges River, Northwestern Bangladesh. *Sains Malaysiana*, **42:** 1219–1229.

Hossain, M. Y., Leunda, P. M., Ohtomi, J., Ahmed, Z. F., Oscoz, J., Miranda, R., 2008: Biological aspects of the Ganges River sprat *Corica soborna* (Clupeidae) in the Mathabhanga River (SW Bangladesh). *Cybium*, **32:** 241-246.

Hossain, M. Y., Ohtomi, J., 2010: Growth of the southern rough shrimp *Trachysalambria curvirostris* (Penaeidae) in Kagoshima Bay, southern Japan. *Journal of Crustacean Biology*, **30:** 75-82.

Hossain, M. Y., Ohtomi, J., Ahmed, J., Jasmine, S., Vadas, R. L., 2012e: Life-history traits of the Monsoon River prawn *Macrobrachium malcolmsonii* (Milne-Edwards, 1844) (Palaemonidae) in the Ganges (Padma) River, northwestern Bangladesh. *Journal of Freshwater Ecology*, **27:** 131-142.

Hossain, M. Y., Ohtomi, J., Ahmed, Z. F., 2009b: Morphometric, Meristic Characteristics and Conservation of the Threatened Fish, *Puntius sarana* (Hamilton, 1822) (Cyprinidae) in the Ganges River, Northwestern Bangladesh. *Turkish Journal of Fisheries and Aquatic Sciences*, **9:** 223-225.

Hossain, M. Y., Ohtomi, J., Ahmed, Z. F., Ibrahim, A. H. M. and Jasmine, S., 2009c: Length-Weight and Morphometric Relationships of the Tank Goby *Glossogobius giuris* (Hamilton, 1822) (Perciformes: Gobiidae) in the Ganges of Northwestern Bangladesh. *Asian Fisheries Science*, **22:** 961-969.

Hossain, M. Y., Rahman, M. M., Abdallah, E. M., 2012d: Relationships between body size, weight, condition and fecundity of the threatened fish *Puntius ticto* (Hamilton, 1822) in the Ganges River, Northwestern Bangladesh. *Sains Malaysiana*, **41:** 803-814.

Hossain, M. Y., Rahman, M. M., Ahamed, F., Ahmed, Z. F., Ohtomi, J., 2014: Length-weight and length-length relationships and form factor of three threatened fishes from the Ganges River (NW Bangladesh). *Journal of Applied Ichthyology*, **30:** 221–224.

Hossain, M. Y., Rahman, M. M., Fulanda, B., Jewel, M. A. S., Ahmed, F., Ohtomi, J., 2012b: Length-Weight and Length-length Relationships of five threatened fish species from the Jamuna (Brahmaputra River tributary) River, Northern Bangladesh. *Journal of Applied Ichthyology*, **28:** 275-277.

Hossain, M. Y., Rahman, M. M., Jewel, M. A. S., Ahmed, Z. F., Ahamed, F., Fulanda, B., Abdallah, E. M., Ohtomi, J., 2012f: Conditions- and Form-Factor of the Five Threatened Fishes from the Jamuna (Brahmaputra River Distributary) River, Northern Bangladesh. *Sains Malaysiana*, **41:** 671–678.

Hossain, M. Y., Rahman, M. M., Miranda, R., Leunda, P. M., Oscoz, J., Jewel, M. A. S., Naif, A., Ohtomi, J., 2012c: Size at first sexual maturity, fecundity, length–weight and length–length relationships of *Puntius sophore* (Cyprinidae) in Bangladeshi waters. *Journal of Applied Ichthyology*, **28:** 818-822.

Hossain, M. Y., Sayed, S. R. M., Rahman, M. M., Ali, M. M., Hossen, M. A., Elgorban, A. M., Ahmed, Z. F., Ohtomi, J., 2015: Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. *Journal of Applied Ichthyology*, **31:** 967–969.

Hussain M. G., Mazid, M. A., 2001: Genetic improvement and conservation of carp species in Bangladesh. Bangladesh Fisheries Research Institute and International Center for Living Aquatic resource Management, 74pp.

Iqbal, K. M., Suzuki, H., 2009: Length–weight relationships and condition factor of the Japanese silver-biddy, *Gerres equulus*, in the Yatsushiro Sea, western Kyushu, Japan. *Journal of Applied Ichthyology*, **25:** 219–222.

IUCN Bangladesh., 2000: Red Book of Threatened Fishes of Bangladesh. In: Mahmud-ul Ameen, Md. Anwarul Islam and Ainum Nishat (eds) The World Conservation Union, xi, 116.

IUCN Sri Lanka., 2000: The 1999 list of threatened fauna and flora of Sri Lanka. Colombo: IUCN Sri Lanka. 114 pp.

Jan, M., Jan, U., Shah, G. M., 2014: Studies on fecundity and gonadosomatic index of *Schizothorax plagiostomus* (Cypriniformes: Cyprinidae). *Journal of Threatened Taxa*, **6:** 5375–5379

Jobling, M., 2008: Environmental factors and rates of development and growth. In: Handbook of fish biology and fisheries, Vol. 1: Fish Biology. P. J. Hart, J. D. Reynolds (Eds). Blackwell Publishing Ltd, Oxford, pp. 97–122.

Khallaf, E., Galal, M., Athuman, M., 2003: The biology of *Oreochromis niloticus* in a polluted canal. *Ecotoxicology,* **12**:405-416.

Khan, H. A., Jhingran, V. G., 1975: FAO fisheries synopsis, FAO Rome, No. 3: p. 100.

Khan, M. A., Khan, S., Miyan, K., 2011: Length-weight relationship of giant snakehead, Channa marulius and stinging catfish, *Heteropneustes fossilis* from the River Ganga, India. *Journal of Applied Ichthyology*, doi: 10.111 /j.1439- 0426.2011.01901.x.

Kibria, G., Ahmed, K. K. U., 2005: Diversity of selective and nonselective fishing gear and their impact on inland fisheries in Bangladesh. NAGA, **28:**43-48.

King, M., 2007: Fisheries Biology, Assessment and Management. 2nd edition, Oxford Press, London, 382 pp.

King, R.P., 1996: Length-weight relationships and related statistics of 73 populations of fish occurring in inland waters of Nigeria. *Naga ICLARM Q*, **19:** 49-52.

Kohler, C. C., Kelly, A. M., 1991: Assessing predator-prey balance in impoundments. In Proceedings of the Warmwater Fisheries Symposium I. pp. 257-260.

Kottelat, M. , 1985: Fresh-water fishes of Kampuchea. *Hydrobiologia*, **121:** 249-279.

Lagler, K. F., 1956: Enumeration of fish eggs. *In Freshwater Fishery Biology*, edited by (2nd ed.) W.M.C. Brown Co. Dubque. pp. 106-110.

Le Cren, E. D., 1951: The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *The Journal of Animal Ecology*, pp. 201-219.

Lucifora, L. O., Valero, J. L., Garcia, V. B., 1999: Length at maturity of the green-eye spurdog shark, *Squalus mitsukuii* (Elasmobranchii: Squalidae) from the SW Atlantic, with comparisons with other regions. *Marine and Freshwater Research*, **50:** 629-632.

Mac Gregoer, J. S., 1959: Relation between fish condition and population size in the sardine (*Sardinops cacrulea*). *U.S. Fishery Wild Service*, *Fish Bulletin*, **60:**215-230.

Manorama, M., Ramanujam, S. N., 2011: Length-weight relationship of freshwater fish, *Puntius shalynius* Yazdani and Talukdar (Cypriniformes: Cyprinidae), in Meghalaya, India. *Journal of Applied Ichthyology*, doi: 10.111 1/j.1439-0426.20 1 1.01785.x.

Marshall, C.T., O'Brian, L., Tomkiewiez, J., Koster, F. W., Kraus, G., Markinsdotti, G., Morgan, M. J., Saborido-ray, F., Blanchard, J. L., Secor, D. H., Wright, P. J., Mukhina, N. V., Bjornsson, H., 2003: Developing alternatie indices of reproductie potentil for use in fiheries management, case studies for stocks spawning, an information gradient. *Journal of Northwest Atlantic Fisheries Society,* **33:**161–190.

Martin, W. R., 1949: The machanics of environmental control of body form in fishes. Univ. Toronto. *Study of Biology*, **58:** 1-91.

Mazlan, A. G., Chung, Y. S., Zaidi, C. C., Samat, A., Arshad, A., Seah, Y. G., Alam, G. M., Simon, K. D., 2012: Meristic, Morphometrics and Length-weight Relationship of Tropical Silverside, *Atherinomorus duodecimalis* (Valenciennes in Cuvier and Valenciennes, 1835) in Seagrass and Mangrove Habitats of Tinggi Island, Johor, Malaysia. *Asian Journal of Animal and Veterinary Advances,* **7:** 921-927.

Mbaru, E. K., Mlewa, C. M., Kimani, E. N., 2010: Length–weight relationship of 39 selected reef fishes in the Kenyan coastal artisanal fishery. *Fisheries Res*earch, **106:** 567-569.

Metin, G., Llkyaz, A. T., Kinacigil, H. T., 2006: Length-weight relationships of poor cod (*Trisopterus minutus* Linnaeus, 1758) in the Central Aegean Sea. *Journal of Applied Ichthyology,* **22:** 288-289.

Mijkherjee, M., Praharaj, A., Das, S., 2002: Conservation of endangered fish stocks through artificial propagation and larval rearing technique in West Bengal, India. *Aquaculture Asia,* **7:** 8-11.

Morales, D. A., 1991: *La Tilapia en Mexico. Biologia, Cultioy Pesquerias.* A G Editor S.A., 190pp.

Morey, G., Moranta, J., MassutI, E., Grau, A., Linde, M., Riera, F., Morales-Nm, B., 2003: Weight-length relationships of littoral to lower slope fishes from the western Mediterranean. *Fisheries Research*, **62:** 89-96.

Muralidharan, M., Arunachalam, M., Raja, M., 2011: Length-weight relationships for fish species from Cauvery River at Hogenakal in South India. *Journal of Applied Ichthyology*, **27:** 968-969.

Mustafa, M. G., de Graf, G., 2008: Population parameters of important species in inland fisheries of Bangladesh. *Asian Fisheries Sciences*, **21:**147-158.

Nikolskii, G. V., 1969: Theory of Fish Population Dynamics as the Biological Background for Rational Exploitation and Management of Fishery Resources. Edinburgh: Oliver & Boyd.

NRC., 1998a: Improving Fish Stock Assessments. National Research Council. National Academy Press. Washington, D.C. 177 p.

NRC., 1998b: Review of Northeast Fishery Stock Assessments. National Research Council. National Academy Press. Washington, D.C. 128 p.

Ohtomi, J., Tashiro, T., Atsuchi, S., Kohno, N., 2003: Comparison of spatiotemporal patterns in reproduction of the kuruma prawn *Marsupenaeus japonicus* between two regions having different geographical conditions in Kyushu, southern Japan. *Fisheries Science*, **69:**501-519.

Pauly, D., 1980: On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour 1 Exploration de la mer*, **39:** 175-192.

Pauly, D., 1983: Some simple methods for the assessment of tropical fish stocks. *FAO Fisheries Technical Papers*, **234:** 52.

Pauly, D., David, N., 1981: ELEFAN I, a BASIC program for the objective extraction of growth parameters from length-frequency data. *Meeresforschung*, **28:** 205-211.

Pauly, D., Munro, J. L., 1984: Once more on the comparison of growth in fish and invertebrates. *Fishbyte*, **2:** 21.

Pethiyagoda, R., 1991: Freshwater fishes of Sri Lanka. The Wildlife Heritage Trust of Sri Lanka, Colombo. 362 p.

Pethiyagoda, R., Meegaskumbura, M., Maduwage, K., 2012: A synopsis of the South Asian fishes referred to *Puntius* (Pisces: Cyprinidae). *Ichthyological Exploration of Freshwaters*, **23:** 69-95.

Porath, M. T., Peters, E. J., 1997: Use of walleye relative weights (*Wr*) to assess prey availability. *North American Journal of Fisheries Management*, **17:** 628-637.

Qasim, S. Z., Qayyum, A., 1963: Fecundities of some freshwater fish. Proceedings of the *National Institute of Sciences of India*, **29:** 373-382.

Rahman, A. K. A., 1989: Freshwater fishes of Bangladesh. Zoological Society of Bangladesh. Department of Zoology, University of Dhaka, Dhaka-1000, pp. 364.

Rahman, M. M., Hossain, M. Y., Hossain, M. A., Ahamed, F., Ohtomi, J., 2012: Sex ratio, Length-frequency distributions and morphometric relationships of length-length and length-weight for spiny eel, *Macrognathus aculeatus* in the Ganges River, NW Bangladesh. *World Journal of Zoology,* **7:** 338-346.

Richter, T. J., 2007: Development and evaluation of standard weight equations for bridge-lip suckers and large-scale suckers. *North American Journal of Fisheries Management,* **27:** 936-939.

Riedel, R., Caskey, L. M., Hurlbert, S. H., 2007: Length weight relations and growth rates of dominant fishes of the Salton Sea: implications for predation by fish-eating birds. *Lake and Reservoir Management,* **23:**528-535.

Ross, N., Islam, M., Thilsted, S. H., 2003: Small indigenous fish species in Bangladesh: contribution to vitamin A, calcium and iron intakes. *Journal of Nutrition,* **1333:** 402 1-4026.

Rypel, A. L., Richter, T. J., 2008: Empirical percentile standard weight equation for the blacktail redhorse. *North American Journal of Fisheries Management*, **28:** 1843-1846.

Salam, A., Naeem, M., Kauser, S., 2005: Weight Length and Condition Factor Relationship of a Fresh Water Wild *Puntius chola* from Islamabad, Pakistan. *Pakistan Journal of Biological Sciences*, **8:** 1112-1114.

Sani, R., Gupta, B. K., Sarkar, U. K., Pandey, A., Dubey, V. K., Singh Lakra, W., 2010: Length–weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary) rivers. *Journal of Applied Ichthyology*, **26:** 456-459.

Santic, M., Pallaoro, A., Jardas, I., 2006: Co-variation of gonadosomatic index and parameters of length—weight relationships of Mediterranean horse mackerel, *Trachurus mediterraneus* (Steindachner, 1868), in the eastern Adriatic Sea. *Journal of Applied Ichthyology*, **22:** 214-217.

Santos, J. M., Reino, L., Porto, M., Oliveira, J., Pinheiro, P., Almeida, P. R., Ferreira, M. T., 2011: Complex size-dependent habitat associations in potamodromous fish species. *Aquatic sciences*, **73:** 233-245.

Sarkar, U. K., Gupta, B. K., Lakra, W. S., 2010: Biodiversity, ecohydrology, threat status and conservation priority of the freshwater fishes of river Gomti, a tributary of river Ganga (India). *Environmentalist*, **30:** 3–17.

Shulman, M. J., Ogden, J. C., 1987: Hot controls tropical reef-fish population: recruitment or benthic mortality? An example in the Caribbean reef fish Haemulon flabolineatum. Mar. Ecol. Prog Ser, 39:233-242.

Sokal, R. R., Rohlf, F. J., 1987: Introduction to Biostatistics. 2$^{nd}$ ed. New York: Freeman Publication.

Solomon, S., Ramprasanth, M. R., Baby, F., Pereira, B., Tharian, J., Ali, A., Raghavan, R., 2011: Reproductive biology of *Puntius denisonil*, an endemic and threatened aquarium fish of the Western Ghats and its implications for conservation. *Journal of Threatened Taxa*, 3: 2071-2077.

Soomro, A. N., Baloch, W. A., Jafri, S. I. H., Suzuki, H., 2007: Studies on length-weight and length-length relationships of a catfish *Eutropiichthyes vacha* Hamilton (Schilbeidae: Siluriformes) from Indus river, Sindh, Pakistan. *Caspian Journal of Environmental Science*, **5:** 143-145.

Soriano, M., Moreau, J., Hoenig, J. M., Pauly, D., 1992: New functions for the analysis of two-phase growth of juvenile and adult fishes, with application to Nile perch. *Transactions of the American Fisheries Society*, **121:** 486-493.

Talwar, P. K., Jhingran, A. G., 1991: Inland Fishes of India and Adjacent Countries, vol. **2**. A. A. Balkema, Rotterdam, pp. 541.

Tareque, A. M. H. B., Biswas, B., Hossain, M. S., Rahman, M. M., Rahman, M. M., 2009: Some Aspects of Biology of *Puntius sophore* (Hamilton) Collected from the Mouri River, Khulna, Bangladesh. *Bangladesh Research Publication Journal*, **2:** 406-422.

Taylor, C. C., 1958: Cod growth and temperature. J. Cons. Int. Explor. Mer., **23:** 366-370.

Templeman, W., 1987: Differences in sexual maturity and related characteristics between populations of thorny skate (*Raja radiate*) from the northwest Atlantic. Journal of *Northwest Atlantic Fisheries Science*, **7:** 155-167.

Tesch, F. W., 1971: Age and growth. In methods for assessment of fish production in fresh waters, edited by Ricker, W.E. Oxford: Blackwell Scientific Publications.

Thilsted, S. H., Ross, N., Hasan. N., 1997: The role of small indigenous fish species in food and nutrition security in Bangladesh, NAGA News letter, Jul.-Dec., pp. 13.

Tracey, S. R., Lyle, J., Haddon, M., 2007: Reproductive biology and per-recruit analyses of striped trumpeter (*Latris lineata*) from Tasmania, Australia: Implications for management. *Fisheries Research*, **84**: 358-368.

Villif, A., Jorgensen, L. B., 1993: Analysis of Naeringgsstoffet l, in An Environmental Monitoring System for GOLDA Project: CARE (Cooperative for Assistance and Relief Everywhere) – Bangladesh Interim Report.

von Bertalanffy, L., 1938: A quantitative theory of organic growth (inquiries on growth laws. II). *Human Biology*, **10:** 181-213.

Wambiji, N., Ohtomi, J., Fulanda, B., Kimani, E., Kulundu, N., Hossain, M. Y., 2008: Morphometric Relationship and Condition Factor of *Siganus stellatus*, *S. canaliculatus and S. sutor* (Pisces: Siganidae) from the Western Indian Ocean Waters. *South Pacific Studies*, **29:** 1-15.

Weatherley, A. H., Gill, H. S., 1987: Growth increases produced by bovine growth hormone in grass pickerel, *Esox americanus* vermiculatus (Le Sueur), and the underlying dynamics of muscle fiber growth. *Aquaculture*, **65:** 55-66.

Wetherall, J. A., 1986: A new method for estimating growth and mortality parameters from length-frequency data. *Fishbyte,* **4:**12-15.

Wilding, T., Young, K., Pitkethley, R., 2000: Bay of Plenty Freshwater Fish Calendar. In: Environmental Report 00/26. Environment Bay of Plenty, Whakatane.

Xue, Y., Ren, Y., Xu, B., Mei, C., Chen, X., Zan, X., 2011: Length–weight relationships of fish species caught by bottom trawl in Jiaozhou Bay, China. *Journal of Applied Ichthyology*, **27:** 949-954.

Yeldan, H., Avsar, D., 2000: A preliminary study on the reproduction of the rabbit fish *Siganus rivulatus* (Forsskal, 1775) in northeastern Mediterranean. *Turkish Journal of Zoology*, **24:** 173-182.

Yilmaz, S., Yazicio1u, O., Yilmaz, M., Polat, N., 2010: Length-Weight and Length-Length Relationships of *Capoeta sieboldii* from Hirfanli Dam Lake, Turkey. *Journal of Freshwater Ecology*, **25***:* 205-209.

Yousaf, M., Salarn, A., Naeem, M., 2009: Length-weight relationships of *Wallago attu* and *Sperata sarwari* from the Indus River, southern Punjab, Pakistan. *Journal of Applied Ichthyology*, **25:** 614-615.