

Length-length relationship, length-weight relationship and condition factor of freshwater fish species of Bangladesh

¹M. Manjurul Alam, ¹S. Nusrat Jahan, ¹M. Afzal Hussain, ²Moumita De, ³M. P. Goutham-Bharathi, ⁴A. L. Barroso Magalhães, ⁵A. Ghaffar Mazlan, ^{2,5}K. Das Simon

¹ Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Bangladesh; ² School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, D. E., Malaysia; ³ Fisheries Science Division, Central Agricultural Research Institute, Port Blair-744101, Andaman & Nicobar Islands, India; ⁴ Grupo de Estudos sobre Organismos Invasores, Instituto Pró-Endêmicas, Belo Horizonte, Minas Gerais, Brazil; ⁵ Marine Ecosystem Research Centre, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor D. E., Malaysia. Corresponding author: K. D. Simon, skdas_maa@yahoo.com / simon@ukm.my

Abstract. The objectives of this study were to describe the length-length relationship (LLR), length-weight relationship (LWR) and condition factor of four important freshwater fish species *Esomus danricus*, *Amblypharyngodon mola*, *Pethia ticto* and *Glossogobius giuris*, collected from different fish market of Gomastapur subdistrict, Chapai Nawabganj, Bangladesh from December 2009 to November 2010. Relationship equations among different body length parameters of each species were found highly significant ($p < 0.01$). LWRs were obtained as $TW = 0.008 TL^{3.01}$, $0.025 TL^{3.03}$, $0.043 TL^{2.93}$ and $0.021 TL^{2.91}$ for *E. danricus*, *A. mola*, *P. ticto* and *G. giuris* respectively. The study period was divided into three major seasons summer (March to June), rainy (July to October) and winter (November to February) for studying the growth and condition of the specimens. The values of the Fulton's and relative condition factors indicated apparent growth variation in different seasons. All the species showed maximum robustness in summer and rainy seasons. The information obtained from this study will be helpful for the fishery managers to implement adequate adaption-centric regulations for sustainable fishery management in the water bodies of Gomastapur as well as the other parts of the country.

Key Words: *Amblypharyngodon mola*, biometric relationship, conservation, *Pethia ticto*, small indigenous fish.

Introduction. Morphometric measurements and statistical relationships of fishes are imperative for both fishery biology (Sparre et al 1989; Mustafa & Brooks 2008) and taxonomy studies (Tandon et al 1993; Simon et al 2010a). Length-weight relationship is an important tool in fish biology, physiology, ecology, fisheries assessment and fish conservation. These studies are used as a tool for fish conservation in several parts of the world providing information on the condition, growth pattern, ontogenic changes and in fish population dynamics (Oscoz et al 2005; Simon et al 2009). Length-weight relationship is also useful for the conversion of growth-in-length equations to growth-in-weight for use in stock assessment models and to estimate stock biomass from limited sample sizes (Binohlan & Pauly 1998; Koutrakis & Tsikliras 2003; Valle et al 2003; Ecoutin et al 2005; Özaydin & Taskavak 2007; Simon & Mazlan 2008; Simon et al 2009; Ndome et al 2012).

The inland fishery of Bangladesh covers about 4.5 million hectares and is considered as the most important aquatic resource base of the country. Economically, more than 90% of the rural community depends on fisheries for their livelihood (Mustafa & Brooks 2008). There are 260 recorded indigenous freshwater bony fish species within

55 families and 145 genera living in and around the wetlands of Bangladesh (Doha 1974; Craig et al 2004; Alam et al 2013; Moumita et al 2011; Flowra et al 2013; Noor 2013). The Indian flying barb *Esomus danricus*, the mola carplet *Amblypharyngodon mola*, the ticto barb *Pethia ticto* all belonging to Cyprinidae and the tank goby *Glossogobius giuris* (Gobiidae) are some of the top commercially important freshwater indigenous fish species found in the country.

Small indigenous fishes are important target species for the small-scale fishermen of Bangladesh, who deploy a variety of traditional gears (Craig et al 2004; Kibria & Ahmed 2005; Hossain et al 2006; Mustafa & Brooks 2008) and these fishes serve as a major source of protein and vitamin A for the local rural community (Rubbi et al 1978; Islam 2004). Vitamins and minerals are found to be much more in small fish than in large fish. For example, *E. danricus*, *A. mola* and *Pethia* species are richer in vitamin A, iron and calcium than large cyprinid species (Gupta & Rai 2011). However, conservation status of some of these fish species is vulnerable (IUCN 2000) indicating the significance of implementing an adequate adaptation-centric regulations for sustainable fishery management of small indigenous fishes in Bangladesh (Mustafa & Brooks 2008). While this could be attributable to numerous reasons, inadequate knowledge with respect to length-length relationship, length-weight relationship and condition factors of small indigenous fishes of Bangladesh might be one of the significant factors of overexploitation of these fish species notwithstanding their conservation status. This paucity of information propelled the current study which aimed at studying the length-weight relationship, length-length relationship and condition factor as tools to conserve these four indigenous fishes (*E. danricus*, *A. mola*, *P. ticto* and *G. giuris*) from a probable depletion of their wild stocks in the future.

Material and Method

Field sampling. Fish samples were collected from different fish markets of Gomastapur (24° 46' 30" N, 88° 17' 0" E) sub-district, Chapai Nawabganj, Bangladesh (Figure 1) from December 2009 to November 2010 at a scheduled interval of one week. During collection, precautions were taken to save the specimens from spoilage or any damage. Specimens (n = 384, 96 of each species) were immediately preserved with ice and fixed with 5% formalin solution upon arrival in the laboratory. Moreover, some voucher specimens were placed for museum collection at the Ichthyology laboratory of Rajshahi University, Bangladesh.

Different lengths were measured with a precision of 0.01 cm (Simon et al 2010a, b) with the help of measuring board fitted with a scale. Weight of the fish was taken with the help of electronic precision balance Model: KD-300KC to an accuracy of 0.1 g (Simon et al 2008; Simon et al 2012).

Length-length relationships. The length-length relationship with total length among different body lengths were determined by the method of least squares to fit a simple linear regression model as $Y = a + bX$, where Y = various body lengths, X = total length, a = proportionality constant and b = regression coefficient (Alam et al 2012).

Length-weight relationships. Length-weight relationship was determined by fitting the data to a potential relationship based on the exponential equation (Le Cren 1951) in the form of $TW = aTL^b$ where, TW is the total weight (expressed in g), TL is the total length (expressed in cm), a is a coefficient related to body form and b is an exponent indicating isometric growth when equal to 3 and indicating allometric growth when significantly different from 3 (Simon & Mazlan 2008; Simon et al 2009).

The parameters 'a' and 'b' of the exponential curve were estimated by linear regression analysis over log-transformed data expressed as: $\log TW = \log a + b \log TL$. The values of the constant 'a' and 'b' of the linear regression was determined by following Rounsefell & Everhart (1953) and Lagler (1966).

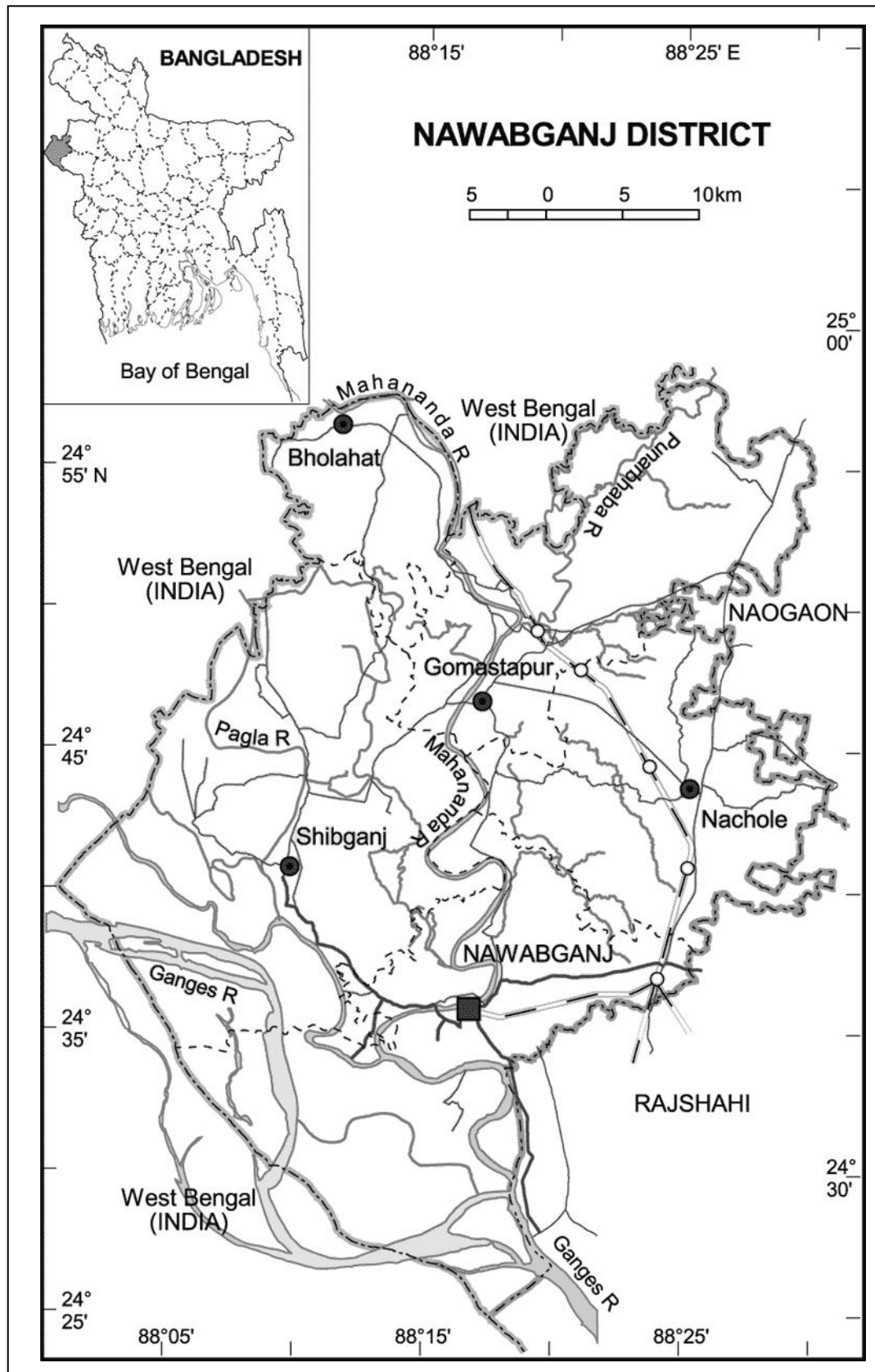


Figure 1. Map showing sampling area in Gomastapur sub-district, Chapai Nawabganj, Bangladesh.

Condition factors. Fulton's condition factor, K was calculated by using the formula, $K = (TW/TL^3) \times 100$ whereas, the relative condition factor was calculated by $K_n = TW/aTL^b$ (Le

Cren 1951; Simon et al 2013). The parameters 'a' and 'b', of the length-weight relationship which have been used in the calculation of condition factors K_n were varied in different seasons. All sorts of statistical analysis were calculated by using SPSS Version 15.0 software (SPSS Inc. 2004; Simon et al 2011).

Results

Length-length relationships. The length-length relationships with total length (TL) among different body lengths of the specimens such as standard length (SL), dorsal length (DL), pelvic length (PvL), anal length (AnL), pectoral length (PL) and head length (HL) and the coefficient of correlation for *E. danricus*, *A. mola*, *P. ticto* and *G. giuris* are shown in Table 1.

Table 1
Length-length relationships with total length among different body lengths of four freshwater fish species collected from different fish markets of Gomastapur, Chapai Nawabganj, Bangladesh

| Species | Relationship parameters | Mean \pm SE (cm) | Regression equation | Coefficient of correlation 'r' | Percentage with TL |
|---|-------------------------|--------------------|---------------------------|--------------------------------|--------------------|
| Esomus danricus TL \pm SE = 6.30 \pm 0.03 cm n = 96 | SL | 5.04 \pm 0.03 | SL = - 0.795 + 0.9266TL | 0.967** | 80.00 |
| | DL | 3.35 \pm 0.02 | DL = - 0.9377 + 0.6798TL | 0.946** | 53.17 |
| | PvL | 2.58 \pm 0.02 | PvL = -1.3284 + 0.6195TL | 0.920** | 40.95 |
| | AnL | 3.75 \pm 0.02 | AnL = -1.4196 + 0.8209TL | 0.910** | 59.52 |
| | PL | 1.13 \pm 0.01 | PL = - 0.394 + 0.2421TL | 0.785** | 17.94 |
| | HL | 1.02 \pm 0.01 | HL = - 0.457 + 0.235TL | 0.821** | 16.19 |
| Amblypharyngodon mola TL \pm SE = 6.44 \pm 0.14 cm n = 96 | SL | 5.12 \pm 0.11 | SL = - 0.795 + 0.9266TL | 0.997** | 79.50 |
| | DL | 2.58 \pm 0.06 | DL = - 0.9377 + 0.6798TL | 0.921** | 40.06 |
| | PvL | 2.46 \pm 0.06 | PvL = -1.3284 + 0.6195TL | 0.975** | 38.20 |
| | AnL | 3.39 \pm 0.08 | AnL = -1.4196 + 0.8209TL | 0.978** | 52.64 |
| | PL | 1.17 \pm 0.02 | PL = - 0.394 + 0.2421TL | 0.955** | 18.17 |
| | HL | 1.30 \pm 0.03 | HL = - 0.457 + 0.235TL | 0.955** | 20.19 |
| Pethia ticto TL \pm SE = 6.26 \pm 0.08 cm n = 96 | SL | 4.88 \pm 0.06 | SL = - 0.1162 + 0.7981TL | 0.959** | 77.96 |
| | DL | 2.35 \pm 0.03 | DL = 0.4452 + 0.3052TL | 0.905** | 37.54 |
| | PvL | 2.29 \pm 0.03 | PvL = 0.0878 + 0.3518TL | 0.942** | 36.58 |
| | AnL | 3.43 \pm 0.05 | AnL = - 0.234 + 0.5863TL | 0.952** | 54.79 |
| | PL | 1.19 \pm 0.01 | PL = 0.2413 + 0.1514TL | 0.877** | 19.01 |
| | HL | 1.28 \pm 0.01 | HL = 0.3323 + 0.1519TL | 0.879** | 20.45 |
| Glossogobius giuris TL \pm SE = 6.82 \pm 0.10 cm n = 96 | SL | 5.39 \pm 0.08 | SL = 0.2756 + 0.7504TL | 0.978** | 79.03 |
| | DL | 2.03 \pm 0.03 | DL = 0.0207 + 0.2952TL | 0.933** | 29.77 |
| | PvL | 1.77 \pm 0.03 | PvL = - 0.3056 + 0.3038TL | 0.950** | 25.95 |
| | AnL | 3.21 \pm 0.05 | AnL = 0.2154 + 0.439TL | 0.900** | 47.07 |
| | PL | 1.64 \pm 0.03 | PL = - 0.194 + 0.2685TL | 0.934** | 24.05 |
| | HL | 1.53 \pm 0.03 | HL = - 0.287 + 0.2657TL | 0.930** | 22.43 |

** Correlation is significant at the 0.01 level.

The regression equations are found highly significant with "r" values ranged from 0.785 to 0.967 for *E. danricus*, 0.921 to 0.997 for *A. mola*, 0.877 to 0.952 for *P. ticto* and 0.900 to 0.978 for *G. giuris*. The interrelationships among the length parameters are also found highly significant ($p < 0.01$) with all "r" values being > 0.711 for *E. danricus*, > 0.910 for *A. mola*, > 0.824 for *P. ticto* and > 0.904 for *G. giuris* (Table 2).

Table 2

Correlation matrix (values of r) of different body length of four freshwater fish species collected from different fish markets of Gomastapur, Chapai Nawabganj, Bangladesh ($p < 0.01$)

| Species | TL | SL | DL | PvL | AnL | PL | HL |
|------------------------------|-----|---------|---------|---------|---------|---------|---------|
| <i>Esomus danricus</i> | TL | 1.000 | | | | | |
| | SL | 0.967** | 1.000 | | | | |
| | DL | 0.946** | 0.946** | 1.000 | | | |
| | PvL | 0.920** | 0.905** | 0.905** | 1.000 | | |
| | AnL | 0.910** | 0.942** | 0.924** | 0.883** | 1.000 | |
| | PL | 0.785** | 0.787** | 0.749** | 0.711** | 0.714** | 1.000 |
| | HL | 0.821** | 0.821** | 0.801** | 0.730** | 0.767** | 0.934** |
| <i>Amblypharyngodon mola</i> | TL | 1.000 | | | | | |
| | SL | 0.997** | 1.000 | | | | |
| | DL | 0.921** | 0.925** | 1.000 | | | |
| | PvL | 0.975** | 0.976** | 0.923** | 1.000 | | |
| | AnL | 0.978** | 0.975** | 0.910** | 0.969** | 1.000 | |
| | PL | 0.955** | 0.962** | 0.913** | 0.950** | 0.946** | 1.000 |
| | HL | 0.955** | 0.961** | 0.919** | 0.946** | 0.948** | 0.980** |
| <i>Pethia ticto</i> | TL | 1.000 | | | | | |
| | SL | 0.978** | 1.000 | | | | |
| | DL | 0.933** | 0.927** | 1.000 | | | |
| | PvL | 0.950** | 0.937** | 0.943** | 1.000 | | |
| | AnL | 0.900** | 0.907** | 0.848** | 0.842** | 1.000 | |
| | PL | 0.934** | 0.915** | 0.935** | 0.988** | 0.829** | 1.000 |
| | HL | 0.930** | 0.914** | 0.919** | 0.954** | 0.824** | 0.954** |
| <i>Glossogobius giuris</i> | TL | 1.000 | | | | | |
| | SL | 0.990** | 1.000 | | | | |
| | DL | 0.968** | 0.967** | 1.000 | | | |
| | PvL | 0.976** | 0.965** | 0.940** | 1.000 | | |
| | AnL | 0.956** | 0.965** | 0.954** | 0.927** | 1.000 | |
| | PL | 0.969** | 0.957** | 0.929** | 0.989** | 0.919** | 1.000 |
| | HL | 0.945** | 0.941** | 0.925** | 0.950** | 0.904** | 0.952** |

** Correlation is significant at the 0.01 level.

Length-weight relationships. Characteristics of parameters 'a' and 'b' of the LWR relationship, 95% confidence limit of 'b', correlation of coefficient (r) and growth types are presented in the Table 3 and LWRs are illustrated in Figure 2. LWR indicated positive allometric growth for *E. danricus*, *A. mola* and *G. giuris* ($TW = 0.008 TL^{3.01}$, $0.025 TL^{3.03}$,

0.021 TL^{2.91} respectively), while *P. ticto* exhibited negative allometric growth (0.043 TL^{2.93}). The correlation of coefficient value for both the categories indicated that the relationship is statistically significant and the equation of LWR is applicable for the total population of each species. The correlation of coefficient value for both the categories indicated that the relationship is statistically significant and the equation of LWR is applicable for the total population of each species.

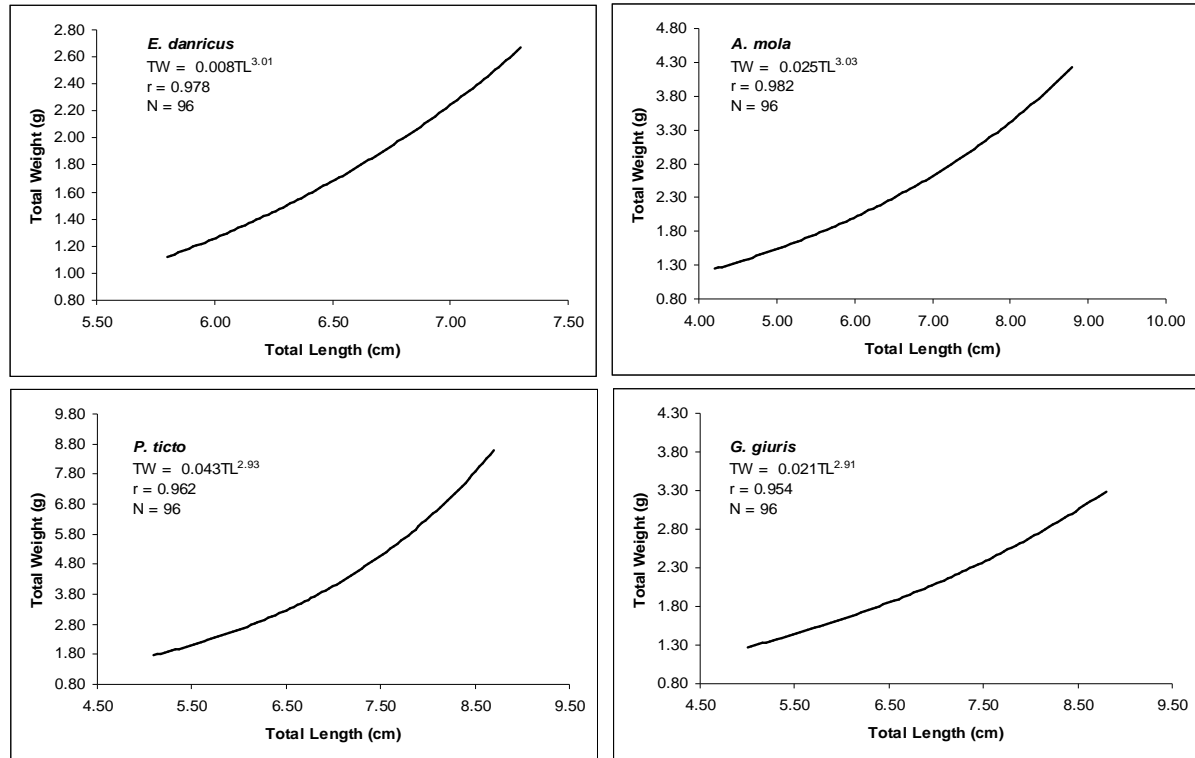


Figure 2. Length-weight relationships of four freshwater fish species collected from different fish markets of Gomastapur, Chapai Nawabganj, Bangladesh.

Table 3
Descriptive statistics and species wise changes in parameters of the growth curves based on $W = aL^b$ plotting one year data

| Species | Total length characteristics | | Total weight characteristics | | Parameters of the relationship | | | | Growth type |
|--------------------|------------------------------|--------------|------------------------------|-------------|--------------------------------|------|--------------------|-------|----------------|
| | Range (cm) | Mean±SE (cm) | Range (g) | Mean±SE (g) | a | b | bCL _{95%} | r | |
| <i>E. danricus</i> | 5.80-7.30 | 6.30±0.03 | 1.06-2.15 | 1.52±0.02 | 0.008 | 3.01 | 2.92-3.15 | 0.978 | A ⁺ |
| <i>A. mola</i> | 4.20-8.80 | 6.44±0.14 | 1.05-4.50 | 2.44±0.09 | 0.025 | 3.03 | 2.67-3.05 | 0.982 | A ⁺ |
| <i>P. ticto</i> | 5.10-8.70 | 6.26±0.07 | 1.40-8.66 | 3.19±0.15 | 0.043 | 2.93 | 2.66-2.89 | 0.962 | A ⁻ |
| <i>G. giuris</i> | 5.50-8.80 | 6.82±0.10 | 1.16-3.91 | 2.11±0.07 | 0.021 | 2.91 | 2.65-3.01 | 0.954 | A ⁺ |

Note: a, proportionality constant; b, slope of the relationship; CL, confidence limits; r, correlation of coefficient; A⁺, positive allometric growth; A⁻, negative allometric growth.

Condition factors. Fulton's condition factor (K) showed positive growth for *A. mola* and *P. ticto* in summer expressing the cube law whereas *E. danricus* and *G. giuris* showed negative growth. In case of relative condition factor all the species showed positive growth in summer excluding the *P. ticto*. In rainy season only *A. mola* showed positive growth but the rest three species showed negative growth according to Fulton's condition factor. But the relative condition factor was positive for all specimens indicating the proper growth in rainy season. During winter the Fulton's condition factors were negative for all specimens where *E. danricus* and *A. mola* showed positive growth; and *P. ticto* and *G. giuris* showed negative growth according to relative condition factor (Figure 3).

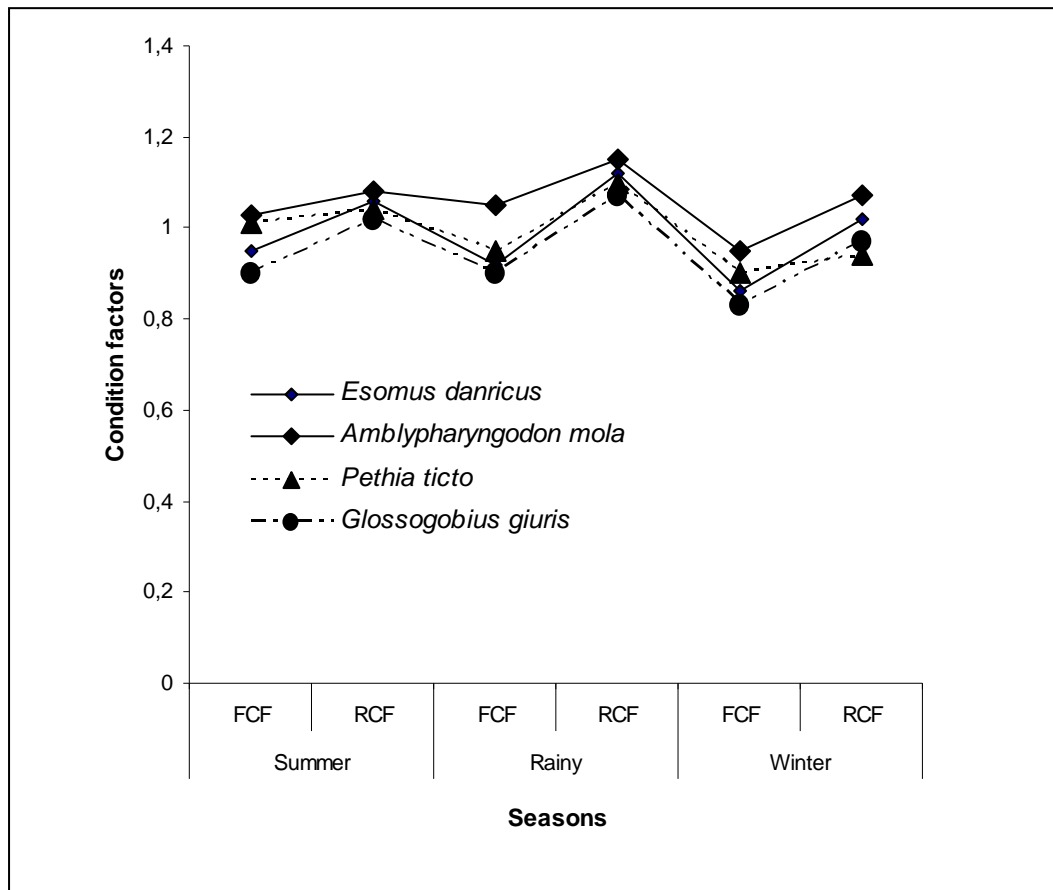


Figure 3. Seasonal variation in Fulton's condition factors (FCF) and relative condition factors (RCF) of four freshwater fish species collected from different fish markets of Gomastapur, Chapai Nawabganj, Bangladesh.

Discussion. The regression equation of LLRs are established for *E. danricus*, *A. mola*, *P. ticto* and *G. giuris* to assess the symmetrical growth in relation to body length *i.e.* relationships with TL among SL, DL, PL, PvL, AnL and HL. It was observed that the equations are highly significant with all 'r' values being > 0.785. The values of the equations clearly revealed that the lengths of the body parts are proportional to the total length which agreed with Tandon et al (1993). The interrelationships among aforementioned length parameters were also found highly significant ($p < 0.01$) with all 'r' values being > 0.711 from the multiple correlation analysis. The findings of the LLR analysis of this present work are similar to the findings of Hossain et al (2009a) for *A. mola*, *P. ticto* and *G. giuris* at Rajshahi district, Bangladesh.

The LWR in fishes is affected by a number of factors including habitat, diet, growth phase, season, degree of stomach fullness, gonad maturity, sex, size range, health and general fish condition and preservation techniques (Tesch 1971). The length-weight data were considered to establish the growth patterns of *E. danricus*, *A. mola*, *P. ticto* and *G. giuris*. The result indicated positive allometric growth for *E. danricus*, *A. mola* and *G. giuris*.

giuris whereas negative allometric growth for *P. ticto* that adequately adjusted to the exponential equation. Similar trends occurred with *A. mola* and *P. ticto* in Rajshahi district (Hossain et al 2009a), and *G. giuris* in lower part of the Ganges, Bangladesh (Hossain et al 2009b).

The 'b' values of the present analysis were found in between 2.92-3.15 for *E. danricus*, 2.67-3.05 for *A. mola*, 2.65-3.01 for *G. giuris* that very close to exact value 3 whereas the 'b' value for *P. ticto* ranged from 2.66-2.89. The values of 'b' were within the limits of 2.5-3.5 reported by Bhuiyan & Biswas (1982); Johal et al (1989); Hoque & Hossain (1992); Moutopoulos & Stergiou (2002); Kiran et al (2004); Oscoz et al (2005); Balart et al (2006); Cicek et al (2006); Esmaeili & Ebrahimi (2006); Froese (2006); Tarkan et al (2006); Britton & Davies (2007); Aguirre et al (2008); Arshad et al (2008); Ferreira et al (2008) for most fishes. Therefore, excluding the *P. ticto* all three species do follow the cube law. The reason behind may be the observed specimens were the inhabitants of quite good environment and gravid females were more in the samples (Le Cren 1951).

Fulton's (K) and relative (K_n) condition factors showed apparent growth variation in different season. However, during summer and rainy seasons the fishes showed maximum robustness due to availability of food and suitable environmental condition, which are in confirmatory with the findings of Bhuiyan & Biswas (1982) on *Puntius chola*, Mia (1984) on *Heteropneustes fossilis*, Afroze et al (1992) on *A. mola*, Hoque & Hossain (1992) on *Mystus vittatus*, Islam & Hossain (1992) on *P. stigma*, Alam et al (1994) on *Ailia coila*, Mir (1996) on *Barbus canis*, Iqbal et al (1995) on *Chanda ranga*, Mortuza & Mokarrama (2000) on *Botia lohachata*, Šantić et al (2006) on *Trachurus mediterraneus*, Dadzie et al (2008) on *Parastromateus niger*, Hossain et al (2012) on *P. ticto*, suggestive of disparities in morphometric characters among the same species due to ecological factors (Niimi & Morgan 1980). So, from the above morphometric studies more reliable characters have been come out to know the growth pattern of the specimens.

Conclusions. The outcome of the present study has provided some new and updated information on the morphometric characters of four indigenous fish species *E. danricus*, *A. mola*, *P. ticto* and *G. giuris* of Gomastapur sub-district, Chapai Nawabganj, Bangladesh. Though the fishes are small, they have very good consumer demand with relatively high nutritional value. Further, these fishes have the potentiality to grow in any type of freshwater bodies. Despite the great relevance of these small fishes as potent nutrient suppliers to the poor people of the country (Mustafa & De Graff 2008; Gupta & Rai 2011), their conservation status calls for precautionary management for maintaining their sustainability. Information derived from the present investigation may play an important role in management and conservation of these four important freshwater fish species, and the following suggestions may be considered for proper management of fisheries in the region of Gomastapur: 1) the system of allocating fishing rights to fishers of different seasons/areas and which may reduce the effects of competition; 2) reduce the number of seine nets and gill nets (mono filament) during peak fishing; 3) closed season should be strictly followed through active participation of community based organizations such as beel management committees or river management committees; 4) the Fish Act 1950 (Act No. XVIII, Section 3, Rule No.: 12, enacted 10 November 2011) should be strictly enforced through active participation of fishers; 5) educating and informing of the fishers; and 6) enhanced co-operation work with the IUCN Bangladesh (2000).

Acknowledgements. We would like to thank Claudiu Gavriloiu (Editor-in-Chief, AACL Bioflux) and the reviewers for their very useful comments. We appreciate the technicians of Ichthyology laboratory, University of Rajshahi Bangladesh for their continuous support throughout the study. We are grateful to Universiti Kebangsaan Malaysia for the financial support through Young Researcher Incentive Grant GGPM-2011-057.

References

- Afroze S., Hossain M. A., Parween S., 1992 Notes on the size frequency distribution and length-weight relationship of freshwater fish *Amblypharyngodon mola* (Hamilton) (Cypriniformes; Cyprinidae). University Journal of Zoology, Rajshahi University 10 & 11:103–104.
- Aguirre H., Amezcua F., Madrid-Vera J., Soto C., 2008 Length-weight relationship for 21 fish species from a coastal lagoon in the southwestern Gulf of California. Journal of Applied Ichthyology 24:91–92.
- Alam M. M., Galib S. M., Islam M. M., Flowra F. A., Hussain M. A., 2012 Morphometric study of the wild population of pool barb *Puntius sophore* (Hamilton, 1822) in the River Padma, Rajshahi, Bangladesh. Trends in Fisheries Research 1(2):10–13.
- Alam M. R., Mortuza M. G., Islam M. S., Hossain M. A., 1994 Notes on the size frequency distribution and length-weight relationship of the freshwater fish *Ailia coila* (Hamilton-Buchanan) (Siluriformes: Schilbeidae). University Journal of Zoology, Rajshahi University 13:69–70.
- Alam M. S., Hossain M. S., Monwar M. M., Hoque M. E., Taimur F. M., 2013 Check-list of bony fish collected from the Upper Halda River, Chittagong, Bangladesh. AACL Bioflux 6(4):333-338.
- Arshad A., Jimmy A., Nurul Amin S. M., Sidik B. J., Harah Z. M., 2008 Length-weight and length-length relationships of five fish species collected from seagrass beds of the Sungai Pulai estuary, Peninsular Malaysia. Journal of Applied Ichthyology 24:328–329.
- Balart E. F., González-Cabello A., Romero-Ponce R. C., Zayas-Alvarez A., Calderón-Parra M., Campos-Dávila L., Findley L. T., 2006 Length-weight relationships of cryptic reef fishes from the southwestern Gulf of California, México. Journal of Applied Ichthyology 22:316–318.
- Bhuiyan A. S., Biswas B., 1982 Studies on the morphometry of *Puntius chola* (Hamilton-Buchanan) (Cyprinidae: Cypriniformes). University Journal of Zoology, Rajshahi University 1:29–34.
- Binohlan C., Pauly D., 1998 The length-weight table. In: Concepts, design and data sources. Froese R., Pauly D. (eds), Fishbase. ICLARM, Manila, Philippines, 293 pp.
- Britton J. R., Davies G. D., 2007 Length-weight relationships of the invasive topmouth gudgeon (*Pseudorasbora parva*) in ten lakes in the UK. Journal of Applied Ichthyology 23:624–626.
- Cicek E., Avsar D., Yeldan H., Ozutok M., 2006 Length-weight relationships for 31 teleost fishes caught by bottom trawl net in the Babadillimani Bight (Northeastern Mediterranean). Journal of Applied Ichthyology 22:290–292.
- Craig J. F., Halls A. S., Barr J. J. F., Bean C. W., 2004 The Bangladesh floodplain fisheries. Fisheries Research 66:271–286.
- Dadzie S., Abou-Seedo F., Manyala J. O., 2008 Length-length relationship, length-weight relationship, gonadosomatic index, condition factor, size at maturity and fecundity of *Parastromateus niger* (Carangidae) in Kuwaiti waters. Journal of Applied Ichthyology 24:334–336.
- Doha S., 1974 Investigation into the biology of the gobi, *Glossogobius giuris* (Hamilton-Buchanan). Bangladesh Journal of Zoology 2:95–106.
- Ecoutin J. M., Albaret J. J., Trape S., 2005 Length-weight relationships for fish populations of a relatively undisturbed tropical estuary: The Gambia. Fisheries Research 72:347–351.
- Esmaeili H. R., Ebrahimi M., 2006 Length-weight relationships of some freshwater fishes of Iran. Journal of Applied Ichthyology 22:328–329.
- Ferreira S., Sousa R., Delgado J., Carvalho D., Chada T., 2008 Weight-length relationships for demersal fish species caught off the Madeira archipelago (Eastern-central Atlantic). Journal of Applied Ichthyology 24:93–95.
- Flowra F. A., Islam M. A., Jahan S. N., Hussain M. A., Alam M. M., Bashir F. A., Mazlan A. G., Simon K. D., 2013 Status and decline causes of fish diversity of Baral River, Natore, Bangladesh. AACL Bioflux 6(4):352-357.

- Froese R., 2006 Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology* 22:241–253.
- Gupta M. C., Rai S., 2011 Effect of dedhuwa (*Esomus danricus*), mara (*Amblypharyngodon mola*) and pothi (*Puntius sophore*) on carp production in Chitwan, Nepal. *Our Nature* 9:112–118.
- Hoque M. A., Hossain M. A., 1992 Length-weight relationship and condition factor of the cat fish *Mystus vittatus* (Bloch) (Cypriniformes: Bagridae). *University Journal of Zoology, Rajshahi University* 10 & 11:113–114.
- Hossain M. Y., Ahmed Z. F., Leunda P. M., Jasmine S., Oscoz J., Miranda R., Ohtomi J., 2006 Condition, length–weight and length–length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhangra 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., Ohtomi J., Ahmed Z. F., Ibrahim A. H. M., Jasmine S., 2009b 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., 2012 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(7):803–814.
- Iqbal M. S., Mortuza M. G., Parween S., Hossain M. A., 1996 Length weight relationship and condition factor of *Chanda nama* (Hamilton) and *Chanda ranga* (Hamilton). *Rajshahi University Stud. Part. B* 23:237–242.
- Islam M. N., 2004 Eco-biology of freshwater Gobi, *Glossogobius giuris* (Hamilton) of the river Padma in relation to its fishery: a review. *Journal of Biological Sciences* 4(6): 780–793.
- Islam M. S., Hossain M. A., 1992 Length-weight relationship and condition factor of common punti, *Puntius stigma* (Cuvier and Valenciennes) (Cypriniformes: Cyprinidae). *University Journal of Zoology, Rajshahi University* 10 & 11:109–110.
- IUCN, 2000 Red Book of Threatened Fishes of Bangladesh. (Eds.). IUCN-The World Conservation Union: 116.
- Johal M. S., Chahal J. S., Kingra J. S., Joir R. S., 1989 On the morphometry of *Colisa fasciata* from Punjab, India (Perciformes: Anabantidae). *Vestnik Ceskoslovenske Spolecnosti Zoologicke* 53:188–194.
- Kibria G., Ahmed K. U., 2005 Diversity of selective and nonselective fishing gear and their impact on inland fisheries in Bangladesh. *NAGA, WorldFish Center Newsletter*, 28:43–48.
- Kiran B. R., Puttaiah E. T., Harish Kumar K., 2004 Length-weight relationship of feather back, *Notopterus notopterus* (Pallas) from Jannapura pond, Karnataka, India. *Zoos' Print Journal* 19(4):1449–1450.
- Koutrakis E. T., Tsikliras A. C., 2003 Length–weight relationships of fishes from three northern Aegean estuarine systems (Greece). *Journal of Applied Ichthyology* 19: 258–260.
- Lagler K. F., 1966 *Freshwater fishery biology* (2nd edn.). Brown W. M. C. (ed), Co. Dubuque, Iowa, 421 pp.
- Le Cren E. D., 1951 The length-weight relationship and seasonal cycle in gonad weights and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology* 20:201–219.
- Mia G. K., 1984 Length-weight relationship and condition factor in the air-breathing catfish, *Heteropneustes fossilis* (Bloch). *Bangladesh Journal of Zoology* 12(1):49–52.
- Mir S., 1996 Length-weight relation of a carp, *Barbus canis* (Cuvier and Valenciennes). *Bangladesh Journal of Zoology* 24(1):89–90.
- Mortuza M. G., Mokarrama N. T., 2000 Notes on the length-weight relationship and condition factor of mud loach *Botia lohachata* (Chaudhuri) (Cypriniformes: Cobitidae). *University Journal of Zoology, Rajshahi University* 19:113–114.

- Moumita D., Hussain M. A., Alam M. M., Mazlan A. G., Simon K. D., 2011 Impact of Sariakandi fish pass on fisheries diversity of Bangali river, Bogra, Bangladesh. *AAFL Bioflux* 4(5):621-626.
- Moutopoulos D. K., Stergiou K. I., 2002 Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). *Journal of Applied Ichthyology* 18:200–203.
- Mustafa M. G., Brooks A. C., 2008 Status of fisheries resource and management approach in the open *Beels* of Bangladesh: a comparative case study. *Asian Fisheries Science* 21:189–203.
- Mustafa M. G., De Graff G., 2008 Population parameters of important species in inland fisheries of Bangladesh. *Asian Fisheries Sciences* 21:147–158.
- Ndome C. B., Eteng A. O., Ekanem A. P., 2012 Length-weight relationship and condition factor of the smoothmouth marine catfish (*Carlarius heudelotii*) in the gulf of Guinea, Niger delta, Nigeria. *AAFL Bioflux* 5(3):163-167.
- Niimi A. J., Morgan S. L., 1980 Morphometric examination of the gills of walleye, *Stizostedion vitreum vitreum* (Mitchill) and rainbow trout, *Salmo gairdneri* Richardson. *Journal of Fish Biology* 16:685–692.
- Noor S. M. A., 2013 Length-length and length-weight relationships of critically endangered striped cat fish *Rita rita* (Hamilton) from the Padda River near Rajshahi of Northwestern Bangladesh. *IOSR Journal of Pharmacy and Biological Sciences* 4(6):32–36.
- Oscoz J., Campos F., Escala M. C., 2005 Weight–length relationships of some fish species of the Iberian Peninsula. *Journal of Applied Ichthyology* 21:73–74.
- Özaydin O., Taskavak E., 2007 Length-weight relationships for 47 fish species from Izmir Bay (eastern Aegean Sea, Turkey). *Acta Adriatica* 47(2):211–216.
- Rounsefell G. A., Everhart W. H., 1953 *Fisheries science: its methods and application*. John Wiley and Sons, Inc., New York, 440 pp.
- Rubbi S. F., Muslemuddin M., Wahab M. A., 1978 The present status of fish technology and inspection in Bangladesh. *FAO/DANIDA Workshop of Fish Technology*, Colombo, Srilanka.
- Šantić 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.
- Simon K. D., Mazlan A. G., 2008 Length-weight and length-length relationships of archer and puffer fish species. *The Open Fish Science Journal* 1:19–22.
- Simon K. D., Mazlan A. G., Cob Z. C., Samat A., Arshad A., 2008 Age determination of archer fishes (*Toxotes jaculatrix* and *Toxotes chatareus*) inhabiting Malaysian estuaries. *Journal of Biological Sciences* 8(6):1096-1099.
- Simon K. D., Bakar Y., Samat A., Zaidi C. C., Aziz A., Mazlan A. G., 2009 Population growth, trophic level, and reproductive biology of two congeneric archer fishes (*Toxotes chatareus*, Hamilton 1822 and *Toxotes jaculatrix*, Pallas 1767) inhabiting Malaysian coastal waters. *Journal of Zhejiang University Science B* 10(12):902–911.
- Simon K. D., Mazlan A. G., Samat A., Zaidi C. C., Aziz A., 2010a Size, growth and age of two congeneric archer fishes (*Toxotes jaculatrix* Pallas, 1767 and *Toxotes chatareus* Hamilton, 1822) inhabiting Malaysian coastal waters. *Sains Malaysiana* 39(5):697–704.
- Simon K. D., Bakar Y., Temple S. E., Mazlan A. G., 2010b Morphometric and meristic variation in two congeneric archer fish species (*Toxotes chatareus*, Hamilton 1822 and *Toxotes jaculatrix*, Pallas 1767) inhabiting Malaysian coastal waters. *Journal of Zhejiang University Science B* 11(11):871–879.
- Simon K. D., Bakar Y., Temple S. E., Mazlan A. G., 2011 Spitting success and accuracy in archer fishes *Toxotes chatareus* (Hamilton, 1822) and *Toxotes jaculatrix* (Pallas 1767). *Scientific Research and Essays* 6(7):1627-1633.
- Simon K. D., Mazlan A. G., Bakar Y., Samat A., Zaidi C. C., Arshad A., Temple S. E., Brown-Peterson N. J., 2012 Aspects of the reproductive biology of two archer fishes *Toxotes chatareus*, (Hamilton 1822) and *Toxotes jaculatrix* (Pallas 1767). *Environmental Biology of Fishes* 93:491–503.

- Simon K. D., Mazlan A. G., Cob Z. C., 2013 Condition factors of two archerfish species from Johor coastal waters, Malaysia. *Sains Malaysiana* 42(8): 1115-1119.
- Sparre P., Ursin E., Venema S. C., 1989 Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper No. 306, Rome, 429 pp.
- SPSS Inc., 2004 SPSS. Version 15.0 [computer program]. SPSS Inc., Chicago.
- Tandon K. K., Johal M. S., Bala S., 1993 Morphometry of *Cirrhinus reba* (Hamilton) from Kanjli wetland, Punjab, India. *Research Bulletin of the Punjab University, Science* 43(1-4): 73-78.
- Tarkan A. S., Gaygusuz Ö., Acipinar H., Gürsoy Ç., Özulug M., 2006 Length-weight relationship of fishes from the Marmara region (NW-Turkey). *Journal of Applied Ichthyology* 22: 271-273.
- Tesch F. W., 1971 Age and growth. In: *Methods for assessment of fish production in freshwaters*. Ricker W. E. (ed), Oxford, Blackwell Scientific Publications, pp. 99-130.
- Valle C., Bayle J. T., Ramos A. A., 2003 Weight-length relationships for selected fish species of the western Mediterranean Sea. *Journal of Applied Ichthyology* 19: 261-262.

Received: 29 August 2013. Accepted: 10 September 2013. Published online: 14 September 2013.

Authors:

M. Manjurul Alam, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Bangladesh, e-mail: mamillat@yahoo.com

Syeda Nusrat Jahan, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Bangladesh, e-mail: jahan_ru@yahoo.com

M. Afzal Hussain, Department of Fisheries, Faculty of Agriculture, University of Rajshahi, Bangladesh, e-mail: afzalh_ru@yahoo.com

Moumita De, School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi Selangor D. E., Malaysia, e-mail: moumitadas_maa@yahoo.com

M. P. Goutham-Bharathi, Central Agricultural Research Institute, Port Blair-744101, Andaman & Nicobar Islands, India, e-mail: gouthamrussia@gmail.com

A. L. Barroso Magalhães, Grupo de Estudos sobre Organismos Invasores, Instituto Pró-Endêmicas, Belo Horizonte, Minas Gerais, Brazil, e-mail: andrebiomagalhaes@gmail.com

A. Ghaffar Mazlan, Marine Ecosystem Research Centre, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor D. E., Malaysia, e-mail: magfish05@yahoo.com

K. Das Simon, School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi Selangor D. E., Malaysia; Marine Ecosystem Research Centre, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, e-mail: skdas_maa@yahoo.com, simon@ukm.my

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Alam M. M., Jahan S. N., Hussain M. A., De M., Goutham-Bharathi M. P., Magalhães A. L. B., Mazlan A. G., Simon K. D., 2013 Length-length relationship, length-weight relationship and condition factor of freshwater fish species of Bangladesh. *AACL Bioflux* 6(5): 498-509.