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Article

Length-length relationship: an index of growth pattern for lesser spine eel *Macrognathus Aculeatus* (Bloch, 1786) in Bangladesh

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Abstract: The study was designed to work on the determination of growth pattern of lesser spiny eel *Macrognathus aculeatus* (Bloch, 1786) evaluating length-length relationships. Lesser spiny eel is a small indigenous fish species collected monthly for a year from Dingaputa haor located at Mohanganj upazila of Netrokona district in Bangladesh. The standard length and total length of male ranged from 93 to 203 mm and from 101 to 214 mm, respectively. The standard length and total length of female ranged from 105 to 243 mm and from 108 to 256 mm respectively. The length-length relationship is described algebraically in the form of y = a + bx, and growth pattern was inferred to the direct proportionality between two lengths. The present study established the relationships between standard length and total length for male, female and combined fish separately. The constants of linear relationship of male in all months varied (slope, 1.01-1.07; intercept, -0.58-9.63). The generalized relationship of male was TL = 1.03 SL + 6.25. The constants of linear relationship of female in all months varied (slope, 0.99-1.05; intercept, 2.59-12.09). The generalized relationship of female was TL = 1.03 SL + 5.826. The constants of linear relationship of combined sex in all months varied (slope, 0.95-1.05; intercept, 2.41-18.78). The generalized relationship of combined sex was TL = 1.02 SL + 7.49. Correlation coefficents, r (≥ 0.913) and coefficients of determination, r^2 (≥ 0.834) were high in all regression analyses in this study. Based upon r and r^2, present study explained that standard length and total length were strongly associated, and standard length was very good predictor of total length. The growth pattern were isometric in September, November, December, February, March and April and allometric in October, January, May, June, July and August based on SL-TL relationship for male population. The growth pattern were isometric in October, March, April, July and August and allometric in November, December, January, February, May, June and September based on SL-TL for female population. The growth pattern were isometric in April, June and August and allometric in September, October, November, December, January, February, March, May and July based on SL-TL for combined population. This study would be beneficial for future research in order to make comparison between years and locations.

Keywords: allometric; lesser spiny eel; population; wholesale market

1. Introduction

Bangladesh is situated in South-East Asia. It has world largest deltaic plain of large rivers flowing from the Himalayans and called land of rivers. In 2011-12 the total inland water production was 26,83,162 mt including natural fish production was 9,57,095 mt and inland closed water was 17,26,067 mt. Otherwise total marine production was 5,78,620 mt. The production from oxbow lake (baor), beel, floodplain, river and kaptai lake were comparatively 5,186 mt; 85,208 mt; 6,96,127 mt; 1,45,613 mt and 8,537 mt (DoF, 2013).

The statistics showed that inland water is the main source of fish production. But in recent year's inland fish production drastically reduced. The inland open water fish production were comparatively 11,23,925 mt; 10,29,937 mt; 10,54,585 mt and 9,57,095 mt in 2008-09, 2009-10, 2010-11 and 2011-12 session. This gives a clear idea about decreasing inland open water fish production in Bangladesh. Tsai and Ali (1985) studied on open-water carp fisheries management and recorded a decline in Padma, Brahmaputra and upper Meghna stocks of major carps. The main reason of such decline are construction of embankments, sedimentation and overfishing for Brahmaputra stock and Farakka barrage, embankments and overfishing for Padma stock, while for the Meghna stock overfishing was identified as the main cause. Inland capture fisheries in Bangladesh are declining due to the increasing human population and environmental changes. The situation has been further aggravated by pollution from agricultural, domestic and industrial wastes. On the other hand flood control and drainage (FCD) projects have severely reduced fish stocks by reducing wetland areas and by blocking fish migration and dispersal routes.

To overcome this situation efficient culture and management practices should be maintained for sustainable fish production. For this application various biological aspects of fish that influence growth is necessary.

The large numbers of small fish species are still available in both open and closed inland waters amongst them, the lesser spiny eel *Macrognathus aculeatus* locally known as Tara baim is one of the important ones (Figure 1). There are currently 23 recognized species in this genus (Froese and Pauly, 2013). This small fish is esteemed as a quality food containing high amount protein, carbohydrate, fat, calcium and vitamin. In spite of having enormous economic and nutritional importance of this fish species to the rural people and fishing community, no adequate studies on their population parameters have done in Bangladesh. The spiny eel, *M. aculeatus* is one of the common species among Mastacembeliformes. It is widely distributed in Bangladesh, China, India, Indonesia, Korea Rep., Laos, Malaysia, Nepal, Singapore, Taiwan, Thailand and Vietnam (Froese and Pauly, 2012).

The lesser spiny eel has an upper-body that is yellow, a black line down the middle and the lower body is usually a mix of white and brown. Along the backbone of the lesser spiny eel, the dorsal fin is preceded by numerous isolated small spines that can be raised giving them the name. The dorsal fin also has many prominent eyespots along the bare. There are many different variations of the spiny eel. They are 14 inches long (35 centimeters), but are usually smaller. The fish is found in Southeast Asia from locations such as Malaysia, Thailand, Borneo and Indonesia. They are found in lowland, ovetlands and peats (Froese and Pauly, 2007). The systematic formula of lesser spiny eel is xvii-xx/45-50.p1 23-24, A.iii/46-50 (Rahman, 2005). The lesser spiny eel breeds during monsoon season (Bhuiyan, 1964).

Fisheries biologists contribute to fisheries science in two main areas one, by studying the basic biology and distribution of resources species and second, by studying the fish population dynamics of the species. So fish population dynamics study is important for the sustainable fish production in open water bodies. Considering the immensely important aspects of biology *M. aculeatus* the present work was designed to study the preceding objectives collection the samples over a period of one year from September, 2012 to August, 2013 from the Dingaputa haor at Mohangonj Upazila in Netrakona district. Length-length relationships (LLRs) are important for comparative growth studies (Moutopoulos and Stergiou, 2002). LLR are still scare for most tropical and sub-tropical fish species (Martin-Smith, 1996). The length-length relationship and length-weight relationship have been applied for basic uses in order to make fish stocks assessment and populations (Ricker, 1975). In fish, size is generally more biologically relevant than age, mainly because several ecological and physiological factors are more size-dependent than age-dependent. Consequently, length-weight regressions have been used frequently to estimate weight from length because direct weight measurements can be time consuming in the field (Sinovcic *et al.*, 2004).

2. Materials and Methods

2.1. Study site

Fish samples of *Macrognathus aculeatus* were collected from its population of the Dingaputa haor at Mohangonj upazila in Netrakona district. The study area is located 30 km east from and approximately between the latitudes of 24˚52'00" N to 24.8667˚ N and between the longitudes of 90˚58'00" E to 90.9667˚ E in Netrakona district (Islam, 2013). Dingaputa haor is connected with the Kongso River which is the main water source. The water body is playing significant role of housing a number self recruiting indigenous fish species contributing to the total fish production in Bangladesh. Dingaputa hoar has immense ecological importance as a major feeding, nursing and breeding grounds of many fish species living in contiguous rivers, floodplains and perennial ponds.

2.2. Fish sampling

About 100 individuals of *M. aculeatus* were collected once in a month during a period of one year. Fishes were collected randomly with fine meshed seine nets. A special emphasis was undertaken to ensure all size groups of *M. aculeatus* population available in the sample of each month. The sample was preserved with ice immediately after catch to prevent decomposition in an insulated fish box. The fish was brought to fish population dynamics laboratory in Bangladesh Agricultural University, Mymensingh.

2.3. Sample preservation

Fish individuals in the sample were taken out from fish box, and were preserved in a plastic container with 10% buffered formalin at each sampling event. Finally the container was labeled with the date and place of collection until required data were recorded.

2.4. Recording of length data

Formalin in the container having fish individuals of a monthly sample was decanted to another large container where used formalin is preserved to treat chemically. Fish specimens were placed in a laboratory wash tray, which was left under a running tap for one hour at least to remove dirt, decomposed substance and formalin. Then fishes were kept on a rectangular iron sieve allow water to drip from the fish for a while. The water from body surface and in the buccal cavity was blotted by tissue paper. Finally the sample was kept in the room temperature for drying the remaining moisture to avoid biased weight of the fish individuals. The standard length (SL) was measured from the tip of the snout to the posterior end of the last caudal vertebra. The end of the ultimate vertebra was detected by a crease formed on caudal peduncle when tail region was bent a little upward. Total length (TL) of the fish was measured from the tip of the snout to the end of caudal fin. Standard length and total length were measured in the laboratory using centimeter scale fitted on a wooden structure to its nearest millimeter. The weight of whole body of an individual fish is called body weight (BW); it was recorded using an electronic balance in g. The data of standard length and body weight were imputed onto Microsoft excel spreadsheet.

2.5. Sex identification

The abdomen of each lesser spiny eel was incised with a scissor. Gonads were taken out by forceps carefully and kept in a petridis. Tissues and muscles remnants and other digestive parts and glands were cleaned from the pair of gonads. Finally, both left and right gonads were measured to the 0.001 g balance together and preserved in a small vial until further study. Fish was sexed into male and female by direct examination of the gonads with naked eyes.

2.6. Length-length relationship

2.6.1. Sample relationship

Length-length relationships are estimated by using following equation:

Y = a + bX

Here,

Y = Dependent variable

X= Independent variable

a = Intercept

b= Slope

Here, parameters '**a**' and '**b**' of the linear equation were obtained using the following formulas.

Slope,

$$b = \frac{[n\sum XY - \sum X \sum Y]}{[n\sum X^2 - (\sum X)^2]}$$

The intercept 'a' is estimated by:

Intercept,

$$a = \bar{Y} - b\bar{X}$$

Where,

$$\bar{X} = \frac{\sum X}{n} \qquad \bar{Y} = \frac{\sum Y}{n}$$

The degree of linear association between two variables is known as correlation coefficient and is expressed by r, the correlation coefficient is calculated as

$$r = \frac{[n\sum XY - \sum X \sum Y]}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}}$$

The coefficient of determination expressed as r^2 which suggests the proportion of variability in the Y observations that is occurred due to the variability in the X observations. Therefore, coefficient of determination is the squared value of the correlation coefficient value.

2.6.2. Population relationship

Calculation of confidence limit at 95% confidence level

The variance of independent variable, x

$$S_{X^2} = \frac{[n\sum X^2 - (\sum X)^2]}{[n(n-1)]}$$

The variance of independent variable, y

$$S_{y^2} = \frac{[n\sum Y^2 - (\sum Y)^2]}{[n(n-1)]}$$

For slope,

The variance of the slope is estimated as:

$$S_{b^2} = [1/(n-2)][(Sy^2/Sx^2) - b^2]$$

The standard deviation of the slope

$$S_b = \sqrt{[1/(n-2)]\left[\left(S_{y^2}/S_{x^2}\right) - b^2\right]}$$

The standard error of the slope

$$S_{e_b} = S_b/\sqrt{n}$$

The 95% confidence limit of the slope

$$b \pm S_{e_b} * t$$

Where 't' is the value from the t-table with (n-2) degree of freedom.

For intercept,

The variance of the intercept is estimated as:

$$S_{a^2} = S_{b^2}[(n-1)S_{x^2}/n + X^2]$$

The standard deviation of the intercept

$$S_a = \sqrt{\{S_{b^2}[(n-1)S_{x^2}/n + X^2]\}}$$

The standard error of the slope

$$S_{e_a} = S_a/\sqrt{n}$$

The 95% confidence limit of the intercept

$$a \pm S_{e_a} * t$$

Where 't' is the value from the t-table with (n-2) degree of freedom

2.7. Growth inference

Since growth of various linear dimensions of fish is proportional to each other, therefore, when the growth of standard length and total length of individuals of lesser spiny eel in a monthly sample are directly proportional, then the growth of that monthly sample is said to be isometric, if not the growth is termed as allometric. The confidence interval for the population intercept of the length-length relationship equation reveals the growth pattern of the population in that month. In this study if the confidence level of population intercept includes zero then the growth is regarded to be isometric.

3. Results

3.1. Fish size

The research work dealt with a total of 1159 lesser spiny eel individuals. Among them 634 were male and 525 were female. The standard length and total length of male ranged from 93 to 203 mm and 101 to 214 mm respectively. The standard length and total length of female ranged from 105 to 243 mm and 108 to 265 mm respectively.

3.2. Length-length relationship and growth pattern

Findings of the standard length and total length relationship and growth pattern of lesser spiny eel are described according to male, female and combined populations.

3.3. Male population

Relationship between standard length and total length of monthly samples showed variation in both constants of the linear equations, correlation coefficient and coefficient of determination. Results of analyses are given in Table 1. The range of intercept varied from -0.58 to 9.63. The lowest value of intercept 'a' was -0.58 found in April and the highest value of 'a' 9.63 found in October. The range of slope varied from 1.01 to 1.07. The minimum value of 'b' was 1.01 found in May, September and October and maximum value was 1.07 in April. The minimum and maximum correlation coefficients ranged from 0.942 to 0.995 and were found in February and June, July respectively. The minimum and maximum coefficient of determination estimated from 0.888 to 0.998. Very high correlation coefficient values (≥ 0.942) indicated strong association between the two variables in all monthly data. Linear equations of all monthly samples for male population revealed high values of coefficient of determination (≥ 0.888) which explained that standard length was a good predictor of total length in all months.

Table 1. Length-length (total length and standard length) relationship parameters of monthly samples for male (*Macrognathus aculeatus*).

Month	No of observation	Slope	Intercept	r^2	$\pm t*se_b$	$\pm t*se_a$
September	31	1.01	8.89	0.961	0.079	9.807
October	56	1.01	9.63	0.993	0.023	3.243
November	40	1.06	2.35	0.997	0.020	2.804
December	50	1.05	2.76	0.956	0.063	9.375
January	63	1.04	5.59	0.996	0.016	2.074
February	63	1.02	7.80	0.888	0.091	12.761
March	58	1.03	5.61	0.975	0.043	6.352
April	32	1.07	-0.58	0.933	0.106	14.896
May	68	1.01	9.44	0.968	0.044	6.383
June	64	1.03	5.16	0.998	0.010	1.613
July	58	1.04	4.73	0.998	0.013	1.721
August	51	1.03	4.77	0.995	0.019	2.824
Generalized	634	1.03	6.25	0.983	0.011	1.507

t=Value from t table; se_a = Standard error of intercept; se_b = Standard error of slope; SL = Standard length; TL = Total length

Table 2. Inference of growth pattern for monthly male populations of *Macrognathus aculeatus*.

Month	No of observation	Intercept	$\pm t*se_a$	Cl of a at 95% CL	Growth inference
September	31	8.89	9.807	-0.71-18.49	Isometric
October	56	9.63	3.243	6.31-12.94	Allometric
November	40	2.35	2.804	-0.45-5.16	Isometric
December	50	2.76	9.375	-6.86-12.37	Isometric
January	63	5.59	2.074	3.47-7.70	Allometric
February	63	7.80	12.761	-5.22-20.82	Isometric
March	58	5.61	6.352	-0.88-12.10	Isometric
April	32	-0.58	14.896	-15.64-14.48	Isometric
May	68	9.44	6.383	2.94-15.94	Allometric
June	64	5.16	1.613	3.51-6.80	Allometric
July	58	4.73	1.721	2.97-6.49	Allometric
August	51	4.77	2.824	1.87-7.66	Allometric
Generalized	634	6.25	1.507	4.74-7.76	Allometric

t=Value from t table; se_a = Standard error of intercept; se_b = Standard error of slope; Cl = Confidence interval; CL = Confidence level; SL = Standard length; TL = Total length

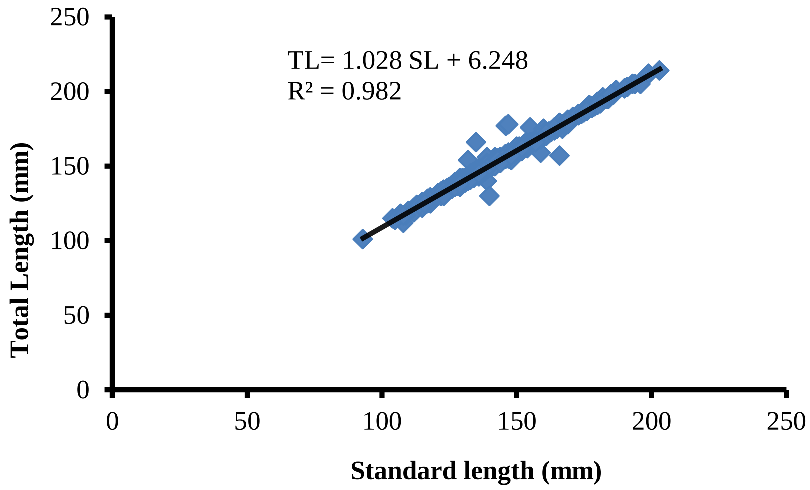

Figure 1. Generalized relationships between standard length and total length of male population of *Macrognathus aculeatus*.

Linear regression of pooled data of standard length vs. total length from all monthly samples of male lesser spiny eel over the study period is shown in Figure 1. The equation revealed that the intercept 'a' and slope 'b' were 6.25 and 1.03 respectively. The correlation coefficient and coefficient of determination were 0.991 and 0.983 respectively. Correlation coefficient of 0.991 indicated perfect positive correlation and high degree of association between standard length and total length. The coefficient of determination of 0.983 suggested that 98.3% of the variation in the total length was due to the variation in the standard length.

3.4. Growth pattern of male population

Sample growth in particular month was determined by the value of intercept of the linear equation between standard length and total length. Intercept values of different months samples indicated that standard length and total length were not directly proportional, therefore sample growth pattern in all months were allometric. Inference of growth pattern for population in a particular month as a whole was drawn on the basis of 95% confidence interval of intercept of the relationship. Since the confidence interval of intercept at 95% confidence level did not include zero in January, May, June, July, August, October and therefore, the growth pattern of male populations of those months were allometric documented in Table 2. Results showed that growth of *Macrogranthus aculeatus* in the Dingaputa Haor at Mohangonj Upazilla in Netrakona district. According to TL-SL relationship was isometric in February, March, April, September, November and December and allometric in January, May, June, July, August and October. The growth of generalized male population as a whole was allometric.

3.5. Female population

Relationship between standard length and total length of monthly samples showed variation in both constants of the linear equations, correlation coefficient and coefficient of determination. Results of analyses are given in Table 3. The range of intercept varied from 2.59 to 12.09. The lowest value of intercept 'a' was 2.59 found in March and the highest value of 'a' 12.09 found in December. The range of slope varied from 0.99 to 1.05. The minimum value of 'b' was 0.99 found in December and maximum value was 1.05 in March and April.

The minimum and maximum correlation coefficients ranged from 0.974 to 0.998 and were found in August and January, May, September respectively. The minimum and maximum coefficient of determination estimated from 0.949 to 0.998. Very high correlation coefficient values (≥ 0.974) indicated strong association between the two variables in all monthly data. Linear equations of all monthly samples for male population revealed high values of coefficient of determination (≥ 0.949) which explained that standard length was a good predictor of total length in all months. Linear regression of pooled data of standard length vs. total length from all monthly samples of male lesser spiny eel over the study period is shown in Figure 2.

The equation revealed that the intercept 'a' and slope 'b' were 5.826 and 1.03 respectively. The correlation coefficient and coefficient of determination were 0.995 and 0.991 respectively. Correlation coefficient of 0.995 indicated perfect positive correlation and high degree of association between standard length and total length.

The coefficient of determination of 0.991 suggested that 99.1% of the variation in the total length was due to the variation in the standard length.

Table 3. Length-length (total length and standard length) relationship parameters of monthly samples for female (*Macrognathus aculeatus*).

Month	No of observation	Slope	Intercept	r^2	$\pm t^*se_b$	$\pm t^*se_a$
September	28	1.00	10.38	0.998	0.019	2.994
October	44	1.02	8.1	0.962	0.063	9.917
November	60	1.03	5.67	0.997	0.015	2.296
December	50	0.99	12.09	0.981	0.039	5.831
January	37	1.04	5.56	0.998	0.014	2.001
February	37	1.02	8.01	0.981	0.048	7.245
March	42	1.05	2.59	0.986	0.039	6.408
April	68	1.05	3.89	0.989	0.026	3.901
May	32	1.04	5.63	0.998	0.014	2.227
June	36	1.03	4.62	0.997	0.017	3.252
July	42	1.04	4.45	0.988	0.036	4.944
August	49	1.04	3.62	0.949	0.068	10.567
Generalized	525	1.03	5.826	0.991	0.008	1.288

t=Value from t table; se_a = Standard error of intercept; se_b = Standard error of slope; SL = Standard length; TL = Total length

Table 4. Inference of growth pattern for monthly female population of *Macrognathus aculeatus*.

Month	No of observation	Intercept	$\pm t^*se_a$	Cl of a at 95% CL	Growth inference
September	28	10.38	2.994	7.43-13.32	Allometric
October	44	8.1	9.917	-1.81-18.01	Isometric
November	60	5.67	2.296	3.33-8.02	Allometric
December	50	12.09	5.831	6.12-18.08	Allometric
January	37	5.56	2.001	3.58-7.54	Allometric
February	37	8.01	7.245	0.73-15.29	Allometric
March	42	2.59	6.408	-3.82-9.00	Isometric
April	68	3.89	3.901	-0.09-7.86	Isometric
May	32	5.63	2.227	3.37-7.88	Allometric
June	36	4.62	3.252	1.25-7.99	Allometric
July	42	4.45	4.944	-0.45-9.39	Isometric
August	49	3.62	10.567	-7.23-14.46	Isometric
Generalized	525	5.826	1.288	4.54-7.12	Allometric

t=Value from t table; se_a = Standard error of intercept; se_b = Standard error of slope; Cl = Confidence interval; CL = Confidence level; SL = Standard length; TL = Total length

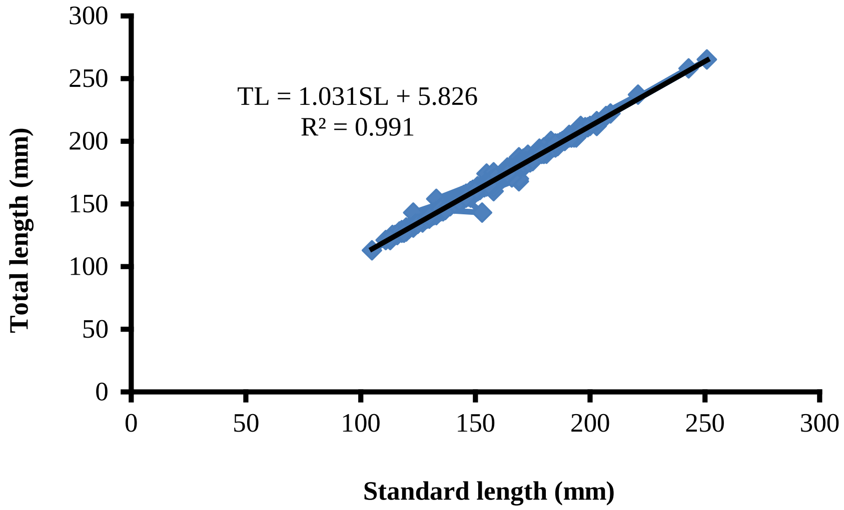

Figure 2. Generalized relationships between standard length and total length of female population of *Macrognathus aculeatus.*

3.6. Growth pattern of female population

Sample growth in particular month was determined by the value of intercept of the linear equation between standard length and total length. Intercept values of different months samples indicated that standard length and total length were not directly proportional, therefore sample growth pattern in all months were allometric. Inference of growth pattern for population in a particular month as a whole was drawn on the basis of 95% confidence interval of intercept of the relationship. Since the confidence interval of intercept at 95% confidence level did not include zero in January, February, May, June, September, November and December and therefore, the growth pattern of female populations of those months were allometric documented in Table 4. Results showed that growth of *Macrogranthus aculeatus* in the Dingaputa Haor at Mohangonj Upazilla in Netrakona district. According to TL-SL relationship was isometric in March, April, July, August, and October and allometric in January, February, May, June, September, November and December. The growth of generalized female population as a whole was allometric.

3.7. Combined population

Relationship between standard length and total length of monthly samples showed variation in both constants of the linear equations, correlation coefficient and coefficient of determination. Results of analyses are given in Table 5. The range of intercept varied from 2.41 to 18.78. The lowest value of intercept 'a' was 2.41 found in April and the highest value of 'a' was 18.78 found in June. The range of slope varied from 0.95 to 1.05. The minimum value of 'b' was 0.95 found in June and maximum value was 1.05 in April. The minimum and maximum correlation coefficients ranged from 0.838 to 0.998 and were found in June and January respectively. The minimum and maximum coefficient of determination estimated from 0.695 to 0.997. Very high correlation coefficient values ($\geq$ 0.838) indicated strong association between the two variables in all monthly data. Linear equations of all monthly samples for male population revealed high values of coefficient of determination ($\geq$ 0.695) which explained that standard length was a good predictor of total length in all months. Linear regression of pooled data of standard length vs. total length from all monthly samples of male lesser spiny eel over the study period is shown in Figure 3. The equation revealed that the intercept 'a' and slope 'b' were 7.49 and 1.02 respectively. The correlation coefficient and coefficient of determination were 0.972 and 0.946 respectively. Correlation coefficient of 0.972 indicated perfect positive correlation and high degree of association between standard length and total length. The coefficient of determination of 0.946 suggested that 94.6% of the variation in the total length was due to the variation in the standard length.

Table 5. Length-length (total length and standard length) relationship parameters of monthly samples for combined population of *Macrognathus aculeatus*.

Month	No of observation	Slope	Intercept	r^2	$\pm t^*se_b$	$\pm t^*se_a$
September	59	1.01	9.50	0.991	0.024	3.406
October	100	1.01	8.75	0.985	0.025	3.723
November	100	1.03	5.08	0.997	0.011	1.587
December	100	1.02	6.71	0.966	0.038	5.701
January	100	1.04	5.18	0.997	0.010	1.386
February	100	1.00	9.52	0.952	0.045	6.527
March	100	1.04	4.43	0.987	0.024	3.701
April	100	1.05	2.41	0.976	0.033	4.889
May	100	1.03	6.34	0.988	0.022	3.284
June	100	1.00	10.36	0.834	0.08	15.09
July	100	1.04	4.62	0.994	0.015	2.106
August	100	1.04	3.89	0.975	0.033	4.843
Generalized	1159	1.02	7.49	0.946	0.014	2.076

t=Value from t table; se_a = Standard error of intercept; se_b = Standard error of slope; SL = Standard length; TL = Total length

Table 6. Inference of growth pattern for monthly combined population of *Macrognathus aculeatus*.

Month	No of observation	Intercept	$\pm t^*se_a$	Cl of a at 95% CL	Growth inference
September	59	9.50	3.406	6.02-12.98	Allometric
October	100	8.75	3.723	4.98-12.52	Allometric
November	100	5.08	1.587	3.48-6.69	Allometric
December	100	6.71	5.701	1.00-12.43	Allometric
January	100	5.18	1.386	3.79-6.58	Allometric
February	100	9.52	6.527	2.97-16.06	Allometric
March	100	4.43	3.701	0.72-8.14	Allometric
April	100	2.41	4.889	-2.49-7.31	Isometric
May	100	6.34	3.284	3.05-9.63	Allometric
June	100	10.36	15.09	-2.66-40.23	Isometric
July	100	4.62	2.106	2.51-6.73	Allometric
August	100	3.89	4.843	-0.96-8.74	Isometric
Generalized	1159	7.49	2.076	5.41-9.57	Allometric

t=Value from t table; se_a = Standard error of intercept; se_b = Standard error of slope; Cl = Confidence interval; CL = Confidence level; SL = Standard length; TL = Total length

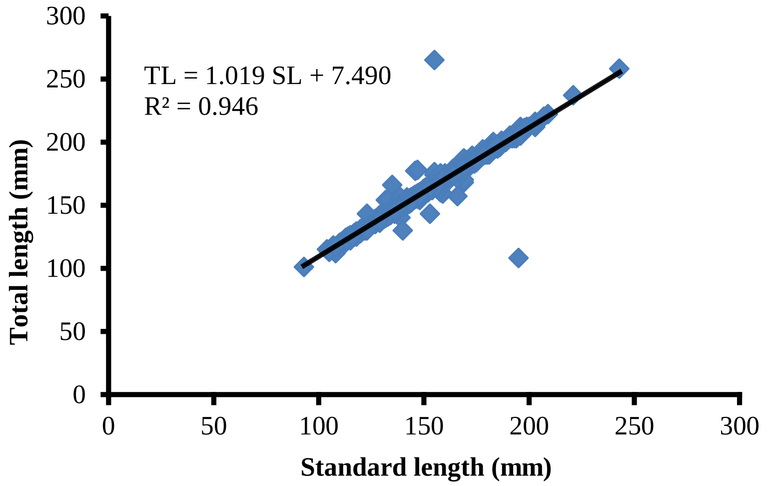

Figure 3. Generalized relationships between standard length and total length of combined population of *Macrognathus aculeatus*.

3.8. Growth pattern of combined population

Sample growth in particular month was determined by the value of intercept of the linear equation between standard length and total length. Intercept values of different months samples indicated that standard length and total length were not directly proportional, therefore sample growth pattern in all months were allometric. Inference of growth pattern for population in a particular month as a whole was drawn on the basis of 95% confidence interval of intercept of the relationship. Since the confidence interval of intercept at 95% confidence level did not include zero in January, February, March, May, July, September, October, November and December and therefore, the growth pattern of male populations of those months were allometric documented in Table 6. Results showed that growth of *Macrogranthus aculeatus* in the Dingaputa Haor at Mohangonj Upazilla in Netrakona district. According to TL-SL relationship was isometric in April, June and August and allometric in January, February, March, May, July, September, October, November and December. The growth of generalized combined population as a whole was allometric

4. Discussion

The objectives of this research work are to determine of Length-length relationship of *Macrognathus aculeatus* collected from the Dingaputa haor at Mohangonj Upazilla in Netrakona District. There are 1159 lesser spiny eel individuals among them 634 male and 525 female. The generalized relationship of standard length and total length of male, *M. aculeatus* was TL = 1.03 SL + 6.25. The generalized relationship of standard length and total length of female, *M. aculeatus* was TL = 1.03 SL + 5.826. The generalized relationship of standard length and total length of combined, *M. aculeatus* was TL = 1.02 SL + 7.49. The generalized coefficient of determination of standard length and total length of male, *M. aculeatus* was 0.983. The generalized coefficient of determination of standard length and total length of female, *M. aculeatus* was 0.991. The generalized coefficient of determination of standard length and total length of combined, *M. aculeatus* was 0.931 ($\geq$ 0.834) which is highly correlated.

Rahman *et al.* (2012) studied 254 lesser spiny eel population in Padma River. He got the length-length relationships between standard length and total length for male and female was comparatively TL= 1.08 SL + 0.1864; TL= 1.09 SL + 0.0477. The coefficient of determination was 0.992 in his study.

Hossain *et al*. (2012) studied in length-length relationships within 919 specimen of five threatened SIS fishes namely *Ailiichthys punctata*, *Botia lohachata*, *Chanda nama*, *Laubuca laubuca* and *Mystus cavasius*, from Jamuna River, a distributary of the Brahmaputra River in northern Bangladesh. He got the coefficient of determination (r^2) of those species were highly correlated (r^2>0.978).

Length-length relationships (LLRs) are essential for comparative growth studies (Moutopoulos and Stergiou, 2002). LLR are still unavailable for most tropical and sub-tropical fish species (Martin-Smith, 1996; Harrison, 2001; Ecoutin *et al.,* 2005). Length-length relationships (LLRs) are also important in fisheries management for comparative growth studies (Moutopoulos and Stergiou, 2002).

The length-length relationship has been applied for fundamental uses in order to make fish stocks assessment and populations (Ricker, 1975). In fish, size is generally more biologically relevant than age, mainly because several ecological and physiological factors are more size dependant than age. Consequently, length-weight regressions have been used frequently to estimate weight from length because direct weight measurements can be time consuming in the field (sinovcic *et al.*, 2004).

The correlation coefficient and coefficient of determination revealed high values in all regression analyses. The LLRs were highly correlated (r^2 > 0.978) (Hossain *et al.*, 2008). When comparing length-length relationships available in the literature, one might find wide variability in parameter estimates for a single species. This is due to fact that size relationships are greatly affected by many factors related to population variability and to sample and estimation methods. Sampling related factors include size, length distribution in the sample and type of length measure, while nutritional conditions account for intrinsic biological variability (Ricker, 1975). Parameter estimates are only good enough for population studied and awareness of time of sampling is essential. Efficient sampling must include the widest possible range of lengths generally obtained with large samples and non-selective fishing techniques.

The ultimate goal of the present research is to provide baseline information for the growth of *M. aculeatus* on the basis of the length-length relationship study. The estimated length-length relationship of *M. aculeatus* in this study could provide valuable information for future research in order to make comparison between years and locations.

5. Conclusions

The main objective of fish Population Dynamics is to determine the sustainability of exploited fish species. The entire research work have been done on length-length relationships and growth pattern of lesser spiny eel in Dingaputa haor at Netrakona district in Bangladesh.

Monthly samples of *M. aculeatus* were collected to one calendar year during the study period. The total 1159 individuals of lesser spiny eel were analyzed by the study among them 634 were male and 525 were female. The standard length and total length of male ranged from 93 to 203 mm and from 101 to 214 mm respectively. The standard length and total length of female ranged from 105 to 243 mm and from 108 to 256 mm respectively. Statistical analyses were performed in Microsoft® Excel-add-in-DDXL. The generalized relationship of standard length and total length male, female and combined *M. aculeatus* were TL = 1.03 SL + 6.25, TL = 1.03 SL + 5.826 and TL = 1.02 SL + 7.49 respectively. The generalized coefficient of determination revealed between standard length and total length of male, female and combined were 0.983, 0.991 and 0.946. The correlation coefficient and coefficient of determination revealed high values in all regression analysis. So, it is very important to determine the accurate length-length relationship of lesser spiny eel fish species. The equation come from the monthly samples are helpful for calculation of length of same species in a fixed month.

The length-length relationship relationships have been applied for basic uses in order to make fish stocks assessment and populations. In fish, size is generally more biologically relevant than age, mainly because several ecological and physiological factors are more size-dependent than age-dependent. Length-length relationships (LLRs) are also important in fisheries management for comparative growth studies.

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Conflict of interest

None to declare.

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