COEFFICIENT OF ALGEBRAIC RELATIONSHIP BETWEEN LINEAR DIMENSIONS AS GROWTH DEDUCTION FOR RAINBOW SARDINE 
Dussumieria acuta IN THE BAY OF BENGAL

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ABSTRACT

The intercept as the coefficient of algebraic relationship between standard length (SL) and total length (TL), the two predominantly used linear dimensions of fin fish species, was referred to growth pattern deduction for rainbow sardine Dussumieria acuta population in the Bay of Bengal. Monthly rainbow sardine samples were collected from the industrial fishing vessel in the Bay of Bengal over a period of a calendar year. The length-length relationship was formed algebraically as y=a+ bx. Linear relationship between SL and TL for male, female and unsexed populations was constructed separately. Chi-squared test affirmed that sex ratio between male and female did not deviate from the parity (P>0.05). The SL and TL ranges of male were 13.1-16.8 and 16.4-20.7 cm respectively, they for female were 13.4-17.2 and 16.5-20.9 cm respectively. Slope and intercept showed variation monthly in all length-length relationships regardless of sexes. The generalized SL-TL relationships of male, female and unsexed populations employing pooled data over the study period were TL=1.130SL+1.571 (R=0.908), TL=1.106SL+1.925 (R=0.911), and TL=1.114SL+1.825 (R=0.908) respectively. The correlation coefficients of all monthly and generalized regression analyses of all sex categories were very high (R≥0.786), a fact that explained the associations between two length dimensions were strongly related. Study revealed isometric growth for male in all months, while algometry was apparent for female and unsexed populations in a few months. Present findings of length-length relationship and growth pattern for D. acuta population in the Bay of Bengal would remain useful for future references.

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INTRODUCTION

Changes of linear dimension describe animal growth and are often used in growth study of fish (King, 1995). Several works emphasized the importance of length-length relationships in fisheries biology (Pauly, 1993; Petrankis and Stergiou, 1995; Binohlan and Pauly, 2000; Binohlan et al. 2000; Froese and Pauly, 2000; Froese, 2006). Length-length relationships are important for comparative growth studies (Moutopoulos and Stergiou, 2002), and are used as the corollary of growth pattern. Fish from birth undergo physiological process having isometric or allometric as a natural consequence over life cycle. Though data on length-length relationships are available for almost all European and North American freshwater and marine fishes (e.g., Petrankis and Stergiou, 1995; Sinovcic et al., 2004), but they are still lacking in most tropical and subtropical fish species (Martin-Smith, 1996; Harrison, 2001; Ecoutin et al. 2005). The length-length relationship has been employed as input data in fish population dynamics and fish stocks assessment (Ricker, 1968). Length-length relationships have been used frequently to estimate unknown lengths readily at later period from equations modelled erstwhile since field data recording is often seemed impossible (Sinovcic et al. 2004). The rainbow sardine Dussumieria acuta (Valenciennes, 1847) (Fig. 1), Clupeiformes: Dussumieridae, locally known as Colombo ilish is an important fish species, commonly caught by industrial from the Bay of Bengal in Bangladesh. Present research was undertaken to provide pilot information of growth pattern of D. acuta deduced from length-length monthly data analysis.

Figure 1. Rainbow sardine Dussumieria acuta (Valenciennes, 1847). Sampled on 15 July 2019 SL 15 cm

MATERIALS AND METHODS

Study area and fish sample collection
Samples of D. acuta were collected once a month over an entire calendar year from January to December from an industrial fishing vessel going to the Bay of Bengal from Chittagong fish landing center. Trawl net with 4 cm-meshed codend was used to catch the fish. All specimens were preserved with crushed ice in a fish box, and subsequently transported to laboratory.

Recording of lengths
Linear dimension of fish as linear distance of body length which is measured by scale. To carry out present research two linear dimensions of standard length and total length were considered. Standard length was measured from the tip of the snout (mouth closed) to the last vertebrae, and total length from the tip of the snout to the end of caudal fin. Both lengths were taken to the nearest cm with the help of a measuring board. Data were input on the spreadsheet of the computer software, Microsoft Excel.

Gonad collection and sex determination
The body cavity of a fish was cut open carefully by scissors, and gonads were extracted with forceps carefully. Fishes were sexed as male and female observing the gonads with naked eye.

Length-length relationship
A linear relationship between standard length (SL) and total length (TL), which can be represented by equation: TL = a+bSL where ‘a’ and ‘b’ are coefficients as intercept and slope respectively. Estimates of ‘a’ and ‘b’, and their 95% confidence limits were computed statistically.
Growth deduction

Somatic growth of fish increases at the same rate in all linear dimensions, and as a matter of fact, standard length and total length are proportional to each other. Identical proportionate growth rate over life cycle implies isometric growth; otherwise, it is termed as allometric. Intercept, the coefficient 'a' in the y=a+bx describes growth type. The 95% confidence intervals for the population intercept of the length-length straight line equation deduce isometry and allometry in this study. If the zero remains within confidence limits of population intercept, then the growth was deduced as isometric.

RESULTS

Fish size

The investigation dealt with a total of 500 rainbow sardine individuals. Among them, 308 were male and 292 were female. The standard length and total length of male measured from 13.1 to 16.8cm, and from 16.4 to 20.7cm respectively. The standard length and total length of female recorded from 13.4 to 17.2cm, and from 16.5 to 20.9cm respectively (Table 1).

Table 1. Collection details for monthly samples of rainbow sardine D. acuta population collected from the Bay of Bengal

| Month    | Male                | Female               |
|----------|---------------------|----------------------|
|          | Obs. | SL (cm) | TL (cm) | Obs. | SL (cm) | TL (cm) |
| January  | 28   | 13.4-16.8 | 16.5-20.6 | 22   | 13.5-17.0 | 16.6-20.4 |
| February | 24   | 14.0-16.6 | 17.3-20.3 | 26   | 14.4-17.0 | 17.5-20.7 |
| March    | 30   | 14.0-16.6 | 16.7-19.9 | 20   | 14.0-17.0 | 17.6-20.8 |
| April    | 24   | 13.8-16.8 | 17.0-20.4 | 26   | 14.0-17.0 | 17.2-20.5 |
| May      | 25   | 14.2-16.7 | 17.5-20.5 | 25   | 14.6-16.4 | 18.2-20.5 |
| June     | 24   | 14.0-16.3 | 17.5-20.2 | 26   | 13.4-16.5 | 16.5-20.7 |
| July     | 29   | 13.1-16.6 | 16.4-20.5 | 21   | 14.4-16.8 | 17.6-20.2 |
| August   | 28   | 14.3-16.2 | 17.5-20.0 | 22   | 14.3-16.8 | 17.1-20.6 |
| September| 27   | 14.0-16.8 | 17.5-20.7 | 23   | 13.7-16.5 | 16.6-20.5 |
| October  | 21   | 13.8-16.0 | 17.2-19.7 | 29   | 14.6-16.4 | 18.2-20.2 |
| November | 25   | 15.2-16.3 | 16.8-20.1 | 25   | 14.3-16.5 | 17.8-20.4 |
| December | 23   | 15.2-16.6 | 18.5-20.5 | 27   | 15.0-17.2 | 18.4-20.9 |

Obs, observations; SL, standard length; TL, total length

Size relationships and growth pattern

Male population

Relationships between standard length vs. total length of monthly samples showed variations in both constants ('a' and 'b') and correlation coefficients (R) of the linear equations. Results of analyses are given in Table 2. The lowest value of 'a' was -0.916 calculated in September, and the highest 3.486 in December. The minimum value of 'b' was 1.021 estimated in December, and the maximum 1.315 in April. The generalized relationship of the pooled data over the study period is TL=1.130SL+1.571; R=0.908 (Fig. 2). The minimum and maximum correlation coefficients ranged from 0.786 to 0.977, and calculated in March and June,
respectively. Very high correlation coefficient values indicated strong association between the two variables in all monthly data. Corollary of monthly growth pattern for the species based on 95% confidence interval of intercept are documented in Table 2. Results showed that growth of *D. acuta* in the Bay of Bengal according to SL-TL relationship was isometric in all months.

![Graph](attachment:image.png)

**Figure 2.** Generalized relationships between standard length and total length. For equations see text.

**Female population**
Relationships between standard length vs. total length of monthly samples showed variations in both constants (‘a’ and ‘b’) and correlation coefficients (R) of the linear equations. Results of analyses are given in Table 2. The lowest value of ‘a’ was -0.761 found in September, and the highest 4.236 found in January. The minimum value of ‘b’ was 0.124 calculated in February, and the maximum 1.280 in September. The generalized relationship of the pooled data over the study period is TL=1.106SL+1.925; R=0.911 (Fig. 2). The minimum and maximum correlation coefficients ranged from 0.874 to 0.980, and were estimated in August and June respectively. Very high correlation coefficient values indicated strong association between the two variables in all monthly data. Corollary of monthly growth pattern for the species based on 95% confidence interval of intercept are documented in Table 2. Results showed that growth of *D. acuta* in the Bay of Bengal according to SL-TL relationship was allometric in January, June, October and December, while it was isometric in other months.

**Unsexed population**
Relationships between standard length vs. total length of monthly samples showed variations in both constants (‘a’ and ‘b’) and correlation coefficients (R) of the linear equations. Results of analyses are given in Table 2. The lowest value of ‘a’ was 0.707 occurred in April, and the highest 3.383 in January. The minimum value of ‘b’ was 0.094 computed in March, and the maximum 1.182 in April. The generalized relationship of the pooled data over the study period is TL=1.114SL+1.825; R=0.908 (Fig. 2). The minimum and maximum correlation coefficients ranged from 0.851 to 0.954, and were calculated in March and June respectively. Very high correlation coefficient values indicated strong association between the two variables in all monthly data. Corollary of monthly growth pattern for this species based on 95% confidence interval of intercept are documented in Table 2. Results showed that growth of *D. acuta* in the Bay of Bengal according to SL-TL relationship was allometric in January, October and December, while it was isometric in other months.
Table 2. Parameters of SL vs TL relationships for rainbow sardine *D. acuta* population collected monthly over the study period with growth deduction

| Month   | Gender | Obs. | r   | b   | (±)Se_b*t | a   | (±)Se_a*t | Growth   |
|---------|--------|------|-----|-----|------------|-----|------------|----------|
| January | M      | 28   | 0.920 | 1.083 | 0.185 | 2.362 | 2.909 | Isometric |
|         | F      | 22   | 0.900 | 0.956 | 0.216 | 4.236 | 3.360 | Allometric |
|         | U      | 50   | 0.908 | 1.015 | 0.136 | 3.383 | 2.130 | Allometric |
|         | M      | 24   | 0.933 | 1.063 | 0.182 | 2.468 | 2.863 | Isometric |
| February| F      | 26   | 0.890 | 0.124 | 0.256 | 0.633 | 3.984 | Isometric |
|         | U      | 50   | 0.909 | 1.102 | 0.147 | 1.921 | 2.300 | Isometric |
|         | M      | 30   | 0.786 | 1.061 | 0.323 | 2.388 | 5.039 | Isometric |
| March   | F      | 20   | 0.925 | 1.034 | 0.210 | 1.578 | 3.315 | Isometric |
|         | U      | 50   | 0.851 | 0.094 | 0.189 | 2.523 | 2.960 | Isometric |
|         | M      | 24   | 0.930 | 1.315 | 0.230 | 1.315 | 0.230 | Isometric |
| April   | F      | 26   | 0.885 | 1.018 | 0.226 | 3.476 | 3.563 | Isometric |
|         | U      | 50   | 0.907 | 1.182 | 0.160 | 0.707 | 2.501 | Isometric |
|         | M      | 25   | 0.909 | 1.133 | 0.224 | 1.633 | 3.395 | Isometric |
| May     | F      | 25   | 0.923 | 1.197 | 0.215 | 0.708 | 3.373 | Isometric |
|         | U      | 50   | 0.926 | 1.171 | 0.138 | 1.094 | 2.137 | Isometric |
|         | M      | 24   | 0.977 | 1.272 | 0.123 | -0.396 | 1.832 | Isometric |
| June    | F      | 26   | 0.980 | 1.155 | 0.097 | 1.662 | 1.533 | Allometric |
|         | U      | 50   | 0.954 | 1.158 | 0.106 | 1.234 | 1.602 | Isometric |
|         | M      | 29   | 0.971 | 1.231 | 0.119 | 0.123 | 1.817 | Isometric |
| July    | F      | 21   | 0.926 | 1.112 | 0.218 | 1.734 | 3.377 | Isometric |
|         | U      | 50   | 0.950 | 1.159 | 0.110 | 1.127 | 1.692 | Isometric |
|         | M      | 28   | 0.918 | 1.182 | 0.206 | 0.748 | 3.013 | Isometric |
| August  | F      | 22   | 0.874 | 1.119 | 0.291 | 1.689 | 4.563 | Isometric |
|         | U      | 50   | 0.911 | 1.143 | 0.150 | 1.337 | 2.318 | Isometric |
|         | M      | 27   | 0.923 | 1.296 | 0.222 | -0.916 | 3.417 | Isometric |
| September| F     | 23   | 0.977 | 1.280 | 0.127 | -0.761 | 1.981 | Isometric |
|         | U     | 50   | 0.899 | 1.177 | 0.167 | 0.927 | 2.587 | Isometric |
|         | M     | 21   | 0.927 | 1.173 | 0.227 | 1.019 | 3.457 | Isometric |
| October | F     | 29   | 0.931 | 1.015 | 0.164 | 3.532 | 2.554 | Allometric |
|         | U     | 50   | 0.935 | 1.110 | 0.125 | 2.025 | 1.927 | Allometric |
|         | M     | 25   | 0.846 | 1.092 | 0.296 | 2.098 | 4.532 | Isometric |
| November| F     | 25   | 0.874 | 1.140 | 0.273 | 1.397 | 4.263 | Isometric |
|         | U     | 50   | 0.870 | 1.124 | 0.185 | 1.632 | 2.860 | Isometric |
|         | M     | 23   | 0.806 | 1.021 | 0.340 | 3.486 | 5.387 | Isometric |
| December| F     | 27   | 0.941 | 1.066 | 0.158 | 2.731 | 2.542 | Allometric |
|         | U     | 50   | 0.885 | 1.032 | 0.158 | 3.294 | 2.515 | Allometric |

U, unsexed; M, male; F, female; Obs, observations; r, correlation coefficient; b and a, slope and intercept of equation (TL=a+bSL); Se_b and Se_a, standard error of b and a; t, value for 95% confidence level from t table
DISCUSSION

Works pertinent to present study as on length-frequencies, length-length and length-weight relationships, age and growth, and otolith of the species are available (Nansen, 1984; Fishbase, 2020; Kulbicki et al., 1993; Dalzell, et al., 1987; Corpuz et al., 1985; Rivaton, 1999). Abdurahiman et al. (2004) reported total length range of male *D. acuta* of 11.0 - 20.4 cm, and that of female 11.4 - 20.2 cm from the southern coast of Karnataka in India. Mousavi-Sabet et al. (2016) documented standard length of unsexed population having range from 7.5 to 11.6 cm caught from the Persian Gulf and Oman sea. Total length ranges of the species from two other marine waters of eastern Mediterranean Sea and western Indonesia at place as 14.0 - 16.9 cm and 6.0 - 20.5 cm respectively (Taskavak and Bilecenoglu, 2001; Pauly, et al. 1996). Size ranges in terms of standard length and total length irrespective of genders of the species mentioned by the above authors are in accord to our length data. Fishbase (2020) referred to several studies on length-length relations of *D. acuta*. The relevant page of the global biodiversity information system on finfishes depicted the relationship between standard length vs total length as $SL=0.809TL$ and $TL=1.154SL$ for unsexed populations, while current effort estimated relationship between two length variables was $TL=1.114SL+1.825$. Growth pattern deduced by the present study could not be examined since references to similar works are absent. The reason, however, why growth pattern happened to be allometric in a few months over the year for female and unsexed populations would be a pressing subject for future inquiry. The research was intended to produce initial information so as to relevant future works may be compared.

CONFLICT OF INTEREST

No conflict of interest among authors exists for publishing the article.

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