Length frequency analysis and length-weight relationship of ribbonfish, *Lepturacanthus savala* (Cuvier, 1829) off Ratnagiri coast, Maharashtra

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ABSTRACT
In the present study, length frequency and length weight relationship analysis of *Lepturacanthus savala* of Ratnagiri coast were done. The fishes ranged in total length from 10 to 70 cm. From the cumulative frequency calculations, it was observed that *L. savala* attained first maturity at the size of 38 cm. *L.∞* calculated for *L. savala* was 68.25 cm, K was 0.55. The length of 43 cm was attained at the end of first year, 58 cm at second year and 65 cm at the end of third year. The analysis of covariance did not show significant difference in length-weight relationship between sexes. The relationship was described as Log \( W = -3.6049 + 3.2285 \text{Log } L. \)

Keywords: *Lepturacanthus savala*, length frequency, Ratnagiri, Maharashtra.

1. Introduction
Ribbonfish form a major and abundant fishery resource among the marine pelagic fin-fishes of the Indian seas. They are distributed in the Atlantic and Indo-Pacific regions as well as all along the Indian coast with abundance in the northwest and central east coasts[1]. The ribbon-fishes belong to the family Trichiuridae and are represented in Indian waters by four species namely, *Trichiurus lepturus*, *Lepturacanthus savala*, *Eupleurogrammus intermedius* and *E. muticus*, the first two species being the most dominant. These fishes are collected between Longitude 68º-70º E and Latitude 8º-22º N on the Gujarat coast, south Kerala and central Maharashtra coast and 15º N and 13º10´N - 92º37´E in Andaman and Nicobar Islands and mainly off Orissa and north Andhra coasts[2]. Occurrence of *L. savala* in high numbers is recorded during October – December in nearshore waters along Ratnagiri coast.

Estimated marine landing of ribbonfish in 2010 in east coast was 19,629 tonnes whereas in west coast estimated marine landing of ribbonfish[3] was 1,25,293. Estimated annual landing of ribbonfish in Maharashtra state in 2011-2012 was 24094 tonnes, while the annual production of ribbonfish along Ratnagiri coast[4] in 2011-2012 was 4362 tonnes. Estimated annual production of ribbonfish in Mirkarwada landing centre in 2011-2012 was 1662 tonnes[4]. Present work was undertaken to study the biological aspects of *L. savala* as it contributes the major marine landings along the Ratnagiri coast. Most of the catch is used for surim production and some catch of this fish is utilized in dried form along this coast.

2. Materials and methods
From the length data, the frequencies of the length classes were tabulated. Total 1650 individuals were studied for length frequency analysis for a period of eleven months from February 2012. Sampling for June – July could not be collected due to ban on fishing during monsoon. From the size frequency analysis, dominant modes of size distribution of *L. savala* were noted. The shifting of the mode values in the graphs for different months was used as the base for interpretation of growth. The length frequencies are used for separating the polymodal length frequency distribution into modal lengths of different year classes.
The estimation of growth parameters were also supplemented by analyzing the data by using FISAT (FAO - ICLARM Stock Assessment Tools) computer software package[8], which includes direct fit of length frequency data by ELEFAN - II (Electronic Length Frequency Analysis) method[9] and developed into a computer software package[10].

Total 680 individuals comprising of 233 males and 305 females and 142 indeterminates in the length range of 25 to 70 cm were studied for estimation of length-weight relationship by using linear regression analysis. The data of total length and weight were statistically treated by the method of least square using the equation given as: log W = log a+b log L, where 'a' and 'b' are constants estimated by linear regression of the log transformed varieties. Length-weight relationship was determined separately for males, females, indeterminates and total.

3. Results and discussion

3.1. Length frequency analysis

Random samples of fish collected from the commercial catches ranged in total length from 10 to 70 cm, mainly clustering between size groups 20-30, 30-40, 40-50 and 50-60 cm (Table 1, Fig. 1). It was observed that modal group of 40-50 cm size fish was caught during all the months along the Ratnagiri coast.

<table>
<thead>
<tr>
<th>Class Interval (cm)</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Total No.</th>
<th>Cumulative frequency</th>
<th>Relative frequency</th>
<th>Percentage frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>16</td>
<td>26</td>
<td>0.0097</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>10 – 20</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>8</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>54</td>
<td>0.0327</td>
<td>3.27</td>
<td></td>
</tr>
<tr>
<td>20 – 30</td>
<td>5</td>
<td>17</td>
<td>5</td>
<td>19</td>
<td>45</td>
<td>12</td>
<td>18</td>
<td>12</td>
<td>17</td>
<td>41</td>
<td>206</td>
<td>276</td>
<td>0.1248</td>
<td>12.48</td>
<td></td>
</tr>
<tr>
<td>30 – 40</td>
<td>5</td>
<td>45</td>
<td>18</td>
<td>53</td>
<td>32</td>
<td>77</td>
<td>30</td>
<td>25</td>
<td>37</td>
<td>47</td>
<td>399</td>
<td>675</td>
<td>0.2418</td>
<td>24.18</td>
<td></td>
</tr>
<tr>
<td>40 – 50</td>
<td>29</td>
<td>52</td>
<td>47</td>
<td>50</td>
<td>34</td>
<td>71</td>
<td>65</td>
<td>45</td>
<td>48</td>
<td>22</td>
<td>61</td>
<td>542</td>
<td>0.3285</td>
<td>32.85</td>
<td></td>
</tr>
<tr>
<td>50 – 60</td>
<td>6</td>
<td>23</td>
<td>66</td>
<td>48</td>
<td>2</td>
<td>85</td>
<td>42</td>
<td>51</td>
<td>18</td>
<td>20</td>
<td>365</td>
<td>1582</td>
<td>0.2212</td>
<td>22.12</td>
<td></td>
</tr>
<tr>
<td>60 – 70</td>
<td>0</td>
<td>8</td>
<td>16</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>14</td>
<td>13</td>
<td>5</td>
<td>68</td>
<td>1650</td>
<td>0.0412</td>
<td>4.12</td>
<td></td>
</tr>
</tbody>
</table>

Shifting of the modes to next modal class was evident from the ELEFAN-II analysis. The analysis showed a curve indicating the broods or spawning periods. The first recruitment was observed in February - March and second recruitment was observed in November - December (Projected values) (Fig. 2).

From the cumulative frequency calculations, it was observed that L. savala attained first maturity at the size of 38 cm. L∞ calculated for L. savala was 68.25 cm, K was 0.55. The length of 43 cm was attained at the end of first year, 58 cm at second year and 65 cm at the end of third year.

Length of the specimens of L. savala collected from the Ratnagiri coast ranged from 100 to 700 mm. L∞ was 68.25 cm, K was 0.55 year⁻¹ and t₀ = 0.03953 years by employing the Ford-Walford plot[10]. In the study of the age and growth parameters of L. savala, L∞ was estimated at 1057.14 mm, K as 0.0887 and t₀ as - 0.03957 years by fitting the von Bertalanffy growth equation[11]. The estimated lengths in mm (T. L.) at ages 1 to 6 are 93.10, 174.96, 249.82, 318.35, 381.06 and 438.44 mm respectively.

In commercial fishery, L. savala specimens were recorded in the range of 200 -700 mm[12]. The size distribution of L. savala occurring off Bombay ranged in size group of L. savala in dolnet was found to vary from 15-19 to 115-119 cm[13]. The widely investigated ribbonfish T. lepturus is relatively a large sized species reaching more than 1200 mm while L. savala grows to approximately 650 mm[14].

The maximum size of L. savala was recorded as 688 mm and the size at 50% maturity was 517 mm[15]. The age of massive maturation was 1.57 years. The higher growth coefficient (K) was 0.87 per year and lower life span was only 3.3 years. It was reported that the highest number of fish frequency (Σf =
215) was observed in 70 cm to 75 cm length group and the lowest ($\sum f = 2$) in 105 cm to 110 cm length group$^{16}$. However, the distribution was found to be normal with minimum numbers in lowest and highest length groups and maximum in mid length groups. The preliminary values of $L_{\infty}$ = 683.3 mm; $K = 0.86$ year$^{-1}$ and $r^2 = 0.707$ were obtained by employing Gulland-Holt method$^{[17]}$. The regression of mean length ($L$) and the growth increments ($\Delta L/\Delta t$) formed basis of the plot of $L_t$, $K$ and $r^2$ with the estimate of 688.02 mm, 0.87 year$^{-1}$ and 0.508 respectively. $L. savala$ grew to the size of 399 mm, 567.2 mm and 637.4 mm at the end of 1, 2 and 3 years respectively. Major recruitment pulse was evident from May-December with peak in October (19%) when 70% recruitment took place and a minor pulse from December-July with peak in March (8%), when remaining 30% fishes were recruited.

![Image](141x523 to 454x679)

**Fig 2**: Modal progression analysis of length frequency observed in $L. savala$ by using ELEFAN II

Though the $L_{\infty}$ value calculated in the current work is on par with the $L_{\infty}$ values calculated by other workers, $L. savala$ occurring along the coast of Ratnagiri appears to attain maturity at length smaller than that reported by other workers. It also showed a slow rate of growth as compared to the length increment per year reported by other workers elsewhere.

Growth parameters of many Trichiurids species were studied by many workers. One of the relatively quick methods involves the study of the length measurements of fish$^{[18]}$. Lengths of individuals of the same age group in a population of fish are approximately normally distributed.

The growth parameters of $L. savala$ occurring off Bombay (61 mm)$^{[19]}$. From the rate of growth arrived at from the length-frequency distribution these appear to be about two months old. He also reported that the maximum size of $L. savala$ was 56.4 cm (S.L.).

The growth parameters of $L. savala$ such as $L_{\infty}$ and $K$ were obtained by many workers$^{[17, 20, 21]}$. The $t_0$ found by von Bertalanffy's plot is 0.000251 year$^{-1}$. The VBGF of growth for the species is expressed as: $L_t = L_{\infty} [1- e^{-(K t - t_0)}]$. From the expression it was found that $L. savala$ grew to the size of 399 mm, 567.2 mm and 637.4 mm at the end of 1, 2 and 3 years respectively. The largest specimen measured was 650 mm, the estimated age of which was 3.3 years. Also by pooling annual length-frequency, it was seen that there were two overlapping pulses of recruitment. Major recruitment pulse was evident from May-December with peak in October (19%) when 70% recruitment took place and a minor pulse from December-July with peak in March (8%), when remaining 30% fishes were recruited. The selection of probability of capture gave $L_{\infty}$ for $L. savala$ as 463.3 mm in trawl, with input parameters of $L_{\infty}$ = 688 mm, $K = 0.87$, $a = 0.00000108$ g cm$^{-1}$, $b = 3.6117$, the terminal exploitation ratio of 0.55 was obtained by iteration for $L. savala$.

3.2. Length weight relationship

Data for all the four groups were analysed separately and following regression equations have been obtained; see in Table 2 and Fig. 3 to 6, ‘x’ variable as length and ‘y’ variable as weight. It was found that out of the total 680 specimens examined for the length-weight relationship 233 males (TL = 26.7-65 cm, W= 10 to 198 gm), 305 were female (TL = 31.4-70 cm, W= 14 to 280 g) and 142 were the indeterminates (TL = 25.58 cm, W= 8 to 34 g). Independent statistical analysis of their length and weight relationship gave the following regression equations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>$\log W = -3.2801 + 3.0311 \log L$</td>
</tr>
<tr>
<td>Female</td>
<td>$\log W = -3.8222 + 3.3608 \log L$</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>$\log W = -3.4377 + 3.1173 \log L$</td>
</tr>
</tbody>
</table>

\[ \text{Fig 2: Modal progression analysis of length frequency observed in } L. \text{ savala by using ELEFAN II} \]

\[ \text{Table 2 and Fig. 3 to 6, 'x' variable as length and 'y' variable as weight.} \]

\[ \text{Independent statistical analysis of their length and weight relationship gave the following regression equations.} \]

\[ \text{1. Male} \quad \log W = -3.2801 + 3.0311 \log L \]
\[ \text{2. Female} \quad \log W = -3.8222 + 3.3608 \log L \]
\[ \text{3. Indeterminate} \quad \log W = -3.4377 + 3.1173 \log L \]
The analysis of covariance indicated that there was no significant difference in the slopes of male, female and indeterminates samples (P > 0.05). The t-test was employed to ensure isometric growth, within the groups. The asymptotic length (L∞) obtained using ELEFAN II software in the present study was 68.25 cm, K (yearly) was 0.86 and t0 was calculated as 0.00029. Size at first maturity was recorded at 38 cm (Fig. 2).

In the present study, the scatter diagram of weight on total length in *L. savala* indicated that the relation to the general pattern of isometric growth. The length-weight regression equations reveal that the weight of fish increased at a rate lower than the cube of length. The difference in regression coefficients between male and female were not significant at 5% level. The 'a' and 'b' values of the length-weight relationship for males were -3.2801 and 3.0311 respectively, for females, -3.8222 and 3.3608 respectively and for indeterminates, -3.4377 and 3.1173 respectively.

The length-weight relationship of fishes was calculated primarily with a twofold aim[8]. First to determine the mathematical relationship between the two variables, length and weight, so that if one was known the other could be computed. Second aim was to measure the variations from the expected weight for length of individual fish or groups of fish as indications of fatness, general well-being or gonad development. It was stated that important departures from isometric growth (n = 3.0) were rare[9].

The length-weight relationship of *L. savala* for the two sexes together was calculated as Log W = -5.5396+3.30715 Log L in which the length was measured from snout to vent[22]. He found that the exponent ‘b’ was significantly different (p < 0.05) from 3. The author also reported the length-weight relationship as Log W = 5.5396+3.30715 Log L, where W was weight in grams and L represented the snout-vent length in mm. The exponent was found to be significantly different from 3.

It was reported[11] that the changes in morphology with increasing age, however, often cause the coefficient of regression of logarithm of weight on logarithm of length to depart substantially from 3.0. The value of the exponent 'n' in the parabolic equation[23, 24] usually lies between 2.5 and 4.0 and for ideal fish which maintains constant shape[25], n = 3. The exponent b lies between 2.5 and 3.5, usually close to 3. Thus, the growth of *L. savala* was found to be isometric[6].

The length-weight relationship of 1119 specimens of *L. savala* (Cuvier, 1829) from the Bay of Bengal, Bangladesh was studied and it was found to be curvilinear (W = 0.0003612 TL^3.18) and linear (Log W = -3.44+3.18 Log TL) for both the sexes combined in arithmetic and logarithmic scales, respectively[10]. The values of regression co-efficient (b) ranged from 3.002 to 3.337 at 95% confidence limit. The regression “b” value (3.18) followed the cube law and did not significantly (P >0.05) differ from the cube. The growth of the fish was found to be isometric.

The length-weight relationships[17] in *L. savala* males was reported as Log W = -6.7808+3.1671Log L (r = 0.83), in females Log W = -7.4918+3.4499 Log L (r=0.85), pooled equation was Log W = -7.9652+3.6117 Log L (r=0.96) and the combined equation was W = 0.00000001 L 3.6117. It was estimated that the length and weight measurements of males *L. savala* were 282 – 585 mm and 8.4 – 104.6 g and for females, 315–601 mm and 13.5–235.6 gm, respectively[26].

Estimated length weight relationships reported in the study of *L. savala*, for males was Log W = -6.7808+3.1671Log L and for females, Log W = -7.4918+3.4499 Log L. In the males the k values were higher in the length group of 321-340 mm and in 581-620 mm.

### Table 2: Linear Regression equations of length-weight relationship of males, females and indeterminates of *L. Savala*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Equation</th>
<th>a</th>
<th>b</th>
<th>r</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>Log W = -3.2801+3.0311 Log L</td>
<td>-3.2801</td>
<td>3.0311</td>
<td>0.89</td>
<td>233</td>
</tr>
<tr>
<td>Females</td>
<td>Log W = -3.8222+3.3608 Log L</td>
<td>-3.8222</td>
<td>3.3608</td>
<td>0.92</td>
<td>305</td>
</tr>
<tr>
<td>Indeterminates</td>
<td>Log W = -3.4377+3.1173 Log L</td>
<td>-3.4377</td>
<td>3.1173</td>
<td>0.89</td>
<td>142</td>
</tr>
<tr>
<td>Total</td>
<td>Log W = -3.6049+3.2285 Log L</td>
<td>-3.6049</td>
<td>3.2285</td>
<td>0.92</td>
<td>680</td>
</tr>
</tbody>
</table>

Fig 3: Logarithmic relationship between length and weight in the males of *L. savala*.
the values were minimum in 261-300 mm group. For the females, a sharp increase in k value was noticed only after 541-580 mm. Another study of this fish reported that the total length and weight of *L. savala* ranged from 15 cm to 40 cm and 80 gm to 950 gm respectively[27]. The parabolic equations and the logarithmic regression equations obtained were represented as for males, $W = 0.000011 L^{2.8948}$ (r = 0.857) and Log $W = -4.715+2.8948 \log L$ (r = 0.71). The pooled equations were $W = 0.0000014 L^{2.5170}$ (r = 0.825) and Log $W = -3.7508+2.5170 \log L$ (r = 0.76). The study postulated negative allometric growth in *L. savala*.

Some workers expressed the length-weight relationship of *L. savala* for the two sexes together as Log $W = -5.5396+3.30715 \log L$ in which the length was measured from snout to vent[10]. He found that the exponent ‘b’ was significantly different (p <0.05) from 3. In the present study also ‘b’ was significantly different for *L. savala* thus exhibiting allometric growth. Similarly, the length-weight relationship was studied in 102 fish measuring 22.5 to 46.5 cm in length[28]. The following regression equation describes the logarithmic relationship between the length and weight in *E. glossodon*: Log $W = -29398+2.8202 \log L$. The length-weight relationship based on study of 1,021 specimens ranging from 46.5 to 124.4 cm and weighing 50 to 1500 gm was expressed as Log $W = -3.8448 +3.352 \log L$ (r² = 0.924)[29].

The von Bertalanffy growth curve was fitted to the TL and age (in years) for *L. savala* and it was found out to be $L_t = 115.90 \{1-e^{-0.3021(t+1.0254)}\}$ (n = 64, $r^2 = 0.76$) for males, $L_t = 128.37 \{1-e^{-0.3918(t+1.0221)}\}$ (n = 296, $r^2 = 0.81$) for females, and $L_t = 127.40 \{1-e^{-0.3994(t+0.9815)}\}$ (n = 378, $r^2 = 0.89$) for all fish combined[30].
A total of 7,352 specimens of *L. savala* in the length range of 75 to 650 mm were measured during the two-year period\textsuperscript{[17]}.

Weight asymptote (W=\text{e}) was calculated as 194 gm. For length-weight relationship of *L. savala*, a total of 608 specimens ranging from 80 to 623 mm in total length and 0.2 to 235 gm in total weight were measured. The specimens comprised of 220 females ranging from 315 to 623 mm in length and 13.5 to 235.6 gm in weight, 123 males ranging from 282 to 585 mm in length and 8.4 to 104.6 gm in weight. The remaining 265 specimens were indeterminate juveniles ranging in size from 80 to 281 mm in length. The length-weight relationships of *L. savala* in logarithmic form were shown as:

Males: \[ \log W = -6.7808+3.6171 \log L \ (r = 0.83) \]

Females: \[ \log W = -7.4918+3.4409 \log L \ (r = 0.85) \]

Pooled: \[ \log W = -7.9652+3.6117 \log L \ (r = 0.96) \]

For sexes combined: \[ W = 0.0000001 \ L ^ {3.6117} \]

Similarly, a total of 608 specimens of *L. savala* ranging from 80-623 mm in total length and 0.2-235 g in weight including 265 indeterminate specimens ranging in length from 80-281 mm were studied. In the males of *L. savala*, the k values were higher in the length group of 321-340 mm and in 581-620 mm; the values were minimum in 261-300 mm group. For the females, a sharp increase in k value was noticed only after 541-580 mm\textsuperscript{[26]}.

4. Conclusion
In the present study also ‘b’ was significantly different for *L. savala* thus exhibiting allometric growth. The regression coefficient ‘b’ indicated that the weight of fish increased more or less in proportion to the cube of its length, but the females grew faster by weight than the males, as their exponential values are more. *L. savala* attained 43 cm in first year, 58 cm in second year and 65 cm in third year. The length frequency data. Meeresforschung 1981; 28:205-211.

5. References
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