Length-weight relationships and sex ratio of *Selaroides leptolepis*, Cuvier 1833 in Tomini Bay, Indonesia

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**Abstract.** *Selaroides leptolepis* is one of the most common pelagic fish, which has high market demand in Gorontalo. This study aimed to provide growth patterns and sex ratio of *S. leptolepis* male and female inhabiting Tomini Bay, Indonesia. Sampling was conducted monthly for six months, from April 2020 to September 2020. A fish sample of 1168 was taken randomly from Tomini Bay fishers who landed their catch at Kampung Tenda Fish Landing Site, Gorontalo City. The length and weight of fish were measured using a ruler (nearest 1 mm) and an analytical scale (nearest 0.01 g) separately. The results showed that almost all captured exhibited positive allometric growth (*b > 3*) and tended to be plump, except for the female in May 2020. The sex ratio between males and females during the sampling periods was 1: 1.17, which means the population proportion is not balanced. Such data are essential for establishing fisheries management in Tomini Bay.

**Keywords:** allometric; condition factor; Indonesia; *Selaroides*; sex ratio; Tomini

1. Introduction

*Selaroides* sp. is a species from the family Carangidae [1, 2] distributed in the Western Indian Ocean, narrowed to coastal waters from the gulf eastward to Sri Lanka, Indo-West Pacific known from the Bay of Bengal, Okinawa, Japan, Gulf of Thailand, the Philippines, Indonesia, and Australia [3]. The fish is the prospective resources of small pelagic fishery in Indonesian waters [4].

The only species of the genus *Selaroides* officially recorded in the FAO and FishBase are *Selaroides leptolepis* (Cuvier, 1833) with two synonyms: *Caranx leptolepis* Cuvier, 1833 and *Caranx procaranx* De Vis, 1884. Internationally, *S. leptolepis* is named yellow stripe scad [5], yellow stripe trevally [6-9], and smooth-tailed trevally [10, 11]. Indonesian people call the fish as Selar Kuning Fish [12-14] or Selar Fish [15-17]. Meanwhile, in several Indonesian regions, the species is also known as Tude [18], Oci [19], and Ciu [1].

As the main catch of Indonesian fishers, which is a source of protein [20, 21], *S. leptolepis* also can be processed [22-25] to be consumed. The fishing season in Indonesia occurs throughout the year [26]. Therefore, market demand for fish is relatively high. Based on data from the Department of Fisheries and Gorontalo Province in 2019 and 2020, *S. leptolepis* is one of the dominant pelagic catches of...
Gorontalo fishers in Tomini Bay with an average price at the consumer level of IDR 20,000 per kg. The spawning season for *S. leptolepis* in the Malacca Strait occurs from March to April [27], while the peak spawning season in Manado Bay occurs at the end of April [28] and in Sunda Strait occurs in May [29]. In some areas, the spawning season of pelagic fish coincides with the upwelling season; nonetheless, in other areas spawning and upwelling are out of phase [30].

Length-weight relationships are beneficial for fisheries study as they: (a) allow the conversion of growth-in-length equations to growth-in-weight for a stock assessment models purposes; (b) allow the estimation of biomass from length observations; (c) allows an estimation of the fish condition, and (d) are useful for between area comparisons of life histories of particular species [31-33]. They are an essential component of Fish Base [3][34]. Therefore, the length-weight relationship remains a popular tool in providing information supporting world fish stock assessment [35-37]. Besides, the sex ratio of the populations is an aspect of reproductive biology used in various studies as it is also needed to support the assessment of stocks and the management of fishery resources.

Tomini Bay is part of the Republic of Indonesia Fisheries Management (WPPNRI) 715 based on Regulation of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 18/Permen-KP/2014 [38] as a rich pelagic fish resources area. The biotic resources in the region are open access and likely to be shared stocks with several countries [39]. Therefore, it is necessary to pay special attention to the sustainability and availability of fish resources in waters to meet community needs. The management and utilization of *S. leptolepis* resources as an economic fish must be supported by necessary comprehensive data regarding population dynamics in nature. This study aimed to determine the growth pattern and sex ratio of *Selaroides leptolepis* in Tomini Bay, Indonesia.

2. Materials and methods

2.1. Sampling technique

The fishing ground and the landing site of *S. leptolepis* are presented in figure 1. Samples were collected monthly using random sampling methods from April 2020 to September 2020 from fishers who capture the fish from Tomini Bay and land the catch at Kampung Tenda Fish Landing Site, Gorontalo. Fish were caught by the fishermen using Purse Seine with a minimum mesh size of ¾ inch.
2.2. Data analysis

2.2.1. Length-weight relationship and growth pattern. A linear allometric model was used to calculate parameters a and b through measurements of length and weight [40] as follows:

\[ W = aL^b \]  \hspace{1cm} (1)

Where:
- \( W \) = body weight (gram)
- \( L \) = total length (mm)
- a and b = polynomial equation constants

The equation model (1) was transformed into a linear equation as follows:

\[ \ln W = \ln a + b \ln L \]  \hspace{1cm} (2)

\[ Y = a + bX \]  \hspace{1cm} (3)

The values a and b in equation (3) are constant regression equations obtained through simple linear regression analysis with "\( \ln L \) data" as independent variables (X) and "\( \ln W \) data" as dependent variables (Y) in linear regression equations (2). Furthermore, the determination of fish growth patterns was carried out by testing the hypothesis of the constant value b in equations (2) and (3) at the 95% confidence level using the t-test [41] as follows:

\[ H_0: b = 3 \]
\[ H_1: b \neq 3 \]

The \( t_{\text{statistic}} \) value was compared with the \( t_{\text{critical}} \) at the 95% confidence level. The rule for decision making is to reject \( H_0 \) if \( t_{\text{statistic}} > t_{\text{critical}} \), or fail to reject \( H_0 \) if \( t_{\text{statistic}} < t_{\text{critical}} \) [42] through the following formula:

\[ t_{\text{statistic}} = \left| \frac{b - 3}{S_b} \right| \]  \hspace{1cm} (4)

\[ S_b = \sqrt{\frac{1}{n-2} \left( \frac{sy^2}{sx^2} - b^2 \right)} \]  \hspace{1cm} (5)

Where,
- b = constant value
- \( S_b \) = deviation standard
- n = number of data
- sy = deviation standard of Y
- sx = deviation standard of X

The coefficient of determination (\( R^2 \)) and correlation (r) of the equation of the length and weight relationships were calculated using Microsoft Excel.

The criteria for fish growth patterns based on the constant b value test are as follows:
- b = 3, fish have an isometric growth pattern, meaning that the weight gain is balanced with the increase in length;
- b \( \neq \) 3, fish have an allometric growth pattern, meaning that the weight gain is imbalanced with the increase in length;
- b > 3, fish have a positive allometric growth pattern, meaning that the weight gain is faster than the length gain
- b < 3, fish have a negative allometric growth pattern, meaning that the weight gain is slower than the length gain.

2.2.2. Sex ratio. The sex ratio was determined by comparing the proportion of male and female samples. Determination of the sex of the sample fish was done visually by looking at the characteristics and
differences in the gonads. The males have whitish gonads in the form of testes, while female fish have gonads that are reddish yellow in the form of ova. The numbers of male and female took monthly from fishers were analysed its sex ratio using the formula [41] as follow:

\[
\text{Sex Ratio} = \frac{\sum \text{male}}{\sum \text{female}}
\]  

(6)

Significant of the fish sex ratio was tested using Chi-square (\(\alpha = 0.05\)) [42]:

\[
\chi^2 = \sum \frac{(O-E)^2}{E}
\]

(7)

Where,

\(\chi^2\) = Chi-square,

O = male and female fish frequency observed,

E = male and female fish frequency expected.

2.2.3. Condition factor. The condition factor shows the excellent condition of the fish in terms of physical capacity for reproduction and survival. The condition factors were calculated using the metric system based on the length-weight relationships of the samples as follows [43]:

\[
K = \frac{10^5W}{L^3} \quad (\text{if the fish growth pattern is isometric})
\]

(8)

\[
K = \frac{W}{aL^b} \quad (\text{if the fish growth pattern is allometric})
\]

(9)

Where,

K = condition factor,

W = body weight (gram),

L = total length (mm).

3. Results and discussion

3.1. Length-weight relationship

The equation's performance of the relationship between male and female weight each month of samples varies (figure 2). The length-weight relationship is naturally influenced by several factors, including water conditions, population density, natural food availability, and seasonality [44]. In general, the coefficient of determination value is relatively high (\(R^2 > 80\%\)) shown for each equation per month of observation indicates that the polynomial length-weight equation (\(W = aL^b\)) is suitable and can be used to predict the fish growth patterns.

Almost all male and female showed a positive allometric fish growth pattern every month, excluding the female in May showed a negative allometric pattern (table 1). It indicates that, overall, Tomini Bay waters' natural conditions support the fish life and survival. The length gain that is more dominant than the weight gain of female fish in May is a characteristic that the fish are at the peak of the month's spawning season. During the egg development process, energy is absorbed for the gonadic growth of the female fish. The \(b\) value depends on environmental and physiological situations, for instance, salinity, temperature, sampling techniques, geographic location, and biological conditions like food availability and gonad development [45].
Male

April 2020

\[ W = 0.000007 L^{3.1249} \]
\[ R^2 = 91.36 \% \]
\[ r = 0.95 \]
\[ n = 138 \]

May 2020

\[ W = 0.000002 L^{3.3898} \]
\[ R^2 = 96.81 \% \]
\[ r = 0.98 \]
\[ n = 217 \]

June 2020

\[ W = 0.000007 L^{3.1052} \]
\[ R^2 = 95.73 \% \]
\[ r = 0.97 \]
\[ n = 171 \]

Female

April 2020

\[ W = 0.000008 L^{3.1009} \]
\[ R^2 = 84.90 \% \]
\[ r = 0.92 \]
\[ n = 315 \]

May 2020

\[ W = 0.1795 L^{1.1311} \]
\[ R^2 = 88.23 \% \]
\[ r = 0.94 \]
\[ n = 175 \]

June 2020

\[ W = 0.000007 L^{3.107} \]
\[ R^2 = 94.16 \% \]
\[ r = 0.97 \]
\[ n = 175 \]
Figure 2. Length-weight relationships of *Selaroides leptolepis* in Tomini Bay, Indonesia.
Table 1. Growth pattern of *Selaroides leptolepis* in Tomini Bay, Indonesia.

| Sampling Time   | Growth Pattern* | Male          | Female         |
|-----------------|-----------------|---------------|----------------|
| April 2020      | allometric positive | allometric positive |
| May 2020        | allometric positive | allometric negative |
| June 2020       | allometric positive | allometric positive |
| July 2020       | allometric positive | allometric positive |
| August 2020     | allometric positive | allometric positive |
| September 2020  | allometric positive | allometric positive |

*significance different (p < 0.05)

3.2. Sex ratio

Understanding the sex ratio is related to efforts to maintain the sustainability of the fish population. The sex ratio of 1:1 (male: female) is a balanced condition [43] due to the ratio is needed to maintain their survival in a population [46, 34]. Based on the Chi-square test (α = 0.05), the sex ratio of the male and female caught from April 2020 to September 2020 in Tomini Bay monthly was equal (1:1), except in April 2020, where female remaining preponderated over the male. In total, its number showed that female numbers generally preponderated over the male (table 2).

Table 2. Sex ratio (male:female) of *Selaroides leptolepis* in Tomini Bay, Indonesia.

| Sex Ratio       | April | May   | June  | July  | August | September | Total     |
|-----------------|-------|-------|-------|-------|--------|-----------|-----------|
| Male : Female   | 1 : 2.28* | 1 : 1.06 | 1 : 1.02 | 1.02 : 1 | 1.10 : 1 | 1.05 : 1 | 1 : 1.17* |

*significance different (p < 0.05)

Even though sex ratios are frequently treated as more or less stable population features, the up-to-date theoretical evidence suggests that sex ratio fluctuates under many conditions and that these variations’ amplitude can be considerable [47]. The sex ratio of the results of this study deviated from the ideal value of 1:1. It is due to the fish samples caught were not in one spawning area; therefore, the chances of being caught were different. Fishing activities also have a considerable influence on the fish sex ratio in nature [48].

![Figure 3](image-url). Average condition factors of *Selaroides leptolepis* in Tomini Bay, Indonesia.
3.3. **Condition factor**

The average condition factor values for males and females of *S. leptolepis* from this study were 1.014 ± 0.133 and 0.007 ± 0.119, respectively (figure 3). The condition factor is shown to be an efficient instrument and shows changes in fish conditions throughout the year [44]. The condition factor can go up and down as it indicates the spawning season, especially for the female [43]. The condition factor value variation depends on the diet, age, sex, and gonad maturity level [49]. In this study, there was no variance in condition factors between males and females. It indicates that the fish are in relatively good condition.

4. **Conclusion**

All captured *Selaroides leptolepis* in Tomini Bay, Indonesia, sampled from April to September 2020, exhibited a positive allometric growth (b > 3) and tended to be plump, unless for the female in May 2020. On average, the male to female sex ratio during the study was not balanced (1:1.17).

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