Population dynamics of sumbo fish *Selar crumenophthalmus* (Pisces: Carangidae) in Banda Aceh waters, Aceh, Indonesia

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**Abstract.** The stock assessment aims to determine the condition of fish in aquatic environment. In addition, there has been very less research on population dynamics of *S. crumenophthalmus*, and particular in Aceh has never been done. The aimed of this study is to analyze the population dynamics of the sumbo fish (*Selar crumenophthalmus*) in Lampulo Fisheries Port, Banda Aceh. The survey has been done from February to April 2019. A total of 164 fish samples were collected. The growth parameters of von Bertalanffy growth function were utilized to analyse the population dynamics of *S. crumenophthalmus*, using FISAT II (FAO-ICLARM Stock Assessment Tools-II). The results show the population dynamic of infinity length (L∞) as193.2mm, growth coefficient (K) = 4.6 year⁻¹, growth performance index (Ø) = 5.23 year⁻¹, time at which length equals zero (t0) = -0.002 year⁻¹ and optimum fishing length (Lopt) = 158.49mm. In addition, the total mortality rate (Z) was 8.08 year⁻¹ with natural mortality rate (M) = 3.02 year⁻¹, fishing mortality rate (F) = 5.06 year⁻¹, and exploitation rate (E) =0.63 year⁻¹. Conclusion has been drawn based on E value analysis which reveals that the exploitation rate of sumbo fish has surpassed the sustainable limit.

1. Introduction
The genus *Selar* is included in the family of Carangidae. This genus have 12 species around the world, including *S. kalla*, *S. djedaba*, *S. megalaspis*, *S. malam*, *S. macrurus*, *S. hasseltii*, *S. mate*, *S. affinis*, *S. boobs*, *S. crumenophthalmus*, *S. leptolepis* and *S. tabulae* [1]. The *S. crumenophthalmus* is recorded as being distributed in Aceh Province, and is one of the high economic value that the Acehnese are interested in.

*S. crumenophthalmus* have morphological character of height 0.25 times the total body length, the muzzle length is same or longer than the diameter of the eye, the number of line lateral scales are between 50-56 scales [2]. The IUCN Red List shows that *S. crumenophthalmus* has begun to be threatened in the least concern category [3]. Therefore, conservation efforts need to be carried out to preserve this fish in the future.

The stock assessment aims to determine the condition of fish in aquatic environment. As for one method used is the population dynamic analysis of fish. In addition, there has been very less research on
population dynamics of *S. crumenopthalmus* [4], and particular in Aceh has never been done. Research on fish population dynamics includes analysis of mortality rates, patterns of recruitment, length distribution, growth parameters can reveal relevant fish growth and environmental information [5]. Therefore, this research is expected to conserve *S. crumenopthalmus* in the future.

2. Materials and Methods

2.1 Location and time
Survey and sampling were conducted during February-April 2019. Data is collected on Lampulo Fisheries Port, Banda Aceh.

2.2 Length frequency
The length frequency formula refers to Pauly [6] as follow:

\[ F_i = \frac{n_i}{N} \times 100 \]

Where \( F_i \) is length frequency of fish sample (%), \( n_i \) is the total number of fish at class length \( i \), and \( N \) is the total fish sample.

2.3 Growth parameters
The von Bertalanffy growth function (VBGF) was calculated using FISAT II (FAO-ICLARM Stock Assessment Tools-II), where calculated referring to the ELEFAN-I method. After that we gave an infinity length (\( L_\infty \)) and coefficient growth (\( K \)) value. Moreover, the theoretical age at fish length equal 0 was analyzed referring to Pauly (1980) as follow:

\[ \log (t_0) = -0.3952 - 0.2752 \log (L_\infty) - 1.038 - \log (k) \]

Where \( t_0 \) is the theoretical age at fish length equal 0, \( L_\infty \) is infinity length, \( K \) is growth coefficient

2.4 Total mortality rate
The total mortality rate (\( Z \)) was analyzed using FISAT II referring to Length-coverted Catch Curve method [7].

2.5 Natural mortality rate
The natural mortality rate (\( M \)) was analyzed referring to [8]:

\[ \log (M) = -0.0066 - 0.279 \log (L_\infty) + 0.6543 \log (K) + 0.4634 \log (T) \]

Where \( M \) is the natural mortality rate, \( L_\infty \) is infinity length, \( K \) is the growth coefficient, \( T \) is the mean temperature of the aquatic environment.

2.6 Fishing mortality rate
The fishing mortality rate (\( F \)) was analyzed referring to Pauly [8] as follows:

\[ F = Z - M \]

Where \( Z \) is the total mortality rate, \( M \) is the natural mortality rate.

2.7 Exploitation rate
The exploitation rate (\( E \)) was analyzed referring to Sparre and Venema [9] as follow:

\[ E = F / Z \]

Where \( E \) is the exploitation rate, \( F \) is the fishing mortality rate, \( Z \) is the total mortality rate.

2.8 The optimum fishing length and recruitment pattern
The optimum fishing length (\( L_{opt} \)) was analyzed referring to Froese and Binohlan [10] as follows: \( L_{opt} = 3 * L_\infty / (3 + M / K) \), where \( L_{opt} \) is the optimum fishing length, \( M \) is the natural mortality rate, \( L_\infty \) is infinity
length, and K is the growth coefficient. The recruitment pattern was calculated using FISAT II by inputting the L∞, K and t₀ values into the growth parameter inputs and graph menu.

3. Results and Discussions

The results of population dynamics analysis showed that *S. crumenopthalmus* has infiniti length (L∞) reaching 193.2 mm, growth coefficient (K) 4.6 year⁻¹, optimum fishing length (Lopt) 158.49 mm and index of growth performance (Ø) reaching 5.23 year⁻¹ (Table 1). The results of previous studies by García and Duarte [4] showed that the asymptotic length of *S. crumenopthalmus* from Salamanca bay, Colombia reached 311 mm and was higher than this study (193.2 mm). But *S. crumenopthalmus* from Salamanca bay, Colombia showed K value (0.26 year⁻¹) was lower compared to this study (4.6 year⁻¹). Furthermore, other studies conducted by Roos et al. [11] revealed that *S. crumenopthalmus* recorded from Reunion Island had a value of L∞ (265 mm) higher than this study, but had a lower K value (1.0 year⁻¹).

In this study the value of the Growth performance index (Ø) reaches 5.23 year⁻¹ (Figure 2a). The results of this study are higher compared to *S. crumenopthalmus* collected from Reunion Island, Bangaa Faru Maldives and North-West Coast of India with each value reaching 0.38 year⁻¹, 2.81 year⁻¹ and 3.13 year⁻¹ [11-13]. According to Pauly and Munro [14], revealed that the value of Ø reflects the overall growth performance, where the value of Ø is high then the performance to grow fish will be higher as well.

**Table 1.** Population dynamic of the sumbo fish *S. crumenopthalmus* in Lampulo Fisheries Port, Aceh Province, Indonesia

| Parameters                          | Value         |
|-------------------------------------|---------------|
| Infinity or Asymptotic length (L∞) | 193.2 mm      |
| The optimum fishing length (Lopt)   | 158.49 mm     |
| Growth coefficient (K)              | 4.6 year⁻¹    |
| Growth performance index (Ø)        | 5.23 year⁻¹   |
| Total mortality rate (Z)            | 8.08 year⁻¹   |
| Natural mortality rate (M)          | 3.02 year⁻¹   |
| Fishing mortality rate (F)          | 5.06 year⁻¹   |
| Exploitation rate (E)               | 0.63 year⁻¹   |

The results of the total mortality rates (Z) analysis showed *S. crumenopthalmus* reached 8.08 year⁻¹ with the exploitation rate reaching 0.63 year⁻¹ or 63% of fish mortality caused by fishing (Table 1 and Figure 3a). These results indicate that *S. crumenopthalmus* is overexploited. The same result was showed in Salamanca Bay, Colombia, E values reached 0.67 year⁻¹ or 67% of fish mortality caused by fishing [4]. Furthermore, research conducted by Peñaflor [15] in 5 catchment areas in the Philippines showed that *S. crumenopthalmus* had been overexploited with values between 0.52-0.74 year⁻¹. In another study by Faizah et al. [16] and Panda et al. [13] showed that *S. crumenopthalmus* from Kwandang Waters, North Gorontalo and North-West Coast of India had been caught maximally and were almost overfishing (E =
0.51 year\(^{-1}\) and 0.52 year\(^{-1}\)). In another study in the Indian Ocean (Bangaa faru, Maldives) showed that \textit{S. crumenophthalmus} had overexploited with the value of fishing mortality rate (F) reaching 56\% year\(^{-1}\) [12].

![Figure 1](image_url)

**Figure 1.** (a) Distribution of length classes of the fish sample (N= 164) (b) The von Bertalanffy Growth Function (VBGF) of sumbo fish \textit{S. crumenophthalmus} in Lampulo Fisheries Port, Aceh Province, Indonesia
Figure 2. (a) The value of growth performance index ($\Theta$) was 5.23 year$^{-1}$; (b) the curve of the length growth and age estimation ($t_0 = -0.002$ year$^{-1}$ and $K = 4.6$ year$^{-1}$) of sumbo fish $S.\ crumenophthalmus$ in Lampulo Fishing Port, Aceh Province, Indonesia.

In this study, the peak of $S.\ crumenophthalmus$ recruitment occurred in August and September with each value reaching 35.14% and 50.81% (Figure 3b). Similar results were expressed by Panda et al. [13] that 50% of the recruitment process of $S.\ crumenophthalmus$ from the North-West Coast of India occurred in August and September. This result is reinforced by Adeeb et al. [12] stated that the peak of $S.\ crumenophthalmus$ recruitment occurred in September. Thus, fish spawning activities are occurred in August and September every year.

Figure 3. (a) Length-converted catch curve method ($Z = 8.08$ year$^{-1}$); (b) Recruitment Pattern for one year (peak of recruitment were August and September) of sumbo fish $S.\ crumenophthalmus$ in Lampulo Fisheries Port, Aceh Province, Indonesia.

4. Conclusion
Based on the results of population dynamics analysis, $S.\ crumenophthalmus$ has growth coefficient ($K$) 4.6 year$^{-1}$, Growth performance index ($\Theta$) 5.23 year$^{-1}$, Infinity or Asymptotic length ($L_\infty$) 193.2 mm and the
optimum fishing length ($L_{opt}$) 158.49 mm. Analysis of mortality rates including total mortality ($Z$), natural mortality ($M$), fishing mortality rate ($F$) and exploitation rate ($E$) have values of 8.08 year$^{-1}$, 3.02 year$^{-1}$, 5.06 year$^{-1}$ and 0.63 year$^{-1}$. Based on the value of the mortality rate, *S. crumenophthalmus* was landed in Lampulo Fisheries Port, Banda Aceh was overexploited (63% of fish mortality caused by fishing).

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