Vulnerability status of longtail tuna (*Thunnus tonggol*) in Southwest Aceh waters, Indonesia

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Abstract. Ujung Serangga fishing port is one of fishing port located in a Fisheries Management Area of Republic Indonesia 572 (WPP572), located in Southwest Aceh. One of catch landed is longtail tuna caught by mini purse seine. Longtail tuna (*Thunnus tonggol*) is a species from the neritic tuna, where this species is often the target of catches in the coastal waters of Southwest Aceh [1,2]. This species has a high economic value in Southwest Aceh but also has a lack of data, both biological and catch production data. This research aims to assess the vulnerability status of longtail tuna in Fishing Port of Ujung Serangga. This research was conducted from December 2018 to February 2019. Analysis of longtail tuna using Productivity and Susceptibility Analysis (PSA) software. This analysis is one method that can be used to analyze the intensity of fish stocks using 22 attributes of productivity and susceptibility parameters. Longtail tuna has a productivity value at 2.30 and susceptibility value at 2.08. Vulnerability index of this species is 1.29. This value indicated that the stock status of longtail tuna landed in Southwest Aceh was low vulnerable or still in the good category.

1. Introduction

Longtail Tuna (*Thunnus tonggol*) is a group of neritic tuna families, which the spread of this species is very widespread in various regions, mostly in the tropical and western Indo-Pacific regions [1]. Longtail tuna caught in neritic waters around 15-30 nautical miles from land with a depth of 20-45 meters [2]. Yesaki [3] stated that longtail tuna are large pelagic fish that have economic value in Indonesian fisheries. According to KKP [4], the estimation of large pelagic fish resources in the Fisheries Management Area 572 is in a fully exploited condition.

Based on preliminary observations it was found that the availability of data at the Ujung Serangga fishing port for longtail tuna was still very limited, so the study of productivity and susceptibility was very appropriate to use. Analysis of productivity and susceptibility can be used for research with a focus on the susceptibility of high species with limited biological information [5,6,7]. The objectives of this
study were to assess the value of the parameters of productivity and susceptibility of longtail tuna (T. tonggol) in Ujung Serangga fishing port in Southwest Aceh; and assess the vulnerability of longtail tuna (T. tonggol) at Ujung Serangga fishing port in Southwest Aceh.

2. Material and Methods

2.1. Site and time
Sampling was conducted at Ujung Serangga fishing port, Southwest Aceh Regency, in December 2018-February 2019 (Figure 1).

![Figure 1](image.png)

**Figure 1.** Research site at Ujung Serangga fishing port

2.2. Sampling and measurement procedures
This research uses census method by collecting data directly on longtail tuna which landed at Ujung Serangga fishing port. The sample is the fisherman's catch landed on the Ujung Serangga fishing port with a total sample taken of 300 fishes for three months, 7 times each month. The collected data includes the total length of fish measured using a ruler (cm), and the wet weight of fish weighed using digital scales (grams). Interviews using a questionnaire were conducted on fishermen who catch longtail tuna. Secondary data collected in the form of catches production data in each year obtained from Dinas Kelautan dan Perikanan (DKP) of Southwest Aceh and obtained in previous research.

2.3 Data analysis
Analysis of the data used for this study is by using attributes of productivity and susceptibility parameters. Productivity and susceptibility parameters have a function to determine the susceptibility of a species in one community [8]. The attributes of productivity parameters include intrinsic growth rate (r), maximum age, maximum size, growth coefficient (k), natural mortality (M), fecundity, breeding strategy, recruitment pattern, gonad maturity, and Mean Trophic Level. The attributes of susceptibility parameters consist of management management, area of spread, geographical concentration, vertical overlap, F / M, Spawning Stock Biomass (SSB), seasonal migration, grouping, influence of fishing gear on fish morphology, Survival After Capture and economic value [5].

2.3.1 Analysis of components of productivity and susceptibility parameters
1. Length frequency distribution
Analysis of the frequency distribution of fish length was carried out using data on the total length of longtail tuna caught [9]. The steps in analyzing long frequency data of fish are: determine the number of class interval of long; determine the width of the class interval; and determine the frequency of the class and enter the frequency of each class by entering the length of each sample fish in the specified class.
The distribution of length frequencies that have been determined in the same length class is then plotted in a graph that illustrates the number of existing age groups and changes in the position size of length [10].

2. Estimation of $L_\infty$, $k$, dan $t_0$

Estimation of growth parameters ($L_\infty$ and $k$) is calculated using the FAO-ICLARM Stock Assessment Tools (FISAT) II version 1.2.2 program with the Electronic Length-frequency Analysis (ELEFAN I) method. Estimation of the $t_0$ (theoretical age of fish at a time equal to zero) value obtained through the equation as follows [11]:

$$\log(-t_0) = -0.0152 - 0.2752 (\log L_\infty) - 1.038 (\log k)$$

(1)

Where:
- $L_\infty$ = asymptotic length of fish;
- $k$ = coefficient of growth;
- $t_0$ = age of fish at length equal to zero.

The value of $k$ and $t$ can be known the maximum age of a fish [11]. Estimation of the maximum age of fish ($t_{\text{max}}$) can be obtained using the following formula:

$$t_{\text{max}} = 3/k + t_0$$

(2)

3. Mortality and exploitation rate

Estimation of the value of natural mortality and total mortality can be found using the FISAT program. Estimation of total mortality through a linear catch curve so that data is based on length. Calculation of total mortality ($Z$) is obtained by using the catch curve method which uses the slope ($b$) and $\ln N/ t$ with the relative age according to the formula [11] as follows:

$$\ln N/t = a - Zt$$

(3)

Where:
- $N$ = Number of fish at time $t$;
- $t$ = The time needed to grow fish with a class interval;
- $a$ = The catch that is converted to length

Natural mortality ($M$) is calculated based on the empirical formula of [11] by entering growth parameters ($k$) per year, asymptomatic length of fish ($L_\infty$) (mm), and average annual water surface temperature in degrees Celsius ($T$). The Pauly empirical formula [11] is as follows:

$$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log k + 0.4634 \log T$$

(4)

Where:
- $M$ = natural mortality (per year);
- $L_\infty$ = asymptotic length in von Bertalanffy's growth equation;
- $k$ = coefficient of growth;
- $t_0$ = age of fish at zero length;
- $T$ = average water surface temperature ($^\circ$C)

Total mortality ($Z$) and natural mortality rate ($M$) is known for the captured mortality rate ($F$) can be determined by the formula:

$$Z = F + M \text{ to be } F = Z - M$$

(5)

The rate of exploitation ($E$) is determined by a comparison of the captured mortality rate ($F$) with the total mortality rate ($Z$), which is as follows:

$$E = F / (F + M) = F / M$$

(6)

Where:
- $M$ = natural mortality rate;
- $F$ = fishing mortality rate;
- $Z$ = total mortality rate

If the value of $E = 0.5$ indicates that the value is optimum ($E_{\text{opt}}$), this is based on the assumption that balanced results are optimum if $F = M$ [11].

4. Economic value
Economic value is obtained from the results of interviews and secondary data, the economic value in question is the value of selling longtail tuna (Rp/kg).

5. Mean trophic level
Mean trophic level is divided into four groups, namely herbivorous (trophic level = 2.0–2.1), omnivores tend to be herbivorous (2.1 < trophic level < 2.9), omnivores tend to be carnivorous (2.9 < trophic level < 3.7), and carnivores (3.7 < trophic level < 4.5). This value is used for productivity and vulnerability analysis [12].

2.3.2 Productivity and susceptibility analysis
Productivity and susceptibility analysis begins with inputting data to the database in excel, then grouping data on all attributes of productivity and susceptibility parameters. Conclusions are obtained through assessment after grouping according to the scores in Table 1 below:

| Tabel 1. Assessment for the attributes of productivity and susceptibility parameters |
|----------------------------------------|----------------------------------------|
| Assessment | Explanation |
| Value | The value indicates the importance of each parameter. This value is quite subjective and is obtained from the assessment of the researcher on which parameters are the most important. The value ranges from 0-4; 0 = not important; 1 = less important; 2 = important; 3 = more important; 4 = very important |
| The score of attributes | The score of attributes are divided based on two parameters, productivity and vulnerability. The score of the parameters range from 1-3 |
| Productivity | Susceptibility |
| 1 = Low | 1 = Low |
| 2 = Moderate | 2 = Moderate |
| 3 = High | 3 = High |
| Data Quality | Data quality ranges from 1-5 |
| 1 = large and complete data; 2 = limited data; 3 = data from the same genus or family; 4 = data must be published information; 5 = no data |

1. Index of vulnerability
Determination of vulnerability index can be calculated using the value of productivity and susceptibility [5], using the formula:

$$v = \sqrt{(p - 3)^2 + (s - 1)^2}$$  \hspace{1cm} (7)

Where:
V = Vulnerability; P = Productivity; S = Susceptibility

Fish that have a vulnerability (v) of more than 1.8 indicate that these fish have a high risk of susceptibility to fishing activities. The vulnerability index has three categories, namely less vulnerable (v < 1.6), moderate susceptibility (1.6v < 1.8) and high range (v ≥ 1.8).

2. Index of Intrinsic Vulnerability catch and Trophic level catch
Index of Intrinsic Vulnerability catch was obtained using the following formula:

$$IV\, catch = \frac{\text{Index of vulnerability of fish species} \times APP}{\text{Total production}}$$  \hspace{1cm} (8)

Where:
IV (Index of Vulnerability catch) = score of vulnerability of fish species
APP (Annual Average Production) = annual average production in tons per year
3. Trophic level catch was obtained using the following formula:

\[
\text{Trophic level catch} = \frac{\text{index of vulnerability of fish species} \times \text{mean trophic level total production}}{\text{total production}}
\]  

(9)

Where: Mean Trophic Level = the position of a species in the food pyramid

3. Results and Discussions

3.1. Value of productivity and susceptibility parameters of longtail tuna (Thunnus tonggol) at Ujung Serangga Fishing Port, Southwest Aceh

The value of the productivity parameters of longtail tuna \((T. tonggol)\) consisting of 10 attributes (Table 2) and susceptibility parameters (Table 3) were examined as follows:

| No. | Parameters                              | Results                          | Value | Score | Quality of data | Unit |
|-----|-----------------------------------------|----------------------------------|-------|-------|-----------------|------|
| 1.  | \(r\) (Intrinsic growth rate)           | 1.00                             | 2     | 2     | 1               | ton/yea r |
| 2.  | Maximum age                             | 11-12                            | 2     | 3     | 1               | year |
| 3.  | Maximum size                            | 71.5                             | 2     | 2     | 1               | cm   |
| 4.  | \(k\) (Von Bertalanffy Growth coefficient) | 0.39                            | 2     | 2     | 1               | /year |
| 5.  | \(M\) (Estimated natural mortality)     | 0.78                             | 2     | 3     | 1               |      |
| 6.  | Measured fecundity                      | 383,347-3,468,350                 | 2     | 3     | 2               | eggs |
| 7.  | Breeding strategy                       | Partial Spawner                  | 2     | 2     | 2               |      |
| 8.  | Recruitment pattern                     | 24.36                            | 2     | 3     | 2               | %    |
| 9.  | Age at maturity                         | 1.90 (Fish base)                 | 2     | 2     | 2               | year |
| 10. | Mean trophic level                      | 4.50 (Fish base)                 | 2     | 1     | 2               |      |

Value of productivity 2.30

High productivity values indicate that longtail tuna \((T. Tonggol)\) has the ability to recover quickly. According Patrick et al. [5], one of characteristics of fisheries resources that have good potential for sustainability is the species of fish that is able to survive well. The results of research on productivity and susceptibility in the Sunda Strait also indicate that the 3 species of tuna have a relatively good level of sustainability of fish resources, which is indicated by a low vulnerability value [7].

| No. | Parameters                          | Results                                     | Value | Score | Quality of data |
|-----|-------------------------------------|---------------------------------------------|-------|-------|-----------------|
| 1.  | Management strategy                 | There are no fishing restriction for target fish | 2     | 3     | 1               |
| 2.  | Areal overlap                       | 80% are in fishing grounds                   | 2     | 3     | 1               |
|   | Information                                                                 | Value |
|---|------------------------------------------------------------------------------|-------|
| 3. | Geographic concentration 80% are spread from fishing grounds                 | 2 1 1 |
| 4. | Vertical overlap 60% are in the same fishing grounds                          | 2 1 1 |
| 5. | F/M (Fishing rate relative to M)                                             | 2 1 1 |
| 6. | Spawning Stock Biomassa (SSB)                                                | 2 1 2 |
| 7. | Seasonal migration The catch decreases                                       | 2 3 1 |
| 8. | Schooling/aggregation and other behavioral responses                           | 2 3 1 |
| 9. | Effect of fishing gear on fish morphology                                    | 2 1 1 |
| 10. | Survival After Capture and release                                           | 2 3 1 |
| 11. | Impact of fishing gear on habitat                                           | 2 2 1 |
| 12. | Economic value Rp. 100.000-150.000 /fish (standard price)                     | 2 3 1 |
|    | Value of susceptibility                                                      | 2.08  |

Analysis of productivity parameters and susceptibility using PSA software also produces a graph of productivity and susceptibility. This graph serves to see the condition of longtail tuna which landed at Ujung Serangga fishing port (Figure 2).

![Graph of productivity and susceptibility](image)

**Figure 2.** Graphs of productivity and susceptibility

The circle numbering in Figure 2 shows the name of the fish sample. This study only uses one type of fish sample, the numbers in the green circle explain the information from the sample of longtail tuna. The color in the circle shows the quality of the data on the attributes of the fish under study. Green circles mean the quality of data used is good or most of the data used is the result of research. If the yellow circle shows the data used is not good. The data used has a data accuracy level that is less then the circle will be red. The longitudinal blue, green and red lines that indicate the limit of susceptibility to fish. Vulnerability can occur if productivity value of species is low and the level of susceptibility is
But the results show that the productivity value are higher than susceptibility values, this means that the longtail tuna has not shown the susceptibility of the species in the fishing grounds (Southwest Aceh waters and WPP 572).

3.2. Vulnerability status of longtail tuna in Southwest Aceh waters, Indonesia
Vulnerability is the threat of fish stocks caused by high capture and low productivity. Based on the results of the vulnerability analysis of longtail tuna (\textit{Thunnus tonggol}) at the Southwest Aceh were 1.29 and value of intrinsik vulnerability catch were 6.44. It showed that longtail tuna at the Ujung Serangga fishing port were in a less vulnerable position. It means that the longtail tuna stock found in the waters of Southwest Aceh is in good condition. This needs to be maintained so that the availability of longtail tuna for the future is guaranteed. Therefore there is a need to limit the capture and sustainable management of fisheries in the purse seine operating area of the Southwest Aceh waters.

4. Conclusion
Longtail tuna (\textit{Thunnus tonggol}) landed at Ujung Serangga Fishing Port have productivity value (2.30) and susceptibility value (2.08) which indicate that this species has a good level of resource sustainability. Vulnerability status of longtail tuna is in good category or low vulnerable with a vulnerability value is 1.29.

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