Population dynamic of Indian scad (*Decapterus russelli*) based on data in Tasikagung fishing Port of Rembang

Aprilia Nur Khasanah, Suradi Wijaya Saputra*, Wiwiet Teguh Taufani
Study Program of Aquatic Resources Management, Department of Aquatic Resources, Faculty Fisheries and Marine Science, Universitas Diponegoro, Jl. Prof. Soedarto, SH, Tembalang, Semarang 50275, Indonesia.
*Corresponding author:: aprilianurkhasanah1@gmail.com

**Abstract.** Indian scad is a small pelagic fish that has important economical value. Indian scad caught by mini purse seine which is the most dominant fishing gear in Tasikagung Fishing Port of Rembang. The high demand of Indian scad in fishermen enlarging their effort. The purpose of this research is to know the growth, mortality rate, exploitation rate and reproduction aspects including gonad maturity level and gonad maturity index of Indian scad. The research was conducted in January – April 2019. The method used was systematic random sampling. Data collected were size of fish (mm), weight (gram), weight of gonads (g) and catching area. The samples were collected twice a month. The length of fish ranged from 102 - 185 mm. The length-weight relationship analysis obtained equation $W = 0.0000546TL^{2.73}$ and $L_{50} = 155$ mm. Estimation of Von Bertalanffy growth equation is $L_{\infty} = 221$ mm, $K = 1.7$ year$^{-1}$, and the time of zero length ($t_0$) = -0.322 year. Total mortality ($Z$) of Indian scad was 2.91 year$^{-1}$, natural mortality ($M$) was 1.48 year$^{-1}$ and the fishing mortality ($F$) was 1.43 year$^{-1}$. This indicates that the rate of exploitation of Indian scad amounted 0.49 year$^{-1}$. The pick recruitment occurred in August and September. The average Indian scad caught in the condition of maturity on gonad maturity level III and IV. Gonad maturity index of male Indian scad was 1.47 and females was 1.59.

1. **Introduction**

Indian scad (*Decapterus* spp) is a small pelagic fish that has an important economic value. The high demand for Indian scad results in fishermen increasing their effort. The potential of small pelagic fish in fisheries management area 712 is 364,663 tons, with the exploitation rate is 0.38 (moderate) [1]. To maintain the conditions of the fish resources in the water need sustainable fish resources management.

Sustainable fish resources management requires biological information about the growth rate, mortality rate, reproductive aspects (gonad maturity level and gonad maturity index), and the exploitation rate. Information about Indian scad in the Java Sea is still lacking especially those landed at Tasikagung fishing port of Rembang, so information is needed about this fish. The result of these resources are expected to be supporting data for sustainable fish resources.

The data collected during January – April 2019 from the trawl landing at Tasikagung fishing port of Rembang. The purpose of this research is to know the estimation of growth, mortality rate, exploitation rate and know the reproduction aspect of Indian scad based on data that is landed in Tasikagung fishing port of Rembang.
2. Material and Method

Method

2.1. Sampling Method

This research was used descriptive method to get description about the biological condition of Indian scad in Java sea that was landed in Tasikagung fishing port of Rembang. Sampling techniques were used a systematic random sampling. The data were collected twice a month from January – April 2019.

![Research Map in Java Sea, Indonesia](image)

**Figure. 1. Research Map in Java Sea, Indonesia**

2.2. Data Collection

Data collected includes primary and secondary data. Primary data include gender, size (mm), weight of fish (g), weight of gonads (g). Secondary data is fishing areas. Sampling area was located in the waters of Karimunjawa, Bawean, Kagean, and Masalembo.

2.3. Data Analysis

Length – weight relationship and condition factor

Length – weight relationship can be obtained from equation:
\[ W = a \cdot L^b \]  

Description: \( W = \) weight (gram); \( L = \) length (mm), \( a = \) intercept; and \( b = \) slope

The linear equation is \( \log W = \log a + b \log TL \). To find value of \( b = 3 \) or \( b \neq 3 \) conducted by \( t \) – test with hypothesis:

- \( H_0 : b = 3 \), Length – weight relationship is isometric
- \( H_1 : b \neq 3 \), Length – weight relationship is allometric. If \( b > 3 \) are allometric positive and \( b < 3 \) are allometric negative.

The condition factors on the growth of isometric fish are determined by a different method of allometric fish growth. The formula used for isometric fish growth (\( b = 3 \)) [2].

\[ K = \frac{W_{10}}{g_{09}/g_{14}} \]  

Description : \( K = \) condition factor, \( W = \) weight (gram); \( L = \) length (mm), \( a = \) intercept; and \( b = \) slope

**Size of first caught (\( L_{50\%} \))**

The size of the first caught can be obtained by plotting the percentage of the cumulative frequency of fish with a long size. The cutting point between curves with 50\% cumulative frequency is a length when \( L_{50\%} \).

**Estimation of growth parameters**

Growth can be estimated using the growth model Von Bertalanffy [3]

\[ L_t = L_\infty \left[ 1 - \exp^{-K(t-t_0)} \right] \]  

\( L_t \) is a fish length at the time of \( t \) (mm), the \( L_\infty \) is the length of fish asymptotic (mm), \( K \) is the coefficient of growth rate (mm/time unit), \( t \) is the age of fish and \( t_0 \) is the fish age when the fish length is 0 (years).

The values of \( L_\infty \) and \( K \) are obtained using the method ELEFAN I (Electronic Length-Frequency Analysis) in the program FiSAT (FAO-ICLARM Stock Assesment Tools) II version 1.2.2 and the value of \( t_0 \) obtained through the Pauly equation [3].

\[ \log(t_0) = 0.3922 - 0.2752 (\log L_\infty) - 1.038(\log K) \]  

**Recruitment**

Determination of recruitment pattern based on the FiSAT II program. The recruitment patterns are predicted from the values of \( L_\infty \), \( K \), and \( t_0 \).

**Mortality rate**

The Parameter to describe death is the mortality rate. The formula of natural mortality rate (\( M \)) is presented as follows

\[ M = 0.8 \exp (-0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T) \]  

The formula of fishing mortality rate (\( F \)) is derived from the calculation

\[ Z = F + M, \text{ be } F = Z - M \]  

The formula to get the exploitation rate (\( E \)) value is specified with the formula:

\[ E = F/(F + M) = F/Z \]  

\( M \) is natural mortality, \( F \) is mortality of arrest, and \( Z \) is total mortality.
Gonad Maturity Level
Observation of the level of maturity of fish gonads is done by noting the morphological traits in fish gonads based on shape, size, colour and filling in the abdominal cavity by looking at the identification key of the maturity of the gonads according to Cassie 1965 [2].

**Gonad Maturity Index**
The gonad maturity index was obtained by comparing the weight of fish's gonads with fish body weight and multiplied by 100% as follows [4]:

\[
GMI = \frac{BG}{BT} \times 100\%
\]

Description: BG: gonad weight (grams); BT: Body weight (gram)

3. **Result**

3.1. **Length-weight relationship and condition factor**
Analysis result of the length-weight relationship of indian scad by caught of a mini purse that was landed in Tasikagung fishing port of Rembang presented in Figure 2.

Equation of length-weight relationship of indian scad is obtained \( W = 0.0000546L^{2.73} \). Value of \( b \) is 2.73, so it can be known that the pattern of fish growth of indian scad is negative allometric. \( b < 3 \) indicates that length-weight relationship have a negative allometry pattern which means length growth is faster than its body weight growth [5]

3.2. **Size structures and Growth parameters**
The length frequency of indian scad caught in Figure 3.

![Figure 2. The graph of length-weight relationship](image)

![Figure 3. The length frequency of Indian Scad](image)
Length size of Indian scad range from 102 – 185 mm (Figure 3). Indian scad most caught on size 150 – 161 mm is 295 fish.

Estimation of Indian scad growth parameter based on $L_\infty = 221$ mm, $K = 1.7 \text{ year}^{-1}$ and $t_0 = -0.322$ year, so that Von Bertalanffy equation is obtained $L_t = 221 \left[1 - e^{-1.7(t+0.322)}\right]$ (Figure 4).

3.3. **Recruitment**

Recruitment is obtained by entering the values of $L_\infty$, $K$, and $t_0$, then calculated using the FiSAT II software. The prediction of peak kite recruitment in Table 1.

| Month      | Recruitment Percentage (%) |
|------------|-----------------------------|
| January    | 0.02                        |
| February   | 0.21                        |
| March      | 0.67                        |
| April      | 1.93                        |
| May        | 5.39                        |
| June       | 11.82                       |
| July       | 17.97                       |
| August     | 27.78                       |
| September  | 28.07                       |
| October    | 5.63                        |
| November   | 0.52                        |
| December   | 0.00                        |

Based on Table 1, Recruitment patterns from Indian scad are widely occurring in August and September with a percentage of 27.7% and 28.07%. This recruitment pattern is useful to suspect the recruitment of fish populations in nature occurring for a year (Figure 5).
3.4. Length of first caught ($L_{50\%}$)

The results measurement against the size of length caught of Indian scad is 155 mm from the total research sample (Figure. 6).

3.5. Mortality rate and exploitation rate

The results of the analysis obtained the value $Z$ is 2.9 year$^{-1}$ year and $M$ is 1.48 year$^{-1}$, so the value of $F$ is 1.43 year$^{-1}$. Based on the result of the calculation, the value $E$ is obtained at 0.49 year$^{-1}$ (Figure. 7). While the value of selectivity fishing was 6.1.
3.6. **Sex ratio**

The results of the research during January – April 2019 were obtained the sex ratio of the male and female is 49.32 : 50.78% or 1:1.03.

3.7. **Gonad maturity level and gonad maturity index**

The indian scad caught during the research in general in the state of mature. Sum of female indian scad in the stage of gonad maturity level IV is 173 fish (Table 2), while the sum of male indian scad in the stage of gonad maturity level I is 107 fish and gonad maturity level III is 110 fish (Table 3).

| Level / Month | Jan | Feb | March | April | Sum |
|---------------|-----|-----|-------|-------|-----|
| I             | 32  | 24  | 11    | 2     | 69  |
| II            | 9   | 17  | 25    | 15    | 66  |
| III           | 3   | 20  | 22    | 24    | 69  |
| IV            | 7   | 54  | 79    | 33    | 173 |
| V             | 8   | 14  | 15    | 8     | 45  |

| Level / Month | Jan | Feb | March | April | Sum |
|---------------|-----|-----|-------|-------|-----|
| I             | 46  | 41  | 18    | 2     | 107 |
| II            | 2   | 30  | 40    | 12    | 84  |
| III           | 2   | 20  | 48    | 40    | 110 |
| IV            | 1   | 22  | 36    | 12    | 71  |
| V             | 11  | 10  | 8     | 8     | 37  |

The value gonad maturity index of female and males indian scad acquired during research is fluctuating each month. The value gonad maturity index of male indian scad is 1.09 – 2.24% and the value gonad maturity index of female indian scad is 1.50 – 1.74%. The highest gonad maturity index of female indian scad occurred in April, while the highest gonad maturity index of male indian scad occurred in March (Fig. 8).

4. **Discussion**

The equation of length-weight relationship of indian scad is obtained \( W = 0.0000546TL^{2.73} \). Some research on indian scad in various waters has also been less distinct. The pattern of growth of indian scad is allometric negative [6]. Indian scad that was landed at Sanggeng Manokwari Papua Fish Landing Base has an allometric negative growth pattern with a value b is 2.03 [7]. Based on some such research it can be noted that the indian scad has a growth pattern that is negative allometric.

The condition Factor value of the indian scad acquired during the research is 1.05. The value of condition factor is 1.34 – 2.95 [6]. The value condition factor of indian scad in Maharashtra water, India amounted to 0.95 – 1.07 [8]. Fish whose condition factor is 1-2, so the body shape of fish is less flattened.
The value of condition factors is closely related to the activity of eating and the availability of eating amounts in nature [9].

Indian fish lengths were range between 102 – 185 mm. Indian scad was arrested in the areas of Karimunjawa, Bawean, Kangean, and Masalembo. The size obtained is not much different from the earlier study[10]. In that study, which did on Latuhalat, was found indian scad susceptible size at 75 – 286 mm. The indian scad in the Makassar Strait has a larger size of 96 – 219 mm, while in Bone Bay 107 – 292 mm [11].

The indian scad in Mumbai Indian waters predictably had the size of the first caught at 183 mm [12]. The indian scad in the Indian Malabar waters had the size of the first caught at 145 mm [13]. Based on the value of L_{50\%} acquired during the research, it showed that the size of fish caught at first was larger than the mesh size of a mini purse seine net. The size of the fish worth catching can be determined by looking for the L_{\infty} value, then calculated with the equation L_{\infty} = L_{\text{max}}/0.95. Based on the equation, it can be concluded if L_{50\%} > 0.5 L_{\infty} shows that the size of fish is still safe and still worth catching [14]. The calculation result size of the first caught is 155 mm which is greater than 0.5 L_{\infty} with a value is 110.5 mm. It shows that in general, the indian scad that caught is still relatively safe for its stock, so it is likely that growth overfishing occurs relatively small.

The result size of the first caught calculation can be used to find the value of the capture tool selectivity with the equation SF = L_{50\%}/mesh size. The net of mini purse seine that used to capture has a mesh size 1 inch or equivalent to 25.4 mm. Based on the equation, the result of SF was 6.1. It indicates the SF is low. It was probably due to the wide difference in the gear used for fishing [15].

Recruitment is the addition of new individuals that occur in a fishery area. Based on the predicted output of data processing, the indian scad recruitment pattern occurred in August and September, with the recruitment of 27.78% and 28.07% (Figure 4). An estimate arrest peak of indian scad in South China Sea, Bawean and Karimun occurred from June to September [16]. The eastern season in Indonesia occurred in July to September, where indian scad migrated through the Java Sea [17]. In the western season that took place from December to January, indian scad entered the Java Sea. Therefore, in eastern season, indian scad was found more in Java Sea, since the weather is relatively calm and fish are already large, so it supports fishermen to catch. The rainy season in Indonesia occurs in September to April. Generally the fish in the tropics do spawning in the rainy season.

Total mortality rate (Z) of indian scad during research is 2.91 year^{-1}, while the natural mortality (M) is 1.48 year^{-1}, fishing mortality (F) is 1.43 year^{-1}. The natural mortality (M) of indian scad in Sorong water-West Wigeo shows greater numbers of 1.68 year^{-1}, while the fishing mortality (F) is 0.82 year^{-1} [18]. The value of M in the waters of Malabar, India for 2.08 year^{-1}, with value of Z is 3.79 year^{-1} and F is 1.71 year^{-1} [12]. Based on a comparison of some of the research data, it is known that the mortality rate of indian scad in Java Sea that was landed in Tasikagung fishing port of Rembang is lower. The analysis of research data can be noted that the value of natural mortality is greater than mortality due to arrest. Natural mortality (M) is influenced by several factors such as competition, predation, disease availability of food, cannibalism and old age [19]. Natural mortality is not the same in every species, depending on the magnitude of predators and competitors in each region [20].

The value of F is 1.43 year^{-1} and Z is 2.91 year^{-1}, it obtained the value of E is 0.49 year^{-1}. This condition can show the utilization status of indian scad according to the criteria Gulland, that the value of E < 0.5 so
that it can be known that the utilization rate of the Indian scad has not exceeded the maximum or under exploited. The higher value of $F$ will be the higher the value of $E$. [13] in the waters of Malabar India has a value of $E$ is 0.49 year$^{-1}$

The exploitation rate of Indian scad in the water district of Anambas Islands is 0.87 year$^{-1}$ [21]. The exploitative species will have an impact on the educations of adult fish so that the adult fish is caught by the gear before the time to perform the spawning at least once in the life cycle [22].

The exploitation rate of Indian scad in Java Sea that landed in Tasikagung fishing port of Rembang is estimated with the formula $E = F/Z$ of 0.49 year$^{-1}$. The value is smaller than the optimum exploitation rate value of $E = 0.5$, so it can be concluded that the Indian scad catching has not exceeded the maximum limit.

The result calculation Chi-Square test of the sex ratio Indian scad as a whole, which is a number of 831 fish shows the result of the genital rate of male and female Indian scad is balanced in the waters. It is evidenced by $X^2$ is 0.024 and $X^2$ table (0.05) is 3.84, with a 95% degree of efficacy of $0.024 \leq 3.84$ so that it can be concluded that the sex ratio of the male and female Indian scad is balanced in the waters or there is no real difference between the number of male and female Indian scad.

The sex ratio of Indian scad in the waters of Bone Bay is 1.01:1.00 [23]. The sex ratio of the Indian scad in the Indian waters of Maharashtra, India amounted to 1:1.45 [8]. The imbalances of the amount of fish in nature have to do with eating habits, spawning or migrating from any kind of fish [23]. Fish-eating habits are influenced by living habitats, preferences for certain types of food, season, size and age of fish. [24] The sex ratio that occurred a significant difference or deviated from the value of one can be caused by the selectivity of the capture equipment on the gender. To obtain a precise conclusion on the difference in gender ratio, additional information is required, including data on arrest areas as well as examples of good and adequate fish in terms of quantity and quality.

The Indian scad caught during the research in general in the state of ripe gonads namely on gonad maturity level III and IV. [25] The higher the tendency of gonad maturity level and gonad maturity index and the higher range of body weight. This can be caused by the environmental condition where the fish is alive, there is no food availability, temperature conformity, salinity and the speed of the fish growth itself. In addition, there is an early distinction of an individual fish experiencing mature gonads caused by the age, size and physiology factor of the fish itself.

The value gonad maturity index of Indian scad is $0.0170-4.8347\%$ [26]. The low value of gonad maturity index occurs due to fish samples obtained largely immature gonads. a fish that has a value of gonad maturity index less than 20% is a fish that can spawn more than once each year [27].

The gonad maturity index is influenced by the length and weight of fish. The weight of Indian scad is likely to rise followed by the weight of the fish body along with the increase of gonad maturity level, on gonad maturity level III and IV there is a rise of gonad weight, thereby affecting the acquired gonad maturity index. In Fig. 8 shows the difference in the value of gonad maturity index significantly, it is due to the number of unbalanced fish samples in each month and has a higher number of maturity, especially in male fish. [28] The gonad maturity index of male and female Indian scad during research shows that increasing the value of gonad maturity index follows the increase in the length of the Indian scad. Where the bigger the size of the fish, the value of the gonad maturity index is greater.
5. **Conclusion**

Based on the research, can be concluded as follows:

1. The growth pattern of Indian scad is an allometric negative with a value of $b$ is 2.73, following the equation Von Bertalanffy $L_t = 221 \left[ 1 - e^{-1.7 (t+0.322)} \right]$; 
2. Natural mortality rate ($M$) of Indian scad that landed in Tasikagung fishing port of Rembang is 1.48 year$^{-1}$ with the value of fishing mortality ($F$) is 1.43 year$^{-1}$, and the exploitation rate ($E$) is 0.49 year$^{-1}$, showing the status of the use of Indian scad is not exceed the maximum limit; and
3. The Indian scad caught at the time of research is generally in the condition of maturity, at the gonad maturity level III and IV. The gonad maturity index of male Indian scad is 1.09 – 2.24% and the gonad maturity index of female Indian scad is 1.50 – 1.74%.

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