Biological aspects of Indian scad (*Decapterus russelli* Ruppell, 1830) in south site of Madura Strait Waters, East Java

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**Abstract.** Indian scad (*Decapterus russelli*) are one of the pelagic fisheries resources in the Madura Strait. The Probolinggo area of the Madura Strait contributes to the scad (*Decapterus spp*) fisheries production in East Java, Indonesia. The purpose of this study was to observe the biological aspects of Indian scad (*D. russelli*) caught in Probolinggo waters which were landed in Paiton (in 2017) and Mayangan (in 2018). The method used was descriptive, with a random sampling technique. Sampling was carried out in Paiton, Probolinggo Regency (January 2017-May 2017) and Mayangan fishing port, Probolinggo City (December 2017-April 2018). Results showed that the growth pattern of Indian scad in Paiton was allometric positive \(W = 0.0049L^{3.2882}\) while in Mayangan it was allometric negative \(W = 0.014L^{2.8513}\). The sex ratio (male:female) was 1:1.67 in Paiton and 1:1.14 in Mayangan. Gonad maturity stages I to IV were found in this study. Gonad maturity of male and female fish was dominated by stages I and II with 79% immature and 21% mature fish in Paiton; 68% immature and 32% mature fish in Mayangan. The mean gonado somatic index (GSI) was 0.83% in Paiton and 0.76% in Mayangan. Length at first capture (Lc) and length at first maturity (Lm) in Paiton were 15.1 cm and 17.1 cm, respectively, whereas in Mayangan Lc and Lm were 15.9 cm and 16.9 cm, respectively. The catch was dominated by immature fish so that fishing efforts need to be controlled to enable sustainable resource use.

1. **Introduction**

Fishes of the genus *Decapterus* are small pelagic fish making a major contribution to fisheries production and therefore have an economic value [1]. The waters of Probolinggo in the Indonesian Malacca Straits are one region where these fishes are caught, with a total recorded catch production of 1518.3 tons/year [2]. One *Decapterus* species caught in Probolinggo is the Indian scad (*Decapterus russelli*) which is commonly landed in several places including in Paiton and Mayangan Fishing Port.

Biological information can describe the condition of fish stocks in a given sea area. The purpose of this study was to evaluate the biological characteristics of Indian scads (*D. russelli*) landed in Paiton and Mayangan. Knowledge regarding these biological aspects could then be used as a basis for sustainable resource management.

2. **Materials and Methods**

This study used descriptive methods with random sampling techniques. The research was conducted in Paiton, Probolinggo Regency (January 2017-May 2017) and Mayangan Fishing Port Probolinggo City (December 2017-April 2018) where landed catches of Indian scad (*Decapterus russelli*) were sampled.
randomly. The data collected for each specimen were the total length (TL, measured from the tip of the snout to the tip of the tail), weight (W), sex, gonad maturity level and gut contents.

2.1. Data analysis

2.1.1. Sea Surface Temperature (SST). Sea surface temperature data were obtained from direct observation during research in Paiton and Mayangan waters, Probolinggo East Java.

2.1.2. Length weight relationship. Length weight relationship was calculated using the formula:

\[ W = aL^b \] ............................(1)

This equation was then log-transformed to produce the linear equation:

\[ \ln W = \ln a + b \ln L, \]

where

- \( W \) = body weight (g)
- \( L \) = total length (cm)
- \( a \) = intercept and \( b \) = slope of the log-transformed linear regression.

To determine the growth pattern, a t test was done on the value of \( b \) with the formula:

\[ \frac{3-b}{sb} \] ..............................(2)

If \( b = 3 \) the relationship is isometric (growth in length proportional to increase in weight); if \( b \neq 3 \) the relationship is allometric (growth in length not proportional to increase in weight). If \( b > 3 \), the relationship is allometric positive (weight increasing faster than length); whereas if \( b < 3 \), the relationship was allometric negative (growth in length faster than increase in weight).

2.1.3. Sex ratio. Sex ratio (number of male fish: number of female fish) was calculated using the formula:

\[ X = \frac{J}{B} \] .............................(3)

where:

- \( X \) = Sex ratio
- \( J \) = Number of male fish
- \( B \) = Number of female fish

Testing for balanced (1:1) or biased (significantly different from 1:1) sex ratio used the Chi-square test with the formula:

\[ X^2 = \sum \frac{(O_i - E_i)^2}{E_i} \] ..........................(4)

where:

- \( X^2 \) = Chi square
- \( O_i \) = The observed value
- \( E_i \) = The expected value

2.1.4. Gonad maturity level (GML). Gonad maturity level was identified macroscopically based on classification introduced by Criscolli [3] in which gonad maturity is divided into five stages: I (Immature), II (maturing virgin and recovering spent), III (ripening), IV (ripe), and V (spent) (Table 1).
Table 1. Gonad Maturity Level [3]

| Stage | Status | Condition |
|-------|--------|-----------|
| I     | Immature | Ovary and testis about 1/3rd length of body cavity. Ovaries pinkish, translucent; testis whitish. Eggs not visible to naked eye. |
| II    | Maturing virgin and recovering spent | Ovary and testis about 1/2 length of body cavity. Ovary pinkish, translucent; testis whitish, more recovering spent or less symmetrical. Invisible eggs |
| III   | Ripening | Ovary and testis are about 2/3rds length of body cavity. Ovary pinkish-yellow colour with granular appearance, testis whitish to creamy. No transparent or translucent visible eggs. |
| IV    | Ripe    | Ovary and testis from 2/3rds to full length of body cavity. Ovary orange-pink in colour with conspicuous superficial blood vessels. Large transparent, ripe visible eggs. Testis whitish creamy, soft. |
| V     | Spent   | Ovary and testis shrunken to about 1/2 length of body cavity. Walls loose. Ovary may contain remnants of disintegrating opaque and ripe eggs, darkened or translucent. Testis bloodshot and flabby. |

2.1.5. Gonadosomatic index (GSI). The gonadosomatic index (GSI) was calculated by dividing the gonad weight and body weight of fish using the formula:

\[
GSI = \frac{W_g}{W} \times 100\% \tag{5}
\]

where:

- GSI = Gonado Somatic Index
- \( W_g \) = Gonad weight (g)
- \( W \) = Body weight (g)

2.1.6. Length at first capture (Lc). The mean length at first capture (Lc) was calculated using the Sparre and Venema [4] formula as follows:

\[
y' = \ln Fc(x+dL) - \ln Fc(x) \tag{6}
\]

where \( Fc(x) \) was a normal distribution curve that has a formula:

\[
Fc(x) = \frac{n}{\sqrt{\pi}} \times \left[ \frac{-(x-x\bar{x})^2}{2s^2} \right] \tag{7}
\]

where:

- Fc = calculated frequency
- n = number of observation
- dL = class interval
- s = standard deviation
- \( x \) = average
- \( \pi \) = 3.14

2.1.7. Length at first maturity (Lm). The length at first maturity (Lm) was estimated using the Sparre and Venema[4] formula as the value of L where \( Q = 0.5 \) in the following equation:

\[
Q = \frac{1}{1 + e^{-a(L-Lm)}} \tag{8}
\]

where:

- Q = proportion of mature fish in size class L
- L = maximum value that indicates 100% maturity
2.1.8. Gut Contents

a. Food Composition. The composition of plankton in the stomach was evaluated using the formulae introduced by Effendie[5] as follows:

\[ \text{Phytoplankton (a): } \% X_a = \frac{a}{a+b} \times 100\% \] ...................................(9)

\[ \text{Zooplankton (b): } \% X_b = \frac{b}{b+a} \times 100\% \] ........................................(10)

where:

- \( X_a \) = Phytoplankton composition (%)
- \( X_b \) = Zooplankton composition (%)
- \( A \) = Number of phytoplankton identified
- \( B \) = Number of zooplankton identified

b. Index of preponderance (IP). The index of preponderance was calculated using the formula according to Effendie [6] as follows:

\[ \text{IP} = \frac{\sum V_i \times O_i}{\sum V_i} \times 100\% \] .........................................(11)

where:

- \( \text{IP} \) = Index Of Preponderance (%)
- \( \text{Vi} \) = Percentage volume of a food (%)
- \( \text{Oi} \) = Percentage frequency of occurrence of a type of food (%)
- \( \sum \text{Vi} \times \text{Oi} \) = Total of \( \text{Vi} \times \text{Oi} \)

Based on the IP value, food was divided into 3 categories. They are main food (IP > 25%), complementary food (IP 4%-25%), and additional food (IP <4%).

3. Results and Discussion

The total Indian scad (Decapterus russelli) sample obtained in Paiton comprised 961 fishes ranging from 9.5 to 19.4 cm in length (TL) and 2 to 102 grams in weight. Of these 961 specimens, biological analysis was conducted on 447 fishes. In Mayangan the total Indian scad sample also comprised 961 specimens with length of 12.3-23 cm TL and 3-131 grams in weight. Of these, biological analysis was performed on 307 of these 961 fishes.

3.1. Sea surface temperature (SST).

Sea surface temperatures in Paiton during the period of January 2017 to May 2017 was between 29.8 and 30.6°C and averaged 30.2 °C (Table 2). Sea surface temperatures in Mayangan during the period of December 2017-April 2018 ranged between 29.1 and 30.2 °C and the average was 29.9 °C (Table 2).

| Table 2. Sea Surface Temperature (SST) in Paiton (2017) and Mayangan (2018) |
|-----------------------------------------------|
| Paiton (2017) | Mayangan (2018) |
|----------------|-----------------|
| Month | SST (°C) | Month | SST (°C) |
| January 2017 | 29.8 | December 2017 | 30.0 |
| February 2017 | 30.4 | January 2018 | 29.4 |
| March 2017 | 30.6 | February 2018 | 29.1 |
| April 2017 | 30.5 | March 2018 | 30.2 |
| May 2017 | 29.8 | April 2018 | 31.0 |
| Average | 30.2 | Average | 29.9 |
3.2. Length weight relationship
The length weight relationship of the Indian scads (D. russelli) sampled at each landing site is presented in the form of scatter graphs (Figure 1 and Figure 2).

![Figure 1. Length Weight Relationship of Indian scads (D. russelli) in Paiton (January-May 2017)](image1)

![Figure 2. Length Weight Relationship of Indian scads (D. russelli) landed in Mayangan (December 2017-April 2018)](image2)

The length weight relationship obtained in Paiton was \( W = 0.0049L^{3.2882} \) with \( R^2 = 0.9224 \), meaning that approximately 96% of the variation in fish weight could be explained by length and 4% was influenced by other factors. The t test analysis (\( t_{\text{count}} > t_{\text{table}} \)) showed that \( b \neq 3 \). The value of \( b \) was higher than 3, so it can be concluded that Indian scads (D. russelli) landed in Paiton had an allometric positive growth pattern, with weight gain dominating over increase in length.

The length weight relationship obtained in Mayangan was \( W = 0.0139L^{2.8515} \), with \( R^2 = 0.9565 \) meaning that approximately 98% of fish weight could be explained by length and 4% was influenced by other factors. The test analysis (\( t_{\text{count}} > t_{\text{table}} \)) showed that the value of \( b \neq 3 \). The value of \( b \) was lower than 3, so it can be concluded that Indian scads (D. russelli) landed in Mayangan had an allometric negative growth with growth in length dominating over weight gain.

Indian scads in Paiton and Mayangan had different growth patterns. These differences were most likely influenced by nutrition and feed consumed by fish [7]. Other factors which can lead to growth pattern differences are the availability of food in the waters, feeding habits, fish growth phase and condition, reproductive cycles (e.g. spawning periods) and also the condition of the surrounding waters [8].

3.3. Sex ratio
The 447 Indian scads sampled in Paiton comprised 280 male (63%) and 167 female (37%) fish. The male:female ratio was 1:1.6 (Figure 3A). The chi square test obtained \( X^2_{\text{count}} = 0.127 < X^2_{\text{table}} = 3.841 \) meaning there was no significant difference between the ratio obtained and the expected ratio. The 307 Indian scads sampled in Mayangan consisted of 164 males (53%) and 143 (47%) females. The
male:female ratio was 1.14:1 (Figure 3B). The chi square test obtained \( X^2_{\text{count}} = 0.009 < X^2_{\text{table}} = 3.841 \) meaning that there was no significant difference between the ratio obtained and the expected ratio.

![Figure 3. Sex Ratio of the sampled Indian scads (D. russelli): A. in Paiton; B. in Mayangan](image)

The sex ratio in Paiton and Mayangan was considered balanced even though the number of male fish was higher than the number of female fish. For most pelagic species, a sex ratio of 1:1 is considered an ideal condition [9]. Assuming equal production of each sex during reproduction, a balanced sex ratio will tend to be maintained if fish of both sexes are similarly active and have the same chance of being caught. A balanced sex ratio also indicates that, on average, one male fish will fertilize one female fish [10]. The spawning season was also thought to be a factor in the balance of the sex ratio because the number of male and female fish can change before spawning. The samples were dominated by male fish during the spawning season; however before the spawning season, male and female fish were in a balanced condition, and after the spawning season the samples were dominated by female fish.

### 3.4. Gonad maturity level (GML)

Gonad maturity found in Paiton and Mayangan were varied from level I-IV (Figure 4) and no gonads were found in level V.

![Figure 4. Gonad Maturity Level of Indian scads (D. russelli): A. in Paiton; B. in Mayangan](image)

The catch in Paiton was dominated by immature fish (level I and II) during every sampling month. The proportion of immature fish (79%) was higher than that of mature fish (21%). In Mayangan the catch in was also dominated by immature fish, although slightly less so, with 68% immature and 32% mature fishes.
3.5. Gonadosomatic index (GSI)

Gonadosomatic index (GSI) of Indian scads \((D.\ russelli)\) in Paiton ranged between 0.03% and 9.96% (mean = 0.83%), and in Mayangan GSI ranged from 0.02% -5.27% (mean 0.76%). Fish with GSI values less than 20% are generally classified as partial spawners, which can spawn more than once in a year [11]. The results indicate that that Indian scads \((D.\ russelli)\) in Probolinggo waters spawned more than once in a year, as previously reported for \(D.\ russelli\) in India by Poojary, et al. [12]. Low GSI values are also reported for \(D.\ russelli\) caught off the north coast of Java in Sumenep [13].

The GSI range for male fish in Paiton was 0.038-3.017% and for females 0.070-9.969%. In Mayangan the GSI range was 0.027-3.512% for males and 0.028-5.275% for females. In both Paiton and Mayangan the GSI of female Indian scads was higher than that of males. This indicates that weight of ovaries was in general greater than that of testes. Mature ovaries tend to be larger than mature testes [12]. When the size of the ovary increases, the weight also increases which also results in an increase in total body weight [14].

3.6. Length at first capture (Lc)

Length at first capture (Lc) in Paiton was 15.1 cm (Figure 5A), and was lower than the Lc in Mayangan which was 15.9 cm (Figure 5B).

![Figure 5](image_url) **Figure 5.** Length at first capture (Lc) of Indian scads \((D.\ russelli)\): A. in Paiton and B. in Mayangan

3.7. Length at first maturity (Lm)

Length at first maturity of indian scad \((D.\ russelli)\) in Paiton was 17.1 cm (Figure 6A) while Lm in Mayangan was 16.9 cm (Figure 6B). The value of Lm in Mayangan was lower than in Paiton.

![Figure 6](image_url) **Figure 6.** Length at first maturity of Indian scads \((D.\ russelli)\): A. in Paiton; B. in Mayangan

Even though the fish are the same species, Indian scads in Paiton and Mayangan had different Lm sizes. According to Dahlan, et al.[15], differences in the size and age at which fish first mature are
likely to occur. Fish in the same species can have different Lm values depending on environmental conditions and geographical location. The size at first maturity Lm can influenced by several factors including genetic characteristics, differences in latitude, water quality, and fishing effort [16]. The lower values of Lc compared to Lm for Indian scads in both Paiton and Mayangan was in accordance with previous research on Indian mackerel (*Rastrelliger kanagurta*) in the Madura Straits [17]. Environmental factors and fishing effort are thought to be the causes of differences in Lm of Indian scads (*D. russelli*) in this study. Sea surface temperatures during the study period in 2017 were warmer than during the 2018 study period. Another possible contributing factor is the difference in fishing effort between Paiton and Mayangan.

3.8. Stomach contents
The main food found in the guts of the Indian scads (*D. russelli*) sampled was arthropods (IP> 25%). Complementary foods (4-25% IP) were Ochrophyta, Ciliopora, Cyanobacteria, and small fish while additional foods (IP <4%) were Cnidaria, Myzozoa, Bacillariophyta, Mollusca, Larvae, Chlorophyta, and Echinodermata (Figure 7). Based on types of food identified, it appears that the Indian scad (*D. russelli*) is a predominantly carnivorous fish because the food was dominated by zooplankton with the proportion of about 60% and the other was phytoplankton with the proportion of about 38%. In addition small fish and molluscs were also found in small numbers in fish guts. Poojary *et al.*[12] found that dominant foods of Indian scad (*D. russelli*) were crustaceans and fish. Other crustaceans such as shrimp and crabs, cephalopods and planktonic crustacea were found in small numbers. These findings differ from those reported from Sumenep on the north coast of Java, where the main food category for the Indian scad (*D. russelli*) was dominated by the phylum Ochrophyta [13].

4. Conclusion
The growth pattern of the Indian scad (*D. russelli*) was allometric positive in Paiton and allometric negative in Mayangan. The sex ratio (male:female) appeared to be male-biased in both Paiton and 1:1.14 Mayangan but was not statistically significantly different from 1:1 (balanced sex ratio). The Gonad Maturity Level (GML) was predominantly I and II at both sites, which means that the catches of Indian scads (*D. russelli*) in both Paiton and Mayangan were dominated by immature fish. The mean gonadosomatic index (GSI) was relatively low in both Paiton and Mayangan, indicating a partial spawning habit with individuals spawning several times in a year. At both sites, Lc was below Lm. The length at first capture (Lc) was lower in Paiton (15.1 cm) was lower than in Mayangan (15.9 cm); conversely the length at first maturity (Lm) was higher in Paiton (17.1 cm) than in Mayangan (16.9 cm).
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References

[1] Suwarsoand A and Zamroni 2013 Stock Spread of Scad (Decapterus spp.) and Utilization risk of Small Pelagic Fisheries Resources in Java Sea J. Fish. Policy Ind. 5 17–24
[2] Fisheries Board of East Java Province 2014 Fisheries Statistical Data Report of East Java Province (Surabaya)
[3] Criscoli A, Colloca F, Carpentieri P, Belluscio A and Ardizzone G 2006 Observations on the reproductive cycle, age and growth of the salema, Sarpasalpa (Osteichtyes: Sparidae) along the western central coast of Italy Sci. Mar. 70 131–8
[4] Sparre P and Venema S C 1999 Introduction to Tropical Fish Sock Assessment (Rome: FAO Fisheries Technical Paper)
[5] Effendie M I 1997 Fisheries Biology (Yogyakarta: PustakaNusatama Foundation)
[6] Effendie M I 2002 Fisheries Biology (Yogyakarta: Pustaka Nusatama Foundation)
[7] Sonnaria N A, Yanti A H and Setyawati T R 2015 Reproduction Aspect of Toman Fish (Channamicropeltes Cuvier) In KelubiLake, TayanHilir District, Sanggau Regency, West Borneo Protobiont. 4 38–45
[8] Liestiana H, Ghofer A and Rudyanti S 2015 Biological Aspect of Scad (Decapterus macrosoma) Landed in Coastal Fishing Port of Sadeng, Gunung kidul, Yogyakarta Lies. 4 10–8
[9] Bal D V and Rao K V 1984 Marine Fisheries (New Delhi: Hill Publishing Company Limited)
[10] Senen B, Sulistiono and Muchsin I 2011 Several Biological Aspect of Scad (Decapterus macrosoma) in Banda Neira Sea. Molucca. Prosiding of National Seminar About Small Islands Development
[11] Adjie S and Fatah K 2015 Biology Reproduction of Red Devil (Amphilopus labiatus) and(Amphilopus citrinellus)in Kedung Ombo Reservoir, Central Java Bawal. 7 17–24
[12] Poojary N, Tiwari L R and Dasaribhoomaiah 2015 Histological studies on the gonads of the Indian scad Decapterus russelli (Ruppell. 1830) from Maharashtra waters. north-west coast of India Indian J. Fish. 62 75–81
[13] Bintoro G, Rudianto T D, Lelono and Syehbiarachman H 2019 Biological Aspect of Indian Scad (Decapterus russelli) Caught by Purse Seine in North Coast of Sumenep Waters, East Java IOP Conference Series: Earth Environment Science
[14] Fadila M, Asriyana and Tadjuddah M 2016 Several Aspect of Reproduction Biology of Mackerel Scad(Decapterus macarellus) Caught by Purse Seine Landed in Ocean Fishing Port of Kendari Journalof Waters Resour. Manag. 1 343–53
[15] Dahlan M A, Omar S B A, Tresnati J, Umar M T and Nur M 2015 Sex Ratio and Length at first mature of Shortfin Scad (Decapterus macrosoma BLEEKER 1841) in Bone Gulf Waters, South Celebes Mar. Sci. Fish. J. 25 25–9
[16] Rahardjo M F and Simanjutak C P H 2007 Reproduction Aspect of Tetet Fish (Johnius belangerii Cuvier, Pisces: Sciaenidae) Mayangan Coastal Waters, East Java J. Fish. Sci. 9 200–7
[17] Bintoro G, Jauhari A, Lelono T D, Rudianto and Wardani H F 2019 Biological AspectAnalysis of Indian Mackerel (Rastrelliger kanagurta Cuvier, 1816) Caught by Purse Seine in Probolinggo Waters, Madura Strait, East Java IOP Conference Series: Material Science and Engineering