Population dynamics of Indian scad (*Decapterus russelli*) in the northern and western waters of Aceh

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Abstract. Indian scad (*Decapterus russelli*) is an important commercial species that landed at the Fishing Port of Kutaradja, Banda Aceh. This research was conducted to investigate the impact of exploitation on *D. russelli* stock based on length-weight relationship, length distribution, length at first capture, von Bertalanffy growth parameters and function, mortality parameters, and exploitation rate. The data collection was conducted from February to March 2020 in the Fishing Port of Kutaradja, Lampulo, Banda Aceh. A total of 170 samples were measured with stratified random sampling method. Analysis of population dynamics parameters used the FAO-ICLARM Stock Assessment Tools (FiSAT) program. The results show that *D. russelli* has a positive allometric growth pattern, with a fork length (FL) ranging from 19.5-31.5 cm. The length of first capture was 23.1 cm. The asymptotic length (*L∞*) of *D. russelli* was 31.50 cm with a growth rate (*k*) of 0.88/year and fish age at length 0 (*t₀*) of 0.178/year. The estimated natural mortality (*M*), fishing mortality (*F*), and total mortality (*Z*) were 1.63/year, 2.22/year and 3.85/year respectively. The exploitation rate (*E*) of *D. russelli* was 0.58/year that indicated *D. russelli* in the northern and western waters of Aceh has been fully exploited.

1. Introduction

Indian scad (*Decapterus russelli*) is a fast and active swimmer fish from the family of *Carangidae* [1] and prefers waters with a high salinity of 32-34 ‰ (stenohalines) [2]. The *D. russelli* are generally caught in the northern waters of Aceh and Malacca Strait. Pelagic fish, such as Indian scad and mackerel, are mostly caught in the northern part of Aceh waters, covering the eastern waters of North Sumatra and East Aceh, North Aceh and Banda Aceh waters [3]. This distribution is due to the higher salinity in the northern part of the Malacca Strait than the surrounding waters. *D. russelli* caught in the northern and southern waters of Aceh often landed at the Fishing Port of Kutaradja, Banda Aceh City. The production of *D. russelli* in this fishing port reaches 200-900 tonnes per month with production per year reaching 5000 tonnes, but the productivity experienced fluctuating conditions in 2011-2016 [4]. Catch per unit effort (CPUE) of scads have increased in the 2011-2015 period, with the highest CPUE occurring in 2015 at 932.51 kg/trip. CPUE experienced a significant decrease in 2016 to 748.48 kg/trip [5].

The exploitation of *D. russelli* will have an impact on decreasing its stock in the waters. Population dynamics studies from *D. russelli* in the northern and western waters of Aceh are needed to assess the
catch response to the biological conditions of fish populations [6-9]. Research related to population dynamics of *D. russelli* has previously been conducted in the eastern waters of the Java Sea, Mapur, Bintan and Sunda Strait waters [10, 11]. The research aims to study the population dynamics of *D. russelli* based on length-weight relationship, length distribution, length at first capture, von Bertalanffy growth parameters and function, mortality parameters, and exploitation rate.

2. Materials and method

2.1. Data collection
The research was conducted from February to March 2020 in the Fishing Port of Kutaraja, Banda Aceh City. Primary data collection was obtained from the measurement of fork length (FL) and weight of the sampled fish by using a randomized layered sampling method on fish landed by purse seines with daily and weekly trip types. The number of fish samples measured during the study was 170 individuals. Samples were taken and measured three times a week.

2.2. Data analysis
The first caught size average (*SL*<sub>50</sub>) calculation used an escape vent selectivity approach with a logistic function [12]. The formula used is as follows:

\[
SL_{50} = \frac{1}{1 + \exp(aL + b)}
\]

Where:
- *SL*<sub>50</sub>: Fish with *L* length caught is divided by fish with length escaped from fishing gear
- *a* and *b*: Curve parameter (*a*<0 and *b*>0), so the length at 50% caught (*SL*<sub>50</sub>) same with –a/b

Growth parameter (*K* and *L*<sub>∞</sub>) was determined by ELEFAN I method based on the von Bertalanffy equation as follows [13].

\[
L_t = L_\infty (1 - e^{-k(t - t_0)})
\]

Where:
- *L*<sub>t</sub>: Length of fish on the age of *t* (cm)
- *L*<sub>∞</sub>: Asymptotic length (cm)
- *k*: Growth rate
- *t*<sub>0</sub>: Fish age at length 0 (cm)

*k* value was obtained by tracing the total length data of fish from month to month. The growth parameter *t*<sub>0</sub> was calculated by the equation as follows [13]:

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

The total mortality rate (*Z*) was estimated by the fish catch curve method using slope (*b*) and Ln *N/t* with relative age according to Pauly [14] formula as follows:

\[
\ln N/t = a - Zt
\]

Where:
- *N*: The number of fish in the *t* period
- *t*: The period needed for growing a length class
- *a*: Fish catch result conversed towards length

Meanwhile, the natural mortality of fish was assumed using the empirical formula as follows [14].
Log $M = -0.0066 - 0.279 \log + 0.654 \log k + 0.4534 \log T$

Where:
- $M$ : natural mortality rate
- $L$ : maximum length (cm)
- $k$ : growth rate (cm/year)
- $T$ : temperature (°C)

For the mortality rate due to fishing was obtained by reducing the total mortality rate ($Z$) with natural mortality rate ($M$) or $F = Z - M$ and the rate of exploitation ($E$) was calculated as $E = F/Z$ [12].

3. Results and discussion

3.1. Length-weight relationship

The length-weight relationship of $D. russelli$ has the equation $W = 0.011L^{3.069}$ with a determination coefficient of 91%. The t-test results indicate that this relationship has a positive allometric growth pattern. This coefficient shows a very strong correlation between fish body length and body weight, meaning that weight gain is closely related to fish body length. The positive allometric growth pattern in $D. russelli$ shows that body weight gain is faster than body length growth. The results differ from the results of research in the waters of the Malacca Strait which state that the growth of $D. russelli$ is negative allometric [15]. Fish growth patterns vary widely depending on environmental conditions and food availability in the fish habitat [16].

![Graph showing length-weight relationship](image)

**Figure 1.** Length-weight relationship of Indian scad ($Decapterus russelli$).

3.2. Length frequency distribution

The fork length of $D. russelli$ in the eastern and western waters of Aceh ranges from 19.5-31.5 cm. The fork length in the eastern and western waters of Java ranges from 10.5-23.5 cm, while in the waters of the Riau Islands it has a fork length of 15-24 cm [10, 11]. This difference occurs due to differences in sampling time, number of samples, geographical location, fish behavior, and fish habitat [17, 18].
3.3. Length at first capture

The first captured length ($L_c$) obtained by plotting the percentage of the cumulative frequency of fish caught with the fork length, where the intersection point between the curve with 50% cumulative frequency is the length at which 50% of the fish were caught. Figure 4 shows that the $L_c$ of $D. russelli$ is 23.1 cm FL. The $L_c$ is the intersection point between the curves with a 50% cumulative frequency. The $L_c$ can predict its sustainable size by comparing the $L_c$ value with 50% of the $L_\infty$ [19].

3.4. Growth parameters

Growth parameter analysis was carried out to estimate the asymptotic length, growth coefficient, and theoretical age when the length of $D. russelli$ was equal to zero, as presented in Table 1.

| Parameter          | Value  |
|--------------------|--------|
| $L_\infty$ (cm)    | 32.5   |
| $k$ (year$^{-1}$)  | 0.88   |
| $t_0$ (year)       | -0.178 |

The growth parameters studied were asymptotic length ($L_\infty$), von Bertalanfyy growth rate ($k$) and fish age at length 0 ($t_0$). Table 1 shows that $L_\infty$ was 32.50 cm FL, $k$ was 0.88 year$^{-1}$ and $t_0 = -0.178$ year. Based on the growth parameters, the von Bertalanfyy growth equation curve is obtained, namely $L_c = 32.50[1-e^{-0.88 (t + 0.178)}]$. Figure 3 shows that the curve is in an upward state until it reaches a maximum length of 32.5 cm FL, which means that the fish experiences fast growth and reaches a maximum length at the age of 5-6 years, after which it will experience slow growth because of the energy generated from it. Metabolic processes are used to reproduce and repair damaged cells [20].

The growth coefficient of $D. russelli$ which is close to the value of 1 indicates that the growth rate of $D. russelli$ is relatively fast [21]. Fish that have a high growth coefficient value will be faster to reach their asymptotic length, but have a relatively short lifespan [22]. The growth parameters of several studies were different. This difference is caused by differences in the maximum length of the samples taken, the aquatic environment characteristics, the number of sample intervals selected, and the mathematical calculations used [23]. Growth parameters are also influenced by the fast and slow growth of fish, which differs based on internal factors such as heredity, sexuality, age, disease, parasites and external factors such as food and water conditions [24].

![Figure 2. Length frequency distribution of Indian scad (Decapterus russelli).](image)
3.5. Mortality parameters and exploitation rate

The mortality rate for *D. russelli* includes the natural mortality (*M*), the fishing mortality (*F*) and the total mortality (*Z*). The mortality rate is obtained by regressing the relative age with the Ln (N/s) function and plotting it into a catch curve graph as shown in Figure 4.

The fishing mortality of *D. russelli* in the northern and western waters of Aceh is higher than its natural mortality. The mortality of *D. russelli* was predominantly caused by high fishing activity rather than natural factors. Research in Mapur waters, Sunda Strait, Malacca Strait, and Camotes Sea showed that the fishing mortality rate was higher than the natural mortality rate [10, 15, 25]. A fish stock experiences an overfishing condition when the fishing mortality rate equals or more than half of its total mortality rate [26]. The exploitation rate of *D. russelli* in the northern and western waters of Aceh is 0.58 per year. The optimal value of exploitation rate is 0.5, and if it is higher than this value, it indicates the fish stock is in a fully exploited condition.
4. Conclusion

The growth pattern of *D. russelli* is positive allometric with a length range of 19.5-31.5 cm FL. The length value first caught (*L_*<sub>c</sub>) was 23.1 cm FL. The growth rate (*k*) was 0.88 year<sup>-1</sup> and the asymptotic length (*L*<sub>∞</sub>) was 32.50 cm FL. The natural mortality rate (*M*) was 1.63 year<sup>-1</sup>, the fishing mortality rate (*F*) was 2.22 year<sup>-1</sup>, and the total mortality rate (*Z*) was 3.85 year<sup>-1</sup>. The fishing mortality shows a higher rate than the natural mortality rate, hence the exploitation rate (*E*) of *D. russelli* to reach 0.53. This value indicates that its utilization is in a fully exploited condition.

References

[1] Nontji A 2005 Laut Nusantara (edisi revisi) Djambatan, Jakarta
[2] Aprilianti H 2000 Aspek Reproduksi Ikan Layang di Perairan Sibolga Skripsi Fakultas Perikanan IPB, Hal 75
[3] Hariati T, Taufik M and Zamroni A 2017 Beberapa aspek reproduksi ikan layang (*Decapterus russelli*) dan ikan banyar (*Rastrelliger kanagurta*) di perairan Selat Malaka, Indonesia Jurnal Penelitian Perikanan Indonesia 11 47-56
[4] DKP Aceh 2019 Statistik Perikanan Provinsi Aceh Tahun 2018 Dinas Kelautan dan Perikanan Aceh
[5] Sari R N, Miswar E and Marwan C 2017 Studi hasil tangkapan ikan layang (*Decapterus* sp.) dengan alat tangkap pukat cincin (*purse seine*) yang didaratkan di Pelabuhan Perikanan Samudera (PPS) Lampulo Jurnal Ilmiah Mahasiswa Selat Malaka 2 129-135
[6] Damora A, Ariyogagautama D, Wahju R I, Susanto H and Wang J 2018 Growth and mortality rate of Black Pomfret *Parapristotomus niger* (Bloch, 1795) and Silver Pomfret *Pampus argenteus* (Euphrasen, 1788) in Paloh Waters, West Kalimantan, Indonesia Biodiversitas Journal of Biological Diversity 19 2247-2251
[7] Damora A and Baihaqi B 2016 Struktur ukuran ikan dan parameter populasi madidihang (*Thunnus albacares*) di perairan Laut Banda BAWAL Widya Riset Perikanan Tangkap 5 59-65
[8] Damora A and Wagiyo K 2016 Parameter populasi ikan kadah (*Valamugil speigleri*) sebagai indikator pemanfaatan sumber daya perairan estuaria di Pemalang BAWAL Widya Riset Perikanan Tangkap 4 91-96
[9] Rahmah A, Makhfirah A, Damora A, Miswar E, Aprilla R and Sembiring A 2019 IOP Conference Series: Earth and Environmental Science 348 012116
[10] Desmawanti D, Efrizal T and Zulfikar A 2013 Kajian Stok Ikan Layang (*Decapterus russelli*) Berbasis Panjang Berat dari Perairan Mapur Yang Didaratkan Di Tempat Pendaratan Ikan Pelantar Kud Kota Tanjungpinang Universitas Maritim Raja Ali Haji. Kepulauan Riau
[11] Prihartini A 2006 Program Pascasarjana Universitas Diponegoro
[12] Sparre P and Venema S 1999 Introduction of tropical fish stock assessment, Book 1: Manual Center for Fisheries Research and Development. Jakarta
[13] Pauly D 1987 ICLARM conf. Proc 13 7-34
[14] Pauly D 1990 Length-converted catch curves and the seasonal growth of fishes *Fishbyte* 8 33-38
[15] Alnanda R, Setyobudiandi I and Boer M 2020 Dinamika populasi ikan layang (*Decapterus russelli*) di perairan Selat Malaka MANFISH JOURNAL 1 1-8
[16] Nikol'skiǐ G V 1963 The ecology of fishes Academic press
[17] Boer M 1996 Pendugaan koefisien pertumbuhan (*L*<sub>∞</sub>, *K*, *t*_0) berdasarkan data frekuensi panjang *Journal Ilmu-ilmu Perairan dan Perikanan Indonesia* 4 75-84
[18] Oktaviyani S, Boer M and Yonvitner Y 2016 Aspek biologi ikan kurisi (*Nemipterus japonicus*) di perairan Teluk Banten BAWAL Widya Riset Perikanan Tangkap 8 21-28
[19] Saputra S W, Soedarsono P and Sulistyawati G A 2009 Beberapa aspek biologi ikan kuniran (*Upeneus spp.*) di perairan Demak *Jurnal Saintek Perikanan* 5 1-6
[20] Anisyah A 2016 Universitas Islam Negeri Maulana Malik Ibrahim
[21] Gulland J A 1983 Fish Stock Assessment: A Manual of Basic Methods
[22] Hasnawati R, Andi Z and Tengku S 2013 Kajian pemanfaatan ikan layang (Decapterus russelli) berdasarkan hubungan panjang berat dan mortalitas pada pelabuhan pendaratan ikan di Desa Malang Rapat Kabupaten Bintan [skripsi] Program Studi Manajemen Sumber Daya Perairan Fakultas Ilmu Kelautan dan Perikanan, Universitas Maritim Raja Ali Haji

[23] Widodo J and Suadi 2006 Pengelolaan Sumberdaya Perikanan Laut Universitas Gajah Mada Press. Yogyakarta

[24] Effendie M I 1997 Biologi perikanan Yayasan Pustaka Nusatama. Yogyakarta 163

[25] Narido C I, Palla H P, Argente F A T and Geraldino P J L 2016 Population dynamics and fishery of roughear scad Decapterus tabl Berry 1968 (Perciformes: Carangidae) in Camotes Sea, Central Philippines Asian Fisheries Science 29 14-27

[26] Gulland J 1971 The Fish Resources of The Ocean. West Byfleet, Surrey Fishing News (Books), Ltd., for FAO 255