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Biological aspects of roundscads (*Decapterus* spp.) inhabiting the waters of Southeast Maluku, Eastern Indonesia

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Abstract

This research was conducted at Langgur City, Southeast Maluku Regency, Maluku Province, Eastern Indonesia from November 2020 to February 2021 to study biological aspects of roundscads (*Decapterus* spp.) which consist of species composition, sex ratio, gonad maturation level, size distribution, length-weight relationship and condition factor. Samples were collected at traditional fish market in Langgur City. Fish samples collected at the market were put into cool box and then brought to the laboratory for further examination. Fish samples were identified, separated based on species, dissected to determine their sex and gonad maturation stage and then measured. Totally, there were 290 specimen collected which consist of five species namely *Decapterus kurroides*, *D. macarellus*, *D. macrosoma*, *D. muroadsi* and *D. russelli*. Sex ratio between male and female for all species showed 1:1. Gonad maturation level showed that stage I and II have higher percentage than stage III and IV indicates immature fish more dominant compare to mature one. Among five species found, *D. macarellus* has larger size while the smaller belongs to *D. muroadsi*. Results of length-weight relationship analysis showed that roundscads inhabiting Southeast Maluku waters have isometric and negative allometric growth pattern with relative condition factor around 1.00.

Keywords: Sex ratio, Gonad maturation level, Size distribution, Length-weight relationship, Condition factor

Introduction

The types of small pelagic fish that dominate the catch and are caught throughout the year by traditional fishers mostly come from the genus Decapterus of family Carangidae. Roundscads (*Decapterus* spp.) or known as *ikan momar* by the people of Maluku is a small pelagic fish that has economic value and is abundant in Indonesian waters. To date, 8 species of roundscads have been reported in Indonesian waters (Baweleng et al., 2018; Dahlan et al., 2015; Firdaus et al., 2020; Latumeten et al., 2019;

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Ongkers et al., 2016; Pattikawa et al., 2017, 2018; Umar et al., 2019).

Roundscads (*Decapterus* spp.) are shoaling small pelagic fishes which are widely distributed in tropical and subtropical waters around the world. These species have low tropic level i.e. around 3.0 (Froese & Pauly, 2022), thus they occur in school in the upwelling areas where the physical environment produces a large biomass of phytoplankton and zooplankton. As zooplankton feeders, roundscads (*Decapterus* spp.) feed on small planktonic invertebrates, primarily consist of copepods and macrurans as well as small fishes and molluscs (Smith-Vaniz, 1999). Roundscads (*Decapterus* spp.) are high quality table fish in great demand and marketed mostly in fresh or iced condition to be consumed by local communities. In addition, these fishes are also used by local fishers to catch large pelagic fish such as tuna.

Research on roundscads has been widely carried out in the waters of Maluku Province, Eastern Indonesia. However, the studies conducted have focused more on certain species of the genus Decapterus or concentrated in the waters around Ambon Island and Seram Island, Northern part of Maluku Province (Ongkers et al., 2016; Pattikawa et al., 2017, 2018; Purnama, 2020; Silooy et al., 2021; Soumokil, 2002; Syahailatua & Sumadhiharga, 1991). Based on the literature search, research on roundscads in southeastern parts of Maluku Province such as in the waters of the Aru islands, Kei islands and Tanimbar islands is very rare, maybe even not available until now.

Southeast Maluku waters in Maluku Province have abundant resources of roundscads. This can be seen by the availability of roundscads in traditional fish markets in Tual City and in Langgur City, Southeast Maluku every day. Despite having abundant resources of roundscads, no information on this resource in the waters of Southeast Maluku have ever been documented. Based on the background stated above, this research was designed to study biological aspects of roundscads in Southeast Maluku waters which consist of species composition, sex ratio, gonad maturation level, size distribution, length weight relationship and condition factor.

Materials and Methods

This research was carried out in West monsoon from November 2020 to February 2021. During this period the waters is calm, so many fishers go to the sea for fishing. Thus this period is considered as a peak fishing season for traditional fishers in Southeast Maluku Regency, Maluku Province Eastern Indonesia. Roundscads (*Decapterus* spp.) were caught using purse seine, lift net and hand line by traditional fishers who sold them directly to the fish traders in the market.

Samples were collected randomly every two weeks at traditional fish market in Langgur city, the capital of Southeast Maluku Regency then brought to laboratory to be investigated. Roundscads (*Decapterus* spp.) were identified based on Smith-Vaniz (1999). Identified fishes were separated based on their species, dissected to determine their sex and gonad stage and then measured. Total length was measured from the tip of the mouth till the end of the tail using plastic ruler with accuracy 0.1 cm and weighted using digital balance to nearest 1 g.

Deviation of 1:1 ratio between male and female was evaluated by using a Chi-square test with significance at $p < 0.05$ (Fowler & Cohen, 1992). Gonad maturity stage was determined macroscopically based on size, color and texture according to Effendie (2002) (Table 1). Length-weight relationship was analyzed using power function $W = aL^b$ (Pauly, 1984) that can be transformed into linear regression as log W = log a + b log L, where

Table 1. Characteristics of gonad maturity stage of female and male fish

Stage	Female	Male
I. Immature or rest	Ovaries are very small, translucent, string shaped. Eggs are invisible to the naked eye	Testes are very small, translucent, string shaped
II. Developing	Ovaries increase in size, opaque, orange color. Eggs are invisible to the naked eye	Testes increase in size, opaque, creamy white in color
III. Ripe	Ovaries are large, opaque, yellow to orange in color. Eggs are visible to the naked eye, round shaped and translucent	Testes are large, white in color
IV. Spawning	Ovaries are larger and release eggs when pressed. Eggs are visible, large and round shaped, yellow in color, free in ovaries	Testes become larger, white in color and release sperm with little pressure
V. Spent	Ovaries shrinking and flabby. Some residual eggs are visible	Testes become smaller and flabby, small quantity of residual sperm release when pressed

W = weight (g), L is total length (cm), a is intercept, and b is slope. Student's t-test and value of b at 95% confidence interval were used to analyze deviation of b value from 3 (Sparre & Venema, 1992). Relative condition factor was calculated using formula $Kn = W / aL^b$ (King, 2007), where Kn is relative condition factor, W is observed weight (g), and aL^b is calculated weight (g) based on length-weight relationship of the species. Data was processed with Excel 2013.

Results and Discussion

Species composition

During the study, 5 species of roundscads were identified (Table 1). The common name for roundscads (*Decapterus* spp.) in Indonesian is *ikan* (fish) *layang* and specific name for all species in Indonesian except *D. Muroadsi* is shown in Table 2.

To date, it has been reported that there are 11 valid species of roundscads worldwide (Froese & Pauly, 2022) and 8 of those species occur in Indonesian waters, namely *D. akaadsi, D. kurroides, D. macarellus, D. macrosoma, D. maruadsi, D. muroadsi, D. russelli* and *D. tabl* (Baweleng et al., 2018; Dahlan et al., 2015; Firdaus et al., 2020; Latumeten et al., 2019; Ongkers et al., 2016; Pattikawa et al., 2017, 2018; Purnama, 2020; Silooy et al., 2021; Umar et al., 2019).

Latumeten et al. (2019) in their research in Doreri Bay, Manokwari found 3 species of roundscads caught by lift net, namely *D. akaadsi, D. macarellus* and *D. macrosoma*. Furthermore, White et al. (2013) reported 3 species, *D. kurroides, D. macarellus* and *D. macrosoma* from landing sites in Java, Bali and Lombok, while Purnama (2020) found 4 species sold at traditional fish markets in Ambon city, the capital of Maluku province namely *D. kurroides, D. macarellus, D. macrosoma, and D. russelli*. Based on those information, it can be concluded that the results of this study are the first research in Indonesia where as many as 5 species (62.5%) of roundscads in Indonesian waters were found in one location, namely the waters of Southeast Maluku.

Sex ratio

A total of 290 individuals of roundscads consisting of 146 males and 144 females were collected during the study. Details number of individuals, both for male and female fishes can be seen in Table 3. The results of the Chi-square test in Table 3 to analyze whether there is a significant difference between the number of male and female individuals indicate that all calculated values are smaller than the value of χ^2 table (3.84) at $p = 0.05$ with $df = 1$. Thus, all species have a sex ratio of 1:1.

Sex ratio 1:1 or a balance number between male and female individuals in this research is in accordance with some studies for roundscads (*Decapterus* spp.) in Indonesia waters. For example, Purnawati et al. (2017) found a balance between the number of male and female individuals of *D. kurroides* in the waters of Palabuhanratu Bay. Furthermore, Ongkers et al. (2016) and Silooy

Table 2. Roundscads (*Decapterus* spp.) in the waters of Southeast Maluku, Indonesia

Scientific name	English name	Indonesian name
Decapterus kurroides (Bleeker, 1855)	Redtail scad	*Ikan layang anggur*
Decapterus macarellus (Cuvier, 1833)	Mackerel scad	*Ikan layang biru*
Decapterus macrosoma (Bleeker, 1851)	Shortfin scad	*Ikan layang deles*
Decapterus muroadsi (Temminck & Schlegel, 1844)	Amberstripe scad	*Ikan layang*
Decapterus russelli (Rüppell, 1830)	Indian scad	*Ikan layang benggol*

Table 3. Number of individuals and Chi-square test for sex ratio of roundscads

Species	n (ind.)	Male (ind.)	Female (ind.)	Ratio M:F	χ^2 calc.	Conclusion ratio
Decapterus kurroides	35	18	17	1 : 0.94	0.03^{ns}	M:F = 1:1
Decapterus macarellus	126	63	63	1 : 1	0.00^{ns}	M:F = 1:1
Decapterus macrosoma	42	24	18	1 : 0.75	0.86^{ns}	M:F = 1:1
Decapterus muroadsi	38	17	21	1 : 1.24	0.42^{ns}	M:F = 1:1
Decapterus russelli	49	22	27	1 : 1.23	0.51^{ns}	M:F = 1:1

ns, not significantly different.

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et al. (2021) found a 1:1 ratio for *D. russelli* and *D. macarellus* in the waters of Ambon Island, respectively. In addition, Dahlan et al. (2015) also found ratio 1:1 for *D. macrosoma* in the waters of Bone Bay, South Sulawesi. On the contrary, Umar et al. (2019) reported unbalance number between male and female individuals of *D. muroadsi* in Manado Bay, North Sulawesi.

Sex ratio 1:1 between male and female is an ideal condition because male and female individuals have the same chance of being caught so that there is a balance that allows one male individual to fertilize one female individual. According to Türkmen et al. (2002), deviations in the ratio of 1:1 may occur due to differences in the distribution, activity and movement of fish, especially during spawning and the change of sex from male to female or vice versa during the growth period. However, none of these factors has been reported for deviation of 1:1 ratio of roundscads.

Gonad maturity stage

The level of gonad maturity of roundscads is depicted in Fig. 1. It can be seen in Fig. 1 that the maturation level of roundscads in the waters of Southeast Maluku varies from stage I to stage IV. However, only *D. macarellus* had stage I to stage IV with a low percentage of stage IV for both male and female individuals.

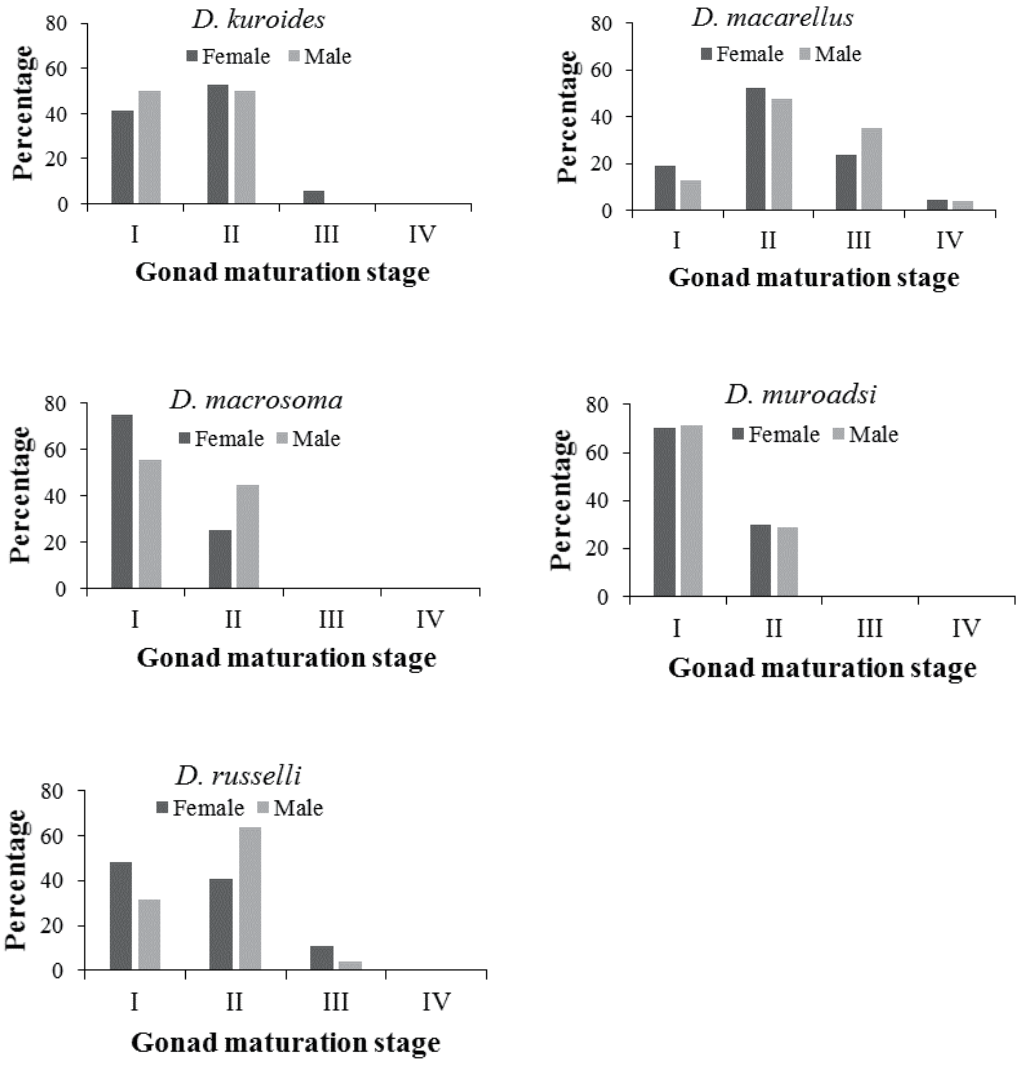

Fig. 1. Gonad maturation stage of roundscads (*Decapterus* spp.).

Overall, Fig. 1 shows that roundscads in Southeast Maluku waters were dominated by immature gonads (stages I and II). There is clear reason for dominance of immature fish. Low percentage of mature fish in this study may indicate that Southeast Maluku waters is not the spawning ground for roundscads or spawning season of those species is just over several month before this research is done. Suwarso et al. (2008) stated that roundscads tend to migrate from fishing ground to the deeper water for spawning. Meanwhile, some researchers reported that spawning season of roundscads varies among species and locations. For example, *D. macrosoma* spawn in April–May in Makassar Strait (Ahmadi, 2020) while in Ambon Bay in July–August (Syahailatua & Sumadhiharga, 1991) and between July and November in Java Sea (Atmaja & Sadhotomo, 2005). Spawning season for *D. macarellus* in Tomini Bay in August (Widiyastuti & Zamroni, 2017) while in Celebes Sea occurs in March (Zamroni et al., 2019).

In general, the results obtained in this study are similar to several studies in Indonesia. Ongkers et al. (2016) in their research in the waters of Ambon Island and Prihartini et al. (2007) in the Java Sea reported a higher percentage of stages I and II compared to stages III and IV for *D. macrosoma* and *D. russelli*. Moreover, Silooy et al. (2019) also found a larger percentage of stage I and stage II for *D. macarellus* in the southern coastal waters of Ambon Island. On the contrary, Widiyastuti et al. (2020) found higher percentage of mature (stages III and IV) of *D. macarellus* in West Sumatera, Western Indonesia. Until now, there is no information about maturation stage of *D. kuroides* and *D. muroadsi* in Indonesian waters.

Low percentage of mature fish in this study may indicate that Southeast Maluku waters is not the spawning ground for roundscads or spawning season of those species is just over several month before this research is done. However, this indication needs further investigation in longer term study.

Size distribution

The descriptive statistic of the length and weight of roundscads in the waters of Southeast Maluku is presented in Table 4 while length relative frequency is depicted in Fig. 2.

Overall, *D. macarellus* has a larger size both for length with an average value of 23.0 cm and 22.5 cm with a range of 19.0–28.0 cm and 18.0–27.0 cm and weight with the average was 108.0 g and 100.1 g with a range of 67.0–200.0 g and 52.0–168.0 g for male and female fishes, respectively. The smallest size for average total length and weight is owned by *D. muroadsi*. In general, male is larger than female fish. For more details on the mean, range and SD measures, see Table 4.

Information about *D. kurroides* in Indonesian waters and even in world waters is lacking. Purnama (2020) reported that the total length of this species sold at traditional fish markets in Ambon City, Eastern Indonesia is in the range of 20.3–21.4 cm. Furthermore, Manginsela et al. (2020) found mean length 15.9 cm for *D. kurroides* with total length ranging from 9.7–20.3 cm in Kema Bay, North Sulawesi. According to Froese & Pauly (2022), this species can reach a maximum total length of 45 cm with a common fork length (FL) of 30 cm, however, there is no information about the size of the first gonad maturity.

There have been many studies conducted on *D. macarellus*, especially in the eastern part of Indonesia. For the total length, Iksan & Irham (2009) found a range of 21.1–31.5 cm in North Maluku waters and Fadila et al. (2016) reported a range of 18.2–31.7 cm in Kendari waters. In addition, Pattikawa et al. (2018) found a total length ranging from 11.0–24.5 cm and Silooy et al. (2019) reported a range of 9.0–31.9 cm for this species in the waters of Ambon Island. According to Silooy et al. (2021), first matured gonads of this species at 24.9 cm (male) and 24.8 cm (female). Based on this information, it can be concluded that most of the *D. macarellus* sold in the traditional fish market of Langgur City are

Table 4. Descriptive statistic of the length and weight of roundscads (*Decapterus* spp.)

Species	Total length (cm)				Weight (g)			
	Male		Female		Male		Female	
	Range	$\bar{x} \pm SD$	Range	$\bar{x} \pm SD$	Range	$\bar{x} \pm SD$	Range	$\bar{x} \pm SD$
Decapterus kurroides	17.8–25.4	20.4 ± 1.6	17.3–23.7	19.8 ± 1.7	55–112	74.4 ± 15.2	48–112	70.2 ± 15.7
Decapterus macarellus	19.0–28.0	23.0 ± 1.7	18.0–27.0	22.5 ± 1.8	67–200	108.0 ± 28.2	52–168	100.1 ± 24.8
Decapterus macrosoma	16.5–20.0	18.3 ± 1.4	16.7–19.7	18.3 ± 1.4	44–79	59.2 ± 13.6	45–71	54.3 ± 11.5
Decapterus muroadsi	17.3–20.0	18.2 ± 1.0	16.2–20.0	17.5 ± 1.0	49–73	57.3 ± 10.6	44–75	52.9 ± 8.7
Decapterus russelli	17.2–23.5	20.4 ± 1.9	16.9–23.9	20.0 ± 1.8	50–110	77.4 ± 17.9	46–120	73.0 ± 17.1

$\bar{x}$, mean.

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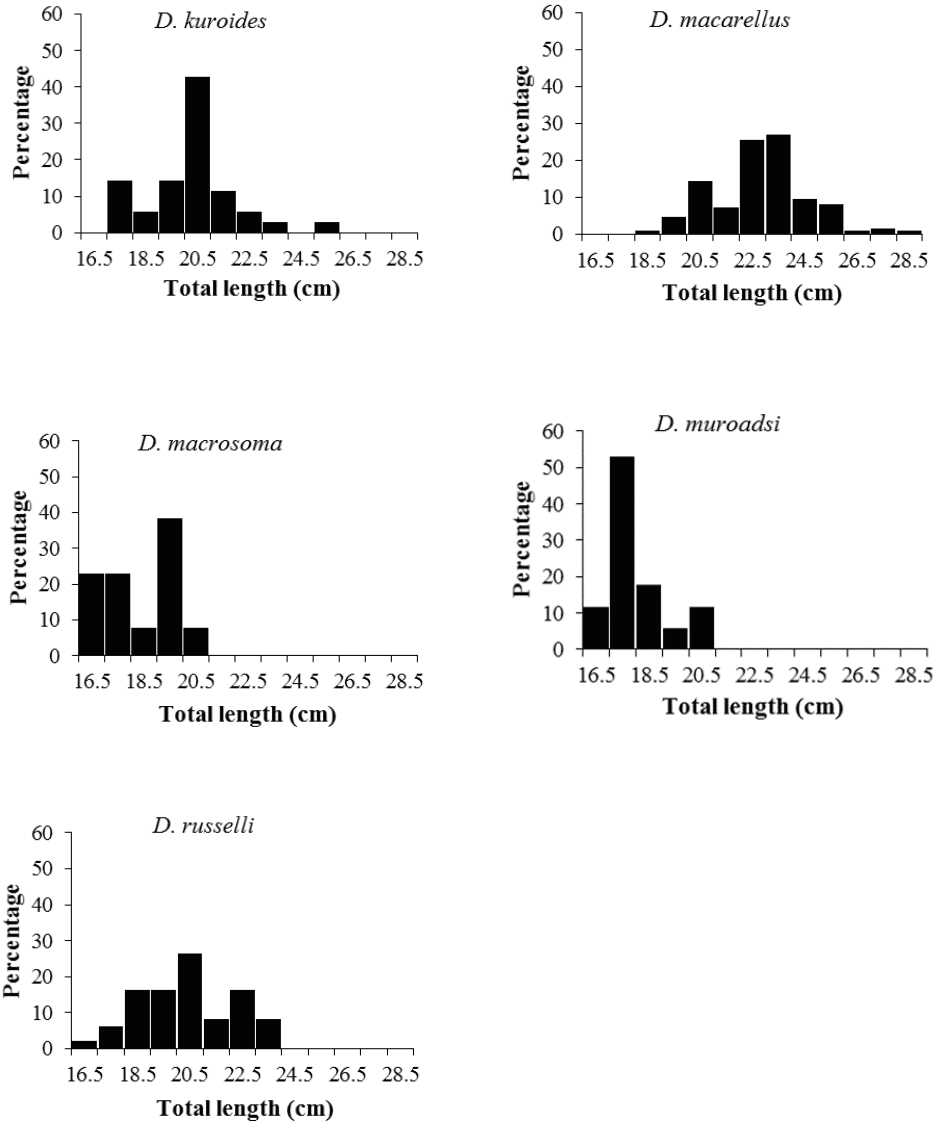

Fig. 2. Relative frequency of length of roundscads (*Decapterus* spp.).

young or juvenile fish (Fig. 2).

Many studies on the size distribution of *D. macrosoma* have been carried out in Indonesian waters. The total length range of *D. macrosoma* in the Java Sea was 13.0–25.3 cm (Widodo, 1988), in Banda Neira waters 7.5–31.5 cm (Senen et al., 2011), in Bone Bay 12.1–29.5 cm (Suwarni et al., 2016) and in Ambon Island waters the range was 13.3 cm to 31.5 cm (Pattikawa et al., 2017). Widodo (1988) and Syahailatua & Sumadhiharga (1991) reported that *D. macrosoma* in the Java Sea and Ambon Bay spawned for the first time at a total length of 16.28 cm and 16.30 cm, respectively. Based on this information and the data in Fig. 2, it can be concluded that the *D. macrosoma* sold in the traditional fish market of Langgur City are adult fish that have spawned at least once.

Currently, information on the size distribution of *D. Muroadsi* is still lacking. The size of the present study is smaller compare to other studies of *D. Muroadsi* in Indonesian waters as well as worldwide. For example, Umar et al. (2019) reported that the total length of this fish in Manado Bay, North Sulawesi Indonesia ranged from 19.0–25.5 cm. Jawad & Al-Mamry (2018) found total length 37.0 cm of this species in the Gulf of Oman in the Sultanate of Oman while Froese & Pauly (2022) reported a maximum FL of 50 cm with the common size at 30 cm.

The size distribution of *D. russelli* in Indonesian waters varies. Manik (2009) found a total length range of 8.4–25.2 cm in Likupang Bay, North Sulawesi while Ongkers et al. (2016) reported a size range of 7.5–28.6 cm. Meanwhile, Faizah & Sadiyah (2020) got a range of 14.1–21.9 cm for *D. russelli* in the waters of the South China Sea. Furthermore, Widodo (1988) and Prihartini et al. (2007) reported that in the Java Sea *D. russelli* gonads matured for the first time at a total length of 13.9 cm and 14.0 cm, respectively. Based on this information and the data in Fig. 2, it can be said that *D. russelli* sold at the Langgur fish market are adult fish that have spawned at least once.

Length-weight relationship and growth pattern

The results of the analysis of the length-weight relationship for male, female and combined sexes of roundscads in Southeast Maluku waters is presented in Table 5. The interval of the value of b at the 95% confidence level (p = 0.05) and the results of the t-test to examine whether the value of b = 3 or b ≠ 3 to determine the growth pattern of roundscads. If the range of b values at the 95% confidence interval (p = 0.05) includes a value of 3.00 or the calculated t value is smaller than the t table value then the b value = 3 and vice versa.

Relationship between length and weight for male, female and combined sexes (Table 5) showed that all b values < 3 and these values are still in the expected range of 2.00–4.00 (Bagenal & Tesch, 1978). Results of further tests using an interval of b values for combined sexes at the 95% confidence level (p = 0.05) and the t-Student test turned out to be only 2 species that had b values < 3, namely *D. kurroides* and *D. russelli*, thus both species had negative allometric growth pattern i.e. length increment is faster than weight increment while the other 3 species had b values that were not significantly different from 3 (b = 3) or isometric growth pattern in which length and weight increase at the same rate.

The combined sexes growth pattern of *D. kurroides* in this study, which was negative allometric, is different from the results reported by Purnawati et al. (2017) for the same species in the waters of Palabuhanratu Bay i.e. isometric. For *D. macarellus*, the isometric growth pattern in the present study is in accordance with that obtained by Pattikawa et al. (2018) in Ambon Island waters but different from the results reported by Iksan & Irham (2009) in North Maluku waters and Nur et al. (2017) in Majene waters, West Sulawesi. Isometric growth pattern for *D. macrosoma* in this study is similar to the results reported by Akerina et al. (2019) in Likupang waters and Widodo (1988) as well as Prihartini et al. (2007) in the Java Sea. On the contrary, Pattikawa et al. (2017) stated that *D. macrosoma* in Ambon Island waters had a positive allometric growth pattern, while Syahailatua & Sumadhiharga (1991) and Senen et al. (2011) reported a negative allometric growth pattern of this species in the waters of Ambon Bay and Banda Neira, respectively. Isometric growth pattern of *D. Muroadsi* in this study is different from that reported by Umar et al. (2019) for this species in Manado Bay, North Sulawesi i.e. positive allometric growth pattern. Indian scad *D. russelli* in the present study has a negative allometric growth pattern. On the contrary, Widodo (1988) reported that this species in the Java Sea has an isometric growth pattern. Furthermore, Manik (2009) stated that the isometric growth pattern of *D. russelli* in Likupang Bay, North Sulawesi was only found in May, while from June to October the growth was positive allometric (b > 3).

The variation in length weight relationship or growth pattern in fishes are affected by some internal factors such as sex, growth stage, gonad maturity and health as well as external factors including habitat, environmental condition and food availability (Eagderi et al., 2020; Le Cren, 1951; Muchlisin et al., 2010). Moreover, variation in length weight relationship could be due to differences in the length range of the fish sample and the

Table 5. Length-weight relationship and growth pattern of roundscads (*Decapterus* spp.)

Species	Male				Female				Combined sexes			
	a	b	*r*	Growth pattern	a	b	*r*	Growth pattern	a	b	*r*	Growth pattern
Decapterus kurroides	0.113	2.150	0.833	A–	0.074	2.292	0.919	A–	0.089	2.230	0.883	A–
Decapterus macarellus	0.017	2.793	0.832	I	0.031	2.590	0.843	I	0.022	2.696	0.840	I
Decapterus macrosoma	0.010	2.999	0.985	I	0.131	2.071	0.814	A–	0.020	2.734	0.925	I
Decapterus muroadsi	0.016	2.813	0.885	I	0.033	2.574	0.983	A–	0.032	2.586	0.938	I
Decapterus russelli	0.072	2.310	0.915	A–	0.125	2.112	0.840	A–	0.094	2.220	0.876	A–

a, intercept; b, slope; *r*, correlation coefficient; A–, negative allometric; I, isometric.

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fishing gear used to capture the fish (Froese, 2006). Length-weight relationship is important in the field of fisheries because apart from being used to see the growth pattern of the studied fish species, this relationship can also be used to determine condition factors and conversion factors (Effendie, 2002) i.e. to convert length to weight and vice versa.

Condition factor

As male and female fishes have same environment, relative condition factor were combined for both sexes of each species studied. Relative condition factor (Kn) for combined sexes of roundscads (*Decapterus* spp.) showed small variation and their values ranging from 1.00 to 1.03. The values of Kn in this study are similar to those values reported by Pattikawa et al. (2018) for *D. macarellus* in Ambon Island and Senen et al. (2011) for *D. macrosoma* in Banda Neira. On the contrary, Kn in this study are lower than those reported by Prihartini et al. (2007) for *D. macrosoma* and *D. russelli* from Java Sea. Currently there is no information on condition factor for *D. kurroides* and *D. muroadsi* in Indonesian waters.

Relative condition factor (Kn) can be used to determine productivity of environment and well-being of individual fish within population at that environment. Some internal and external factors affect the value of Kn such as sex and age of fish, fullness of stomach, stage of gonad development, availability of food and season (Froese, 2006; Le Cren, 1951). The higher the value of Kn, the better well-being of the species (Jisr et al., 2018) which reflects satisfactory condition of habitat for the species or fish population in the waters of Southeast Maluku in term of growth and reproduction.

Conclusion

Based on the results, it can be concluded that roundscads in Southeast Maluku waters, Eastern Indonesia contains 5 species, namely *D. kurroides, D. macarellus, D. macrosoma, D. maruadsi* and *D. russelli* with equal number of male and female individuals or sex ratio 1:1. Roundscads in the area are dominated by immature individuals at gonad maturity levels I and II. Species *D. macarellus* has a larger size compared to the other 4 species. Roundscads in Southeast Maluku waters show isometric and negative allometric growth patterns with relative condition factors (Kn) around 1. Information on biological aspects of roundscads in this study could be utilized to fill the gap in data and to be helpful in order to manage this valuable resource.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

This article does not require IRB/IACUC approval because there are no human and animal participants.

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