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RESEARCH ARTICLE

Length-weight relationship, body condition, and fishing gear selectivity of shortfin scad (*Decapterus macrosoma*) landed in Banjarmasin fishing port, Indonesia

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Abstract.: The present study provides scientific information on the growth pattern and relative condition of shortfin scad, *Decapterus macrosoma* Bleeker landed in Banjarmasin fishing port, Indonesia. A total of 313 individual scad comprising 178 males and 135 females ranging from 152 to 225 mm total length and from 37 to 110 g weight were investigated. The body shape of both males and females showed isometric growth patterns indicating that all body dimensions grew at the same rate. The regression coefficient was significantly different between the sexes. The total length (TL), body weight (W), body depth (BD), W/TL, and BD/TL ratios and condition factors of the females were comparatively higher than those of males. The highest percentage of the catch was between 180 and 189 mm TL (32.59–40.45%) and 50 and 59 g W (20.65-21.79%). The relative condition factor values ranged from 0.799 to 1.433, which reflected the good condition of the fish samples. The estimated length at first capture (L_{c50}) and selection factor values were 180 mm and 3.54 for males and 185 mm and 3.64 for females. In the present work, the purse seine was considered to be a male-biased gear, with a sex ratio of 1.3 : 1. The outcomes of this research could be useful for sustainable pelagic fisheries management and for developing precautionary measures to prevent the overexploitation of this species.

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Introduction

The shortfin scad *Decapterus macrosoma* Bleeker is a commercially important pelagic fisheries resource that beneficially supports food supply and the fish processing industry, and it is also fish bait for the tuna longline fishing industry (Asni et al. 2019). It belongs to the family Carangidae, which is in high market demand locally as it is less expensive than other pelagic fishes. At least four species of scad mackerel inhabit Indonesian waters, i.e., *Decapterus kurroides* Bleeker, *Decapterus macarellus* (Cuvier), *Decapterus russelli* (Rüppell), and *Decapterus macrosoma* Bleeker (Atmaja and Sadhotomo 2005). These fishes are mostly caught with purse seines, gill nets, ring nets, mini-trawls, and rod and line fishing (Ohshimo et al. 2014, Narido et al. 2016). The scad fishery is very important in Indonesia, since it employs large numbers of fishers and takes a significant proportion of the total catch. However, high demand for these species has resulted in declining fish populations from overfishing or overexploitation (Kalhoro et al. 2017, Zamroni and Suwarso 2017).

Decapterus species are well-documented in several studies by researchers from Asian, European, and South Pacific countries that focus on growth and reproduction (Shiraishi et al. 2010, Ohshimo et al. 2014), growth and mortality (Mansor and Abdullah 1995), food and feeding habits (Jaiswar et al. 1993), feeding behavior (Ory et al. 2017), length-weight relationship and condition factor (Liestiana et al. 2015, Ashwini et al. 2016), population dynamics (Suwarni et al. 2015), optimization of enzymatic hydrolysis conditions (Rasli and Sarbon 2018), genetic diversity (Zamroni and Suwarso 2017), major allergen identification (Misnan et al. 2008), species description (Kimura et al. 2013), stock assessment (Kalhoro et al. 2017), factors affecting catches (Tsitsika and Maravelis 2006), bioeconomic analysis and resource management (Piliana et al. 2015), and market price analysis for this species (Nababan et al. 2014). Each species of the family Carangidae has own its characteristics, and they can exhibit different performance and behavior even in the same habitat (McBride et al. 2002, Ohshimo et al. 2006).

Managing the shortfin scad fishery resource rationally requires in-depth knowledge of its biology, feeding habits, and ecology (Narido et al. 2016, Asni et al. 2019). The length-weight relationship is the most common scientific approach used to analyze growth and morphometrics in individual fish species (Ongkers et al. 2016, Pattikawa et al. 2017) and also for understanding fish biomass and stock assessment (Kalhoro et al. 2017) of various species from different geographical regions. It is also useful for local and interregional morphological and life historical comparisons in species and populations (Sani et al. 2010, Shiraishi et al. 2010). Fish length is the best indicator of production efficiency (Ghorbani et al. 2012), while weight is considered to be a function of length (Weatherley and Gill 1987). According to Bagenal and Tesch (1978), heavier fish of a given length are in better condition. Fish condition is determined by the condition factor (K), which is derived from the length-weight relationship. Information on the condition factor of scad is also required for determining gonad maturity and growth level (Shiraishi et al. 2010, Mehanna et al. 2015), as well as for monitoring stock assessments and fishery resource management (Piliana et al. 2015, Kalhoro et al. 2017).

It is acknowledged that changes in fish population structure in a certain area associated with fish life history (e.g., stock size and age structures) are greatly influenced by size-selective fishing gear (Jorgensen et al. 2009, Hsieh et al. 2010, Liang et al. 2014). Managing fishing practices without considering fish population stability directly and adversely affects not only ecosystem balance and biodiversity but also the socioeconomic impacts of the fisheries overall (Kigbu et al. 2014, Kalita et al. 2015, Hanif et al. 2019).

In South Kalimantan Province, the scad fishery contributes about 25% of the total catch landed. Based on daily reports issued by Banjarmasin fishing port authority, about 5–20 tons of scad are landed daily by one vessel, which is equal to 50–100 tons landed by ten vessels (6–30 GT). A total of 1,808,700 L/year of the fuel quota is regularly provided by PT AKR Corporindo, Tbk, and it is distributed proportionally to each vessel group (Shafari et al. 2019). Banjarmasin fishing port has no fish auction center. All transactions of the marketing channels are organized by a fish distributor agent (Rahman et al. 2019). The wholesale and retail fish prices for fishers and consumers are IDR 12,000 and IDR 35,000, respectively. The fish price fluctuates seasonally depending on supply and demand. To draw a clear picture of scad fishery, we started investigating the length-weight relationship, body condition, and fishing gear selectivity of shortfin scad landed in Banjarmasin fishing port to provide some fundamental suggestions for better fisheries management.

Materials and Methods

The shortfin scad were caught with purse seines from the Masalima Sea around Makassar Strait, which was part of Fisheries Management Area 713

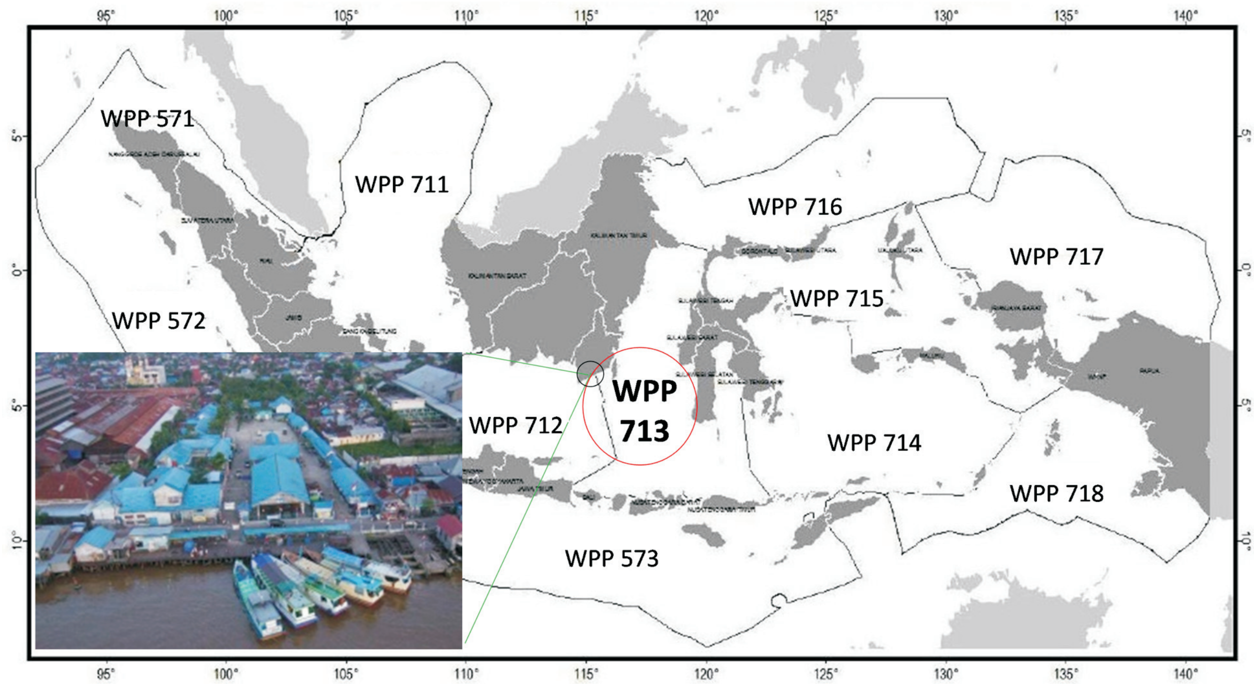

Figure 1. Location of Masalima Sea in Fisheries Management Area/WPP 713 (red circle) and Banjarmasin fishing port (black circle link with a photograph)

(WPP-713), Indonesia. The catch was transshipped from purse seiners (100–175 GT) to fish carrier vessels (25–30 GT) for landing in Banjarmasin fishing port in South Kalimantan Province (Fig. 1), located at 03°18’03’’ S and 114°33’02’’ E. This fishing port is one of the regional technical implementing units (UPTD) under the Marine and Fisheries Service of South Kalimantan Province. The fishing port was built in 1975, and it is the oldest fishing port on Kalimantan Island. It is very strategic area because it is accessible by fish carrier vessels from both Java and Sulawesi.

A total of 313 individuals of shortfin scad comprising 178 males and 135 females were purchased directly from Banjarmasin fishing port. The fish were measured for total length (TL), body depth (BD), and weight (W). Total length was taken from the tip of the snout to the extended tip of the caudal fin. Body depth was measured from the dorsal fin origin vertically to the ventral midline of the body. The total length and body depth of each individual were measured with a ruler to the nearest 1 mm, while whole body weight was determined on a digital scale to the nearest 0.01 g (CE, SF-400, China). The size distribution of the fish sampled was set at 10 cm and 10 g for length and weight sizes.

The length-weight relationship (LWR) of the fish was expressed with the following equation (Froese 2006):

$$W = aL^b \qquad (1)$$

where: W is the total weight (g), L is the total length (mm), *a* is the constant showing the initial growth index, and *b* is the slope showing growth coefficient. The *b* exponent with a value between 2.5 and 3.5 is used to describe typical growth dimensions of relative wellbeing of fish population (Bagenal 1978). Analysis of covariance was applied to check any differences between males and females in term of growth pattern. The statistical significance of isometric exponent (*b*) was analyzed with the following function (Pauly 1984):

$$t = \left(\frac{SD(x)}{SD(y)}\right)\left(\frac{|b-3|}{\sqrt{1-R^2}}\right)(\sqrt{n-2}) \qquad (2)$$

where t is the t student statistics test value, SD (x) is the standard deviation of log L, SD (y) is the standard deviation of log W, b is the slope of the curve, R^2 is coefficient determination, and n is the number of samples. The t-value was compared with the t-table value (0.05) for degrees of freedom at a 95% significance level. If the t-value was less than the t-table value, this indicated that the fish grew isometrically (b = 3). If the t-value was greater than the t-table value, this indicated that the fish grew allometrically ($b \neq 3$). The b value has an important biological meaning (Froese 2006); isometric growth indicates that all body dimensions grow at the same rate. When weight increases more than length, it shows positive allometric growth ($b > 3$), but when length increases more than weight, it indicates negative allometric growth ($b < 3$). The maximum and minimum length thresholds for individuals were also estimated to determine whether there were any changes in growth patterns during their life histories. The determination (R^2) and regression (r) coefficients of morphological variables between males and females were also computed.

The ratio of body depth to the total length (BD/TL) was determined with the non-dimension number based on the empirical method. The condition factor (K) of fish was estimated using the following formula (Weatherley and Gill 1987):

$$K = 100(W/L^3) \qquad (3)$$

where K is Fulton's condition factor, L is total length (cm), and W is weight (g). A factor of 100 was used to bring K close to the value of one. The K value is used in assessing the health condition of fish of different sex and in different seasons. The relative condition factor (Kn) was further estimated with the Le Cren (1951) formula:

$$Kn = W \times \hat{W}^{-1} \qquad (4)$$

where Kn is the relative condition factor of the fish, W is the observed weight, and W is the calculated weight derived from length-weight relationship. The metric indicates that the higher the Kn value, the better the condition of the fish.

The length at first capture (L_{c50}) is the total length at which 50% of individuals are caught with purse seines. It also indicates that 50% of the recruits are under full exploitation. The probability of capture is estimated by plotting the cumulative frequency of the catch (%) with the total length (mm), and it is analyzed using a standard selectivity logistic curve (Saputra 2009). This is taken at 50% of the resultant cumulative curve.

The selection factor (SF) is the index related to the escapement factor expressing the relation between L_{c50} and the mesh size involved. This is also known as the coefficient of selectivity. The selection factor for shortfin scad was simply estimated using the following formula (Pauly 1984):

$$SF = \frac{L_{c50}}{Mesh\ size} \qquad (5)$$

The mesh size used as the main input for calculating the SF value was 50.8 mm for both males and females. The SF value was derived from the corresponding L_{c50} values (180–185 mm) and the mesh size used.

The t-test was applied to compare body sizes, size ratios, and condition factors between males and females. All tests were analyzed at a 0.05 level of significance using SPSS-18 software.

Results

All estimated length-weight relationship parameters, body size ratios, and condition factors including the length at first capture, and the selection factors of shortfin scad are presented in Tables 1 and 2. Significant differences were noted in total length and body weight between males and females ($P < 0.01$). The male body size range was 155–223 mm TL (186.56 ± 12.60 mm) and 37–110 g W (60.45 ± 13.94 g); while those of females were 152–225 mm TL (191.19 ± 13.64 mm) and 42–108 g W (67.10 ± 15.07 g). The sex ratio of male to female was 1.3 : 1.

The body shapes of both males and females showed isometric growth patterns (Fig. 2), indicating

Table 1
Estimated length-weight parameters of shortfin scad (*D. macrosoma*) landed at Banjarmasin fishing port

		Total length (mm)		Weight (g)					
Sex	n	Min	Max	Min	Max	a	b	R^2	r
Male	178	155	223	37	110	0.80×10^{-5}	3.02	0.881	0.939
Female	135	152	225	42	108	0.10×10^{-4}	2.96	0.893	0.945

n = Number of fish samples, a = constant, b = exponent, R^2 = determination coefficient, r = regression coefficient

Table 2
Ratio of main body sizes of the shortfin scad (*D. macrosoma*) landed at Banjarmasin fishing port

Sex	n	W/TL	a	b	R^2	r	BD/TL	a	b	R^2	r
Male	178	0.32 ± 0.05	0.80×10^{-5}	2.0251	0.7686	0.8767	0.19 ± 0.02	0.70×10^{-2}	0.6293	0.2021	0.4496
Female	135	0.35 ± 0.05	0.40×10^{-4}	1.7296	0.6226	0.7891	0.20 ± 0.02	0.80×10^{-2}	0.6048	0.1938	0.4402

n = Number of fish samples, a = constant, b = exponent, R^2 = determination coefficient, r = regression coefficient, TL = total length, W = body weight, BD = body depth

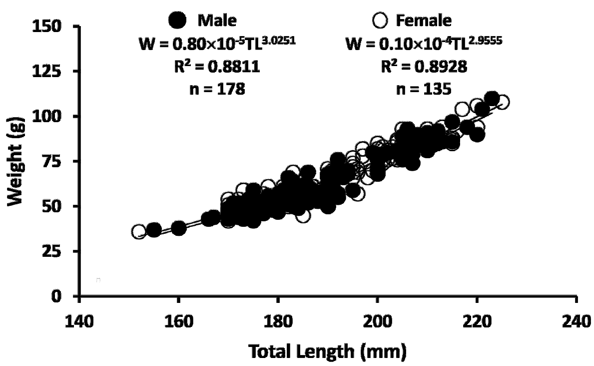

Figure 2. Relationship between body weight and total length of the shortfin scad (*D. macrosoma*) landed at Banjarmasin fishing port. Both males and females showed isometric growth patterns.

that the length and body weight of the fish increased in equal proportions. The length-weight relationships for males and females were expressed as: $W = 0.80 \times 10^{-5}\ TL^{3.0251}$ and $W = 0.10 \times 10^{-4}\ TL^{2.9555}$, respectively. The estimated *b* values in the LWR equations were 3.02 for males and 2.96 for females. The *t*-test values for males and females were less than the *t*-table values confirming that the fish grew isometrically. The R^2 values range was 0.881–0.893 indicating that more than 88% of weight variability was explained by length. The male and female regression correlations were 0.939 and 0.945, which were higher than 0.5 and indicated that the length-weight relationship was strongly correlated. Regardless of sex, we observed that individuals smaller than 180 mm TL grew negatively allometrically with an exponent lower than the cubic value ($b = 2.65$, $R^2 = 0.925$), while individuals larger than 209 mm TL grew positively allometrically with an exponent comparatively higher than the cubic value ($b = 3.37$, $R^2 = 0.932$).

As shown in Table 2, the mean ratio of body weight to total length (W/TL) of females was significantly higher that of males ($P < 0.001$). The mean W/TL ratios obtained for females and males were 0.35 ± 0.05 (0.237–0.482) and 0.32 ± 0.05 (0.238–0.493), respectively. Females also had a greater mean body depth (38.44 ± 5.52 mm) than males (35.99 ± 5.17 mm). The increased body depth was directly proportional to total length. The relationship between body depth and total length were provided by the following equations: $BD = 0.84 \times 10^{-2}\ TL^{1.6048}$ ($R^2 = 0.6287$) for females, and $BD = 0.71 \times 10^{-2}\ TL^{1.6293}$ ($R^2 = 0.6293$) for males (Fig. 3). The regression correlation (r = 0.793) obtained showing this relationship was also positively correlated. The mean ratio of body depth to total length (BD/TL) of females was considerably higher than that of males ($P < 0.0001$). The mean BD/TL ratios estimated for females and males were 0.20 ± 0.02 (0.162–0.283) and 0.19 ± 0.02 (0.158–0.295), respectively.

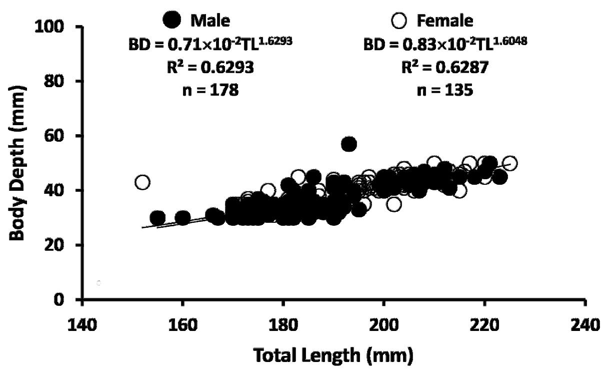

Figure 3. Relationship between body depth and total length of shortfin scad (*D. macrosoma*). Body depth increased proportionally to total length.

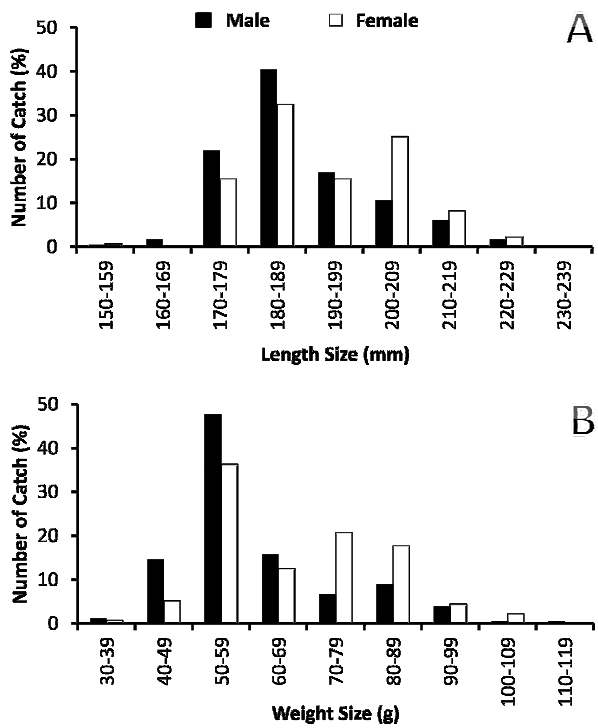

Figure 4. Percentages of length (a) and weight (b) size distributions between male and female shortfin scad (*D. macrosoma*) collected at Banjarmasin fishing port.

The Fulton's condition factor (K) value of females was significantly higher than that of males ($P < 0.05$). The K values obtained ranged from 0.729 to 1.009 (0.92 ± 0.07) for males and from 0.711 to 1.139 (0.95 ± 0.07) for females. The available data indicated that the relative condition factor (Kn) value of females was also significantly higher than that of males ($P < 0.0001$). The Kn values obtained for males ranged from 0.799 to 1.209 (1.01 ± 0.07), while for females it ranged from 0.897 to 1.433 (1.20 ± 0.09), which reflected the good condition of the fish samples. The estimated K and Kn values are presented in Table 3.

The fish samples in the present study were mostly distributed in the middle size class (Fig. 4A). The highest percentage of the catch was 40.45% for males and 32.59% for females, which falls between 180 and 189 mm TL, followed by 200 and 209 mm TL (25.19%) for females and between 170 and 179 mm TL (21.91%) for males. A low number of catch was observed for both smaller individuals < 170 mm TL (< 2%) and larger individuals > 219 mm TL (< 3%). The heaviest catch of males (47.75%) and females (36.30%) weighed between 50 and 59 g. The body weight of females was greater than that of males weighing over 70 g (Fig. 4B). The t-test analysis showed that there were significant differences in individual class intervals of the length-weight size ranges between males and females ($P < 0.05$), particularly in

Table 3

Descriptive statistics of the parameters observed in shortfin scad (*D. macrosoma*) collected from Banjarmasin fishing port

Parameters	Mean ± SD of Body sizes		t-test for Equality of Means		
Observed	Male (n = 178)	Female (n = 135)	t	df	Sig. (2-tailed)
TL (mm)	186.56 ± 12.60	191.19 ± 13.64	-3.107	311	0.002
W (g)	60.45 ± 13.94	67.10 ± 15.07	-4.228	311	0.000
BDD (mm)	35.99 ± 5.17	38.44 ± 5.52	-4.032	311	0.000
W/TL	0.32 ± 0.05	0.35 ± 0.05	-4.392	311	0.000
BDD/TL	0.19 ± 0.02	0.20 ± 0.02	-3.715	311	0.000
K	0.92 ± 0.07	0.95 ± 0.07	-3.480	311	0.001
Kn	1.01 ± 0.07	1.20 ± 0.09	-20.944	311	0.000

TL = total length, W = body weight, BDD = body depth, K = Fultons' condition factor, Kn = relative condition factor

Table 4
Significance test for the shortfin scad (*D. macrosoma*) based on the range of length-weight size distribution

	Number of Catch		t-test for Equality of Means		
The length size	Male	Female	t	df	Sig. (2-tailed)
150-159	1	1	-	0	
160-169	3	0	37.591	2	0.001
170-179	39	21	0.518	58	0.606
180-189	72	44	0.636	114	0.526
190-199	30	21	-5.346	49	0.000
200-209	19	34	2.092	51	0.041
210-219	11	11	-0.735	20	0.471
220-229	3	3	125.484	2	0.000
230-239	0	0	-	0	-
	Number of Catch		t-test for Equality of Means		
The weight size	Male	Female	t	df	Sig. (2-tailed)
30-39	2	1	1.732	1	0.333
40-49	26	7	0.149	31	0.882
50-59	85	49	-0.135	132	0.893
60-69	28	17	0.873	43	0.388
70-79	12	28	-0.283	38	0.779
80-89	16	24	0.269	38	0.789
90-99	7	6	-0.362	11	0.725
100-109	1	3	-0.866	2	0.478
110-119	1	0	-	0	-

the length size ranges of 160–169 mm, 190–199 mm, 200–209 mm, and 220–229 mm, but no significant differences in the weight size range between males and females were observed (Table 4).

The length at first capture (L_{c50}) was estimated at 180 mm for males and 185 mm for females, which indicated the sizes at which 50% of the catches were retained by purse seines. Based on L_{c50}, we also roughly estimated the proportion of smaller and larger individuals of scad males retained by the fishing gear at 24.16% (< 180 mm) and 75.84% (> 180 mm) respectively, while those of scad females were estimated at 32.59% (< 185 mm) and 67.41% (> 185 mm). This indicated that the majority of the catch was dominated by larger sizes (Fig. 5).

The estimated selection factors (SF) for males and females were 3.54 and 3.64, respectively.

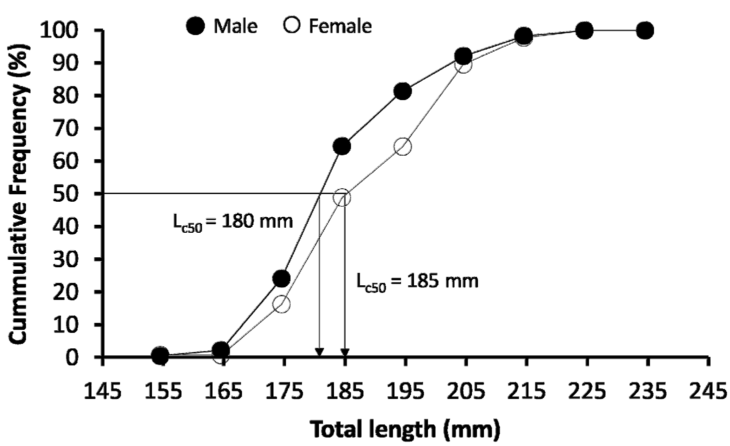

Figure 5. Selectivity logistic curve clearly shows that the estimated L_{c50} values for male and female shortfin scad (*D. macrosoma*) were 180 and 185 mm, respectively, caught with 50.8 mm mesh size purse seines.

Discussion

The most important result of the present study was that *D. macrosoma* grew isometrically (b = 2.96–3.02), which indicated that length increased proportionally to body weight. We estimated the maximum and minimum length thresholds for individuals at 179 and 210 mm to determine the range of size distribution in which fish showed an isometric growth pattern or shifts in their growth patterns. Such a growth pattern was in agreement with *D. macrosoma* from the Eastern Java Sea of Central Java (Prihartini et al. 2007), *D. russelli* from the Mumbai waters and Mangaluru of India (Jaiswar et al. 2001, Ashwini et al. 2016), *Decapterus tabl* Berry from the Camotes Sea of the Philippines (Narido et al. 2016), and *Decapterus maruadsi* (Temnick & Schlegel) from the Gulf of Suez of Egypt (Mehanna et al. 2015). However, it was contrary to *D. macrosoma* from the Ambon Island of the Maluku and Makassar waters of South Sulawesi (Pattikawa et al. 2017, Asni et al. 2019), *D. russelli* from the Mumbai waters of India (Panda et al. 2011), the Latulahalat waters of Maluku (Ongkers et al. 2016), and *D. tabl* from Suruga Bay of Japan (Iwasaki and Aoki 2001), which all displayed positive allometric growth patterns. Meanwhile, *D. macarellus* from the North Maluku Sea (Iksan and Irham 2009), *D. russelli* from the northern Arabian Sea of Pakistan (Kalhoro et al. 2017), and *D. macrosoma* from PPI Sanggeng-Manokwari of West Papua (Randongkir et al 2018) exhibited negative growth patterns or slower growth when compared to our findings (Table 5). Variation in slope could be attributed to sample size variation, life stages, growth difference, seasonal fluctuations, changes in physiological condition during spawning periods, gonad development, sex, or environmental factors such as food and space (Mehanna et al. 2015, Ashwini et al. 2016, Kalhoro et al. 2017).

The spawning period of shortfin scad is around April and May, and fishing activities could be done when spawning is completed. This also implies that fishes caught in the spawning period are likely to be heavier than those caught afterward. Since the catch data were collected in July, the results of this study were still applicable. In Banda Neira of Maluku, *D. macrosoma* was reported spawning between February and March (Senen et al. 2011). While in Ambon Bay (eastern Indonesia), it was occurred twice a year between July and August and between November and December (Syahailatua and Sumadhiharga 1996). When fishing intensity increases, it can disturb spawning activity and also adversely impact spawning habitats (van Overzee and Rijnsdorp 2014). Establishing seasonal area closures during spawning periods is not only beneficial for ecological aspects but also for the socio-economic aspects of the fishing community itself (Clarke et al. 2015).

In the present work, the purse seine was considered to be male-biased gear as indicated by the male catch ratio that was 1.3 times higher than that for females. This might be attributable to reproductive and migration cycles during which spawning females migrate out of the fishing grounds. A higher proportion of males to females has also been documented for *D. macrosoma* from PPI Sadeng of Yogyakarta (Liestiana et al. 2015), *D. russelli* from Mangaluru of India (Ashwini et al. 2016), and *D. macrosoma* from the Makassar waters of South Sulawesi (Asni et al. 2019). Meanwhile, a female-biased ratio was reported for *D. macrosoma* from Javanese waters (Prihatini et al. 2007) and *for D. macarellus* from North Maluku (Iksan and Irham 2009). Variations in fish sex ratios are closely related to food availability, water temperature, dissolved oxygen, migration cycle, and geographical differences (Poojary et al. 2015, Awan et al. 2017, Asni et al. 2019).

In the present study, the mean K and Kn values obtained for *D. macrosoma* females were comparatively higher than those for males (see Table 3), and the values were close or equal to those that indicated the scad were in good condition. Compared to other species, the current K values were relatively similar to *D. macrosoma* from Banda Nera Island of Maluku and PPI Sadeng of Yogyakarta (Senen et al. 2011, Liestiana et al. 2015) and *D. russelli* from Maharashtra and Mangaluru of India (Poojary et al. 2015, Ashwini et al. 2016), but these K values were

Table 5
Comparative length-weight relationship, condition factor, and growth patterns of shortfin scad (*D. macrosoma*) from different geographical areas

Area of Studies	Province	Species	Sex	n	Body size (mm) Min	Max	Growth pattern	b	Kn	References
Banjarmasin Fishing Port	South Kalimantan	*D. macrosoma*	M	178	155	223	I	3.03	1.01	Present study
Banjarmasin Fishing Port	South Kalimantan	*D. macrosoma*	F	135	152	225	I	2.96	1.20	Present study
Western Java Sea	Central Java	*D. macrosoma*	P	610	96	216	I	2.98	2.08-2.97	Prihartini 2006
Makassar waters	South Sulawesi	*D. macrosoma*	M	201	128	340	A+	3.37	-	Asni et al. 2019
Makassar waters	South Sulawesi	*D. macrosoma*	F	169	120	330	A+	3.73	-	Asni et al. 2019
PPI Sadeng, Gunung Kidul	Yogyakarta	*D. macrosoma*	P	1,324	145	380	A-	2.88	1.05	Liestiana et al. 2015
Bone Bay	South Sulawesi	*D. macrosoma*	P	849	121	295	-	-	-	Suwarni et al. 2015
PPI Sanggeng, Manokwari	West Papua	*D. macrosoma*	M	222	109	303	A-	1.84	0.67-1.86	Randongkir et al. 2018
PPI Sanggeng, Manokwari	West Papua	*D. macrosoma*	P	278	125	299	A-	2.03	0.72-1.80	Randongkir et al. 2018
Banda Nera Island	Maluku	*D. macrosoma*	P	1,134	75	315	A+	3.19	1.11	Senen et al. 2011
Ambon Island	Maluku	*D. macrosoma*	P	1,018	133	315	A+	3.59	-	Pattikawa et al. 2017
North Maluku	Maluku	*D. macarellus*	M	645	211	311	A-	2.28	-	Iksan and Irham 2009
North Maluku	Maluku	*D. macarellus*	F	1,355	215	315	A-	2.98	-	Iksan and Irham 2009
Eastern Java Sea	Central Java	*D. russelli*	P	756	86	214	I	3.03	1.66- 2.23	Prihartini 2006
Northwest coast	India	*D. russelli*	P	1,831	80	218	I	3.00	-	Jaiswar et al. 2013
Latulahalat, Ambon Island	Maluku	*D. russelli*	M	220	75	235	A+	3.63	-	Ongkers et al. 2016
Latulahalat, Ambon Island	Maluku	*D. russelli*	F	223	94	286	A+	3.89	-	Ongkers et al. 2016
Mangaluru	India	*D. russelli*	M	667	110	230	I	3.02	1.02	Ashwini et al. 2016
Mangaluru	India	*D. russelli*	F	339	130	220	I	3.09	1.05	Ashwini et al. 2016
Northern Arabian Sea	Pakistan	*D. russelli*	P	997	10	310	A-	2.66	-	Kalhoro et al. 2017
Maharashtra	India	*D. russelli*	P	812	110	229	-	-	0.93-1.08	Poojary et al. 2015
Mumbai waters	India	*D. russelli*	P	235	142	230	A+	3.17	-	Panda et al. 2011
Malabar	India	*D. russelli*	M	193	65	242	A-	2.32	-	Manojkumar 2007
Malabar	India	*D. russelli*	F	179	65	242	I	2.98	-	Manojkumar, 2007
Gulf of Suez	Egypt	*D. maruadsi*	P	1,864	73	251	I	2.90	-	Mahenna et al. 2015
Camotes Sea	Philippines	*D. tabl*	P	317	125	314	I	2.99	-	Narido et al. 2016
Suruga Bay	Japan	*D. tabl*	P	…	180	430	A+	3.18	-	Iwasaki and Aoki 2001

A+ – positive allometric; A- – negative allometric; I – isometric; W – weight; TL – total length; Kn – relative condition factor; M – male; F – female; P – pooled

lower than those for *D. russelli* from the Eastern Java Sea of Central Java or for *D. macrosoma* landed in PPI Sanggeng of West Papua (Randongkir et al. 2018). Variations in K values can be attributed to biological interactions involving intraspecific competition for food and space among species including sex, stage of maturity, and food availability (Poojary et al. 2015, Ashwini et al. 2016).

The estimated L_{c50} values for *D. macrosoma* (180–185 mm) landed at Banjarmasin fishing port were comparatively lower than for *D. macrosoma* (255 mm) landed at PPI Sadeng of Yogyakarta (Liestiana et al. 2015) or for *D. macrosoma* (201 mm) landed at PPN Pekalongan (Prihatini et al. 2007), but they were relatively higher than the L_{c50} values for *D. tabl* (175 mm) from the Camotes Sea of the Central Philippines (Narido et al. 2016). This variation can be affected by many factors such as time and duration of sampling, number and size of fish sampled, as well as the type and mesh size of the fishing gear used. Because of the effect of fishing pressure or environmental changes (e.g., water temperature and food availability), scad behavior can shift from a pelagic to a demersal mode of life as they increase in size, hence larger fish may not be caught by these gears. Based on an example of purse seine fishery in the Pagasitikos Gulf of Greece, catches were also restricted by the maximum height of the purse seine (± 30 m), which implied that any species below this depth were out of reach (Tsitsika and Maravelis 2006).

Based on the 50.8 mm (2-inch) mesh size of the purse seine, the selection factor (3.54–3.64) for *D. macrosoma* in the present study was relatively lower than that landed in PPI Sadeng of Yogyakarta (5.02) (Liestiana et al. 2015). However, the current SF values obtained were comparatively higher than those for *Sardinella aurita* Val. (1.63) and *Sardinella maderensis* (Lowe) (1.83), which corresponded to an 83 mm mesh size (Ofori-danson et al. 2018). Seemingly, the value of the selection factor increased with mesh size and the corresponding L_{c50} value for this species. These SF values were large enough to show that the purse seine can be considered a selective fishing gear for *D. macrosoma* since two-thirds of total catch comprised larger individuals between 181–225 mm TL. The selection factor of the purse seine was not only determined by the mesh size, but it was also affected by gear construction, fish behavior, and netting materials (Widjopriono and Mahiswara 2008).

Thomson and Ben-Yami (1984) classified purse seines as less selective fishing gear because the fish species caught with them exhibited a wider range of sizes or ages than did fishes caught with gill nets. In point of fact, Javanese fishers that still operated purse seines with a smaller mesh size (38 mm) to catch the mackerel scad led to fish population declines (Prihartini et al. 2007). It is acknowledged that purse seines have higher productivity in comparison with other fishing gears such as beach seines, drift gillnets, and mini trawls (Yonvitner et al. 2020). Besides using larger mesh sizes (63–76 mm), the selectivity of purse seine can be improved by installing rigid metal sorting grids in the pocket sections (Beltestad and Misund 1995) or panels of diamond-shaped meshed can be inserted in the posterior parts (Goncalves et al. 2004) to reduce and minimize fisheries by-catch. Moreover, the sinking performance of purse seines with larger mesh-sized panels and heavier material was also simulated numerically (Hosseini et al. 2011). Although the existing scad fishery is sustainable, precautionary control measures should be taken into consideration. Therefore, further improvement of real-time monitoring of catch per unit effort (CPUE) in the investigated area should be done to ensure that fish continue to be landed in good, marketable condition and that they are not being fully exploited. Fishing intensity should be rationalized to effectively prevent the overexploitation of the scad population.

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