Comparative life history and dynamics analysis of shortfin scad (*Decapterus macrosoma* Bleeker, 1851) in the Java Sea for sustainable fisheries management

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Abstract. This study aims to analyze the life history and dynamics of shortfin scad (*Decapterus macrosoma*) in the Java Sea to determine sustainable fisheries management measures. Two fishing ports where the fish landed where used in this study, i.e. Nizam Zachman Marine Fishing Port and Pekalongan National Fishing Port. The results showed that the growth pattern of both male and female of shortfin scad was allometrically negative. The male fish landed at the Nizam Zachman Marine Fishing Port had a gonad first mature size (Lm) of 146 mm, whereas the size of the first capture (Lc) was 191.36 mm. In contrast, female fish showed Lm of 171 mm and Lc of 131.08 mm. In addition, the value of the shortfin scad condition factor at the Nizam Zachman Marine Fishing Port was lower than at the Pekalongan National Fishing Port. The sex ratio of shortfin scad showed an unbalanced proportion, with the dominance of male fish in stage 3 of gonad maturity at Nizam Zachman Marine Fishing Port and stage 2 gonad maturity at Pekalongan National Fishing Port. The study also revealed that shortfin scad have a selective diet, with high food overlap between males and females. These findings provide important insights for sustainable management of shortfin scad in the Java Sea. Some sustainable management measures that can be used are: 1) regulation of net size, adjusting the size of the net to avoid catching immature females (Lc < Lm), 2) protection zones, enforcing the closure of the fishing season during the peak of spawning to ensure the sustainability of stocks, and 3) pressure monitoring. These findings reinforce the importance of a population biology data-based approach in the management of Java Sea fisheries. The integration of Lm, Lc, and reproductive dynamics parameters into the management policy may mitigate the risk of overfishing in shortfin scad.

Key Words: biology, feeding, length, shortfin scad, small pelagic fisheries.

Introduction. The State Fisheries Management Area of the Republic of Indonesia 712 (FMA 712) consists of the Java Sea which is connected to the South China Sea through the Karimata Strait. The Java Sea has a potential fisheries resources of around 1,034,485 tons year^{-1} (MMAF 2022). According to Ministerial Decree No. 19 of 2022, the small pelagic fish group has the highest potential compared to other groups such as large pelagic and reef fish, as well as other fisheries resurces such as shrimps and squids. Small pelagic fish are schooling fishes measuring at 7-25 cm, and living in the zone near the sea surface. They have rapid growth and a relatively short lifespan (Sekadende et al 2020). Small pelagic fishes caught in the Java Sea waters include shortfin scad (*Decapterus macrosoma*), Indian mackerel (*Rastrelliger kanagurta*), yellowstripe scad (*Selaroides leptolepis*) and sardines (*Sardinella* spp.) (Rizal et al 2023).

According to electronic logbook (e-logbook) records, the landing production of small pelagic fish in FMA 712 exhibits annual fluctuations. The largest production was in 2022 at 134,983,700 kg, while the lowest production was in 2018 at 8,126,129 kg. The composition of the fish types caught consists of more than 85 types originating from large pelagic fish, small pelagic fish, demersal fish, and squid. Based on the analysis of the composition of fish catches in FMA 712, 5 (five) fish species were obtained as the dominant catches each year for five consecutive years. These fish species consist of longtail tuna/kawa-kawa (*Euthynnus affinis*) and scad (*Decapterus* spp.). Meanwhile, the group of mackerel (*R. kanagurta*), lemuru (*Sardinella lemuru*), and sardines (*Sardinella* spp.) are included in the composition of the dominant catch in a particular year. In 2021, longtail tuna (*E. affinis)* had the largest production of up to 36.13% followed by scad at 26.36%, and sardines (16.35%). While other types of fish including yellowstripe scad (*Selaroides leptolepis*), Indian mackerel (*R. kanagurta*), and Bali sardinella (*S. lemuru*) had a catch percentage below 5% (Patmiarsih et al 2023).

The sustainability of shortfin scad (*Decapterus macrosoma* Bleeker, 1851) is very important due to its high economic value, being as the most catched and traded fish species in South East Asia, and protein sources for coastal communities (Lubis et al 2019; Magallanes et al 2022; Tampubolon & Oh 2023). The declining production trend of this species in FMA 712 indicates that some biological aspects of the fish which includes growth, reproduction, and food habits may be in disturbance due to biotic and abiotic factors (Taurusman et al 2020). Therefore, study on growth, reproduction and food habits of this species is critically important. Fish growth can be determined through the length and weight of the fish, so that the growth pattern of small pelagic fish can be known through the analysis of the length-weight relationship (Oliveira et al 2020). Fish growth is affected by feeding habits, activity patterns, habitat conditions, and seasonal changes. Variations in diet, behavior, and habitat use, as well as seasonal shifts in food availability, all contribute to differences in fish growth rates and overall population structure (Soe et al 2021).

Understanding reproductive parameters such as sex ratio, gonad maturity stages, fecundity, and the size at first maturity is crucial for maintaining the sustainability of small pelagic fish such as shortfin scad. These factors provide valuable information on population structure, spawning periods, and the number of eggs produced, which are essential for developing effective management strategies (Sululu et al 2022). Furthermore, the study of fish feeding habits is crucial for understanding how these species utilize the food resources available in aquatic environments. This analysis not only reveals the diverse types of natural food consumed by fish but also provides deep insights into the extent of their food ecological niches (niche breadth) and the degree of overlap in resource utilization among species or niche overlap (Herawati et al 2020). Thus, research on life history and dynamics including aspects of growth, reproduction, and eating habits of shortfin scads in FMA 712 is aimed in determine the current biological aspects of the fish to aid their sustainable use.

Material and Method

Data collection. This research was conducted in March and June 2024. The sampling sites of landed shortfin scad were obtained at two fishing ports i.e Nizam Zachman Ocean Fishing Port (100 fishes) and Pekalongan Archipelagic Fishing Port (76 fishes) (Figure 1). The fish samples obtained were then analyzed at the Fisheries Biology Laboratory, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University to determine food habits, reproduction and growth of shortfin scad within FMA 712. All fishes were measured at total length and food item were collected from the gut.

Data analysis. The life history data analysis consisted of (1) food habits, namely Index of Preponderance, niche area, overlap, and relative intestinal length, and (2) gonad maturity level. Meanwhile, the population dynamics analysis consisted of (1) length and weight relationship, (2) condition factor, (3) sex ratio, (4) fecundity, and (5) length at first gonad maturity (Lm) and length at first capture (Lc).

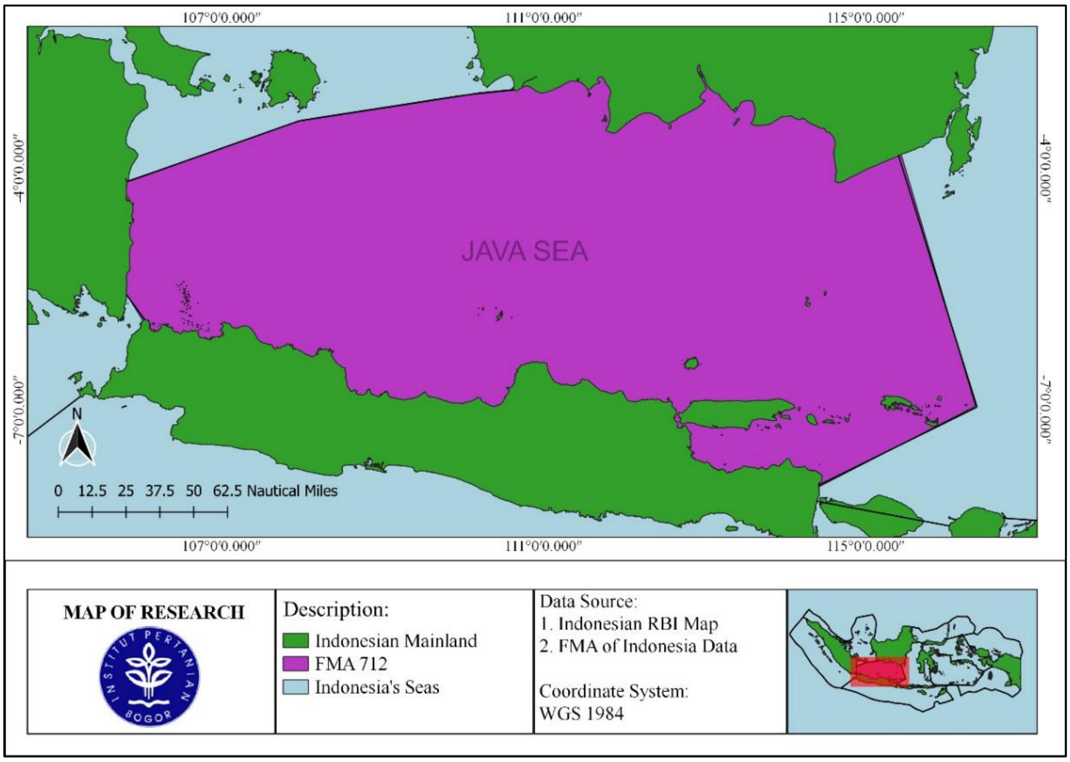

Figure 1. The sampling location of landed shortfin scad within FMA 712 or Java Sea, Indonesia.

Life history analysis

Index of preponderance. The index of preponderance (IP) was calculated based on equation in Mishra (2020), as follows:

$$IP\ (\%) = \frac{Vi \times Oi}{\sum Vi \times Oi} \times 100 \quad (1)$$

where: IP = index of preponderance (%);
Vi = percentage volume of food type i;
Oi = percentage of frequency of occurrence of food type i.

Based on the classification proposed by Nikolsky (1963), food items with an IP value exceeding 40% are categorized as main food sources, those with IP values ranging from 4% to 40% are considered complementary foods, and those with IP values below 4% are regarded as additional or incidental foods.

Relative intestine length. The length of fish intestines was calculated as relative intestinal length based on the ratio between intestine length and total body length of the fish as explained in the study by Duque-Correa et al (2024):

$$RIL = \frac{\text{Intestine Length (cm)}}{\text{Total fish length (cm)}} \quad (2)$$

where: RIL = relative intestinal length.

Niche breadth. The niche breadth (B) was calculated using equation in Corrêa et al (2011) as follows:

$$B = \frac{1}{\sum Pi^2} \quad (3)$$

and the actual niche breadth (B_A) was obtained using the following equation:

$$B_A = \frac{B - 1}{n - 1} \quad (4)$$

where: B_A = niche breadth standardisation;
B = niche breadth of food;
Pi = proportion of i-the species found;
n = total number of food categories.

Food overlaping or Morisita index. The following equation was used to calculate food overlaping as suggested in Krebs (1989):

$$C_H = \frac{2 \sum Pij \times Pik}{\sum Pij^2 + \sum Pik^2} \quad (5)$$

where: CH = Morisita index or food type similarity ;
Pij = proportion of the i-th species of the j-th fish group;
Pik = proportion of the i-th species of the k-th fish group.

Gonad maturity frequency. Gonad maturity level (GML) determination was conducted prior calculating gonad maturity frequency by referencing established morphological characteristics. This morphological assessment process encompasses observation of gonad shape, length, and coloration, as well as the developmental stage of gonad contents, adhering to standardized procedures (Asni et al 2019). GML was determined based on a five-stage classification: GML I (immature) – gonads are small, translucent, and thread-like; GML II (maturing) – gonads increase in size, becoming opaque with visible vascularization; GML III (mature) – gonads are well-developed, occupying a significant portion of the body cavity, with eggs or milt clearly visible; GML IV (spawning) – gonads are fully developed, soft in texture, and ready for gamete release; and GML V (spent) – gonads appear flaccid, reduced in size, with residual gametes present (Tampubolon & Oh 2023). The gonad maturity frequency was calculated according to the equation in Rahman & Samat (2021), as follows:

$$\text{Frequency (\%)} = \frac{x}{b} \times 100 \quad (6)$$

where: x = gonad maturity level at certain class interval;
b = all gonad maturity levels at certain class interval.

Dynamic population analysis

Relationship between length and weight. Growth pattern analysis was done by calculating the relationship between length (L) and weight (W) of shortfin scad using the cubic equation. The general form of the equation is:

$$W = aL^b \text{ or } \log W = \log a + b \log L \quad (7)$$

where: W = individual fish weight (g);
L = fork length (cm);
a = intercept (intersection between the regression line and the y-axis);
b = regression coefficient (angle of the lineslope).

Fork length (FL) is the length of a fish measured from the tip of the snout to the deepest point of the fork in the caudal fin for fish with a forked caudal fin. The growth pattern of shortfin scad can be determined based on the obtained b value. If b = 3, the growth is classified as isometric growth, meaning the increase in length is equal to the weight gain of the fish. If b > 3, the growth is classified as positive allometric growth, indicating that the weight increase is faster than the length increases of the fish. If b < 3, the growth pattern is negative allometric, which means the length increase is faster than the weight gain of the fish. To determine whether the b value is greater, equal to, or less than 3, a t-test was conducted at a 95% confidence interval.

Condition factor. The condition factor value is calculated based on the results of the length-weight relationship analysis. To calculate the condition factor value, the following equation from Lawadjo et al (2021) was used:

$$CF = \frac{10^5 \times W}{L^3} \quad (8)$$

or

$$CF = \frac{W}{aL^b} \quad (9)$$

where: CF = condition factor;
Kn = relative condition factor;
L = fork length of the fish sample;
W = body weight of the fish sample.

If the length-weight relationship calculation yields a b value equal to 3 or an isometric growth pattern, the calculation uses the first equation, i.e., the absolute condition factor. If the results of the length-weight relationship calculation yield a b value different than 3 or an allometric growth pattern, the calculation uses the Kn formula.

Sex ratio. The following equation from Shin et al (2023) was used to calculate sex ratio:

$$SR = \frac{\Sigma F}{\Sigma M} \quad (10)$$

where: SR = sex ratio;
∑J = number of female fish;
∑M = number of male fish.

Furthermore, to determine whether the sex ratio is balanced or not, the chi-square test is used with the equation proposed by Wudji et al (2016):

$$X^2 = \sum \frac{(Oi-ei)^2}{ei} \quad (11)$$

where: X^2 = sex distribution values;
Oi = frequency of male or female fish observed;
ei = frequency of expectation of male or female fish.

Fecundity. Fecundity was calculated according to equation in Musyali et al (2022), as follows:

$$F = \frac{(G)\times(V)\times(X)}{Q} \quad (12)$$

where: F = fecundity;
G = gonad weight (g);
V = dilution volume (mL) ;
X = number of eggs per mL;
Q = sample egg weight (g) .

Length at first maturity (Lm) and length at first capture (Lc). The length at first maturity (Lm) was estimated by analyzing the relationship between the proportion of mature individuals (GML III–V) and total length classes. Total length (TL) data were grouped into 12 cm class intervals, and the proportion of mature fish in each class was calculated. The equation used to estimate the length of the first maturity (Lm) is the Spearman-Karber equation carried out by Pramulati et al (2023) as follows:

$$Lm = X_k + \frac{x}{2} - (X \textstyle\sum_{i=\rho i}^{n}) \quad (13)$$

or

$$Lm = \text{antilog } m = m \pm 1.96 \sqrt{x^2 \Sigma \frac{piqi}{ni-1}} \quad (14)$$

where: Lm = length at first maturity (mm);

Xk = length class size at 100% gonad maturity (mm);
X = difference from the increase in the median of the length;
Pi = proportion of mature gonads in size group i.

The length at first capture (Lc) was estimated from length–frequency data and was calculated using the Beverton and Holt equation as follows (Sparre & Venema 1998):

$$SL = \frac{1}{1 + \exp(a - bL)} \quad (15)$$

or

$$Lc = -\frac{a}{b} \quad (16)$$

where: SL = estimated length (mm);
L = median class length (mm);
a = constant;
b = constant;
Lc = length at first capture (mm).

Results and Discussion

Index of proponderance. Different values of IP of shortfin scad was observed between fish landed at Pekalongan National Fishing Port and Nizam Zachman Ocean Fishing Port. Higher IP at 50.39% of shortfin scad was found in Pekalongan Fishing Port that was dominated by cycloid compared to those landed at Nizam Zachman fishing port at 43.79 % that was dominated by crustaceans. Wide range of food was found in the stomach of scad from crustaceans to diatom indicating the opportunistic nature of scad in feeding. The main food of the scad fish landed in Pekalongan was cycloid, the complementary food was crustaceans and *Nitzschia* sp. Meanwhile, in Nizam Zachman, the main food scad was crustacea, the complementary food was cycloid and *Nitzschia* sp., and the additional food consisted of Nematoda, Copepoda, *Coscinodiscus* sp., *Ceratium* sp., *Trichodesmium* sp., *Goniodoma* sp., *Navicula* sp., and *Brachionus* sp. (Figure 2).

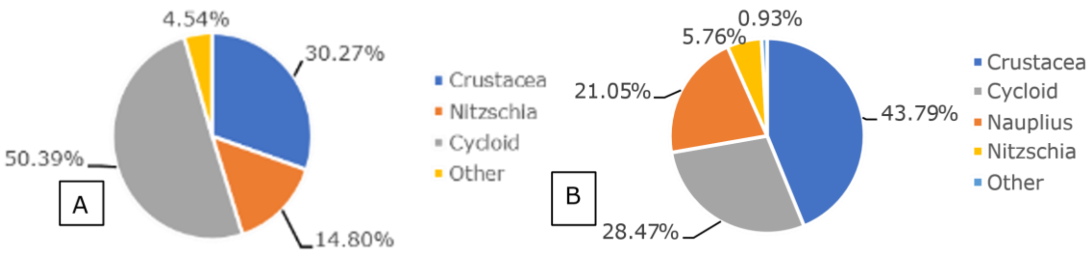

Figure 2. Index of preponderance of shortfin scad landed at Pekalongan Archipelagic Fishing Port (A) and Nizam Zachman Ocean Fishing Port (B).

The difference in main food utilized by shortfin scad in different landing sites may indicate different food availability in different habitat that can be connected to environmental parameters. Shortfin scad is a carnivorous fish that primarily feeds on other fish, crustaceans, and zooplankton. They are known to be opportunistic feeders, consuming a variety of prey items based on availability. The food composition of shortfin scad in this study is different compared to study by Lubis et al (2019) who found that shortfin scad diet in south coast of Gunung Kidul, Yogyakarta was composed by fish (84.15%), phytoplankton (8.91%), zooplankton (4.47%), and snapping shrimp (3.19%). Furthermore, they found that based on the molecular identification, the main fish species eaten by shortfin scad was *Cololabis saira* (Scomberesocidae).

Niche breadth. The area of the niche of the scad fish landed at both Pekalongan and Nizam Zachman fishing ports showed a narrow niche breadth that was < 0.4 (Table 1). Narrow niche breadth indicated that the shortfin scads at the two landing locations are classified as specific and more selective in utilizing its food resources. Consequently, shortfin scads population rely on a limited set of resources or environmental conditions (Carscadden et al 2020).

Table 1
Niche breadth of shortfin scad landed at Pekalongan and Nizam Zachman Fishing Port

Fishing port	*Niche breadth*	
	B	*Ba*
Pekalongan	2.59	0.23
Nizam Zachman	3.26	0.21

Notes: B = niche breadth; B_A = niche breadth standardization.

Niche breadth of fish population is highly affected by environmental factors (both abiotic and biotic) that in turn determines the sustainability and persistence of the fish population. Abiotic drivers such as habitat structure (e.g., depth and area), water chemistry (including dissolved oxygen, temperature, nutrient concentrations), and hydrological variability determine the range of physical and chemical settings a population can tolerate (e.g., bathymetry fostering habitat complexity and intraspecific divergence). Biotic influences - such as competition, predation, and population density - further shape resource use and niche adaptation. Populations exhibiting broader niche breadth (generalists) can exploit a more diverse set of resources and environmental conditions, thereby enhancing resilience and reducing dependence on immigration for population persistence. Conversely, specialists with narrow niche breadth are more vulnerable to environmental change and demographic stress. This nuanced understanding of niche breadth emphasizes its role not only as a descriptor of environmental tolerance but also as a predictive indicator of population sustainability and adaptive potential (Gebrekiros 2016; Carscadden et al 2020). The desirable niche breadth is a broad niche or generalist, where the fish can utilize a wide range of biotic and abiotic conditions in order to maintain non negative growth rate without immigration, although that is not the case in this study. The declining production trend of shortfin scad from 2018-2022 based on logbook data may be attributed to the narrow niche breadth of this fish population in both study sites, indicating changes in environment conditions and catching effort.

Feed overlapping. Feed overlapping or similarity of shortfin scad landed at Pekalongan was higher compared to those that was landed at Nizam Zachman fishing port. However, both fish population showed high feed overlapping that was close to 1 (Table 2).

Table 2
Feed overlapping of shortfin scad landed at Pekalongan and Nizam Zachman fishing port

Fishing port	*Feed overlapping*
Pekalongan	0.99
Nizam Zachman	0.80

The higher the overlap value, the higher the similarity of food, indicating competition from other species, while the lower the overlap value, the smaller the similarity of food. High food overlap such as in shortfin scad found in this study, especially when resources are limited, can result in increased competition and potentially reduced growth or survival rates for some species (Corrêa et al 2011). High food overlap combined with narrow niche breadth of shortfin scad in this study indicated a vulnerability of this species and therefore there is a need to implement sufficient fisheries management measures to ensure the sustainability of this species.

Relative intestine length. The relative intestine length of the scad fish landed at Pekalongan and Nizam Zachman fishing ports was the same, namely 0.55. This shows that the shortfin scad is classified as a carnivore because it has a relative intestine length of < 1.

Table 3

Relative intestine length of shortfin scad landed at Pekalongan and Nizam Zachman fishing port

Fishing port	*RIL*	*Feeding habit*
Pekalongan	0.55	Carnivore
Nizam Zachman	0.55	Carnivore

Small pelagic carnivore fish including shortfin scad are generally considered more vulnerable than larger, longer-lived fish. They are often "forage fish" and highly sensitive to environmental changes and fishing pressure, leading to fluctuations in their populations. Their fast growth, short lifespans, and tendency to form schools make them particularly susceptible to both natural and human-induced pressures (Lloret-Lloret et al 2022).

Gonadal maturity frequency. In Pekalongan fishing port, GML 1 was found in the class interval of 218-231 to 288-301 mm with a relative low frequency that was under 20%. GML 2 was found in the class interval of 204-217 to 274-287 mm. GML 3 was found in the class interval of 232-245 to 288-301 mm. GML 4 was found in all class intervals with a relatively large frequency, ranging from 20 to 100%. This shows that the scads landed in Pekalongan are dominated by GML 4. Meanwhile, in Nizam Zachman fishing port, GML 2 was only found in the class intervals of 146-159 mm and 174-187 mm. GML 3 was found in almost all class intervals, with frequency ranging from 20 to 100%. GML 4 was found in the class interval of 174-187 mm to 202-215 mm. These data show that the scads landed in Nizam Zachman fishing port are dominated by GML 3 (Figure 3).

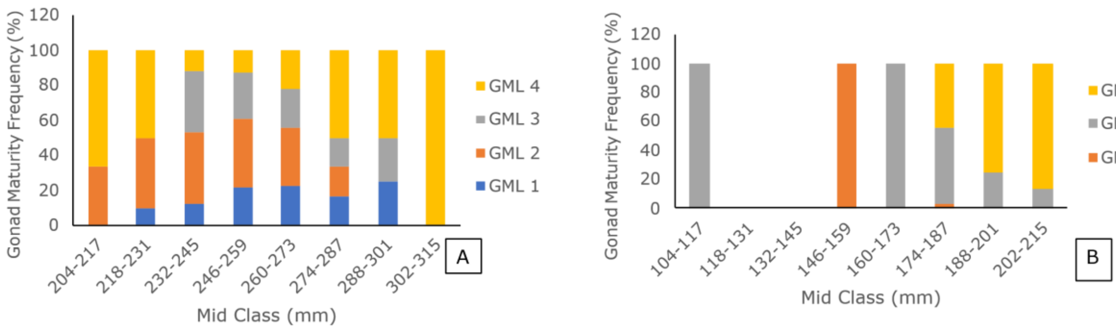

Figure 3. Gonad maturity frequency and GML of shortfin scad in Pekalongan fishing port (A); and Nizam Zachman fishing port (B).

Length and weight relationship*.* The relationship between the length and combined weight of shortfin scad at Pekalongan fishing port followed a linear equation of y = 2.0896x0.7821, which means that each additional unit of length affected the weight by 0.7821 grams (Figure 4).

The relationship between the length and combined weight of the shorfin scad at Nizam Zachman fishing port followed a linear equation of y = 0.4852x0.9409, which means that each additional unit of length affected the weight by 0.9409 grams (Figure 5). Furthermore, growth of shortfin scad landed in both fishing ports was negative allometric indicating that length increases faster than weight (Table 4).

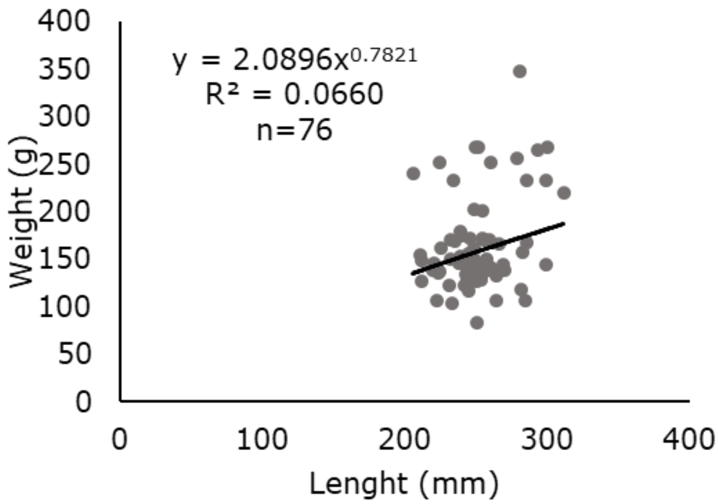

Figure 4. Length-weight relationship of shortfin scad landed at Pekalongan fishing port.

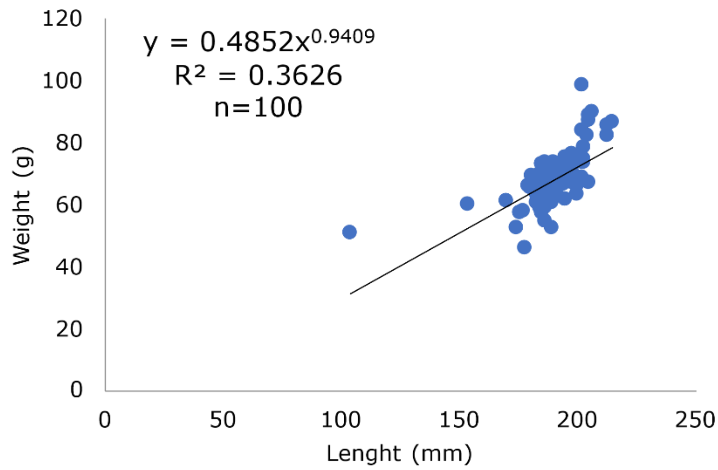

Figure 5. Length-weight relationship of shortfin scad landed at Nizam Zachman fishing port.

Table 4

Growth pattern of shortfin scad landed at Pekalongan and Nizam Zachman fishing port

Fishing Port	*Sex*	*Growth pattern*
Pekalongan	Total	Negative allometric
	Male	Negative allometric
	Female	Negative allometric
Nizam Zachman	Total	Negative allometric
	Male	Negative allometric
	Female	Negative allometric

Growth patterns are influenced by several factors including the number and variety of fish observed, sex, environmental conditions, and ontogenetic development (Dewiyanti et al 2020). The growth pattern of shortfin scad is generally allometric, meaning that the rate of weight gain is not proportional to the rate of length increase. Specifically, it can be positive allometric (weight increases faster than length) or negative allometric (weight increases slower than length), depending on the study and specific population. Growth patterns can vary between different locations. For example, studies in Bali Strait and Banda Islands have shown slightly different growth patterns and size distributions. Tampubolon & Oh (2023) reported that shortfin scad from Bali Strait that landed at Pengambengan fishing port exhibited hyper allometric growth pattern similar to those in Matang, Malaysia whereas the shortfin scad population in Barru Water of Makassar Strait that was landed in

Sumpangbinange fishing port showed a negatively allometric growth pattern (Asni et al 2024), similar to the present study.

Condition factor. Lower condition factor of shortfin scad was observed in Pekalongan fishing port than those of Nizam Zachman but with higher length class interval. The condition factor value in Nizam Zachman fishing port ranged between 0.461 and 2.927 with the highest average being in length class interval of 120-133 mm at 2.0792±0.000. The lowest average of condition factor was observed in length class interval of 134-147 mm at 0.9381±0.1041 (Figure 6).

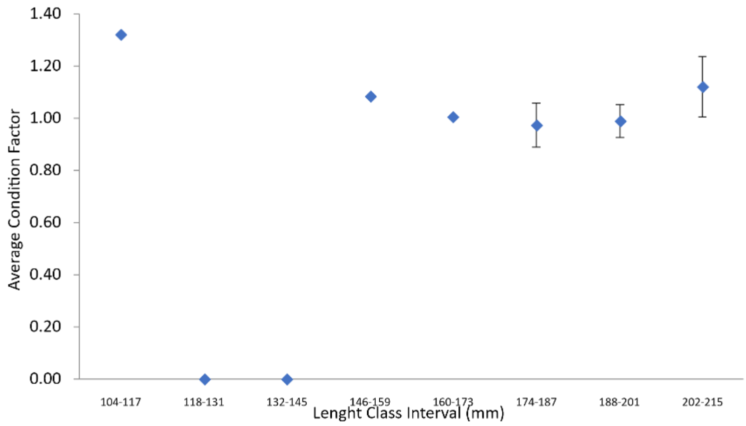

Figure 6. Average condition factor of shortfin scad landed at Nizam Zachman fishing port.

The highest average condition factor at Pekalongan fishing port was found in length class interval of 206-219 mm at 1.8216±0.6311, whereas at length class interval of 304-317 mm it was average condition factor being the lowest at 0.7228±0.000 (Figure 7).

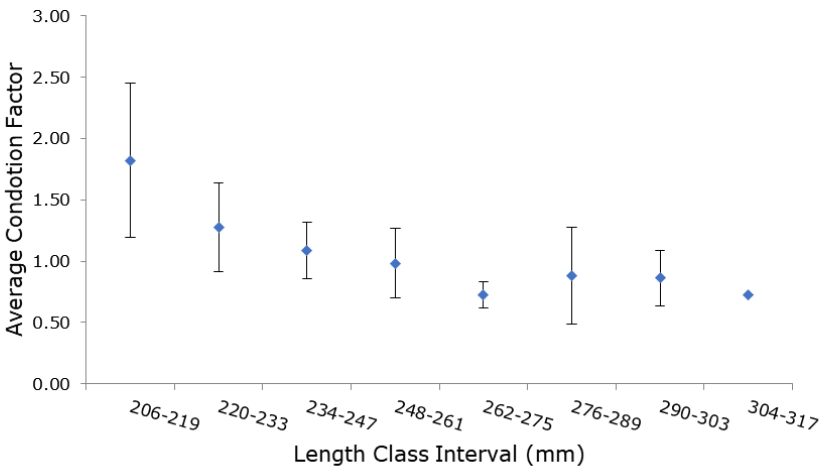

Figure 7. Average condition factor of shortfin scad landed at Pekalongan fishing port.

This study showed that both shortfin scad landed at Pekalongan and Nizam Zachman was in good condition. A low condition factor can be an indication that the fish are not getting enough food intake, while a high condition factor indicates that the fish are in a development phase approaching or already in gonad maturity. The relative condition factor (Kn) of shortfin scad generally indicates good fish health, with values often ranging from 0.799 to 1.433. Higher Kn values suggest the fish are in better condition, potentially due to good feeding or gonad maturation. For example, Ahmadi (2020) found that Kn values tended to increase with fish size, with the highest values observed in larger fish, potentially indicating good feeding and gonad development. Another study reported Kn values ranging from 0.99 to 3.39, also suggesting the fish were in good condition (Magallanes et al 2022).

Sex ratio. The sex ratio of the shortfin scad fish in two port locations is 1≠1 or unbalanced (Table 5). An imbalance in the sex ratio can affect population dynamics and the sustainability of fish reproduction. An imbalance in the sex ratio can be influenced by the mortality rate, temperature on sex determination, differences in grouping behavior between females and males, and growth (Fryxell et al 2015). The sex with faster growth will reach a larger size, so the risk of predation is lower. Conversely, individuals with slower growth tend to remain small, making them more vulnerable to predators.

Table 5

Sex ratio of shortfin scad at Nizam Zachman and Pekalongan fishing port

Fishing Port	*Number of male fish*	*Number of female fish*	*Xhit*	*Xtab*	*Sex ratio*
Nizam Zachman	89	11	60.9397	7.8147	1≠1
Pekalongan	47	29	16.7037	7.8147	1≠1

Fecundity. The fecundity of shortfin scad landed at Nizam Zachman fishing port ranged from 18,172 to 80,016 eggs with an average of 42,896 eggs. The fecundity of shortfin scad landed at Pekalongan fishing port ranged from 12,464 to 244,571 eggs with an average of 81,341 eggs. This study showed that 7.8% of the fecundity variation at Nizam Zachman fishing port was influenced by body weight whereas higher percentage of fecundity variation to body weight was observed in shortfin scad landed at Pekalongan fishing port at 41.6% (Figure 8).

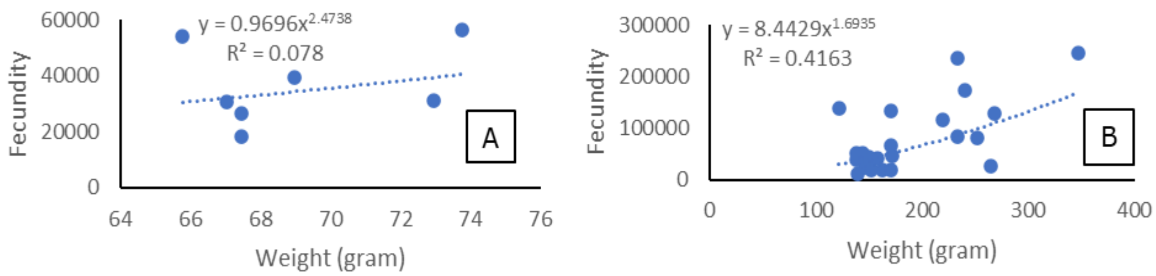

Figure 8. Fecundity related to body weight of shortfin scad landed at Nizam Zachman fishing port (A); and Pekalongan (B) fishing port.

In small pelagic fish, fecundity, or the number of eggs produced, generally increases with body weight. Larger fish tend to have a higher fecundity, meaning they produce more eggs, both in total and per unit of body weight. This relationship can be linear or exponential. However, fecundity is not solely determined by body weight; it can also be influenced by factors like age, food availability, and environmental conditions (Genovia et al 2023). This study showed that body weight of shortfin scad landed at Pekalongan fishing port was higher than those landed at Nizam Zachman fishing port indicating the more mature population. Catching mature fish population may posses several threats such as decreasing reproductive potential, decreasing genetic diversity and decreasing recruitment thus population growth that may lead to overfishing or population collapse (Lavin et al 2021).

Length at first maturity (Lm) and length at first capture (Lc). Shortfin scad landed at Pekalongan fishing port exhibited a higher length both at first maturity and first capture in male and female population. The Lm in male shortfin scad landed at Pekalongan fishing port was 288.50 mm and the Lc was 248 mm. Whereas, the Lm of female shortfin scad was 225 mm and the Lc was 252.62 mm. Male shortfin scad landed at Nizam Zachman fishing port had a lower Lm (146 mm) than their female counterpart (171 mm). Conversely, the Lc in male was higher (191.36 mm) compared to the female fish population (131.08 mm).

A general trend shows that female shortfin scad mature at a smaller size than males. The Lm for shortfin scad varies between males and females, with females generally reaching maturity at a smaller size. However, in this study, the shortfin scad population landed at Nizam Zachman fishing port was excluded from the general trend because the male shortfin scad mature at smaller size at 146 mm compared to the female population that reached Lm at 171 mm. In Makassar waters, males mature at fork lengths between 182.4 and 195.4 mm, while females mature at 164.5-172.4 mm (Asni et al 2019). Studies in other locations show similar trends, with females maturing at around 162-169 mm FL and males at 164-180 mm FL (Tampubolon & Oh 2023). Female shortfin scad may mature at around 162 mm FL, while males may mature at 164 mm FL.

While length is a key factor, other factors like growth patterns and environmental conditions can also influence the size at which shortfin scad reach maturity. For example, one study noted that female shortfin scad in Makassar had a higher GML than males, indicating they mature earlier (Asni et al 2019). Another study by Suharti et al (2024) showed that the length-weight relationship for shortfin scad can vary, with some showing allometric positive growth and others showing allometric negative growth.

The length at first capture (Lc) for this species typically ranges from 180 mm to 189 mm, yet in this study larger individuals were recorded, particularly from landings at Pekalongan Fishing Port - possibly indicating either a shift in size composition due to seasonal recruitment or exploitation patterns. Studies have also estimated Lc at 119.6 mm TL for short fin scad population in the waters off Antique province, Philippines (Magallanes et al 2022) and 184 mm FL for short fin scad Bali Strait waters (Tampubolon & Oh 2023). Another study found that the most common size class at capture of short fin scad landed at Banjarmasin fishing port is around 217.5 mm FL (Ahmadi 2020). These variations likely reflect differences in study locations and methodologies but also may be attributed to fishing pressures.

It is well established that life history traits and population dynamics of a fish species provide critical insights into its potential production. For shortfin scad, attributes such as growth rate, size at first maturity, reproductive seasonality, and mortality rates are fundamental for estimating sustainable yield and assessing resilience to fishing pressure. Understanding these biological characteristics is essential for developing effective management strategies - especially in small pelagic fisheries - to ensure long-term sustainability (King 2007; Wootton & Smith 2014). Fish production is also influenced by natural factors such as season, sea surface temperature, chlorophyll-*a* distribution, salinity, and so on (Rizal et al 2023). In addition, the growth of fishery resources is dynamic, fish stocks in nature will recover along with natural carrying capacity and reproductive activities. However, the stocks population growth will be disrupted if there is excessive fishing.

Another factor contributing to the low recorded production of shortfin scad in recent years is the incomplete implementation of the SILOPI e-logbook system. Over the past five years, the platform has been under development in the form of an Android-based application, resulting in limited data entry and inconsistent catch reporting. These gaps in reporting can lead to underestimation of actual landings, reduced accuracy in stock assessments, and delayed management responses, ultimately affecting the effectiveness of fisheries management measures.

Findings in this study provide important insights for sustainable management of shortfin scad in the Java Sea. Some sustainable management measures that can be used are: 1) regulation of net size, adjusting the size of the net to avoid catching immature females (Lc < Lm), 2) protection zones, enforcing the closure of the fishing season during the peak of spawning to ensure the sustainability of stocks, and 3) pressure monitoring, involves collecting and analyzing data to understand the impact of fishing and other factors on fish stocks and habitats, which informs management decisions and helps assess the effectiveness of conservation measures. By measuring "pressure" (e.g., fishing effort), "state" (e.g., fish population health), and "response" (e.g., management actions), managers can identify trends, detect emerging problems, test management hypotheses, and ultimately ensure the sustainability of the fishery thus ultimately of sustainable food production (Hilborn et al 2025). These findings reinforce the importance of a population biology data-based approach in the management of Java Sea fisheries. The integration of Lm, Lc, and reproductive dynamics parameters into the management policy can mitigate the risk of overfishing in shortfin scad.

Conclusions. There is an imbalance in the reproduction of the shortfin scad found in this study, especially in the Nizam Zachman fishing port where many female shortfin scad are caught before gonad maturity, thus potentially reducing the long-term spawning stock. Conversely, in the Pekalongan fishing port, male short fin scad were caught too early that potentially would affect their contribution to reproduction. The growth of shortfin scad in the two landing locations is negative allometric, meaning that body length increases faster than weight gain. This condition indicates limited food sources or environmental pressure, which is clarified by the lower condition factor value in the Pekalongan fishing port. The sex ratio of scad fish in the two landing locations is unbalanced, dominated by male fish. This imbalance threatens the sustainability of natural reproduction because females as egg producers are limited in number. Shortfin scad are selective carnivores with different main foods per location, relatively high overlapping of feed triggers tight competition. The dynamics of gonads vary, in the Pekalongan fishing port dominated by fish ready to spawn (GML 4), supported by high fecundity (average 81,341 eggs). Meanwhile, at Nizam Zachman fishing port, the fish were dominated by fish that were not ready to spawn (GML 3) with lower fecundity (42,896 eggs). There is necessary to integrate the Lm, Lc, and reproductive dynamics parameters into the management policy to mitigate the risk of overfishing of shortfin scad population in FMA 712.

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