BIODIVERSITAS
Volume 26, Number 6, June 2025
Pages: 2557-2564

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260601

Length-weight relationship, condition factor, and reproductive biology of the bigeye thresher *Alopias superciliosus* in Southern Java, Indonesia

MUHAMMAD ARIF RAHMAN[1,2,♥], LEDHYANE IKA HARLYAN[1,2], ABU BAKAR SAMBAH[1,2], ARIEF SETYANTO[1,2], ALYAA FARAH QONITAH[3], MIFTAH WISNU PURNOMO AJI[3], ERLYN YULIANTI[1]

[1]Study program of Fisheries Resource Utilization, Faculty of Fisheries and Marine Science, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia. Tel.: +62-341-553512, Fax.: +62-341-557837, ♥email: arifelzain@ub.ac.id

[2]Marine Resources Exploration and Management Research Group, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia

[3]Coastal and Marine Resources Management Agency of Serang. Jl. Raya Carita Km 4.5, Caringin, Pandeglang 42264, Banten, Indonesia

Manuscript received: 27 February 2025. Revision accepted: 10 May 2025.

Abstract. *Rahman MA, Harlyan LI, Sambah AB, Setyanto A, Qonitah AF, Aji MWP, Yulianti E. 2025. Length-weight relationship, condition factor, and reproductive biology of the bigeye thresher Alopias superciliosus in Southern Java, Indonesia. Biodiversitas 26: 2557-2564.* The bigeye thresher shark *Alopias superciliosus* is one of two known Alopiidae species lived in Indonesian waters. This species was usually captured in southern waters of Indonesia (Indian Ocean) by various fishing gears. This study aims to investigate size structure, length-weight relationships, relative condition factor, and length at first maturity of *A. superciliosus* landed at Cilacap Ocean Fishing Port, Central Java, Indonesia, providing data for sustainable management. Sampling was conducted monthly over seven months, documenting fork length, body weight, and identifying sex through external examination from 484 sharks (241 males and 243 females). Results revealed a wide size range (77-256 cmFL) of samples and a balanced overall sex ratio, although monthly fluctuations were observed. Growth pattern was negative allometric with value of b: 2.871, 2.789, and 2.936 for combined sex, males, and female, respectively. Relative condition factor predominantly exceeded 1.00. The length at first maturity for males was 150.61 cm, with around 40% of sampled individuals caught prior to sexual maturity. These results underscore the vulnerability of *A. superciliosus* populations and highlight the urgent need for management measures such as size-limit regulations and modifications of fishing operations to reduce bycatch. Overall, this study provides crucial baseline data for policymakers, laying the groundwork for more effective conservation of bigeye thresher sharks in Indonesian waters and beyond.

Keywords: Alopiidae, FMA 573, size at maturity, size structure, sustainable shark fisheries

INTRODUCTION

Far beyond the past decade, shark fisheries have exhibited significant global and local trends characterized by overfishing, regulatory challenges, and evolving conservation efforts. Worldwide, shark populations have experienced alarming declines, with estimates indicating a reduction of over 70% in oceanic shark abundance since the 1970s, primarily due to unsustainable fishing practices and inadequate management systems (Dulvy et al. 2021; Pacoureau et al. 2021; Braccini et al. 2024). Sharks are often referred to as keystone species due to their significant impact on the structure of marine communities (Stevens et al. 2018; Hasan and Widodo 2020; Hasan et al. 2021a). The removal or decline of shark populations can lead to trophic cascades, where the absence of these apex predators results in unchecked growth of prey species, ultimately disrupting the entire ecosystem (Hasan et al. 2021b; Pontavice et al. 2021). *Alopias superciliosus* (Lowe, 1841) is a pelagic shark species inhabits a broad depth range from the surface to approximately 500 meters (Coelho et al. 2015), occupying both coastal and oceanic environments associated with continental and insular shelves (Fernandez-Carvalho et al. 2015). As a specialized yet opportunistic predator, it primarily consumes teleost fish, cephalopods, and crustaceans (González-Pestana et al. 2020; Arnés-Urgellés 2024). This predatory role helps regulate the populations of its prey species, thereby maintaining the balance within the marine ecosystem.

Length-weight relationships, relative condition factors, and length at first maturity are critical information in shark fisheries management, offering essential data for assessing population dynamics, sustainability, and conservation strategies (Bouyoucos et al. 2018; Simeon et al. 2018; Booth et al. 2019; Sherman et al. 2022; Smukall et al. 2022; Temple et al. 2024). Each metric contributes uniquely to understanding shark populations and informing management decisions. Length-weight relationships are a fundamental parameter for modeling biomass dynamics. It provides essential insights into the condition and status of fish populations, supporting stock assessments and informing management decisions for the sustainable exploitation of species (King 2007; Logan et al. 2018). The relative condition factor indicates fish health and signals environmental or fishing impacts, prompting necessary interventions (Bouyoucos et al. 2018; Smukall et al. 2022). Moreover, length at first maturity is fundamental information for implementing size limits that protect juveniles (Booth et al. 2019; Temple et al. 2024). Integrating these metrics into management frameworks helps identify overfishing, maintain healthy stocks, and support shark conservation efforts worldwide, ensuring long-term viability and recovery of vulnerable species.

The conservation status of *A. superciliosus* has been assessed by various international bodies, highlighting its vulnerability and the need for protective measures. According to the International Union for Conservation of Nature (IUCN), *A. superciliosus* is classified as Vulnerable (VU) on the IUCN Red List (Rigby et al. 2019), reflecting concerns about its declining populations primarily due to overfishing and bycatch in tuna longline fisheries (Anderson et al. 2022; Kanedi et al. 2023). This classification indicates that the species faces a high risk of extinction in the wild if the factors contributing to its decline are not addressed. In addition to the IUCN assessment, *A. superciliosus* is listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This listing means that while the species is not currently threatened with extinction, it may become so if trade is not regulated (Bramasta et al. 2021; Kanedi et al. 2023). The CITES Appendix II designation requires that international trade in this species be controlled to ensure that it does not threaten its survival in the wild. In Indonesia, this species is regulated under ministerial regulation No.12/2012. This regulation requires the release of captured Alopiidae sharks when alive, and to report the incidental catch to the port officer when the sharks are retrieved dead.

The biological aspects of a species are fundamental information for its management. The previous studies regarding the biological aspects of *A. superciliosus* have been conducted worldwide, such as Fernandez-Carvalho et al. (2015) in the Atlantic; Briones-Mendoza et al. (2021) in the Ecuadorian Pacific; Calle-Morán et al. (2023a) in the Tropical Eastern Pacific Ocean; Ramadhani et al. (2023) in Muncar Fishing Port, Indonesia; Mohanraj et al. (2024) in the Southern Coast of India; Raharjo et al. (2024) and Nurastri et al. (2024) in the Southern Java Seas, Indonesia. However, few studies have considered the condition factor in the analysis. This analysis complements the length-weight relationship, as the condition factor serves as indicators of fish welfare and the overall health of fish populations within their habitats, offering insights into environmental quality and habitat suitability (Ragheb 2023). This research aimed to determine the length-weight relationship, the relative condition factor, and length at first maturity of *A. superciliosus* landed in Cilacap Ocean Fishing Port, Central Java, Indonesia. The outcome is expected to provide updated information for fisheries managers to sustainably manage the shark fishery.

MATERIALS AND METHODS

Study area

This study was conducted at Ocean Fishing Port Cilacap, Central Java, Indonesia. Most sharks at Cilacap Ocean Fishing Port were landed from long line, hand line, and gill net fishing vessels operating in the Indian Ocean, managed by the Indonesian Fisheries Management Area (FMA) 573 (Figure 1). In Cilacap, sharks are primarily caught as bycatch of tuna longline and gillnet fishery (Fahmi and Dharmadi 2015). There are two species of Alopiidae landed in this fishing port, which are the pelagic thresher *Alopias pelagicus* (Nakamura, 1935) and big eye thresher shark *A. superciliosus*. The visual morphological characteristics to distinguish these species were conducted by examining its head profile, eyes, dorsal fin, and white part of belly (Carpenter and Niem 1998; White et al. 2006). These morphological characters are fit with Carpenter and Niem (1998) and White et al. (2006). The head profile of *A. superciliosus* is nearly straight between the eyes, with a deep groove on both sides of the nape. The eyes are very large, positioned so that the upper part is almost level with the dorsal surface of the head. The first dorsal fin is situated closer to the base of the pelvic fin than to the rear tip of the pectoral fin. The white portion of the belly does not extend over the base of the pectoral fin (White et al. 2006; Briones-Mendoza et al. 2021).

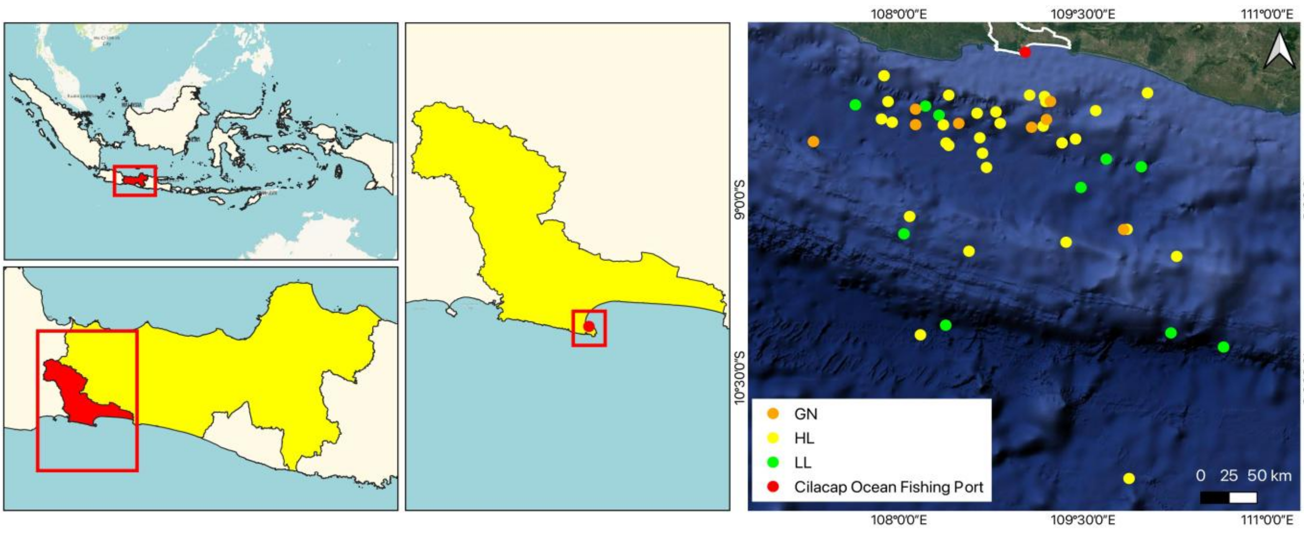

Figure 1. Fishing Ground of Longline (LL), Handline (HL), Gillnet (GN) and Location of Cilacap Ocean Fishing Port, Central Java, Indonesia

Data collection

The samplings were carried out monthly between July 2023 and January 2024. During the seven-month period, samples were obtained from local fishers immediately upon landing. Each landed shark was identified to species level, ensuring a focus on *A. superciliosus*. The sampling was conducted on a weekly basis, depending on vessel arrival schedules. In total, 484 individuals of bigeye thresher sharks were collected to measure their weight (kg) and fork length (cm). The presence or absence of claspers was used to determine the sex of each shark, while for males, the stage of clasper calcification was observed to categorize maturity status.

Data analysis

Length-weight relationship

The length-weight relationship was evaluated using the standard power function (King 2007) with the formula:

$$W = aL^b \quad [1]$$

Where, W is total weight (kg) and L is Fork Length (cm) of *A. superciliosus*. The constant a is the intercept, while b is the slope of the linear regression model. The constant a and b were used to estimate the formula was transformed into a linear regression model:

$$\ln(W) = \ln(a) + b\ln(L) \quad [2]$$

The constant of b value was tested by the student's t-test to identified whether the growth pattern was isometric (b=3) or allometric (b≠3; negative allometric b<3, and positive allometric b>3) growth (Tsikliras and Dimarchopoulou 2021). The formula of t-test is:

$$t_{hit} = \frac{3-b}{sd_b/\sqrt{n}} \quad [3]$$

Where, Sd_b is standart deviation of b, and n is total samples of *A. superciliosus*.

Relative condition factor

The relative condition factor (K_n) was calculated to evaluate the health and nutritional status of the sampled sharks, following established models by Le Cren in 1951. The formula of K_n is:

$$k_n = \frac{W_o}{W_c} \quad [4]$$

Where, K_n is relative weight condition factor, W_o is the observed weight of shark, and W_c is predicted weight of shark from length-weight regression. A Kn value of 1 or higher signifies that the shark is in good growth condition, meaning its weight aligns with its length as expected for a healthy individual. Conversely, a Kn value below 1 indicates poor growth condition compared to an average shark of the same length (Jisr et al. 2018; Ragheb 2023).

Sex ratio

The ratio between male and female was calculated using formula (Khouw 2016):

$$NK = \frac{N_{f/m}}{N} \times 100\% \quad [5]$$

Where, NK is sex ratio, $N_{f/m}$ is number of females or males shark, N is total number of shark observed. The balanced of sex ratio was investigated using the Chi-square test (X^2) with the equation (Wulandari et al. 2021):

$$X^2 = \sum \frac{(f_o - f_e)^2}{f_e} \quad [6]$$

where f_o is the frequency observed, and f_e is the frequency expected. The expected sex ratio of male:female was 1:1 (equal or balanced).

Length at first maturity

Maturity stages was calculated from male shark by observing the clasper. Shark with either Non-Calcified (NC) or Not-Fully Calcified (NFC) claspers were considered as immature, while those with Fully Calcified (FC) claspers were considered as mature shark. The length at 50% maturity (L_{50} or L_m) was then calculated using a logistic function (King 2007):

$$P = \frac{1}{(1 + e^{-r(L-L_{50})})} \quad [7]$$

Where, P is the proportion of sexually mature individuals, r is the steepness of the curve, L is sharks' fork length, and L_m is the fork length at which 50% of sharks are mature. Since L_m (L50) is estimated from logistic regression, the bootstrapping was used to estimate its 95% Confidence Intervals (CI) using R software.

RESULTS AND DISCUSSION

Sample composition and size distribution

A total of 484 bigeye thresher sharks were sampled during the study period. This species was distinguished by its very big eye and nearly level with the head's dorsal surface, the shape of the head is almost straight between the eyes with a deep curve at the nape of the neck, the first dorsal fin is closer to the base of the ventral fin than to the rear tip of the pectoral fin, and white part of belly not extending over pectoral fin base (Figure 2). Samples consisted of 241 males and 243 females with a wide range of fork length and weight (Table 1). On average, male sharks were longer and heavier than female. Moreover, the length frequency distribution demonstrates that the dominant size of males and females was 151-160 and 141-150 cm FL length class, respectively. Meanwhile, the very large individuals exceeding 230 cm FL for both sexes constituted less than 1% of the samples (Figure 3).

Figure 2. *Alopias superciliosus* landed at Cilacap Fishing Port, Indonesia

Table 1. Descriptive data for *Alopias superciliosus* during the study

Parameter	Male (n: 241)		Female (n: 243)	
	Fork length (cm)	Weight (kg)	Fork length (cm)	Weight (kg)
Minimum	94	8	77	10
Maximum	237	150	256	165
Std.Dev.	28.83	27.39	29.19	30.56
Average±S.E	156.14±1.86	55.19±1.76	147.6±1.87	48.3±1.96

Sex ratio

A total of 241 males (49.8%) and 243 females (50.2%) were recorded, resulting in an overall sex ratio of approximately 1:1. A chi-square goodness-of-fit test yielded no significant deviation (X^2: 0.008, $p>0.05$) from the expected 1:1, indicating that both sexes have equal representation in the sampled catches. Despite the overall balance, monthly comparisons revealed instances where females outnumbered males or vice versa (Table 2).

Length-weight relationship

The length-weight relationship of *A. superciliosus* for the combined sexes presented the following parameters: a: 0.00003, b: 2.871 (R^2: 0.86, n: 484), resulting the estimated equation W: $0.00003*FL^{2.871}$. The b coefficient value showed a significant deviation from the isometric value of 3 ($p<0.05$). Similar value of b coefficient was also observed in male (W: $0.00004*FL^{2.789}$, R^2: 0.84, n: 241) and female (W: $0.00002*FL^{2.936}$, R^2: 0.88, n: 243). The b slope indicated negative allometric growth ($b<3$), suggesting that weight gain occurred at a slower rate compared to the increase in length.

Relative condition factor

The relative condition factor (K_n) was computed for each shark to evaluate its nutritional and physiological status. Overall, K_n-values were ranged from 0.53 to 3.23, with an average of 1.02 (±0.01, SE). The condition factor of males was ranged from 0.64 to 3.23 (1.03±0.02; Average±S.E), and females from 0.53 to 2.57 (1.01 ± 0.02; Average ± S.E). In average, *A. Superciliosus* presented a healthy nutritional condition since values larger than the threshold (1).

At a monthly scale, the highest average Kn values for males was observed in July (Kn: 1.28) and August (Kn: 1.02). Meanwhile, the highest average of Kn values for females were recorded in December (1.26), followed by July, November, and October with Kn value 1.13, 1.04, and 1.02, respectively (Figure 4).

Length at first maturity

In this study, data on the sexual maturity of female thresher sharks was not available. Hence, the analysis focused solely on male maturity. Macroscopic inspection of claspers enabled the classification of maturity stages for 210 males. Logistic regression analyses indicated that the length at which 50% of males reached sexual maturity (Lm) was 150.61 cm FL (95% CI: 146-154.81) (Figure 5) with value of a: -10.3 and b: 0.069. According to length at first maturity, more than half of male sharks were caught in mature condition (n: 146; 61%) and the rest were immature (n: 95; 39%).

Discussion

This study investigated *A. superciliosus* Indonesian waters, providing insights into the species' life history and population structure in a tropical environment. Size distribution of individuals in the present study exhibited a wide range of fork lengths (77-256 cm FL), with the largest female reaching 256 cm FL (Table 1). This broad size range reflects the presence of various age groups within the fishery landings. Similar patterns were noted in other studies, such as Ramadhani et al. (2023) in Muncar, Indonesia, Mohanraj et al. (2024) in the Southern coast of India, and Briones-Mendoza et al. (2021) in Ecuador, which also observed considerable variation in specimen lengths. This variation is particularly noteworthy because *A. superciliosus* is known for its late maturity, around nine to ten years for males and up to thirteen years for females (Liu et al. 1998). Combined with irregular breeding cycles, this slow growth makes the species especially vulnerable to overfishing. The presence of large individuals in the catch suggests that certain adults survive to older ages, although the extent to which these adults contribute to recruitment remains unclear.

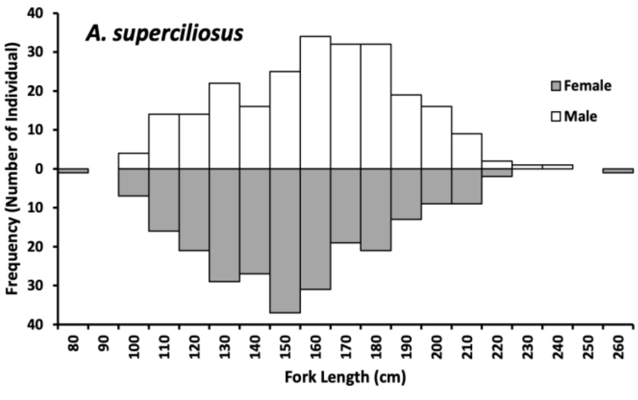

Figure 3. Length frequency distribution of *Alopias superciliosus* by sexes

Table 2. Monthly sex ratios of *Alopias superciliosus* during study. Degrees of freedom: 1

Months	n	Males	Females	Expected value	X^2	p
July	75	27	48	37.5	5.9	< 0.05*
August	217	94	123	108.5	3.9	< 0.05*
September	44	20	24	22	0.4	> 0.05
October	44	24	20	22	0.4	> 0.05
November	10	3	7	5	1.6	> 0.05
December	4	0	4	2	4	< 0.05*
January	90	73	17	45	34.8	< 0.05*
Total	484	241	243	242	0.008	> 0.05

Note: * significant differences

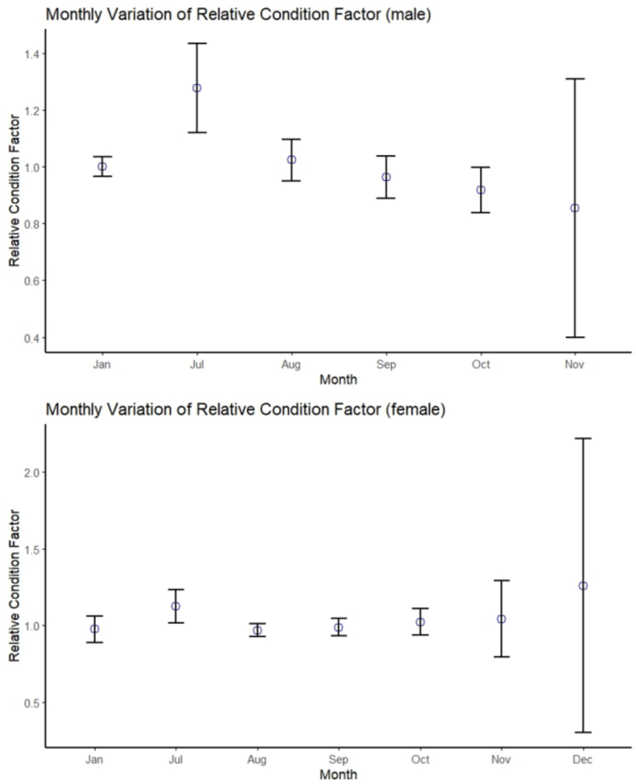

Figure 4. Monthly variations in the relative condition factor of *Alopias superciliosus* by sexes (white circles means, sticks: 95% confidence intervals for the mean)

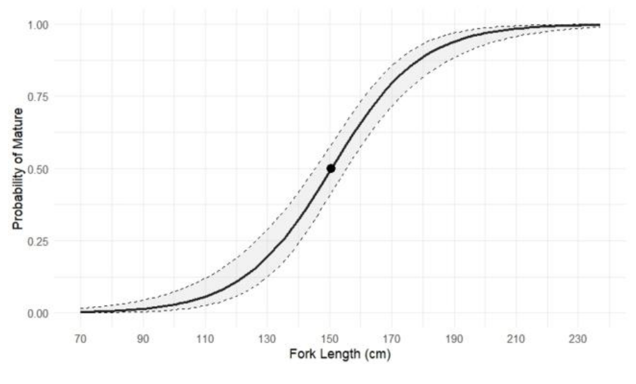

Figure 5. Length at first maturity (black dot) for males *Alopias superciliosus*. Dashed line: IC 95%

In addition, the sex ratio observed in this study was generally balanced but showed noticeable monthly fluctuations. Compared to other studies in the southern Java Sea, this result was similar with Chodrijah et al. (2020), but different from Nurastri et al. (2024). The variation of sex ratio indicating that local fishing practices and environmental factors can play a significant role in influencing the balance between male and female bigeye thresher sharks (Márquez-Farías et al. 2023). Likewise, Kanedi et al. (2023) emphasized the importance of understanding sex ratios in Indonesian shark populations for effective conservation strategies, highlighting the critical need for continuous monitoring to support long-term sustainability.

The present study investigated the length-weight relationships of *A. superciliosus* estimating a hypoallometric or negative allometric growth. The b value was commonly reported falls within range of 2.5 to 3.5 (Froese 2006; Calle-Morán et al. 2023b). Studies on *A. superciliosus* reported growth pattern that are similar to those found in this study, though some studies have shown different results (Table 3). The length-weight relationship in sharks is influenced by a complex interplay of factors, including life stage, sex, and reproductive status, which can cause growth patterns to shift between isometric and allometric (Logan et al. 2018; Thomas et al. 2021). Resource competition within the study area may further affect weight gain, highlighting the role of biotic interactions in shaping growth trajectories (Ramses et al. 2019), while environmental factors like temperature, salinity, and prey availability may also impact the length-weight relationship (Drymon et al. 2020).

This study evaluated the health and nutritional status of the sampled shark population using relative condition factor. There are three kinds of condition factors, which are Fulton's condition factor or Fulton's K (Kc) developed by Fulton, the allometric condition factor (Ka) by Bagenal and Tesch, and the relative weight condition factor (Kn) by Le Cren. In this study, the relative condition factor (Kn) was used as Kc assumes isometric growth (Hards et al. 2019), which may not be strictly applicable to species exhibiting allometric growth patterns, while Ka was less commonly used in practice (Ragheb 2023).

Table 3. Length-weight relationship of *A. superciliosus* from some studies

Location	Sex	a	b	R^2	Type of growth	Kn	Authors
Indian coast, India*	Pooled	0.000003	2.98	0.87	Isometric	-	Varghese et al. (2015)
Cilacap, Indonesia**	Male	0.00005	2.835	0.91	Isometric	-	Chodrijah et al. (2020)
Cilacap, Indonesia**	Female	0.00006	3.209	0.94	Allometric (+)	-	Chodrijah et al. (2020)
Cilacap, Indonesia**	Pooled	0.00007	2.667	-	Allometric (-)	-	Raharjo et al. (2024)
Tamil Nadu, India**	Male	0.517	2.49	0.99	Allometric (-)	1.77	Mohanraj et al. (2024)
Tamil Nadu, India**	Female	0.530	2.48	0.99	Allometric (-)	1.73	Mohanraj et al. (2024)
Cilacap, Indonesia**	Pooled	0.00003	2.87	0.86	Allometric (-)	1.02	*This study*
Cilacap, Indonesia**	Male	0.00004	2.79	0.84	Allometric (-)	1.03	*This study*
Cilacap, Indonesia**	Female	0.00002	2.94	0.88	Allometric (-)	1.01	*This study*

Note: * TL; ** FL

The average of Kn results suggest that the sampled individuals had values exceeding 1.00, implying that these sharks were in better physical condition than predicted by the general length-weight regression. These findings align with Pulapparambil et al. (2020), who note that a Kn greater than 1 to favorable environmental or nutritional conditions that enable enhanced weight to gain relative to length. The Kn values provide a more nuanced indication of the sharks' condition. These values capture deviations from the expected weight for a given length based on the specific length-weight relationship observed (Gichuru et al. 2019).

In this study, the length at first maturity (Lm) for male *A. superciliosus* was estimated at 150.61 cm FL. When compared to previous research in similar location, this length was within the range of Lm reported by Nurastri et al. (2024) (145.97 cm FL), and Raharjo et al. (2024) (160.8 cm FL). Looking at the length frequency analysis for male sharks (Figure 2), around 60.5% of *A. superciliosus* were harvested above the size of maturity. However, the capture of approximately 40% of sharks below their estimated length at maturity (Lm) raises concerns, as it may adversely affect the sustainability of shark populations in this area. This practice poses a risk to the long-term viability of the species, potentially disrupting their reproductive capacity and overall population dynamics. In addition, Lm estimation for female *A. superciliosus* was 315.7 cm TL ≈ 186.97 cm FL (conversion equation: TL: 1.7273 (FL) - 7.2529) (Calle-Morán et al. 2023a). Implementing this estimation into female length frequency distribution resulting only 11% of female harvested above Lm. This condition could be an indication that the thresher shark fishery is experiencing growth overfishing, where a significant number of small individuals are being harvested before they reach optimum size for mating (King 2007).

In summary, this study enhances the understanding of *A. superciliosus* biology in Indonesian waters and emphasizes its susceptibility to overexploitation. By analyzing key parameters such as the length-weight relationship, relative condition factor, and length at first maturity, fisheries managers are equipped with valuable insights to design more sustainable management strategies. Results indicated that the habitat and environmental conditions in which *A. superciliosus* live support their growth. However, the present of sharks harvested below Lm (around 40% for males and 89% of females) raises concerns regarding potential overexploitation. Implementing a size-limit policy for *A. superciliosus*, which was also suggested by Raharjo et al. (2024), represents a management strategy that warrants consideration for sustainable fisheries management. In addition, given that *A. superciliosus* is primarily caught as bycatch in tuna longline, handline and gillnet fisheries, implementing policy measures related to fishing gear operations could be another viable approach. Strategies such as adjusting fishing grounds or modifying the depth at which fishing gears are deployed in areas with lower shark presence may help mitigate bycatch and contribute to more sustainable fisheries management for shark. According to Ministerial Regulation No. 12/2012, the capture of Alopiidae (*A. pelagicus* and *A. superciliosus*) species is prohibited in Indonesia, and these sharks should only be landed at fishing ports if they cannot be safely released from fishing gear. However, enforcing this regulation remains challenging, especially since Alopiidae has been included in the benchmark price list for the utilization of protected and/or regulated fish species under Ministerial Decree No. 40/2024, raising concerns that this may lead to increased catches in the future. Therefore, continuous monitoring is essential to track shark populations and support future management and conservation efforts.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Santoso Budi Widiarto, S.Sos., M.P. (Head of Coastal and Marine Resources Management Agency of Serang, Indonesia), all staffs of Cilacap Ocean Fishing Port and the Coastal, Indonesia and Marine Resources Management Agency of Serang for assisting and supporting data collection in field. This study is part of Basic Research Grant (*Penelitian Dasar Pemula*) 2024 funded by Universitas Brawijaya, Indonesia number: 00146.7/N10.A0501/B/PT.01.03.2/2024.

REFERENCES

Anderson T, Meese EN, Drymon JM, Stunz GW, Falterman B, Menjivar E, Wells RJD. 2022. Diel vertical habitat use observations of a scalloped hammerhead and a bigeye thresher in the northern Gulf of Mexico. Fishes 7 (4): 148. DOI: 10.3390/fishes7040148.

Arnés-Urgellés C, Galván-Magaña F, Elorriaga-Verplancken FR, Delgado-Huertas A, Páez-Rosas D. 2024. Ontogenetic feeding shifts in two thresher shark species in the Galapagos Marine Reserve. PeerJ 12: e18681. DOI: 10.7717/peerj.18681.

Booth H, Squires D, Milner-Gulland EJ. 2019. The neglected complexities of shark fisheries, and priorities for holistic risk-based management. Ocean Coast Manag 182: 104994. DOI: 10.1016/j.ocecoaman.2019.104994.

Bouyoucos IA, Talwar BS, Brooks EJ, Brownscombe JW, Cooke SJ, Suski CD, Mandelman JW. 2018. Exercise intensity while hooked is associated with physiological status of longline-captured sharks. Conserv Physiol 6 (1): 74. DOI: 10.1093/conphys/coy074.

Braccini M, Watt M, Syers C, Blay N, Navarro M, Burton M. 2024. The social and economic dimensions of one of the world's longest-operating shark fisheries. Mar Freshw Res 75 (6): 1-10. DOI: 10.1071/mf23094.

Bramasta RC, Faiqoh E, Hendrawan IG, Sembiring A, Yusmalinda NLA. 2021. Identification of traded sharks in Bali using DNA barcoding methods and phylogenetic analysis. J Mar Aquat Sci 7 (1): 84-93. DOI: 10.24843/jmas.2021.v07.i01.p12. [Indonesian]

Briones-Mendoza J, Carrasco-Puig P, Toala-Franco D. 2021. Reproductive biology aspects of *Alopias pelagicus* and *A. superciliosus* (Lamniformes: Alopiidae) in the Ecuadorian Pacific. Neotrop Ichthyol 19 (4): e210015. DOI: 10.1590/1982-0224-2021-0015.

Calle-Morán MD, Fogacho-Guingla MP, Hernández-Téllez AR, Galván-Magaña F. 2023a. Reproductive biology of the bigeye thresher, *Alopias superciliosus*, in the tropical Eastern Pacific Ocean. Reg Stud Mar Sci 61: 102867. DOI: 10.1016/j.rsma.2023.102867.

Calle-Morán MD, Oddone MC, Márquez-Farías JF, Bonfil R. 2023b. Size structure, length-body mass relationship, and relative condition factor of the crocodile shark, *Pseudocarcharias kamoharai*, in the Southeastern Pacific Ocean, Ecuador. Reg Stud Mar Sci 60: 102890. DOI: 10.1016/j.rsma.2023.102890.

Carpenter KE, Niem VH. 1998. FAO Species Identification Guide for Fishery Purposes: The Living of Marine Resources of the Western Central Pacific Vol. 2. Food and Agriculture Organization of the United Nations, Rome.

Chodrijah U, Prihatiningsih P, Panggabean AS, Herlisman H. 2020. Size structure and population parameters of bigeye thresher shark (*Alopias superciliosus* lowe, 39) in the Southern of Java's Indian Ocean. Jurnal Penelitian Perikanan Indonesia 26 (1): 21-28. DOI: 10.15578/jppi.26.1.2020.21-28. [Indonesian]

Coelho R, Fernandez-Carvalho J, Santos MN. 2015. Habitat use and diel vertical migration of bigeye thresher shark: Overlap with pelagic longline fishing gear. Mar Environ Res 112: 91-99. DOI: 10.1016/j.marenvres.2015.10.009.

Drymon JM, Dedman S, Froeschke JT, Seubert EA, Jefferson AE, Kroetz AM, Mareska JF, Powers SP. 2020. Defining sex-specific habitat suitability for a northern Gulf of Mexico shark assemblage. Front Mar Sci 7: 35. DOI: 10.3389/fmars.2020.00035.

Dulvy NK, Pacoureau N, Rigby CL, Pollom RA, Jabado RW, Ebert DA, Finucci B, Pollock CM, Cheok J, Derrick DH, Herman KB, Sherman CS, VanderWright WJ, Lawson JM, Walls RHL, Carlson JK, Charvet P, Bineesh KK, Fernando D, Ralph GM, Matsushiba JH, Hilton-Taylor C, Fordham SV, Simpfendorfer CA. 2021. Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. Curr Biol 31 (21): 4773-4787. DOI: 10.1016/j.cub.2021.08.062.

Fahmi, Dharmadi. 2015. Pelagic shark fisheries of Indonesia's Eastern Indian Ocean Fisheries Management Region. Afr J Mar Sci 37 (2): 259-265. DOI: 10.2989/1814232X.2015.1044908.

Fernandez-Carvalho J, Coelho R, Mejuto J, Cortés E, Domingo A, Yokawa K, Liu KM, García-Cortés B, Forselledo R, Ohshimo S, Ramos-Cartelle A. 2015. Pan-Atlantic distribution patterns and reproductive biology of the bigeye thresher, *Alopias superciliosus*. Rev Fish Biol Fisher 25 (3): 551-568. DOI: 10.1007/s11160-015-9389-7.

Froese R. 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. J Appl Ichthyol 22: 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x.

Gichuru NN, Manyala JO, Raburu PO. 2019. Some aspects of reproduction and feeding habits of nile tilapia (*Oreochromis niloticus*) in three dams in Uasin Gishu County, Kenya. Lakes Reserv Res Manag 24 (2): 181-189. DOI: 10.1111/lre.12271.

González-Pestana A, Mangel JC, Alfaro-Córdova E, Acuña-Perales N, Córdova-Zavaleta F, Segura-Cobeña E, Benites D, Espinoza M, Coasaca-Céspedes J, Jiménez A, Pingo S, Moscoso V, Alfaro-Shigueto J, Espinoza P. 2020. Diet, trophic interactions, and possible ecological role of commercial sharks and batoids in northern Peruvian waters. J Fish Biol 98 (3): 768-783. DOI: 10.1111/jfb.14624.

Hards AR, Gray MA, Noël SC, Cunjak RA. 2019. Utility of condition indices as predictors of lipid content in slimy sculpin (*Cottus cognatus*). Diversity 11 (5): 71. DOI: 10.3390/d11050071.

Hasan V, Gausmann P, Ottoni FP. 2021a. First scientific observation of the threatened speartooth shark *Glyphis glyphis* (Müller & Henle, 1839) (Carcharhiniformes: Carcharhinidae) in Indonesia. Cybium 45 (4): 321-324. DOI: 10.26028/cybium/2021-454-010.

Hasan V, Samitra D, Widodo MS, Gausmann P. 2021b. A new inland record of the bull shark *Carcharhinus leucas* (Müller & Henle 1839) from Peninsular Malaysia. Sains Malays 50 (10): 3153-3158. DOI: 10.17576/jsm-2021-5010-26.

Hasan V, Widodo M. 2020. The presence of Bull shark *Carcharhinus leucas* (Elasmobranchii: Carcharhinidae) in the fresh waters of Sumatra, Indonesia. Biodiversitas 21 (9): 4433-4439. DOI: 10.13057/biodiv/d210962.

Jisr N, Younes G, Sukhn C, El-Dakdouki MH. 2018. Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. Egypt J Aquat Res 44 (4): 299-305. DOI: 10.1016/j.ejar.2018.11.004.

Kanedi MM, Wijayanti, DP, Widowati I, Malik MD, Yusmalinda, NLA, Sembiring A. 2023. Genetic diversity of bigeye thresher shark (*Alopias superciliosus* lowe, 1841) landed in Palabuhanratu fishing port, Sukabumi, West Java, Indonesia. Biodiversitas 24 (6): 3488-3494. DOI: 10.13057/biodiv/d240646.

Khouw AS. 2016. Methods and Quantitative Analysis in Bioecology. Alfabet, Bandung. [Indonesian]

King M. 2007. Fisheries Biology Assessment, and Management. Blackwell Publishing Ltd., Oxford. DOI: 10.1002/9781118688038.

Liu KM, Chiang PJ, Chen CT. 1998. Age and growth estimates of the bigeye thresher shark *Alopias superciliosus*, in northeastern Taiwan waters. Fish Bull 96 (3): 482-491.

Logan RK, White CF, Winkler C, Jorgensen SJ, O'Sullivan JB, Lowe CG, Lyons K. 2018. An evaluation of body condition and morphometric relationships within Southern California juvenile white sharks *Carcharodon carcharias*. J Fish Biol 93 (5): 842-849. DOI: 10.1111/jfb.13785.

Márquez-Farías JF, Carrillo-Colín LD, Santana-Hernández H, Vélez-Marín R. 2023. Sex ratio and size structure of *Carcharhinus longimanus, Galeocerdo cuvier,* and *Alopias superciliosus* incidentally caught in a longline fishery from the Central Mexican Pacific. Arquivos De Ciências Do Mar 56 (1): 82913. DOI: 10.32360/acmar.v56i1.82913.

Mohanraj T, Rajathy TJ, Cross SRTS. 2024. Length-weight relationship, condition factor, and diet analysis of thresher sharks (Family: Alopiidae) along the southern coast of India. Fish Res 277: 107067. DOI: 10.1016/j.fishres.2024.107067.

Nurastri VD, Prayitno SB, Saputra SW. 2024. Biological characteristics of bigeye thresher shark (*Alopias superciliosus*) landed in Cilacap Ocean Fishing Port, Cilacap Regency, Central Java, Indonesia. Asian J Curr Res 9 (4): 197-206. DOI: 10.56557/ajocr/2024/v9i49017.

Pacoureau N, Rigby CL, Kyne PM, Sherley RB, Winker H, Carlson JK, Fordham SV, Barreto R, Fernando D, Francis MP, Jabado RW, Herman KB, Liu K, Marshall AD, Pollom RA, Romanov EV, Simpfendorfer CA, Yin JS, Kindsvater HK, Dulvy NK. 2021. Half a century of global decline in oceanic sharks and rays. Nature 589 (7843): 567-571. DOI: 10.1038/s41586-020-03173-9.

Pontavice H, Gascuel D, Reygondeau G, Stock C, Cheung WWL. 2021. Climate-induced decrease in biomass flow in marine food webs may severely affect predators and ecosystem production. Glob Change Biol 27 (11): 2608-2622. DOI: 10.1111/gcb.15576.

Pulapparambil A, Nirichan MS, Mahadevan H, Karuppaswamy SP. 2020. Length weight relationship and relative condition factor study in *Sahyadria chalakkudiensis* inhabiting Western Ghat river systems of south India. J Trop Life Sci 10 (1): 9. DOI: 10.11594/jtls.10.01.09.

Ragheb E. 2023. Length-weight relationship and well-being factors of 33 fish species caught by gillnets from the Egyptian Mediterranean waters off Alexandria. Egypt J Aquat Res 49 (3): 361-367. DOI: 10.1016/j.ejar.2023.01.001.

Raharjo B, Hartati R, Redjeki S. 2024. Population status of thresher shark listed in Appendix II CITES of Southern Java Seas, Indonesia. Egypt J Aquat Res 50 (2): 260-266. DOI: 10.1016/j.ejar.2024.03.007.

Ramadhani H, Lelono TD, Bintoro G, Setyanto A, Rahman MA, Bahtiar NH, Salim MG, Gozali IC. 2023. Biological aspects of *Alopias pelagicus* nakamura, 1935 and *Alopias superciliosus* lowe, 1839 land in Muncar coastal fishing port (PPP). J Fish Mar Res 7 (3): 54-64. DOI: 10.21776/ub.jfmr.2023.007.03.

Ramses R, Ismarti I, Syamsi F. 2019. Length-weight relationships and condition factors of four dominant fish caught by coral bubu trap on the west coast of Batam Island, Indonesia. Aceh J Anim Sci 5 (1): 14902. DOI: 10.13170/ajas.5.1.14902.

Rigby CL, Barreto R, Carlson J, Fernando D, Fordham S, Francis MP, Herman K, Jabado RW, Liu KM, Marshall A, Pacoureau N, Romanov E, Sherley RB, Winker H. 2019. *Alopias superciliosus*. The IUCN Red List of Threatened Species 2019: e.T161696A894216. DOI: 10.2305/IUCN.UK.2019-3.RLTS.T161696A894216.en.

Sherman CS, Sant G, Simpfendorfer CA, Digel ED, Zubick P, Johnson G, Usher M, Dulvy NK. 2022. M-risk: A framework for assessing global fisheries management efficacy of sharks, rays and chimaeras. Fish Fisheries 23 (6): 1383-1399. DOI: 10.1111/faf.12695.

Simeon BM, Muttaqin E, Mardhiah U, Ichsan M, Dharmadi, Prasetyo AP, Fahmi, Yulianto I. 2018. Increasing abundance of silky sharks in the Eastern Indian ocean: Good news or a reason to be cautious? Fishes 3 (3): 29. DOI: 10.3390/fishes3030029.

Smukall MJ, Carlson J, Kessel ST, Guttridge TL, Dhellemmes F, Seitz AC, Gruber S. 2022. Thirty-five years of tiger shark *Galeocerdo cuvier* relative abundance near Bimini, the Bahamas, and the southeastern United States with a comparison across jurisdictional bounds. J Fish Biol 101 (1): 13-25. DOI: 10.1111/jfb.15067.

Stevens J, Bonfil R, Dulvy N, Walker P, 2018. The effects of fishing on sharks, rays, and chimaeras (Chondrichthyans), and the implications for marine ecosystems. ICES J Mar Sci 57: 476-494. DOI: 10.1006/jmsc.2000.0724.

Temple AJ, Berggren P, Jiddawi N, Wambiji N, Poonian CNS, Salmin YN, Berumen ML, Stead SM. 2024. Linking extinction risk to the economic and nutritional value of sharks in small-scale fisheries. Conserv Biol 38 (6): 14292. DOI: 10.1111/cobi.14292.

Thomas S, Muktha M, Sen S, Kizhakudan SJ, Akhilesh KV, Purushottama GB, Mahesh V, Rahangdale S, Zacharia PU, Najmudeen TM, Manojkumar PP, Remya L, Wilson L, Roul SK, Pradhan R, Seetha PK, Yousuf KSSM, Nataraja GD. 2021. Status of the hammerhead shark (Carcharhiniformes: Sphyrnidae) fishery in Indian waters with observations on the biology of scalloped hammerhead *Sphyrna lewini* (Griffith & Smith, 1834). Aquat Conserv Mar Freshw Ecosyst 31 (11): 3072-3086. DOI: 10.1002/aqc.3686.

Tsikliras A, Dimarchopoulou D. 2021. Filling in knowledge gaps: Length-weight relations of 46 uncommon sharks and rays (Elasmobranchii) in the Mediterranean sea. Acta Ichthyologica Et Piscatoria 51 (3): 249-255. DOI: 10.3897/aiep.51.65858.

Varghese SP, Vijayakumaran K, Tiburtius A, Mhatre VD. 2015. Diversity, abundance and size structure of pelagic sharks caught in tuna longline survey in the Indian seas. Indian J Geo-Mar Sci 44 (1): 26-36.

White WT, Last PR, Stevens JD, Yearsley GK, Fahmi, Dharmadi. 2006. Economically Important Sharks and Rays of Indonesia. ACIAR, Australia.

Wulandari TL, Taurusman AA, Nurani TW, Yuwandana DP, Muttaqin E, Yulianto I, Simeon BM. 2021. Catch composition, sex ratio, and clasper maturity of wedgefish (*Rhynchobatus* spp.) landed in Tegalsari, Central Java, Indonesia. AACL Bioflux 14 (6): 3487-3499.