



# Biological Characteristics of Bigeye Thresher Shark (*Alopias superciliosus*) Landed in Cilacap Ocean Fishing Port, Cilacap Regency, Central Java, Indonesia

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

Shark is the top predator of the marine food chain which has a unique biological condition, namely a long life cycle and is prone to population decline in nature if its utilization is not carried out wisely. This study aims to analyze the biological conditions of bigeye thresher shark (*Alopias superciliosus*) which includes sex ratio, length at first capture (Lc), length-weight relationship, condition factor, sexual maturity and length at first maturity (Lm) in male sharks during March-June 2023 landed at Cilacap Ocean Fishing Port. The results of the analysis of the sex ratio of female and male bigeye thresher sharks were 1:1.74, indicating that the sex ratio of female and male sharks is not balanced. The length at first capture (Lc) of female, male and combined sharks were 145.38 cmFL, 148.12 cmFL and 148.79 cmFL, respectively. Length-weight relationships of female, male and combined bigeye thresher sharks showed an isometric growth pattern. Condition factor values of the length-weight relationship equation ranged from 0,82-3,07. The level of sexual maturity of bigeye thresher shark was classified as 14,5% NC category, 19,7% NFC category, and 65,8% FC category, indicating that most were in the ready to spawn category. The length at first maturity (Lm) in male sharks was 145,97 cmFL. The sharks caught are mostly mature in size, so the utilization of bigeye thresher shark requires catch quotas and size restrictions as well as monitoring of shark fishing areas, which are indispensable in bigeye thresher shark conservation management efforts.

**Keywords:** Bigeye thresher shark; biologis; conservation; Cilacap Ocean Fishing Port.

## 1. INTRODUCTION

Sharks are one of the species of the sub-class elasmobranchii that are of global conservation concern due to the increasing demand for shark products including fins, cartilage, teeth [1], skin, meat and internal organs [2,3]. A quarter of the world's shark and ray populations are estimated to be in decline due to overfishing [4]. Declining population trends were also reported in a study [5]. The capture of sharks, which are apex predators in the food chain, can affect the balance of the ecosystem and the sustainability of their populations in nature.

Indonesia is one of the countries with a high level of shark utilization [6,7]. This is because Indonesia has a large marine area that has considerable fisheries potential [8]. Indonesia has 20% of the global elasmobranch diversity [9], one of which is from the Alopiidae family (thresher sharks). The Alopiidae family consists of three species including the common thresher shark (*Alopias vulpinus*), bigeye thresher shark (*Alopias superciliosus*) and pelagic thresher shark (*Alopias pelagicus*) [10]. Two species were identified in Indonesian waters including *Alopias superciliosus* and *Alopias pelagicus* [11].

Fish landing sites that contribute the most shark production in Indonesia include PPS Palabuhan Ratu (West Java), PPS Cilacap (Central Java) and PPI Tanjung Luar (West Nusa Tenggara) [12]. Cilacap Ocean Fishing Port (PPS) is a fishing port that is included in the management area of WPP 573 in Indian Ocean Waters.

Sharks caught by fishermen at PPS Cilacap are the result of catches from shark longline gear, tuna longline, gill nets and drift gill nets [7]. The dominant shark caught is the oceanic shark group [13], one of which is bigeye thresher shark. Research [14] reported an increase in the catch of bigeye thresher shark landed at PPS Cilacap.

The biological characteristics of the bigeye thresher shark are prone to population decline in nature because it has a long life cycle, slow sexual maturity, low fecundity and low population growth rate compared to other Alopiidae family sharks [15,16] Population decline caused by biological conditions, one of which is low reproduction, was also revealed in research [5]. The conservation status of bigeye thresher shark globally has been categorized as Vulnerable [17], but in Europe [18] and the Mediterranean [19] it has moved from vulnerable to Endangered based on the IUCN list.

Information related to the population of *Alopias* spp. one of which is bigeye thresher shark is still limited and not comprehensive [5]. Knowing the biological characteristics of different geographical locations can be basic information in developing a database of sharks exploited from Indonesian territory and landed at PPS Cilacap. This study aims to determine the biological condition of bigeye thresher shark (*Alopias superciliosus*) including sex ratio, length at first capture (Lc), length-weight relationship, condition factor, sexual maturity level and length first maturity (Lm) in male sharks.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

This research was conducted at the fish landing site of Cilacap Ocean Fisheries Port (PPS) with geographical reference 7°43'25.59"S-109°1'22.53"E, Cilacap Regency, Central Java Province, Indonesia. The research was conducted during March-June 2023. The research map is presented in Fig. 1.

### 2.2 Procedures

This study used observation method to explain the actual utilization condition of bigeye thresher shark. Bigeye thresher shark samples were collected by purposive selective sampling, taken every two weeks during March-June 2023. The number of samples taken was 181 bigeye thresher sharks. Sample determination has inclusion criteria which are general requirements [20] in sampling. The inclusion criteria for sampling bigeye thresher sharks in this study are that the samples are morphologically intact, the samples are not frozen and the samples are the

catch at the time of the study from vessels operating in WPP 573 and unloading at PPS Cilacap.

Measurements of bigeye thresher shark length were taken based on the length of the fork (FL), because the condition of the sharks landed is often not intact and the tail is not straight and folded, making it difficult to get an accurate total length measurement. Length measurements used a 5 m meter with an accuracy of 0,5 m and the weight of the shark was measured with a digital scale with a capacity of 150 kg with an accuracy of 0,1 g. The sex of the bigeye thresher shark was determined by observing the presence or absence of a claspers at the anus, which indicates the genitals of male sharks while the genitals of female sharks are called cloaca. The level of sexual maturity based on male sharks was determined by looking at the condition of the claspers and measuring their length. Measurement and data collection guidelines are based on shark and ray data collection guidelines [11].



**Fig. 1. Research location map**  
(Source: Geographic Information Agency, 2024)

## 2.3 Data Analysis

### • Sex Ratio Analysis

Sex ratio was calculated using the equation from [21] as follows:

$$NK = \frac{N_{b(i)}}{N_{j(i)}}$$

NK: sex ratio, N<sub>bi</sub>: number of female fish, and N<sub>ji</sub>: number of male fish. Then the analysis was based on chi-square statistics with a 95% confidence level. The hypothesis used is H<sub>0</sub>: if the sex ratio of females and males is in a balanced condition (1: 1), hypothesis H<sub>1</sub>: if the sex ratio of females and males is in an unbalanced condition. The chi-square (X<sup>2</sup>) test analysis is as follows [22].

$$X^2 = \frac{\sum (O_i - e_i)^2}{e_i}$$

X<sup>2</sup>: chi-square value, O<sub>i</sub>: number of female and male shark frequencies, and e<sub>i</sub>: number of female and male shark frequencies. The decision to accept the hypothesis or reject the hypothesis in the female and male shark sex ratio test is as follows.

1. If  $X^2_{cal} < X^2_{crit}$  then accept H<sub>0</sub> (Female and male shark sex ratio is equal)
2. Jika  $X^2_{cal} > X^2_{crit}$  then reject H<sub>0</sub> (Female and male shark sex ratio is not balanced).

### • Length at First Capture (Lc)

The length at first capture (L<sub>c</sub>) was obtained from the calculation of a sigmoid-shaped logistic curve, by plotting the 50% intersection point of the cumulative frequency curve with the shark length (FL) [23]. The calculation used the Sparre and Venema equation [22] as follows:

$$SL_{est} = \frac{1}{1 + \exp(S_1 - S_2 \times L)}$$

Note SL<sub>est</sub>: estimation on the logistic curve, S<sub>1</sub>: intercept (a), S<sub>2</sub>: slope (b) and L: length measure based on staggered length (cm).

### • Length-Weight Relationship

The length-weight relationship uses the Sparre and Venema equation as follows [24].

$$W = aL^b$$

If a logarithmic transformation is made, the equation is: Log W = Log a + b Log L. Note W: Weight (kg), a and b: the linear regression constant, L: size based on stout length (cm). The constant value of b was tested using a t-test at the 95% confidence level, with the hypothesis H<sub>0</sub>: b = 3 (the relationship between length and weight is isometric), hypothesis H<sub>1</sub>: b ≠ 3 (the relationship between length and weight is allometric). The condition factor is obtained based on the equation  $Kn = W \cdot 10^5 / L^3$  if the growth pattern is isometric and  $Kn = W / aL^b$  if allometric growth pattern [25].

### • Sexual Maturity Level of Male Sharks

The level of sexual maturity of the bigeye thresher shark can be known by observing the condition of the claspers, a rather soft condition indicates that there is no calcification (NC), for a rather hard claspers condition indicates that some of the claspers have calcification (NFC), and if the claspers condition is hard and rigid, it indicates that it is filled with lime substances which indicates that the claspers are mature and ready to mate (FC). The observation data were then grouped according to the clasper condition and then analyzed descriptively [11].

### • Length at First Maturity (Lm) in Male Sharks

A measure of sexual maturity was determined as a measure of 50% of individuals in a population having matured [5]. The analysis of the length at first maturity was analyzed by sex through a logistic model [5] as follows:

$$P = \frac{1}{1 + \exp[-r(L - L_m)]}$$

Notes P: proportion of mature or sexually mature individuals, L: size based on stalk length (cm), -r: steepness of the curve describing the change from immature to sexually mature individuals and L<sub>m</sub>: size based on stalk length in natural logarithm (a/r).

## 3. RESULTS AND DISCUSSION

### 3.1 Sex Ratio

Female bigeye thresher sharks landed at the Cilacap PPS fish landing site were caught on

average at a size interval of 91-243 cmFL, while male bigeye thresher sharks were caught on average at a size interval of 88-243 cmFL. The results of research on 181 bigeye thresher shark samples during March-June 2023 had a variety of sex ratios but tended to be dominant in male sharks. The sex ratio of female and male sharks was 1:1.74. The results of the chi-square test on 181 female and male bigeye thresher sharks showed that the  $X^2_{cal}$  and  $X^2_{crit}$  values were 9,56 and 5,99, so  $H_0$  was rejected. The sex ratio of female and male sharks was unbalanced at the 95% confidence level. The proportion of male sharks was more dominant than female sharks except in March 2023.

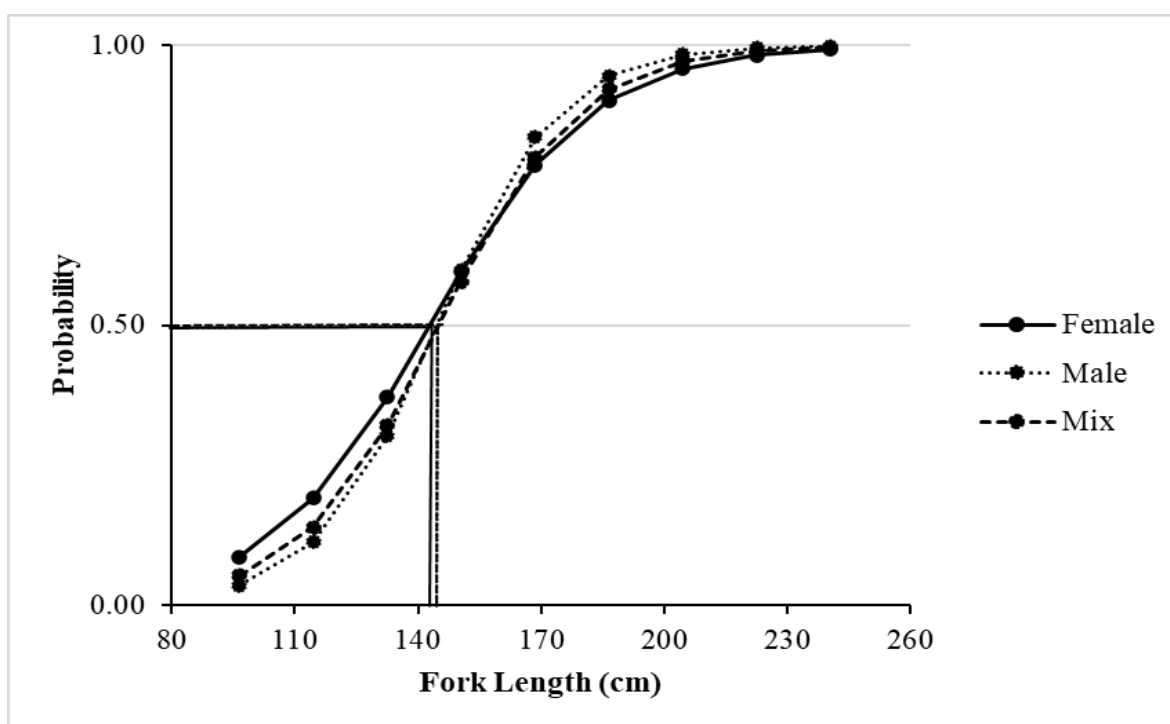
This has a difference in research [15] obtained a sex ratio of females and males of 1,02 : 1 which means that the sex ratio of females and males is

in a balanced condition. This shows that the sex ratio is always changing. Sex ratio can be used in estimating the size of the population and as a control of the size of the next generation population [15]. The sex ratio of bigeye thresher shark during March-June 2023 is presented in Table 1.

Based on research on crocodile sharks (*Pseudocarcharias kamoharai*) in the waters of the Eastern Pacific Ocean, comparisons in sex ratio are at risk of overexploitation because fishing pressure will fall on one species [5]. Research [26] reported that male individuals have a tendency to be more active in swimming and searching for females, while females tend to stay still and hide. Unbalanced sex ratio conditions cause a population of male individuals to compete for females as their mates.

**Table 1. Sex ratio of bigeye thresher shark**

Month	Shark Count (Indv)			Sex Rasio	
	Female	Male	Totally	Female	Male
March	21	18	39	1,17	1,00
April	23	65	88	1,00	2,83
May	0	0	0	0,00	0,00
June	22	32	54	1,00	1,45
Totally	66	115	181	1,00	1,74



**Fig. 2. Length at first capture (Lc) in bigeye thresher shark**

### 3.2 Length at First Capture (Lc)

The results showed the size of the length of the first time capture (Lc) based on the length of the footprint (FL) in female, male and combined bigeye thresher shark is 145,38 cm, 148,12 cm and 148,79 cm presented in Fig. 2. Based on the value of Lc, it is known that the bigeye thresher shark capture mostly in a condition that has matured in size. The length of the first time capture in the female bigeye thresher shark is smaller than the male bittern shark. Research [27] in February-December 2022 showed the Lc value based on the length of the stout (FL) in bigeye thresher shark combined females and males was 153. While the Lc value in research [20] on female and male bigeye thresher sharks is 147 cm and 154 cm. Variations in the number of samples affect the difference in Lc values, in addition to the selectivity of fishing gear, seasons and fishing areas [28,15].

### 3.3 Length Weight Relationship

The length-weight relationship of female bigeye thresher shark is obtained by the equation  $W=0,0062 FL^{3,095}$  and in male bittern sharks the equation is obtained  $W=0,0080 FL^{2,972}$ . If both

genders are combined, a regression equation is obtained  $W=0,0074 FL^{3,012}$ . The estimated values of the length-weight relationship coefficient (b) in female, male and combined bitterness sharks were 3,095, 2,972 and 3,012. The results of the t-test on female bigeye thresher shark showed  $t_{cal} (0,89) < t_{crit} (2,00)$ , then the H0 hypothesis is accepted. While the results of the t-test on bigeye thresher shark males show  $t_{cal} (0,36) < t_{crit} (1,98)$ , then hypothesis H0 is accepted. The results of the t-test on the combined gender result in a similar hypothesis with the value showing  $t_{cal} (0,20) < t_{crit} (1,97)$ , then the H0 hypothesis is accepted. Based on the results of the t-test value on female, male and combined bitterness sharks, it shows an isometric growth pattern ( $b = 3$ ), namely the increase in length is balanced with the growth of shark weight during March-June 2023. The coefficient of determination ( $r^2$ ) in female, male and combined bitterness sharks is 0,92, 0,89 and 0,91, the correlation value has a strong to very strong closeness. Length and weight growth rates are relatively balanced in the range of 89-92%, while the rest is influenced by other factors that support growth including environmental factors and fish age. The length-weight relationship is presented in Fig. 3.

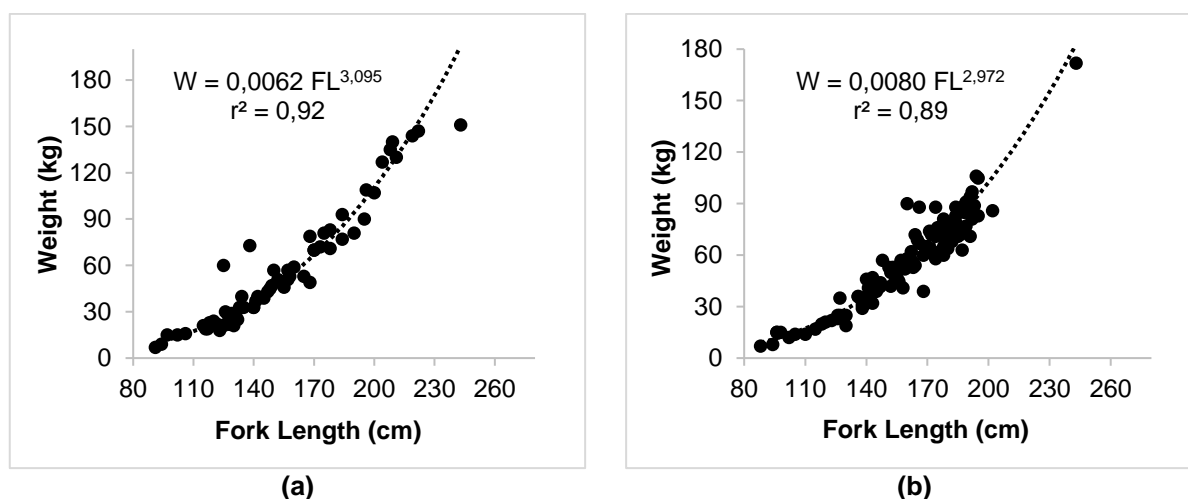


Fig. 3. Length-weight relationship of female (a) and male (b) bigeye thresher sharks during March-June 2023

Table 2. Condition factor of bigeye thresher shark length-weight relationship during March-June 2023

Sex Ratio	N	Equations	a	b	R <sup>2</sup>	Condition Factor
Female	66	$W = 0,0062 FL^{3,09}$	0,0062	3,09	0,92	0,93-3,07
Male	115	$W = 0,0079 FL^{2,97}$	0,0079	2,97	0,89	0,82-2,20
Mix	181	$W = 0,0074 FL^{3,01}$	0,0074	3,01	0,91	0,82-3,07

**Table 3. Classification of sexual maturity in male bigeye thresher sharks**

Classification	Clasper Length cm)	Shark count (indv)	Percentage (%)
NC	2-7	17	14,8
NFC	8-18	23	20,0
NF	14-26	75	65,2

Description: NC = Non Calcified, NFC = Non Full-Calcified, FC = Full Calcified

Condition factor values based on isometric growth patterns of length-weight relationships ranged from 0,82-3,07. The condition factor of bigeye thresher shark during March-June 2023 varied but tended to be in the range of 1-3 (Table 2). Condition factor values ranging from 1-3 indicate a plump fish body and good physical condition for survival and reproduction [25]. Condition factor values indicate the suitability of environmental factors for shark growth [4]. Similarly, [15] stated that differences in environmental conditions affect fish growth. Bigeye thresher sharks caught in the waters of WPP 573 and landed at PPS Cilacap are in good growth conditions in their habitat so that they are good at survival and reproduction.

### 3.4 Shark Sexual Maturity Level

Determination of sexual maturity by looking at the maturity class in Table 3. The results showed that bigeye thresher sharks landed at PPS Cilacap were found to be immature with 14,8% in the NC category and 20,0% in the NFC category. However, most were in the Full-Calcified (FC) category with a percentage of 65,2%. This indicates that the claspers are mature and the sharks are ready to mate. Male bigeye thresher sharks landed during March-June 2023 were mostly in adult condition.

The tendency of sexual maturity can be influenced by high fishing pressure and selectivity in fishing gear, the lower the fishing pressure, the smaller the size of the fish caught [15]. Need to know the area that is *nursery ground*, *spawning ground* and *feeding ground*. bigeye thresher shark is vulnerable to overfishing [29], because its life cycle takes a long time to reach sexual maturity and has a very low recruitment rate. Based on the biological information of bigeye thresher shark landed at PPS Cilacap, monitoring of bigeye thresher shark habitat, setting quotas for utilization in nature and limiting the size of the catch that can be taken are needed.

### 3.5 Length at First Maturity (Lm)

The length at first maturity was estimated based on the size of the claspers in male sharks and analyzed according to the size of the body length. The results of the study during March-June 2023 showed the length at first maturity (Lm) of male bigeye thresher shark was 145,97 cmFL. A similar study [27] in February-December 2022, showed the Lm value based on the length of the carapace was around 160 cm. Differences in Lm values are influenced by the time of observation in the field related to seasonal differences, selectivity of fishing gear and the number of samples analyzed. Sharks from the Alopiidae family are generally caught by handline fishing, fishing rods have selectivity based on the size of the fishing line [30].

The length at first capture (Lc) of 148,12 in male bigeye thresher sharks was greater than the length at first maturity (Lm) of 145,97. This condition indicates the capture of mature male sharks. In contrast to the results of research [27], the value of Lc is smaller than the value of Lm, which indicates that the bigeye thresher shark caught is immature in length. The need for monitoring of the fishing area. It is estimated that *spawning ground* (spawning area), *feeding ground* (the area to find food) and *nursery ground* (nursery area). Based on the Lc and Lm values obtained from this study as information that supports regulations in limiting overexploitation of bitterness sharks caught as target catch or by-catch [31,32].

## 4. CONCLUSION

The size structure of bigeye thresher shark during March-June 2023 averaged 82-243 cmFL. The sex ratio of female and male bigeye thresher sharks was 1:1.74, indicating an unbalanced sex ratio. The first caught size ratio (Lc) was greater than the first sexually mature size (Lm) indicating that the sharks caught were mature. The length-weight relationship of bigeye thresher shark showed an isometric growth pattern ( $b=3$ )

indicating a balanced length increase with weight growth. The sexual maturity obtained shows that most of the sharks caught and landed at TPI PPS Cilacap during March-June 2023 are in a mature clasper condition and ready to spawn. Based on these biological conditions, monitoring of fishing areas that become bigeye thresher shark habitat is needed, regulation of catch quotas and selectivity of shark sizes that can be utilized.

### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Updated Ecological Risk  
Assessment (ERA) for shark species

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