Growth estimates of pelagic thresher shark (*Alopias pelagicus* Nakamura, 1935) in the Indian Ocean Southern Java waters

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Abstract. *Alopias pelagicus* were highly migratory species, oceanic and almost always found in tropical and temperate seas. This species was particularly vulnerable to exploitation of both targets and side catches. Research was conducted in May 2015 to November 2016 at the landing site of the Cilacap Fishing Port. This research aims to estimate the growth as the foundation for knowing the stock status utilization rate. The research method was used through observation and data collection by the enumerator. The 1410 individual shark were a catch of long line caught in the Indian Ocean Southern Java waters. The results showed that the size structure of the pelagic thresher shark ranged between 60-270 cm FL with a mode ranging between the size of 140 cm FL. The length weight relationship of the male and female shark indicates the growth were allometric positif. A comparison of male and female shark was not balance (1:2.82). Mortality parameters for the covering the total mortality rate (Z), natural mortality rate (M) and the rate of fishing mortality (F), respectively at 0.796/year, 0.295/year and 0.50/year. The rate of exploitation (E) of pelagic thresher shark was 0.73/year. Thus, the utilization rate of pelagic thresher shark was over fishing.

1. Introduction

*Alopias pelagicus* is included in the Alopiidae family of the Lamniformes order, consisting of three species; *Alopias vulpinus, A. superciliosus* and *A. pelagicus*. The local names are; *hiulancur* (Bali), *hiutikus* (Lombok), *hiupedang* (Jakarta) and *titusan* (Cilacap). *Alopias* spp. are a group of long-tailed sharks that live in continental to oceanic shelf waters [1].

The conservation status of pelagic thresher according to the International Union for the Conservation of Nature and Natural Resources (IUCN) is endangered [2]. Types of *Alopias* spp. was included in the Appendix II list on October 4th, 2017 [3]. As a follow up, Indonesia has developed a National Action Plan for Sharks and Rays 2016-2020. This document is a national reference in the conservation and management of shark and ray resources in Indonesia [4].

Sharks are generally very vulnerable to overfishing pressure [5]. This is due to several biological characteristics of sharks such as slow growth rate, long life, slow growth in sexual maturity and also their reproductive cycle [6]. Therefore, monitoring of the population status of pelagic thresher shark and other shark species is necessary so that management can be carried out in a sustainable manner. Utilization activities from year to year in these waters tend to increase. Twenty-five percent of the total shark catch landed in Indonesia is *Alopias pelagicus* and *Sphyrna lewini* [7].

Based on statistical data on capture fisheries at the Cilacap Ocean Fishing Port, it provides information that the production of *A. pelagicus* in 2004 was 22.6 tons [8] then increased to 113.5 tons in 2018 [9]. The composition of the pelagic thresher shark that was caught in the waters of the South Indian Ocean in Java and landed in Cilacap was 32.69%, so it is suspected that this species is under
high utilization pressure [10]. Most of the use of pelagic thresher shark resources in Indonesia comes from longline fishing gear. Thresher shark is the bycatch of tuna longline fishing gear and it is difficult to avoid being caught [11].

This study aims to estimate the age and growth parameters of thresher shark caught in the Indian Ocean Southern Java waters. One approach commonly used is the estimation of the utilization rate based on the length distribution data. The information generated is expected to be one of the basic information in the planning of the management of the thresher shark resource that can be utilized in a sustainable manner.

2. Materials and methods

2.1. Site and Time

This research was conducted in Cilacap Fishing Port from May 2015 to November 2016. Species identification was carried out using several references according to [1].

2.2. Sampling and Measurement Procedures

The continuous sampling of 1410 thresher sharks was carried out by trained enumerators. Biological parameters measured include fork length (FL) (in cm) and sex. Sex determination was carried out based on the characteristics of a pair of claspers (for male sharks), which is a modification of the extension of the two male shark pelvic fins used during copulation.

The balance of the sex ratio was analyzed using the Chi-square test [12]:

\[ X^2 = \sum_{i=1}^{k} \frac{(f_o - f_n)^2}{f_n} \]  

(1)

where:
- \( X^2 \) = Chi Square
- \( f_o \) = observed frequency
- \( f_n \) = expected frequency

The length-weight relationship of thresher sharks follows the cubic law with the equation [13]:

\[ W = aL^b \]  

(2)

Where \( W \) = weight (gram), \( L \) =fork length (cm) and \( a \) and \( b \) as constants

The growth of the thresher shark is calculated based on the von Bertalanffy growth equation [14]:

\[ L_t = L_\infty (1 - e^{-kt}) \]  

(3)

Where \( L_t \) = fork length of the thresher sharks at age \( t \), \( L_\infty \) = the maximum fork length (asymptotic fork length), \( K \) = growth rate and \( t_o \) is the theoretical lifespan at zero fork length. Asymptotic fork length (\( L_\infty \)) and growth rate (\( K \)) were analyzed through the TropFishR package with the R program [15, 16] Age before entering the fishery (\( t_o \)) was estimated based on the [17] equation :

\[ \log(t_o) = 0.3922 - 0.2752 \log(L_\infty) + 0.6543 \log(K) + 0.4634 \log(T) \]  

(4)

The mortality rate includes the total mortality (\( Z \)), natural mortality (\( M \)) and fishing mortality (\( F \)). The total mortality rate (\( Z \)) was estimated by the length converted catch curve method [18]. Estimation of the natural mortality rate (\( M \)) using the equation [19] with the addition of an average temperature (\( T \)) of 29°C as follows:

\[ \log(M) = -0.0066 - 0.279 \log(L_\infty) + 0.6543 \log(K) + 0.4634 \log(T) \]  

(5)
where:
\[ L_\infty = \text{asymptotic length (cmFL)} \]
\[ K = \text{growth rate} \]
\[ T = \text{average temperature of the aquatic environment} = 29^\circ C \]

The catch mortality rate and exploitation rate are estimated using equation [18]:
\[ F = (Z - M) \]  
\[ E = F / Z \]  
(6) (7)

3. Results and discussion
Based on the results of the study, 1410 pelagic thresher shark (A. pelagicus) were caught, distributed in fork length around 60-270 cmFL with the mode being 140 cmFL (Figure 1). The results of this research are almost the same as those of [20] in the same waters ranged between 150-170 (immature gonads) and 250-270 cm (mature gonads). According to [21] stated that the total length range of pelagic thresher shark caught in the West Sumatra waters is 143-300 cm TL. A. pelagicus from artisanal fisheries in Manta, Ecuador obtained a size length of 68-183 cmPCL (male) and 70-180 cmPCL (female) [22]. The length of A. pelagicus found in the Pacific Northwest ranges from 90-190 cmFL[23]. [11] added that the length of pelagic thresher shark ranges from 202-309 cm TL and females range from 206-328 cm TL, while [24] states that the thresher shark can reach 330 cm. The difference in the size of the shark species A. pelagicus is due to differences in the aquatic environment, selectivity of fishing gear, differences in habitat and genetic variation [25]. In addition, the difference in the size range of the caught is also thought to be due to differences in the selectivity of the fishing gear used, the habitat and the fishing area [26]. According to [27] that high fishing pressure and low gear selectivity will cause the size of the fish caught to be smaller and affect the maturity size of the gonads.

![Figure 1](image)

**Figure 1.** Fork length distribution of pelagic thresher shark in the Indian Ocean Southern Java waters.

The length and weight relationship of female pelagic thresher shark based on 562 samples obtained a coefficient value of \( a = 0.000003 \) and a value of \( b = 3.2899 \) (\( r^2 = 0.9201 \)). In the male thresher shark group of 199 samples, the coefficient \( a = 0.000006 \) and the value of \( b = 3.1636 \) (\( r^2 = 0.8791 \)) was obtained.

After the t test was carried out with a confidence level of 95%, the female thresher sharks obtained the value of \( t \) count = 7.20151 which was greater than \( t \) table = 1.9642. Whereas for male, the value of \( t \) count = 1.999 was obtained which was greater than \( t \) table = 1.972. The growth pattern both for female and male was positive allometric, which means that the increase in weight was faster than the length. A graph of the relationship between the length and weight of male and female is presented in Figure 2.
The growth patterns of female and male thresher shark based on the results of the t test with a confidence level of 95% are allometric positive. The results of this study are different from previous studies, that the relationship between caudal length and weight of A. pelagicus fish were 2165 W-PCL (W = 2.25 × 10 - 4 × PCL 2.533) [28]. In general, the value of "b" is influenced by internal and external factors. Internal factors such as physiological conditions, genetics, sex, age, parasites or disease [29]. Furthermore, [30] adds external factors that come from the environment such as temperature, pH, salinity and geographic location as well as biological conditions such as gonad development and the availability of food in the area.

Based on the results of research on 761 pelagic thresher shark (A. pelagicus), 199 males and 562 females were obtained. The sex ratio of male and female in this study showed the results as 1: 2.82 with a percentage of 26% male and 74% female. Based on the Chi-square test with a confidence level of 95% (α = 0.05), the value of t count (173.15) > t table (3.84) was obtained, the sex ratios male and female were in an unbalanced condition.

Sex ratio is related to the number of fish produced in the next generation and as a control for population size [31]. The results showed that the sex ratio between male and female thresher shark was 1: 2.82 with a percentage of 26% male and 74% female. Chi-square test with a confidence level of 95% (α = 0.05) showed the value of t count (173.15) > t table (3.84), it is means that the sex ratios male and female are in an unbalanced condition. The results of this study are supported by previous research which reported that the sex ratio of male: female A. pelagicus landed in Lampulo and Sibolga was 1: 1.9 [21]. Female individuals usually inhabit areas where food sources are available [32]. According to the research results of [33] reported that male individuals tend to swim more actively in search of females, whereas females can only stay in hiding places. An unbalanced ratio of male and female will increase the vulnerability of thresher shark in the wild if overexploited and will threaten the continuity of the reproductive process of a fish species in the waters. This is because in a population individual male will compete to get a partner to reproduce [34]. However, the results of this study are different from previous studies which stated that the sex ratio of male and female was close to 1: 1 (51%: 49%) [35].

Length frequency data is one of the data that can be used to estimate the growth parameters of a fish species [14]. The estimated growth parameters for Von Bertalanffy for this species were L∞ = 278.52 cmFL, K = 0.16 / yr and t0 = 0.01285 / year following the equation : 

\[ L(t) = L(\infty)(1 - e^{(-K(t+t0)}) \]

Based on the results of previous research from [23] stated that L ∞ = 197.2 cm PCL and K = 0.085 / year (female) and L∞ = 182.2 cm PCL with K = 0.118/year (male). The asymptotic length of A. pelagicus is 3169 mmTL, k value is 0.2, and the age at maturity is estimated to be 10.4 years (male) and 13.2 years (female) [7].

The total mortality (Z) derived from the linearized catch curve gave a yield of 1.092/year, while the natural mortality (M) at 29°C was 0.295/year. Using the empirical equation, the estimated mortality
rate due to fishing mortality is 0.797/year. The estimated exploitation rate (E) of the pelagic thresher shark in the Indian Ocean Southern Java waters derived from the equation gives an estimated E value of 0.73.

Figure 3. Growth curve of pelagic thresher shark in the Indian Ocean Southern Java waters.

The value of K affects the metabolic of fish or shrimp, which is a function of temperature. [36] stated that the growth curve parameter (K) is related to the age of the fish, because K represents the time needed to reach \( L_\infty \) and long life is related to mortality. In general, fish with high K values have high M values and species with low K values have low mortality. Fish with slow growth (low K) will quickly become extinct if the mortality is high. Elasmobranch growth is influenced by several environmental factors such as food, temperature and light [37,38]. Furthermore, [39] states that environmental differences can affect growth rates. Based on the analysis, the total mortality value of thresher shark is 1.092/year, natural mortality (M) is 0.295/year and fishing mortality is F = 0.50/year.

The F value shows how much fishing pressure has increased on fish stocks in a water [40]. The thresher shark is a species that has a high vulnerability to exploitation. Not only the pressure from fishing activities, but also because of the biological characteristics that take a long time to reach gonad maturity and the recruitment rate is very low [41]. The species of \( A. \) pelagicus reached sexual maturity at a size of 282-292 cmTL (female) around 8-9.2 years and 267-276 cmTL around 7-8 years (male) [23]. The estimated age of adult females was 12.3–13.4 years [42]. The gestation period of this species is thought to be 12 months [43]. The results showed the exploitation rate of thresher shark (\( A. \) pelagicus) in the South Indian Ocean Java water with a value of E = 0.73. This exploitation rate is higher than the optimal value of the exploitation rate (E = 0.5). The rational and sustainable value of exploitation rates in a water is <0.5 or the highest E = 0.5 [18]. The exploitation level of the thresher sharks is indicated in an over fishing condition, so it is necessary to manage and regulate the catch quota so that its use remains sustainable.

4. Conclusions
The size structure of thresher shark (\( A. \) pelagicus) in the South Indian Ocean Java water, which landed in Cilacap ranges from 50-240 cmFL with a mode ranging from 140 cmFL. The length-weight relationship between male and female showed positive allometrics. The sex ratio of male and female is not balanced (1: 2.82). The equation for Von Bertalanffy's growth curve for thresher shark as \( L(t) = 278.52 (1 - e^{(-0.16(t + 0.01285)}) \). The mortality parameter, includes the total mortality rate (Z) was 0.85/year, natural mortality (M) was 0.35/year and fishing mortality (F) was 0.50/year. The exploitation rate (E) was 0.73/year, the use of thresher shark is already at a saturated level.
necessary to improve research and monitoring of landed catch so that statistical data of thresher sharks and other shark species can be recorded properly so that they can be useful in the management of shark fisheries in Indonesia.

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