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Structure and growth pattern of yellowfin tuna *Thunnus albacores* (Bonnatere, 1788) in the waters of Simeulue Islands, Aceh

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Abstract
Yellowfin tuna (*Thunnus albacores*) is a large pelagic fish originating from the Scombridae family. This fish can be found almost in all tropical and subtropical waters even often found in Indonesian waters, especially the waters of Semeulue islands. Data pertaining to the growth pattern of the fish are meaningful as a reference for tuna fish resource management in Semeulue waters. This research aimed to investigate the current condition of tuna growth through understanding the size and growth pattern of yellowfin tuna in Simeulue waters. The study was conducted for 4 months from August to November 2016 in Simeulue waters in fisheries managemen area 572. Fork length (FL) of yellowfin tuna was randomly collected on a weekly basis using a roll meter (5 m). The fish length frequency for the determinationof class interval was obtained using frequency distribution formula, while a FiSAT II program was employed to observe biological properties of the fish. A total of 85 yellowfin tuna was successfully assessedusing a fishing pole in the waters of Semeulue Islands (Lasia Island and Babi Island). This number was relatively small because of weather factors; the fishersdecided not to catch the fish in the sea. The results showed that fork length of Yellowfin tuna was 45.5-111.5 cm. Furthermore, length frequency of Yellowfin tuna was assessed using von Bertanlanffy growth functions. Maximum length ($L\infty$) of the fish reached 117.08 cm, while K value was 0.93 per year, theoretical age of 0.10 years and growth prospecting index (Ø) of 4.10. The analysis using length-converted catch curve showed total mortality (Z) of 2.11, natural mortality (M) of 1.22, with an average temperature of 31 °C, capture mortality (F) of 0.89, exploitation rate (E) of 0.42 per year.

Keywords: Size, growth, yellowfin tuna (*Thunnus albare*), fishing pole, Semeulue waters

1. Introduction

Yellowfin tuna is a big pelagic fish, and reported capable of swimming at 80 km/h (FAO) [6]. Its torpedo-like body makes the fish able to migrate across seas. Tuna migrates in a wide geographic, and always moves around every time. Indonesian waters became the location of tuna migration centered on the borders of the Indian Ocean and Pacific Ocean (Saputra *et al.*) [24]. some tuna landed in Indonesian waters include yellowfin tuna (*Thunnus albacores*), bigeye tuna (*Thunnus obesus*), albacore (*Thunnus alalunga*), and bluefin tuna (*Thunnus maccoyi*) as reported by Triharyuni *et al*. [26].

Fishers operate several fishing methods to catch the tuna, such as troll line, purse seine, long line, and handling. As the easiest tool, many fishers operate handling to capture yellowfin tuna with the aid of FADs (Fish Aggregating Devices) (Kantun *et al.*) [13].

Increased capture intensity may reduce future catches, leading to decreased stock of both individual size and population size. The decline in the production of yellowfin tuna has almost been observed in all waters around the world (Kantun *et al*. [13]. Nomura [18] reported that the decline in yellowfin tuna over the world reached 14.33%, which was about1, 439, 503 tons in 2003 to 1, 009, 628 tons in 2007. This reduced capture of yellowfin tuna also occurred in Indonesia drastically, from 163, 241 tons in 2000 to 103, 655 in 2007, equal to an average decrease of 7.94% per year (Indonesian Fisheries Statistic Index) [10].

In absence of proper management, long-term exploitation of tuna with the aid of advanced technologies leads to a detrimental effect on the fish population. This current work aimed to study the size and growth pattern of yellowfin tuna in the island of Lasia and Babi island Simeulue waters was such a study conducted in the given area.

2. Materials and Methods

This research was conducted from August 2016 to November 2016 in Sumeulue waters of fisheries managemen area 572. Random sampling was carried out once a week. Fork length (FL) was obtained using a roll meter (5 m).The fish was captured using hand line in around Lasia Island and Babi Island (Figure 1).

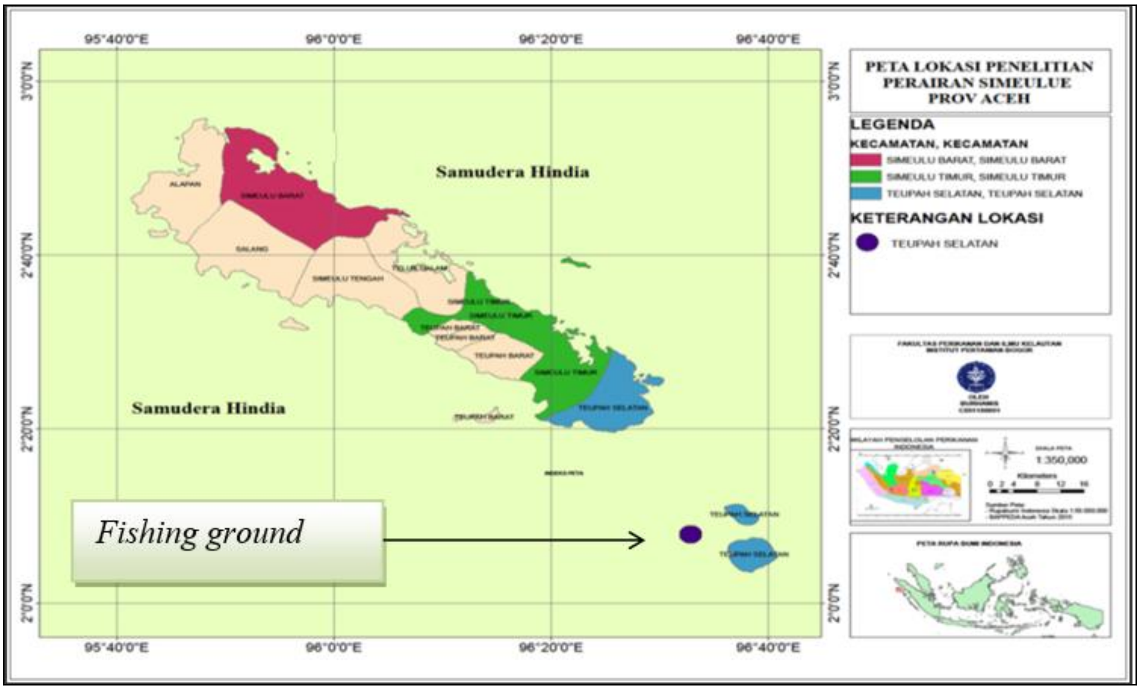

Fig 1: Sampling locations in the waters of Simeuleu islands (Lasia Island and Babi Island)

Frequency of fish length determined interval, mean, and frequency in each group. Measurement of fish length was based on frequency distribution equation (Walpole) [27].

$$K = 1 + 3{,}32\ log\ n \quad \text{.......(1)}$$

$$i = R/K \quad \text{.......(2)}$$

Where:

K = number of classes;
N = number of data;
i = class interval;
R = maximum value and minimum value.

Fish growth parameters (K and L) were estimated using *ELEFAN* I sub-program of FiSAT II software (Gayanilo *et al*) [8]. The age data were assessed using *von Bertalanffy Growth Function* (VBGF) and (Bevertonand Holt [2]) formula:

$$Lt = L\infty(1-e^{-k(t-t0)}) \quad \text{.......(3)}$$

Lt = fish length at age t;
L∞ = asymptotic length;
K = growth coefficient;
t_0 = theoretical age when the sample was at zero length.

The theoretical age of fish was estimated when the sample was at zero length using following formula (Pauly [21]):

$$Log\ -(t_0) = 0{,}3922 - 0{,}2752\ (Log\ L\infty) - 1{,}038\ (Log\ K) \quad \text{.......(4)}$$

Natural mortality (M) was determined using empirical equations (Pauly [20]) as follow:

$$Log\ (M) = -0{,}0066 - 0{,}279\ Log\ (L\infty) + 0{,}654\ Log\ (K) + 0{,}4634\ Log(T) \quad \text{.......(5)}$$

Where:

M = natural mortality;
L = asymptotic length;
K = growth coefficient;
T = average temperature of 31°C (data collected).

Total mortality (Z) was obtained using length-converted catch curve (Pauly) [19]. Exploitation (E) was obtained from E= F/Z, while fishing mortality (F) was obtained from following formula: F= Z-M (Sainsbury [23] and Appeldoom [1]; Kantun and Amir) [13].

Where:

M = natural mortality;
E = exploitation rate;
Z = total mortality;
F = fishing mortality.

Excessive stock was not based on the assumption of optimal value (E_{opt}) > 0, 50. This assumption showed that the sustainable capture could be reached onF > M (Gulland,) [9].

3. Results

Length frequencies

A total of 85 yellowfin tuna was successfully observed. This tuna catch from Semeulue Islands was relatively small due to weather conditions. Fishers decided not to capture the fish, leading to reduced fish capture. Figure 2 exhibits the fork length of the fish (ranging from 45.5 cm to 111.5 cm) and catch frequency.

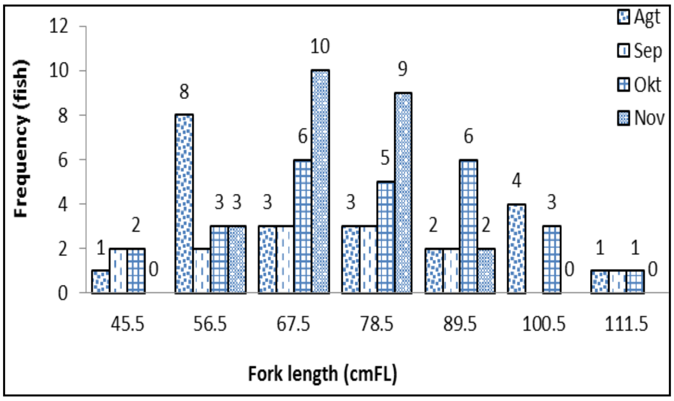

Fig 2: Frequency distribution of yellowfin tuna captured from Simeulue waters

Growth Pattern

The length frequency of yellowfin tuna was analyzed using von Bertanlanffy, as depicted in Figure 3. The results showed that maximum length (L∞) and K value was 117.08 cm and 0.93 per year, respectively. Theoretical age was 0.10 years, while the growth prospecting index (Ø) was 4, 10.

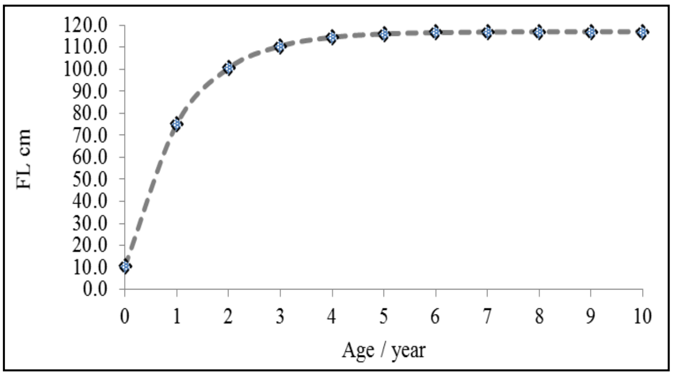

Fig 3: Growth curve of yellowfin tuna in waters of Simeulue Islands (Lasia and Babi islands)

Mortality

Analysis based on length-converted catch curve showed that total mortality (Z) and natural mortality (M) reached 2.11 and 1.22, respectively, with an average temperature of 31°C. The fishing mortality (F) was 0.89, while the exploitation ratio (E) was 0.42. The results are depicted in Figure 4.

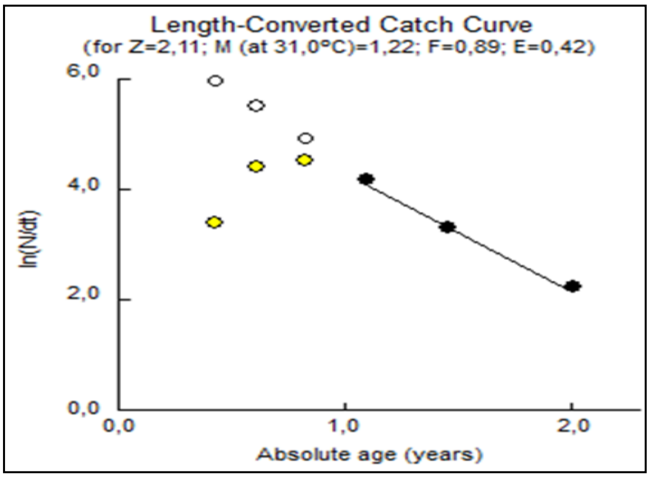

Fig 4: Amount of fish capture according to length of yellowfin tuna caught from the waters of Simeulue Islands (Lasia and Babi islands)

4. Discussion

The length of yellowfin tuna caught in waters of Simeulue Island ranged from 45.5 cm to 111.5 cm. Kantun *et al.* [13] reported the size of captured tuna was 42.60-163.20 cm, while the dominant size of the fish for market demand was 65-160 cm. Kantun *et al.* [14] found that the length of yellowfin tuna caught at FADshallow and deep water was 30-120 cm and 100-170 cm, respectively. Differences in the frequency of fish length are strongly influenced by the water depth. Fonteneau [7] found that diverse environmental conditions could affect the fish length.

At a young age,yellowfin tuna enable to grow fast, but the growth rate gradually decreases when the fish reaches old age (almost reaching maximum length) as presented in Figure 2. As exhibited in Table 1, maximum age (t_{max}) required by yellowfin tuna caught in waters of Semeulue Islands to reach the maximum length was 9 years.

According to Collette and Nauen [3], saying that the maximum length reached the age of 8 years. The result were greater than t_{max} reported by Rohit *et al.* [22] by 9.8 years, in which the fish was captured from the east coast of India in 2009. We also found that t_{max} was smaller than the fish captured in the western pacific, namely 7.65 years. Lehodey and Leroy [16] found a maximum fish age of 7.5 years in the Western Pacific and Central Region. Table 1 shows differences in age of yellowfin tuna captured from various locations.

Table 1: Differences in age of yellowfin tuna captured from various locations

References	Method used	Locations	Fork Length (FL)				
			Age				
			1	2	3	4	5
Rohit *et al.* [22]	Length	Hindia Ocean	56	92,8	120	140,0	155
Somvanshi *et al.* [25]	Length	Exclusive Economic Zone (EEZ)	35	63,9	87,5	107	123
John [11]	Length	Andaman and Nicobar Islands	58	88,7	111	128	139
John and Reddy [12]	Length	Hindia Ocean	77.0	101.7	120.1	134.0	144.3
Current work	Length	Semeulue Waters	75,0	100.5	110.5	114,5	116.5

Everhart and Younge [5] and Driggers *et al.* [4] employed length frequency data to predict growth parameters. However, this has limitation in the presence of data overlapping, thus, estimation of age and growth rate of fish were difficult to determine. The results exhibited that the current condition of yellowfin tuna in Simeulue Island (Lasia and Babi Islands) was not in an excessive capture, indicated by F<M orexplicitly € was less than 0.05.

Estimated growth pattern of yellowfin tuna using length frequency data in some locations was presented in Table 2.

Table 2: Estimated growth pattern of yellowfin tuna in some locations

L∞(cm)	K	To	Locations	Source
175.00	0,29	-	East coast of India Ocean	John and Reddy [12]
171,50	0,32	-0,31	Andaman and Nicobar	John [11]
193,00	0,20	-	EEZ India	Somvanshi *et al.* [25]
197,42	0,30	-0,12	East coast of India Ocean	Rohit *et al.* [22]
117.08	0.93	0.10	Semeulue waters	Current work

The current study indicated that yellowfin tuna status in the waters of Semeulue reached 18% sustainable condition. Nurdin *et al*. [17] reported the results according to analysis of length-converted catch curve showedtotal mortality (Z) of 1.27 per year, natural mortality (M) of 0.66 per year, fishing mortality (F) of 0.61 per year, and the exploitation rate (E) of 0.48 per year.

Rohit *et al*. [22] found that tuna captured in East Coast of India had total mortality (Z) of 0.71 per year, natural mortality (M) of 0.48 per year, fishing mortality (F) of 0.23 per year, and the exploitation rate (E) of 0.32 per year. Zhu *et al*. [28] reported the different results of the fish captured in the East and Central Pacific Ocean, including total mortality (Z) of 1.56 per year, fishing mortality (F) of 0.91 per year, and natural mortality (M) of 0.65 per year, and exploitation rate (E) of 0.46 per year, This can be seen in Table 3.

Table 3: Estimated mortality of yellowfin tuna in some research locations

Z	M	F	E	Location	References
2.04	0.48	1.56	0.76	Oman sea	Kaymaram*et al* [15]
0.71	0.48	0.23	0.32	East Cost of India	Rohit*et al* [22]
1.56	0.65	0.91	0.46	Eastern & Central Pacific Ocean	Zhu *et al* [28]
1.27	0.66	0.61	0.48	Palabuhanratu	Nurdin *et al* [17]

Based on the method of Beverton and Holt [2], sustainable fish stock was attained at F = M (fishing mortality was equal to natural mortality) or exploitation rate (E) of 0.5. Our result revealed that the current condition of yellowfin tuna in Simeulue waters was of excessive catch.

A different study sites may result in various results of analysis due to the effect of fishing on the recruitment, behavior and migration patterns of yellowfin tuna. In addition, the use of fishing gear, fishing methods, type of bait, and fishing line strongly contributed to the selectivity of the fish size.

4. Conclusion

Yellowfin tuna was dominantly captured in November, namely 19 fish. The result also revealed that the growth of the fish length seemed to be low, and exhibited that natural mortality (M) was greater than fishing mortality (F) and exploitation rate (E).

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