

Vertical distribution of blue Shark (*Prionace glauca*) in The Indian Ocean

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Abstract. Each fish species tends to choose a suitable environment suitable for its survival and reproduction horizontally and vertically. Blue shark (*Prionace glauca*) is the dominant catch of pelagic sharks by-catch in the Eastern Indian Ocean longline tuna fishery, with about 70% of the total sharks caught in this fisheries. This study aims to provide the information and the vertical analysis distribution of blue sharks based on temperature and depth in the Indian Ocean. The scientific observer collected 2,951 set-by-set longline fishing data based on Research Institute For Tuna Fisheries (RITF) from January 2006 to December 2018, on which the present analysis was made. The mini logger was used to measure the vertical distribution of blue sharks in the longline fisheries. This result indicated that blue shark was caught between 75.18-445.46 m depth, with 84% of which live at thermocline area (70-300 m depth), and 16% lived in underlayer area (>300 m depth). Blue sharks distributed in the underlayer area have a larger body size than those in the thermocline area with a size >180 cmFL compared to 50-170 cmFL in the thermocline area.

1 Introduction

The blue shark is a highly migratory species. Its range widely across many national boundaries and spending its time up to 92% in high seas makes it challenging to control and monitor [1]–[3]. The blue shark is by-catch species in longline tuna fisheries caught together with tuna species [3]–[5]. As a by-cath species in longline activity, the capture of blue sharks is unavoidable. It is difficult to release in the water; even if it can be done, it may not necessarily live again in nature due to injuries and stress during capture. A blue shark was the main catch of sharks, where blue shark dominates more than 60% of shark catches. It can be seen from the tabulation of catch data during the onboard observer program from 2006-2019 in this research data. The blue shark caught in the Indian Ocean is an incidental catch taken for fins, cutlets meat without ahead, and used and stored in a storage box [6], [7]. The use of blue sharks in the Indian Ocean is very different from that of the North Atlantic. [3], [8] reported that the discharged rate of blue sharks of the U.S and Canadian tuna fisheries approached 100% due to the non-commercial value of this species in North America. This information is a significant problem, and the current state of sharks includes those faced by the blue shark species in the Indian Ocean where this study was conducted.

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Blue sharks and other shark species have different characteristics from teleost species and tend to be closer to mammals, especially in terms of longevity, reproduction, low fecundity, and delayed sexual maturity [9]. Blue sharks reach adulthood at 220 cm at the age of 6 years, with the number of births per year is only 35 individuals with a gestation period of 12 months [3]. Despite this, the blue shark is considered the most prolific species among the elasmobranchs (productivity r_{\max} 0.29) [9] and closer to bluefin tuna. Meanwhile, based on age on sexual maturity, it will take a long time to recover if the stock has been significantly degraded [10].

The distribution of blue sharks does occur horizontally and vertically following the desired depth and temperature of the waters where the availability of nutrients is met [11], [12]. Environmental factors from the surrounding waters significantly affect the horizontal and vertical distribution of fish or sharks in the ocean [11]. This research aims to provide information on the vertical analysis distribution of blue sharks based on temperature and depth in the Indian Ocean and retaliation with longline fisheries. It is hoped that this information can provide an overview of the scope of life of the blue shark so that it can be a reference in the capture and management of blue sharks in the future.

2 Materials and methods

2.1 Study

This research is a part of the Research Institute for Tuna Fisheries (**RITF**) scientific observer program from January 2006 to December 2018. The area study covered 75.00°E-131°E and 1.00°S-35°S of the Indian Ocean, from the west coast of Sumatra, south of Java/Bali /Nusa Tenggara, west of Australia, and east of Madagascar (Fig. 1). The scientific observation is carried out by participating in fishing activities based in four main ports, including Benoa (Bali), Cilacap (Central Java), Palabuhanratu (West Java), and Muara Baru (Jakarta). One hundred fifty-four ships were involved with 128 trips and 2,951 fishing sets of tuna longliners operated in the eastern Indian Ocean. The QGIS 3.16.2 Hannover was used for spatial data analysis where base map representation using Environmental Systems Research Institute (ESRI) standard map obtained from https://server.arcgisonline.com/ArcGIS/rest/services/World_Street_Map/MapServer/tile/{z}/{y}/{x} and the maritime boundaries geodatabase: naval boundaries and exclusive economic zone (200 NM) version 7 obtained from <https://www.marineregions.org/downloads.php> as of 27 January 2021.

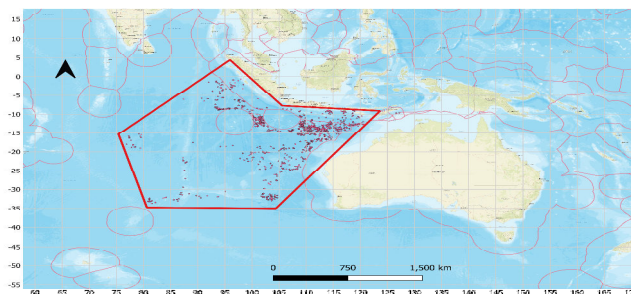


Fig. 1. Blue shark (BSH) catches coordinate in RITF scientific observer program 2006-2018 in the Eastern Indian Ocean (inside the red line)

1.2 Data analysis

The research material is blue shark data which is the catch data of the RITF onboard observer program from January 2006 to December 2018. The data collected included catch species data, catch coordinates, longline tuna, and fishing line numbers. The swimming depth data of the blue shark was obtained from the validation of the mini logger data from 2007-2019. Minilogger is a device that uses recording data on fishing line depth and water temperature at a certain depth. The minilogger can record fishing depth data from 0 to 1200 m depth with an accuracy of 3.6 meters and a resolution of 36 cm. Minilogger is also equipped with a temperature recorder with specifications from -5°C to 35°C. The type of minilogger used is the SP2T-1200 brand NKE Micrel with plastic and titanium raw materials ranging from 80 grams to 85 grams. There is three types of longline tuna research using mini logger device (2007-2019), among others are:

- a. Surface Longline Type: consists of 1-5 fishing lines with a 92.23 to 180.81 m depth with a temperature of 21.84°C to 26.80°C. This type of surface longline is used by ex. Taiwan boat until 2014
- b. Mid Longline Type: consists of 1-12 fishing lines with a depth of 117.83 to 341.52 m with a temperature from 10.39°C to 21.83°C. This type of mid-longline is widely used by Bagan Boat (North Sumatera).
- c. Deep longline Type: consists of 1-18 fishing lines with a 75.18-445.46 m depth with a temperature of 9°C to 25.5°C. The deep longline type is used by PT Samudera Indonesia, Inti Mas Surya, and other companies that catch tuna in the high seas.

The tabulation of the depth and temperature data from the mini logger research was then used to determine the swimming layer and water temperature. The blue sharks were caught using onboard observer data for 2006-2018.

3 Results and discussion

3.1 Blue shark swimming layer and temperature

The depth and temperature of the waters significantly affect the vertical distribution of fish and the vertical distribution of blue sharks. Temperature stratification at each depth dramatically affects the distribution of fish. It can be seen from previous studies conducted by [4] and [5]. This research indicated that the blue shark was caught at a depth of 75.18 m to 445.46 m, with temperatures ranging from 9°C to 26°C (Figure 2). 84% of blue sharks caught in the thermocline area with a depth of 70 to 300 m, while 16% are distributed slightly below the thermocline area up to a maximum 445.46 m depth. (Table 1).

Table 1. The number and CPUE (no. of fish/100 hooks) of blue sharks at depth and temperature strata of longliners in the Indian Ocean.

Depth (m)	Temperature (°C)	Catch (No. of Fish)	CPUE (no. of fish/100 hooks)		
			min	max	mean
0-100	26	552	0.04	0.6	0.14
100-200	20	531	0.04	1.38	0.17
200-300	14	569	0.04	1.34	0.18
300-400	11	239	0.04	1.37	0.16
>400	9.5	74	0.04	0.54	0.13

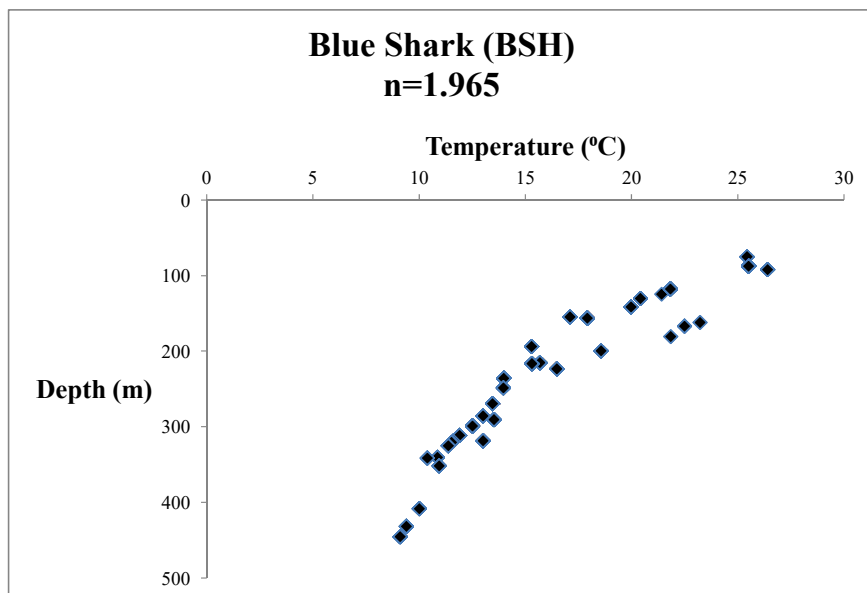


Fig. 2. Vertical distribution of blue shark (BSH) based on depth (m) and temperature (°C) caught by longliner in the Indian Ocean

This study found that the vertical distribution of blue sharks was wider than several tuna species, with a distribution range of 75.18 m to 445.46 m and a depth temperature ranging from 9°C to 26°C. Some tuna species such as yellowfin tuna, albacore, and southern bluefin tuna have vertical migrations from 35 m to 299 m with temperatures ranging from 11°C to 27°C [11], [12], [13]. The vertical distribution of blue sharks is almost the same as the vertical distribution of bigeye tuna with a swimming layer range between 92.23–470.12 m depth with almost the same temperature, between 8.35°C to 26.80°C. However, a blue shark has an optimum thermocline area with a depth between 70 m to 300 m based on mini logger data (Table 2). Research using archival tags has revealed that some highly migratory and endothermic shark species can dive up to 1000 meters below sea level. Shortfin mako (*Isurus Oxyrinus*) distributed from 28 m to 866 m depth [14], oceanic whitetip shark (*Carcharhinus longimanus*) capable of reaching a depth of 1000 m [15], and salmon shark (*Lamna ditropis*) able to reach a depth of 968 m depth [16] and blue shark (*Prionace glauca*) can reach maximum 1160 m depth [17]. However, 90% of the activities are carried out in the thermocline area (< 300 m depth) with warmer temperatures and an abundance of prey [14]–[16].

The water layer consists of 3 layers: a homogeneous layer, a thermocline layer, and an underlayer. The homogeneous layer is characterized by relatively the same temperature at different depths, while the thermocline layer is characterized by a drastic drop in temperature and increasing depth. The underlayer is characterized by a shallow temperature but remains stable during increasing depth levels [18]. Tuna, tuna-like species, and the top predator such as blue sharks are retaliated against each other. These fish species are closely related to the thermocline layer [19] where this layer has a consistent temperature ($\pm 19^{\circ}\text{C}$), salinity (± 34.78 PSU), dissolve Oxygen (± 4.68 ml/l), and relatively good nutritional levels (Nitrate; $15.39 \mu\text{mol/l}$, Phosphate; $1.15 \mu\text{mol/l}$, Silicate; $21.80 \mu\text{mol/l}$) [12]. This results in high primary productivity and the availability of prey for blue sharks.

Blue sharks caught in the thermocline layer (75–300 m) have a size of 50–170 cmFL, while blue sharks caught below the thermocline layer have a larger size (> 180 cmFL). Blue sharks have negative buoyancy and do not have swimbladders like teleosts, so reaching a

certain depth requires high swimming energy. If the blue shark's body size is small, it will be challenging to reach the most profound areas because the hydraulic lift is small in proportion to the size of the fish[3].

Table 2. The swimming layer and depth temperature of several tuna species from previous studies.

Species	Swimming Layer (m)		Temperature		Remarks (Reference)
	Min-Max	Optimum	Min-Max	Optimum	
YFT	35.15-299.04	85.73-167.80	12.51-26.96	22.20-26.40	[11]
ALB	35.15-299.05	85.73-124.74	12.51-26.97	21.41-26.40	[11]
ALB	118-341	118-291	11.10-20.47	12.41-20.47	[12]
ALB		150-199		20-20.9	[13]
BET	92.23-470.12	193.97-470.12	8.35-26.80	8.35-15.30	[11]
BET		300-399		10-13.9	[13]
SBT	118.23-194.21	190.15-194.21	14.99-22.59	14.99-15.12	[11]
BSH	75.18-445.46	75.18-299.04	9.0-26	13-26	This Study

Description: YFT (yellowfin tuna), ALB (albacore), BET (bigeye tuna), SBT (southern bluefin tuna) and BSH (blue shark)

4 Conclusion

Blue sharks are dominantly vertically distributed in the thermocline area with an estimated depth of 70 to 300 m, where 84% of the total blue shark catch is in that area. Only 16% of the blue sharks were caught below the thermocline (underlayer) with larger body size than blue sharks in the thermocline area.

5 Suggestion

We hope this research will be perfected with real-time environmental data from remote satellite sensing, so the research results are perfect for suitable habitat indexes and fish behaviors.

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