FISHING, SIZES AND SEX-RATIOS OF BLUE SHARK AND SILKY SHARK CAUGHT BY INDONESIAN TUNA LONGLINE IN THE EASTERN INDIAN OCEAN

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Abstract
The production of shark captures in Indonesia is derived from multiple forms of fisheries, where these fisheries make shark resources the primary catch (target species) on artisanal fisheries and economically valuable by catch on fishing tuna industries. Silky sharks (Carcharhinus falciformis) and blue sharks (Prionace glauca) are the predominant shark species caught in artisanal and tuna fishing industries respectively. Datasets included information on catch location and CPUE, and specimen size and sex. a total of 3,181 shot-by-shot catch and effort data were acquired from the Indonesian scientific observer activity. The main fishing grounds cover the western and southern part of Indonesian waters, extending from 75^o E to 35^o S, with greatest CPUE tending to occur at latitudes 90^o-100^o E to 30^o-35^o S while silky shark very rare caught and more to occur near to neritic zone. A total of 1,756 blue shark and 99 silky shark records collected between 2006 and 2021 were compiled, with the sizes ranging from 50 to 312 cmFL and 29 to 200 cmFL (fork length) with differences in the sex ratios by quarter were also detected.
Keywords: *Blue shark, silky shark, fishing, catch-at-size, sex ratio, Indian Ocean*

Introduction

More than 200 landing sites are employed for shark and ray fisheries throughout Indonesia's Fisheries Management Areas (FMAs), with the eastern Indian Ocean and southern waters of the island of Java (WPP 573) containing the greatest shark fishing potential in Indonesia (Figure 1). The tuna fishing industries in WPP 573 has four key ports: Bungus Oceanic Fishing Port (West Sumatra), Cilacap Oceanic Fishing Port (Central Java), Palabuhan Ratu National Fishing Port (West Java), and port of Benoa in Denpasar, Bali. Meanwhile, traditional fisheries are evenly distributed around the coasts of Aceh Province and East Nusa Tenggara Province, with the Tanjung Luar fishing port being the traditional fishery in Indonesia that catches the most sharks.

Historically, shark catches in the longline tuna fishing industries were incidental catches (by-catch) with little economic worth. However, as the export market has become increasingly competitive, shark exploitation has increased in Indonesia. The production of shark captures in Indonesia is derived from multiple forms of fisheries, where these fisheries make shark resources the primary catch (target species) on artisanal fisheries (Sentosa et al., 2016) and economically valuable by catch on fishing tuna industries (Setyaji & Nugraha, 2012; Novianto & Nugraha, 2014). Silky sharks (*Carcharhinus falciformis*) and blue sharks (*Prionace glauca*) are the predominant shark species caught in artisanal (Blaber et al., 2009; Fahmi & Dharmadi 2013, 2015) and tuna fishing industries (Gautama & Prawira, 2014; Coelho et al, 2015) respectively.

Since 2005, a scientific monitoring observer program on commercial tuna fishing industries in Indonesia has been conducted with a focus on collecting data on tuna and like fisheries in the Indian Ocean (Proctor et al. 2011). This program is conducted to meet the data needs and reporting requirements of regional fisheries management organizations, especially the IOTC (IOTC 2010). This program has entered its eighteenth year of development, during which obstacles and challenges are becoming increasingly difficult to overcome. However, the data and information obtained from this program have contributed to the creation of sustainable fisheries management policies for Indonesia and have become a reporting database for RFMOs. This study aims to present information regarding the length structure distribution, spatial-temporal distribution, sex ratios and relative abundance (number of fish/1,000 hooks) of two shark species obtained from the scientific observer program database of the Tuna Fisheries Research Institute between 2006 and 2021.

Materials and Methods

This research data gathered by the Indonesian scientific observers on commercial tuna longline vessels, which are mainly situated in port of Benoa in Denpasar, Bali. The observation program started in 2005 through an Australia-Indonesia collaboration (Project FIS/2002/074 of Australian Centre for International Agricultural Research), and since 2012 it has been conducted by the Research Institute for Tuna Fisheries (RITF Indonesia). Data collected in 2005 were excluded from analysis, as it was the beginning of the trial scientific observer program and therefore it might contain species misidentification.

A total of 118 trips, fishing trips usually last from three weeks to three months with total 3,181 set-by-set data span in detail 1x1 degree latitude and longitude grid from January 2006 to December 2021 were obtained from Indonesia scientific observer, which covers commercial tuna longline vessels mostly based in Port of Benoa, Bali. The data informing a fishing position, date, the number of hooks used, catch number by species, length and sex of each shark.

The size measurement were taken either in fork length (FL), pre-caudal or standard length (PCL), total length (TL), Pectoral anterior margin (P1A) for some reason, observers can record size in different formats. As such, all sizes BSH were converted to FL using the following equations created specifically for the Indian Ocean (Coelho et al, 2015), As for FAL were converted using equations from Tanjung Luar artisanal shark fisheries (Oktaviani et al, 2020).

These data were plotted according to longitude, latitude, period of fishing, location of deployment, number of operated hooks in daily deployed, catch in number and length. The length frequency was aggregated and the average length was analysed throughout the period of observation. The nominal fishing effort of tuna longline fishery was described as the number of hooks used on certain of fishing ground, while hook rates (CPUE) calculated as number of fishes caught per 1000 hooks. Range of hook rates on each hauls were pooled and plotted according to its geo-reference to describe the geographical distribution of species.

Result and Discussion

Indonesia's tuna fishing fleet is active throughout the year in the eastern Indian Ocean, pursuing a variety of huge pelagic species. Currently, the pattern of storage of captured fish is nearly totally retained, including shark species, and only a small fraction, such as other hair tail species (*Alepisaurus* spp, *Gempylus serpens*) and other species of shark and rays, is discarded (*Pseudocarcharias kamoharai* and *Pteroplatytrygon violacea*). With an average trip length of 10 to 12 months (frozen tuna) and 5 to 8 months (fresh tuna) and 150 to 200 settings on average, cause any difference between the number of sea days and the number of settings is due to barriers such as travel time to the fishing region, shifting fishing grounds, engine damage, stormy weather, and other technical issues.

Table 1 shows the achievements of the observations made by the scientific observer. From January 2006 to December 2021, a total of 3,181 shot-by-shot catch and effort data were acquired from the Indonesian scientific observer activity, which covers commercial tuna longline vessels with onboard trips lasting between three weeks and four months (not fully trips of vessel operation). It appears that monitoring activities fluctuate every year where activities in 2020 are the year with the lowest number of trips this is due to the outbreak of the Covid-19 pandemic that has hit almost all parts of the world.

The main fishing grounds cover the western and southern part of Indonesian waters, extending from 75º E to 35º S. As with other longline tuna fisheries, the blue shark is the most abundant species of pelagic sharks caught in the Indian Ocean. At latitudes 90º-100º E to 30º-35º S, the blue shark taken by the Indonesian longline tuna fleet has the greatest CPUE value (Figure 2). During onboard observer period, silky shark were captured seldom and tend caught primarily within the Indonesian economic exclusive zone (Figure 3).

Figure 4 depicts the length distribution of blue sharks by sex and sex ratios (n=1756). The greatest length of blue sharks captured ranged from 50 cmFL to 312 cmFL, with an average length of 179 cmFL; more males were caught than females during onboard observer period. The composition of the sex ratio by quarter indicates that the size trend is largely consistent, the size of fish collected in the third quarter is smaller than in other quarters (Figure 5). Figure 5 depicts the length distribution by sex and sex ratio for the silky shark (n = 99). Maximum length was 200 cmFL, minimum length measured 29 cmFL, with a ratio of 48% males to 52% females. Due to the tiny sample size, the distribution of length and sex composition per quarter does not establish a discernible trend (Figure 6).

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Appendix

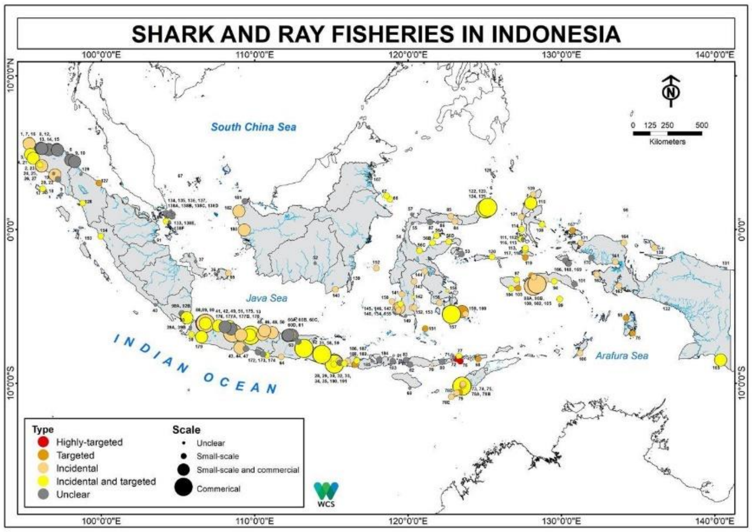

Figure 1. Shark and Ray landings in Indonesia (WCS, 2018)
source https://pdf.usaid.gov/pdf_docs/PA00XGHX.pdf

Table 1. Summary of observed effort from Indonesian tuna longline fishery during 2006–2021. Results are pooled and also presented by year of observation

Year	Trips	Sets	Total hooks	Hook per set (mean ±s.d.)		Hook per float (mean ±s.d.)	
2006	13	400	575,989	1,440	(215.3)	11.02	(3.9)
2007	13	262	403,333	1,539	(323.0)	14.00	(4.4)
2008	15	396	510,702	1,290	(383.7)	12.07	(4.5)
2009	13	288	328,718	1,141	(234.4)	12.02	(4.9)
2010	6	166	221,274	1,333	(457.5)	13.06	(5.2)
2011	3	105	110,384	1,051	(173.9)	12	(0.0)
2012	8	198	290,265	1,466	(559.1)	14.01	(2.3)
2013	7	210	231,990	1,105	(204.4)	12.04	(2.2)
2014	6	184	216,705	1,178	(181.1)	15.00	(1.9)
2015	5	150	174,655	1,164	(144.6)	14.01	(3.2)
2016	3	130	175,868	1,353	(209.0)	11.03	(3.3)
2017	4	139	192,188	1,383	(398.7)	15.03	(1.8)
2018	6	195	262,856	1,348	(230.6)	14.08	(2.5)
2019	9	164	216,836	1,322	(193.9)	10.08	(4.5)
2020	2	63	86,845	1,378	(144.2)	13.47	(0.9)
2021	5	131	198,864	1,518	(310.41)	11.29	(3.3)

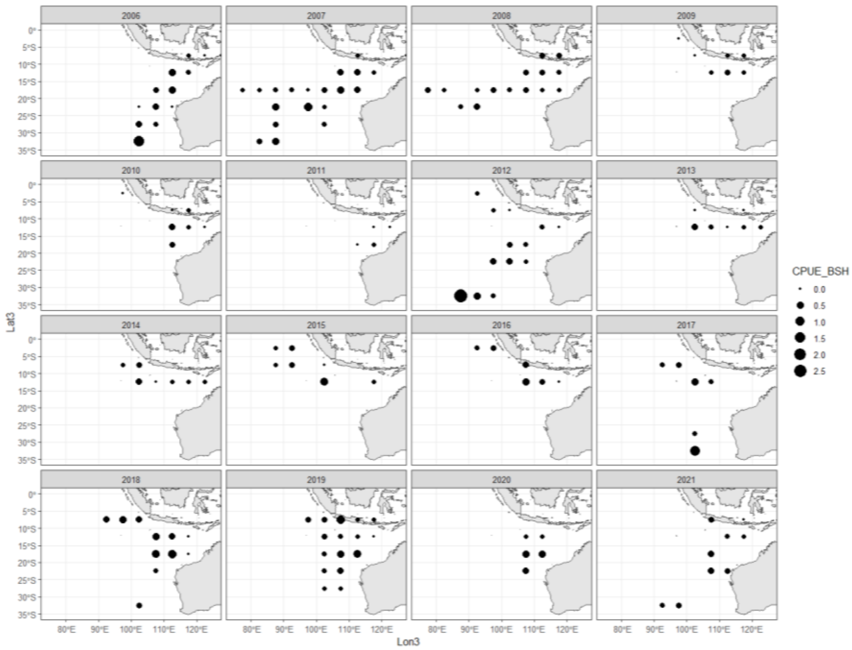

Figure 2. The spatial abundance of blue shark in the eastern Indian Ocean period 2006-2021 provided into 5x5 grid map

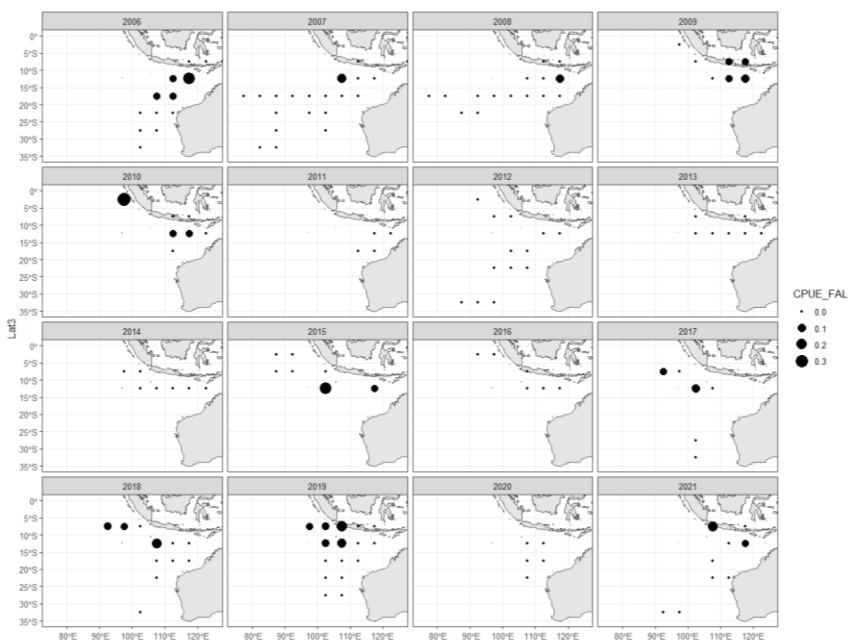

Figure 3. The spatial abundance of silky shark (*Carcharhinus falciformis*) in the eastern Indian Ocean period 2006-2021 provided into 5x5 grid map

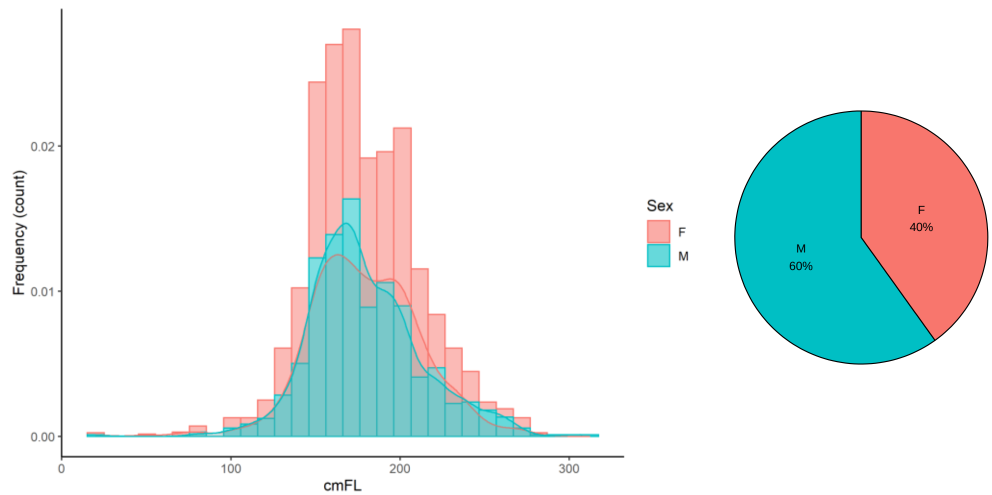

Figure 4. Overall size distribution (histogram) and sex ratio (pie chart) of male and female blue shark (*Prionace glauca*) caught in Eastern Indian Ocean

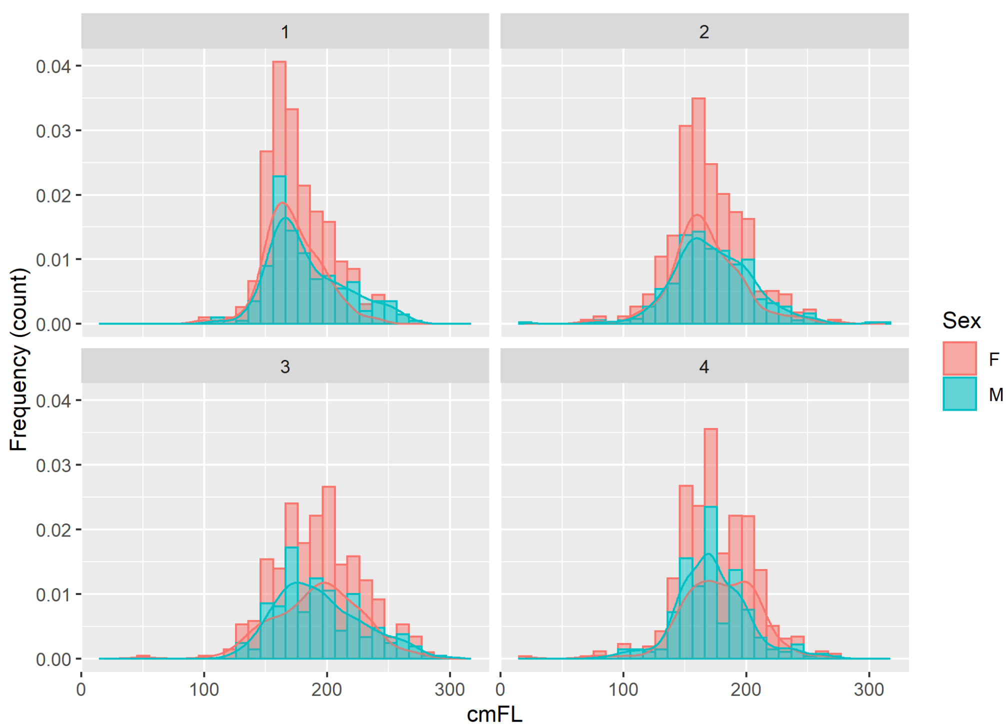

Figure 5. Size distribution of male and female blue shark (*Prionace glauca*) by quarter of the year caught in Eastern Indian Ocean

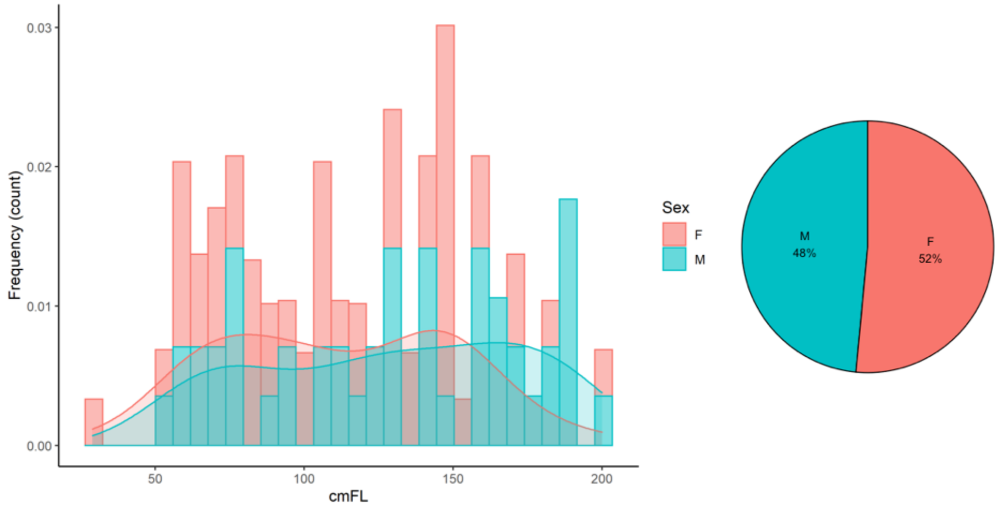

Figure 6. Overall size distribution (histogram) and sex ratio (pie chart) of male and female silky shark (*Carcharhinus falciformis*) caught in Eastern Indian Ocean

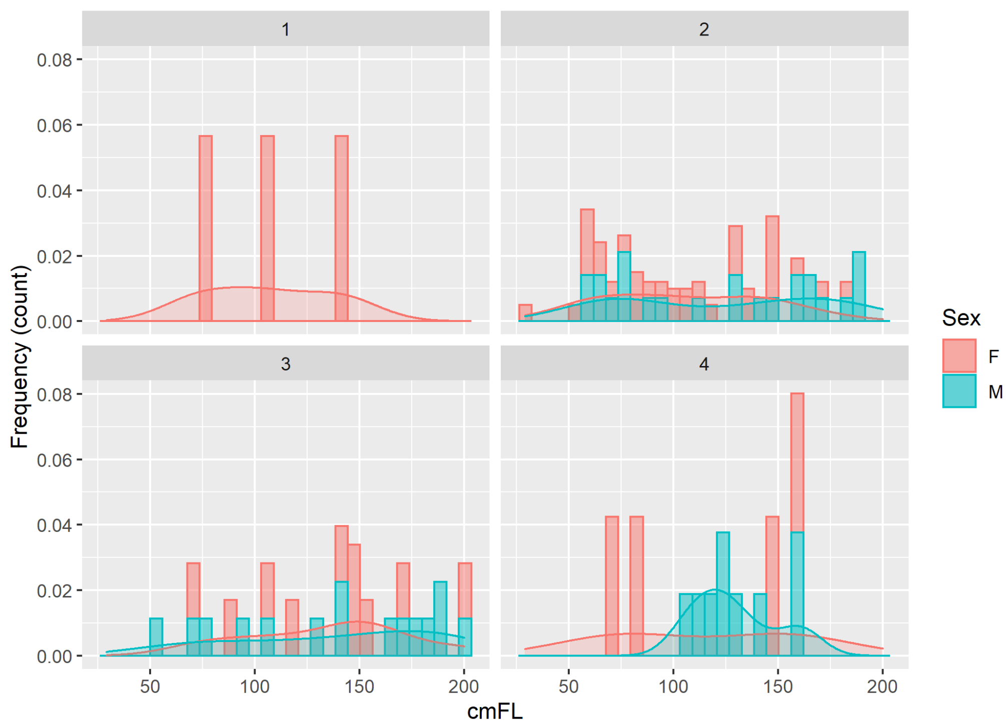

Figure 7. Size distribution of male and female silky shark (*Carcharhinus falciformis*) by quarter of the year caught in Eastern Indian Ocean