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Irwan Jatmiko, Tegoeh Noegroho, Lilis Sadiyah, and Fayakun Satria

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Billfish are high-value marine predators of significant ecological and socio-economic importance in the Indian Ocean, where Indonesia accounts for approximately 13% of total production. This study evaluates the maturity composition and length-frequency distribution of billfish species caught by the Indonesian tuna longline fishery between 2005 and 2021. Using data from 1,969 individuals collected by scientific observers, the research compares lower-jaw fork lengths (LJFL) with established length-at-first-maturity (*Lm*) values for six species: black marlin, blue marlin, striped marlin, Indo-Pacific sailfish, shortbill spearfish, and swordfish. The results indicate that while mature individuals were dominant in blue marlin and swordfish catches, a high proportion of immature individuals were harvested among Indo-Pacific sailfish, male black marlin, and female striped marlin. These findings reveal that fishing pressure varies significantly across species and life stages, with some species being caught before they have a chance to reproduce.

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Research Centre for Biota Systems, National Research and Innovation Agency of Indonesia

Email: irwan.jatmiko@gmail.com

Abstract

Billfish are high-value marine predators of significant ecological and socio-economic importance in the Indian Ocean, where Indonesia accounts for approximately 13% of total production. This study evaluates the maturity composition and length-frequency distribution of billfish species caught by the Indonesian tuna longline fishery between 2005 and 2021. Using data from 1,969 individuals collected by scientific observers, the research compares lower-jaw fork lengths (LJFL) with established length-at-first-maturity (*Lm*) values for six species: black marlin, blue marlin, striped marlin, Indo-Pacific sailfish, shortbill spearfish, and swordfish. The results indicate that while mature individuals were dominant in blue marlin and swordfish catches, a high proportion of immature individuals were harvested among Indo-Pacific sailfish, male black marlin, and female striped marlin. These findings reveal that fishing pressure varies significantly across species and life stages, with some species being caught before they have a chance to reproduce.

Keywords: billfish, longline fishery, Length-at-first-maturity, Indian Ocean.

Introduction

Billfish catches in the Indian Ocean were important during 2015–2024, with total production estimated at around 930 thousand tonnes over 10 years. The catch was dominated by Indo-Pacific sailfish and swordfish, which together accounted for nearly 70% of total billfish production. Catches were also highly concentrated among a several countries, with the 10 highest-harvesting countries contributing approximately 90% of total billfish production. Among these countries, Iran was the largest harvester, for about 25%, followed by Sri Lanka (14.5%), and Indonesia (approximately 13%) (IOTC-WPB23, 2025).

Billfish are high-value marine predators, including marlins, sailfish, and swordfish, which are widely distributed throughout the tropical and subtropical waters of the Indian Ocean. These species are of important ecological and socio-economic significance,

supporting various fishing sectors ranging from large-scale industrial longline operations to artisanal fisheries. Despite their importance, several billfish populations are facing fishing pressure; recent assessments by the Indian Ocean Tuna Commission (IOTC) indicate that blue marlin (*Makaira nigricans*) and striped marlin (*Kajikia audax*) are currently overfished and subject to overfishing, while black marlin (*Istiompax indica*) is subject to overfishing, and swordfish (*Xiphias gladius*) and Indo-Pacific sailfish (*Istiophorus platypterus*) are in healthy condition. Another billfish species, shortbill spearfish (*Tetrapturus angustirostris*), is not included in the important species to manage by the Indian Ocean Tuna Commission (IOTC). The sustainability of these fisheries can be threatened by the fact that these species are frequently caught as incidental bycatch in industrial tuna fisheries (IOTC-WPB23, 2025).

Sustainable fisheries management and effective stock rebuilding strategies depend heavily on accurate biological data, particularly regarding the reproductive cycles of these species. A vital component of this biological understanding is the length-at-first-maturity (*Lm*), defined as the length at which 50% of a population reaches sexual maturity. Information of the length-at-first-maturity (*Lm*) is important for determining if a sufficient proportion of the population is reaching spawning age before being harvested (Farley et al., 2014; Hossain et al., 2012; Humphreys & Brodziak, 2019).

The objective of this study is to determine the proportion of matured billfishes in the Indian Ocean compared to their established Length-at-first-maturity (*Lm*). By evaluating size-frequency distributions, this research seeks to identify the extent to which current fishing efforts target immature individuals. Understanding these proportions is important for assessing the Spawning Potential Ratio (SPR) and informing conservation measures (Hordyk et al., 2015).

Methods

Length data for billfishes were collected from the Indonesian tuna longline fishery from 2005 to 2021 in the eastern Indian Ocean. Data were collected by scientific observers who were deployed onboard commercial tuna longline vessels. For each billfish caught, observers recorded the species and measured the lower-jaw fork length (LJFL) to obtain individual length measurements. The observed length data were compiled by species and to describe the length-frequency distribution of billfishes in the Indonesian longline fishery.

The length-frequency distribution was constructed separately for each billfish species using the observed LJFL measurements. To assess the maturity composition of the catch, the

observed length of each individual was compared with the length at first maturity (*Lm*) reported for the corresponding species. Information on *Lm* was obtained from the references (Table 1) (Girault et al., 2019; Sun et al., 2009). Individuals with lengths below the reported *Lm* were classified as immature, whereas individuals with lengths equal to or greater than the *Lm* were classified as mature. This analysis was used to characterize the maturity composition of billfish catches in the Indonesian tuna longline fishery and to determine the relative contribution of immature and mature individuals to the observed catch.

Table 1. Length-at-first maturity of billfish species from previous studies.

Common name	Species name	Species code	Lm (cm)		References
			Male	Female	
Black marlin	*Istiompax indica*	BLM	185	-	Girault, et al. (2019)
Blue marlin	*Makaira nigricans*	BUM	130	180	Sun, et al. (2009)
Striped marlin	*Kajikia audax*	MLS	-	232	Girault, et al. (2019)
Indo-Pacific sailfish	*Istiophorus platypterus*	SFA	210	203	Girault, et al. (2019)
Shortbill spearfish	*Tetrapturus angustirostris*	SSP	-	-	-
Swordfish	*Xiphias gladius*	SWO	129	152	Girault, et al. (2019)

Results and discussions

A total of 1,969 billfish individuals were recorded from the observed catches, comprising six species: black marlin (*Istiompax indica*), blue marlin (*Makaira nigricans*), striped marlin (*Kajikia audax*), Indo-Pacific sailfish (*Istiophorus platypterus*), shortbill spearfish (*Tetrapturus angustirostris*), and swordfish (*Xiphias gladius*). Swordfish was the most dominant species, accounting for 54% of the total billfish catch, followed by black marlin and blue marlin with 15% and 13%, respectively. The length-frequency distributions showed differences between sexes among species. Females generally had larger lower-jaw fork lengths (LJFL) than males, except for Indo-Pacific sailfish, for which males had a larger length distribution than females (Table 2).

Length-at-first-maturity comparisons could be conducted for both sexes of blue marlin, Indo-Pacific sailfish, and swordfish. For black marlin, the comparison was limited to males, whereas only females of striped marlin could be assessed. The shortbill spearfish could not be evaluated because the available length-frequency information was insufficient

for comparison with the length-at-first-maturity reference. The comparison between observed LJFL and length-at-first maturity indicated differences in the dominant maturity condition among species and sexes (Figure 1 and Figure 2). Mature individuals were dominant for both males and females of blue marlin and swordfish. In contrast, immature individuals predominated among both sexes of Indo-Pacific sailfish, as well as among male black marlin and female striped marlin. These results indicate that the proportion of individuals occurring above or below the length-at-first-maturity threshold varied considerably among species (Table 3).

The annual mean LJFL exhibited considerable interannual fluctuations across all billfish species. Black marlin and blue marlin generally had mean lengths of approximately 200 cm, while striped marlin showed mean lengths ranging from approximately 150 to 200 cm. Indo-Pacific sailfish and shortbill spearfish generally had mean lengths around 150 cm. Swordfish displayed a comparatively broader annual variation, with mean LJFL ranging from approximately 100 to 160 cm. Despite these annual fluctuations, the relative size ranges among species remained broadly consistent, with marlin species generally exhibiting larger mean LJFL than sailfish and swordfish (Figure 4).

Table 2. Summary of lower-jaw fork length of billfishes (males, females, and unknown sex).

Species	Total	Lower-jaw fork length (cm) Males				Lower-jaw fork length (cm) Females				Lower-jaw fork length (cm) Unknown			
		Count	Average	Min	Max	Count	Average	Min	Max	Count	Average	Min	Max
BLM	303	121	188.30	89	300	108	195.58	132	307	74	184.72	72	383
BUM	254	72	197.92	110	305	104	212.65	127	332	78	185.55	130	280
MLS	114	44	181.44	128	265	38	195.79	139	248	32	163.63	85	270
SFA	111	34	179.53	105	229	26	177.17	116	220	51	163.02	106	285
SSP	132	22	152.18	110	180	62	157.76	139	190	48	148.15	107	190
SWO	1,055	247	146.83	58	272	304	164.46	64	402	504	109.68	42	249
Total	1,969	540				642				787			

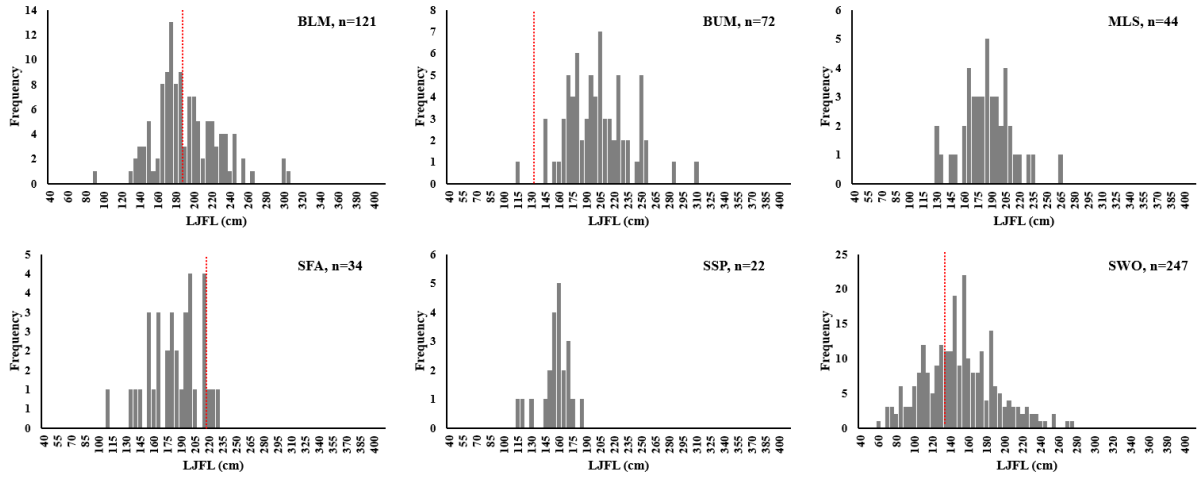

Figure 1. Lower-jaw fork length of males' billfish. Red dash line is the length at first maturity (Lm).

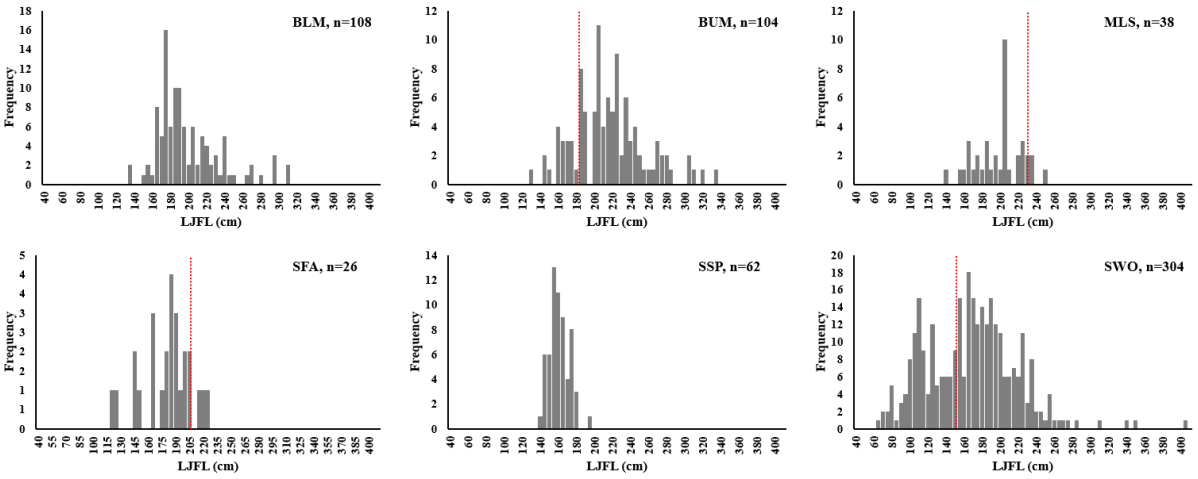

Figure 2. Lower-jaw fork length of females' billfish. Red dash line is the length at first maturity (Lm).

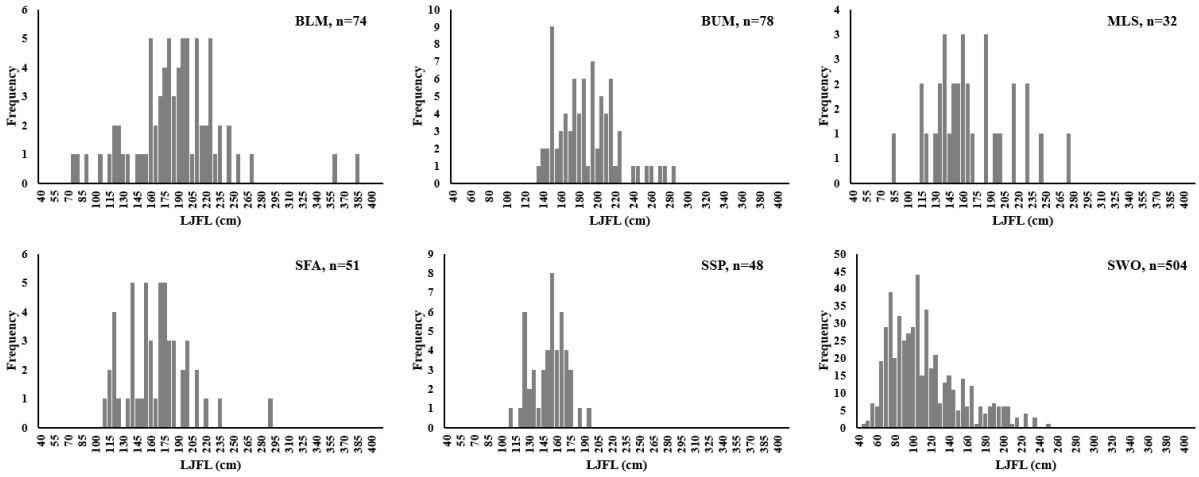

Figure 3. Lower-jaw fork length of unknown sex billfish.

Table 3. The percentage of matured billfish.

Species code	Male			Female		
	Total	Matured	Percentage (%)	Total	Matured	Percentage (%)
BLM	121	56	46.28	108	-	-
BUM	72	71	98.61	104	86	82.69
MLS	44	-	-	38	1	2.63
SFA	34	7	20.59	26	3	11.54
SSP	22	-	-	62	-	-
SWO	247	158	63.97	304	188	61.84

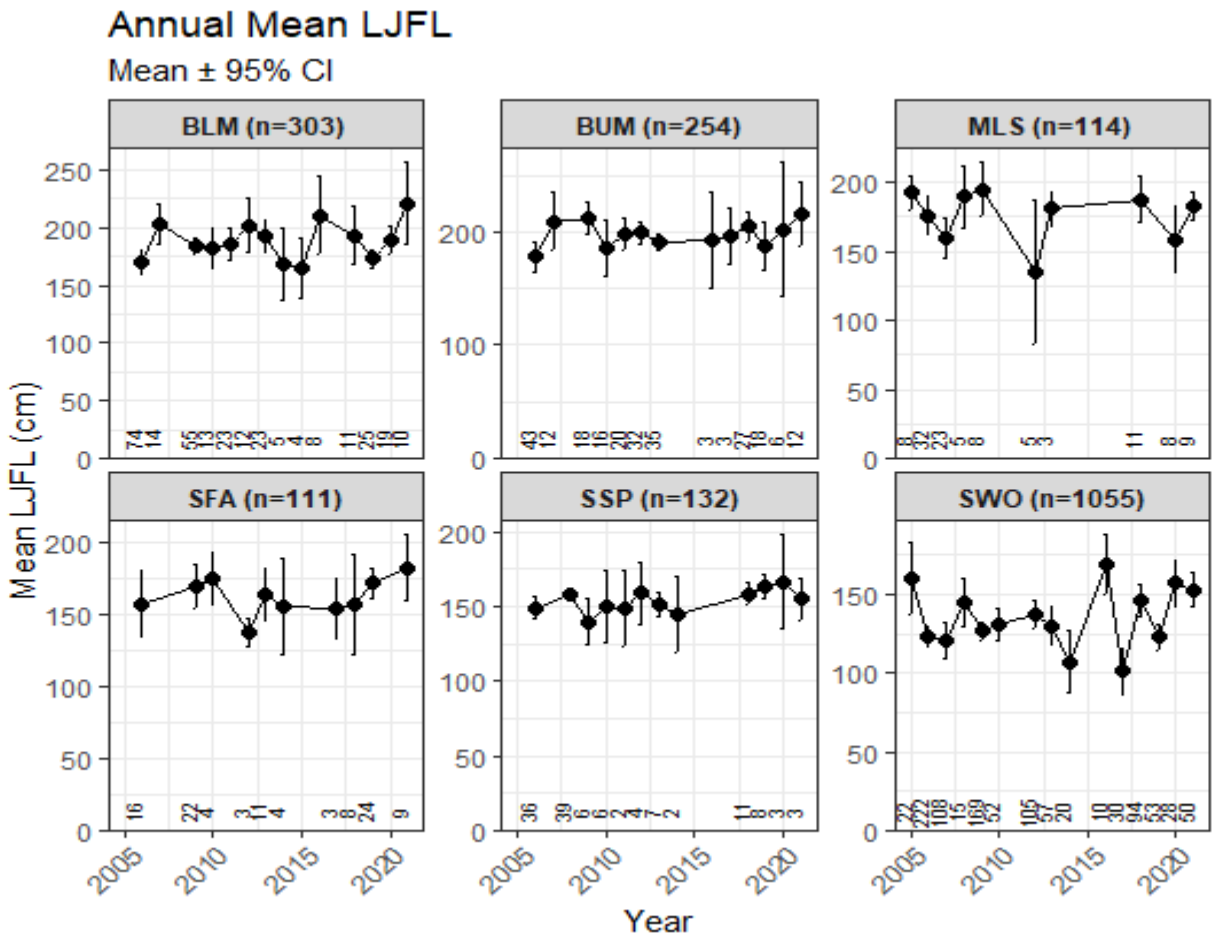

Figure 4. The yearly average lower-jaw fork length of pooled sex billfish (Mean +/- 95% CI).

Conclusions

The analysis reveals that the Indonesian tuna longline fishery caught different billfish species at varying stages of biological maturity. While the catch for blue marlin and swordfish consists primarily of mature individuals, there is a significant catch of immature Indo-Pacific sailfish, male black marlin, and female striped marlin.

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