

---

## Length at maturity of four billfish species in the Indian Ocean based on Chinese longline observer data

Cheng Zhou, Xuefang Wang, Feng Wu, Liuxiong Xu, Jiangfeng Zhu, Xiaojie Dai  
College of Marine Sciences, Shanghai Ocean University, 999 Hucheng Huan Road,  
Shanghai 201306, China;

Key Laboratory of Oceanic Fisheries Exploration, Ministry of Agriculture, 999  
Hucheng Huan Road, Shanghai 201306, China;

Fisheries College, Ocean University of China, 238 Songling Road, Qingdao  
266003, China

zhoucheng286@126.com

### Abstract

Billfish are commercially important by-catch species in tuna longline fishery. In the latest stock assessments in WPB16, the stock status of striped marlin in the Indian Ocean is determined to be overfished and subject to overfishing, while black marlin is considered not be overfished, but overfishing is occurring. Considering that the biology of some billfishes is different between the sexes, sex-specific model was suggested to develop in the future. WPB encouraged more collection of biological information (e.g. from observer) to make those key parameters available for the model. On this account, based on the new supplementary data from four observers sampling aboard tuna longliner in 2018, this paper made an update on the length at maturity of four billfish species in the IO. Relatively sufficient data for blue marlin (254 samples for male and 160 for female) and striped marlin (86 samples for male and 88 for female) allowed the development of sex-specific maturity curves. Calculation results showed 50% & 95% maturity length for blue marlin are 179.6 & 221.1 for male, and 178.0 & 207.8 for female, while for striped marlin are 183.7 & 222.9 for male, and 169.0 & 211.0 for female. Gender-mixed maturity length for black marlin (sample size ~90) and Indo-Pacific sailfish (sample size ~112) are 179.1 & 208.5, and 195.8 & 239.6, respectively.

### Introduction

In the Indian Ocean (IO), billfish are commercially important by-catch species which are harvested mainly by longline fisheries targeting tunas. In the 21th Scientific Committee, two stocks, blue marlin (*Makaira nigricans*) and Indo-Pacific sailfish (*Istiophorus platypterus*) have been reported to be overfishing but not overfished (IOTC, 2018). In the latest stock assessments in WPB16, the stock status of striped marlin (*Tetrapturus audax*) in the Indian Ocean is

determined to be overfished and subject to overfishing, while black marlin (*Makaira indica*) is considered not be overfished, but overfishing is occurring, despite still large uncertainties in the model.

Biological information as the input parameters is essential for assessment model, which currently, SS3 for example, referred to many estimates of billfish species from Pacific Ocean. WPB encouraged more collection of biological information of IO billfishes to enable those key parameters available for the model. Especially, studies from other areas reported some species, e.g., blue marlin, black marlin, etc., exhibit sexual dimorphism with females growing to larger size than males due to distinct growth patterns or mortalities (Shimose et al., 2008; Sun et al., 2015; Chang et al., 2018; Hoolihan et al., 2006). The major work of this study is to make an update on the size at maturity of four billfish species in the IO based on incorporating new supplementary data from four observers in 2018 so as to allow the development of sex-specific maturity curves.

## Material and method

Data was collected by 12 Chinese tuna longline scientific observers in the Indian Ocean from 2013 to 2017, as well as 4 observers in 2018. There were records of daily fishing positions (latitude and longitude), lower jaw-fork length (LJFL, in centimeters), sex, and mature stage.

Stages of sexual maturity were determined by macroscopic observation of the gonads. For each ovary, the oocytes in the most-developed mode were classified as: (1) I - undeveloped stage; (2) II - early developing stage; (3) III - later developing stage; (4) IV - mature stage; (5) V - spawned stage; (6) VI - spent stage. The similar classification criterion (6 stages) was conducted to the testis.

The length at which 50% of all individuals were sexually mature ( $L_{50}$ ) was estimated from the percentage of mature individual fish in each length class of 20-cm using a logistic curve as follows:

$$P_i = 1 / (1 + \exp(-\ln 19(L_i - L_{50}) / (L_{95} - L_{50})))$$

Where  $P_i$  is the percentage of mature individuals within a length class  $i$ ,  $L_i$  is the mean LJFL at length class  $i$ ,  $L_{50}$  and  $L_{95}$  are the LJFLs corresponding to 50% and 95% of individuals reaching maturity. These two parameters was estimated using maximum likelihood method by assuming a binomial error distribution (Sun et al., 2009). Fitting was processed in R with *maxLik* package.

## Results

Sample sizes for blue marlin, black marlin, striped marlin, and Indo-Pacific sailfish from observer data from 2013 to 2018 are 414, 90, 174, and 112, respectively. Relatively sufficient data for blue marlin (254 samples for male and 160 for female) and striped marlin (86 samples for male and 88 for female) allowed sex-specific maturity curves to be further developed.

The smallest observed mature male and female for blue marlin are both 164 cm LJFL. The smallest observed gender-mixed mature black marlin is 169 cm LJFL. The smallest observed

mature male for striped marlin is 152 cm LJFL, and 150 cm LJFL for female. The smallest observed gender-mixed mature Indo-Pacific sailfish is 164 cm LJFL.

As shown in Tab. 1 and Fig. 1, fitted logistic curve showed estimated 50% & 95% maturity length for blue marlin are  $179.6 \pm 2.6$  cm (estimate  $\pm$  standard error, SE) &  $221.1 \pm 5.1$  cm for male, and  $178.0 \pm 2.8$  cm &  $207.8 \pm 5.0$  cm for female, while for striped marlin are  $183.7 \pm 5.3$  cm &  $222.9 \pm 15.9$  cm for male, and  $169.0 \pm 4.0$  cm &  $211.0 \pm 7.0$  cm for female. Gender-mixed maturity length for black marlin (sample size ~90) and Indo-Pacific sailfish (sample size ~112) are  $179.1 \pm 3.1$  cm &  $208.5 \pm 8.4$  cm, and  $195.8 \pm 5.1$  cm &  $239.6 \pm 15.2$  cm, respectively.

## Acknowledgement

The scientific observer program of Chinese distant-water fishery was funded by Ministry of Agriculture. This study was also supported by National Engineering Research Center for Oceanic Fisheries at Shanghai Ocean University, and Scientific Observing and Experimental Station of Oceanic Fishery Resources, Ministry of Agriculture.

## Reference

Chang H-Y., Sun C-L., Yeh S-Z., Chang Y-J., Su N-J., Dinardo G., 2018. Reproductive biology of female striped marlin, *Kajikia audax*, in the western Pacific Ocean. *Journal of Fish Biology*, 92: 105-130.

Hoolihan., 2006. Age and growth of Indo-Pacific sailfish, *Istiophorus platypterus*, from the Arabian Gulf. *Fisheries Research*, 78:218-226.

IOTC, 2018. Report of the 21<sup>st</sup> Session of the IOTC Scientific Committee. IOTC–2018–SC21–R[E].

Shimose T., Fujita M., Yokawa K., Saito H., Tachihara K., 2008. Reproductive biology of blue marlin *Makaira nigricans* around Yonaguni Island, southwestern Japan. *Fisheries Science*, 75: 109-119.

Sun C-L., Chang H-Y., Liu T-Y., Yeh S-Z., Chang Y-C., 2015. Reproductive biology of the black marlin, *Istiompax indica*, off southwestern and eastern Taiwan. *Fisheries Research*, 166:12-20.

Sun C-L., Chang Y-J., Tszeng C-C., Yeh S-Z., Su N-J., 2009. Reproductive biology of blue marlin (*Makaira nigricans*) in the western Pacific Ocean. *Fisheries Bulletin*, 107 (4): 420-432.

Tab. 1 Summary for size-at-maturity

Species	Sample size		LJFL range		LJFL of smallest observed mature		$P_i = 1 / (1 + \exp(-\ln 19(L_i - L_{50}) / (L_{95} - L_{50})))$			
	Male	Female	Min	Max	Male	Female	$L_{50}$ (mean $\pm$ SE)		$L_{95}$ (mean $\pm$ SE)	
							Male	Female	Male	Female
Blue Marlin	254	160	98 cm	325 cm	164 cm	164 cm	179.6 $\pm$ 2.6 cm (***)	178.0 $\pm$ 2.8 cm (***)	221.1 $\pm$ 5.1 cm (***)	207.8 $\pm$ 5.0 cm (***)
Striped Marlin	86	88	144 cm	240 cm	152 cm	150 cm	183.7 $\pm$ 5.3 cm (***)	169.0 $\pm$ 4.0 cm (***)	222.9 $\pm$ 15.9 cm (***)	211.0 $\pm$ 7.0 cm (***)
Black Marlin	90		162 cm	272 cm	169 cm		179.1 $\pm$ 3.1 cm (***)		208.5 $\pm$ 8.4 cm (***)	
Indo-Pacific sailfish	112		134 cm	230 cm	164 cm		195.8 $\pm$ 5.1 cm (***)		239.6 $\pm$ 15.2 cm (***)	

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

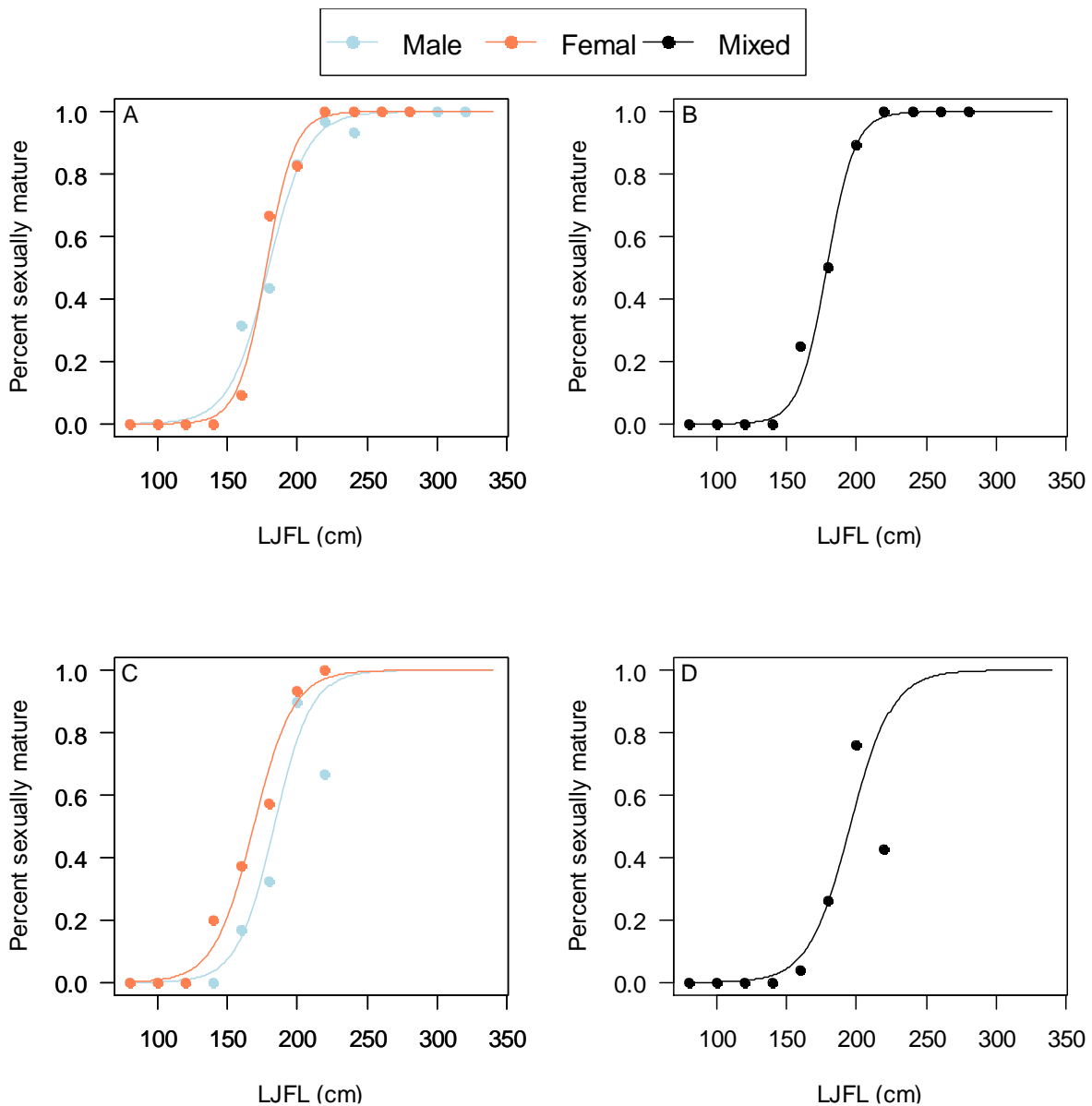


Fig. 1 Maturity-at-length (LJFL) relationship for male and female blue marline (A) and striped marlin (C), and gender-mixed black marlin (B) and Indo-Pacific sailfish (D). Length classes are aggregated by 20 cm intervals