Comparing the biology of four billfish species in the Indian Ocean based on Chinese longline observer data

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Abstract

Billfish are commercially important by-catch species in Chinese tuna longline fishery, which have received greater attention in the last few years. In 2016, total landing of three common billfishes from Chinese tuna longline fishery in the Indian Ocean reached its peak since recent years. High CPUE for blue marlin (*Makaira nigricans*) and striped marlin (*Tetrapturus audax*) were distributed in the southeast Indian Ocean in 2015 by deep frozen longline (deep frozen LL) and ice longline (ice LL), and the northwest Indian Ocean in 2016 by deep frozen LL. High CPUE for black marlin (*Makaira indica*) were distributed in the central Indian Ocean in 2015 by deep frozen LL and ice LL. This paper presented some aspects of biology of four billfish stocks based on fisheries data from Chinese tuna longline scientific observers in the Indian Ocean from 2013 to 2017. A total of 1,269 fishing operations and 153,543 observed baskets targeting bigeye or albacore tuna were examined with sampling numbers 350, 47, 375, and 151 for blue marlin, black marlin, striped marlin and Indo-Pacific sailfish (*Istiophorus platypterus*), respectively. In this order, the sex ratios, i.e., proportion of female to total of male and female, were 0.38, 0.55, 0.42, and 0.37, respectively. Proportion of fish number of each hook to the total number of fish showed that, some shallow hooks took a relatively larger percentage of the total fishes for hook per basket (HPB) 26, 16, and 17. All four billfish species were hooked at lower jaw-fork length (LJFL) over 70 cm. LJFL frequency at different classes of fate status at haul-back were compared, demonstrating a weak relationship between body size and its alive status. Maturity schedule at size showed Indo-Pacific sailfish had a maximum 50% and 95% maturity length (192.6 and 254.4 cm) among that of all billfishes, followed by striped marlin (177.0 and 238.1 cm), black marlin (166.9 and 180.0 cm), and blue marlin (161.4 and 226.2 cm).

Introduction

Billfish are commercially important by-catch species in Chinese tuna longline fishery, which were widely distributed throughout the tropical and subtropical waters in the Indian Ocean (IOTC, 2015a; IOTC, 2015b; IOTC, 2015c; IOTC, 2015d). In the last few years, catch for some common billfishes, including blue marlin (*Makaira nigricans*) striped marlin (*Tetrapturus audax*) and black marlin (*Makaira indica*), has been maintained in a level of 2 to 5% of total catch of Chinese tuna longline in the Indian Ocean, other than a dramatic increase to over 10% in 2015. This species have received greater attention by China due to the economic importance and stock status.

In the 20th Scientific Committee, four stocks, i.e., blue marlin, black marlin, striped marlin and Indo-Pacific sailfish (*Istiophorus platypterus*), have been reported to be overfishing and in some cases overfished (IOTC, 2018). In active response to billfish species conservation, relevant scientific researches are urgently needed. However, knowledges of biology and capture status of Indian Ocean billfish species remain scarce due to lack of data and information of the fishery. On this account, the objectives of this paper are i) to review the fishery status on billfish species base on Chinese tuna longline logbooks; ii) to present the hook number and length-frequency distribution of four billfishes based on Chinese tuna longline observer data; iii) to identify the haul-back fate status of billfishes, and iv) to estimate the maturity schedule at size.

Material and method

Data was collected by 12 Chinese tuna longline scientific observers in the Indian Ocean from 2013 to 2017. Integrated dataset included daily fishing positions (latitude and longitude), at-vessel fate, lower jaw-fork length (LJFL, in centimeters), hook number at which fish was caught, sex, and mature stage.

At haul-back fate was recorded according to the code of IOTC observer manual, i.e., D: dead; A1: alive and in good health condition; A2: alive with minor injuries; A3: alive with life threatening injuries. Proportion of numbers with fish caught by each hook to the total numbers of fish was calculated by classifying three gear configurations: hooks per basket (HPB) 16 and 17 for targeting bigeye tuna, and 26 for albacore.

Sex and 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. Sex ratio was calculated as the ratio of the number of females to the total numbers of females and males. Chi-square tests were used to test for significant differences.

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 40-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

Fishery status on billfish species

In recent years, total landing of three common billfishes from Chinese tuna longline fishery in the Indian Ocean reached its peak in 2016 for deep frozen longline, yielding 926 t for blue marlin (*Makaira nigricans*) and 424 t for striped marlin (*Tetrapturus audax*). Catch for black marlin (*Makaira indica*) was relatively low (no more than 30 t) whether for deep frozen longline or ice longline form 2013 to 2017. Breakdown of effort (in 1000 hooks), catch in weight and number for blue marlin, striped marlin and black marlin by deep frozen longline (deep frozen LL) and ice longline (ice LL) can be referred to Figs.1-3. CPUE (defined as number per 1000 hooks) distribution for blue marlin, striped marlin and black marlin by deep frozen LL and ice LL from 2013 to 2017 were shown in Figs. 4-9. High CPUE for blue marlin and striped marlin by deep frozen LL were distributed in the southeast Indian Ocean in 2015 and the northwest Indian Ocean in 2016. High CPUE for blue marlin and striped marlin by ice LL were distributed in the southeast Indian Ocean in 2015. High CPUE for black marlin by deep frozen LL and ice LL were distributed in the central Indian Ocean in 2015.

Biological information on billfish species

A total of 1,269 fishing operations and 153,543 observed baskets were sampled from 2013 to 2017 with total deployed hooks ranging from 1,530 to 3,895. HPB varied between 16 and 19 for targeting bigeye and between 25 and 30 for targeting albacore (Table 1). These sites distributed within the region of 10~30°S and 40~80°E (Fig. 10). The number of sampled for blue marlin, black marlin, striped marlin and Indo-Pacific sailfish were 350, 47, 375, and 151, respectively.

A total of 242 fishes were recorded with the corresponding hook number, of which 199 were from bigeye tuna longline and 43 from albacore longline. We examined the numbers of each hook at which fishes were caught in the case of three categories of gear configuration, i.e., HPB 16 and 17 for bigeye tuna and 26 for albacore tuna. Proportion of fish number of each hook to the total number of fish caught showed that hooks number 1, 3, 5, and 7 took a relatively larger percentage (15% or higher) of the total fishes for HPB 26 targeting albacore (Fig. 11). HPB 16 and 17 targeting bigeye tuna also showed a higher catch rate of billfishes at shallow hooks (e.g., number ~15).

Fig. 12 showed the length-frequency distribution of the four billfishes, i.e., blue marlin, black marlin, striped marlin, and Indo-Pacific sailfish. LJFL of blue marlin ranged from 90 to 350 cm with the highest frequency at 190~210 cm; LJFL of black marlin ranged from 150 cm to 310 cm with the highest frequency at 170~190 cm. Striped marlin and Indo-Pacific sailfish had similar LJFLs range narrowly distributing between 130 and 250 cm, with the highest frequency for the former at 190~210 cm and the latter at 170~190 cm. The LJFLs of all the four billfishes hooked were over 70 cm.

The sex ratio for blue marlin was 0.38, which was significantly different from 1:1 (Chi-square test, $P<0.05$, $\chi^2=14.4$); The sex ratio for black marlin was 0.55, which was equal with 1:1 ($P>0.05$, $\chi^2=0.31$); The sex ratio for striped marlin was 0.42, which was significantly different from 1:1 ($P<0.05$, $\chi^2=4.9$); The sex ratio for Indo-Pacific sailfish was 0.37, which was equal with 1:1 1:1

(P>0.05, χ^2=3.63).

LJFL frequency classified by fate at haul-back for blue marlin was shown in Fig. 13. Individuals with LJFL below 130 cm were not observed in a state of good health (A1). Predominant LJFL for A1 distributed at 170~270 cm in comparison with a concentrated length range (170~230 cm) for A2, i.e., alive with minor injuries. Under status of dead (D) or alive with life threatening injuries (A3) it was found a nearly identical length frequency broadly covering from small to large sized fish.

Sampled number for fate status A1, A2, A3, and D of black marlin were very scarce (6, 0, 22, and 19, respectively). Under condition of A1, LJFL at 170 to 210 cm occupied a higher frequency for black marlin (Fig. 14). A narrower LJFL range from 170 to 190 cm was found dominant for A3. For status of D, although there was a wide size composition, medium size of fish (190~230 cm) were more likely to be dead after catch on deck.

Small sized fishes for striped marlin with LJFL below 150 cm were not observed in the haul-back state of A1 (Fig. 15). LJFL at 190~210 cm was found the most dominated size for both A1 and D. In comparison, A2 and A3 had a slightly smaller LJFL in high frequency of size (bellow 170 cm).

For Indo-Pacific sailfish, small sized fishes with LJFL below 130 cm were not observed for A1 (Fig. 16). However, the dominated size group was 150~170 cm, which was smaller than that for A2 with only one observed LJFL group and that for D with a small quantity of small sized fishes (below 130 cm).

Numbers with recorded mature stage for blue marlin, black marlin, black marlin, and Indo-Pacific sailfish were 197, 25, 121, and 53, respectively. Indo-Pacific sailfish was estimated to have a maximum 50% and 95% maturity length (192.6 and 254.4 cm) among that of all billfishes, followed by striped marlin (177.0 and 238.1 cm), black marlin (166.9 and 180.0 cm), and blue marlin (161.4 and 226.2 cm) (Fig. 17). Black marlin had a maturity rate significantly faster than that of the others.

Acknowledgement

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Tab. 1 Status of tuna longline deployment between years

Year	Numbers of set	Observed number of baskets	Hooks per basket (for bigeye/albacore)	Total hooks (for bigeye/albacore)
2013	79	8100		
2014	111	12036		
2105	15	1749	16~19/25~30	1530~3850/2600~3895
2016	267	33962		
2017	797	97696		

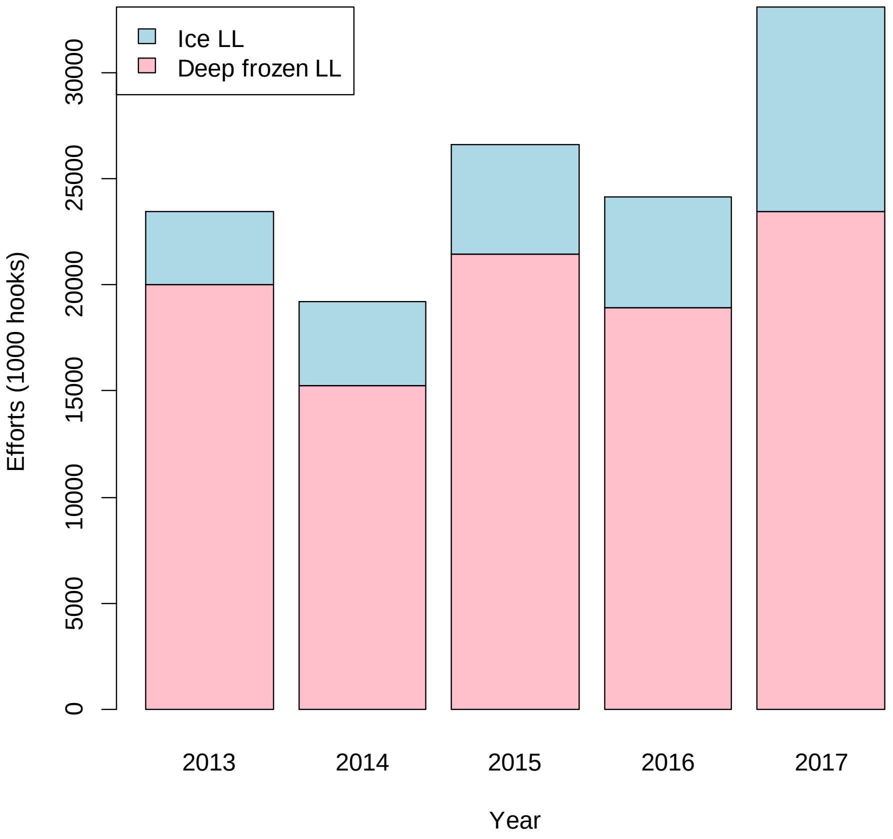

Fig.1 Effort in 1000 hooks by deep frozen LL and ice LL from 2013 to 2017

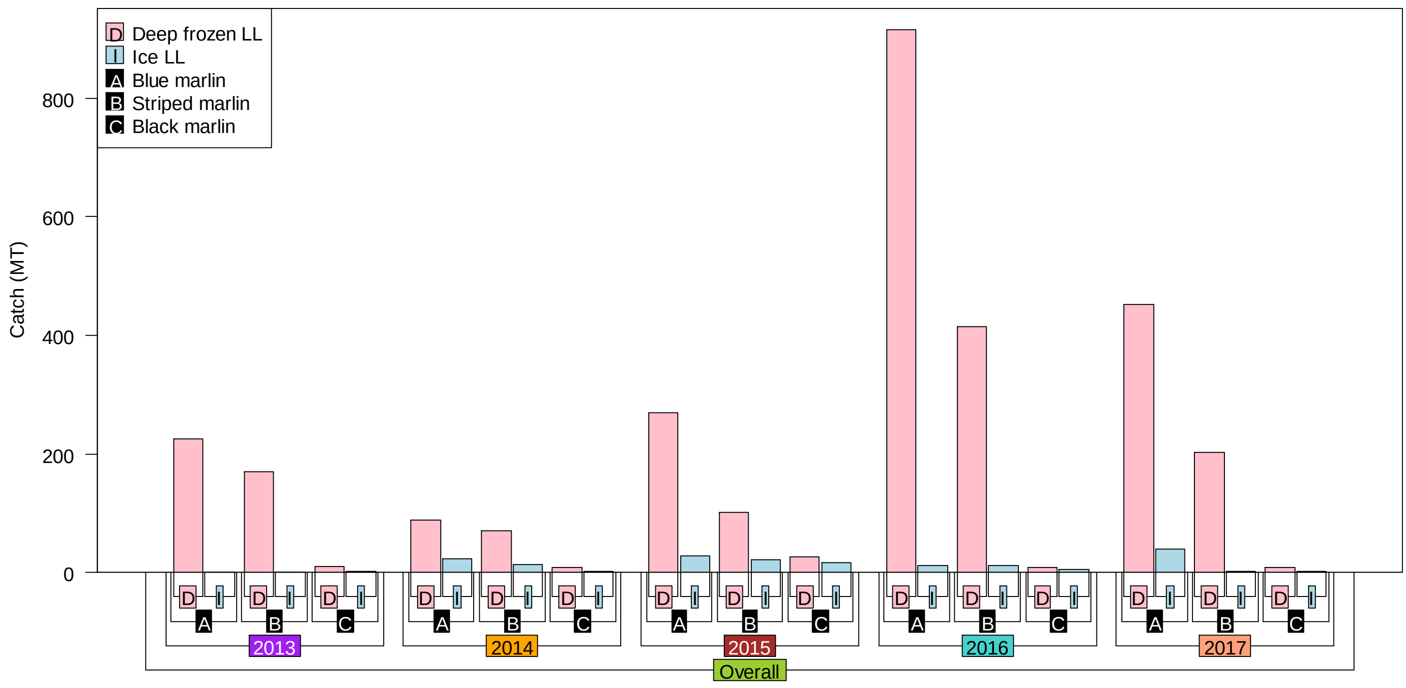

Fig.2 Hierarchic catch in tonnes for blue marlin, striped marlin and black marlin by deep frozen LL and ice LL from 2013 to 2017

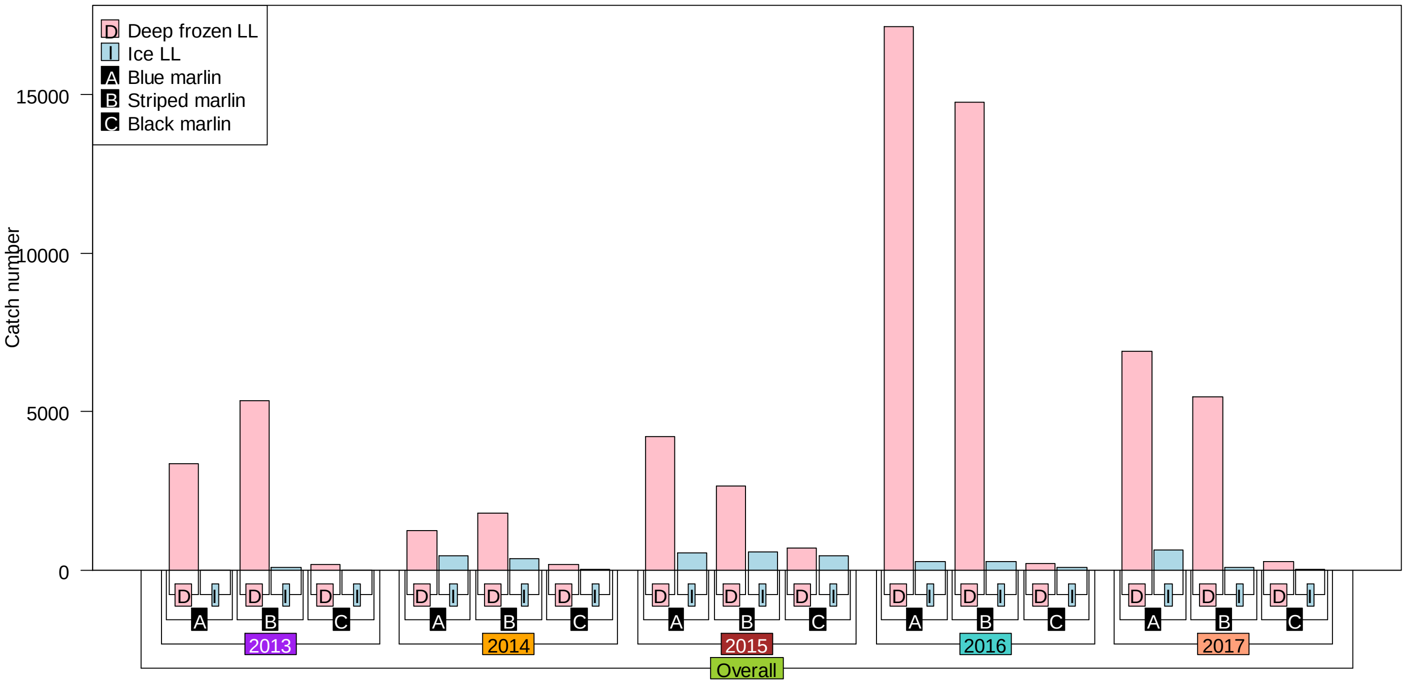

Fig.3 Hierarchic catch number for blue marlin, striped marlin and black marlin by deep frozen LL and ice LL from 2013 to 2017

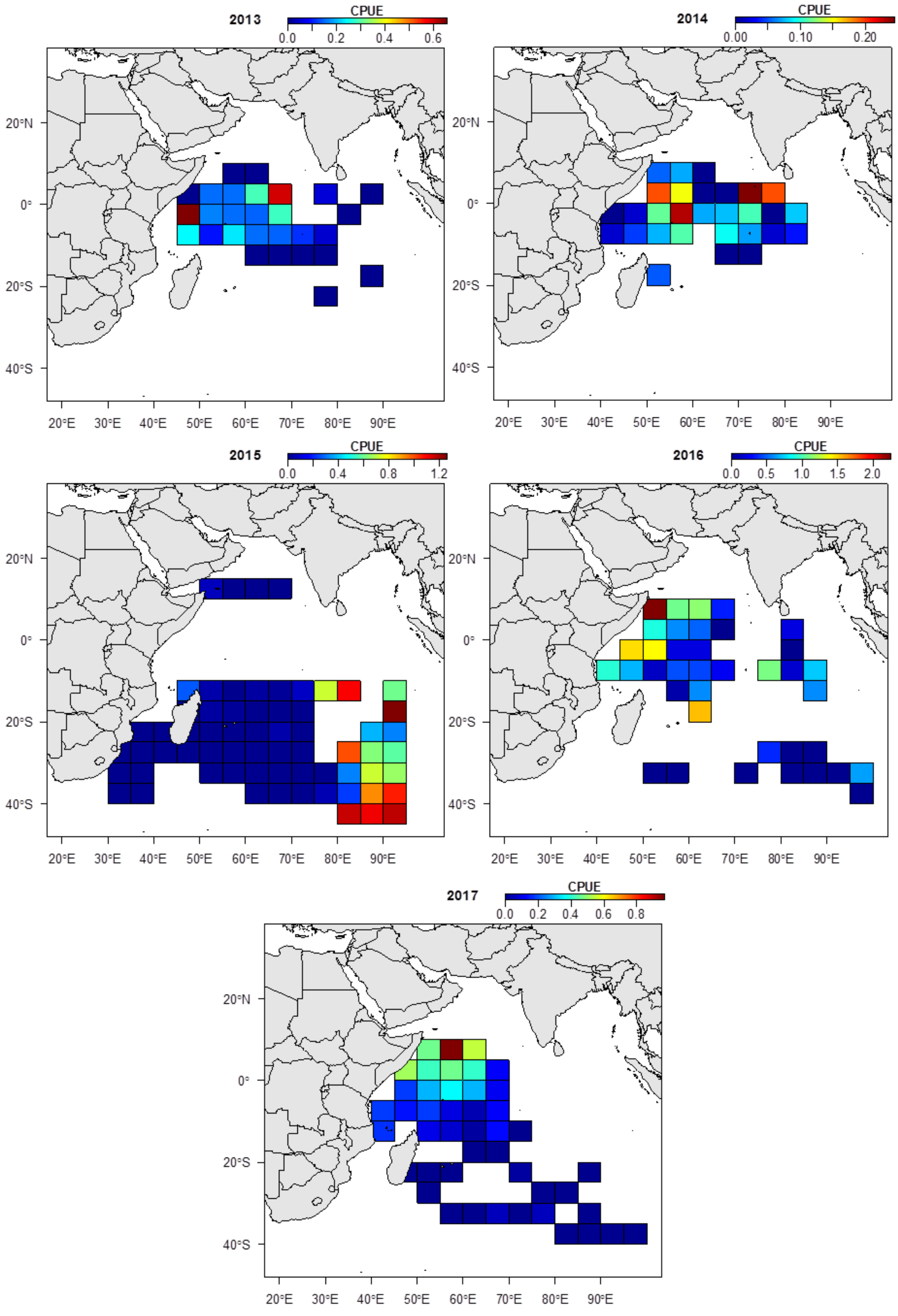

Fig. 4 CPUE (number/1000 hooks) distribution for blue marlin by deep frozen LL from 2013 to 2017

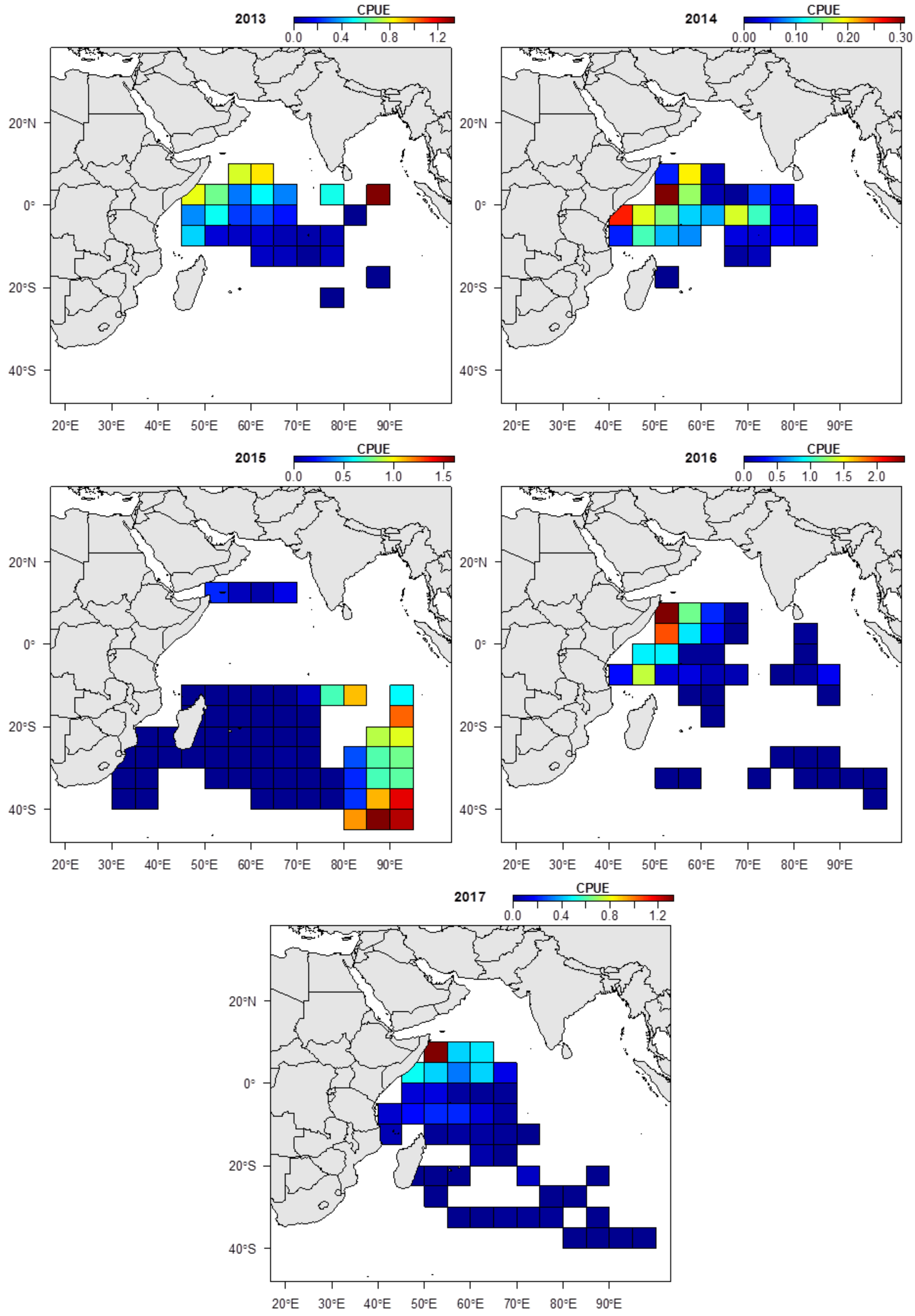

Fig. 5 CPUE (number/1000 hooks) distribution for striped marlin by deep frozen LL from 2013 to 2017

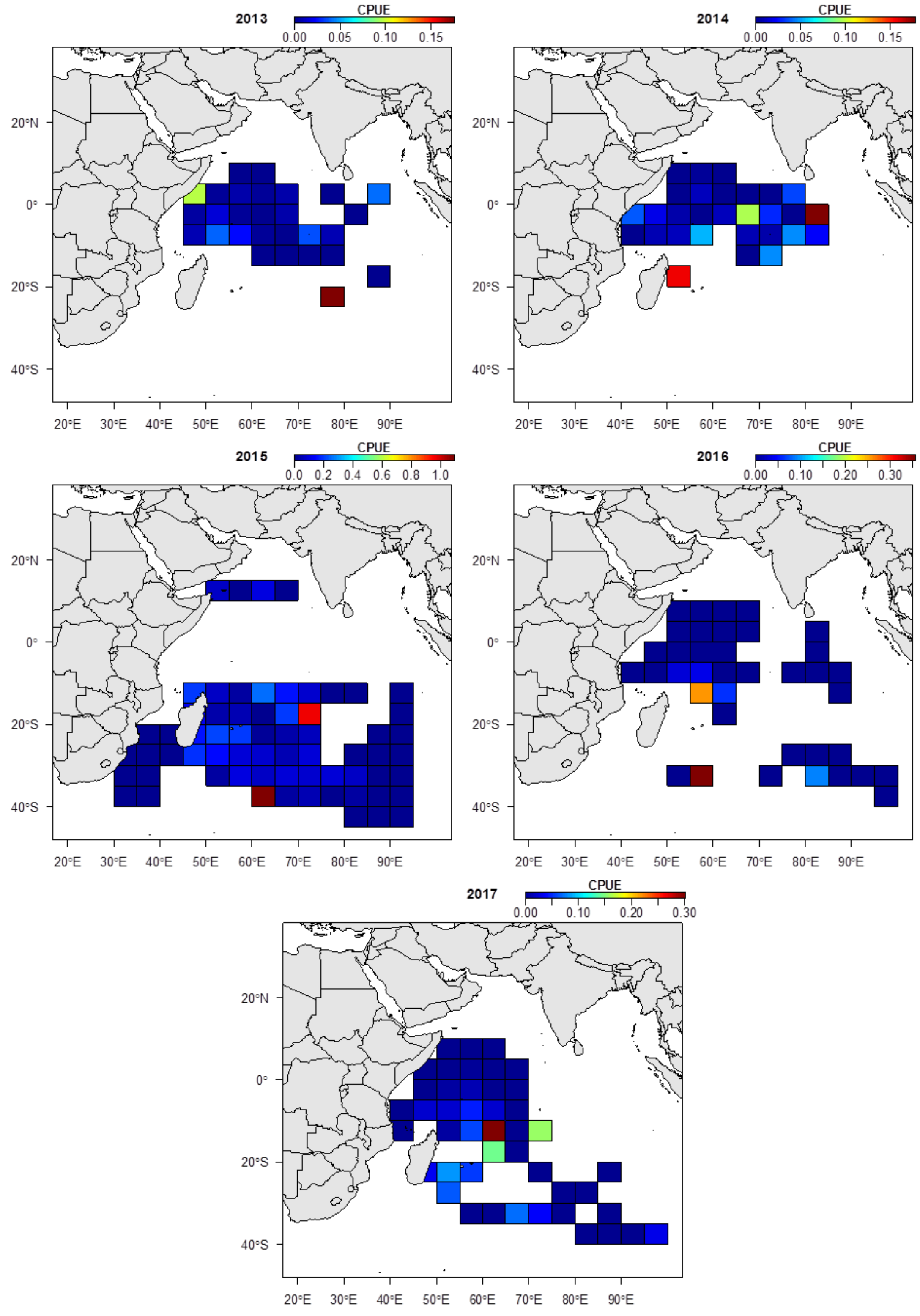

Fig. 6 CPUE (number/1000 hooks) distribution for black marlin by deep frozen LL from 2013 to 2017

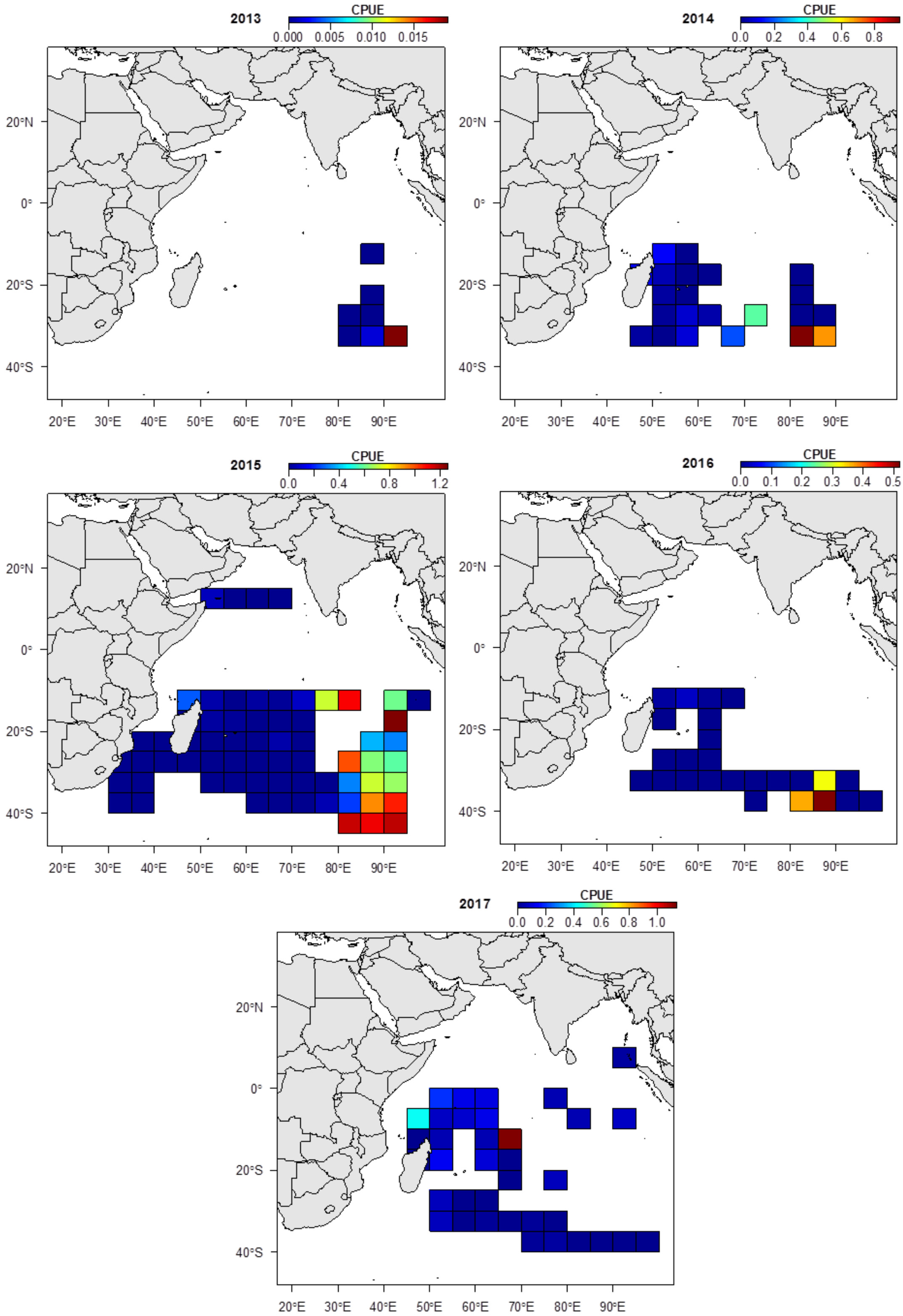

Fig. 7 CPUE (number/1000 hooks) distribution for blue marlin by ice LL from 2013 to 2017

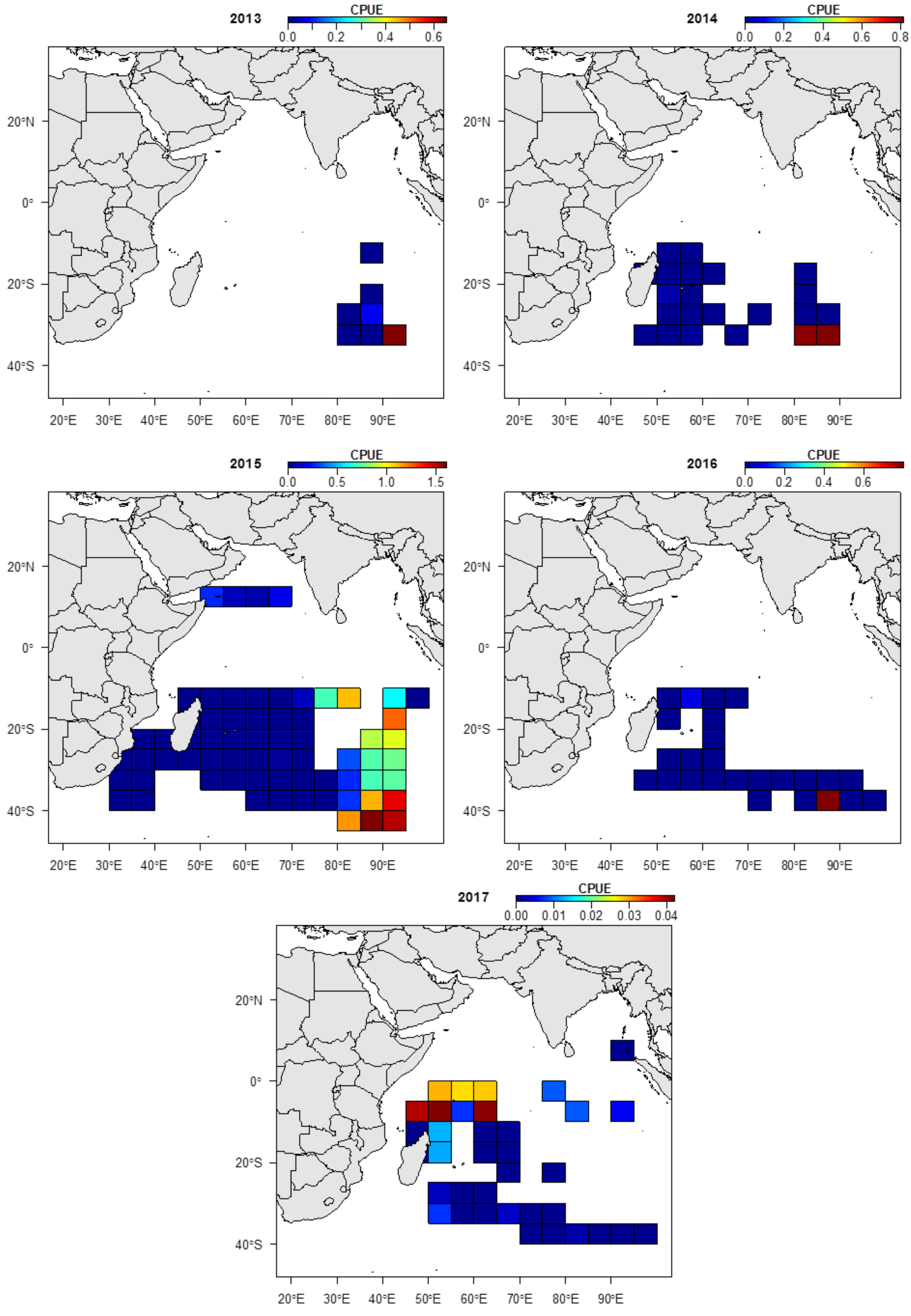

Fig. 8 CPUE (number/1000 hooks) distribution for striped marlin by ice LL from 2013 to 2017

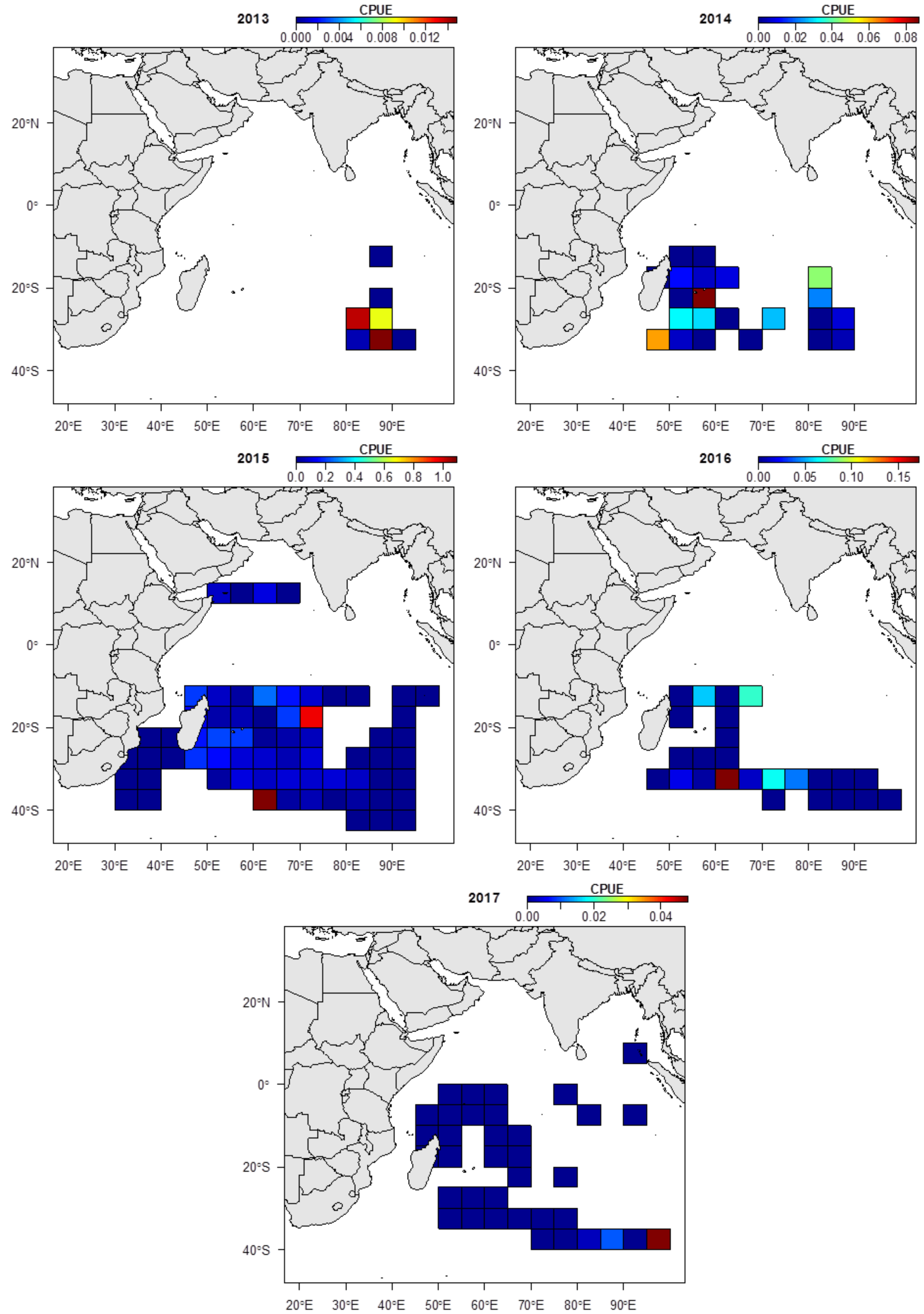

Fig. 9 CPUE (number/1000 hooks) distribution for black marlin by ice LL from 2013 to 2017

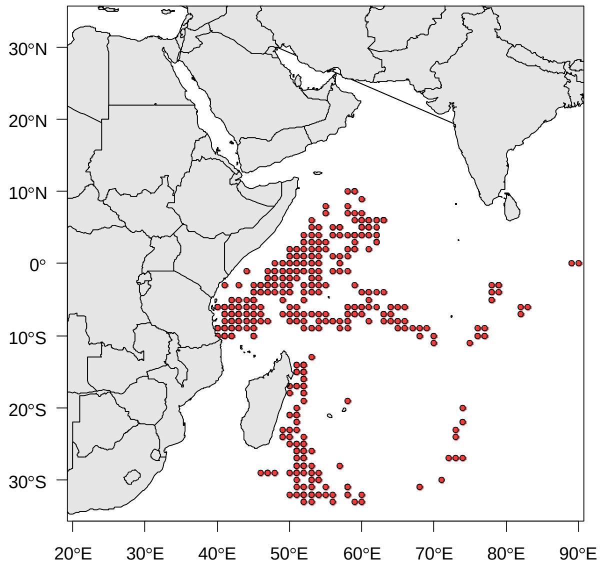

Fig. 10 Geographical distribution (gridded into 1 degree square) of fishing operation site in the Indian Ocean

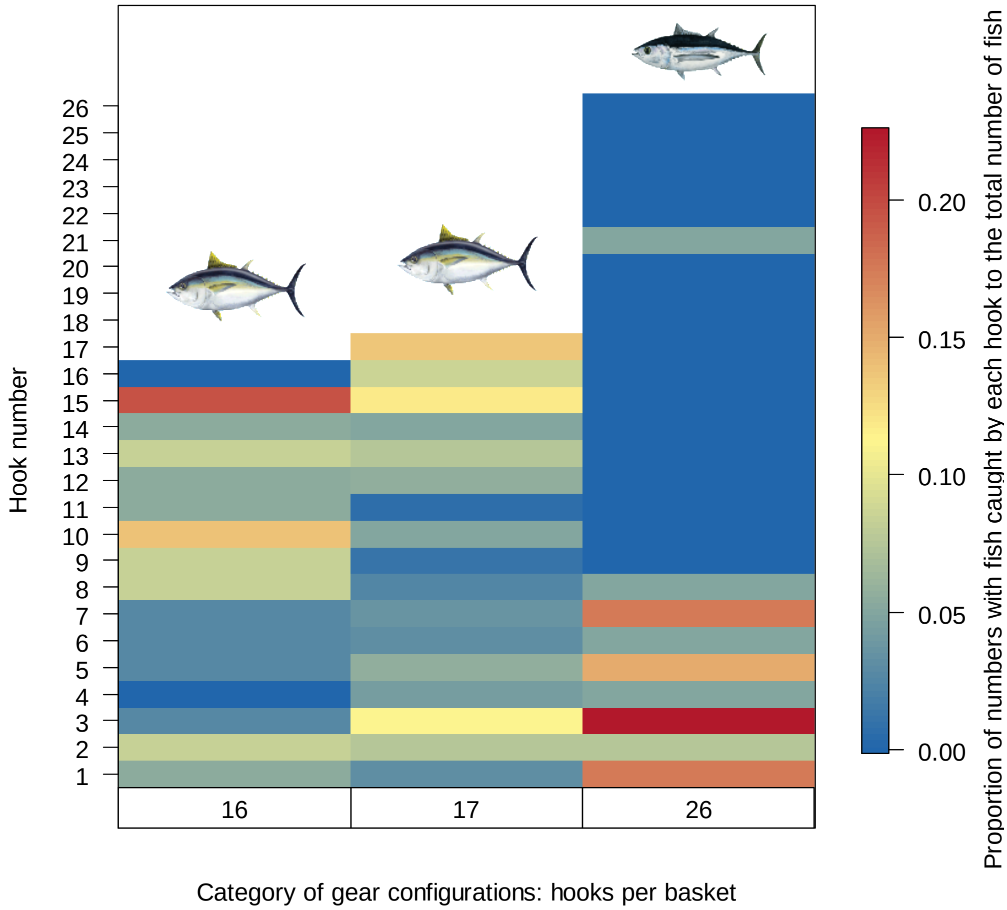

Fig. 11 Proportion of numbers with fish caught by each hook to the total numbers of fish for three

categories of gear configuration (HPB 16, 17 for bigeye tuna and 26 for albacore)

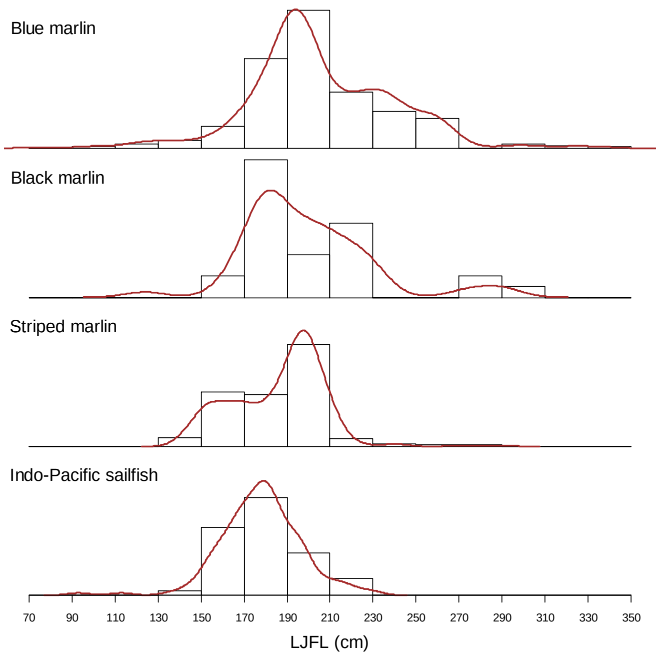

Fig. 12 Frequency of LJFL for four billfish species

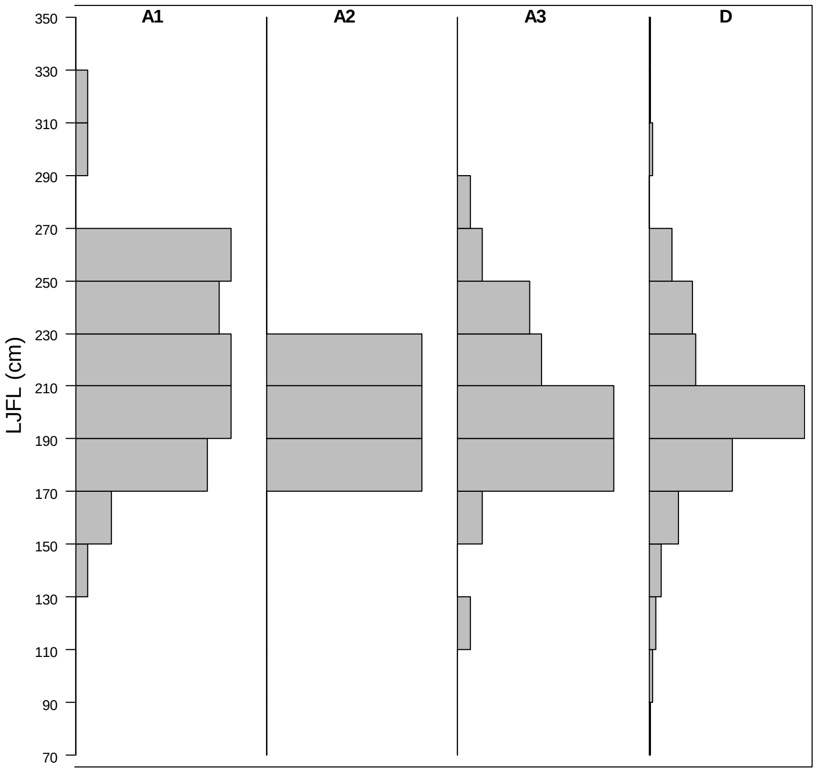

Fig. 13 LJFL frequency at different classes of haul-back fate status for blue marlin. A1: alive and in good health condition; A2: alive with minor injuries; A3: alive with life threatening injuries; and D: dead

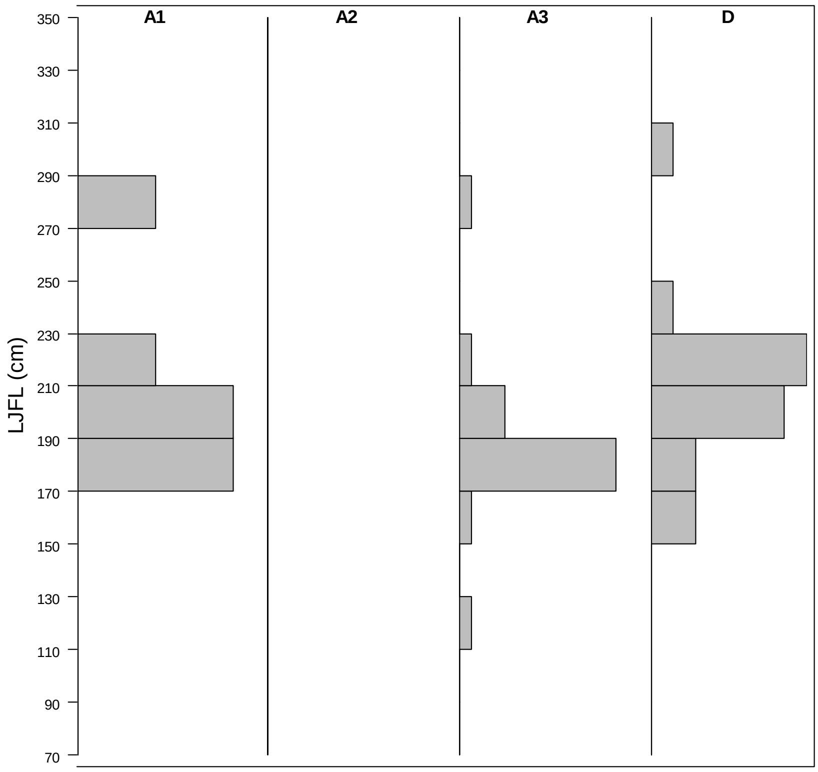

Fig. 14 LJFL frequency at different classes of haul-back fate status for black marlin. A1: alive and in good health condition; A2: alive with minor injuries; A3: alive with life threatening injuries; and D: dead

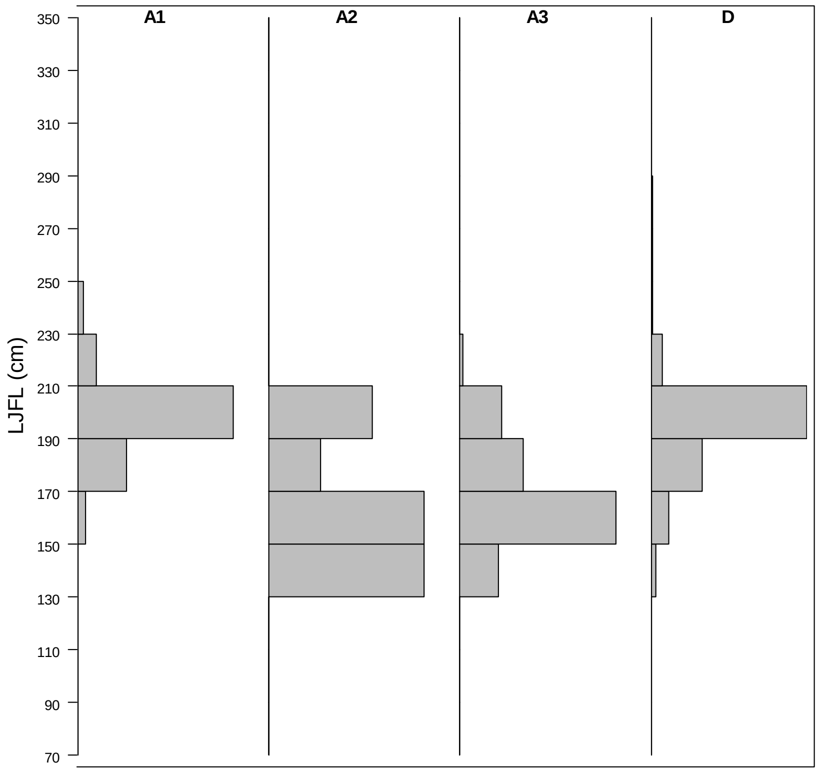

Fig. 15 LJFL frequency at different classes of haul-back fate status for striped marlin. A1: alive and in good health condition; A2: alive with minor injuries; A3: alive with life threatening injuries; and D: dead

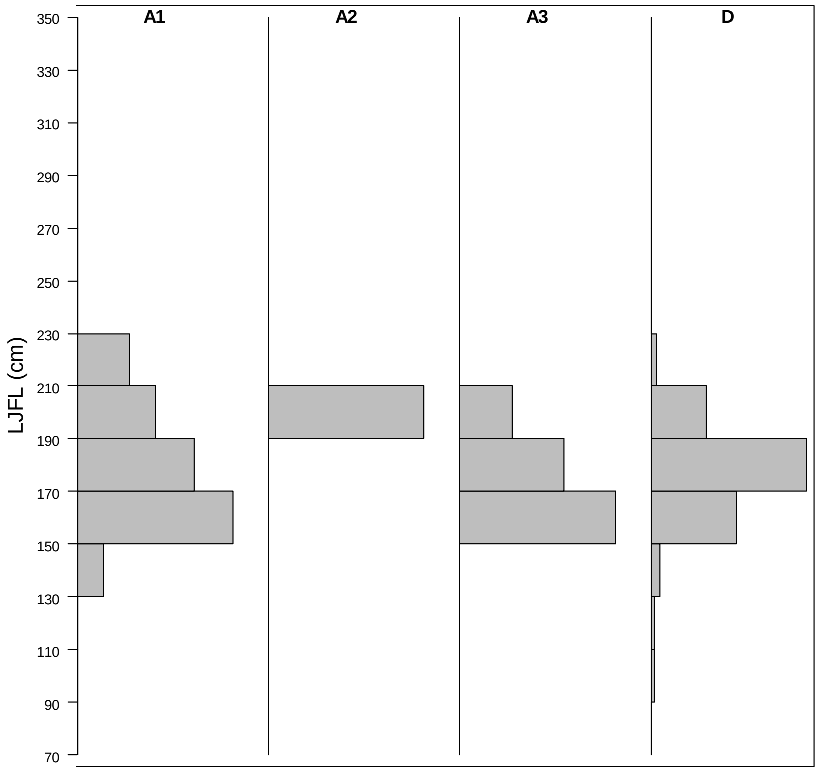

Fig. 16 LJFL frequency at different classes of haul-back fate status for Indo-Pacific sailfish. A1: alive and in good health condition; A2: alive with minor injuries; A3: alive with life threatening injuries; and D: dead

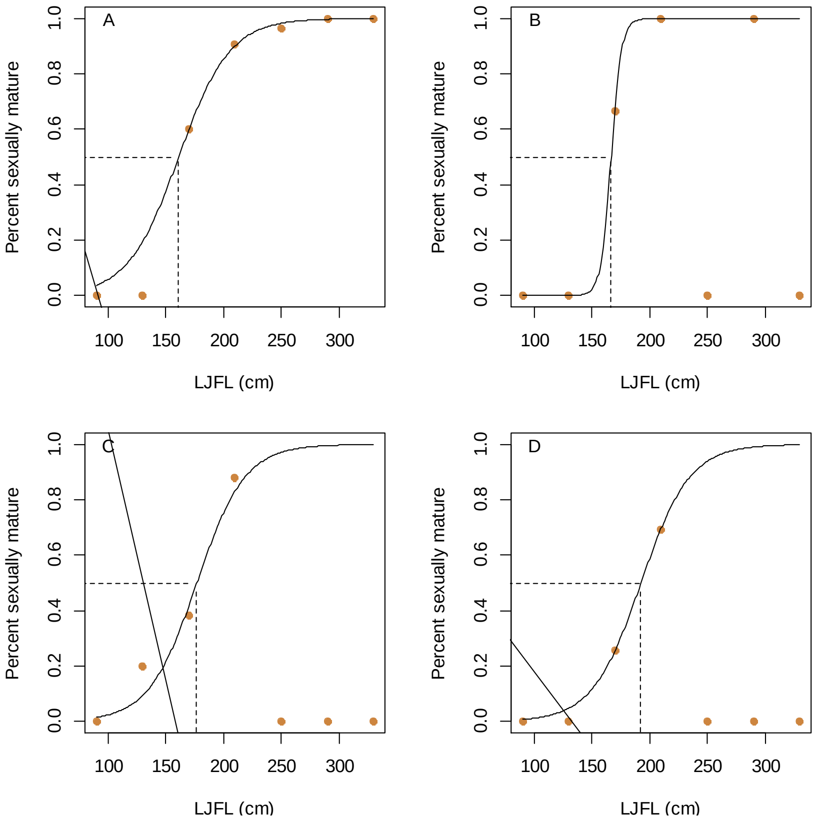

Fig. 17 Relationship between percentages of mature individuals and the length classes by 40 cm intervals for billfishes