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A preliminary analysis of size frequency and CPUE for the Indian Ocean bigeye tuna (*Thunnus obesus*) using Chinese longline observer data

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Summary

This study presents the spatial pattern of length frequency and catch-per-unit-effort (CPUE) for the Indian Ocean bigeye tuna (*Thunnus obesus*) based on the Chinese longline fishery observer data from 2012 to 2019. Contour lines map and G-statistic method was used to make spatial distribution and autocorrelation analysis of size data, respectively. The standardization of CPUE (annual series as well as quarterly series in number/1000 hooks) was conducted by Generalized Additive Model (GAM) with variables including: year (year-quarter), latitude, longitude, area, target species, and depth of hooks. Spatial strata were defined by an adaptive area stratification used in the previous study. The results of spatial length frequency showed the large size groups (fork length greater than 110 cm) were mainly caught in the Northwest Indian Ocean; while the small size groups (fork length less than 110 cm) were more caught in the Southwest Indian Ocean. Both standardized indices indicate an overall decline, except for an increase in 2017 and decreased again after that. CPUE index mainly distributed in the medium-size group.

1. Introduction

Bigeye tuna (*Thunnus obesus*) is one of the essential target species of Chinese longline fishery in the Indian Ocean. China began to implement scientific observer data collection in IOTC since 2002. However, the standard observer data was only available since 2010 when China implemented an improved observer program with new protocol. In 2010 we only have one observer trip with Escolar (*Lepidocybium flavobrunneum*) as target species. Because of piracy activity, no observers were sent out in 2011. Therefore, the data we used in this study is from 2012 to 2019.

The objectives of this research are,1) analyze the spatial distribution of length for bigeye tuna; 2) conduct the CPUE (catch per unit effort) standardization by using Chinese longline observer data; 3) analyze the relationship between the length frequency and abundance index.

2. Methods and data

Data

Data for this analysis comes from the China observer program, which covers 1842 observer records for years 2012 to 2019. These longline vessels mainly set in the West Indian Ocean (Figure1). Fishing effort had been reported as the number of hooks per set, thus the unit of nominal catch rates was counted as the number of BET per 1000 hooks in this case. For each observer trip, the following information had been recorded: number and weight of the harvest, date, location, vessel targeted species, gear information and biological information for most species. The observed fishing set targeted bigeye tuna and albacore, which account for 64% and 36% of total records respectively, and the target species had been assumed as a factor in our CPUE standardization model.

Spatial structure

Based on the previous research in joint CPUE standardization in the Indian Ocean (Simon *et al.*,2017), we partitioned the spatial domain into four areas. In this case, region 1 (R1), region 2 (R2), region 3 (R3) and region 4 (R4) had been used to denoted the northwest, the northeast, the southwest and the southeast, respectively (Figure 2).

Spatial distribution analysis of length frequency data

The size data we got from the observer program is the fork length data. Spatial analysis was conducted by ArcGIS software (version 10.3). Inverse Distance Weight (IDW) method (Shepard,1968) was used to estimate spatial interpolation among each vessel operating station (refer to the control point). Given the data visualization, similar length values have been connected by various contour lines based on the spatial interpolation. Besides, we used hotspot analysis, a quantitative tool which can identify spatial clusters of high values (indicated hot spots) and low values (indicated cold spots), to evaluate whether the distribution of length data is random, discrete or aggregated. Referring to the previous stock assessment for bigeye tuna in Indian Ocean (Adam, 2016) which used 110.89 cm as the value of the 50% maturity length and the hist graph of length distribution (Figure 3), we roughly considered four length groups corresponding to the ranges: less than 110 cm,110-140 cm,140-170 cm and more than 170 cm.

CPUE standardization model

In the present study, Generalized Additive Model (GAM) was selected as the CPUE standardization model, and the model defined as follows:

Log (CPUE) ~ year(year-quarter) + latitude + longitude + target species + depth of hooks + mean length + errors

where the depth of hooks was calculated using the method by Yoshihara (1951). Both year and year-quarter in number were estimated as the temporal interval in the model. Year-quarter was divided as Quarter 1(Q1) includes January, February and March; Quarter 2(Q2) contains April, May and June; Quarter 3(Q3) includes July, August, September; Quarter 4(Q4) includes October, November and December. Proportion of deviance explanation, residuals distribution and variables effects on CPUE were conducted to diagnose the models' performance.

3. Results

Spatial and temporal distribution of length data

The qualitative result of contour lines map (Figure 4) indicates bigeye tuna caught in the North Indian Ocean were bigger than that in the South Indian Ocean, especially in R1 zone (northwest of the Indian Ocean). Quantitatively spatial analysis was showed in the hotspots map (Figure 5).

High values (hot spots) are aggregated in area 5°S-10°S, 40°E-50°E and 0°-10°N, 55°E-65°E, in which the confidence of clusters is 99%. Low values (cold spots) are mainly aggregated in area 20°S - 35°S ,45°E- 55°E, in which the confidence is 99%.

Time series of length data were shown in Figure 6 from 2012 to 2019, indicating an overall increase from 2012 to 2017, followed by a peak in 2018 and a decrease after 2018. Time series in different areas were shown in Figure 7(a,b). All the figures in different areas used same coordinates to compare directly. In R1, length data had a similar trend as the whole Indian Ocean; based on the current data, the length of bigeye tuna in R3 was decreased from 2017 to 2019.

CPUE Standardization

Time series of nominal CPUE of the whole Indian Ocean from 2012 to 2019 was shown in Figure 8, which indicates a decline over years. Time series in different areas were shown in Figure 9(a,b). The trend in R1 is similar with that of the whole Indian Ocean, and the value in R3 were lower than that in R1.

In this study, the standardization of CPUE was conducted by six models estimated year and year-quarter effects for R1&R3 and the Indian Ocean, respectively. As the data in region 2&4 only have one "year" variable, thus we didn't calculate the standardized CPUE.

Q-Q plots and histogram of residuals distribution of "Year-effects" models and "Year-Quarter effects" was shown in Figures 10 and 11, respectively. The trend of year effects on CPUE standardization in R1 was similar to the whole Indian Ocean expect 2015, and from 2016 CPUE in R3 was higher than R1(Figure 12). Year-Quarter effects on CPUE were shown in Figure 13. All three areas had similar trends: have an overall decline, except an increase in 2017 and decrease again after that. The standardized CPUE has lower values than the nominal CPUE and a noticeable difference with nominal CPUE (Figure 14), especially in 2016 and 2018.

Except for time effects, the variables of latitude, longitude, length, and depth of hooks all have significant influences on CPUE (Figure 15).

CPUE in different length group

We divided length data of whole area into four groups as the method motioned previously. The time series of nominal CPUE in different length groups were shown in Figure 16,17. CPUE of small bigeye tuna (group 1) and big bigeye tuna (group 4) was lower than other groups, indicating most bigeye tuna composition of observer data is medium-size. The CPUE of four groups all had a peak in 2018. Figure 18 showed the spatial distribution of nominal CPUE in different length groups. Bigger bigeye tuna mainly distributed in the north Indian Ocean.

4. Discussion

The observer data didn't cover a long time series and have a data-poor problem in the earlier period (before 2017). As the observer coverage increasing recent years (after 2017), the results in 2017-2019 become more convinces. This study aimed to explore information for understanding Chinese longline fishery for bigeye tuna.

5. Reference

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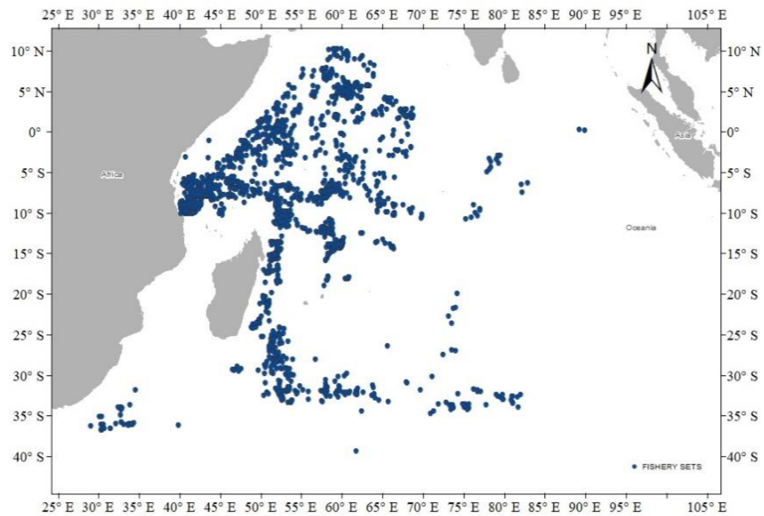


Figure 1. Spatial distribution of Chinese longline observer sets from 2012 to 2019.

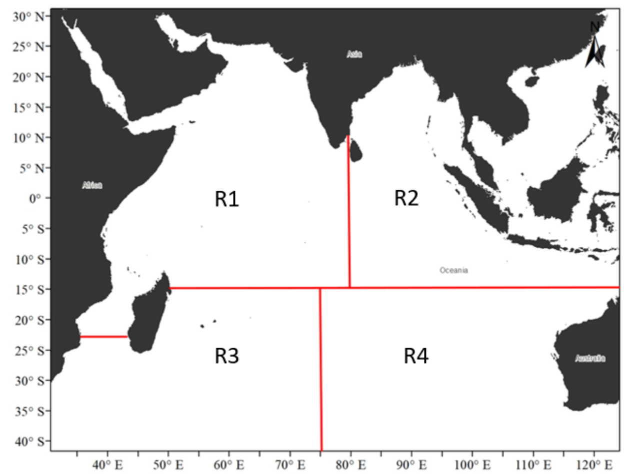


Figure 2. The regional structure for Chinese bigeye tuna longline fishery from 2012 to 2019.

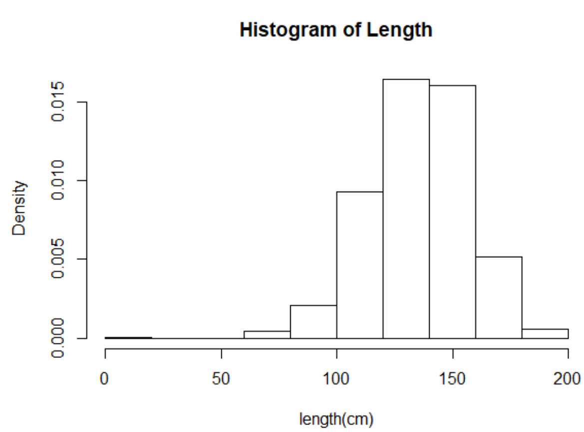


Figure 3. Histogram of length frequency of bigeye tuna.

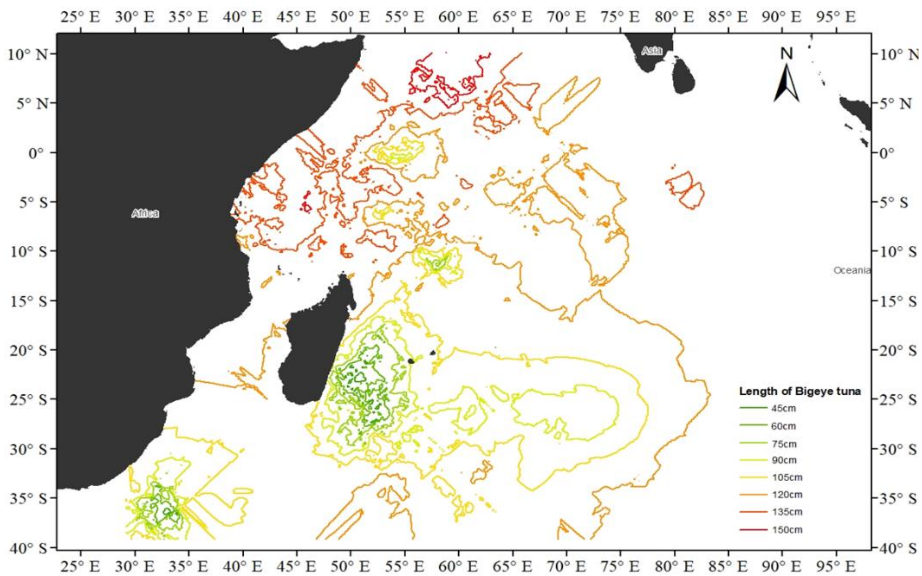


Figure 4. Contour lines map of length frequency of bigeye tuna from 2012 to 2019.

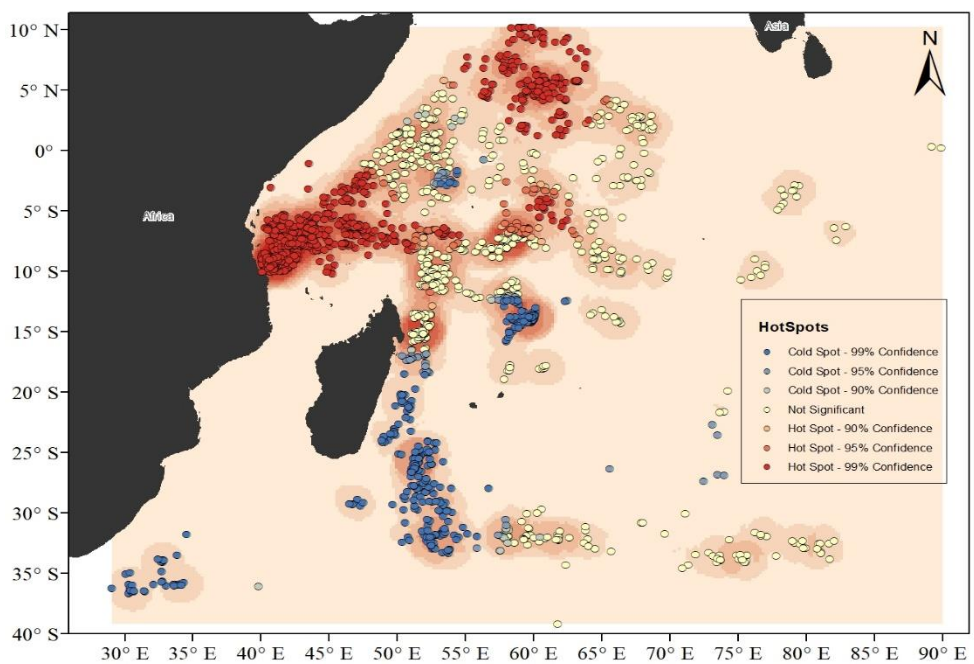


Figure 5. Hotspots of size data. Cold spot denotes lower value; hot spot denotes higher value; dark color means higher spatial autocorrelation.

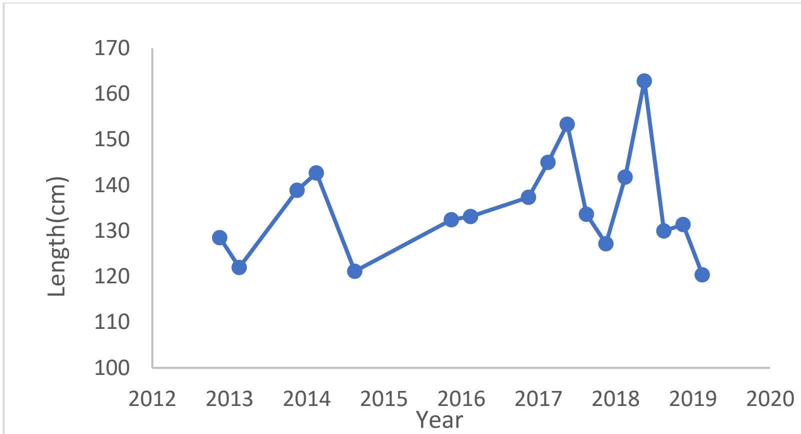
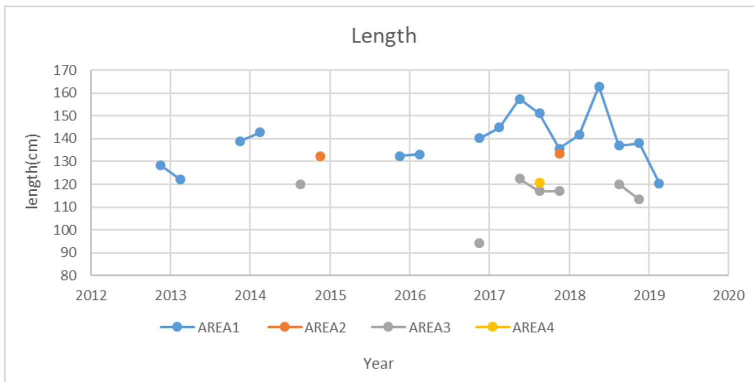


Figure 6. Time series of length data of bigeye tuna in the Indian Ocean from 2012 to 2019.



a

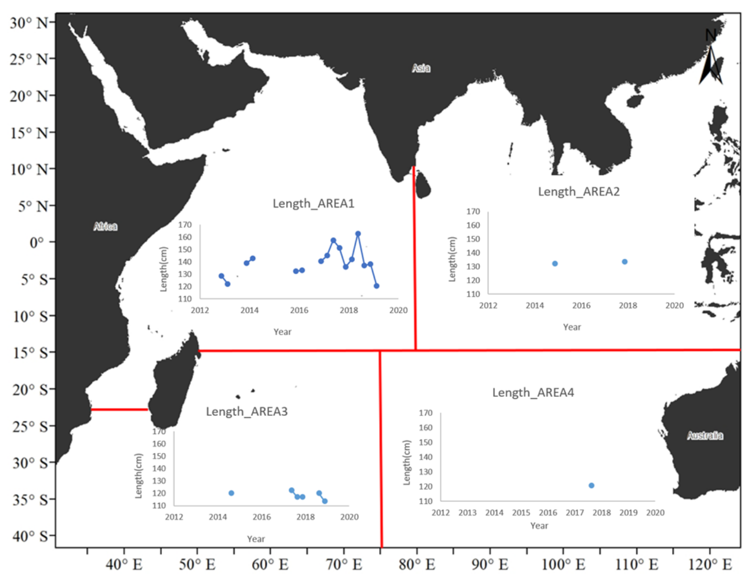


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Figure 7. Time series of length frequency of bigeye tuna in different areas, showed in one graph (**a**) and in geographical map separately (**b**).

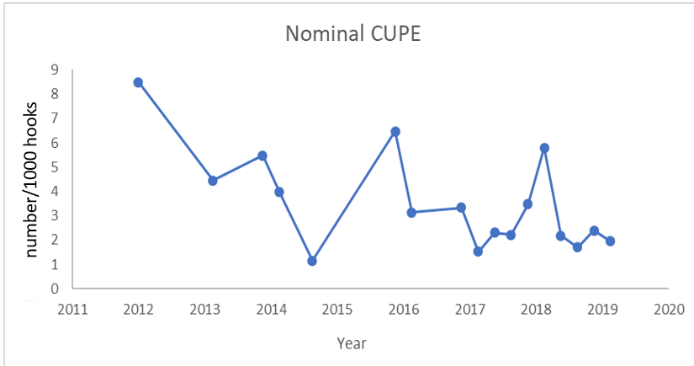
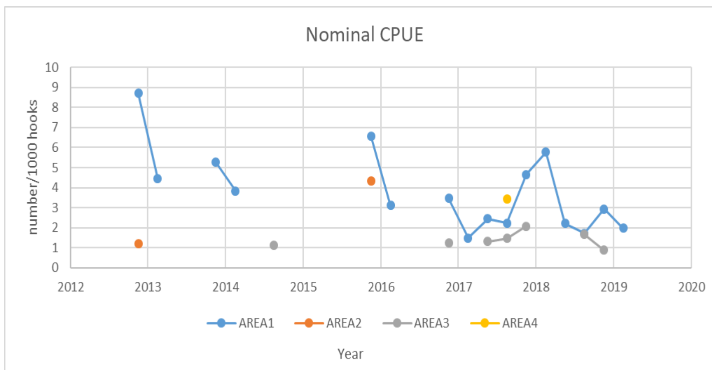
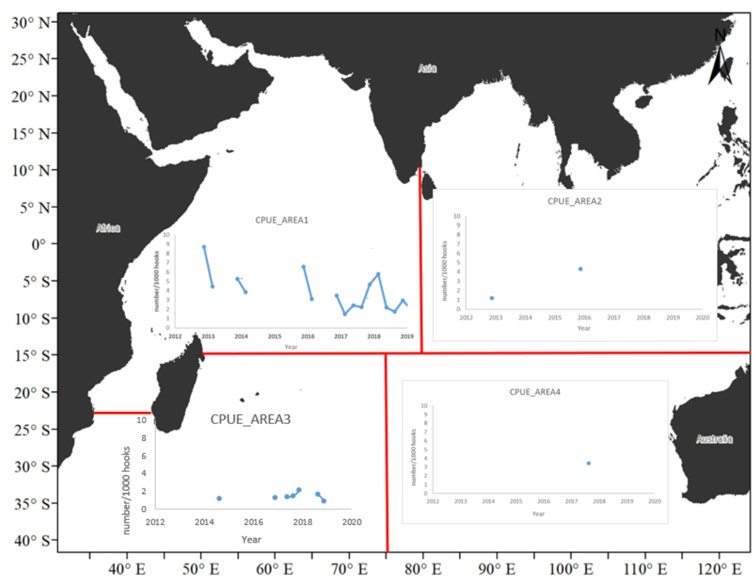


Figure 8. Time series of nominal CPUE of bigeye tuna.



a



b

Figure 9. Time series of nominal CPUE in different areas, showed in one graph (**a**) and in geographical map separately (**b**).

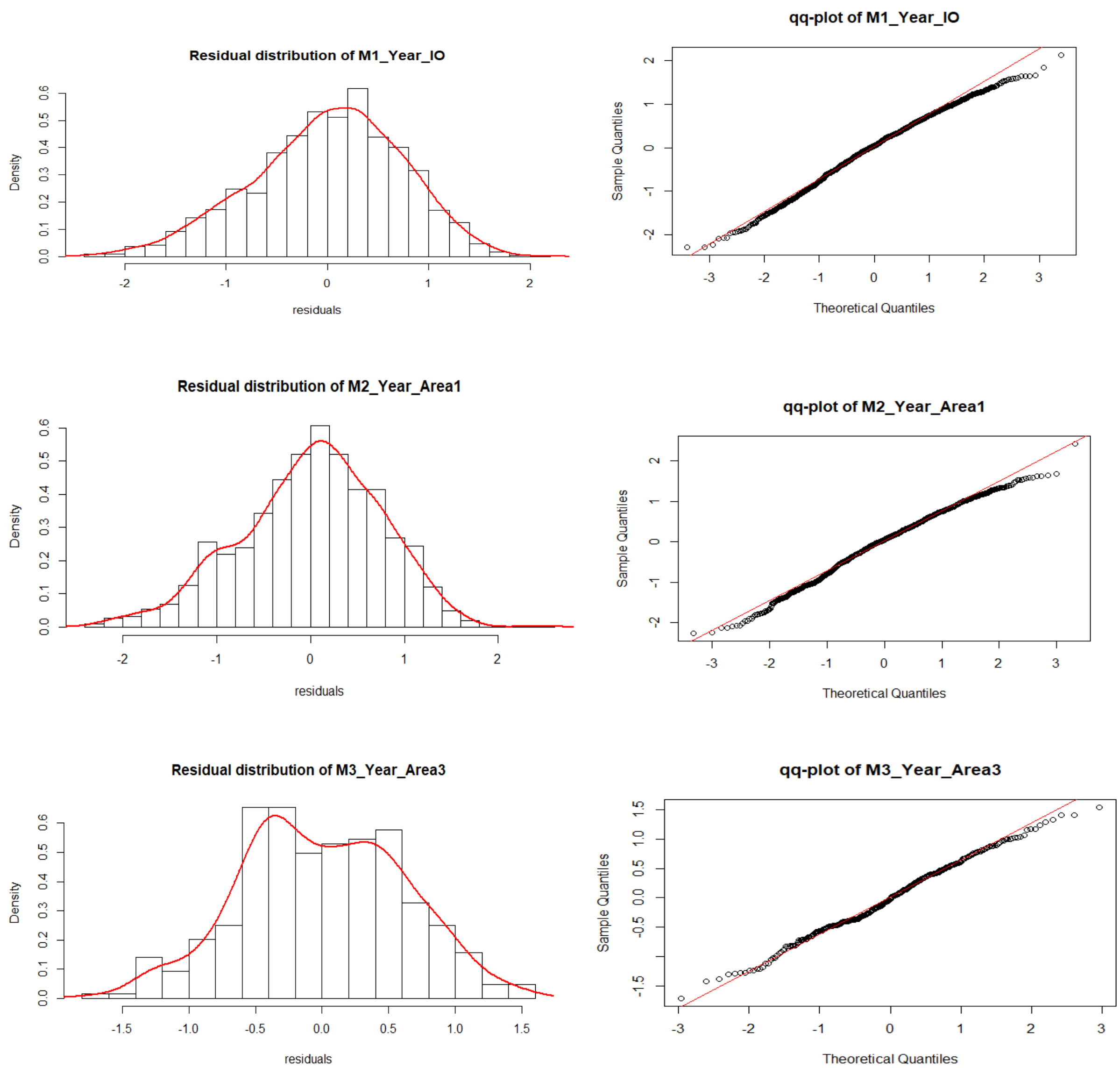


Figure 10. Residuals distribution of CPUE standardization models by year.

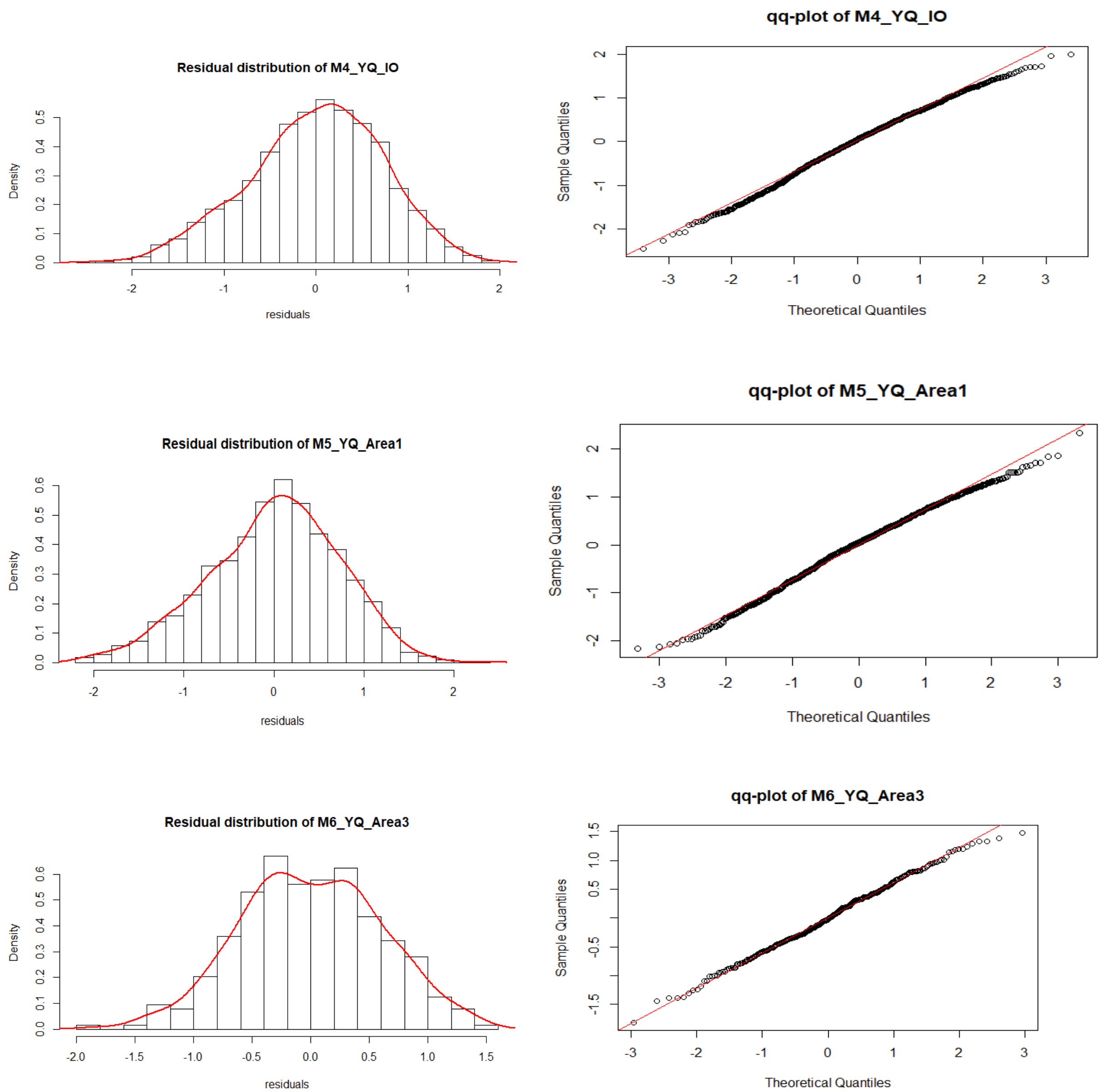


Figure 11. Residuals distribution of CPUE standardization models by year-quarter.

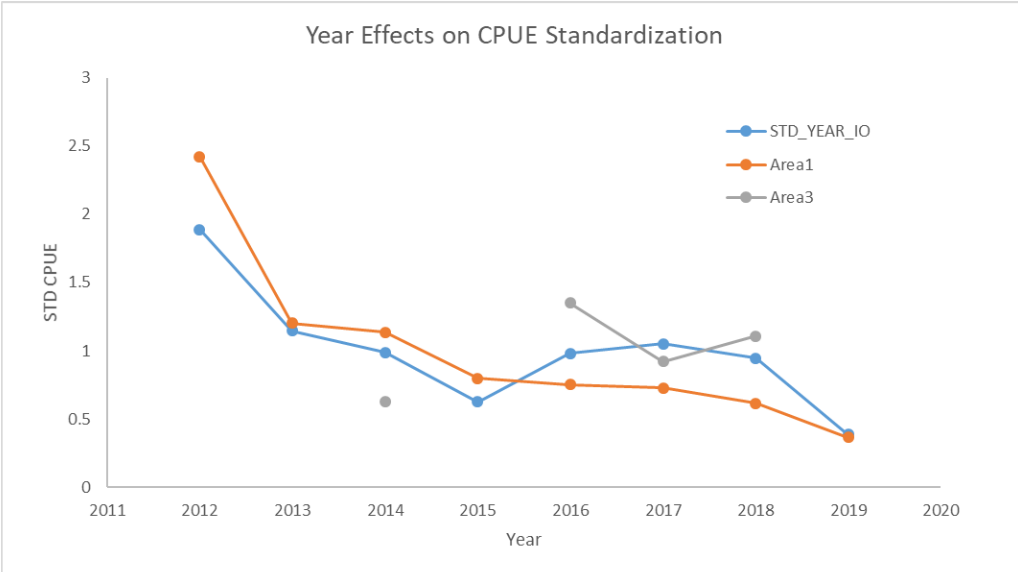


Figure 12. Year effects of Standardized CPUE of bigeye tuna in region1, region 3 and the Indian Ocean.

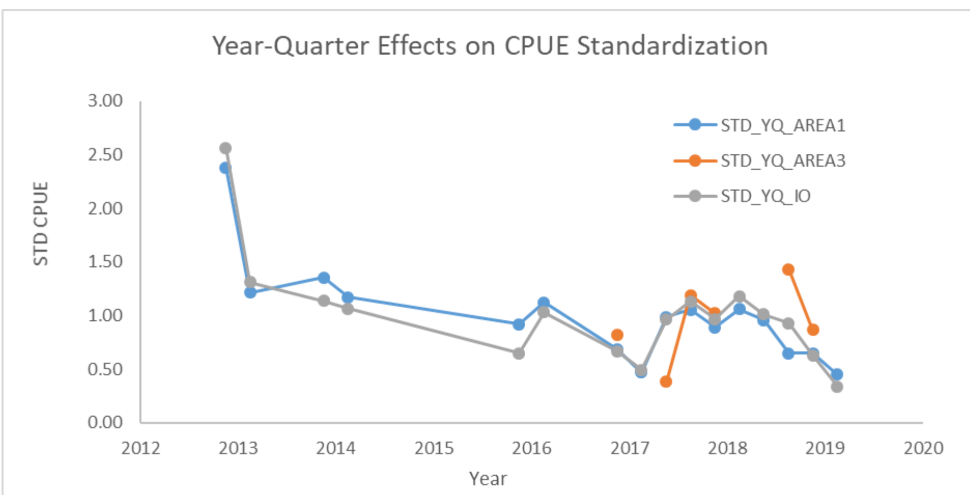


Figure 13. Year-quarter effects of Standardized CPUE of bigeye tuna in region1, region 3 and the Indian Ocean.

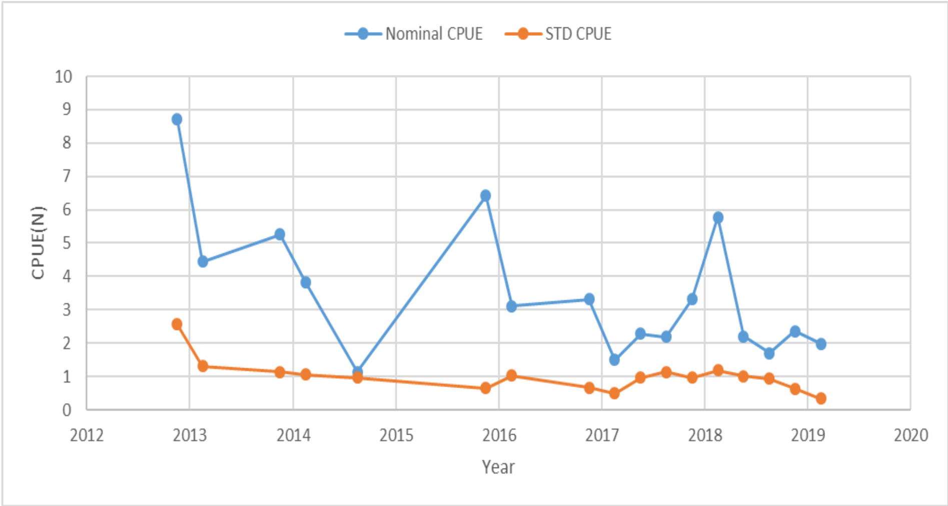


Figure 14. Standardized CPUE and nominal CPUE of bigeye tuna in Indian Ocean.

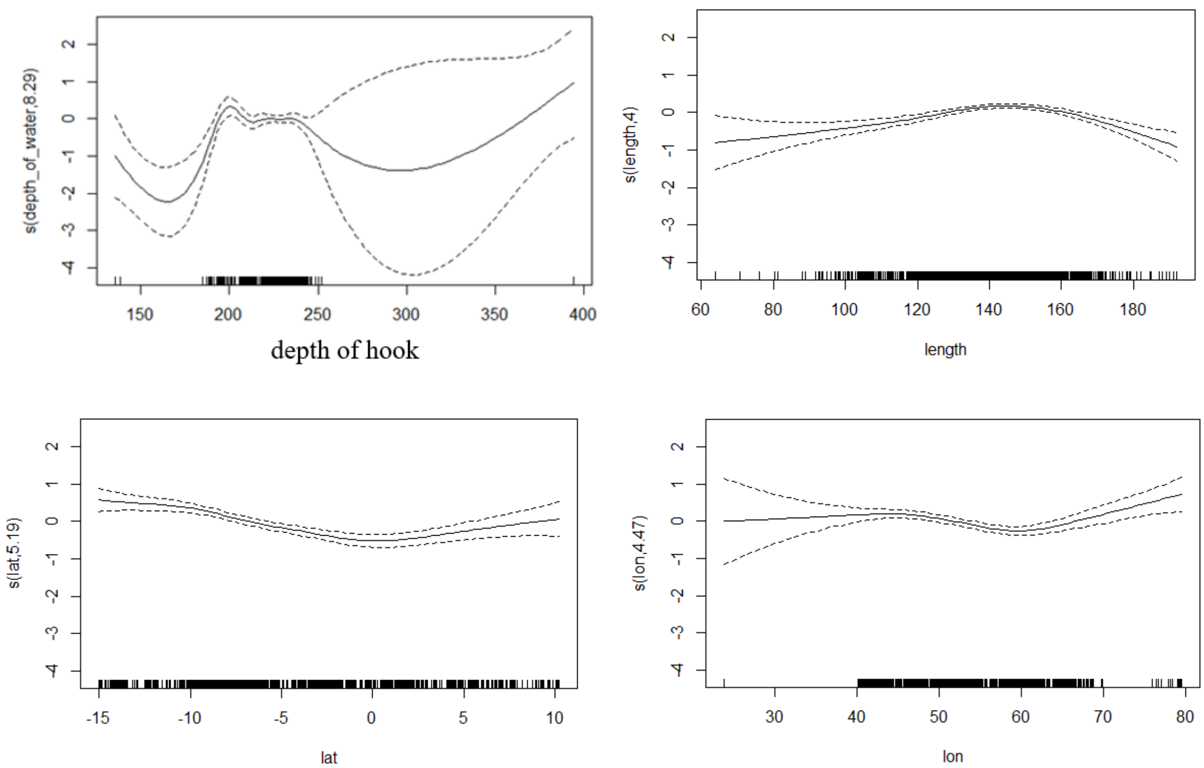


Figure 15. Effects of depth of hook, length, latitude, longitude on CPUE of bigeye tuna in longline fishery derived from the GAM analysis in the Indian Ocean.

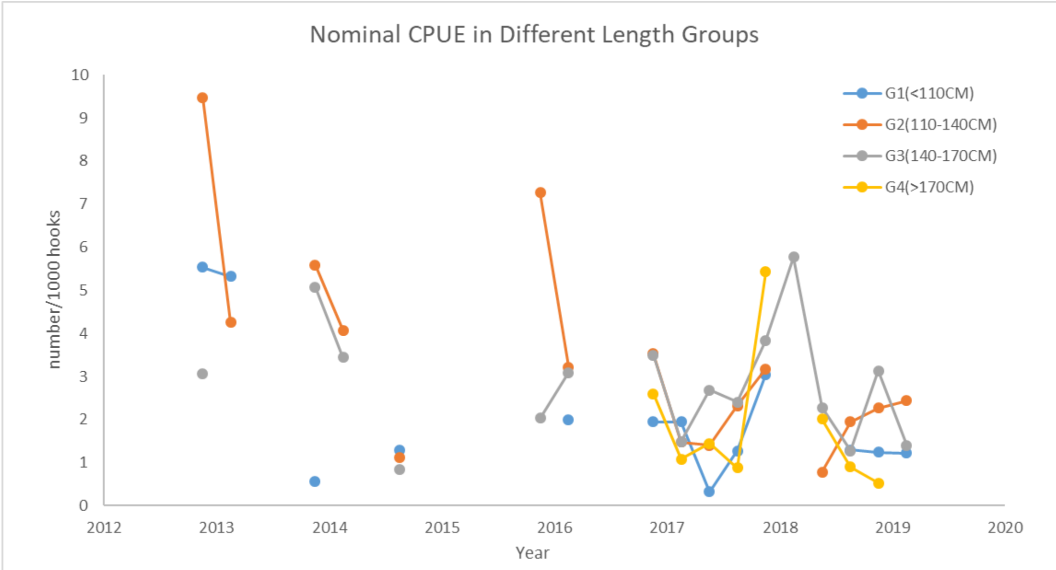
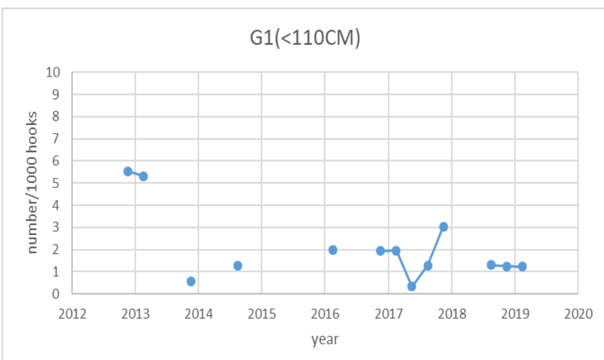
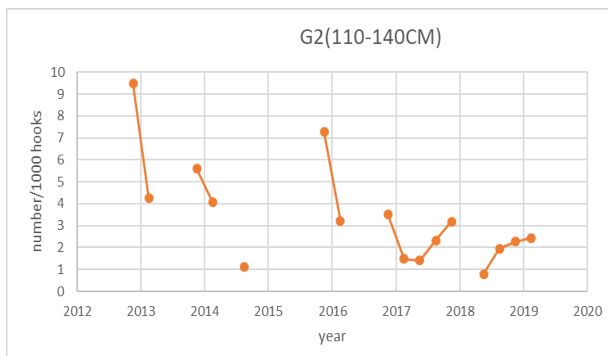
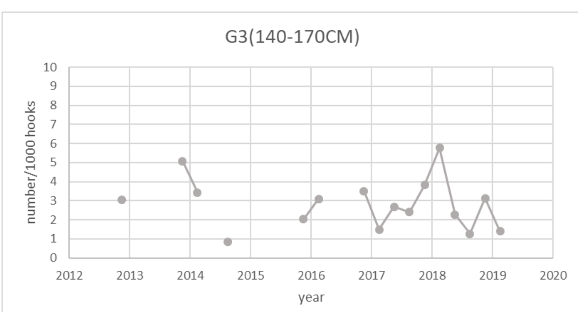


Figure 16. Time series of nominal CPUE in different length groups.







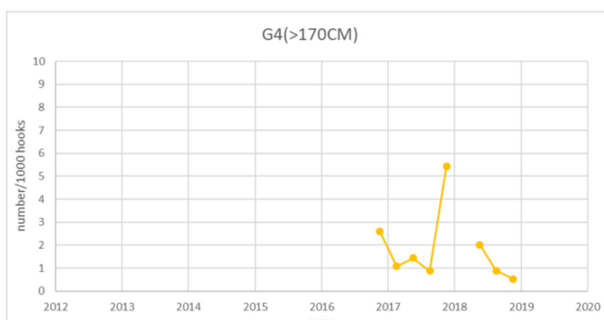


Figure 17. Time series of nominal CPUE in different length groups, separately.

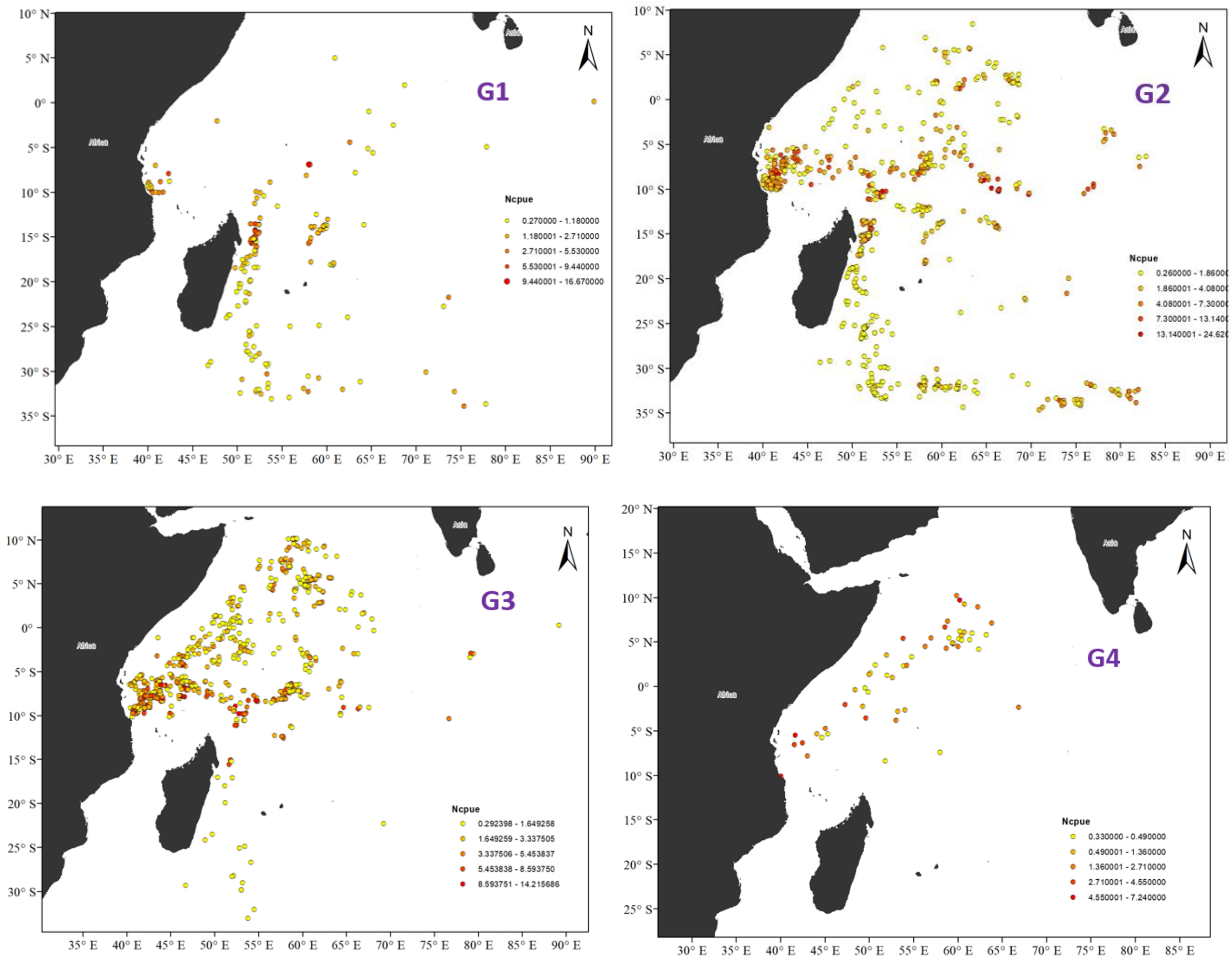


Figure 18. Spatial distribution of nominal CPUE in different length groups