Standardization of albacore CPUE by Japanese longline fishery in the Indian Ocean

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Summary

Standardization of albacore CPUE by Japanese longline fishery in the Indian Ocean was conducted using the Generalized Linear Model (GLM) with log-normal error structure (LN model). Operational level catch and effort data as well as environmental factor (sea surface temperature) were used for standardization. Area definition is the same as that for longline joint CPUE. All CPUEs sharply declined in the early period (until around 1970). CPUE in the north area was comparatively constant after that. CPUE in the south area increased after early 2000s. Some difference of CPUE trend was observed between the present study and CPUE with 'new' method (with cluster analysis and vessel effect).

1. INTRODUCTION

Albacore in the Indian Ocean has been exploited since the early 1950s. Albacore catch increased with fluctuation, and it reached to about 46,000 t in 2001 at the historical highest level, though the range of the catch had been from 12,000 t to 36,000 t during the period from the 1960s to the mid-1990s. Japanese longline fishery commenced in this Ocean in 1952. The fishery caught albacore ranging from 9,000 to 18,000 t in the 1960s that corresponds to the beginning of the long history of the fishery. Since then the catch decreased rapidly and reached to 400 t in 1977. This drastic change is due to the change of target species of the longline fishery, i.e., from yellowfin tuna and albacore to southern bluefin tuna and bigeye tuna, during the 1970s. The catch continued to be in a low level ranging from 400 t to 2,500 t until early 1990s. After that the catch slightly increased and was 6,200 t in 2006, which was highest during the past 40 years. However, it is still about one third of the catch at the peak in 1964. In recent years, although albacore seems to be not a target species by Japanese longline fishery in the Indian Ocean, albacore catch and catch rate are higher than before.

For the Indian Ocean albacore caught by Japanese longline fishery, CPUE standardization using the Generalized Linear Model (GLM) with the assumption that the error structure belongs to log-normal had been carried out for 1960-1991 (Uozumi, 1994) and for 1960-2002 (Uosaki, 2004). Both log-normal and negative binomial error structures were examined by Matsumoto and Uosaki (2011) and Matsumoto et al. (2012) based on aggregated catch and effort data by 5 degree latitude-longitude and operational level data, respectively, considering that negative binomial error structure may be better for standardization of albacore CPUE by Japanese longline which includes certain amount of zero catch data, but log-normal error structure was considered to be better based on information criteria or distribution of the standardized residuals. Therefore, Matsumoto et al. (2014) and Matsumoto and Kitakado (2016) used only log-normal and negative binomial error structure. In May to June 2018, IOTC joint CPUE analysis was conducted and joint standardized CPUEs for albacore were created using operational level data for Japanese, Korean and Taiwanese longline fishery combined, as well as Japanese longline CPUE by the same method (IOTC, 2018). Those CPUE incorporate cluster analysis and vessel effect. One of the objectives of this study is to compare CPUE indices with those by the joint CPUE analysis.

2.MATERIALS AND METHODS

2.1. Catch and effort data

The data used here is the logbook data that has been compiled at National Research Institute of Far Seas Fisheries (NRIFSF) based on the logbook mandatory submitted by the fishermen of the longline vessel larger than 20 gross ton (GRT). Original (operational level) logbook data for 1952-2017 were used, which include the number of hooks per basket. CPUE was defined as the number of fish caught per 1,000 hooks.

2.2. Area and period for CPUE

In this study, area definition is the same as that for IOTC joint CPUE analysis in 2018 ("regA4", Fig. 1), which is similar to the area used in the last stock assessment. In addition to area specific CPUE, CPUEs for north area (area 1+2), south area (area 3+4) and all area (area 1-4) were also calculated

In the previous studies, CPUE in the early period was truncated due to sharp decline for using in the stock assessment models. In the present study, one of the objectives is to compare CPUE indices with those by 2018 CPUE collaborative analysis, in which start year of CPUEs is 1950s. Therefore, also in this study start year was set as early as possible, and it differed depending on availability of catch and effort data by area.

2.3. Environmental factors

As an environmental factor, SST (Sea Surface Temperature) was incorporated into the regression analysis. The original SST data, whose resolution was 1-degree latitude and 1-degree longitude by month from 1946 to 2017, were downloaded from NEAR-GOOS Regional Real Time Data Base of Japan Meteorological Agency (JMA) website (http://goos.kishou.go.jp/rrtdb/database.html).

The original data were merged with catch and effort data. The SST was used as a categorical factor at 1 degree interval in the GLM models. The SST data for several months during 2014-2017 were replaced by SST data for the same month for nearest past year because these data were unreleased in the data base.

2.4. Gear effects

The number of hooks between floats (hooks per basket, HPB), which was divided and categorized into four levels (4-7, 8-11, 12-15 and 16-21 HPB), was incorporated for gear effect. As for the information on gear configuration before 1975 which is partly not available, each observation was regarded as 4-7 HPB in that period where not available. Main and branch line materials were categorized into two (1 = nylon, 2 = the others). Although this information on the materials has been collected since 1994, the nylon material was started to be used by distant water longliner around the late 1980s and spread quickly in the early 1990s (Okamoto, 2005). In this study, material of main and branch lines before 1994 was tentatively regarded as 'the others'.

2.5. Standardization

For standardizing albacore CPUE data, generalized linear model (GLM) with log-normal error structure (LN model) was employed as in the final models for the past analyses. The model is the same as that by Matsumoto and Kitakado (2016). The effects of gear material (main and branch lines) were incorporated. As for the effect of fishing area, 5 degree blocks were used. In addition to the effects mentioned above, the effect of fishing season (quarter) was used as with the previous analyses. In order to deal with observations with no catch of albacore, a constant of 10% of mean CPUE was added to the CPUE. Initial models used are:

Model for area aggregated CPUE (all area and south)

$\ln(CPUE+C) = \mu + Y + Q + G + ML + BL + SST + LT5LN5 + Q*G + Y*Q + ML*G + BL*G + e$

<u>Model for area aggregated (north area) and area specific CPUE</u>

$\ln(CPUE+C) = \mu + Y + Q + G + ML + BL + SST + LT5LN5 + Q*G + ML*G + BL*G + e$

where
- μ: intercept — C: constant (10% of mean CPUE)
- Y: effect of year — Q: effect of quarter
- G: effect of gear (HPB) — ML: effect of material of main line
- BL: effect of material of branch line — SST: effect of sea surface temperature
- LT5LN5: effect of each latitude 5 degree and longitude 5 degree block
- Q*G: interaction term between quarter and gear
- Y*Q: interaction term between year and quarter
- ML*G: interaction term between material of main line and gear
- BL*G: interaction term between material of branch line and gear
- e : error term

Standardized CPUE was calculated as follows:

Standardized $CPUE_i = EXP (LSM (Y_i)) – C$ (annual CPUE)

where
- $LSM(Y_i)$: least square mean of year effect in year i
- C: constant (10% of mean CPUE)

As for north area and area specific CPUE, year-quarter interaction was not used because of missing of the information. Based on the result of ANOVA (type III SS), non-significant effects ($p<0.05$ using F-test) were removed from the initial model in a step-wise way. In the cases if the factor was not significant as main effect but was significant as interaction with another factor, the main effect was kept in the model.

All the analyses were conducted using SAS Enterprise Guide version 7.15.

2.6. Catch and effort by Japanese longline fishery

Historical trend of fishing effort and catch of albacore and other major species were compiled to understand historical trend and potential targeting. Fig. 2 shows the trend of fishing effort, albacore catch as well as species composition of the catch by Japanese longline fishery. Fishing effort fluctuated, and is in a low level in recent years. Albacore catch was high during early to mid 1960s, sharply decreased in the late 1960s to early 1970s and kept in a low level between 1970s and early 2000s. It sharply increased after that, but was still lower than the level during 1960s. Catch is decreasing trend after mid 2000s.

Fig. 3 shows geographical distribution of species composition by decade. In the 1950s, when the effort increased, the effort was deployed mainly in the region north of 15˚S. The main component of the catch was yellowfin tuna in this period. In the period from the late 1970s to the mid 1980s, the effort increased again and reached to 130 million hooks, the same level as the previous peak in the 1960s. This increase was seen in the regions off Somalia and the south of 35˚S, targeting bigeye tuna and high quality (=oily) southern bluefin tuna, respectively. In the period from the mid 1980s to the early 1990s, the effort decreased again. This decrease was due to the decrease of the effort in the region south of 35˚S, corresponding to the fishing ground for southern bluefin tuna, by introduction of the TAC for southern bluefin tuna in 1986. In the period from the early to late1990s the effort increased. The increase was seen in the regions off west coast of Australia probably targeting bigeye tuna, and south of Madagascar Island where yellowfin, albacore and bigeye were mainly caught. In those regions, albacore was substantially caught, and this contributes to the increase of total catch in the period. In the period from 2000s the effort kept high until 2007, sharply decreased until 2012, and kept in a low level after that. The decrease has been seen especially in the regions off Somalia since 2010. This is due to the effect of piracy activities in this area. The proportion of albacore is high in the south area especially west off Australia. Fig. 4 shows geographical distribution of species composition in recent years.

3. RESULT AND DISCUSSION

The analysis of variance for the GLM analyses is shown in Table 1. This shows all the effects were significant at 5 % level except for main line effect in the area 1. As for main factor except for year effect, in the north area, the effect of LT5LN5 was largest followed by quarter. In the south and all areas, the effect of LT5LN5 was largest followed by SST. The distributions of standardized residual are shown in Fig. 5 (distribution of standardized residual and QQ-plot) and Fig. 6 (box plot for annual value). It seems that standardized residuals for north area are somewhat unbiased, whereas those for south and all areas are less biased.

Fig. 7 shows trend of standardized CPUE with confidence limits and nominal CPUE. Sharp decline of CPUE was observed in the early period (until around 1970) for all the areas. After that CPUE was almost constant in the north area. CPUE in the south area was also almost constant until early 2000s, and it increased during mid 2000s, and kept higher level after that. There are some differences between standardized and nominal CPUEs especially all and south areas during the early period. There are some differences of the trend of CPUE among areas.

Fig. 8 shows comparison of albacore CPUE by Japanese longline in the present study with those created at 2018 CPUE collaborative analysis (Matsumoto and Hoyle, 2019), which incorporated vessel effect and cluster analysis. The trend of both CPUEs was generally similar, but there are some differences especially during the early period. The decrease in the early period by the new method is less steep. This is probably because of the results of incorporating vessel effect and/or targeting. However, recent increase in the south area and area 4 has not yet been so much relieved. We need more consideration and to interview to the fishermen as for this period.

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Table 1. Analysis of variance for the GLM analyses.

North (10-25S, 20-140E)

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	146	185156.3	1268.2	1320.01	<.0001
Error	236442	227160.4	0.96		
Corr. Tot.	236588	412316.7			
R-square=	0.449063	C.V.=	86.44759		

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
y	63	36471.63	578.91	602.57	<.0001
Q	3	5972.01	1990.67	2072.01	<.0001
G	3	432.06	144.02	149.91	<.0001
ml	1	108.46	108.46	112.90	<.0001
sst	12	2966.76	247.23	257.33	<.0001
LT5LN5	52	31684.56	609.32	634.21	<.0001
Q*G	9	949.73	105.53	109.84	<.0001
G*ml	3	343.90	114.63	119.32	<.0001

South 25-40S, 20-140E (Area 3+4)

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	332	508462.7	1531.5	1617.61	<.0001
Error	523491	495627.5	0.95		
Corr. Tot.	523823	1004090.2			
R-square=	0.506391	C.V.=	107.526		

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
y	58	79967.20	1378.74	1456.26	<.0001
Q	3	3924.17	1308.06	1381.60	<.0001
G	3	76.88	25.63	27.07	<.0001
ml	1	136.45	136.45	144.12	<.0001
sst	18	27592.78	1532.93	1619.11	<.0001
LT5LN5	63	42367.48	672.50	710.31	<.0001
Q*G	9	355.70	39.52	41.74	<.0001
y*Q	174	36196.25	208.02	219.72	<.0001
G*ml	3	169.19	56.40	59.57	<.0001

All 10-40S, 20-140E (Area 1-4)

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	408	673625.1	1651.0	1683.7	<.0001
Error	760132	745389.1	0.98		
Corr. Tot.	760540	1419014.3			
R-square=	0.474713	C.V.=	101.0948		

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
y	63	137962.51	2189.88	2233.19	<.0001
Q	3	6806.19	2268.73	2313.60	<.0001
G	3	1036.50	345.50	352.34	<.0001
ml	1	82.15	82.15	83.78	<.0001
sst	21	30561.65	1455.32	1484.10	<.0001
LT5LN5	116	100169.77	863.53	880.61	<.0001
Q*G	9	1268.64	140.96	143.75	<.0001
y*Q	189	42806.01	226.49	230.97	<.0001
G*ml	3	494.50	164.83	168.09	<.0001

Area 1 10-25S, 20-75E

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	114	105874.9	928.7	1335.35	<.0001
Error	95683	66547.1	0.70		
Corr. Tot.	95797	172421.9			
R-square=	0.614045	C.V.=	62.95519		

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
y	63	15990.38	253.82	364.94	<.0001
Q	3	1365.01	455.00	654.21	<.0001
G	3	268.62	89.54	128.74	<.0001
ml	1	0.03	0.03	0.04	0.834
sst	10	1370.99	137.10	197.12	<.0001
LT5LN5	22	5283.51	240.16	345.31	<.0001
Q*G	9	479.03	53.23	76.53	<.0001
G*ml	3	191.75	63.92	91.90	<.0001

Area 2 10-25S, 75-140E

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	123	83317.8	677.4	605.77	<.0001
Error	140667	157296.6	1.12		
Corr. Tot.	140790	240614.4			
R-square=	0.346271	C.V.=	106.7315		

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
y	63	25530.17	405.24	362.40	<.0001
Q	3	4441.13	1480.38	1323.87	<.0001
G	3	46.35	15.45	13.82	<.0001
ml	1	49.39	49.39	44.17	<.0001
sst	12	2248.93	187.41	167.60	<.0001
LT5LN5	29	10431.34	359.70	321.67	<.0001
Q*G	9	1020.39	113.38	101.39	<.0001
G*ml	3	51.79	17.26	15.44	<.0001

Area 3 25-40S, 20-75E

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	125	198563.1	1588.5	1690.29	<.0001
Error	253762	238480.9	0.94		
Corr. Tot.	253887	437044.0			
R-square=	0.454332	C.V.=	74.26725		

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
y	60	85971.52	1432.86	1524.67	<.0001
Q	3	743.64	247.88	263.76	<.0001
G	3	272.24	90.75	96.56	<.0001
ml	1	416.67	416.67	443.37	<.0001
sst	16	3305.23	206.58	219.81	<.0001
LT5LN5	30	17769.14	592.30	630.26	<.0001
Q*G	9	1522.56	169.17	180.01	<.0001
G*ml	3	85.12	28.37	30.19	<.0001

Area 4 25-40S, 75-140E

Source	DF	SS	Mean Sq.	F Value	Pr > F
Model	127	327704.0	2580.3	2952.7	<.0001
Error	269936	235895.3	0.87		
Corr. Tot.	270063	563599.3			
R-square=	0.581449	C.V.=	213.8225		

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
y	61	37478.37	614.40	703.06	<.0001
Q	3	3472.48	1157.49	1324.53	<.0001
G	3	178.10	59.37	67.93	<.0001
ml	1	63.04	63.04	72.14	<.0001
sst	15	20096.42	1339.76	1533.09	<.0001
LT5LN5	32	7240.86	226.28	258.93	<.0001
Q*G	9	1205.94	133.99	153.33	<.0001
G*ml	3	312.99	104.33	119.39	<.0001

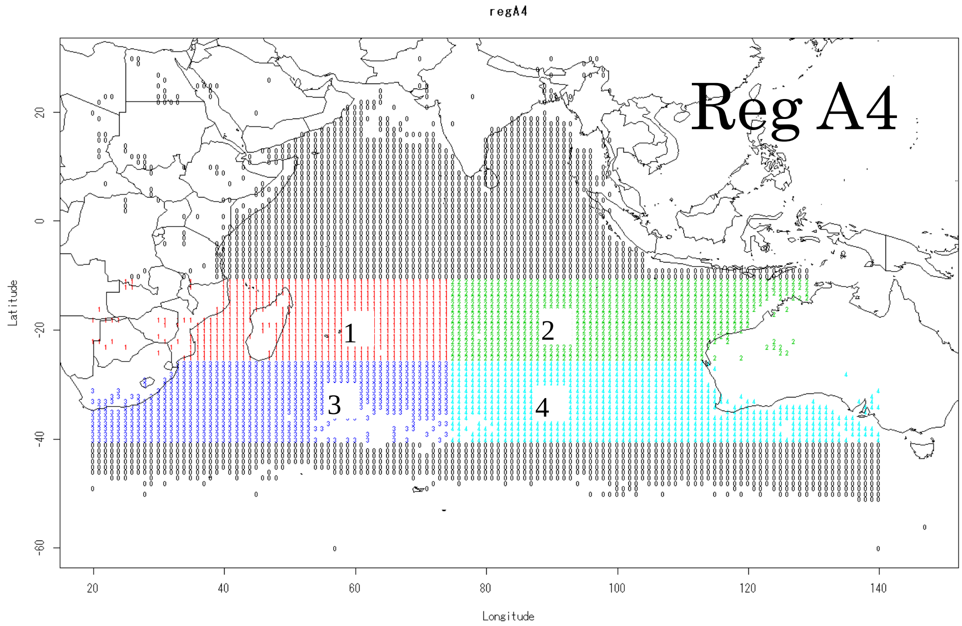


Fig. 1. Area used for the GLM analysis.

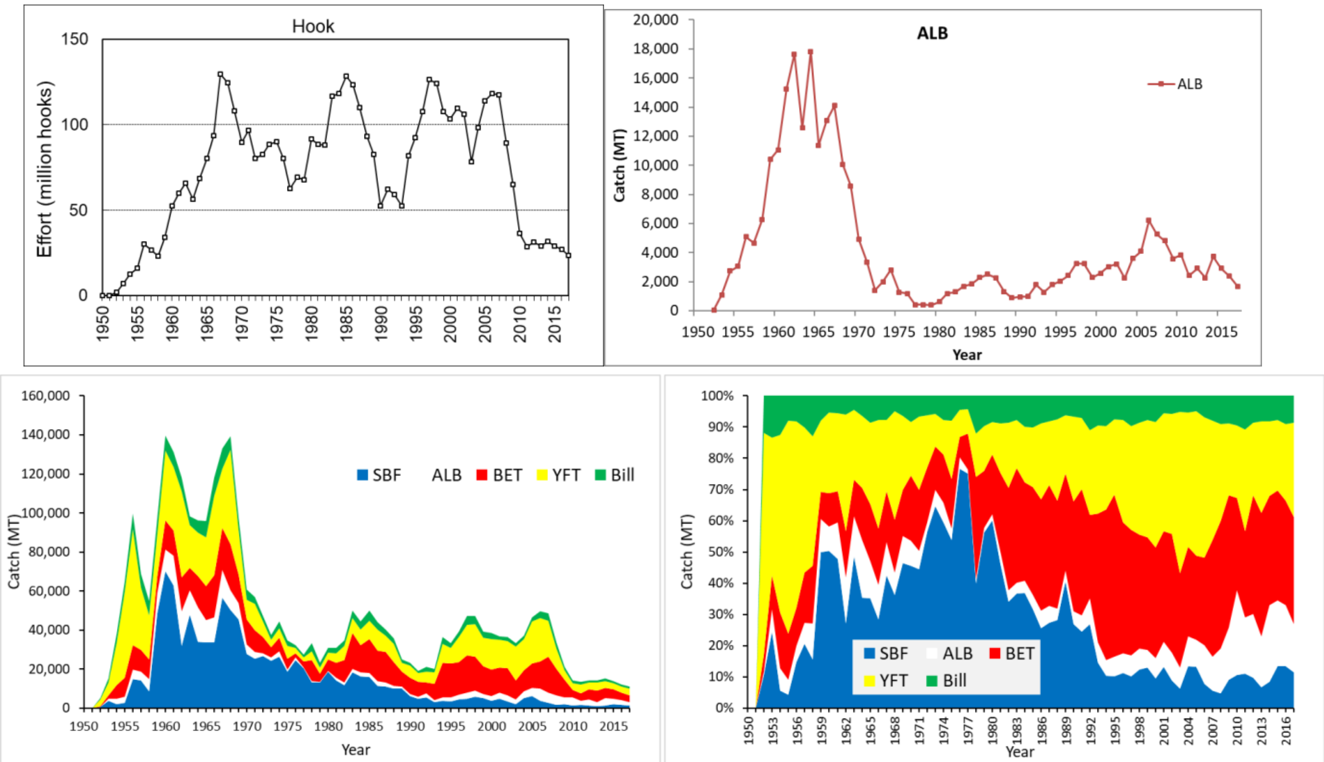


Fig. 2. Trend of number of hooks (top left), catch and trend for albacore (top right), catch by species (bottom left), and catch composition of major species (bottom right) by Japanese longline fishery in the Indian Ocean.

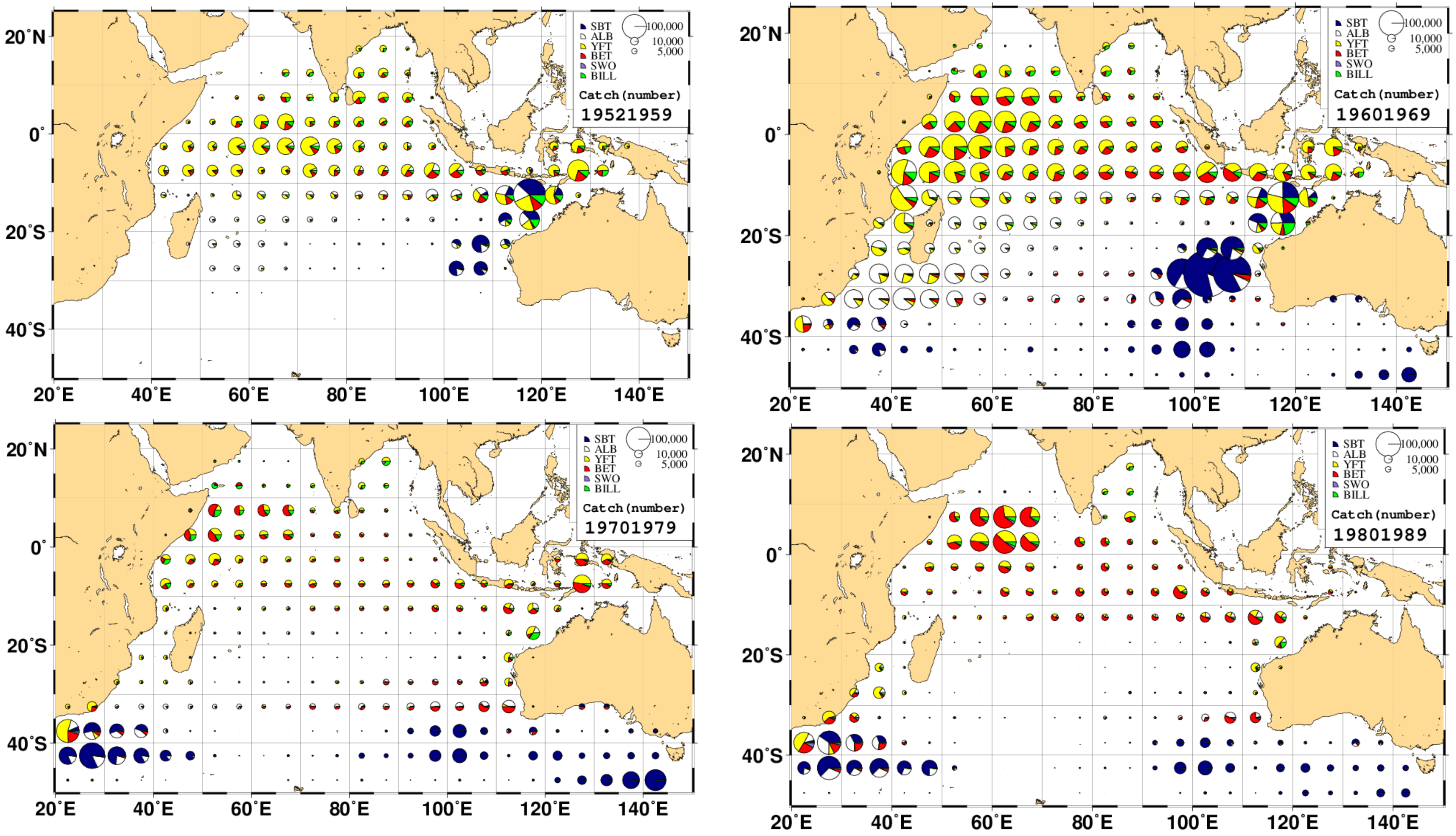
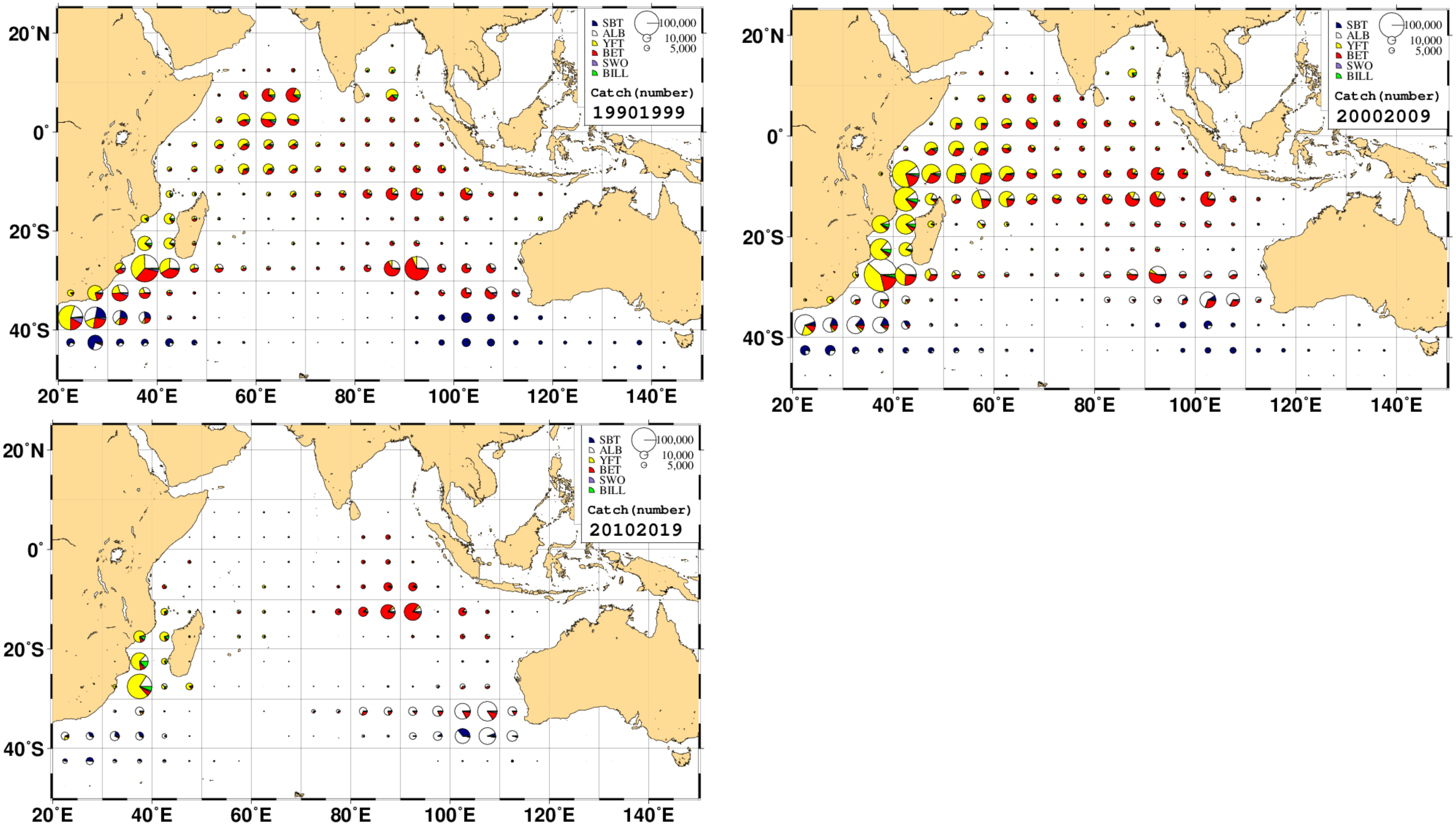


Fig. 3. The averaged distribution of amount of catch in number by species for each decade. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (Bill).



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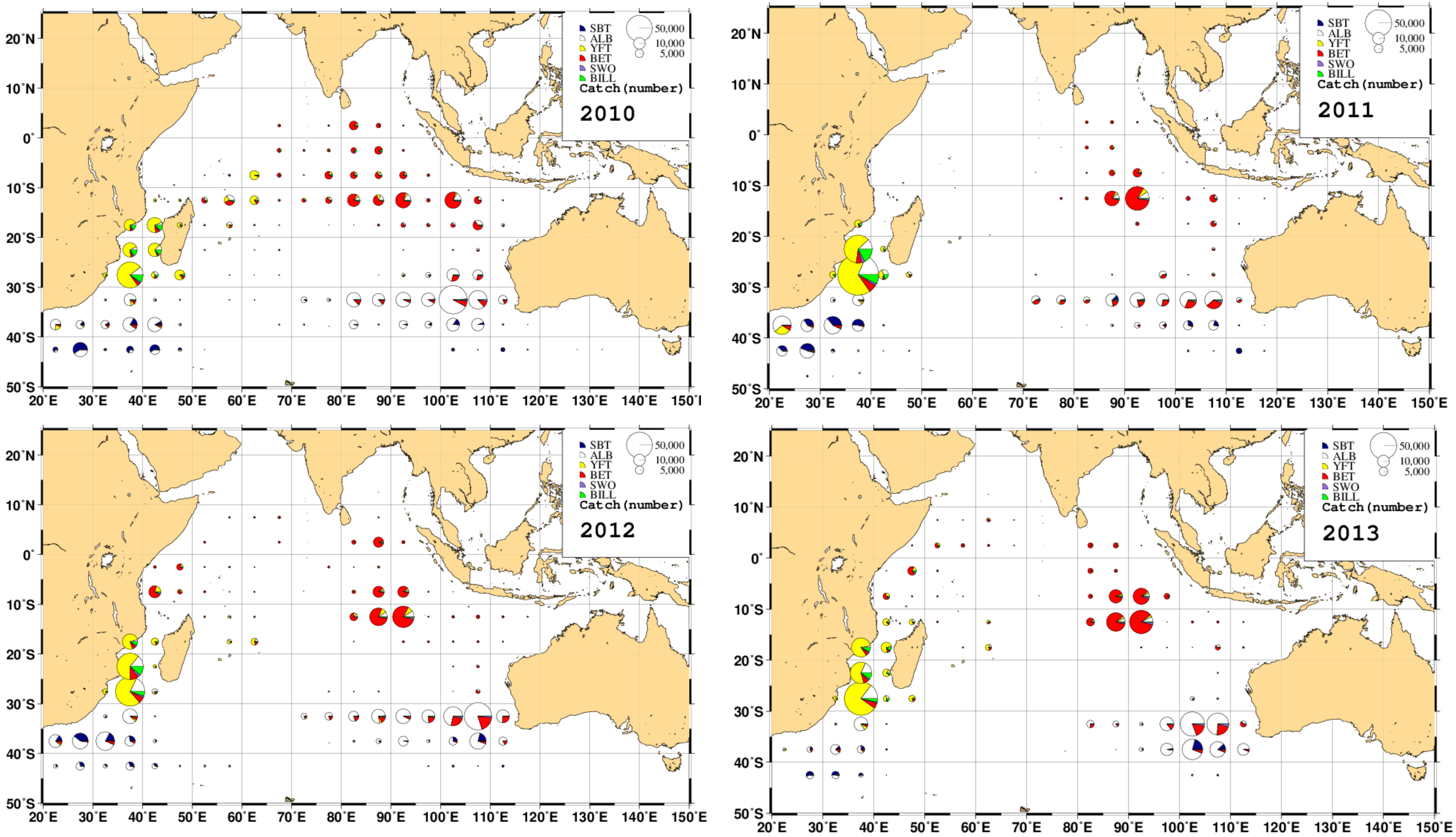


Fig. 4. The averaged distribution of amount of catch in number by species in recent years. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (Bill).

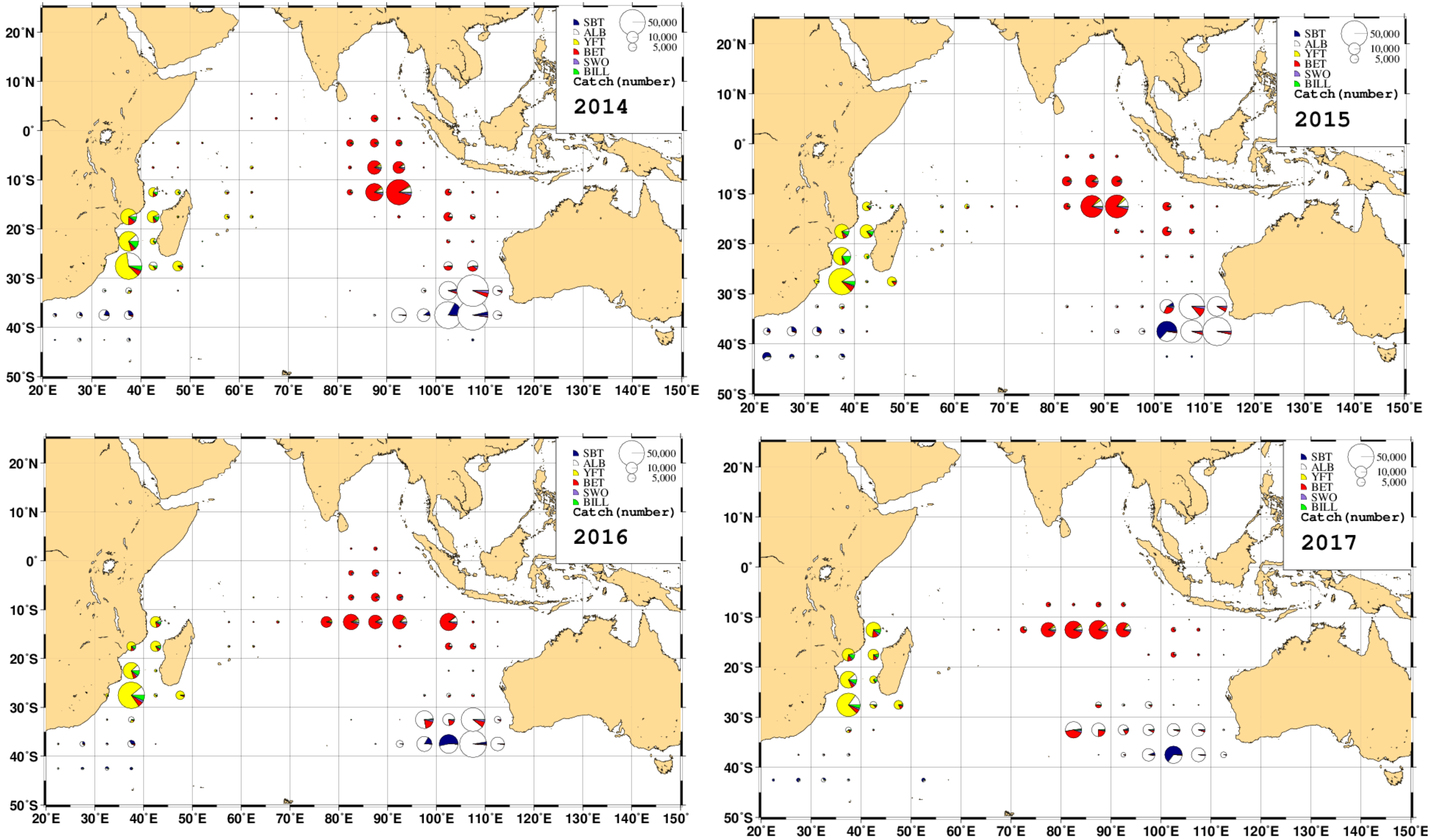
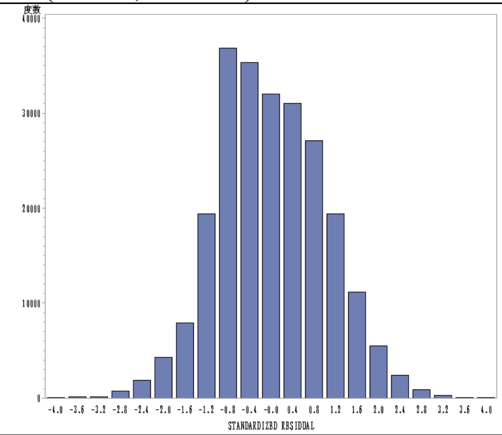
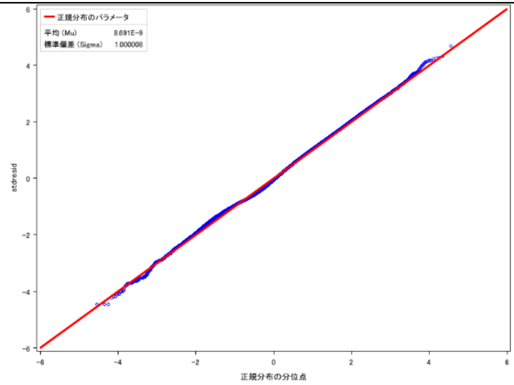


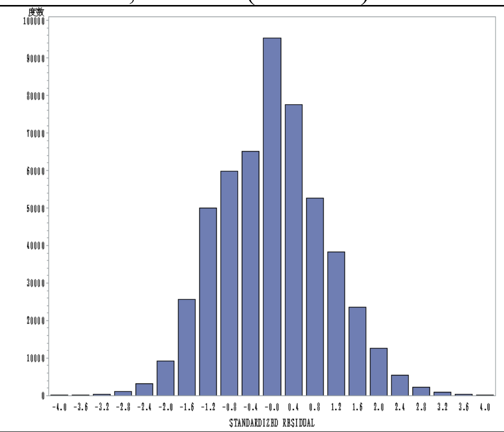
Fig. 4. The averaged distribution of amount of catch in number by species in recent years. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (Bill). (continued)

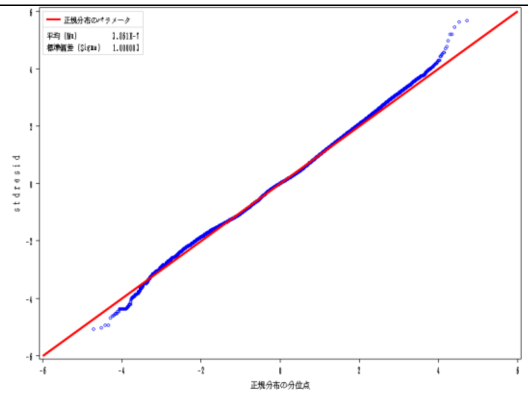
North (10-25S, 20-140E)



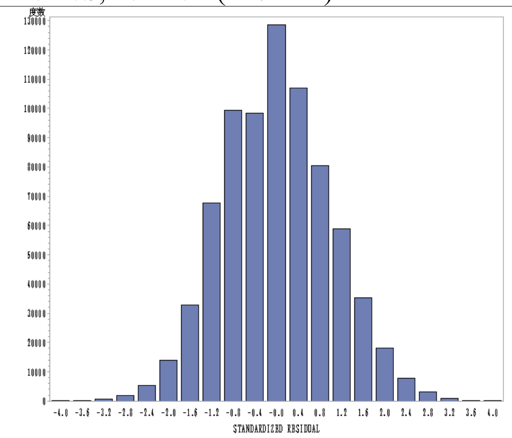


South 25-40S, 20-140E (Area 3+4)





All 10-40S, 20-140E (Area 1-4)



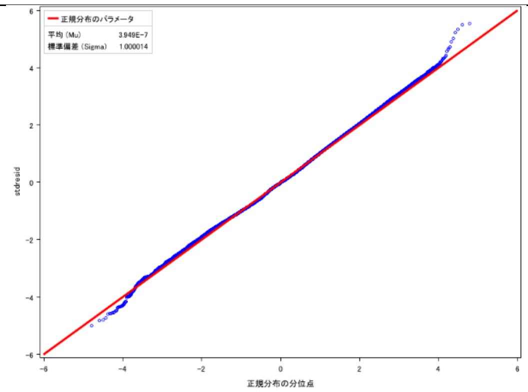
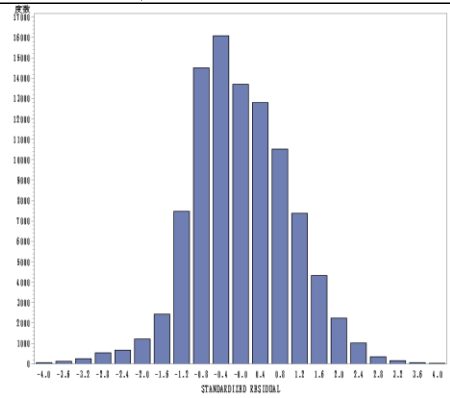
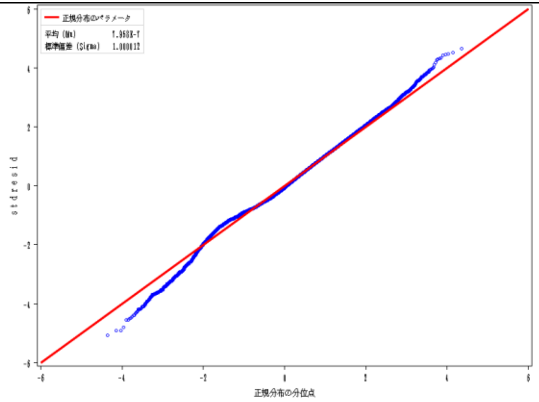


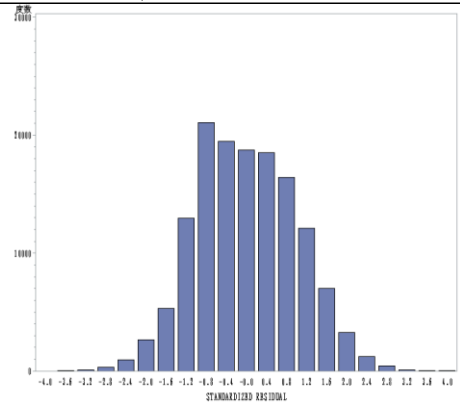
Fig. 5. Distribution of the standardized residual and QQ-plot of standardized residual.

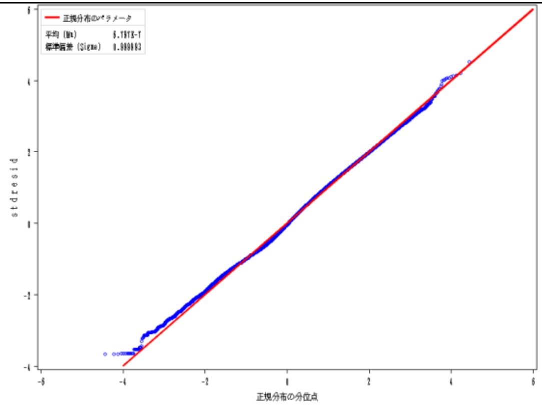
Area 1 10-25S, 20-75E



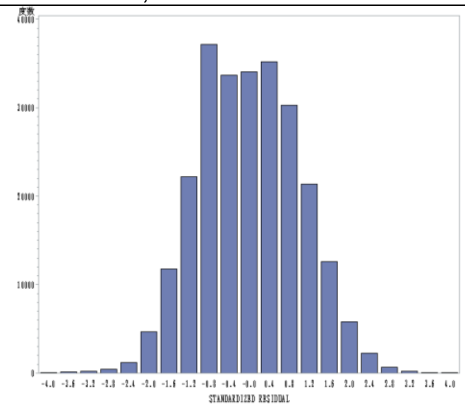


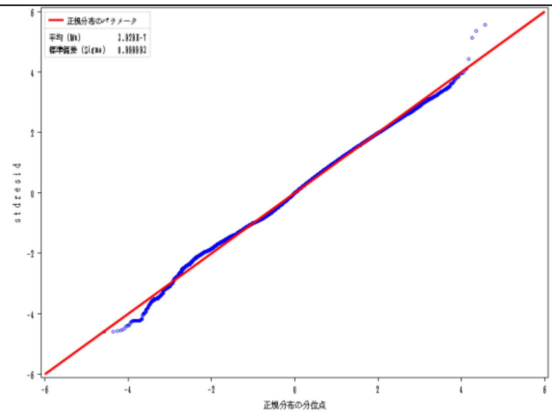
Area 2 10-25S, 75-140E



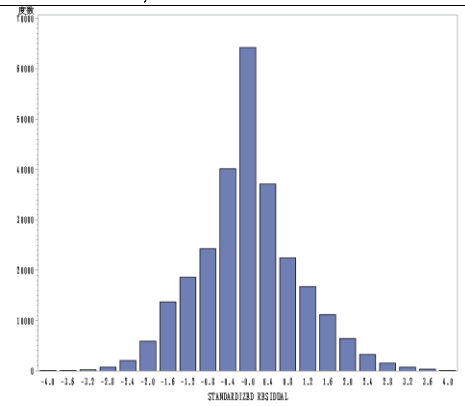


Area 3 25-40S, 20-75E





Area 4 25-40S, 75-140E



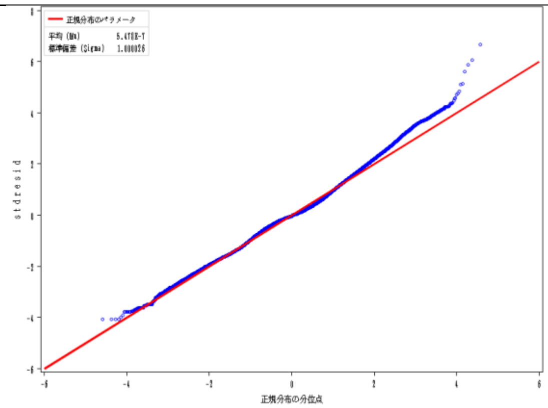
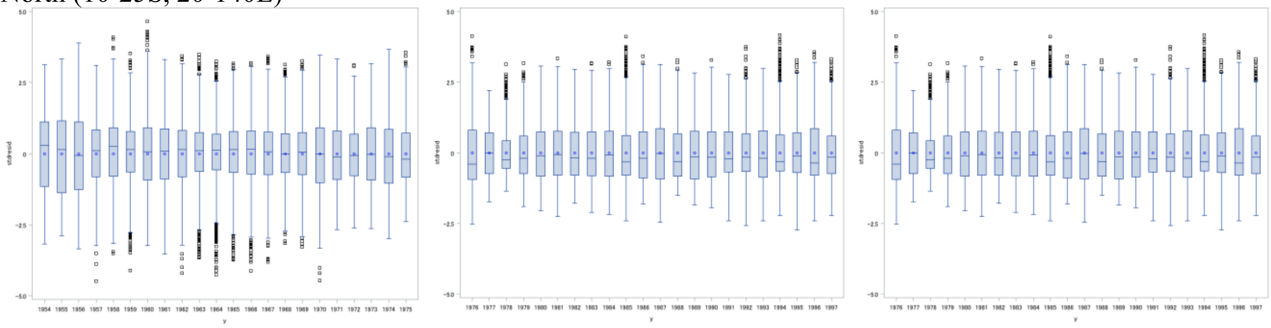
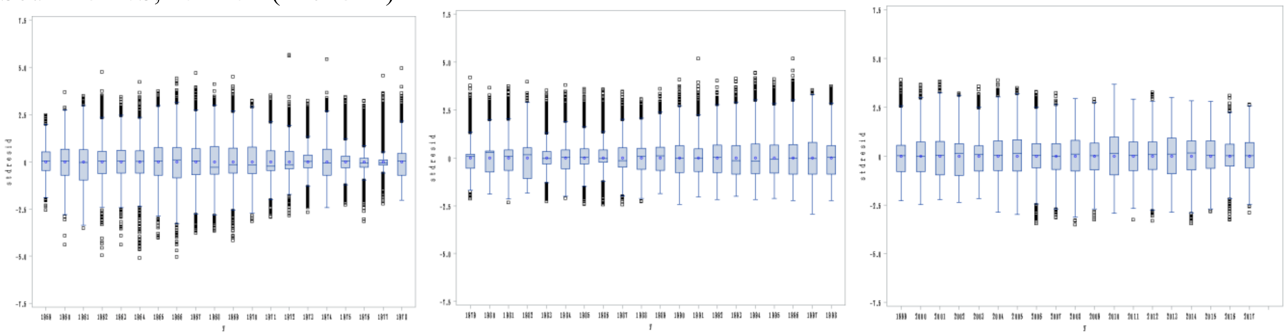


Fig. 5. Distribution of the standardized residual and QQ-plot of standardized residual. (continued)

North (10-25S, 20-140E)



South 25-40S, 20-140E (Area 3+4)



All 10-40S, 20-140E (Area 1-4)

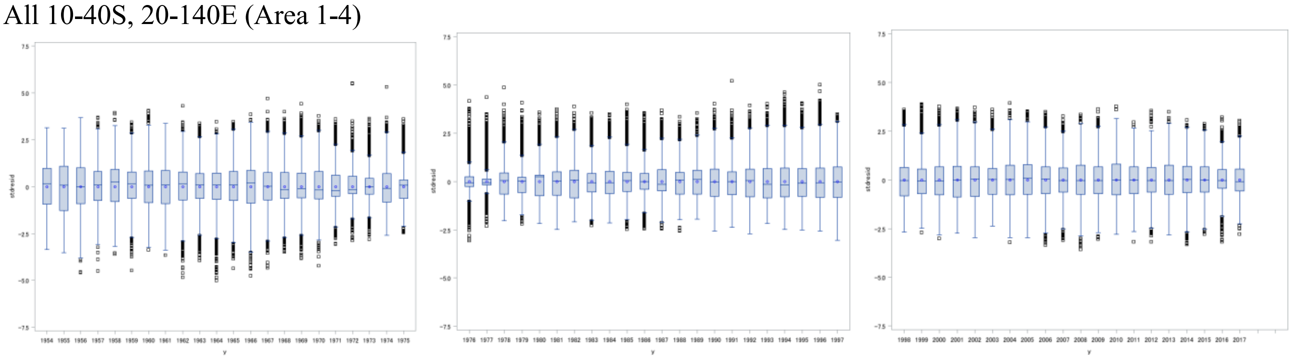


Fig. 6. Box plot of the standardized residual by year for the GLM analysis. Circle: mean, box: 25th and 75th percentile, horizontal line in the box: median, bars: maximum and minimum observation between 1.5 IQR (interquartile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers.

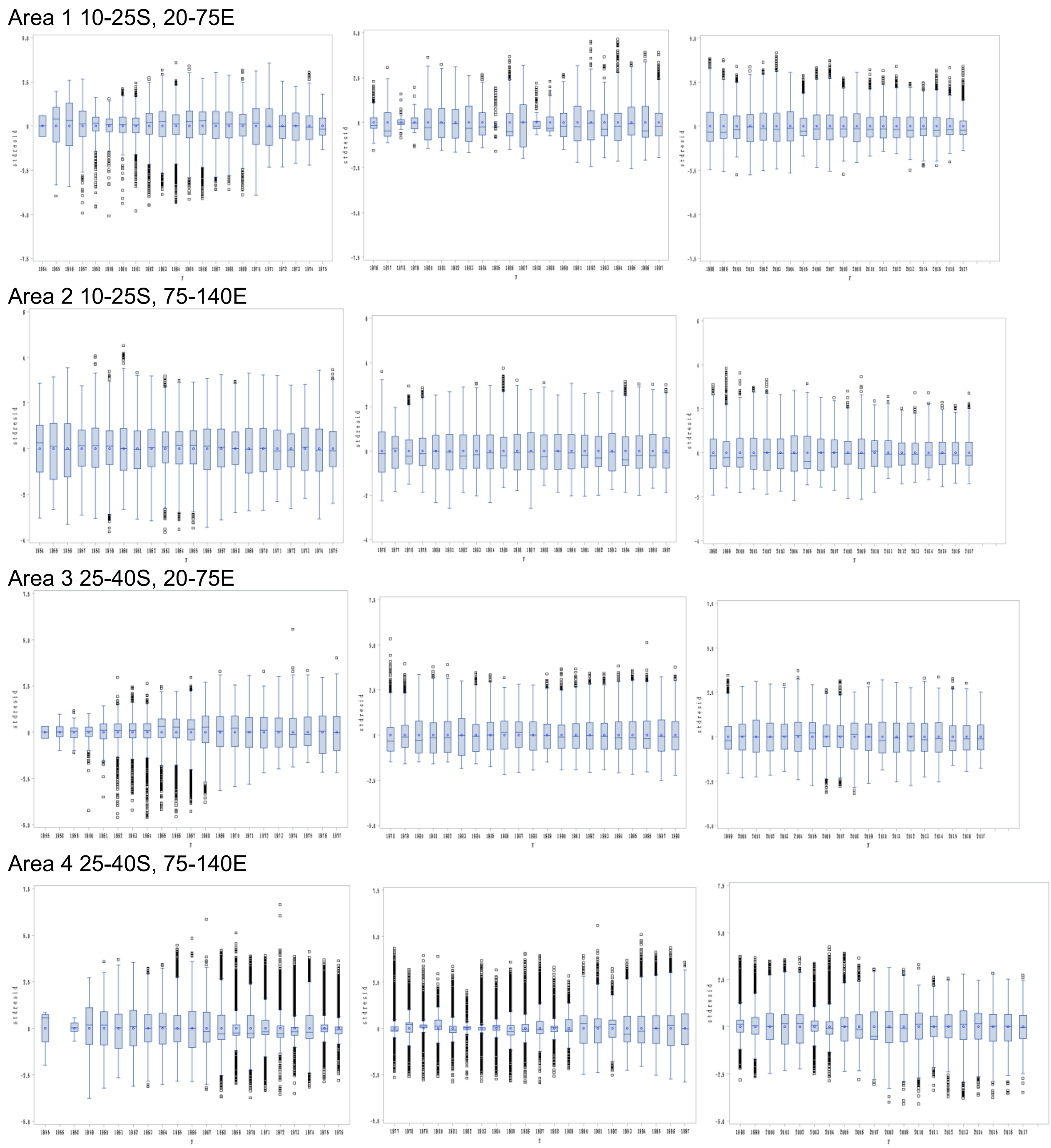


Fig. 6. Box plot of the standardized residual by year for the GLM analysis. Circle: mean, box: 25th and 75th percentile, horizontal line in the box: median, bars: maximum and minimum observation between 1.5 IQR (interquartile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers. (continued)

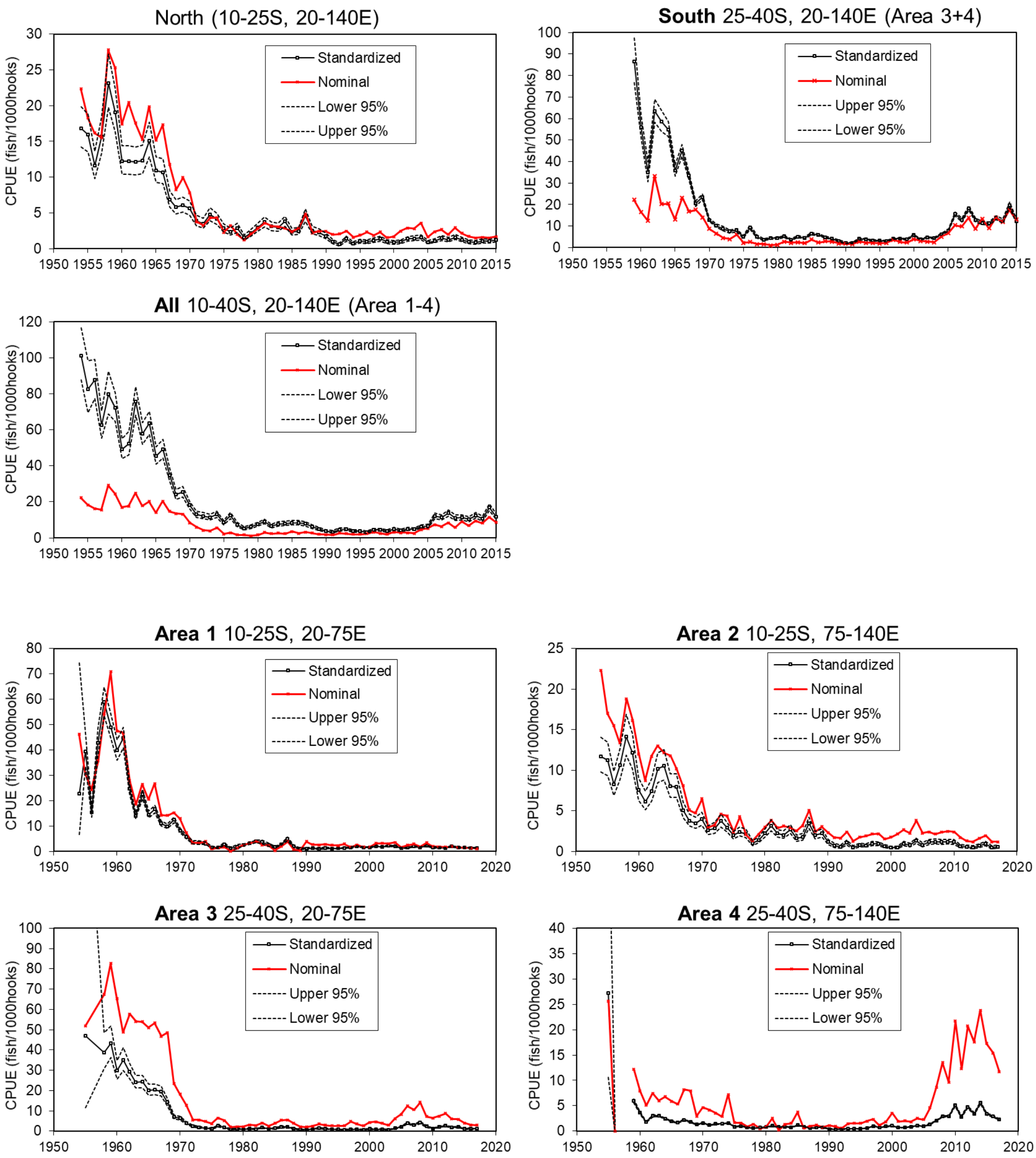


Fig. 7. Standardized CPUE (annual) for albacore in the Indian Ocean for each area with 95% confidence limits and nominal CPUE.

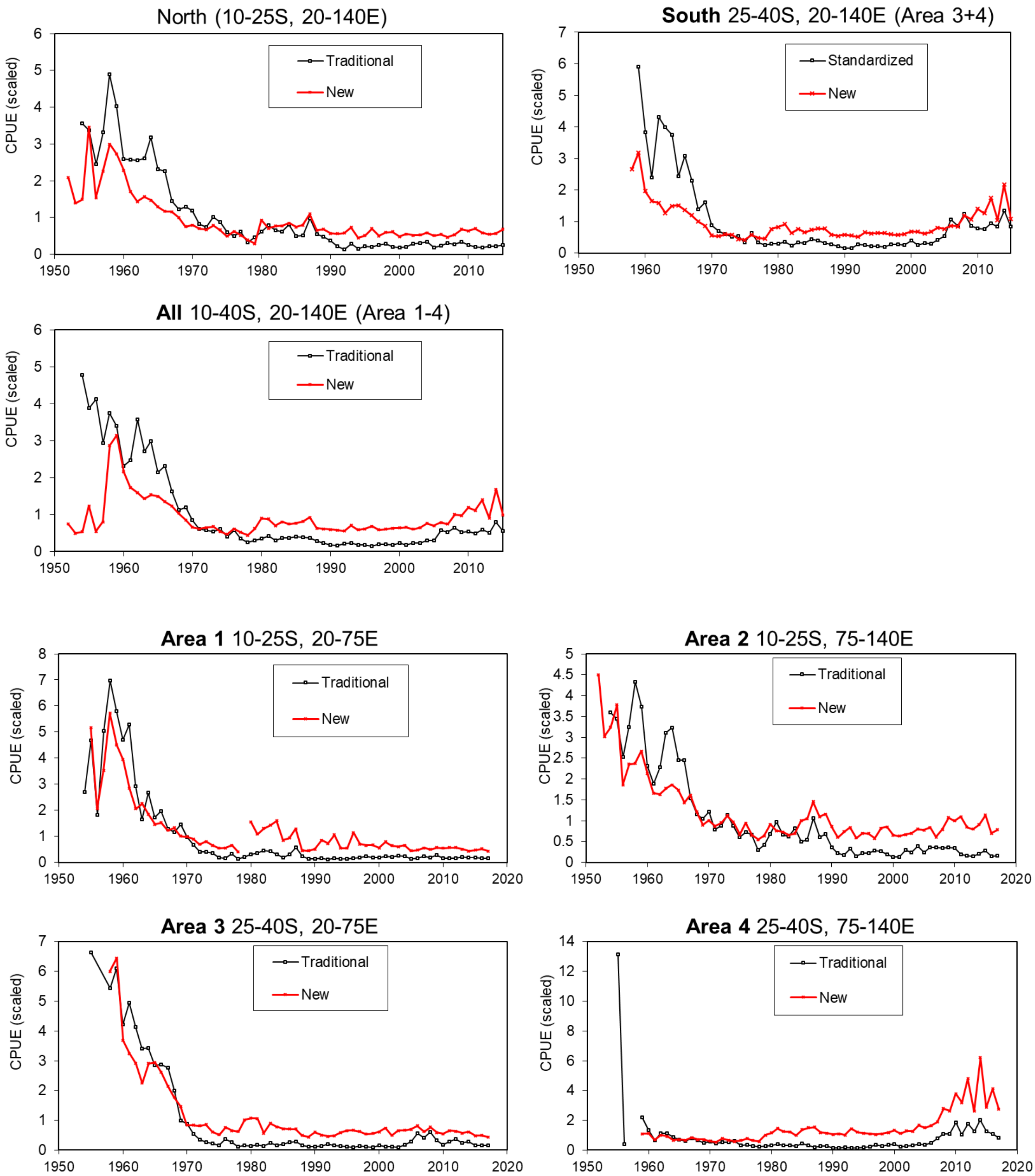


Fig. 8. Comparison of area aggregated and area specific CPUE series of albacore in this study with those by new method in the CPUE collaborative analysis (Matsumoto and Hoyle, 2019). "Traditional" and "new" show the indices by traditional (this study) and new method (with vessel ID) conducted in 2018, respectively.