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STANDARDIZATION OF BIGEYE TUNA CPUE IN THE MAIN FISHING GROUND OF ATLANTIC OCEAN BY THE JAPANESE LONGLINE FISHERY USING REVISED METHOD

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SUMMARY

Bigeye tuna CPUE for 1961-2016 by Japanese longline in the main fishing ground of Atlantic Ocean, standardized by GLM applying log-normal error assumption was created using revised methods from the previous studies. Only annual CPUEs in number were calculated to examine difference of CPUE based on the methods. As for environmental factor, sea surface temperature (SST) was applied. Standardized CPUE decreased after early 1990s and became the lowest in 2011, increased until 2013, and slightly decreased after that. Standardized CPUE based on the new method was similar to that by the previous method except for early period. Alternative area definition of main fishing ground was made based on the amount of catch and species composition. Standardized CPUE in the alternative area was similar to that in the original area except for a part of the period during 1970s.

RÉSUMÉ

La CPUE du thon obèse capturé par les palangriers japonais entre 1961 et 2016 dans la principale zone de pêche de l'océan Atlantique, standardisée au moyen du modèle GLM en appliquant un postulat d'erreur lognormal, a été mise au point à l'aide des méthodes révisées des études précédentes. Seules les CPUE annuelles en nombre ont été calculées pour examiner la différence de CPUE reposant sur les méthodes. La température à la surface de la mer (SST) a été appliquée comme facteur environnemental. La CPUE standardisée a diminué après le début des années 90 et a atteint le niveau le plus faible en 2011, avant d'augmenter jusqu'en 2013 et de légèrement diminuer par la suite. La CPUE standardisée fondée sur la nouvelle méthode était similaire à celle obtenue au moyen de la méthode précédente, sauf en ce qui concerne le début de la période. Une autre définition de la zone de pêche principale a été établie sur la base de la quantité de prises et de la composition des espèces. La CPUE standardisée dans la zone alternative était similaire à celle de la zone d'origine, sauf pour une partie de la période au cours des années 70.

RESUMEN

Se creó la CPUE de patudo para 1961-2016 de la pesquería de palangre japonesa en los principales caladeros del océano Atlántico, estandarizada mediante un GLM aplicando un supuesto de error lognormal, utilizando los métodos revisados a partir de estudios anteriores. Solo se calcularon las CPUE anuales en número para examinar la diferencia de la CPUE basada en los métodos. En cuanto al factor medioambiental, se aplicó la temperatura de la superficie del mar (SST). La CPUE estandarizada descendió después de comienzos de 1990 y llegó a su punto más bajo en 2011, incrementándose hasta 2013, y ha descendido ligeramente tras dicho año. Las CPUE estandarizadas basadas en el nuevo método fueron similares a las estimadas con el método anterior, excepto el periodo temprano. La definición de área alternativa de los principales caladeros se realizó basándose en la cantidad de captura y en la composición por especies. La CPUE estandarizada en el área alternativa fue similar a la del área original, con la excepción de una parte del periodo durante la década de los setenta.

KEY WORDS

Atlantic, Bigeye, Longline, Catch/effort

1 Introduction

Longline is the only tuna-fishing gear deployed by Japan at present in the Atlantic Ocean, and bigeye tuna is one of the target species (Matsumoto, 2015). Fishing effort for Japanese longline fishery covers almost entire Atlantic and bigeye tuna is mainly caught in the tropical area (Matsumoto 2015).

There are several past studies which provided standardized CPUE for bigeye tuna caught by Japanese longline fishery in the Atlantic Ocean. In Okamoto (2008), Japanese longline CPUE for bigeye was standardized for up to 2005. The model used in that analyses was the same as that used in the CPUE standardization for bigeye assessment in 2004 (Okamoto et al., 2004) except that the mixed layer depth (MLD) was removed from environmental factors used in 2004. Matsumoto and Satoh (2014) and Ashida et al. (2015) estimated the standardized CPUE using the method of Okamoto (2008). Satoh and Okamoto (2011) also reported standardized CPUE using similar method as that in the previous studies, but they didn't incorporate environmental factors due to availability of data.

At the ICCAT bigeye tuna data preparatory meeting in 2015, the group suggested or recommended several issues for standardization of Japanese longline CPUE, such as, to solve over-parametarization, better understanding of spatial structure of the catch and better incorporation of SST data (ICCAT 2015).

In this paper, standardization of bigeye CPUE by Japanese longline up to 2016 for in the main fishing area of Atlantic Ocean was conducted using methods some of which are revised from the previous analyses. To focus on the revision of methodology, standardization of only number based annual CPUE was conducted. It was also aimed to provide latest stock indicator of this species.

2 Materials and methods

2.1 Catch and effort data used

The Japanese longline catch in number and effort statistics from 1961 to 2016 were used to provide CPUE. Data for 2016 are preliminary. The catch and effort data set was aggregated by month, 5-degree square, the number of hooks between floats (NHF) and material of main and branch lines. The data sets in which the number of hooks was less than 5000 were not used for analyses. The NHF from 1961 to 1974 was not available in the aggregated data and so was regarded to be 5 for all years and areas.

2.2 Area definition

Area definition for the main fishing ground of bigeye in the central part of Atlantic Ocean (**Figure 1**) is the same as that in the previous studies. In the previous analyses, four sub-areas were defined and used to incorporate the effect of fishing ground. In this study, to incorporate the effect of fishing ground more in detail, five degree latitude and longitude blocks were used.

2.3 Environmental factors

As environmental factor, which is available for the analyzed period, SST (Sea Surface Temperature) was applied. The original SST data, whose resolution is 1-degree latitude and 1-degree longitude by month from 1946 to 2014, was downloaded from NEAR-GOOS Regional Real Time Data Base of Japan Meteorological Agency (JMA, http://near-goos1.jodc.go.jp/index_j.html).The SST data of from November 2014 onward were replaced by those for the same month in the nearest year (2013 or 2014) because these data were unreleased in the data base.

The original data was recompiled into 5-degree latitude and 5-latitude longitude by month from 1961 to 2016 using the procedures described in Okamoto et. al. (2001), and was used in the analyses. SST in integer value was used as a categorical value in the standardization model.

2.4 Gear effects

The number of hooks between floats (NHF) which was divided into 5 classes (NHFCL1: less than 6, NHFCL2: 6-8, NHFCL3: 9-12, NHFCL4: 13-16, NHFCL5: more than 16), and main and branch line materials were categorized into two, 1 = Nylon and 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 in 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 Model used for standardization

Several revisions were made for the standardization of CPUE from the previous method, that is, to reduce the number of parameters, incorporating SST as categorical variable, and incorporating five degree blocks instead of subareas. GLM (log-normal error structured model) was applied to standardize CPUE as with previous studies. Detail of initial models of GLM is as follows. GLM procedure of SAS software (SAS Enterprise guide Version 7.13) was used for this analysis. All interactions included in the models were described as “fixed effect”.

The following initial model was applied to standardize annual based CPUE.

- Initial Model for main fishing ground area definition-

Log (CPUE+const)= μ+YR+QT+LT5LN5+NHFCL+SST+ML+BL+YR*QT+ LT5LN5 *QT

Where Log : natural logarithm,
CPUE : catch in number of bigeye per 1000 hooks of bigeye per hooks
Const : 10% of overall mean of CPUE
μ : overall mean,
YR : effect of year,
QT : effect of fishing season (quarter)
LT5LN5: effect of five degree latitude and longitude blocks,
NHFCL : effect of gear type (category of the number of hooks between floats),
SST : effect of SST (as a categorical variable),
ML : effect of material of main line,
BL : effect of material of branch line,
YR*QT : interaction term between year and quarter,
LT5LN5 *QT: interaction term between five degree latitude and longitude blocks and quarter,
e(ijkl…..) : error term.

To compare the results, CPUE standardization in the main fishing ground based on the same method (updated CPUE) as that in the 2015 analysis (Ashida et al., 2015) was also conducted. The model used is as follows.

- Model for updated CPUE in the main fishing ground area definition-

Log (CPUE+const)=μ+YR+QT+Area+NHFCL+SST+SST^2+SST^3+ML+BL+
QT*SST+NHFCL*SST+ML*NHFCL+BL*NHFCL+YR*QT+Area*QT +Area*NHFCL+Area*SST

Where Log : natural logarithm,
CPUE : catch in number of bigeye per 1000 hooks or catch in weight of bigeye per hooks
Const : 10% of overall mean of CPUE
μ : overall mean,
YR : effect of year,
QT : effect of fishing season (quarter)
Area: effect of area,
NHFCL : effect of gear type (category of the number of hooks between floats),
SST : effect of SST (as a continuous variable),
SST^2 : effect of SST^2 (=SST x SST, as a continuous variable),
SST^3 : effect of SST^3 (=SST x SST x SST, as a continuous variable),
ML : effect of material of main line,
BL : effect of material of branch line,
QT*SST : interaction term between fishing season and SST,
NHFCL*SST interaction term between gear type and SST,
ML*NHFCL: interaction term between material of main line and gear type,
BL*NHFCL: interaction term between material of branch line and gear type,
YR*QT : interaction term between year and quarter,
Area*NHFCL : interaction term between area and gear type,
Area*SST : interaction term between area and SST,
e(ijkl…..) : error term.

Based on the result of ANOVA (type III SS), non-significant effects were removed in step-wise from the initial model based on the F-value ($p<0.05$). In the cases in which the factor is not significant as main factor but is significant as interaction with another factor, the main factor was kept in the model.

3 Results and discussion

Of the main effects and interactions in the initial model, the effect of material of branch line (BL) was not significant and so was removed. Therefore, final model is as follows.

Log (CPUE+const)= μ+YR+QT+LT5LN5+NHFCL+SST+ML+YR*QT+ LT5LN5 *QT

Standardized annual CPUE in number for main fishing ground are shown in **Figure 2**. Results of ANOVA and distributions of the standard residual in each analysis are shown in **Table 1** and **Figure 3**, respectively. Trend of standardized CPUE was mostly similar to that based on the model for 2015 analysis with comparatively large difference during 1960s. Standardized CPUE decreased after early 1990s and became the lowest in 2011, increased until 2013, and slightly decreased after that.

Figure 4 shows geographical distribution of standardized CPUE for each five degree block. Substantial difference of CPUE was observed by area even in the same subarea used for the previous analyses. CPUE was lower in the north area (north of 25°N) and in the inner part of Gulf of Guinea. In the northern area, catch was not abundant except in the 1970s, and in the inner part of Gulf of Guinea catch was not abundant and/or main component of the catch was yellowfin tuna (**Appendix Figure 1**). Therefore, these two regions may not be appropriate to include in the main fishing ground for bigeye tuna. So, alternative area for main fishing ground was defined by removing these regions (**Figure 5**).

Figure 6 shows trend of CPUE for the alternative area overlaid with CPUE in the original area and CPUE based on the model for 2015. Overall trend was similar to that in the original area, but large difference is observed in the 1970s. The decrease after 1990s is only slightly slower than the CPUE in the original area.

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Table 1. Results of ANOVA table of year based CPUE in number and weight for main fishing area definition in the Atlantic Ocean.

Main fishing		**Number**				
Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square
Model	446	8808.37	19.75	75.24	<.0001	0.4674
yr	55	2159.43	39.26	149.57	<.0001	
qt	3	13.57	4.52	17.23	<.0001	
LT5LN5	51	1280.93	25.12	95.68	<.0001	
nhfcl	4	108.72	27.18	103.54	<.0001	
sst	14	101.20	7.23	27.54	<.0001	
ML	1	4.34	4.34	16.53	<.0001	
yr*qt	165	461.74	2.80	10.66	<.0001	
qt*LT5LN5	153	794.65	5.19	19.79	<.0001	

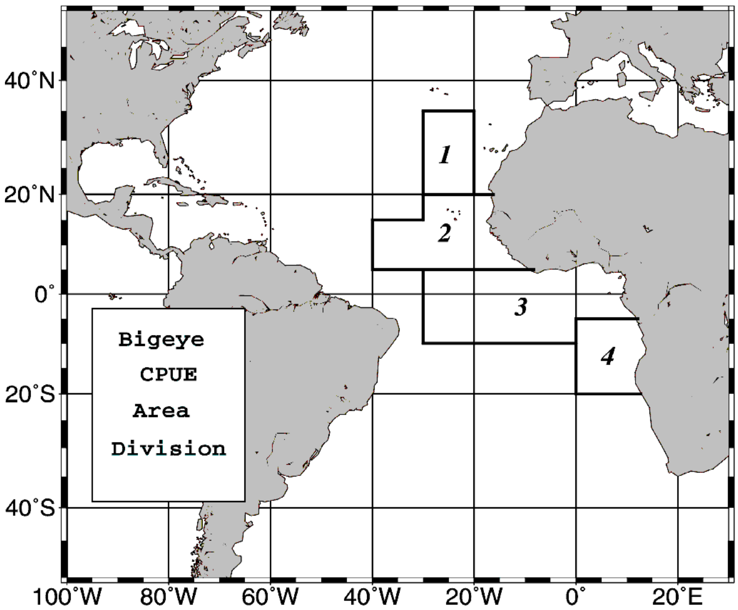


Figure 1. Area definitions (main fishing ground) used in this study.

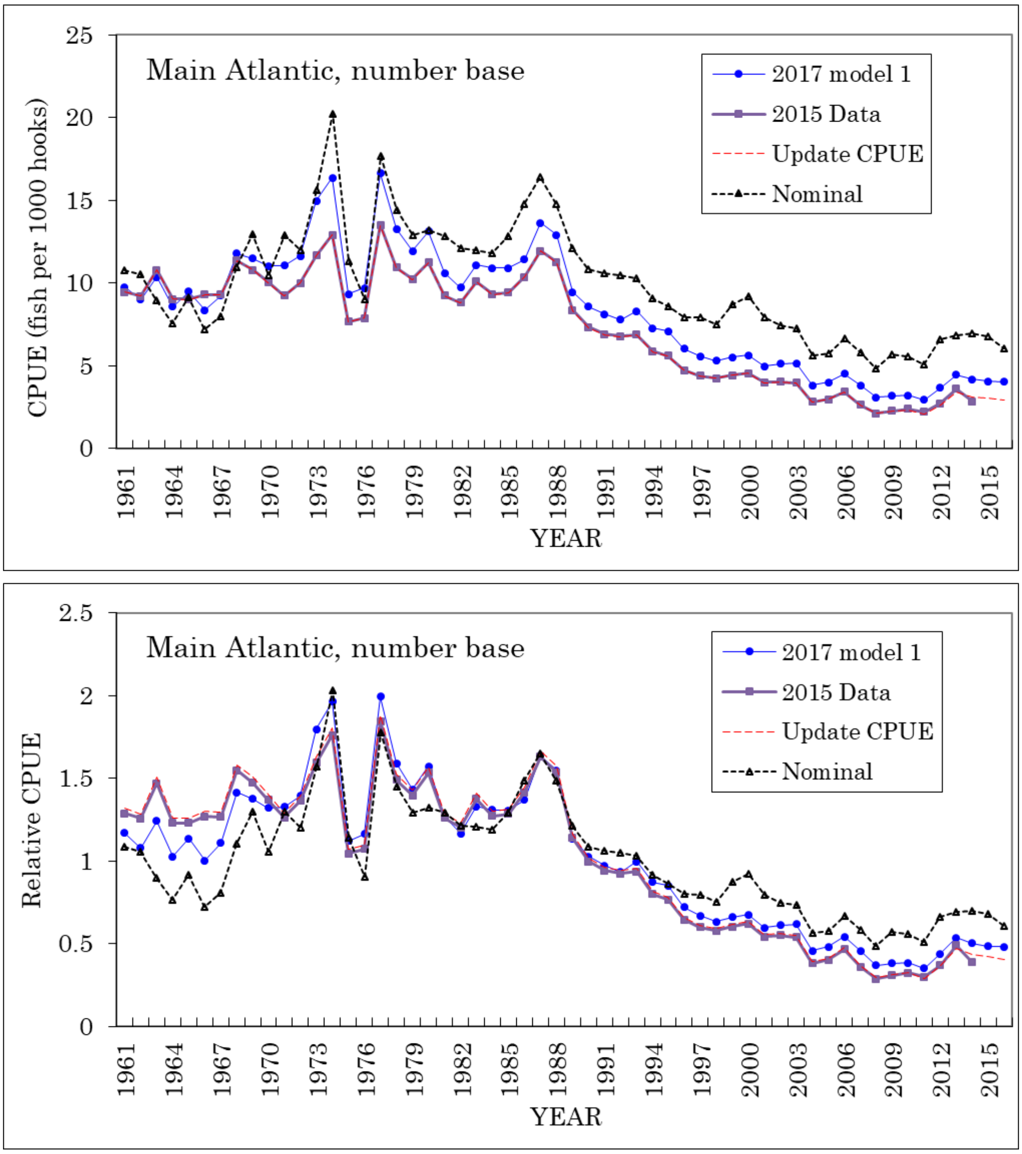


Figure 2. Standardized CPUE (Std CPUE) for main fishing ground area definition in number (top: real scale, bottom: relative scale) overlaid with nominal CPUE. “2015 Data”, “2017 model 1” and “Update CPUE” indicate CPUE in 2015, CPUE based on new model and CPUE based on the model for 2015, respectively.

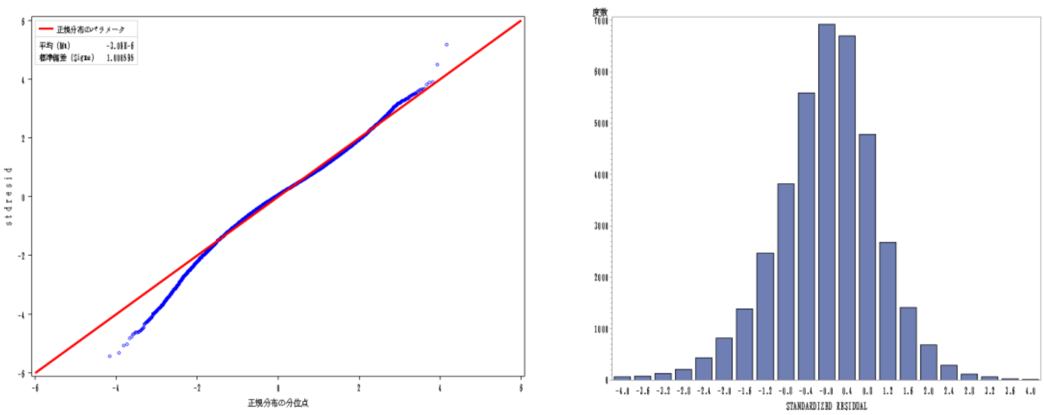


Figure 3. Overall histogram and QQ-plot of standard residuals from the GLM analyses for bigeye CPUE for main fishing ground definition.

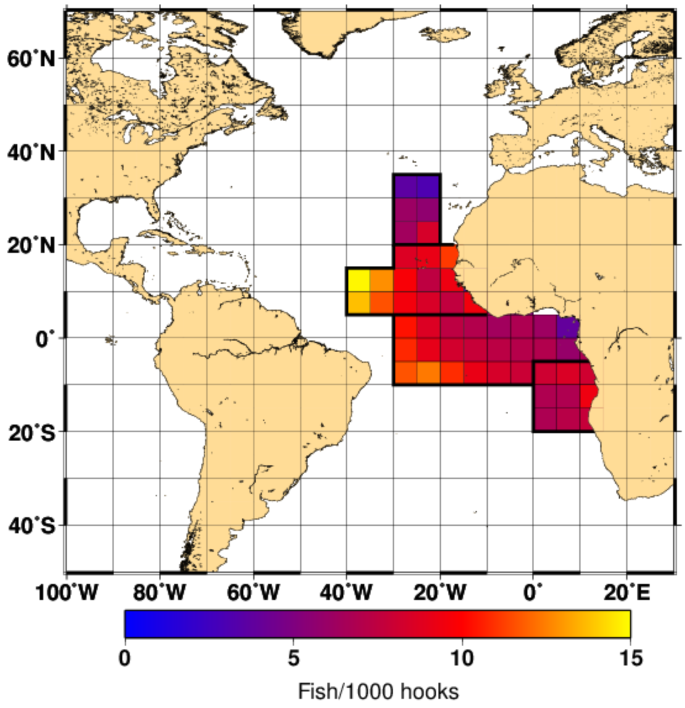


Figure 4. Distribution of standardized CPUE (based on the new model) in each five degree block.

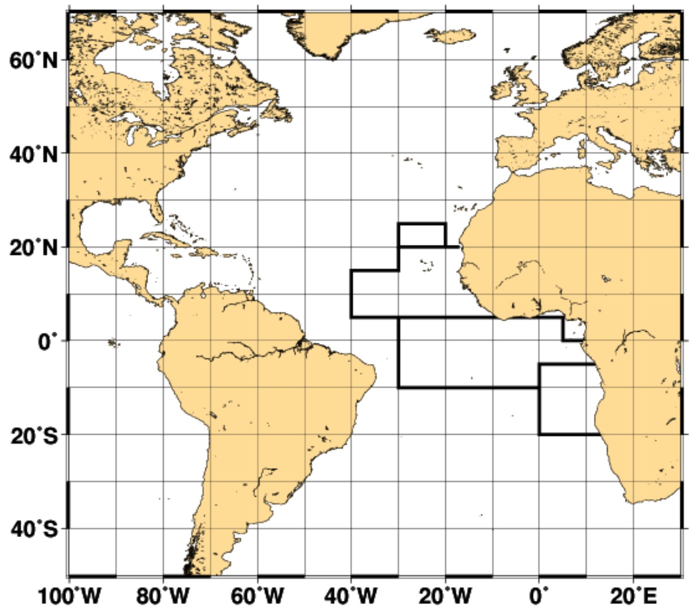


Figure 5. Alternative area definitions for main fishing ground.

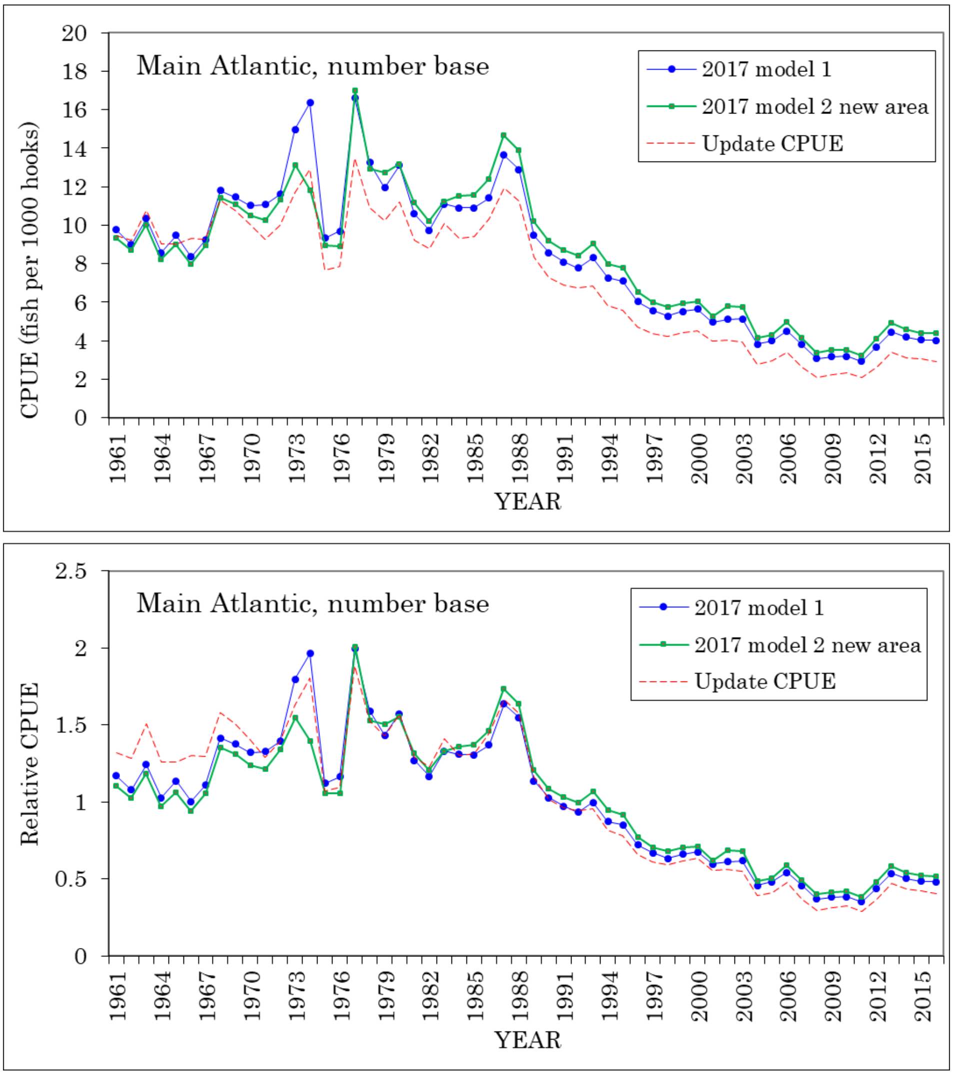
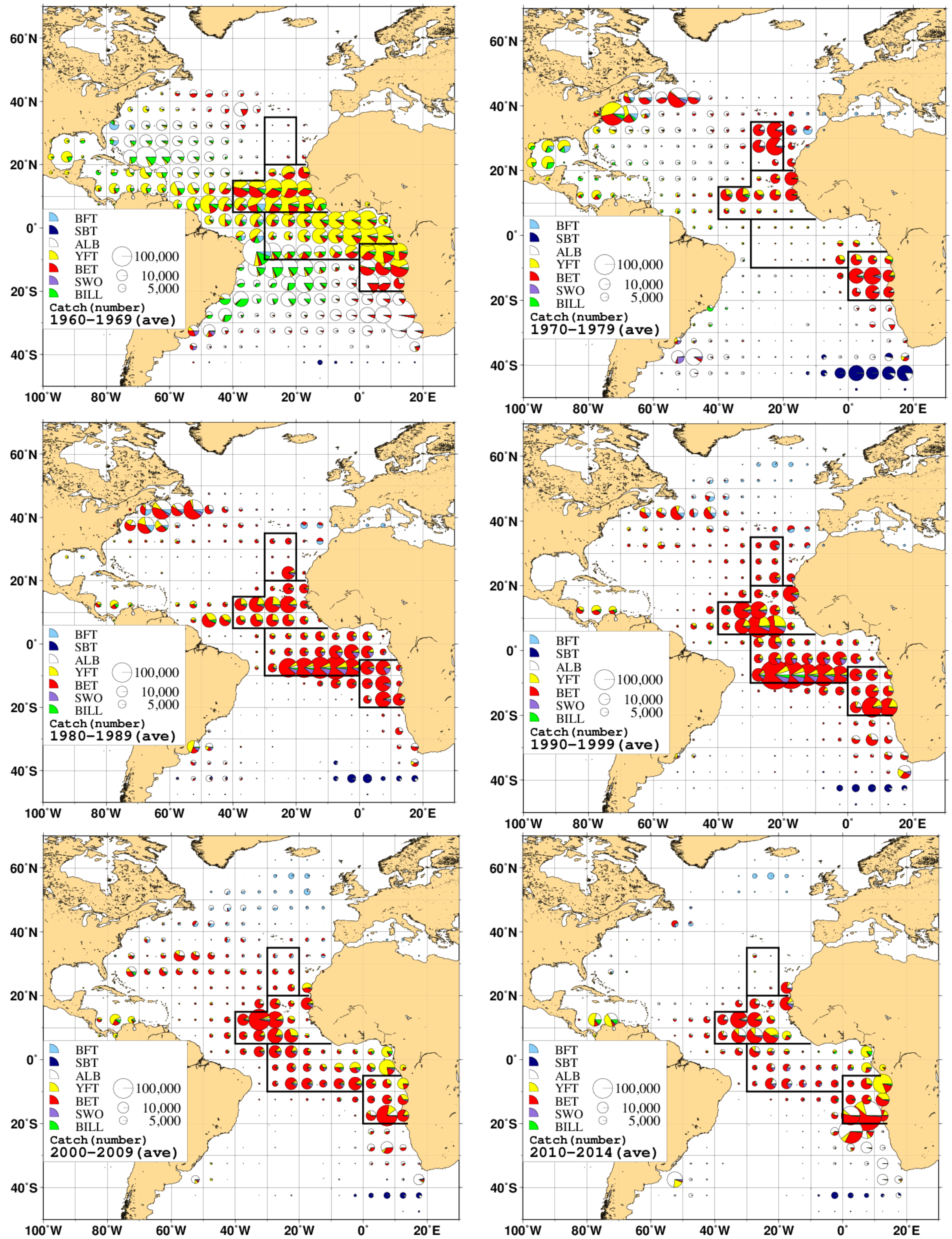


Figure 6. Standardized CPUE (Std CPUE) for alternative main fishing ground area definition in number (top real scale, bottom relative scale) overlaid with CPUE in the original area and CPUE based on the model for 2015.



Appendix Figure 1. 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. bluefin tuna (BFT), southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (BILL). Black lines show area for CPUE standardization with subareas used for previous studies and updated CPUE.