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STANDARDIZATION OF CPUE FOR SOUTH ATLANTIC ALBACORE BY THE JAPANESE LONGLINE FISHERY USING REVISED METHOD

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SUMMARY

*Standardization of CPUE for south Atlantic albacore (*Thunnus alalunga*) caught by Japanese longline fishery was conducted using negative binominal model, based on revised methods from the previous studies. CPUE series were separated into two periods (before and after 1993) due to availability of logbook database. Core area (main fishing ground for albacore) was selected and used. Effects of quarter, five degree latitude and longitude blocks, fishing gear (number of hooks between floats), branch and main line materials, bait, and one interaction were incorporated, although effect of bait can be used only before 1993. The effect of five degree latitude and longitude blocks was greatest or second greatest. Standardized CPUE sharply declined during the 1960s, slightly decreased or was comparatively constant after that. CPUE sharply increased in recent years. It seems that the trend of CPUE is affected by albacore targeting.*

RÉSUMÉ

La standardisation de la CPUE du germon de l'Atlantique Sud (Thunnus alalunga) *capturé par la flottille palangrière japonaise a été réalisée au moyen d'un modèle négatif binomial, reposant sur des révisions de méthodes provenant d'études antérieures. Les séries de CPUE ont été séparées en deux périodes (avant et après 1993) compte tenu de la disponibilité de la base de données des carnets de pêche. La zone principale (principale zone de pêche de germon) a été sélectionnée et utilisée. Les effets du trimestre, des carrés de cinq degrés de longitude et de latitude, de l'engin de pêche (nombre d'hameçons entre flotteurs), du matériel de la ligne principale et de l'avançon, de l'appât et une interaction ont été incorporés, même si l'effet de l'appât ne peut être utilisé qu'avant 1993 uniquement. L'effet des carrés de cinq degrés de longitude et de latitude était le plus important, ou le deuxième plus important. La CPUE standardisée a drastiquement baissé pendant les années 60 et a légèrement diminué, ou était relativement constante, après cette décennie. La CPUE a fortement augmenté ces dernières années. Il semble que la tendance de la CPUE est affectée par le ciblage du germon.*

RESUMEN

*La estandarización de la CPUE para el atún blanco del Atlántico sur (*Thunnus alalunga*) capturado por la flota palangrera japonesa se realizó utilizando un modelo binomial negativo, basado en métodos de estudios previos revisados. Las series de CPUE se desglosaron en dos periodos (antes y después de 1993) debido a la disponibilidad de bases de datos de cuadernos de pesca. Se seleccionó y utilizó la zona principal (principal caladero de atún blanco). Se incorporaron los efectos de trimestre, cuadrículas de 5º de latitud y longitud, arte de pesca (número de anzuelos entre flotadores), materiales de la línea principal y brazolada, cebo y una interacción, aunque el efecto de cebo puede utilizarse solo antes de 1993. El efecto de las cuadrículas de 5º de latitud y longitud fue el más importante o el segundo en importancia. La CPUE estandarizada experimentó un marcado descenso en los años sesenta, y descendió ligeramente o fue comparativamente constante tras dicha década. En años recientes la CPUE se ha incrementado en gran medida. Parece ser que la tendencia de la CPUE se ve afectada por la estrategia de pesca en función de la especie objetivo.*

KEYWORDS

Catch/effort, longlining, abundance index, standardization, albacore

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1. Introduction

For south Atlantic 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 (Uozumi, 1996a). Uosaki (1997) carried out standardization assuming error structure with Poisson as an attempt to overcome a problem of zero CPUE (or zero catch) treatment.

While Poisson model has merit as no need of concerning zero catch, standardized CPUE estimated using Poisson model may have bias due to an over-dispersion. Poisson model assumes that the mean and variance are equal (mean=variance=λ), but in real data it is often difficult to have such assumption, so an over-dispersion parameter ϕ is used (mean=λ, variance=$\phi\lambda$) to fit to model for CPUE standardization. In this case estimate is impossible to obtain using common likelihood approach, instead this, parameters can estimate using Quasi-likelihood. This may lead estimate having bias. To avoid this problem, it can be suggested to assume negative binomial of error structure instead of Poisson, which assumes that mean and variance have different values.

In the previous studies to supply abundance indices of Japanese longline fishery for stock assessment models for south Atlantic, the indices were calculated separately for the three periods (1959-69, 1969-75, 1975 and after) according to the review by Uozumi (1996b), which classified three periods of "Target", "Transition" and "Bycatch" according to the history of the Japanese longline fishery on the Atlantic Ocean based on their fishery strategy (Uozumi, 1996a).

Uosaki and Shono (2008) and Matsumoto and Uosaki (2012) calculated standardized CPUEs as abundance index for three periods in the north and/or south stocks in the Atlantic Ocean using two different models, namely log-normal and negative binomial, and discussed which model was more appropriate. During ICCAT albacore stock assessment session in 2007, the Group decided to use the standardized CPUEs for the NB model for three periods for the north and south stocks as indices of abundance (ICCAT, 2008). According to this decision, Matsumoto (2014; 2016b) reported standardized CPUE for south stock based on negative binomial model using the method same as in Uosaki and Shono (2008) and Matsumoto and Uosaki (2012).

Previous studies used data for almost entire area, and subareas for the effect of fishing ground. Recently, ‘core area’ (main fishing ground) is often used for CPUE standardization. Also, instead of subareas, small blocks (e.g. 5 degree latitude and longitude blocks) are often used.

At 2016 ICCAT SCRS meeting, it was recommended to produce new, or improve existing CPUE indices in the south Atlantic, in which Japanese longline is required to consider alternative ways to incorporate targeting effects (e.g. based on species composition) to try to recover the early periods (ICCAT 2016).

In this study, some improvements have been made from the previous studies for standardization of annual CPUE for south Atlantic albacore by Japanese longline fishery.

2. Data and method

2.1. Data

The data used in this study were obtained from the Japanese longline fishery statistics based on the logbooks and compiled at the National Research Institute of Far Seas Fisheries. Operational (set by set) level logbook data were used which include gear configuration, i.e., number of hooks per basket (between floats) and branch and main line material (only from 1994) and bait (1966-1993). CPUE was defined as the number of catch of albacore per 1,000 hooks.

2.2. Standardization

Core area (main albacore fishing ground for Japanese longline) was used (**Figure 1**), which was selected based on the amount of fishing effort and the proportion of albacore in the catch, unlike previous studies in which almost entire area was used (**Figure 2**).

Standardized CPUE was estimated for two periods separately (1966-93 and 1994-2015) according to availability of information in the logbook data including bait. For comparison of the results and for creating longer series CPUE, the model without the effect of bait was also examined before 1993 (for entire period in which logbook data in the core area is available). In order to standardize CPUE of albacore, generalized linear model with negative binomial error structure (NB model) were used as with previous studies.

Year, season, fishing area, number of hooks per basket and bait were incorporated as main effects for early period (before 1993), and branch and main line material was added and bait was eliminated for late period (from 1994). Quarter was used for fishing season. Five degree latitude and longitude blocks were used for the effect of fishing area. The number of hooks per basket was categorized into four levels (3-7, 8-11, 12-15 and 16-20 hooks per basket). Before 1975, the information on the number of hooks per basket is not fully available, and it was regarded as category 1 (3-7 hooks per basket) if information is not available.

Calculations of modeling for those GLM was done using SAS software package (SAS Enterprise guide Version 6.1). Followings are GLM models considered in this study;

Stock	Error structure	Period	Model
South	NB model	Early (1966-93)	$E[C]= H\cdot\exp(\mu+Y+Q+LT5LN5+G+bait+\varepsilon)$
		Early (1961-93)	$E[C]= H\cdot\exp(\mu+Y+Q+LT5LN5+G+\varepsilon)$
		Late (1994-2015)	$E[C]= H\cdot\exp(\mu+Y+Q+LT5LN5+G+ml+bl+Y*Q+\varepsilon)$

where
E(C): expectation of catch in number, which follows negative binominal distribution.
μ: intercept Y: effect of year
Q: effect of quarter LT5LN5: effect of five degree latitude and longitude blocks
G: effect of gear (number of hooks per basket) bait: effect of bait
ml: effect of material of main line bl: effect of material of branch line
H: number of hooks used (thousand) ε: error term.

Interaction terms were indicated as two symbols of effect and asterisk (e.g. Y*Q for year and quarter). Interactions were incorporated as fixed effect.

3. Results

The goodness of fit for the NB model is shown in **Table 1**. Scaled Pearson chi-square shows the model was highly significant. However, the effect of branch line during 1994-2015 was less significant. The effect of five degree latitude and longitude blocks was largest or second largest. The effect of quarter was also comparatively high.

Estimated standardized CPUE is shown in **Table 2** and **Figure 3**. Standardized CPUE showed sharp declining trend during the 1960s and slight declining trend during the early 1970s (**Figure 3a**). It was comparatively constant with fluctuation after that. It sharply increased after late 2000s (**Figure 3b**). During late period (after 1994), the trend of CPUE is similar to that of nominal CPUE (**Figure 3d**). The trend is also similar to that for the CPUE provided last year with some small scale differences.

Figure 4 shows trends of CPUE standardized for each effect: quarter, bait, main and branch line materials, and gear (number of hooks between floats) in the south Atlantic core area. CPUE in the third quarter was highest during 1966-1993, and was highest in the second quarter during 1994-2015. Saury bait got highest CPUE. Nylon line got higher CPUE than other material both for branch and main lines. Regarding fishing gear, category 1 (3-7 hooks between floats) and category 2 (8-11 hooks between floats) got highest CPUE during 1966-1993 and during 1994-2015, respectively.

Figure 5 shows the number and proportion of zero catch observation in catch-and-effort data used for CPUE standardization in the same area as that for CPUE standardization. High proportion (more or less 60%) of zero catch observation is seen during the late 1970s to late 2000s. Zero catch rate was lower when CPUE was higher. NB model in this study, which uses catch as response variable, has advantage in terms of zero catch problem due to no need to add small constant to CPUE when CPUE is zero. Also, in this study, we calculated number based CPUE, which follows discrete distribution. In that case, NB model, which assumes discrete distribution, is more appropriate. Taking these facts into account, CPUEs based on NB model, which was recommended by ICCAT albacore working group, are considered to be more appropriate for CPUEs of south Atlantic albacore by Japanese longline. **Figure 7 and Figure 8** show QQ-plots and yearly residuals for the model, respectively.

Figure 8 shows change in the proportion of number of hooks between floats and main and branch line materials. The proportion of deep longline (12-15 and 16-20 hooks between floats) is increasing, and the proportion of nylon material is increasing both for the main and branch lines.

4. Discussion

Although some improvements, such as selecting core area and incorporating additional effects, were made from past analyses, there is no major changes for the trend of CPUE including sharp decline during the early period. There seems to be decreased targeting and increased targeting of albacore in the early period and recent years, respectively (Matsumoto, 2016a). Probably it is almost impossible to fully incorporate targeting issue in CPUE standardization. Therefore, it is better to specify the period and/or area in which CPUE appears to reflect abundance of the stock. To do so, it is necessary to review in detail about the fishery including interview to the fishermen. It will be done in the future.

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Table 1. Goodness of fit for the NB model for each period in the south Atlantic core area.

South Atlantic core area from 1966 to 1993 with bait

Source	DF	Chi-Square	Pr>Chi
y	27	4477.3	<.0001
q	3	4185.4	<.0001
LT5LN5	19	12969.7	<.0001
G	3	341.6	<.0001
bait	2	912.4	<.0001

South Atlantic core area from 1961 to 1993 without bait

Source	DF	Chi-Square	Pr>Chi
y	32	15090.4	<.0001
q	3	5922.4	<.0001
LT5LN5	20	14265.4	<.0001
G	3	477.1	<.0001

South Atlantic core area from 1994 to 2015 without bait

Source	DF	Chi-Square	Pr>Chi
y	21	4888.4	<.0001
q	3	2155.1	<.0001
LT5LN5	19	13650.9	<.0001
G	3	377.5	<.0001
ml	1	32.8	<.0001
bl	1	5.5	0.0193
y*q	63	5746.6	<.0001

Table 2. Standardized CPUE and CV (standard error) for the NB model for the south stock (core area).

	With bait				Without bait			
Year	Std CPUE	CV	Upper CL	Lower CL	Std CPUE	CV	Upper CL	Lower CL
1961					88.006	0.178	62.041	124.836
1962					68.683	0.087	57.928	81.443
1963					76.792	0.076	66.109	89.193
1964					63.149	0.053	56.934	70.042
1965					33.425	0.044	30.643	36.456
1966	15.136	0.063	13.863	16.525	23.843	0.043	21.931	25.925
1967	15.344	0.059	13.762	17.105	25.938	0.052	23.434	28.712
1968	16.740	0.077	15.174	18.467	26.515	0.047	24.162	29.093
1969	6.087	0.052	5.408	6.850	8.674	0.058	7.747	9.712
1970	7.154	0.048	6.278	8.153	9.204	0.065	8.108	10.447
1971	9.920	0.047	9.016	10.915	12.769	0.049	11.608	14.044
1972	5.031	0.042	4.446	5.693	5.283	0.061	4.684	5.959
1973	3.575	0.040	3.215	3.974	4.193	0.053	3.780	4.652
1974	4.123	0.043	3.678	4.620	4.974	0.057	4.450	5.558
1975	5.520	0.047	4.981	6.117	5.843	0.052	5.279	6.468
1976	3.958	0.051	3.296	4.753	3.332	0.088	2.802	3.963
1977	2.194	0.051	1.861	2.586	2.048	0.079	1.753	2.392
1978	3.502	0.056	3.015	4.067	2.836	0.072	2.463	3.267
1979	4.737	0.071	4.187	5.359	3.027	0.061	2.686	3.411
1980	2.265	0.062	2.032	2.524	1.701	0.054	1.529	1.893
1981	8.404	0.076	7.559	9.343	4.581	0.052	4.141	5.068
1982	9.694	0.083	8.802	10.677	5.060	0.047	4.614	5.548
1983	3.352	0.145	2.887	3.892	1.868	0.071	1.624	2.149
1984	4.527	0.085	4.045	5.065	2.606	0.055	2.339	2.904
1985	10.167	0.081	8.993	11.494	5.381	0.059	4.789	6.045
1986	6.485	0.131	5.780	7.276	3.374	0.055	3.030	3.757
1987	2.291	0.313	1.971	2.663	1.343	0.072	1.165	1.548
1988	2.124	0.197	1.918	2.353	1.181	0.050	1.071	1.303
1989	3.056	0.066	2.780	3.360	1.766	0.046	1.613	1.934
1990	1.709	0.098	1.559	1.874	1.151	0.047	1.049	1.263
1991	1.661	0.152	1.529	1.804	1.141	0.042	1.050	1.240
1992	1.832	0.085	1.695	1.980	1.191	0.041	1.099	1.291
1993	2.945	0.065	2.708	3.202	1.597	0.041	1.474	1.730
1994					1.041	0.047	0.949	1.142
1995					0.673	0.051	0.609	0.744
1996					1.013	0.051	0.917	1.118
1997					1.418	0.056	1.272	1.581
1998					1.910	0.071	1.662	2.196
1999					1.793	0.062	1.587	2.026
2000					2.992	0.076	2.577	3.473
2001					3.035	0.083	2.580	3.571
2002					1.477	0.145	1.112	1.962
2003					0.608	0.085	0.514	0.719
2004					1.919	0.081	1.637	2.250
2005					1.741	0.131	1.348	2.249
2006					1.566	0.313	0.848	2.893
2007					1.121	0.197	0.763	1.648
2008					6.225	0.066	5.471	7.082
2009					3.824	0.098	3.159	4.630
2010					2.532	0.152	1.880	3.409
2011					6.168	0.085	5.218	7.292
2012					10.519	0.065	9.263	11.946
2013					8.064	0.071	7.020	9.263
2014					7.794	0.082	6.631	9.160
2015					9.327	0.062	8.261	10.530

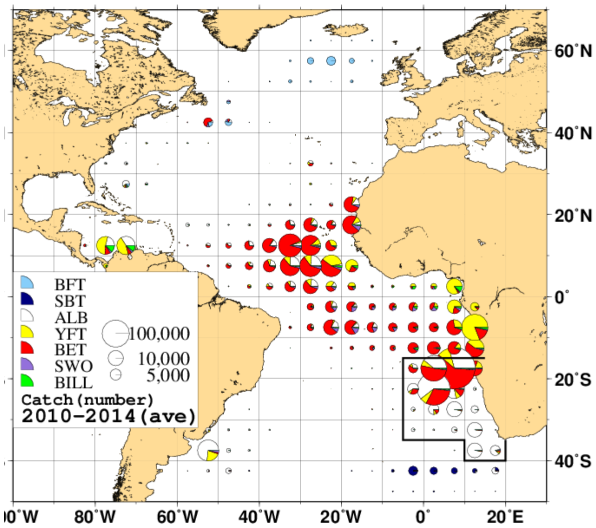


Figure 1. Area stratification for CPUE standardization in the present study with average distribution of species composition for 2010-2014.

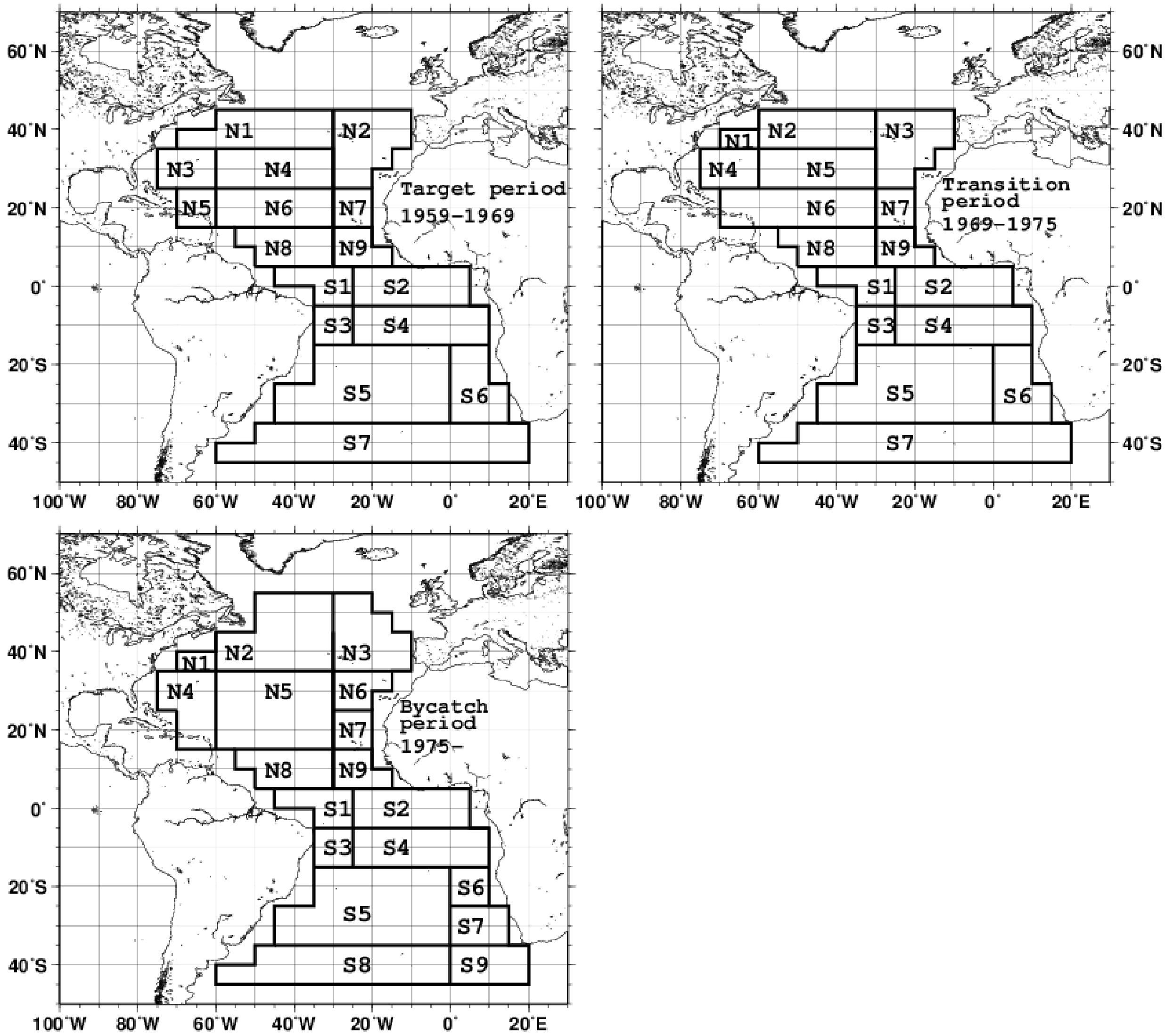


Figure 2. Area stratification for CPUE standardization in the previous studies. S1-S9: subareas for southern stock.

a

b

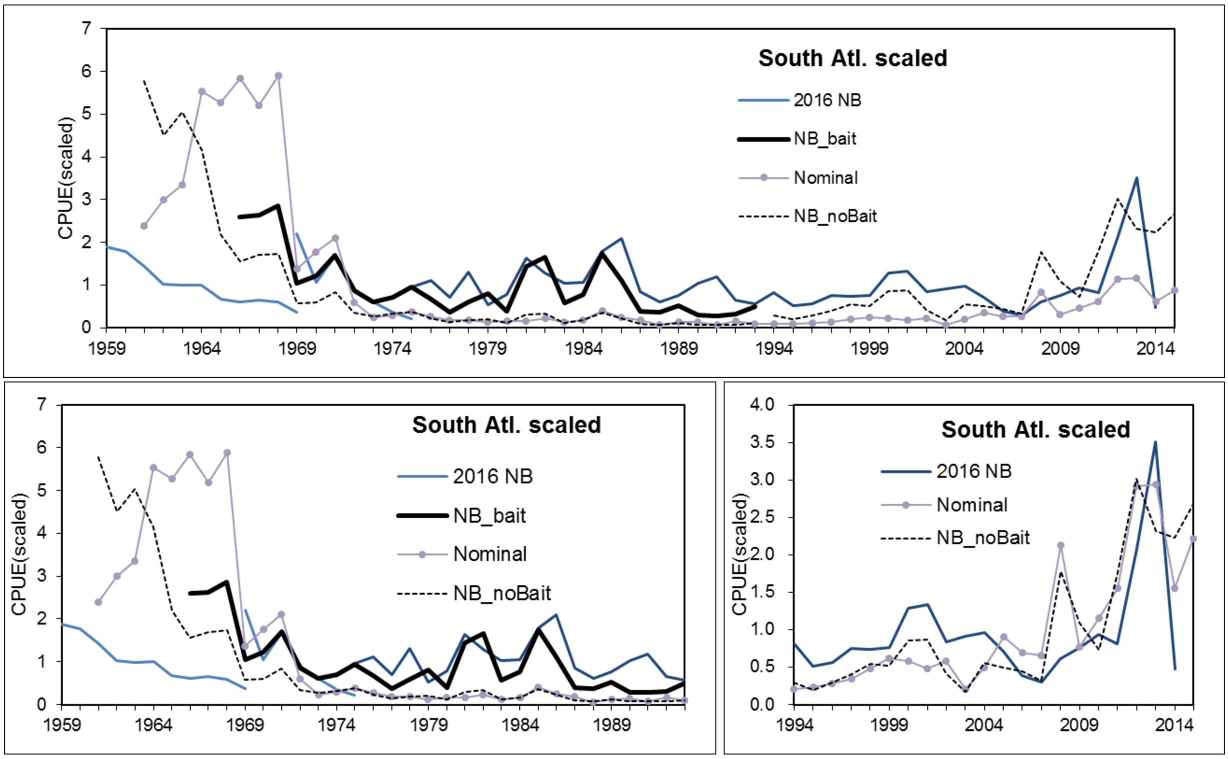


Figure 3. Time series of standardized CPUEs for the south Atlantic albacore with nominal CPUE and standardized CPUE provided last year. **a:** Entire period, **b:** separate period.

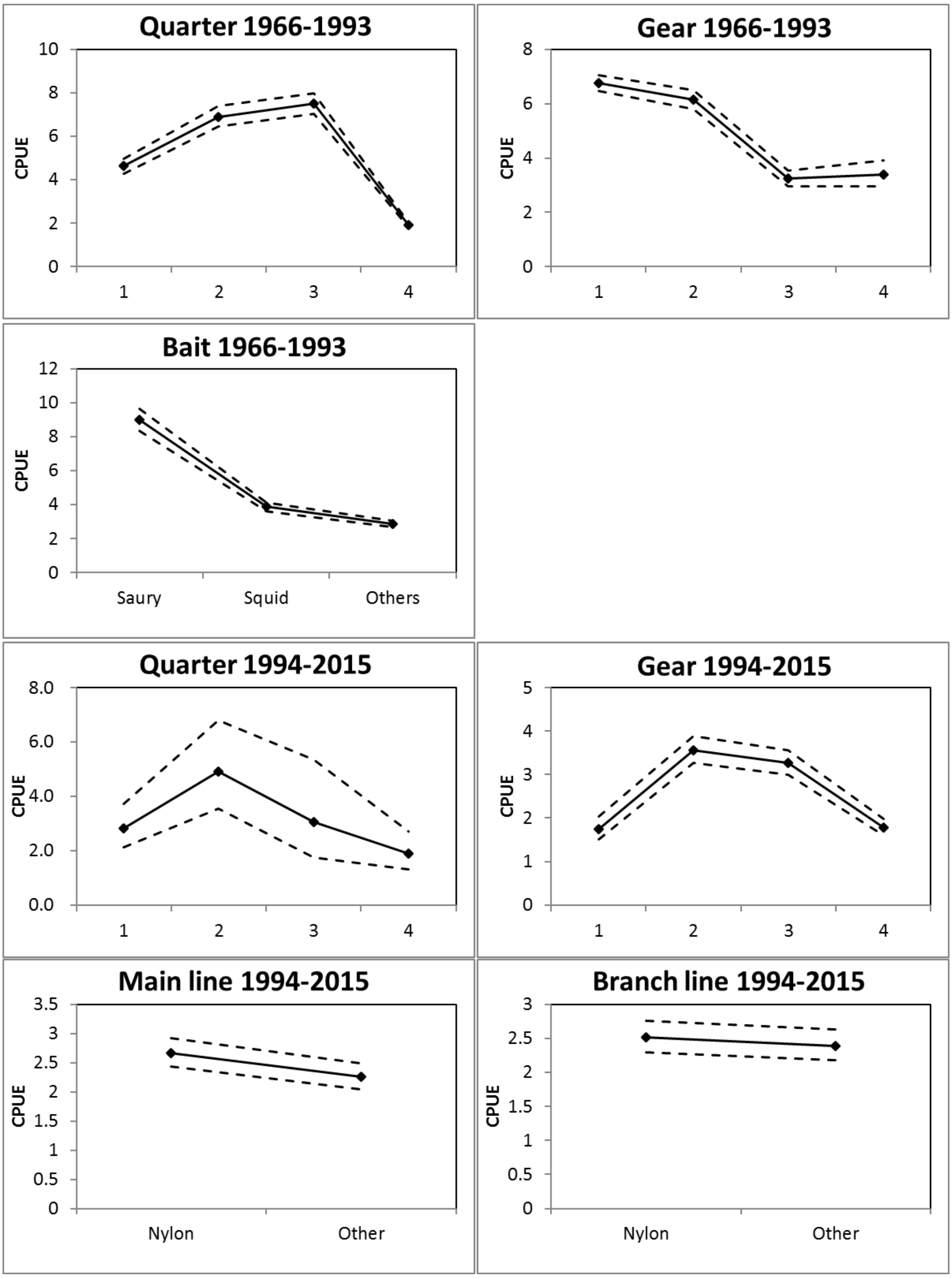


Figure 4. Trends of CPUE standardized for each of quarter, gear (number of hooks between floats: NHF and materials of main and branch lines) and bait for the south Atlantic core area.

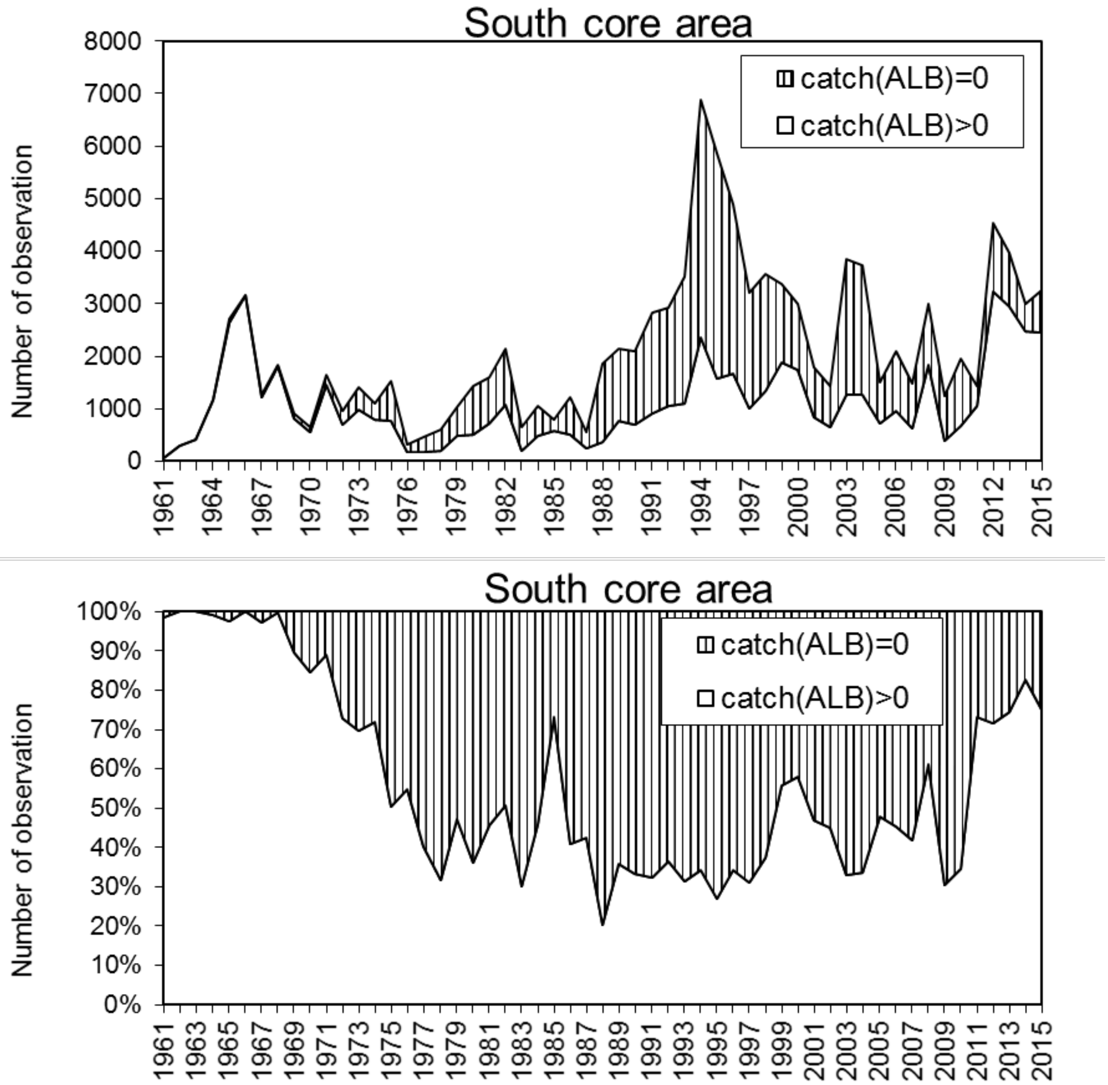
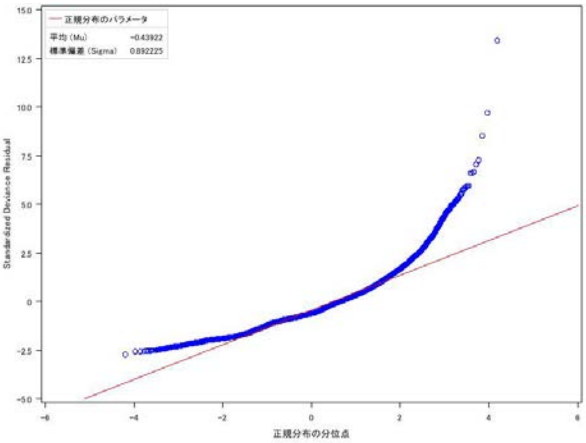
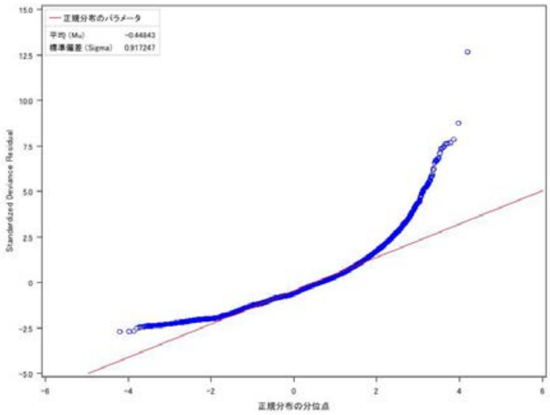


Figure 5. Number of observations of catch of albacore is zero/non-zero in catch-and-effort data used for CPUE standardization in the core area.

South 1966-1993



South 1961-1993



South 1994-2015

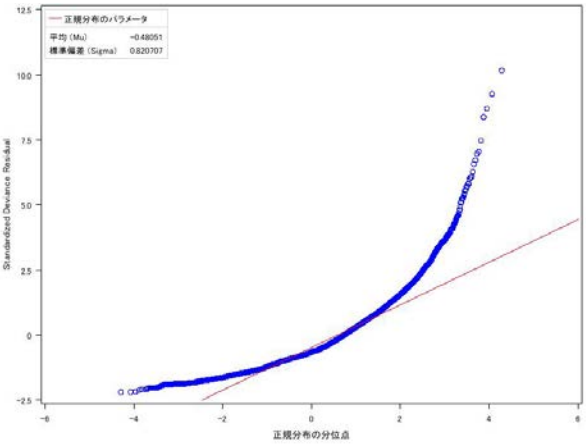
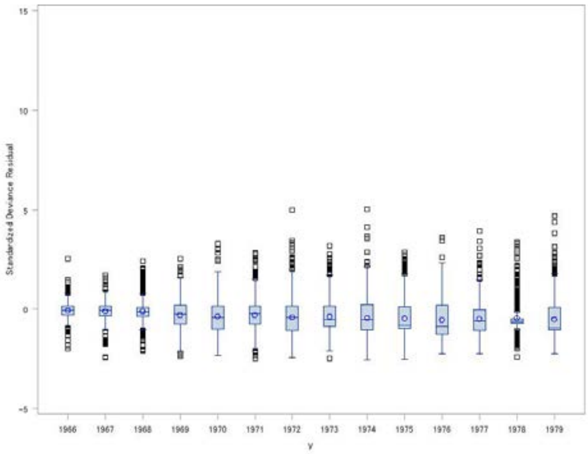
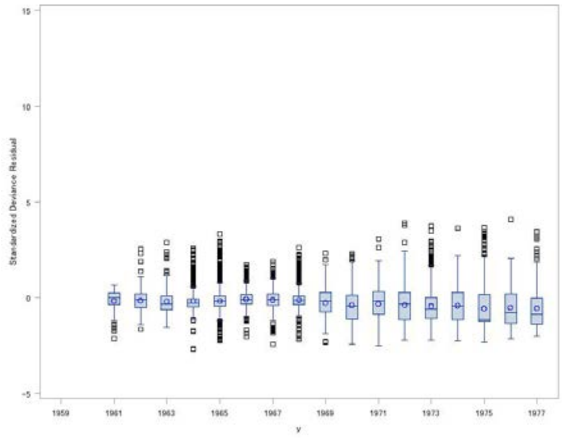


Figure 6. QQ-plots of standardized residual for the NB model for three periods for south stock.

South 1966-1993



South 1961-1993



South 1994-2015

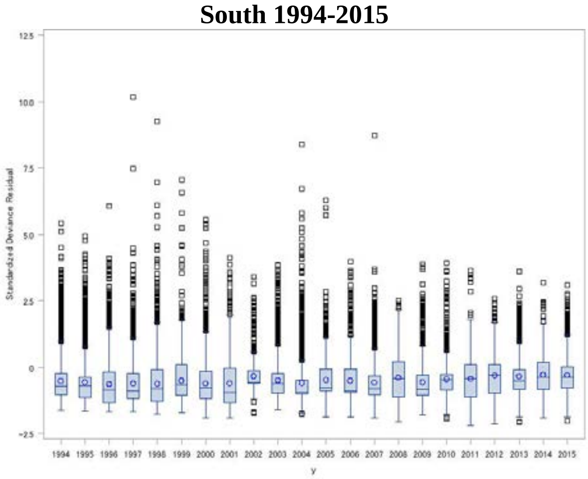


Figure 7. Box plots of standardized deviance residual for the NB model for three periods for south stocks. Circle: mean, box: 25th and 75th percentile, horizontal line in the box: median, bars: maximum and minimum observation between 1.5 IQR (interquartile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers.

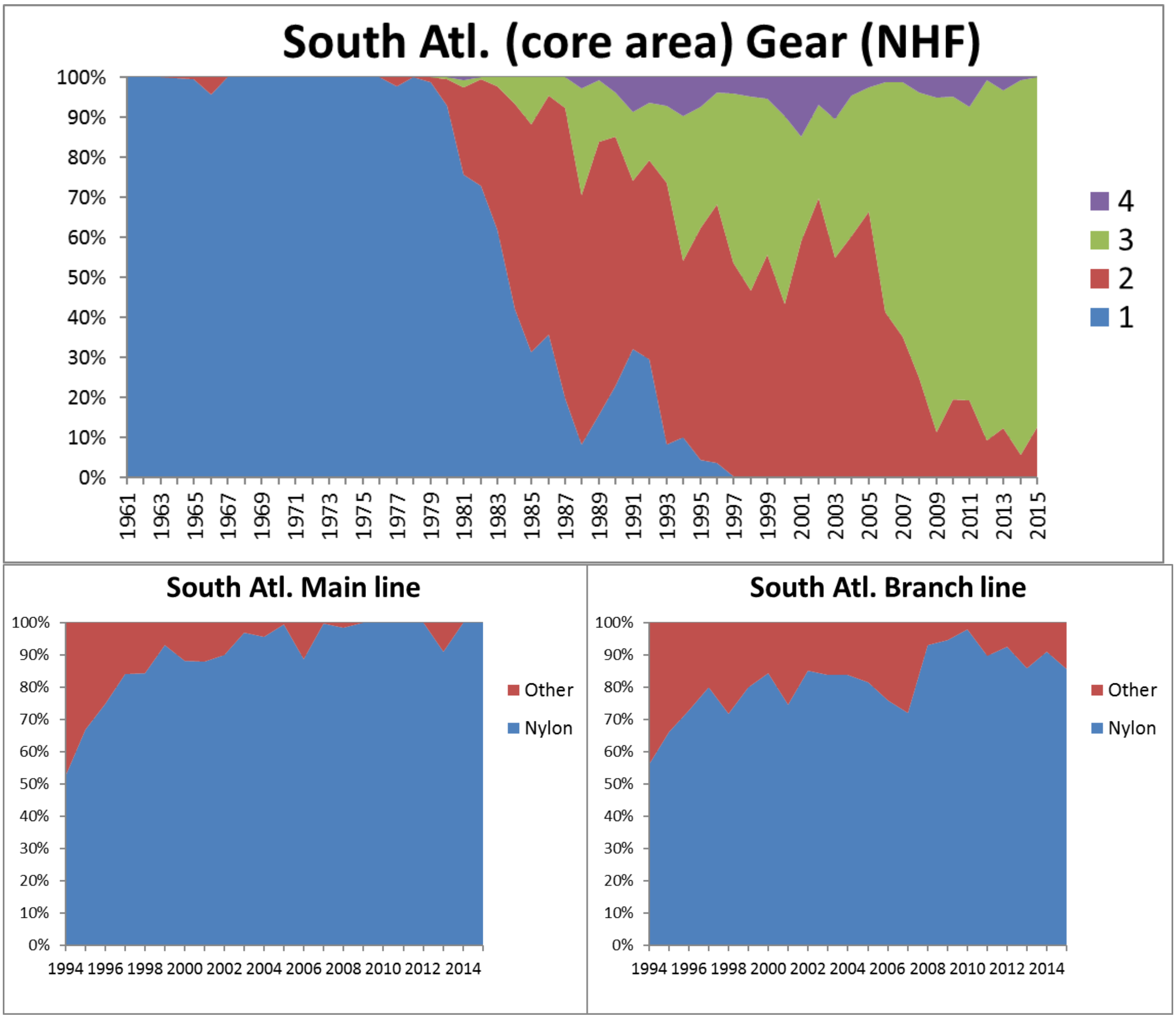
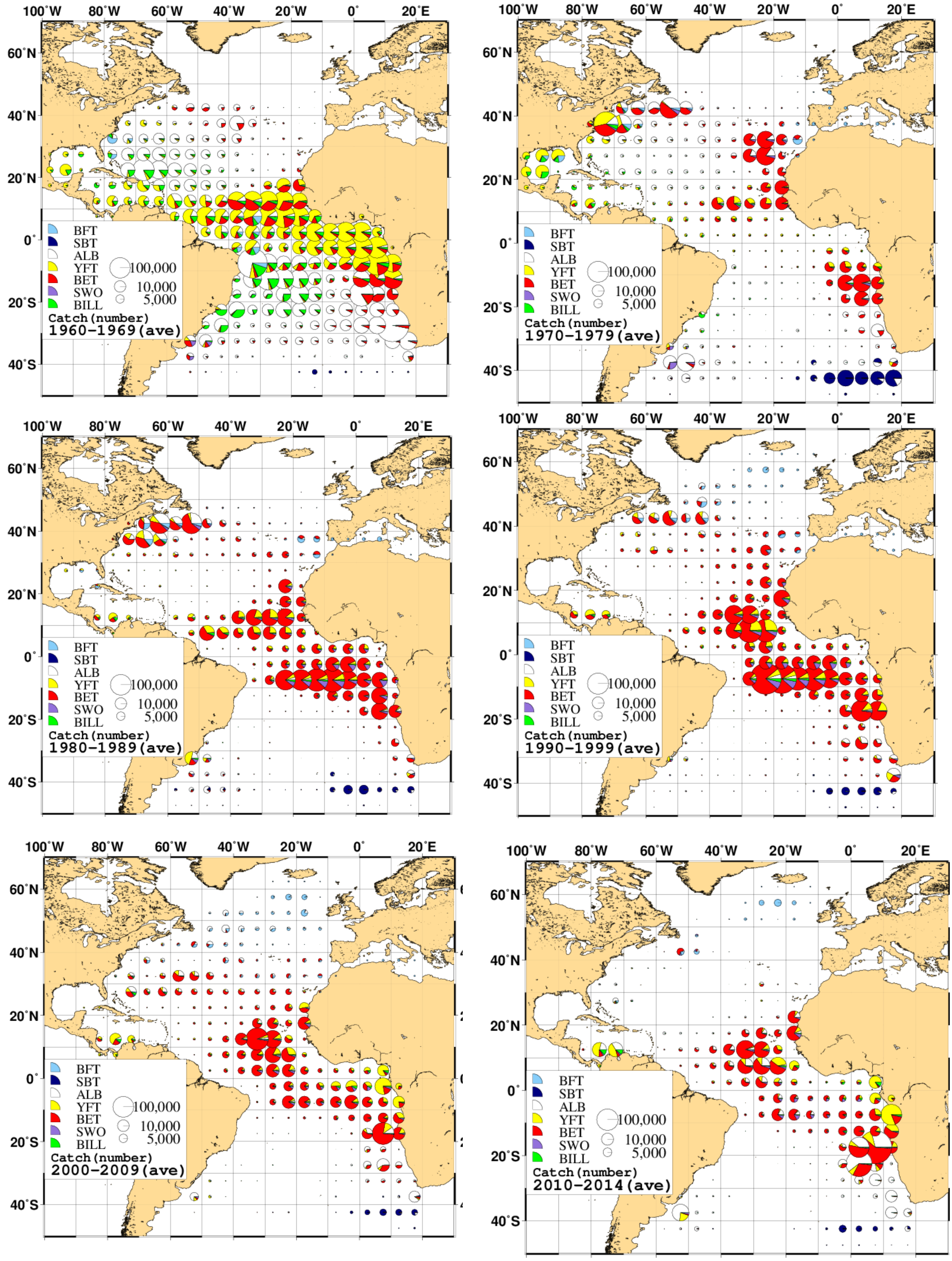


Figure 8. Proportion in the number of operation by category of number of hooks between float and main and branch line materials in catch-and-effort calculated from the data used for CPUE standardization (core area).



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) (Matsumoto, 2016a).