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CPUE STANDARDIZATION OF THE SOUTH ATLANTIC SWORDFISH CAUGHT BY JAPANESE LONGLINERS FOR 1990 – 2012

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SUMMARY

CPUE of the South Atlantic swordfish caught by Japanese longliners is standardized in the period between 1990 and 2012 using the similar GLM method to the previous analysis except for the area stratification and gear configuration. Fishing area was separated into six subareas using new area stratification method, GLM-tree which is a simulation method to partition the fishing area. Gear configuration, the number of branch lines between floats, is simply classified into shallower sets and deeper sets to include the effect of some interaction terms in relation to gear. The general trends of standardized CPUEs were similar between the model with and without new area stratification. The CPUEs in the 1990s with the new method were slightly lower than that with the old method, while the CPUEs in the late 2000s with the new method were conversely higher. The standardized CPUE reached to the historical low level in the early 2000s and it gradually has been increasing since 2005. These results suggest that the adult stock size in the south Atlantic would be recovering in recent years.

RÉSUMÉ

La CPUE de l'espadon de l'Atlantique Sud capturé par les palangriers japonais est standardisée pour la période courant de 1990 à 2012 en utilisant la méthode GLM similaire à celle des analyses précédentes, sauf en ce qui concerne la stratification spatiale et la configuration des engins. La zone de pêche a été divisée en six sous-zones en utilisant une nouvelle méthode de stratification spatiale, arbre-GLM qui est une méthode de simulation visant à diviser la zone de pêche. La configuration des engins, le nombre d'avançons entre les flotteurs, est simplement classée en opérations en eaux superficielles et opérations en eaux profondes afin d'inclure l'effet de quelques termes d'interaction par rapport à l'engin. Les tendances générales des CPUE standardisées étaient similaires entre le modèle doté de la nouvelle stratification spatiale et celui qui en était dépourvu. Avec la nouvelle méthode, les CPUE dans les années 90 étaient légèrement plus faibles que celles avec l'ancienne méthode, tandis qu'avec la nouvelle méthode les CPUE à la fin des années 2000 étaient en revanche plus élevées. La CPUE standardisée a atteint un faible niveau historique au début des années 2000 et elle est en progression depuis 2005. Ces résultats suggèrent que la taille du stock adulte dans l'Atlantique Sud est en train de se rétablir au cours de ces dernières années.

RESUMEN

Se estandariza la CPUE del pez espada del Atlántico sur capturado por los palangreros japoneses en el periodo entre 1990 y 2012 usando un método GLM similar al anterior análisis excepto por la estratificación del área y la configuración del arte. La zona de pesca fue separada en seis subáreas utilizando un nuevo método de estratificación del área, un GLM-árbol que es un método de simulación para dividir el área de pesca. La configuración del arte, el número de brazoladas entre flotadores, se clasifica en lances más superficiales y lances más profundos para incluir el efecto de algunos términos de interacción en relación con el arte. Las tendencias generales de las CPUE estandarizadas eran similares entre el modelo con y sin nueva estratificación de área. Las CPUE en los 90 con el nuevo método eran ligeramente inferiores a las realizadas con el antiguo método, mientras que las CPUE de finales de la primera década del 2000 eran, por el contrario, mayores con el nuevo método. La CPUE estandarizada alcanzó el nivel histórico más bajo a principios de los 2000 y ha ido aumentando gradualmente desde 2005. Estos resultados sugieren que el tamaño del stock adulto en el Atlántico sur estaría recuperándose en años recientes.

KEYWORDS

South Atlantic swordfish, Xiphias gladius, *Longline, CPUE, GLMtree*

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1. Introduction

South Atlantic swordfish, *Xiphias gladius*, is one of the important species for Japanese fishermen and is caught by Japanese longliners as the bycatch. Accurate estimation of the abundance indices is difficult due to the bycatch as well as discards and releases (Yokawa and Kai 2013). In the previous paper (Yokawa 2009), the catch per unit effort (CPUE) of the south Atlantic swordfish caught by Japanese longliners in the period between 1975 and 2007 were standardized using traditional GLM method. For example, the area stratification was given arbitrarily. The objectives of this paper are; (1) to update the standardization of CPUE for the stock assessment of South Atlantic swordfish; (2) to improve the analyzing method such as an area stratification method. We focused on the data after 1989 in order to avoid the missing data in consideration of the interaction effects between main factors such as year, quarter, area, and gear configuration.

2. Material and methods

South Atlantic swordfish catch (catch in number) and effort (number of hooks) data for 1990-2012 were used to update the previous study (Yokawa 2009). In order to carry out the appropriate separation of the area, different area stratification method ("new method") was applied using GLM-tree (Ichinokawa and Broziak 2010), which is a simulation method to separate the area into some subareas objectively. Gear configuration of the number of the branch lines between floats (HPB; hooks per basket) was simply classified into shallower sets ($12 > \text{HPB} \geqq 5$) and deeper sets ($31 > \text{HPB} \geqq 12$) gears to include the effect of some interaction terms in relation to gear. The other shallower and deeper sets were removed.

Swordfish CPUE (CPUE_{ijk}, where catch had units of number of swordfish per 1000 hooks in year *i*, quarter *j*, area *k*, and gear configuration *l*) was standardized using GLMs with a lognormal error distribution. Explanatory variables for the GLMs included year (YR), quarter (QT), area (AR), and gear configuration (GE) with some interaction terms (INTER) between YR*QT, YR*GE, and GE*AR :

$$\ln(\text{CPUE}_{ijkl}+\text{const})= (\text{YR}_i)+(\text{QT}_j)+(\text{AR}_k)+(\text{GE}_l)+ (\text{INTER})$$

A constant term (const) was added to the observed CPUE_{ijkl} in order to rescale the value of zero catches, where 10% of minimum nominal CPUE was given. The interaction term between year and area was not employed due to a lot of missing data. The GLM analysis was made using computer software, “SAS Ver. 9.3”.

3. Results and Discussions

Since it was difficult to determine the optimal number of areas using GLM-tree algorithm based on the AIC criteria, which was one way decreasing trend (**Figure 1**), we gave the same number of areas (i.e. six areas) as that in the previous study (Yokawa 2009). Ichinokawa and Brodziak (2010) suggested that strict optimization until AIC minimum may not always be needed to derive robust estimates of abundance indices, from a practical point of view. **Figure 2** shows the increasing number of areas created by the boundaries selected by the GLM-tree algorithm. The new method produced different area stratification from the old area stratification (**Figure 2**).

Table 1 shows ANOVA table for the model with and without new area stratification. The values of R-square and AIC criteria indicated that the fitting of the model with new area stratification method was better than that with old area stratification method. This result means that the fitting of new method was better than that of old method.

The general trends of standardized CPUEs of the south Atlantic swordfish stock were similar between the model with and without new area stratification (**Table 2**, **Figure 3**). The CPUEs in the 1990s with new method were slightly lower than that with old method, while the CPUEs in the late 2000s with new method were conversely higher (**Table 2**, **Figure 4**). The standardized CPUE reached to the historical low level in the early 2000s and it gradually has been increasing since 2005. These results suggest that the adult stock size in the south Atlantic would be recovering in recent years.

The distribution of residuals of the CPUE analysis shows bimodal pattern for both of two models using new and old area stratifications (**Figure 5**). This supposed to be primary due to the rapid and consistent increasing trend of the number of hooks between float mainly used in Japanese longliners, especially for sets in the tropical area targeting bigeye tuna with deeper gear configuration (Yokawa 2003). In the early 1990s, the deep gear set (number of hooks; 16-19) is main gear type, and the deeper gear (number of hooks; 20-25) becomes main type in the late 1990s. In the 2000s, the shallower gear set (HPB; 10-11) becomes the main type in the high latitude areas.

The observed drop of CPUE in the period between 2000 and 2005 would be due to the activities of the discards and releases of swordfish by Japanese longliners in the north Atlantic (north of 5N). Because swordfish is one of bycatch species for Japanese longliners targeting bigeye and bluefin tunas in the Atlantic, skippers would not accurately recognize the position of the boundary between the northern and southern swordfish stocks. As the southeastern tropical Atlantic is most important fishing ground of Japanese longliners targeting bigeye tuna, many sets conducted in the southern side of the stock boundary and part of longline boats operated in that area would discard and release swordfish in 2000 and 2005.

References

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Table 1. Anova table for the models with and without new area stratification.

(a) The model with new area stratification

	DF	Sum of square	Mean square	F value	Pr > F
Model	124	375124	3025	797	<.0001
Error	307350	1166022	4		
Corrected Total	307474	1541146			

R-Square=0.243, AIC=1282680

Effects	DF	Type III SS	Mean square	F value	Pr > F
year	22	47152	2143	565	<.0001
area	5	37833	7567	1994	<.0001
gear	1	127	127	33	<.0001
qt	3	4142	1381	364	<.0001
year*qt	66	14729	223	59	<.0001
year*gear	22	5263	239	63	<.0001
area*gear	5	4279	856	226	<.0001

(b) The model with old area stratification

	DF	Sum of square	Mean squar	F value	Pr > F
Model	124	321302	2591	653	<.0001
Error	307350	1219844	4		
Corrected Total	307474	1541146			

R-Square=0.208, AIC=1296554

Effects	DF	Type III SS	Mean squar	F value	Pr > F
year	22	56457	2566	647	<.0001
area	5	30915	6183	1558	<.0001
gear	1	88	88	22	<.0001
qt	3	3955	1318	332	<.0001
year*qt	66	20608	312	79	<.0001
year*gear	22	6356	289	73	<.0001
area*gear	5	3470	694	175	<.0001

Table 2. Standardized CPUEs by year and the 95% confidence intervals.

	(a) New area stratification			(b) Old area stratification		
Year	CPUE	Higher CI	Lower CI	CPUE	Higher CI	Lower CI
1990	3.410	3.564	3.263	3.777	3.947	3.615
1991	1.908	2.001	1.819	1.854	1.946	1.767
1992	1.474	1.552	1.401	1.515	1.595	1.439
1993	1.377	1.449	1.309	1.395	1.468	1.326
1994	1.509	1.581	1.441	1.574	1.649	1.502
1995	1.049	1.101	0.999	1.016	1.066	0.968
1996	1.109	1.166	1.055	1.105	1.161	1.050
1997	0.935	0.991	0.882	0.934	0.989	0.881
1998	0.790	0.841	0.742	0.818	0.870	0.769
1999	0.703	0.748	0.660	0.669	0.712	0.628
2000	0.495	0.529	0.463	0.444	0.474	0.416
2001	0.364	0.393	0.337	0.398	0.428	0.370
2002	0.524	0.568	0.483	0.492	0.533	0.454
2003	0.436	0.465	0.409	0.373	0.398	0.350
2004	0.489	0.521	0.458	0.459	0.489	0.431
2005	0.329	0.360	0.301	0.335	0.365	0.307
2006	0.653	0.703	0.605	0.630	0.678	0.584
2007	0.983	1.081	0.894	0.829	0.912	0.752
2008	0.775	0.843	0.711	0.806	0.875	0.741
2009	1.005	1.088	0.928	1.008	1.091	0.931
2010	0.895	0.968	0.826	0.807	0.874	0.745
2011	0.738	0.796	0.683	0.667	0.719	0.618
2012	1.048	1.154	0.951	1.095	1.204	0.995

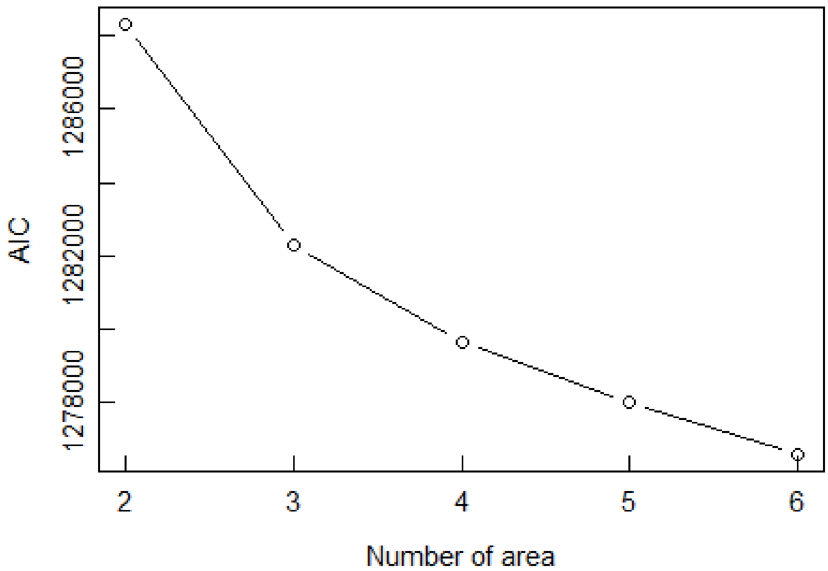

Figure 1. Trajectories of AIC versus the number of areas.

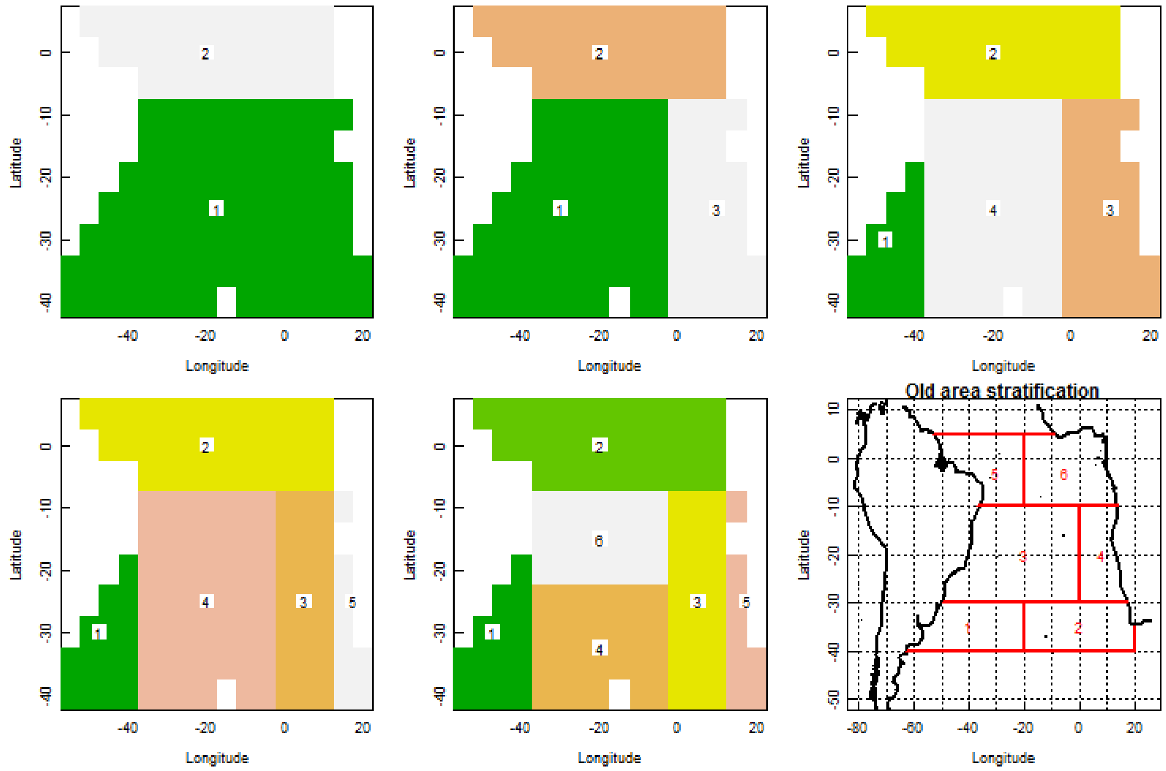

Figure 2. The increasing number of areas created by the boundaries selected by the GLM-tree algorithm. Bottom-right panel represents previous area staratification by Yokawa (2009).

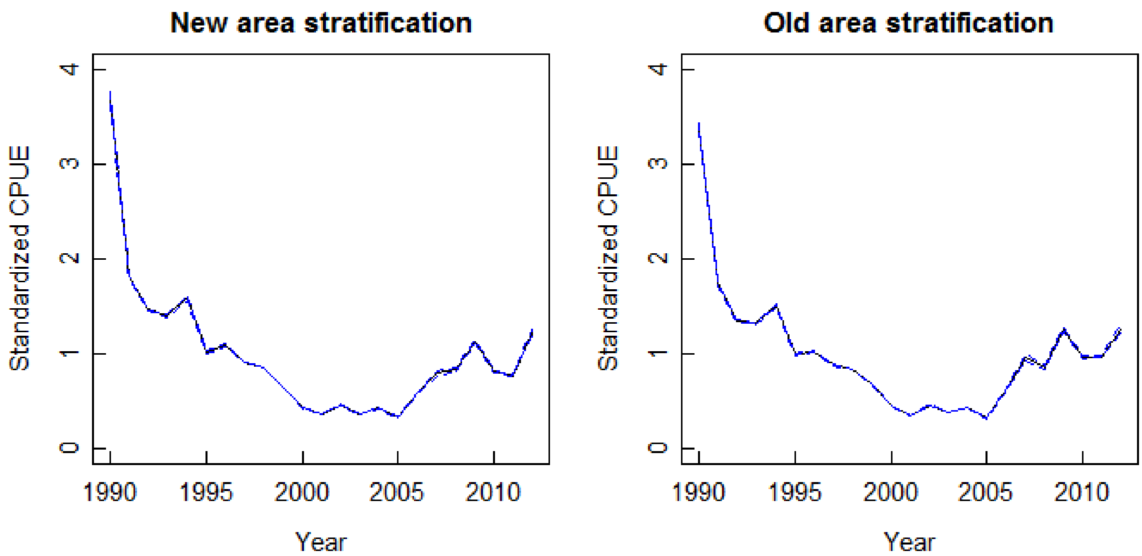

Figure 3. Estimated standardized CPUEs with 95 % confidence intervals (dotted-lines) for 1990-2012. The values are scaled by the mean value.

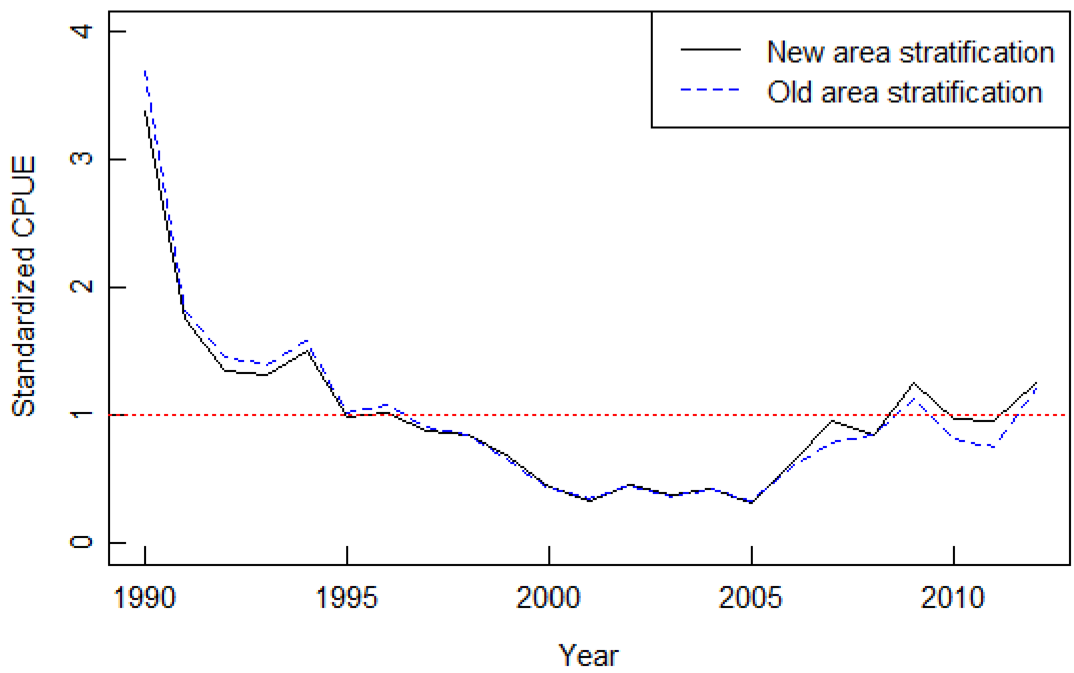

Figure 4. Comparison of the estimated standardized CPUEs between the model with and without new area stratification. The values are scaled by the mean value.

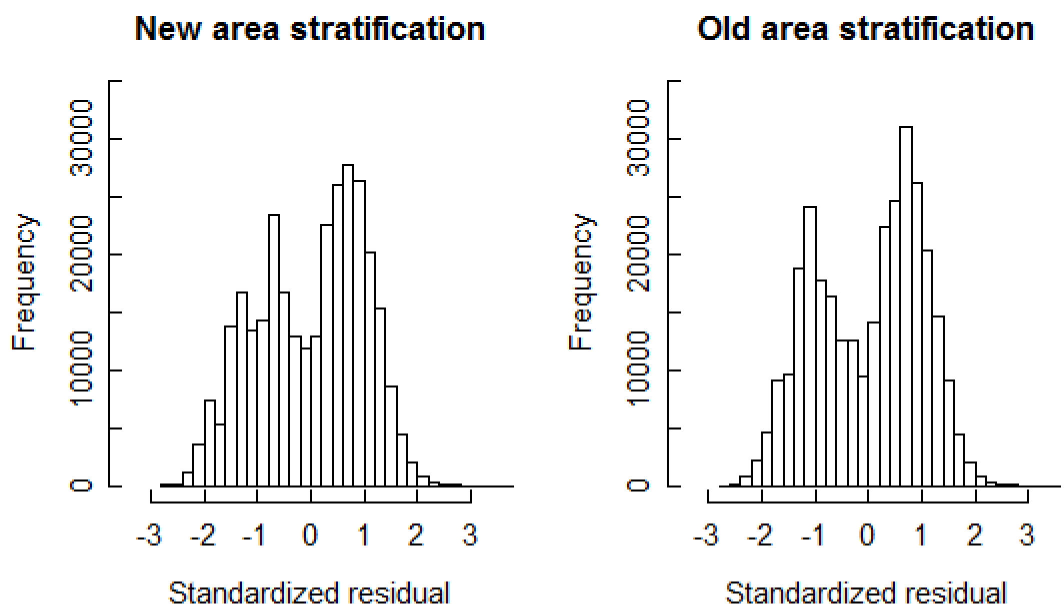

Figure 5. Standardized residuals of the model with and without new area stratification.