UPDATE CPUE STANDARDIZATION OF THE ATLANTIC SWORDFISH CAUGHT BY JAPANESE LONGLINERS

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SUMMARY

We updated the standardized CPUE of the Atlantic swordfish caught by Japanese longliners in the northern and southern Atlantic Ocean for the use of stock assessments of these stocks. The North Atlantic CPUE was standardized according to the final model of previous stock assessment and that period is between 2006 and 2015, and both were reasonably converged. Updated CPUE of northern stock showed increased trend in the period between 2006 and 2011, and suddenly dropped between 2012 and 2013. It showed some recovery in most recent years has recovered. The CPUE of the southern stock was also updated using the similar GLM methodology of the previous assessment and was also updated. The result of updated CPUE showed a similar trend as the previous analysis result, and the recent CPUE showed a stable trend. The overall trends of updated CPUE of southern stocks was similar to the one estimated by the previous study. The updated results of this study indicated that the level of the southern stock have not changed since the mid 2000s.

RÉSUMÉ

La CPUE standardisée de l'espadon de l'Atlantique capturé par les palangriers japonais dans le nord et le sud de l'océan Atlantique a été mise à jour pour l'évaluation de ces stocks. La CPUE de l'Atlantique Nord a été standardisée selon le modèle final de l'évaluation des stocks précédente et cette période se situe entre 2006 et 2015, et les deux ont raisonnablement convergé. La CPUE mise à jour du stock du Nord présentait une tendance à la hausse entre 2006 et 2011 et a brusquement chuté entre 2012 et 2013. Elle a présenté un léger rétablissement ces dernières années. La CPUE du stock du Sud a également été mise à jour en utilisant la même méthodologie GLM de l'évaluation précédente. La CPUE mise à jour présentait une tendance similaire à celle du résultat de l'analyse précédente, et la récente CPUE affichait une tendance stable. Les tendances globales de la CPUE actualisée des stocks du sud étaient similaires à celles estimées dans l'étude précédente. Les résultats mis à jour de cette étude indiquent que le niveau du stock du sud n'a pas changé depuis le milieu des années 2000.

RESUMEN

Hemos actualizado la CPUE estandarizada del pez espada del Atlántico capturado por los palangreros japoneses en el Atlántico septentrional y meridional para su uso en las evaluaciones de estos stocks. La CPUE del Atlántico norte se estandarizó de acuerdo con el modelo final de la evaluación previa del stock y dicho periodo es entre 2006 y 2015 y ambos convergieron razonablemente. La CPUE actualizada del stock septentrional mostraba una tendencia ascendente en el periodo 2006-2011 y caía bruscamente entre 2012 y 2013. En los años más recientes mostraba alguna recuperación. La CPUE del stock meridional fue también actualizada utilizando la metodología del GLM similar a la evaluación anterior. El resultado de la CPUE actualizada mostraba una tendencia similar a la del resultado del análisis previo y la CPUE reciente mostraba una tendencia estable. Las tendencias globales de la CPUE actualizada de los stocks meridionales eran similares a la estimada por el estudio anterior. Los resultados actualizados de este estudio indicaban que el nivel del stock meridional no había cambiado desde mediados de 2000.

KEYWORDS

North Atlantic swordfish, South Atlantic swordfish, Xiphias gladius, Longline, CPUE

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1. Introduction

Japanese longliners have been catching Atlantic swordfish, Xiphias gladius as the bycatch species for tunas fishery. The International Commission for the Conservation of Atlantic Tunas (ICCAT) divided the Atlantic Ocean into North and South area and carried out the stock assessment for North and South Atlantic swordfish stocks using standardized Japanese longliner's catch per unit effort (CPUE) (ICCAT 2014).

In the previous stock assessment of North Atlantic Ocean, Yokawa and Kai (2014) addressed the improvement the discard and the release issue that was occurred between 2001 and 2005 for standardizing Japanese longliner's CPUE. However, this result still included discard effect. In the data preparatory meeting, the working group discussed this standardized CPUE and requested to revise Japanese CPUE that was standardized by Area 5 (temperate area of the northwest Atlantic) of the earlier period (1975-2001) (ICCAT 2014). The reason was indicated that the gear configuration frequently in the tropical areas was changed in the 1990s due to the rapid improvement of the gear materials (ICCAT 2014). Finally, North Atlantic Japanese CPUE in Area 5 was standardized in two periods (1975-2001 and 2006-2012) for the assessment models, (ICCAT 2014).

For the Southern area, Kai and Yokawa (2014) updated standardized Japanese longliner's CPUE using the previous study methodology. They updated 1990-2012 period, and the working group removed the years 1990 and 1991 from the standardized CPUE because this period may not represent the stock trend (ICCAT 2014). In this study, we addressed simple update for Japanese longliners CPUE indices using the same procedure as previous Atlantic swordfish assessment.

2. Material and methods

2.1 North Atlantic sword fish

The catch weight and effort (number of 1000 hooks) data were compiled in the previous analysis (Yokawa and Kai 2014). In this study, we added updated data sets between 2013 and 2015 for the previous data set. Analysis area for the CPUE standardization is the Area 5 where was used in the previous stock assessment (ICCAT 2014) (Figure 1). We applied generalized linear models (GLMs) for this analysis. The gear configuration (Hooks per basket) is also similar that shallower sets are between 5 and 11 HPB, deeper sets are between 12 and 31.

The catch weight of swordfish per 1000 hooks of North Atlantic Swordfish in year *i*, quarter *j* and gear configuration *k* ($CPUE_{i,j,k}$) is

$$\ln\left(CPUE_{i,j,k} + const\right) = year_i + quarter_j + gear_k + e \text{ and } e \sim N(0, \sigma^2),$$

where *const* is the 10% of the mean of nominal CPUE that is to rescale the value of zero catches. We used a computer R software package, "stats" and "lsmeans" for this GLM analysis.

2.2 South Atlantic sword fish

We used South Atlantic swordfish catch number and effort (number of 1000 hooks) data between 1990 and 2012 that was compiled by the previous study (Yokawa 2010, Kai and Yokawa 2014). We updated data sets between 2013 and 2015. We assumed same sub-area stratification as the earlier study that separates the area into some subareas objectively (Ichinokawa and Broziak 2010, Kai and Yokawa 2014) (**Figure 1**). The classification of the gear configuration was set same as previous analysis (Kai and Yokawa 2014). We assumed two type gear configurations that are shallower sets (12 > HPB >= 5) and deeper sets (31 > HPB >= 12). We did not use the other shallower (HPB<5) and deeper (31<=HPB) sets. We also applied generalized linear models (GLMs) for this analysis.

The catch number of swordfish per 1000 hooks of South Atlantic Swordfish in year *i*, quarter *j* area *k* and gear configuration *l* ($CPUE_{i,jk,l}$) is

$$\ln\left(CPUE_{i,j,k,l} + const\right) = year_i + quarter_j + area_k + gear_l + INTER + e \text{ and } e \sim N(0, \sigma^2),$$

where const is the 10% of minimum nominal CPUE that is to rescale the value of zero catches. Inter is the interaction between $year \times quarter$, $year \times gear$ and $area \times gear$. We also used a computer R software package, "stats" and "lsmeans" for this GLM analysis.

3. Results and Discussions

3.1 North Atlantic sword fish

ANOVA table shows that year effect is the largest impact for the CPUE standardization (**Table 3**). The standardized CPUE of the North Atlantic Swordfish is relatively smaller than nominal CPUE and previous study result before 2012 **(Figure 2 (a))**. The updated results of the Northern stock CPUE standardization revealed that the magnitude of increase of CPUE in the period of 2006-2012 was not large as suggested by both the nominal CPUEs and the standardized CPUE in the previous study. The standardized CPUE decreased in 2013 and recovered between 2014 and 2015 quickly **(Figure 2 (a))**. The standardized CPUE shows large down and up during 2012-2015, and this could be the reflects of the annual changes of the level of recruit as the catches in the area used in the CPUE standardization contains many small fishes. The Pearson residual was distributed randomly against the predicted CPUEs. The trends of Pearson residuals of year, quarter and gear effect were different by each covariate (Figure (b)-(d)). These differences of Pearson residuals were relatively small. These results suggest that standardized CPUE was good fitted. Thus, this standardized CPUE is represent the stock trend of the North Atlantic sword fish. There was a sharp decline in the standardized CPUE in the North area between 2011 to 2013 **(Figure 2 (a))**. This result indicated that the biomass level fell to a fraction of a year. However, this phenomenon was not realistic for adult stock of North Atlantic swordfish. It is probably reasonable to think that the decrease affected by the annual fluctuation of the recruitment level because the areas used for standardization are waters where recruitment groups appeared. If we check the catch average weight during this period, it might be a trend to the opposite of CPUE. (When the CPUE falls abruptly, the average weight goes up, and when it recovers, the average weight decreases.)

3.2 South Atlantic sword fish

ANOVA table shows that area effect is the largest impact for the CPUE standardization **(Table 4)**. The standardized CPUE of South Atlantic swordfish shows the approximately similar trend with the previous study **(Table 2, Figure 3 (a))**. The overall trends of updated CPUE of southern stocks was similar to the one estimated by previous study. The updated results of this study indicated the level of the Sothern stock were not changed since the mid 2000s. Kai and Yokawa (2014) indicated that the effect of the change of gear configuration for the CPUE standardization of South Atlantic swordfish. The primary gear type in the early 1990s was deep sets (number of hooks; 16-19), and the main gear type became even deeper than before (number of hooks; 20-25) in the late 1990s. This is because the quality of bigeye tunas, which is one of the primary target for Japanese longliners in the South Atlantic, becomes better as their dwelling depth becomes deeper targeting Bigeye tuna (Kai and Yokawa 2014). Reflecting this operational changing of Japanese longliners, the standardized residual (Pearson residual) plot shows a bimodal pattern and were different annually **(Figure 3 (b), (c))**. On the contrary, there are no particularly trends in seasonal Pearson residual (Figure 3 (d)). Pearson residual of sub-area and gear were different by each covariate **(Figure 3 (e)(f))**. It was thought that the standardized CPUE of South Atlantic swordfish was well estimated because these Pearson residual trends were relatively small and distributed randomly. In The nominal CPUE have declined in recent years, however standardized was flat **(Figure 3 (a))**. For some reason, it is thought that the operation pattern of the Japanese fishing boat might change compared to the past.

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Table 1. Annual standardized CPUE of North Atlantic swordfish.

Year	CPUE	Lower CI	Upper CI
2006	4.744	2.623	7.645
2007	5.823	2.920	10.118
2008	9.318	5.552	14.716
2009	18.956	11.970	29.172
2010	18.937	12.240	28.551
2011	26.051	16.597	40.034
2012	21.305	12.776	34.405
2013	7.574	3.862	13.254
2014	11.709	6.807	19.030
2015	20.417	12.364	32.656

Table 2. Annual standardized CPUE of South Atlantic swordfish (relative scale).

Year	CPUE	Lower CI	Upper CI
1990	2.677	2.608	2.748
1991	1.610	1.562	1.659
1992	1.328	1.284	1.373
1993	1.299	1.257	1.342
1994	1.484	1.441	1.528
1995	1.074	1.041	1.108
1996	1.090	1.055	1.126
1997	0.961	0.924	0.999
1998	0.942	0.903	0.982
1999	0.801	0.768	0.836
2000	0.576	0.550	0.603
2001	0.476	0.451	0.503
2002	0.601	0.566	0.637
2003	0.515	0.492	0.539
2004	0.551	0.526	0.576
2005	0.444	0.416	0.473
2006	0.783	0.743	0.824
2007	1.041	0.973	1.113
2008	0.929	0.875	0.985
2009	1.038	0.981	1.097
2010	0.955	0.902	1.010
2011	0.797	0.755	0.842
2012	1.038	0.968	1.112
2013	0.976	0.924	1.031
2014	1.006	0.919	1.101
2015	1.007	0.938	1.079

Table 3. ANOVA table of North area.

	SS	Df	F	Pr(>F)
yr	137.60969	9	15.889242	0.001>
qtr	10.9835	3	3.804662	0.001>
gear	18.16606	1	18.878057	0.001>
Residuals	916.09454	952	-	-

Table 4. ANOVA table of South area.

	SS	Df	F	Pr(>F)
yr	5322.0809	25	130.8882	0.001>
qtr	217.692	3	44.61492	0.001>
area	8832.4225	5	1086.09759	0.001>
gear	422.1012	1	259.52284	0.001>
yr:qtr	8172.3768	75	66.99558	0.001>
yr:gear	2793.7084	25	68.70686	0.001>
area:gear	5446.7755	5	669.77432	0.001>
Residuals	539046.517	331425	-	-

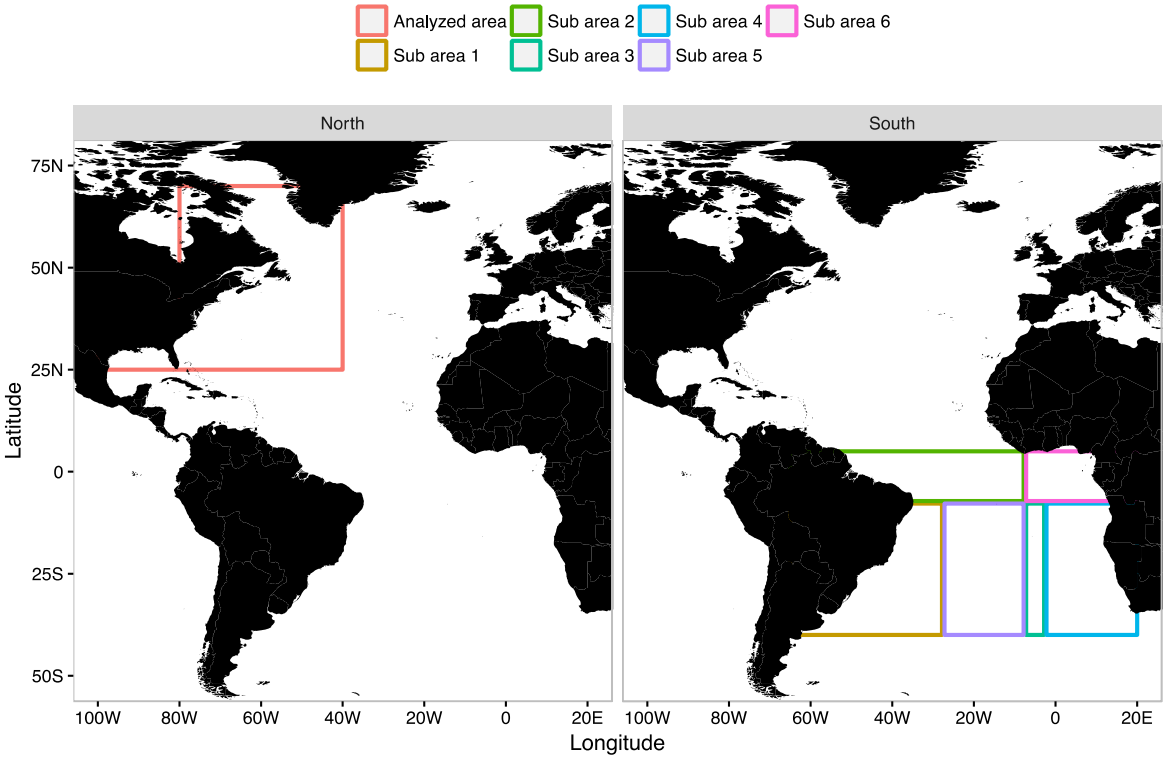


Figure 1. Analysis area of Atlantic sword fish. Left panel is area definition of the Northern area. Right panel is area definition of the Southern area.

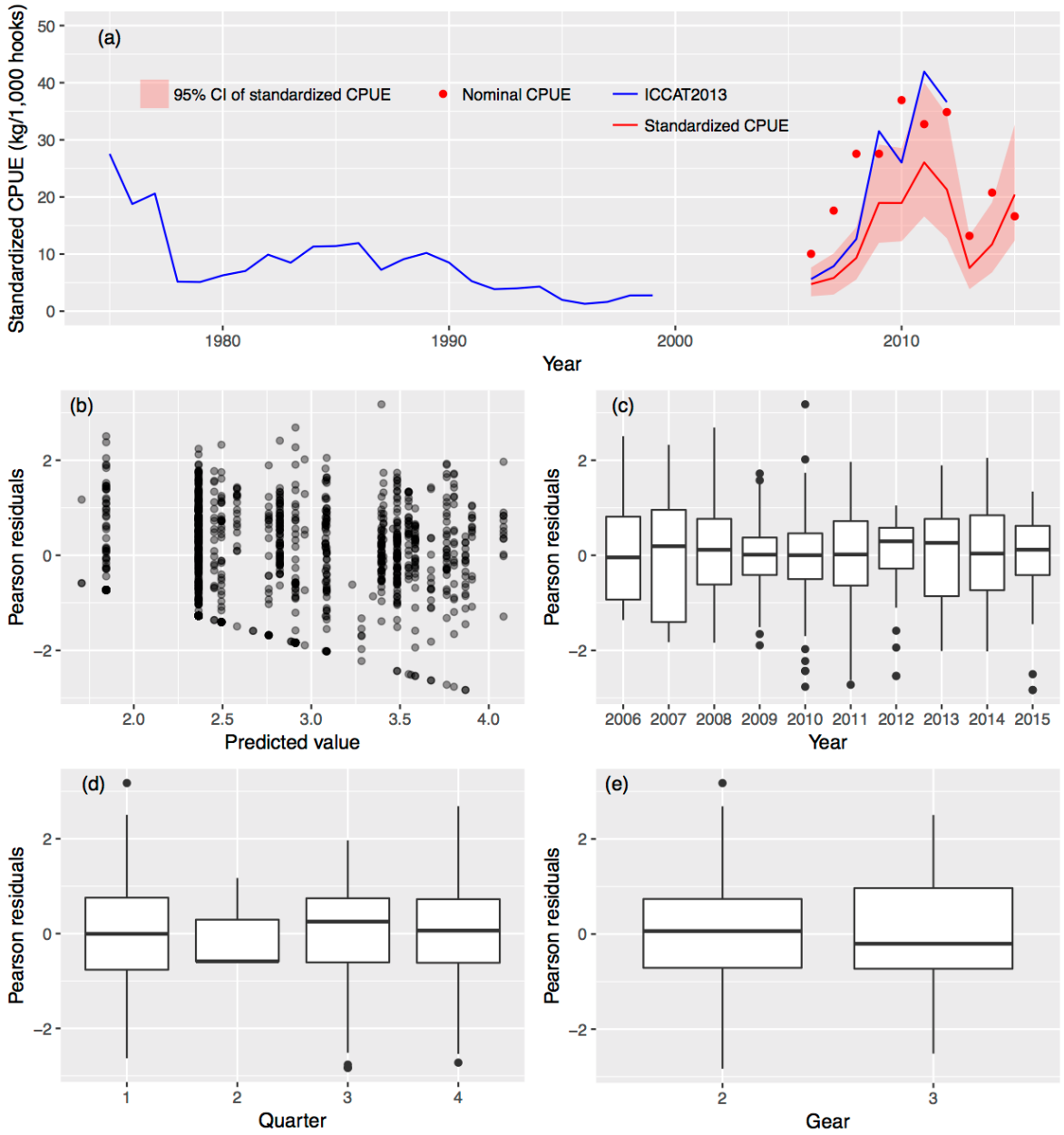
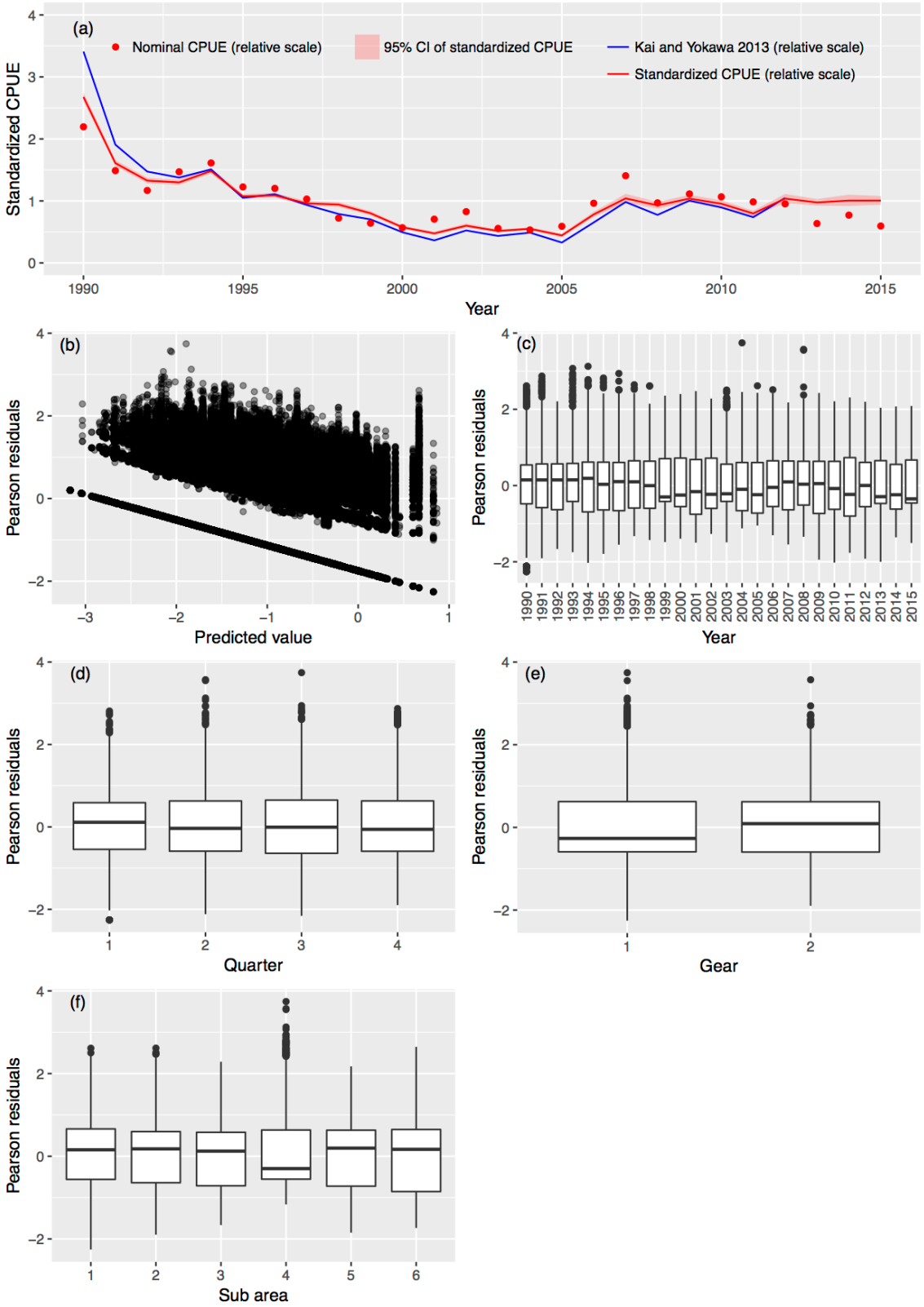


Figure 2. Result of CPUE standardization analysis of North Atlantic Swordfish by Japanese longline fishery. (a) Comparison between nominal, previous and standardized CPUE. (b)-(d) The Pearson residual trend.



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