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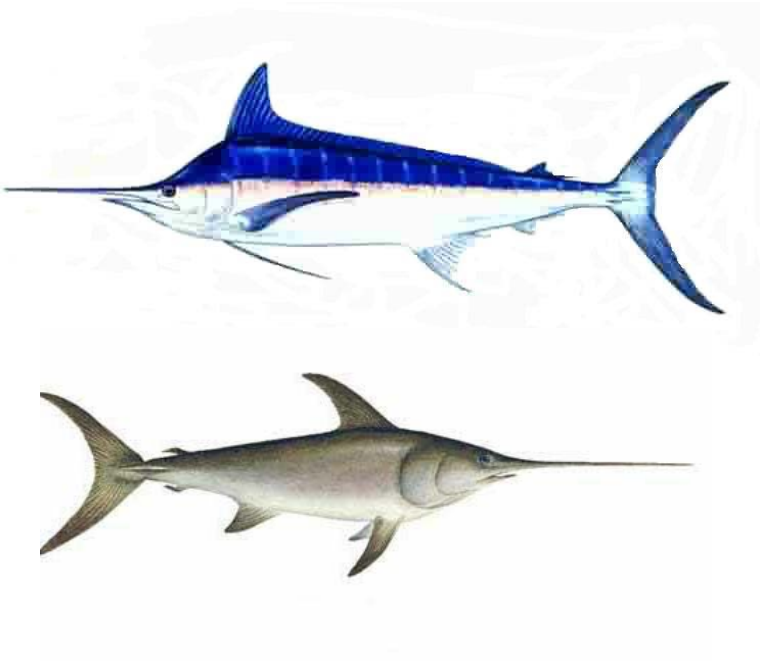

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Update of the Catch per Unit Effort (CPUE) trend of Swordfish (*Xiphias gladius*) by the Japanese offshore and distant-water longline fishery in the Pacific

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Introduction

In 2007, Japan reported standardized CPUE of Swordfish caught by Japanese longliners as well as some biological information collected in the longline log book. This document is the update the CPUE of the previous study, which was calculated standardized CPUE up to 2006 (Ishimura *et al*. 2008).

This study calculated standardized CPUEs for two swordfish stock scenarios: a single stock in the North Pacific Ocean (NPO) including the entire Pacific Ocean north of the equator (Figure 1), and a two stocks scenario with a boundary between the NPO and the Eastern Pacific Ocean (EPO) (Figure 2, the NPO and EPO stock), by the request from the Billfish Working Group.

Materials and Methods

Generally, the same data and method as in the previous study was used in this study.

(1) Japanese longline data

This study adapted data compiled over 56 years from logbooks from the Japanese offshore and distant water longline fishery (1952-2007) by the Agency of Fisheries, Japan. These data included species-specific catch for tuna (e.g., bigeye tuna, bluefin tuna), tuna-like species (e.g., marlin), and sharks, and operational descriptions (e.g., number of hooks, gear configurations, locations) for each longline set. In this study, aggregated data by 5x5 degree grids, month, and gear configurations were used. Information about gear configuration is only available since 1975, which roughly coincide with the introduction of deeper setting in the Japanese distant water longliners to target bigeye tuna. Thus, this study analyzed two periods separately: 1952-1974 (calculation was done by 1979) and 1975-2007.

The configuration of single gear set is classified by the number of branch lines with baited hooks between float lines which often referred as hooks per basket (HPB). The gear deployment depth, which influences species specific catchability, is specified vertical down force by the total weight of a set defined by the number of branch lines. In a case of swordfish targeted effort by Japanese longline vessels mainly employ 3-4 HPB which is often referred as “night set” or “surface set” and intend to make hooks stay in surface. The five categories of the gear configurations arbitrarily employed in this study are presented in table 1. Data with its HPB is smaller than 2 or larger than 23 were excluded

from the analysis.

Observations which had less than 10,000 total hooks given time, spatial location and gear configurations were considered as minor fishing efforts and eliminated. As the result, the total number of observations is 288,728 (61,583 in 1952-1979, and 227,145 in 1975-2007). The CPUE for each grid cell over time (56 years and 4 seasons) was calculated by the number of swordfish caught divided by the number of hooks as the unit of fishing effort.

(2) Spatial stratifications

We spatially stratified the study area to articulate heterogeneity of the fishing grounds in model representations. This study basically followed the previous area stratifications by Ishimura *et al*. (2008). In the single stock scenario, the north Pacific was stratified into 11 areas (Figure 1a). In the two stock scenario, the entire north and east Pacific was stratified into 19 areas (Figure 1b): areas 1-9 for the NPO stock, and areas 10-19 for the EPO stock. The areas 11 and 12 by Ishimura *et al*. (2008) were combined into area 11 in the both scenarios, due to the lack of data in recent year which was found in the pre-analysis described below (Figure 3). The part of areas 8 and 9 by the previous study for the EPO stock of the two stock scenario were also combined to keep the continuous coverage of data.

(3) CPUE standardizations for the period between 1952 and 2007

Standardized CPUE series of the Japanese distant-water longliners for the period between 1952 and 2007 are analyzed by using GLM analysis. The standardized CPUE values of each area was weighted by the approximate size of each area and summed up to the total CPUE. Two periods between 1952-1974 and 1975-2007 are analyzed separately, because information about gear configuration is only available since 1975. Analysis was made through the GLM procedure of computer software, “SAS Ver. 9.1”.

A) Pre-analysis and Period between 1975 and 2006

The standardized log–transformed CPUE with Gaussian errors (ε) was fitted for four categorical explanatory variables, year (y), quarter (q), gear configuration (g), area (a), and their interaction terms;

$$\ln(CPUE_{ijkl}+\text{const})=y_i+q_j+g_k+a_l+(\text{interaction terms})+\varepsilon$$

where the interaction terms were year*area and year*quarter.

Pre-analysis for the the single north Pacific stock scenario was done, because of the shortage of data in 2007. To settle input data by this model, pre-analysis made with three sets of data: excluding 2007, excluding area 11 by Ishimura et *et al*. (2008), or excluding 2007 and combined areas 11 and 12 by the previous study.

The standardized CPUEs for the period between 1975 and 2006 were calculated by the GLM model excluding 2007, since the result of the pre-analysis showed the failure in the estimation of

standardized CPUEs including 2007 (Figure 3).

B) Period between 1952 and 1974

In this study, GLM was fitted to the data which is slightly longer period: 1952 and 1979. The standardized log–transformed CPUE with Gaussian errors (ε) was fitted for three categorical explanatory variables, year (y), quarter (q), area (a), and their interaction terms;

$$\ln(CPUE_{ijkl}+\text{const})=y_i+q_j+a_l+(\text{interaction terms})+\varepsilon$$

where the interaction terms were year*area and year*quarter (model A). However, due to the shortage of year*area data, data between 1952 and 1961 was excluded from the analysis. The standardized CPUE values of each area were weighted by the approximate size of each area and summed up to the total CPUE.

To obtain standardized CPUE series for period between 1952 and 1979, the same model with the interaction terms which were quarter*area and year*quarter (model B) were also calculated.

C) Period between 1952 and 2006

The standardized CPUEs of two periods were roughly combined into one period between 1952 and 2006, using the average ratio of the standardized CPUEs for the overlapping period between 1975 and 1979.

Results and Discussion

(1) The single north Pacific stock scenario

A) Period between 1975 and 2006

Figure 4a shows the standardized CPUEs between 1975 and 2006. The CPUE peaked in 1987 and decreased thereafter by 1998, when the historical lowest level was recorded. In 2001, the historical highest level was observed immediately after the lowest record in 1998. The CPUE in 2006 was increased compared to those between 2002 and 2005 which were roughly in the averaged level of the analyzed period. The trends of CPUE largely fluctuated in most recent year (1998-2006).

Figure 5 shows trends of standardized CPUEs by the area. The first peak of standardized CPUE in 1998 mainly consisted by the increase of CPUE in areas 4, 6, and 7. However, it is thought that the area 7 should be observed carefully, because the trend in the area largely fluctuated in the 80s compared to those in the other areas. Because this observed larger fluctuation would be due to the incomplete standardization of CPUE, further study would be necessary. The historical highest level in 2001 was caused by mainly areas 9-11. All areas, except areas 1-4, were contribute to the most recent peak in 2006, and especially in areas 10 and 11, large CPUEs were observed. Because the possibility of existence of spawning ground of swordfish in around areas 10 and 11 is indicated by Kume and Joseph (1969), this increase of CPUE may be attributed to the occurrence of the strong year class.

B) Period between 1952 and 1974

Figure 9a shows the standardized CPUEs in the period between 1952 and 1979. Since the trend

between 1952 and 1979 with the model B showed similar results as those between 1962 and 1979 with the model A (Figure 8a), this study adopted the one with longer period as a final result. The standardized CPUE showed stabilized trends in the analyzed period.

C) Period between 1952 and 2006

Figure 10a shows the standardized CPUEs between 1952 and 2006. The trend before the early 80s showed lower CPUEs than the average of the whole period. Two peaks were observed in 1987 and 2001 which were historically high records, while the historical lowest record was observed in 1998. In 2006, the standardized CPUE was also large value.

(2) The two stock scenario

A) Period between 1975 and 2006

Figures 4b and 4c show the standardized CPUEs between 1975 and 2006 for the NPO and the EPO stock in the two stocks scenario. The NPO stock shows a similar trend to the one in the single stock scenario in the period before 1998. The historical lowest level was also observed in 1997 and 1998. The CPUE in 2001 was not so prominent as the one in the single stock scenario, though the peak in 2001 and the increase in 2006 were also observed.

On the other hand, the standardized CPUE decreased since 1975 for the EPO stock, and the historical lowest level was recorded in 1984. In the late 80s and the 90s, it showed a continuous increasing trend. The peak of CPUE in 2001 and the increase in 2006 were also observed for the EPO stock.

Figures 6 and 7 show trends of standardized CPUEs by the area for the NPO and the EPO stock. For the NPO stock, the peak of standardized CPUE in the late 80s was mainly caused by the increase of CPUE in area 7, while the peak in 2001 was caused by area 9. The observed increase in 2006 was caused by the increase of CPUEs in areas 5-9, especially in area 7. For the EPO stock, the peak of standardized CPUE in 2001 consisted areas 10-12, while the increase in 2006 is mainly due to the increases in areas 10-12, 13, 15-16, and 19.

For the NPO stock, among the trends of CPUEs by the area, the one in area 7 should be observed carefully, because the trend of standardized CPUE in the area largely fluctuated in the 80s comparing to those in the other areas, which was also observed in the single stock scenario. The increasing trend of CPUEs in the early 2000s in areas 8 and 9 are also noticeable. For the EPO stock, areas 10-12 showed a similar trend to the standardized CPUE in a total area. The CPUEs in areas 14 and 16 were also debatable, because the trend in the areas largely fluctuated in the whole period compared to those in the other areas. Further check of the detailed data would be necessary to obtain more reliable indices.

B) Period between 1952 and 1974

Figure 9b and 9c show the standardized CPUEs between 1952 and 1979 for the NPO and the EPO

stock. Due to the lack of data before 1954, the standardized CPUEs started in 1954. Since the trend between 1955 and 1979 with the model B was similar to those between 1962 and 1979 with the model A (Figure 8b and 8c), this study adopted the one with the longer period as a final result for both stocks. For the NPO stock, the standardized CPUE showed stabilized trends in the period of 1952 and 1974. On the other hand, for the EPO stock, it showed the increasing trend since the late 50s, and a peak of standardized CPUE was also observed in 1970. In the 70s, the trend of CPUE was stable.

C) Period between 1952 and 2006

Figures 10b and 10c show the standardized CPUEs between 1952 and 2006 for the NPO and the EPO stock. The NPO stock showed a similar trend to the one in the single stock scenario before 1996. The historical lowest levels were observed in the following years, 1997 and 1998. Although the increase of standardized CPUE was observed in 2001 and 2006, the values were not so prominent compared to the result for the one in the single stock scenario.

For the EPO stock, the peak of standardized CPUE in 1970 was observed and decreased thereafter. The peak was appeared in 2001, after the historical lowest CPUE was observed in 1984. In 2006, the CPUE was increased and showed relatively large value. Compared to the NPO stock, the standardized CPUE after 1997 obviously showed larger values for the EPO stock.

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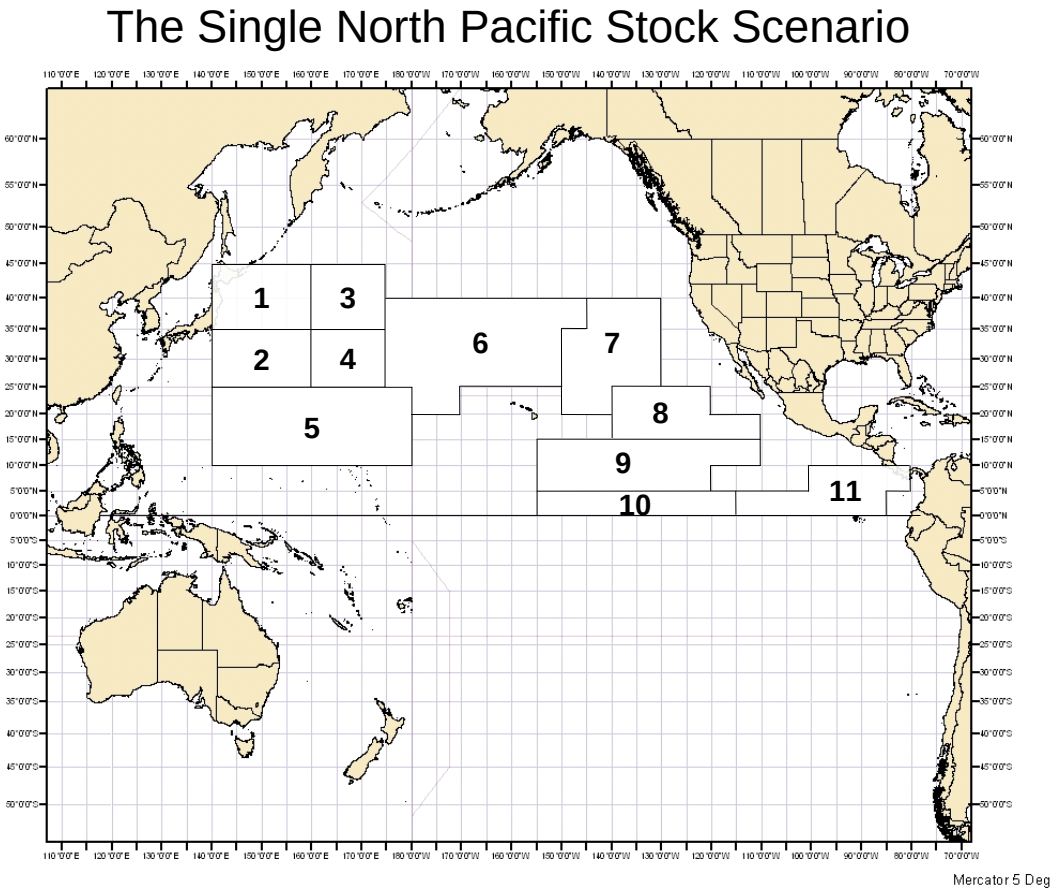

Figure 1. Area stratifications used in the CPUE analysis of swordfish caught by Japanese distant water longliners for the single north Pacific stock scenario.

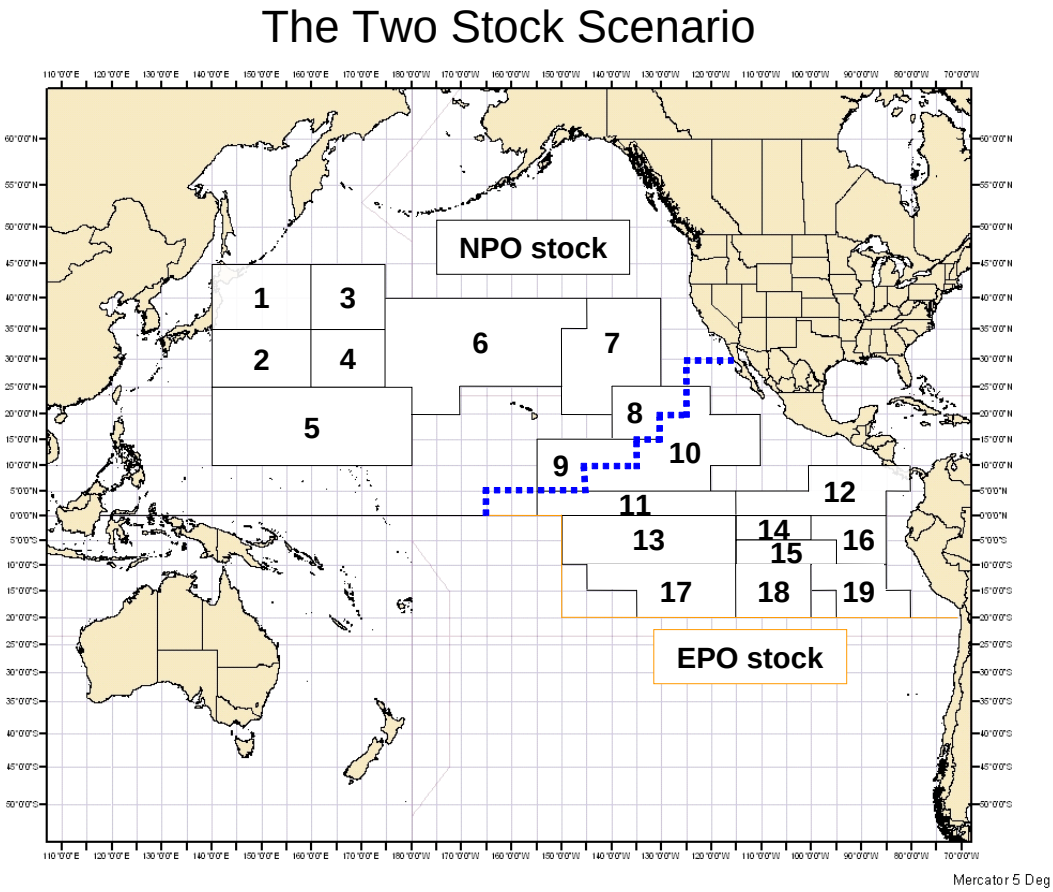

Figure 2. Area stratifications used in the CPUE analysis of swordfish caught by Japanese distant water longliners for the two stock scenario (the NPO and the EPO stock).

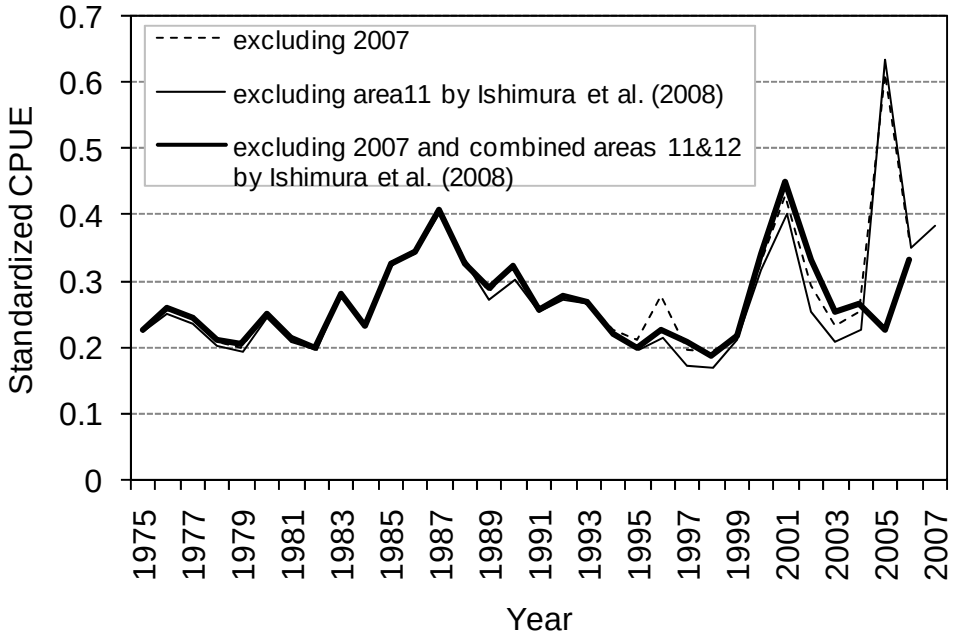

Figure 3. Pre-analysis for the standardized CPUEs of swordfish caught by Japanese longliners for the period between 1975 and 2007 in the north Pacific (the single stock scenario) with the GLM model (Materials and Methods 3-A).

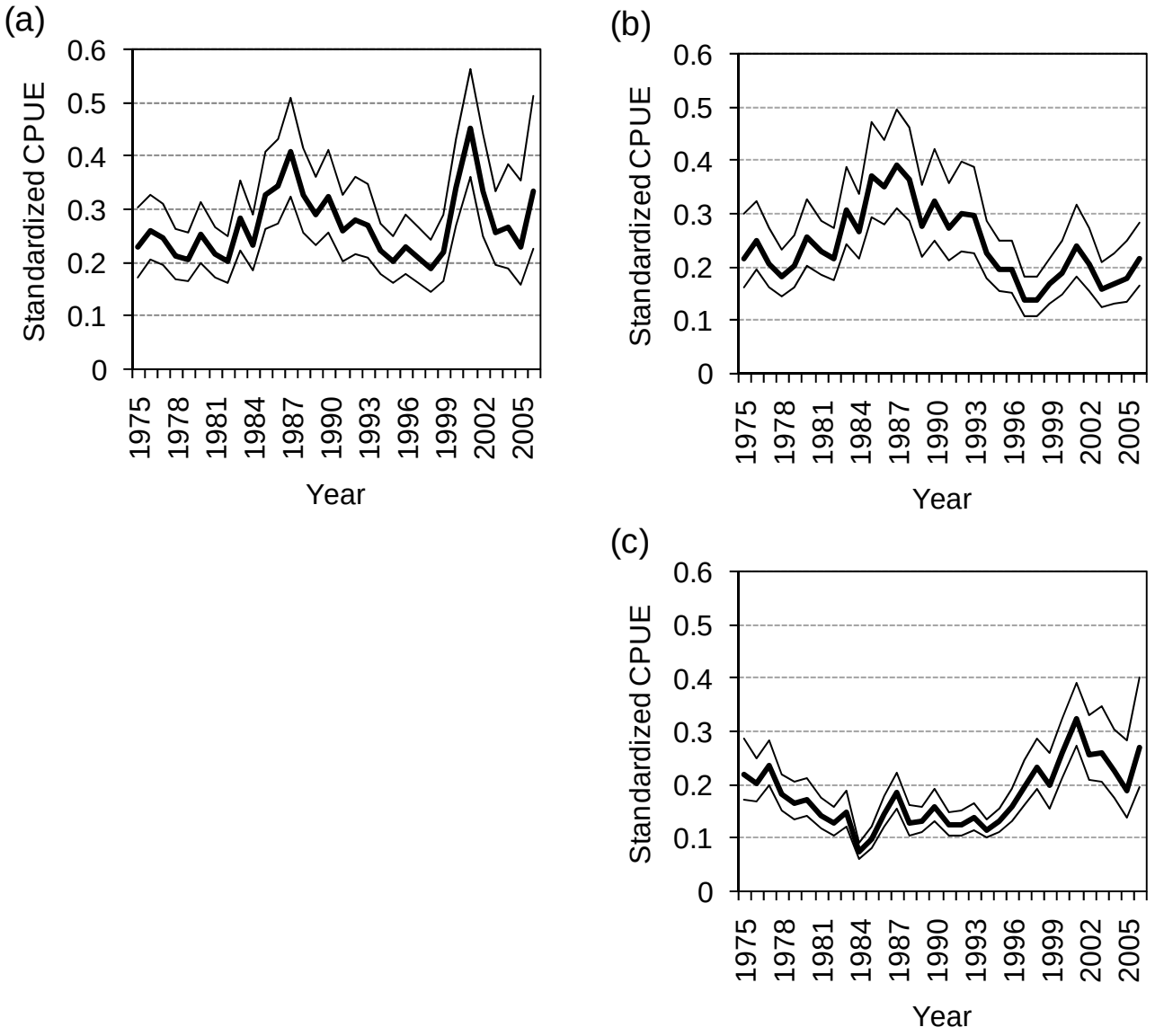

Figure 4. Trends of standardized CPUEs for the period between 1975 and 2006 with their confidence interval of swordfish caught by Japanese longliners for (a) the single north Pacific stock scenario, and for (b) the NPO and (c) the EPO stock in the two stock scenario.

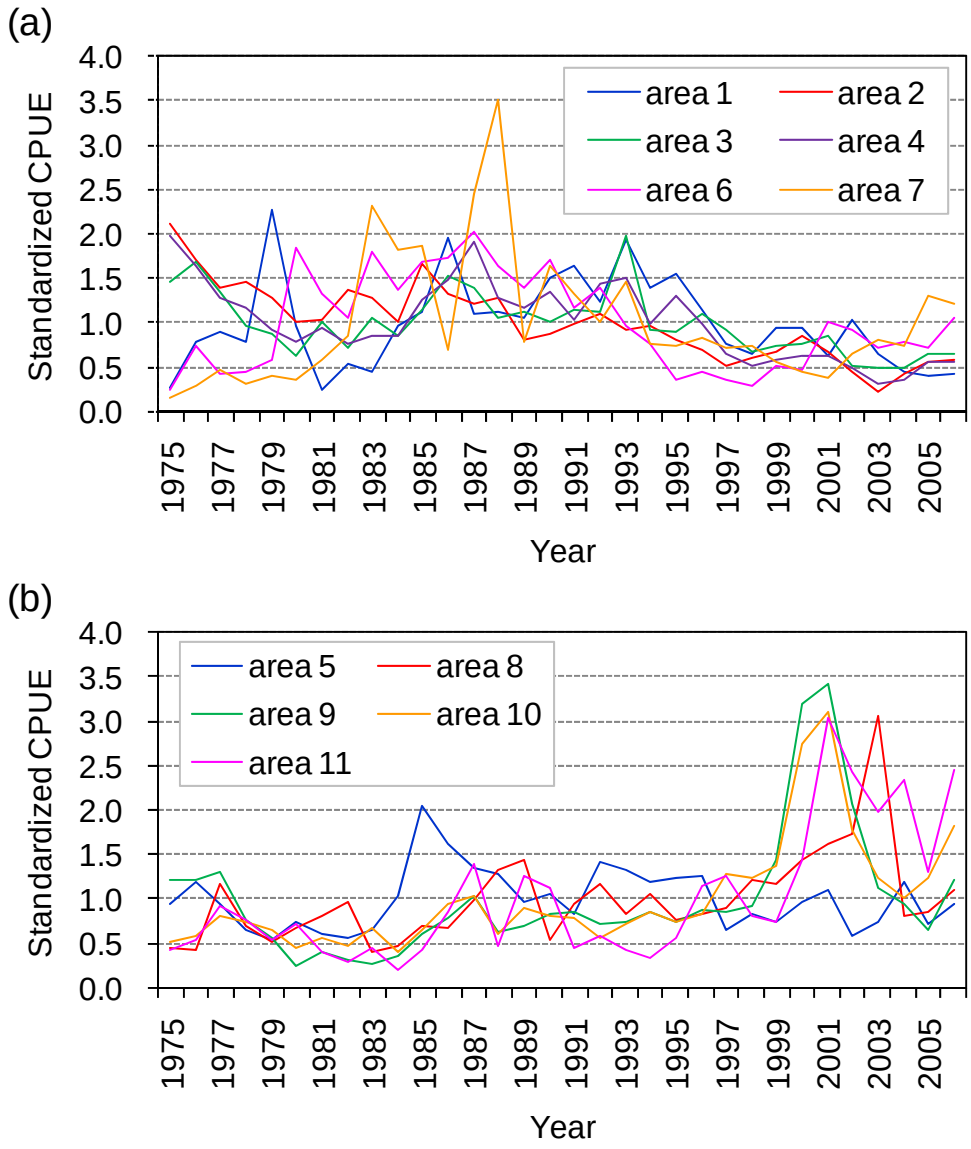

Figure 5. Trends of standardized CPUEs of swordfish caught by Japanese longliners of areas for the single north Pacific stock scenario, (a) areas 1-4 and 6-7, (b) areas 5 and 8-11.

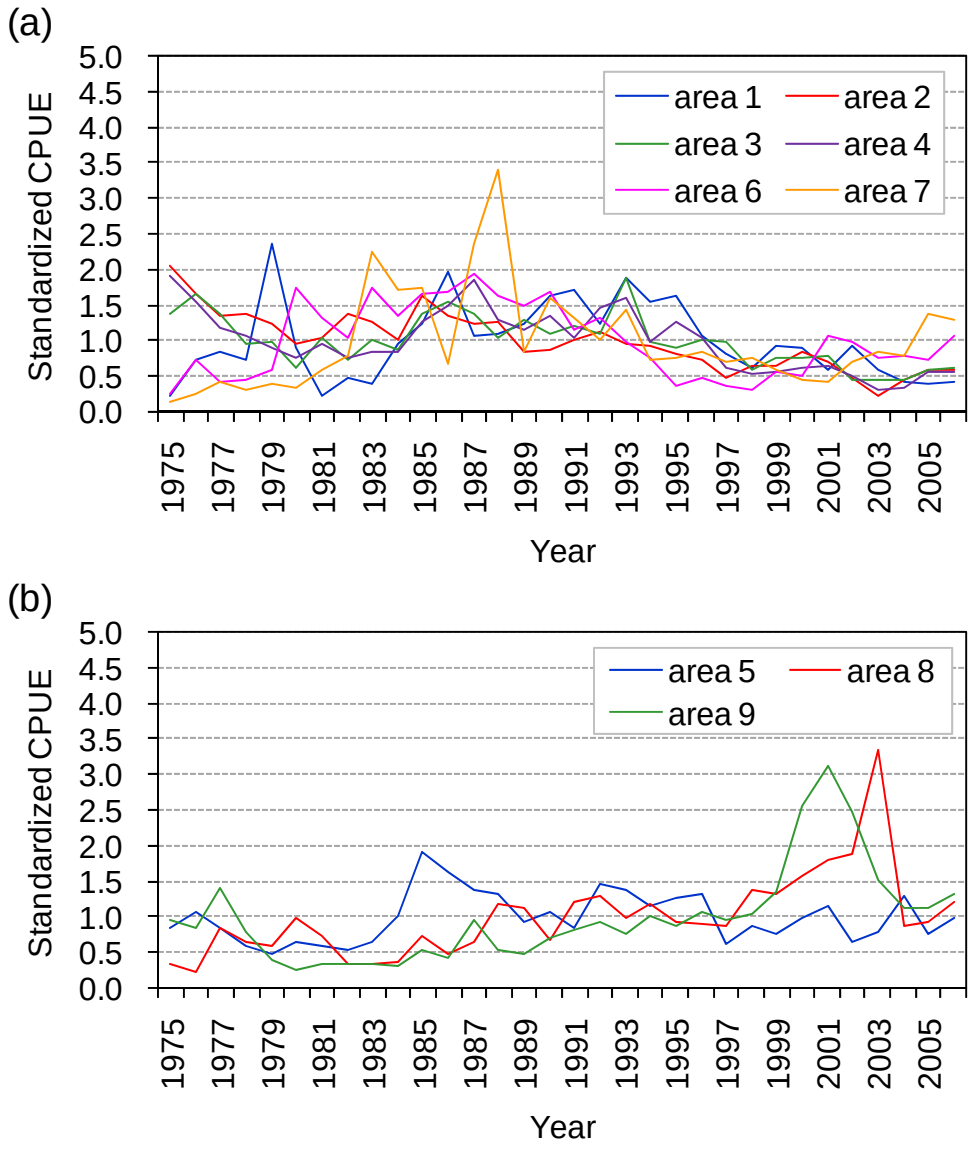

Figure 6. Trends of standardized CPUEs of swordfish caught by Japanese longliners of areas for the NPO stock in the two stock scenario, (a) areas 1-4 and 6-7, (b) areas 5 and 8-9.

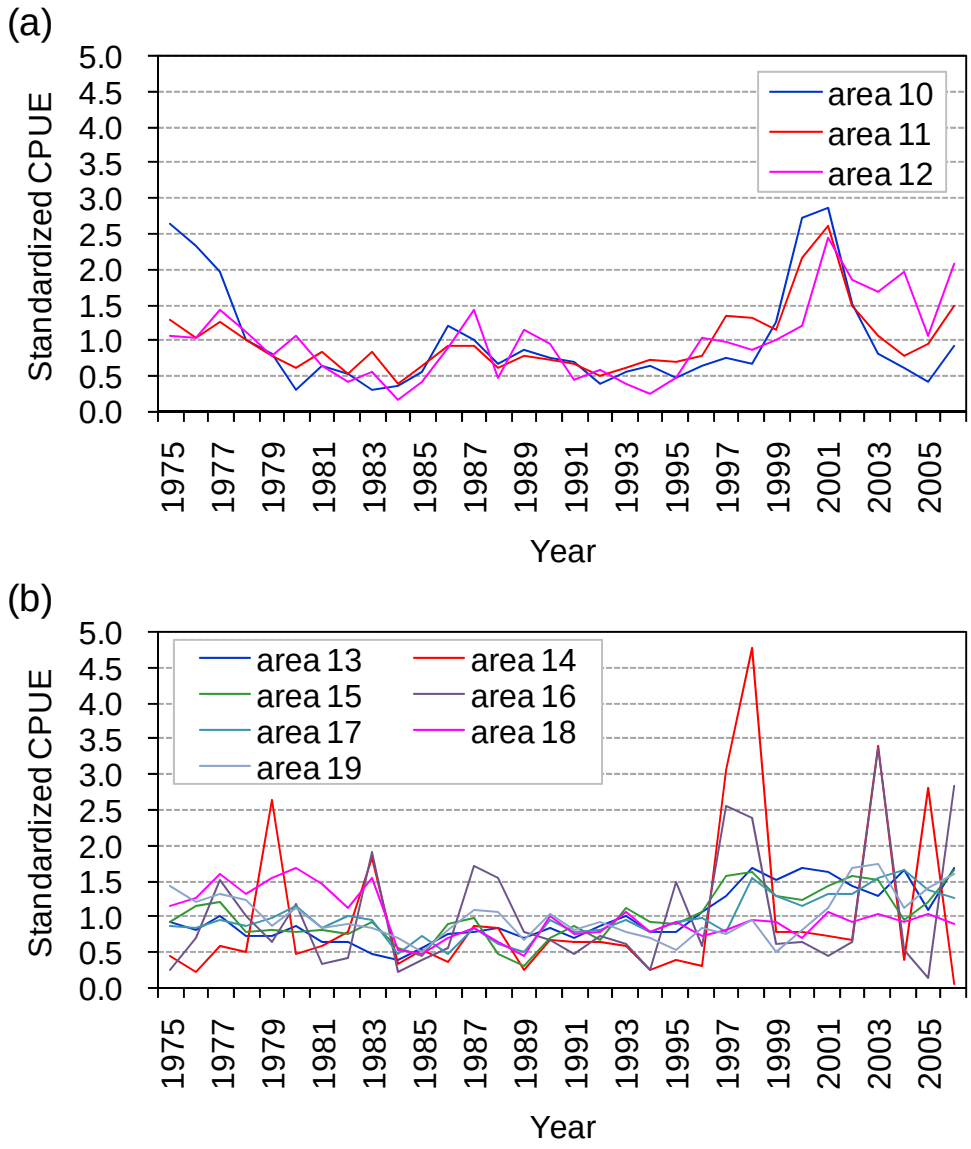

Figure 7. Trends of standardized CPUEs of swordfish caught by Japanese longliners of areas for the EPO stock in the two stock scenario, (a) areas 10-12, (b) areas 13-19.

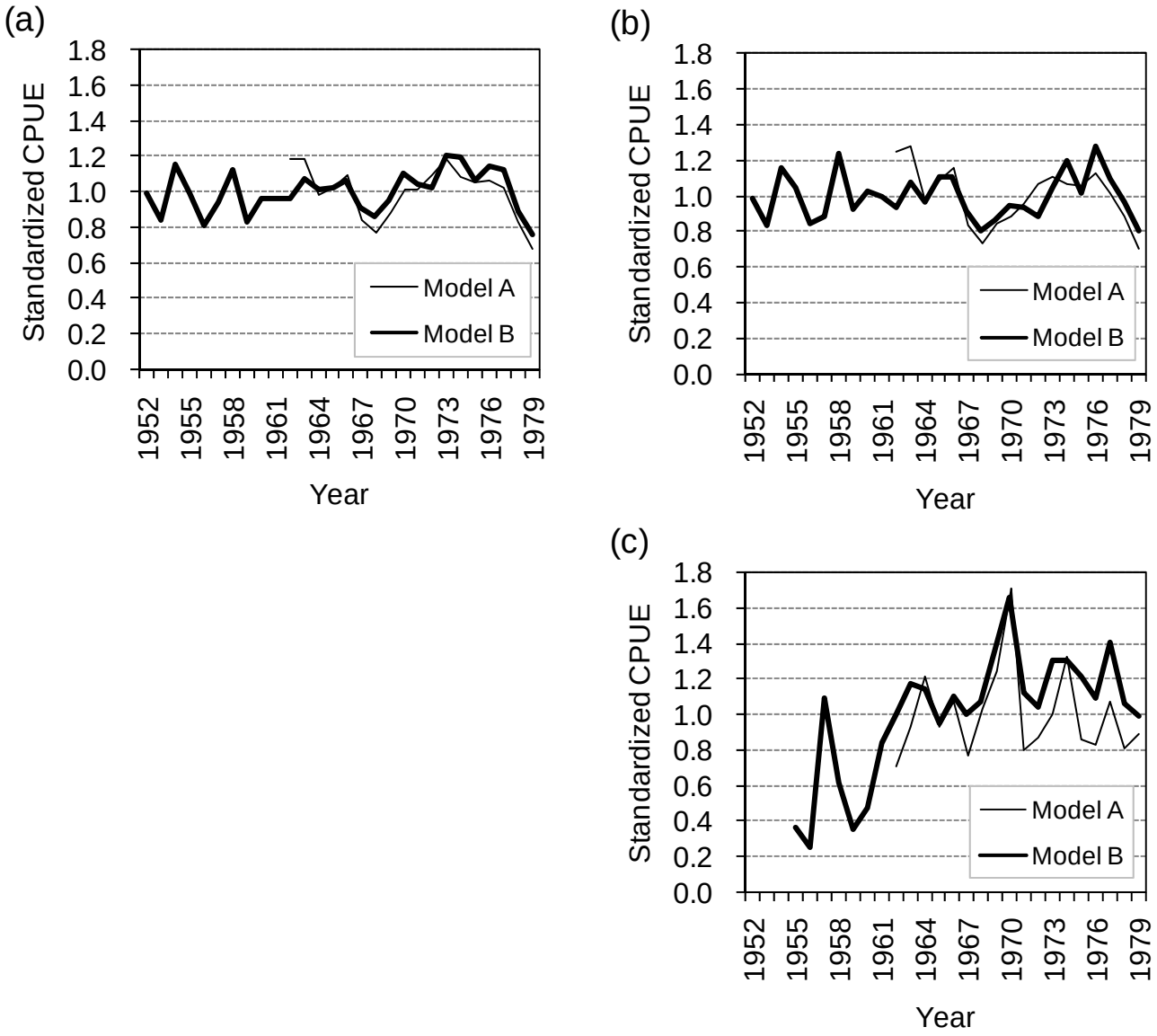

Figure 8. Model comparison for the standardized CPUEs of swordfish caught by Japanese longliners for the period between 1952 and 1979 for (a) the single north Pacific stock scenario, and for (b) the NPO and (c) the EPO stock in the two stock scenario.

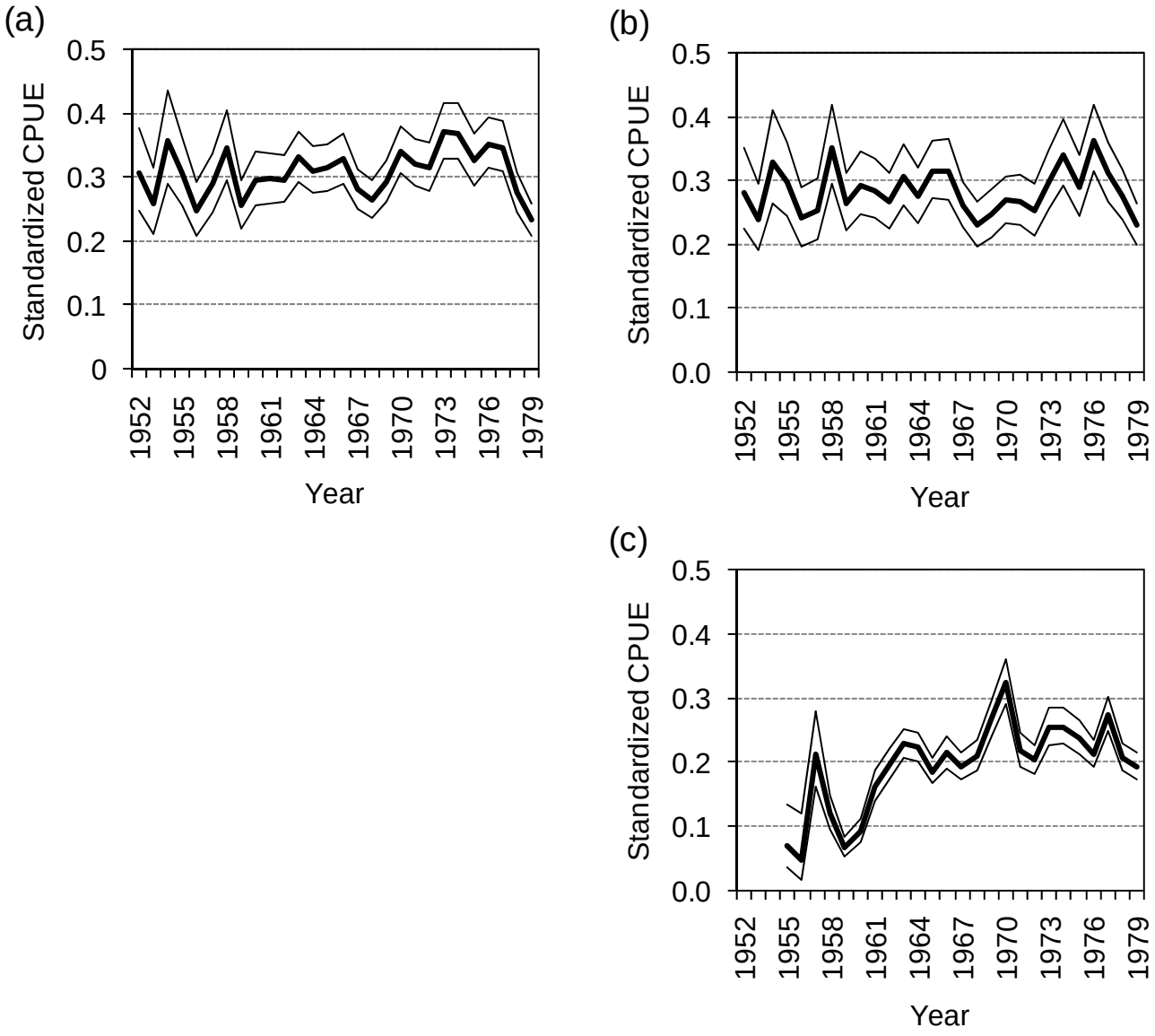

Figure 9. Trends of standardized CPUEs for the period between 1952 and 1979 with their confidence interval of swordfish caught by Japanese longliners for (a) the single north Pacific stock scenario, and for (b) the NPO and (c) the EPO stock in the two stock scenario.

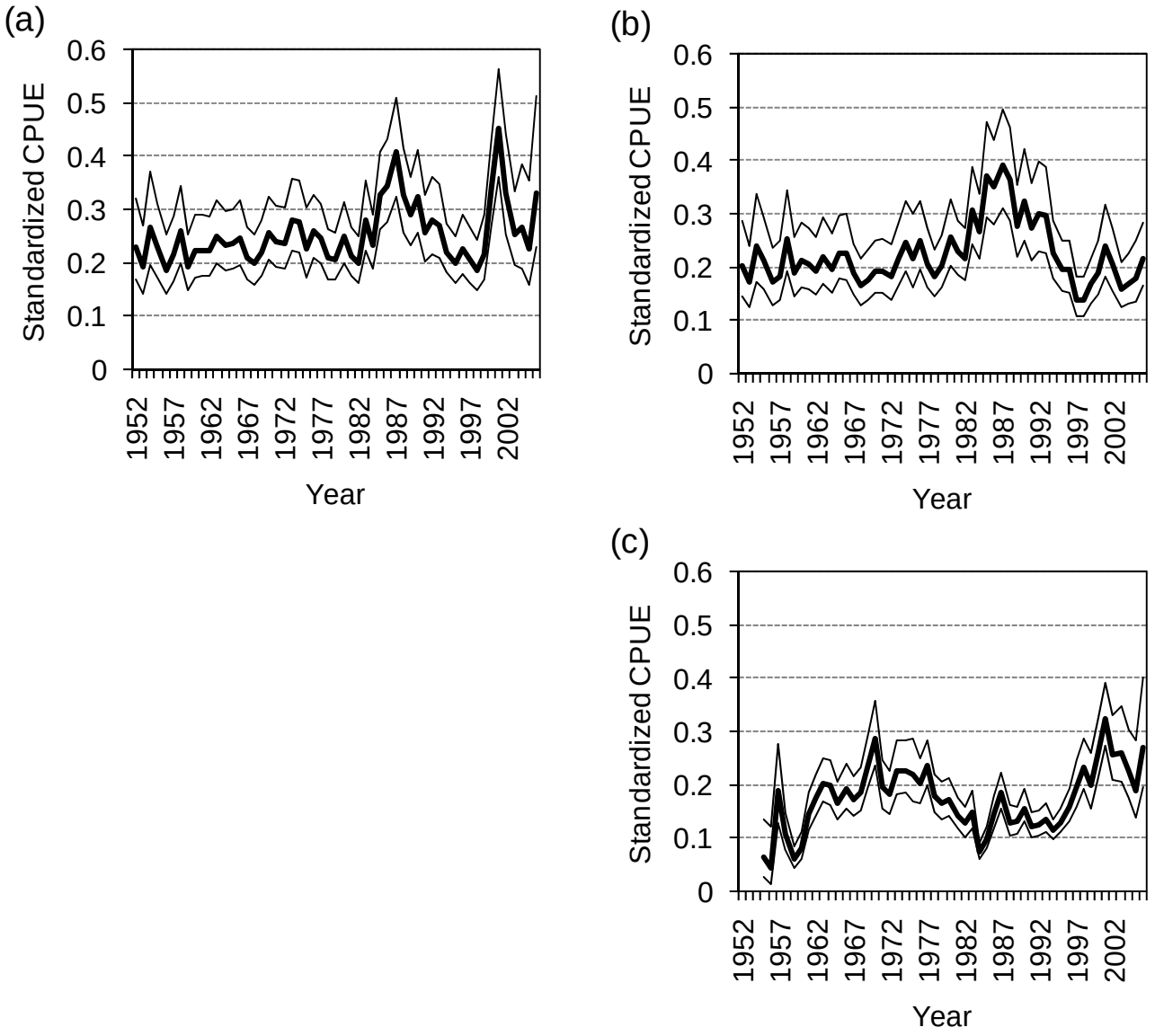

Figure 10. Trends of standardized CPUEs of swordfish caught by Japanese longliners for the period between 1952 and 2006 for (a) the single north Pacific stock scenario, and for (b) the NPO stock and (c) the EPO stock in the two stock scenario, from Figures 3 and 8.

Table 1: Categories of gear configurations

Number	Number of branch lines (HPB)
1	3-4
2	5-6
3	7-9
4	10-18
5	19-22