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

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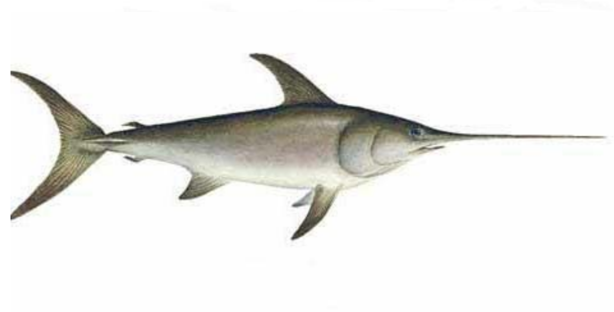

[1]Working document submitted to the ISC Billfish Working Group Workshop, June 11-19, 2008, Abashiri, Hokkaido, Japan. Document not to be cited without authors' written permission.

Introduction

Swordfish (*Xiphias gladius*), *a.k.a* broadbill swordfish, inhabit a wide region of the Pacific between the latitudes of 50˚ N and 50˚ S (Ward et al., 2000). Like other tuna and tuna-like species, swordfish is a highly migratory species with high economic value in both commercial and recreational fisheries. In the Northern Pacific, the annual total catch has stayed around 15,000 mt since 2001. The majority of catch has been taken by longline fishing vessels from Japan, Taiwan and the U.S. (94.5% of the total harvest in 2005) and a minor amount of catch has been taken by Korea and Mexico (Yokawa, 2007). In the Southern Pacific, the swordfish fishery in Chile rapidly developed during the early '90s; the maximum annual catch was 7,255 mt in 1991 and dropped to between 2000-4000 mt during the '90s (Ward et al., 2000). Rising interest in harvesting swordfish calls for an appropriate stock assessment, management for conservation, and the sustainable development of the fishery. However, due to its high migratory nature overlapping the high seas and several jurisdictions, the biology of swordfish in Pacific and its stock status have not been well studied.

CPUE of swordfish from Japanese off-shore and distant water longline fisheries is one of a few available datasets that could provide information on the relative abundance of swordfish in the Pacific. One issue is that nominal CPUE data from such commercial fisheries do not necessarily directly reflect the relative abundance or availability of a fish species in particular fishing grounds, rather they are a mixed indicator of overall abundance, temporal local availability of fish, and fishers' decisions about their operations. For instance, most Japanese longline fishing vessels operating in the Pacific target tuna species such as bigeye, bluefin, yellowfin and albacore tuna. The number of Japanese longline fishing vessels[2] targeting swordfish is limited and their operating area is mainly west of 150˚ E and north of 25˚ N. In the rest of the Pacific, swordfish is not a target species of the Japanese longline fishery. As a result data from log-books of Japanese longline operations contain both target and non-target (i.e., bycatch) CPUE for swordfish. This implies that the nominal CPUE and the distribution of the observed data would be affected by the spatial/temporal choice of gear configurations and fishing grounds for other target species. Therefore, the nominal CPUE from the Japanese longline log-books would bias an index of stock abundance, and removing the effect of the above elements is an indispensable part of the CPUE analysis for the stock assessment of swordfish.

The method of reducing the effects of such factors to refine nominal CPUE is referred to as the standardization of CPUE, and generalized linear models (GLMs) are the most common approach for standardized CPUE (Maunder and Punt, 2004). GLMs are applications of linear statistical

[2] Currently less than 23 vessels from Kesen-numa, which is located in the Northern Honsyu Island of Japan, seasonally target swordfish (*pers.comm.).*

model by reducing effects of various factors on nominal CPUE . Since Gavaris (1980) applied GLMs to look at catch rate and effort in commercial fisheries, GLM analysis and its extensions (e.g., generalized additive models, GAM) have predominated CPUE analysis in fisheries (Hinton and Maunder, 2004). Several CPUE studies of Japanese off-shore and distant water longline fisheries have been done. In the main fishing grounds of Japanese longline operations in the North Pacific, Yokawa (2004) concluded that there were different trends of standardized CPUE between areas south and north of 15˚ N. Ichinokawa and Yokawa (2007) found relatively stable trends of standardized CPUE of swordfish in the north Pacific. Yokawa (2007) found a sudden decrease in CPUE in 1999 in the Eastern Pacific Ocean (EPO), a drop after 2001 in the Northern EPO, and a relatively stable trend for the South EPO.

The object of this document is to update the CPUE analysis of the Japanese offshore and distant-water longline fishery done by Yokawa (2007) and Ichinokawa and Yokawa (2007). To do so, this study integrated areas covered by the aforementioned studies and added newly available data for 2006 for Ichinokawa and Yokawa (2007) and 2004-2006 for Yokawa (2007). Note that this is a tentative report for the CPUE analysis of the Japanese swordfish fishery rather than the final.

Materials and Methods

Japanese longline data

This study adapted data compiled over 32 years from logbooks from the Japanese offshore and distant water longline fishery (1975-2006) by the Agency of Fisheries, Japan. These data included species-specific catch for tuna (e.g., big eye, blue marlin), tuna-like species (e.g., marlin), and sharks, and operational descriptions (e.g., number of hooks, gear configurations, locations) for each longline set. This data were rectified on 5x5 degree grids, years (1975-2006), seasons (January-March, April-June, July-September and October-December) and gear configurations. 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” and intend to make hooks stay in surface. The six categories of the gear configurations employed in this study are presented in table 1.

Observations which had less than 3000 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 123,374. The CPUE for each grid cell over time (32 years and 4 seasons) was calculated by the number of swordfish caught divided by the number of hooks as the unit of fishing effort.

Spatial stratifications

We spatially stratified the study area to articulate heterogeneity of the fishing grounds in model representations. Two types of spatial stratification were applied in this study, (i) 21 area stratifications for the entire Pacific (Area 1-21 Figure 1.a) and four blocks (Block 1-4 Figure 2.b). First, this study developed one GLM model by using 21 area stratifications based on historical spatial distributions of the average CPUE distributions. Based on CPUE information, Ichinokawa and Yokawa (2007) modified previous area stratifications for the Northern Pacific developed by Saito and Yokawa (2004). Yokawa (2007) used CPUE data to develop areas of spatial stratification for the EPO. Because the primary purpose of this paper is to update their studies, this study integrated the previous spatial stratifications of Ichinokawa and Yokawa (2007) and Yokawa (2007) in the Pacific. Secondly, this study developed separate GLM models for four area blocks. Four area blocks have been identified as historically heterogeneous fishing grounds for swordfish; these areas are also defined by their associated oceanographic and topographical features. Block 1 represents the main fishing ground for Japanese offshore longline operations which is an extension grounds of the Sanriku coastline of Japan (Area 1-5). Block 2 represents an area near Hawaiian fishing grounds in which Hawaiian longline vessels are also operating. Block 3 represents a fishing ground with an upwelling ecosystem. Block 4 represents a fishing ground for the aforementioned Chilean longline vessels and their extensions.

Ichinokawa and Brodzia (2007) developed a 'tree-GLM' algorithm to find the set of spatial stratifications which produce a statistically better fit to nominal swordfish CPUE data for Japanese longline vessel data in the North Pacific. While they acknowledged bias-variance effects due to the increase in the number of areas as parameters, they concluded 27 area stratifications were the best choice to fit nominal CPUE from the log-book data. This study aims to investigate a wider area in the Pacific than their study and will leave their 27 area stratifications for future studies to test.

Model development

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;

$$\ln\left(CPUE_{ijkl} + 1\right) = y_i + q_j + g_k + a_l + (interaction\ terms) + \epsilon$$

For each set of candidate explanatory variables, as a goodness-of-fit measure to select a model, the Akaike Information Criteria (AIC, Akaike 1983) and Bayesian Information Criteria (BIC, Shwarz 1978) were computed.

$$\mathrm{AIC} = -2\log L(\hat{\theta}) + p$$

Where $L(\hat{\theta})$ is the maximum likelihood (ML) and *p* is the number of parameters. As ML increases as the number of samples increase, the penalty effects of *p* vanish ($2\log L(\hat{\theta}) \gg p$). The AIC is equivalent to the ML (Shono, 2005). This implies that the parameter penalty term in the AIC would not be effective for a large sample size. While a model selected by AIC may not be sensitive enough for over-parameterizations with a large number of samples, the Bayesian Information Criteria (BIC) includes the effect of the sample size (*n*) in its penalty term.

$$\mathrm{BIC} = -2\log L(\hat{\theta}) + p\log(\mathrm{n})$$

Since this study involves a relatively large sample size (n=123,374), both criteria are applied and examined for model selection.

Results

The total number of operations and swordfish caught for each area over time

The number of operations of Japanese longline vessels was distributed across all areas from 1975 to 2006(Figure2). The main fishing grounds for Japanese longline vessel targeting swordfish are in areas 1-7. These areas showed a continuous diminishing in the number of operations over time. The number of operations in area 13 has dominated total operations in all years. Area 13 is one of the active fishing grounds for big eye tuna. Operations in Area 13 and the adjacent Area 10-18 would be activities directed toward big eye rather than swordfish. For all years, the greatest numbers of swordfish were caught in Areas 2, 4, and 6 (Figure 3). In Area 2 and 4, a continuous trend of diminishing catch has been observed since the 1980's. The total catch in Area 6 showed a rapid decrease in the late 1980's, but has increased since 2000. The diminished catch in Area 2 and 4 gave fishery operators targeting swordfish incentives to expand their fishing grounds west. The trend of increased catch in area 6 might be the result of this western expansion of swordfish fishing grounds.

Changes in gear configurations

Proportionate changes in gear configurations revealed apparent efforts to shift from shallower gear sets (Gear 2) to deeper gear sets (Gear 5 and 6) in the Pacific (Figure 4). Furthermore, Gear 2, 3 and 4 disappeared during the 90's, and gear configurations are now polarized toward either shallower sets (Gear 1) or deeper sets (Gear6. This is the result of the development of area specific gear configurations for longline operations (Figure 4). While in Area 1-4 and 6, which are swordfish targeting fishing grounds, the proportion of Gear 1 has increased, the rest of the areas in Pacific have shifted to deeper gear configurations, mostly Gear 5 and 6.

Standardized CPUE changes over time

The GLM (Table 2) was fitted to the data. The AIC and BIC were calculated for both models. Since the amount of data and potential explanatory variables are large, we adopted the BIC as criteria to sufficiently reflect the penalty of over-parameterization. Consequently, Model 3, which has four interaction terms (Year*Area, Quarter*Gear, Quarter*Area and Gear*Area), was selected as the final area model. The results of an ANOVA indicated that Model 3 is statistically significant (Table 3). Although we applied BIC to avoid over-parameterization, yet a potential issue for this model is over parameterization due to interaction terms of 21 area stratifications. All models exhibited similar trends and there was no significant difference in the trends of standardized CPUE from these models (Figure 5). In addition, five models were selected for four blocks, respectively (Table 4). Because of the more dynamic changes in gear configurations in Block 3, the model was divided into two time periods; (i) a 1975-83 model which excluded gear 6 and (ii) a 1984-2006 model which excluded Gear 1.

Histograms of the distribution of standardized residuals for Areas 1-4 and 6 exhibited skew, and quasi-multivariate normal distributions emerged for all other areas (Figure 6). This skew occurs because of the large portion of data representing zero catch. For example, 45.12% of data in Area 8 represents zero catch. Figure 7 shows histograms of the distribution of standardized residuals when zero catch data were excluded. These histograms were not extremely different from Gaussian distributions, and verified the effect of zero catch in the distributions of standardized residuals. The overall effects on the area model are the same as found in Ichinokawa and Yokawa (2007). Shallower gear (e.g., Gear 1) exhibited higher CPUE. In the block models, while Block 1 and 2 exhibited the same trend which validated the advantage of shallower gear in the swordfish fishery, Block 3 and 4 did not demonstrate this apparent trend of advantageous gear configurations. This is an additional verification that swordfish was not targeted in Block 3 and 4. Seasonal (quarter) effects for the area model show high CPUE in quarter 1 (January – March) and quarter 4 (October- December). In the block models, this apparent trend was not observed except in Block 2.

In the area model, the overall historical trends of standardized CPUE in each area varied and could not be generalized to one trend for swordfish CPUE in the Pacific. Area 1 and 2 show a trend of relatively minor decreases in CPUE since the early 90s' (Figure 11). Ichinokawa and Yokawa (2007) showed results for Area 1 and 2 combined as demarcated in this study and did not recognized major changes in trends in CPUE. Our study confirmed their results. When this study is updated with data from 2006, it suggests that noticeable changes did not occur in 2006. Area 3, 6 and 7 showed a trend of increased CPUE in the past four years. Yokawa (2007) showed a decreased trend in the northern and southern EPO since 2001. Our area model did not explicitly show this trend (Area 8-17 for the northern and Area 18-20 for the southern EPO.) Area 9 and 10 showed a similar sudden increase and decrease between 1999 and 2004, then an increase in CPUE from 2005 to 2006. Area 13, 15, 17 and 19 showed a trend of continued increase in CPUE since 1990.

For the block model, the area-averaged standardized CPUE for Block 1 and 2, which is weighted by the approximate size of the area, showed stable trends since 2000 (Figure 15). These results are consistent with Ichinokawa and Yokawa (2007). Additional results from 2006 in Block 1 and 2 (Area 1-6) still followed these stable trends. Results from Block 3, which represents the North EPO, confirmed a decreased trend in CPUE since 2001 found by Yokawa (2007); updated data for 2001-2006 suggested a recovery given a trend toward higher CPUE. In the Southern EPO, the averaged standardized CPUE for block 4 suggested a relatively stable trend from 1975 to 2006. This result is consistent with that found in the southern EPO by Yokawa (2007).

Discussion

This document reported updated standardized CPUE for swordfish from Japanese longline fishing vessel operations. Our results utilized two spatial stratifications over the fishing grounds. We confirmed results from previous studies and suggested minor changes for years with updated data. The results presented here is tentative rather than final and further analysis is required to develop the depth of the analysis. CPUE trends in the area model varied for each area. This variation indicates the difficulties in applying spatial stratification to CPUE analysis. One potential issue could be the spatial resolution of data. Ichinokawa and Brodziak (2007) developed an algorithm to detect statistically significant sets of spatial stratification to fit to swordfish CPUE data. They found that an increased number of areas improved the fit for nominal CPUE data. In this study, the data was aggregated into 5 by 5 degree cells. Using the spatial area as a minimum unit to cluster fishing grounds may not be sufficiently small enough to represent the selection of fishing grounds by fishing operators. Smaller spatial resolution and individual vessel identification information would reveal information associated with the choice of fishing grounds by fishermen, e.g., costs incurred from home ports and potential target species as driven by the ex-vessel price of alternative catch and expected abundance by skippers. These improvements may be possible by analyzing original log book data and with additional information associated with the economics of fishing vessel operations.

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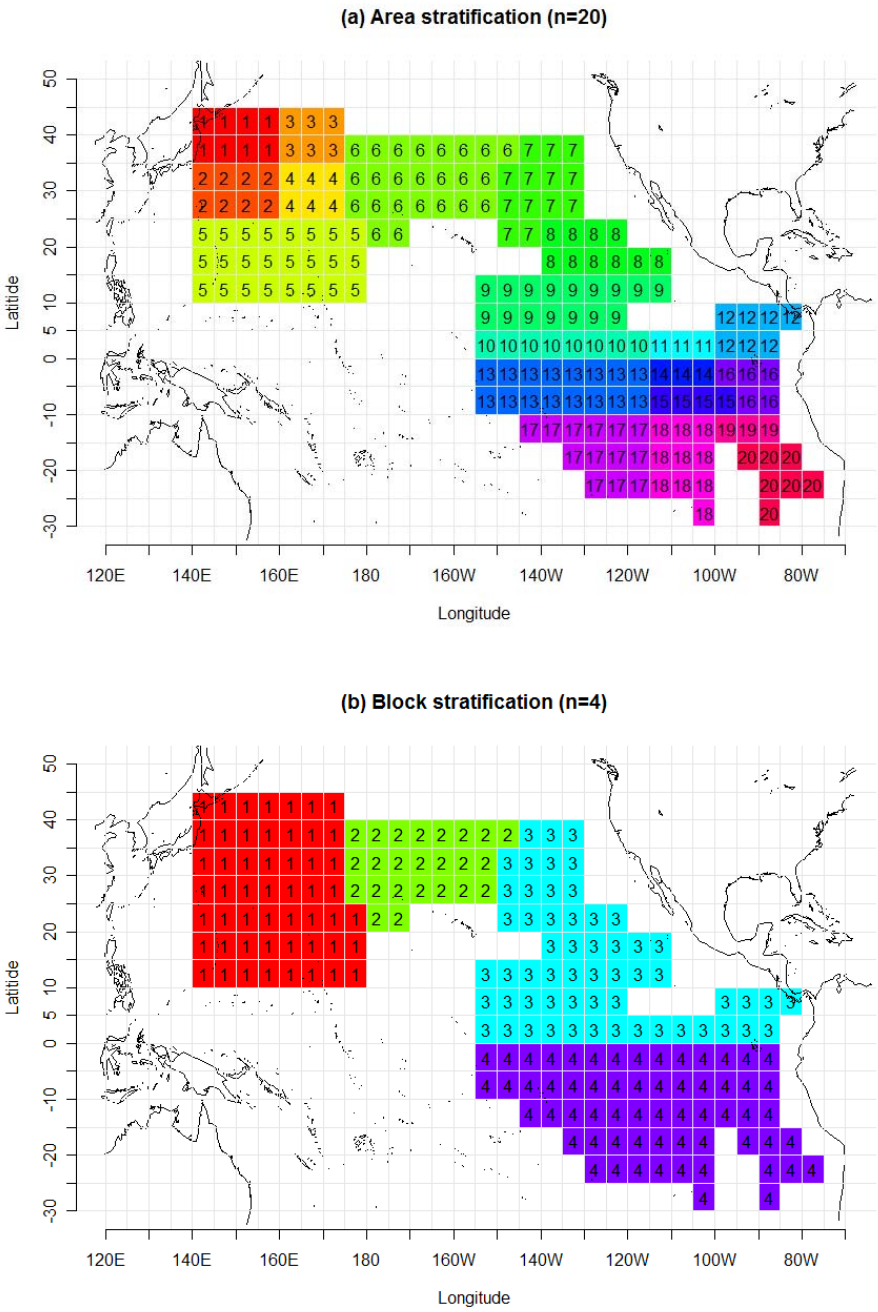


Figure 1: Two types of spatial stratification applied in this study (a) 20 area and (b) 4 block stratifications.

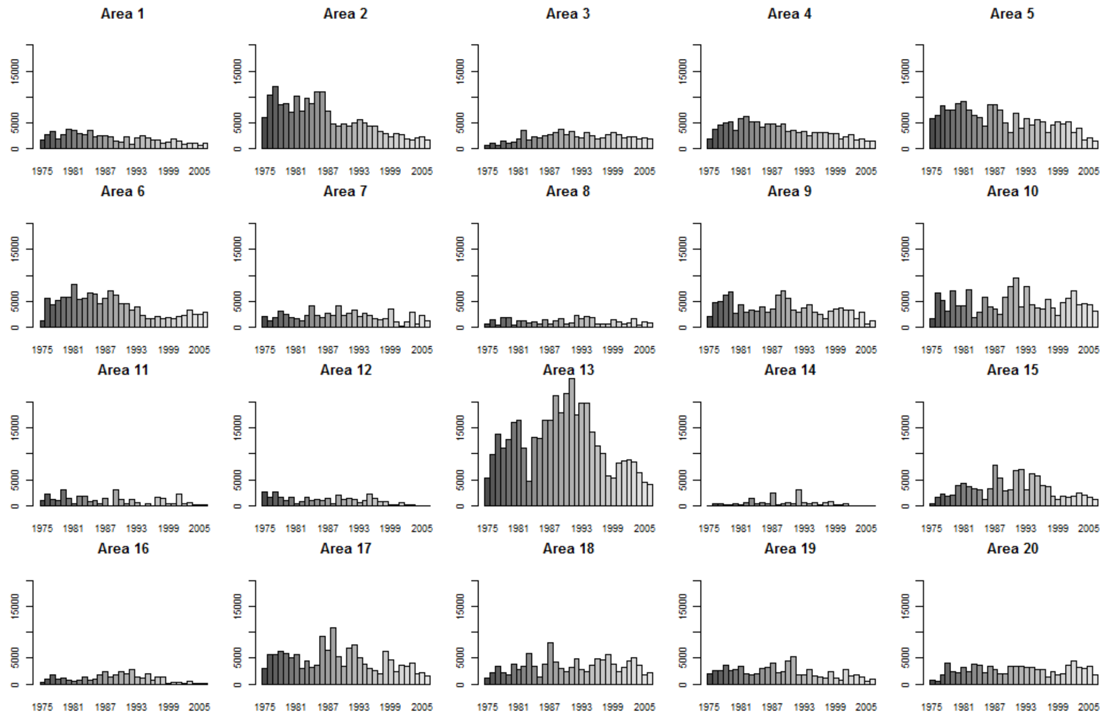


Figure 2: Historical changes in the number of operations for each area

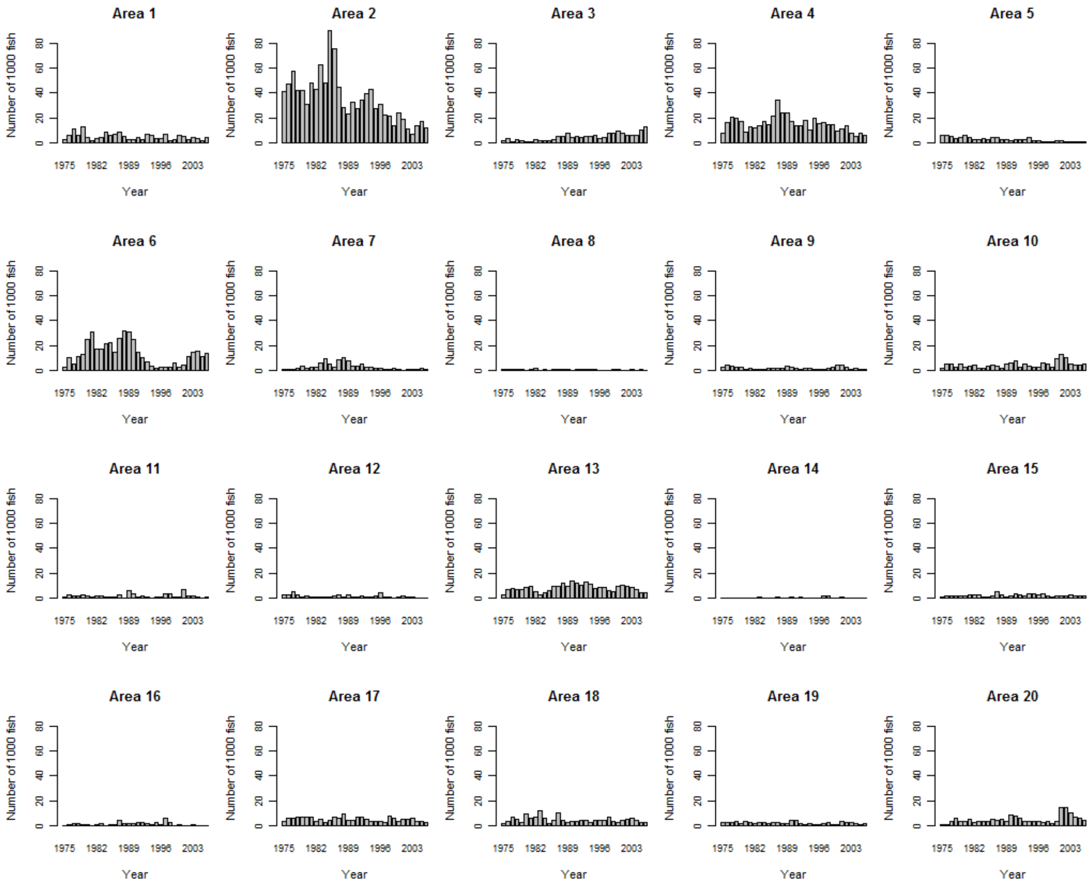
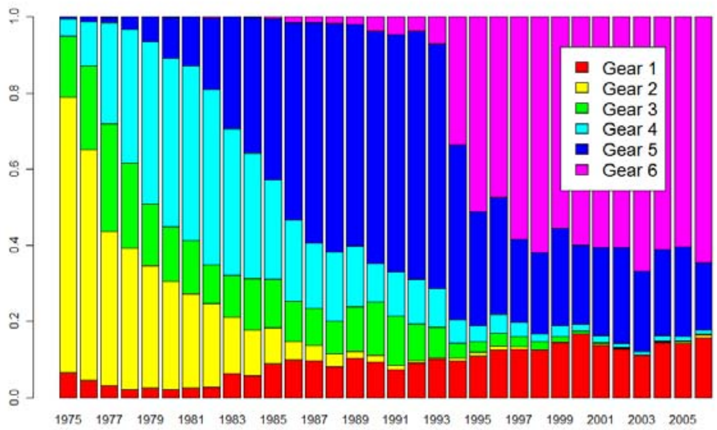


Figure 3: Number of swordfish caught in each area

(a) Historical changes in the proportion of gear configurations for all areas



(b) Historical changes in the proportion of gear configurations in each area

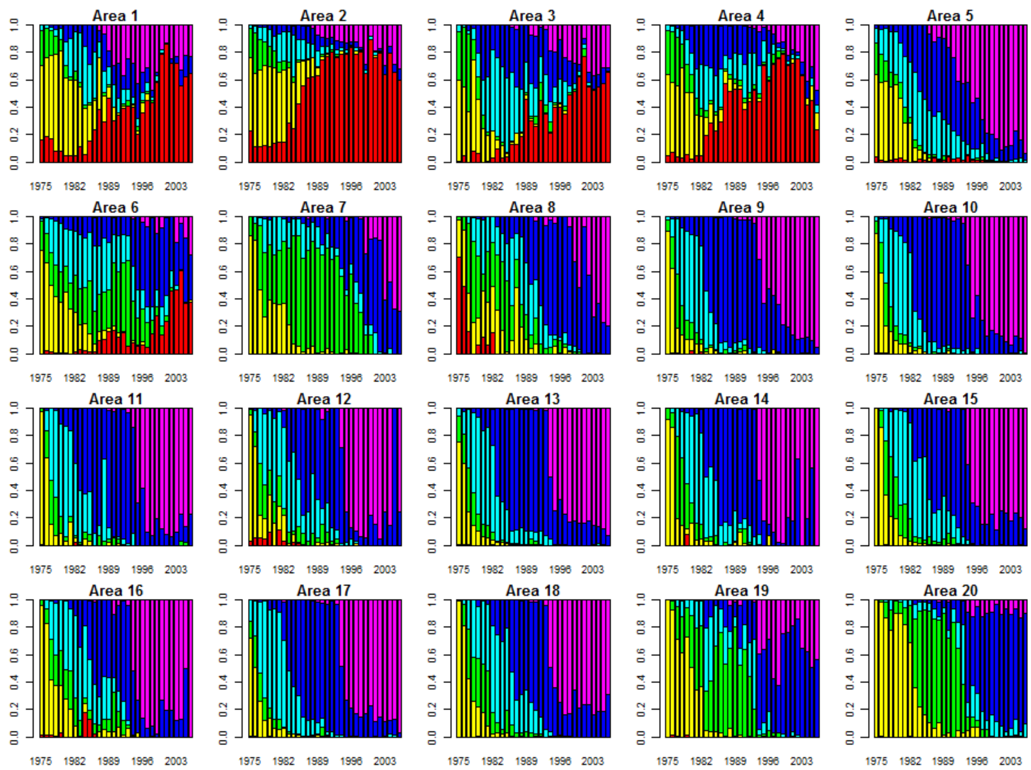


Figure 4: Historical changes in the share of gear configurations for (a) all areas and (b) each area.

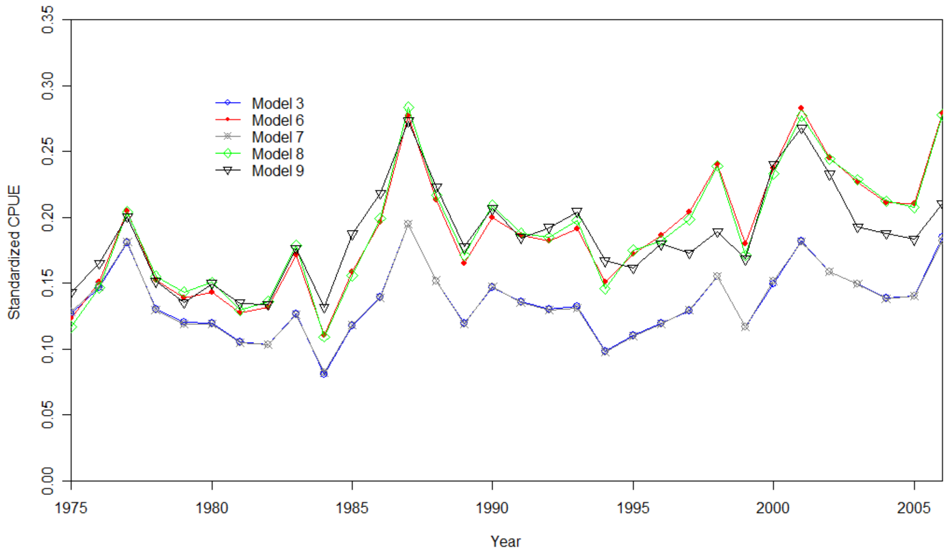


Figure 5 : Model comparisons from table 2.

(a) Including zero catch

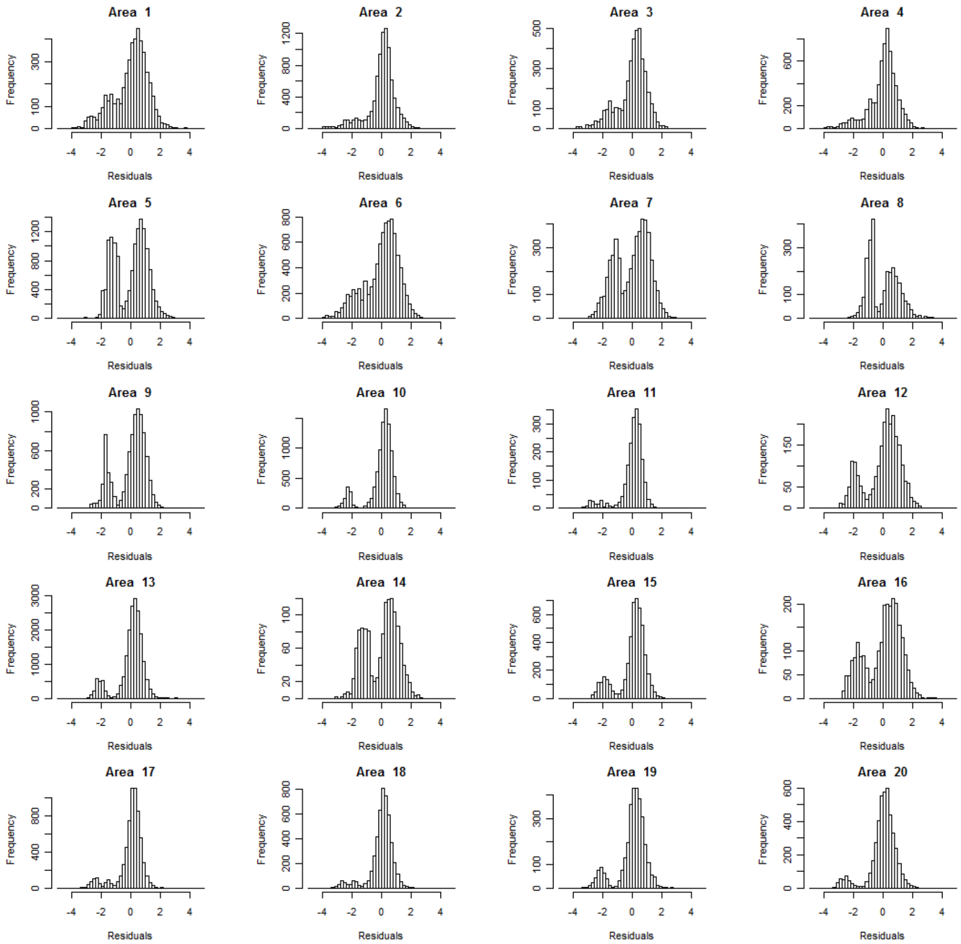


Figure 6: The distributions of residuals for each area (a) including and (b) excluding zero catch data.

(b) Excluding zero catch

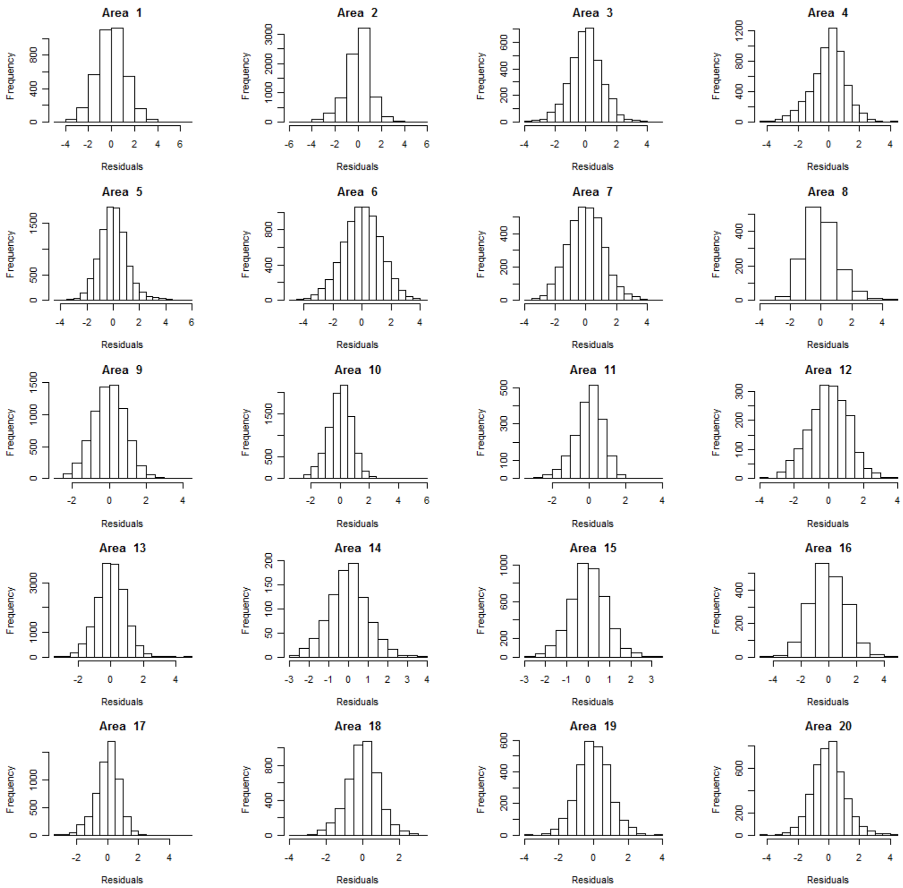


Figure 7: The distributions of residuals for each area (a) including and (b) excluding zero catch data.

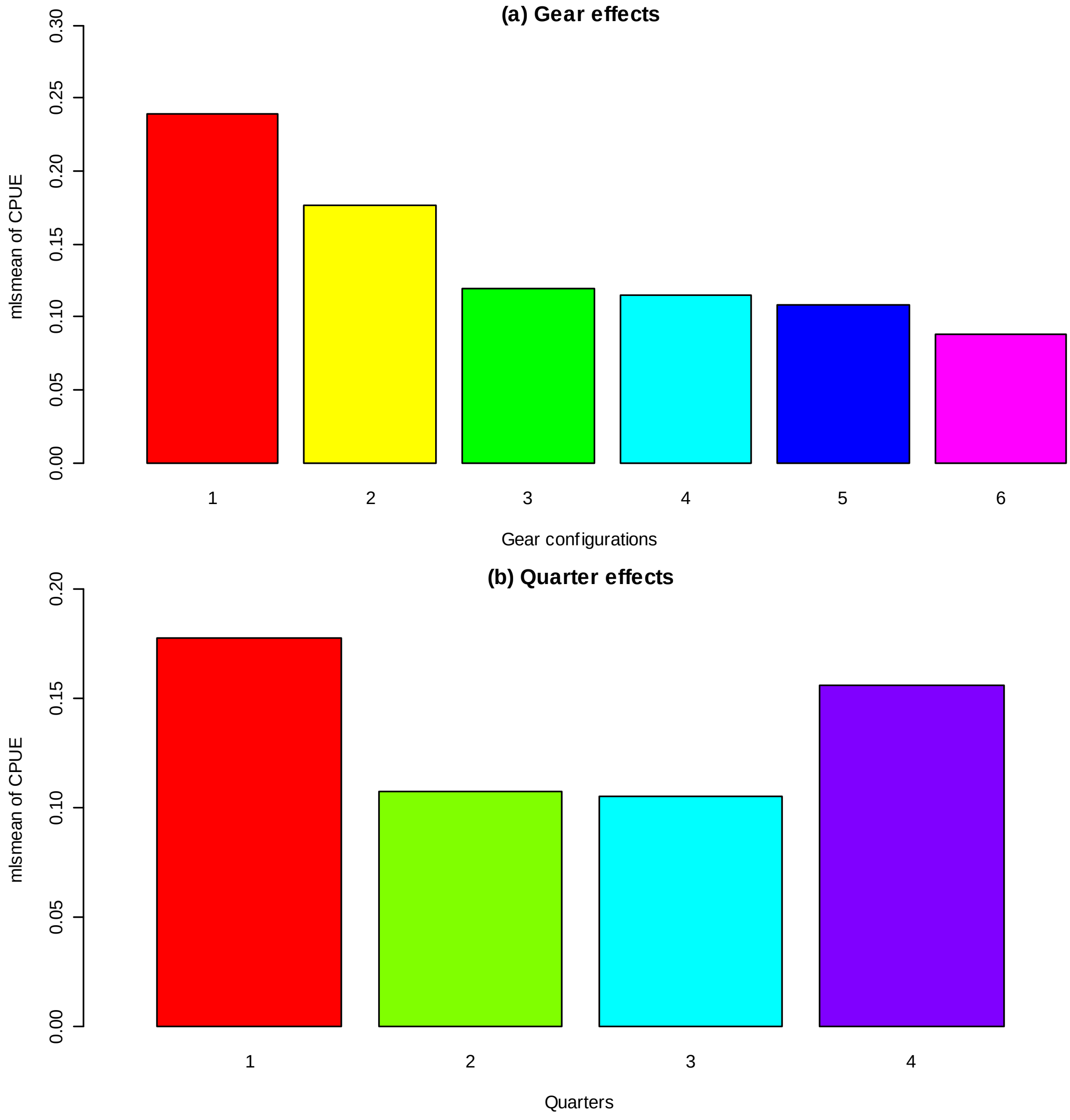


Figure 8: (a) Gear effects and (b) seasonal (quarter) effects on standardized CPUE for the area model.

(i) Gear effects

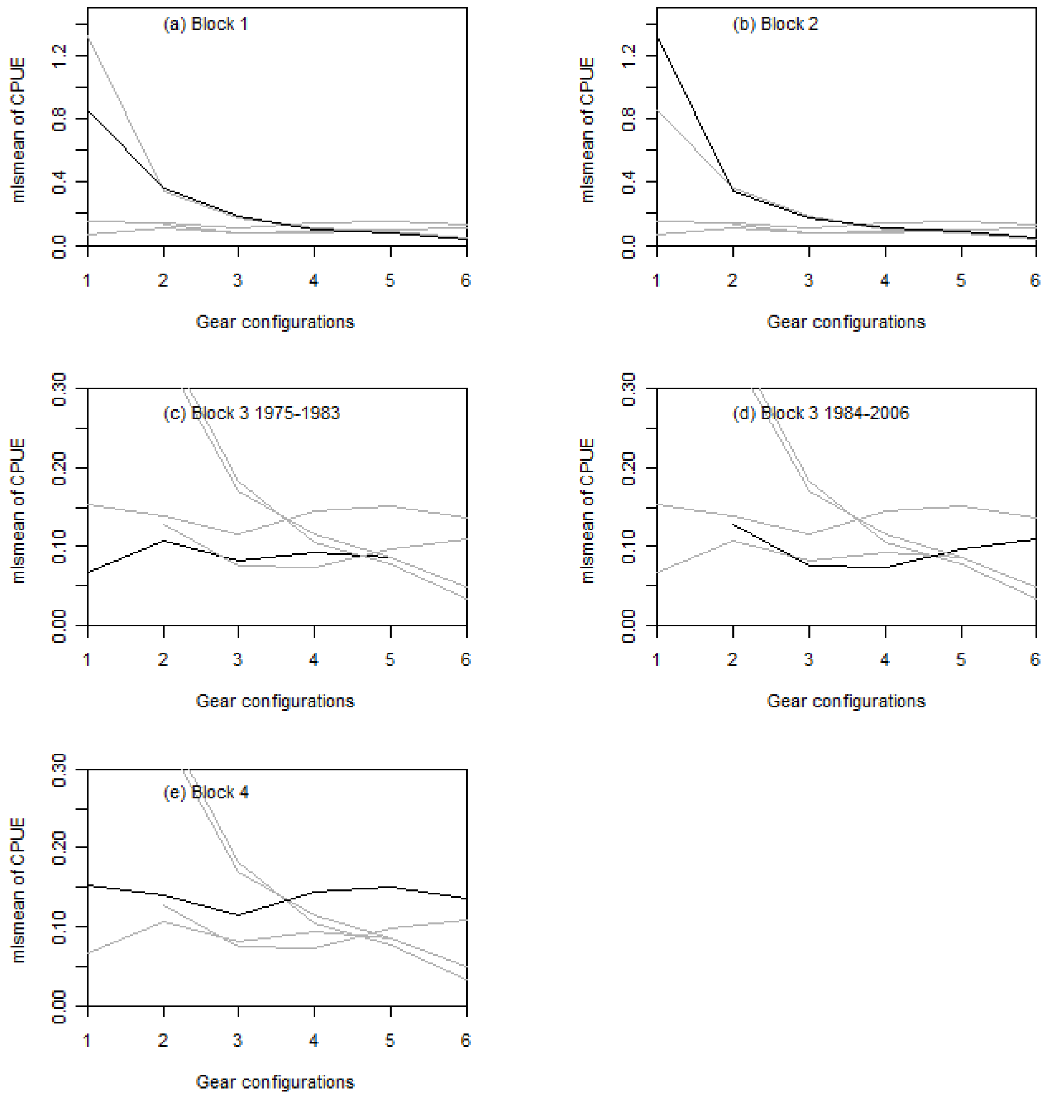


Figure 9 : (i) gear and (ii) seasonal (quarter) effects on standardized CPUE for the block models

(ii) Seasonal effects

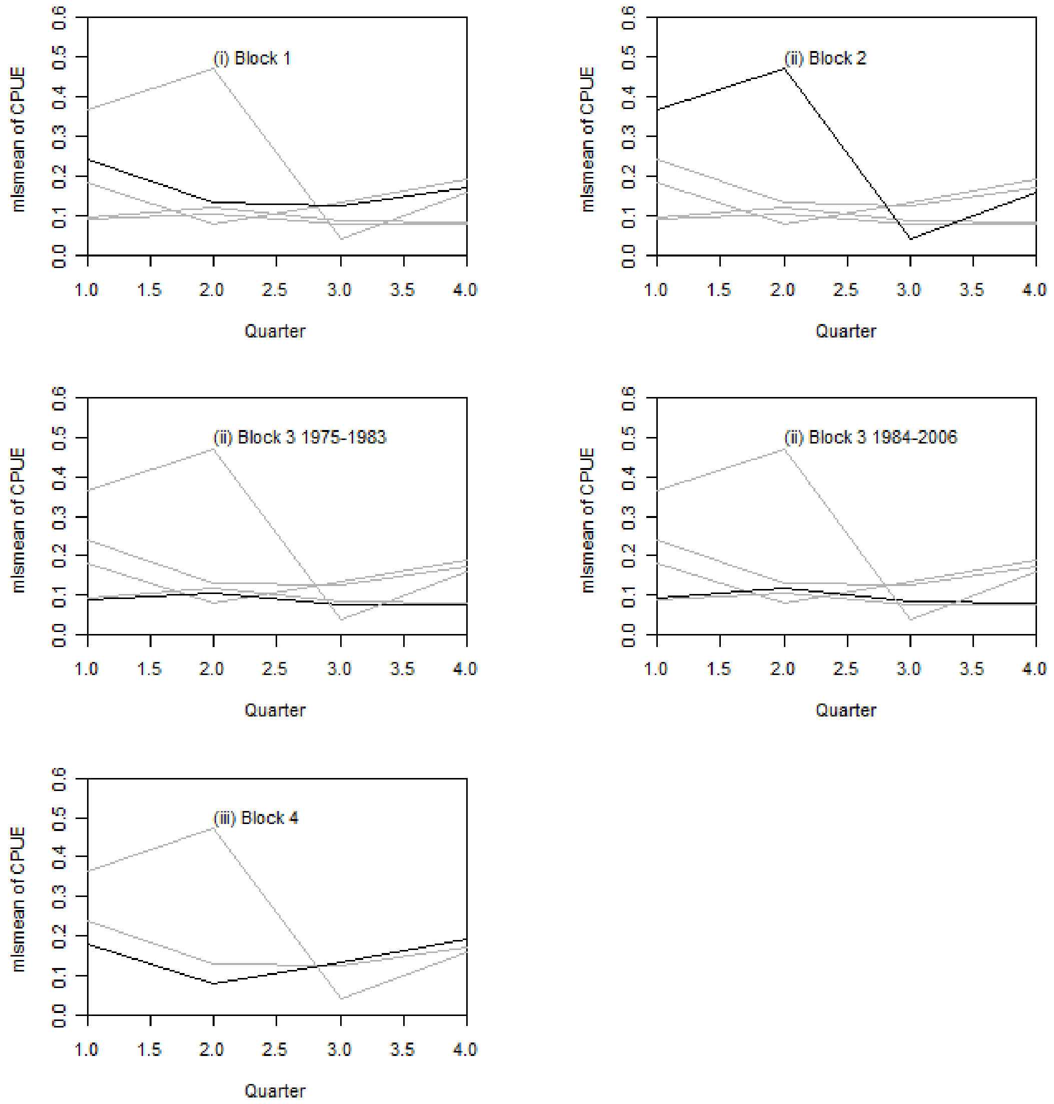


Figure 10 : (i) gear and (ii) seasonal (quarter) effects on standardized CPUE for the block models

(a) Standardized swordfish CPUE with the branch line data for 1975-2006 for areas 1-5

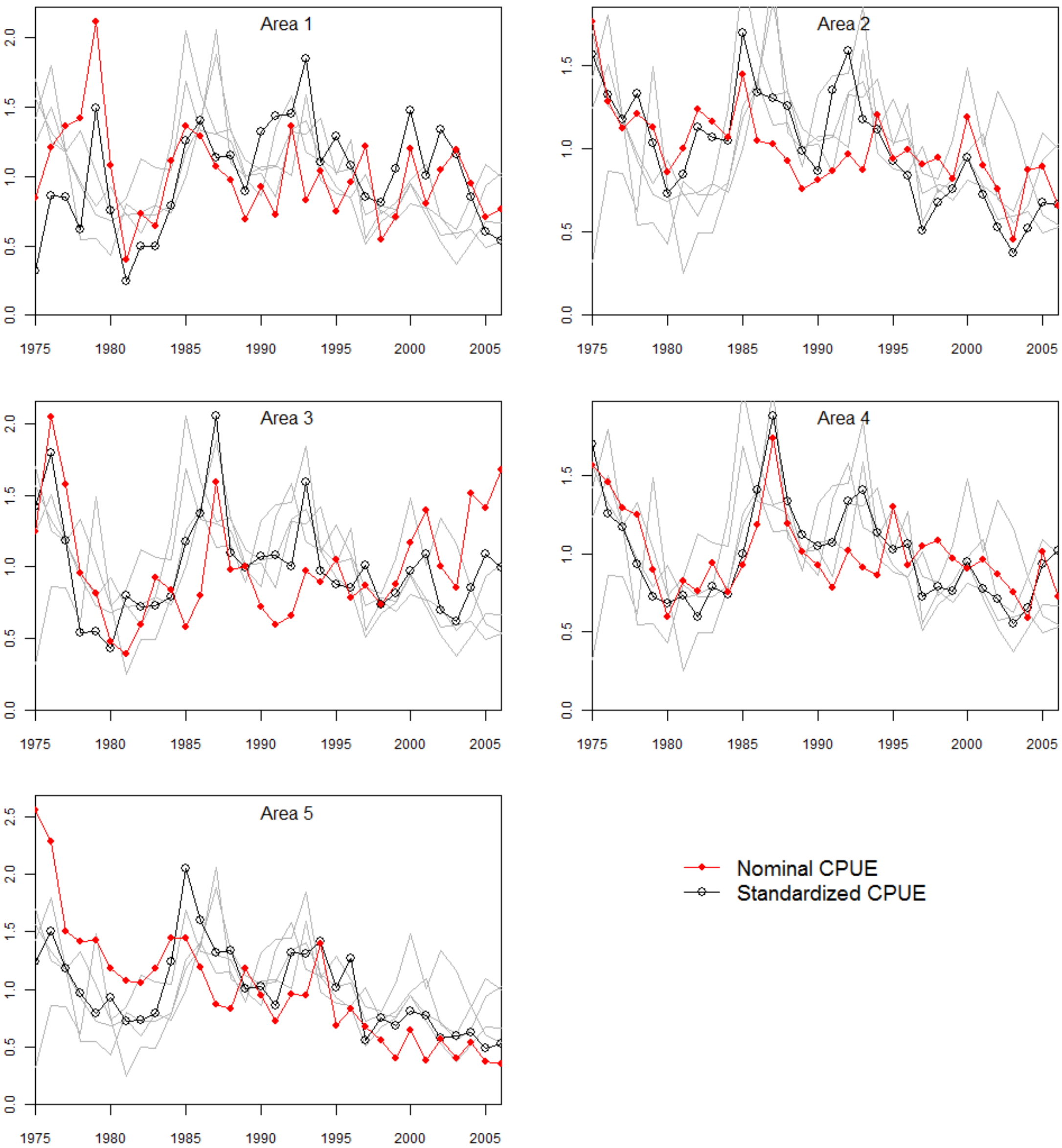


Figure 11: Standardized swordfish CPUE from 1975-2006 in (a) areas 1 -5, (b) areas 6-10, (c) areas 11-15 and (d) areas 16-20. The black and red line in each figure indicates standardized and nominal CPUE respectively. The light gray lines indicate standardized CPUE from other area. All CPUE were normalized by dividing its average over time.

(b) Standardized swordfish CPUE with the branch line data for 1975-2006 for areas 6-10

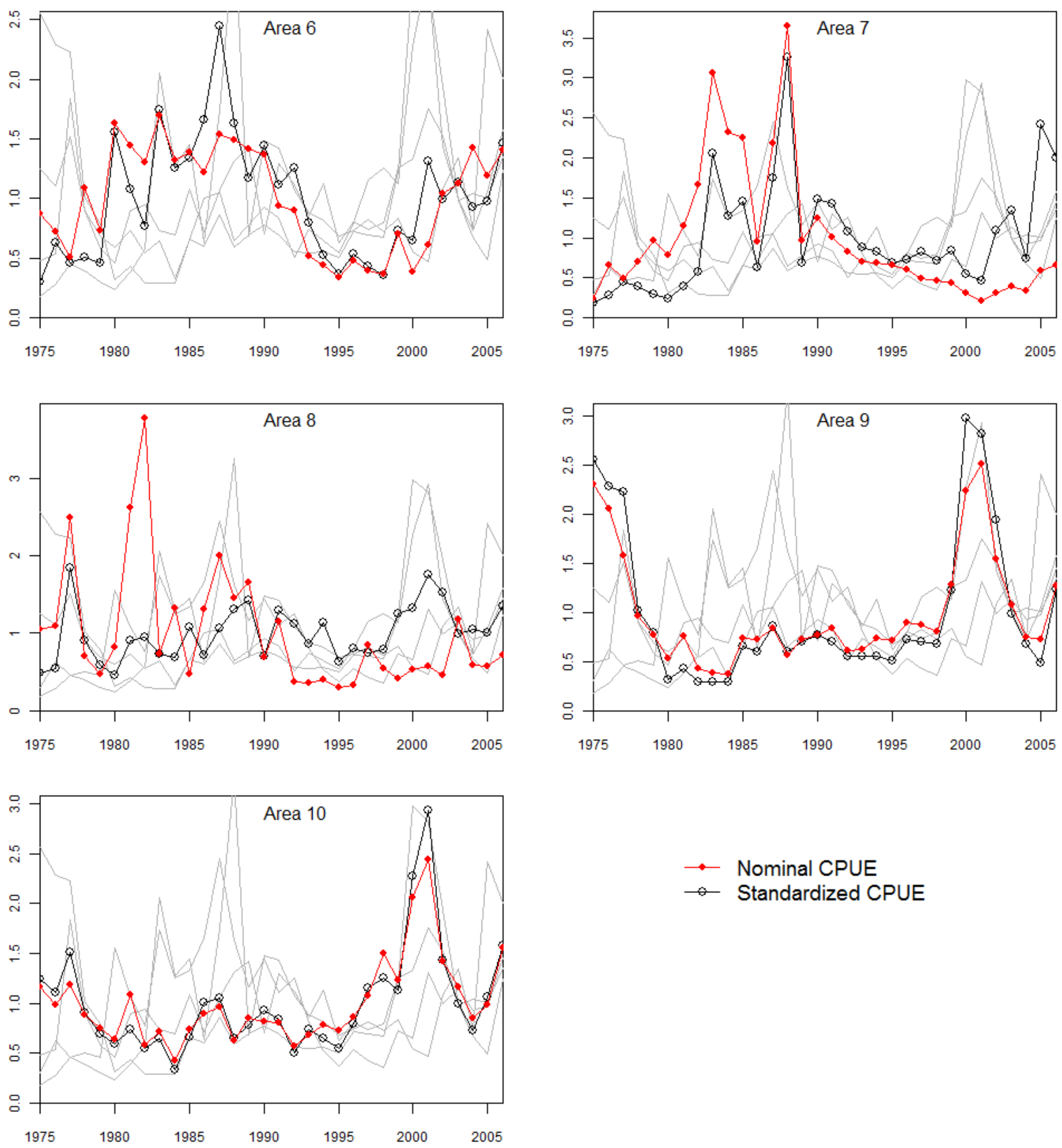


Figure 12: Standardized swordfish CPUE from 1975-2006 in (a) areas 1 -5, (b) areas 6-10, (c) areas 11-15 and (d) areas 16-20. The black and red line in each figure indicates standardized and nominal CPUE respectively. The light gray lines indicate standardized CPUE from other area. All CPUE were normalized by dividing its average over time.

(c) Standardized swordfish CPUE with the branch line data for 1975-2006 for areas 11-15

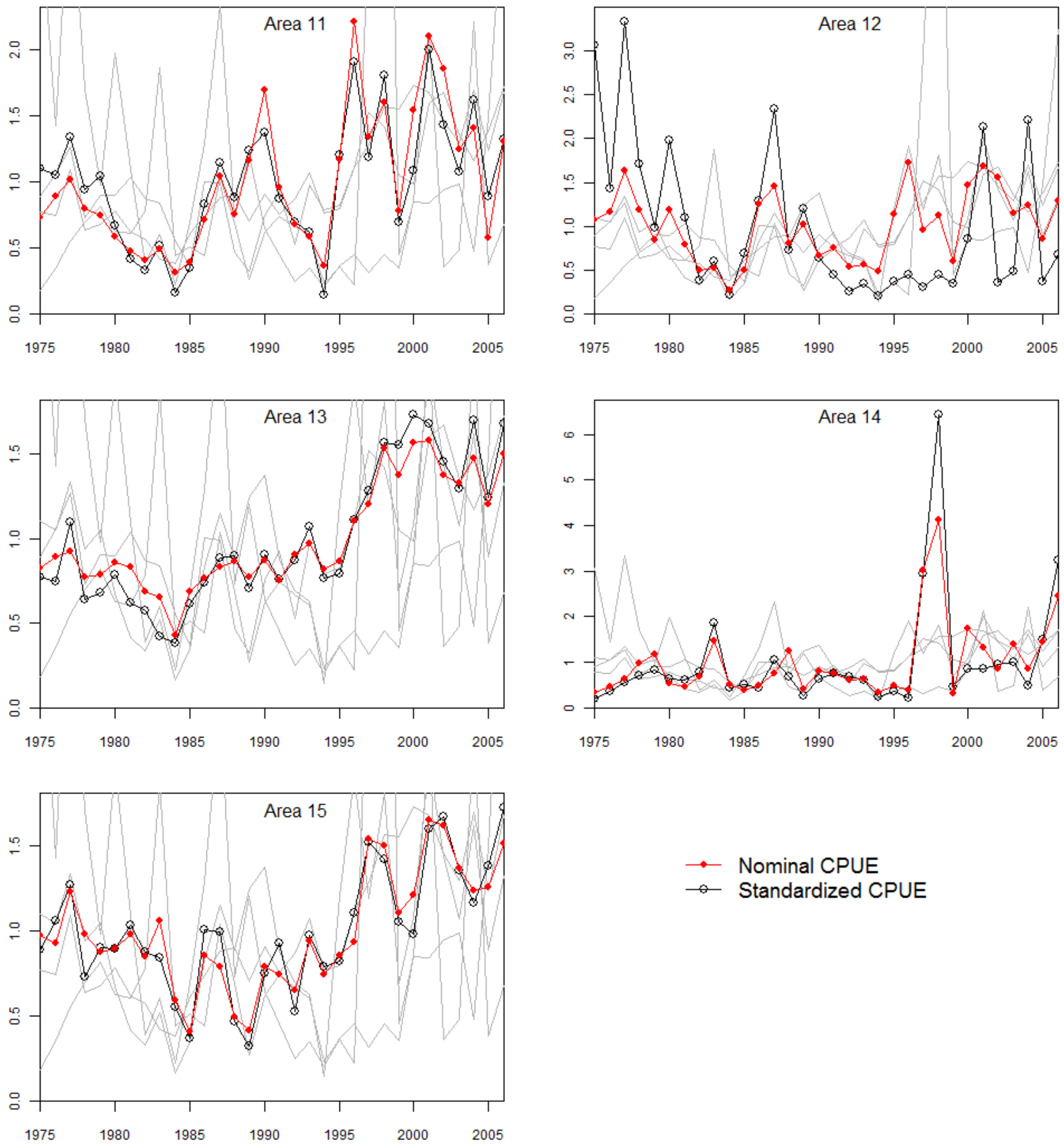


Figure 13: Standardized swordfish CPUE from 1975-2006 in (a) areas 1 -5, (b) areas 6-10, (c) areas 11-15 and (d) areas 16-20. The black and red line in each figure indicates standardized and nominal CPUE respectively. The light gray lines indicate standardized CPUE from other area. All CPUE were normalized by dividing its average over time.

(d) Standardized swordfish CPUE with the branch line data for 1975-2006 for areas 16-20

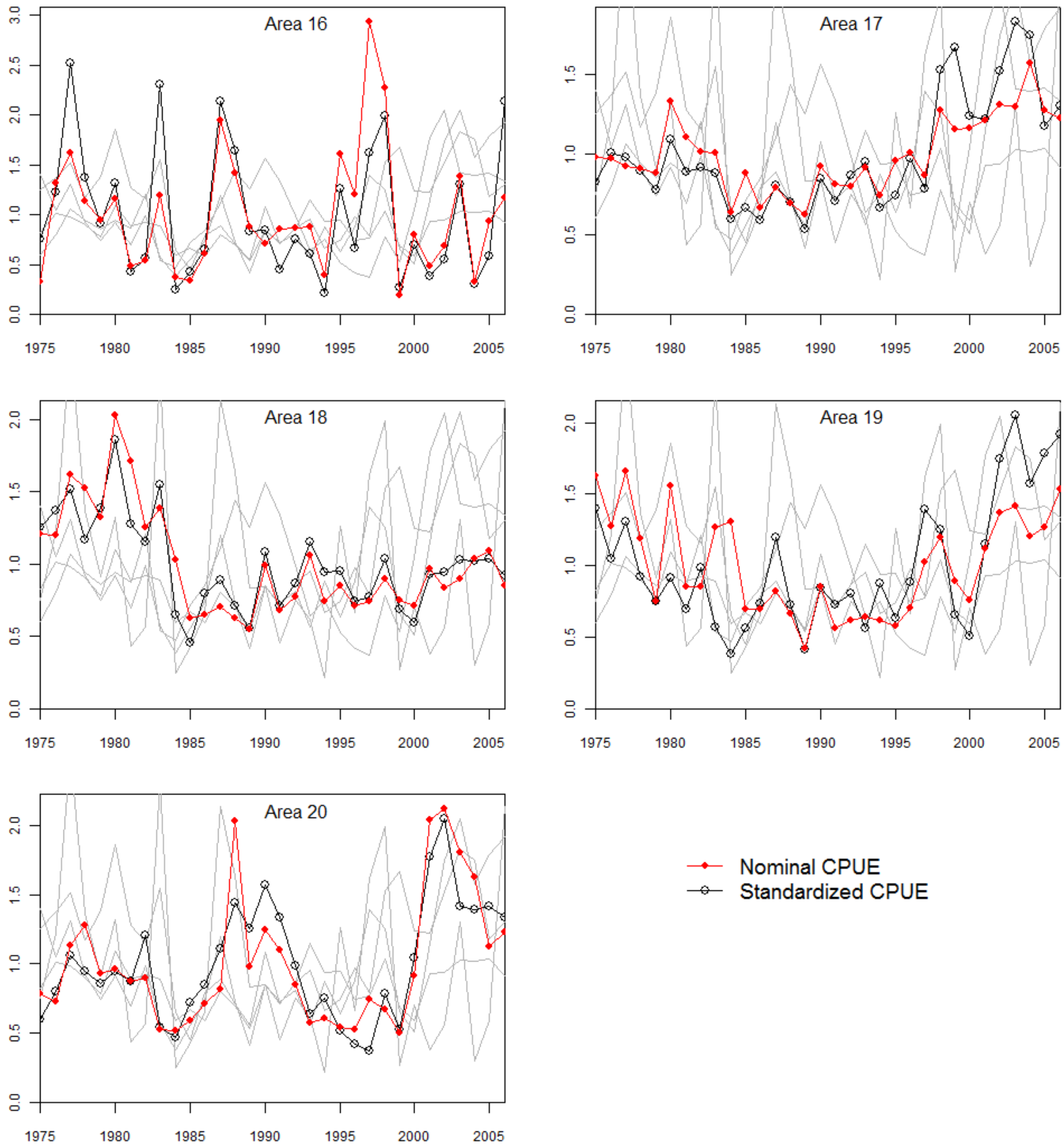


Figure 14: Standardized swordfish CPUE from 1975-2006 in (a) areas 1 -5, (b) areas 6-10, (c) areas 11-15 and (d) areas 16-20. The black and red line in each figure indicates standardized and nominal CPUE respectively. The light gray lines indicate standardized CPUE from other area. All CPUE were normalized by dividing its average over time.

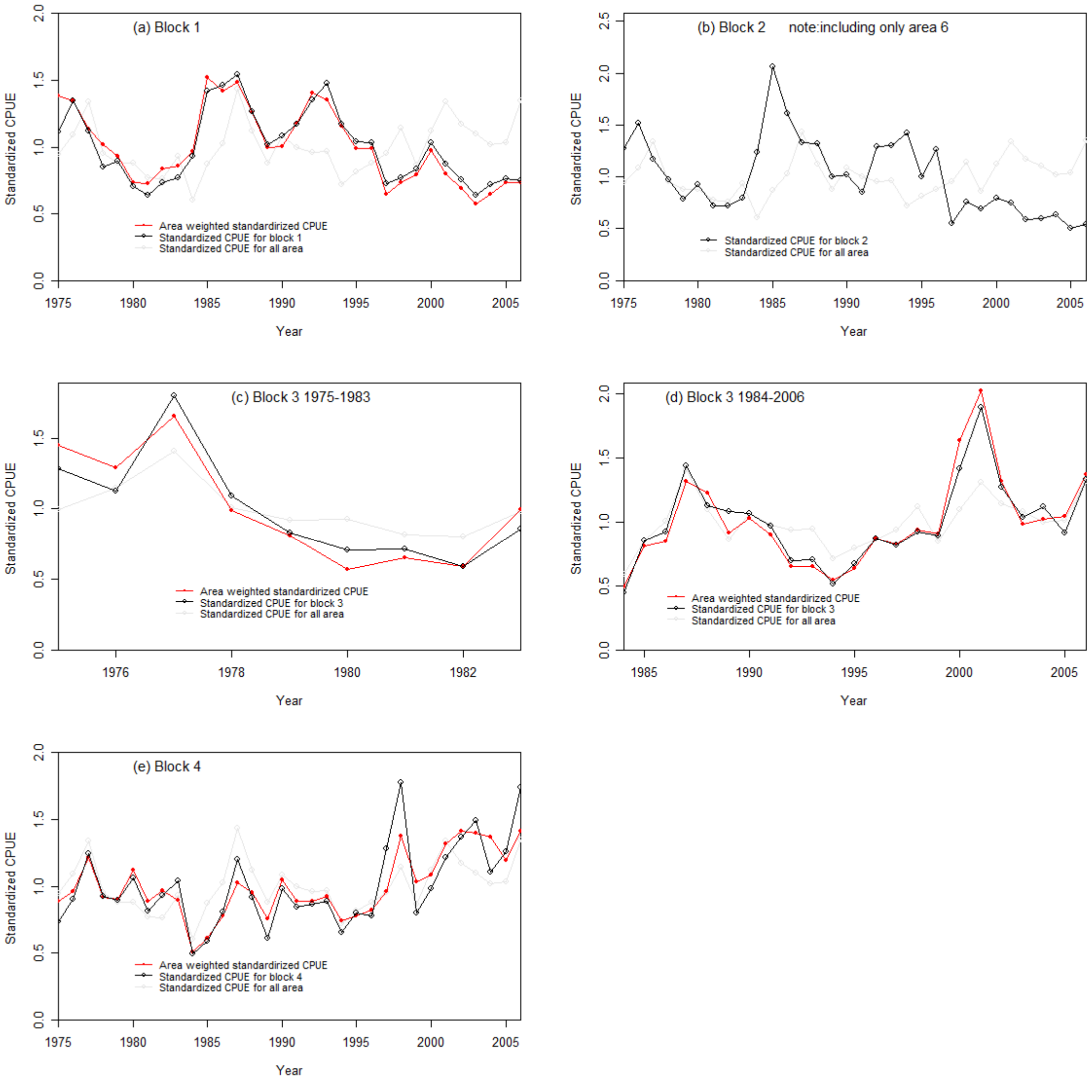


Figure 15: Standardized and area-weighted standardized swordfish CPUE for four blocks

Table 1: Categories of gear configurations

Number	Name of gear configuration	Number of branch lines (HPB)
1	night set	3-4
2	partial night set	5-6
3	normal set	7-9
4	super normal set	10-11
5	deep set	12-15
6	super deep set	16-20

Table 2: Results of model selection for a CPUE model for all area and information criteria of AIC, and BIC.

The full model includes year, quarter, area and gear configuration as main effects, and year*quarter, year*area, year*gear, quarter*area, quarter*gear and area*gear as interaction terms. n: number of observations, SSE: sum of squares of error term, p: number of parameters.

					Interuction terms										AIC		BIC	
Model #	Year	Quarter	Gear	Area	Year*Quarter	Year*Gear	Year*Area	Quarter*Gear	Quarter*Area	Gear*Area	n	SSE	DF	p	Value	Rank	Value	Rank
1	*	*	*	*	*	*	*	*	*	*	123374	285074.6	1059	1060	455569.7	1	465876.1	4
2	*	*	*	*		*	*	*	*	*	123374	285858	966	967	455722.4	2	465124.5	2
3	*	*	*	*			*	*	*	*	123374	287839.5	814	815	456270.5	3	464194.8	1
4	*	*	*	*	*	*	*				123374	308837.5	892	893	465113.6	7	473796.2	8
5	*	*	*	*		*	*	*			123374	308397.6	814	815	464781.7	5	472706	6
6	*	*	*	*			*	*	*		123374	296235.9	719	720	459627.9	4	466628.5	5
7	*	*	*	*			*		*	*	123374	312148.5	75	76	464795.2	6	465534.2	3
8	*	*	*	*	*		*	*			123374	312148.5	755	756	466155.2	8	473505.8	7
9	*	*	*	*							123374	340333.8	58	59	475426.7	19	476000.3	19

Table 3: Results of the ANOVA for model 3

	DF	SS	Mean Squares	F value	Pr>F
Model	814	160,145	197	84	<.0001
Error	122,920	287,839	2		
Corrected Total	123,734	447,984	12,866		

	DF	Type III SS	Mean Square	F value	Pr>F
Year	31	2,263	73	31	<.0001
Quarter	3	1,966	655	279	<.0001
Gear	19	1,151	230	98	<.0001
Area	5	10,271	540	230	<.0001
Year*Area	589	15,484	26	11	<.0001
Quarter*Gear	95	847	56	24	<.0001
Quarter*Area	57	14,988	262	112	<.0001
Gear*Area	95	8,396	88	37	<.0001

Table 4: Results of model selection for a CPUE model for all area and information criteria of AIC, and BIC for (a) Block 1, (b) Block 2, (c) Block 3 from 1974-84, (d) Block 3 from 1985-2006 and (e) Block 4. For the final models, a model that yielded the lowest BIC was chosen.

(a) Block 1

					Interuction terms										AIC		BIC	
Model #	Year	Quarter	Gear	Area	Year*Quarter	Year*Gear	Year*Area	Quarter*Gear	Quarter*Area	Gear*Area	n	SSE	DF	p	Value	Rank	Value	Rank
1	*	*	*	*	*	*	*	*	*	*	38067	95440.71	456	457	143933	1	147839.1	7
2	*	*	*	*		*	*	*	*	*	38067	96137.2	363	364	144023.8	2	147135	4
3	*	*	*	*			*	*	*	*	38067	97757.78	214	215	144362.2	3	146199.8	1
4	*	*	*	*	*	*	*				38067	102310.5	424	425	146515	9	150147.5	13
5	*	*	*	*		*	*	*			38067	103684.2	331	332	146836.7	12	149674.3	11
6	*	*	*	*			*	*	*		38067	100164.8	194	195	145248.1	6	146914.8	3
7	*	*	*	*			*		*	*	38067	98501.44	199	200	144620.7	4	146330.1	2
8	*	*	*	*	*		*	*			38067	104737	275	276	147109.3	13	149468.3	10

(b) Block 2

				Interuction terms							AIC		BIC	
Model #	Year	Quarter	Gear	Year*Quarter	Year*Gear	Quarter*Gear	n	SSE	DF	p	Value	Rank	Value	Rank
1	*	*	*	*	*	*	8839	26084.684	284	285	35219.3363	1	37239.11	8
2	*	*	*		*	*	8839	27246.651	191	192	35418.5603	4	36779.25	4
3	*	*	*			*	8839	28294.432	54	55	35478.0948	6	35867.88	1
4	*	*	*	*	*		8839	26311.436	269	270	35265.8411	2	37179.31	7
5	*	*	*		*	*	8839	27246.651	191	192	35418.5603	4	36779.25	4
6	*	*	*			*	8839	27063.13	147	148	35270.8236	3	36319.69	3
7	*	*	*				8839	28343.277	176	177	35737.3407	7	36991.73	6
8	*	*	*	*		*	8839	29365.394	39	40	35776.4803	8	36059.96	2

(c) Block 3 for 1974-1984

					Interuction terms										AIC		BIC	
Model #	Year	Quarter	Gear	Area	Year*Quarter	Year*Gear	Year*Area	Quarter*Gear	Quarter*Area	Gear*Area	n	SSE	DF	p	Value	Rank	Value	Rank
1	*	*	*	*	*	*	*	*	*	*	8612	20315.57	161	162	32154.88	1	33298.75	10
2	*	*	*	*		*	*	*	*	*	8612	20569.8	137	138	32213.99	3	33188.39	7
3	*	*	*	*			*	*	*	*	8612	20676.79	107	108	32198.66	2	32961.24	3
4	*	*	*	*	*	*	*				8612	21596.38	114	115	32587.4	10	33399.41	12
5	*	*	*	*		*	*	*			8612	21707.87	102	103	32607.75	11	33335.02	11
6	*	*	*	*			*	*	*		8612	21027.01	87	88	32303.31	6	32924.67	2
7	*	*	*	*			*		*	*	8612	20796.31	95	96	32224.3	4	32902.15	1
8	*	*	*	*	*		*	*			8612	21540.57	96	97	32529.12	9	33214.03	9

(d) Block 3 for 1985-2006

					Interuction terms										AIC		BIC	
Model #	Year	Quarter	Gear	Area	Year*Quarter	Year*Gear	Year*Area	Quarter*Gear	Quarter*Area	Gear*Area	n	SSE	DF	p	Value	Rank	Value	Rank
1	*	*	*	*	*	*	*	*	*	*	21970	49523.35	332	333	80870.64	1	83533.78	13
2	*	*	*	*		*	*	*	*	*	21970	50137.34	266	267	81009.34	2	83144.66	10
3	*	*	*	*			*	*	*	*	21970	50660.67	191	192	81087.48	3	82622.99	2
4	*	*	*	*	*	*	*				21970	50474.22	285	286	81194.47	8	83481.74	11
5	*	*	*	*		*	*	*			21970	50878.44	231	232	81261.72	11	83117.12	9
6	*	*	*	*			*	*	*		21970	50474.22	285	286	81194.47	8	83481.74	11
7	*	*	*	*			*		*	*	21970	50775.11	179	180	81113.05	5	82552.59	1
8	*	*	*	*	*		*	*			21970	51062.58	222	223	81323.09	13	83106.52	8

(e) Block 4

					Interuction terms										AIC		BIC	
Model #	Year	Quarter	Gear	Area	Year*Quarter	Year*Gear	Year*Area	Quarter*Gear	Quarter*Area	Gear*Area	n	SSE	DF	p	Value	Rank	Value	Rank
1	*	*	*	*	*	*	*	*	*	*	46124	86598.59	525	526	161002.1	1	165598.8	12
2	*	*	*	*		*	*	*	*	*	46124	87220.34	432	433	161146	2	164930.1	7
3	*	*	*	*			*	*	*	*	46124	88157.62	323	324	161421	5	164252.5	3
4	*	*	*	*	*	*	*				46124	88438.16	464	465	161849.6	8	165913.3	13
5	*	*	*	*		*	*	*			46124	89249.95	395	396	162133	12	165593.7	11
6	*	*	*	*			*	*	*		46124	88473.67	295	296	161530.1	7	164116.9	1
7	*	*	*	*			*		*	*	46124	88315.12	311	312	161479.4	6	164206	2
8	*	*	*	*	*		*	*			46124	89278.61	367	368	162091.8	11	165307.8	8