Standardized CPUE of striped marlin caught by Japanese distant water longliners using set-by-set data in the north Pacfic[1]

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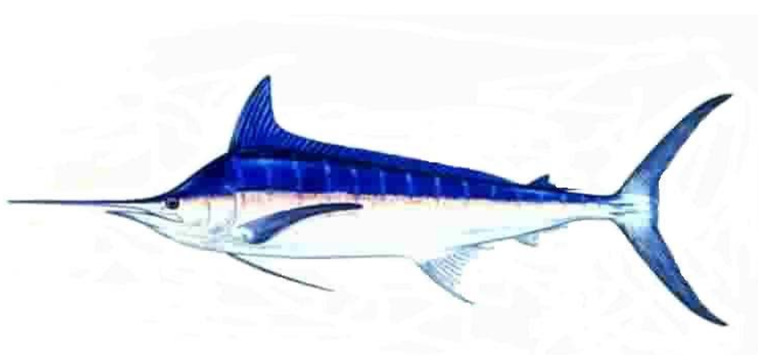

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Introduction

Fishing data of Japanese longliners, recorded for more than 50 years since 1952, have been used for estimating abundance indices for many oceanic species. Whereas the estimated index has been trusted as representative showing a trend of abundance/biomass of a focused species, there remain some problems for calculating abundance index with the Japanese longline data. In particular, the effect of gear configuration is remained as a large concern when standardizing CPUE (cf. Yokawa 2003). Because number of hooks per basket in each longline operation controls depth of hooks, the gear configuration can affect catchability of target species that have different vertical habitat preferences. In addition, the detailed gear configuration of Japanese longliner, such as length of float and branch line, material of gear and shortening ratio which would affect on the depth of gear, has been changed historically.

One of the major problems in the data of Japanese longliners is no information about number of hooks per basket before 1975. For the previous stock assessment of striped marlin, standardizations of CPUE are conducted separately for the periods of 1952-1975 without information of HPB and 1975-2002 with. Effect of gear configuration was not so clearly observed as expected by the generally known habitat preference of striped marlin (e.g. Yokawa et. al., 2005; Brill et al., 1993) except for only limited area in the data after 1975 in the previous analysis. However, considering vertical distribution of striped marlin, the model of CPUE standardizations used in the previous study could not fully adjust the effects of striped marlin especially before 1975. In particular, CPUE of striped marline calculated from the Japanese longline data showed rapid decline during 1970th (Yokawa and Clark 2005). Therefore, additional information about gear configuration before 1975 might explain the rapid decline during 1970th.

In this document, we used set-by-set data of Japanese distant longliners from 1962, which partially includes information about HPB before 1970, for standardization of CPUE of striped marlin in the North Pacific. These data of gear configuration before 1970 were recently compiled by National Research Institute of Far Seas Fisheries from log-book data by each fisheries cruse although coverage of the data was still low and preliminary (not perfectly error checked) to the total number of recorded data. This document reports results of detailed analysis about the effects of gear configuration, and standardized CPUE using generalized linear model (GLM). For the use of stock assessment task, 5 CPUE series are presented in 5 oceanic regions in addition to the overall CPUE series after 1962.

Materials and Methods

Data stratification

Area stratification used in this study is shown in Fig. 1. This stratification with 13 area in the North Pacific is according to Yokawa and Clark (2005). 13 series of CPUE calculated at each area were combined into 5 series of CPUE representing 5 different regions defined by Fig 1b for the stock assessment of the North Pacific striped marlin. 5 series of CPUE calculated within the defined oceanic regions were weighted mean of CPUE at each area by approximate size of area. Number of hooks per basket (HPB), was classified into 3 categories (3-4, 5-7, 8-23). Because the effect of hooks per basket would be not changed so largely at more than 8 according to Yokawa and Clarke (2004), HPB of >8 was combined into one category for avoiding too much blank columns in the earlier time.

According to the data stratification, total number of operation recorded by Japanese longline database is shown in Table. 1. Revived data with information about gear configuration are from 1962 to 1967. The revived data show that longliners conducted their operations mainly with 5-7 HPB and occasionally with 3-4 in the all area except for area 11 during 1960th. After the period without information about HPB from 1968 to 1974, their main settings were still 5-7 HPB, but occasionally used deeper setting of 8- HPB and rarely used shallower HPB of 3-4. The percentages of the deeper setting have been increased for the following decades at area 3-10 and 12-13 to reach almost 100% to the total operations during 1990th. At area 1 and 2, shallower sets with 3-4 HPB have been sharing approximately half of total logline operations since 1980th, which target sharks and swordfish.

All the data of Japanese distant longliners from 1962 have been recorded and compiled by the National Research Institute of Far Seas Fisheries. Data since 1992 at area 11 and from 1999 at 13 were not used for calculation of CPUE because small number of operations during the period caused extremely wide confidence limit of the estimated CPUE. We also removed data in the strata where total number of operations was less than 6.

<u>Standardization of CPUE using generalized liner model (GLM)</u>

Standardization of CPUE was conducted using GLM assuming negative binomial error distribution because the set-by-set data include many zero-catch data. The catch model explaining catch number of striped marline (STM) is written as the following (eq. 1).

$$STM = effect + Hooks + error \quad \text{(eq. 1)}$$

The term of 'effect' represents any possible effects such as year, quarter and gear configuration, which is depending on the model structure. Selection of models used for standardization of CPUE was conducted with the following steps.

(1) Preliminary analysis detecting the effect of gear configuration

Before starting main calculation of standardized CPUE, we conducted preliminary analysis to detect possible effects of gear configuration. This is because effect of HPB was not clearly shown at some area in the previous analysis, which indicated that effect of HPB would be changed by area and other factors. Then, we conducted GLM 'by each area' to test any effects of gear configuration as following (eq. 3).

$$STM = yr + qt + gear + yr \cdot qt + gear \cdot qt + Hooks + error \quad \text{(eq.3)}$$

,where *yr*: effect of year, *qt*: quarter, *gear*: category of HPB.

(2) Calculating abundance index

Effects included by main models for estimating abundance index in each region are according to results of the preliminary analysis. If there is no or only minor effect of gear configuration, we used the model without the effect of gear configuration (eq. 3).

$$STM = yr + qt + area + yr \cdot qt + yr \cdot area + qt \cdot area + Hooks + error \quad \text{(eq. 3)}$$

If there is a possible effect of gear configuration, we used the model including the effect of gear configuration (eq. 4).

$$STM = yr + qt + area + gear + yr \cdot qt + yr \cdot area + qt \cdot area + gear \cdot qt + Hooks + error \quad \text{(eq. 4)}$$

In addition, we also calculated CPUE under some assumptions about hooks per basket during 1967 to 1974 when there is no information about gear configuration. This is because the model including the effect of gear configuration can not calculate CPUE during the period. Then, we compared 3 models, those without and with effect of gear configuration (model 1 and 2, respectively), and that with effect of gear configuration and assumption of hooks per basket during 1968 to 1974 (model 3), as for the area where the effect of gear configuration is significant. HPB during 1968-1974 was assumed as 3-4 for area 11 and 5-7 for the other area according to Table 1. The calculations of GLM were conducted using GENMOD procedure of computer software, "SAS Ver. 9.1".

Result

Effect of gear configuration by area and quarter

Effects of HPB with relatively high score of chi-squared values were observed especially at the area 1, 2, 11 and 13 (Table 2), but the patterns were complicated because they are highly depending on area and season (Figure 2). In the summer season of qt 2 and 3 at area 1 and 2 in the Western Pacific, CPUE of shallower set was higher than that of deeper, which is corresponding with habitat preferences of striped marlin. However, in the winter season, the pattern was revised as the CPUE was higher at deeper set at qt 1 and 4 of area 1 and qt 4 of area 2 although difference of CPUEs between deeper and shallower is relatively small. In addition, almost reversed pattern are observed between seasons at area 11 and 13 in the Eastern Pacific. At area 11 and 13, CPUE of shallower set was higher than that of deeper in the winter seasons (qts 1 and 4), while CPUE of deeper set was higher than that of shallower in summer. Other area at 3-11 and 12 did not clear pattern of HPB because small number of observation of 3-4 HPB widened confidence limit of the estimates.

Effect of gear configuration to the total CPUE trends at area 1, 2, 12 and 13

According to the previous analysis, we conducted GLM with effect of HPB and interaction tem between HPB and quarter as for area 1, 2, 11 and 13 in addition to GLM without effect of HPB. CPUE trends resulted from three models (model 1: without effect of HPB, model 2: with HPB, and model 3: with HPB under the assumption of HPB during 1967-1974) are shown in Figure 3 for area 1 and 2, and Figure 4 for area 11 and 13.

Regardless of statistically significant effects of HPB at area 1 and 2 as seen in Table 2, differences of model structure with and without HPB did not affect CPUE trends clearly (Figure 3). In the whole period at area 1 and 2, CPUE calculated from model with HPB (model 1) was only slightly smaller then that without HPB (model 2). CPUE at area 1 in 1962 from model 2 was approximately 3/4 of that from model 1. CPUEs estimated from model 2 and 3 were not different each other.

CPUE trends derived from model 1 and 2 were different at area 12 (Figure 5): estimated CPUE with model including HPB effect was smaller than that from model without HPB effect especially during 1960th and early 1970th (according to model 3). Consequently, the CPUE estimated from model 2 and 3 seems to make better recovery in 1980th compared to the CPUE level during 1960th although there are many missing years resulted from small number of observations after 1980th. Extremely low CPUE in 1978 attributed to that most of operations were not conducted in the main fishing ground within area 11 (Appendix figure 1). CPUE trends from model 1-3 were different only very slightly each other as same as at area 1 and 2.

CPUE trends among regions

Considering the fact that results from model 2 and 3 show very similar trends each other, we selected CPUEs calculated from model 3 as the representative in each area. The weighted CPUE for each region is shown in bottom panels in Figure 3 for region1 and Figure 4 for region5. CPUE at region 3, 4 and 5, estimated from the model without the effect of HPB, was also shown at Figure 5.

All CPUE estimated in the different oceanic regions show similar trends: high CPUE at 1960th followed by decline until late of 1970th, and gradual recover from 1980th to 1990th (Figure 6, lower). In the recent period after late of 1990, indices in the all regions except for region 5 (missing) show declining trends again. It is also noteworthy that the absolute value of CPUE was different. In particular, CPUE at region 5 was much higher than those in the other regions.

The trends estimated in this document were approximately similar to the trends calculated from the previous analysis (Yokawa and Clark 2005, Figure 7).

Discussion

This document standardized CPUE using set-by-set data, catch model with negative binomial distribution and effect of hooks per basket before 1975. Regardless of differences in resolution of data (set-by-set vs. aggregated one), model structure (negative binomial vs. log-normal distribution), and information about gear configuration during 1960th, trends of CPUEs were not largely changed from the previous analysis: high during 1960th, and then decreasing, but increasing until 1995. Two points of data in 2004 and 2005 were added in this document, they indicate further decline of CPUE of striped marline in 2004 and 2005 (Figure 7).

In contrast to the declining trends in the almost all area, CPUE at area 11 seems to be recovering rather than declining from middle of 1980th to 1990th (Figure 4). Because area 11 is known to be one of major spawning area for striped marline in the North Pacific (Bromhead et al., 2004), average CPUE in the area is extremely higher than those in the other area (5.5 at area 11, and 0.08-1.83 at the other area, Table 3). Consequently, CPUE at area 12 was largely reflected by oveall CPUE and CPUE of region 5, because combined CPUE was calculated from weighting average of least squared mean of CPUE (not scaled) by size of each area.

Therefore, abundance index in area 11 would be important to know allover abundance trends although Japanese longliners was not conducted in the area recently to miss the sequential calculation after 1991. Figure 8 show recent trends of nominal CPUE at area 11, which is removed from the calculation of standardized CPUE because of small number of operations. After 1992, nominal CPUE at area 11 was largely fluctuated from approximately zero to 40-50 striped marlin per 1000 hooks basket. This fluctuated pattern of nominal CPUE as seen in Figure 8 was owing to differences of positions where longliners conducted fishing within area 11 (Appendix Figure 1). High nominal CPUE from 1995 to 1998 was from main fishing ground south to California, while poorly low CPUE in 1992, 1993, 2001 and 2002 was from boundary area near to area 7 or 12 rather the main fishing ground. In addition, observational cruise by Shoyo-maru in 2004 fished about 9.2 striped marline per 1000 hooks by 16 operations in the main fishing area south to California (Yokawa et al. 2005). Those indicated that there is some possibility that the abundance in their main spawning grounds in EPO was not so decreasing even after 1990th.

This document also shows possible effects of gear configuration that is complicatedly interacted by area and quarter, which affect trends of CPUE only very slightly. The pattern of the effect of HPB was reversed in between the Western and Eastern Pacific. This would be the reason why any gear configuration effects consistent with habitat preferences of striped marlin have not been detected in the previous analysis even at area 1 and 2. The observed pattern of the effect of gear configuration may be reflected by their habitat preference such as mixed layer depth and water temperature. However, at the same time, such kind of highly variable pattern of effect of gear configuration could be attributed to skewed distribution pattern of data. Yokawa (2004) reveal that skewed distribution pattern of Japanese longline data can affect the estimation of the effect of gear configuration in the Atlantic. If shallower sets were quite minor gear configuration in particular area and season and they did not conducted near the main fishing ground of that stratum, CPUE of shallow sets in that stratum would become lower than that of deeper sets. Future study is needed to explain the complicated pattern of the effect of gear configuration.

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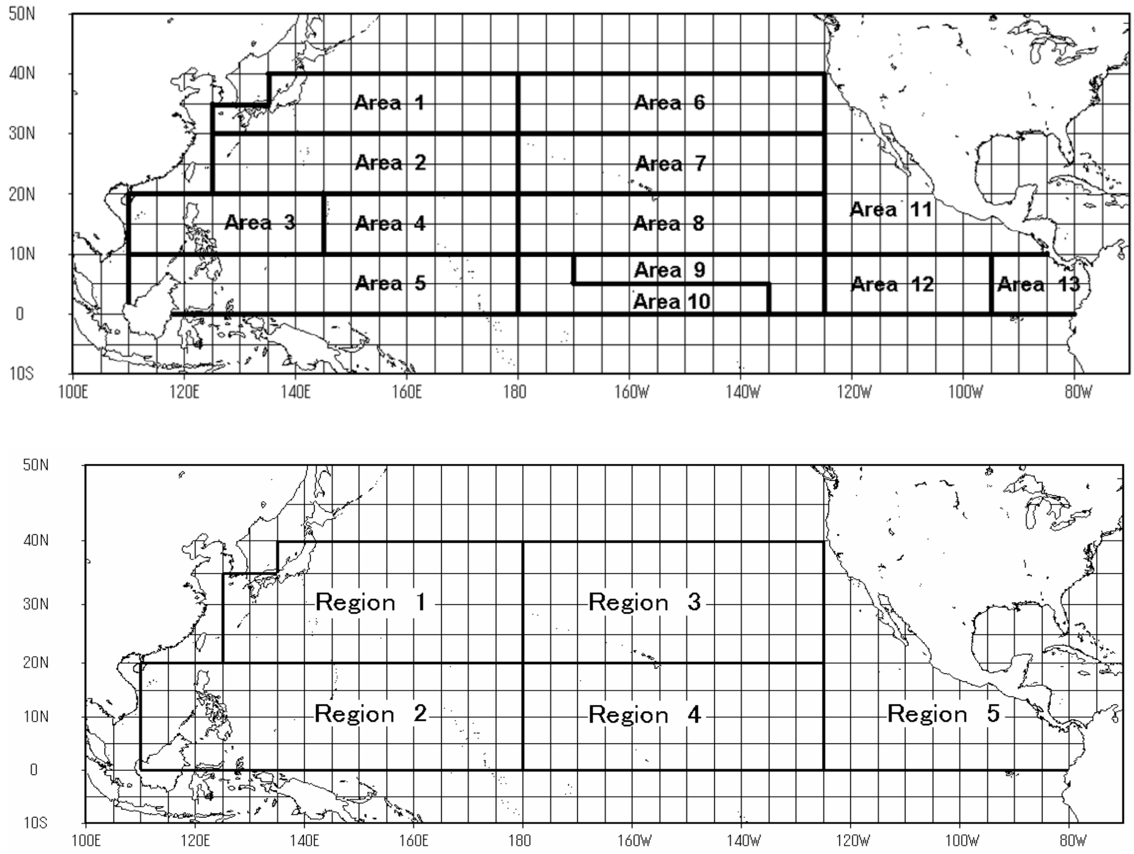


Figure 1. Area stratification used in the standardization of CPUE of striped marlin caught by Japanese distant-water longliners (upper panel) and area stratification scheme adopted for current assessment (lower panel). This definition is followed from the previous stock assessment.

(a) Effects of HPB in area 1, 2, 11 and 13 where chi-squared values were relatively large.

(b) Effects of HPB in area in 3-10 and 12 where chi-squared values were minor.

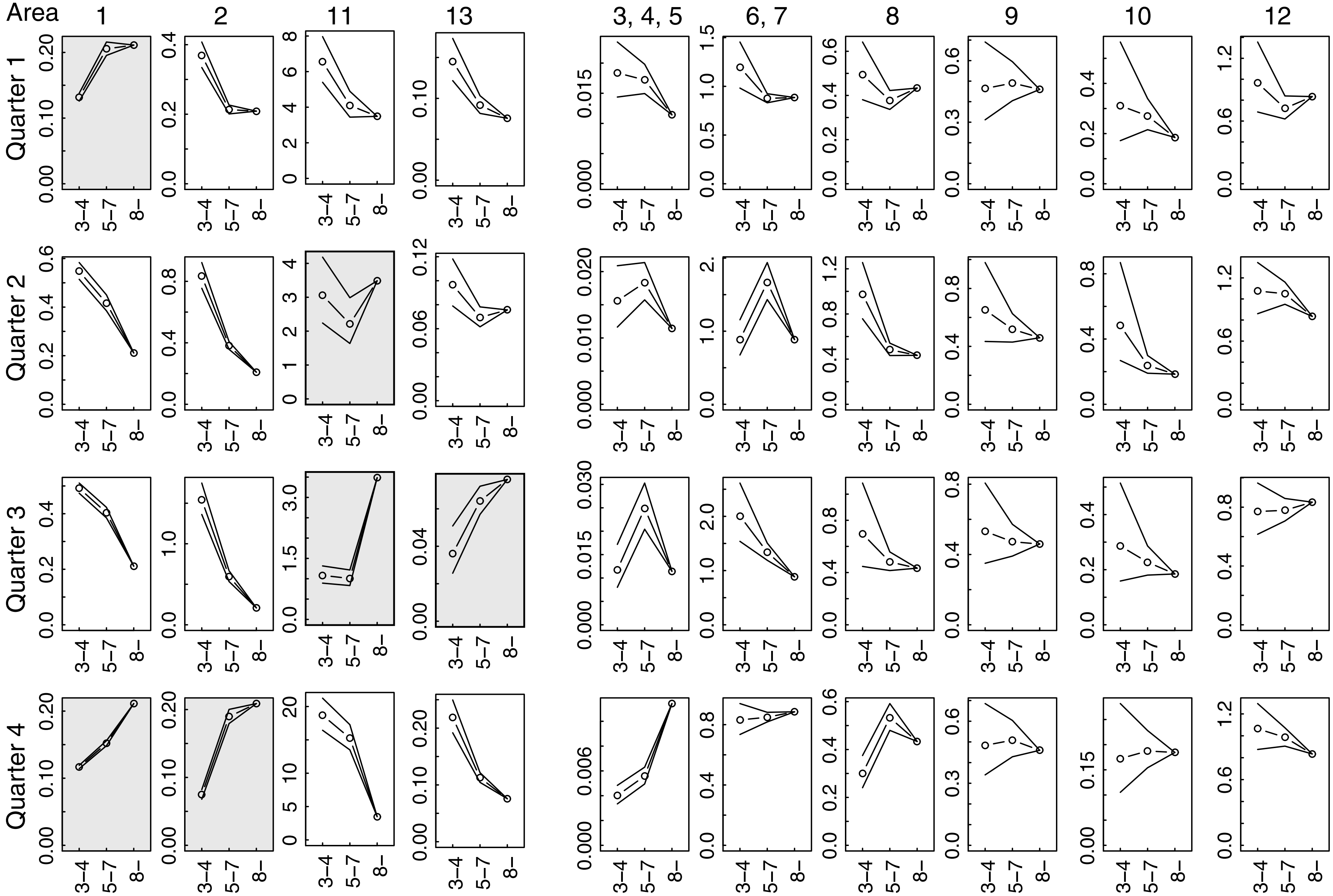


Figure 2. Effect of HPB by area and quarter. The x-axis represents 3 categories of HPB: 3-4, 5-7, and >8. The shaded boxes in figure (a) represents area and quarter when the pattern of the effects seems to be inconsistent with habitat distribution of striped marlin.

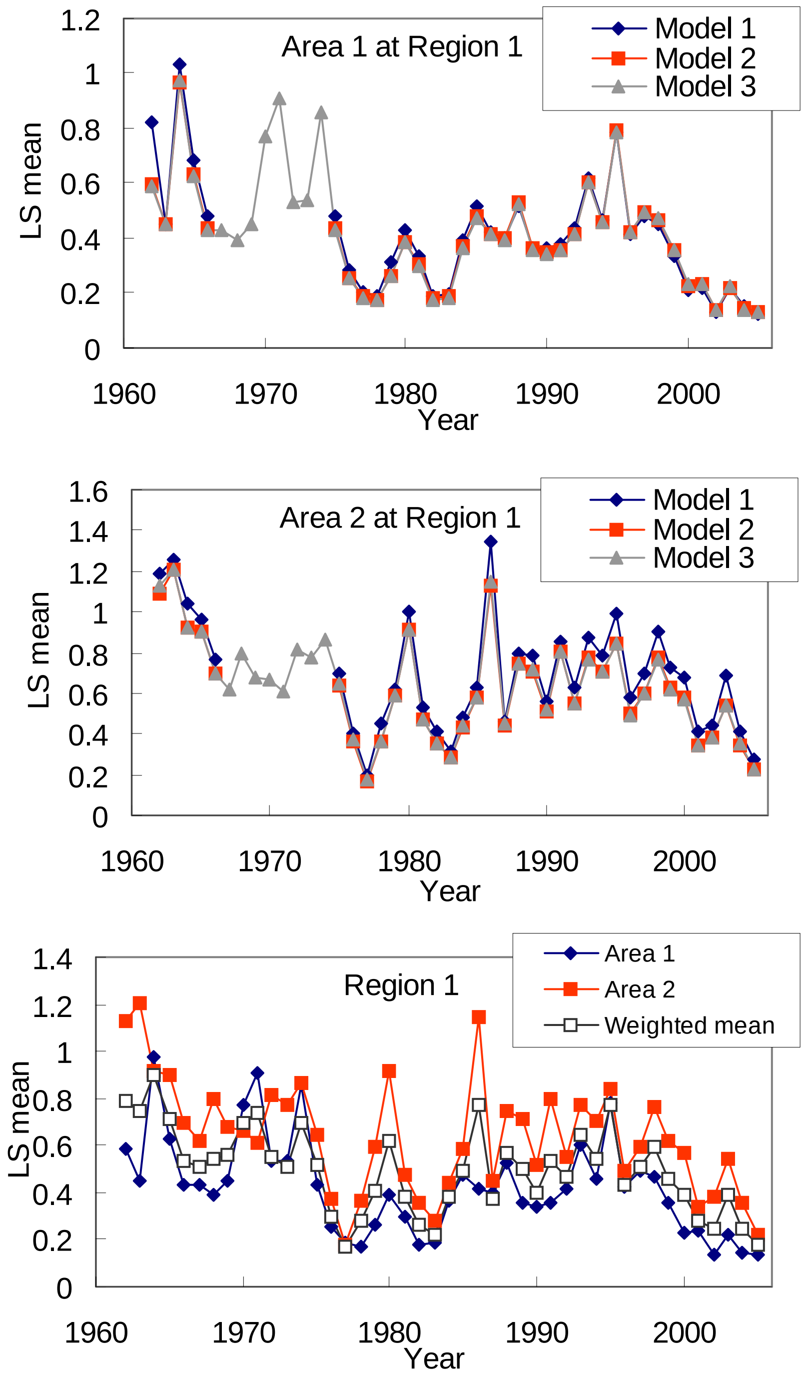


Figure 3. Estimated least squared means at area 1 and 2 in region 1. Upper and middle: Indices from the different models of model 1 (without HPB), 2 (with HPB) and 3 (with HPB and assumption of HPB during 1967-1975) are compared in the upper 2 panels. Model 3 was based on the assumption that HPB during 1967-1975 is 5-7 according to Table 1. Bottom: selected indices of each area (model 3) and weighted mean for region 1.

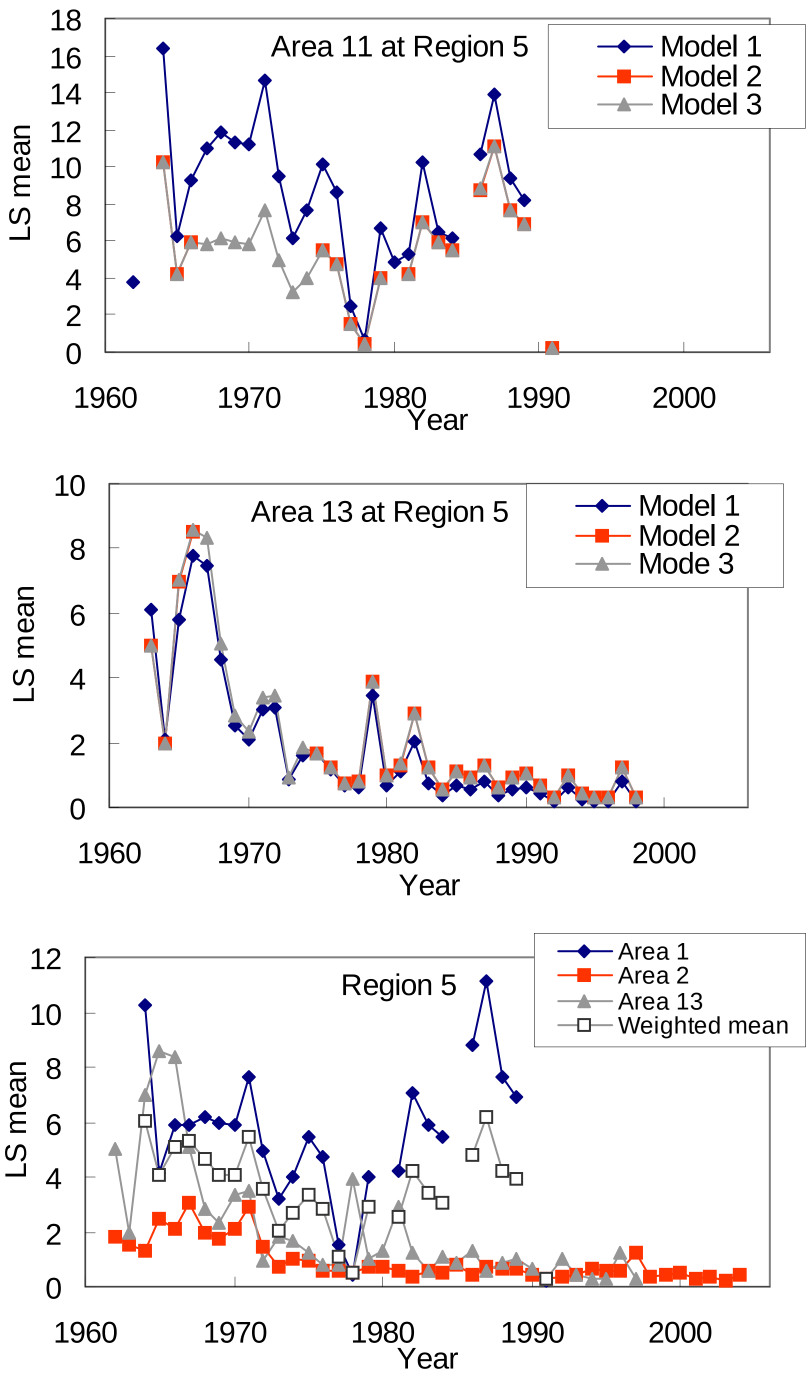


Figure 4. Estimated least squared means at area 11-13 in region 5. Upper and middle: Indices from the different models of model 1 (without HPB), 2 (with HPB) and 3 (with HPB and assumption of HPB during 1967-1975) are compared in the upper 2 panels. Model 3 was based on the assumption that HPB during 1967-1975 is 3-4 for area 11 and 5-7 for area 13 according to Table 1. Bottom: selected indices of each area (model 3) and weighted mean for region 5.

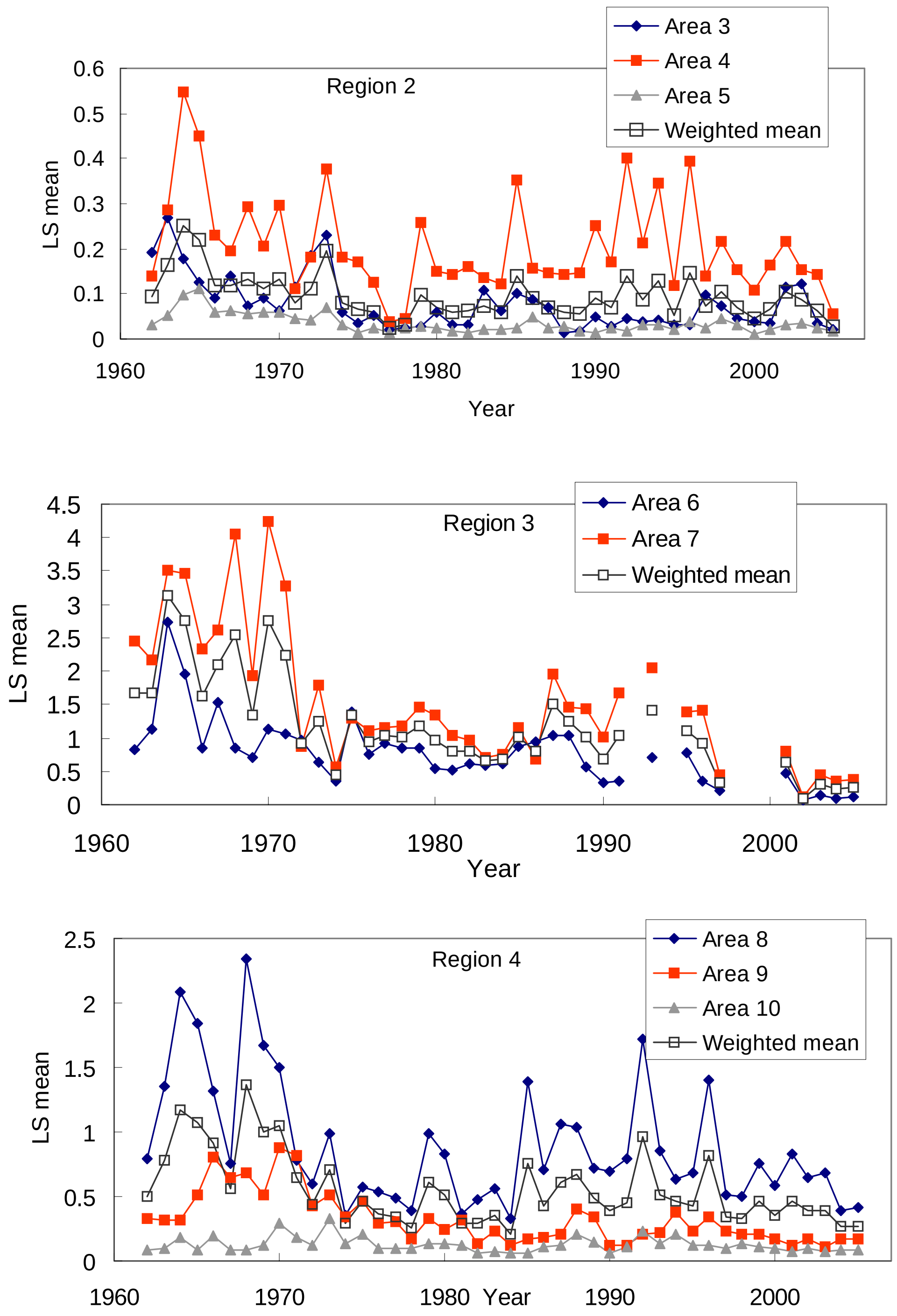


Figure 5. Estimated least squared means in region 2, 3 and 4, and average CPUE weighted by size of each area. Those indices were calculated from GLM that did not include the effect of gear configuration.

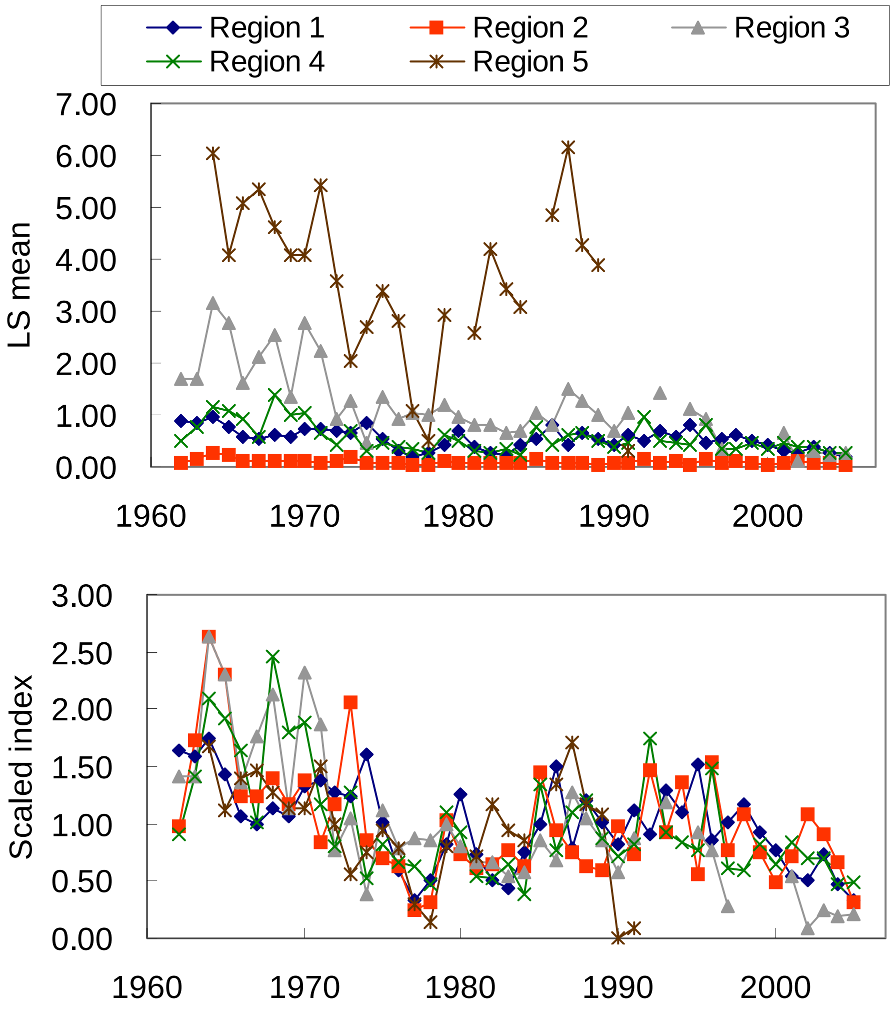
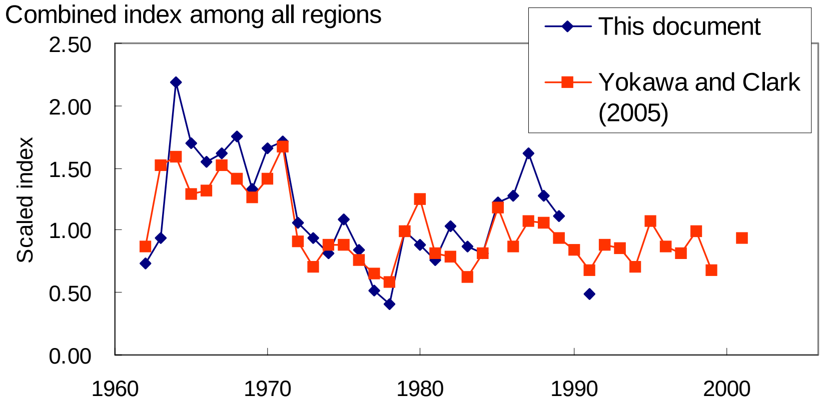


Figure 6. Least squared means (upper) and scaled (lower) CPUE among 5 regions.



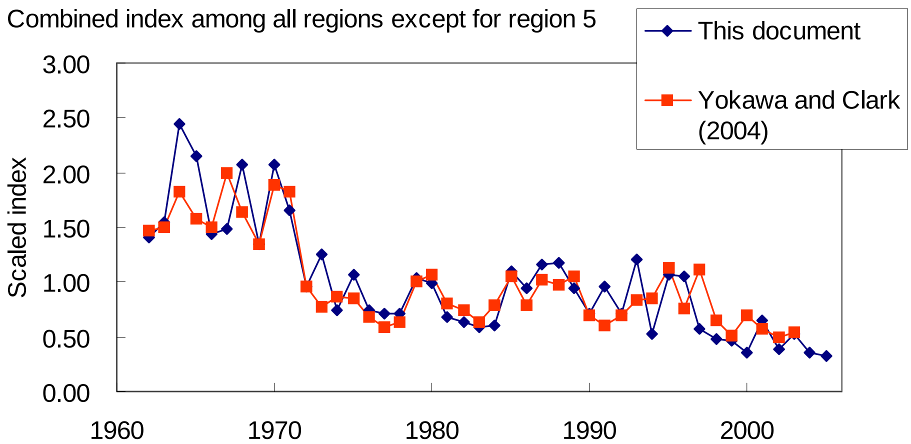


Figure 7. Comparison of allover trend of CPUE in this document and Yokawa and Clarke (2005). The allover trends were from Table 3, where some data points of missing year were compensated by average values of CPUE in the nearest years.

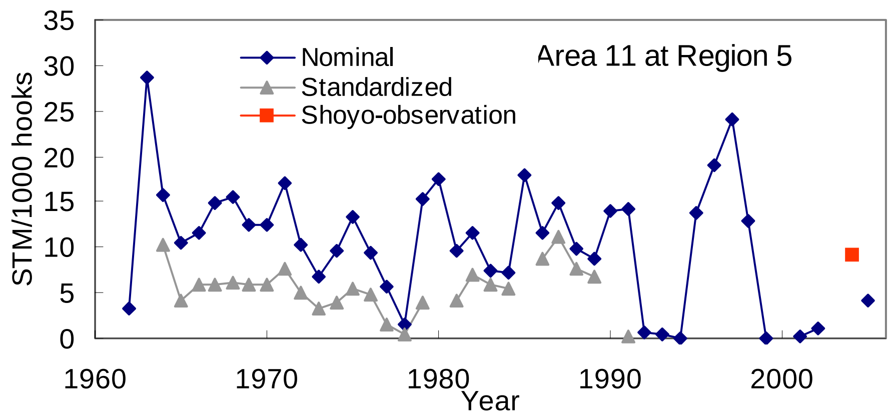


Figure 8. Nominal and standardized CPUE with scaled by each average. CPUE observed by Syoyo-maru at area 11 in 2004 is also shown.

Table 1. Total number of longline operations recorded by Japanese set-by-set data. All data are categorized by number of hooks per basket (HPB) of unkown, 3-4, 5-7 and more than 8. The figure below the table represents historical trends of percentages of Hpb to the total operations.

	Area 1				Area 2				Area 3				Area 4			
	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-
1962	7544	505	2782	293	9455	370	2908	657	1777	151	228	0	2396	121	348	17
1963	10244	978	3476	357	8795	332	722	122	1427	217	345	0	1320	77	211	5
1964	9053	3321	15327	655	5805	2188	6328	514	1887	893	1420	48	1908	197	795	0
1965	839	4866	23813	775	1209	3771	10690	478	284	1499	1670	66	309	767	2380	0
1966	544	2702	18645	786	427	2451	10679	402	254	2012	1407	61	143	622	1792	79
1967	25629	16	564	76	12587	21	195	26	4525	29	38	0	2584	26	214	21
1968	17037	0	0	0	12449	0	0	0	4225	0	0	0	2135	0	0	0
1969	15054	0	0	0	8510	0	0	0	3600	0	0	0	2094	0	0	0
1970	13919	0	0	0	8268	0	0	0	2766	0	0	0	3665	0	0	0
1971	12328	0	0	0	6370	0	0	0	2375	0	0	0	2199	0	0	0
1972	7156	0	0	0	3411	0	0	0	2008	0	0	0	1094	0	0	0
1973	6806	0	0	0	4155	0	0	0	3764	0	0	0	1823	0	0	0
1974	7398	0	0	0	4863	0	0	0	6996	0	0	0	4778	0	0	0
1975	322	874	4981	1600	244	977	2959	1430	391	43	5577	1377	226	0	2925	896
1976	465	984	8270	3987	428	913	5193	2319	253	18	7290	1415	250	12	2668	1207
1977	136	1015	7425	3285	139	876	6666	4197	272	0	6057	1341	140	44	3339	1664
1978	149	882	7646	2871	234	979	5743	2639	66	0	4570	1478	106	0	3126	2309
1979	4292	924	7786	4785	1745	840	4589	2566	1752	3	2699	629	2131	23	2810	2416
1980	2436	438	6185	5763	1383	1011	5547	4093	783	34	1325	1006	1632	0	2538	2505
1981	616	716	7028	9071	587	1265	5575	6002	82	0	1846	1489	306	47	2726	5275
1982	581	909	5906	10604	507	833	4613	5977	45	0	778	954	61	0	1454	3895
1983	443	2597	5021	9687	242	1840	2425	4862	26	0	488	1195	184	5	282	4047
1984	299	1706	4501	11619	220	2696	2520	3719	7	0	226	1890	27	2	326	5257
1985	287	3721	3187	10487	130	2886	2021	2449	23	0	87	842	53	0	149	3877
1986	387	5245	1821	9630	229	3330	1190	3821	8	0	48	368	89	0	205	7234
1987	150	4466	1476	7040	175	4364	689	2105	12	0	37	436	61	0	24	7596
1988	581	5303	1123	8713	181	2702	587	1649	35	0	0	500	35	14	39	7522
1989	742	5928	507	7035	258	2875	208	2366	9	0	2	406	72	12	61	4628
1990	842	5081	251	6610	230	2643	100	1588	23	0	0	498	17	0	77	3118
1991	1032	4484	261	8130	530	2345	88	2330	89	0	0	602	352	38	0	6532
1992	731	4943	72	5589	518	2997	72	2141	94	0	0	1348	238	0	0	3784
1993	915	4787	80	6328	334	3142	58	2729	57	0	0	424	117	0	17	4934
1994	890	4245	194	7767	398	2595	67	2094	0	0	0	492	0	31	18	3744
1995	785	4379	167	4998	524	2664	49	2000	17	3	5	625	138	0	0	4622
1996	826	4494	229	3799	752	2301	28	2638	26	0	1	159	188	0	0	3558
1997	1094	4514	323	3528	700	1911	0	2540	12	0	0	254	75	0	0	1583
1998	738	4739	141	2885	534	1867	0	2146	21	0	0	194	122	0	0	3515
1999	642	5345	31	3504	336	1351	0	2467	1	0	0	88	57	0	0	3606
2000	503	6261	44	2250	414	859	0	1946	33	0	0	326	75	0	0	3836
2001	308	6151	136	1780	150	622	7	2022	36	0	14	566	31	0	0	4219
2002	281	5118	35	2479	197	1013	0	1432	0	0	0	172	65	0	5	2534
2003	55	4509	12	3504	128	428	0	1615	6	0	4	686	18	0	0	3258
2004	81	4072	99	3026	13	337	0	1229	0	0	0	698	0	0	0	1432
2005	1	2915	72	2049	0	402	7	812	0	0	0	380	0	0	0	1846

	Area 5				Area 6				Area 7				Area 8			
	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-
1962	8157	705	1127	9	2013	50	321	0	1254	51	325	0	2441	550	391	0
1963	8882	455	972	0	3519	397	686	0	1235	94	350	0	3592	226	586	0
1964	6924	1563	2718	19	1608	112	263	0	1808	99	304	0	6287	200	734	0
1965	1472	6234	8398	24	114	213	991	0	161	157	1021	1	523	396	1121	0
1966	936	3551	6581	47	64	200	1697	10	63	75	769	0	126	268	1476	17
1967	10338	155	371	1	2503	1	80	0	4038	0	168	0	2535	26	106	0
1968	9967	0	0	0	1773	0	0	0	3765	0	0	0	1829	0	0	0
1969	10490	0	0	0	1904	0	0	0	3578	0	0	0	1507	0	0	0
1970	8044	0	0	0	2924	0	0	0	6078	0	0	0	4889	0	0	0
1971	7713	0	0	0	2415	0	0	0	3897	0	0	0	2716	0	0	0
1972	11069	0	0	0	4190	0	0	0	4822	0	0	0	2775	0	0	0
1973	10308	0	0	0	3100	0	0	0	5109	0	0	0	4161	0	0	0
1974	11585	0	0	0	1679	0	0	0	3393	0	0	0	5187	0	0	0
1975	1044	58	8948	2648	74	9	1187	91	176	3	2446	203	219	13	3788	666
1976	1065	31	10963	3944	276	61	2919	497	262	49	2540	672	149	23	3525	1753
1977	875	116	10003	5117	1	0	1841	1015	101	52	2426	1603	192	42	1604	1875
1978	252	1	11107	6725	111	1	1280	1515	168	49	2981	3522	64	0	2086	5007
1979	3425	1	12192	8878	249	0	2117	1433	389	5	2646	4065	260	0	1290	3930
1980	4781	18	12827	10320	102	5	3100	2109	76	11	841	1168	183	0	1210	4431
1981	698	0	13559	13571	9	0	2603	2954	18	0	1971	2080	270	0	1048	5590
1982	642	0	5331	15126	47	0	2216	1802	54	0	1479	1665	200	0	414	5035
1983	327	0	3895	13199	68	0	2302	3315	10	0	887	1859	84	0	343	4128
1984	209	0	1286	19374	130	0	4118	4657	45	0	742	1693	134	0	396	4210
1985	359	0	431	18273	217	0	2801	3890	51	0	454	1513	91	0	350	3431
1986	308	0	286	12214	124	0	947	2416	124	0	338	4031	94	0	190	4524
1987	286	0	153	15022	151	0	1186	4305	7	0	144	2183	271	0	123	4712
1988	177	0	90	7906	76	1	1549	4437	131	1	289	2560	134	0	218	9703
1989	524	34	110	11446	128	48	1030	5228	118	42	221	3662	188	0	273	9606
1990	1019	0	94	15791	179	32	396	4040	141	40	190	2550	253	0	82	6050
1991	569	0	0	9710	152	24	383	4555	47	17	53	2112	144	0	38	6577
1992	975	0	0	11603	1	20	198	3444	111	22	33	4356	308	0	31	3691
1993	522	0	6	8947	0	5	67	3874	44	0	57	3966	317	0	1	5543
1994	153	0	61	8799	0	5	79	1704	0	0	10	4314	0	0	1	4812
1995	70	0	28	8238	0	19	53	2093	30	0	67	3832	12	0	2	6383
1996	190	0	0	9543	0	64	128	2558	0	1	53	1813	58	0	0	3699
1997	186	20	0	8716	7	17	49	2043	3	1	25	1890	0	0	2	2972
1998	155	0	0	8413	0	0	13	1691	0	0	0	2122	10	0	5	2328
1999	88	0	0	11054	40	0	4	2046	29	0	0	4293	108	0	9	2862
2000	84	0	0	9190	24	0	0	669	45	0	0	2685	6	1	4	2281
2001	56	0	0	9745	11	45	0	1043	0	0	0	1336	12	0	9	2389
2002	101	0	0	8243	15	30	0	328	0	20	0	2639	0	0	8	1760
2003	14	0	0	6209	0	290	3	1094	0	83	0	4402	8	0	0	3131
2004	51	0	0	6192	0	580	0	246	0	275	0	1336	9	0	0	3196
2005	27	0	0	4814	0	221	9	349	0	98	0	2302	0	0	0	2730

	Area 9				Area 10				Area 11				Area 12				Area 13			
	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-
1962	1928	293	970	0	1786	212	518	0	2	2	64	0	1371	359	1988	0	121	7	385	0
1963	2393	203	1211	0	4552	351	1639	0	45	54	56	0	1581	161	1604	0	494	58	493	0
1964	5607	174	1445	1	3345	65	557	0	2851	623	1206	0	2928	145	1755	0	798	15	511	0
1965	730	440	3050	0	671	488	3299	0	523	2039	2091	0	415	142	2182	0	66	36	755	0
1966	243	96	2196	0	299	162	1642	2	44	1854	1332	0	133	106	2074	0	10	75	987	1
1967	3843	32	246	0	3078	1	98	0	2830	51	51	0	3391	12	212	0	1386	21	291	0
1968	2648	0	0	0	2677	0	0	0	5368	0	0	0	3383	0	0	0	2338	0	0	0
1969	4682	0	0	0	2816	0	0	0	2956	0	0	0	3754	0	0	0	2550	0	0	0
1970	7981	0	0	0	4214	0	0	0	3469	0	0	0	3934	0	0	0	1806	0	0	0
1971	5844	0	0	0	4916	0	0	0	2888	0	0	0	3306	0	0	0	1170	0	0	0
1972	4551	0	0	0	7322	0	0	0	3205	0	0	0	3265	0	0	0	1806	0	0	0
1973	6126	0	0	0	2252	0	0	0	2993	0	0	0	2883	0	0	0	3675	0	0	0
1974	7543	0	0	0	3980	0	0	0	3134	0	0	0	2459	0	0	0	2542	0	0	0
1975	192	4	2652	271	156	5	1219	248	183	1210	169	0	237	31	3929	145	102	78	2952	177
1976	187	31	5301	1865	410	33	4141	2422	0	2523	440	44	125	13	3272	1042	89	256	1426	411
1977	237	20	2298	3812	444	47	2022	3524	7	735	32	59	288	3	1580	4072	128	260	1358	2120
1978	29	0	1437	5173	15	0	783	2336	0	77	45	4	107	0	576	4443	103	88	744	2971
1979	209	0	1028	7348	252	0	753	4833	17	292	46	13	63	15	923	7850	50	102	368	343
1980	200	4	428	3413	402	0	878	5000	156	261	812	161	243	5	208	4333	80	23	591	2549
1981	94	0	424	4478	201	0	243	3046	0	218	1294	132	78	0	366	3431	0	57	306	538
1982	28	20	240	3859	190	13	572	6713	0	526	1789	60	43	87	324	5265	35	9	204	684
1983	136	0	147	3645	155	0	254	4058	0	0	1851	139	77	0	185	5431	152	0	162	2871
1984	115	0	243	4268	233	0	334	6964	0	0	761	131	0	0	168	3065	0	32	14	685
1985	95	0	250	5968	114	0	151	6343	0	0	55	3	0	1	191	4217	0	17	9	773
1986	25	0	40	4437	37	0	37	4055	3	0	681	65	0	0	41	2332	16	10	43	1164
1987	66	0	12	4849	117	0	0	2942	0	0	1318	5	0	0	132	5001	15	0	18	1254
1988	31	0	15	5668	29	0	16	2371	0	0	1207	79	19	0	11	1162	32	0	77	1754
1989	120	0	17	6994	35	0	15	3779	55	0	617	34	248	0	146	6357	0	0	39	1320
1990	194	0	154	7428	137	0	144	6260	0	0	194	12	60	0	41	3581	183	0	43	526
1991	198	0	18	5507	59	0	39	4891	0	40	182	13	45	0	10	3338	91	0	46	1250
1992	232	0	0	4495	204	0	0	2040	1	0	0	65	166	0	17	4310	40	0	1	1689
1993	57	0	0	6248	21	0	0	5435	2	0	0	30	50	0	2	2809	0	0	12	307
1994	149	0	0	5408	15	0	19	3274	0	0	0	2	90	0	0	1704	11	0	0	1236
1995	124	0	0	3556	108	0	0	2639	0	0	176	82	54	0	0	1798	0	0	0	3379
1996	99	1	0	3239	70	0	0	3065	0	0	29	14	5	0	0	459	0	0	0	2010
1997	22	0	0	2534	24	0	0	3692	0	0	33	20	13	0	45	4007	0	0	13	424
1998	4	0	0	3727	1	0	0	1557	0	0	175	3	0	0	0	4648	0	0	0	1426
1999	65	0	1	4123	52	0	0	2383	0	0	0	4	13	0	0	1622	0	0	0	25
2000	88	0	0	5212	116	0	4	4655	0	0	0	0	10	0	0	1088	0	0	0	7
2001	5	0	2	4608	14	0	2	4053	0	0	0	7	32	0	0	4226	0	0	0	3
2002	0	0	0	5294	0	0	0	6347	0	0	0	14	0	0	0	1445	0	0	0	0
2003	2	0	3	3293	8	0	1	2092	0	0	0	0	0	0	0	2410	0	0	0	123
2004	2	0	0	3989	0	0	0	4556	0	0	0	0	0	0	0	1441	0	0	0	0
2005	2	0	0	1501	6	0	0	1862	0	22	0	0	0	0	0	758	0	0	0	0

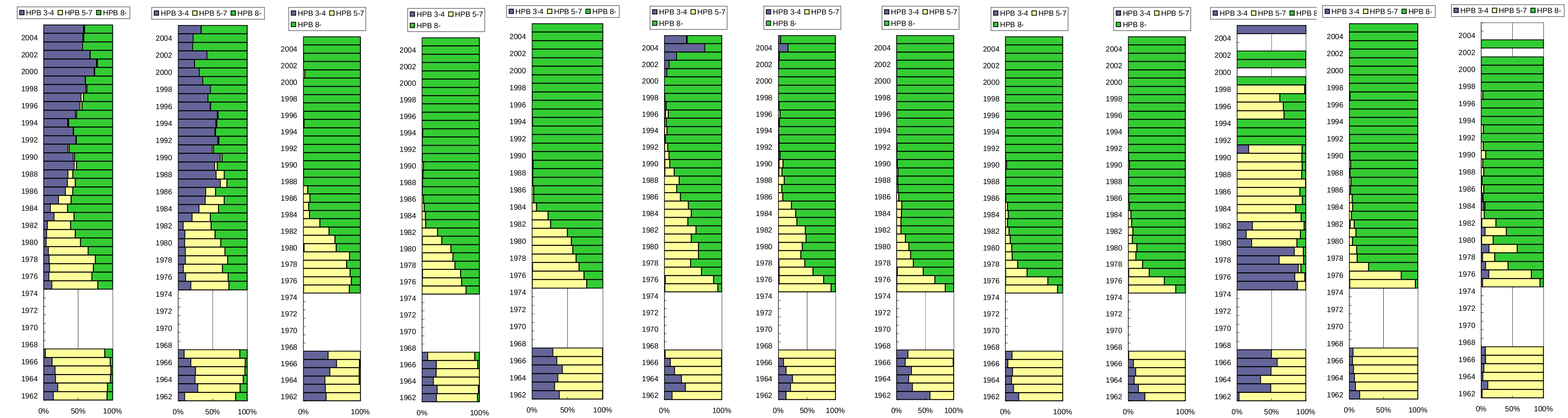


Table 2. Chi-squaed values calculated in each model. The effects of hooks per basket (HPB) and interaction with quarter (qt) are relatively high at area 1, 2, 11 and 13.

Effect	Df	Chi-squared	Pr
Area 1			
yr	36	17002	<.0001
qt	3	26760	<.0001
HPB	2	849	<.0001
yr*qt	105	14479	<.0001
qt*HPB	6	3942	<.0001
Area2			
yr	36	6401	<.0001
qt	3	9102	<.0001
HPB	2	652	<.0001
yr*qt	105	6566	<.0001
qt*HPB	6	2517	<.0001
Area 3-5			
yr	36	2884	<.0001
qt	3	798	<.0001
HPB	2	222	<.0001
area	2	4939	<.0001
yr*qt	105	2839	<.0001
yr*area	72	1828	<.0001
qt*area	6	245	<.0001
qt*HPB	6	92	<.0001
Area 6-7			
yr	36	2652.9	<.0001
qt	3	634.97	<.0001
HPB	2	81.81	<.0001
area	1	348.03	<.0001
yr*qt	101	3656.89	<.0001
yr*area	36	2145.45	<.0001
qt*area	3	523.98	<.0001
qt*HPB	6	171.07	<.0001
Area 8			
yr	36	6932.93	<.0001
qt	3	1254.96	<.0001
HPB	2	211.46	<.0001
yr*qt	106	8073.33	<.0001

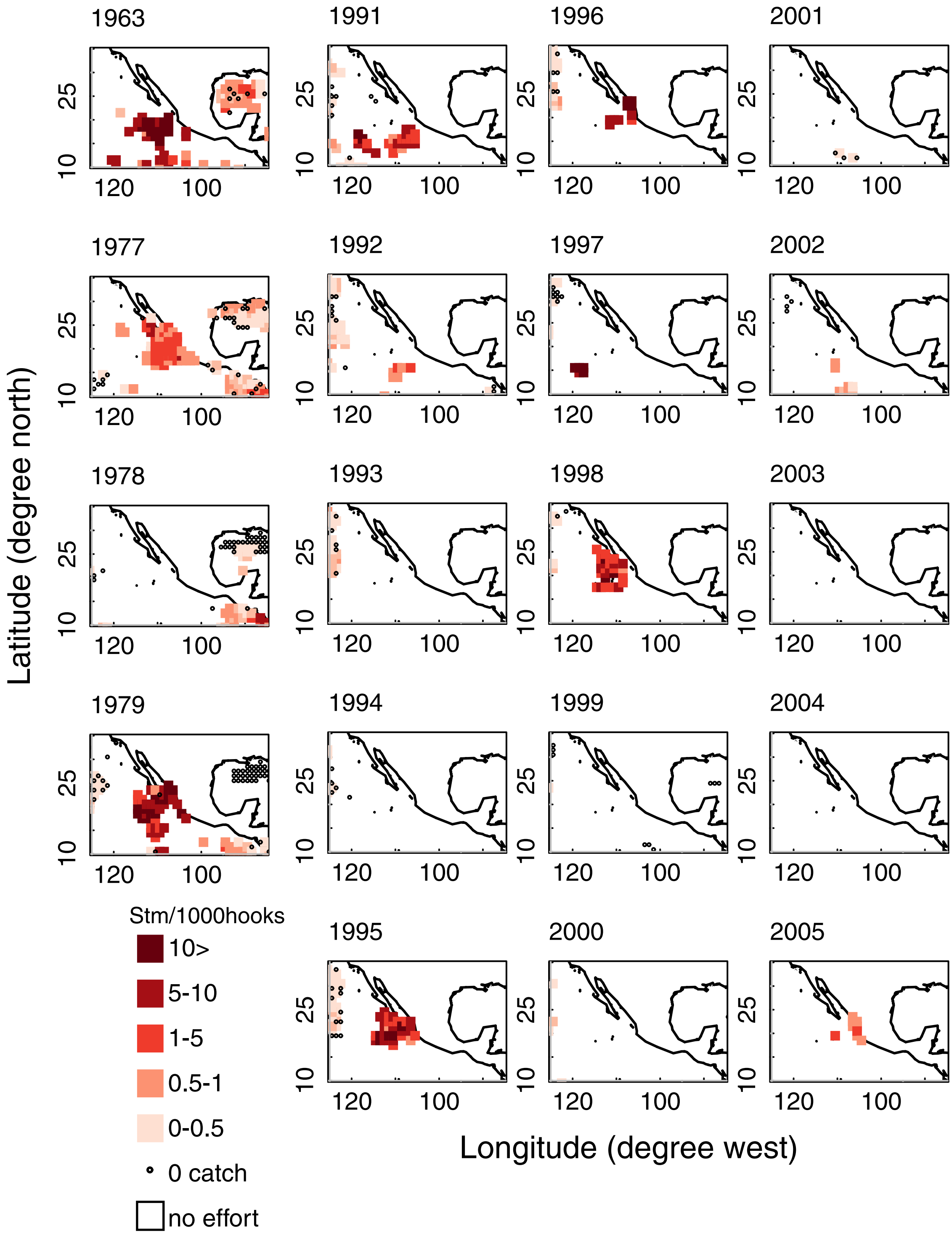
Effect	Df	Chi-squared	Pr
Area 9			
yr	43	5573.11	<.0001
qt	3	163.29	<.0001
HPB	2	30.04	<.0001
yr*qt	129	10725.4	<.0001
qt*HPB	6	8.36	0.2126
Area 10			
yr	36	2136.68	<.0001
qt	3	55.96	<.0001
HPB	2	43.87	<.0001
yr*qt	106	3506.23	<.0001
qt*HPB	6	21.35	0.0016
Area 11			
yr	22	2681.93	<.0001
qt	3	240.06	<.0001
HPB	2	963.48	<.0001
yr*qt	59	3647.22	<.0001
qt*HPB	6	387.47	<.0001
Area 12			
yr	43	10368	<.0001
qt	3	388.97	<.0001
HPB	2	77.66	<.0001
yr*qt	128	7917.37	<.0001
qt*HPB	6	82.55	<.0001
Area 13			
yr	29	9316.72	<.0001
qt	3	213.85	<.0001
HPB	2	629.21	<.0001
yr*qt	83	3730.09	<.0001
qt*HPB	6	104.42	<.0001

Table 3. Calculated least squared means of CPUE by area and region. The index used for area weighting is also shown. The scaled indices used in the previous analysis were also shown.

	Area												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Model	3	3	1	1	1	1	1	1	1	1	3	1	3
Area size	9.0	10.6	4.1	6.7	11.2	9.6	10.6	10.2	5.3	4.9	9.1	5.8	2.8
Average CPUE	0.38	0.56	0.08	0.21	0.03	0.78	1.56	0.88	0.32	0.13	5.50	0.95	1.83
Learst squared mean of CPUE													
1962	0.59	1.13	0.19	0.14	0.03	0.83	2.45	0.79	0.33	0.09		1.80	
1963	0.45	1.20	0.27	0.29	0.05	1.13	2.17	1.35	0.32	0.10		1.55	5.00
1964	0.97	0.92	0.18	0.55	0.10	2.72	3.51	2.09	0.32	0.18	10.29	1.34	1.99
1965	0.62	0.90	0.13	0.45	0.11	1.97	3.46	1.84	0.51	0.08	4.16	2.48	7.02
1966	0.43	0.70	0.09	0.23	0.06	0.86	2.33	1.32	0.80	0.19	5.88	2.13	8.57
1967	0.43	0.62	0.14	0.19	0.06	1.54	2.62	0.75	0.65	0.08	5.86	3.06	8.33
1968	0.39	0.80	0.07	0.29	0.06	0.84	4.05	2.34	0.69	0.08	6.18	1.97	5.09
1969	0.45	0.68	0.09	0.21	0.06	0.71	1.92	1.67	0.51	0.12	5.93	1.78	2.84
1970	0.77	0.66	0.06	0.30	0.06	1.13	4.23	1.50	0.88	0.29	5.87	2.09	2.33
1971	0.91	0.61	0.11	0.11	0.05	1.07	3.28	0.79	0.82	0.19	7.66	2.89	3.38
1972	0.53	0.81	0.18	0.18	0.04	0.96	0.87	0.60	0.43	0.12	4.96	1.43	3.47
1973	0.54	0.78	0.23	0.38	0.07	0.65	1.80	0.99	0.51	0.33	3.22	0.73	0.94
1974	0.86	0.87	0.06	0.18	0.03	0.35	0.56	0.35	0.34	0.13	3.99	1.05	1.82
1975	0.43	0.65	0.03	0.17	0.02	1.38	1.29	0.57	0.47	0.21	5.46	0.92	1.68
1976	0.25	0.37	0.05	0.13	0.02	0.75	1.11	0.54	0.29	0.10	4.72	0.61	1.24
1977	0.18	0.17	0.02	0.04	0.02	0.92	1.14	0.48	0.30	0.10	1.54	0.56	0.77
1978	0.17	0.36	0.02	0.05	0.02	0.85	1.17	0.38	0.17	0.10	0.44	0.49	0.80
1979	0.26	0.59	0.03	0.26	0.03	0.86	1.47	0.99	0.33	0.13	4.02	0.76	3.91
1980	0.39	0.92	0.06	0.15	0.02	0.54	1.34	0.83	0.25	0.14		0.71	1.01
1981	0.30	0.48	0.03	0.14	0.02	0.51	1.04	0.37	0.32	0.12	4.21	0.60	1.33
1982	0.18	0.36	0.03	0.16	0.01	0.61	0.97	0.48	0.14	0.06	7.03	0.39	2.92
1983	0.19	0.28	0.11	0.14	0.02	0.58	0.71	0.56	0.23	0.08	5.89	0.61	1.22
1984	0.36	0.44	0.06	0.12	0.02	0.62	0.75	0.33	0.12	0.06	5.48	0.48	0.56
1985	0.48	0.58	0.10	0.35	0.02	0.86	1.16	1.38	0.17	0.06		0.78	1.09
1986	0.41	1.15	0.09	0.16	0.05	0.94	0.68	0.71	0.18	0.11	8.81	0.47	0.90
1987	0.39	0.45	0.07	0.15	0.03	1.03	1.94	1.07	0.21	0.12	11.10	0.75	1.31
1988	0.52	0.75	0.01	0.14	0.03	1.04	1.45	1.03	0.40	0.21	7.64	0.67	0.60
1989	0.36	0.71	0.02	0.15	0.02	0.56	1.43	0.72	0.34	0.15	6.88	0.64	0.90
1990	0.34	0.52	0.05	0.25	0.01	0.32	1.02	0.69	0.12	0.06		0.47	1.04
1991	0.36	0.80	0.03	0.17	0.03	0.36	1.66	0.79	0.12	0.10	0.23	0.28	0.66
1992	0.42	0.55	0.04	0.40	0.02			1.72	0.20	0.23		0.36	0.32
1993	0.60	0.77	0.04	0.21	0.03	0.71	2.04	0.85	0.21	0.14		0.45	1.00
1994	0.46	0.71	0.04	0.34	0.03			0.64	0.37	0.21		0.64	0.41
1995	0.78	0.84	0.03	0.12	0.02	0.79	1.39	0.68	0.23	0.12		0.61	0.30
1996	0.42	0.50	0.03	0.39	0.04	0.35	1.41	1.40	0.35	0.13		0.55	0.29
1997	0.49	0.60	0.10	0.14	0.02	0.21	0.45	0.51	0.23	0.09		1.23	1.25
1998	0.47	0.77	0.07	0.22	0.05			0.50	0.20	0.13		0.38	0.31
1999	0.36	0.62	0.05	0.15	0.03			0.75	0.21	0.12		0.40	
2000	0.23	0.57	0.04	0.11	0.01			0.58	0.17	0.10		0.49	
2001	0.23	0.34	0.04	0.16	0.02	0.48	0.80	0.83	0.12	0.08		0.26	
2002	0.14	0.38	0.11	0.22	0.03	0.08	0.12	0.65	0.17	0.09		0.34	
2003	0.22	0.54	0.12	0.15	0.03	0.14	0.44	0.68	0.11	0.07		0.19	
2004	0.14	0.35	0.04	0.14	0.02	0.10	0.35	0.39	0.17	0.09		0.47	
2005	0.13	0.22	0.02	0.05	0.02	0.12	0.37	0.41	0.17	0.09			

Table 3. Continued. The columns by shaded by gray were the year when CPUE at region 4 was compensated by average values of CPUE in the nearest years.

	Region					Region 1-4	All	Scaled index in Yokawa & Clark (2005)	
	1	2	3	4	5			All region	Region 1-4
1962	0.88	0.09	1.68	0.50		0.77	0.74	0.88	0.64
1963	0.86	0.16	1.68	0.78		0.86	0.93	1.53	0.65
1964	0.94	0.25	3.14	1.17	6.05	1.35	2.18	1.59	0.79
1965	0.78	0.22	2.75	1.07	4.06	1.18	1.69	1.28	0.69
1966	0.58	0.12	1.63	0.91	5.07	0.80	1.55	1.31	0.65
1967	0.53	0.12	2.11	0.56	5.34	0.82	1.61	1.52	0.86
1968	0.61	0.13	2.53	1.37	4.63	1.14	1.76	1.42	0.71
1969	0.57	0.11	1.35	1.00	4.08	0.74	1.34	1.27	0.58
1970	0.71	0.13	2.77	1.05	4.08	1.14	1.66	1.42	0.82
1971	0.75	0.08	2.24	0.65	5.42	0.91	1.71	1.67	0.79
1972	0.68	0.11	0.91	0.44	3.57	0.53	1.06	0.91	0.42
1973	0.67	0.19	1.25	0.71	2.04	0.69	0.93	0.71	0.33
1974	0.86	0.08	0.46	0.29	2.69	0.41	0.81	0.88	0.38
1975	0.55	0.07	1.34	0.46	3.38	0.59	1.08	0.88	0.37
1976	0.32	0.06	0.94	0.37	2.83	0.41	0.84	0.76	0.30
1977	0.18	0.02	1.04	0.34	1.09	0.39	0.51	0.65	0.25
1978	0.28	0.03	1.02	0.26	0.51	0.39	0.41	0.58	0.28
1979	0.44	0.10	1.18	0.61	2.93	0.57	0.99	0.99	0.44
1980	0.68	0.07	0.96	0.51		0.54	0.89	1.26	0.46
1981	0.39	0.06	0.79	0.30	2.57	0.38	0.77	0.81	0.35
1982	0.27	0.06	0.80	0.29	4.21	0.35	1.03	0.79	0.32
1983	0.24	0.07	0.65	0.36	3.42	0.32	0.87	0.63	0.28
1984	0.41	0.06	0.69	0.21	3.07	0.33	0.82	0.82	0.34
1985	0.53	0.14	1.02	0.75		0.60	1.22	1.19	0.46
1986	0.81	0.09	0.80	0.43	4.83	0.52	1.28	0.87	0.34
1987	0.43	0.07	1.51	0.61	6.16	0.64	1.62	1.07	0.44
1988	0.65	0.06	1.26	0.67	4.25	0.65	1.28	1.05	0.43
1989	0.55	0.06	1.02	0.49	3.89	0.52	1.11	0.93	0.46
1990	0.44	0.09	0.69	0.39		0.40		0.84	0.30
1991	0.60	0.07	1.05	0.45	0.31	0.53	0.49	0.68	0.26
1992	0.49	0.14		0.97		0.39		0.89	0.30
1993	0.69	0.09	1.41	0.51		0.66		0.86	0.36
1994	0.59	0.13		0.47		0.29		0.71	0.37
1995	0.82	0.05	1.11	0.43		0.59		1.07	0.49
1996	0.46	0.15	0.91	0.82		0.58		0.87	0.33
1997	0.55	0.07	0.33	0.34		0.32		0.81	0.49
1998	0.63	0.10		0.33		0.26		0.99	0.28
1999	0.50	0.07		0.46		0.25		0.68	0.22
2000	0.41	0.05		0.36		0.20			0.30
2001	0.29	0.07	0.65	0.47		0.36		0.94	0.25
2002	0.27	0.10	0.10	0.39		0.21			0.22
2003	0.40	0.09	0.30	0.39		0.29			0.23
2004	0.26	0.06	0.23	0.26		0.20			
2005	0.18	0.03	0.25	0.27		0.18			



Appendix figure 1. CPUE distribution within area 11 in representative years before 1990 (1962, 1977-1979) and after 1991. There were no efforts in 1994, 1999, 2000, 2003 and 2004 in area 11. Because the data are unsorted ones, inconsistent data are contained in this figure more or less.

Appendix 2: extending CPUE series back to 1952

For the use of stock assessment that estimates stock status from 1952, CPUE of striped marlin in the North Pacific was standardized from 1952.

Table A in Appendix 2 shows historical number of operations including data before 1961. Because some parts of set-by-set data before 1961 is very scarce, especially in region 5 and 1957-1958, data in region 5 and in the other region during 1957-1958 was removed when calculating standardized CPUE. Information about HPB is also missing during 1952-1957.

Model for standardizing CPUE was same as used in the main document. Model 1 without effect of HPB was applied to region2-4. Model 3 including effect of HPB and assumption of HPB was applied to region 1. HPB during 1952-1957, when HPB information is missing, in region 1 was assumed as in category of 5-7 HPB.

The addition of new data before 1961 might affect of CPUE trends after 1962 through the changes of effects, the estimated trends in each region was not different each other (Appendix figure A). In addition, pattern of effect of HPB was also not changed from that calculated in the main document (Appendix 2 Table B).

CPUE trends extending back to 1952 were shown in Appendix figure B. LS mean of standardized CPUE before 1961 was relatively higher than that during 1960th at area 1, 2 and 3 in region 1 and 2, while it was lower in region 3 and 4. Consequently, scaled indices are different among regions especially between region 1-2 and 3-4 during 1950th. Then, overall CPUE during 1950th was settled at moderate level.

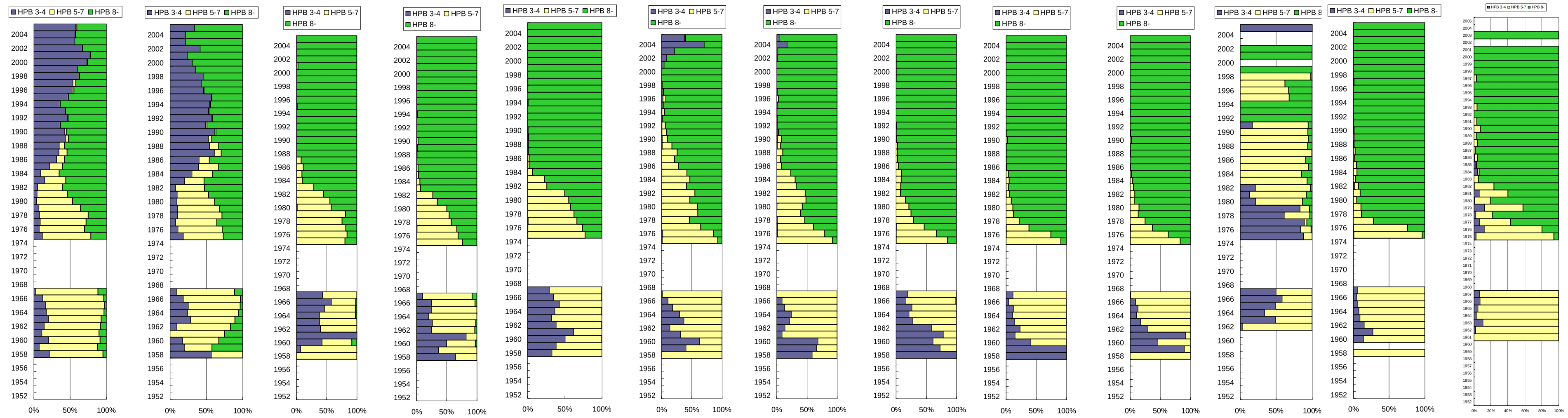
This result indicates that calculation of overall CPUE before 1960 seems to be a little problematic. In addition, it is another problem that CPUE in region 5 could not be calculated before 1961 because of lack of effort during the period.

Appendix 2: table A. Total number of longline operations recorded by Japanese set-by-set data from 1952. All data are categorized by number of hooks per basket (HPB) of unkown, 3-4, 5-7 and more than 8. The figure below the table represents historical trends of percentages of Hpb to the total operations.

	Area 1				Area 2				Area 3				Area 4			
	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-
1952	6846	0	0	0	2987	0	0	0	82	0	0	0	360	0	0	0
1953	7944	0	0	0	3259	0	0	0	226	0	0	0	426	0	0	0
1954	14386	0	0	0	10378	0	0	0	381	0	0	0	123	0	0	0
1955	16007	0	0	0	8621	0	0	0	344	0	0	0	424	0	0	0
1956	13887	0	0	0	11215	0	0	0	403	0	0	0	545	0	0	0
1957	10507	0	0	0	8728	0	0	0	245	0	0	0	939	0	0	0
1958	21	24	79	5	45	17	13	0	0	0	1	0	5	11	6	0
1959	640	80	902	137	957	160	313	345	120	1	13	0	111	100	175	0
1960	11899	2260	7901	981	5864	729	2111	1380	599	123	143	24	601	552	526	29
1961	15985	32	230	30	10415	0	98	33	1928	25	0	0	1594	37	8	0
1962	7705	505	2782	293	9542	370	2908	657	1789	151	228	0	2411	121	348	17
1963	10244	978	3476	357	8795	332	722	122	1427	217	345	0	1320	77	211	5
1964	9053	3321	15327	655	5805	2188	6328	514	1887	893	1420	48	1908	197	795	0
1965	839	4866	23813	775	1209	3771	10690	478	284	1499	1670	66	309	767	2380	0
1966	544	2702	18645	786	427	2451	10679	402	254	2012	1407	61	143	622	1792	79
1967	25629	16	564	76	12587	21	195	26	4525	29	38	0	2584	26	214	21
1968	17037	0	0	0	12449	0	0	0	4225	0	0	0	2135	0	0	0
1969	15054	0	0	0	8510	0	0	0	3600	0	0	0	2094	0	0	0
1970	13919	0	0	0	8268	0	0	0	2766	0	0	0	3665	0	0	0
1971	12328	0	0	0	6370	0	0	0	2375	0	0	0	2199	0	0	0
1972	7156	0	0	0	3411	0	0	0	2008	0	0	0	1094	0	0	0
1973	6806	0	0	0	4155	0	0	0	3764	0	0	0	1823	0	0	0
1974	7398	0	0	0	4863	0	0	0	6996	0	0	0	4778	0	0	0
1975	322	874	4981	1600	244	977	2959	1430	391	43	5577	1377	226	0	2925	896
1976	465	984	8270	3987	428	913	5193	2319	253	18	7290	1415	250	12	2668	1207
1977	136	1015	7425	3285	139	876	6666	4197	272	0	6057	1341	140	44	3339	1664
1978	149	882	7646	2871	234	979	5743	2639	66	0	4570	1478	106	0	3126	2309
1979	4292	924	7786	4785	1745	840	4589	2566	1752	3	2699	629	2131	23	2810	2416
1980	2436	438	6185	5763	1383	1011	5547	4093	783	34	1325	1006	1632	0	2538	2505
1981	616	716	7028	9071	587	1265	5575	6002	82	0	1846	1489	306	47	2726	5275
1982	581	909	5906	10604	507	833	4613	5977	45	0	778	954	61	0	1454	3895
1983	443	2597	5021	9687	242	1840	2425	4862	26	0	488	1195	184	5	282	4047
1984	299	1706	4501	11619	220	2696	2520	3719	7	0	226	1890	27	2	326	5257
1985	287	3721	3187	10487	130	2886	2021	2449	23	0	87	842	53	0	149	3877
1986	387	5245	1821	9630	229	3330	1190	3821	8	0	48	368	89	0	205	7234
1987	150	4466	1476	7040	175	4364	689	2105	12	0	37	436	61	0	24	7596
1988	581	5303	1123	8713	181	2702	587	1649	35	0	0	500	35	14	39	7522
1989	742	5928	507	7035	258	2875	208	2366	9	0	2	406	72	12	61	4628
1990	842	5081	251	6610	230	2643	100	1588	23	0	0	498	17	0	77	3118
1991	1032	4484	261	8130	530	2345	88	2330	89	0	0	602	352	38	0	6532
1992	731	4943	72	5589	518	2997	72	2141	94	0	0	1348	238	0	0	3784
1993	915	4787	80	6328	334	3142	58	2729	57	0	0	424	117	0	17	4934
1994	890	4245	194	7767	398	2595	67	2094	0	0	0	492	0	31	18	3744
1995	785	4379	167	4998	524	2664	49	2000	17	3	5	625	138	0	0	4622
1996	826	4494	229	3799	752	2301	28	2638	26	0	1	159	188	0	0	3558
1997	1094	4514	323	3528	700	1911	0	2540	12	0	0	254	75	0	0	1583
1998	738	4739	141	2885	534	1867	0	2146	21	0	0	194	122	0	0	3515
1999	642	5345	31	3504	336	1351	0	2467	1	0	0	88	57	0	0	3606
2000	503	6261	44	2250	414	859	0	1946	33	0	0	326	75	0	0	3836
2001	308	6151	136	1780	150	622	7	2022	36	0	14	566	31	0	0	4219
2002	281	5118	35	2479	197	1013	0	1432	0	0	0	172	65	0	5	2534
2003	55	4509	12	3504	128	428	0	1615	6	0	4	686	18	0	0	3258
2004	81	4072	99	3026	13	337	0	1229	0	0	0	698	0	0	0	1432
2005	1	2915	72	2049	0	402	7	812	0	0	0	380	0	0	0	1846

	Area 5				Area 6				Area 7				Area 8			
	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-
1952	1730	0	0	0	6	0	0	0	82	0	0	0	659	0	0	0
1953	2817	0	0	0	362	0	0	0	258	0	0	0	496	0	0	0
1954	2912	0	0	0	485	0	0	0	630	0	0	0	341	0	0	0
1955	4978	0	0	0	2454	0	0	0	1112	0	0	0	1046	0	0	0
1956	4174	0	0	0	1509	0	0	0	946	0	0	0	199	0	0	0
1957	6929	0	0	0	1463	0	0	0	577	0	0	0	287	0	0	0
1958	27	38	78	0	0	0	1	0	10	7	5	0	4	23	0	0
1959	252	311	504	0	0	12	18	0	14	64	33	0	40	204	76	0
1960	2534	2632	2585	18	374	978	574	2	911	1931	912	0	180	618	396	0
1961	10434	86	53	0	1525	15	33	0	1258	2	21	0	2367	64	18	0
1962	8302	705	1128	9	2038	50	321	0	1262	51	325	0	2463	550	391	0
1963	8882	455	972	0	3519	397	686	0	1235	94	350	0	3592	226	586	0
1964	6924	1563	2718	19	1608	112	263	0	1808	99	304	0	6287	200	734	0
1965	1472	6234	8398	24	114	213	991	0	161	157	1021	1	523	396	1121	0
1966	936	3551	6581	47	64	200	1697	10	63	75	769	0	126	268	1476	17
1967	10338	155	371	1	2503	1	80	0	4038	0	168	0	2535	26	106	0
1968	9967	0	0	0	1773	0	0	0	3765	0	0	0	1829	0	0	0
1969	10490	0	0	0	1904	0	0	0	3578	0	0	0	1507	0	0	0
1970	8044	0	0	0	2924	0	0	0	6078	0	0	0	4889	0	0	0
1971	7713	0	0	0	2415	0	0	0	3897	0	0	0	2716	0	0	0
1972	11069	0	0	0	4190	0	0	0	4822	0	0	0	2775	0	0	0
1973	10308	0	0	0	3100	0	0	0	5109	0	0	0	4161	0	0	0
1974	11585	0	0	0	1679	0	0	0	3393	0	0	0	5187	0	0	0
1975	1044	58	8948	2648	74	9	1187	91	176	3	2446	203	219	13	3788	666
1976	1065	31	10963	3944	276	61	2919	497	262	49	2540	672	149	23	3525	1753
1977	875	116	10003	5117	1	0	1841	1015	101	52	2426	1603	192	42	1604	1875
1978	252	1	11107	6725	111	1	1280	1515	168	49	2981	3522	64	0	2086	5007
1979	3425	1	12192	8878	249	0	2117	1433	389	5	2646	4065	260	0	1290	3930
1980	4781	18	12827	10320	102	5	3100	2109	76	11	841	1168	183	0	1210	4431
1981	698	0	13559	13571	9	0	2603	2954	18	0	1971	2080	270	0	1048	5590
1982	642	0	5331	15126	47	0	2216	1802	54	0	1479	1665	200	0	414	5035
1983	327	0	3895	13199	68	0	2302	3315	10	0	887	1859	84	0	343	4128
1984	209	0	1286	19374	130	0	4118	4657	45	0	742	1693	134	0	396	4210
1985	359	0	431	18273	217	0	2801	3890	51	0	454	1513	91	0	350	3431
1986	308	0	286	12214	124	0	947	2416	124	0	338	4031	94	0	190	4524
1987	286	0	153	15022	151	0	1186	4305	7	0	144	2183	271	0	123	4712
1988	177	0	90	7906	76	1	1549	4437	131	1	289	2560	134	0	218	9703
1989	524	34	110	11446	128	48	1030	5228	118	42	221	3662	188	0	273	9606
1990	1019	0	94	15791	179	32	396	4040	141	40	190	2550	253	0	82	6050
1991	569	0	0	9710	152	24	383	4555	47	17	53	2112	144	0	38	6577
1992	975	0	0	11603	1	20	198	3444	111	22	33	4356	308	0	31	3691
1993	522	0	6	8947	0	5	67	3874	44	0	57	3966	317	0	1	5543
1994	153	0	61	8799	0	5	79	1704	0	0	10	4314	0	0	1	4812
1995	70	0	28	8238	0	19	53	2093	30	0	67	3832	12	0	2	6383
1996	190	0	0	9543	0	64	128	2558	0	1	53	1813	58	0	0	3699
1997	186	20	0	8716	7	17	49	2043	3	1	25	1890	0	0	2	2972
1998	155	0	0	8413	0	0	13	1691	0	0	0	2122	10	0	5	2328
1999	88	0	0	11054	40	0	4	2046	29	0	0	4293	108	0	9	2862
2000	84	0	0	9190	24	0	0	669	45	0	0	2685	6	1	4	2281
2001	56	0	0	9745	11	45	0	1043	0	0	0	1336	12	0	9	2389
2002	101	0	0	8243	15	30	0	328	0	20	0	2639	0	0	8	1760
2003	14	0	0	6209	0	290	3	1094	0	83	0	4402	8	0	0	3131
2004	51	0	0	6192	0	580	0	246	0	275	0	1336	9	0	0	3196
2005	27	0	0	4814	0	221	9	349	0	98	0	2302	0	0	0	2730

	Area 9				Area 10				Area 11				Area 12				Area 13			
	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-	HPB unknown	HPB 3-4	HPB 5-7	HPB 8-
1952	113	0	0	0	534	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1953	110	0	0	0	1067	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1954	362	0	0	0	652	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	852	0	0	0	1081	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
1956	954	0	0	0	741	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
1957	1241	0	0	0	1822	0	0	0	0	0	0	0	33	0	0	0	0	0	0	0
1958	2	1	0	0	1	0	11	0	0	0	0	0	0	0	1	0	0	0	0	0
1959	9	1	0	0	22	55	6	0	0	0	0	0	0	0	0	0	0	0	0	0
1960	583	653	946	0	313	525	643	0	0	0	0	0	41	8	49	0	5	0	0	0
1961	3448	3	17	0	3220	12	1	0	0	0	0	0	822	6	16	0	285	0	10	0
1962	1931	293	970	0	1786	212	518	0	2	2	64	0	1372	359	1988	0	121	7	385	0
1963	2393	203	1211	0	4552	351	1639	0	45	54	56	0	1581	161	1604	0	494	58	493	0
1964	5607	174	1445	1	3345	65	557	0	2851	623	1206	0	2928	145	1755	0	798	15	511	0
1965	730	440	3050	0	671	488	3299	0	523	2039	2091	0	415	142	2182	0	66	36	755	0
1966	243	96	2196	0	299	162	1642	2	44	1854	1332	0	133	106	2074	0	10	75	987	1
1967	3843	32	246	0	3078	1	98	0	2830	51	51	0	3391	12	212	0	1386	21	291	0
1968	2648	0	0	0	2677	0	0	0	5368	0	0	0	3383	0	0	0	2338	0	0	0
1969	4682	0	0	0	2816	0	0	0	2956	0	0	0	3754	0	0	0	2550	0	0	0
1970	7981	0	0	0	4214	0	0	0	3469	0	0	0	3934	0	0	0	1806	0	0	0
1971	5844	0	0	0	4916	0	0	0	2888	0	0	0	3306	0	0	0	1170	0	0	0
1972	4551	0	0	0	7322	0	0	0	3205	0	0	0	3265	0	0	0	1806	0	0	0
1973	6126	0	0	0	2252	0	0	0	2993	0	0	0	2883	0	0	0	3675	0	0	0
1974	7543	0	0	0	3980	0	0	0	3134	0	0	0	2459	0	0	0	2542	0	0	0
1975	192	4	2652	271	156	5	1219	248	183	1210	169	0	237	31	3929	145	102	78	2952	177
1976	187	31	5301	1865	410	33	4141	2422	0	2523	440	44	125	13	3272	1042	89	256	1426	411
1977	237	20	2298	3812	444	47	2022	3524	7	735	32	59	288	3	1580	4072	128	260	1358	2120
1978	29	0	1437	5173	15	0	783	2336	0	77	45	4	107	0	576	4443	103	88	744	2971
1979	209	0	1028	7348	252	0	753	4833	17	292	46	13	63	15	923	7850	50	102	368	343
1980	200	4	428	3413	402	0	878	5000	156	261	812	161	243	5	208	4333	80	23	591	2549
1981	94	0	424	4478	201	0	243	3046	0	218	1294	132	78	0	366	3431	0	57	306	538
1982	28	20	240	3859	190	13	572	6713	0	526	1789	60	43	87	324	5265	35	9	204	684
1983	136	0	147	3645	155	0	254	4058	0	0	1851	139	77	0	185	5431	152	0	162	2871
1984	115	0	243	4268	233	0	334	6964	0	0	761	131	0	0	168	3065	0	32	14	685
1985	95	0	250	5968	114	0	151	6343	0	0	55	3	0	1	191	4217	0	17	9	773
1986	25	0	40	4437	37	0	37	4055	3	0	681	65	0	0	41	2332	16	10	43	1164
1987	66	0	12	4849	117	0	0	2942	0	0	1318	5	0	0	132	5001	15	0	18	1254
1988	31	0	15	5668	29	0	16	2371	0	0	1207	79	19	0	11	1162	32	0	77	1754
1989	120	0	17	6994	35	0	15	3779	55	0	617	34	248	0	146	6357	0	0	39	1320
1990	194	0	154	7428	137	0	144	6260	0	0	194	12	60	0	41	3581	183	0	43	526
1991	198	0	18	5507	59	0	39	4891	0	40	182	13	45	0	10	3338	91	0	46	1250
1992	232	0	0	4495	204	0	0	2040	1	0	0	65	166	0	17	4310	40	0	1	1689
1993	57	0	0	6248	21	0	0	5435	2	0	0	30	50	0	2	2809	0	0	12	307
1994	149	0	0	5408	15	0	19	3274	0	0	0	2	90	0	0	1704	11	0	0	1236
1995	124	0	0	3556	108	0	0	2639	0	0	176	82	54	0	0	1798	0	0	0	3379
1996	99	1	0	3239	70	0	0	3065	0	0	29	14	5	0	0	459	0	0	0	2010
1997	22	0	0	2534	24	0	0	3692	0	0	33	20	13	0	45	4007	0	0	13	424
1998	4	0	0	3727	1	0	0	1557	0	0	175	3	0	0	0	4648	0	0	0	1426
1999	65	0	1	4123	52	0	0	2383	0	0	0	4	13	0	0	1622	0	0	0	25
2000	88	0	0	5212	116	0	4	4655	0	0	0	0	10	0	0	1088	0	0	0	7
2001	5	0	2	4608	14	0	2	4053	0	0	0	7	32	0	0	4226	0	0	0	3
2002	2	0	0	5294	0	0	0	6347	0	0	0	14	0	0	0	1445	0	0	0	0
2003	2	0	3	3293	8	0	1	2092	0	0	0	0	0	0	0	2410	0	0	0	123
2004	2	0	0	3989	0	0	0	4556	0	0	0	0	0	0	0	1441	0	0	0	0
2005	2	0	0	1501	6	0	0	1862	0	22	0	0	0	0	0	758	0	0	0	0



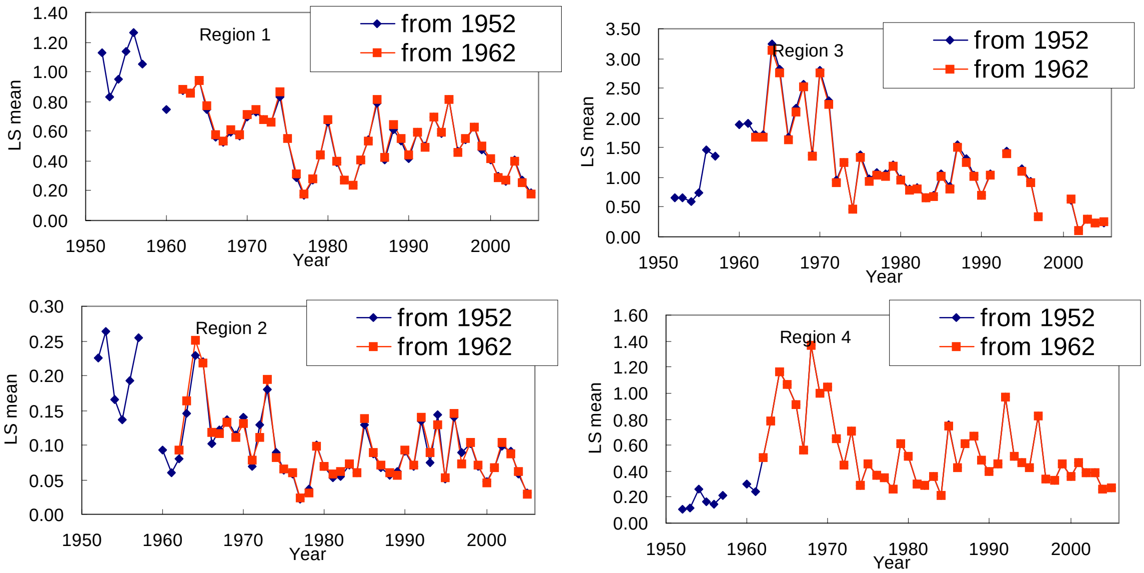
Appendix 2: Table B. Chi-squaed values calculated in each model using set-by-set data from 1952 in area 1-10.

Effect	Df	Chi-squared	Pr
Area 1			
yr	40	17424	<.0001
qt	3	31063	<.0001
HPB	2	780	<.0001
yr*qt	111	14741	<.0001
qt*HPB	6	3929	<.0001
Area2			
yr	40	6735	<.0001
qt	3	2919	<.0001
HPB	2	633	<.0001
yr*qt	111	6751	<.0001
qt*HPB	6	2332	<.0001
Area 3-5			
yr	40	2586	<.0001
qt	3	760	<.0001
HPB	2	233	<.0001
area	2	19283	<.0001
yr*qt	110	2983	<.0001
yr*area	79	1935	<.0001
qt*area	6	331	<.0001
qt*HPB	6	81	<.0001
Area 6-7			
yr	40	3023	<.0001
qt	3	735	<.0001
HPB	2	80	<.0001
area	1	39	<.0001
yr*qt	106	3772	<.0001
yr*area	40	2180	<.0001
qt*area	3	498	<.0001
qt*HPB	6	183	<.0001
Area 8			
yr	40	7023	<.0001
qt	3	546	<.0001
HPB	2	203	<.0001
yr*qt	111	8131	<.0001

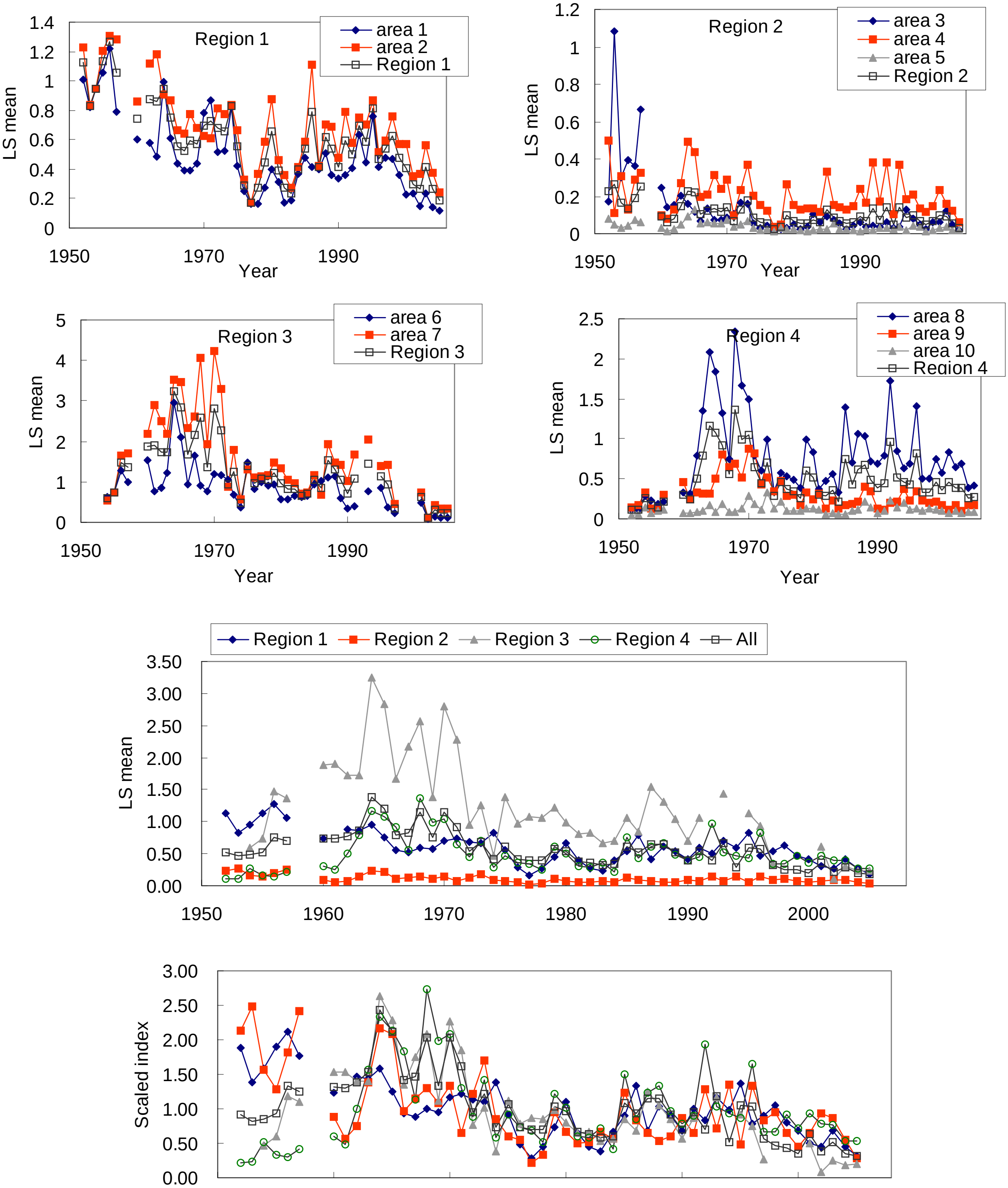
Effect	Df	Chi-squared	Pr
Area 9			
yr	40	3381	<.0001
qt	3	165	<.0001
HPB	2	30	<.0001
yr*qt	110	5613	<.0001
qt*HPB	6	14	0.0275
Area 10			
yr	40	2183	<.0001
qt	3	77	<.0001
HPB	2	43	<.0001
yr*qt	110	3518	<.0001
qt*HPB	6	18	0.0054

Appendix 2: Table C. Calculated least squared means of CPUE by area and region from 1952. The index used for area weighting is also shown. The columns by shaded by gray were the year when the overall CPUE was compensated by average values of CPUE of the nearest years in region missing estimates. CPUE at region 5 before 1961 was not calculated because of inadequate number of efforts before 1961.

	Area										Region				All region of 1-4
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	
Model	3	3	1	1	1	1	1	1	1	1					
Area size	9.0	10.6	4.1	6.7	11.2	9.6	10.6	10.2	5.3	4.9					
Average CPUE	0.42	0.63	0.07	0.20	0.04	0.84	1.56	0.88	0.32	0.13					
Learst squared mean of CPUE															
1952	1.01	1.23	0.17	0.50	0.08			0.12	0.15	0.05	1.13	0.23		0.11	0.52
1953	0.82	0.84	1.09	0.11	0.05			0.11	0.18	0.05	0.83	0.26		0.12	0.46
1954	0.95	0.95	0.30	0.31	0.03	0.62	0.55	0.28	0.33	0.15	0.95	0.17	0.58	0.26	0.48
1955	1.05	1.20	0.39	0.13	0.04	0.73	0.74	0.23	0.13	0.07	1.13	0.14	0.73	0.17	0.53
1956	1.22	1.31	0.36	0.29	0.07	1.27	1.65	0.19	0.11	0.10	1.27	0.19	1.47	0.15	0.75
1957	0.79	1.28	0.67	0.33	0.06	0.99	1.69	0.21	0.30	0.11	1.06	0.26	1.36	0.21	0.71
1958															
1959															
1960	0.60	0.86	0.25	0.10	0.03	1.54	2.20	0.33	0.46	0.07	0.74	0.09	1.89	0.30	0.74
1961			0.14	0.08	0.02	0.78	2.91	0.32	0.25	0.08		0.06	1.90	0.24	0.74
1962	0.58	1.12	0.15	0.13	0.02	0.85	2.50	0.79	0.33	0.09	0.87	0.08	1.72	0.50	0.78
1963	0.48	1.18	0.20	0.27	0.05	1.22	2.17	1.36	0.32	0.10	0.86	0.15	1.72	0.78	0.86
1964	0.99	0.91	0.16	0.50	0.09	2.95	3.52	2.09	0.32	0.18	0.95	0.23	3.25	1.17	1.37
1965	0.61	0.87	0.12	0.44	0.13	2.11	3.47	1.84	0.51	0.08	0.75	0.22	2.83	1.07	1.20
1966	0.44	0.66	0.07	0.20	0.06	0.93	2.33	1.32	0.80	0.19	0.56	0.10	1.67	0.91	0.80
1967	0.39	0.64	0.14	0.21	0.06	1.66	2.62	0.75	0.65	0.08	0.53	0.12	2.16	0.56	0.83
1968	0.39	0.77	0.08	0.31	0.05	0.91	4.07	2.34	0.69	0.08	0.60	0.14	2.57	1.37	1.15
1969	0.44	0.68	0.08	0.24	0.06	0.76	1.93	1.67	0.51	0.12	0.57	0.12	1.38	1.00	0.75
1970	0.78	0.62	0.08	0.29	0.07	1.21	4.23	1.50	0.88	0.29	0.70	0.14	2.80	1.05	1.15
1971	0.87	0.61	0.11	0.10	0.04	1.15	3.29	0.79	0.82	0.19	0.73	0.07	2.28	0.65	0.91
1972	0.52	0.81	0.16	0.23	0.05	1.04	0.87	0.60	0.43	0.12	0.68	0.13	0.95	0.44	0.54
1973	0.52	0.77	0.16	0.37	0.07	0.69	1.78	0.99	0.51	0.33	0.66	0.18	1.26	0.71	0.69
1974	0.82	0.84	0.05	0.21	0.03	0.37	0.56	0.35	0.34	0.13	0.83	0.09	0.47	0.29	0.41
1975	0.42	0.66	0.03	0.16	0.02	1.48	1.29	0.57	0.47	0.21	0.55	0.06	1.38	0.46	0.60
1976	0.25	0.33	0.05	0.12	0.02	0.81	1.11	0.54	0.29	0.10	0.29	0.06	0.97	0.37	0.41
1977	0.16	0.18	0.02	0.04	0.01	0.99	1.15	0.48	0.30	0.10	0.17	0.02	1.07	0.34	0.40
1978	0.16	0.37	0.02	0.05	0.03	0.91	1.18	0.38	0.17	0.10	0.27	0.04	1.05	0.26	0.40
1979	0.28	0.58	0.03	0.26	0.03	0.93	1.47	0.99	0.33	0.13	0.44	0.10	1.21	0.61	0.58
1980	0.40	0.88	0.05	0.15	0.03	0.58	1.34	0.83	0.25	0.13	0.66	0.07	0.98	0.51	0.54
1981	0.31	0.46	0.03	0.13	0.02	0.55	1.04	0.37	0.32	0.12	0.39	0.05	0.81	0.30	0.38
1982	0.18	0.36	0.04	0.14	0.01	0.66	0.97	0.48	0.14	0.06	0.27	0.05	0.82	0.29	0.35
1983	0.19	0.27	0.11	0.14	0.02	0.62	0.71	0.56	0.23	0.08	0.23	0.07	0.67	0.36	0.33
1984	0.37	0.42	0.06	0.12	0.02	0.66	0.74	0.33	0.12	0.06	0.40	0.06	0.70	0.21	0.34
1985	0.48	0.59	0.09	0.33	0.02	0.94	1.17	1.39	0.17	0.06	0.54	0.13	1.06	0.75	0.61
1986	0.41	1.11	0.07	0.15	0.06	1.01	0.69	0.71	0.18	0.11	0.79	0.09	0.84	0.43	0.53
1987	0.40	0.42	0.05	0.14	0.03	1.10	1.94	1.07	0.21	0.12	0.41	0.07	1.54	0.62	0.65
1988	0.51	0.71	0.02	0.13	0.03	1.13	1.46	1.03	0.40	0.21	0.61	0.06	1.31	0.67	0.65
1989	0.36	0.69	0.04	0.15	0.02	0.60	1.43	0.72	0.34	0.15	0.54	0.06	1.04	0.49	0.52
1990	0.34	0.48	0.06	0.24	0.01	0.35	1.02	0.69	0.12	0.06	0.41	0.09	0.70	0.39	0.39
1991	0.36	0.79	0.03	0.17	0.02	0.39	1.67	0.79	0.12	0.10	0.59	0.07	1.07	0.45	0.53
1992	0.41	0.58	0.04	0.38	0.02			1.72	0.20	0.23	0.50	0.13		0.97	0.40
1993	0.63	0.75	0.03	0.18	0.03	0.76	2.04	0.85	0.21	0.14	0.70	0.08	1.44	0.51	0.67
1994	0.44	0.71	0.06	0.38	0.03			0.64	0.37	0.21	0.59	0.14		0.47	0.29
1995	0.76	0.86	0.03	0.11	0.02	0.85	1.40	0.68	0.23	0.12	0.82	0.05	1.14	0.43	0.59
1996	0.41	0.52	0.04	0.37	0.04	0.38	1.41	1.40	0.35	0.13	0.47	0.14	0.93	0.82	0.58
1997	0.48	0.59	0.13	0.18	0.02	0.22	0.44	0.51	0.23	0.09	0.54	0.09	0.34	0.34	0.32
1998	0.47	0.76	0.08	0.21	0.04			0.50	0.20	0.13	0.63	0.10		0.33	0.26
1999	0.36	0.57	0.05	0.14	0.04			0.75	0.21	0.11	0.47	0.07		0.46	0.25
2000	0.22	0.57	0.02	0.12	0.01			0.58	0.18	0.10	0.41	0.05		0.36	0.20
2001	0.23	0.35	0.06	0.15	0.02	0.48	0.74	0.83	0.12	0.08	0.30	0.07	0.62	0.47	0.36
2002	0.15	0.37	0.06	0.23	0.03	0.09	0.12	0.65	0.17	0.09	0.27	0.10	0.10	0.39	0.21
2003	0.23	0.56	0.13	0.16	0.04	0.15	0.44	0.68	0.11	0.07	0.41	0.09	0.30	0.39	0.29
2004	0.14	0.37	0.05	0.13	0.02	0.10	0.34	0.39	0.17	0.09	0.27	0.06	0.23	0.26	0.20
2005	0.12	0.24	0.02	0.06	0.02	0.13	0.34	0.41	0.17	0.09	0.19	0.03	0.24	0.27	0.18



Appendix 2: Figure A. Estimated CPUE extending back to 1952 in region 1-4.



Appendix 2: Figure B. Estimated CPUE extending back to 1952 in region 1-4.