STANDARDIZED CPUE OF ATLANTIC BLUEFIN IN THE EASTERN ATLANTIC AND MEDITERRANEAN SEA OBTAINED FROM THE JAPANESE LONGLINE FISHERY

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SUMMARY

The Japanese longline fishery data in the east Atlantic and Mediterranean were analyzed to develop an index of abundance of the eastern stock of bluefin tuna. By applying the General Linear Model procedure, abundance of fish 8 years-old and older was estimated for 1974-1991. The results showed a decreasing trend after the mid-1980's, with some annual fluctuation. The most recent level of abundance was about 50 percent of the mid-1970's.

RESUME

Les données de la pêche palangrière japonaise dans l'Atlantique est et la Méditerranée ont été analysées pour établir l'indice d'abondance du stock est de thon rouge. L'abondance des poissons de 8 ans et plus a été estimée pour 1974-91 en appliquant la méthode du modèle linéaire généralisé. Les résultats montraient une tendance décroissante à partir du milieu des années quatre-vingt, avec quelques fluctuations annuelles. Le niveau d'abondance le plus récent était 50 % environ de celui du milieu des années soixante-dix.

RESUMEN

Se analizan los datos de la pesquería de palangre de Japón en el Atlántico este y el Mediterráneo, para desarrollar índices de abundancia del stock oriental de atún rojo. Se estimó la abundancia de las edades 8 años y más, 1974-1991, mediante la aplicación del Modelo Lineal Generalizado. Los resultados mostraron una tendencia descendente a partir de mediada la década de los años 80, con algunas fluctuaciones anuales. El nivel más reciente de abundancia era de aproximadamente el 50% del que había a mediados de la década de los 70.

1. Introduction

The abundance index from the commercial fishery is essential in the tuning process of VPA for the east Atlantic bluefin at ICCAT, since no other fishery independent index is available. The Japanese longline fishery has covered the widest distributional area of this species and accounted for the large part of the total adult bluefin catch.

In this study, the age specific CPUE series for 8 years old and older (8+) for the period of 1974 to 1991 were developed from the Japanese longline fishery. This CPUE series were standardized by General Linear Model (GLM) procedure applying multiplicative model.

2. Material and Method

The Japanese longline catch and effort data were used in this study. Two sets of data were available. One is categorized by month, 5-degree square (referred to as "5 BY 5 DATA" and is identical data which is submitted to ICCAT as Task II catch and effort data. This data was used to compare with the past results developed during stock assessment session at ICCAT. The other, which is nearly the subset of the 5 BY 5 DATA, includes additional information on the number of branch line between floats that characterizes the gear configuration to some extent (referred to as "BRANCH LINE DATA"). This data set seems superior to 5 BY 5 DATA because it not only includes additional information (i.e. gear) but also less aggregated.

The annual geographical distribution of the Japanese longline catch in the eastern Atlantic and Mediterranean was shown historically in Fig. 1. Catches were mostly concentrated in the area between 30°-40°N and 30°W-20°E. The catch of this species by Japan became significant in 1974 and onward, and this fact is also seen in Fig. 2 which shows monthly catch and effort of the Japanese longline fishery in the eastern Atlantic and the Mediterranean Sea since 1970. From Fig. 2, it is clear that the main fishing season lasted from March through July, although some catches were observed in winter season both in mid-1970s and recent several years. Taking all the information into account, it is decided to use the data for 1974-1991, March to July for area which is shown in Fig. 3 in GLM analysis.

Nominal CPUEs were aged by the slicing method on monthly basis applying the growth equation estimated by Cort (1991) to the available size data (fork length) measured on board of the Japanese longline boats. The recent catch-at-size (Fig. 4) shows this fishery targets adult fish mostly over 160 cm in fork length (FL). Fig. 4 also indicates there were not so big differences in catch-at-size between the eastern Atlantic and the Mediterranean. Then, it was decided to age nominal CPUE for fish age 8 (about 180 cm in FL) and older. The matching between CPUE and size data was done to use as small strata as possible (the smallest is by month and 5 (Lat.) X 10 (Long.) rectangle. However, size data was not always available and in that case substitutions were made with nearby strata. In the case of 1974, 1978 and 1982, catch-at-size data (data from the second quarter for the east Atlantic and the Mediterranean) were employed due to the small number of available size data.

GLM technique was applied to obtain annual trend of stock abundance. The multiplicative model was used as were the cases of recent works for the west Atlantic bluefin (Cramer 1991; Miyabe 1991, 1992). The model includes main effects of year, fishing season, area, gear (for BRANCH LINE DATA only), total other species caught (by-catch) and interaction term among them. The model is shown below.

LOG (CPUE + min(CPUE)) =

$$\mu + Y_i + M_j + A_k + O_l + (+ G_m) + \text{Interaction} + e_{ijkl(m)}$$

where LOG : natural logarithm,
min(CPUE) : minimum CPUE observed in data set,
CPUE : number of bluefin caught per 10^3 hooks,
μ : overall mean,
Y_i : effect of year,
M_j : effect of fishing season (month),
A_k : effect of area,
O_l : effect of total other catch (tunas and billfishes except bluefin),
G_m : effect of gear (number of branch line between floats) for "BRANCH LINE DATA",
Interaction : interaction term among main effects,
$e_{ijkl(m)}$: error term with $N(0,\sigma)$.

Regarding to fishing season, month was selected. Area used in GLM analysis was defined in Fig. 3, while original data resolution was maintained (5-degree square). Number of observations by main effect was tabulated in Tables 1 and 2.

In order to make use of zero (0) catch observation, it is common to add some constant to the observed CPUE to make log-transformation possible. It is known that the results do differ depending on the magnitude of constant being added, and it is not known the way to determine what the best constant is. In this analysis, zero catch observations were used by adding small constant (minimum CPUE observed) following the recent studies. The number of zero catch observation and its percentage were shown in Table 3. The percentage of zero catch observation on annual basis was low for 5 BY 5 DATA (<10%). The same percentage for BRANCH LINE DATA was larger and fluctuated between few and 20 % of the total number of observation. Both of them did not exhibit any temporal trend.

Preliminary runs were made using main effect only in order to categorize (set level) the total other catch and gear. For the former, catch rates of total other catch were classified by 1.0 per 1000 hooks. After these preliminary runs and investigation of the parameters estimated, following levels were set.

5 BY 5 DATA

Year : 1974 - 1991 (18 levels)
Month : Apr. - Jul. (4 levels, March is included in April)
Area : 1, 2, 4, 5, 6 (5 levels, area 3 and 7 are included in area 1 and 6, respectively)
Other : 0 to 4, 5 to 7, 8 and larger per 1000 hooks (3 levels)

BRANCH LINE DATA

Year : 1975 - 1991 (17 levels)
Month : Apr. - Jul. (4 levels, March is included in April)
Area : 1 - 7 (7 levels)
Other : 0 to 2, 3 to 5, 6 to 7, 8 and larger per 1000 hooks (4 levels)
Gear : 4 to 5, 6 to 8, 9 to 12 hooks between floats (3 levels)

The inclusion or exclusion of these main effects and interaction terms were determined statistically on the basis of F-test. At the same time, missing observation to any cell is not allowed in this analysis so as to make use of Least Square Mean (LSMEAN).

In addition to above analysis, some trials were made in order to incorporate oceanographic factors. This was responding to the recommendation made at 1990 SCRS (ICCAT 1991). Dr. B. Liorzou kindly provided the maps of weekly sea surface temperature (SST) in the Mediterranean Sea for 1984 - 1991. SST was read by 0.5°C accuracy for each month - 5-degree square strata. BRANCH LINE DATA were used and the same procedure stated above was applied except 5-degree square was used as main effect of area.

3. Result and Discussion

The east Atlantic and the Mediterranean Sea

Parameters were estimable in models shown in Table 4. According to the criterion of AIC, the best model was chosen. As the results, (Y + M + A + M*A + M*O) was selected for 5 BY 5 DATA, and (Y + M + A + B + O + M*A + B*O + M*O) was selected for BRANCH LINE DATA.

In general the largest contributor to Sum of Square (SS) among main effects is the other catch followed by gear and year terms in this order. It is considered very effective to include other catch information (by-catch) to the model. In contrast, month and, to lesser extent, area shared relatively small amount of SS. Reflecting this fact, interaction terms with other catch tended to be significant.

The distribution of overall residual from the final model (Fig. 5) was almost close to normal curve and considered to be acceptable. The results of ANOVA are listed in Table 4. R-square ranged from 0.51 to 0.61.

In Table 5, parameter estimate, least square mean of main effect year and their standard error were given. The estimated relative abundance were shown in Fig. 5 and Table 5. The abundance of 2 data sets (5 BY 5 and BRANCH LINE DATA) indicates almost identical trend; two high peaks in 1977 and 1982, medium to large fluctuation, decreasing trend after mid 1980s. These trend seemed consistent with previous analyses (ICCAT 1991). The abundance in recent 5 years is about 50 % of that of mid 1970s.

Fig. 6 showed the effect of the different constant added to CPUE before log-transformation. It is rather clear that the estimated abundance with large constant was underestimated for recent years.

Trials to incorporate oceanographic factors

SST, square and cube of SST were tested in the model which included only main effects. It was found they were all statistically insignificant as well as other catch. Month and year contributed the large part of SS by model. The resolution of data (month and 5-degree square) might be too wide to pick up the effect of SST on bluefin CPUE. It is desirable to obtain SST for the east Atlantic as well to develop the better abundance index for total eastern stock of this species.

Table 1. Number of observations for CPUE analysis by year, month and area.

5 BY 5 DATA

YEAR	MAR	APR	MAY	JUN	JUL	A1	A2	A3	A4	A5	A6	A7	TOTAL
74	8	12	11	7	5	7	8	2	4	10	8	4	43
75	7	12	12	6	4	6	12	2	5	8	4	4	41
76	5	10	11	6	7	5	10	1	6	8	5	4	39
77	6	4	12	6	4	5	10	0	7	6	3	1	32
78	6	7	10	9	1	8	8	2	8	4	3	0	33
79	5	3	7	6	2	4	3	3	7	2	3	1	23
80	6	8	11	2	1	6	7	1	6	4	3	1	28
81	7	6	9	2	0	4	5	0	6	6	2	1	24
82	6	8	7	7	5	2	6	3	10	6	5	1	33
83	6	10	10	3	6	5	5	4	10	4	5	2	35
84	7	10	12	10	7	7	7	2	10	5	7	8	46
85	2	6	10	4	4	3	3	0	8	3	5	4	28
86	4	8	13	6	3	3	7	3	9	6	4	2	34
87	7	8	14	2	2	4	6	2	7	7	4	3	33
88	7	8	13	4	3	1	7	1	9	8	5	4	35
89	5	9	13	2	1	2	8	2	8	5	3	2	30
90	8	12	12	7	1	7	9	4	9	6	4	1	40
91	6	10	11	8	6	9	8	8	9	4	3	0	41
TOTAL	108	151	198	97	62	88	129	40	138	102	76	43	616

BRANCH LINE DATA

YEAR	MAR	APR	MAY	JUN	JUL	A1	A2	A3	A4	A5	A6	A7	TOTAL
75	13	20	25	19	8	18	28	2	8	15	8	6	85
76	11	24	25	6	11	11	25	0	10	14	10	7	77
77	9	11	24	12	9	7	26	0	11	13	7	1	65
78	14	17	18	9	2	21	15	2	13	4	5	0	60
79	13	8	12	9	5	7	9	7	14	3	6	1	47
80	11	16	17	2	1	11	15	1	7	6	5	2	47
81	18	14	10	2	0	11	12	0	10	8	2	1	44
82	10	14	23	18	13	3	9	6	37	11	11	1	78
83	17	24	24	7	14	16	9	7	30	11	11	2	86
84	24	28	25	20	9	18	22	2	33	11	12	8	106
85	2	15	22	6	4	5	7	0	17	5	10	5	49
86	11	17	19	9	3	5	13	4	20	7	7	3	59
87	16	21	25	3	2	5	19	2	12	16	9	4	67
88	16	16	18	6	3	1	17	1	15	12	9	4	59
89	14	23	31	2	1	2	27	3	24	8	4	3	71
90	18	30	35	13	1	18	24	9	28	9	8	1	97
91	16	26	26	19	7	22	13	17	28	9	5	0	94
TOTAL	233	324	379	162	93	181	290	63	317	162	129	49	1191

BRANCH LINE DATA (Mediterranean only)

YEAR	MAR	APR	MAY	JUN	JUL	A1	A2	A3	A4	A5	A6	A7	TOTAL
84	0	5	9	5	4	1	1	3	4	8	4	2	23
85	0	4	8	1	3	0	2	1	2	8	3	0	16
86	0	3	7	1	1	0	0	2	2	5	2	1	12
87	0	3	11	0	0	0	1	1	4	5	1	2	14
88	0	4	9	0	2	1	1	2	4	5	1	1	15
89	0	1	6	0	1	0	0	1	1	3	2	1	8
90	0	2	7	0	0	0	0	0	4	4	1	0	9
91	0	2	3	0	0	0	0	0	3	2	0	0	5
TOTAL	0	24	60	7	11	2	5	10	24	40	14	7	102

* Area is 5-degree square in the Mediterranean Sea.

Table 2. Number of observation by level of main effect "gear".

East Atlantic and Mediterranean

YEAR	NUMBER OF BRANCH LINE												ALL
	NA	4	5	6	7	8	9	10	11	12	13	14>	
75	17	31	24	13	.	.	.	.	.	.	.	.	85
76	5	29	23	11	.	9	.	.	.	.	.	.	77
77	6	24	18	16	1	.	.	.	.	.	.	.	65
78	.	27	3	7	10	1	5	7	.	.	.	.	60
79	14	16	11	3	2	1	.	.	.	.	.	.	47
80	.	14	14	13	5	1	.	.	.	.	.	.	47
81	.	20	5	8	7	4	.	.	.	.	.	.	44
82	.	25	19	13	.	.	6	8	1	6	.	.	78
83	10	25	14	11	3	2	3	14	4	.	.	.	86
84	10	43	12	19	4	5	3	2	5	1	.	2	106
85	6	19	8	7	.	.	2	3	2	2	.	.	49
86	.	28	7	9	6	1	3	1	1	2	.	1	59
87	.	30	13	9	4	6	1	1	1	2	.	.	67
88	.	32	6	.	1	10	3	.	3	1	.	3	59
89	1	27	14	8	.	2	3	.	1	2	2	11	71
90	.	32	23	9	3	4	.	1	.	5	8	12	97
91	2	31	21	20	8	3	.	4	.	1	1	3	94
ALL	71	453	235	176	54	49	29	41	18	22	11	32	1191

Mediterranean

YEAR	NUMBER OF BRANCH LINE									ALL
	NA	4	5	6	8	9	11	13	14>	
84	3	16	.	4	.	.	.	.	.	23
85	3	7	4	2	.	.	.	.	.	16
86	.	7	1	4	.	.	.	.	.	12
87	.	7	4	2	1	.	.	.	.	14
88	.	10	2	.	2	.	.	.	1	15
89	.	5	.	.	.	2	1	.	.	8
90	.	3	1	1	.	.	.	3	1	9
91	.	3	1	1	.	.	.	.	.	5
ALL	6	58	13	14	3	2	1	3	2	102

Table 3. Number of "zero catch" and "positive catch" observation in CPUE series used for GLM analysis.

5 BY 5 DATA

YEAR	CPUE				ALL
	zero catch		positive		
	N	PCTN	N	PCTN	N
74	3	7	40	93	43
75	1	2	40	98	41
76	.	.	39	100	39
77	2	6	30	94	32
78	1	3	32	97	33
79	1	4	22	96	23
80	2	7	26	93	28
81	2	8	22	92	24
82	1	3	32	97	33
83	.	.	35	100	35
84	.	.	46	100	46
85	1	4	25	96	26
86	1	3	33	97	34
87	.	.	33	100	33
88	.	.	35	100	35
89	1	3	29	97	30
90	.	.	40	100	40
91	2	5	39	95	41
ALL	18	3	598	97	616

BRANCH LINE DATA

YEAR	CPUE				ALL
	zero catch		positive		
	N	PCTN	N	PCTN	N
75	10	12	75	88	85
76	2	3	75	97	77
77	8	12	57	88	65
78	12	20	48	80	60
79	3	6	44	94	47
80	4	9	43	91	47
81	6	14	38	86	44
82	10	13	68	87	78
83	7	8	79	92	86
84	11	10	95	90	106
85	9	18	40	82	49
86	5	8	54	92	59
87	3	4	64	96	67
88	2	3	57	97	59
89	4	6	67	94	71
90	11	11	86	89	97
91	15	16	79	84	94
ALL	122	10	1069	90	1191

Table 4. Models with estimable parameters and the results of ANOVA from the General Linear Model.

5 BY 5 DATA

Source of variation	Sum of square	Degree of freedom	Mean Square	F statistics	R^2	AIC
Y + M + A + O + M*A						
Model	857.97	38	22.58	15.97	0.51	-3667.1
Error	815.97	577	1.41			
Total	1673.94	615				
Y + M + A + O + M*A + M*O						
Model	916.46	44	20.83	15.70	0.55	-3891.1
Error	757.48	571	1.33			
Total	1673.94	615				

BRANCH LINE DATA

Source of variation	Sum of square	Degree of freedom	Mean Square	F statistics	R^2	AIC
Y + M + A + B + O + M*A						
Model	2177.93	48	45.37	27.12	0.56	-6869.2
Error	1719.65	1028	1.67			
Total	3897.58	1076				
Y + M + A + B + O + M*A + M*B						
Model	2204.48	54	40.82	24.64	0.57	-6863.7
Error	1693.10	1022	1.66			
Total	3897.58	1076				
Y + M + A + B + O + M*A + M*O						
Model	2257.25	57	39.92	25.07	0.58	-6904.1
Error	1622.33	1019	1.59			
Total	3897.58	1076				
Y + M + A + B + O + M*A + A*B						
Model	2243.64	60	37.39	22.97	0.58	-6871.3
Error	1653.94	1016	1.63			
Total	3897.58	1076				
Y + M + A + B + O + M*A + B*O						
Model	2244.66	54	41.57	25.70	0.58	-6890.0
Error	1652.92	1022	1.62			
Total	3897.58	1076				
Y + M + A + B + O + M*A + B*O + M*O						
Model	2332.38	63	37.02	23.96	0.60	-6919.5
Error	1565.20	1013	1.55			
Total	3897.58	1076				
Y + M + A + B + O + M*A + B*O + A*B						
Model	2287.52	66	34.66	21.74	0.59	-6886.1
Error	1610.06	1010	1.59			
Total	3897.58	1076				
Y + M + A + B + O + M*A + B*O + M*O + A*B						
Model	2372.49	75	31.63	20.76	0.61	-6916.6
Error	1525.09	1001	1.52			
Total	3897.58	1076				

Table 5. Parameter estimates and Least Square Means for main effect of year in the GLM analysis, and estimated relative annual CPUE scaled to the earliest year.

5 BY 5 DATA

	Parameter		Least Square Mean		Relative
Year	Estimate	Std Err	Estimate	Std Err	CPUE
74	0.250904	0.264449	-0.871102	0.203805	1.0000
75	0.335392	0.263929	-0.786613	0.203319	1.0888
76	0.571410	0.266197	-0.550596	0.213710	1.3804
77	0.876141	0.282527	-0.245865	0.218122	1.8746
78	-0.041754	0.277573	-1.163760	0.228220	0.7445
79	-0.501409	0.306882	-1.623414	0.266064	0.4676
80	-0.089531	0.297783	-1.211537	0.245595	0.7095
81	-0.275650	0.305712	-1.397656	0.259048	0.5878
82	0.800376	0.279590	-0.321630	0.223905	1.7374
83	0.178726	0.274036	-0.943280	0.222578	0.9299
84	0.106931	0.257945	-1.015075	0.195772	0.8650
85	0.217652	0.303582	-0.904354	0.246326	0.9671
86	-0.563928	0.273458	-1.685934	0.233563	0.4389
87	0.164268	0.279396	-0.957737	0.234385	0.9164
88	-0.180083	0.273500	-1.302089	0.222637	0.6475
89	-0.996623	0.286334	-2.118629	0.242522	0.2823
90	-0.510861	0.262241	-1.632866	0.217351	0.4632
91	0.000000		-1.122006	0.206040	0.7766

BRANCH LINE DATA

	Parameter		Least Square Mean		Relative
Year	Estimate	Std Err	Estimate	Std Err	CPUE
75	0.342526	0.212598	-1.492213	0.190808	1.0000
76	0.425475	0.207271	-1.409264	0.193748	1.0891
77	1.052041	0.220470	-0.782698	0.197250	2.0646
78	0.180226	0.217709	-1.654514	0.201959	0.8457
79	-0.081060	0.258657	-1.915800	0.250632	0.6442
80	0.479829	0.236688	-1.354910	0.221287	1.1517
81	0.114930	0.237280	-1.719809	0.227653	0.7903
82	0.800881	0.203615	-1.033859	0.178193	1.5992
83	0.294018	0.204122	-1.540722	0.186348	0.9512
84	-0.137264	0.193022	-1.972004	0.166715	0.6073
85	0.088716	0.240791	-1.746023	0.221553	0.7690
86	-0.464639	0.216126	-2.299378	0.203789	0.4292
87	0.205851	0.210685	-1.628889	0.198137	0.8684
88	-0.038013	0.221556	-1.872753	0.206047	0.6739
89	-0.759739	0.220320	-2.594479	0.209496	0.3117
90	-0.453076	0.199167	-2.287815	0.191130	0.4346
91	0.000000		-1.834739	0.176052	0.7012

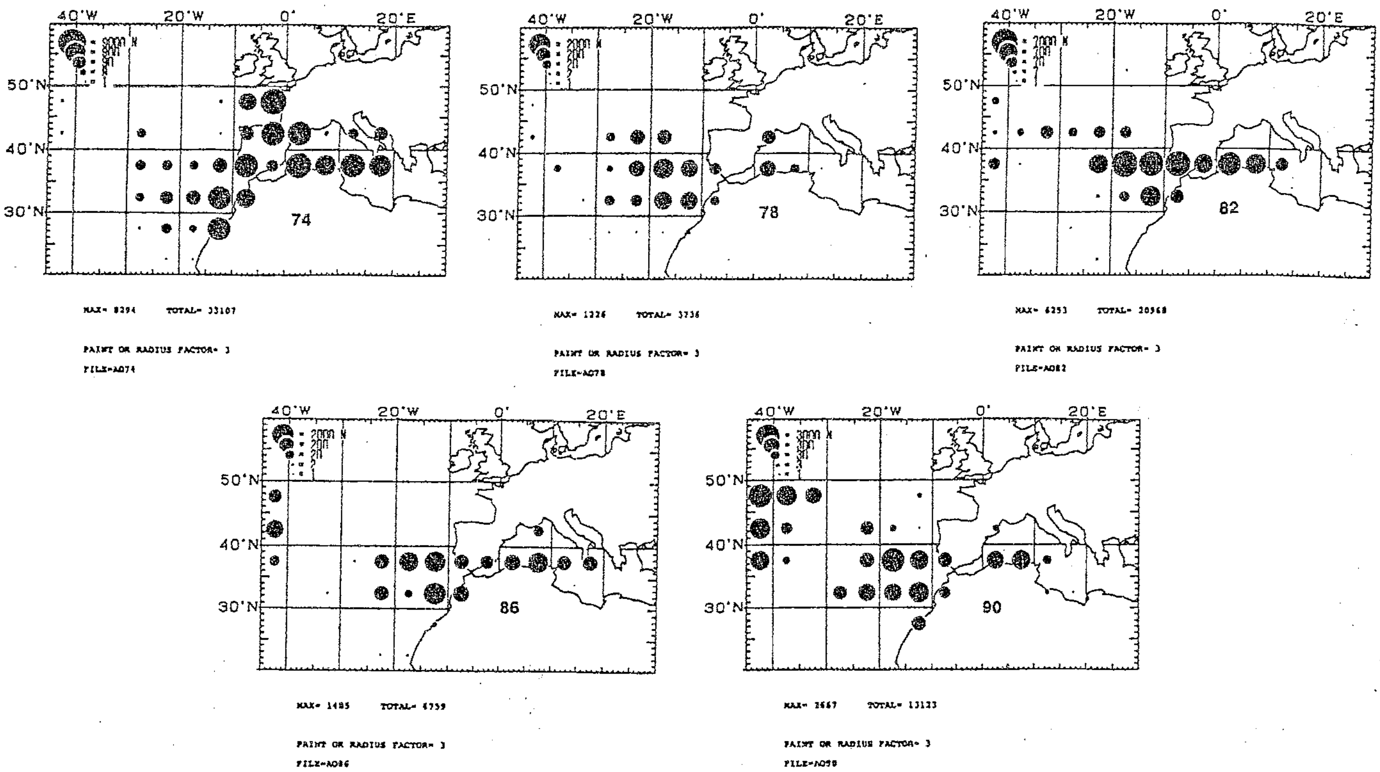

Fig. 1. The annual geographical distribution of the Japanese longline catch in number for 1974, 1978, 1982, 1986 and 1990.

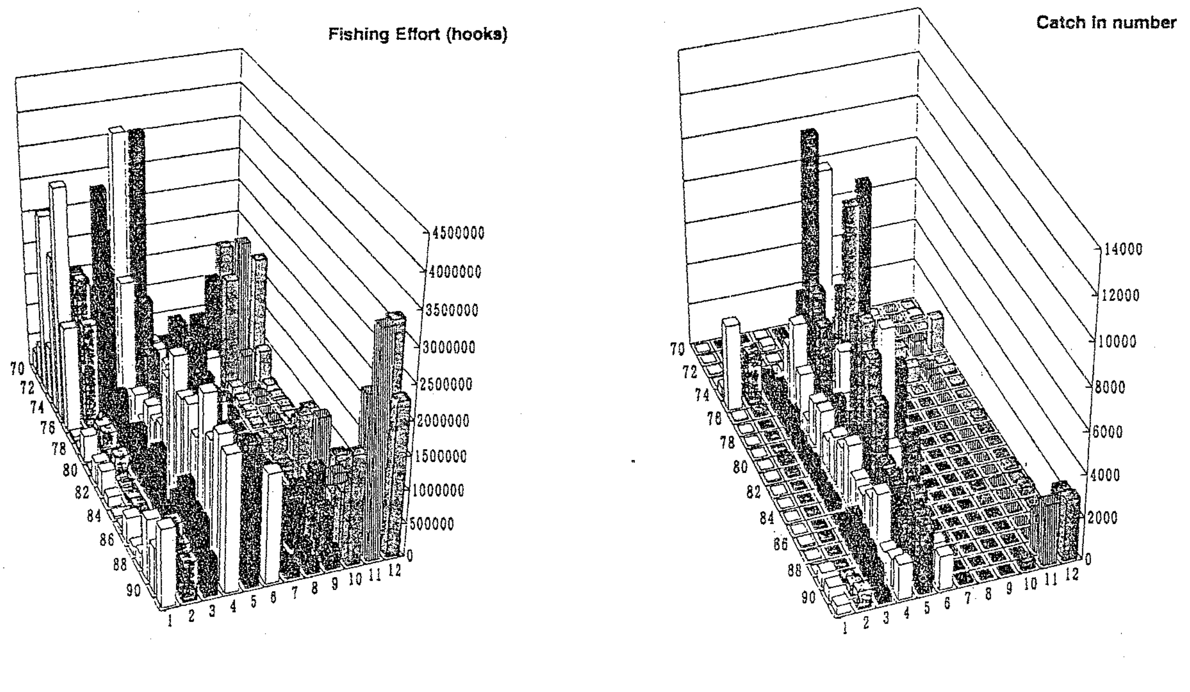

Fig. 2. Monthly catch and effort of the Japanese longline fishery in the eastern Atlantic and the Mediterranean Sea for 1970 - 1991.

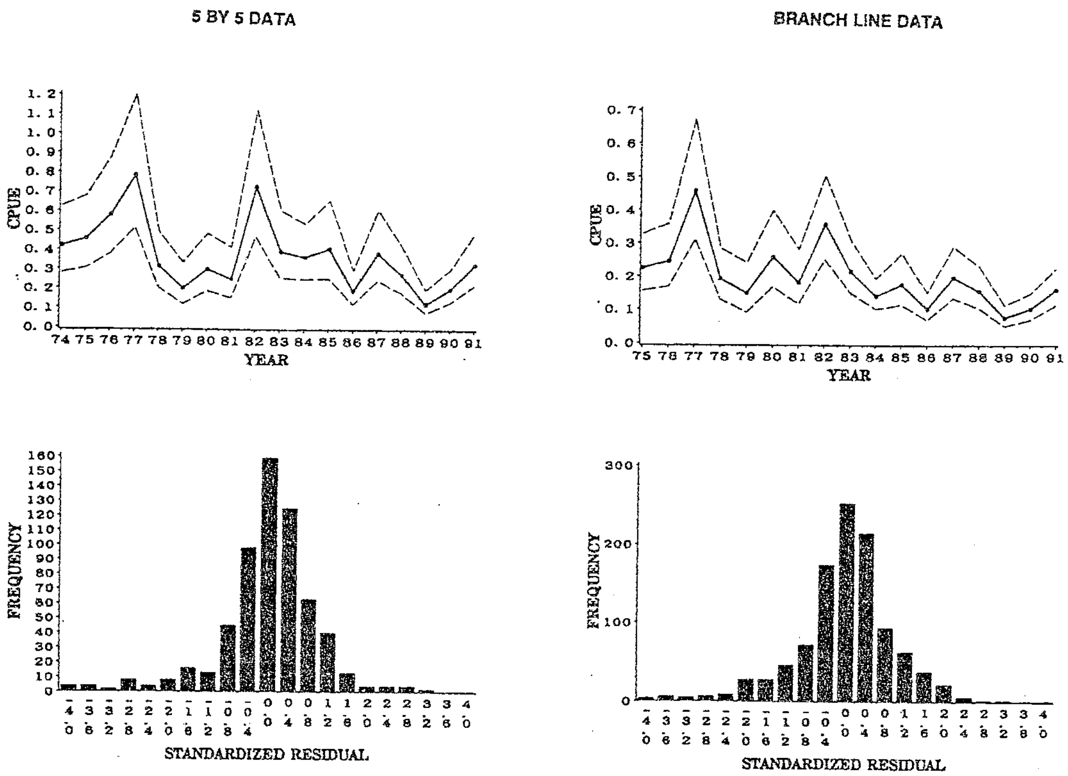

Fig. 5. The estimated abundance index (upper panel) and the overall distribution of standardized residual (lower panel) from the final model.

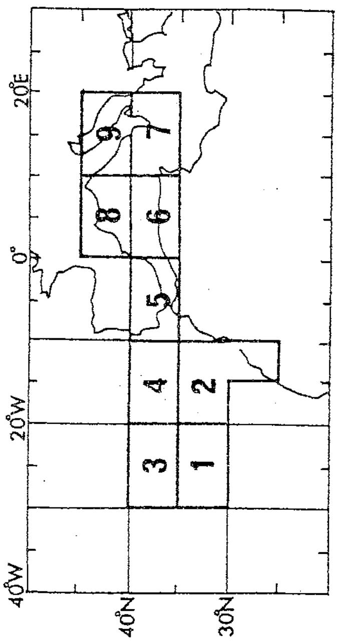

Fig. 3. Area definition used in GLM analysis.

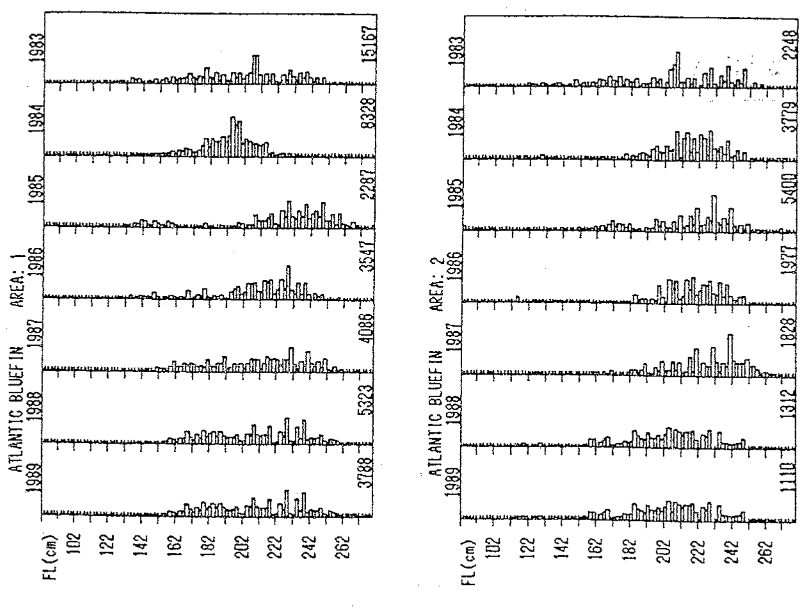

Fig. 4. Recent catch-at-size for the Japanese longline fishery for the second quarter of the year. Upper and lower panels indicates the east Atlantic and the Mediterranean, respectively.

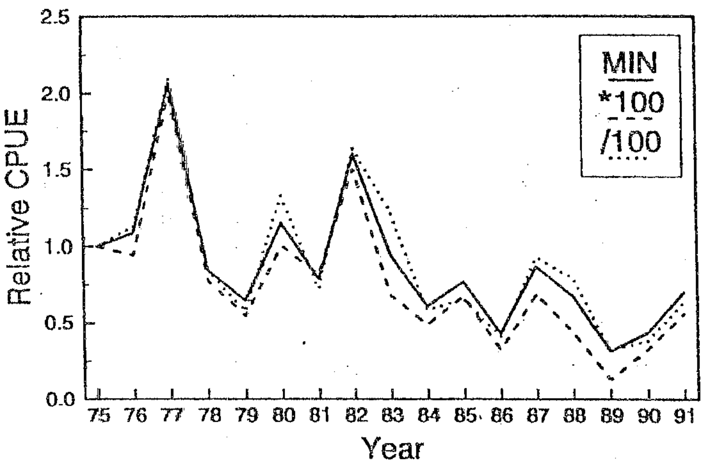

Fig. 6 The effect of the magnitude of constant. "MIN", "*100" and "/100" denote minimum CPUE observed, 100 times and one hundredth of minimum CPUE, respectively. "MIN" line is identical to BRANCH LINE DATA in Fig. 5.

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