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ESTIMATION OF STANDARDIZED CPUE FOR THE ATLANTIC SWORDFISH USING THE DATA FROM THE JAPANESE LONELINE FISHERY

by

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SUMMARY

The CPUE of Atlantic swordfish by four areas was estimated using the log linear model. The multiplicative model was applied to the Japanese longline fishery data and the best model was determined by F-test and Akaike´s Information Criterion. The CPUEs showed a slight downward trend in all three areas in the North Atlantic, whereas in the Gulf of Guinea the CPUE appeared to be stable.

RESUME

La CPUE de l'espadon de l'Atlantique par quatre zones a été estimée en utilisant le modèle linéaire logarithmique. Le modèle multiplicatif a été appliqué aux données de la pêcherie palangrière japonaise et le meilleur modèle a été déterminé par le test-F et l'Information Criterion de Akaike. Les CPUE montraient une tendance lègèrement à la baisse dans les trois zones de l'Atlantique nord, alors que la CPUE du golfe de Guinée semblait être stable.

RESUMEN

Se calculó la CPUE del pez espada atlântico, utilizando el modelo lineal logarítmico. El modelo multiplicativo se aplicó a los datos de la pesquería japonesa de palangre, y se determinó el mejor modelo mediante el test-F y el Information Criterion, de Akaike. Las CPUE muestran una tendencia ligeramente decreciente en las tres âreas del Atlântico Norte, mientras que en el Golfo de Guinea la CPUE parecía mostrarse estable.

1.Introduction

The Japanese longline fishery in the Atlantic was targeting initially albacore and yellowfin tuna, whereas it shifted the target species to bigeye and bluefin tuna in the early 1970's. Although Atlantic swordfish has been a by-catch for this fishery, the catch accounted for more than negligible amount for certain fishing grounds of the Atlantic, particularly in recent years (ICCAT 1987).

It is known that the interpretation of nominal CPUE from the longline gear is often difficult due to the variation in the gear construction, fishing strategy and/or oceanographic factors. In this paper, considering these features, standardized CPUE of Atlantic swordfish was estimated from the Japanese longline data using log linear model.

2.Materials and methods

Japanese longline catch and effort data, which categorized by month of the year, kind of bait used and lat. 10° x long. 10° square(subarea), were used. Data in 1987 were provisional. Four areas were designated(Fig. 1) to cover the waters where swordfish catches were significant by the Japanese longline fishery. Standardized CPUEs were calculated for each area.

Quarter of the year was chosen as fishing season for one of main effects in the model. So data within the same quarter by month were regarded as repeated records in it.

CPUE was calculated as catch in number of fish per 1,000 hooks. Records with less than 10,000 hooks in each stratum were excluded from the analysis. Records with null catch of swordfish were retained. Histograms of the nominal CPUE by area were shown in Fig. 2.

Since Koido and Yonemori (1986) already pointed out that the efficiency of the deep longline gear in catching swordfish surpassed the conventional longline gear in area 4 (Fig. 1), adjustment of gear efficiency was made for effort data after 1979 using the deployment rate (Table 1) and the efficiency rate (1.5, Koido and Yonemori 1986) of the deep longline gear over the conventional gear. Deployment rate in 1987 was assumed to be the same as in 1986.

As was the case of Suzuki (1985) and Turner (1986), multiplicative model was applied as follows:

$$\log(\mathrm{CPUE} + 1.0) = Y_i + Q_j + A_k + \overset{\text{two-way}}{\text{Interaction}} + e_{ijk}$$

where log : natural logarithm
CPUE : logarithm of nominal CPUE (catch in number of swordfish divided by the number of hooks and multiplied by 1,000) in year i, quarter j and subarea k
Y_i : logarithm of the effect of year i
Q_j : logarithm of the effect of quarter j
A_k : logarithm of the effect of subarea k
e_{ijk} : logarithm of the error term

Constraints ($\exp(\Sigma Y_i) = \exp(\Sigma Q_j) = \exp(\Sigma A_k) = 0$) were also incorporated in order to reduce the number of parameters to be estimated. Standards in each main effect were chosen for the earliest year, the earliest quarter and the northern-west-most subarea in each area.

Calculation was performed through computer software, ('Universal Mathematical Software System') on NEC computer ACOS930.

Partial F-test and AIC (Akaike's Information Criterion, Akaike 1973, 1974 and 1985) were utilized as criteria in the selection of the model. It is known that the model with the lowest AIC gives the best selection. In this study, the model with the lowest AIC among the models which show the significant partial F-value was determined to be the best model. AIC is expressed in a equation,

$$AIC = -2\ LML + 2\ Y$$

where LML is logged maximum likelihood and Y is the number of parameters to be estimated. Since AIC's can be compared relatively, constants were ignored and AIC was calculated by the following equation.

$$AIC = X \log(SSQ) + 2\ Y$$

where X is the number of observations, SSQ is sum of squares in the model.

3.Results and Discussion

Models including all main effects and any combinations of two-way interaction term were tested as long as data allowed. Results were shown in Table 2. Based on the partial F-test and AIC, the best model was determined as follows:

Area 1 $\log(\mathrm{CPUE} + 1.0) = Y + Q + A + QA + YA$
Area 2 $\log(\mathrm{CPUE} + 1.0) = Y + Q + A + QA$
Area 3 $\log(\mathrm{CPUE} + 1.0) = Y + Q + A + QA$
Area 4 $\log(\mathrm{CPUE} + 1.0) = Y + Q + A + QA$

The distributions of the standardized residuals($(r-\bar{r})/\sigma$) plotted at each level of the main effects and the histogram of standardized residuals were shown in Fig. 3 and 4. The former seems to be acceptable. The latter, histogram of standardized residuals, in areas 3 and 4 are normally distributed while those in areas 1 and 2 were somewhat peaked at between -1 and 0. This may be attributable to the difference in the distribution of nominal CPUE(Fig. 2). CPUE was lower and there appeared more 0 catch in area 1 and 2 than the others.

Estimated CPUEs were shown in Fig. 5 and Table 3. In general, all the areas in the north Atlantic(areas 1-3) showed a moderate decreasing trend through the period. However, yearly up and down trend differed among areas. CPUE in area 4 was stable and indicated almost no trend. It seems that these trend coincide with the change in nominal CPUE(ICCAT 1987).

It is reasonable that the interaction term QA was included in all the final model because this interaction term explains the migratory nature of the species and was expected to appear in the model. Models including interaction term YA, which explains the effect of yearly variation of the fishing ground, were also significant for area 1 and 2 (Table 2). Since oceanographic variation tends to be large in the higher latitudes, such as area 1 and 2, compared to tropical waters, the location of the fishing ground is likely to be affected by this variation. Honma (1976) reported that YA was also significant in his area N'3(30°N-45°N, 30°W-60°W) when he analyzed CPUE of Atlantic yellowfin tuna. In this type of analysis, however, if main effect Y is included in interaction term, it may cause problem in the statistical test on Y_i since error term is no more independent.

The 95% confident limits of the standardized CPUE were narrow compared to other results of this type. The procedure that catch and effort data from single longline operation were summed up to make the input data was seemed to be the cause which gave less variable CPUEs.

The rate of variability explained by the model(i.e., R square) was rather low ranging 0.21 to 0.55 among areas. This means that there is still a room to improve the model. For further analysis, the inclusion of other factors, for example such as main target species and oceanographic conditions, is worth considering.

References

Akaike, H. 1973: Information theory and an extension of the maximum likelihood principle. p. 267-281. In B. N. Petrov and F. Csaki, eds. 2nd international symposium on information theory. Akademiai Kiado, Budapest.

Akaike, H. 1974: A new look at the statistical model identification. IEEE Trans. Autom Contr. AC-19: 716-723.

Akaike, H. 1985: Prediction and entropy, p. 1-24. In A. C. Atkinson and S. E. Fienberg, eds. A celebration of statistics, the ISI centenary volume. Springer-Verlag, New York.

Honma, M. 1974: Estimation of overall effective fishing intensity of tuna longline fishery - Yellowfin tuna in the Atlantic Ocean as an example of seasonally fluctuating stocks. Far Seas Fish. Res. Lab. Bull. 10:63-85.

ICCAT 1987: Report of the Swordfish Workshop. ICCAT, CVSP. Vol. XXVII:1-126.

Koido, T. T. Yonemori 1986: Trend in hook rate of Atlantic swordfish. ICCAT, CVSP. Vol. XXVI:396-401.

Suzuki, Z. 1985: CPUE analysis of the Atlantic bluefin tuna up to 1983. ICCAT, CVSP. Vol. XXVI:161-166.

Turner, S. C. 1986: Catch rates of bluefin tuna in the Japanese longline fishery recorded by United States observers. ICCAT, CVSP. Vol. XXVI:323-338.

Table 1. Deployment rate of deep longline gear by quarter and subarea in area 4.

Subarea	Quarter of the year			
1	1	2	3	4
1980	-	-	-	-
1981	0.69	0.68	-	0.79
1982	0.65	0.83	-	0.86
1983	1.00	-	-	0.83
1984	1.00	0.47	0.92	0.91
1985	1.00	0.99	0.96	1.00
1986	1.00	-	1.00	0.94

Subarea	Quarter of the year			
2	1	2	3	4
1980	0.26	1.00	0.80	0.84
1981	1.00	-	1.00	0.66
1982	0.80	0.74	1.00	0.98
1983	1.00	-	-	0.69
1984	0.89	1.00	0.83	0.99
1985	1.00	0.97	0.94	0.93
1986	1.00	1.00	0.96	0.97

Subarea	Quarter of the year			
3	1	2	3	4
1980	0.54	-	0.92	0.87
1981	1.00	-	0.87	0.78
1982	1.00	-	0.90	0.93
1983	1.00	-	0.53	0.82
1984	1.00	1.00	0.74	1.00
1985	-	1.00	0.96	0.93
1986	-	1.00	0.91	1.00

Subarea	Quarter of the year			
4	1	2	3	4
1980	-	-	-	-
1981	0.83	0.97	1.00	0.57
1982	0.87	0.55	-	0.78
1983	0.95	1.00	-	0.88
1984	0.93	-	1.00	0.98
1985	0.99	0.97	1.00	1.00
1986	0.96	0.62	1.00	1.00

Subarea	Quarter of the year			
5	1	2	3	4
1980	0.68	0.75	0.71	0.81
1981	0.72	0.82	0.56	0.53
1982	0.91	1.00	0.73	0.87
1983	0.95	-	-	0.66
1984	0.88	-	0.66	1.00
1985	0.97	1.00	0.93	0.90
1986	1.00	1.00	0.71	0.92

Subarea	Quarter of the year			
6	1	2	3	4
1980	0.48	0.62	0.61	0.29
1981	0.71	0.53	0.30	0.34
1982	0.74	0.44	0.61	0.32
1983	1.00	-	0.18	0.24
1984	0.96	0.69	0.57	0.48
1985	0.92	0.94	0.85	0.46
1986	1.00	0.85	0.55	0.05

Table 2. Results of ANOVA and calculated AIC values. * and ** indicate significant at 1% and 5 % level, respectively.

AREA 1

Model	SV	DF	SS	MS	Partial F-value	R^2	AIC
Y+Q+A	Reg.	14	10.4276	0.7448		0.27	1508.7
	Resid.	426	28.5884	0.0671			
Y+Q+A+QA	Reg.	20	11.6380	0.5819	3.0944**	0.30	1501.6
	Resid.	420	27.3780	0.0652			
Y+Q+A+YA	Reg.	32	20.7052	0.6470	12.7223**	0.53	1348.2
	Resid.	408	18.3108	0.0449			
Y+Q+A+QA+YA	Reg.	38	21.4134	0.5635	2.6956*	0.55	1342.8
	Resid.	402	17.6025	0.0438			

AREA 2

Model	SV	DF	SS	MS	Partial F-value	R^2	AIC
Y+Q+A	Reg.	13	6.5627	0.5048		0.41	478.7
	Resid.	188	9.3121	0.0495			
Y+Q+A+QA	Reg.	16	6.8834	0.4302	2.1992*	0.43	477.6
	Resid.	185	8.9915	0.0486			
Y+Q+A+YA	Reg.	22	7.1455	0.3248	1.3277*	0.45	483.7
	Resid.	179	8.7294	0.0488			
Y+Q+A+QA+YA	Reg.	25	7.3744	0.2950	1.5798	0.46	484.3
	Resid.	176	8.5005	0.0483			

AREA 3

Model	SV	DF	SS	MS	Partial F-value	R^2	AIC
Y+Q+A	Reg.	17	6.4080	0.3769		0.16	2042.1
	Resid.	551	33.9771	0.0617			
Y+Q+A+QA	Reg.	32	8.6621	0.2707	2.5392**	0.21	2033.1
	Resid.	536	31.7231	0.0592			
Y+Q+A+YQ	Reg.	44	10.9444	0.1680	2.9906**	0.27	2044.6
	Resid.	524	29.4408	0.0562			

AREA 4

Model	SV	DF	SS	MS	Partial F-value	R^2	AIC
Y+Q+A	Reg.	17	10.8877	0.6405		0.26	2084.1
	Resid.	574	31.8070	0.0554			
Y+Q+A+QA	Reg.	32	16.9358	0.5292	8.7501**	0.40	1989.3
	Resid.	559	25.7589	0.0461			

Table 3. Standardized CPUE of Atlantic swordfish, 1978-1987.

	Area 1	Area 2	Area 3	Area 4
1978	0.8670	0.6655	1.2144	0.4548
1979	0.5018	0.7151	0.8866	0.9876
1980	0.4085	0.5708	1.0202	1.0037
1981	0.4786	0.5680	0.8650	1.1216
1982	0.6170	0.3292	0.7828	1.0427
1983	0.3974	0.4104	0.7498	1.2136
1984	0.5573	0.4724	0.6642	1.0271
1985	0.3817	0.3248	0.6839	0.8922
1986	0.3479	0.3060	0.6186	0.7794
1987	0.1606	0.2511	0.8093	1.2074

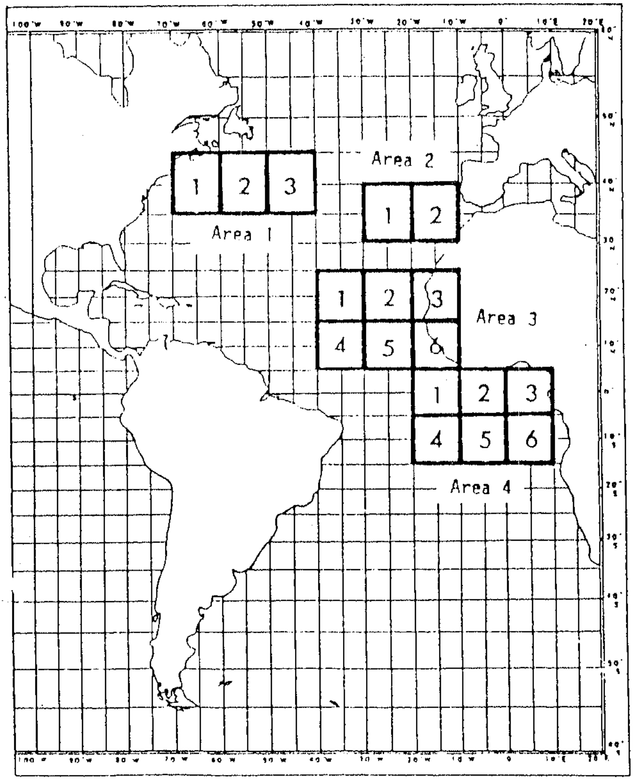


Fig. 1 Areas used to develop standardized CPUE of Atlantic swordfish. Number in the square show subarea in each area.

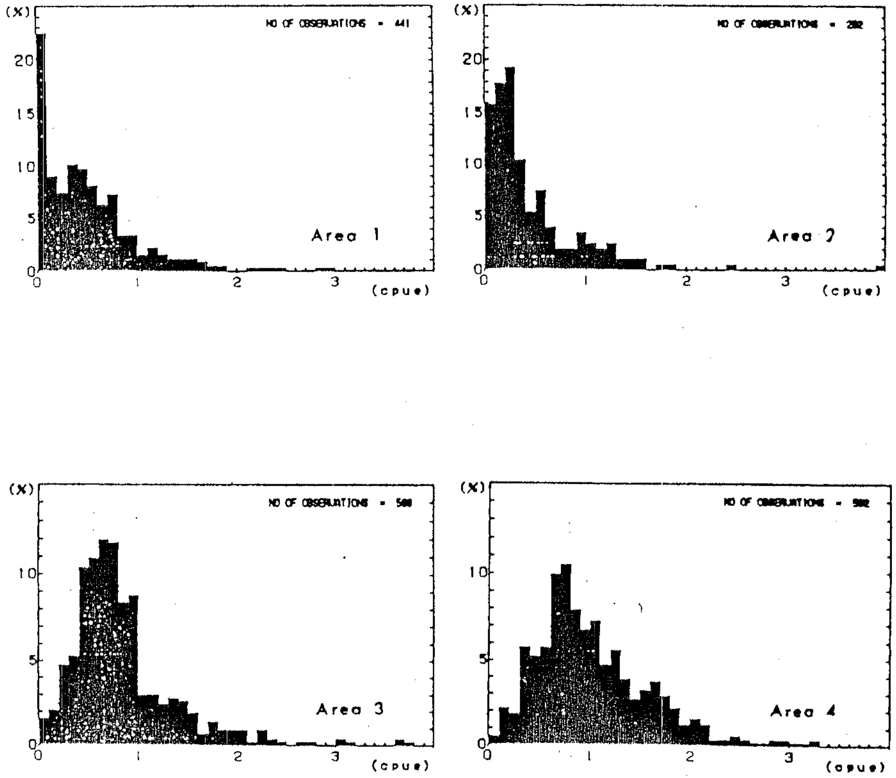


Fig. 2 Histograms of nominal CPUE(per 1,000 hooks) by area.

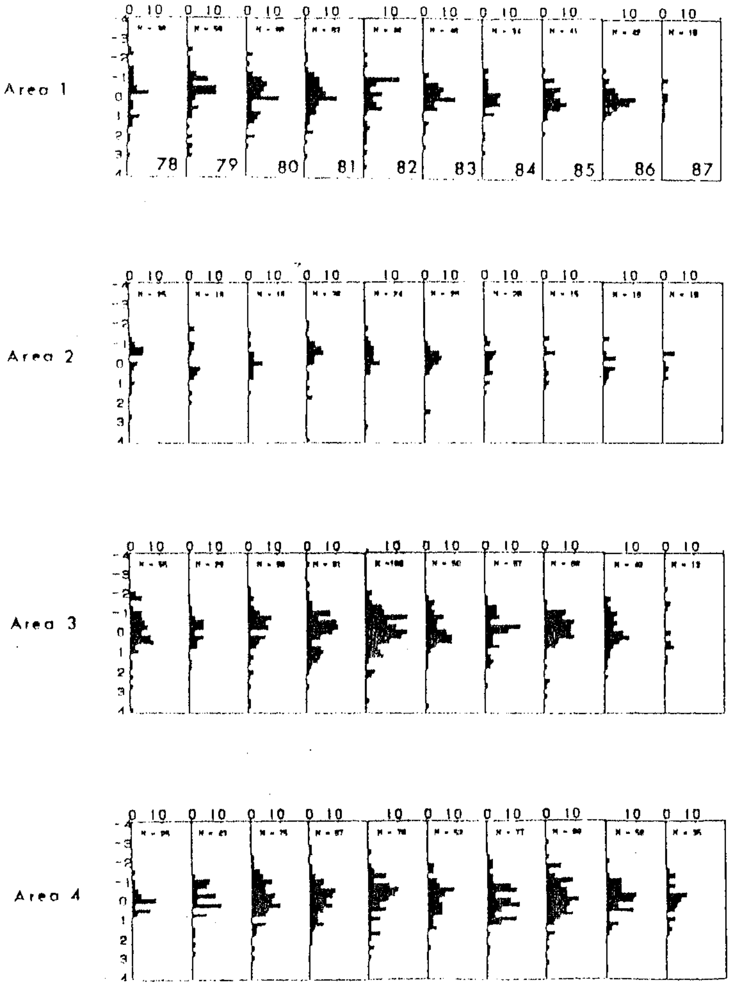


Fig. 3-1 The distributions of standardized residuals plotted at main effect 'year', 1978-1987.

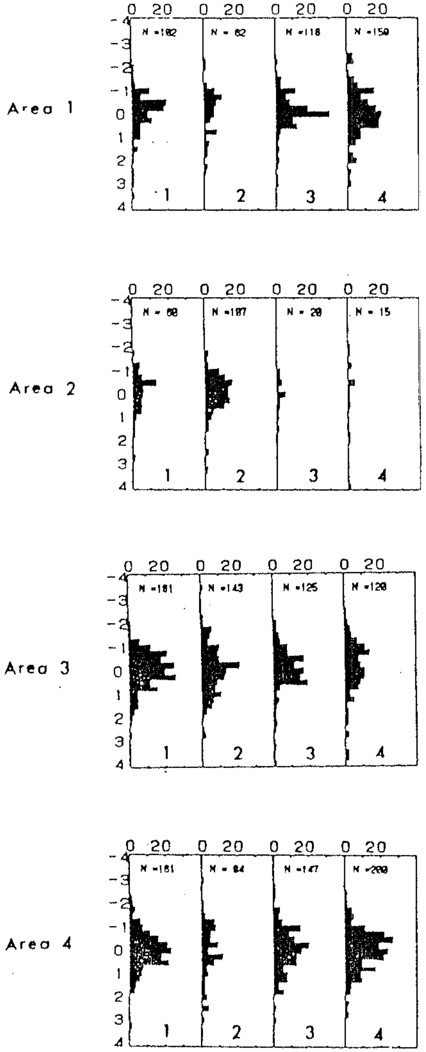


Fig. 3-2 The distributions of standardized residuals plotted at main effect 'quarter of the year'.

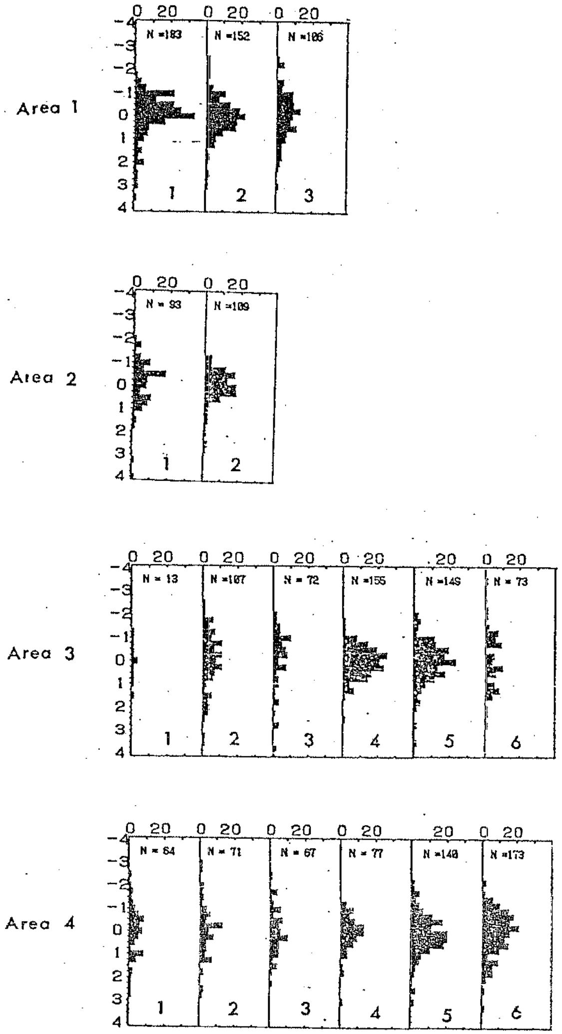


Fig. 3-3 The distributions of standardized residuals plotted at main effect 'area'.

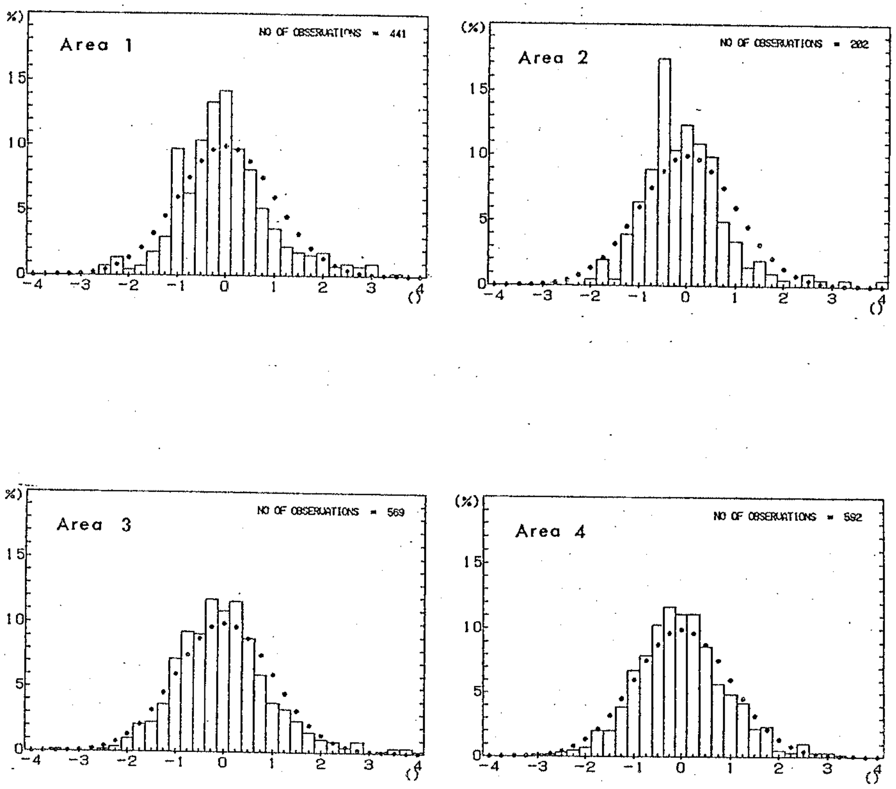
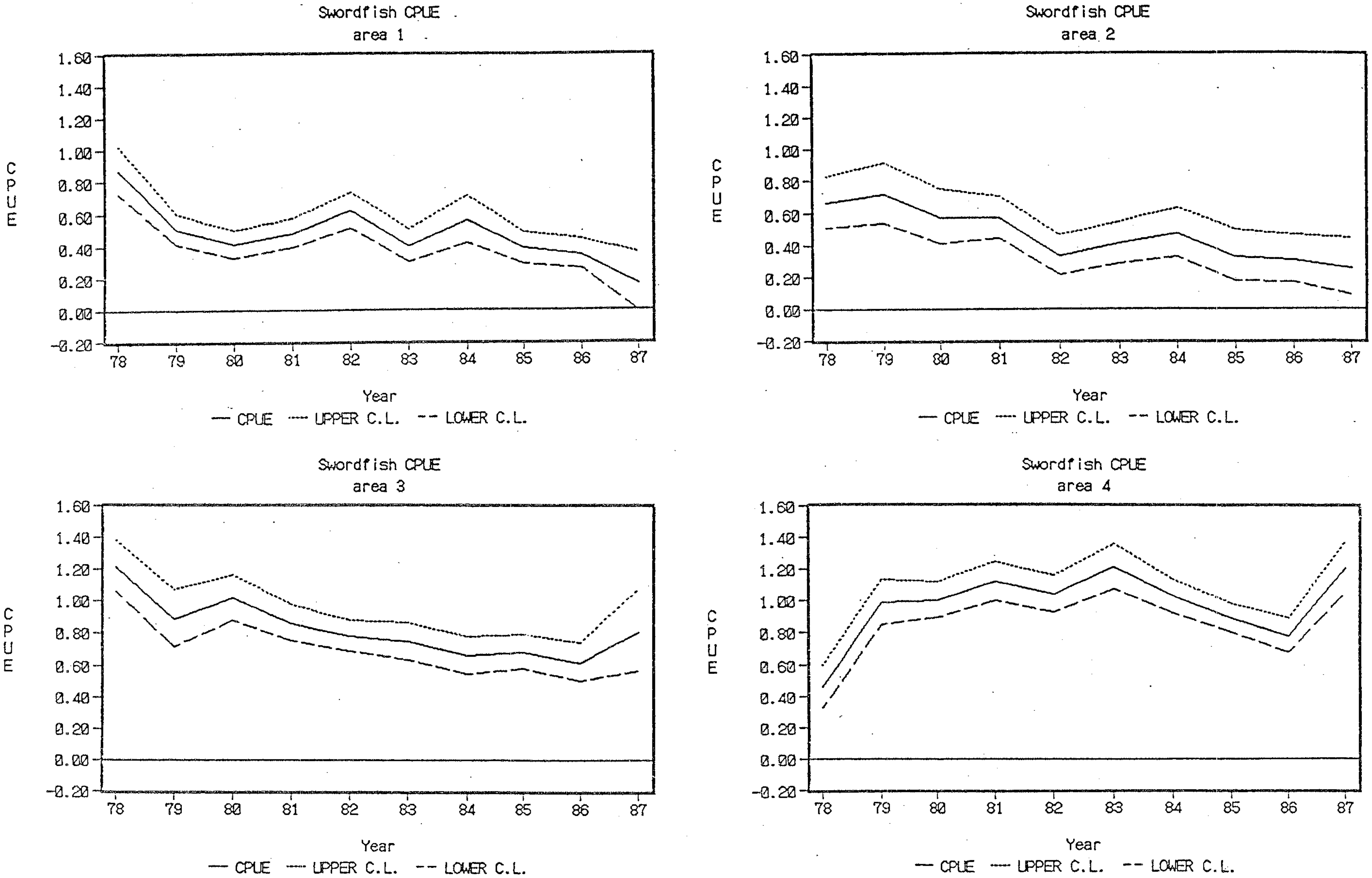


Fig. 4 Histograms of standardized residuals by area. Dots show normal distribution.



Swordfish CPUE area 1

Swordfish CPUE area 2

Swordfish CPUE area 3

Swordfish CPUE area 4

Fig. 5 Standardized CPUE of Atlantic swordfish by area, 1978-1987. Straight line and dotted lines show estimated annual CPUE and its 95% confident limits, respectively.