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A PRELIMINARY EXAMINATION OF THE TAIWANESE LONGLINE CATCH AND EFFORT DATA (1967 TO 1992) FOR SOUTH ATLANTIC ALBACORE (*THUNNUS ALALUNGA*)

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ABSTRACT

One of the abundance indices used when assessing the south Atlantic stock of albacore (Thunnus alalunga) is derived from a Generalized Linear Modelling (GLM) analysis of the Taiwanese longline catch and effort data. We examine the sensitivity of this abundance index to the specifications of the linear model applied, the level of data aggregation, and the method used to include changes in targeting in the analysis. The results are sensitive to the value of the "small" additive constant used to avoid taking the natural logarithm of a zero catch rate. It is suggested that methods which do not require such constants be examined. The approach of including the percentage by-catch as a factor in a GLM analysis leads to biased results and should not be used. A more defensible approach is to use the catch rate of by-catch species in the GLM.

RESUME

L'un des indices d'abondance utilisés au moment d'évaluer le stock de germon (Thunnus alalunga) de l'Atlantique Sud est dérivé de l'analyse par le Modèle Linéaire Généralisé (GLM) des données de prise et d'effort de la palangre taïwanaise. Nous examinons la sensibilité de cet indice d'abondance aux particularités du modèle linéaire appliqué, au degré d'agrégation des données, et à la méthode utilisée pour prendre en compte les changements de cible dans l'analyse. Les résultats sont sensibles à la valeur de la "petite" constante supplémentaire utilisée pour éviter de prendre le logarithme naturel d'un taux de capture nul. Il est suggéré d'examiner des méthodes n'exigeant pas ces constantes. L'approche qui consiste à inclure le pourcentage de prise accessoire comme un facteur dans l'analyse GLM donne des résultats biaisés et ne devrait pas être utilisée. Une approche plus défendable consiste à utiliser dans le GLM le taux de capture des espèces capturées accessoirement.

RESUMEN

Uno de los índices de abundancia usados para evaluar el stock de atún blanco (Thunnus alalunga) del Atlántico sur se deriva de un análisis hecho por un Modelo Lineal Generalizado (GLM) de los datos taiwaneses de captura y esfuerzo del palangre. Se examina la sensibilidad de este índice de abundancia a las especificaciones del modelo lineal aplicado, al nivel de agregación de los datos, y al método empleado para incluir en el análisis los cambios de objetivo. Los resultados son sensibles al valor aditivo constante "pequeño" usado para evitar tomar el logaritmo natural de una tasa de captura cero. Se sugiere que se examinen métodos que no requieran tales constantes. El incluir el porcentaje de la captura fortuita como factor en un análisis de GLM, produce resultados sesgados y no debe hacerse. Un enfoque más defendible es usar en el GLM la tasa de captura de especies de captura fortuita.

1. INTRODUCTION

Recent assessments of the stock of albacore (*Thunnus alalunga*) in the south Atlantic (e.g. Punt *et al.* 1992, 1996a; Yeh *et al.* 1992, 1994a) have been based on abundance indices derived from applications of generalized linear modeling (GLM) techniques to the Taiwanese longline catch and effort data (e.g. Hsu and Chang 1993; Wu *et al.* 1996). There are a number of ways in which to apply these techniques in order to standardize series by removing the effects of changes in efficiency, targeting and other aspects over time, and it is seldom obvious which of these is the most appropriate for a particular fishery. To address this issue, we examine the sensitivity of the trend of the abundance

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index derived from the Taiwanese longline data for south Atlantic albacore to alternative methods of applying GLM techniques.

The factors considered in this examination of sensitivity are: (a) the level of data aggregation across spatial and temporal strata, (b) the approach used to weight each data point, (c) the minimum effort to be taken into account in an analysis, (d) the "small" constant added to a catch rate before taking natural logarithms, and (e) the method of including by-catch in the analysis. Note that the analyses of this paper are preliminary because the catch and effort information for 1993 are not yet available. However, the qualitative conclusions regarding the sensitivity of the abundance indices to GLM assumptions, and the recommended set of such assumptions should be robust to the inclusion of this information.

2. MATERIALS AND METHODS

2.1 Data utilized

The raw data used in this paper consists of the catch and effort information by year, month and 5^0x5^0 statistical square (see Figure 1 for a map showing the locations of the 5^0x5^0 statistical squares and the numbering convention used - taken from Wu *et al.* (1996)). Data are available from 1967 to 1992 (Table 1), but as in previous analyses of these data (e.g. Chang and Hsu 1993; Wu *et al.* 1996), the data for 1967 are ignored because the catch during that year was very small (Table 1). Each record contains information on the effort (number of hooks) as well as the catch of albacore and other species (e.g. bigeye, yellowfin, etc.)

The south Atlantic is divided into the three large statistical areas selected by Yeh *et al.* (1994) for the purposes of the analyses of this paper (areas A, B, and C - see Figure 1). (Note that it was necessary to extend Area C (as defined by Yeh *et al.* 1994) further south and west to ensure that all of the effort in the south Atlantic (south of 5^0 N) is allocated to one of those large statistical areas.) We have not considered the sensitivity of the results to changes to the definitions of these spatial strata due to time considerations.

Note that there remain some errors in the raw data as these indicate that catch and effort information are given for two statistical squares which lie on land (Tables 2 and 3). For the purposes of these preliminary analyses, these data have been considered to pertain to statistical area A. Although 57600 hooks of effort were recorded for statistical square 86,03 for September 1978, zero catch was recorded. This was assumed to be an error and this record was accordingly omitted from the analyses.

2.2 GLM models considered

2.2.1 Basic model

The generalized linear model considered in this paper is of the form:

$$\ln[(C/E)_{y,m,s} + \Gamma] = \alpha_y + \ldots\ldots + \epsilon_{y,m,s} \qquad (1)$$

where $(C/E)_{y,m,s}$ is the catch rate (numbers caught per 1000 hooks) of albacore for 5^0x5^0 statistical square s during month m of year y,

Γ is a constant added to avoid difficulties with zero catch rates,

$\alpha_y + \ldots$ is a linear model, and

$\epsilon_{y,m,s}$ is the error term (assumed to be drawn from a normal distribution).

2.2.2 Fitting procedure

All of the models considered incorporate a factor for each year from 1968 to 1992. The other factors included in the models for which results are reported in the Tables are chosen from the following:

a) Month (if the data are resolved at this level of resolution), otherwise quarter
b) Large statistical area
c) Catch rate of bigeye tuna
d) Catch rate of yellowfin tuna
e) Catch rate of all other species, excepting bigeye and yellowfin, combined
f) Month x area (or quarter x area) interaction

In all of the analyses factors c), d) and e) have been included together. The area factor incorporated in the model is large statistical area rather than $5^0 x 5^0$ square because of numerical difficulties in estimating factors for each such square. The information for each $5^0 x 5^0$ statistical square is thus treated as an independent datum for fitting purposes. The range of factors considered in these analyses has deliberately been kept to a minimum to reduce the volume of results. In principle, other covariates such vessel characteristics (if data can be made available on a vessel-by-vessel basis) and environmental variables could be included in the analyses. Some interactions such as year-area factors are not included in the list above as they were found to have limited effect, as discussed in more detail below.

2.2.3 The base-case analysis

The base-case analysis (GLM No 1 - see Table 5) fits the model to the raw data without weighting the observations. Only records for which the effort is at least 10000 hooks are considered because the precision with which records with fewer hooks than this can index trends in population size is probably poor. The value of the constant Γ (see Equation (1)) is taken to be 1 in these analyses (as in Wu *et al.* 1996).

Note that the catch rate of a by-catch species (or set of by-catch species) rather than the percentage of the total catch made up of the by-catch species is considered in the base-case analysis (unlike in Wu *et al.* (1996)). This is because if the size of a population of interest exhibits a trend over time, the percentage of the total catch comprised of by-catch is negatively correlated with the catch rate for the target species. This is illustrated in Table 4 for a hypothetical fishery. This fishery commences in year 0. In this year, the catch rate of the target species is 90 units and the catch rate of the by-catch species is 10 units (i.e. by-catch makes up 10% of the total catch in that year). Over the next 10 years, the target species is reduced to 50% of its initial size, but the population size of (and hence catch rate for) the by-catch species remains unchanged.

It is possible to fit a model of the form:

$$\ln(C/E)_t = C + \beta \text{ (by-catch)} \tag{2}$$

to the data in Table 4, where "by-catch" is either the catch rate of the by-catch species or the percentage of the catch comprising the by-catch species. Equation (2) is based on the assumption that the abundance of the target species has not changed over time but rather that there has been a change in targeting (in order to model a change in the biomass of the target species, it is necessary to add a factor to Equation (2) which depends on time). As by-catch is assumed not to have affected the abundance of the species concerned, the r^2 of regressions based on Equation (2) should be zero. Modeling "by-catch" by the catch rate of the by-catch species leads to an r^2 of zero, whereas modeling "by-catch" by the percentage of the catch comprising the by-catch species leads to an very high correlation coefficient (r^2=0.972). These results might lead to the latter model being preferred, and hence to the incorrect conclusion being drawn that the abundance of the target species has remained unchanged over a period during which the fishery has been targeting increasingly on the by-catch species. However, it is the former model which indicates correctly that there has been no change in targeting. The same problem (though with signs reversed) occurs if percentage of catch is used for "by-catch" when the target species has been increasing in abundance (i.e. the heightened catch rate is incorrectly attributed to an increased level of targeting on the target species). An examination of the effects of modelling "by-catch" inappropriately in this manner is considered below as a sensitivity test of the results of the base-case model.

2.2.4 The sensitivity tests

A summary of the specifications of the various sets of GLMs fitted is given in Table 5.

The analyses examine the effects of different levels of data aggregation by applying the GLM approach at three such levels:

i) No aggregation (the base-case analysis - 5492 data points; data for each $5^0 x 5^0$ statistical square are treated as independent for fitting purposes).
ii) The data for each large statistical area are pooled (i.e. each data point is the catch rate for a large statistical area for a month and a year - 765 data points).
iii) The data for each quarter and each large statistical area are pooled (286 data points).

The sensitivity of the results to the value for Γ is examined by using 0.1 rather than the base-case value of 1, and the sensitivity to the tolerance used to reject records by including all data points in the analysis. The effect on the results of the replacement of the by-catch rate by the percentage of the total catch made up by each by-catch species is also examined.

Fishing effort is not uniformly distributed spatially and temporally (Table 3). It is likely that the precision of a catch rate depends in some way on the amount of effort expended (the larger the effort, the more precise the catch rate should be as an index of abundance). The sensitivity of the results to weighting each data point by the associated effort is therefore examined (this assumes that the variance of a catch rate estimate is inversely proportional to the associated effort).

3. RESULTS AND DISCUSSION

The percentage composition of the total catch by species (Table 1) suggests that there has been no major redirection of effort from albacore by the Taiwanese longline fleet over the period considered in the analysis. Table 6 lists the r^2 values for each fit of the model to the catch and effort information. These r^2s are generally relatively large (compare the r^2s in Table 6 with those of Punt *et al.* (1996b) concerning the South African baitboat catch rate standardization). The r^2s are highest when each by-catch species is included in the model as the percentage of total catch made up by the by-catch species. However, as explained above, the high r^2s for such analyses are artifacts of the implicit negative correlation between the catch rate of the target species and the fraction of the total catch made up of by-catch. The results for such analyses are therefore ignored in the balance of this paper.

Estimating a separate factor for each year from 1968 to 1992 explains between 11 and 20% of the overall variation in catch rate (Table 6). The year-factors explain the greatest fraction of the variation when the data are aggregated spatially and temporally (Table 6, runs 2, 3, 8 and 9). This is not surprising because pooling data reduces its variability and also the number of data points analysed.

Including the catch rate of by-catch species in the analysis increases the r^2 by some 30 or 40 percentage points. The effects of including factors for each month (or quarter) and large statistical area are less marked, but nevertheless improvements in r^2 by at least 5 percentage points are evident in Table 6 for all 12 sets of GLMs. Figure 2 shows the month-factors from the fit of case "All" of GLM 1 (see Tables 5 and 6 for details). A cyclic pattern is evident in this Figure. This is consistent with the behaviour of the fleet which changes gear during the year (although it may also be a consequence of environmental factors such as increased albacore shoaling densities at different times during the year). The values of the factors for all three by-catch species are negative, as expected because one effect of increased targeting on by-catch species should be the reduction of the catch rate for the target species.

Including area-month interaction terms into the model does not increase the r^2 substantially (particularly given the number of parameters involved) - Table 6. The sensitivity of the r^2s to adding other interaction terms (e.g. area-year, area-by-catch, etc.) was examined, but none of these interactions led to a marked improvement in r^2. The remainder of the results in this paper relate to the case "All" (i.e. including year, month, large statistical area and by-catch in the model).

Figure 2 shows a histogram of the residuals for case "All" of GLM 1. The residuals appears to be roughly normally distributed and there is no obvious indication of bimodality or skewness.

Table 7 provides estimates and bootstrap 90% confidence intervals for the slope of a linear regression of the year-factors against year, and the ratio of 1992 to 1968 abundance predicted therefrom, for analyses which include the contributions of year, month, large statistical area and by-catch in the model. The base-case analysis suggests a marked reduction in standardised catch rate (and hence abundance) between 1968 and 1992 (Table 7; Figure 3). These results are little affected by weighting each data point by its effort, except when the data are pooled across spatial / temporal strata. This pooling leads to more pessimistic appraisals of rates of population decline (Table 7). The effect of including records with less than 10000 hooks is minimal, even though the number of data points used in the analysis is increased by 800 (or 15%) when such records are included.

The results are sensitive to the choice of a "small" additive constant (the point estimate of the ratio of 1992 to 1968 abundance (as estimated from a linear regression of year-factor against year) decreases from 0.301 to 0.227 as this constant is changed from 1 to 0.1 (Table 7; Figure 3). It is not easy to select a value for this constant *a priori* (but see Porch *et al.* 1994). However, methods such as that of Miyabe (1995) do not require such a constant as they deal straightforwardly with zero catches. Time limitations precluded a detailed examination of such methods, but this would seem to be a high priority for future work.

4. POSSIBLE FUTURE WORK

- Errors have been found in the raw data considered in this paper. These should be corrected by the national scientists concerned.

- The implications of assuming error distributions which take account of zero catches in a natural way (e.g. Miyabe 1994) should be examined.

- Taiwanese national scientists should attempt to analyse catch and effort data by individual set.

5. CONCLUSIONS

Analyses which include the fraction of the total catch made up of by-catch can lead to biased results - a high value of r^2 associated with such fits to the data may be misleading. It is recommended that if by-catch is to be included in models to analyse catch rate data, this rather be done by including the catch rate of the by-catch species in the model.

The estimate of the trend in population abundance is sensitive to the value assumed for the "small" constant added to avoid difficulties with zero catch rates. Methods which do not require the introduction of such constants should therefore be examined.

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Table 1. Total albacore catch (in number), total effort (1000s of hooks), nominal catch rate for albacore, bigeye, yellowin and all remaining species combined (in numbers per 1000 hooks), and percentage contribution of albacore, bigeye and yellowfin to the total catch of all species.

Year	Albacore Catch	Total Effort	Catch rate				%composition		
			Albacore	Bigeye	Yellowfin	Other	Albacore	Bigeye	Yellowfin
1967*	40560	953	42.55						
1968	722354	19805	36.47	5.22	8.90	3.16	67.9	9.7	16.6
1969	854517	26385	32.39	4.28	5.09	2.76	72.8	9.6	11.4
1970	632263	21190	29.84	2.48	1.99	3.65	78.6	6.5	5.2
1971	1227251	35716	34.36	2.42	2.95	2.03	82.3	5.8	7.1
1972	1140235	39017	29.22	1.83	2.62	1.83	82.3	5.2	7.4
1973	956580	36029	26.55	1.49	1.57	1.57	85.1	4.8	5.0
1974	904390	32378	27.93	1.95	1.21	1.30	86.2	6.0	3.7
1975	1017371	30463	33.40	2.51	0.68	1.24	88.3	6.6	1.8
1976	1441284	42151	34.19	1.51	0.09	0.81	93.4	4.1	0.2
1977	1692946	53426	31.69	1.86	0.09	0.61	92.6	5.4	0.3
1978	1740450	48799	35.67	1.55	0.11	0.68	93.8	4.1	0.3
1979	1076032	33153	32.46	1.08	0.12	0.89	93.9	3.1	0.3
1980	1112958	33954	32.78	1.06	0.17	0.66	94.5	3.1	0.5
1981	1119056	39794	28.12	1.00	0.13	0.59	94.2	3.4	0.4
1982	1319951	47806	27.61	0.69	0.11	0.45	95.7	2.4	0.4
1983	634522	22389	28.34	0.84	0.10	0.76	94.3	2.8	0.3
1984	535771	16898	31.71	0.96	0.27	0.85	93.9	2.8	0.8
1985	1365486	48175	28.34	0.48	0.15	0.61	95.8	1.6	0.5
1986	2017255	68268	29.55	0.51	0.28	0.47	95.9	1.6	0.9
1987	2006183	86530	23.18	0.88	0.44	1.04	90.7	3.5	1.7
1988	1398287	72754	19.22	0.55	0.69	1.21	88.7	2.5	3.2
1989	1161575	68935	16.85	0.56	0.42	1.70	86.3	2.9	2.1
1990	1531423	85228	17.97	0.92	0.48	0.72	89.5	4.6	2.4
1991	938890	66748	14.07	1.11	0.84	2.27	76.9	6.1	4.6
1992	1354940	77795	17.42	1.22	0.81	3.46	76.1	5.3	3.5

* Not utilized in further analyses

Table 2. Number of years (1967-1992) for which catch and effort information is available by 5x5 statistical areas. The entries indexed by asterisks are errors as they fall inland.

Year	Longitude Code																	
	23	21	19	17	15	13	11	9	7	5	3	1	2	4	6	8	10	12
73	-	-	1	7	8	12	9	11	12	11	8	8	9	4	-	-	-	-
74	-	-	-	1	4	6	12	11	11	11	11	10	10	7	-	-	-	-
76	-	-	-	-	-	18	18	9	14	15	13	13	15	13	8	-	-	-
78	-	-	1*	-	14	24	24	23	22	20	12	8	12	13	6	-	-	-
80	-	-	-	-	24	24	24	23	22	21	16	20	18	18	4	-	-	-
82	1*	-	-	6	24	22	23	19	14	19	18	23	25	23	21	-	-	-
84	-	1	11	23	22	20	19	17	18	20	20	24	25	24	23	10	-	-
86	-	10	23	24	22	17	15	17	17	22	23	23	20	23	25	25	-	3
88	2	19	23	24	21	19	16	17	15	14	17	19	22	22	24	22	13	13
90	-	6	16	23	16	8	6	1	2	-	1	1	1	1	3	7	3	5

Table 3. Number of months (1967-1992) for which catch and effort information is available by 5x5 statistical areas. The entries indexed by asterisks are errors as they fall inland.

	Longitude Code																	
	23	21	19	17	15	13	11	9	7	5	3	1	2	4	6	8	10	12
73	-	-	2	15	21	47	29	31	36	33	31	35	31	5	-	-	-	-
74	-	-	-	1	7	17	24	17	20	29	25	27	36	16	-	-	-	-
76	-	-	-	-	-	30	31	29	38	29	33	35	54	43	12	-	-	-
78	-	-	1*	-	27	107	97	91	79	62	23	14	24	27	14	-	-	-
80	-	-	-	-	66	107	77	72	77	71	44	36	43	45	5	-	-	-
82	1*	-	-	7	81	80	51	49	28	41	38	54	72	95	99	-	-	-
84	-	1	17	64	59	48	44	37	34	53	49	67	86	131	195	12	-	-
86	-	23	106	100	51	39	42	39	49	64	57	75	86	103	190	161	-	4
88	3	69	151	131	82	55	44	52	48	37	48	59	74	87	115	95	34	42
90	-	10	36	56	36	19	12	1	2	-	1	1	1	2	5	9	5	11

Table 4. Data for a hypothetical fishery for which the catch rate for the target species declines from 90 units in year 0 to 45 units in year 10, and in which the by-catch rate remains at 10 units throughout this 11-year period. The catch rates for the target species and the by-catch species as well as the fraction of the total catch made by-catch is given in subtable (a). Subtable (b) provides the estimates of the catch rate for the target species using models of the form of Equation (2) which incorporate (i) the catch rate of the by-catch species or (ii) the percentage of the total catch made up of by-catch.

(a)

Year	Catch rate (Target species)	Catch rate (By-catch species)	Fraction of the catch made up of by-catch
0	90.0	10.0	0.100
1	85.5	10.0	0.105
2	81.0	10.0	0.110
3	76.5	10.0	0.116
4	72.0	10.0	0.122
5	67.5	10.0	0.129
6	63.0	10.0	0.137
7	58.5	10.0	0.146
8	54.0	10.0	0.156
9	49.5	10.0	0.168
10	45.0	10.0	0.182

(b)

Year	Catch rate (Target species)	Predicted catch rate (by-catch rate included in model)	Predicted catch rate (Fraction of the catch made up by by-catch included in the model)
0	90.0	67.5	86.0
1	85.5	67.5	83.4
2	81.0	67.5	80.5
3	76.5	67.5	77.4
4	72.0	67.5	73.9
5	67.5	67.5	70.0
6	63.0	67.5	65.7
7	58.5	67.5	60.7
8	54.0	67.5	55.1
9	49.5	67.5	48.6
10	45.0	67.5	41.1
r^2		0	0.972

Table 5. Specifications of the GLM applications considered in this paper (see text for details).

GLM No	Aggregation	Weighting /Γ/ tolerance (#hooks)	Years	By-catch
1	5x5, month, year	None (Γ =1) 10000	1968/92	Catch rate
2	area, month, year	None (Γ =1) 10000	1968/92	Catch rate
3	area, quarter, year	None (Γ =1) 10000	1968/92	Catch rate
4	5x5, month, year	None (Γ =0.1) 10000	1968/92	Catch rate
5	5x5, month, year	None (Γ =1) 0	1968/92	Catch rate
6	5x5, month, year	None (Γ =1) 10000	1968/92	% Total
7	5x5, month, year	By effort (Γ =1) 10000	1968/92	Catch rate
8	area, month, year	By effort (Γ =1) 10000	1968/92	Catch rate
9	area, quarter, year	By effort (Γ =1) 10000	1968/92	Catch rate
10	5x5, month, year	By effort (Γ =0.1) 10000	1968/92	Catch rate
11	5x5, month, year	By effort (Γ =1) 0	1968/92	Catch rate
12	5x5, month, year	By effort (Γ =1) 10000	1968/92	% Total

Table 6. **Values of the r ^ 2 statistic for various GLM fits to the Taiwanese longline catch and effort data. The notation "+factor" indicates that the results given pertain to a model which includes year and the factor concerned. The model "All" includes year, month, area and by-catch. The definitions of the various GLMs is given in Table 5.**

GLM No	1	2	3	4	5	6
Sample Size	5492	765	286	5492	6292	5492
Year Range	68-92	68-92	68-92	68-92	68-92	68-92
Year	0.117	0.169	0.200	0.111	0.100	0.117
+Month	0.196	0.222	0.238	0.164	0.173	0.196
+Area	0.363	0.331	0.386	0.334	0.343	0.363
+By-Catch	0.418	0.548	0.577	0.406	0.364	0.815
+Month, area	0.387	0.383	0.426	0.355	0.366	0.387
+Month, by-catch	0.486	0.593	0.610	0.452	0.435	0.844
+Area, by-catch	0.552	0.595	0.625	0.524	0.509	0.840
All	0.572	0.636	0.659	0.538	0.530	0.854
All+ Month*area	0.599	0.671	0.689	0.565	0.558	0.856

GLM No	7	8	9	10	11	12
Sample Size	5492	765	286	5492	6292	5492
Year Range	68-92	68-92	68-92	68-92	68-92	68-92
Year	0.130	0.165	0.186	0.115	0.128	0.130
+Month	0.249	0.343	0.356	0.197	0.247	0.249
+Area	0.372	0.489	0.566	0.332	0.371	0.372
+By-Catch	0.486	0.566	0.592	0.472	0.481	0.804
+Month, area	0.392	0.515	0.572	0.350	0.390	0.392
+Month, by-catch	0.573	0.680	0.707	0.531	0.569	0.848
+Area, by-catch	0.608	0.707	0.758	0.576	0.604	0.847
All	0.624	0.730	0.772	0.587	0.620	0.858
All+ Month*area	0.663	0.785	0.814	0.630	0.660	0.862

Table 7 Estimates and bootstrap 90% confidence intervals (in parenthesis) for the slope of a liner regres of year-factor on year and the ratio of 1992 to 1968 abundance predicted therefrom. The results based on the "All" model, and the abundance in a given year is taken to be the linear model predi year-factor for that year exponentiated. The definitions of the various GLMs are given in Table

GLM No	Slope		Ratio	
1	-0.050	(-0.066 ; -0.046)	0.301	(0.204 ; 0.333)
2	-0.062	(-0.082 ; -0.059)	0.224	(0.141 ; 0.243)
3	-0.063	(-0.081 ; -0.060)	0.223	(0.144 ; 0.239)
4	-0.062	(-0.085 ; -0.057)	0.227	(0.130 ; 0.256)
5	-0.047	(-0.063 ; -0.042)	0.324	(0.222 ; 0.363)
6	-0.037	(-0.047 ; -0.035)	0.416	(0.326 ; 0.427)
7	-0.048	(-0.065 ; -0.048)	0.317	(0.211 ; 0.319)
8	-0.053	(-0.072 ; -0.053)	0.282	(0.179 ; 0.277)
9	-0.052	(-0.071 ; -0.053)	0.285	(0.181 ; 0.279)
10	-0.057	(-0.081 ; -0.058)	0.213	(0.142 ; 0.250)
11	-0.048	(-0.064 ; -0.047)	0.319	(0.213 ; 0.321)
12	-0.036	(-0.045 ; -0.036)	0.422	(0.336 ; 0.426)

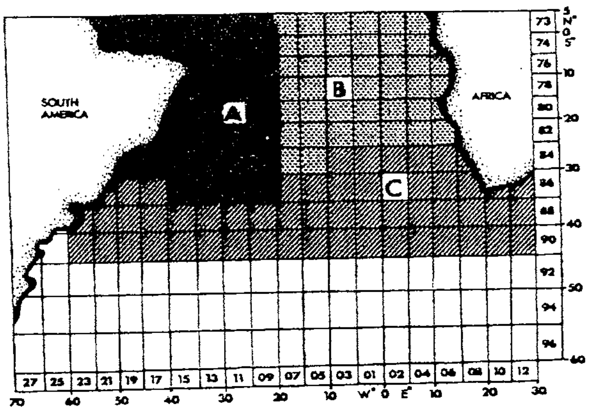

Fig. 1 Map of the south Atlantic showing the *5ox5o* statistical reporting system and three large areas (A-C) considered in the analysis.

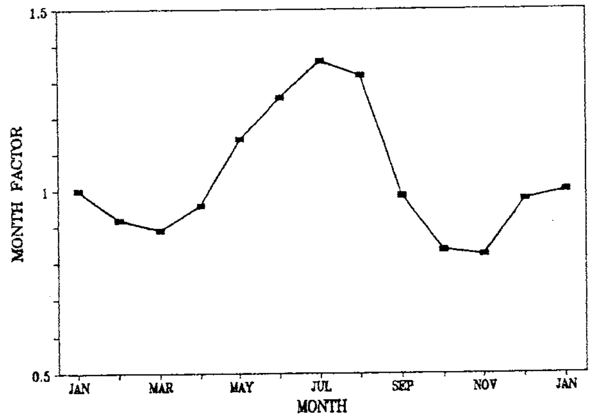

Fig. 2 The month-factors estimated from case "All" (i.e. incorporating terms for month, large statistical area, by-catch and year) of GLM 1.

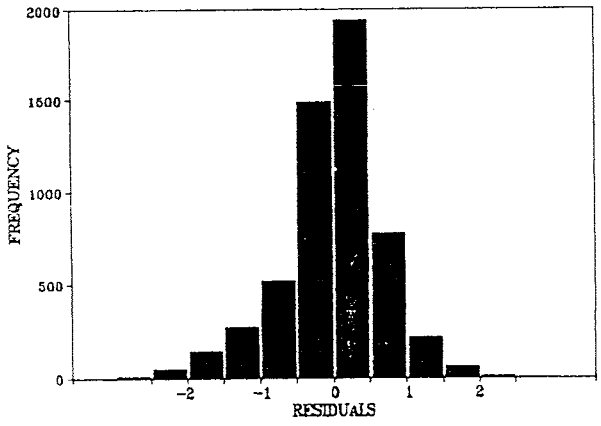

Fig. 3 Residuals about the fit of case "All" of GLM 1.

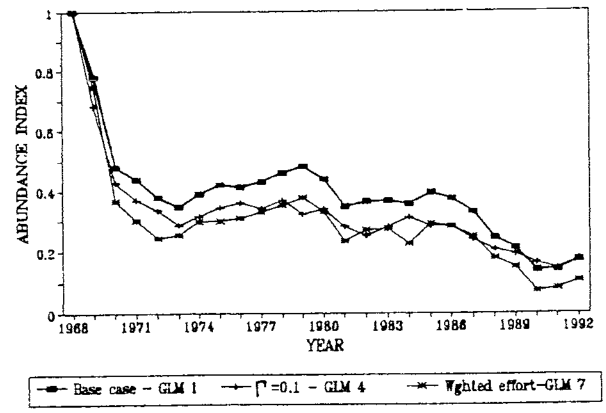

Fig. 4 Abundance indices derived from various GLM applications. All of the results correspond to the case "All".