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STANDARDIZED CATCH RATES OF BLUEFIN TUNA IN THE UNITED STATES FISHERY CONSERVATION ZONE FOR 1983-1986

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SUMMARY

Data collected by U.S. observers aboard all Japanese longline boats fishing in the United States Fishery Conservation Zones were used to develop indices of abundance for 3-9 year bluefin tuna in the western Atlantic north of 35 degrees latitude for 1983-1986.

Size was recorded for nearly every bluefin tuna caught and was used to calculate catch rate at age for each set. Standardized catch rates were developed, using a general linear model, and used to develop indices of abundance. Ages were combined into three groups--3 to 5, 6 to 7, and 8 to 9 year olds for separate analyses. An adequate linear model could not be derived to develop standardized indices for 1 to 2 year olds. The 90 percent confidence intervals around the standardized estimates were broad, reflecting the low proportion of total variation explained by the final analysis.

RESUME

Les données rassemblées par les observateurs américains à bord de tous les palangriers japonais pêchant dans la Zone de Conservation des Etats-Unis ont été utilisées pour développer des indices de l'abondance du thon rouge de l'Atlantique ouest de 3-9 ans au nord de 35 º de latitude pour la période 1983-1986.

La taille a été notée pour presque tous les thons rouges capturés et a servi à calculer le taux des prises à un âge donné par lancer. Les taux des prises standardisées ont été développés en utilisant un modèle linéaire général et ont été utilisés pour développer des indices de l'abondance. Les âges ont été combinés en 3 groupes - 3 à 5, 6 à 7 et 8 à 9 ans pour des analyses séparées. Un modèle linéaire adéquat n'a pu être tiré pour développer des indices standardisés pour ceux de 1 à 2 ans. Les intervalles de confiance de 90 % en relation avec les estimations standardisées ont été amples, reflétant le faible pourcentage de variation totale expliquée par la dernière analyse.

RESUMEN

Los datos recopilados por observadores norteamericanos a bordo de todos los palangreros japoneses que faenan en la "Fishing Conservation Zone" de Estados Unidos, se utilizaron para desarrollar índices de abundancia para el atún rojo de 3.9 años en el Atlántico Oeste norte de 35 grados de latitud para 1983-1986.

Se registró la talla de prácticamente todos los ejemplares de atún rojo capturados, y se utilizó para calcular la tasa de captura a una edad dada para cada conjunto. Se desarrollaron las tasas de captura normalizadas utilizando un modelo lineal general y se emplearon para desarrollar índices de abundancia. Se combinaron las edades en 3 grupos - 3 a 5, 6 a 7 y 8 a 9, para análisis independientes. No pudo deducirse un modelo lineal adecuado para desarrollar índices normalizados para las edades 1 a 2. El 90% de los intervalos de confianza alrededor de las estimaciones normalizadas fueron amplios, reflejando la baja proporción de variación total explicada por los análisis finales.

Introduction

U.S. observers have recorded catch and effort data from all Japanese longline vessels fishing within the U.S. Fishery Conservation Zone (FCZ) since June 1982. An adequate sample size of small to medium bluefin tuna exists with which indices of abundance can be estimated.

Standardized abundance indices were developed by Turner (1987) using a general linear model approach for 1983-1985. The purpose of this research is to develop indices of abundance for 1983-1986 using the same method.

Materials & Methods

U.S. observers record data on each animal caught. Each record contains data on: vessel identification; date, time, temperature, and location of each set and haulback; gear parameters, including floatline length, gangion length, number of floats, number of hooks between floats, distance between hooks, and bait used; as well as size, sex, status (dead or alive), and landing time of each animal. Length is usually recorded for all tunas, billfish, and sharks. Length units may be recorded as straight or curved and as measured or estimated. Weight, if recorded is measured as round weight.

Sets that contained less than 1000 hooks or had missing lengths for 67% or more of the bluefin on that set were not used in the analyses. Length was assigned to any unmeasured fish on a set by using the length composition of the measured bluefin on that set.

Bluefin were aged with the Parrack and Phares (1979) growth equation and the algorithm used by the Bluefin Working Groups of 1984 and 1985 to age the catch in recent assessments (Anon. 1985, 1986 and 1987). The equation included the variable T_0 (Nichols 1985), using the value of -0.96 for 1985 and 1986. Catch rates at age were calculated for each set using the catch at length. Bluefin over 9 years old were not included.

Histograms of total catch rates by year were examined to determine if saturation might effect the observed bluefin catch rates.

A general linear model (Draper and Smith 1966) approach to analysis of variance (ANOVA) was used to examine logged catch rates + 1 for differences among the effects of years, months, areas, hooks between floats, and their interactions. The frequency distributions of standardized residuals (residuals divided by the standard deviation) were examined to be sure that they approximated the normal distribution. F tests were conducted on all two-way interactions and on all main effects except for year that were not involved in a significant two-way interaction and were used to select the best model for developing standardized catch rates.

Age specific mean catch rates by year and month were used to group the bluefin into age groups for analysis. The data used in the analysis were limited to insure a more balanced design; this was done by generally requiring that for each level of a main effect in the model there had to be at least 5 observations in at least 2 levels of every other main effect.

Results

The histograms of catch rates by year of all animals caught revealed very few sets in which catch rates exceeded 10% (Figure 1), therefore, no adjustments for saturation were made.

The relative distribution of mean catch rates across ages by year and month (Table 1) generally followed those that were observed by Turner (1987), therefore, the age groups of 3-5, 6-7, and 8-9 year old bluefin were used in this analysis.

After restricting the data to insure a more balanced design, the following main effects were included in the analysis: years: 1983, 1984, 1985, and 1986; months: January, February, and December; areas: 36°N74°W, 39°N66°W, 39°N67°W, 39°N68°W, 40°N66°W and 40°N67°W (Figure 2); number of hooks between floats: 7, 8, and 10 (Table 2). The data restriction criteria had to be relaxed for 1983 (there were less than 5 observations at some levels) so it could be included in the model for continuity with Turner's analysis. There were sufficient data to test the interaction between month and area. No other interactions could be tested.

The analyses were initiated on the 3-5 year old bluefin, because they constitute the largest sample size. The same procedure will initially be applied to 6-7 and 8-9 year olds in subsequent analyses.

Analysis of Variance

ANOVA for 3-5 year olds revealed that the month-area interaction and hooks between floats were significant. The distribution of residuals among areas from the initial analysis on 3-5 year olds showed that area 36°N74°W was quite different, so catch rates from 36°N74°W were removed from the analysis. The model was tested again; the distributions of the residuals at each level of the other main effects appeared reasonable and were accepted (Figure 3). The histogram of standardized residuals appeared normally distributed (Figure 4). The final model of logged catch rate among 4 levels of year, 3 levels of month, 5 levels of area, 3 levels of hooks between floats, and the month-area interaction (Table 3) was accepted. The standardized estimates of abundance (Table 3, Figure 5) increased from 1983 to 1984 and have decreased from 1985 through 1986.

F-tests for the analysis of 6-7 year olds revealed that the month-area interaction did not have a significant effect on logged catch rates. Initial anaylses indicated that the distribution of residuals at the level of 10 hooks between floats were quite different from those at the other 2 levels of that effect, therefore, 10 hooks between floats were removed from analysis of 6-7 year olds. F-tests revealed that the month-area interaction was highly insignificant, whereas hooks between floats had an F value of 0.10. The model including year, month, and area, was tested with and without the 2 remaining levels of hooks between floats, and it was found that hooks between floats did not significantly effect the standardized catch rate without hooks between floats in the model. The distributions of residuals at the levels of the main effects appeared reasonable and were accepted (Figure 6), and the distribution of the standardized residuals appeared to approximate the normal distribution (Figure 7). Thus the final model for 6-7 year olds including 4 levels of year, 3 levels of month, and 5 levels of area (Table 3) was accepted. The standard estimates of abundance increased from 1983-1985, then decreased in 1986 (Table 3, Figure 8).

Analyses for 8-9 year olds revealed that the month-area interaction was highly significant, while hooks between floats had an F value of .07. Initial analysis showed that the distribution of residuals at the level of 10 hooks between floats were different from those at the other 2 levels, therefore, catch rates from that level of hooks between floats were removed from further analysis. Subsequent analysis revealed that the month-area interaction was still highly significant, whereas, hooks between floats were highly insignificant. Hooks between floats were removed from the model and subsequent testing showed that the residuals were not evenly distributed within the levels of the main effects (Figure 9). Removal of those levels of main effects caused the distribution of standardized residuals to become peaked and increasingly biased. Therefore, the model with the effects of year, month, area, and the month-area interaction was accepted (Table 3). The distribution of residuals at the levels of the main effects (Figure 9) were not evenly distributed as noted above, and the frequency distribution of standardized residuals were peaked and somewhat biased (Figure 10), however, they were consistent to those observed by Turner (1987) for 1983-1986. The standardized estimates of abundance for 8-9 year old bluefin remained nearly stable from 1983 through 1985, then slightly decreased in 1986 (Table 3, Figure 11).

Discussion

These indices of abundance suggest that the population size of juvenile tuna was expanding from 1983 through 1985 and then began declining in 1986. These results are somewhat questionable due to the relatively low coefficients of multiple determination (R^2) that were derived for the three models (.26 for 3-5, .38 for 6-7, and .31 for 8-9 year old analyses). The low proportion of total variation explained by the analyses was probably due to the inability to incorporate environmental (i.e., favorable conditions that may concentrate fish) data into the analyses.

The standard deviations about the estimated catch rates in log units were similar to two of the levels of standard deviation in log normal error (0.1 and 0.32) introduced into the abundance indices by Vaughn et al. (1987) in sensitivity analyses of CAL, the tuning procedure recently used by the SCRS for bluefin virtual population analyses. These levels of standard deviation indicate that there is only a moderate amount of error in the catch rates derived from Japanese longline data.

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Table 1. Mean catch rates (CR) of bluefin tuna ages 1-9 caught by Japanese longline vessels fishing north of 35°N in the western Atlantic from 1983-1986 by year and month

YEAR	MONTH		AGE								
			1	2	3	4	5	6	7	8	9
82	7	MEAN CR	0.00	0.00	0.00	0.00	0.00	0.43	0.44	0.46	0.44
82	8	MEAN CR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00
82	9	MEAN CR	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00
82	12	MEAN CR	0.00	1.35	1.25	0.00	0.00	0.00	0.00	0.00	0.00
83	2	MEAN CR	0.36	0.37	0.00	0.74	0.00	0.00	0.37	0.37	0.00
83	12	MEAN CR	0.54	1.40	1.31	2.29	0.78	0.79	0.56	0.48	0.43
84	1	MEAN CR	0.00	0.71	1.48	4.12	6.40	1.77	0.64	0.55	0.48
84	2	MEAN CR	0.00	0.54	0.96	4.38	4.86	1.23	0.36	0.36	0.35
84	11	MEAN CR	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	12	MEAN CR	0.91	9.06	5.10	5.18	3.27	3.25	1.57	0.69	0.69
85	1	MEAN CR	0.55	0.58	5.54	2.92	2.53	5.70	3.64	1.58	0.87
85	2	MEAN CR	0.55	0.63	9.38	3.92	6.51	6.92	3.41	1.42	0.47
85	3	MEAN CR	0.38	0.62	12.33	3.42	4.78	1.98	0.85	0.72	0.50
85	6	MEAN CR	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	7	MEAN CR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
86	1	MEAN CR	0.37	0.57	0.99	11.56	2.16	1.37	1.15	0.70	0.63
86	2	MEAN CR	0.00	0.38	1.35	3.38	4.91	1.70	0.89	0.44	0.00
86	9	MEAN CR	0.35	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00
86	10	MEAN CR	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00
86	12	MEAN CR	0.00	0.88	4.56	6.39	4.57	0.83	0.69	0.43	0.42

Table 2. Number of sets initially used to develop indices of abundance for bluefin tuna as recorded from Japanese longline vessels fishing north of 35°N in the western Atlantic U.S. FCZ by levels of main effects

	No. of Sets
YEAR	
1983	13
1984	85
1985	150
1986	126
MONTH	
Jan	126
Feb	96
Dec	152
AREA	
3674	28
3966	36
3967	50
3968	29
4066	130
4067	101
HOOKS BETWEEN FLOATS	
7	216
8	87
10	71

Table 3. Annual standardized catch rates (number of bluefin per 1000 hooks) 1000 hooks) for 3-5, 6-7, and 8-9 year old bluefin in the western Atlantic with the final analyses of variance models (cr = catch rate, Y = year, M = month, A = area, H = Number of hooks between floats, MA = month-area interaction)

3-5 YEAR OLDS

Model: $\ln(cr + 1) = Y + M + A + H + MA$

$R^2 = .26$

Year	Estimated Catch Rate	Standard Deviation
83	4.4304	.475
84	11.4347	.271
85	10.8471	.223
86	6.8342	.323

6-7 YEAR OLDS

Model: $\ln(cr + 1) = Y + M + A$

$R^2 = .38$

Year	Estimated Catch Rate	Standard Deviation
83	2.1639	.333
84	2.8369	.155
85	5.1944	.138
86	1.5607	.180

8-9 YEAR OLDS

Model: $\ln(cr + 1) = Y + M + A + MA$

$R^2 = .28$

Year	Estimated Catch Rate	Standard Deviation
83	1.3825	.204
84	1.4135	.085
85	1.5570	.096
86	1.1217	.108

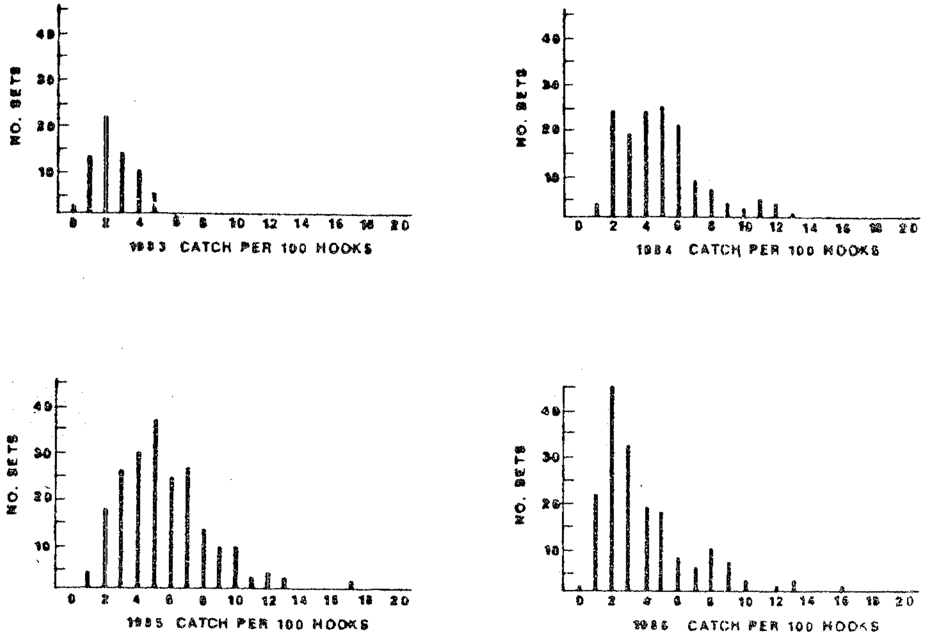

Figure 1. Histograms of catch rates by year of all animals caught in the western Atlantic U.S. FCZ north of 35°N by Japanese longline vessels for 1983-1986

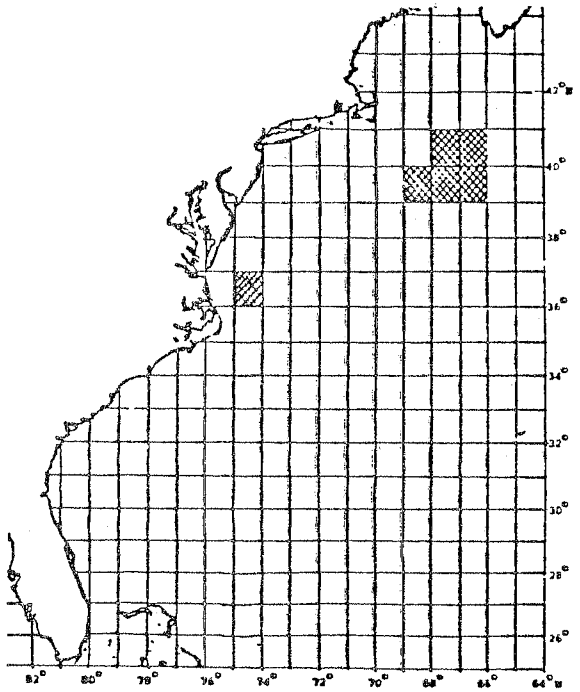

Figure 2. Map of areas used in developing indices of abundance in the initial analysis of bluefin tuna for 1983-1986

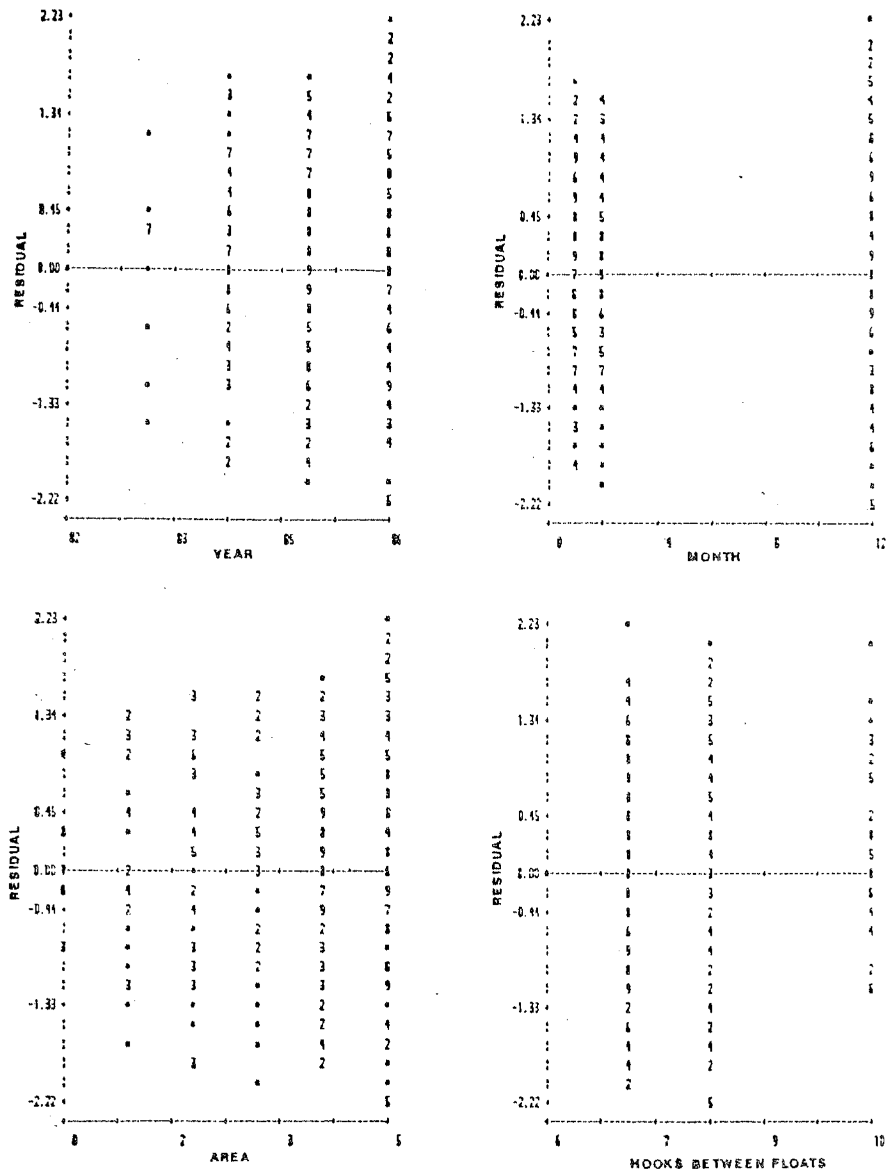

Figure 3. Plot of residuals against levels of the main effects in the final analysis of catch rates for 3-5 year old bluefin. The area codes are 1=39°N66°W, 2=39°N67°W, 3=39°N68°W, 4=40°N66°W and 5=40°N67°W

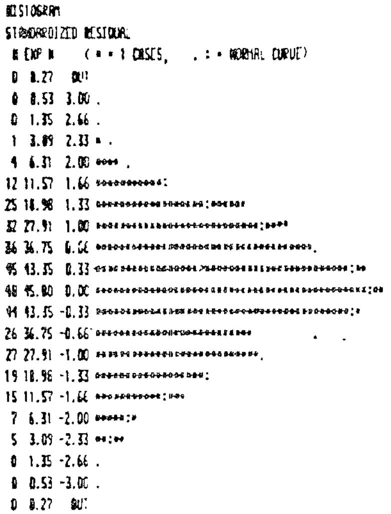

Figure 4. Histogram of the frequencies of standardized residuals from the final analysis of 3-5 year old bluefin. N is the number of observations at each level of standardized residuals. N EXP is the number expected if the standardized residuals were normally distributed. Values that fall between ±3 are shown, all others are designated by OUT

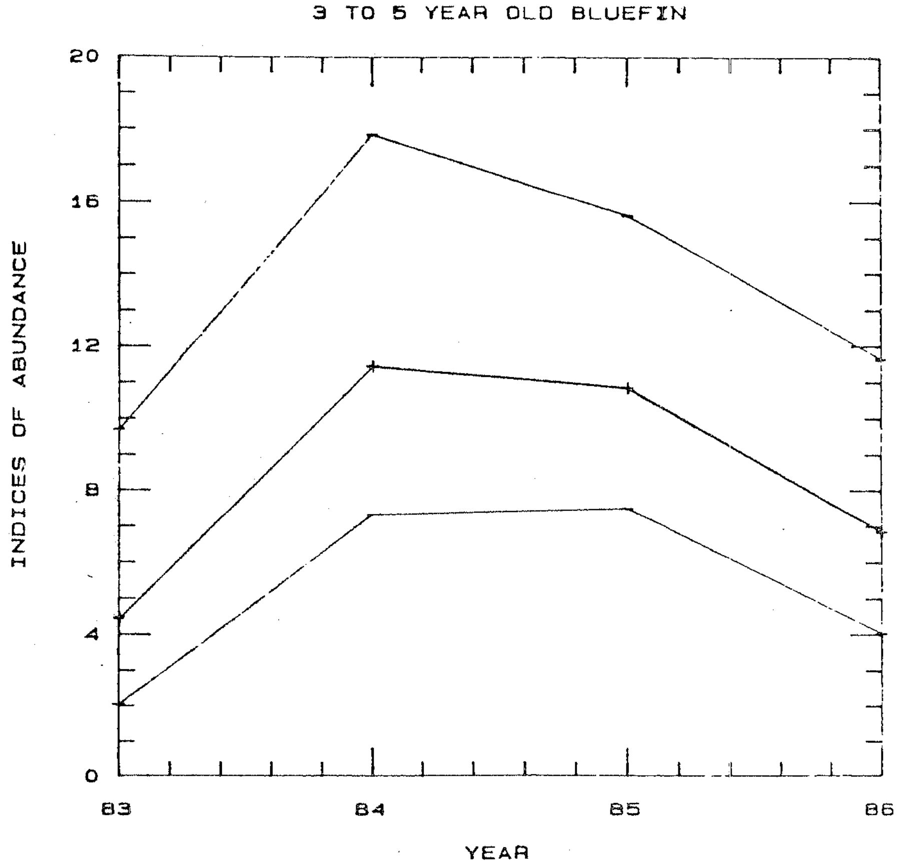

Figure 5. Plot of the standardized indices of abundance for 3-5 year old bluefin caught in the U.S. FCZ north of 35°N with a 90% confidence interval

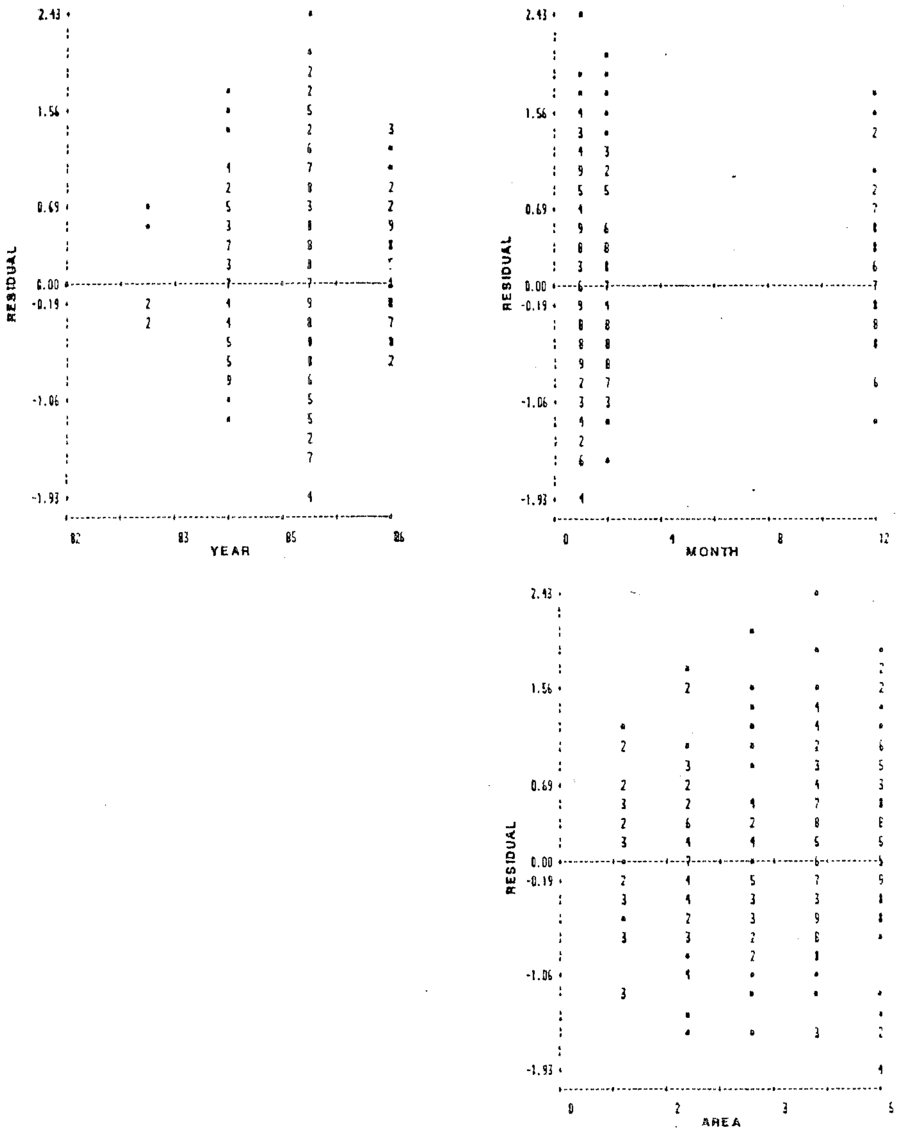

Figure 6. Plot of residuals against levels of the main effects in the final analysis of catch rates for 6-7 year old bluefin. The area codes are 1=39°N66°W, 2=39°N67°W, 3=39°N68°W, 4=40°N66°W and 5=40°N67°W

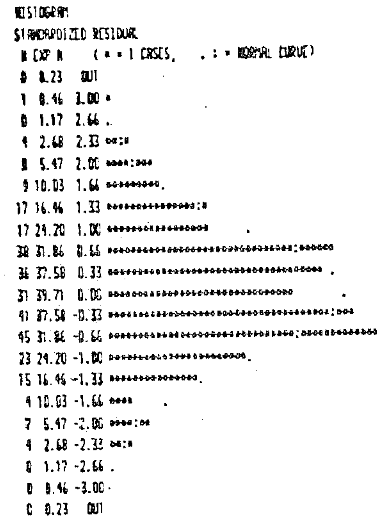

Figure 7. Histogram of the frequencies of standardized residuals from the final analysis of 6-7 year old bluefin. N is the number of observations at each level of standardized residuals. N EXP is the number expected if the standardized residuals were normally distributed. Values that fall between ±3 are shown, all others are designated by OUT

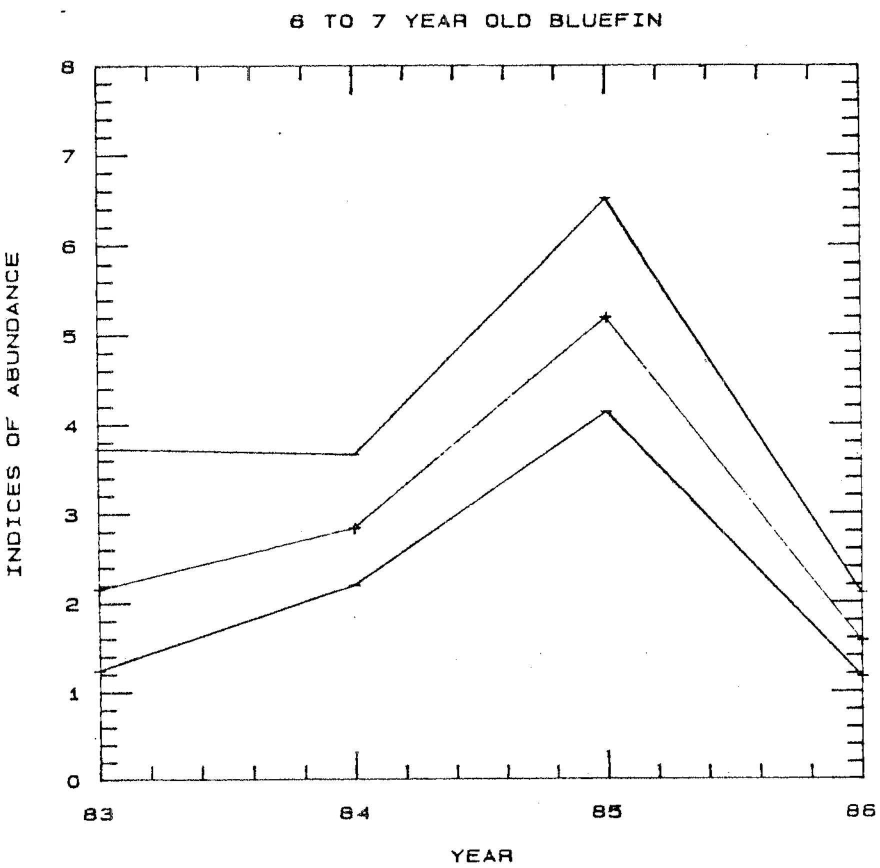

Figure 8. Plot of the standardized indices of abundance for 6-7 year old bluefin caught in the U.S. FCZ north of 35°N with a 90% confidence interval

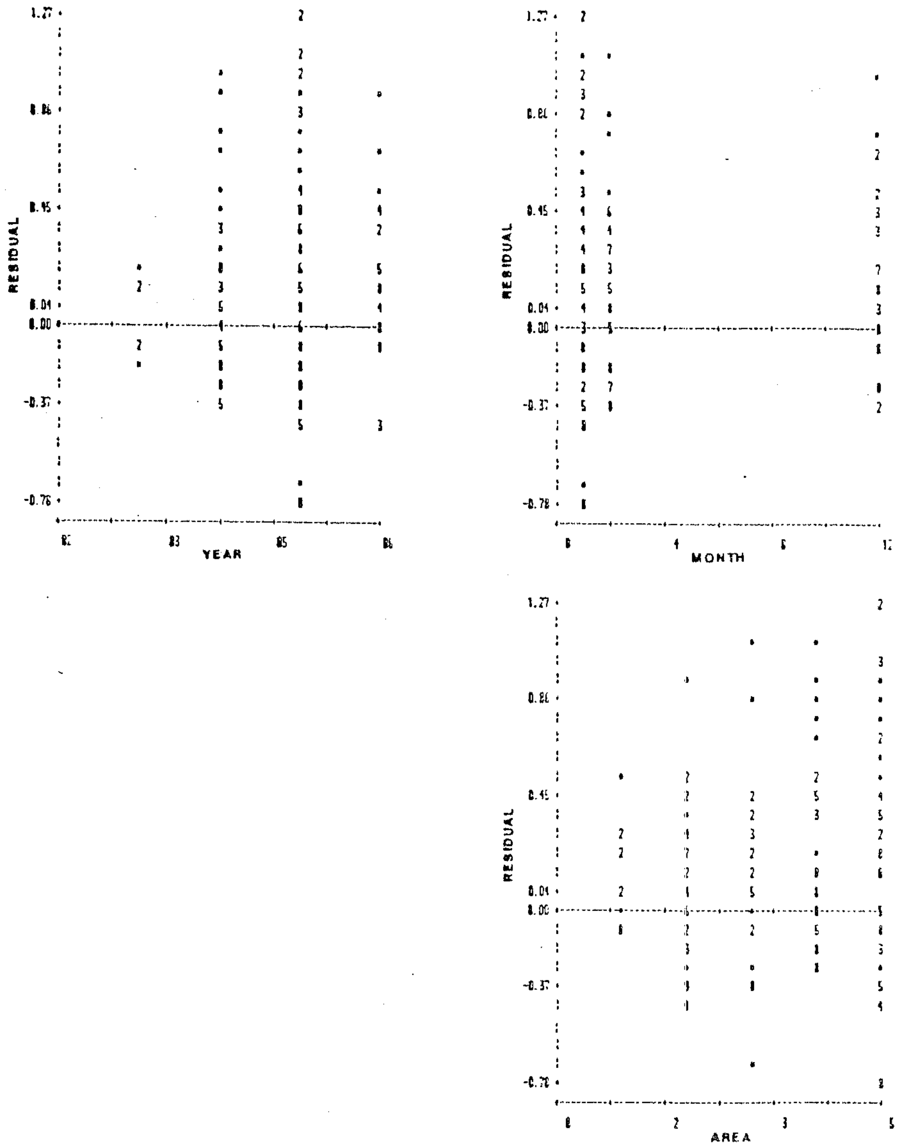

Figure 9. Plot of residuals against levels of the main effects in the final analysis of catch rates for 8-9 year old bluefin. The area codes are 1=39°N66°W, 2=39°N67°W, 3=39°N68°W, 4=40°N66°W and 5=40°N67°W

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HISTOGRAM
STANDARDIZED RESIDUAL
N EXP N      ( * = 1 CASES,    . : = NORMAL CURVE)
 2  0.23   OUT **
 2  0.46  3.00 **
 4  1.17  2.66 :***
 5  2.68  2.33 **:**
 4  5.47  2.00 ****.
 3 10.03  1.66 ***      .
14 16.46  1.33 ************** .
16 24.20  1.00 ****************        .
24 31.86  0.66 ************************       .
28 37.58  0.33 ****************************      .
43 39.71  0.00 ***************************************:***
63 37.58 -0.33 *************************************:*************************
47 31.86 -0.66 *******************************:***************
27 24.20 -1.00 ***********************:***
 7 16.46 -1.33 *******      .
 1 10.03 -1.66 *     .
10  5.47 -2.00 ****:*****
 0  2.68 -2.33   .
 0  1.17 -2.66 .
 0  0.46 -3.00
 0  0.23   OUT
```

Figure 10. Histogram of the frequencies of standardized residuals from the final analysis of 8-9 year old bluefin. N is the number of observations at each level of standardized residuals. N EXP is the number expected if the standardized residuals were normally distributed. Values that fall between ±3 are shown, all others are designated by OUT

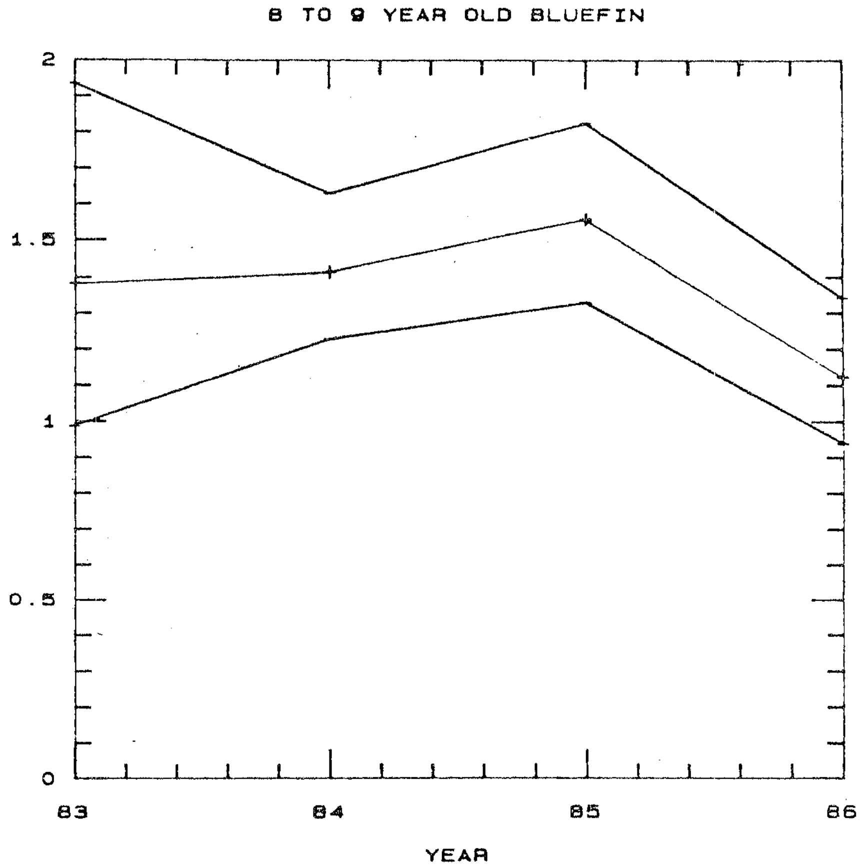

Figure 11. Plot of the standardized indices of abundance for 8-9 year old bluefin caught in the U.S. FCZ north of 35°N with a 90% confidence interval