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STANDARDIZED CATCH RATES OF LARGE BLUEFIN TUNA IN THE NEW ENGLAND (U.S.) ROD AND REEL/HANDLINE FISHERY

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SUMMARY

Abundance indices for large bluefin tuna in the Gulf of Maine and off the south coast of New England from 1983-1989 were developed using data obtained during interviews of anglers in that fishery. Data from interviews having the same year/month/area/sea surface temperature were combined into groups of 15 trips in order to derive standardized catch rates and standardized indices using a general linear model.

RESUME

Les indices d'abondance des gros thons rouges dans le golfe du Maine et au large de la côte sud de la Nouvelle Angleterre de la période 1983-1989 ont été élaborés en utilisant les données obtenues au cours d'entretiens avec des pêcheurs de cette pêcherie. Les données provenant d'entretiens et ayant la même année/mois/zone/température de surface ont été combinées en groupes de 15 sorties pour obtenir, au moyen du modèle linéaire généralisé, les taux standardisés de prise ainsi que les indices standardisés.

RESUMEN

Se desarrollaron índices de abundancia de grandes ejemplares de atún rojo en el golfo de Maine y frente a la costa sur de Nueva Inglaterra, de 1983 a 1989, utilizando datos obtenidos durante entrevistas a los pescadores deportivos de esa pesquería. Los datos de aquellas entrevistas que tenían el mismo año/mes/área/temperatura de la superficie del mar, se combinaron en grupos de 15 viajes para deducir tasas de captura estandarizadas e índices estandarizados, utilizando un modelo lineal generalizado.

Introduction

Catch per unit effort data on rod and reel (RR) and handline (HL) fisheries off the coast of New England in the United States were collected from 1982-1989. Fishermen were interviewed as they returned to the dock to determine if the trip was directed at large bluefin tuna (>200 cm straight fork length (SFL)). Interviewers recorded the number and sizes of bluefin caught and the effort expended for each trip targeting large bluefin.

This fishery is generally restricted to the waters just south of New England (SONE) and in the Gulf of Maine (GOMA). Because of regulations imposed on the fishery during the period of this survey, catch is generally limited to one large bluefin per vessel per trip. The distribution of catch per unit effort (CPUE) for large bluefin tuna essentially consists of CPUE's of zero or one fish per trip, with unsuccessful trips predominating.

The variation in area fished, time of year, and environmental factors make it inappropriate to compare nominal CPUE across years. A general linear model (GLM) approach (Draper and Smith 1966) is used in this paper to develop standardized indices of abundance for large bluefin tuna in the New England RR/HL fishery during 1983-1989. The same approach was used to develop standardized abundance indices for this fishery from 1982 to 1986 (Brown and Turner 1988) and 1983 to 1988 (Brown and Turner 1989).

Materials and Methods

Each trip interview record includes data on: target species, date, gear, time fished (hours), number of lines, fishing location (except in 1984, when no fishing location was recorded), landing location, number of each bluefin tuna caught and, in most cases, size information. Catch was determined from the number of bluefin of at least 200 cm SFL; effort was evaluated in terms of line-hrs (LHR). For this analysis data were restricted to only those trips which targeted large bluefin.

For cases in which size information was absent, records were cross referenced to a size data base derived from mandatory sales reports of all medium and large bluefin. If sizes could not be found, the fish were considered to be small. This assumes that non-compliance with the mandatory reporting, if it occurs, does not vary significantly from year to year. Released fish were also assumed small. The release of large bluefin is rare; during 1988, only one fish was reported released out of a sample of 233 large bluefin.

The variables chosen for the initial analysis were year, month, area, and sea surface temperature (SST). Gear type was not included as a factor in the analysis as a previous study (Brown and Turner 1988) had indicated that gear (HL or RR) had no significant effect on catch rates.

Data from 1982 were excluded from the analysis since there were too few observations to insure a balanced design; only data from months July, August, and September were included in the analysis for similar reasons. Data from 1987 were excluded from the analysis because interviewer reports suggested that a bias existed toward interviews of successful trips during that year (Brown and Turner 1988).

The two areas studied (GOMA and SONE) were defined based on fishing location. An exception was data from 1984, when only landing location was available. The GOMA was defined by the bounds of 41° 20'N, 43°N and 69°W. For 1984, interviews conducted in Massachusetts from Chatham north were also assigned to this area. The SONE area was bounded by 40° 40'N, 41° 20'N, 69°W and 72°W (Fig. 7). For 1984, this area included interviews conducted along the southern coast of Massachusetts, Rhode Island, Connecticut and the Montauk, Long Island region. The relative scarcity of trips targeting large bluefin prevented the inclusion of vessels fishing out of western Long Island (New York), New Jersey and states further south.

Values of SST were incorporated by examination of the weekly oceanographic analysis charts modified by the National Marine Fisheries Service, Northeast Fisheries Center, Narragansett Laboratory, Marine Climatology Investigation Division. A weekly temperature for each area was assigned based on the SST at a location determined to be the major fishing grounds. These values generally reflected the temperature throughout each area.

Since there were very few occurrences with SST values less than 15°C or greater than 22°C; records having SST values outside this range were excluded from the analyses. This temperature range is smaller than the range used in the 1989 analysis (14°C to 23°C) so some differences in nominal CPUE will be seen in Table 1. Average Catch per line-hour (CPLHR*1000) by SST varied from a low of 2.76 at 19°C to a high of 12.13 at 17°C within this temperature range.

The high proportion of unsuccessful trips (80%, 88%, 89%, 85% for 1983-1986 respectively, 92% for 1988 and 96% for 1989) prevented the analysis of single trip observations. Trip records were randomized, then grouped by year/month/area/temperature to create summary catch and effort observations, each representing exactly 15 trips. Summary observations were created within each stratum until less than 15 interviews remained; these remaining interviews were excluded to ensure that each summary observation represented an identical number of interviews. Summation across 15 trips reduced the proportion of zero valued observations to (0%, 26%, 30%, 23% for 1983-1986 respectively, 27% for 1988 and 74% for 1989).

A GLM (Draper and Smith 1986) approach to analysis of variance was used to examine logged catch rates per 1000 LHR for differences among the effects of year month, area and SST, as well as all possible two-way interactions of month, area and SST. The square of SST (SST*SST) was also tested to determine if a nonlinear relationship between SST and logged catch rates existed. The value of catch rate per unit effort for each summary observation was increased by ten to improve the residual distributions and to permit taking the natural logs of all catch rate values, including nominal catch rates of 0. The model was rerun with one instead to ten added to each summary observation in order to determine if the any bias was introduced. The magnitudes changed but the relative trends were unaffected. It was concluded that substantial bias was not introduced. F-tests were conducted on all main effects and interactions to determine whether or not each contributed significantly to the model.

The frequency distribution of standardized residuals [(observed - predicted)/standard error of the estimate] were examined at each level of the main effects and for the whole model to ensure that they approximated the normal distribution. The final model was used to develop standardized catch rates for each year.

Results

Nominal CPUE data for each year, month, and area obtained from single trip records and from summary observations are contrasted in Table 1. The mean catch rates shown were obtained by averaging the catch rates of the observations within each cell. Total catch (in numbers of fish) and effort (in trips and line-hours) is shown for each cell. The comparison of these values between the single trip data and the summary observations indicates that little information was lost during the summation process, despite the elimination of all remaining trip data within each cell when there were fewer than 15 trips.

The yearly mean nominal CPUE, derived from summary observations, is plotted in Figure 1. The range of observations is also shown.

F tests indicated that the main effects of year, month, area, temperature, and all two-way interactions of these effects significantly affected logged catch rates in the GLM analysis. Although the effect of temperature on catch rate appears to be nonlinear (Table 2) SST squared (SST*SST) did not contribute significantly to the model. This may be due to the comparatively low sample sizes at the lower temperatures.

The standardized abundance index for each year was corrected for log transformation bias (Brown and Lucy 1990) and adjusted to average temperature (19°C). Abundance indices, year parameter estimates, standard errors and the formula for log transformation bias are listed in Fig. 2.

Distributions of the standardized residuals remained somewhat peaked or skewed for most levels of the main class effects of year (Fig. 3), month (Fig. 4) and area (Fig. 5). This occurred because catch rates of zero remained the mode, even for summary observations. The technique of grouping trips to reduce zeros did not work as well in 1989 as in previous years because there were more unsuccessful trips and most of the large bluefin were caught in GOMA while very few were caught in SONE. The distribution of standardized residuals for the whole model (Fig. 6) was also peaked and skewed as a result of the remaining catch rates of zero. Standardized indices of abundance have remained fairly level from 1984-89 (Fig. 2). Despite the less than normal distribution patterns of the standardized residuals, we feel that the catch rates of zero are valuable information. However, if the current trend in proportion of unsuccessful trips continues, different modeling techniques will be required.

Discussion

The nominal catch rates of large bluefin fluctuated significantly during 1983-1989 (Fig. 1). Declining from nearly 13 fish per 1000 LHR in 1983 to less than 3 fish per 1000 LHR in 1985, the nominal catch rate increased to over 12 fish per 1000 LHR in 1986. This level dropped to a mean of about 1 fish per 1000 LHR in the final year (1989).

Standardization of the catch rates using a GLM approach permits comparisons across years by separating the effects of each significant factor. The confidence intervals (+/-2 standard errors) shown in Figure 2 for 1984-1989 reflect uncertainty in the year effect. The confidence intervals (CI) for 1983 (Fig. 2) is very large because 1983 is the standard year. And the standard year (1983) CI includes uncertainty introduced by all variables of the model.

These abundance indices suggest that the population size of large bluefin tuna have fluctuated only slightly from 1984-1989. The CIs around each estimate result from a relatively moderate coefficient of multiple determination (R^2) that was derived for the model (0.42).

Literature Cited

Brown, C.A. and J.A. Lucy. 1990. Standardized catch rates of small bluefin tuna in the Virginia (U.S.) offshore rod and reel fishery. ICCAT Working Document SCRS/90/81.

Brown, C.A. and S.C. Turner. 1988. Standardized catch rates of large bluefin tuna in the New England (U.S.) rod and reel/handline fishery 1982-1986. Int. Comm. Conserv. Atl. Tunas, Col. Vol. Sci. Pap. 30(2):302-310.

Brown, C.A. and S.C. Turner. 1989. Standardized catch rates of large bluefin tuna in the New England (U.S.) rod and reel/handline fishery. Int. Comm. Conserv. Atl. Tunas, Col. Vol. Sci. Pap. 32(2):248-254.

Draper, N.R., and H. Smith. 1986. Applied Regression Analysis. John Riley and Sons, Inc., New York, 407 p.

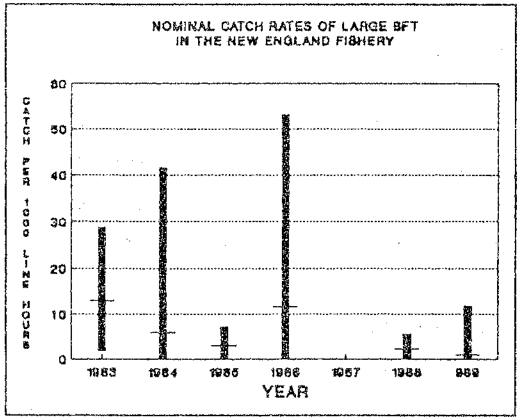
Table 1. Nominal CPUE (in catch per 1000 line-hours) by year, month and area.

			Single Trips						Observations summarized by year/month/area/SST, representing 15 trips each					
YR	MON	AREA	MEAN	SD	N	catch	Line -Hrs	No. 0's	MEAN	SD	N	catch	Line -Hrs	No. 0's
83	7	SONE	62.50	176.78	8	1	318	7	.	.	.	.	.	.
	8	SONE	25.79	60.70	128	34	2836	94	16.89	9.51	7	30	2112	0
	9	SONE	13.82	37.02	162	25	3584	137	10.20	7.71	10	25	3201	0
		GOMA	125.00	.	1	1	8	0	.	.	.	.	.	.
84	7	SONE	21.43	66.58	313	48	5379	265	10.60	6.42	20	47	4876	1
		GOMA	3.82	13.19	61	5	1490	56	3.16	2.79	4	4	1470	1
	8	SONE	12.65	49.71	491	55	10301	436	7.28	9.29	32	55	9803	10
		GOMA	6.94	32.78	504	35	12387	469	2.85	3.31	32	31	11559	13
	9	SONE	0.00	.	38	0	701	38	0.00	0.00	2	0	519	2
		GOMA	11.88	41.88	455	68	14822	387	5.64	5.97	30	67	14300	4
85	7	SONE	0.00	.	1	0	18	1	.	.	.	.	.	.
		GOMA	3.10	12.46	125	11	4664	114	2.44	1.84	7	9	3611	2
	8	SONE	0.00	.	1	0	36	1	.	.	.	.	.	.
		GOMA	2.99	11.33	215	19	8447	196	2.41	2.43	13	18	7367	5
	9	GOMA	6.86	11.77	68	19	2977	49	6.52	0.68	3	12	1854	0
86	7	SONE	39.98	111.93	152	48	3134	104	20.51	14.99	9	48	2678	1
		GOMA	0.00	.	17	0	496	17	.	.	.	.	.	.
	8	SONE	4.05	33.26	104	3	2882	101	1.73	2.38	5	3	1903	3
		GOMA	4.78	28.60	81	5	2204	76	1.42	2.46	3	2	1123	2
	9	SONE	0.00	.	7	0	172	7	.	.	.	.	.	.
		GOMA	5.68	15.77	24	3	542	21	.	.	.	.	.	.
88	7	SONE	0.00	.	21	0	451	21	0.00	.	1	0	290	1
		GOMA	2.66	8.72	71	7	2156	64	2.74	2.65	3	3	1328	1
	8	SONE	0.00	0.00	18	0	442	18	.	.	.	.	.	.
		GOMA	2.77	9.01	145	14	5124	131	2.38	2.00	8	10	4139	2
	9	SONE	0.00	.	5	0	124	5	.	.	.	.	.	.
		GOMA	0.00	.	2	0	36	2	.	.	.	.	.	.
89	7	SONE	0.35	4.04	489	4	14305	485	0.30	0.80	31	4	13700	27
		GOMA	10.50	38.81	150	21	4453	130	5.06	3.49	7	15	3088	0
	8	SONE	0.00	.	271	0	9533	271	0.00	.	17	0	9000	17
		GOMA	9.94	40.48	104	9	3129	95	1.28	1.11	3	2	1524	1
	9	SONE	1.49	15.75	112	1	3872	111	0.30	0.80	7	1	3622	6
		GOMA	4.56	13.99	72	9	2363	63	3.43	2.45	4	7	1999	1

Table 2. Mean nominal CPUE (catch per 1000 line-hours) by temperature.

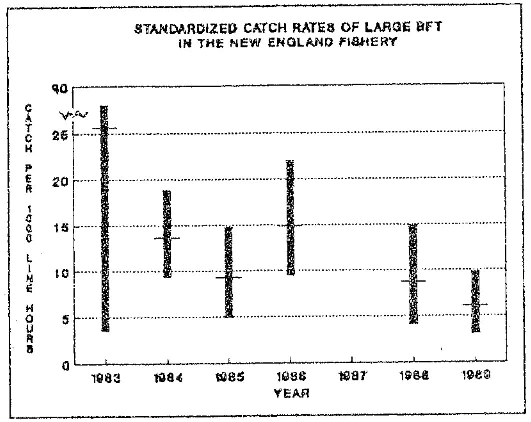
TEMP	No.	Mean CPUE	Min. CPUE	Max CPUE
15	38	5.21	0	24.03
16	11	4.07	0	7.27
17	14	12.13	0	53.33
18	31	6.50	0	20.83
19	31	2.76	0	28.71
20	54	4.61	0	41.67
21	53	5.11	0	26.43
22	27	3.08	0	23.53

Figure 1. Mean annual nominal CPUE (catch per 1000 line-hours). Error bars indicate the range of values within each year.



YEAR	Mean CPUE	Min. observed CPUE	Max. observed CPUE
1983	12.95	1.85	28.71
1984	5.99	0.00	41.67
1985	2.96	0.00	7.27
1986	11.62	0.00	53.33
1988	2.27	0.00	5.59
1989	1.03	0.00	11.80

Figure 2. Annual standardized indices of abundance (catch per 1000 line-hours) with error bars at +/- 2 standard errors (SE) for large bluefin tuna in the New England RR/HL fishery. (Indices were derived from the antilog (e^x) of the model parameter estimates using summary observations.



Final model:

$$\ln(1000*(CPLHR+10)) = Y + M + A + T + M*A + M*T + A*T$$

where Y = year
M = month
A = area
and T = SST

$R^2 = 0.4143$
Square root of mean square error = 0.2960
Number of observations = 258

YEAR	Y	SE	Ab Index	-2SE	+2SE	EXP(Y)
1983	0.0000	0.0000	25.57	3.57	83.23	1.000
1984	-0.4019	0.1017	13.67	9.40	18.89	0.669
1985	-0.6053	0.1298	9.25	4.92	14.83	0.546
1986	-0.3474	0.1273	14.92	9.42	21.99	0.707
1988	-0.6309	0.1462	8.72	4.06	14.94	0.532
1989	-0.7880	0.1061	6.08	3.06	9.80	0.455

*Logarithmic bias correction:

$$\text{Abundance Index} - 10 = \exp[I+Y+T*A+(S^2_I+S^2_T)/2+(E-S^2_Y)*(DF+1)/2*DF]$$

I =	intercept parameter	=	2.0172
Y =	year parameter	=	see table
T =	temperature parameter	=	0.07311
A =	average temperature	=	19^0F
S^2_I =	intercept SE squared	=	0.49161
S^2_T =	temperature SE squared	=	0.03202
E =	mean square error	=	0.08760
S^2_Y =	year SE squared	=	see table
DF =	degree of freedom error	=	243

Figure 3. Distributions of standardized residuals at each level of year tested in the GLM procedure.

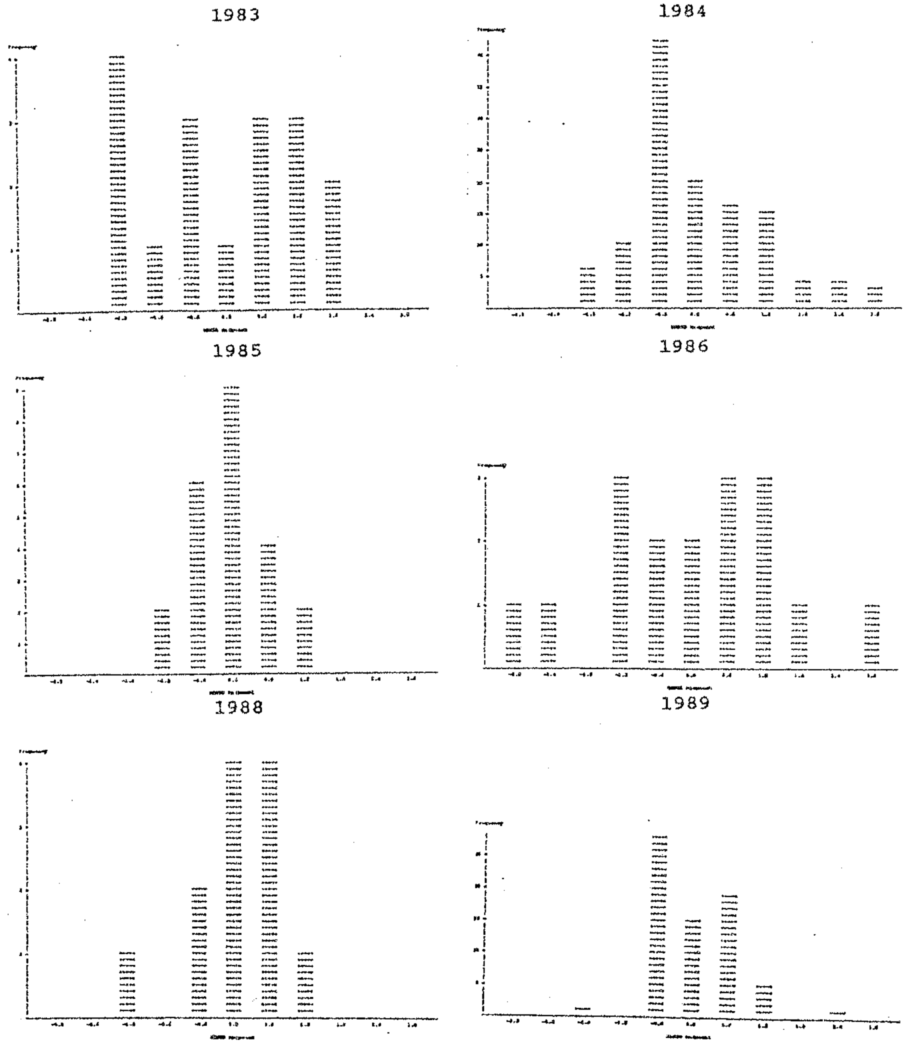


Figure 4. Distributions of standardized residuals at each level of month tested in the GLM procedure.

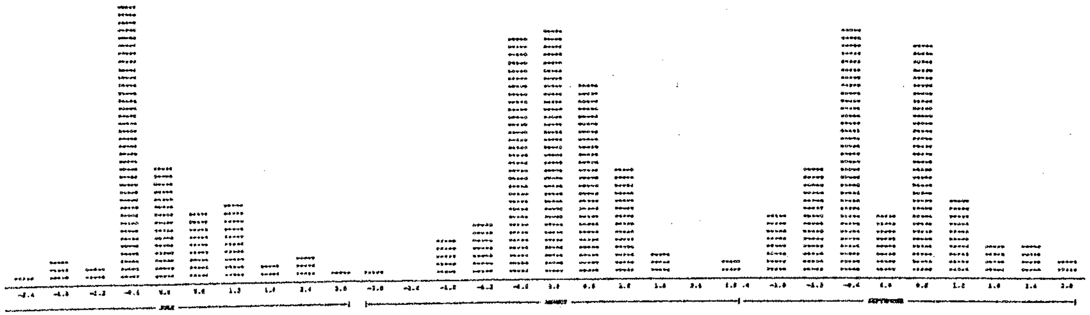


Figure 5. Distributions of standardized residuals at each level of area tested in the GLM procedure.

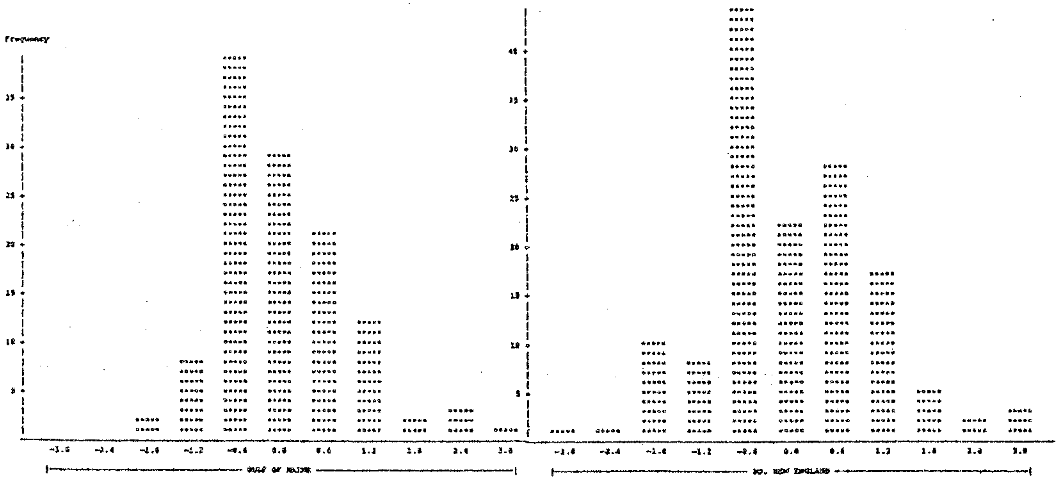
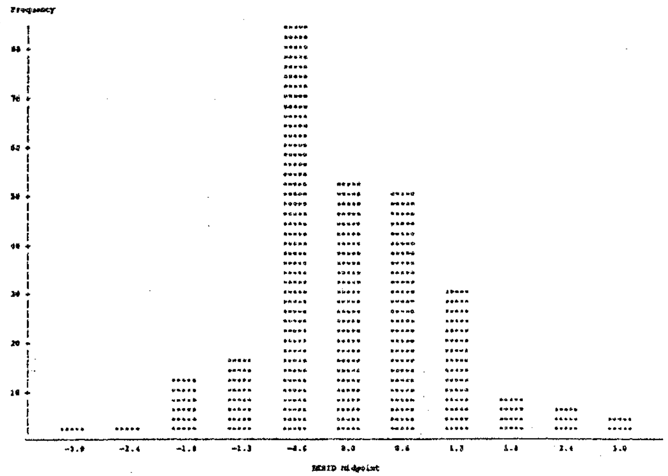


Figure 6. Distributions of standardized residuals of the final model determined using the GLM procedure.



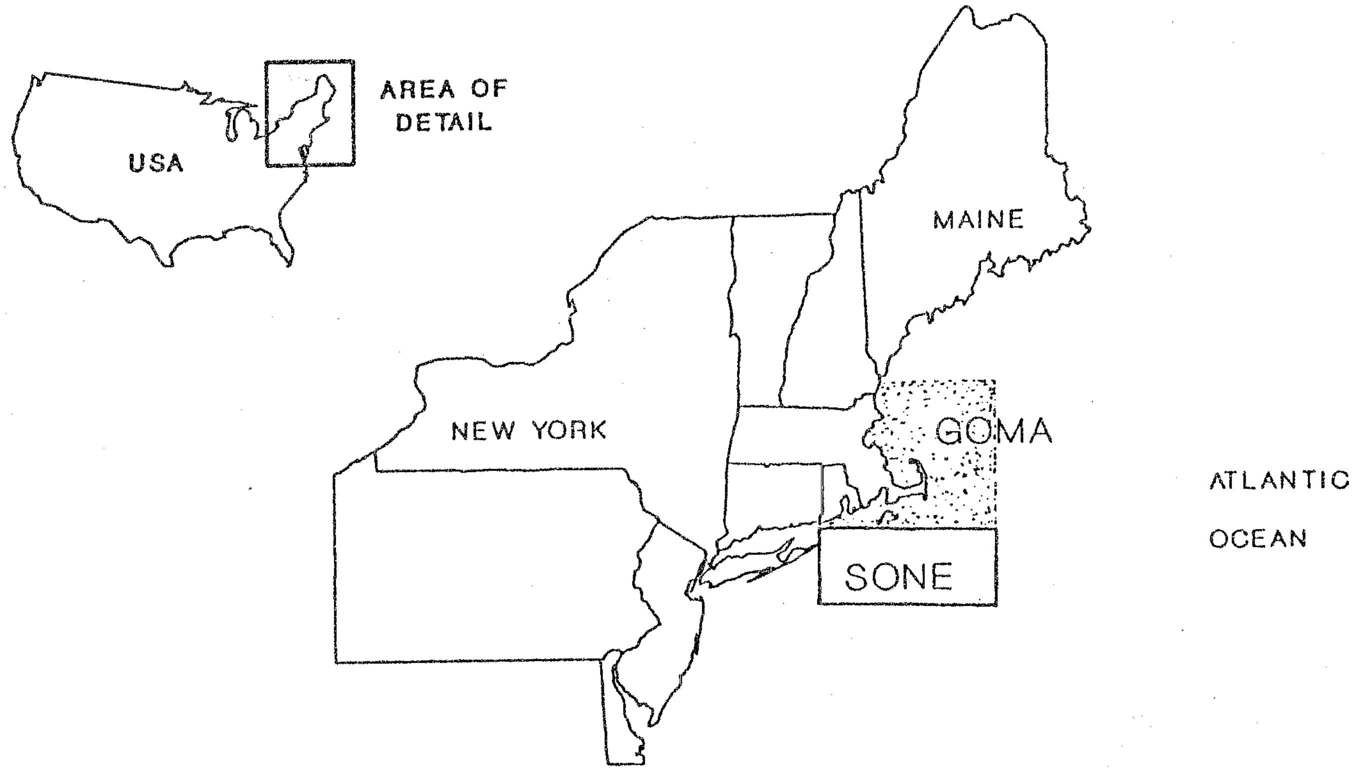


FIGURE 7: LARGE BLUEFIN TUNA FISHING AREAS