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STANDARDIZED CATCH RATES OF YELLOWFIN TUNA, Thunnus albacares, FROM THE UNITED STATES LONGLINE FISHERY IN THE ATLANTIC OCEAN

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SUMMARY

Yellowfin tuna catch and effort data collected from the U.S. longline fleet operating over a wide geographical range of the western north Atlantic Ocean were used to develop indices of abundance of western Atlantic yellowfin tuna. Standardized catch rates were estimated using the General Linear Modelling approach.

RESUME

Les données de prise et d'effort sur l'albacore recueillies sur la flottille palangrière américaine qui pêche sur une ample aire géographique dans l'Atlantique nord-ouest ont servi à élaborer des indices d'abondance pour l'albacore ouest-atlantique. Des taux de capture standardisés ont été estimés au moyen de la méthode du modèle linéaire généralisé.

RESUMEN

Se emplearon datos de captura y esfuerzo de rabil obtenidos de la flota palangrera norteamericana que opera en una amplia zona geográfica del Atlántico noroeste, para hallar índices de abundancia de rabil en el Atlántico oeste. Se estimaron tasas de captura por medio del Modelo Lineal Generalizado.

Introduction

For assessment purposes, ICCAT's SCRS considers Atlantic yellowfin tuna to be comprised of two stocks, one in the eastern and one in the western Atlantic. The conclusions drawn from data collected during the Yellowfin Year Program (YYP) confirmed the widely held belief that some mixing occurs between the western and eastern Atlantic stocks. Eastern Atlantic yellowfin stocks have received considerable attention at SCRS. The SCRS considered the fisheries operating on the eastern Atlantic yellowfin stock to be near full exploitation levels. This view was offered after review of production modelling results that suggested the stock might be underexploited. However, the SCRS felt that the effective effort measures used for model fitting, may not have adequately accounted for changes in catchability of yellowfin due to some technological advances in the fleet. The SCRS has not yet conducted formal assessment of western Atlantic yellowfin stock status. However, in 1990, a preliminary production model analysis of western Atlantic yellowfin was presented to SCRS based on Venezuelan purse seine effort from 1972-1989. Results of this analysis suggested that the western stock could be near full exploitation. However, the yellowfin tuna working group considered the data and assumptions on which the analysis was based too preliminary to consider the results of the model to be conclusive.

The US fishery for yellowfin tuna in the western Atlantic Ocean has only recently developed (Browder *et al.* 1990). Standardized catch rate information from this fishery may provide a basis for further consideration of stock status. The purpose of this manuscript is to provide a preliminary description of the patterns in catch rates for yellowfin tuna in the US longline fishery, standardized for numerous factors thought to influence these rates.

Methods

Hoey and Bertolino (1988) described the available catch and effort data available from the US longline fleet. These data have been used for developing swordfish abundance indices using a General Linear Modelling (GLM) approach (Hoey *et al.*, 1989; Scott and Bertolino, 1990). In addition to swordfish, the carcass weight data base, developed from pack-out sheet information, contains trip-specific landings information for yellowfin tuna and other large pelagic species from a portion of the US fleet. The present analysis is a first step in the application of the GLM approach to the catch rate information for yellowfin tuna available in this data set.

Effort information (hooks fished and days fished) has been developed from several sources. Prior to 1987, effort was obtained by examination of captain's logbooks and interviews with vessel captains. After 1986, in addition to these information sources, effort reported in mandatory set-specific logbook records were also available for defining trip effort for the fleet. For this analysis, only information for which landings were believed representative of the catch were used for analysis.

A total of 2346 vessel trips were available for analysis over the time frame from 1982-1989. Information on yellowfin tuna prior to 1982 was considered too sparse for consideration in analysis (see Table 1). These data were cross-classified by year, geographical area of fishing (see Figure 1), calendar quarter (Jan.-Mar., Apr.-May, June-Aug., and Sept.-Nov.), average size of set (<500 hooks/set and ≥500 hooks/set), and proportion of yellowfin tuna in the catch (in number) relative to the combined swordfish and yellowfin catch (in number). The groupings used for classification were: ≤25% yellowfin, 25%< yellowfin ≤50%, 50%< yellowfin ≤75%, and >75% yellowfin.

The geographical areas used in analysis (Figure 1) were: Caribbean (CAR), Gulf of Mexico (GOM), Florida East Coast (FEC), and North of Cape Hatteras (NCH). No information from the Grand Banks fishing grounds (area number 7 on Figure 1) was used in this analysis since we believe that the landings of yellowfin from this area may not be representative of the catch. For the same reason, information from the Caribbean for the second two calendar quarters was not used in analysis. We believe that some additional proportion of the data set may not be representative of catch rates for species other than swordfish. In order to avoid this, we only used trip catch information for vessels reporting species other than swordfish. Trips for which only swordfish were reported landed in the data set were not used; while trips reporting swordfish and other species or species other than swordfish were used.

Little information is available in the data set to define targeting for yellowfin tuna. Although time of set would be an appropriate method for discriminating swordfish targeted effort from tuna directed effort, this information is not available for the present data set. Because of this, two classifiers, set size and proportion of yellowfin in the catch, were used to attempt to control for hypothesized targeting effects. Specific vessel operation style was available for only a small portion of the available information. For this reason, operation style was not used in this analysis.

Nominal CPUE data were normalized through the natural log transform. Zero CPUE was included in analysis by the transform: Ln((catch/hooks + 1)). For this analysis, main effect models and models with interaction terms were tested. Interaction terms were included in the model if the F-statistic showed significance at the 0.05 level. The models were standardized to the most recent year's information (1989) and the highest level of all other classifiers. To examine the influence of the Gulf of Mexico data on the overall CPUE patterns, fits to the data with and without Gulf of Mexico were conducted. Residual patterns were examined for symmetry. Relative abundance patterns were taken as the arithmetic scale transformed year parameter estimates from the final GLM runs.

Results and Discussion

The number of trips available each year for analysis increased from 20-40 in 1982-1985 to several hundred in the late 1980's, reflecting the imposition of the mandatory log book program in October 1986 and increased efforts to obtain carcass weight data from U.S fisheries for large pelagic fish (Table 1). The data from the early 1980's were primarily from the Florida east coast and the area north of Cape Hatteras, fishing grounds which have been exploited by U.S. longline vessels for many years. The proportion of trips from the Caribbean and Gulf of Mexico areas has increased substantially in recent years reflecting both the expansion of the fishery and increased efforts to obtain carcass weight information from those area. It should be noted that the area called Caribbean refers to both within the Caribbean Sea and in the western tropical Atlantic (Figure 1).

The expansion of the fishery in the Gulf of Mexico and the Caribbean areas have differed. The Caribbean fishery developed primarily as a swordfish fishery (Browder and Scott SCRS/91/5) with some increase in fishing for yellowfin especially in the Atlantic off South America in recent years. The fishery in the Gulf of Mexico has developed as a yellowfin fishery and fishing practices have changed rapidly. Initially fishing was conducted with frozen bait; subsequently fishing with live bait on the longlines was introduced; then some fishermen began monitoring the gear while it was fishing and pulling it when there were signs that a fish had been caught and rebaiting the hooks.

Because of the differences in the fisheries inside and outside of the Gulf of Mexico, three sets of analyses were conducted. One included only the Gulf of Mexico data, one included data from outside of the Gulf and the third included all of the data.

Analysis of variance (ANOVA) results for the models fit to the CPUE data are shown in Tables 2, 3, and 4, along with the year parameter estimates and back transformed abundance index values resulting from the final models fit to the data. The models fit explained between 50% and 63% of the total variability observed in the data. The standardized residual patterns for each of the three final models fit are shown in Figures 2, 3, and 4.

The patterns in relative catch rate showed some differences between fits to the data sets comprised only of Gulf of Mexico information and of excluding Gulf of Mexico (Figure 5). The 95%

confidence intervals about the standardized relative catch rates overlapped in all years (Figure 5 and Tables 2, 3 and 4).

Future research on yellowfin catch rate trends should investigate 1) the effects of differences in size or age composition of the yellowfin catch throughout this range and 2) the effects of targeting and fishing methods. Recent efforts to increase the coverage of the carcass weight samples is improving our ability to address the first topic and recent expansion of the information requested in log books should permit investigation of the second.

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Table 1. Trip data with yellowfin tuna catch and effort information available for analysis from the US longline fleet, 1981-1989.

Frequency	82	83	84	85	86	87	88	89	Total
CAR	0	0	0	4	26	65	98	60	253
FEC	17	9	17	21	77	280	334	239	994
GOM	0	4	1	9	56	113	235	214	632
NCH	3	15	15	5	81	146	92	110	467
Total	20	28	33	39	240	604	759	623	2346

Note: Area definitions: CAR, Caribbean; FEC, Florida East Coast; GOM, Gulf of Mexico; and NCH, north of Cape Hatteras.

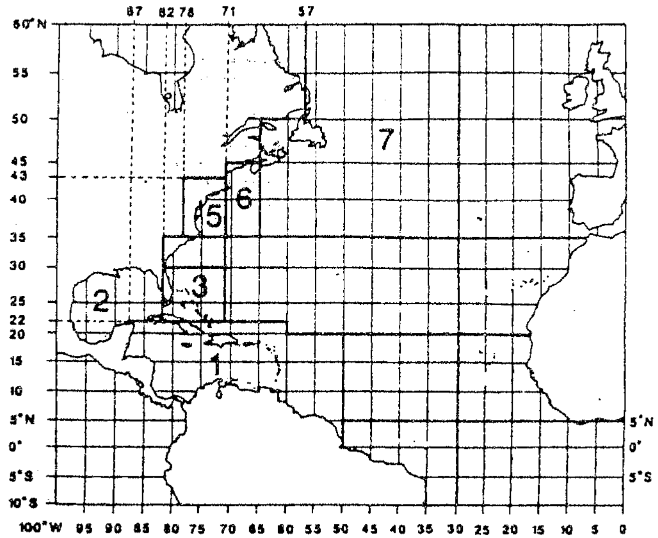

Figure 1. Geographical areas used in the yellowfin tuna CPUE analysis. On this figure area 1 represents the Caribbean (CAR); area 2 the Gulf of Mexico (GOM); area 3, Florida East Coast (FEC); area 5 plus area 6, North of Cape Hatteras (NCH). No information from area 7 (Grand Banks) was used in analysis since it is likely that for yellowfin tuna, landings are not representative of the catch in this region.

Table 2. GLM for full data set, 1982-1989.

Dependent Variable: LCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	35	3058.7926163	87.3940748	115.01	0.0
Error	2310	1755.2559165	0.7598510		
Corrected Total	2345	4814.0485328			

R-Square	C.V.	Root MSE	LCPUE Mean
0.635389	61.53759	0.8716944	1.41652333

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
YR	7	18.73238451	2.67605493	3.52	0.0009
QTR	3	86.71784783	28.90594928	38.04	0.0001
AREA	3	6.17367127	2.05789042	2.71	0.0437
SZST	1	47.53924456	47.53924456	62.56	0.0001
QTILE	3	285.47435022	95.15811674	125.23	0.0001
QTR*AREA	7	12.35301119	1.76471588	2.32	0.0232
AREA*QTILE	8	13.23592788	1.65449099	2.18	0.0264
SZST*QTILE	3	13.19750464	4.39916821	5.79	0.0006

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		3.198664999	17.34	0.0001	0.18442549
YR	82	0.320533713	1.60	0.1098	0.20034221
	83	0.132809474	0.77	0.4429	0.17305284
	84	-0.140449241	-0.88	0.3769	0.15890461
	85	-0.129125518	-0.88	0.3795	0.14689140
	86	-0.021883203	-0.32	0.7513	0.06904381
	87	-0.018232042	-0.36	0.7221	0.05124908
	88	0.165424185	3.38	0.0007	0.04887197
	89	0.000000000	.	.	.

YEAR	CPUE_L95	CPUE	CPUE_U95
82	0.9304	1.3779	2.0405
83	0.8135	1.1420	1.6032
84	0.6364	0.8690	1.1865
85	0.6590	0.8789	1.1721
86	0.8545	0.9784	1.1201
87	0.8881	0.9819	1.0857
88	1.0721	1.1799	1.2985
89	.	1.0000	.

Note: YR - year, AREA - Fishing Area (Florida East Coast, Caribbean, North of Cape Hatteras, and Gulf of Mexico), QTR - Calendar quarter, SZST - Average set size (<500 hooks or ≥500 hooks), QTILE - Quartile for the proportion of yellowfin tuna relative to the the catch of swordfish and yellowfin tuna combined. Parameter estimates for the GLM model represent the relative weight given to the year effect, relative to 1989, in the GLM and are frequently used as relative abundance index values. CPUE, CPUE_L95, and CPUE_U95 represent the arithmetic, relative scale and associated approximate 95% confidence limits for the index values.

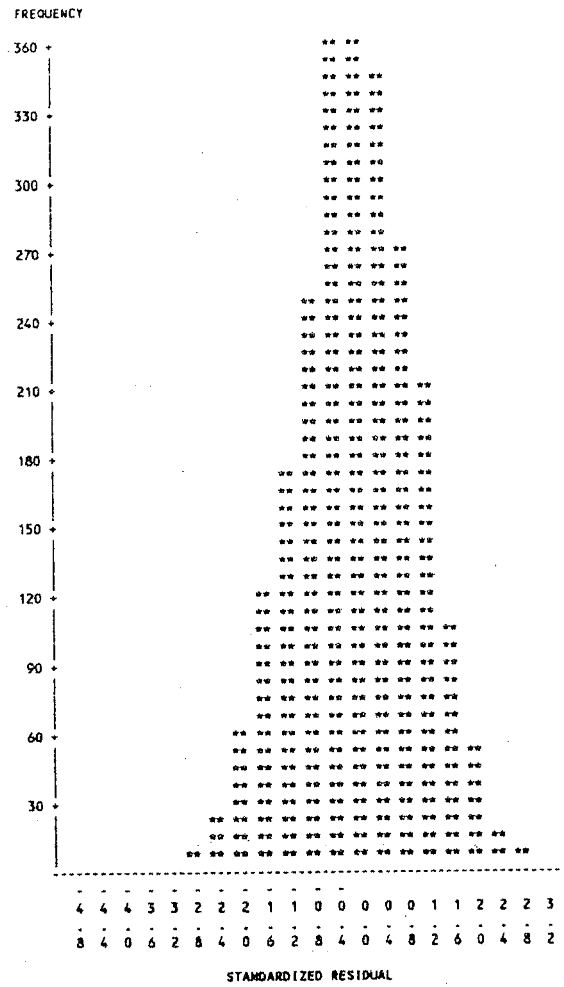

Figure 2. Standardized residual plot for the GLM applied to the full data set (see Table 2).

Table 3. GLM applied to the data from the Gulf of Mexico only.

Dependent Variable: LCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	644.13705184	29.27895690	37.94	0.0001
Error	609	470.02006246	0.77178992		
Corrected Total	631	1114.15711430			

R-Square	C.V.	Root MSE	LCPUE Mean
0.578138	33.63791	0.8785157	2.61168341

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
YR	6	46.62904098	7.77150683	10.07	0.0001
QTR	3	14.43934406	4.81311469	6.24	0.0004
SZST	1	11.37025405	11.37025405	14.73	0.0001
QTILE	3	299.51905496	99.83968499	129.36	0.0001
QTR*QTILE	9	22.12617785	2.45846421	3.19	0.0009

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		3.303291446	30.91	0.0001	0.10687242
YR	83	0.930179579	1.99	0.0471	0.46748647
	84	-0.935238546	-1.05	0.2927	0.88811650
	85	0.046698707	0.15	0.8791	0.30697678
	86	-0.369403465	-2.72	0.0067	0.13583654
	87	-0.670852050	-6.33	0.0001	0.10600734
	88	-0.010441332	-0.12	0.9072	0.08957362
	89	0.000000000	.	.	.

YEAR	CPUE_L95	CPUE	CPUE_U95
83	1.0140	2.5350	6.3373
84	0.0688	0.3925	2.2377
85	0.5741	1.0478	1.9124
86	0.5296	0.6911	0.9020
87	0.4154	0.5113	0.6293
88	0.8303	0.9896	1.1795
89	.	1.0000	.

Note: YR - year, QTR - Calendar quarter, SZST - Average set size (<500 hooks or ≥500 hooks), QTILE - Quartile for the proportion of yellowfin tuna relative to the the catch of swordfish and yellowfin tuna combined. Parameter estimates for the GLM model represent the relative weight given to the year effect, relative to 1989, in the GLM and are frequently used as relative abundance index values. CPUE, CPUE_L95, and CPUE_U95 represent the arithmetic, relative scale and associated approximate 95% confidence limits for the index values.

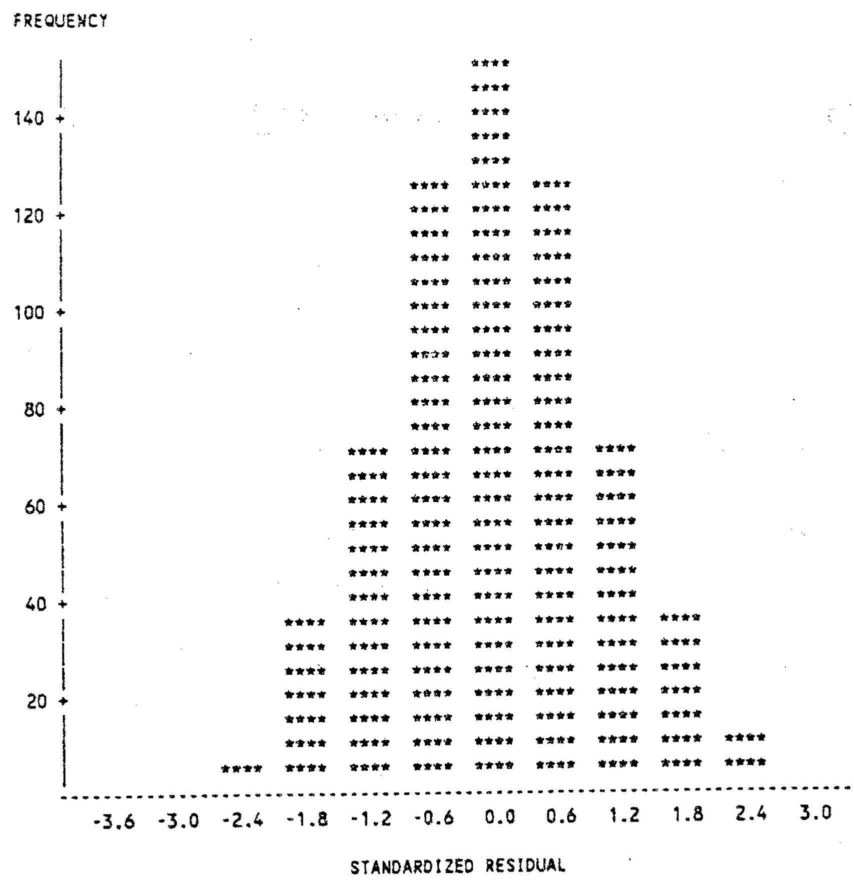

Figure 3. Standardized residuals from the GLM applied to the data for the Gulf of Mexico only (see Table 3).

Table 4. GLM applied to the data excluding information from the Gulf of Mexico.

Dependent Variable: LCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	20	1236.6698237	61.8334912	85.28	0.0001
Error	1693	1227.5973404	0.7251018		
Corrected Total	1713	2464.2671641			

R-Square	C.V.	Root MSE	LCPUE Mean
0.501841	87.26166	0.8515291	0.97583420

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
YR	7	17.39163459	2.48451923	3.43	0.0012
AREA	2	4.84423924	2.42211962	3.34	0.0357
QTR	3	48.47314500	16.15771500	22.28	0.0001
SZST	1	40.05912553	40.05912553	55.25	0.0001
QTILE	3	685.45076844	228.48358948	315.11	0.0001
AREA*QTR	4	12.69016686	3.17254172	4.38	0.0016

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		2.740252380	15.66	0.0001	0.17500575
YR	82	0.391357433	1.99	0.0466	0.19654695
	83	0.077645428	0.43	0.6700	0.18214708
	84	-0.040532603	-0.26	0.7981	0.15838862
	85	-0.192974988	-1.19	0.2344	0.16222137
	86	0.121157057	1.54	0.1246	0.07885526
	87	0.172838697	2.98	0.0030	0.05808197
	88	0.222471751	3.90	0.0001	0.05710825
	89	0.000000000	.	.	.

YEAR	CPUE_L95	CPUE	CPUE_U95
82	1.0061	1.4790	2.1740
83	0.7563	1.0807	1.5444
84	0.7040	0.9603	1.3098
85	0.5999	0.8245	1.1331
86	0.9672	1.1288	1.3175
87	1.0608	1.1887	1.3320
88	1.1169	1.2492	1.3971
89	.	1.0000	.

Note: YR - year, AREA - Fishing Area (Florida East Coast, Caribbean, North of Cape Hatteras), QTR - Calendar quarter, SZST - Average set size (<500 hooks or ≥500 hooks), QTILE - Quartile for the proportion of yellowfin tuna relative to the the catch of swordfish and yellowfin tuna combined. Parameter estimates for the GLM model represent the relative weight given to the year effect, relative to 1989, in the GLM and are frequently used as relative abundance index values. CPUE, CPUE_L95, and CPUE_U95 represent the arithmetic, relative scale and associated approximate 95% confidence limits for the index values.

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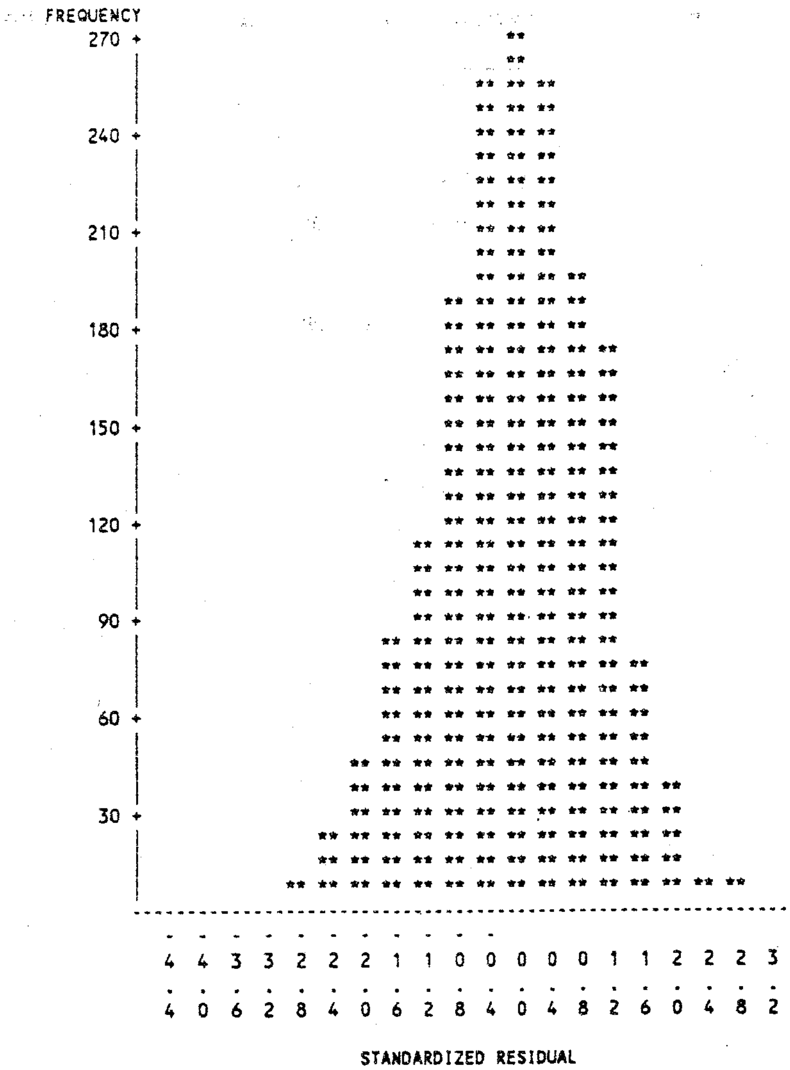

Figure 4. Standardized residual plot from the GLM fit to the data excluding information from the Gulf of Mexico (see Table 4).

Figure 5. Standardized Relative CPUE trends with estimated 95% confidence regions for GLM analyses appied to the full data set (bottom plate), and the data sets excluding Gulf of Mexico information (upper right) and the data set from only the Gulf of Mexico (upper left).