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STANDARDIZED CATCH RATES OF SMALL BLUEFIN TUNA IN THE VIRGINIA (U.S.) ROD AND REEL FISHERY

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SUMMARY

Abundance indices for small bluefin tuna off the coast of Virginia from 1980-1990 were developed using data obtained during interviews with anglers in that fishery. Subsets of the data were analyzed to assess effects of time of year, area fished, boat type (private or charter), interview type (dockside or phone) and sea surface temperature on catch per unit effort. Standardized catch rates were developed from single trip data and from combined data using a general linear model.

RESUME

Les indices d'abondance des petits thons rouges au large de la côte de Virginia de 1980-1990 ont été développés, en utilisant les données obtenues au cours des entretiens entre les pêcheurs de cette pêcherie. Les sous-ensembles des données ont été analysés pour évaluer les effets de la période de l'année, la zone exploitée, le type de bateau (privé ou loué), le type d'entretien (à quai ou par téléphone) et la température de surface de l'eau sur la prise par unité d'effort. Les taux de prise standardisés ont été développés à partir des données obtenues lors d'une seule sortie et à partir des données combinées en utilisant le modèle linéaire généralisé.

RESUMEN

Se desarrollaron índices de abundancia para pequeños ejemplares de atún rojo frente a la costa de Virginia, de 1980 a 1990, utilizando datos obtenidos durante entrevistas a los pescadores deportivos de esa pesquería. Se analizaron los subconjuntos de datos para evaluar los efectos del momento del año, área de captura, tipo de barco (particular o alquilado), tipo de entrevista (a pie de muelle o por teléfono) y temperatura de la superficie del mar sobre la captura por unidad de esfuerzo. Se crearon tasas de captura estandarizadas a partir de datos de un viaje único y de datos combinados que utilizan un modelo lineal generalizado.

Introduction

Catch per unit effort (CPUE) data on rod and reel (RR) and handline (HL) fisheries off the coast of Virginia in the United States were collected from 1980-1990. Fishermen were interviewed as they returned to the dock and by phone to determine if the trip was directed at juvenile bluefin tuna (less than 145 cm straight fork length (SFL), age 1-5 years). Interviewers recorded the number and sizes of bluefin caught and the effort expended for each trip.

This fishery is primarily located in the waters off the coast of Virginia, roughly between latitudes 36° N and 37° 30'N and longitudes 74° 30'W and 75° 54'W. The season begins during the first two weeks of June and may extend through July. The Virginia fishery was chosen as the study area primarily because we believe that the behavior of the Virginia fisherman is more consistent than the fishermen in other areas.

The variation in area fished, time of year, boat type (private/charter), interview type (dockside/phone), 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 small bluefin tuna in the Virginia RR fishery during 1980-1990. A similar approach was used to develop standardized abundance indices for this fishery from 1980 to 1989 (Brown and Lucy 1990).

Materials and Methods

Each trip interview record includes data on: target species, date, boat type, interview type (same day dockside or recall phone), time fished (hours), number of lines, fishing location (except in 1984, when no fishing location was recorded), landing location, number of bluefin tuna caught and, in many cases, size information. Catch was determined from the number of bluefin of less than 145 cm SFL; effort was evaluated in terms of line-hrs (LHR).

For this analysis data were restricted to only those trips which targeted juvenile bluefin. The analysis was also limited to time periods when tuna were likely to be present. Records having dates earlier than the date of the first bluefin caught or after bluefin stopped appearing as a significant component of the Virginia catch were excluded from the analysis. Dates within this period were grouped in weekly intervals.

The variables chosen for analysis were year, month, week, area, region, boat type, interview type and sea surface temperature (SST). Gear type, method of fishing, bait used, and number of previous trips were not included as factors in the analysis because this information was not recorded before 1985.

Twelve fishing areas were defined based on bottom topography and spacial distribution of effort. Each area was approximately 15 minutes square. Adjacent areas with catch rates that were not significantly different were combined to form regions. Data from 1984 were excluded from the analysis because fishing area locations were not recorded.

Values of sea surface temperature 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. For purposes of temperature evaluation the Virginia fishery was divided into three zones approximately 30' of latitude wide. Sea surface temperature (SST) for each zone was assigned based on the SST at a location determined to be the major fishing grounds.

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, week, area, region, SST, and interactions. The value of catch rate per unit effort for each observation was increased by one to permit taking the natural logs of all catch rate values, including nominal catch rates of 0. F-tests were conducted on all main effects and interactions to determine whether or not each contributed significantly to the model. Tukey's studentized range test was used to identify significant differences between the mean CPUE's of model variables.

GLM analyses of subsets of the data base were initially run to determine which variables and variable interactions should be included in the final model. Subsets were used because variables and combinations of variables were often not present in all years and GLM analyses having empty cells may be unreliable, particularly when testing the significance of interactions between variables. Each variable was tested for significance as a main effect. Tests for significant interactions between variables were made in cases where it was possible to construct a subset database that allowed analysis with all cells filled.

The high proportion of unsuccessful trips per year ranging from 60% to 10% resulted in residual distributions which were skewed when the model applied to single trip data. Summarized observations were created to minimize the proportion of catch rate values of zero while retaining catch rate information. Trip records were divided into sets having identical model variables (year/month/region/boat type/SST). Within these sets, five trip records were randomly combined. Summation of catch and effort from these sets of five formed a new data base of summed-by-5 observations. GLM analysis of summed-by-five observations resulted in less skewed residual distributions (Figures 11-17).

Age distribution of juvenile bluefin (Table 1) was derived by applying the age slicing algorithm used by the 1990 SCRS to the catch at size data . The available size data (straight fork lengths) were reexamined and the table was revised from that reported in Brown and Lucy (1991).

Results

Mean annual nominal CPUE for dockside interviews was not consistently higher than CPUE for phone interviews (Figure 1). A GLM including only variables year and interview type was run on a subset of the data which excluded years having only one type of interview (1981 and 1982). Interview type was not significant as a main effect. Interview type * year interaction was significant in the two variable model. However interview type * year interaction became insignificant when other variables were added to the model. In a GLM analysis using a subset excluding years 1981-1985 and 1990 no interactions between interview type and other testable variables (year, month, type and SST) were significant. Interview type and interactions between interview type and other variables were not included in the final model.

Since 1983 yearly nominal CPUE for charter boats was consistently higher than CPUE for private vessels (Figure 2). In a GLM analysis, using a data subset excluding data from 1981 and 1983, sums of squares of interactions between boat type and several other model variables (mo, SST, year) were significant but, together, accounted for less than 4% of the model sums of squares. Boat type was consistently significant as a main effect.

Investigation of time of year effects included tests of both weeks and months as model variables. Both variables were significant as main effects and had significant interactions with year. Month was chosen as the time of year effect because month * year interaction was less than week * year interaction and examination of plots of nominal data suggested that the most consistent differences in catch rates within years occurred between months rather than between weeks (Figures 3 and 4). Month * type and month * SST interactions were not consistently significant in subset analyses.

GLM analysis indicated that area was a significant variable. However geographic distribution of fishing effort has not been consistent from year to year and catch and effort data were unavailable in one to five years for ten of the twelve areas. In addition, areas infrequently fished in early years tended to be more frequently fished in recent years and in some cases accounted for a high percentage of the fishing effort. In order to retain data, particularly from recent years, rather than reduce the data to the few areas where fishing consistently occurred over years, areas were combined into regions. Tukey's studentized range test was used to identify areas having similar CPUE's. Adjacent areas with similar CPUE's were combined to make six regions (Figure 8). Region was significant as a main effect. Interactions between region and year were significant but the interaction sums of squares were less 10% of the model sums of squares.

The final model included the variables year, month, region, and SST as main effects and no interactions (Table 3). Annual standardized CPUE +/- 2 standard errors from the final model run with summed and with single tips data is plotted in Figure 5. There appears to have been no consistent trend in annual standardized CPUE since 1983. Estimates were not significantly affected by summing data.

Discussion

Revisions made in the data base since the 1990 analysis included both revision of individual records (1980, 1982,1985-1989) and addition of data (1980 and 1986). In order to show the effect of these revisions on the parameter estimates, the GLM used in 1990 (Ln(CPUE)=yr+week+boat type+area+week*SST) was run using revised data. For comparison, these results were plotted on the same graph (Figure 5) as the estimates from Brown and Lucy (Table 2, 1990). Data base revisions had little effect on estimated CPUE's .

In Figure 6 estimates from the 1990 [Ln(CPUE)=yr+week+boat type+area+week*SST] and 1991 [Ln(CPUE)=yr+month+boat type+region+SST] models run on the revised data base are compared. Standardized indices of abundance were not significantly different between models for any year.

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.

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

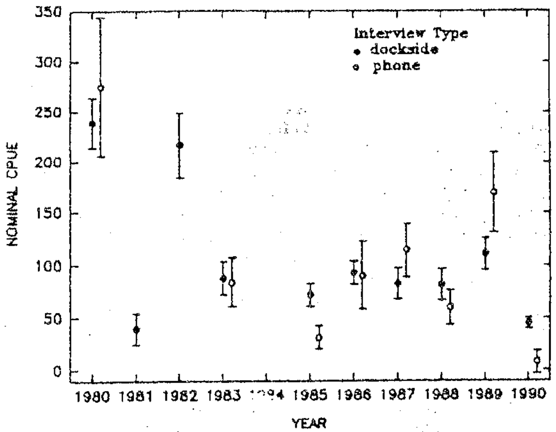


Figure 1. Mean annual nominal CPUE (catch per 1000 line-hours) for dockside and phone interview type data in the Virginia juvenile bluefine tuna RR/HL fishery.

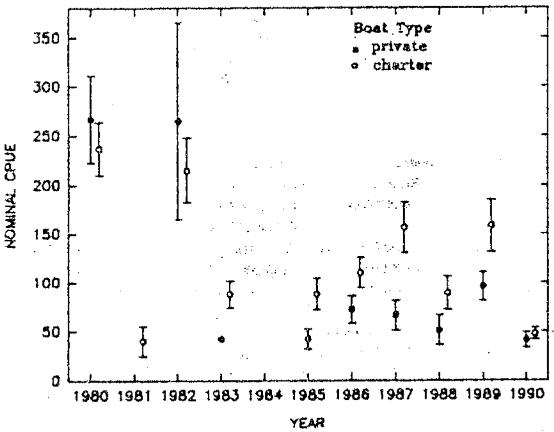


Figure 2. Mean annual nominal CPUE (catch per 1000 line-hours) for private or charter boat type data in the Virginia juvenile bluefin tuna RR/HL fishery.

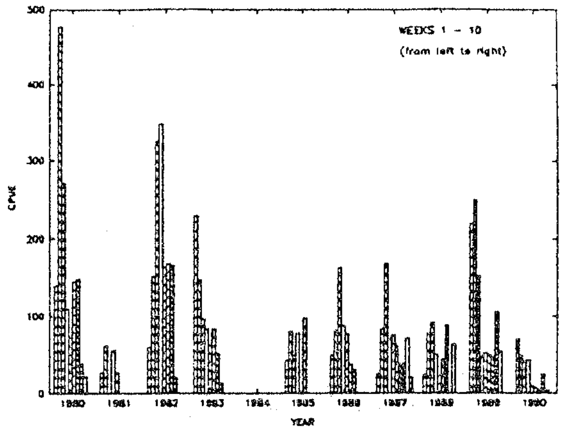


Figure 3. Mean nominal CPUE (catch per 1000 line-hours) for each week for each year in the Virginia juvenile bluefin tuna RR/HL fishery.

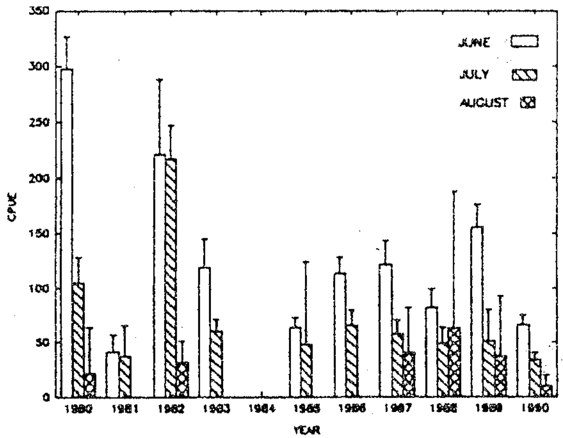


Figure 4. Mean nominal CPUE (catch per 1000 line-hours) and + 2 standard errors (SE) for months June through August in the Virginia juvenile bluefin tuna RR/HL fishery.

Table 1. Age Frequency of juvenile bluefin tuna in the Virginia RR/HL fishery.

YEAR	NUMBER OF OBSERVATIONS	AGE 1	2	3	4	5
1980	1202	.1298	.8220	.0324	.0133	.0008
1981	154	.0260	.7338	.2273	.0000	.0130
1982	806	.4330	.4380	.1005	.0223	.0062
1983	774	.2080	.5801	.2016	.0090	.0013
1985	578	.0571	.4204	.4983	.0225	.0017
1986	467	.0428	.4989	.4325	.0214	.0000
1987	185	.0865	.7027	.1946	.0108	.0054
1988	249	.3092	.3976	.2892	.0000	.0040
1989	627	.0494	.8628	.0750	.0112	.0016
1990	465	.0839	.1204	.7462	.0366	.0086

Table 2. Mean annual nominal CPUE (catch per 1000 line-hours) for summed and single record data in the Virginia juvenile bluefin tuna RR/HL fishery.

	Summed			Single		
YEAR	Mean CPUE	Observed Min	Max	Mean CPUE	Observed Min	Max
1980	241	17	651	246	0	1292
1981	42	0	326	40	0	750
1982	195	6	901	219	0	2875
1983	84	0	280	88	0	1500
1984						
1985	60	0	213	64	0	563
1986	90	0	377	94	0	500
1987	99	0	387	98	0	1143
1988	70	0	174	68	0	583
1989	118	0	380	126	0	1714
1990	46	0	103	49	0	292

Table 3. Final model used to estimate annual standardized indices of abundance.

Final model:

ln(1000*(CPLHR+1)) = Y + M + R + B + T

where CPLHR = catch per line hour
Y = year
M = month
R = region
B = Boat type
T = SST

	Summed	Single
R^2 =	0.467338	0.231138
Square root of mean square error =	0.070233	0.117051
Number of observations =	598	3620

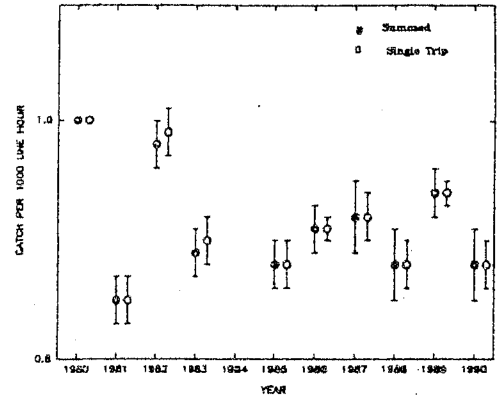


Figure 5. Annual standardized indices of abundance (adjusted to standard year 1980) with error bars at +/- 2 standard errors (SE) for summed and single trip data in the Virginia juvenile bluefine RR/HL fishery.

	LS MEANS						PARAMETER ESTIMATES			
	Summed			Single			Summed		Single	
YEAR	MEAN	-2SE	+2SE	MEAN	-2SE	+2SE	Y	SE	Y	SE
1980	1.00	1.00	1.00	1.00	1.00	1.00	0.000	0.000	0.000	0.000
1981	0.85	0.87	0.82	0.85	0.87	0.83	-0.166	0.015	-0.164	0.011
1982	0.98	1.00	0.95	0.99	1.01	0.97	-0.023	0.013	-0.008	0.009
1983	0.89	0.91	0.87	0.90	0.91	0.88	-0.117	0.013	-0.110	0.009
1984										
1985	0.88	0.90	0.86	0.88	0.89	0.86	-0.132	0.012	-0.130	0.009
1986	0.91	0.93	0.89	0.91	0.93	0.90	-0.096	0.012	-0.091	0.008
1987	0.92	0.95	0.89	0.92	0.94	0.90	-0.085	0.015	-0.085	0.010
1988	0.88	0.90	0.85	0.88	0.89	0.86	-0.133	0.015	-0.131	0.010
1989	0.94	0.96	0.92	0.94	0.96	0.93	-0.065	0.012	-0.060	0.008
1990	0.88	0.91	0.85	0.88	0.90	0.87	-0.128	0.015	-0.125	0.010

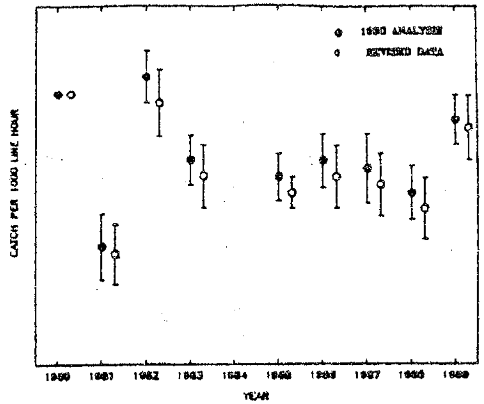


Figure 6. Effect of data base revisions on annual standardized indices of abundance (catch per 1000 line-hours) from the 1990 model (ln (CPUE)=year+week+area+boattype+week*SST.

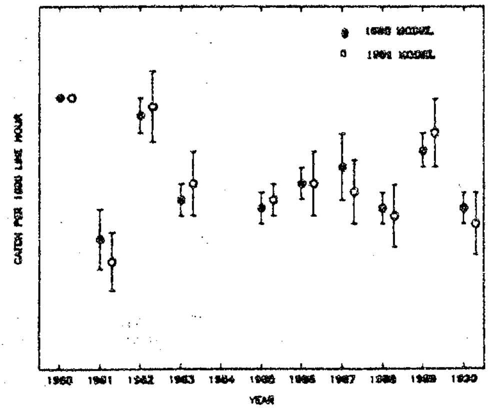


Figure 7. Differences in annual standardized indices of abundance between models: 1991 ln(CPUE)= year+month+region+boat type+SST and 1990 ln(CPUE)= year+week+area+boat type+week*SST.

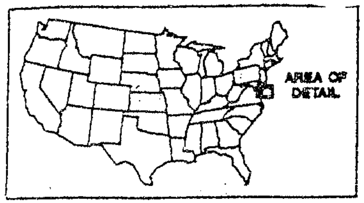
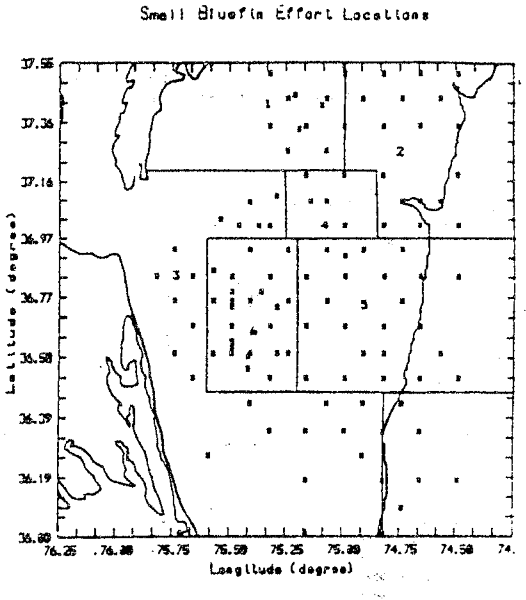
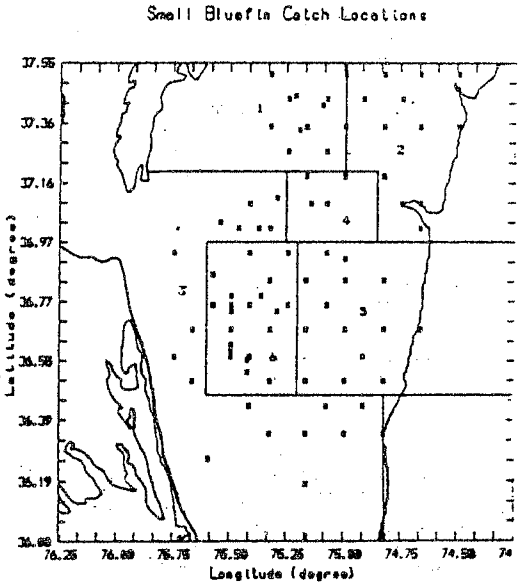


Figure 8. Virginia fishery small bluefin catch and effort locations. Curved lines represent the continental shoreline and the 200 meter depth contour. Regions are numbered and defined by straight lines.





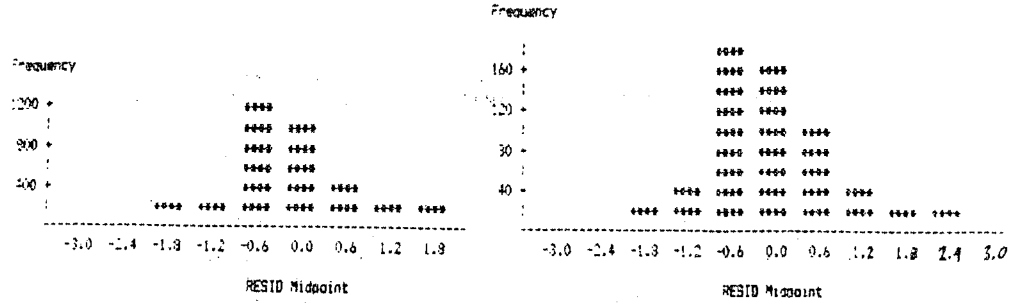


FIGURE 9. Distributions of standardized residuals [single trip (left) and summed data (right)].

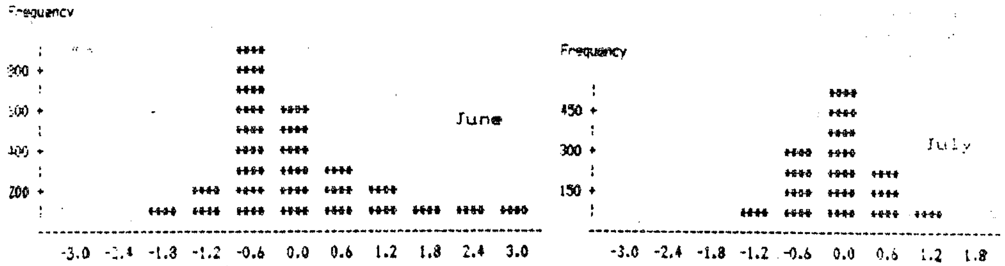


FIGURE 10. Distributions of standardized residuals at each month level for single trip data.

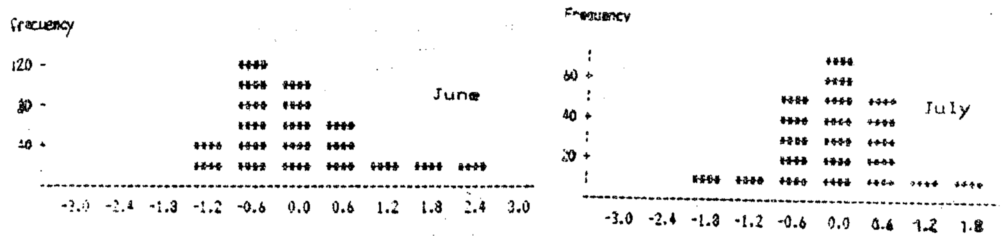


FIGURE 11. Distributions of standardized residuals at each month level for summed data.

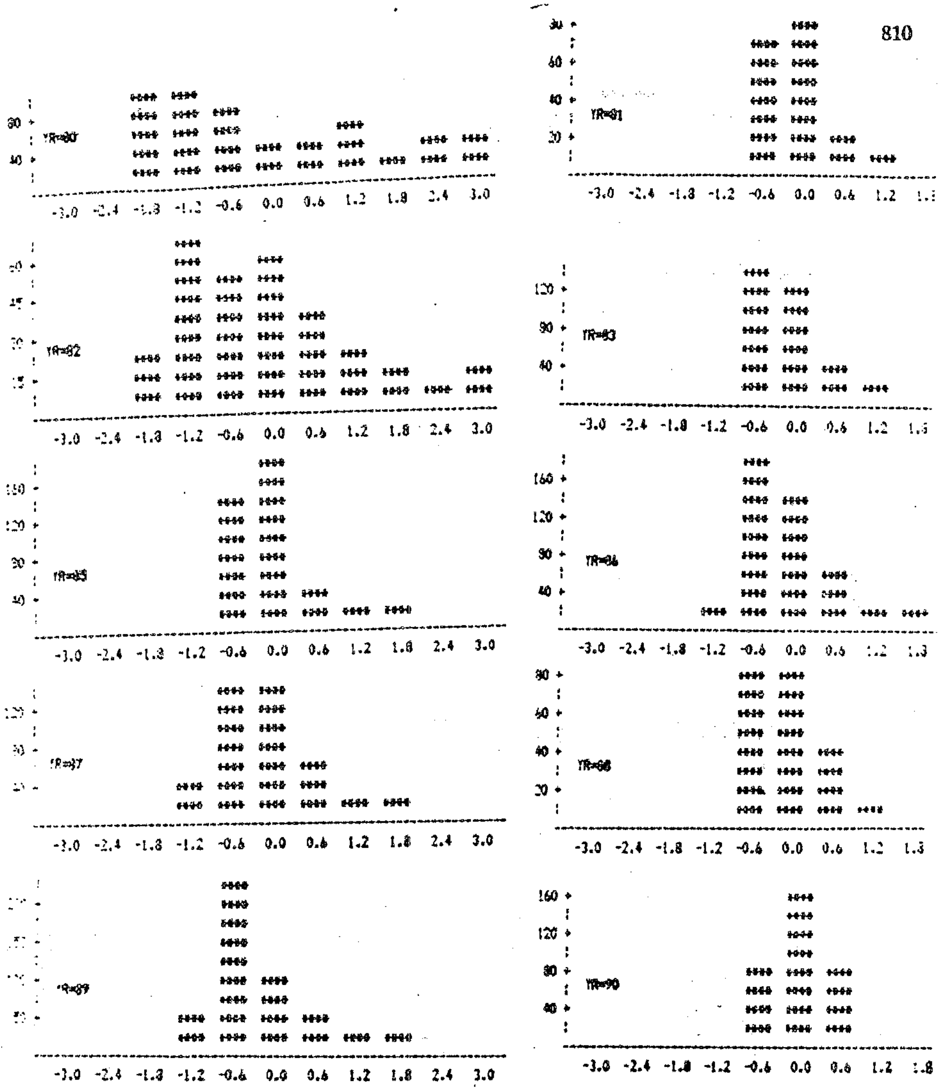


FIGURE 12. Distributions of standardized residuals at each year level for single trip data.

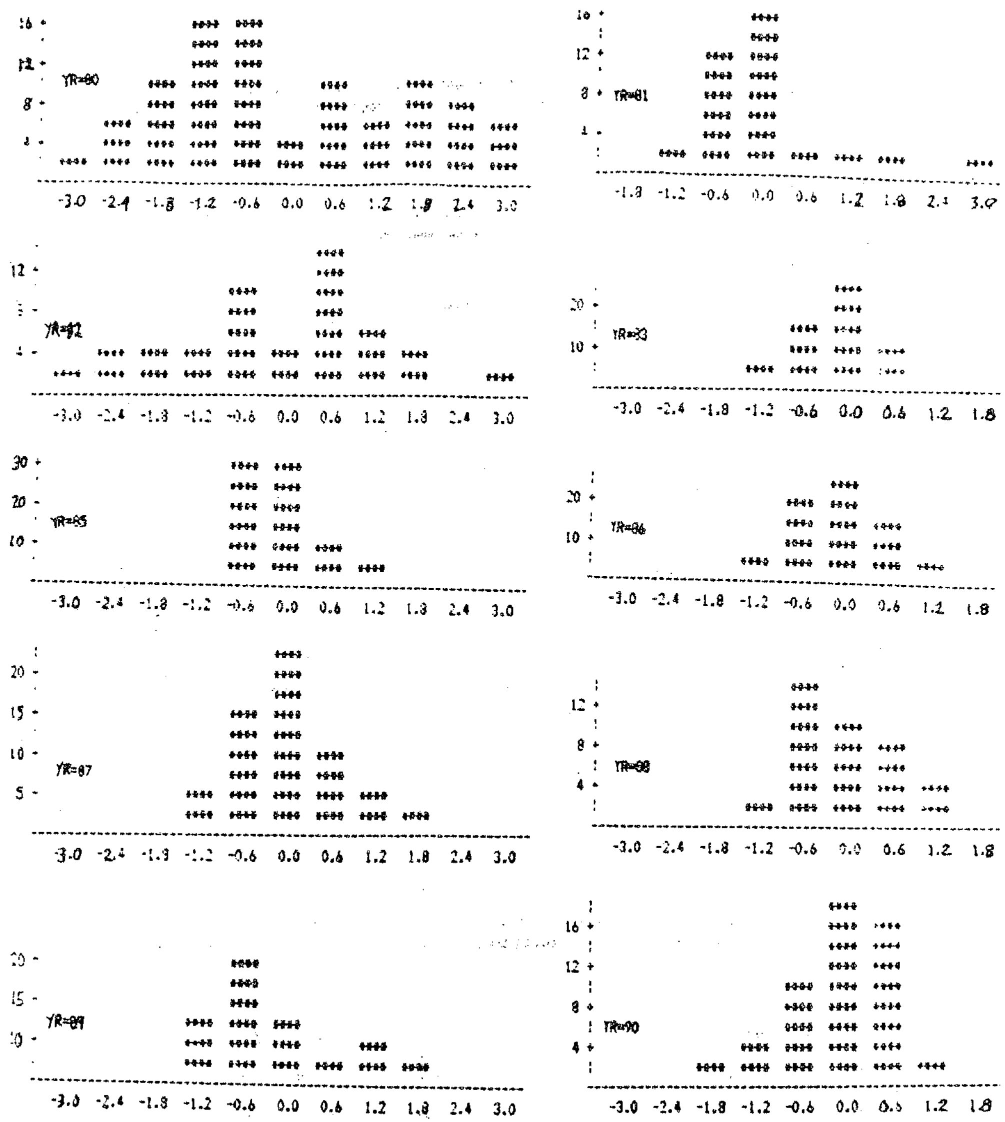


FIGURE 13. Distributions of standardized residuals at each year level for summed data.

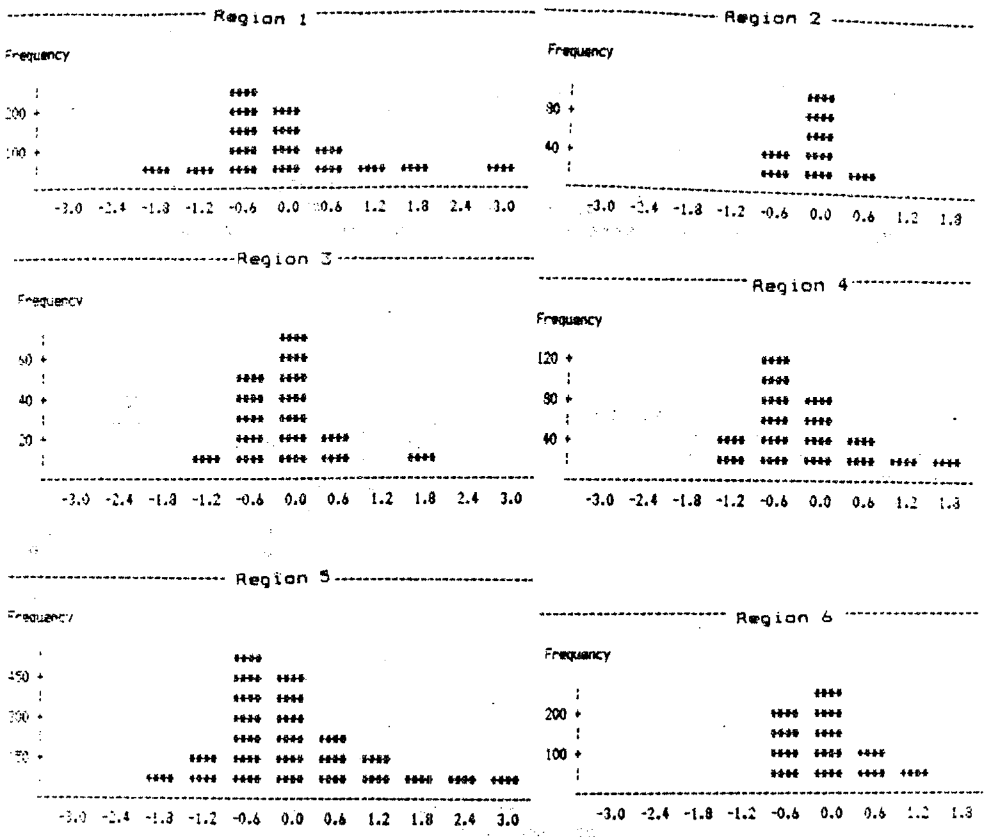


FIGURE 14. Distributions of standardized residuals at each region level for single trip data.

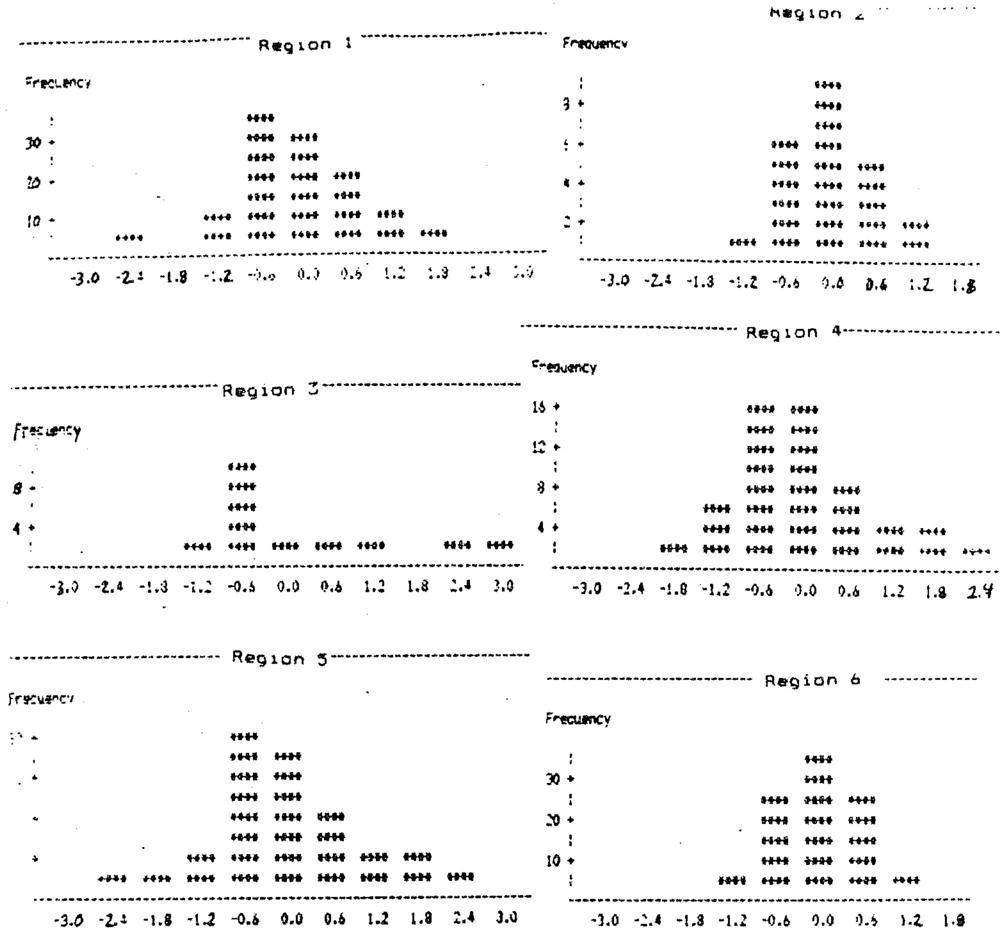


FIGURE 15. Distributions of standardized residuals at each region level for summed data.

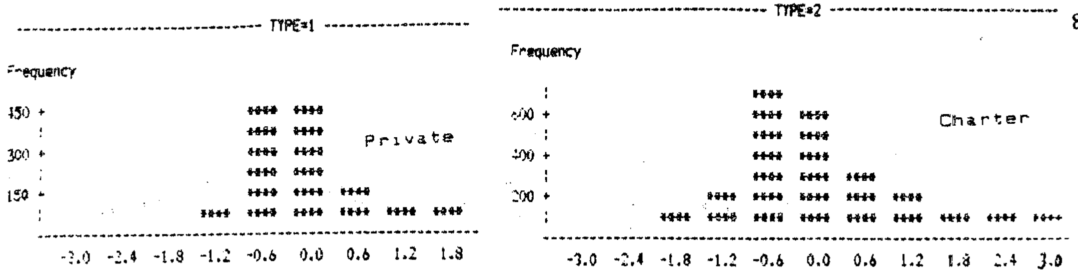


FIGURE 16. Distributions of standardized residuals for boat type = private (1) and boat type = charter (2) for single trip data.

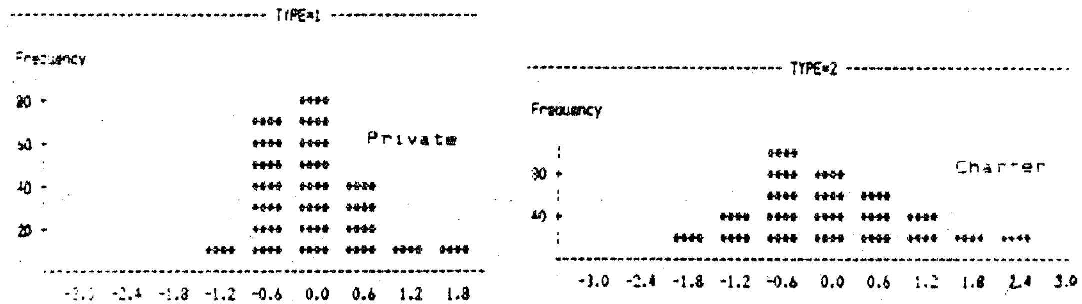


FIGURE 17. Distributions of standardized residuals for boat type = private (1) and boat type = charter (2) for summed data.