STANDARDIZED CATCH RATES OF SMALL BLUEFIN TUNA, *THUNNUS THYNNUS*, IN THE VIRGINIA-RHODE ISLAND (U.S.) ROD AND REEL FISHERY

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SUMMARY

Abundance indices for small bluefin tuna off the coast of the United States from Virginia through Rhode Island were developed using data obtained during interview of anglers in 1980-1993. 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 aggregated data using general linear models.

RESUME

Des indices d'abondance pour les thons rouges de petite taille au large des Etats-Unis entre la Virginie et Rhodes Island ont été élaborés à partir de données obtenues au cours d'entretiens avec des pêcheurs entre 1980 et 1993. Des sous-ensembles de données ont été analysés pour évaluer les effets de saison, de zone, de type de bateau (privé ou en location), de type de questionnaire (au port ou par téléphone) et de la température de surface de la mer sur les captures par unité d'effort. Les taux de capture standardisés ont été élaborés à partir de données concentrées avec des modèles linéaires généraux.

RESUMEN

Se desarrollaron índices de abundancia de atún rojo pequeño frente a la costa de Estados Unidos, desde Virginia hasta Rhode Island, utilizando datos obtenidos durante entrevistas sostenidas con pescadores en 1980-1993. Se analizaron los subconjuntos de datos para evaluar los efectos de la época del año, zona 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 en la captura por unidad de esfuerzo. Se desarrollaron tasas de captura estandarizadas a partir de datos agregados utilizando modelos lineales generalizados.

Introduction

Catch per unit effort (CPUE) data on rod and reel (RR) and handline (HL) fisheries off the coast of the United States from Virginia through Rhode Island were collected between 1980 and 1993. 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.

The variation in area fished, time of year, boat type (private/charter), interview type (dockside/telephone), 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 RR fishery during 1980-1990. A similar approach has been used to develop standardized abundance indices for the Virginia portion of this fishery (Brown and Lucy 1991, Cramer et al. 1992).

The Virginia fishery is roughly located 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 has been chosen as the study area in the past primarily because it was believed that the behavior of the Virginia fisherman is more consistent than the fishermen in other areas. However, recent trends in catch levels in different areas have raised the possibility that catch rates off Virginia may reflect the duration and intensity of fish concentrations in those waters, irrespective of population abundance. Accordingly, Brown and Browder (1994) developed standardized abundance indices for the larger Virginia-Rhode Island fishery as well as for the Virginia fishery alone. This paper serves to update the Virginia-Rhode Island fishery analysis, which more nearly encompasses the region of significant exploitation by U.S. RR effort and may thereby reflect abundance trends even if fish concentrations change location from year to year along the U.S. coast.

Materials and Methods

Each trip interview record includes data on: target species, date, boat type, interview type (same day dockside or recall telephone), 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 hours fished. Fishing location information is not yet available for 1993 recall telephone data; therefore, analysis of variables dependent upon relatively precise fishing locations (such as fishing area or sea surface temperatures) are restricted to dockside data only for 1983.

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 catch were excluded from the analysis.

As proposed by Brown and Browder (1994) hours fished is used as the measure of effort. The variables chosen for analysis were year, month, week, area, 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. Data from 1984 were excluded from the analysis because boat type and fishing area locations were not recorded.

Regions for the Virginia-Rhode Island (full fishery) analysis were somewhat large (Figure 1). Region 1 approximated the region of the Virginia fishery. Region 2 covered a zone usually fished by anglers from Maryland, Delaware and southern New Jersey. Region 3 was usually fished out of northern New Jersey and western Long Island (New York). Region 4 was usually the destination of anglers from eastern Long Island, Connecticut and Rhode Island.

Sea surface temperatures (SSTs) for points corresponding to fishing locations were obtained from SST fields prepared from NOAA satellite imagery. The NOAA-7 satellite was the original source of the 1983 data, whereas the NOAA-11 satellite was the original source of the 1985-1993 data. Point estimates were obtained directly from 5-day composites prepared from 4-km resolution versions of the imagery. The 4-km resolution fields were obtained from the Rosenstiel School of Marine and Atmospheric Science (RSMAS) of the University of Miami. Compositing images across several days was one of several techniques used to reduce interference by clouds. Compositing was accomplished by retaining the warmest SST observed in all the images available for the 5-day period. After compositing and cloud screening, a 3-by-3 pixel median filter was applied to the images to smooth the SST fields. The 5-day composites were prepared using software developed by RSMAS in DSP, a software system supporting image processing and oceanographic satellite data analysis. Programs written in DSP then allowed a file of dates and coordinates to be read, SST fields most nearly corresponding to each date to automatically be selected, a point estimate of SST to be extracted from that field, and an output file with an SST for each date and coordinate to be written.

A GLM (Draper and Smith 1986) approach to analysis of variance was used to examine logged catch rates per 100 hours for differences among the effects of year, month, week, area, region, SST, and interactions. The high proportion of unsuccessful trips per year ranging from 60% to 10% would have resulted in residual distributions which were skewed when the model was applied to single trip data. Aggregated 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/area/boat type/interview type). Within these sets, five trip records were randomly combined. Aggregation of catch and effort from these sets of five formed a new data base of aggregated-by-5 observations. SST for these aggregated observations was the average of the 5 SST values (the observations were sorted by SST within each cell prior to aggregation to increase the representativeness of this mean SST, and aggregated observations with SST ranges of greater than 2 degrees Celsius were excluded from any analyses of the SST effect). 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.

It was necessary to add a constant to each observation prior to performing each GLM to permit taking the natural logs of all catch rate values, including nominal catch rates of 0. Previous analyses have employed a constant of one (1); Porch and Scott (1994) have suggested that a constant equal to 10 times the maximum catch rate being logged may be superior. A constant of 10, which is about 10% of the mean catch per 100 hours is used in this paper. This value is therefore small relative to the nominal values to which it is being added.

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.

Age distribution of juvenile bluefin (Tables 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 Cramer et al. (1992).

A review of the data available to Brown and Browder (1994) revealed errors in the 1983 and 1992 data. These errors resulted in underestimates of the catch rates for small bluefin in those years. These data have been corrected for the present analysis.

Results

Mean yearly nominal CPUE for both aggregated and single trip data are shown in Table 2. 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 as well as using the full data set, boat type was consistently significant as a main effect.

Examination of plots of nominal data indicated that differences in catch rates within years between months were fairly consistent (Figure 3). The month effect was shown as significant in the GLM analysis. Overall yearly nominal CPUE trends for aggregated data are illustrated in Figure 4.

Mean annual nominal CPUE for dockside interviews was not consistently higher than CPUE for telephone interviews. 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, 1982 and 1992). Interview type was significant as a main effect in the two variable model. SST was significant as a main effect and as an interaction with month and region when tested on subsets of data where SST was available (1983-1993, cloudless days). Similarly, region tested as significant in the two variable model. The effects of SST interactions as well as interview type, and region all tested as significant when the model was applied to both data subsets and the full data set. However, each effect and their interactions only accounted for between 2.5% and 7.5% of the model sum of squares and so were dropped from the final model.

Interactions between factors were also tested for significance by using data subsets that allowed analysis with all cells filled. Interactions between region and other factors (boat type and month) were not significant. The interaction between boat type and month was significant but accounted for less than 1% of the model sums of squares. Interactions between each factor and year were significant, but only accounted for between 3% and 10% of the model sums of squares when tested individually.

The final model included the variables year, boat type and month as main effects and no interactions (Table 3). Annual relative indices of abundance +/- 2 standard errors from the final models run with aggregated trips data are shown in Table 4 and plotted in Figure 5.

Discussion

Many of the effects of the final model can be clearly deduced from the plots of the nominal data. There is no consistent pattern to the interview type data; in some years, higher catch rates are reported on dockside interviews, in other years the opposite is true. However, it is obvious that charter boat catch rates are significantly higher than private boat catch rates in nearly every year. Also, June is usually the most successful month, followed by July and then August-October. There appears to have been no consistent trend in annual relative indices in any model following the extreme high years of 1980 and 1982 and the low year of 1981. Despite the errors in the data, a similar conclusion was reached by Brown and Browder (1994). However, there were differences in both observed and estimated values as a consequence of data corrections and an additional year's data. The mean nominal CPUE for aggregated data in 1983 and 1992 were erroneously reported as 31 and 14 fish per 100 hours; the corrected values are about 51 and 35 fish per 100 hours, respectively. Brown and Browder (1994) had reported indices in 1983 and 1992 as being roughly 25% and 10% of the index in 1982, respectively; the present analysis on the corrected data with an additional year available estimates these values at about 39% for 1983 and 32% for 1992.

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Table 1. Age frequency of juvenile bluefin in the Virginia - Rhode Island RR/HL fishery (in percentage of yearly total).

	AGE					
YEAR	1	2	3	4	5	N. OBS.
1980	11.72	78.60	5.10	3.76	0.83	1570
1981	56.06	32.31	9.69	0.97	0.97	619
1982	41.96	43.03	11.47	2.60	0.95	846
1983	32.94	45.53	18.68	2.26	0.59	1017
1984	6.45	69.35	15.01	5.56	3.62	3703
1985	5.96	39.66	51.57	2.35	0.47	638
1986	4.21	46.27	39.77	8.03	1.72	523
1987	6.43	50.00	28.57	10.71	4.29	280
1988	42.89	32.29	20.96	2.17	1.69	415
1989	4.46	80.06	7.67	6.56	1.26	717
1990	9.56	13.35	70.32	3.78	2.99	502
1991	20.16	48.39	26.61	2.82	2.02	248
1992	7.06	80.79	11.02	0.85	0.28	354
1993	5.56	14.55	68.25	10.85	0.79	378
Total	**16.02**	**56.73**	**20.81**	**4.48**	**1.96**	11810

Table 2. Mean annual nominal CPUE (catch per 100 hours) for aggregated and single record data in the Virginia - Rhode Island juvenile bluefin tuna RR/HL fishery. Data from 1984 are shown but were not used in the analysis as fishing location and boat type information were not collected.

	AGGREGATED					SINGLE				
YEAR	N	CPUE	STDERR	MIN	MAX	N	CPUE	STDERR	MIN	MAX
1980	140	91.69	6.74	0.00	373.53	720	95.84	5.24	0.00	775.00
1981	89	21.39	2.56	0.00	110.03	454	25.62	2.73	0.00	388.08
1982	59	109.63	4.61	20.00	195.65	308	114.94	7.45	0.00	1150.0
1983	89	51.14	3.45	7.50	147.50	465	51.46	3.31	0.00	600.00
1984	141	80.00	4.00	3.00	237.00	716	83.00	3.00	0.00	658.00
1985	81	30.82	2.45	0.00	120.69	416	33.39	2.38	0.00	333.33
1986	105	40.26	3.32	0.00	182.35	539	42.63	2.56	0.00	325.00
1987	94	51.77	4.89	0.00	200.00	489	53.82	3.90	0.00	800.00
1988	69	38.76	3.17	0.00	103.23	357	38.97	2.65	0.00	280.00
1989	124	57.69	4.51	0.00	190.91	644	61.21	3.79	0.00	1200.0
1990	128	34.30	3.12	0.00	152.78	667	34.75	2.26	0.00	400.00
1991	118	72.45	8.78	0.00	454.17	619	89.68	8.84	0.00	2050.0
1992	113	35.68	4.77	0.00	313.64	590	41.23	4.41	0.00	1200.0
1993	41	33.11	6.05	0.00	193.75	228	36.90	5.15	0.00	600.00

Table 3. GLM output for Virginia - Rhode Island fishery (added constant = 10).

Source	DF	Sum of Squares	F Value	Pr > F
Model	17	336.09073826	46.55	0.0001
Error	1232	523.20162012		
Corrected Total	1249	859.29235838		

R-Square	C.V.	LNCPH Mean
0.391125	17.19928	3.78894945

Source	DF	Type I SS	F Value	Pr > F
YEAR	12	131.68679188	25.84	0.0001
BOATTYPE	1	70.85091646	166.83	0.0001
MONTH	4	133.55302993	78.62	0.0001

Source	DF	Type III SS	F Value	Pr > F
YEAR	12	115.22185047	22.61	0.0001
BOATTYPE	1	78.04031292	183.76	0.0001
MONTH	4	133.55302993	78.62	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		4.338107956 B	25.67	0.0001	0.16896371
YEAR	80	0.343141672 B	2.89	0.0039	0.11857660
	81	-0.581203921 B	-4.61	0.0001	0.12595819
	82	0.907020719 B	6.64	0.0001	0.13664826
	83	0.091783905 B	0.73	0.4665	0.12599690
	85	-0.305692647 B	-2.36	0.0186	0.12966517
	86	0.120515065 B	0.99	0.3219	0.12160691
	87	0.304329646 B	2.45	0.0143	0.12407365
	88	0.027774459 B	0.21	0.8308	0.12996651
	89	0.292778424 B	2.45	0.0145	0.11955333
	90	-0.116082818 B	-0.98	0.3257	0.11806181
	91	0.227166426 B	1.91	0.0569	0.11918762
	92	-0.083503145 B	-0.70	0.4837	0.11920064
	93	0.000000000 B	.	.	.
BOATTYPE					
	1	-0.578802113 B	-13.56	0.0001	0.04269724
	2	0.000000000 B	.	.	.
MONTH	6	-0.162016026 B	-1.17	0.2442	0.13905029
	7	-0.773220420 B	-5.56	0.0001	0.13911766
	8	-0.895432442 B	-6.21	0.0001	0.14422740
	9	-0.038972208 B	-0.27	0.7890	0.14563079
	10	0.000000000 B	.	.	.

YEAR	LCPUE	UC_CPU	GA	BC_CPUE	GB	VAR_CP	CV
1980	4.01792	45.5854	1.23379	58.581	1.51447	23.977	0.08359
1981	3.09357	12.0558	1.23273	17.189	1.51023	4.573	0.12441
1982	4.58180	87.6900	1.23100	110.257	1.50178	129.732	0.10330
1983	3.76656	33.2312	1.23286	43.298	1.51084	17.002	0.09523
1985	3.36909	19.0520	1.23213	25.796	1.50641	9.906	0.12201
1986	3.79529	34.4913	1.23334	44.873	1.51323	15.660	0.08819
1987	3.97911	43.4693	1.23297	55.926	1.51141	25.206	0.08977
1988	3.70255	30.5507	1.23235	39.972	1.50833	17.009	0.10318
1989	3.96756	42.8553	1.23370	55.208	1.51500	19.642	0.08028
1990	3.55870	25.1174	1.23435	33.347	1.51817	6.726	0.07777
1991	3.90195	39.4986	1.23390	51.077	1.51598	16.030	0.07839
1992	3.59128	26.2803	1.23372	34.760	1.51506	9.212	0.08732
1993	3.67478	29.4399	1.22974	38.501	1.49565	25.864	0.13209

Table 4. Indices of abundance for juvenile bluefin tuna in the Virginia - Rhode Island fishery. INDEX represents catch/100 hours; RELATIVE is the standardized index relative to 1982. CV signifies the estimated coefficient of variation. UCL and LCL are the upper and lower confidence limits (+/- 2 standard errors). Fits were made using data from 1982-1993, exclusive of 1984.

YEAR	INDEX	RELATIVE	CV	UCL	LCL
1980	58.581	0.5313132	0.08359	0.6183589	0.4442675
1981	17.189	0.1558994	0.12441	0.193914	0.1178848
1982	110.257	1	0.1033	1.202476	0.797524
1983	43.298	0.3927007	0.09523	0.466	0.3194014
1984					
1985	25.796	0.2339625	0.12201	0.2899123	0.1780126
1986	44.873	0.4069855	0.08819	0.4773325	0.3366385
1987	55.926	0.5072331	0.08977	0.5964818	0.4179844
1988	39.972	0.3625348	0.10318	0.4358492	0.2892204
1989	55.208	0.500721	0.08028	0.5795059	0.4219360
1990	33.347	0.3024479	0.07777	0.3485508	0.2563450
1991	51.077	0.463254	0.07839	0.5344273	0.3920808
1992	34.76	0.3152634	0.08732	0.3692178	0.2613090
1993	38.501	0.349193	0.13209	0.439599	0.2587870

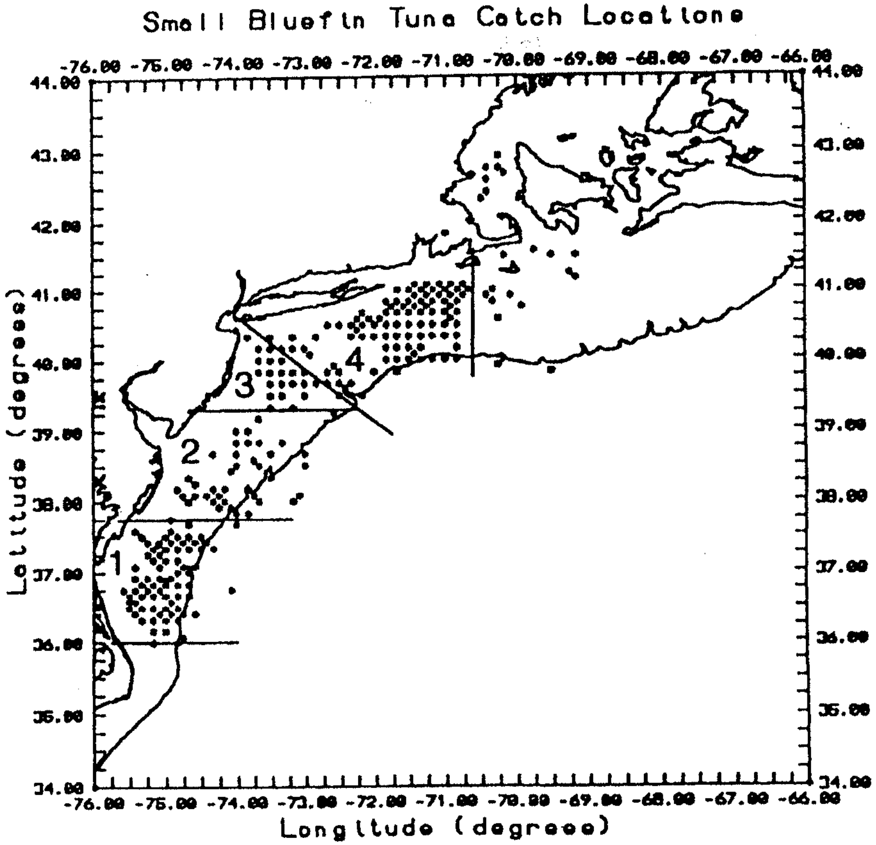

FIGURE 1. Virginia - Rhode Island fishery small bluefin catch and effort locations. Curved lines represent the continental shoreline and the 200 meter depth contour. Study areas are numbered and defined by straight lines.

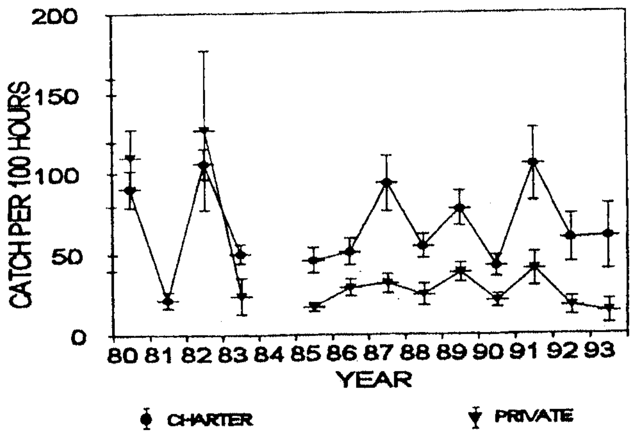

FIGURE 2. Mean annual nominal CPUE (catch per 100 hours) +/- 2 standard errors (SE) for private or charter boat interview data in the Virginia - Rhode Island juvenile bluefin tuna RR/HL fishery.

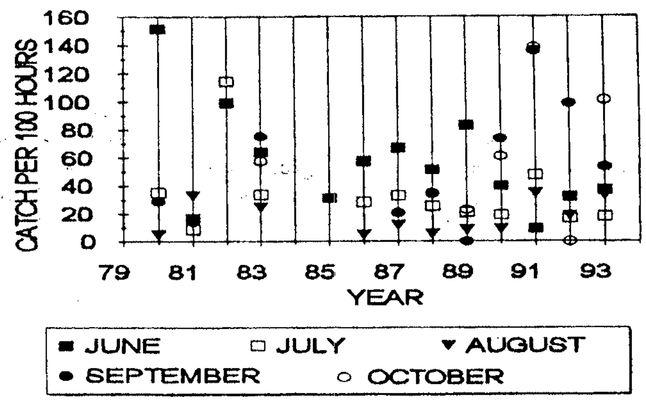

FIGURE 3. Mean annual nominal CPUE (catch per 100 hours) for months June through October in the Virginia - Rhode Island juvenile bluefin tuna RR/HL fishery. Error bars have been omitted for clarity.

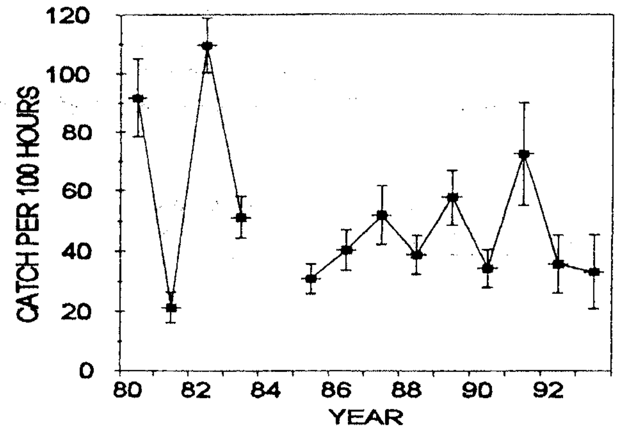

FIGURE 4. Annual nominal CPUE with error bars at +/- 2 SE for aggregated trip data in the Virginia - Rhode Island juvenile bluefin RR/HL fishery.

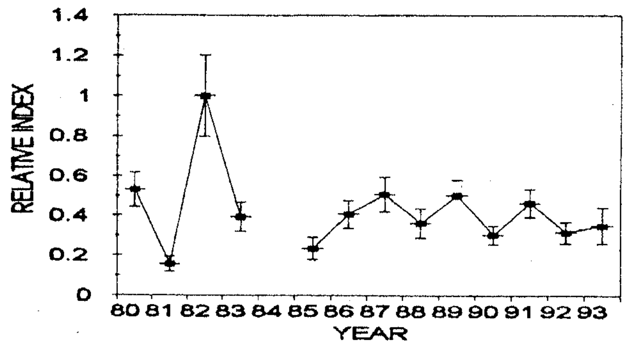

FIGURE 5. Annual relative indices of abundance (standardized to value for 1982) with error bars at +/- 2 SE for aggregated trip data in the Virginia - Rhode Island juvenile bluefin RR/HL fishery. The model used an additive constant equal to 10 .