STANDARDIZED ABUNDANCE INDICES FOR WESTERN NORTH ATLANTIC YELLOWFIN TUNA FROM THE U.S. RECREATIONAL FISHERY FROM VIRGINIA TO NEW YORK: AN UPDATE

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SUMMARY

Abundance indices for western north Atlantic yellowfin tuna from Virginia to New York were obtained by means of general linear modeling. Catch and effort data were obtained from the U.S. recreational fishery, which operates from early summer to late fall. Data were prepared by combining individual trip records into groups of 15 trips. The analysis was an update of a previous analysis by Cramer and Eklund (1992). Results were compared to those from the early analysis.

RESUME

Les indices d'abondance de l'albacore de l'Atlantique nord, de la Virginie à New York, ont été obtenus au moyen du modèle linéaire généralisé. Des données de capture et d'effort ont été obtenues sur la pêcherie sportive des Etats-Unis, qui fonctionne du début de l'été à la fin de l'automne. Les donnés ont été préparées en regroupant les registres de sorties individuelles par groupes de 15 sorties. L'analyse représente une mise à jour de l'analyse antérieure de Cramer et Ecklund (1992). Les résultats ont été comparés à ceux de l'analyse précédente.

RESUMEN

Por medio del modelo lineal generalizado, se obtuvieron índices de abundancia del rabil del Atlántico noroeste, desde Virginia a Nueva York. Se obtuvieron datos de captura y esfuerzo de la pesquería de recreo estadounidense, que opera desde principios del verano hasta finales de otoño. Los datos se prepararon combinando registros de viajes individuales en grupos de 15 viajes. El análisis era una actualización de un análisis anterior realizado por Cramer y Eklund (1992). Los resultados se compararon con los del análisis anterior.

INTRODUCTION

Yellowfin tuna are an important component of a rod and reel fishery in the Western North Atlantic consisting of anglers that fish for both sport and money. In terms of U.S. yellowfin landings, this fishery generally is second only to the longline fishery (Browder and Scott 1992). The catch in this fishery is not landed at the dock of traditional dealers whose catches are acquired by resource agencies through canvases of dealers' houses; rather this catch is landed at marinas and private, non-commercial docks. Therefore, the catch in this fishery is estimated based on a sampling survey operated by the National Marine Fisheries Service (Turner et al. 1993). Both catch and effort are estimated by a Monte Carlo approach (Brown 1993). These catch and effort data can be used to develop an index of relative abundance through methods that standardize catch rates for variable factors that influence sampling, the fishery, or the relative availability or abundance of the fish. Use of standardized catch rates as an index of abundance is based on the assumption that catch rates are a linear function of abundance. We applied a general linear modeling technique to survey data to compute annual relative abundance for the years 1985 through 1991.

DESCRIPTION OF THE ANALYSIS

The general linear modeling approach we pursued was similar to that of Cramer and Eklund (1992). The dependent variable was catch per unit of effort (CPUE)--catch per 1000 line hours. The follow-ing class, or categorical, variables were the independent variables considered in modeling:

YEAR (1985-1991),
MONTH (July, August, and September),
DEP73 (depth less than [IN73] or greater than [OUT73) 73 meters (40 fathoms),
DEP200 (depth less than [IN200] or greater than [OUT200] 200 meters (109 fathoms),
AREA (North Carolina to Delaware [DC-DE]), New Jersey to New York ([NJNY]), and Southern New England (Connecticut to Massachusetts [SONE]),
BOATTYPE (CHARTER or PRIVATE),
TOURN (whether or not the fishing trip was part of a tournament (TOURNAMENT or NON-TOURNAMENT),
PHONDOCK (interview type, PHONE or DOCK-intercept)
FISHMETH (CHUM or TROLL).

Yellowfin tuna is one of several large pelagic fish species caught by rod and reel anglers along the eastern U.S. seaboard. By means of fishing strategy (i.e., details of gear and fishing location), each trip is generally directed at a particular target or group of targets. All species were covered by the survey, and five categories of "target" were coded in the data: marlin/tuna, sharks, large bluefin, small bluefin, and other. To better define the portion of the fishery primarily seeking yellowfin, we included only those records in which catching marlin/tuna (target=1) was given as the principal reason for the trip. Since we excluded all records except those directed at marlin/tuna, TARGET was not included as a class variable in our analysis.

Defined fishing areas (Fig. 1) were the same as to those delineated in analyses of bluefin tuna catches by the U.S. rod and reel fishery (see Browder et al., 1993, for a listing of reports), except that we defined two areas, rather than one, off the coast from Delaware to North Carolina. We distinguished the Virginia-North Carolina grounds from the Delaware-Maryland grounds because both fishing effort and yellowfin catch rates appeared greater in the Virginia-North Carolina area (Fig. 1). The Gulf of Maine was omitted from our analysis due to the low yellowfin catch rates in that area, which is principally a fishing ground for large bluefin tuna. The separating boundaries of our areas were as follows:

SONE - bounded by 41.67°N or the coastline on the north, by 72°W on the west, and by 39°N on the south

NYNJ - bounded by 72°W on the east, by 39°N on the south, by Long Island on or 40.67°N on the north, and by the continental coastline on the east

DEMD - bounded by 39°N on the on the north, by 37.50°N on the south, and the coastline on the east

VANC - bounded by 37.50°N on the north, by 34°N on the south, and by the coastline on the east

We assigned each record to area first on the basis of latitude and longitude. If either was missing, we used inlet, combination of marina and port state, or port state alone to assign records to area. Our data set was more extensive than that used by Cramer and Eklund (1992) because they excluded records that did not contain latitude and longitude.

Figure 1 shows the defined fishing areas of this analysis, the location of effort most likely to be directed at yellowfin (target-1 effort, 1985-1991), and the locations in which yellowfin tuna were caught, 1985-1991.

Bottom depth was examined as a possible factor influencing either fish abundance or availability and, thereby, catch rates. Two class variables were defined. In model development, the two depth zone classifications were tested separately and were not used in the same model.

Depth-Zone Class Variable 1. Reported effort locations were classified into two depth zones by means of depth data accompanying the catch data (DEP73). We defined two zones: inside and outside 73 meters (40 fathoms). This was the same classification by depth used in the Cramer and Eklund (1992) analysis.

Depth-Zone Class Variable 2. In our analysis, we also tested the effect on CPUE of the 200-m depth contour (DEP200), which approxi-mates the continental shelf margin, or "shelf break". Where latitude and longitude were available, which was true for much of the data, the catch location relative to the 200-m contour was determined by means of remote-sensing, image-analysis software (DSP, developed by the University of Miami Rosenstiel School of Marine and Atmospheric Science). Where latitude and longitude had been omitted from the record, we used the depth originally recorded with the catch data to estimate whether the effort location was inside or outside the 200-m contour.

Position relative to a depth contour may be a more reliable estimator of depth zone than the depth recorded on the catch record, because the former is not affected by small-scale depth variation. A data set for the 73-meter contour was not available to us, however, at the time of this analysis.

Our analysis included two more years of data than that covered by Cramer and Eklund (1992). As was the case in the earlier analysis, we included only the months July, August, and September, when most of the yellowfin catch in this fishery is taken. The variables TOURN, BOATTYPE, PHONDOCK, and FISHMETH were the same as those used previously in the Cramer and Eklund (1992) analysis and in other analyses of catches of large pelagic species by U.S. anglers fishing on or near the North American continental shelf off the states of North Carolina through Massachusetts.

Following Cramer and Eklund (1992) and others, we grouped the trips within common strata (i.e., year, month, depth zone, etc.) into randomly selected units of 15 to create multiple-trip records for this analysis. The sum of catch was divided by the sum of effort over the 15 trips to create the grouped CPUE. By this means we reduced the large proportion of zero-catch records that affect the performance and reliability of statistical treatments. Single-trip records left over after all groups of 15 records were combined were discarded so that all group records were made up of the same number of trips. Cramer and Eklund (1992) showed that summation across 15 trips reduced the proportion of zero-catch records to 0 to 19% per year. Cramer and Eklund (1992) compared the mean CPUEs of single-trip records to that of group CPUE, by strata, and found that little information was lost during the summation process, despite discarding some records.

Like Cramer and Eklund (1992) and others, we logtransformed the data to make the residuals more closely conform to the normal distribution. Because there were some zero-catch records in the grouped data, we added a 1 to CPUE, after first multiplying by 1000 to express it in terms of catch per 1000 line-hours.

In general, the GLM approach we used conformed to Draper and Smith (1986). We used the least squares difference (LSD) method to test for differences between categories in class variables. SAS statistical software on a VAX 3600 computer was used for data preparation and analysis. For determination of significant differences between our regression coefficients and zero, we assumed an alpha of 0.1.

Back-transformed year least square-means (LSM) obtained from the analysis were considered the indices of annual abundance (L). Confidence limits on LSM (UL and LL) were computed before back-transformation, after first adding to LSM a correction factor (SE^2 / 2, where SE is standard error of the estimate) to account for transformation bias (Sprugel 1983). Confidence limits on LSM were computed as L + (1.96 x SE) and L - (1.96 x SE). Then back-transformation was accomplished by taking the exponential of L, UL, and LL. Finally, 1 was subtracted from the result to yield CPUE and its confidence limits in terms of fish caught per 1000 line hours.

RESULTS AND DISCUSSION

Main-Effects Model

Most of the class variables listed in our methods section were highly significant explaining variables in a main-effects model, but the best main effects model, in terms of the coefficient of determination, explained only about 21% of the variation in CPUE. This model included DEP73 rather than DEP200, so we used DEP73 in developing the model with interactions. PHONDOCK was not a significant variable in the best main-effects model. This model was highly significant (alpha=0.0001), despite the low proportion of variation in CPUE the model explained.

Models with Interactions

We initiated development of a model with interactions by starting with four different models, which evolved independently from each other: (1) a model that included all main variables and plausible 2-way interactions, (2) a model that included all variables but FISHMETH, and (3) a model that included all variables but TOURN, and (4) a model that included all variables but FISHMETH and TOURN. Models without FISHMETH were examined because data restrictions that were necessary with inclusion of FISHMETH caused exclusion of all the 1985 data, therefore we could not obtain an estimate of relative abundance for 1985 with a model containing FISHMETH. TOURNAMENT was excluded as a variable from some models because yellowfin are not a sought-after species in tournaments, and, therefore, yellowfin CPUE from tournaments may be artificially low. When FISHMETH was included in the model, only the classes CHUM and TROLL were included in the data; because the other classes are not well distributed across years and areas. When TOURN was excluded in the model, only the NON-TOURNAMENT data were used. We guided the evolution of each model by eliminating factors or interactions whose regression coefficients were not significantly different from zero. We eliminated only one main effect between each execution of the model. Main effects were retained, even if they were not significant, if their interaction with any other variable was a significant term in the model.

This approach led us to three alternative models. Annual CPUE, as standardized by the three models, differed greatly in magnitude, but differed little in pattern of change across years (Fig. 2). Since the other two models included FISHMETH, they did not compute a standardized CPUE for 1985. The "standard" year in all three models was 1991. Included terms, r^2's, and significance levels (Pr > F) for the three models are given in Table 1.

We selected Model 1 (Table 1) as the best model, not only because of the substantially higher proportion of variation in CPUE it explained (see Table 1), but also because it had fewer terms than the other models. The lower number of interactions minimized the possible proportion of empty cells, which can make standard least square methods of calculating regression coefficients inaccurate (Searle 1987). In addition to INTERCEPT, the terms in this model are as follows: YEAR, MONTH, AREA, DEP40, TOURN, MONTH*AREA, AND DEP40*AREA. Regression coefficients and their probabilities of differing from zero by chance alone are listed in Table 2.

The abundance index time series produced by Model 1 is shown with confidence limits in Figure 3. For the years 1985 to 1989, the pattern of change in CPUE across years is similar to that in Cramer and Eklund (1992). Our results suggest continued low abundance in 1990 and an increase in abundance in 1991, relative to the three immediately preceding years. Standardized catch rates in 1991 were roughly double those of the three preceding years and roughly 66% of the highest year of record, 1986.

The pattern of annual variation in yellowfin tuna standardized CPUE resulting from our model of the U.S. rod and reel fishery is strikingly different from that obtained by Prager and Scott (SCRS/93/31). Based on catch and effort data from the U.S. longline fishery, their results suggest a consistent decline in yellowfin abundance each year through 1991, after a maximum in 1988, in the Western North Atlantic, excluding the Gulf of Mexico. Their standardized CPUE for the Gulf of Mexico also reached a maximum in 1988, but declined substantially in 1989, then increased slightly to a level in 1990 that was maintained in 1991.

Possible reasons for these substantive differences in model results need to be explored. Our model is based on data for an area that is at the outer limit of the range of this tropical species. Year-to-year variation in water temperature on the shelf or other oceanographic conditions related to the Gulf Stream (i.e., streamers, rings, or Gulf Stream position relative to the shelf) could affect yellowfin catch rates in the North Carolina-Massachusetts fisheries. Sea surface temperature has been shown to be a factor influencing small bluefin tuna catches in the Virginia fishery (see review by Browder et al. 1993).

Coefficients of determination from our best model was lower than that of Cramer and Eklund (1992), who obtained r^2's of 0.52 and 0.57 for their two models, one with and the other without FISHMETH. We had two more year's of catch and effort data in our analysis. Furthermore, we included records from 1985 through 1989 that were not included in the earlier analysis because they did not contain latitude and longitude information. The expanded data set is a likely reason for the lower r2 and the different model configuration that resulted from our model development. The fact that so many different models (i.e., the two from Cramer and Eklund [1992] and the three from our analysis) showed similar patterns of change in standardized CPUE over time attests to the stability of the general method.

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Table 1. Terms tested and terms included in final alternative models for standardizing yellowfin catch rates in the U.S. Atlantic rod and reel fishery. (An X in the column for a given model indicates the term was included in that model.)[1]

Model Terms	Model 1	 2	 3
INTERCEPT	X	X	X
YEAR	X	X	X
MONTH	X	X	X
DEP73	X	X	X
AREA	X	X	X
BOATTYPE			X
TOURN	X	X	
PHONDOCK		X	X
FISHMETH		X	X
AREA*MONTH	X	X	X
AREA*DEP73	X	X	X
AREA*BOATTYPE			X
AREA*TOURN		X	
AREA*PHONDOCK		X	X
AREA*FISHMETH		X	X
MONTH*DEP73		X	X
MONTH*TOURN			
TOURN*BOATTYPE			
Pr > |F|	.0001	.0001	.0001
r^2	0.3403	0.2898	0.2870

Table 2. Regression coefficients of the best model (Model 1), with significance levels (Pr > |T| and standard errors of estimate.

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		1.811429327 B	10.03	0.0001	0.18059748
YEAR	85	-0.049716522 B	-0.41	0.6832	0.12177367
	86	0.388160077 B	3.28	0.0011	0.11842906
	87	0.173342912 B	1.62	0.1056	0.10702982
	88	-0.792411209 B	-5.74	0.0001	0.13805070
	89	-0.573395271 B	-5.03	0.0001	0.11405899
	90	-1.131361731 B	-10.21	0.0001	0.11082995
	91	0.000000000 B	.	.	.
MONTH	7	1.475869684 B	8.50	0.0001	0.17371559
	8	0.368239814 B	2.03	0.0424	0.18126335
	9	0.000000000 B	.	.	.
DEP73	IN73	-0.036091210 B	-0.27	0.7859	0.13285806
	OUT73	0.000000000 B	.	.	.
AREA	DEMD	1.039399776 B	5.11	0.0001	0.20343374
	NYNJ	1.291689427 B	5.77	0.0001	0.22367246
	SONE	1.253286285 B	6.14	0.0001	0.20404745
	VANC	0.000000000 B	.	.	.
TOURN	UNKNOWN	0.482913234 B	1.94	0.0526	0.24890173
	NON TOURN	0.735315129 B	10.55	0.0001	0.06971248
	TOURNAMENT	0.000000000 B	.	.	.
MONTH*AREA	7 DEMD	-1.408725366 B	-6.01	0.0001	0.23420548
	7 NYNJ	-1.988073270 B	-7.56	0.0001	0.26310915
	7 SONE	-2.175808959 B	-8.93	0.0001	0.24356402
	7 VANC	0.000000000 B	.	.	.
	8 DEMD	-0.759735489 B	-3.21	0.0014	0.23652804
	8 NYNJ	-1.039156081 B	-3.98	0.0001	0.26133737
	8 SONE	-0.704549072 B	-2.96	0.0032	0.23840544
	8 VANC	0.000000000 B	.	.	.
	9 DEMD	0.000000000 B	.	.	.
	9 NYNJ	0.000000000 B	.	.	.
	9 SONE	0.000000000 B	.	.	.
	9 VANC	0.000000000 B	.	.	.
DEP73*AREA	IN73 DEMD	0.117718761 B	0.62	0.5344	0.18941004
	IN73 NYNJ	0.536576688 B	2.58	0.0100	0.20789564
	IN73 SONE	-0.666273596 B	-2.81	0.0050	0.23715258
	IN73 VANC	0.000000000 B	.	.	.
	OUT73 DEMD	0.000000000 B	.	.	.
	OUT73 NYNJ	0.000000000 B	.	.	.
	OUT73 SONE	0.000000000 B	.	.	.
	OUT4 VANC	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

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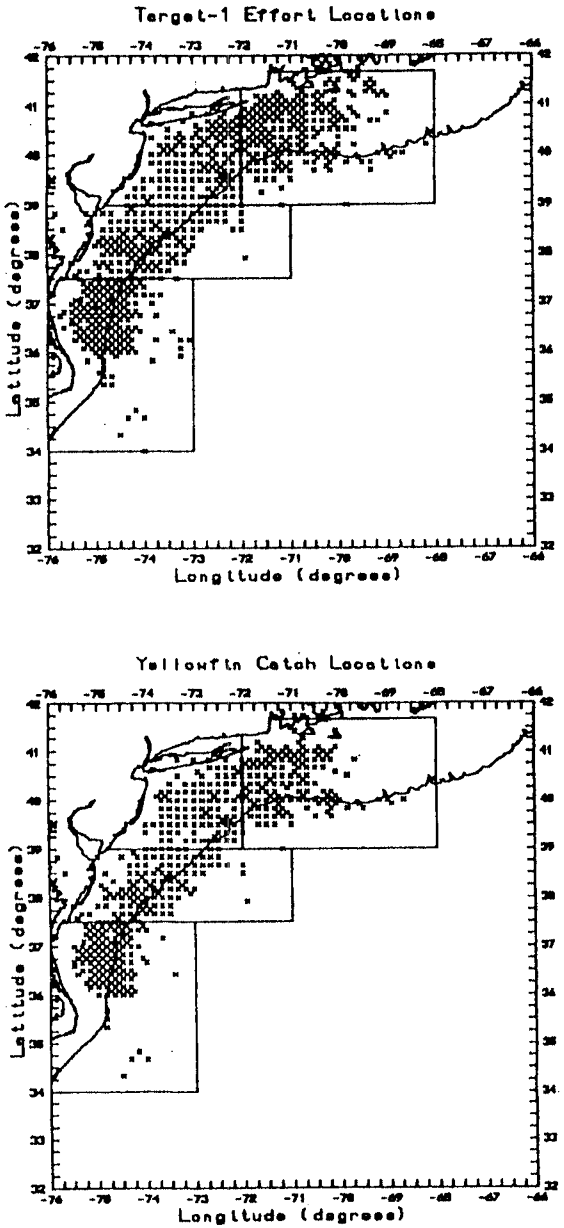
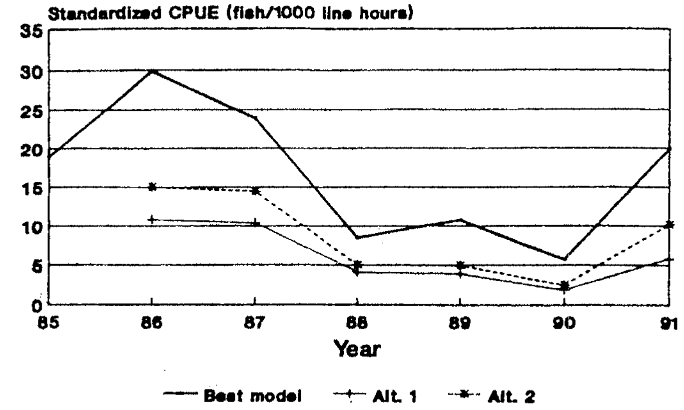
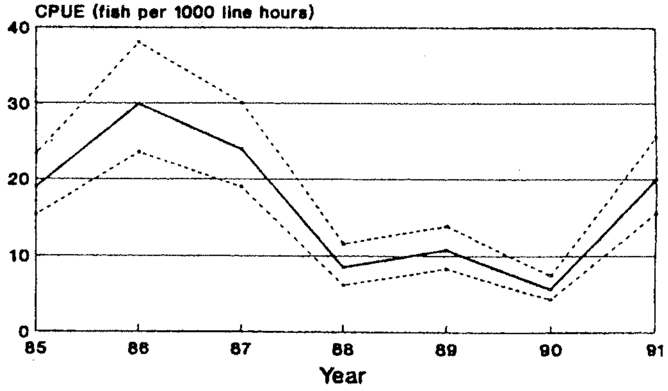
[1] Main effects included in the models were either significant as main effects or were components of significant interaction terms.



1. Map of the western North Atlantic along the North American coastline, showing fishing zones defined in this analysis for the U.S. rod and reel fishery, locations of effort most likely to have been directed at yellowfin tuna (left), and locations where yellowfin tuna were caught (right).



2. Standardized annual abundance indices from the "best" model and two alternative models (model descriptions in Table 1).



3. Standardized annual abundance index, 1985 to 1991, in the yellowfin tuna U.S. rod and reel fishery in the Western North Atlantic.