UPDATED STANDARDIZED CATCH RATES OF YELLOWFIN TUNA, *THUNNUS ALBACARES*, FROM THE U.S. LONGLINE FISHERY IN THE ATLANTIC OCEAN

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SUMMARY

Data on yellowfin tuna catch and effort are collected from the U.S. longline fleet operating in the western north Atlantic Ocean, including the Gulf of Mexico and Caribbean Sea. These data were used to develop indices of relative abundance of yellowfin tuna in this region for the years 1982 through 1991. The indices are based on standardized catch rates (CPUE in biomass) and were estimated by the general linear modeling approach (analysis of variance). A large fraction of U.S. yellowfin landings comes from the Gulf of Mexico. For this reason, three indices were computed: for the Gulf of Mexico, for the balance of the study area, and a combined index for all areas. Confidence intervals on the three series are quite wide before 1985, especially for the Gulf of Mexico series. From 1985 to 1987, the indices disagree on whether relative abundance was increasing or decreasing. Each of the three indices estimates that abundance has decreased in the period 1988 through 1991.

RESUME

Des données sur la capture et l'effort de l'albacore sont recueillies sur la flottille palangrière des Etats-Unis qui pêche dans l'Atlantique nord-ouest, y compris le golfe du Mexique et la mer des Antilles. Ces données ont été utilisées pour élaborer des indices de l'abondance relative de l'albacore dans cette région pour les années 1982 à 1991. Les indices se fondent sur des taux standardisés de capture (CPUE en biomasse) et ont été estimés par la méthode du modèle linéaire généralisé (analyse de la variance). Une partie importante des débarquements d'albacore des Etats-Unis provient du golfe du Mexique. Pour cette raison, trois indices ont été calculés: pour le golfe du Mexique, pour le reste de la zone sous étude, et un indice combiné tous secteurs. Les intervalles de confiance des trois séries sont très amples avant 1985, en particulier pour la série du golfe du Mexique. De 1985 à 1987, les indices diffèrent quant à une baisse ou à un accroissement de l'abondance relative. Chacun de ces trois indices estime que l'abondance a décru pendant la période 1988 à 1991.

RESUMEN

Se recogen datos de captura y esfuerzo de rabil, de la flota palangrera estadounidense que opera en el Atlántico noroeste, incluyendo el Golfo de México y el mar Caribe. Estos datos se usaron para desarrollar índices de abundancia relativa del rabil en esta zona en los años 1982 a finales de 1991. Estos índices se basan en las tasas estandarizadas de captura (CPUE en biomasa) y se estimaron por medio del modelo lineal generalizado (análisis de varianza). Una gran parte de los desembarques de rabil proceden del Golfo de México. Por esta razón, se computerizaron tres índices: para el Golfo de México, para el balance de la zona en estudio y un índice combinado para todas las zonas. Los intervalos de confianza en las tres series son muy amplios antes de 1985, en especial en la serie del Golfo de México. De 1985 a 1987, existe desacuerdo entre los índices sobre si la abundancia relativa estaba en alza o en descenso. Cada uno de los tres índices estima que la abundancia había descendido en el período que media entre 1988 y finales de 1991.

INTRODUCTION

At the meeting of the ICCAT Working Group on Western Atlantic Tropical Tunas held in Miami in 1991, Turner and Scott (1992) presented abundance indices for yellowfin tuna for the years 1982 through 1989. Those indices were based on standardized catch rates (CPUE in numbers) of the US longline fisheries in the western north Atlantic, including the Gulf of Mexico and the Caribbean Sea. In the present document, we develop updated indices, based on data from 1982 through 1991, developed by similar methodology. However, the indices presented here are based on CPUE in biomass, for use in production modeling. The same techniques could be used to obtain indices reflecting abundance in numbers for use in catch-at-age modeling.

DATA AND METHODS

The major source of landings data for this study was the "weigh-out" database maintained at the Southeast Fisheries Science Center in Miami. This database contains records obtained from fish dealers on trip-specific landings of yellowfin tuna and other large pelagic species.

Data on fishing effort (hooks fished and days fished) were obtained from several sources. Before 1987, effort data were obtained from captain's logbooks and interviews with captains of fishing vessels. Since 1987, additional infomation on fishing effort has been provided by set-specific logbooks that are required as a condition of holding a fishing permit.

Data on 4219 fishing trips from 1982 through 1991 were available for analysis (Table 1). The trips were examined by year, geographical area of fishing, calendar quarter (starting January 1), average size of set (<500 hooks or ≥500 hooks), and the proportion of yellowfin tuna in the catch of yellowfin and swordfish. The values assigned to this last classification (denoted "quartile") were (1) 0% to 24.9%, (2) 25% to 49.9%; 50% to 74.9%; (4) 75% or greater yellowfin.

The geographical areas used in the analysis, from South to North are—

CAR Caribbean
GOM Gulf of Mexico
FEC East coast of Florida
NCH North of Cape Hatteras
MAB Mid-Atlantic bight
NEC New England Coast

As is discussed below, all areas except for GOM and CAR were combined into one region for the analysis. As in previous analyses, we did not use data from the Grand Banks, as landings data on yellowfin in that are not believed representative of the total catch. Because the data base includes no record of any yellowfin tuna landings from the Caribbean in calendar quarters 3 and 4, data from the Caribbean was limited to quarters 1 and 2.

The data base contains little information that might define target species. Knowing the hour of day at which a set was made would indicate whether tuna or swordfish were being targeted; however, the time of each set is not recorded. We used two classifiers to attempt to control for target species: set size and proportion of yellowfin in the catch. Information on vessel operation style is not available for most records in the data base, so information on operation style was not used in this analysis. Because much of the fleet (especially outside the Gulf of Mexico) targets swordfish, we used only data from vessels that reported catch of species other than swordfish (although many of them reported swordfish as well).

Because there are differences between fisheries inside and outside the Gulf of Mexico (Turner and Scott 1992), three analyses were conducted. The first used data from all areas, the second used data from the Gulf of Mexico only, and the third used data from all areas except the Gulf of Mexico. Nominal data on CPUE (kg caught per 1000 hooks) were log transformed before GLM analysis. Each CPUE value was increased by 1 before transformation; this made it possible to use records with zero CPUE for yellowfin.

Variable selection was made in a stepwise fashion, including main effects and two-way interaction terms. First, a model was fit with all main effects, and any effects that were not statistically significant were removed from the model one at a time. Then all two-way interactions (except those including year) were tested one at a time for statistical significance, and effects were added and removed from the model in accordance with significance levels. Finally, all two-way interactions with year were tested and the results noted. No year interactions were included in the model, even if significant, as they make it difficult to interpret the results as an abundance index over time. No three-way or higher interactions were tested. In this stepwise procedure, statistical significance was based on an F-test of "Type III" sums of squares; i.e., sums of squares conditional on all other effects already being in the model. The threshold significance probability was computed by a modified Bonferroni procedure in which a nominal P value of 0.05 was divided by the total number of main effects and two-way interactions to be tested. For example, for the model including all areas, there were 5 main effects and 15 two-way interactions to be tested, so the significance probability for inclusion was set at 0.05/20 = 0.0025. Following estimation, residual patterns were examined for symmetry and lack of time trend. Relative abundance patterns were taken as the arithmetic-scale-transformed estimates of the "year" parameter from the linear model. Derived abundance indices were standardized so that the 1991 value was unity.

RESULTS AND DISCUSSION

In examining model results, no significant differences were found among the parameters associated with several geographic areas. Therefore, the set of areas was reduced to three: Caribbean Sea (CAR), Gulf of Mexico (GOM), and all other areas (ATL).

Statistically significant interaction terms with year were found for all three models. Model 1 (all data) had significant year interactions with quarter, area, set size, and quartile. Model 2 (Gulf of Mexico only) had significant year interactions with quarter, set size, and quartile. Model 3 (all data except Gulf of Mexico) had significant year interactions with quarter, area, and set size. As stated above, year interactions were omitted from the models so that year effects could be used to estimate relative abundance. However, the presence of year interactions makes interpretation of the results less certain. Thus, the estimated intervals on such results underestimate the amount of uncertainty present in estimating abundance fluctuations.

Although *statistically* significant year interactions were found, it is not known how *biologically* significant they are. It is entirely possible that even when year is found to interact with, for example, variable *A*, that the year trajectories corresponding to different levels of variable *A* may be quite similar. To determine the biological significance of these interactions, then, would require an extensive sensitivity analysis. Such an analysis would be valuable in this regard.

Results for the model including all data (Model 1) are given in Table 2 and Figure 1. Results for the model on the Gulf of Mexico only (Model 2) are given in Table 3 and Figure 2. Results for the model excluding the Gulf of Mexico (Model 3) are given in Table 4 and Figure 3. The models are compared in Figure 4.

Nominal confidence intervals on the three series are quite wide before 1985, especially for the Gulf of Mexico series (Fig. 1, 2, 3). From 1985 to 1987, the indices disagree on whether relative abundance was increasing or decreasing. However, the three indices all estimate that abundance has decreased in the period 1988 through 1991 (Fig. 4).

Further research would be useful in resolving at least two issues. First, what is the meaning of the year interaction effects noted above, and how sensitive are the results to these interactions? Second, can any biological or practical reason be found why the index for the Gulf of Mexico differs so sharply from the index for other areas?.

REFERENCES CITED

Turner, S. C., and G. P. Scott. 1992. Standardized catch rates of yellowfin tuna, *Thunnus albacares*, from the United States longline fishery in the Atlantic Ocean. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap. 38: 245–253.

Table 1. Number of fishing trips reporting yellowfin landings. Fishing zones are CAR, Caribbean Sea; FEC, east coast of Florida; GOM, Gulf of Mexico; MAB, Mid-Atlantic Bight; NCH, north of Cape Hatteras; NEC, New England coast. Zones MAB, NCH, and NEC were combined into one area for modeling.

YFT		Fishing zone						
		CAR	FEC	GOM	MAB	NCH	NEC	ALL
N	Year landed							
	82	0	17	0	0	3	0	20
	83	0	9	4	0	15	0	28
	84	0	17	1	0	15	0	33
	85	4	21	9	0	5	0	39
	86	26	77	56	0	81	0	240
	87	65	280	113	0	146	0	604
	88	98	334	235	0	92	0	759
	89	60	239	214	0	110	0	623
	90	0	281	222	135	0	29	667
	91	0	393	491	279	0	43	1206
	ALL	253	1668	1345	414	467	72	4219

Table 2. Modeling results for full data set. (a) Summary ANOVA table; (b) summary statistics; (c) Type III sums of squares and significance probabilities; (d) year-effect parameter estimates; (e) back-transformed year effects (abundance index, standardized to 1991) with lower and upper 95% confidence limits.

Dependent Variable: LWCPUE Log CPUE (kg/kHk) of YFT

(a) Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	27	17901.69060733	663.02557805	246.40	0.0
Error	4191	11277.38165301	2.69085699		
Corrected Total	4218	29179.07226034			

(b)	R-Square	C.V.	Root MSE	LWCPUE Mean
	0.613511	42.92903	1.64038318	3.82115100

(c) Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	9	412.44959724	45.82773303	17.03	0.0001
ZONE2	2	267.74549967	133.87274984	49.75	0.0001
SZST	1	37.78357603	37.78357603	14.04	0.0002
QTR*QTILE	15	9747.90963958	649.86064264	241.51	0.0

(d) Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
YR	82	0.102424678 B	0.28	0.7829	0.37170784
	83	0.593321178 B	1.88	0.0602	0.31565156
	84	-0.037772534 B	-0.13	0.8968	0.29131961
	85	-0.080233295 B	-0.30	0.7653	0.26877296
	86	0.512683320 B	4.27	0.0001	0.11992701
	87	0.557293455 B	6.59	0.0001	0.08461122
	88	0.815178828 B	10.39	0.0001	0.07844624
	89	0.641431048 B	7.72	0.0001	0.08303404
	90	0.109993132 B	1.36	0.1746	0.08101565
	91	0.000000000 B	.	.	.

(e)	Yr	LCL95	CPUE	UCL95
	82	0.56656	1.18676	2.47580
	83	1.02354	1.90564	3.54164
	84	0.56223	1.00262	1.78278
	85	0.56082	0.95415	1.61921
	86	1.34424	1.68273	2.10591
	87	1.50188	1.75389	2.04796
	88	1.97214	2.27119	2.61538
	89	1.63813	1.90842	2.22308
	90	0.95496	1.11838	1.30952
	91	0.87706	1.00000	1.14001

Table 3. Modeling results for Gulf of Mexico only. (a) Summary ANOVA table; (b) summary statistics; (c) Type III sums of squares and significance probabilities; (d) year-effect parameter estimates; (e) back-transformed year effects (abundance index, standardized to 1991) with lower and upper 95% confidence limits.

Dependent Variable: LWCPUE Log CPUE (kg/kHk) of YFT

(a) Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	4499.68174564	214.27055932	130.03	0.0001
Error	1323	2180.16447411	1.64789454		
Corrected Total	1344	6679.84621975			

(b)	R-Square	C.V.	Root MSE	LWCPUE Mean
	0.673621	22.92910	1.28370345	5.59857865

(c) Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	8	140.66777315	17.58347164	10.67	0.0001
SZST*QTILE	6	2582.46309155	430.41051526	261.19	0.0001
QTR*SZST	6	107.40557029	17.90092838	10.86	0.0001

(d) Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
YR	83	1.423058729 B	2.15	0.0321	0.66313979
	84	1.321324750 B	1.03	0.3055	1.28886342
	85	0.544307989 B	1.23	0.2207	0.44424287
	86	0.061761216 B	0.33	0.7382	0.18477646
	87	-0.336664312 B	-2.50	0.0124	0.13444273
	88	0.359477135 B	3.43	0.0006	0.10484188
	89	0.613689073 B	5.72	0.0001	0.10725012
	90	-0.297631102 B	-2.80	0.0052	0.10625681
	91	0.000000000 B	.	.	.

(e)	Yr	LCL95	CPUE	UCL95
	83	1.41637	5.16869	18.815
	84	0.68369	8.63065	108.056
	85	0.79642	1.90034	4.522
	86	0.75602	1.07861	1.538
	87	0.55143	0.71655	0.931
	88	1.18604	1.43840	1.744
	89	1.53237	1.85660	2.249
	90	0.61119	0.74240	0.901
	91	0.86343	1.00000	1.158

Table 4. Modeling results for all ares except Gulf of Mexico. (a) Summary ANOVA table; (b) summary statistics; (c) Type III sums of squares and significance probabilities; (d) year-effect parameter estimates; (e) back-transformed year effects (abundance index, standardized to 1991) with lower and upper 95% confidence limits.

Dependent Variable: LWCPUE   Log CPUE (kg/kHk) of YFT

(a) Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	7407.99921453	284.92304671	91.62	0.0
Error	2847	8853.46324362	3.10975175		
Corrected Total	2873	16261.46245816			

(b)	R-Square	C.V.	Root MSE	LWCPUE Mean
	0.455556	58.99135	1.76344882	2.98933465

(c) Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	9	393.43500563	43.71500063	14.06	0.0001
SZST	1	35.75098594	35.75098594	11.50	0.0007
ZONE2	1	139.26190031	139.26190031	44.78	0.0001
QTR*QTILE	15	6693.95859788	446.26390653	143.50	0.0

(d) Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
YR	82	0.258759485 B	0.64	0.5199	0.40206690
	83	0.554145684 B	1.50	0.1325	0.36827093
	84	0.053538126 B	0.17	0.8676	0.32110058
	85	-0.271837958 B	-0.82	0.4138	0.33255298
	86	0.741042475 B	4.82	0.0001	0.15384607
	87	0.866392696 B	7.87	0.0001	0.11002104
	88	1.056931390 B	9.71	0.0001	0.10879597
	89	0.724658141 B	6.33	0.0001	0.11451102
	90	0.341872211 B	3.10	0.0020	0.11043721
	91	0.000000000 B	.	.	.

(e)	Yr	LCL95	CPUE	UCL95
	82	0.62271	1.40418	3.14957
	83	0.88956	1.86395	3.89282
	84	0.57643	1.10755	2.11903
	85	0.40951	0.79841	1.54711
	86	1.55009	2.12343	2.90735
	87	1.88327	2.39572	3.04681
	88	2.29805	2.89943	3.65746
	89	1.63026	2.07793	2.64771
	90	1.10299	1.41408	1.81205
	91	0.79846	1.00000	1.25173

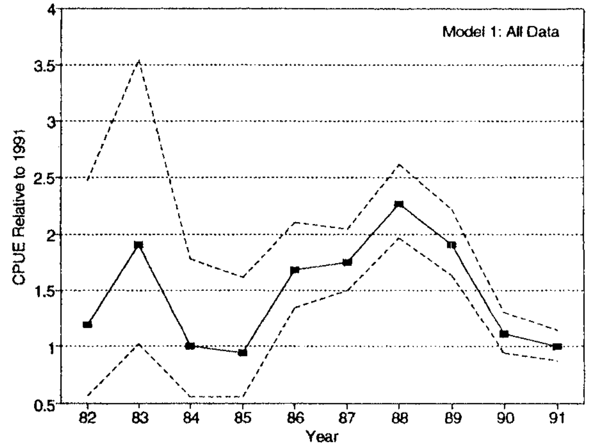

Figure 1. Estimated abundance index (CPUE in biomass) for yellowfin tuna in the western North Atlantic Ocean. Index is based on data from the US longline fleet operating in the area, including the Caribbean and Gulf of Mexico. Index is standardized to 1991 = 1.0.

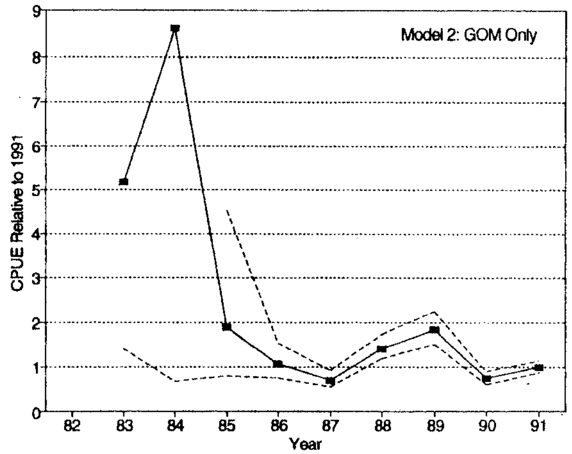

Figure 2. Estimated abundance index (CPUE in biomass) for yellowfin tuna in the western North Atlantic Ocean. Index is based on data from the US longline fleet operating in the Gulf of Mexico (other areas omitted from this analysis). Index is standardized to 1991 = 1.0.

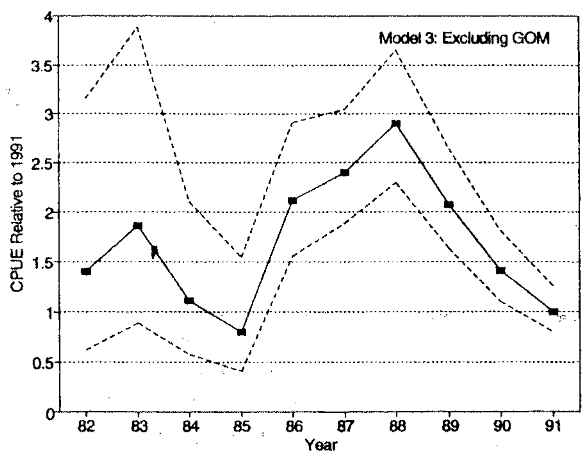

Figure 3. Estimated abundance index (CPUE in biomass) for yellowfin tuna in the western north Atlantic Ocean. Index is based on data from the US longline fleet operating in the area, including the Caribbean but excluding the Gulf of Mexico. Index is standardized to 1991 = 1.0.

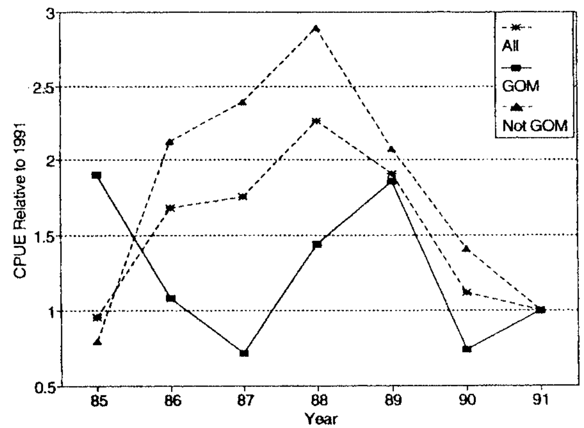

Figure 4. Comparison of estimated abundance indices for yellowfin tuna in the western north Atlantic. Indices are based on data from the US longline fleet, but vary in geographic coverage. Index 1, all areas; Index 2, Gulf of Mexico only; Index 3, all areas but Gulf of Mexico.