SCRS/1980/045

Col.Vol.Sci.Pap. ICCAT, 15 (2): 246-251 (1981)

ANALYSIS OF CATCH/EFFORT TRENDS IN BLUEFIN TUNA

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SUMMARY

Catch and effort data are analyzed to discern temporal and geographical trends in yields to various fishing gears. Factors affecting the significance of the results are discussed.

RESUME

On a analysé les données de capture et effort pour tenter de déceler les tendances temporelles et géographiques de la production de divers engins de pêche. On traite de divers facteurs affectant l'interprétation des résultats.

RESUMEN

Se analizan los datos de captura y esfuerzo, para determinar las tendencias temporales y geográficas en los rendi - mientos de los diferentes artes de pesca. Asímismo, se debaten los factores que afectan al significado de los resultados obtenidos.

INTRODUCTION

Evidence pertaining to the lack of geographical discreteness of Atlantic bluefin tuna resources is available from mark-recapture studies, parasite infestation patterns, morphometric and genetic analyses, and geographical and temporal aspects of fisheries (cf. Brunenmeister, 1980; Mather, 1980). However, estimates of the degree of intermixing between western Atlantic, eastern Atlantic and Mediterranean resources available from these studies vary in magnitude and reliability. Mark-recapture data on juvenile bluefin suggest trans-Atlantic migrations are sporadic and variable in degree. These data show that migrations have occurred at least once every ten years with known migrants representing from 10.0% to 1.5% of the total recaptures of fish with the same tagging history within a single year. Studies of parasite infestation patterns have suggested that western Atlantic juvenile abundance is augmented by an annual influx of fish amounting to 15-16% (Walters, 1980). Exchanges of small fish between the eastern Atlantic and Mediterranean have not been documented by mark-recapture data. However, captures of bluefin in the Mediterranean carrying tackle characteristic of eastern Atlantic fisheries were cited as evidence by Sella (1930) of migration of bluefin into the Mediterranean from the eastern Atlantic and at least one example he reports is a juvenile fish.

Data pertaining to large bluefin demonstrate migrations from the western Atlantic to the eastern Atlantic and from the eastern Atlantic into the Mediterranean. Mark-recapture data show 100% to 0.0% of annual recaptures of western Atlantic released fish have occurred in the eastern Atlantic. Tiews (1964) estimated an average of 12% migration of giant tuna from the western Atlantic to the eastern Atlantic based on the distributions of length/weight ratios in German tuna catches, since fish known to have crossed the Atlantic arrive in a very lean condition. Migration of large fish into the Mediterranean is evidenced by four of 19 recaptures (ca. 20%) of fish tagged in the eastern Atlantic. Thus variability in estimates and concomitant data deficiencies make it difficult to assess the degree of interaction between bluefin resources fished in various areas.

This paper uses catch per unit effort (CPUE) data to compare relationships between bluefin fished in the western Atlantic, eastern Atlantic and Mediterranean. The first analysis utilizes step-wise multiple regression to select catch history variables most predictive of changes in CPUE of a large fish fishery. This analysis shows cumulative catches of cohorts fished in the western Atlantic at ages 1-4 and in the Mediterranean at ages 3-5 account for 82% of the variation in CPUE of those cohorts at ages 11 and 12 in the Spanish trap fishery. The second analysis compares CPUE trends of cohorts fished at young ages in the eastern and western Atlantic. This analysis shows a significant concordance between trends in CPUE of cohorts fished at ages 2-4 by purse seiners in the northwestern Atlantic and by baitboats in the Bay of Biscay.

METHODS

In the first analysis, the Spanish trap fishery operating in the Iberian-Morocco Bay and Straits of Gibralter was selected as the criterion fishery since fishing effort data and size-frequency samples of catches were available for several years (cf. Rodriguez-Roda, 1978; Rodriguez-Roda, unpubl.). Examination of estimated age distributions from years between 1960 and 1979 for which size samples were available ($n = 15$) showed that the average age caught during this period was 10.8 ± 1.0 years. Tallying these ages by the first and second most abundant representation in catches showed ages 11 and 12 were most fully recruited. Hence CPUE on cohorts was calculated as numbers of fish at these ages caught per trap day. Year classes 1952-1968 are considered in this analysis.

Predictor variables were constructed from cumulative catches of these year classes fished at young ages by various gears operating in different geographical regions. Ages utilized were those typically recruited to the fisheries. Catches of fisheries with similar characteristics were pooled (Table 1.). All catches were aged by the method employed by Parrack (1980). Information on catches prior to 1960 were obtained from Bard (1978), Laurent (1980), Piccinetti (1980), Farrugio (1980), Power (1958-1961), Anonymous (1956, 1959, 1960). Catches for which no size samples were available were aged from size distributions typically caught by those fisheries.

Predictor variables were grouped geographically into northeast Atlantic (NEA), Mediterranean (MEDI), and northwestern Atlantic (NWA) variable sets (cf. Table 2.). Step-wise regression was performed on variable arrays composed of NEA, NEA AND MEDI, and NEA, MEDI and NWA variables, respectively. Each analysis was performed with critical values for variable admittance and retention set at 90% and 95% significance levels, respectively. All variables were transformed to log (10) because this transformation linearized variable relationships and improved correlations of predictor variables with the criterion variable.

In the second analysis, catch per unit effort on cohorts fished at ages 2-4 were computed utilizing effort data from Cort and Bard (1980), Bard (1978) and ICCAT Task II. Catches were aged by the method employed by Parrack (1980). Catch and effort data available for U.S.A. and Canadian purse seine fisheries were found to exhibit similar patterns and were therefore pooled in this analysis. French and Spanish catch and effort data were pooled since Bard (1978) has shown that these fisheries exhibit similar CPUE trends.

RESULTS AND DISCUSSION

Amounts of variation explained in CPUE of cohorts at ages 11 and 12 in the Spanish trap fishery (R^2) significantly improved as Mediterranean and NWA predictor variables were successively incorporated into the NEA data array and selected analytically as significant variables. (Table 2.). The most predictive least squares fit utilized the cumulative catches of cohorts made by Canadian and U.S.A. purse seiners on ages 1-4 in the northwestern Atlantic, and by French purse seiners on ages 3-5 in the Mediterranean. That 82% of the variation in CPUE of these cohorts observed in the Spanish trap fishery is explained by these variables resulting in a correlation (r) of 0.9035 is suggestive of a significant relationship between these geographical resources. Observed and expected values are plotted in Figure 1. This plot shows that the fitted model estimates the observed trend with no consistent bias temporally. Also residual plots showed no trends in lack of fit with either predictor variable.

Comparison of the Spanish trap CPUE of cohorts at ages 11 and 12 with estimated Atlantic-wide stock sizes of these cohorts at age 11 made on log e of stock size showed a relatively low correlation ($r = 0.548$, $p<0.05$). However, examination of the data revealed that representation of age 12 fish of the 1960 cohort was abnormally low. The catch ratio of age 13/age 12 of this cohort was 3.93 compared to a high of 1.92 observed in all other years. Rodriguez-Roda (1974) noted that in 1972 operation of traps changed ownership and the number of traps operating was reduced to two. Hence the overall low value of CPUE in this year may be due to factors extraneous to stock availability. Deletion of this point significantly improved the correlation ($r = 0.740$ $p<0.01$) suggesting that these estimates of CPUE may generally reflect cohort abundance Atlantic-wide. The aberrance of this point is also reflected in the fact that the most deviant negative residual ($Y-\hat{Y}$) observed from the model discussed above was for this cohort. Complete correspondence between these variables, however, would not be expected due to variation in catchability related to local environmental factors. Rodriguez-Roda (1978) has noted water temperature, turbidity, wind direction and presence of killer whales can affect daily trap catches. While these effects would not be expected to be great, it is worthwhile to note that such variability will impart an inherent lack of fit to the regression model.

CPUE of cohorts at ages 2-4 fished in the western Atlantic by U.S.A. and Canadian purse seiners and in the eastern Atlantic by French and Spanish bait boats exhibit similar trends (Figure 3.). The comovements were found to be significantly concordant ($p<0.05$) using a test procedure developed by Goodman and Grunfeld (1961). The lack of correspondence between these trends observed for the 1964, 1965, and 1966 cohorts is interesting since it was tagged fish at ages 1-4 of these cohorts which exhibited notable trans-Atlantic migrations.

In summary, the evidence produced from analyses of CPUE on cohorts in this paper suggests that significant relationships exist between bluefin resources of the western Atlantic, eastern Atlantic and Mediterranean since trends in apparent abundance of cohorts can be related among these regions.

SUMMARY

Catch per unit effort data is used to compare relationships between bluefin tuna resources fished in the western Atlantic, eastern Atlantic and Mediterranean. Step-wise multiple regression shows cumulative catches of cohorts fished in the western Atlantic at ages 1-4 and in the Mediterranean at ages 3-5 account for 82% of the variation in the CPUE of those cohorts at ages 11 and 12 in the Spanish trap fishery. CPUE variables are significantly related to Atlantic-wide stock sizes of these cohorts at age 11 estimated by Parrack's (1980) VPA analysis. Comparison of CPUE trends of cohorts fished at ages 2-4 by purse seiners in the northwestern Atlantic and by bait boats in the Bay of Biscay shows significant concordance. These results suggest significant relationships exist between bluefin resources fished in the north Atlantic and Mediterranean.

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Table 1. Characteristics of constructed predictor variables

Variable	Ages	Catch Location	Gear	Fisheries
X_1	1-4	NEA: Bay of Biscay	Baitboat	France, Spain
X_2	0-2	NEA: Moroccan Coast	Purse Seine	Morocco
X_3	3-5	Mediterranean	Purse Seine	France
X_4	1-4	MEDI: Adriatic Sea	Purse Seine	Italy, Yugoslavia
X_5	1-4	NWA: Off U.S.A.	Purse Seine	U.S.A., Canada

Table 2. Results of step-wise multiple regression analysis
SL = significance level for variable entry and retention

Variable Array	SL	Variable Selected	Fitted Equation	Proportion Explained Variation R^2	Overall F_s	Correlation r
NEA: X_1, X_2	0.90	X_1	$\hat{Y} = -4.1256 + 0.8556X_1$	0.392	9.015*	0.626
	0.95	X_1	" "	"	"	"
NEA + MEDI: $X_1 - X_4$	SL 0.90	X_3, X_4	$\hat{Y} = 1.9809 - 0.9943X_3 + 0.5297X_4$	0.574	8.759*	0.758
	0.95	X_3	$\hat{Y} = 3.7580 - 0.8575X_3$	0.471	12.462*	0.686
NEA + MEDI + NWA: $X_1 - X_5$	SL 0.90	X_5,X_3	$\hat{Y} = 2.4193 = 0.1406X_5 - 0.3909X_3$	0.816	28.830**	0.903
	0.95	X_5 X_3	" " "	"	"	"

* $p < 0.01$
** $p < 0.001$

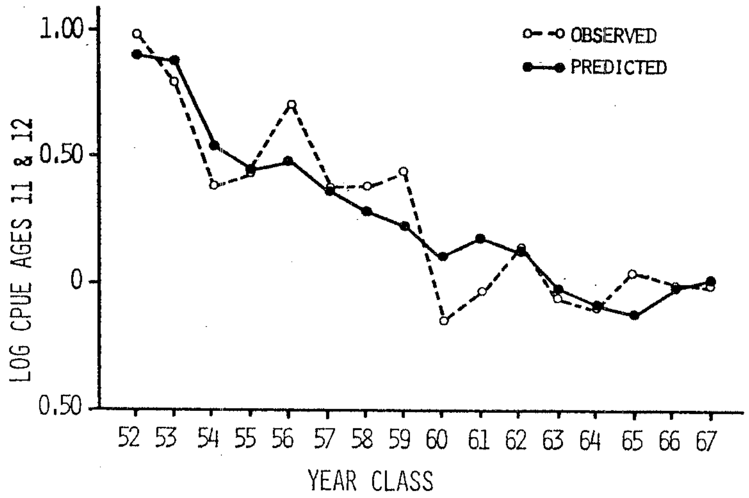

Figure 1. Comparison of observed with predicted CPUE of cohorts at ages 11 and 12 for Spanish traps from regression analysis utilizing cummulative catches of cohorts at ages 1-4 and 3-5 from northwest Atlantic and Mediterranean purse seiners, respectively.

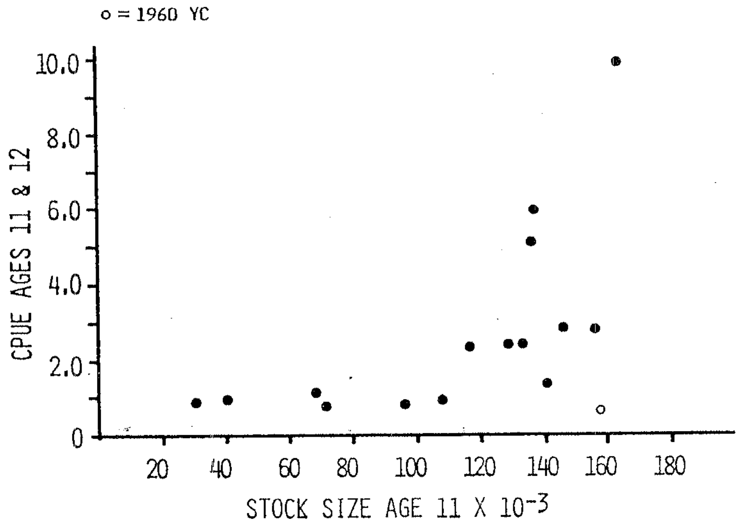

Figure 2. Relationship between CPUE of cohorts at ages 11 and 12 from Spanish traps and estimated stock size of cohorts at age 11 from Parrack (1981).

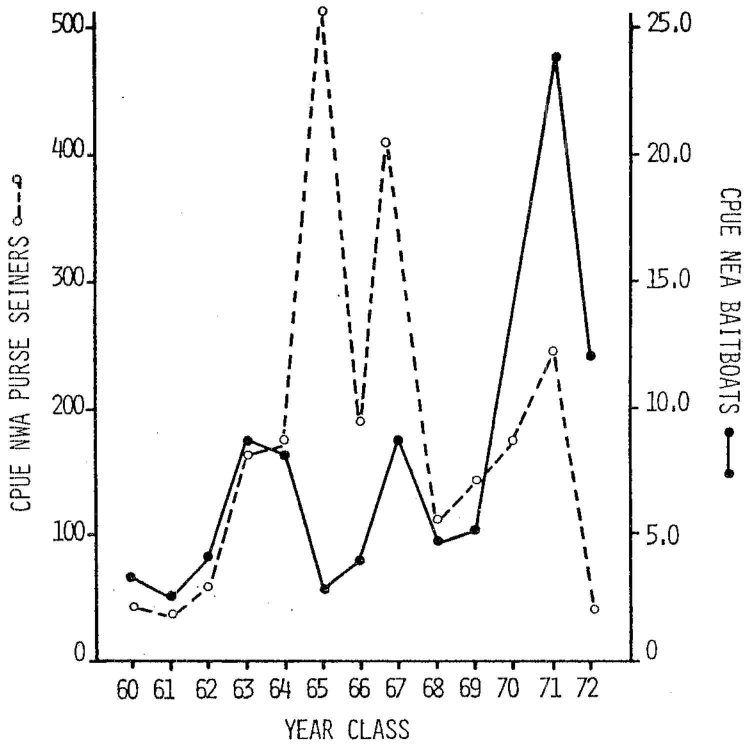

Figure 3. Trends in CPUE of cohorts at ages 2-4 from French and Spanish baitboats in the Bay of Biscay and from USA and Canadian purse seiners in the northwest Atlantic, respectively.