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AN EXAMINATION OF THE U.S.A. ROD AND REEL JUVENILE BLUEFIN TUNA CATCH-PER-UNIT EFFORT

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SUMMARY

Catch per effort data for the U.S. recreational fishery for juvenile bluefin have been collected since 1975 using a dock-side fishing trip sample survey. These data were examined to derive an index of recruitment strength. These data appear to index relative abundance at age 2, if adjusted for same-year exploitation. The 1973 year-class was estimated to be 5.6 times more abundant than the 1974-79 year-classes at age 2.

RESUME

Des données de CPUE de la pêche sportive au thon rouge juvénile des Etats-Unis ont été rassemblées depuis 1975 au moyen d'enquêtes à quai pour échantillonner les sorties. Ces données ont été examinées pour en tirer un indice de l'importance du recrutement. Elles semblent indexer l'abondance relative à l'âge 2, si on les ajuste à l'exploitation de la même année. La classe annuelle de 1973 a été estimée être 5,6 fois plus abondante que celles de 1974-79 à l'âge 2.

RESUMEN

Desde 1975, se compilaron datos de captura y esfuerzo de la pesquería deportiva norteamericana de atún rojo juvenil, mediante estudios de muestras obtenidas en salidas al mar dentro de la dársena. Se examinaron estos datos para deducir un índice de fuerza de reclutamiento, los cuales parecen indicar la abundancia relativa a la edad 2, si se ajustan a la explotación del mismo año. Se estimó que la clase anual de 1973 era 5.6 veces más abundante que las clases anuales de edad 2 de 1974-79.

Introduction

Past assessments of recruitment abundance for bluefin tuna in the west Atlantic have relied on virtual population analysis. Obtaining independent estimates of recruitment strength is desirable. This paper investigates the feasbility of using catch per effort data from the U.S. rod and reel fishery for juvenile bluefin to index recruitment abundance.

The Fishery

Small bluefin are fished recreationally between Cape Hatteras, North Carolina and Cape Cod, Massachusetts. The fishery begins May or June with the appearance of large schools of bluefin in the coastal waters off North Carolina. The fishery progresses northward during the summer, until the bluefin leave the coastal waters in the fall. Time and location of peak catches vary considerably from year to year. Fishing success is highly correlated with favorable water temperature, and the northward progression of favorable temperatures is highly variable (M. Roffer, in prep.).

Probably 10,000 to 20,000 boats actively fish for bluefin. Most are over 7 m long, and are privately owned. Charter and party boats are also involved in the fishery. Trolling with artificial lures is the most common mode of fishing. In general, trips are less than one day's duration. Since 1975, a legal limit of 4 fish landed per angler per day has been in effect. No more than 1 of the 4 may be less than 14 pounds, and no more than 1 may be greater than 115 pounds.

The Data Base

Catch and effort have been sampled since 1975 using dockside interviews of fishing trips. A distinction was made between interviews made the same day fishing took place and interviews made some time later. Each same-day interview supposedly represented 1 trip; each later-day interview could represent 1 or more trips.

The distribution of interviews has not been constant over the range of the fishery from year to year. In 1975, the study concentrated in New York and New Jersey. Virginia was added in 1976; Rhode Island in 1979; North Carolina and Maryland in 1980. Prior to 1979, port agent activity was shifted in time and space in response to reports of landings. In 1979, formal preselection of ports for interview coverage on a scheduled basis was established. Port selections were based on past landings, and thus were systematic (not random) components of sampling.

For 1979-1982, the fraction of trips interviewed was estimated from overflights of traditional bluefin fishing grounds. Decreases in the estimated fraction interviewed with increases in estimated total effort were reported. Therefore, the number of interviews in any chosen time/area stratum does not measure the total level of fishing for bluefin in that stratum.

Data collected continuously over the 1975-1982 period include location and date of landing, indication of same-day or later-day interview, number of lines fished, hours fished, target species, number of bluefin landed (with notation of whether counted or estimated), and associated length and/or weight measurements of individual fish. The identity of vessels, type of vessel, fishing gear, fishing location, number of anglers, whether fishing was part of a competative contest and information about other species were not recorded for all years during the study period. For 1981 and 1982, only sample trips directed at bluefin have been put in computer-accessible files.

Analysis Procedures

Only "same day" interviews indicating bluefin as the target species were used in this analysis. Interviews with unrecoverable recording or keypunch errors were rejected. The few records with large numbers of bluefin per trip often lacked information, and were likely improperly documented composites of several trips. Interviews reporting over 40 bluefin per trip were rejected. The number 40 was arbitrary.

The recreational fleet is diverse with respect to vessel size, so heterogeneity in fishing power was expected. Number of lines fished is the only statistic available possibly related to fishing power (Figure 1). Only catch per effort from trips reporting 4, 5, or 6 lines fished (about 75% of the data) were used in order to reduce fleet heterogeneity. Computation without that restriction produced virtually the same results, indicating that fishing power heterogeneity, at least as measured by numbers of lines, was not an important problem.

No adjustment for the legal limit on number of fish per angler per day was made. I believe that change in catchability due to approaching the limit are unlikely. Additionally, if number of lines fished approximated the number of anglers, only 2% of the trips reached the limit of 4 per angler per day.

Subdivision of the annual data into smaller categories of time and space is not feasible due to the absence of location-fished data in some years, changes in the time and area coverage of the surveys, and decreases in fraction interviewed with increasing effort. Isolating a continually covered subarea of the fishery was not practical, because local fluctuations in availabililty would dominate the results. Therefore, each interview was treated as a random, independent observation from the population of trips made by the fishery each year.

The length and weight measurements made during the interviews were used to establish age composition. Initially, the von Bertalanffy length-age equation developed by Parrack and Phares (1979), and the weight-length relationships tabulated in that same paper were used to age the samples. However, for some years, application of the Parrack and Phares equation lead to dividing obvious modal groups into separate ages. Inspection of the data for all years showed that the progression of all modal groups (cohorts) followed the Parrack and Phares curve, but that some cohorts remained offset from their predicted position. This suggests that changes in the age length relationship were due to events in the early (pre-recruit) life history. Unbiased ageing was accomplished by estimating cohort-specific t_0 parameters in the von Bertalanffy equation via least squares (Table 1). This method produced age boundaries almost identical to initial, eye-fitted boundaries made by simple examination of the modal progressions.

The fish were not measured for about 5% of the interviewed trips, so an adjustment of the number of trips reporting no fish was made to compensate (multiplication by the number of trips with sized catch/number of trips with catch, sized or not). The effect of this adjustment was minor.

The numbers of observations each year in the final data set are shown in Figure 2. The frequency distriubtion for number of bluefin reported per trip for all years combined is shown in Figure 3.

Two statistics of catch per effort (by age) were considered: relative frequency of trips catching fish (for each age group), and mean catch (of each age) per trip. Catch per hour fished was also computed, but time fished is not reported for many observations. For those interviews where time fished was reported, the results almost parallel catch per trip, so catch per hour was dropped.

Relative frequency of positive trips is the better choice for an index of abundance. Bannerot and Austin (1983) demonstrated that frequency of positive trips was a sensitive measure of abundance, while average catch per unit effort was not, by conducting a series of experiments in a recreational fishery where absolute local abundance was observed directly by divers.

Results

Yearly estimates of catch per effort by age, expressed as relative frequency of positive trips, are shown in Table 2. For comparison, catch per effort values expessed as mean catch per trip are shown in Table 3. Figure 4 summarizes the passage of an "average" cohort through the fishery. On the average, and for the majority of cohorts individually, catch per effort does not peak until age 2, indicating that recruitment to the recreational fishery is not complete until at least age 2. Catch per effort drops rapidly after age 2, more rapidly than expected based on the mortality rates estimated in any of the earlier virtual population analyses (Parrack 1980, 1981, 1982; Powers et al. 1983), indicating that the fish become increasingly unavailable to this fishery with increasing age. Information about abundance from the recreational catch per effort data will thus be maximal at age 2. Variability in catch per effort for other ages will likely be dominated by fluctuations in availability.

Catch per effort estimates for age 2, as relative frequency of positive trips, are plotted against year class in Figure 5. The relatively small range of variation (maximum value only 3.6x the minimum), and the absence of an outstanding value for the 1973 year class are the most apparent features. Both features were initially surprising, but were found to arise because same-year exploitation had not been accounted for.

The effects of exploitation, as well as variation in abundance can be seen in Figure 6, where the relative frequency catch per effort index is plotted against catch at age 2 for the same season. Location of any year class in the graph is expected to be the result of 4 major factors: 1) abundance of the year class entering the coastal waters at the start of the season, 2) depletion of that abundance, primarily by exploitation, 3) real variation in catchability due to fluctuations in local concentrations, and 4) sampling error in the catch per effort estimation.

The 1973 class is clearly unique in Figure 8. The remaining year classes fall in a fairly narrow envelope, with a pattern indicating a negative relationship between catch per effort index and same year exploitation.

The most straightforward interpretation of Figure 8 is that the 1973 year class was unique in its abundance, whereas the variation among the 1974-1979 cohorts was dominated by the effects of exploitation, with variations in initial abundance, catchability, and sampling error having much less effect on the pattern.

The low apparent variation in initial population and catchability for the 1974-79 cohorts can be used to advantage to estimate the relative strength of the 1973 year class to the average strength of the 74-79 cohorts. (Thanks are due to J. Beddington and M. Sissenwine for suggesting this approach). Assume, as an approximation, that the initial abundance and catchability are constant for the 74-79 year classes. The x-intercept of the linear regression between the catch per effort index and the same season catch for the 1974-1979 points in Figure 8 provides a Leslie-type estimate of average initial population strength for the 74-79 year classes at age 2 (see Ricker 1975, for a convenient summary of the Leslie method). Assuming the same catchabililty (slope) holds for the 1973 year class, the x-intercept of the line with the same slope, passing through the 1973 data point estimates the initial population of the 1973 cohort at age 2. The ratio of these estimates is 5.6, which compared favorably with the ratios of initial population size at age 2 calculated from the results of previous VPA assessments. (4.5 from Powers, Conser, and Parrack 1983, 6.9 from Parrack 1982, 5.1 from Parrack 1981, 4.3 from Parrack 1980).

Discussion

Several cautions are necessary before accepting the estimated ratio of 5.6. Catch values are assumed to be measured without error. The population values projected by the Leslie-type procedure are well removed from the data, and thus are subject to considerable random error even if no potential sources of bias were present. The changes in procedures and in geographic and temporal coverage of the surveys prohibit evaluation of the sampling error structure for the catch per effort estimates. There is no guarantee that the relative frequency index will be linearly related to population size all the way to zero catch per effort. (As a frequency, arcsine transformation may be appropriate at very low values; Bannerot and Austin (1983) reported some success with a square root transformation. Both were tried, resulting in ratios of 1973 to the other classes of 5.7x and 4.1x, respectively). The Leslie-type procedure is an approximation, ignoring natural mortality, and treating catch as an instantaneous event. (However, these approximations may be realistic. The dominant fishery in these catches was the purse seine, which for 1976-1979, reached quota in about a 2- to 3-week period. In those years, the purse seine fishery preceded most of the recreational survey observations. In other years, the purse seine and recreational fisheries overlap in time). The constant catchability and initial population size assumptions are clearly approximations only. Despite these varied sources of "noise", two signals came through clearly:

1) the 1973 year class was exceptionally strong compared to those following, and 2) variation in catch per effort among the weaker classes was most strongly related to variations in exploitation that season.

The x-intercepts in the Leslie-type estimations are nominally the population sizes for the fraction of the age 2 stock that entered the coastal waters. It is probably inadvisable to put much reliance on the absolute numbers estimated, even though the relative strengths may be realistic. All the caveats of the first paragraph in this section apply. The ratios of the Leslie-type intercept for 1974-79 to the average population sizes at age 2 presented in previous VPA assessments are nominally estimates of the fraction of the stock entering coastal waters. These ratios range from 49% (based on Parrack 1982, which seems low, but plausible) to 12% (based on Parrack 1981, which seems implausibly low). Authors of previous VPA assessments have stressed that the analyses were methods of identifying relative trends, with only limited reliance to be placed on the estimated absolute population sizes. For the present, the caveat should be also extended to the Leslie-type intercepts, which should not now be taken as precise estimates of the absolute population sizes of the component of the stock entering coastal waters.

Conclusions

Catch per effort of the U.S. recreational fishery may be used to index relative abundance at age 2 if same-year exploitation is taken into account. Catch per effort indexing does not appear feasible before age 2. Because there is exploitation before age 2, recreational catch per effort will not index abundance at first recruitment directly. However, relative abundance estimates at age 2 may be used in the future to calibrate virtual population analysis based assessment.

Improvement is possible by improving stabililty in survey design, and redirecting survey procedures to obtain more representative samples of catch per effort. Maximal coverage of recreational catch, not derivation of a catch per effort index has been the primary goal of the recreational surveys, and the early years of the survey concentrated on developing survey techniques (Berry et al. 1978). The relative clarity of the "signals", despite the limitations of the survey, bode well for continued development.

At present, inferences about abundance based on existing recreational survey data suggest that, as a best estimate, the 1973 year class at age 2 was 5.6 times more abundant than the average abundance of the 1974-1979 year classes, and that variations in abundance among the 1974-1979 year classes at age 2 were too small to be detectable.

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Table 1. Best estimates of von Bertalanffy t_o parametric by year class. The t_o estimated by Parrack and Phares (1979) was -0.96 years.

Year class	73	74	75	76	77	78	79	80	81
$t_o(y)$	-0.98	-1.02	-1.00	-1.10	-1.22	-1.29	-1.30	-1.27	-1.04

Table 2. Catch per effort estimated as relative frequency of positive trips.

	Year							
Age	75	76	77	78	79	80	81	82
0	.009	0	0	0	.005	.002	.004	.005
1	.382	.206	.079	.222	.338	.262	.200	.386
2	.404	.130	.312	.362	.474	.328	.215	.390
3	.022	.109	.073	.037	.150	.080	.066	.233
4	.107	.004	.035	.004	.015	.055	.009	.042
5	.009	.012	.006	.016	.018	.016	.004	.038

Table 3. Catch per effort estimated as mean catch per trip.

	Year							
Age	75	76	77	78	79	80	81	82
0	.013	0	0	0	.005	.002	.004	.005
1	1.178	.835	.338	.716	1.233	.820	.779	1.872
2	.900	.529	1.326	1.861	1.630	2.193	.528	1.950
3	.036	.343	.224	.086	.251	.234	.103	.983
4	.134	.004	.118	.004	.015	.224	.021	.141
5	.028	.012	.037	.161	.020	.016	.004	.164

Figure 1. Frequency distribution of number of lines fished for all years combined.

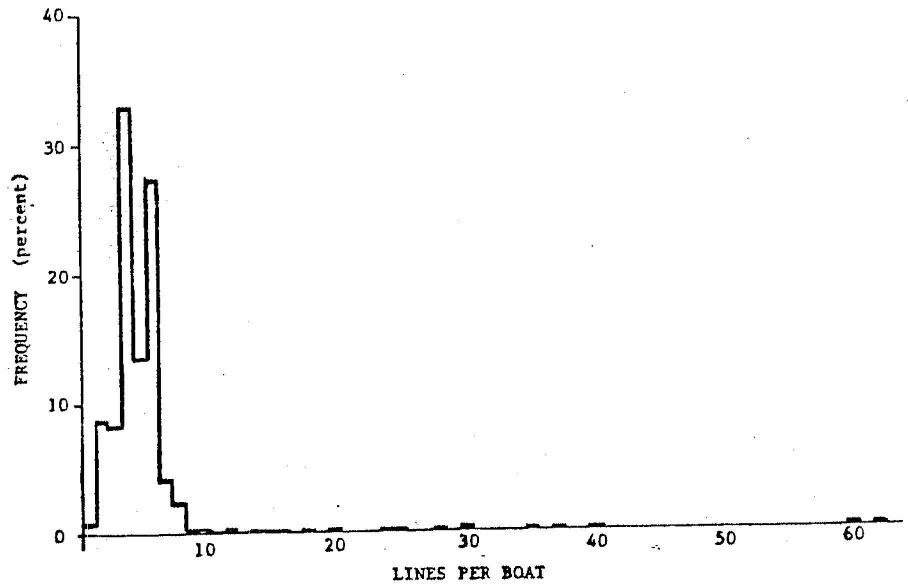

Figure 2. Number of observations (interviewed trips) used in the estimation of catch per effort.

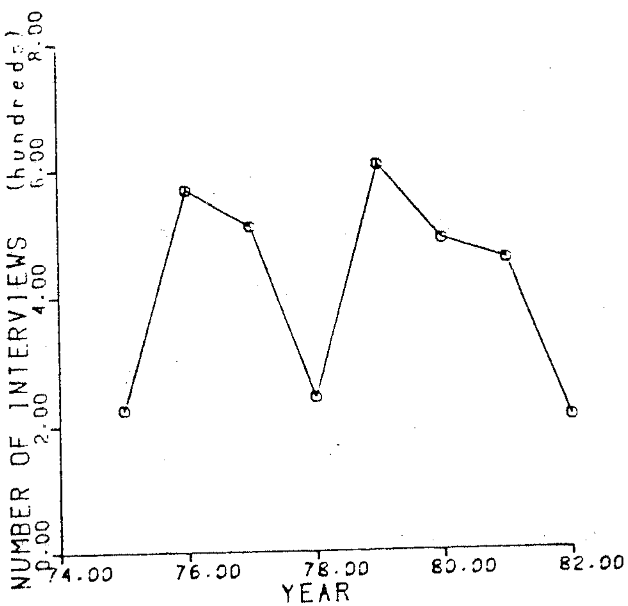

Figure 3. Frequency distribution of number of bluefin landed per trip (all ages) for all years combined.

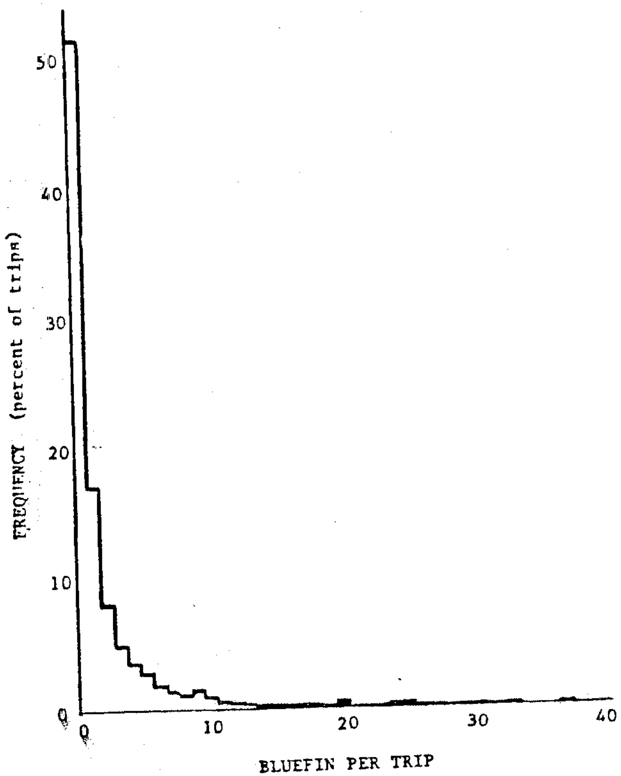

Figure 4. Relative catch per effort by age for an "average" cohort progressing through the recreational fishery. Values are geometric means of relative frequencies of positive trips for each cohort, expressed as a fraction of mean catch per effort at age 2.

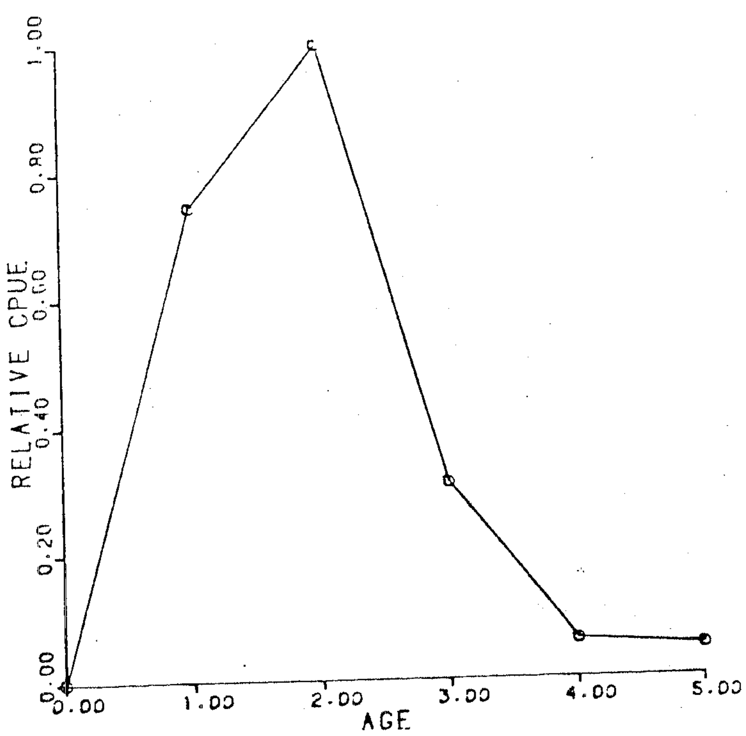

Figure 5. Catch per effort at age 2 (as relative frequency of positive trips) vs year class.

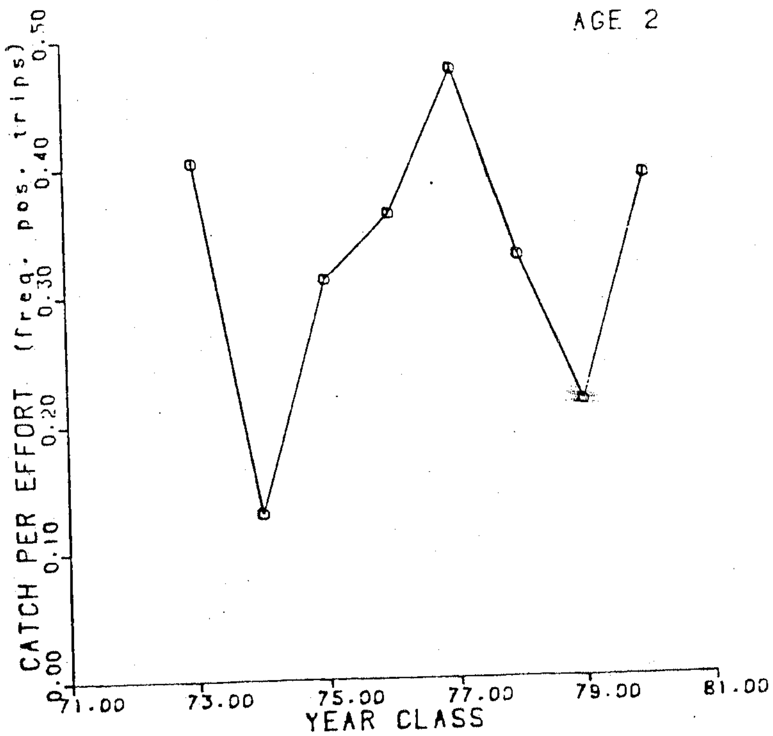

Figure 6. Catch per effort at age 2 (as relative frequency of positive trips) vs same-year catch at age 2. The x-intercept of a linear regression though the 1974-79 points was 36000, which is a Leslie-type estimate of the average number of age 2 fish entering the coastal waters at the start of the 1976-1981 seasons.