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RECENT YIELD PER RECRUIT TRENDS OF ATLANTIC BLUEFIN TUNA

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SUMMARY

Trends in yield per recruit are used to index changes in utilization patterns of bluefin since 1960. Trade-offs among yields of different size categories, and changes in catch patterns among different fishing gears are considered.

RESUME

On a utilisé les tendances de la production par recrue pour indexer les modifications des caractéristiques de l'exploitation du thon rouge depuis 1960. On considère une répartition variable de la production entre les diverses catégories de taille, ainsi que des modifications des caractéristiques de pêche des divers engins.

RESUMEN

Las tendencias en el rendimiento por recluta se utilizan desde 1960 como índice a los cambios efectuados en los tipos de pesca del atún rojo. Se toman en consideración los intercambios entre rendimiento por recluta, de diferentes tallas, y variaciones entre los distintos artes de pesca.

INTRODUCTION

Parrack (1981) has estimated fishing mortality rates and stock sizes by age for Atlantic bluefin tuna (1960–1979) elsewhere in this volume (SCRS 80/43). This paper uses Parrack's estimates to study changes in the exploitation patterns over the last two decades, primarily using yield per recruit techniques.

CATCH HISTORY

Figure 1 shows the catch history (in numbers) for three size or age classes of Atlantic bluefin. The top line in each graph represents the total catch for that size group. The interior lines partition the total catches into catches by different gear types.

The small fish catch (age 0–5) has been dominated by the purse seine fisheries throughout the 1960–1979 period. Fluctuations roughly follow fluctuations in year class strength (see Fig. 7). Total catches of medium tuna (age 6–9), and the catches of mediums by the separate gear types have fluctuated erratically.

The catches of large fish (age 10+) declined markedly from 1962 to 1973, increased in 1974 and 1975, and have declined again since then. There have also been major changes in the contributions of different gear types to the large fish catch. The trap catch has declined throughout the period. The 1976–1978 trap catches were about 10% of the 1960–1962 levels. The trap's "share" of the large fish catch has also declined, from nearly 50% in the early 1960's to about 10% since 1974. Longline catches became the major component of the large fish catch in 1963–1964, and again in 1974–1977. Purse seine and surface fisheries have dominated the large fish catches intermittently since 1971. Only the documented "surface" fisheries have shown increased catch levels of large fish. Part of that increase may have resulted from reporting some of the "surface" catch as "unclassified" in earlier years.

It appears that the most interesting catch trend has been the decline in the large fish catch, and that this trend has been accompanied by a shift from gear requiring relatively high local population densities to gear capable of exploiting lower, and more patchy population densities, as the major contributor to the catch. These features of the catch history are consistent with the trends in stock size for large fish estimated by Parrack (SCRS 80/43), recapitulated here in Figure 2.

YIELD PER RECRUIT HISTORY

All yields per recruit in this paper were calculated by simulating the death, removal, and individual growth of fish from a cohort through time. The growth curve used was the von Bertalanffy length-age relation developed by Parrack and Phares (1979), coupled with the length-weight relation for all northwest Atlantic data presented in that same paper. Size at age and yields were calculated in discrete time steps of two per year. Recruitment was assumed to have occurred when a fish reached 26 cm fork length, corresponding to the theoretical size at age 0 in the growth equation used. The natural mortality rates used were the same as those used by Parrack (1981): 0.14 per year for fish age 5 or less, 0.18 per year for fish age 6 and greater. Fishing mortality rates used were derived from Parrack's (1981) estimate for the total Atlantic.

Potential yield per recruit for a given year can be defined as the yield per recruit that would result if a cohort were fished throughout its life at the rates described by the vector of age-specific fishing mortality rates for that year. Potential yield per recruit allows the comparison of the exploitation patterns of past years in their abilities to produce yields, unconfounded with variations in year class strength.

Figure 3 presents the potential yields per recruit for the 1960–1979 period. Total yield per recruit is depicted by the top line on the graph; the interior lines partition that total into yields of small, medium and large fish. Parrack made two estimates of fishing mortality rates on juveniles in 1979. These two estimates generate two estimates of yield per recruit from 1974 forward, indicated by diverging lines with shaded areas between. The shaded areas thus represent the uncertainty caused by uncertainty over the fishing mortality rates on juveniles in recent years.

Figure 3 documents a change from an orientation toward large fish yields in the early 1960's to a small-fish oriented fishery in the late 60's and early 70's. Potential yield per recruit over all sizes has fluctuated widely during the period, but was clearly higher during the early 1960's than in the late 60's and earlier 70's. If Parrack's lower estimate for recent juvenile fishing mortality is more accurate, very little continuing trend is evident. If the higher is more accurate, a continuing downward trend is suggested.

CURRENT YIELD PER RECRUIT

Figure 4 presents the isopleth plots of the familiar Ricker yield per recruit model for the age specific fishing mortality rates averaged over the 1976-1978 period. Figure 4a applies to Parrack's lower estimate of juvenile fishing mortality rates; Figure 4b, to the higher. The two patterns are very similar qualitatively. Expansion of the entire fishery (increase in the F-multiplier) would produce a decrease in yield per recruit. A very slight increase in yield per recruit would occur with a reduction in fishing mortality rates to 70-80% of existing values; further reduction would decrease yield. Delaying first capture to age 5 would increase the yield per recruit 50 to 90%.

Yields per recruit over all age classes are not particularly relevant to the concerns of the individual national fisheries. Most individual fisheries can be identified as either "small-fish" or "large-fish" fisheries, so the yields per recruit of small and large fish will be examined in response to variations in fishing mortality rates on small and large fish.

Figure 5 shows the yield per recruit of age 1-5 fish in response to fishing mortality rates on ages 1-5. Figure 5a represents the case with Parrack's lower fishing mortality rate estimates for juveniles; Figure 5b, the higher estimates. Increasing the fishing mortality rate on small fish could produce a 2 to 20% increase in yield per recruit of small fish, at fishing mortality rates of twice the lower fishing mortality rate estimate; at 1.2 times the higher. Further fishing mortality rate increases would decrease small fish yields. Any contraction of the small fish fisheries would decrease small-fish yield per recruit.

Figure 6 presents the yield per recruit of large bluefin (age 10+) in response to fishing mortality rates on age 1-5, and on ages 10+. Figure 6a represents the case for Parrack's lower fishing mortality rate estimates on juveniles. Figure 6b, the higher estimates. Near recent mortality levels, yield per recruit of large fish is relatively insensitive to increasing fishing mortality rates on large fish. For example, doubling the large fish mortality rates would produce only a 25% increase in large fish yield per recruit. Large fish yields are more sensitive to variations in fishing mortality rates on small fish. Halving the fishing mortality rate on age 1-5 fish would increase large fish (age 10+) yield per recruit 64% to 230%, depending on the current juvenile stock size.

EXPLOITATION OF SELECTED COHORTS

A twenty-year catch history is not long enough to follow any individual cohorts completely through the fishery, but some cohorts can be followed far enough to analyze the apparent reduction in the availability of large fish in recent years. Changes in the stock estimates of fish at age 10 (fully available to most large-fish fisheries) will be partitioned into changes due to: 1) changes in year class strength, 2) changes in exploitation rates on small bluefin, and 3) changes in exploitation rates on mediums.

Figure 7 shows the stock sizes at ages 1,6, and 10 estimated by Parrack (SCRS 80/43) for 1960-1979. I have selected two groups of cohorts to examine in detail: the 1959-1962 year classes, adn the 1967-1970 year classes. The variation in estimated stock size at age 10 is relatively small within each group, but the contrast between the groups is large. The 1959-1962 cohorts have been a major component of the large-fish fisheries since those fisheries expanded in 1974. The 1967-1970 cohorts are just now entering the large fish fisheries.

The mean value for estimated stock size at age 10 for the 1959-1962 cohorts is 175,000 fish. In contrast, the 1967-1970 cohorts averaged 34,000 fish at age 10, only 19% of the level of the 1959-1962 cohorts. The average stock size at age 1 for the 1959-1962 year classes was 1,730,000 fish; for the 1967-1970 classes, 930,000 fish (54% of 59-62). By age 6, the average stock size of the 1967-1970 cohorts was down to 28% of the 1959-1962 cohorts' age 6 stock size. Assuming that the natural mortality rates have not changed with time, the sources of the reduced stock size at age 10 for the 1967-1970 cohorts compared to 1959-62 cohorts can be partitioned multiplicatively:

Stock size at age 10 reduced to		Reduced to		Reduced to		Reduced to
19%	=	54%	X	52%	X	68%
		due to reduction in year class strength		due to increased exploitation age 1-5		due to increased exploitation age 6-9

The realized yield per recruit (up to age 20) for the 1959-1962 year classes was 12.0 kg. If the 1967-1970 cohorts are fished between ages 10 and 20 at the 1976-1978 average fishing mortality rates, yield per recruit from these cohorts will be 14.9 kg. The total yield per recruit from the 1967-1970 cohorts would be 24% greater than the yield from the 1959-1962 cohorts, achieved by essentially doubling the yield per recruit of small and medium fish, halving the yield per recruit of large fish, and tolerating a stock size of large fish on the order of 10% of the adult stock size of the 1959-1962 cohorts. Because the recruitment strength in 1967-1970 was about 54% of the 1959-1962 levels, the total yeild expected from the 1967-1970 cohorts will be 67% of the yield of the 1959-1962 cohorts.

LITERATURE CITED

PARRACK, M.L. 1981. An assessment of the Atlantic bluefin tuna resource. Submitted to ICCAT as SCRS 80/43.

PARRACK, M.L. and P.L. PHARES 1979. Aspects of the growth of Atlantic bluefin tuna determined from mark-recapture data. ICCAT Coll. Vol. Sci. Pap. VIII, pp. 256-366. (SCRS/78/37).

Figure 1. Catch in numbers of fish vs. time for three size/age groups. The top line for each graph is the total catch in that size/age group. The interior lines partition the total catch into gear categories, so that each gear's contribution is plotted cumulatively.

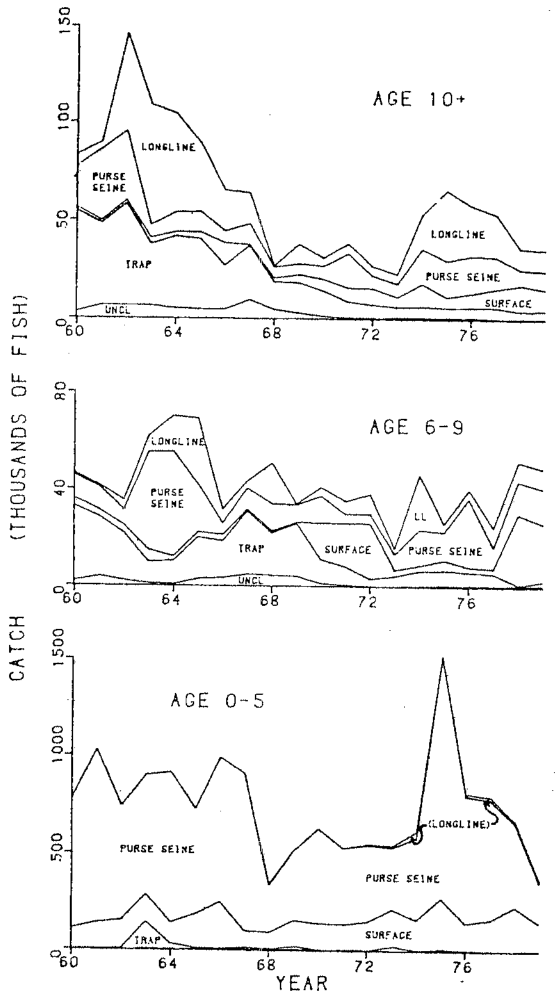


Figure 2. Estimated stock size for bluefin, age 10 and greater vs time. (Data from Parrack, SCRS 80/43).

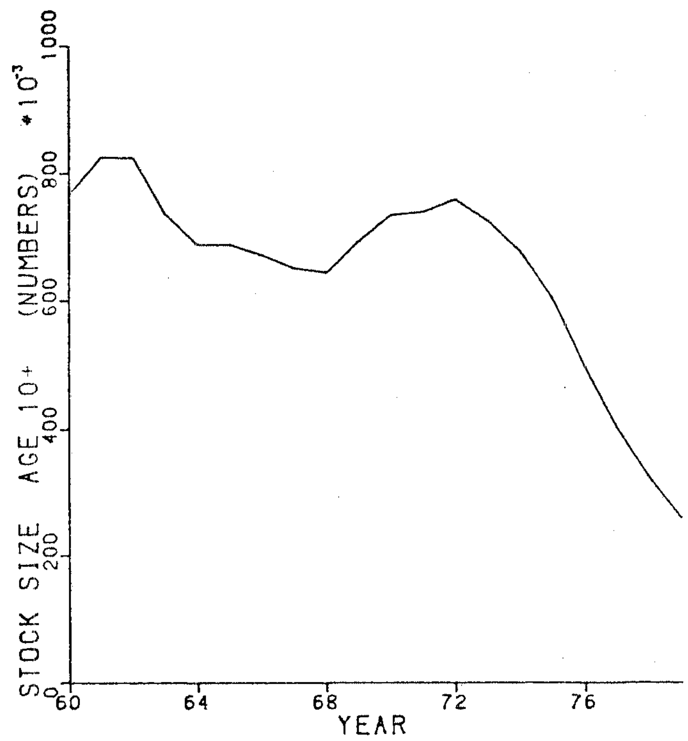


Figure 3. Potential yield per recruit vs time. The top line is the yield per recruit over all ages. The interior lines partition that yield into size/age categories (cumulative plot). The pairs of lines with shading between after 1973 show the yield calculated from Parrack's (SCRS 80/43) two estimates of recent juvenile fishing mortality rates.

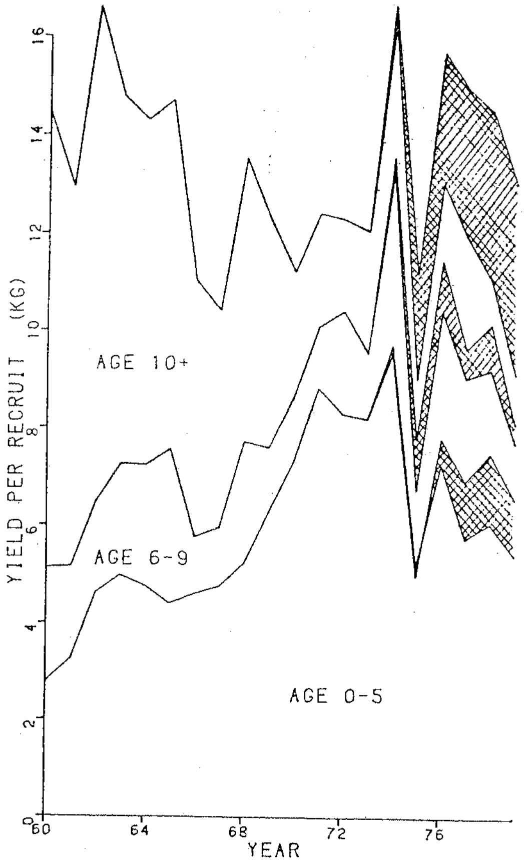
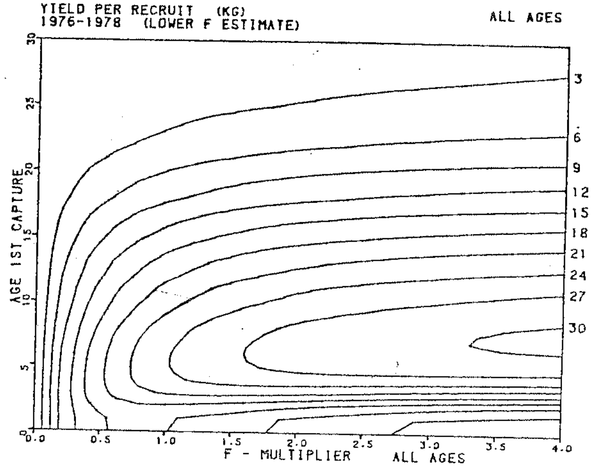
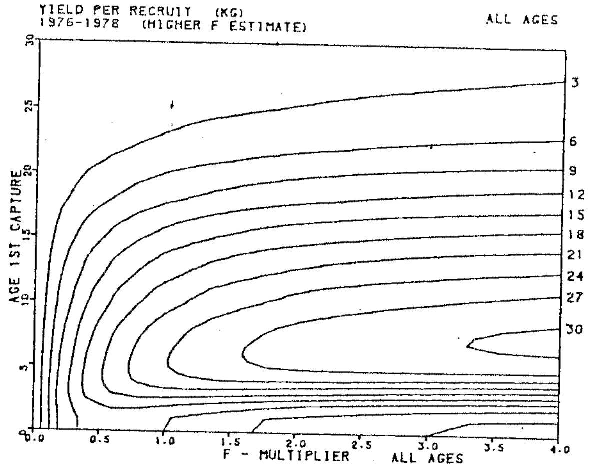


Figure 4. "Ricker plots" of yield per recruit based on 1970-1978 average fishing mortality rates. 4a) based on Parrack's (SCRS 80/43) lower estimate of juvenile fishing mortality rates. 4b) based on Parrack's higher estimate.

a.



b.



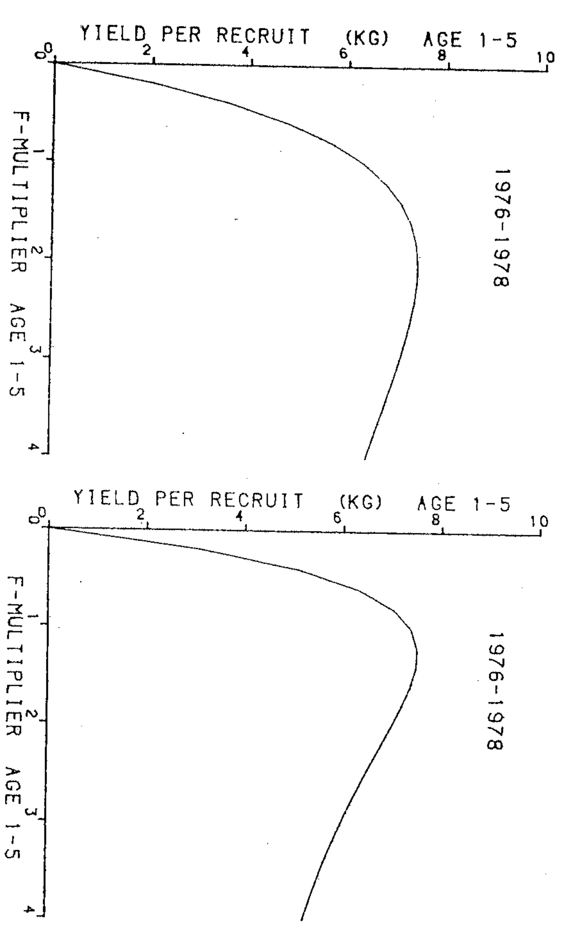


Figure 5. Yield per recruit of small fish (age 1-5) vs fishing mortality rate of small fish (as multiplier of 1976-1978 average fishing mortality rates). 5a) based on Parrack's (SCRS 80/43) lower estimate of juvenile fishing mortality rates. 5b) based on Parrack's higher estimate.

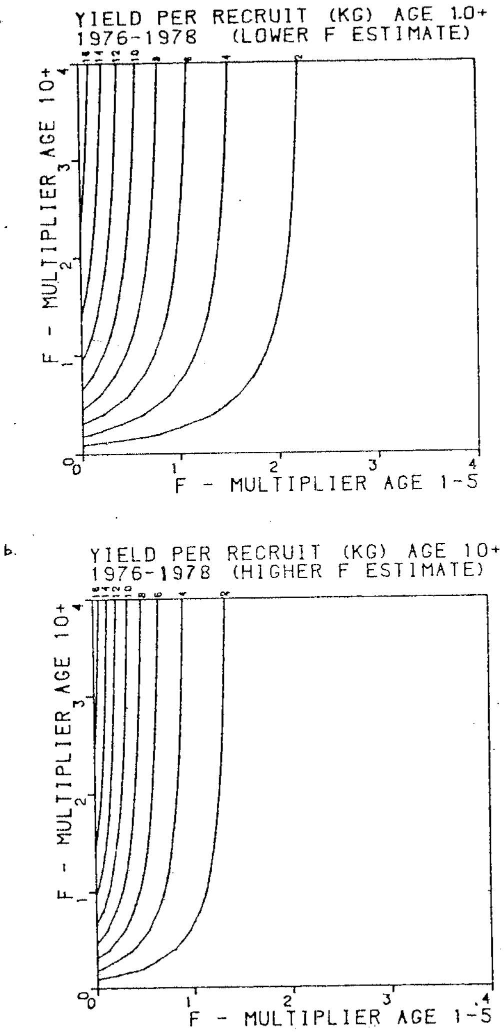


Figure 6. Yield per recruit isopleths of large fish (age 10+) plotted against fishing mortality rates on small fish (age 1-5), and on large fish (age 10+) (as multipliers of 1976-1978 average fishing mortality rates). 6a) based on Parrack's (SCRS 80/43) lower estimate of juvenile fishing mortality rates. 6b) based on Parrack's higher estimate.

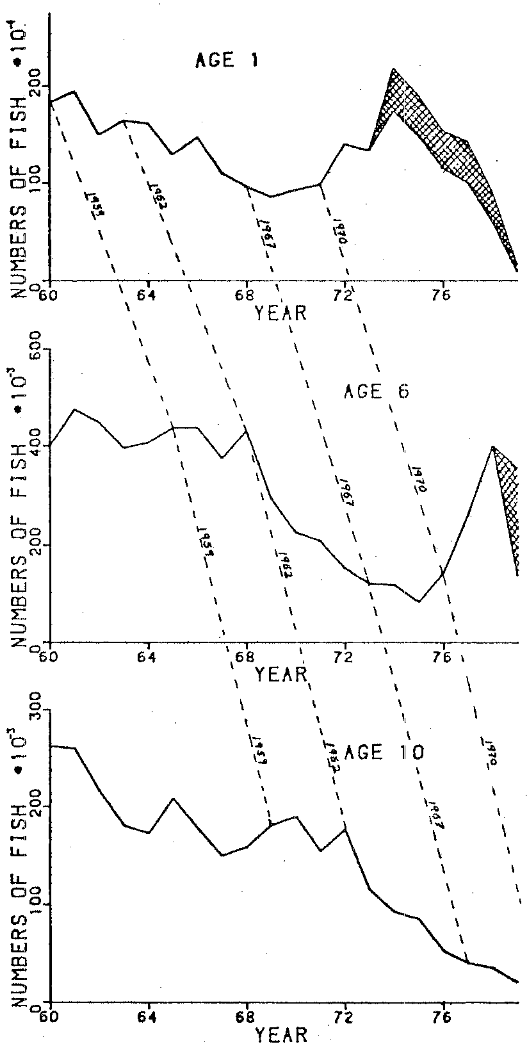


Figure 7. Estimated Stock sizes at age 1,6, and 10 vs time (data from Parrack's SCRS 80/43). The 1959–1962 and the 1967–1970 cohorts (marked with dotted lines) are compared in the text. The pairs of lines with shading between are the different stock size estimates from Parrack's two estimates of recent fishing mortality rates on small and medium bluefin.