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# A PRODUCTION MODEL APPROACH TO EVALUATE RECENT BIGEYE STOCK CONDITIONS IN THE ATLANTIC

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SUMMARY

The latest stock evaluation made by the ICCAT SCRS in 1978 indicated that the bigeye tuna resource(s) in the Atlantic has been utilized recently on high level of exploitation, in the proximity giving the MSY estimated by a production model analysis. In this connection, to reevaluate the stock status of the Atlantic bigeye tuna, a production model analysis was performed again using updated catch, effort and CPUE data obtained during the years 1961 to 1977. The analyses were conducted on two sets of data, reported and estimated catch statistics, and on the two cases of hypothesized stock structure: a single Atlantic stock and north-south separated stocks.

RESUME

La dernière évaluation des stocks effectuée par le SCRS de l'ICCAT en 1978, indique que les ressources de thons obèses de l'Atlantique ont été récemment exploitées à un niveau élevé, proche de celui qui donne la PEM estimée par l'analyse du modèle de production. A cet égard, afin de réévaluer l'état des stocks de thon obèse de l'Atlantique, on a procédé à l'analyse du modèle de production en utilisant les données actualisées de prise, l'effort, et la PUE recueillies de 1961 à 1977. Les analyses ont été menées sur deux jeux de données, statistiques de capture déclarées et estimées, et sur deux hypothèses de structure des stocks: un stock unique pour tout l'Atlantique et deux stocks séparés, nord et sud.

RESUMEN

La última evaluación del stock realizada por el SCRS de ICCAT en 1978, indica que los recursos de patudo en el Atlántico se han utilizado recientemente sobre un alto nivel de explotación, acercandose al RMS estimado, a través de un análisis de modelo de producción. En relación con esto, para evaluar la situación del stock del patudo en el Atlántico, se realizó un nuevo análisis del modelo de producción utilizando la captura y esfuerzo, datos actualizados y CPUE, obtenidos durante los años 1961 a 1977. Los análisis fueron realizados sobre dos conjuntos de datos de las estadísticas de captura (informadas y estimadas) y en los dos casos de hipótesis de la estructura del stock: un stock individual en el Atlántico y stocks separados al Norte y Sur.

1. Catch statistics

Utilized in this paper are two sources of catch data until 1977.

(1) Officially reported catch by country and tabulated in Statistical Bulletin Vol. 8 (ICCAT 1978) and,

(2) North-south separated surface bigeye tuna catch estimated by Marcille (1979).

Longline fishery ..... All data were extracted from Statistical Bulletin Vol. 8 and north-south separation was estimated by Kume (1979 c: SCRS/79/62).

Surface fishery ..... Two sets of data were used.

Case-1 Data from Statistical Bulletin Vol. 8 as reported (Data set-1). North-south separation was made as under:

North ..... Portugal, Spain baitboat fishery and unclassified surface catch.

South ..... Ghana, Japan, Korea, Panama US and South Africa

FISM (France, Ivory Coast, Senegal and Morroc) ..... The catch was prorated into north and south using the catch ratio shown in Table 2 of Marcille and Armada (1979), Catch ratio of Dakar being assigned to the north.

Case-2 Estimated north-south surface catch by Marcille (1979 (Data set-2).

2. CPUE and estimation of effective fishing effort

The annual CPUE of bigeye tuna caught by the longline fishery was estimated in terms of catch in number per 100 hooks based on the catch and effort data of Japanese and Taiwanese longline fisheries for the years up to 1977 (Kume, 1979 c). This CPUE was converted into the CPUE in terms of weight using the annual average weight that was calculated from annual age composition of the bigeye tuna caught by the longline fishery for the years 1965 to 1976 (Kume 1978 and 1979 a). The values prior to 1964 were obtained from the available data on catch in number and weight, and 1977 average weight was substituted by 1976 value.

Using the CPUE obtained above, the effective fishing effort for whole longline fishery was estimated by dividing the total longline catch by the CPUE. The CPUE of surface fisheries has not been made available yet, so that the overall fishing effort was estimated as a product of the total catch (longline and surface catches combined) divided by the CPUE. The same procedure was excercised for three cases of hypothesized unit stocks and the results are shown in Tables 1-4.

3. Model analysis and the results

The fishery data above estimated were fitted to the computer program PRODFIT of a generalized production model by Fox (1975) for two cases of hypothesized stock structure. As imput parameters of the model, three basic m's, 0, 1.001 and 2, were selected and the number of dominant year class in the catch (k) was chosen as 4 and 5. The outputs on calculated maximum sustainable yield (Y-max), optimum fishing effort (f-opt) and degree of fit index, with observed catch in 1977, are tabulated in Table 5 for the case k=4. Although degree of fit indices were higher in the case of k=4 than k=5, except those of South Atlantic, the magnitude of difference in estimated parameters which were calculated by different k's were very small and less than those between Data sets. Estimated equilibrium curves are shown in Figs. 1-3 for the case of Data set-1 and k=4.

Atlantic-wide stock

The best fit to the model was obtained for m=0 for both Data sets, but their Y-max appears to be unlikely because they are realized at an infinite amount of effort and the shape of the curve beyond the experienced level of effort is not predictable. Y-max was higher in the case of Data set-2 than Data set-1 most likely due to the larger estimated surface catch. As far as the analysis indicates, it seems that the average MSY would be between 48-55 thousand tons, which brought about no substantial difference from the previous estimates made at last SCRS (Kume 1979 b). The observed catch in 1977 was 43,400 (or 49,600 for Data set-2) MT, being yet below the MSY and less than the estimated equilibrium catch (47,500 or 50,000 MT) of corresponding effort in 1977 (275 or 296 million hooks), for the Data set-1 case.

It seems that Atlantic-wide bigeye tuna stock has been exploited recently on high level, but the fishing effort has not exceeded the MSY level.

North Atlantic

The degree of the fitness of the data to the model was lowest among three cases of the stock structure, although it was higher than the previous analysis (Kume 1979 b). The best fit was obtained for m=2 in the Data set-1 and m=0 for the Data set-2. It is likely that the possible MSY would be between 32,500 and 40,300 MT, resulting in approximately the same as the previous estimates. The recent year-to-year change in catch and effort relation disclosed similar trend in the Atlantic-wide stock, but the degree of fluctuation has been greater (Fig. 2). The observed 1977 catch, 25,500 (or 26,700 for the case of Data set-2) MT, was a little below the average equilibrium catch

(31,700 or 31,300 MT) that corresponds to 1977 effort (173 million hooks).

South Atlantic

The data fitted relatively well to the model for both Data sets. It is uncertain which model describe the change in the stock in the future, but the average MSY would be in the range of 17-21 thousand MT. Both the observed catch and effort in 1977 were situated around the MSY level.

Without regard to the hypothesis on the stock structure, it appears that the recent status of the bigeye tuna fishery in the Atlantic has been near the MSY level since 1971, although never exceeded beyond that level. If the Atlantic stock is separated into north and south Atlantic, northern stock might be underutilized but the increase in catch would be marginal with the increased effort, whereas southern stock has been more heavily exploited and no increase in sustainable catch would be expected by increasing recent effort level.

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Table 1. Catch, hook rates in number and in kg per 100 hooks, average weight and effective effort for the bigeye fishery in the whole Atlantic, 1961-77.

WHOLE ATLANTIC (1)

| YEAR | HOOK RATE (NUMBER) | MEAN WEIGHT (KG) | HOOK RATE (WEIGHT) | CATCH($10^3$ MT) LONGLINE | TOTAL | EFFORT IN $10^6$ HOOKS |
|---|---|---|---|---|---|---|
| 1961 | 0.818 | 45 | 36.81 | 11.2 | 11.2 | 30.4 |
| 1962 | 0.682 | 43 | 29.33 | 15.9 | 16.0 | 54.6 |
| 1963 | 0.602 | 51 | 30.70 | 14.7 | 17.4 | 56.7 |
| 1964 | 0.563 | 50 | 28.15 | 17.6 | 20.4 | 72.5 |
| 1965 | 0.550 | 50 | 27.50 | 28.9 | 29.2 | 106.2 |
| 1966 | 0.482 | 48 | 23.14 | 18.7 | 19.0 | 82.1 |
| 1967 | 0.569 | 50 | 28.45 | 13.6 | 14.4 | 50.6 |
| 1968 | 0.541 | 48 | 25.97 | 17.9 | 19.8 | 76.2 |
| 1969 | 0.601 | 44 | 26.44 | 22.0 | 25.2 | 95.5 |
| 1970 | 0.504 | 49 | 24.70 | 21.4 | 29.6 | 119.8 |
| 1971 | 0.416 | 47 | 19.55 | 36.3 | 47.3 | 241.9 |
| 1972 | 0.372 | 44 | 16.37 | 32.5 | 36.6 | 222.4 |
| 1973 | 0.406 | 40 | 16.24 | 35.0 | 45.1 | 277.7 |
| 1974 | 0.534 | 47 | 25.10 | 35.7 | 55.2 | 219.9 |
| 1975 | 0.369 | 50 | 18.45 | 35.6 | 55.8 | 302.4 |
| 1976 | 0.290 | 47 | 13.63 | 25.8 | 40.9 | 300.1 |
| 1977 | 0.357 | 47 | 16.78 | 29.2 | 43.4 | 258.6 |

Table 2. Catch, hook rates in number and in kg per 100 hooks, average weight and effective effort for the bigeye fishery in the north Atlantic, 1961-77.

NORTH ATLANTIC (1)

| YEAR | HOOK RATE (NUMBER) | MEAN WEIGHT (KG) | HOOK RATE (WEIGHT) | CATCH(10 MT) LONGLINE | SURFACE | TOTAL | EFFORT IN $10^4$ HOOKS |
|---|---|---|---|---|---|---|---|
| 1961 | 0.742 | 46 | 34.13 | 3.1 | - | 3.1 | 9.1 |
| 1962 | 0.684 | 43 | 29.41 | 8.5 | - | 8.5 | 28.9 |
| 1963 | 0.635 | 51 | 32.39 | 8.4 | 2.7 | 11.1 | 25.9 |
| 1964 | 0.586 | 50 | 29.30 | 10.9 | 2.8 | 13.7 | 46.8 |
| 1965 | 0.601 | 53 | 31.85 | 14.7 | 0.1 | 14.8 | 46.5 |
| 1966 | 0.486 | 43 | 20.90 | 8.9 | 0.3 | 9.2 | 44.0 |
| 1967 | 0.507 | 43 | 21.80 | 3.8 | 0.3 | 4.1 | 18.8 |
| 1968 | 0.536 | 48 | 25.73 | 5.6 | 0.9 | 6.5 | 25.3 |
| 1969 | 0.528 | 50 | 26.40 | 5.8 | 2.6 | 8.4 | 31.8 |
| 1970 | 0.545 | 47 | 25.62 | 11.0 | 7.9 | 18.9 | 73.8 |
| 1971 | 0.390 | 45 | 17.55 | 18.6 | 10.2 | 28.8 | 164.1 |
| 1972 | 0.377 | 41 | 15.46 | 14.8 | 3.3 | 18.1 | 117.1 |
| 1973 | 0.469 | 36 | 16.88 | 19.1 | 9.2 | 28.3 | 167.7 |
| 1974 | 0.623 | 48 | 29.90 | 25.5 | 16.6 | 42.1 | 140.8 |
| 1975 | 0.363 | 52 | 18.88 | 23.1 | 16.3 | 39.4 | 208.7 |
| 1976 | 0.255 | 46 | 11.73 | 12.0 | 8.8 | 20.8 | 177.3 |
| 1977 | 0.348 | 46 | 16.01 | 15.6 | 9.9 | 25.5 | 159.3 |

Table 3. Catch, hook rates in number and in kg per 100 hooks, average weight and effective effort for the bigeye fishery in the south Atlantic, 1961-77.

SOUTH ATLANTIC (1)

| YEAR | HOOK RATE (NUMBER) | MEAN WEIGHT (KG) | HOOK RATE (WEIGHT) | CATCH($10^3$ MT) LONGLINE | SURFACE | TOTAL | EFFORT IN $10^6$ HOOKS |
|---|---|---|---|---|---|---|---|
| 1961 | 0.833 | 46 | 38.32 | 8.2 | - | 8.2 | 21.4 |
| 1962 | 0.627 | 43 | 26.96 | 7.4 | - | 7.4 | 27.4 |
| 1963 | 0.519 | 51 | 26.47 | 6.3 | - | 6.3 | 23.8 |
| 1964 | 0.498 | 51 | 25.40 | 6.7 | - | 6.7 | 26.4 |
| 1965 | 0.502 | 48 | 24.10 | 14.3 | 0.1 | 14.4 | 59.8 |
| 1966 | 0.480 | 53 | 25.44 | 9.7 | - | 9.7 | 38.1 |
| 1967 | 0.598 | 54 | 32.29 | 9.8 | 0.5 | 10.3 | 31.9 |
| 1968 | 0.541 | 48 | 25.97 | 12.3 | 1.1 | 13.4 | 51.6 |
| 1969 | 0.644 | 41 | 26.40 | 16.2 | 0.6 | 16.8 | 63.6 |
| 1970 | 0.477 | 51 | 22.80 | 10.4 | 0.3 | 10.7 | 46.9 |
| 1971 | 0.442 | 48 | 21.22 | 17.7 | 0.7 | 18.4 | 86.7 |
| 1972 | 0.369 | 47 | 17.34 | 17.7 | 0.9 | 18.6 | 107.3 |
| 1973 | 0.370 | 44 | 16.28 | 15.9 | 1.0 | 16.9 | 103.8 |
| 1974 | 0.380 | 44 | 16.72 | 10.2 | 3.0 | 13.2 | 78.9 |
| 1975 | 0.379 | 47 | 17.81 | 12.5 | 3.9 | 16.4 | 92.1 |
| 1976 | 0.372 | 48 | 17.86 | 13.7 | 6.3 | 20.0 | 112.0 |
| 1977 | 0.389 | 48 | 18.67 | 13.4 | 4.2 | 17.6 | 94.3 |

Table 4. Alternative estimates of cathes and efforts on bigyee tuna in the north, south and whole Atlantic, 1961-77, when differnet estimates of surface catch (Marcille 1978) are used.

| YEAR | NORTH ATLANTIC (2) CATCH ($10^3$ MT) SURFACE | TOTAL | EFFORT IN $10^6$ HOOKS | SOUTH ATLANTIC (2) CATCH ($10^3$ MT) SURFACE | TOTAL | EFFORT IN $10^6$ HOOKS | WHOLE ATLANTIC (2) TOTAL CATCH ($10^3$ MT) | EFFORT IN $10^6$ HOOKS |
|---|---|---|---|---|---|---|---|---|
| 1961 | - | 3.1 | 9.1 | - | 8.2 | 21.4 | 11.3 | 30.7 |
| 1962 | - | 8.5 | 28.9 | - | 7.4 | 27.4 | 15.9 | 54.6 |
| 1963 | 2.7 | 11.1 | 25.9 | - | 6.3 | 23.8 | 17.4 | 56.7 |
| 1964 | 8.8 | 19.7 | 67.2 | - | 6.7 | 26.4 | 26.4 | 93.8 |
| 1965 | 5.5 | 20.2 | 63.4 | 0.1 | 14.4 | 59.8 | 34.6 | 125.8 |
| 1966 | 5.2 | 14.1 | 67.5 | - | 9.7 | 38.1 | 23.8 | 114.2 |
| 1967 | 9.0 | 12.8 | 58.7 | 0.9 | 10.7 | 33.1 | 23.5 | 82.6 |
| 1968 | 4.1 | 9.7 | 37.7 | 1.4 | 13.7 | 52.8 | 23.4 | 90.1 |
| 1969 | 8.0 | 13.8 | 52.3 | 1.1 | 17.3 | 65.5 | 31.1 | 117.6 |
| 1970 | 8.1 | 19.1 | 74.6 | 1.0 | 11.4 | 50.0 | 30.5 | 123.5 |
| 1971 | 10.1 | 28.7 | 163.5 | 3.4 | 21.1 | 99.4 | 49.8 | 254.7 |
| 1972 | 8.0 | 22.8 | 147.5 | 2.2 | 19.9 | 114.8 | 42.7 | 260.8 |
| 1973 | 10.5 | 29.6 | 175.4 | 3.5 | 19.4 | 119.2 | 49.0 | 301.7 |
| 1974 | 12.6 | 38.1 | 127.4 | 4.5 | 14.7 | 87.9 | 52.8 | 210.4 |
| 1975 | 14.1 | 37.2 | 197.0 | 5.0 | 17.5 | 98.3 | 54.7 | 296.5 |
| 1976 | 7.5 | 20.8 | 177.3 | 10.4 | 24.1 | 134.9 | 44.9 | 306.9 |
| 1977 | 11.1 | 26.7 | 166.8 | 9.5 | 22.9 | 122.7 | 49.6 | 295.6 |

Table 5. Population parameters estimated by production model analysis for the Atlantic bigeye tuna fishery, 1961-77. (k=4)

| | | m | Degree of fit index | f-opt ($10^6$ hooks) | $Y_{max}$ ($10^3$ MT) | 1977 catch (1,000 MT) |
|---|---|---|---|---|---|---|
| Data set - 1 | Whole Atlantic | 0 | 0.637 | ∞ | 99.6 | 43.4 |
| | | 1.001 | 0.634 | 459 | 52.8 | |
| | | 2 | 0.632 | 322 | 48.1 | |
| | North Atlantic | 0 | 0.322 | ∞ | 85.1 | 25.5 |
| | | 1.001 | 0.333 | 377 | 40.3 | |
| | | 2 | 0.377 | 244 | 34.6 | |
| | South Atlantic | 0 | 0.811 | ∞ | 29.5 | 17.6 |
| | | 1.001 | 0.821 | 133 | 17.5 | |
| | | 2 | 0.821 | 101 | 16.6 | |
| Data set - 2 | Whole Atlantic | 0 | 0.624 | ∞ | 98.6 | 49.6 |
| | | 1.001 | 0.622 | 465 | 54.9 | |
| | | 2 | 0.619 | 328 | 50.1 | |
| | North Atlantic | 0 | 0.363 | ∞ | 71.1 | 26.7 |
| | | 1.001 | 0.361 | 314 | 36.3 | |
| | | 2 | 0.362 | 216 | 32.5 | |
| | South Atlantic | 0 | 0.801 | ∞ | 36.2 | 22.9 |
| | | 1.001 | 0.800 | 165 | 20.5 | |
| | | 2 | 0.787 | 124 | 19.4 | |

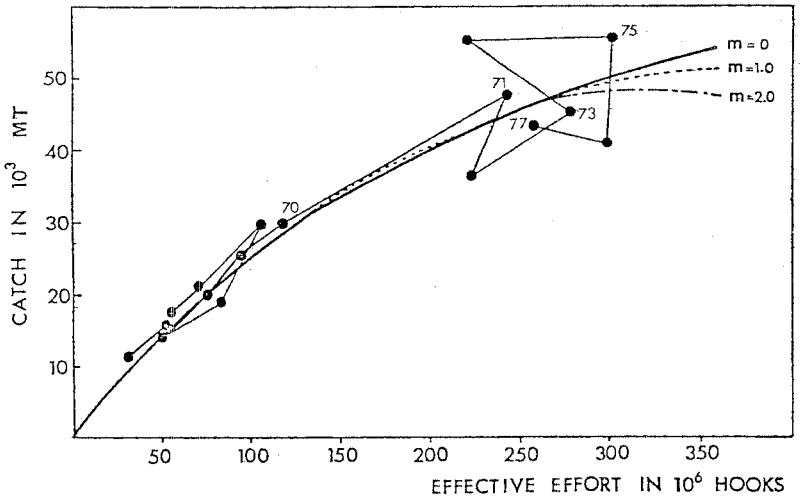


Fig. 1. Yield curves obtained from the production model analysis and observed catch and effort for bigeye tuna in the whole Atlantic Ocean, 1961-77 (k=4).

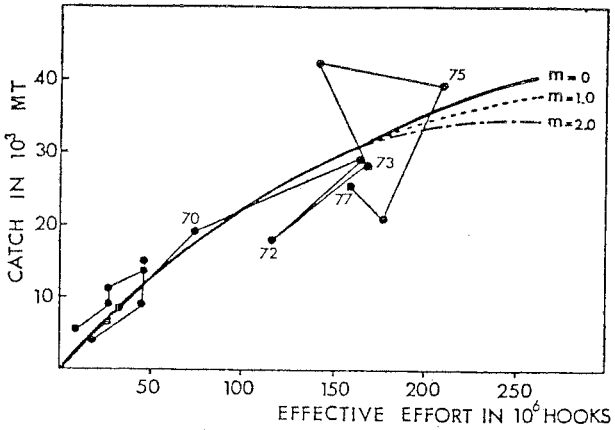


Fig. 2. Yield curves obtained from the production model analysis and observed catch and effort for bigeye tuna in the north Atlantic Ocean, 1961-77 (k=4).

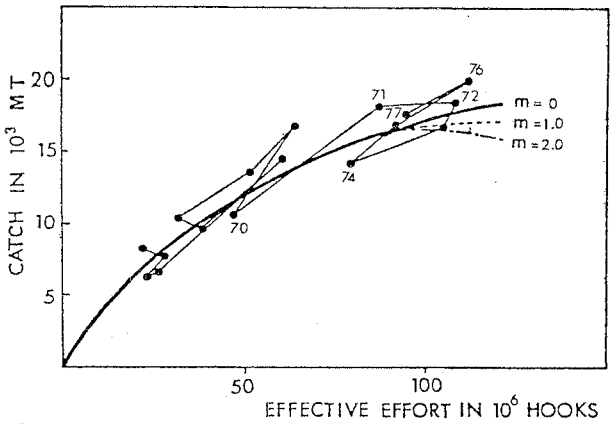


Fig. 3. Yield curves obtained from the production model analysis and observed catch and effort for bigeye tuna in the north Atlantic Ocean, 1961-77 (k=4).