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EVALUATION OF STOCK STATUS ON ATLANTIC BIGEYE TUNA, BY PRODUCTION MODEL ANALYSIS

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SUMMARY

An approach to the current appraisal on the stock status of Atlantic bigeye tuna was made by production model analysis. The input effort data of the model were obtained on the basis of standardized effort using Japanese catch and effort data. The results for two stock structure hypotheses, whole Atlantic or north and south Atlantic, indicated about the same stock conditions as documented in last year's analysis (SCRS/81/34). In recent years, the stock(s) has been harvested nearly at the level of estimated maximum sustainable yield.

RESUME

Une tentative d'évaluation actuelle de l'état du stock de thon obèse de l'Atlantique a été faite au moyen de l'analyse du modèle de production. Les données d'effort du modèle en entrée ont été obtenues à partir de l'effort standard en utilisant les données japonaises de prise et effort. Les résultats pour deux hypothèses de structure de stock, Atlantique entier ou Atlantique nord et sud, montrent que les conditions du stock sont restées les mêmes que ce que l'analyse de l'an dernier démontrait (SCRS/81/34). Le(s) stock(s) ont été exploités ces dernières années à un niveau proche des estimations de la production maximale équilibrée.

RESUMEN

Por análisis del modelo de producción se hizo una evaluación tentativa de la situación del stock de patudo atlántico. Los datos de esfuerzo para el modelo se obtuvieron en base al esfuerzo normalizado, empleando datos japoneses de captura y esfuerzo. Los resultados obtenidos bajo las dos hipótesis de estructura del stock - todo el Atlántico, o Norte y Sur del Atlántico - señalaban hacia las mismas condiciones presentadas en el análisis del año pasado (SCRS/81/34). En años recientes, el stock, o stocks, ha sido explotado a un nivel cercano al rendimiento máximo sostenible estimado.

1. INTRODUCTION

Bigeye tuna in the Atlantic are distributed widely in temperate and tropical waters encompassed between 40° N and 40° S. Spawning group and juveniles inhabit in equatorial waters and the fish at feeding stage migrate into temperate waters north of 20° N or south of 20° S. Whether or not the Atlantic bigeye are composed of single unit of stock is still uncertain, and present understanding on the stock structure is that there may be more than a single stock, possibly being separated into two substocks in the north and south Atlantic, respectively.

Annual catch in the past recorded the highest of nearly 60,000 MT in 1974, and since then it ranged at fairly high level between 38,000 and 56,000 MT. The largest share of the catch has been historically made by longline fishing gear, recently being accounted for two thirds of the total catch (Fig. 1).

The last appraisal of the stock condition of Atlantic bigeye resources indicated that the stock has been exploited at a high level, but not exceeding the level of maximum sustainable yield, regardless of the stock structure hypothesis (ICCAT 1981). It is noted that the size limit regulation has been effective since September 1980, to increase further benifit of the production from the stock and to avoid reporting of undersized yellowfin tuna as bigeye tuna. This paper updated the estimation of effective fishing effort of longline fishery up to 1980, on the basis of which production model analysis was conducted to evaluate the status of the stock.

2. Estimation of longline effective effort on bigeye

It is essential that nominal fishing effort of the longline fishery should be standardized, since the gear directs its effort for various species. For this purpose, estimation of effective effort on bigeye tuna has been up-todated based on estimation procedure developed by Honma (1973). The procedure employs, in summary, the adjustment technique such that the nominal effort is converted into the effective effort using the ratio of the density of a small unit area to average density of the stock, namely the nominal effort invested in the area of average density is equivalent to the effective effort. Correction factors in 5 x 5 area were calculated from the average density of Japanese longline catch and effort data during 1965-75, when the longline fishery covered entire bigeye longline fishing grounds. As described in the previous study (Kume 1982), the standardized Japanese effort was used as basic data, upon which CPUE of bigeye tuna in terms of hook rate was calculated. Overall longline fishing effort was estimated by extrapolating with the catch ratio between Japanese catch and total longline catch. Longline catch data, including north-south separation, were obtained from the Statistical Bulletin (ICCAT 1982). The results of estimated effort statistics are tabulated in Table 1 for three possible stock unit; Atlantic-wide, north and south Atlantic, respectively.

3. Trend in hook rate

The Japanese longline fishery has been covering vast bigeye fishing grounds in the Atlantic, and the share of the bigeye catch in the total has also been large. Therefore, catch rate of the fishery represents relative abundance of the stock well. An annual changes in hook rate, expressed by catch in number per 100 effective hooks, are shown in Fig. 2 for whole, north and south Atlantic. The hook rates in 1980 remained at about the same level of recent years average. In the case of north Atlantic, the 1980 hook rate indicated a small increase. As to long-term fluctuation, since 1961 when longline fishery expanded to cover nearly entire bigeye distribution, the annual hook rate of the whole Atlantic stock has been on the gradual decreasing trend. Annual changes in hook rates in north and south Atlantic followed almost similar long-term trend to that of the whole Atlantic, except the difference in temporal peak year as in 1969 for the south Atlantic and in 1974 for the north Atlantic. Recent level of relative abundance of the stock(s) is assumed to be two thirds of the level of the initial exploitation.

Because the longline catch is composed of medium- and large-sized individuals, it appears that the adult or spawning biomass of Atlantic bigeye tuna is still remaining at relatively higher level.

4. Production model analysis

Production model analysis has been applied to evaluate the Atlantic bigeye tuna stock. The effort data as necessary input in the model were estimated for the year up to 1980 by the following procedure;

(1) the annual hook rate, in terms of number of fish caught was converted into hook rate in terms of weight using annual average weight (Table 1), and

(2) the effort for surface fisheries was substituted by the longline effort, and the total fishing effort was obtained by dividing the total catch by the hook rate in weight. All input data are shown in Table 2. Three basic m's (shape parameter; 0, 1.001 and 2) and k, number of dominant year classes in the catch and selected as 4, were fitted to the computer program PRODFIT of a generalized production model (Fox 1975). The calculation was made for three hypothesized unit stocks. The results on calculated maximum sustainable yield (Y-max), optimum fishing effort (f-opt) and degree of fit index, with observed catch in 1980, are shown in Table 3, and estimated yield curves are shown in Figs. 3-5.

Atlantic-wide stock

The present analysis resulted in almost the same outcome as the last year's analysis (Kume 1982). The average MSY (Y-max) obtained from m=0 case was 111,200 MT, which appears to be unrealistic because it is realized at an infinite amount of effort. The other two estimates of MSY were 58,700 and 52,900 MT, for m=1.001 and m=2, respectively. During recent three years, 1978-80, the catch ranged between 39,600 and 56,100 MT and the effort 214-269 million hooks. The 1980 catch exceeded the estimated MSY of the case of m=2, although the corresponding effort was still below the optimum level. It may be concluded that Atlantic-wade bigeye stock has recently been exploited at a high level, and that the increase in catch would not be expected if the effort is increased from the present level.

North Atlantic stock

It is again unlikely that the possible MSY of 70,900 MT with m=0 is realistic, though the best fit was resulted in. The past catches exceeded the smallest estimate of MSY, 32,900 MT, in 1974 and 1975, with the effort less than the level of MSY. Both the catches and efforts recently observed, 20,500-28,400 MT and 116-133 million hooks, during 1977-80, have been far below the estimated level of MSY. It may be that the catch increase, though probably marginal, would be expected by increasing effort from the present level.

South Atlantic stock

The model fitted to the data best among three analyses. The best fit was with m=2, by which msy of 21,400 is expected with the effort of 125 million hooks. Both the observed catches and efforts until 1979 were situated around MSY level. The 1980 catch increased in excess of the levels of two estimates of MSY, with the effort around optimum efforts.

In summary, as far as the present production model analysis is concerned, it appears that the recent status of the Atlantic-wide stock has been close or around the MSY level since 1971, suggesting the level of exploitation has been high. If the Atlantic stock is separated into north and south Atlantic, northern stock may be less utilized, whereas southern stock has been more heavily exploited and further increase in effort would not turn out an increased production.

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Table 1. Catch, effective effort and CPUE(hook rate) on Atlantic bigeye tuna by the longline fleet, 1957-80.

WHOLE ATLANTIC

YEAR	JAPANESE LONGLINE FLEET: CATCH IN NUMBER (1000)	YIELD IN WEIGHT (1000 MT)	EFFECTIVE HOOKS (MILLION)	HOOK RATE	WHOLE LL FLEET: YIELD IN WEIGHT (1000 MT)	EFFECTIVE HOOKS (MILLION)
1957	8.7	0.5	2.7	0.320	0.5	2.7
1958	14.8	0.5	5.9	0.251	0.5	5.9
1959	44.8	1.5	11.4	0.394	1.5	11.4
1960	70.6	2.9	15.5	0.454	3.0	16.0
1961	243.7	11.0	29.8	0.619	11.2	30.3
1962	367.9	15.7	54.0	0.682	16.0	55.0
1963	285.3	14.5	47.4	0.602	15.0	49.0
1964	343.7	17.3	61.1	0.563	17.8	62.9
1965	648.3	28.5	117.9	0.530	29.4	121.6
1966	222.1	17.6	48.1	0.482	19.6	53.6
1967	180.9	8.5	31.3	0.575	13.2	48.9
1968	204.6	10.3	31.2	0.653	18.8	56.9
1969	263.6	10.3	38.1	0.691	23.0	85.1
1970	187.3	9.0	33.5	0.559	28.1	104.6
1971	394.9	20.3	85.7	0.461	39.1	165.1
1972	346.0	18.1	79.5	0.485	32.5	142.7
1973	391.3	20.0	77.1	0.507	37.9	146.1
1974	457.3	20.9	69.0	0.663	39.1	129.1
1975	449.1	17.4	111.5	0.396	40.8	266.1
1976	171.0	7.3	50.6	0.338	27.4	189.9
1977	189.6	9.2	36.5	0.520	29.1	115.3
1978	209.2	9.3	48.9	0.428	28.2	148.3
1979	270.4	12.0	64.4	0.420	27.2	146.0
1980	451.3	20.5	96.9	0.466	41.0	193.8

NORTH ATLANTIC

YEAR	JAPANESE LONGLINE FLEET: CATCH IN NUMBER (1000)	YIELD IN WEIGHT (1000 MT)	EFFECTIVE HOOKS (MILLION)	HOOK RATE	WHOLE LL FLEET: YIELD IN WEIGHT (1000 MT)	EFFECTIVE HOOKS (MILLION)
1957	7.3	0.4	2.0	0.196	0.4	2.0
1958	13.0	0.4	5.1	0.256	0.4	5.1
1959	39.9	1.3	9.6	0.417	1.3	9.6
1960	50.1	2.1	10.3	0.488	2.1	10.3
1961	67.6	3.1	9.1	0.742	3.1	9.1
1962	199.1	8.5	29.1	0.684	8.5	29.1
1963	146.0	8.4	26.2	0.635	8.4	26.2
1964	219.2	10.9	37.4	0.586	10.9	37.4
1965	339.1	14.7	56.5	0.601	14.7	56.5
1966	121.6	8.8	25.0	0.486	9.1	25.9
1967	75.3	3.4	14.9	0.506	4.1	18.0
1968	86.1	4.0	18.3	0.645	6.2	20.6
1969	65.2	2.4	12.9	0.504	6.4	34.4
1970	103.9	4.7	17.2	0.603	15.1	55.3
1971	258.5	13.1	60.0	0.431	18.6	85.2
1972	227.8	11.8	56.9	0.401	14.8	71.4
1973	219.6	11.1	37.0	0.593	19.1	62.7
1974	388.9	17.6	54.0	0.720	23.6	78.5
1975	320.0	12.4	83.0	0.385	24.6	164.7
1976	137.2	5.9	44.7	0.307	14.0	106.1
1977	107.5	5.3	21.7	0.495	16.1	65.9
1978	126.8	5.8	28.8	0.440	13.2	65.5
1979	127.4	5.1	30.9	0.412	10.8	65.6
1980	268.2	11.1	51.5	0.520	17.6	81.7

SOUTH ATLANTIC

YEAR	JAPANESE LONGLINE FLEET: CATCH IN NUMBER (1000)	YIELD IN WEIGHT (1000 MT)	EFFECTIVE HOOKS (MILLION)	HOOK RATE	WHOLE LL FLEET: YIELD IN WEIGHT (1000 MT)	EFFECTIVE HOOKS (MILLION)
1957	1.4	0.1	0.6	0.218	0.1	0.6
1958	1.8	0.1	0.8	0.219	0.1	0.8
1959	4.9	0.2	1.8	0.266	0.2	1.8
1960	20.5	0.8	6.2	0.333	0.9	7.0
1961	176.0	8.0	21.1	0.833	8.1	21.4
1962	168.8	7.2	26.9	0.627	7.5	28.0
1963	119.3	6.1	23.0	0.519	6.6	24.9
1964	124.6	6.4	25.0	0.498	6.9	27.0
1965	309.2	13.9	61.6	0.502	14.7	65.1
1966	110.5	8.8	23.0	0.480	10.6	27.7
1967	105.6	5.2	17.3	0.610	9.2	30.6
1968	118.5	6.2	18.0	0.458	12.6	36.6
1969	198.4	7.9	24.5	0.810	16.6	51.5
1970	83.4	4.3	16.3	0.512	13.0	49.3
1971	136.5	7.1	26.4	0.517	20.5	76.2
1972	118.2	6.3	24.1	0.490	17.7	67.7
1973	171.9	8.8	38.7	0.445	18.8	82.7
1974	68.4	3.2	14.9	0.458	13.5	62.9
1975	129.0	5.0	32.4	0.398	16.2	105.0
1976	33.8	1.4	6.3	0.539	13.4	60.3
1977	82.2	3.9	14.7	0.561	13.0	49.0
1978	82.5	3.6	20.5	0.402	15.0	85.4
1979	143.0	6.8	34.3	0.417	16.4	82.7
1980	183.1	9.4	44.1	0.415	23.4	109.8

Table 2. Input fishery data on production model for Atlantic bigeye tuna, 1961-80.

WHOLE ATLANTIC

YEAR	MEAN WEIGHT (KG)	HOOK RATE (KG/100 HOOKS)	TOTAL CATCH (1000 MT)	TOTAL EFFORT (MILLION)
1961	45	36.8	17.0	46.2
1962	43	29.3	23.1	78.8
1963	51	30.7	26.0	84.7
1964	50	28.2	23.5	83.3
1965	50	27.5	39.2	142.5
1966	48	23.1	25.0	108.2
1967	50	28.8	24.7	85.8
1968	48	31.4	23.0	73.2
1969	44	30.4	33.6	110.5
1970	49	27.4	39.2	143.1
1971	47	21.7	52.1	240.1
1972	44	19.1	42.8	224.1
1973	40	20.3	53.9	265.5
1974	47	31.2	60.0	192.3
1975	50	19.8	56.7	286.4
1976	47	15.9	38.4	241.3
1977	49	25.5	45.7	179.2
1978	45	19.3	45.3	234.7
1979	44	18.5	39.6	214.1
1980	45	21.0	56.1	267.1

NORTH ATLANTIC

YEAR	MEAN WEIGHT (KG)	HOOK RATE (KG/100 HOOKS)	TOTAL CATCH (1000 MT)	TOTAL EFFORT (MILLION)
1961	46	34.1	8.9	26.1
1962	43	29.4	15.6	53.1
1963	51	32.4	19.3	59.6
1964	50	29.3	16.6	56.7
1965	53	31.9	24.4	76.5
1966	43	20.9	14.4	68.9
1967	43	21.8	15.1	69.3
1968	48	31.0	9.3	30.0
1969	50	25.2	15.0	59.5
1970	47	28.3	24.8	87.6
1971	45	19.4	29.0	149.5
1972	41	16.4	22.1	134.8
1973	36	21.3	30.0	140.8
1974	48	34.6	40.4	116.8
1975	52	20.0	39.0	195.0
1976	46	14.1	22.6	160.3
1977	49	24.3	28.1	115.6
1978	46	20.2	26.8	132.7
1979	40	16.5	20.5	124.2
1980	41	21.3	28.4	133.3

SOUTH ATLANTIC

YEAR	MEAN WEIGHT (KG)	HOOK RATE (KG/100 HOOKS)	TOTAL CATCH (1000 MT)	TOTAL EFFORT (MILLION)
1961	46	38.3	8.1	21.1
1962	43	27.0	7.5	27.8
1963	51	26.5	6.7	25.3
1964	51	25.4	6.9	27.2
1965	48	24.1	14.8	61.4
1966	53	25.4	10.6	41.7
1967	54	32.9	9.6	29.2
1968	48	31.6	13.7	43.4
1969	41	33.2	18.6	56.0
1970	51	26.1	14.5	55.6
1971	48	24.8	23.0	92.7
1972	47	23.0	20.7	90.0
1973	44	19.6	24.0	122.4
1974	44	20.2	19.6	97.0
1975	47	18.7	17.7	94.7
1976	48	25.9	15.8	61.0
1977	47	26.4	17.6	66.7
1978	44	17.7	18.5	104.5
1979	48	20.0	19.1	95.5
1980	51	21.2	27.7	130.7

Table 3. Maximum sustainable yield (Y-max) and corresponding effort (f-opt) estimated by production model analysis for Atlantic bigeye tuna fishery, 1961-1980.

	m	Degree of fit index	f-opt (million hooks)	Y-max (1,000 MT)	1980-catch (1,000 MT)
Whole Atlantic	0	0.558		111.2	56.1
	1.001	0.552	441	58.7	
	2	0.546	306	52.9	
North Atlantic	0	0.369		70.9	28.4
	1.001	0.367	282	36.8	
	2	0.366	194	32.9	
South Atlantic	0	0.623		49.2	27.7
	1.001	0.632	192	24.8	
	2	0.636	125	21.4	

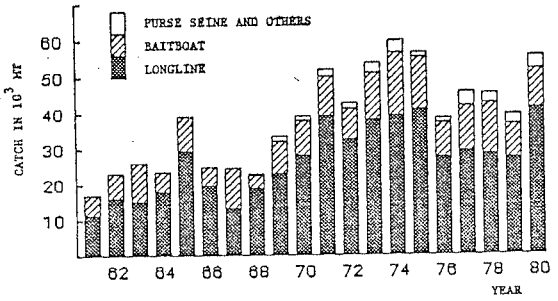

Fig. 1. Yearly bigeye catch by gear in the Atlantic, 1961-80.

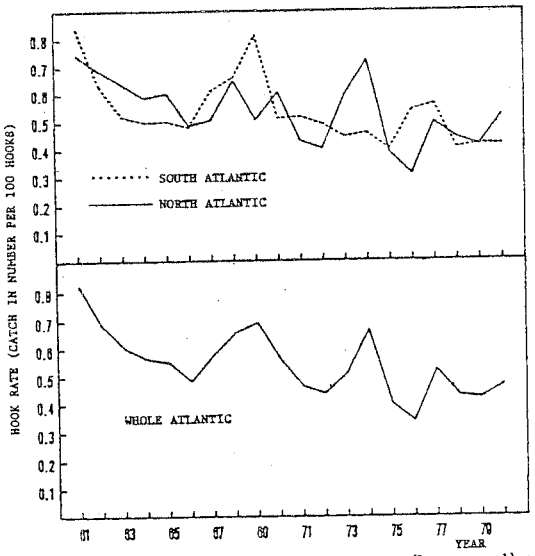

Fig. 2. Annual change in hook rates in the whole Atlantic (lower pannel) and in the north and south Atlantic (upper pannel), 1961-80.

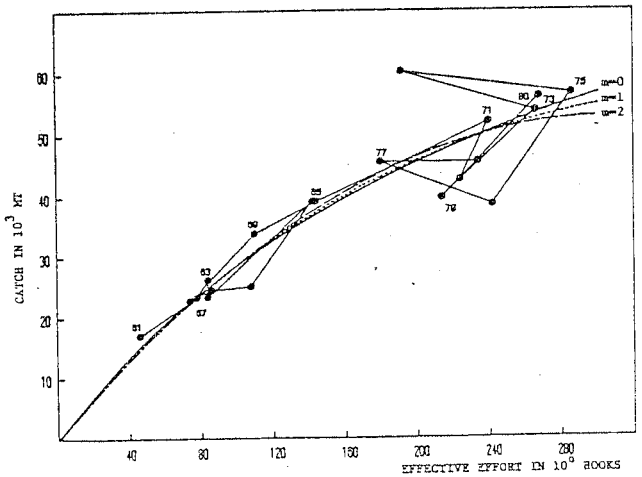

Fig. 3. Yield curves obtained from production model analysis for bigeye tuna in the whole Atlantic, 1961-80.

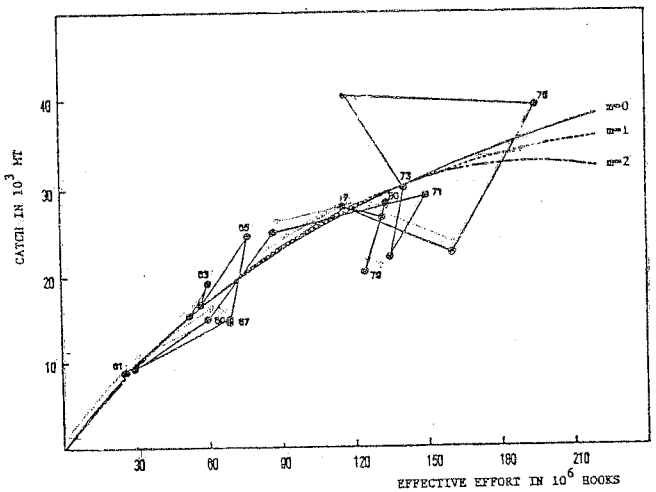

Fig. 4. Yield curves obtained from the production model analysis for bigeye tuna in the north Atlantic, 1961-80.

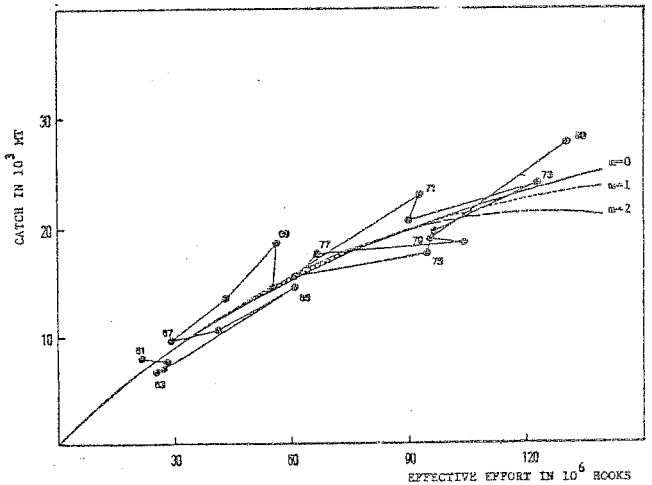

Fig. 5. Yield curves obtained from the production model analysis for bigeye tuna in the south Atlantic, 1961-80.