

OVERALL FISHING INTENSITY ON ATLANTIC BIGEYE TUNA CAUGHT BY LONGLINE FISHERY AND
EVALUATION OF THE STOCK STATUS BY PRODUCTION MODEL ANALYSIS

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SUMMARY

A series of studies on estimation of effective fishing effort on bigeye tuna is updated. Based on the results, a production model analysis is conducted to evaluate the stock status.

RESUME

Le présent document met à jour un certain nombre d'études sur l'estimation de l'effort de pêche effectif du thon obèse. Une analyse du modèle de production est effectuée à partir de ces résultats pour évaluer l'état du stock.

RESUMEN

Se han puesto al día una serie de estudios sobre la estimación del esfuerzo de pesca efectivo con respecto al patudo. Basándose en los resultados, se ha realizado un análisis del modelo de producción para evaluar la situación del stock.

1. Introduction

Atlantic bigeye tuna are distributed in wide area encompassed between 40°N and 40°S. Spawning group and juveniles inhabit in equatorial waters and the fish at feeding stage occur in the temperate waters north of 20°N or south of 20°S. The annual catch in 1974 recorded the highest of nearly 60,000 MT, and it ranged between 40,000 and 50,000 MT in recent three years, 1977-79. Main fishing gear for harvesting bigeye tuna has been longlining, recently being accounted for 2/3 of the total catch (Fig. 1).

The latest stock assessment on the condition of the Atlantic bigeye resources revealed that the stock is currently exploited at a high level (ICCAT 1980). In addition, the size limit regulation common to that of yellowfin tuna has been effective since September 7, 1980, to increase further benefit from the resources and to avoid reporting of the undersized yellowfin tuna as bigeye tuna. Under these circumstances, this paper updated the estimation on effective fishing effort of longline fishery up to 1979, on the basis of which production model analysis was conducted to evaluate current status of the stock.

2. Estimation of effective effort on bigeye caught by longline fishery

Updating of estimation of effective effort of longline fishery for bigeye tuna has been continued every year based on estimation procedure by Honma (1973). In essence, standardization of nominal effort to effective effort is to adjust the former 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 equals to the effective effort. Correction factors in 5x5 area were calculated from the average density of Japanese longline data during 1965-75, when the longline fishery covered entire bigeye longline fishing grounds. As was treated in the previous study (Kume 1981), the Japanese effort data were standardized into effective fishing effort as basic data, upon which CPUE of bigeye tuna in terms of hook rate was calculated. Based on the Japanese effective effort, overall longline fishing effort was estimated by

extrapolating with catch ratio. Longline catch data, including north-south separation, were obtained from revised data base at ICCAT. The results of above fishing effort statistics are tabulated in Tables 1 for three possible stock unit: Atlantic-wide, north and south Atlantic.

3. Trend in hook rate and catch-effort relation of longline fishery

An annual change in hook rate, expressed by catch in number per 100 effective hooks, is shown in Fig. 2 for whole Atlantic and north and south Atlantic. The hook rates in 1979 remained at about the same level of recent three years average. An addition of one year point, 1979, does not alter the explanation of the trend previously given. 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 on long-term basis, although high hook rates were observed in 1964 and 1974. Annual changes in hook rates in north and south Atlantic indicate almost similar long-term trend to that of 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 or stocks is assumed to be two thirds of the level of the initial exploitation. Since the longline catch is composed medium- and large-sized individuals, it seems that the adult or spawning stock of Atlantic bigeye has remained still at relatively higher level compared to other tuna species exploited in the Atlantic.

Relation between catch and effort of bigeye tuna caught by longline fishery for three assumed stock units are shown in Figs. 3-5. In all cases, the relationship followed almost straight increase until early 1970s. In 1975, the effort increased remarkably to the record highest, but the corresponding catch did not increase to the extent that could be expected from the past relationship. During recent three years, 1977-79, both levels of catch and effort did not vary much and stationed below the highest record of 1975, except for the catch of south Atlantic in 1979.

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 years up to 1979: 1) the annual hook rate, in terms of number of fish caught (Table 1) was converted into hook rate in terms of weight in kg, by multiplying the former hook rate with respective average weight of the catch that were updated after Kume (1981), 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 pertinent input data are shown in Table 2. Three basic m 's (shape parameter: 0, 1.001 and 2) and k , parameter for 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 1979, are tabulated in Table 3, and estimated yield curves are shown in Figs. 6-8.

Atlantic-wide stock

Although there were revisions in the past catch data, especially for Portuguese catch, and addition of one year's data point, the interpretation of the present results does not change from the last year's analysis (Kume 1981). The average MSY (Y_{max}) obtained from $m=0$ case was 111,900 MT, which appears to be unrealistic because it is realized at an infinite amount of effort. The other two estimates of MSY were 58,200 MT and 52,800 MT, for $m=1.001$ and $m=2$, respectively. During recent three years, 1977-79, the catch ranged between 41,100 and 45,700 MT and the effort 179-235 million hooks. Such levels of catch and effort are fairly below the possible estimates of MSY level obtained in this study. It may be concluded as previously that Atlantic-wide bigeye stock has been under-exploited but recent exploitation has been relatively at a high level, and that the increase in catch would be marginal when the effort is increased from the present level.

North Atlantic stock

It is again unlikely that the possible MSY of 72,000 MT with $m=0$ is realistic, though the best fit was resulted in. The past catches exceeded the smallest estimate of MSY, 33,100 MT, in 1974 and 1975, with the effort less than the level of MSY. Both the catches and efforts recently observed, 20,500-28,100 MT and 116-133 million hooks, during 1977-79, have been far below the estimated level of MSY. It seems that the catch increase would be expected by increasing effort from the recent 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 20,600 is expected with the effort of 119 million hooks. Both the observed catches and efforts in 1978 and 1979 were situated around the MSY level.

As far as the production model is concerned, general conclusion on the status of Atlantic bigeye stock(s) is nearly the same as that derived by the previous analysis (Kume 1981). It appears that the recent status of the Atlantic-wide stock has been close to the MSY level since 1971, and increase in catch would be marginal by increasing the present effort. If the Atlantic stock is separated into north and south Atlantic, northern stock might be less utilized, whereas southern stock has been more heavily exploited and no increase of sustainable catch would be expected by increasing recent level of effort.

References

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Table 1. Catch, effective effort and fishing intensity on bigeye tuna caught by the longline fleet in the Atlantic ocean, 1957-79.

WHOLE ATLANTIC						
Year	Japanese longline data				Whole longline fleet	
	Catch in number (10 ³) (A)	Yield in weight (10 ³ MT) (B)	Effective hooks (10 ⁶) (C)	Hook rate 100x(A)/(C)	Yield in weight (10 ³ MT) (E)	Effective hooks (10 ⁶) (C)x(E)/(B)
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	29.5	0.818	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	0.550	29.4	121.6
1966	232.1	17.6	48.1	0.482	19.6	53.6
1967	180.9	8.5	31.5	0.575	13.2	48.9
1968	204.6	10.3	31.2	0.655	18.8	56.9
1969	263.6	10.3	38.1	0.691	23.1	85.4
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	0.435	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	113.5	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	115.5
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

NORTH ATLANTIC						
Year	Japanese longline data				Whole longline fleet	
	Catch in number (10 ³) (A)	Yield in weight (10 ³ MT) (B)	Effective hooks (10 ⁶) (C)	Hook rate 100x(A)/(C)	Yield in weight (10 ³ MT) (E)	Effective hooks (10 ⁶) (C)x(E)/(B)
1957	7.3	0.4	2.0	0.396	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	0.884	8.5	29.1
1963	166.0	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	14.8	56.9
1966	121.6	8.8	25.0	0.486	9.2	26.1
1967	75.3	3.4	14.9	0.506	4.2	18.4
1968	86.1	4.0	13.3	0.645	6.5	21.6
1969	65.2	2.4	12.9	0.504	6.9	37.1
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	219.4	11.1	37.0	0.593	19.1	63.7
1974	388.9	17.6	54.0	0.720	25.6	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	65.4

SOUTH ATLANTIC						
Year	Japanese longline data				Whole longline fleet	
	Catch in number (10 ³) (A)	Yield in weight (10 ³ MT) (B)	Effective hooks (10 ⁶) (C)	Hook rate 100x(A)/(C)	Yield in weight (10 ³ MT) (E)	Effective hooks (10 ⁶) (C)x(E)/(B)
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	1.6
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	48.9
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	10.4	27.2
1967	105.6	5.2	17.3	0.610	9.0	29.9
1968	118.5	6.2	18.0	0.658	12.3	35.7
1969	198.4	7.9	24.5	0.810	16.2	50.2
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

Table 2. Catch, hook rates in number and in weight per 100 hooks, average weight and effective effort for the Atlantic bigeye fishery, 1961-79.

WHOLE ATLANTIC					
Year	Hook rate (Number)	Mean weight (kg)	Hook rate (Weight)	Total catch (10 ³ MT)	Effort in 10 ⁶ Hooks
1961	0.818	45	36.8	17.0	46.2
1962	0.682	43	29.3	23.1	75.6
1963	0.802	51	30.7	26.0	84.7
1964	0.563	50	25.2	23.5	53.3
1965	0.550	50	27.5	39.2	142.5
1966	0.482	46	23.1	25.0	108.2
1967	0.575	50	25.8	24.7	85.8
1968	0.655	46	31.4	23.0	73.2
1969	0.691	44	30.4	33.6	110.5
1970	0.559	49	27.4	39.2	143.1
1971	0.461	47	21.7	52.1	240.1
1972	0.435	44	19.1	42.8	224.1
1973	0.507	40	20.3	53.9	265.5
1974	0.663	47	31.2	59.4	190.4
1975	0.396	50	19.5	56.7	256.4
1976	0.336	47	15.9	38.4	241.5
1977	0.520	49	25.5	45.7	179.2
1978	0.425	45	19.3	45.3	234.7
1979	0.420	44	16.5	41.1	222.2

NORTH ATLANTIC					
Year	Hook rate (Number)	Mean weight (kg)	Hook rate (Weight)	Total catch (10 ³ MT)	Effort in 10 ⁶ Hooks
1961	0.742	46	34.1	3.9	26.1
1962	0.684	43	29.4	15.6	53.1
1963	0.635	51	32.4	19.3	59.6
1964	0.586	50	29.3	16.6	56.7
1965	0.601	53	31.9	24.5	76.3
1966	0.486	43	20.9	14.5	59.4
1967	0.506	43	21.3	13.5	61.9
1968	0.445	48	31.0	9.5	30.6
1969	0.504	50	25.2	15.5	61.5
1970	0.603	47	29.3	24.3	87.6
1971	0.431	45	19.4	29.0	149.5
1972	0.401	41	16.4	22.1	134.3
1973	0.593	36	21.3	30.0	140.9
1974	0.720	48	34.6	39.3	115.0
1975	0.385	52	20.0	39.0	195.0
1976	0.307	46	14.1	22.5	160.3
1977	0.495	49	24.3	29.1	115.6
1978	0.440	46	20.2	26.3	132.7
1979	0.412	40	16.5	20.5	124.2

SOUTH ATLANTIC					
Year	Hook rate (Number)	Mean weight (kg)	Hook rate (Weight)	Total catch (10 ³ MT)	Effort in 10 ⁶ Hooks
1961	0.833	46	38.3	9.1	21.1
1962	0.627	43	27.0	7.5	27.3
1963	0.519	51	26.5	6.7	25.3
1964	0.498	51	25.4	6.9	27.2
1965	0.502	48	24.1	14.3	61.4
1966	0.480	53	25.4	10.4	40.9
1967	0.610	54	32.9	9.5	28.9
1968	0.658	48	31.6	13.4	42.4
1969	0.610	41	33.2	18.2	54.3
1970	0.512	51	26.1	14.5	55.6
1971	0.517	48	24.3	23.0	92.7
1972	0.490	47	23.0	20.7	90.0
1973	0.445	44	19.6	24.0	122.4
1974	0.458	44	20.2	19.6	97.0
1975	0.398	47	18.7	17.7	94.7
1976	0.539	48	25.9	15.9	61.0
1977	0.561	47	26.4	17.6	66.7
1978	0.402	44	17.7	18.5	104.5
1979	0.417	48	20.0	20.6	103.0

Table 3. Population indices estimated by production model analysis for the Atlantic bigeye tuna fishery, 1961-79.

	m	Degree of	F-opt	Y-max	1979 catch
		ftt index	(10 ⁶ hooks)	(10 ³ MT)	(10 ³ MT)
Whole Atlantic	0	0.5396	∞	111.9	
	1.001	0.5327	434	58.2	41.1
	2	0.5277	306	52.8	
North Atlantic	0	0.3533	∞	72.0	
	1.001	0.3515	286	37.1	20.5
	2	0.3516	196	33.1	
South Atlantic	0	0.6155	∞	47.7	
	1.001	0.6293	182	23.8	20.6
	2	0.6396	119	20.6	

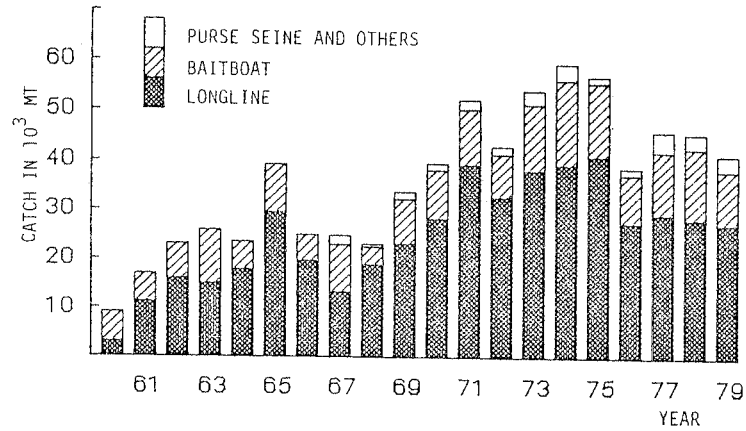


Fig. 1. Yearly bigeye catch by gear in the Atlantic, 1960-79.

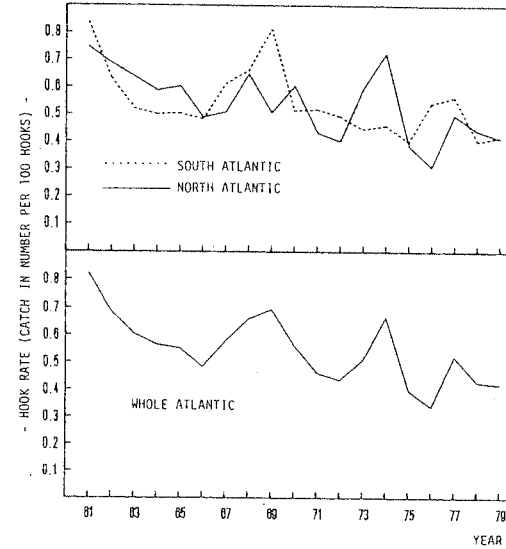


Fig. 2. Annual change in hook rates in the whole Atlantic (lower panel) and in the north and south Atlantic (upper panel), 1961-79.

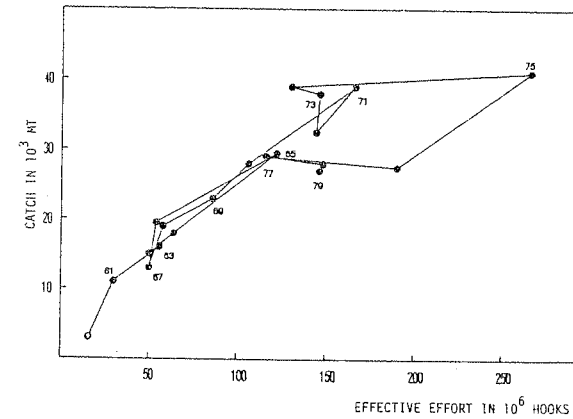


Fig. 3. Relation between catch and effort on bigeye tuna caught by longline fishery in the whole Atlantic, 1960-79.

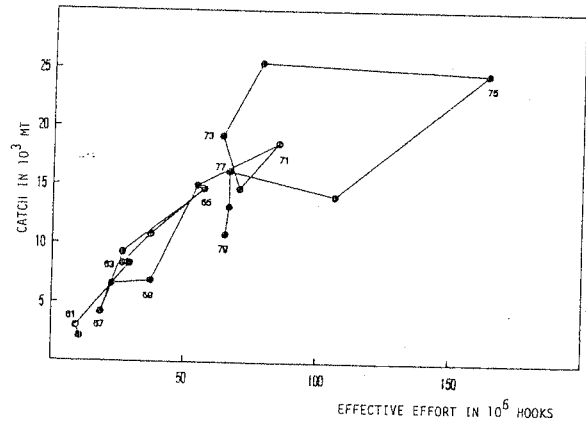


Fig. 4. Relation between catch and effort on bigeye tuna caught by longline fishery in the north Atlantic, 1960-79.

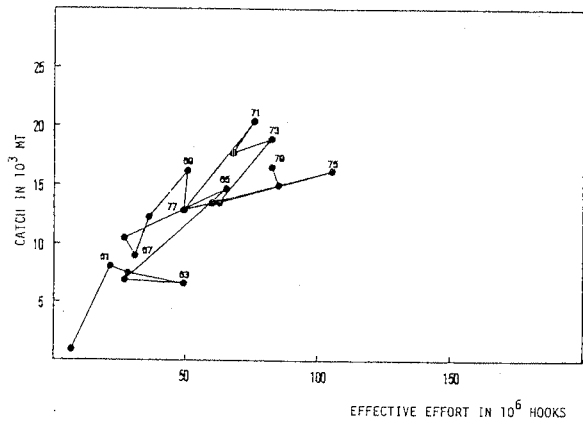
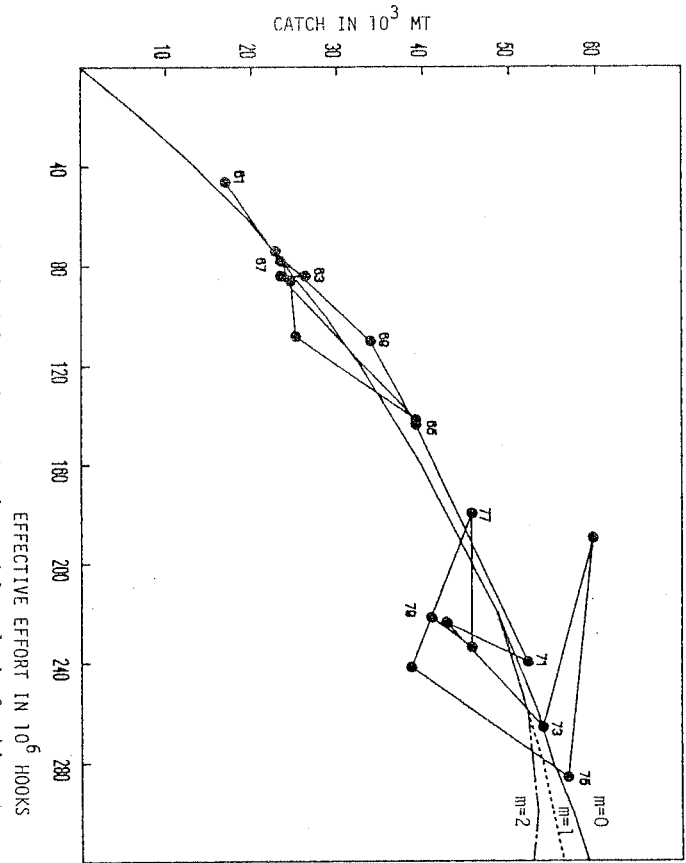


Fig. 5. Relation between catch and effort on bigeye tuna caught by longline fishery in the south Atlantic, 1960-79.

Fig. 6. Yield curves obtained from the production model analysis for bigeye tuna in the whole Atlantic, 1961-79.



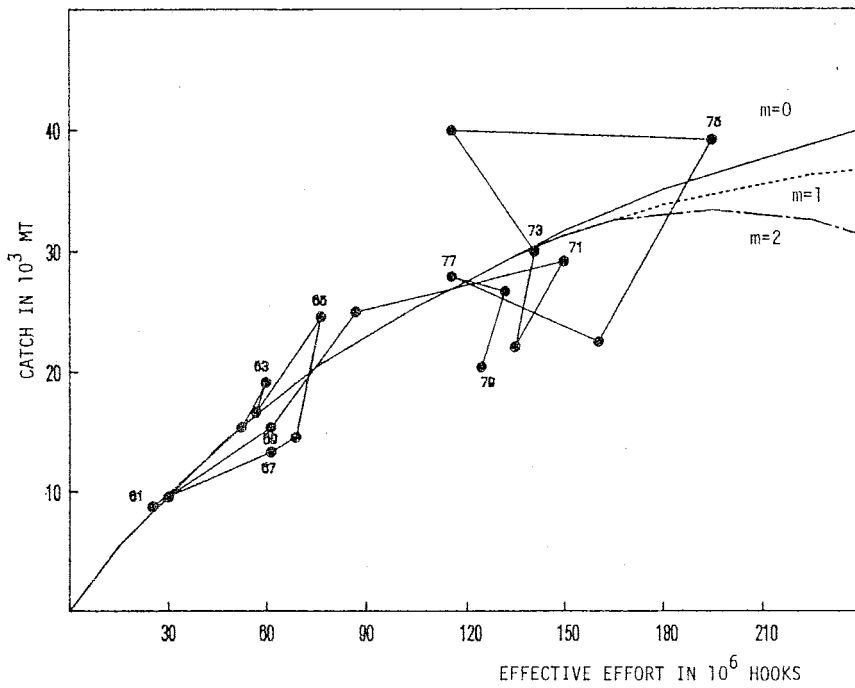


Fig. 7. Yield curves obtained from the production model analysis for bigeye tuna in the north Atlantic, 1961-79.

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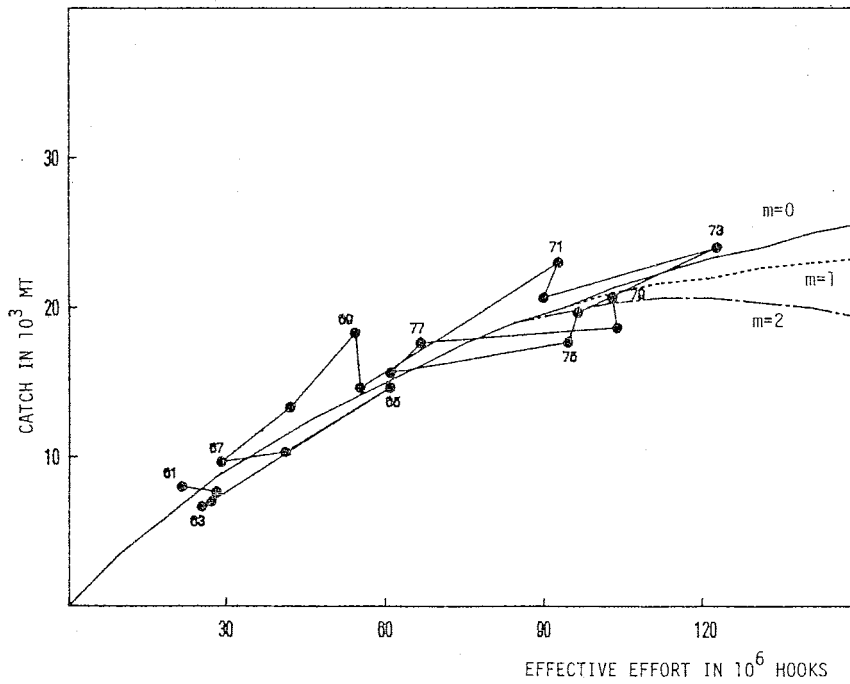


Fig. 8. Yield curves obtained from the production model analysis for bigeye tuna in the south Atlantic, 1961-79.