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STATE OF THE BIGEYE TUNA STOCKS OF THE ATLANTIC OCEAN FROM PRODUCTION MODEL ANALYSIS, 1957-1975

by

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SUMMARY

The production model was used to evaluate the state of the bigeye tuna (*Thunnus obesus*) stocks of the Atlantic Ocean. The model did not fit the available fishery data very well. Estimates of the average maximum sustainable yield with the assumption of a single exploited stock, however, varied between 42,800 metric tons and 180,700 metric tons. Because the present catch is at a record high of 59,000 metric tons and increased production in recent years has been obtained from removing younger fish, it is concluded that further development of the fishery should proceed with caution.

RESUME

L'état des stocks de thon obèse (*Thunnus obesus*) dans l'Atlantique a été évalué au moyen du modèle global, qui ne s'ajuste pas très bien aux données disponibles sur la pêcherie. Les estimations de la moyenne de production maximale soutenue effectuées en supposant l'existence d'un stock unique exploité varient cependant de 42.800 à 180.700 TM. La prise actuelle se situant à un niveau record de 59.000 TM, et la production accrue de ces dernières années ayant été obtenue par prélèvement de poissons plus jeunes, la conclusion du présent rapport est que tout développement ultérieur de la pêcherie doit procéder avec prudence.

RESUMEN

Se emplea el modelo de producción para evaluar el estado de los stocks de patudo (*Thunnus obesus*) en el Atlántico, si bien dicho modelo no se ajusta con precisión a los datos disponibles sobre la pesquería. Sin embargo, las estimaciones de la media de producción máxima sostenible, en el supuesto de que sea uno solo el stock explotado, oscilan entre 42.800 y 180.700 TM. Considerando que la captura actual ha alcanzado un nivel record de 59.000 TM, y que el aumento en la producción de los últimos años ha sido consecuencia de la pesca de peces más jóvenes, se llega a la conclusión de que el desarrollo futuro de la pesquería debe realizarse con precaución.

INTRODUCTION

Bigeye tuna (*Thunnus obesus*) supports a major tuna fishery in the Atlantic Ocean. Before 1971 the annual production of the fishery was less than 30,000 metric tons and over 90% of the production was produced by longliners (Figure 1). Most of the production was taken incidentally to fishing for yellowfin (*T. albacares*) and albacore (*T. alalunga*) tunas. The bigeye stocks at that time were considered healthy and capable of sustaining much higher yields (FAO, 1968; Hayasi et al., 1970; Hisada, MS[1]).

In 1971 production increased sharply to 45,000 metric tons (Figure 1) owing to increased catches by the surface fishery and concentrated effort of longliners in areas of high abundance of bigeye tuna. The standardized catch rate for the Japanese longline fleet recorded a sudden decline that year and Kume (MS[2]) hypothesized that the yield was approaching the maximum sustainable from the stocks. In the following year production declined to about 35,000 metric tons but quickly recovered in 1973. Since then, the catch has increased each year and 1975 was a record year with about 59,000 metric tons landed (Figure 1).

More recent analyses on the state of the Atlantic bigeye tuna stocks by Kume (MS[3]; 1976a) and Sakagawa (1976) showed that the total catch appears to be approaching the maximum sustainable yield with the existing configuration of the fishery, i.e., mixture of gears and area-time distribution of fishing effort, and assuming a single exploited stock. With the assumption of separate north and south Atlantic stocks, however, Sakagawa's analysis suggested that the yield from the northern stock could be increased whereas the maximum sustainable yield was being removed from the southern stock. In this report, previous production model analyses (Kume, 1976; Sakagawa, 1976) to determine the state of the Atlantic bigeye tuna stocks are updated with new information.

DATA SOURCES AND ANALYTICAL PROCEDURES

Bigeye tuna catches by gear, country and year were tabulated from ICCAT (1976) and partitioned into catches made in the north and south Atlantic (Table 1). Partitioning was based on available information about the fishing areas of the fleets. For the longline catches, longline data on catch-effort by 5° area (Fishery Agency of Japan, 1966-76; Shiohama, Myojin and Sakamoto, 1965) and sizes of bigeye tuna caught by area (Kume, pers. commun.) within year of the Japanese fleet were used to partition the catch. The Japanese longline fleet lands between 42 and 100% of the annual longline catch. It is assumed that the other longline fleets operate similarly to the Japanese fleet.

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[1]K. Hisada. MS. Overall fishing intensity of Japanese longline fishery for bigeye tuna in the Atlantic Ocean, 1956-1970. ICCAT Collective Vol. Sci. Pap.,1(SCRS-1972): 479-488.

[2]S. Kume. MS. Overall fishing intensity of Japanese Atlantic longline fishery for bigeye tuna, 1956-1971. ICCAT Collective Vol. Sci. Pap., 2(SCRS-1973): 145-149.

[3]Kume, S. MS. Overall fishing intensity of Japanese Atlantic longline fishery for bigeye tuna, 1956-1972. ICCAT Collective Vol. Sci. Pap., 4(SCRS-1974): 60-64.

For the surface fishery (pole-and-line, seine and troll) catches, data on catch-effort by 1° area of the American and Japanese purse seine fleets (CCAT, 1973a; 1973b; 1974; 1975a; 1975b, 1976b) were used to partition the purse seine catches. Catches of these two fleets make up about 6 to 100% of the total purse seine catch of bigeye tuna. All pole-and-line and troll catches were assumed to be taken from the south Atlantic.

Standardized catch rates in number of fish per 100 hooks for 1957-1973 from data of the Japanese longline fleet were estimated by Kume (1976b). The rates are assumed to be representative indices of abundance for the Atlantic bigeye tuna stocks. They were converted to weight per 1000 hooks with average size data (Table 2) of bigeye tuna caught by Japanese longliners. Total standardized fishing effort for the Atlantic-wide fishery was then estimated by dividing total catch by the catch rate (Table 2).

Hayasi et al. (1970) proposed that separate north Atlantic and south Atlantic stocks of bigeye tuna were possibly being exploited. So far no comprehensive study has been made to investigate this proposal. However, on the assumption that separate stocks exist in the Atlantic, Sakagawa (1976) estimated indices of apparent abundance for the north and south Atlantic stocks using nominal catch rates (numbers/1,000 hooks) from index regions of the Atlantic and quarters of the year. His time series of indices was extended to include estimates for 1974, and the indices converted to weight per 1,000 hooks (Table 3) with average weight data. Total fishing effort in the north and south Atlantic was then estimated by dividing total catch by the index (Table 3).

RESULTS OF ANALYSES

The production model was fitted to the data on bigeye tuna of the Atlantic Ocean with the computer program PRODFIT (Fox, 1975). Separate analyses were performed to investigate (1) a single exploited stock in the Atlantic, and (2) two separate exploited stocks, north and south, in the Atlantic.

Single Stock

Three special cases (m=0, m→1, and m=2) of the production model were fitted to the Atlantic-wide data (Table 1), first with four significant year classes (k=4) contributing to the catch and second, with k=5. These two conditions of number of significant year classes in the catch were chosen on the basis of previous analysis of the age composition of the catch (Sakagawa, 1976).

In general, the model did not fit the data very well, judging from the low values for the degree of fit index[4] (Table 4). Among the three cases of the model tried, however, the marginal best fit was obtained with m=2.0, or the parabolic-shaped model. Y_{max}, the average maximum sustainable yield, for this best case is 42,800 metric tons with k=5 and 53,800 metric tons with k=4. For the other cases, Y_{max} is higher (Table 4).

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[4]The degree of fit index ranges from 0 to 1.0, or poor fit to perfect fit.

If we assume that a single Atlantic-wide stock is exploited and the production curve is parabolic, it appears that the maximum sustainable yield from the stock is currently being surpassed. With these assumptions, further catches at or above the record 1975 catch of 59,000 metric tons would result in overexploitation and subsequent decline in catch. Judging from the poor overall fit of the model to the data, however, it is difficult to say whether the shape of the production curve is indeed parabolic. The actual shape could almost as likely be flat-topped (m=0) or skewed-dome (m→1) (Figure 2), cases in which Y_{max} is generally much greater than the 1975 catch (Table 4). In these cases, except when k=4 and m→1, production could increase substantially above the 1975 level without a subsequent decline in catch.

Separate North and South Atlantic Stocks

The production model was fitted to data (Table 3) for the separate north and south Atlantic bigeye tuna fisheries. The model did not fit the data very well and estimates of Y_{max} appeared unreasonable; several million metric tons for the north Atlantic fishery and about 13,000 metric tons for the south Atlantic fishery. The poor fit apparently is due to the poor relationship between catch and estimated effective effort (Figure 3). The catch rates for the index areas and quarters appear to be inadequate estimators of stock abundance for the presumed separate stocks. No management advice is therefore drawn from these results.

MANAGEMENT ADVICE

The catch of bigeye tuna from the Atlantic Ocean has been increasing virtually uninterrupted since 1967 at an annual rate of about 6,000 metric tons, and the surface fishery has been landing an increasing proportion of the total catch (Figure 1). The longline fishery, however, still lands the bulk of the total Atlantic catch of bigeye tuna (67% in 1975), and a high level of fishing effort is directed to catching this species. Since 1970, the longline catch has leveled off, averaging about 36,000 metric tons per year.

In contrast, the landings of the surface fishery has been increasing markedly since 1971 at an annual rate of about 6,000 metric tons. Virtually all the catch is small bigeye tuna caught in the eastern tropical Atlantic incidentally to yellowfin tuna fishing, for which there is a high level of fishing effort (Fox and Coan, 1976). The reported bigeye tuna landings of this fishery, however, is suspected to be substantially underestimated (Fonteneau, 1976) owing to the practice of reporting incidental catches of bigeye tuna as yellowfin tuna. This practice is especially common with catches of small bigeye tuna which are difficult to differentiate from small yellowfin tuna.

The actual shape of the production curve for the bigeye tuna stocks of the Atlantic is unclear from data currently available. Depending on the assumptions one wishes to accept, the production model analysis give average maximum sustainable yields ranging from 42,800 metric tons to 180,700 metric tons (Table 4) for the entire Atlantic fishery. Probably the high end of this range is too optimistic, judging from Y_{max} of about 110,000 metric tons for the apparently more abundant Atlantic yellowfin tuna (Fox and Coan, 1976). The low end of this range is, on the other hand, probably too pessimistic, judging from the average recent production (1966-1975) of 74,000 metric tons for Atlantic albacore (ICCAT, 1976a), a species that is slower growing, longer lived and probably more easily depressed with intense fishing than bigeye tuna (Suda and Kume, 1970).

By comparison, the shape of the production curve for Pacific bigeye tuna is skewed-dome with a maximum sustainable yield at about 90,000 metric tons (Suda and Kume, 1970). The fishery is much larger than the Atlantic fishery and currently produces about 80,000 metric tons per year (IATTC, 1976) from an ocean that is about double the size of the Atlantic.

The total Atlantic bigeye tuna catch is currently at record high and increased production is being obtained by removing younger fish. An accurate assessment of the amount of young fish being removed by the surface fishery is not available but it is suspected to be greater than the record 19,400 metric tons landed in 1975. It is not known how much of an impact the recent large removal of small fish will have on available recruits to the longline fishery in coming years and thus affect the yield from the longline fishery.

Fishing effort is currently at a high level and apparently increasing. Unless the fishery is able to focus the increased effort onto bigeye tuna stocks that heretofore have not been exploited or lightly exploited, if there are any, or onto segments (e.g., young fish) of the present exploited stocks that do not contribute much to the longline yield, the catch will probably not increase proportionately with increased effort and average recruitment. In light of all these events, the course of further development of the fishery should therefore proceed with caution and the fishery monitored closely.

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Table 1. Estimated bigeye tuna catches (metric tons) by regions of the Atlantic Ocean

Year	North Atlantic			South Atlantic			Entire Atlantic		
	Longline	Surface	Total	Longline	Surface	Total	Longline	Surface	Total
57	70	-	70	430	-	430	500	-	500
58	205	-	205	295	-	295	500	-	500
59	285	-	285	1215	-	1215	1500	-	1500
1960	958	-	958	2046	-	2046	3004	-	3004
61	2651	-	2651	8593	-	8593	11244		11244
62	6295	26	6321	9643	-	9643	15938	26	15964
63	6829	2715	9544	8102	-	8102	14931	2715	17646
64	5737	2830	8567	12047	-	12047	17784	2830	20614
65	14892	125	15017	14146	-	14146	29038	125	29153
66	11819	2	11821	7141	-	7141	18960	2	18962
67	4674	428	5102	6826	35	6861	11500	463	11963
68	6885	730	7615	10208	347	10555	17093	1077	18170
69	11128	3226	14354	9678	96	9774	20806	3322	24128
1970	10406	1360	11766	15074	1358	16432	25480	2718	28198
71	22082	7054	29136	14722	1229	15951	36804	8283	45087
72	17533	3313	20846	13776	588	14364	31309	3901	35210
73	20050	4696	24746	15218	2502	17720	35268	7198	42466
74	31698	13993	45691	4515	2140	6655	36213	16133	52346

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Table 2. Catch per unit of effective effort and estimate of effective effort for the bigeye tuna fishery of the entire Atlantic

Year	CPUE[1] (number/ 1000 hooks)	W̄ (kg)	Catch (M tons/ 1000 hooks)	Catch (M tons x 10^3)	Standardized effort (x 10^3 hooks)
1957	2.79	57.8	0.161	0.50	3,106
58	2.06	33.7	0.069	0.50	7,246
59	3.44	33.5	0.115	1.50	13,043
1960	4.06	41.1	0.167	3.00	17,988
61	6.83	45.5	0.311	11.24	36,154
62	6.16	42.6	0.262	15.96	60,931
63	5.46	50.8	0.277	17.65	63,704
64	5.05	50.4	0.255	20.61	80,839
1965	5.12	43.9	0.225	29.16	129,613
66	4.87	75.7	0.369	18.96	51,388
67	5.07	47.3	0.240	11.96	49,846
68	5.76	52.3	0.301	18.17	60,365
69	6.04	38.9	0.235	24.13	102,672
1970	5.04	47.5	0.240	28.20	117,492
71	4.06	52.6	0.213	45.09	211,676
72	4.09	53.5	0.219	35.21	160,776
73	4.36	51.6	0.225	42.47	188,738

[1] S. Kume. MS. Overall fishing intensity of the Japanese Atlantic longline fishery for bigeye tuna, 1956-1973. ICCAT, Collective Vol. Sci. Pap. 5 (SCRS. 1975): 160-164.

Table 3. Estimated effective effort for the north and south Atlantic bigeye tuna fisheries

	North			South		
Year	Catch rate (metric tons/ 1,000 hooks)	Catch (10^3 metric tons)	Effort (10^3 hooks)	Catch rate (metric tons/ 1,000 hooks)	Catch (10^3 metric tons)	Effort (10^3 hooks)
1957	1.59	0.07	44	-	0.43	-
58	0.02	0.20	10,000	-	0.30	-
59	1.79	0.28	156	-	1.22	-
1960	0.58	0.96	1,655	0.44	2.05	4,659
61	0.50	2.65	5,300	1.10	8.59	7,809
62	0.94	6.32	6,723	0.57	9.64	16,912
63	0.47	9.54	20,298	0.57	8.10	14,211
64	0.80	8.57	10,713	0.63	12.05	19,127
1965	1.04	15.02	14,442	0.75	14.15	18,867
66	0.73	11.82	16,192	0.34	7.14	21,000
67	0.45	5.10	11,333	0.90	6.86	7,622
68	0.55	7.62	13,855	0.99	10.56	10,667
69	1.00	14.35	14,350	0.87	9.77	11,230
1970	0.57	11.77	20,649	0.77	16.43	21,338
71	0.81	29.14	35,975	0.74	15.95	21,554
72	0.58	20.85	35,948	0.98	14.36	14,653
73	1.18	24.75	20,975	0.47	17.72	37,702
74	0.66	45.69	69,227	0.49	6.66	13,592

Table 4. Estimates of some parameters of the production model for the bigeye tuna fishery of the Atlantic Ocean with the assumption of a single, exploited stock

m	Y_{max} ($x10^3$ ton)	fop ($x10^6$ hooks)	U_{opt} (tons per 1,000 hooks)	degree of fit index	1975 catch ($x10^3$ tons)
4 major year classes					
0	180.7	∞	-	0.136	59.0
→1	72.2	664.6	0.109	0.144	59.0
2.0	53.8	365.5	0.147	0.151	59.0
5 major year classes					
0	116.3	∞	-	0.312	59.0
→1	52.3	447.5	0.117	0.317	59.0
2.0	42.8	274.1	0.156	0.319	59.0

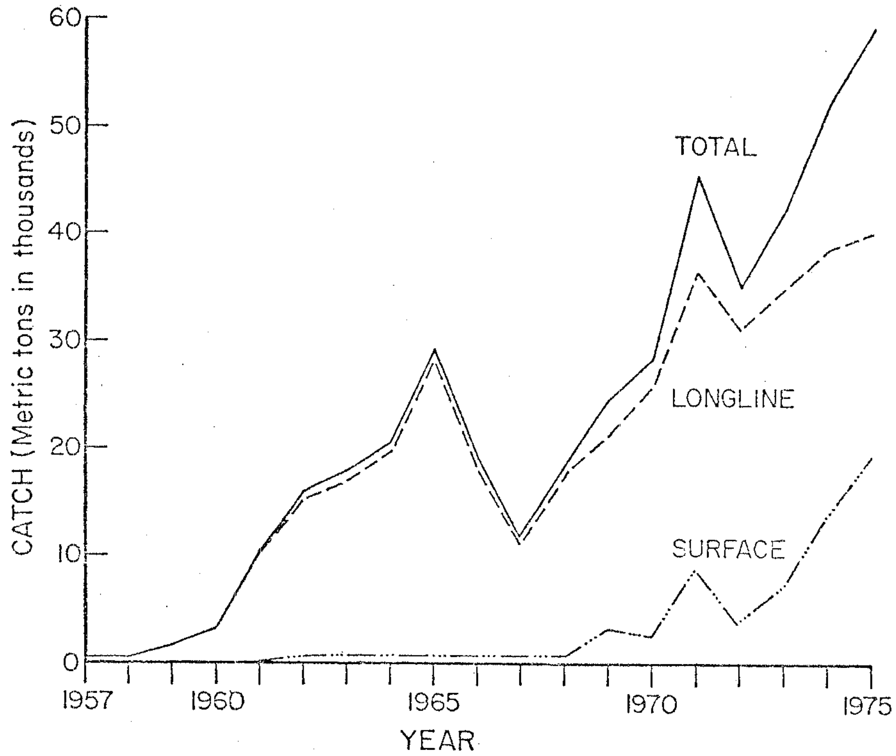

Figure 1. Catch of bigeye tuna from the Atlantic, 1957-1975

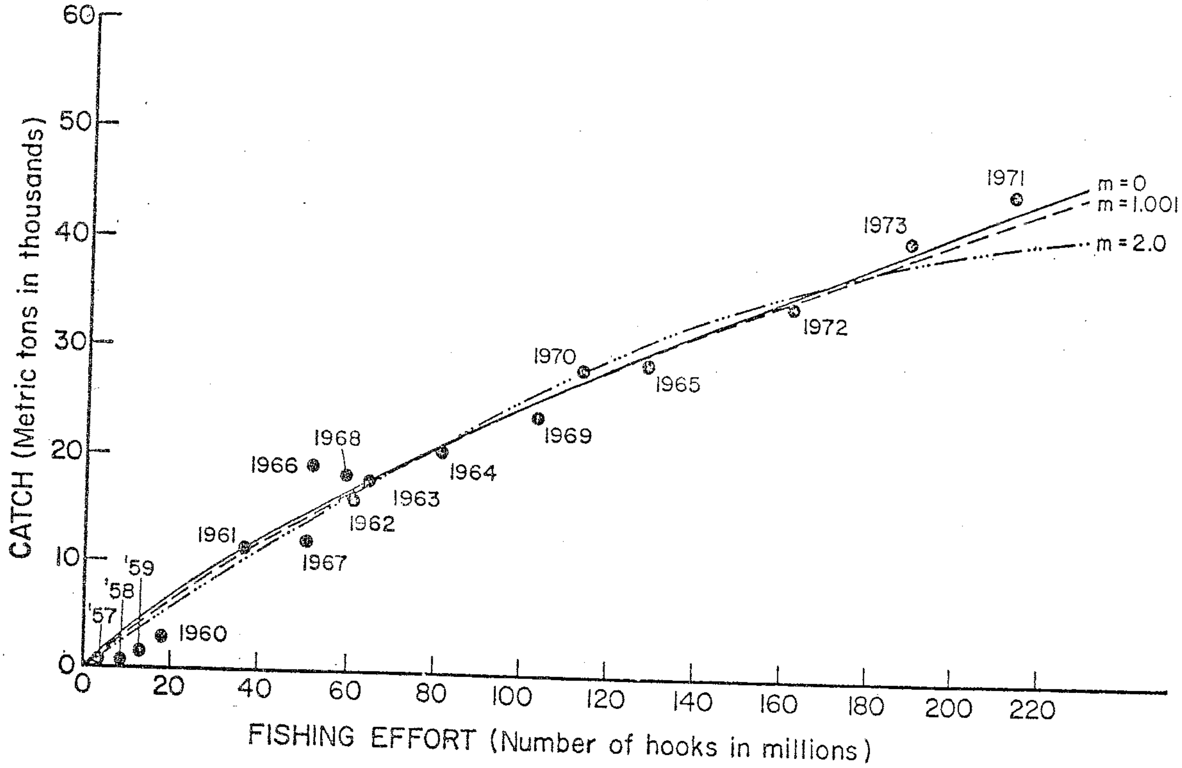

Figure 2. Relation between catch and fishing effort for bigeye tuna of the Atlantic Ocean. Average sustainable yield curves for three special cases of the production model with k=5 are shown

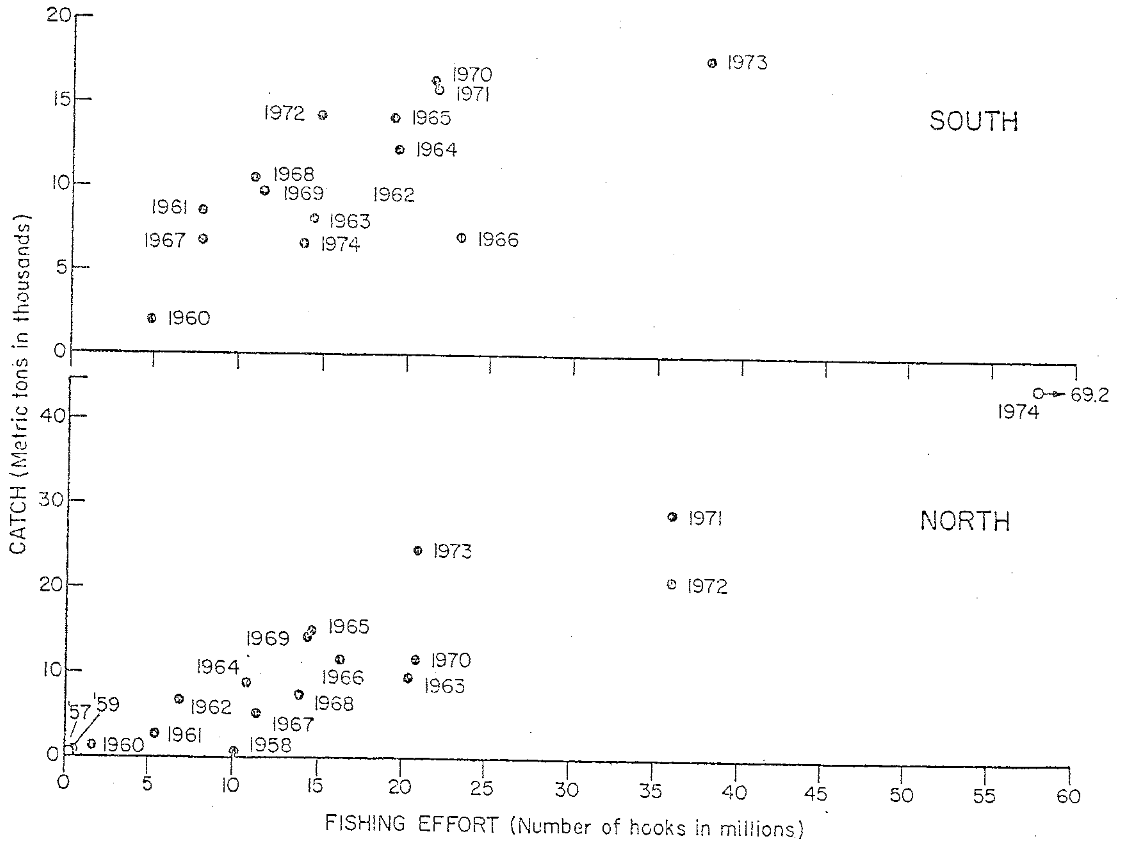

Figure 3. Relation between catch and fishing effort for bigeye tuna of the northern and southern Atlantic