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PRODUCTION MODEL ANALYSIS OF BIGEYE TUNA (*Thunnus obesus*) FROM THE ATLANTIC OCEAN, 1965-1975

by

E. C. Weber, G.T. Sakagawa

SUMMARY

Bigeye tuna (*Thunnus obesus*) in the Atlantic Ocean continue to be exploited at high levels. The 1975 catch of 50,597 MT was slightly below the 1974 record catch of 52,352 MT. Although longlining remains the principal method of capture, accounting for 67% of the 1975 catch by weight, the surface fishery is expanding.

Bigeye production in the Atlantic Ocean for 1965-1975 was evaluated using the generalized production model with assumptions: 1) separate north and south stocks and 2) a single exploited stock. The best fits were obtained with a flat-topped (m=0) equilibrium yield model. While the available data for the south Atlantic fit the model reasonably well, data for the north and entire Atlantic did not and the resulting predictions for MASY seem unrealistically high. The authors conclude that the "best" MASY prediction for the southern fishery is 17,100 MT.

RESUME

L'exploitation intensive du thon obèse (*Thunnus obesus*) se poursuit dans l'Atlantique. La prise de 1975, 50.597 TM, se situait légèrement en-dessous de la prise record de 1974, 52.352 TM. Bien que la palangre soit toujours la principale méthode de capture, ayant donné 67% de la prise en poids de 1975, la pêche de surface est en expansion. La production de thon obèse dans l'Océan Atlantique en 1965-1975 a été évaluée au moyen du modèle global, en supposant: (1) qu'il existe un stock nord et un stock sud, et (2) qu'un stock unique est exploité. L'ajustement optimal a été obtenu avec un modèle donnant une production équilibrée au sommet aplani (m = 0). Les données disponibles pour l'Atlantique Sud s'ajustent assez bien au modèle; ceci n'est pas le cas pour celles de l'Atlantique Nord et entier. Les prévisions qui en découlent concernant la production maximale équilibrée semblent anormalement élevées; les auteurs du présent document en concluent que la "meilleure" précision pour la pêcherie du sud serait de 17.100 TM.

RESUMEN

Continúa la fuerte explotación del patudo (*Thunnus obesus*) en el Atlántico. La captura en 1975 de 50.597 TM fue ligeramente inferior a la cifra record de 52.352 TM alcanzada en 1974. La pesquería de superficie está en expansión, si bien el palangre sigue siendo el principal método de pesca, representando en 1975 el 67% de la captura en peso.

La producción de patudo en el Atlántico en el periodo 1965-1975 se evaluó según el modelo de producción generalizado, en base a las siguientes hipótesis: (1) stocks separados al norte y al sur, y (2) un stock único explotado. Los mejores ajustes se obtuvieron con un modelo de producción en condiciones de equilibrio sin un máximo definido (m = 0). Se bien los datos disponibles del Atlántico Sur se ajustaban suficientemente al modelo, no así los correspondientes al Norte y al conjunto del Atlántico, por lo que los pronósticos del RMS parecen ser demasiado altos. Los autores deducen que el "mejor" pronóstico de RMS respecto a la pesquería en la zona sur es de 17.100 toneladas.

THE FISHERY

Bigeye tuna (Thunnus obesus) is a valuable fishery resource of the Atlantic Ocean. It contributed about 50,000 mt of catch in 1975, slightly below the record catch of 52,000 mt of 1974, and the catch is worth more than $40 million (ex-vessel).

The Atlantic fishery began in the late 1950's with longline gear, and this gear continues to land the bulk of the bigeye tuna catch. However, in recent years the percentage of catch taken by longliners have decreased from 90% in 1970 to 67% in 1975. In fact, despite record total catches during this period, the longline catch has remained fairly constant at about 32,000 mt whereas the catch of baitboats and purse seiners has increased. Recent gains in the total bigeye tuna catch are therefore attributed to expansion of the surface fishery and not to expansion of the longline fishery.

Since about 1966 the catch rate of bigeye tuna by longliners has been around 0.5 fish per 10,000 hooks. Together with the stable catch of longliners, some scientists have suggested that the level of fishing was near the maximum average sustainable yield MSAY for the stocks (Kume, 1974; Sakagawa, 1977).

In this report we appraise the condition of the bigeye tuna stocks using the generalized production model and updated fishery data. We perform separate analyses to deal with different stock structure hypotheses for the Atlantic bigeye tuna population. One hypothesis states that there are north and south stocks in the Atlantic, separated at approximately the equator (Hayasi et al., 1970). Another hypothesis holds that a single Atlantic-wide stock, separated at times near the equator possibly by unfavorable environmental conditions, exists in the Atlantic. Neither of these hypotheses has yet been empirically tested.

DATA AND ANALYTICAL PROCEDURES

Atlantic bigeye catches by ICCAT area, for all gears and countries, for 1965-1975 were taken from ICCAT (1976a). The catches were partitioned into north (bigeye areas 1-4; ICCAT, 1976b) and south (areas 5-8; ICCAT, 1976b). Catches not reported by ICCAT areas were apportioned in a manner described by Kume (1977) with the following exceptions. Unclassified Japanese catches were apportioned according to the distribution of catches in the Japanese catch-effort data (Fisheries Agency of Japan, 1967-1977). Taiwan catches were apportioned using catch-effort data from the Taiwan Fisheries Bureau (1968-1976). Taiwanese catch-effort data were unavailable for 1966 and the catch for that year was apportioned using 1967 data. In 1975 mixed species catches were included by Spain in her total bigeye tuna catch. The actual bigeye in the total catch was estimated using the proportion of bigeye in the 1975 Spanish catch from the Canary Island, which is reported by species (ICCAT, 1976a).

Apparent abundance estimates for the Atlantic bigeye tuna stocks were based entirely on Japanese longline data (Fisheries Agency of Japan, 1958-1977). The data are the most complete time series available. Although the longline fishery exploits larger sizes of bigeye tuna than does the surface fishery, it is assumed that longline data adequately index the relative abundance of Atlantic bigeye tuna.

The areas (Figure 1) that served to index the abundance of the stocks were chosen by examining the proportion of bigeye tuna caught in the cumulative years 1956-1975 by 5° squares. All areas with more than 1% of the total catch were considered index areas. A single annual catch per unit of effort (CPUE) for each stock was then computed by summing the total catch from the appropriate index areas and dividing by the total number of hooks, summed in a similar manner.

CPUE estimates from the Japanese longline data are in numbers of fish. The estimates were converted to CPUE in weight, using estimates of average weight of bigeye tuna in the annual Japanese longline catch by north, south and entire Atlantic. Average weights were obtained from length-frequency samples for 1966-1969 (Kume, pers. commun., Far Seas Fisheries Research Laboratory, Shimizu, Japan) and for 1970-1975 (ICCAT, 1973; 1974; 1976c). The samples were converted to weight-frequencies with the length-weight relation of Lenarz (1974):

$W = 0.000012494\ L^{3.12082}$
W = weight in kg
L = fork length in cm,

weighted by the catches they were taken from and then average weights calculated.

No length-frequency samples were available from the 1965 longline catch. Average weight of bigeye in that year's catch is assumed to be the same as the average of the 1966-1975 estimates.

A generalized production model was fitted to the fishery data using the computer program PRODFIT (Fox, 1975). Separate analyses for the different stock structure hypotheses were performed to determine the health of the stocks. Models were fitted with values of m = 0, 1 and 2. Four year classes were assumed to contribute to each yearly catch.

STATUS OF STOCKS

In general, the production model did not fit the available data well. Large variability among CPUE estimates affected the analysis. The variability may be the result of several factors, including unreliable catch data; inaccurate estimates of apparent abundance with CPUE of a multi-species, multi-gear fishery; and environmental fluctuations that affect the availability and distribution of bigeye tuna.

Separate north and south stocks

The production model fit the available data for the south Atlantic stock reasonably well (Table 2). The best fit index was obtained with a flat-topped equilibrium yield model (m = 0; Figure 2), although with all values of m the fit indices are quite similar. MASY estimates range from 13,700 to 17,100 mt, or approximately the level of recent catches. This suggests that further increases in the level of effort would not result in substantial increases in equilibrium yield from the south Atlantic stock.

For the north Atlantic stock, the model did not fit the available data. The scatter of data points is too great to be adequately described by the production model (Figure 3). No estimate of MASY is therefore available for this stock. However, judging from historic levels of catches, the north Atlantic stock is capable of yielding a greater tonnage than the southern stock. Recent catches have averaged 31,000 mt with about 4.8 million hooks of effort (Table 2). CPUE estimates, although quite variable, have remained reasonably high.

Single Atlantic-wide stock

Analysis of the Atlantic-wide stock data with the production model gave marginal results (Table 2). MASY estimates range from 910,400 to 9,000,700 mt. These estimates appear to be unrealistically high. The low fit indices of the analysis also indicate that the model is inappropriate for the data.

The equilibrium yield curve (Figure 4) indicates that the fishery is characterized by linear growth. This suggests that with increased fishing effort a proportionate amount of catch would result. However, in fact, this cannot happen without eventually damaging the spawning stock and causing a collapse of the fishery. Whether this point has been reached is unclear, but it is prudent to say that increased fishing should be monitored closely, especially that effort devoted to catching small bigeye tuna.

The 1976 catch is about 35,100 mt and below the level reported in the previous 3 years. Fishing effort appears to have also been lower in 1976, so we cannot judge whether the lower catch in 1976 is a sign that the stocks are being too heavily exploited until final fisheries statistics are made available.

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Table 1. Reported catch, estimated effort and CPUE for bigeye tuna in the north, south and entire Atlantic, 1965-1975

	North Atlantic			South Atlantic			Entire Atlantic		
	Catch (mt)	Effort ($X\ 10^4$ hooks)	CPUE (mt.X 10^4 hooks)	Catch (mt)	Effort ($X\ 10^4$ hooks)	CPUE (mt X 10^4 hooks)	Catch (MT)	Effort ($X\ 10^4$ hooks)	CPUE (mt X 10^4 hooks)
1965	14769	2462	5.999	14394	2053	7.012	29163	4508	6.469
1966	9303	1570	5.927	9659	2039	4.736	18962	3434	5.522
1967	4131	1292	3.197	7832	742	10.553	11963	2047	5.844
1968	6451	1066	6.050	11719	1180	9.935	18170	2300	7.900
1969	8408	1714	4.905	15720	2066	7.610	24128	4357	5.538
1970	16626	2353	7.066	11573	1518	7.624	28199	3791	7.437
1971	28027	4661	6.013	17061	2219	7.688	45088	6827	6.605
1972	2235	4703	4.754	12854	1812	7.093	35211	6577	5.354
1973	26151	4031	6.487	16316	2797	5.834	42467	6937	6.121
1974	39936	4127	9.676	12416	1850	6.712	52352	5676	9.224
1975	37014	5593	6.618	13583	2217	6.127	50597	7772	6.510

Table 2. Estimated MASY (Y max) and optimum effort (f opt) for Atlantic bigeye tuna

	m	Y max ($X\ 10^4$ mt)	f opt ($X\ 10^4$ hooks)	FIT Index	Averaged 1972-1975 Catch ($X\ 10^3$ mt)	Averaged 1972-1975 Effort ($X\ 10^4$ hooks)
South Atlantic	0	17.1	--	0.854	13.4	2182
	1	13.7	2296	0.848		
	2	13.7	2065	0.842		
North Atlantic					31.4	4752
Entire Atlantic	0	9000.7	--	0.305	44.6	6857
	1	910.4	345794	0.301		
	2	2496.7	705677	0.305		

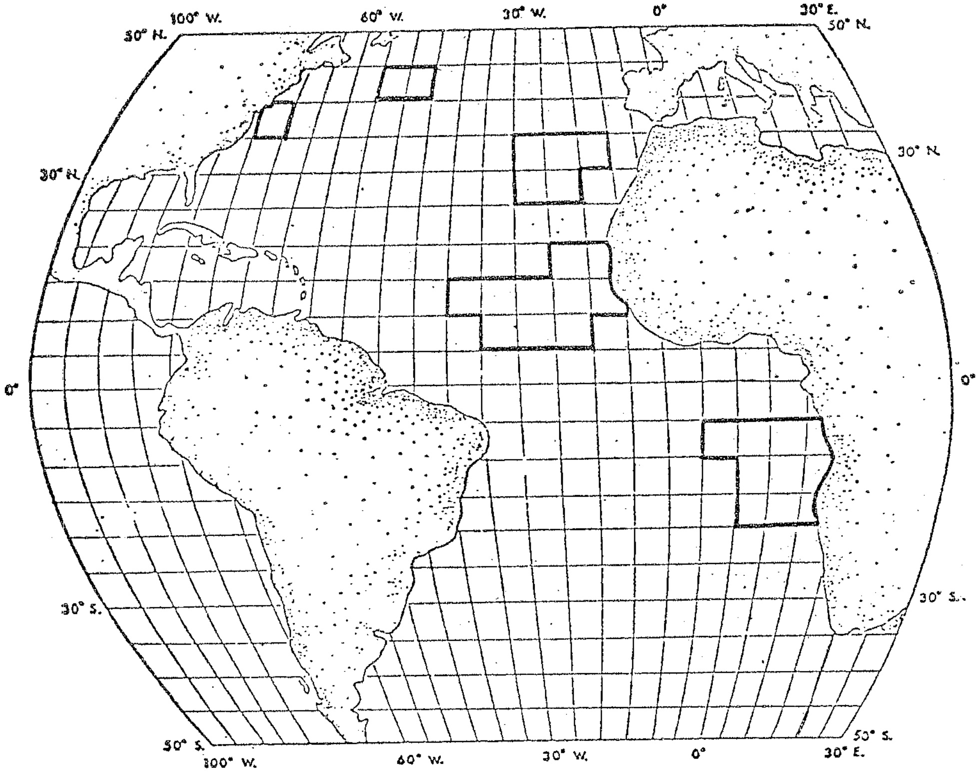

Figure 1. Index areas for indexing the apparent abundance of Atlantic bigeye tuna stocks.

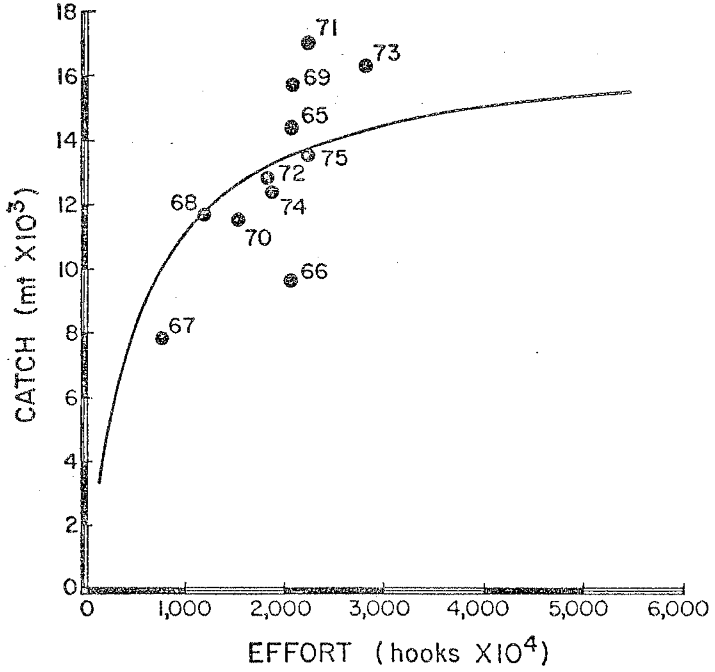

Figure 2. Equilibrium yield curve and observed data for the south Atlantic bigeye tuna fishery, 1965-1975.

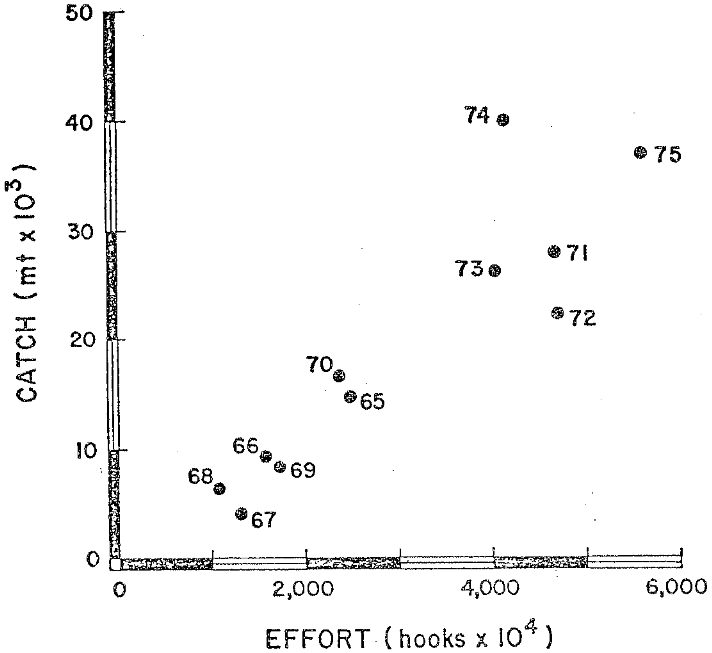

Figure 3. Observed data from the north Atlantic bigeye tuna fishery, 1965-1975.

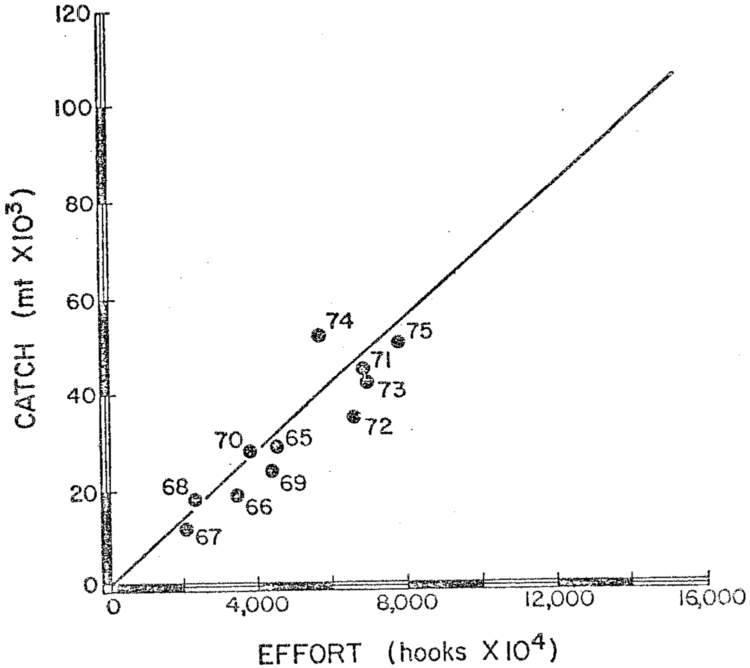

Figure 4. Equilibrium yield curve and observed data for the Atlantic bigeye tuna fishery, 1965-1975.