A PRODUCTION MODEL ANALYSIS OF THE STATUS OF YELLOWFIN TUNA IN THE ATLANTIC OCEAN, 1964-1975

by

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SUMMARY

The generalized stock production model was used to evaluate the status of the yellowfin tuna fishery in the Atlantic Ocean for 1964-1975. Previous analyses (Fox and Coan, 1976) are updated and the results reinforce the conclusion of previous years. Our best results were obtained with a broad, flat-topped (m=0) yield-effort curve. Estimates of maximum sustainable average yield are 95,700 metric tons for the eastern Atlantic surface fishery and 116,100 metric tons for the total Atlantic fishery (surface and longline). Catches for these fisheries in 1975 are 90,700 metric tons and 119,400 metric tons, respectively.

RESUME

L'état de la pêcherie à l'albacore dans l'Atlantique de 1964 à 1975 a été évalué au moyen des modèles globaux. Des analyses antérieures (Fox & Coan, 1976) ont été mises à jour, et les résultats viennent appuyer les conclusions tirées les années passées. Les meilleurs résultats ont été obtenus au moyen d'une courbe ample et aplanie (m = 0). Les estimations de la moyenne de production maximale soutenue sont de 95.700 TM pour la pêche de surface dans l'Atlantique Est et de 116.100 TM pour l'ensemble de la pêcherie atlantique (surface et palangre). Les prises de ces pêcheries en 1975 avaient été respectivement de 90.700 TM et 119.400 TM.

RESUMEN

Se emplea el modelo generalizado de producción del stock para evaluar la situación de la pesquería de rabil en el Atlántico durante el período 1964-1975. Se ponen al día análisis previos (Fox y Coan, 1976) y las conclusiones corroboran las de años anteriores. Los mejores resultados se obtienen por medio de una curva producción/esfuerzo amplia y aplanada (m = 0). El cálculo de la media de rendimiento máximo sostenible de la pesquería de superficie en el Atlántico oriental es de 95.700 TM, y de 116.100 TM para el conjunto de la pesquería atlántica (superficie y palangre). La captura de dichas pesquerías en 1975 es de 90.700 TM y 119.400 TM respectivamente.

INTRODUCTION

This study updates our previous production model analysis on the status of yellowfin tuna fishery (Fox and Coan, 1976). Revised data for 1974 as well as preliminary data for 1975 are used in this study. The production model was used with data from the eastern Atlantic surface fishery (baitboats and purse seiners) alone and on the total Atlantic fishery (surface and longline). Our analysis, therefore, considered two possible stock structures of the exploited yellowfin tuna population of the Atlantic Ocean--one stock or two stocks separated at 30°W longitude.

CATCH DATA AND ASSUMPTIONS

Catch data were obtained from the ICCAT Statistical Bulletin Vol. 5 (ICCAT, 1975a) for 1964 to 1974. Preliminary catch data for the 1975 fishery were obtained from ICCAT (pers. commun., Madrid, Spain). All catches from unclassified gears are assumed to be longline catches except for 1,800 metric tons from the Spanish catch in 1972 and 1,200 metric tons from the Angola catch in 1973 and 1974, which are assumed to be from surface gears.

Additional assumptions are made to separate surface catches into the eastern and western Atlantic.

1) Canada - all catches are assumed to be from the eastern Atlantic.

2) Korea - all baitboat catches are assumed to be from the eastern Atlantic.

3) Japan - all baitboat catches are assumed to be from the eastern Atlantic.

4) Spain - all catches are assumed to be from the eastern Atlantic.

5) Cuba - all purse seine catches are assumed to be from the eastern Atlantic.

6) Panama - all baitboat catches are assumed to be from the eastern Atlantic.

CATCH PER UNIT EFFORT DATA AND METHODS

Catch per unit effort data for the eastern Atlantic surface fishery were obtained from various sources. Fonteneau and Soisson (1974) developed a catch per unit effort index for yellowfin tuna, 1969-1973, from the FIS (French-Ivory Coast-Senegalese) fleet by gear type and size class, and corrected for fishing effort not directly on yellowfin tuna. Fonteneau and Soisson (1974) provided both catch per days at sea (CPDA) and catch per days fishing (CPDF). A. Fonteneau (pers. commun., ORSTOM, Abidjan, Ivory Coast) provided CPDA for 1964-1968 and J. Marcille (pers. commun., ORSTOM, Abidjan, Ivory Coast) provided CPDA for 1974 and 1975 (Table 1). Marcille reported that no catch per unit effort indices were available for baitboats in 1975 as their catches were insignificant. Due to the limited data available for class 5 purse seiners, class 6 purse seiners were eliminated from all calculations.

Standardization of effort for the eastern Atlantic surface fishery was accomplished with the method described by Fox and Coan (1976) with a few modifications. First, CPDA was used instead of CPDF due to the absence of CPDF data for many of the years. Second, a correlation analysis of CPDA for baitboat and seiners (Table 1) revealed that class 5 seiners were very poorly correlated to other classes of baitboats and seiners (Table 2). Since most of the time series is based upon baitboat and smaller seiner data, class 5 seiners were eliminated from all calculations. In the future, however, more comprehensive studies to standardize the data from large purse seiners (classes 5 and 6) should be made. Third, the data were standardized to class 3 seiners by using the ratio of the 1969-74 average CPDA of class 3 seiners to the average CPDA of each respective gear type and size class. Fourth, the catch per standard days at sea (CPSDA) of the baitboat and seiner classes were averaged and a composite CPSDA was obtained by calculating a weighted average within years using the approximate catch of each gear as weights (Table 3). This composite CPSDA was used for the eastern Atlantic surface fishery (Table 4) and for the total Atlantic surface fishery (Table 6).

The catch per unit effort data for the longline fishery were treated as in the past (Fox and Coan, 1976; Table 5). Data from only the Japanese fishery were utilized. A plot of Hook Rate I to Hook Rate II (Honma, 1976) indicated that the relationship was linear (Figure 1). The regression relation was therefore used to estimate Hook Rate II for 1974 from Hook Rate I. The average weights for yellowfin tuna caught by Japanese longline vessels were multiplied by Hook Rate II to obtain an index by weight (Hook Rate III; Table 5).

Hook Rate III for the longline fishery (Table 5) was standardized to CPSDA of a class 3 FIS purse seiner by multiplying each year's value by the ratio of the 1964-1974 average surface CPSDA to the 1964-1974 average Hook Rate III. To estimate the 1975 longline CPSDA, linear trend lines were fitted to both the surface and longline CPSDA for the period 1964-1974 and the 1975 longline fishery point was assumed to have the same deviation from its trend line as the 1975 surface fishery point. Annual effective effort in thousands of days at sea was calculated for the surface and longline fisheries and then summed to get the effective effort for the total Atlantic fishery.

The computer program PRODFIT (Fox, 1975) was used to estimate the parameters for the generalized stock production model (Pella and Tomlinson, 1969) for the eastern Atlantic surface fishery alone and for the total Atlantic fishery. The number of significant year classes (A_∞) in the catch was assumed to be three for the surface fishery and four for the total fishery (Fox and Lenarz, 1973).

RESULTS

Eastern Atlantic surface fishery

Three special cases of the generalized stock production model (m=0, m→1 and m=2) were fitted to the data from the eastern Atlantic surface fishery for yellowfin tuna (Table 4) using three significant year classes in the catch. As in the past, the highest degree of fit was obtained with m=0, or the broad, flat-topped production model (Table 7) and the degree-of-fit index (0.780) is improved over the previous year (0.707). The maximum sustainable average yield (MSAY) was estimated at 95,700 metric tons at an infinite amount of fishing effort. The equilibrium sustainable average yield at the 1975 level of fishing effort was estimated at 80,000 metric tons which is 10,700 metric tons below the 1975 catch. The equilibrium curves for all three cases are shown in Figure 2.

Total Atlantic fishery

The same three cases of the production model were fit to the data from the total Atlantic fishery (Table 6) using four as the number of significant year classes in the catch (A_n). The best fitting model was again m=0 (Table 8). However, the degree-of-fit index (0.826) declined slightly from 0.835 last year. The MSAY was estimated at 116,100 metric tons at an infinite amount of fishing effort. The equilibrium sustainable average yield at the 1975 level of fishing effort was estimated at 96,500 metric tons, 22,900 metric tons below the actual 1975 catch. All three estimated equilibrium curves are plotted in Figure 3.

CONCLUSION

Addition of the preliminary 1975 point results in the best fitting model with m=0, which is the same as results of past years' production model analyses. This year's estimate of MSAY for the eastern Atlantic surface fishery has increased by approximately 7% over last year's estimate of MSAY. Therefore, estimates of MSAY from the eastern Atlantic surface fishery continue to increase approximately 10% per year perhaps due to averaging out of the effects of the poor year class in 1969 (Fonteneau and Lenarz, 1973). Estimates of MSAY for the total Atlantic fishery have fluctuated between 92,000 and 115,000 metric tons, and this year's MSAY has increased slightly to 116,100 metric tons.

The total catch from the total Atlantic surface fishery has increased by approximately 11,500 metric tons over last year's total catch. The best estimates, however, indicate that such increases should not continue on the same scale with further increases in fishing effort even if recruitment remains near average and the effects of large quantities of small fish being caught in recent years has little net effect on the fishery (ICCAT, 1975b, p. 75). The true form of the right-hand side of the curve is still very obscure (Figures 2 and 3) and therefore, the fishery should be monitored closely.

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Table 1. Yellowfin tuna catch per day at sea (CPDA) and catch per days fishing (CPDF) for six groups of French-Ivory Coast-Senegalese tuna vessels corrected for effort on skipjack, 1964-1975 [1,2]

Year	Baitboat Class 2[3]		Baitboat Class 3		Seiner Class 3		Seiner Class 4		Seiner Class 5		Seiner Class 6	
	CPDA	CPDF	CPDA	CPDF	CPDA	CPDF	CPDA	CPDF	CPDA	CPDF	CPDA	CPDF
1964	1.66		2.91		2.74							
1965	1.80		2.16		2.46							
1966	1.78		2.74		3.43							
1967	2.28		2.88		3.63							
1968	2.59		4.51		3.47							
1969	1.50	2.09	2.18	3.20	3.34	4.48	4.68	5,54	5.40	7.28		
1970	1.16	1.42	1.60	1.93	2.30	2.89	3.39	3.32	6.08	7.80		
1971	1.20	1.67	1.55	1.92	2.10	2.47	3.18	3.57	4.48	5.29		
1972	1.33	2.44	2.22	3.43	2.86	4.07	3.65	4.76	5.47	7.14		
1973	1.19	1.75	1.73	2.42	2.10	2.76	2.89	3.40	5.33	6.44		
1974	1.35		1.84		2.26		3.75		5.43		8.24	
1975					1.81		3.47		6.86		12.01	
$\bar{x}$, '69 - '74	1.29		1.85		2.49		3.59					

1 In metric tons per day

2 1964-1968 from A. Fonteneau (pers. commn. ORSTOM, Abidjan, Ivory Coast)
1969-1973 from Fonteneau and Soisson (1974)
1974, 1975 from J. Marcille (pers. commun. ORSTOM, Abidjan, Ivory Coast)

3 Class 2 = 100-200 metric tons carrying capacity
Class 3 = 200-300 metric tons carrying capacity
Class 4 = 300-450 metric tons carrying capacity
Class 5 = 450-600 metric tons carrying capacity
Class 6 = 600+ metric tons carrying capacity

Table 2. Correlation Coefficients of CPDA for five groups of French-Ivory Coast-Senegalese tuna vessels, 1969-1975.

	Baitboat class 2	Baitboat class 3	Purse seine class 3	Purse seine class 4	Purse seine class 5
Baitboat class 2	1.000	0.831	0.857	0.930	0.017
Baitboat class 3		1.000	0.878	0.717	0.191
Purse seine class 3			1.000	0.893	0.216
Purse seine class 4				1.000	0.189
Purse seine class 5					1.000

Table 3. Yellowfin tuna catch per standard days at sea (CPSDA) of French-Ivory Coast-Senegalese tuna vessels standardized to class 3 purse seiners and corrected for effort on skipjack tuna, 1964-1975.

Year	Baitboat class 2&3		Purse seine class 3&4		Weighted average[2]	
	CPSDA	Catch[1]	CPSDA	Catch[1]	CPSDA	Catch[1]
1964	3.56	13.2	2.74	4.3	3.36	17.5
1965	3.19	14.7	2.46	5.4	2.99	20.1
1966	3.57	15.9	3.43	7.5	3.53	23.4
1967	4.14	14.9	3.63	8.9	3.95	23.8
1968	5.54	19.9	3.47	12.6	4.74	32.5
1969	2.92	14.2	3.30	14.7	3.11	28.9
1970	2.20	8.1	2.33	18.0	2.29	26.1
1971	2.21	7.8	2.16	18.0	2.18	25.8
1972	2.78	8.4	2.70	24.6	2.72	33.0
1973	2.32	5.6	2.05	25.0	2.10	30.6
1974	2.55	6.4	2.43	32.0	2.45	30.4
1975			2.11	44.2	2.11	44.2

1 Source: ICCAT (1975a)

2 Weighted by the amount of catch taken by each vessel category

Table 4. Catch, catch per unit effort, and effective effort for the eastern Atlantic surface fishery for yellowfin tuna, 1964-1975

Year	Catch (X 10^3 metric tons)	Catch per unit effort (CPSDA)	Effective effort (X 10^3 SDA)
1964	28.1	3.36	8.36
1965	29.1	2.99	9.73
1966	37.7	3.53	10.68
1967	36.5	3.95	9.24
1968	54.2	4.74	11.43
1969	62.3	3.11	20.03
1970	45.1	2.29	19.69
1971	50.8	2.18	23.30
1972	63.3	2.72	23.27
1973	59.6	2.10	28.38
1974	75.9	2.45	30.98
1975	90.7	2.11	42.99

Table 6. Catch, catch per unit effort (CPSDA), and effective effort (SDA) for the Atlantic yellowfin tuna fishery, 1964-1975.

Year	Surface			Longline			Total		
	Catch ($\times 10^3$ metric tons)	CPSDA	Effort ($\times 10^3$ SDA)	Catch ($\times 10^3$ metric tons)	CPSDA[1]	Effort ($\times 10^3$ SDA)	Catch ($\times 10^3$ metric tons)	CPSDA	Effort ($\times 10^3$ SDA)
1964	28.1	3.36	8.36	40.5	3.68	11.01	68.6	3.54	19.37
1965	29.1	2.99	9.73	40.5	3.28	12.35	69.6	3.15	22.08
1966	37.7	3.53	10.68	26.9	4.20	6.40	64.6	3.78	17.08
1967	36.8	3.95	9.32	21.7	3.65	5.95	58.5	3.83	15.27
1968	54.2	4.74	11.43	28.2	4.40	6.41	82.4	4.62	17.84
1969	62.3	3.11	20.03	30.6	3.21	9.53	92.9	3.14	29.56
1970	45.1	2.29	19.69	31.1	2.35	13.23	76.2	2.31	32.92
1971	50.8	2.18	23.30	29.0	2.18	13.30	79.8	2.18	36.60
1972	66.1	2.72	24.30	29.6	2.49	11.89	95.7	2.64	36.19
1973	61.7	2.10	29.38	32.0	1.88	17.02	93.7	2.02	46.40
1974	77.6	2.45	31.67	30.3	2.11	14.36	107.9	2.34	46.03
1975	90.7	2.11	42.99	28.7	(1.77)[2]	16.21	119.4	2.02	59.20

1 Hook Rate III (table 5) adjusted to CPSDA

2 Assumed to be the same deviation from trend line as the 1975 surface CPSDA

Table 5. Yellowfin tuna catch per unit effort (Hook Rate) for Japanese longline vessels in the Atlantic Ocean, 1964-1974

Year	Hook Rate I[1] (fish/100 hooks)	Hook Rate II[2]	Catch (fish X 10^3)[1]	Catch (metric tons X 10^3)[5]	Hook Rate III
1964	1.03	0.91	179.2	35.1	36.34
1965	0.95	0.82	927.3	36.6	32.38
1966	0.73	0.74	394.5	22.1	41.49
1967	1.18	1.03	366.0	12.8	36.04
1968	0.91	0.86	274.2	13.9	43.46
1969	0.82	0.78	241.8	9.8	31.68
1970	0.46	0.66	189.6	6.7	23.24
1971	0.52	0.57	292.1	11.0	21.52
1972	0.36	0.52	159.0	7.5	24.62
1973	0.30	0.48	108.6	4.2	18.52
1974[4]	0.25	0.46[3]	94.7	4.3	20.86

1 Fisheries Agency of Japan (1967a, 1967b, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975)

2 Honma (1976)

3 Calculated by the relation:
Hook Rate II = 0.316 + 0.580 (Hook Rate I)

4 Preliminary catch and effort statistics, Kume (pers. commun., Far Seas Laboratory, Shimuzu, Japan)

5 ICCAT (1975a)

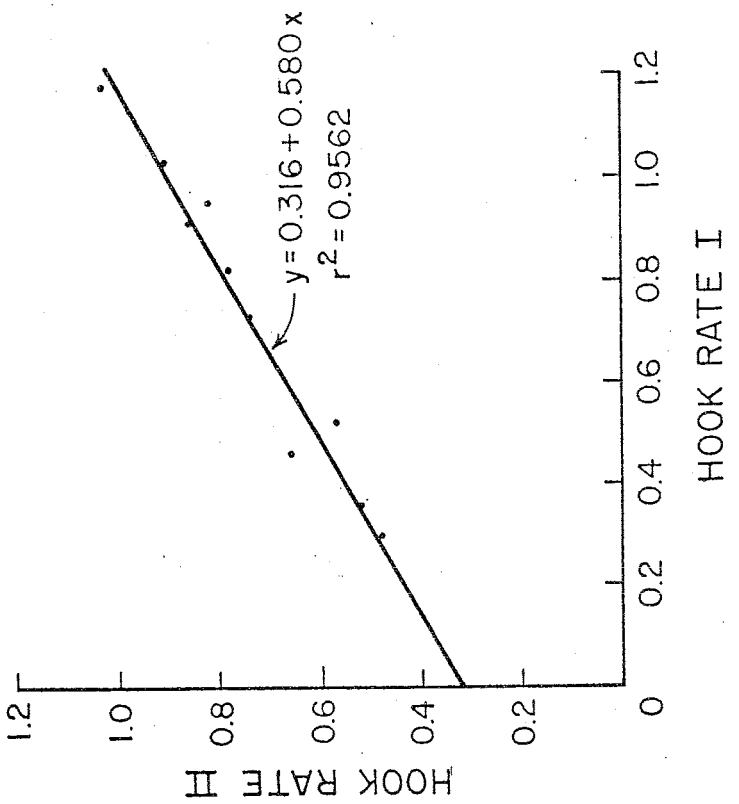

Figure 1. Relationship between Hook Rate I and Hook Rate II for the Japanese longline fishery in the Atlantic Ocean, 1964-1973

Table 7. Estimated production model parameters for the eastern Atlantic surface fishery for yellowfin tuna, 1964-1975, assuming A_n=3

m	Ymax (X 10^3 M. tons)	Umax CPSDA	fopt (X 10^3 SDA)	q (X 10^{-2})	Degree of fit index (r^2)	1975 actual catch (X 10^3 M. tons)	1975 equilibrium catch (X 10^3 M. tons)
0	95.7	6.74	∞	2.58	0.780	90.7	80.0
1	67.8	4.99	36.9	2.33	0.728	90.7	66.9
2	69.5	4.35	31.9	2.40	0.667	90.7	62.0

Table 8. Estimated production model parameters for the total Atlantic yellowfin fishery, 1964-1975, assuming A_n=4

m	Ymax (X 10^3 M. tons)	Umax (CPSDA)	fopt (X 10^3 SDA)	q (X 10^{-2})	Degree of fit index (r^2)	1975 actual catch (X 10^3 M. tons)	1975 equilibrium catch (X 10^3 M. tons)
0	116.1	9.65	∞	1.99	0.826	119.4	96.5
1	92.7	5.56	45.3	2.35	0.775	119.4	88.7
2	95.9	4.61	41.6	1.75	0.720	119.4	76.6

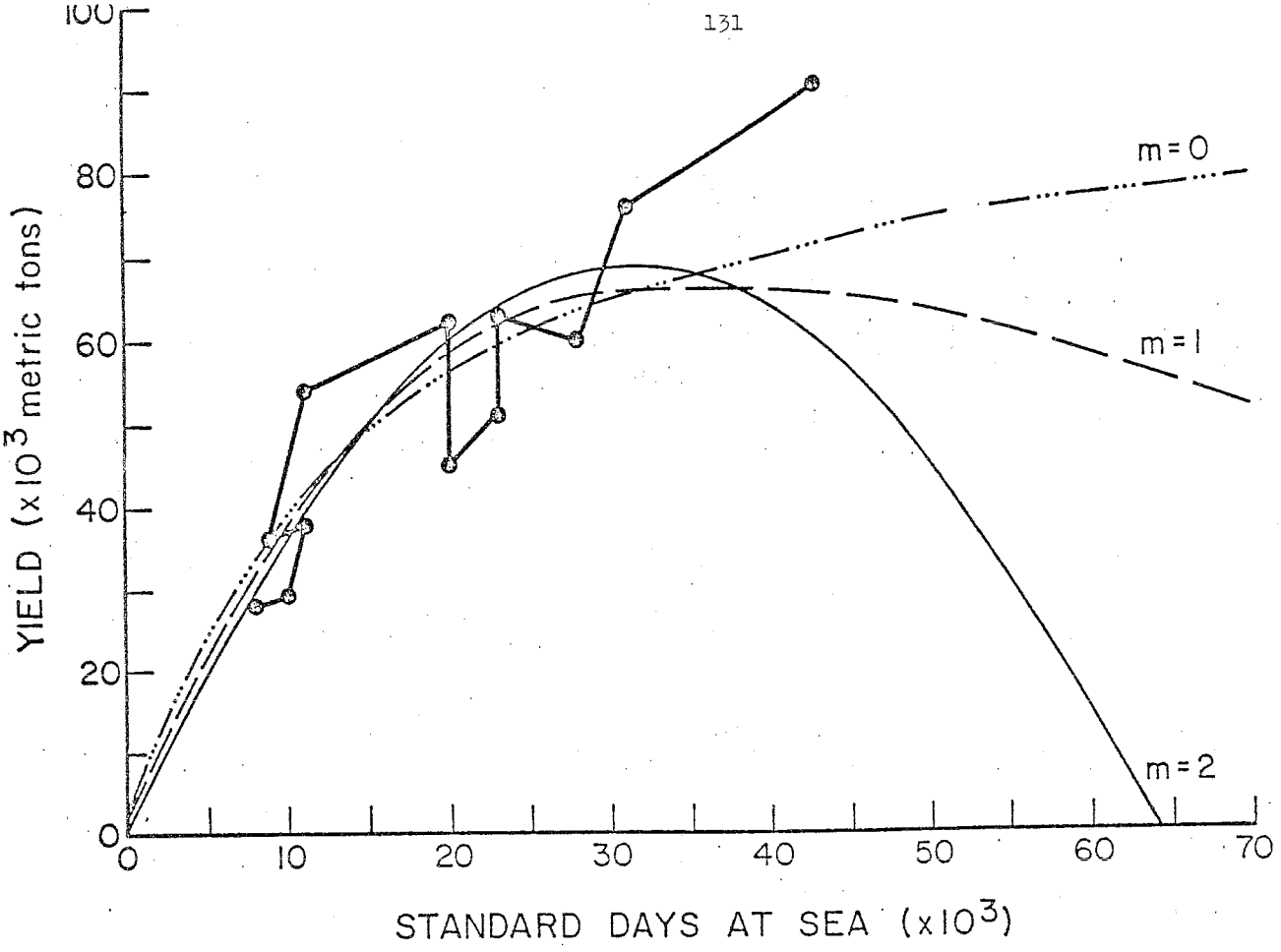

Figure 2. Sustainable average yield curves and observed data, 1964-1975, for the eastern Atlantic yellowfin tuna surface fishery

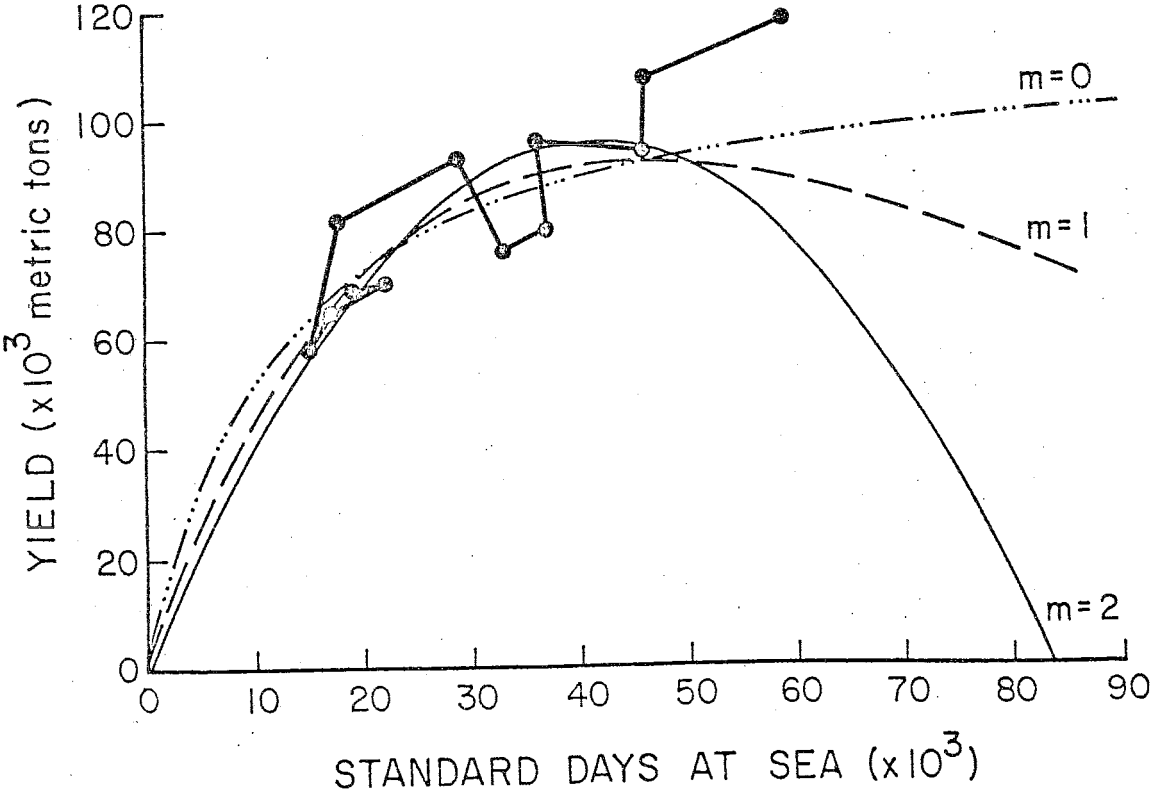

Figure 3. Sustainable average yield curves and observed data, 1964-1975, for the total Atlantic yellowfin tuna fishery