RESUMEN

La evaluación del status del rabil del Atlántico de 1964 a 1976 se hizo por medio del modelo generalizado de producción del stock. Se actualizaron análisis anteriores (Coan y Fox 1977). Sigue siendo válida la conclusión según la cual no se puede aumentar en forma significativa el nivel sostenible de capturas de rabil, sin un cambio importante en la naturaleza de la pesquería. Se estudió el efecto de un cambio en ese sentido: el desarrollo de una importante pesquería de altura en superficie en 1975 y 1976. Dicho desarrollo da como resultado, hasta el momento, un alza en las estimaciones del rendimiento máximo sostenible medio (MSAY), de 10.000 a 30.000 toneladas para la pesquería de superficie del Atlántico oriental y para el total de la pesquería en dicho océano. Generalmente, las mejores estimaciones del MSAY se derivan de una curva de rendimiento sin máximos definidos (m = 0), siendo de 112.000 toneladas para la pesquería de superficie del Atlántico oriental y de 138.000 toneladas para el total de la pesquería en dicho océano. Sin embargo, en teoría, estas estimaciones del MSAY se dan con un esfuerzo de pesca infinito, y los cálculos del rendimiento sostenible, a los niveles de esfuerzo de 1976, son 76.000 y 99.000 toneladas para la pesquería de superficie de la zona oriental y para el total de las pesquerías, respectivamente. Las capturas en 1976 fueron: 90.000 toneladas (superficie/zona oriental) y 112.000 toneladas (total Atlántico). Por consiguiente, si la naturaleza y el esfuerzo de la pesquería permanecen constantes, la captura futura de rabil en el Atlántico promediaría de 13 a 14.000 toneladas menos, respecto al nivel alcanzado en 1976.

INTRODUCTION

This report updates production model analyses of Fox and Coan (1976) and Coan and Fox (1977) on yellowfin tuna (Thunnus albacares) from the Atlantic Ocean. Revised catch and catch per effort data are used in this analysis. This analysis assumes two possible stock structures for yellowfin tuna from the Atlantic Ocean; 1) one unit stock and 2) western and eastern Atlantic stocks separated at 30°W longitude. Due to increased fishing effort and catches of yellowfin tuna in the offshore area (Figure 1) of the eastern Atlantic, especially in 1975 and 1976, the production model was used with three sets of catch and effort data; 1) data from the entire eastern Atlantic surface fishery (baitboats and purse seiners), 2) data from the surface fishery in the eastern Atlantic excluding catch and effort from the offshore area (Figure 1), and 3) data from the total Atlantic longline and surface fishery.

FISHERY DATA AND ANALYTICAL METHODS

The computer program PRODFIT (Fox, 1975) was used to estimate the parameters of the generalized stock production model (Pella and Tomlinson, 1969) for the three sets of data mentioned previously. The number of significant age groups (A_p) contributing to the catch of the surface fishery in the eastern Atlantic and the eastern Atlantic excluding the offshore area was assumed to be three. Four significant age groups were assumed for catches of the total Atlantic longline and surface fishery. Two types of data are needed for the program PRODFIT; 1) total annual catches in tons and 2) standardized effort.

Total annual catches

Catches of yellowfin tuna from the Atlantic Ocean were compiled from the International Commission for the Conservation of Atlantic Tunas (ICCAT) Statistical Bulletin (ICCAT, 1977; ICCAT, 1976; ICCAT, 1975). The following assumptions were made for catches reported as unclassified by area and/or gear in the statistical bulletin:

1) Cuban catches in 1966 to 1970, reported as unclassified area and gear, were assumed to be longline catches and were used as part of the total Atlantic longline and surface fishery catches.

2) Cuban purse seine catches in 1971 and 1973, reported as unclassified area, were assumed to be eastern Atlantic catches and were used with the eastern Atlantic surface fishery catches.

3) Panamanian baitboat catches in 1972 to 1974, reported as unclassified area, were assumed to be catches from the eastern Atlantic and were used with the eastern Atlantic surface fishery catches.

4) Japanese baitboat catches in 1976, reported as unclassified area, were assumed to be catches from the eastern Atlantic and were used with eastern Atlantic surface fishery catches.

Yellowfin tuna catches of the entire eastern Atlantic surface fishery in 1969 to 1976 (Table 3) were decreased by the amount of the catch from the offshore area (Figure 1). Catch and effort data by one-degree squares for the French-Ivory Coast-Senegalese (FIS) fleet were used to find the percentage of the total FIS catch of baitboat and purse seiners in the offshore area. These percentages were applied to the total reported catches of baitboats and purse seiners from the FIS fleet (Table 2). These percentages were also used to reduce the total catches of Spanish and FIS fleets and catches from the entire eastern Atlantic surface fishery were reduced by the calculated amounts for the Spanish and FIS fleets (Table 3). Catch and effort data by one degree square for the American fleet were used to estimate the percentage of the American total catches that were from the offshore area. These percentages were applied to the total reported catches of the American fleet and the catches of the entire eastern Atlantic surface fishery were reduced by the calculated amounts (Table 3).

Standardized effort

Catch per unit effort indices by gear and size class, corrected for fishing effort not directly on yellowfin tuna are available for the FIS fleet in 1964 to 1976 (Table 1). The indices in catch per days at sea (CPDA) for 1964 to 1968 and 1976 were provided by A. Fonteneau (pers. commun.). Fonteneau and Soisson (1974) provided the indices for 1969 to 1973 in both CPDA and catch per days fishing (CPDF) and J. Marcille (pers. commun.) provided indices of CPDA for 1974 and 1975. No indices were reported for baitboats in 1975 and 1976 since their catches were considered insignificant. These indices are assumed to be representative indices of yellowfin abundance for the surface fishery in the Atlantic Ocean and were used as a basis for standardizing effort.

Standardization of effort from the entire eastern Atlantic surface fishery was accomplished using the methods of Coan and Fox (1977). Briefly the procedures followed are:

1) CPDA for all gears and class sizes (Table 1), excluding class 5 and 6 purse seiners, were standardized to class 3 purse seiners using the ratio of the 1969 to 1974 average CPDA of class 3 purse seiners to the average CPDA of each gear and size class.

2) Catch per standard days at sea (CPSDA) for the purse seine and baitboat classes were weighted by the catch of each gear and a composite weighted average CPSDA for the entire surface fishery was calculated (Table 2).

3) CPSDA for baitboats in 1975 and 1976 were calculated from the linear regression of CPSDA of purse seiners to CPSDA of baitboats.

These composite estimates of CPSDA were used to calculate standard days at sea for the entire eastern Atlantic surface fishery (Table 3) and the total Atlantic surface fishery (Table 5).

Estimates of CPSDA for 1969 to 1976 of FIS baitboats and purse seiners (Table 2) were adjusted to exclude catch and effort from the offshore area using the following procedure:

1) Estimates of the percentage of the total FIS catch and effort taken from the inshore areas 1 to 4 (Figure 1) were calculated for purse seiners and baitboats in 1969 to 1976.

2) The ratio of the percent catch taken in the inshore areas to the percent effort taken in the inshore areas by year and gear was multiplied by the CPSDA of the FIS baitboats and purse seiners for 1969 to 1976 (Table 2).

3) Catches for FIS baitboats and purse seiners were reduced by the percentage of the total FIS catch taken in the offshore area (Table 2).

4) Adjusted CPSDA from FIS baitboats and purse seiners, excluding the offshore area, were weighted by the reduced catches and a composite average CPSDA was calculated for the eastern Atlantic surface fishery excluding the offshore area (Table 3).

5) The composite CPSDA for the eastern Atlantic excluding the offshore area was used to calculate standard days at sea.

Japanese longline catch and effort data were analyzed as in the past (Coan and Fox, 1977; Table 4) and were assumed to be representative of all longline catches. Hook Rate II was converted to Hook Rate III, an index by weight, by multiplying Hook Rate II by the average weight of yellowfin tuna caught by Japanese longliners (Table 4).

Hook Rate III was standardized to CPSDA of class 3 FIS purse seiners by multiplying each year's Hook Rate III by the ratio of the 1964 to 1975 average surface fishery CPSDA to the average Hook Rate III. The CPSDA for the longline catches in 1976 was estimated from the linear regression line of CPSDA of the surface fishery to CPSDA of the longline fishery. Annual effective effort in standard days at sea (SDA) were calculated for the surface and longline fisheries and then summed to obtain effective effort for the total Atlantic fishery.

RESULTS

Eastern Atlantic surface fishery

Three special cases of the generalized stock production model ($m = 0.0$, $m = 1.0$, $m = 2.0$) were fitted to the data from the entire eastern Atlantic surface fishery (Figure 2). The broad flat-topped equilibrium yield curve ($m = 0.0$), as in past analyses (Coan and Fox, 1977), gives the highest degree-of-fit index ($r^2 = 0.755$; Table 6) although the degree-of-fit index has decreased from the previous years analysis ($r^2 = 0.780$). Estimated maximum sustainable average yield (MSAY) at infinite fishing effort has increased from 95.7 thousand tons of Coan and Fox (1977) to 111.8 thousand tons with the addition of the 1976 point. The estimated equilibrium catch at the 1976 level of effort (40.2 thousand standard days at sea) is 75.8 thousand tons and is 14.7 thousand tons under the actual 1976 eastern Atlantic surface catch. The estimates equilibrium catch at this level of effort is about the same as for the model fitted last year.

The same three cases of the generalized stock production model were applied to the data from the eastern Atlantic surface data excluding the offshore area (Figure 2). The $m = 0.0$ case again yielded the best degree-of-fit index ($r^2 = 0.834$; Table 7). The MSAY is 88.0 thousand tons compared to 111.8 thousand tons with the entire eastern Atlantic data. The estimated 1976 equilibrium catch is 66.1 thousand tons at the 1976 level of effort (36.2 thousand standard days at sea). The actual 1976 catch is 6.4 thousand tons over the estimated 1976 equilibrium catch.

Total Atlantic fishery

The production model was fitted to the data from the longline and surface fisheries in the total Atlantic with four significant year classes (A_n) in the catch (Figure 3). The $m = 0.0$ case was again the best fitting model with a degree-of-fit index of 0.754 (Table 8) which has decreased from estimates of $r^2 = 0.826$ from Coan and Fox (1977). The MSAY has increased from 116.1 thousand tons of Coan and Fox (1977) to 137.7 thousand tons in this analysis, but occurs at infinite fishing effort. The estimated 1976 equilibrium catch at the 1976 level of effort (50.3 thousand standard days at sea) is 99.0 thousand tons which is 13.0 thousand under the actual 1976 catch. The estimated equilibrium catch at this level of effort is about the same as for the model fitted last year.

CONCLUSION

The special case, $m = 0.0$, of the production model continues to be the best fitting model as in the past years' production model analysis of the fishery (Coan and Fox, 1977). This year's estimate of MSAY for the entire eastern Atlantic surface fishery is approximately 17% higher than estimates of MSAY for the past year's analysis. This increase in MSAY appears to be caused by increases in catches and effort in the

offshore area of the eastern Atlantic, since the MSAY for data from the eastern Atlantic surface fishery excluding the offshore area is about the same as fits obtained prior to the inclusion of 1975 and 1976 data. Estimates of MSAY for the total Atlantic fishery are 19% higher than the past year's analysis. There is, however, no appreciable change in the status of Atlantic yellowfin.

Total catch from the total Atlantic fishery in 1976 has decreased 5.3 thousand tons from catches in 1975. This decrease is in part attributed to the decreased participation by American seiners in 1976. The longline catch declined 6.3 thousand tons in 1976. Preliminary estimates of 1977 catches indicate that catches should be as high as catches in 1976, possibly caused by increased catches in the offshore area or by a possible strong year class entering the eastern Atlantic fishery.

The true form of the right side of the equilibrium yield curve is still uncertain. The fishery should be monitored closely since estimation of effort does not include the large seiners that are exerting effort in the offshore area. Estimates of standardized effort using data from the large seiners should be investigated since total fishery effort may be underestimated for recent years and could have some effect on the shape of the equilibrium yield curve.

In addition, the effects of changes in the enforcement of the minimum size limit on yellowfin tuna and the effects of underreporting of yellowfin catches due to landing small yellowfin as bigeye tuna need investigation, since they affect our present understanding of the status of yellowfin tuna.

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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, 1964-1976 [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	
1976					2.01		3.53		5.48		8.87	
$\bar{x}$ '69-'74	1.29		1.85		2.49		3.59					

[1] In metric tons per day

[2] 1964-1968 from A. Fonteneau (pers. commun. ORSTOM, Abidjan, Ivory Coast)
1969-1973 from Fonteneau and Soisson (1974)
1976 from A. Fonteneau (pers. commun. ORSTOM, Paris, France)
1974, 1975 from J. Marcille (pers. commun. ORSTOM, Paris, France)

[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. Yellowfin tuna catch (tons X 10^3) and 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, 1964-1976, for the entire eastern Atlantic and for the eastern Atlantic excluding the offshore area

Year	Entire Eastern Atlantic						Eastern Atlantic Excluding Offshore Area					
	Baitboat class 2&3		Purse seine class 3&4		Weighted average[2]		Baitboat class 2&3		Purse seine class 3&4		Weighted average[2]	
	CPSDA	Catch[1]	CPSDA	Catch[1]	CPSDA	Catch[1]	CPSDA	Catch[1]	CPSDA	Catch[1]	CPSDA	Catch[1]
1964	3.56	13.2	2.74	4.3	3.36	17.5	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	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	3.57	15.9	3.43	7.5	3.53	23.4
1967	4.14	14.9	3.63	8.9	3.95	28.8	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	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	2.99	14.0	3.30	14.7	3.15	28.7
1970	2.20	8.1	2.33	18.0	2.29	26.1	2.21	8.0	2.32	17.8	2.28	25.8
1971	2.21	7.8	2.16	18.0	2.18	25.8	2.23	7.7	2.16	17.9	2.18	25.6
1972	2.78	8.4	2.70	24.6	2.72	33.0	2.81	8.3	2.70	24.4	2.73	32.7
1973	2.32	5.6	2.05	25.0	2.10	30.6	2.39	5.5	2.04	24.8	2.10	30.3
1974	2.55	6.4	2.43	32.8	2.45	39.2	2.57	6.3	2.42	32.3	2.44	38.6
1975	2.24[3]	2.8	2.11	42.9	2.12	45.7	2.28	2.8	1.82	33.2	1.85	36.0
1976	2.41[3]	4.0	2.23	44.0	2.25	48.0	2.46	4.0	1.95	34.0	2.00	38.0

[1] Source: ICCAT (1977).

[2] Weighted by the amount of catch taken by each vessel category.

[3] Calculated by the relation: CPSDA (baitboat) = 1.38 CPSDA (purse seine) - 0.66
$r^2 = 0.61$

Table 4. Yellowfin tuna catch per unit effort (Hook Rate) for Japanese long-line vessels in the Atlantic Ocean, 1964-1975.

Year	Hook Rate I[1] (fish/100 hooks)	Hook Rate II[2]	Catch (fish x 10^3)[1]	Catch (metric tons x 10^3)[3]	Hook Rate III
1964	1.03	0.96	879.2	35.1	38.32
1965	0.95	0.83	927.3	36.6	32.76
1966	0.73	0.72	394.5	22.4	40.88
1967	1.18	0.94	366.0	12.8	32.87
1968	0.91	0.84	274.2	13.9	42.58
1969	0.82	0.76	241.8	10.0	31.43
1970	0.46	0.65	189.6	6.8	23.81
1971	0.52	0.56	292.1	11.0	21.09
1972	0.36	0.51	159.0	7.5	24.06
1973	0.30	0.48	108.6	4.2	18.56
1974	0.25	0.63	94.7	4.3	28.61
1975	0.20	0.40	116.3	6.0	20.64

[1] Fisheries Agency of Japan (1967-1977)

[2] Kume (pers. commun., Far Seas Laboratory, Shimizu, Japan).

[3] ICCAT (1977).

Table 3. Catch (tons x 10^3), catch per standard days at sea (CPSDA), and effective effort (standard days at sea, SDA x 10^3), for the eastern Atlantic surface fishery for yellowfin tuna, 1964-1976, for the entire eastern Atlantic and the eastern Atlantic excluding the offshore area[1].

Year	Entire Eastern Atlantic			Eastern Atlantic Excluding Offshore Area		
	Catch	CPSDA	Effective effort	Catch	CPSDA	Effective effort
1964	28.1	3.36	8.36	28.1	3.36	8.36
1965	29.1	2.99	9.73	29.1	2.99	9.73
1966	37.7	3.53	10.68	37.7	3.53	10.68
1967	36.5	3.95	9.24	36.5	3.95	9.24
1968	54.2	4.74	11.43	54.2	4.74	11.43
1969	62.3	3.11	20.03	61.3	3.15	19.46
1970	45.1	2.29	19.69	44.7	2.28	19.60
1971	50.8	2.18	23.30	50.6	2.18	23.21
1972	63.3	2.72	23.27	62.4	2.73	22.86
1973	59.6	2.10	28.38	59.2	2.10	28.19
1974	75.9	2.45	30.98	75.0	2.44	30.74
1975	88.3	2.12	41.65	70.8	1.85	38.27
1976	90.5	2.25	40.22	72.5	2.00	36.25

Table 5. Catch (tons x 10^3), catch per standard days at sea (CPSDA), and effective effort (standard days at sea, SDA x 10^3) for the Atlantic yellowfin tuna fishery, 1964-1976.

Year	Surface			Longline			Total		
	Catch	CPSDA	Effort	Catch	CPSDA[1]	Effort	Catch	CPSDA	Effort
1964	28.1	3.36	8.36	40.5	3.51	11.54	68.6	3.45	19.90
1965	29.1	2.99	9.73	40.5	3.00	13.50	69.6	3.00	23.23
1966	37.7	3.53	10.68	27.2	3.74	7.27	64.9	3.62	17.95
1967	36.7	3.95	9.29	21.7	3.01	7.21	58.4	3.54	16.50
1968	54.3	4.74	11.46	28.2	3.90	7.23	82.5	4.41	18.69
1969	62.3	3.11	20.03	30.8	2.88	10.69	93.1	3.03	30.72
1970	45.1	2.29	19.69	31.3	2.13	14.69	76.4	2.22	34.38
1971	50.8	2.18	23.30	29.0	1.93	15.03	79.8	2.08	38.33
1972	66.1	2.72	24.30	29.6	2.20	13.45	95.7	2.54	37.75
1973	61.7	2.10	29.38	32.0	1.70	18.82	93.7	1.94	48.20
1974	77.6	2.45	31.67	30.3	2.62	11.56	107.9	2.50	43.23
1975	90.2	2.12	42.55	27.1	1.89	14.34	117.3	2.06	56.89
1976	91.2	2.25	40.53	20.8	2.13	9.76	112.0	2.23	50.29

[1]Hook Rate III (Table 4) adjusted to CPSDA of Class III purse seiners

[2]Calculated by the relation: CPSDA (longline) = .301 + 813 CPSDA (surface). (r^2 = .79)

Table 6. Estimated production model parameters for the entire eastern Atlantic surface fishery for yellowfin tuna, 1964-1976, assuming A_n = 3

m	Ymax (X 10^3 tons)	Umax CPSDA	fopt (X 10^3 SDA)	q (X 10^{-2})	Degree of fit index (r^2)	1976 actual catch (X 10^3 tons)	1976 equilibrium catch (X 10^3 tons)
0	111.8	5.93	∞	2.27	0.755	90.5	75.8
1	75.8	4.68	44.0	1.79	0.700	90.5	75.4
2	76.2	4.18	36.5	2.71	0.643	90.5	75.5

Table 7. Estimated production model parameters for the eastern Atlantic yellowfin tuna surface fishery excluding the offshore area , 1964-1976, assuming A_n = 3

m	Ymax (X 10^3 tons)	Umax CPSDA	fopt (X 10^3 SDA)	q (X 10^{-2})	Degree of fit index (r^2)	1976 actual catch (X 10^3 tons)	1976 equilibrium catch (X 10^3 tons)
0	88.0	7.30	∞	3.26	0.834	72.5	66.1
1	64.4	5.16	34.0	2.89	0.796	72.5	64.4
2	66.4	4.44	29.9	2.20	0.748	72.5	63.8

Table 8. Estimated production model parameters for the total Atlantic yellowfin fishery, 1964-1976, assuming A_n = 4

m	Ymax (X 10^3 tons)	Umax (CPSDA)	fopt (X 10^3 SDA)	q (X 10^{-2})	Degree of fit index (r^2)	1976 actual catch (X 10^3 tons)	1976 equilibrium catch (X 10^3 tons)
0	137.7	7.24	∞	1.44	0.754	112.0	99.0
1	100.0	4.99	54.5	1.77	0.710	112.0	99.7
2	100.6	4.30	46.7	1.57	0.666	112.0	99.9

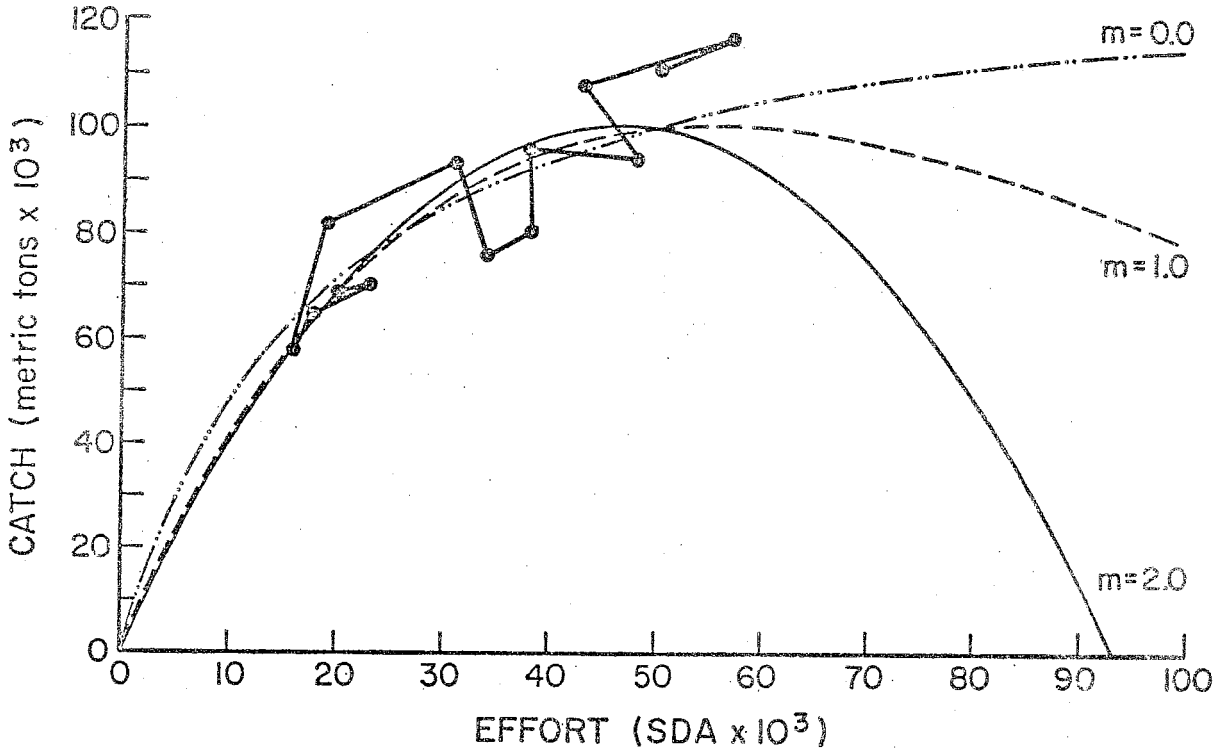

Figure 3. Equilibrium yield curves and observed data, 1964 to 1976, for the total Atlantic yellowfin tuna longline and surface fishery.

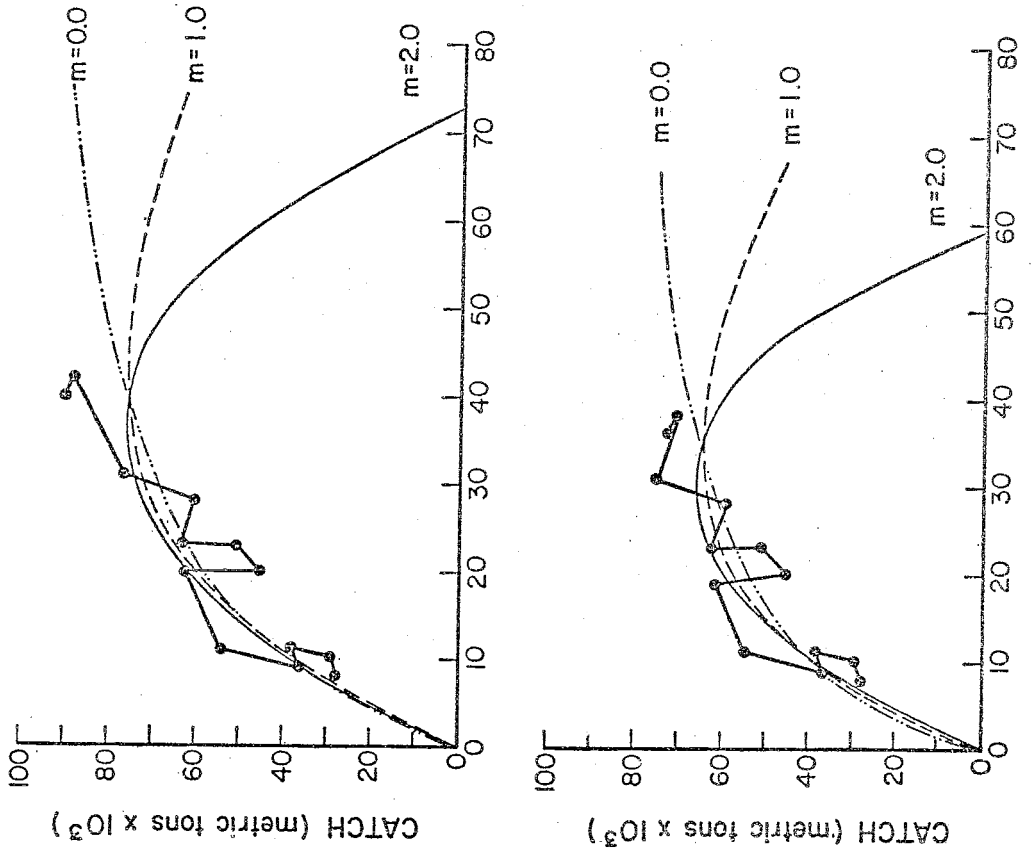

Figure 2. (Top) Equilibrium yield curves and observed data, 1964 to 1976, for the entire eastern Atlantic yellowfin tuna surface fishery.

(Bottom) Equilibrium yield curves and observed data, 1964 to 1976, for the eastern Atlantic yellowfin tuna surface fishery excluding the offshore area.