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STATUS OF ATLANTIC YELLOWFIN TUNA FROM PRODUCTION MODEL ANALYSIS 1964-1974

by

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SUMMARY

The generalized stock production model was used to evaluate the status of the Atlantic yellowfin tuna fishery through 1974. Our best estimates of the maximum sustainable average yield are 88,600 metric tons and 101,500 metric tons for analysis of the eastern Atlantic surface fishery alone and entire (longline plus surface) Atlantic fishery, respectively. Catches for these fisheries in 1974 are 74,200 metric tons and 107,400 metric tons, respectively. Our best estimate is that the yield-effort curve is broad and flat topped (m = 0) and the 1974 point reinforces this conclusion of previous years. However, the 1974 effort level is 27 percent and 76 percent above the optimum level of fishing effort for the respective eastern surface and entire analyses assuming a more pessimistic curve (m = 2).

RESUME

Le modèle généralisé de production a été utilisé pour évaluer l'état de la pêcherie à l'albacore dans l'Atlantique au cours de l'année 1974. Notre meilleure estimation du niveau moyen de production maximale soutenue est de 88.600 TM pour l'analyse de la pêcherie de surface de l'Atlantique Est seule, et de 101.500 TM pour celle de l'ensemble (palangre + surface) de la pêcherie atlantique. Les prises de ces pêcheries en 1974 étaient de 74.200 et 107.400 TM. Notre meilleure estimation est que la courbe production/effort est ample et aplatie au sommet (m = 0), et la position de 1974 appuie cette conclusion pour les années précédentes. Les niveaux de l'effort en 1974 étaient cependant de 27% et de 76% au-dessus du niveau optimum d'effort de pêche pour les analyses de la pêche de surface de l'Atlantique Est et celles de l'ensemble de la pêche, ce qui s'exprime par une courbe plus pessimiste (m = 2).

RESUMEN

El modelo de producción generalizado del stock se empleó para evaluar el status de la pesquería de rabil del Atlántico, durante el año 1974. Nuestras mejores estimaciones del nivel promedio de rendimiento máximo sostenible, son de 88.600 toneladas métricas, y de 101.500 toneladas métricas, para el análisis de la pesca de superficie en el Atlántico oriental únicamente, y para el conjunto de la pesca en el Atlántico (palangre y superficie), respectivamente. Las capturas de estas pesquerías en 1974 son de 74.200 toneladas métricas y de 107.400 toneladas métricas, respectivamente. Nuestra mejor estimación es que la curva rendimiento-esfuerzo es amplia y plana en su parte superior (m = 0) y el caso de 1974 refuerza esta conclusión deducida también de años anteriores. Sin embargo, el nivel de esfuerzo del 74 es del 27% y del 76% sobre el nivel óptimo de esfuerzo de pesca, respectivamente para la pesca de superficie en el Atlántico oriental, y para el análisis del conjunto, suponiendo una curva más pesimista (m = 2).

INTRODUCTION

This paper updates previous production model analyses of the status of the Atlantic yellowfin tuna (ICCAT, 1972; Fox and Lenarz, 1972, 1973; and Lenarz and Fox, 1974). Data from the fishery for 1974 and revision of previous year's data are incorporated in this year's analysis. As before, the analysis is conducted under the alternate yellowfin stock structure assumptions--all one stock or two stocks separated at 30°W longitude.

DATA AND METHODS

Catch statistics were obtained from the ICCAT Statistical Bulletin Vol. 5 (ICCAT, 1975a). The minor amounts of catch listed as taken by unclassified gear were assumed to be taken by longline with the exception of the Spanish catch of 1.8 thousand metric tons in 1972.

Catch per unit effort data for the eastern Atlantic surface fishery are different than those used in previous years. Fonteneau and Soisson (1974) developed a catch per unit effort index for yellowfin tuna, 1969-1973, by gear type and size class for the French-Ivory Coast-Senegalese (FIS) tuna fleet which is adjusted for fishing effort not directly on yellowfin tuna. Fonteneau and Soisson (1974) provided both the catch per day at sea (CPDA) and catch per day's fishing (CPDF). Fonteneau (Pers. Comm.)[1] provided similar data for 1974 and the CPDA for 1964-68 (Table 1).

A plot of the relationship between CPDF and CPDA indicates that it is linear over the observed range 1969-74 (Figure 1), so the 1964-68 CPDA data were converted to CPDF using the regression line (Table 1). The data were standardized to a Class 5 seiner using the ratio of the 1969-74 average CPDF of Class 5 seiners to the 1969-74 average CPDF of each respective gear type and size class. The CPSDF of the baitboat classes and the small seiner classes were averaged (Table 2). A composite catch per standard days fishing (CPSDF) was obtained by calculating a weighted average within years using the approximate catch of each gear type as weights (Table 2). Table 3 provides the data utilized in our analysis of the eastern Atlantic surface fishery alone.

The catch per unit effort data for the longline fishery were treated as in the past (Table 4). Data from only the Japanese fishery were utilized. The overall number of yellowfin tuna per 100 hooks (Hook Rate I) for 1972 and 1973 were converted to the index (Hook Rate II) developed in the Abidjan Report (ICCAT, 1972) through the linear regression calculated by Lenarz and Fox (1974). The average weights of yellowfin tuna taken by Japanese longline vessels were multiplied by the Hook Rate II data to obtain an index by weight (Hook Rate III; Table 4).

The data for the total Atlantic yellowfin tuna fishery are given in Table 5. Hook Rate III for the longline fishery (Table 4) was standardized to CPSDF of a Class 5 FIS seiner by multiplying each year's value by the ratio of the 1964-1973 average surface CPSDF to the 1964-1973 average Hook Rate III. To estimate the 1974 longline CPSDF, linear trend lines were fitted to both the surface and longline CPSDF for the period 1964-1973 and the 1974 longline point was assumed to be the same deviation from its trend line as the 1974 surface point, since the deviations are correlated ($r = 0.89$). Annual effective fishing effort in thousands of standard days fishing was computed for the surface and longline fisheries separately and then summed to get the total Atlantic effective fishing effort (Table 5).

The computer program PRODFIT (Fox, 1975) was used to estimate the parameters of the generalized stock production model (Pella and Tomlinson, 1969) for the eastern Atlantic surface fishery alone and for the total Atlantic fishery. The significant number of year classes in the catch (A_n) was assumed to be 3 for the surface fishery and 4 for the total fishery (Fox and Lenarz, 1973).

RESULTS

Eastern Atlantic Surface Fishery

Three special cases of the generalized stock production model ($m = 0$, $m \to 1$, and $m = 2$) were fit to the data (Table 3) with three different values for the number of significant year classes in the catch (Table 6). In each case the broad, flat-topped production model where $m = 0$ was the best fit (highest degree of fit index). The estimate of the maximum sustainable yield (Y_{max}) and optimum fishing effort (f_{opt}) for $m \to 1$ and $m = 2$ are not appreciably affected by the choice of A_n.

The complete set of parameters are given in Table 7 and the curves are plotted in Figure 2. The weighted least-squares estimate of m is 0.0, the maximum sustainable average yield (MSAY) is estimated at 88.6 thousand metric tons but at infinite fishing effort. The sustainable average yield is estimated at 64.0 thousand metric tons, 10.2 thousand tons less than the 1974 catch. The MSAY is estimated at about 60 thousand metric tons for $m \to 1$ and $m = 2$ at levels of fishing effort about the same as generated in 1974 and 1973 respectively.

[1]Alain Fonteneau, Centre de Recherches Oceanographiques, Abidjan, Ivory Coast

Total Atlantic Fishery

The same three cases of the production model were fit to the data (Table 5) from the total Atlantic fishery using three values for A_n (Table 8). Again, the best fitting model is with m = 0--all of the parameters are given in Table 9 and the curves are plotted in Figure 3. The MSAY is estimated at 101.5 thousand metric tons, but at infinite fishing effort. The sustainable average yield at the 1974 level of fishing effort is estimated at 88.6 thousand tons, 18.8 thousand tons less than the 1974 catch. For the other two models ($m \to 1$ and m = 2) the MSAY is estimated at about 88 thousand metric tons, but at the 1971-72 levels of fishing effort (Figure 3).

DISCUSSION

For the previous 2 years, the best fitting production model has been the broad, flat-topped model with m = 0. Addition of the preliminary 1974 point again results in m = 0 as being the best fitting model. Estimates of the MSAY from the eastern Atlantic surface fishery alone have increased about 10 percent a year for the past 3 years, with the present best estimate at 88.6 thousand metric tons. This is due, perhaps, to averaging out the effects of a poor year class which entered the fishery in 1969 (Fonteneau and Lenarz, 1973), or to a continued replacement of longline catch by the surface fishery in the eastern Atlantic, or both. However, this analysis assumes that either the surface fishery is operating on a separate stock from the longline fishery or that the rate of exploitation by the longline fishery has remained constant. Estimates of the MSAY from the total Atlantic fishery for the past 2 years have fluctuated between 92 and 115 thousand metric tons, with the present best estimate at 101.5 thousand metric tons--this analysis assumes one stock throughout the Atlantic Ocean.

It is apparent that the total Atlantic yellowfin tuna fishery is not likely to catch more than, or perhaps even repeat, the 1974 catch of 107.4 thousand metric tons under present conditions and the present constitution of the fishery. The best estimates indicate that the surface fishery may increase its catch marginally provided recruitment remains near average and there is little net effect of the large quantities of very small fish being caught in recent years (ICCAT, 1975b, p. 75). However, the true right-hand side of the yield-effort curve is still poorly known (Figures 2 and 3) and the 1974 level of fishing effort has exceeded f_{opt} estimates for the pessimistic model (m = 2) by 27 and 76 percent, respectively for the eastern Atlantic surface and total Atlantic analyses. Therefore, the fishery should continue to receive close attention.

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Table 1. Yellowfin tuna catch per day at sea (CPDA) and catch per days fishing (CPDF) for five groups of French-Ivory Coast-Senegalese tuna vessels corrected for effort on skipjack, 1964-1974 1/, 2/

Year	Baitboat Class 2 3/		Baitboat Class 3		Seiner Class 3		Seiner Class 4		Seiner Class 5	
	CPDA	CPDF	CPDA	CPDF	CPDA	CPDF	CPDA	CPDF	CPDA	CPDF
1964	1.66	(2.27) 4/	2.91	(3.70)	2.74	(3.50)	-	-	-	-
1965	1.80	(2.43)	2.16	(2.84)	2.46	(3.18)	-	-	-	-
1966	1.78	(2.41)	2.74	(3.50)	3.43	(4.29)	-	-	-	-
1967	2.28	(2.98)	2.88	(3.66)	3.63	(4.52)	-	-	-	-
1968	2.59	(3.33)	4.51	(5.53)	3.47	(4.34)	-	-	-	-
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	1.28	1.83	1.67	2.86	2.15	3.14	3.63	3.73	5.17	5.35
$\overline{X}$,'64-'68		2.68		3.85		3.97		-		-
$\overline{X}$,'69-'74		1.87		2.63		3.30		4.05		6.55
$\overline{X}$,'64-'74		2.24		3.18		3.60		-		-

1/ In metric tons per day

2/ Source: 1964-1968, 1974 from A. Fonteneau (Pers.Comm.)
1969-1973 from Fonteneau and Soisson (1974)

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

4/ Numbers in parentheses were calculated from the relationship:
CPDF = 0.3695 + 1.1439 (CPDA)

Table 2. Yellowfin tuna catch per standard days fishing (CPSDF) of French-Ivory Coast-Sengalese tuna vessels standardized to class 5 seiners and corrected for effort on skipjack tuna, 1964-1974.

Year	Baitboat Class 2 & Class 3		Seiner Class 3 & Class 4		Seiner Class 5		Weighted average 3/	
	CPSDF	Catch 2/	CPSDF	Catch 2/	CPSDF	Catch 2/	CPSDF	Catch 2/
1964	8.59	13.2	6.94	4.3	-	-	8.19	17.5
1965	7.81	14.7	6.31	5.4	-	-	7.40	20.1
1966	8.59	15.9	8.51	7.5	-	-	8.57	23.4
1967	9.79	14.9	8.97	8.9	-	-	9.48	23.8
1968	12.73	19.9	8.61	12.6	-	-	11.14	32.5
1969	7.66	8.6	8.92	11.8	7.28	2.9	8.25	23.3
1970	4.90	5.8	5.55	11.3	7.80	6.7	6.03	23.8
1971	5.33	5.1	5.33	12.3	5.29	5.7	6.32	23.1
1972	8.55	6.0	7.89	15.9	7.14	8.7	7.81	30.6
1973	6.09	2.8	5.49	16.1	6.44	8.9	5.86	27.8
1974	6.77	2.7	5.13	15.2	5.35	17.6	5.79	35.5

1/ See Table 1 for class designations

2/ Source: ICCAT (1975a)

3/ Weighted by the amount of catch taken by each vessel category

Table 3. Catch, catch per unit effort, and effective fishing effort for the eastern Atlantic surface fishery for yellowfin tuna, 1964-1974

Year	Catch (1,000 M. tons)	Catch per unit effort (CPSDF)	Effective effort (1,000 SDF)
1964	28.2	8.19	3.44
1965	29.0	7.40	3.92
1966	37.7	8.57	4.40
1967	36.5	9.48	3.85
1968	54.3	11.14	4.87
1969	62.3	8.25	7.55
1970	45.1	6.03	7.48
1971	50.8	5.32	9.55
1972	63.3	7.81	8.10
1973	59.7	5.86	10.19
1974	74.2	5.79	12.82

Table 4. Yellowfin tuna catch per unit effort (hook rate) for Japanese Longline vessels in the Atlantic Ocean, 1964-1973.

Year	Hook Rate I 1/ (Fish per 100 hooks)	Hook Rate II 2/	Catch (1,000's fish) 1/	Catch (1,000's M. tons) 3/	Hook Rate III
1964	1.03	0.90	879	35.1	35.93
1965	0.95	0.76	927	36.6	30.01
1966	0.73	0.69	395	22.1	38.61
1967	1.17	1.01	366	12.8	35.32
1968	0.91	0.82	274	13.9	41.60
1969	0.82	0.72	242	9.8	29.16
1970	0.46	0.51	190	6.7	17.98
1971	0.52	0.57	292	11.0	21.47
1972	0.36	(0.44) 4/	159	7.5	20.75
1973	0.30	(0.40) 4/	109	4.2	15.41

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

2/ ICCAT (1972)

3/ ICCAT (1975a)

4/ Calculated from Lenarz and Fox (1974) by:
$Y = 0.205 + 0.658 X$, where Y = Hook Rate II and
X = Hook Rate I

Table 5. Catch, catch per unit effort (CPSDF), and effective fishing effort (SDF) for the Atlantic yellowfin tuna fishery, 1964-1974.

Year	Surface			Longline			Total		
	Catch (1,000 M. tons)	CPSDF	Effort (1,000 SDF)	Catch (1,000 M. tons)	CPSDF 1/	Effort (1,000 SDF)	Catch (1,000 M. tons)	CPSDF	Effort (1,000 SDF)
1964	28.2	8.19	3.443	40.5	9.80	4.133	68.7	9.06	7.58
1965	29.0	7.40	3.919	40.4	8.18	4.939	69.5	7.84	8.86
1966	37.7	8.57	4.399	26.9	10.53	2.555	64.6	9.29	6.95
1967	36.7	9.48	3.871	21.7	9.63	2.253	58.5	9.56	6.12
1968	54.3	11.14	4.874	28.2	11.34	2.487	82.5	11.21	7.36
1969	62.3	8.25	7.552	30.7	7.95	3.862	92.9	8.14	11.41
1970	45.1	6.03	7.479	31.1	4.90	6.347	76.2	5.51	13.83
1971	50.8	5.32	9.549	30.5	5.85	5.214	81.3	5.51	14.76
1972	66.1	7.81	8.464	31.4	5.66	5.548	97.5	6.96	14.01
1973	61.7	5.86	10.529	32.0	4.20	7.619	93.7	5.16	18.15
1974	75.8	5.79	13.092	31.7	(3.74) 2/	8.476	107.4	4.98	21.57

1/ Hook Rate III (Table 4) adjusted to CPSDF

2/ Assumed to be same deviation from trend line as 1974 surface CPSDF.

Table 6. Degree of fit index, Ymax and f_{opt}, for three values of m and number of significant year classes (A_n) for the eastern Atlantic surface fishery for yellowfin tuna, 1964-1974.

m	A_n 2	3	4
	Degree of Fit Index (r^2)		
0	0.599+	0.707	0.713
1	0.599-	0.694	0.688
2	0.584	0.669	0.656
	Estimate of Ymax		
0	107.3	88.6	79.8
1	65.7	60.3	57.9
2	63.7	59.9	58.2
	Estimate of f_{opt}		
0	∞	∞	∞
1	14.5	12.1	11.1
2	11.5	10.1	9.6

Table 7. Estimated production model parameters for the eastern Atlantic surface fishery for yellowfin tuna, 1964-1974, assuming A_n = 3

m	Ymax (1,000 M. tons)	Umax (CPSDF)	f_{opt} (1,000 SDF)	q ($x10^{-2}$)	r^2	1974 Actual catch (1,000 M. tons)	1974 Equilibrium catch (1,000 M. tons)
0	88.6	18.0	∞	4.93	0.707	74.2	64.0
1	60.3	13.5	12.1	5.82	0.694	74.2	60.1
2	59.9	11.8	10.1	6.33	0.669	74.2	56.0

Table 8. Degree of fit index, Ymax and f_{opt} for three values of m and number of significant year classes (A_n) for the total Atlantic fishery for yellowfin tuna, 1964-1974.

m	A_n 3	4	5
	Degree of Fit Index (r^2)		
0	0.875	0.835	0.793
1	0.843	0.800	0.749
2	0.795	0.754	0.701
	Estimate of Ymax		
0	108.2	101.5	93.1
1	88.8	85.9	83.2
2	92.5	89.4	86.3
	Estimate of f_{opt}		
0	∞	∞	∞
1	16.1	15.3	14.6
2	15.1	14.6	14.2

Table 9. Estimated production model parameters for the total Atlantic yellowfin tuna fishery, 1964-1974, assuming A_n=4.

m	Ymax (1,000 M. tons)	Umax (CPSDF)	f_{opt} (1,000 SDF)	q ($x10^{-2}$)	r^2	1974 Actual catch (1,000 M. tons)	1974 Equilibrium catch (1,000 M. tons)
0	101.5	32.3	∞	4.20	0.835	107.4	88.6
1	85.9	15.3	15.3	2.47	0.800	107.4	80.4
2	89.4	12.3	14.6	2.87	0.754	107.4	68.7

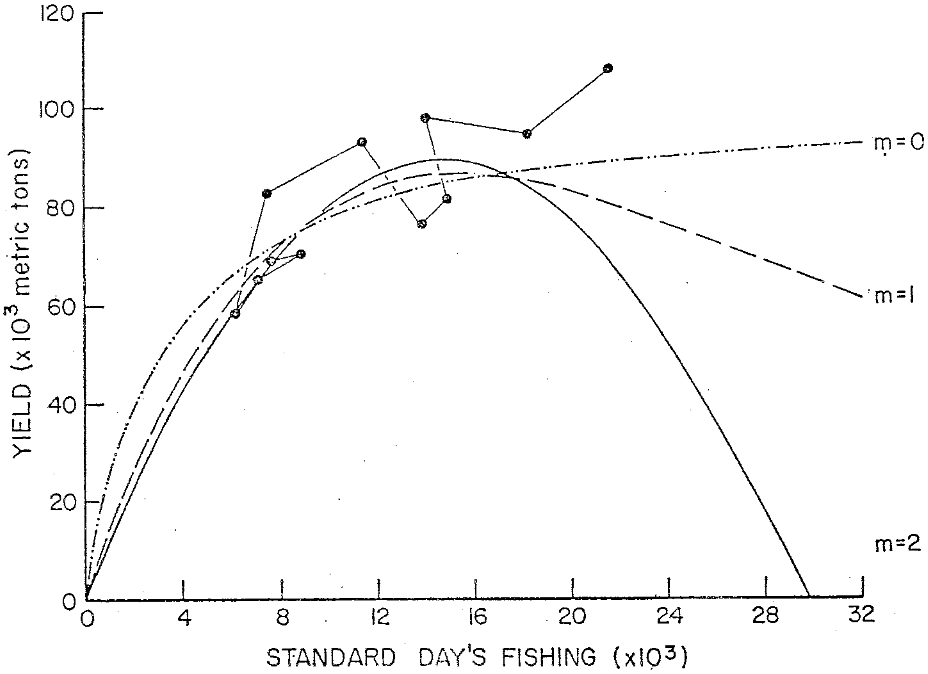

Figure 3. Sustainable average yield curves and observed data, 1964-1974, for the total Atlantic yellowfin tuna fishery

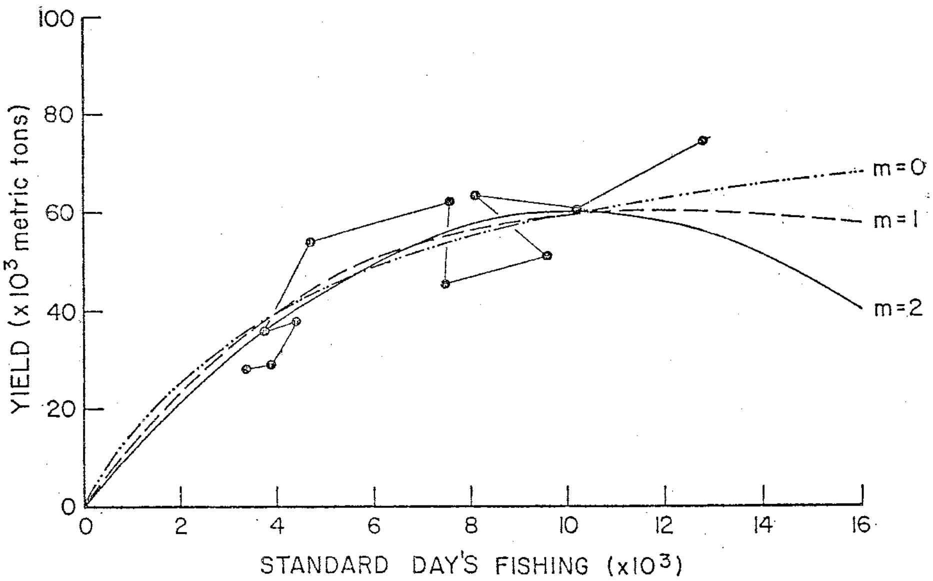

Figure 2. Sustainable average yield curves and observed data, 1964-1974, for the eastern Atlantic yellowfin tuna surface fishery

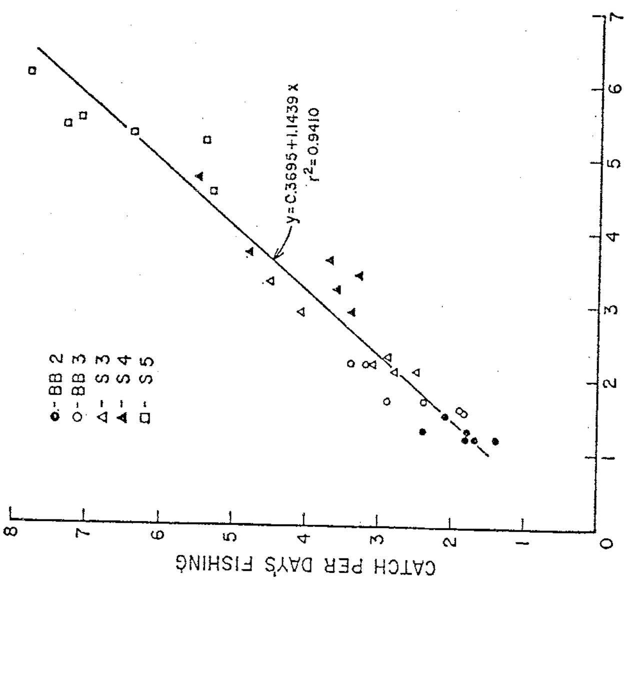

Figure 1. Relationship between catch per day at sea and catch per days fishing for FIS tuna vessels, 1969-1974