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YIELD OF ATLANTIC YELLOWFIN TUNA UNDER DIFFERENT HYPOTHESES ON THE STOCK STRUCTURE

by

Z. Suzuki

SUMMARY

Yield of Atlantic yellowfin based on two stock structure hypotheses, western and eastern Atlantic stocks, was analyzed by examining catch and effort relationship as well as CPUE between longline and surface fisheries. The analysis seemed to support two different stock hypotheses and showed some possibility on the eastern stock that the tuna exploited by the longline and surface gears mixed at a high rate.

In an attempt to study stock structure of yellowfin tuna caught in the inshore and offshore fishing grounds of the eastern Atlantic, cohort analysis was conducted. Although it is suggested that the recruitment has increased from the period 1966-68 to 1969-71, no information was obtained on the relationship between the inshore and offshore stocks.

Best estimates of the MSY for the western stock calculated by production model analysis using only the longline data was about 20,000 MT and the estimates of the MSY for the total Atlantic yellowfin tuna was insensitive in relation to stock hypothesis whether it was single Atlantic-wide or separated in the western and the eastern Atlantic.

RESUME

Selon l'hypothèse de l'existence de deux stocks, ouest-atlantique et est-atlantique, la production d'albacore atlantique a été analysée en comparant la relation capture/effort, ainsi que les CPUE, des pêcheries palangrière et de surface. L'analyse semble appuyer l'hypothèse des deux stocks, et laissait entrevoir, en ce qui concerne le stock est-atlantique, la possibilité d'un taux élevé de mélange des poissons pêchés en surface et à la palangre.

On a procédé à l'analyse des cohortes pour tenter d'étudier la structure du stock d'albacore pêché au large et près de la côte dans l'Atlantique Est. Bien qu'il ait été suggéré que le recrutement s'était accru entre 1966-68 et 1969-71, on n'a obtenu aucun renseignement sur la relation entre les stocks du large et ceux du littoral.

La meilleure estimation de la PEM pour le stock ouest-atlantique, calculée au moyen de l'analyse du modèle de production à partir des seules données palangrières, était d'environ 20 milliers de tonnes; les estimations de la PEM pour l'albacore dans l'ensemble de l'Atlantique ne se sont pas montrées sensibles aux hypothèses sur le stock, que l'on suppose l'existence d'un seul stock pour tout l'Atlantique, ou celle de deux stocks distincts, ouest-atlantique et est-atlantique.

RESUMEN

En base a dos hipótesis de estructura del stock -Este y Oeste del Atlántico- se analiza el rendimiento del rabil en dicho océano, examinando la relación captura/esfuerzo así como la CPUE entre las pesquerías de palangre y superficie. El análisis parecía apoyar la hipótesis de dos stocks diferentes y señalaba la posibilidad de una alta tasa de mezcla en el stock oriental, entre los peces explotados por artes de palangre y de superficie.

Se efectuó un análisis de cohorte en un intento de estudiar la estructura del stock del rabil capturado en zonas costeras y de altura en el Atlántico oriental. Si bien se sugiere que el reclutamiento aumentó en el periodo 1969-71 con respecto a 1966-68, no se obtuvo información referente a la relación entre los stocks de las zonas costeras y de altura. La mejor estimación del RMS respecto al stock occidental, calculada por análisis del modelo de producción, utilizando sólo datos de palangre, era de unas 20.000 toneladas, y la estimación del RMS para el total del rabil atlántico, no era sensible a la relación con la hipótesis de stocks, tanto en lo que se refiere a un supuesto stock unitario en el conjunto del océano, como a dos unidades separadas al Este y al Oeste del mismo.

Introduction

Atlantic yellowfin fishery has developed rapidly and the estimated MSY for this fishery increased in the course of accumulating the newly available data. On the other hand, knowledge of stock structure on this species in the Atlantic remains still in a poor condition. As the Atlantic yellowfin fishery undergoes considerable amount of qualitative and quantitative changes at present as well as in the past, the assumptions made on the stock structures or interaction between surface and longline fisheries would exert large influence on the resultant estimation of the MSY.

The present study was attempted, on the basis of data collected from Japanese longline fishery, to re-analyze some of these problems left unclear.

1) Catch and effort relationship of longline caught yellowfin tuna in the western and eastern Atlantic

No fundamental progress seems to be made in the field of study on the stock structure of Atlantic yellowfin tuna after Hayasi's (1973) review on this subject. The hypothesis so far proposed could be summarized as follows:

1) Single stock over the whole Atlantic
2) Two stocks in the western and eastern Atlantic separated by 30°W
3) Plural stocks in the eastern Atlantic surface fishery

As the present data on the Japanese longline fishery are inadequate to deal with the hypothesis 3), the first and second hypotheses are assessed.

Data processing

Catches of the longline caught yellowfin tuna in the western and eastern Atlantic have been made public for the period 1966-1976 (Coan 1978). Comparable data for the period 1957-1965 were derived as follows.

Hayasi and Honma (1971) estimated percentages of annual catches in number for yellowfin caught in the western and eastern Atlantic by the Japanese longliners for the years 1956-1965. Annual catches in weight of yellowfin by the whole longline fleet (Hayasi et al. 1972) were divided into the western and eastern Atlantic using the annual percentages aforementioned because the Japanese longline catches had predominated in the total longline fishery at that period. However, it is noticed that the average weight of this species in the Japanese longline catches in the eastern Atlantic tends to heavier than that in the western Atlantic. To check this, the average weight by the two areas were calculated from the length composition of yellowfin tuna caught by the Japanese longline boats (ICCAT 1973, 1975a, 1975b, 1976-1978 and Honma 1974b) through length-weight relationship by Lenarz (1974).

The tendency of heavier average weight in the eastern Atlantic is clear for the recent years (Table 1). However, there appears no consistent difference in it before 1970 although the data during 1957-1965 which is in question are fragmental. Since the fishing strategy of the Japanese longline fishery did not change so much before 1970, the separation of total catches in weight by the numbers of catches in the two areas will not cause significant bias for the period before 1966.

Overall effective fishing effort on yellowfin tuna caught by the Japanese longline fishery (Honma 1974a) was calculated separately for the western and eastern Atlantic divided by 30°W (Fig. 1). For both areas, "average year" utilized in the calculation covers for 1965-1975 and monthly patterns of yellowfin distribution in terms of hook rates were chosen as a base of processing the data. Total effective fishing effort by the whole longline fishery in each area were estimated raising the Japanese effective fishing effort by the ratio of total catches to the Japanese ones (Table 2).

Catch and effort relationship of yellowfin exploited by the whole longline fishery shows different patterns in the western and eastern Atlantic during 1957-1975 period (Fig. 2). In the eastern Atlantic, the longline fishery is almost collapsing after around 1965 during which period the surface fishery, mainly capturing the smaller yellowfin tuna than the longline, has become dominant. On the other hand, augmentation of efforts appears to be associated with corresponding increase of catches in the western Atlantic. If yellowfin tuna taken in the western and eastern Atlantic by the longline fishery form the same single stock, such a difference in the two area would not be expected under the existence of a huge surface fishery in the eastern Atlantic. Therefore, the result seems to support the two stock hypothesis in the Atlantic.

2) Comparison of CPUE between surface and Japanese longline fisheries in the eastern Atlantic

Two measures of CPUE by surface and the Japanese longline fisheries in the eastern Atlantic behaved fairly comparably (Fig. 3) despite different sizes of fish caught by the two fisheries and dimensions of unit utilized in calculation of the CPUE. Since 1974, the surface fishery has begun to capture a far

greeter number of large fish (ages 3, 4 and 5) than that by the longline fishery (Coan 1978). Longline CPUE (fish/100 effective hooks) showed rather sharp decline from 0.44 to 0.30 (32 % drop) during 1974-1976. This fact infers the possibility of existence of highly mixing yellowfin stock taken both by the surface and longline fisheries in the eastern Atlantic. If this inference is valid and the surface fishery continued to aim at large fish, further substantial decline of CPUE in the eastern Atlantic longline fishery could be observed in the future.

3) Recruitment of yellowfin tuna in the eastern Atlantic

Estimation of magnitude of recruitment at the beginning of age 1 was attempted using the age composition of catches from the total eastern Atlantic fishery (Coan 1978). Two kinds of composite cohorts fished with different strategy, 1966-1968 and 1969-1971 cohorts were chosen. In the latter period, the fishery intensified tis exploitation toward smaller (1 and 2 years old) and larger (4 and 5 years old) fish (Fig. 4).

Due to difficulty in chosing inital F set in the course of cohort analysis, a vector F which accounts for actual catches and number of dead fish due to natural mortality in a given cohort was first calculated (Shingu and Hisada 1977). The 1971 cohort which appeared as 5 years old fish in 1976 catches was the last cohort used in the composite cohort of the latter period because catches of fish at 5 years old after 1971 cohort have not been available at present (Appendix Table 1).

As the fish at age 6 was assumed to be eradicated by the fishery in the course of getting the first series of vector F, the value of F for this age was extraordinarily high. This value of F for age 6 fish was not used in the further calculations, instead the F for age 5 fish was arbitrarily borrowed for that at age 6. For the cohort roughly corresponding to the composite cohort in the former period 1966-1968, Lenarz et al. (1974) selected an initial F=0.2. This value was adopted for the former cohort, with reverse iteration, to get second series of vector F. As second series of vector F for the latter composite cohort, values of F that give about a half of that at age 5 obtained under the first series of vector F scheme were arbitrarily chosen (in this case F at age 6 was about 0.3).

Vector F and recruitment estimated under the different assumptions were summarized in Table 3. Y/R was also calculated for each case using Le Guen and Sakagawa's(1973) age-length key. Only in the case of second series vector F with M=0.8, the value of Y/R showed increase during the two period. Even in this case, however, the increase in the Y/R, if recruitment is assumed constant, is only 7 % and this is not the case in the actual fishery.

Therefore, it is inferred that the recruitment has increased during the period although the selection of vector F are highly subjective, hence the present results are in provisional nature. However, it is not certain whether the apparent increase of the recruitment is from the traditional area in the inshore fishing ground or related with the large fish in the offshore area formerly unexploited. Investigations on this problem would be important for the stock structure and future development of yellowfin fishery. If the catches of large fish in the offshore eastern Atlantic is from new stock different from the traditional coastal stock, then the MSY from the whole eastern Atlantic may further increase. However, due to inital stages of the offshore fishery and very little information about the fishery, no further inference is possible at present.

4) Estimation of MSY from the western longline fishery

As only small scale surface fishery is operating in the western Atlantic, the MSY of yellowfin tuna taken by the longline fishery in this area was estimated by production model analysis (Fox 1975). The data used for the analysis are shown in Table 2.

Estimated MSY under the several combinations of parameters ranged from 17.1 to 22.8 thousand tons (Table 4). The best estimates of the MSY was 20.0 thousand tons with m=0.0 and k=4 [illegible] (degree of fit index [illegible] r^2=0.84).

5) Conclusion

If there are two stocks of yellowfin tuna in the Atlantic as is indicated in the present study, the MSY from the whole Atlantic yellowfin stocks does not appear to differ so much from the level of presently estimated equilibrium catches, 137.7 thousand tons calcualted over the whole Atlantic (Fox and Coan 1978) as the sum of the MSY's estimated separately in the western Atlantic longline fishery (20.0 thousand tons) and eastern Atlantic fishery without longline data (111.8 thousand tons, Fox and Coan op. cit.) turns out nearly the same figure. However, there still remaines vagueness on the stock structure of the species in general, especially on the nature and derivation of the large yellowfin taken recently in the offshore fishing ground of the eastern Atlantic.

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Table 1. Average weight of yellowfin tuna caught by the Japanese longline fleet in the western and eastern Atlantic

	1957	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
										Unit: Kg				
Western Atlantic	56.3	53.6	51.5	51.7	56.5	48.3	47.0	48.3	33.5	33.4	30.2	32.3	34.1	46.9
Eastern Atlantic	64.1	54.4	40.8	50.2	52.6	54.0	48.6	42.3	41.2	49.1	51.0	44.5	53.2	54.1

No data were available for the years 1958-1962

Table 2. Estimated catch (10^3 tons) and effort (10^3 effective hooks) of yellowfin tuna caught by the whole and Japanese longline fleets in the western and eastern Atlantic, 1957-1975

	Western Atlantic				Eastern Atlantic			
	Catch		Effort		Catch		Effort	
	Whole fleet	Japanese fleet	Whole fleet	Japanese fleet	Whole fleet	Japanese fleet	Whole fleet	Japanese fleet
1957	3.0	2.9	1689	1609	10.8	10.3	5220	4971
1958	13.5	13.1	9036	8773	14.6	14.1	9162	8895
1959	11.9	11.5	9750	9375	33.8	32.6	20367	19584
1960	10.6	10.2	11347	10911	42.3	40.6	27414	26360
1961	2.2	2.1	4172	3973	42.4	40.5	39068	37208
1962	16.5	15.2	31145	28573	29.3	26.8	48728	44705
1963	12.5	10.9	33324	29232	30.5	26.8	58680	47088
1964	11.5	10.5	58633	53792	26.8	24.6	52491	48157
1965	10.6	9.9	45235	41884	28.8	26.7	90725	84005
1966	16.0	11.8	34292	25215	11.1	10.6	37483	35698
1967	11.0	2.7	45958	11292	10.7	10.1	34841	32869
1968	9.6	4.2	32543	14211	16.4	9.8	37269	22317
1969	11.4	3.6	48095	15172	13.4	6.4	41706	19955
1970	19.9	4.3	98725	21323	11.4	2.5	52549	11524
1971	21.5	9.1	100288	42495	7.5	2.0	52418	13978
1972	16.1	4.2	76186	19892	13.5	3.4	48529	12224
1973	19.3	2.5	108358	14036	12.6	1.7	79080	10672
1974	17.8	2.8	85415	13430	12.5	1.5	23307	2798
1975	14.4	3.9	74117	20086	12.7	2.1	68117	11076

Table 3. Estimated age specific F, recruitment and Y/R for the whole fisheries operating in the eastern Atlantic

	First series				Second series			
	M=0.6		M=0.8		M=0.6		M=0.8	
Age	1966-1968 cohort	1969-1971 cohort	1966-1968 cohort	1969-1971 cohort	1966-1968 cohort	1969-1971 cohort	1966-1968 cohort	1969-1971 cohort
1	0.35	0.57	0.25	0.40	0.30	0.55	0.19	0.38
2	0.58	0.33	0.45	0.25	0.46	0.32	0.32	0.23
3	0.84	0.76	0.70	0.63	0.56	0.70	0.40	0.56
4	1.67	1.18	1.43	1.05	0.65	0.98	0.49	0.83
5	0.38	2.42	0.34	2.28	0.07	1.22	0.06	1.08
6	0.38	2.42	0.34	2.28	0.20	0.30	0.20	0.30
Recruit in million fish	7.1	12.5	10.3	18.0	8.0	12.8	13.1	18.9
Y/R in Kg	7.26	6.45	5.21	4.46	6.54	6.34	3.98	4.27

Recruit at the beginning of age 1

Table 4. Estimated production model parameters for the western Atlantic longline fishery, 1957-1975

	m=0.0	m=1.0	m=2.0	m=variable(0.0)
		k=3		
MSY (10^3 tons)	18.4	18.7	22.8	18.4
f_{opt} (10^7 effective hooks)	-	5.6	6.1	-
R.S.S.	1.04	1.71	2.40	1.04
		k=4		
MSY	20.0	17.1	19.5	20.0
f_{opt}	-	6.6	6.6	-
R.S.S.	0.88	1.20	1.57	0.88

K.and.R.S.S. denote number of significant year classes in the catch and residual sum of squares, respectively.

Appendix Table 1. Age composition of yellowfin tuna (10^3 fish) in the surface and longline catches from the Atlantic Ocean

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	1160.9	682.1	3194.4	911.5	4405.8	4228.6	3914.5	6125.4	6831.6	2703.6	7082.2
2	1168.3	1180.1	449.5	1970.1	372.7	528.7	1282.7	738.1	437.8	1594.7	1161.1
3	256.6	277.2	470.0	394.4	446.1	280.5	417.6	465.0	1022.2	586.3	941.3
4	93.7	59.7	228.9	78.8	112.7	152.6	128.2	123.2	218.8	311.5	214.8
5	3.1	2.7	60.0	16.1	34.5	2.9	6.0	6.2	109.6	25.5	17.4
6	0.2	0.4	5.5	0.6	4.7	0.2	1.1	2.6	17.6	4.4	1.3

The data were cited from the paper by Coan (1978).

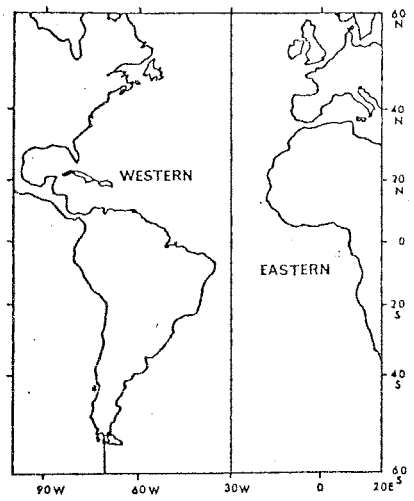

Fig. 1. Division of the Atlantic Ocean into the western and eastern regions by 30° W

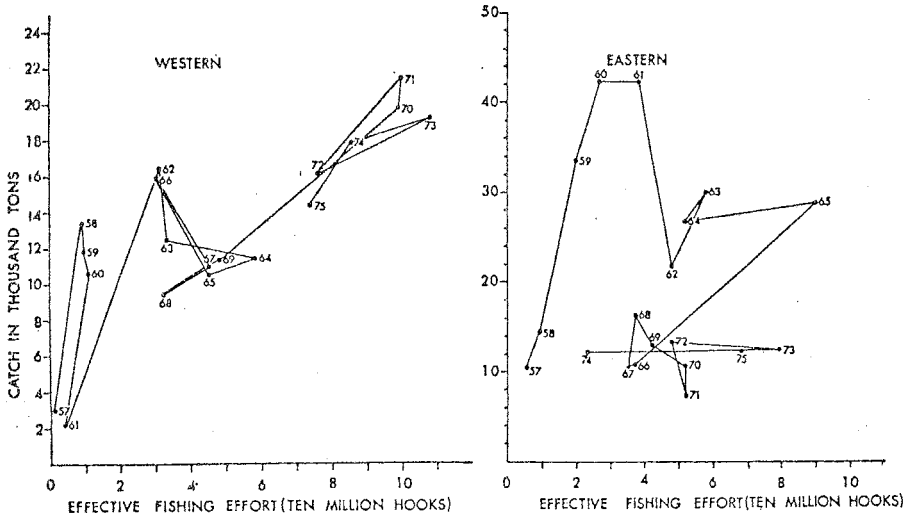

Fig. 2. Catch and effort relationship of yellowfin tuna taken by longline fleet in the western and eastern Atlantic, 1957-1975

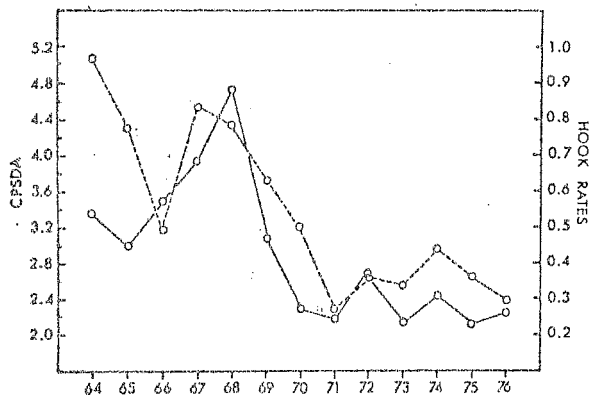

Fig. 3. Trends of CPUE by entire surface (straight line) and Japanese longline (dotted line) fisheries in the eastern Atlantic.

The CPUE's for the surface fishery (CPSDA, catch per standard days at sea) were cited from the paper by Fox and Coan (1978).

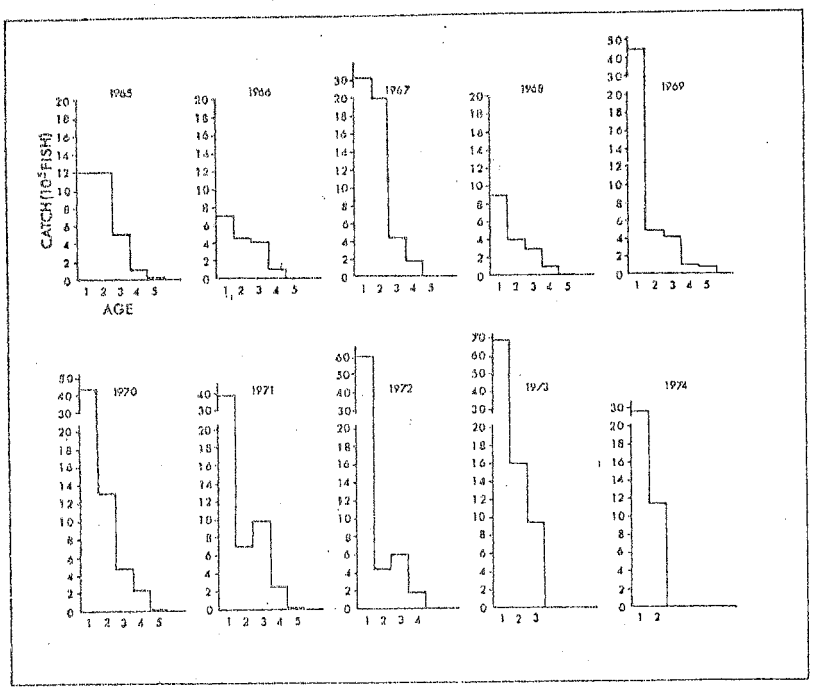

Fig. 4. Numbers of fish of the 1965 through 1974 cohorts at ages 1 to 5 captured by the surface and longline fisheries operating in the eastern Atlantic