STOCK ASSESSMENT OF SOUTH ATLANTIC ALBACORE BY PRODUCTION MODEL ANALYSIS, 1967-1985

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SUMMARY

The generalized production model was used to evaluate the status of the south Atlantic albacore stock for the years 1967 through 1985. Analysis was made in two cases. Effective effort was expressed by effective hooks in Case 1, and by effective fishing intensity in Case 2.

The best fitting model for the fishery was the broad flat-topped equilibrium yield curve (m=0.0). Depending on the models used, the maximum sustained yield (MSY) appears to be in the range of 21,890 to 25,890 MT for Case 1 and in the range of 21,360 to 25,320 MT for Case 2. The current catch (24,880 MT in 1985) is near the MSY while the current effort level is about 1.30 times that needed to produce MSY. It is apparent that the stock has been fully exploited since 1981 and careful monitoring of the fishery should be continued.

RESUME

Le modèle global de production est utilisé pour évaluer l'état du stock de germon sud-atlantique pour les années 1967 à 1985. Deux cas ont été analysés. L'effort effectif a été représenté par les hameçons effectifs dans le premier cas, et par l'intensité efective de pêche dans le deuxième cas

La modèle qui s'ajuste le mieux à la pêcherie est la courbe d'équilibre ample à sommet aplani (m = 0.0). Selon les modèles utilisés, la production maximale équilibrée (PME) semble se situer dans la gamme de 21.890 à 25.890 TM pour le Cas 1 et de 21.360 à 25.320 pour le Cas 2. La prise actuelle (24.880 TM en 1985) était très proche de la PME, alors que l'effort actuel de pêche était environ 1.30 fois plus important que celui qui donne la PME. Il est évident que le stock est pleinement exploité depuis 1981, et qu'il faut continuer à suivre la pêcherie de près.

RESUMEN

Se empleó el modelo generalizado de producción para evaluar la condición de la población de atún blanco del Atlántico Sur en el periodo 1967 hasta finales de 1985. Se hizo un análisis suponiendo dos casos. Se expresó el esfuerzo efectivo por anzuelos efectivos en el Caso 1 y por intensidad efectiva de pesca en el Caso 2.

El mejor ajuste del modelo para la pesquería era la curva de rendimiento sin máximos definidos en condiciones de equilibrio (m=0.0). Dependiendo del modelo aplicado, la captura máxima sostenible (RMS) parece encontrarse entre 21.890 y 25.890 t en el Caso 1 y entre 21.360 y 25.320 t en el Caso 2. La captura actual (24.880 t en 1985) estaba muy cercana al RMS, mientras que el nivel del esfuerzo era alrededor de 1.30 veces el necesario para alcanzar el RMS. Es evidente que la población está siendo explotada al máximo desde 1981 y que la pesquería debe seguir vigilándose con atención.

INTRODUCTION

Albacore (Thunnus alalunga) is an important tuna species fished throughout the Atlantic Ocean by longline and surface fleets. The Atlantic albacore population is thought to be divided into two presumably distinct and separate stocks, one in north of 5°N lat. and the other one in south of the same demarcation (Yang et al., 1969; Yang, 1970; Bartoo, 1979; Yang and Sun, 1983).

Scientists of the Standing Committee on Research and Statistics (SCRS) of the International Commission for the Conservation of Atlantic Tunas (ICCAT) have expressed concern about the ability of Atlantic tuna stocks to sustain the high catch level since 1973. The south albacore stock is one of the stocks they are concerned which led to previous analyses of the status of South Atlantic albacore. (e.g. Shiohama, 1977; 1978; 1979; Bartoo and Coan, 1983; Yang and Sun, 1983; Yang and Sun, 1984).

This study is to update our previous report (Yang and Sun, 1984) of stock assessment of South Atlantic albacore by production model analysis to 1985, and to assess the status of stock with the same production model analysis.

ANALYTICAL METHOD AND DATA SOURCES

Production models form one of the two groups of models used in studying fish population and assessing the state of fish stock (Gulland, 1983). They originated from Graham (1935), who utilized the logistic model to estimate the yield which might be expected from North Sea fish stock. Schaefer (1954, 1957) developed a modified version of the logistic model and used it to estimate the maximum sustainable yield (MSY) for the California sardine, the Pacific halibut, and the yellowfin tuna of the eastern tropical Pacific Ocean. Pella and Tomlinson (1969) developed a more flexible formulation that allows the simple parabola of the Schaefer model to be skewed to the left or right, permitting the best empirical fit to the observed data. Fox (1975) described a procedure for fitting the Pella-Tomlinson model that requires equilibrium approximations. Finally, Schnute (1977) derived linear and nonlinear methods for estimating the coefficients of the Schaefer model.

The model

The general production model for a single-species system is given by (Schaefer, 1954):

$$dP/dt = P(t,g(P(t)) - F(t,h(f(t))) \qquad (1)$$

where $P(t)$ is the population size at time t, $g(P(t))$ is the regulatory function of the rate of population increase, $h(f(t))$ is the function of fishing mortality excerted by $f(t)$, units of fishing effort. Pella and Tomlinson (1969) introduced the most flexible simple function for $P(t)g(P(t))$ as

$$P(t)g(P(t)) = HP^m(t) - KP(t) \qquad (2)$$

where H, K, m are constant parameters and H, K must be positive when m < 1, or H, K must be negative when m > 1. The general assumption about the function of fishing mortality is:

$$h(f(t)) = F(t) = qf(t) \qquad (3)$$

where $F(t)$ is the fishing mortality rate, q is the catchability coeffficient. $f(t)$ is the fishing effort standardized to be proportional to the $F(t)$. Substituting (2) and (3) into (1), the generealized stock production model was obtained (Pella and Tomlinson, 1969) as follows:

$$\frac{dP}{dt} = HP^m(t) - KP(t) - qf(t)p(t) \qquad (4)$$

At equilibrium; we have:

$$Y = qf\left(\frac{qf+K}{H}\right)^{1/(m-1)} = f(a+bf)^{1/(m-1)} \qquad (5)$$

$$U = Y/f = q\left(\frac{qf+K}{H}\right)^{1/(m-1)} = (a+bf)^{1/(m-1)} \qquad (6)$$

where Y is the equilibrium yield and U is the equilibrium catch per unit effort, a and b are parameters; i.e., a and b are recombinations of H, K, and q. The relationships of interest in fishery management are obtained by differentiating equation (5) with respect to f:

$$f_{opt} = \frac{K(1-m)}{mq} = a\left(\frac{1}{m} - 1\right)/b \qquad (7)$$

$$U_{opt} = \left(\frac{qK}{Hm}\right)^{1/(m-1)} = (a/m)^{1/(m-1)} \qquad (8)$$

$$Y_{max} = MSY = f_{opt} \cdot U_{opt} = H\left(\frac{K}{mH}\right)^{m/(m-1)} - K\left(\frac{K}{mH}\right)^{1/(m-1)}$$

$$= (m)^{1/(1-m)} \cdot a^{m/(m-1)} \left(\frac{1}{m} - 1\right)/b \qquad (9)$$

where fopt is the optimum fishing efffort required to produce Ymax, the maximum sustainable yield. Uopt is the catch per unit effort at point where Y is maximized.

From the above equations, we know that m cannot equal 1, for other values of m in equations (5), (6), we get a family of curves, for which m=0 (asymptotic model), m approaches but does not equal 1 (Gompertz model, or Fox's exponential model) (Fox 1970) and m=2 (logistic model) (Schefer, 1954 1957) are special cases.

Fox (1975) developed a computer program PRODFIT to fit generalized production models through control parameter, m. PRODFIT fits the model by average fishing effort as suggested by Gulland (1961,1969).

The average fishing effort ($\overline{f}i$) is computed by following the formula with SUBROUTINE AVEFF OF PRODFIT (Fox,1975) as:

$$\overline{f}i = \{kfi + (k-1).fi-1 + ... + fi-k+1 / \{k + (k-1) + ... + 1\}$$

where k is the number of year class which contributes most significantly to the catch.

In this study, PRODFIT was used to fit the three models (m=0.0, 1.001 and 2.0) to the fishery data. The number of significant year classes contributing to the catch of albacore fishery in the South Atlantic Ocean was obtained by checking the age composition. It was set at 3 (k=3) then later at 4 (K=4), following Bartoo and Coan (1983).

The data

Two types of data were needed for PRODFIT:

1) Total annual catch: Annual catch data of albacore in the South Atlantic Ocean from 1967 to 1985 were compiled from ICCAT Statistical Bulletins (ICCAT, 1982; 1981; 1985), there data are shown in Fig. 1 and Table 2.

2) Standardization of effort: The longline effort measured in hooks was chosen as the standard measure of fishing effort for South Atlantic albacore fishery because nearly all catch from south stock is exploited by longline boats (Fig.1). The detailed procedure for the standardization of longline fishing effort using Honma's method (1973) is described by Yang and Sun (1983). Two cases of effective effort in this report were used as inputs to PRODFIT. Effective effort in Case 1 was expressed by effective hooks and in Case 2 by fishing intensity (effective hooks per 5 square). The results of the standardization of longline fishing effort are shown in Table 1. This effective effort was then raised to the total catch. The results of which are shown in Table 2.

RESULTS

Catch and Standardized Effort

From the fluctuation of annual CPU1 ($MT/10^2$ hooks/5° sq.) and CPU2 ($MT/10^3$ hooks) (Fig. 1), it shown the stock of South Atlantic albacore has been arrived equilibrium although the annual total catch fluctuate very much. Annual total catch of albacore in the south Atlantic Ocean fluctuated between 13,310 and 33,260 metric tons (mt) during the years 1967 to 1973. It become fairly stable between 17,540 and 23,590 mt during the period 1974 to 1981 . In 1982 was 28,970 mt, but the following two years descending to 13,310 in 1984, and acending to 24,880 in 1985. (Table 2, Fig. 2).

Effective effort rose rapidly from 1968 and reached its high value of about 93.20 million hooks (1.19 million hooks per 5 square) in 1973, and then fluctuated between 70.0 to 88.8 million hooks (0.90 to 1.14 million hooks per 5 square) during the years of 1974 to 1980, then increased steadily to 118.7 million hooks(1.51 million hooks per 5 square) in 1982. But in recent years, 1983 and 1984 descending to 60.8 million hooks (0.76 million hooks per 5 sqare) after that acending to 101.9 million hooks (1.3 million hooks per 5 square) in 1985.

Production Model Analysis

Catch and standardized effort data for Case 1 and Case 2 in the South Atlantic albacore fishery (Table 2) were used as inputs to the PRODFIT computer program to estimate production model parameters.

Case 1

For Case 1, effective effort was expressed in effective hooks. The results of the estimated maximum sustainable yield (MSY) and optimum fishing effeort (fopt) are compared in Table 3 with the observed catch and effort of 1985. Table 3 also lists the optimal value of catch per unit effort (Uopt) and degree of fit (r2). Estimated yield curves for K=3 and K=4 are shown in Fig. 3 and 4.

For K=3, the best fitted model (r2=0.653) has a broad, flat-topped equilibrium yield curve (m=0.0) with the estimated MSY is 25,320 mt at an infinite amount of fishing effort. The poorest fitted model (r2=.942) is the parabolic-shaped equilibrium yield curve (m=2.0), in which the MSY is 23,680 mt with fopt at 75.40 million effective hooks. The skew dome-shaped equilibrium yield curve (m=1.001, r2=.951) gives an estimated MSY of 22,650 mt for fopt at 83.02 million effective hooks.

For K=4, when m=0.0 (r2=0.947), the estimated MSY is 21,360 mt and fopt is infinite. At m=2.0 (r2=0.945) the estimated MSY is 23,040 mt and the fopt is 77.52 million effective hooks. When m=1.001 (r2=0.948), the estimated MSY 22,230 mt and the fopt is 74.00 million effective hooks.

Case 2

For Case 2, effective effort was expressed in fishing intensity. The results shown in Table 4 and Fig. 5 and 6 are similar to those in Case 1. For K=3, the best fitted model (r2 =0.953)is m=0.0 with a predicted MSY of 25,890 mt with infinite fishing effort. The poorest fitted model (r2=0.945) is m=2.0 with an estimated MSY of 23,670 mt with fopt at 0.96 million hooks per 5 square. At m=1.001 (r2=0.950), the estimated MSY is 22,640 mt with fopt at 0.99 million hooks per 5 square.

For K=4, when m=0.0 (r2=0.947), the estimated MSY is 21,890 mt while fopt is infinite. At m=2.0 (r2=0.944), the estimated MSY is 23,030 mt and the fopt was 0.99 million hooks per 5 square. When m=1.001 (r2=0.948), the estimated MSY was 22,280 mt and fopt was 1.08 million hooks per 5 square.

DISCUSSION

Production model analysis is crude compared with a truly biological analysis. Pella and Tomlinson (1969), Fox and Lenera (1974), Fox (1974) and Rinaldo and Coan (1979) considered that some assumptions, such as the following, are necessary for applying this model approach to particular stock:

(a) the population is either an isolated population or a unit stock.
(b) an equilibrium condition can be achieved.
(c) the constitution of the fishery has remained constant (selectivity, temporal distribution and catchability.)
(d) there are no time lags in the population response to its equilibrium mechanism.

More detailed discussion of the assumptions can be found in Pella and Tomlinson (1969) and Fox (1974).

However, as stated by Fox (1970) " Since use of surplus yield models require only catch and effort data, these models are particularly advantageous when age determination and tagging are difficult, when such biological data don't exist, or when knowledge of the biological system is insufficient to describe recruitment, growth, or natural mortality if cannot be assumed constant through all ranges of population size."Csirke and Caddy (1983) also noted "Production models are among the simplest and most widely used approaches in the assessment of exploited fish populations" and because of the ease of application of these models in their simple form, the collection of catch and effort statistics, and their subsequent utilization models has become the standard approach to fisheries assessment in many parts of the world." So, Uhler (1979) predicted that production models" will continue for some time to serve as a basis for management of many of the world's fisheries". The SCRS of ICCAT also considered production model analysis to be one of the standard methods for evaluating tuna stocks in the Atlantic Ocean. Therefore, these previous studies on the status of South Atlantic albacore all employed production models (Shiohama, 1977, 1978, 1979; Bartoo and Coan, 1983; Yang and Sun, 1984).

The value of MSY estimated by this present study are lower than those of Yang and Sun (1984), and the fopt also lower 0.84 times. The difference in results seem to be due to the recent two years (1983 and 1984) had very lower catch and effort for albacore in the South Atlantic Ocean. And the effective effort data based on combined Taiwanese and Japanese longline fisheries in Yang and Sun (1984), but in this study the recent three years (1983, 1984 and 1985) data only based on Taiwanese longline fishery due to the catch of albacore by Japanese longline fishery is very low in recent three years. Based on the deterministic production model analyses for Cases 1 and 2. the current catch (24,880 mt in 1985) near to the predicted equilibrium MSY but the current effort is about 1.30 times of that needed to produce the equilibrium MSY The status of the South Atlantic albacore stock, judged by present study, appears that the stock has been fully exploited beyond MSY level since 1981. We should continue to use the production model as one of the means of monitoring the status of the stock.

ACKNOWLEDGEMENTS

We would like to express our appreciation to Pro. S.Y. Yeh for reading the manuscript. and Miss Chiou-Yueh Chang, Bi-Lin Lai and In-Chin Chen and Mr. Shui-Kai Chang and Ying-Chou Lee research assistants at the Tuna Research Center, Institute of Oceanography, National Taiwan Univesity, for their assistance with this work.

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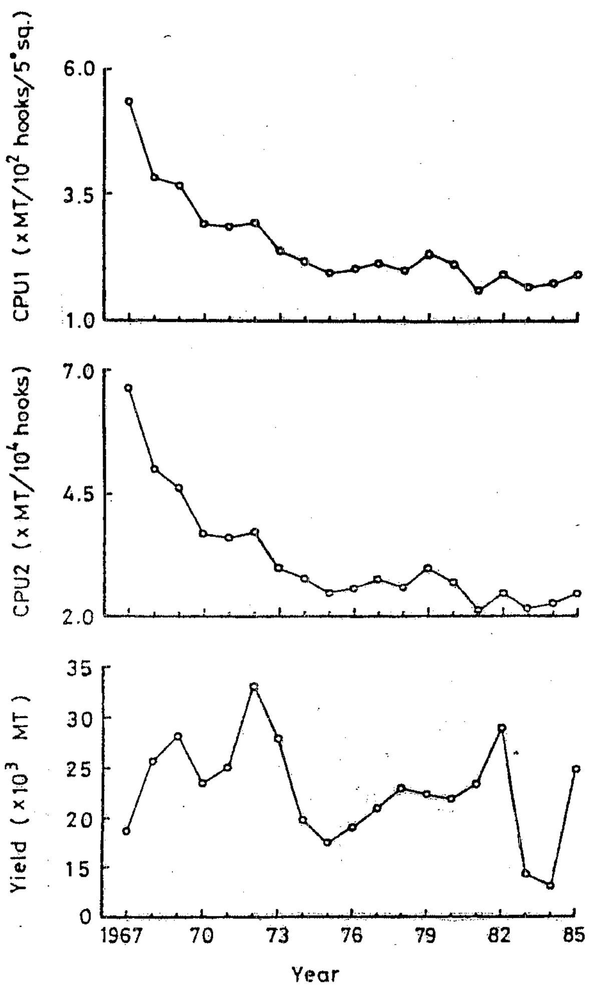

Fig. 1. Fluctuation of annual CPU1, CPU2 and total catch of South Atlantic albacore in 1967 - 1985.

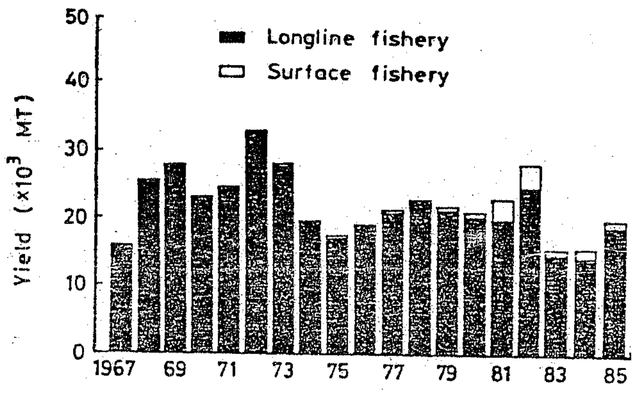

Fig. 2. Annual yield by longline and other surface fishery of South Atlantic albacore in 1967 - 1985.

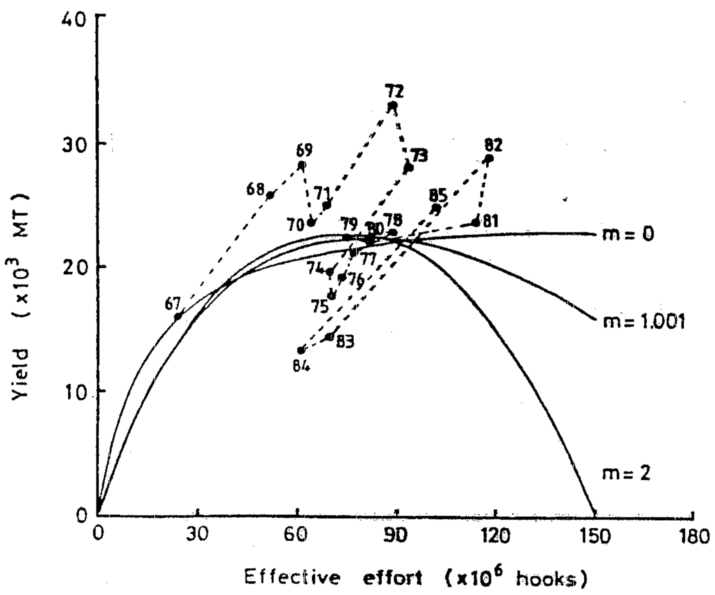

Fig. 3. Equilibrium yield curves and observed data for South Atlantic albacore fishery and assuming three significant year-classes in the catch, 1967-1985. (Case 1)

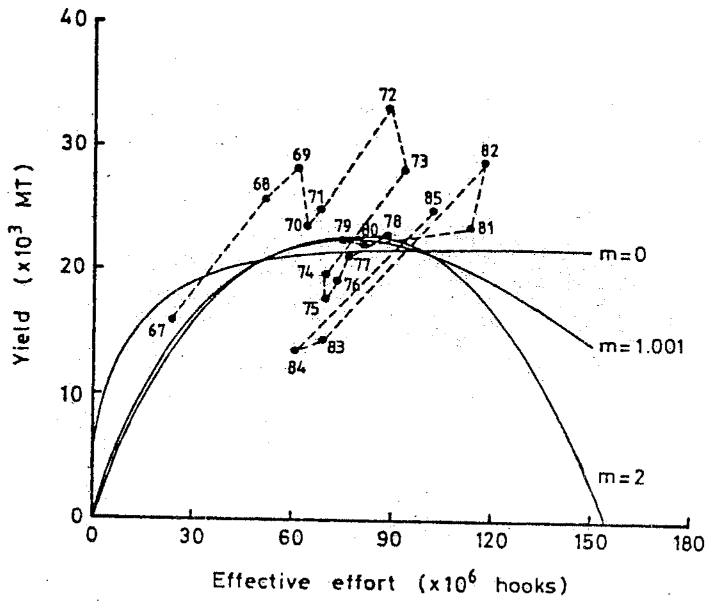

Fig. 4. Equilibrium yield curves and observed data for South Atlantic albacore fishery and assuming four significant year-classes in the catch, 1967-1985. (Case 1)

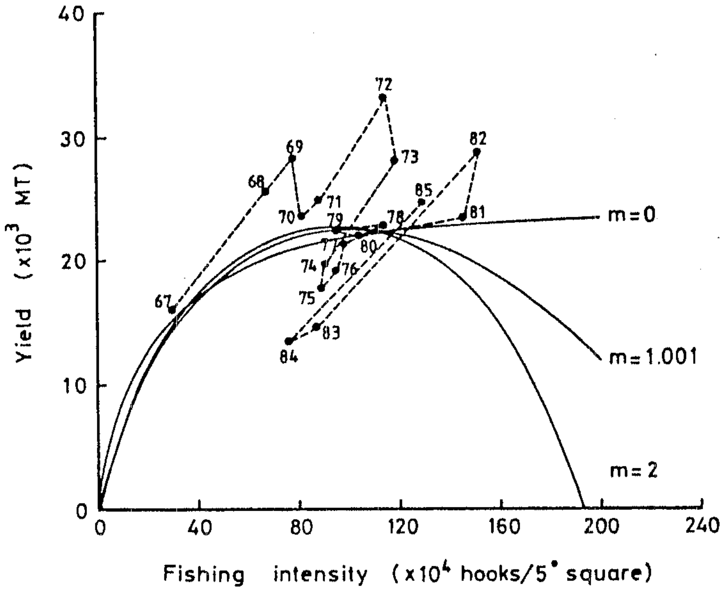

Fig. 5. Equilibrium yield curves and observed data for South Atlantic albacore fishery and assuming three significant year-classes in the catch, 1967-1985. (Case 2)

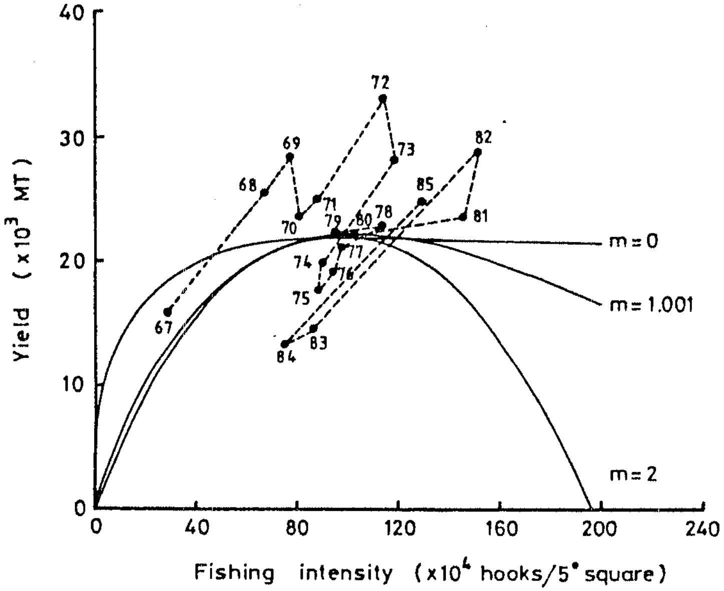

Fig. 6. Equilibrium yield curves and observed data for South Atlantic albacore fishery and assuming four significant year-classes in the catch, 1967-1985. (Case 2)

Table 1. Hook rate, catch in number, yield in weight, effective effort and fishing intensity of albacore in Taiwanese, Japanese and in the whole longline fishery in the South Atlantic Ocean, 1967-1985.

	Taiwanese Longline Fishery					Japanese Longline Fishery					Whole Longline Fishery			
Year	Hook rate (%)	Catch in No. (10^3)	Yield* in weight (mt)	Effective effort (10^5 hooks)	Fishing intensity (10^3 hooks /5°sq.)	Hook rate (%)	Catch in No. (10^3)	Yield* in weight (mt)	Effective effort (10^5 hooks)	Fishing intensity (10^3 hooks /5°sq.)	Catch in No. (10^3)	Yield* in weight (mt)	Effective effort (10^5 hooks)	Fishing intensity (10^3 hooks /5°sq.)
1967	3.58	41	1,059	11.3	15.0	3.60	437	7,719	121.3	149.7	865	15,883	240.0	298.0
1968	4.04	722	6,792	178.9	235.6	3.75	739	11,857	197.3	254.9	2,010	25,650	517.4	674.6
1969	2.87	850	12,546	296.4	375.0	2.22	244	6,331	110.0	137.5	1,651	28,493	613.5	773.6
1970	2.36	672	12,225	285.4	363.2	2.22	454	5,898	204.8	257.2	1,470	23,653	639.7	809.7
1971	2.71	1,272	17,491	470.2	603.0	2.25	218	3,218	97.0	123.0	1,801	25,022	685.3	877.3
1972	1.91	1,210	24,985	633.0	813.7	1.60	148	2,087	92.6	116.3	1,664	33,163	888.9	1,139.2
1973	1.57	1,099	22,157	700.9	896.5	0.97	38	277	39.7	48.1	1,426	28,131	928.7	1,184.5
1974	1.69	973	16,686	574.9	736.5	0.95	26	109	27.4	33.6	1,163	19,551	701.1	896.5
1975	1.99	1,032	13,384	519.4	666.0	0.98	27	306	27.3	34.4	1,345	17,382	694.0	889.3
1976	1.66	928	14,600	557.7	714.6	0.98	6	73	6.5	7.8	1,220	19,163	736.8	943.5
1977	1.87	1,074	16,092	573.3	732.3	0.62	8	105	12.2	15.4	1,401	20,979	758.4	968.5
1978	1.84	1,424	20,467	774.9	997.3	0.51	11	135	20.9	26.5	1,587	22,784	880.1	1,132.2
1979	1.62	1,074	20,340	663.9	844.7	0.35	8	105	22.3	27.7	1,155	21,826	732.5	931.3
1980	1.72	1,091	18,710	633.0	805.2	0.38	26	333	69.4	87.7	1,209	20,618	760.5	966.7
1981	1.43	1,102	18,187	773.0	991.1	0.29	40	558	140.0	170.4	1,239	20,335	990.4	1,260.0
1982	1.53	1,311	22,800	856.0	1,096.0	0.42	43	569	101.2	121.3	1,464	25,275	1,035.2	1,316.6
1983	1.41	627	9,502	458.0	576.0						782	11,847	571.0	718.2
1984	1.52	532	7,889	360.3	451.6						669	9,926	453.3	568.2
1985	1.50	1,421	19,643	804.6	1,023.2						1,479	20,445	837.4	1,065.0

Note 1. * Data Source: 1967-1969, ICCAT Historical Statistical Bull. Vol. 2 (1982)
1970-1971, ICCAT Statistical Bull. Vol. 11 (1981)
1972-1985, ICCAT Statistical Bull. Vol. 16 (1985)
2. 1983 - 1985, the whole longline fishery raised only by Taiwanese longline fishery

Table 2. Catch, effective effort and fishing intensity data for South Atlantic albacore fishery, 1967-1985.

Year	Catch* (10^3 mt)	Effective effort (10^6 hooks)	Fishing intensity (10^4 hooks/5°sq.)
1967	15.88	24.00	29.80
1968	25.69	51.82	67.56
1969	28.49	61.35	77.36
1970	23.65	63.97	80.97
1971	25.02	68.53	87.73
1972	33.26	89.16	114.26
1973	28.23	93.20	118.87
1974	19.70	70.63	90.31
1975	17.54	70.02	89.67
1976	19.20	73.82	94.53
1977	21.26	76.86	98.14
1978	22.99	88.82	114.26
1979	22.33	74.93	95.27
1980	22.10	81.50	103.60
1981	23.59	114.88	146.15
1982	28.97	118.66	150.90
1983	14.40	69.40	87.30
1984	13.31	60.78	76.19
1985	24.88	101.91	129.60

* ICCAT report catch (see Table 1.)

Table 3. Estimated production model parameters for South Atlantic albacore, 1967-1985 (Case 1).

No. of significant year class (K)	m	Uopt (mt/10^3 effective hooks)	fopt (10^6 effective hooks)	MSY (10^3 mt)	Degree of fit index (r2)	1985 Actual catch (10^3 mt)	1985 Effort (10^6 effective hooks)
3	0.0	0	∞	25.32	.953	24.88	101.91
3	1.001	.273	83.02	22.65	.951	24.88	101.91
3	2	.314	75.40	23.68	.942	24.88	101.91
4	0.0	0	∞	21.36	.947	24.88	101.91
4	1.001	.300	74.00	22.23	.948	24.88	101.91
4	2	.297	77.52	23.04	.945	24.88	101.91

Table 4. Estimated production model parameters for South Atlantic albacore, 1967-1985 (Case 2).

No. of significant year class (K)	m	Uopt (mt/10^3 hooks/5° sq.)	fopt (10^4 hooks/5° sq.)	MSY (10^3 mt)	Degree of fit index (r2)	1985 Actual catch (10^3 mt)	1985 Effort (10^4 hooks/ 5° sq.)
3	0.0	0	∞	25.89	.953	24.88	129.60
3	1.001	22.90	98.86	22.64	.950	24.88	129.60
3	2	24.58	96.28	23.67	.945	24.88	129.60
4	0.0	0	∞	21.89	.947	24.88	129.60
4	1.001	20.86	106.78	22.28	.948	24.88	129.60
4	2	23.28	98.94	23.03	.944	24.88	129.60