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STOCK ASSESSMENT OF SOUTH ATLANTIC ALBACORE BY USING PRODUCTION MODEL ANALYSIS, 1967-1987.

南大西洋長鰭鮪資源評估（1967-1987）

by

Shean-Ya Yeh[1] and Hsi-Chiang Liu[1]

葉顯椏　劉錫江

ABSTRACT

This paper deals with stock assessment of the south Atlantic albacore resource by using surplus yield models to analyze 1967-1987 catch and effort statistics. Effective effort analyses were primarily based on the Taiwanese longline fishery data and assumed the rest of the albacore caught can be expressed in terms of the equivalent Taiwanese longline effort. The results obtained are as follow: (1) a generalized production model with parameter m equals 2.00 and significant year class k equals 4 appeared to be the best fit of the data set; (2) the MSY of the resource was estimated to be in the range of 25,650 - 28,500 mt per year.

The current catch level (about 25,600 mt in 1986) is in the lower bound of the estimated MSY while the current effort level was about 10% higher than the estimated maximum level of producing the MSY. It is suggested that the stock has been reaching its maximum yield phase since early 1980s and hence carefully monitoring of the fishery should be continued.

1. Institute of Oceanography, National Taiwan University, Taipei, Taiwan, ROC.

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摘　　要

本文係依據1967-1987年南大西洋產長鰭鮪漁獲統計資料，以餘量模式(Surplus Yield Model)評估該長鰭鮪資源之現況。以臺灣鮪釣漁業資料爲有效努力量之分析基礎，其他類型之長鰭鮪漁獲努力量亦以臺灣鮪釣努力量表示，結果如下：(1)當m＝2.00及k＝4 時模式最爲適用：(2)年最大持續生產量(MSY)估計在25,650-28,500公噸。

目前的漁獲水準(1986年約25,600公噸)在最大持續生產量之下限內，漁獲努力量則比最大持續生產量相對應之最高努力量高出約10%，顯示1980年代已達最大生產狀態。因此，應繼續嚴密監測本漁業之發展。

1.中華民國臺灣省臺灣大學海洋研究所

INTRODUCTION

Albacore (Thunnus alalunga) is one of the most abundant and economically important tuna species in Atlantic Ocean. In early 1950s, the resource began under industrial exploitation pioneered by Japanese longliners. Since early 1970s, however, Japanese fleet gradually switching their target species from albacore to bigeye and bluefin tunas. Taiwanese longliners ventured tunas fishing since mid 1960s and have developed the major longline fleet targetting on the albacore resource. In 1986, e.g., the albacore harvested by Taiwanese fleet comprised 85% of the total albacore caught in the Atlantic. In recent years, however, the bait boat and the purseiner fisheries developed in Atlantic Ocean have also taken sizable amount of smaller albacore in the surface layer.

Albacore resource in Atlantic Ocean is believed to be two distinct and separate stocks by the 5"N latitude (Yang et al. 1969; Yang 1970; Bartoo 1979; Yang & Sun 1983). The southern stock was since early 1970s being primarily utilized by Taiwanese longliners (Liu 1985; Yeh & Liu 1987). Fisheries scientists of the Standing Committee on Research and Statistics (SCRS) of the International Commission for the Conservation of Atlantic Tunas (ICCAT) have expressed concerns about the ability of Atlantic tuna stocks to sustain the high catch level since mid 1970s. The south albacore stock is one of the stocks they are concerned and hence have led to previous analyses on stock status of the south Atlantic albacore resource (Shiohama 1977, 1978, 1979; Bartoo & Coan 1983; Yang & Sun 1983; Liu 1985; Liu & Yeh 1987).

Main purpose of this study is thus to assess current status of the south Atlantic albacore resource by adopting the surplus yield analyses on the updated 1967-1987 catch and standardized fishing effort data.

MATERIAL AND METHOD

ICCAT Statistical Bulletins (1967-1987) are the major souce of data on annual catch and nominal effort statistics of south Atlantic albacore fisheries. Detailed catch and effort data, compiled by locality and by month, of (1) 1967-1987 Taiwanese longline fishery and (2) 1967-1985 Japanese and Korea longline fisheries, provided by the ICCAT secretariate, were the major source of data for effective effort analyses in this study.

Regarding that albacore caught by longliners always comprised a majority of total albacore landings from the south Atlantic albacore fisheries, catch per unit effort derived from longline fishery was thus used as the relative abundance index of the resource. Effective longline fishing effort expressed as effective hooks were derived based on the Taiwanese longline fishery data by using Honma's algorithm (Honma 1973).

Pella and Tomlinson (1969) suggested the generalized form of production model for a single-species system as follow:

$$dP/dt = HP^{m}(t) - KP(t) - qf(t)P(t)$$

where P(t) is the population size at time t;
H, K, m are constant parameters and H, K must be positive when m < 1, or H, K must be negative when m > 1;
q is the catchability coeffficient;
f(t) is the fishing effort standardized to be proportional to its fishing mortality rate.

At equilibrium situation; we then have:

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

$$U = Y/f = q\left(\frac{qf + k}{H}\right)^{1/(m-1)} = (a+bf)^{1/(m-1)} \qquad (2)$$

where Y is the equilibrium yield;
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.

Formulas having fishery management interest are, obtainable by differentiating equation (1) with respect to f, as follow:

$$fopt = \frac{K(1-m)}{mq} = a\left(\frac{1}{m} - 1\right) / b \qquad (3)$$

$$Uopt = \left(\frac{qK}{Hm}\right)^{1/(m-1)} = (a/m)^{1/(m-1)} \qquad (4)$$

$$Ymax = MSY = fopt.Uopt = H\left(\frac{K}{mH}\right)^{m/(m-1)} - K\left(\frac{K}{mH}\right)^{1/(m-1)}$$

$$= (m)^{1/(1-m)}\, a^{m/(m-1)} \left(\frac{1}{m} - 1\right)/b \qquad (5)$$

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

Equations (1) and (2) are usually referred as asymptotic model when m equals 0, as Gompertz model or exponential model when m approaches 1 but not equals 1 (Fox 1970), and as logistic model when m equals 2 (Schaefer 1954, 1957).

For better expressing the concept of equilibrium, a method of averaging fishing effort through a period of years was proposed by Gulland (1961, 1969) as follow:

$$\bar{f}_i = (kf_i + (k-1).f_{i-1} + ... + f_{i-k+1}) / (k + (k-1) + ... + 1)$$

where k is the number of year classes which contributed most significantly to total catch of the i-th year.

Three forms of production models, i.e., when m=0.0, 1.001 and 2.0, was adopted to fit the catch and effort data of the south Atlantic albacore fisheries. The number of significant year class which would have contributions to the present catch was set set to be 3 and 4 (Bartoo & Coan 1983).

RESULTS

Catch and Catch Rate

CPU1 (no. of albacore caught/100 effective hooks) and CPU2 (Kg caught/100 effective hooks) can be viewed as a relative abundance indicator of the resource. As shown in Fig. 1, both CPU1 and CPU2 have revealed a similar trend in the studied period. The stock abundance seemed to decrease quite rapidly from late 1960s until mid 1970s then stablized at about 30 Kg per 100 effective hooks upto present; although a slightly decreasing trend was shown in very recent couple of years. Annual catch of albacore from south Atlantic fluctuated between 13,310 mt and 33,200 mt during the years 1967 to 1973. It become fairly stable between 17,540 mt and 23,590 mt during the period 1974 to 1981. Catch increased to 28,980 mt in 1982 and after two years of low catch level (13,300 - 14,400 mt) and increased again in 1985 to a high level of 28,050 mt and remained the same high level of 25,600 mt in 1986 (Table 1).

Effective effort rose rapidly from 1968 and reached its high value of about 90.2 million effective hooks in 1973, and then fluctuated between 50 to 70 million effective hooks in the years of 1974 to 1980, and increased to 94.6 million effective hooks in 1982. In 1983 and 1984, however, effective hooks droped to about 56.7 million but rose again to a level of about 90 million effective hooks since 1985 (Table 1).

Production Models Analyses

Catch and effective effort data for the South Atlantic albacore fisheries (Table 1) were fitted into production models for parameter estimation. The best fit of applying surplus models on the catch and effective fishing effort data set appears at when m value approaches 2.0 and the significant year class k value set to 3 or 4. The surplus curve thus obtained is shown in Figure 2. The range of maximum potential yield estimated for the stock appeared to be from 25,500 - 28,500 mt per year and the correstponding optimum fishing effort will be at about 80.0 million effective hooks per year.

DISCUSSION

It has well aknowledged that production models are among the simplest and most widely used approaches in the assessment of exploited fish populations despite the fact that some common theoretical requirements such as: (a) the population is either an unit stock or an isolated population; (b) an equilibrium condition can be achieved; (c) the constitutions (selectivity, catchability and temporal distribution pattern) of the fishery have remained constant; and (d) there is no time lag in the population response to its equilibrium mechanism; are generally not easy to meet in reality (Pella & Tomlinson 1969, Fox 1974). It is also believed by the authors that production models will continue for some time to serve as a basis for management of important fish stocks 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. Previous studies on the status of south Atlantic albacore resource have all employed production models (Shiohama 1977, 1978, 1979; Bartoo & Coan 1983; Yang & Sun 1984; Liu 1985; Yeh & Liu 1987).

The value of MSY estimated by this present study are lower than those of Yang and Sun (1984) but slightly higher than the previous year results (Yeh & Liu 1987). In last year's analyses, Japanese longline data was included in effective effort analyses while Japaese fleet evidently are not targetting on albacore since mid 1970s; although some incidental catch do happen. The inclusion of Japanese data lacking an appropriate adjustment may result in a lower estimation of MSY.

The current catch level (25,600 mt in 1986) is slightly over the lower boundary of predicted equilibrium MSY but the current effort is about 1.10 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. It is thus recommended that a closely monitoring on status of the stock should be continued.

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Table 1. Catch and effective effort analyses of the south Atlantic albacore fisheries based on the Taiwanese longline fishery data in the south Atlantic Ocean, 1967-1987.

	Taiwan Longline Fishery					All Fisheries	
Year	Catch in Number (x1000)	Mean Wt./ fish (Kg)	Nominal Effort (x100000 Hooks)	Catch in Number Per 100 Effect. Hooks	Catch in Kg Per 100 Effective Hooks	Catch in Weight (mt) x1000	Effective Effort ($x10^5$ Hooks)
1967	11.6	15.0	2.47	4.13	48.7	19.80	319.99
1968	196.5	14.2	4.52	5.07	72.1	27.84	386.19
1969	261.7	15.7	69.11	3.52	55.4	34.56	623.75
1970	506.0	15.0	72.73	3.17	47.5	23.65	244.38
1971	1268.2	15.2	312.79	4.05	61.5	25.02	406.67
1972	1209.6	14.7	375.68	2.51	36.9	33.20	900.66
1973	1092.0	13.8	376.07	2.27	31.3	28.23	902.19
1974	1052.3	13.7	334.49	2.46	33.6	19.70	520.26
1975	1029.3	14.6	289.85	2.79	40.8	17.53	429.50
1976	1500.5	12.8	418.39	2.78	35.6	19.25	600.57
1977	1491.1	14.4	414.64	2.69	38.7	21.37	595.57
1978	1740.5	13.6	487.96	2.52	34.2	23.05	707.05
1979	1076.0	13.6	331.53	2.27	30.8	22.50	733.02
1980	1113.0	14.7	339.54	2.48	36.4	22.54	619.70
1981	1119.1	15.0	396.72	2.24	33.7	23.59	700.23
1982	1320.0	14.4	476.61	2.14	30.6	28.98	946.11
1983	634.6	13.7	223.90	1.85	25.4	14.40	566.71
1984	535.8	14.9	168.61	2.60	38.6	13.31	345.20
1985	1365.5	13.9	481.75	2.12	29.4	28.05	955.17
1986	1532.0	13.5	499.07	2.17	29.1	* 25.61	878.33
1987	1128.7	13.9	464.05	1.61	22.3	**15.71	703.35

*: Japanese data is not included.
**: Only Taiwanese data is used.

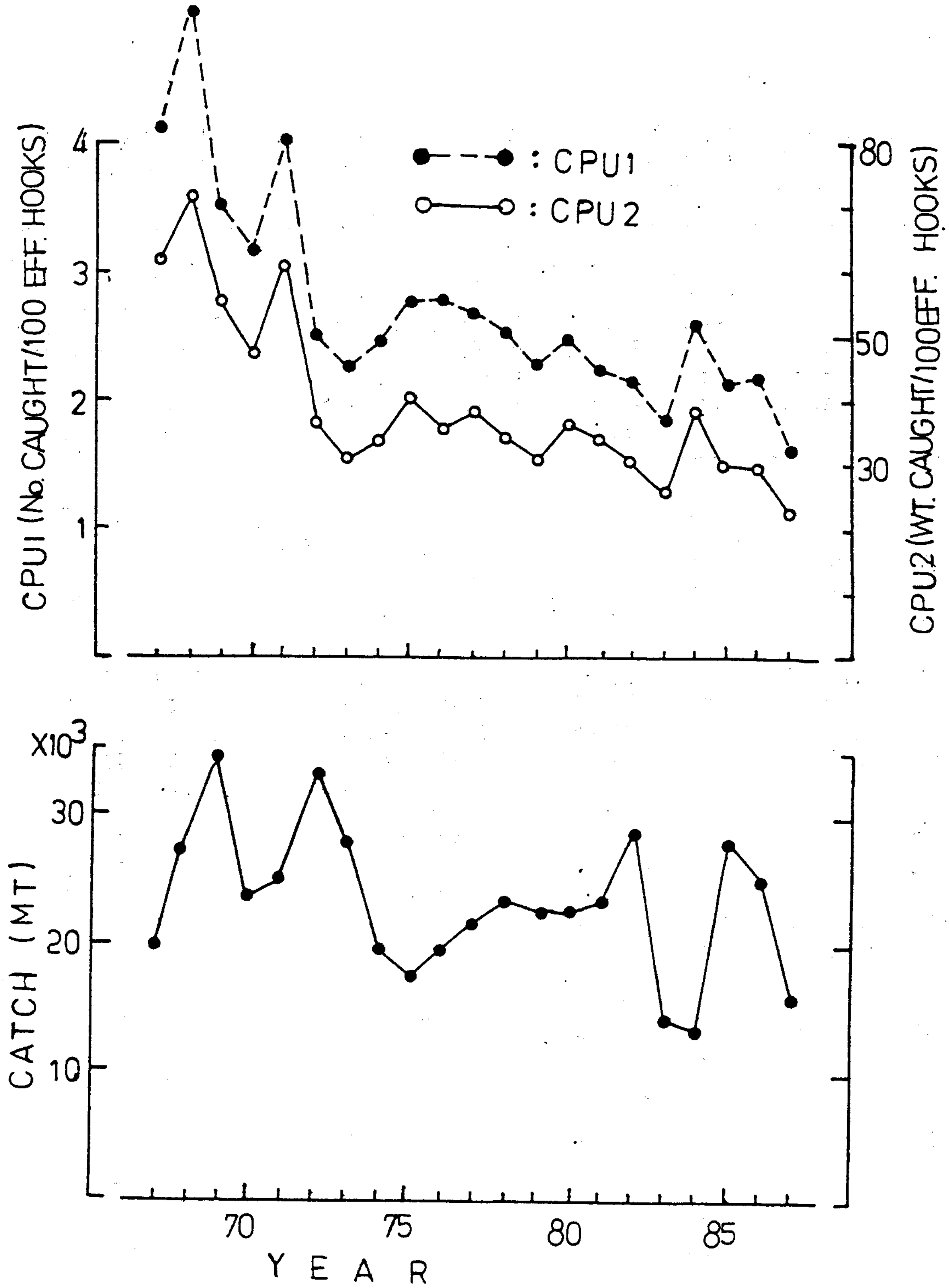

Fig. 1. Trends of annual CPU1 (in no. fish caught/100 effective hooks) and CPU2 (in weight caught/100 effective hooks) and total catch of south Atlantic albacore in 1967-1987.

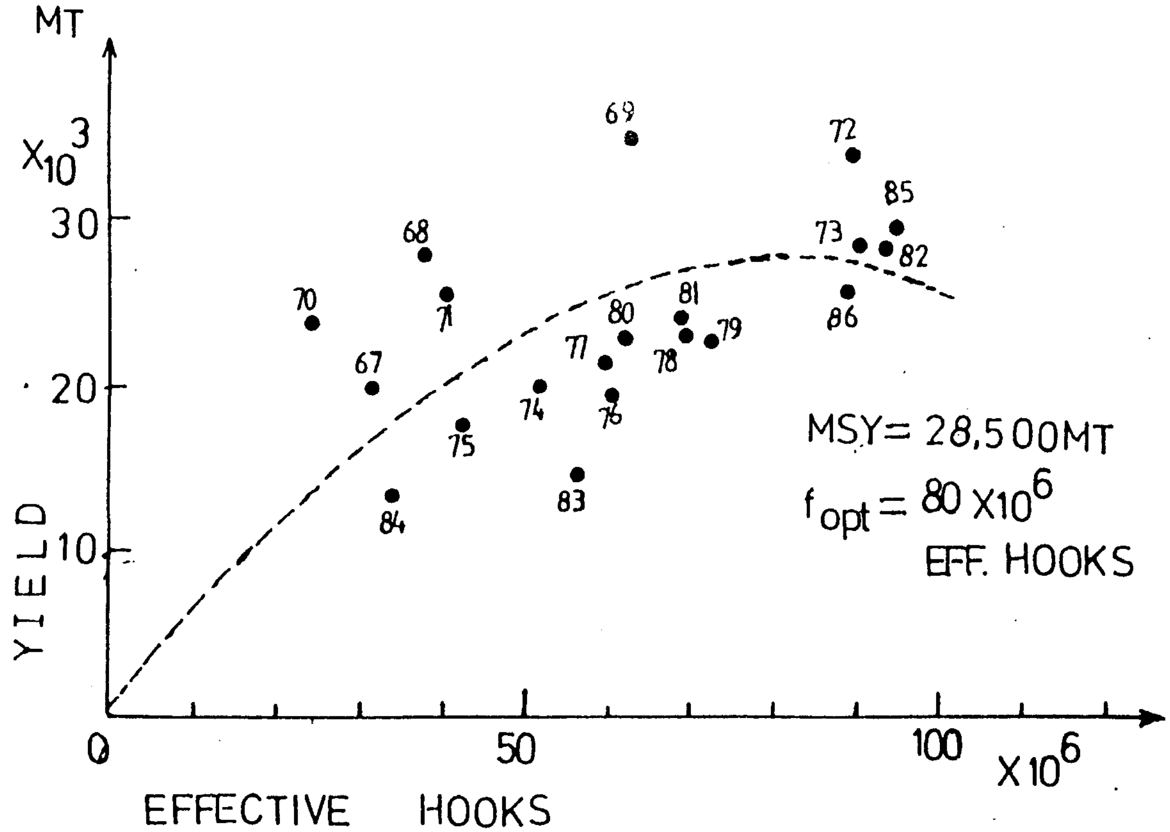

Fig. 2. Equilibrium yield curve and the observed data for south Atlantic albacore fisheries, 1967-1987.