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Further Calibration Incorporating with Yearly Changes of Biomass and Surplus Production from Results of Virtual Population Analysis for North Atlantic Albacore

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ABSTRACT

Northern Atlantic albacore is one of the most important target species of Taiwanese longline fishery. Traditionally the stock is assessed and managed by production models analysis and recently by adaptive virtual population analysis. Although results obtained from those assessments have indicated that the stock is in fully exploited condition, the incoincident assessing results among those analyses have difficulty to conclude the stock status definitely, therefore this paper is dealt with the analyses of annual surplus production, changes of stock biomass and catchability to understand the status of the stock suffering surface and longline gears.

Taiwanese and Japanese longline and Spanish and French troll standardized abundance indices were used to estimate relative abundance at age, fishing mortality at age by adaptive virtual population analysis. Accordingly, the annual 2-year-old recruited biomass and annual surplus production (ASP) were estimated.

The results show that annual 2-year-old recruited biomass declined abruptly from 1976 to 1987, and sharply increased to 1993 as the 1984 level. There are three catch peaks, in 1976, 1983 and 1987, those peaks resulted in declining of the ASP in 1979, 1984 and 1989. The delays of ASP decreasing during 1976-1979 and 1986-1989 may be affected by the high catches, the appearance of strong 1987-1988 year-classes, and the high abundance of the stock in 1970's.

After 1987, Taiwanese longline fleets have changed their fishing pattern and total catch in the north Atlantic was abruptly decreased, consequently, the biomass and ASP of the stock gradually increased year to year. The annual catch is almost equivalent to or lower than the corresponding ASP in 1993 due to the introduction of new fishing gears. Recently the annual recruit biomass increased significantly, it could be concluded that the stock was in full to moderate exploited condition.

Key words: *Atlantic albacore, Catchability, Annual surplus production, Abundance index.*

INTRODUCTION

Two unit stocks, northern and southern stocks, of Atlantic albacore, *Thunnus alalunga,* are assessed and managed by International Commission for the Conservation of Atlantic Tunas (ICCAT). The commissioners of the Commission have reached an agreement to manage the southern Atlantic albacore stock during

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the Nineth Special Meeting held in Madrid, Spain, 2-6 December 1994, while no management issues related resource improvement were made for the northern Atlantic albacore stock until the population is reevaluated in 1996 Session (Anon., 1995). The management measures are always made in accordance with the resultant assessments of Species Working Group Sessions of Standing Committee on Research and Statistics (SCRS) of ICCAT. The Working Group constitutes of scientists from fishing nations to assess the stock and appropriately to recommend the management measures. Since 1970's the fishermen using longline gear for exploiting north Atlantic albacore were mostly Taiwanese, Japanese and Korean; using troll and baitboat were mostly Spainish, and French, using purse seine was French, and using pelagic driftnet were French and Irish (Anon., 1995).

During the latest 1994 assessing session for north Atlantic albacore stock, one analysis of surplus production model incorporating covariates (ASPIC, Prager, 1991; 1992), and two catch- age analyses, age-structured production model (ASPM, Punt and Butterworth, 1991; Punt et al., 1992; Punt, 1994) and adaptive virtual population analysis (Powers and Restrepo, 1991) had been pursued. The results obtained from above analyses are definitely apparent with results discrepancies among the analyses, showing that the north Atlantic albacore stock is near fully exploited condition and that the current level of fishing efforts is in appropriateness to maintain a healthy stock status (Anon., 1994b). Depending upon the assessing and reviewing reports of the 1994 and 1995 SCRS albacore sessions, the status of albacore in the north Atlantic was not in further advanced understanding because the results obtained from the analyses were in some degree uncertainty (Anon., 1994a; 1995), also the results obtained from adaptive VPA seemed not well explained the real fishery which could be concluded in further by the annual surplus production. The report of 1995 SCRS assessing meeting was reviewed by Albacore Working Group in according to 1994 data base (Anon., 1995), the surplus recruited each year was still wanted to investigate how the yearly recruited stock status is by alternative assessing methods.

Recalling Atlantic albacore fisheries during past two decades, the surface gears including troll, baitboat and driftnet target juvenile fish almost aged 2-, 3- and 4-year-olds; on the other hand, the longline gear targets on adult fish aged 5-year-old and above (5+ group) almost. The recruited age during assessments mentioned always sets to 2-year-old. As the result, the recurits were supposed to be added for target of surface gears rather than of longline gear (Hsu and Liu, 1988), following this circumstance, the amount of catch of surface fisheries may seriously influence the recruited biomass (or usable biomass) for longline gear, because longline catch for recruited age (assumed 5-year-old) are much later than for surface catch as compared with the age compositon from catch (Anon., 1994a). On the other hand, extremely unreasonable longline catches which are almost adult fish may possibly affect the recruitment which surface gears targeted. Hence summing many biomasses caught and many biomasses left after fisheries during a year is the main concept of annual surplus production of a stock, and the investigation of annual surplus production is the way to solve the intermingled question proposed between surface and longline gears for the albacore stock. However, whether or not those possibilities can be investigated from annual surplus production and biomass change, unfortunately, those stock parameters have not yet been estimated for the time being.

Therefore, three main objectives will be pursued in the present paper. First, to estimate the surplus production and biomass change of entire usable stock; second, to compare the surplus production, biomass change of stocks and catchabilities by surface gears (say, 2-, 3-, and 4-year-olds fish), and longline gear (5-year-old and 5+ fish), and finally, to estimate the expected abundance indices by different gears (here, surface gears and longline gear will be used) and to compare with observed abundance indices. Those analyses are helpful for additional supplementary understanding the stock status, fisheries and catch data base quality of the north Atlantic albacore stock.

MATERIALS AND METHODS

The north Atlantic albacore resource has been studied by ICCAT since 1969, and recently been pursued by the ICCAT Albacore Research Program during the period between 1989 and 1994 (Anon., 1994a). The Final Meeting of the ICCAT Albacore Research Program was held at Sukarrieta, Vizcaya, Spain in June, 1994 to review and finalize the data bases of Atlantic albacore collected by the major nations fishing in the ICCAT convention area. Those data bases of Atlantic albacore by nations and by gears were analyzed in using age-structured models by Albacore Working Group of Standing Committee on Research and Statistics (SCRS) in the Annual Meeting held at ICCAT Headquarter, during November 14-25, 1994 in Madrid, Spain. The analysis of this study extended and continued the researches of above two Meetings, thus the similar data bases and parts of former results (Anon., 1994a; 1994b) were adopted to pursue evaluation of stock status in advance.

Basically, the standardized time series of catch per unit effort (CPUE) by nations and by gears, and the resultant outputs (Anon., 1994b) obtained from adaptive virtural population analysis (adaptive VPA, Gavaris, 1988; Powers and Restrepo, 1991) during the latest SCRS meeting (Anon., 1994b) were used to pursue the following analyses, although the data bases have been available till 1994, the only one additional year has not affected the results in using CPUE analyses, therefore the results from 1975-1993 CPUE series were used in the present analysis.

I. Abundance at age

The original data bases of abundance at age (in number) was adopted from the result of the base case virtual population analysis (VPA) that was runned during the SCRS annual meeting (Anon., 1994b). The abundance at age was estimated by using VPA adaptive methodology for sequential population analyses. The relative abundance indices in numbers selected for the VPA base case were Spanish troll (ages 2 and 3 combined) for the period 1981-1993, French troll (ages 2 and 3 combined) for the period 1975-1980, Japanese longline (ages 5+) for the period 1975-1993, and Taiwanese longline (ages 5+) for the periods 1975-1989 and 1990-1993 incorporating with changing fishing patterns.

Then, those estimated abundance at age (in number) were used to calculate biomass at age and were aggregated appropriately for the analysis in accordance with different corresponding ages targeted by different gears.

II. Biomass at age

The biomass were estimated based on relative abundance at age and weight-age analysis. Usually the biomass at age were estimated by abundance at age obtained from catch-age analysis (such as VPA etc.), multiplying mean weight at age, or

$$S_a = N_a \overline{w}_a \qquad (1)$$

where S_a is the biomass, N_a is the abundance, and $\overline{w}_a$ is the mean weight for age a. Therefore, the annual biomass was to sum all biomass at age in year.

III. Annual surplus production

Annual surplus production (ASP) is defined as the excess of what is required to replenish the population biomass each year due to removals from fishing and other causes (Deriso and Quinn, 1983). In accordance with Quinn et al. (1984), the ASP is estimated by:

$$ASP_t = \triangle S_t + Y_t \qquad (2)$$

where ASP_t is the ASP in year t, $\triangle S_t$ is the annual change in biomass during the time interval (t, t+1), and Y_t is the catch in year t. The annual change in biomass ($\triangle S_t$) was estimated by the difference of biomass in year t+1 (S_{t+1}) and in year t (S_t), i.e., $S_{t+1}-S_t$. It is obvious that both of $\triangle S_t$ and Y_t fluctuate yearly, if the population is not in equilibrium. The abundance, biomass, and ASP were smoothed by a robust, nonlinear procedure (Velleman, 1980) which was used by Deriso and Quinn (1983) to assess the Pacific halibut resource and fishery in regulatory area 2.

To investigate the difference of targeting age-classes of surface and longline gears, biomasses, ASPs and catches of overall fisheries (fish aged 1-year-old and above), surface gear (ages 2-, 3-, and 4-year-olds), longline gear (5-year-old and above), and assumed recruited age (2-year-old) were studied.

IV. Catchability

The catchability, which is the probability of catching a fish with one unit of fishing effort, is defined as the quotient of instantaneous fishing mortality divided by fishing effort, that is $q=F/f$, where q is the catchability, F is the instantaneous fishing mortality, and f is the fishing effort. Apparently the catchability are considerable fluctuations when those were estimated over time and among different age-classes, in particular between younger and older classes.

Annual estimates of selectivity were obtained from separable virtual population analysis (separable VPA) which was runned for the period 1987-1993 assuming F(1993) = 0.3 per year, a reference age of 2 and a selectivity at age 7 of 0.2 (i.e., a dome-shaped selection pattern). The resulting selectivity vector for age 1 to 7 was 0.28, 1.0, 0.988, 0.329, 0.146, 0.182, 0.2, and selectivity of age 8+ fish was assumed to equal that of age 7 (Anon. 1994b).

V. Catch per unit effort and biomass relation

Catch per unit effort (CPUE), based on fishing success information, usually is a measure of stock density in an area of fishing. Quinn et al. (1982) have manipulated stock density measurement in a area occupied by the stock to obtain a measure of biomass that can be compared between two areas.

The stock abundance index of north Atlantic albacore is the standardized CPUE, usually is expressed by three time series, the Spainish and French troll series (Mejuto and Garcia, 1996), Taiwanese longline series (Chang and Hsu, 1996a; 1996b), and Japanese longline series

(Uojumi, 1996; Uosaki, 1996) for different target sizes. The accurate abundance index should require the constant catchability for a fishery. Thus the relation between CPUE and biomass is:

$$\mathrm{CPUE}_{a,t} = q\ S_{a,t} \qquad (3)$$

where $\mathrm{CPUE}_{a,t}$ is the catch per unit effort for age class a in year t, q is the catchability that expresses the ratio relation between CPUE and biomass, and was assumed to be a constant for all age classes targeted by a fishery here because the selectivity by age was considered for each fishery during the analysis; and $S_{a,t}$ is the stock biomass for age a in year t.

The relation between CPUE and biomass provides support for their use in examining biomass changes.

RESULTS

I. Estimation of abundance and Biomass at age

The results of base case adaptive VPA with equal weighting for three abundance indices are given in Table 1 (Anon., 1994b). Futher, three versatile growth equations, Beardsley (1971), Bard and Compean-Jimenez (1980), and Gonzalez-

Table 1. Results of the base case VPA in terms of abundance of north Atlantic albacore stock for ages 1+, the unit is in million number at age. (Data are adopted from Anon., 1994b)

Year	Ages							
	1	2	3	4	5	6	7	8+
1975	13.69	6.20	6.03	4.37	1.45	0.75	0.42	0.20
1976	10.89	9.88	3.83	3.38	2.94	0.86	0.36	0.21
1977	13.87	7.30	5.51	2.09	1.75	1.83	0.33	0.25
1978	16.37	9.89	3.44	2.71	1.21	0.96	1.08	0.28
1979	9.57	9.75	5.27	1.36	1.48	0.70	0.52	0.90
1980	13.91	6.32	4.47	2.12	0.80	0.97	0.42	0.90
1981	11.27	8.75	3.13	2.08	1.30	0.50	0.67	0.91
1982	9.07	7.41	5.13	1.47	1.25	0.90	0.33	1.08
1983	9.04	6.54	4.10	2.29	0.74	0.86	0.61	0.89
1984	7.48	5.96	3.70	1.60	1.04	0.34	0.49	0.96
1985	9.40	5.19	3.46	1.87	0.90	0.57	0.14	0.80
1986	12.26	6.10	2.79	1.63	1.15	0.45	0.29	0.49
1987	11.12	8.42	3.31	1.01	0.86	0.48	0.18	0.38
1988	7.85	7.93	4.45	1.11	0.56	0.60	0.31	0.33
1989	8.91	4.34	4.07	2.25	0.65	0.38	0.43	0.45
1990	11.69	5.67	1.77	1.74	1.52	0.45	0.26	0.63
1991	11.06	7.73	2.08	0.57	1.06	1.05	0.26	0.56
1992	10.61	7.22	3.83	1.02	0.33	0.75	0.75	0.55
1993	10.07	6.75	3.81	2.07	0.56	0.22	0.47	0.90

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Garces and Farina-Perez (1983), were compared and to be considered with Santiago's length-weight relation (Santiago, 1992) in converting mean length into mean weight for each age. The results are given in Fig. 1. Due to wide range of sizes considered in samples to fit growth equation, Bard and Compean-Jimenez (1980) equation was considered in the present study.

The biomass at age estimated from abundance at age (Table 1) multiplying with mean weight of each corresponding age are given in Table 2 with summaried some age group together in accordance to the fisheries that 2-, 3- and 4-year-old groups were targeted by surface fisheries and 5-year-old and above by longline fishery. The recruited age was reasonably assumed as 2-year-old mainly for the surface fishery targeting.

II. Estimation of ASP

The ASP estimated from equation (1) is given in Fig. 2 with showing the trends of annual catch, and biomass. The trends of ASP and catch show that except 1981, the catches were almost higher than ASP from 1976 to 1986, equivalent to ASP from 1987 to 1990, and lower than ASP in 1991 and 1992, then equivalent to ASP again possibly in 1993. The trend of stock biomass indicates that a decreasing trend

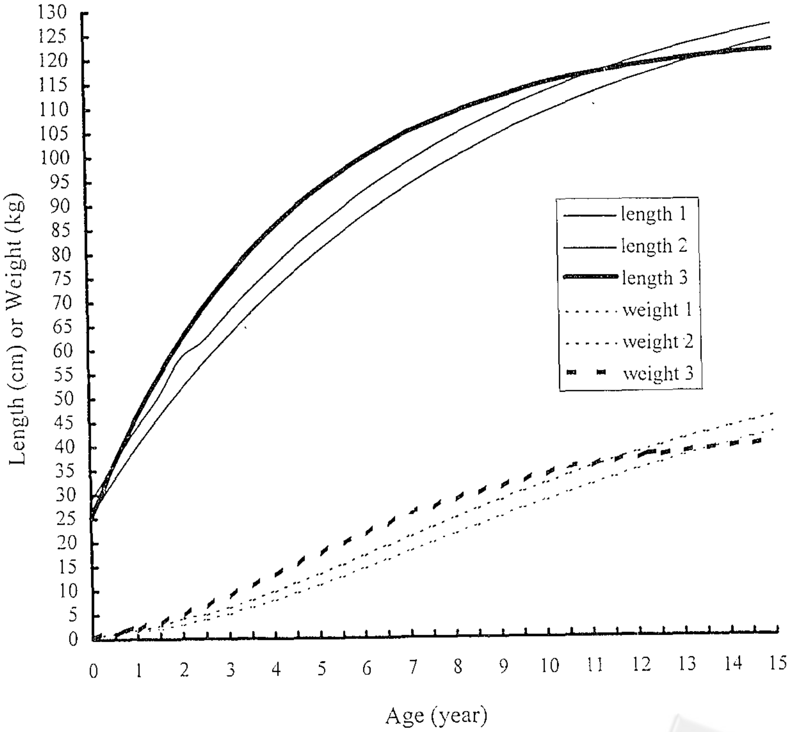

Fig. 1. Conversion of length-age relationships to weight-age realtionships by three kinds of growth equations: Length 1 - the Gonzalez-Garces and Farina-Perez (1983) equation, $l_t = 140.0[1-e^{-0.141(t+1.63)}]$; length 2 - the Beardsley (1971) equation, $l_t = 140.08[1-e^{-0.129(t+1.57)}]$; and length 3 - the Bard and Compean-Jimenez (1980) equation, $l_t = 124.74\ [1-e^{-0.2284(t+0.9892)}]$. The Santiago's length-weight relationship ($W = 1.339\times10^{-5} l^{3.1066}$, Santiago, 1992) was used to convert length at age to weight at age.

Table 2. Estimated year-class strength (number of 2 year-old), and abundance, and biomass of adults (5+ year-old) of the north Atlantic albacore.

Year	Year-class strength (millions of fish)	Year-class strength (1000MT)	2, 3 and 4 year-olds Abundance (millions of fish)	2, 3 and 4 year-olds Biomass (1000MT)	5+ year-olds Abundance (millions of fish)	5+ year-olds Biomass (1000MT)	Total stock Biomass (1000MT)
1975	6.20	30.23	16.60	140.53	2.82	58.27	224.75
1976	9.88	48.17	17.09	126.15	4.37	85.41	232.21
1977	7.30	35.59	14.90	111.42	4.16	86.00	223.72
1978	9.89	48.22	16.04	113.99	3.53	77.80	222.83
1979	9.75	47.54	16.38	111.69	3.60	82.02	211.85
1980	6.32	30.81	12.91	97.90	3.09	73.44	197.71
1981	8.75	42.66	13.96	97.45	3.38	78.69	197.51
1982	7.41	36.13	14.01	100.49	3.56	83.10	200.78
1983	6.54	31.89	12.93	97.95	3.10	74.52	189.61
1984	5.96	29.06	11.26	82.56	2.83	67.71	164.45
1985	5.19	25.31	10.52	80.23	2.41	56.38	154.43
1986	6.10	29.74	10.52	75.64	2.38	52.31	151.19
1987	8.42	41.05	12.74	83.39	1.90	41.69	146.17
1988	7.93	38.66	13.49	92.33	1.80	40.78	147.99
1989	4.34	21.16	10.66	86.43	1.76	44.39	147.72
1990	5.67	27.65	9.18	66.02	2.86	62.36	150.54
1991	7.73	37.69	10.38	63.44	2.93	65.06	149.48
1992	7.22	35.20	12.07	82.24	2.38	57.98	160.33
1993	6.75	32.91	12.63	93.54	2.15	54.39	167.02

occurred from 1976 to 1987, sustained stably at the historically lowest level from 1987 to 1991, and then recovered to increase onward. The current biomass (1993) was about 72% of that in 1976 which was the estimated relatively highest biomass for the time series data.

The catches of surface gear are stationary around 30,000 MT from 1975 onward (Fig. 3). The ASP estimated for surface gears was increasing from 1975 to 1977, fluctuated decreasing to 1985, increasing to 1987, then decreasing to the minimum of the series to 1989, and increasing again to 1991. The catches from 1977 to 1985 were almost higher than their corresponding ASP, and alternated for the rest years (Fig. 3). The biomass was decreasing from 1975 to 1991, and then increasing. It is noted that the fluctuated decreasing of biomass year by year seems related to the slight decreasing or increasing of catches, and ASP as well.

In contrast, the catches of longline gear (Fig. 4) were decreasing from 1976 to 1981, increasing to 1986, and decreasing to the historical minimum from 1987 to 1991, and a slight increasing from 1992.

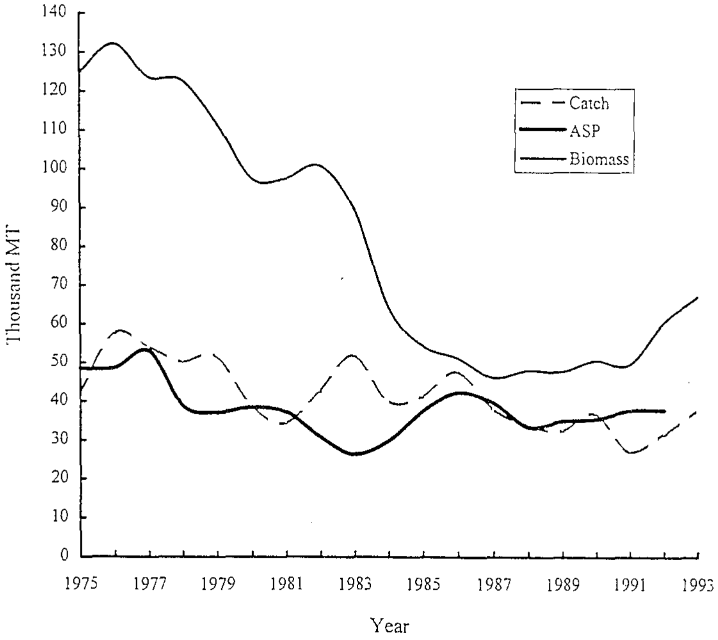

Fig. 2. The relationships among annual catch, annual surplus production (ASP), and annual estimated biomass for the total population of north Atlantic albacore.

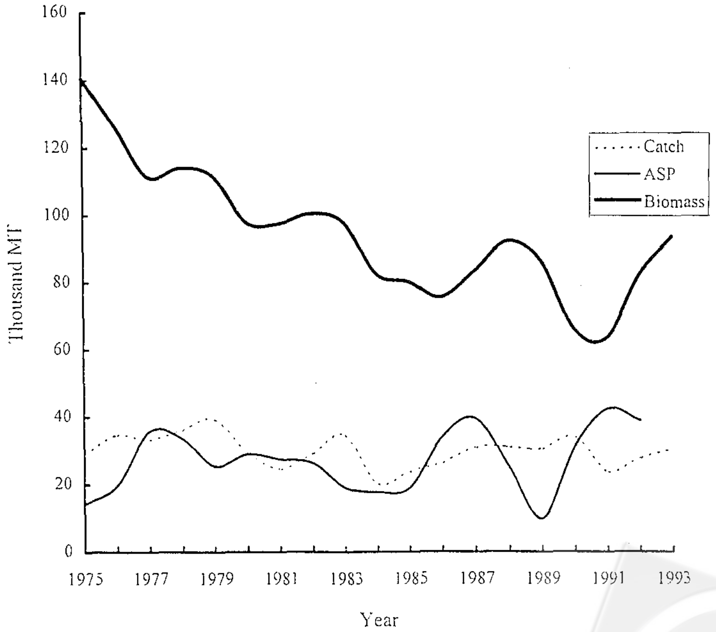

Fig. 3. The relationships among annual catch, annual surplus production (ASP), and annual estimated biomass for the surface fishery targeted individuals (Ages 2, 3, and 4) of north Atlantic albacore.

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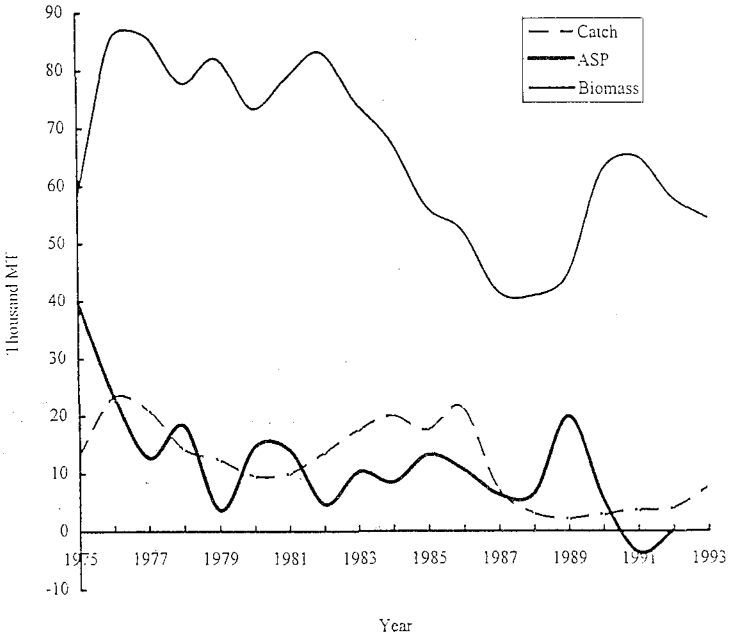

Fig. 4. The relationships among annual catch, annual surplus production (ASP), and annual estimated biomass for the longline fishery targeted individuals (age 5 and above) of north Atlantic albacore.

This trend of catches made fluctuated decreasing of ASP from 1976 to 1981, and the levels of catch and ASP alternated during this period, ASPs were in more stable level but lower than catches from 1982 to 1987, and great fluctuation of ASPs from 1987 afterward. Basically the adult biomass (5-year-old and above) was stable in high level from 1976 to 1981, decreasing to lowest level till 1987, then increasing till 1990, and decreasing again.

For the recruited age-class (2-year-old fish), there were minus ASP in 1976, 1979 and 1988. It was significant that increasing catch occurred in those years to result in decreasing of stock biomass for the following year (Fig. 5). The recruited stock biomass was decreasing with a very great fluctuation, there was about 30,000 MT in average recently, and about 10,000 MT was caught every year.

III. Catchability

The catchability was estimated by equation $f_{i,k}=C_{i,k}/CPUE_{i,k}$ first to obtain the effective fishing effort for year i and gear type k, where $C_{i,k}$ is the catch of year i by gear type k and $CPUE_{i,k}$ is the stock abundance indices for year i and gear type k; then the equation $q_{i,k}=F_{i,k}/f_{i,k}$ was used to eatimate the catchability by gear type k in year i, where $F_{i,k}$, indicating the instantaneous fishing mortality for year i and gear type k, was given as Table 3.

The catch by gear type was aggregated into two type *per se* in complying with the stock abundance index series, which are surface gear type including troll, baitboat and other surface gears (Mejuto and Garcia, 1995), and longline gear type (Anon., 1994b).Therefore, the fishing mortality was taken as average of ages

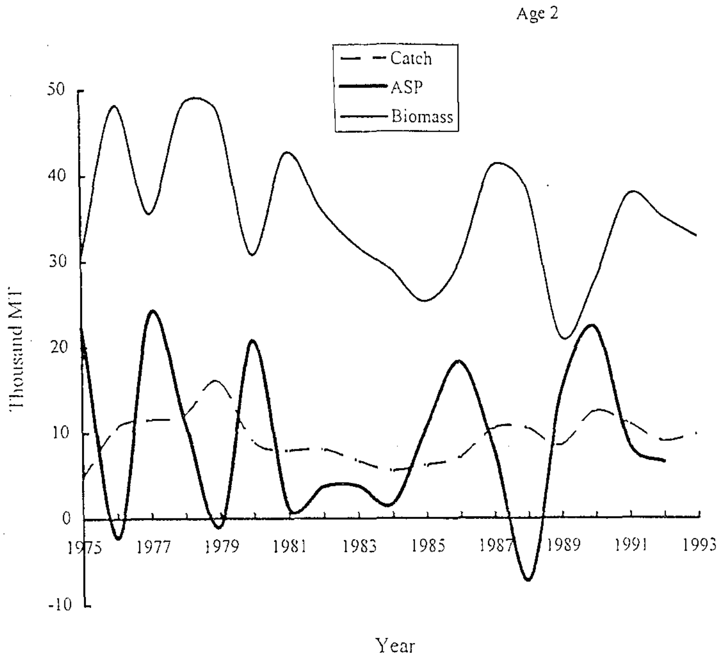

Fig. 5. The relationships among annual catch, annual surplus production (ASP), and annual estimated biomass for the recruits (age 2) of north Atlantic albacore.

2-, 3- and 4-year-old fish for surface gear type, and average of fish aged 5+ for longline gear type. Due to the availability of most recent CPUE by gear type, the catchability was estimated from 1981 to 1993, and results were shown in Fig. 6.

The surface catchability shows slight increase from 1991 as the level of 1988, comparatively , the longline catchability shows a slight decreasing trend before 1990, and then decreasing significantly after 1991 (Fig. 6). This indicates that the surface gears target on albacore directly and longline gear has shifted their target in recent years.

IV. Expected abundance indices vs. observed abundance indices

The expected abundance indices (expected catch per unit effort) was estimated by equation (3), and was given with observed abundance indices in Fig. 7. The results reveal that the tendency of expected abundance indices of surface fisheries is much coincident with observed abundance indices, and however, the tendency of expected abundance indices of longline fishery is only coincident with the segment from 1981 to 1988, and is phasing out from 1989 afterward.

The incoincidence between longline expected and observed abundance indices from 1989 onward shows that the fishery was not targeting on albacore any more, and the expected abundance indices represent the real fishery targeting on the studied species.

DISCUSSION

The current results indicate three keypoints concerning the status of north Atlantic albacore stock. First of all, the stock is in fully exploited but in healthy

Table 3. Results of the base case VPA in terms of fishing mortality at age (F at age) of north Atlantic albacore stock for ages 1+. (Data are adopted from Anon., 1994b)

Year	Ages							
	1	2	3	4	5	6	7	8+
1975	0.026	0.182	0.278	0.095	0.225	0.428	0.760	0.760
1976	0.100	0.284	0.308	0.362	0.177	0.655	0.554	0.554
1977	0.038	0.453	0.411	0.245	0.297	0.223	0.417	0.417
1978	0.218	0.331	0.631	0.307	0.254	0.312	0.113	0.113
1979	0.115	0.480	0.609	0.227	0.118	0.208	0.161	0.161
1980	0.163	0.402	0.467	0.187	0.164	0.065	0.069	0.069
1981	0.120	0.235	0.456	0.205	0.068	0.130	0.080	0.080
1982	0.027	0.291	0.507	0.382	0.078	0.097	0.159	0.159
1983	0.117	0.271	0.639	0.488	0.473	0.254	0.149	0.149
1984	0.066	0.242	0.379	0.280	0.298	0.628	0.299	0.299
1985	0.133	0.320	0.452	0.190	0.382	0.392	0.348	0.348
1986	0.075	0.309	0.720	0.338	0.576	0.639	0.416	0.416
1987	0.038	0.338	0.792	0.278	0.067	0.122	0.224	0.224
1988	0.293	0.367	0.381	0.235	0.090	0.035	0.062	0.062
1989	0.153	0.594	0.550	0.093	0.081	0.080	0.036	0.036
1990	0.113	0.701	0.836	0.190	0.069	0.235	0.154	0.154
1991	0.126	0.403	0.414	0.238	0.057	0.032	0.110	0.110
1992	0.153	0.339	0.317	0.307	0.131	0.158	0.064	0.064
1993	0.115	0.411	0.406	0.135	0.182	0.232	0.255	0.255

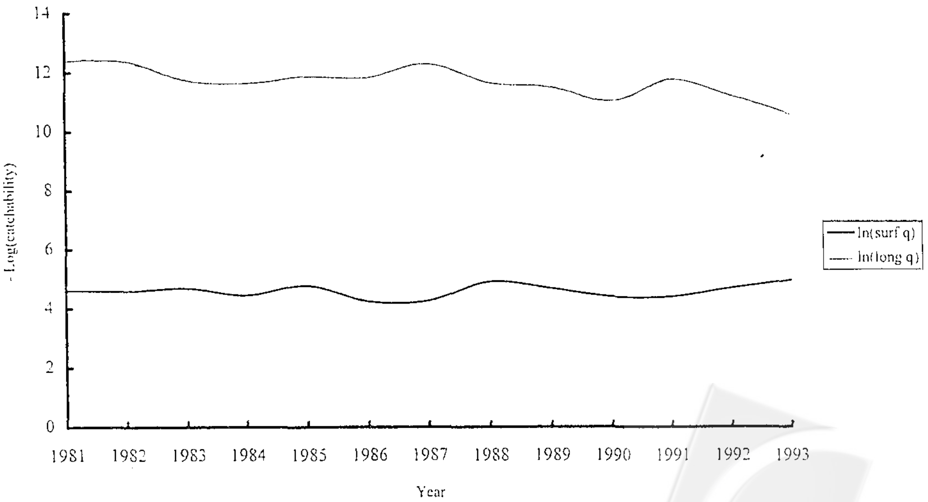

Fig. 6. The annual changes of catchability for longline and surface fisheries individually for north Atlantic albacore from 1981 to 1993.

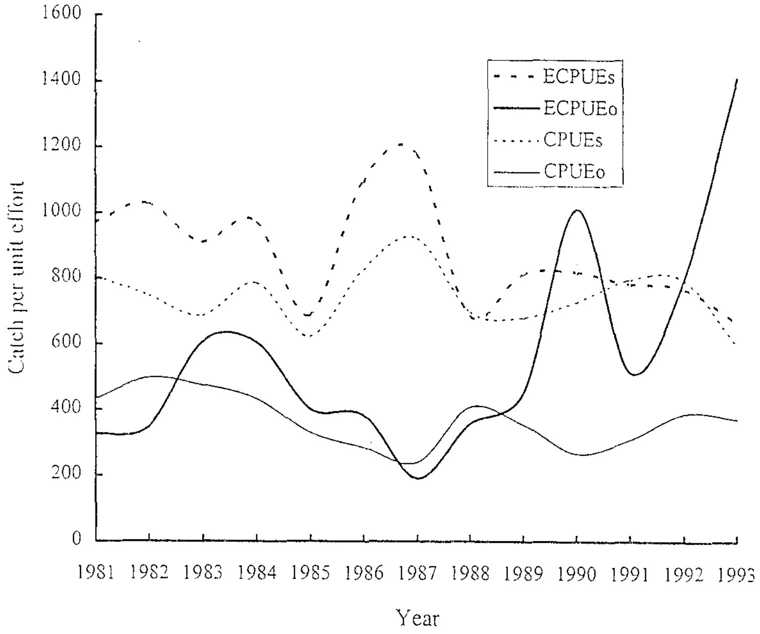

Fig. 7. The expected abundance indices and observed abundance indices for surface (ECPUEs and CPUEs, in kg/fishing day) and longline (ECPUEo and CPUEo, in kg/1000 hooks) fisheries, respectively.

condition; second, the heavy exploitation of any fishery can affect seriously the catches of other fisheries, and third, the recent catch estimates of longline fishery seems underestimated, especially in 1991 as the minus surplus production occurred.

The minus surplus production is resulted from that the difference of annual biomass is much less than annual catch in according to equation (2). In the present study, minus ASP occurred in the estimates of longline ASP in 1991 (Fig. 5) and recruited ASP in 1988 (Fig. 6). In 1991, Taiwanese catch by longline fishery increased from a series of decreasing from 1987, and the nominal efforts targeted on albacore increased sharply (cf. ALB-Table 2, Anon., 1994b). Obviously, the catch seems underestimated *in situ*. Moreover, the longline catch is far lower than that of surface fishery, it is no any evidence that the longline ASP in 1991 appeared in minus surplus (say, $S_{5+,1992}-S_{5+,1991} = \triangle S_{5+,1991} < -C_{5+,1991}$). The other possibility is related to the minus ASP of surface fishery in 1988. If taking account the rescruited fish (age 2) targeted by surface fisheries, then the heavy catches in 1988 for age 2 fish by surface catches may cause the depletion of recruits in 1988, and of longline recruits (5-year-olds fish) with a 3 years lag in 1991, this fact has been proven by exploited size distribution (Anon. 1994a). Whether or not those are so, the stock status is still in exploited. It can be negligible of those minus ASP for any management implications, because the conditions were resulted from gear interaction, and the stock biomass still in high level as early 1980's (Fig. 2).

Total mortality, the sum of F and M is much more accurate from the result of the adaptive VPA procedure. The instantaneous natural mortality (M) was assumed to be 0.3 per year. Compared with the intrinsic growth rate (K) 0.141/year (Gonzalez-Garces and Farina-Perez, 1983), 0.129/year (Beadsley, 1971), and 0.2284/year (Bard and Compean-Jimenez, 1981), the M=0.3/year is tending to high. On the circumstance, the stock is favorable to fish in young or juvenile ages because it is higher in M than in K. Thus either how is the optimal catch by surface fisheries (targeted on juvenile albacore) or how to balance the catches of surface fisheries and longline fishery should become interested in study in future.

Smoothed ASP estimate, biomass and catch of entire stock since 1975 are contrasted in Fig. 2. When catch exceeded ASP from1976 to 1986, biomass and ASP decreased substantially (Fig. 2). Although ASP estimates are constant apparently thenafter, this is perhaps due to the abrupt decreasing of longline catches from 1987, and this may result in increasing of adult biomass from 1988 (Fig. 4), and of juvenile biomass from 1990 (Fig. 3). The decreasing of adult biomass in 1992 and 1993 (Fig. 4) is not in compliance with the increasing of biomasses of entire stock and juvenile stock, this may obviously result from high catches of surface fisheries in 1989 and 1990 to cause the depletion of adult stock, and in contrast, the decreasing of catch of adult stock has not affected the recruitment since 1987. Whether or not the juvenile stock is overexploited is suspected because that the ASP estimates for recent years, i.e, 1990, 1991, and 1992, exceeded the catch for the juvenile stock (Fig. 3), but the minus ASP estimate in 1988 for age 2 recruited fish (Fig. 5) and highly excess of catch over ASP estimate for juvenile stock (Fig. 3) in 1989 and 1990 may result in a minus ASP estimate for adult stock in 1991 (Fig. 4).

The evidence of catchability shows that the current population of north Atlantic albacore was mostly sufferred by surface gear rather than longline gear. When the longline gear shifted their target in the north Atlantic from 1987, obviously the annual catchability of longline gear decreased from that time except in 1991, this gives a good proof of target shift of longline gear (Hsu and Liu, 1993). The estimated catchability is coincident with the real fishery, and further the estimated abundance indices of surface and longline gears indicate that the enitre time series of observed abundance index of surface gear and 1981-1988 observed longline series are able to represent the status of the study stock, and in constrast, the 1989-1993 longline series are not. The incoincident series appeared in longline fishery is likely resulted from whether or not the longline gear targets. To obtain more reliable analysis between surface and longline gears influenced the stock can be investigated from spawner-recruit relationship and projection, hence a useful spawner-recruit relationship will be built, and the stock will be projected based on this relationship in future study.

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應用年級群分析結果配合生物量和餘量生產的年度變化對北大西洋長鰭鮪系群狀態做進一步的評估

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大西洋長鰭鮪爲臺灣鮪延繩釣漁業最重要的漁獲物之一。歷年來該族群爲大西洋鮪類資源保護委員會以北緯五度分隔成北、南系群加以管理和評估。然而，近來年級群分析和生產量模式評估結果的差異，使資源狀態的判定產生不確定性，因此，本報告採用年級群分析的結果，進一步估算年度餘量生產、生物量的變化和漁獲能率，以了解在表層漁具和鮪延繩釣漁具開發下，北大西洋長鰭鮪系群的資源和漁業狀態。首先，以臺灣和日本的鮪延繩釣漁業及西班牙和法國的表層漁業標準化單位努力漁獲量做爲基本資源量指標，先以年級群分析法估計出年齡別資源量和漁獲死亡率，再依據此一結果估計年度總生物量、加入群生物量和年度餘量生產。

結果顯示：1976年至1987年的加入群生物量呈急速下降趨勢，再上升到1993年約爲1984年的水準。本系群在1976年、1983年和1987年有被漁獲高峰，這些漁獲高峰造成在1979年、1984年和1989年的年度餘量生產下降。且在1976年至1979年間和1986年至1989年間的年度餘量生產下降延滯可能是受高捕獲量、1987年至1988年強年級群的出現和1970年代之高資源量所致。

1987年以後，由於臺灣鮪延繩釣漁船的轉移和作業方式的改變，在北大西洋的總漁獲量大幅下降，因此，北大西洋長鰭鮪系群的生物量和年度餘量生產年年增加，1993年因新漁具的加入漁獲量約略相等於年度餘量生產。近來，年度加入生物量有顯著增加，故本研究系群應是處於中度至完全開發的狀態。

關鍵詞: 大西洋長鰭鮪， 漁獲能率， 年度餘量生產， 資源量指標。

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