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ASSESSMENT OF SOUTH ATLANTIC ALBACORE RESOURCE BASED ON 1959-2005 CATCH AND EFFORT STATISTICS FROM ICCAT

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SUMMARY

For assessing the current stock status of South Atlantic albacore , explanatory fittings on Japanese, South African, Brazilian and Taiwanese CPUE trends were performed by using age structured production model (ASPM) with stochastic recruitment. The results obtained from the "Base case" analysis of this model indicate that (1) B^{mat}/B^{mat}_{MSY} ratios of the stock from 1959 to 2005 are always greater than unity and the current $B^{mat}_{2005}/B^{mat}_{MSY}$ value of 1.61 implies that the stock is still in a healthy condition; (2) current exploitable biomass is estimated to be 41.1% of that in 1959, which is larger than the threshold (0.20) of biomass to be concerned of; (3) despite of yields in the recent years were larger or close to the MSY of this resource, fishing mortality F were always smaller than its corresponding values at MSY , in particular the F_{2005} is at the level of 42.9 % F_{MSY}. The current status of albacore stock in the South Atlantic can be concluded as in a condition of not being over-exploited.

RÉSUMÉ

Afin d'évaluer l'état actuel du stock de germon de l'Atlantique sud, des ajustements explicatifs des tendances de la CPUE du Japon, de l'Afrique du sud, du Brésil et du Taïpei chinois ont été réalisés en utilisant un modèle de production structuré par âge (ASPM) avec un recrutement stochastique. Les résultats obtenus de l'analyse du « cas de base » de ce modèle indiquent que (1) les ratios B^{mat}/B^{mat}_{MSY} du stock, de 1959 à 2005, ont toujours été supérieurs à l'unité et la valeur actuelle de $B^{mat}_{2005}/B^{mat}_{MSY}$ de 1,61 implique que le stock se trouve encore dans de bonnes conditions ; (2) la biomasse exploitable actuelle est estimée se situer à 41,1% de celle de 1959, ce qui est supérieur au seuil de biomasse (0,20) qui susciterait des préoccupations ; (3) bien que les productions des dernières années aient été plus élevées ou proches de la PME de cette ressource, la mortalité par pêche F a toujours été inférieure à ses valeurs correspondantes de PME, notamment F_{2005} qui se situe au niveau de 42,9 % de F_{PME}. On peut donc conclure que le stock de germon de l'Atlantique sud ne fait actuellement pas l'objet de surexploitation.

RESUMEN

Para evaluar la situación actual del stock de atún blanco del Atlántico sur, se llevaron a cabo ajustes explicativos en las tendencias de la CPUE de Japón, Brasil, Sudáfrica y Taipei Chino, utilizando un modelo de producción estructurado por edad (ASPM) con un reclutamiento estocástico. Los resultados obtenidos del análisis del Caso base de este modelo indican que (1) las ratios B^{mat}/B^{mat}_{MSY} de este stock desde 1959 hasta 2005 son siempre mayores que la unidad y que el valor actual de $B^{mat}_{2005}/B^{mat}_{MSY}$ de 1,61 implica que el stock sigue estando en buenas condiciones; (2) la biomasa explotable actual se estima en el 41,1% de la de 1959, cifra superior al umbral (0,20) de biomasa que produciría inquietud; (3) a pesar de que los rendimientos en años recientes eran superiores o cercanos al RMS de este recurso, la F mortalidad por pesca siempre era menor que sus valores correspondientes en RMS, en especial la F_{2005} se encuentra al nivel del 42,9% F_{RMS}. Puede concluirse que el stock de atún blanco en el Atlántico sur no se encuentra actualmente sobreexplotado.

KEY WORDS

Albacore, Age-structured production model

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1. Introduction

Taiwanese longline fleet commenced around 1960 and began to fish tunas in the Atlantic in the early 1960s. Albacore soon became one of the most important species targeted by Taiwanese longliners in the Atlantic since early 1970s. As one of the major fishing fleets utilize the South Atlantic albacore resource, the status or the healthiness of the stock is always the utmost concern to the fishing industry and fisheries managerial sector of Taiwan.

Longline fleets of Taiwan, Japan and Brazil and surface baitboat fleets of Namibia and South Africa are the major fishing fleets that utilize albacore resource in the South Atlantic. The surface baitboat fleets are albacore targeted fishery and mainly catch juvenile albacore. Longline fleets, which contain two types of fishing gears, mainly catch adult albacore. According to International Commission for the Conservation of Atlantic Tunas (ICCAT), annual harvest of South Atlantic albacore ranged from 15,000 t (t) to 40,000 t the past three decades.

On stock assessment, the production model is the most useful way to understand the resource status due to the data which contain the age composition of annual catches are not easy to obtain. Prior to 1992, assessments of South Atlantic albacore resource were conducted using the generalized production model (Yeh and Liu, 1988; Yeh *et al.* 1991, 1992). Thereafter, Punt (1992) developed the age structured production model (ASPM) that took direct account of the age structure of the population in the model. It replaces estimation of the parameters of the surplus production function by estimation of the parameters of a stock-recruitment relationship. The ASPM (Punt, 1992) modeled the resource dynamics by the equations:

$$N_{y+1,a} = \begin{cases} N_{y+1,0} & a = 0 \\ N_{y,a-1}\, e^{-(M_{a-1} + S_{y,a-1} F_y)} & a = 1,\ldots,m-1 \\ N_{y,m-1}\, e^{-(M_{m-1} + S_{y,m-1} F_y)} + N_{y,m}\, e^{-(M_m + S_{y,m} F_y)} & a = m \end{cases}$$

where $N_{y,a}$: the number of fish of age a at the start of year y;
M_a : the rate of natural mortality on fish of age a;
$N_{y,0}$: the number of 0-year-olds at the start of year y;
$S_{y,a}$: the age-specific selectivity function (for all fleets and gears combined);
m : the maximum age considered (taken to be a plus-group);
F_y : the (asymptotic) fishing mortality during year y.

Besides, the strength of the 0-year-class is related deterministically to spawner stock size by the Beverton-Holt stock-recruitment relationship:

$$N_{y,0} = \frac{\alpha\, B_y^s}{\beta + B_y^s}$$

$$B_y^s = \sum_{a=1}^{m} f_a w_a N_{y,a}$$

where B_y^s : the spawner stock size at the start of year y;
w_a : the mass of a fish of age a at the start of the year;
f_a : the fecundity of a fish of age *a*;
α, β : the stock-recruitment relationship parameters.

Due to the recruitment is deterministic with spawner biomass in ASPM model, Restrepo and Legault (1997) indicate that it may result in inconsistencies between the estimated level of recruitment and the observed level of catches and thus modified the ASPM with deterministic recruitment by including the stochastic recruitment into the model.

The stochastic ASPM model consists of a forward population projection. It is essentially similar to that of Punt (1994) but age 1 is assumed here as the age of recruitment. Besides, this model requires that a recruitment value be estimated for every year. The recruitment estimates are obtained with the stock recruitment relationship as

$$N_{1,y+1} = \frac{\alpha\, B_y^s}{\beta + B_y^s} e^{\varepsilon_{y+1}}$$

with $\varepsilon_{y+1} = \rho\varepsilon_y + \eta_{y+1}$, $|\rho| < 1$, $\eta \sim (0, \sigma_\eta^2)$.

In this study, the author applies the ASPM with stochastic recruitment to data of South Atlantic albacore to assess the resource status.

2. Data and methods

The stochastic ASPM model is used for South Atlantic albacore to assess the resource status. For the selection of "Base case", yields of two fisheries (longline and surface fishery) starting in 1959, 7 indices of abundance and the biological parameters etc. are made. Also, a series of model fits making different assumptions or parameters to examine the sensitivity of the results to these choices are carried out. These include examining the effects of different abundance indices, error distribution, growth equation, nature mortality and so on.

A. Base case

(1) Data utilized

(I) Annual abundance indices:

Seven CPUE indices from 4 fleets: Taiwanese longline (1968-2005; Log Normal), Japanese longline (1959-1969; 1969-1975; 1975-2002; Log Normal), Brazil-Chinese Taipei longline (1992-2001; Log Normal) and South African baitboat (1985-1998; 1999-2005; Log Normal) are used as the Base case application (**Table 1**). The data of forenamed indices are adapted from the Table 8 of ICCAT (2004) but index of Taiwanese longline is changed from Chang and Yeh (2008). Furthermore, the index of South African baitboat (1999-2005; Log Normal) is adapted from Smith and Glazer (2007).

(II) Catches in weight:

Catches in weight of longline and surface fisheries from 1959 to 2005 were obtained from the Table1 of ICCAT (2004) and ALB-Table 1 of ICCAT (2006).

(III) The age specific selectivity:

Fleet specific domed shape selectivity at age (Legault and Restrepo, 1999) was applied in this study. Fig. 1 that modified from the Fig. 26 of ICCAT (1999) depicts the estimated selectivity patterns for Japanese longline, Taiwanese longline and South African bait boat fleets by blocks of years. The selectivity pattern of Brazil-Chinese Taipei longline was followed the example of Taiwanese longline. In Fig. 1, selectivities at age 9-13 were assumed as the same as that at age 8.

(2) The specification of parameter values

(I) It is assumed that fish are not to live beyond their thirteenth year of life, so that the plus group is defined at age 13.

(II) Natural mortality is assumed to be equal to 0.3 per year for age 1 to age 13 and infinite thereafter.

(III) The weight of a fish of age *a* in years is specified using the growth curve (Lee and Yeh, 2007) and the length-mass relationship of Penney (1994):

$La = 147.5(1 - e^{-0.126\,(a + 1.89)})$ and

$Wa = 1.3718 \times 10^{-5} La^{3.0973}$

(IV) The fecundity schedule is given by:

$$fa = \begin{cases} 0 & \text{if } a < 5 \\ 0.5 & \text{if } a = 5 \\ 1 & \text{if } a > 5 \end{cases}$$

B. Sensitivity tests

Eight additional applications of the ASPM procedures were performed to assess the sensitivity of the results to other sources of uncertainty. The acronyms used to identify those sensitivity tests are detailed in **Table 2**. In Case 1, growth equation was replaced from Base case by Bard (1981). In Case 2 ~ Case 6, indices were either changed in model or removed. As for Case 7 and Case 8, the nature mortality of Base case was substituted with 0.2 yr^{-1} and 0.4 yr^{-1}, respectively.

3. Results

Figures 2-Figure 5 show the fitting results of Base case by stochastic ASPM.

The ratios between the yield and the MSY (Yield/MSY) are shown in **Figure 2**. It indicates that annual yield > MSY occurred mainly from 1985, though it happened in a few early years.

Figure 3 shows the trend of the estimates of depletion (i.e. B / K). It decreased sharply since 1962 to its lowest level in 1990, then rose slightly and leveled off. All the estimates of depletion are higher than 0.2.

The ratios between the mature biomass and the mature biomass at MSY (B^{mat}/ B_{MSY}^{mat}) are shown in **Figure 4**. Though the ratios decrease rapidly, the mature biomass (B^{mat}) is still larger than the mature biomass at MSY (B_{MSY}^{mat}) in all the years. The value of $B_{2005}^{mat}/B_{MSY}^{mat}$ is equal to 1.61.

Figure 5 shows the ratios between the fishing mortality and the fishing mortality at MSY (F/F_{MSY}). It indicates that the fishing mortality (F) is larger than the mortality at MSY (F_{MSY}) only in the year of 1992 ~ 1994. The current fishing mortality F_{2005} is 42.9 % of that at MSY level.

Table 3 provides nine management-related parameters derived from the Base case analysis and the corresponding sensitivity tests. These nine quantities are: the mature biomass in 2005 (B_{2005}^{mat}), the mature biomass at MSY (B_{MSY}^{mat}) of 2005, the virgin biomass (K), MSY, the fishing mortality of 2005 (F_{2005}), the fishing mortality at MSY of 2005 (F_{MSY}), the ratio between the mature biomass of 2005 and the corresponding value at MSY ($B_{2005}^{mat}/B_{MSY}^{mat}$), the depletion of 2005 (B_{2005}/K) and the ratio between the fishing mortality of 2005 and the corresponding value at MSY (F_{2005}/F_{MSY}). It indicates that Case 8 has the largest MSY (34,556 t) when the nature mortality (M) for all age class was assumed to be 0.4 y^{-1}, and the smallest one (23,551 t) appeared in Case 6 when the index of Taiwanese longline is removed. The MSY value of Base case is 28,771 t. Furthermore, Base case has the largest value of $B_{2005}^{mat}/B_{MSY}^{mat}$ (1.607) and Case 7 has the smallest one (0.379). With regard to the ratio of F_{2005}/F_{MSY}, Case 7 has the largest value (1.112) and Case 8 has the smallest one (0.333). As for the depletion of 2005 (B_{2005}/K), all cases are larger than 0.2.

Figure 6 compares the trajectories of the ratio of the exploitable biomass to that in 1959 as the virgin biomass for South Atlantic albacore obtained from the Base case and cases 1, 4, 7 fitting on ASPM. All the variation of annual B/K trends is the same as the Base case, particularly for Case 1, in which the growth equation was replaced from Base case by Bard (1981).

Figure 7 shows the trajectories of the ratio of fishing mortality to that resulting in MSY for South Atlantic albacore obtained from the Base case and cases 1, 4, 7 fitting on ASPM. Base case and Case 1 also have the most similar trends and smallest discrepancy of ratio between these trajectories, and only a few annual fishing mortalities (F) were larger than its corresponding values at MSY (F_{MSY}). On the contrary, almost all annual fishing mortalities (F) were larger than its corresponding values at MSY (F_{MSY}) from 1985 on in Case 4 and Case 7.

4. Discussion and conclusion

For South Atlantic albacore, owing to reliable estimates of the age-composition of the historic catches, assessment techniques of *ad hoc* tuned VPA (Pope and Shepherd, 1985) and ADAPT (Gavaris,1988) are not applied to this stock. Thus, assessments of this stock prior to 1992 were based on the effort-averaging estimator developed by Fox (1975). However, effort-averaging estimation methods have been criticized (Butterworth and Andrew, 1984; Punt, 1988). It has been demonstrated that these methods would lead to severely positively biased estimates of MSY and optimal effort when applied to CPUE series which decline over time (Butterworth and Andrew, 1984; Punt, 1988).

In view of the disadvantages of effort-averaging estimation methods, Punt (1992) developed the age structured production model that estimates parameters by using age-structured computations internally and directly estimates parameters of a stock-recruitment relationship. Originally, the parameters in ASPM were estimated under the assumption that recruitment is deterministic with spawner biomass. However, this deterministic stock-recruitment relationship may result in inconsistencies between the estimated level of recruitment and the observed level of catches. Restrepo and Legault (1997) relax the deterministic assumption by incorporating stochasticity in recruitment around the deterministic predictions, and suggest that the stochastic ASPM model is perhaps more appropriate than the deterministic one for projections because it more naturally accounts for fluctuations in year-class strength, which are important in establishing the initial projection conditions.

In **Table 3**, the estimates of MSY range from 23,551 t (Case 6) to 34,556 t (Case 8), and the MSY of Base case 28,771 t which is larger than 25,200 t of Punt *et al.* (1996) but smaller than 30,900 t (Base case of ICCAT 2004). The results are more or less sensitive to change to the values of the model parameters. Although Case 8 (M=0.4) has the largest MSY value, it also has the ultra-lower annual F value and unusual values of the virgin biomass (*K*) and annual B^{mat} than other Cases. When the growth equation is replaced by Bard (1981) from Base case, the estimate of MSY has become smaller from 28,771 t to 27,371 t(Case 1). However, the discrepancy is the smallest one in all Cases but Case4. As for the selection of abundance indices used when fitting the model, it appears some degree effect on the estimates of MSY when the indices of Brazilian longline (Case 3), Japanese longline (Case 4), South African longline (Case 5) and Taiwanese longline (Case 6) were removed, respectively. When the indices of Japanese longline were removed (Case 4), it appears little effect on the estimate of MSY. This could be attributed to the fact that the Japanese longline has the same fishery pattern with Taiwanese longline but has a low level in albacore catches since 1970s. On the contrary, it appears larger effect on the estimate of MSY when the index of Taiwanese longline was removed (Case 6). This might reflect the catch of South Atlantic albacore by the Taiwanese longline fleet still occupies the major part of the total albacore harvested in the South Atlantic. On the other hand, the exclusion of the South African bait boat indices will result in the estimate of MSY becoming smaller (Case 5). It shows that the importance of the data of the surface fishery in the resource assessment of South Atlantic albacore though the surface fishery constituted only a small portion about 25 % of the total catches in the recent 20 years.

Figure 3 shows the estimates of B/K obtained from Base case analysis. Although the ratios appeared to decline from the initial stage, this seems a reasonable condition for a new fishery; it rose slightly and leveled off since 1990. The current exploitable biomass is estimated to be 41.1 % of that in 1959 (the beginning of albacore longline fishery in the South Atlantic is assumed). From Table 3, we can find all ratios of B_{2005}/K of sensitivity tests also to be larger than 0.2, a threshold of "something bad" when the biomass falling below this level (Francis, 1992).

Furthermore, from **Figure 4**, we can find all ratios of B^{mat}/B^{mat}_{MSY} obtained from the "Base case" analysis to be larger than 1.0, and the current ratio $B^{mat}_{2005}/B^{mat}_{MSY}$ is equal to 1.61. It means the stock is still in a healthy condition and the mature biomass in 2005 could support the fishery.

Although the yields in the recent years are larger or close to the MSYs, the estimates of fishing mortality F are smaller than its corresponding values at MSY based on the Base case analysis (**Figure 5**). F_{2005} is at the level of 42.9 % F_{MSY}. This result, with the results of B/*K* and B^{mat}/B^{mat}_{MSY}, it can be concluded that the current resource is not in the condition of over-exploitation.

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Table 1. The standardized CPUEs of South Atlantic albacore used in ASPM analysis.

	Japan LL			*Japan LL*			*Taiwanese LL*	*Brazil-Chinese Taipei LL*	*South Africa BB*
Catch Units	Numbers			Numbers			Numbers	Biomass	Biomass
Model	Lognormal			Poisson			Lognormal	Lognormal	Lognormal
Used in assessment	Base Case & Sensitivity			Sensitivity			Base Case & Sensitivity	Base Case & Sensitivity	Base Case & Sensitivity
1959	45.626			7.231					
1960	36.419			6.192					
1961	27.832			4.325					
1962	23.544			3.267					
1963	21.071			2.755					
1964	22.339			3.008					
1965	15.338			2.436					
1966	16.143			2.390					
1967	17.137			2.285					
1968	14.767			2.274			18.494		
1969	7.825	10.249		1.000	7.109		19.721		
1970		6.554			4.808		14.799		
1971		7.774			6.208		14.901		
1972		6.252			3.377		10.340		
1973		4.044			1.674		9.016		
1974		4.902			1.749		10.191		
1975		3.738	0.948		1.000	1.487	11.906		
1976			0.966			1.900	12.596		
1977			0.861			0.996	13.752		
1978			1.007			0.628	12.280		
1979			0.717			0.427	11.425		
1980			0.875			1.223	10.506		
1981			1.209			2.034	8.385		
1982			1.096			2.178	8.393		
1983			0.878			1.260	8.228		
1984			0.875			1.297	9.291		
1985			1.227			2.034	8.881		1.077
1986			1.117			2.235	8.784		1.223

1987	0.809	0.928	7.764		1.120	
1988	0.651	0.673	5.600		0.858	
1989	0.767	0.965	5.047		0.737	
1990	0.763	0.862	5.237		0.786	
1991	0.792	0.988	6.055		0.635	
1992	0.716	1.035	7.194	9.523	0.921	
1993	0.698	0.877	6.126	8.825	0.848	
1994	0.765	0.881	7.790	13.288	0.822	
1995	0.600	0.639	7.745	4.951	0.908	
1996	0.641	0.837	8.167	8.400	1.012	
1997	0.716	1.091	7.674	8.503	1.008	
1998	0.733	1.064	6.664	15.710	1.574	
1999	0.784	1.216	5.550	6.974		1.387
2000	0.943	1.425	5.104	10.867		1.173
2001	0.831	1.410	6.178	14.842		1.411
2002	0.644	1.000	5.001	10.188		1.388
2003	0.844*	1.000#	4.644	10.188		1.321
2004	0.844*	1.000#	6.721	10.188		1.102
2005	0.844*	1.000#	5.953	10.188		1.256

#: assumed as that of 2002.

*: assumed as the mean value of years 1975-2002.

Table 2. The “base case” and the sensitivity tests for ASPM analysis.

Acronym	*Base case*
Specifica-tion	Indices: Japanese longline (Lognormal) Taiwanese longline (Lognormal) Brazilian longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.3 yr^{-1} for all age classes

Acronym	*Case 1*	*Case 2*
Specifica-tion	Indices: Japanese longline (Lognormal) Taiwanese longline (Lognormal) Brazilian longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Bard (1981) M: 0.3 yr^{-1} for all age classes	Indices: Japanese longline (Poisson) Taiwanese longline (Lognormal) Brazilian longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.3 yr^{-1} for all age classes

Acronym	*Case 3*	*Case4*
Specifica-tion	Indices: Japanese longline (Lognormal) Taiwanese longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.3 yr^{-1} for all age classes	Indices: Taiwanese longline (Lognormal) Brazilian longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.3 yr^{-1} for all age classes

Acronym	*Case 5*	*Case 6*
Specifica-tion	Index: Japanese longline (Lognormal) Taiwanese longline (Lognormal) Brazilian longline (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.3 yr^{-1} for all age classes	Indices: Japanese longline (Lognormal) Brazilian longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.3 yr^{-1} for all age classes

Acronym	*Case 7*	*Case 8*
Specifica-tion	Indices: Japanese longline (Lognormal) Taiwanese longline (Lognormal) Brazilian longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.2 yr^{-1} for all age classes	Indices: Japanese longline (Lognormal) Taiwanese longline (Lognormal) Brazilian longline (Lognormal) South Africa bait boat (Lognormal) Growth equation: Lee and Yeh (2007) M: 0.4 yr^{-1} for all age classes

Table 3. Management-related parameters derived from the *base case* analysis and the corresponding sensitivity tests from applying stochastic ASPM to South Atlantic albacore.

Quantity	*Acronym*								
	Base case	*Case 1*	*Case 2*	*Case 3*	*Case 4*	*Case 5*	*Case 6*	*Case 7*	*Case 8*
B^{mat}_{2005}	24177	15537	7883	15622	20850	10700	10965	15203	681064
B^{mat}_{MSY}	15047	10602	12953	13740	14460	13422	12397	40106	431501
Virgin *(K)*	139366	121924	119060	126799	133477	123318	113936	158327	897353
MSY	28771	27371	24617	26186	27579	25457	23551	24804	34556
F_{2005}	0.313	0.402	0.602	0.453	0.384	0.466	0.515	0.486	0.023
F_{MSY}	0.729	0.804	0.721	0.724	0.725	0.718	0.720	0.437	0.069
$B^{mat}_{2005}/B^{mat}_{MSY}$	1.607	1.465	0.609	1.137	1.442	0.797	0.884	0.379	1.578
B_{2005}/K	0.411	0.366	0.250	0.312	0.350	0.312	0.306	0.233	0.854
F_{2005}/F_{MSY}	0.429	0.500	0.835	0.626	0.530	0.649	0.715	1.112	0.333

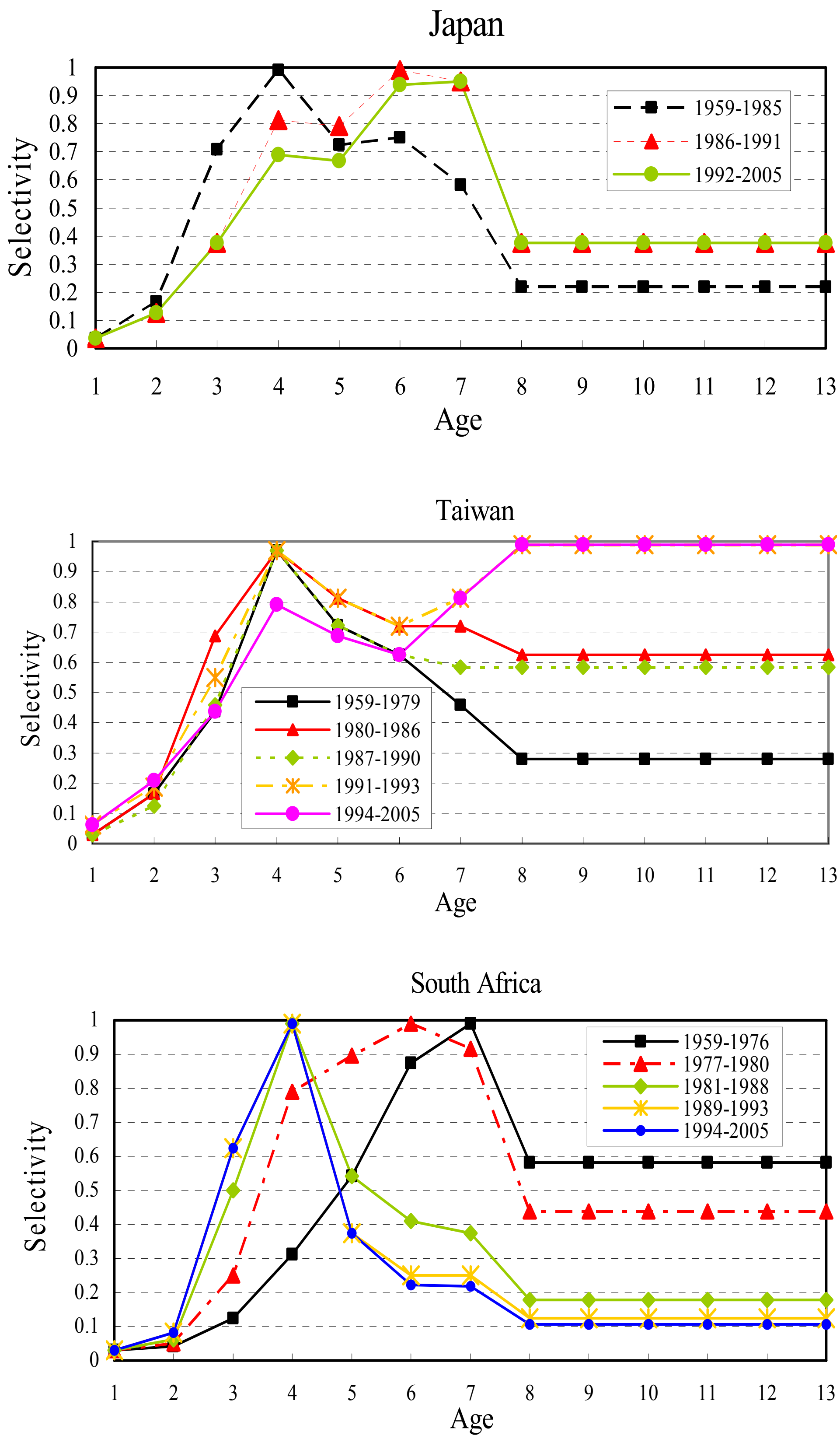

Figure 1. Selectivity for South Atlantic albacore by three main fleets. (modified from ICCAT 1999).

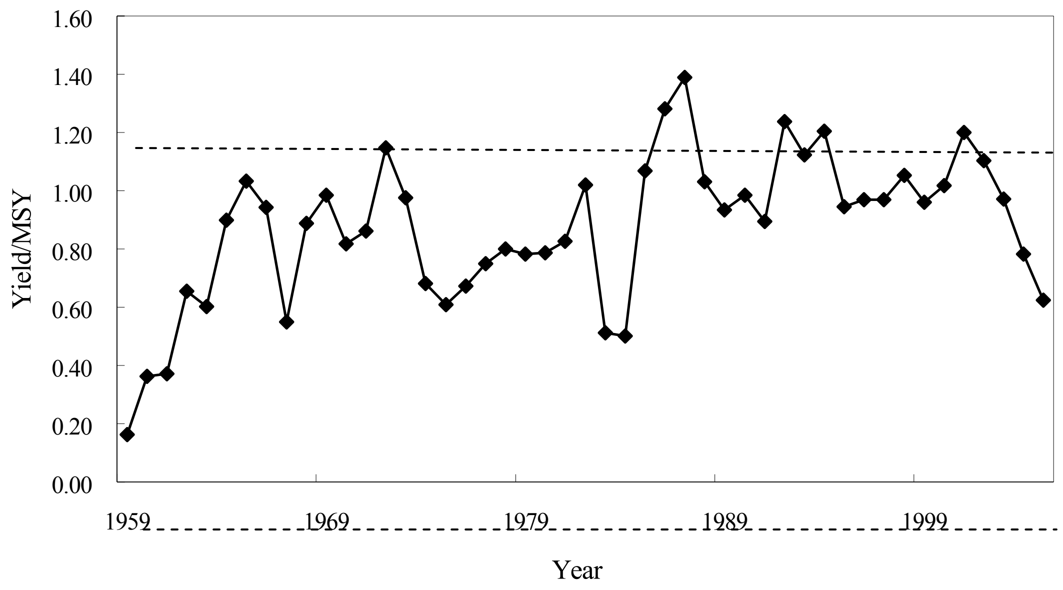

Figure 2. The ratios between the yield and the MSY (Yield/MSY) of South Atlantic albacore obtained from the "Base case" analysis.

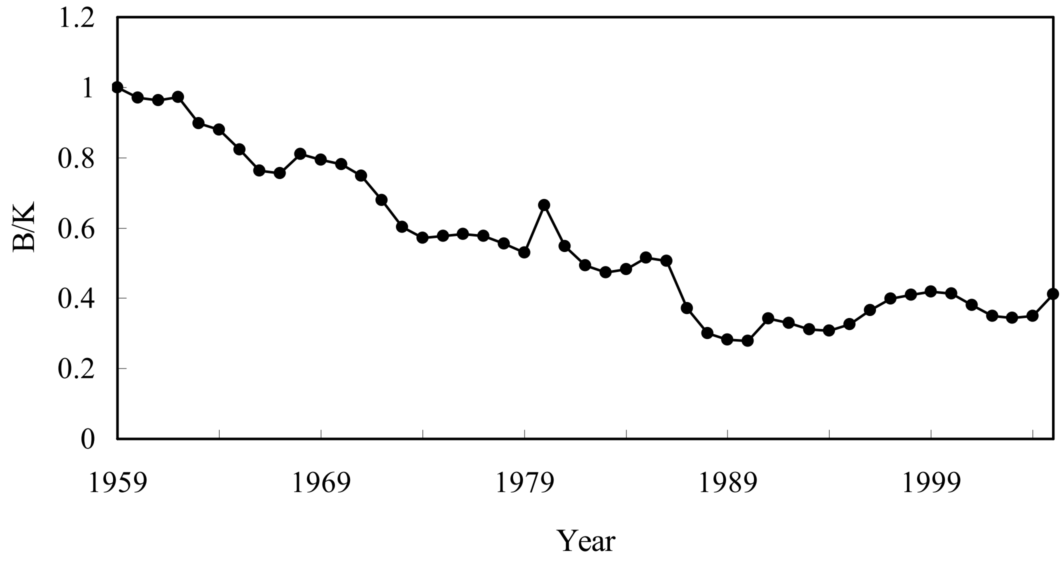

Figure 3. Exploited biomass as a fraction of pre-exploited biomass (B/K) of South Atlantic albacore obtained from "Base case" analysis.

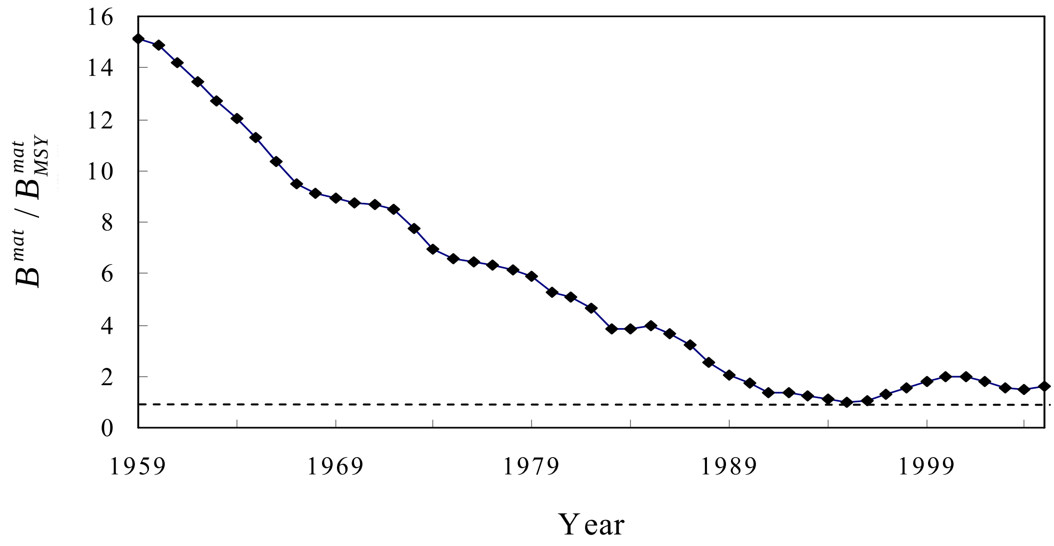

Figure 4. The ratios between the mature biomass and the mature biomass at MSY (B^{mat}/ B^{mat}_{MSY}) of South Atlantic albacore obtained from the "Base case" analysis.

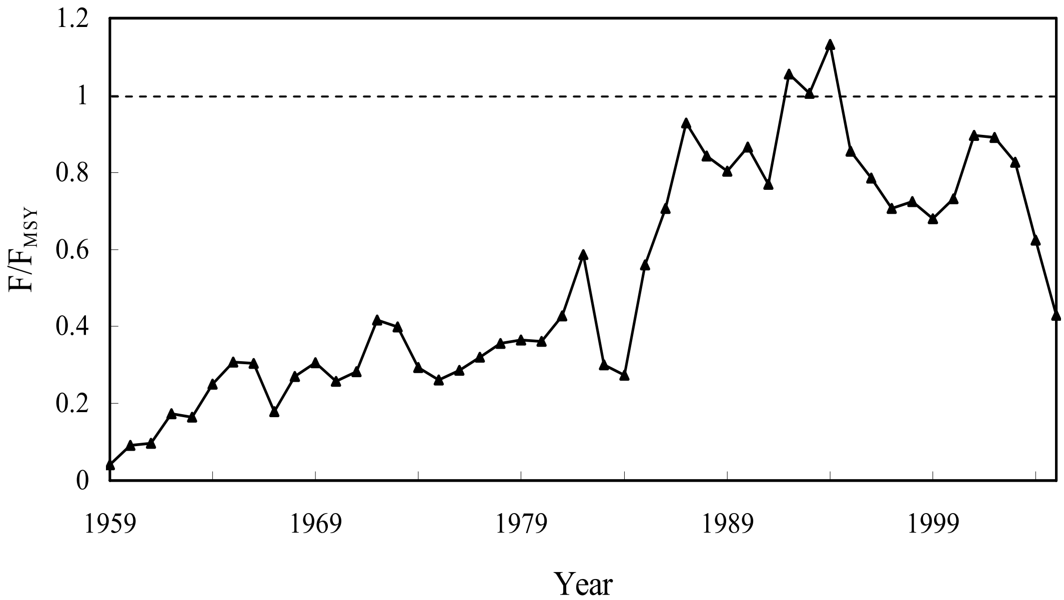

Figure 5. The ratios between the fishing mortality and the fishing mortality at MSY (F/F_{MSY}) of South Atlantic albacore obtained from "Base case" analysis.

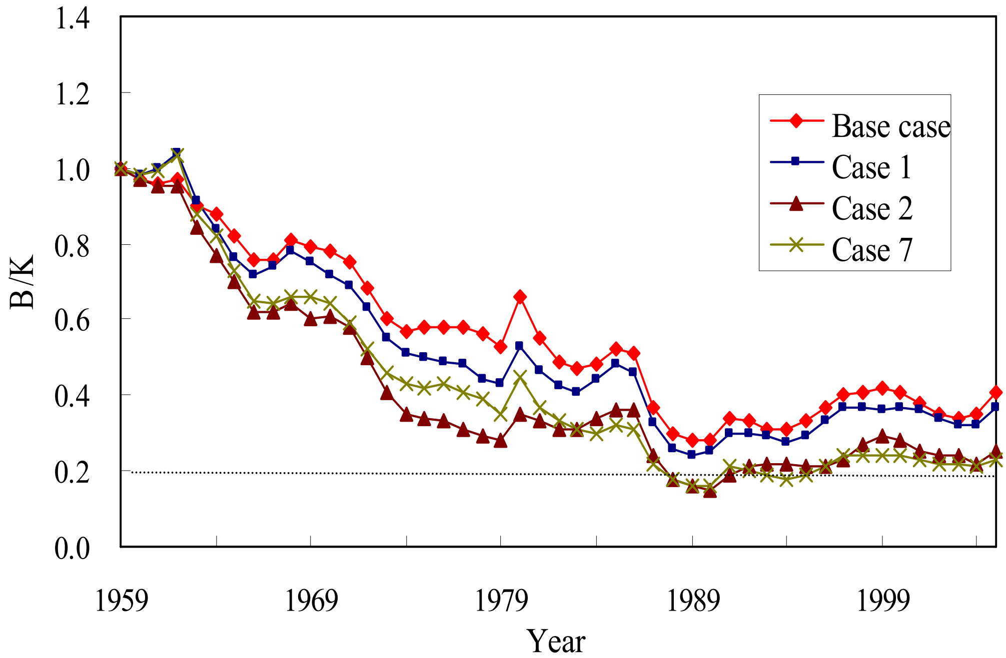

Figure 6. Estimated trajectories of the ratio of the exploitable biomass to that in 1959 as the virgin biomass for South Atlantic albacore obtained from the Base case, case 1, Case2 and Case 7 (defined in Table 2) fitting on ASPM.

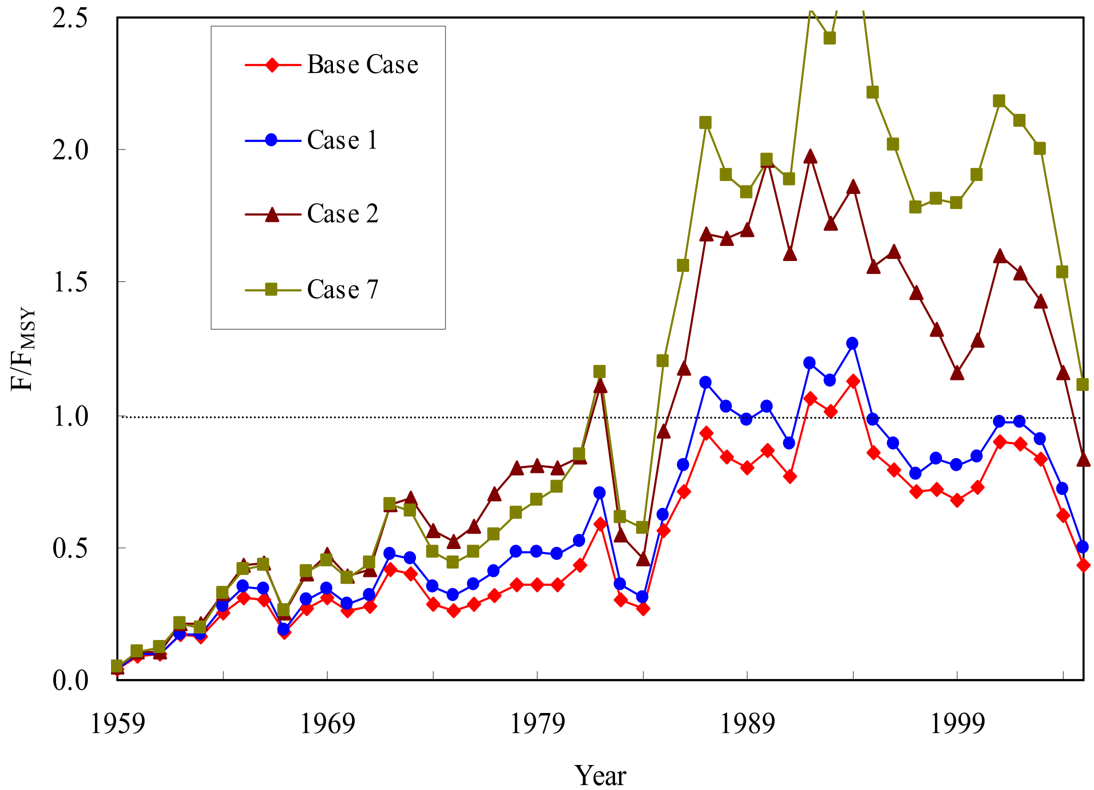

Figure 7. Estimated trajectories of the ratio of fishing mortality to that resulting in MSY for South Atlantic albacore obtained from the Base case, Case 1, Case 2 and Case 7 (defined in Table 2) fitting on ASPM.