STOCK ASSESSMENT FOR SOUTH ATLANTIC ALBACORE USING A NON-EQUILIBRIUM PRODUCTION MODEL

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SUMMARY

A Stock-Production Model Incorporating Covariates (ASPIC), a non-equilibrium surplus-production model, was attempted for the stock assessment for the southern Atlantic Ocean albacore, using the software package ASPIC ver. 5.34. The model configuration and fleet categorization are similar to those for 2013 stock assessment. Four models, which were selected for final models at 2013 assessment, were examined. In general, all the models predicted that at some stage in the recent past, the southern Albacore stock had been overfishing and had been overfished. In these cases, the fishing pressure appears to have eased in recent years, with a subsequent recovery in biomass. Based on the results of future projection, stock status will be in green zone with high probability (>90%) if future catch is 24,000 t or lower.

RÉSUMÉ

Un modèle stock-production incorporant des covariances (ASPIC), un modèle de production excédentaire en conditions de non-équilibre, a été testé pour l'évaluation du stock de germon de l'océan Atlantique Sud, en utilisant le logiciel ASPIC version 5.34. La configuration du modèle et la catégorisation des flottilles sont similaires à celles de l'évaluation du stock de 2013. Quatre modèles, qui ont été sélectionnés comme modèles finaux à l'évaluation de 2013, ont été examinés. En règle générale, tous les modèles ont prédit qu'à un moment donné dans le passé récent, le stock de germon du Sud avait fait l'objet de surpêche et avait été surexploité. Dans ces cas, la pression de la pêche semble s'être atténuée au cours de ces dernières années, la biomasse s'étant rétablie par la suite. Sur la base des résultats de projections futures, l'état du stock se situera dans la zone verte avec une forte probabilité (>90%) si la prise future s'élève à 24.000 t ou moins.

RESUMEN

Se probó un modelo de producción de stock que incorporaba covariables (ASPIC), un modelo de producción excedente en no equilibrio, para la evaluación de stock de atún blanco el océano Atlántico sur, utilizando un paquete ASPIC versión 5.34. La configuración del modelo y la categorización de las flotas fueron similares a las de la evaluación de stock de 2013. Se examinaron cuatro modelos seleccionados para modelos finales en la evaluación de 2013. En general, todos los modelos predijeron que en alguna etapa del pasado reciente, el stock de atún blanco del sur había sido objeto de sobrepesca y había estado sobrepescado. En estos casos, la presión pesquera parece haberse atenuado en años recientes, con la consiguiente recuperación de la biomasa. Basándose en los resultados de la proyección de futuro, el estado del stock se situará en la zona verde con una elevada probabilidad (>90%) si la captura futura se sitúa en 24.000 t o en una cifra inferior.

KEYWORDS

Stock assessment, mathematical model, yield predictions, albacore, catch/effort

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1. Introduction

At 2013 ICCAT albacore stock assessment meeting, stock assessment of south Atlantic albacore was held based on a Stock-Production Model Incorporating Covariates (ASPIC) (Matsumoto et al, 2014) and Bayesian Surplus Production (BSP) (Babcock, 2014) model because there are not enough size data for the south Atlantic and so age structured model was not used. At that time the results for both models, which were comparatively similar, were adopted for management advice. At 2015 ICCAT SCRS meeting, it was decided that ASPIC and BSP will again be used for stock assessment of south Atlantic albacore held in April-May 2016.

This paper provides preliminary stock assessment results based ASPIC model version 5.34 (Prager, 1992) applied to the albacore tuna stock in the southern Atlantic Ocean.

2. Model description and data input

2.1. Data

The model was fit to eight time series of catch (1956-2014) and four time series of CPUE (1959-2014) data covering 8 distinct fishing fleets. Fleet description (**Table 1**) is similar to that used for ASPIC model at 2011 (ICCAT, 2012) or 2013 (ICCAT, 2014) assessment, and several fisheries, which were not included in the data for previous assessment, were added. In 2011, eight CPUE series were used. However, at 2013 ICCAT Atlantic albacore data preparatory meeting, the working group decided not to use indices for Japanese longline transition period (1970-1975), Brazilian longline and South African baitboat (ICCAT, 2014). In this study the same CPUE series as those in 2013 were used for base case scenarios. Some other indices were used for sensitivity analysis. **Table 2** and **Figure 1** show catch by fleet and **Table 3** and **Figure** 2 show CPUE indices used for the models.

2.2. Structural assumptions of the model

Basically, the same models as those for 2011 or 2013 assessment were examined. Both logistic (Schaefer) and FOX shape were used to fit the data. B_1/K was fixed to 0.9 based on decision at 2011 stock assessment meeting (ICCAT, 2012), which was also applied at 2013 assessment. Thus four scenarios (**Table 4**) were examined.

2.3. Future projection

Software package ASPICP ver 3.16 was used for future projections. Based on bootstrapping (500 times) of above four scenarios, future projections were conducted. Projection period is 15 years (2016-2030). Constant future catch with 12,000 t to 34,000 t (at 2,000 t interval) or constant future F with $0.75*F_{2014}/F_{MSY}$ to $1.00*F_{2014}/F_{MSY}$ (at $0.05*F_{2014}/F_{MSY}$ interval) was assumed. Catch for 2015 and 2016 was assumed to be the same as 2014 level, which was applied also for constant F scenarios.

2.4. Sensitivity analysis

Several sensitivity and retrospective analyses were conducted for one scenario (Run08) of ASPIC model (**Table 5**). Sensitivity analyses include scenarios with different B1/K, scenarios which exclude one or more CPUE, and a scenario which excludes Japanese LL index for 2012-2014 considering increased targeting and start of TAC (Matsumoto, in press).

3. Result and discussion

Table 6 shows summary results of ASPIC runs. Estimation of MSY ranged 26 to 29 thousand tons, which was much higher than 2014 catch (14 thousand tons). Estimation of r (intrinsic growth rate) differed depending on scenarios.

Model fits to the indices of abundance are similar among scenarios, and **Figure 3** shows an example (Run 02). CPUE fit was good except for fleet 2 (Japanese longline target period). The level of fishing mortality differed depending on scenarios, but the trends are similar; it increased up until 2001, and then decreased (**Figure 4**). **Figure 5** shows trends of B-ratio (B/B_{MSY}) and F-ratio (F/F_{MSY}) for each scenario, and
Figure 6 shows Kobe I plot. It appears that the stock had been overfishing and overfished during the last 10-20 years, but is recovering in recent years and the stock is in a green zone.

Figure 7 and
Figure 8 show the trends of F-ratio and B-ratio, respectively, for the future projection. It was estimated that F exceeds and biomass drops under MSY level within 15 years if future catch is 30,000 t or larger.

Table 7 shows Kobe II matrixes (risk assessment) based on future projections of four scenarios. If future catch is 24,000 t or lower, the probability of being in the green zone of the Kobe plot is very high (>90%).

It seems that, in recent years, due to lower catch level (**Figure 1**), south Atlantic albacore stock is recovering, and will continue to recover if current catch level is continued.

Figure 10 shows the results of sensitivity and retrospective analyses. As for sensitivity analyses, B-ratio of initial period changed for different B_1/K. Large difference except for the early period was observed both for B-ratio and F-ratio if only Japanese longline CPUE for the recent period (1976-2014) was used. The model with South African baitboat CPUE did not converge. The results were very close to that in the base case as for the other scenarios. As for retrospective analysis, the results were close to that for the base case, but slight difference was observed in the recent years.

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Table 1. Fleet descriptions used in the ASPIC models for south Atlantic in this study.

Fleet	Fleet 1	Fleet 2 (1956 –1969) Fleet 3 (1970 –1975) Fleet 4 (1976 –2014)	Fleet 5	Fleet 6 (1956 –1998) Fleet 7 (1999 –2014)	Fleet 8
CPUE	Chinese Taipei (LL)	Japan (LL) None (1970-1975)	None	None	Uruguay (LL)
Catch	Chinese Taipei (LL) Korea (LL)	China LL EU-Spain (LL) EU-Portugal (LL) Japan (LL) Philippines (LL) St Vincent and Grenadier (LL) USA (LL) Vanuatu (LL) Honduras (LL) Nei (LL) Côte D'Ivoire (LL) EU-United Kingdom (LL) Seychelles (LL) UK.Sta Helena (LL) Angola (LL) Senegal (LL)	Brazil (LL, SU) Panama (LL) South Africa (LL, UN) Argentina (LL, TW, UN) Belize (LL) Cambodia (LL) Cuba (LL, UN) Namibia (LL)	Brazil (BB, GN, HL, PS, TW, UN) EU-Spain (PS) EU-France (BB, PS) EU-Portugal (BB, PS) Japan (BB, PS) Namibia (BB) Korea (BB) Maroc (PS) Panama (PS) South Africa (BB, HL, PS, RR, SP) USA (PS) USSR (SU) UK St Helena (BB, RR) Chinese Taipei (GN) Nei (BB, PS) Argentina (PS) Belize (PS) Cape Verde (PS) Curaçao (PS) Guatemala (PS) Côte D'Ivoire (PS) Ghana (BB, PS) Guinea Ecuatorial (UN, HL) Guinée Rep. (PS)	Uruguay (LL)

Table 2. Catches (t) of south Atlantic albacore for each fleet listed in **Table 1**.

Year	Fleet 1	Fleet 2	Fleet 3	Fleet 4	Fleet 5	Fleet 6	Fleet 7	Fleet 8	Total
1956		21							21
1957		725							725
1958		1,047							1,047
1959		3,015			1,700				4,715
1960		8,673			1,802				10,475
1961		8,893			1,872				10,765
1962		16,422			2,549				18,971
1963		15,104			2,281				17,385
1964	115	23,738			2,124	22			25,999
1965	346	28,309			1,190				29,845
1966	5,275	21,023			998				27,296
1967	7,412	7,719			752				15,883
1968	12,489	11,857			1,304	38			25,688
1969	21,732	6,331			430				28,493
1970	17,255		5,898		500				23,653
1971	21,323		3,218		344				24,885
1972	30,640		2,087		352	110			33,189
1973	25,888		277		1,969	100			28,234
1974	19,079		109		365	163			19,716
1975	16,614		306		536	151			17,607
1976	17,976			73	1,129	197			19,375
1977	19,858			105	1,162	330			21,455
1978	21,837			135	867	256			23,095
1979	21,218			105	666	651			22,640
1980	19,400			333	1,024	2,189			22,946
1981	18,869			558	996	3,594		23	24,040
1982	23,363			569	1,114	4,391		235	29,672
1983	10,101			162	1,360	2,922		373	14,918
1984	8,237			224	1,061	4,551		526	14,599
1985	20,154			623	517	8,272		1,531	31,097
1986	27,913			739	1,263	7,111		262	37,288
1987	29,173			357	1,733	9,189		178	40,630
1988	20,926			405	816	7,926		100	30,173
1989	18,440			450	788	7,450		83	27,212
1990	20,461			587	638	6,973		55	28,714
1991	19,914			804	1,333	3,930		34	26,016
1992	23,068			1,001	3,374	9,089		31	36,562
1993	19,420			748	3,753	8,863		28	32,813
1994	22,576			923	1,684	10,100		16	35,300
1995	18,354			695	941	7,513		49	27,552
1996	18,974			785	1,165	7,426		75	28,426
1997	18,169			673	769	8,354		56	28,022
1998	16,113			487	3,098	10,787		110	30,595
1999	17,391			1,560	1,651		6,965	90	27,656
2000	17,239			3,041	4,027		6,989	90	31,387
2001	15,834			5,235	6,834		10,757	135	38,796
2002	17,321			1,142	3,097		10,074	111	31,746
2003	17,356			534	2,641		7,364	108	28,002
2004	13,325			703	606		7,789	120	22,543
2005	10,772			1,446	727		5,905	32	18,882
2006	12,359			2,247	3,041		6,713	93	24,453
2007	13,202			1,313	538		5,195	34	20,283
2008	10,054			2,633	478		5,650	53	18,867
2009	9,052			2,470	493		10,152	97	22,265
2010	11,105			1,693	649		5,754	24	19,225
2011	13,103			1,888	1,417		7,684	37	24,129
2012	12,902			3,708	1,226		7,213	12	25,061
2013	8,553			4,136	966		5,399	209	19,263
2014	6,677			1,645	564		4,790		13,677

Table 3. Standardized CPUE series included in the ASPIC models for south Atlantic albacore.

Fleet	Fleet 1	Fleet 2	Fleet 3*	Fleet 4	Fleet 5	Fleet 6	Fleet 7*	Fleet 8
CPUE series flag	Chinese Taipei LL	Japan LL1	Japan LL2	Japan LL3	(None)	(None)	SA BB	Uruguay LL
1959		1.888						
1960		1.780						
1961		1.430						
1962		1.025						
1963		0.992						
1964		0.996						
1965		0.671						
1966		0.610						
1967	2.517	0.648						
1968	2.487	0.598						
1969	2.335	0.362						
1970	1.884		1.057					
1971	1.976		1.673					
1972	1.305		0.897					
1973	1.003		0.603					
1974	1.078		0.357					
1975	1.272		0.213					
1976	1.177			1.133				
1977	1.413			0.716				
1978	1.207			1.320				
1979	1.107			0.538				
1980	1.135			0.796				
1981	1.009			1.656				
1982	0.946			1.307				
1983	0.926			1.049				1.689
1984	1.156			1.072				1.459
1985	0.945			1.808				1.526
1986	0.928			2.126				1.509
1987	0.828			0.868				1.411
1988	0.614			0.613				1.467
1989	0.520			0.767				1.754
1990	0.558			1.050				1.148
1991	0.620			1.205				1.333
1992	0.674			0.665				0.884
1993	0.685			0.566				1.546
1994	0.886			0.824				0.690
1995	0.867			0.523				1.103
1996	0.918			0.570				1.511
1997	0.969			0.764				1.110
1998	0.885			0.750				1.532
1999	0.622			0.771				1.217
2000	0.548			1.298				0.970
2001	0.686			1.349				0.564
2002	0.550			0.847				0.455
2003	0.481			0.925			1.077	0.317
2004	0.635			0.979			0.753	0.229
2005	0.797			0.717			1.077	0.145
2006	0.635			0.392			1.002	0.561
2007	0.751			0.300			1.202	0.706
2008	0.780			0.624			0.919	0.531
2009	0.824			0.767			1.225	0.671
2010	0.900			0.951			1.038	0.589
2011	0.756			0.828			0.842	0.371
2012	0.788			2.118			0.677	
2013	0.849			3.552			1.012	
2014	0.567			0.477			1.175	

* Only for sensitivity analysis.

Table 4. Details of model runs presented in this paper.

Run No.	Weighting	B_1/K (fixed)	Model (shape parameter)
2	Equal for all fleets	0.9	Logistic
6	Equal for all fleets	0.9	Fox
7	Weighted by catch	0.9	Logistic
8	Weighted by catch	0.9	Fox

Table 5. Scenarios of sensitivity analyses for the ASPIC model runs for south Atlantic albacore.

Scenario	Abbreviation in the graph
B1/K fix at 0.8	B1/K 0.8
B1/K fix at 1.0	B1/K 1.0
Drop index of Japan LL3 for 2012-20014	no JPLL2012-14
Without index of Japan LL1 (1959-69)	no JPLL1
Only with Taiwanese LL index	only TWLL
Only with Taiwanese LL and JPN LL1 indices	only TWLL&JPLL1
Only with index of Japan LL3 (1975-2014)	only JPLL3
Without Uruguay LL index	no URG LL

Table 6. Results of the ASPIC model runs with those of 2013 assessment.

Results								2013 results				
Model run	MSY (t)	F_{MSY}	B_{MSY} (t)	B_{2015}/B_{MSY}	F_{2014}/F_{MSY}	K (t)	r	MSY (t)	F_{MSY}	B_{MSY} (t)	B_{2012}/B_{MSY}	F_{2011}/F_{MSY}
Run2	28,580	0.354	80,700	1.294	0.394	161,400	0.71	28,060	0.301	93,330	0.813	1.076
Run6	26,820	0.264	101,800	1.235	0.435	276,600	0.26	25,660	0.199	128,800	0.861	1.098
Run7	26,670	0.165	161,600	1.155	0.459	323,300	0.33	22,620	0.070	323,000	0.816	1.301
Run8	26,050	0.180	144,600	1.224	0.444	393,100	0.18	24,250	0.127	191,300	0.950	1.047

Table 7. Kobe II risk matrix for TB ratio and F-ratio (probability of not exceeding MSY level) based on ASPIC results for south Atlantic albacore

Run02 Probability B>BMSY

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12,000	70%	90%	94%	97%	97%	97%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
14,000	70%	90%	94%	96%	96%	96%	96%	97%	97%	97%	97%	97%	97%	97%	97%	97%
16,000	70%	90%	94%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
18,000	70%	90%	94%	94%	93%	93%	93%	93%	92%	92%	92%	92%	92%	92%	92%	92%
20,000	70%	90%	94%	92%	91%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
22,000	70%	90%	94%	91%	89%	88%	87%	86%	86%	86%	86%	86%	86%	86%	86%	86%
24,000	70%	90%	94%	89%	87%	84%	82%	81%	80%	79%	78%	78%	78%	78%	77%	77%
26,000	70%	90%	94%	88%	83%	78%	75%	73%	72%	72%	70%	69%	68%	68%	67%	66%
28,000	70%	90%	94%	87%	78%	73%	68%	63%	60%	58%	56%	54%	54%	53%	52%	51%
30,000	70%	90%	94%	85%	73%	65%	58%	54%	50%	44%	40%	37%	33%	30%	26%	24%
32,000	70%	90%	94%	82%	68%	57%	50%	40%	34%	27%	22%	17%	11%	7%	4%	2%
34,000	70%	90%	94%	79%	61%	51%	38%	28%	20%	12%	7%	4%	2%	1%	1%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0.75*FMSY	70%	90%	94%	84%	73%	68%	64%	63%	61%	60%	60%	60%	59%	59%	59%	59%
0.80*FMSY	70%	90%	94%	81%	70%	62%	58%	55%	54%	52%	51%	50%	50%	49%	49%	49%
0.85*FMSY	70%	90%	94%	79%	64%	56%	51%	46%	43%	42%	41%	41%	40%	39%	39%	39%
0.90*FMSY	70%	90%	94%	75%	59%	50%	43%	39%	37%	35%	33%	31%	30%	30%	29%	29%
0.95*FMSY	70%	90%	94%	71%	55%	44%	37%	32%	28%	25%	24%	22%	21%	21%	19%	19%
1.00*FMSY	70%	90%	94%	70%	51%	38%	31%	25%	20%	18%	16%	14%	13%	12%	12%	12%

Run02 Probability F<FMSY

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
22,000	100%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
24,000	100%	100%	99%	98%	97%	97%	96%	96%	95%	95%	95%	95%	95%	95%	95%
26,000	100%	100%	97%	93%	90%	88%	86%	85%	83%	83%	82%	81%	81%	80%	80%
28,000	100%	100%	90%	83%	75%	71%	65%	62%	60%	57%	56%	54%	54%	53%	52%
30,000	100%	100%	81%	67%	56%	51%	44%	39%	34%	31%	27%	25%	22%	19%	17%
32,000	100%	100%	66%	51%	39%	30%	24%	19%	15%	9%	6%	4%	3%	2%	1%
34,000	100%	100%	51%	33%	23%	16%	9%	5%	4%	2%	1%	1%	1%	0%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	100%	100%	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%	72%
0.80*FMSY	100%	100%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%	58%
0.85*FMSY	100%	100%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%
0.90*FMSY	100%	100%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
0.95*FMSY	100%	100%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
1.00*FMSY	100%	100%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%

Run02 Probability green zone of Kobe plot

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	70%	90%	94%	97%	97%	97%	98%	98%	98%	98%	98%	98%	98%	98%	98%
14,000	70%	90%	94%	96%	96%	96%	96%	97%	97%	97%	97%	97%	97%	97%	97%
16,000	70%	90%	94%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
18,000	70%	90%	94%	94%	93%	93%	93%	93%	92%	92%	92%	92%	92%	92%	92%
20,000	70%	90%	94%	92%	91%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
22,000	70%	90%	94%	91%	89%	88%	87%	86%	86%	86%	86%	86%	86%	86%	86%
24,000	70%	90%	94%	89%	87%	84%	82%	81%	80%	79%	78%	78%	78%	78%	77%
26,000	70%	90%	94%	88%	83%	78%	75%	73%	72%	72%	70%	69%	68%	68%	67%
28,000	70%	90%	90%	83%	75%	71%	65%	62%	60%	57%	56%	54%	54%	53%	52%
30,000	70%	90%	81%	67%	56%	51%	44%	39%	34%	31%	27%	25%	22%	19%	17%
32,000	70%	90%	66%	51%	39%	30%	24%	19%	15%	9%	6%	4%	3%	2%	1%
34,000	70%	90%	51%	33%	23%	16%	9%	5%	4%	2%	1%	1%	1%	0%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	70%	90%	72%	71%	68%	65%	63%	61%	60%	60%	60%	59%	59%	59%	59%
0.80*FMSY	70%	90%	58%	58%	57%	56%	54%	52%	51%	51%	50%	50%	49%	49%	49%
0.85*FMSY	70%	90%	42%	42%	41%	41%	41%	40%	40%	40%	40%	40%	40%	39%	39%
0.90*FMSY	70%	90%	30%	30%	30%	30%	30%	30%	30%	30%	30%	29%	29%	29%	29%
0.95*FMSY	70%	90%	20%	20%	20%	20%	20%	20%	20%	20%	19%	19%	19%	19%	18%
1.00*FMSY	70%	90%	13%	13%	13%	13%	13%	13%	13%	13%	13%	12%	12%	12%	11%

Table 7. Kobe II risk matrix for TB ratio and F-ratio (probability of not exceeding MSY level) based on ASPIC results for south Atlantic albacore (continued).

Run06 Probability $B>B_{MSY}$

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
22,000	95%	99%	100%	100%	99%	99%	100%	100%	100%	99%	99%	99%	99%	99%	99%	99%
24,000	95%	99%	100%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	96%	96%	96%
26,000	95%	99%	100%	99%	99%	98%	97%	96%	95%	94%	93%	92%	90%	88%	86%	84%
28,000	95%	99%	100%	99%	99%	96%	94%	92%	87%	81%	75%	67%	59%	51%	41%	34%
30,000	95%	99%	100%	99%	97%	94%	88%	79%	67%	56%	41%	32%	24%	18%	12%	9%
32,000	95%	99%	100%	99%	96%	89%	75%	60%	41%	29%	19%	13%	8%	6%	3%	2%
34,000	95%	99%	100%	99%	94%	81%	60%	39%	25%	15%	9%	6%	3%	1%	1%	1%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0.75*FMSY	95%	99%	100%	99%	99%	99%	98%	97%	97%	97%	96%	96%	96%	96%	96%	96%
0.80*FMSY	95%	99%	100%	99%	99%	97%	96%	95%	95%	94%	94%	94%	93%	93%	93%	93%
0.85*FMSY	95%	99%	100%	99%	98%	95%	94%	92%	91%	90%	88%	88%	87%	87%	87%	87%
0.90*FMSY	95%	99%	100%	99%	96%	94%	90%	88%	85%	82%	78%	77%	77%	76%	76%	75%
0.95*FMSY	95%	99%	100%	99%	95%	91%	86%	79%	75%	73%	70%	68%	67%	66%	64%	64%
1.00*FMSY	95%	99%	100%	98%	94%	87%	77%	72%	67%	63%	59%	56%	53%	51%	50%	49%

Run06 Probability $F<F_{MSY}$

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
22,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
24,000	100%	100%	100%	100%	99%	99%	99%	99%	99%	98%	98%	98%	98%	98%	98%
26,000	100%	100%	99%	99%	97%	96%	94%	93%	91%	89%	88%	84%	80%	78%	75%
28,000	100%	100%	97%	94%	89%	83%	75%	66%	58%	52%	43%	34%	29%	25%	20%
30,000	100%	100%	92%	82%	67%	55%	43%	31%	25%	18%	14%	9%	7%	6%	4%
32,000	100%	100%	79%	59%	42%	29%	20%	14%	9%	6%	5%	2%	1%	1%	1%
34,000	100%	100%	60%	38%	25%	15%	9%	6%	4%	1%	1%	1%	1%	0%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	100%	100%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
0.80*FMSY	100%	100%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
0.85*FMSY	100%	100%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%
0.90*FMSY	100%	100%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%
0.95*FMSY	100%	100%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%
1.00*FMSY	100%	100%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%

Run06 Probability green zone of Kobe plot

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20,000	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
22,000	95%	99%	100%	100%	99%	99%	100%	100%	100%	99%	99%	99%	99%	99%	99%
24,000	95%	99%	100%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	96%	96%
26,000	95%	99%	99%	99%	97%	96%	94%	93%	91%	89%	88%	84%	80%	78%	75%
28,000	95%	99%	97%	94%	89%	83%	75%	66%	58%	52%	43%	34%	29%	25%	20%
30,000	95%	99%	92%	82%	67%	55%	43%	31%	25%	18%	14%	9%	7%	6%	4%
32,000	95%	99%	79%	59%	42%	29%	20%	14%	9%	6%	5%	2%	1%	1%	1%
34,000	95%	99%	60%	38%	25%	15%	9%	6%	4%	1%	1%	1%	1%	0%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	95%	99%	98%	98%	98%	98%	97%	97%	97%	97%	96%	96%	96%	96%	96%
0.80*FMSY	95%	99%	95%	95%	95%	94%	94%	94%	94%	94%	93%	93%	93%	93%	93%
0.85*FMSY	95%	99%	88%	88%	88%	88%	87%	87%	87%	87%	86%	86%	86%	86%	86%
0.90*FMSY	95%	99%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%
0.95*FMSY	95%	99%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%
1.00*FMSY	95%	99%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%	47%	46%

Table 7. Kobe II risk matrix for TB ratio and F-ratio (probability of not exceeding MSY level) based on ASPIC results for south Atlantic albacore (continued).

Run07 Probability B>BMSY

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	90%	95%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	100%	100%	100%	100%	100%	100%	100%
20,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
22,000	90%	95%	99%	99%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%	97%
24,000	90%	95%	99%	99%	98%	96%	95%	95%	95%	94%	94%	93%	93%	93%	92%	92%
26,000	90%	95%	99%	98%	96%	95%	93%	92%	91%	90%	89%	88%	87%	85%	83%	82%
28,000	90%	95%	99%	97%	94%	92%	90%	88%	85%	82%	77%	72%	66%	60%	52%	42%
30,000	90%	95%	99%	96%	93%	90%	87%	79%	73%	63%	51%	37%	27%	19%	12%	10%
32,000	90%	95%	99%	95%	91%	87%	78%	66%	51%	33%	21%	14%	9%	7%	4%	4%
34,000	90%	95%	99%	94%	90%	81%	67%	46%	27%	16%	10%	7%	4%	3%	1%	1%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0.75*FMSY	90%	95%	99%	98%	98%	96%	96%	95%	95%	95%	95%	95%	95%	95%	95%	95%
0.80*FMSY	90%	95%	99%	98%	96%	95%	94%	93%	93%	93%	93%	93%	93%	93%	93%	93%
0.85*FMSY	90%	95%	99%	97%	95%	93%	93%	92%	91%	91%	90%	90%	90%	90%	90%	90%
0.90*FMSY	90%	95%	99%	96%	94%	93%	91%	90%	90%	88%	87%	86%	86%	86%	85%	84%
0.95*FMSY	90%	95%	99%	95%	93%	91%	90%	87%	85%	83%	81%	80%	78%	77%	76%	75%
1.00*FMSY	90%	95%	99%	95%	92%	90%	86%	82%	79%	76%	73%	70%	68%	66%	64%	63%

Run07 Probability F<FMSY

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
22,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
24,000	100%	100%	99%	99%	99%	99%	97%	97%	96%	95%	95%	95%	94%	94%	94%
26,000	100%	100%	95%	93%	92%	90%	89%	88%	85%	83%	81%	79%	77%	74%	72%
28,000	100%	100%	89%	84%	78%	72%	66%	59%	49%	39%	32%	25%	20%	18%	15%
30,000	100%	100%	75%	63%	48%	34%	24%	19%	15%	12%	9%	7%	5%	4%	3%
32,000	100%	100%	49%	30%	19%	15%	11%	8%	5%	4%	3%	2%	1%	1%	1%
34,000	100%	100%	24%	15%	12%	7%	4%	4%	2%	1%	1%	1%	1%	1%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	100%	100%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
0.80*FMSY	100%	100%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
0.85*FMSY	100%	100%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%
0.90*FMSY	100%	100%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%
0.95*FMSY	100%	100%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
1.00*FMSY	100%	100%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%

Run07 Probability green zone of Kobe plot

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	90%	95%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	100%	100%	100%	100%	100%	100%
20,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
22,000	90%	95%	99%	99%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%
24,000	90%	95%	99%	99%	98%	96%	95%	95%	95%	94%	94%	93%	93%	93%	92%
26,000	90%	95%	95%	93%	92%	90%	89%	88%	85%	83%	81%	79%	77%	74%	72%
28,000	90%	95%	89%	84%	78%	72%	66%	59%	49%	39%	32%	25%	20%	18%	15%
30,000	90%	95%	75%	63%	48%	34%	24%	19%	15%	12%	9%	7%	5%	4%	3%
32,000	90%	95%	49%	30%	19%	15%	11%	8%	5%	4%	3%	2%	1%	1%	1%
34,000	90%	95%	24%	15%	12%	7%	4%	4%	2%	1%	1%	1%	1%	1%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	90%	95%	98%	98%	98%	96%	96%	95%	95%	95%	95%	95%	95%	95%	95%
0.80*FMSY	90%	95%	95%	95%	95%	94%	94%	93%	93%	93%	93%	93%	93%	93%	93%
0.85*FMSY	90%	95%	91%	91%	91%	91%	91%	91%	91%	90%	90%	90%	90%	90%	90%
0.90*FMSY	90%	95%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%
0.95*FMSY	90%	95%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
1.00*FMSY	90%	95%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%

Table 7. Kobe II risk matrix for TB ratio and F-ratio (probability of not exceeding MSY level) based on ASPIC results for south Atlantic albacore (continued).

Run08 Probability $B>B_{MSY}$

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
12,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	90%	95%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	100%	100%	100%	100%	100%	100%	100%
20,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
22,000	90%	95%	99%	99%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%	97%
24,000	90%	95%	99%	99%	98%	96%	95%	95%	95%	94%	94%	93%	93%	93%	92%	92%
26,000	90%	95%	99%	98%	96%	95%	93%	92%	91%	90%	89%	88%	87%	85%	83%	82%
28,000	90%	95%	99%	97%	94%	92%	90%	88%	85%	82%	77%	72%	66%	60%	52%	42%
30,000	90%	95%	99%	96%	93%	90%	87%	79%	73%	63%	51%	37%	27%	19%	12%	10%
32,000	90%	95%	99%	95%	91%	87%	78%	66%	51%	33%	21%	14%	9%	7%	4%	4%
34,000	90%	95%	99%	94%	90%	81%	67%	46%	27%	16%	10%	7%	4%	3%	1%	1%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0.75*FMSY	90%	95%	99%	98%	98%	96%	96%	95%	95%	95%	95%	95%	95%	95%	95%	95%
0.80*FMSY	90%	95%	99%	98%	96%	95%	94%	93%	93%	93%	93%	93%	93%	93%	93%	93%
0.85*FMSY	90%	95%	99%	97%	95%	93%	93%	92%	91%	91%	90%	90%	90%	90%	90%	90%
0.90*FMSY	90%	95%	99%	96%	94%	93%	91%	90%	90%	88%	87%	86%	86%	86%	85%	84%
0.95*FMSY	90%	95%	99%	95%	93%	91%	90%	87%	85%	83%	81%	80%	78%	77%	76%	75%
1.00*FMSY	90%	95%	99%	95%	92%	90%	86%	82%	79%	76%	73%	70%	68%	66%	64%	63%

Run08 Probability $F<F_{MSY}$

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
22,000	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
24,000	100%	100%	99%	99%	99%	99%	97%	97%	96%	95%	95%	95%	94%	94%	94%
26,000	100%	100%	95%	93%	92%	90%	89%	88%	85%	83%	81%	79%	77%	74%	72%
28,000	100%	100%	89%	84%	78%	72%	66%	59%	49%	39%	32%	25%	20%	18%	15%
30,000	100%	100%	75%	63%	48%	34%	24%	19%	15%	12%	9%	7%	5%	4%	3%
32,000	100%	100%	49%	30%	19%	15%	11%	8%	5%	4%	3%	2%	1%	1%	1%
34,000	100%	100%	24%	15%	12%	7%	4%	4%	2%	1%	1%	1%	1%	1%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	100%	100%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%	98%
0.80*FMSY	100%	100%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
0.85*FMSY	100%	100%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%	91%
0.90*FMSY	100%	100%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%
0.95*FMSY	100%	100%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
1.00*FMSY	100%	100%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%

Run08 Probability green zone of Kobe plot

Catch (t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
12,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
14,000	90%	95%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
16,000	90%	95%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
18,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	100%	100%	100%	100%	100%	100%
20,000	90%	95%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
22,000	90%	95%	99%	99%	99%	99%	99%	99%	98%	98%	98%	98%	97%	97%	97%
24,000	90%	95%	99%	99%	98%	96%	95%	95%	95%	94%	94%	93%	93%	93%	92%
26,000	90%	95%	95%	93%	92%	90%	89%	88%	85%	83%	81%	79%	77%	74%	72%
28,000	90%	95%	89%	84%	78%	72%	66%	59%	49%	39%	32%	25%	20%	18%	15%
30,000	90%	95%	75%	63%	48%	34%	24%	19%	15%	12%	9%	7%	5%	4%	3%
32,000	90%	95%	49%	30%	19%	15%	11%	8%	5%	4%	3%	2%	1%	1%	1%
34,000	90%	95%	24%	15%	12%	7%	4%	4%	2%	1%	1%	1%	1%	1%	0%

F	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
0.75*FMSY	90%	95%	98%	98%	98%	96%	96%	95%	95%	95%	95%	95%	95%	95%	95%
0.80*FMSY	90%	95%	95%	95%	95%	94%	94%	93%	93%	93%	93%	93%	93%	93%	93%
0.85*FMSY	90%	95%	91%	91%	91%	91%	91%	91%	91%	90%	90%	90%	90%	90%	90%
0.90*FMSY	90%	95%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%
0.95*FMSY	90%	95%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
1.00*FMSY	90%	95%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%

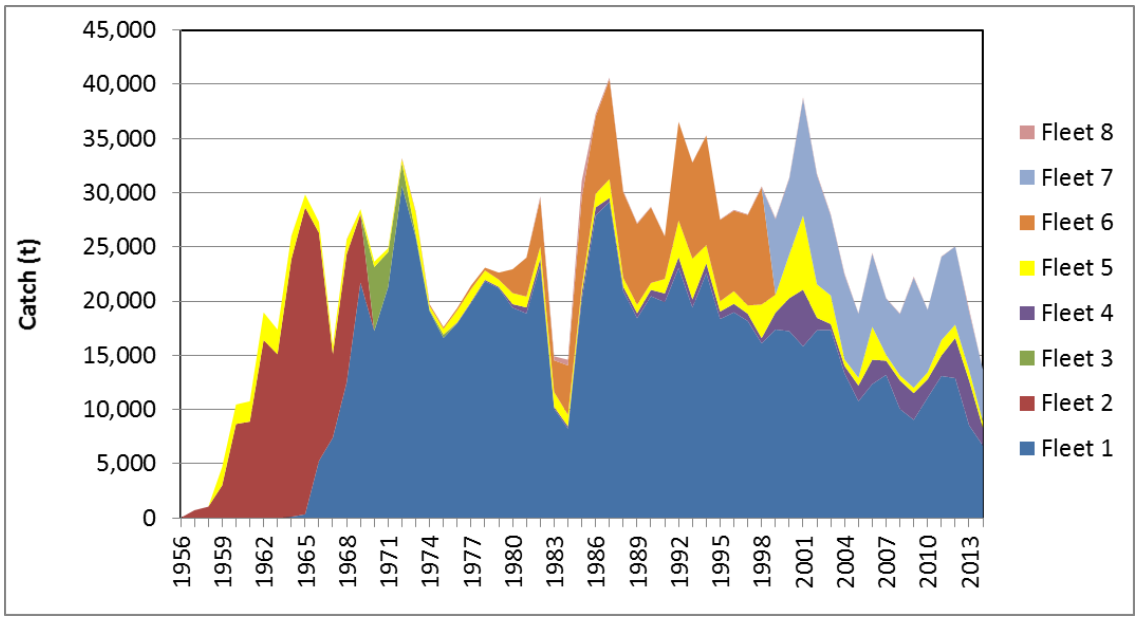

Figure 1. Annual trend of catch amount by fleet for ASPIC models for the south Atlantic.

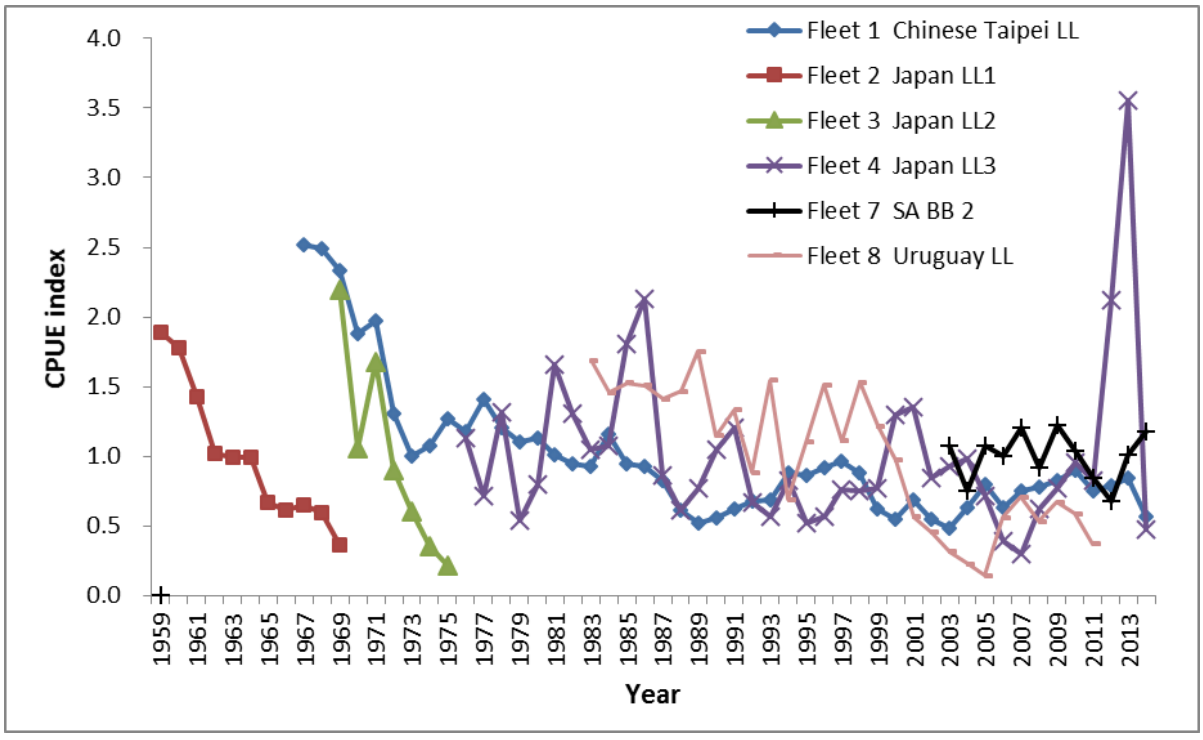

Figure 2. Annual trend of standardized CPUE included in the ASPIC models for the south Atlantic.

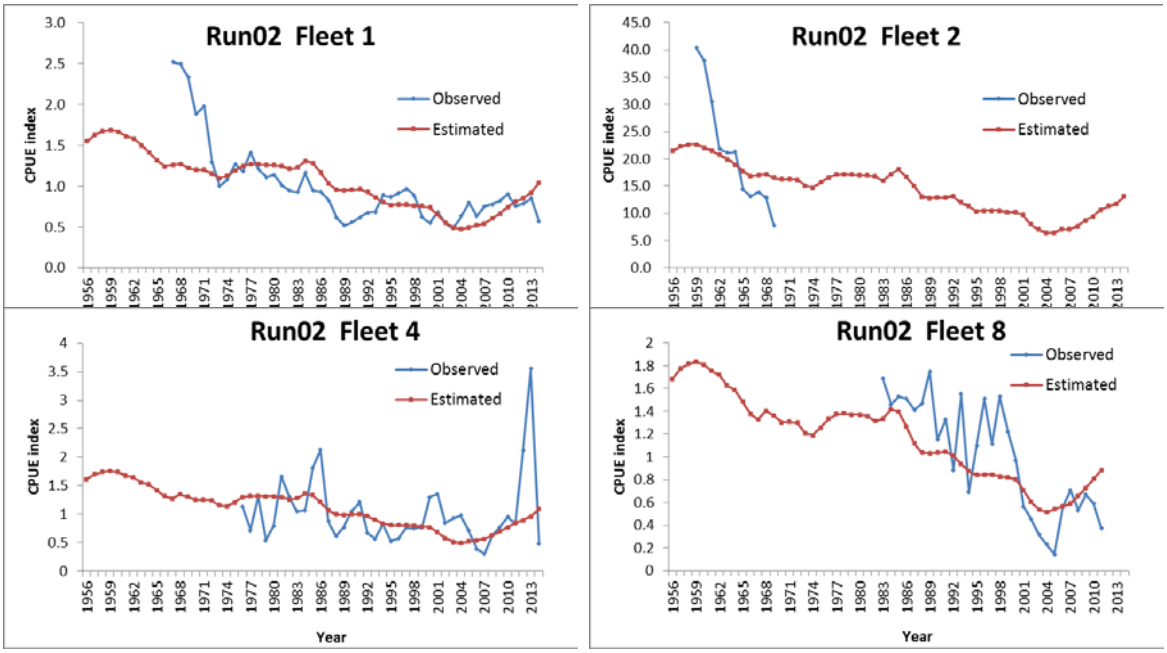

Figure 3. CPUE fit for ASPIC Run02.

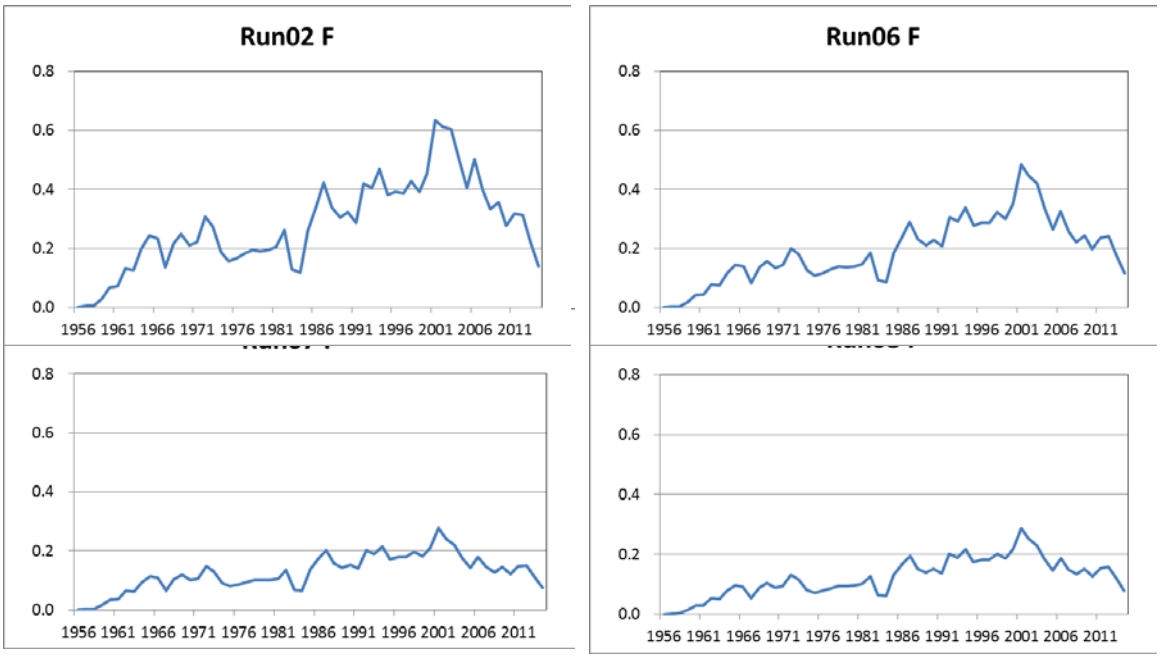

Figure 4. Trajectories of fishing mortality for 4 ASPIC runs.

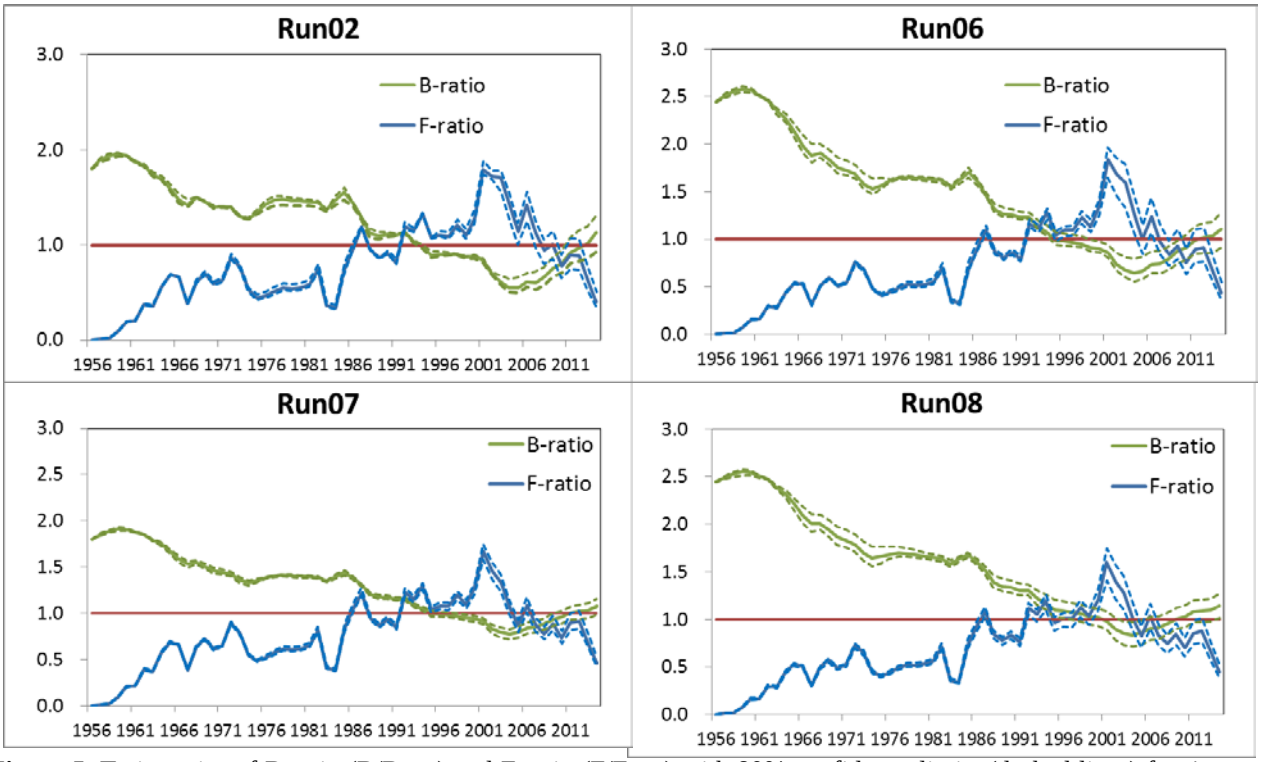

Figure 5. Trajectories of B-ratio (B/B_{MSY}) and F-ratio (F/F_{MSY}) with 80% confidence limits (dashed lines) for 4 ASPIC runs.

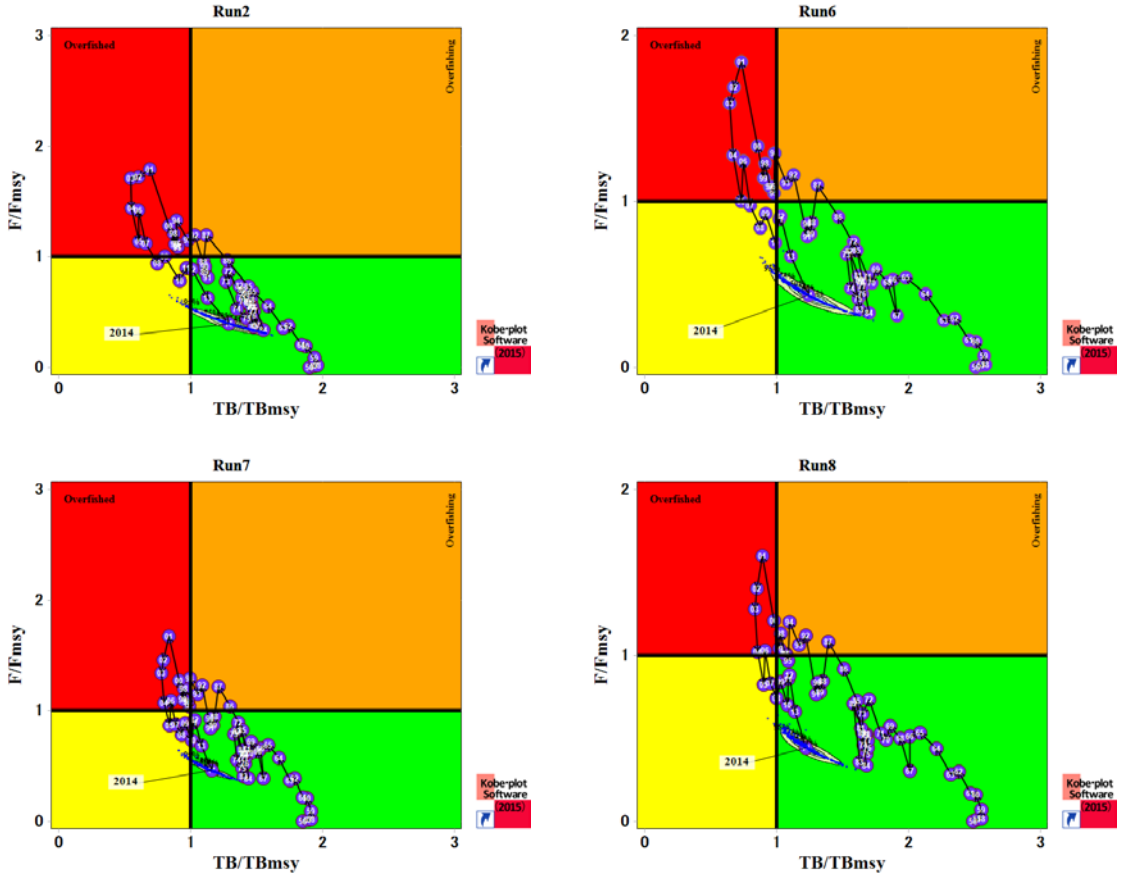

Figure 6. Kobe I plot for 4 ASPIC runs.

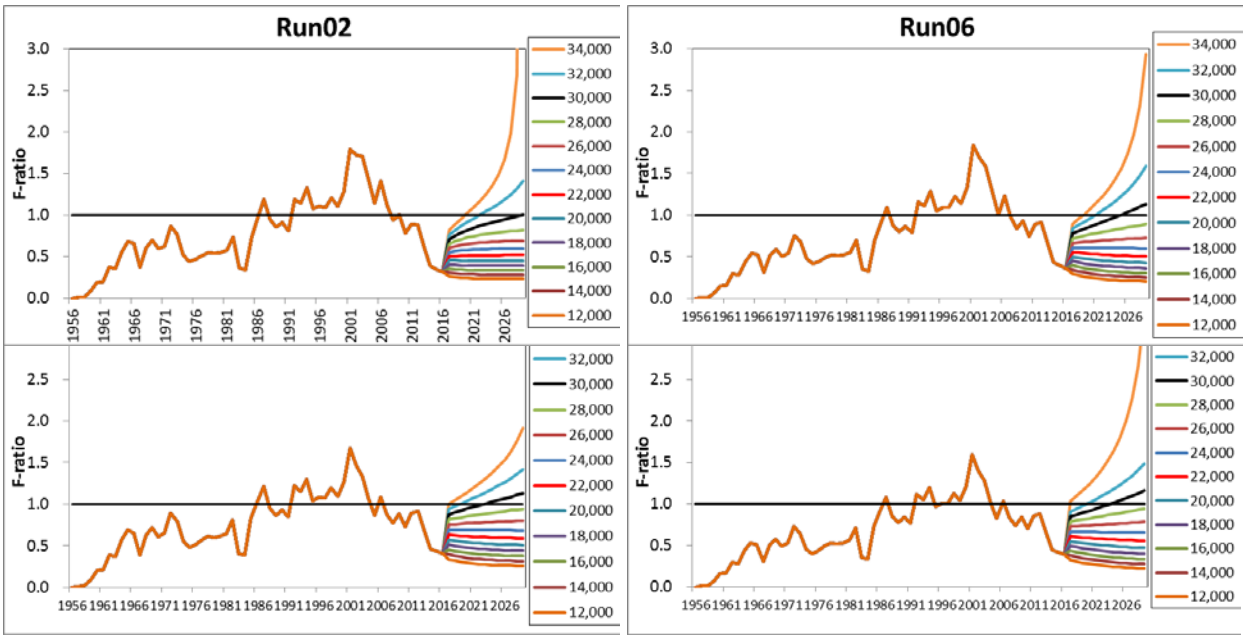

Figure 7. Future projection of F-ratio (F/F_{MSY}) for 4 ASPIC runs under constant catch.

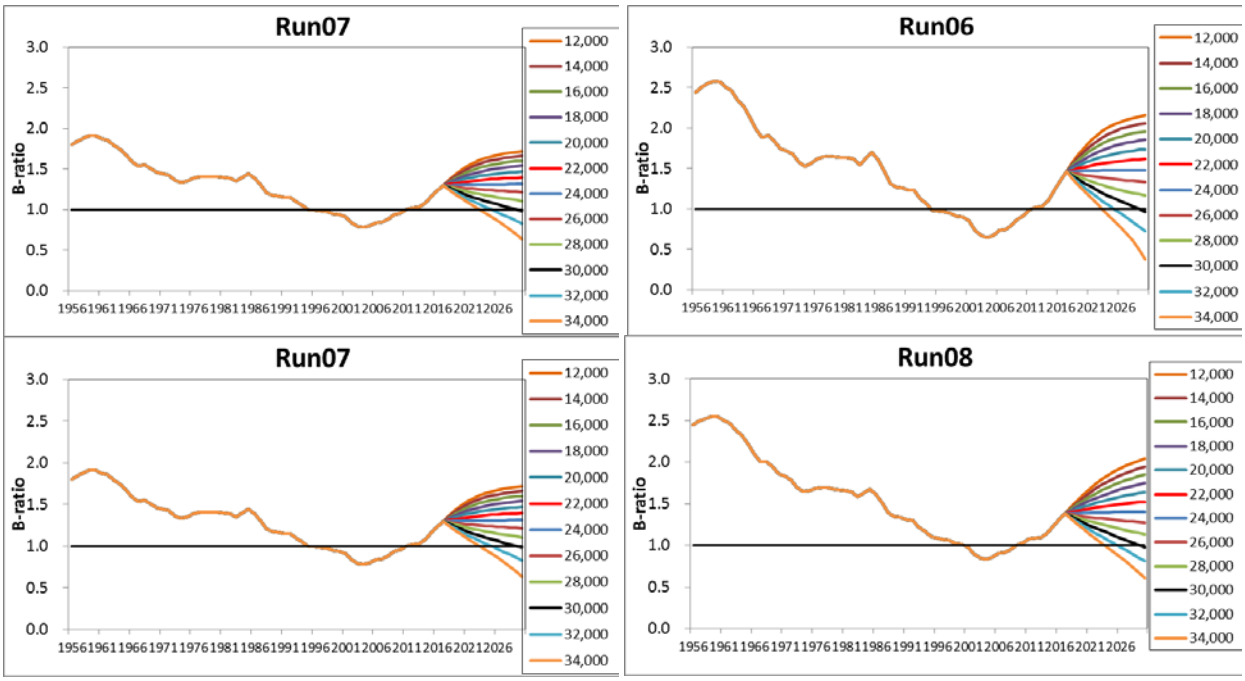

Figure 8. Future projection of B-ratio (B/B_{MSY}) for 4 ASPIC runs under constant catch.

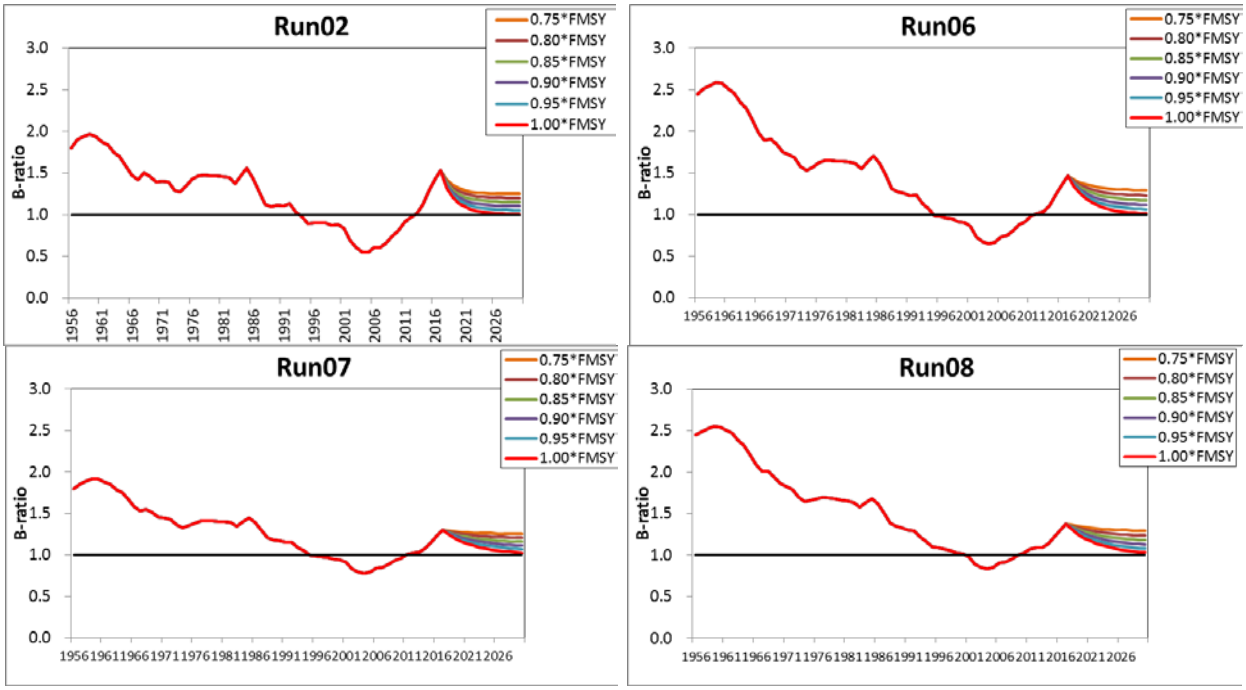

Figure 9. Future projection of B-ratio (B/B_{MSY}) for 4 ASPIC runs under constant F.

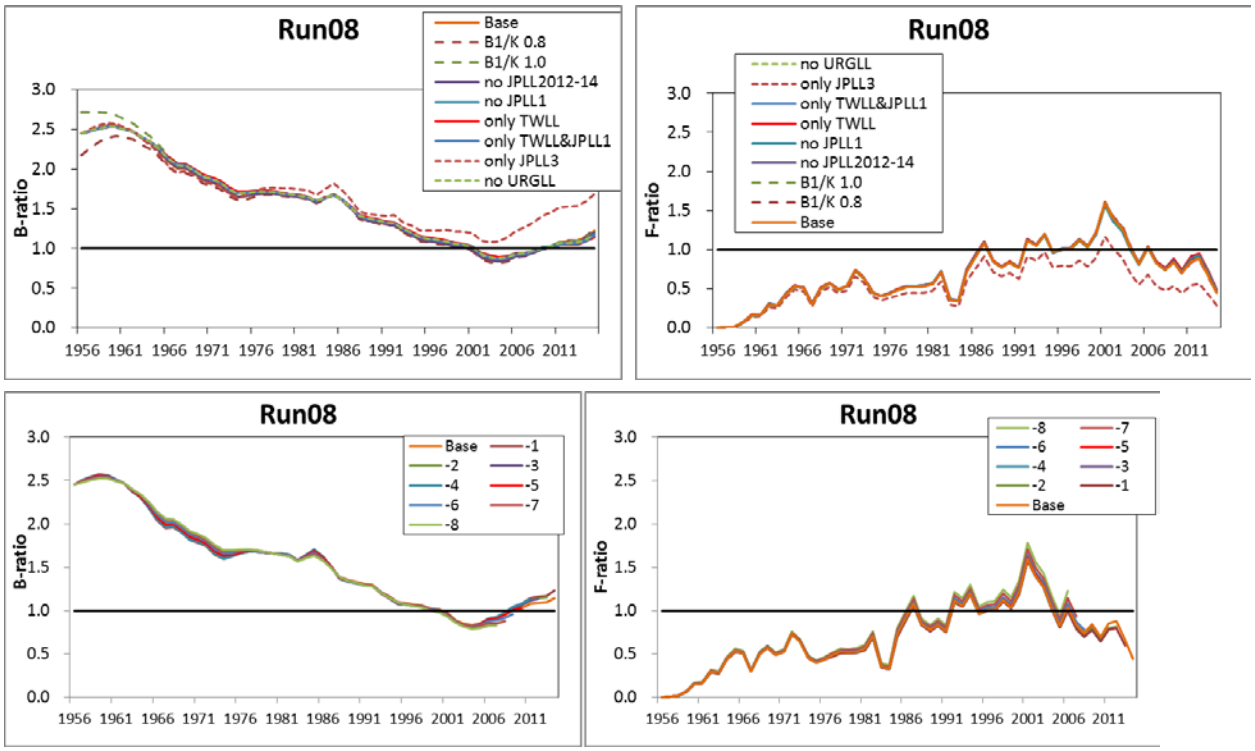

Figure 10. Results of sensitivity (upper) and retrospective (lower) analyses for ASPIC Run08 for south Atlantic albacore.