PRELIMINARY ANALYSIS FOR THE SOUTH ATLANTIC ALBACORE STOCK 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, using the software package ASPIC ver. 5.34. The model configuration and fleet categorization are similar to those for 2011 stock assessment. Several CPUE indices used for the last assessment were not used based on decision at 2013 albacore data preparatory meeting. Four models, which were selected for final models at 2011 assessment, were examined. In general, all the models except for one 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, both fishing mortality and total biomass will recover to MSY level if future catch is same as or slightly (<10%) higher than current (2011) level.

RÉSUMÉ

Un modèle stock-production incorporant des covariances (ASPIC), un modèle de production excédentaire en conditions de non-équilibre, a été tenté pour l'évaluation du stock de germon de l'océan Atlantique Sud, en utilisant le logiciel ASPIC ver 5.34. La configuration du modèle et la catégorisation des flottilles sont similaires à celles de l'évaluation du stock de 2011. Plusieurs indices de CPUE utilisés dans la dernière évaluation n'ont pas été utilisés conformément à la décision prise lors de la réunion de préparation des données sur le germon de 2013. Quatre modèles, qui ont été sélectionnés comme modèles finaux à l'évaluation de 2011, ont été examinés. En règle générale, tous les modèles, sauf un, 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 futures projections, la mortalité par pêche et la biomasse totale se rétabliront au niveau de la PME si les prises futures sont similaires ou légèrement supérieures (<10%) au niveau actuel (2011).

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 para 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 2011. Varios de los índices de CPUE utilizados en la última evaluación no se utilizaron basándose en las decisiones tomadas durante la Reunión de preparación de datos de atún blanco de 2013. Se examinaron cuatro modelos seleccionados para modelos finales en la evaluación de 2011. En general, todos los modelos, excepto uno, 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 proyecciones futuras, la mortalidad por pesca y la biomasa total se recuperarán hasta el nivel de RMS si la captura futura se sitúa en el mismo nivel o en un nivel ligeramente superior (<10%) que el nivel actual (2011).

KEYWORDS

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

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1 Introduction

At 2011 ICCAT albacore stock assessment meeting, stock assessment of south Atlantic albacore was held based on a Stock-Production Model Incorporating Covariates (ASPIC) and Bayesian Surplus Production (BSP) model. At that time the results of ASPIC analyses indicated that in many cases the stock was in the "red" zone of Kobe plot, and current catch was below MSY level. At 2013 ICCAT Atlantic albacore data preparatory meeting, the working group decided to use ASPIC and BSP for stock assessment of south Atlantic albacore held in June 2013. At that time the group also discussed which CPUE indices to use.

This paper provides preliminary results for 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 (1956-2011) and four time series of CPUE (1959-2011) data covering 8 distinct fishing fleets. Fleet description (

Table 1) is similar to that used for ASPIC model at 2011 assessment (ICCAT 2012), and several fisheries, which were not included in the data for 2011 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. **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 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). Thus four scenarios (**Table 4**) were examined.

2.3. Future projection

Based on bootstrapping (500 times) of above four scenarios, future projections were conducted. Projection period is 10 years (2012-2021). Constant future catch with -40% to +40% (at 10% interval) of 2011 level (24,122 t) was assumed (**Table 5**). Catch for 2012 was assumed to be the same as 2011 level.

3 Result and discussion

Table 6 shows summary results of ASPIC runs. Estimation of MSY ranged 20 to 28 thousand tons, which was more or less 2011 catch (24 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. In the case of Run 02, 06 and 08, it appears that the stock had been overfishing and overfished during the last 10-20 years, but is recovering in recent year especially as for B-ratio, which has become almost MSY level. The results of Run 07 are much more pessimistic and the stock is not recovering in recent years. Confidence surface of the current level for Run 07 in the Kobe I plot seems strange.

Figure 7 and **Figure 8** show the trends of B-ratio and F-ratio, respectively, for the future projection. As for Run 02, both B-ratio and F-ratio were estimated to be almost MSY level in 2021 with 10% increase of current catch. As for Runs 06 and 08, both B-ratio and F-ratio were estimated to be almost MSY level if current catch level will be continued.

Table 7 and **Table 8** show Kobe II matrixes (risk assessment) based on future projections of four scenarios. As for both biomass and F, the risk of exceeding MSY level become higher if future catch is higher than 2011 level except for Run 07, which is much more pessimistic.

It seems that, in recent years, due to lower catch level (**Figure 1**), south Atlantic albacore stock shows sign of recovery, and will continue to recover if current catch level is continued. The results for Runs 02, 06 and 08 are comparatively similar, but Run 08 and Runs 02 and 06 are more optimistic as for biomass and F, respectively.

Of the four runs examined, the results of Run 07 seem to be not reasonable because fishing mortality and r are a bit too low and confidence surface of Kobe I plot appears strange. Therefore, Runs 02, 06 and 08, which have similar results, will be potential base cases.

References

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

Fleet	Fleet 1	Fleet 2 (1956 –1969) Fleet 3 (1970 –1975) Fleet 4 (1976 –2011)	Fleet 5	Fleet 6 (1956 –1998) Fleet 7 (1999 –2011)	Fleet 8
CPUE	Chinese Taipei (LL)	Japan (LL) None (1970-1975)	None	None	Uruguay (LL)
Catch	Chinese Taipei (LL) Korea (LL)	China (LL) E. C. Spain (LL) E. C. Portugal (LL) Japan (LL) Philippines (LL) St Vincent and Grenadier (LL) USA (LL) USSR (LL) Vanuatu (LL) Honduras (LL) Nei (LL) Côte D'Ivoire (LL) EU.United Kingdom (LL) Seychelles (LL) UK.Sta Helena (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, UN) E. C. Spain (PS) E. C. France (PS) E. C. Portugal (BB, PS) Japan (BB, PS) Namibia (BB) Korea (BB) Maroc (PS) Panama (PS) South Africa (BB, HL, PS, RR, SP) USA (PS) USSR (PS, SU) UK St Helena (BB, RR) Chinese Taipei (GN) Nei (PS) Netherlands (PS) Argentina (PS) Belize (PS) Cape Verde (PS) Curaçao (PS) Guatemala (PS)	Uruguay (LL)

Table 2. Catches (t) for each fleet listed in **Table 1**.

Year	*Fleet 1*	*Fleet 2*	*Fleet 3*	*Fleet 4*	*Fleet 5*	*Fleet 6*	*Fleet 7*	*Fleet 8*
1956		21						
1957		725						
1958		1,047						
1959		3,015			1,700			
1960		8,673			1,802			
1961		8,893			1,872			
1962		16,422			2,549			
1963		15,104			2,281			
1964	115	23,738			2,124	22		
1965	346	28,309			1,190			
1966	5,275	21,023			998			
1967	7,412	7,719			752			
1968	12,489	11,857			1,304	38		
1969	21,732	6,331			430			
1970	17,255		5,898		500			
1971	21,323		3,218		344			
1972	30,640		2,087		352	110		
1973	25,888		277		1,969	100		
1974	19,079		109		365	163		
1975	16,614		306		536	151		
1976	17,976			73	1,129	197		
1977	19,858			105	1,162	330		
1978	21,837			135	867	256		
1979	21,218			105	666	651		
1980	19,400			333	1,024	2,189		
1981	18,869			558	996	3,594		23
1982	23,363			569	1,114	4,391		235
1983	10,101			162	1,360	2,922		373
1984	8,237			224	1,061	4,551		526
1985	20,154			623	517	8,272		1,531
1986	27,913			739	1,263	7,111		262
1987	29,173			357	1,733	9,189		178
1988	20,926			405	816	7,926		100
1989	18,440			450	788	7,450		83
1990	20,461			587	638	6,973		55
1991	19,914			804	1,333	3,930		34
1992	23,068			1,001	3,374	9,089		31
1993	19,420			748	3,753	8,863		28
1994	22,576			923	1,684	10,100		16
1995	18,354			695	941	7,513		49
1996	18,974			785	1,165	7,426		75
1997	18,169			673	769	8,354		56
1998	16,113			487	3,098	10,787		110
1999	17,391			1,560	1,651		6,965	90
2000	17,239			3,041	4,027		6,989	90
2001	15,834			5,235	6,834		10,757	135
2002	17,321			1,142	3,097		10,074	111
2003	17,356			534	2,641		7,364	108
2004	13,325			703	606		7,789	120
2005	10,772			1,446	727		5,905	32
2006	12,359			2,247	3,041		6,712	93
2007	13,202			1,313	538		5,181	34
2008	10,054			2,633	478		5,640	53
2009	9,052			2,470	493		10,133	97
2010	11,105			1,693	649		5,721	24
2011	13,102			1,888	1,417		7,677	37

Table 3. Standardized CPUE series included in the ASPIC models.

Fleet represented	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)	(None)	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	2.078	0.648						
1968	2.135	0.598						
1969	2.275	0.362	2.199					
1970	1.713		1.057					
1971	1.730		1.673					
1972	1.190		0.897					
1973	1.034		0.603					
1974	1.172		0.357					
1975	1.376		0.213	1.040				
1976	1.442			1.220				
1977	1.579			0.781				
1978	1.406			1.421				
1979	1.305			0.580				
1980	1.197			0.852				
1981	0.956			1.761				
1982	0.953			1.396				
1983	0.934			1.105				1.689
1984	1.051			1.143				1.459
1985	0.993			1.902				1.526
1986	0.977			2.212				1.509
1987	0.872			0.906				1.411
1988	0.627			0.649				1.467
1989	0.558			0.808				1.754
1990	0.597			1.111				1.148
1991	0.671			1.286				1.333
1992	0.798			0.707				0.884
1993	0.683			0.608				1.546
1994	0.869			0.878				0.690
1995	0.867			0.563				1.103
1996	0.922			0.614				1.511
1997	0.872			0.813				1.110
1998	0.753			0.793				1.532
1999	0.631			0.834				1.217
2000	0.583			1.435				0.970
2001	0.706			1.477				0.564
2002	0.570			0.950				0.455
2003	0.534			0.996				0.317
2004	0.650			1.067				0.229
2005	0.752			0.818				0.145
2006	0.574			0.438				0.561
2007	0.654			0.332				0.706
2008	0.679			0.691				0.531
2009	0.660			0.839				0.671
2010	0.749			1.039				0.589
2011	0.672			0.936				0.371

* Only for sensitivity analysis

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

Run	Weight	B_1/K (fixed)	Model
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. Amount of future catch (2013-2021) for ASPIC future projections.

Catch level compared with 2011 catch	-40%	-30%	-20%	-10%	2011 catch	+10%	+20%	+30%	+40%
Catch (t)	14,473	16,885	19,298	21,710	24,122	26,534	28,946	31,359	33,771

Table 6. Results of the ASPIC model runs with those of 2011 assessment.

Results								2011 results				
Model run	MSY (t)	FMSY	BMSY (t)	B2012/BMSY	F2011/FMSY	K (t)	r	Model run	MSY (t)	FMSY	B2009/BMSY	F2009/FMSY
Run2	28,060	0.301	93,330	0.813	1.076	186,700	0.60	Run2	27,390	0.248	0.624	1.342
Run6	25,660	0.199	128,800	0.861	1.098	350,000	0.20	Run6	25,650	0.204	0.762	1.180
Run7	20,160	0.052	390,300	0.695	1.704	780,700	0.10	Run7	23,630	0.072	0.931	1.038
Run8	24,250	0.127	191,300	0.950	1.047	520,000	0.13	Run8	24,850	0.095	1.204	0.765

Table 7. Kobe II risk matrix for TB ratio (probability of exceeding MSY level).

Run02

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.532	0.770	0.742	0.524	0.242	0.086	0.054	0.048	0.044	0.042	0.038
−30%	16,885	0.532	0.770	0.742	0.600	0.356	0.150	0.078	0.058	0.056	0.052	0.052
−20%	19,298	0.534	0.770	0.742	0.644	0.454	0.296	0.150	0.094	0.080	0.074	0.066
−10%	21,710	0.536	0.770	0.742	0.682	0.564	0.452	0.338	0.228	0.174	0.148	0.132
0%	24,122	0.540	0.770	0.742	0.750	0.768	0.764	0.762	0.764	0.762	0.752	0.722
10%	26,534	0.540	0.770	0.742	0.750	0.768	0.764	0.762	0.764	0.762	0.752	0.722
20%	28,946	0.584	0.776	0.746	0.794	0.826	0.870	0.898	0.918	0.934	0.942	0.954
30%	31,359	0.658	0.796	0.766	0.834	0.882	0.918	0.950	0.968	0.982	0.992	0.998
40%	33,771	0.790	0.842	0.814	0.868	0.918	0.952	0.970	0.988	0.994	0.996	0.998

Run06

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.556	0.754	0.754	0.624	0.444	0.228	0.088	0.014	0.004	0.002	0.002
−30%	16,885	0.556	0.754	0.754	0.658	0.518	0.362	0.204	0.094	0.020	0.010	0.008
−20%	19,298	0.556	0.754	0.754	0.690	0.612	0.496	0.382	0.250	0.160	0.082	0.042
−10%	21,710	0.556	0.754	0.754	0.728	0.684	0.646	0.564	0.512	0.434	0.354	0.274
0%	24,122	0.556	0.754	0.754	0.744	0.742	0.742	0.722	0.712	0.708	0.694	0.658
10%	26,534	0.556	0.754	0.754	0.762	0.792	0.812	0.828	0.844	0.862	0.876	0.892
20%	28,946	0.556	0.754	0.754	0.786	0.824	0.850	0.886	0.902	0.928	0.952	0.964
30%	31,359	0.556	0.754	0.754	0.808	0.840	0.890	0.926	0.944	0.964	0.974	0.982
40%	33,771	0.562	0.754	0.754	0.822	0.882	0.918	0.948	0.966	0.980	0.988	0.994

Run07

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.616	0.804	0.812	0.812	0.810	0.820	0.818	0.822	0.822	0.824	0.824
−30%	16,885	0.616	0.804	0.812	0.822	0.832	0.840	0.844	0.852	0.862	0.862	0.874
−20%	19,298	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
−10%	21,710	0.616	0.804	0.812	0.826	0.836	0.848	0.852	0.860	0.866	0.884	0.894
0%	24,122	0.616	0.804	0.812	0.834	0.840	0.852	0.858	0.874	0.888	0.898	0.906
10%	26,534	0.616	0.804	0.812	0.834	0.848	0.858	0.870	0.884	0.900	0.910	0.926
20%	28,946	0.616	0.804	0.812	0.836	0.852	0.864	0.876	0.898	0.906	0.924	0.940
30%	31,359	0.616	0.804	0.812	0.840	0.852	0.868	0.888	0.904	0.916	0.938	0.952
40%	33,771	0.616	0.804	0.812	0.840	0.862	0.874	0.894	0.910	0.930	0.950	0.964

Run08

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.488	0.556	0.558	0.494	0.418	0.308	0.202	0.110	0.062	0.028	0.016
−30%	16,885	0.488	0.556	0.558	0.506	0.452	0.394	0.300	0.224	0.146	0.092	0.060
−20%	19,298	0.488	0.556	0.558	0.528	0.492	0.450	0.410	0.356	0.286	0.232	0.186
−10%	21,710	0.488	0.556	0.558	0.544	0.532	0.512	0.490	0.460	0.450	0.424	0.398
0%	24,122	0.488	0.556	0.558	0.564	0.566	0.568	0.568	0.580	0.586	0.588	0.590
10%	26,534	0.488	0.556	0.558	0.580	0.598	0.620	0.640	0.654	0.666	0.692	0.712
20%	28,946	0.488	0.556	0.558	0.592	0.634	0.656	0.686	0.710	0.742	0.780	0.818
30%	31,359	0.488	0.556	0.558	0.616	0.652	0.698	0.726	0.766	0.812	0.854	0.878
40%	33,771	0.488	0.556	0.558	0.632	0.678	0.718	0.766	0.816	0.862	0.888	0.912

Table 8. Kobe II risk matrix for F ratio (probability of exceeding MSY level).

Run02

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.532	0.564	0.012	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000
−30%	16,885	0.532	0.564	0.028	0.006	0.004	0.004	0.004	0.004	0.004	0.004	0.004
−20%	19,298	0.532	0.564	0.094	0.034	0.016	0.010	0.010	0.006	0.006	0.006	0.006
−10%	21,710	0.532	0.564	0.276	0.126	0.078	0.042	0.034	0.032	0.030	0.028	0.030
0%	24,122	0.532	0.564	0.686	0.678	0.684	0.678	0.638	0.632	0.628	0.622	0.602
10%	26,534	0.532	0.564	0.686	0.678	0.684	0.678	0.638	0.632	0.628	0.622	0.602
20%	28,946	0.532	0.564	0.812	0.842	0.878	0.904	0.922	0.932	0.946	0.962	0.974
30%	31,359	0.532	0.564	0.902	0.930	0.950	0.964	0.976	0.990	0.992	0.998	0.998
40%	33,771	0.532	0.564	0.932	0.956	0.970	0.986	0.992	0.994	0.998	0.998	0.998

Run06

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.552	0.668	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
−30%	16,885	0.552	0.668	0.044	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
−20%	19,298	0.552	0.668	0.212	0.108	0.036	0.006	0.002	0.000	0.000	0.000	0.000
−10%	21,710	0.552	0.668	0.456	0.384	0.290	0.208	0.146	0.096	0.048	0.028	0.016
0%	24,122	0.552	0.668	0.654	0.648	0.646	0.618	0.600	0.584	0.568	0.542	0.518
10%	26,534	0.552	0.668	0.792	0.816	0.828	0.840	0.860	0.874	0.890	0.902	0.918
20%	28,946	0.552	0.668	0.864	0.898	0.916	0.932	0.946	0.962	0.966	0.974	0.982
30%	31,359	0.552	0.668	0.922	0.944	0.956	0.968	0.980	0.986	0.990	0.996	0.996
40%	33,771	0.552	0.668	0.952	0.962	0.980	0.986	0.990	0.996	0.996	0.996	0.996

Run07

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.616	0.876	0.626	0.618	0.610	0.594	0.576	0.562	0.538	0.522	0.488
−30%	16,885	0.616	0.876	0.802	0.802	0.804	0.820	0.828	0.832	0.846	0.854	0.862
−20%	19,298	0.994	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998
−10%	21,710	0.616	0.876	0.856	0.862	0.866	0.874	0.886	0.896	0.900	0.910	0.920
0%	24,122	0.616	0.876	0.884	0.892	0.904	0.912	0.924	0.940	0.948	0.962	0.968
10%	26,534	0.616	0.876	0.920	0.926	0.940	0.954	0.960	0.966	0.980	0.984	0.986
20%	28,946	0.616	0.876	0.946	0.958	0.968	0.976	0.984	0.988	0.988	0.992	0.996
30%	31,359	0.616	0.876	0.968	0.980	0.986	0.988	0.992	0.992	0.996	0.996	0.996
40%	33,771	0.616	0.876	0.984	0.988	0.992	0.992	0.996	0.996	0.996	0.996	0.998

Run08

Year/catch level	Catch (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
−40%	14,473	0.492	0.552	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
−30%	16,885	0.492	0.552	0.062	0.028	0.010	0.000	0.000	0.000	0.000	0.000	0.000
−20%	19,298	0.492	0.552	0.204	0.150	0.098	0.068	0.040	0.022	0.010	0.002	0.000
−10%	21,710	0.492	0.552	0.412	0.382	0.350	0.308	0.264	0.238	0.208	0.180	0.142
0%	24,122	0.492	0.552	0.554	0.564	0.564	0.562	0.568	0.580	0.584	0.588	0.588
10%	26,534	0.492	0.552	0.672	0.694	0.704	0.712	0.730	0.744	0.770	0.794	0.818
20%	28,946	0.492	0.552	0.744	0.768	0.798	0.814	0.848	0.868	0.882	0.900	0.914
30%	31,359	0.492	0.552	0.810	0.846	0.866	0.882	0.902	0.922	0.940	0.950	0.958
40%	33,771	0.492	0.552	0.866	0.884	0.908	0.930	0.946	0.954	0.958	0.968	0.974

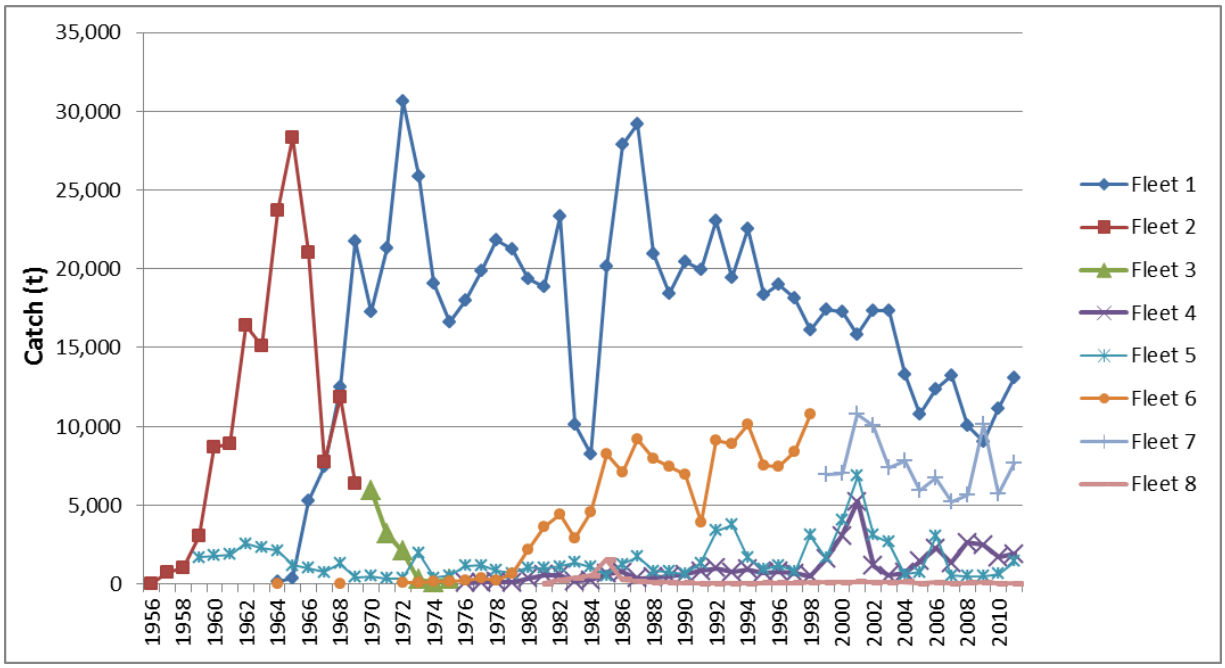

Figure 1. Annual trend of catch amount by fleet for ASPIC models.

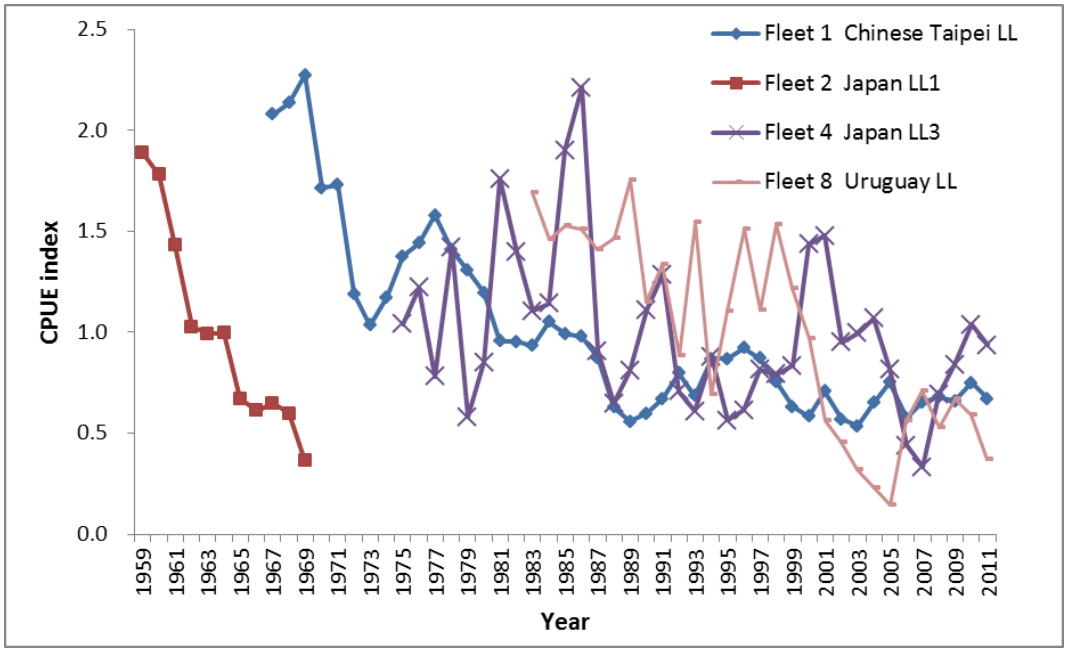

Figure. 2. Annual trend of standardized CPUE included in the ASPIC models.

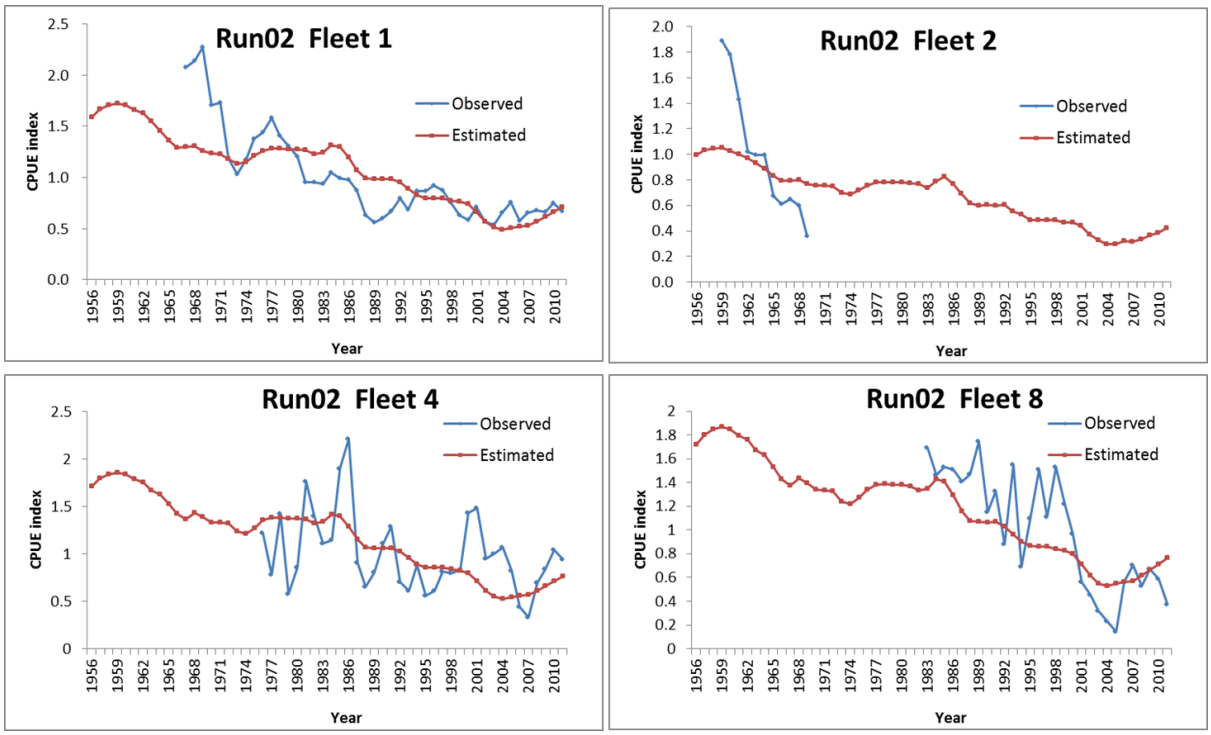

Figure 3. CPUE fit for ASPIC Run02.

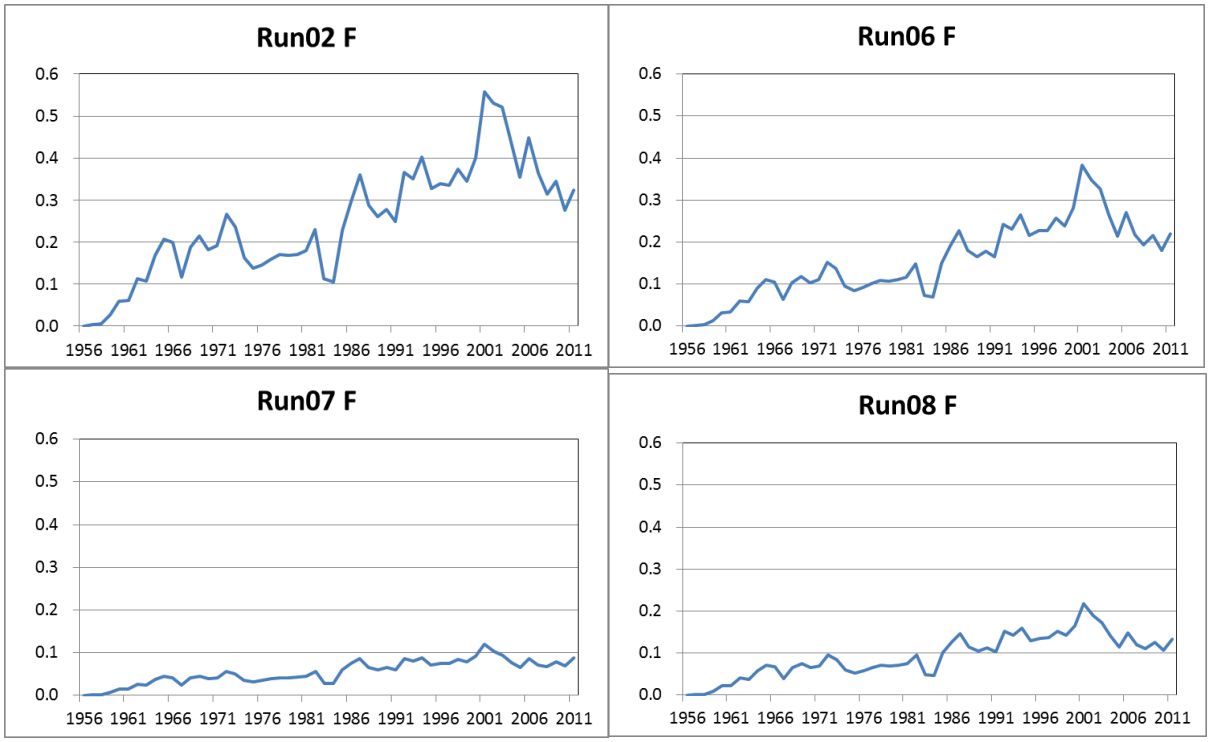

Figure 4. Trajectories of fishing mortality for 4 ASPIC runs.

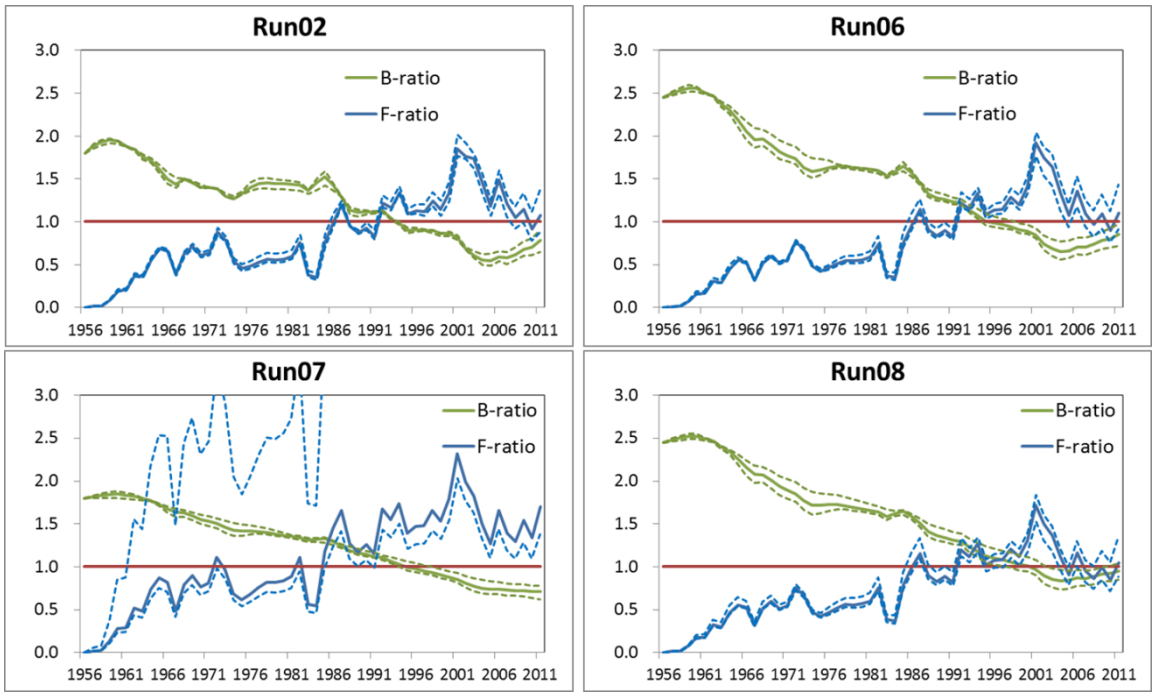

Figure 5. Trajectories of B-ratio (B/B_{MSY}) and F-ratio (F/F_{MSY}) with 80% confidence limits (dashed lines) for 4 ASPIC runs.

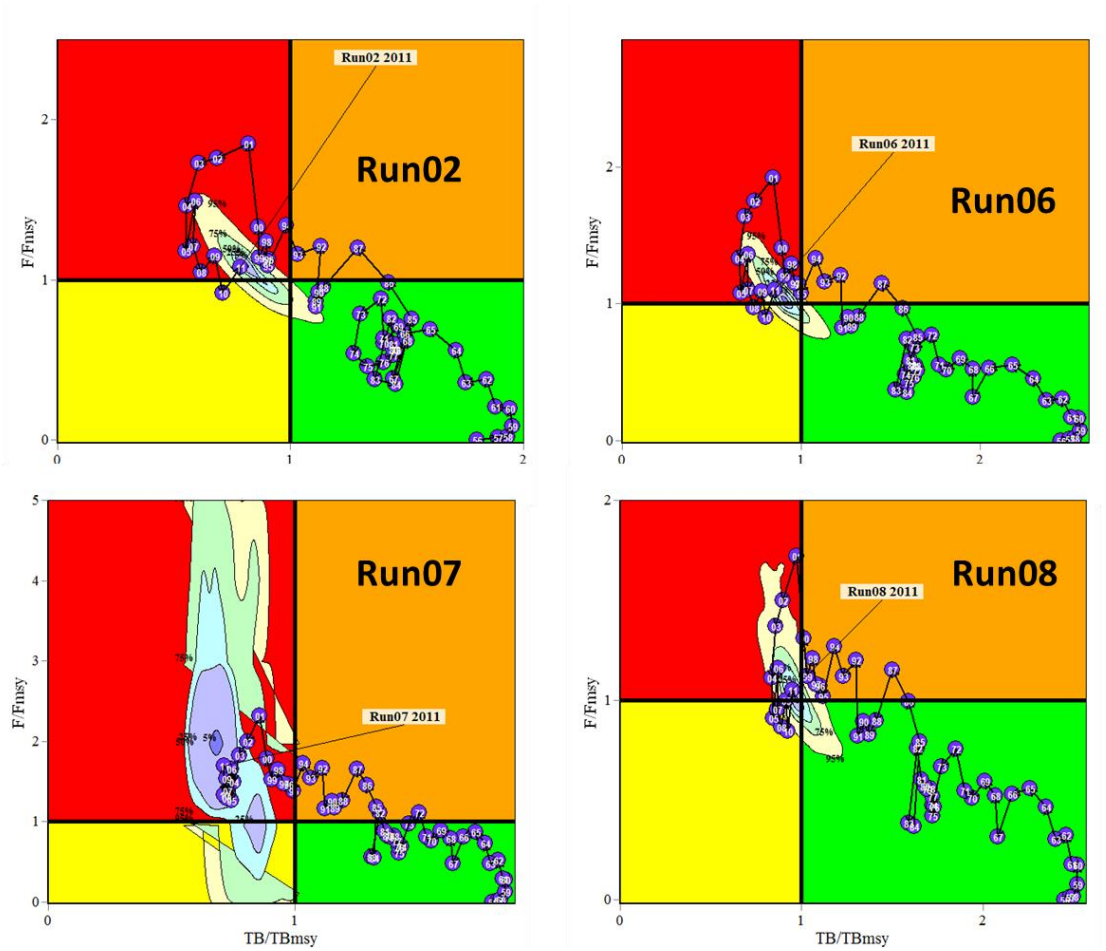

Figure 6. KobeI plot for 4 ASPIC runs.

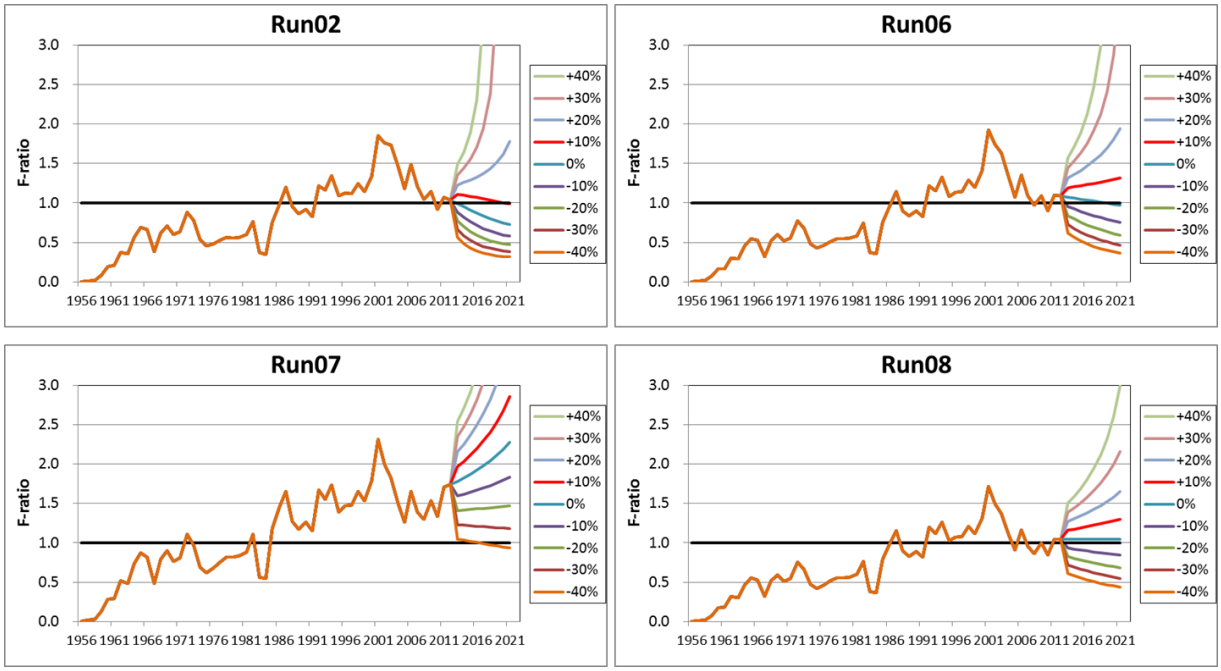

Figure 7. Future projection of F-ratio (F/F_{MSY}) for 4 ASPIC runs under constant catch.

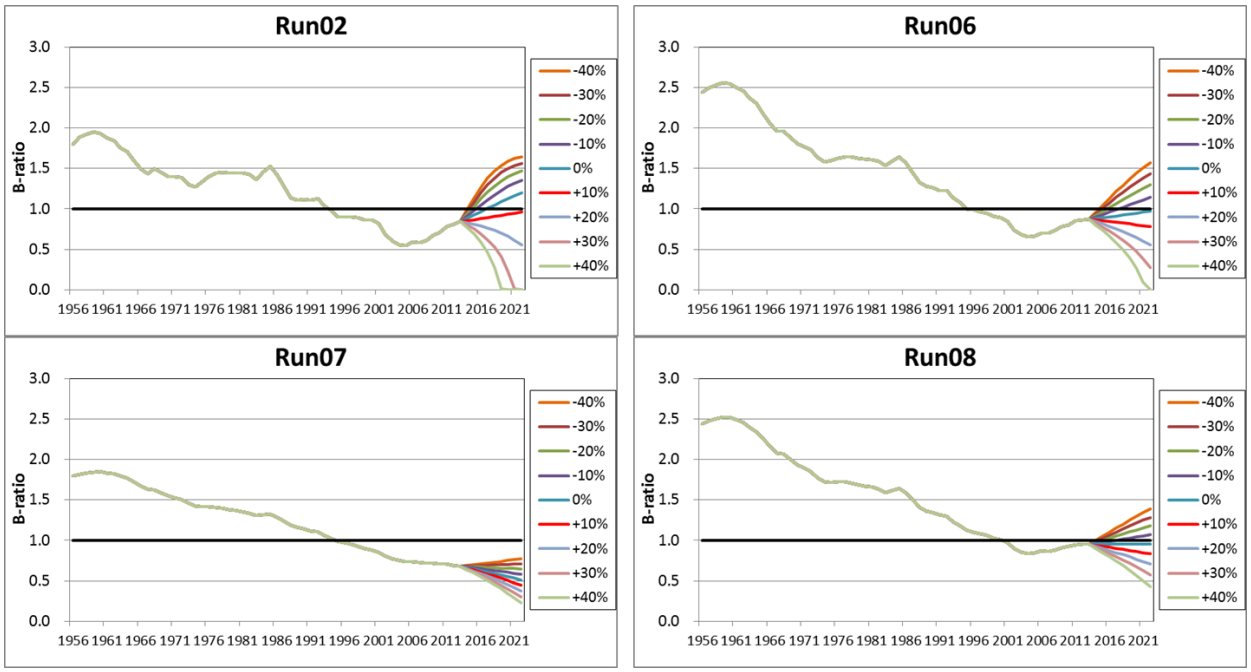

Figure 8. Future projection of B-ratio (B/B_{MSY}) for 4 ASPIC runs under constant catch.