Retrospective and exploratory analyses using the abalone ASPM for Zones A-D

Éva Plagányi and Doug Butterworth
Department of Mathematics and Applied Mathematics, University of Cape Town
November 2008

SUMMARY

The following exploratory analyses were done using the 2007 abalone assessment model (Plagányi 2007 a,b):

I) Retrospective Analysis / FIAS data

It has been argued that the FIAS data suggest a more negative resource status than do the commercial CPUE data. It was thus assumed that commercial CPUE data were only available up until 1995, when the FIAS series commenced. The model was run under the three scenarios:

a) all CPUE and FIAS data available;
b) CPUE data available only up until 1995, and all FIAS data available thereafter; and
c) CPUE data available only up until 1995 and only the first 5 years FIAS data assumed available.

In each instance the pre-exploitation spawning biomass estimates per zone were re-estimated, and compared with the Reference case model. Table 1 also shows a comparison of the current depletion estimates under each scenario. Note the Tables show Hessian-based CVs, whereas the Figures 1a,b give the Hessian-based 90% probability intervals.

Results presented here focus on Zones A and B. Projection results together with their associated uncertainties are also provided for a scenario in which it is assumed that future commercial catches remain set at zero but future poaching catches are half the current estimated level.

II) No Inshore/Offshore Division

The current assessment model assumes that commercial catches extend further offshore than the area covered by the inshore FIAS transects, and thus has an inshore and offshore model component in each zone. As a sensitivity (requested by the AWG), the model was reurn assuming a single component only. To simplify the analysis, this was done by assuming a very small offshore component remains. For Zones A and B, the inshore spawning biomass is estimated to have been approximately double the offshore biomass, but given relatively greater exploitation of the inshore versus offshore regions (due to poaching) in recent years, the current estimates of the biomass in each region suggest they are approximately the same.

III) Zone B sensitivity

A sensitivity analysis was run in which Zone B was fitted on its own, ie independently of the other Zones. Secondly, a more negative input FIAS series for Zone B was used (Table 3 and Fig. 3).

IV) Lower current depletion

The current depletion estimates for Zones A and B are roughly 0.3 of the pre-exploitation spawning biomass estimates (when combining inshore and offshore). Given concerns that these estimates are too high, model sensitivity analyses were run in which current depletion in these zones was forced (by adding a penalty term to the likelihood) approximately 0.2 and b) 0.1. Results are presented in Table 4 and Figs 4a,b and 5.

V) Replacement Yields

Rough model estimates of 10 yr Replacement Yields for Zones A and B were computed for a number of the scenarios above (Table 5). These were computed assuming commercial selectivity (i.e. zero future poaching catches), with a single example for comparison done assuming poaching selectivity (ie zero future commercial catches). Note that these results are illustrative only for purposes of discussion and are not intended as a basis for management advice. Fig. 6. shows the difference between the model-estimated selectivity patterns for the commercial and poaching sectors. Fig. 7 shows historic fishing proportions for the various sectors and in total.

RESULTS AND DISCUSSION

I) Retrospective Analysis / FIAS data

Table 1 illustrates the increase in uncertainty associated with model predictions (particularly for Zone A) when using a shorter time series of data to fit to. The 90% confidence interval associated with the Reference Case estimate of the current depletion level in Zone A is 0.27-0.43, compared to 0.18-0.35 under the scenario with no recent commercial data and all recent FIAS data (Table 1). Fitting to FIAS data only thus results in a more negative assessment of current resource status in Zone A but not much difference for Zone B.

II) No Inshore/Offshore Division

For Zones A and B, the inshore spawning biomass is estimated to have been approximately double the offshore biomass, but given relatively greater exploitation of the inshore versus offshore regions (due to poaching) in recent years, the current estimates of the biomass in each region suggest they are approximately the same (Fig. 2). The spawning biomass trajectory under the sensitivity scenario which assumed the offshore component is negligibly small suggested similar overall trends in spawning biomass to the Reference case scenario. The overall current depletion estimates are similar but the overall model fit is substantially worse when not separating between inshore and offshore model regions (Table 2, Appendix Table A.1).

III) Zone B sensitivity

When Zone B was fitted on its own, ie independently of the other Zones, this did not substantially change estimates for Zone B (Table 3 and Fig. 3). However, a substantially different picture of resource status emerges if a more negative input FIAS series for Zone B is used which is adjusted to exclude the high estimates from station 11 (Table 1 and Fig. 3).

This changes the 90% confidence interval associated with current depletion estimates from 0.23-0.36 down to 0.11-0.19, with the inshore area particularly heavily depleted (Fig. 3)

IV) Lower current depletion

Substantially worse model fits result when current depletion in Zones A and B is forced to lower values of approximately 0.2 and b) 0.1 (Table 4). This is particularly so for the more extreme case. In the first case it is mainly the Zone A fit which deteriorates, whereas in the 0.1 depletion example the fit to the CPUE data deteriorates dramatically for both Zones A and B (Fig. 4a). There is less of a deterioration in the FIAS fits (Fig. 4b). Fig. 5 shows the spawning biomass trajectories under the depletion to 0.1 scenario, and when projecting forwards with future catches as shown in Table 5.

V) Replacement Yields

The estimated 10 yr Replacement Yields for Zones A and B when assuming commercial selectivity (i.e. zero future poaching catches) are approximately 1.5 times estimates which assume poaching selectivity (ie zero future commercial catches) (Table 5, Fig. 6). Estimates

Note that these results are illustrative only for purposes of discussion and are not intended as a basis for management advice. Fig. 6. shows the difference between the model-estimated selectivity patterns for the commercial and poaching sectors. A useful diagnostic is provided by the pattern and scale of the fishing proportion F_y^s (Fig. 7). Note that the fishing proportion underlying these analyses represents the fished proportion of a fully selected age class rather than the more familiar annual fishing mortality rate referred to in fisheries stock assessment literature. The F_y^s values in Fig. 7 have been plotted on approximately the same scale for ease of comparison, and suggest that historically Zone B was more heavily fished than Zone A. Note however that the F values for the different sectors are not precisely comparable – although they all refer to a common age 11, they spread differently over age-classes and apply differentially to inshore and offshore areas. F_y^{poa} has increased dramatically during the last few years. In Zone A the total fishing proportions as estimated by the model for recent years have exceeded even the initially high *F* values corresponding to the initial "mining out" of the abalone resource.

Literature cited

Plagányi, É.E. 2007a. A summary of the assessment and management approach applied to South African abalone in Zones A-D. Marine and Coastal Management document WG/AB/07/Jun/01: 20 pp

Plagányi, É.E. 2007b. Projection results for Zones A, B, C and D in 2007. Marine and Coastal Management document: WG/AB/07/Aug/27: 11 pp.

Table 1. Comparison of the uncertainty associated with key model results when using the full 2007 Reference Case assessment model as compared to a scenario in which the commercial CPUE and catch-at-age information from the last five years are excluded when fitting the model.

	a) Reference Case with CPUE			b) No recent CPUE; all FIAS			c) No recent CPUE and first 5 yrs FIAS		
Parameter	Value	90% Confidence Interval		Value	90% Confidence Interval		Value	90% Confidence Interval	
$B(2008)^{sp}/B(0)^{sp}$ *(zone A)*	0.35	0.27	0.43	0.27	0.18	0.35	0.34	0.21	0.46
$B(2008)^{sp}/B(0)^{sp}$ *(zone B)*	0.29	0.23	0.36	0.31	0.23	0.40	0.32	0.27	0.36
$B(0)^{sp}$ *(A)*	7385	5384	9387	7133	6096	8171	7205	5655	8755
$B(0)^{sp}$ *(B)*	5754	5347	6161	6479	5858	7100	5917	5511	6322
$B(0)^{sp}$ *(C)*	6991	6472	7510	7075	6396	7754	7075	6396	7754
$B(0)^{sp}$ *(D)*	9173	6533	11814	10262	7891	12633	10262	7891	12633
$B(current)^{sp}$ *(A)*	2842	1638	4045	2117	1245	2988	2671	1210	4132
$B(current)^{sp}$ *(B)*	1757	1371	2143	1988	1368	2607	1929	1503	2354
$B(current)^{sp}$ *(C)*	405	0	2089	959	353	1565	959	353	1565
$B(current)^{sp}$ *(D)*	1353	0	7453	2157	575	3739	2157	575	3739

Table 2. Comparison of selected model results when using the full 2007 Reference Case assessment model as compared to a scenario in which the "offshore" component in the model is assumed to be very small compared to the inshore component. (Full results given in Table A.1).

Model	a) Ref. case					a) Very small offshore				
Zone	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
$B(0)^{sp}$	7385	5754	2606	4385	9173	6657	5628	1073	4348	7564
$-ln$ L TOTAL			-357.588					-325.230		
Depletion statistics										
$B^{sp}(2007)/K$ (Insh. + Offsh)	0.38	0.31	0.05	0.06	0.15	0.36	0.28	0.37	0.02	0.13
$B^{sp}(2007)/K$ (Insh.)	0.29	0.27	0.00	0.00	0.03	0.36	0.28	0.38	0.02	0.13
$B^{sp}(2007)/K$ (Offsh.)	0.57	0.39	0.16	0.26	0.38					
$B^{total}(2007)/K$	0.43	0.35	0.05	0.05	0.13	0.41	0.33	0.34	0.02	0.12
$B^{commercial}(2007)/K$	0.33	0.22	0.07	0.07	0.19	0.30	0.18	0.00	0.03	0.16
FIAS N_{2007}/N_{1951}	0.28	0.33	0.00	0.00	0.01	0.40	0.40	0.16	0.00	0.05

Table 3. Comparison of model results for Zone B when a) using the full 2007 Reference Case assessment model, as compared to b) fitting the model to Zone B on its own and c) fitting to Zone B on its own as in (b), but using a more negative FIAS input series. (Fuller results given in Table A.2)

Model	a) Ref. case	b) Zone B only fitted	c) Zone B only & adjusted FIAS
$B(0)^{sp}$	5628	5692	5577
$-ln$ L zone subtotal	-97.628	-101.937	-91.404
Depletion statistics			
$B^{sp}(2007)/K$ (Insh. + Offsh)	0.28	0.31	0.17
$B^{sp}(2007)/K$ (Insh.)	0.28	0.28	0.06
$B^{sp}(2007)/K$ (Offsh.)	0.56	0.39	0.27
$B^{total}(2007)/K$	0.33	0.35	0.20
$B^{commercial}(2007)/K$	0.18	0.20	0.16
FIAS N_{2007}/N_{1951}	0.40	0.40	0.04

Table 4. Comparison of model results when a) using the 2007 Reference Case assessment model, as compared to forcing current depletion (2008 combined inshore and offshore spawning biomass as a proportion of the pre-exploitation estimate) for Zones A and B to be b) 0.2 and c) 0.1. (Fuller results given in Table A.3).

Model	a) Ref. case		b) Depletion forced to approx 0.2		c) Depletion forced to approx 0.1	
Zone	**A**	**B**	**A**	**B**	**A**	**B**
$B(0)^{sp}$	7385	5754	6004	5837	5602	6144
$-ln$ L zone subtotal	-74.251	-98.637	-68.115	-97.675	-48.387	-81.367
Depletion statistics						
$B^{sp}(2007)/K$ (Insh. + Offsh)	**0.38**	**0.31**	**0.24**	**0.23**	**0.12**	**0.11**
$B^{sp}(2007)/K$ (Insh.)	0.29	0.27	0.16	0.20	0.06	0.08
$B^{sp}(2007)/K$ (Offsh.)	0.57	0.39	0.41	0.29	0.26	0.18
$B^{total}(2007)/K$	0.43	0.35	0.28	0.27	0.14	0.14
$B^{commercial}(2007)/K$	0.33	0.22	0.20	0.15	0.10	0.07
FIAS N_{2007}/N_{1951}	0.28	0.33	0.14	0.26	0.04	0.13

Table 5. Comparison of 10 yr Replacement Yield estimates for Zones A and B assuming commercial selectivity (i.e. zero poaching catches) for four model scenarios as shown. The last set of values show the Reference Case estimates when assuming poaching selectivity (i.e. zero commercial catches).

	10 yr Replacement Yield	
	Zone A	Zone B
Commercial selectivity		
Reference Case	400	300
Zone B with adjusted FIAS		240
Depletion to 0.2	300	250
Depletion to 0.1	150	160
Ref case (with *poaching selectivity)*	260	195

APPENDIX TABLE 1.

Table A.1. Comparison of selected model results when using the full 2007 Reference Case assessment model as compared to a scenario in which the "offshore" component in the model is assumed to be very small compared to the inshore component.

Model	a) Ref. case					b) Very small offshore component				
No. parameters			30					30		
Zone	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
Ave confiscation %	14%	45%	7%		5%	14%	45%	7%		5%
$B(0)^{sp}$	7385	5754	2606	4385	9173	6657	5628	1073	4348	7564
ρ	0.033	0.033	0.033	0.017	0.033	0.000	0.000	0.000	0.000	0.000
r^I	0.9	0.9	0.9	0.9	0.9	0.99	0.99	0.99	0.99	0.99
Cpmax (no.)	1283760	7.85E+05		561607	800613	1124190	7.78E+05		591645	739427
Cpmax (MT)	440	356		269	394	371	345		266	344
Cpmax (YEAR)	2006	2002		1995	2002	2006	2002		1995	2002
CP(2007) (MT)	524	243		0	97	486	247		41	87
M_0			0.324					0.322		
M_{15}			0.137					0.134		
a(CS)			8.99892					8.98441		
a(RS)			8.99951					8.99964		
a(PS)			4.52556					4.76422		
a(FS)			6.72678					6.65003		
a(OS)			4.55789					4.81991		
a(IS)			-					-		
μ(CS)			0.000331					1.79E-08		
μ(RS)			0.001219					0.001888		
μ(PS)			0.000185					0.00104		
μ(FS)			0.001692					0.002525		
μ(OS)			4.74E-12					5.73E-07		
μ(IS)			-					-		
δ(CS)			477.913					36.4179		
δ(RS)			617.99					604.828		
δ(PS)			1.45491					1.21178		
δ(FS)			0.779493					0.817544		
δ(OS)			0.668497					0.665953		
δ(IS)			-					-		
Model	a) Ref. case					b) Very small offshore component				
	A	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
-*ln* L CPUE	-44.402	-50.722	-35.323	-44.862	-34.480	-43.533	-52.457	-33.299	-45.953	-36.428
-*ln* L FIAS	0.630	-4.472	-3.394	4.724	-4.038	1.235	-3.838	-4.434	4.733	-3.890
-*ln* L age CS	-17.044	-18.464	-8.483	-10.540	-11.797	-16.296	-17.618	16.588	-10.194	-11.704
-*ln* L age RS	-1.642	-8.002	-6.819	-0.006	-8.854	-1.663	-7.810	-7.124	-0.054	-9.294
-*ln* L age PS	-2.777	-3.299		-1.803	-3.751	-2.644	-2.761		-1.907	-3.172
-*ln* L age FIAS	-1.934	-9.925	-3.913	-0.352	-5.395	-1.864	-10.191	-4.618	-0.248	-4.830
-*ln* L age OS inshore	-3.463	-1.060		-1.269	-0.945	-2.741	-0.958		-1.271	-0.654
-*ln* Lage OS offsh.	-3.618	-1.689		-0.810	-1.855	-1.328	-0.967		-0.338	-0.126
-*ln* L age IS insh+offsh.		-1.004	-0.735				-1.027	-0.572		
-*ln* L zone subtotal	-74.251	-98.637	-113.585		-71.115	-68.834	-97.628	-88.671		-70.097
***-ln* L TOTAL**			-357.588					-325.230		
σ CPUE	0.119	0.094	0.151	0.064	0.172	0.123	0.089	0.163	0.061	0.160
σ age CS	0.079	0.073	0.114	0.094	0.097	0.083	0.077	0.582	0.096	0.098
σ age RS	0.114	0.057	0.061	0.201	0.059	0.113	0.059	0.058	0.188	0.056
σ age PS	0.122	0.131		0.153	0.098	0.124	0.140		0.150	0.109
σ age FIAS	0.132	0.070	0.093	0.132	0.086	0.133	0.068	0.082	0.136	0.094
σ OS insh.	0.036	0.063		0.053	0.073	0.051	0.070		0.053	0.096
σ OS offsh.	0.038	0.043		0.082	0.035	0.092	0.075		0.118	0.133
σ IS		0.036	0.071				0.035	0.087		
Additional variance	0.402					0.406				
q CPUE	0.00033	0.000645	0.003734	0.00098	0.000272	0.000369	0.000677	1.4863	0.001006	0.000362
Depletion statistics										
$B^{sp}(2007)/K$ (Insh. + Offsh)	0.38	0.31	0.05	0.06	0.15	0.36	0.28	0.37	0.02	0.13
$B^{sp}(2007)/K$ (Insh.)	0.29	0.27	0.00	0.00	0.03	0.36	0.28	0.38	0.02	0.13
$B^{sp}(2007)/K$ (Offsh.)	0.57	0.39	0.16	0.26	0.38					
$B^{total}(2007)/K$	0.43	0.35	0.05	0.05	0.13	0.41	0.33	0.34	0.02	0.12
$B^{commercial}(2007)/K$	0.33	0.22	0.07	0.07	0.19	0.30	0.18	0.00	0.03	0.16
FIAS N_{2007}/N_{1951}	0.28	0.33	0.00	0.00	0.01	0.40	0.40	0.16	0.00	0.05

APPENDIX TABLE 2

Table A.2. Comparison of model results for Zone B when a) using the full 2007 Reference Case assessment model, as compared to b) fitting the model to Zone B on its own and c) fitting to Zone B on its own as in (b), but using a more negative FIAS input series.

Model	a) Ref. case	b) Zone B only fitted	c) Zone B only & adjusted FIAS
$B(0)^{sp}$	5754	5692	5577
ρ	0.033	0.019	0.070
Cpmax (no.)	7.85E+05	6.53E+05	1.42E+06
Cpmax (MT)	356	336	395
Cpmax (YEAR)	2002	2002	2002
CP(2007) (MT)	243	232	192
-*ln* L CPUE	-50.722	-51.660	-52.285
-*ln* L FIAS	-4.472	-3.682	-6.300
-*ln* L age CS	-18.464	-18.672	-15.308
-*ln* L age RS	-8.002	-7.969	-8.036
-*ln* L age PS	-3.299	-6.338	3.325
-*ln* L age FIAS	-9.925	-9.837	-9.672
-*ln* L age OS inshore	-1.060	-1.032	-1.171
-*ln* Lage OS offsh.	-1.689	-1.739	-1.132
-*ln* L age IS insh+offsh.	-1.004	-1.008	-0.824
-*ln* L zone subtotal	-98.637	-101.937	-91.404
χ^2 CPUE	0.094	0.091	0.089
χ^2 age CS	0.073	0.072	0.088
χ^2 age RS	0.057	0.058	0.057
χ^2 age PS	0.131	0.090	0.300
χ^2 age FIAS	0.070	0.070	0.071
χ^2 OS insh.	0.063	0.065	0.057
χ^2 OS offsh.	0.043	0.041	0.066
χ^2 S	0.036	0.036	0.045
q CPUE	0.000644999	0.000660369	0.000704232
Depletion statistics			
$B^{sp}(2007)/K$ (Insh. + Offsh)	0.31	0.31	0.17
$B^{sp}(2007)/K$ (Insh.)	0.27	0.28	0.06
$B^{sp}(2007)/K$ (Offsh.)	0.39	0.39	0.27
$B^{total}(2007)/K$	0.35	0.35	0.20
$B^{commercial}(2007)/K$	0.22	0.20	0.16
FIAS N_{2007}/N_{1951}	0.33	0.40	0.04

APPENDIX Table A.3. Comparison of model results when a) using the 2007 Reference Case assessment model, as compared to forcing current depletion (2008 combined inshore and offshore spawning biomass as a proportion of the pre-exploitation estimate) for Zones A and B to be b) 0.2 and c) 0.1.

Model	a) Ref. case					b) Depletion for A & B forced to approx 0.2					c) Depletion for A & B forced to approx 0.1				
No. parameters			30					30					30		
Zone	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
Ave confiscation %	14%	45%	7%		5%	14%	45%	7%		5%	14%	45%	7%		5%
$B(0)^{sp}$	7385	5754	2606	4385	9173	6004	5837	2595	4540	8036	5602	6144	3015	4772	7612
Cpmax (no.)	1283760	7.85E+05		561607	800613	1036480	7.09E+05		496484	642004	937579	7.80E+05		437191	542491
Cpmax (MT)	440	356		269	394	342	319		239	318	262	306		192	267
Cpmax (YEAR)	2006	2002		1995	2002	2006	2002		1995	2002	2006	2002		1995	2002
CP(2007) (MT)	524	243		0	97	375	211		0	69	248	173		0	66
M_0			0.324					0.305					0.285		
M_{15}			0.137					0.118					0.098		
	A	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
-*ln* L CPUE	-44.402	-50.722	-35.323	-44.862	-34.480	-36.639	-50.152	-34.341	-44.896	-35.968	-22.754	-36.029	-33.010	-43.050	-36.875
-*ln* L FIAS	0.630	-4.472	-3.394	4.724	-4.038	0.794	-4.880	-3.203	4.721	-3.965	4.323	-5.039	-2.621	4.008	-3.568
-*ln* L age CS	-17.044	-18.464	-8.483	-10.540	-11.797	-17.714	-18.200	-8.372	-11.034	-11.867	-17.650	-19.284	-8.298	-11.049	-12.091
-*ln* L age RS	-1.642	-8.002	-6.819	-0.006	-8.854	-1.557	-7.913	-6.420	-0.008	-8.696	-1.225	-7.717	-5.226	0.021	-8.637
-*ln* L age PS	-2.777	-3.299		-1.803	-3.751	-2.958	-3.122		-1.685	-3.757	-1.041	-0.691		-1.388	-3.086
-*ln* L age FIAS	-1.934	-9.925	-3.913	-0.352	-5.395	-2.855	-9.713	-3.899	-0.355	-5.346	-2.949	-8.801	-3.325	-0.342	-5.118
-*ln* L age OS inshore	-3.463	-1.060		-1.269	-0.945	-3.556	-1.097		-1.240	-0.898	-3.595	-1.023		-1.185	-0.778
-*ln* Lage OS offsh.	-3.618	-1.689		-0.810	-1.855	-3.629	-1.695		-0.854	-1.826	-3.498	-1.962		-0.789	-1.676
-*ln* L age IS insh+offsh.		-1.004	-0.735				-0.904	-0.768				-0.821	-0.722		
-*ln* L zone subtotal	-74.251	-98.637	-113.585		-71.115	-68.115	-97.675	-112.354		-72.322	-48.387	-81.367	-106.974		-71.828
-*ln* L TOTAL			**-357.588**					**-350.466**					**-308.556**		
λCPUE	0.119	0.094	0.151	0.064	0.172	0.159	0.096	0.157	0.064	0.163	0.266	0.163	0.165	0.070	0.158
λage CS	0.079	0.073	0.114	0.094	0.097	0.076	0.074	0.115	0.091	0.097	0.076	0.070	0.116	0.091	0.095
λage RS	0.114	0.057	0.061	0.201	0.059	0.118	0.058	0.066	0.201	0.061	0.133	0.060	0.082	0.209	0.061
λage PS	0.122	0.131		0.153	0.098	0.119	0.134		0.155	0.098	0.155	0.181		0.162	0.111
λage FIAS	0.132	0.070	0.093	0.132	0.086	0.114	0.071	0.093	0.131	0.087	0.112	0.078	0.103	0.132	0.090
λOS insh.	0.036	0.063		0.053	0.073	0.035	0.061		0.054	0.077	0.034	0.066		0.057	0.085
λOS offsh.	0.038	0.043		0.082	0.035	0.038	0.043		0.080	0.036	0.040	0.035		0.084	0.040
λS		0.036	0.071				0.041	0.068				0.045	0.072		
Additional variance	0.402					0.401					0.460				
q CPUE	0.00033	0.000645	0.003734	0.00098	0.000272	0.000524	0.000762	0.004402	0.001085	0.000356	0.000786	0.000915	0.005644	0.001241	0.000451
Depletion statistics															
B^{sp} (2007)/*K* (Insh. + Offsh)	**0.38**	**0.31**	**0.05**	**0.06**	**0.15**	**0.24**	**0.23**	**0.05**	**0.06**	**0.13**	**0.12**	**0.11**	**0.03**	**0.05**	**0.10**
B^{sp} (2007)/*K* (Insh.)	0.29	0.27	0.00	0.00	0.03	0.16	0.20	0.00	0.00	0.01	0.06	0.08	0.00	0.00	0.02
B^{sp} (2007)/*K* (Offsh.)	0.57	0.39	0.16	0.26	0.38	0.41	0.29	0.14	0.24	0.34	0.26	0.18	0.11	0.22	0.30
B^{total} (2007)/*K*	0.43	0.35	0.05	0.05	0.13	0.28	0.27	0.04	0.05	0.12	0.14	0.14	0.03	0.04	0.10
$B^{commercial}$ (2007)/*K*	0.33	0.22	0.07	0.07	0.19	0.20	0.15	0.06	0.07	0.16	0.10	0.07	0.04	0.05	0.12
FIAS N_{2007}/N_{1951}	0.28	0.33	0.00	0.00	0.01	0.14	0.26	0.00	0.00	0.00	0.04	0.13	0.00	0.00	0.00

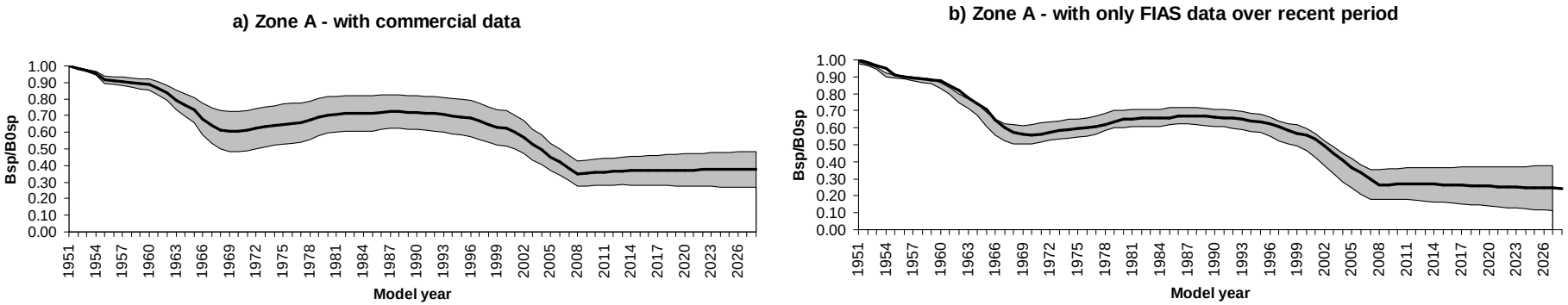


Fig. 1a. Total spawning biomass trajectories (inshore and offshore combined shown as a proportion of the pre-exploitation level) for Zone A when a) **using the 2007 Reference Case model and b) when using a version of the model that uses no recent commercial data and fits instead to the FIAS data**. The shaded areas represent the associated Hessian-based 90% probability intervals. Projections assume future commercial catches are set to zero and that poaching levels in the future are fixed at half the current estimated level.

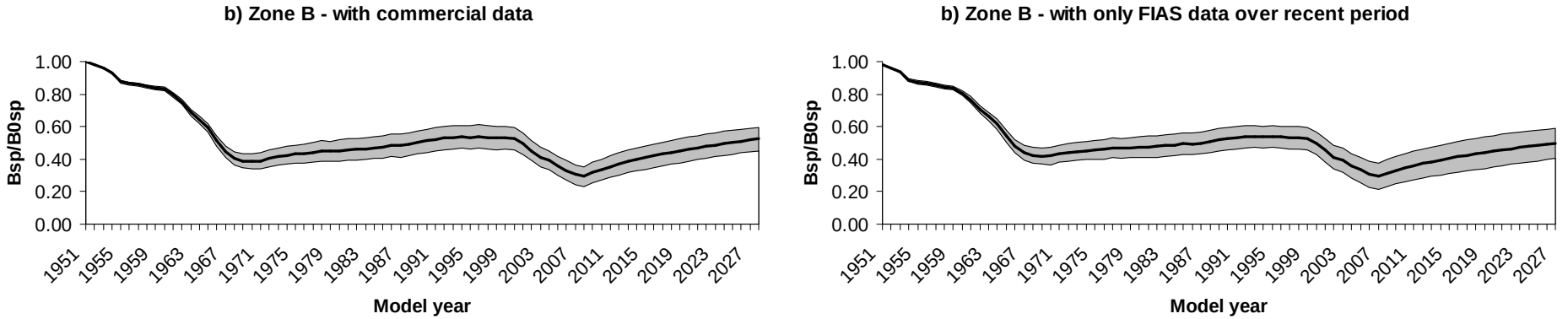


Fig. 1b. Total spawning biomass trajectories (inshore and offshore combined shown as a proportion of the pre-exploitation level) for Zone B when a) **using the 2007 Reference Case model and b) when using a version of the model that uses no recent commercial data and fits instead to the FIAS data**. The shaded areas represent the associated Hessian-based 90% probability intervals. Projections assume future commercial catches are set to zero and that poaching levels in the future are fixed at half the current estimated level.

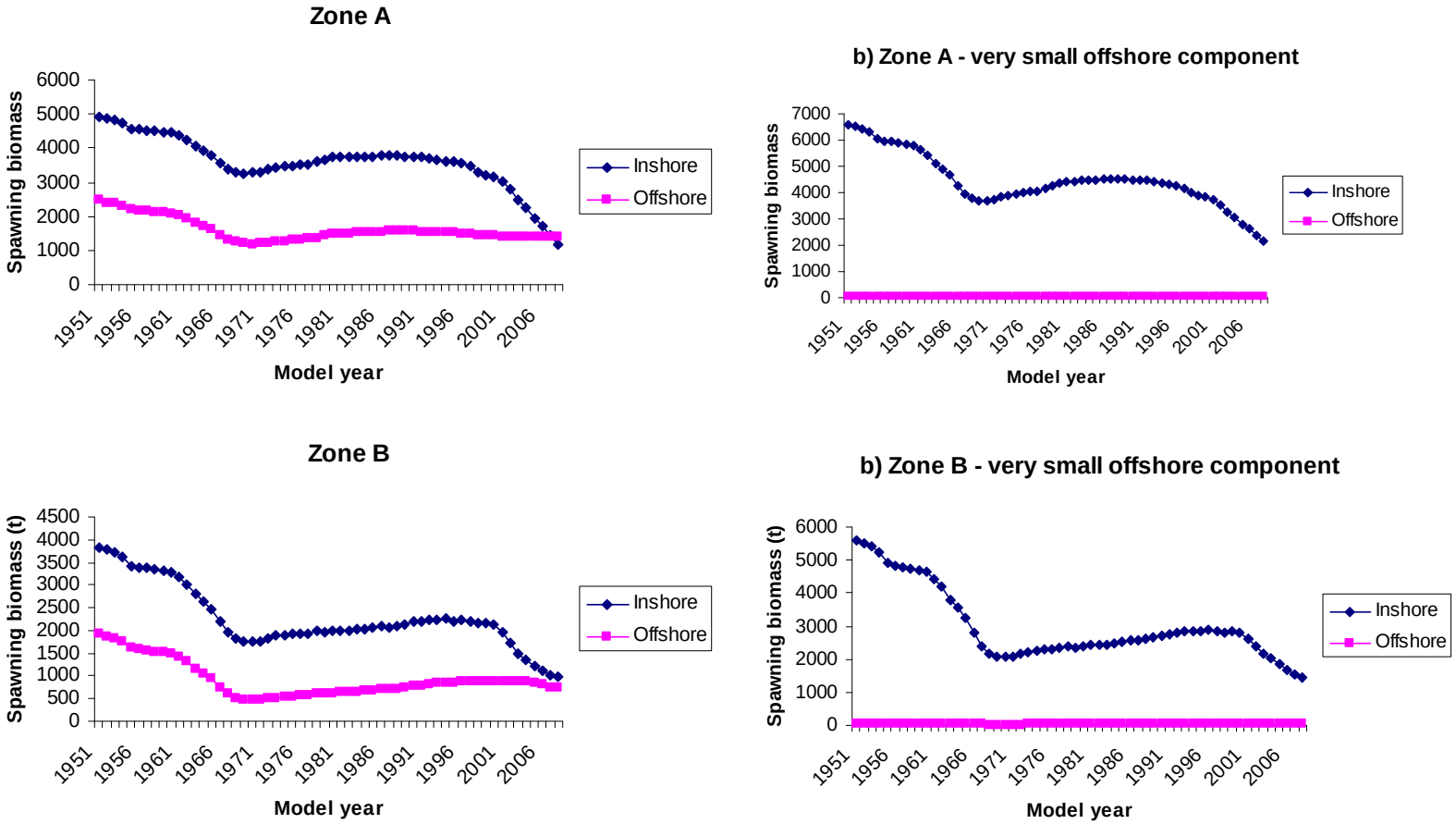


Fig. 2. Comparisons of Reference Case spawning biomass trajectories for Zones A and B, with an alternative model version which assumes there is a negligibly small offshore component.

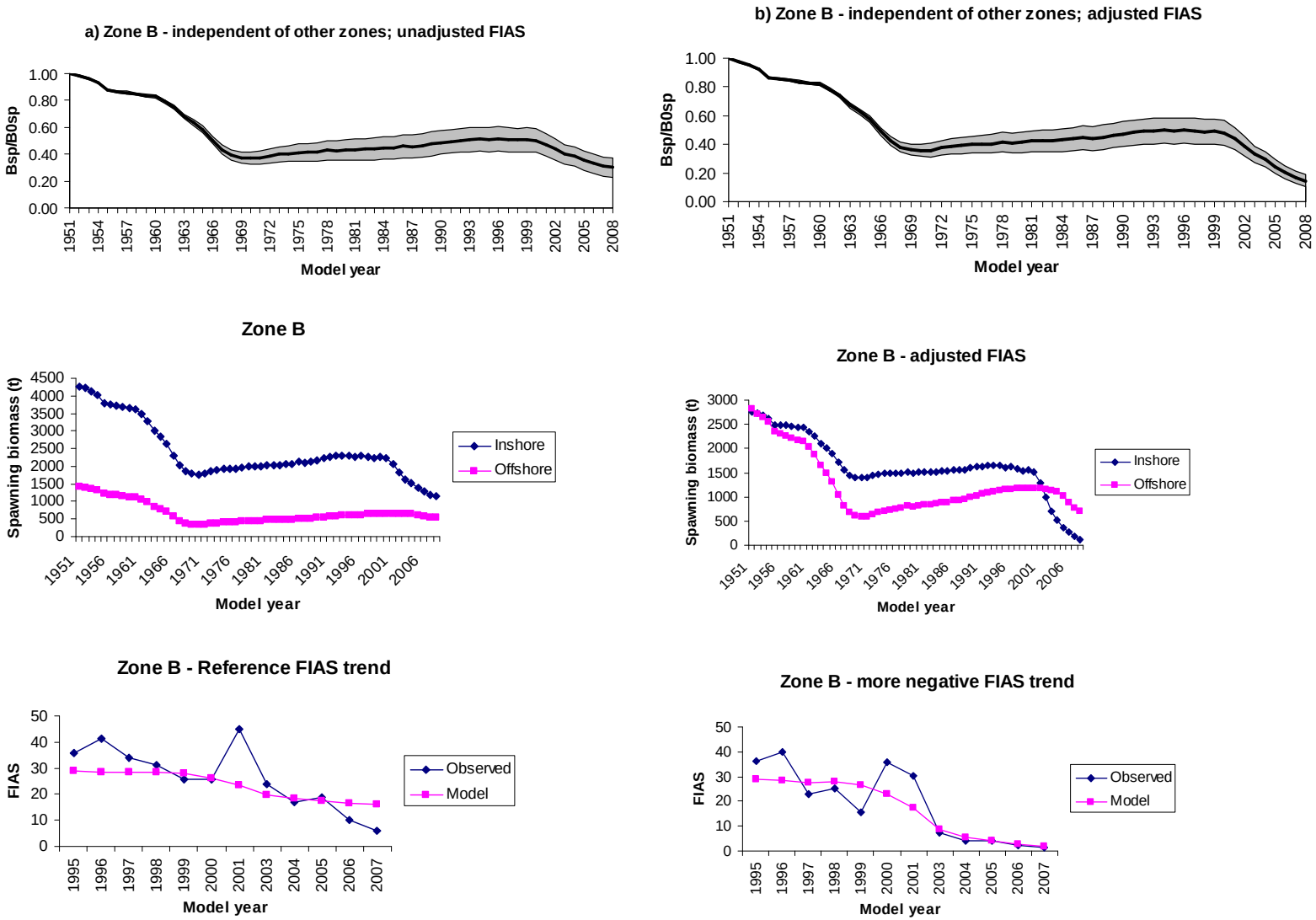
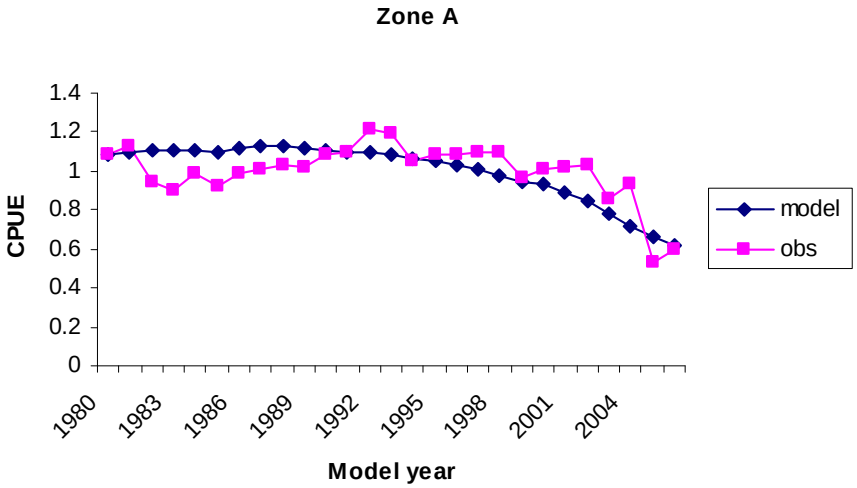
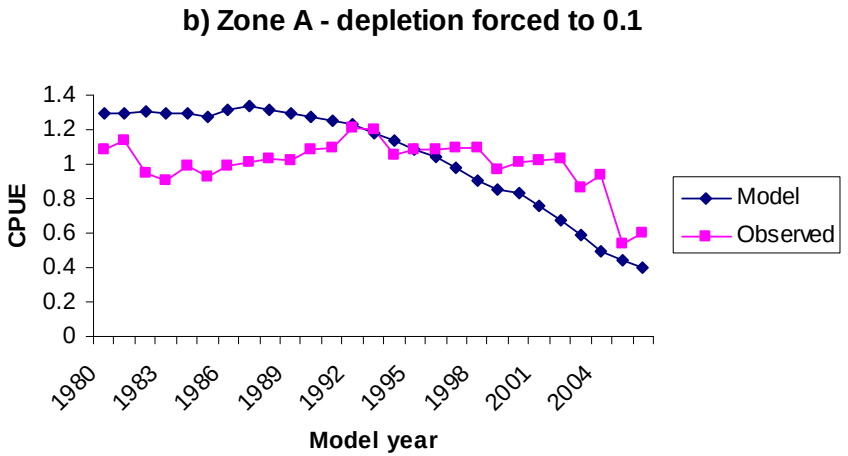
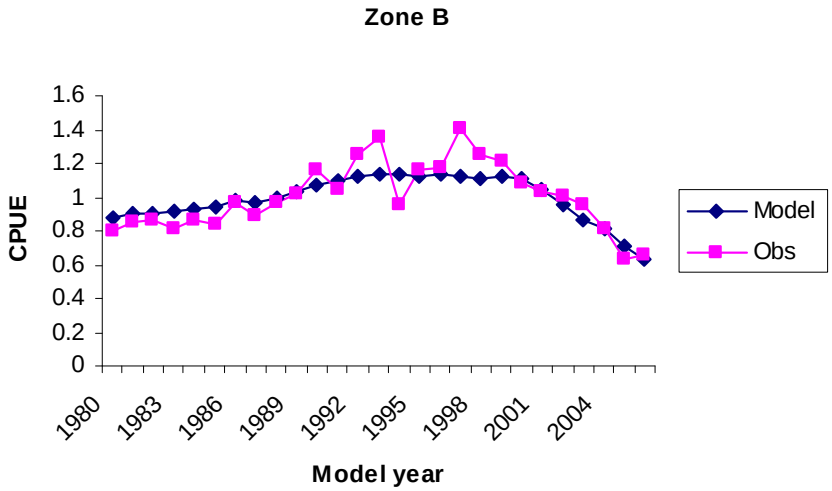


Fig. 3. Model results when fitting to Zone B in isolation. The left hand side panels are when using the Reference Case model but fitting to Zone B only, whereas the right hand side panel shows model results when assuming a more negative trend in FIAS.







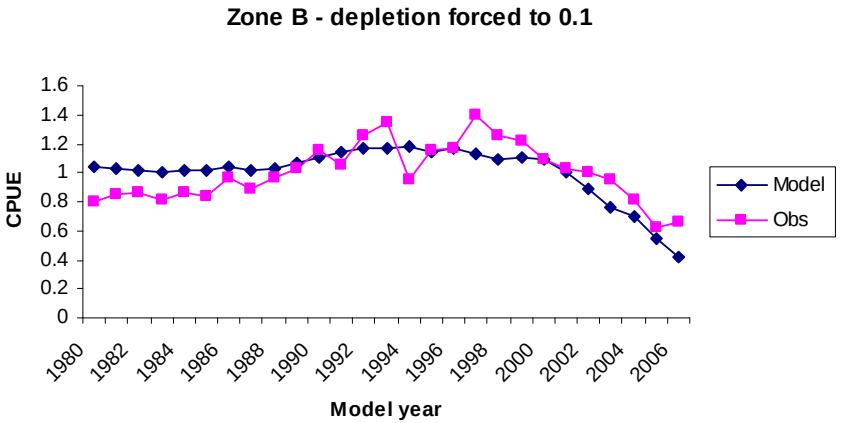


Fig. 4a. Example of deterioration in model fit when forcing depletion in Zone A to be 0.1.

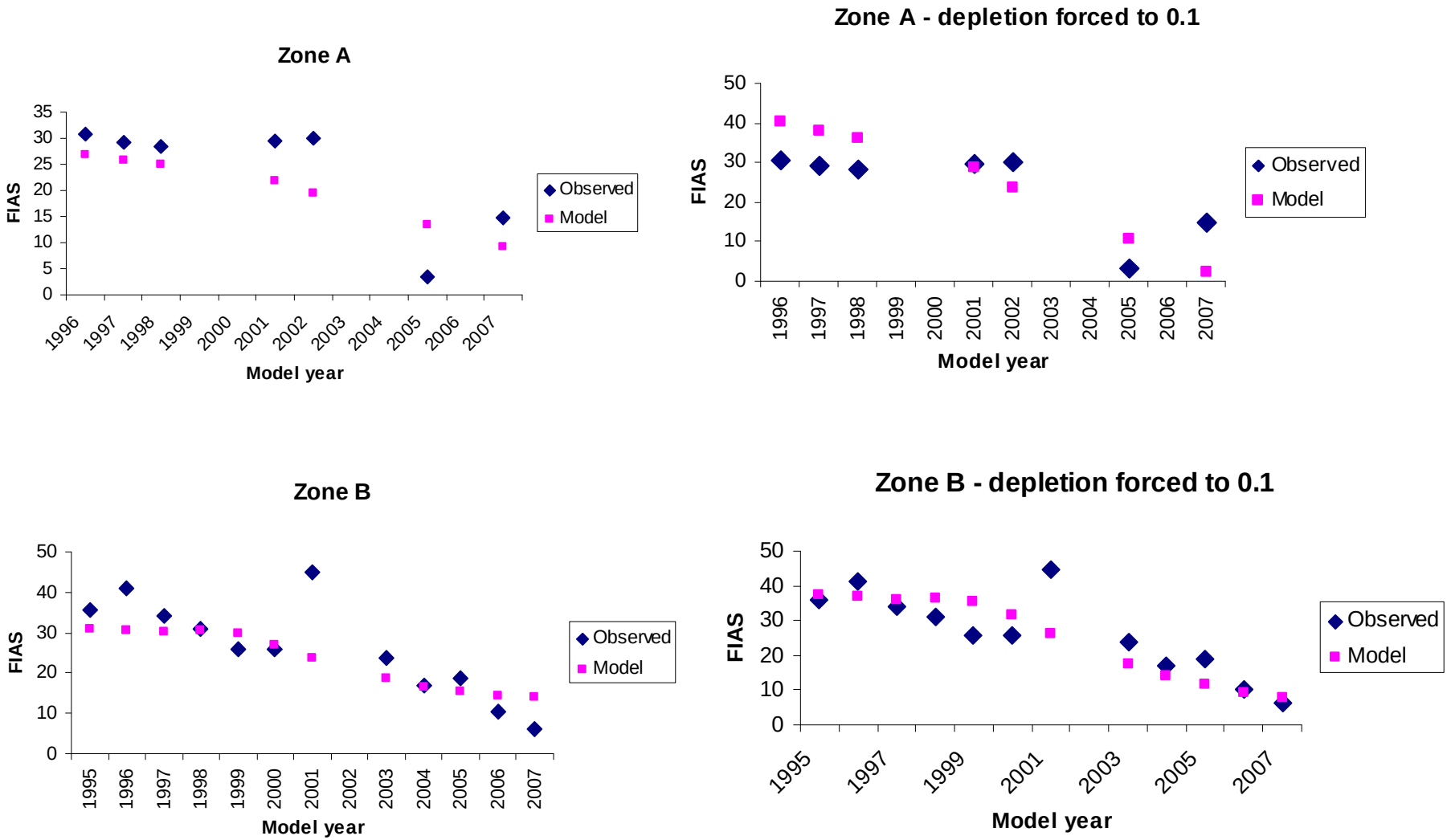


Fig. 4b. Example of deterioration in FIAS model fits when forcing depletion in Zone A to be 0.1

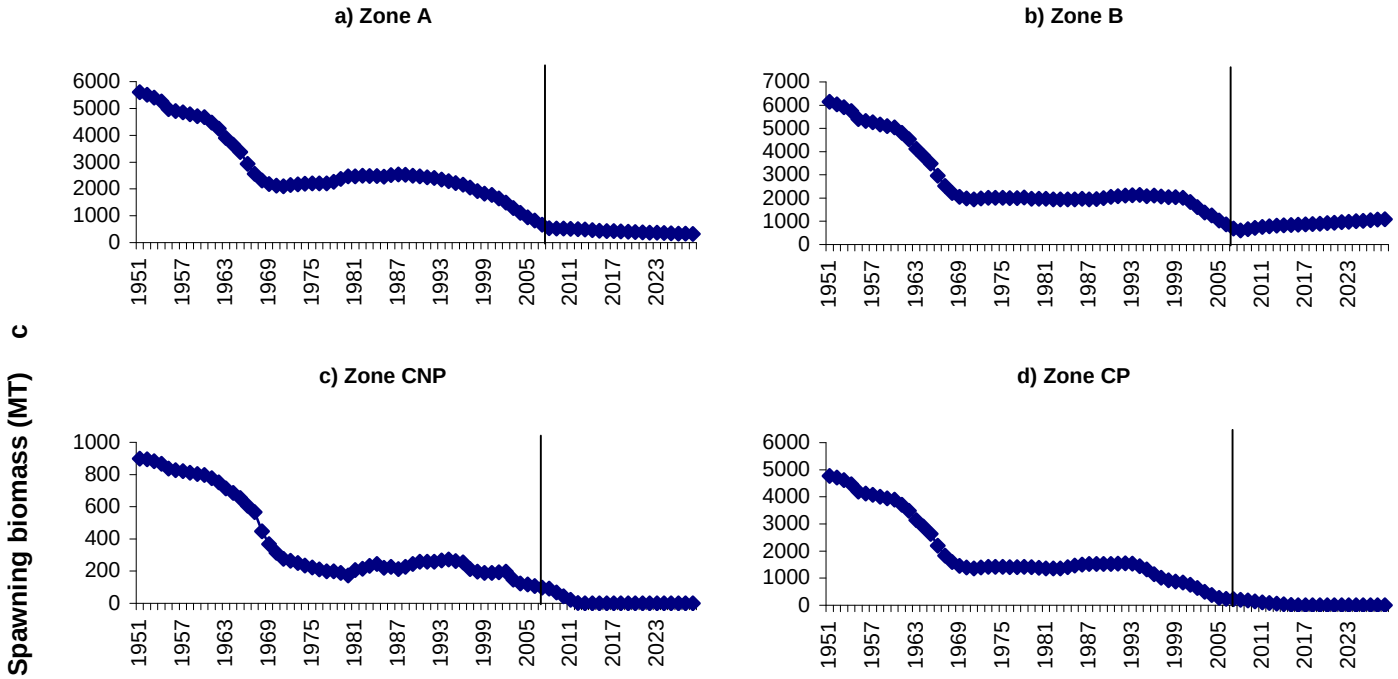


Fig. 5. Spawning biomass trajectories under the depletion forced to 0.1 scenario.

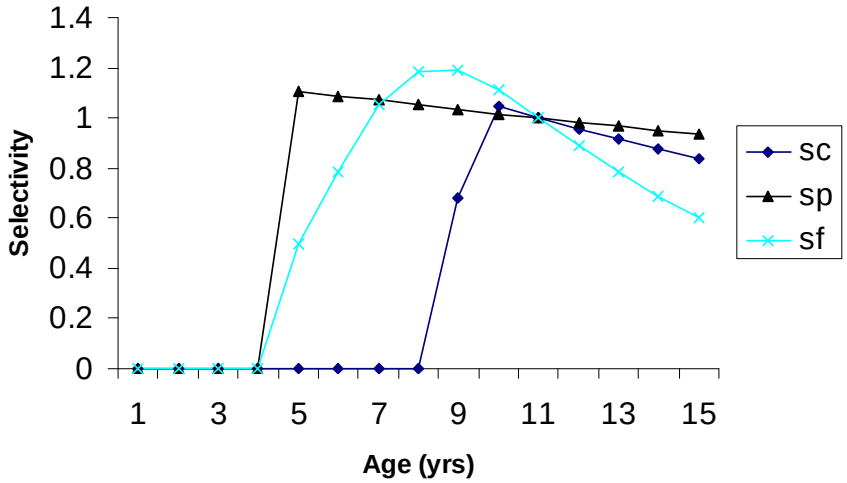


Fig. 6. Reference case model selectivity patterns for th4e commercial (sc), poaching (sp) and fias (sf) sectors.

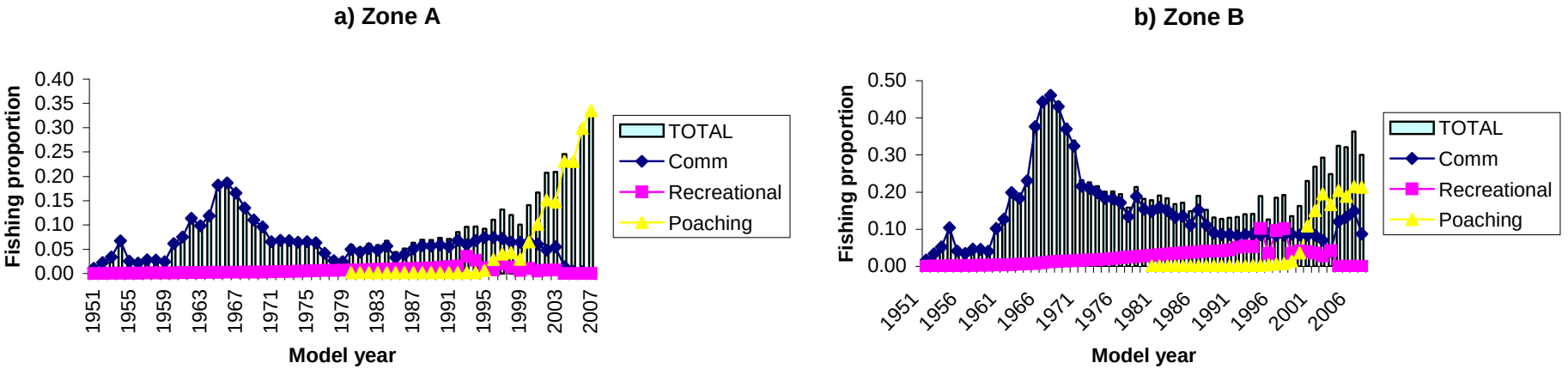


Fig. 7. Changes in the fishing proportion *F* over time for each of a) Zone A and b) Zone B. The figures show the contribution to the total fishing proportion by the three sectors: commercial (comm.), recreational and poaching for the Reference Case model.

APPENDIX TO DOC 15

Model sensitivity with current depletion for Zones A and B forced to 0.05

Model	a) Ref. case				
No. parameters			30		
Zone	**A**	**B**	**CNP**	**CP**	**D**
Ave confiscation %	14%	45%	7%		5%
$B(0)^{sp}$	5597	6353	3471	4926	7653
ρ	0.015	0.015	0.015	0.007	0.015
r^{1}	0.9	0.9	0.9	0.9	0.9
Cpmax (no.)	841012	8.07E+05		399059	475517
Cpmax (MT)	225	310		176	244
Cpmax (YEAR)	2006	2002		1995	2002
CP(2007) (MT)	208	152		0	60
M_0			0.277		
M_{15}			0.090		
a(CS)			8.89668		
a(RS)			9.17437		
a(PS)			4.98105		
a(FS)			6.70655		
a(OS)			4.32694		
a(IS)			-		
⎫(CS)			0.000185		
⎫(RS)			0.001939		
⎫(PS)			0.000385		
⎫(FS)			0.00228		
⎫(OS)			1.04E-10		
⎫(IS)			-		
⎫(CS)			4.98407		
⎫(RS)			2.20011		
⎫(PS)			0.121062		
⎫(FS)			0.686018		
⎫(OS)			0.591494		
⎫(IS)			-		
Model	a) Ref. case				
	A	**B**	**CNP**	**CP**	**D**
-*ln* L CPUE	-16.161	-25.156	-32.469	-40.611	-36.665
-*ln* L FIAS	6.436	-3.817	-2.217	3.527	-3.078
-*ln* L age CS	-15.978	-20.344	-8.350	-10.814	-12.280
-*ln* L age RS	-0.939	-7.699	-4.681	0.057	-8.403
-*ln* L age PS	-0.557	-0.102		-0.507	-2.668
-*ln* L age FIAS	-2.759	-7.187	-3.068	-0.356	-4.858
-*ln* L age OS inshore	-3.543	-0.933		-1.116	-0.718
-*ln* Lage OS offsh.	-3.244	-2.198		-0.766	-1.622
-*ln* L age IS insh+offsh.		-0.831	-0.732		
-*ln* L zone subtotal	-36.745	-68.267	-102.101		-70.292
***-ln* L TOTAL**			-277.405		
⎫CPUE	0.340	0.243	0.169	0.080	0.159
⎫age CS	0.084	0.066	0.115	0.092	0.094
⎫age RS	0.147	0.060	0.090	0.220	0.063
⎫age PS	0.166	0.195		0.183	0.119
⎫age FIAS	0.115	0.093	0.108	0.131	0.094
⎫OS insh.	0.035	0.071		0.061	0.090
⎫OS offsh.	0.044	0.029		0.085	0.042
⎫S		0.045	0.071		
Additional variance	0.524				
q CPUE	0.000942	0.000985	0.006137	0.001278	0.00049
Depletion statistics					
$B^{sp}(2007)/K$ (Insh. + Offsh)	0.09	0.07	0.03	0.04	0.10
$B^{sp}(2007)/K$ (Insh.)	0.04	0.05	0.00	0.00	0.03
$B^{sp}(2007)/K$ (Offsh.)	0.21	0.14	0.10	0.22	0.29
$B^{total}(2007)/K$	0.10	0.09	0.03	0.04	0.09
$B^{commercial}(2007)/K$	0.07	0.04	0.03	0.05	0.11
FIAS N_{2007}/N_{1951}	0.02	0.07	0.00	0.00	0.01

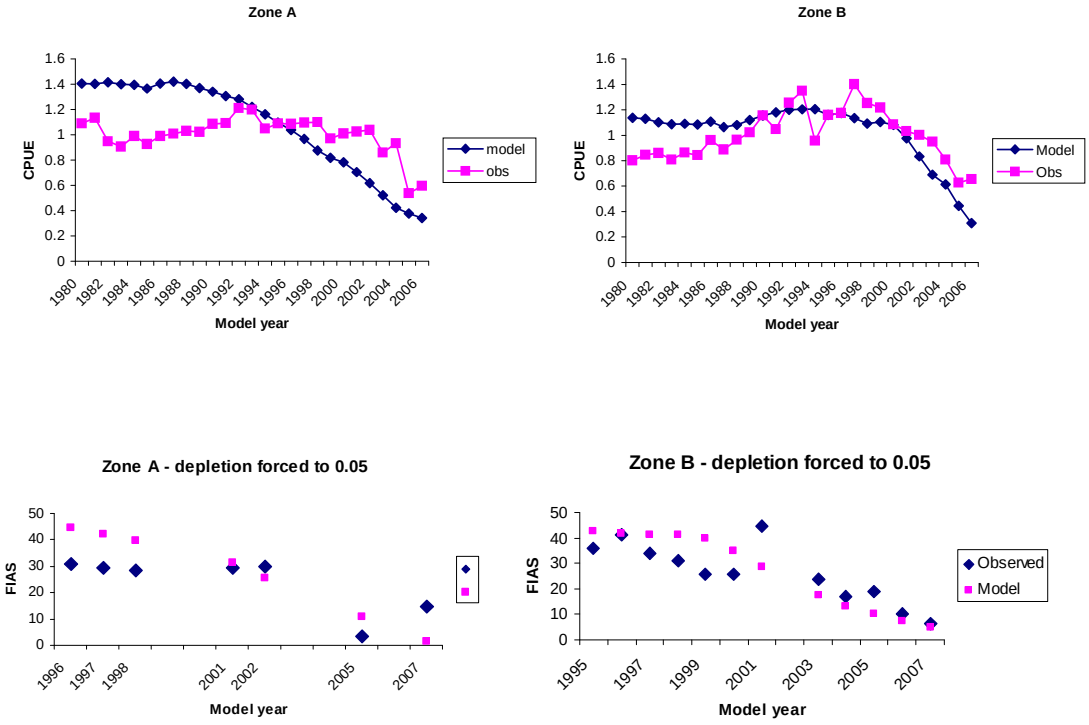
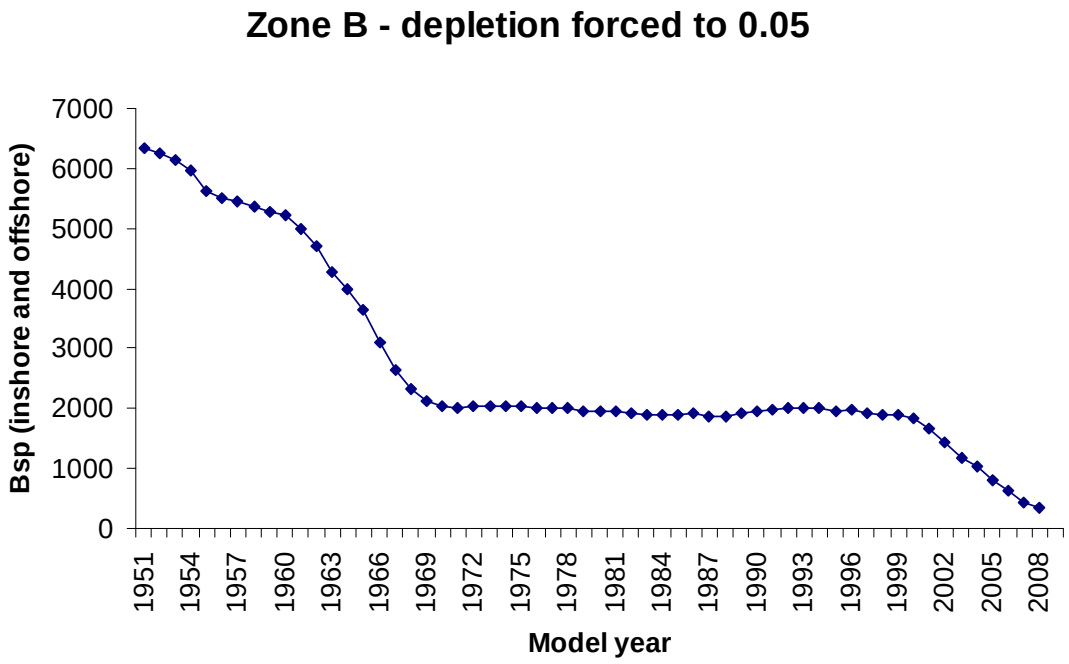


Fig. 1. Model fits under this scenario for Zones A and B. For Zone B, note the poor fit to the CPUE data and FIAS data.



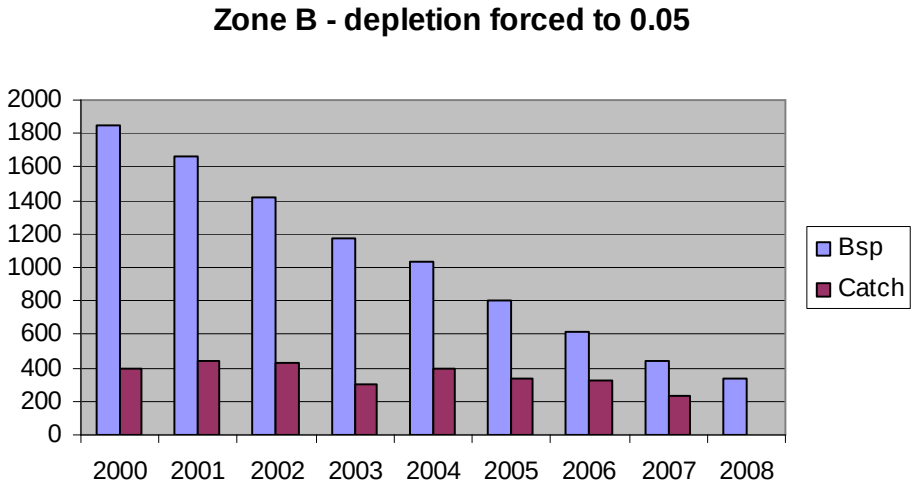


Fig. 2. Figure shows recent catches (largely illegal catches) are about the same size as the total remaining biomass in Zone B, ie. It will be almost completely fished out by the end of the next season. Under this scenario, the remaining spawning biomass in Zone B is approx 340 t, compared to the most recent poaching estimate of 242 t.

Model Reference Case UPDATED fit to FIAS data, following addition of 2008 data and correction to 2004 data point. Still to query discrepancy re 2001 data point.

Fig. 1. Reference case with correction to 2004 data point.

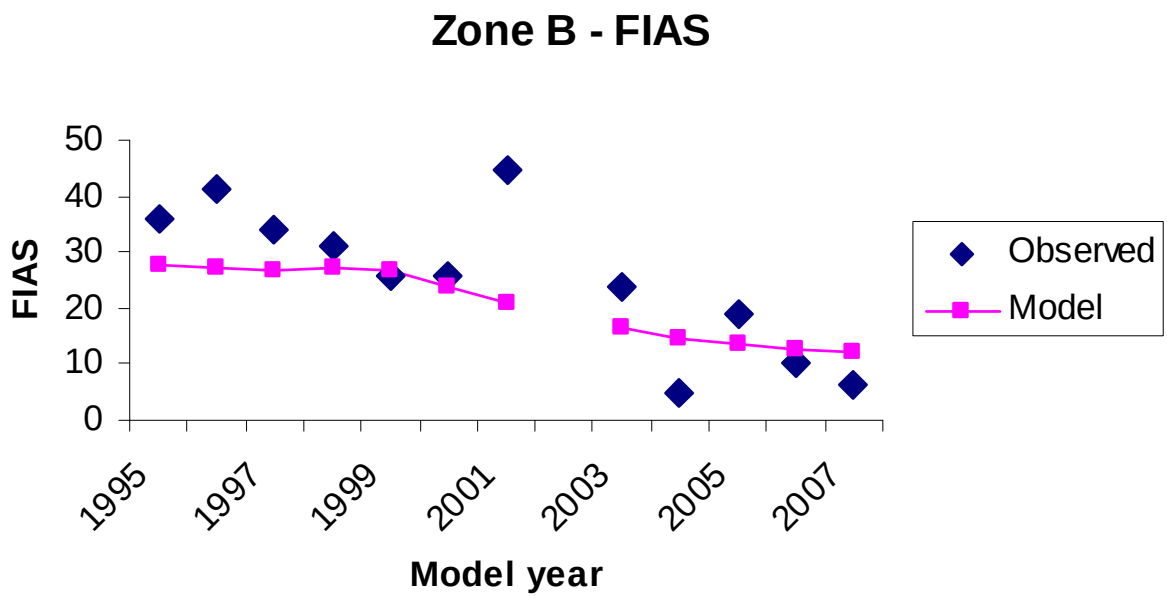


Fig. 2. Reference case with correction to 2004 data point and 2008 included.