Abalone spatial- and age-structured assessment model preliminary results for Zones A, B, C and D in 2008

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SUMMARY

A summary is presented of the results obtained from the 2008 Reference-case model that was fit to Zones A, B, CNP, CP and D in combination (hereafter referred to as the "combined ABCD model"). The full details of the spatial- and age-structured production model (ASPM) are provided in previous documents (Plagányi and Butterworth 2007). The 2008 base-case model uses an updated CPUPE index, and differs from last year's base-case in estimating one more parameter for Zone A (the historic catch multiplier). The results of an "Alternative Policing Efficiency index" model version are also presented, based on the "Pedro case" series as described in document SWG-AB17.

Model base-case results estimate a pristine spawning biomass, B_0^{sp} (in tonnes), of 8185, 5735, 6765 and 9064 for Zones A, B, C and D respectively. The current (inshore+offshore) spawning biomasses of abalone in Zones A, B and D are estimated at ca. 33 %, 35 % and 13 % respectively of their pre-exploitation levels. The "nonpoached" CNP and "poached" CP areas of Zone C are estimated at ca. 5 % and 4 % respectively with the inshore region particularly depleted: the model predicts zero remaining abalone in the inshore CNP, CP and Zone D areas. Equivalent est8imates for Zones A and B are 16% and 32%. Natural mortality is reasonably estimated (e.g. 0.33 yr^{-1} for age 0 and 0.14 yr^{-1} for age 15+) and in Zones C and D, the additional mortality estimated for 0-yr old abalone (due to the ecosystem-change effect) corresponds to near zero current annual survival rates. Poaching is severely impacting the resource, with Zone A particularly impacted in recent years. The combined Zones A-D model-predicted 2008 poaching estimate is 580 MT and corresponds to the assumption that, on average, 23% of all poached abalone are confiscated.

INTRODUCTION

This document provides **preliminary** results from fitting the abalone spatial- and age-structured production model (ASPM) to Zones/Subareas A, B, CNP, CP and D in combination (hereafter referred to as the "combined ABCD model") using the updated 2008 data. The full details of the spatial- and age-structured production model are provided in Appendix 1 and 2 of document WG/AB/07/20. A summary of model parameters is given in Table 1. Table 2 presents a summary of inshore and offshore relative proportions compared with data presented in document SWG-AB/14. This paper focuses on presenting results for the 2008 updated base-case model only.

Parameters

The Reference-case ABCD model estimates the following 30 parameters:

1) B_0^{sp} for A, B, CNP, CP and D [5 parameters]
2) Inshore-offshore migration parameter ρ (CP) [1 parameter]
3) Poaching estimate for yr with assumed highest level of poaching: $CP_{\max}$ estimated for A, B, C (combined), and D. [4 parameters]
4) $\boldsymbol{p_{poach}}$ [1 parameter] – equates roughly to old assumption that 10% of the Zone C poaching take is from CNP;
5) ***Cmult*** – historic catch multiplier for Zone A.
6) $M_a : \mu$ $(\lambda = 0.2)$ where the formulation to model age-dependent mortality rates is $M_a = \mu + \frac{\lambda}{a+1}$. Natural mortality parameter assumed common to all Zones [1 parameter]
7) Two "recruitment failure" effect parameters common to CNP, CP and D: a steepness of recruitment failure parameter ν and a maximum increase in mortality parameter M_{max}. [2 parameters]
8) Three parameters for each of five selectivity functions (assumed common to all Zones) [15 parameters]

RESULTS

Model parameter estimates as well as log-likelihood contributions for the Reference case combined ABCD model and some sensitivities are summarised in Table A.1. The model selectivity functions and fits to the abundance indices are presented in Figs. 1 to 14. A number of additional diagnostics results are presented for purposes of indepth discussion of model results.

Model results for the case presented are similar to last year's assessment except that the resource in Zone A is estimated to be much more depleted following the inclusion of more recent FIAS data and as a consequence of high poaching estimates. The model shows generally reasonable fits to all indices.

Parameter estimates

Model results suggest a pristine spawning biomass, B_0^{sp}, of 2447 and 4318 tonnes respectively for subareas CNP and CP, and hence a total Zone C spawning biomass of ca. 6765 tonnes. The difference in the pristine spawning biomass estimates $B_0^{sp}[CNP]$ and $B_0^{sp}[CP]$ are in the main due to the partitioning of the historic zone C catch data between the two subareas. The pristine spawning biomass estimates for the other zones are on a similar scale to the Zone C estimates, with 8185, 5735 and 9064 tonnes estimated for Zones A, B and D respectively (Table A.1). These values are similar to those used in last year's assessment.

The Reference-case selectivity estimates are illustrated in Fig. 1. The estimated commercial and recreational selectivity functions reflect the fact that the minimum legal size corresponds to an age of approximately 9 years, whereas the estimated poaching selectivity function reflects the fact that sub-legal-size animals are caught. The minimum size of animals caught has been set at 3. The estimated FIAS selectivity function reflects the fact that the FIAS transects are situated inshore where smaller animals occur (Fig. 1).

Based on the results of the Reference-case model, the current spawning biomasses of abalone in Zones A, B and D are estimated at ca. 33 %, 35 % and 13 % respectively of their pre-exploitation levels (Table A.1, Fig. 7). The "nonpoached" CNP and "poached" CP areas of Zone C are estimated at ca. 5 % and 4 % respectively of their pre-exploitation levels. The inshore region is particularly depleted, with the model predicting zero remaining abalone in the inshore Zone C and D areas (Table A.1).

Catch-at-age comparisons

To assist in identifying potential yearly patterns in the catch-at-age residuals, selected standardized residuals ($\varepsilon_{y,a} \rightarrow \frac{\left(\ell n\, p^{i}_{y,a} - \ell n\, \hat{p}^{i}_{y,a}\right)}{\sigma^{i} / \sqrt{\hat{p}^{i}_{y,a}}}$) have been plotted for Zones A and B (Fig. 8). Some indications of systematic effects in the residuals are evident. For example, the model systematically predicts too many too many age 14-15+ abalone corresponding to the recent commercial catch-at-age data for Zones A. This may reflect errors with the cohort slicing or that the model overestimates the number of older abalone. The fits to the Zone A catch-at-age data corresponding to the FIAS and POACHING sector are particularly poor, with the model consistently tending to over-estimate the proportion of animals in the larger age classes and *vice versa* for the smaller age classes. This aspect is currently being explored further.

In general, the patterns of residuals do not indicate any very obvious model-misspecification. However, the selectivity functions may warrant some further exploration to see whether it is possible to improve the residuals for the fits to the proportions-at-age data to reflect better randomness and homoscedasticity.

The poaching sector is thought to have possibly changed its mode of fishing during recent years by moving into deeper waters, and the residuals are currently being examined for any changes in selectivity over time for the poaching sector.

Poaching estimates

Poaching is severely impacting the resource, with Zone A particularly impacted in recent years. The combined Zones A-D model-predicted 2008 poaching estimate is 580 MT and corresponds to the assumption that, on average, 23% of all poached abalone are confiscated. See Figs. 14 and 15.

Table 1. Summary description of model parameters and definitions of other abbreviated terms utilised in the text.

Parameter	Description	Units
$B_0^{sp} = K$	Pre-exploitation (assumed to be 1951) spawning biomass	MT
B^{sp}, B_{insh}^{sp}, B_{offsh}^{sp}	Spawning biomass (total per zone), Inshore spawning biomass, Offshore spawning biomass	MT
ρ	Rate at which inshore animals move offshore at the start of each Model year	yr^{-1}
r_I	Proportion of the recruits which settle inshore	-
$CP_{\max}$ (number) (zone)	The total number of abalone poached in the year corresponding to the poaching maximum for the zone under consideration	no.
$CP_{\max}$ (MT) (zone)	The poaching maximum in terms of mass	MT
C_{mult}	Historic catch multiplier for Zone A	-
p_{poach}	Parameter that specifies the relative exploitation rate effected by poachers in subareas CP and CNP	-
$M_a : \mu$ $(\lambda = 0.2)$ $\left(M_a = \mu + \frac{\lambda}{a+1}\right)$	Age-dependent mortality rate parameters; M_0 is the mortality rate of 0-yr old animals; M_{15} is the plus group mortality rate etc.	yr^{-1}
υ	Parameter that controls the steepness of the function describing an increase in 0-yr old mortality due to the ecosystem-change effect	-
$M_{\max}$	Maximum increase in 0-yr old mortality rate due to the ecosystem-change effect	yr^{-1}
$\hat{a}$ (sector)	Selectivity parameter for sector as indicated; shifts the selectivity function to the left or right	-
μ (sector)	Selectivity parameter that controls the slope of the right hand limb of the function	-
δ (sector)	Selectivity parameter that controls the steepness of the ascending left hand limb of the selectivity function.	-
<u>Other definitions</u>		
Zone	Fishery area / management unit: Zones A-G	
CNP, CP	Two subareas comprising Zone C, with CNP subject to less poaching historically than CP	
FIAS	Fishery Independent Abalone Survey	
FIAS N_{2006}/N_{1951}	FIAS depletion statistics expressing depletion in terms of *number* rather than mass	
CS	Commercial sector	
RS	Recreational sector	
PS	Poaching sector (corresponding to illegal catches)	
FS	Parameters pertaining to FIAS	
OS	Parameters pertaining to the Old Surveys conducted during the 1980's	
IS	Industry/MCM joint full population surveys conducted in 2002	
Co/Po_{yr}	Confiscations (i.t.o. number) as a proportion of the model-estimated number of animals poached in year *yr*.	
CI	Confidence Interval (typically 95% CI) determined by likelihood profile method	
MSY	Maximum Sustainable Yield	
MSYL	Maximum Sustainable Yield Level	
TAC	Total Allowable Catch (annual catch allocation)	

Table 2. Comparison of observed and model-estimated proportions inshore vs offshore for Zones A and B.

	MODEL (1987) Zone A	OBS (1980-87) Zone A	MODEL (1987) Zone B	OBS (1980-87) Zone B
Inshore percentage	70.3%	85.0%	74.0%	75.8%
Offshore percentage	29.7%	15.0%	26.0%	23.6%

Table A.1. Best fit estimates of the pre-exploitation spawning biomass B_0^{sp} (or *K*) for the "poached" CP and "nonpoached" CNP areas of Zone C, and for each of Zones A, B and D, the estimated natural mortality estimates M_a, the inshore-offshore migration parameters ρ (yr^{-1}), the proportions of recruitment in each subarea that occur inshore versus offshore r_I, and the poaching maximum CP_{max} (i.t.o. NUMBERS). The CP_{max} estimates are also shown in terms of biomass and the years to which these estimates apply are given in the row below. Minimum values of the negative of the log-likelihood function are also shown. The estimated selectivity parameters are shown for the commercial sector (CS), recreational sector (RS), poaching sector (PS), FIAS (FS) and the old 1980's survey (OS). Note that for the 2002 industry survey (IS), $S_a^{IS} = 1$. Note also that all *-ln*L contributions from catch-at-age data have been multiplied by 0.1 as an *ad hoc* adjustment to compensate for likely positive correlation in these data.

Model	a) Ref. case					b) Ref. with Cmult fixed at 1.5					c) Alternative Policing Efficiency				
No. parameters			30					30					30		
Zone	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
Ave confiscation %	16%	61%	9%		7%	17%	56%	9%		6%	12%	66%	9%		8%
$B(0)^{sp}$	8185	5735	2447	4318	9064	7534	5785	2395	4342	9577	9452	6054	2291	4184	11243
ρ	0.038	0.038	0.038	0.019	0.038	0.041	0.041	0.041	0.021	0.041	0.049	0.049	0.049	0.025	0.049
r^I	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Cpmax (no.)	1582490	8.44E+05		545000	673354	1456570	9.20E+05		566932	761512	1447500	1.03E+06		565870	1029420
Cpmax (MT)	500	403		272	411	428	405		270	455	649	473		274	565
Cpmax (YEAR)	2007	2002		1995	2002	2007	2002		1995	2002	2006	2002		1997	2002
CP(2008) (MT)	470	109		0	0	407	109		0	1	617	97		0	117
Cmult (Zone A)	2.18					1.50					1.50				
Ppoach			0.90					0.90					0.89		
M_0			0.326					0.326					0.337		
M_{15}			0.138					0.138					0.149		
ν (steepness of recruitment failure)			0.2677					0.2573					0.2533		
Mmax (Recruitment failure scale parameter|)			13.9579					13.9584					13.9533		
h	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
a(CS)			8.99944					8.9995					8.99945		
a(RS)			8.99619					8.99349					8.99813		
a(PS)			4.90516					4.56357					4.90337		
a(FS)			6.14103					6.45032					6.46786		
a(OS)			5.25305					4.91528					4.67841		
a(IS)			-					-					-		
μ(CS)			0.000271					0.000365					0.000418		
μ(RS)			0.001004					0.001001					0.000936		
μ(PS)			1.28E-13					0.000138					2.29E-05		
μ(FS)			0.001331					0.001396					0.001338		
μ(OS)			8.93E-13					1.99E-12					1.32E-12		
μ(IS)			-					-					-		
δ(CS)			973.306					997.543					897.705		
δ(RS)			91.0156					51.1236					164.318		
δ(PS)			306.2					1.17438					306.198		
δ(FS)			0.820938					0.805429					0.765695		
δ(OS)			0.562009					0.61593					0.638251		
δ(IS)			-					-					-		

Model	a) Ref. case					b) Ref with Cmult fixed					c) Alternative Policing Efficiency				
	A	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
-*ln* L CPUE	-49.794	-51.089	-34.931	-44.903	-34.321	-45.175	-50.489	-35.027	-44.827	-33.973	-42.991	-46.291	-35.448	-44.913	-33.645
-*ln* L FIAS	0.018	-0.142	-3.300	4.093	-3.471	-0.432	-0.505	-3.529	4.185	-3.592	-0.183	1.415	-3.296	3.871	-3.285
-*ln* L age CS	-16.472	-19.067	-8.583	-10.275	-11.496	-17.065	-19.273	-8.623	-10.435	-11.595	-16.732	-20.010	-8.555	-9.239	-11.531
-*ln* L age RS	-1.665	-8.060	-7.056	0.016	-8.564	-1.635	-8.072	-7.011	-0.006	-8.739	-1.638	-8.149	-7.134	0.054	-8.544
-*ln* L age PS	-4.288	-3.797		-0.781	-3.193	-4.707	-3.367		-0.962	-3.559	-4.465	-3.269		-1.403	-3.587
-*ln* L age FIAS	-3.633	-9.488	-4.587	-0.391	-4.894	-2.356	-9.743	-4.535	-0.416	-5.264	-2.400	-9.350	-4.196	-0.348	-5.143
-*ln* L age OS inshore	-3.594	-1.072		-1.248	-0.839	-3.535	-1.080		-1.294	-0.915	-3.234	-0.997		-1.308	-1.081
-*ln* Lage OS offsh.	-3.527	-1.664		-1.420	-1.741	-3.646	-1.709		-1.401	-1.844	-3.345	-1.459		-1.239	-2.057
-*ln* L age IS insh+offsh.		-1.059	-0.981				-0.996	-0.871				-1.106	-0.870		
-*ln* L zone subtotal	-82.955	-95.437	-114.346		-68.519	-78.550	-95.233	-114.752		-69.481	-74.988	-89.216	-114.023		-68.873
-*ln* L TOTAL			-361.257					-358.016					-347.099		
σ CPUE	0.098	0.093	0.153	0.064	0.173	0.116	0.095	0.152	0.064	0.176	0.126	0.111	0.150	0.064	0.178
σ age CS	0.082	0.074	0.114	0.096	0.099	0.079	0.073	0.113	0.095	0.098	0.081	0.070	0.114	0.103	0.099
σ age RS	0.113	0.057	0.059	0.208	0.062	0.114	0.057	0.059	0.201	0.060	0.114	0.056	0.058	0.219	0.062
σ age PS	0.104	0.125		0.176	0.109	0.099	0.132		0.171	0.102	0.102	0.133		0.161	0.101
σ age FIAS	0.107	0.078	0.082	0.130	0.093	0.123	0.071	0.083	0.129	0.088	0.122	0.074	0.088	0.132	0.089
σ OS insh.	0.034	0.063		0.054	0.081	0.035	0.062		0.052	0.075	0.040	0.067		0.051	0.065
σ OS offsh.	0.040	0.044		0.051	0.038	0.038	0.042		0.052	0.036	0.043	0.051		0.059	0.030
σ IS		0.034	0.052				0.036	0.060				0.032	0.060		
Additional variance	0.462					0.444					0.483				
q CPUE	0.000307	0.000639	0.003559	0.001022	0.000271	0.000319	0.000631	0.003518	0.00101	0.000253	0.000236	0.000538	0.003202	0.00104	0.000203
Confiscation percentage			Zone C					Zone C					Zone C		
$\%Co/Po_{1997}$		0.25	0.05		0.03		0.23	0.05		0.03		0.34	0.07		0.05
$\%Co/Po_{1998}$		0.31	0.07		0.05		0.28	0.07		0.04		0.16	0.08		0.03
$\%Co/Po_{1999}$		0.07	0.06		0.02		0.06	0.06		0.02		0.19	0.05		0.02
$\%Co/Po_{2000}$	0.12	0.30	0.13		0.07	0.13	0.27	0.13		0.06	0.13	0.22	0.07		0.03
$\%Co/Po_{2001}$	0.05	0.23	0.06		0.04	0.06	0.21	0.06		0.03	0.10	0.04	0.06		0.01
$\%Co/Po_{2002}$	0.13	0.52	0.08		0.06	0.14	0.48	0.08		0.05	0.07	0.20	0.13		0.04
$\%Co/Po_{2003}$	0.10	0.44	0.09		0.09	0.11	0.40	0.08		0.08	0.03	0.16	0.06		0.02
$\%Co/Po_{2004}$	0.11	0.48	0.10		0.04	0.12	0.44	0.10		0.04	0.09	0.43	0.08		0.04
$\%Co/Po_{2005}$	0.09	0.53	0.09		0.07	0.10	0.49	0.09		0.06	0.10	0.46	0.08		0.07
$\%Co/Po_{2006}$	0.16	0.73	0.09		0.09	0.17	0.67	0.09		0.08	0.13	0.66	0.10		0.06
$\%Co/Po_{2007}$	0.26	0.78	0.07		0.07	0.28	0.72	0.07		0.06	0.11	0.74	0.09		0.09
$\%Co/Po_{2008}$	0.17	0.54	0.10		0.07	0.18	0.50	0.10		0.06	0.18	1.00	0.09		0.11
Ave prop over last 5 yrs	**0.16**	**0.61**	**0.09**		**0.07**	**0.17**	**0.56**	**0.09**		**0.06**	**0.12**	**0.66**	**0.09**		**0.08**

Table 1 continued. Depletion statistics.

Model	a) Ref. case					b) Ref with Cmult fixed					c) Alternative Policing Efficiency				
	A	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
Catches	579.8	24	24.15892			516.8	24	21.53299			644.2	24	26.84316		
Ccomm(2008)	0	24	0	0	0	0	24	0	0	0	0	24	0	0	0
Cpoa(2008)	470.3	109.3	0.0	0.0	0.3	407.4	108.7	0.0	0.0	0.7	491.1	88.1	0.0	0.0	65.0
Catch total (2008) MT	470.3	133.3	0.0	0.0	0.3	407.4	132.7	0.0	0.0	0.7	491.1	112.1	0.0	0.0	65.0
	A	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
Depletion comp. yr	1986/87	1982		1981	1983	1986/87	1982		1981	1983	1986/87	1982		1981	1983
Insh OBS	0.33	0.67		0.33	0.36	0.33	0.67		0.33	0.36	0.33	0.67		0.33	0.36
Insh PRED	0.74	0.54		0.45	0.70	0.78	0.55		0.45	0.72	0.85	0.63		0.48	0.79
Offsh OBS	0.20	0.54		0.24	0.50	0.20	0.54		0.24	0.50	0.20	0.54		0.24	0.50
Offsh PRED	0.58	0.35		0.25	0.58	0.65	0.36		0.25	0.61	0.73	0.41		0.26	0.68
Model	a) Ref. case					b) Ref with Cmult					c) Alternative Policing Efficiency				
Depletion statistics															
$B^{sp}(2008)/K$ (Insh. + Offsh)	0.33	0.35	0.05	0.04	0.13	0.35	0.34	0.06	0.04	0.14	0.43	0.43	0.07	0.04	0.14
$B^{sp}(2008)/K$ (Insh.)	0.16	0.32	0.00	0.00	0.00	0.19	0.31	0.00	0.00	0.00	0.31	0.43	0.00	0.00	0.01
$B^{sp}(2008)/K$ (Offsh.)	0.59	0.40	0.15	0.20	0.34	0.59	0.40	0.16	0.20	0.35	0.62	0.44	0.16	0.20	0.35
$B^{total}(2008)/K$	0.38	0.40	0.05	0.04	0.12	0.39	0.39	0.05	0.04	0.13	0.48	0.48	0.06	0.04	0.13
$B^{commercial}(2008)/K$	0.29	0.24	0.07	0.05	0.16	0.31	0.25	0.07	0.05	0.17	0.38	0.32	0.08	0.06	0.19
FIAS N_{2008}/N_{1951}	0.14	0.46	0.00	0.00	0.00	0.18	0.43	0.00	0.00	0.00	0.33	0.57	0.00	0.00	0.00

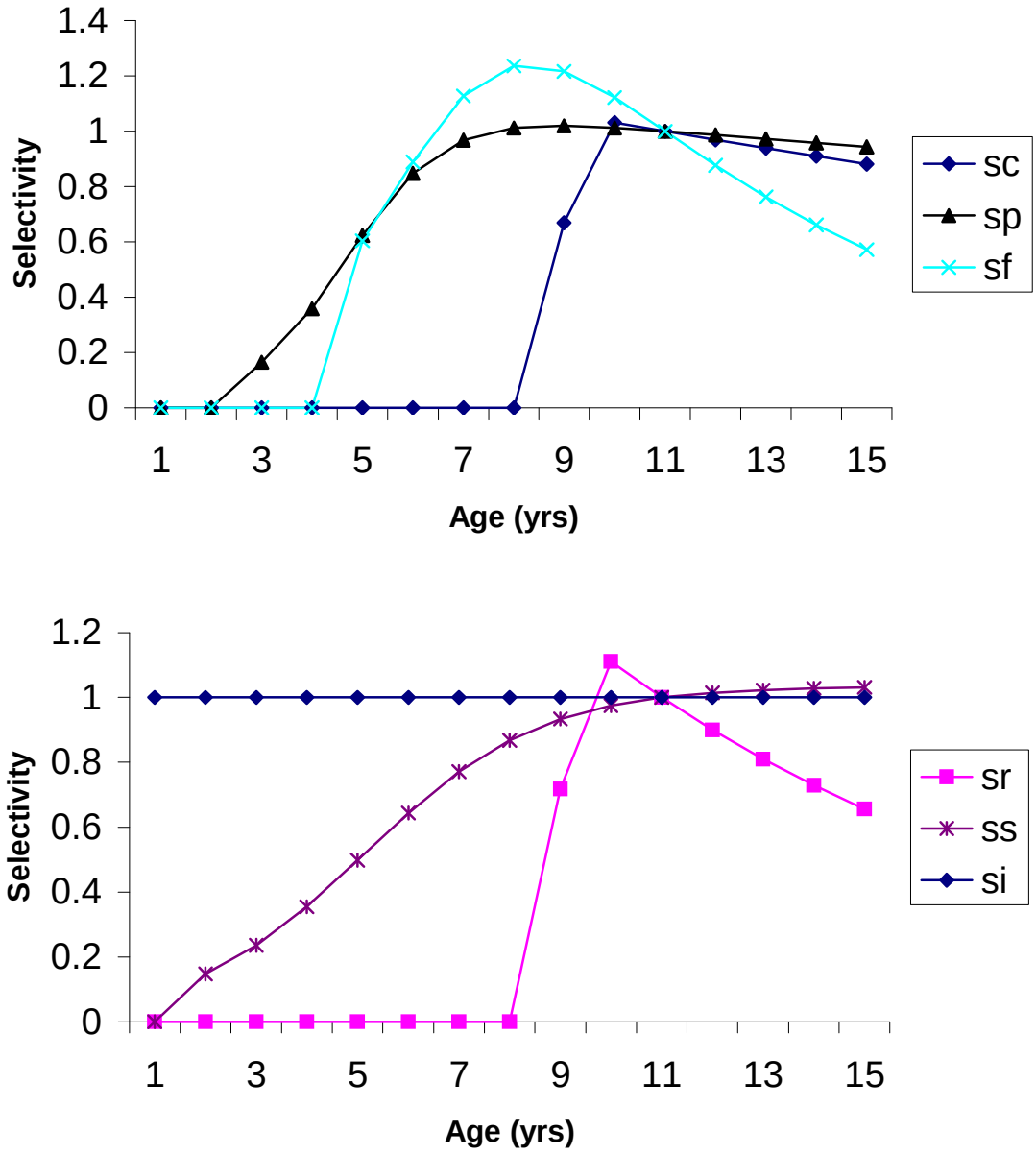


Fig. 1. Plots of the Reference-case combined ABCD model selectivity functions estimated for the commercial (sc), recreational (sr) and poaching (sp) fishery sectors, and for FIAS (sf) and the old 1980's surveys (ss). A description of the general functional form used is given in Appendix 1 and the fitted parameter values are listed in Table 4. A uniform value is assumed for the industry/MCM survey (si) because of the extractive nature of the sampling methodology used.

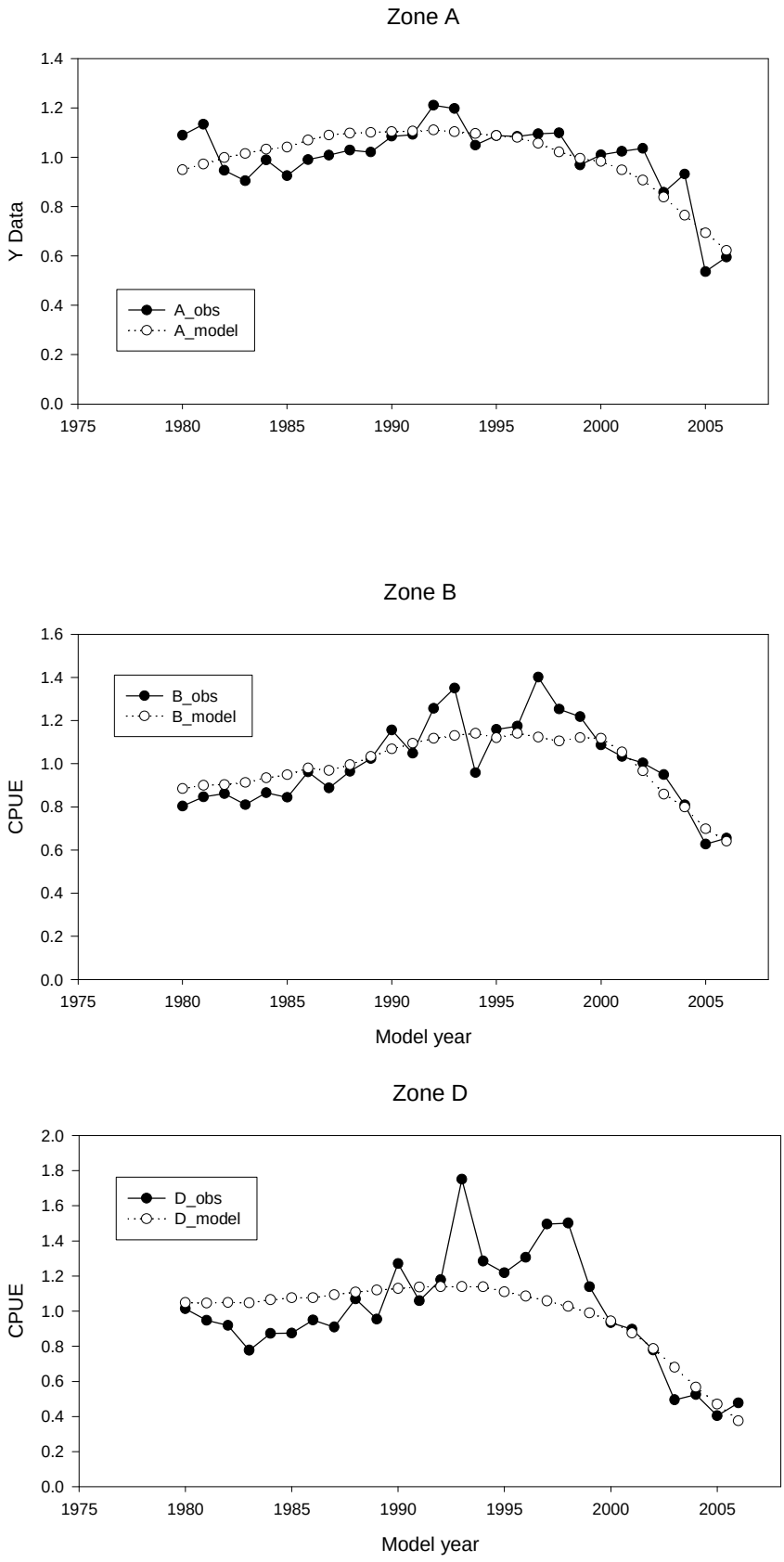
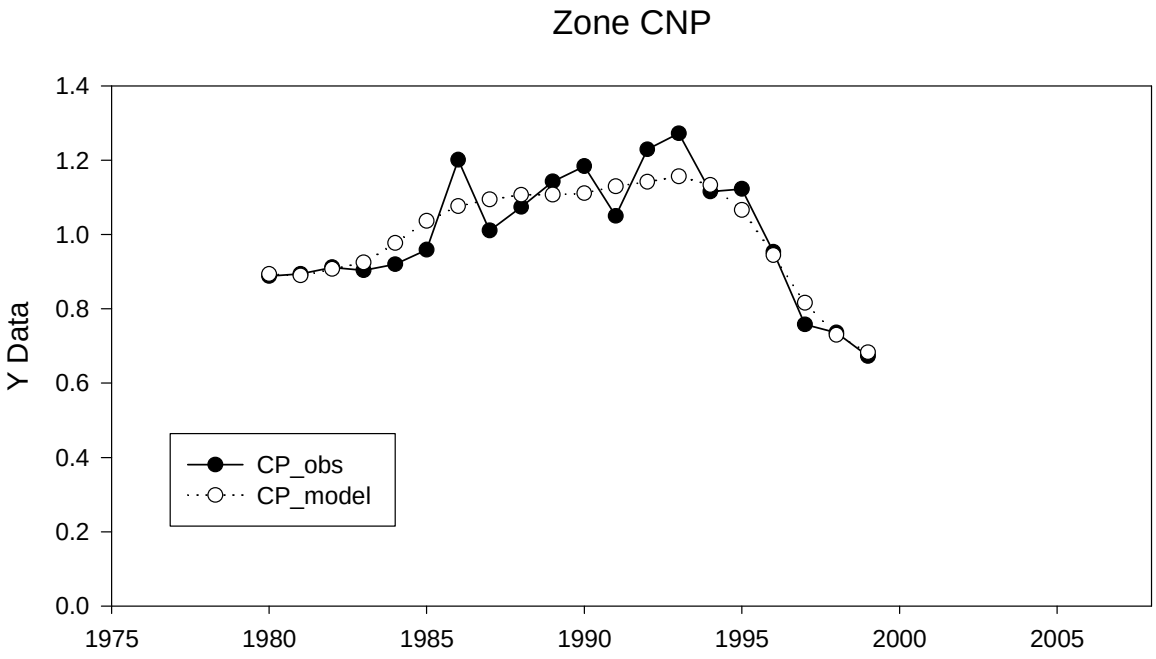


Fig. 2. Comparisons between the standardised CPUE and model-predicted CPUE values (for the Reference-case combined ABCD model) for each of Zones A, B and D.



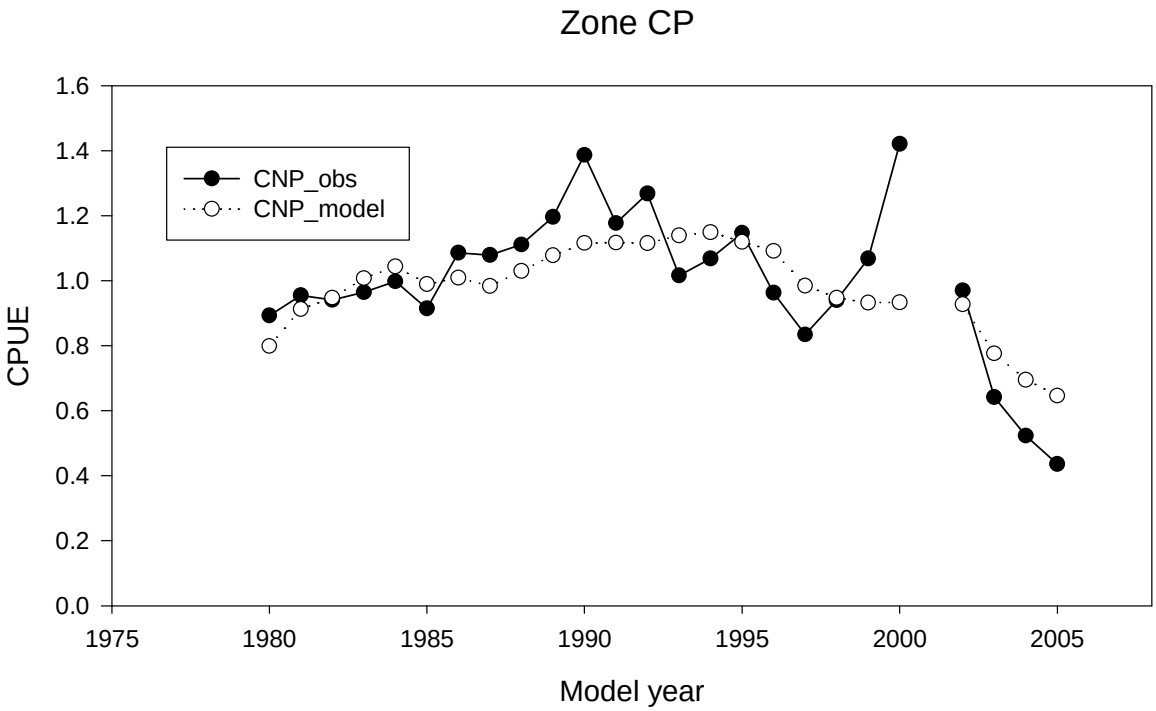


Fig. 3. Comparisons between the standardised CPUE and model-predicted CPUE values (for the Reference-case combined ABCD model) for each of Zones CNP and CP.

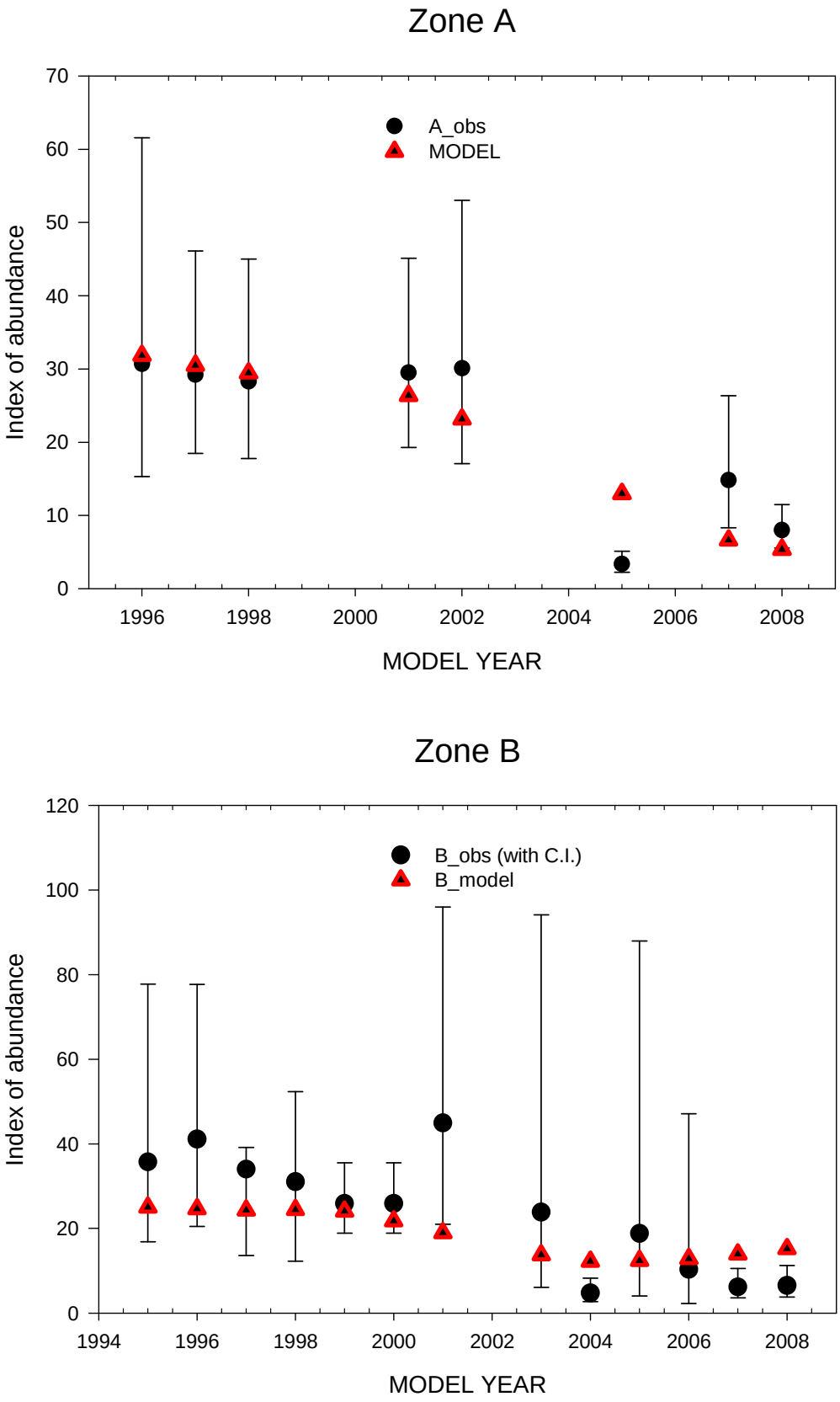


Fig. 4 Comparison of model-predicted (Reference-case combined ABCD model) and observed FIAS trends for each of Zones A and B. Note that 95% confidence intervals have been computed as estimate*exp(±1.96*CV).

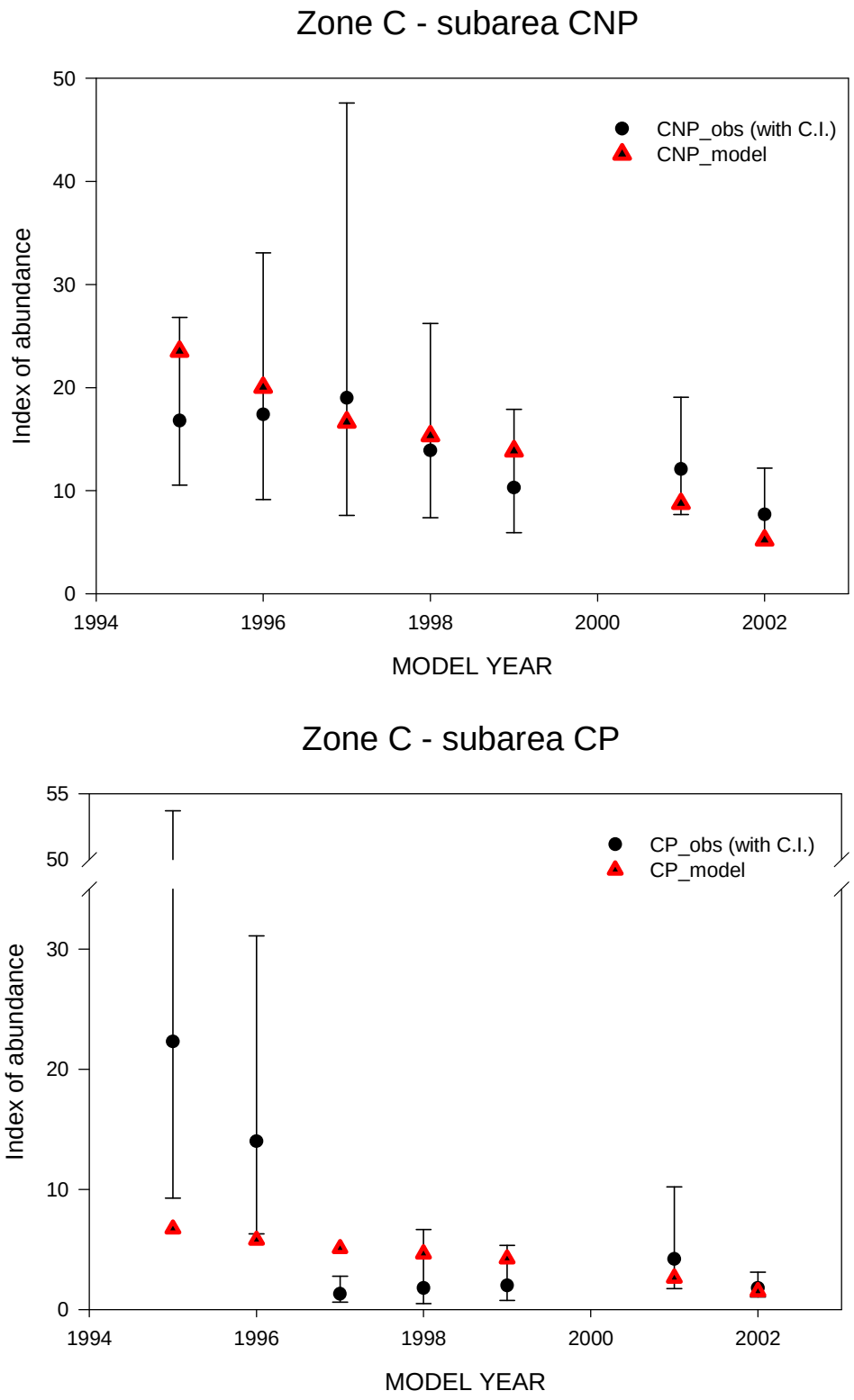


Fig. 5. Comparison of model-predicted (Reference-case combined ABCD model) and observed FIAS trends for each of subareas CNP and CP in Zone C. Note that 95% confidence intervals have been computed as estimate*exp(±1.96*CV). Note the break inserted on the y-axis for subarea CP for ease of viewing purposes (because it allows amplification of the rest of the figure).

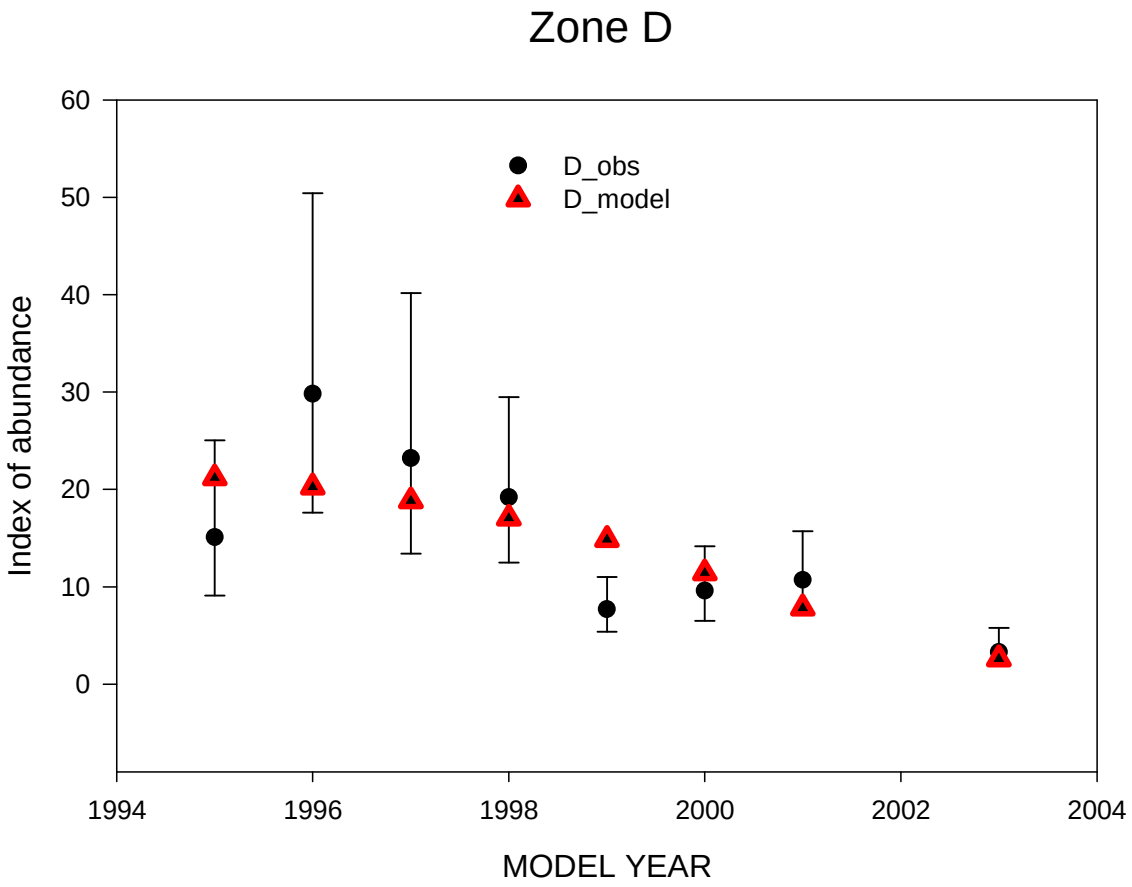


Fig. 6. Comparison of model-predicted (Reference-case combined ABCD model) and observed FIAS trends for each of Zone D. Note that 95% confidence intervals have been computed as estimate*exp(±1.96*CV).

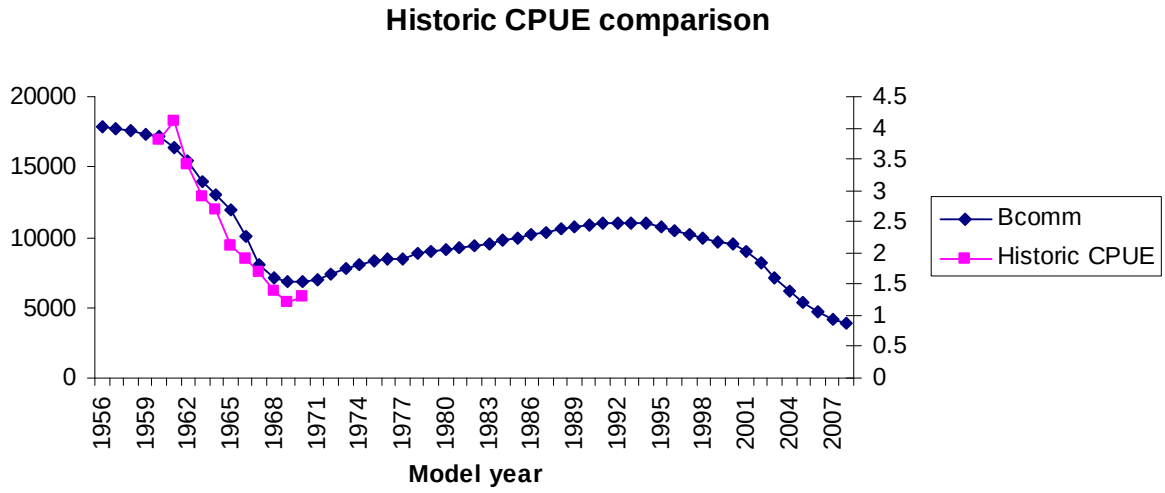


Fig. 7. Historic CPUE Comparison with Zones A-D combined commercial exploitable biomass trajectory.

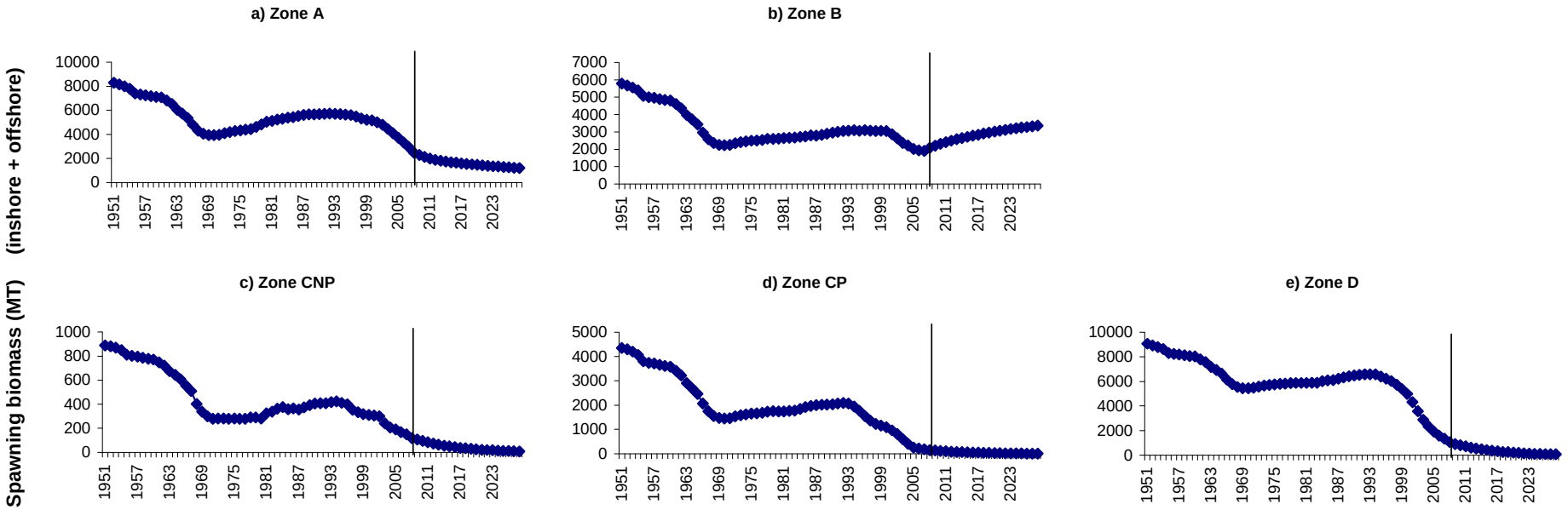


Fig. 8. Reference-case combined ABCD model total (inshore + offshore) spawning biomass trajectories shown for Zones A to D. Note that the 20-yr projections shown (indicated by vertical bar) represent scenarios under which future poaching levels are assumed to remain at the current estimated level (average of 2007 and 2008) and future commercial catches are set to zero.

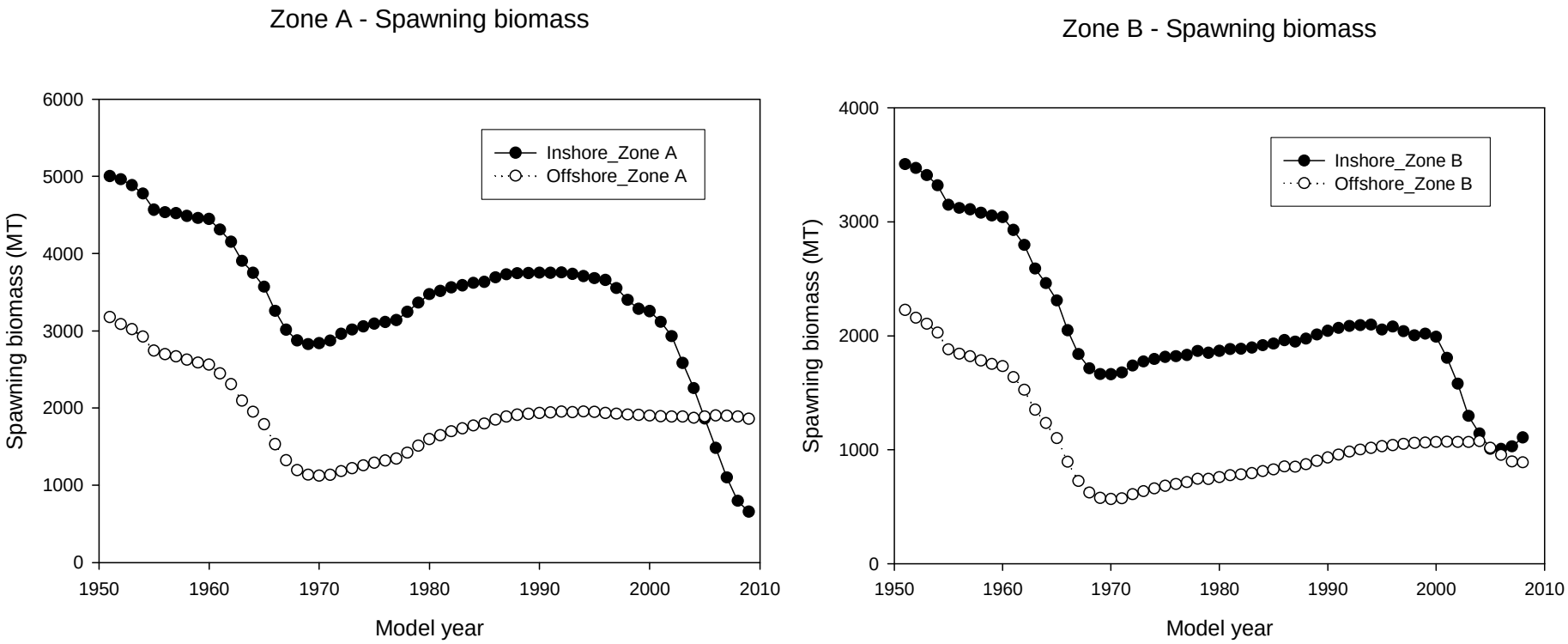


Fig. 9. Spawning biomass trajectories for the inshore and offshore components of Zones A and B, from the base-case model.

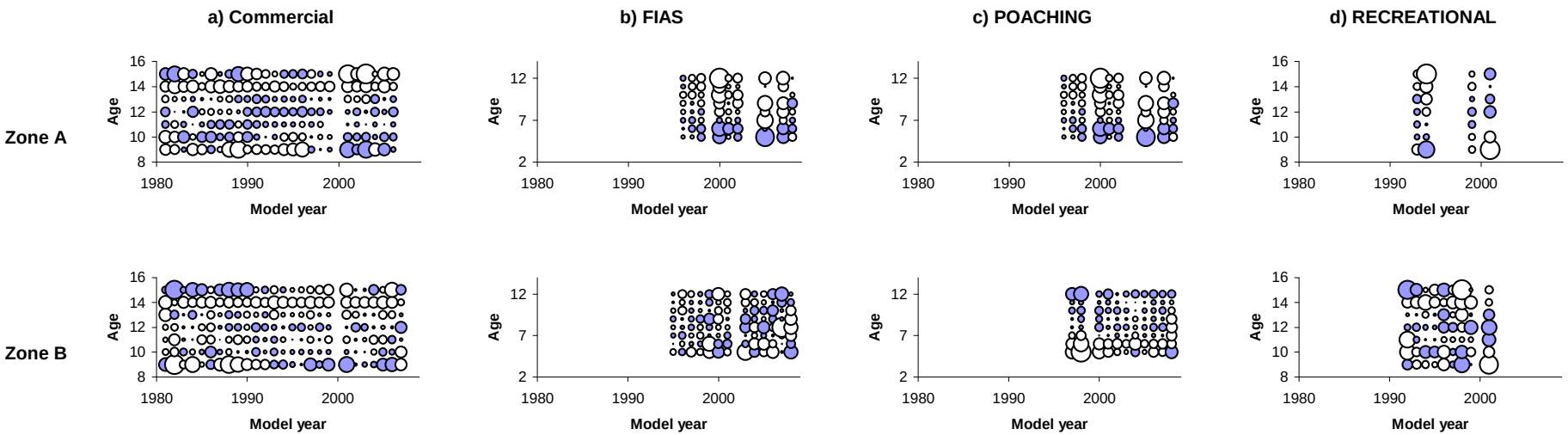


Fig . 10. Catch-at-age residuals for Zones A and B for a) the commercial data, b) the FIAS data, c) the recreational data and d) the poached sector (based on confiscation data) for the base-case combined ABCD model. The size (radius) of the "bubble" in the plots is proportional to the corresponding standardized residual ((ln(obs)-ln(pred))/(sigma/sqrt(pred))). White bubbles represent negative residuals and grey bubbles represent positive residuals.

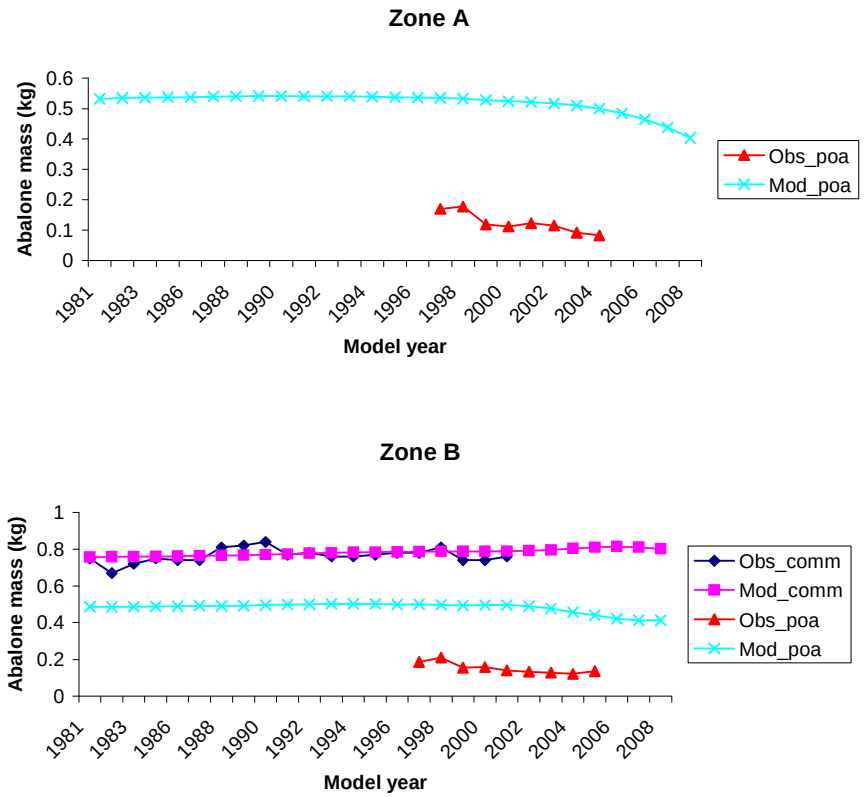


Fig. 11. Comparison of observed and model-predicted average mass (kg) of abalone in the commercial catch and from illegal confiscations.

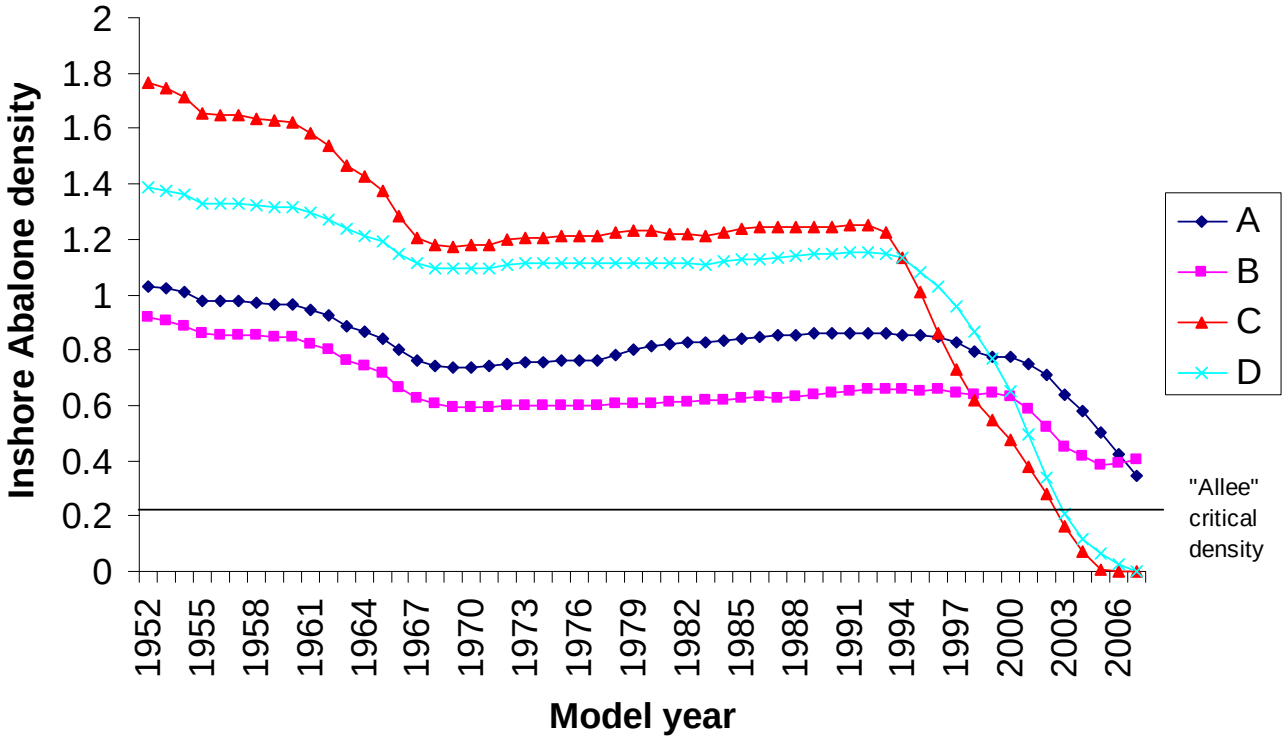


Fig. 12. Model-estimated densities per Zone.

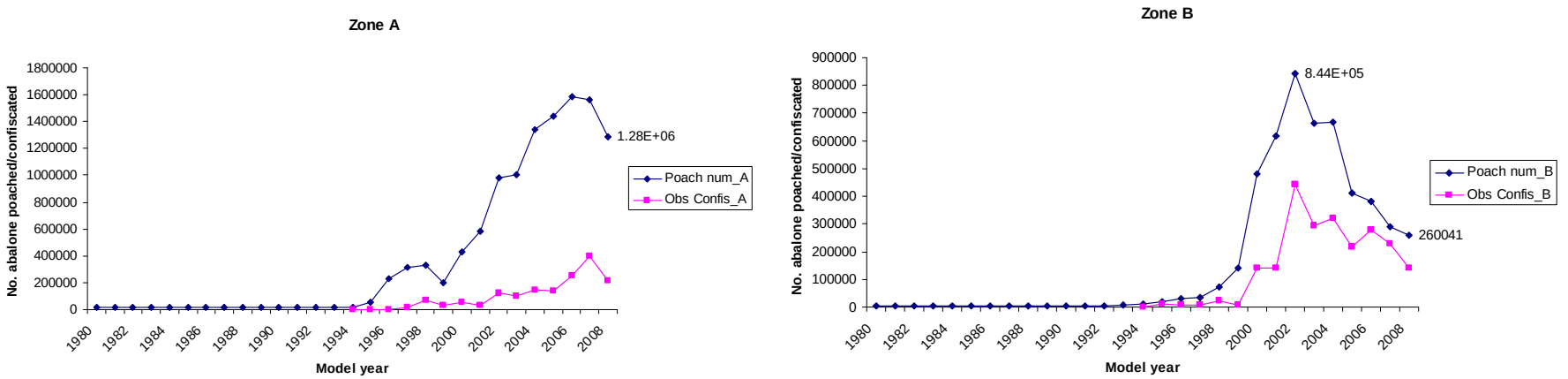


Fig . 13. Comparison of model-predicted numbers of abalone poached per Zone A and B with "observed" numbers confiscated (after allocating confiscated abalone from the Unknown category to each of Zones A-D). The numerical value (units are numbers) corresponding to selected points on the graph is given.

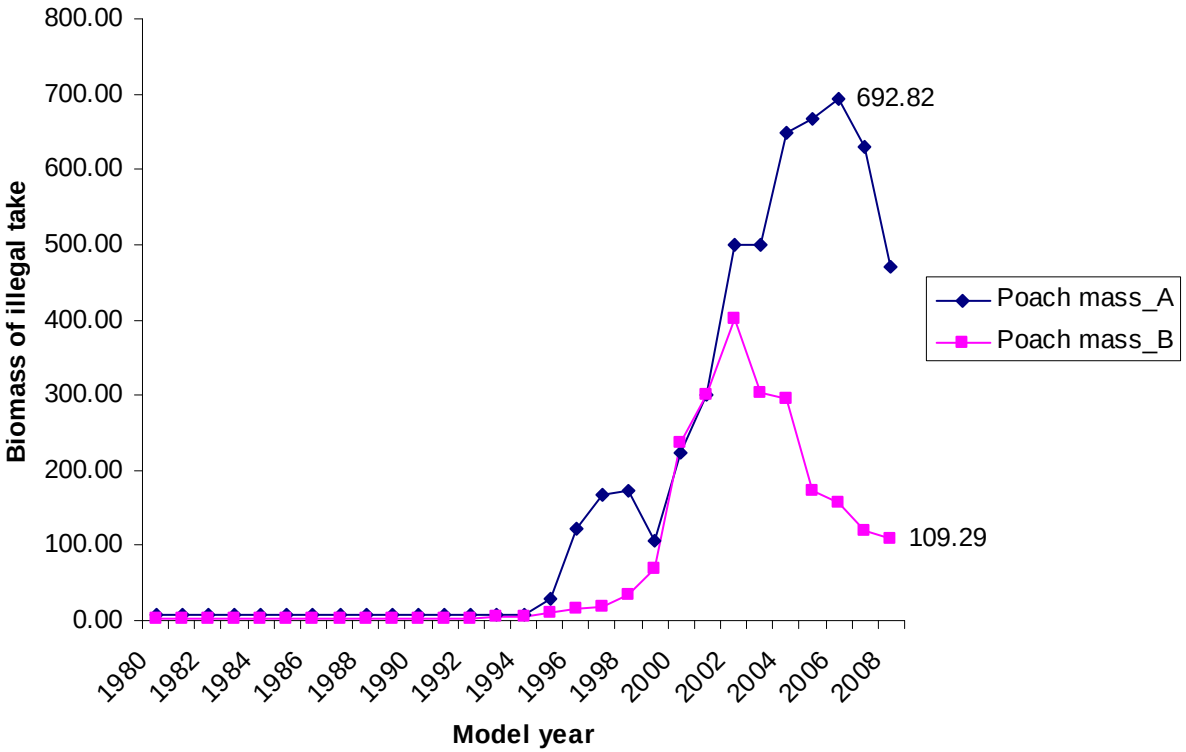


Fig . 14. Model-predicted **biomass** of abalone poached per Zone.

APPENDIX TO Abalone spatial- and age-structured assessment model preliminary results for Zones A, B, C and D in 2008

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Table A.2. Summary of the uncertainty associated with key model results when using the 2008 base-case assessment model.

Parameter	Value	90% Confidence Interval	
$B(2009)^{sp}/B(0)^{sp}$ *(zone A)*	0.33	0.27	0.39
$B(2009)^{sp}/B(0)^{sp}$ *(zone B)*	0.35	0.29	0.41
$B(0)^{sp}$ *(A)*	8185	5767	10604
$B(0)^{sp}$ *(B)*	5735	5326	6145
$B(0)^{sp}$ *(C)*	6765	6352	7179
$B(0)^{sp}$ *(D)*	9064	6575	11552
$B(current)^{sp}$ *(A)*	2683	1536	3830
$B(current)^{sp}$ *(B)*	1995	1601	2389
$B(current)^{sp}$ *(C)*	300	222	379
$B(current)^{sp}$ *(D)*	1203	646	1760

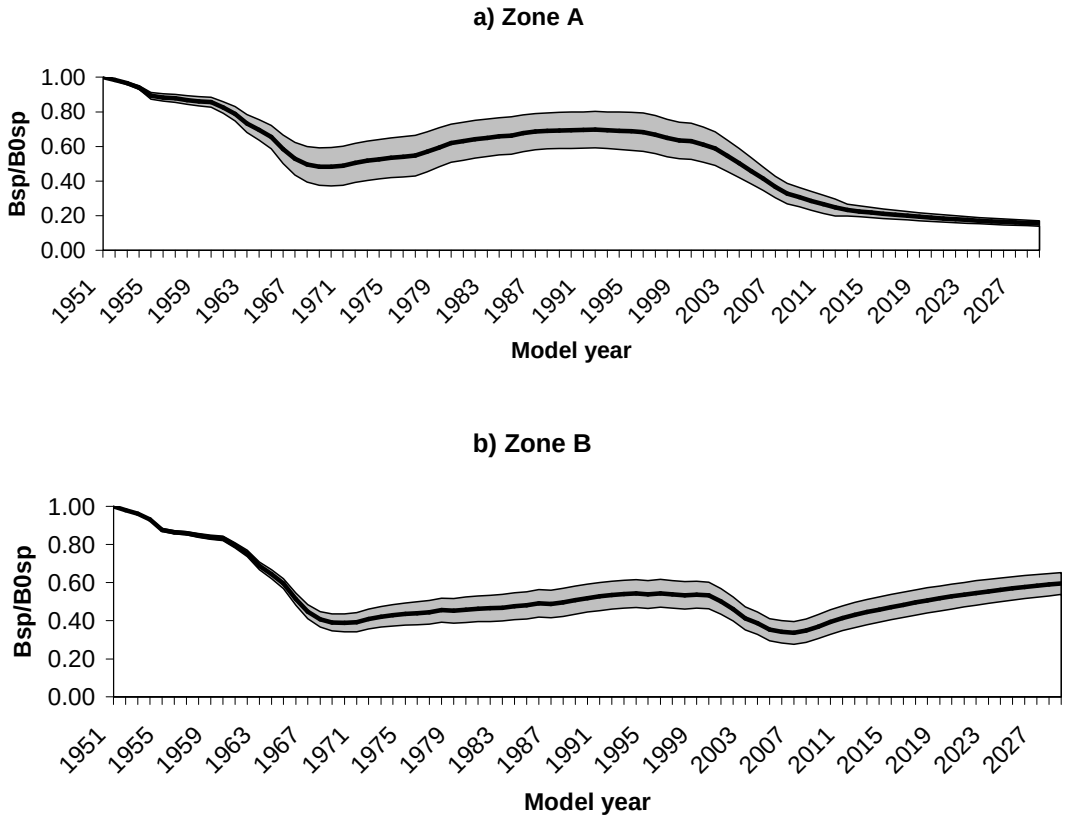

Fig. A.1. Total spawning biomass trajectories (inshore and offshore combined shown as a proportion of the pre-exploitation level) for a) Zone A and b) Zone B from the 2008 base-case model.. The shaded areas represent the associated Hessian-based 90% probability intervals. Projections assume future commercial catches are set to zero and that poaching levels in the future continue at the current estimated level.

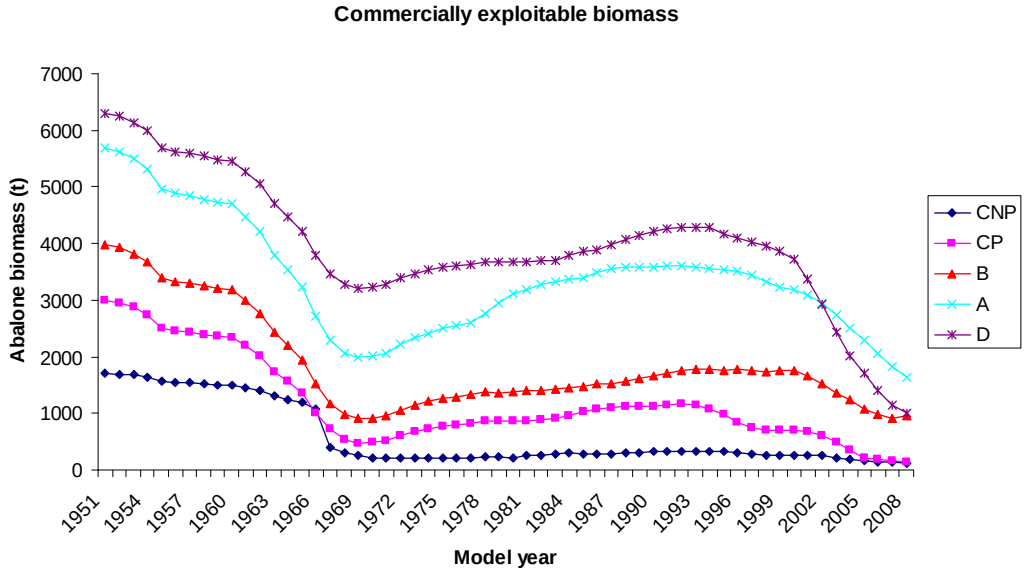

Fig. A.2. Comparison of abalone commercial exploitable biomass in Zones as indicated.

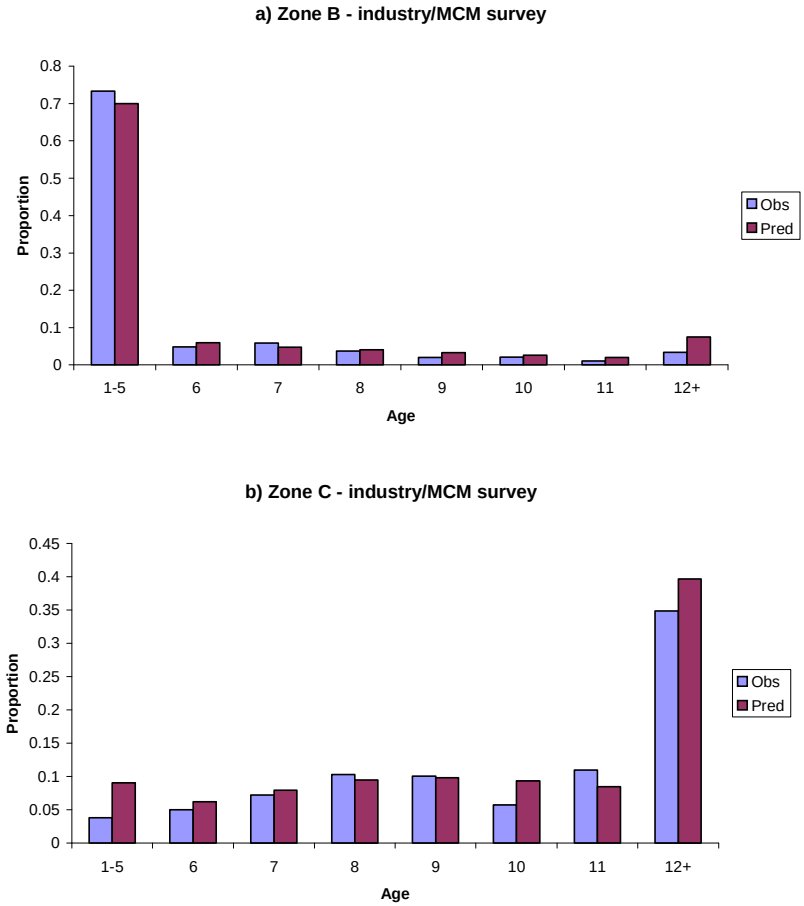

Fig. A.3. Fit to industry/MCM survey data.

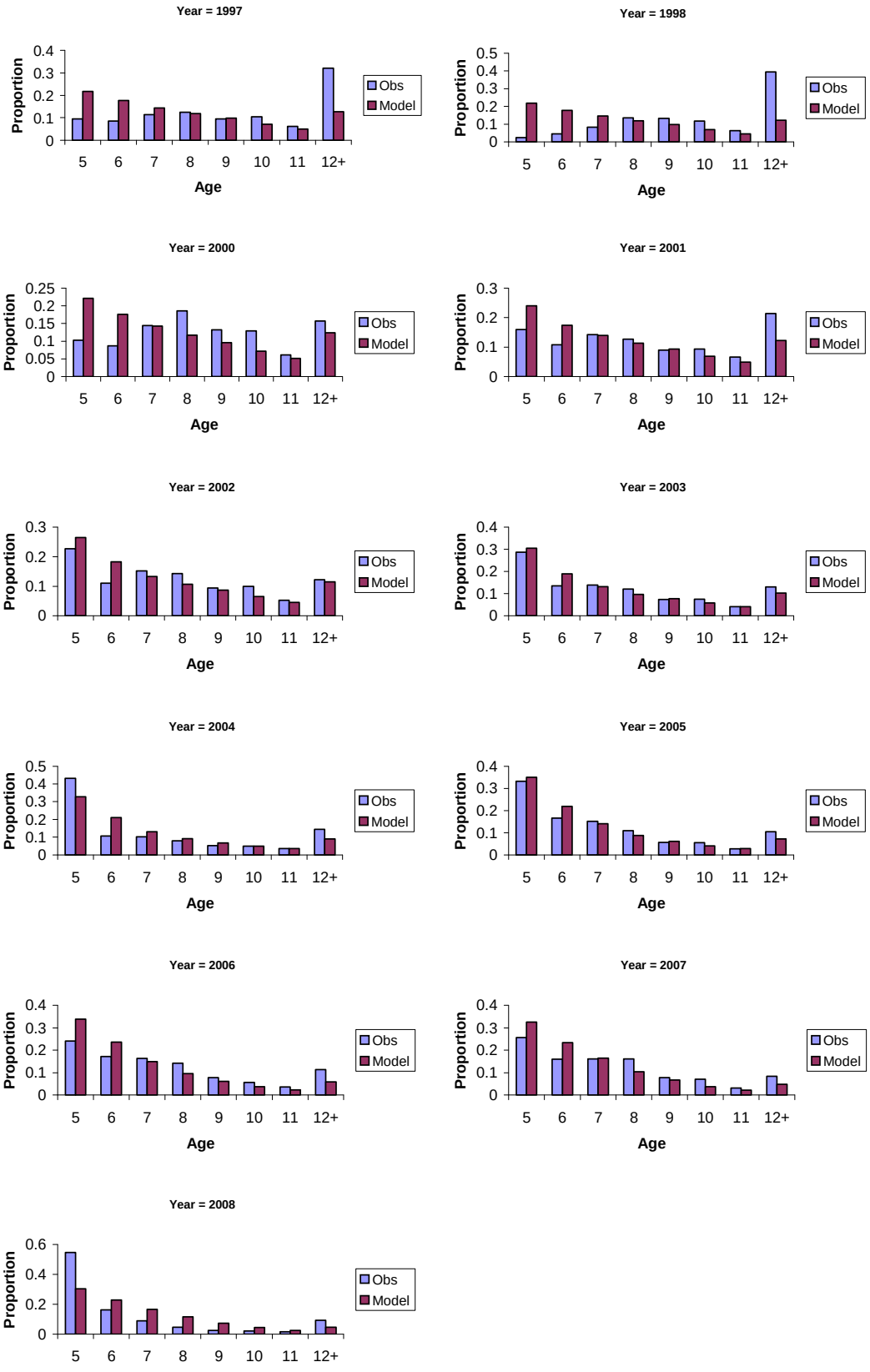

Fig. A.4. Fits to poaching catch-at-age data – Zone B.

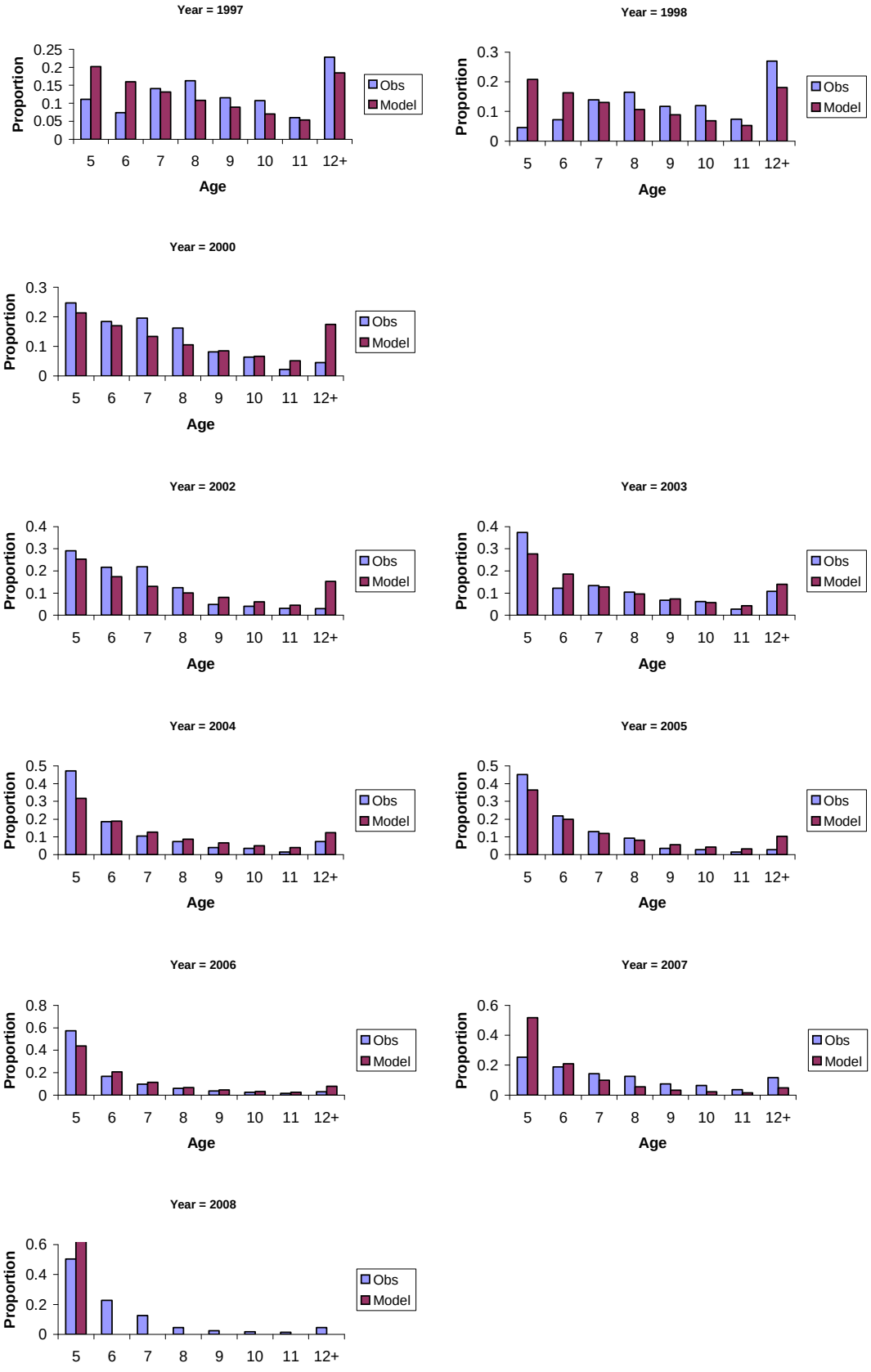

Fig. A5. Fits to poaching catch at age data – Zone A.