Further results using the 2008 abalone assessment model for Zones A, B, C and D

Éva Plagányi
Marine Resource Assessment and Management Group (MARAM), UCT

SUMMARY

A summary is presented of the results obtained from the 2008 Reference-case model and three variants 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 four model versions presented in Table 1 are as follows:

Model a) The new Reference case model is similar to the model presented in document 18, except that concern was expressed by the AWG that the CPUPE trend for Zone B declines too steeply in recent years. This may be attributable to an incorrect partitioning of confiscated abalone between Zones A and B. This model version thus estimates the Zone B poaching amount (in numbers), that is assume to apply from 2005-2008. This model had the lowest (i.e. best) negative log likelihood and AIC value.

Model b) The old Reference Case, as described in document SWG-AB 18.

Model c) Rather than estimating the amount poached in Zone B in recent years, this model combines the estimates of the amount poached form Zones A and B and then estimates a parameter that describes the proportion of this total that is taken from Zone A versus Zone B from 2000 onwards. The model estimated proportion is 0.7 from Zone A. This model had a worse AIC value than model version a).

Model d) This model version used a single compartment per zone, rather than assuming inshore and offshore model regions. This model had the worst AIC value.

The new Reference Case Model estimates a pristine spawning biomass, B_0^{sp} (in tonnes), of 8470, 5810, 6800 and 9290 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 %, 27 % 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 estimates for Zones A and B are 14% and 19%. 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 800 MT and corresponds to the assumption that, on average, 15% of all poached abalone are confiscated.

BACKGROUND

This document provides **selected** 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. This paper focuses on presenting results for the 2008 new Reference Case model only, with some selected results shown for other scenarios.

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) $\boldsymbol{p}_{\mathbf{poach}}$ [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 12. A number of additional diagnostics results are presented for purposes of indepth discussion of model results.

Parameter estimates

Model results estimates a pristine spawning biomass, B_0^{sp} (in tonnes), of 8470, 5810, 6800 and 9290 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 %, 27 % 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 estimates for Zones A and B are 14% and 19%.

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 (Table A.1).

The Reference-case selectivity estimates are illustrated in Fig. 1a. 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. 1a).

Fig. 1b shows the estimated selectivity trends when using the combined inshore/offshore model version (Model c). The model tries to distinguish between the commercial and poaching selectivities by estimating a near-linear decline in selectivity with age for the poaching sector (Fig. 1b).

Fits to data

The new Reference Case model fits to the CPUE and FIAS data are shown in Figs. 2-6. In particular, there is an improvement in the fit to the Zone B FIAS data.

The inshore/offshore combined model version also fits the FIAS data reasonably (Fig. 7), but the overall model fit is significantly and substantially worse.

Biomass trajectories and projections

Fig. 8. shows the combined Zones A-D commercially exploitable biomass trajectory compared to historic data. Overall, the resource is estimated to be at 18% of the pre-exploitation spawning biomass level.

Fig. 9 shows the new Reference-case total (inshore + offshore) spawning biomass trajectories 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. 10 shows the inshore and offshore spawning biomass components separately.

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 from the new reference case model is 800 MT and corresponds to the assumption that, on average, 15% of all poached abalone are confiscated. Figs. 11 and 12 show the model estimates of the numbers and corresponding biomass of abalone poached.

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.	-
Other definitions		
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 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) NEW REF CASE-ZONE B POACHING ESTIMATE					b) OLD REF CASE					c) Combined A & B poach estimate from 2000-1					d) Combined inshore and offshore regions				
No. parameters	31					30					31 prop in A = 0.701					28				
Zone	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
Ave confiscation %	19%	26%	9%		8%	16%	61%	9%		7%	13%	31%	9%		11%	18%	30%	11%		7%
$B(0)^{sp}$	8469	5811	2496	4310	9286	8185	5735	2447	4318	9064	12980	5822	2347	4337	9739	7205	5749	1202	4426	7472
ρ	0.037	0.037	0.037	0.018	0.037	0.038	0.038	0.038	0.019	0.038	0.044	0.044	0.044	0.022	0.044	0.000	0.000	0.000	0.000	0.000
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.)	1649240	7.04E+05		546372	680564	1582490	8.44E+05		545000	673354	2753240	8.59E+05		548835	832856	1421110	6.39E+05		535829	685149
Cpmax (MT)	524	342		273	419	500	403		272	411	982	405		270	461	440	310		257	388
Cpmax (YEAR)	2006	2002		1995	2002	2006	2002		1995	2002	2006	2002		1995	2002	2006	2002		1995	2002
CP(2008) (MT)	495	306		0	1	470	109		0	0	632	256		0	17	495	322		156	190
Cmult (Zone A)	2.22					2.18					3.51					2.15				
Ppoach			0.90					0.90					0.90					0.80		
M_0			0.327					0.326					0.326					0.315		
M_{15}			0.139					0.138					0.138					0.127		
ν (steepness of recruitment failure)			0.2690					0.2677					0.2603					0.2185		
Mmax (Recruitment failure scale parameter|)			13.9546					13.9579					13.9578					13.9685		
a(CS)			8.99916					8.99944					8.99949					8.99935		
a(RS)			8.99743					8.99619					8.99401					8.9969		
a(PS)			4.90401					4.90516					4.90516					4.90554		
a(FS)			6.10419					6.14103					6.27668					6.71512		
a(OS)			5.15731					5.25305					5.24255					4.75827		
a(IS)			-					-					-					-		
μ(CS)			0.000327					0.000271					0.000443					4.57E-13		
μ(RS)			0.001082					0.001004					0.000975					0.001933		
μ(PS)			2.65E-13					1.28E-13					0.000102					0.000811		
μ(FS)			0.001373					0.001331					0.001311					0.002504		
μ(OS)			9.5E-13					8.93E-13					9.03E-13					3.88E-12		
μ(IS)			-					-					-					-		
δ(CS)			640.349					973.306					974.582					989.104		
δ(RS)			129.36					91.0156					56.6303					68.0937		
δ(PS)			306.199					306.2					306.2					306.204		
δ(FS)			0.916378					0.820938					0.874264					0.793031		
δ(OS)			0.576726					0.562009					0.563262					0.649558		
δ(IS)			-					-					-					-		

Model	a) Ref. case					b) OLD REF CASE					c) Combined A & B poach estimate					d) Combined inshore and offshore regions				
	A	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
-*ln* L CPUE	-50.016	-50.359	-35.189	-44.821	-34.138	-49.794	-51.089	-34.931	-44.903	-34.321	-46.327	-50.455	-35.117	-44.926	-34.479	-49.701	-50.758	-33.152	-46.046	-36.380
-*ln* L FIAS	0.281	-3.629	-3.683	4.651	-3.890	0.018	-0.142	-3.300	4.093	-3.471	-0.290	-3.539	-3.937	4.678	-3.671	-0.293	-1.998	-4.359	4.831	-3.736
-*ln* L age CS	-16.536	-19.387	-8.670	-10.081	-11.503	-16.472	-19.067	-8.583	-10.275	-11.496	-14.727	-19.208	-8.620	-10.214	-11.528	-15.772	-18.542	16.537	-9.531	-11.779
-*ln* L age RS	-1.666	-8.101	-7.076	0.027	-8.604	-1.665	-8.060	-7.056	0.016	-8.564	-1.572	-8.113	-7.090	-0.011	-8.708	-1.716	-7.861	-7.007	-0.047	-9.227
-*ln* L age PS	-4.234	-4.177		-0.693	-3.080	-4.288	-3.797		-0.781	-3.193	-5.105	-3.550		-1.059	-3.459	-3.996	-4.066		-2.185	-3.446
-*ln* L age FIAS	-3.351	-9.960	-4.738	-0.436	-4.898	-3.633	-9.488	-4.587	-0.391	-4.894	-3.226	-9.983	-4.604	-0.424	-5.177	-2.576	-10.686	-4.124	-0.265	-4.949
-*ln* L age OS inshore	-3.575	-1.043		-1.267	-0.837	-3.594	-1.072		-1.248	-0.839	-3.521	-1.067		-1.245	-0.859	-3.048	-0.922		-1.219	-0.645
-*ln* Lage OS offsh.	-3.562	-1.729		-1.380	-1.758	-3.527	-1.664		-1.420	-1.741	-3.527	-1.627		-1.499	-1.973	-0.962	-1.065		-0.361	-0.159
-*ln* L age IS insh+offsh.		-0.933	-0.990				-1.059	-0.981				-0.970	-0.910				-0.859	-0.439		
-*ln* L zone subtotal	-82.659	-99.319	-114.344		-68.708	-82.955	-95.437	-114.346		-68.519	-78.295	-98.511	-114.978		-69.853	-78.065	-96.757	-87.347		-70.321
-*ln* L TOTAL & AIC			-365.030	**-668.060**				-361.257	**-662.514**				-361.636	**-661.272**				-332.489	**-608.978**	
σ CPUE	0.097	0.096	0.151	0.065	0.174	0.098	0.093	0.153	0.064	0.173	0.111	0.095	0.152	0.064	0.172	0.098	0.094	0.164	0.061	0.161
σ age CS	0.081	0.072	0.113	0.097	0.099	0.082	0.074	0.114	0.096	0.099	0.090	0.073	0.113	0.096	0.099	0.085	0.076	0.580	0.101	0.097
σ age RS	0.113	0.057	0.059	0.211	0.062	0.113	0.057	0.059	0.208	0.062	0.117	0.056	0.059	0.200	0.061	0.111	0.059	0.059	0.190	0.056
σ age PS	0.105	0.120		0.178	0.111	0.104	0.125		0.176	0.109	0.094	0.129		0.169	0.104	0.108	0.122		0.145	0.104
σ age FIAS	0.112	0.074	0.080	0.128	0.093	0.107	0.078	0.082	0.130	0.093	0.114	0.074	0.082	0.129	0.089	0.125	0.069	0.090	0.135	0.092
σ OS insh.	0.035	0.064		0.053	0.081	0.034	0.063		0.054	0.081	0.035	0.063		0.054	0.079	0.044	0.072		0.056	0.096
σ OS offsh.	0.039	0.042		0.053	0.038	0.040	0.044		0.051	0.038	0.040	0.045		0.048	0.032	0.106	0.070		0.116	0.130
σ IS		0.039	0.052				0.034	0.052				0.038	0.057				0.043	0.103		
Additional variance	0.410					0.462					0.401					0.418				
q CPUE	0.000293	0.00061	0.003566	0.0010253	0.000263	0.000307	0.000639	0.003559	0.001022	0.000271	0.000186	0.000619	0.003449	0.001025	0.0002501	0.000392	0.000671	0.000671	0.001015	0.000379
Confiscation percentage			Zone C					Zone C					Zone C					Zone C		
%Co/Po$_{2006}$	0.15	0.34	0.09		0.08	0.16	0.73	0.09		0.09	0.13	0.34	0.10		0.14	0.18	0.35	0.12		0.08
%Co/Po$_{2007}$	0.25	0.27	0.07		0.07	0.26	0.78	0.07		0.07	0.20	0.27	0.08		0.11	0.29	0.29	0.09		0.07
%Co/Po$_{2008}$	0.16	0.17	0.10		0.07	0.17	0.54	0.10		0.07	0.13	0.20	0.10		0.11	0.19	0.18	0.12		0.07
Ave prop over last 5 yrs	**0.19**	**0.26**	**0.09**		**0.08**	**0.16**	**0.61**	**0.09**		**0.07**	0.13	0.31	0.09		0.11	**0.18**	**0.30**	**0.11**		**0.07**
Catches																				
Ccomm(2008)	0	24	0	0	0	0	24	0	0	0	0	24	0	0	0	0	24	0	0	0
Cpoa(2008)	495.3	305.7	0.0	0.0	1.2	470.3	109.3	0.0	0.0	0.3	632.1	255.8	0.0	0.0	17.4	495.4	321.5	39.4	116.9	190.3
Catch total (2008) MT	495.3	329.7	0.0	0.0	1.2	470.3	133.3	0.0	0.0	0.3	632.1	279.8	0.0	0.0	17.4	495.4	345.5	39.4	116.9	190.3
	A	**B**	**CNP**	**CP**	**D**	**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	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	0.33	0.67		0.33	0.36
Insh PRED	0.75	0.55		0.45	0.71	0.74	0.54		0.45	0.70	0.77	0.56		0.45	0.73	0.58	0.42		0.38	0.54
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	0.20	0.54		0.24	0.50
Offsh PRED	0.60	0.37		0.25	0.60	0.58	0.35		0.25	0.58	0.62	0.36		0.25	0.61	0.60	0.44		0.39	0.59

Table 1 continued. Depletion statistics.

Model	a) Ref. case					b) OLD REF CASE					c) Combined A & B poach estimate					d) Combined inshore and offshore regions				
Depletion statistics																				
$B^{sp}(2008)/K$ (Insh. + Offsh)	0.33	0.27	0.05	0.04	0.13	0.33	0.35	0.05	0.04	0.13	0.39	0.28	0.06	0.04	0.14	0.22	0.20	0.06	0.04	0.09
$B^{sp}(2008)/K$ (Insh.)	0.16	0.18	0.00	0.00	0.00	0.16	0.32	0.00	0.00	0.00	0.22	0.19	0.00	0.00	0.00	0.22	0.20	0.06	0.04	0.09
$B^{sp}(2008)/K$ (Offsh.)	0.61	0.41	0.15	0.20	0.35	0.59	0.40	0.15	0.20	0.34	0.62	0.40	0.16	0.20	0.34					0.38
$B^{total}(2008)/K$	0.38	0.32	0.05	0.03	0.12	0.38	0.40	0.05	0.04	0.12	0.43	0.33	0.06	0.04	0.13	0.27	0.25	0.06	0.04	0.08
$B^{commercial}(2008)/K$	0.29	0.19	0.07	0.05	0.16	0.29	0.24	0.07	0.05	0.16	0.34	0.21	0.08	0.05	0.18	0.17	0.12	0.00	0.05	0.11
FIAS N_{2008}/N_{1951}	0.14	0.19	0.00	0.00	0.00	0.14	0.46	0.00	0.00	0.00	0.22	0.20	0.00	0.00	0.00	0.23	0.28	0.01	0.00	0.02
Projections	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**	**A**	**B**	**CNP**	**CP**	**D**
Ccomm(2008)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cpoa(2008) (NUMBERS)	1481840	828885	91984	91477	186134	1421870	275660	86186	94989	184162	1812720	770483	81967	95816	121181	1276870	788753	36463	111217	187388
Cpoa(2008) (MT)	512	296.6	0.0	0.0	0	486	119.0	0.0	0.0	0	678	277.6	0.0	0.0	1	526	317.0	22.9	38.7	183
Catch total (2008) MT	512.3	296.6	0.0	0.0	0.1	486.1	119.0	0.0	0.0	0.0	678.0	277.6	0.0	0.0	1.2	526.2	317.0	22.9	38.7	183.2
$B^{sp}(2013)/K$	0.23	0.22	0.03	0.02	0.07	0.23	0.45	0.03	0.02	0.07	0.31	0.24	0.03	0.02	0.08	0.07	0.12	0.00	0.00	0.00
$B^{sp}(2028)/K$	0.16	0.15	0.00	0.00	0.01	0.16	0.59	0.00	0.00	0.01	0.18	0.16	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
$B^{sp}(2013)/B^{sp}(2008)$	0.70	0.82	0.54	0.53	0.50	0.71	1.28	0.54	0.53	0.51	0.80	0.88	0.54	0.53	0.52	0.33	0.62	0.00	0.01	0.01
$B^{sp}(2028)/B^{sp}(2008)$	0.47	0.56	0.07	0.07	0.06	0.48	1.70	0.07	0.07	0.06	0.46	0.58	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00

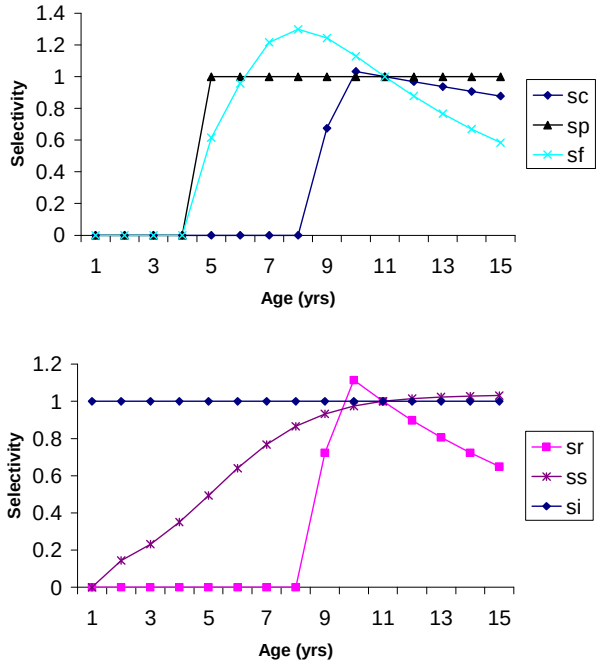

Fig. 1a. Plots of the Reference-case combined ABCD model selectivity functions estimated for the commercial (sc), recreational (sr) and poaching (sp) fishery sectors, and for FIAS (sf) and the old 1980's surveys (ss). A description of the general functional form used is given in Appendix 1 and the fitted 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.

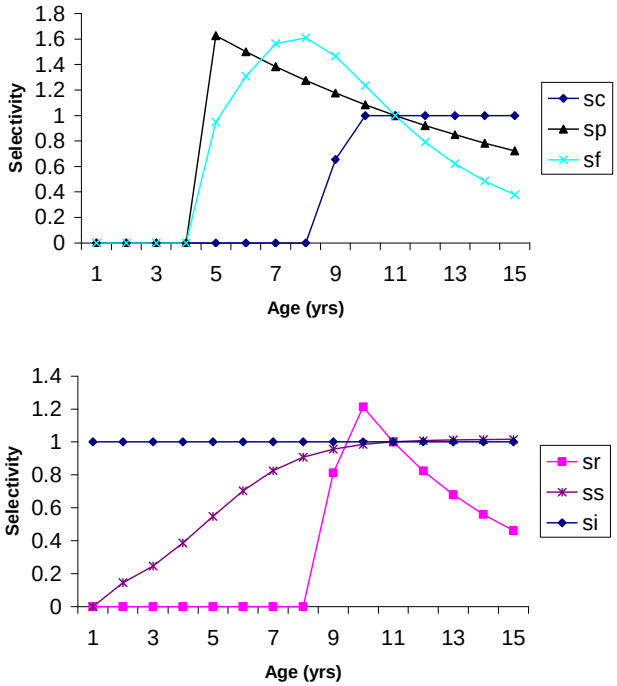

Fig. 1b. Plots of the model selectivity functions estimated for Model version d) which assumes a combined inshore/offshore region.

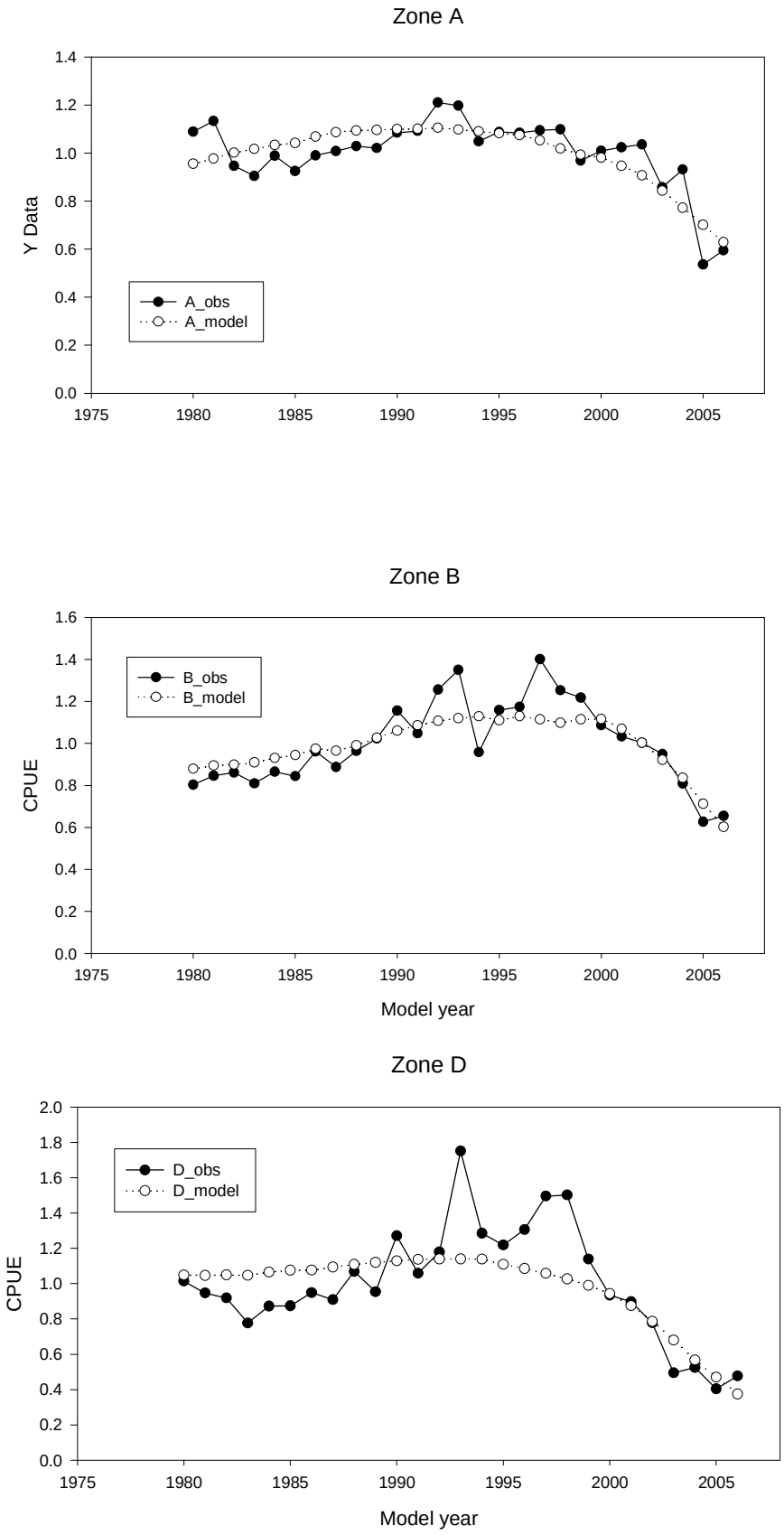

Fig. 2. Comparisons between the standardised CPUE and model-predicted CPUE values (for the Reference-case combined ABCD model) for each of Zones A, B and D.

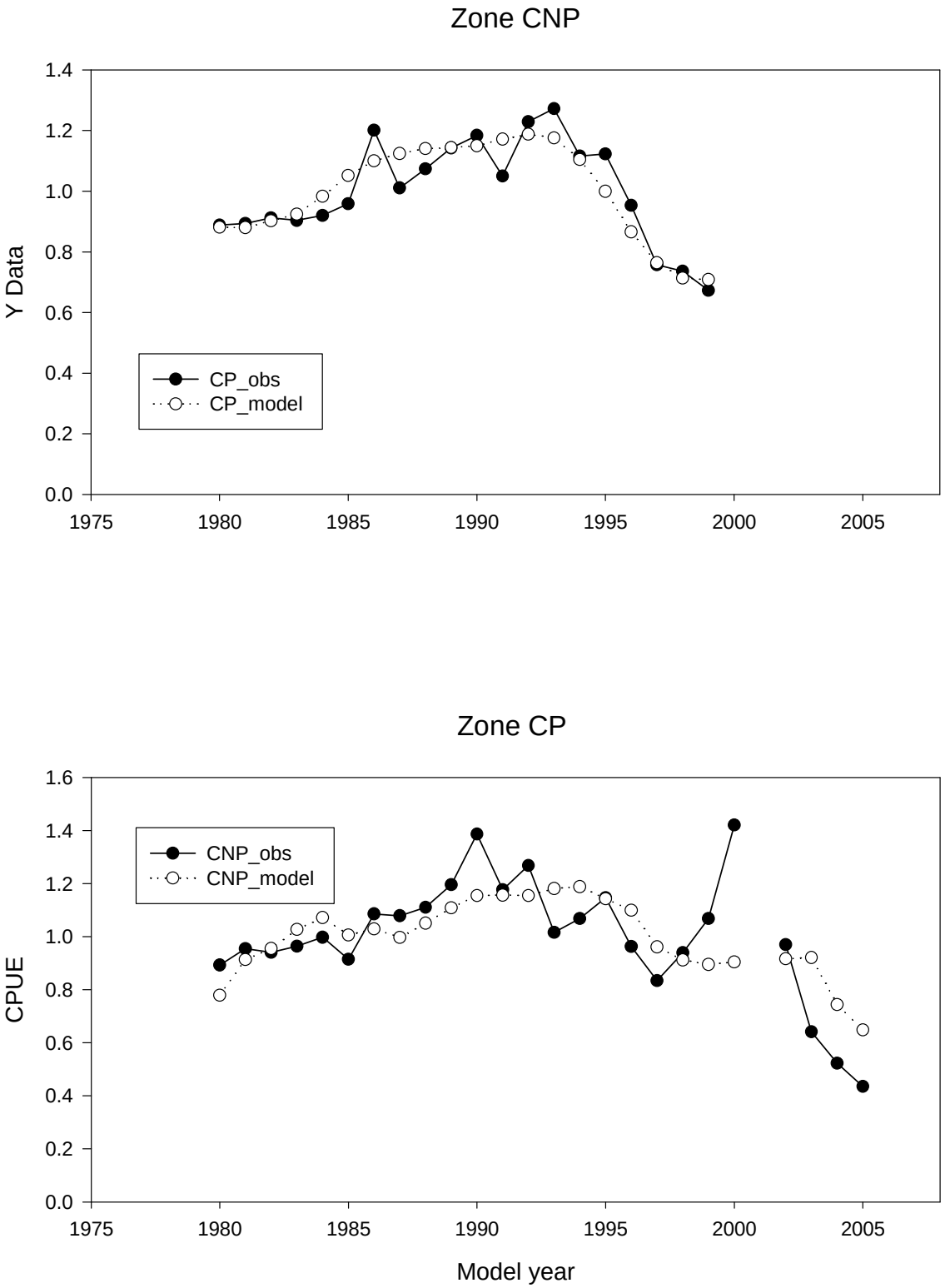

Fig. 3. Comparisons between the standardised CPUE and model-predicted CPUE values (for the Reference-case combined ABCD model) for each of Zones CNP and CP.

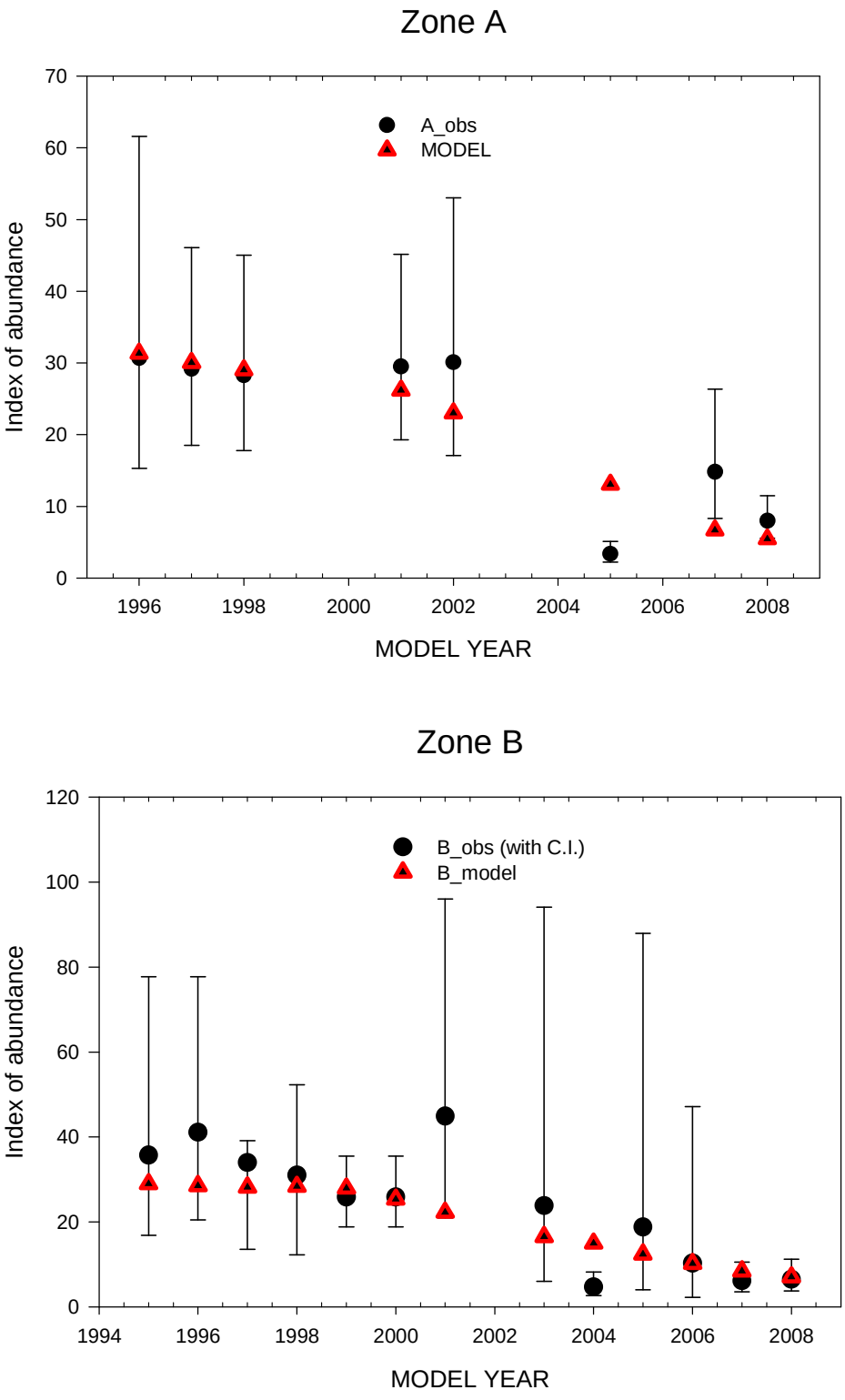

Fig. 4 Comparison of model-predicted (NEW Reference-case combined ABCD model) and observed FIAS trends for each of Zones A and B. Note that 95% confidence intervals have been computed as estimate*exp(±1.96*CV).

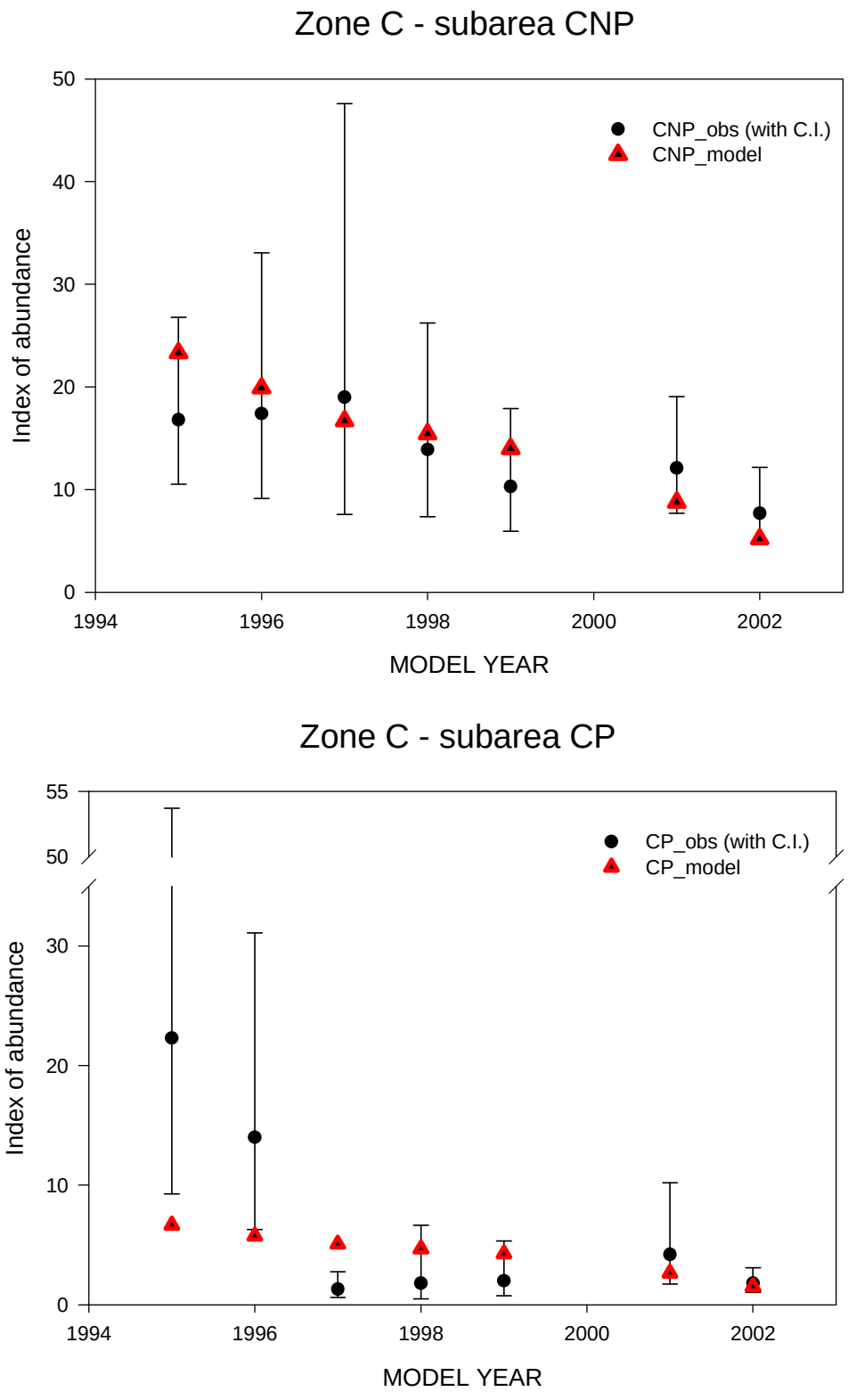

Fig. 5. Comparison of model-predicted (Reference-case combined ABCD model) and observed FIAS trends for each of subareas CNP and CP in Zone C. Note that 95% confidence intervals have been computed as estimate*exp(±1.96*CV). Note the break inserted on the y-axis for subarea CP for ease of viewing purposes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

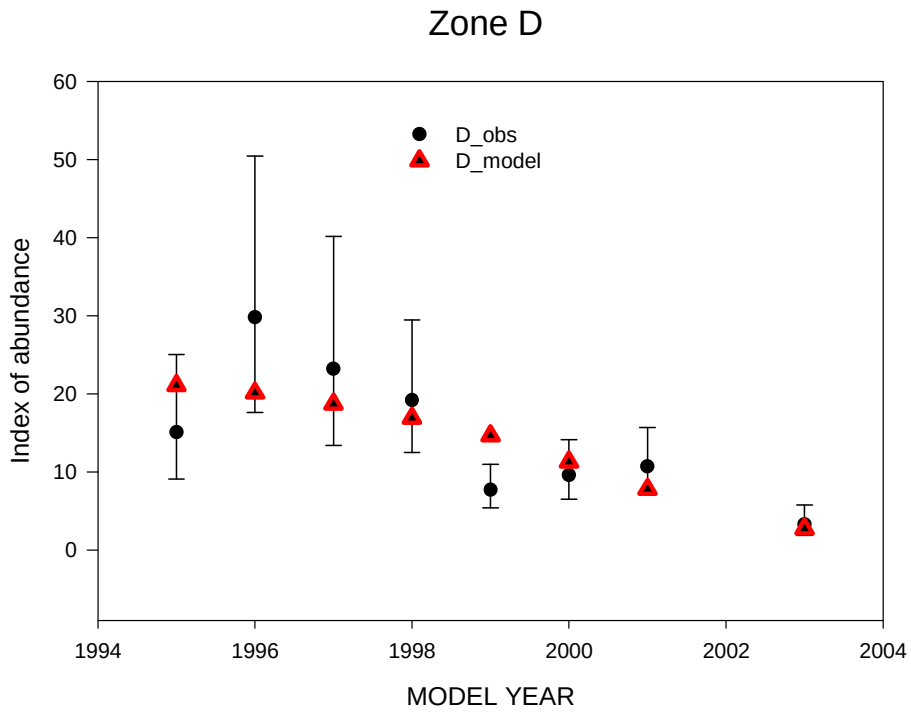

Fig. 6. Comparison of model-predicted (Reference-case combined ABCD model) and observed FIAS trends for each of Zone D. Note that 95% confidence intervals have been computed as estimate*exp(±1.96*CV).

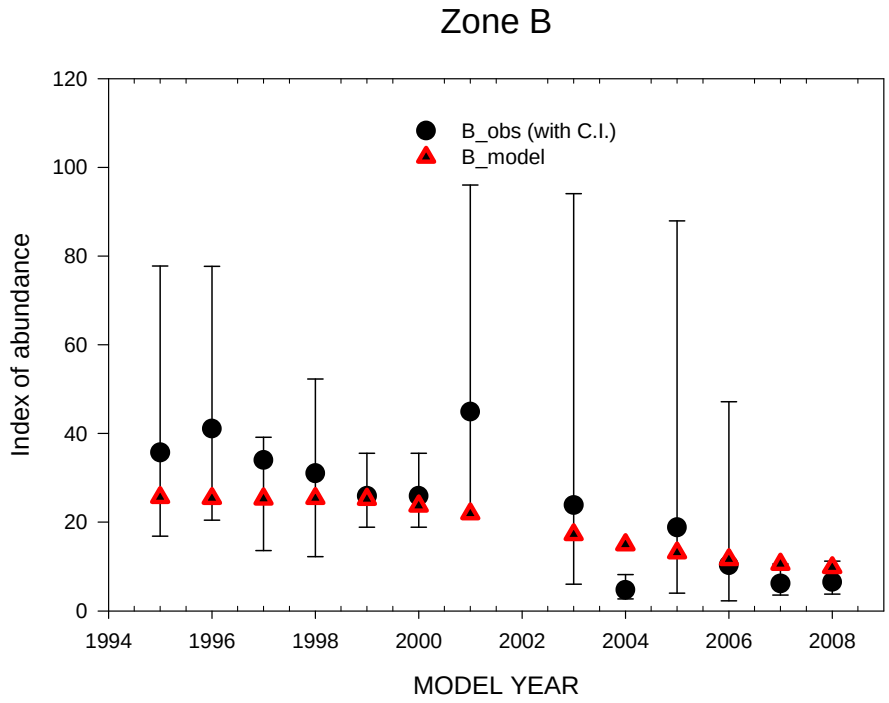

Fig. 7. Zone B fit to FIAS when using the combined inshore/offshore model version.

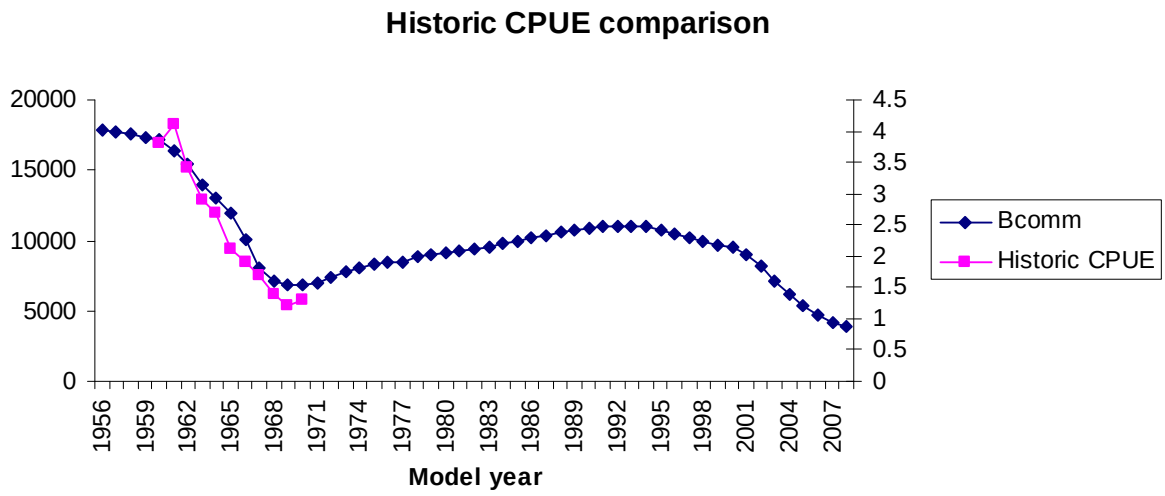

Fig. 8. Historic CPUE Comparison with Zones A-D combined commercial exploitable biomass trajectory.

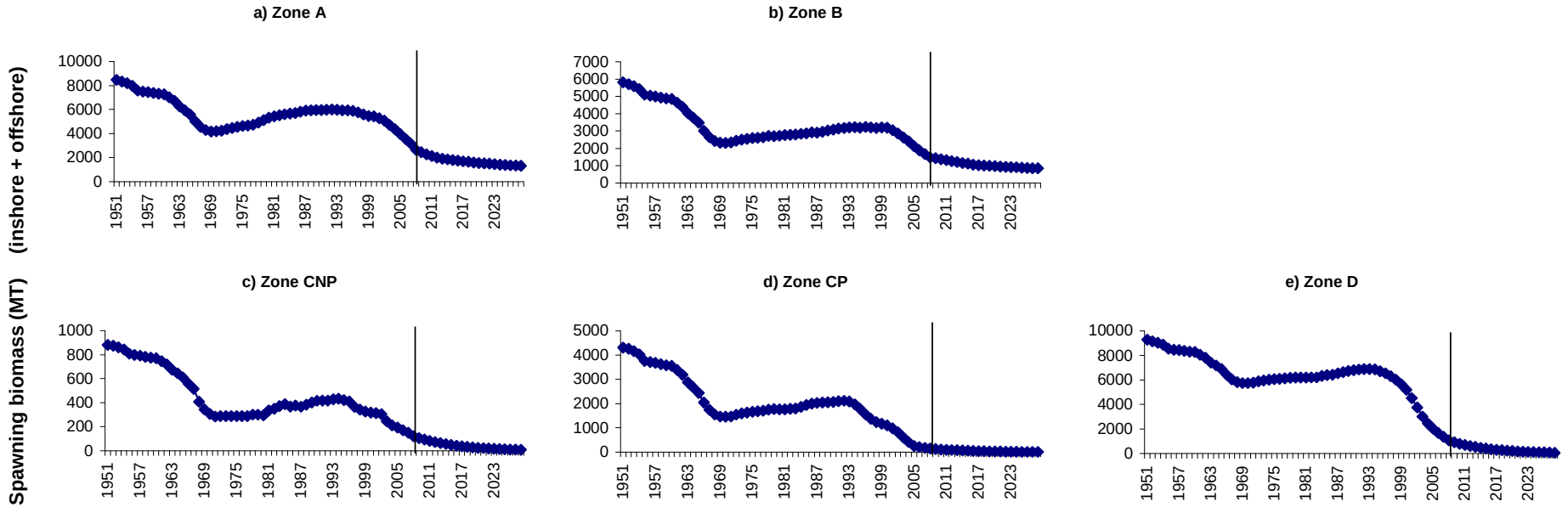

Fig. 9. New Reference-case combined ABCD model total (inshore + offshore) spawning biomass trajectories shown for Zones A to D. Note that the 20-yr projections shown (indicated by vertical bar) represent scenarios under which future poaching levels are assumed to remain at the current estimated level (average of 2007 and 2008) and future commercial catches are set to zero.

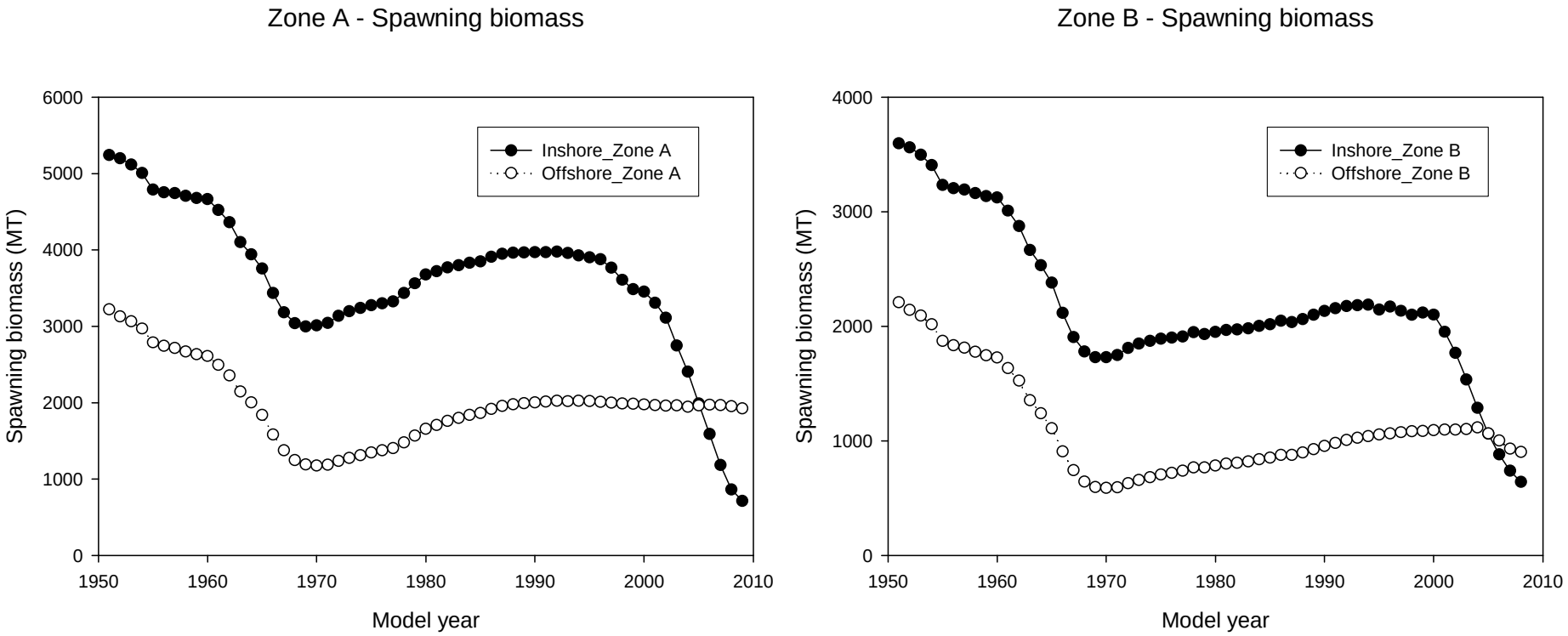

Fig. 10. Spawning biomass trajectories for the inshore and offshore components of Zones A and B, from the base-case model.

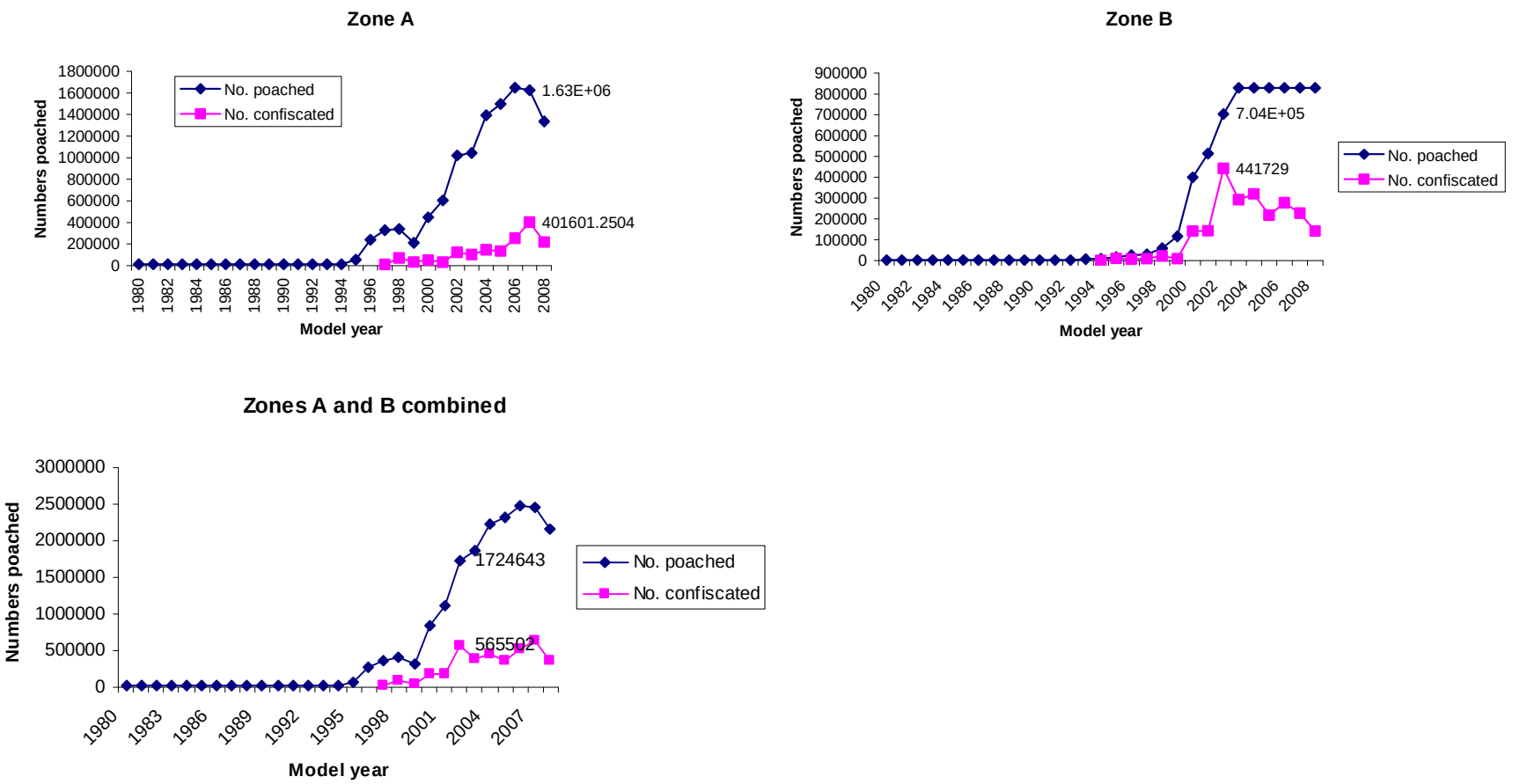

Fig . 11. Comparison of model-predicted numbers of abalone poached per Zone A and B with "observed" numbers confiscated (after allocating confiscated abalone from the Unknown category to each of Zones A-D). The numerical value (units are numbers) corresponding to selected points on the graph is given.

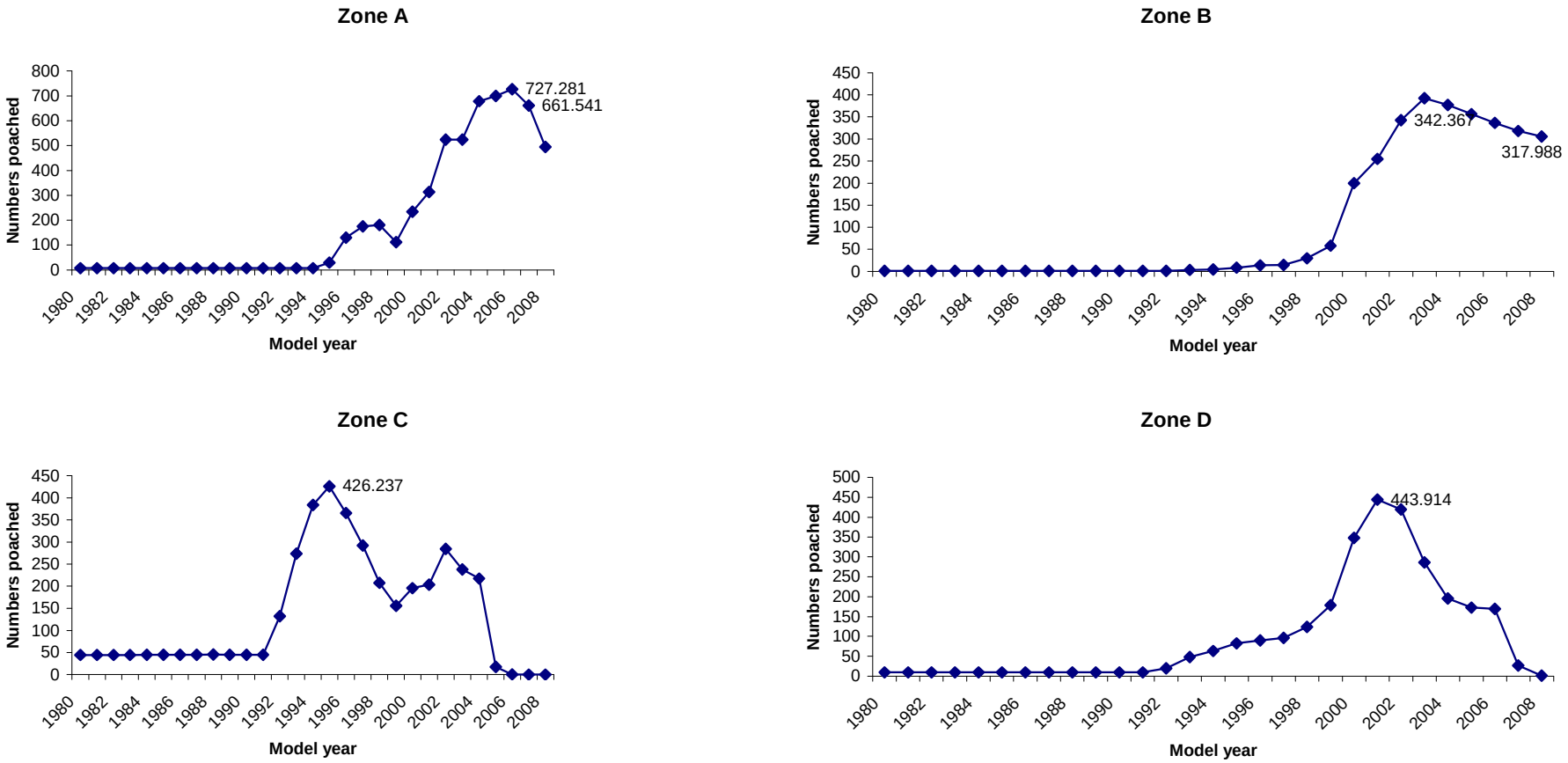

Fig . 12. Model-predicted **biomass** of abalone poached per Zone.