APPENDIX G

FISHERY REPORT: *DISSOSTICHUS ELEGINOIDES*
SOUTH GEORGIA (SUBAREA 48.3)

CONTENTS

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SOUTH GEORGIA (SUBAREA 48.3)

1. Details of the fishery

1.1 Reported catch (time series)

At its 2004 meeting, WG-FSA recommended the subdivision of Subarea 48.3 into areas, one containing the South Georgia–Shag Rocks (SGSR) stock and other areas, to the north and west, that do not include the SGSR stock. Within the SGSR area, the Commission defined three management areas (A, B and C) (Conservation Measure 41-02/A).

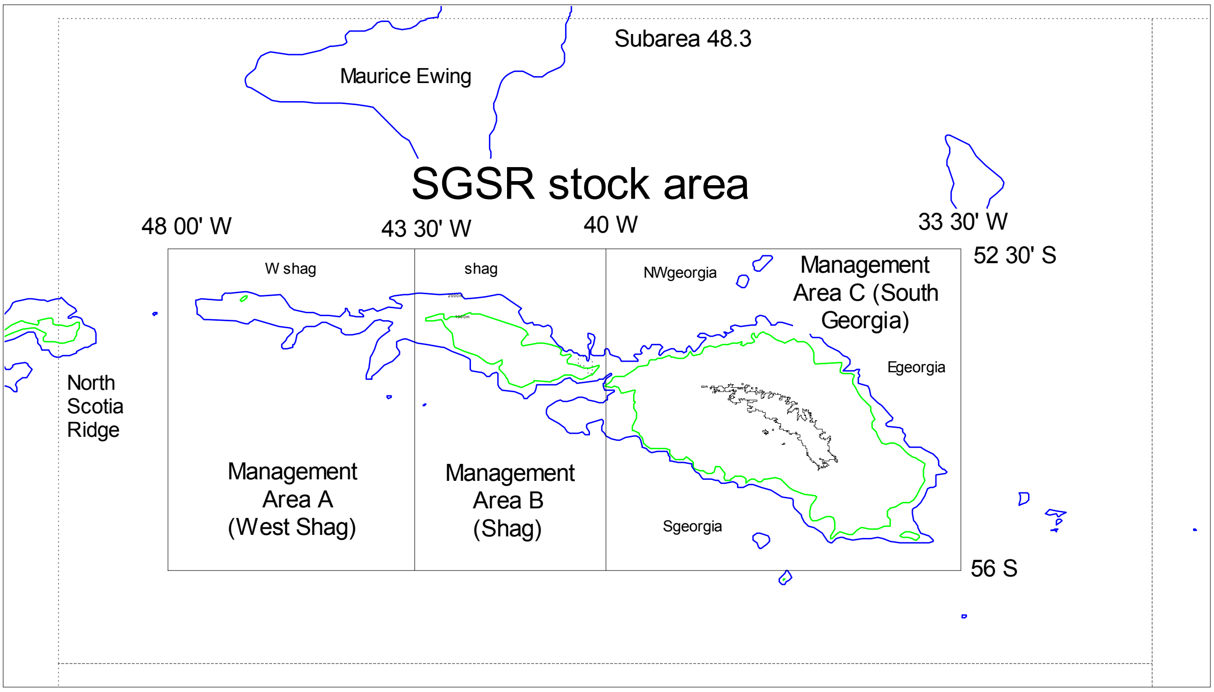


Figure 1: Definition of the SGSR stock area, with its three management areas A, B and C.

2. The catch limits in the 2004/05 season for areas A, B and C were 0 (excepting 10 tonnes for research fishing), 915 and 2 135 tonnes, with an overall catch for SGSR of 3 050 tonnes. The total declared catch was 3 018 tonnes. An additional 23 tonnes was taken by a single IUU vessel (the *Elqui*) apprehended by the UK prior to the fishery. The total removals were therefore 3 041 tonnes. Catches in areas A, B and C were 9, 910 and 2 122 tonnes respectively.

3. The area limits set for the 2004/05 fishing season were designed to redirect some effort from areas A and B to area C. The proportion of catches in A and B declined from 35% in 2003/04 to 30% in 2004/05.

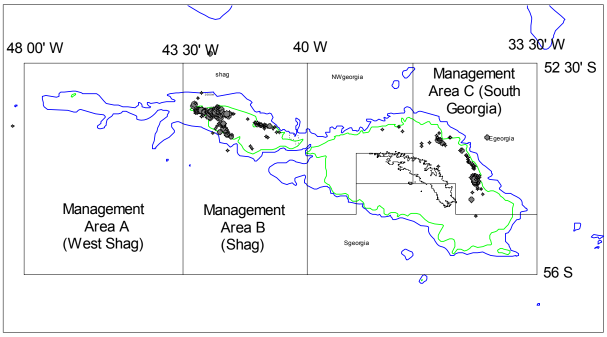
Table 1: Catch history for *Dissostichus eleginoides* in Subarea 48.3. Fishing seasons are given (i.e. 1988/89 is 1 December 1988 to 30 November 1989). Management areas are defined in Conservation Measure 41-02. Source: STATLANT and fine-scale data to 2004, catch and effort reports 2005, SCIC reports, WG-FSA-05/6 Rev. 1.

Season	Regulated fishery			Estimated IUU catch (tonnes)	Total removals (tonnes)	
	Reported effort (no. vessels)	*D. eleginoides*			Subarea 48.3	SGSR stock[1]
		Catch limit (tonnes)	Reported catch (tonnes)			
1984/85	1		521	0	521	521
1985/86	1		733	0	733	733
1986/87	1		1954	0	1954	1954
1987/88	2		876	0	876	876
1988/89	3		7060	144	7204	7204
1989/90	1		6785	437	7222	7222
1990/91	1	2500	1756	1775	3531	3531
1991/92	19	3500	3809	3066	6875	6871
1992/93	18	3350	3020	4019	7039	7039
1993/94	4	1300	658	4780	5438	5438
1994/95	13	2800	3371	1674	5045	4998
1995/96	13	4000	3602	0	3602	3542
1996/97	10	5000	3812	0	3812	3812
1997/98	9	3300	3201	146	3347	3347
1998/99	12	3500	3636	667	4303	4303
1999/00	17	5310	4904	1015	5919	5919
2000/01	16	4500	4047	196	4243	4243
2001/02	17	5820	5742	3	5745	5722
2002/03	19	7810	7528	0	7528	7513
2003/04	16	4420	4497	0	4497	4447
2004/05	8	3050	3018	23	3041	3041

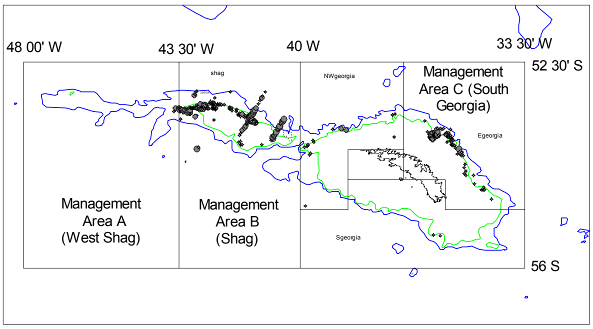
[1] These were the total catches used in both the ASPM and CASAL assessments. They are identical to those in Table 5.14 of SC-CAMLR-XXIII, Annex 5, except for the 2004/05 catch, but they differ to a minor extent from a new catch series calculated by the Secretariat immediately prior to the 2005 meeting. A test run with the revised Secretariat catches revealed only very small differences in the assessment.

Distribution of the fishery

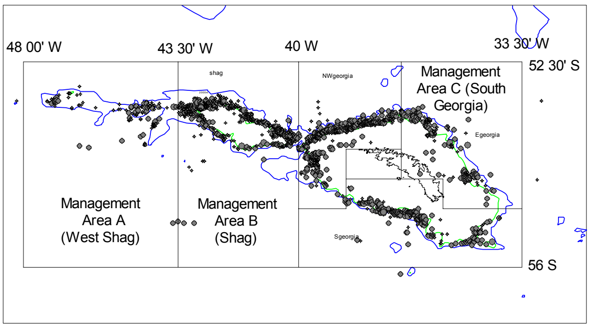
1985–1988



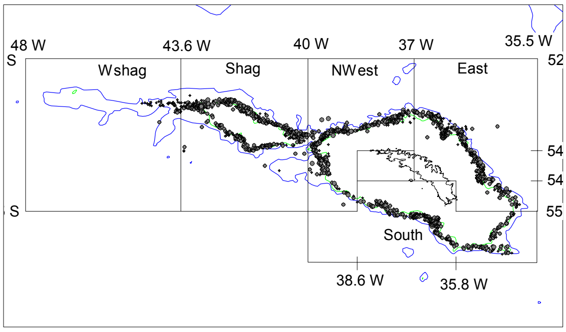
1989–1991



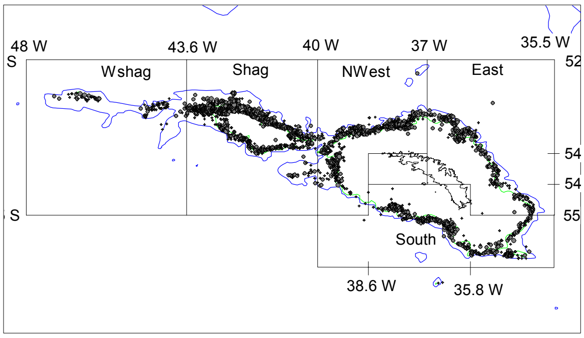
1992–1995



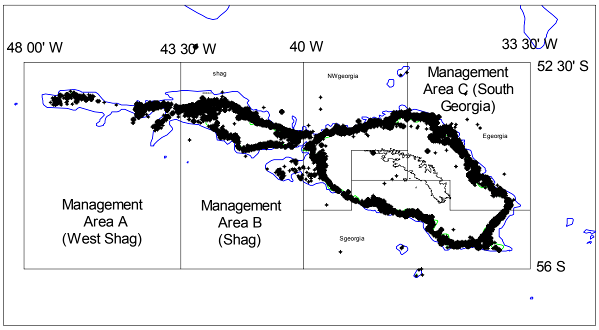
1996–1997



1998–2000



2001–2004



2005

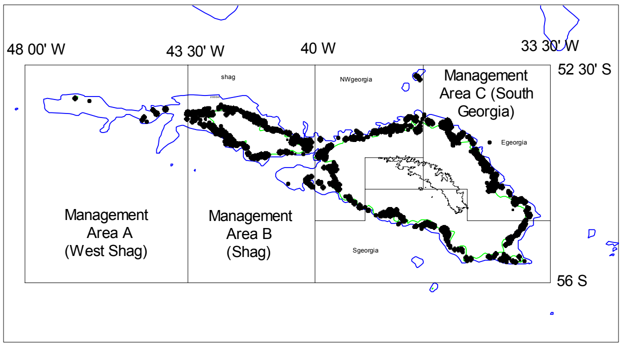


Figure 2: Distribution of catches in discrete time periods, graduated by the number of hooks set. Wshag – western Shag Rocks; Shag – Shag Rocks; NWest –northwest South Georgia; East – east South Georgia; South – south South Georgia.

1.2 IUU catch

4. The estimated IUU catch from Subarea 48.3 in the 2005 fishing season was 23 tonnes.

1.3 Size distribution of catches (time series)

5. Catch-weighted length-frequency data are shown in Figure 1. Catch-weighted length frequencies are not normally calculated for the years 1985–1991 because the sampling in these years was very poor with only a few animals being collected (Table 2). Observer data have been available since 1996. Initially fishing in deep water only (>850m) around both Shag Rocks and South Georgia, there was a marked shift in behaviour of the fishery in 1998 to utilise a wider depth range, including shallow water.

6. As there were difficulties in analysing the data prior to the 1992/93 season, the Working Group requested that the Secretariat continue to liaise with data owners in trying to establish a credible time series of catch-weighted length frequencies between 1985 and 1992.

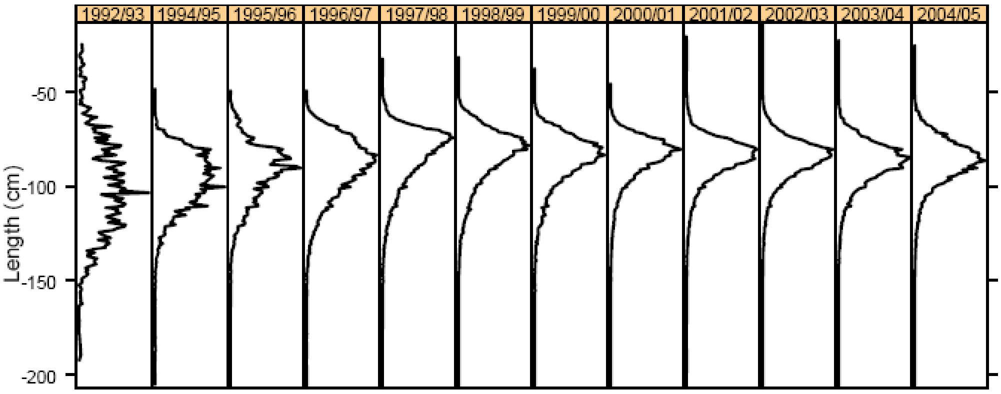


Figure 3: Catch-weighted length frequencies for *Dissostichus eleginoides* in Subarea 48.3 derived from observer, fine-scale and STATLANT data reported by 5 October 2005.

Table 2: Number of fish measured in the fishery (from B2 data) and by observers. The sampling rate (number of fish sampled per tonne caught) is also shown.

Season	Commercial lengths	Observer lengths	Number of fish measured/tonne of catch
1984/85	83		0.16
1985/86	210		0.29
1986/87			0.00
1987/88			0.00
1988/89			0.00
1989/90	296		0.04
1990/91	112		0.03
1991/92	2 809		0.41
1992/93	3 178		0.45
1993/94	910		0.17
1994/95	6 621		1.32
1995/96	590	10 496	2.96
1996/97	1 946	82 887	21.74
1997/98		81 275	24.28
1998/99		55 074	12.80
1999/00		47 374	8.00
2000/01		74 056	17.49
2001/02		107 592	18.80
2002/03		86 549	11.52
2003/04		51 836	11.66
2004/05		36 000	11.84

7. Fisheries data (reports of weight and number of fish caught) were analysed in a standard GLM of the form given in section 3.1. Mean weight declined from 1992 to 1998, and has been increasing gradually thereafter.

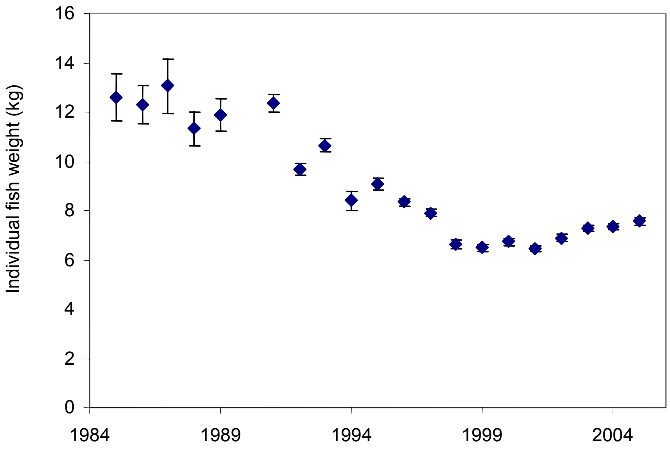


Figure 4: Mean weight of toothfish in the catch calculated using a GLM of similar form to that for the standard GLM (SC-CAMLR-XXIII, Annex 5, paragraphs 5.111 to 5.113), standardised to Chilean vessels fishing in depths between 1 000 and 1 500 m in the southern sector of South Georgia.

2. Stocks and areas

8. It has been demonstrated that there is genetic separation of those fish present in Subarea 48.3 from those found on the Patagonian Shelf (FAO Area 41). The SGSR stock, occurring within management areas A, B and C (Figure 1), is genetically separate from fish taken in the extreme north and west of Subarea 48.3.

9. All assessments consider only the SGSR stock.

3. Parameters and available data

3.1 Standardised CPUE

10. The GLM and GLMM (with random vessel effects) standardised CPUE analyses were updated (SC-CAMLR-XXIII, Annex 5, paragraph 5.111).

11. Figure 5 shows that CPUE has remained fairly constant between 2004 and 2005, dropping only slightly.

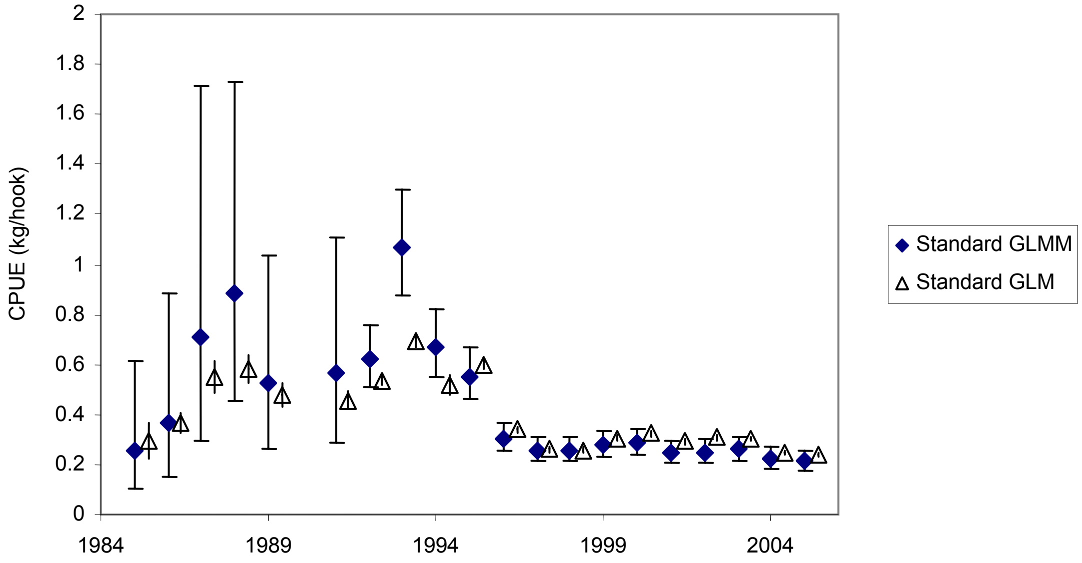


Figure 5: Standardised longline CPUE by fishing season for Subarea 48.3 using the GLMM method with vessel random-effects (♦) and the standard GLM method (Δ). Both series have been standardised for Chilean vessels fishing in depths between 1 000 and 1 500 m in the southern sector of South Georgia.

12. Last year the Working Group had examined a GLMM with random year–area interactions. This suggested that the CPUE at Shag Rocks and West Shag had declined over the last few years, whereas it had remained constant at South Georgia. This year the Working Group fitted two separate GLMM models with random vessel effects only for Shag Rocks and South Georgia. These confirm the relatively constant CPUE at South Georgia in recent years, compared with the initial increase and then decrease at Shag Rocks.

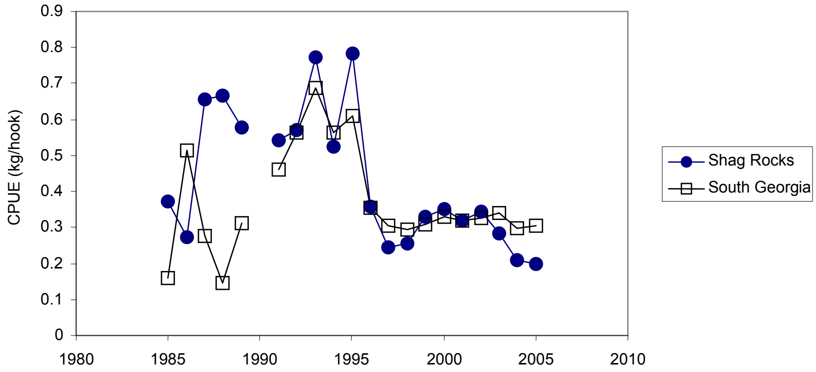


Figure 6: Standardised longline CPUE by fishing season for Shag Rocks and South Georgia separately within Subarea 48.3 using the GLMM method, clearly demonstrating some differences since 1997.

13. The GLMM standardised CPUE was used in assessments.

Table 3: Standardised CPUE calculated during the meeting using the GLMM method. The series used in the ASPM and CASAL assessments was estimated prior to the meeting using the catch and effort data available at that time. This series is also shown for comparison. A test CASAL run using the latest standardised CPUEs indicated no change in the CASAL assessments. No catch and effort data were reported for the 1989/90 season.

Fishing season	Standardised CPUE used in assessments	Latest standardised CPUE	Upper 95% CI	Lower 95% CI
1984/85	0.253	0.253	0.612	0.104
1985/86	0.369	0.369	0.881	0.155
1986/87	0.695	0.713	1.714	0.296
1987/88	0.863	0.885	1.731	0.453
1988/89	0.512	0.524	1.038	0.265
1989/90				
1990/91	0.574	0.565	1.111	0.287
1991/92	0.626	0.623	0.759	0.512
1992/93	1.064	1.067	1.295	0.880
1993/94	0.701	0.671	0.823	0.547
1994/95	0.552	0.554	0.666	0.461
1995/96	0.306	0.302	0.363	0.252
1996/97	0.263	0.259	0.310	0.216
1997/98	0.259	0.259	0.311	0.216
1998/99	0.279	0.280	0.336	0.234
1999/00	0.284	0.283	0.339	0.236
2000/01	0.244	0.244	0.293	0.204
2001/02	0.252	0.251	0.300	0.209
2002/03	0.262	0.261	0.312	0.218
2003/04	0.238	0.224	0.269	0.187
2004/05	0.211	0.212	0.255	0.177

14. Interpreting the CPUE trends, the Working Group noted that there had been major changes in fleet, time of fishing and observer coverage over the period 1993–1998. In the early 1990s the fleet was dominated by Russian and, towards the mid-1990s, a Chilean fleet. In 1994 CCAMLR undertook a depletion experiment with only four vessels. Between 1995 and 1997 there was a gradual move to a winter fishery, and the fleet almost completely changed its makeup, both in terms of individual vessels and national fleets. Of the 13 vessels

fishing in 1995, only one had fished previously (and then only in the experimental fishery in 1994; none of these vessels fished prior to 1994) and only two fished regularly thereafter. In 1996 the international observer program produced its first set of very comprehensive data on the fishery (Table 3); prior to this only commercial data had been available. By 1998 the fishery had stabilised in terms of fleet structure and depths and times of year fished. The distribution of catches by season and depth is shown in Figure 7.

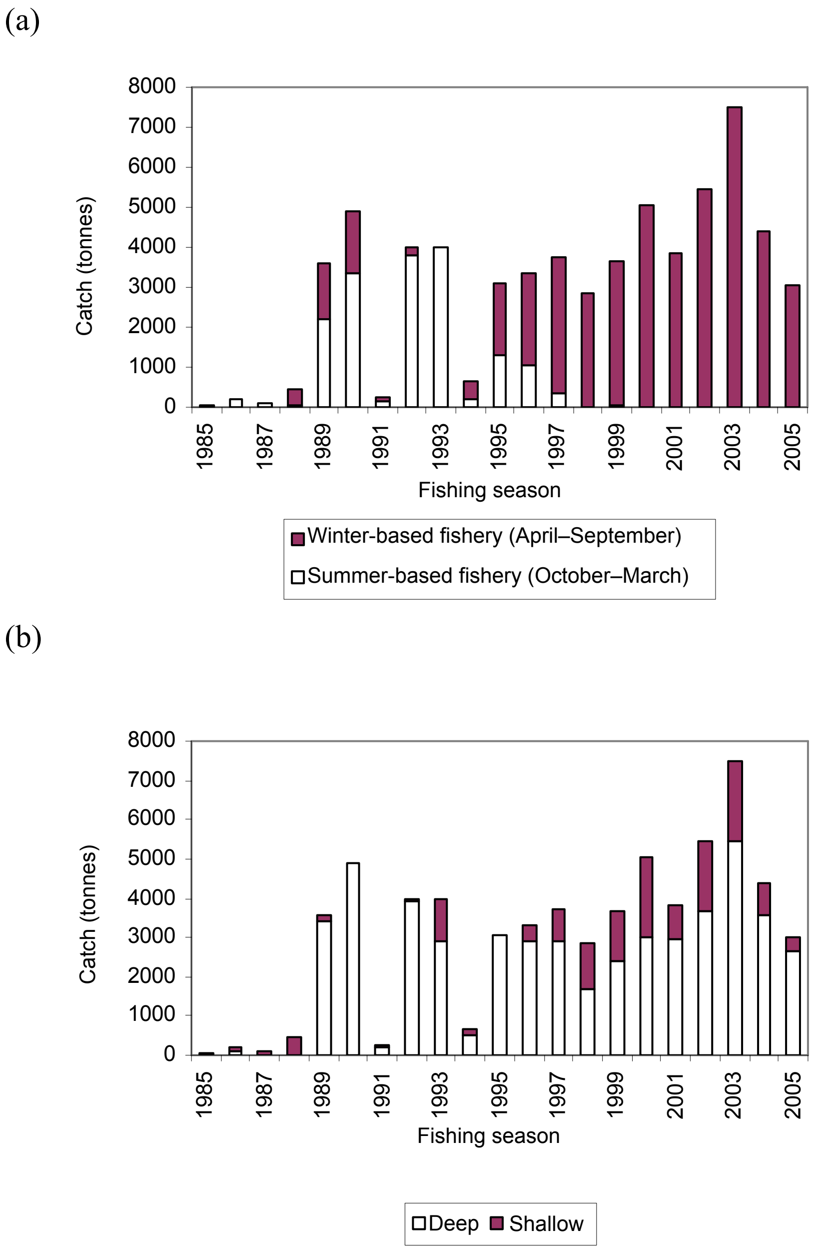


Figure 7: Distribution of catches by: (a) season and (b) depth zones (above or below 850 m).

3.2 Recruitment

15. The Working Group did not revise its calculation of CMIX estimates of recruitment in Subarea 48.3. The CMIX estimates of numbers-at-age and corresponding CVs available for use in assessment models are given in Table 4.

Table 4: Recruitment survey data for Subarea 48.3: area-scaled estimates of numbers at age and their CVs in brackets. Roman numbers differentiate multiple surveys in some years.

Age	3	4	5	6	7
1987	234 761 (0.04)	890 137 (0.34)	1 085 772 (0.16)	73 362 (0.93)	na
1990	83 320 (1.22)	1 106 314 (0.42)	648 050 (0.55)	356 427 (0.45)	143 496 (1.03)
1991	3 605 231 (0.37)	225 789 (0.49)	236 894 (0.56)	1 617 542 (0.75)	2 254 195 (1.07)
1992	525 799 (0.34)	5 957 678 (0.23)	306 371 (0.77)	579 621 (0.41)	na
1994 (i)	1 465 903 (0.31)	1 312 447 (0.48)	1 570 898 (0.43)	92 880 (1.70)	76 727 (0.32)
1994 (ii)	217 924 (1.42)	98 065 (1.59)	1 394 715 (0.20)	14 528 (7.25)	na
1995	824 263 (1.66)	937 955 (0.57)	3 642 190 (0.26)	2 221 056 (0.24)	na
1996	837 148 (0.32)	2 787 619 (0.37)	297 748 (0.80)	1 324 766 (0.41)	293 433 (0.75)
1997 (i)	321 481 (0.71)	671 814 (0.31)	774 853 (0.38)	803 704 (0.50)	746 002 (0.43)
1997 (ii)	95 163 (0.52)	165 501 (1.88)	1 874 304 (0.37)	405 478 (1.65)	910 257 (0.41)
2000	1 134 828 (0.34)	593 478 (0.36)	240 599 (0.72)	324 809 (0.78)	1 951 082 (0.17)

3.3 Mark–recapture data

16. WG-FSA-04/17 presented the results of the mark–recapture program in Subarea 48.3. The Working Group noted that additional papers on this program had been presented to WG-FSA-SAM. These presented details of the modified Petersen estimator adapted for S-plus and a toothfish movement model that was used for exploring bias in the method given different distributions of tagging events and recapture fishing (WG-FSA-SAM-05/6 Rev. 1 and 05/7).

17. In total some 8 000 fish have now been tagged in Subarea 48.3 since the program started in 2000. Tagging effort, fishing effort and recaptures were well distributed over the whole of the fishable grounds in Subarea 48.3 this year.

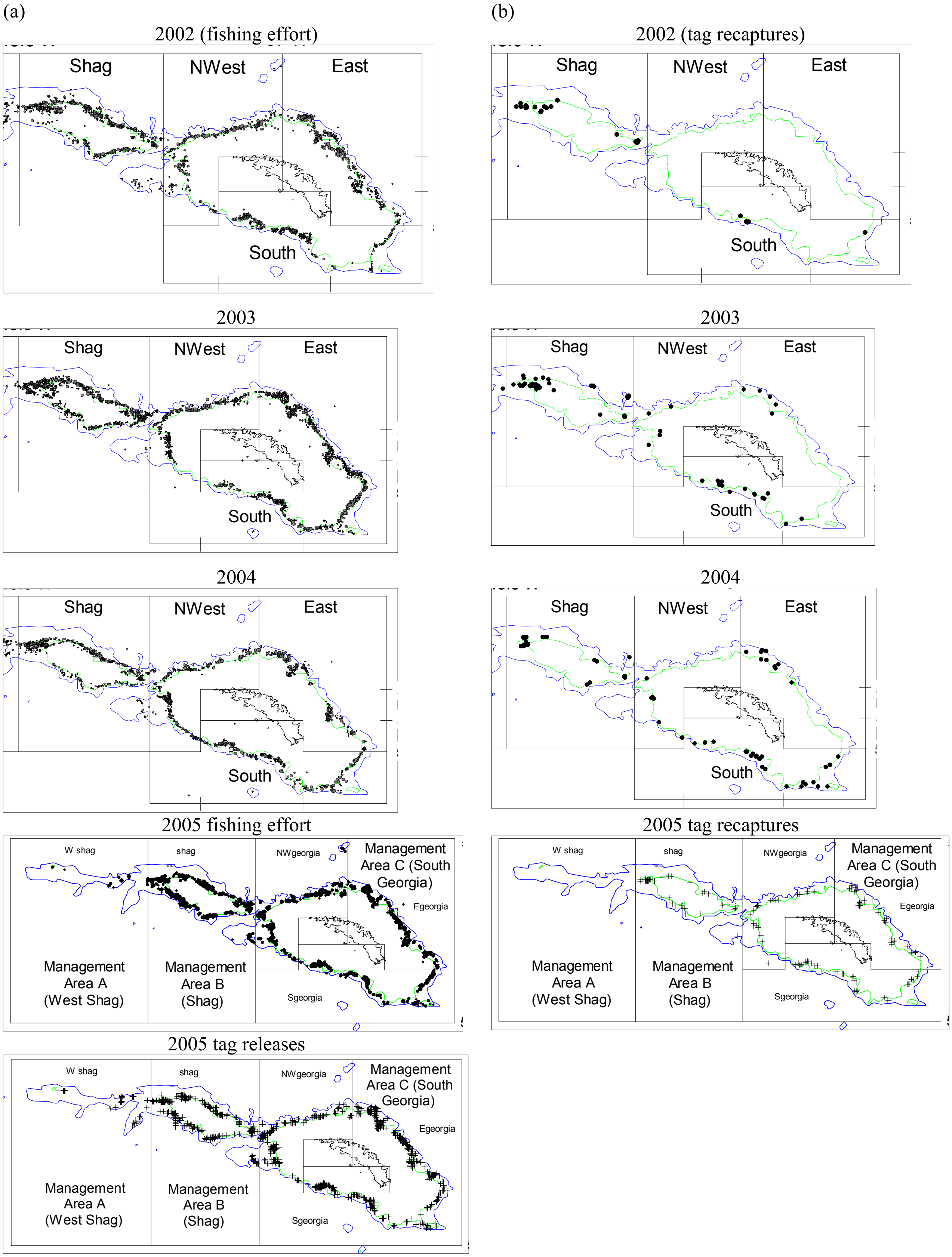


Figure 8: Distribution of (a) fishing effort and (b) recaptured tags by year since the commencement of the tagging program in Subarea 48.3, and tag releases in 2005. See Figure 2 for area definitions.

Table 5: Numbers of marked animals released in different areas in Subarea 48.3.

Release year	East	NWest	South	Shag	Wshag	Total
2000	37	7		91		135
2001	3	4	16	324		347
2002		99	116	186		401
2003	92		134	129		355
2004	600	319	762	1229	4	2914
2005	1110	793	641	1284	116	3944

18. WG-FSA-05/17 analysed the movement of toothfish between areas Shag, NWest, East and South (as defined in Figure 2). On average about 5% of tagged toothfish moved out of any particular area each year. The crossovers between areas are shown in Table 6 for animals tagged in 2004 and recaptured in 2005, together with the numbers of scanned fish.

Table 6: Movement of fish tagged in 2004 between areas in Subarea 48.3. See Figure 2 for area definitions.

Tag area	Recapture area	Number released (2004)	Number recovered 2005	Scanned (numbers) 2005
East	East	600	28	149 346
East	NWest		1	
NWest	NWest	319	11	92 107
NWest	South		1	
South	East		2	
South	South	762	26	78 516
Shag	Shag	1 229	24	131 119

19. The Working Group noted that the annual movement of tags between the main areas around South Georgia and Shag Rocks is low, as expected considering the low annual movement rates of toothfish. It recalled the simulation study in WG-FSA-SAM-05/6 Rev. 1 that modelled toothfish movement in Subarea 48.3 and found that the current tagging program, including positions of release, fishing and recapture, was likely to produce unbiased or negatively biased estimates of vulnerable population size. This was discussed in the 2005 WG-FSA-SAM report (WG-FSA-05/4, paragraphs 2.15 and 2.16).

20. Dr A. Constable (Australia) commented that as a result of the low level of exchange over one year, the annual recapture rate within an area may be important in understanding whether or not the estimate of abundance from the mark–recapture program is biased. When tag-return data are pooled across smaller areas without weighting for differences in recapture rates, then it is implied that the recapture rate in one area is an estimate of the recapture rate in the other areas and vice versa and this might introduce a bias into the estimate. The overall bias in the estimate of abundance will be dependent on the contribution of scanned fish in each of the local areas to the overall number of scanned fish in the region, such that:

(i) if the contribution to the total number of scanned fish is high from an area with a low recapture rate, then there is potential for an upward bias in the estimate of abundance from pooled data; or

(ii) if the contribution of scanned fish is high from an area with a high recapture rate, then there is potential for a downward bias.

21. Dr G. Kirkwood (UK) pointed out that this effect had been investigated within the simulation model presented to WG-FSA-SAM (WG-FSA-SAM-05/6 Rev. 1), and that moreover this comment would apply to all mark–recapture data, not just those in Subarea 48.3. Dr D. Agnew (UK) noted that Figure 8 shows that tagging release and recapture events, and fishing effort, are well distributed over the whole of the South Georgia and Shag Rocks fishing grounds. Table 6 shows that the annual recapture rate (measured as number recovered/number released/scanned numbers) is consistent between the various areas, with the possible exception of Shag Rocks. The fact that estimates of vulnerable biomass (vB) from the mark–recapture data were very consistent between the last two years of recaptures, 2004 and 2005 (WG-FSA-05/17), in spite of the re-distribution of some effort from Shag Rocks to South Georgia as a result of the Commission's decision last year (paragraph 3), provided additional evidence that such biases were not apparent. He recalled that this issue had been investigated by WG-FSA last year (SC-CAMLR-XXIII, Annex 5, paragraph 5.311) and that significant bias had not been identified.

22. In view of the importance of tag–recapture data for assessments in many areas, the Working Group requested further investigation into possible bias in estimates of abundance based on pooled mark–recapture data for all tagging experiments.

23. The Working Group used the tag data and the modified Petersen estimate to estimate vulnerable biomass of toothfish in Subarea 48.3 with two different selectivity functions.

Table 7: Results of the modified Petersen estimator of vulnerable biomass with two different selectivity functions.

Tag year	Recapture year	
	2004	2005
2000	1	2
2001	15	4
2002	8	16
2003	23	12
2004		93
CASAL base-case selectivity		
Vulnerable biomass *t*	53 926	54 105
Lower CI	38 827	44 770
Upper CI	69 025	63 441
ASPM base-case selectivity		
Vulnerable biomass *t*	53 506	53 377
Lower CI	38 525	44 167
Upper CI	68 487	62 586

3.4 Biological parameters

24. Table 8 summarises the parameter values used in the CASAL assessments of Subarea 48.3. Note that as well as the two selectivity trials for growth curves mentioned in section 3.1, it was agreed that, in addition to a base-case value of 0.165 for the natural

mortality rate, *M*, an additional sensitivity trial using a lower value for *M* of 0.13 be used. This represents the lower end of the range of values of *M* used in last year's assessment (0.13–0.20). It was considered that the upper end of the range was more unlikely, given the slow growth rates of *D. eleginoides* and the issues raised in WG-FSA-05/18 (see also Appendix I).

Table 8: Biological parameter values for *Dissostichus eleginoides* in Subarea 48.3.

Component	Parameter	Base-case growth	Low L_∞ growth	Base-case *M*	Low *M*	All	Units
Natural mortality	M	0.165	0.165	0.165	0.13		y^{-1}
VBGF	K	0.066	0.067	0.066	0.066		y^{-1}
VBGF	t_0	–0.21	–1.49	–0.21	–0.21		y
VBGF	L_∞	1946	1528	1946	1946		mm
Tag-related growth retardation						0.5	y
Tag loss rate						0.06	Tag. y^{-1}
Immediate tagging survivorship						0.9	
Tag probability of detection						1.0	
Length to mass	'*a*'					2.5E-09	mm, kg
Length to mass	'*b*'					2.8	
Maturity	L_{m50}					930	mm
Range: 0 to full maturity						780–1080	mm
Stock-recruit relationship steepness for CASAL assessments[1]	h					0.8	
Stock-recruit relationship steepness for GY projections	h					1.0	
Lognormal recruitment SD for GY and CASAL MPD projections	σ_R					0.8	
Lognormal recruitment SD for CASAL MCMC projections	σ_R					0.7	

[1] The stock recruitment steepness is estimated in ASPM assessments.

3.5 Total removals

25. Estimated total removals are set out in Table 1.

4. Stock Assessment

26. Two separate assessments were presented for consideration, each assessing the fishery using a different modelling strategy. The first was an Integrated Assessment (IA), implemented in CASAL, that used data on catches, standardised catch rates, catch-at-length, recruitment indices-at-age and tagging data. The base-case involved two fleets with separate

estimated selectivity curves and two catchability estimates across the time series of catch rates. The second assessment used an augmented ASPM, implemented in an Excel workbook, which used data on catches, standardised catch rates and catch-at-length. The ASPM base-case involved a single fleet with two periods of different selectivity (estimated outside the model) and a single catchability estimate across the catch rate time series plus an estimate of the steepness of the recruitment relationship. More details are given below.

4.1 Comparison between CASAL and ASPM

27. Two different methods for assessing toothfish stock in Subarea 48.3 were available to the Working Group: CASAL (WG-FSA-05/16) and ASPM (WG-FSA-05/73). Although the underlying basic age-structured population dynamics models assumed in each were similar, there were considerable differences in assumptions and implementation of the two methods. The Working Group agreed that first it wanted to check that the two approaches would produce sufficiently similar estimates when applied to the same datasets and when the assumptions made were as similar as possible without requiring substantial modifications to the methods. If this comparison was satisfactory, then subsequent differences in assessment results between the two methods could reasonably be attributed to differences in assumptions and input data, rather than fundamental differences in the assessment methods.

28. Accordingly, both methods were applied to a reduced dataset consisting of:

- the total catch series
- the full GLMM CPUE series
- catch length-frequency data from 1992 to 2005.

The following assumptions were made:

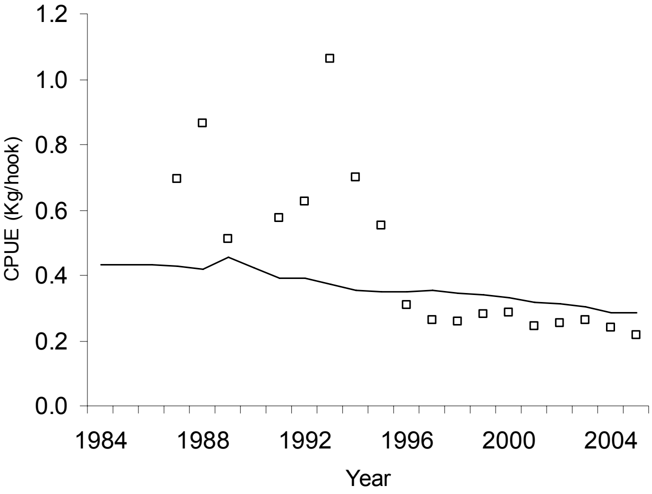
- no interannual recruitment variability
- fixed steepness of 0.8 for stock-recruitment relationship
- selectivity-at-age functions were fixed as defined in WG-FSA-05/73
- a single catchability coefficient relating CPUE to vulnerable biomass.

29. Estimates of unexploited (SSB_0) and current spawning stock biomass (SSB_{2005}) are given in Table 9 and the fits to the CPUE data for the two methods are shown in Figure 9. While there are slight differences in estimates and CPUE trends between the two sets of results, they are almost certainly due to minor differences in fitting the CPUE data (GLMM observation errors were used in CASAL and a process error was estimated, but only the GLMM point estimates were used in ASPM). The Working Group therefore agreed that the two assessment approaches had produced sufficiently similar results to be confident that subsequent differences in results were due to differences in assumptions.

Table 9: Results of comparison trials between CASAL and ASPM. CASAL trial results are MPD estimates with iterative reweighting of effective sample sizes of catch-at-length data. ASPM results are maximum likelihood estimates fitting to total catches, standardised CPUE and catch length frequencies.

Method	SSB_0 (in tonnes)	SSB_{2005} (in tonnes)	SSB_{2005}/SSB_0
ASPM	105 202	57 831	0.55
CASAL	113 647	63 386	0.56

(a)



(b)

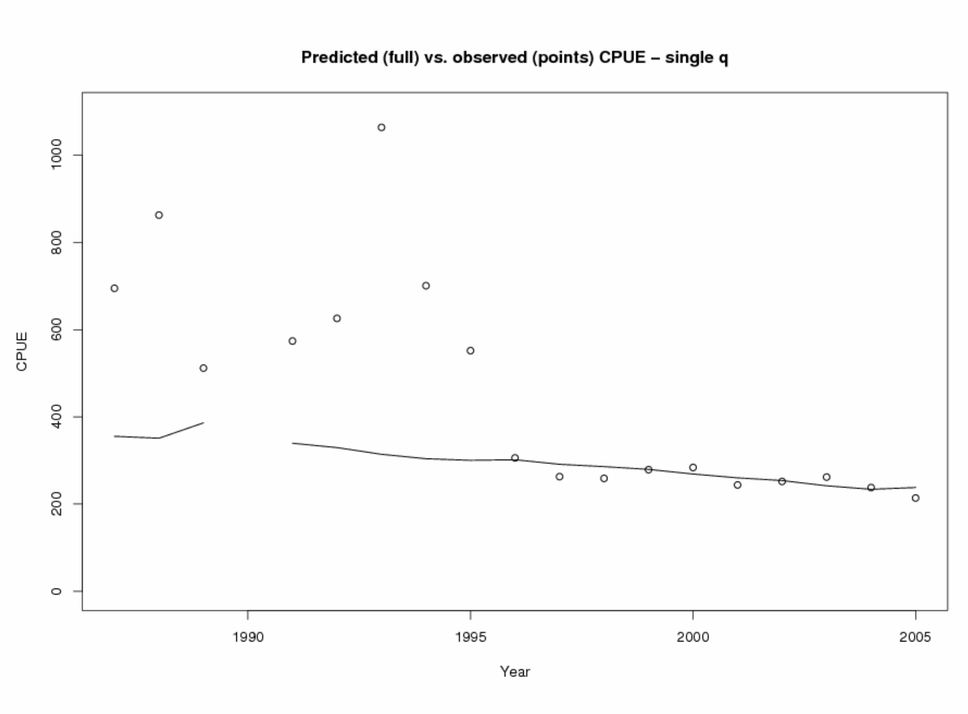


Figure 9: (a) fits to CPUE data for ASPM; (b) fits to CPUE data for CASAL.

4.2 CASAL Implemented Integrated Assessment (see also WG-FSA-05/16 to 05/18)

CASAL model structure and assumptions

Population dynamics

30. The CASAL population model used in the assessment of toothfish in Subarea 48.3 was a combined sex, single-area, three-season model. The annual cycle was defined as follows: the first season (1 December to 31 April) is where only recruitment (at the start) and natural mortality occurs; the second season, ranging from the beginning of May to the end of August, includes both natural mortality and fishing and contains the spawning period – half the mortality in that particular season being accounted for before spawning occurs; the final season runs from the beginning of September to the end of November, thus completing the annual cycle, with only natural mortality occurring. It was assumed throughout that the proportions of natural mortality and growth occurring in each season were equal to that season's length as a proportion of a year. The models were run over the years 1985 to 2005, with an initial unexploited equilibrium age-structure, and with a Beverton-Holt stock-recruit relationship with fixed steepness.

31. Data used in the model included the recorded catch, catch-at-length data (1992–2005), GLMM standardised CPUE data, tag–release and recapture data, and the CMIX recruitment survey estimates-at-age.

32. The length-frequency data prior to 1995 are very difficult to interpret, because the sampling rates were very low (Table 2), and also because the units of length measurement were different between different fleets, some measuring to the nearest 1 cm below, some to the nearest 3 cm and some to the nearest 5 cm. The difficulties in calculating a representative catch-weighted length frequency for these early years are explained in some detail in WG-FSA-05/18, and are particularly bad for years prior to 1992, there being no data whatsoever from the fishery in 1987, 1988 or 1989. The CASAL assessment therefore used length-frequency data only from 1992 to 2005 and moreover used data from all fleets fishing in these years.

33. Given the major changes that the fishery underwent between 1995 and 1998 described in paragraph 14 (changing fishing period, fleets, vessels and depth distribution), it is most unlikely that the selectivity and catchability of the fleet was the same after the changes (i.e. from 1998) as prior to them (i.e. before 1997). The CASAL base-case assessment therefore assumed that effectively two fleets have fished in Subarea 48.3 for toothfish: the initial Russian/Chilean fleet, fishing from 1985 (but with major catches only from 1989) to 1997; and a later mixed-nationality fleet fishing from 1998 to the present. The 1997/98 season was chosen as the first year for the second fleet principally because from this year the fleet started to fish in a markedly different way than previously, taking smaller fish in shallower water exclusively in the winter. The differences in fishing practices between the two periods are reflected in the marked shift in the modes of the length-frequency data from 1992–1997 to those seen from 1998 onwards (Figure 6). The fleet has remained very stable from this point to the present.

34. Consequently, in the CASAL assessment, as a base-case, a two-fleet model was used, each fleet with its own (estimated) double-normal selectivity-at-age function. The first fleet

operated from 1985 to 1997, and the second from 1998 to the present. The reason for this temporally split two-fleet model was to account for the marked shift in the modes of length-frequency data from 1992–1997, to those seen from 1998 onwards. As an alternative, a single-fleet model was also considered, with a single (estimated) double-normal selectivity-at-age.

Model estimation

35. Exploratory runs and sensitivity analyses were run using a point estimate Bayesian analysis (MPD: maximum posterior density) – akin to maximum likelihood estimation, but with prior beliefs on parameters of interest also accounted for in the objective function. To account for parametric uncertainty in the final runs, CASAL's implementation of the Markov Chain Monte Carlo (MCMC) method for extracting a sample from the parameter's posterior (data updated) probability distribution was used. This allows a full exploration of the model's parameter space, not just the most likely parameter values, as is the case with the exploratory MPD method.

Observation assumptions

36. The catch proportions-at-length data for 1992–2005 were fitted to the model-expected proportions-at-length composition, using a multinomial likelihood.

37. CPUE indices were assumed to be lognormally distributed about the model-predicted vulnerable biomass half way through the fishing season, via a constant catchability q. Observation error was accounted for by using the annual CV estimates obtained from the GLMM standardisation. An additional process error CV was also estimated, to account for the extra variance required for the population model to interpret the CPUE observations.

38. Tag–release events for 2000, 2001, 2002, 2003 and 2004 were incorporated into the model, but given the comparatively low number of returns and spread in return lengths/ages in the recaptures in 2001–2003, only the recapture events in 2004 and 2005 were used. Within year/season recaptures were omitted from the observations to allow for possible incomplete mixing in the first few months after release. Tag–release and recapture events occurred during the fishing season (season 2), with a probability of detection of recaptured tags of one. The estimated number of scanned fish for each length class relevant to those in the recapture data, were calculated using the total catch biomass, the catch-at-length proportions and the mean weight of the fish.

39. In each year, the length frequencies of releases and recaptures ranged from 20 to 220 cm in 10 cm length bins.

Process error and data weighting

40. As well as process error being estimated for the CPUE observations, the appropriate effective sample sizes to be used to weight the length-frequency data, and the levels of

possible over-dispersion apparent in the estimated tagged populations, were investigated. For both sets of observations, standard formulae were used to estimate these quantities after an initial MPD run of the model with the original sample sizes/dispersion values. The actual effective sample sizes/dispersion values predicted by the model's fit to the relevant dataset were then adopted, and a secondary MPD run was performed. If the implied recalculated sample values/dispersion values were close to those calculated from the first MPD run, then it can be concluded that each dataset was being given the correct weighting in the likelihood.

Penalties

41. Two types of penalties were included within the model. First, a penalty on the catch constrained the estimated harvest rate in any year from exceeding a specified maximum, set at 0.4[1] in the CASAL assessment models. Second, a tagging penalty discouraged population estimates that were too low to allow the correct number of fish to be tagged.

Priors

42. Within a Bayesian model, all free parameters estimated require both the definition of a prior and bounds that constrain the estimation. Table 10 shows the free parameters estimated in the CASAL models, along with their respective extrema, and prior parameterisations.

Table 10: Free parameters, and their priors and bounds in the CASAL assessment models.

Parameter	Prior	Lower bound	Upper bound
B_0 (virgin SSB)	Uniform-log	20 000	1e+6
Q (catchability)	Uniform-log	1e-8	1e-1
A^* (max. sel. age)	Uniform	1	50
s_l (left sel. decay)	Uniform	0.05	500
s_r (right sel. decay)	Uniform	0.05	500
CV (CPUE obs.)	Uniform-log	0.01	10

Selectivity and growth

43. In CASAL, fishing selectivity is directly estimated as part of the integrated assessment. Selectivity-at-age is expressed as a double-normal curve with the following form:

$$s(a) = 2^{-\frac{(a-m)^2}{l^2}} \quad \text{if a < m} \qquad (1)$$

$$s(a) = 2^{-\frac{(a-m)^2}{r^2}} \quad \text{if a} \geq \text{m}$$

---

[1] During the review of these assessments, it was suggested that for those assessments that showed the greatest decline in SSB, a higher maximum harvest rate (e.g. 1.0) might be more appropriate.

where *s*(*a*) is the selectivity at age *a*, *m* is the age at maximum selection, *l* is the left-hand decay term, *r* is the right-hand decay term. The primary data that inform these selectivities are the annual catch length frequencies and the tag returns at length. When predicting the annual catch length frequencies and tag returns at length, the selectivity-at-age curve is interpreted via the specified growth curve, the specified CV of length-at-age (another input parameter to CASAL) and the population dynamics. Consequently, there is a strong interaction between the estimated selectivity curve and the assumed growth curve.

44. Similarly, as noted by Candy (2005 – WG-FSA-SAM-05/13) and WG-FSA-05/18, length-at-age data collected from the commercial fishery is also affected by selectivity. WG-FSA-05/18 applied the WG-FSA-SAM-05/13 method to estimate von Bertalanffy growth curve parameters accounting for selectivity patterns estimated in CASAL assessments reported in WG-FSA-05/16. These were revised during the meeting and a set of growth curve parameters so obtained for different selectivity curves is shown in Figure 10.

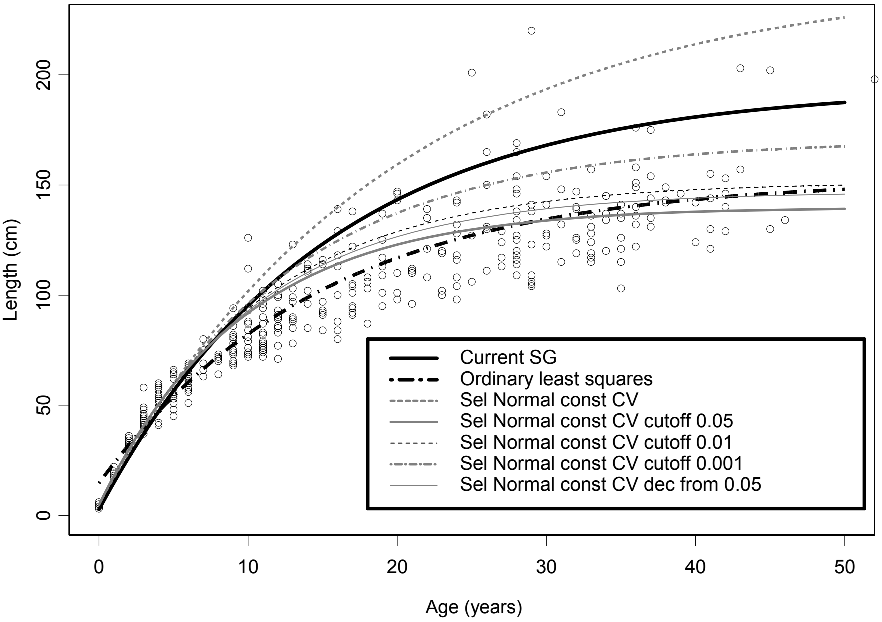


Figure 10: Current Subarea 48.3 von Bertalanffy growth curve and growth curves fitted to the Belchier (2004, WG-FSA-04/86) length-at-age data (circles) by ordinary least squares and when corrected for selectivity as estimated in base-case CASAL assessment(Sel normal, constant CV).

45. The Working Group noted that it is not currently possible to reliably estimate a single selectivity-corrected growth curve for *D. eleginoides* in this region. One reason for this is that the vulnerability function estimated in CASAL is a mixture of length- and age-based selectivity/availability. The impact of this will be dependent on the contribution of length-based selectivity to these parameters. An additional likely source of uncertainty is the difference in growth between sexes. Observations for toothfish from other areas indicated that they exhibit sexual dimorphism in growth and maturity.

46. The Working Group agreed that, in addition to the base-case von Bertalanffy growth curve with parameters equal to those used in last year's assessment (L_∞ = 194.6, K = 0.066

and t_0 = –0.21; subsequently labelled 'base-case'), as an alternative test the growth curve estimated by ordinary least squares to the Belchier data (ignoring selectivity effects) should also be used in assessments carried out at this meeting. The parameters of this growth curve were L_∞ = 152.8, K = 0.067 and t_0 = –1.49 (subsequently labelled 'Low L_∞').

47. A cross-check was performed against the results of the tagging data using the methods described in WG-FSA-05/17. For the three recapture years 2003, 2004 and 2005 the number of tagged fish in the population was estimated at different lengths given the time at release and assumed fish growth since release, assuming a 0.5 year tag-induced growth retardation period and natural mortality equal to fishing mortality (estimated from tagging data in WG-FSA-05/18). It was assumed that tagged fish would be distributed evenly with respect to length, and would have an equal probability of capture by length group. Figure 11 shows that the tag recoveries at length follow the selectivity profiles determined by CASAL and other assessment methods, and are dependent on the growth model used (see above).

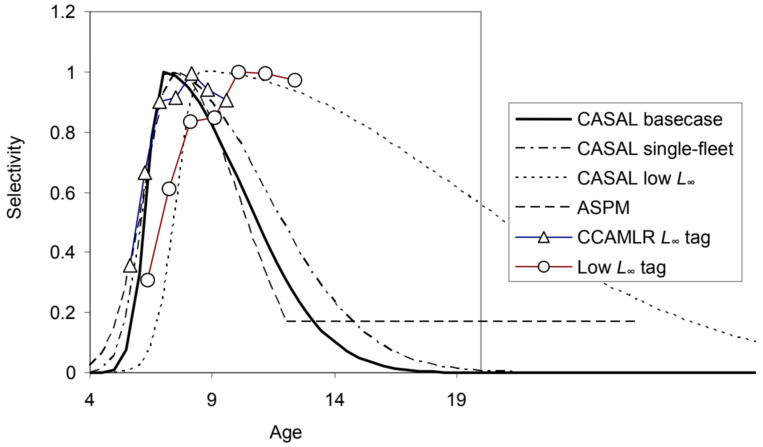


Figure 11: Selectivity functions for Subarea 48.3: Using the current South Georgia growth parameters (CCAMLR L_∞ tag, L_∞ 194.5 cm) two CASAL-derived selectivities are presented, associated with the base-case and single-fleet runs, the ASPM selectivity (WG-FSA-05/73) and the tag-derived selectivity (Δ). Using the ordinary least-squares growth parameters (L_∞ = 152.8 cm), the CASAL selectivity and the tag-derived selectivity (○) expand.

48. Dr Constable noted that historically the Working Group had assumed the longline catch had a large proportion of mature fish. The size-at-maturity in Table 8 combined with the selectivity functions and corresponding growth curves indicate that the CASAL base-case scenario would be taking primarily juvenile fish while the Low L_∞ scenario would comprise a larger proportion of mature fish. Given that the latter scenario seems to coincide with previous assumptions by the Working Group, he suggested that analyses of proportion of mature fish in the catch could be used in the future to help differentiate between these two hypotheses, if needed.

Base-case CASAL runs and sensitivity analyses

49. For the CASAL assessment model runs, the base-case model was the two-fleet model, fitting to the GLMM CPUE data, catch-at-length data, recruitment survey data and the mark–recapture data (base-case). Three further models were identified by the Working Group as sensitivity trials:

(i) a single fleet assessment (One fleet);

(ii) two-fleet assessment, using an alternative growth curve, derived from the ordinary least-squares fit to the length-at-age data (Low L_∞);

(iii) a two-fleet assessment with a lower natural mortality rate, $M = 0.13$ (Low M).

50. An important issue for all the CASAL assessment runs was how to treat the issue of interannual recruitment variability, estimation of which is an option in CASAL. Key issues are the extent of information on recruitment variability in the different datasets and their consistent estimation.

51. In principle, the primary source of information on annual recruitment comes from the recruitment survey data, but the CMIX-derived age-density estimates show few, if any, cohorts moving consistently and predictably through the younger age classes. When the survey estimates-at-age were included in the base-case CASAL assessment model, the fit to them was particularly poor, and the estimated annual recruitment series was virtually identical to that estimated when the survey data were omitted from the estimation. Even when the recruitment survey data were given very high weight in the assessment (by artificially reducing the observation error CVs substantially), the same effect was observed. This implies that the survey data were providing no useful information on annual recruitment in the context of the integrated assessment.

52. The remaining data that potentially inform recruitment variability are the catch length-frequency data and the CPUE data. The catch length frequencies are very stable, particularly in recent years and show no sign of year classes moving through the exploitable population. In earlier years, the CPUE data show considerable variation, but they are also subject to substantial observation errors, and it is extremely doubtful that any variation is caused by variation in recruitment. By contrast, the CPUE data in the later years have both low observation error and are very stable, again suggesting no variability in recruitment.

53. Clearly, the data used in these CASAL scenarios have no information on recruitment variability. This does not necessarily mean that there was no variability in recruitment. It is possible that the fishery behaves in subtly different ways each year to give rise to no indication of changes in recruitment. For example, operational considerations may result in differences (or not) in CPUE and size structure of the catch that is unrelated to the characteristics of the stock (WG-FSA-05/4, paragraph 2.10). Under these circumstances, the model will have insufficient data to capture all the relationships between, and the magnitude of, the different parameters, one of which could be recruitment variability.

54. Trials in which the weight given to the CPUE data was varied relative to that given to the other observations revealed that the estimated annual recruitment trends varied markedly with the relative CPUE weights. When high relative weighting was given to the CPUE data,

then the estimated recruitment variations were arranged so as to give as close a fit to the CPUE data as possible, and provide a substantially reduced quality fit to the other datasets. In effect, the model was adjusting recruitment minutely between years so as to provide as good a fit as possible to CPUE. When the CPUE data were down-weighted, a different recruitment series was estimated, which now obtained a marginally better fit to the other observations in the model. This behaviour, in circumstances where the data sources show little, if any, visual evidence of recruitment variability, gives a clear indication of an over-parameterised model, where the additional estimable parameters represented by recruitment variations are used simply to refine the quality of the fit, depending on the relative weighting of the observations, rather than providing a consistent representation of the annual variations in recruitment. Consequently, in the base-case and sensitivity analyses, no historic recruitment variations were included in the CASAL model. Recruitment and recruitment variability from the parent stock was estimated by the model directly through the stock-recruit relationship, but with the parametric uncertainty in this relationship implicitly accounted for in the MCMC simulations.

Point-estimate (MPD) results

55. Even though MCMC simulations were undertaken, for clarity, the fits of each of the four proposed CASAL models were recapped with respect to the point estimate MPD runs. Table 11 shows an overview of the major parameter values calculated for the four runs, as well as their respective BIC (Bayesian information criterion) values, which are interpreted in a very similar manner to the Akaike information criterion (AIC): the model that minimises the BIC or AIC is the most probable. Although the base-case assessment has the numerically smallest BIC, there is little to suggest it is a truly better model than the others considered.

Table 11: Review of parameter estimates for the four CASAL models, using the MPD estimation results. BIC – Bayesian information criterion.

Model	BIC	B_0 (tonnes)	Selectivity 1 parameters (see eq. 1)	Selectivity 2 parameters (see eq. 1)	Process error CV (CPUE)
Base-case	774.32	176 969	9.21, 2.17, 4.53	6.95, 0.74, 3.9	0.39
Low L_∞	777.91	70 372	12.4, 3.22, 13.8	8.1, 1.07, 12.5	0.36
Low M	782.4	266 953	9.02, 2.2, 4.27	6.92, 0.76, 3.8	0.39
One fleet	785.9	163 986	7.74, 1.4, 5.35	N/A	0.46

56. The estimates of q for the early and later fleets for the base-case assessment were 0.0080 and 0.0051 respectively.

57. Model-fit diagnostics and goodness-of-fit achieved by the base-case model are shown in Figures 12 to 16.

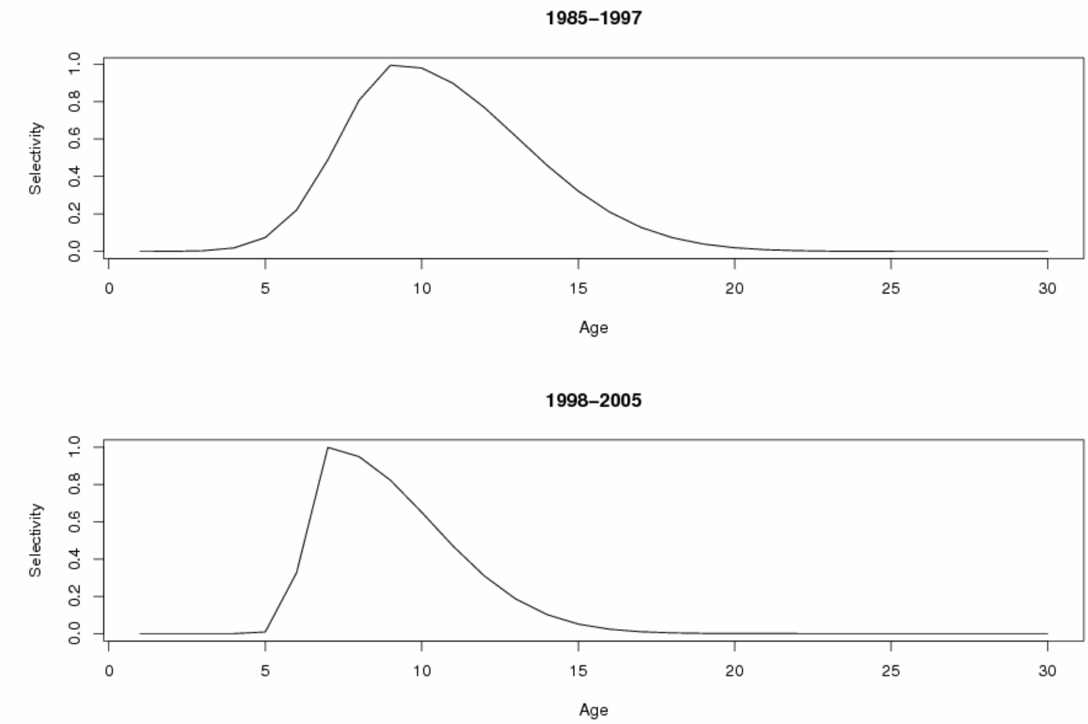


Figure 12: Estimated selectivity curves in the base-case model.

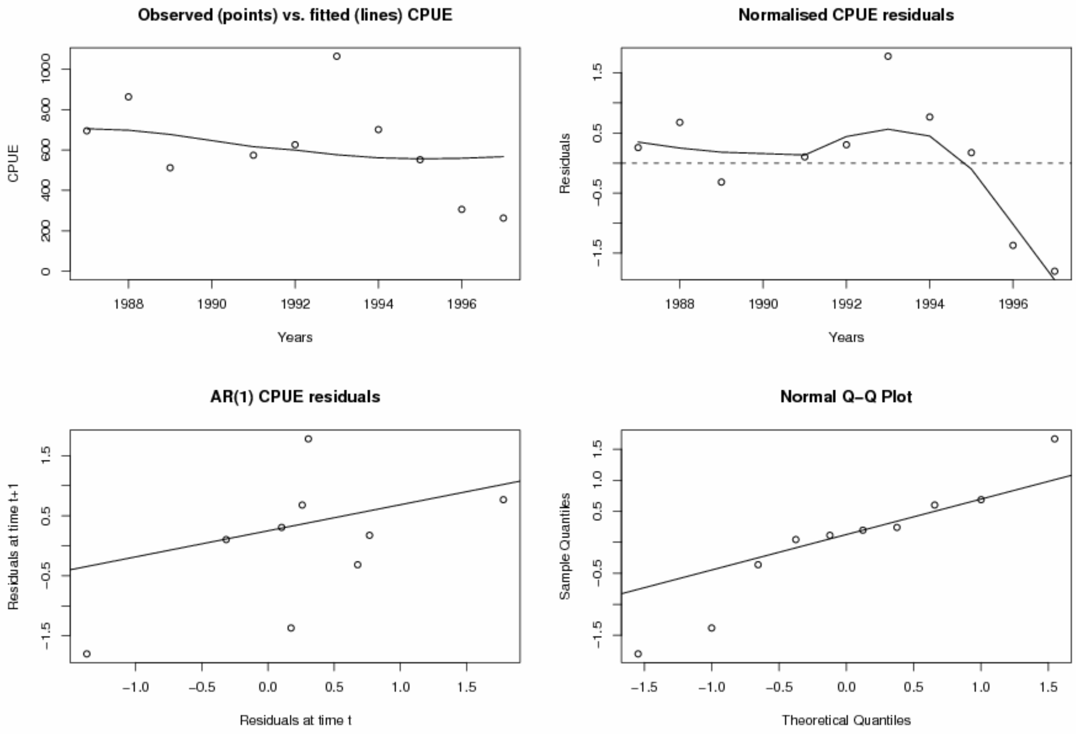


Figure 13: Fit to first-fleet CPUE series, base-case model.

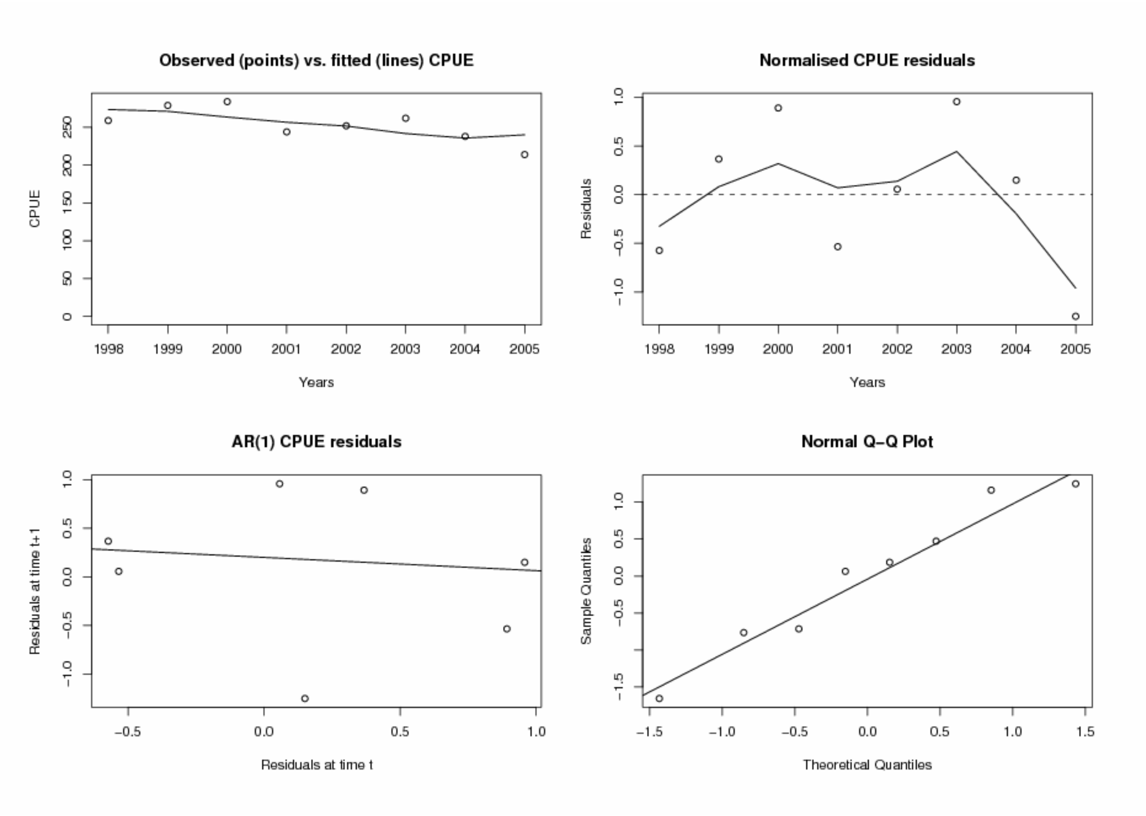


Figure 14: Fit to second-fleet CPUE series, base-case model.

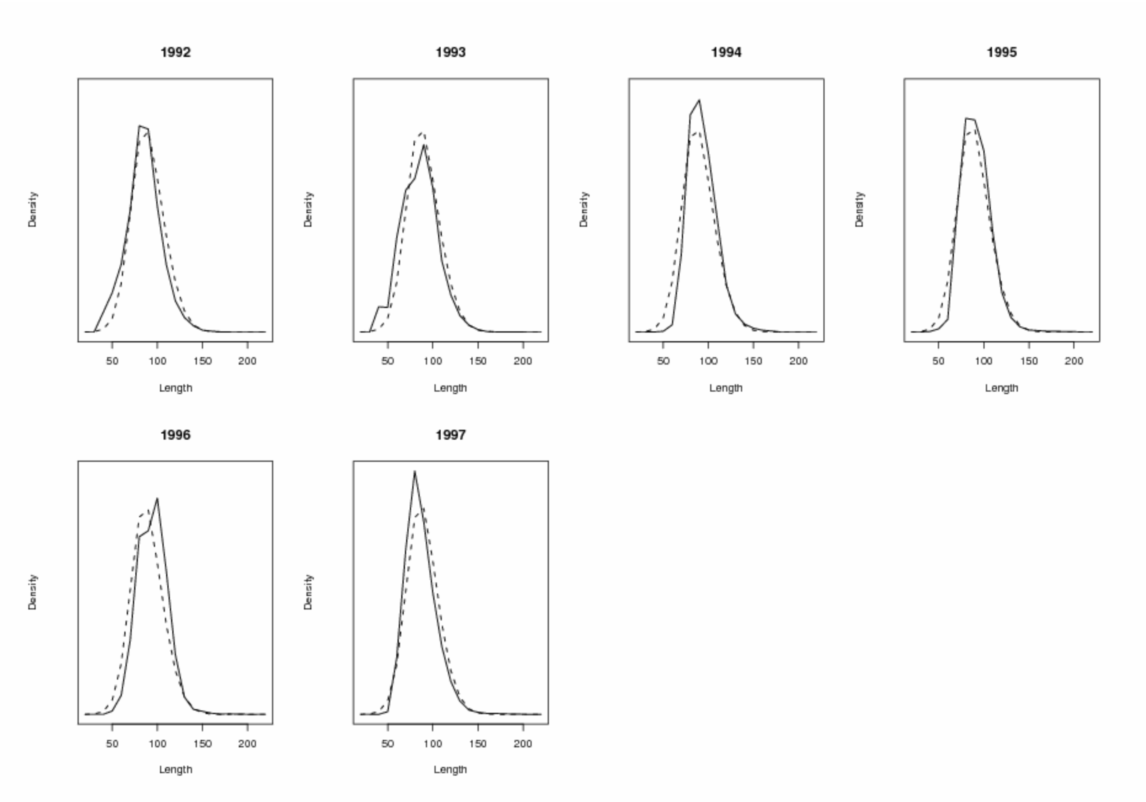


Figure 15: Fit to first-fleet catch length frequencies, base-case model.

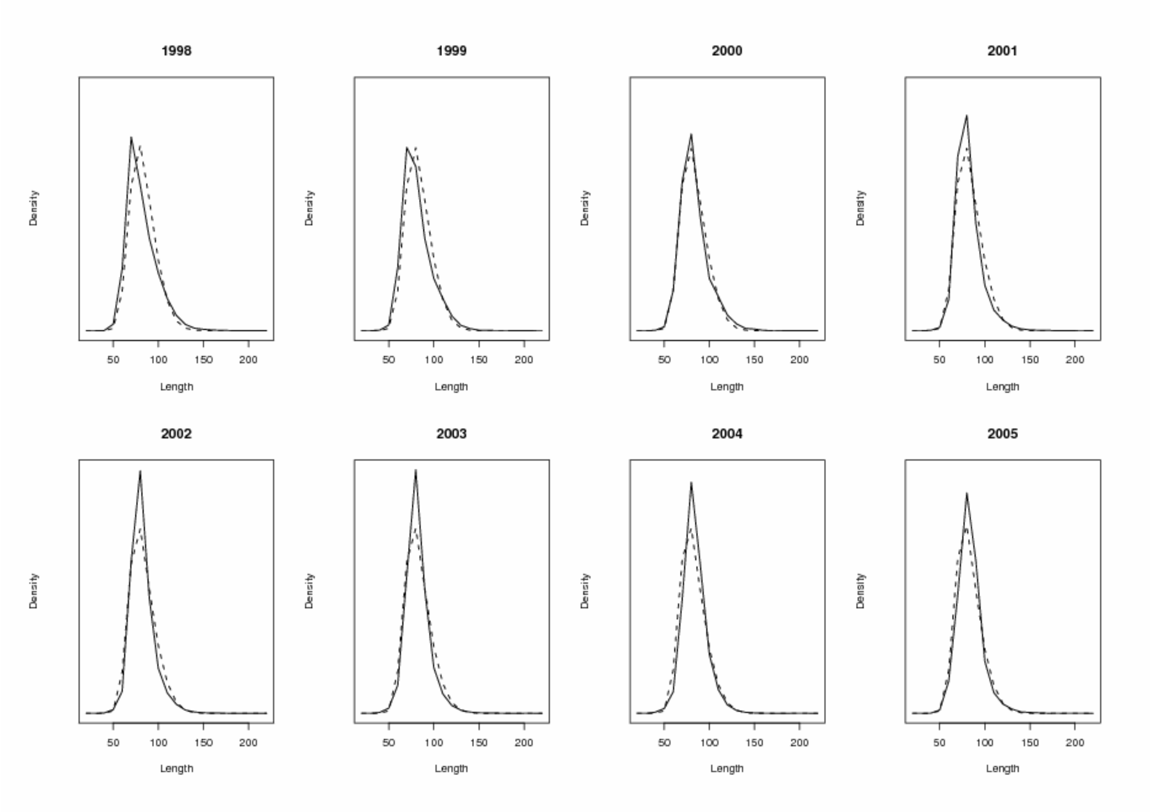


Figure 16: Fit to second-fleet catch length frequencies, base-case model.

58. Stock trajectories are shown in Figure 17.

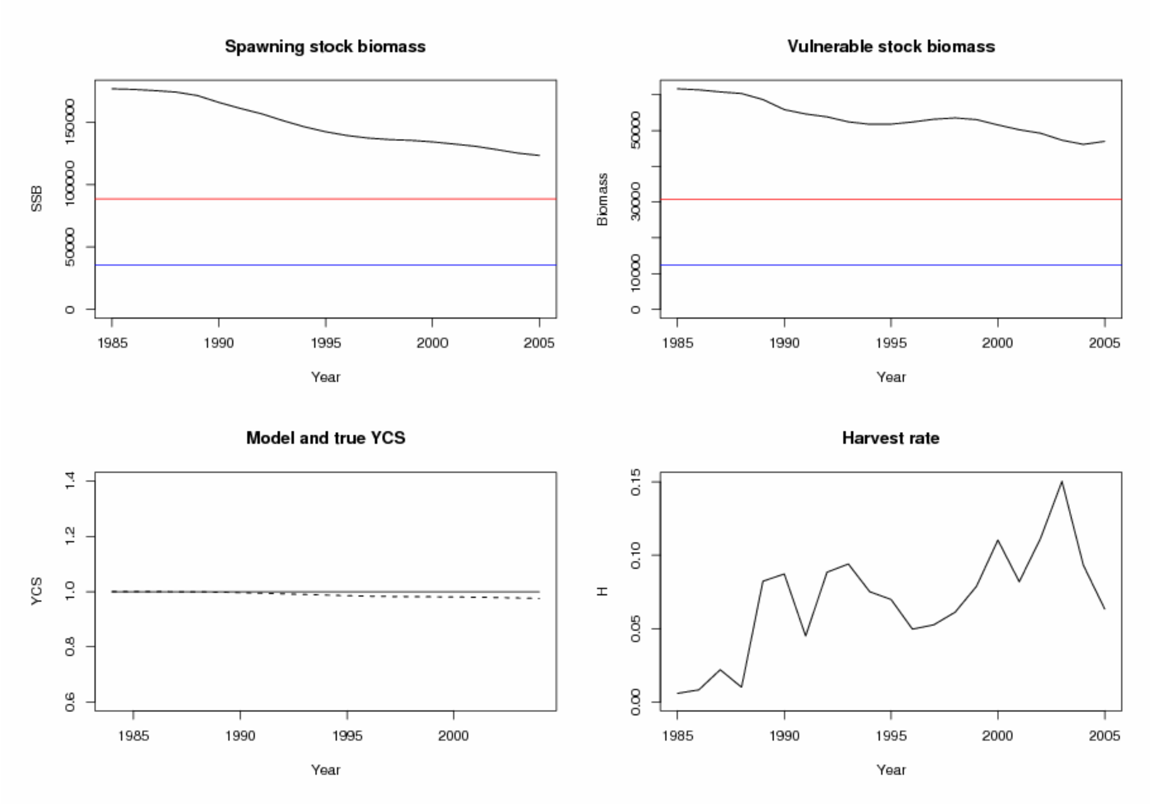


Figure 17: Stock trajectories for base-case CASAL fit.

59. As can be seen, excellent fits are achieved to all datasets except the CPUE data for the first fleet, where the fit is poor and a process error with a CV of 0.4 is estimated. The quality of the fit, however, must be judged in relation to the high observation errors for most of this series (see Figure 5).

60. All models with two fleets had very similar fits to the data. The one-fleet model appeared to fit the length-frequency data less well.

61. The selectivity-at-age functions estimated in the different models showed similarities between the base case, Low M and one-fleet scenarios while the Low L_∞ scenario had a much wider selectivity-at-age, which would be expected, given the reduced length-at-age for fish older than 5 years and the need to fit to the same length-frequency data (see Figure 11).

MCMC results

62. Due to the time taken to complete a full MCMC run (for these particular CASAL models, around 27 hours on a powerful processor), the standard CASAL MCMC algorithm was used for the base-case, two-fleet model only. There was insufficient time remaining at the meeting to complete similar MCMC runs for all the alternatives. For the other three cases, a well-defined approximation was used, using the data coming from the CASAL MPD results. The posterior probability distribution can be approximated by a multivariate normal distribution, with mean defined by the posterior mode, and variance defined by the covariance matrix approximated in the minimisation process. Given good estimates from the minimisation algorithm, this approximation is well defined, and consistent with more time-consuming MCMC methods, while very quickly yielding an MCMC sample with the same posterior mode and approximate variance–covariance structure as that contained in the actual posterior distribution of interest. The accuracy of the approximate multivariate normal method was examined by repeating the base-case MCMC run using this approximation. The multivariate normal approximation estimated median SSB_0 as 176 043 tonnes with 95% credibility interval (152 848–198 608 tonnes). The greatest discrepancy is around 3% in the tails.

63. For the CASAL MCMC run, the convergence tests outlined in WG-FSA-05/16 indicated that convergence had been satisfactorily achieved. Median and 95% credibility intervals for the four CASAL fits are shown in Table 12.

Table 12: Median and 95% credible intervals (in tonnes) for the initial equilibrium SSB (B_0), the current SSB (B_{2005}), the ratio of current to initial SSB (B_{2005}/B_0), the initial vulnerable biomass (VB_0) and current vulnerable biomass (VB_{2005}) for each of the CASAL models.

Model	B_0 *(thousands)*	B_{2005} *(thousands)*	B_{2005}/B_0	VB_0 *(thousands)*	VB_{2005} *(thousands)*
Base-case	177.3 (157.7–202.1)	124.0 (104.6–148.7)	0.69 (0.66–0.74)	61.9 (55.1–70.6)	47.2 (40.2–56.1)
Low L_∞	70.3 (61.8–77.9)	35.6 (27.3–43.5)	0.51 (0.44–0.56)	83.3 (72.4–97.2)	53.2 (43.6–64.9)
Low M	267.3 (235.1–300.4)	197.2 (163.9–229.9)	0.74 (0.71–0.76)	64.8 (56.9–72.8)	49.7 (41.6–57.7)
One fleet	163.8 (139.9–188.4)	108.6 (84.6–133.5)	0.67 (0.61–0.71)	81.8 (69.6–94.9)	61.1 (48.8–74.7)

Yield calculations

64. CASAL allows the historic stock dynamics to be projected into the future, for a variety of future scenarios. A constant catch projection allows calculation of the long-term yield that satisfies the CCAMLR decision rules. The long-term yield is the minimum yield, γ, which:

(i) gives a probability of greater than 0.5 of being above the 50% of the initial equilibrium SSB after 35 years;

(ii) never allows the SSB trajectory to go below 20% of the initial equilibrium SSB, more than 10% of the time.

65. Long-term yield calculations based on the four CASAL assessment results are most easily carried out using the CASAL model to project forward. There are two ways of doing this. The first is to use the point-estimate projection method, which randomises the historic and future recruitments (based on a lognormal user-specified deviate) to introduce additional uncertainty into the interpretation of the future dynamics. The second projection method uses the MCMC sample directly. For this projection method, each element in the Markov chain produces a corresponding historic and future stock trajectory. Extra uncertainty can be included in this projection process, by again defining a suitable form for the stochastic recruitment deviations. Given the lack of a consistent estimated value for the magnitude of these recruitment variations across the assessed stocks, it was agreed that:

(i) for projections, such as those using the MPD CASAL projection method or the GYM, a lognormal recruitment deviate would be applied, with a standard deviation of 0.8;

(ii) for MCMC projections, a lognormal recruitment deviate with a standard deviation of 0.7 would be used.

66. The reason for this lower value of the standard deviation in the recruitment deviates for the MCMC case is that parametric uncertainty is an integral part of the MCMC estimation process, and having a lower value of the projection recruitment variability acknowledges this fact.

67. Last year, estimates of long-term yields corresponding to the tagging estimates of vulnerable biomass were calculated using the GYM, by adjusting the mean recruitment so that the current median vulnerable biomass in GYM matched the tagging estimate. Investigations by the Working Group revealed that the GYM could produce very similar historic trends in either SSB or vulnerable biomass to those obtained in the CASAL fits, but not both. Consequently, two sets of GYM calculations were conducted, in which either the GY estimates of current median SSB or current vulnerable biomass were matched to the corresponding CASAL estimates[2].

68. Table 13 shows the resulting calculated long-term yields. The GY projection yields are close to the MCMC projection, especially when matched to current SSB.

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[2] In practice, for each model a GYM was run in which SB_{2005} closely approximated the CASAL estimate of SB_{2005}, and median spawning, vulnerable biomass and yield were calculated. This yield was adjusted pro-rata so that either SB_{2005} or VB_{2005} from the GYM runs matched the CASAL estimates exactly.

Table 13: Long-term yields (in tonnes) meeting the CCAMLR decision rules, for each CASAL assessment model, using the MPD and MCMC CASAL projection methods, and the two GY methods.

Model	MPD projection	MCMC projection	GY projection matching current SSB	GY projection matching current vulnerable biomass
Base-case	5573	5629	5590	6128
Low L_∞	3315	3407	3030	3207
Low M	5794	5876	6055	6709
One fleet	5371	5428	5434	6643

4.3 Age-Structured Production Model (ASPM)

General description of the model

69. The ASPM is an implementation of the version used in the Patagonian Shelf. It was derived from that used by Brandão and Butterworth (2003, 2004) to assess the biomass of *D. eleginoides* in the Prince Edward Islands and modified to allow variability in recruitment and fitting of the catches. The general formulation of the model is described in WG-FSA-05/73.

Data input

CPUE data

70. The base-case model was implemented as a single-area single-fishery model. The CPUE values corresponding to the years 1993–1995 were not included in the base-case fitting of the model because they were considered not to be representative of toothfish abundance. Details on this topic are given in WG-FSA-05/73 and WG-FSA-SAM-05/5.

71. The standardised CPUE series from GLM and GLMM shows an initial positive trend in 1985–1987 and a weak negative trend between 1988 and 1991 (Figure 5). Afterwards CPUE values increase from 1992 to 1993 and decline quickly over the period 1993–1996. Finally, CPUE appears to show a relatively stable trend until 2005, more evident in the GLMM CPUE series.

72. As described in the previous papers, the initial positive trend of CPUE is probably related with the training of the fleet to locate the main fishing grounds of toothfish, as usual in the early development of a new fishery. In this sense, the second period (1988–1992), showing a slight declining trend, could be indicative of the fish density in surveyed fishing grounds. The subsequent marked variation, observed in CPUE between years 1992 and 1996, might respond to different reasons. Agnew et al. (2004 – WG-FSA-SAM-04/17) mentioned possible changes in fishing areas or depths, changes in the behaviour of the fleet because of the presence of international observers on board since 1994, errors in the estimation of effort (underestimation) in early years, errors in the standardised CPUE estimation due to vessel changes in the period, or IUU fishing not taken accurately into account between 1995 and 1996. All of them, jointly or individually, might affect CPUE estimates, making standardised values not indicative of toothfish abundance. Thus, the CPUE increment between 1992 and

1993 was considered to indicate a higher availability of toothfish to the fleet, but not a real shift in abundance. Also, it cannot be considered that an abrupt increase in recruitments might be the cause of the highest observed CPUE since it could be hardly attributed to one or two year classes. This consideration arises from the fact that in a population composed of at least 35 year classes, the relative contribution of recruitment would be absorbed by the other 34 year classes. Additionally, if a single or two exceptionally strong successive year classes were incorporated to the exploitable population, this should be clearly observed in catch-at-length structure, but this is not evident in any year.

73. On the other hand, the strong decrease of CPUE over the 1993–1996 period can hardly be attributed to the amount of the total catch, because with quite similar extraction levels the CPUE values increased slightly during 1992–1993.

74. The best available signal of abundance is then provided by the early and late periods of the standardised CPUE series, as mentioned in last year's WG-FSA report (SC-CAMLR-XXIII, Annex 5). In the CPUE series estimated at this meeting, the values corresponding to 1993–1995 appear as anomalous values. It was then concluded that the annual CPUE data between 1993 and 1995 cannot be considered as indicative of toothfish abundance in Subarea 48.3. As a consequence, it was decided to tune the base-case model with CPUE data corresponding to 1987–1992 and 1996–2005 standardised using GLMM.

Selectivity-at-age

75. Selectivity was modelled accordingly to the function given by Brandão and Butterworth (2003, 2004), modified to include an asymptotic parameter. The selectivity pattern was calculated separately for shallow and deep fishing and applied accordingly to the depth phases of the fishery described in WG-FSA-SAM-04/17. The shallow pattern was applied to the periods from 1985–1988 and 1997–2005 and the deep pattern to 1989–1996. Considerations about fitting of the selectivity functions are also given in WG-FSA-05/73 and WG-FSA-SAM-05/5.

76. To derive the selectivity curves it was assumed that at equilibrium (before fishing) the size structure of the stock is stable and independent of total abundance. Knowing this structure, the selectivity pattern that produced the observed length proportion in catches was estimated. The observed proportions of catch-at-length were similar during the first four years of the fishery, when the catches had not been large (870 tonnes y^{-1}) thus, the same selectivity curve was applied. Bearing in mind these relatively low catches, when the fishery changed its pattern from shallow to deep in 1989 (WG-FSA-SAM-04/17) a new selectivity pattern was estimated and used assuming that the stock remains at, or very close to, equilibrium. Thus, two selectivity functions were used, depending on the fishery being in a deep or shallow phase (Figure 18). For comparison purposes, the selectivity curves previously used by WG-FSA are also shown in Figure 18.

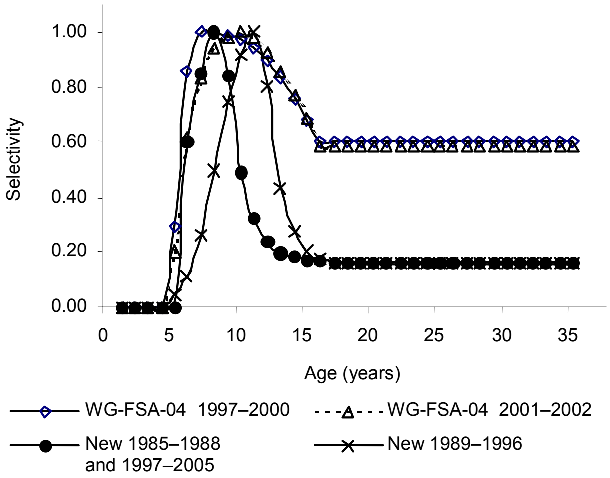


Figure 18: Selectivity-at-age used in the present implementation of the ASPM and those previously used by WG-FSA.

Proportion-at-length in catches

77. Data on the catch proportions-at-length were provided by the Secretariat for the period 1993–2005; previous years' data were the same dataset used by Agnew and Kirkwood (2004 – WG-FSA-04/82). Data were grouped in 4 cm intervals from 48 to 156 cm.

Tag–recapture data

78. No tagging data were included in the fit of the model because the present implementation has not been adapted to use this kind of data in the fitting process. It is expected that the model will be modified to include this type of data in the future.

Recruitment data from surveys

79. Recruitment estimates from surveys were not included in the fit of the model, since the bottom trawl survey design and the number of stations trawled at South Georgia are apparently inadequate to provide reliable estimates of toothfish recruitment (WG-FSA-04/82). The survey recruitment series is used for comparison purposes only.

Assumptions of the model

80. (i) Catches are measured with error. In this case catches are estimated by the model estimating the annual harvest rates to fit to the observed catches.

(ii) Selectivity-at-age is an input vector of parameters fixed in the model. Selectivity of older ages is considered a constant equal to 0.16 and 0.15 in the two selectivity sets used in the fitting process.

(iii) Recruitment is variable, depending on SSB and fitting the parameters *h* (steepness of stock-recruitment relationship) and ε_y (vector of annual recruitment variability).

(iv) Constant catchability coefficient (*q*) for the CPUE index was analytically estimated from the following equation:

$$\ln q = \frac{1}{n} \sum_{y=1,}^{n} \ln \left(CPUE_y^{obs} / VB_y\right),$$

where *n* is the number of years with available CPUE data and *VBy* is the vulnerable biomass.

(v) Minimisation of the objective function (includes CPUE, annual catches and length proportions in catches) assuming lognormal errors, was achieved varying the parameters: B_0, F_y, (y = 1984, 2005), *h* (steepness of the stock-recruitment relationship), the vector of recruitment variability ε_y, and the parameter ψ, related to the standard deviation of length-at-age.

(vi) The estimation of variance and confidence intervals was obtained by parametric bootstrap, generating random values of φ_y, with $\varphi_y \approx N\left(0, \sigma^2\right)$, where $\tilde{I}_y = \hat{I}_y e^{\varphi y}$, and $\hat{I}_y$ is the estimated value from the model of the index *I*. $\hat{\sigma}^2$ is the estimated variance of the residuals from the linear regression model $\ln\left(I_y\right) = \ln\left(\hat{I}\right) + \varphi_y$. This method allows generation of new values of the indices. For each run the model is fitted and new estimates of all parameters are obtained. Then basic statistics for all parameters are calculated. The confidence intervals were estimated by the percentile method.

81. Input values of the fixed parameters used in the base-case model are given in Table 14.

Table 14: Parameter values used in the base-case run of the ASPM for *Dissostichus eleginoides* in Subarea 48.3.

Parameters	Values
Annual catch (tonnes) (1984–2004)	268; 521; 733; 1954; 876; 7204; 7222; 3531; 6875; 7039; 5438; 5045; 3602; 3812; 3347; 4303; 5919; 4243; 5747; 7534; 4482; 3041
Age structure (Recruitment age, plus class accumulation)	1; 35
Natural mortality (min, max, mean)	0.13, 0.2, 0.165
VBGF (L_∞, K, t_0)	194.6; 0.066; –0.21
Length to mass (*a*, *b*)	0.000025; 2.8
Maturity-at-age (1 to 35+)	0.00; 0.00; 0.00; 0.00; 0.00; 0.00; 0.00; 0.03; 0.34; 0.91; 1.00
Standardised CPUE (GLMM) 1987–2005	see Table 3, column 1.
Vulnerability (1985–1988; 1997–2005) ages 1 to 35+	0.000; 0.000; 0.000; 0.000; 0.001; 0.602; 0.849, 1.000, 0.842; 0.491; 0.319; 0.237; 0.199; 0.181; 0.172; 0.168; 0.166; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165; 0.165
Vulnerability (1989–1996) ages 1 to 35+	0.000; 0.000; 0.000; 0.000; 0.045; 0.112; 0.259; 0.496; 0.746; 0.916; 1.000; 0.803; 0.434; 0.274; 0.206; 0.177; 0.164; 0.159; 0.157; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156; 0.156

Model results

82. The model shows good agreement between the predicted and the observed values for CPUE indices and annual catches and catch proportions-at- length, as observed in Figures 19 to 23. The fit of the catch proportion at length was reasonable until 1996, but from 1997 to 2005 there was increasing systematic bias suggesting underestimation of abundance in later years (Figure 23).

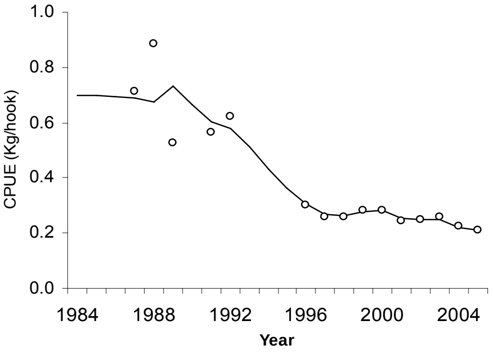


Figure 19: Fit of the model to CPUE indices.

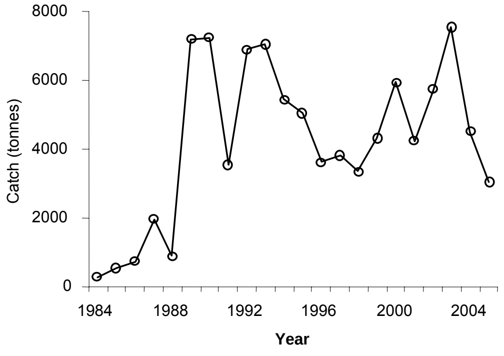


Figure 20: Fit of the model to observed catches.

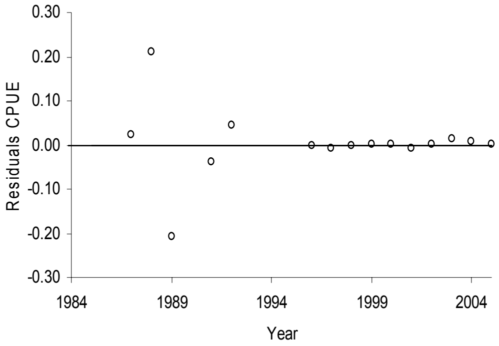


Figure 21: Residuals of the CPUE fit of the model.

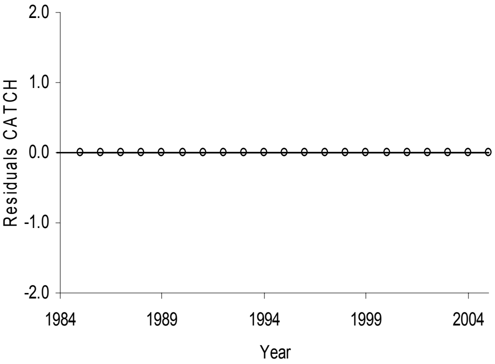


Figure 22: Residuals of the observed catch fitted by the model.

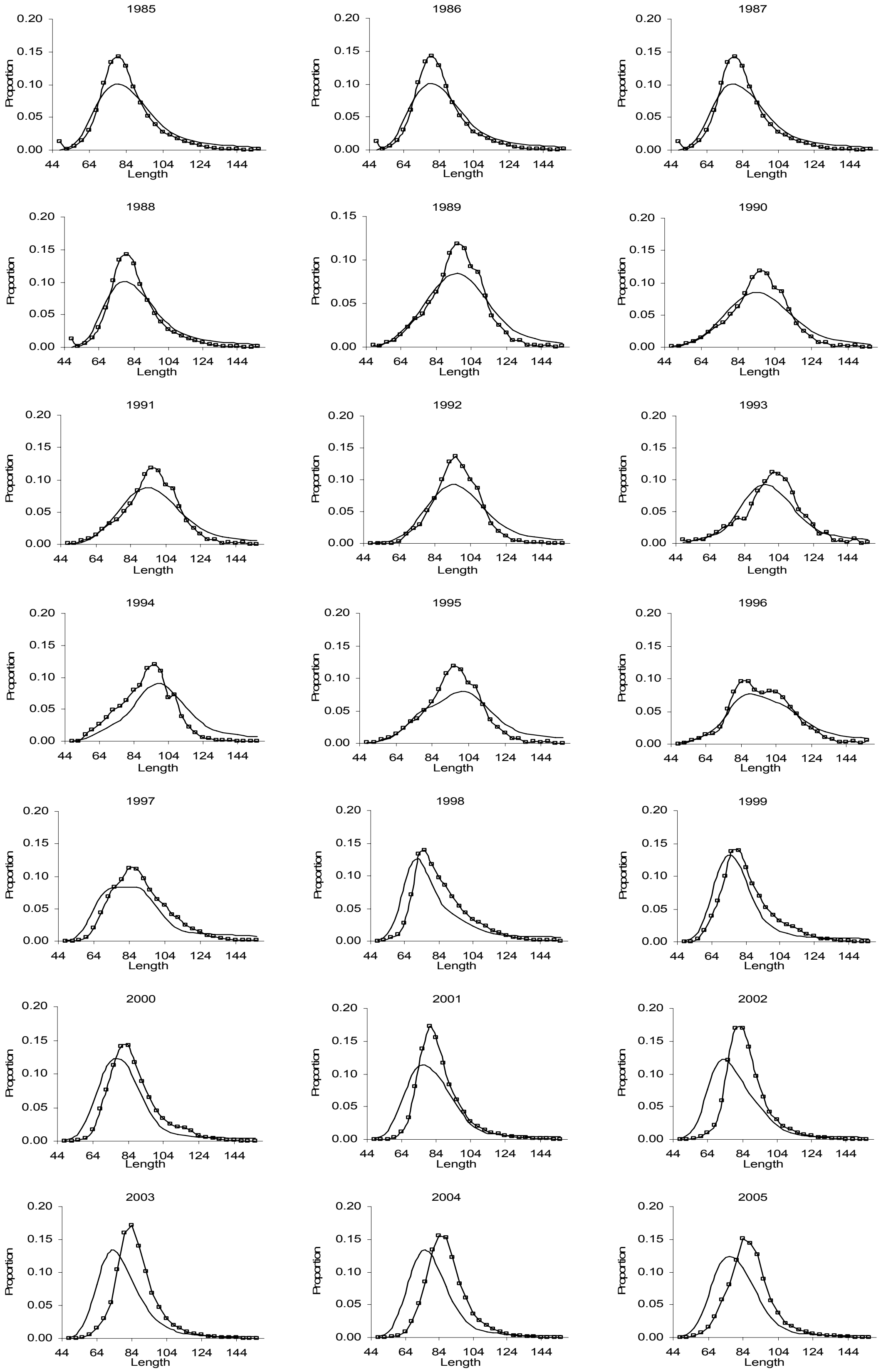


Figure 23: Observed (dotted line) and predicted (straight line) length proportions in catch from the base-case model.

83. The base-case model indicates that the estimated vB followed the decreasing trend of the standardised CPUE. The 2005 value of vB represents 30% of the initial value, while the SSB would have declined to 20% of the virginal value (Figure 24). Declining trend in standardised CPUE series indicate that the last value (2005) represents 31% of CPUE estimated in 1987.

84. The trend in the estimated annual fishing mortality is closely related to the catches (Figure 25). The model suggests fishing mortality steadily increased until 2003, when the highest catches and *F* were recorded.

85. The recruitments at age 1 estimated by the model do not show a relationship with the spawning stock biomass as observed in Figure 26. The estimated moderate variability in recruitment is a consequence of not fixing recruitment in the configuration of the model. Estimates of number of fish at age 4 from the model are very different to recruitment estimates from the trawl survey series from Table 4 (Figure 27). The ASPM suggests a period of low recruitment at age 4 from 1990–1995, which is the period of highest recruitment estimated from the trawl surveys. As was indicated in WG-FSA-05/73, recruitment at age 4 estimated by the ASPM shows more stability than those directly estimated from surveys (Figure 27). This pattern is more credible for a long-living deep-water fish, as *D. eleginoides*. In addition, similarities observed in annual catch length-frequency distributions, did not suggest that recruitments were highly variable as estimates from surveys.

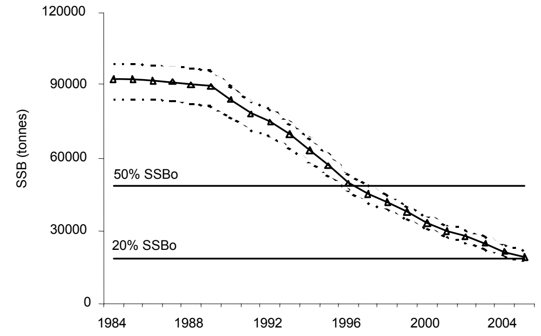


Figure 24: Spawning Stock Biomass trajectory and confidence intervals (90%) estimated by ASPM.

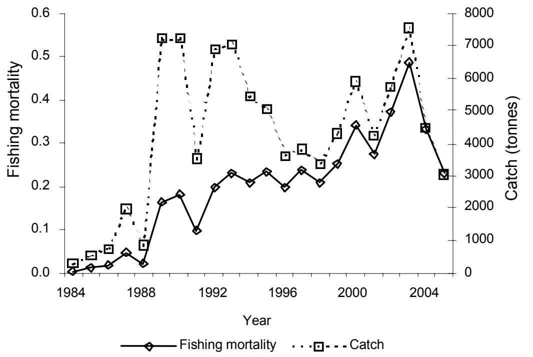


Figure 25: Fishing mortality and annual catches.

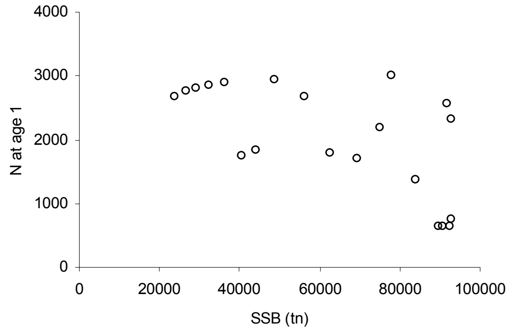


Figure 26: Stock-recruitment relationship.

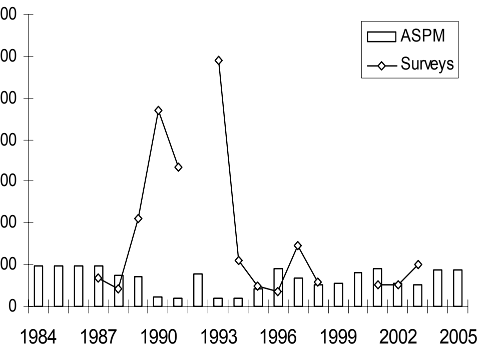


Figure 27: Recruitment at age 4 estimated by the ASPM and from surveys.

Retrospective analyses

86. Retrospective analyses were conducted restricting the data available to the series from 1984–2004, 1984–2003 and 1984–2002. The initial and 2002 estimates of total and spawning biomass are presented for comparison in Table 15. The results obtained from this analysis do not show any evident trend.

Table 15: Initial spawning (SSB_0) and vulnerable (vB_0) biomasses (in tonnes) and values corresponding to 2002 estimated by the base-case model and retrospective runs of ASPM.

Model	SSB_0	vB_0	SSB_{2002}	vB_{2002}
Base (1984–2005)	92 950	38 661	26 849	13 738
1984–2004	93 006	38 685	26 828	13 714
1984–2003	90 881	37 801	25 572	13 242
1984–2002	93 251	38 787	27 000	13 777

Sensitivity analysis

87. A sensitivity alanysis of the model to changes in parameters and structure was conducted in the runs described in Table 16. The trials were calculated as modifications to the base-case model, being used to analyse the effect of alternative assumptions and parameter input within the model.

Table 16: Trials and description of the sensitivity runs for *Dissostichus eleginoides* in Subarea 48.3 using ASPM.

Trial		Description
1	Base	Base-case run
2	Selectivity	Same as the base case, but with selectivity-at-age as in the CASAL base case.
3	Full CPUE	Same as the base case, but including CPUE indices from 1993–1995.
4	Growth	Same as the base case, but with $L_\infty = 152.8$, $k = 0.067$ and $t_0 = -1.44$.
5	Low *M*	Same as the base case, but with $M = 0.13$ y^{-1}.
6	High *M*	Same as the base case, but with $M = 0.20$ y^{-1}.
7	Likelihood w1	Same as the base case, but setting the weight of CPUE index equal to 1.5.
8	Likelihood w2	Same as the base case, but setting the weight of annual catches equal to 1.5.
9	Likelihood w3	Same as the base case, but setting the weight of length proportions to 0.5.

88. Results of the sensitivity analysis are given in Table 17. Most of the runs gave similar results, both in biomass values and in the declining trend. However, the run using selectivity derived from CASAL yielded different results. The declining trend was less marked than in the base-case model. This result could be related to the different selectivity of older ages (Figure 28). Due to the differences in the biomass trajectory obtained in this run of the ASPM, the results of this fit are presented in detail in the following section.

Table 17: Initial spawning stock (SSB) and vulnerable (vB) biomasses and values corresponding to 2005 (all in tonnes) estimated by the base-case model and sensitivity trials of ASPM for *Dissostichus eleginoides* in Subarea 48.3.

Model	SSB_0	vB_0	SSB_{2005}	vB_{2005}	SSB_{2005}/SSB_0
Base	92 950	38 661	18 384	11 634	0.20
Selectivity	92 539	45 498	28 132	12 150	0.30
Full CPUE	92 526	38 485	19 441	12 139	0.21
Growth	93 954	38 663	18 385	11 635	0.20
Low *M*	111 141	37 165	25 621	10 828	0.23
High *M*	79 882	40 896	14 830	11 619	0.19
Likelihood w1	92 269	38 378	18 333	11 637	0.20
Likelihood w2	92 977	38 673	18 481	11 727	0.20
Likelihood w3	92 554	38 497	18 502	11 484	0.20

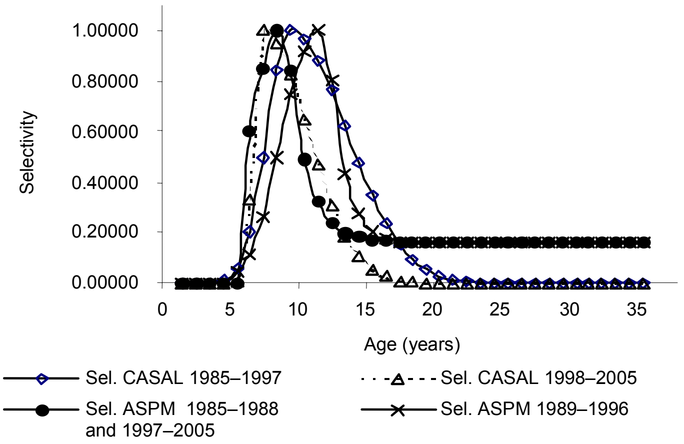


Figure 28: Comparison of the selectivity functions used in the base case and in the selectivity trial.

Results of ASPM selectivity trial

89. The model predictions were in good agreement with CPUE indices and catch history (Figures 29 to 32). However, with this selectivity the model was still unable to fit unbiasedly the proportion-at-length in recent years, and produced worse fittings to the length proportions at the beginning of the fishery (Figure 33).

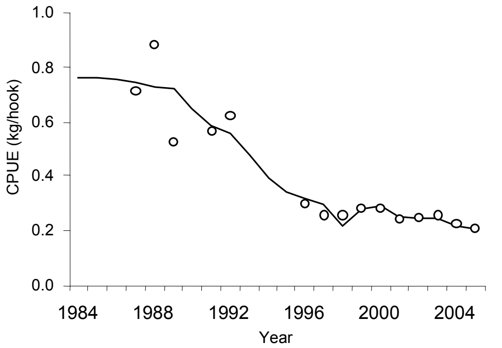


Figure 29: Fit of the model to CPUE indices (ASPM selectivity trial).

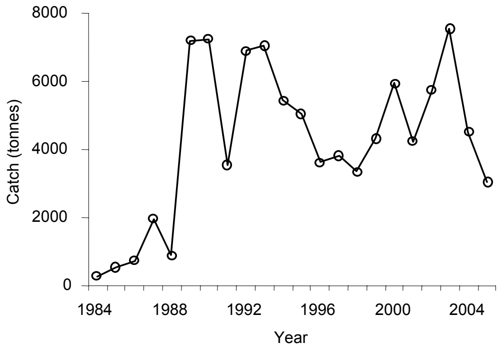


Figure 30: Fit of the model to observed catches (ASPM selectivity trial).

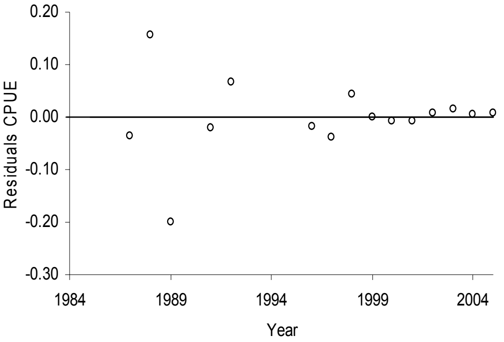


Figure 31: Residuals of the CPUE fit of the model (ASPM selectivity trial).

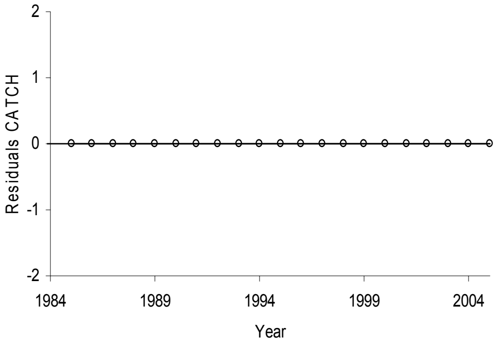


Figure 32: Residuals of the observed catch fitted by the model (ASPM selectivity trial).

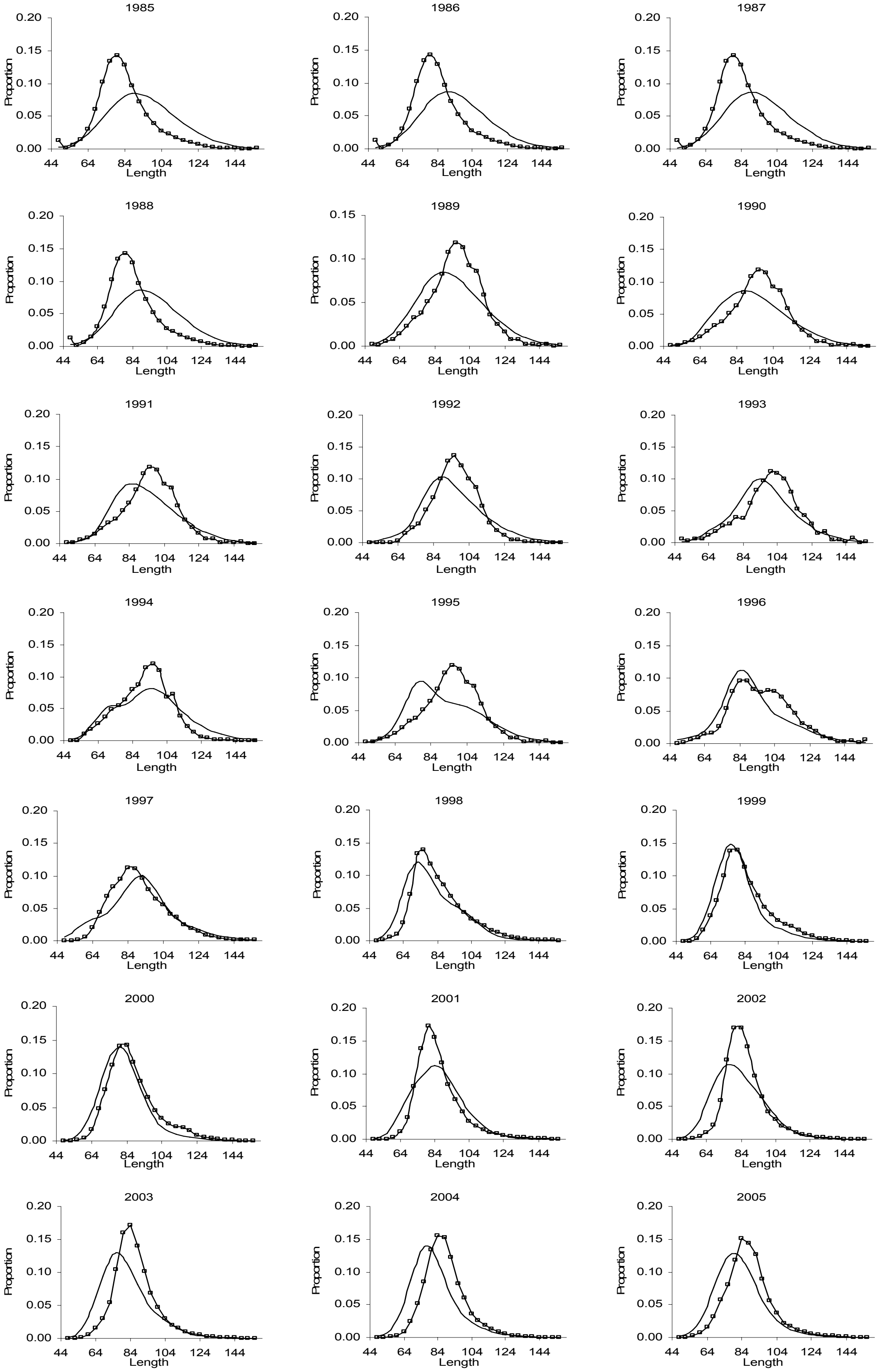


Figure 33: Observed (dotted line) and predicted (straight line) length proportions in catch from the ASPM selectivity trial.

90. The biomass trajectory closely follows the CPUE indices and annual catches. The fishing mortality shows the same features described for the base case, while the SSB declines to 30% of the initial equilibrium (SSB_0) (Figure 34), being 50% higher than the base-case model result. This is because the selectivity scenario assumes no fishing mortality for older fish, producing a higher estimation of spawning biomass. Fishing mortality estimated in this trial results in lower values, but a similar trend with respect to the base-case model (Figure 35).

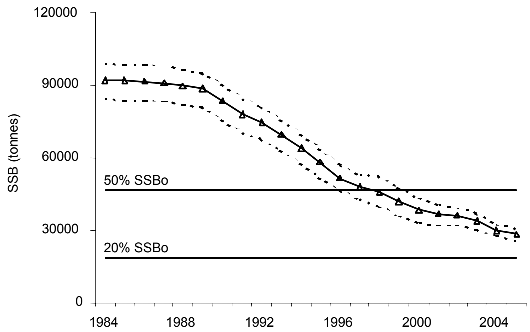


Figure 34: Spawning stock biomass (SSB) trajectory and confidence intervals (90%) estimated by ASPM Selectivity trial.

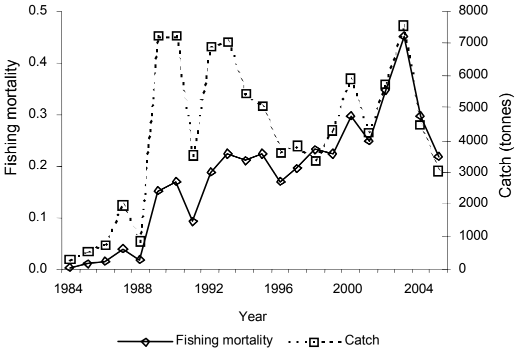


Figure 35: Fishing mortality and annual catches.

Yield calculation

91. Yield estimates for the base-case assessment were calculated by projecting the estimated current status of the stock in the long term under a constant catch (using GY software), taking into account the CCAMLR decision rules.

92. The constant catch that produced a probability of 10% of spawning biomass dropping to less than 20% of the initial spawning biomass (rule 1) was estimated as 696 tonnes. The long-term yield for which there was median escapement of 50% of the median pre-exploitation spawning biomass level (rule 2) at the end of the 35-year projection period was 2 389 tonnes.

5. By-catch of fish and invertebrates

5.1 Estimation of by-catch removals

93. The priority by-catch taxa for which assessments of status are required are the macrourids and rajids (SC-CAMLR-XXI, Annex 5, paragraphs 5.151 to 5.154).

Table 18: By-catch (tonnes) reported from longline fisheries in Subarea 48.3. GRV – *Macrourus* spp., SRX – rajids.

Fishing season	GRV		SRX		Others	
	Removals	Limit	Removals	Limit	Removals	Limit
1988/89	2		22		0	*
1989/90	0		0		0	*
1990/91	9		26		0	*
1991/92	1		2		0	*
1992/93	2		0		0	*
1993/94	0		12		0	*
1994/95	13		98		11	*
1995/96	40		58		0	*
1996/97	34		44		4	*
1997/98	24		15		2	*
1998/99	21		19		1	*
1999/00	18		12		5	*
2000/01	22		28		3	*
2001/02	53	291	26	291	13	
2002/03	75	390	38	390	19	
2003/04	30	221	6	221	4	
2004/05	112	152	9	152	19	

* None specified

Estimated cut-off catch

94. Estimates of total mortality for fish cut from longlines in Subarea 48.3 were made in 2003. Sufficient data to repeat these calculations was not available at the 2005 WG-FSA meeting.

5.2 Assessments of impact on affected populations

95. No assessments for rajids or macrourids in Subarea 48.3 have yet been undertaken.

5.3 Mitigation measures

96. By-catch limits and move-on rules are included in the annual conservation measure established for this fishery (Conservation Measure 41-02). In addition, mitigation measures for rajids consist of cutting rajids off lines at the water surface.

6. By-catch of birds and mammals

97. Details of seabird by-catch (taken from Table O3) are summarised in Table 19. Estimated potential seabird removals in the IUU fishery are summarised in SC-CAMLR-XXIV/BG/27 and Table 19.

Table19: Estimated by-catch of seabirds in Subarea 48.3.

Fishing season	By-catch rate (birds/thousand hooks)	Estimated by-catch
1996/97	0.23	5 755
1997/98	0.032	640
1998/99	0.013*	210*
1999/00	0.002	21
2000/01	0.002	30
2001/02	0.0015	27
2002/03	0.0003	8
2003/04	0.0015	27
2004/05	0.0015	13

* Excluding *Argos Helena* line-weighting experiment cruise

98. Ad hoc WG-IMAF has assessed the level of risk of incidental mortality of seabirds in Subarea 48.3 as category 5 (SC-CAMLR-XXIV/BG/26).

6.1 Mitigation measures

99. Conservation Measure 25-02 applies to this subarea.

6.2 Interactions involving marine mammals with longline fishing operations

100. No interactions were reported in the 2004 fishing season.

7. Ecosystem effects

101. The Working Group did not examine the ecosystem effects of the longline fishery for toothfish in Subarea 48.3.

8. Harvest controls for the 2004/05 season and advice for 2005/06

8.1 Conservation measures

Table 20: Summary of provisions of Conservation Measure 41-02 for *Dissostichus eleginoides* in Subarea 48.3 and advice to the Scientific Committee for the 2005/06 season.

Paragraph and topic	Summary of CM 41-02 for 2004/05	Advice for 2005/06	Paragraph reference
1. Access (gear)	Longlines and pots only	Continue[1]	
2. Subdivision of Subarea 48.3	Definition of area open to the fishery	Continue	
3. Closure of other areas of 48.3	Closure of fishing outside the area of the fishery	Continue	
4. Catch limit	3 050 tonnes for the whole area	Review	Main report 5.77
4. Catch limit applied to management areas	Management Area A: 0 tonnes Management Area B: 915 tonnes Management Area C: 2 135 tonnes	Revise as pro-rata calculation on catch limit	Main report 5.78
5. Season: longline	1 May to 31 August 2005 Extension possible to 14 September 2005 for vessel complying fully with CM 25-02 in 2003/04.	Update	
5. Season: pots	1 December 2004 to 30 November 2005	Update	
5. Season: seabirds	During extension period (1–14 September 2005) any vessel catching three (3) seabirds to cease fishing.	Update	
6. By-catch: crabs	By-catch of crabs to be counted against crab catch limit.	Continue	
7. By-catch: finfish	Total combined catch of skates and rays 152 tonnes Total catch of *Macrourus* spp. 152 tonnes	Revise as pro-rata calculation on catch limit	
8. By-catch: any species	Move-on rule	Continue	
9. Mitigation	In accordance with CM 25-02.	Continue	
10. Observers	Each vessel to carry at least one CCAMLR scientific observer and may include one additional scientific observer.	Continue	
11. Data: catch and effort	(i) Five-day reporting system as in CM 23-01 (ii) Monthly fine-scale reporting system as in CM 23-04 on haul-by-haul basis.	Continue	
12. Target species	For the purposes of CMs 23-01 and 23-04, *Dissostichus eleginoides* is the target species and the by-catch is any species other than *D. eleginoides.*	Continue	
13. Jellymeat	Number and weight of fish discarded, including those with jellymeat condition, to be reported. These catches count towards the catch limit.	Continue	
14. Data: biological	Monthly fine-scale reporting system as in CM 23-05. Reported in accordance with the Scheme of International Scientific Observation.	Continue	
15. Research fishing	Limitation to 10 tonnes and one vessel in management area A.	Continue	

[1] Revising to the new season as appropriate

8.2 Management advice

102. The Working Group recalled that it had been unable to agree on an assessment of toothfish in Subarea 48.3 at its 2004 meeting, and that the Scientific Committee had asked the Working Group to undertake work to address uncertainties in the assessment of this stock (SC-CAMLR-XXIII, paragraphs 4.62 and 4.63). The Working Group recognised that due to the large amount of work being carried out in the intersessional period, during the meeting of WG-FSA-SAM and during the course of the WG-FSA meeting, considerable progress had been made in addressing these issues.

103. The Working Group noted the various results, which are given in Tables 12, 13 and 16 and paragraph 92, along with the consideration of parameter inputs and conclusions in this appendix, should be considered as the basis of advice on catch limits for 2005/06. For example, in respect of the CASAL results, the MCMC projections of yield (Table 13) are as follows:

(i)	base case	5 629 tonnes
(ii)	low L_∞	3 407 tonnes
(iii)	low M	5 876 tonnes
(iv)	one fleet	5 428 tonnes.

In respect of the ASPM run the GY projection of yield is as follows (paragraph 92):

(v)	base case	696 tonnes.

104. Because of the complexity of the modelling assumptions, hypotheses and model results, the Working Group was unable to provide advice on which of the base cases, or the sensitivity runs, was the best estimate of current stock status of toothfish and an appropriate yield. Accordingly, it could not recommend an appropriate catch limit in the 2005/06 season.

105. Taking account of its consideration of by-catch and other fisheries issues, the Working Group recommended the continuation of all other aspects of management under Conservation Measure 41-02 for the 2005/06 fishing season (Appendix G, Table 20).

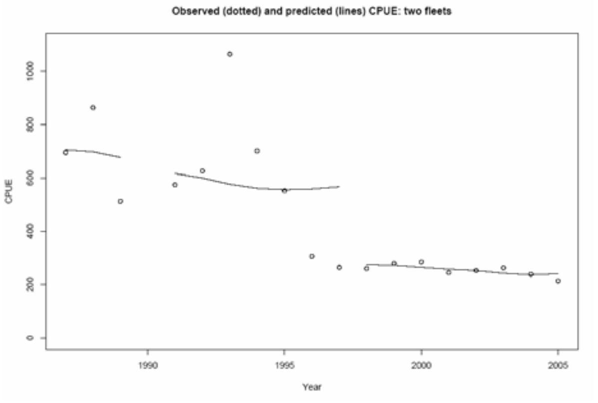
106. Drs E. Marschoff and O. Wöhler (Argentina) made the following comments:

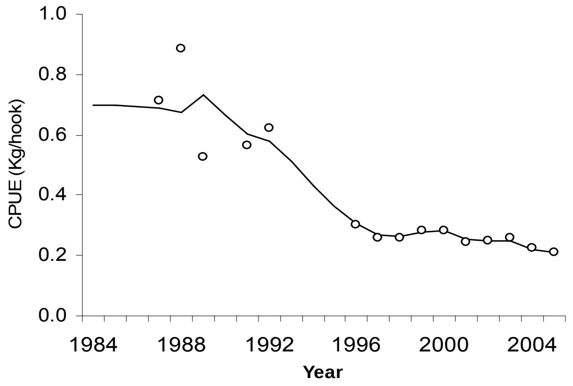
(i) In the CASAL implementation, recruitment is derived from a fixed h value, without interannual variability. Under this condition, it is difficult to fit the model to the CPUE entire series. The definition of two fleets fishing from 1984 to 1997 and from 1998 to 2005 absorbs the observed decline in CPUE which is considered as a change in catchability (around 50% from 1997 to 1998). Finally, the selectivity function is estimated through the model, which ensures good fit to the catch proportions-at-length. Those restrictions combined determine that the vulnerable biomass estimated by the model cannot follow the entire CPUE standardised trend. In terms of the estimation, the consequence of this is an overestimation of spawning stock, vulnerable biomass and long-term estimation of yield.

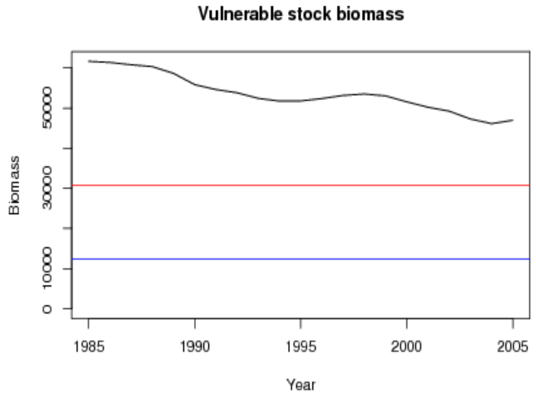
(ii) The ASPM model assumes variable recruitment estimated from a fitted h parameter and a vector of recruitment variability. The absence of constraints in the stock-recruitment relationship allows the vulnerable biomass to be fitted to the entire CPUE series. Thus, the estimated vulnerable biomass follows the decline in the CPUE series. The assumptions of two fixed selectivities-at-age, entered as input data, results in biased fits to the proportions of length in the catches in the last years. This results in an underestimation of the current SSB and a consequent underestimation of long-term yield.

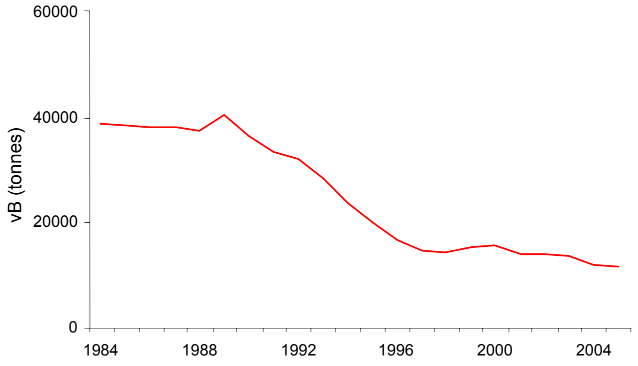
CASAL approach

ASPM approach









107. Drs Kirkwood, Agnew and R. Hillary (UK) pointed out several difficulties with the methodological approach, underlying hypotheses and fits of the ASPM that in their view invalidated that assessment of toothfish in Subarea 48.3:

(i) The ASPM assumption that there is a single CPUE series takes no account of the major changes in fleet structure and behaviour that occurred in the middle of the CPUE series, and which have been detailed above. This is an unlikely assumption given the major changes that have occurred. By contrast, the assumption of different fleets and catchabilities in the base-case CASAL model directly accounts for the known changes in the fishery.

(ii) To examine the possibility that catchability and selectivity had not changed over the course of the fishery, a CASAL sensitivity run was performed which did assume a single fleet. This produced very similar results to the CASAL base case.

(iii) The CASAL model fits to all the data available: length frequencies, CPUE, mark–recapture and recruitment indices. The fits to all the data, except the early CPUE, are good, including to the later CPUE series. By contrast, the ASPM effectively ignores all data except CPUE, by giving very high weighting to these data and hypothesizes a strong declining recruitment to create the apparent drop in CPUE between 1995 and 1997. The fits to length-frequency data are poor, and the model does not make use of the tagging data.

(iv) The authors of the ASPM model did not express any doubt in the validity of the mark–recapture data, or the Petersen estimates of biomass arising from the use of these data. The lack of use of tagging data in the ASPM arose solely from an inability to incorporate the data within the model. Our experience in fitting both CPUE data and tagging data in CASAL would suggest that once the tagging data are incorporated into the ASPM the fit to CPUE will deteriorate.

(v) The ASPM estimate of current vulnerable biomass of 11 600 tonnes is clearly an underestimate, for several reasons.

(vi) The estimated length frequencies in the ASPM model show a very poor fit to the data, particularly in the early and recent years. By contrast, good fits were achieved by all CASAL model runs. The ASPM fit gets progressively worse from 1997 to 2005. This is because the model is estimating a very strong decline in biomass, a removal of large animals from the population and high recruitment. The model predicts that the fishery should not be able to catch large fish, in direct contradiction of the actual catches made by the fishery.

(vii) We note that the authors acknowledge that the model underestimates current biomass and that in discussion many members of the Working Group agreed with this conclusion.

(viii) Since 1997 the fishery has experienced average annual removals of 4 700 tonnes, with only a minor effect on CPUE. It is most unlikely that such catches taken from a vulnerable biomass of about 13 000 tonnes would not have caused significant changes in CPUE.

(ix) The selectivity used in the ASPM base case generates a similar mark–recapture estimate of current vulnerable biomass as the CASAL base-case selectivity does (Table 6). In the case of CASAL, estimates of the confidence limits of current vulnerable biomass overlap with the confidence limits estimated from tagging data alone (Table 6). In the case of ASPM, the estimates of current vulnerable biomass are substantially lower (11 600 tonnes) than the tagging estimates (53 400 tonnes), without overlapping confidence limits. The ASPM estimate of current biomass is clearly not supported by the tagging data.

(x) CASAL estimates selectivities from the data. ASPM fixes the selectivities according to calculations made outside the model. Moreover, the fixed lower limit on selectivity at older ages used in the ASPM model is completely arbitrary, and is not estimated by any data.

(xi) The GLMM estimates very high observation error for the CPUE series in the early 1990s (Figure 5) and low error after 1996. The ASPM ignores this very significant change in variance, which leads to a very poor fit to the early 1990s CPUE and improbably perfect fits to the late 1990s CPUE. The fits to the early 1990s CPUE are no better than the fits of the CASAL model, which does take the differences in observation error into account.

(xii) One of the most important parameters in the ASPM model is annual recruitment, although there are no observational data to inform the estimation of these parameters. The only purpose of allowing interannual recruitment variations is to allow the model to fit very closely to the CPUE trend. Low recruitments are estimated in the period preceding the drop in CPUE (1990–1995), which depletes the stock as required to fit the decline in observed CPUE. Higher recruitment values are necessary in the late 1990s to create a stable CPUE. These trends are in direct opposition to the indications of the relative levels of recruitment in the survey data (Table 4).

(xiii) The ASPM's estimate of very low recruitment in the early 1990s, which is necessary to fit the sharp decline in CPUE, creates a depression of recruitment at high biomass. The resulting inverse relationship between stock and recruitment is not plausible, as was pointed out by several members of the Working Group.

(xiv) In conclusion, the ASPM assumptions are not supported by the known history of the fishery, the assessment does not attempt to utilise all the data that are available, and does not fit some of the data well (the early CPUE series and the length data). By contrast, the CASAL model is consistent with the known history of the fishery, it makes use of all the available data and obtains a good fit to each dataset (with the sole exception of early CPUE data, which have high CVs, and for which it obtains a fit as good as that obtained by ASPM). The base-case and range of sensitivities run using CASAL are informative. It is plausible that natural mortality could be lower for toothfish, but less plausible that the single-fleet model accurately reflects the history of this fishery. It is unlikely that the L_∞ is as low as that used in the Low L_∞ trial.

References

Brandão, A. and D.S. Butterworth. 2003. Progress on the application of an age-structured production model fitted to commercial catch-rate and catch-at-length data to assess the toothfish (*Dissostichus eleginoides*) resource in the Prince Edward Islands vicinity. Document *WG-FSA-03/97*. CCAMLR, Hobart, Australia.

Brandão, A. and D.S. Butterworth. 2004. Variants of the ASPM assessment of the toothfish (*Dissostichus eleginoides*) resource in the Prince Edward Islands vicinity which attempt to reconcile CPUE and catch-at-length data. Document *WG-FSA-SAM-04/12*. CCAMLR, Hobart, Australia.