APPENDIX L

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

CONTENTS

FISHERY REPORT: *DISSOSTICHUS ELEGINOIDES* 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).

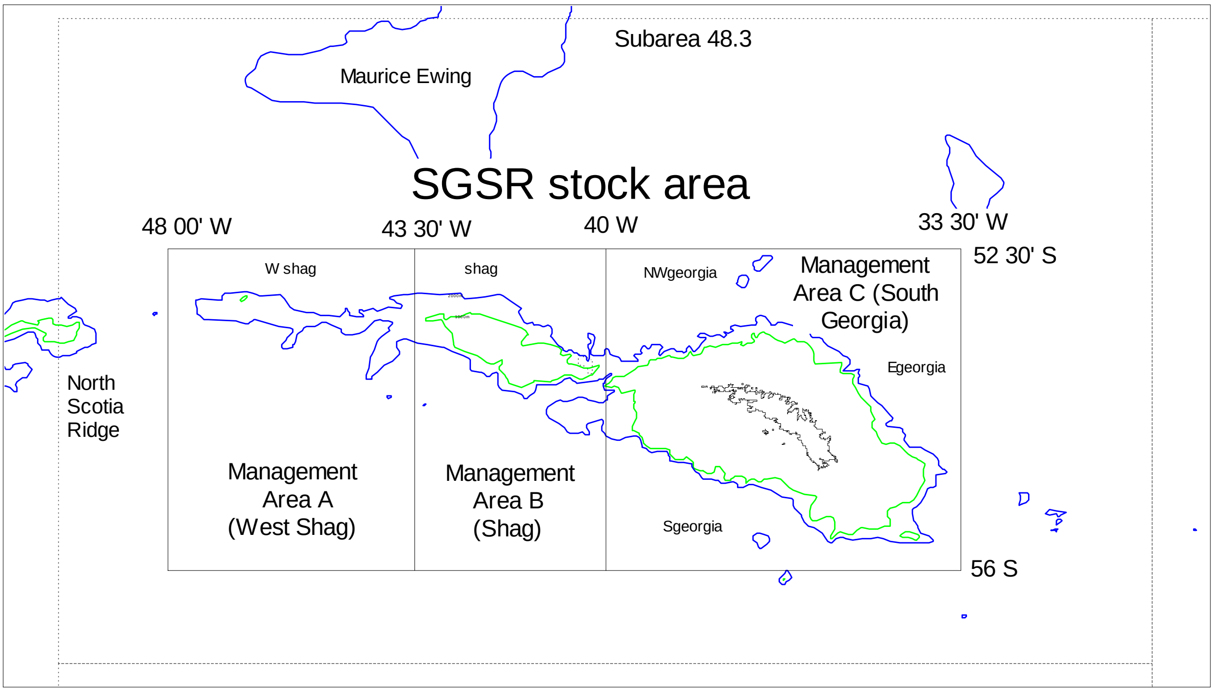

Figure 1: Definition of the SGSR stock area, with its three management areas A, B and C.

2. The catch limits in the 2005/06 season for areas A, B and C were 0 (excepting 10 tonnes for research fishing), 1 067 and 2 489 tonnes, with an overall catch for SGSR of 3 556 tonnes. The total declared catch was 3 534 tonnes. Catches in areas A, B and C were 10, 983 and 2 541 tonnes respectively.

3. Most catch has been taken by longlines, but 66 tonnes was taken by pots in 2001 and 24 tonnes in 2006. These data are included in the total catch.

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, WG-FSA-06/4.)

Season	Regulated fishery			Estimated IUU catch (tonnes)	Total removals (tonnes)	
	Reported effort (no. vessels)	*D. eleginoides*			48.3 west[1]	48.3 SGSR stock
		Catch limit (tonnes)	Reported catch (tonnes)			
1984/85	1		521	0	4	517
1985/86	1		733	0	1	732
1986/87	1		1954	0	0	1954
1987/88	2		876	0	0	876
1988/89	3		7060	144	242	6962
1989/90	1		6785	437	394	6828
1990/91	1	2500	1756	1775	0	3531
1991/92	19	3500	3809	3066	11	6864
1992/93	18	3350	3020	4019	0	7039
1993/94	4	1300	658	4780	193	5245
1994/95	13	2800	3371	1674	74	4971
1995/96	13	4000	3602	0	66	3536
1996/97	10	5000	3812	0	0	3812
1997/98	9	3300	3201	146	4	3343
1998/99	12	3500	3636	667	2	4301
1999/00	17	5310	4904	1015	9	5910
2000/01	16	4500	4047	196	12	4231
2001/02	17	5820	5742	3	29	5716
2002/03	19	7810	7528	0	17	7511
2003/04	16	4420	4497	0	37	4460
2004/05	8	3050	3039	23	0	3062
2005/06	10	3556	3534	0	0	3534

[1] Subarea 48.3 outside the SGSR stock area, i.e. to the west and north of the SGSR stock area.

Distribution of the fishery

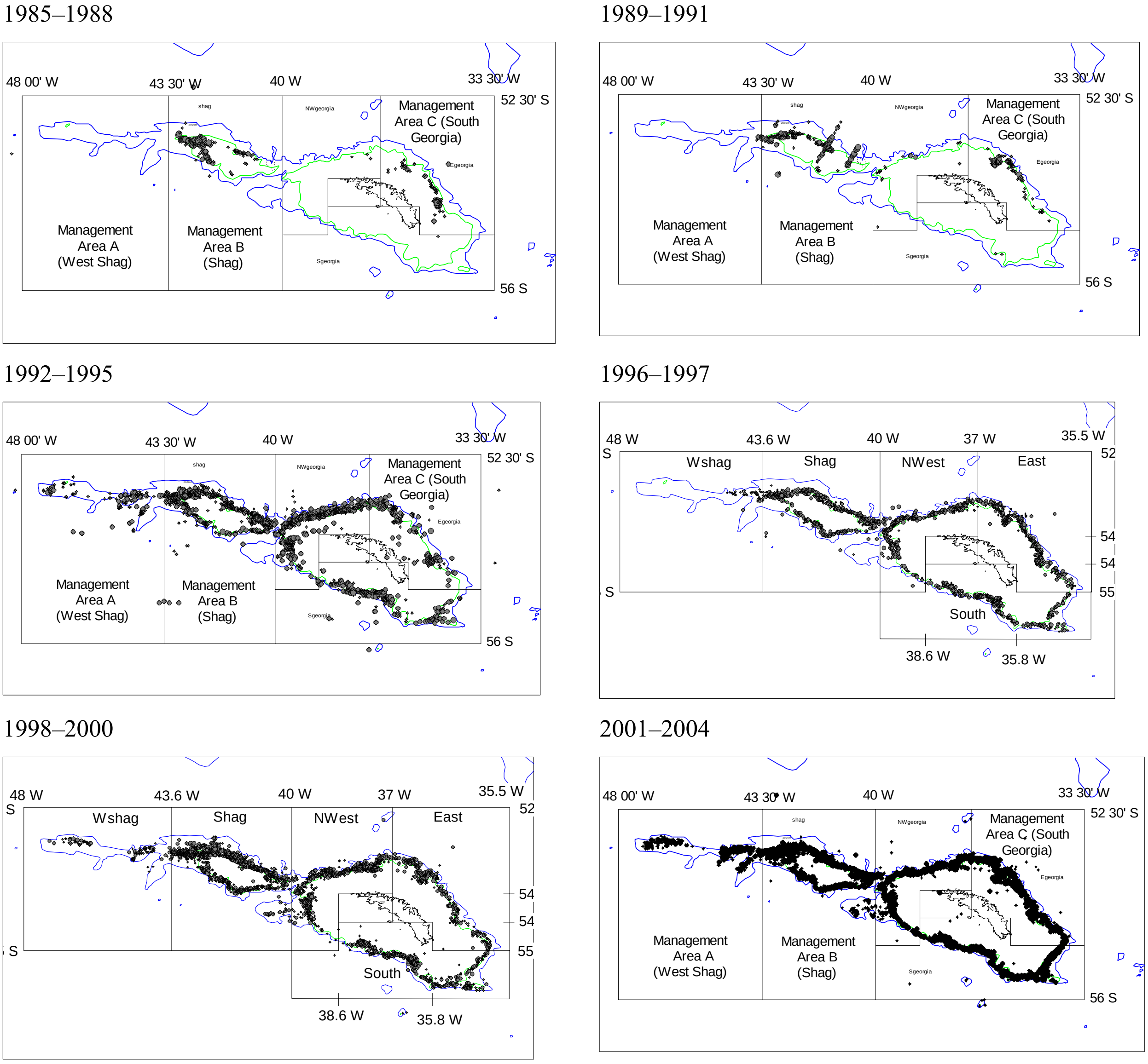

Figure 2: Distribution of effort in discrete time periods, graduated by the number of hooks set. Wshag – western Shag Rocks; Shag – Shag Rocks; NWest – northwest South Georgia; East – east South Georgia; South – south South Georgia. The distribution of effort for all years from 2002 is also shown in Figure 7.

1.2 IUU catch

4. There was no IUU catch in Subarea 48.3 in the 2005/06 season.

1.3 Size distribution of catches (time series)

5. Catch-weighted length-frequency data are shown in Figure 3. In previous years calculations of catch-weighted length frequencies have not used data from seasons earlier than

1992/93 because of a Flag State mismatch which occurred between catch and length data. This problem has been resolved by the Secretariat (WG-FSA-SAM-06/4, WG-FSA-06/4).

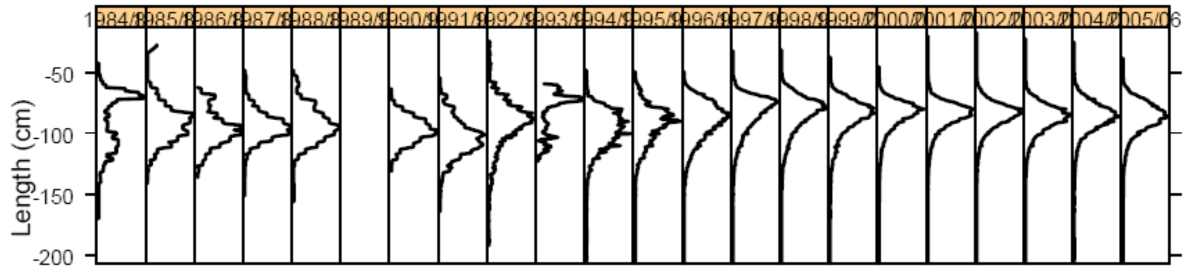

Figure 3: Catch-weighted length frequencies for *Dissostichus eleginoides* in Subarea 48.3 derived from observer, fine-scale and STATLANT data reported by 5 October 2006.

6. Fisheries data (reports of weight and number of fish caught) were analysed in a standard GLM. Mean weight declined from 1992 to 1998, increased from 1998 to 2003 and has been similar thereafter.

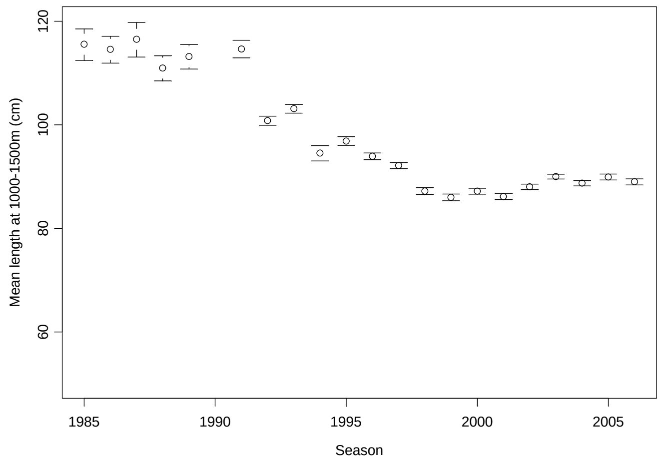

Figure 4: Mean weight of toothfish in the catch calculated using a GLM of similar form to that for the standard GLM (SC-CAMLR-XXIII, Annex 5, paragraphs 5.111 to 5.113), standardised to Chilean vessels fishing in depths between 1 000 and 1 500 m in the southern sector of South Georgia.

2. Stocks and areas

7. 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.

8. All assessments consider only the SGSR stock.

3. Parameters and available data

3.1 Standardised CPUE

9. The GLMM (catch weight as the response variable; season, year, nation of vessel, depth class and an offset for log-hooks as the fixed effects; vessel as the random effect) standardised CPUE analysis was updated. Figure 5 shows that CPUE has remained constant between 2004 and 2006.

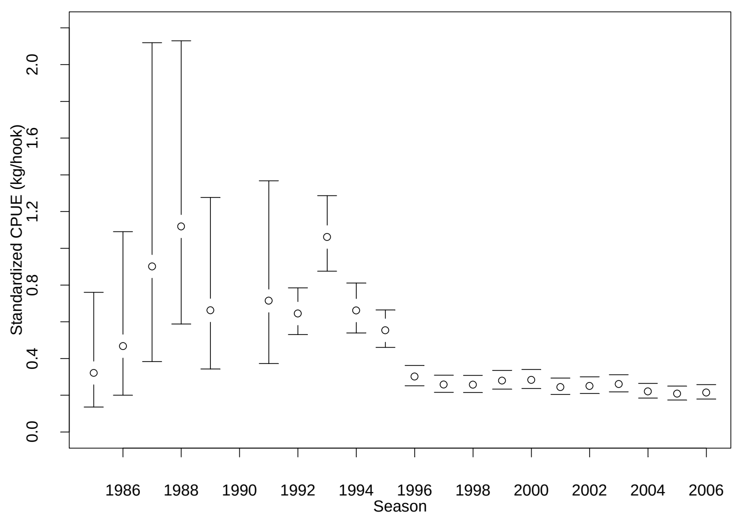

Figure 5: Standardised longline CPUE by fishing season for Subarea 48.3 using the GLMM method with vessel random-effects. The series has been standardised for Chilean vessels fishing in depths between 1 000 and 1 500 m. No data were available for 1990, which is the reason it is absent from the above results.

10. WG-FSA-06/53 provided an interpretation of these CPUE trends. There were clearly three major periods in the development of the toothfish fishery in Subarea 48.3. An early development phase undertaken by Russian/Ukrainian vessels led to a relatively stable fishing pattern which lasted until 1992. From 1993 the fishery entered a second phase, a four-year period of rapid change. This saw the introduction of a large Chilean fleet (1992 and 1993), unusual spatial fishing patterns (a concentration on shallow water in Shag Rocks in 1993, a widely dispersed pattern during the 1994 depletion experiment and a concentration on NW South Georgia in 1995) and the development of new management measures. The key management changes were the move to a winter fishing period which started in 1995 and was completed by 1998, an associated requirement for night-time setting of longlines, and the introduction of observers in 1994. This led to an immediate change in longline configuration (fewer, longer lines containing more hooks were set each day). CPUE in winter is lower than in summer because spawning occurs in July and August.

11. The present multinational fleet developed in 1996 was fully established from 1997, and it is possible to consider the period between 1997 to the present as a third phase in the development of the fishery. There is very little overlap of vessels between the first and third phases. Thirty vessels fished only in the first phase and up to 1995 of the second phase, 36 vessels fished only from 1996 in the second phase and in the third phase.

12. The CPUE data (Figure 5) display high levels of variability up to 1995, and lower variability from 1996 to the present, the apparent discontinuity arising in the middle of the second phase of rapid change. Only four vessels (0.6% of the total number that have fished in Subarea 48.3) fished in both 1995 and 1996. The changes in CPUE are even more abrupt when South Georgia and Shag Rocks are considered separately (Figure 6).

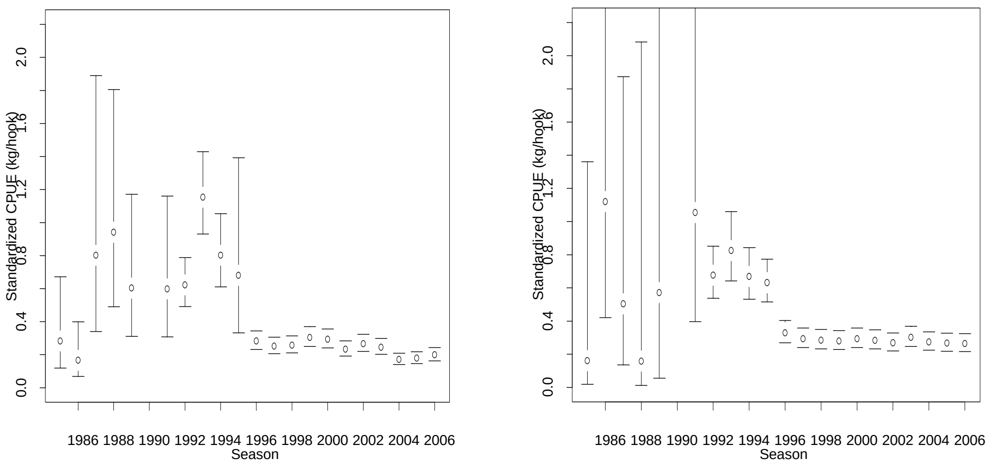

Figure 6: Standardised longline CPUE by fishing season for Subarea 48.3 using the GLMM method with vessel random-effects, separated for the two areas Shag Rocks (left) and South Georgia (right). The series has been standardised for Chilean vessels fishing in depths between 1 000 and 1 500 m.

13. The Working Group agreed that the three periods of the fishery had very different characteristics, and that interpreting the CPUE as a single series was not possible (see also main report, paragraph 3.34). Accordingly, the two-fleet CASAL model developed last year was used for the basic assessment model this year.

Table 2: Standardised CPUE (kg/hook) calculated during the meeting using the GLMM method.

Fishing season	Standardised CPUE using single GLMM	CV (%)
1984/85	0.321	48.6
1985/86	0.467	47.6
1986/87	0.901	48.1
1987/88	1.119	34.5
1988/89	0.663	35.2
1989/90		
1990/91	0.714	34.8
1991/92	0.645	9.9
1992/93	1.062	9.7
1993/94	0.661	10.2
1994/95	0.554	9.2
1995/96	0.302	9.1
1996/97	0.258	9.1
1997/98	0.258	9.1
1998/99	0.280	9.1
1999/00	0.284	9.0
2000/01	0.245	9.0
2001/02	0.251	9.0
2002/03	0.261	9.0
2003/04	0.221	9.1
2004/05	0.209	9.1
2005/06	0.215	9.1

3.2 Recruitment

14. The Working Group did not revise its calculation of CMIX estimates of recruitment in Subarea 48.3 (SC-CAMLR-XXIV, Annex 5, Appendix G, Table 4). The primary reason for this was that these data were not being used in the assessment process.

3.3 Mark–recapture data

15. WG-FSA-06/53 presented the results of the mark–recapture program in Subarea 48.3. Tagging effort, fishing effort and recaptures were well distributed over the whole of the fishable grounds in Subarea 48.3 this year (Figure 7).

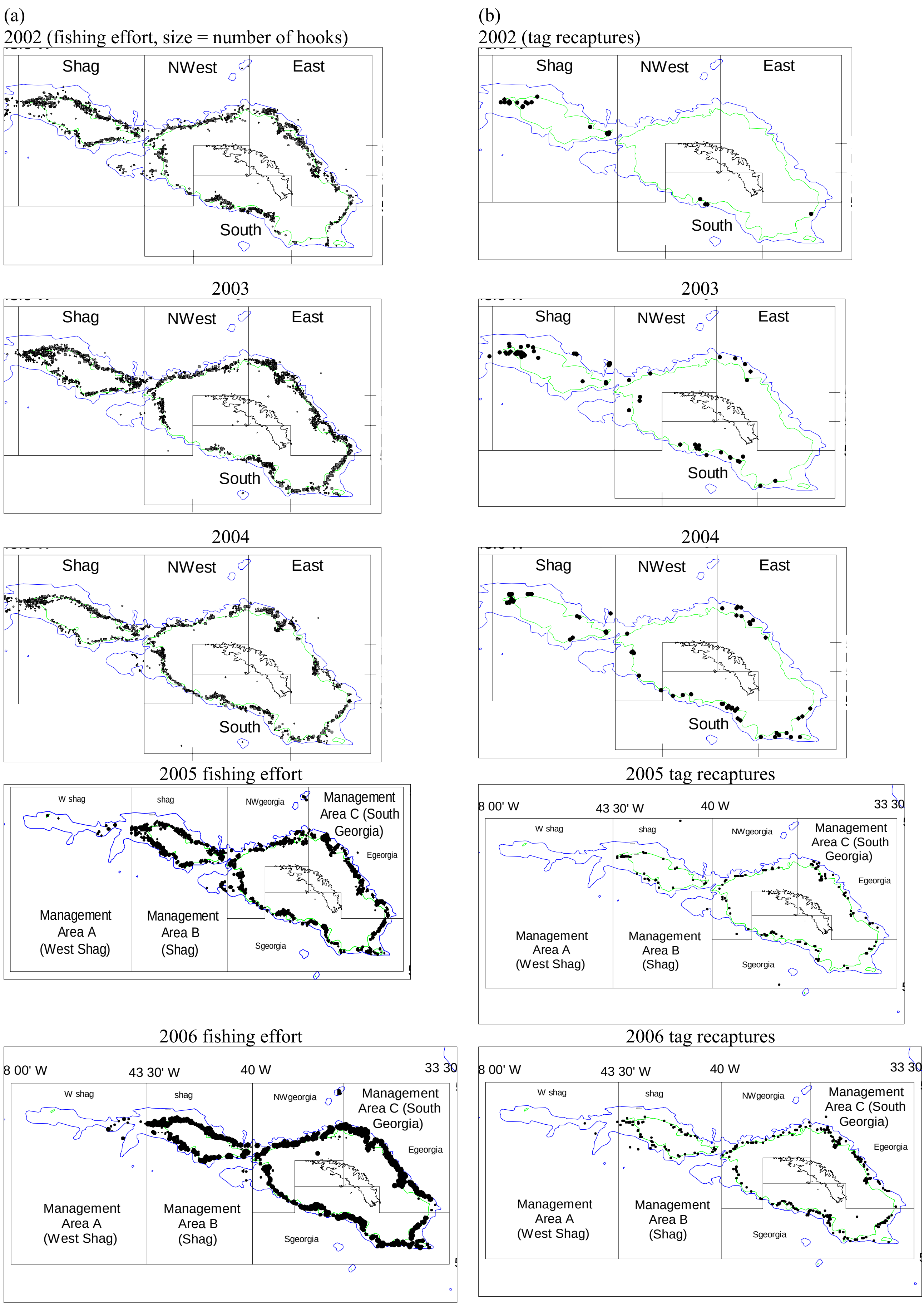

Figure 7: Distribution of (a) fishing effort and (b) recaptured tags by year since the commencement of the tagging program in Subarea 48.3.

16. In total, 13 162 fish have been tagged in Subarea 48.3 since the program started in 2000 (Table 3). Fish have moved between each of the areas defined in Figure 2 with the exception of Wshag, which has only exchanged animals with Shag. 364 tagged animals were recovered in 2006: 10 tagged in 2001, 15 tagged in 2002, 9 tagged in 2003, 128 tagged in 2004 and 192 tagged in 2005.

Table 3: Numbers of marked animals released in different areas in Subarea 48.3. See Figure 2 for area definitions.

Release year	East	NWest	South	Shag	Wshag	Total
2000	37	7		91		135
2001	3	4	16	324		347
2002		99	117	188		404
2003	120	8	134	189		451
2004	601	456	795	1 361	5	3 218
2005	1 110	795	641	1 284	117	3 947
2006	1 273	760	1 442	1 085	100	4 660
Totals	3 144	2 129	3 145	4 522	222	13 162

Table 4: Movement of animals between areas (all tag and recapture years)

Release area	Recapture area				
	Egeorgia	NWgeorgia	Sgeorgia	Shag	Wshag
Egeorgia	148	6	6	1	
NWgeorgia	8	75	3	4	
Sgeorgia	12	6	156	1	
Shag	7	9	2	217	2
Wshag				4	1
Totals	175	91	167	227	3

3.4 Biological parameters

17. WG-FSA-06/53 reported a reanalysis of the scientific observer data to estimate age-at-maturity, using the current growth curve (L_∞ = 152.8 cm) (Figure 8). The Working Group reanalysed the data presented in WG-FSA-06/53 and Figure 8 taking into account the distribution of length-at-age, and established appropriate parameters for a double linear approximation of a mixed-sex maturity ogive to be used in CASAL assessments: 0% mature at age 6, rising to 50% mature at age 11 and 100% mature at age 23. This ogive is presented in Table 5.

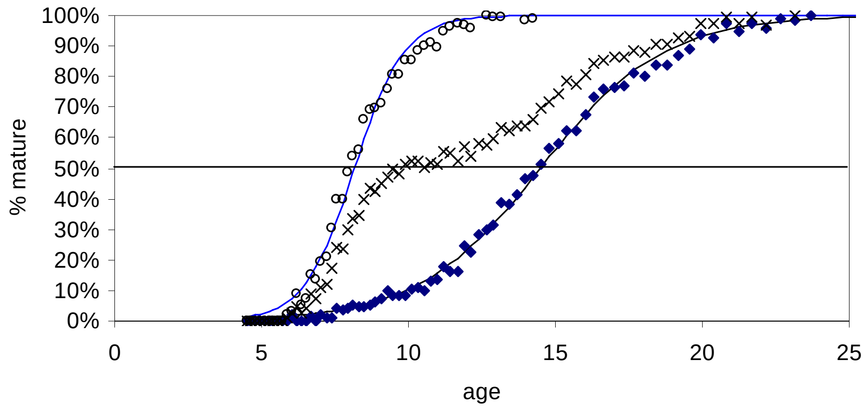

Figure 8: Maturity-at-age for males (open circles), females (diamonds) and all sexes combined (crosses) from observer data 1997–2006. Animals are considered to be mature if they have gonad stages III and above at spawning time (July and August).

Table 5: Revised maturity ogive used for the SGSR stock.

Age	2005 maturity ogive	New maturity ogive
6	0.00	0.00
7	0.00	0.10
8	0.00	0.20
9	0.00	0.30
10	0.13	0.40
11	0.25	0.50
12	0.38	0.54
13	0.50	0.58
14	0.63	0.63
15	0.75	0.67
16	0.88	0.71
17	1.00	0.75
18	1.00	0.79
19	1.00	0.83
20	1.00	0.88
21	1.00	0.92
22	1.00	0.96
23	1.00	1.00

18. Table 6 summarises the parameter values used in the CASAL assessments of Subarea 48.3.

Table 6: New biological parameter values for *Dissostichus eleginoides* in Subarea 48.3.

Component	Parameter	Value	Component	Parameter	Value
Natural mortality	M	0.13	Tag-related growth retardation		0.5
VBGF	K	0.067	Single tag loss rate		0.06
VBGF	t_0	–1.49	Immediate tagging survivorship		0.9
VBGF	L_∞	152.8	Tag probability of detection		1
Length to mass	a (mm to t)	2.5e-9			
Length to mass	b	2.8	Stock-recruit relationship steepness	h	0.75
Maturity range: 0 to full maturity		7–23	Lognormal recruitment SD		0.6

3.5 Total removals

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

4. Stock assessment

20. WG-FSA-06/53 presented two alternative model structures for a CASAL assessment of SGSR toothfish, the two-fleet model fitting to catches at length, CPUE and tagging data applied by the Working Group in 2005 and a single-fleet model fitting to catches-at-age, CPUE and tagging data. The latter made use of a new set of data which has become available, including between 300 and 500 random age samples of the catch for each year from 2000 to 2005 and resulted in estimates of yield that were very similar to those from the catch-at-length model.

21. The Working Group agreed that the new model had considerable potential for providing an alternative to the catch-at-length assessment, and might be particularly useful in providing information on year-class strength. However, more data and model development would be required before the Working Group would have confidence in its results. The Working Group therefore decided to proceed with the two-fleet model developed last year.

4.1 CASAL model structure and assumptions

Population dynamics

22. 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 2006, with an initial unexploited equilibrium age structure, and with a Beverton-Holt stock-recruit relationship with fixed steepness.

Model estimation

23. 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 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. The MCMC samples were obtained by first running the sampler for a 'burn-in' period of 500 000 iterations, and a further 1 000 000 iterations of the sampler were obtained, which were then thinned by a factor of 1 000, to yield a parameter sample of length 1 000. Convergence of this chain on the posterior distribution was checked using the methods described in WG-FSA-05.

Observation assumptions

24. The catch proportions-at-length data were fitted to the model-expected proportions-at-length composition, using a multinomial likelihood.

25. CPUE indices were assumed to be lognormally distributed about the model-predicted vulnerable biomass halfway through the fishing season, via a constant catchability q. The CPUE series shown in Table 2 was divided into two series corresponding to the time periods of the two fleets. Observation error was accounted for by using the annual CV estimates obtained from the GLMM standardisation. An additional process error CV was also estimated for the first time period, to account for the extra variance required for the population model to interpret the CPUE observations.

26. Tag–release events for 2000, 2001, 2002, 2003, 2004 and 2005 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, 2005 and 2006 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 1. The estimated numbers 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.

27. 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

28. 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

29. 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 1 (see the *U_max* parameter, in the fishery definition in the *population.csl* file) 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

30. Within a Bayesian model, all free parameters estimated require both the definition of a prior and bounds that constrain the estimation. Table 7 shows the free parameters estimated in the CASAL models, along with their respective bounds, and prior parameterisations.

Table 7: 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	5

4.2 Selectivity and growth

31. Selectivity-at-age was expressed as a double-normal curve with the following form:

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

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

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.

32. In 2005, the Working Group re-estimated the growth curve for the SGSR stock based on new data from the fishery and research surveys. This resulted in a revision of the growth parameters to $L_\infty = 152.8$, $K = 0.067$ and $t_0 = -1.49$. These parameters were used in the 2006 assessment.

4.3 CASAL runs

33. At WG-FSA-05 four different CASAL runs were undertaken: a two-fleet model with high M and high L_∞, a one-fleet model with high M and high L_∞, a two-fleet model with high M and low L_∞ and a two-fleet model with low M and high L_∞ (SC-CAMLR-XXIV, Annex 5, Appendix G). The Scientific Committee considered that the most appropriate parameter set would have been one with both low M and low L_∞, and used an interpolated value of yield of 3 556 tonnes to provide advice to the Commission on the level of catch limit (SC-CAMLR-XXIV, paragraphs 4.59 to 4.62). A full run of the two-fleet model with both low M and low L_∞ was therefore never undertaken by the Working Group. The results of such a model are shown in Table 9.

34. Two runs of the two-fleet low M low L_∞ model were developed for the 2006 assessment: an 'update' model and a 'reference' model. The update model was a simple update of the assessment used by CCAMLR in 2005 to calculate sustainable yield, updated with 2006 data. The reference model changed other parameters as discussed above. The model details are shown in Table 8. Other parameter values are given in Table 6.

Table 8: CASAL model structure descriptions.

Feature	The reference model	The update model
Model structure	Two-fleets (1985–1997, 1998–2006), fitted to catch at length, CPUE and tagging data	No change
Catches	Revised according to Table 1 (minor revisions only)	As used in 2005, updated with 2006 data.
Catch-at-length	Revised according to the Secretariat calculations in WG-FSA-06/4. Fitted years were [1988, 1989, 1992, 1993, 1995, 1996, 1997] and [1998–2006]. 1990, 1991, 1994 were omitted due to inadequate data or, in the case of 1994, unrepresentative fishing behaviour.	As used in 2005, updated with a single additional 2006 year derived from WG-FSA-06/4. Fitted years were [1992–1997] and [1998–2006].
CPUE	Revised GLMM (Table 2)	No change
Tag releases	Updated for all years (release data from 2000–2004 changed only slightly with revisions to the database; 2005 data were new)	No change
Tag recaptures	Updated for all years (release data from 2000–2004 changed only slightly with revisions to the database; 2005 data were new). Only recaptures in 2004, 2005 and 2006 were used.	No change
Scanned population	Recalculated based on the new catch-at-length data from WG-FSA-06/4.	Recalculated based on the new catch at length data from WG-FSA-06/4.
Mean weight in the catch	Calculated from haul-by-haul data as total kg catch divided by total numbers caught for all hauls where numbers were recorded.	No change
Maturity ogive	New ogive (Table 5)	2005 ogive (Table 5)
Steepness, sigma *R*	0.75, 0.6	0.8, 0.8

4.4 Point-estimate (MPD) results

35. Even though MCMC samples are used to calculate the long-term yield, the diagnostics for the reference model are displayed using only the MPD results, for clarity. Table 9 shows the MPD summary for the reference model, the update of last year's base-case assessment, and the model used to eventually set the long-term yield at last year's Scientific Committee meeting.

Table 9: Review of parameter estimates for the four CASAL models, using the MPD estimation results.

Model	B_0 (1000 tonnes)	Selectivity 1 parameters (see eq. 1)	Selectivity 2 parameters (see eq. 1)	Process error CV (CPUE)
2005 low L_∞ low M	109.0	11.84, 3.10, 10.34	7.07, 0.05, 10.13	0.36 (fixed)
Update	97.1	11.94, 3.12, 10.37	8.65, 1.13, 12.5	0.41
Reference model	103.5	11.61, 2.49, 7.42	7.10, 0.05, 8.61	0.41

36. The estimates of q for the early and later fleets for the reference model were 0.012 and 0.0057 respectively.

37. Model-fit diagnostics and goodness-of-fit achieved by the reference model are shown in Figures 9 to 19.

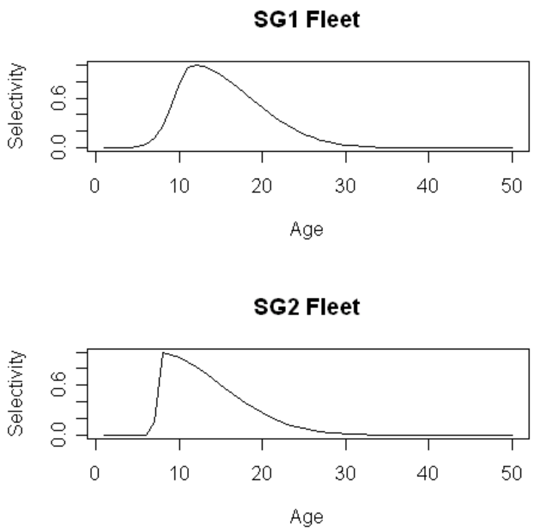

Figure 9: Estimated selectivity curves in the reference model.

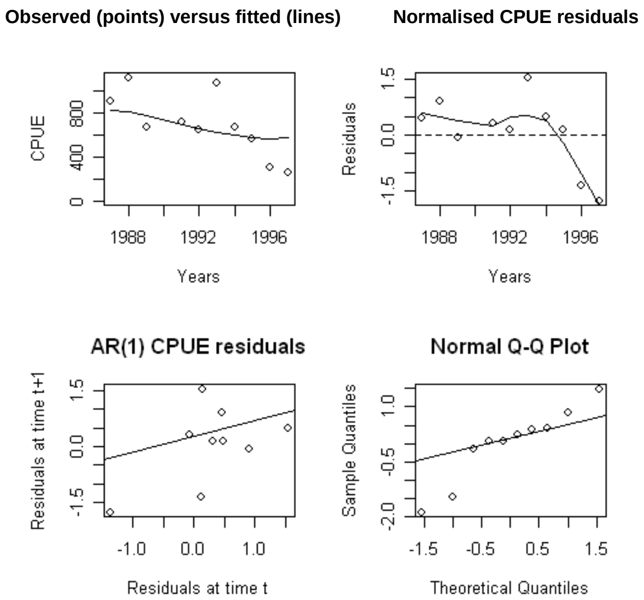

Figure 10: Fit to first-fleet CPUE series in the reference model.

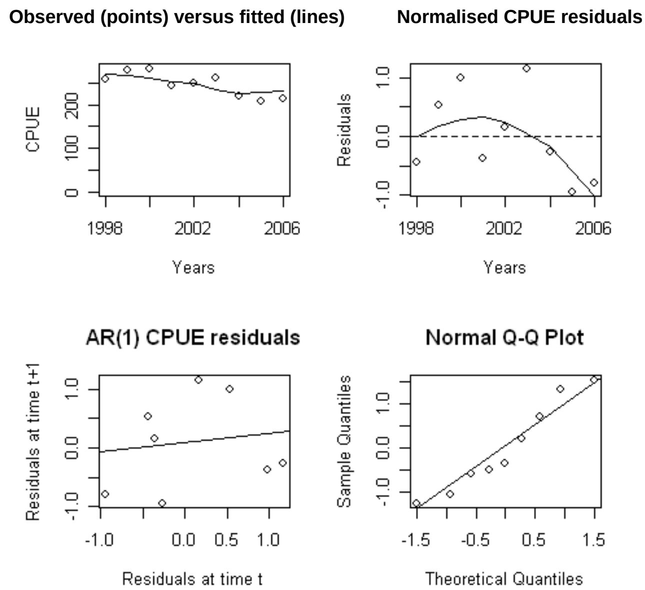

Figure 11: Fit to second-fleet CPUE series for the reference model.

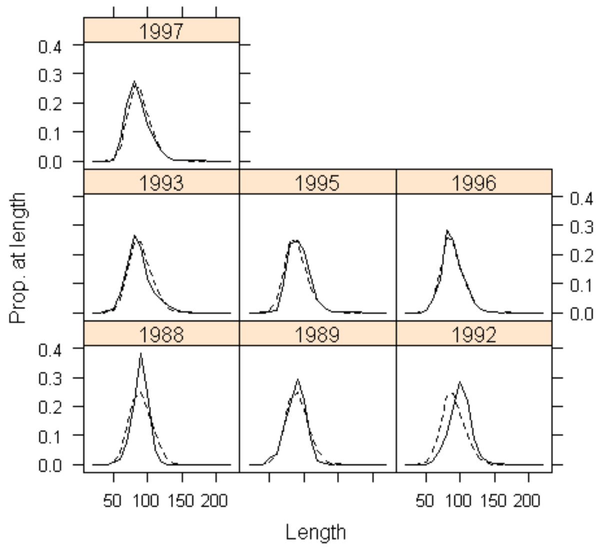

Figure 12: Fit to first-fleet catch-length frequencies for the reference model. The full and dotted lines represent the observed and predicted length frequencies respectively.

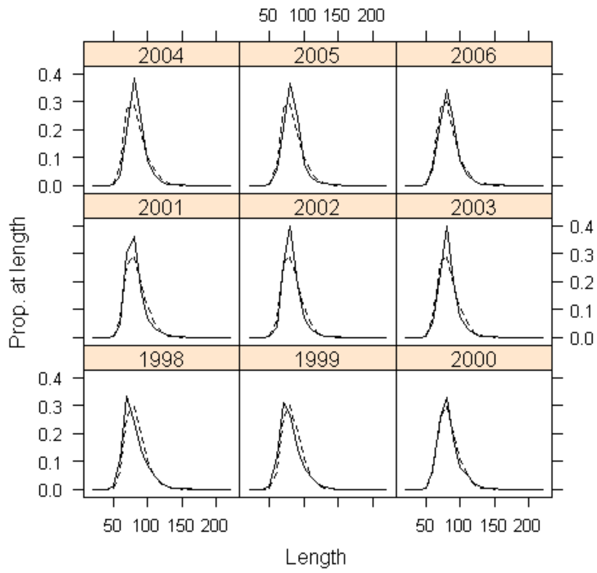

Figure 13: Fit to second-fleet catch-length frequencies for the reference model. The full and dotted lines represent the observed and predicted length frequencies respectively.

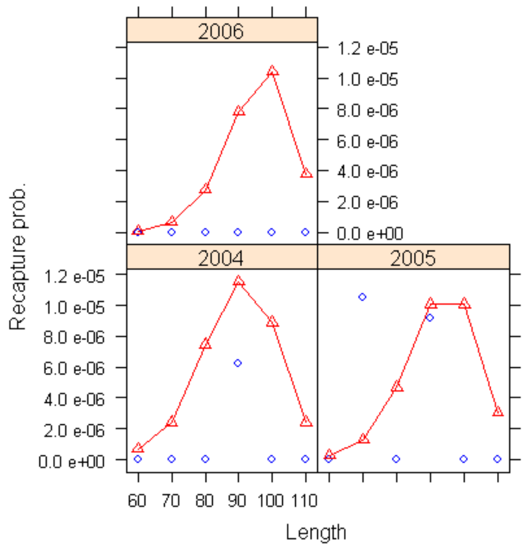

Figure 14: Fits to the 2000 tag–release data – observed recapture probabilities are the circles, with the joined triangles the expected recapture probabilities.

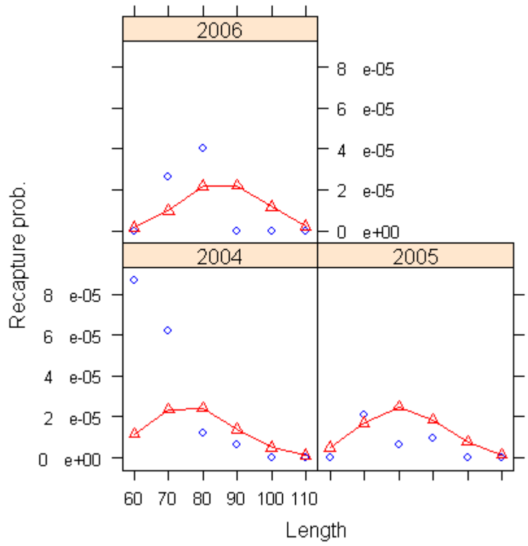

Figure 15: Fits to the 2001 tag–release data – observed recapture probabilities are the circles, with the joined triangles the expected recapture probabilities.

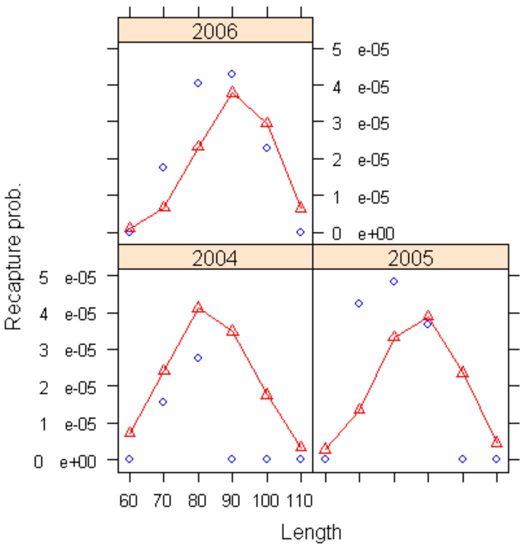

Figure 16: Fits to the 2002 tag–release data – observed recapture probabilities are the circles, with the joined triangles the expected recapture probabilities.

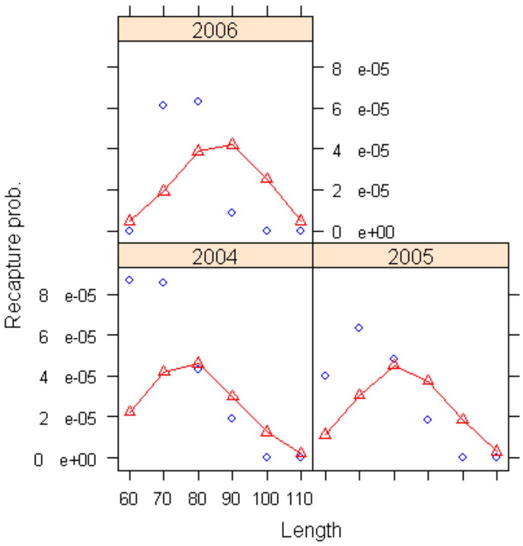

Figure 17: Fits to the 2003 tag–release data – observed recapture probabilities are the circles, with the joined triangles the expected recapture probabilities.

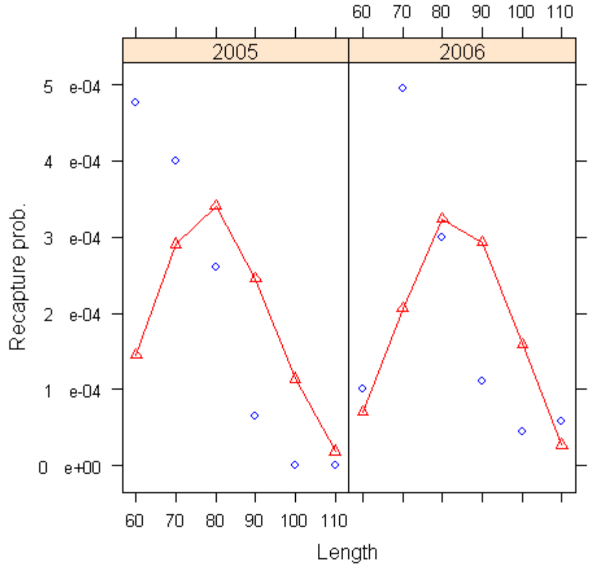

Figure 18: Fits to the 2004 tag–release data – observed recapture probabilities are the circles, with the joined triangles the expected recapture probabilities.

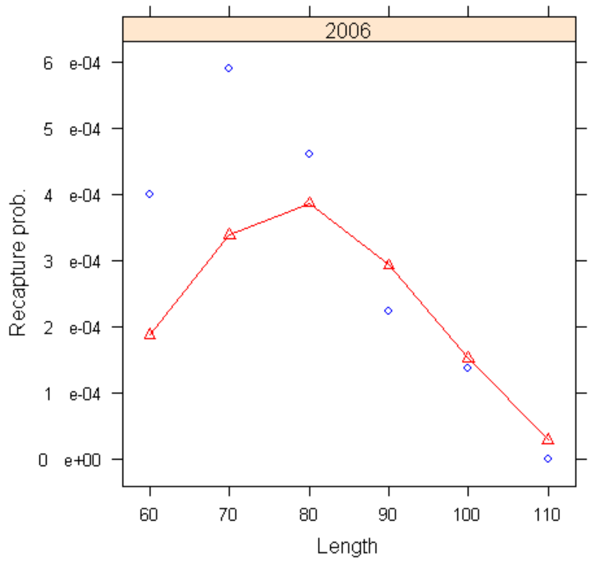

Figure 19: Fits to the 2005 tag–release data – observed recapture probabilities are the circles, with the joined triangles the expected recapture probabilities.

38. Stock trajectories are shown in Figure 20.

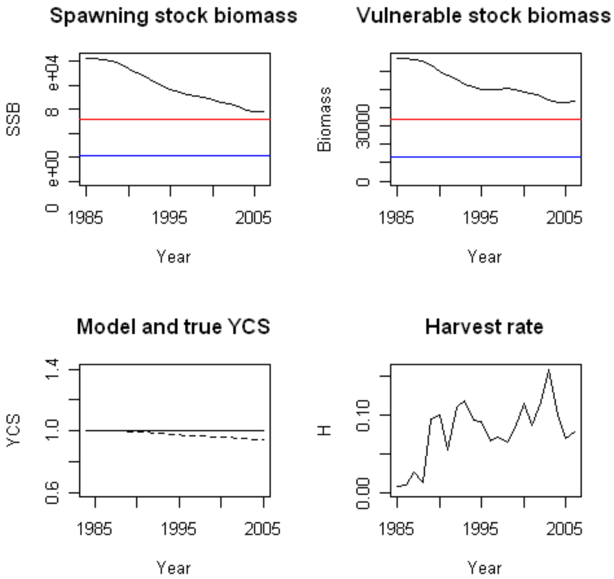

Figure 20: Stock trajectories for the reference model.

39. As can be seen, good 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 – and some of the tag–recapture data. The quality of the fit to the early CPUE data, however, must be judged in relation to the high observation errors for most of this series (see Figure 5), and the comments above about the CPUE series (particularly the likely anomalous 1993 CPUE and the abrupt change in the series from 1995 to 1996). With respect to the fits to the tagging data (see Figures 14 to 19), in some cases there is an apparent underestimation of the recaptures of the shorter fish, with some overestimation of the recaptures of larger fish. This is not likely to introduce significant bias into the assessment, since, when this trend is apparent, the plots indicate an overestimation of the biomass of small fish and an underestimate of large fish.

40. It is not clear which factors are creating this effect. Numerous potential drivers were discussed, such as age-dependent changes in *M* or selectivity, and changes in year-class strength, with the potential for interactions between drivers. It should also be noted that the number of tags recaptured represent a very small proportion of the scanned population (numbers actually caught in the fishery) and that strong inferences, based on trends in the fits, should not be stated at this stage. What was agreed was that work should be done intersessionally to try and understand where the trends could arise from. What is not clear is how potential changes in such vital parameters as natural mortality will change the nature of the results of future assessments.

41. Figure 21 shows the likelihood profile plot for B_0, for each of the datasets, priors and penalties. With respect to information coming from the CPUE data, the early series holds little if any information on abundance, which is unsurprising given the discussions already detailed on these data. The later CPUE series contains some information on a lower limit for the initial biomass (around 70 000 tonnes), which one would expect as the current CPUE data suggest a stable current exploitable population. The length-frequency data from both fleets seem to contain information on minimum values of the initial SSB – again around the level of 70 000 tonnes.

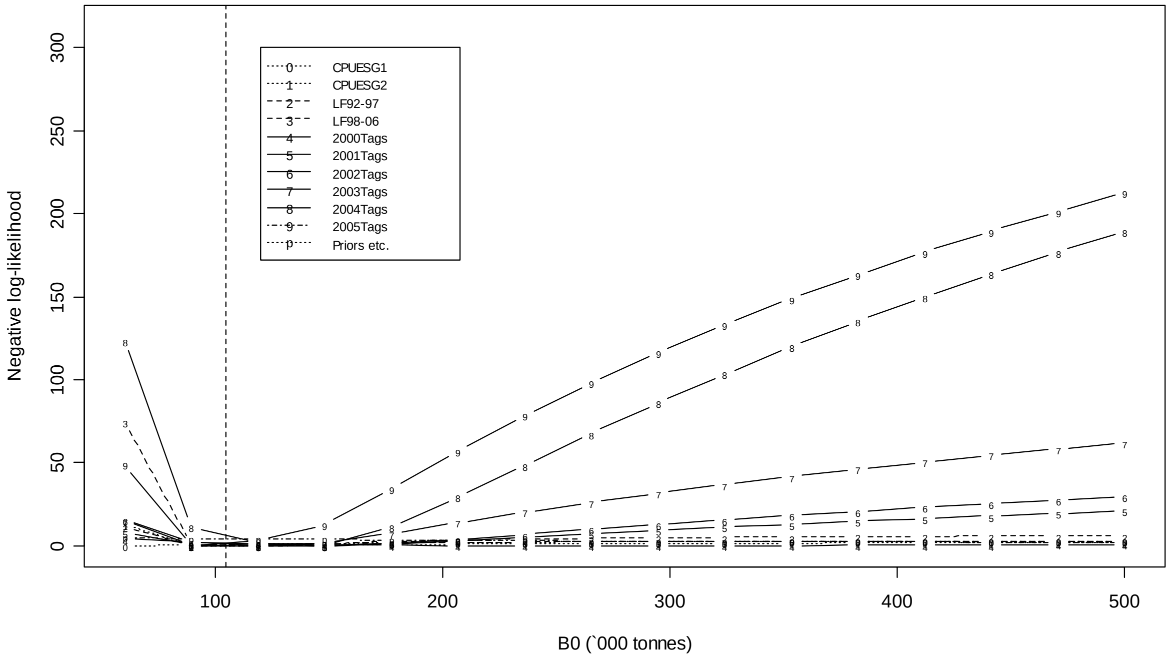

Figure 21: Likelihood profiles for the reference model. The legend refers the particular numbered curve in the figure to the relevant dataset etc. used in the assessment.

42. The strongest information on abundance – especially in relation to upper values of the initial SSB – comes from the mark–recapture data. While there is little information in the 2000 release data (to be expected given the numbers of releases and subsequent recaptures) an increasing level of information can be seen coming from the tag data as an increase in the numbers of releases and associated recaptures can also be seen (from 2001 to 2005). The value of B_0 the tag data suggest for 2000 (albeit very weakly), 2001, 2002, 2003 and 2005 is consistently close to 100 000. The 2004 data estimate a value closer to 120 000 tonnes, but the MPD estimate of B_0 is not overly influenced (shifted to the right) by the 2004 tag data. These results do, however, suggest an explanation for the reduction in B_0, resulting from a simple update of the model run in 2005 (Table 10).

43. The priors and penalties seem to exert little if any influence on the estimates of B_0.

4.5 MCMC results

44. Due to the time taken to complete a full MCMC run, the standard CASAL MCMC algorithm was used for the reference model only. For the CASAL MCMC run, the convergence tests outlined in WG-FSA-05/16 indicated that convergence had been satisfactorily achieved. Median and 95% credible intervals (CIs) for the reference model are shown in Table 10. As can be seen from Table 10, the size of the 95% CI for the SSB is quite small (around ±10%), which is driven by the information coming from the increasing number of tag returns (see the likelihood profile in Figure 21). Although calculations of the model-predicted value of the over-dispersion in the tag data (the effective down-weighting coefficient for the recapture data) do not appear to support a reduction in the tag weighting, it is perhaps sensible in the future to consider a mandatory value of this down-weighting, as the current uncertainties in the posteriors for the SSB are already becoming perhaps unbelievably low, and are likely to remain so as more tags are released and recovered. Also, at the

WG-FSA-SAM-06 meeting, a mechanism for incorporating uncertainty in M was outlined, and even though this was noted as a somewhat ad hoc procedure, it is a sensible way to incorporate uncertainty in the assumed parameters of the assessment model.

Table 10: Median and 95% CIs (in tonnes) for the initial equilibrium SSB (B_0), the current SSB (B_{2006}), the ratio of current to initial SSB (B_{2006}/B_0), the initial vulnerable biomass (VB_0) and current vulnerable biomass (VB_{2006}) for the reference model.

Model	B_0 (thousands)	B_{2006} (thousands)	B_{2006}/B_0	VB_0 (thousands)	VB_{2006} (thousands)
Reference	102.8 (96.3–109.4)	57.8 (51.2–64.4)	0.56 (0.53–0.59)	68.9 (61.2–77.8)	44.2 (38.7–51.1)

4.6 Sensitivity runs

45. Within the overall series of IUU catches in the Convention Area, the catch in 1995 appears unusually low, occurring as it does at a time when the IUU fleet was still in the Atlantic sector and before its appearance in the Indian Ocean sector around March 1996. Anecdotal reports, and preliminary investigations by the UK reported in WG-FSA-06/53, suggest that IUU catch might have been higher in this year than previously reported.

46. The Working Group was unable to comment on the likelihood that catches were higher in 1995 than previously reported, and had no additional data with which to undertake an analysis of this issue. However, it noted that the results reported in WG-FSA-06/53 suggested that the effects of additional IUU catch in 1995 would be relatively small. For instance, according to the results reported in that paper, assuming an additional 10 000 tonnes of catch in 1995 would lead to a 10% reduction in estimated current spawning stock size, no change to estimated vulnerable stock size, and a 1% reduction in sustainable yield. Furthermore, the inclusion of this additional 10 000 tonnes of catch did not substantially improve the fit of the model to the CPUE data.

47. The Working Group concluded that uncertainty about IUU catch in 1995 would not significantly affect the current assessment and estimation of yield.

4.7 Yield calculations

48. 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:

(i) Choose a yield γ_1, so that the probability of the spawning biomass dropping below 20% of its median pre-exploitation level, over a 35-year harvesting period, is 10% (depletion probability).

(ii) Choose a yield γ_2, so that the median escapement in the SSB over a 35-year period is 50% of the median pre-exploitation level, at the end of the projection period.

(iii) Select the lower of γ_1 and γ_2 as the yield.

49. The depletion probability was calculated as the proportion of samples from the Bayesian posterior, where the predicted future spawning biomass (SSB) was below 20% of B_0 in the respective sample of any one year, for each year in the 35-year projection period.

50. The level of escapement was calculated as the proportion of samples from the Bayesian posterior, where the projected future status of the SSB was below 50% of B_0 in the respective sample, at the end of the 35-year projection period. For the Subarea 48.3 toothfish CASAL model, the median pre-exploitation spawning biomass was interpreted as the estimate of B_0 for each Monte Carlo sample. This will result in a small downward bias of the status of the stock in each trial, and a small upward bias in the probability of depletion. The effect of these biases will be a small downwards bias in the estimate of yield. The probability of depletion and the level of escapement were calculated by projecting forward for a period of 35 years, under a scenario of constant catches, for each Monte Carlo sample of the Bayesian posterior.

51. The randomisations in future recruitment were begun in 2003, to account for the fact that no information on the year classes from these years onwards was available when conditioning the model parameters. The appropriate long-term yield for the reference model was 3 554 tonnes, with the escapement, not the depletion rule, deciding this value. Figure 22 shows a plot of the probability of depletion of the SSB below 50%, for a long-term yield of 3 554 tonnes imposed from 2007 to 2042.

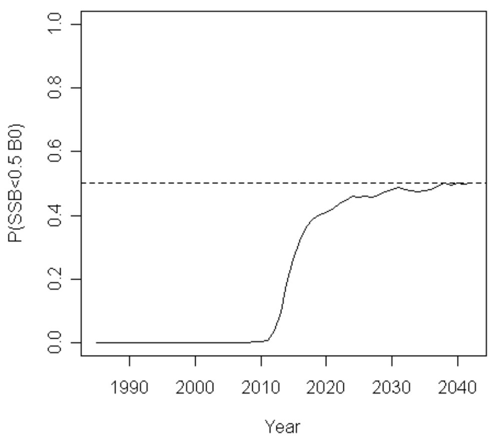

Figure 22: Probability that the future SSB is less than 50% of the initial unfished SSB, for a long-term yield of 3 554 tonnes.

4.8 Future work

52. With regards to future direction for this toothfish assessment model, there are several potential directions to pursue:

- the further development of assessment models using catch-at-age, not catch-at-length data;
- reliable estimate of year-class strength;

- the exploration of the possibility of a two-sex model;
- investigation of a pseudo-spatial fishery model, separating South Georgia and Shag Rocks;
- further investigation and refinement of the CPUE data, to obtain a core subset of catch and effort data, with which to generate the standardised CPUE indices.

5. By-catch of fish and invertebrates

5.1 Estimation of by-catch removals

53. 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 11: 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	*
2005/06	136	177	7	177	44	*

* None specified

Estimated cut-off catch

54. Estimates of total mortality for fish cut from longlines in Subarea 48.3 were made in 2003. Sufficient data to repeat these calculations were not available at the 2006 WG-FSA meeting.

5.2 Assessments of impact on affected populations

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

5.3 Mitigation measures

56. 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

57. Details of seabird by-catch (taken from Appendix D, Table 3) are summarised in Table 12. Estimated potential seabird removals in the IUU fishery are summarised in SC-CAMLR-XXV/BG/27 and Appendix D, Table 17.

Table 12: 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
2005/06	0	0

* Excluding *Argos Helena* line-weighting experiment cruise

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

6.1 Mitigation measures

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

6.2 Interactions involving marine mammals with longline fishing operations

60. Interactions with cetaceans continue to be reported by observers in Subarea 48.3. Dr D. Agnew (UK) reported that the UK has studies under way to characterise the behaviour of sperm whales and orcas and their impact on the fishery, and would hope to report to WG-FSA in 2007.

7. Ecosystem effects

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

8. Harvest controls for the 2005/06 season and advice for 2006/07

8.1 Conservation measures

Table 13: Summary of provisions of Conservation Measure 41-02 for *Dissostichus eleginoides* in Subarea 48.3 and advice to the Scientific Committee for the 2006/07 season.

Paragraph and topic	Summary of CM 41-02 for 2005/06	Advice for 2006/07	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	3 556 tonnes for the whole area Management Area A: 0 tonnes Management Area B: 1 067 tonnes Management Area C: 2 489 tonnes	3 554 A: 0 B: 1 066 C: 2 488	Main report
5. Season: longline	1 May to 31 August 2006 Extension possible to 14 September 2006 for vessel complying fully with CM 25-02 in 2004/05.	Update	
pots	1 December 2005 to 30 November 2006	Update	
seabirds	During extension period (1–14 September 2006) 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	
finfish	Total combined catch of skates and rays 177 tonnes Total catch of *Macrourus* spp. 177 tonnes	Revise as pro-rata calculation on catch limit	
any species	Move-on rule	Continue	
7. Mitigation	In accordance with CM 25-02.	Continue	
8. Observers	Each vessel to carry at least one CCAMLR scientific observer and may include one additional scientific observer.	Continue	
9. 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	
10. 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	
11. Jellymeat	Number and weight of fish discarded, including those with jellymeat condition, to be reported. These catches count towards the catch limit.	Continue	
12. Data: biological	Monthly fine-scale reporting system as in CM 23-05. Reported in accordance with the Scheme of International Scientific Observation.	Continue	
13. 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

62. The Working Group agreed that the reference case would be the only model variant to be used in the yield calculation. As defined above, the MCMC samples were used in the yield calculation, and the appropriate long-term yield calculated was 3 554 tonnes, with the 50% rule, not the 20% rule, being invoked.

63. The Working Group recommended that the catch limit for toothfish in Subarea 48.3 (SGSR stock) should be 3 554 tonnes for the 2006/07 fishing season.

64. The catch limits for management areas A, B and C should be adjusted in a pro-rata manner to 0, 1 066 and 2 488 tonnes respectively. By-catch limits for skate/rays and macrourids should be similarly revised to 177 and 177 tonnes respectively.