Fishery Report: *Dissostichus eleginoides* South Georgia (Subarea 48.3)

1. Details of the fishery

1.1 Reported catch (time series)

Table 5.13: 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).

Fishing season	Catch limit	Reported catch (tonnes)	IUU Catch (tonnes)	Total extractions (tonnes)
1984/85		521	0	521
1985/86		733	0	733
1986/87		1954	0	1954
1987/88		876	0	876
1988/89		7060	144	7204
1989/90		6785	437	7222
1990/91	2500	1756	1775	3531
1991/92	3500	3809	3066	6875
1992/93	3350	3020	4019	7039
1993/94	1300	658	4780	5438
1994/95	2800	3371	1674	5045
1995/96	4000	3602	0	3602
1996/97	3540	3812	0	3812
1997/98	3330	3201	146	3347
1998/99	3500	3636	667	4303
1999/00	5310	4904	1015	5919
2000/01	4500	4047	196	4243
2001/02	5820	5744	3	5747
2002/03	7810	7534	0	7534
2003/04	4420	4482	0	4482

5.103 During the 2003/04 season the fishery was active from 1 May to 21 August 2004 (Table 5.13).

5.104 The Working Group agreed to define a new area within Subarea 48.3 relevant to the South Georgia and Shag Rocks stock (paragraph 5.107). The revised catches attributed to the South Georgia and Shag Rocks stock are given in Table 5.14.

Table 5.14: Catches from South Georgia and Shag Rocks in Subarea 48.3.

Fishing season	Official catch from Subarea 48.3	Corrected catch from South Georgia and Shag Rocks
1984/85	521	521
1985/86	733	733
1986/87	1954	1954
1987/88	876	876
1988/89	7204	7204
1989/90	7222	7222
1990/91	3531	3531
1991/92	6875	6871
1992/93	7039	7039
1993/94	5438	5438
1994/95	5045	4998
1995/96	3602	3542
1996/97	3812	3812
1997/98	3347	3347
1998/99	4303	4303
1999/00	5919	5911
2000/01	4243	4234
2001/02	5745	5722
2002/03	7528	7513
2003/04	4482	4447

Distribution of the fishery

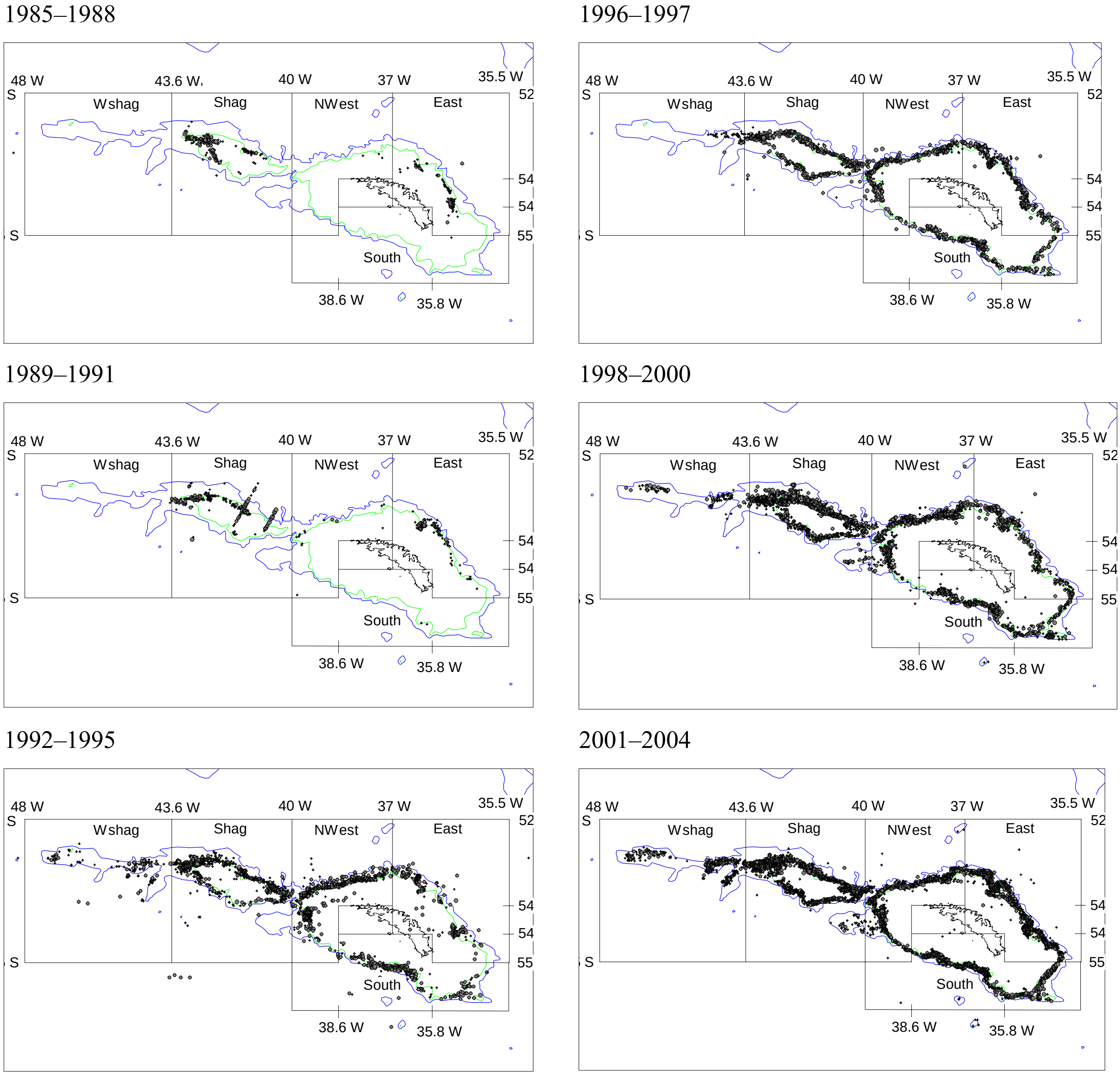


Figure 5.3: Distribution of catches in discrete time periods, graduated by the number of hooks set. Wshag – western Shag Rocks; Shag – Shag Rocks; NWest –northwest South Georgia; East – east South Georgia; South – south South Georgia.

1.2 IUU catch

5.105 The estimated IUU catch from Subarea 48.3 in the 2004 fishing season is zero. Dr Agnew informed the Working Group that the UK had continued to undertake patrols in the area, and apply the model estimating IUU catch described by Agnew and Kirkwood (2002).

1.3 Size distribution of catches (time series)

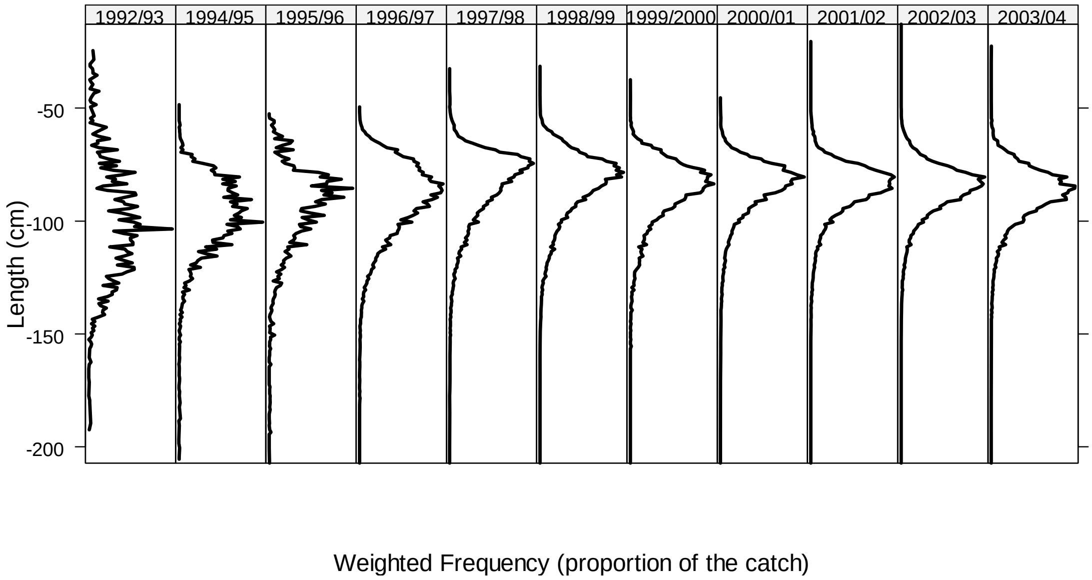


Figure 5.4: Catch-weighted length frequencies for *Dissostichus eleginoides* in Subarea 48.3 derived from observer, fine-scale and STATLANT data reported by 6 October 2004.

2. Stocks and areas

5.106 The fishery is largely restricted to waters adjacent to South Georgia and Shag Rocks in water down to 1 800 m depth. Much of Subarea 48.3 has a water depth in excess of 2 000 m and toothfish are known to occur there, albeit at low density. Toothfish are known to occur in adjacent areas. 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).

5.107 The Working Group considered the information on stock structure provided by WG-FSA-04/21 that indicated that *D. eleginoides* occurring on Burdwood Bank and the North Scotia Ridge could be considered separate from the populations around Shag Rocks and South Georgia. The Working Group agreed to divide Subarea 48.3 into the area relevant to the South Georgia and Shag Rocks population, and other areas, according to Figure 5.5.

5.108 The Working Group agreed that its assessment would only apply to the Shag Rocks and South Georgia stock.

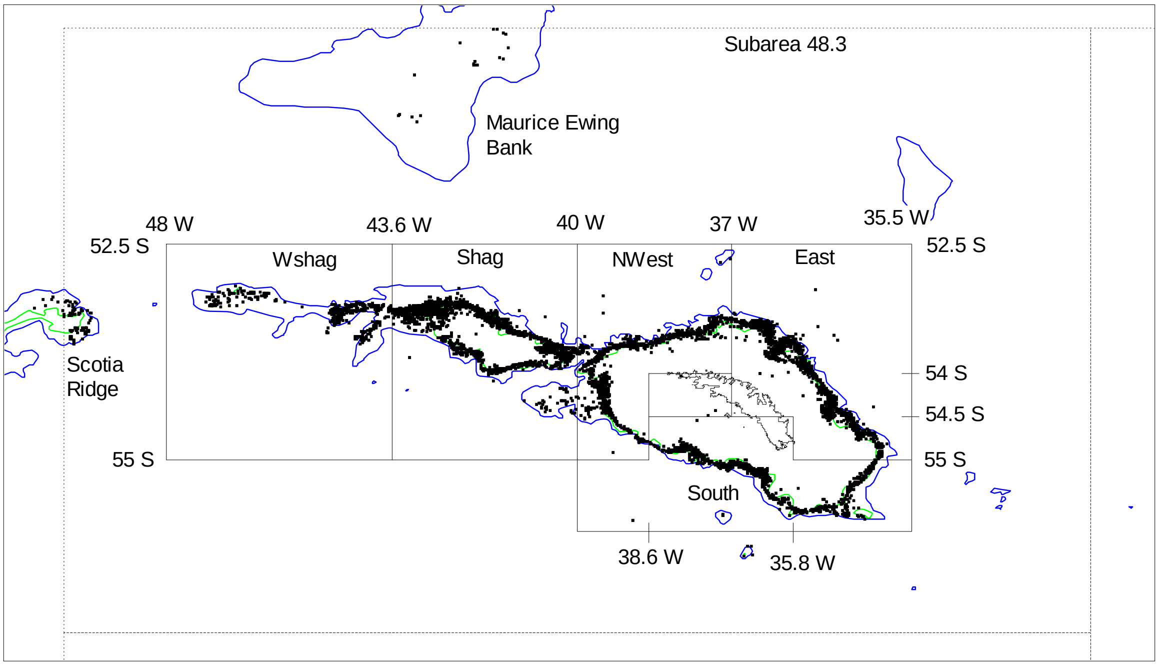


Figure 5.5: Definition of new areas in Subarea 48.3. The South Georgia and Shag Rocks stock is only present in areas Wshag, Shag, NWest, East and South (Table 5.14). See Figure 5.3 for area definitions.

3. Parameter estimation

3.1 Estimation methods

Trends in fishing vulnerability

5.109 The method (WG-FSA-02/64), used in 2002 and 2003, takes specific account of the tendency for the size of fish taken in the longline fishery to be positively correlated with depth fished, and that shifts in effort distribution by depth between years will result in different fishing pressures being placed on fish in different length (or age) classes.

5.110 The method first estimates vulnerabilities-at-length using estimates of length densities by depth zone and region around South Georgia and Shag Rocks obtained from the observer data. These are then converted to vulnerabilities-at-age using the growth curve estimated for Subarea 48.3. The analyses this year incorporated all available data for 2004 and indicated that the ‘deep’ vulnerability curve was most appropriate for the 2004 season (Figure 5.6). The age-specific vulnerabilities were updated for 2004 and projection years in the GYM.

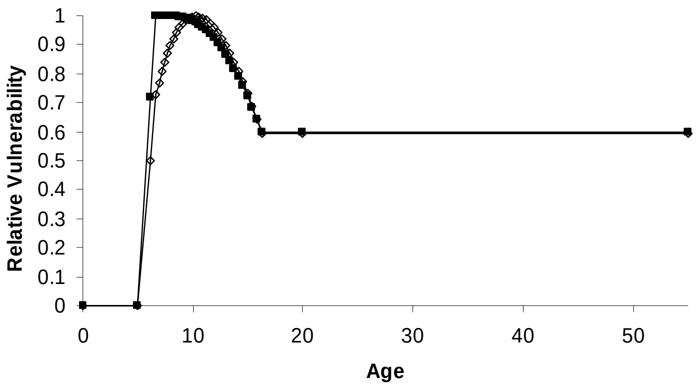


Figure 5.6: Vulnerability functions for Subarea 48.3: 'Deep' pattern (open squares) and 'Shallow' pattern (closed squares).

CPUE standardisation

5.111 WG-FSA agreed that the method used to standardise the CPUE series would be reviewed. Two methods are currently available to the Working Group – the previously used GLM and the GLMM approach described by Candy (2004). Drs Agnew and S. Candy (Australia) reviewed the characteristics of the fits using both methods and, in particular examined the area-by-year interaction. The QQ diagnostic plots for the GLMM model indicated that the random effects assumptions of the GLMM model (Candy, 2004) were reasonable (Figure 5.7). Examination of the area–season random effects indicated that there was not a significant trend in CPUE for the majority areas, although there was a suggestion of a trend for the Shag Rocks areas in the latter part of the series (Figure 5.8). Area interactions with the other main effects were also considered, but none were found to be significant.

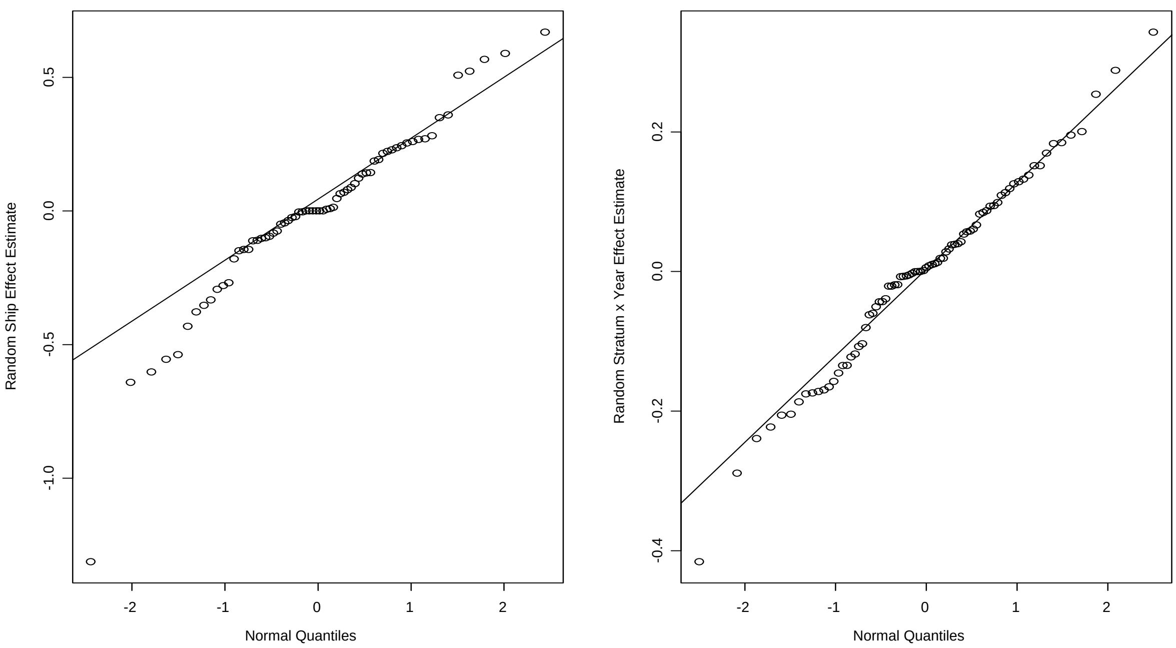


Figure 5.7: QQ diagnostic plots for the random vessel and area-by-season effects for the GLMM for Subarea 48.3.

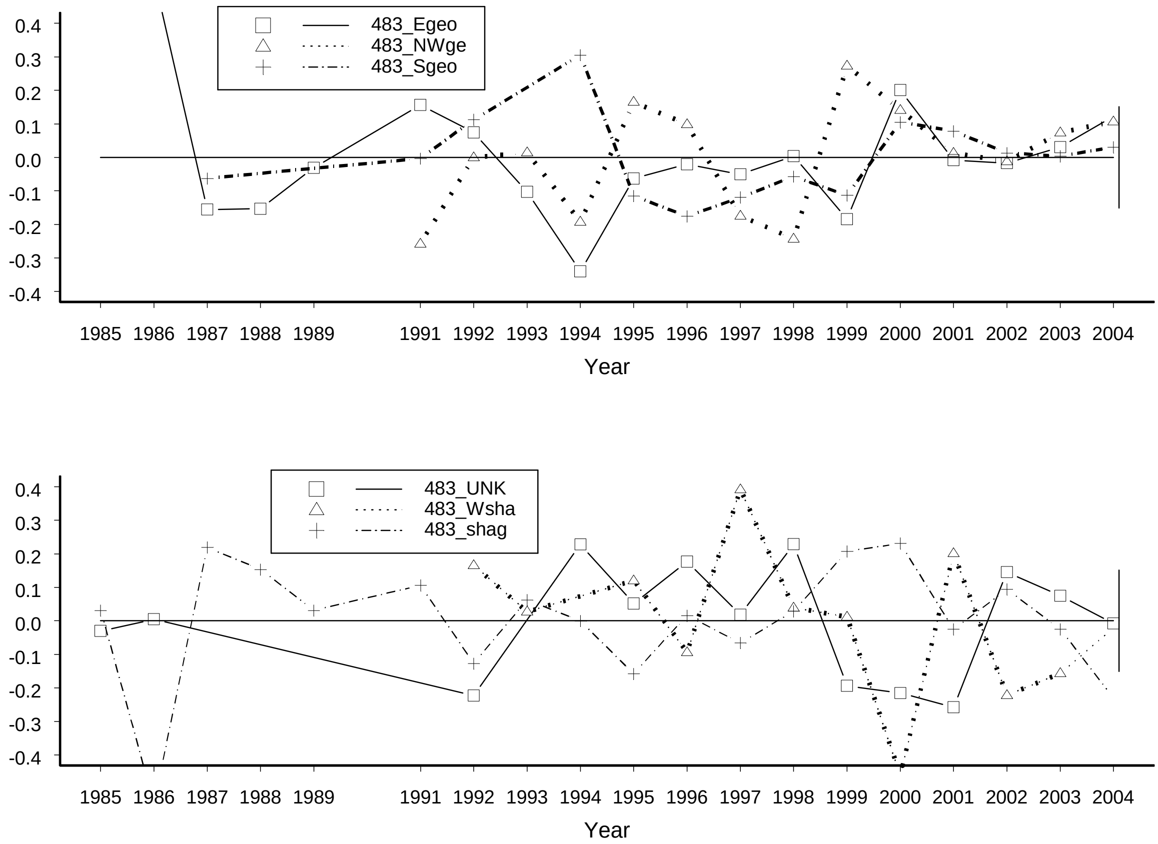


Figure 5.8: Deviation from the standardised CPUE trend by area for Subarea 48.3. Egeo – east South Georgia, NWge – northwest South Georgia, Sgeo – south South Georgia, UNK – unknown location, Wshag – west Shag Rocks, Shag – Shag Rocks.

5.112 On the basis of the outcomes of these analyses, the Working Group agreed that the random-effects GLMM should be used as the method for standardisation of CPUE series for use in GYM assessments for this year and for further development of the ASPM method. The revised series was calculated using the GLMM with area–season as a random effect and area as a fixed effect, with CPUE scaled to the south South Georgia area. The revised series is given in Figure 5.9 along with the equivalent standardisation using the standard GLM used in previous years.

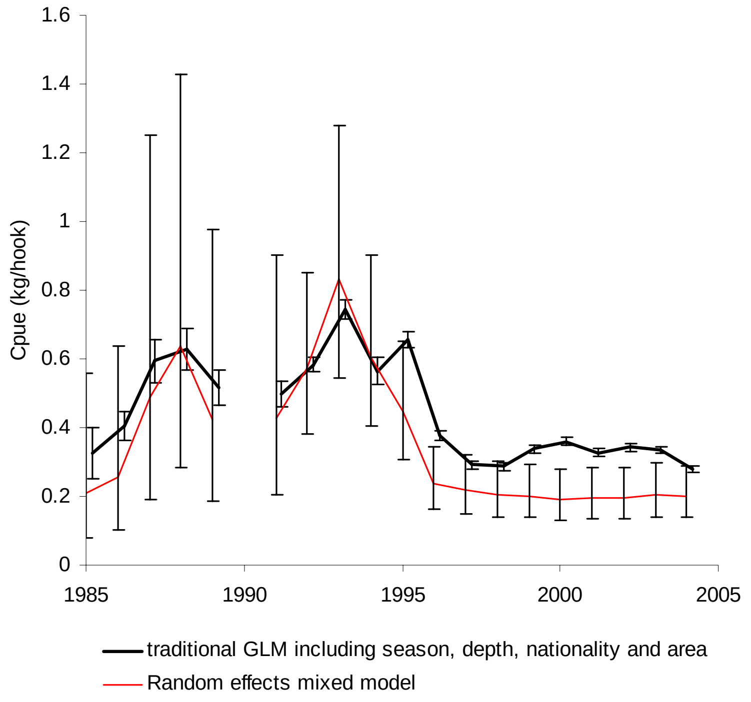


Figure 5.9: Standardised longline CPUE by fishing season for Subarea 48.3 using the GLMM method with a random-effects model (thin line) and the standard GLM method (thick line) previously used by the Working Group. Both series have been standardised for Chilean vessels fishing between depths of 1 000 and 1 500 m in the southern sector of South Georgia.

5.113 In addition, the Working Group examined the spatial variation in catch and effort around South Georgia and Shag Rocks over the period from 1986 to 2004 (Figure 5.3).

Mean size in commercial catch

5.114 Fisheries data (reports of weight and number of fish caught) were analysed in a standard GLM (Figure 5.10). Mean weight declined from 1992 to 1998, increasing gradually thereafter.

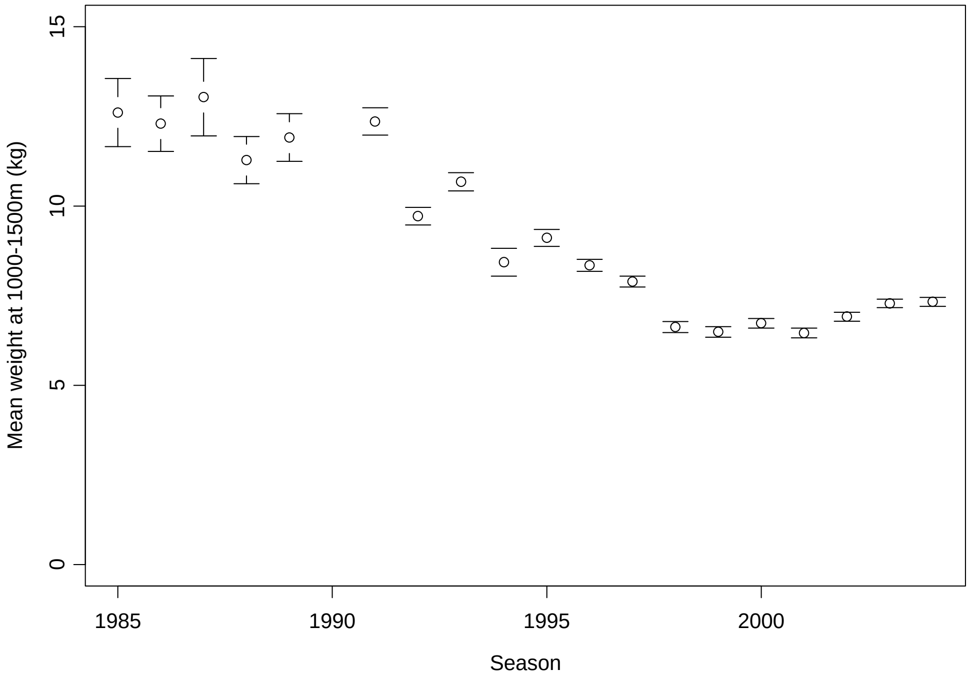


Figure 5.10: Mean weight of toothfish in the catch calculated using a GLM of similar form to that for the standard GLM (paragraphs 5.111 to 5.113), standardised to Chilean vessels fishing between depths of 1 000 and 1 500 m, in the southern sector of South Georgia.

<u>Recruitment</u>

5.115 Estimates of numbers of recruits at age 4 are calculated by applying the CMIX program to length-density data (numbers/km^2 for each length class) from each survey haul, weighted by the proportion of the stratum area in the overall survey and the inverse proportion of the number of survey hauls in the stratum. The data extractions for the 2004 survey were done using six strata: three depth strata (50–150, 150–250 and 250–500 m) each for South Georgia and Shag Rocks (see SC-CAMLR-XXI, Annex 5, paragraph 5.60).

5.116 The Working Group considered the review of approaches to estimating recruitment presented in WG-FSA-04/92 which suggested that a number of issues be considered in the process of estimating and revising the time series of recruitments for toothfish:

(i) Establish what would be a reasonable length for a fish at age 0 (time zero in the year).

(ii) Establish the birthday of the fish in the year (time 0). If this needs to be varied in some years, then the period in the year that would accommodate time 0 will need to be considered.

(iii) Estimate (establish) the lengths-at-age (e.g. from growth parameters) and their variances to be used for validating the observed distributions in the mixture analyses.

(iv) Adjust the t_0 of the growth parameters so that the length-at-age of 0.0 is appropriate and then estimate lengths-at-age for the given survey time (adding a proportion of the year from the birthday to the survey).

(v) Choose the bounds around the estimated mean length-at-age to accommodate a plausible birthday, plausible interannual variation in growth and consistency with other surveys.

(vi) Choose appropriate ranges of the standard deviations of length-at-age to ensure that cohort growth (across all lengths of the cohort) are plausible.

5.117 The Working Group agreed to review the CMIX analyses presented in order to arrive at a revised series of recruitments for Subarea 48.3 based on the recruitment series calculated using the current Subarea 48.3 and Belchier et al. (2004) (in WG-FSA-SAM-04/16) growth parameters presented in WG-FSA-04/92.

5.118 A number of issues associated with the estimation of mean recruitment and the recruitment series for Subarea 48.3 were identified by the Working Group for review during the meeting. These included:

(i) the length range used in the CMIX analyses that are sampled consistently by the surveys;

(ii) individual components that may need to be excluded due to poor fits of the CMIX analyses;

(iii) individual surveys that may need to be excluded due to particularities of the survey resulting in poor coverage of the cohorts of interest.

5.119 In light of the above, Drs C. Davies (Australia) and G. Kirkwood (UK) reviewed the CMIX analyses presented in WG-FSA-04/92 and, on the basis of their review, recommended the following with respect to the estimation of revised recruitment series for Subarea 48.3:

(i) the size range for components to be included in the estimation should be 200–600 mm;

(ii) the 2000 Russian survey should be excluded on the basis of very low densities and less than adequate coverage;

(iii) the CMIX analysis for the 1988 UK survey presented in WG-FSA-04/92 for the Subarea 48.3 growth parameters should be revised to obtain a better fit.

5.120 The recruitment series, mean recruitment and its CV were re-estimated in the GYM (version 5.0.1e, GYUI 5.0.1e build 92) following these revisions. The Working Group agreed that the series generated using the Subarea 48.3 growth parameters would be used as a base-case for this year's assessment and the series estimated using the Belchier et al. (2004) parameters would be used in sensitivity analyses.

Effects of stratification on CMIX estimates of abundance

5.121 Usually, CMIX is used to process trawl survey data by pooling data across strata using a transformation of individual hauls within a stratum in order to have a single pooled dataset, weighted by the area of the stratum and the proportion of hauls within a stratum. Following consideration of the survey design and the distribution of length classes between strata, some checks were undertaken of the total abundances of fish being estimated from the pooled data compared to summing the estimates for individual strata. These were also compared to outcomes from using all the data without assigning them to strata or transforming them in any way.

5.122 The differences in outcomes are illustrated in Tables 5.15 to 5.17.

5.123 These differences might be a function of the transformation to pool the data and the manner in which the proportion of non-zeros in each stratum affect the Aitcheson delta estimator. They might also arise from the non-linear function in the density calculation. It was also noted that a difficulty with using the data without strata is that it assumes the sampling density for a stratum is the same across all strata. If the sampling density is not the same across strata then biases might arise. The Working Group had insufficient time to explore these issues further and recommended that WG-FSA-SAM review this at its next meeting.

Table 5.15: CMIX results from UK surveys in 2002 and 2004 in Subarea 48.3 where data are pooled across strata using the formula to weight individual hauls by the proportion of the total area in the stratum and the inverse proportion of all hauls in that stratum. This analysis was on the basis of six strata.

Index	Age 3	Age 4	Age 5	Age 6	Age 7	Total
2002 Survey:						
Means of mixture components		327.139	444.872	515.692	581.92	
Standard deviations of mixture components		29.3328	24.5213	6.08945	50	
Total density of each mixture component		46.4708	22.2315	4.43781	12.4313	
SD of each mixture component density		8.43531	13.2061	2.79363	2.5423	
Abundance		1904991	911343	181920	509600	3 507 854
2004 Survey:						
Means of mixture components	216.474	334.442	470.818	487.879	650.355	
Standard deviations of mixture components	16.9256	25.6042	35.6371	36.8922	48.8452	
Total density of each mixture component	58.8412	32.8541	6.18E-02	10.7741	4.11461	
SD of each mixture component density	356.29	7.48437	0.396087	1.95942	1.79337	
Abundance	2412095	1346798	2534	441666		4 203 093

Table 5.16: CMIX results from UK surveys in 2002 and 2004 in Subarea 48.3 for each stratum. Strata for which CMIX did not successfully resolve fits are shown.

Survey, Stratum	Index	Age 3	Age 4	Age 5	Age 6	Age 7	Total
2002							
1	Means of mixture components	252.9	333.1	470.9	516.5	629.7	
	Standard deviations of mixture components	8.7	8.7	8.8	8.8	8.8	
	Total density of each mixture component	51.5	403.0	55.6	99.9	33.0	
	SD of each mixture component density	26164.3	912989.0	28281.9	50783.8	16803.7	
	Abundance	75820	593778	81956	147163	48694	947 411
2	Not resolved						
3	Not resolved						
4	Not resolved						
5	Not resolved						
6	Means of mixture components	227.9	334.5	467.5	477.3	645.8	
	Standard deviations of mixture components	20.2	28.4	38.8	39.5	52.6	
	Total density of each mixture component	5.3	2.3	54.3	4.4	3.0	
	SD of each mixture component density	1960.7	903.9	16903.4	1045.3	1295.9	
	Abundance	41995	18508	433125	34728	24010	552 366
	Sum of abundance from 2002 strata 1 and 6	117815	612286	515081	181891	72704	1 499 777
2004							
	Means of mixture components	321.3	436.2	559.8			
1	Standard deviations of mixture components	25.6	25.6	25.6			
	Total density of each mixture component	181.7	37.8	21.3			
	SD of each mixture component density	28.3	17.7	24.9			
	Abundance	267686	55652	31401			354 740
2	Means of mixture components	332	439	521	590	668	
	Standard deviations of mixture components	20	21	21	22	22	
	Total density of each mixture component	198	43	11	9	16	
	SD of each mixture component density	105	12	5	4	22	
	Abundance	369716	79506	20801	15998	30578	516 599
3	Means of mixture components	332.4	438.2	512.0	582.2	709.9	
	Standard deviations of mixture components	21.9	21.9	21.9	21.9	21.9	
	Total density of each mixture component	86.9	142.2	96.2	43.9	2.2	
	SD of each mixture component density	27.8	46.6	32.2	14.3	38.8	
	Abundance	139846	229019	154811	70704	3472	597 852
4	Not resolved						
5	Not resolved						
6	Not resolved						
	Sum of abundance from 2004 strata 1–3	777247	364178	207013	86702	34050	1 469 190

Table 5.17: CMIX results from UK surveys in 2002 and 2004 in Subarea 48.3 assuming no strata.

Index	Age 3	Age 4	Age 5	Age 6	Age 7	Total
2002 Survey:						
Means of mixture components	324.4	440.4	525.7	592.1	675.4	
Standard deviations of mixture components	25.8	25.8	25.8	25.8	25.8	
Total density of each mixture component	124.0	39.4	13.6	10.8	3.6	
SD of each mixture component density	25.3	7.7	4.4	3.3	3.1	
Abundance	5082103	1614505	556603	441895	149572	7 844 678
2004 Survey:						
Means of mixture components	339.4	482.2	565.9	662.5		
Standard deviations of mixture components	23.3	28.6	31.8	35.4		
Total density of each mixture component	69.6	25.9	6.8	6.6		
SD of each mixture component density	152.8	69.1	56.1	40.0		
Abundance	2853310	1061931	279416	269448		4 464 106

Mark–recapture estimates of vulnerable biomass

5.124 WG-FSA-04/82 presented a refinement of a Petersen mark–recapture estimator of toothfish vulnerable biomass in Subarea 48.3 initially considered at WG-FSA-SAM-04 (WG-FSA-SAM-04/17). As requested by the subgroup, the authors revised the estimator and the data inputs to take account of:

- selectivity in the fishery (e.g. Tuck et al. (2003) selectivities were calculated according to Kirkwood (2002) using a deep selectivity pattern for 2002 and 2004 and a shallow pattern for 2003);
- initial tag mortality (assumed to be 10%);
- tag loss rate (calculated from double tag returns to be 6% per year);

and had provided estimates of confidence intervals. WG-FSA-04/82 also investigated the sensitivity of the results to different levels of tag loss rate, natural mortality and initial tag mortality.

5.125 The tagging program in the commercial fishery in Subarea 48.3 was initiated in 2000, hence some tagged fish have now been four years at liberty. Data on distance moved by individual recaptures presented in WG-FSA-04/82 suggested that although most toothfish move less than 50 km at least in the short term, significant numbers were moving several hundred km over several years at South Georgia. WG-FSA-04/82 ignored tags recovered in the same year in which they were released. Since fishing takes place in mid-winter, this equates to a minimum time at liberty of approximately 180 days to allow sufficient time for mixing. All tag return rates reported below utilise this day-at-liberty definition. The paper also reported the results of the Jolly–Seber estimator, but considered that there were not enough time periods of future sampling for it yet to provide a robust estimator of population size.

5.126 In the implementation of the analysis presented in WG-FSA-04/82 tagged fish were treated differently depending on whether they were ever recovered or not. The tagged population at the time of sampling was calculated from two populations of tagged fish:

- the population that was tagged but has never been recaptured. For these a probability of recapture was calculated taking into account natural mortality, tag mortality and tag loss rate;

- the population that was tagged and was later recaptured (i.e. their presence in the tagged population is known at the time of sampling). These were given a probability of recapture of 1.

5.127 The Working Group investigated the effect of treating all tagged fish equally to the various mortality estimates. This reduced the estimates of the tagged population at the time of sampling, and consequently the estimates of vulnerable biomass (from 52 400, 53 800 and 61 800 tonnes to 44 600, 50 800 and 60 300 tonnes for 2002, 2003 and 2004 respectively).

5.128 The overall recovery rate of tags (recovery of tags that were tagged in a previous season expressed as a percentage of the tagged population) was 12, 15 and 7% in 2002, 2003 and 2004 representing 30, 82 and 48 tag recoveries respectively. There was not sufficient time at the meeting to examine the potential source of this variability in recapture rate among years further. However, on the basis of distribution of effort and tag recaptures presented in Figure 5.11 it does not seem to be a result of changes in the distribution of fishing effort.

5.129 The spatial analysis presented in Figure 5.11 indicates that tags were recovered from a much more restricted area in 2002 than in subsequent years and that a large proportion of the returned tags recaptured in 2002 were from a restricted area at Shag Rocks. Following this analysis, the Working Group agreed that it would be important to further investigate the relationship between the distribution of effort and recaptures at a finer spatial scale intersessionally.

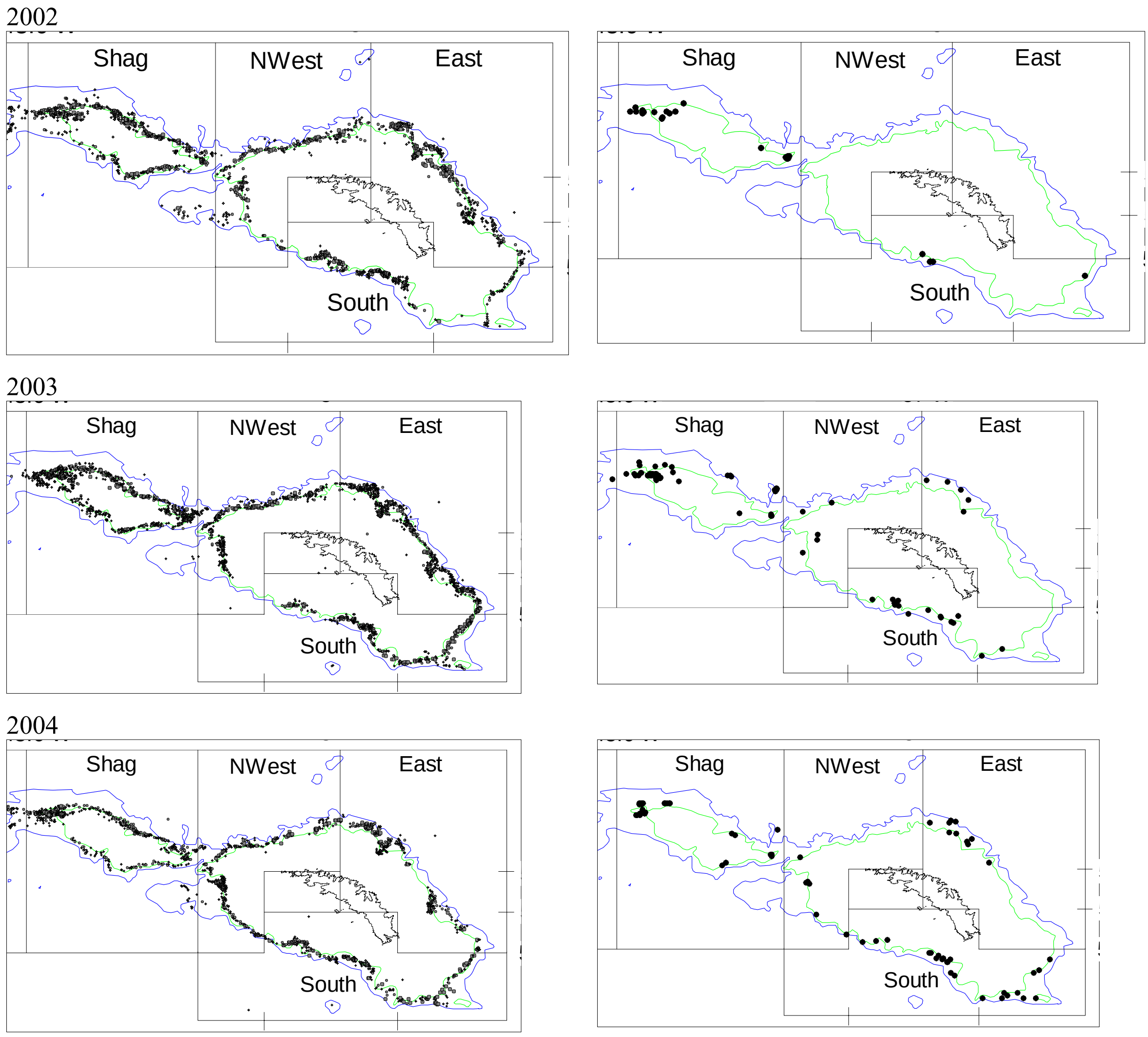


Figure 5.11: Distribution of (a) fishing effort and (b) recaptured tags by year since the commencement of the tagging program in Subarea 48.3. See Figure 5.3 for area definitions.

5.130 Issues of mixing were investigated by calculating Petersen estimates for three separate areas, Shag Rocks (including west Shag Rocks), northwest and east South Georgia and south South Georgia (see Figure 5.3 for area definitions). The distribution of releases by area and year are given in Table 5.18. The distribution of returns indicated movement between each of these three areas (Table 5.19). However, there was a larger proportion of returns within Shag Rocks and south South Georgia than in the northwest and east South Georgia area (Table 5.19). Fish were recorded to move between northwest and east South Georgia and both other areas.

Table 5.18: Distribution of releases of *Dissostichus eleginoides* among areas within Subarea 48.3 (not including 2004).

South Georgia	Number of fish tagged and released				
	2000	2001	2002	2003	Total
Shag Rocks	91	324	186	129	730
Northwest and east	44	7	99	92	242
South		16	116	134	266
Total	135	347	401	355	1238

Table 5.19: Distribution of recaptures of *Dissostichus eleginoides* among areas within Subarea 48.3. Data are pooled over the 2001/02 and 2003/04 fishing seasons.

Tagged at South Georgia	Recovered at South Georgia			Total
	Shag Rocks	Northwest and east	South	
Shag Rocks	112	5	0	117
Northwest and east	2	7	1	10
South	0	2	31	33
Total	114	14	32	160

Table 5.20: Results of Petersen estimates of vulnerable biomass in Subarea 48.3. Estimates were made for three separate areas (rows 1–3) and the whole area combined. The standard error is Bailey's binomial variance calculated according to Seber (1985, p. 61).

South Georgia	No. tags recovered			Exploitable biomass (tonnes)			se		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
Shag Rocks	29	59	26	17 197	17 354	20 599	6 054	4 355	7 630
South	1	15	16	6 146	8 708	10 219	6 955	4 139	4 721
Northwest and east	0	8	6		36 152	38 419		22 407	26 623
Total	30	82	48						

5.131 Estimates of vulnerable biomass for each area and associated standard errors are given in Table 5.20. The level of movement between northwest and east South-Georgia and the other areas, and the relatively low number of tags recovered in this area, created larger variances around the Petersen estimates for northwest and east South-Georgia than for the other areas.

5.132 The results of Petersen estimates considering South Georgia and Shag Rocks as a whole are also presented in Table 5.21. The variance estimate was derived using Bailey's binomial variance (Seber, 1985, p. 61). Confidence intervals were also independently estimated by bootstrapping daily commercial catch and tag recovery data. The bootstrap Petersen estimates were slightly skewed (Table 5.21).

Table 5.21: (a) Petersen estimates and Bailey's binomial variance estimated upper and lower confidence intervals; and (b) bootstrap Petersen estimates of vulnerable biomass.

Fishing season	(a) Analytical estimate			(b) Bootstrap estimate			
	Estimate	Lower 95%	Upper 95%	Mean	Median	Lower 95%	Upper 95%
2001/02	44 615	29 157	60 073	46 890	45 861	33 331	66 801
2002/03	50 777	39 918	61 635	51 328	50 916	41 896	63 556
2003/04	60 270	43 565	76 975	61 573	60 521	47 228	82 023

5.133 Several of the analyses described above highlight sensitivities of estimates of biomass to the number and distribution of recaptures during the early period of a tagging program. For example, in the case of the 2002 estimate most recaptured fish (97%) had only been at liberty for one year. By contrast, 50% of fish recaptured in both 2003 and 2004 had been at liberty for two or more years. Figure 5.11 shows that recaptures were initially concentrated in the Shag Rocks area and have become progressively more widely distributed over 2003 and 2004.

5.134 The Working Group considered the results of the sensitivity analyses and identified a number of issues that would need to be considered in using the estimates of vulnerable biomass in assessments of long-term yield:

(i) the point estimate of vulnerable biomass and the variance measure to be used in projections;

(ii) the extent to which the closed population and mixing assumptions of the Petersen estimator is violated;

(iii) the differences between the estimates obtained using Petersen and Jolly–Seber estimators, and which may be more robust and precautionary.

5.135 Some of these issues were addressed to a degree in the time available during the meeting. The Working Group agreed that future work should focus on further examination of the Petersen, Jolly–Seber and alternative mark–recapture estimators to better understand the properties of the estimators for estimating vulnerable biomass of *D. eleginoides*. The Working Group suggested that a broader review of alternative estimators in use elsewhere, and evaluation of alternative estimators using simulated data to explore the sensitivity of the methods to known violations of the underlying assumptions would be useful.

5.136 In light of the work completed during the meeting, some members thought it appropriate to use the Petersen mark–recapture estimate of vulnerable biomass to guide the GYM projections. Dr P. Gasyukov (Russia) considered that the Working Group had not had sufficient opportunity to review and validate the methods and that it may be premature to use this method, particularly given the relatively early stage of the tagging program. Drs Kirkwood and Agnew pointed out, however, that an assessment using mark–recapture data had been presented at WG-FSA-SAM-04, that they had subsequently implemented the modifications requested by the subgroup, and that the data and spreadsheet implementing the model had been made available to the Working Group at the meeting.

5.137 The Working Group agreed to use the 2003 and 2004 bootstrap estimates of vulnerable biomass to adjust two GYM runs as part of the sensitivity analysis for this year's assessment of long-term yield. This adjustment was to scale the survey recruitment data in order that the median vulnerable biomass in 2004 from tagging corresponded to the estimated biomass from the GYM projections.

ASPM estimate of biomass

5.138 The ASPM, implemented in AD Model Builder initially by Brandão and Butterworth (WG-FSA-03/97) and modified by Agnew and Kirkwood (WG-FSA-04/82), was reviewed by the Working Group and revised to include the point estimates of exploitable biomass from tagging data as a third data source to be used in the fitting procedure (the other two sources being the annual catch–length frequencies and the standardised CPUEs). Each of these observations is compared with model predictions and a joint likelihood is calculated as the weighted sum of the individual likelihoods. This approach allows different weightings to be given to each of the three sets of observations in the fitting procedure.

5.139 Several different combinations of input data and weightings of data series were investigated. Although in the original formulation by Brandão and Butterworth the model is free to estimate fishing selectivity, selectivity was fixed in these runs to the selectivities estimated by the method of Kirkwood (2002). Following the analysis presented in WG-FSA-04/82, deep selectivity was assigned to years 1989–1997 and 2001–2004, and shallow selectivity to 1985–1988 and 1998–2000. The results are shown in Table 5.22 and examples of fits to the different data input series are given in Figure 5.12.

Table 5.22: Results of sensitivity tests of the current ASPM formulation in AD Model Builder. B_0 is the estimated unexploited vulnerable biomass and B_{exp} is the estimated current (2004) vulnerable biomass in thousands of tonnes.

Run number	Sensitivity test	CPUE	Steepness	Length weighting	Tag weighting	B_0 (1985)	B_{exp} (2004)
1	Different weightings on standardised CPUE	Standard GLM	0.6	1	0	114	79
2			0.6	0.1	0	73	36
3			0.6	1	1	91	56
4	Different weightings on standardised CPUE	Random effects GLMM	0.6	1	0	118	84
5			0.6	0.1	0	65	28
6			0.6	10	0	132	98
7	Steepness	Random effects GLMM	0.8	1	0	120	87
8	Tag weighting	Random effects GLMM	0.6	1	1	92	57
9			0.6	0.1	1	88	53
10			0.6	1	0.1	114	80
11	GLM from 1997only	Standard GLM ≥1997	0.6	10	0	135	101
12			0.6	0.1	0	186	152
13	GLMM from 1997 only	GLMM ≥1997	0.6	10	0	137	103
14			0.6	0.1	0	299	266

Figure 5.12(a)

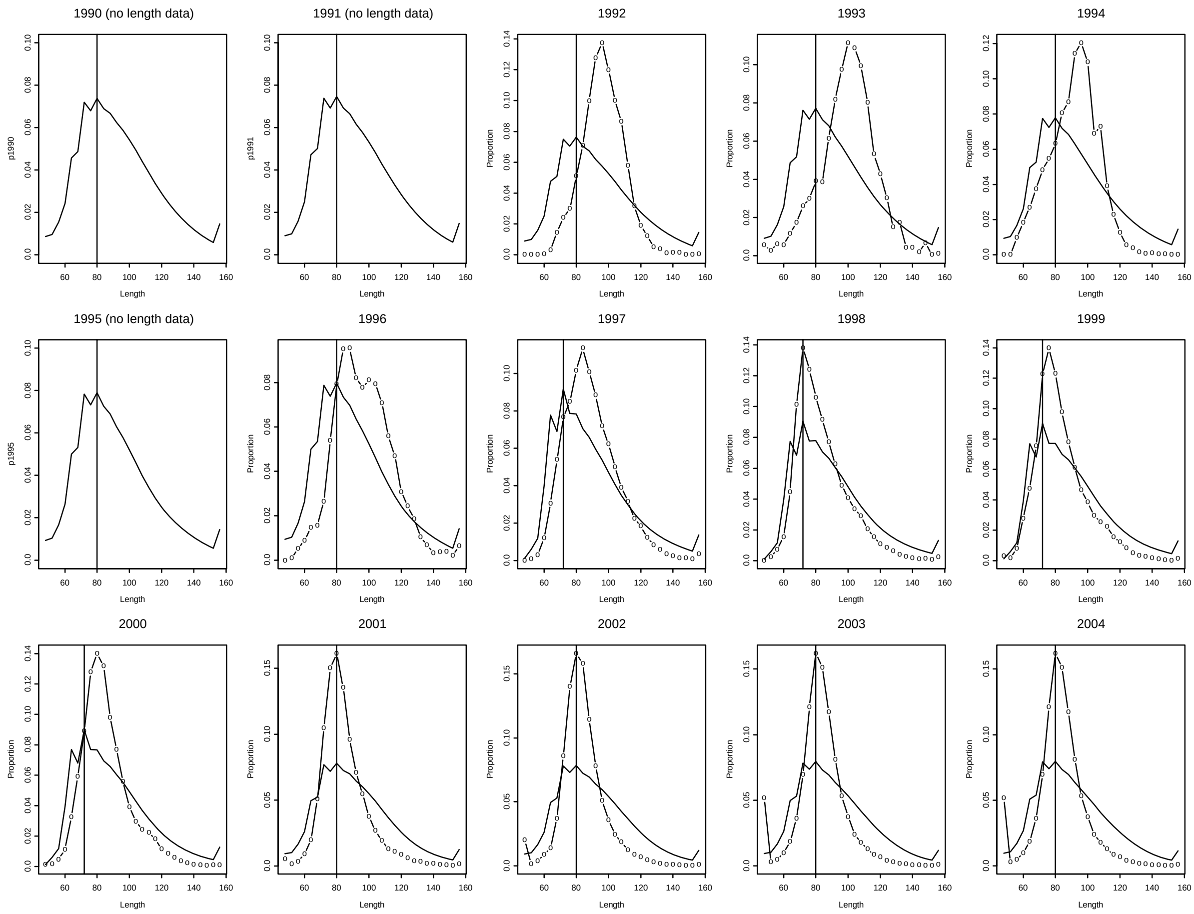


Figure 5.12(b)

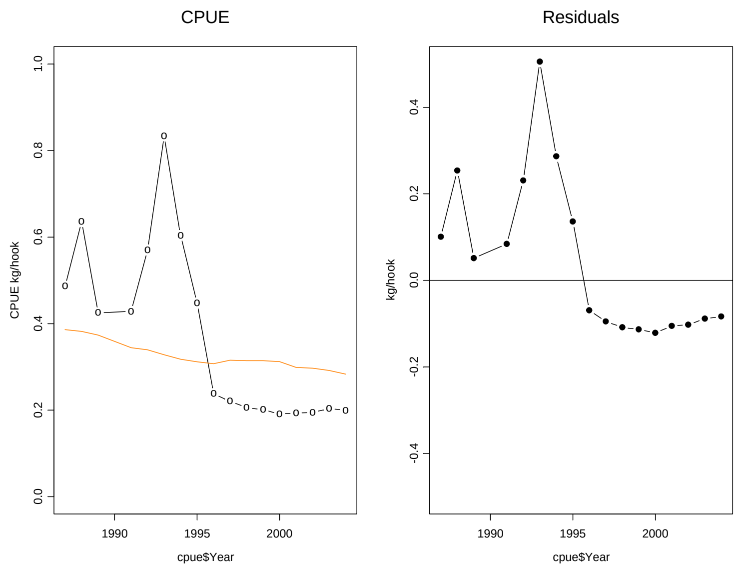


Figure 5.12(c)

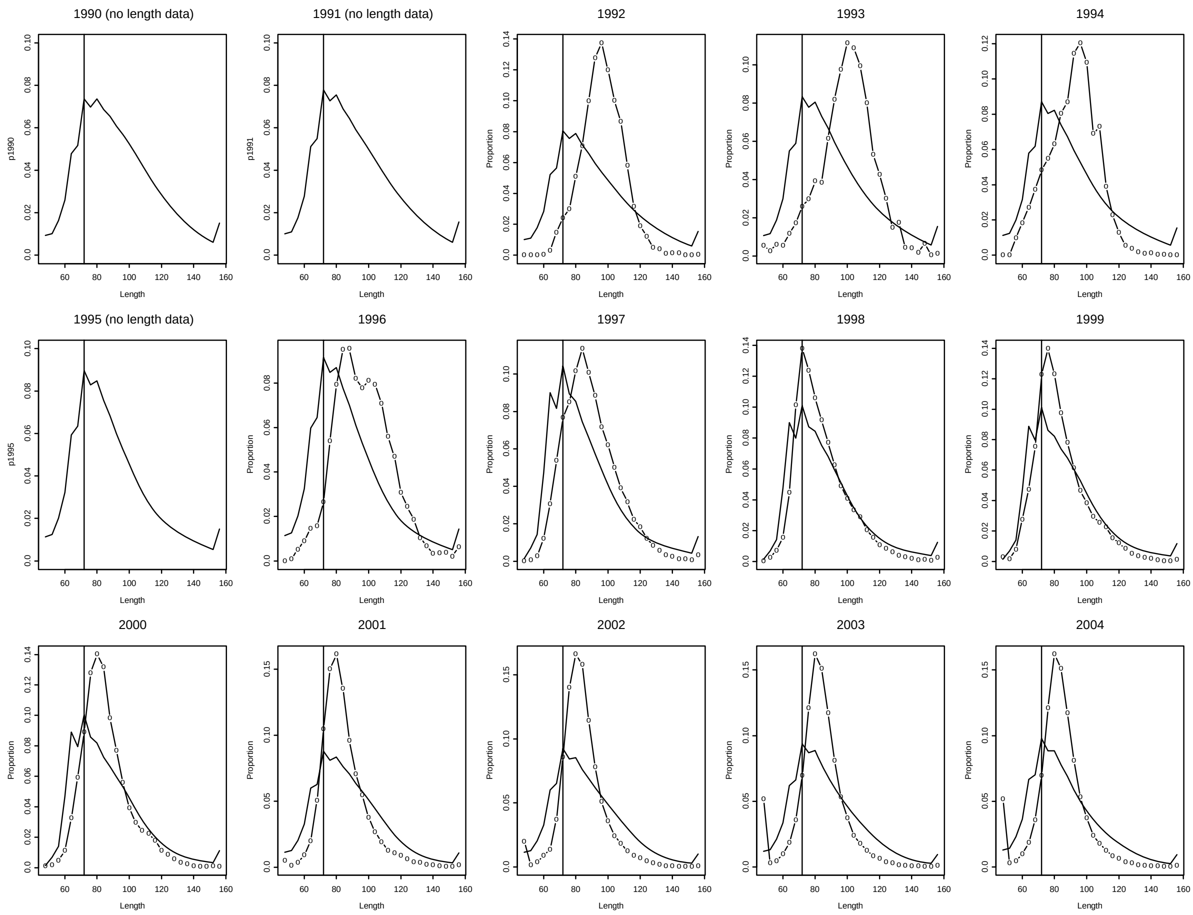


Figure 5.12(d)

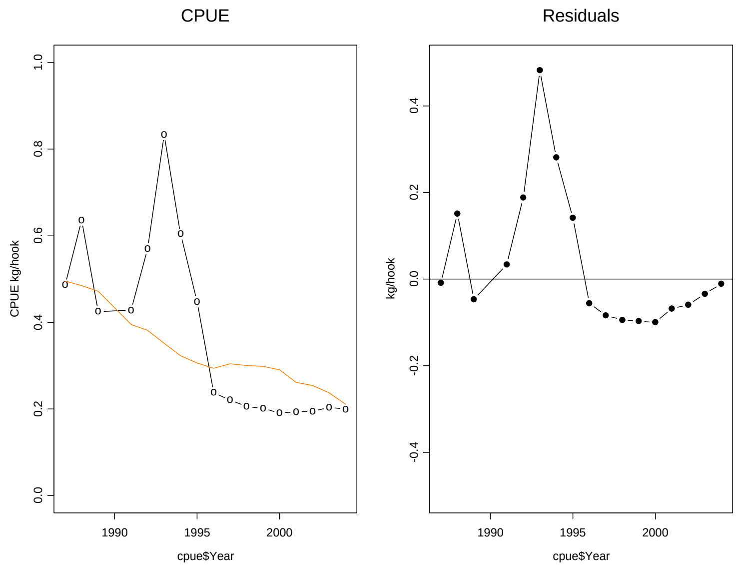


Figure 5.12(e)

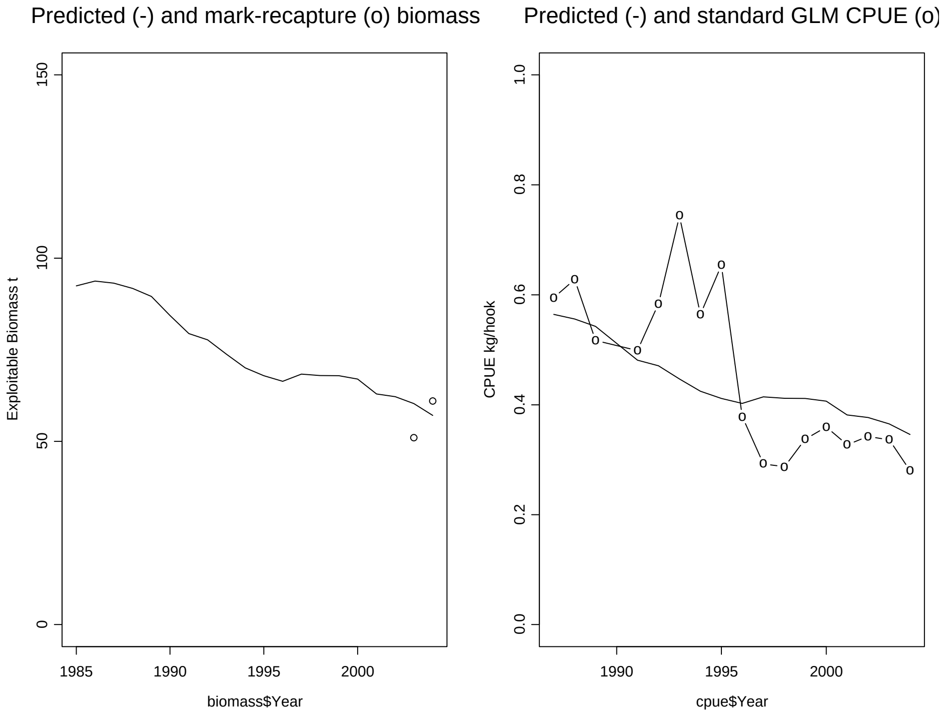


Figure 5.12: Two runs of the AD Model Builder ASPM implementation using the GLMM CPUE series. (a) length composition (-o- = observed, ___ = predicted, with the mode of the predicted identified by a vertical bar) with length composition weighting = 10; (b) CPUE fit (-o- = observed, ___ = predicted) and residuals with length composition weighting = 10; (c) and (d), the same with length composition weighting = 0.1. (run numbers 5 and 6 in Table 5.22), (e) ASPM fit to the standard GLM and tagging data with an equal weighting (1). Exploitable biomass and tag-estimated exploitable biomass (o) is shown (run number 3 in Table 5.22). Note that for the years 1990, 1991 and 1995 there was no observed length-frequency data.

5.140 Reviewing these sensitivity trials, the Working Group noted that the results of the ASPM were highly dependent on the weighting factors used, and the values specified for fixed parameters. None of the fits to the full CPUE series were satisfactory, there being large trends in the residuals. The most significant residual discrepancies are the inability of the model to predict the rapid decline in CPUE over the period from 1995 to 1996, or the relatively constant CPUE since 1997. Although the runs with high weighting on the length composition data were able to predict reasonably accurately the catch composition from about 1997 onwards, the fits to data from the early 1990s were poor. Adjusting the weighting factors to produce a better fit to either the length or CPUE dataset results in a much poorer fit to the other dataset, and no weighting factor produced a satisfactory fit to both length and CPUE data. Inclusion of the tagging estimates of biomass in 2003 and 2004 assisted the model, but did not improve the fit to the CPUE data.

5.141 The Working Group therefore agreed that the ASPM cannot be used at this meeting to provide reliable estimates of stock abundance. However, the revisions to the model and detailed review of the sensitivity trials provided several promising lines of further research, and it is recommended that these be pursued in the intersessional period for review by WG-FSA-SAM.

3.2 Parameter values

Biological parameters

Table 5.23: Parameter values for *Dissostichus eleginoides* in Subarea 48.3.

Component	Parameter	Value	Units
Natural mortality	M	0.132–0.2	y^{-1}
VBGF	K	0.066	y^{-1}
VBGF	t_0	–0.21	y
VBGF	L_∞	1946	mm
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

Time series

Total removals

5.142 Estimated total removals are set out in Table 5.14.

Selectivity-at-age

Table 5.24: Schedule of estimated *Dissostichus eleginoides* relative vulnerabilities-by-age for the seasons 1986–2003 in Subarea 48.3.

Age (years)	Relative vulnerabilities	
	1998–2000, 2003	2001–2002, 2004, future projections
0	0.00	0
4.9	0.00	0
6.17	0.72	0.5
6.67	1.00	0.73
6.91	1.00	0.77
7.17	1.00	0.81
7.42	1.00	0.84
7.68	1.00	0.87
7.95	1.00	0.90
8.21	1.00	0.92
8.49	1.00	0.94
8.77	1.00	0.96
9.05	1.00	0.97
9.34	0.99	0.98
9.64	0.99	0.99
9.94	0.98	1.00
10.25	0.98	1.00
10.56	0.97	1.00

Age (years)	Relative vulnerabilities	
	1998–2000, 2003	2001–2002, 2004, future projections
10.88	0.96	0.99
11.21	0.95	0.99
11.54	0.94	0.97
11.88	0.92	0.96
12.23	0.91	0.94
12.59	0.89	0.92
12.96	0.87	0.90
13.33	0.84	0.87
13.72	0.82	0.84
14.12	0.79	0.81
14.52	0.76	0.77
14.94	0.72	0.73
15.37	0.68	0.69
15.81	0.64	0.64
16.27	0.60	0.59
20.00	0.60	0.59
55.00	0.60	0.59

Standardised CPUE

5.143 The standardised CPUE series for the 2004 season was estimated using the GLMM method proposed by Candy (2004). The revised CPUE series is presented in Table 5.25. This revised series was used as the base-case series for the GYM assessment.

Table 5.25: Standardised series of CPUEs in kg/hook for *Dissostichus eleginoides* in Subarea 48.3, from the random effects GLMM standardised for Chilean vessels fishing between depths of 1 000 and 1 500 m in the southern sector of South Georgia used in the GYM assessments for 2004. The years prior to 1989 were not used in the GYM assessments.

Fishing season	CPUE estimate	Upper 95% CI	Lower 95% CI
1984/85	0.2106	0.5576	0.0795
1985/86	0.2564	0.6393	0.1028
1986/87	0.4866	1.2494	0.1895
1987/88	0.6358	1.4297	0.2827
1988/89	0.4249	0.9748	0.1852
1989/90	-	-	-
1990/91	0.4284	0.9035	0.2032
1991/92	0.5701	0.8509	0.3820
1992/93	0.8338	1.2807	0.5428
1993/94	0.6042	0.9002	0.4055
1994/95	0.4478	0.6504	0.3083
1995/96	0.2381	0.3462	0.1637
1996/97	0.2205	0.3229	0.1506
1997/98	0.2059	0.3028	0.1400
1998/99	0.2014	0.2935	0.1381
1999/00	0.1909	0.2782	0.1310
2000/01	0.1934	0.2815	0.1328
2001/02	0.1947	0.2832	0.1338
2002/03	0.2035	0.2981	0.1390
2003/04	0.1997	0.2905	0.1373

Recruitment

5.144 The recruitment series for Subarea 48.3 was revised based on the results of the CMIX analyses completed using the Subarea 48.3 growth parameters (WG-FSA-04/92). The series was also estimated using the growth parameters provided by Belchier et al. (2004) (WG-FSA-04/92).

5.145 Both of the revised series result in substantially lower estimates of mean recruitment and, in the case of the Belchier et al. (2004) series, a higher CV than those used in the 2002 assessment or the revised estimate used in the 2003 assessment (Table 5.26). The Working Group noted that this reduction in mean recruitment was largely due to the identification of the errors in previous analyses (SC-CAMLR-XXII, Annex 5, paragraphs 5.104 to 5.115), the sources of which had subsequently been rectified (WG-FSA-SAM-04/16).

Table 5.26: Revised recruitment series for Subarea 48.3 based on review of data extractions and CMIX analysis presented in WG-FSA-SAM-04/16 and WG-FSA-04/92, and revisions to CMIX analysis for the 1998 UK survey completed during the meeting. Both series exclude the Russian 2000 survey. The FSA-04 48.3 vB series was used as the base-case for the 2004 long-term yield assessment. The FSA-04 48.3 Belchier et al. (2004) vB series was used in sensitivity analyses. See paragraphs 5.144 and 5.145 for details of revised series.

Split-year	FSA-02	FSA-03 new 02	FSA-04 48.3 vB	FSA-04 Belchier et al. (2004) vB
1986				0.120
1987	1.349	1.349	0.846	0.834
1988	0.845	0.845	0.568	0.558
1989	4.214	4.244	0.017	0.195
1990	9.374	9.374	1.954	1.096
1991	6.7	6.700	1.227	0.005
1992			0.260	2.018
1993	11.799	11.799	5.312	4.633
1994	2.13	2.225	1.259	0.561
1995	1.003	0.984	1.252	0.004
1996	0.691	0.690	1.118	0.258
1997	2.947	2.947	1.794	1.549
1998	1.14	1.140	0.659	0.659
1999			0.124	0.038
2000			0.139	0.148
2001	2.504	1.067	0.664	0.155
2002	4.207	1.066	0.992	0.677
2003	10.694	2.015	1.814	0.074
2004			-	0.840
2005			1.379	0.756
2006			2.47	0.649
Mean	4.257	3.318	1.255	0.754
CV	0.90	1.06	0.949	1.369

4. Stock assessment

4.1 Model structure and assumptions

5.146 The GYM, using input data from Section 3 of this Fishery Report, was used to estimate the constant catch that would satisfy the CCAMLR decision rules. These are:

1. Depletion rule: Determine the catch that results in a probability of the spawning stock biomass falling below 20% of its estimated pre-exploitation level of not more than 10% over the 35-year projection period.

2. Escapement rule: Calculate the catch that results in a median escapement of 50% of the spawning stock biomass in the final year of the 35-year projection;

3. Choose the lower of the two estimates of long-term yield.

Model configuration

5.147 The GYM was run (Table 5.27) according to the configuration detailed in Table 5.42.

Table 5.27: GYM configuration for the assessment of *Dissostichus eleginoides* in Subarea 48.3.

Age structure	Recruitment age	4 years
	Plus class accumulation	35 years
	Oldest age in initial structure	55 years
Simulation specification	Number of runs	10 001
	Depletion level	0.2
	Seed for random number generator	–24 189
Individual trial specifications	Years to remove initial age structure	1
	Observations to use in median SB_0	1001
	Year prior to projection	1983
	Reference start date	01/12
	Increments in year	24
	Years to project stock in simulation	35
	Reasonable upper bound for annual *F*	5.0
	Tolerance for finding *F* in each year	0.000001

5.148 In the Subarea 48.3 recruitment series (Table 5.26) the likelihood method was used to weight each trial projection based using the standardised CPUE series in Table 5.25.

4.2 Model estimates

5.149 In preparation for the assessment, the Working Group considered the preliminary assessment using the GYM provided in WG-FSA-04/82. In particular, it noted that in the initial assessment presented, a large proportion (~40%) of trials did not realise the known catches in the latter part of the known series (WG-FSA-04/82, Figure 6).

5.150 The Working Group considered a range of factors that may contribute to the known catch series not being realised, these included:

(i) the revised estimates of absolute recruitment being biased;

(ii) the nature of the real time series of recruitments immediately prior to the known series;

(iii) the upper end of the range of natural mortality (M) currently used in the assessment being too high; and/or

(iv) the current growth parameters being biased.

5.151 The Working Group noted that the unrealised catches could result from any one or a combination of the above.

4.3 Sensitivity analyses

5.152 The Working Group conducted an initial series of sensitivity analyses using the GYM to explore the potential source of the unresolved catches in the current assessment. The analyses included examining the effect of :

(i) a the range of M used (0.13–0.2 and 0.13–0.165)
(ii) the uses of point estimates of M (0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19, 0.20)
(iii) assuming different values to scale the estimates of recruitment over the known period (1987–2004) of the fishery (1, 2 and 3).

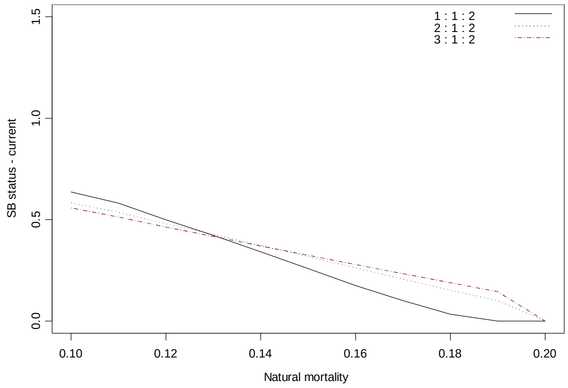
5.153 The base-case for these analyses was: M = 0.13–0.20, and recruitment scaler = 1. The revised Subarea 48.3 recruitment series (Table 5.26), GLMM CPUE series (Table 5.25) and likelihood weighting of trials (Kirkwood and Constable, 2001) were consistently used for all diagnostic analyses.

5.154 The results of the diagnostic analyses are presented in Figure 5.13. The Working Group noted that the estimate of M had a significant effect on the proportion of trials with unresolved catches, and in particular that for values of M less than 0.15 the known catch history was resolved in all trials, whereas the proportion of trials for which the catches were not resolved increased rapidly for values of M greater than 0.16. The Working Group also noted that scaling the estimated recruitment series resulted in 100% of trials resolving the catch series, up to values of M of approximately 0.18 or higher. Above values of 0.18 for M, the proportion of trials with unresolved catches increased markedly and the results for other variables examined were also unrealistic.

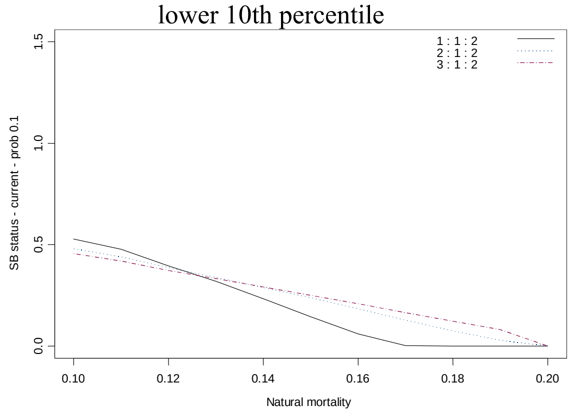
Figure 5.13(a)

Current spawning stock status

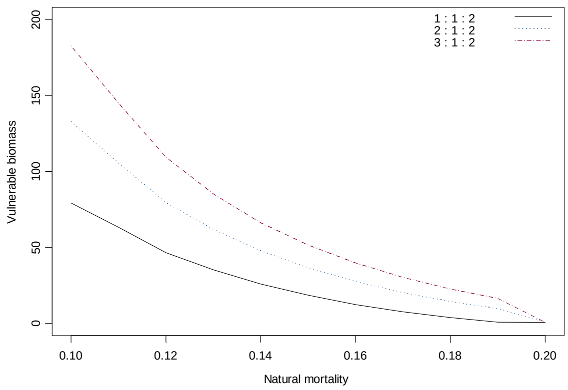
median



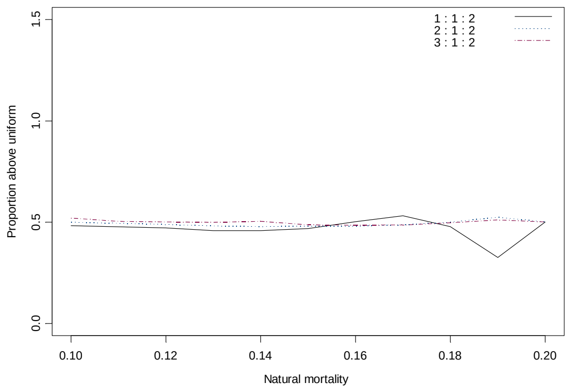
lower 10th percentile



Vulnerable biomass (thousand tonnes)



Proportion of trials
with statistical weight above uniform weight



not resolving known catch series

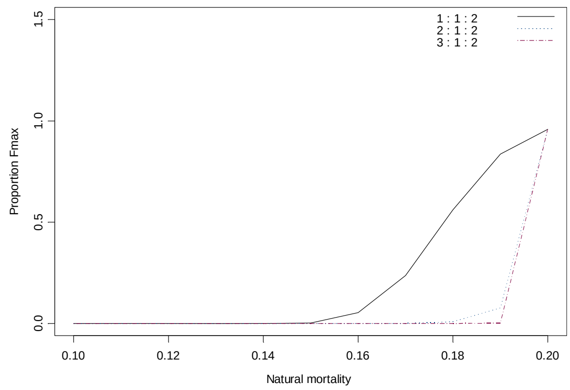
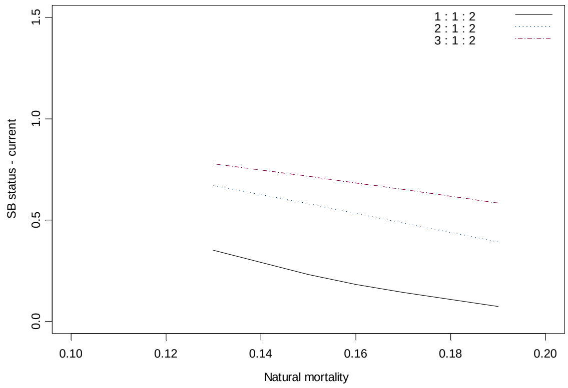


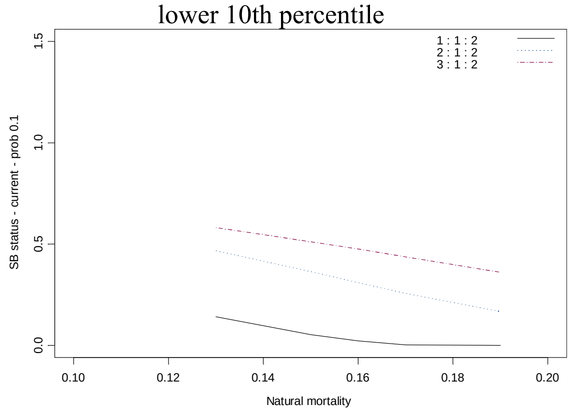
Figure 5.13(b)

Current spawning stock status

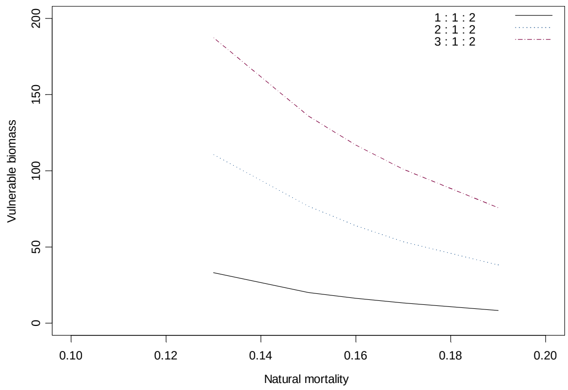
median



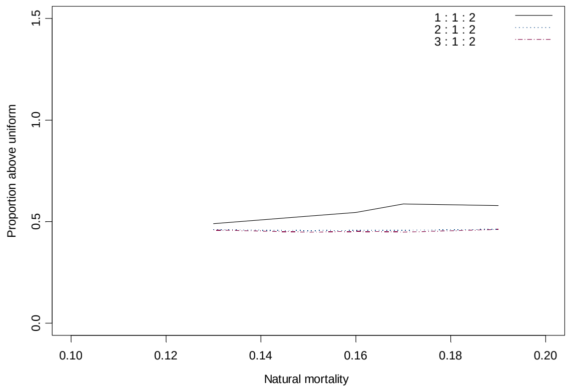
lower 10th percentile



Vulnerable biomass (thousand tonnes)



Proportion of trials
with statistical weight above uniform weight



not resolving known catch series

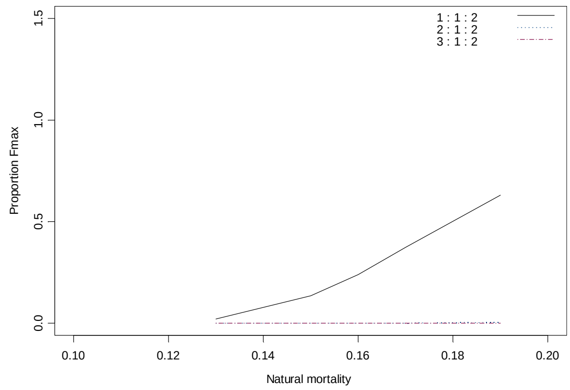


Figure 5.13: Results of initial sensitivity trials using the GYM examining the possible attributes of the stock of *Dissostichus eleginoides* in Subarea 48.3 with different scenarios for recruitment and natural mortality. Values of spawning stock status and vulnerable biomass shown here are the median values for each year. Trials were weighted by the goodness of fit to the standardised CPUE series before the medians were determined.

(a) Recruitment is modelled as a lognormal function with recruitments in 1984–2005 estimated from the surveys. Mean recruitment in years for which no observations were made is modelled as the estimate from the surveys (solid line), 2x the estimate (dotted line) and 3x the estimate (dashed line).

(b) Recruitment is modelled as a lognormal function in all years of the trials. Mean recruitment is modelled as the estimate from the surveys (solid line), 2x the estimate (dotted line) and 3x the estimate (dashed line).

4.4 Discussion of model results

Alternative scenarios for the 2004 assessment

5.155 On the basis of the results of the sensitivity analyses and the considerable uncertainty in the current status of the stock in Subarea 48.3, the Working Group agreed that a range of scenarios should be run for the 2004 assessment for consideration in providing advice for 2004. The factors to be included in the scenarios are given in Table 5.28. The results are presented in Tables 5.29 and 5.30 and Figure 5.14.

Table 5.28: Summary of alternative scenarios examined for *Dissostichus eleginoides* in Subarea 48.3 for the 2004 assessment. The base-case assessment was: M = 0.13–0.20, recruitment scaler = 1 and test values of 500 and 1 500 tonnes.

Factor	Levels	Values
Range of natural mortality	2	(0.13–0.20); (0.155–0.175)
Scaling of recruitment series	4–5	0.5, 1, 1.5, 1.78, 2
Constant catch level*	3–4	500–4 780 tonnes

* The test values for catch level varied among scenarios, including a catch value that resulted in an estimate of vulnerable biomass that approximated the estimate of vulnerable biomass from the Petersen mark–recapture estimate (Table 5.21).

Table 5.29: Results of the alternative scenarios examined for the 2004 assessment of *Dissostichus eleginoides* in Subarea 48.3. M range = range of natural mortality; Rec. = scaler used to multiply estimated densities of recruits (ages 2–4); Year: 1984 = year prior to known series; 2004 = end of 2004/05 season; SB.stat50 = median spawning biomass over the projection period; SB.stat10 = lower 10th percentile of spawning biomass; TB.50 = median total biomass prior to known catch series; VB50 = medium vulnerable biomass at start of know catch series; P.depl. = probability of the spawning stock biomass being below 0.2 of unfished biomass over the projection period; P.Fmax = proportion of trials for which the known catch series was not resolved; P. > wt = proportion of trials with a greater than uniform weight (for CPUE adjustment). All scenarios were run using the revised Subarea 48.3 recruitment series given in Table 5.26 with 2 001 trials per scenario. The base-case (see paragraph 5.153) is shown in bold.

M range	Rec.	Test catch (tonnes)	Year	SB.stat50	SB.stat10	TB.50	VB50	P.depl.	P.Fmax	P. > wt
0.13–	0.5R								0.991	0.395
0.20			1984	1.000	0.791	36.657	0.000			
			2004	0.000	0.000	2.344	0.423			
		1000	2005	0.000	0.000	2.233	0.511			
		1000	2039	0.520	0.211	22.827	16.566	0.991		
		3000	2005	0.000	0.000	2.233	0.480			
		3000	2039	0.000	0.000	2.118	0.413	1.000		
0.13–	**1R**								**0.311**	**0.586**
0.20			**1984**	**1.023**	**0.810**	**87.155**	**0.000**			
			2004	**0.217**	**0.001**	**25.116**	**15.231**			
		500	**2005**	**0.186**	**0.000**	**23.517**	**14.289**			
		500	**2039**	**0.895**	**0.685**	**77.265**	**53.904**	**0.526**		
		1500	**2005**	**0.182**	**0.000**	**23.517**	**14.247**			
		1500	**2039**	**0.697**	**0.466**	**63.827**	**45.408**	**0.548**		
0.13–	1.5R								0.000	0.463
0.20			1984	1.017	0.806	119.595	0.000			
			2004	0.454	0.260	57.019	36.755			
		500	2005	0.418	0.226	55.457	35.096			
		500	2039	0.931	0.719	109.187	76.459	0.057		
		1500	2005	0.414	0.222	55.457	35.050			
		1500	2039	0.793	0.572	96.849	68.561	0.079		
0.13–	1.78R								0.000	0.459
0.20			1984	1.017	0.806	141.960	0.000			
			2004	0.552	0.385	78.050	50.994			
		3000	2005	0.506	0.338	76.157	48.763	0.020		
		3000	2039	0.655	0.413	99.194	71.261			
		3500	2005	0.504	0.336	76.157	48.740	0.053		
		3500	2039	0.598	0.339	92.895	66.710			
0.13–	2R								0.000	0.456
0.20			1984	1.017	0.806	159.543	0.000			
			2004	0.611	0.457	94.376	61.993			
		1000	2005	0.568	0.416	92.401	59.436	0.000		
		1000	2039	0.901	0.685	141.987	99.583			
		3000	2005	0.562	0.409	92.401	59.345	0.005		
		3000	2039	0.694	0.460	116.580	83.369			
		3500	2005	0.560	0.407	92.401	59.320	0.020		
		3500	2039	0.644	0.400	110.009	79.082			

Table 5.29 (continued)

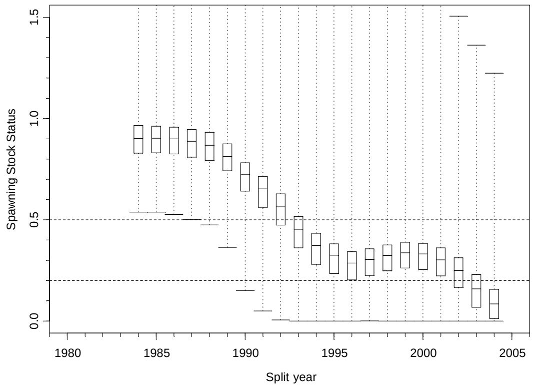
M range	Rec.	Test catch (tonnes)	Year	SB.stat50	SB.stat10	TB.50	VB50	P.depl.	P.Fmax	P. > wt
0.155–0.175	0.5R								1.000	0.542
			1984	0.985	0.773	34.843	0.000			
			2004	0.000	0.000	2.246	0.422			
		1000	2005	0.000	0.000	2.116	0.479	1.000		
		1000	2039	0.495	0.220	21.619	15.732			
		3000	2005	0.000	0.000	2.116	0.454	1.000		
		3000	2039	0.000	0.000	1.978	0.386			
0.155–0.175	1R								0.139	0.544
			1984	1.026	0.813	79.414	0.000			
			2004	0.149	0.027	18.701	10.635			
		500	2005	0.121	0.013	17.069	9.982	0.785		
		500	2039	0.893	0.677	70.402	49.318			
		1500	2005	0.117	0.012	17.069	9.936	0.814		
		1500	2039	0.683	0.449	57.236	40.910			
0.155–0.175	1.5R								0.000	0.458
			1984	1.018	0.805	115.949	0.000			
			2004	0.454	0.352	55.676	36.072			
		500	2005	0.419	0.323	54.026	34.712	0.001		
		500	2039	0.931	0.715	107.001	74.957			
		1500	2005	0.415	0.319	54.026	34.666	0.001		
		1500	2039	0.797	0.575	94.696	67.024			
		3590	2005	0.406	0.311	54.026	34.567	0.134		
		3590	2039	0.487	0.233	66.434	47.725			
0.155–0.175	2R								0.000	0.452
			1984	1.019	0.805	154.879	0.000			
			2004	0.613	0.505	92.762	61.171			
		500	2005	0.573	0.473	90.955	58.835	0.000		
		500	2039	0.950	0.734	145.004	101.459			
		1500	2005	0.570	0.470	90.955	58.790	0.000		
		1500	2039	0.851	0.633	133.134	93.801			
		4780	2005	0.560	0.461	90.955	58.638	0.109		
		4780	2039	0.496	0.248	89.925	64.338			

Table 5.30: Estimates of constant catch that will satisfy the decision rules for each alternative scenario for the 2004 assessment of *Dissostichus eleginoides* in Subarea 48.3. The third part of the decision rule states that the lower of the two catch levels is selected as the estimate of long-term yield. All scenarios were run using the revised Subarea 48.3 recruitment series given in Table 5.26 with 2 001 trials per scenario. See Table 5.29 for description of column heading. The base-case (see paragraph 5.153) is shown in bold.

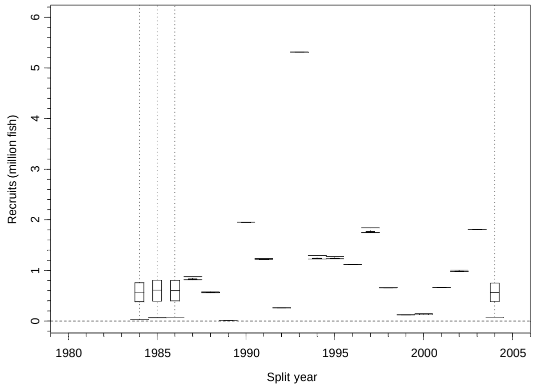
M range	Rec.	SB.stat50	P.depl.	P.Fmax	P. > wt	Escapement rule catch	Depletion rule catch
0.13–0.20	0.5R	0.000	1.000	0.991	0.395	1075.6	0
0.13–0.20	**1R**	**0.697**	**0.548**	**0.311**	**0.586**	**2499**	**0**
0.13–0.20	1.5R	0.793	0.079	0.000	0.463	3626.4	2454.55
0.13–0.20	1.78R	0.598	0.053	0.000	0.459	4347.1	4216
0.13–0.20	2R	0.644	0.020	0.000	0.456	4918.4	6166.67
0.155–0.175	0.5R	0.000	1.000	1.000	0.542	977.79	0
0.155–0.175	1R	0.683	0.814	0.139	0.544	2373	0
0.155–0.175	1.5R	0.487	0.134	0.000	0.458	3503.7	3055.71
0.155–0.175	2R	0.496	0.109	0.000	0.452	4739.1	4509.17

Figure 5.14(a)

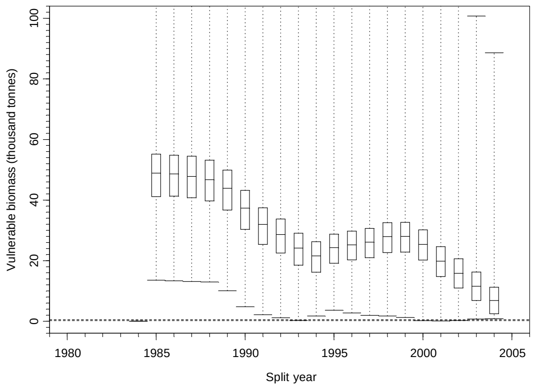
Spawning stock status



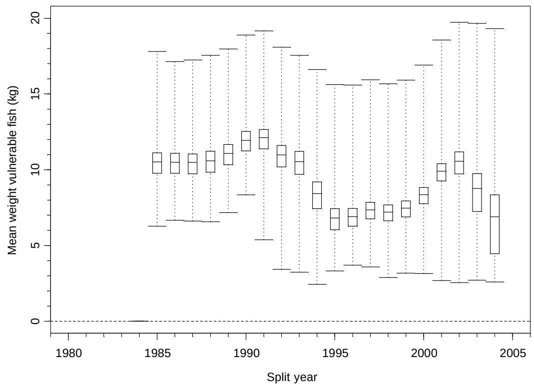
Recruitment



Vulnerable biomass



Mean weight of vulnerable fish



Fishing mortality

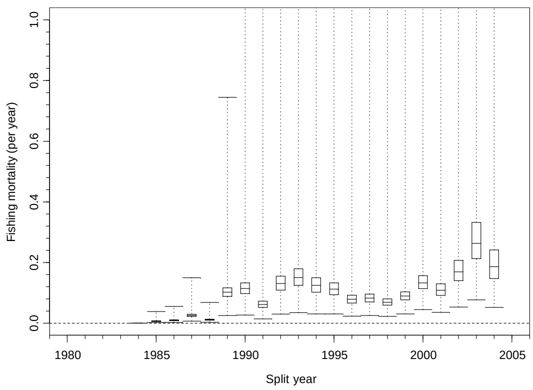
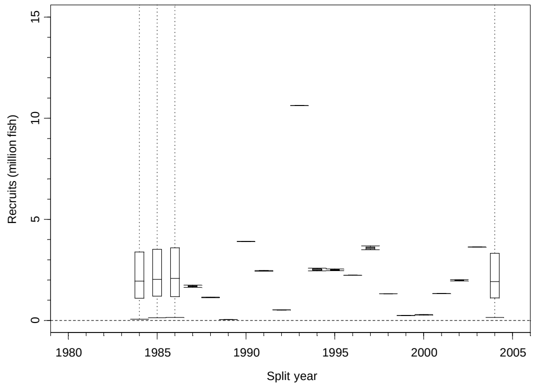


Figure 5.14(b)

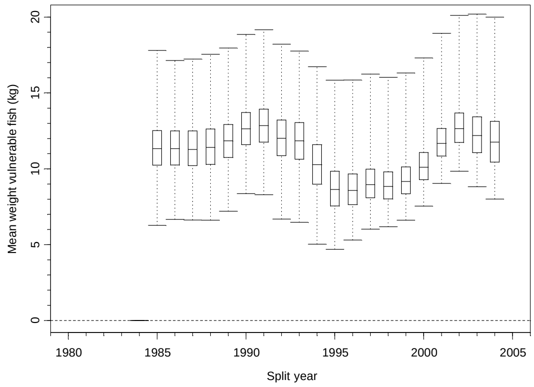
Spawning Stock Status

Recruitment



Vulnerable biomass

Mean weight of vulnerable fish



Fishing mortality

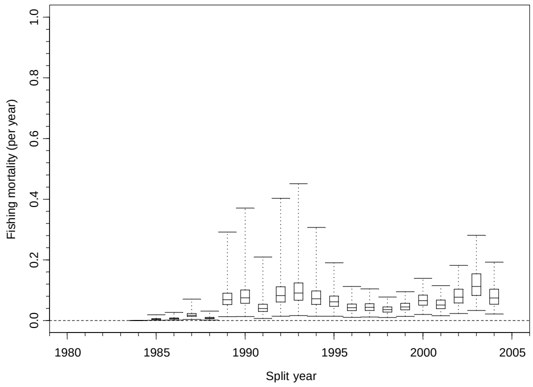


Figure 5.14: Box plots showing the results of trials using the GYM examining the possible attributes of the stock of *Dissostichus eleginoides* in Subarea 48.3 with different scenarios for recruitment for the range of natural mortality between 0.13 and 0.2. The known catch series is taken between 1984 and 2004. Trials were weighted by the goodness of fit to the standardised CPUE series before estimating the values of the box plots. The mid-line in each box is the median. The upper and lower limits to the box are the lower (0.25) and upper (0.75) quartiles. The ends of the whiskers show the minimum and maximum values observed in the trials.

(a) Base case: recruitment is modelled as a lognormal function with recruitments in 1984–2005 estimated from the surveys. Mean recruitment in years for which no observations were made is modelled as the estimate from the surveys.

(b) Recruitment is modelled as a lognormal function with recruitments in 1984–2005 estimated from the surveys. Survey data were scaled by 2x in these projections. Mean recruitment in years for which no observations were made is modelled as the estimate from the surveys.

5. By-catch of fish and invertebrates

5.1 Estimation of by-catch removals

5.156 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 5.31: 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	

* None specified

Estimated cut-off catch

5.157 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 2004 WG-FSA meeting.

5.2 Assessments of impact on affected populations

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

5.3 Mitigation measures

5.159 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

5.160 Details of seabird by-catch (taken from Table 7.3) are summarised in Table 5.32. Estimated potential seabird removals in the IUU fishery are summarised in SC-CAMLR-XXIII/BG/23 and Table 7.15.

Table 5.32: 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	0.001	18

* Excluding *Argos Helena* line-weighting experiment cruise

5.161 Ad hoc WG-IMAF has assessed the level of risk of incidental mortality of seabirds in Subarea 48.3 as category 5 (SC-CAMLR-XXIII/BG/21).

6.1 Mitigation measures

5.162 Conservation Measure 25-02 applies to this subarea.

6.2 Interactions involving marine mammals with longline fishing operations

5.163 No interactions were reported in the 2004 fishing season.

7. Ecosystem effects

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

8. Harvest controls for the 2003/04 season and advice for 2004/05

8.1 Conservation measures

Table 5.33: Summary of provisions of Conservation Measure 41-02 for *Dissostichus eleginoides* in Subarea 48.3 and advice to the Scientific Committee for the 2004/05 season.

Paragraph and topic	Summary of CM 41-02	Advice for 2004/05	Paragraph reference
1. Access (gear)	Longlines and pots only		
2. Catch limit	4 420 tonnes	Review	
3. Season: longline	1 May to 31 August 2004 Extension possible to 14 September 2004 for vessel complying fully with CM 25-02 in 2002/03.		
3. Season: pots	1 December 2003 to 30 November 2004		
3. By-catch: seabirds	During extension period (1–14 September 2004) any vessel catching three (3) seabirds to cease fishing.		
4. By-catch: crabs	By-catch of crabs to be counted against crab catch limit.		
5. By-catch: finfish	Total combined catch of skates and rays ≤221 tonnes Total catch of *Macrourus* spp. ≤221 tonnes		
6. By-catch: any species	Move-on rule		
7. Mitigation	In accordance with CM 25-02.		
8. Observers	Each vessel to carry at least one CCAMLR scientific observer and may include one additional scientific observer.		
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.		
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.*		
11. Jellymeat	Number and weight of fish discarded, including those with jellymeat condition, to be reported. These catches count towards the catch limit.		
12. Data: biological	Monthly fine-scale reporting system as in CM 23-05. Reported in accordance with the Scheme of International Scientific Observation.		

8.2 Management advice

5.165 In summary the Working Group noted the following points arising from the various analyses undertaken during the meeting:

(i) Size distribution of the catch: in the early 1990s the catch was characterised by a range of fish sizes (approximately 60–145 cm) with a mode just greater than 100 cm. In the late 1990s, the size of fish ranged from 60 to 120 cm with a mode between 70 and 80 cm. In recent years, the mode has increased slightly.

(ii) Distribution of fishing effort: the fishery and assessment relate to the fishing areas around South Georgia/Shag Rocks, not to Maurice Ewing Bank or North Scotia Ridge (Figure 5.5). Fishing has occurred throughout the area, although the pattern has changed over the development of the fishery. During the early period (1989–1996), the fishery expanded across the area from an initial concentration of effort around Shag Rocks. Since 1996 the fishery has extended over the entire area (Figure 5.3).

(iii) Trends in standardised CPUE by area: the main fishing areas have different trends in CPUE. The main trends evident in the data are for Shag Rocks and the southern South Georgia area. At Shag Rocks, the CPUE has been variable over the early period (up to 1995) and then increased through to 1999, after which time it has declined. In the southern South Georgia area, the CPUE declined between 1994 and 1996 and has been increasing more recently.

(iv) Trends in standardised CPUE overall: the CPUE time series is characterised by an early period (1987–1994), a period of rapid decline (1995–1996) and a later period of relatively constant CPUE since 1996. The later period in the GLMM is approximately 35% of the level in the early period. The later period in the GLM is approximately 50% of the level in the early period.

(v) Trends in standardised mean weight of fish in the commercial catch: this time series is similar to the expectation derived from the size distribution of the catch with the mean weight declining from approximately 12 kg in the early period to 6–7 kg in the later period.

(vi) Recruitment: the time series of recruitments estimated from surveys shows the trends in recruitment in the region. The number of survey hauls and their distribution could be improved to increase precision of the estimates for each year. Interannual variation in the performance of the surveys is likely to be a random factor. Such variation will influence the magnitude of the coefficient of variation of the estimated mean recruitment. Improvements in survey design will most likely reduce the CV but may not alter the mean. The estimate of mean recruitment may be influenced (biased) by other factors but there is no direct information at present to estimate bias, if it exists.

(vii) Biomass estimates from mark–recapture data: these estimates are based on 160 recaptures, with variable representation between areas. The most coverage was for Shag Rocks. The tagging program at South Georgia has been expanded in 2004 but the releases are much less than for other areas in the Convention Area. The Working Group explored some of the underlying assumptions of the Petersen method, such as that the tagged population is well mixed with the untagged population and there is a constant recapture rate (tags recaptured / tags in the population) over time, although there may not be a sufficiently long time series to determine if the assumptions are met at this stage. With respect to mixing, a large proportion of the tagged fish have been recaptured less than 20 km from their location of release. The annual recapture rate has been 12% in 2002, 12% in 2003 and 7% in 2004. If the fish are not well mixed and the distribution of release and recapture effort were to vary among years, then estimates of abundance from the tagging experiment could be biased.

(viii) Results of the ASPM: the ability for the ASPM to fit to the data is dependent on a number of assumptions and parameter inputs, including recruitment, growth and mortality rates. It could also be influenced by the selectivity/vulnerability function and the accuracy of the estimates of vulnerability at age/length.

(ix) Sensitivity tests on estimates of current status of the population using the GYM: the problem of realising the known catch series in the GYM projections using the parameters applied in the assessment by WG-FSA last year could be resolved by lowering the range of natural mortality, increasing the starting biomass while retaining the estimated recruitment series, or by increasing the magnitude of recruitment during the known catch series. These trials showed that estimates of vulnerable biomass, along with the known catch series, could be realised by different combinations of these parameters. The respective combinations will influence the status of the stock when the trajectory is passed through a specific vulnerable biomass.

(x) Estimated catch from a recruitment-based long-term annual yield assessment: following the revision of the recruitment series and the application of this in the usual assessment of the past, the resulting long-term annual yield would be zero. If the assessment is undertaken using the lognormal parameters derived from the time series of recruitments but without applying the known catch and recruitment series, then the long-term annual yield would be estimated to be approximately 1 900 tonnes.

5.166 Dr Constable noted that there were a number of issues that remain to be resolved in the assessment for *D. eleginoides* in Subarea 48.3 and that it would be useful to undertake an evaluation of the robustness of the different approaches considered at this meeting to achieving the objectives of the Commission. Dr Constable summarised a number of points for the Working Group to consider in reconciling some of the different outcomes from the work at this meeting. On the basis of those points, Dr Constable also suggested advice on the status of the stock and potential yield in the coming season. The points included:

(i) The early and later periods of the standardised CPUE series provide a strong signal of the abundance of the vulnerable biomass. The standardisation process has aimed to remove variation in CPUE that might arise from different vessels (nationality), depths and seasons. Consequently, the series provides an estimation of the relative trends in abundance of the vulnerable biomass. The series is then used to weight the outcomes of the GYM projections so that those consistent with the CPUE series are given greater weight. The series can be divided into two main periods – an early, high period and a later, lower period. These two periods involve different fishing fleets operating in the area.

(a) If the early phase of each period was the time when the respective fleets were learning about the area, then the values of CPUE from these parts would be expected to represent the general catch density of the area. The ratio of the standardised CPUE at these times would therefore reflect the relative change in abundance of the vulnerable biomass.

(b) After the learning period, the fleets would be expected to focus on areas of greatest catch density. There is potential for the CPUE to become stable if the areas being fished are areas of aggregations of toothfish, even though the overall biomass might be declining. It is not known if this is or is not the case in Subarea 48.3.

(ii) In view of the results of the GYM projections from 1984 to 2004 based on the survey estimates of recruitment (unscaled recruitment series) and those projection results based on a scaling of the recruitment series by a factor of 2:

(a) the relative differences in the standardised CPUE and in the standardised mean weight of fish between the period of the late 1980s compared to the period in the late 1990s are most closely reflected in the relative differences in the respective median values of vulnerable biomass and mean weight of fish in the GYM projections using the unscaled recruitment series;

(b) if the median vulnerable biomass from these GYM projections are examined in the early 1990s and the early 2000s, the GYM projections decline compared to the CPUE series remaining constant in those periods. In this respect, the Working Group would need to undertake a finer-resolution analysis of the fishing effort to determine if hyper-stability in the CPUE series could have arisen;

(c) an alternative interpretation is that the relative difference between the median vulnerable biomass in 1989 compared to 2004 in the 2x scaled recruitment projections is in agreement with the relative differences between those years in the CPUE series. In this case, the decline in mean weight of vulnerable fish in the projections is not matched by the standardised series.

(iii) With respect to the tagging experiment, there has been insufficient time to explore fully whether the assumptions of mixing, and the degree to which the recapture rate is relatively constant, are met. Biases in the estimation of biomass may arise due to the high rate of recaptures less than 20 km from release, the low number of tags in the water and the potential for relative concentrations of fishing effort to have shifted from one year to another during the tagging experiment. A longer time series and a greater number of tags will help identify whether the mixing assumptions and, consequently, constant recapture rates can be satisfied.

(iv) The sensitivity trials of the GYM projections indicate that a combination of parameters other than mean recruitment could improve the fits of the model to the known catch series as well as estimates of the vulnerable biomass, such as those arising from the tagging experiment.

(v) The manner in which advice can be given needs to be based on the precautionary approach and the potential consequences of being incorrect in the interpretation of the data.

(vi) If the unscaled recruitment series is correct, then the sustainable long-term annual yield of a pristine stock might be around 1 900 tonnes. The results of the projections in this case imply that the spawning stock is likely to be nearing depletion. It is not known at what level a reduction in recruitment might arise but the critical level has widely been regarded as 20% of the pre-exploitation median spawning biomass, as reflected in the CCAMLR decision rules.

(vii) If the scaled recruitment series to give the estimate of vulnerable biomass estimated from the tagging experiment is correct, then the fishery might be able to be maintained at the current level.

(viii) The consequences of applying the CCAMLR decision rules and accepting one case when the other is correct are respectively:

(a) unscaled recruitments – the estimate of yield would be zero for the coming year. Once the methods have been resolved and a robust estimate of yield from a new method is obtained then the fishery would be reopened;

(b) scaled recruitment – the fishery would continue with unknown consequences for recruitment and stock recovery and a greater potential for long-term depletion.

(ix) A difficulty with this assessment is the degree to which parameters other than scaling the recruitments could influence the process and result in a different outcome for spawning stock status, such as estimates of growth rate, selectivity and natural mortality.

(x) Given the extent to which the tagging program has increased and the work on evaluating management procedures is under way, it is conceivable that progress could be made in the coming year to resolve some of the issues and use new data from the tagging program to help address the assumptions and to better estimate the magnitude of the vulnerable population.

(xi) On that basis and considering precaution, it would seem prudent to at least ensure the catch would not lead to the probability of depletion increasing by more than a small amount over the next year while the issues are examined in more detail over the coming year. This would protect future options for the fishery and help ensure that the stock status is not appreciably altered in the short term. This method would require estimates of the probability of depletion with no catch in the future. There was insufficient time to undertake that work. The following steps could be followed to help determine whether a nominal catch might lead to an increased probability of depletion:

(a) Table 5.29 presents the status of the spawning stock under alternative scenarios for recruitment, natural mortality and future catch rates. The lower 10th percentile of spawning stock status in specific years shows the spawning stock status for which there is a 10% chance it will be less than or equal to that value in that year. This corresponds to the part of the decision rule that relates to depletion in that a catch is chosen with a 10% chance of depletion below 20% of the median pre-exploitation biomass.

(b) The aim would be for that 10th percentile to not be appreciably reduced over one year. In this respect, the change in value of the lower 10th percentile of spawning stock status between 2004 and 2005 is a guide to the consequence of the nominated catch levels in the scenarios. A large reduction in the 10th percentile would indicate that a catch at that level would be unlikely to retain the status quo.

5.167 Drs Kirkwood and Agnew noted the following points for discussion and suggested possible advice:

(i) Results of a GYM run with 2 000 trials using the standard set of input parameters, the revised standardised CPUE series and the revised recruitment series are shown in Figure 5.14. Examining these results, the following features are apparent:

(a) Diagnostic statistics collected during this run indicate that in over 31% of the trials, the population abundance from 1984 to 2004 was insufficiently large to allow all the known catches to be taken.

(b) Despite the fact that the CPUE likelihood weighting of trials had been applied, the time series of predicted median vulnerable biomass indicate trends that are incompatible with those in the standardised CPUE series:

- There is a severe decline of about 80% in predicted vulnerable biomass from 1999 to 2004. This is a period during which the standardised GLMM CPUE was almost completely flat, and even the standard GLM only shows a 15% decline.

- The relative declines from 1985 to 2004 are also much greater than in the standardised CPUE; 90% in the GYM in Figure 5.14(a) versus 50–60% in the GLM/GLMM.

- By contrast, declines in the scaled runs are much closer to the GLM and GLMM runs (Figure 5.14(b); 50% decline compared to 50–60% decline in GLM/GLMM).

(c) There is no evidence from the plots of fishing distribution for the severe contractions of fishing area that would be expected if hyper-stability was the explanation for these discrepancies.

(d) It was inconceivable, if current vulnerable biomass is only 2 to 3 times higher than the catch level, that major signals would not be seen in the CPUE series.

(e) The estimated vulnerable biomass in 2004 (around 15 000 tonnes) is considerably less than half the lower 95% confidence limit of the mark–recapture abundance estimates for 2003 and 2004.

(f) If the analysis by Dr Gasyukov was correct (paragraph 5.169), the level of recruitment estimated by the survey would be even lower. This would mean that more than 50% of GYM trials, and up to 99% (Table 5.29, 0.5R) would not realise the catch. This is clearly implausible, and serves to emphasise the severe uncertainty surrounding the survey estimates of recruitment and the CMIX procedure.

(g) If there is the possibility that the GYM can be reconciled with current recruitment simply by adjusting natural mortality, growth etc., then confidence in GYM runs must surely be undermined. Following points made by Dr Gasyukov, Drs Agnew and Kirkwood saw no justification for changing these fundamental parameters, and are therefore driven to the conclusion that the explanation for the fact that the unscaled recruitment GYM fails to match other analyses (CPUE, tagging and ASPM) is because surveys are not providing an accurate estimate of recruitment.

(ii) In the view of Drs Agnew and Kirkwood, the most likely reason for these incompatibilities is that the calculated recruitment estimates are downwardly biased estimates of the true absolute recruitment. These incompatibilities also rule out direct use of these GYM results to calculate long-term yields according to the usual CCAMLR decision rules.

(iii) One way of resolving these problems is to treat the calculated recruitment series as providing a relative, rather than absolute, index of actual recruitment. As described in WG-FSA-04/82, this can be done by determining a raising factor for the recruitment series that results in a GYM prediction of current median vulnerable biomass equal to an estimate of current biomass obtained using a different estimation method. As discussed at WG-FSA-SAM-04, this approach would also accommodate use of the CCAMLR decision rules used for setting long-term catch limits.

(iv) In WG-FSA-04/82, three different estimators of current biomass were discussed: mark–recapture, ASPM and a depletion estimator. During this meeting, the mark–recapture and the ASPM estimators were further considered and modified:

(a) The range of estimates of current biomass calculated using the ASPM ranged from 28 000 to 266 000 tonnes, but in all cases the fits to the input data were sufficiently poor that the Working Group agreed that none of the ASPM estimates calculated at this meeting could be considered reliable.

(b) Bootstrapped median estimates of vulnerable biomass using the mark–recapture data for 2003 and 2004 were respectively 51 000 and 60 500 tonnes, with 95% confidence intervals 42 000–63 500 and 47 000–82 000 tonnes.

(v) Sensitivity trials run during the meeting included use of raising factors for the recruitment series used in the GYM of 1.5, 1.78 and 2.0. These produced median vulnerable biomasses in 2004 of 37 000 tonnes, 51 000 tonnes and 62 000 tonnes, corresponding respectively to a biomass lower than the lower confidence limit of the lowest mark–recapture estimate (42 000 tonnes), and approximately the median mark–recapture estimates for 2003 and 2004.

(vi) Application of the CCAMLR decision rules to these three sets of GYM calculations would result in long-term yields of 2 450, 4 200 and 4 900 tonnes. Accordingly, it is believed that an appropriate long-term yield calculated according to the CCAMLR decision rules would be 4 200 tonnes, corresponding to the lower of the two median mark–recapture estimates. Should a greater degree of precaution be desired for the forthcoming year, then a lower catch limit in the range 2 450–4 200 tonnes would be appropriate.

5.168 Dr Gasyukov reminded the Working Group that it has agreed rules of procedure for conducting assessments. These included standard methods and software for assessments, for example, the CMIX program and Excel add-in. In this context he was concerned that a range of methods had been introduced for the assessment of *D. eleginoides* in Subarea 48.3 (tagging estimates of abundance, ASPM estimate of abundance) in response to the outcomes of the review of the recruitment series and initial assessment of the implications. He noted that the current assessment method had been used by the Working Group for 10 years and that it was necessary to more thoroughly investigate and understand the reasons for the observed results before considering alternative methods. He considered it important that the Working Group acknowledge the errors that have affected previous assessments, that these errors had resulted in the catch limit being set at nearly 8 000 tonnes and that in this context it was not a surprise that the stock may be very depleted.

5.169 Dr Gasyukov noted that very few Members had the opportunity, in terms of time and documentation, to appropriately review or verify the application of the alternative methods to the assessment and, therefore, were not in a position to provide advice on their robustness for use in the assessment of *D. eleginoides*. He emphasised that he did not want to discourage the exploration, development and adoption of alternative methods, such as the ASPM and mark–recapture methods, only that the Working Group be afforded appropriate opportunity to review and understand methods before their application to assessments, including the provision of appropriate specifications and documentation for their use. In light of this, he expressed great concern over the use of the mark–recapture estimates of abundance to scale the revised recruitment series so that the median vulnerable biomass from the GYM projections corresponded to the estimates of biomass from the mark–recapture method. He noted that the assessment using the current assessment method and the revised recruitment series indicated a long-term yield in the order of 1 900 tonnes, that the stock may be very depleted and that there was no scientific basis to disregard the current assessment. In addition, he noted that the preliminary examinations of the effect of stratification on the estimates of recruitment from CMIX indicate that the revised series of recruitments may not be correct and that this required urgent investigation.

5.170 Given these issues, Dr Gasyukov urged the Working Group to be precautionary in its advice, and not modify the current assessment approach until there had been the opportunity to better understand the issues that had not been resolved at this meeting, and that resolving these issues should be the priority for the next meeting of WG-FSA-SAM.

5.171 Drs Kock and O. Wöhler (Argentina) indicated that they shared a number of the concerns expressed by Dr Gasyukov with respect to changing the current assessment methods and the use of the mark–recapture estimates of biomass, particularly given the potential for the stock to be depleted. They also considered that the views expressed by Dr Constable were a balanced assessment of the information available to the Working Group.

5.172 Dr R. O'Driscoll (New Zealand) noted that much of the information used for assessments, including CPUE and tagging estimates, are fishery-dependent and would not be available if the fishery is closed.

8.3 Comments from general discussion on assessment of *D. eleginoides* in Subarea 48.3

5.173 The Working Group noted that Shag Rocks and west Shag Rocks are primary recruitment areas and that the CPUE has been declining since 1999 at Shag Rocks. An additional measure might be to establish local-area limits in the defined areas to protect parts of the stock. The Working Group agreed that it might be useful to consider a much lower catch in the area of Shag Rocks and west Shag Rocks to protect recruits but not so low that the tagging experiment could not continue.

5.174 The Working Group considered that more detailed analysis of the spatial pattern of the fishery should be a high priority to investigate the potential for hyper-stability in the standardised CPUE series raised by Dr Constable.

5.175 The Working Group was unable to provide further advice on assessments this year.