APPENDIX I

FISHERY REPORT: *DISSOSTICHUS ELEGINOIDES* HEARD ISLAND (DIVISION 58.5.2)

CONTENTS

FISHERY REPORT: *DISSOSTICHUS ELEGINOIDES* HEARD ISLAND (DIVISION 58.5.2)

1. Details of the fishery

1.1 Reported catch

The catch limit of *Dissostichus eleginoides* in Division 58.5.2 for the 2004/05 season was 2 787 tonnes (Conservation Measure 41-08) for the period from 1 December 2004 to 30 November 2005. The catch reported for this division as of 1 October 2005 was 2 783 tonnes. Reported catches along with the respective catch limits and number of vessels active in the fishery are shown in Table 1. In Division 58.5.2, the fishery was a trawl fishery from the 1996/97 to the 2001/02 season. For the last three seasons the fishery has been prosecuted by both trawlers and longliners. The longline fishery was active from 1 May to 14 September 2005 and the trawl fishery was active from 1 December 2004 to 30 November 2005.

Table 1: Catch series of *Dissostichus eleginoides* in Division 58.5.2 from 1989/90 to 2004/05. T – Trawler; LL – longliner; *season will finish on 30 November 2005.

Fishing season	Number vessels	Catch limit (tonnes)	Reported catch (tonnes)			IUU estimate (tonnes)	Total removals (tonnes)
			Total	Trawl	Longline		
1989/90			1	1	0	0	1
1990/91			0	0	0	0	0
1991/92			0	0	0	0	0
1992/93			0	0	0	0	0
1993/94			0	0	0	0	0
1994/95		297	0	0	0	0	0
1995/96		297	0	0	0	3 000	3 000
1996/97	2	3 800	1 927	1 927	0	7 117	9 044
1997/98	3	3 700	3 765	3 765	0	4 150	7 915
1998/99	2	3 690	3 547	3 547	0	427	3 974
1999/00	2	3 585	3 566	3 566	0	1 154	4 720
2000/01	2	2 995	2 980	2 980	0	2 004	4 984
2001/02	2	2 815	2 756	2 756	0	3 489	6 245
2002/03	2T + 1LL	2 879	2 844	2 574	270	1 512	4 356
2003/04	2T + 1LL	2 873	2 864	2 296	567	637	3 501
2004/05	2T + 1LL	2 787	2 783*	2 170*	613	0–265	2 783–3 048*

1.2 IUU catch

2. Details of the IUU catches attributed to Division 58.5.2 in 2005 are given in the WG-FSA report, Table 3.3 and questions of the attribution of IUU catches reported in Areas 47 and 51 are considered in the WG-FSA report, paragraph 8.6. It was noted that WG-FSA could not determine a final figure for IUU fishing in this area until SCIC had agreed on the data used to estimate the IUU catch. The range of 0 to 265 tonnes was used in the assessments for this year.

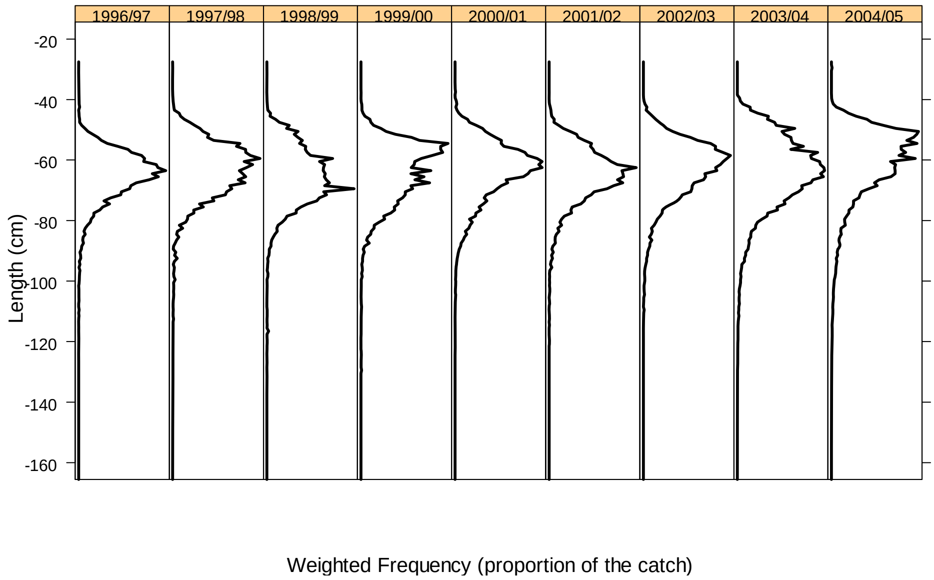

Figure 1: Catch-weighted length frequencies for *Dissostichus eleginoides* in Division 58.5.2 derived from data from the trawl fishery provided by Australia in consultation with the Secretariat (WG-FSA-05/6 Rev. 1).

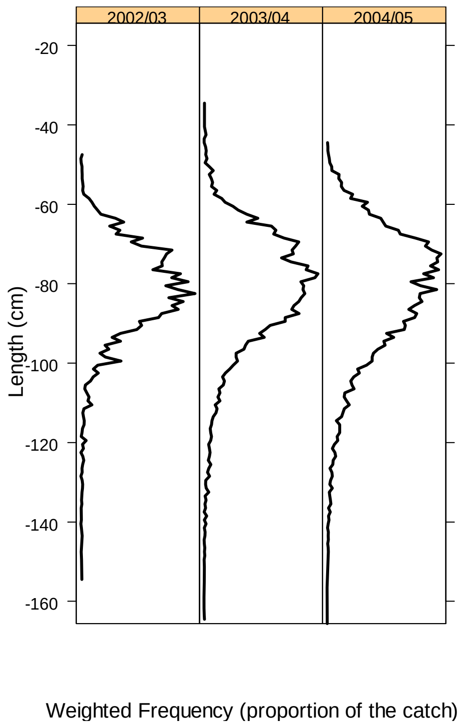

Figure 2: Catch-weighted length frequencies for *Dissostichus eleginoides* in Division 58.5.2 derived from observer, fine-scale and STATLANT data from the longline fishery reported by 5 October 2005.

1.3 Size distribution of catches

3. Catch-weighted length frequencies are illustrated in Figures 1 (trawl fishery) and 2 (longline fishery). The Working Group noted that the modal size of fish caught in the longline fishery was greater than that in the trawl fishery. The difference in selectivities between trawl and longline fishing methods in Division 58.5.2 was estimated in WG-FSA-05/65. This work showed that longline gear is more able to catch larger fish than trawl gear, which has reduced selectivity for fish greater than 800 mm declining to zero at 1 730 mm. It also showed that fish were larger in deeper water. The length-frequency distribution for the longline fishery will therefore have larger fish because of gear selectivity as well as the fishery occurring in deeper water.

2. Stocks and areas

4. *Dissostichus eleginoides* occurs throughout the Heard Island and the McDonald Islands Plateau, from shallow depths near Heard Island to at least 1 800 m depth around the periphery of the plateau. Random stratified trawl surveys have been conducted since 1990 with surveys occurring annually to cover the range of juvenile fish since 1999. Younger fish (less than about 600 mm TL) predominate on the plateau in depths less than 500 m, but no areas of local abundance have been discovered. As fish grow, they move to deeper waters, and are recruited to the trawl fishery on the plateau slopes in depths of 450 to 800 m. Here there are several areas of local abundance that constitute the main trawling grounds where the majority of fish caught are between 500 and 750 mm TL (Figure 1). Older fish are seldom caught in the trawl fishery, and it is assumed that they move into deeper water (>1 000 m depth) where they are caught by the longline fishery. This fishery mostly operates between 1 000 and 1 200 m depth and catches larger fish than in the trawl fishery (Figure 1), but few fish are >1 000 mm TL. It is assumed that the largest fish are at depths greater than 1 200 m.

5. Genetic studies have demonstrated that the *D. eleginoides* population at Heard Island and McDonald Islands is distinct from those at distant locations such as South Georgia and Macquarie Island (Appleyard et al., 2002), but that within the Indian Ocean sector there appears to be no distinction between fish at Heard, Kerguelen, Crozet or Marion/Prince Edward Islands based on genetic studies (Appleyard et al., 2004). This, combined with results from tagging data which show movement of some fish from Heard Island to Kerguelen and Crozet Islands (Williams et al., 2002) suggests that a metapopulation of *D. eleginoides* may exist in the Indian Ocean sector (WG-FSA-03/72).

3. Parameter estimation

3.1 Parameter values

<u>Fixed parameters</u>

6. The von Bertalanffy growth parameters from the 2004 assessment were replaced this year by a length-at-age vector based on the two-segment linear model described in WG-FSA-05/64 Rev. 1. This model provides the best fit to length-at-age data from the trawl fishery. It

is now based on validated age data (WG-FSA-05/60 and 05/61) and provides more sensible results for size-at-age 0 (134 mm). The Working Group noted that estimates of length-at-age for fish greater than 20 years of age would improve with data from the longline fishery.

7. Current assessments of this stock assume a range of natural mortality of 0.13–0.20. As a consequence of the slower growth estimated for *D. eleginoides* in this area, the Working Group agreed that natural mortality was unlikely to be as great as 0.2 year^{-1}. The Working Group agreed that an alternative to the previous range of 0.13–0.20 year^{-1} was needed. For this year an acceptable alternative range of natural mortality in the assessments was 0.13–0.165 year^{-1}.

8. The input parameters used in the assessment are included in Table 2.

Table 2: Input parameters for the assessment of *Dissostichus eleginoides* in Division 58.5.2.

Component	Parameter	Value	Units
Natural mortality	*M*	0.13–0.20 0.13–0.165	y^{-1}
Length-at-age (age in parentheses)	(0) 134; (1) 204; (2) 274; (3) 344; (4) 414; (5) 484; (6) 554; (7) 593; (8) 631; (9) 668; (10) 706; (11) 743; (12) 781; (13) 818; (14) 856; (15) 894; (16) 931; (17) 969; (18) 1006; (19) 1044; (20) 1082; (21) 1119; (22) 1157; (23) 1194; (24) 1232; (25) 1269; (26) 1307; (27) 1345; (28) 1382; (29) 1420; (30) 1457; (31) 1495; (32) 1533; (33) 1570; (34) 1608; (35) 1645		(year) mm
Length to mass	‘*a*’	2.59E-09	mm, kg
Length to mass	‘*b*’	3.2064	
Maturity	L_{m50}	930	mm
Range: 0 to full maturity		780–1 080	mm

Recruitment survey

9. A report of the results of the Australian research survey in 2005 was tabled in WG-FSA-05/30, along with the methods used in the survey. Australia undertook a trawl survey of Division 58.5.2 in May 2005 to estimate the density of juvenile toothfish (WG-FSA-05/30). The survey used the same design as in the 2004 survey, following the review of the survey design for estimating abundance of juvenile *D. eleginoides* presented to the 2004 meetings of WG-FSA-SAM (WG-FSA-SAM-04/19) and WG-FSA (WG-FSA-04/76) (Table 3).

Table 3: Details of the 2005 Heard Island survey for *Dissostichus eleginoides*.

Area name	Mean survey date (DOY)	Area (km^2)	No. hauls allocated	No. hauls completed	No. useable hauls
Ground B	27 June (158)	480.8	20	20	20
Gunnari Ridge	1 June (152)	520.7	18	18	18
Plateau deep east	12 June (163)	13 120	30	30	30
Plateau deep northeast	19 June (170)	15 090	10	10	10
Plateau deep southeast	3 June (154)	5 340	10	10	10
Plateau deep west	23 June (174)	13 370	10	10	10
Plateau north	19 June (170)	15 170	10	10	10
Plateau southeast	7 June (158)	10 620	30	30	30
Plateau west	23 June (174)	10 440	10	10	10
Shell Bank	10 June (161)	1 758	10	10	10
All strata		85 909	158	158	158

Recruitment estimates

10. Survey data were not available from the CCAMLR Secretariat, as they had been submitted in fine-scale format, rather than research-survey format. The data were provided directly by the Australian scientists. Length densities were estimated from the Heard Island survey in June 2005 using the CMIX program, with both mean length (estimated from von Bertalanffy growth parameters used in 2004) and standard deviation of length fixed (Table 4). The standard deviations are calculated using a CV of length-at-age of 0.12, which was estimated during the fitting of the growth curve to size-at-age. There are no clear modes present in the length-density data and the fitting relies entirely on the growth curve parameters, which are based on size-at-age data. It was noted that there had been insufficient time to rerun the CMIX program using the new two-segment linear growth model of WG-FSA-05/64 Rev. 1 as the basis for setting length-at-age in reanalysing all the survey data.

Table 4: Input parameters for CMIX analysis of survey data to estimate length densities of *Dissostichus eleginoides* in Division 58.5.2 in June 2005.

Age class	Mean size (mm fixed)	SD (estimated)
2	330	44
3	391	52
4	450	60
5	508	68
6	564	75
7	618	82
8	671	89
9	722	96

Parameter	Value
Minimisation	Yes
Maximum number of function calls	10 000
Minimum reporting frequency	100
Stopping criteria	1.0E-10
Frequency for convergence testing	5
Fit quadratic surface	No
Simplex expansion coefficient	1

11. The CMIX analysis indicates that three main age classes were present in the sampled population (ages 5, 6 and 9; Figure 3). Ages 3 and 4 were absent, as were ages 7 and 8. The 9-year-old cohort was not used to estimate the recruitment series as it was considered not fully sampled by the survey and this fitted cohort probably encompasses a number of age classes.

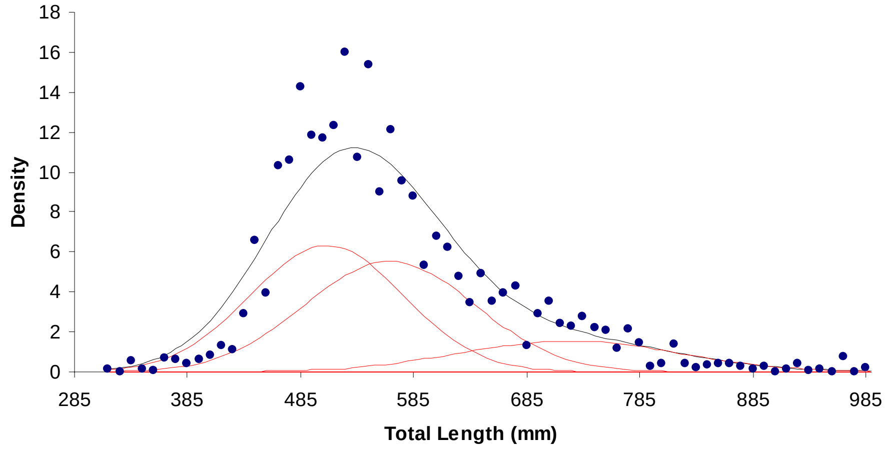

Figure 3: Results of CMIX analysis of survey data to estimate length densities of *Dissostichus eleginoides* in Division 58.5.2 in June 2005.

12. The estimated length densities from the CMIX program were converted to a biomass estimate using the length–weight relationship, the seafloor area and the mean size-at-age. This biomass was checked against the Trawl CI estimate from the survey (Table 5), and produced a similar estimate of biomass.

Table 5: Biomass check for the estimated densities generated by CMIX.

Age	5	6	9	
Density (numbers km^{-2})	107.2	104.2	37.5	a = 2.59E-09
Area (km^2)	85 909	85 909	85 909	b = 3.20640
Numbers	9 211 507	8 955 498	3 222 567	
Mean size (mm)	508	564	722	
Weight (kg)	1.229	1.718	3.792	
Biomass (tonnes)	11 316	15 385	12 221	38 923
Trawl CI (tonnes)				39 334

13. The results of the CMIX analysis for the 2005 survey were added to the time series of survey results for this area shown in Table 6.

Table 6: Estimated cohort strengths of *Dissostichus eleginoides*, from surveys undertaken in Division 58.5.2 from 1990 to 2005. The table is derived from Table 5.39 in the report of WG-FSA-04 (SC-CAMLR-XXIII, Annex 5) and only shows those data included in the 2004 assessment along with the results of the 2005 survey. Observed (Obs.) and expected (Exp.) data are from the mixture analyses, the closeness of which indicates the quality of the fit. The time of the survey is relative to 1 December.

Survey year	Time	Area (km^2)	Observed	Expected		Density (n.km^{-2})					
						Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
1990	0.50	97106	107.2	108.1	Mean	8.080	33.508	20.208	0.827	25.226	
					SE	*5.897*	*13.552*	*11.251*	*11.505*	*14.082*	
1993	0.77	71555	97.4	114.7	Mean	13.567	38.259	8.191	16.961	3.066	
					SE	*8.804*	*18.172*	*13.483*	*12.606*	*30.294*	
1999	0.33	85428	366.2	357.9	Mean	17.741	16.206	138.11	56.785	60.897	40.323
					SE	*7.862*	*13.323*	*42.657*	*55.348*	*50.870*	*38.189*
2001	0.48	85169	247.5	252.4	Mean	19.542	34.018	38.172	45.538	32.165	
					SE	*7.798*	*12.849*	*20.534*	*30.762*	*42.367*	
2002	0.48	85910	208.5	204.8	Mean	18.590	29.333	59.400	20.726	53.199	
					SE	*6.722*	*11.475*	*21.202*	*21.993*	*17.117*	
2003	0.42	42280	116.8	115.6	Mean	15.798	17.298	22.452	45.041		
					SE	*13.552*	*29.967*	*43.976*	*36.105*		
2004	0.42	85910	242.8	246.0	Mean	0.001	64.620	70.273	81.607	0.001	
					SE	*0.001*	*38.548*	*67.242*	*40.211*	*0.001*	
2005	0.43	85910	247.0	248.8	Mean	0.001	0.001	107.22	104.24	0.001	
					SE	*0.001*	*0.001*	*38.96*	*48.70*	*0.001*	

14. Dr P. Gasyukov (Russia) noted that the CMIX estimates of abundance-at-length were calculated using Aitchison's method. Issues surrounding the use of this method were discussed in WG-FSA-05/78. There was no time to examine all these CMIX analyses, so he concentrated on the estimates of recruits from the 1999 survey, which provided the highest estimates of recruitment of *D. eleginoides* in Division 58.5.2. Using data from this survey, Dr Gasyukov applied the methods described in WG-FSA-05/78. The corresponding length compositions are presented in Figure 4.

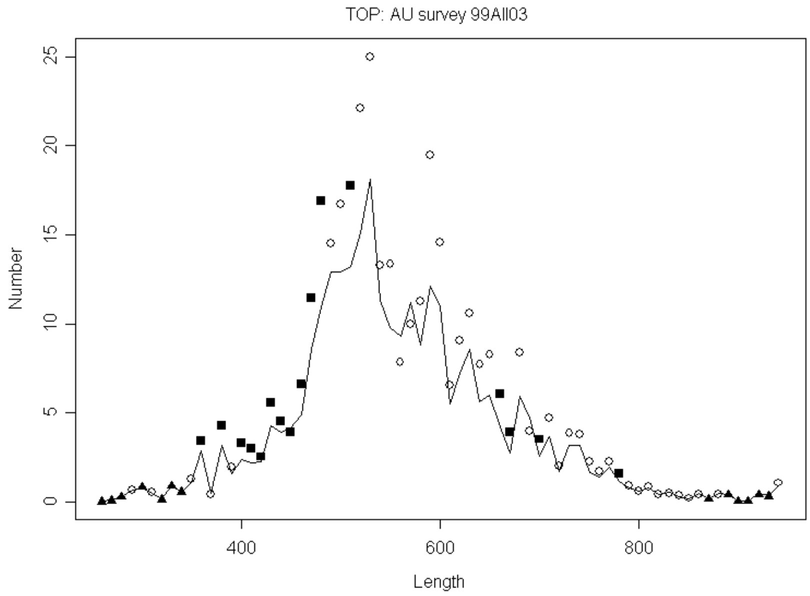

Figure 4: Density of fish in each length class from the 1999 Australian bottom trawl survey in Division 58.5.2. The line indicates the frequency distribution obtained with the bootstrap method, while the points indicate respective estimates obtained with the method by Aitchison with the different types of dots representing: ○ – non-zero data fit a lognormal distribution, ■ – non-zero data fail to fit a lognormal distribution, ▲ – non-zero data only comprise 1–3 values.

15. These results show that the Aitchison method may be overestimating the abundances-at-length in this dataset, compared to the bootstrap methods. The differences are especially pronounced in modal length groups. Parameters of the mixture distributions estimated by the updated methods of MacDonald and Pitcher implemented in *R* (see WG-FSA-05/78 for details) and by CMIX in this trial are presented in Table 7 and Figure 5. In this trial, the mean length and standard deviation are estimated while retaining a constant CV. In the MacDonald and Pitcher implementation in *R*, the error distribution for abundance-at-length was assumed to be multinomial.

Table 7: Mixture parameters of indices based on length composition by CMIX and MacDonald and Pitcher methods.

Age groups	CMIX (total density = 356.7)				MacDonald and Pitcher (total density = 280.6)			
	π	μ	σ	Density	π	μ	σ	Density
1	0.051	36.63	3.66	18.19	0.04	37.02	2.12	11.22
2	0.03	45.47	4.55	10.70	0.069	43.23	2.48	19.36
3	0.303	50.16	5.02	108.08	0.373	50.27	2.89	104.66
4	0.249	54.22	5.42	88.82	0.077	55.25	3.17	21.61
5	0.154	59.13	5.91	54.93	0.227	58.75	3.37	63.70
6	0.105	63.68	6.37	37.45	0.081	64.4	3.7	22.73
7	0.069	68.31	6.83	24.61	0.085	69.68	4	23.85
8	0.03	72.5	7.25	10.70	0.025	75.87	4.35	7.02
9	0	76.67	7.67	0.00	0.008	75.87	4.35	2.24
10	0.01	90.39	9.04	3.57	0.014	89.23	5.12	3.93

16. These results show substantial differences in the proportions of the different age classes in the population and in the estimates of total density for this dataset. This results in differences in the estimates of density for some of the year classes, although not always in the same direction or of the same magnitude. The likely impacts on the assessment are not clear from this analysis given these results as well as that the mean lengths-at-age were not fixed to take account of the knowledge of length-at-age.

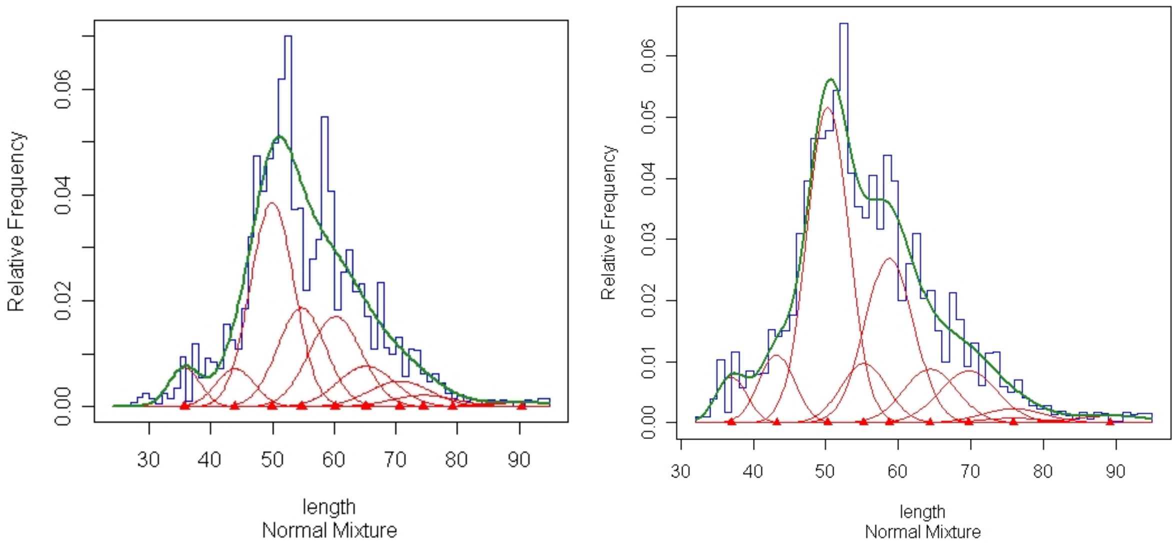

Figure 5: Mixture distributions for *Dissostichus eleginoides* in Division 58.5.2 arising from analyses of trawl survey data from 1999. The left panel shows the results from CMIX. The right panel shows the results using the updated MacDonald and Pitcher method implemented in *R*.

17. As a consequence of these analyses, the Working Group agreed that the means by which recruitment cohort strength is estimated from toothfish survey data should be reviewed in the intersessional period. This review should also investigate the possible effects of using the new two-segment growth model.

18. The Working Group also noted that, given the lack of defined modes in the length-density data, it would be useful to use age–length keys, if possible, as an alternative method for estimating densities of cohorts. The Working Group encouraged studies on optimal sampling schemes for establishing age–length keys.

<u>CPUE series</u>

19. The CPUE series was not updated at the 2005 meeting. The series was updated in 2003 (Candy, 2004). The CPUE series is not used in the assessment procedure as the trawl fishery is confined to a relatively small proportion of the area occupied by the stock, and therefore trends in commercial CPUE are not expected to reflect trends in stock status.

Tagging studies

20. A tagging study has been undertaken at Heard Island since 1998 (Williams et al., 2002). It is anticipated that these data will provide important inputs to future integrated assessments using methods such as CASAL.

Recruitment series

21. The recruitment series was updated with the recruitment estimates from the 2004 survey (Table 6). At WG-FSA-03 it was agreed that recruitment data from two trawl surveys (1992 and 2000 in Table 6) should be excluded from the assessment. The 1992 survey was excluded because it did not sample below 500 m and the Working Group agreed that it did not adequately cover the depth distribution of fish in the age range 3 to 8 years used from other surveys (see WG-FSA-96/38). The 2000 survey was also excluded because of Working Group concerns about the sampling design. The 2000 survey specifically targeted *Champsocephalus gunnari*, and did not sample strata where *D. eleginoides* were known to occur in greater densities. Thus, it is likely this survey underestimated the density of some cohorts.

22. The Working Group considered that fish younger than age 3 were not adequately sampled by the trawl surveys. Cohorts older than age 6 may be underestimated due to fishing on these cohorts. However, the process of mixture analysis can result in incorrectly assigning cohorts at older ages and inclusion of age-7 fish would potentially mitigate this possibility. The Working Group agreed that the 2003 survey did not adequately sample age-7 fish, and so these were not included in the series. The Working Group further agreed to include the estimate of the age-8 cohort from the 1999 survey. The 1999 survey targeted *D. eleginoides*, included intensive sampling in areas where fish ages 5 and above were known to occur, and provided the only estimate of recruitment for this cohort. Estimates of recruitments updated with the most recent survey and based on a mean natural mortality rate of 0.165 year^{-1} are provided in Table 8.

Table 8: Updated recruitment series used in the assessment of *Dissostichus eleginoides* in Division 58.5.2. Based on a natural mortality of 0.165 yr^{-1}.*

Year at age 4 birthday	Recruitment (millions of fish)
1986	4.3273
1987	0.1207
1988	2.4920
1989	3.7900
1990	1.1200
1991	0.6690
1992	2.7427
1993	0.8248
1994	7.2051
1995	9.2260
1996	7.2946
1997	14.171
1998	6.5321
1999	2.3324
2000	2.5369
2001	1.8547
2002	3.6796
2003	7.3021
2004	0.001
2005	0.001
Mean	3.9111
CV	0.9442

* In the GYM projections, the recruitment series is re-estimated from the survey data for each trial based on a value of M randomly selected from a specified range for that trial. The series presented here is for one such value of M.

Fishing vulnerabilities (FV)

23. In Division 58.5.2, the fishery was a trawl fishery from the 1996/97 to the 2001/02 season. For the last two seasons both trawlers and longliners have prosecuted the fishery. Age-based fishing vulnerabilities have been applied since 1996/97. The change in length-at-age requires a change in the age-based vulnerabilities, which were originally derived from length data. The Working Group agreed that, in the interim of re-estimating new vulnerability patterns, the historical vulnerability patterns be simply transformed back to length using the previous von Bertalanffy growth parameters and then into age using the new length-at-age vector. The vulnerability patterns are provided in Table 9.

24. It was noted that the same trawl-based vulnerabilities are applied to both the trawl and longline fisheries between 1996/97 and 2004/05. For future projections, two alternative age-based selectivities were examined: the standard trawl-only selectivity and an age-based selectivity function representing a combined trawl/line/trap fishery. It should be noted that the actual selectivity for a combined fishery will vary with the fishing effort applied by the

three gears, so the combined selectivity function can only be an approximation. Use of a trawl-only selectivity will result in a more conservative estimate of yield than applying the combined selectivity function.

25. In the 1995/96 season a length-based vulnerability function was applied, with vulnerability starting at 550 mm TL, 50% vulnerability at 670 mm TL and full vulnerability at 790 mm TL. This was to account for IUU fishing by longline vessels in that period.

Table 9: Fishing vulnerabilities for *Dissostichus eleginoides* in the trawl and longline fishery in Division 58.5.2.

Fishing season	Ages over which FV = 0	Ages over which FV = 1	Ages over which FV = 0
1995/96	Length based (see text)		
1996/97	0–6.8	6.9–8.2	8.4–max
1997/98	0–5.7	5.8–11.1	13.7–max
1998/99	0–5.3	5.8–14.9	17.3–max
1999/00	0–4.1	4.1–16.1	17.3–max
2000/01	0–8.2	8.4–16.1	17.3–max
2001/02	0–8.2	8.4–16.1	17.3–max
2002/03	0–8.2	8.4–16.1	17.3–max
2003/04	0–8.2	8.4–16.1	17.3–max
2004/05	0–8.2	8.4–16.1	17.3–max
Future (trawl only)	0–8.2	8.4–16.1	17.3–max

26. The alternative combined-gear selectivity function is shown in Table 10.

Table 10: Alternative combined-gear fishing vulnerabilities for *Dissostichus eleginoides* in the trawl and longline fishery in Division 58.5.2.

Age	0–4.1	4.9	5.8	7.0	8.4	9.8–13.7	14.9	16.1	17.3	18.4+
FV	0	0.14	0.5	0.8	0.9	1.0	0.9	0.85	0.4	0.3

4. Stock assessment

4.1 Model structure and assumptions

27. The GYM, using input data from paragraphs 6 to 26, 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 (SSB) 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 SSB in the final year of the 35-year projection.

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

Model configuration

28. The GYM was run according to the configuration detailed in Table 11.

Table 11: GYM model configuration for the assessment of *Dissostichus eleginoides* in Division 58.5.2.

Category	Parameter	Value
Recruitment age	Start	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 specification	Years to remove initial age structure	1
	Observations to use in median SB_0	1 001
	Year prior to projection	1985
	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

4.2 Model estimates

29. Three main model runs were carried out based on the parameters considered above and including the 2005 survey of juvenile fish and the revised length-at-age vector from the two-segmented linear model:

(i) M = 0.13–0.20 year^{-1}, trawl vulnerability in future projections;

(ii) M = 0.13–0.20 year^{-1}, combined gear (trawl, longline, pot) vulnerability in future projections;

(iii) M = 0.13–0.165 year^{-1}, trawl vulnerability in future projections.

30. Each of these was undertaken with IUU catch in the 2004/05 season at 0 tonnes and 265 tonnes.

31. The results for each of the six scenarios are presented in Table 12, which shows the constant yield for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period and the yield at which there is a 10% chance of spawning biomass dropping to less than 20% of the initial biomass.

Table 12: Long-term annual yields estimated using the GYM for six scenarios for *Dissostichus eleginoides* in the trawl and longline fishery in Division 58.5.2.

Scenario	2004/05 IUU catch	Escapement rule yield	Depletion rule yield	Long-term yield
1	265	2 302	2 555	2 302
	0	2 304	2 562	2 304
2	265	2 439	2 648	2 439
	0	2 440	2 655	2 440
3	265	2 440	2 655	2 440
	0	2 444	2 562	2 444

32. An example of the trends in status of the SSB is shown in Figure 10 for Scenario 1 with the IUU catch of 265 tonnes in the 2004/05 season. In this case, the median estimated unexploited SSB was 61 634 tonnes (95% CI 32 307–120 142 tonnes) and the median estimated SSB at the start of 2005/06 was 43 299 tonnes (19 885–93 507 tonnes).

33. The Working Group noted that the estimates of SSB in any year are derived from the recruitment surveys and randomly drawn recruitments from the recruitment function when a cohort has not been observed combined with the growth and mortality (natural and fishing) functions. The uncertainty in these estimates is accounted for in the assessment process by projecting over a generation time (35 years in this case) and noting the probability of depletion and the median target status at the end of the projection (i.e. once all cohorts had experienced the effects of fishing). Lower values of SSB for a given year of a particular trial are more likely to contribute to that trial counting towards the depletion probability. The overall probability of depletion is derived from the number of projection trials in which the stock becomes depleted (0.2 of the median pre-exploitation SSB) recorded as a proportion of all 10 001 trials.

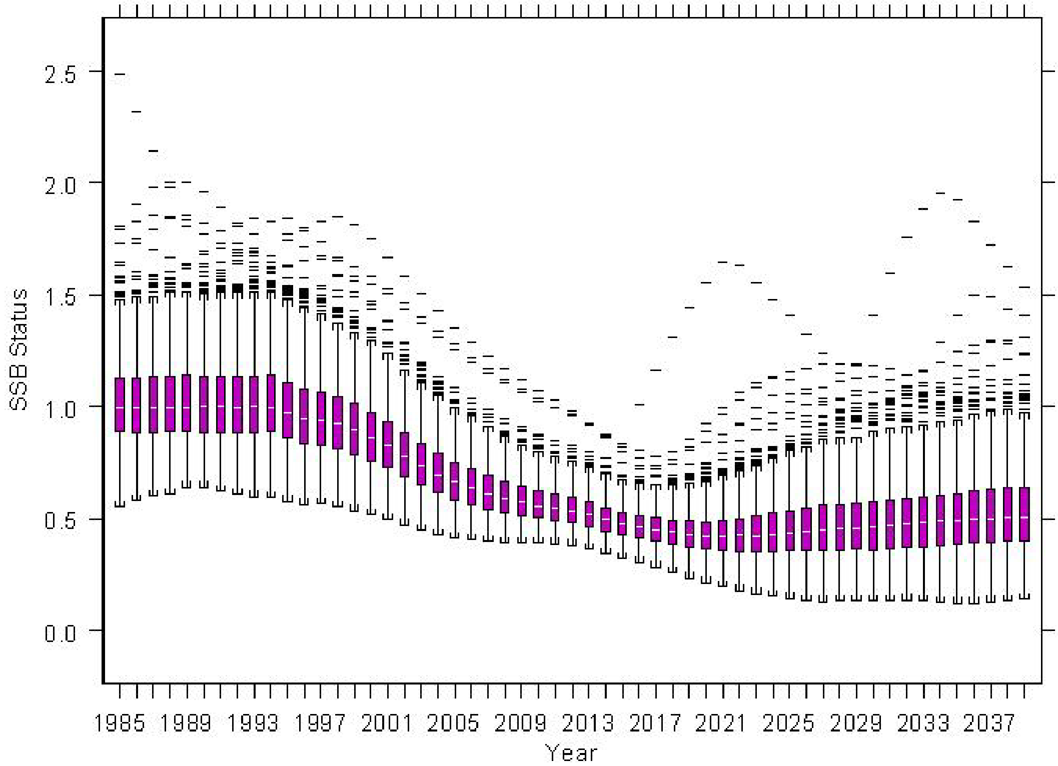

Figure10: Trajectories of SSB status for *Dissostichus eleginoides* in Division 58.5.2 with a constant catch of 2 302 tonnes in Scenario 1 with an IUU catch of 265 tonnes.

4.3 Discussion of model results

34. The Working Group noted the value of using the validated length-at-age vector in these assessments, removing the uncertainty surrounding length-at-age in younger fish. It agreed that the revised vulnerability in Table 10 is likely to be closer to the actual future vulnerability of toothfish to fishing because of the increase in the proportion of the catch to be taken by longlines and pots (increasing to two-thirds of the catch limit) compared to trawls (one-third). This expectation is based on the fishery comprising one vessel of each gear type. Similarly, the Working Group agreed that a natural mortality rate of 0.2 is likely to be too high for *D. eleginoides* in this division.

35. The Working Group recommended that the outcomes of the three scenarios be used as the basis for setting catch limits in the 2005/06 season. The following estimates of long-term annual yield are for the IUU catch of 265 tonnes:

(i)	M = 0.13–0.20 year^{-1}, trawl vulnerability in future projections;	2 303 tonnes
(ii)	M = 0.13–0.20 year^{-1}, combined gear (trawl, longline, pot) vulnerability in future projections;	2 439 tonnes
(iii)	M = 0.13–0.165 year^{-1}, trawl vulnerability in future projections.	2 440 tonnes

If SCIC decides that the IUU catch is lower than 265 tonnes, then the recommended limits could be revised upwards according to Table 12.

36. In reviewing the outcomes of the different trials, the Working Group noted that the vulnerability for combined trawl, longline and pot gears was not combined with a range of lower natural mortality rates into a single assessment. Such a combination would be expected to give a higher estimate of yield than those presented here.

37. The Working Group also noted other conservative aspects of this assessment, including:

(i) age-7 fish have been included as being absent from the population in the 2004 and 2005 recruitment surveys. It is unlikely that they have disappeared from the population because they are being caught in the longline fishery (Figure 2);

(ii) longline catches (including IUU catches, except for 1995/96) are incorporated in the assessments with a vulnerability equivalent to the trawl fishery, which will result in an impact on the assessment of IUU fishing greater than would be expected in reality due to the catching of larger fish by illegal fishers;

(iii) the age-8 cohort in the 1999 survey is likely to have been exploited by fishing in previous years and is therefore likely to be an underestimate.

38. The Working Group also noted that these scenarios do not account for the uncertainty surrounding the estimation of cohort strength using CMIX, although the effects of this uncertainty are unlikely to result in a uniform positive or negative bias in estimates of cohort abundance across all surveys.

39. Dr Gasyukov gave an alternative interpretation of the dynamics of the SSB presented in Figure 10. In his view, this figure shows a high degree of uncertainty in the state of the stock of *D. eleginoides* in Division 58.5.2. The nature of the model is such that it is not possible to determine the real biomass estimate in any year but only the potential range of abundance of the spawning biomass. For example, the 95% confidence interval of the SSB in the 2005 season has the range of 19 885–93 507 tonnes. This might mean that the real biomass value can be 19 885 tonnes, the lower bound of that confidence interval. As a result, Dr Gasyukov made the following points:

(i) management advice should be given for 1–2 years from the current year, as in the case of *C. gunnari*; advice for the 2005/06 and 2006/07 seasons should be based on the SSB estimates in the 2004/05 season and should take into account its uncertainty. Using the approach for *C. gunnari*, the projection should be calculated on the basis of the one-sided lower 95% confidence interval of the spawning biomass derived from the GYM projections;

(ii) he believes that this approach would be more likely to achieve target levels and avoidance of depletion for the stock when the confidence intervals suggest a low abundance of fish;

(iii) it would be useful to include short-term assessments as well as long-term assessments in order to take account of the status of the stock in the most recent years.

40. Dr A. Constable (Australia) welcomed suggestions on alternative methods for taking account of uncertainty. However, in this case, the existing projection framework takes uncertainty into account with the application of the current decision rules; the implications of low biomass for a given year in a trial are accounted for in the estimated probability of depletion (see paragraph 33). In that case, a low biomass in any year of the projection in the past, present or future will contribute to assessing the probability of depletion. A short-term assessment will require different decision rules and appropriate assessment methods. It will be important to evaluate the consequences of changes in the decision rules as well as evaluating methods for assessing yield in *D. eleginoides* in order to be confident that the advice derived from those assessments is robust to uncertainties.

4.4 Future research requirements

41. The Working Group noted the progress in developing an integrated assessment of *D. eleginoides* in CASAL and in evaluating the assessment methods and overall management strategy for this division (WG-FSA-05/69). It agreed that this work should be regarded as a high priority because:

(i) it will enable separating longline fishing from trawl fishing in the historical series as well as using other data such as length composition of catches and the mark–recapture data;

(ii) both short-term (such as the approach for *C. gunnari* described in paragraph 39) and long-term assessments, such as CASAL and GYM, should be evaluated (WG-FSA report, paragraphs 12.7 to 12.9).

42. The Working Group also recommended that:

(i) the means by which recruitment cohort strength is estimated from toothfish survey data should be reviewed in the intersessional period, including investigating the possible effects of using the new two-segment growth model;

(ii) given the lack of defined modes in the length-density data, it would be useful to use age–length keys, if possible, as an alternative method for estimating densities of cohorts;

(iii) studies on optimal sampling schemes for establishing age–length keys should be encouraged.

5. By-catch of finfish and invertebrates

5.1 By-catch removals

43. By-catch removals for the toothfish fisheries (longline and trawl) are detailed in Table 13 from fine-scale data (paragraphs N19 to N25). By-catch will also arise from the directed fishery for *C. gunnari* in the same division (Table N3). By-catch removals from observer data are detailed in WG-FSA-05/68 and paragraph N28. By-catch in the trawl

fisheries is generally low comprising less than 1% of the total catch. Landed by-catch in the longline fisheries ranged from 6 to 13% of the total catch and including cut-offs revised these estimates to between 11 and 26% of the total catch.

Table 13: By-catch limits and associated removals (in tonnes) from the toothfish fisheries in Division 58.5.2. OT – otter trawl, LLS – longlines set, LIC – *Channichthys rhinoceratus*, NOS – *Lepidonotothen squamifrons*, GRV – *Macrourus* spp., SRX – rajids.

Fishing season	LIC – OT	LLS	Limit	NOS – OT	LLS	Limit	GRV – OT	LLS	Limit	SRX – OT	LLS	Limit	Other – OT	LLS	Limit
1995/96	0	0		0	0		0	0		0	0		0	0	5%*
1996/97	0	0		0	0		0	0		2	0		5	0	50**
1997/98	0	0	80	0	0	325	0	0		4	0	120	36	0	50
1998/99	0	0	150	8	0	80	1	0		2	0		3	0	50
1999/00	0	0	150	0	0	80	4	0		7	0		4	0	50
2000/01	0	0	150	5	0	80	1	0	50	5	0	50	7	0	50
2001/02	1	0	150	1	0	80	4	0	50	4	0	50	54	0	50
2002/03	0	0	150	0	0	80	1	3	465	8	5	120	5	0	50
2003/04	0	0	150	2	0	80	2	42	360	5	62	120	6	3	50
2004/05	36	0	150	2	0	80	2	72	360	8	8	120	7	3	50

* 5% move-on rule if individual haul exceeds 5%, limit not specified.
** Move-on rule if catch of any by-catch species exceeds 5% of target species.

5.2 Assessments of impact on affected populations

44. Updated length–weight relationships, length-at-maturity data and estimates of abundance from survey data for rajids were presented in WG-FSA-05/70. Insufficient information was available to update assessments.

45. No stock assessments of individual by-catch species were undertaken in 2005. By-catch limits of *Channichthys rhinoceratus* and *Lepidonotothen squamifrons* are based on assessments carried out in 1998 (SC-CAMLR-XVII, Annex 5, paragraphs 4.204 to 4.206) and by-catch limits of the grenadier *Macrourus carinatus* are based on assessments carried out in 2002 and 2003 (SC-CAMLR-XXII, Annex 5, paragraphs 5.245 to 5.249).

5.3 Mitigation measures

46. The fishery operates under Conservation Measure 33-02.

47. The Working Group recommended that, where possible, all rajids should be cut from the line while still in the water, except on the request of the scientific observers during their sampling period (WG-FSA report, paragraphs 6.25 and 6.26).

6. By-catch of birds and marine mammals

48. No seabird mortality has been reported in the three years to date of longline fishing in Division 58.5.2 (Table O3). In the trawl fishery in this area, six seabirds were killed in 2003. Seabirds were released alive in 2002 (1), 2003 (11) and 2004 (7). In 2004/05, two white-chinned petrels were killed in the trawl fishery (Table O17).

49. In 2003/04 three fur seals were killed when the *Austral Leader* (trawl fishery) was targeting toothfish.

50. In 2004/05 three elephant seal mortalities were reported in the longline fishery for toothfish (WG-FSA report, paragraph 7.47) and there was a single fur seal caught and released alive in the toothfish trawl fishery (paragraph O216).

6.1 Mitigation measures

51. Longline fishing is conducted in accordance with Conservation Measures 24-02 and 25-02 and the special requirements outlined in Conservation Measure 41-08, paragraph 3; trawl fishing in accordance with Conservation Measure 25-03.

7. Ecosystem implications/effects

52. Fishing gear deployed on the seabed can have negative effects on sensitive benthic communities. The potential impacts of fishing gear on the benthic communities in Division 58.5.2 are limited by the small size and number of commercial trawl grounds and the protection of large representative areas of sensitive benthic habitats from direct effects of fishing in an IUCN category Ia marine reserve (SC-CAMLR-XXI/BG/18). The marine reserve and associated conservation zone comprises around 17% of the area of the Australian EEZ around Heard Island and McDonald Islands and falls entirely within CCAMLR Division 58.5.2.

53. The Working Group noted that by-catch of benthos was monitored by observers in the early stages of the development of the fishery and that by-catch of benthos was much lower in areas that have subsequently become the main fishing grounds.

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

8.1 Conservation measures

Table 14: Summary of provisions of Conservation Measure 41-08 for *Dissostichus eleginoides* in Division 58.5.2 and advice to the Scientific Committee for the 2005/06 season.

Paragraph and topic	Summary of CM 41-08 for 2004/05	Advice for 2005/06	Paragraph reference
1. Access (gear)	Trawls or longlines or pots		
2. Catch limit	2 787 tonnes west of 79°20'E (see CM 32-14)	Yield according to scenarios, pending discussion	34–40
3. Season: trawl	1 December 2004 to 30 November 2005	Update	
3. Season: longline	1 May to 31 August 2005, with possible extension to 14 September for any vessel that has demonstrated full compliance with CM 25-02 in the 2003/04 season.	Update	
4. By-catch	Fishing shall cease if the by-catch limit of any species, as set out in CM 33-02, is reached.		
5. Mitigation	In accordance with CMs 24-02, 25-02 and 25-03.		
6. Observers	Each vessel to carry at least one scientific observer and may include one additional CCAMLR scientific observer.		
7. Data: catch and effort	(i) Ten-day reporting system as in Annex 41-08/A (ii) Monthly fine-scale reporting system as in Annex 41-08/A on haul-by-haul basis.		
8. Target species	For the purpose of Annex 41-08/A, the target species is *Dissostichus eleginoides* and the by-catch is any species other than *D. eleginoides.*		
9. Jellymeat	Number and weight of fish discarded, including those with jellymeat condition, to be reported. These catches count towards the catch limit.		
10. Data: biological	Fine-scale reporting system as in Annex 42-02/B. Reported in accordance with the Scheme of International Scientific Observation.		

References

Appleyard, S.A., R.D. Ward and R. Williams. 2002. Population structure of the Patagonian toothfish around Heard, McDonald and Macquarie Islands. *Ant. Sci.*, 14 : 364–373.

Appleyard, S.A., R. Williams and R.D. Ward. 2004. Population genetic structure of Patagonian toothfish in the West Indian Ocean sector of the Southern Ocean. *CCAMLR Science*, 11: 21–32.

Candy, S.G. 2004. Modelling catch and effort data using generalised linear models, the Tweedie distribution, random vessel effects and random stratum-by-year effects. *CCAMLR Science*, 11: 59–80.

Williams, R., G.N. Tuck, A.J. Constable and T. Lamb. 2002. Movement, growth and available abundance to the fishery of *Dissostichus eleginoides* Smitt, 1898 at Heard Island, derived from tagging experiments. *CCAMLR Science*, 9: 33–48.