APPENDIX N

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

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**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 2005/06 season was 2 584 tonnes (Conservation Measure 41-08) for the period from 1 December 2005 to 30 November 2006. The catch reported for this division as of 5 October 2006 was 1 825 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 four seasons the fishery has been prosecuted by both trawlers and longliners. The longline fishery was active from May to September 2006 and the trawl fishery was active throughout the whole season.

Table 1: Catch history for *Dissostichus eleginoides* in Division 58.5.2 (source: STATLANT data, catch and effort reports and SCIC reports).

Season	Regulated fishery						Estimated IUU catch (tonnes)	Total extraction (tonnes)
	Reported effort (number of vessels)	Catch limit (tonnes)	Reported catch (tonnes)					
			Longline	Pot	Trawl	Total		
1989/90			0	0	1	1	0	1
1991/92			0	0	0	0	0	0
1992/93			0	0	0	0	0	0
1994/95		297	0	0	0	0	0	0
1995/96		297	0	0	0	0	3000	3000
1996/97	2	3800	0	0	1927	1927	7117	9044
1997/98	3	3700	0	0	3765	3765	4150	7915
1998/99	2	3690	0	0	3547	3547	427	3974
1999/00	2	3585	0	0	3566	3566	1154	4720
2000/01	2	2995	0	0	2980	2980	2004	4984
2001/02	2	2815	0	0	2756	2756	3489	6245
2002/03	3	2879	270	0	2574	2844	1274	4118
2003/04	3	2873	567	0	2296	2864	531	3395
2004/05	3	2787	613	0	2170	2783	265	3048
2005/06*	3	2584	656	72	1097	1825	112	1937

* Fishing season ends 30 November

2. The spatial and temporal structure of the fishing for *D. eleginoides* is summarised in Table 2. The Working Group noted that no longline fishing has occurred in trawl ground B to date and that some longline fishing occurs in areas other than the known grounds but these are not appreciable at this stage. The pot fishery has only been experimental to date (72 tonnes).

Table 2: Spatial and temporal structure of the fishing activities for *Dissostichus eleginoides* in Division 58.5.2 including summary codes for the different elements of the fishery. f – fishery; s – season.

Gear type	Season			
	Approximate area (km^2)	Prior to longline	Longline	Post longline
Survey	85 694	-	f1	-
Trawl ground B	442	f2-s1	f2-s2	f2-s3
Trawl ground C	2 033	f3-s1	f3-s2	f3-s3
Longline ground B	442	-	f4-s2	-
Longline ground C	2 033	-	f5-s2	-
Longline ground D	16 760	-	f6-s2	-
Pot		-	-	-

1.2 IUU catch

3. An IUU catch of 112 tonnes was estimated in Division 58.5.2 in 2005/06, and this was the lowest since IUU fishing began in 1995/96.

1.3 Size distribution of catches

4. 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 sub-fisheries in Division 58.5.2 was estimated in WG-FSA-06/64. This work showed that longline gear is more able to catch older fish (>25 years), than trawl gear, which has high selectivity for 6-year-old fish, effectively declining to zero for fish older than 20. The length-frequency distribution for the longline fishery will therefore have larger fish because of gear selectivity, as well as the longline fishery occurring in deeper water where toothfish tend to be larger. As indicated in Table 2, the longline fishery does occur in similar locations to the trawl fishery. In those areas, the length of fish in the catch tend to be the same as for the trawl.

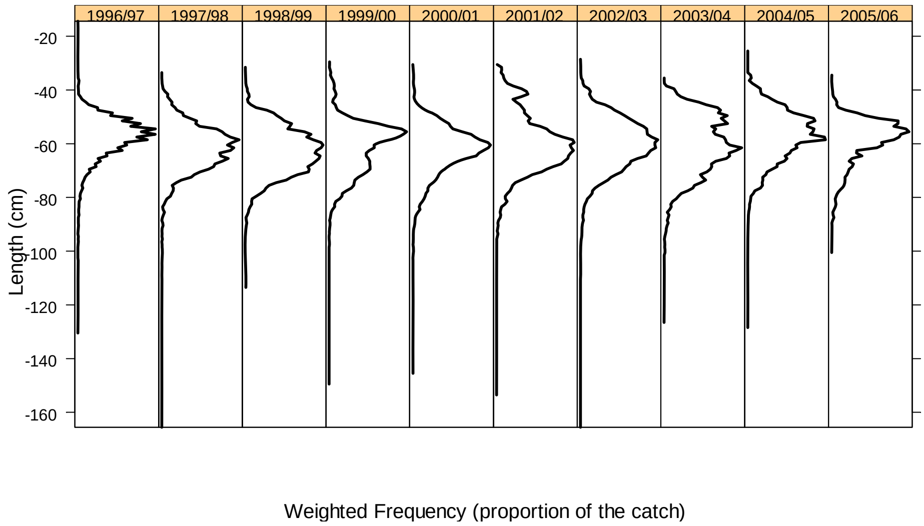


Figure 1: Catch-weighted length frequencies for *Dissostichus eleginoides* in Division 58.5.2 derived from observer, fine-scale and STATLANT data from the trawl fishery reported by 5 October 2006.

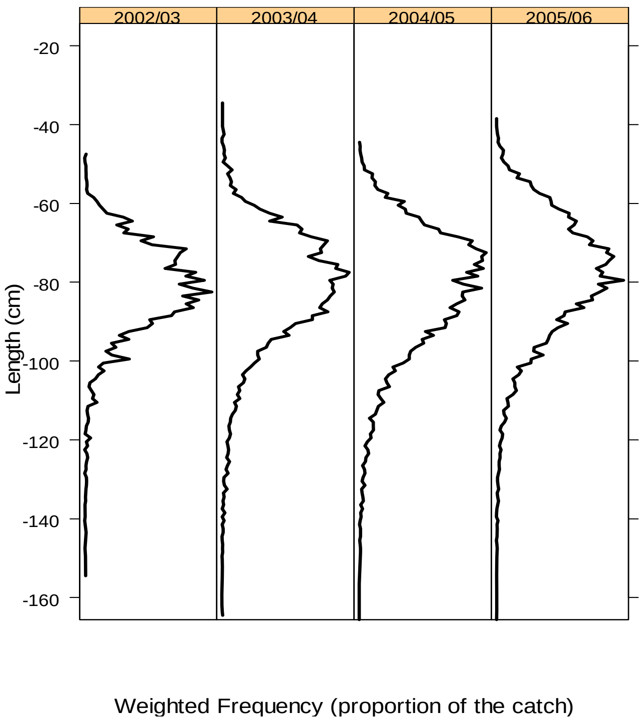


Figure 2: Catch-weighted length frequencies for *Dissostichus eleginoides* in Division 58.5.2 derived from observer, fine-scale and STATLANT data from the longline fishery reported by 5 October 2006.

2. Stocks and areas

5. *Dissostichus eleginoides* occurs throughout the Heard Island and 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 survey

designs described in detail in WG-FSA-06/44 Rev. 1. 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.

6. 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. Parameters and available data

3.1 Parameter values

<u>Fixed parameters</u>

7. The von Bertalanffy growth parameters from the 2005 assessment were replaced this year by a mean length-at-age vector based on the two-segment linear model described in WG-FSA-SAM-06/7. This model is based on validated age data (WG-FSA-05/60 and 05/61) and provides the best fit to length-at-age data from the trawl fishery. The Working Group recalled that estimates of length-at-age for fish greater than 20 years of age would improve with data from the longline fishery.

8. Current assessments of this stock assume a natural mortality of 0.13. 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. In 2005, the acceptable alternative range of natural mortality in the assessments was 0.13–0.165 year^{-1}. The default value of *M*, 0.13 year^{-1}, has been adopted for this year pending new analyses and/or the general considerations on natural mortality of this species.

9. The input parameters used in the assessment are included in Table 3.

Table 3: Input parameters for the assessment of *Dissostichus eleginoides* in Division 58.5.2.

Component	Parameter	Value	Units
Natural mortality	*M*	0.13	y^{-1}
Length-at-age (age in parentheses)	(1) 251.0 (2) 307.5 (3) 367.3 (4) 430.4 (5) 497.0 (6) 547.5 (7) 594.8 (8) 641.1 (9) 686.5 (10) 730.9 (11) 774.5 (12) 817.1 (13) 858.9 (14) 899.9 (15) 940.0 (16) 979.3 (17) 1017.8 (18) 1055.5 (19) 1092.5 (20) 1128.7 (21) 1164.1 (22) 1198.8 (23) 1232.9 (24) 1266.2 (25) 1298.9 (26) 1330.9 (27) 1362.2 (28) 1392.9 (29) 1423.0 (30) 1452.5 (31) 1481.3 (32) 1509.6 (33) 1537.3 (34) 1564.5 (35) 1591.1 (36) 1617.1 (37) 1642.6 (38) 1667.6 (39) 1692.1 (40) 1716.1 (41) 1739.6 (42) 1762.6 (43) 1785.2 (44) 1807.3 (45) 1828.9 (46) 1850.2 (47) 1870.9 (48) 1891.3 (49) 1911.2 (50) 1930.8		(year) mm
CV of length-at-age		0.1	
Length to mass	‘*a*’	2.59E-09	mm, kg
Length to mass	‘*b*’	3.2064	
Maturity (age based)	(11) 0.0 (12) 0.1667 (13) 0.3333 (14) 0.5000 (15) 0.6667 (16) 0.8333 (17) 1.0000		

10. Recruitment is modelled without assuming a stock-recruitment relationship. Variability in recruitment is estimated from the time series of estimates of abundance of cohorts arising from the surveys described below. Where year-class strength is estimated in the integrated assessment, recruitment variability is estimated from the vector of year-class strengths estimated in the model.

Recruitment surveys

11. Surveys of young toothfish have been undertaken since 1990 (Table 4). The survey design was consolidated in 2001 with the distribution of stations undertaken during a survey revised in 2003 (WG-FSA-04/74).

Table 4: Details of trawl surveys considered for estimating the abundance of juvenile *Dissostichus eleginoides* in waters less than 1 000 m deep in Division 58.5.2. AA = RV *Aurora Australis*, SC = FV *Southern Champion*, DT = demersal trawl.

Survey year	Group	Date	Vessel	Gear	Original design area (km^2)	Area following reassignment (km^2)	Hauls	Catch (tonnes)
1990	3	May	AA	DT	97 106	53 383	59	16
1992	4	Feb	AA	DT	55 817	38 293	49	3
1993	5	Sep	AA	DT	71 555	53 383	62	12
1999	2	Apr	SC	DT	84 528	80 661	139	93
2000	6	May	SC	DT	39 839	32 952	103	9
2001	1	May	SC	DT	85 170	85 694	119	45
2002	1	May	SC	DT	85 910	85 694	129	35
2003	7	May	SC	DT	42 280	42 064	111	13
2004	1	May	SC	DT	85 910	85 694	145	65
2005	1	May	SC	DT	85 910	85 694	158	21
2006	1	May	SC	DT	85 694	85 694	158	12

12. A report of the methodology and results of the Australian research survey in 2006 was tabled in WG-FSA-06/42 Rev. 1, along with the methods used in the survey. Australia undertook a trawl survey of Division 58.5.2 in May–June 2006 to estimate the density of juvenile toothfish (WG-FSA-06/42 Rev. 1). The survey used the same design as in the 2005 survey, with the exclusion of hauls in Shell Bank which are intended for assessing *Champsocephalus gunnari* abundance (Table 5).

Table 5: Dates and number of planned and completed hauls for each stratum in the 2006 random stratified trawl survey.

Stratum	Dates sampled	Area (km^2)	No. hauls allocated	No. hauls completed	No. valid hauls
Ground B	19–21 May	480.8	20	21	20
Gunnari Ridge	16–19 May	520.7	18	18	18
Plateau Deep East	10–14 May	13 120	30	30	30
Plateau Deep Northeast	23–27 May	15 090	15	15	15
Plateau Deep Southeast	5–6 May	5 340	10	10	10
Plateau Deep West	28 May–1 June	13 370	10	10	10
Plateau North	22–28 May	15 170	15	15	15
Plateau Southeast	16–25 May	10 404	30	33	30
Plateau West	29 May–3 June	10 440	10	10	10
All Strata	5 May–3 June	83 935.5	158	162	158

13. The allocation of stations to strata in the historical surveys was reviewed in 2006 (WG-FSA-06/44 Rev. 1). The Working Group agreed to the reassignment of stations according to the stratification of the survey design finalised in 2003 and noted the following groupings of surveys:

- Group 1 – the core surveys with the most reliable estimates of the abundance of young fish in the vicinity of Heard Island and McDonald Islands in waters less than 1 000 m deep in May–June. Random stratified trawl surveys undertaken by a commercial vessel – 2001, 2002, 2004, 2005, 2006.

- Group 2 – the first large-scale random stratified trawl survey for *D. eleginoides* in the of the region taking into account deep water but with an emphasis on fishing grounds. The survey was undertaken by a commercial vessel in April 1999.

- Group 3 – the first survey in the region, undertaken by the RV *Aurora Australis* – autumn 1990.

- Group 4 – the second survey in the region, undertaken by the RV *Aurora Australis* – winter 1992. This survey is considered incomplete for the purposes of estimating abundance of juvenile toothfish.

- Group 5 – the third survey in the region, undertaken by the RV *Aurora Australis* – spring 1993.

- Group 6 – the second survey in the region undertaken by a commercial vessel – 2000. This survey is considered incomplete for the purposes of estimating abundance of juvenile toothfish.

- Group 7 – a survey undertaken by a commercial vessel but not sampling all strata – 2003.

14. The time series of abundance-at-length for these surveys is given in Figure 3 based on a bootstrap resampling procedure and the Aitchison delta lognormal method (WG-FSA-06/64). In the past, there has been a question as to whether the Aitchison delta lognormal distribution is the appropriate error distribution for modelling mixtures (SC-CAMLR-XXIV, Annex 5, Appendix I, paragraphs 14 to 18). The results in WG-FSA-06/64 show little overall difference between estimates of abundance-at-length based on a bootstrap procedure and those based on the delta lognormal method, although the bootstrap procedure resulted in lower estimates of abundances-at-length in many cases. The Working Group encouraged further exploration into the reasons for the differences in the two methods.

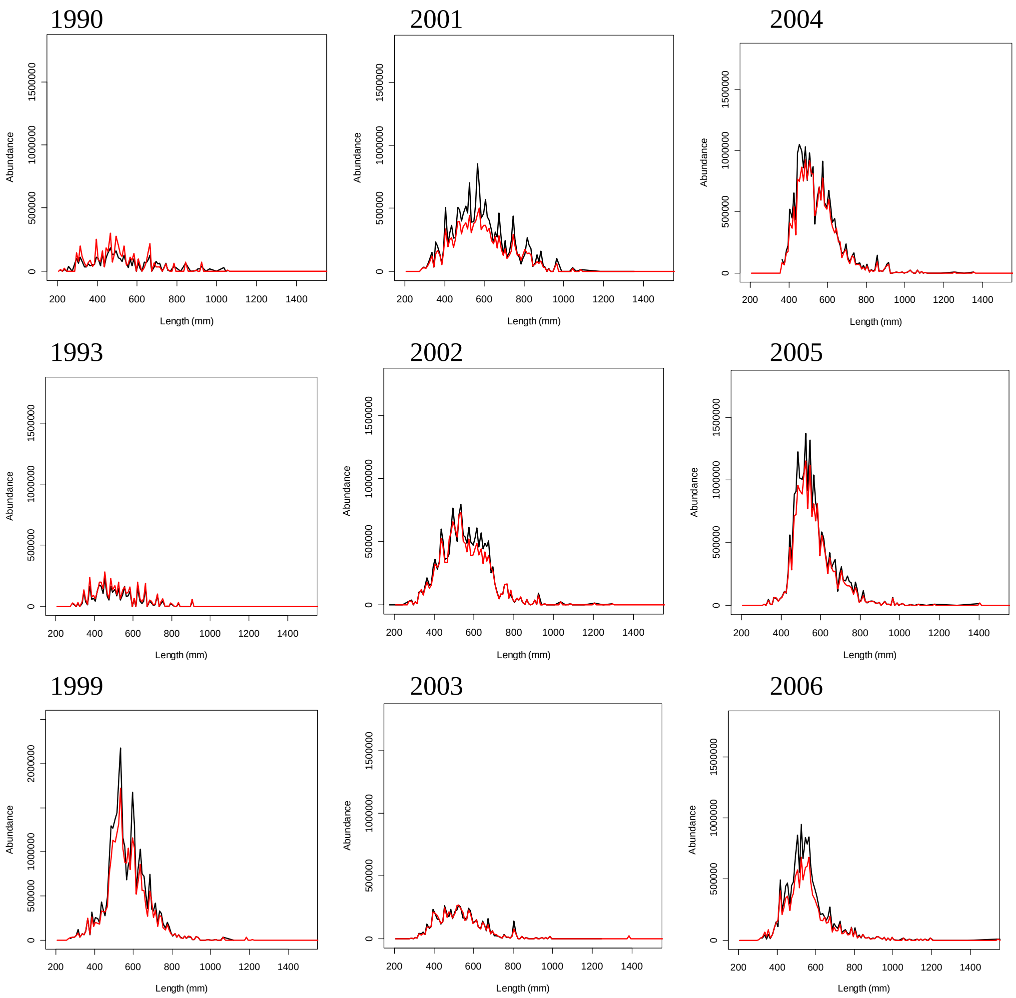


Figure 3: Abundances of *Dissostichus eleginoides* in Division 58.5.2 in 10 mm length bins estimated for each survey. Estimates are compared for two methods – bootstrap (red) and delta lognormal (black). Standard errors are not shown.

15. These surveys have been used to estimate the abundance of recruits, notably ages 3 to 6, using mixture analyses on each of the surveys independently. This was undertaken using the software CMIX (de la Mare, 1994; WG-FSA-02/61). Since beginning these analyses in 1996, WG-FSA has drawn the following conclusions about the use of the surveys in estimating recruitment using mixture analyses:

- At WG-FSA-03 it was agreed that recruitment data from the 1992 and 2000 surveys 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 *C. 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.

- The Working Group considered that fish younger than age 3 were not fully sampled by the trawl surveys. Cohorts older than age 6 may also be underestimated due to fishing on these cohorts.

- 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 that survey in this series.

- The estimate of the age-8 cohort from the 1999 survey should be included because the 1999 survey targeted *D. eleginoides*, including intensive sampling in areas where fish ages 5 and above were known to occur, and provided the only estimate of recruitment for this cohort.

16. Following these considerations, the estimates of density for cohorts from these surveys using mixture analyses are given in Table 6. Estimates of recruitments from these analyses were obtained by projecting each cohort to age 4 using the nominated natural mortality rate and, where multiple estimates of a cohort are present, obtaining an estimate of abundance for that cohort as an inverse variance weighted mean. The time series of recruitments was updated with the most recent survey and the reassignment of hauls to different strata. Results are in Table 7 based on a mean natural mortality rate of 0.13 year^{-1}. Values based on a mean *M* of 0.165 year^{-1} are also given for comparison to estimates in previous years.

Table 6: Estimated cohort strengths of *Dissostichus eleginoides*, from surveys undertaken in Division 58.5.2 from 1990 to 2006 determined by applying the Heard Island and McDonald Islands 2006 growth model to the length-density data resulting from the reassignment of random stratified trawl survey data as described in WG-FSA-06/44 Rev. 1. Observed (Obs.) and expected (Exp.) data are from the mixture analyses, the closeness of which indicates the quality of the fit. Time is the time of the survey relative to 1 December. The number in italics below each mean density is the standard error of the mean.

Survey year	Time	Area (km^2)	Obs.	Exp.	Mean density (n.km^{-2})					
					Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
1990	0.49	53 383	70.3	74.6	0.01	30.56	6.83	0.01	0.01	
					0.01	*8.96*	*7.13*	*0.01*	*0.01*	
1993	0.77	53 383	67.5	85.2	8.01	27.06	0.01	16.80	5.66	
					8.97	*12.90*	*0.01*	*19.26*	*21.84*	
1999	0.33	80 661	373.6	371.5	25.85	0.01	85.13	174.83	0.01	66.34
					7.63	*0.01*	*65.51*	*104.99*	*0.01*	*31.68*
2001	0.48	85 694	198.5	200.6	27.32	5.80	59.59	32.98	29.64	
					8.31	*15.56*	*35.74*	*47.78*	*30.16*	
2002	0.48	85 694	207.1	206.7	14.40	47.26	0.01	101.72	9.30	
					9.37	*17.19*	*0.01*	*42.56*	*37.05*	
2003	0.42	42 064	142.8	140.1	24.57	28.16	18.55	56.89		
					10.36	*23.40*	*30.15*	*21.35*		
2004	0.43	85 123	234.7	231.6	0.01	102.51	24.19	54.69		
					0.01	*28.86*	*66.00*	*74.47*		
2005	0.43	85 694	240.4	241.8	0.01	0.01	168.88	20.36		
					0.01	*0.01*	*29.37*	*29.24*		
2006	0.47	85 694	173.09	175.94	0.01	52.75	0.01	99.76		
					0.01	*11.17*	*0.01*	*18.49*		

Table 7: Updated recruitment series used in the assessment of *Dissostichus eleginoides* in Division 58.5.2 based on an M of 0.13 yr^{-1}, and data based on 0.165 yr^{-1} for comparison with assessments in previous years. In 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 are for selected values of *M*.

Year at age 4 birthday	Recruitment $M = 0.13\ yr^{-1}$	Recruitment $M = 0.165\ yr^{-1}$
1986	793	897
1987	697	760
1988	417 856	440 380
1989	1 736 990	1 799 870
1990	13 522	14 105
1991	534	569
1992	1 303 800	1 350 240
1993	338 888	338 888
1994	9 451 050	10 998 900
1995	1 251	1 406
1996	19 204 500	20 838 700
1997	6 297 720	6 783 180
1998	16 400	17 325
1999	4 022 340	4 154 530
2000	1 222 600	1 325 900
2001	3 075 120	3 128 240
2002	1 408 060	1 439 970
2003	11 344 900	12 024 200
2004	950	978
2005	3 487 980	3 606 800
2006	843	843
Mean	3 017 000	3 251 000
CV	1.627	1.647

CPUE series

17. The CPUE series were updated for the assessment in WG-FSA-06/64 for trawl grounds B and C based on the method by Candy (2004). These two series are for trawl grounds that are relatively confined (Table 2). The results are illustrated in Figure 4.

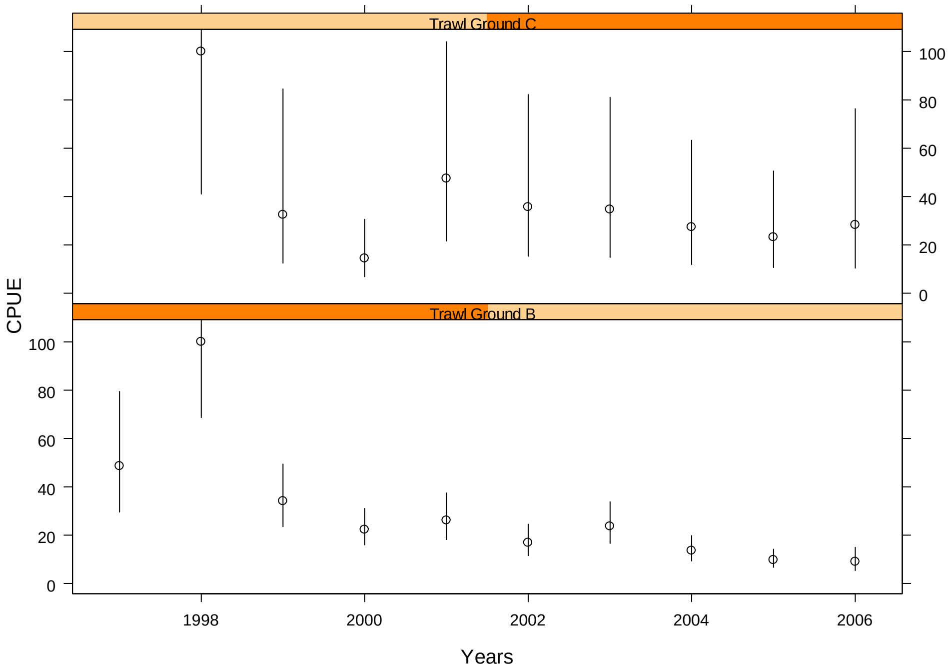


Figure 4: Estimated standardised CPUE for *Dissostichus eleginoides* in Division 58.5.2 from the GLMM for trawl grounds B and C. Bars correspond to ± one standard error of the estimate.

Tagging studies

18. A tagging study has been undertaken at Heard Island since 1998 (Williams et al., 2002). Tag releases and recoveries are shown in Table 8. It is anticipated that these data will provide important inputs to future integrated assessments using methods such as CASAL.

19. WG-FSA-06/64 described the methods estimating the tag shedding rate, tag detection probability and potential overdispersion of scanned fish in a tagging study.

20. The Working Group noted that the tagging program has been largely restricted to the main trawl ground B and is likely to underestimate the abundance of fish of this age/length range. At present, the assessment is unable to accommodate the small spatial extent of the program and the limited mixing from this ground to the other areas. These data are, therefore, not utilised in the integrated assessment.

21. The rate of tagging in other fishing grounds has been increased to broaden the area covered by the tagging program.

Table 8: Summary of tagging data for *Dissostichus eleginoides* in Division 58.5.2 for the fishing seasons 1998 to 2005.

(a) Releases and recaptures by year

Year of release:	1998	1999	2000	2001	2002	2003	2004	2005
Number released[1]:	749	704	1103	885	1164	1293	1200	1052
Year of recapture				Number recaptured				
1998	2							
1999	58	6						
2000	24	68	46					
2001	9	19	94	73				
2002	10	2	63	56	83			
2003	3	1	11	34	134	73		
2004	2	1	8	10	36	110	116	
2005	1	0	1	0	12	23	109	18
2006	0	1	1	0	2	8	13	28
Total recaptures	109	98	224	173	267	214	238	46

(b) Releases and recaptures by fishing ground indicating the spread of tags and the degree of mixing.

Area released:	Ground B	Ground C	Ground D
Number released[1]:	5639	1943	592
Area recaptured		Number recaptured	
Ground B	1122	0	0
Ground C	0	189	2
Ground D	4	6	17

[1] Number of tags released excludes tags for which recaptures occurred within the same fishing season (early, mid, late) within the same year of release and/or within 60 days of the release date.

Commercial catch–length composition

22. Random length samples were obtained from commercial catches and binned by observers in 10 mm bins. For use in the assessment these length-frequency data were aggregated into 100 mm bins. The length distributions are given as a proportion of catch in 100 mm length bins from 200 mm to 1 900 mm along with the associated sample size.

23. WG-FSA-06/64 described the methods for deriving these length distributions using a bootstrap procedure and for accounting for over-dispersion of the length-frequency data relative to a multinomial distribution by estimating an effective sample size for each distribution.

4. Stock assessment

24. The Working Group considered two different assessments for *D. eleginoides* in Division 58.5.2. The first assessment of long-term annual yield was based on the GYM

(WG-FSA-06/45 Rev. 1). The second assessment was an integrated assessment using CASAL (WG-FSA-06/64). The methods and results of the GYM assessment are summarised briefly for the purposes of comparing these results with the integrated assessment, which is described in more detail. Both methods were used to determine the long-term annual yield that satisfied the CCAMLR decision rule for toothfish.

4.1 Assessment of yield using the GYM

25. The parameters used in assessment of yield using the GYM are primarily those used in the assessment in 2005 (SC-CAMLR-XXIV, Annex 5), but including the adjustments in the parameters described above. The basic parameters used in the model are given in Table 9.

Table 9: Input parameters for assessment of long-term annual yield of Patagonian toothfish (*Dissostichus eleginoides*) in Division 58.5.2 using the GYM.

Category	Parameter	Values
Age structure	Recruitment age	4 years
	Plus class accumulation	35 years
	Oldest age in initial structure	55 years
Recruitment		See Table 6
Natural mortality	Mean annual M	0.13
Growth model	Length-at-age	See Table 3
Weight-at-age	Weight–length parameter – A	2.59E-09 (kg)
	Weight–length parameter – B	3.2064 (mm)
Maturity	L_{m50}	930 mm
	Range: 0 to full maturity	780–1080 mm
Spawning season		1 Jul–1 Jul
Simulation specifications	Number of runs in simulation	1001
	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	1 001
	Year prior to projection	1 985
	Reference start date in year	01/12
	Increments in year	24
	Vector of known catches	See Table 1
	Annual selectivities for fisheries	See Table 10
	Years to project stock in simulation	35
	Reasonable upper bound for annual F	5.0
	Tolerance for finding F in each year	0.000001

Table 10: Fishing vulnerabilities (selectivities) for *Dissostichus eleginoides* in Division 58.5.2 from 1995/96 to 2005/06 used in the GYM.

Season	Size/age (vulnerability)	Size/age units
1995/96	550 (0), 790 (1)	mm
1996/97	0.0 (0), 5.8 (0.0), 7.0 (1), 8.2 (1), 8.4+ (0)	Years
1997/98	0.0 (0), 4.9 (0.0), 5.8 (1), 11.1 (1), 13.7+ (0)	Years
1998/99	0.0 (0), 5.3 (0.0), 5.8 (1), 14.9 (1), 17.3+ (0)	Years
1999/00 to 2004/05	0.0 (0), 4.1 (0.0), 8.4 (1), 16.1 (1), 17.3+ (0)	Years
2005/06 and future	0.0 (0), 4.1 (0), 4.9 (0.14), 5.8 (0.5), 7.0 (0.8), 8.4 (0.9), 9.8 (1), 13.7 (1), 14.9 (0.9), 16.1 (0.85), 17.3 (0.4), 18.4+ (0.3)	Years

26. The projections of spawning stock biomass and spawning stock status are illustrated in Figure 5. The estimate of long-term annual yield that satisfies the CCAMLR decision rules for toothfish is 2 848 tonnes. This was triggered by the escapement rule. The probability of depletion for this yield is 0.055. The median value of the pre-exploitation median spawning biomass was 109 719 tonnes.

(a) (b)

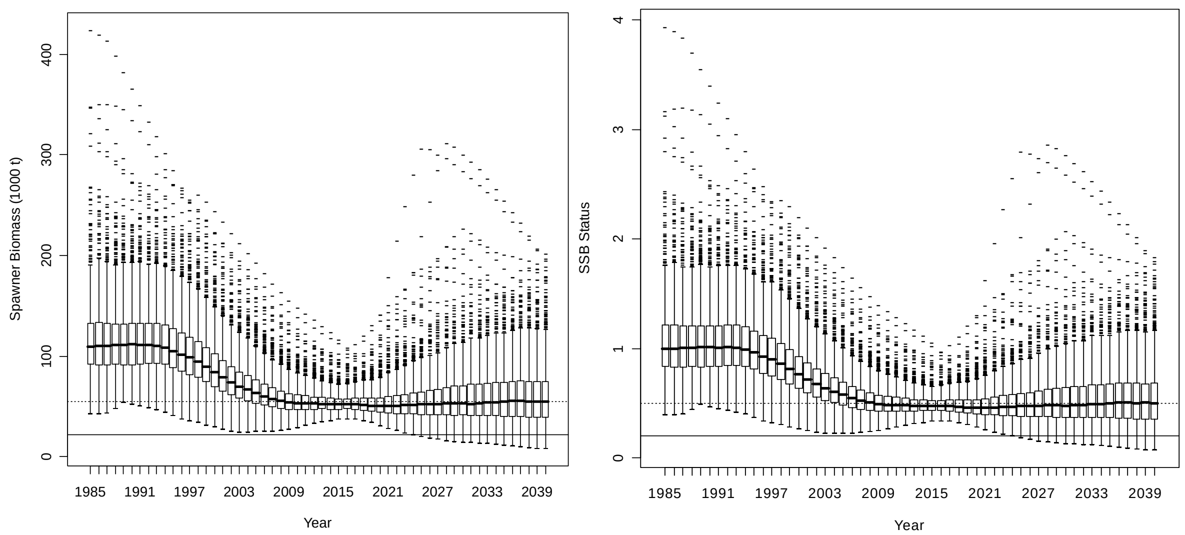


Figure 5: Boxplots showing the time series of spawning stock biomass (a) and status (b) (relative to pre-exploitation median spawning biomass in a given trial) in the 2006 GYM assessment of long-term annual yield for *Dissostichus eleginoides* in Division 58.5.2. Projections are for a yield of 2 850 tonnes.

4.2 CASAL model structure and assumptions

27. The CASAL population model used in the assessment of toothfish in Division 58.5.2 was a combined sex, single-area, three-season model. The annual cycle was defined in three seasons: 1 December–30 April, 1 May–30 September, 1 October–30 November. Mortality and growth occurred uniformly over the year. Fisheries were distributed in these seasons according to the spatial and temporal structure of the fisheries in Table 2. Spawning was timed to occur on 1 July. The time series for the assessment was 1982 to 2006 with future projections for another 35 years. The initial age structure assumed in the assessment was for a

constant recruitment at equilibrium. No stock-recruitment relationship was assumed. All fisheries were modelled with a double-normal plateau age-based selectivity function with the different selectivities for each gear*area combination. Selectivities were assumed to remain constant across seasons.

Model estimation

28. Exploratory analyses were undertaken using a point estimate Bayesian analysis (MPD: maximum posterior density). Initial exploration of uncertainty in parameter estimates, and its impacts on estimates of yield, used multivariate normal approximation based on the covariance matrix (e.g. WG-FSA-06/64). The final assessment accounted for uncertainty by implementing the MCMC method for extracting a sample from the parameters' posterior (data updated) probability distribution. These were estimated using a burn-in length of 500 000 iterations with every 3 000th sample taken from the next 3 million iterations (i.e. a final sample of length of 1 000).

Observation assumptions

29. Numbers-at-length for each survey were used as the primary observations. Observation error was incorporated by using the CV estimates from the bootstrap procedure. These were applied as lognormal errors in the likelihood. Surveys were grouped according to Table 4. Survey Group 1 was assumed to be the most accurate in estimating abundance of young fish and was assumed to have a catchability $q = 1$. The other survey groups each had a q estimated with the 1990 and 1993 surveys considered to have the same catchability. This is further considered under sensitivity trials.

30. The catch proportions-at-length data were fitted to the model-expected proportions-at-length composition using a multinomial likelihood with effective sample sizes calculated according to the method described above.

31. CPUE indices were assumed to be relative mid-season vulnerable biomass indices with an associated catchability constant q. A lognormal likelihood was used for the CPUE indices. Observation error was accounted for by using the CV estimates from the GLMM standardisation.

Process error and data weighting

32. Observations were primarily weighted using estimates of effective sample sizes and CVs. Process error of 0.1 was added to all surveys and was set to zero for the CPUE series. Sensitivity trials indicated that zero process error for survey group 1 gave improved likelihood profiles, which were used in the final assessment. This result is consistent with the expectation that survey group 1 is the most accurate series of surveys for estimating abundance of juvenile fish.

Penalties

33. Two types of penalties were included within the model. First, the penalty on the catch constrained the model from returning parameter estimates where the population biomass was such that the catch from an individual year would exceed the maximum exploitation rate. Second, an increasing penalty was applied according to the degree to which the mean of the vector of estimated year class strengths deviated from 1. Likelihood profiles showed that the penalties played little role in the final assessment.

Priors

34. The parameters estimated by the model, their priors, starting values for the minimisation, and their bounds are given in Table 11. In the model presented here, priors were chosen that were relatively non-informative.

Yield calculations

35. Yield estimates were calculated by projecting the estimated current status for each model under a constant catch assumption, using the rules:

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

2. Choose a yield, γ_2, so that the median escapement at the end of a 35-year period is 50% of the median pre-exploitation level.

3. Select the lower of γ_1 and γ_2 as the yield.

36. The depletion probability was calculated as the proportion of samples from the Bayesian posterior where the predicted future spawning stock biomass was below 20% of the pre-exploitation median spawning biomass in any one year, for each year over a 35-year projected period.

37. The level of escapement was calculated as the proportion of samples from the Bayesian posterior where the predicted future status of the spawning stock biomass was below 50% of the pre-exploitation median spawning biomass at the end of a 35-year projected period.

38. Random recruitments for the projection begin in 2006 and are derived from a lognormal recruitment function where mean recruitment is R_0 for the trial and recruitment variability is estimated from the time series of year-class strengths estimated in the model.

Table 11: Number (N), start values, priors and bounds for free parameters estimated for *Dissostichus eleginoides* in Division 58.5.2.

Parameter		N	Description	Prior	Lower bound	Upper bound	Start value
B_0		1		uniform-log	50 000	200 000	100 000
YCS		22	1983–2004	Lognormal mu = 1, CV = 1.1	0.001	100	1
Selectivities – surveys	S_L	9	Survey groups 1, 2, 3, 5, 7 Fisheries f2, f3, f5, f6	uniform	1	10	3, 3, 3, 3, 3 3, 3, 6, 6
	a_L	9	Survey groups 1, 2, 3, 5, 7 Fisheries f2, f3, f5, f6	uniform	2	20	5.29, 5.29, 5.29, 4, 4 5.29, 5.29, 7, 7
	da	9	Survey groups 1, 2, 3, 5, 7 Fisheries f2, f3, f5, f6	uniform	0.02	20	1, 1, 1, 1, 1 1, 1, 3, 3
	S_R	9	Survey groups 1, 2, 3, 5, 7 Fisheries f2, f3, f5, f6	uniform	1	12	9, 7.05, 7.05, 4, 4 7.05, 7.05, 8, 8
Survey group q		3	1999 survey 1990/1993 surveys 2003 survey	Lognormal mu = 1, CV = 1	1e-6	1 000	-
CPUE q		2	Trawl ground B Trawl ground C	uniform-log	1e-6	1 000	-

39. For a given trial, the pre-exploitation median spawning stock biomass is derived as the median of spawning biomass derived from 1 000 age structures drawn from the lognormally distributed recruitments derived above.

40. The future catch was divided amongst the fisheries according to the recent catch history as well as consideration of the expected trends in the use of different grounds. The following ratios were used:

Trawl ground B – season 1	0.36
Trawl ground B – season 2	0.30
Trawl ground C – season 2	0.06
Longline ground C – season 2	0.08
Longline ground D – season 2	0.2

Sensitivity analyses

41. Scenarios were based on the primary scenario in WG-FSA-06/64. The new scenarios focussed on exploring the assumptions surrounding the catchability *q* for the different survey groups. Survey group 1 (2001, 2002, 2004, 2005, 2006) retained a *q* = 1 (Survgrp1_q) as it was considered to provide the most accurate estimates of abundance of juvenile fish. Survey group 2 (1999) was considered to have a comparatively high estimate of abundance of juvenile fish compared to survey group 1. Consequently, it may have a different q to all other surveys (Survgrp2_q). Survey groups 3 (1990) and 5 (1993) were considered to have potentially underestimated the abundance of juvenile fish. They were given the same *q* which was estimated (Survgrps_q). Survey group 7 (2003) was also considered to have potentially underestimated the abundance of juvenile fish and had a separate *q* to be estimated (Survgrp7_q). The process error applied to each survey group was 0.1.

42. In order to examine the influence of the 1999 survey, the first scenario estimated *q* for survey group 2 (scenarios 1 and 4). The second scenario fixed this *q* to 1 (scenarios 2 and 3). As there is greater confidence in survey group 1 than the other surveys, its process error was reduced to zero in scenarios 3 and 4.

4.3 Model estimates

43. MPD estimates of the key parameters for the different scenarios are shown in Table 12.

Table 12: Input parameters and MPD estimates of the key parameters for the different scenarios.

Scenario	Survey group 2 (1999) *q*	Survey group 1 process error	Year-class series	B_0	B_{2006}
1	*q* = 1.13*	0.1	1983–2005	178 293	171 369
2	*q* = 1	0.1	1983–2005	160 394	146 167
3	*q* = 1	0.0	1983–2005	160 580	142 647
4	*q* = 1.19*	0.0	1983–2004	159 345	141 362

* Estimated

44. Reviews of the diagnostics and likelihood profiles showed that the likelihood surface is relatively flat in the vicinity of the MPD with a number of local minima in different parameters causing the fits to be variable. The likelihood profiles are best behaved for scenario 4 when *q* for the 1999 survey is estimated and the process error for the group 1 surveys is set at zero. The Working Group agreed to estimate yield based on the MCMC output for scenario 4. This scenario was also used to explore the uncertainty in key parameters.

45. The posterior densities from the MCMC for scenario 4 of estimated B_0 and the spawning stock biomass in 2006 are shown in Figure 6. The time series of spawning biomass is shown in Figure 7 and the estimated year-class strengths in Figure 8. These results indicate that, in general, year-class strength is likely to be highly variable but the uncertainty in a given year is large as well. The year-class strengths in three recent years are uncharacteristically low.

46. The posterior densities for the different survey group *q*'s (Figure 9) show that the view of the 1999 survey as overestimating the abundance of young fish is justified, although there remains uncertainty in the degree of overestimation. The 1990, 1993 and 2003 surveys have underestimated the abundance of fish.

47. The estimated selectivity ogives for each survey and fishery are shown in Figure 10. Clearly, different age ranges of fish are taken in the different fisheries with longlines taking the oldest fish and trawl surveys taking the youngest fish of those being caught.

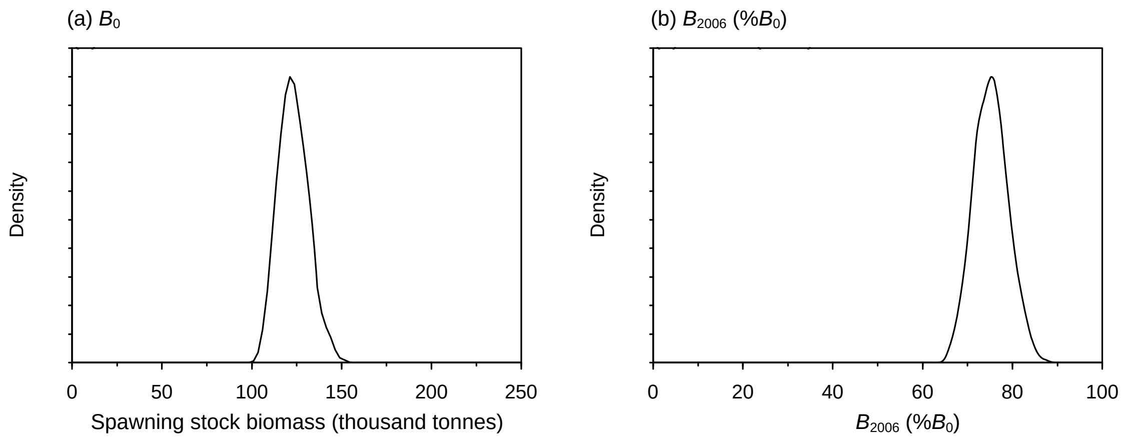


Figure 6: Posterior densities from the MCMC for scenario 4 of B_0 and the spawning biomass in 2006 as a percentage of B_0.

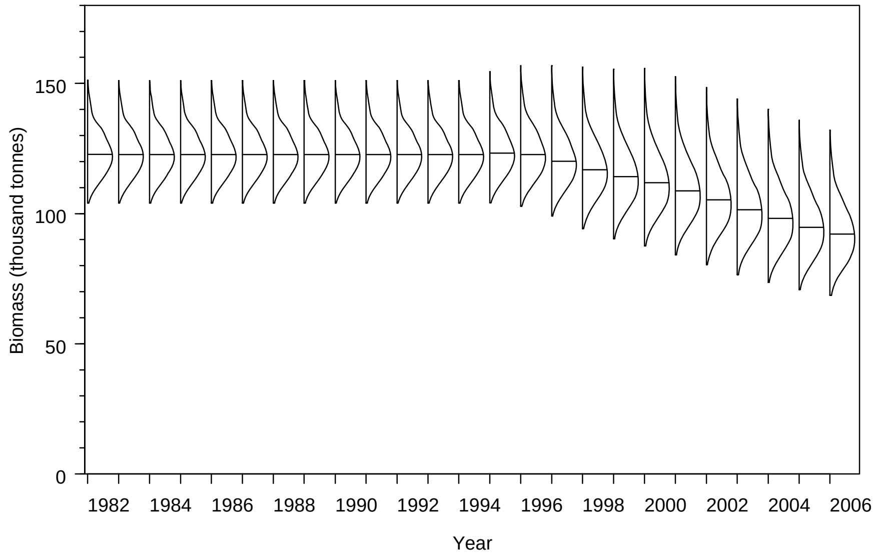


Figure 7: Smoothed posterior densities from the MCMC for scenario 4 of the spawning biomass in each year of the estimation period 1982–2006. (Horizontal lines indicate the median of the distribution.)

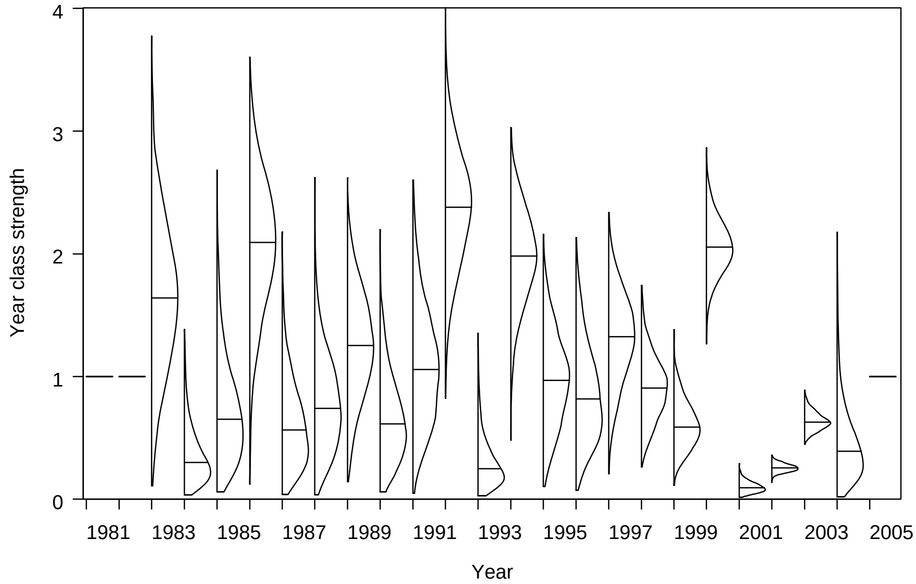


Figure 8: Smoothed posterior densities from the MCMC for scenario 4 of the year-class strength in each year of spawning for the estimation period. (Horizontal lines indicate the median of the distribution.) Medians without accompanying distributions show year classes not estimated.

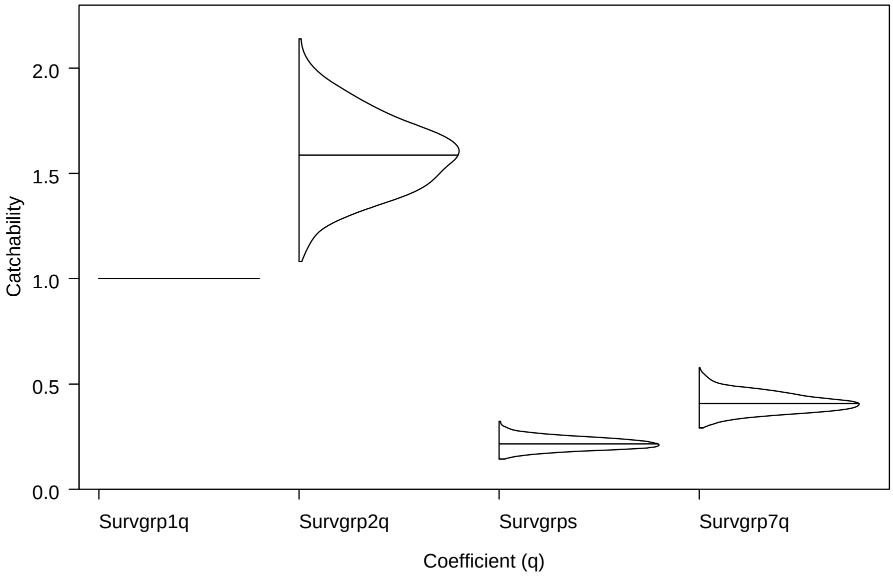


Figure 9: Smoothed posterior densities from the MCMC for scenario 4 of the catchabilities (*q*) of the surveys – Survgrp1_q (surveys 2001, 2002, 2004, 2005, 2006), Survgrp2_q (1999), Survgrps_q (1990, 1993), Survgrp7_q (2003).

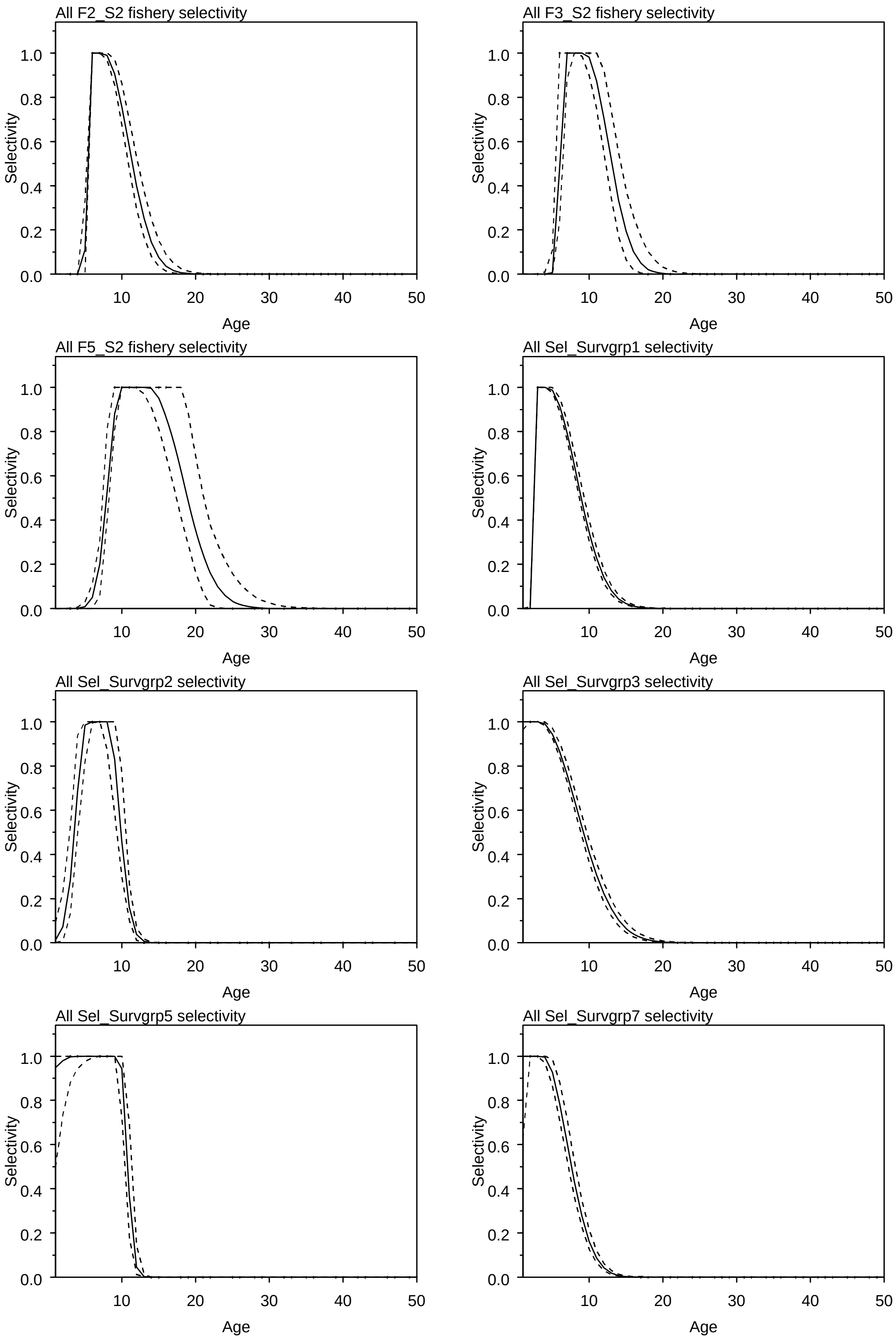


Figure 10: Estimated selectivity ogives for each survey group and fishery for scenario 4. (Solid lines indicate the median and dashed lines indicate the marginal 95% credible intervals.)

4.4 Estimation of yield

48. Projections based on the MCMC outputs were undertaken and used to estimate the long-term annual yield that would satisfy the CCAMLR decision rules. This resulted in a yield in the vicinity of 3 000 tonnes which was almost 200 tonnes greater than that estimated using the GYM. The Working Group noted that the mean recruitment (R_0) (median of the MCMC projected to age 4 = 2.879 million fish – Table 13) was in a similar range but less than that estimated using the GYM (3.017 million fish at age 4 – Table 7) and yet the median pre-exploitation spawning biomasses were in the vicinity of 125 000 tonnes using the CASAL results (Table 13 and Figure 11) compared to approximately 110 000 tonnes from the GYM results (Figure 5).

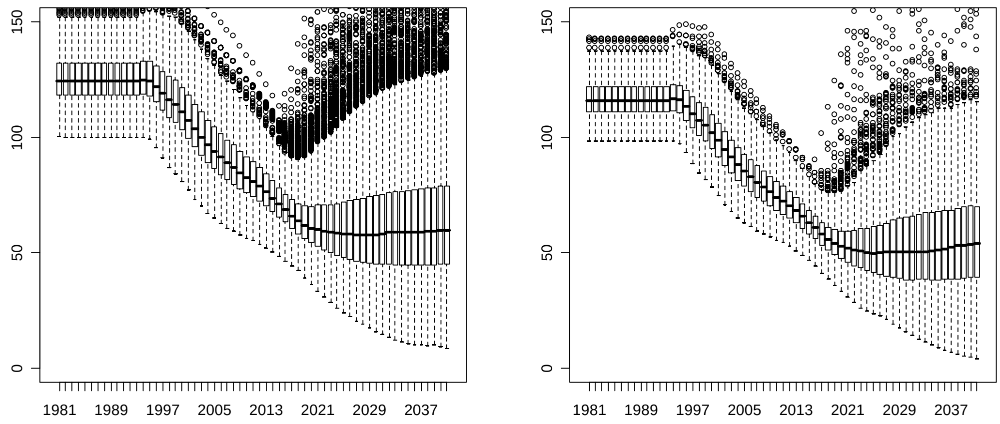
49. These differences in results were found not to be due to the different assessment methods alone. An important difference in the initial calculations using the CASAL results was that the age structure of the spawning stock had a plus class at 50 years rather than 35 years used in the GYM. Given the lengths-at-age continue to increase after age 35, then the CASAL population assumes that the fish continue to grow after that age resulting in a higher productivity (7% per recruit) of the spawning stock than originally assumed. This means that a greater catch can be taken from the stock before affecting the status of the spawning stock.

50. As there is no accurate estimation of lengths-at-age for fish in this age range, the Working Group agreed that the yield calculations should be repeated using a plus class at 35 years old. It was considered that such a change would not impact on the estimates of the parameters as the fishery selectivity ogives do not extend to fish older than 35 years. The B_0 parameter estimates in the MCMC outputs were converted to R_0 and the projections undertaken with the new age structure. The differences in stock status are shown in Table 13. The projections of spawning stock biomass and status are shown in Figure 11. The resulting estimate of yield is 2 427 tonnes under the escapement rule.

Table 13: Estimates of recruitment.

Trial	Parameter	Median	95% credible interval
	Median R_0	4.252 million (age 4 – 2.879 million)	3.723–5.455 million
50+	B_0	124 302 tonnes	108 848–159 475 tonnes
	B_{2006}	9 4079 (76%)	74 536–141 548 tonnes
35+	B_0	116 061	102 675–133 602 tonnes
	B_{2006}	85 481 (74%)	68 422–108 589 tonnes

(a) SSB



(b) Status (SSB/pre-exploitation median spawning biomass)

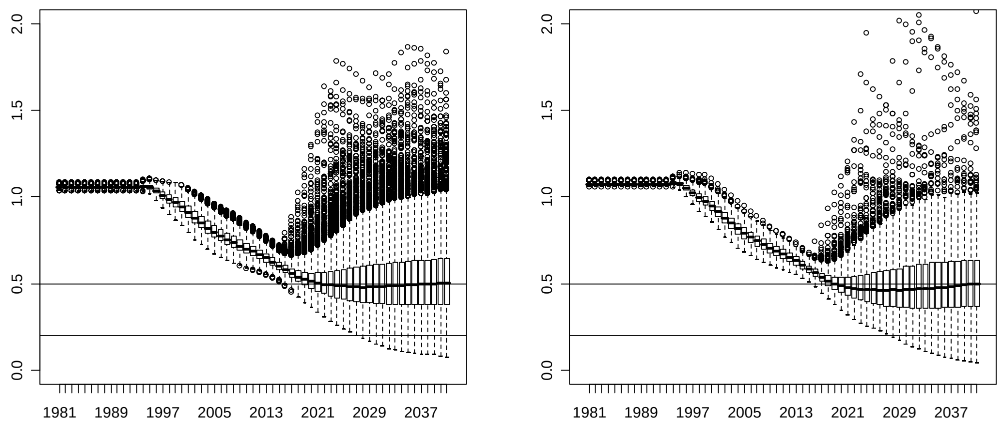


Figure 11: Boxplots of spawning biomass and status in 1 000 projections from 1 000 samples of parameters from the CASAL assessment for *Dissostichus eleginoides* in Division 58.5.2. Projections are for a long-term annual yield of 2 430 tonnes. Left and right panels are for populations with ages 1–50+ and 1–35+ respectively.

Table 14: (a) Comparison of median escapement and probability of depletion for a long-term annual yield of 2 430 tonnes.

Age range	Median escapement	Probability of depletion
1–50+	0.501	0.041
1–35+	0.499	0.062

(b) Long-term annual yield for the escapement and depletion decision rules applied to the 35 age-class projections.

Long-term annual yield – escapement rule	2 427 tonnes
Long-term annual yield – depletion rule	2 635 tonnes

51. The Working Group agreed that the CASAL assessment provides a foundation for advice on stock status and yield for toothfish in this division. The results arising from CASAL are similar to the GYM when undertaken with a similar model structure. The CASAL assessment now takes better account of the potential differences in selectivities and *q*'s of the different surveys. It also provides a better method for including data from the fishery. As such, the Working Group agreed that the estimate of yield from the CASAL assessment be used as a foundation for advice to the Scientific Committee.

4.5 Future research requirements

52. The Working Group noted the successful progress in developing an integrated assessment of *D. eleginoides* in CASAL. It agreed that further work could be undertaken to refine this assessment including examining:

(i) the relative weighting of different datasets;

(ii) whether or how the 2003 survey should remain being used in the assessment;

(iii) the appropriate population structure, including the number of age classes to be used in the model and whether the model could be developed as a two-sex model;

(iv) whether improvement in the model structure can be made to allow the inclusion of tagging data in the assessment;

(v) the relationships between the estimated parameters, including the potential interaction between the catchabilities, *q*, of the different datasets, particularly the surveys, and the other parameters.

53. The Working Group also recommended that:

(i) 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;

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

54. The Working Group encouraged the evaluation of the assessment and harvest strategy in Division 58.5.2 along with the further development and evaluation of management strategies for toothfish fisheries considered in general by the Working Group (see main report, section 12). It noted the estimated status of spawning stock at the beginning of the time series (B_0) is greater than the pre-exploitation median spawning biomass (i.e. status is greater than 1 in Figure 11), the latter of which is estimated from a lognormal distribution of recruitments based on mean recruitment, R_0, and the recruitment variability determined from the estimated time series of year-class strengths. This highlights how the quantities in decision rules may be different from the objectives. The Working Group encouraged evaluation of these alternative reference points in the decision rules (using estimates of B_0 or the pre-exploitation median spawning biomass as used here) to determine their robustness for meeting the underlying objectives of the Commission.

5. By-catch of finfish and invertebrates

5.1 By-catch removals

55. By-catch removals for the toothfish fisheries (longline and trawl) are detailed in Table 15 from fine-scale data. By-catch removals from observer data are detailed in WG-FSA-06/37 Rev. 1. By-catch in the toothfish 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 15: Catch history for by-catch species with catch limits for toothfish fisheries in Division 58.5.2. Rajids cut from the longlines and released are not included in these estimates. (Source: fine-scale data.)

Season	Catch limit (tonnes)	Reported catch (tonnes)		
		Longline	Trawl	Total
Macrourids				
1996/97			0	0
1997/98			0	0
1998/99			1	1
1999/00			4	4
2000/01			1	1
2001/02	50		3	3
2002/03	465	3	1	4
2003/04	360	42	3	45
2004/05	360	72	2	74
2005/06	360	26	1	27

(continued)

Table 15 (continued)

Season	Catch limit (tonnes)	Reported catch (tonnes)		
		Longline	Trawl	Total
Rajids				
1996/97			2	2
1997/98	120		3	3
1998/99			2	2
1999/00			6	6
2000/01	50		4	4
2001/02	50		3	3
2002/03	120	5	7	12
2003/04	120	62	11	73
2004/05	120	70	3	73
2005/06	120	17	0	17
Channichthys rhinoceratus				
1996/97			0	0
1997/98	80		0	0
1998/99	150		0	0
1999/00	150		0	0
2000/01	150		0	0
2001/02	150		1	1
2002/03	150	0	0	0
2003/04	150	0	1	1
2004/05	150	0	2	2
2005/06	150	0	0	0
Lepidonotothen squamifrons				
1996/97			0	0
1997/98	325		0	0
1998/99	80		0	0
1999/00	80		0	0
2000/01	80		3	3
2001/02	80		1	1
2002/03	80	0	0	0
2003/04	80	0	3	3
2004/05	80	0	2	2
2005/06	80	0	2	2
Other Species				
1996/97	50		4	4
1997/98	50		0	0
1998/99	50		1	1
1999/00	50		4	4
2000/01	50		5	5
2001/02	50		9	9
2002/03	50	0	5	5
2003/04	50	3	14	17
2004/05	50	3	5	8
2005/06	50	3	1	4

5.2 Assessments of impact on affected populations

56. 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.

57. No stock assessments of individual by-catch species were undertaken in 2006. 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

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

59. 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.

6. By-catch of birds and marine mammals

60. No seabird mortality has been reported in the four years to date of longline fishing in Division 58.5.2. Seabird interactions are reported in Table 16.

Table 16: Seabird mortality totals and rates (BPT: birds/trawl) and species composition of by-catch, recorded by observers in Division 58.5.2 trawl fisheries over the last six seasons. DIM – black-browed albatross; PRO – white-chinned petrel; DAC – Cape petrel (data from Appendix D, Table 14).

Season	Target species	BPT	Dead			Total dead	Alive (all species combined)
			DIM	PRO	DAC		
2001	*D. eleginoides* *C. gunnari*	<0.10				0	0
2002	*D. eleginoides* *C. gunnari*	<0.10				0	1
2003	*D. eleginoides* *C. gunnari*	<0.10	2	2	2	6	11
2004	*D. eleginoides* *C. gunnari*	<0.10				0	13
2005	*D. eleginoides* *C. gunnari*	<0.11	5	3		8	0
2006	*D. eleginoides* *C. gunnari*	0.00				0	0

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

62. In 2004/05 three elephant seal mortalities were reported in the longline fishery for toothfish (SC-CAMLR-XXIV, Annex 5, paragraph 7.47) and there was a single fur seal caught and released alive in the toothfish trawl fishery (SC-CAMLR-XXIV, Annex 5, Appendix O, paragraph 216).

63. In 2005/06 one Antarctic fur seal was reported entangled and released alive in the longline fishery (Appendix D, paragraph 33) and one leopard seal was caught and killed in the trawl fishery (Appendix D, paragraph 36).

6.1 Mitigation measures

64. 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

65. 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.

66. 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 2005/06 season and advice for 2006/07

8.1 Conservation measures

Table 17: Summary of provisions of Conservation Measure 41-08 for *Dissostichus eleginoides* in Division 58.5.2 and advice to the Scientific Committee for the 2006/07 season.

Paragraph and topic	Summary of CM 41-08 for 2005/06	Advice for 2006/07	Paragraph reference
1. Access (gear)	Trawls or longlines or pots		
2. Catch limit	2 584 tonnes west of 79°20'E (see CM 32-14)	2 427 tonnes	50
3. Season: trawl	1 December 2005 to 30 November 2006	Update	
longline	1 May to 31 August 2006, with possible extension to 30 September for any vessel that has demonstrated full compliance with CM 25-02 in the 2004/05 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.		

8.2 Management advice

67. The Working Group recommended that the catch limit for toothfish in Division 58.5.2 west of 79°20'E should be 2 427 tonnes for the 2006/07 fishing season.

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