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 2010/11 season was 2 550 tonnes (CM 41-08) for the period from 1 December 2010 to 30 November 2011. The catch of *D. eleginoides* reported for this division by October 2011 was 1 676 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 1996/97 to 2001/02. In recent seasons the fishery has been prosecuted by trawl, longline and pot. The longline fishery was active from April 2011 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 for past seasons, and catch and effort reports for current season, WG-FSA-11/10 and past reports for IUU catch).

Season	Regulated fishery						Estimated IUU catch (tonnes)	Total removals (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	0	0
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	621	0	2122	2744	265	3009
2005/06	3	2584	659	68	1801	2528	74	2602
2006/07	2	2427	601	0	1787	2387	0	2387
2007/08	3	2500	835	0	1445	2280	0	2280
2008/09	3	2500	1168	10	1287	2464	0	2464
2009/10	4	2550	1213	30	1215	2459	0	2459
2010/11*	3	2550	1122	33	521	1676	0	1676

* 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 a minor amount of longline fishing has occurred in trawl ground B to date and that some longline fishing occurs in areas other than the known grounds, and that this has increased with the addition of a second longline fishery in 2007/08. The pot fishery has only been experimental to date (68 tonnes in 2005/06, 13 tonnes in 2008/09, 30 tonnes in 2009/10, and 33 tonnes in 2010/11).

Table 2: Spatial and temporal structure of the main areas of historical fishing activity for *Dissostichus eleginoides* in Division 58.5.2, including summary codes for the different elements of the fishery (sub-fishery). f – sub-fishery; s – season.

Gear type	Season			
	Approximate area (km^2)	Prior to longline	Longline	Post longline
Survey[a]	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 A	16 678	-	f4_s2	-
Longline ground C	2 033	-	f5_s2	-
Longline ground D	90 625	-	f6_s2	-

[a] Random stratified trawl survey.

1.2 IUU catch

3. There has been no evidence of IUU fishing in Division 58.5.2 since 2006/07 (Table 1).

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-09/20, including large amounts of catch-at-age data for the first time (Welsford et al., 2009). This work confirmed previous modelling indicating that pot and longline gear is more able to catch older fish (>20 years) than trawl gear which has high selectivity for 6-year-old fish, effectively declining to zero for fish older than 20 years. 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.

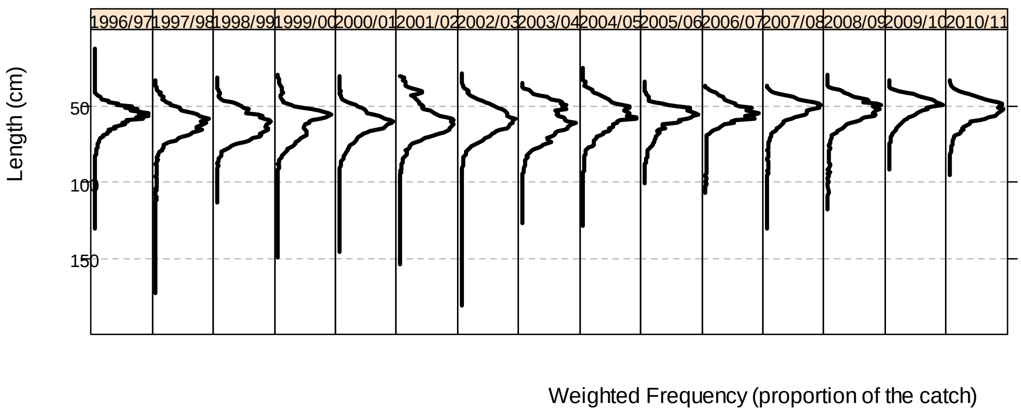

Figure 1: Catch-weighted length frequencies for *Dissostichus eleginoides* caught by trawl in Division 58.5.2 (source: observer, fine-scale and STATLANT data).

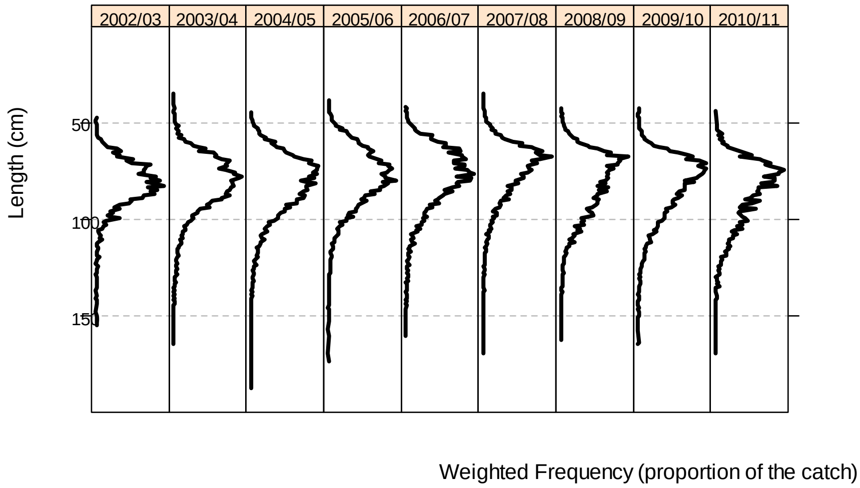

Figure 2: Catch-weighted length frequencies for *Dissostichus eleginoides* caught by longline in Division 58.5.2 (source: observer, fine-scale and STATLANT data).

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, and for the 2010 and 20011 surveys in WG-FSA-11/23. 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 1 800 m depth and catches larger fish than 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 (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; WG-FSA-07/48 Rev. 1), 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

Fixed parameters

7. With the exception of the natural mortality parameter, parameter estimates remained unchanged from those used in the Division 58.5.2 toothfish assessment as detailed in SC-CAMLR-XXVI, Annex 5, Appendix L and Candy and Constable (2008). Natural mortality was estimated from catch-at-age and aged mark-recapture data (Candy et al., 2011; and Candy 2011 for the simulation method) as M = 0.155, whereas a value of 0.13 was used previously.

8. A substantial amount of ageing of otoliths from the commercial catch, surveys, and mark–recapture experiments were undertaken in 2008 and 2009 (WG-FSA-09/21; WG-SAM-09/9). Tables of numbers of fish aged, length-frequency data, and effective sample sizes for catch-at-length and catch-at-age proportions by sub-fishery and year are given in WG-FSA-09/20. Since then a substantial number of fish have been aged for all survey years from 2006 to 2011 and abundance-at-age data were available for all these years.

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	0.155	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		(year) mm
CV of length-at-age	CV_{VB}	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 output of the CASAL integrated assessment and is determined largely from the variability across years in estimated year-class strength.

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). See also paragraph 5 above for recent survey designs.

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. Note: surveys since 2007 exclude Shell Bank.

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
2007	1	Jul	SC	DT	83 936	83 936	158	12
2008	1	Jul	SC	DT	83 936	83 936	158	4
2009	1	Apr–May	SC	DT	83 936	83 936	161	19
2010[a]	1	Apr	SC	DT	83 936	83 936	134	6
2010	1	Sep	SC	DT	83 936	83 936	158	9
2011	1	Mar–May	SC	DT	83 936	83 936	156	7

[a] Incomplete survey

12. Australia undertook two trawl surveys of Division 58.5.2 in 2010 (an incomplete survey in April 2010 and one in September 2010) and one trawl survey in March–May 2011 to estimate the density of juvenile toothfish (WG-FSA-11/23). The surveys used the same design as the 2007 survey, with the exclusion of hauls in Shell Bank which are intended for assessing *Champsocephalus gunnari* abundance.

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 (RSTS) undertaken by a commercial vessel – 2001, 2002, 2004–2011.

- Group 2 – the first large-scale random stratified trawl survey for *D. eleginoides* in 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 Working Group confirmed that the bootstrap resampling procedure for estimating annual abundance by length bin and the corresponding coefficients of variation is preferred over the Aitchison delta lognormal method (WG-FSA-06/64).

15. Survey abundance (abundance-at-length) was used as observations in the CASAL model for all years up to 2005. Sufficient aged fish from otoliths collected during the survey were available for the years 2006–2011 to determine abundance-at-age using survey- and year-specific ALKs. The method of calculating the CV for abundance-at-age data is described in WG-FSA-11/24.

<u>Tagging studies</u>

16. A tagging study has been undertaken in Division 58.5.2 since 1998 (Williams et al., 2002). Numbers of tag-releases and recaptures up to 2007 are given in Candy and Constable (2008). It is anticipated that, as the spatial extent of fishing effort is more widely distributed, these data will provide important inputs to future integrated assessments using methods such as CASAL.

17. The Working Group noted that the tagging program has historically been largely restricted to the main trawl ground B and is likely to underestimate the abundance of fish of this age/length range (Candy and Constable, 2008). 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, however, the tag data from trawl ground B were used to estimate natural mortality independently of CASAL as described in Candy et al. (2001).

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Commercial catch-at-age and catch-at-length data

18. Random length samples were obtained from commercial catches. 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 to 1 900 mm along with the associated sample size. Commercial catch-at-length data was used only for 2009–2011 for each sub-fishery since there were no aged fish available for these years. Candy (2008) described the profile maximum likelihood method used for accounting for over-dispersion of the length-frequency data relative to a multinomial distribution by estimating an effective sample size for each distribution.

19. Random length samples were combined with year-specific ALKs to obtain catch-at-age data for input as observations in CASAL for each year between 1997 and 2008. Proportions-at-length, that were combined with ALKs, were calculated specifically for each sub-fishery, fishing season and CASAL period (where more than one period was fished) (WG-FSA-11/24). The method of calculating effective sample sizes for catch-at-age data was described in WG-SAM-09/8 and tables of effective sample sizes are given in WG-FSA-11/24.

Standardised CPUE series

20. The method for standardising catch-and-effort time series data described in Candy (2004) was used to provide a CPUE series for each of the main trawl grounds (grounds B and C) and the longline fishery on ground D up to, and including, 2011 and these were used as a series of relative abundance observations in CASAL. The catchability constant (*q*_CPUE), treated as 'relative' observations, is an estimated parameter calculated separately for each of the three CPUE series.

4. Stock assessment

4.1 CASAL model structure and assumptions

21. The CASAL population model used in the assessment of toothfish in Division 58.5.2 was a combined-sex, single-area, three-season model (Candy and Constable, 2008). 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 2011 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 either a double-normal plateau or double-normal age-based selectivity function with the different selectivities for each gear × area combination. Selectivities were assumed to remain constant across seasons with the exception of the trawl ground B fishery which was estimated to have different selectivity parameters for the late season (s3) compared to the combined early seasons (s1, s2). In addition, for this fishery, separate selectivity parameters were estimated for 2006 and 2007 catches due to the generally smaller size of fish caught in these recent seasons compared to previous seasons. In WG-FSA-SAM-06/14 and WG-FSA-07/64 the

coefficient of variation, CV_{VB}, for the normal distribution for length-at-age, required to convert length frequencies to age frequencies in CASAL, was obtained independently of CASAL from the fit of the von Bertalanffy growth model to length-at-age data (Candy et al., 2007; WG-SAM-09/9) and was not estimated using CASAL. The updated model to that described in Candy and Constable (2008) is denoted *a2-2009-alkall-PE*. The Double Normal Plateau (DNP) function used previously for the main survey group (Group 1, years 2001, 2002, 2004–2011) was replaced by a Double Normal (DN) function since the plateau length, parameter a_2, was typically estimated to be very small (~ 0.1 yr), thus collapsing to a DN function and estimation of this parameter caused numerical problems when calculating the profile likelihood for B_0. The reduction in goodness of fit to the survey abundance data was not detectable when this parameter was dropped (i.e. set to zero) by fitting the DN function. CASAL allows a single ageing error matrix (AEM) as input that is used to 'smudge' predicted catch-at-age proportions in order to compare these to observed values. WG-FSA-09/21 described the method used to construct the AEM.

Model estimation

22. Analyses were undertaken using a point estimate Bayesian analysis (MPD: maximum posterior density). Exploration of uncertainty in parameter estimates, and its impacts on estimates of yield, used a multivariate normal (MVN) approximation based on the covariance matrix (e.g. WG-FSA-07/53). Non-informative (i.e. uniform) priors were used for all parameters. The MCMC method was not adopted for this assessment due to the problems identified in WG-FSA-SAM-06/14 of unacceptably high autocorrelation in MCMC samples even after a long burn-in and very heavy 'thinning' of the sequence of MCMC samples which has continued in subsequent revisions of the model. Until improvements can be made in the ability to obtain independent samples from the posterior distribution of the parameters using MCMC, the MVN method is recommended for this assessment. The MVN method is guaranteed to draw independent samples based on the MPD estimates and the Hessian matrix. Additionally, given that uniform priors are used for all parameters, the need to implement an MCMC sampling approach is not obvious since the validity of the quadratic approximation of the likelihood surface for an appropriately parameterised model is well established.

Observation assumptions

23. Numbers-at-length for all survey years up to 2005 and numbers-at-age for 2006–2011survey years were used as the primary observations. Observation error was incorporated by using the CV estimates (see paragraph 15). These were applied as lognormal errors in the likelihood. 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.

24. The catch proportions-at-age for 1997–2008 and proportions-at-length for 2009–2011 were fitted to the model-expected proportions using a multinomial likelihood with effective sample sizes calculated according to the method described in paragraph 19.

25. 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 described in Candy (2004).

Process error and data weighting

26. Observations were primarily weighted using estimates of effective sample sizes (ESS) and CVs. The ESS for catch-at-age and catch-at-length proportions were further adjusted (i.e. reduced) through a number of iterations by accounting for process error until ESS values (Candy 2008). For a small number of fishing years, the ESS values could not be determined due to insufficient years of data, so a value of either 200 or 400 was assigned. Process error for catch rate data was calculated using the method described in Appendix 2 of Candy and Constable (2008). The process error was estimated to be greater than zero only for the f2 CPUE series and at the final iteration the process error CV estimate (i.e. 'cv_process_error' for lognormal distributed data) was 0.147. No process error component was calculated for the abundance-at-age and abundance-at-length data to give extra statistical weight to the survey data (Francis 2011).

Penalties

27. 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.

Priors

28. The parameters estimated by the model, their priors, starting values for the minimisation and their bounds are given in Table 5. In the model presented here, uniform priors were chosen that are non-informative given CASAL's Bayesian implementation.

Yield calculations

29. 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.

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

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

Table 5: 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 values
B_0		1		Uniform	50 000	250 000	100 000
YCS		24	1983–2007	Uniform	0.001	100	1
Selectivities – surveys	S_L	15	Survey Groups 1, 2, 3, 5, 7 Fisheries f2, f2_s3, f2_s2r, f3, f5, f6, f7, f8, f9, f10	Uniform	1	10	1, 1, 1, 1, 1 1, 1, 1, 1, 3, 3, 3, 3, 3, 3
	a_1	15	Survey Groups 1, 2, 3, 5, 7 Fisheries f2, f2_s3, f2_s2r, f3, f5, f6, f7, f8, f9, f10	Uniform	2	20	4, 4, 4, 4, 4 4, 4, 4, 3, 6, 6, 6, 6, 6, 6
	a_2	10	Survey Groups 1, 2, 5 Fisheries f3, f5, f6, f7, f8, f9, f10	Uniform	0.02	20	2, 4, 4 4, 7, 7, 7, 7, 7, 7
	S_U	15	Survey Groups 1, 2, 3, 5, 7 Fisheries f2, f2_s3, f2_s2r, f3, f5, f6, f7, f8, f9, f10	Uniform	1	12	6, 4, 7.5, 4, 7.5 7.5, 7.5, 7.5, 4, 8, 8, 8, 8, 8, 8
Survey group q		3	1999 survey 1990/1993 surveys 2003 survey	Uniform	1e-6	1 000	-
CPUE q		3	Trawl ground B Trawl ground C Longline ground D	Uniform	1e-6	1 000	-

32. Random recruitments for the projection begin in 2009 and are derived from a lognormal recruitment function where mean recruitment is R_0 for the trial and recruitment variability was estimated from the fit of a LMM to the MVN sample of historic recruitments (1986 to 2007).

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

34. For removals not included in the 2010/11 season due to unverified catch and catch still to be taken, the anticipated remaining catch for CASAL season 3 was added to that shown in Table 1 to bring total removals to 2 550 tonnes.

35. The future catch was divided amongst the fisheries according to the 2010 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	0.055
Trawl ground B – season 2	0.055
Trawl ground B – season 3	0.088
Trawl ground C – season 2	0.037
Trawl ground E – season 2	0.062
Longline ground C – season 20.198	
Longline ground D – season 2	0.201
Longline ground E – season 2	0.201
Longline ground F – season 2	0.055
Pot – season 1	0.048.

4.3 Model estimates

36. MPD estimates of the key parameters for the different scenarios are shown in Tables 6 and 7.

Table 6: Results of assessments of stock status of *Dissostichus eleginoides* in Division 58.5.2 using CASAL. B_0 is the MPD estimate of the pre-exploitation median spawning biomass, SSB status 2011 is the ratio of the CASAL prediction of SSB in 2011 to B_0, R_0 is the MPD estimate of mean age-1 recruitment prior to exploitation (1981), and CV_R is the coefficient of variation of the annual recruitment series (1996–2008).

Model	Description	B_0 (SE)	SSB status 2009	R_0 (million)	CV_R
a2-2011-alkall-PE	Update model *a2-2009-alkall* in WG-FSA-09/20, new *M*	86 400 (1 915)	0.629	5.765	0.78

Table 7: Estimates of selectivity parameters in Survey Group 1 and catchability of the other survey groups in assessments of stock status of *Dissostichus eleginoides* in Division 58.5.2 using CASAL (see Candy and Constable, 2008).

Model	Selectivity parameter estimates Survey Group 1 (SE below estimate)			Survey group q-estimate[a]			
	s_L	s_U	a_1	SG3 (1990)	SG5 (1993)	SG2 (1999)	SG7 (2003)
a2-2011-alkall-PE	0.9449 (0.1006)	4.8183 (0.0908)	3.8640 (0.1290)	0.187	0.187	1.982	0.748

[a] Catchability q set to 1 for Survey Group 1 (2001, 2002, 2004–2011).

37. Figure 3 shows the fitted selectivity functions for each sub-fishery while for the trawl ground B fishery an extra selectivity function (*Sel_f2_s2r*) was fitted for recent years. These curves show the distinct differences in how the surveys, trawl and longline activities overlap with the stock, notably that the surveys observe the youngest fish (less than age 5), the trawl fishery concentrates on larger but pre-adult fish, and the longline fishery concentrates on larger fish again, including mature fish. The notable exception is for the last two fishing seasons in trawl ground B for which the fitted selectivity function (*Sel_f2_s2r*) indicates that fish younger than 5 years have been selected.

38. Figure 4 shows the fit to the Survey Group 1 (SG1) abundance-at-length data from the RSTS. Fitted values in the figure appear to show a consistent underestimation of abundance for length bins that contain most of the fish compared to observed values, indicating that the abundance of young fish, indicated by other datasets, is not as high as that observed in the surveys. Figure 5 shows the fit in that model for the abundance-at-age data for 2006 -2011. Figure 6 shows total survey abundance (a) and biomass (b), aggregated over length bins and age classes showing single SE bars and fitted regression. Note: survey abundances are used in CASAL as abundance-at-length and abundance-at-age as shown in Figures 4 and 5 respectively.

39. Figures 7 to 10 show the fit to the commercial length-frequency data for the main trawl fisheries (grounds B and C) and the two main longline fisheries (grounds C and D) for the main fishing season (s2) for each sub-fishery.

40. Figure 11 shows the standardised CPUE series versus the fitted trend from the CASAL model for the main trawl ground (ground B). Note that the standardised CPUE series was obtained from the haul-by-haul data combined across all three CASAL seasons based on the standardisation model given by Candy (2004) and updated using data up to, and including, 2011. All three standardised CPUE series made a negligible contribution to model parameter estimation as demonstrated in Figure 12.

41. Figure 12 shows the profile of the objective function value minimised by the fit (i.e. equivalent to twice the negative log-likelihood) across values of the B_0 parameter (i.e. this parameter is held constant at the profiled value while all other model parameters are jointly estimated) for each major source of data. The MPD estimate (i.e. corresponding in this case to the maximum likelihood estimate) of B_0 is also shown and appears as the minimum point of the profile. This indicates estimation is well behaved with respect to B_0, with the MPD estimate at 86 400 tonnes.

42. Figure 13 shows the estimated year-class strengths for the period 1982 to 2007. Year-class strength was fixed at 1 for the remaining years of the historical fishery (i.e. 1981–1983 and 2008–2010) since the data do not allow these year classes to be estimated reliably (or sensibly for the 2008–2010 period). Figure 14 shows the estimated historical recruitment series using year random effect estimates obtained from the fit of the LMM to the log of number of age-1 recruitments for size-1 000 sample from the MVN distribution for the set of estimated parameters when processed through CASAL's projection procedure. The estimate of yearly process error CV from the fit of the LMM was 0.78. This value was used for the forward projections using the random lognormal recruitment option in CASAL.

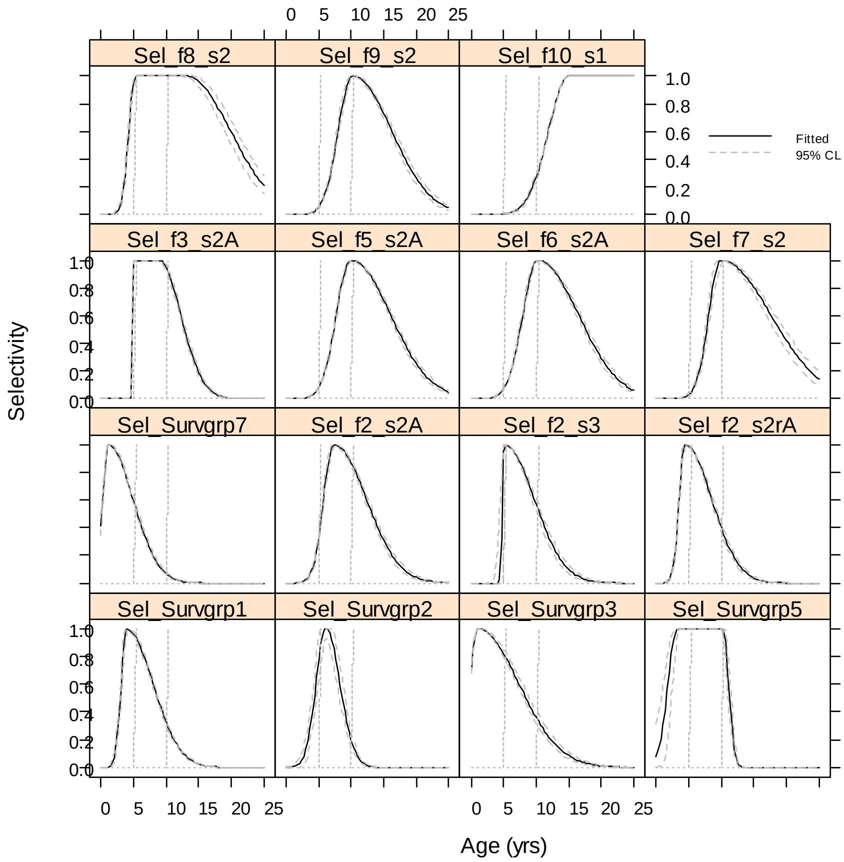


Figure 3: Double-normal-plateau (DNP) and double-normal (DN) fishing selectivity curves from fit of model a2-2011-alkpool-PE showing 95% confidence bounds obtained from the MVN sample. Panel headings: Survgrp1 (survey years 2001, 2002, 2004- 2011), Survgrp2 (survey year 1999), Survgrp3 (survey year 1990), Survgrp5 (survey year 1993), Survgrp7 (survey year 2003), f2_s2, f2_s3 (trawl ground B, seasons 1 and 2, season 3), f2_s2r (trawl ground B 2006, 2007 all seasons), f3_s2 (trawl ground C, all seasons), f5_s2 (longline ground C, season 2), f6_s2 (longline ground D, season 2), f7_s2 (longline ground E, season 2), f8_s2 (trawl ground E, all seasons), f9_s2 (longline gound F, season 2), f10_s1 (pot, seasons 1 and 2). Reference lines are shown at ages 5 and 10.

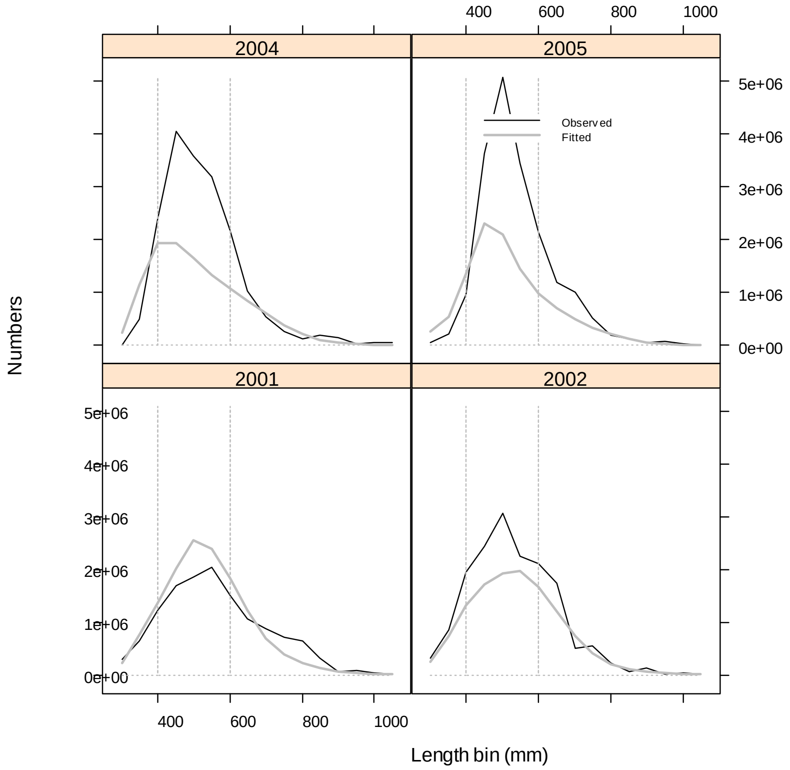


Figure 4: Model fits to Survey Group 1 abundance-at-length data from the RSTS with observed (black line) and expected numbers (grey line) and reference lines at 400 and 600 mm.

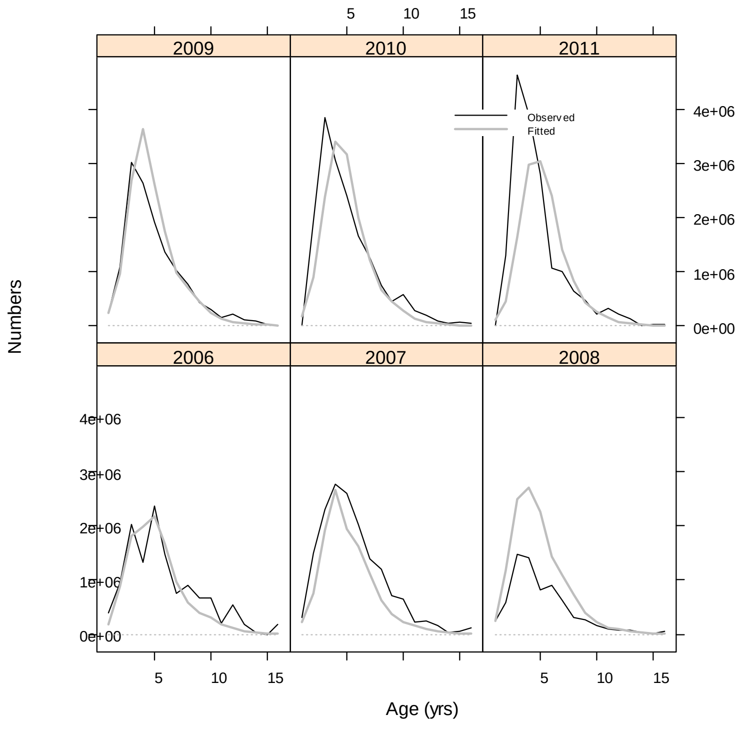
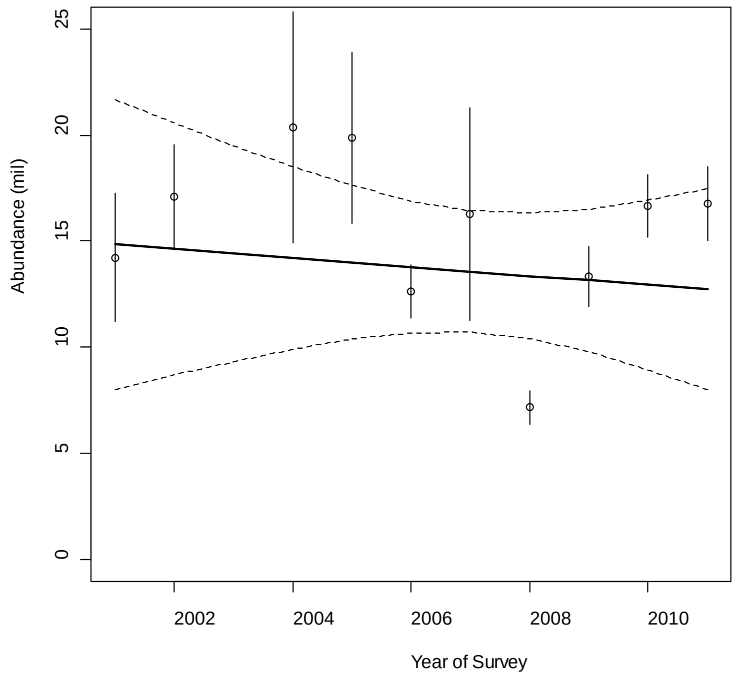


Figure 5: Model fits to to Survey Group 1 abundance-at-age data from RSTS with observed (black line) and expected numbers (grey line).

(a)



(b)

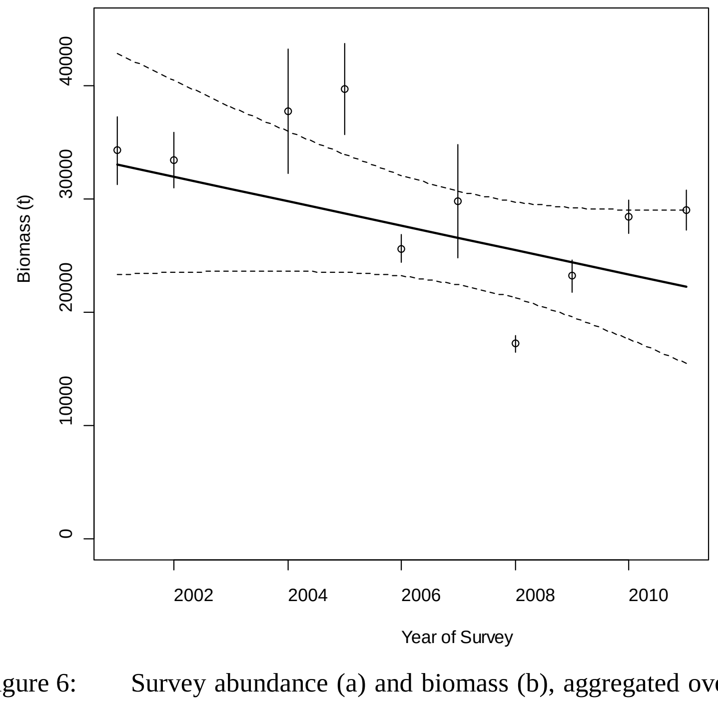
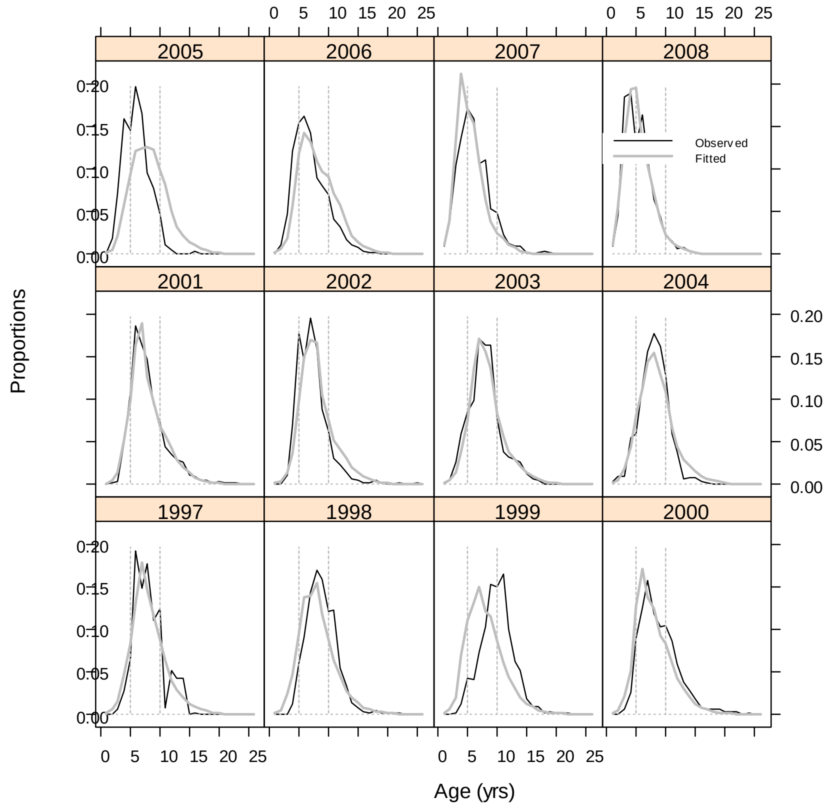


Figure 6: Survey abundance (a) and biomass (b), aggregated over length bins and age classes showing single SE bars and Dashed lines show the 95% confidence bounds on the regression. Note the slope of the fitted line is not significantly different from zero. Note: survey abundances are used as observations in CASAL as abundance-at-length and abundance-at-age as shown in Figures 4 and 5 respectively.

(a)



(b)

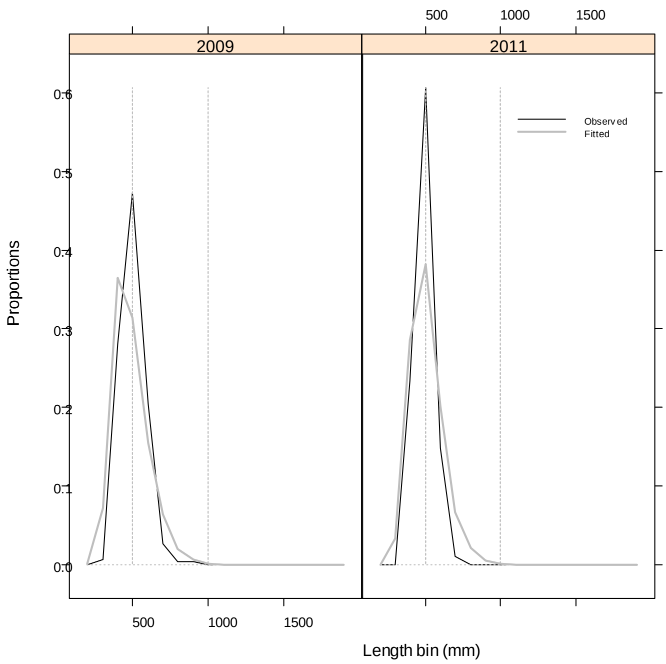


Figure 7: Model fits to (a) catch-at-age proportions with reference lines at ages 5 and 10, and (b) catch-at-length proportions with reference lines at 500 and 1 000 mm, for trawl ground B, season 2 (Fishery f2_s2) .

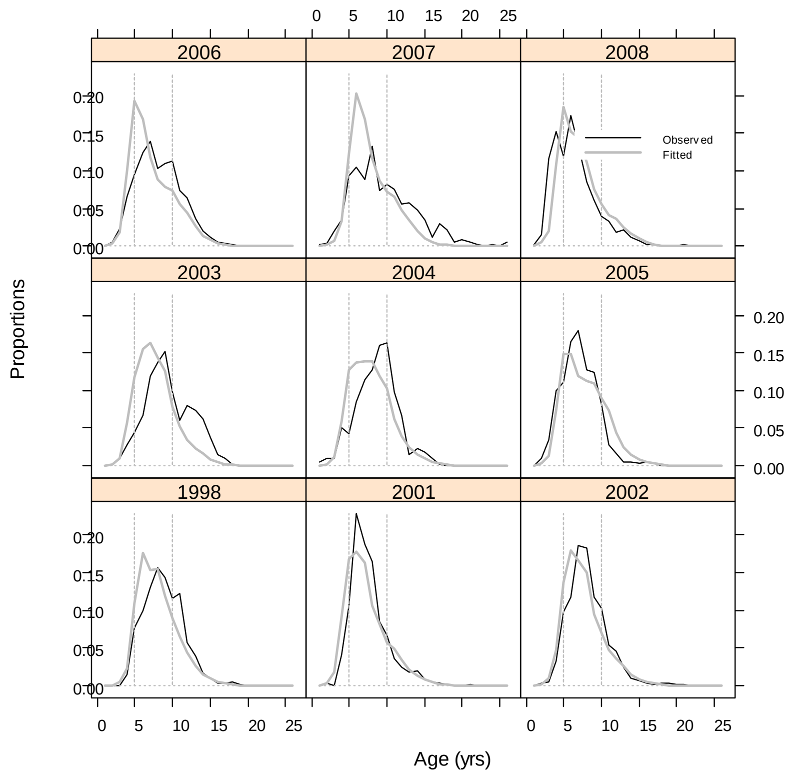
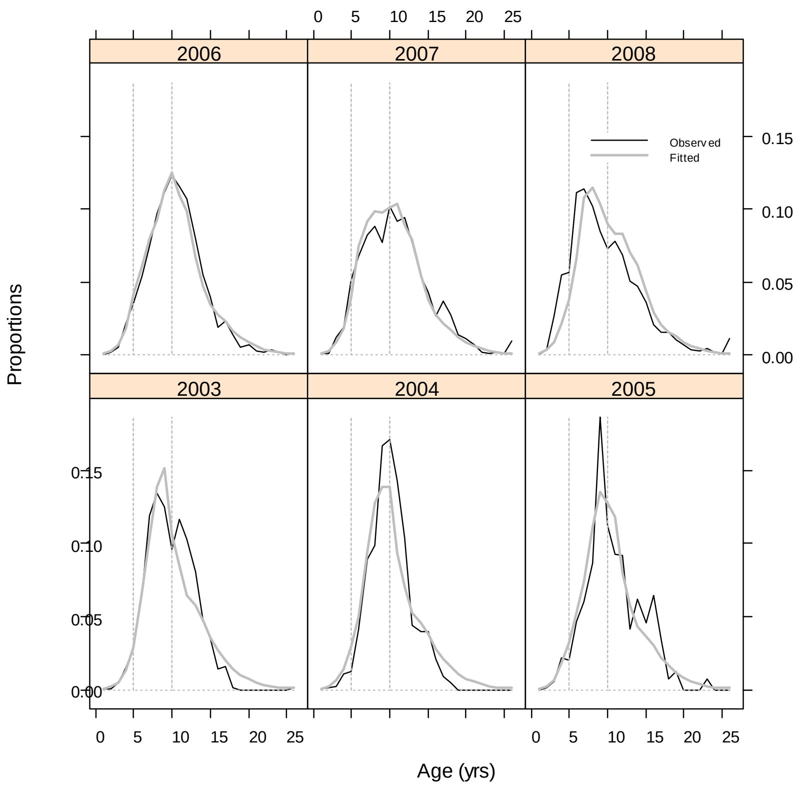


Figure 8: Model fits to catch-at-age proportions with reference lines at ages 5 and 10for trawl ground C, season 2 (Fishery f3_s2).

(a)



(b)

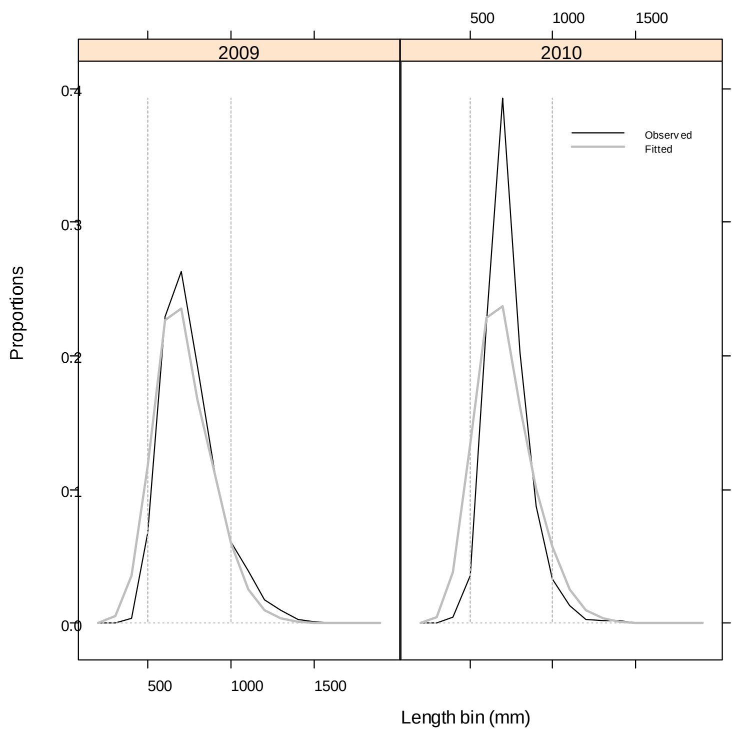
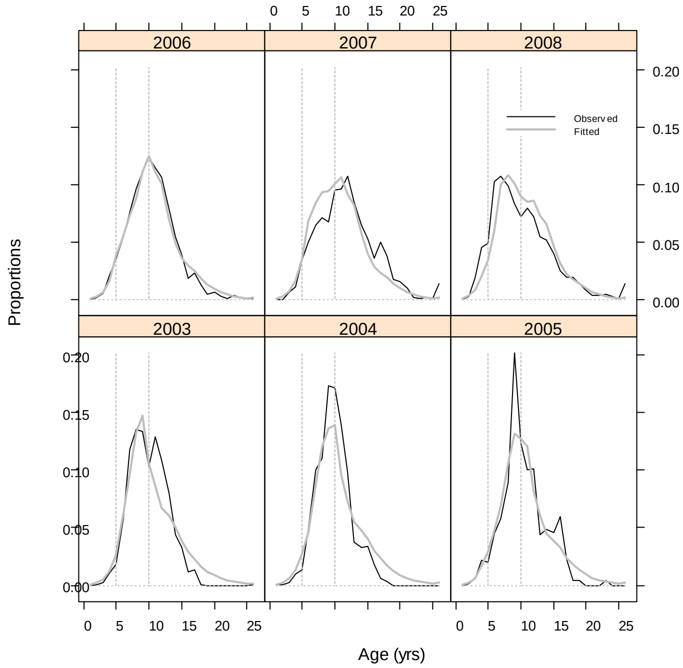


Figure 9: Model fits to (a) catch-at-age proportions with reference lines at ages 5 and 10, and (b) catch-at-length proportions with reference lines at lengths 500 and 1000 mm for longline ground C, season 2 (Fishery f5_s2).

(a)



(b)

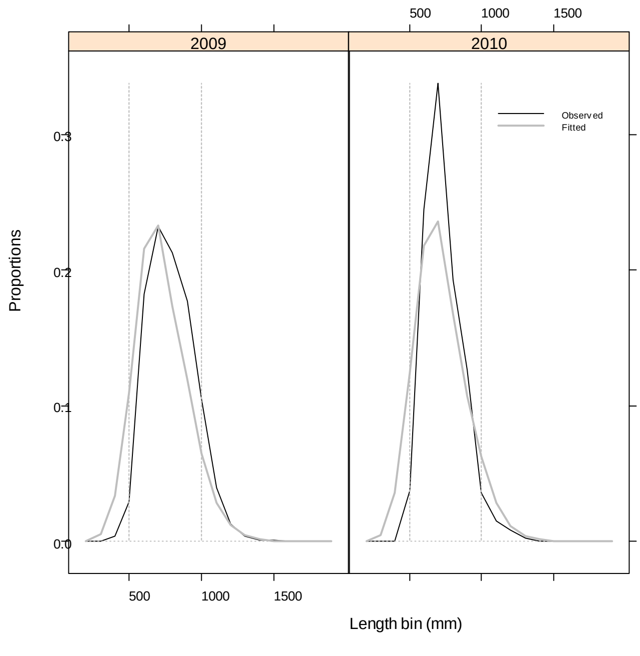


Figure 10: Model fits to (a) catch-at-age proportions with reference lines at ages 5 and 10, and (b) catch-at-length proportions with reference lines at lengths 500 and 1 000 mm for longline ground D, season 2 (Fishery f6_s2).

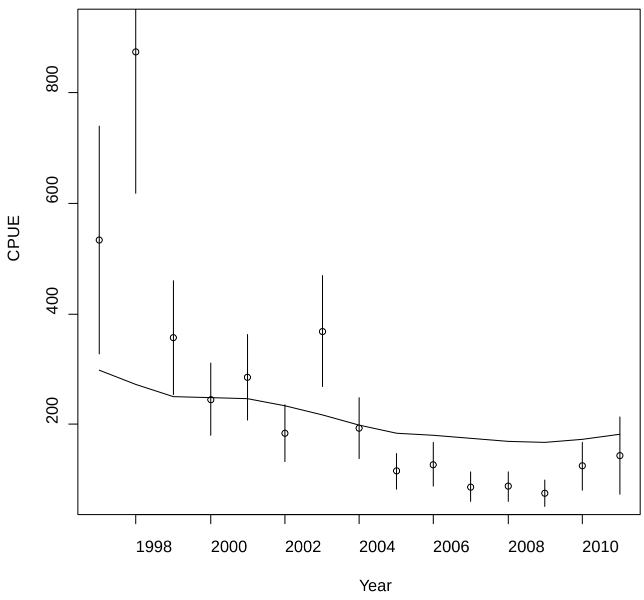


Figure 11: Estimated CPUE series from GLMM model for trawl ground B (f2) (circles) with bars corresponding to ± one standard error of the estimate and the fitted series (line).

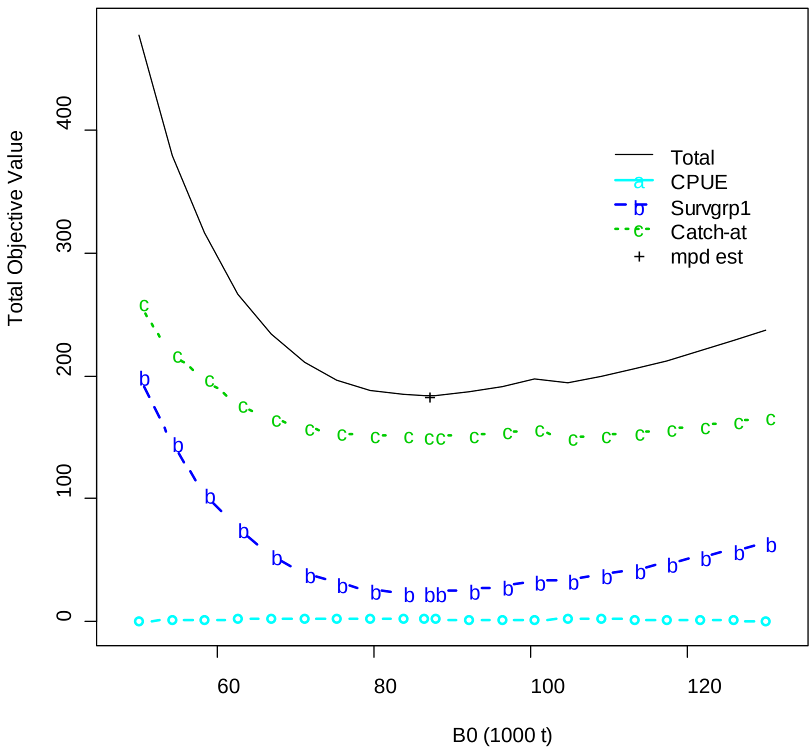


Figure 12: Profile -2log-likelihood for B_0 for major observation datasets.

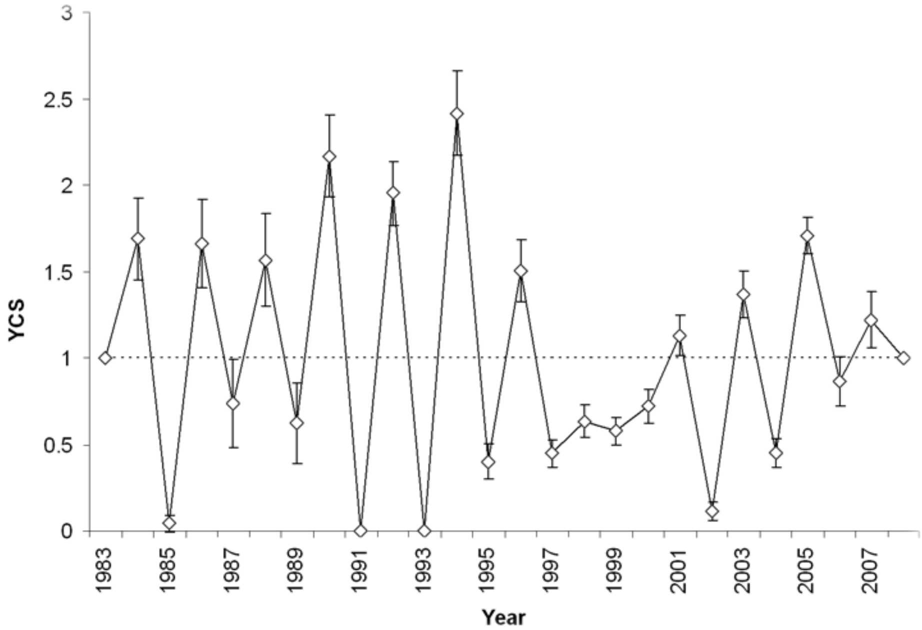


Figure 13: Estimates of year-class strength (showing ± SE bars).

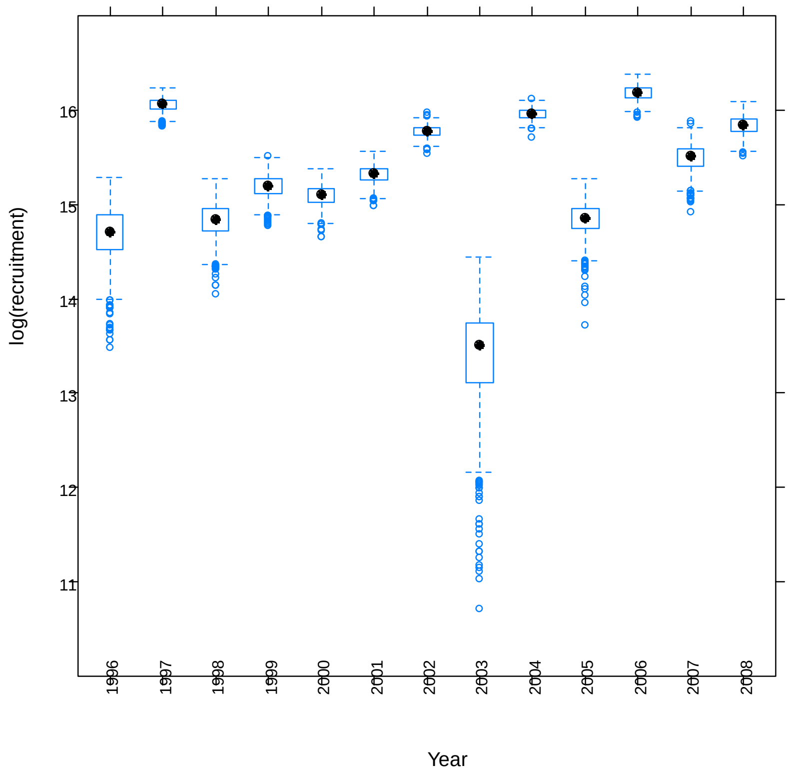
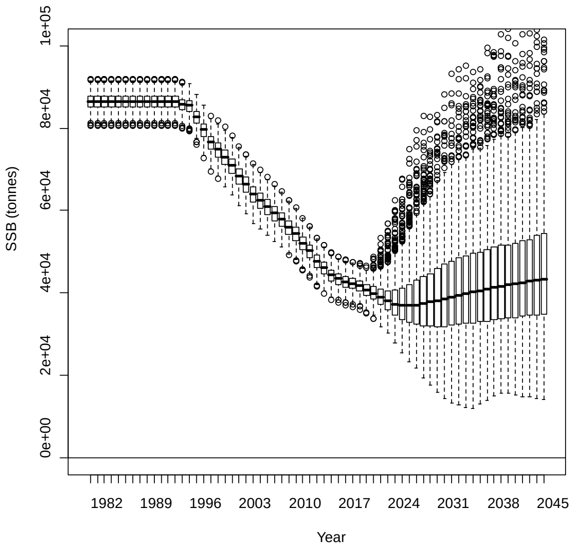


Figure 14: Box plots of age-1 recruitment series on the log scale for the historical period (1996–2008) with variability generated using 1 000 MVN samples to calculate recruitment CV.

4.4 Estimation of yield

43. The estimated long-term yield was 2 730 tonnes with depletion probability of 0.001 and escapement probability of 0.501. Figure 15 shows box and whisker plots of SSB and status of SSB (i.e. SSB/B_0) under random recruitments from 2009 onwards using the lognormal recruitment variability with a CV of 0.78.

(a)



(b)

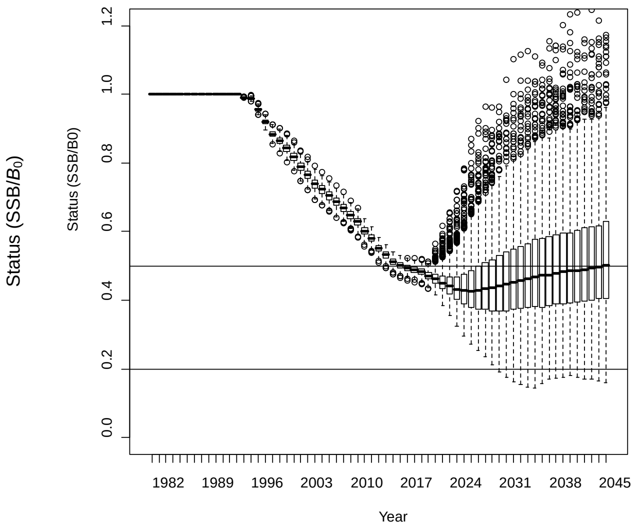


Figure 15: Projection results using future random lognormal recruitment from 2009 with an annual catch of 2 730 tonnes between 2012 and 2046. Each box represents the distribution of the variable across 1 000 projection trials for that year: (a) spawning stock biomass; (b) status of spawning stock biomass in a trial relative to B_0 in that projection trial (used in CCAMLR decision rules – lines show the 50% and 20% status levels for reference).

44. The Working Group agreed that the CASAL assessment provides a foundation for advice on stock status and yield for toothfish in this division. The CASAL assessment using age-classified data in place of length-classified data now allows historical recruitment trends to be more accurately reconstructed with a corresponding large reduction in the estimate of recruitment variability compared to that obtained in previous assessments. 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

45. 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) continue regular surveys across Division 58.5.2

(ii) re-estimate the von Bertalanffy growth function using the additional length-age data obtained in 2008 to 2011

(iii) investigate simplification of the spatial structuring of fishing selectivity functions

(iv) investigate whether the model could be developed as a two-sex model

(v) investigate improvements in the model structure that can be made to allow the inclusion of tagging data to assist the estimation of parameters in the model using CASAL; in order to provide it with some confidence that significant progress in understanding key uncertainties, common to all toothfish assessments, occur for this division before it is forecast that stock trajectory of SSB reaches the target level

46. 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.

5. By-catch of finfish and invertebrates

5.1 By-catch removals

47. By-catch removals for the toothfish fisheries (longline and trawl) are detailed in Table 8 from fine-scale data. By-catch in the toothfish trawl fisheries is generally less than 10% 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. No species was caught in quantities approaching the catch limits.

Table 8: Catch history for by-catch species (macrourids, rajids, *Channichthys rhinoceratus*, *Lepidonotothen squamifrons* and other species), catch limits and number of rajids released alive in Division 58.5.2. Catch limits are for the division (see CM 33-02 for details). (Source: fine-scale data)

Season	Macrourids				Rajids				
	Catch limit (tonnes)	Reported catch (tonnes)			Catch limit (tonnes)	Reported catch (tonnes)			Number released
		Longline	Trawl	Total		Longline	Trawl	Total	
1996/97	-	0	0	0	-	0	3	3	-
1997/98	-	0	0	0	120	0	3	3	-
1998/99	-	0	1	1	-	0	2	2	-
1999/00	-	0	4	4	-	0	6	6	-
2000/01	-	0	1	1	50	0	5	5	-
2001/02	50	0	4	4	50	0	4	4	-
2002/03	465	3	1	4	120	7	27	33	-
2003/04	360	42	3	46	120	62	14	76	155
2004/05	360	72	2	74	120	71	8	79	8 412
2005/06	360	26	1	27	120	17	19	36	3 814
2006/07	360	61	5	66	120	8	10	18	7 886
2007/08	360	81	5	86	120	13	9	22	9 799
2008/09	360	110	2	112	120	15	16	32	10 738
2009/10	360	100	3	103	120	11	18	29	19 318
2010/11	360	106	4	110	120	8	1	9	5 983

Season	*Channichthys rhinoceratus*				*Lepidonotothen squamifrons*			
	Catch limit (tonnes)	Reported catch (tonnes)			Catch limit (tonnes)	Reported catch (tonnes)		
		Longline	Trawl	Total		Longline	Trawl	Total
1996/97	-	0	2	2	-	0	0	0
1997/98	80	0	2	2	325	0	3	3
1998/99	150	0	1	1	80	0	0	0
1999/00	150	0	3	3	80	0	0	0
2000/01	150	0	1	1	80	0	4	4
2001/02	150	0	4	4	80	0	1	1
2002/03	150	0	21	21	80	0	0	0
2003/04	150	0	7	7	80	0	3	3
2004/05	150	0	36	36	80	0	2	2
2005/06	150	0	32	32	80	0	5	5
2006/07	150	0	15	15	80	0	10	10
2007/08	150	0	37	37	80	0	20	20
2008/09	150	0	53	53	80	0	27	27
2009/10	150	0	78	78	80	0	48	48
2010/11	150	0	2	2	80	0	7	7

(continued)

Table 8 (continued)

Season	Other species			
	Catch limit (tonnes)	Reported catch (tonnes)		
		Longline	Trawl	Total
1996/97	50	0	6	6
1997/98	50	0	3	3
1998/99	50	0	3	3
1999/00	50	0	5	5
2000/01	50	0	6	6
2001/02	50	0	10	10
2002/03	50	0	10	10
2003/04	50	3	16	19
2004/05	50	3	9	12
2005/06	50	3	7	12
2006/07	50	1	4	5
2007/08	50	2	18	21
2008/09	50	9	17	26
2009/10	50	6	16	22
2010/11	50	8	4	12

5.2 Assessments of impact on affected populations

48. Updated length–weight relationships, length-at-maturity data and estimates of abundance from survey data for rajids were presented in WG-FSA-05/70, details of the skate tagging program in WG-FSA-08/55 and distribution and abundance of skates across the Kerguelen Plateau in WG-FSA-09/42. Insufficient information was available to update assessments.

49. No stock assessments of individual by-catch species were undertaken in 2011. 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

50. The fishery operates under CM 33-02.

51. The Working Group recommended that, where possible, all rajids should be cut from the line, except on the request of the scientific observers during their sampling period.

6. By-catch of birds and mammals

52. No seabird mortalities were observed in the trawl or longline fisheries in Division 58.5.2 in 2010/11 (Table 9). Seabird/trawl interactions are reported in Table 9.

Table 9: Seabird mortality totals and rates (BPT: birds/trawl) and species composition of by-catch, recorded by observers in Division 58.5.2 trawl fisheries since 2000/01. DIM – black-browed albatross; PRO – white-chinned petrel; DAC – Cape petrel (data from SC-CAMLR-XXVIII, Annex 7, Table 5).

Season	Target species	BPT	Dead			Total dead	Alive (all species combined)
			DIM	PRO	DAC		
2000/01	*D. eleginoides*	<0.10				0	0
2001/02	*D. eleginoides*	<0.10				0	1
2002/03	*D. eleginoides*	<0.10	2	2	2	6	11
2003/04	*D. eleginoides*	<0.10				0	13
2004/05	*D. eleginoides*	<0.11	5	3		8	0
2005/06	*D. eleginoides*	0.00				0	0
2006/07	*D. eleginoides*	<0.10			2	2	0
2007/08	*D. eleginoides*	0.00				0	1
2008/09	*D. eleginoides*	0.002			1	1	0
2009/10	*D. eleginoides*	0.00				0	0
2010/11	*D. eleginoides*	0.00				0	0

53. In 2011, as in previous years, WG-IMAF agreed the level of risk of incidental mortality of seabirds in Division 58.5.2 is category 4 (average-to-high) (SC-CAMLR-XXX, Annex 8).

54. No instances of marine mammal mortalities or entanglements were observed in either the trawl (Table 10) or longline fishery in Division 58.5.2 in the 2010/11 season.

Table 10: Seal mortality totals and rates (SPT: seals/trawl) and species composition of by-catch, recorded by observers in Division 58.5.2 trawl fisheries since 2000/01. SLP – leopard seal; SEA – Antarctic fur seal; SES – southern elephant seal (data from SC-CAMLR-XXVIII, Annex 7, Table 7).

Season	Target species	SPT	Dead			Total dead	Alive (all species combined)
			SLP	SEA	SES		
2000/01	*D. eleginoides*	0.001		1		1	2
2001/02	*D. eleginoides*	0.001		1		1	0
2002/03	*D. eleginoides*	0.003		2	2	4	2
2003/04	*D. eleginoides*	0.002		3		3	0
2004/05	*D. eleginoides*	0.00				0	1
2005/06	*D. eleginoides*	0.00	1			1	0
2006/07	*D. eleginoides*	0.00				0	0
2007/08	*D. eleginoides*	0.00		1		1	0
2008/09	*D. eleginoides*	0.00				0	0
2009/10	*D. eleginoides*	0.00				0	0
2010/11	*D. eleginoides*	0.00				0	0

6.1 Mitigation measures

55. Longline fishing is conducted in accordance with CMs 24-02 and 25-02 and the special requirements outlined in CM 41-08, paragraph 3; trawl fishing in accordance with CM 25-03.

7. Ecosystem implications/effects

56. 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.

57. 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 and management advice

8.1 Conservation measures

58. The limits on the fishery for *D. eleginoides* in Division 58.5.2 are defined in CM 41-08. The limits in force applied to 2009/10 and 2010/11, and the Working Group's advice to the Scientific Committee, are summarised in Table 11.

Table 11: Limits on the exploratory fishery for *Dissostichus eleginoides* in Division 58.5.2 in force in 2009/10 and 2010/11 (CM 41-08) and advice to the Scientific Committee.

Element	Limit in force	Advice
Access (gear)	Trawls or longlines or pots	
Catch limit	2 550 tonnes west of 79°20'E (see CM 32-14)	Revise to 2 730 tonnes
Season:		
trawl and pot	1 December to 30 November	Carry forward
longline	1 May to 14 September, with possible extension from 15 to 30 April and 15 September to 31 October each season for any vessel that has demonstrated full compliance with CM 25-02 in the previous season.	Carry forward
By-catch	Fishing shall cease if the by-catch limit of any species, as set out in CM 33-02, is reached.	Carry forward
Mitigation	In accordance with CMs 24-02, 25-02 and 25-03.	Carry forward
Observers	Each vessel to carry at least one scientific observer and may include one additional CCAMLR scientific observer.	Carry forward
Data	Ten-day reporting system as in Annex 41-08/A.	Carry forward
	Monthly fine-scale reporting system as in Annex 41-08/A on haul-by-haul basis.	
	Fine-scale reporting system as in Annex 42-02/B. Reported in accordance with the CCAMLR Scheme of International Scientific Observation.	

(continued)

Table 11 (continued)

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.*	Carry forward
Jellymeat	Number and weight of fish discarded, including those with jellymeat condition, to be reported. These catches count towards the catch limit.	Carry forward
Environmental protection	Regulated by CM 26-01.	Carry forward

8.2 Management advice

59. The Working Group recommended that the catch limit for *D. eleginoides* in Division 58.5.2 west of 79°20'E should be 2 730 tonnes for 2011/12 and 2012/13.

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