APPENDIX J

FISHERY REPORT: EXPLORATORY FISHERY FOR *DISSOSTICHUS* SPP. IN SUBAREAS 88.1 AND 88.2

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FISHERY REPORT: EXPLORATORY FISHERY FOR *DISSOSTICHUS* SPP. IN SUBAREAS 88.1 AND 88.2

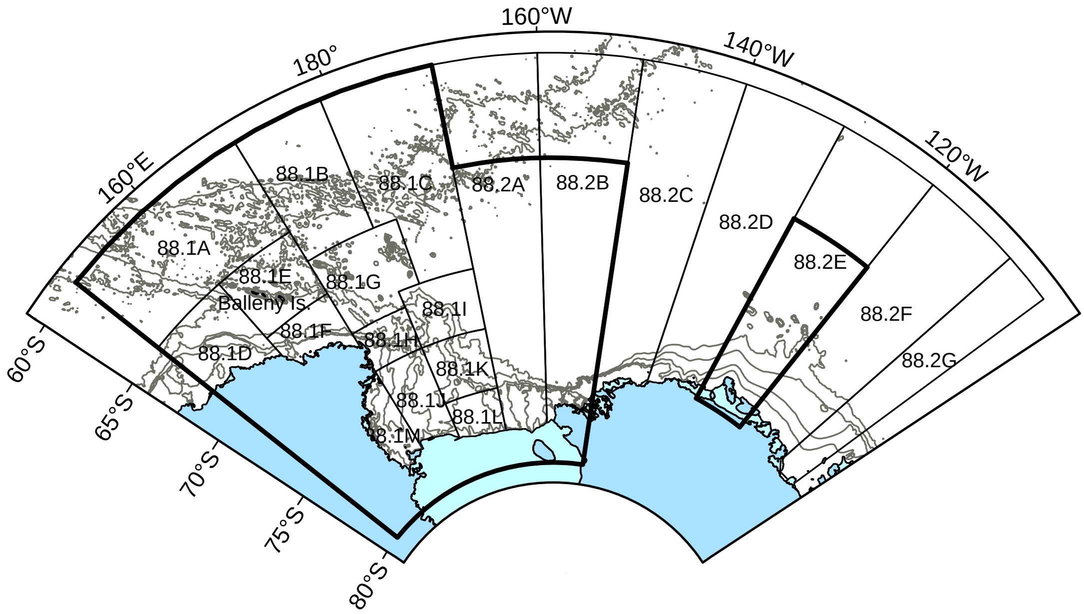

Figure 1: Ross Sea (Subarea 88.1 and SSRUs 882A–B) and SSRU 882E (bounded regions). Depth contours plotted at 500, 1 000, 2 000 and 3 000 m.

1. Details of the fishery

In 2005 the Working Group recommended that Subareas 88.1 and 88.2 be split into two areas for the purposes of stock assessment: (i) the Ross Sea (Subarea 88.1 and SSRUs 882A–B) (WG-FSA-05/4), and (ii) SSRU 882E.

2. The catch limits for the Subarea 88.1 and 88.2 SSRUs in the Ross Sea were changed as part of a three-year experiment starting in 2005/06 (SC-CAMLR-XXIV, paragraphs 4.163 to 4.166). The SSRUs between 150°E and 170°E (881A, D, E, F) and between 170°W and 150°W (882A–B) were closed to fishing to ensure that effort was retained in the area of the experiment. To assist administration of the SSRUs, the catch limits for SSRUs 881B, C and G were amalgamated into a ‘north’ region and those for SSRUs 881H, I and K were amalgamated into a ‘slope’ region. Within Subarea 88.2, SSRU 882E was treated as a separate SSRU with its own catch limit, whilst SSRUs 882C, D, F and G were amalgamated with a single catch limit. However, in each of the closed SSRUs and prior to 2008/09, a nominal catch of up to 10 tonnes of *Dissostichus* spp. remained permissible under the research fishing exemption; these fishing research catch limits were removed in 2008. SSRU J was subdivided into two SSRUs (SSRU J and SSRU M) in 2008 (Figure 1), and the catch limits for SSRUs 881J and L were amalgamated to assist administration.

3. In 2008/09, the exploratory fishery for *Dissostichus* spp. in Subarea 88.1 was limited to Argentine, Chilean, Korean, New Zealand, Russian, South African, Spanish, UK and Uruguayan vessels using longlines only (Conservation Measure 41-09). The precautionary catch limit for *Dissostichus* spp. was 2 700 tonnes applied as follows: 352 tonnes total could be taken in SSRUs B, C and G; 1 994 tonnes total in SSRUs H, I and K; 354 tonnes in SSRUs J and M (Figure 1). Five SSRUs (A, D, E, F and M) were closed to fishing. The catch limits for by-catch species were defined in Conservation Measures 33-03 and 41-09. The fishing season was from 1 December 2008 to 31 August 2009.

4. In Subarea 88.2, the exploratory fishery for *Dissostichus* spp. was limited to Argentine, Chilean, Korean, New Zealand, Russian, South African, Spanish, UK and Uruguayan vessels using longlines only (Conservation Measure 41-10). The precautionary catch limit for *Dissostichus* spp. was 567 tonnes south of 65°S, applied as follows: 214 tonnes total could be taken in SSRUs C, D and F; and 353 tonnes in SSRU E (Figure 1). Two SSRUs (A and B) were closed to fishing. The catch limits for by-catch species were defined in Conservation Measures 33-03 and 41-10. The fishing season was from 1 December 2008 to 31 August 2009.

5. Details of notifications of intentions to fish in 2009/10 are summarised in CCAMLR-XXVIII/13. For Subarea 88.1, notifications were submitted by seven Members with a total of 18 vessels. For Subarea 88.2, notifications were submitted by seven Members with a total of 17 vessels.

1.1 Reported catch

6. In 2008/09, six Members and 13 vessels fished in the exploratory fishery in Subarea 88.1 (Table 1). Fishing was restricted due to sea-ice and vessels fished between December 2008 and January 2009. The fishery was closed on 25 January 2009 and the total reported catch of *Dissostichus* spp. was 2 434 tonnes (90% of the limit) (CCAMLR-XXVIII/BG/6, Table 2). The following SSRUs were closed during the course of fishing:

- SSRUs B, C and G closed on 22 December 2008, triggered by the catch of *Dissostichus* spp. (total catch 410 tonnes; 116% of the catch limit);
- SSRUs H, I and K closed on 22 January 2009, triggered by the catch of *Dissostichus* spp. (total catch 1 957 tonnes; 98% of the catch limit).

7. Seven Members and 10 vessels fished in the exploratory fishery in Subarea 88.2 (Table 2). Fishing was restricted due to sea-ice and vessels fished between December 2008 and February 2009. SSRU E was closed on 8 February 2009, triggered by the catch of *Dissostichus* spp. (total catch 316 tonnes; 89% of the catch limit). The fishery closed on 31 August 2009 and the total reported catch of *Dissostichus* spp. was 484 tonnes (85% of the limit) (CCAMLR-XXVIII/BG/6).

8. The number of active fishing vessels and the catch of *Dissostichus* spp. in Subareas 88.1 and 88.2 in 2008/09 are shown in Tables 1 and 2 respectively.

Table 1: Number of vessels authorised in Conservation Measure 41-09, number of vessels that fished, and the catch of *Dissostichus* spp. in Subarea 88.1 in 2008/09 (source: catch and effort reports).

Flag State	Vessels authorised in CM 41-09	Number of vessels that fished	Reported catch (tonnes)		
			D. mawsoni	*D. eleginoides*	Total
Argentina	2	0			
Chile	1	1	98		98
Korea, Republic of	4	4	630	16	646
New Zealand	4	4	734	<1	734
Russia	3	0			
South Africa	1	0			
Spain	1	1	372	<1	372
UK	3	2	532	<1	532
Uruguay	2	1	51		51
Total	21	13	2418	17	2434

Table 2: Number of vessels authorised in Conservation Measure 41-10, number of vessels that fished, and the catch of *Dissostichus* spp. in Subarea 88.2 in 2008/09 (source: catch and effort reports).

Flag State	Vessels authorised in CM 41-10	Number of vessels that fished	Reported catch (tonnes)		
			D. mawsoni	*D. eleginoides*	Total
Argentina	2	0			
Chile	1	1	4		4
Korea, Republic of	2	1	13		13
New Zealand	4	2	90		90
Russia	3	0			
South Africa	1	1	118	<1	118
Spain	1	1	13		13
UK	3	3	208		208
Uruguay	2	1	38		38
Total	19	10	484	<1	484

9. The Ross Sea fishery saw a steady expansion of effort (number of sets) from 1997/98 to 2000/01, a slight drop in 2001/02, followed by an increase in 2002/03, and an almost three-fold increase in 2003/04. Since 2004/05 effort has been slightly more stable ranging from 1 000–1 500 sets per year. Although most SSRUs in Subareas 88.1 and 88.2 have been fished over time, the proportion of effort in each SSRU has varied considerably each year in relation to the catch limits of the target and by-catch species and ice conditions. Fishing in 2006/07 and 2007/08 saw a high level of catch and effort in SSRU 881H, whilst in 2008/09, effort reduced in SSRU H but increased in SSRU K.

10. The length of the fishing season in the Ross Sea fishery has contracted over time. In the first few years the fishery was mainly carried out from January to March, and between 2001 and 2003 extended into April and May. More recently, fishing has started in early December (ice permitting) and has usually finished by early February. In 2008/09 fishing was finished by the end of January. Fishing in SSRU 882E and, to a lesser extent SSRUs 882C, D, F and G, have shown a similar pattern with a trend towards starting and finishing earlier over the course of the fishery.

11. The catch of *Dissostichus* spp. has shown a steadier increasing trend over the same period, peaking at 3 079 tonnes in Subarea 88.1 for the 2004/05 season, declining to 2 952 tonnes in 2005/06, and increasing to 3 096 in 2006/07, and falling to 2 434 in 2008/09 reflecting the annual changes in catch limits.

12. Catches and catch limits for *Dissostichus* spp. and by-catch species by SSRU and SSRU groups reported from Subareas 88.1 and 88.2 in 2008/09 are summarised in Table 3 (see CCAMLR-XXVIII/BG/6).

Table 3: Catches and catch limits for *Dissostichus* spp. and by-catch species (macrourids, rajids and other species) by SSRU and SSRU groups reported from Subareas 88.1 and 88.2 in 2008/09 (source: catch and effort reports).

SSRU Groups	*Dissostichus* spp. catch (tonnes)		Macrourids catch (tonnes)		Rajids catch (tonnes)		Other species catch (tonnes)	
	Limit	Catch	Limit	Catch	Limit	Catch*	Limit	Catch
881A	0	0	0	0	0	0	0	0
881BCG	352	410	40	2	50	0	50	0
881D	0	0	0	0	0	0	0	0
881E	0	0	0	0	0	0	0	0
881F	0	0	0	0	0	0	0	0
881HIK	1994	1957	320	177	99	7	60	0
881JL	354	68	70	4	50	0	40	0
882A	0	0	0	0	0	0	0	0
882B	0	0	0	0	0	0	0	0
882CDFG	214	168	34	25	50	0	80	0
882E	353	316	56	33	50	0	20	0

* Note: Includes skates landed, and excludes skates cut-off at surface or tagged and released.

13. The historical catches of *Dissostichus* spp. caught in Subareas 88.1 and 88.2 are given in Tables 4 and 5 respectively.

Table 4: Catch history for *Dissostichus* spp. in Subarea 88.1. Reported catch includes catch from research fishing. (Source: STATLANT data for past seasons, and catch and effort reports for current season, WG-FSA-09/5 Rev. 1 and past reports for IUU catch.)

Season	Regulated fishery						Estimated IUU catch (tonnes)	Total removals (tonnes)
	Effort (number of vessels)		*Dissostichus* spp.					
			Catch limit (tonnes)	Reported catch (tonnes)				
	Limit	Reported		*D. eleginoides*	*D. mawsoni*	Total		
1996/97	-	1	1980	0	0	0	0	0
1997/98	-	1	1510	1	41	42	0	42
1998/99	2	2	2281	1	296	297	0	297
1999/00	-	3	2090	0	751	751	0	751
2000/01	6	10	2064	34	626	660	0	660
2001/02	10	3	2508	12	1313	1325	92	1417
2002/03	13	10	3760	26	1805	1831	0	1831
2003/04	26	21	3250	13	2184	2197	240	2437
2004/05	21	10	3250	7	3098	3105	23	3128
2005/06	21	13	2964	1	2968	2969	0	2969
2006/07	21	15	3072*	12	3079	3091	0	3091
2007/08	21	15	2700	9	2251	2259	186	2445
2008/09	21	13	2700	17	2418	2434	0	2434

* Includes 40 tonnes for research fishing (CCAMLR-XXV, paragraph 12.56).

Table 5: Catch history for *Dissostichus* spp. in Subarea 88.2. Reported catch includes catch from research fishing. (Source: STATLANT data for past seasons, and catch and effort reports for current season, WG-FSA-09/5 Rev. 1 and past reports for IUU catch.)

Season	Regulated fishery						Estimated IUU catch (tonnes)	Total removals (tonnes)
	Effort (number of vessels)		*Dissostichus* spp.					
			Catch limit (tonnes)	Reported catch (tonnes)				
	Limit	Reported		*D. eleginoides*	*D. mawsoni*	Total		
1996/97	-	0	1 980	0	0	0	-	0
1997/98	-	0	63	0	0	0	-	0
1998/99	-	0	0	0	0	0	-	0
1999/00	-	0	250	0	0	0	-	0
2000/01	2	0	250	0	0	0	-	0
2001/02	7	1	250	0	41	41	0	41
2002/03	9	2	375	0	106	106	0	106
2003/04	18	3	375	0	374	375	0	375
2004/05	10	4	375	0	411	411	0	411
2005/06	17	7	487	0	514	514	15	529
2006/07	16	7	567*	0	347	347	0	347
2007/08	15	4	567	<1	416	416	0	416
2008/09	15	10	567	<1	484	484	0	484

* Includes 20 tonnes for research fishing (CCAMLR-XXV, paragraph 12.60).

1.2 IUU catch

14. The estimated IUU catch in Subarea 88.1 was 92 tonnes in 2001/02, 240 tonnes in 2003/04, 23 tonnes in 2004/05 and 186 tonnes in 2007/08 (Table 4). There was no evidence of IUU fishing in Subarea 88.1 in 2008/09 (WG-FSA-09/5 Rev. 1).

15. There was an estimated 15 tonnes of IUU catch in Subarea 88.2 (SSRU 882A) in 2005/06 (Table 5). This was the first observed occurrence of IUU fishing in Subarea 88.2. There was no evidence of IUU fishing in Subarea 88.2 in 2008/09 (WG-FSA-09/5 Rev. 1).

1.3 Size distribution of the catches

16. *Dissostichus mawsoni* ranged from 50 to 180 cm (Figures 2 and 3). In all seasons, there was a broad mode of adult fish at about 120–170 cm. In 2005/06, there was a strong mode at about 60 cm in Subarea 88.2. These fish were predominantly caught at the edge of the continental shelf in SSRUs 882F and G. This mode was again apparent in 2008/09, due to fishing on the shelf and slope in SSRUs 882D, E and F in 2008/09.

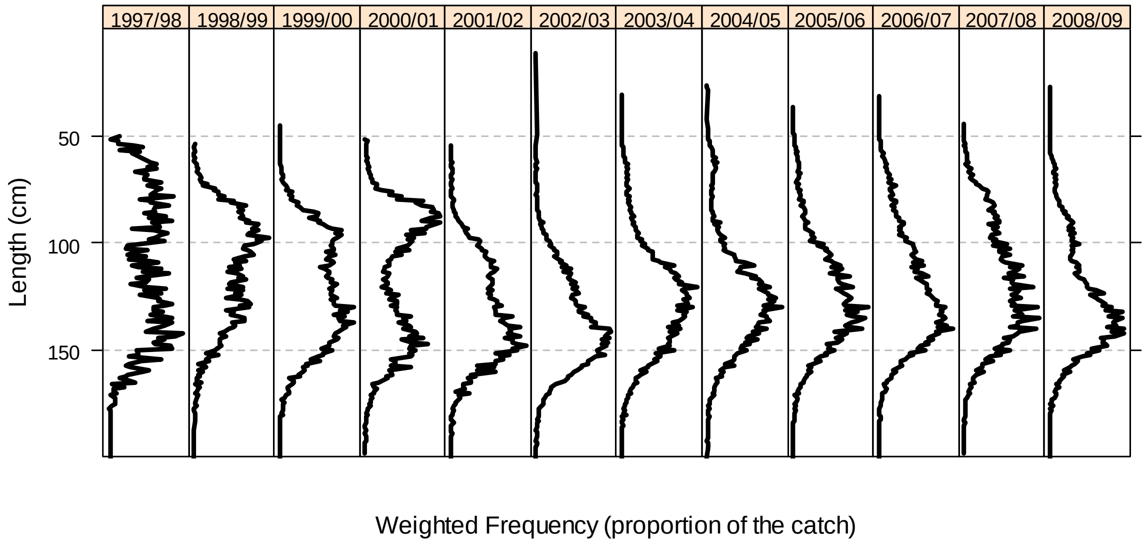

Figure 2: Catch-weighted length frequencies for *Dissostichus mawsoni* in Subarea 88.1 (source: observer, fine-scale and STATLANT data).

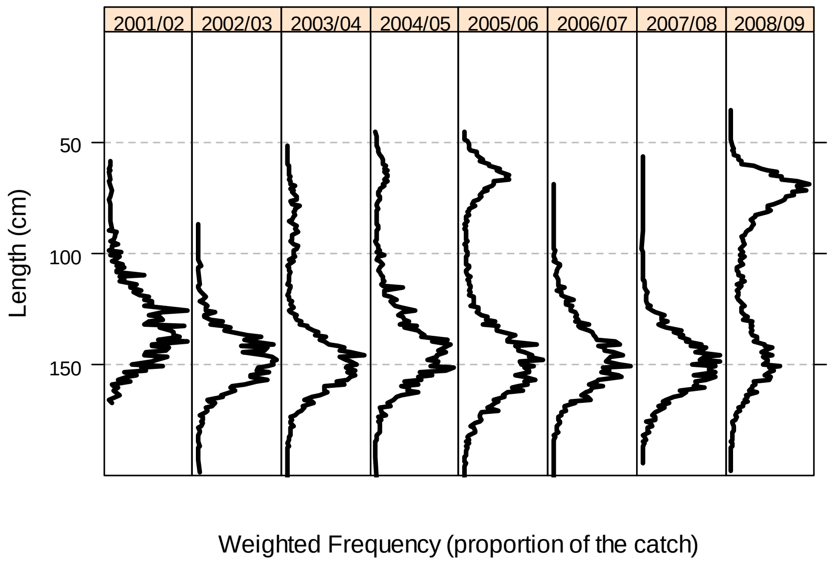

Figure 3: Catch-weighted length frequencies for *Dissostichus mawsoni* in Subarea 88.2 (source: observer, fine-scale and STATLANT data, and the length–weight relationship was taken from observations on *D. mawsoni* in Subarea 88.1).

17. The length-frequency data from the Ross Sea fishery have been very consistent over the past three to four seasons. There was no evidence of any truncation of the overall length-frequency distribution, and no evidence for a reduction in fish length in any SSRU over time (WG-FSA-09/36). Although moderate numbers of small fish are caught in some years (e.g. on the shelf in 1999 and 2001), these year classes are not seen in large numbers in later years in the fishery, and there was no evidence for recent strong variation in year-class strength in the fishery (WG-FSA-09/36). It should be noted that the scaled length frequencies only represent the landed part of the *D. mawsoni* catch, and do not include the (often smaller) fish that were selected for tagging before the catch was sampled by observers (WG-FSA-09/39).

2. Stocks and areas

18. Analysis of the genetic diversity for *D. mawsoni* from Subareas 48.1 and 88.1 and Division 58.4.2 found weak genetic variation between the three areas (Smith and Gaffney, 2005). This differentiation is supported by oceanic gyres, which may act as juvenile retention systems, and by limited movement of adult tagged fish.

19. Previous research has found that length modal distribution, sex ratio, fish body condition factor and reproductive development of *D. mawsoni* differ between the northern and southern SSRUs in Subarea 88.1, with sampling from the northern SSRUs suggesting that there was a significant higher ratio of males to females that were in poorer condition, and were more advanced in reproductive development (Fenaughty, 2006). Spawning is suspected to occur on isolated geographic features north of the main Antarctic shelf areas, north of 70°S (WG-FSA-06/26).

20. However, considerable uncertainty remains over spawning dynamics and early life history of *D. mawsoni*. The present hypothesis is that *D. mawsoni* in Subareas 88.1 and 88.2 spawn to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific-Antarctic Ridge (Hanchet et al., 2008). The spawning appears to take place during winter and spring, and may extend over a period of several months. Depending on the exact location of spawning, eggs and larvae become entrained by the Ross Sea gyres (a small clockwise rotating western gyre located around the Balleny Islands and a larger clockwise rotating eastern gyre covering the rest of Subareas 88.1 and 88.2), and may either move west settling out around the Balleny Islands and adjacent Antarctic continental shelf, south onto the Ross Sea shelf, or eastwards with the eastern Ross Sea gyre settling out along the continental slope and shelf to the east of the Ross Sea in Subarea 88.2. As the juveniles grow in size, they move west back towards the Ross Sea shelf and then move out into deeper water (>600 m). The fish gradually move northwards as they mature, feeding in the slope region in depths of 1 000–1 500 m, where they gain condition before moving north onto the Pacific-Antarctic ridge to start the cycle again. Spawning fish may remain in the northern area for up to two or three years. They then move southwards back onto the shelf and slope where productivity is higher and food is more plentiful and where they regain condition before spawning.

3. Parameter estimation

3.1 Observations

<u>Catch history</u>

21. The catch history of *D. mawsoni*, used in the Ross Sea and SSRU 882E assessment models is given in Table 6.

Table 6: Total *Dissostichus mawsoni* catch (tonnes) for the Ross Sea and SSRU 882E for the seasons 1996/97 to 2008/09 (source: C2 data). (The Ross Sea shelf, slope and north fisheries are defined in WG-FSA-SAM-05/8).

Season	Ross Sea				882E
	Shelf	Slope	North	Total	Total
1996/97	0	0	0	0	-
1997/98	8	29	4	41	-
1998/99	14	282	0	296	-
1999/00	64	688	0	752	-
2000/01	113	347	132	592	-
2001/02	10	933	412	1 355	-
2002/03	2	609	1 158	1 769	106
2003/04	141	1 667	371	2 178	362
2004/05	393	2 257	551	3 201	270
2005/06	251	2 373	343	2 967	318
2006/07	68	2 438	573	3 079	325
2007/08	61	1 939	251	2 250	333
2008/09	135	1 904	393	2 432	323
Total	1 066	11 638	3 558	16 260	2 037

Standardised CPUE

22. Raw CPUE indices have shown no clear trend over time for any area (WG-FSA-09/36). Standardised CPUE analyses of *D. mawsoni* in the Ross Sea or SSRU 882E were not updated for 2008/09 or used within the assessment models, as the Working Group considered that CPUE indices are not indexing abundance at the current time.

Catch-at-age

23. Strata for the *D. mawsoni* length- and age-frequency data for the Ross Sea were determined using a tree-based regression (a post-stratification method) (WG-FSA-SAM-05/8). The analysis used the median length of fish in each longline set, and the explanatory variables SSRU and depth.

24. On average, about 800 *D. mawsoni* otoliths collected by observers were selected for ageing each year, and used to construct annual area-specific ALKs. Age data were available for the 1998/99 to 2007/08 seasons, but were not yet available for the 2008/09 season. In the Ross Sea, ALKs for each sex were applied to the shelf/slope fisheries, and the north fishery separately. The ALKs were applied to the scaled length-frequency distributions for each year to produce catch-at-age distributions (WG-FSA-09/36). In SSRU 882E, otoliths were only available from the New Zealand fleet, who did not fish SSRU 882E every year. Therefore, for SSRU 882E, a single ALK for each sex using otolith ages from all available years was used to construct annual age frequencies.

Tag release and recapture

25. Under Conservation Measure 41-01, each longline vessel fishing in exploratory fisheries for *Dissostichus* spp. is required to tag and release *Dissostichus* spp. at the rate of one toothfish per tonne of green weight caught throughout the season. A limit of 500 fish tagged per vessel applied until the end of 2006/07.

26. Tagging rates, by vessel and Flag State since 2004/05, are given in Table 7 for Subarea 88.1 and Table 8 for Subarea 88.2. The tagging rates were determined from tagging data and catch and effort reports submitted to the Secretariat.

Table 7: Number of individuals of *Dissostichus* spp. tagged and released (a) and the tagging rate (b) reported by vessels operating in the exploratory fishery for *Dissostichus* spp. in Subarea 88.1 since 2004/05. (Source: observer data and catch and effort reports.)

(a) Number of individuals of *Dissostichus* spp. tagged and released. The number of *D. eleginoides* is indicated in brackets. NT – no tagging reported.

Flag State	Vessel name	Season				
		2004/05	2005/06	2006/07	2007/08	2008/09
Argentina	*Antartic II*		122 (0)	227 (0)		
	Antartic III	291 (1)			NT	
Chile	*Isla Eden*					93 (0)
Korea, Republic of	*Hong Jin No. 707*				255 (0)	235 (84)
	Insung No. 1					158 (15)
	Insung No. 2				13 (8)	
	Insung No. 22			352 (20)		
	Jung Woo No. 2			198 (19)	212 (11)	242 (0)
	Jung Woo No. 3					164 (0)
New Zealand	*Antarctic Chieftain*					185 (0)
	Avro Chieftain		266 (0)	289 (0)	50 (0)	
	Janas	456 (6)	283 (1)	184 (0)	179 (0)	166 (0)
	San Aotea II	500 (12)	512 (2)	385 (10)	196 (3)	186 (0)
	San Aspiring	580 (0)	432 (0)	463 (1)	370 (0)	271 (1)
Norway	*Froyanes*	319 (1)	121 (0)	168 (0)		
Russia	*Volna*	174 (0)	250 (0)	103 (0)		
	Yantar	111 (0)	246 (0)	375 (0)	283 (0)	
South Africa	*Ross Mar*			51 (0)	128 (3)	
Spain	*Tronio*				46 (38)	507 (13)
UK	*Argos Froyanes*				370 (0)	307 (1)
	Argos Georgia		50 (0)	249 (20)	196 (14)	
	Argos Helena	381 (0)	275 (3)	270 (3)	181 (1)	338 (1)
Uruguay	*Paloma V*	188 (1)	142 (16)			
	Punta Ballena	223 (1)	211 (0)			
	Ross Star			152 (2)	95 (1)	54 (0)
	Viking Sur		62 (0)	141 (0)		
Total		3223 (22)	2972 (22)	3607 (75)	2574 (79)	2906 (115)

(b) Tagging rate (number of fish tagged per tonne of green weight caught) of *Dissostichus* spp. NT – no tagging reported.

Flag State	Vessel name	Season				
		2004/05	2005/06	2006/07	2007/08	2008/09
Argentina	*Antartic II*		0.83	1.45	NT	
	Antartic III	1.15				
Chile	*Isla Eden*					0.95
Korea, Republic of	*Hong Jin No. 707*				1.20	1.22
	Insung No. 1					1.29
	Insung No. 2				1.24	
	Insung No. 22			1.16		
	Jung Woo No. 2			1.24	1.05	1.09
	Jung Woo No. 3					1.52
New Zealand	*Antarctic Chieftain*					1.09
	Avro Chieftain		1.05	1.06	1.20	
	Janas	1.05	1.05	1.13	1.03	1.09
	San Aotea II	1.00	(>500 fish)	1.25	1.22	1.10
	San Aspiring	(>500 fish)	1.01	1.11	1.08	1.12
Norway	*Froyanes*	1.54	1.23	1.11		
Russia	*Volna*	0.74	0.76	1.04		
	Yantar	0.43	0.71	1.12	1.13	
South Africa	*Ross Mar*			1.00	1.06	
Spain	*Tronio*				1.00	1.36
UK	*Argos Froyanes*				1.06	1.13
	Argos Georgia		1.14	1.03	1.32	
	Argos Helena	1.46	1.02	1.36	1.30	1.30
Uruguay	*Paloma V*	1.19	1.33			
	Punta Ballena	1.06	1.04			
	Ross Star			1.14	1.56	1.05
	Viking Sur		0.94	1.34		
Mean rate		1.07	1.01	1.17	1.18	1.18
Required rate		1.00*	1.00*	1.00*	1.00	1.00

* Limit of 500 fish per vessel

Table 8: Number of individuals of *Dissostichus* spp. tagged and released (a) and the tagging rate (b) reported by vessels operating in the exploratory fishery for *Dissostichus* spp. in Subarea 88.2 since 2004/05. (Source: observer data and catch and effort reports.)

(a) Number of individuals of *Dissostichus* spp. tagged and released. The number of *D. eleginoides* is indicated in brackets. NT – no tagging reported.

Flag State	Vessel name	Season				
		2004/05	2005/06	2006/07	2007/08	2008/09
Argentina	*Antartic II*		16 (0)	2 (0)		
Chile	*Isla Eden*					3 (0)
Korea, Republic of	*Hong Jin No. 707*					17 (0)
New Zealand	*Antarctic Chieftain*					78 (0)
	Avro Chieftain	269 (0)			349 (0)	
	Janas		64 (0)			58 (0)
Norway	*Froyanes*	NT	196 (2)	97 (0)		
Russia	*Volna*	NT	NT	55 (0)		
	Yantar	72 (0)	NT	100 (0)	NT	
South Africa	*Ross Mar*					118 (0)
Spain	*Tronio*					15 (0)
UK	*Argos Froyanes*				38 (0)	54 (0)
	Argos Georgia		76 (0)	NT		182 (0)
	Argos Helena		92 (1)	14 (0)		24 (0)
Uruguay	*Ross Star*				2 (0)	53 (0)
	Viking Sur			10 (0)		
Total		341 (0)	444 (3)	278 (0)	389 (0)	602 (0)

(b) Tagging rate (number of fish tagged per tonne of green weight caught) of *Dissostichus* spp. NT – no tagging reported.

Flag State	Vessel name	Season				
		2004/05	2005/06	2006/07	2007/08	2008/09
Argentina	*Antartic II*		0.24	0.05		
Chile	*Isla Eden*					0.70
Korea, Republic of	*Hong Jin No. 707*					1.27
New Zealand	*Antarctic Chieftain*					1.84
	Avro Chieftain	1.01			1.01	
	Janas		1.13			1.22
Norway	*Froyanes*	NT	0.91	0.89		
Russia	*Volna*	NT	NT	1.03		
	Yantar	0.85	NT	1.01	NT	
South Africa	*Ross Mar*					1.00
Spain	*Tronio*					1.18
UK	*Argos Froyanes*				1.09	2.32
	Argos Georgia		1.86	NT		1.06
	Argos Helena		1.72	0.46		1.94
Uruguay	*Ross Star*				0.21	1.40
	Viking Sur			1.07		
Mean rate		0.93	1.17	0.75	0.77	1.39
Required rate		1.00*	1.00*	1.00*	1.00	1.00

* Limit of 500 fish per vessel

27. A quality tag dataset for the assessment of *D. mawsoni* was selected on the basis of data quality metrics for individual trips (WG-FSA-09/35). The method first selected an initial informative dataset comprising trips with (i) high (above median) rates of recovery of previously released tags, and (ii) where tags released on the trip were subsequently recaptured at a high rate. The method then used these trips to define the upper and lower bounds of data quality metrics that were informative with respect to tagging data. Other trips with data quality metric values within these ranges were then added to the initial informative dataset.

28. The method for selecting trips with high data quality was recommended by WG-SAM-2009 (SC-CAMLR-XXVIII, Annex 6), except that the method was modified to include only trips that meet criteria (i) **and** (ii) in paragraph 27 rather than (i) **or** (ii). The Working Group noted that the choice of **(i)-and-(ii)** condition resulted in a smaller and more conservative dataset than that for **(i)-or-(ii)** condition, and had achieved the aim of the Scientific Committee in including a larger proportion of vessel trips, whilst maintaining an objective data quality criteria.

29. Since 2000/01, more than 22 000 *Dissostichus* spp. have been tagged in Subareas 88.1 and 88.2, with almost 19 000 and 2 000 *D. mawsoni* in the Ross Sea and SSRU 882E respectively. The number of released and recaptured *D. mawsoni* from selected data quality trips used in the Ross Sea and SSRU 882E assessments are given in Tables 9(a) and 9(b) respectively.

Table 9(a): Numbers of *D. mawsoni* with tags released for the years 2001–2008 for selected data quality trips, and the number recaptured in 2002–2009, ignoring within-season recaptures (WG-FSA-09/40 Rev. 1).

Tagged fish released		Tagged fish recaptured								
Year	Number	2002	2003	2004	2005	2006	2007	2008	2009	Total
2001	127	1	1	0	0	0	1	0	1	4
2002	684	-	9	3	5	7	13	5	4	46
2003	808	-	-	7	6	2	9	2	2	28
2004	1 811	-	-	-	21	19	30	22	8	100
2005	2 808	-	-	-	-	25	25	18	8	76
2006	2 443	-	-	-	-	-	84	51	14	149
2007	2 871	-	-	-	-	-	-	42	17	59
2008	1 756	-	-	-	-	-	-	-	12	12
Total	13 308	1	10	10	32	53	162	140	66	474

Table 9(b): Numbers of *D. mawsoni* with tags released for the years 2003–2008 for selected data quality trips, and the number recaptured in 2004–2009, ignoring within-season recaptures (WG-FSA-09/41).

Tagged fish released		Tagged fish recaptured						
Year	Number	2004	2005	2006	2007	2008	2009	Total
2003	94	0	-	2	0	0	0	2
2004	159	-	-	5	2	1	0	8
2005	0	-	-	-	-	-	-	0
2006	251	-	-	-	18	3	2	23
2007	100	-	-	-	-	4	3	7
2008	343	-	-	-	-	-	7	7
Total	947	0	0	7	20	8	12	47

3.2 Fixed parameter values

30. Natural mortality, length–mass, growth and maturity parameters for *D. mawsoni* in Subareas 88.1 and 88.2 are given in Table 10.

31. The Working Group adopted the revised estimates of the length and age at maturity for male and female *D. mawsoni* presented in WG-FSA-09/37. Revised estimates for the mean age and length at 50% spawning for females on the Ross Sea slope region were 16.6 years and 133.2 cm and for the mean age and length at 50% maturity for males were 12.8 years and 120.4 cm. The Working Group noted that the female estimates were based on the slope, which included fish which were skip spawning, and that estimates including fish from the north would lead to a slightly smaller age and length at 50% spawning.

32. A total of 10 of the 668 *D. mawsoni* tags (1.5%) from Subareas 88.1 and 88.2 were not able to be linked to a release event. To account for these unlinked tags, a tag-detection rate of 98.5% was assumed in the assessment models.

Table 10: Parameter values for *Dissostichus mawsoni* in Subareas 88.1 and 88.2.

Component	Parameter	Value			Units
		Male	Female	All	
Natural mortality	M	0.13	0.13		y^{-1}
VBGF	K	0.093	0.090		y^{-1}
VBGF	t_0	–0.256	0.021		y
VBGF	L_∞	169.07	180.20		cm
Length-to-mass	‘a’	0.00001387	0.00000715		cm, kg
Length-to-mass	‘b’	2.965	3.108		
Length-to-mass variability (CV)				0.1	
Maturity	L_{m50}	12.8	16.6		y
Range: 5 to 95% maturity		9.3–16.3	9.3–23.9		y
Recruitment variability	σ_R			0.6	
Stock recruit steepness (Beverton-Holt)	h			0.75	
Ageing error (CV)				0.1	
Initial tagging mortality				10%	
Instantaneous tag loss rate (single tagged)				0.062	y^{-1}
Instantaneous tag loss rate (double tagged)				0.004	y^{-1}
Tag detection rate				98.5%	
Tagging-related growth retardation (TRGR)				0.5	y

4. Stock assessment

4.1 Model structure and assumptions

Population dynamics

33. The Ross Sea (Subarea 88.1 and SSRUs 882A–B) and 882 E were assessed using CASAL integrated stock assessment models.

34. The CASAL stock models were sex- and age-structured, with ages from 1–50 and the last age group was a plus group (i.e. an aggregate of all fish aged 50 and older). The annual cycle is given in Table 11. Various model structures were investigated, and the base-case

model and sensitivity models for the Ross Sea and SSRU 882E are described below (WG-FSA-09/40 Rev. 1 and WG-FSA-09/41). A complete description of the CASAL modelling software was given in WG-FSA-05/P3.

Table 11: Annual cycle of the stock model, showing the processes taking place at each time step, their sequence within each time step, and the available observations. Fishing and natural mortality that occur within a time step occur after all other processes, with half of the natural mortality for that time step occurring before and half after the fishing mortality.

Step	Period	Processes	M^1	Age[2]	Observations	
					Description	M^3
1	November–April	Recruitment and fishing mortality	0.5	0.0	Tag–recapture Catch-at-age proportions	0.5 0.5
2	May–November	Spawning	0.5	0.0		
3	-	Increment age	0.0	1.0		

[1] *M* is the proportion of natural mortality that was assumed to have occurred in that time step.
[2] Age is the age fraction, used for determining length-at-age, that was assumed to occur in that time step.
[3] *M* is the proportion of the natural mortality in each time step that was assumed to have taken place at the time each observation was made.

35. The Secretariat undertook a validation of the CASAL parameter files, maximum of the posterior density (MPD) outputs, and yield calculations used for the Ross Sea and SSRU 882E models.

36. The models were run from 1995 to 2009 (Ross Sea) or 2002–2009 (SSRU 882E), and were initialised assuming an equilibrium age structure at an unfished equilibrium biomass, i.e. a constant recruitment assumption. Recruitment was assumed to occur at the beginning of the first (summer) time step. Recruitment was assumed to be 50:50 male to female.

37. The Ross Sea base-case model was implemented as a single-area, three-fishery model. A single area was defined with the catch removed using three concurrent fisheries (slope, shelf and north). Each fishery was parameterised by a sex-based double-normal selectivity ogive (i.e. domed selectivity) and allowed for annual selectivity shifts that shifted left or right (shelf fishery) with changes in the mean depth of the fishery (slope and north fisheries in the Ross Sea). The double-normal selectivity was parameterised using four estimable parameters and allowed for differences in maximum selectivity by sex – the maximum selectivity was fixed at one for males, but estimated for females. The double-normal selectivity ogive was employed as it allowed the estimation of a declining right-hand limb in the selectivity curve. SSRU 882E was implemented as a single-area, single-fishery model, with selectivity assumed to be double-normal.

38. Fishing mortality was applied only in the first (summer) time step. The process was to remove half of the natural mortality occurring in that time step, then apply the mortality from the fisheries instantaneously, then to remove the remaining half of the natural mortality.

39. The population model structure includes tag-release and tag-recapture events. Here, the model replicated the basic age-sex structure described above for each tag-release event. The age and sex structure of the tag component was seeded by a tag-release event. Tagging was applied to a 'cohort' of fish simultaneously (i.e. the 'cohort' of fish that were tagged in a given year and time step). Tagging from each year was applied as a single tagging event. The usual population processes (natural mortality, fishing mortality etc.) were then applied

over the tagged and untagged components of the model simultaneously. Tagged fish were assumed to suffer a retardation of growth from the effect of tagging (TRGR), equal to 0.5 of a year.

Model estimation

40. The model parameters were estimated using a Bayesian analysis, first by maximising[1] an objective function (MPD), which is the combination of the likelihoods from the data, prior expectations of the values of those parameters and penalties that constrain the parameterisations; and second, by estimating the Bayesian posterior distributions[2] using MCMCs.

41. Initial model fits were evaluated at the MPD by investigating model fits and residuals.

42. Parameter uncertainty was estimated using MCMCs. These were estimated using a burn-in length of either 4 x 10^5 (Ross Sea) or 5 x 10^5 (SSRU 882E) iterations, with every 1 000th sample taken from the next 1 x 10^6 iterations (i.e. a final sample of length 1 000 was taken).

Observation assumptions

43. The catch proportions-at-age data for the 1997/98–2007/08 (Ross Sea) or 2003/04–2007/08 (SSRU 882E) seasons were fitted to the modelled proportions-at-age composition using a multinomial likelihood.

44. Tag-release events were defined for the 2000/01–2007/08 (Ross Sea) or 2003/04–2007/08 (SSRU 882E) seasons. Within-season recaptures were ignored. Tag-release events were assumed to have occurred at the end of the first (summer) time step, following all (summer) natural and fishing mortality.

45. The estimated number of scanned fish (i.e. those fish that were caught and inspected for a possible tag) was derived from the sum of the scaled length frequencies from the selected trips' quality observer records (for the base case), plus the numbers of fish tagged and released. Tag-recapture events were assumed to occur at the end of the first (summer) time step, and were assumed to have a detection probability of 98.5% to account for unlinked tags.

46. For each year, the recovered tags-at-length for each release event were fitted, in 10 cm length classes (range 40–230 cm), using a binomial likelihood.

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1 Technically, this is done by minimising the negative log objective function.

2 The analysis produces point estimates of parameters, but this ignores uncertainty in their values. Other combinations of parameters may also be likely, though not necessarily as likely as the point estimates. Bayesian posterior distributions describe the likely distribution of the parameters, given the uncertainty in the observations and model. One way of finding these distributions is to search within the parameter space of all parameters, using a technique called Monte Carlo Markov Chains (MCMC). A useful analogy is a landscape in which the lowest point (the point estimate) is found by juggling a ball around the landscape (the parameter space). Then look around the landscape and find all the other places that, given the uncertainty about the measurements, might also be low. In a Bayesian analysis, the resulting distribution is referred to as a Bayesian posterior distribution.

Process error and data weighting

47. Additional variance, assumed to arise from differences between model simplifications and real-world variation, was added to the sampling variance for all observations. Adding such additional errors to each observation type has two main effects: (i) it alters the relative weighting of each of the datasets (observations) used in the model, and (ii) it typically increases the overall uncertainty of the model, leading to wider credible bounds on the estimated and derived parameters.

48. The additional variance, termed process error, was estimated for the base-case MPD run, and the total error assumed for each observation was calculated by adding process error and observation error. A single process error was estimated for each of the observation types (i.e. one for the age data and one for the tag data).

Penalties

49. 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 (here, set equal to 0.999). Second, a tagging penalty discouraged population estimates that were too low to allow the correct number of fish to be tagged.

Priors

50. The parameters estimated by the models, their priors, starting values for the minimisation, and their bounds are given in Table 12. In models presented here, priors were chosen that were relatively non-informative but also that encouraged conservative estimates of B_0.

Table 12: Number (*N*), start values, priors and bounds for the free parameters (when estimated) for the base-case and sensitivity models.

Parameter		*N*	Start value	Prior	Bounds	
					Lower	Upper
B_0		1	150 000	Uniform-log	$1\text{x}10^4$	$1\text{x}10^6$
Male fishing selectivities	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	9	10.0	Uniform	1.0	500.0
Female fishing selectivities	a_{max}		1.0	Uniform	0.01	10.0
	a_1		8.0	Uniform	1.0	50.0
	s_L		4.0	Uniform	1.0	50.0
	s_R	12	10.0	Uniform	1.0	500.0
Selectivity shift ($\text{yr}\cdot\text{km}^{-1}$)	E	2	0.0	Uniform	0.0	50.0
Annual selectivity shift (shelf)	E_f	12	Mean depth	Uniform	–10.0	10.0

Yield calculations

51. 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.

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

53. 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 B_0 at the end of a 35-year projected period.

54. Note that in applying the CCAMLR decision rules using CASAL, the pre-exploitation median SSB was replaced with the estimate of B_0 in each sample. This will result in a small downwards bias of the status of the stock in each trial and a small upwards bias in the probability of depletion. The effect of these biases will be a small downwards bias in the estimate of yield. The probability of depletion and the level of escapement were calculated by projecting forward for a period of 35 years, under a scenario of a constant annual catch (i.e. for the period 2010–2044), for each sample from the posterior distribution.

55. Recruitment from 2003–2043 was assumed to be lognormally distributed with a standard deviation of 0.6 with a Beverton-Holt stock-recruitment steepness $h = 0.75$.

56. For the Ross Sea, future catch was assumed to follow the same split between fisheries as that in the most recent four seasons (i.e. based on the distribution of the 2007–2009 catch, 3.5%, 81.2% and 15.3% of the total future catch was allocated to the shelf, slope and north fisheries respectively). The selectivity shift was assumed to be the average of shifts estimated for the years 1998–2008.

57. For SSRU 882E, future catch was assumed to have a selectivity equal to the estimated selectivity from the catch history.

58. Note that historically, the catch limit has not always been fully taken due to adverse ice conditions. Possible ice-cover restrictions on future catch are ignored, and the yields were calculated assuming that for each future season the total available catch would be taken, subject to the maximum exploitation rate constraint (here, set equal to 0.999).

4.2 Model estimates

Likelihood profiles

59. The likelihood profiles for the Ross Sea base-case model are given in Figure 4. The likelihood profiles were carried out by fixing B_0 at values across a range of plausible values (i.e. 30 000–130 000 tonnes), while estimating the remaining model parameters. The catch-at-age data and tag-recaptures from 2003 and 2005 suggested that very low biomass levels were less likely, whilst tag-recaptures from 2006 and 2004 suggest very high biomass estimates were less likely. As with the 2007 assessment model, the 2006 release data were the most dominant of the tag data series.

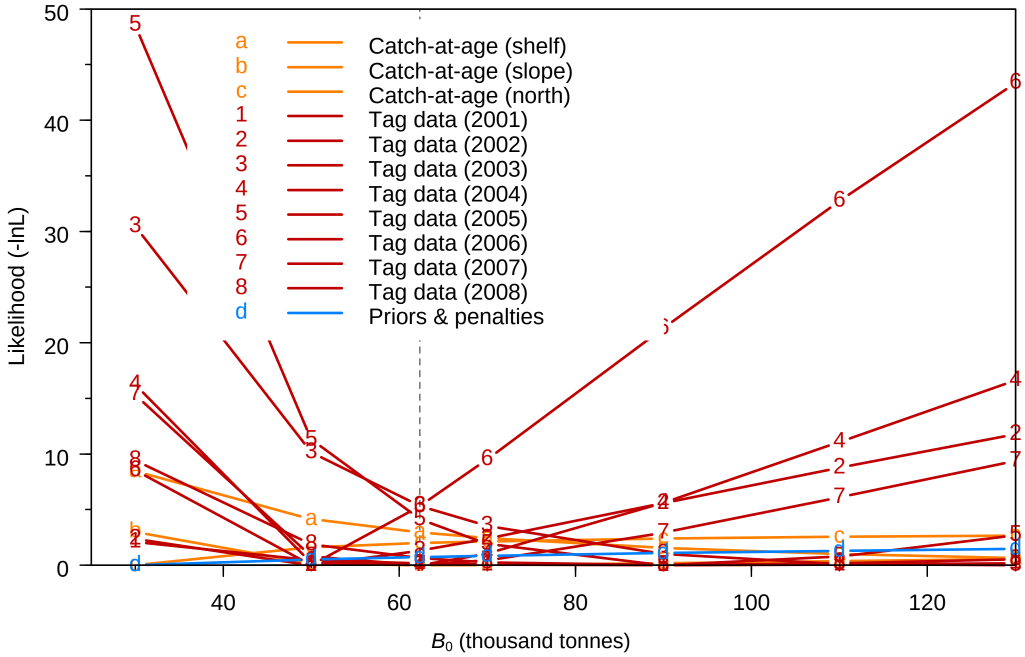

Figure 4: Likelihood profiles for the base-case model for values of B_0. Negative log likelihood values were rescaled to have minimum 0 for each dataset. The dashed vertical line indicates the MPD.

MCMC diagnostics

60. For the base-case model run, 1 000 MCMC posterior samples were taken from 1 000 000 iterations, after a burn-in of 400 000 (Ross Sea) or 500 000 (SSRU 882E) iterations. MCMC diagnostics suggested no evidence of poor convergence in the key biomass parameters and between-sample autocorrelations were low.

Ross Sea model estimates

61. Key output parameters for the Ross Sea base-case assessment model are summarised in Table 13. MCMC estimates of initial (equilibrium) spawning stock abundance (B_0) were

62 080 tonnes (95% credible interval (CI) 56 020–70 090 tonnes), and current (B_{2009}) biomass was estimated as 80% B_0 (95% CI 78–82%). The projected biomass trajectory assuming a future constant catch of 2 850 tonnes is shown in Figure 5.

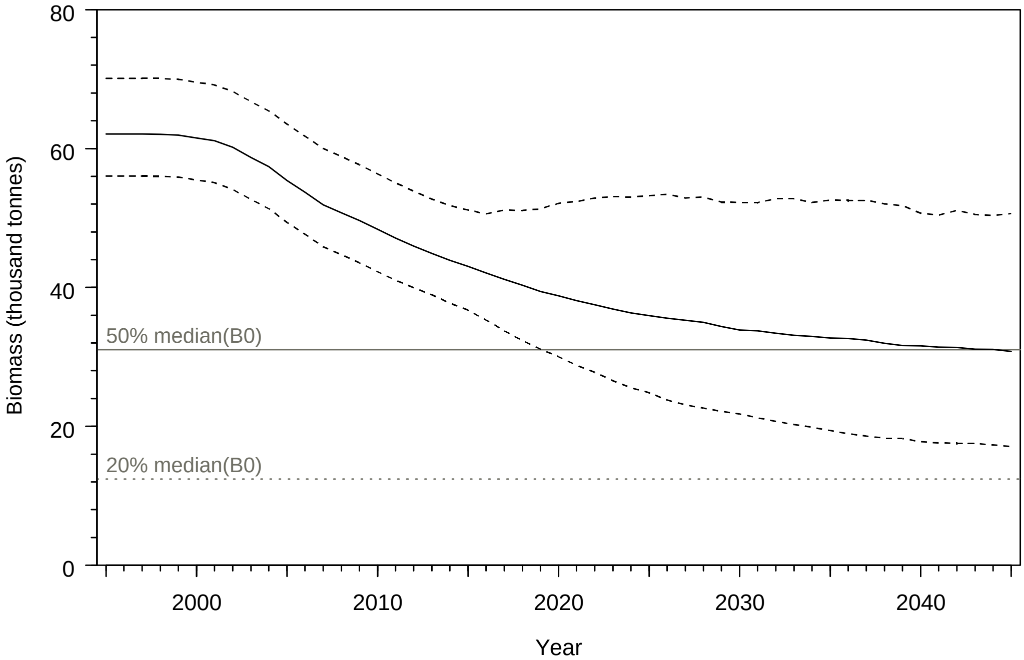

Figure 5: Estimated spawning stock biomass median (solid line) and 95% CI (dashed lines) for the base-case Ross Sea model.

SSRU 882E model estimates

62. Key output parameters for the SSRU 882E base-case assessment model are summarised in Table 13. MCMC estimates of initial (equilibrium) spawning stock abundance (B_0) were 7 540 tonnes (95% CI 5 870–10 020 tonnes), and current (B_{2009}) biomass was estimated as 81% B_0 (95% CI 75–86%). The projected biomass trajectory assuming a future constant catch of 361 tonnes is shown in Figure 6.

Table 13: Median MCMC estimates (and 95% CI) of B_0, B_{2009} and B_{2009} as $\%B_0$ for the Ross Sea and SSRU 882E base-case models, and the Ross Sea 2007 base-case model, and the SSRU 882E 2006 base-case model.

Model	B_0	B_{2009}	B_{2009} ($\%B_0$)
2007 Ross Sea base case	71 200 (59 570–87 900)	-	-
Ross Sea base case	62 080 (56 020–70 090)	49 580 (43 530–57 670)	79.9 (77.7–82.2)
2006 882E base case	10 300 (5 340–25 210)	-	-
882E base case	7 540 (5 870–10 020)	6 090 (4 420–8 560)	80.7 (75.3–85.5)

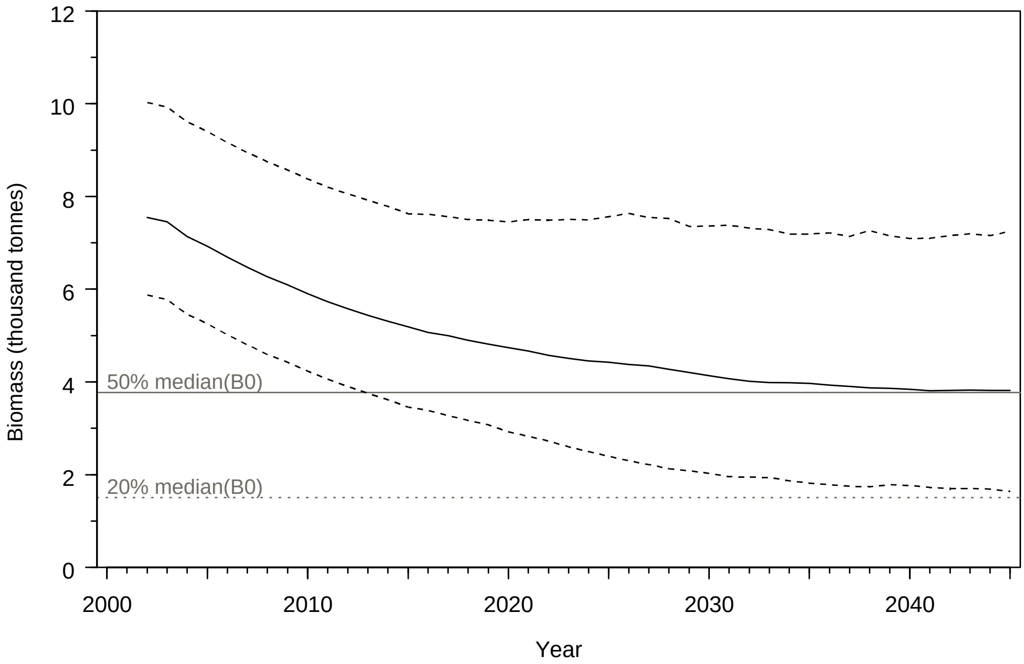

Figure 6: Estimated spawning stock biomass median (solid line) and 95% CI (dashed lines) for the base-case SSRU 882E model.

63. Plots of the observed proportions-at-age of the catch versus expected values showed little evidence of inadequate model fit for either the Ross Sea or SSRU 882E assessment models. Estimated selectivity curves for the Ross Sea base-case model (Figure 7) and SSRU 882E base-case model (Figure 8) appeared reasonable, with strong evidence of dome-shaped selectivity in the three fisheries. Fits to the tag data appeared adequate, and posterior densities of the observed and expected number of tags at length, by release event and recapture year, are given in Figure 9.

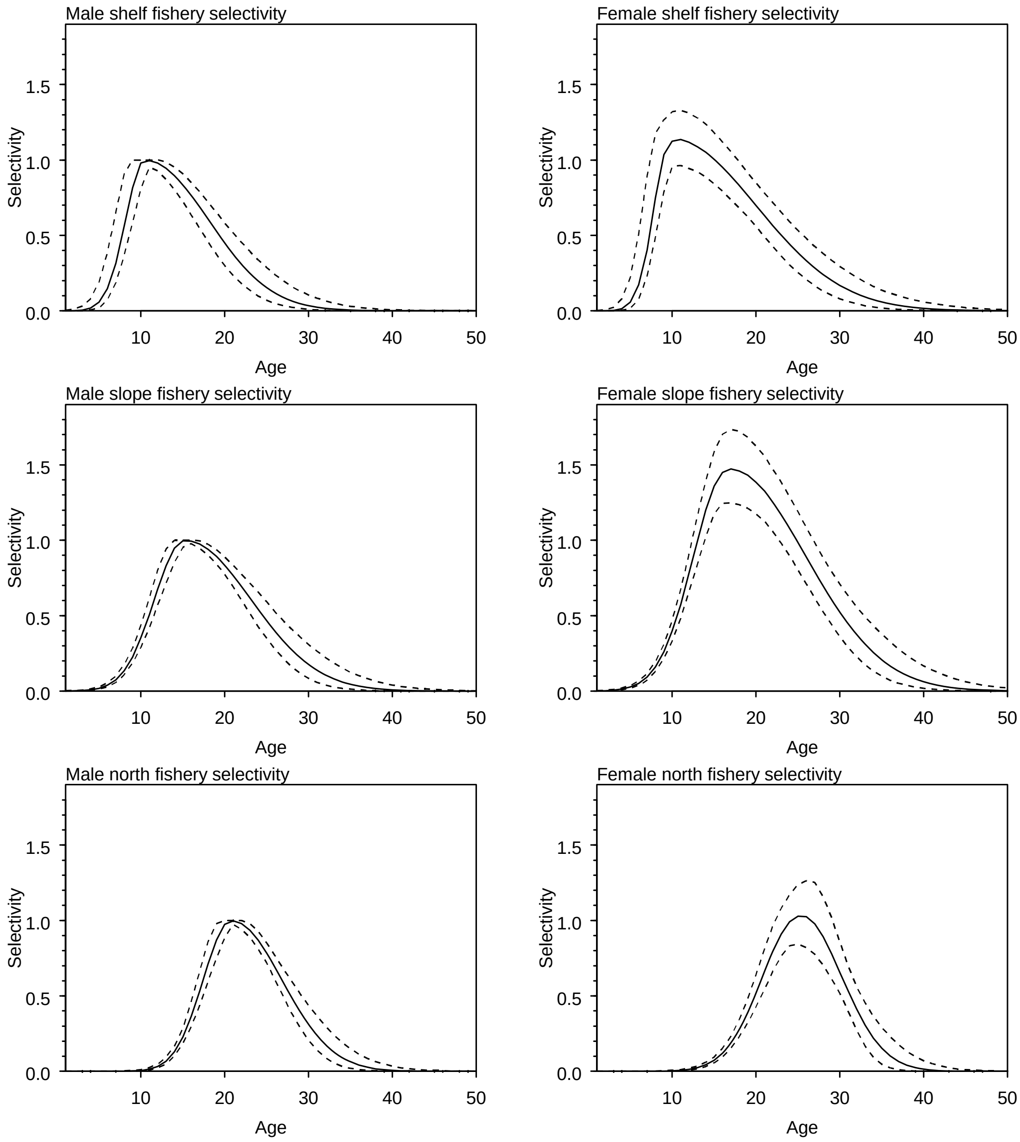

Figure 7: Estimated male and female selectivity ogives for the shelf, slope and north fisheries for the Ross Sea base-case model (solid lines indicate the median, and dashed lines indicate the marginal 95% CI).

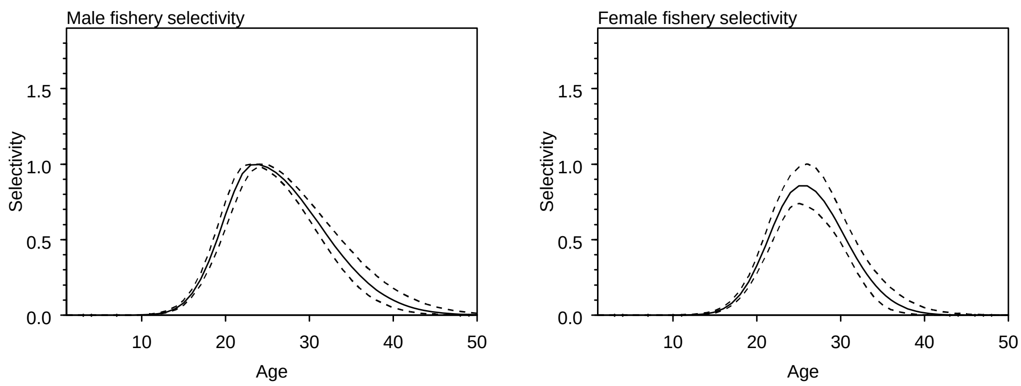

Figure 8: Estimated male and female selectivity ogives for the SSRU 882E base-case model (solid lines indicate the median, and dashed lines indicate the marginal 95% CI).

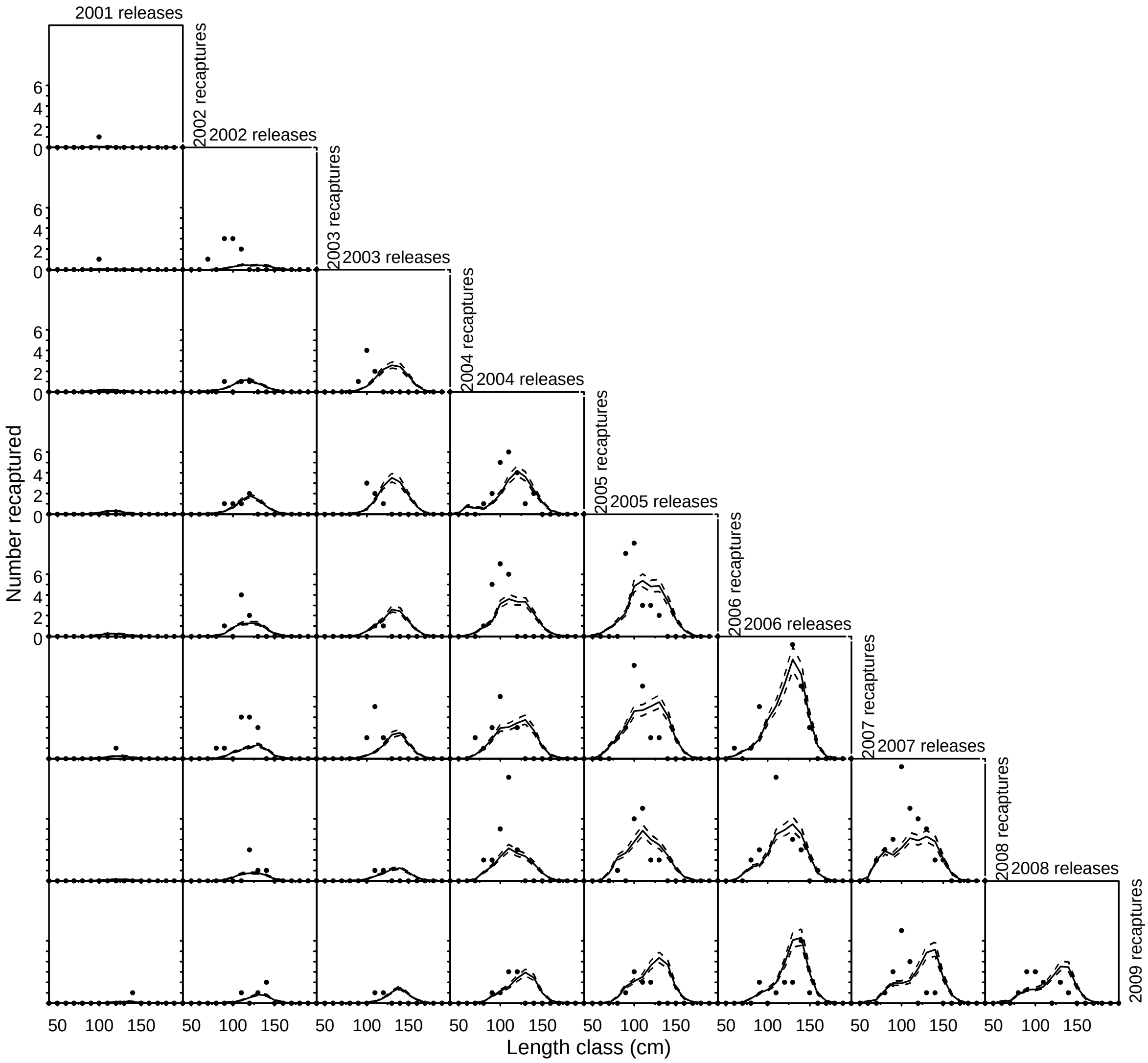

Figure 9: Observed (points) and posterior estimates (lines, MCMC median and 95% CI) of the number of tags recaptured (y-axis) by length class (x-axis), year of release (columns) and year of recapture (rows) for the Ross Sea base-case model.

Sensitivity analyses

64. Model sensitivity runs for the Ross Sea are described in Table 14(a). The base-case models included tag-release and recapture data from selected data quality trips. Sensitivity runs were determined as modifications to the base-case runs, and were chosen to investigate the effect of alternative assumption of maturity or data within the model.

65. Model sensitivity runs for SSRU 882E are described in Table 14(b). The base-case models included tag-release and recapture data from selected data quality trips. Sensitivity runs were determined as modifications to the base-case runs, and were chosen to investigate the effect of alternative assumption of maturity or data within the model.

Table 14(a): Labels and description of the Ross Sea assessment model sensitivity runs.

Model run		Description
R1	Base	Base-case run (i.e. 2009 reference case reported in WG-FSA-09/40 Rev. 1).
R2	New Zealand tag data	The base-case run, but using New Zealand vessel tag data only and with the 2007 assumption of maturity.
R3	Selected trips + 2007 maturity	The base-case run, but with the 2007 assumption of maturity.

Table 14(b): Labels and description of the SSRU 882E assessment model sensitivity runs.

Model run		Description
R1	Base	Base-case run (i.e. 2009 reference case reported in WG-FSA-09/41).
R2	New Zealand tag data	The base-case run, but using New Zealand vessel tag data only and with the 2007 assumption of maturity.
R3	Selected trips + 2007 maturity	The base-case run, but with the 2007 assumption of maturity.

66. For the Ross Sea assessment models, the selected trips' model runs (R1 and R3) indicated a higher biomass than that indicated by the use of tag data from New Zealand vessels. In model R1, the revised maturity ogive indicated that the spawning stock biomass was a lower proportion of the vulnerable biomass than was assumed in models R2 and R3. In all sensitivity cases, current biomass was estimated to be at 76–83% B_0.

67. For the SSRU 882E assessment models, the selected trips' model runs (R1 and R3) indicated a lower biomass than that indicated by the use of tag data from New Zealand vessels. In model R1, the revised maturity ogive indicated that the spawning stock biomass was a lower proportion of the vulnerable biomass than was assumed in models R2 and R3. In all sensitivity cases, current biomass was estimated to be at 71–94% B_0.

4.3 Yield estimates

Ross Sea

68. The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 2 850 tonnes. At this yield there is less than a 10% chance of spawning biomass dropping to less than 20% of the initial biomass. Following the third CCAMLR decision rule, the yield of 2 850 tonnes is recommended.

SSRU 882E

69. The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period was 361 tonnes. At this yield there is less than a 10% chance of spawning biomass dropping to less than 20% of the initial biomass. Following the third CCAMLR decision rule, the yield of 361 tonnes is recommended.

4.4 Discussion of model results

70. The Working Group recommended that the model described as the 2009 reference case in WG-FSA-09/40 Rev. 1 be the base-case assessment model for the Ross Sea, and that the model described as the 2009 reference case in WG-FSA-09/41 be the base-case assessment model for SSRU 882E.

71. The Working Group also noted that the inclusion of the larger number of tag-releases and recaptures from the high-quality tag dataset led to wider spatial and temporal coverage of the tag program. Within the Ross Sea, the high-quality tag dataset resulted in a higher estimate of initial biomass than models that used only the New Zealand tag data. However, in the SSRU 882E assessment, the quality tag dataset resulted in a lower estimate of initial biomass than models that used only the New Zealand tag data.

4.5 Future research requirements

72. The Working Group welcomed the updated assessment models of the Ross Sea and SSRU 882E, and thanked New Zealand for the work that had gone into these.

73. The Working Group noted that the method for selecting high-quality tag datasets still needs to be refined, and that potential biases caused by vessel preferences for localised fishing grounds are likely to require further investigation using the SPM.

74. The Working Group recommended that, in order to distinguish between different methods for providing advice on harvest strategies, the robustness of different assessment methods for achieving the objectives of the Commission be evaluated using simulation evaluation methods.

5. By-catch of fish and invertebrates

5.1 By-catch removals

75. Catches of by-catch species groups (macrourids, rajids and other species) reported in fine-scale data, their respective catch limits, and number of rajids cut from lines and released alive are summarised for Subareas 88.1 and 88.2 in Tables 15 and 16 respectively.

Table 15: Catch history for by-catch species (macrourids, rajids and other species), catch limits and number of rajids released alive in Subarea 88.1. Catch limits are for the whole fishery (see Conservation Measure 33-03 for details). (Source: fine-scale data)

Season	Macrourids		Rajids			Other species	
	Catch limit (tonnes)	Reported catch (tonnes)	Catch limit (tonnes)	Reported catch (tonnes)	Number released	Catch limit (tonnes)	Reported catch (tonnes)
1996/97	-	0	-	0	-	-	0
1997/98	-	9	-	5	-	50	1
1998/99	-	22	-	39	-	50	5
1999/00	-	74	-	41	-	50	7
2000/01	-	61	-	9	-	50	14
2001/02	100	154	-	25	-	50	10
2002/03	610	65	250	11	966	100	12
2003/04	520	319	163	23	1 745	180	23
2004/05	520	462	163	69	5 057	180	24
2005/06	474	258	148	5	14 640	160	18
2006/07	485	153	152	38	7 336	160	43
2007/08	426	112	133	4	7 190	160	20
2008/09	430	183	135	7	7 088	160	16

Table 16: Catch history for by-catch species (macrourids, rajids and other species), catch limits and number of rajids released alive in Subarea 88.2. Catch limits are for the whole fishery (see Conservation Measure 33-03 for details). (Source: fine-scale data)

Season	Macrourids		Rajids			Other species	
	Catch limit (tonnes)	Reported catch (tonnes)	Catch limit (tonnes)	Reported catch (tonnes)	Number released	Catch limit (tonnes)	Reported catch (tonnes)
1996/97	-	0	-	0	-	-	0
1997/98	-	0	-	0	-	-	0
1998/99	-	0	-	0	-	-	0
1999/00	-	0	-	0	-	-	0
2000/01	-	0	-	0	-	-	0
2001/02	40	4	-	0	-	20	0
2002/03	60	18	-	0	-	140	8
2003/04	60	37	50	0	107	140	8
2004/05	60	21	50	0	-	140	3
2005/06	78	92	50	0	923	100	12
2006/07	88	54	50	0	-	100	13
2007/08	88	17	50	0	-	100	4
2008/09	90	58	50	0	265	100	14

76. The macrourid by-catch limit was exceeded in Subarea 88.2 in 2005/06, but no catch limits were exceeded in either area in 2006/07, 2007/08 or 2008/09.

77. Current catch limits for rajids in the Ross Sea are proportional to the catch limit of *Dissostichus* spp. in each SSRU based on the following rule from Conservation Measure 33-03:

- the limit for rajids is 5% of the catch limit of *Dissostichus* spp. or 50 tonnes whichever is greater.

78. Current catch limits for macrourids in SSRUs 881H–L were based on a biomass of the IPY-2008 trawl survey from the slope of the Ross Sea. Yield estimates for macrourids were calculated from that estimate, and then apportioned across the five SSRUs taking into account maximum historical catches.

79. There were no new assessments of by-catch species or recommendations for revised catch limits by SSRU in 2008/09.

5.2 Assessments of impacts on affected populations

Macrourids

80. The estimate of γ for *Macrourus whitsoni* in Subarea 88.1 in 2003 was 0.01439 for a CV of 0.2 (SC-CAMLR-XXII, paragraph 4.132) or 0.01814 for a CV of 0.5 (SC-CAMLR-XXII, Annex 5, paragraph 5.242). This indicates that *M. whitsoni* has relatively low productivity and thus may be vulnerable to overexploitation.

81. WG-FSA-05/24 updated the standardised CPUE for *M. whitsoni* in Subareas 88.1 and 88.2 based on an analysis of fine-scale data from all vessels in the exploratory fishery from 1997/98 to 2004/05. Standardised CPUE increased to a peak in 2002 and 2003, dropped in 2004, before increasing again in 2005.

82. WG-FSA-05/22 considered approaches to monitoring and assessing macrourids and rajids in Subarea 88.1 and recommended that a random bottom trawl survey would be the best approach towards obtaining abundance estimates. Tag-recapture experiments for rajids and experimental manipulation of fishing effort are alternative methods which show some promise for monitoring abundance.

83. WG-FSA-08/32 provided biomass and yield estimates of *M. whitsoni* for the Ross Sea fishery (Subareas 88.1 and SSRUs 882A–B) based on extrapolations under three different density assumptions from a trawl survey (Table 17). The resulting biomass estimates had a CV of about 0.3. WG-FSA welcomed the concept of decoupling by-catch limits from those of target species and agreed to use estimates of biomass for Subarea 88.1, noting that SSRUs 882A–B are currently closed.

Table 17: Biomass estimates from the trawl surveys for the BioRoss 400–600 and 600–800 m and IPY-CAML 600–1 200 and 1 200–2 000 m strata (bold numbers) and extrapolated biomass estimates (with CVs) for the remaining strata based on three methods of extrapolation.

Survey	Depth range (m)	Biomass (tonnes)	Extrapolated biomass (tonnes)		
			Constant density	CPUE (all vessels)	CPUE (NZ vessels)
BioRoss – 881H	400–600	**230**	**230 (49)**	**230 (49)**	**230 (49)**
BioRoss – 881H	600–800	**3 531**	**3 531 (38)**	**3 531 (38)**	**3 531 (49)**
SSRU 881H west	800–1 200		92 (50)	83 (54)	103 (55)
SSRU 881H west	1200–2 000		713 (40)	1 114 (49)	1 038 (47)
IPY – 881H	600–1 200	**975**	**975 (50)**	**975 (50)**	**975 (50)**
IPY – 881H	1200–2 000	**3 356**	**3 356 (40)**	**3 356 (40)**	**3 356 (49)**
SSRU 881 I	600–1 200		3 297 (50)	7 883 (51)	5 992 (50)
SSRU 881 I	1200–2 000		4 670 (40)	11 168 (42)	8 576 (41)
SSRU 881 K	600–1 200		1 539 (50)	5 027 (51)	2 774 (51)
SSRU 881 K	1200–2 000		2 998 (40)	5 995 (45)	9 111 (43)
SSRUs 882 A–B	600–1 200		1 404 (50)	1 396 (58)	857 (60)
SSRUs 882 A–B	1200–2 000		4 087 (40)	525 (70)	-
Total			26 892 (29)	41 823 (28)	36 542 (30)

84. Yield estimates were calculated using the constant density assumption when extrapolating the biomass estimate across the slope region, noting that this would provide a more precautionary estimate of yield than one based on extrapolations using longline CPUE data. The resulting biomass estimate for SSRUs 881H, I and K and small portions of SSRUs 881J–L was 21 401 tonnes which gave a yield estimate of 388.2 tonnes. This yield estimate was then apportioned across the five SSRUs taking into account maximum historical catches. Yields per SSRU are detailed in Table 18. Existing move-on rules are retained, and macrourid by-catch limits and catches are expected to be reviewed on an annual basis.

Table 18: Proposed catch limits of grenadiers in Subarea 88.1 assuming a CV of 0.5 for the estimate of B_0 and that the grenadier density was constant across the entire slope (WG-FSA-08/32).

SSRU	Current catch limit	Estimated yield	Maximum historic catch	Proposed catch limit
881B, C, G	50	-	34	40
881H, I, K	271	} 388	390	320
881J	79		46	50
881L	24		6	20
882A–B	0	100	8	0
Total	424	488		430

Rajids

85. WG-FSA-06/31 reviewed the biological parameters of skates, whilst WG-FSA-06/32 characterised the results of the skate tagging program. Neither can currently be used to estimate total abundance.

86. WG-SAM-07/4 presented data and a preliminary developmental model for Antarctic skates in SSRUs 881H, I, J and K of the Ross Sea. The developmental model attempted to

create a catch history of all skates and rays in the Ross Sea, and integrate these data with the available observational data (including tag-recapture data) into a single integrated stock assessment model.

87. The paper concluded that aspects of the catch history were very uncertain, including the species composition, the weight and number of skates caught, the proportion discarded, and the survival of those tagged or discarded. The size composition of the commercial catch was also very uncertain because of the low numbers sampled each year. Most aspects of the tagging data were also uncertain, including the actual numbers of skates released, the initial mortality of tagged skates, the tag-loss rate and the numbers of skates scanned for tags. While updated summaries of the numbers of skate tag-releases and recaptures have been reported, these data are still preliminary and further work is required. Lastly, there is great uncertainty over the biological parameters, including age and growth, natural mortality, steepness and size and age-at-maturity. However, the paper noted that whilst many aspects of this uncertainty remain, changes to the C2 data form since 2005 have led to substantial improvements in the landings and release data.

5.3 Identification of levels of risk

88. WG-FSA-05/21 presented risk categorisation tables for *M. whitsoni* and *Amblyraja georgiana*, which are the major by-catch species in Subareas 88.1 and 88.2 (SC-CAMLR-XXIV, Annex 5, Appendix N, Tables 5 and 6).

5.4 Mitigation measures

89. WG-FSA-05/24 used a standardised CPUE analysis to determine factors affecting by-catch rates of macrourids and rajids in the exploratory fishery for toothfish in Subareas 88.1 and 88.2. The analysis was based on fine-scale haul-by-haul data and observer data from all vessels in the fishery from 1997/98 to 2004/05.

90. The major factors influencing macrourids by-catch were vessel, area and depth (SC-CAMLR-XXIV, Annex 5, Appendix N, Figures 1 and 2). Catch rates of *M. whitsoni* were highest along the shelf edge (SSRUs 881E, I, K and 882E) in depths from 600 to 1 000 m, and there was an order of magnitude difference in macrourid catch rates between different vessels. Examination of vessel characteristics showed that catch rates of macrourids were lower with the Spanish line system than with the autoline system. This effect was confounded by the bait type, as Spanish line vessels tended to use the South American pilchard as bait, whereas autoline vessels used varying species of squid and/or mackerel. However, the difference in macrourid catch rates between the few Spanish line vessels that used squid and mackerel for bait, and the majority that used pilchards, was much less than the overall difference between Spanish line and autoline vessels. Russian and Korean vessels had extremely low catch rates compared to other vessels fishing in the same location.

91. It was not possible to reliably determine factors influencing catch rates of rajids in Subareas 88.1 and 88.2 from either fine-scale or observer data because a proportion of skates are cut free and released at the surface and these are not accurately recorded or reported in either dataset (SC-CAMLR-XXIV, Annex 5, Appendix N, paragraphs 42 to 53).

92. This analysis suggested that it might be possible to reduce by-catch of macrourids in Subareas 88.1 and 88.2 by avoiding fishing in the depth ranges and areas where by-catch rates are highest. However, the Working Group noted that there is a considerable overlap with the spatial and depth distribution of *Dissostichus* spp. and area and/or depth restrictions would also impact on the ability of the fleet to catch *Dissostichus* spp.

93. The Working Group recommended that further work should be carried out in the intersessional period to compare by-catch levels arising from different gear configurations and to determine whether this information could be used to develop mitigation and avoidance measures for by-catch (SC-CAMLR-XXIV, Annex 5, paragraph 6.22).

94. The current by-catch limits and move-on rules are given in Conservation Measure 33-03.

95. In 2008, the Commission agreed that during the Year-of-the-Skate (CCAMLR-XXVII, paragraph 4.55):

(i) all skates should be brought on board or alongside the hauler to be correctly identified, scanned for tags and for their condition to be assessed;

(ii) all skates that are likely to survive if released (condition 3 or 4) should be released by cutting the snood as close to the hook as possible or cutting the snood and removing the hook from the skate, providing this does not further injure the skate;

(iii) all skates which are dead or with life-threatening injuries (condition 1 or 2 in the logbook) should be retained by the vessels;

(iv) skates released alive should be doubled-tagged (i.e. two tags per skate) at a rate of one skate in every five skates caught in exploratory fisheries, up to a maximum of 500 skates per vessel;

(v) tagged skates should be identified to species, measured before they are released and that, where possible, tagging experiments be undertaken to compare different tag types and estimate tag-shedding rates;

(vi) the tagging program will be coordinated by the Secretariat, which will be the repository for skate tagging kits;

(vii) when skates are caught on a line, they should be randomly sampled by observers at a rate of three skates per thousand hooks for the purpose of collecting biological measurements;

(viii) skates should not be sacrificed for biological sampling, and female maturity stage should only be recorded if the skate is dead or has sustained life-threatening injuries (conditions 1 and 2);

(ix) all live skates which are part of the biological sampling, which have not sustained life-threatening injuries, should be handled with care and released after biological information has been recorded, if they are still suitable for release (i.e. still in condition 3 or 4).

6. By-catch of birds and mammals

6.1 By-catch removals

96. There have been no observed seabird mortalities for the past five seasons in Subareas 88.1 and 88.2 (Table 19).

Table 19: Seabird by-catch limit, observed mortality rate and total estimated mortality of seabird by-catch in Subareas 88.1 and 88.2 (from SC-CAMLR-XXVIII, Annex 7, Table 4).

Season	By-catch limit (number of birds)	Mortality rate (birds/thousand hooks)	Total estimated mortality (number of birds)
1997/98		0	0
1998/99		0	0
1999/00		0	0
2000/01		0	0
2001/02	3*	0	0
2002/03	3*	0	0
2003/04	3*	0.0001	1
2004/05	3*	0	0
2005/06	3*	0	0
2006/07	3*	0	0
2007/08	3*	0	0
2008/09	3*	0	0

* Per vessel during daytime setting.

97. WG-IMAF assessed the risk levels of seabirds in this fishery in Subarea 88.1 as category 1 (low) south of 65°S, category 3 (average) north of 65°S and overall as category 3 and recommended (SC-CAMLR-XXVIII, Annex 7, Table 14 and Figure 2):

- strict compliance with Conservation Measure 25-02 (but with the possibility of exemption to paragraph 4 to allow for daytime setting);
- south of 65°S, no need to restrict longline fishing season;
- north of 65°S, restrict longline fishing to the period outside at-risk species' breeding season where known/relevant unless line sink rate requirement is met at all times;
- daytime setting permitted subject to line sink rate requirements and seabird by-catch limits;
- no offal dumping.

98. WG-IMAF assessed the risk level of seabirds in this fishery in Subarea 88.2 as category 1 (low) (SC-CAMLR-XXVIII, Annex 7, Table 14 and Figure 2) and recommended:

- strict compliance with Conservation Measure 25-02 (but with exemption to paragraph 4 to allow for daytime setting);
- no need to restrict longline fishing season;

- daytime setting permitted subject to line sink rate requirement;
- no offal dumping.

99. There were two observed incidental mortalities of crabeater seals in the longline fishery of Subarea 88.1 in 2008/09 (WG-IMAF-09/6 Rev. 2, Table 2).

6.2 Mitigation measures

100. Conservation Measure 25-02 applies to these areas and in recent years has been linked to an exemption for night setting in Conservation Measure 24-02 and subject to a seabird by-catch limit. Offal and other discharges are regulated under annual conservation measures (e.g. Conservation Measures 41-09 and 41-10).

7. Ecosystem implications/effects

101. Developments in evaluating ecosystem effects of the *D. mawsoni* fishery were discussed at the FEMA and FEMA2 Workshops (SC-CAMLR-XXVI/BG/6, paragraphs 45 to 48 and SC-CAMLR-XXVIII, Annex 4) and are summarised below.

102. Two key trophic interactions were identified as being important for *D. mawsoni*. The first concerned the nature of the interaction between toothfish predators (e.g. Type C killer whales, sperm whales and Weddell seals) and toothfish. Results from the ECOPATH model suggest that toothfish only forms about 6–7% of the diet of its predators (WG-EMM-09/42). However, it was noted that the consumption of toothfish in particular locations, at particular times of the year, or by particular parts of the population may be especially important to predators, even though the total consumption of toothfish by all individuals of a species is relatively low. This may be more important if there are small sub-populations of predators. WG-EMM-09/42 also noted that a balanced ecosystem model for the Ross Sea provided no support for the hypothesis that depletion of toothfish stocks would greatly change the diet of toothfish predators.

103. The second key trophic interaction was between toothfish and its prey – in particular demersal fish species. Results from the ECOPATH model suggest that toothfish consumes 70% of the annual production of demersal species (WG-EMM-07/18), and so a reduction of the toothfish population could have a large impact on the natural mortality of these species. The FEMA Workshop recognised the additional complex interaction with the fishery, whereby demersal fish are taken as by-catch, so that a reduction in natural mortality may be partially offset by an increase in fishing mortality.

104. The FEMA and FEMA2 Workshops considered that it was important to further develop the ecosystem modelling work in the Ross Sea to specifically address these interactions, including a scoping exercise be undertaken to determine the complexity of the model. They noted that models would need to be spatially and temporally explicit to take into account the spatio–temporal effects of the predation. They considered that a Minimum Realistic Model approach would be most appropriate. Given the paucity of data, they agreed

that the model should be as simple as possible, yet complex enough to test the key functional relationships, and that modelling results in the first instance would by necessity need to be used in a strategic, rather than tactical, sense.

105. The workshops also noted that the modelling was likely to identify a number of areas requiring extra data collection. These included understanding the 3-D foraging area of toothfish, its predators and its prey and how it may change seasonally and spatially, as well as a better understanding of toothfish movements, spawning dynamics and early life history.

106. In regard to spatial overlap, the FEMA2 Workshop examined information on foraging patterns of marine mammals and concluded that the available evidence suggests that the spatial overlap of Weddell seals and killer whales with the fishery is negligible. However, information currently available addressed the distribution of predators (and toothfish) only during summer. Information on toothfish distribution, and the distribution and behaviour of predators in winter may assist this analysis of potential overlap. The Working Group noted that models such as the SPM could be used to help evaluate whether this would be important.

107. The FEMA2 Workshop noted that the decision rule to estimate long-term precautionary yield for toothfish to satisfy Article II of the Convention (which relates to maintenance of ecological relationships between harvested, dependent and related species) is the proportion of spawning biomass permitted to escape the fishery to safeguard predators. This is set at 50% for the Ross Sea, as well as all other assessed toothfish fisheries.

108. The FEMA2 Workshop noted that the escapement level in the decision rule for the spawning biomass may need to be modified upwards if the size/age classes of *Dissostichus* spp. that are important prey for predators are reduced below a suitable escapement level for those classes.

8. Harvest controls and management advice

8.1 Conservation measures

Table 20: Limits on the exploratory fishery for *Dissostichus* spp. in Subarea 88.1 in force in 2008/09 (Conservation Measure 41-09) and advice to the Scientific Committee for 2009/10.

Element	Limit in force	Advice for 2009/10
Access (gear)	Limited to notified vessels using longlines.	Review
Catch limit	Precautionary catch limit for *Dissostichus* spp. was 2 700 tonnes for Subarea 88.1 applied as follows: SSRUs A, D, E, F and M – 0 tonnes SSRUs B, C and G – 352 tonnes total SSRUs H, I, K – 1 994 tonnes total SSRUs J and L – 354 tonnes.	Review
Season	1 December to 31 August	Same period
Fishing operations	In accordance with CM 41-01 and the setting of research hauls is not required (Annex B, paragraphs 3 and 4).	Carry forward
By-catch	Regulated by CMs 33-03 and 41-09.	Review
Mitigation	In accordance with CM 25-02, except paragraph 5 if requirements of CM 24-02 are met.	Carry forward
	Daylight setting allowed under CM 24-02, subject to a catch limit of three seabirds per vessel.	Carry forward
Observers	Each vessel to carry at least two scientific observers, one of whom shall be appointed in accordance with the CCAMLR Scheme of International Scientific Observation.	Carry forward
VMS	To be operational in accordance with CM 10-04.	Carry forward
CDS	In accordance with CM 10-05.	Carry forward
Research	Undertake research plan and tagging program as set out in CM 41-01, Annexes B and C.	Carry forward
	Toothfish tagged at a rate of at least one fish per tonne green weight caught.	Carry forward
Data	Five-day catch and effort reporting under CM 23-01.	Carry forward
	Haul-by-haul catch and effort data under CM 23-04.	Carry forward
	Biological data reported by the CCAMLR scientific observer.	Carry forward
Target species	For the purposes of CMs 23-01 and 23-04, the target species is *Dissostichus* spp. and the by-catch is any species other than *Dissostichus* spp.	Carry forward
Environmental protection	Regulated by CMs 26-01, 22-06 and 22-07. No offal discharge. Fishing prohibited in depths shallower than 550 m.	Carry forward
Additional element	Fishing within 10 n miles of Balleny Islands is prohibited.	Carry forward

Table 21: Limits on the exploratory fishery for *Dissostichus* spp. in Subarea 88.2 in force in 2008/09 (Conservation Measure 41-10) and advice to the Scientific Committee for 2009/10.

Element	Limit in force	Advice for 2009/10
Access (gear)	Limited to notified vessels using longlines.	Review
Catch limit	Precautionary catch limit for *Dissostichus* spp. was 567 tonnes for Subarea 88.2 south of 65°S, applied as follows: SSRUs A and B – 0 tonnes SSRUs C, D, F and G – 214 tonnes total SSRU E – 353 tonnes.	Review
Season	1 December to 31 August	Same period
Fishing operations	In accordance with CM 41-01 and the setting of research hauls is not required (Annex B, paragraphs 3 and 4).	Carry forward
By-catch	Regulated by CMs 33-03 and 41-10.	Review
Mitigation	In accordance with CM 25-02, except paragraph 4 if requirements of CM 24-02 are met.	Carry forward
	Daylight setting allowed under CM 24-02.	Carry forward
Observers	Each vessel to carry at least two scientific observers, one of whom shall be appointed in accordance with the CCAMLR Scheme of International Scientific Observation.	Carry forward
VMS	To be operational in accordance with CM 10-04.	Carry forward
CDS	In accordance with CM 10-05.	Carry forward
Research	Undertake research plan and tagging program as set out in CM 41-01, Annexes B and C.	Carry forward
	Toothfish tagged at a rate of at least one fish per tonne green weight caught.	Carry forward
	Skates tagged at a rate of at least one skate per five skates caught, up to a maximum of 500 skates per vessel.	Carry forward
Data	Five-day catch and effort reporting under CM 23-01.	Carry forward
	Haul-by-haul catch and effort data under CM 23-04.	Carry forward
	Biological data reported by the CCAMLR scientific observer.	Carry forward
Target species	For the purposes of CMs 23-01 and 23-04, the target species is *Dissostichus* spp. and the by-catch is any species other than *Dissostichus* spp.	Carry forward
Environmental protection	Regulated by CMs 26-01, 22-06 and 22-07. No offal discharge. Fishing prohibited in depths shallower than 550 m.	Carry forward

8.2 Management advice

109. The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period for the Ross Sea (Subarea 88.1 and SSRUs 882A–B) was 2 850 tonnes. At this yield, there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass. A yield of 2 850 tonnes is therefore recommended.

110. The constant catch for which there was median escapement of 50% of the median pre-exploitation spawning biomass level at the end of the 35-year projection period for

SSRU 882E was 361 tonnes. At this yield, there is a less than 10% chance of spawning biomass dropping to less than 20% of the initial biomass. A yield of 361 tonnes is therefore recommended.

111. For SSRUs 882C, D, F and G, the Working Group could provide no new advice, but noted that the catches in these areas had provided some useful biological data for toothfish. Therefore, the Working Group recommended the current catch limits in these SSRUs be continued for the 2009/10 season.

112. The Working Group recommended that the allocation method used to set the 2005/06 catch limits for SSRUs in Subarea 88.1 be continued for the 2009/10 season.

113. The Working Group recalled its advice that the current designations of SSRUs in Subareas 88.1 and 88.2 are almost certainly not optimal, but a detailed revision of these would require, at least, a consolidated movement model for fish in these subareas, which is not yet available. Such a revision should take account not only of the principal target species, but also of by-catch species and ecosystem considerations.

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