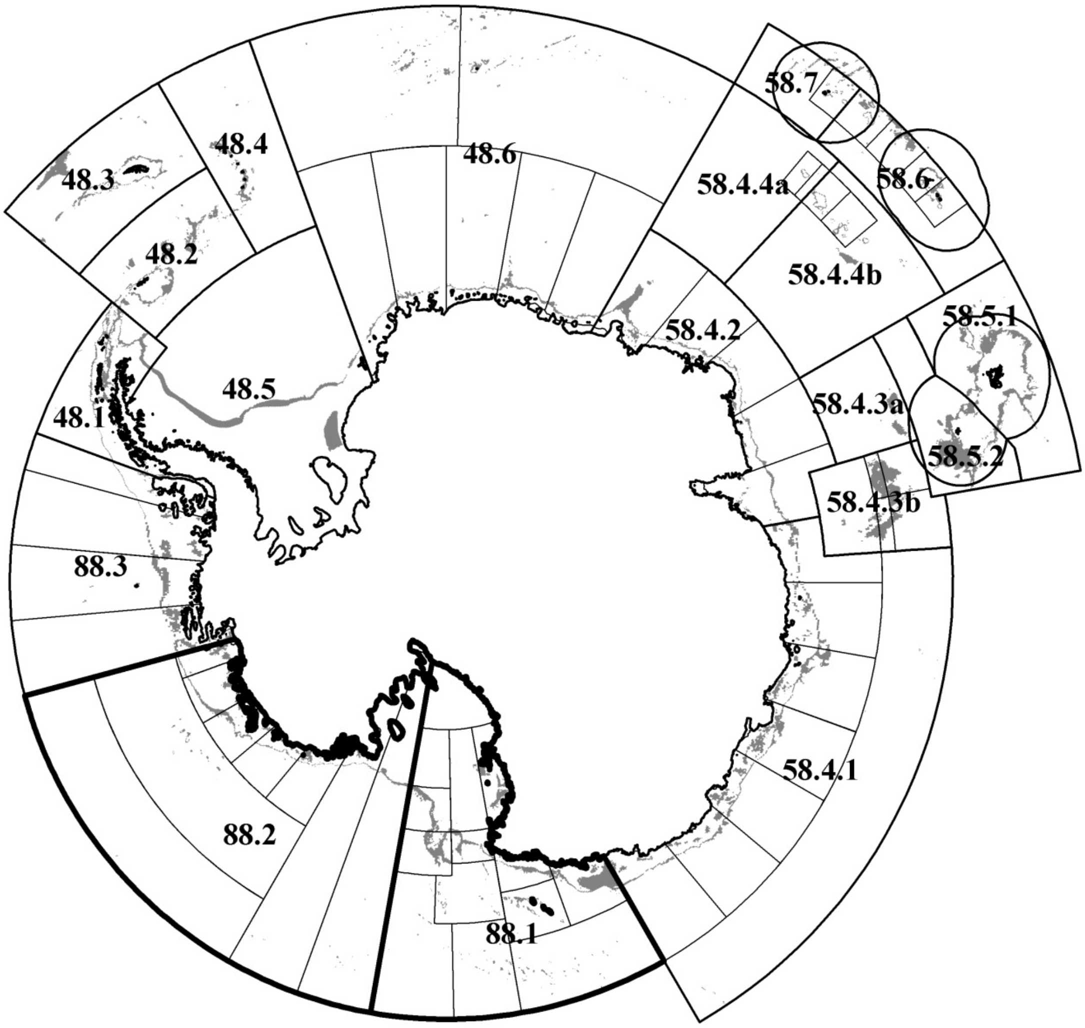
Fishery Report 2014: Exploratory fishery for *Dissostichus* spp. in Subareas 88.1 and 88.2



CONTENTS

The map on the cover page shows the management areas within the CAMLR Convention Area, the specific region related to this report is outlined in bold. Depths between 600–1 800m (the ‘fishable depths’ for *Dissostichus* spp.) are shaded.

Throughout this report the CCAMLR fishing season is represented by the year in which that season ended, e.g. 2014 represents the 2013/14 CCAMLR fishing season (from 1 December 2013 to 30 November 2014).

Fishery Report 2014: Exploratory fishery for *Dissostichus* spp. in Subareas 88.1 and 88.2

Introduction to the fishery

1. This report describes the exploratory longline fishery for Antarctic (*Dissostichus mawsoni*) and Patagonian toothfish (*D. eleginoides*) in Subareas 88.1 and 88.2.

2. The distribution of catch limits to the small-scale research units (SSRUs) in Subareas 88.1 and 88.2 was part of a three-year experiment starting in 2006 when 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 (SC-CAMLR-XXIV, paragraphs 4.163 to 4.166). SSRU 881M was defined and closed to fishing in 2009 to protect the likely toothfish migration corridor in the western Ross Sea and Terra Nova Bay (SC-CAMLR-XXVII, paragraphs 4.160 and 4.161). For the purposes of stock assessment, Subareas 88.1 and 88.2 are split into two areas: (i) Subarea 88.1 and SSRUs 882A–B, referred to as the Ross Sea region, and (ii) SSRUs 882C–H (referred to as Subarea 88.2).

3. In 2011, the Commission revised the boundaries of the SSRUs in Subarea 88.2 such that 76% of the yield was assigned to the region between 70°50'S and 65°00'S (SSRU 882H) and the remaining 24% of the yield was assigned to the region south of 70°50'S (SSRUs 882C–G) as outlined in SC-CAMLR-XXX, paragraph 6.127.

4. The limits on the exploratory fishery for *Dissostichus* spp. in Subarea 88.1 are described in Conservation Measure (CM) 41-09. To assist administration of the fishery, the catch limits for SSRUs 881B, C and G were combined into a ‘north’ region (881B, C, G), those for SSRUs 881H, I and K were combined into a ‘slope’ region (881H, I, K) and those for SSRUs 881J and L into a ‘shelf’ region (881J, L).

5. These ‘administrative’ boundaries are used for the management of the fishery, however, the allocation of catches to these regions in the assessment process uses a tree-based regression based on the median length of fish in each longline set, and the explanatory variables SSRU and depth. This leads to slight differences in the catch histories allocated to the ‘north’, ‘slope’ and ‘shelf’ in the catch histories in Table 1 and in the assessment process. Furthermore, the catch histories in Table 1 are based on subareas so that catches in SSRUs 882A–B are reported from that subarea, whereas in the catch history for the assessment these catches are included in the Ross Sea region to better correspond to the presumed geographical distribution of the Ross Sea toothfish stock.

6. The precautionary catch limit in Subarea 88.1 in 2014 for *Dissostichus* spp. is 3 044 tonnes, of which 13% could be taken in SSRUs 881B, C, G; 74% in SSRUs 881H, I, K; and 13% in SSRUs 881J, L. Within the SSRU 881J, L catch limit, a research catch limit of 43 tonnes was set aside to enable completion of the 2014 sub-adult survey. The catch limits for by-catch species were defined in CMs 33-03 and 41-09. The fishing season was from 1 December 2013 to 31 August 2014.

Table 1: Catch history for *Dissostichus* spp. in Subareas 88.1 and 88.2. (Source: STATLANT data for past seasons, and catch and effort reports for current season, past reports for IUU catch.)

Season	Subarea 88.1					Subarea 88.2				
	Catch limit (tonnes)	Reported catch (tonnes)			Estimated IUU catch (tonnes)	Catch limit (tonnes)	Reported catch (tonnes)			Estimated IUU catch (tonnes)
		D. mawsoni	*D. eleginoides*	Total			*D. mawsoni*	*D. eleginoides*	Total	
1997	1980	0	0	0	0	1980	0	0	0	-
1998	1510	41	1	42	0	63	0	0	0	-
1999	2281	296	1	297	0	0	0	0	0	-
2000	2090	751	0	751	0	250	0	0	0	-
2001	2064	626	34	660	0	250	0	0	0	-
2002	2508	1313	12	1325	92	250	41	0	41	0
2003	3760	1805	26	1831	0	375	106	0	106	0
2004	3250	2184	13	2197	240	375	374	0	375	0
2005	3250	3098	7	3105	28	375	411	0	411	0
2006	2964	2968	1	2969	0	487	514	0	514	15
2007	3032[1]	3079	12	3091	0	547[1]	347	0	347	0
2008	2700	2251	9	2259	272	567	416	0	416	0
2009	2700	2432	17	2448	0	567	484	0	484	0
2010	2850	2868	<1	2869	0	575	314	0	314	0
2011	2850	2836[q]	3	2839	*	575[1]	590	0	590	*
2012	3282[1]	3173	5	3178	*	530[1]	424	0	425	*
2013	3282[1]	3162	<1	3163	*	530	476	0	476	*
2014	3044[1]	2896	4	2900	*	390	426	0	426	*

[1] In Subarea 88.1, the catch limit includes 40 tonnes set aside for research fishing in 2007, 80 tonnes in 2012, 49 tonnes in 2013 and 43 tonnes in 2014.
In Subarea 88.2, the catch limit includes 20 tonnes for research fishing in 2007 and 10 tonnes for research fishing in 2011 and 2012.

* IUU catch levels not estimated; no evidence of IUU presence or activity reported.

[q] Some catch data in this year is quarantined. The following catch is not included in the reported catch table above:
2011 – vessel *In Sung No. 7*, 45 tonnes of *D. mawsoni*.

7. The limits on the exploratory fishery for *Dissostichus* spp. in Subarea 88.2 (SSRUs 882C–H) are described in CM 41-10. In 2014, the precautionary catch limit for *Dissostichus* spp. of 390 tonnes was applied as follows: 124 tonnes total could be taken in SSRUs C–G and 266 tonnes could be taken in SSRU H. Three SSRUs (A, B and I) were closed to fishing. In some seasons, fishing in closed SSRUs has occurred under exemptions for research. The catch limits for by-catch species were defined in CMs 33-03 and 41-10. The fishing season was from 1 December 2013 to 31 August 2014.

8. In 2014, 20 vessels (from 7 Members) and 14 vessels (from 6 Members) fished in Subareas 88.1 and 88.2 respectively. For 2015, nine Members with a total of 19 vessels have notified their intention to participate in the exploratory fishery for *Dissostichus* spp. in Subarea 88.1, and eight Members with a total of 18 vessels have notified their intention to participate in the exploratory fishery for *Dissostichus* spp. in Subarea 88.2.

9. The Ross Sea fishery saw a steady expansion of effort (number of sets) from 1998 to 2001, and an almost three-fold increase in 2004. Since 2005 effort has been slightly more stable. In the Ross Sea, in earlier years most vessels fished with the autoline system, but the number of vessels fishing with trotlines has been increasing since 2009, and preliminary data suggest that this has more than doubled to 10 vessels in 2013. 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. The two slope SSRUs, 881H and 881I, have been the most consistently fished SSRUs. In years with favourable ice conditions (2005, 2009, 2011–2013), fishing has also extended into SSRU 881K. Within Subarea 88.2 most fishing has been carried out in SSRU 882H.

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 and has usually finished in January or February depending on ice conditions. Fishing in SSRU 882H and, to a lesser extent, SSRUs 882C–G, has shown a similar pattern with a trend towards starting and finishing earlier over the course of the fishery.

11. Catches of *D. eleginoides* have mainly come from the northwest of the Ross Sea region in SSRUs 881A–C (WG-FSA-13/48). Catches were quite high in the early part of the fishery, particularly in 2001, but have been relatively low since then. The catch rates for *D. eleginoide*s have been much higher in SSRU 881A than the other SSRUs, and this SSRU has been closed to fishing since 2008.

Reported catch

12. The historical catches of *Dissostichus* spp. from Subareas 88.1 and 88.2 are provided in Table 1. The catches reported from Subarea 88.1 include catch data from particular vessels that CCAMLR has agreed should be quarantined as there is no confidence in the amount and/or the location of those catches (SC-CAMLR-XXXIIII, paragraph 3.68). Those years that include quarantined data are indicated with a superscript q and vessel-specific details are

provided in the footnote to Table 1. All ancillary data associated with these vessels (e.g. by-catch, tagging, observer data) is also quarantined and is not included in the data presented in this report.

13. In 2014 the total reported commercial catch of *Dissostichus* spp. in Subarea 88.1 was 2 900 tonnes (97% of the limit); the following SSRUs were closed during the course of fishing:

- SSRUs B, C, G closed on 19 December 2013, triggered by the catch of 344 tonnes of *Dissostichus* spp., reaching 87% of the catch limit of 397 tonnes
- SSRUs H, I, K closed on 11 January 2014, triggered by the catch of 2 237 tonnes of *Dissostichus* spp., reaching 100% of the catch limit of 2 247 tonnes
- SSRUs J, L closed on 17 January 2014, triggered by the catch of 319 tonnes of *Dissostichus* spp., reaching 89% of the catch limit of 357 tonnes.

14. In addition, 25 tonnes were taken from SSRUs 881J, L, M during the sub-adult survey conducted by New Zealand (SC-CAMLR-XXXIII, Annex 5). The total reported catch of *Dissostichus* spp. in Subarea 88.1 in 2014 was 2 925tonnes.

15. The catch limits for *Dissostichus* spp. in Subarea 88.2 were exceeded in 2014 (see CCAMLR-XXXIII/BG/01) and the total reported catch of *Dissostichus* spp. was 426 tonnes. The following SSRUs were closed during the course of fishing:

- SSRUs C–G closed on 26 January 2014, triggered by the catch of 152 tonnes of *Dissostichus* spp., reaching 122% of the catch limit of 124 tonnes
- SSRU H closed on 24 January 2014, triggered by the catch of 274 tonnes of *Dissostichus* sp., reaching 103% of the catch limit of 266 tonnes.

Illegal, unreported and unregulated (IUU) fishing

16. The estimated illegal, unreported and unregulated (IUU) catch in Subarea 88.1 was 240 tonnes in 2004, 28 tonnes in 2005 and 272 tonnes in 2008 (Table 1).

17. In Subarea 88.2 (SSRU 882A) there was an estimated 15 tonnes of IUU catch in 2006 (Table 1), which is the only observed occurrence of IUU fishing in this subarea.

18. Following the recognition of methodological issues regarding the estimation of IUU catch levels since 2011, evidence of IUU presence or activity has continued to be recorded but no corresponding estimates of the IUU catch for *Dissostichus* spp. have been provided (SC-CAMLR-XXIX, paragraph 6.5). No evidence of IUU presence or activity has been reported in Subareas 88.1 or 88.2 during that period (Table 1).

Data collection

19. Catch limits for *D. mawsoni* and *D. eleginoides* in Subareas 48.3, 88.1 and 88.2 and Division 58.5.2 are set by CCAMLR using fully integrated assessments; more basic approaches are used for the 'data-poor' fisheries (in Subarea 48.6 and in Area 58 outside the EEZs). In Subareas 88.1 and 88.2 the assessment is for *D. mawsoni* with catches of *D. eleginoides* included as part of the overall catch limits. Subareas 88.1 and 88.2 are managed under the umbrella of the exploratory fisheries CM41-01 and, as such, have an associated data collection plan (Annex 41-01/A), a research plan (Annex 41-01/B) and a tagging program (Annex 41-01/C). The data collected under this conservation measure are described below.

Biological data

20. The collection of biological data under CM 23-05 is conducted as part of the CCAMLR Scheme of International Scientific Observation. In exploratory longline fisheries targeting *D. mawsoni* and *D. eleginoides*, biological data collection includes representative samples of length, weight, sex and maturity stage, as well as collection of otoliths for age determination of the target and most frequently taken by-catch species.

Length distributions of catches

21. The length-frequency distributions of *D. mawsoni* and *D. eleginoides* caught in this fishery from 2005 to 2014 are presented in Figures 1 to 3. These length-frequency distributions are unweighted (i.e. they have not been adjusted for factors such as the size of the catches from which they were collected). The interannual variability exhibited in the figure may reflect differences in the fished population but is also likely to reflect changes in the gear used, the number of vessels in the fishery and the spatial and temporal distribution of fishing. The actual stock assessment uses scaled length frequencies, which may differ from patterns displayed here; a description of how length data are used in assessments is provided in the relevant section of this report.

22. The length-frequency distribution of the catches for *D. mawsoni* in this fishery ranged from 50 to 180 cm (Figure 1). In all seasons and areas, there has been a broad mode at about 120–170 cm. In most years there has also been a mode of smaller fish, at 50–100 cm, caught on the Ross Sea shelf, but the length distribution of fish captured here is more variable between years due to less consistency of fishing effort patterns.

23. The length-frequency distribution of the *D. mawsoni* catch in SSRU 882H appears to be very stable with little evidence of change in length, or of sex ratio, over time (Figure 2). In years when fishing occurred in the south of Subarea 88.2 (SSRUs C–G), there was also usually a strong mode at about 60–80 cm.

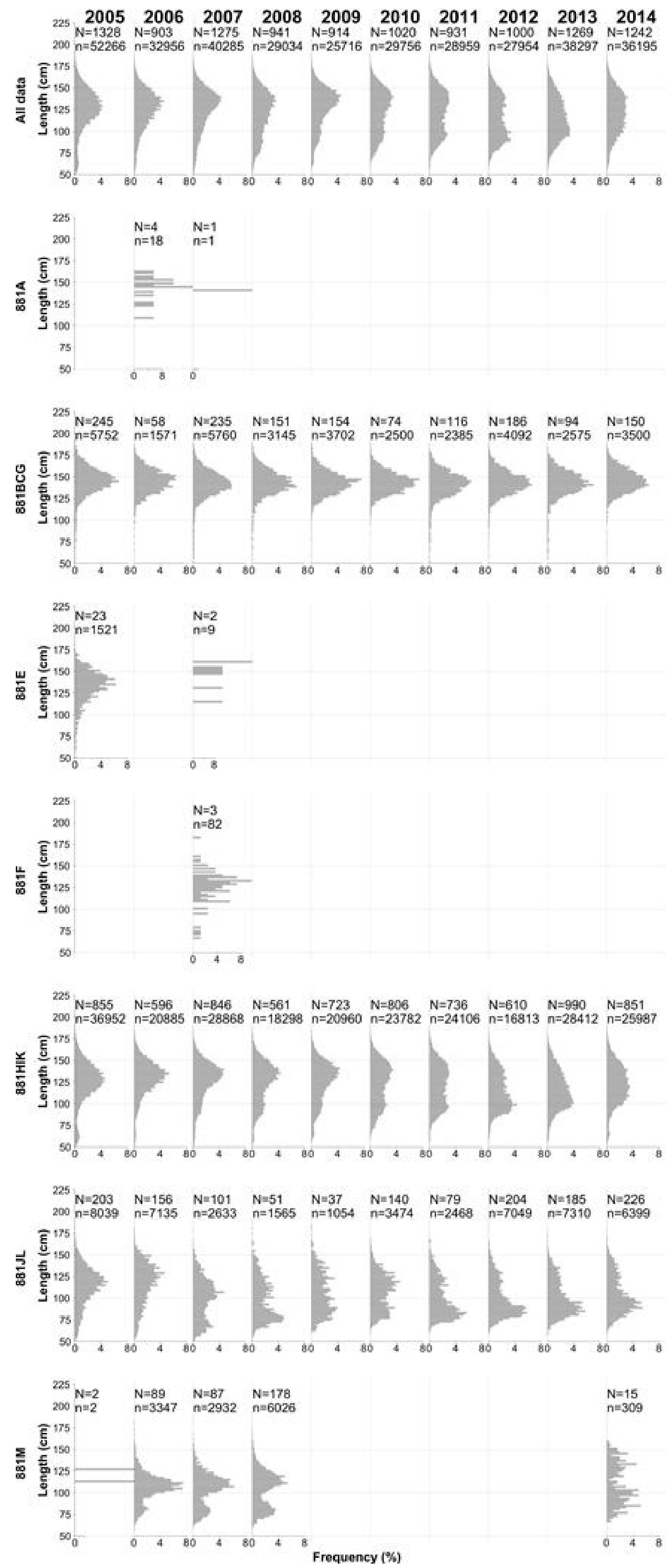


Figure 1: Annual length-frequency distributions of *Dissostichus mawsoni* caught in Subarea 88.1 (top panel) and in each SSRU (lower panels). The number of hauls from which fish were measured (N) and the number of fish measured (n) in each year are provided.

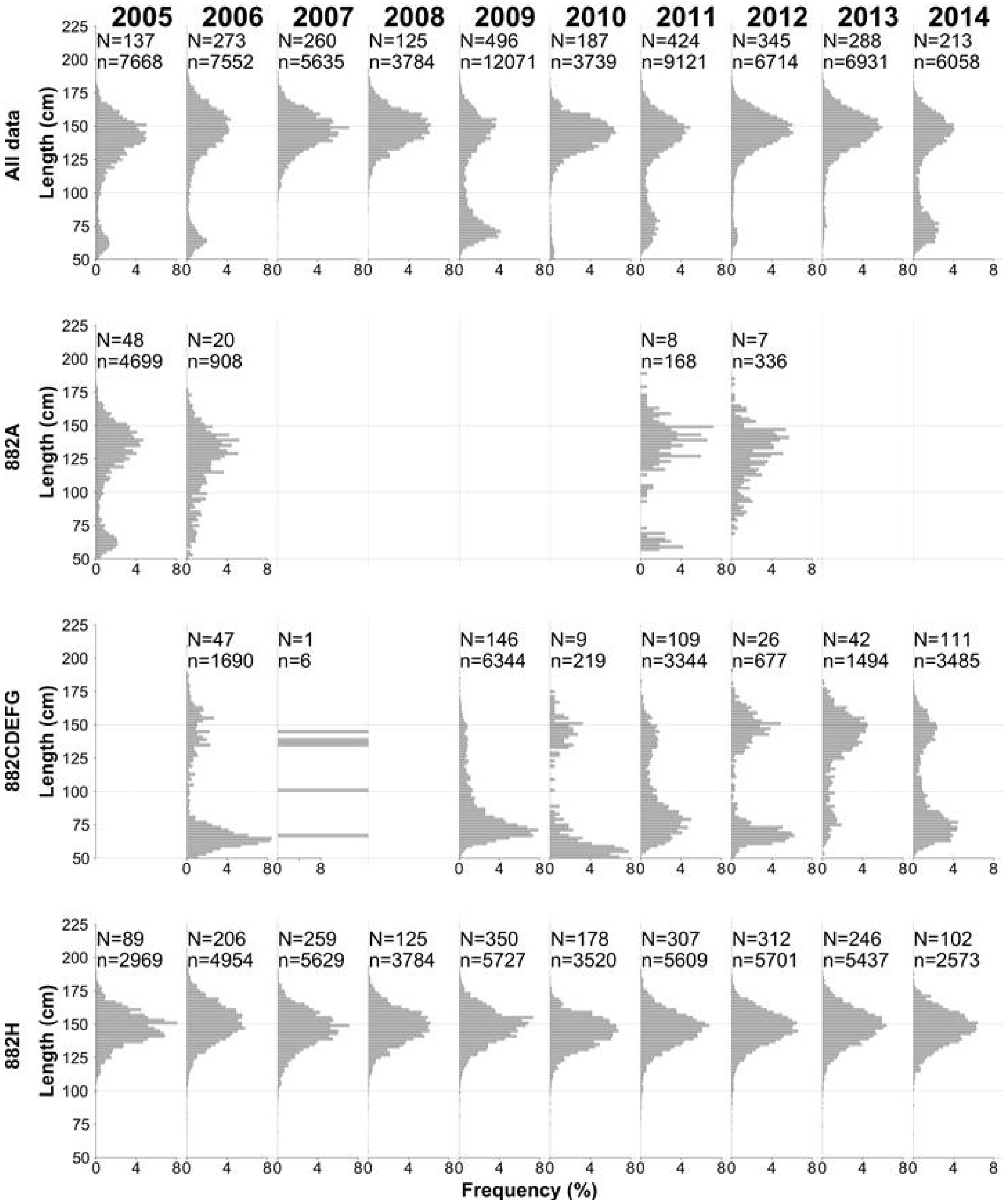


Figure 2: Annual length-frequency distributions of *Dissostichus mawsoni* caught in Subarea 88.2 (top panel) and in each SSRU (lower panels). The number of hauls from which fish were measured (N) and the number of fish measured (n) in each year are provided.

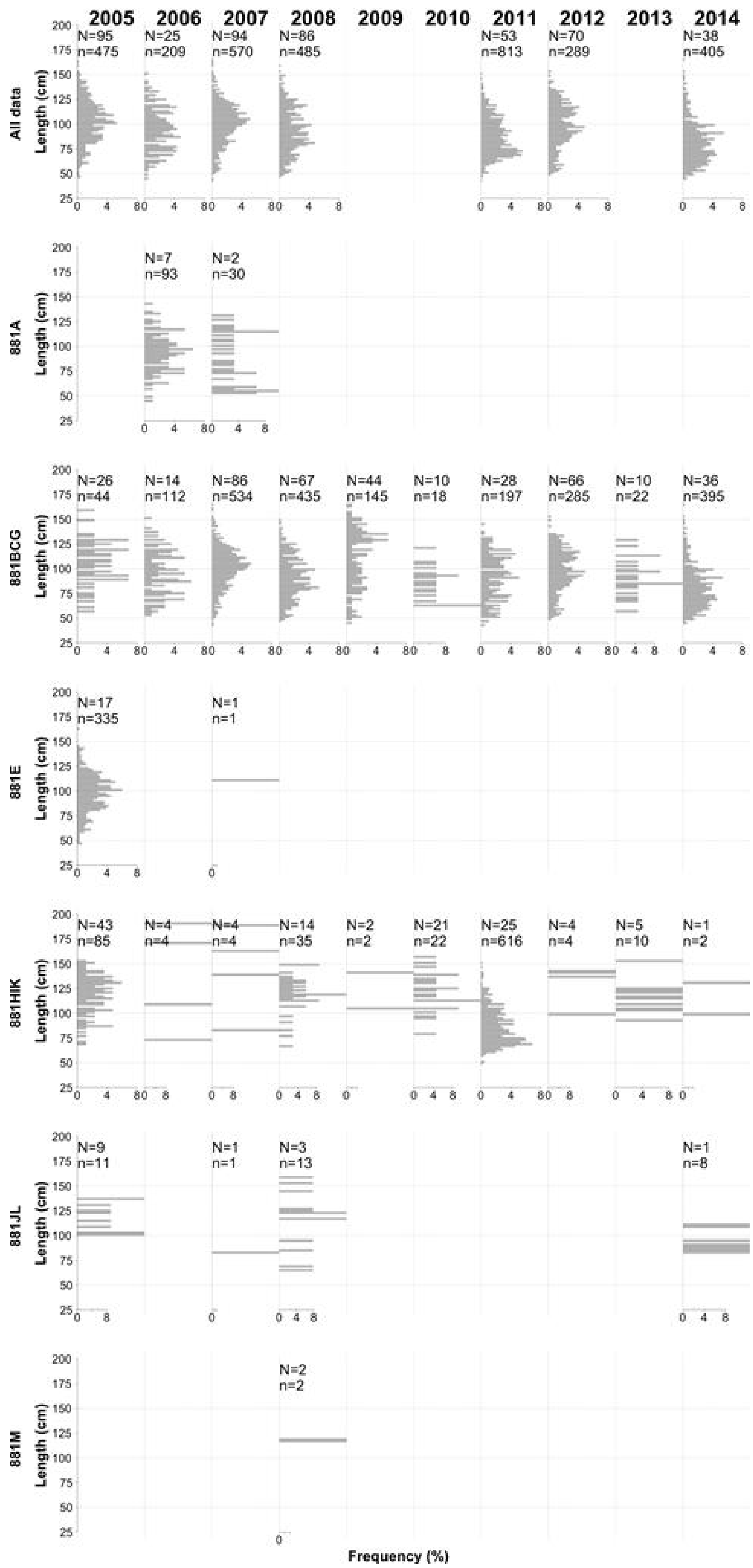


Figure 3: Annual length-frequency distributions of *Dissostichus eleginoides* caught in Subarea 88.1 (top panel) and in each SSRU (lower panels). The number of hauls from which fish were measured (N) and the number of fish measured (n) in each year are provided.

24. *Dissostichus eleginoides* length-frequency data are sparse in some years with very few fish caught and/or measured; the length-frequency distributions for most years were remarkably consistent (Figure 3; see also WG-FSA-10/23, Table 9, Figure 13). The notable exception was 2009, where the modal length was much larger; in that sample, males outnumbered females (in contrast to the usual female-biased sex ratio found in catches of this species) and it is considered likely that the fish measured were misidentified *D. mawsoni*.

Tagging

25. Under CM 41-01, each longline vessel fishing in exploratory fisheries for *Dissostichus* spp. has been required to tag and release *Dissostichus* spp. at the rate of one toothfish per tonne of green weight caught throughout the season since 2004. An upper limit of 500 fish tagged per vessel applied until the end of 2007. In order to ensure that there is sufficient overlap between the length distribution of those fish that are tagged by a vessel and of all the fish that are caught by that vessel, each vessel catching more than 10 tonnes of each species of *Dissostichus* is required to achieve a minimum tag-overlap statistic[1] (see Annex 41-01/C, footnote 3). The requirement to achieve a minimum tag-overlap statistic of 50% was first introduced for the 2011 season and this was then increased to 60% for the 2012 and subsequent seasons.

26. All vessels fishing in Subareas 88.1 and 88.2 have consistently exceeded the required tagging rate of one fish per tonne, with the exception of the *Hong Jin No. 707* in 2011, at 0.9 fish per tonne. All vessels have exceeded the minimum tag-overlap requirements of 60%, with most achieving more than 80% (Tables 2 and 3) with the exception of the *Simeiz* in Subarea 88.1 in 2013, and *Palmer*, *Yantar 31* and *Argos Georgia* in Subarea 88.2 in 2014.

27. A total of 35 536 *D. mawsoni* and 1 208 *D. eleginoides* have been tagged and 1 783 and 86 respectively have been recaptured in Subarea 88.1 (Table 4). In Subarea 88.2, 5 115 *D. mawsoni* and 6 *D. eleginoides* have been tagged and 459 and four respectively have been recaptured (Table 5).

28. A relative index of vessel-specific tag detection performance for the Ross Sea fishery using a case-control methodology was developed in WG-SAM-13/34. The method controls for the interannual spatial and temporal variability of commercial fishing operations from which tags are released and recaptured. Selection criteria to determine a subset of vessels for which there was confidence in their tag-recapture data were developed and then applied, resulting in the tagging dataset used for the assessment models (WG-FSA-13/50 and 13/51).

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[1] The tag-overlap statistic estimates the similarity in size distributions of fish that are tagged and all fish caught by a vessel (Annex 41-01/C, footnote 3).

Table 2: Annual tagging rate, reported by vessel, operating in the exploratory fishery for *Dissostichus* spp. in Subarea 88.1 since 2005. The tag-overlap statistics (CM 41-01) for *D. mawsoni* and *D. eleginoides* respectively are provided in brackets. Values for the tag-overlap statistic are not calculated for catches of less than 10 tonnes (*).

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Argentina	*Antartic II*		0.8	1.5 (9, -)							
	Antartic III	1.2			0 (-, -)						
	Argenova XXI						1.1 (52, -)				
Chile	*Isla Eden*					1.4 (26, -)					
Korea,	*Bonanza No. 707*										
Republic of	*Hong Jin No. 701*								1.3 (72, *)	1.1 (82, -)	1.1 (83, -)
	Hong Jin No. 707				1.2 (18, -)	1.2 (25, 21)	1.1 (50, -)	1.1 (64, *)	1.0 (71, -)	1.0 (82, -)	1.1 (83, -)
	Insung No. 1					1.3 (15, *)	1.1 (23, -)				
	Insung No. 2				1.2 (3, *)						
	Insung No. 22			1.2 (19, *)							
	Insung No. 3									1.5 (91, *)	
	Insung No. 5									1.6 (91, -)	
	Jung Woo No. 2			1.2 (29, *)	1.0 (25, *)	1.1 (19, -)	1.2 (26, -)	1.1 (93, -)	1.2 (91, -)		
	Jung Woo No. 3					1.5 (21, -)	1.1 (42, -)	1.0 (88, -)	1.2 (86, -)		
	Kostar									1.1 (94, -)	1.1 (78, -)
	Sunstar									1.2 (85, -)	1.1 (76, -)
New Zealand	*Antarctic Chieftain*					1.1 (57, -)	1.0 (61, -)	1.0 (96, -)	1.2 (89, *)		1.1 (74, -)
	Avro Chieftain		1.0	1.1 (52, -)	1.2 (12, -)						
	Janas	1.0	1.0	1.1 (69, -)	1.0 (80, -)	1.1 (43, -)	1.0 (79, -)	1.0 (85, -)	1.3 (81, -)	1.0 (91, -)	1.1 (88, *)
	San Aotea II	1	(>500 fish)	1.2 (52, *)	1.2 (69, *)	1.1 (77, -)	1.1 (79, -)	1.1 (88, *)	3.8 (87, *)	1.8 (80, -)	1.8 (88, *)
	San Aspiring	(>500 fish)	1.0	1.1 (76, *)	1.1 (74, -)	1.1 (81, *)	1.1 (88, *)	1.1 (90, *)	1.1 (92, *)	1.2 (93, -)	1.1 (91, -)
Norway	*Froyanes*	1.5	1.2	1.1 (18, -)							
	Seljevaer								1 (79, -)	1.1 (76, -)	1.0 (81, -)

(continued)

Table 2 (continued)

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Russia	*Chio Maru No. 3*							1.4 (78, -)	1 (75, *)		
	Gold Gate							1.3 (88, *)			
	Mys M arii										1.1 (79, -)
	Ostrovka							1.0 (65, -)			
	Palmer										1.2 (83, -)
	Sparta							1.2 (63, -)	1.6 (-, *)	1.1 (*, -)	1.1 (72, -)
	Ugulan									1.0 (74, -)	1.0 (78, -)
	Volna	0.7	0.8	1.0 (16, -)							
	Yantar	0.4	0.7	1.1 (27, -)	1.1 (34, -)						
	Yantar 31								1.2 (90, -)	1.1 (83, -)	1.0 (81, -)
	Yantar 35									1.1 (78, -)	1.2 (82, -)
South Africa	*Ross Mar*			1.0 (68, -)	1.1 (40, *)						
	South Princess										
Spain	*Arnela*										
	Tronio				1.0 (22, *)	1.4 (19, *)	1.0 (69, -)	1.0 (69, *)	1.0 (69, -)	1.0 (90, *)	1.0 (77, -)
UK	*Argos Froyanes*				1.1 (46, -)	1.1 (43, *)	1.0 (54, -)	1.1 (76, -)	1.3 (61, -)	1.0 (91, -)	1.0 (89, -)
	Argos Georgia		1.1	1.0 (55, *)	1.2 (65, *)		1.1 (47, -)	1.0 (68, -)	1.1 (90, *)	1.1 (78, *)	1.1 (80, -)
	Argos Helena	1.5	1.0	1.4 (57, *)	1.3 (66, *)	1.3 (35, *)					
Ukraine	*Poseydon I*										1.0 (68, -)
	Simeiz									1.2 (43, -)	1.1 (83, -)
	Sonrisa										
Uruguay	*Paloma V*	1.2	1.3								
	Piscis										
	Punta Ballena	1.1	1.0								
	Ross Star			1.1 (20, *)	1.6 (21, *)	1.1 (48, -)					
	Viking Sur		0.9	1.3 (13, -)							
Required tagging rate		1	1	1	1	1	1	1	1	1	1

Table 3: Annual tagging rate, reported by vessel, operating in the exploratory fishery for *Dissostichus* spp. in Division 88.2 since 2005. The tag-overlap statistics for *D. mawsoni* and *D. eleginoides* respectively are provided in brackets and are not calculated for catches of less than 10 tonnes (*).

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Argentina	*Antartic II*		0.2	0 (0, -)							
	Argenova XXI						1.0 (*, -)				
Chile	*Isla Eden*					1.2 (*, -)					
Korea,	*Hong Jin No. 701*									1.3 (*, -)	1.1 (84, -)
Republic of	*Hong Jin No. 707*					1.3 (36, -)		0.9 (73, -)	1.5 (62, -)		1.4 (78, -)
	Jung Woo No. 3						1.1 (*, -)	1.1 (84, -)			
	Kostar									1.1 (82, -)	1.0 (*, -)
	Sunstar									1.1 (*, -)	1.0 (65, -)
New Zealand	*Antarctic Chieftain*					1.8 (61, -)		1.0 (92, -)	1.0 (96, -)	1.1 (86, -)	1.0 (80, -)
	Avro Chieftain	1.0			1.0 (54, -)						
	Janas		1.1			1.2 (73, -)		1.1 (81, -)	1.0 (83, -)	1.1 (82, -)	1.4 (76, -)
	San Aspiring							1.1 (77, -)			
Norway	*Froyanes*	0	0.9	0.9 (41, -)							
	Seljevaer									1.2 (*, -)	1.1 (86, -)
Russia	*Chio Maru No. 3*							2.2 (*, -)			
	Gold Gate							1.1 (76, -)			
	Palmer									1.0 (75, -)	1.0 (58, -)
	Sparta							1.2 (79, -)	1.1 (62, -)	1.2 (75, -)	1.0 (70, -)
	Volna	0.2	0	1.0 (13, -)							
	Yantar	0.9	0	1.0 (14, -)	0 (-, -)						
	Yantar 31									2.1 (*, -)	1.0 (57, -)
	Yantar 35									1.6 (*, -)	
South Africa	*Ross Mar*					1.0 (60, -)					
Spain	*Tronio*					1.2 (17, -)	1.2 (49, -)				
UK	*Argos Froyanes*				1.1 (31, -)	2.2 (55, -)	1.0 (55, -)	1.0 (77, -)	1.0 (66, -)	1.1 (68, -)	1.2 (73, -)
	Argos Georgia		1.9	0 (-, -)		1.1 (56, -)	1.1 (*, -)	1.1 (50, -)			1.2 (52, -)
	Argos Helena		1.7	0.5 (53, -)		1.9 (61, -)					
Ukraine	*Simeiz*									1.7 (*, -)	1.2 (77, -)
Uruguay	*Ross Star*				0.2 (*, -)	1.4 (64, -)		1.2 (68, -)			
	Viking Sur			1.1 (*, -)							
Required tagging rate		1	1	1	1	1	1	1	1	1	1

Table 4: The number of individuals of (a) *Dissostichus mawsoni* and (b) *D. eleginoides* tagged in each season in Subarea 88.1. The number of fish recaptured by each vessel is provided in brackets.

(a)

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Argentina	*Antartic II*		122 (0)	228 (1)							
	Antartic III	290 (7)									
	Argenova XXI						33 (2)				
Chile	*Isla Eden*					139 (1)					
Korea,	*Hong Jin No. 701*								106 (0)	209 (4)	270 (2)
Republic of	*Hong Jin No. 707*				255 (4)	153 (11)	368 (24)	224 (9)	456 (8)	291 (1)	405 (6)
	Insung No. 1					143 (3)	313 (29)				
	Insung No. 2				5 (0)						
	Insung No. 22			332 (11)							
	Insung No. 3									249 (10)	
	Insung No. 5									427 (16)	
	Jung Woo No. 2			179 (22)	201 (35)	242 (11)	270 (3)	283 (0)	186 (3)		
	Jung Woo No. 3					164 (0)	185 (8)	157 (2)	236 (5)		
	Kostar									223 (1)	117 (1)
	Sunstar									154 (4)	122 (1)
	Antarctic Chieftain					185 (8)	164 (36)	238 (18)	127 (2)		
New Zealand	*Avro Chieftain*		266 (8)	289 (29)	50 (4)						
	Janas	450 (13)	282 (12)	184 (6)	179 (15)	166 (5)	415 (34)	172 (4)	168 (0)	130 (13)	150 (14)
	San Aotea II	488 (15)	510 (18)	375 (27)	193 (45)	186 (19)	288 (24)	321 (50)	289 (4)	348 (21)	354 (70)
	San Aspiring	579 (10)	432 (7)	462 (37)	370 (28)	264 (31)	513 (59)	199 (19)	527 (62)	243 (32)	307 (76)
	Froyanes	316 (2)	121 (1)	168 (5)							
Norway	*Seljevaer*								178 (14)	238 (53)	264 (55)
	Chio Maru No. 3							196 (4)	201 (3)		
Russia	*Gold Gate*							98 (1)			
	Mys Marii										21 (1)
	Ostrovka							18 (3)			
	Palmer										54 (7)
	Sparta							110 (8)		7 (1)	28 (3)
	Ugulan									41 (3)	49 (2)
	Volna	160 (4)	250 (1)	103 (0)							
	Yantar	106 (0)	245 (0)	375 (8)	283 (15)						
	Yantar 31								362 (7)	82 (8)	93 (0)
	Yantar 35									166 (9)	125 (8)

(continued)

Table 4(a) (continued)

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
South Africa	*Ross Mar*			51 (1)	125 (8)						
Spain	*Tronio*				8 (0)	494 (1)	308 (23)	429 (12)	546 (8)	388 (12)	298 (22)
	Argos Froyanes				370 (38)	301 (0)	158 (4)	332 (28)	38 (1)	183 (23)	220 (25)
UK	*Argos Georgia*		50 (0)	220 (35)	182 (4)		51 (2)	213 (48)	300 (13)	293 (10)	244 (22)
	Argos Helena	381 (0)	272 (17)	267 (6)	180 (14)	337 (6)					
Ukraine	*Pseydon I*										30 (2)
	Simeiz									75 (1)	73 (4)
	Sonrisa										
Uruguay	*Paloma V*	187 (1)	126 (2)								
	Punta Ballena	222 (1)	211 (1)								
	Ross Star			150 (1)	94 (0)	54 (0)					
	Viking Sur		62 (2)	141 (1)							
		3179 (53)	2949 (69)	3524 (190)	2494 (210)	2828 (96)	3066 (248)	2990 (206)	3720 (130)	3747 (222)	3249 (322)

(b)

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Argentina	*Antartic III*	1 (0)									
Korea,	*Hong Jin No. 701*								3 (6)		
Republic of	*Hong Jin No. 707*					84 (5)		34 (6)			
	Insung No. 1					15 (0)					
	Insung No. 2				8 (0)						
	Insung No. 22			20 (6)							
	Insung No. 3									1 (0)	
	Jung Woo No. 2			19 (3)	11 (2)				0 (1)		
New Zealand	*Antarctic Chieftain*								1 (2)		
	Janas	6 (2)	1 (0)					0 (2)			4 (0)
	San Aotea II	12 (3)	2 (0)	10 (2)	3 (0)			2 (0)	15 (4)		4 (4)
	San Aspiring			1 (0)		1 (0)	2 (1)	3 (0)	1 (1)		
Norway	*Froyanes*	1 (0)									
Russia	*Chio Maru No. 3*								2 (1)		
	Gold Gate							1 (3)			
	Sparta								2 (0)		
	Volna	0 (1)									
South Africa	*Ross Mar*				3 (2)						
Spain	*Tronio*				38 (2)	13 (0)		1 (2)		1 (0)	
UK	*Argos Froyanes*					1 (2)					1 (0)
	Argos Georgia			20 (2)	1 (0)		1 (0)		1 (0)	3 (1)	
	Argos Helena		3 (2)	3 (3)	1 (0)	1 (0)					
Ukraine	*Simeiz*										11 (1)
Uruguay	*Paloma V*	1 (0)	16 (0)								
	Punta Bellena	1 (0)									
	Ross Star			2 (0)	1 (0)						
Total		22 (6)	22 (2)	75(16)	66 (6)	115 (7)	2 (2)	41(13)	25 (15)	5 (1)	20 (5)

Table 5: The number of individuals of (a) *Dissostichus mawsoni* and (b) *D. eleginoides* tagged in each season in Subarea 88.2. The number of fish recaptured by each vessel is provided in brackets.

(a)

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Argentina	*Antartic II*		16(4)	2(1)							
	Argenova XXI						8 (0)				
Chile	*Isla Eden*					5 (0)					
Korea,	*Hong Jin No. 701*									7 (0)	20 (0)
Republic of	*Hong Jin No. 707*					17 (3)		40 (3)	38 (1)		22 (1)
	Jung Woo No. 3						6 (0)	35 (0)			
	Kostar									11 (0)	10 (0)
	Sunstar									8 (1)	33 (1)
New Zealand	*Antarctic Chieftain*					78 (0)		46 (1)	59 (9)	321 (42)	171 (19)
	Avro Chieftain	269 (16)			349 (33)						
	Janas		64 (3)			58 (2)		30 (3)	99 (17)	62 (0)	21 (0)
	San Aspiring	1 (0)						190 (17)			
Norway	*Froyanes*		194 (18)	97 (18)							
	Seljevaer									9 (1)	30 (0)
Russia	*Chio Maru No. 3*							90 (2)	101 (1)		
	Gold Gate							44(16)			
	Palmer									55 (3)	24 (0)
	Sparta							50 (3)	36 (10)	12 (3)	27 (0)
	Volna	14 (0)		55 (2)							
	Yantar	77 (0)	1 (0)	100 (4)							
	Yantar 31									2 (0)	13 (0)
	Yantar 35									2 (0)	
South Africa	*Ross Mar*					120 (27)					
Spain	*Tronio*					15 (2)	52 (4)				
UK	*Argos Froyanes*				38 (0)	51 (0)	250 (38)	68 (2)	210 (49)	15 (4)	67 (3)
	Argos Georgia		76 (0)	0 (1)		182 (21)	9 (1)	58 (13)			13 (5)
	Argos Helena		91 (3)	14 (7)		24 (0)					
Ukraine	*Simeiz*									4 (0)	12 (0)
Uruguay	*Ross Star*				2 (3)	53 (0)		16 (0)			
	Viking Sur			10 (0)							
Total		361 (16)	442 (28)	278 (33)	389 (36)	603 (55)	325 (43)	667 (60)	543 (87)	508 (54)	463 (29)

(b)

Flag State	Vessel name	Season									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
New Zealand	*Antarctic Chieftain*								0 (1)		
	Avro Chieftain	0 (1)									
Norway	*Froyanes*		2 (0)								
South Africa	*Ross Mar*					0 (1)					
UK	*Argos Froyanes*						0 (1)				
	Argos Helena		1 (0)								
Total		0 (1)	3 (0)	0 (0)	0 (0)	0 (1)	0 (1)	0 (0)	0 (1)	0 (0)	0 (0)

Life-history parameters

Stock structure

29. The current working hypothesis regarding spawning dynamics and early life history of *D. mawsoni* in Subareas 88.1 and 88.2 is described in Hanchet et al. (2008). A multidisciplinary approach incorporating otolith microchemistry, age data and Lagrangian particle simulations reached similar conclusions (Ashford et al., 2012). Under this hypothesis, spawning takes place to the north of the Antarctic continental slope, mainly on the ridges and banks of the Pacific–Antarctic Ridge (Hanchet et al., 2008). Spawning appears to take place during winter, 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, 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 (WG-FSA-12/48). 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 deeper as they grow, 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, although this pattern may be different for males versus females. They may 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.

30. 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 tagged fish. Kuhn and Gaffney (2008) expanded the work of Smith and Gaffney (2005) by examining nuclear and mitochondrial single nucleotide polymorphisms (SNPs) on tissue samples collected from Subareas 48.1, 88.1 and 88.2 and Division 58.4.1. They found broadly similar results to those of the earlier studies, with some evidence for significant genetic differentiation between the three ocean sectors but limited evidence for differentiation within ocean sectors. A lack of differentiation between stocks was reported in WG-FSA-13/07.

31. *Dissostichus eleginoides* in Subarea 88.1 are clearly at the southern edge of their range, only extending into the northwest corner of Subarea 88.1 in significant numbers. The fishery catches very few small fish (<50 cm) and the origin of *D. eleginoides* in this area is unclear. It is possible that these fish may be related to *D. eleginoides* around Macquarie Island as one *D. eleginoides* tagged at Macquarie Island was caught in SSRU 881B in 2007.

Parameter estimates

Standardised CPUE

32. Standardised CPUE analyses of *D. mawsoni* in the Ross Sea were updated for 2013 (WG-FSA-13/48) for the first time since 2006. In 2006 it was concluded that the CPUE

indices did not appear to be monitoring abundance of toothfish in the Ross Sea fishery (SC-CAMLR-XXV, Annex 5, paragraph 5.58). In the 2013 update of the CPUE analyses, the individual indices were quite variable between years, whilst the overall trends had very wide confidence bounds and varied widely between the north, slope and shelf fisheries. It is likely that variable ice conditions affecting access to preferred areas, and the total number of vessels competing for space in the Olympic fishery, are the major drivers of changing CPUE.

Catch at age

33. For purposes of estimating fishery selectivity for the Ross Sea fishery, three strata are defined using *D. mawsoni* length- and age-frequency data using a tree-based regression (a post-stratification method) (WG-FSA-SAM-05/08). The analysis used the median length of fish in each longline set, and the explanatory variables SSRU and depth and has given similar results when using more recent data (WG-FSA-13/48).

34. On average, about 800 *D. mawsoni* otoliths collected by observers from New Zealand vessels have been selected for ageing each year, and used to construct annual area-specific age–length keys (ALKs). Age data were available from 1999 to 2012, but were not yet available for 2013. In the Ross Sea, annual ALKs for each sex were applied to the shelf/slope fisheries and the north fishery separately. The annual ALKs were applied to the scaled length-frequency distributions for each year to produce annual catch-at-age distributions (WG-FSA-13/48).

35. In Subarea 88.2, aged otoliths are only available from the New Zealand fleet, and are consequently not available for every year. The numbers of otoliths aged in Subarea 88.2 (mainly from SSRU 882H) have been generally small and are not sufficient to generate reliable ALKs for each year and are missing for those years in which no aged otoliths are available (WG-FSA-13/48). In the past, a single ALK for each sex was developed by combining otolith age–length data from all available years, and this was then applied to annual length-frequency data to determine annual age frequencies. However, a recent re-examination of the age–length data showed that there had been a decreasing trend in mean age at length over time and that the use of a single ALK across all years was no longer valid. Therefore, several models were run in the 2013 assessment to evaluate the sensitivity of the model results to the age data.

36. Although the length-frequency distribution of the toothfish catch in the north of the Ross Sea fishery has been reasonably stable over time, there has been a change in the mean age of males and females in the catch with a slight increase in the early years followed by a decline since 2005 (WG-FSA-13/48). An analysis of the ages of the larger fish showed a similar pattern, suggesting some reduction in the proportion of older fish caught in northern SSRUs over time. There has been a similar decline in mean age of the catch in the slope fishery over the past four years and a slight decline in the mean age of the larger fish since 2005.

37. There has been a marked trend in sex ratio in the north, and to a much lesser extent on the slope and shelf, over time (WG-FSA-13/48). Even after discounting the first two years'

data (which are likely to be unrepresentative because fishing occurred mainly in shallow water in SSRU 881G) there has still been a substantial increase in the proportion of males in the catch in the north over time.

38. Although the length-frequency distribution of the toothfish catch in SSRU 882H continues to be very stable, there has been a decline in the mean age of males and females in the catch since 2005, similar to that seen in the north of the Ross Sea fishery (WG-FSA-13/48). However, because of the small number of fish aged, there is still considerable uncertainty regarding the age distribution of the catch in this fishery.

Recruitment surveys

39. Two research longline surveys of sub-adult (70–110 cm) toothfish have now been carried out in the southern Ross Sea (WG-FSA-12/41; WG-SAM-13/32). Catches and size structure were very similar between the two surveys and some indication of year class progression was apparent in the age distributions. Incorporating the survey age structure into the assessment had the effect of stabilising the index of year-class strength, and continuing the survey series has been recommended by the Scientific Committee.

Tag-recapture data

40. The tagging program in the Ross Sea and Subarea 88.2 is now approaching 40 000 tagged fish released and 2 000 recaptured fish (WG-FSA-13/49). The process by which the tagging and recapture data is used in the Ross Sea, and Subarea 88.2 assessments (C2, observer and tagging databases) were processed and prepared for input into CASAL, was described in WG-FSA-13/56.

Parameter values

41. Estimates of natural mortality, length–mass, growth and maturity parameters for *D. mawsoni* in Subareas 88.1 and 88.2 are given in Table 6. The estimates of mean age and length at 50% spawning for females on the Ross Sea slope region were updated in 2012 to 16.9 years and 135 cm for females and 12.0 years and 109 cm for males (WG-FSA-12/40).

42. To account for the 26 *Dissostichus* spp. (1.3%) tagged in Subareas 88.1 and 88.2 that were recaptured but could not be linked to a release event (WG-FSA-13/51), a tag-detection rate of 98.7% was assumed in the assessment models.

Stock assessment status

43. Catch limits for *D. mawsoni* and *D. eleginoides* fisheries in Subareas 48.3, 88.1 and 88.2 and Division 58.5.2 are set by CCAMLR using fully integrated assessments. In Subareas 88.1 and 88.2 the assessment is for *D. mawsoni* with catches of *D. eleginoides* included as part of the overall catch limits.

Table 6: Parameter values for *Dissostichus mawsoni* for base-case models in Subareas 88.1 and 88.2.

Relationship	Parameter	Value	
		Male	Female
Natural mortality	M (y^{-1})	0.13	0.13
Von Bertalanffy	t_0 (y)	–0.256	0.021
	k (y^{-1})	0.093	0.090
	L_∞ (cm)	169.07	180.20
	c.v.	0.102	0.102
Length–weight	a (t cm^{-1})	1.387e-008	7.154e-009
	b	2.965	3.108
Age at maturity (y)	A_{50} ($\pm A_{to95}$)	11.99 (±5.25)	16.92 (±7.68)
Stock recruit steepness (Beverton-Holt)	h	0.75	
Recruitment variability	σ_R	0.6	
Ageing error (CV)	*c.v.*	0.1	
Initial tagging mortality		10%	
Initial tag loss (per tag)		3.3%	
Instantaneous tag loss rate (per tag)		0.062y^{-1}	
Tag detection rate		98.8%	
Tag related growth retardation		0.5 y	

Model structure and assumptions

44. The Ross Sea (Subarea 88.1 and SSRUs 882A–B) and SSRUs 882C–H fisheries for *D. mawsoni* were assessed using CASAL integrated stock assessment models.

45. Details of the assessments for 2013 are provided in Appendix 1.

Yield estimates

Ross Sea

46. 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 3 044 tonnes. At this yield there is less than a 10% chance of spawning biomass dropping to less than 20% of the initial biomass.

SSRUs 882C–H

47. 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 266 tonnes. At this yield there is less than a 10% chance of spawning biomass dropping to less than 20% of the initial biomass.

Model results and management advice

48. In 2013 WG-FSA recommended that the catch limit for *D. mawsoni* in Subarea 88.1 should be set at 3 044 tonnes for 2014 and 2015, based on the outcome of the assessment. The precautionary catch limit for *Dissostichus* spp. was set at 3 044 tonnes for 2014 and 2015, of which 43 tonnes was allocated to the sub-adult survey in 2014 (CCAMLR-XXXII, paragraph 5.31).

49. WG-FSA also considered that because all of the tag-recapture data, and most of the catch-at-age data, used in the Subarea 88.2 assessment has come from SSRU 882H, the estimate of biomass and yield from the assessment applies mainly to SSRU 882H rather than to SSRUs 882C–H as a whole. Therefore, WG-FSA considered three options for management advice:

Option 1 – To apply a catch limit of 266 tonnes across all SSRUs (882C–H)

Option 2 – To apply a catch limit of 266 tonnes to the northern area (SSRU 882H) and to apply a catch limit of 124 tonnes for the southern area (SSRUs 882C–G)

Option 3 – To apply the management measures that had applied in 2013 – which equalled 406 tonnes in the northern area (SSRU 882H) and 124 tonnes for the southern area (SSRUs 882C–G).

50. Consistent with option 2, the precautionary catch limit for *Dissostichus* spp. was set at 266 tonnes in SSRU 882H and 124 tonnes in SSRUs 881C–G for 2014 (CCAMLR-XXXII, paragraph 5.44).

Future research requirements

51. WG-FSA-13 supported the advice of WG-SAM-13 (SC-CAMLR-XXXII, Annex 4, paragraphs 3.25 and 3.26) and recommended that the sub-adult survey be continued and further recommended (SC-CAMLR-XXXII, Annex 6, paragraphs 4.106 and 4.107) that research proposals be developed for additional surveys to address priority research questions in the Ross Sea fishery, including for research fishing in the northern Ross Sea during winter to address life-cycle movements and spawning dynamics, research fishing in the south of SSRU 882A (on the slope) to better understand toothfish distribution and movements, and spatially stratified longline surveys in previously unfished SSRUs to inform the parameterisation of the spatial population model (SPM), described in WG-FSA-13/53.

52. WG-FSA also recommended that the depth-shift parameters should be omitted from future assessments, and that length-based tag mortality, as applied for *D. eleginoides* in Subarea 48.3, be investigated as a sensitivity.

By-catch of fish and invertebrates

Fish by-catch

53. Catch limits for by-catch species groups (macrourids, rajids and other species) are defined in CM 33-03 and provided in Table 7. Within these catch limits, the total catch of by-catch species in any SSRU or combination of SSRUs, as defined in relevant conservation measures, shall not exceed the following limits:

- skates and rays (rajids) – 5% of the catch limit of *Dissostichus* spp. or 50 tonnes, whichever is greater
- current catch limits for macrourids in SSRUs 881H–L were based on biomass and yield estimates from the International Polar Year (IPY) 2008 trawl survey from the slope of the Ross Sea (see 'Assessments of impacts on affected populations')
- all other species combined – 20 tonnes.

Table 7: 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 CM 33-03 for details). (Source: fine-scale data.)

Season	Macrourids		Rajids			Other species	
	Catch limit (tonnes)	Reported catch (tonnes)	Catch limit (tonnes)	Reported catch landed dead (tonnes)	Number released	Catch limit (tonnes)	Reported catch (tonnes)
1997	-	0	-	0	-	-	0
1998	-	9	-	5	-	50	1
1999	-	22	-	39	-	50	5
2000	-	74	-	41	-	50	7
2001	-	61	-	9	-	50	14
2002	100	154	-	25	-	50	10
2003	610	65	250	11	966	100	12
2004	520	319	163	23	1 745	180	23
2005	520	462	163	69	5 057	180	24
2006	474	258	148	5	14 640	160	18
2007	485	153	152	38	7 336	160	43
2008	426	112	133	4	7 190	160	20
2009	430	183	135	7	7 088	160	16
2010	430	119	142	8	6 796	160	15
2011	430	189	142	4	5 439	160	8
2012	430	143	164	1	2 238	160	4
2013	430	127	164	4	5 675	160	10
2014	430	129	152	2	5 534	160	16

54. If the by-catch of any one species is equal to, or greater than, 1 tonne in any one haul or set, then the fishing vessel must move at least 5 n miles away for a period of at least five days.

55. If the catch of *Macrourus* spp. taken by a single vessel in any two 10-day periods in a single SSRU exceeds 1 500 kg in a 10-day period and exceeds 16% of the catch of *Dissostichus* spp. in that period, the vessel shall cease fishing in that SSRU for the remainder of the season.

56. Skates thought to have a reasonable chance of survival are released at the surface in accordance with CM 33-03. The current by-catch limits and move-on rules for rajids are given in CM 33-03.

57. Catches of non-target species groups (macrourids, rajids and other species), 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 7 and 8 respectively.

58. The retained by-catch in Subareas 88.1 and 88.2 consists predominantly of macrourids with a maximum, over the past 10 years, of 462 tonnes (88% of the annual catch limit for that group) being reported in Subarea 88.1 in 2005 (Table 7).

Table 8: 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 CM 33-03 for details). (Source: fine-scale data.)

Season	Macrourids		Rajids			Other species	
	Catch limit (tonnes)	Reported catch (tonnes)	Catch limit (tonnes)	Reported catch landed dead (tonnes)	Number released	Catch limit (tonnes)	Reported catch (tonnes)
1997	-	0	-	0	-	-	0
1998	-	0	-	0	-	-	0
1999	-	0	-	0	-	-	0
2000	-	0	-	0	-	-	0
2001	-	0	-	0	-	-	0
2002	40	4	-	0	-	20	0
2003	60	18	-	0	-	140	8
2004	60	37	50	0	107	140	8
2005	60	21	50	0	-	140	3
2006	78	92	50	0	923	100	12
2007	88	54	50	0	-	100	13
2008	88	17	50	0	-	100	4
2009	90	58	50	0	265	100	14
2010	92	49	50	0	-	100	15
2011	92	52	50	0	171	100	13
2012	84	29	50	0	-	120	11
2013	84	25	50	0	-	120	8
2014	62	7	50	0	28	120	3

59. A characterisation of the by-catch (WG-FSA-12/42) showed that the three other most important by-catch species were icefish (mainly *Chionobathyscus dewitti*), eel cods (probably mainly *Muraenolepis evseenkoi*) and morid cods (mainly violet cod, *Antimora rostrata*). The total catch for each of these species groups from 1998 to 2012 was 100, 102 and 97 tonnes respectively, and each formed about 0.3% of the total catch. Further details on the catch and biology of eel cods is summarised in WG-FSA-12/50.

Assessments of impacts on affected populations

Macrourids

60. The estimate of γ for *Macrourus* spp. 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).

61. WG-FSA-08/32 provided biomass and yield estimates of *Macrourus* spp. for the Ross Sea fishery based on extrapolations under three different density assumptions from a trawl survey (Table 9). Yield estimates for macrourids 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 was 21 401 tonnes with an estimated CV of 0.5, which gave a yield estimate of 388 tonnes. This yield estimate was then apportioned taking into account maximum historical catches. Yields per SSRU are detailed in Table 10. Existing move-on rules are retained, and macrourid by-catch limits and catches are expected to be reviewed on an annual basis.

Table 9: Biomass estimates of *Macrourus* spp. 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	1 200–2 000		713	(40)	1 114	(49)	1 038	(47)
IPY – 881H	600–1 200	**975**	**975**	**(50)**	**975**	**(50)**	**975**	**(50)**
IPY – 881H	1 200–2 000	**3 356**	**3 356**	**(40)**	**3 356**	**(40)**	**3 356**	**(49)**
SSRU 881I	600–1 200		3 297	(50)	7 883	(51)	5 992	(50)
SSRU 881I	1 200– 2000		4 670	(40)	11 168	(42)	8 576	(41)
SSRU 881K	600–1 200		1 539	(50)	5 027	(51)	2 774	(51)
SSRU 881K	1 200–2 000		2 998	(40)	5 995	(45)	9 111	(43)
SSRUs 882A–B	600–1 200		1 404	(50)	1 396	(58)	857	(60)
SSRUs 882A–B	1 200–2 000		4 087	(40)	525	(70)	-	
Total			26 892	(29)	41 823	(28)	36 542	(30)

Table 10: Catch limits (tonnes) 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		390	320
881J	79	388	46	50
881L	24		6	20
882A–B	0	100	8	0
Total	424	488		430

62. In 2011, it was recognised that specimens originally identified in the Ross Sea region as *M. whitsoni* did in fact comprise two sympatric species: *M. whitsoni* and *M. caml* (McMillan et al., 2012). *Macrourus caml* grows larger than *M. whitsoni* and is about 20% heavier for a given length (Pinkerton et al., 2013). The two species can be distinguished morphologically through two main characters (number of rays in the left pelvic fin; number of rows of teeth in the lower jaw). The distribution of *M. whitsoni* and *M. caml* seems to almost completely overlap by depth and area, with both appearing to be abundant in depths between 900 and 1 900 m. Catches of females of both species exceed that of males (especially for *M. caml*) and this sex selectivity cannot be explained by size or age of fish (Pinkerton et al., 2013). It is almost certain that previous work which was presumed to have been carried out on *M. whitsoni* would actually have been carried out on a mix of the two species.

63. Otolith aging data show that the two species have very different growth rates (Pinkerton et al., 2013). *Macrourus whitsoni* approaches full size at about 10–15 years of age and can live to at least 27 years, whereas *M. caml* reaches full size at about 15–20 years and can live in excess of 60 years. Sexual maturity in female *M. whitsoni* is reached at 52 cm and 16 years, but in female *M. caml* at 46 cm and 13 years. Gonad staging data imply that the spawning period of both species is protracted, extending from before December to after February. Work describing the distribution and ecology of each species is ongoing.

Rajids

64. WG-SAM-07/04 presented data and a preliminary developmental model for Antarctic skates in SSRUs 881H, I, 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.

65. WG-FSA-10/25 provided a characterisation of skate catches in the Ross Sea region and 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 fish that were tagged. While the size composition of the commercial catch was uncertain before 2009 because of the low numbers sampled each year, data collected in the Year-of-the-Skate (2009) resulted in improved estimates of the length frequency of the catch. During the Year-of-the-Skate a total of about 3 300 *Amblyraja georgiana* and 700 *Bathyraja* cf. *eatoni* were tagged and a total of 179 skates recaptured.

66. WG-FSA-05/21 presented risk categorisation tables for *M. whitsoni* and *A. 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).

67. *Amblyraja georgiana* were categorised as risk category 3 (on a scale of 1 to 5). The risk to *A. georgiana* is potentially mitigated due to the requirement to cut rajids from longlines whilst still in the water and release them. *Macrourus whitsoni* were categorised as between risk category 2 and 3 but this did not take into account the presence of two different species of *Macrourus* in the Ross Sea region with potentially different risks.

Invertebrate by-catch including VME taxa

68. All Members are required to submit, within their general new (CM 21-01) and exploratory (CM 21-02) fisheries notifications, information on the known and anticipated impacts of their gear on vulnerable marine ecosystems (VMEs), including benthos and benthic communities such as seamounts, hydrothermal vents and cold-water corals. All of the VMEs in CCAMLR's VME Register are currently afforded protection through specific area closures.

69. Two registered VMEs and 48 VME Risk Areas have been identified in Subarea 88.1, while 16 VME Risk Areas have been identified in Subarea 88.2. The locations and other details can be found in Annex 22-09/A.

Incidental mortality of birds and mammals

Incidental mortality

70. In 2014, a single mortality of a southern giant petrel (*Macronectes giganteus*) was observed in Subarea 88.1. This is the first reported seabird mortality in Subareas 88.1 and 88.2 since 2004. There have been no reports of incidental marine mammal mortalities since 2009.

71. The risk levels of seabirds in the fishery in Subarea 88.1 is category 1 (low) south of 65°S, category 3 (average) north of 65°S and overall is category 3 (SC-CAMLR-XXX, Annex 8, paragraph 8.1).

Mitigation measures

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

Ecosystem implications and effects

73. 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, together with more recent developments.

74. Two key types of trophic interactions were identified as being potentially 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 Ross Sea mass balance model suggest that, at the scale of the Ross Sea and averaged over a full annual cycle, toothfish only forms about 6–7% of the diet of its predators (Pinkerton et al., 2010). However, these estimates are premised on top-predator population estimates that

are themselves uncertain, and the consumption of toothfish in particular locations, at particular times of the year or by particular parts of the population, may be important to these predators, even though the total contribution of toothfish to the diet of the predator population in a year is relatively low.

75. The second key type of trophic interaction was between toothfish and its prey – in particular demersal fish species. Results from the Ross Sea trophic model suggest that toothfish consumes 64% of the annual production of medium-sized demersal fish species (Pinkerton et al., 2010), and so a reduction of the toothfish population could have a substantial impact on the natural mortality of these species. Mixed trophic impact analysis (WG-EMM-12/53) suggests that the impact of toothfish on medium-sized demersal fish was the strongest negative (top-down) impact in the Ross Sea food web. The FEMA Workshop recognised the 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.

76. 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. More recent work on diving depths of killer whales in the Ross Sea has shown that killer whales in the Ross Sea dive to much greater depths than was previously assumed (WG-EMM-13/29) but the majority of the fished area (i.e. over the Ross Sea slope and north) is still deeper than diveable depths. The balance of evidence suggests that toothfish are unlikely to constitute a major component in the diet of Type C killer whales throughout the year or at the scale of the entire Ross Sea ecosystem, but are likely to be important for Type C killer whales in McMurdo Sound in summer, and potentially in other locations on the Ross Sea shelf (SC-CAMLR-XXXII, Annex 5, paragraph 4.2).

77. WG-EMM-13/28 reviewed information on interactions between Weddell seals and toothfish from habitat overlap, diver observations, animal-mounted cameras, observations from field scientists in McMurdo Sound, stomach contents, vomit and scats analysis and stable isotopes of carbon and nitrogen, and also compared natural mortality rates of Antarctic toothfish in McMurdo Sound with potential consumption by Weddell seals based on population estimates.

78. The paper noted that available evidence does not support the conclusion that toothfish are a major component in the diet of Weddell seals throughout the entire year or at the scale of the entire Ross Sea ecosystem, but that toothfish are likely to be important for Weddell seals in particular locations (e.g. McMurdo Sound) and at particular times of the year when dietary energetic demand is high (SC-CAMLR-XXXII, Annex 5, paragraph 4.1).

79. 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 for other toothfish fisheries for which robust stock assessments are available. It also 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.

80. WG-SAM-10/21 reported on progress towards a minimum realistic model (MRM) for investigating trophic relationships between *D. mawsoni* and four groups of demersal fish in the Ross Sea. The paper outlined an approach that could be taken to investigate potential changes in the trophic relationships between *D. mawsoni* and (i) macrourids (especially *M. whitsoni* and *M. caml*); (ii) icefish (especially *C. dewitti*); (iii) deep-sea cods (especially *A. rostrata*); and (iv) eel (moray) cods (*Muraenolepis* spp.). While no results were available as yet, the authors indicated that work was ongoing and would be presented to the Scientific Committee working groups in due course.

81. WG-EMM-12/53 used a balanced ecosystem model to explore biomass and flow of organic matter by trophic level, and mixed trophic impacts to evaluate ecosystem-level characteristics of the Ross Sea shelf and slope. The six groups with the highest 'indices of ecological importance' in the food web were phytoplankton, mesozooplankton, Antarctic silverfish (*Pleuragramma antarcticum*), small demersal fishes, Antarctic krill (*Euphausia superba*) and cephalopods. Crystal krill (*E. crystallorophias*) and pelagic fishes were also likely to be important in the food web. It was suggested that these eight groups could be priorities for further monitoring of ecosystem change in the region. *Dissostichus mawsoni* was found to have a moderate index of ecological importance for the wider ecosystem, although it would have a greater impact on 'medium-sized' demersal fish.

82. WG-FSA-12/P04 provided an updated analysis of a McMurdo Sound vertical longline survey for *D. mawsoni*, which started in 1972, for which recent changes in the CPUE were attributed to the effects of the longline fishery in the Ross Sea.

83. In relation to this data, including the results presented in WG-FSA-12/P04, WG-FSA:

(i) considered that the apparent decline in toothfish CPUE at McMurdo Sound since 2001 was not consistent with data from the fishery. For example, the standardised catch rates from a research longline survey of pre-recruit toothfish (70–110 cm total length (TL)) in the southern Ross Sea in 2012 were similar to those made by the same vessel fishing in the area earlier in the fishery, between 1999 and 2003 (WG-FSA-12/41)

(ii) considered that the potential changes in the mean number of killer whales per pod during the past decade (presented in WG-FSA-12/P03) may also be related to local effects

(iii) agreed that the time series in McMurdo Sound could be a useful tool to monitor local toothfish abundance and ecology within McMurdo Sound and recommended it be continued. However, it also emphasised the importance of the standardisation of the survey with respect to hook and bait type, time of sampling, fishing depth and fishing location

(iv) noted that, given the spatial scale of the Ross Sea and the location of McMurdo Sound, a local sampling effort would not be expected to provide an index of the status of the stock centred well over 500 km away.

Current management advice and conservation measures

84. The limits on the exploratory fishery for *Dissostichus* spp. in Subareas 88.1 and 88.2 are defined in CMs 41-09 and 41-10 respectively. The limits in force and the advice of WG-FSA to the Scientific Committee for the forthcoming season are summarised in Tables 11 and 12.

Table 11: Limits on the exploratory fishery for *Dissostichus* spp. in Subarea 88.1 in force (CM 41-09).

Element	Limit in force (2014)
Access (gear)	Limited to notified vessels using longlines.
Catch limit	Precautionary catch limit for *Dissostichus* spp. is 3 044 tonnes for Subarea 88.1, applied as follows: SSRUs A, D, E, F and M – 0 tonnes SSRUs B, C, G – 371 tonnes total SSRUs H, I, K – 2 099 tonnes total SSRUs J, L – 306 tonnes* A research catch limit of 200 tonnes is set aside for the research survey in Statistical Subarea 88.2 SSRUs A and B as set out in CM 41-10.
Season	1 December to 31 August
Fishing operations	In accordance with CM 41-01 and the setting of research hauls is not required (Annex B, paragraphs 3 and 4).
By-catch	Regulated by CMs 33-03 and 41-09
Mitigation	In accordance with CM 25-02, except paragraph 5 if requirements of CM 24-02 are met Daylight setting allowed under CM 24-02, subject to a catch limit of three seabirds per vessel
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.
VMS	To be operational in accordance with CM 10-04
CDS	In accordance with CM 10-05
Research	Undertake research plan and tagging program as set out in Annexes 41-01/B and 41-01/C Toothfish tagged at a rate of at least one fish per tonne green weight caught.
Data	Daily and five-day catch and effort reporting under CMs 23-01 and 23-07. Haul-by-haul catch and effort data under CM 23-04. Biological data reported by the CCAMLR scientific observer
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.
Environmental protection	Regulated by CMs 22-06, 22-07, 22-08 and 26-01
Additional element	Fishing within 10 n miles of Balleny Islands is prohibited

* Does not include 43 tonnes which were set aside for the southern Ross Sea sub-adult survey.

Table 12: Limits on the exploratory fishery for *Dissostichus* spp. in Subarea 88.2 in force (CM 41-10).

Element	Limit in force (2014)
Access (gear)	Limited to notified vessels using longlines
Catch limit	Precautionary catch limit for *Dissostichus* spp. is 619 tonnes for Subarea 88.2, applied as follows: SSRUs A, B and I – 0 tonnes SSRUs C, D, E, F and G – 419 tonnes total SSRU H – 200 tonnes
Season	1 December to 31 August
Fishing operations	In accordance with CM 41-01 and the setting of research hauls is not required (Annex 41-01/B, paragraphs 3 and 4)
By-catch	Regulated by CMs 33-03 and 41-10
Mitigation	In accordance with CM 25-02, except paragraph 4 if requirements of CM 24-02 are met Daylight setting allowed under CM 24-02.
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.
VMS	To be operational in accordance with CM 10-04
CDS	In accordance with CM 10-05
Research	Undertake research plan and tagging program as set out in Annexes 41-01/ B and 41-01/C Toothfish tagged at a rate of at least one fish per tonne green weight caught
Data	Daily and five-day catch and effort reporting under CMs 23-01 and 23-07 Haul-by-haul catch and effort data under CM 23-04 Biological data reported by the CCAMLR scientific observer
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.
Environmental protection	Regulated by CMs 22-06, 22-07, 22-08 and 26-01

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Stock assessment

A1. The Ross Sea (Subarea 88.1 and SSRUs 882A–B) and SSRUs 882C–H fisheries for *D. mawsoni* were assessed using CASAL integrated stock assessment models.

A2. The catch history of *D. mawsoni*, used in the Ross Sea and SSRU882C–H assessment models, is given in Tables A1 and A2.

Table A1: Total *Dissostichus mawsoni* catch (tonnes) for the Ross Sea for the seasons 1997 to 2013. (Source: WG-FSA-13/51.) The Ross Sea shelf, slope and north fisheries are defined in WG-FSA-SAM-05/08.

Year	Area			Total	Catch limit
	Shelf	Slope	North		
1997	0	0	0	0	1 980
1998	8	29	4	41	1 573
1999	14	282	0	296	2 281
2000	64	688	0	752	2 340
2001	113	347	132	592	2 314
2002	10	933	412	1 355	2 758
2003	2	609	1 158	1 769	4 135
2004	141	1 667	370	2 178	3 625
2005	397	2 262	550	3 210	3 625
2006	251	2 373	343	2 967	2 964
2007	68	2 438	573	3 079	3 072
2008	61	1 939	251	2 250	2 700
2009	135	1 904	393	2 432	2 700
2010	328	2 171	370	2 868	2 850
2011	483	2 052	347	2 884	2 850
2012	277	2 375	547	3 199	3 282
2013	260	2 450	411	3 121	3 282
Total	2 611	24 521	5 862	32 994	-

Table A2: Total *Dissostichus mawsoni* catch (tonnes) for SSRUs 882C–H for the seasons 2003 to 2013. (Source: WG-FSA-13/52.) Slope consists of SSRUs 882C–F; north consists of SSRU 882H.

Year	Area			Total	Catch limit
	Slope	882G	North		
2003	-	-	106	106	250
2004	-	-	362	362	375
2005	-	-	270	270	375
2006	66	-	360	425	487
2007	0.2	-	346	347	547
2008	-	-	416	416	547
2009	157	-	327	484	567
2010	5	1	308	314	575
2011	164	-	406	570	575
2012	18	-	396	415	530
2013	-	118	359	476	530
Total	410	118	3 656	-	-

A3. The stock assessment models were sex- and age-structured, with ages from 1 to 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 A3. Various model structures were investigated, and the base-case model and sensitivity models for the Ross Sea and SSRUs 882C–H are described below (WG-FSA-13/51 and 13/52). A complete description of the CASAL modelling software was given in Bull et al., 2005.

Table A3: 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.

A4. The Secretariat undertook a validation of the CASAL parameter files, maximum of the posterior density (MPD) estimates, and yield calculations for the Ross Sea and SSRUs 882C–H models.

A5. The models were run from 1995 to 2013 for the Ross Sea and from 2002 to 2013 for SSRUs 882C–H, 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.

A6. 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). 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. The SSRUs 882C–H model was implemented as a single-area three-fishery model. A single area was defined with the catch removed using three concurrent fisheries: slope (SSRUs 882C–F), SSRU 882G and north (SSRU 882H). 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 with changes in the mean depth of the fishery.

A7. 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.

A8. 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

A9. The model parameters were estimated using a Bayesian analysis, first by maximising[2] 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[3] using Monte Carlo Markov Chains (MCMCs).

A10. Initial model fits were evaluated at the MPD by investigating model fits and residuals.

A11. Parameter uncertainty was estimated using MCMCs. These were estimated using a burn-in length of 5×10^5 iterations, with every 1 000th sample taken from the next 1×10^6 iterations (i.e. a final sample of length 1 000 was taken).

Observation assumptions

A12. The catch proportions-at-age data for the 1998–2012 (Ross Sea) or 2004–2012 (SSRUs 882C–H) seasons were fitted to the modelled proportions-at-age composition using a multinomial likelihood.

A13. Tag-release events were defined for the 2001–2012 (Ross Sea) or 2004–2012 (SSRUs 882C–H) seasons, and tag-recapture observations for the 2001–2013 (Ross Sea) and 2004–2013 (SSRUs 882C–H) seasons. Within-season recaptures and recaptures after six years at liberty were ignored. Tag-release and tag-recapture observations from SSRUs 882C–G were also ignored because of the very few recoveries (WG-FSA-13/52). Tag-release events were assumed to have occurred at the end of the first (summer) time step, following all (summer) natural and fishing mortality.

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

3 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 rolling 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.

A14. 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 with high-quality tagging data (for the base case), plus the numbers of fish tagged and released from all trips. 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 98.7% to account for unlinked tags.

A15. 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.

Process error and data weighting

A16. 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.

A17. 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

A18. 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

A19. The parameters estimated by the models, their priors, starting values for the minimisation and their bounds are given in Table A4. In models presented here, priors were chosen that were relatively non-informative but also encouraged lower estimates of B_0.

Table A4: 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	80 000	Uniform-log	1×10^4	1×10^6
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 (yr km^{-1}) for Subarea 88.2 model only	E	2	0.0	Uniform	0.0	20.0
Annual selectivity shift (shelf) for Subarea 88.2 model only	E_f	14	Mean depth	Uniform	–10.0	10.0

Yield calculations

A20. 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.

A21. 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.

A22. 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.

A23. 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 2014–2049) for each sample from the posterior distribution.

A24. Recruitment from 2003 to 2048 was assumed to be lognormally distributed with a standard deviation of 0.6 with a Beverton-Holt stock-recruitment steepness, h = 0.75.

A25. For the Ross Sea, future catch was assumed to follow the same split between fisheries as that in the most recent three seasons (i.e. based on the distribution of the 2011–2013 catch, 11%, 75% and 14% of the total future catch was allocated to the shelf, slope and north fisheries respectively).

A26. For SSRUs 882C–H, future catch was assumed to follow the same split between fisheries as that in the most recent three seasons (i.e. based on the distribution of the 2011–2013 catch, 12.4%, 8.1% and 79.5% of the total future catch was allocated to the shelf, SSRU 882G and north fisheries respectively).

A27. 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).

Model estimates

Likelihood profiles

A28. The likelihood profiles for the Ross Sea base-case model are given in Figure A1 (the run labelled as R2 reference case in WG-FSA-13/51). The likelihood profiles were carried out by fixing B_0 at values across a range of plausible values (i.e. 40 000–120 000 tonnes), while estimating the remaining model parameters. The catch-at-age data and tag recaptures from 2005, 2009, 2010, 2011 and particularly 2012 suggested that very low biomass levels were less likely, whilst tag recaptures from 2002, 2004, 2006 and 2007 suggested that very high biomass estimates were less likely.

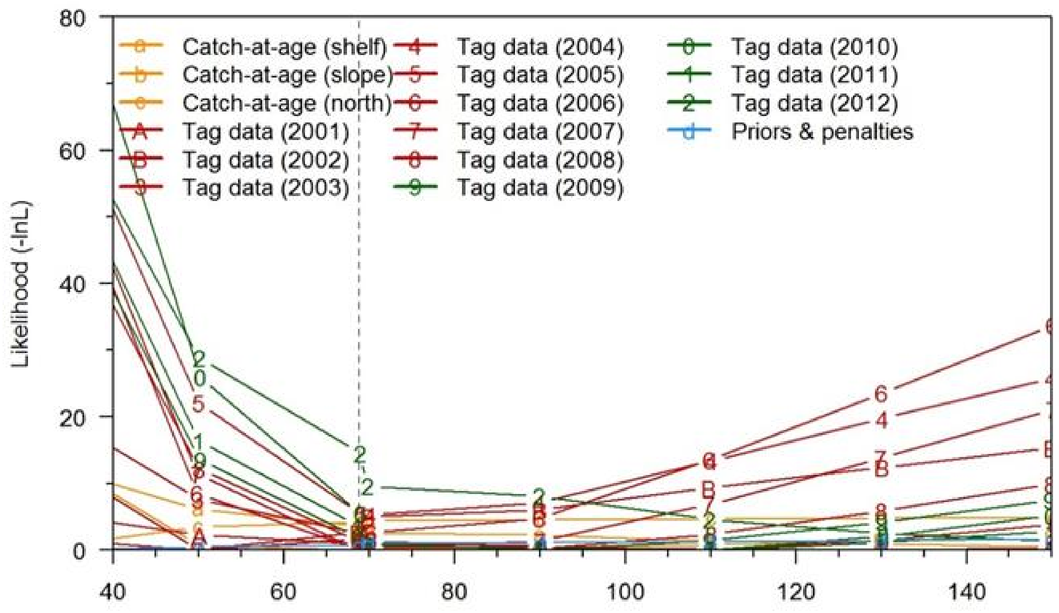

Figure A1: Likelihood profiles for the base-case model for the Ross Sea fishery for values of B_0. Negative log likelihood values were rescaled to have minimum 0 for each dataset. The dashed vertical line indicates the MPD.

A29. The likelihood profiles for the base-case model for SSRUs 882C–H are given in Figure A2 (the run labelled as R4 in WG-FSA-13/52). The likelihood profiles were carried out by fixing B_0 at values across a range of plausible values (i.e. 2 000–20 000 tonnes), while estimating the remaining model parameters. The catch-at-age data and tag recaptures from 2004 to 2009 suggested that very low biomass levels were less likely, whilst tag recaptures from 2010 and 2012 suggested very low biomass estimates were likely.

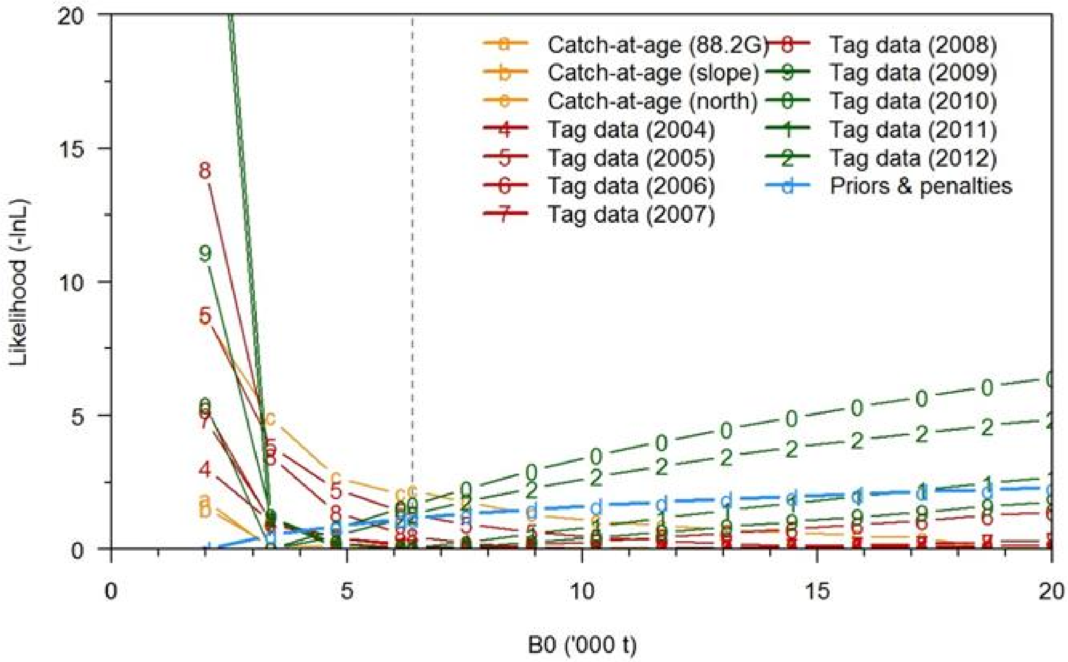

Figure A2: Likelihood profiles for the base-case model for the SSRUs 882C–H fishery for values of B_0. Negative log likelihood values were rescaled to have minimum 0 for each dataset. The dashed vertical line indicates the MPD.

MCMC diagnostics

A30. For the base-case model runs in both the Ross Sea and SSRUs 882C–H assessments, 1 000 MCMC posterior samples were taken from 1 000 000 iterations, after a burn-in of 500 000 iterations. MCMC diagnostics suggested no evidence of poor convergence in the key biomass parameters and between-sample autocorrelations were low.

Ross Sea model estimates

A31. Key output parameters for the Ross Sea base-case assessment model are summarised in Table A5. The projected biomass trajectory assuming a future constant catch of 3 044 tonnes is shown in Figure A3.

Table A5: Median MCMC estimates (and 95% CI) of B_0, B_{2013} and B_{2013} as %B_0 for the Ross Sea and SSRUs 882C–H base-case models.

Area	B_0		B_{2013}		B_{2013} (%B_0)	
Ross Sea	68 790	(59 540–78 470)	51 530	(42 330–61 120)	74.8	(71–78)
SSRU882C–H	6 590	(4 800–9 190)	4 280	(2 510–6 900)	65.1	(52–75)

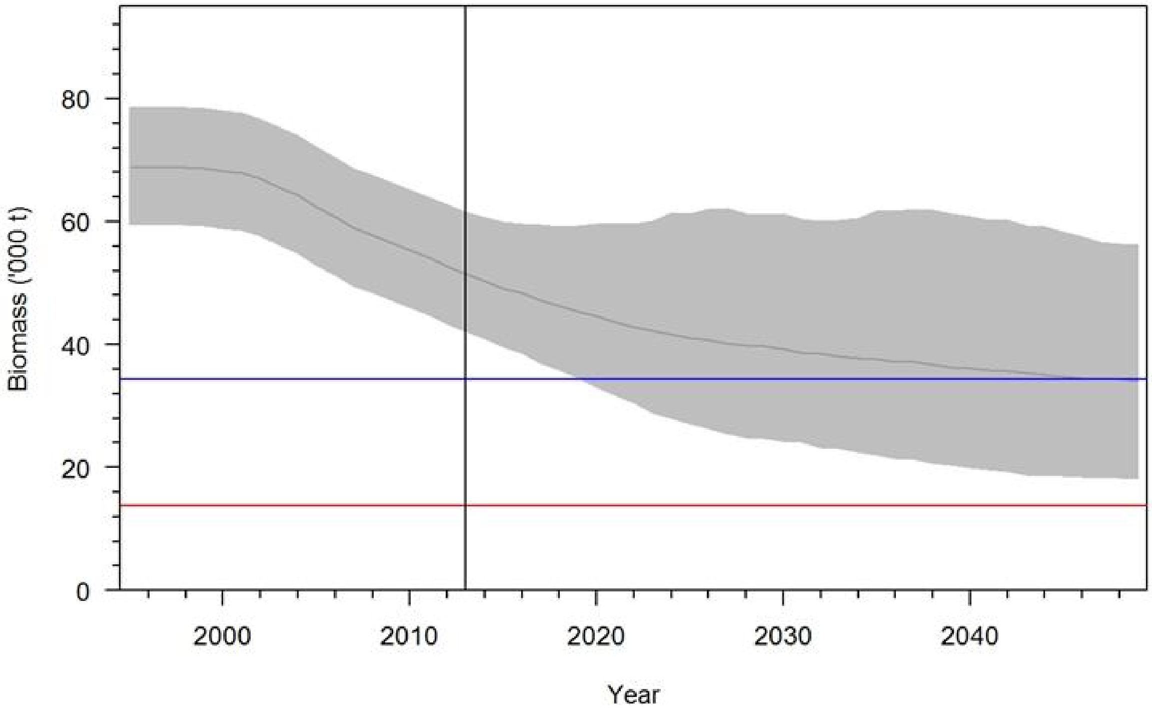

Figure A3: Estimated spawning stock biomass median (grey line) and 10–90% CI (grey region) for the base-case model for the Ross Sea fishery projected for 35 years. Horizontal lines indicate $B_{50\%}$ and $B_{20\%}$ thresholds.

SSRUs 882C–H model estimates

A32. Key output parameters for the SSRUs 882C–H base-case assessment model are summarised in Table A5. The projected biomass trajectory assuming a future constant catch of 266 tonnes is shown in Figure A4.

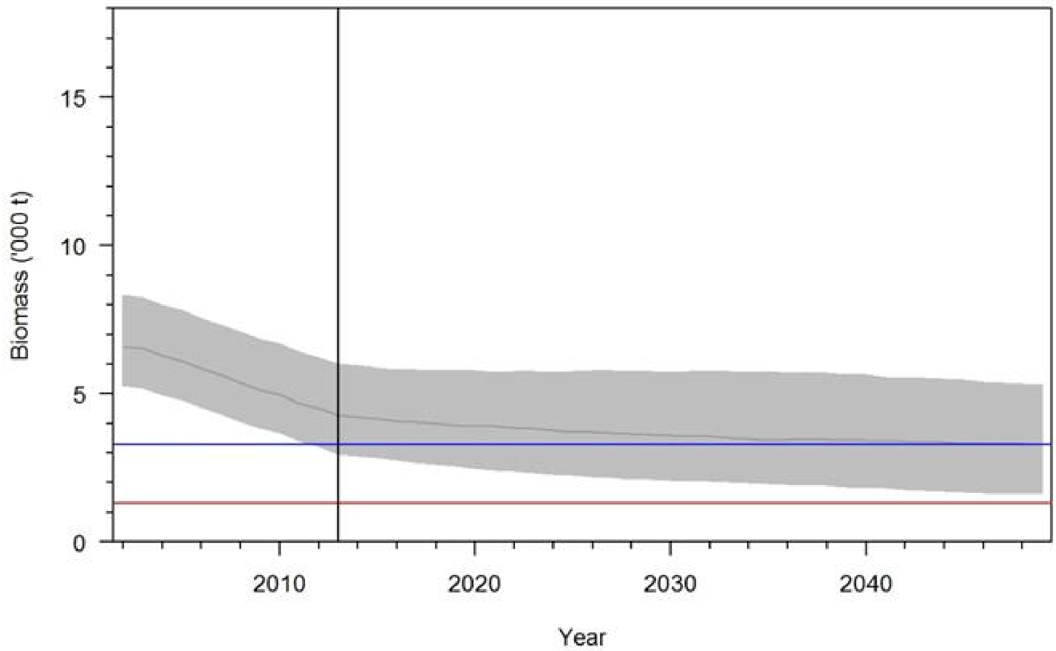

Figure A4: Estimated spawning stock biomass median (grey line) and 10–90% CI (grey region) for the base-case SSRUs 882C–H model projected for 35 years. Horizontal lines indicate $B_{50\%}$ and $B_{20\%}$ thresholds.