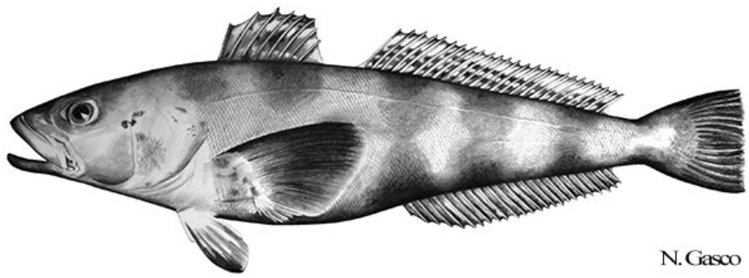
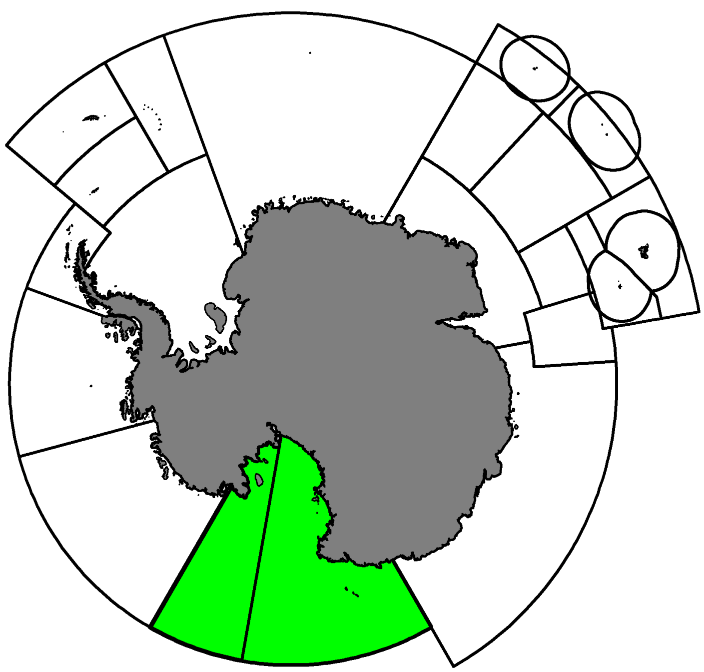
Fishery Report 2020: *Dissostichus mawsoni* in Subarea 88.1

CCAMLR Secretariat

16 March 2021



Antarctic Toothfish, *Dissostichus mawsoni* Norman, 1937.



Map of the management areas within the CAMLR Convention Area. Subarea 88.1, SSRUs 882A and 882B, the regions discussed in this report are shaded in green. Throughout this report, "2020" refers to the 2019/20 CCAMLR fishing season (from 1 December 2019 to 30 November 2020).

Contents

1. Introduction to the fishery

1.1. History

This report describes the exploratory longline fishery for Antarctic toothfish (*Dissostichus mawsoni*) in Subarea 88.1 and Small-Scale Research Units 882A and 882B (Fig. 1). The area spans 150°E to 150°W longitude and from the Antarctic Continent to 60°S latitude. Fishing occurs around seamounts and ridges of the Pacific-Antarctic fracture zone, the continental slope, and the continental shelf areas. The Ross Sea region Marine Protected Area (RSrMPA) was implemented through Conservation Measure 91-05 in 2017, closing much of the continental shelf to commercial fishing.

The fishery began in 1997 and slowly grew in number of vessels and catch until 2003. The Small-Scale Research Units (SSRU) definitions were changed in 2006 when several were closed to concentrate fishing in the central Ross Sea region (SC-CAMLR-XXIV, paragraphs 4.163 to 4.166). SSRU 881M was defined and closed in 2009 to protect the likely toothfish migration corridor in the western Ross Sea (SC-CAMLR-XXVII, paragraphs 4.160 and 4.161).

Prior to 2017, this fishery was an exploratory fishery for *Dissostichus* spp., however, in order to better align the target species with the assessment process, the target species was specified as *D. mawsoni*, with any Patagonian toothfish (*D. eleginoides*) caught counting towards the catch limit for *D. mawsoni*.

Catches of *D. eleginoides* have mainly come from the northwest of the 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 as fishing occurred in more easterly areas. The catch rates for *D. eleginoides* have been much higher in SSRU 881A than the other SSRUs; this SSRU was closed to fishing from 2008 to 2017, and reopened in 2018 as part of the N70 management area.

The only type of fishing gear allowed in the fishery is bottom longline. Three types of bottom longline gear are used, Autoline, Spanish Line, and Trotline (See the CCAMLR Gear Library for details). Although toothfish do inhabit shallow water to some degree, they are mainly a deep-water species and the fishery is restricted to fishing deeper than 550m (Conservation Measure 22-08). Most fishing occurs at depths between 800m and 1800m.

The length of the fishing season in this fishery has changed 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. Each year since 2005, the fishery has been closed through attaining the allocated catch limit. The duration of the fishery has been decreasing in recent years, typically lasting only 6-9 weeks.

Sea ice is a major constraint on the timing and location of fishing within open areas of this fishery. Significant sea ice can prevent access by vessels to many areas, especially early in the fishing season. Typically, a large sea ice bridge must be navigated through to reach the main fishing area on the continental slope.

CCAMLR established the RSrMPA in 2017, the largest Marine Protected Area (MPA) in the world to date. The MPA has a lifetime of 35 years. It can be renewed subject to a final review in 2052. The MPA has multiple objectives including providing a reference area to better understand the ecosystem effects of climate change and fishing, preserving a representative portion of the Ross Sea environment (including benthic and pelagic marine environments), and, protecting core foraging areas for land-based predators. A Scientific Research and Monitoring Plan has been developed for this MPA. New Zealand along with other nations, including Italy, the Republic of Korea and the USA are actively conducting research to feed into the first scientific review of the MPA in 2022. A dedicated Conservation Measure defining the Ross Sea MPA is due for review at least every 10 years to evaluate whether the specific objectives of the MPA are still relevant and are being achieved.

Many nations are involved in scientific research in this fishery.

1.2. Conservation Measures currently in force

The catch limits and regulation of by-catch for this fishery are defined in Conservation Measures 33-03 and 41-09 with additional requirements outlined in 91-05.

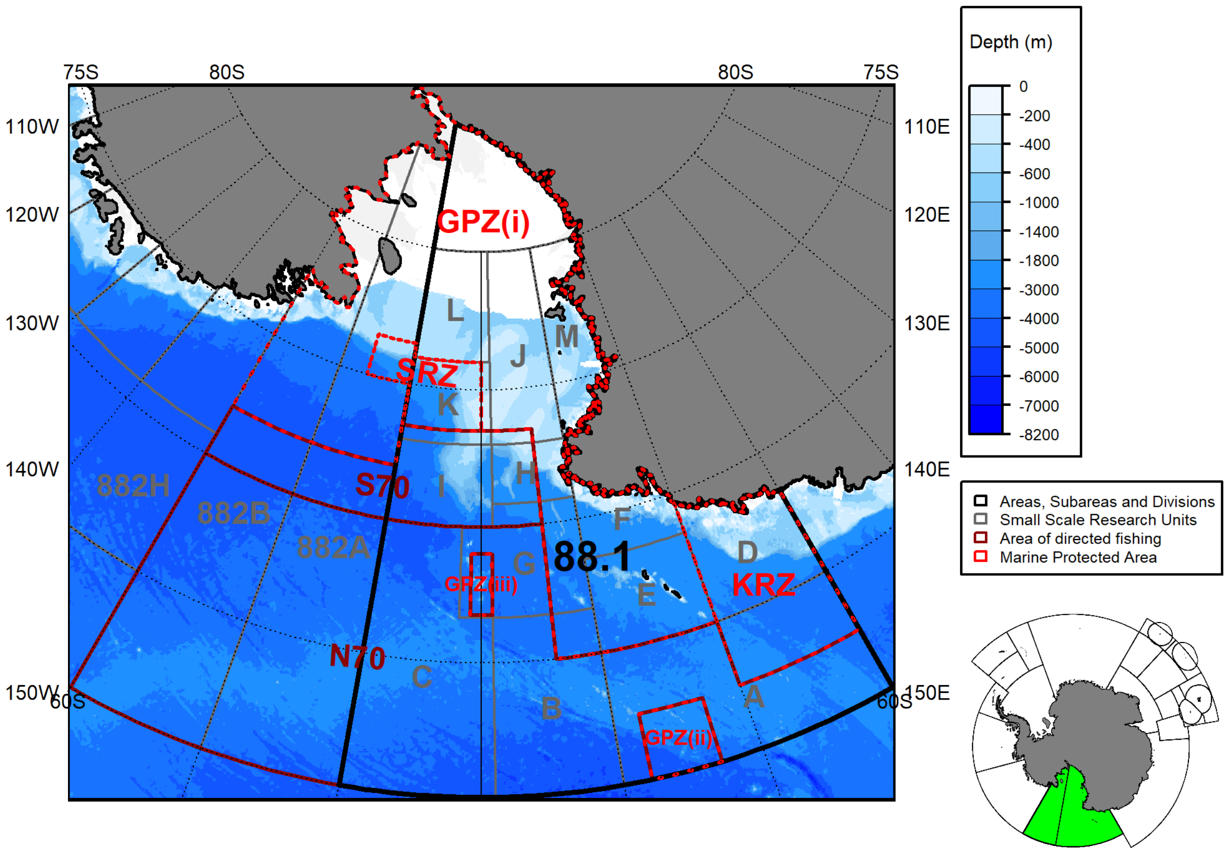


Figure 1: Location of Small Scale Research Units, Areas of directed fishing and Marine Protected Areas in this fishery.

1.3. Active vessels

In 2020, 19 vessels participated in this fishery. For the 2021 fishing season, a total of 20 vessels notified their intention to participate in this fishery (1 from Australia; 1 from Japan; 3 from New Zealand; 1 from Spain; 5 from the Republic of Korea; 1 from the Russian Federation; 3 from the United Kingdom; 5 from Ukraine).

1.4. Timeline of spatial management

The limits on the exploratory fishery for *D. mawsoni* in this fishery are described in Conservation Measure 41-09.

From 2006 through 2016, the distribution of catch limits to the Small-Scale Research Units (SSRUs) in Subareas 88.1 and 88.2 was part of an experiment with the SSRUs between 150°E and 170°E (881A, D, E, F) and between 170°W and 150°W (882A-B) being closed to fishing to ensure that effort was retained in the area of the experiment (SC-CAMLR-XXIV, paragraphs 4.163 to 4.166). 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). These administrative boundaries were 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.

After 1 December 2017, when the Ross Sea region Marine Protected Area (RSrMPA) came into force (Conservation Measure 91-05), the regions to which catch limits apply were modified to all areas outside the RSrMPA and north of 70°S (N70), all areas outside the RSrMPA and south of 70°S (S70), and, the Special Research Zone (SRZ). The MPA comprises General Protection Zones (GPZ) with three separate areas (i, ii, iii), the Special Research Zone (SRZ) and a Krill Research Zone (KRZ) (see Figure 1).

2. Reported catch

2.1. Latest reports and limits

The catches of *D. mawsoni* and *D. eleginoides* from this region are provided in Table 1. In this fishery, the catch of *D. mawsoni* reached a maximum of 3210 tonnes in 2005. In 2020, 0 tonnes of *D. eleginoides* and 2972 tonnes of *D. mawsoni* were caught.

The catches reported from this fishery 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-XXXIII, paragraph 3.68). All ancillary data associated with these vessels (*e.g.*, by catch, tagging, observer data) are also quarantined and not included in the data presented in this report.

Table 1. Catch (tonnes) and effort history for *Dissostichus* spp. in this fishery (Subarea 88.1 and SSRUs 882A-B). Source: Fine scale data and past estimates for IUU catch (-: no IUU estimate available; q: catch data currently quarantined).

Season	Number of vessels	Catch limit (tonnes)	*D. eleginoides*	*D. mawsoni*	Estimated IUU catch (tonnes)
1997	1	1980	0		0
1998	1	1510	1	41	0
1999	2	2281	1	296	0
2000	3	2090	0	752	0
2001	7	2064	31	592	0
2002	2	2508	12	1355	92
2003	9	3760	26	1769	0
2004	21	3250	12	2178	240
2005	10	3250	7	3210	28
2006	13	2964	1	2967	0
2007	15	3032	12	3079	0
2008	15	2700	9	2250	272
2009	13	2700	17	2432	0
2010	12	2850	0	2868	0
2011	15	2850	3	2803 (q: 44)	-
2012	15	3282	5	3209	-
2013	18	3282	0	3030 (q: 156)	-
2014	20	3044	4	2221 (q: 700)	-
2015	14	2844	1	2360 (q: 473)	-
2016	13	2870	5	2484 (q: 194)	-
2017	16	2870	1	2771 (q: 50)	-
2018	17	3157	1	2637 (q: 188)	-
2019	19	3157	1	3046	-
2020	19	3140	0	2972	-

2.2. By-catch

Catch limits for by-catch species groups (macrourids, skates (Rajids) and other species) are defined in Conservation Measure 41-09, paragraph 6, and in Conservation Measure 33-03; these are also provided in Table 2.

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 nautical miles away for a period of at least five days.

If the catch of *Macrourus* spp. taken by a single vessel in any two 10-day periods in a single SSRU exceeds 1,500kg in a 10-day period and exceeds 16% of the catch of *D. mawsoni* in that period, the vessel shall cease fishing in that management area (SSRU or group of SSRUs) for the remainder of the season.

Skates evaluated to have a good chance of survival (based on a skate condition guide) are released at the surface in accordance with Conservation Measure 33-03. The current by-catch limits and move-on rules for rajids are given in Conservation Measure 41-09.

Table 2. Reported catch and catch limits for by-catch species (*Macrourus* spp., Rajids and others) in this fishery (Subarea 88.1 and SSRUs 882A-B). see Conservation Measure 33-03 for details. Source: fine-scale data. q: Some data in these years is currently quarantined.

Season	*Macrourus* spp.		Rajids			Other catch	
	Catch Limit (tonnes)	Reported Catch (tonnes)	Catch Limit (tonnes)	Reported Catch (tonnes)	Number Released	Catch Limit (tonnes)	Reported Catch (tonnes)
1997	0	0	0	0	0	0	<1
1998	0	9	0	5	0	0	<1
1999	0	22	0	39	0	0	5
2000	0	70	0	41	0	0	7
2001	0	61	0	9	0	0	11
2002	0	158	0	25	0	0	10
2003	0	65	0	11	966	0	11
2004	520	319	163	23	1852	180	23
2005	520	462	163	69	5057	180	21
2006	474	266	148	5	14698	160	16
2007	485	153	152	38	7336	160	41
2008	426	112	133	4	7190	160	18
2009	430	183	135	7	7088	160	15
2010	430	119	142	8	6796	160	15
2011	430	190 q	142	4	5440	160	8
2012	430	143	164	1	2238	160	4
2013	430	125 q	164	4 q	5675 q	160	9 q
2014	430	127 q	152	2 q	5534 q	160	15 q
2015	430	87 q	152	5 q	12978 q	160	24 q
2016	430	87 q	152	7 q	6016 q	160	21 q
2017	430	66	143	4	3857	160	10 q
2018	485	78 q	157	8	5924	157	13 q
2019	485	147	157	9	8870	157	26
2020	485	117	157	15	15620	157	31

A characterisation of the by-catch (WG-FSA-12/42) showed that the three most frequently recorded 'other' by-catch species were icefish (mainly *Chionobathyscus dewitti*), eel cods (mainly *Muraenolepis evseenkoi*) and morid cods (mainly *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 by weight.

In 2008 biomass and yield estimates of *Macrourus* spp. for this fishery were based on extrapolations under three different density assumptions from a trawl survey (WG-FSA-08/32). The resulting biomass estimate was 21,401 tonnes with an estimated CV of 0.5 for the slope area, which gave a yield estimate of 388 tonnes in that region. This yield estimate was then apportioned to SSRUs taking into account the spatial distribution of maximum historical catches. The catch limit on the Shelf was set at slightly higher than the maximum catches (70 t) with the remaining yield on the Slope (320 t); and the catch limit in the North was set at a nominal 40 t (SC-CAMLR XXXVII, Appendix 3 paragraphs 6.16-6.22). Bycatch limits for macrourids, skates and other species were adapted to the RSrMPA management areas for the 2018 fishing year resulting in small changes to each catch limit (SC-CAMLR-XXXVI Paragraph 3.149, Annex 7 Table 8).

In 2011, it was recognised that specimens originally identified in the region as Whitson's grenadier (*Macrourus 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 the number of pelvic fin rays and the 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 1,900m. Initial data suggest that 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). 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.

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

WG-FSA-10/25 provided a characterisation of skate catches in the 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 georgian ray (*Amblyraja georgiana*) and 700 Eaton's skate (*Bathyraja cf. eatonii*) were tagged and a total of 179 skates recaptured. Analysis of recaptures from that experiment were presented in WG-FSA-18/38 and a second pulse of tagging to index abundance was agreed for 2020 and 2021 (including marking some skates with either strontium or oxytetracycline for age validation; SC-CAMLR-38 paragraph 5.5).

2.3. Vulnerable marine ecosystems (VMEs)

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

By the end of this fishing season, there were 9 VMEs and 60 VME Risk Areas designated in the Ross Sea Region.

2.4. Incidental mortality of seabirds and marine mammals

Only one seabird mortality has ever been reported by vessels in this toothfish fishery: a Southern giant petrel (*Macronectes giganteus*) in 2014. Considerable effort has been put into the mitigation of seabird captures in CCAMLR fisheries, through implementation of Conservation Measures regarding line sink rate, use of streamer lines, seasonal restrictions on fishing, prohibition of offal dumping, line weighting and only allowing daytime setting under strict conditions.

The risk levels of interactions with birds 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-XXVIII, Annex 7, Table 14 and Figure 2).

Conservation Measure 25-02 applies to this subarea and, in addition to the specific mitigation measures in place, there is also a bird by-catch limit specified in Conservation Measure 41-09. The discharge of offal or discards is prohibited in this subarea under Conservation Measure 26-01.

In 2008, one mortality of a Crabeater seal (*Lobodon carcinophagus*) was reported by a vessel in this fishery.

3. Illegal, Unreported and Unregulated (IUU) fishing

Past estimates of illegal, unreported and unregulated (IUU) catch in this fishery are shown in Table 1.

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). One IUU-listed fishing vessel was observed in Subarea 88.1 during 2008 and an unknown vessel sighting was reported in 2012. Information relating to the retrieval of unidentified fishing gear in Subarea 88.1 in 2017 was submitted by the Republic of Korea and provided to Members in COMM CIRC 17/100.

4. Data collection

4.1. Data collection requirements

The collection of biological data as part of the CCAMLR Scheme of International Scientific Observation (SISO) 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.

This fishery is managed under the umbrella of the exploratory fisheries Conservation Measure 41-01 and, as such, has an associated data collection plan (Annex 41-01/A), a research plan (Annex 41-01/B) and a tagging program (Annex 41-01/C).

In addition to exploratory fishing requirements, a Medium Term Research Plan for the Ross Sea Region has been developed to further increase the quality and volume of data needed to manage the fishery (CCAMLR-XXXIII, paragraph 5.52). This plan includes priority research topics to improve the stock assessment and to understand the ecosystem impacts of fishing.

4.2. Length frequency distributions

The length frequency distributions of *D. mawsoni* and *D. eleginoides* caught in this fishery in recent years are shown in Figures 2 and 3 respectively. These length frequency distributions are unweighted; 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 changes 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 distributions of fishing.

The length frequency distribution of the catches for *D. mawsoni* in all areas for this fishery ranged from about 70cm to 190cm (Fig. 2) with a consistent mode at about 140cm in the fishery north of 70°S (N70). The size distributions in the S70 or SRZ depend on the spatial (and depth) distribution of fishing in a given year. The size distribution of fish on the Ross Sea shelf (not shown) is comprised of a mode of smaller fish (80-110 cm) with a pronounced tail of larger fish spanning the full length distribution. Size distributions for *D. mawsoni* on the shelf are summarised as part of the Ross Sea shelf survey (WG-FSA-17/57). Observations of *D. eleginoides* length are few and typically smaller than *D. Mawsoni* in this fishery (Fig. 3).

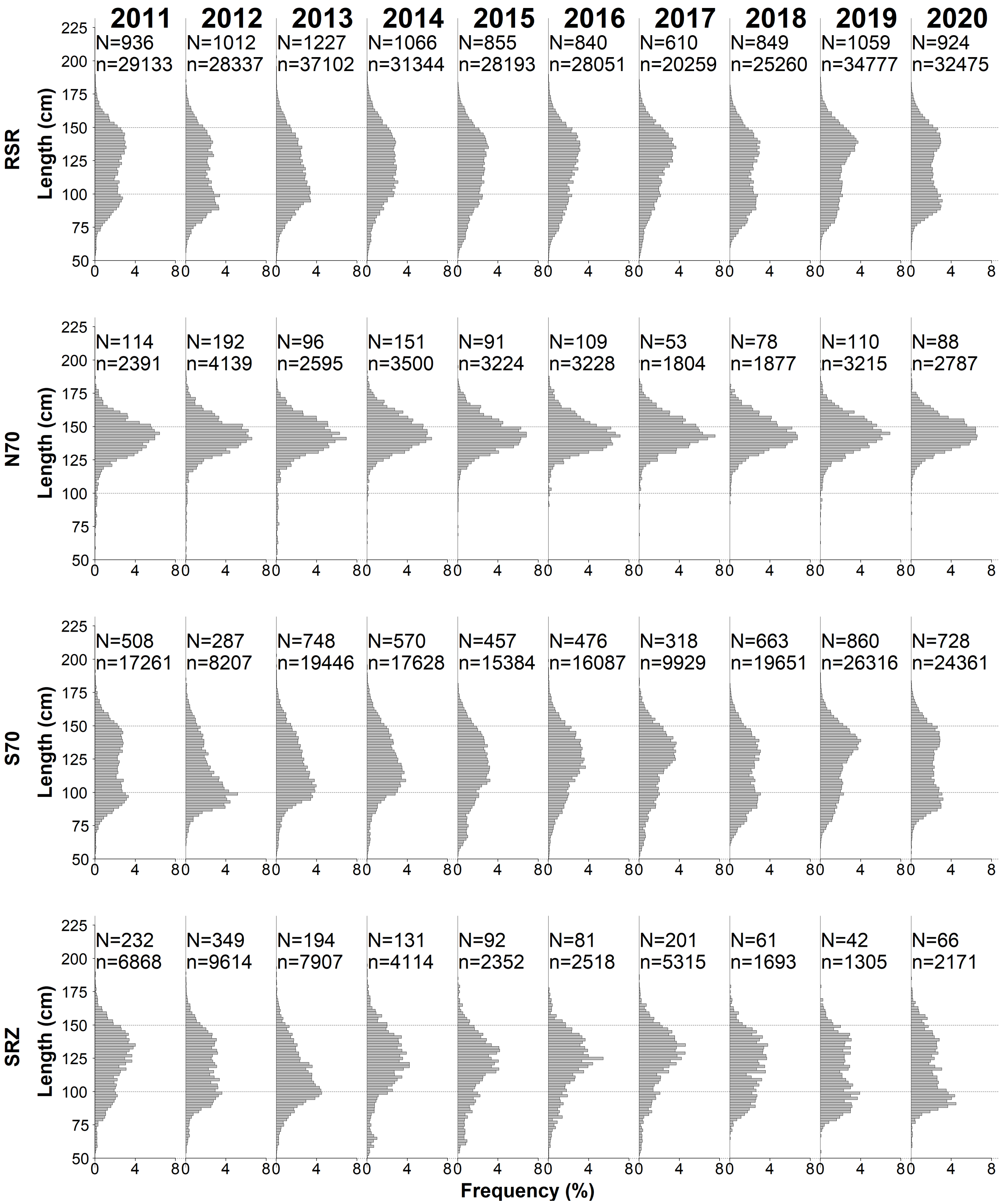


Figure 2. Annual length frequency distributions of *Dissostichus mawsoni* caught in this fishery (RSR; Subarea 88.1 and SSRUs 882A-B) (top panel) and the three areas of the fishery. The number of hauls from which fish were measured (N) and the number of fish measured (n) in each year are indicated. Note: length frequency distributions are only shown where more than 150 fish were measured.

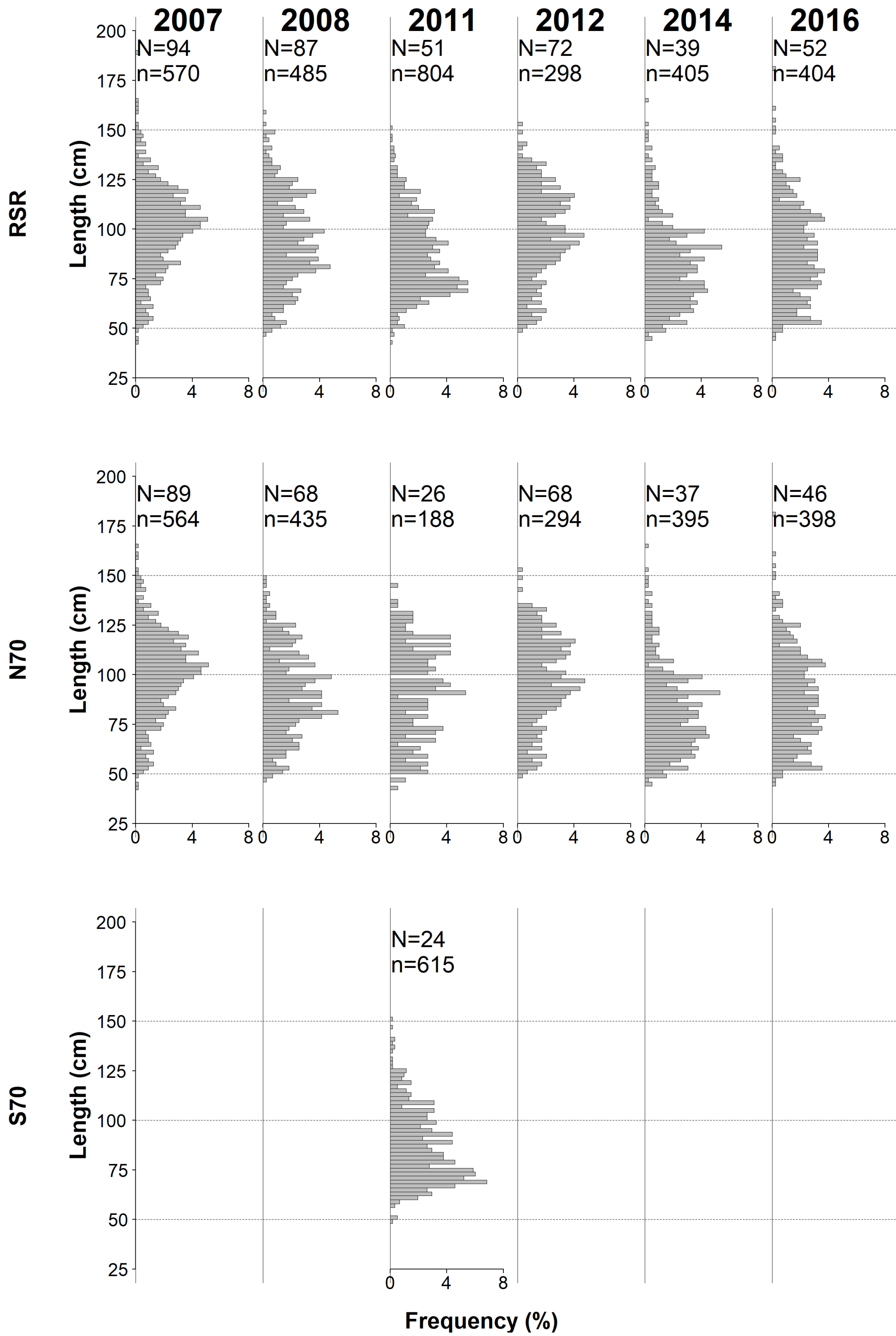


Figure 3. Annual length frequency distributions of *D. eleginoides* caught in this fishery (RSR; Subarea 88.1 and SSRUs 882A-B) (top panel) and two other areas of the fishery. The number of hauls from which fish were measured (N) and the number of fish measured (n) in each year are indicated. Note: length frequency distributions are only shown where more than 150 fish were measured.

4.3. Tagging

Under Conservation Measure 41-01, each longline vessel fishing in exploratory fisheries for either *D. mawsoni* or *D. eleginoides* is required to tag and release toothfish at the rate of 1 fish per tonne of green weight caught throughout the season since 2004 following the CCAMLR tagging protocol. In order to ensure that there is sufficient overlap between the length distribution of all fish caught and those fish that are tagged, a vessel is required to achieve a minimum tag-overlap statistic (see Annex 41-01/C, footnote 3). The requirement to achieve a minimum tag-overlap statistic of 50% was first introduced for 2011 and this was then increased to 60% for 2012 and subsequent seasons (Table 3). The tagging data is used as the main source of information on trends in abundance for stock assessment.

To date in this area, 56476 *D. mawsoni* have been tagged and released (3258 have been recaptured; Table 4), and, 1244 *D. eleginoides* have been tagged and released (94 have been recaptured; Table 5).

Vessel-specific tag-detection rates (the relative rate at which tagged fish are recaptured by a vessel) and recapture rates (the relative rate of recapture of fish that were tagged by a vessel) were developed using a methodology which controls for the spatial and temporal variability of fishing operations by pairing each individual tag release or recapture event with all other fishing events which occurred in the same time and place (*i.e.*, within a specific distance and in the same fishing season) (WG-SAM-14/30). The resulting indices were used to derive the effective tag release and recaptures for each vessel in the tagging dataset used for the assessment model (WG-FSA-17/36). Both indices, for the fishery as a whole and weighted by the relative catches of each vessel, show effective tagging rates at about 65% and effective tag-detection rates at about 85%; both generally decreasing over time. This decrease is due to the combination of changes in individual vessel performance over time and changes in relative contribution of vessels with lower rates; as such it does not indicate a decrease in rates for all vessels.

Table 3. Annual tagging rate (number of fish tagged per tonne of total catch), reported by vessels operating in this exploratory fishery (Subarea 88.1 and SSRUs 882A-B). The tag-overlap statistics (CM 41-01) for *D. mawsoni* and *D. eleginoides* respectively are provided in brackets (NC: Tag-overlap statistic is Not Calculated for less than 30 fish tagged; -: no fish were tagged).

		Fishing Season										
Flag State	Vessel name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Argentina	Argenova XXI	1.1 (50.5,NC)										
Australia	Antarctic Discovery								1.1 (79.5,NC)	1 (88.6,NC)	1.2 (NC,-)	1 (77.5,-)
Chile	Globalpesca I											1.5 (NC,-)
Spain	Tronio	1 (63.5,NC)	1 (73.5,NC)	1 (77.9,-)	1 (90,NC)	1 (80.1,-)	1.1 (81.5,NC)	1.1 (89.7,NC)	1.1 (70.8,NC)	1 (84.1,-)	1 (89.6,NC)	1 (69.3,-)
Spain	Yanque							1.2 (77,NC)				
United Kingdom	Argos Froyanes	1 (66.4,-)	1 (75.1,-)	1.3 (66.1,-)	1 (90,-)	1 (87.9,NC)	1.5 (81.1,NC)	1.1 (84.9,NC)	1 (79.9,-)	1.3 (89.1,-)	1.1 (86,-)	1.7 (75.1,-)
United Kingdom	Argos Georgia	1.1 (45.6,NC)	1 (70.7,NC)	1 (92,NC)	1.1 (86.2,NC)	1.1 (72.3,-)	1.1 (85.9,-)	1.2 (84,-)			2.2 (91.4,-)	1.2 (88.8,-)
United Kingdom	Nordic Prince										1.3 (86.6,-)	1 (90.3,-)
Republic of Korea	Greenstar									1.1 (87.1,-)		1 (75.1,-)
Republic of Korea	Hong Jin No. 701			1.3 (77.1,NC)	1.1 (84.6,-)				1.1 (79.8,-)	1.1 (86.6,NC)	1 (78.5,-)	
Republic of Korea	Hong Jin No. 707	1.1 (51.8,-)	1.1 (67.5,49.6)	1.1 (78.8,NC)	1 (81.3,-)							1.1 (79.5,-)
Republic of Korea	Insung No. 1	1.1 (30,-)										
Republic of Korea	Insung No. 3				1.5 (90.6,NC)							
Republic of Korea	Insung No. 5				1.6 (93.1,-)							
Republic of Korea	Jung Woo No. 2	1.2 (30.1,-)	1.1 (95.5,-)	1.2 (86.1,NC)								
Republic of Korea	Jung Woo No. 3	1.1 (44.8,-)	1 (87.5,-)	1.2 (81.1,NC)								
Republic of Korea	Kingstar								1.1 (88.5,-)		1.1 (75.3,-)	1 (88.5,-)
Republic of Korea	Kostar				1.1 (87.5,-)	1.1 (80.1,-)	1 (79.4,-)	1 (76.9,-)	1 (81.4,-)	1.1 (80.4,-)	1.1 (64.9,-)	
Republic of Korea	Southern Ocean									1.1 (88.8,-)		
Republic of Korea	Sunstar				1.2 (85,-)	1.1 (78.4,-)	1.1 (67.6,-)	1.1 (87.5,-)	1 (87.5,-)	1 (81.8,-)	1.1 (78.5,-)	1.1 (87.2,-)
Norway	Argos Georgia								1.1 (84.9,-)	1.4 (79.9,NC)		
Norway	Seljevaer			1 (79.9,-)	1.1 (74.6,NC)	1 (81.7,NC)	1.2 (66.1,NC)					
New Zealand	Antarctic Chieftain	1 (58.3,-)	1 (92.5,NC)	1.2 (92,NC)		1.1 (NC,NC)						
New Zealand	Janas	1 (78.2,-)	1 (84.2,NC)	1.3 (88.1,NC)	1 (86.2,NC)	1.1 (87.1,NC)	1.8 (79.8,NC)	1.6 (89.5,NC)	1.1 (85.7,NC)	1.1 (82.6,-)	2.5 (87.3,NC)	1.1 (88.2,NC)
New Zealand	San Aotea II	1.1 (77.2,NC)	1.1 (88.5,NC)	2.7 (79.5,NC)	1.8 (78,NC)	1.6 (80.7,NC)	1.7 (83,NC)	1.7 (79.8,NC)	1.8 (81.1,NC)	1.6 (81.3,NC)	2.1 (84.1,NC)	3 (86.7,NC)
New Zealand	San Aspiring	1.1 (88.4,NC)	1.1 (92.9,NC)	1.1 (92.7,NC)	1.2 (91.2,NC)	1.1 (91.2,NC)	1.1 (92,NC)	1.1 (87.6,NC)	1 (89.2,NC)	1.1 (75,NC)	1.1 (80.3,-)	1.1 (79.9,-)
Russian Federation	Chio Maru No. 3		1.7 (80.1,NC)	1.5 (76.8,NC)								
Russian Federation	Gold Gate		1.3 (88,NC)									
Russian Federation	Mys Marii					1.1 (NC,-)	1 (63.9,NC)					
Russian Federation	Mys Velikan									1 (77,-)		
Russian Federation	Oladon 1							1 (87.1,-)				
Russian Federation	Ostrovka		1 (NC,NC)									
Russian Federation	Palmer					1.2 (83.5,-)	1 (79.5,-)	1 (75,NC)	1 (77.1,NC)	1.3 (81.7,-)	1 (67.2,-)	1 (84.7,-)
Russian Federation	Sparta		1.2 (62.6,NC)	1.5 (NC,NC)	1.1 (NC,-)	1.1 (NC,-)			1.1 (42.4,-)		1.1 (79.6,NC)	
Russian Federation	Ugulan				1 (71.7,NC)	1 (72.7,NC)			1.1 (74.7,-)			
Russian Federation	Volk Arktiki										1.2 (85.3,-)	
Russian Federation	Yantar 31			1.2 (86.4,-)	1.1 (86.3,-)	1 (84.8,-)	1 (73.7,NC)	1.1 (85,-)				
Ukraine	Calipso										1 (69.6,-)	1 (79.3,NC)
Ukraine	Marigolds								1.3 (NC,-)	1.1 (73,-)	1.3 (82,-)	1.2 (78.9,-)
Ukraine	Polus 1											0.9 (NC,-)
Ukraine	Poseydon I					1 (69.4,-)						
Ukraine	Simeiz				1.2 (39.9,-)	1.1 (83,NC)					1.3 (NC,-)	1.1 (85.5,-)
Uruguay	Altamar										1.5 (62.7,NC)	1.3 (83.5,-)

Table 4. Number of *D. mawsoni* tagged in recent fishing Seasons in this exploratory fishery (Subarea 88.1 and SSRUs 882A-B). The number of fish recaptured by each vessel in each Season is provided in brackets.

		Fishing Season										
Flag State	Vessel name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Argentina	Argenova XXI	33 (2)										
Australia	Antarctic Discovery								85 (2)	148 (36)	15 (3)	74 (9)
Chile	Globalpesca I											21 (8)
Spain	Tronio	308 (23)	429 (12)	546 (8)	388 (12)	298 (22)	311 (20)	230 (18)	359 (30)	180 (24)	307 (19)	192 (10)
Spain	Yanque							46 (7)				
United Kingdom	Argos Froyanes	158 (4)	332 (28)	38 (1)	183 (23)	220 (25)	389 (30)	70 (4)	230 (20)	221 (14)	120 (20)	223 (10)
United Kingdom	Argos Georgia	51 (2)	213 (48)	300 (13)	293 (10)	244 (22)	287 (26)	263 (37)			691 (43)	246 (14)
United Kingdom	Nordic Prince										369 (78)	156 (34)
Republic of Korea	Greenstar									333 (21)		331 (11)
Republic of Korea	Hong Jin No. 701			106 (0)	209 (4)				39 (0)	34 (1)	277 (10)	
Republic of Korea	Hong Jin No. 707	368 (25)	218 (9)	462 (8)	291 (1)							242 (10)
Republic of Korea	Insung No. 1	313 (29)										
Republic of Korea	Insung No. 3				249 (10)							
Republic of Korea	Insung No. 5				427 (16)							
Republic of Korea	Jung Woo No. 2	268 (3)	285 (0)	186 (3)								
Republic of Korea	Jung Woo No. 3	185 (8)	157 (2)	236 (5)								
Republic of Korea	Kingstar								276 (11)		128 (14)	246 (17)
Republic of Korea	Kostar				223 (1)	117 (1)	352 (2)	312 (15)	313 (15)	299 (17)	120 (12)	
Republic of Korea	Southern Ocean									64 (0)		
Republic of Korea	Sunstar				154 (4)	122 (1)	199 (6)	206 (7)	218 (4)	224 (15)	167 (10)	262 (6)
Norway	Argos Georgia								203 (25)	243 (28)		
Norway	Seljevaer			178 (14)	238 (53)	264 (55)	251 (27)					
New Zealand	Antarctic Chieftain	164 (36)	238 (18)	127 (2)		25 (1)						
New Zealand	Janas	415 (34)	172 (4)	168 (0)	130 (13)	150 (14)	270 (4)	338 (42)	206 (12)	139 (27)	420 (13)	172 (18)
New Zealand	San Aotea II	288 (24)	321 (50)	289 (4)	348 (21)	354 (70)	299 (20)	412 (50)	457 (22)	338 (10)	466 (33)	284 (14)
New Zealand	San Aspiring	513 (59)	199 (19)	527 (62)	243 (32)	307 (76)	193 (40)	408 (64)	298 (37)	300 (59)	344 (51)	175 (26)
Russian Federation	Chio Maru No. 3		242 (4)	302 (4)								
Russian Federation	Gold Gate		98 (1)									
Russian Federation	Mys Marii					21 (1)	44 (4)					
Russian Federation	Mys Velikan									82 (4)		
Russian Federation	Oladon 1							188 (3)				
Russian Federation	Ostrovka		18 (3)									
Russian Federation	Palmer					54 (7)	68 (0)	336 (1)	279 (0)	467 (2)	213 (1)	375 (0)
Russian Federation	Sparta		110 (8)	0 (0)	7 (1)	28 (6)			31 (3)		55 (5)	
Russian Federation	Ugulan				41 (3)	49 (2)			81 (3)			
Russian Federation	Volk Arktiki										99 (3)	
Russian Federation	Yantar 31			362 (7)	82 (8)	93 (0)	178 (2)	126 (5)				
Ukraine	Calipso										123 (12)	122 (17)
Ukraine	Marigolds								23 (5)	43 (7)	158 (7)	48 (4)
Ukraine	Polus 1											8 (0)
Ukraine	Poseydon I					30 (2)						
Ukraine	Simeiz				75 (1)	73 (4)					16 (1)	160 (7)
Uruguay	Altamar										55 (0)	89 (10)
	Total	**3064 (249)**	**3032 (206)**	**3827 (131)**	**3581 (213)**	**2449 (309)**	**2841 (181)**	**2935 (253)**	**3098 (189)**	**3115 (265)**	**4143 (335)**	**3426 (225)**

Table 5. Number of *D. eleginoides* tagged in recent fishing Seasons in this exploratory fishery (Subarea 88.1 and SSRUs 882A-B). The number of fish recaptured by each vessel in each Season is provided in brackets.

		Fishing Season										
Flag State	Vessel name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Argentina	Argenova XXI	0 (0)										
Australia	Antarctic Discovery								0 (0)	1 (0)	0 (0)	0 (0)
Chile	Globalpesca I											0 (0)
Spain	Tronio	0 (0)	1 (2)	0 (0)	1 (0)	0 (0)	2 (0)	0 (0)	2 (0)	0 (0)	0 (0)	0 (0)
Spain	Yanque							0 (0)				
United Kingdom	Argos Froyanes	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
United Kingdom	Argos Georgia	0 (1)	0 (0)	1 (0)	3 (1)	0 (0)	0 (0)	0 (0)			0 (0)	0 (0)
United Kingdom	Nordic Prince										0 (0)	0 (0)
Republic of Korea	Greenstar									0 (0)		0 (0)
Republic of Korea	Hong Jin No. 701			3 (6)	0 (0)				0 (0)	0 (1)	0 (0)	
Republic of Korea	Hong Jin No. 707	0 (0)	34 (5)	0 (1)	0 (0)							0 (0)
Republic of Korea	Insung No. 1	0 (0)										
Republic of Korea	Insung No. 3				1 (0)							
Republic of Korea	Insung No. 5				0 (0)							
Republic of Korea	Jung Woo No. 2	0 (0)	0 (0)	0 (1)								
Republic of Korea	Jung Woo No. 3	0 (0)	0 (0)	0 (0)								
Republic of Korea	Kingstar								0 (0)		0 (0)	0 (0)
Republic of Korea	Kostar				0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Republic of Korea	Southern Ocean									0 (0)		
Republic of Korea	Sunstar				0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Norway	Argos Georgia								0 (0)	0 (0)		
Norway	Seljevaer			0 (0)	0 (0)	0 (0)	0 (1)					
New Zealand	Antarctic Chieftain	0 (0)	0 (0)	1 (2)		0 (0)						
New Zealand	Janas	0 (0)	0 (2)	0 (0)	0 (0)	4 (0)	3 (2)	17 (1)	0 (0)	0 (0)	3 (0)	0 (1)
New Zealand	San Aotea II	0 (0)	2 (0)	15 (4)	0 (0)	4 (4)	0 (1)	2 (0)	0 (0)	0 (0)	0 (0)	1 (0)
New Zealand	San Aspiring	2 (1)	3 (0)	1 (1)	0 (0)	0 (0)	1 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)
Russian Federation	Chio Maru No. 3		0 (0)	2 (1)								
Russian Federation	Gold Gate		1 (3)									
Russian Federation	Mys Marii					0 (0)	0 (0)					
Russian Federation	Mys Velikan									0 (0)		
Russian Federation	Oladon 1							0 (0)				
Russian Federation	Ostrovka		0 (0)									
Russian Federation	Palmer					0 (0)	0 (0)	1 (0)	1 (0)	0 (0)	0 (0)	0 (0)
Russian Federation	Sparta		0 (0)	2 (0)	0 (0)	0 (0)			0 (0)		0 (0)	
Russian Federation	Ugulan				0 (0)	0 (0)			0 (0)			
Russian Federation	Volk Arktiki										0 (0)	
Russian Federation	Yantar 31			0 (0)	0 (0)	0 (0)	0 (0)	0 (0)				
Ukraine	Calipso										0 (0)	0 (0)
Ukraine	Marigolds								0 (0)	0 (0)	0 (0)	0 (0)
Ukraine	Polus 1											0 (0)
Ukraine	Poseydon I					0 (0)						
Ukraine	Simeiz				0 (0)	11 (1)					0 (0)	0 (0)
Uruguay	Altamar										0 (0)	0 (0)
	Total	**2 (2)**	**41 (12)**	**25 (16)**	**5 (1)**	**20 (5)**	**6 (4)**	**20 (1)**	**3 (1)**	**1 (1)**	**3 (0)**	**1 (1)**

5. Research

5.1. Status of the science

Recruitment surveys The Ross Sea shelf survey (WG-SAM-19/03) has been conducted since 2012. The objectives of the survey include monitoring the abundance and age structure of sub-adult (< 110 cm TL) toothfish in the southern Ross Sea and monitoring trends in larger (large sub-adult and adult) toothfish in two areas of importance to mammalian toothfish predators. Catches and size structure are similar among the surveys but consistently show year class progression in the age distributions (WG-FSA-17/57). The survey age structure and local biomass estimations were incorporated into the 2017 assessment and were shown to stabilise the index of year class strength; on this basis, continuation of the survey has been recommended.

Standardised CPUE Standardised catch-per-unit-effort (CPUE) analyses of *D. mawsoni* in the Ross Sea are updated routinely (WG-FSA-19/07). 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). The trend in CPUE shows increases and decreases throughout the period among the north, slope and shelf fisheries. The CPUE trend through time was not expected to reflect changes in biomass but rather location of fishing and fisher experience as the fishery developed.

Sex, Length, and Age Composition Approximately 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). In the Ross Sea, annual ALKs for each sex are developed and 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-18/46).

There has been a small increase in the proportion of males in the north, and to a much lesser extent on the slope and shelf, over time (WG-FSA-18/46) even after discounting the first two years' data (which are likely to be unrepresentative because fishing occurred mainly in shallow water in SSRU 881G). In 2019, the proportion of males in N70 and the SRZ showed an increasing trend through time (WG-FSA-19/07). These trends may be the result of spatial differences in fishing through time.

No trends through time were apparent in scaled median, 10th and 90th percentile of length, or sex-specific condition factor (WG-FSA-19/07).

Antarctic toothfish are older in the North compared to other areas, which is a reflection of ontogenetic migration and depths fished in each area (larger/older fish tend to be deeper). Interannual variability in age distributions are likely due to differences in depth and location fished within each management area. No trends were apparent within each of the management areas (WG-FSA-19/07).

Sea-ice The effect of sea-ice has a major influence on fishing operations in high latitudes. The major effects of sea-ice are firstly to restrict or deny access to preferred fishing grounds, but of much more consequence, to hamper fishing operations, with resulting effects on catches and time spent on the grounds. An ice index developed for Subarea 88.1 provides a quantitative index of the influence of variable sea-ice conditions on the operation of a fishery at the resolution of a season (WG-FSA-15/35).

5.2. Research plans

The medium-term research plan for this area has been developed and implemented by 5 Members. It is designed to collect the data required to improve the stock assessment and to improve the understanding of the potential impacts of the fishery on the broader ecosystem (Table 6). Additional ecosystem objectives and research priorities are specified in Conservation Measure 91-05 and in the Ross Sea region MPA research and monitoring plan, which details a large multi-member research effort to further understand ecosystem dynamics and the potential impacts of fishing in the Ross Sea region (SC-CAMLR-XXXVI/20).

Table 6. Medium-Term Research Plan (MTRP) objectives (WG-FSA-14/60; SC-CAMLR-XXXIII, paragraph 3.209 and CCAMLR-XXXIII, paragraph 5.52), alignment of proposed and current research proposals with the objectives and their status.

MTRP objectives	Research proposals	Paper number	Year running
(a) Reduce uncertainty in toothfish model parameters			
(i) To spatially and temporally delineate toothfish spawning grounds.	Winter research	WG-SAM-15/47, WG-FSA-18/40	2019
(ii) To delineate stock structure - especially in relation to SSRUs 882C-I.	Structured fishing 882C-G	WG-FSA-18/36	2019
(iii) To define and quantify fine-scale movement patterns, including by size and sex.	Satellite pop-up tags	WG-FSA-15/08	2019
(iv) To improve estimates of initial (and longer-term tagging) mortality, and tag detection.			
(v) To continue monitoring the relative abundance of sub-adults and to estimate recruitment variability and autocorrelation.	Shelf survey	WG-FSA-18/41	2016, 2017
(vi) To monitor key population-level parameters (e.g. growth, age/length at maturity, sex ratio) which could potentially be affected by fishing.			
(b) Reduce management uncertainty			
(i) To continue to improve the stock assessment (e.g. improve diagnostics, estimation of year-class strength etc.).	Shelf survey	WG-FSA-15/34	2018, 2019
(ii) To develop simple stock performance indicators/dashboard.			
(iii) To develop prioritised list of management strategy evaluation (MSE) scenarios and begin MSE testing of high-priority issues (e.g. alternative model parameters, spatial management, movement and stock assumptions etc.).			
(iv) To continue development of operating models as additional tag and fishery data are collected, through improved predictive layers (e.g. ice coverage) and better knowledge of life cycle.	882A-B North	WG-FSA-18/34	2018, 2019
(c) Maintenance of ecosystem structure and function			
(i) To determine the temporal and spatial extent of the overlap in the distribution of toothfish and its key predators (in particular, killer whales and Weddell seals).			
(ii) To investigate the abundance, foraging ecology, habitat use, functional importance and resilience of key toothfish predators (in particular, killer whales and Weddell seals).	McMurdo ice-based survey		2015, 2016
(iii) To develop methods of monitoring changes in relative abundance of key prey/by-catch species (in particular, macrourids and icefish) on the Ross Sea slope and hence assess the potential impact of the toothfish fishery on these species.			
(iv) To monitor diet of toothfish in key areas, especially on the Ross Sea slope.			
(v) To simulate the effect of the fishery on populations of toothfish, its predators, and its prey (using minimum realistic models or similar).			
(vi) To develop quantitative and testable hypotheses as to the second-order effects (such as trophic cascades, regime shift) and ensure data collection is adequate to monitor for any risks deemed reasonable.			
(vii) To assess the impact of the toothfish fishery on Patagonian toothfish (Dissostichus eleginoides).			
(viii) To estimate survivorship of released skates.			
(ix) To develop semi-quantitative and spatially explicit risk assessments for macrourids and Antarctic skates (Amblyraja georgiana), especially in the slope fishery of the Ross Sea.			
(x) To develop methods to assess whether the potential impacts of the toothfish fishery on the ecosystem are likely to be reversible in two to three decades.			

Additional research has occurred under Conservation Measure 24-01 (with more than 5t toothfish catch, including two winter longline surveys (WG-SAM-15/47, WG-FSA-16/37, WG-FSA-18/40) to study the timing and distribution of Antarctic toothfish spawning and early life history.

6. Stock status

6.1. Summary of current status

Models estimates (WG-FSA-19/08) using the updated data for 1998-2017, new data from 2018 and 2019, revised growth and length-weight parameters, and a similar model structure as in 2017 estimated the equilibrium pre-exploitation spawning stock biomass to be about 71,730 tonnes (95% CIs 65,890-78,730 tonnes) and the current stock status to be 66% B0 (63-69% B0).

6.2. Assessment method

This fishery (Subarea 88.1 and SSRUs 882A-B) for *D. mawsoni* was assessed using a CASAL Bayesian sex- and age-structured integrated stock assessment model (WG-FSA-19/08).

6.3. Year of last assessment, year of next assessment

Assessments are reviewed biennially, the last assessment was in 2019.

7. Climate Change and environmental variability

The impact of Anthropogenic climate change in the short-term could be expected to be related to changes in sea ice and physical access to fishing grounds, whereas longer-term implications are likely to include changes in ecosystem productivity affecting target stocks (FAO 2018).

In anticipation of potential impacts of climate change on targeted fish stocks, the Scientific Committee indicated that changes in productivity parameters may impact assessments and management advice, and these changes may be related to long-term environmental change, shorter-term variability, or potential effects of fishing (SC-CAMLR XXXVII paragraph 3.51, Annex 9 paragraph 2.28).

The parameters that could be evaluated for the effects of environmental variability and change would include mean recruitment, recruitment variability, mean length at age, mean weight at length, natural mortality, and maturation ogives.

Patterns in recruitment from the assessment model, analyses of residuals in fits to length-weight relationships, and analysis of residuals in the mean length at age showed no evidence of trends or variability over time that would influence the management for Antarctic toothfish in this area.

Other factors that may impact assumptions underlying the assessments that could also be considered, including stock distribution (for example, for its impact on tagged fish distribution or research survey interpretation), sex ratio (indicating maturation or other sex specific changes), and the ages or lengths observed in the fishery (indicating changes in vulnerability patterns or mortality).

The workplan associated with the impacts of climate change on this fishery is to:

i. Use historical data to investigate trends in key parameters affecting estimates of toothfish yield (and hence management advice).

ii. If trends are identified, adjust parameters in stock assessment and yield estimate to allow for trends continuing in future.

iii. Investigate evidence for trends being related to physical, oceanographic or ecological drivers, but note that establishing causality of trends may not be possible and is not essential.

References

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Pinkerton, M., P.J. McMillan, J. Forman, P. Marriott, P. Horn, S.J. Bury and J. Brown. 2013. Distribution, morphology and ecology of *Macrourus whitsoni* and *M. caml* (gadiformes, macrouridae) in the Ross Sea region. CCAMLR Science, 20: 37-61.

Additional Resources

- Fishery Summary: pdf, html
- Species Description: pdf, html
- Fisheries Documents Browser