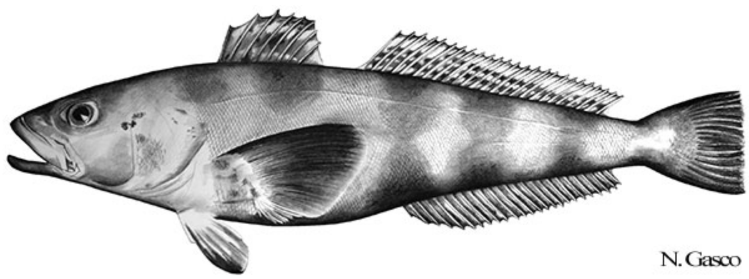
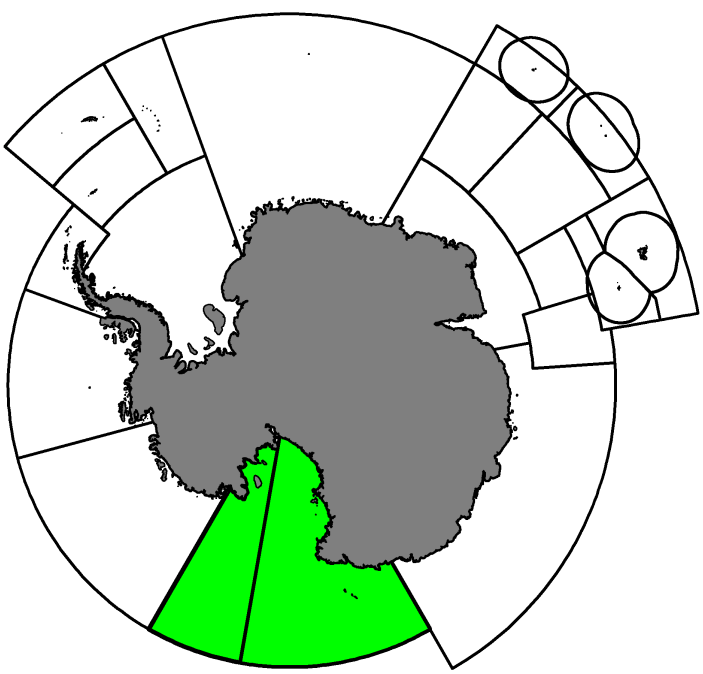
Fishery Report 2022: *Dissostichus mawsoni* in Subarea 88.1

CCAMLR Secretariat

17 April 2023



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, “2022” refers to the 2021/22 CCAMLR fishing season (from 1 December 2021 to 30 November 2022).

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 (north of 70°S) 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 high seas 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. 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.

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.

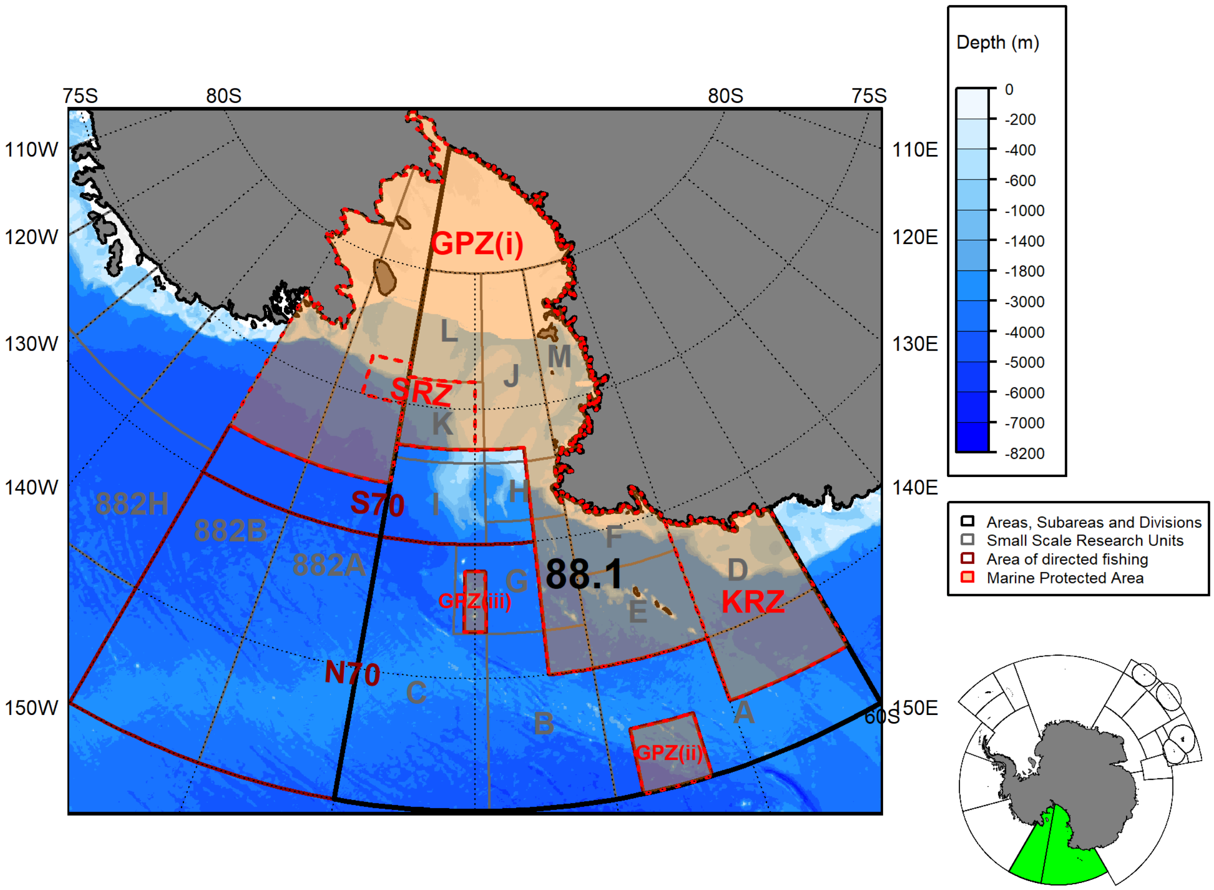


Figure 1: Location of Small Scale Research Units, Areas of directed fishing and Marine Protected Areas in this fishery.

1.3. Active vessels

In 2022, 19 vessels participated in this fishery. For the 2023 fishing season, a total of 24 vessels notified their intention to participate in this fishery (2 from Australia; 1 from Chile; 1 from Japan; 3 from New Zealand; 1 from Spain; 5 from Ukraine; 1 from Uruguay; 6 from the Republic of Korea; 4 from the United Kingdom).

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 3274 tonnes in 2022. In 2022, 14 tonnes of *D. eleginoides* and 3274 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	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	-
2021	17	3140	10	3135	-
2022	19	3495	14	3274	-

2.2. By-catch

Catch limits for by-catch species groups (*Macrourus* spp., skates and rays, 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.

Table 2. Reported catch and catch limits for by-catch species (*Macrourus* spp., skates and rays, 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.

	Macrourus spp.		Skates and rays			Other catch	
Season	Catch Limit (tonnes)	Reported Catch (tonnes)	Catch Limit (tonnes)	Reported Catch (tonnes)	Number Released	Catch Limit (tonnes)	Reported Catch (tonnes)
1997		0		0	0		<1
1998		9		5	0		<1
1999		22		39	0		5
2000		70		41	0		7
2001		61		9	0		14
2002		158		25	0		10
2003		65		11	966		12
2004	520	319	163	23	1852	180	23
2005	520	462	163	69	5057	180	24
2006	474	266	148	5	14698	160	18
2007	485	153	152	38	7336	160	43
2008	426	112	133	4	7190	160	20
2009	430	183	135	7	7088	160	16
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	16 q
2015	430	87 q	152	5 q	12978 q	160	24 q
2016	430	87 q	152	7 q	6016 q	160	22 q
2017	430	66	143	4	3857	160	12 q
2018	485	78 q	157	8	5924	157	14 q
2019	485	147	157	9	8870	157	26
2020	485	117	157	15	15620	157	33
2021	485	125	157	10	9490	157	33
2022	494	229	170	7	15654	170	52

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.

In 2012, 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.

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).

In 2021, a summary of available bycatch data in the region indicated that, as found in other areas of the Convention, macrourids were the most commonly observed bycatch group by both weight and numbers. Macrourids, skates, icefish, eel cods and morid cods comprised almost 99.5% of the total bycatch by weight WG-FSA-2021/32. Also, WG-FSA-2021/33 provided an update on a 2-year skate tagging programme, implemented in the 2020 and 2021 fishing seasons, aiming at population size estimation and to validate the thorn ageing method for Antarctic starry skate (*Amblyraja georgiana*).

In 2022, a study comparing the biology of *M. caml* and *M. whitsoni* reported that the former lived longer, grew slower, attained a larger maximum length than the latter, and, that for both species, females of a given age were larger and reached a greater maximum age than males (WG-FSA-2022/P04). WG-FSA-2022/42 and WG-FSA-2022/43 provided updates on the skate tagging programme where 2408 Antarctic starry skates (*Amblyraja georgiana*) were injected with a cartilage-marking chemical, 27 of which were recaptured and will enable validating age determination using caudal thorns. WG-FSA-2022/48 updated an analysis using the VAST (Vector Autoregressive Spatio-Temporal) modelling approach to predict spatio-temporal changes in macrourid by-catch in this fishery, and confirmed that it was appropriate to employ the results of the VAST models for *M. whitsoni* and *M. caml* to set by-catch limits for Macrourus spp. in this fishery. WG-FSA-2022/47 provided a summary of trends in performance indicators, including catches, fishing effort, catch rates, fish size, sex ratios and fish body condition, for the main bycatch species/species groups in this fishery.

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. This plan was updated in 2022 (SC-CAMLR-41, paragraphs 3.141 and 5.4).

4.2. Summary of available data

Both the vessel's crew and observers collect fishing effort, catch, and by-catch information.

Following Conservation Measure 22-07, vessels participating in this fishery must report the occurrence of VME indicator organisms on hauled lines. To do so, the vessel's crew observe lines in segments (1000-hook sections or 1200m sections, whichever is the shorter) and report the number of VME indicator units (either one litre of those VME indicator organisms that can be placed in a 10-litre container, or one kilogram of those VME indicator organisms that do not fit into a 10-litre container). Depending on the number of VME indicator units landed, vessels must immediately report and potentially cease fishing in the area (termed a Risk Area) until further review of the data is completed (see Conservation Measure 22-07). Based on the portion of the line monitored, observers further identify VME indicator organisms to the lowest taxonomic level possible.

The vessel's crew report total catch of non-VME by-catch (mostly fishes) by coarse taxonomic groups given the taxonomic expertise required to discriminate similar species. Observers collect biological information on toothfish and by-catch specimens at a finer taxonomic resolution, as well as data on individual specimens such as size and maturity.

Summaries of data reported to CCAMLR for the past five years are given in Tables 3 and 4.

Table 3. Summary of VME indicator taxa by-catch, by-catch of other species and biological data reported by vessels crew and observers in each of the last five seasons. By-catch records correspond to the number of observations of total weight and count of individuals for each taxon identified. Observers may take further biological measurements on toothfish and by-catch taxa. Taxonomic identification may occur at different levels.

Data source	Data class	Variable	2018	2019	2020	2021	2022
Vessel crew	VME	line segments	7313	8741	9683	9284	13244
		VME indicator units > 5 and < 10	2	1	10	1	0
		VME indicator units > 10	0	0	0	0	0
	by-catch	taxa identified	30	22	33	39	34
		records	2436	3237	3227	3386	4201
Observer	VME	line segments	6502	5295	6737	6246	6295
		taxa identified	30	23	20	20	21
		weight or volume measurements	3867	1643	1999	2142	2281
	toothfish	specimens examined	25383	34886	32500	33592	39055
		length measurements	25278	34879	32497	33573	39028
		weight measurements	24822	33203	32407	32405	37788
		sex identifications	25350	34877	32457	33580	39038
		maturity stage identifications	23281	34790	32260	33384	38812
		gonad weight measurements	19019	26503	27684	27666	34247
		otolith samples	8700	11083	9626	10061	11809
	by-catch	specimens examined	9246	12298	8385	8947	12820
		taxa identified	42	36	46	46	43
		length measurements	6875	10532	7937	8316	11951
		weight measurements**	9190	12232	8297	8554	12794
		standard length measurements*	0	728	402	318	1051
		wingspan measurements*	780	455	424	640	574
		pelvic length measurements*	538	433	417	522	510
		snout to anus measurements*	5213	6217	2925	3965	6125
		sex identifications**	6792	10498	6543	6438	7472
		maturity stage identifications**	5147	10112	6232	5673	7157
		gonad weight measurements**	3604	4863	2380	2446	1868
		otolith samples**	1435	1267	919	1269	1472

*: Species-dependent records

**: Voluntary records

Table 4. Summary of biological data for predominant by-catch groups reported by observers (from random subsets of lines) in each of the last five seasons. Taxonomic identification may occur at different levels.

By-catch group	Variable	2018	2019	2020	2021	2022
Macrourus spp.	specimens examined	5130	6539	2902	3955	6105
	taxa identified	5	5	6	6	5
	length measurements	3172	4926	2582	3446	5344
	weight measurements**	5112	6519	2899	3950	6093
	snout to anus measurements*	5106	6217	2885	3931	6086
	sex identifications**	4299	5728	2258	3026	3549
	maturity stage identifications**	3496	5630	2232	2909	3491
	gonad weight measurements**	3057	3185	75	1339	738
	otolith samples**	1326	1173	91	851	1181
Skates and rays	specimens examined	784	455	424	940	573
	taxa identified	5	8	7	6	6
	length measurements	417	309	423	932	526
	weight measurements**	780	433	422	557	570
	wingspan measurements*	777	455	424	640	571
	pelvic length measurements*	538	433	417	522	510
	sex identifications**	783	449	424	907	571
	maturity stage identifications**	140	266	232	515	504
	gonad weight measurements**	10	1	0	0	0
Other fish	specimens examined	3299	5293	4921	3949	6075
	taxa identified	17	21	22	27	26
	length measurements	3263	5293	4910	3934	6070
	weight measurements**	3265	5269	4838	3944	6064
	standard length measurements*	0	428	386	317	1038
	sex identifications**	1702	4318	3855	2502	3346
	maturity stage identifications**	1506	4216	3764	2249	3162
	gonad weight measurements**	536	1677	2305	1107	1130
	otolith samples**	108	94	827	415	290

*: Species-dependent records
**: Voluntary records

The counts of by-catch taxa reported above (Table 4) correspond to specimens that have been individually sampled by observers. These are a subset of all the specimens counted by observers and are generally identified at a more precise taxonomic level. The figures below (Figs. 2 and 3) display the distribution of the most frequently examined by-catch taxa in time and space. It is important to note that observers sample a random subset of lines and do not individually examine all taxa; as such these figures are more representative of the distribution of biological observations than the catch of these taxa or their spatial distribution. At a coarse taxonomic level, the total catch of by-catch species groups is provided in section 2.2 above.

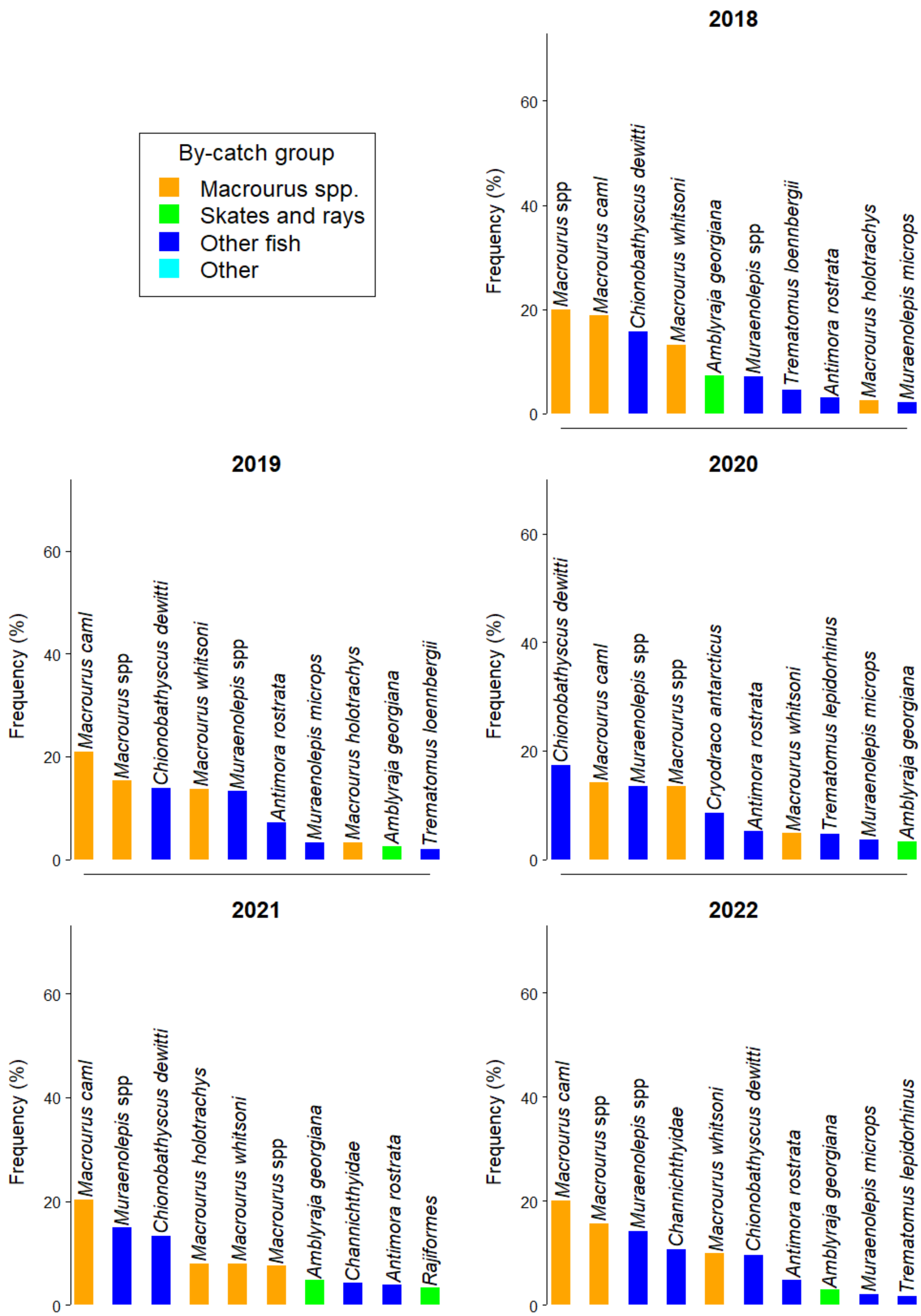


Figure 2. Relative frequencies of the most commonly examined by-catch taxa in each of the last five seasons, from the observer data (unweighted raw counts of individually examined specimens). Taxonomic identification may occur at different levels.

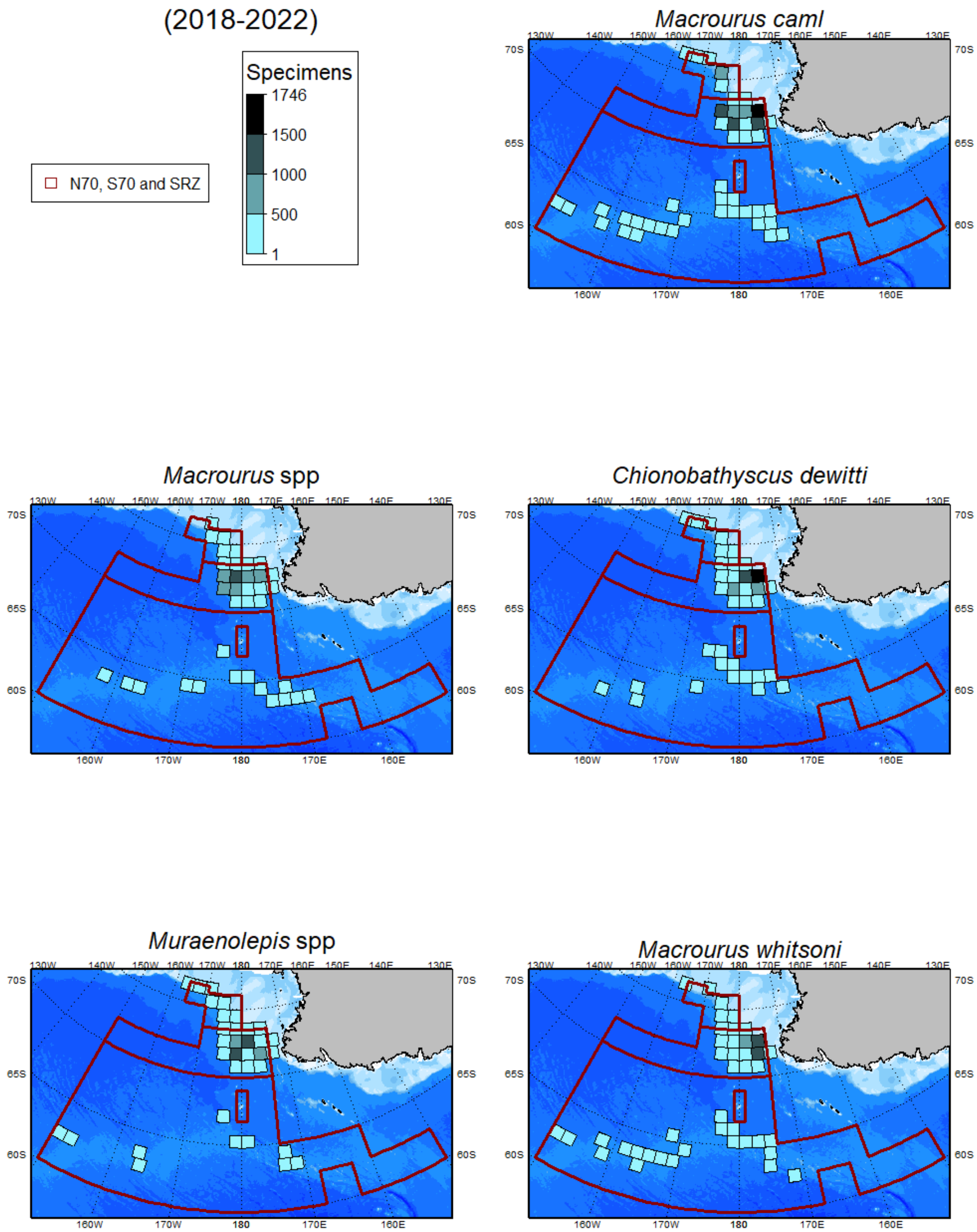


Figure 3. Spatial distribution of the most commonly examined by-catch taxa across the last five seasons, from the observer data (unweighted raw counts of individually examined specimens in each cell). The data were aggregated using equal area (100 km x 100 km) cells. Taxonomic identification may occur at different levels. Refer to Figure 1 for more details on the boundaries shown.

4.3. Length frequency distributions

The length frequency distributions of *D. mawsoni* and *D. eleginoides* caught in this fishery in recent years are shown in Figures 4 and 5 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. 4) 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 report (WG-FSA-2022/40). Observations of *D. eleginoides* length are few and typically smaller than *D. mawsoni* in this fishery (Fig. 5).

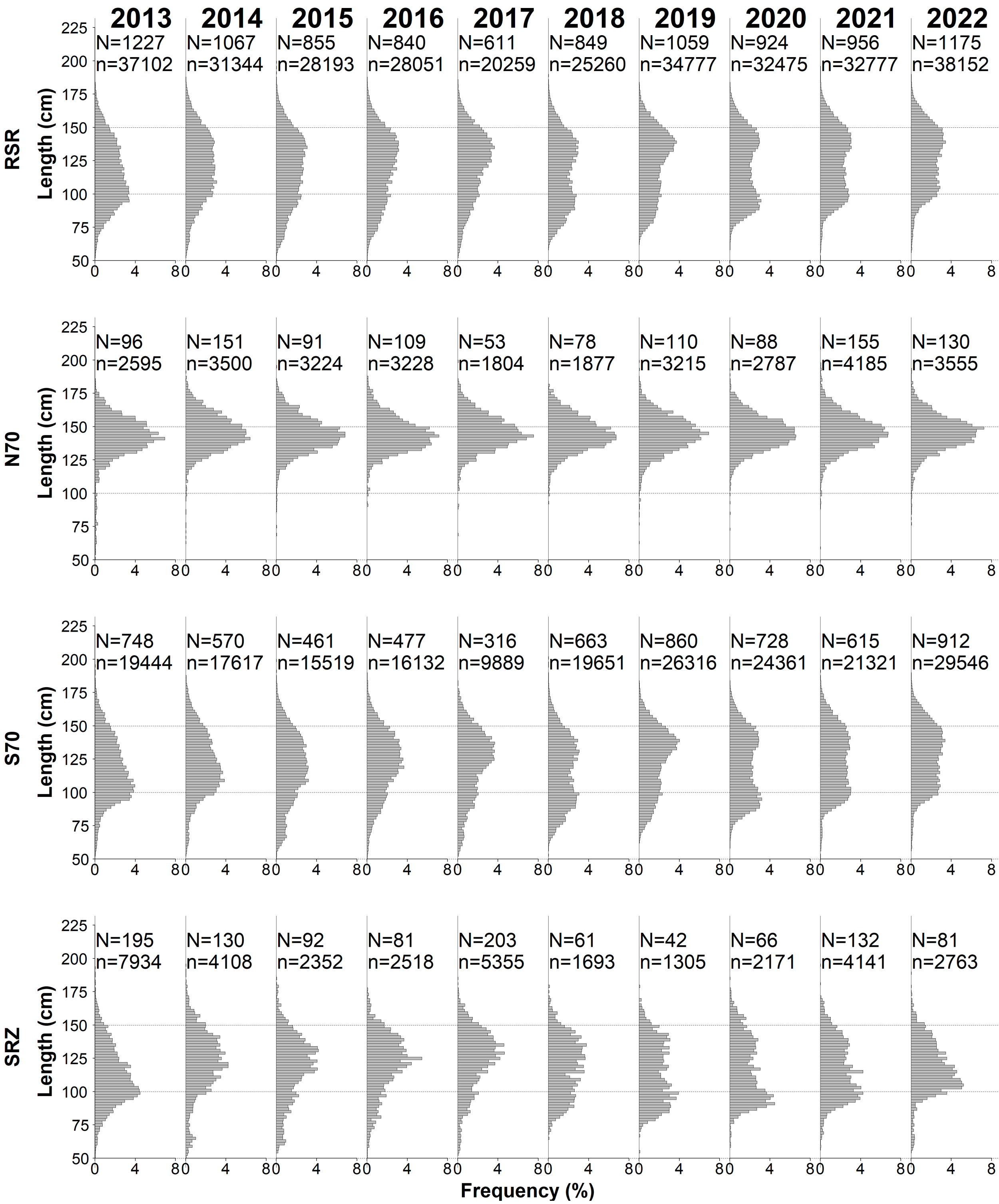


Figure 4. Annual length frequency distributions of *Dissostichus mawsoni* caught in this fishery (RSR; Subarea 88.1 and SSRUs 882A-B) (top panel) and the three areas of the fishery. The number of hauls from which fish were measured (N) and the number of fish measured (n) in each year are indicated. Note: length frequency distributions are only shown where more than 150 fish were measured in a given season/area.

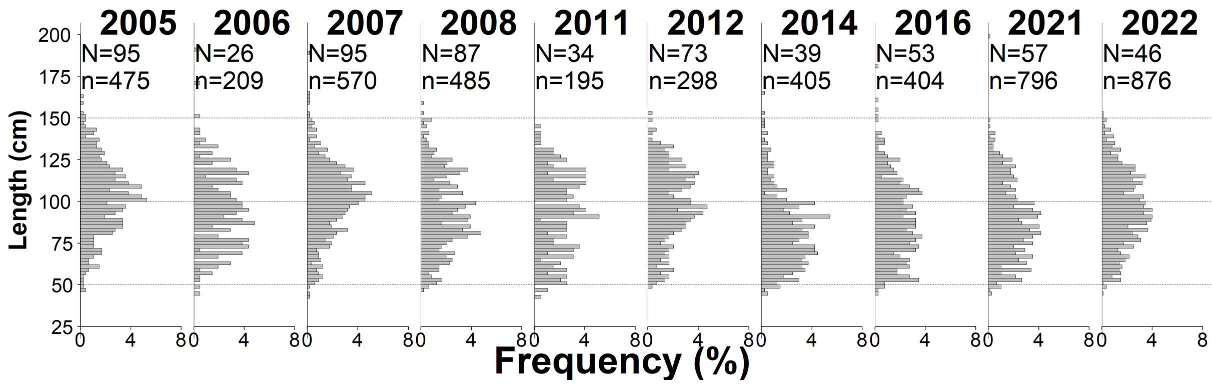


Figure 5. Annual length frequency distributions of *D. eleginoides* caught in this fishery (RSR; Subarea 88.1 and SSRUs 882A-B). The number of hauls from which fish were measured (N) and the number of fish measured (n) in each year are indicated. Note: length frequency distributions are only shown where more than 150 fish were measured in a given season/area.

4.4. 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 5). The tagging data is used as the main source of information on trends in abundance for stock assessment.

To date in this area, 65322 *D. mawsoni* have been tagged and released (3943 have been recaptured; Table 6), and, 1314 *D. eleginoides* have been tagged and released (110 have been recaptured; Table 7).

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 5. 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). In the last row, the tagging rate and tag-overlap statistic were computed using all fish tagged and all fish caught in the area.

		Fishing Season												
Flag State	Vessel name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Argentina	Argenova XXI	1.1 (50.5,NC)												
Australia	Antarctic Aurora													1 (81.9,NC)
Australia	Antarctic Discovery								1.1 (79.5,NC)	1 (88.6,NC)	1.2 (NC,-)	1 (77.5,-)	0.6 (69.4,NC)	
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,-)	1.1 (69.4,NC)	2.7 (72.9,-)
Spain	Yanque							1.2 (77,NC)						
United Kingdom	Argos Froyanes	1 (66.3,-)	1 (75.2,-)	1.3 (66.1,-)	1 (90,-)	1 (87.9,NC)	1.5 (81.1,NC)	1.1 (84.9,NC)	1 (79.8,-)	1.3 (89.1,-)	1.1 (86,-)	1.7 (75.1,-)	1.1 (92,NC)	
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,-)	1.1 (90.5,-)	1.1 (80.7,NC)
United Kingdom	Argos Helena													1.1 (81.7,NC)
United Kingdom	Nordic Prince										1.3 (86.6,-)	1 (90.2,-)	1.2 (80.3,-)	1.1 (87.4,-)
Japan	Shinsei Maru No. 8												1.4 (NC,NC)	1.1 (85.5,NC)
Republic of Korea	Blue Ocean													1.1 (91.4,NC)
Republic of Korea	Greenstar									1.1 (87.1,-)		1 (75.1,-)	1.1 (85.8,-)	
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,-)		1.8 (92.6,-)	1.5 (88.4,-)
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,-)	1.9 (82.8,-)	2.6 (93,-)
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,-)	1 (88.3,-)	1.2 (81.1,NC)
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,-)				1.2 (81.8,-)
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,-)	1 (85.7,-)	1 (81.7,NC)
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)	1.1 (85.8,NC)	1 (88.3,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 (81.2,NC)	1.6 (81.3,NC)	2.1 (84.1,NC)	3 (86.7,NC)	1.8 (66,NC)	2.3 (79.6,-)
New Zealand	San Aspiring	1.1 (88.4,NC)	1.1 (92.8,NC)	1.1 (92.8,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 (80.2,-)	1.1 (79.9,-)	1 (80.8,-)	1 (90.3,-)
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,-)											
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 (69.7,-)	1 (79.3,NC)	2.2 (83.8,NC)	1.1 (86,NC)
Ukraine	Marigolds								1.3 (NC,-)	1.1 (73,-)	1.3 (82,-)	1.2 (78.9,-)	2.1 (78.3,NC)	1.1 (83,-)
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,-)	1.3 (NC,NC)	1.1 (85.7,-)
Uruguay	Altamar										1.5 (62.7,NC)	1.3 (83.4,-)		
Uruguay	Ocean Azul													1.1 (79.8,-)
Total		**1.1 (66,NC)**	**1.1 (84.5,68.6)**	**1.2 (86.4,NC)**	**1.2 (92.3,NC)**	**1.1 (87,NC)**	**1.2 (82.3,NC)**	**1.2 (84.9,NC)**	**1.1 (81.4,NC)**	**1.2 (86.2,NC)**	**1.4 (85.5,NC)**	**1.2 (82.7,NC)**	**1.4 (82,75.4)**	**1.4 (82,84.2)**

Table 6. 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	2021	2022
Argentina	Argenova XXI	33 (2)												
Australia	Antarctic Aurora													117 (20)
Australia	Antarctic Discovery								85 (2)	148 (36)	15 (3)	74 (9)	68 (26)	
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)	199 (28)	758 (24)
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)	160 (9)	
United Kingdom	Argos Georgia	51 (2)	213 (48)	300 (13)	293 (10)	244 (22)	287 (26)	263 (37)			691 (43)	246 (14)	97 (16)	124 (24)
United Kingdom	Argos Helena													82 (19)
United Kingdom	Nordic Prince										369 (78)	156 (34)	81 (22)	331 (27)
Japan	Shinsei Maru No. 8												24 (0)	74 (7)
Republic of Korea	Blue Ocean													336 (11)
Republic of Korea	Greenstar									333 (21)		331 (11)	269 (40)	
Republic of Korea	Hong Jin No. 701			106 (0)	209 (4)				39 (0)	34 (1)	277 (10)		388 (4)	333 (17)
Republic of Korea	Hong Jin No. 707	368 (25)	218 (9)	462 (8)	291 (1)							242 (10)	592 (9)	540 (3)
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)	293 (17)	245 (13)
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)				252 (1)
Republic of Korea	Sunstar				154 (4)	122 (1)	199 (6)	206 (7)	218 (4)	224 (15)	167 (10)	262 (6)	350 (5)	214 (17)
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)	172 (28)	185 (41)
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)	546 (78)	270 (28)
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)	309 (65)	186 (45)
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)	526 (3)	201 (4)
Ukraine	Marigolds								23 (5)	43 (7)	158 (7)	48 (4)	200 (1)	55 (3)
Ukraine	Polus 1											8 (0)		
Ukraine	Poseydon I					30 (2)								
Ukraine	Simeiz				75 (1)	73 (4)					16 (1)	160 (7)	18 (0)	183 (22)
Uruguay	Altamar										55 (0)	89 (10)		
Uruguay	Ocean Azul													68 (8)
Total		**3064 (249)**	**3032 (206)**	**3827 (131)**	**3581 (213)**	**2449 (309)**	**2841 (181)**	**2935 (253)**	**3098 (189)**	**3115 (265)**	**4143 (335)**	**3426 (225)**	**4292 (351)**	**4554 (334)**

Table 7. 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	2021	2022
Argentina	Argenova XXI	0 (0)												
Australia	Antarctic Aurora													1 (0)
Australia	Antarctic Discovery								0 (0)	1 (0)	0 (0)	0 (0)	4 (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)	5 (2)	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)	2 (0)	
United Kingdom	Argos Georgia	0 (1)	0 (0)	1 (0)	3 (1)	0 (0)	0 (0)	0 (0)			0 (0)	0 (0)	0 (0)	0 (0)
United Kingdom	Argos Helena													1 (0)
United Kingdom	Nordic Prince										0 (0)	0 (0)	0 (0)	0 (0)
Japan	Shinsei Maru No. 8												11 (0)	15 (1)
Republic of Korea	Blue Ocean													9 (1)
Republic of Korea	Greenstar									0 (0)		0 (0)	0 (0)	
Republic of Korea	Hong Jin No. 701			3 (6)	0 (0)				0 (0)	0 (1)	0 (0)		0 (0)	0 (0)
Republic of Korea	Hong Jin No. 707	0 (0)	34 (5)	0 (1)	0 (0)							0 (0)	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)	0 (0)	5 (3)
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)				0 (0)
Republic of Korea	Sunstar				0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (4)
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)	7 (3)	0 (0)
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)	0 (0)	0 (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)	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)	0 (0)	2 (0)
Ukraine	Marigolds								0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)
Ukraine	Polus 1											0 (0)		
Ukraine	Poseydon I					0 (0)								
Ukraine	Simeiz				0 (0)	11 (1)					0 (0)	0 (0)	4 (2)	0 (0)
Uruguay	Altamar										0 (0)	0 (0)		
Uruguay	Ocean Azul													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)**	**34 (7)**	**36 (9)**

5. Research

5.1. Status of the science

Recruitment surveys The Ross Sea shelf survey (WG-FSA-2022/40) 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 areas but consistently show year class progression in the age distributions (WG-FSA-2022/40). The survey age structure and local biomass estimations were incorporated into the 2021 assessment and were shown to stabilise the index of year class strength; on this basis, continuation of the survey has been recommended (WG-FSA-2022/41 Rev. 1).

Standardised CPUE Standardised catch-per-unit-effort (CPUE) analyses of *D. mawsoni* in the Ross Sea are updated routinely (WG-FSA-2022/49). 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-2019/07). 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. 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-2019/07).

In 2021, scaled annual length and age distributions of the catch showed several modes of strong recruitment progressing through time on the slope (south of 70°S), while the size and age distributions in the north had not changed WG-FSA-2021/24. There was a small change in the sex ratio of Antarctic toothfish, with a gradual pattern of more males caught in all areas until 2015. The number of Antarctic toothfish recaptured in 2020-21 was higher than the average annual number over the past decade, likely a consequence of the concentration of fishing effort on the Ross Sea slope with the implementation of the RSrMPA.

In 2022, scaled length distributions showed no decrease in the size of fish caught through time in any of the management areas, although there was strong interannual variability in the area south of 70°S that was likely driven by changes in the fine-scale spatial distribution of fishing effort or the influence of strong and weak year classes entering the fishery. There was a small change in the sex ratio of Antarctic toothfish catch, with a gradual pattern of more males caught in all areas until 2015. The number of Antarctic toothfish recaptured in 2021 and 2022 was higher than the average annual number of recaptures over the past decade, likely a consequence of the concentration of fishing effort on the Ross Sea slope following the implementation of the RSrMPA.

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 fishing 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).

Antarctic toothfish diet In 2021, WG-FSA-2021/35 and WG-FSA-2021/36 presented results of diet analyses using molecular methods and stomach contents analyses. In line with previous studies, the diet of *D. mawsoni* mainly comprised fish (mostly *Macrourus caml* and *Cryodraco antarcticus*) and small amounts of cephalopods and crustaceans WG-FSA-2021/35. Results indicated that *D. mawsoni* is an opportunistic piscivorous fish WG-FSA-2021/36.

In 2022, WG-FSA-2022/27 and WG-FSA-2022/28 presented analyses of diet composition, feeding strategy and spatial diet variations of Antarctic toothfish. Macrouridae, *Chionobathyscus dewitti* and mollusks were found to be dominant prey items, and diet was found to differ between slope and shelf areas, reflecting the different prey assemblages between these areas. Also, a genetic study using microsatellite markers (WG-FSA-2022/29 Rev. 1) reported a higher genetic diversity in the Ross Sea region than other areas within Area 88.

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. 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).

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.

In 2021, WG-FSA-2021/30 indicated that the 5-year report of activities in support of the Research and Monitoring Plan for the RSrMPA was expected, and proposed a workshop to:

1. Identify fishery based medium-term research objectives,
2. Develop an associated fishery data collection plan to meet the research objectives,
3. Identify high priority non-Olympic fishery surveys or research activities, and
4. Identify voluntary programmes to develop and test novel data collection mechanisms

In 2022, WG-FSA-2022/44 reported on the Workshop on the Ross Sea Data Collection Plan 2022, WG-FSA-2022/46 presented a review of progress against the medium-term research plan and WG-FSA-2022/45 presented a proposal to update this plan (including research activities and voluntary programmes, and a data collection plan). The updated plan, focused on maintaining ecosystem processes and functions and monitoring, included 7 themes each with specific objectives:

(i) Maintenance of the Antarctic toothfish population in the Ross Sea region above target levels,
(ii) Top predators,
(iii) By-catch,
(iv) Ecosystem effects of fishing,
(v) Marine debris,
(vi) Alien species,
(vii) Climate change.

SC-CAMLR-41/BG/36 presented a compilation of Member activity reports related to the Ross Sea Region Marine Protected Area totaling 192 projects (26 active grants and 166 published studies) from 20 Members, in the period from 2016 to 2022.

6. Stock status

6.1. Summary of current status

A stock assessment using the updated catch and effort data for 1998-2021, tag-release data for 2001-2020 and associated tag-recapture observations for 2002-2021, commercial fishery age frequencies for 1998-2020, abundance observations from the Ross Sea Shelf Survey (RSSS) for 2012-2021, and age observations from the RSSS for 2012-2021, with a similar model structure as in 2019, estimated the equilibrium pre-exploitation spawning stock biomass to be 78,373 tonnes (95% CIs 71,999-85,663 tonnes) and the current stock status to be 62.7% B0 (95% CIs 59.9-65.6% 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.

6.3. Year of last assessment, year of next assessment

Assessments are reviewed biennially, the last assessment was in 2021.

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 maturity 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.

In 2022, the Commission recognised that climate change is already having effects in the Convention Area (CCAMLR-41, paragraph 6.3) and agreed that it needed to act urgently to prepare for, and adapt to, the effects of climate change on the marine ecosystems within the Convention Area (CCAMLR-41, paragraph 6.5). The Commission noted (CCAMLR-41, paragraph 6.4) that the Scientific Committee had incorporated climate change into its advice (SC-CAMLR-41, paragraph 7.8) and through discussions at the SC-Symposium (SC-CAMLR-41, Annex 11) had also added climate change to the work plans and terms of reference of its Working Groups (SC-CAMLR-41, paragraph 7.14). The Commission also welcomed (CCAMLR-41, paragraph 6.8) the Scientific Committee's agreement to hold a workshop on climate change in the first half of 2023 (SC-CAMLR-41, paragraph 7.10) and encouraged the inclusion of a range of scientific experts as well as policy makers to foster integration of the best available science into management actions. The Commission adopted (CCAMLR-41, paragraph 6.28) Resolution 36/41.

References

McMillan, P., T. Iwamoto, A. Stewart and P.J. Smith. 2012. A new species of grenadier, genus Macrourus (Teleostei, Gadiformes, Macrouridae) from the southern hemisphere and a revision of the genus. Zootaxa, 3165: 1-24.

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
- Stock Assessment Report: pdf
- Stock Annex: pdf
- Fisheries Documents Browser