South Pacific Regional Fisheries Management Organisation

13th MEETING OF THE SCIENTIFIC COMMITTEE

8 to 13 September 2025, Wellington, New Zealand

SC13 - DW 07

New Zealand's final report on its toothfish exploratory fishery (CMM 14a-2022)

New Zealand

SC9-DWXX

Final report on NZ’s exploratory fishery for toothfish in the SPRMO Area 2022-2024

New Zealand

South Pacific Regional Fisheries Management Organisation

14th Meeting of the Scientific Committee

Report on the New Zealand exploratory bottom longline fishing for toothfish in the SPRFMO Convention Area 2022 to 2024.

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Abstract

Between 2022 and 2024, New Zealand conducted exploratory fishing research in the SPRFMO Convention Area to study Antarctic toothfish (*Dissostichus mawsoni*) and Patagonian toothfish (*Dissostichus eleginoides*). This research aimed to improve understanding of the distribution, movement, spawning dynamics, and stock structure of these species, while contributing to CCAMLR stock assessment models. The studies were conducted under the framework of CMM 14a-2022, with strict conservation measures ensuring sustainability and minimal environmental impact.

The findings from 2022–2024 continue to confirm the northern SPRFMO area as a spawning ground for Antarctic toothfish, with consistent observations of adult fish in pre-spawning or spent conditions. Toothfish tagging continued, providing data to support stock connectivity and migration patterns. Bycatch levels remained minimal, and benthic interactions were well below SPRFMO thresholds, in compliance with environmental regulations.

Environmental conditions varied across the three years, influencing fish distribution and catch rates. In 2024, the only late winter sampling, fish shifted from southern slopes to hilltops, reflecting changes in sea temperatures and currents.

The research highlighted discrepancies between observer-recorded maturity indices and gonadosomatic index (GSI), recommending GSI as a more reliable measure of reproductive maturity.

As this was the final New Zealand research programme in this eastern SPRFMO area, data from all trips conducted since 2016 have been included in some sections to provide greater context.

The comprehensive dataset from these efforts over the eight years of exploratory fishing by New Zealand highlights the wider geographic extent of Antarctic toothfish spawning, extending north of the SPRFMO-CCAMLR boundary at 60°S and has significantly advanced scientific understanding of toothfish biology and stock dynamics, providing a basis for future management and exploratory fishing efforts in the region.

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Introduction and background to the 2022 - 2024 exploratory fishing by New Zealand

Antarctic and Patagonian toothfish (*Dissostichus mawsoni* and *Dissostichus eleginoides*) have circumpolar distributions and can move over large distances (CCAMLR Secretariat, 2016). The observed distribution of Antarctic toothfish in the SPRFMO Convention Area immediately north of the CCAMLR Convention Area in Area 88 is consistent with current stock hypotheses for Antarctic toothfish (Parker et al. 2014; Hanchet et al. 2008 and 2015).

New Zealand has been actively involved in exploratory fishing for Antarctic and Patagonian toothfish within the South Pacific Regional Fisheries Management Organisation (SPRFMO) Convention Area since 2016. These activities have focused on understanding the biology, distribution, and stock dynamics of toothfish species, while adhering to strict conservation and management measures. The research has evolved with significant milestones achieved in data collection, tagging, and collaboration with the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

New Zealand initiated a two-year exploratory fishing programme in 2016 under CMM 4.14. The demersal longline vessel *San Aspiring* conducted research in two designated blocks, collecting bathymetric, biological, and operational data. A total of 28,961 kg of Antarctic toothfish (*Dissostichus mawsoni*) was caught in 2016, with 85% being males in spawning or spent condition. Bycatch was minimal, with rattails (*Macrourus* spp.) comprising 1.21% of the total catch for the 2022-2024 period (see Table 2 for all catch figures. Observations of seabirds and marine mammals were recorded, with no injuries or fatalities reported. The programme successfully met tagging requirements, with 104 toothfish tagged in 2016—the second trip in 2017 continued data collection, focusing on spawning dynamics and stock structure.

Following the success of the initial programme, New Zealand proposed an expanded exploratory fishery, approved under CMM 14a-2019. Research trips were conducted annually from 2019 to 2021, targeting new research blocks (L–O), see Figure 2. Catch rates in SPRFMO areas were higher than those in adjacent CCAMLR regions, indicating productive fishing grounds. The research confirmed the northern SPRFMO area as a spawning ground for Antarctic toothfish, with consistent records of adult Antarctic toothfish in pre-spawning or spent conditions. Bycatch remained below 1% of total catch weight, and benthic interactions were minimal. The tagging programme expanded, with 671 toothfish tagged by 2021, contributing to CCAMLR's integrated stock assessment models.

In 2022, New Zealand commenced a new three-year exploratory programme under CMM 14a-2022, with an annual catch limit of 240 tonnes across eight research blocks. A single research trip in 2022 yielded 38.7 tonnes of toothfish, with the number of biological samples consistent with previous years. Tagging efforts resulted in 155 tagged fish, supporting stock linkage studies.

Details of the research trips conducted in 2022–2024, including catch rates, tagging efforts, and environmental observations, are outlined in the Methods section.

New Zealand's research in SPRFMO since 2016 has employed rigorous methodologies, including bathymetric mapping to identify fishable areas, biological sampling of toothfish and bycatch species focusing on length, weight, sex, and gonad condition, tagging programmes to study stock movement and connectivity, and observations of seabirds and marine mammals to ensure compliance with mitigation measures.

New Zealand has adhered to SPRFMO and CCAMLR conservation measures, including the use of bird scaring lines, weighted longlines, and night-time setting to minimise seabird interactions, monitoring benthic bycatch to avoid triggering vulnerable marine ecosystem (VME) thresholds, and collaboration with CCAMLR to share data and align methodologies. While operational challenges, such as adverse weather and gear loss, have occasionally hindered research, New Zealand's exploratory fishing activities within SPRFMO have significantly advanced scientific understanding of Antarctic toothfish. The research has provided valuable insights into spawning dynamics and stock structure north of the traditional CCAMLR fishing area. Continued efforts through 2025 will further contribute to the effective management of toothfish stocks in the region.

At the 2021 meeting (SC9), the SPRFMO Scientific Committee considered a new proposal by New Zealand to further extend and expand the Exploratory Fishery into 2022, 2023, and 2024 (SC9-DW01_rev1). The final research results from the 2019 – 2021 trips were presented as part of that proposal. The extension of the Exploratory Fishery was approved in 2022 under CMM 14a-2022.

The 2022 approval allowed for up to two authorised New Zealand vessels to take up to 240 tonnes of toothfish annually (both species combined). Fishing is restricted to eight Research Strata (L – S, Figure 1), each having a catch limit of 40 tonnes a year. Up to 50% of the total annual catch (120 tonnes) can be taken outside the post-spawning period (August – October).

This report summarises results from the 2022-2024 exploratory fishing by the New Zealand vessel *San Aspiring*.

Objectives

The objectives of the Exploratory Fishery are set out in the CMM 14a-2022 as follows:

- To continue mapping the bathymetry of the fishable area (shallower than about 2,500 m) in mid-Pacific to the north of the SPFRMO-CCAMLR boundary.
- Document the spatial distribution, catch rates, and relative abundance of Antarctic and Patagonian toothfish in likely suitable habitat to the north of the CAMLR Convention area by latitude, area, and depth.
- Characterise the biology, life history and spawning dynamics of both species of toothfish in the area.
- Tag enough toothfish to inform stock linkage and life history studies, and for use in the multi-area CCAMLR stock assessment model.
- Collect information on the distribution, relative abundance, and life history of bycatch and other associated or dependent species.
- Collect toothfish eggs using plankton net tows, if practical.
- As feasible, given the availability of equipment, conduct Continuous Plankton Recorder (CPR) tows for planktonic studies and potentially for eggs; and
- Collect acoustic data using existing procedures as carried out within the CAMLR Convention Area.

Methods

The 2022 approval allowed for up to two authorised New Zealand vessels to take up to 240 tonnes of toothfish annually (both species combined). Fishing was restricted to eight Research Strata (L – S, Figure 2), each having a catch limit of 40 tonnes a year, with up to 50% of the total annual catch (120 tonnes) to be taken outside the post-spawning period (August – October).

The first exploratory trip each year was to occur any time in 2022, 2023, and 2024, with fishing restricted to a maximum of four trips per year. Some of these trips were to be conducted between August and October to characterise post-spawning dynamics. The final trip took place in October and November of 2024 to look at the potential post-spawning of Antarctic toothfish.

The fishing method was bottom longlining using the autoline system with integrated weight mainlines. This approach was complemented by bathymetric mapping to identify fishable areas before setting gear, biological sampling of toothfish and bycatch species, and a tagging programme compatible with the adjoining CAMLR Convention Area to study stock movement and connectivity [CMM 14a-2022, Par 16 b)] Tagging rates were set at three fish per tonne for Patagonian toothfish and one per tonne for Antarctic toothfish. Biological data collected included measurements of length, weight, sex, gonad stage, and otoliths for ageing studies. Observations of seabirds and marine mammals were conducted to ensure compliance with mitigation measures, such as bird scaring lines, weighted longlines, and nighttime setting.

Additional research activities included acoustic data collection and sampling of bycaught benthic catch to monitor interactions with vulnerable marine ecosystems (VMEs). The sampling of benthic bycatch followed CCAMLR protocols, with benthic material identified at least to the most appropriate taxonomic level and weighed. The number of line segments sampled is obviously a direct relationship with the number of lines set – noting only 5 lines were set in Environmental data, such as depth-temperature profiles, were collected using Mangōpare sensors, contributing to broader oceanographic studies.

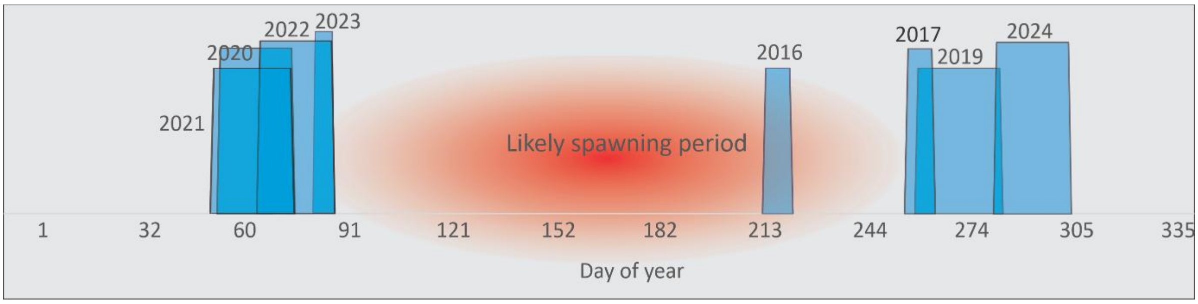

Figure 1. Annual seasonal timings of the eight research periods 2016, 2017, 2019 – 2021, and 2022-2024 referenced to the likely spawning period for Antarctic toothfish Dissostichus mawsoni. The labelled blue boxes identify the timing (day of year) for each of the research trips.

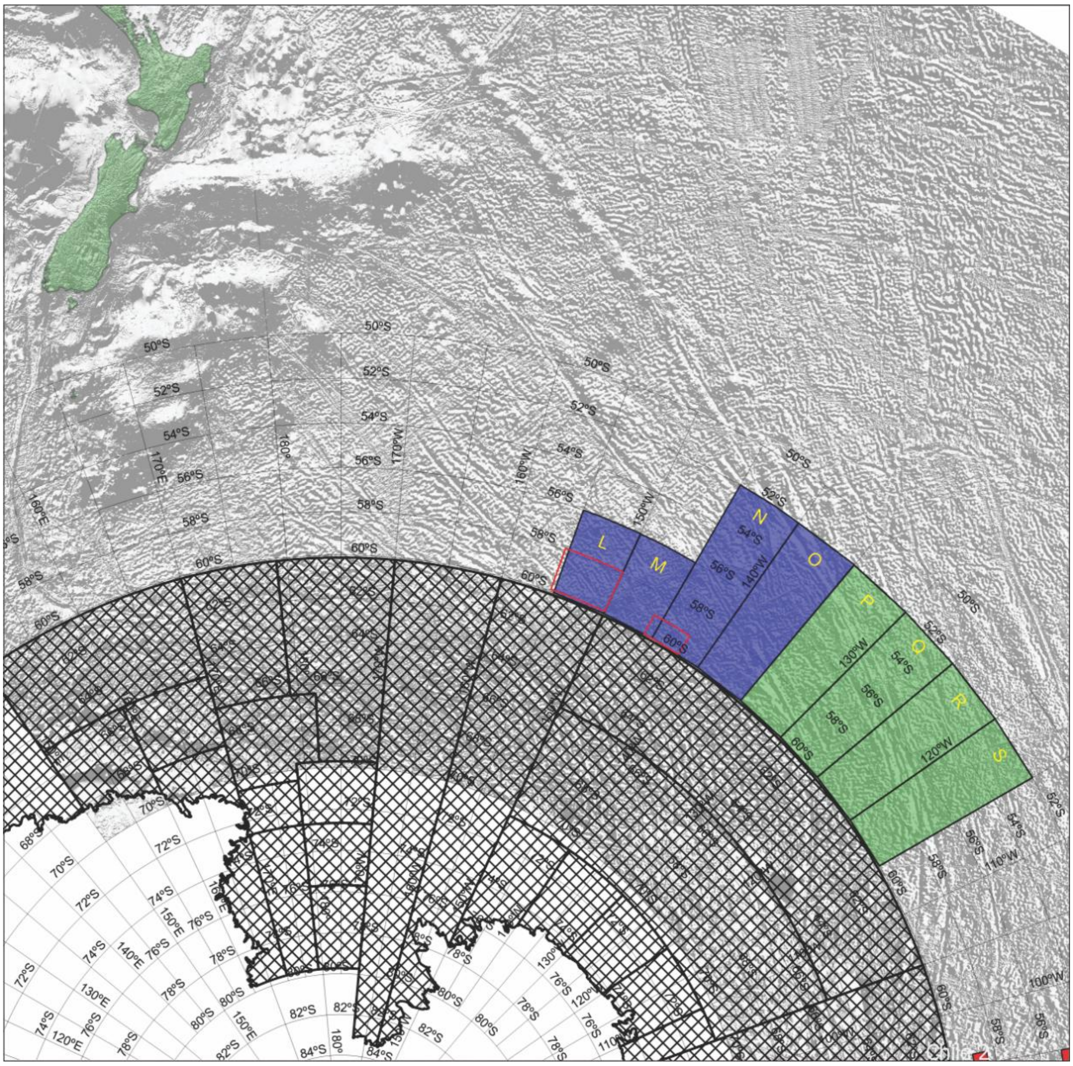

Figure 2. Survey area for 2022-24 research. Research areas P, Q, R, and S are the 2022-2024 areas added, in addition to the 2019-21 research areas L, M, N, and O. The open red boxes are the initial research boxes from 2016-2017, which are now included within research areas L-O. The hashed area is the CAMLR Convention Area.

The research design incorporated a cluster approach to minimise localised depletion and ensure sustainable fishing practices. Data collected during the exploratory fishing trips were shared with SPRFMO and CCAMLR to support integrated stock assessment models.

The measure expired following the regular meeting of the Commission in February 2025.

New Zealand presented a further proposal to carry out exploratory fishing further to the east of areas surveyed from 2016 to 2024 which was supported by the scientific committee in October 2024 and endorsed by the SPRFMO Commission Meeting in February 2025. This current research is governed by CMM 14i-2025.

Results

Toothfish catch

Table 1. Station summary for the toothfish research sorted by fishing block. There were 31 sets overall made in 2022, 5 sets in 2023, and 14 in 2024 (one was aborted with no catch due to a baiting machine failure). Start and end dates refer to the beginning and end of all recorded fishing operations in each Fishing Block. TOA is the FAO/CCAMLR code for Antarctic toothfish. Catch rates are shown both in kg (retained) per hook recovered and in numbers of TOA per 1000 hooks recovered, which includes captured toothfish subsequently released with tags. For additional context, previous results from 2019 to 2021 are also shown in the lighter text.

Area Name	Fishing season	No of sets	Start of fishing	End of fishing	TOA Catch (kg)	Total TOA caught	No of hooks set	Average soak time	No of hooks recovered	TOA catch rate in kg per recovered hook	Number of TOA per 1000 hooks	Avg TOA weight
L	2019	10	7/10/2019	11/10/2019	452.6	14	31709	13.24	31709	0.01	0.4	32.3
L	2020	10	23/02/2020	27/02/2020	2965.6	115	29138	13.30	29138	0.10	3.9	25.8
L	2021	10	24/02/2021	5/03/2021	484.2	20	36851	11.06	34901	0.01	0.6	24.2
L	**2022**	**10**	**1/03/2022**	**4/03/2022**	**66.9**	**4**	**29995**	**15.50**	**29995**	**0.00**	**0.1**	**16.7**
L	**2023**	**2**	**22/03/2023**	**24/03/2023**			**8570**	**14.76**	**8570**			
L	**2024**	**5**	**9/10/2024**	**13/10/2024**			**16283**	**12.89**	**16283**			
M	2021	2	8/03/2021	9/03/2021			6099	10.25	5229			
M	**2022**	**2**	**5/03/2022**	**6/03/2022**			**5142**	**16.65**	**5142**			
N	2019	12	25/09/2019	5/10/2019	36048.8	1265	41803	13.29	41803	0.86	30.3	28.5
N	2020	12	28/02/2020	7/03/2020	37980.9	1399	42421	13.65	42421	0.90	33.0	27.1
N	2021	19	1/03/2021	14/03/2021	23548.2	896	57473	10.65	41405	0.57	21.6	26.3
N	**2022**	**6**	**7/03/2022**	**13/03/2022**	**38643.4**	**1327**	**19711**	**12.26**	**19711**	**1.96**	**67.3**	**29.1**
N	**2023**	**3**	**25/03/2023**	**29/03/2023**	**34398.8**	**1072**	**6945**	**14.05**	**4428**	**7.77**	**242.1**	**32.1**
N	**2024**	**5**	**14/10/2024**	**21/10/2024**	**32523.5**	**1086**	**11141**	**11.91**	**11141**	**2.92**	**97.5**	**29.9**
O	2019	13	16/09/2019	23/09/2019			50617	12.69	50617			
O	2020	10	11/03/2020	15/03/2020			26567	12.56	26567			
O	2021	2	15/03/2021	16/03/2021			5999	10.01	5159			
O	**2024**	**4**	**24/10/2024**	**27/10/2024**	**129.4**	**4**	**11998**	**12.68**	**11998**	**0.01**	**0.3**	**32.3**
Q	**2022**	**13**	**18/03/2022**	**29/03/2022**			**34280**	**10.49**	**34280**			

Bycatch

Bycatch (Table 2) was about 2.02% of the total catch by weight in 2021, 0.02 % in 2023 and 3.93% in 2024. The increase in the proportion of bycatch from a very low level recorded in 2016 and 2017 is mainly attributable to a much wider survey area during the 2019 to 2021 periods, reflecting many more sets made in areas where toothfish were not located (but other species caught). The depth range fished was also increased to extend the survey deeper. Typically, bycatch levels for all nontarget species combined in the CCAMLR target fishery immediately south are about 5% of the overall catch.

Non-toothfish bycatch comprised mostly Macrourids (grenadiers or rattails). Macrourids are generally recorded under a collective category by the vessel for reporting; however, these were further identified by the scientific observers as Caml rattail *Macrourus caml*, Whitson's grenadier *Macrourus whitsoni*, bigeye grenadier *Macrourus holotrachys*, ridge-scaled rattail *Macrourus carinatus* , and cosmopolitan rattail *Coryphaenoides armatus*. In 2019, bigeye grenadier was found to dominate the species group north of 57°S latitude, while Caml grenadier and Whitson's grenadier were mainly found south of 56°S latitude. Two cosmopolitan rattails and one ridge-scaled rattail were caught in Fishing Block O.

Other main bycatch taxa included moray cods (*Muraenolepididae*), blue antimora, and Lepidions. Six Patagonian toothfish were taken over the three years, although one was tagged and released. All *Etmopterus* were identified by observers in 2020 as blue-eyed lantern shark *Etmopterus* viator, see Figure 3.

Table 2. Catch and proportions by species for the 2022 to 2024 research sets. Data are from the vessel-reported catches.

Fishing year	**Taxonomic description**	**Common name**	**FAO code**	**Total weight**	**Numbers caught**	**Numbers Lost at surface**	**% of total trip catch**
2022	*Dissostichus mawsoni*	Antarctic Toothfish	TOA	38,710.29	1176	43	97.82%
	Macrourus spp	Rat tails, Grenadiers	GRV	375.17	170	9	0.95%
	Antomora rostrata	Blue Antimora	ANT	216.32	155	7	0.55%
	Chimaeras, etc. nei	Chimaera	HOL	117.79	14	0	0.30%
	Lepidion spp	Lepidion codlings	LEV	51.73	8	0	0.13%
	Bathylagus euryops	Goiter blacksmelt	BBE	28.56	14	1	0.07%
	Etmopterus spp	Lantern sharks	SHL	24.78	60	8	0.06%
	Dissostichus eleginoides	Patagonian Toothfish	TOP	22.80	1	0	0.06%
	Psychrolutes macrocephalus	Fathead sculpin	PEF	13.24	8	0	0.03%
	Moras nei	Morid cods	MOR	4.10	11	0	0.01%
	Apristurus spp	Deep-water catsharks	API	3.88	3	0	0.01%
	Diastobranchus capensis	Basketwork eel	SDC	1.87	2	0	0.00%
	Lithodidae	Crab spp.	KCX	1.84	4	0	0.00%
	Muraenolepis spp	Moray Cods	MRL	0.58	2	0	0.00%
	Channichthyidae spp	Icefish	ICX	0.30	1	0	0.00%
Total				**39,573.25**			

2023	*Dissostichus mawsoni*	Antarctic Toothfish	TOA	34,400.80	1072	29	99.96%
	Antomora rostrata	Blue Antimora	ANT	7.80	7	0	0.02%
	Macrourus spp	Rat tails, Grenadiers	GRV	6.10	6	0	0.02%
	Lithodidae	Crab spp.	KCX	0.30	1	0	0.00%
Total				**34,415.00**			
2024	*Dissostichus mawsoni*	Antarctic Toothfish	TOA	32,652.82	1090	55	96.24%
	Macrourus spp	Rat tails, Grenadiers	GRV	921.06	387	6	2.71%
	Hyperoodon planifrons	Southern Bottlenose whale	HYP	150.77	39	0	0.44%
	Antomora rostrata	Blue Antimora	ANT	127.69	114	1	0.38%
	Lepidion spp	Lepidion codlings	LEV	51.68	6	0	0.15%
	Psychrolutes macrocephalus	Fathead sculpin	PEF	10.05	3	0	0.03%
	Etmopterus spp	Lantern sharks	SHL	8.20	28	0	0.02%
	Octopodidae	Octopus spp.	OCT	2.27	1	0	0.01%
	Alepocephalus spp	Slickheads	ALH	1.91	1	0	0.01%
	Muraenolepis spp	Moray Cods	MRL	1.11	3	0	0.00%
	Moras nei	Morid cods	MOR	0.99	2	0	0.00%
	Asteroidea	Starfish	STF	0.19	3	0	0.00%
	Lithodidae	Crab spp.	KCX	0.11	1	0	0.00%
Total				**33,928.85**			

Biological data were collected from *Dissostichus* spp. and bycatch species from each set. Antarctic toothfish were sampled for length, weight, sex, gonad stage, and gonad weight (Table 3). Stomachs were examined to provide information on feeding, and otoliths were subsampled from each line. The five Patagonian toothfish brought aboard were also sampled for full biological data and otoliths. Biological data were collected from some key bycatch species. As toothfish ageing is a priority focus, bycatch species were not sampled for otoliths. One Patagonian toothfish was tagged and released in 2021.

Table 3. Biological measurements recorded for the 2022 to 2024 research. The numbers indicate the number of measurements made for each category.

2022	Abyssal grenadier	*Coryphaenoides armatus*	CKH	2	1	0	2	2	0	0	2
	Antarctic Toothfish	*Dissostichus mawsoni*	TOA	289	0	0	289	289	289	289	289
	Bigeye grenadier	*Macrourus holotrachys*	MCH	48	37	5	48	48	31	0	48

	Blue Antimora	*Antomora rostrata*	ANT	124	0	0	124	124	116	0	124
	Caml genadier	*Macrourus caml*	QMC	28	28	0	28	28	17	0	28
	Chimaera	*Chimaeras, etc. nei*	HOL	14	0	0	14	14	0	0	14
	Crab spp.	*Lithodidae*	KCX	4	0	0	4	4	0	0	4
	Fathead sculpin	*Psychrolutes macrocephalus*	PEF	8	0	0	8	8	1	0	8
	Icefish spp.	*Chionobathyscus dewitti*	CHW	1	0	0	1	1	0	0	1
	Lantern sharks	*Etmopterus spp*	SHL	53	0	0	53	53	1	0	53
	Lepidion codlings	*Lepidion spp*	LEV	8	0	0	8	8	5	0	8
	Moray Cods	*Muraenolepis spp*	MRL	1	0	0	1	1	0	0	1
	Morid cods	*Moras nei*	MOR	9	0	0	9	9	2	0	9
	Patagonian Toothfish	*Dissostichus eleginoides*	TOP	1	0	0	1	1	1	1	1
	Pearleyes	*Benthalbella elongata*	BEE	12	0	0	12	12	6	0	12
	Rat tails, Grenadiers	*Macrourus spp*	GRV	22	22	0	22	22	11	1	22
	Rattail	*Macrourus carinatus*	MCC	16	15	0	16	16	3	0	16
	Rattail	*Macrourus whitsoni*	WGR	20	20	0	20	20	19	0	20
	Sharks, skates and rays	*Elasmobranchii*	SKX	2	0	0	2	2	0	0	2
2023	Antarctic Toothfish	*Dissostichus mawsoni*	TOA	154	0	0	154	154	154	69	154
	Bigeye grenadier	*Macrourus holotrachys*	MCH	3	0	0	3	0	0	0	0
	Blue Antimora	*Antomora rostrata*	ANT	5	0	0	5	2	2	2	2

2024	Antarctic Toothfish	*Dissostichus mawsoni*	TOA	180	0	180	180	180	180	180	181
	Bigeye grenadier	*Macrourus holotrachys*	MCH	40	40	0	40	40	19	40	40
	Rattail	*Macrourus whitsoni*	WGR	16	16	0	16	16	11	16	16

Figure 4 shows the relationship between the average depth of fishing (equivalent to bottom depth) and catch for the 2022 to 2024 research. The number of zero values in the bottom plot in the figure highlights a relatively high proportion of lines with no toothfish caught.

As the total catch of Antarctic toothfish by set significantly varied (20 to 19,462 kg), the upper plot showing the observed catch weight by mean depth is plotted on a logarithmic scale for precision (with zero values ignored). The lower plot by the number of toothfish shows the zero values for all lines and thus indicates the range of depths sampled during the years 2022 to 2024.

This research fishing was intentionally designed to spread effort widely through the research area, fishing in a range of depths (as deep as 2190 m. in 2022). The highly variable catch rates of toothfish reflect the exploratory nature of this project, as the region is almost unexplored. There is no previous fishing information or accurate bathymetry available other than explorations during the 2019-2021portion of the overall project. This effect is also reflected in the generally higher bycatch levels seen in Table 2 when compared with the CCAMLR target fishery immediately south, in which bycatch is typically about 5% of the overall catch.

Figure 3. Some examples of the many samples taken during the most recent trip in 2024. Pending further identification, Clockwise from top left Psychrolutes spp., *Alepocephalus* spp., *Neolithodes* spp., and <u>*Apristurus*</u> spp.

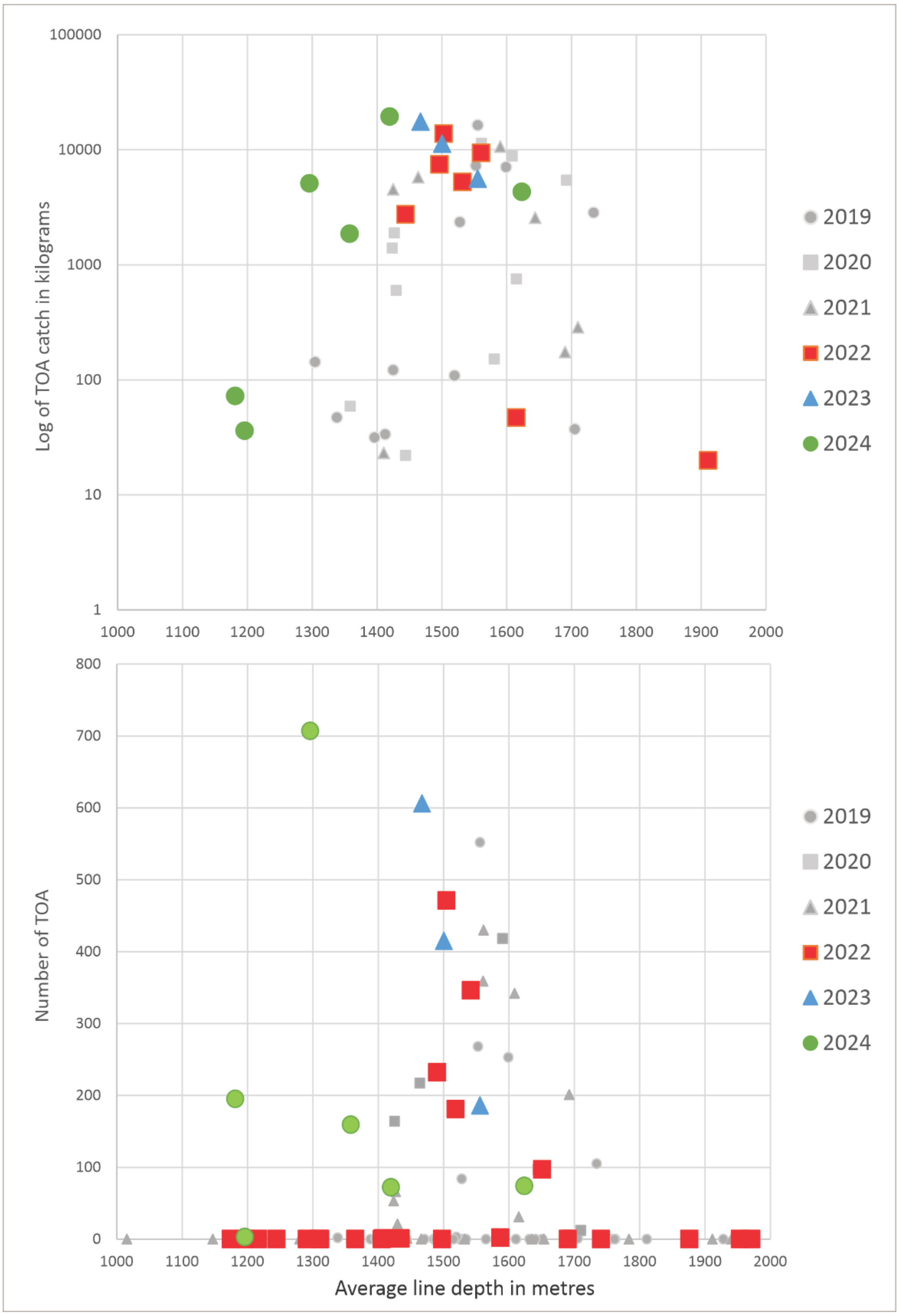

Figure 4. Retained catch (kg) per set of Antarctic toothfish (top) and numbers of Antarctic toothfish (TOA) caught, including tagged and released fish (bottom), with the average recorded fishing depth for each observation during New Zealand's exploratory fishing in the SPRFMO Area in 2022 to 2024. Note that the y-axis on the top plot is logarithmic, and zero values are excluded. For additional context, the previous 2019-202 1results are included in grey.

Toothfish biology

Length frequency

Antarctic toothfish total lengths ranged from 99 to 193 cm over the three years of the research (Figure 6). . The sex ratio was generally skewed to males at 60.2% of the catch-weighted sample in 2022 and 73% in 2024, but only 49% in 2023. This reflects the typical results from previous records from this area, observations from the northern hills area of CCAMLR Subarea 88.1, and CCAMLR winter survey results.

Approximately 3.5% of the catch-weighted samples (and 2.7% of raw measurements) for the 2022-2024 years were fish shorter than 120 cm total length, indicating a population of almost entirely reproductively mature adult toothfish. Reinforcing all previous results, the length distribution of males during 2019 to 2021 was slightly smaller than that of females, which is also consistent with records from the northern areas of Area 88 to the south-west and south

Figure 6 shows the scaled length distribution (numbers weighted by the overall number of fish caught for each line) information collected from the *San Aspiring* research within SPRFMO during 2022 to 2024. While the number of length observations collected is relatively low (a function of the highly variable catch rates resulting from the exploratory nature of the research), the length distribution between the three seasons is very similar. For ease of comparison between fishing years, we have grouped the data by 5 cm length bins, and these are plotted in Figure 8.

The 2022 and 2023 samples were collected in the late austral summer (March) and likely reflect a pre-spawning population compared with the 2024 sample taken from late spring (October), a post-spawning population. Despite the differences in timing, the relative size range and general length distributions are very similar (Figure 7) over all three years. However, the nearly even sex ratio from 2023 was anomalous and possibly reflects the fact that those samples were taken closest in time to the hypothesised winter spawning period.

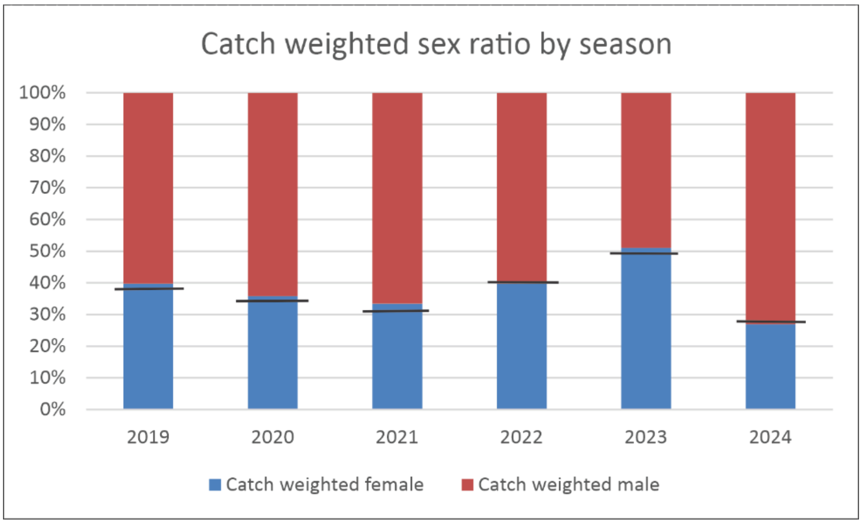

Figure 5. Sex ratio of Antarctic toothfish from the catch-weighted data for 2019 to 2024. The black bar represents the ratio of the unadjusted raw length measurements.

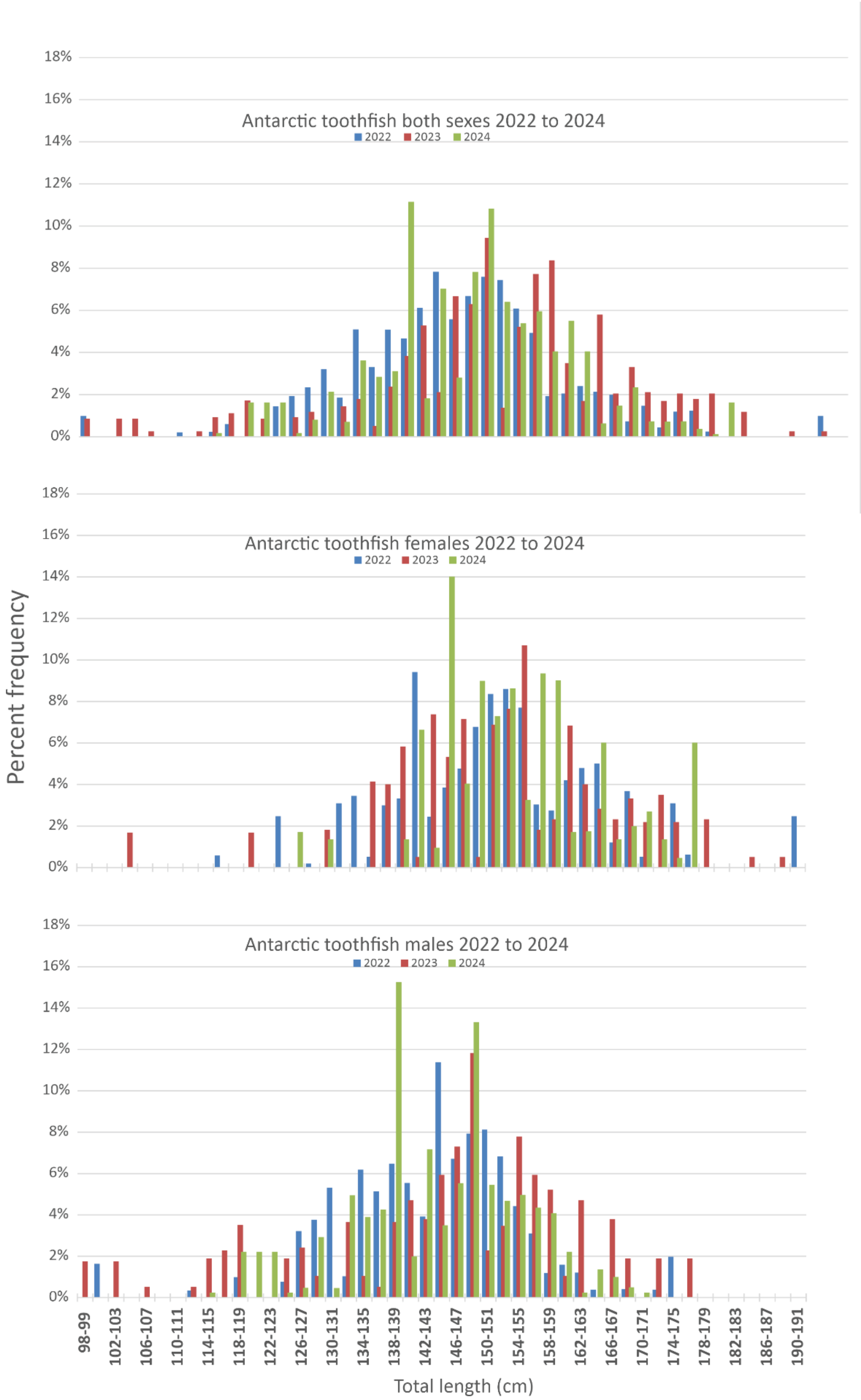

Figure 6. Antarctic toothfish (Dissostichus mawsoni) length frequency by sex and sexes combined for 2022 to 2024 research. Scaled to total catch numbers. The total scaled sample is 1330 fish for 2022, 1207 fish in 2023 and 1211 fish in 2024.

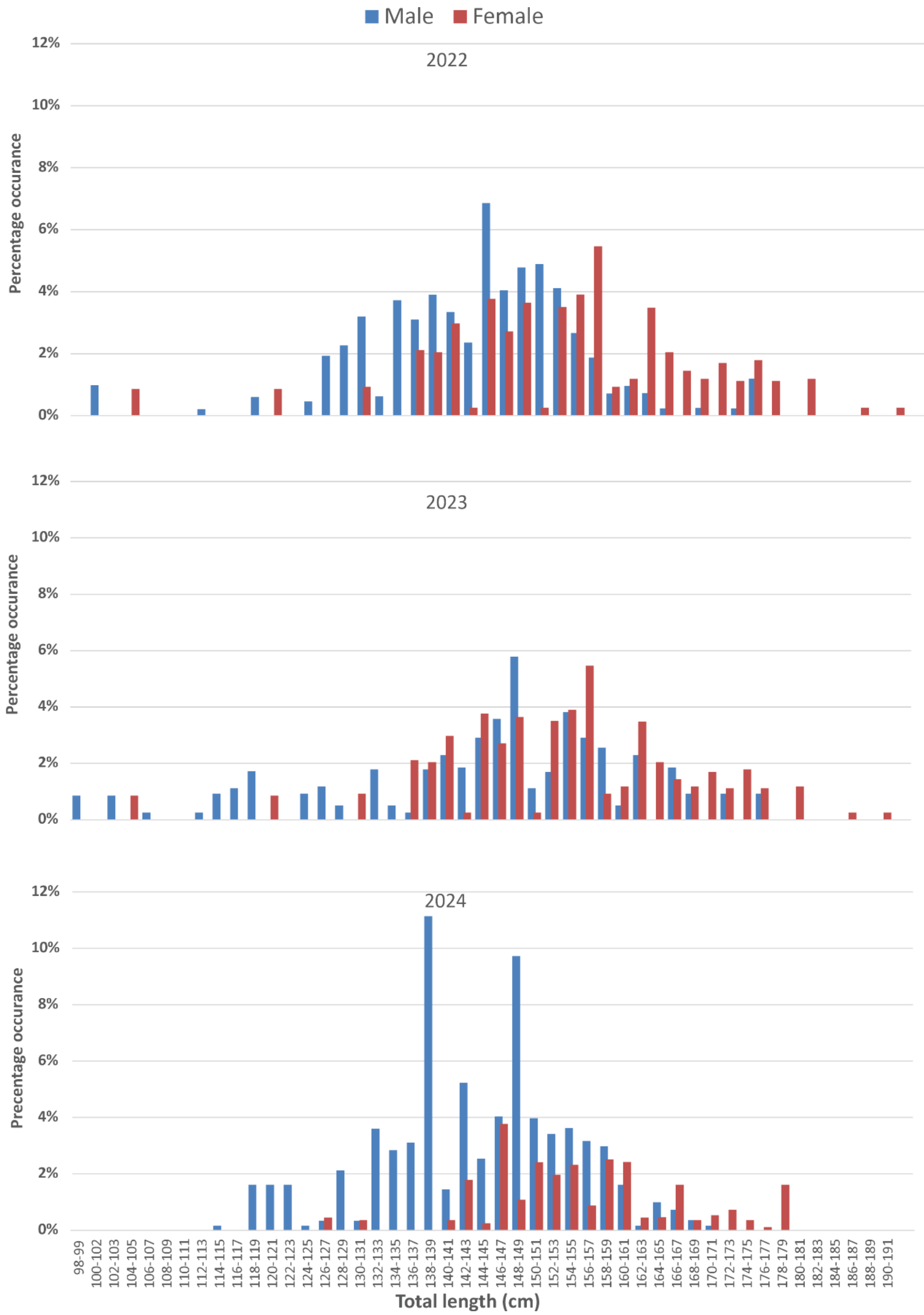

Figure 7. Antarctic toothfish Dissostichus mawsoni scaled length frequency by sex for 2022 to 2024 research. Proportions are of the total sample of both sexes. The total scaled sample is 1330 fish for 2022, 1207 fish in 2023 and 1211 fish in 2024.

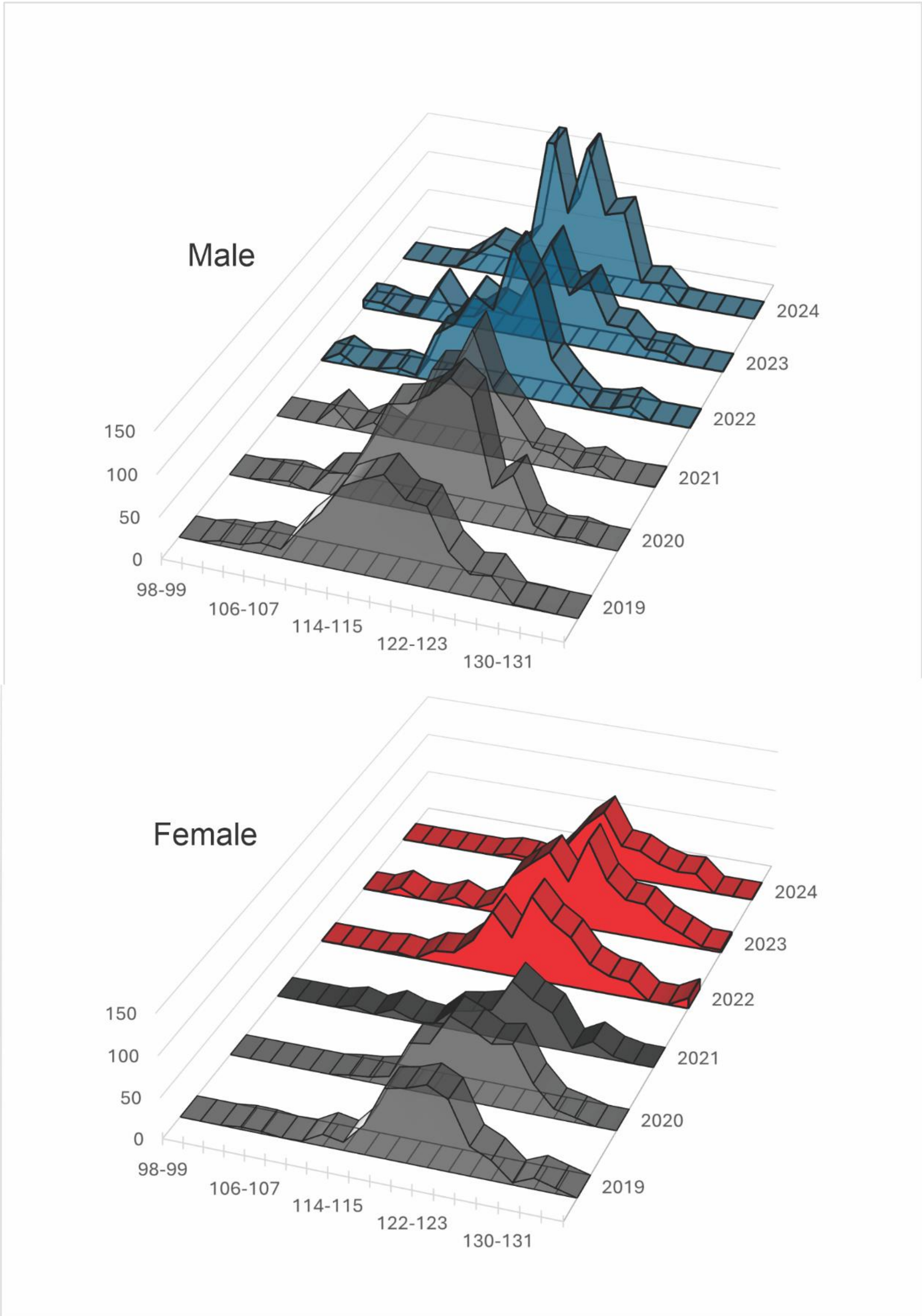

Figure 8. Catch weighted length frequency by sex and season. For simplicity and ease of comparison, the data are grouped by 5 cm length bins. The previous 3 years are included in grey for additional context.

Antarctic toothfish Reproduction

Reproduction and Gonad developmental stage (GMI) records for Antarctic toothfish are routinely collected by observers as part of the sampling protocol. Staging criteria and numbers by year are shown in detail in Appendix 1.

In 2022, these GMI records indicate a central peak at stage III, reflecting developing ovaries (98% of female fish sampled) with a single fish recorded as developing and a second with a gravid ovary. During the season, observer staging indicates a predominant number of developing males (99%) with one fish recorded as gravid.

In 2023, a broader range of female GMI was recorded, but still essentially concentrated on stage III (68%), with a higher number of maturing (21%) and gravid females (9%). Likewise, for males, 18% of the male sample was recorded as developing, 51% with ripening gonads, 27% recorded as developed, and 4% recorded as spent.

In 2024, when the sampling took place in the likely post-spawning period, the majority of female toothfish were recorded as developing (51%) or maturing (46%) and mature (2%). Most males were recorded as stage 2 or developing (83%), with 17% developed. Note the more extreme sex imbalance for this year (Figure 5).

Fish gonads generally increase in weight up to the spawning period and then decrease afterwards. This weight increase is primarily due to the development and maturation of eggs (in females) or sperm (in males). After spawning, the gonads reduce in size as the mature gametes are released. GMI is regarded as a less precise measure of reproductive maturity as the measure is subjective and prone to variation in individual interpretations (Williams, 2007). In addition, some reproductive stages cannot be reliably identified by macroscopic methods (Hunter and Macewicz, 2001). It is difficult to macroscopically distinguish between stage 5 (spent) and stage 2 (recovering/resting) except immediately before and after the peak spawning.

For this reason, we believe that a better way of tracking a potential spawning event is by using the Gonadosomatic Index (GSI). This is an easy and objective way to track this process, as GSI measures the ratio of gonad weight to body weight, providing a more robust indicator of the progression of gonad development rather than the use of a visually based and subjective multiclass classification. In simple terms:

- **Maturation (should equate to stages 2-3):**

During the maturation phase, the GSI typically increases as the gonads accumulate more gametes.

- **Spawning (should reflect Stage 4 and 5)**

As spawning occurs, the mature eggs or sperm are released, and the GSI decreases.

- **Spent or recovering (stage 5- back to 2):**

Thus, in toothfish, as in most species, gonad development and spawning are seasonal events, with cyclical increases and decreases in gonad weight corresponding to the reproductive cycle.

However, when the subjective observer recorded GMI is plotted by GSI, it becomes evident that the perceived SMI stages are not consistent with this biological process (Figure 9 and Figure 10)

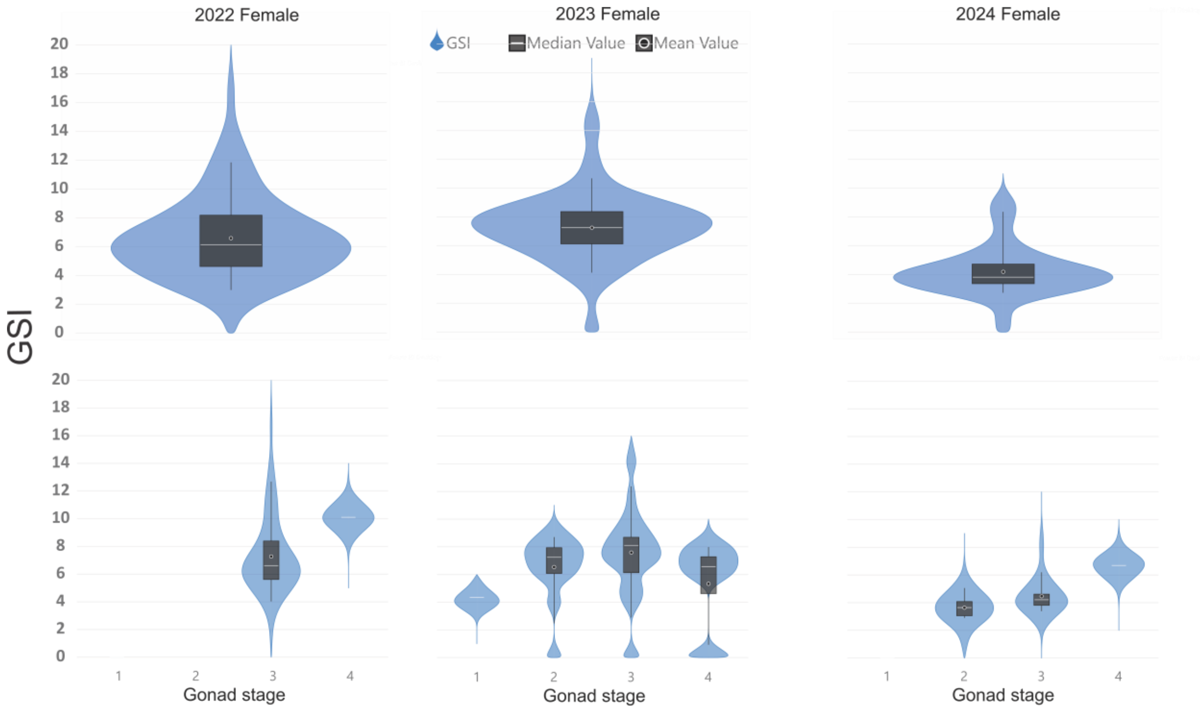

Figure 9. Female Antarctic toothfish Gonadosomatic indices (GSI) plotted by sex and fishing year for the 2022-24 exploratory fishing. The centre box in each plot shows the median and mean values, the box itself shows the range between the first and third quartiles, the whisker shows the 5% and 95% confidence ranges, and the violin plot maps variations in the GSI. The lower section splits the annual data based on the observer-recorded gonad maturity index. See Appendix 1 for gonad staging details.

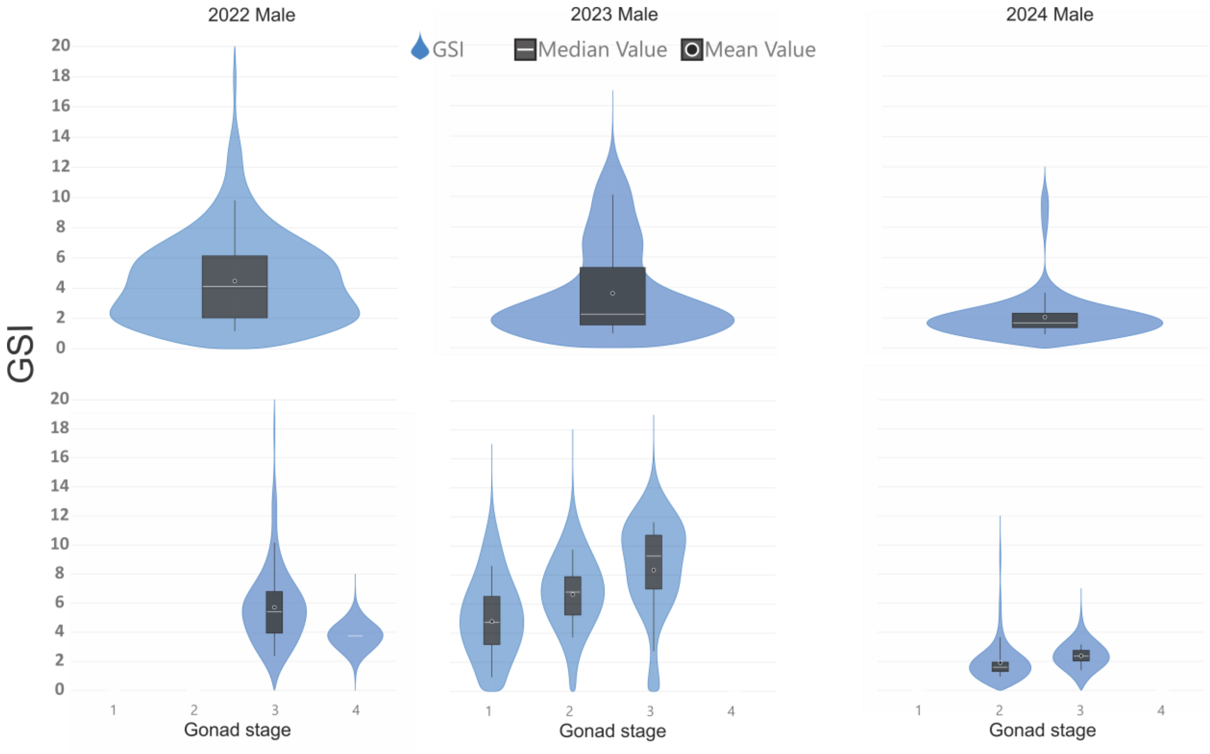

Figure 10. Male Antarctic toothfish Gonadosomatic indices (GSI) plotted by sex and fishing year for the 2022-24 exploratory fishing. The centre box in each plot shows the median and mean values, the box itself shows the range between the first and third quartiles, the whisker shows the 5% and 95% confidence ranges, and the violin plot maps variations in the GSI. The lower section splits the annual data based on the observer-recorded gonad maturity index. See Appendix 1 for gonad staging detail.

The blue violin plots provided show the 'shape' of the data using a Probability Density Function (PDF), or a density plot. The width of the PDF describes how frequently that value occurs in the data set. The wider regions of the density plot indicate values that appear more frequently.

When the data is plotted in this way, it is more evident that the 2022 and 2023 data, which were pre-spawn (Figure 11) are generally larger, and the 2024 values, which were the latest samples post-spawn, are much lower. However, while the observer-derived GMI values still indicate developing and developed gonads in 2024, the GSI values are not consistent with these records.

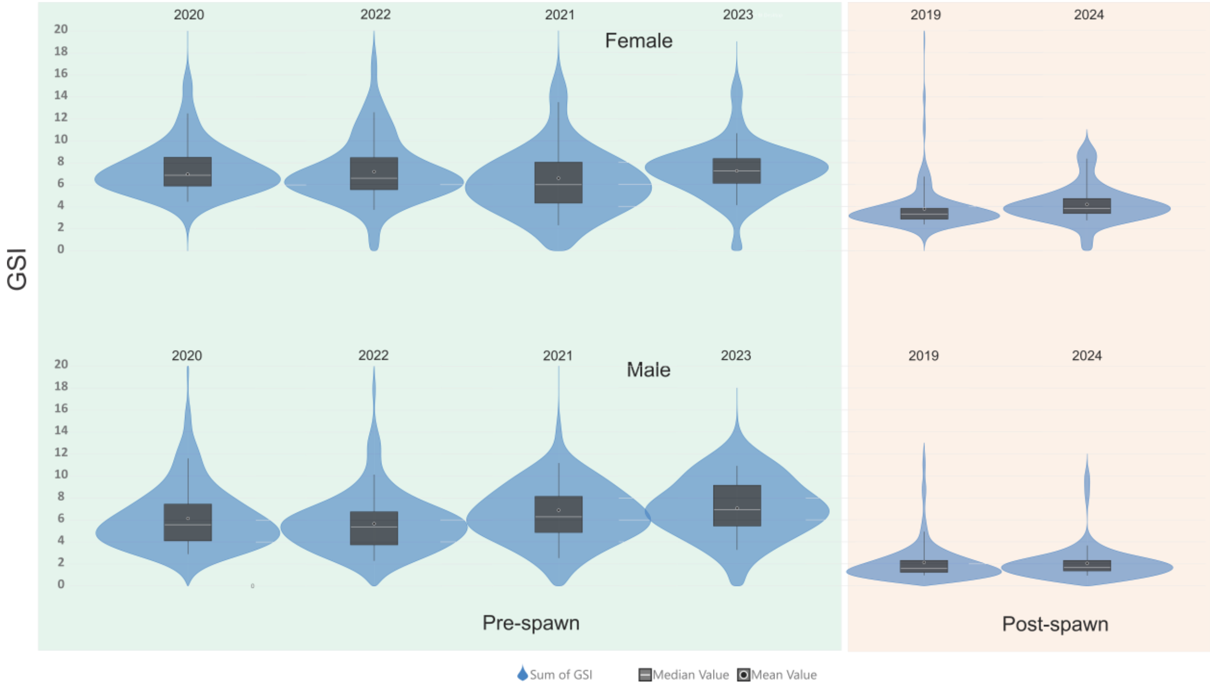

Figure 11. GSI by year for the period 2019 to 2024, showing pre- and post-spawning values. The years are ordered roughly by sampling date. See Figure 10 for an explanation of the plots.

The relative body condition ('fatness') of a toothfish also appears to be correlated with spawning and reproduction and is an additional indicator available for analysis. Fulton's condition factor or Condition Index (CI or K) is often used to define general fish body condition. This is traditionally based on the relationship between the fish length and body weight for fish species that grow isometrically, of which the toothfish species are a good example. Higher (K) values generally indicate a fish with more fat reserves and a more "full-bodied" appearance for its length, while lower values suggest a leaner or more slender fish. There is good information to indicate that body condition may be a trigger for the start of the spawning process and that this decreases as spawning takes place due to the 'burning' of reserve lipid fat, reduced availability of food on the spawning hills and the compression of the gut by gonad mass. Higher K values generally indicate a fish with more fat reserves and a more "full-bodied" appearance for its length. In comparison, lower values suggest a leaner or more slender fish, often referred to in the fishery as 'axe handles'. As toothfish species have both a large egg size and a massive gonad mass, fish condition can be biased by including the gonads in the calculation. For this reason, a modified somatic condition factor (SCF) was also calculated by subtracting the recorded gonad weight from each fish to better approximate the somatic weight[3]. This is premised on the recorded data from the Antarctic toothfish biological record within SPRFMO, showing very few sampled fish with any stomach contents that could further bias the analysis, and assumes that liver mass remains relatively constant and is a minor contributor to overall body mass.

The Fulton's condition factor for Antarctic toothfish has been calculated and is summarised in Figure 12 for female Antarctic toothfish and Figure 13 for males. The figures generally show this trend of

[3] SCF Somatic body mass here is calculated as the recorded fish weight less the weight of the gonads. Toothfish in general have large gonads at spawning – in females this can be up to 25% of body mass. For this reason, to remove any bias caused by gonad development over a season in this calculation, a separate analysis based on the somatic body weight (i.e. the body weight less weight of reproductive tissue) is used.

decreasing body condition after the (hypothesised) winter spawning, although showing seasonal variation in fish condition.

In general, however, Antarctic toothfish seen in the SPRFMO area over all seasons fished, generally show a lower body condition, which is typical of other recognised spawning grounds such as the northern Ross Sea 'hills' and the South Sandwich Islands (CCAMLR Subarea 48.4). In the Ross Sea, this is postulated to be an effect caused by a migration of well-conditioned mature fish that had been feeding in the southern slope area moving northward into an area of low food abundance for spawning (Fenaughty 2006 and Fenaughty et al 2008).

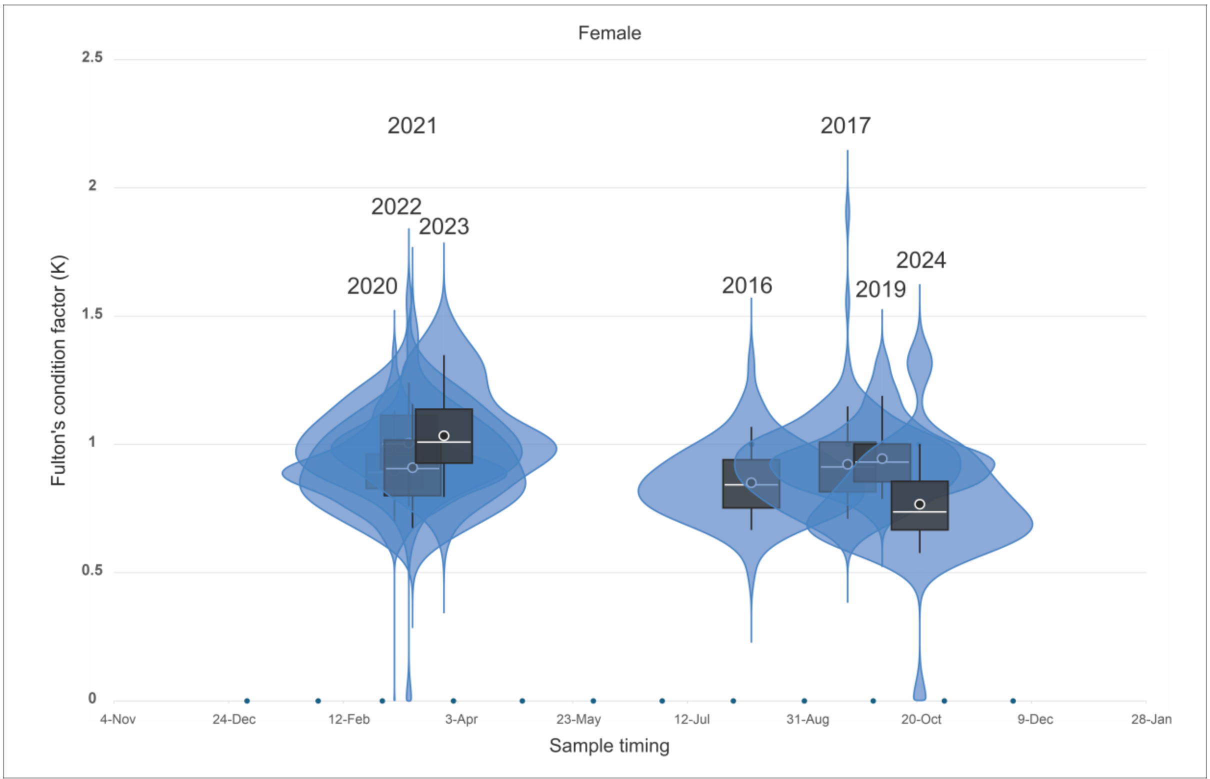

Figure 12. Fulton's condition factor plotted by sampling year for the whole sampling series (2016-17 and 2019-2024) for female Antarctic toothfish. The data are ordered by final sampling date for each season.

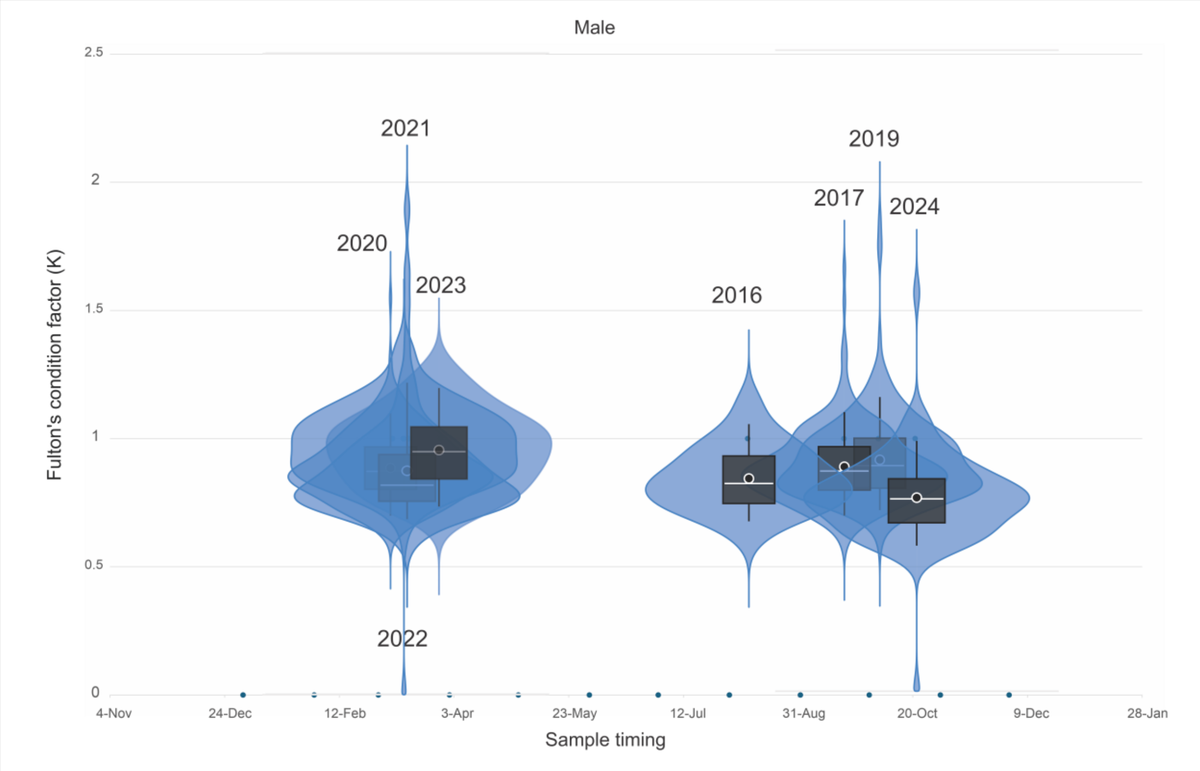

Figure 13. Fulton's condition factor plotted by sampling year for the full sampling series (2016-17 and 2019-2024) for male Antarctic toothfish. The data are ordered by final sampling date for each season.

Figure 14 shows these two relationships as mean values plotted together by approximate sampling date for each sex. Figure 1 showing the likely spawning time is included for ease of reference. While there are apparent differences between years, there are still clear trends pre- and post-spawning, demonstrating both the decrease in gonad mass and body condition between the pre- and post-spawning toothfish examined.

This is consistent with results from the 2016 and 2019 CCAMLR winter survey conducted further south of the SPRFMO research area in the CCAMLR convention area. From the 2016 winter survey, the sex-specific fish condition factor for males was 5% lower than that observed in the summer fishery in SSRUs 881B–C. However, females showed the same median value as in the summer fishery (Stevens et al 2016). Parker et al (2020) reported that sex-specific condition factors from the 2019 survey were lower than those observed in the summer or pre-spawning winter periods, and much lower than those observed on the Ross Sea slope during the summer fishery.

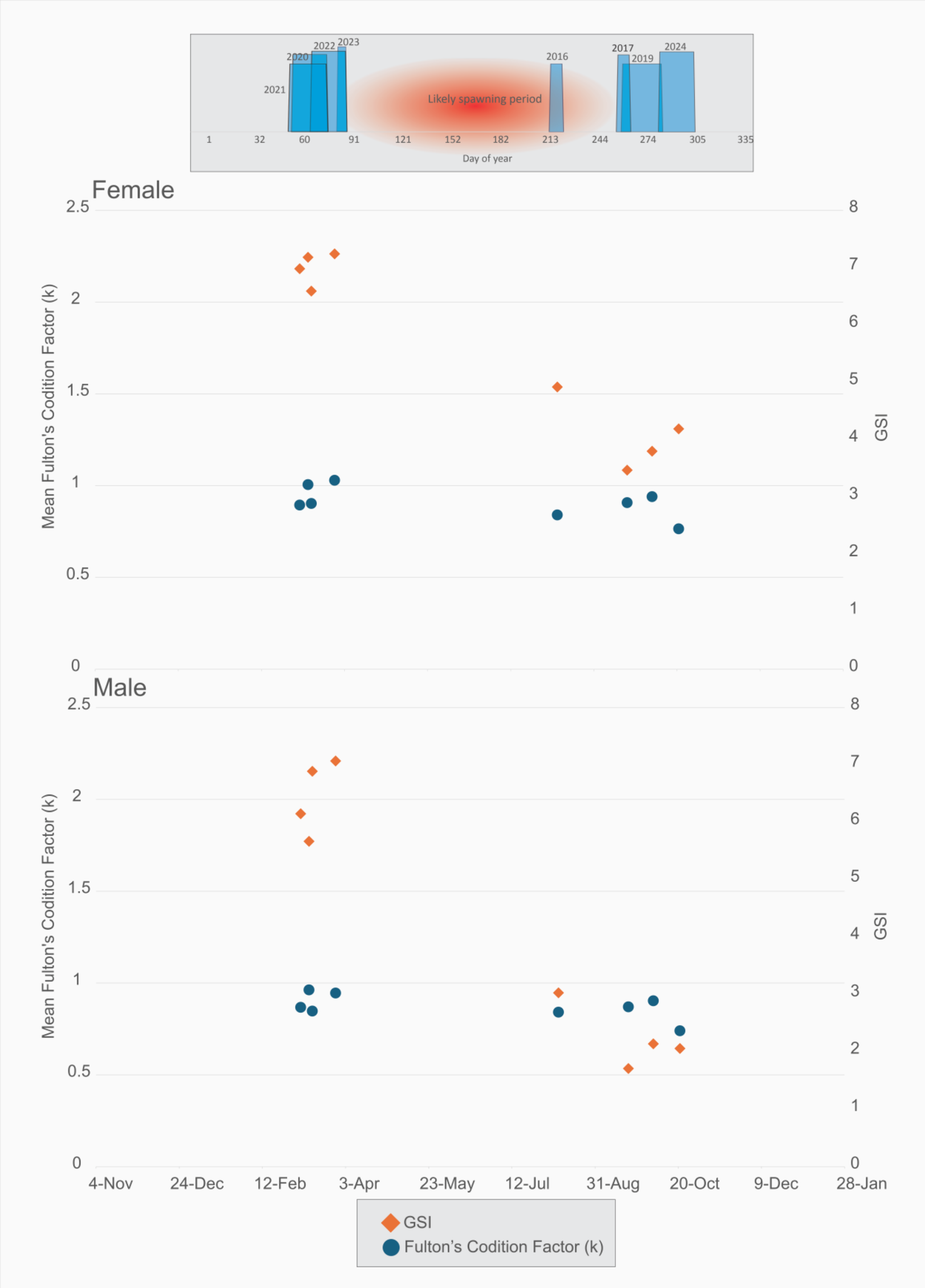

Figure 14. Mean values of Fulton's condition factor and GSI for the New Zealand exploratory fishing series 2016-2024 plotted by approximate time of sampling for male and female Antarctic toothfish. For ease of reference Figure 1 is reproduced here to show our suggested spawning period.

Length-weight relationships by sex can also be used to show relative body condition for each sex (Figure 15).

The trendlines from this figure are subsequently incorporated into Figure 16 which additionally provides a comparison of length-weight regression trendlines from other research sampling by Sanford vessels from CCAMLR subarea 88.1[4], where much of the previous research on spawning fish has been carried out. While not shown here, Fenaughty et al. (2018, Figure 7) also showed that pre-spawning Antarctic toothfish sampled from the South Sandwich Islands show a similar (and consistent) trend over time to that seen in the northern area of Subarea 88.1. The 2016-17 records from SPRFMO research had first indicated that Antarctic toothfish sampled during the post-spawning period were in poorer condition than seen in either 88.1 north or in the South Sandwich Islands pre-spawning sample and are generally a close match with the 2019-2024[5] results. Interestingly, the 2022 result from early March is the closest match with that recorded from the larger 88.1 hills sample. The length-weight regression coefficients used to produce these plots are summarised in Table 4.

In particular, the trendline from the southern area of 88.1 (labelled 88.1 south in Figure 15) provides a reasonable basis to compare a ‘spawning’ ground with a ‘feeding’ ground. 88.1 south is a slope area supporting a large population of mostly mature Antarctic toothfish, feeding in an area of relatively high productivity/prey density. This population is thought to be feeding and enhancing body condition in preparation for spawning. The better fish condition of these fish is clear; a fish of a given length in the south of 88.1 is proportionally heavier than one of the same length in the spawning areas. Clearly, fish sampled from this SPRFMO area (both pre-spawning and post-spawning) are in an even poorer condition than those seen in other spawning fisheries, such as the north of 88.1 (and although not shown here, from the South Sandwich Islands fishery in CCAMLR Subarea 48.4). A similar very low condition factor was also observed by Parker et al. (2020) during the 2019 winter survey in CCAMLR to the south.

[4] CCAMLR subarea 88.1, data as used by Fenaughty et al. 2008.
[5] See Fenaughty 2021 – SC9-DW04

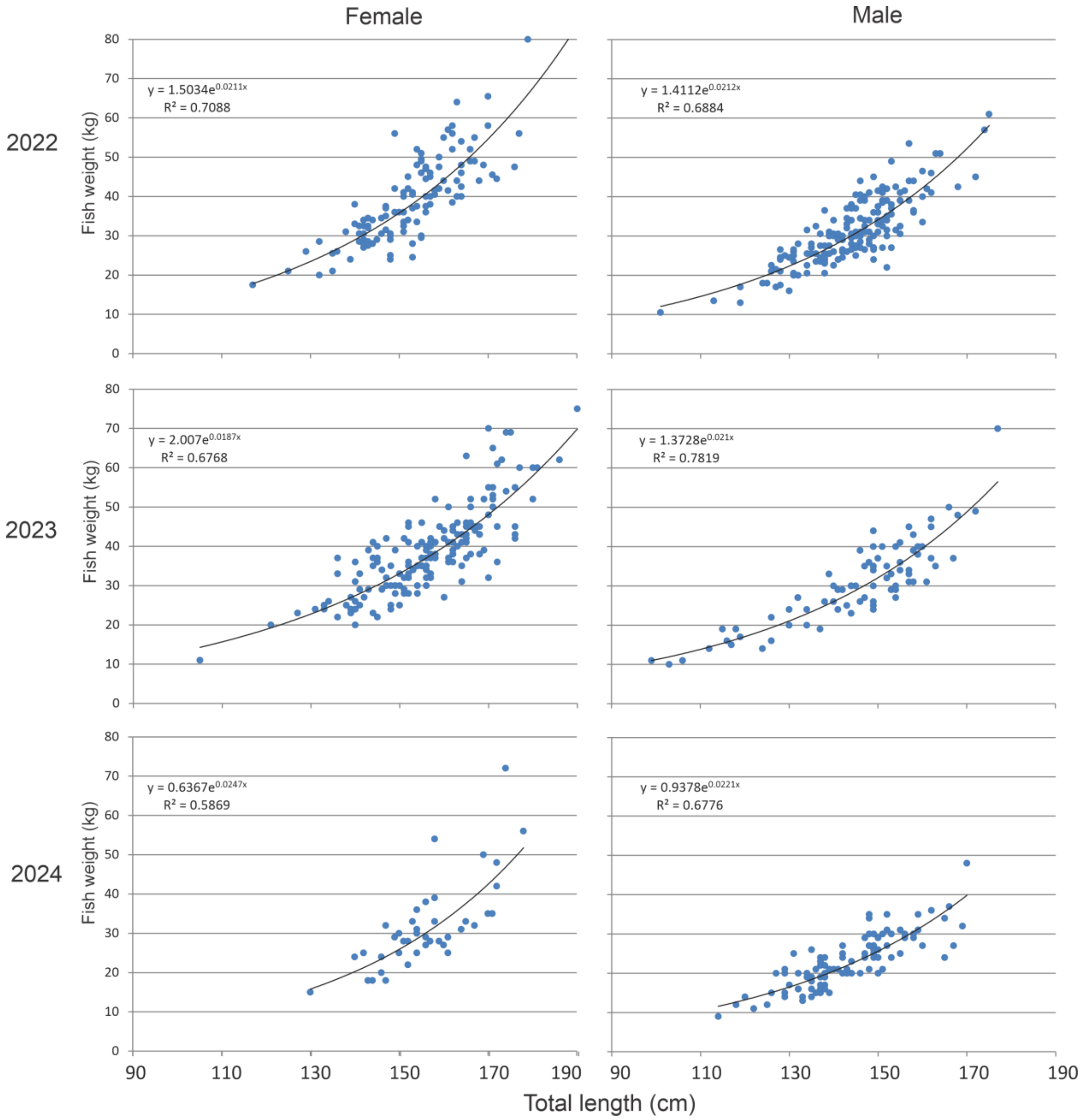

Figure 15. Length-weight relationship of male and female Antarctic toothfish sampled during the SPRFMO exploratory toothfish fishery in 2022 to 2024.

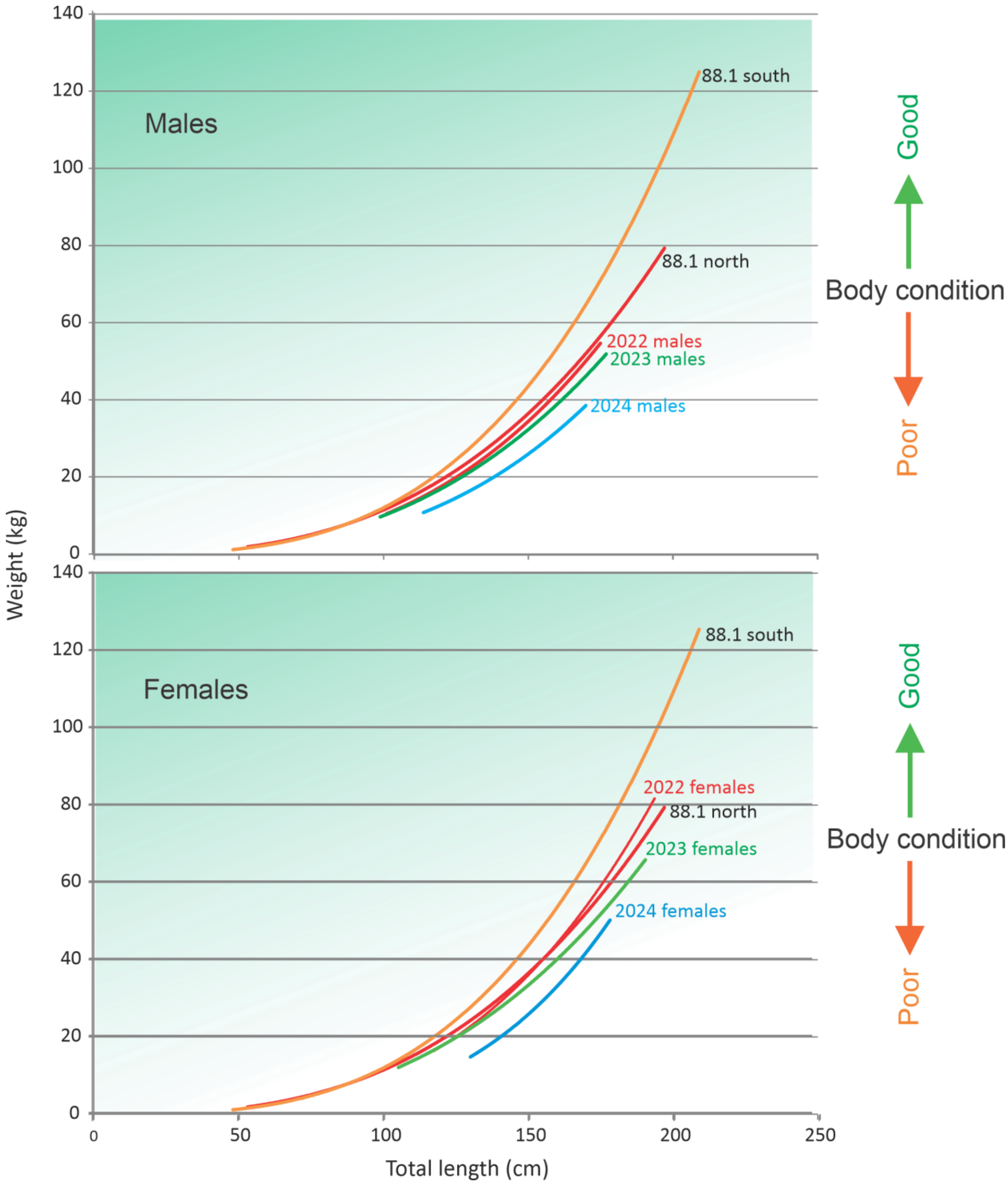

Figure 16. Length-weight regression trendlines (power) from CCAMLR 88.1 data 2001 to 2006 (data from Fenaughty et al, 2008) with the 2022 to 2024 SPRFMO data plotted for comparison. The colour of the trendline is match by the year label. The data used to produce these plots are summarised in Table 4.

*Table 4. Length-weight regression coefficients calculated from records taken from Sanford research sets in Subarea 88.1 (Ross Sea) north and south of 70 degrees south between 2001 and 2006 and from SPRMO Research for 2016 and 2017 combined, and SPRFMO research from 2019 to 2024. The weight is in grams and total length in centimetres. The standard equation is W=aL^b^*

Sex	Area	Season	*a*	*b*	N	R^2
All	88.1 North	2001-2006	0.0176	2.9045	13 073	0.78
	88.1 South	2001-2006	0.0046	3.2068	40 657	0.96
	SPRFMO	2016-17	0.0180	2.8540	565	0.77
	SPRFMO	2019	0.0147	2.9079	473	0.78
	SPRFMO	2020	0.0075	3.0405	509	0.75
	SPRFMO	2021	0.0441	2.6828	158	0.71
	SPRFMO	2022	0.0041	3.1886	289	0.75
	SPRFMO	2023	0.0051	3.1207	154	0.80
	SPRFMO	2024	0.0012	3.3677	142	0.74
Male	88.1 North	2001-2006	0.0326	2.7708	6 547	0.73
	88.1 South	2001-2006	0.0048	3.1979	16 247	0.96
	SPRFMO	2016-17	0.0357	2.7123	365	0.76
	SPRFMO	2019	0.0346	2.7315	293	0.75
	SPRFMO	2020	0.0099	3.0297	282	0.75
	SPRFMO	2021	0.0897	2.5357	109	0.70
	SPRFMO	2022	0.0099	3.0054	173	0.72
	SPRFMO	2023	0.0198	2.8557	78	0.83
	SPRFMO	2024	0.0033	3.1673	101	0.71
Female	88.1 North	2001-2006	0.0188	2.8474	6 496	0.80
	88.1 South	2001-2006	0.0043	3.2178	24 092	0.97
	SPRFMO	2016-17	0.0177	2.8637	200	0.73
	SPRFMO	2019	0.0208	2.8611	179	0.75
	SPRFMO	2020	0.0295	2.7768	173	0.63
	SPRFMO	2021	0.1027	2.5261	48	0.64
	SPRFMO	2022	0.0037	3.2010	115	0.71
	SPRFMO	2023	0.0221	2.8397	174	0.70
	SPRFMO	2024	0.0001	3.8345	40	0.63

Otoliths

During the 2022 to 2024 survey period, 253 otolith pairs were collected for ageing. Once these have been read, this age information will be available to be incorporated in the overall New Zealand research assessment on Antarctic toothfish, which covers both the SPRFMO and CCAMLR areas.

Interactions with seabirds, marine mammals, turtles, or other species of concern

Seabirds

All line setting was carried out after nautical dusk with no deck lighting and with a tori line deployed. The vessel uses an integrated weighted main line (50 grams per metre). A bird exclusion device (Brickle curtain) is permanently deployed to protect the immediate area of water near the hauling position. Offal, used bait, and bycatch is minced and then discharged on the opposite side to the haul room only when no setting or hauling is taking place. Sump grates are used to prevent the accidental discharge of offal from the factory floor.

The governing CMM 14a-2022 for the period mandated the use of electronic monitoring systems to ensure compliance and facilitate data collection. Vessels undertaking fishing activities under this measure were required to be equipped with a video monitoring and recording system positioned over the hauling area to observe or record all hauled lines and hooks. The recorded footage has been submitted to the New Zealand Ministry for Primary Industries at the conclusion of each voyage. Additionally, the system recorded both the setting and hauling operations, specifically to monitor any interactions with marine mammals, seabirds, turtles, and other species of concern.

These systems are designed to record fishing operations throughout the entirety of the voyage, serving as a supplementary tool to observer coverage, aligning with SPRFMO's data collection and reporting standards, ensuring robust monitoring and compliance with regulatory requirements.

CMM 14a-2022 also required specific actions for seabird observations during fishing activities. Observers undertook standardised seabird abundance counts during the setting and hauling of each line. Opportunistic observations, including photography and identification of seabirds, were conducted in collaboration with the crew. Observers aimed to monitor at least 10% of hooks hauled for seabird captures. Additionally, all live birds released and any birds colliding with the vessel that could be recovered were photographed, while all dead birds were retained for formal identification and necropsy.

Observations were generally ad hoc, and the number of birds seen varied depending on location and time spent in an area. Most birds were observed circling the vessel or sitting on the water astern of the vessel. The most common bird species observed were Wandering albatross or non-specified great albatross, Cape and Antarctic petrels, black browed albatross, grey petrel, and blue petrel. Also present in the three years of observations were giant petrel, light-mantled sooty albatross, sooty shearwaters, and Antarctic fulmar. Less commonly recorded were white chinned petrels, Salvin’s albatross, Westland petrel, Buller’s albatross, and grey-headed albatross.

In 2024, one blue petrel was found dead on the vessel deck. It was disposed of overboard following the High Pathogenicity Avian Influenza (HPAI) bird flu protocols, under the supervision of an MPI observer and following MPI instructions. During the same year, a prion was found alive and released following the same HPAI protocols. No seabird interactions were recorded during fishing operations within the SPRFMO area 2022-2024.

Table 5. Seabird observation summary 2022-2024.

Here is the updated seabird observation table, including 2024 data and a column for geographical locations:

Year	Seabird Species Observed	Taxonomic Name	Behaviour	Fatalities	Mitigation Measures	Geographical Location	Additional Notes
2022	Wandering Albatross, Royal Albatross	*Diomedea exulans*,	Flying laps around the vessel,	None	Tori line, Brickle curtain, integrated	Not specified	Very low numbers observed

		Diomedea epomophora	rarely sitting on water		weighted line, offal discharge opposite to haul room		during hauling
	Giant Petrels, Grey Petrels	*Macronectes spp.*, *Procellaria cinerea*	Flying laps around the vessel, rarely sitting on water	1 (Mottled Petrel, deck strike during transit)	Same as above	Not specified	Very low numbers observed during hauling
	Antarctic Fulmars	*Fulmarus glacialoides*	Flying laps around the vessel, rarely sitting on water	None	Same as above	Not specified	Very low numbers observed during hauling
	Light-Mantled Sooty Albatross	*Phoebetria palpebrata*	Flying laps around the vessel, rarely sitting on water	None	Same as above	Not specified	Very low numbers observed during hauling
2023	Great Albatross (Wandering/Royal)	*Diomedea exulans*, *Diomedea epomophora*	Flying laps around the vessel, not sitting near hauler	None	Same as 2022	Not specified	Juvenile Emperor Penguins observed milling around vessel
	Antarctic Prions	*Pachyptila spp.*	Flying laps around the vessel, not sitting near hauler	None	Same as 2022	Not specified	Juvenile Emperor Penguins observed milling around vessel
	Petrels (possibly Grey Petrels)	*Procellaria cinerea*	Flying laps around the	None	Same as 2022	Not specified	Juvenile Emperor Penguins

			vessel, not sitting near hauler				observed milling around vessel
	Emperor Penguins (juveniles)	*Aptenodytes forsteri*	Milling around vessel	None	Same as 2022	Not specified	Juvenile Emperor Penguins observed milling around vessel
2024	Cape Petrel, Blue Petrel, Prions	*Daption capense*, *Halobaena caerulea*, *Pachyptila spp.*	Circling the vessel, not feeding on fish, offal, or bait	1 (Blue Petrel, deck strike), 1 (Prion, deck strike, released alive)	Same as 2022	59°40’ S, 144°20'W	Strong winds likely contributed to deck strikes; HPAI protocols followed for disposal

Marine mammals, turtles, or other species of concern

Whale sightings during New Zealand’s exploratory fishing trips were systematically recorded to contribute to ecological monitoring and research in the SPRFMO area. Observations were conducted opportunistically during steaming and fishing operations, with species identification based on visual characteristics such as body shape, size, and behaviour, supplemented by field guides where necessary. In 2022, several pods of whales, likely Sei (*Balaenoptera borealis*) or Fin Whales (*Balaenoptera physalus*), were observed while steaming towards the fishing grounds, although distance precluded identification. In 2023, Fin Whales were sighted feeding and spouting in multiple locations across the Southern Ocean, with over 12 individuals recorded. Southern Bottlenose Whales (*Hyperoodon planifrons*) were tentatively identified based on body spots, with 2–5 individuals observed porpoising past the vessel. Additionally, a large pod of approximately 100 Pilot Whales (*Globicephala* spp.) was seen travelling north, and Hourglass Dolphins (*Lagenorhynchus cruciger*) were observed following the vessel in open waters. In 2024, whale observations included Fin Whales feeding and diving near the vessel, as well as Hourglass Dolphins and Southern Bottlenose Whales exhibiting typical behaviours such as spouting and porpoising.

Table 6 summarises whale sightings for the 2022-2024 period. Hourglass Dolphins (*Lagenorhynchus cruciger*) were briefly spotted during steaming to the fishing grounds in 2024, but no other marine mammal sightings were made during this trip.

Table 6. Whale sightings 2022-2024

Year	Whale Species Observed	Taxonomic Name	Number of Individuals	Behaviour	Location	Additional Notes
2022	Likely Sei or Fin Whales	*Balaenoptera borealis* or *Balaenoptera physalus*	Several pods	Observed while steaming towards fishing grounds	Not specified	Distance precluded positive identification
2023	Fin Whale	*Balaenoptera physalus*	1	Approached vessel, veered off within 50-100m, rested at surface 300-400m away, disappeared	59°S, 144°W	Observed during hauling downline (not yet on hooks).
2023	Fin Whale	*Balaenoptera physalus*	1	Presumably feeding (repeated diving) in area around vessel	59°S, 144°W	Observed while vessel was stationary (no gear in water).
2023	Fin Whales	*Balaenoptera physalus*	≥12	Presumably feeding (repeated diving) in area around vessel	59°S, 144°W	Observations over several hours while vessel was stationary (no gear in water).
2023	Southern Bottlenose Whale	*Hyperoodon planifrons*	2-5	Porpoised past vessel within 50m, dolphin-sized, clear spots visible	59°S, 144°W	Tentative identification based on distinctive spots on the body.
2023	Fin Whales	*Balaenoptera physalus*	2	Spouts observed	58°S, 138°W	Observed while vessel was steaming.
2023	Pilot Whales	*Globicephala sp.*	~100	Very large group travelling north	55°S, 128°W	Observed while vessel was steaming.
2024	Hourglass Dolphins	*Lagenorhynchus cruciger*	?	Observed while steaming		Briefly spotted during steaming to

				towards fishing grounds		the fishing grounds.

Tagging

Toothfish are required to be tagged at a rate of 3 fish per tonne of green weight catch retained (approximately 1 in each 10 fish captured). In both seasons, the required rate was met.

CMM-14a-2022 Objective 16 par b) requires that: *A minimum tagging rate of three fish of each Dissostichus species per green weight (live weight) tonne of retained catch shall be implemented. The rules applied by CCAMLR in the immediately adjacent CCAMLR SSRUs ' north region', where tagged fish were released starting in early 2015, shall be applied (CM 41-01 Annex C). These rules require a minimum tagging size overlap statistic (a comparison between the observed length frequency from vessel biological information and the size composition of fish returned alive with tags, see CCAMLR's calculator) of at least 60% once 30 or more Dissostichus of a species have been successfully released with tags.*

Tagging of Antarctic toothfish was a central component of New Zealand's exploratory fishing activities for 2022 - 2024, conducted following CCAMLR protocols to support research into stock structure, movement, and population dynamics. In 2022, a total of 155 toothfish were tagged, achieving a tagging rate of 4 fish per tonne of green weight catch, which exceeded the minimum requirement of 3 fish per tonne. The tagged fish represented a size distribution consistent with the overall catch, ensuring random selection and compliance with scientific standards. One recapture was recorded during the season, involving a fish tagged in 2021 - valuable data on the movement and survival of tagged individuals, contributing to the understanding of stock connectivity and migration patterns.

In 2023, tagging efforts continued with 135 toothfish successfully tagged, achieving a tagging rate of 3.9 fish per tonne, again surpassing the required threshold. The tagged fish ranged in length from 100 to 170 cm, reflecting the fish size of the catch and ensuring robust data collection across different size classes. Two recaptures were documented during the season, one of which occurred within the same fishing season. In-season recaptures offer insights into short-term movement patterns and survivability, while the second recapture added to the growing dataset on longer-term migration and stock structure.

Tagging activities during the 2024 exploratory fishing trip were conducted under challenging weather and operational conditions yet still achieved significant results. A total of 122 Antarctic toothfish (*Dissostichus mawsoni*) were tagged and released, again surpassing the required tagging rate of 3 fish per tonne of green weight catch retained. The tagging overlap statistic reached 86.7%, a strong alignment between the size distribution of tagged fish and the overall catch. The tagging strategy adhered to company protocols, with the first suitable fish caught being tagged and released, followed by every tenth fish. During rough weather, smaller specimens were prioritised for tagging due to their better condition and higher survival chances, while larger fish often suffered injuries during hauling in these conditions. Any imbalance was corrected during calmer conditions. Tagging efforts were concentrated on several fishing lines, particularly at a newly explored ridge line in Strata O. Notable tagging outcomes included 70 tagged fish on one line, which also yielded two recaptures, and 17 tagged fish from another. Recaptures continue to provide valuable data, including one fish tagged and released earlier in the trip.

Tagging data from all years (2016-2024) is integrated into CCAMLR and SPRFMO stock assessment models, which play a critical role in informing sustainable management practices and ensuring the long-term viability of toothfish populations in the region.

Sanford tagging efforts not only meet international scientific requirements but also provide a foundation for understanding the ecological dynamics of Antarctic toothfish. By tracking the movement, growth, and survival of tagged individuals, researchers can better assess the connectivity between fishing areas, the impact of fishing on local populations, and the overall health of the stock - essential for developing effective conservation measures and ensuring that fishing activities remain sustainable in these Southern Ocean fisheries.

In all seasons, the required rate and overlap statistic were met. These are shown for the most recent three seasons in Figure 17. Over the eight years of the exploratory fishery to date, 928 Antarctic toothfish have been tagged and released.

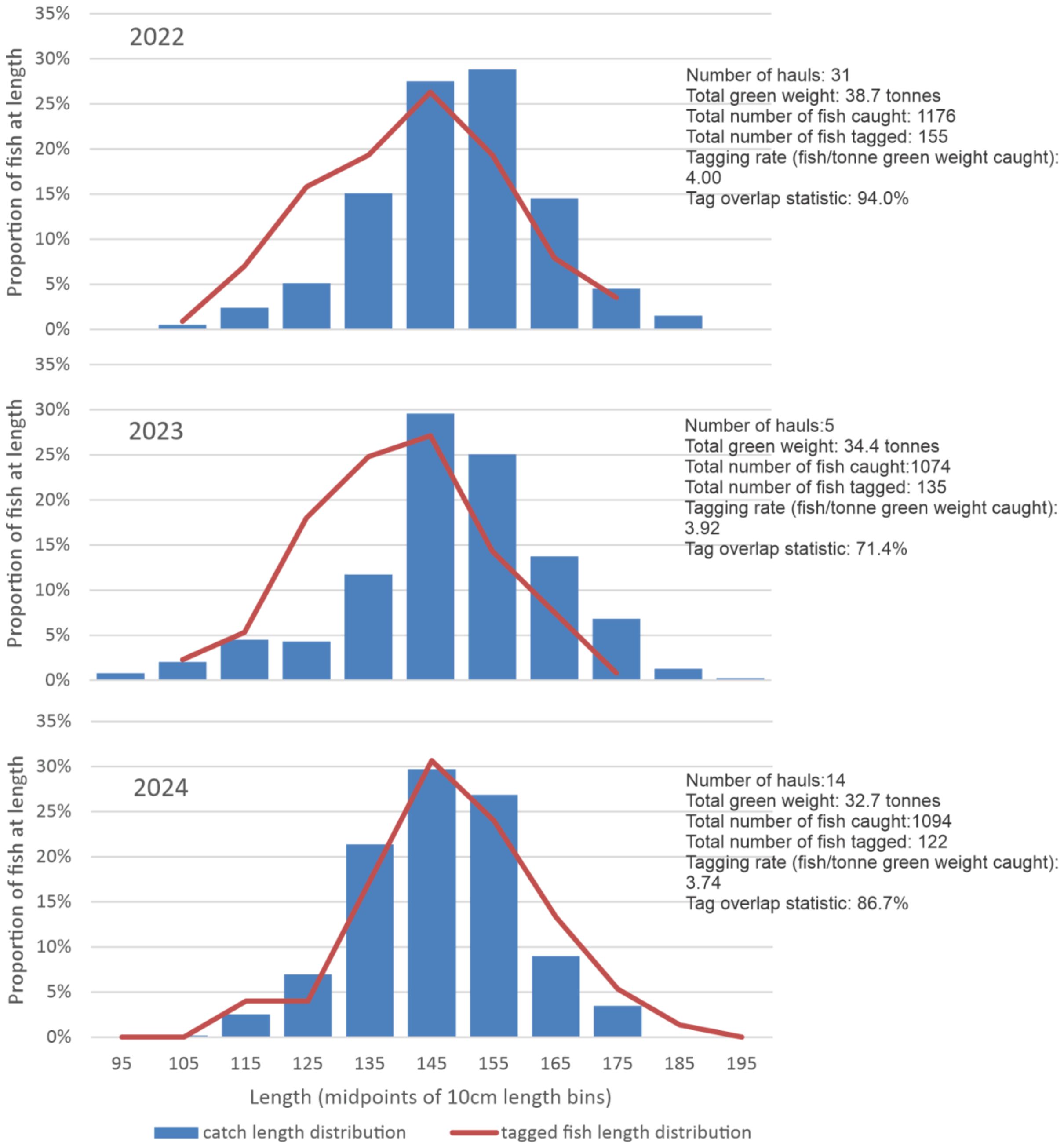

Figure 17. Tagging size overlap statistic for Antarctic toothfish from the SPRFMO exploratory toothfish fishery 2019-2021. Weights are for all toothfish retained.

Tagging was carried out by crew members experienced in retrieving large fish in harsh weather conditions while still preserving them in suitable physical condition for tagging. The scientific observer provides oversight. Fish of this size require more than one person to handle appropriately. To ensure that fish to be tagged were randomly selected by size, the haul room crew were instructed at regular intervals in the hauling process[6] (well before the fish coming on board) to tag the next suitable[7] fish caught. The fish was then carefully removed from the water using a net, placed on a mat on the haul room floor and assessed for condition. If the condition was suitable for tagging and release, the hook was removed, the fish was then measured for total length, and two white CCAMLR

[6] Having regard to the tagging rate and general size of the toothfish in the catch.

[7] Conforming to the suitability requirements specified in the CCAMLR Toothfish and Skate tagging instructions - https://www.ccamlr.org/en/system/files/Toothfish%20and%20Skate%20Tagging%20Instructions.pdf

T-bar tags were inserted (one tag on either side of the anterior part of the second dorsal fin) following the CCAMLR tagging protocol. Once the tag data had been accurately recorded, the fish was released back into the water.

Ongoing tagging and recovery of tagged Antarctic toothfish from SPRFMO research when combined with the use of the CCAMLR tagging protocols enable SPRFMO tagging results to be incorporated in the integrated CCAMLR stock assessment for Antarctic toothfish. This work also increases the geographical area covered by the tagging programmes and consequently enhances our ability to investigate the geographical movements of toothfish.

Benthic interactions and potential interactions with VMEs (2022–2024)

Here we summarise Vulnerable Marine Ecosystem (VME) sampling activities conducted during exploratory fishing trips in the SPRFMO area from 2022 to 2024. The data is derived from observer reports and scientific committee progress reports. All line segments were assessed against the CCAMLR protocol. However, for 2022, it was difficult to isolate individual taxa weights from the total segment weight due to inconsistent recording when multiple items occurred in a given segment.

2022 VME Sampling

In 2022, a total of 28.7 kg of VME indicator taxa was recovered during exploratory fishing. Sampling was conducted across 134 line-segments, with VME taxa observed in 82 segments. Research Area Q contributed nearly 85% of the total weight (24.1 kg), indicating a significant concentration of benthic biodiversity. Gorgonians were the dominant taxa, accounting for 59.4% of the total weight (17.07 kg), followed by hard corals (21.2%, 6.09 kg), zoanthids (9.7%, 2.78 kg), and glass sponges (5.1%, 1.46 kg). Other taxa included sea anemones, soft corals, black corals, basket stars, bryozoans, siliceous sponges, hydroids, and sea pens. Benthic bycatch remained well below CCAMLR and SPRFMO thresholds, ensuring minimal impact on VMEs.

2023 VME Sampling

In 2023, the total weight of VME indicator taxa dropped significantly to 1.35 kg. Sampling was conducted across 21 line-segments, with VME taxa observed in 12 segments. Research Area L contributed 61% of the total weight, while Area N accounted for the remaining 39%. Siliceous sponges dominated the samples, comprising 59.3% of the total weight (0.80 kg), followed by glass sponges (26.7%, 0.36 kg), black corals (8.15%, 0.11 kg), and gorgonians (4.44%, 0.06 kg). Other taxa included hydroids and hard corals. Similar to 2022, benthic bycatch remained below established thresholds, ensuring compliance with environmental regulations.

2024 VME Sampling

In 2024, the total weight of VME indicator taxa was 6.32 kg. Sampling was conducted across 40 line-segments, with VME taxa observed in 30 segments. Key observations in 2024 include the widespread presence of Sea Anemones (*Actiniaria)* and Glass Sponges (*Hexactinellida*), which are recorded in several areas. Additionally, less frequently observed species such as Brachiopods (Brachiopoda) and Hydrozoans (Hydrozoa) were seen.

The recorded weights are generally modest, with Hard Corals (Scleractinia) in area "O" standing out at 5.55 kg.

Table 7. Observer identified and recorded benthic species from required benthic sampling protocols. VME codes are the FAO codes as used by CCAMLR. The CCAMLR VME guide is available on their website.

Season	Area Name	VME Species Code	Common name	Scientific name	Weight (kg)
2022	L	AJZ	Alcyonacea soft corals	*Alcyonacea*	0.02
2022	L	ATX	Sea anemones	*Actiniaria*	0.03
2022	L	BZN	Bryozoans	*Bryozoa*	0.01
2022	L	DMO	Siliceous sponges	*Demospongiae*	0.05
2022	L	GGW	Gorgonians	*Gorgoniidae*	0.67
2022	L	HXY	Glass sponge	*Hexactinellida*	1.27
2022	L	ZOT	Zoanthids	*Zoanthidea*	0.03
2022	N	AJZ	Alcyonacea soft corals	*Alcyonacea*	0.11
2022	N	ATX	Sea anemones	*Actiniaria*	0.66
2022	N	GGW	Gorgonians	*Gorgoniidae*	1.36
2022	N	HXY	Glass sponge	*Hexactinellida*	0.09
2022	Q	AJZ	Alcyonacea soft corals	*Alcyonacea*	0.15
2022	Q	AQZ	Black corals and thorny corals	*Antipatharia*	0.14
2022	Q	ATX	Sea anemones	*Actiniaria*	0.01
2022	Q	AZN	Hydroids, hydromedusae	*Anthoathecatae*	0.01
2022	Q	BZN	Bryozoans	*Bryozoa*	0.04
2022	Q	CSS	Hard corals, stony corals	*Scleractinia*	6.09
2022	Q	GGW	Gorgonians	*Gorgoniidae*	15.04
2022	Q	HXY	Glass sponge	*Hexactinellida*	0.1
2022	Q	NTW	Pennatulacea sea pens	*Pennatulacea*	0.01
2022	Q	OEQ	Basket stars	*Euryalida*	0.08
2022	Q	ZOT	Zoanthids	*Zoanthidea*	2.75
2023	L	AZN	Hydroids, hydromedusae	*Anthoathecatae*	0.01
2023	L	CSS	Hard corals, stony corals	*Scleractinia*	0.01
2023	L	DMO	Siliceous sponges	*Demospongiae*	0.8
2023	N	AQZ	Black corals and thorny corals	*Antipatharia*	0.11
2023	N	GGW	Gorgonians	*Gorgoniidae*	0.06
2023	N	HXY	Glass sponge	*Hexactinellida*	0.36
2024	L	ATX	Sea anemones	*Actiniaria*	0.05
2024	L	BVH	Brachiopods, lamp shells	*Brachiopoda*	0.01

2024	L	HXY	Glass sponge	*Hexactinellida*	0.01
2024	N	CNI	Cnidarians nei	*Cnidaria*	0.32
2024	N	HQZ	Hydrozoans	*Hydrozoa*	0.03
2024	O	ATX	Sea anemones	*Actiniaria*	0.11
2024	O	CSS	Hard corals, stony corals	*Scleractinia*	5.55
2024	O	HQZ	Hydrozoans	*Hydrozoa*	0.17
2024	O	HXY	Glass sponge	*Hexactinellida*	0.05
2024	O	NTW	Pennatulacea sea pens	*Pennatulacea*	0.02

Table 8. table summarising the depth ranges and brief observations for the full series of NZ Exploratory Research 2016-2024 sorted by number of observations.

VME code	Common name	Scientific name	No of observations	Depth range	Mean Depth	Average VME Weight
GGW	Gorgonians	*Gorgoniidae*	102	771 - 1831	1263	0.74
HXY	Glass sponge	*Hexactinellida*	53	462 - 1735	1255	0.28
CSS	Hard corals, stony corals	*Scleractinia*	26	659 - 1638	1085	0.44
ATX	Sea anemones	*Actiniaria*	16	462 - 2020	1275	0.21
AJZ	Alcyonacea soft corals	*Alcyonacea*	12	771 - 1326	1121	1.03
CWD	Feather stars and sea lilies	*Crinoidea*	12	1148 - 2020	1515	0.2
OEQ	Basket stars	*Euryalida*	12	1241 - 1553	1385	0.17
DMO	Siliceous sponges	*Demospongiae*	10	1121 - 1767	1382	0.18
ZOT	Zoanthids	*Zoanthidea*	10	768 - 1443	1137	0.01
HQZ	Hydrozoans	*Hydrozoa*	10	420 - 1499	1105	0.33
BZN	Bryozoans	*Bryozoa*	7	768 - 1608	1096	0.01
BVH	Brachiopods, lamp shells	*Brachiopoda*	6	776 - 1109	990	0.99
AXT	Hydrocorals	*Stylasteridae*	6	1249 - 1831	1626	0.58
NTW	Pennatulacea sea pens	*Pennatulacea*	5	1089 - 1464	1295	0.02
AZN	Hydroids, hydromedusae	*Anthoathecatae*	4	773 - 1832	1237	0.02
AQZ	Black corals and thorny corals	*Antipatharia*	4	1152 - 1355	1260	0.06
CNI	Cnidarians	*Cnidaria*	1	1309 - 1309	1309	0.32

Other Research

TDR data collection

During the March/April 2023 SPRFMO Exploratory Fishery trip, depth-temperature profiles were obtained using the New Zealand-designed Mangōpare sensor, designed to be attached to fishing gear for temperature data collection by depth. When the sensor is hauled aboard, it automatically offloads data to a counterpart deck box. The sensor was deployed on three sets, targeting a depth of 800 m. It is important to note that the first cast (A) was made within the southern NZ EEZ. Data from all sets revealed a cold layer between 124 – 146 m with temperatures 2.08 to 2.35° colder than the surface temperature. For set 3, hauling difficulties caused the sensor to descend below its maximum depth tolerance of 1,000 m, leading to a temporary pause in data recording.

In 2024, 5 TDRs were deployed but during the October–November 2024 trip, which focused on Research Areas L, N, and O. Interestingly the more southern casts also show a strong thermocline at between 95 and 142 m with temperatures still colder by between 0.27 – 2.2° colder than the surface. However, the two casts made further north and east showed no discernible thermocline. Sea temperatures and currents were reported by the skipper as varying significantly, leading to a shift in fish distribution from the southern slopes of hills in 2023 to the tops of hills in 2024.

See Figure 18 and Table 9 for the TDR profiles and a summary of these profiles. Figure 19 shows the relative positions of TDR casts made within SPRFMO during 2023 and 2024.

Table 9. Summary of 2023 and 2024 TDR casts

Season	Cast	Surface temp	Min temp at thermocline with depth	Bottom depth and temp
2023	A (NZ EEZ)	1.3°	-0.78° at 146 m	0.90° at 974 m
2023	B	1.3°	-0.90 at 124 m	1.06° at 803 m
2023	C	1.5°	-0.85 at 145 m	1.29° at 429.5 m
2024	D	-1.23°	-1.5 at 95 m	-1.31° at 1100 m
2024	E	0.04°	-0.98 at 123.6 m	0.77° at 1321.7 m
2024	F	1.2°	-1 at 142 m	0.81° at 1292 m
2024	G	5.38°	no discernible thermocline	4.93° at 482 m
2024	H	6.38°	no discernible thermocline	2.56° at 1230.3 m

There is considerable research supporting a well-defined thermocline, or transition layer between warmer surface waters and colder deep waters, often found at a depth of around 150 meters in the Antarctic Zone (AZ) of the Southern Ocean (Chaigneau 2004). This depth marks the base of the well-mixed Antarctic Winter Water (WW) layer, which is overlain by fresher and warmer Antarctic Surface Water (AASW) during the summer. The thermocline's position and characteristics can vary seasonally and interannually due to factors like temperature, salinity, and wind-driven currents.

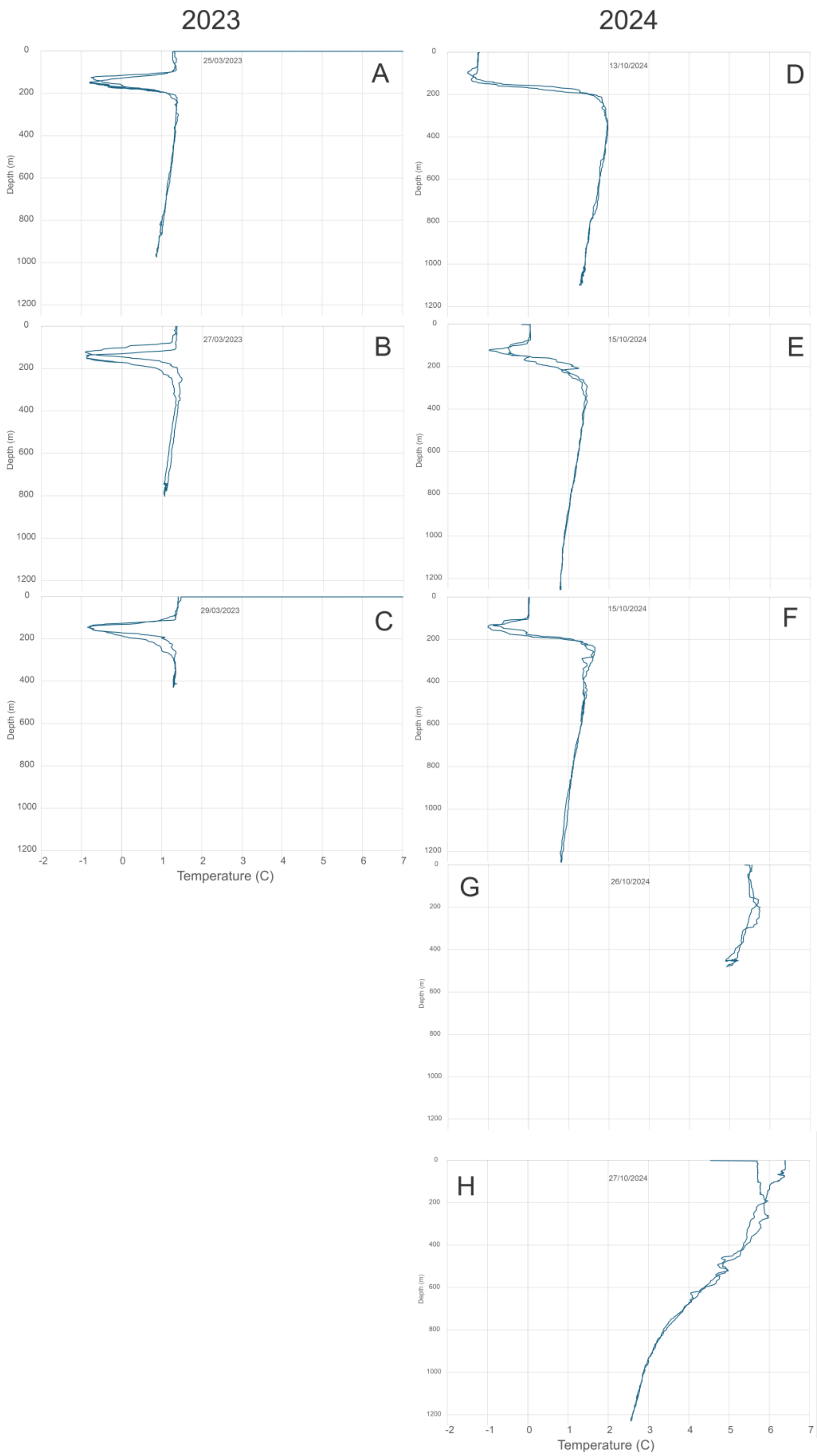

Figure 18. TDR cast profiles from 2023 and 2024. The bottom left box shows the relative position of the sampling.

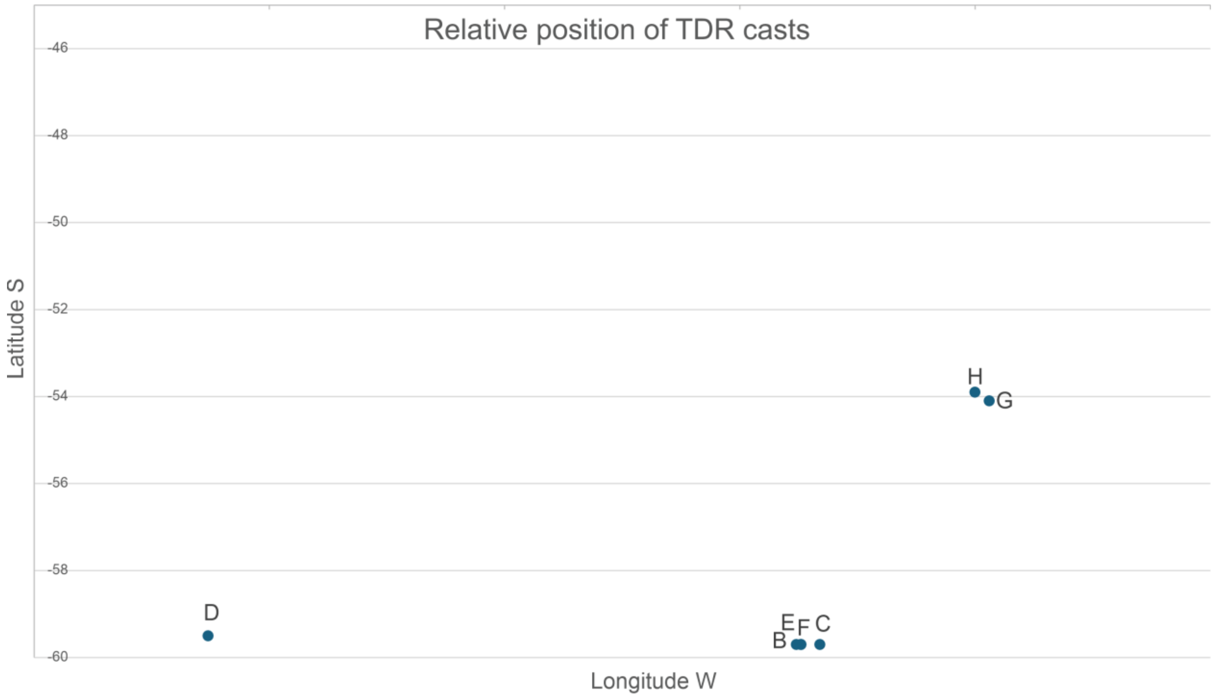

Figure 19. Relative positions of TDR casts within SPRFMP 2023 and 2024.

Shark tagging

Shark tagging was conducted as part of New Zealand's exploratory fishing programme in the SPRFMO Convention Area during the 2024 fishing season. This initiative was undertaken at the request of the National Institute of Water and Atmospheric Research (NIWA) and focused on tagging sleeper sharks (*Somniosus spp.*) to gather data on their survivorship and movement patterns. The tagging was carried out using Wildlife Computers 'sPAT' tags[8], which are designed to measure survivorship for up to 60 days post-release.

The tagging process involved capturing live sleeper sharks during fishing operations (Figure 20). When a shark was spotted, the vessel stopped the line, and the shark was carefully brought onboard using a net. The snood was cut, and the hook was removed to minimise injury. The scientific observer assessed the shark's suitability for tagging, examining its condition and ensuring it was healthy enough for release. Once deemed suitable, the shark was placed on a measuring board, where its total length, sex, and estimated weight were recorded. A fin clip was taken for DNA analysis, and the sPAT tag was attached to the shark. After tagging, the shark was released back into the sea, and its initial swimming behaviour was observed to confirm its ability to return to depth.

One sleeper shark was successfully tagged during the 2024 fishing season. The shark was observed swimming back down after release, indicating a positive outcome for survivorship. The sPAT tag is expected to provide valuable data on the shark's movement and survivorship over the 60-day period following its release. If successful, this information will contribute to understanding the behaviour and ecology of sleeper sharks in the SPRFMO area. The fin clip collected during tagging will be analysed to provide genetic insights into the sleeper shark population, potentially aiding in species identification and stock assessments.

[8] The sPAT is a pop-up archival transmitting tag (PAT tag, also known as a PSAT) specifically optimised for short-term survivorship studies. The sPAT uses a suite of sensors and algorithms to monitor the status of the tagged animal for up to 60 days.

Careful handling was required during tagging to ensure the safety of both the shark and the crew. The observer noted that the process was labour-intensive and required coordination between the vessel crew and scientific personnel. Additionally, the rarity of sleeper shark captures limited the number of tagging opportunities during the trip.

Further exploration within SPRFMO could include exploring opportunities to expand shark tagging efforts in future trips. These efforts could deepen understanding of sleeper shark ecology and inform conservation strategies.

Figure 20. Tagging a sleeper shark, a joint effort by the scientific observer and Sanford Science support officer.

Discussion

An exploratory longline fishery for toothfish in CCAMLR Subareas 88.1 and 88.2 has been in operation since 1997. The more than two decades of research undertaken during the Austral summer in this CCAMLR fishery now provides a good and ever-increasing understanding of the biology and ecology of Antarctic toothfish. There are, however, several important aspects of the spawning behaviour and early life history of Antarctic toothfish that are still relatively unknown (Hanchet et al., 2015). Until 2016, there had been little fishing, and consequently, limited research sampling was carried out during the late autumn and winter period when the spawning of Antarctic toothfish is thought to take place. The historical timeline moving towards a better understanding of the spawning behaviour and early life history of Antarctic toothfish is summarised here.

Fenaughty (2006) used four separate biological measurements to analyse toothfish biological data from five summer seasons from 2000/01 to 2004/05. This work indicated that there were clear differences between the Antarctic toothfish populations found on the hills and ridges of the Pacific-Antarctic Ridge to the north and from the main Ross shelf to the south of Subarea 88.1. A key indicator was that the body condition of Antarctic toothfish in the northern hills and ridges was much poorer for both sexes. An extended, asynchronous spawning in the northern area outside the polar summer season was suggested as the best explanation for these differences.

A further paper in 2008 (Fenaughty et al. 2008) attributed the body condition differences seen in the northern area to metabolic loss of muscular and subcutaneous lipid stores, and probably proteins, from white muscle. This paper considered energy metabolism as related to migration, feeding and reproduction. An important conclusion was that both lipid and protein stores of the axial portion of Antarctic toothfish were metabolically volatile and were mobilised for energetic and/or gametogenic purposes during spawning. Neutral buoyancy, previously thought to be based on the relative age of fish of this species, was considered more likely an ephemeral phenomenon that is gained and lost cyclically in sexually mature adults. As in other species, once feeding is resumed and forage species are abundant, it was suggested that both lipid stores and muscular protein could be restored rapidly (Jobling 1994).

A review of existing knowledge on Antarctic toothfish biology, coupled with ocean circulation, was also carried out by Hanchet et al. (2008) to predict where larvae and juvenile Antarctic toothfish might be found. Additional work by Dunn et al. (2012) and Ashford et al. (2012) further supported the hypothesis that spawning is likely to occur on ridges and banks to the north of the Ross Sea during the austral winter (June to October) and that eggs spawned in this region would be retained within the wider Ross Sea region through entrainment in the Ross Gyre.

In 2013, the Scientific Committee of CCAMLR (SC-CAMLR) acknowledged the need for research fishing in the northern Ross Sea region during winter to address uncertainties in toothfish life-cycle movements and spawning dynamics (SC-CAMLR-XXXII, para 3.76 (iv)), and requested proposals be developed by Members to address this need.

Up to then, while there were strong indications that toothfish spawn in the northern region of Subareas 88.1 and 88.2 during the winter months (Hanchet et al, 2008; Stevens et al., 2016), the spatial and temporal distribution of spawning activity was still theoretical. The collection of better information to inform these inferred aspects of spawning ecology to improve the structural assumptions of the spatially explicit operating model was identified in the CCAMLR medium-term research plan for the Ross Sea region (Delegations of New Zealand, Norway, and the United Kingdom 2014) as a key task which was subsequently endorsed by the Scientific Committee (SC-CAMLR XXXII, para 3.76 (iv)).

Progress advanced considerably when the New Zealand vessel FV *Janas* carried out research fishing operations in the northern Ross Sea region between June and July 2016 to investigate the timing and locations of spawning Antarctic toothfish. Spawning and spent Antarctic toothfish were captured late in the survey on undersea features. Gonad staging and gonadosomatic indices suggested that males in spawning condition may aggregate earlier than females and that spawning had begun in early July. Nineteen toothfish eggs were captured using a plankton net in the top 200 m of the water column, and eggs from two running ripe females were successfully fertilised and reared for several days in flow-through incubators. Egg buoyancy measurements conducted with fertilised eggs in density gradient cylinders were carried out. As part of this project, Antarctic toothfish reproductive status, gonadosomatic index (GSI), histological characteristics, sex ratio, and condition factor were collected. The sex-specific fish condition factor for males was seen at this time was 5% lower than that observed in the summer fishery in SSRUs 881B–C. However, females showed the same median value as in the summer fishery.

A second winter survey for Antarctic toothfish in the Ross Sea region was conducted from the FV *Janas* during September and October 2019. This survey followed the northern extent of sea ice from SSRU 882B through 881B. Antarctic toothfish sampled during this survey were in spent condition by the beginning of September, and gonadosomatic indices were less than 5%, suggesting that spawning had ended by mid-August. This research also indicated that sex-specific condition factors were lower than those observed in the summer or pre-spawning winter periods, and much lower than those observed on the Ross Sea slope during the summer fishery. Antarctic toothfish eggs were also found during this survey, but were rare in the areas sampled with the bongo nets, captured in six tows.

The exploratory fishing programme conducted by New Zealand between 2016 and 2024, which this report updates, provided valuable insights into the biology, distribution, and stock dynamics of Antarctic toothfish (*Dissostichus mawsoni*) within the SPRFMO Convention Area. The most recent research was carried out under the framework of CMM 14a-2022, with annual catch limits of 240 tonnes and a maximum of 40 tonnes per research block. Fishing operations were strategically timed to occur both before and after the assumed spawning period to investigate spatial and seasonal trends.

For detailed results of the research trips conducted in 2022–2024, including catch rates, tagging efforts, and environmental observations, see the Results section. Across all three years, the research confirmed the northern SPRFMO area as a spawning ground for Antarctic toothfish, with consistent findings of adult fish in pre-spawning or spent conditions.

The relationship between spawning time, gonadosomatic index (GSI), and the body condition of Antarctic toothfish provides critical insights into the reproductive dynamics and energy allocation of this species. GSI, which measures the ratio of gonad weight to body weight, serves as a reliable indicator of reproductive maturity and the progression of spawning. Fulton's condition factor (K), a measure of body condition based on the relationship between fish length and weight, complements GSI by reflecting the overall health and energy reserves of the fish.

During pre-spawning periods, GSI values typically increase as gonads develop and mature, indicating the accumulation of reproductive material such as eggs or sperm. Concurrently, body condition tends to decline as energy reserves are redirected from somatic growth and maintenance towards gonad development. This metabolic shift is particularly evident in spawning grounds, where fish exhibit lower Fulton's condition factor values, suggesting a depletion of lipid and protein stores to support reproductive processes.

Post-spawning, GSI values decrease sharply as mature gametes are released, and gonads shrink in size. This reduction in gonad weight is accompanied by further declines in body condition, as spawning fish often experience limited feeding opportunities and rely on stored energy reserves. Observations from the SPRFMO exploratory fishery confirm this pattern, with Antarctic toothfish sampled during the post-spawning periods showing significantly lower GSI and body condition values compared to pre-spawning samples. These findings align with previous research in CCAMLR Subarea

88.1, where spawning fish were found to metabolise muscular and subcutaneous lipid stores during reproduction.

The cyclical nature of gonad development and body condition underscores the energetic demands of spawning for Antarctic toothfish. Fish sampled in pre-spawning periods exhibit higher GSI values and moderate body condition, while post-spawning individuals show depleted energy reserves and reduced gonad mass.

From 2022 to 2024, data collected during New Zealand's exploratory fishing programme in the SPRFMO Convention Area confirmed this clear relationship between spawning time, gonadosomatic index (GSI), and the body condition of Antarctic toothfish. In 2022 and 2023, pre-spawning fish exhibited higher GSI values, reflecting gonad development and maturation. During these pre-spawning periods, Fulton's condition factor (K) values were moderate, indicating that energy reserves were being redirected toward gonad development. In contrast, post-spawning fish sampled in 2024 showed significantly lower GSI values. Body condition during this period was also poor, as fish had depleted energy reserves following spawning.

This updated data from New Zealand's exploratory fishing programme highlights discrepancies between observer-recorded maturity indices (GMI) and the gonadosomatic index (GSI), again suggesting that GMI may be a less reliable measure of reproductive maturity. For instance, in 2024, observer-recorded GMI indicated that a majority of female Antarctic toothfish were in developing or maturing stages. However, their GSI values were significantly lower, consistent with post-spawning conditions. Similarly, males were predominantly classified as developing or resting based on GMI, but their GSI values showed a marked decline, further supporting post-spawning status. This inconsistency arises because GMI relies on subjective visual assessments, which can vary between observers and fails to capture subtle changes in gonad development. In contrast, GSI provides an objective, quantifiable measure of gonad weight relative to body weight, offering a more accurate representation of reproductive status. GSI better aligns with biological processes, such as the cyclical increase and decrease in gonad mass during spawning, making it a superior tool for tracking reproductive maturity in Antarctic toothfish.

We strongly recommend that the use of observer-recorded maturity indices (GMI) be at least supplemented or replaced by the collection of gonad weights to calculate the gonadosomatic index (GSI), which provides a more objective and accurate measure of reproductive maturity. Observers should be equipped with appropriate scales to ensure precise gonad weight measurements, as this data is critical for understanding the cyclical changes in gonad development during spawning. Prioritising the collection of gonad weights will reduce reliance on subjective visual assessments inherent in GMI, thereby improving the consistency and reliability of reproductive data. Additionally, training observers in standardised protocols for gonad weight collection and ensuring the availability of calibrated equipment will enhance the quality of data and support more robust analyses of Antarctic toothfish reproductive dynamics.

Most Antarctic toothfish examined in all seasons had either empty stomachs or only contained bait, with less than 2% of the sample from 2019 to 2021 containing any food. However, a higher proportion (about 7%) of the 2017 sample was found with prey in the gut during the suggested post-spawning period. Again, the apparent lack of feeding is entirely consistent with results from the northern hills area of CCAMLR Subarea 88.1.

The current working hypothesis for the species life history in the general area of Area 88 (Figure 21) postulates that eggs and larvae spawned on the seamounts in CCAMLR subareas 88.1 and 88.2 are advected to the east and then to the south of Subarea 88.3. The juvenile toothfish are then believed to grow and slowly move west back towards Subarea 88.2 and 88.1. As they develop into adults on the slope (500 to 1200 m), they undergo maturation and then migrate to the northern seamounts again to spawn (Parker et al. 2014). Juvenile (50–80 cm) toothfish have been recorded from Subarea 88.3, but until recently, few subadult toothfish have been caught there (Delegations of Korea and New Zealand, 2017). This SPRFMO research carried out north of the CCAMLR Convention Area in concert with the CCAMLR winter surveys infers that spawning is potentially more extensive than originally postulated - possibly taking place throughout much of the southern section of the Pacific Antarctic Ridge.

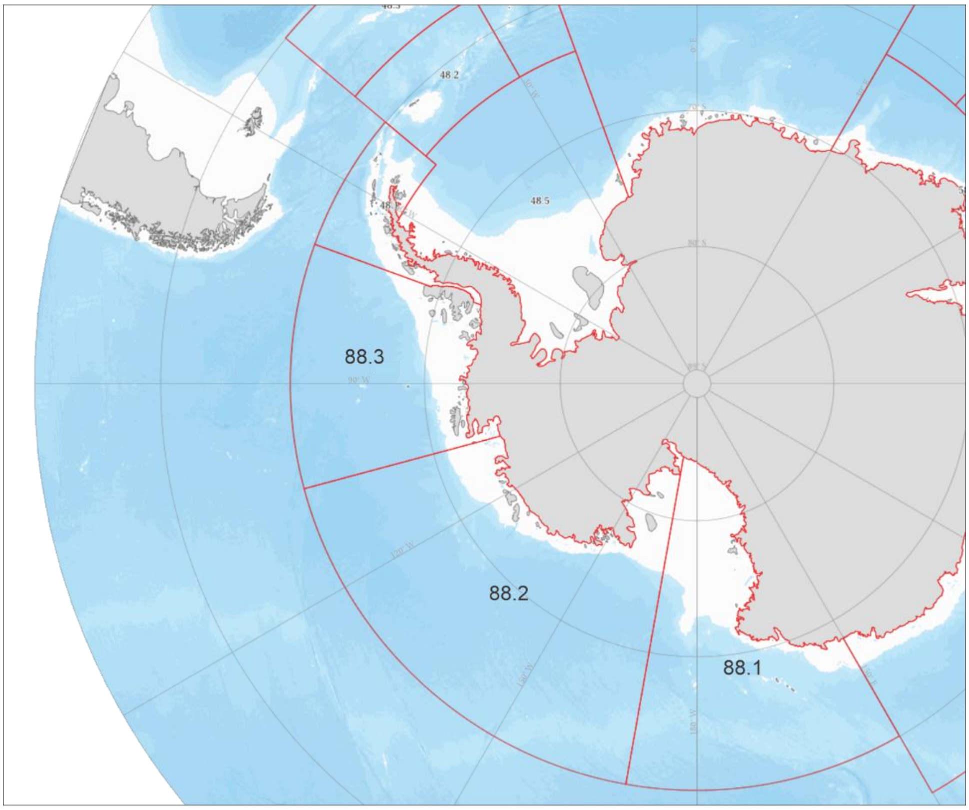

Figure 21. FAO Area 88 showing CCAMLR Subareas 88.1. 88.2 and 88.3

It is possible that this most northern SPRFMO spawning cohort is not substantially supported by migration from the south, or alternatively, that any migration from more southern regions takes place later in the year, during autumn and early winter, possibly associated with seasonal sea ice movement northward and southward. The collection of liver weights during biological sampling, as has been the case within CCAMLR, may assist in this work, as this may provide a good independent signal of fish condition.

The length-weight relationships of Antarctic toothfish sampled during the 2022–2024 exploratory fishing programme demonstrated trends consistent with previous studies in the SPRFMO and CCAMLR areas. The data revealed differences in body condition between pre-spawning and post-spawning periods, as well as between males and females.

Fish sampled during the post-spawning period in 2024 were in poorer condition compared to those sampled during pre-spawning periods in 2022 and 2023. This trend additionally supports the hypothesis that spawning fish metabolise stored energy reserves, including muscular and subcutaneous lipid stores, during the spawning process. In particular, fish sampled in 2024 exhibited lower body weights for a given length, reflecting the depletion of energy reserves post-spawning.

When compared to CCAMLR Subarea 88.1 data, the body condition of Antarctic toothfish in the SPRFMO area was generally poorer, both pre- and post-spawning. Fish sampled from the southern slope of Subarea 88.1, a feeding ground with high prey availability, showed better body condition than those from the SPRFMO spawning areas. This difference again highlights the energetic demands of spawning and the limited food availability in spawning grounds.

Approximately 97% of Antarctic toothfish sampled in 2016 and 2017, and over 99% during the 2019–2021 period, were adults with a total length of 120 cm or greater. For the 2022–2024 period, the data indicate that the proportion of fish sampled that were 120 cm or greater in total length during 2022–2024 was approximately 96.5–98.8%.

The length frequency analysis of Antarctic toothfish sampled during the 2022–2024 exploratory fishing programme thus confirms a population predominantly composed of reproductively mature adults. Total lengths ranged from 99 cm to 193 cm, with only 1.2–3.5% of the catch-weighted samples (and 2.7% of raw measurements) being fish shorter than 120 cm. Again, consistent with previous findings from the SPRFMO and CCAMLR areas, indicating that the northern SPRFMO region likely serves as a spawning ground for Antarctic toothfish.

The length distribution of males was slightly smaller than that of females, a trend observed in previous studies from the northern areas of CCAMLR Subarea 88.1 and CCAMLR winter surveys. Despite seasonal differences in sampling, the relative size range and general length distributions remained similar across the three years of research. The 2023 data, collected closest to the hypothesised winter spawning period, showed a nearly even sex ratio, which was anomalous compared to other years.

The sex ratio analysis showed a general skew towards males, with males comprising 60.3% of the catch-weighted sample in 2022, 62.7% in 2024, and 64.2% in 2020. However, in 2023, the sex ratio was nearly even, with males accounting for 49% of the sample. This anomaly may reflect the timing of sampling relative to the hypothesised winter spawning period. These findings align with previous observations from the northern hills area of CCAMLR Subarea 88.1 and other spawning grounds, reinforcing the hypothesis of a winter spawning period for Antarctic toothfish in the region.

The environmental conditions observed during the 2022–2024 exploratory fishing programme in the SPRFMO Convention Area showed notable variations across the three years, influencing fish distribution and catch rates. In 2022, environmental conditions were relatively stable, with consistent sea temperatures and currents across the surveyed research areas. In 2023, environmental conditions began to shift, with changes in sea temperatures and currents influencing fish distribution. Fish were found predominantly on the southern slopes of hills, contrasting with previous years. In 2024, significant environmental changes were observed, including more major variations in sea temperatures and currents. These changes led to a notable shift in fish distribution, with fish moving from the southern slopes of hills in 2023 to the tops of hills in 2024.

For detailed results of the 2022-2024 tagging efforts see the Results section.

Since the inception of New Zealand's exploratory fishing programme in 2016, tagging has been a cornerstone of research efforts, with a total of 928 Antarctic toothfish tagged and released over eight years. The tagging programme has consistently met or exceeded international scientific requirements, providing a robust dataset for stock assessment and management. Seven previously tagged fish have been recovered after at least one season, including one fish tagged in the Ross Sea slope area and recaptured after 15 years. These recaptures provide invaluable data on long-term movement and survival, supporting the hypothesis that Antarctic toothfish spawning extends north of the SPRFMO-CCAMLR boundary at 60°S. By tracking the movement, growth, and survival of tagged individuals, we can better assess the impact of fishing on local populations and the overall health of the stock. The 2016-2024 tagging efforts have contributed to CCAMLR's integrated stock assessment models, enhancing understanding of stock structure, migration patterns, and population dynamics.

Bycatch during New Zealand's exploratory fishing programme from 2022 to 2024 remained minimal and well below SPRFMO and CCAMLR thresholds, ensuring compliance with environmental regulations. Across the three years, bycatch levels ranged from 4.2% to 5.9% of the total catch by weight, reflecting sustainable fishing practices. Area O showed high bycatch rates and relatively high benthic diversity. Key benthic taxa included gorgonians, hard corals, and glass sponges, although benthic interactions remained well below established thresholds, ensuring minimal impact on vulnerable marine ecosystems (VMEs).

Summary of key results from the 2022-2024 SPRFMO exploratory fishing.

Category	**Key Findings**
Catch Rates	High catch rates observed, particularly in Research Blocks L and M, similar to spawning areas in CCAMLR Subareas 88.1 and 88.2. A total of 38.7 tonnes of toothfish was caught in 2022, 34.4 tonnes in 2023, and 32.6 tonnes in 2024.
Species Composition	Almost entirely Antarctic toothfish; six Patagonian toothfish caught since 2016, including one tagged and released.
Sex Ratios	Males dominated overall: 60.3% in 2022, 49% in 2023 (almost even), and 73% in 2024, reflecting seasonal and spawning dynamics.
Body Condition	Poor body condition observed across all years, consistent with spawning activity and energy depletion during reproduction. Gonadosomatic index (GSI) values indicated pre-spawning conditions in 2022 and 2023, and post-spawning conditions in 2024. Observer-recorded gonad maturity indices (GMI) showed discrepancies with GSI, highlighting the need for more objective measures of reproductive maturity.
Otolith Collection	253 otolith pairs collected for ageing during 2022–2024, contributing to stock assessment models.
Tagging	806 Antarctic toothfish tagged since 2016; tagging rates consistently exceeded the required three fish per tonne, with seven recaptures, including one after 15 years. A total of 412 Antarctic toothfish were tagged during the last three years,

Bycatch	Minimal bycatch recorded, ranging from 4.2% to 5.9% of total catch weight, well below SPRFMO and CCAMLR thresholds.
Seabird Interactions	No seabird injuries or fatalities were recorded; mitigation measures, such as bird scaring lines and nighttime setting, were employed.
Marine Mammals	Occasional sightings of species such as Fin Whales and Hourglass Dolphins; no interactions during fishing operations.
Benthic Bycatch	Low benthic bycatch; quantities below notification thresholds, with key taxa including gorgonians, hard corals, and glass sponges.
Spawning Area	The Northern SPRFMO region is confirmed as a spawning ground for Antarctic toothfish, with consistent findings of pre-spawning and spent adults.
Environmental Observations	Environmental conditions varied significantly across the three years, influencing fish distribution. This is likely due to the difference between autumn and late winter sampling times. In March 2023, fish were predominantly found on the southern slopes of hills, while in October 2024, fish shifted to the tops of hills, thought to be due to changes in sea temperatures and currents.
Scientific Contributions	Tagging data and biological samples were integrated into CCAMLR's stock assessment models, enhancing understanding of stock structure, migration patterns, and population dynamics. Findings confirmed the northern SPRFMO area as a spawning ground for Antarctic toothfish, extending north of the SPRFMO-CCAMLR boundary at 60°S

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Appendix 1: Reproductive summary

The following describes the CCAMLR staging that is applied in assessing the fish caught within SPRFMO.

Females

Maturity stage Description

F1. Immature Ovary small, firm, no eggs visible to the naked eye.

F2. Maturing virgin or resting Ovary more extended, firm, small oocytes visible, giving ovary a grainy appearance.

F3. Developing Ovary large, starting to swell the body cavity, colour varies according to species, contains oocytes of two sizes.

F4. Gravid Ovary large, filling or swelling the body cavity, when opened large ova spill out.

F5. Spent Ovary shrunken, flaccid, contains a few residual eggs and many small ova.

Males

Maturity stage Description

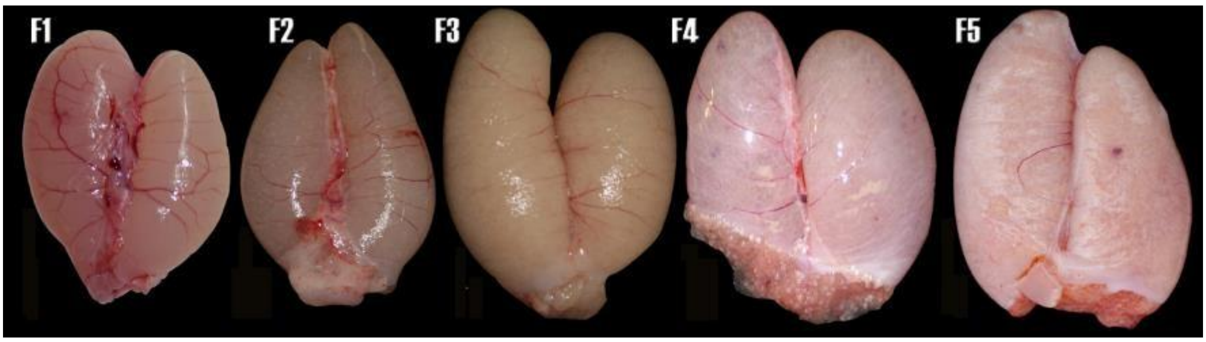
M1. Immature Testis small, translucent, whitish, long, thin strips lying close to the vertebral column.

M2. Developing or resting Testis white, flat, convoluted, easily visible to the naked eye, about 1/4 length of the body cavity.

M3. Developed Testis large, white and convoluted, no milt produced when pressed or cut.

M4. Ripe Testis large, opalescent white, drops of milt produced when pressed or cut.

M5. Spent Testis shrunk, flabby, dirty white in colour.



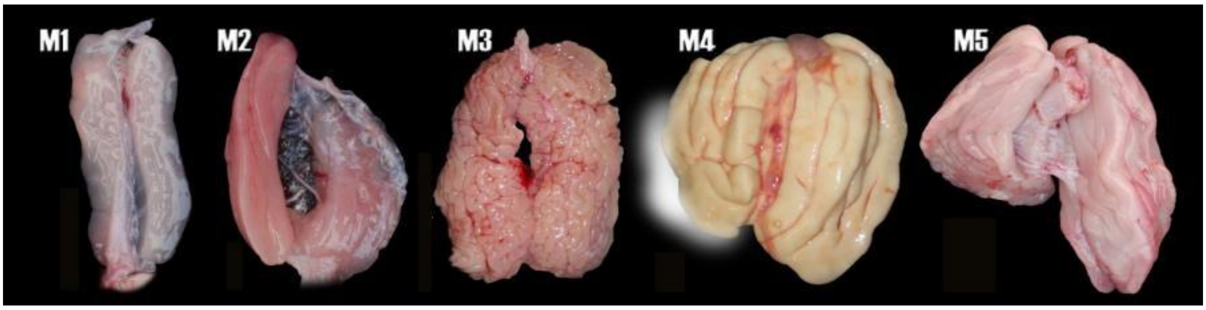


Table 10. Reproductive information collected in 2022.

Stage	Description males	Males	Males % of sample	Description females	Females	Females % of sample
2	Developing or resting Testis white, flat, convoluted, easily visible to the naked eye, about 1/4 length of the body cavity	182	62.1%	Maturing virgin or resting. Ovary more extended, firm, small oocytes visible, giving ovary a grainy appearance.	89	49.9%
3	Developed - Testis large, white and convoluted, no milt produced when pressed or cut.		0.0%	Developing - Ovary large, starting to swell the body cavity, colour varies according to species, contains oocytes of two sizes	26	14.4%
4	Ripe - Testis large, opalescent white, drops of milt produced when pressed or cut	21	7.2%	Gravid Ovary large, filling or swelling the body cavity, when opened large ova spill out.	7	3.8%
5	Spent -Testis shrunk, flabby, dirty white in colour	90	30.7%	Spent Ovary shrunken, flaccid, contains a few residual eggs and many small ova.	58	32.2%
Grand Total		**293**			**180**	

Table 11. Reproductive information collected in 2023.

Stage	Description males	Males	Males % of sample	Description females	Females	Females % of sample
2	Developing or resting Testis white, flat, convoluted, easily visible to the naked eye, about 1/4 length of the body cavity	274	81.8%	Maturing virgin or resting. Ovary more extended, firm, small oocytes visible, giving ovary a grainy appearance.	62	35.4%
3	Developed - Testis large, white and convoluted, no milt produced when pressed or cut.	54	16.1%	Developing - Ovary large, starting to swell the body cavity, colour varies according to species, contains oocytes of two sizes	107	61.1%
4	Ripe - Testis large, opalescent white, drops of milt produced when pressed or cut	7	2.1%	Gravid Ovary large, filling or swelling the body cavity, when opened large ova spill out.	6	3.4%
5	Spent -Testis shrunk, flabby, dirty white in colour	0	0.0%	Spent Ovary shrunken, flaccid, contains a few residual eggs and many small ova.	0	0.0%
Grand Total		**335**			**175**	

Table 12. Reproductive information collected in 2024.

Stage	Description males	Males	Males % of sample	Description females	Females	Females % of sample
2	Developing or resting Testis white, flat, convoluted, easily visible to the naked eye, about 1/4 length of the body cavity	8	7.3%	Maturing virgin or resting. Ovary more extended, firm, small oocytes visible, giving ovary a grainy appearance.	2	4.1%
3	Developed - Testis large, white and convoluted, no milt produced when pressed or cut.	83	76.1%	Developing - Ovary large, starting to swell the body cavity, colour varies according to species, contains oocytes of two sizes	33	67.3%
4	Ripe - Testis large, opalescent white, drops of milt produced when pressed or cut	2	1.8%	Gravid Ovary large, filling or swelling the body cavity, when opened large ova spill out.	7	14.3%
5	Spent -Testis shrunk, flabby, dirty white in colour	16	14.7%	Spent Ovary shrunken, flaccid, contains a few residual eggs and many small ova.	7	14.3%
Grand Total		**109**			**49**	