CCAMLR

Commission for the Conservation of Antarctic Marine Living Resources
Commission pour la conservation de la faune et la flore marines de l'Antarctique
Комиссия по сохранению морских живых ресурсов Антарктики
Comisión para la Conservación de los Recursos Vivos Marinos Antárticos

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Continuation of multi-Member research on the Dissostichus mawsoni exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2) from 2018/19 to 2021/22

Delegations of Australia, France, Japan, Republic of Korea and Spain

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Abstract

Exploratory fishing for toothfish (*Dissostichus mawsoni*) in East Antarctica (Divisions 58.4.1 and 58.4.2) began in 2003. Robust stock assessments and catch limits according to CCAMLR decision rules remain to be determined for these Divisions. WG-FSA-16/29 outlined the first multi-member toothfish exploratory fishery research plan up to 2017/18 for East Antarctica, which the Scientific Committee agreed was appropriate to achieve the research objectives (SC-CAMLR 2016, para. 3.244). Subsequent research progress including the evaluation of standard approaches to identify precautionary catch limits (WG-FSA-17 para. 4.28-4.38) and bycatch mitigation (Maschette et al. 2017), suggests a low risk profile for this fishery. Furthermore, examination of bycatch data and underwater video footage have not led to the identification of vulnerable marine ecosystem (VME) indicator species (Maschette et al. 2017, Eléaume et al. 2018). Here, we update the research plan for 2018/19 to 2021/22 (WG-FSA-18/59), in accordance with ANNEX 24-01/A, Format 2. This plan has been designed as a 4-year plan, based on the low risk profile of this fishery and to allow more time for review by Working Groups of major reporting and review years in non-stock-assessment years.

Compared to last year (WG-FSA-18/59), this research plan has been updated with 2019/20 operating details, the inclusion of modelling work under Objective 2, and a re-ordering of milestones under Objective 4.

Based on a recommendation by WG-SAM-19, inter-sessional discussions have been held between the existing co-proponent and the Russian Federation, but no agreement has been reached so far. Should the Russian Federation agree to become a co-proponent of this proposal, Russian research contributions could be integrated in an additional research objective as shown in the example below (marked as track changes in this document). One option would be to evaluate the impact of survey design on estimates of toothfish biomass and biological parameters.

1. Main objective

(a) Objectives for the research

Objective 1: Provide an assessment of the status and productivity of toothfish stocks in Divisions 58.4.1 and 58.4.2.

Objective 2: Identify the spatial distributions of toothfish, important habitats and vulnerable marine ecosystems (VME) in order to inform spatial management approaches.

Objective 3: Identify the spatial and depth distributions of bycatch species, and inform bycatch mitigation measures.

Objective 4: Improve the understanding of trophic relationships and ecosystem function to assist the development of ecosystem-based fisheries management approaches.

Objective 5: Evaluate the effect of standardised sampling design on the estimation of toothfish biomass and biological parameters.

(b) Detailed description of how the proposed research will meet the objectives, including annual research goals

Objective 1: Provide an assessment of the status and productivity of toothfish stocks in Divisions 58.4.1 and 58.4.2

Standard catch, fishing effort, tagging and biological data will be collected under Conservation Measures 41-05 and 41-11 to inform an assessment of the status and productivity of toothfish stocks in Divisions 58.4.1 and 58.4.2. Annual milestones include updated reports on research activity and collected data, ageing of collected toothfish otoliths, and updated estimation of biological parameters (Table 1). Stock assessment models for toothfish will be updated and refined biennially in non-stock-assessment years. Year 2022 will see an evaluation of existing management arrangements in Divisions 58.4.1 and 58.4.2, and updated advice on precautionary catch limits as appropriate.

Table 1. Scheme of milestones under Objective 1. Contribution refers to data processing and analyses. 'All' means all members who fish under this research plan.

Date	Milestone	Contribution	Coordination
WG-FSA-19	1.1 Report on research activity and collected data	Australia	Australia
	1.2 Ageing of collected toothfish otoliths & updated estimation of biological parameters	All	Spain
WG-FSA-20	1.3 Report on research activity and collected data	Australia	Australia
	1.4 Ageing of collected toothfish otoliths & estimation of biological parameters	All	Spain and Republic of Korea
	1.5 Migration of toothfish using satellite Pop-up tags	Republic of Korea	Republic of Korea

Date	Milestone	Contribution	Coordination
	1.6 Update and refine stock assessment models for toothfish within and across research blocks and Divisions	All	Australia and France
WG-FSA-21	1.7 Report on research activity and collected data	Australia	Australia
	1.8 Ageing of collected toothfish otoliths & updated estimation of biological parameters	All	Spain
WG-FSA-22	1.9 Report on research activity and collected data	Australia	Australia
	1.10 Ageing of collected toothfish otoliths & updated estimation of biological parameters	All	Spain
	1.11 Update and refine stock assessment models for toothfish within and across research blocks and Divisions	All	Australia and France

Objective 2: Identify the spatial distributions of toothfish, important habitats and vulnerable marine ecosystems (VME) in order to inform spatial management approaches

The collection of environmental data will continue annually and will be summarised in 2022 (Table 2). Environmental data collection will entail the attachment of conductivity, temperature and depth loggers (CTD loggers) and Benthic Video Cameras (BVCs) to fishing gear. BVCs will be deployed from vessels flagged to Australia, France and likely Spain, and CTD loggers will be deployed from vessels flagged to Australia, France, Republic of Korea and Spain (see Section 2b, 3a).

BVCs and CTD loggers will record, or be used to infer:

- Water temperature
- Salinity
- Depth of longline deployments
- Substrate composition
- Density and species composition of benthic communities.

A summary of collected environmental data will be presented in 2022, with an evaluation of their use in habitat models for toothfish. Toothfish distribution models and the resulting hypothesis for toothfish stock structure across East Antarctica (Yates et al. 2017) will be updated in 2022. Data on benthic communities will also provide information on the distribution of benthic organisms, particularly of Vulnerable Marine Ecosystems (VME), within the study regions. Furthermore, vertical depth, temperature and salinity profiles will be shared with the Southern Ocean Observing System (SOOS), delivering additional value from the proposed research.

In addition to the collection of in-situ observations of environmental data, egg and larval transport over the East Antarctic region will be examined using a Lagrangian particle tracking model to improve the understanding of toothfish recruitment processes. This investigation will include multiple sensitivity analyses to assess which biological and physical factors affect the transport pattern of early development stages of toothfish. Results of the simulations will be updated every year from 2019-2021.

Table 2. Scheme of milestones under Objective 2. Contribution refers to data processing and analyses.

Date	Milestone	Contribution	Coordination
WG-FSA-19	2.1 Update hypotheses of transport of toothfish early life stages in East Antarctic using dispersal models (30°E-150°E)	Japan	Japan
WG-FSA-20	2.2 Update hypotheses of transport of toothfish early life stages in East Antarctic using dispersal models (30°E-150°E)	Japan	Japan
WG-FSA-21	2.3 Update hypotheses of transport of toothfish early life stages in East Antarctic using dispersal models (30°E-150°E)	Japan	Japan
WG-FSA-22	2.4 Summary of collected environmental data, and evaluation of their use in habitat models and for informing on the distribution of VMEs	Australia, France, Republic of Korea and Spain	France
	2.5 Update hypothesis for toothfish stock structure across East Antarctica and links with other areas	Australia and Republic of Korea	Australia and Republic of Korea

Objective 3: Identify the spatial and depth distributions of bycatch species, and inform bycatch mitigation measures

Bycatch data will be collected in accordance with relevant conservation measures (CMs 33-03, 41-05 and 41-11). These data will help to inform estimations of the distribution, relative abundance, and life history of the main bycatch species. These analyses will be presented biennially (Table 3).

Table 3. Scheme of milestones under Objective 3. Contribution refers to data processing and analyses.

Date	Milestone	Contribution	Coordination
WG-FSA-20	3.1 Update estimation of spatial distribution, relative abundance, and life history of main bycatch species	Australia and France	Australia and France
WG-FSA-22	3.2 Update estimation of spatial distribution, relative abundance, and life history of main bycatch species	Australia and France	Australia and France

Objective 4: Improve the understanding of trophic relationships and ecosystem function to assist the development of ecosystem-based fisheries management approaches

Samples of fish muscle tissue, stomach contents, plankton and zooplankton will be used for the investigation of trophic relationships and ecosystem function using stable isotope analyses. Trophic and ecosystem relationships will be evaluated and reported on as presented in Table 4.

Table 4. Scheme of milestones under Objective 4. Contribution refers to data processing and analyses.

Date	Milestone	Contribution	Coordination
WG-FSA-19	4.1 Analysis of stomach contents by morphological and genetic study	Republic of Korea	Republic of Korea
WG-FSA-20	4.2 Plan for continuing research in 2021 and 2022	Republic of Korea	Republic of Korea
WG-FSA-22	4.3 Diet of Antarctic toothfish based on fatty acids and stable isotopes	Republic of Korea	Republic of Korea

Objective 5: Evaluate the effect of standardised sampling design on the estimation of toothfish biomass and biological parameters

The potential effects of sampling design will be evaluated in a research block by a comparison of hauls following a standardised sampling design (i.e. hauls in randomized-stratified locations), and following a non-standardised sampling design (i.e. hauls only depth-stratified).

Table 5. Scheme of milestones under Objective 5. Contribution refers to data processing and analyses.

Date	Milestone	Contribution	Coordination
WG-FSA-20	5.1 Comparison of estimates of toothfish biomass and biological parameters from standardised and unstandardised sampling design & recommendations for future sampling design and statistical analyses to account for impacts	All	TBA
WG-FSA-21	5.3 Comparison of estimates of toothfish biomass and biological parameters from standardised and unstandardised sampling design & recommendations for future sampling design and statistical analyses to account for impacts	All	TBA

Table 5. Chronological view of milestones for the 2018/19 – 2021/22 research plan (also listed in Table 2 – Table 5) and proposed achievement dates, shaded blue. Milestones are based on (1) succession of research following the 2015/16 – 2017/18 research plan, and (2) list example milestones for data-poor fisheries set out in WG-FSA 2017, Table 2.

Milestone	2019		2020		2021		2022	
	WG-SAM	WG-FSA	WG-SAM	WG-FSA	WG-SAM	WG-FSA	WG-SAM	WG-FSA
1.1, 1.3, 1.7 & 1.9 Report on research activity and collected data		AUS		AUS		AUS		AUS
1.2, 1.4, 1.8 & 1.10 Ageing of collected toothfish otoliths & updated estimation of biological parameters		ESP		ESP (age) & KOR (maturity)		ESP		ESP
1.5 Migration of toothfish using satellite Pop-up tags				KOR				
1.6 & 1.11 Update and refine stock assessment models for toothfish within and across research blocks and Divisions				AUS & FRA				AUS & FRA
2.1, 2.2 & 2.3 Update hypotheses of transport of toothfish early life stages in East Antarctic using dispersal models (30°E-150°E)		JPN		JPN		JPN		
2.4 Summary of collected environmental data, and evaluation of their use in habitat models and for informing on the distribution of VMEs								FRA
2.5 Update hypothesis for toothfish stock structure across East Antarctica and links with other areas								AUS & KOR
3.1 & 3.2 Update estimation of spatial distribution, relative abundance, and life history of main bycatch species				AUS & FRA				AUS & FRA
4.1 Analysis of stomach contents by morphological and genetic study		KOR						
4.2 Plan for continuing research in 2021 and 2022				KOR				
4.3 Diet of Antarctic toothfish based on fatty acids and stable isotopes								KOR
5.1 & 5.2 Comparison of estimates of toothfish biomass and biological parameters from standardised and unstandardised sampling design & recommendations for future sampling design and statistical analyses to account for impacts				TBA		TBA		

(c) Rationale for research, including relevant existing information on the target species from this region, and information from other fisheries in the region or similar fisheries elsewhere

Toothfish utilise a broad range of habitats throughout their lifespan, from the epipelagic as planktonic larvae, to benthopelagic slope habitats in excess of 2000 m in depth (Hanchet et al. 2010). Previous studies have revealed varied movement patterns among individuals but also a relatively predictable distribution of these fish along the Antarctic continental shelf (Welsford 2011, Yates et al. 2017). Results of genetic studies have been consistent with the existence of limited gene flow among *D. mawsoni* populations across regions (East Antarctica, Ross Sea and the South Shetland Islands; Kuhn and Gaffney 2008, Mugue et al. 2013). However, an additional genetic analysis is underway (Maschette et al. 2018a and 2018b) to determine whether this species exhibits discrete stock structure or a pattern of isolation by distance across its global distribution.

Significant research progress has been made in Divisions 58.4.1 and 58.4.2 over the last few years:

- Development of an integrated stock assessment and preliminary estimation of toothfish biomass (WG-FSA-18/58 Rev.1)
- Updated toothfish habitat models and stock hypothesis (WG-FSA-17/16, WG-FSA-18/64)
- Depth and temperature preferences of *D. mawsoni* using popup satellite archival tags (WG-FSA-18/22)
- Updated toothfish ageing and growth estimation of *D. mawsoni* (WG-FSA-17/15, WG-FSA-17/66, WG-FSA-18/54)
- Description of reproductive biology and maturity (WG-FSA-17/09, WG-FSA-18/65)
- Diet composition and feeding ecology of *D. mawsoni* (WG-FSA-17/12, WG-FSA-18/24)
- Genetic sequencing of stomach contents collected from *D. mawsoni* (WG-FSA-17/P03)
- Description of bycatch (WG-FSA-18/28), and development of approaches for mitigation of Macrourus by-catch in research block 58.4.1_6 and estimation of Macrourus biomass and sustainable bycatch in Divisions 58.4.1 and 58.4.2 (WG-FSA-17/16)
- Description of invertebrate and VME indicator species bycatch (WG-SAM-16/34, WG-FSA 18/51)
- Analysis of illegal, unreported and unregulated (IUU) fishing activities (WG-FSA-18/60)

The combination of results from this research, an evaluation of the previous research proposals against a set of generic criteria for research proposals in data-poor fisheries (WG-FSA-17, para. 4.7), the development of a standard approach to set precautionary catch limits (WG-FSA-17 para. 4.28-4.38), and historically low levels of IUU fishing activity suggests a low risk profile for this fishery.

Further data collection, the development of methods to improve the estimation of toothfish biomass and productivity including an update of the integrated stock assessment, and a better understanding of stock structure are research priorities. The dominance of large mature fish and absence of juveniles on nearby BANZARE Bank (Division 58.4.3b) suggest that it may be an important spawning ground for *D. mawsoni* (Welsford et al. 2008; Taki et al. 2011). In contrast, based on catches across Divisions 58.4.1 and 58.4.2 between years 2003–2011, the region around Prydz Bay (SSRU 58.4.2E) had the highest predicted catch rate of juvenile *D. mawsoni* (Yates et al. 2017). Therefore, it is hypothesised that mature fish on BANZARE Bank originate from nearby locations in East Antarctica, especially Prydz Bay (Welsford et al. 2008), which may serve as nursery areas (Welsford 2011). This stock hypothesis was supported by subsequent distribution modelling by Yates et al. (2017), and includes similar latitudinal patterns in sexual maturity and size composition to those hypothesised for the Ross Sea (Hanchet et al., 2008; Welsford et al. 2008). Combined, these stock models suggest a single stock across Prydz Bay in Division 58.4.2, Division 58.4.1, and Subdivision 58.4.3b. Further data on the

distribution of different size-classes and maturity stages of toothfish, along with estimates of biological parameters and genetic studies, will allow for the refinement of models of stock structure, and the development of assessments models.

2. Fishery operations

(a) Fishing Members

Australia, France, Japan, Republic of Korea and Spain.

(b) Vessels to be used

Table 6. Fishing vessels of Australia

Vessel name	*Antarctic Chieftain*
Information	https://www.ccamlr.org/en/node/90599
Vessel owner	Australian Longline Pty Ltd
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Fremantle, Registration 859032
Radio call sign	VJT6415
Overall length and tonnage	62.8 m, 1148 MT
Equipment for determining position	GPS and other vessel monitoring systems required under CM10-04
Fishing processing/storage capacity	15 tonnes per day headed & gutted, blast frozen. Carrying capacity 480t. Capacity of all fish holds 1,090m^3
Divisions	58.4.1 and 58.4.2
Vessel name	*Antarctic Discovery*
Information	https://www.ccamlr.org/en/node/90595
Vessel owner	Australian Longline Pty Ltd
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Hobart, Registration 861507
Radio call sign	VKAD
Overall length and tonnage	55.3 m, 1580 MT
Equipment for determining position	GPS and other vessel monitoring systems required under CM10-04
Fishing processing/storage capacity	15 tonnes per day headed & gutted, blast frozen. Carrying capacity 410t. Capacity of all fish holds 851m^3
Divisions	58.4.1

Table 7. Fishing vessels of France

Vessel name	*Le Saint-André*
Information	https://www.ccamlr.org/en/node/94853
Vessel owner	SNC Saint-André
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Port aux Français FK 928451
Radio call sign	FNTD
Overall length and tonnage	56.4 m, 416 tonnes
Equipment for determining position	Balise Irridium type Thorium
Fishing processing/storage capacity	Fish processing capacity: $\leq$ 10 tons per day Freezer hold capacity: 300 tons.
Divisions	58.4.1 and 58.4.2
Vessel name	*Cap Kersaint*
Information	To be updated
Vessel owner	CAP BOURBON
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Port aux Français FK 932444
Radio call sign	FISH
Overall length and tonnage	59.45 m, 2086 UMS
Equipment for determining position	GPS FURUNO GP170
Fishing processing/storage capacity	Fish processing capacity: 15 tonnes per day Freezer hold capacity: 900 m^3
Divisions	58.4.1

Table 8. Fishing vessel of Japan

Vessel name	*Shinsei maru No.3*
Information	www.ccamlr.org/en/node/75733
Vessel owner	TAIYO A & F CO., LTD.
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Yaizu-Japan / 128862
Radio call sign	JAAL
Overall length and tonnage	47.2 m, 735 t
Equipment for determining position	GPS FURUNO GP500MK2
Fishing processing/storage capacity	Fish processing capacity: 10 tonnes per day Freezer hold capacity: 502.4 m^3
Divisions	58.4.1

Table 9. Fishing vessel of Republic of Korea

Vessel name	*No. 707 Hongjin*
Information	www.ccamlr.org/en/node/100335
Vessel owner	Hongjin Corporation
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Busan, Korea / 0704001 6261108
Radio call sign	DTBT2
Overall length and tonnage	50.77 m, 587 t
Equipment for determining position	ARGOS MAR-V3 (ID : 155451)
Fishing processing/storage capacity	Fish processing capacity: 30 tonnes per day Freezer hold capacity : 906 m3
Divisions	58.4.1
Vessel name	*Kingstar*
Information	www.ccamlr.org/en/node/102672
Vessel owner	SUNWOO CORPORATION
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Busan, Korea / 1405002 6261100
Radio call sign	6KCD4
Overall length and tonnage	51.01 m, 573 t
Equipment for determining position	ARGOS MAR-V2
Fishing processing/storage capacity	Fish processing capacity: 25 tonnes per day Freezer hold capacity : 633 m3
Divisions	58.4.1

Table 10. Fishing vessel of Spain

Vessel name	*Tronio*
Information	https://www.ccamlr.org/en/node/94831
Vessel owner	Pesquerías Georgia S.L.
Vessel type	Commercial bottom longline fishing vessel
Registration port/number	Cillero/ 3GC-1-2-05
Radio call sign	ECJF
Overall length and tonnage	55 m, 1058 tonnes (GRT)
Equipment for determining position	VMS-c
Fishing processing/storage capacity	42.7t / 635.3 m^3
Divisions	58.4.1

(c) Target species

Antarctic toothfish (*Dissostichus mawsoni*) will be the primary species caught, and the focus for Objectives 1, 2 and 4.

(d) Fishing or acoustic gear to be used

Longline type

This research will employ a combination of Mustad Autoline system with integrated weight-longline (Australia and France), Spanish longline (Spain) and trotline (Japan and Republic of Korea). Full descriptions of gear configurations and deployment are located in the CCAMLR Fishing Gear Library at http://www.ccamlr.org/en/publications/fishing-gear-library.

Other sampling gear

- Echosounders (e.g. Simrad ES60; ES 70, 38 kHz; JRC JFV-250)
- Conductivity, temperature and depth (CTD) loggers
- Benthic video cameras
- Archival tags (MiniPAT; Wildlife computers)

Type of acoustic gear and frequency

If possible, vessels will collect acoustic 18, 38 and 120 kHz data as part of a program by the Integrated Marine Observing System (IMOS) for risk-based analyses of potential impacts on non-target fish populations or ecosystem interactions arising from impacts on the target stock.

(e) Fishing regions (divisions, subareas and SSRUs) and geographical boundaries

This research plan proposes research blocks in Divisions 58.4.1 and 58.4.2 as outlined in Section 3.

(f) Estimated dates of entering and leaving the CCAMLR Area

Table 11. Estimated months of operation during the 2019/20 season (shaded blue) in the CCAMLR Area for each notifying Member. Cut-off dates for confirmation of intention to fish, and commencement of fishing are outlined in Section 4a.

Notifying Member	2019	2020										
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Australia												
France												
Japan												
Rep. of Korea												
Spain												

3. Survey design, data collection and analysis

(a) Research survey/fishing design (description and rationale)

Spatial arrangements or maps of stations/hauls (e.g. randomised or gridded)

The geographical boundaries of research blocks in Divisions 58.4.1 and 58.4.2 for the research plan are listed in Conservation Measures 41-11 and 41-05 and are presented in Figure 1:

Division 58.4.1:

- 5841_1 (SSRU 58.4.1C)
- 5841_2 (SSRU 58.4.1C)
- 5841_3 (SSRU 58.4.1E)
- 5841_4 (SSRU 58.4.1E)
- 5841_5 (SSRU 58.4.1G)
- 5841_6 (SSRU 58.4.1G)

Division 58.4.2:

- 5842_1 (SSRU 58.4.2E)

WG-SAM-18/17 proposed an approach to review locations of research blocks based on recommendations for the designation of research areas in data-poor fisheries WG-SAM-11 (para. 2.40):

a) The area should be chosen with a reference to the stated objective of the research.
b) Priority areas include those where catch rates indicate that a viable toothfish fishery may be present depending on catch rates, catch history and size of fishable seabed areas.
c) Consideration should also be given to the likely role of a particular SSRU in the plausible stock hypothesis (i.e. is it only juveniles in the area?).

A list of criteria was developed to enable an evaluation of geographic areas according to the recommendation above (Table 12, with data layers in Appendix 2). Criteria to meet research objectives include the numbers of released and recaptured tagged fish, the ability to develop local and wider-area assessments, areas of key life-history stages such as spawning grounds, the availability (or lack) of data to develop habitat models, and the risk of encountering VMEs. Criteria to indicate a viable fishery include previous catch rates and catch history, likely fish habitat area, and spatio-temporal distributions of sea ice.

For each criteria, thresholds were used to rank geographic areas according to their suitability as research locations. This ranking system was applied to 24 five-degree-longitude sections across the longitudinal extent of Divisions 58.4.1 and 58.4.2 (Figure *2*).

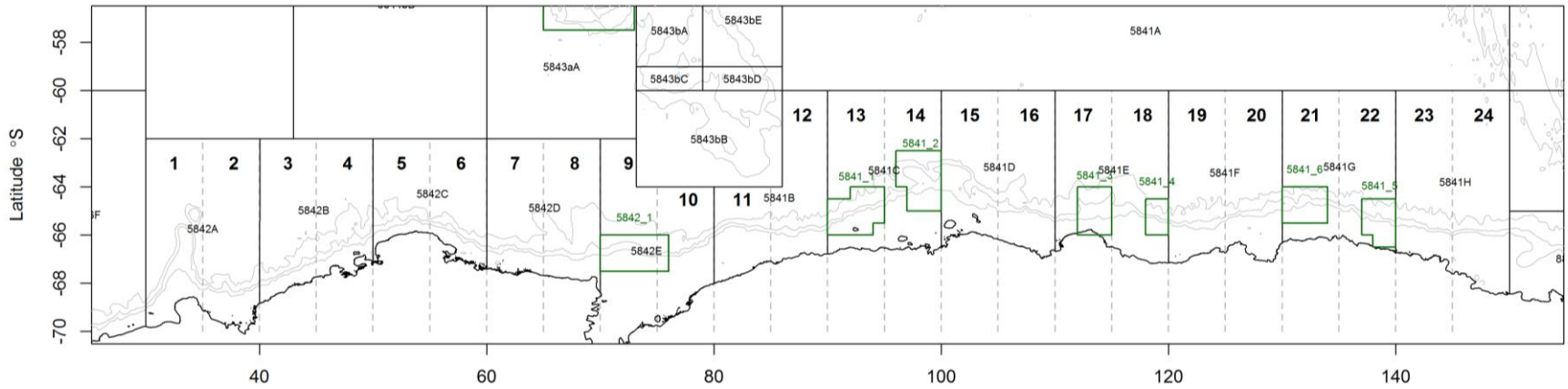
The research objectives of this research plan require the collection of a range of data types, including recapture data to develop toothfish stock assessments, and data on ageing and maturity to inform stock productivity. The development of local assessments depends on local recaptures, while an area-wide assessment is facilitated by data collection from locations that are in relatively close proximity to each other. For the stock hypothesis, key life-history stages in observed and predicted locations of spawning and settlement are of highest interest. The existing habitat model (Yates et al. 2017) is mainly informed from data collected in existing research blocks and can make predictions for surrounding areas, but lacks data from the more western parts of Division 58.4.2. VMEs have so far been detected only in SSRU 58.5.1H, but fishing effort in some of the remaining areas has been low.

Viable research blocks also require a combination of good catch rates, sufficient suitable toothfish habitat area where bycatch is low (e.g. in the 1000-1700 m depth range) and accessibility with low sea ice conditions.

Following discussion at WG-SAM-18 (paragraph 6.36), these criteria were used to review the location of research blocks for the 2018/19 - 2021/22 research plan. Sections with research blocks from the research plan up to 2017/18 (WG-FSA-16/29) scored highest overall for suitability as research blocks. Therefore, this research plan retained all research blocks.

Table 12. Criteria and thresholds for evaluating geographic sections according to their suitability as research areas. H = high, M = medium, L = low.

Criteria	Rank	Thresholds
Available tags	H	> 100 tags
	M	10-99 tags
	L	< 10 tags
Recaptures	H	> 5 recaptures
	M	1-5 recaptures
	L	0 recaptures
Local assessment	H	High likelihood (given existing data, e.g. ageing data)
	M	Medium likelihood
	L	Low likelihood
Wider-area assessment	H	High likelihood (given existing data and close spatial proximity)
	M	Medium likelihood
	L	Low likelihood
Key life-history stages	H	High interest as potential spawning (high proportion of stage 3+ fish) or settlement area (small fish)
	M	Medium interest
	L	Low interest
No data for habitat	H	High level of uncertainty due to lack of data
model	M	Medium level of uncertainty due to lack of data
	L	Low level of uncertainty due to lack of data
VME	H	High suitability: no reported VME despite high level ('M' or 'H') of total removals
	M	Medium suitability: no reported VME but no or only low-level ('L) of total removals
	L	Low suitability: reported VME
Catch rates	H	Maximum CPUE > 200 kg/1000 hooks (model prediction)
	M	Maximum CPUE of 100-200 kg/1000 hooks
	L	Maximum CPUE < 100 kg/1000 hooks
Fishing history	H	Total catch > 100 tonnes
	M	Total catch 20-100 tonnes
	L	Total catch < 20 tonnes
Habitat area	H	Area > 8000 km^2 (Area in 1000-1700 m depth)
	M	Area 4000-8000 km^2
	L	Area < 4000 km^2
Sea ice	H	> 70% of years accessible in Jan-March (averaged across months and for areas with depths between 1000 and 2000 m)
	M	20-70% of years accessible in Jan-March
	L	< 20% accessible in Jan-March



Division		58.4.2										58.4.1													
SSRU		A	A	B	B	C	C	D	D	E	E	B	B	C	C	D	D	E	E	F	F	G	G	H	H
With research block		-	-	-	-	-	-	-	-	1	1	-	-	1	2	-	-	3	4	-	-	6	5	-	-
Segment		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
a) Objectives	Available tags	M	L	L	L	L	L	L	L	H	H	L	L	H	H	M	L	H	H	L	L	H	H	H	M
	Recaptures	L	L	L	L	L	L	L	L	L	L	L	L	M	H	L	L	H	M	L	L	H	H	M	L
	Local assessment	L	L	L	L	L	L	L	L	H	L	L	L	H	H	L	L	H	H	L	L	H	H	L	L
	Area-wide assessment	L	L	L	L	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	L	L
	Key life-history stages (i.e. stock hypothesis)	H	M	L	L	L	L	L	M	H	H	M	L	M	H	H	L	M	M	L	L	L	L	L	L
	No data for habitat model	M	H	H	H	H	H	M	L	L	L	M	L	L	L	L	L	L	L	L	L	L	L	L	L
	Avoid VME	M	M	M	M	M	M	M	M	H	H	M	M	H	H	M	M	H	H	M	M	H	H	L	M
b) Viable fishery	Catch rates (max)	M	L	M	M	H	H	H	H	H	M	M	H	H	H	M	L	M	M	M	M	M	M	H	M
	Fishing history (tonnes)	L	L	L	L	L	L	L	L	M	M	L	L	H	H	M	L	H	M	L	L	H	M	M	L
	Habitat area (km^2)	H	L	L	M	L	L	L	L	L	L	L	L	L	M	H	L	M	L	L	M	M	L	L	L
	Sea ice	H	L	M	M	H	M	M	M	M	M	M	M	M	M	M	M	M	M	M	H	H	H	M	M
c) Stock hypothesis	See Key life-history stages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Figure 1. Suitability of five-degree-longitude sections (upper panel) against the criteria under WG-SAM-11 para 2.40 (lower panel). Suitability is marked as high (H, green), medium (M, orange) or low (L, red). Upper panel: Black lines = SSRU boundaries, green lines = research blocks in Divisions 58.4.1 and 58.4.2 as set out in Conservation Measures 41-11 and 41-05.

Stratification according to e.g. depth or fish density

Fishing in all research blocks will be distributed across a range of depth strata where possible (<1000, 1001–1500, 1501–2000 m). Each Member will deploy at least 5 longlines in each depth strata (where present and sea-ice permitting) in each research block surveyed. In instances of large Macrourus bycatch, fishing should cease in areas with depths shallower than 1000m (Maschette et al. 2018). Once these minimum requirements for sampling in depth strata are fulfilled, vessels may conduct additional fishing within the research blocks, catch limit permitting. Hence it is anticipated that a combination of stratified and exploratory fishing may occur within each research block.

For Objective 5… [to be specified]

Calibration/standardisation of sampling gear

A full description of gear configuration (see Section 2d) and deployment is located in the CCAMLR Fishing Gear Library at http://www.ccamlr.org/en/publications/fishing-gear-library. Additional information about longline deployments, such as minimum separation distance and soak time, can be found in the Data Collection Plan for Exploratory Fisheries (Conservation Measure 41-01 Annex 41-01/A). Details on the fishing gears and deployment methods, as well as variables that can be difficult to control (e.g. soak time and percentage of hooks baited), will be recorded so they may be standardised a posteriori.

Proposed number and duration of stations/hauls

Fishing in all research blocks within each research block will include at least 5 longlines in each depth strata, where present, and catch limit and sea-ice permitting (see above). Once these minimum requirements have been met, the vessels will assess sea ice conditions and bycatch rates and may continue sampling within the same research block. Minimum soak time of each set will be 6 hours.

For Objective 5… [to be specified]

Tagging rates and other performance metrics such as tag overlap statistics for tagging programs

A key element of this multi-member research plan is a well-coordinated multi-year tagging program involving repeatedly visiting relatively small areas, and a commitment from all vessels to high tagging performance and to optimising the health of tagged fish.

The research will target toothfish of all sizes in order to meet CCAMLR tagging requirements outlined in Conservation Measure 41-01 Annex C. Only fish in suitable condition according to the CCAMLR Tagging Protocol (https://www.ccamlr.org/en/science/ccamlr-tagging-program) will be tagged and released. Five fish per retained tonne (green weight) will be tagged with two external T-bar tags inserted into the dorsal musculature (CM 41-05 para. 11 and CM 41-11 para. 11). Tag-size overlap will be maintained at > 60%, with an aim to achieve > 80% tag-size overlap.

Other requirements

CTD loggers will be attached from *Antarctic Chieftain* (AUS), *Antarctic Discovery* (AUS), *No. 707 Hongjin* (KOR), *Kingstar* (KOR), *Saint André* (FRA), *Cap Kersaint* (FRA) and *Tronio* (ESP). We propose to continue the use of Star-Oddi CTD loggers (www.star-oddi.com/products/3/salinity-temperature-depth-logger/default.aspx) as well as CTD loggers developed at Saint Andrews (http://www.smru.st-andrews.ac.uk/ Instrumentation/Products/).

Benthic video cameras (BVCs) will be attached from *Antarctic Chieftain* (AUS; Figure *2*), *Antarctic Discovery* (AUS), *Saint André* (FRA), *Cap Kersaint* (FRA) and *Tronio* (ESP) to 50% of their longline sets across all research blocks, or as often as operationally possible.

b) Data collection: types and sample size or quantities of catch, effort and related biological, ecological and environmental data (e.g. sample size by location/haul)

Table 13. Summary of data collection by each participating Member. AUS – Australia; ESP – Spain; FRA – France; JPN – Japan; KOR – Republic of Korea. 'All' means all members who have fished under this research plan.

Data type	Member	Number/size of samples	Collection method/device	Objective
Catch and effort	All	Every longline deployment. All fish will be identified to species where possible, including those lost at the surface.	Catch and effort data will be recorded and reported according to CCAMLR Conservation Measures in force within the proposed SSRUs (summarised in Conservation Measures 41–05 and 41–11).	1–3
Toothfish biological data: Length (cm), weight (kg), sex and gonad stage	All	Target of 50 fish set^{-1}. Fine-scale biological data will be collected and recorded in accordance with Conservation Measures 23–07 and 23–04. KOR will collect samples of muscle tissue (5 fish per 10cm length bin per sex per SSRU), and stomach contents (20 fish per haul), as well as plankton and zooplankton samples, for investigation of trophic relationships and ecosystem function using stable isotope analyses (Objective 4). AUS will also collect up to 5 stomach samples per 5cm length class in SSRU 58.4.2 E which will be used by KOR under Objective 4.	Biological data will be collected using electronic fish measuring board and scales (AUS) or equivalent equipment (ESP, FRA, JPN and KOR). Gonad stage will be determined by visual inspection at sea.	1, 4
Toothfish ageing	All	Target of five otolith pairs per 1-cm length class between 100–200 cm. Otoliths will be collected from all fish < 100 cm.	According to the AAD ageing protocol and/or CCAMLR guidelines.	1
Toothfish tagging	All	Five fish per retained tonne (green weight). In addition, KOR will continue with deployment of archival tags.	T-bar tags in accordance with the CCAMLR Tagging Protocol. One archival tag will be deployed by KOR in Division 58.4.1 during the 2016/17 season.	1
Environmental and habitat data • Depth (m) • Temperature (°C) • Salinity (PSU) • Substrate composition • Benthic species composition	AUS, FRA, KOR	CTD loggers (AUS, FRA, KOR) and BVCs (AUS and FRA) will be attached to at least 50% of longlines across all research blocks, or as often as operationally possible (i.e.$\geq$ 1 CTD deployment per SSRU by KOR). Seafloor and fished areas will be mapped using vessel-based single-beam acoustics throughout the voyage	CTDs and BVCs attached to fishing gear.	2
Fish bycatch biological data; Length (cm), weight (kg), sex and gonad stage	All	Target of 50 fish $species^{-1}$ set^{-1} (length (cm), weight (kg), sex and gonad stage) Catches (kg) of VME indicator taxa will be recorded for each longline segment following protocols in Conservation Measures 22-07 and other bycatch following limits set out in 33-03.	Electronic fish measuring board and scales (AUS), or equivalent equipment (ESP, FRA, JPN and KOR). Gonad stage determined by visual inspection at sea.	3
Invertebrates bycatch data	All	Catches (kg) of VME indicator taxa will be recorded for each longline segment following protocols in Conservation Measures 22-07 and other bycatch following limits set out in 33-03. FRA will collect all benthic organisms as specified in Martin et al. (2017).	Standard on-board equipment or according the protocol outlined in Martin et al. (2017) (FRA)	2

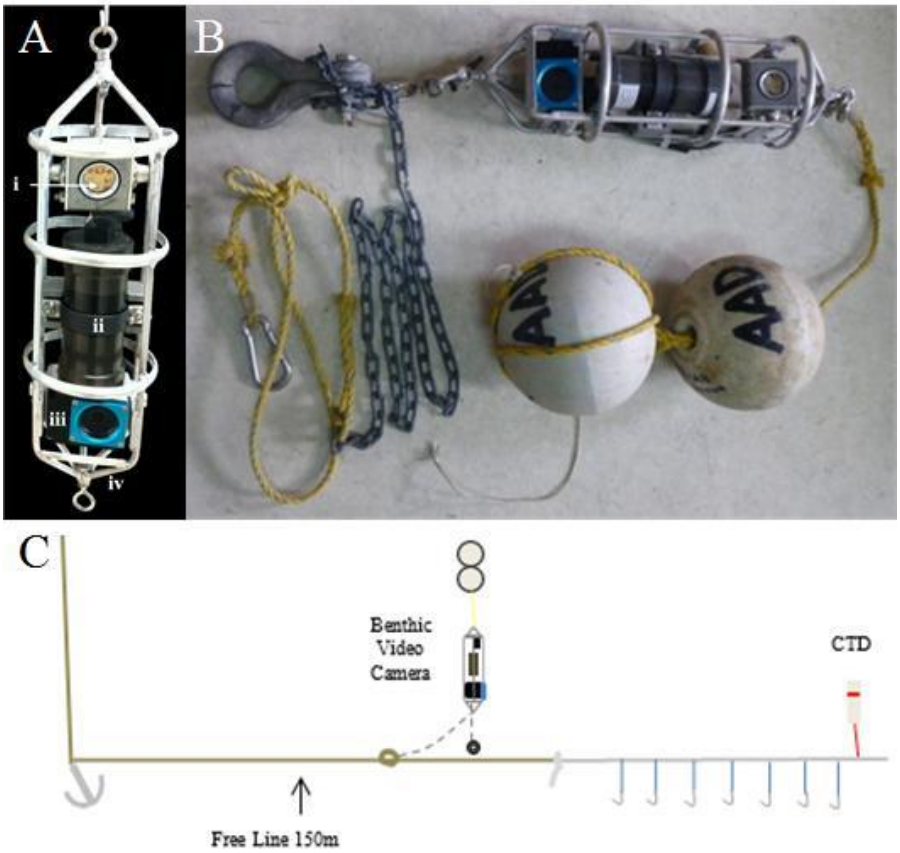


Figure 2. Benthic Video Camera system (panel A) containing light (i), battery housing (ii) and camera (iii) in crash frame (iv); its deployment setup (panel B); and attachment of BVC and CTD units on longlines (panel C). Diagram is not to scale.

(c) Method for data analysis to achieve the objectives in Section 1(a)

Objective 1: Toothfish catch rates, life-history-stage composition and size distributions will be summarized and compared between locations and depth strata. In areas where tagged fish are recovered, a detailed analysis of their movement, growth, and time at liberty will be made. Tagging and recapture data will be used in mark-recapture analyses (e.g. using Petersen tag-recapture models or integrated assessments) to estimate biomass within and across research blocks. Stock assessments for toothfish will utilize the following data:

- Toothfish catch (number and weight)
- Number of tagged and released fish
- Number of recaptured fish
- Catch length and age composition
- Biological parameters including estimates for growth, length-weight relationship, maturity, and natural mortality.

Objective 2: The processing of digital visual footage will be similar to those described in Welsford et al. (2014). Analysis may also be undertaken using computer programs such as *Benthic Video Annotator* (BVA) to derive benthos diversity and abundance counts from both stills and video footage. Spatially-explicit models (e.g. Generalized Linear or Generalized Additive Models) will be used to characterize

the relationships between toothfish relative density and the environmental covariates listed in Table 13, and make predictions of toothfish relative densities in un-fished sites.
Transport pathway and connection (sink and source) of egg and larvae of toothfish in East Antarctica is examined using Lagrangian particle tracking models. To simulate movements of particles, satellite altimetry data (IceSat, CryoSat, Jason series and AMSR) and ocean-ice coupling model output data (COCO) are employed with assessing various key physical and biological parameters which control and/or affect the distribution of particles. These sensitivity analyses will provide insights into potential transport patterns of egg and larval toothfish with the effective key factors inducing successful recruitment mechanism in East Antarctica. This modelling work is composed of the following parts:

1. Understanding the dynamic pattern of egg and larval transport of toothfish in East Antarctic using more than 10 years satellite data sets. The egg and larval movement is simulated using particle tracking techniques.
2. Investigating egg and larval transport patterns using various biological and physical parameters and ocean-ice coupling model output data. The egg and larval movement is simulated with various driving parameters such as eddies, sea ice, egg buoyancy, DVM, and spawning depth.
3. Sensitivity analysis to assess key factors affecting successful recruitment.

Objective 3: Information and models of bycatch composition, species distribution and, catch rates will be updated. Demographic and biological information on the species encountered will provide additional information for assessments of predominant bycatch species.

Objective 4: Trophic transfers from organic-matter sources to higher trophic levels will be traced using stable isotope ratios and fatty acid profiles. This will include investigation of trophic relationships between *D. mawsoni* and its prey, and subsequent biomarker analyses, to better understand carbon-energy transfer throughout Antarctic ecosystems.

Objective 5: The potential effects of sampling design will be evaluated in a research block by a comparison of hauls following a standardised sampling design (i.e. hauls in randomized-stratified locations), and following a non-standardised sampling design (i.e. hauls only depth-stratified). … [to be specified]

(d) How and when will the data meet the objectives of the research? (e.g. lead to a robust estimate of stock status and precautionary catch limits). Include evidence that the proposed methods are highly likely to be successful

This research plan aims to provide a comprehensive evaluation of existing management arrangements for toothfish in Divisions 58.4.1 and 58.4.2, and updated advice on precautionary catch limits as appropriate in 2022. In addition, environmental data will contribute to models of toothfish habitat use following surveys in 2021/22. It is also expected that data collected up to 2021/22 will allow for an updated assessment of spatial and depth distributions and comparison of relative densities between areas for predominant bycatch species.

The methods are likely to be successful based on the well-established fishing methods and sampling approaches already in place in Divisions 58.4.1 and 58.4.2, and Subareas 88.1 and 88.2. The notified vessels have extensive experience with these methods and their implementation in the Southern

Ocean. Further, the research providers have a good track record of delivering science that informs management advice in CCAMLR.

BVC systems have been developed and successfully deployed in Division 58.4.1 during the 2015/16 and 2016/17 seasons. Similar devices have been deployed successfully on longlines during commercial and research fishing activities at Heard Island and McDonald Islands, and BANZARE Bank (see Welsford et al. 2014). Data from these recordings readily enabled the identification and enumeration of benthic invertebrates, and were utilized in assessments of fishing impacts on benthic habitats. More recently, WG-SAM-16/34 reported on environmental and video data collected in Division 58.4.1 by the FV Antarctic Discovery (AUS) in 2015/16. This video footage indicated that the seafloor of 15 surveyed locations consisted of soft sediments or cobbles with low densities of VME indicator organisms. Mobile fauna, including squids, fish and echinoderms were also recorded. Thus the video technologies needed for Objective 2 have been demonstrated to be successful.

The employment of crew who are experienced in ice navigation and vessel handling will ensure that the vessels do not enter into areas beyond their ice classification. Fishing surveys have been planned with consideration of recent sea ice concentrations across the area using Passive Microwave Data (from Nimbus-7 Scanning Multichannel Microwave Radiometer [SMMR] and Defence Meteorological Satellite Program Special Sensor Microwave/Imager-Special Sensor Microwave Imager Sounder [DMSP SSM/I-SSMIS]) (Cavalieri et al. 1996), and detailed ice and weather forecasting from the Institute for Marine and Antarctic Studies (based in Hobart). Based on spatio-temporal overlap between historical sea ice concentrations and fishing activities, a threshold of 25% sea ice cover indicated the transition from fished to non-fished conditions. This threshold is much lower than the 60% used in the Ross Sea (Parker et al. 2014) due to the much harder and thicker sea ice found in this area. Based on these data, research blocks in Divisions 58.4.1 and 58.4.2 typically become accessible to longline fishing from January to April (Figure 11, Appendix 2). This generalisation is supported by exploratory fishing experience in Division 58.4.1 and 58.4.2 during the 2016/17 (WG-FSA-17/17r1) and 2017/18 (WG-SAM-18/17) fishing seasons.

4. Proposed catch limits

(a) Proposed catch limits and justification. (Note that the catch limits should be at a level not substantially above that necessary to obtain the information specified in the Research Plans and required to meet the objectives of the proposed research.)

The proposed catch limits for each fishing season will be those set annually by CCAMLR based on updated local biomass estimates.

We propose to adopt a similar approach to research catch allocation among CCAMLR Members to that adopted by the Commission in 2015 to 2018 (e.g. SC-CAMLR 2017, para 3.118); and set out in WG-FSA 15/54. Allocations of catch limits among members for the 2019/20 season will be discussed during the 2019 meetings in conjunction with the updated local biomass estimates.

The actual catch taken will be influenced by factors such as operational restrictions, macrourid by-catch limits, and sea-ice conditions. The allocation system in place to distribute initial catch shares between the research proponents in this area guarantees an agreed catch proportion in a research block, but can also lead to the catch limit not being taken in a research block.

We propose that notifying Members will confirm whether they intend to pursue research by SC CIRC by 1st January 2020. If any Member is not able to confirm that they will pursue research, their allocation will be evenly redistributed amongst the other notifying Members that have confirmed they will pursue research. If any Member has not commenced research activities by 1st February 2020, their allocation will also be evenly redistributed amongst the Members that have commenced research activities, or by another means agreed by all of members that have commenced research activities.

(b) Evaluation of the impact of the proposed catch on stock status

Rationale that proposed catch limits are consistent with Article II of the Convention

The proposed research is not expected to have an additional impact on stock status. The catch allocations referenced in Section 4a will be based on revised catch limits which are designated to provide reasonable assurances against negative impacts on stock status, consistent with the objective of CCAMLR and a precautionary approach.

Evaluation of timescales involved in determining the responses of harvested, dependent and related populations to fishing activities

Conditional upon CCAMLR review, survey and tag-recovery fishing from 2018/19 to 2021/22 will provide information on the biomass present in fished areas, and estimated long-term population responses to fishing activities.

Information on estimated removals, including IUU fishing activities, where available

IUU fishing activities have been recorded in Divisions 58.4.1 and 58.4.2 (SC-CAMLR 2015a, b). Evidence of IUU presence or activity continues to be recorded however no recent estimates of IUU toothfish catch exist.

CCAMLR-XXXVI/28 Rev. 2 provided information on IUU activity, including in Division 58.4.1. Catch data obtained by Spain from three IUU-listed vessels, the *Asian Warrior, Zemour 1* and *Zemour 2* operating in Division 58.4.1 in 2014. This data is likely to represent typical IUU fishing activity in Division 58.4.1 since 2004, when the vessels were first sighted, until 2015. Analyses of this data, including investigation of its utility for estimating total IUU removals for East Antarctica (WG-FSA-17 paragraph 2.16), were presented in WG-FSA 18/60. These results will be used in future assessments to account for historical IUU catches in Divisions 58.4.1 and 58.4.2.

(c) Details of dependent and related species and the likelihood of their being affected by the proposed fishery

Based on catches in Divisions 58.4.1 and 58.4.2, fish bycatch was dominated by the two families Macrouridae and Channichthydae (SC-CAMLR 2018a,b) which represented 98% of the fish bycatch biomass (WG-FSA-18/28). Other bycatch included:

- *Muraenolepis* spp.
- *Antimora rostrata*
- *Notothenidae*
- *Pogonophryne* spp.
- *Rajiformes*

The proposed research will maintain strict compliance with conservation measures regarding bycatch (CMs 41-05, 41-11 and 33-03) and the protection of seabirds and marine mammals (CMs 41-05, 41-11 and 25-02). Previous cases of seabird and mammal mortalities in Divisions 58.4.1 and 58.4.2 have involved the southern giant petrel (*Macronectes giganteus*), sooty shearwater (*Puffinus griseus*) and leopard seal (*Hydrurga leptonyx*;); however no seabird or mammal mortalities have been reported since 2005 (SC-CAMLR 2018a,b).

Previously, two VMEs and no VME risk areas, have been identified in Division 58.4.1, and no fishing will occur in those VMEs identified in CM-22-09 Annex 22-09/A. VME-related data will be collected and notified in accordance with Conservation Measure 22-06. Preliminary results indicated that the dominant macro-invertebrates bycatch species in Divisions 58.4.1 and 58.4.2 are Pennatulacea, Actinaria, Gorgonidae, Hexactinellidae and Ascidiacea (WG-FSA 18/51).
All registered and newly discovered vulnerable marine ecosystems (VMEs) will be avoided during fishing operations in accordance with Conservation Measure 22-07. Bycatch data and underwater video footage collected in Division 58.4.1 have been examined for the presence of vulnerable marine ecosystem (VME) indicator species, and these data have not lead to the identification of new VMEs (Maschette et al. 2017).

5. Research capability

(a) Name(s) and address of the chief scientist(s), research institute or authority responsible for planning and coordinating the research

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(b) Number of scientists and crew to be on board the vessel

Each vessel will carry at least two scientific observers, one of whom shall be appointed in accordance with the CCAMLR Scheme of International Scientific Observation. The other will be an observer appointed by fisheries management body/s of the Members participating in this research.

(c) Is there opportunity for inviting scientists from other Members? If so, indicate a number of such scientists

There is no space available for scientists from other Members aboard the fishing vessels.

(d) Commitment that the proposed fishing vessel(s) and nominated research provider(s) have the resources and capability to fulfil all obligations of the proposed Research Plan

The nominated vessels and on-board scientific observers have the resources and capability to fulfil all obligations of the proposed research plan. For example, the vessels (listed in Section 2b) are equipped with the fishing gear and all other facilities required to conduct this research in accordance with relevant conservation measures; as well as communication systems that allow direct telephone, fax, email and internet communication between the vessel and observer coordinators and fishery scientists. The nominated vessels and fishing companies are experienced operating in CCAMLR fisheries, including in Divisions 58.4.1 and 58.4.2.

Both Australian fishing vessels Antarctic Discovery (seasons 2015/16, 2016/17 and 2017/18) and Antarctic Chieftain (2017/18 and 2018/19) have experience participating in research in Division 58.4.1 and/or 58.4.2. Australian Longline Pty Ltd (ALPL) has a long history of high compliance and reporting performance in CCAMLR fisheries, including exploratory toothfish fisheries. In 1997, ALPL entered the Heard Island and McDonald Islands (HIMI) fishery (Division 58.5.2) and has subsequently operated three vessels in the HIMI fishery (including the *Antarctic Chieftain* from 2009–2014). In 2007/08, *Janas* successfully conducted a random stratified longline survey to collect data on the relative abundance of toothfish and bycatch species across the entire fished area of the BANZARE Bank (Division 58.4.3b) while flagged to Australia. The information collected on this voyage revealed the importance of BANZARE Bank as a spawning ground for *D. mawsoni* (Welsford et al. 2008), since reinforced by data

collected by Japan; and supported the hypothesis that the population in the area was likely to have been depleted by a combination of IUU and exploratory fishing (McKinlay et al 2008).

The fishing vessel *Le Saint-André* (France) has conducted exploratory fishing in Divisions 58.4.3a and 58.4.4b since 2012/13, in 58.4.2 since 2016/17 and in 58.4.1 in 2017/18. The fishing vessel *Cap Kersaint* (France) has operated along *Le Saint-André* in toothfish fisheries in Subarea 58.6 and Division 58.5.1 (French EEZ) since 2015/16. The Muséum National d'Histoire Naturelle (MNHN) has previously planned and carried out four scientific surveys of the toothfish stock (POKER) around the Kerguelen Islands in Division 58.5.1. The MNHN has developed stock assessments for *D. eleginoides* in Division 58.5.1 and in the vicinity of Crozet Islands (part of Subarea 58.6) using CASAL.

The fishing vessel *Shinsei maru No. 3* (Japan) has conducted exploratory fishing in these Divisions in three seasons since 2008/09. The National Research Institute of Far Seas Fisheries of Japan is developing formal collaborations with colleagues from New Zealand to consolidate its experience in toothfish aging.

The fishing vessel *Kingstar* (Republic of Korea) has conducted exploratory fishing in Divisions 58.4.1 and 58.4.2 in three seasons since 2014/15, the *No. 707 Hongjin* has fished in the Ross Sea for some years. . The National Institute of Fisheries Science (NIFS) of Republic of Korea is developing formal collaborations with colleagues from New Zealand to consolidate its experience in toothfish aging, analyses of archival tag data, and stock assessment using CASAL.

The fishing vessel *Tronio* (Spain) has conducted exploratory fishing in Divisions 58.4.1 and 58.4.2 in five seasons since 2012/13. It has fished in Division 58.4.1 from 2006, always in compliance with conservation measures. Researchers of the Spanish Institute of Oceanography (IEO) have collaborated with CCAMLR since 1986 when a Spanish Scientific Survey was conducted on the Scotia Arc and Antarctic Peninsula. Currently a program on otolith aging is underway, as well as molecular analysis for species identification.

6. Reporting for evaluation and review

(a) List of dates by which specific actions will be completed and reported to CCAMLR. If the research is a stand-alone survey, Members shall commit to providing a progress report to WG-FSA and/or WG-EMM for review and comment and a final report within 12 months of completion of the research to the Scientific Committee

A list of dates by which specific actions will be completed and reported to CCAMLR is provided in section 1b. A final report will be provided to WG-FSA in 2022, which will contain a comprehensive evaluation of existing management arrangements and updated advice on precautionary catch limits as appropriate.

(b) If research is multi-annual, Members shall commit to providing annual research reviews to be submitted to WG-FSA and/or WG-EMM, including review of progress towards meeting research objectives and associated proposed time lines in initial proposal, and proposals for adjustments to the research proposal if required

Following each season of data collection, a progress report will be submitted to WG-SAM and WG-FSA that addresses how the research is meeting objectives and whether any changes are required to research plans (details in section 1b).

References

Baeck GW, Choi S-G, Chung S and An DH (2018) Diet composition and feeding strategy of Antarctic toothfish, *Dissostichus mawsoni* in the research blocks 58 and 88 for the exploratory longline fishery in 2014–2018 of Korea. CCAMLR Document WG-FSA-18-24

Bestley S, Raymond B, Gales NJ, Harcourt RG, Hindell MA, Jonson ID, Nicol S, Péron C, Sumner MD, Weimerskirch H, Wotherspoon SJ and Cox MJ (2017) Predicting krill swarm characteristics important for marine predators foraging off East Antarctica. Ecography 40:001–016

Cavalieri D, Parkinson C, Gloersen P and Zwally HJ (1996, updated yearly). Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data. USA: NASA DAAC at the National Snow and Ice Data Center, Colorado

Delegation of Australia (2015) Research plan for exploratory fishing for toothfish (*Dissostichus* spp.) in East Antarctica (Divisions 58.4.1 and 58.4.2) by Australia. CCAMLR Document WG-FSA-15/47 Rev. 1

Delegations of Australia, France, Japan, Republic of Korea and Spain (2016) Joint research proposal for the *Dissostichus* spp. exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2) by Australia, France, Japan, Republic of Korea and Spain. CCAMLR Document WG-FSA-16/29

Delegations of Australia, France, Japan, Republic of Korea and Spain (2017) Continuation of multi-member research on the *Dissostichus mawsoni* exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2) by Australia, France, Japan, Republic of Korea and Spain. CCAMLR Document WG-FSA-17/18

Delegations of Australia, France, Japan, Republic of Korea and Spain (2018) Draft proposal for multi-Member research on the *Dissostichus mawsoni* exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2) from 2018/19 to 2021/22. CCAMLR Document WG-SAM-18/17

Delegations of Australia, France, Japan, Republic of Korea and Spain (2018) Proposal for multi-Member research on the *Dissostichus mawsoni* exploratory fishery in East Antarctica (Divisions 58.4.1 and 58.4.2) from 2018/19 to 2021/22. CCAMLR Document WG-FSA-18/59

Delegation of Australia and CCAMLR Secretariat (2018) Analyses of illegal, unreported and unregulated (IUU) fishing activities in Divisions 58.4.1 during the 2013/14 season and 58.4.3b during the 2014/15 season. CCAMLR Document WG-FSA-18/60

Eléaume M, Chazeau C, Martin A and Blettery J (2018) Preliminary report on invertebrate by-catch in research blocks 58.4.1, 58.4.2, 54.4.3a and 58.4.4b. CCAMLR Document WG-FSA-18-51

Hanchet SM, Rickard GJ, Fenaughty JM, Dunn A and Williams MJ (2008) A hypothetical life cycle for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region. CCAMLR Science 15: 35-53

Hanchet SM, Mormede S and Dunn A (2010). Distribution and relative abundance of Antarctic toothfish (*Dissostichus mawsoni*) on the Ross Sea shelf. CCAMLR Science 17: 33-51

Hartigan JA and Wong MA (1979) A K-means clustering algorithm. Applied Statistics 28:100–108

Kang C-K, Choi S-G, Lee J, Lee J and An D (2017) Diets of Antarctic toothfish estimated from fatty acids and stable isotopes. CCAMLR Document WG-FSA-17/12

Kim J, Choi S-G, Lee J, Lee J and An D (2017) Gonad analysis of Antarctic toothfish in Subareas 58.4 and 88.3. CCAMLR Document WG-FSA-17/09

Kim J-W, Choi S-G, Chung S and An D.H. (2018) Reproductive ecology of Antarctic toothfish, D*issostichus mawsoni* (Norman, 1937) (Actinopterygii: Nototheniidae), in the Antarctic waters (SSRUs 58 and 88). CCAMLR Document WG-FSA-18-65

Kuhn KL and Gaffney PM (2008) Population subdivision in the Antarctic toothfish (*Dissostichus mawsoni*) revealed by mitochondrial and nuclear single nucleotide polymorphisms (SNPs). Antarctic Science 20:327-338

Lam CH, Choi S-G, Kim E, Chung S, Lee J and An DH (2018) Depth and temperature preferences of Antarctica toothfish (*Dissostichus mawsoni*) from a pilot popup satellite archival tag study in the Mawson Sea. CCAMLR Document WG-FSA-18-22

López-Abellán LJ, Santamaría MTG, Sarralde R and Barreiro S (2017) Update of ongoing work on age and growth of Antarctic toothfish (*Dissostichus mawsoni*) from Division 58.4.1 by Spain. CCAMLR Document WG-FSA-17/66

Maschette D, Lamb T, Welsford D, Yates P and Ziegler P (2016) Report on the collection of environmental data during exploratory fishing by Australia in Division 58.4.1 during the 2015/16 fishing season. CCAMLR Document WG-SAM-16/34

Maschette D, Burch P, Yates P and Ziegler P (2017) Mitigation of Macrourus by-catch in research block 58.4.1_6 and estimation of *Macrourus* biomass and sustainable catch in Divisions 58.4.1 and 58.4.2. CCAMLR Document WG-FSA-17/16

Maschette D, Welsford D, Deagle B, Ziegler P and Yates P (2018a) Analysis of *Dissostichus mawsoni* population structure to inform CCAMLR management using high-throughput sequencing. CCAMLR Document WS-DmPH-18/08

Maschette D, Polanowski A, Deagle B, Welsford D and Ziegler P (2018b) Progress update on Antarctic toothfish inter-connectivity project. CCAMLR Document WG-FSA-18/64

Martin A, Eléaume M, Améziane N and Duhamel G (2017) New data acquisition protocol for benthos by-catch in the French fisheries of the Southern Ocean, presentation of the protocol and first preliminary results. CCAMLR Document WG-EMM-17/09

McKinlay JP, Welsford DC, Constable AJ and Nowara GB (2008) An assessment of the exploratory fishery for *Dissostichus* spp. on BANZARE Bank (CCAMLR Division 58.4.3b) based on fine-scale catch and effort data. CCAMLR Science 15:55-78

Mormede S and Dunn A (2013) Quantifying vessel performance in the CCAMLR tagging program: spatially and temporally controlled measures of tag-detection rates. CCAMLR Science 20:00-00

Mormede S, Dunn A, Hanchet S and Parker S (2014) Spatially explicit population dynamics models for Antarctic toothfish in the Ross Sea region. CCAMLR Science 21:19-37

Mugue N, Petrov A, Zelenina D, Gordeev I and Sergeev A (2013) Low genetic diversity and temporal stability in the Antarctic toothfish (*Dissostichus mawsoni*) from near-continental seas of the Antarctica. CCAMLR Document WG-FSA-13/07.

Nowara G, Farmer B, Barnes T, Ziegler P and Welsford D (2017) An update on the ageing of Antarctic toothfish, *Dissostichus mawsoni*, from East Antarctica and the Amundsen Sea. CCAMLR Document WG-FSA-17/15

Parker SJ, Hoyle SD, Fenaughty JM and Kohout A (2014) Methodology for automated spatial sea ice summaries in the Southern Ocean. CCAMLR Document WG-FSA-14/15

Robinson LM and Reid K (2014) Modelling the circumpolar distribution of Antarctic toothfish using correlative species distribution modelling methods. CCAMLR Document WG-FSA-14/65

Sarralde R, López-Abellán LJ and Barreiro S (2014) Results of the Spanish exploratory longline fishery for *Dissostichus* spp. in Divisions 58.4.1 and 58.4.2 in the 2013/14 season. CCAMLR Document WG-SAM-14/12 Rev. 1

López-Abellán LJ, Santamaría MTG, Sarralde R, Barreiro S, Farmer B and Barnes T (2018) Update of ongoing work on age and growth of Antarctic toothfish (*Dissostichus mawsoni*) from Division 58.4.1 by Australia and Spain. CCAMLR Document WG-FSA-18/54 Rev. 1

Péron C, Yates P, Maschette D, Chazeau C, Ziegler P, Welsford D, Gasco N and Duhamel G (2018) Report on fish by-catch on exploratory fishing in Divisions 58.4.1 and 58.4.2. CCAMLR Document WG-FSA-18/28

SC-CAMLR (2016) Report of the Thirty-Fifth Meeting of the Scientific Committee (SC-CAMLR-XXXVI). CCAMLR, Hobart, Australia

SC-CAMLR (2017a) Report of the Thirty-Sixth Meeting of the Scientific Committee (SC-CAMLR-XXXVII). CCAMLR, Hobart, Australia

SC-CAMLR (2018a) Fishery Report 2018: Exploratory fishery for *Dissostichus* spp. in Division 58.4.1. CCAMLR, Hobart, Australia

SC-CAMLR (2018b) Fishery Report 201b: Exploratory fishery for *Dissostichus* spp. in Division 58.4.2. CCAMLR, Hobart, Australia

Taki K, Kiyota M, Ichii T and Iwami T (2011) Distribution and population structure of *Dissostichus eleginoides* and *D. mawsoni* on BANZARE Bank (CCAMLR Division 58.4.3b), Indian Ocean. CCAMLR Science 18:145-153

Welsford DC, Robertson T and Nowara G (2008) Report on a longline survey conducted by the FV Janas in May 2008 on BANZARE Bank, and an assessment of the status of *Dissostichus* spp. in Division 58.4.3b. CCAMLR Document WG-FSA-08/57

Welsford DC (2011) Estimation of catch rate and mean weight in the exploratory *Dissostichus* fisheries across Divisions 58.4.1 and 58.4.2 using generalised additive models. CCAMLR Document WG-FSA-11/35

Welsford DC, Ewing GP, Constable AJ, Hibberd T and Kilpatrick R (2014) An assessment of the vulnerability of benthic habitats to impact by demersal gears. Australian Antarctic Division, Final Report for FRDC Project 2006/042

WG-FSA (2017) Report of the Working Group on Fish Stock Assessment. CCAMLR, Hobart, Australia

Yates P, Ziegler P, Burch P, Maschette D, Welsford D and Wotherspoon S (2017) Spatial variation in Antarctic toothfish (*Dissostichus mawsoni*) catch rate, mean weight, maturity stage and sex ratio across Divisions 58.4.1, 58.4.2 and 58.4.3b. CCAMLR Document WG-FSA-17/16

Yates PM, Ziegler P, Welsford DC, McIvor J, Farmer B and Woodcock E (2018) Spatial and temporal dynamics in the reproductive biology of Patagonian toothfish (*Dissostichus eleginoides*) on the Kerguelen Plateau. Journal of Fish Biology 19:34-54. doi: 10.1111/jfb.13479

Yates P and Ziegler P (2018) Report on *Dissostichus mawsoni* exploratory fishery research in East Antarctica (Divisions 58.4.1 and 58.4.2) between the 2011/12 and 2017/18 fishing seasons. CCAMLR Document WG-FSA-18/58 Rev.1

Yoon T-H, Kang H-E, Lee SR, Lee J-B, Baeck GW, Park H and Kim H-W (2017) Metabarcoding analysis of the stomach contents of the Antarctic toothfish (*Dissostichus mawsoni*) collected in the Antarctic Ocean. CCAMLR Document WG-FSA-17/P03

Appendices

Appendix 1. Quick-reference for the information required to assess research proposals using the criteria in SC-CAMLR-XXXVI, Annex 7, paragraph 4.7 and Tables 4 to 6.

Criteria	Response/reference
Conservation measure under which proposal submitted	CM 21-02
(i)[a] Is the proposed research likely to generate an index of local stock abundance?	Local biomass estimates form research blocks have been combined with habitat models using the method presented in WG-FSA-17/16 to provide broader-scale abundance indices (WG-FSA-18/58 Rev.1).
(i)[b] Is the proposed research likely to generate estimates of biological parameters relating to productivity?	Age and growth and maturation were reported in WG-FSA-18/54 Rev.1 and WG-FSA-18/65.
(i)[c] Is the proposed research likely to test a hypothesis of relationship of fish in the research area to the overall stock?	The stock hypothesis was presented in WG-FSA-17/16. This stock hypothesis is scheduled for a review in 2022 (Table 5).
(ii) Is the catch limit for the proposed research plan sufficient to achieve the agreed research objectives and consistent with Article II of the Convention?	Significant progress has been made under CCAMLR's precautionary catch limits for research blocks (summarised in WG-SAM-18/35 Rev. 1 and WG-SAM-18/17). Future catch limits will be based on agreed methods (e.g. based on trend analyses, WG-SAM-18/23) and revised biomass estimates.
(iii) Are the likely impacts from the proposed research to dependent and related species consistent with Article II?	Section 4c.
(iv) Does the proposed research contain the details needed for WG-SAM, WG-FSA and the Scientific Committee to evaluate the likelihood of success, and relevant milestones specified with the detail necessary to evaluate the likelihood of success of the proposal?	Table 5, and sections 1a and 3d.
(v) Do the proposed research platforms intended for this work have demonstrated experience and performance in toothfish tagging programs?	Section 5d. Tagging performance of the vessels was summarised in WG-FSA-18/58 Rev.1.
(vi) Has the collective research team demonstrated a thorough understanding of environmental conditions and associated logistics and capacity to carry out the proposed research plan (on the water)?	Section 3d (sea ice), and section 5d (vessel capability and experience),
(vii) Has the collective research team demonstrated experience and sufficient resources and capacity, or identified a reliable mechanism, for analysis of data to achieve the objectives of the research (data and sample analyses)?	Past progress is summarised in this document. Planning for future milestones is set out in Table 5.

Appendix 2. Review of spatial design

WG-SAM-11 para. 2.40 recommended three themes to be considered for the designation of research areas in data-poor fisheries. Here, we present data that has been used to evaluate the suitability of geographic areas for research against these themes.

(a) The area should be chosen with a reference to the stated objective of the research

Objective 1: Provide an assessment of the status and productivity of toothfish stocks in Divisions 58.4.1 and 58.4.2.

Tagging data is an important input in CCAMLR's approach to toothfish stock assessments. To identify areas with the highest probability of tag recaptures, the number of tagged fish in each research block in year *t* was estimated using the equation in WG-SAM-11 para. 2.42:

$$T_t = X_{t-1} C_{t-1} (1 - M_x) (e^{-\lambda}) (e^{-M}) + X_{t-2} C_{t-2} (1 - M_x) (e^{-2\lambda}) (e^{-2M}) + X_{t-3} C_{t-3} (1 - M_x) (e^{-3\lambda}) (e^{-3M}) + \text{.... etc.}$$

where T_t = tagged fish in year t
X_t = tagging rate (fish per tonne) in year t
C_t = (catch) in year t
M_x = tagging mortality
λ = annual tag loss rate approximation
M = natural mortality.

This equation does not include emigration, and therefore assumes that tagged fish do not move large distances. Although some tagged and recaptured *D. mawsoni* have undertaken long-distance movements, the majority of recaptured individuals remained in the vicinity where they were tagged (WG-FSA-17/06). The estimated numbers of tagged fish available in 2018/19, released from 2010-2018, are shown in Figure 3, and total numbers of recaptures from 2010-2018 are shown in Figure 4. Year 2010 was chosen as the start year based on advice of WG-FSA-15 (para 5.22).

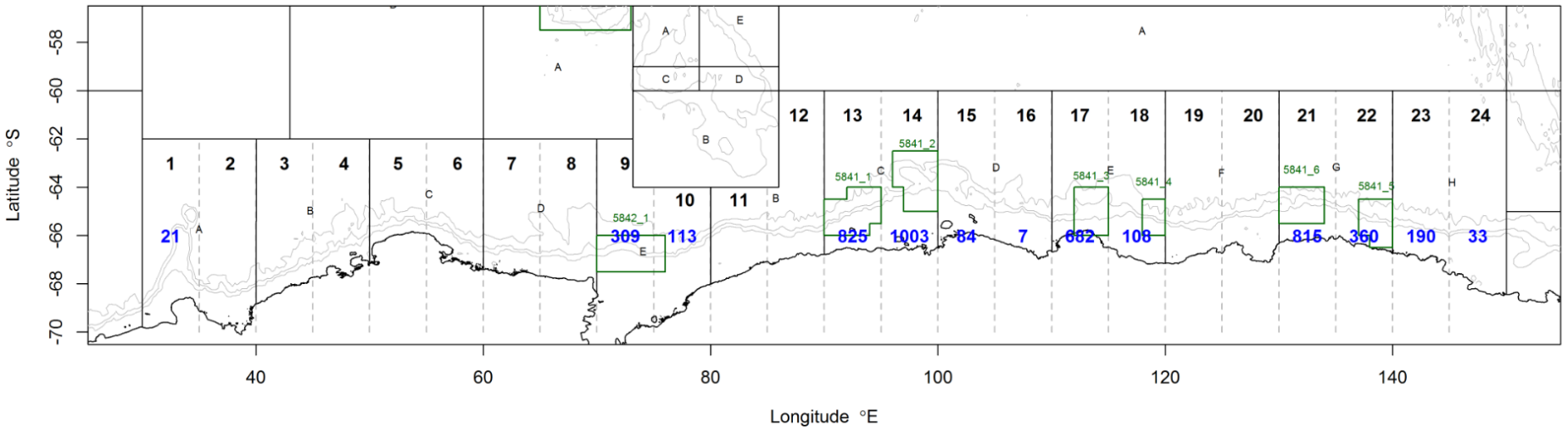

Figure 3. Estimated number of tags available in the 2018/19 fishing season (blue text) estimated using the equation in WG-SAM-11 para. 2.42. Black lines = SSRU boundaries, green lines = research block boundaries, grey dashed lines = areas considered in the review of research locations.

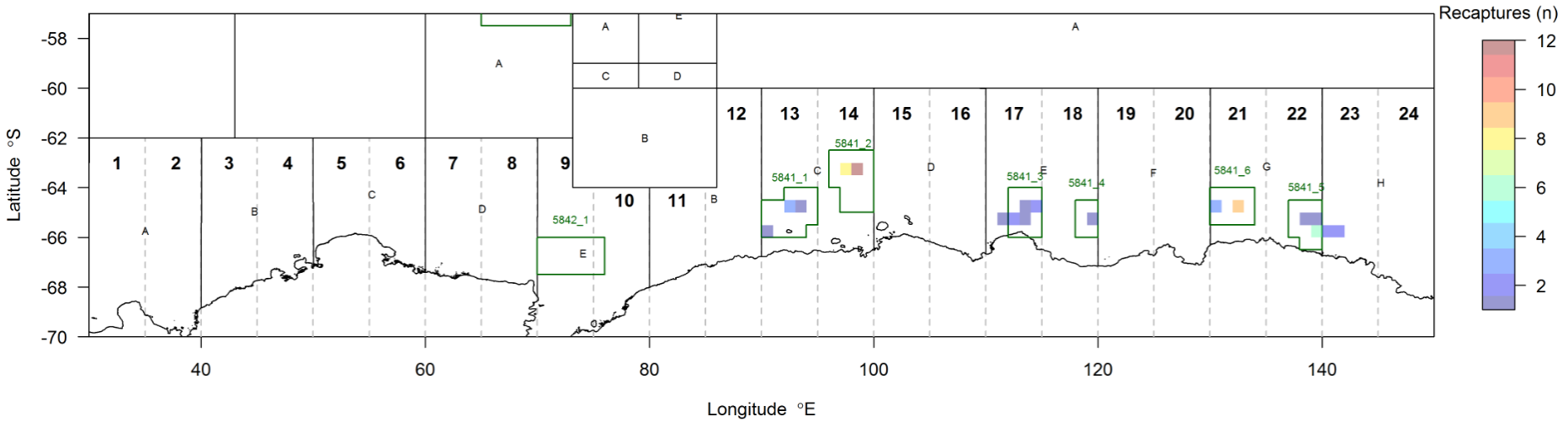

Figure 4. Number of tag recaptures from 2010-2018. Black lines = SSRU boundaries, green lines = research block boundaries, grey dashed lines = areas considered in the review of research locations.

Objective 2: Identify the spatial distributions of toothfish, important habitats and vulnerable marine ecosystems (VME) in order to inform spatial management approaches.

Stock delineation and functioning is an important consideration for the development of spatial management approaches. Yates et al. (2017) used generalised additive mixed models to characterise relationships between environmental variables and (1) relative density, (2) mean weight, and (3) proportion of mature *D. mawsoni*; across Divisions 58.4.1, 58.4.2 and 58.4.3b. Considerable spatial heterogeneity in mean weight and maturity indicated that *D. mawsoni* are not randomly distributed across East Antarctica (Figure 5, Figure 6), and these results were used to refine hypotheses regarding stock structure and function. It has been hypothesised that spawning fish on BANZARE Bank originate from nearby locations along the slope and shelf, especially Prydz Bay (Welsford et al. 2008, Taki et al. 2011, Welsford 2011). Individuals of macroscopic gonad stage ≥ 3 were considered to have the potential to spawn during the season in which they were sampled (Yates et al. 2018). Therefore the predicted proportions of mature fish were used to investigate potential spawning areas. The majority of fish were in spawning condition on Gunnerus Ridge (SSRU 58.4.2A), BANZARE Bank (Division 58.4.3b) and on Bruce Rice Plateau within SSRUs 58.4.1C–D and 58.4.1E (Figure 5), providing additional evidence these may be important spawning areas. One of these putative spawning areas is within an existing research block, i.e. 5841_2 in SSRU 58.4.1C.

The models for relative density, mean weight and proportion mature used by Yates et al. (2017) are based on data sampled by fishing vessels and extrapolated into un-sampled areas. These, in some areas extensive, data gaps can introduce large uncertainty in predicting biological features and catch rates.

Objective 3: Identify the spatial and depth distributions of bycatch species, and inform bycatch mitigation measures.

Maschette et al. (2017) proposed to concentrate fishing effort to a depth range with the highest ratio of target to bycatch species, i.e. 1000 - 1700 m, in areas with large amounts of bycatch (Figure 7).
VMEs have been notified in SSRU 58.4.1H, adjacent to research block 5841_5 and fishing should be avoided in this area (CM-22-09 Annex 22-09/A).

Objective 4: Improve the understanding of trophic relationships and ecosystem function to assist the development of ecosystem-based fisheries management approaches.
Sampling across a range of locations and toothfish bode size and life-history stages will be important as reflected in Objectives 1-3.

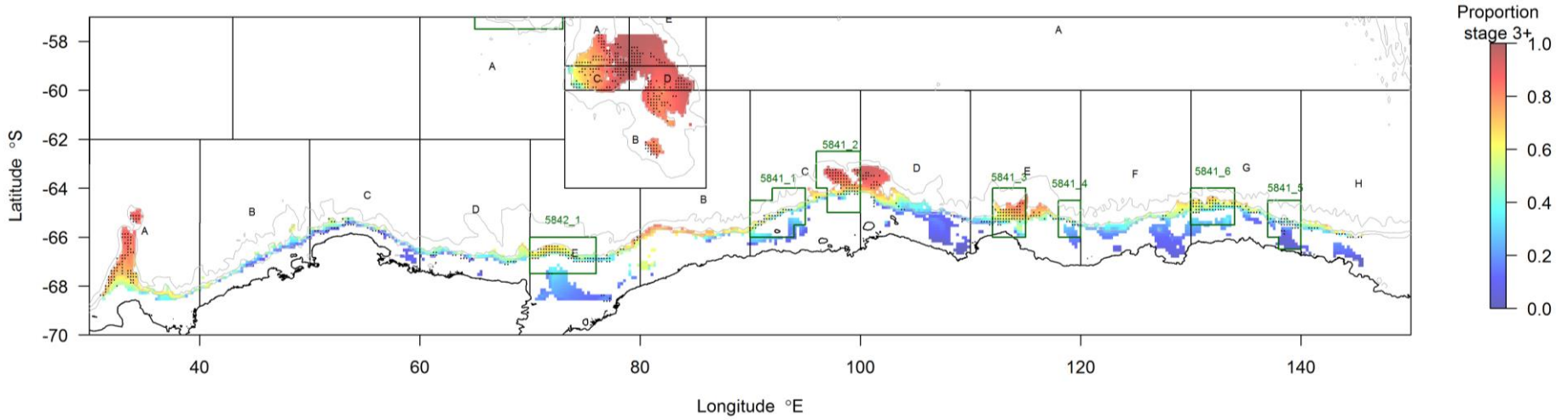

Figure 5. Predicted proportions of fish with maturity stage ≥ 3, from WG-FSA-17/16. Black lines = SSRU boundaries, green lines = research block boundaries.

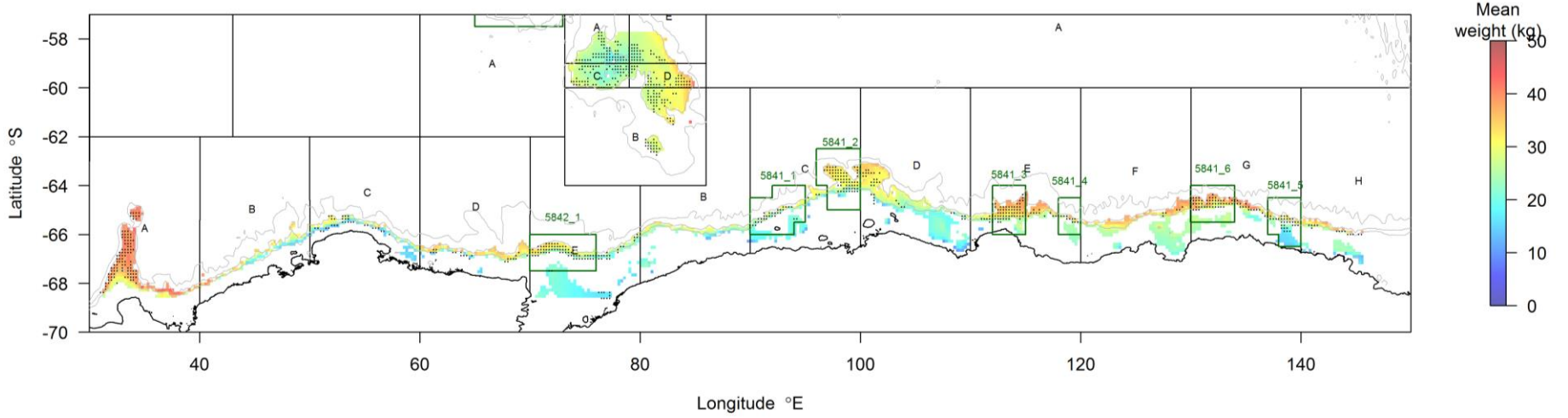

Figure 6. Predicted mean individual weight (kg), from WG-FSA-17/16. Black lines = SSRU boundaries, green lines = research block boundaries.

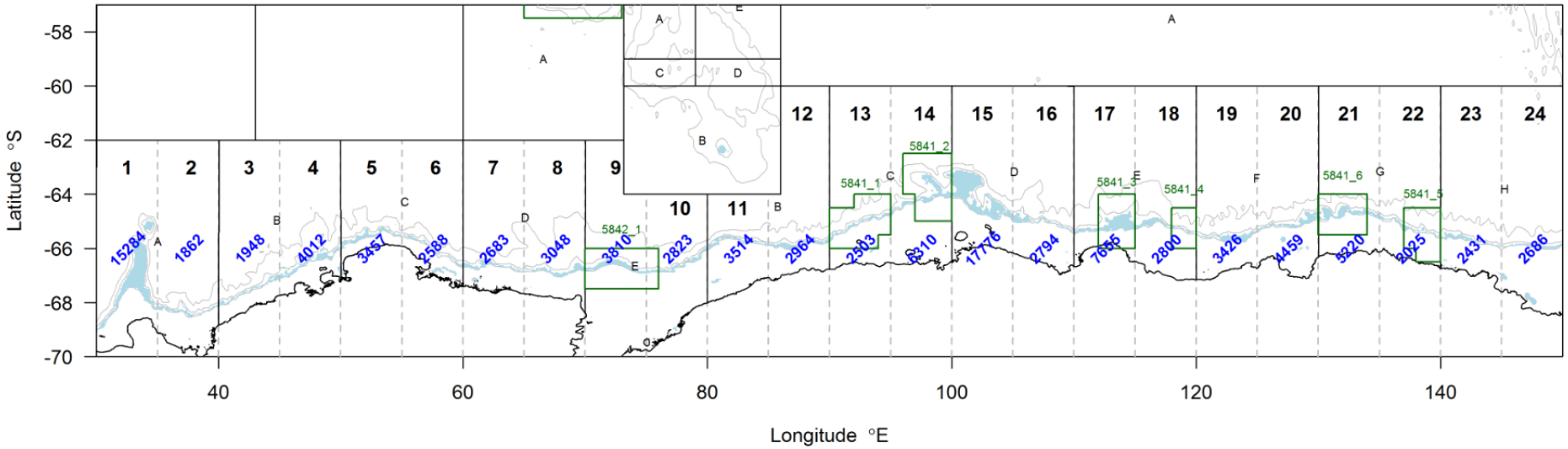

Figure 7. Distribution of depths between 1000 and 1700 m with the highest ratio of target to bycatch species (Maschette et al. 2017). Blue text is the total area (km^2) with depth between 1000–1700 m. Black lines = SSRU boundaries, green lines = research block boundaries, grey dashed lines = areas considered in the review of research locations.

(b) Priority areas include those where catch rates indicate that a viable toothfish fishery may be present depending on catch rates, catch history and size of fishable seabed areas

Data on predicted catch rates (Figure 8), catch history (Figure 9), previous fishing effort (Figure 10), and sea ice accessibility (Figure 11, Figure 12) can be used to evaluate the viability of fishing areas. The distribution of seabed areas within a depth range identified as (a) accessible to longline fishing, and (b) having high ratio of target to bycatch catch rates is provided in Figure 7.

(c) Consideration should also be given to the likely role of a particular SSRU in the plausible stock hypothesis (i.e. is it only juveniles in the area?)

Outputs for the consideration of the likely role of areas in the stock hypothesis are presented under section (a).

Table 14. Values underlying the ranking of area suitability in Figure 1. Rows with letters (L, M, H) were evaluated as described in section 3a. The raster layers used to calculate these values are presented in Figure 8 – Figure 12.

Division	58.4.2										58.4.1													
SSRU	A	A	B	B	C	C	D	D	E	E	B	B	C	C	D	D	E	E	F	F	G	G	H	H
With research block									1				1	2			3	4			6	5		
Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Available tags (n)	21	0	0	0	0	0	0	0	309	113	0	0	825	1003	84	7	682	108	0	0	815	360	190	33
Recaptures (n)	0	0	0	0	0	0	0	0	0	0	0	0	5	20	0	0	7	1	0	0	12	8	4	0
Local assessment	L	L	L	L	L	L	L	L	H	L	L	L	H	H	L	L	H	H	L	L	H	H	L	L
Area-wide assessment	L	L	L	L	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H	L	L
Key life-history stages	H	M	L	L	L	L	L	M	H	H	M	L	M	H	H	L	M	M	L	L	L	L	L	L
No data for habitat model	M	H	H	H	H	H	M	L	L	L	M	L	L	L	L	L	L	L	L	L	L	L	L	L
Avoid VME	H	M	M	M	H	M	M	M	H	H	M	M	H	H	M	M	H	H	M	M	H	H	L	L
Catch rates (max, kg/1000 hooks)	164	94	133	178	218	224	246	247	245	159	140	283	249	206	134	95	133	153	162	186	173	153	351	287
Fishing history (tonnes)	12.84	0	0	0	0	0	0	0	87.55	42.35	0	0	260.73	275.42	28.4	2.53	244.51	44.44	0	0	258.18	99.78	73.52	11.24
Habitat area (km^2)	15284	1862	1948	4012	3457	2588	2683	3048	3810	2823	3514	2964	2503	6310	17776	2794	7655	2800	3426	4459	5220	2025	2431	2686
Sea ice (mean, see **Error! Reference source not found.**)	0.86	0.18	0.4	0.57	0.74	0.46	0.62	0.58	0.63	0.44	0.4	0.52	0.57	0.66	0.7	0.6	0.7	0.55	0.57	0.72	0.92	0.74	0.69	0.25
See Key life-history stages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

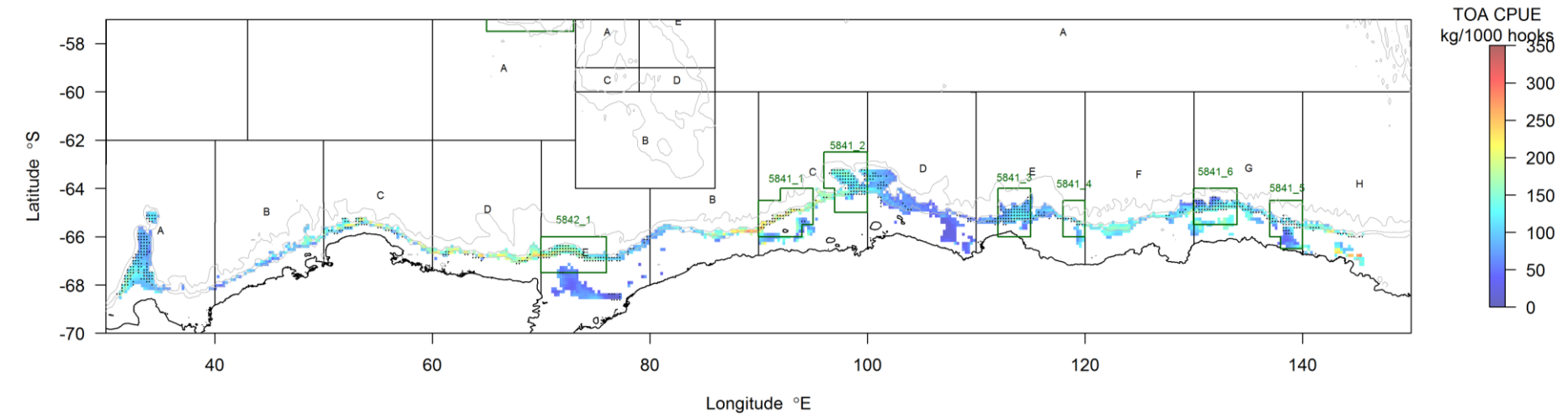

Figure 8. Predicted TOA CPUE from WG-FSA-17/16, based on data from 2003-2017. Black lines = SSRU boundaries, green lines = research block boundaries.

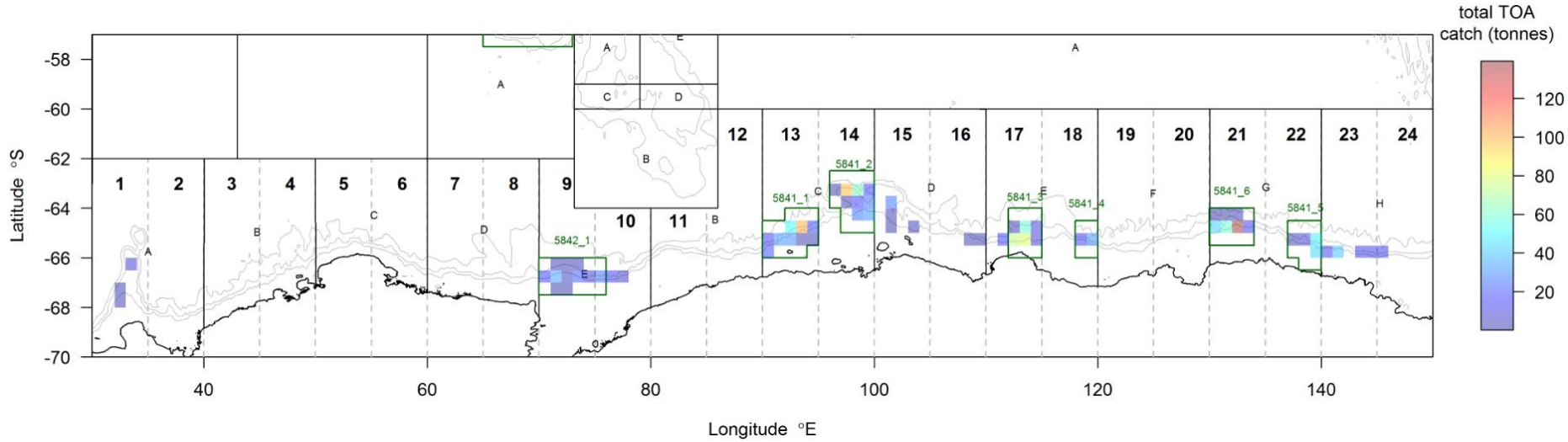

Figure 9. Total toothfish removals (t) between 2010 and 2018. Black lines = SSRU boundaries, green lines = research block boundaries.

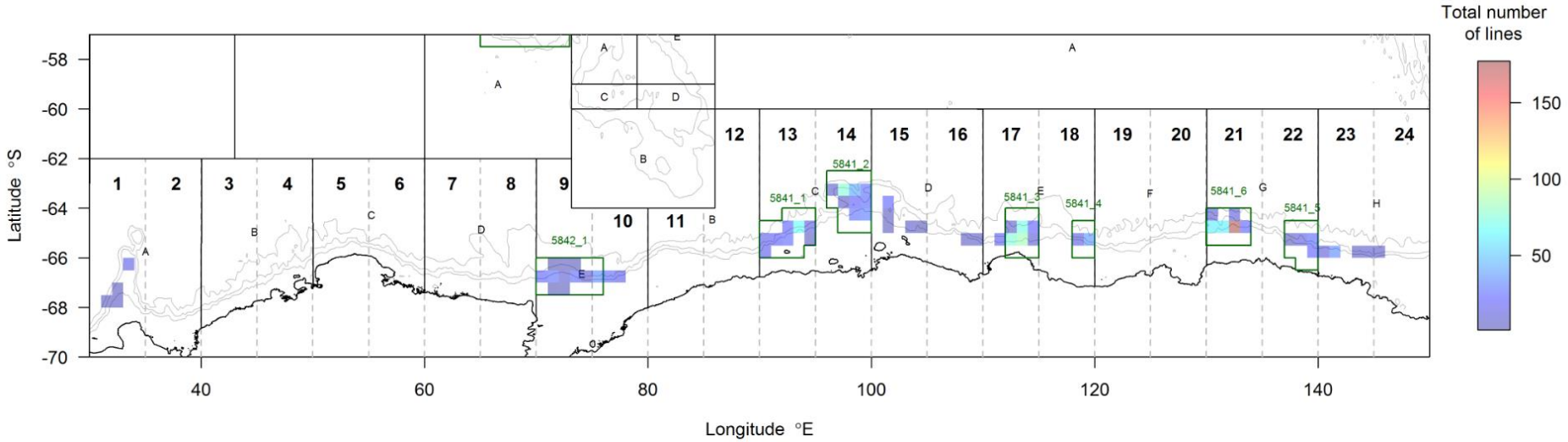

Figure 10. Distribution of fishing effort between 2010 and 2018. Black lines = SSRU boundaries, green lines = research block boundaries.

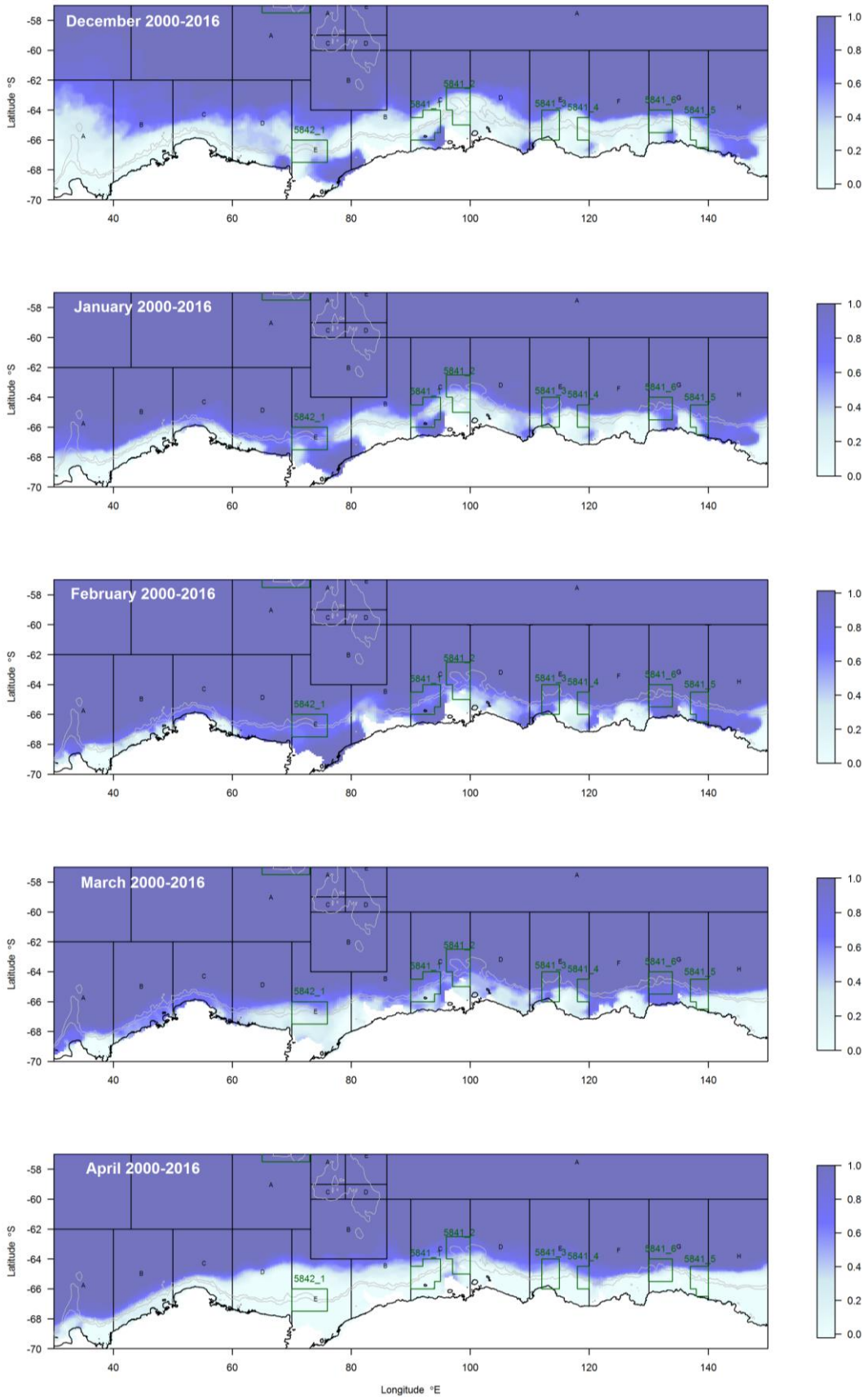

Figure 11. Proportion of years from 2000–2016 with sea ice cover < 25% during December, January, February, March and April. Research blocks in Divisions 58.4.1 and 58.4.2 typically become accessible to longline fishing during January to April. Sea ice data are from Cavalieri et al. (1996). Bathymetric contours (GEBCO; grey lines) are for 2000 and 1000 m.

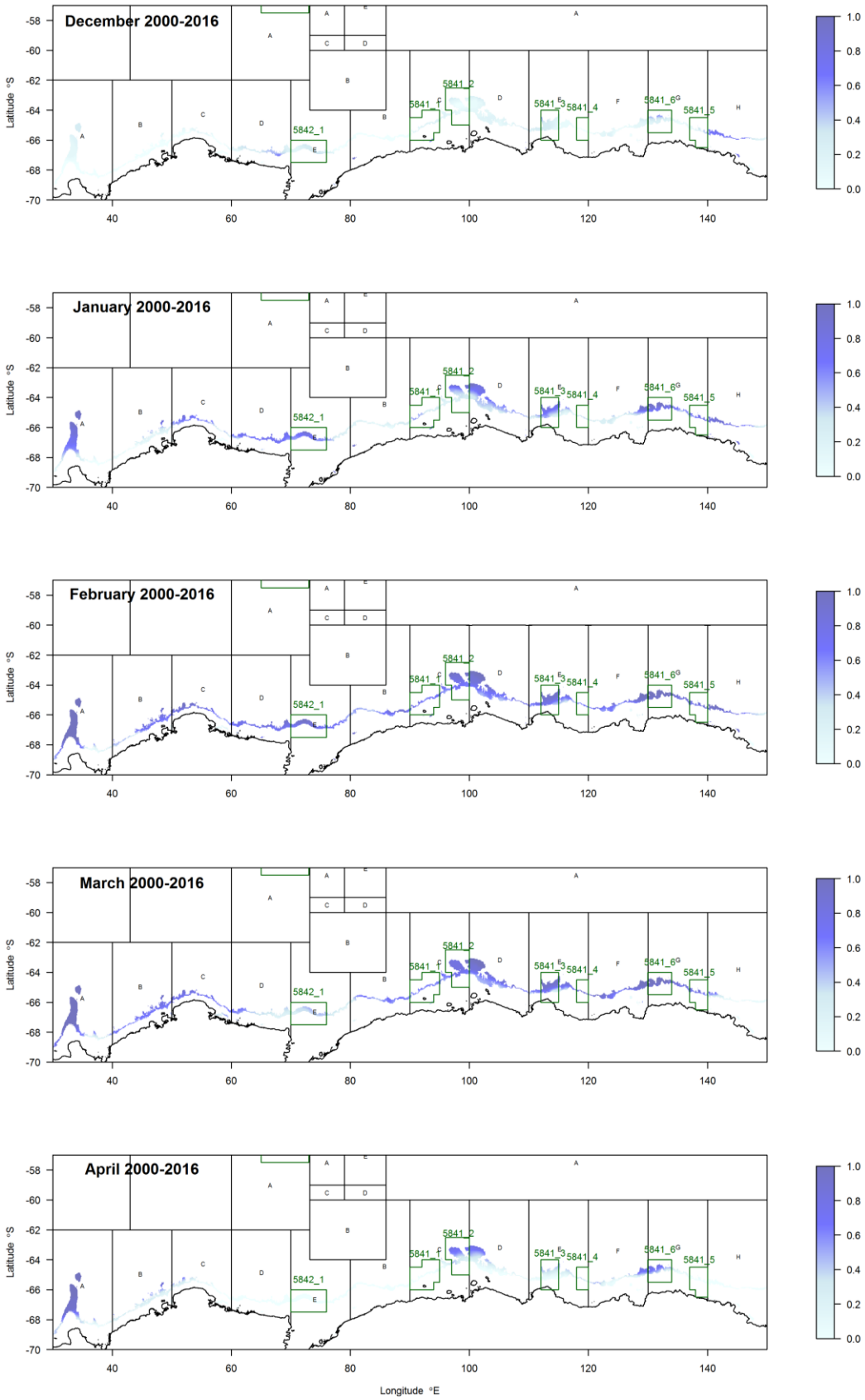

Figure 12. Proportion of years from 2000–2016 with sea ice cover < 25% during December, January, February, March and April. This is the same ice data as in Figure 11, however it is cropped to areas with depths between 1000-2000 m to aid in visual interpretation of ice conditions in potential fishing areas. Sea ice data are from Cavalieri et al. (1996).