



SCIENTIFIC COUNCIL WORKING GROUP ON ECOSYSTEM SCIENCE AND ASSESSMENT – NOVEMBER 2025

**Report of the 18th Meeting of the NAFO Scientific Council
Working Group on Ecosystem Science and Assessment (WG-ESA)**

**Instituto Español de Oceanografía (IEO), Madrid, Spain
4-12 November 2025**

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**REPORT OF THE SCIENTIFIC COUNCIL WORKING GROUP ON ECOSYSTEM SCIENCE AND ASSESSMENT
(WG-ESA)**

4-12 November 2025

1. Opening by the co-Chairs

The NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA) met during 4 - 12 November 2025 to address matters referred to it by the Scientific Council relating to various Commission requests, as well as its wider terms of reference.

The meeting was opened at 11:02 (GMT +1) on 4 November 2025 by the co-Chairs, Mar Sacau Cuadrado (EU) and Alfonso Pérez Rodríguez (EU). The meeting was conducted in a hybrid format, with participants attending both in person and remotely. The co-Chairs presented the detailed agenda and outlined the work plan for the meeting as well as the terms of reference and the Commission requests relevant to the working group. The Terms of Reference (ToRs) and Commission requests are presented in the Agenda in Annex 1. A list of participants is presented in Appendix 2.

2. Appointment of Rapporteur

The NAFO Secretariat (Andrea Perreault) was appointed as rapporteur.

3. Adoption of Agenda

The agenda and detailed agenda were adopted as circulated (see Appendix 1).

THEME 1: SPATIAL CONSIDERATIONS

4. Update on identification and mapping of sensitive species and habitats (VMEs) in the NAFO area.

a) ToR 1.1. Update on VME indicator species data and VME indicator species distribution from EU; EU-Spain Groundfish Surveys and Canadian Surveys. Temporal trends on VME catches.

i) EU-Spain and Portugal and EU-Spain Groundfish Surveys (2025)

During 2025, R/V *Vizconde de Eza* carried out three surveys: 1) In Division 3L (Flemish Pass) sampling between 125 - 1467 meters depth, with a total of 90 tows (82 valid); 2) In Division 3M (Flemish Cap) sampling between 135 - 1464 m depth, with a total of 189 tows (182 valid); and 3) In Divisions 3NO (Grand Banks of Newfoundland) sampling between 46 - 1444 m depth with a total of 116 tows (113 valid). In total there were 377 bottom trawl tows, 18 of them considered invalid due to technical problems during the fishing operation. In addition, 8 hauls were conducted inside VME closures. 109 hauls out of 377 valid tows have shown zero catches (i.e. no presence) of VME indicator species groups. This represents the 28.91% of the total valid hauls. A brief description of the survey methodology can be found in Durán Muñoz *et al.* (2020). Sponges were recorded in 203 of the 377 valid tows (53.85% of valid tows analyzed), at mean depths between 135 and 1467 m. There was one significant catch of sponges (≥ 100 kg/tow) in these tows, which fell outside the VME polygons for sponges, but inside VME closures. Large gorgonians were recorded in 4 of the 377 valid tows (1.06% of valid tows analyzed), at mean depths between 572 and 681 m. There was one significant catch of large gorgonians (≥ 0.6 kg/tow) in these tows, which fell outside VME closed areas and outside the VME polygons for large gorgonians. Small gorgonians were recorded in 57 of the 377 valid tows (15.12% of valid tows analyzed), at mean depths between 231 and 1464 m. There were no significant catches of small gorgonians (≥ 0.2 kg/tow) in these tows. Sea pens were recorded in 160 of the 377 valid tows (42.44% of valid tows analyzed), at mean depths between 66 and 1448 m. There was one significant catch of sea pens (≥ 1.3 kg/tow) in these tows, which fell within the VME polygons for sea pens, but outside VME closures. Black corals were recorded in 31 of the 377 valid tows (8.22% of valid tows analyzed), at mean depths between 231 and 1265 m. There were two significant catches of black corals (≥ 0.4 kg/tow) in these tows, both of which fell outside the VME polygons for black corals and outside VME closures. Sea squirts (*Boltenia ovifera*) were recorded in 7 of the 377 valid tows (1.86% of valid tows analyzed), at mean depths between 57 and 681 m. There was one significant catch of sea squirts (≥ 0.35 kg/tow) in these tows (Figure 7A), which fell within the VME polygons for sea squirts and outside VME closures. Bryozoans were recorded in 30 of the 377 valid tows (7.96% of valid tows analyzed), at mean depths between 46 and 1199 m. There were no significant catches of bryozoans (≥ 0.2 kg/tow) in these tows.

ii) Canadian Surveys (2023 Fall / 2025 Spring)

From fall 2023 to spring 2025, the Canadian Multispecies Surveys, conducted by Fisheries and Oceans Canada, DFO (McCallum and Walsh, 1996), sampled the Grand Bank of Newfoundland (NAFO Divs. 3LNO) between mean depths of 39 - 1404 m, with a total of 338 tows (313 valid). A total of 9 hauls were conducted inside VME closures. Data is presented for two periods: Fall 2023/Spring 2024 and Fall 2024/Spring 2025 for corals because in 2024 coral data was not presented at the WG-ESA meeting. For sponges, bryozoans and sea squirts, Fall 2024/Spring 2025 data is presented. DFO is transitioning from the CCGS *Teleost* and CCGS *Alfred Needler* to new vessels, the CCGS *Capt Jacques Cartier* and CCGS *John Cabot* for its annual spring (Div. 3LNOPs) and fall (Div. 2HJ3KLNO) multispecies surveys. The MV *Calvert* was also used as part of the comparative fishing. The new vessels use the same fishing protocols as previous (*Needler* and *Teleost*), but minor modifications have been made to the trawl (Wheeland *et al.*, 2023). Conversion factors between these vessels are not available for corals, bryozoans, and *Boltenia ovifera*, because the available data were insufficient for their development. For this reason, caution should be taken when interpreting the data presented here based on the new vessels. For sponges, on the other hand, analysis of the CCGS *Teleost*- *Capt Jacques Cartier/John Cabot* comparison (Fall 2021-2022, 2HJ3KL) and CCGS *Needler*-*John Cabot* comparison (Fall 2021-2022, Fall 3KL) indicated no significant difference in catchability of sponges, and conversion factors do not need to be applied for this group (DFO, 2024, 2025). The Fall 2023 sets that fell within the NRA were conducted using the CCGS *John Cabot* (35% of all sets, with one unsuccessful set), CCGS *Capt Jacques Cartier* (51% of all sets, with one unsuccessful set), and CCGS *Teleost* (14% of all sets, with one unsuccessful set). The Spring 2024 sets were conducted using the CCGS *John Cabot* (61% of all sets, with four unsuccessful sets), and MV *Calvert* (39% of all sets, with one unsuccessful set). The Fall 2024 sets were conducted using the CCGS *John Cabot* (100% of all sets, with 10 unsuccessful sets). The Spring 2025 sets were conducted using the CCGS *John Cabot* (100% of all sets, with seven unsuccessful sets). Sponges were recorded in 84 of the 128 valid tows (65.62% of valid tows analyzed, 2024-2025), at mean depths between 44 and 704 m. There were no significant catches of sponges (≥ 100 kg/tow) in these tows. Large gorgonians were recorded in 8 of the 313 valid tows (2.56% of valid tows analyzed, 2023-2025), at mean depths between 389 and 652 m. There were three significant catches of large gorgonians (≥ 0.6 kg/tow) in these tows, one of which fell within the VME polygons for large gorgonians and within VME closures. Small gorgonians were recorded in 12 of the 313 valid tows (3.83% of valid tows analyzed, 2023-2025), at mean depths between 53 and 1048 m. There were two significant catches of small gorgonians (≥ 0.2 kg/tow) in these tows, one of which fell within the VME polygons for small gorgonians, and the another one fell inside VME closures. Sea pens were recorded in 52 of the 313 valid tows (16.61% of valid tows analyzed, 2023-2025), at mean depths between 61 and 1184 m. There were four significant catches of sea pens (≥ 1.3 kg/tow) in these tows (Figure 5B), all of them outside VME closures, but one of which fell within the VME polygons for sea pens. Black corals were not recorded in any of the DFO Fall 2023 - Spring 2025 surveys. Sea squirts were recorded in 2 of the 128 valid tows (1.56% of valid tows analyzed, 2024-2025), at mean depths between 205 and 206 m. There were no significant catches of sea squirts (≥ 0.35 kg/tow) in these tows. Bryozoans were recorded in 7 of the 128 valid tows (5.47% of valid tows analyzed, 2024-2025), at mean depths between 189 and 604 m. There were no significant catches of bryozoans (≥ 0.2 kg/tow) in these tows.

Above information of EU-Spain/Portugal and Canadian surveys, including distribution maps of VME species groups, is further detailed in SCR Doc. 25/050.

Acknowledgements

The data collection of the EU Groundfish Surveys used in this paper has been funded by the EU through the European Maritime, Fisheries and Aquaculture Fund (EMFAF) within the Spanish Work Plan for the collection of data in the fisheries and aquaculture sectors in relation to the Common Fisheries Policy. SAM's contract was supported by BATISCAFO project. This output reflects only the author's view (SAM; MS & PDM) and the European Union cannot be held responsible for any use that may be made of the information contained therein. BMN, RC, and VWH acknowledge and thank DFO-NL personnel and Canadian Coast Guard captains and crew for Canadian data collection.

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Abalo-Morla, S., Sacau, M., Command, R.J., Neves, B.M., Hayes, V., and Durán-Muñoz, P. (2025). New preliminary data on VME encounters in NAFO Regulatory Area (Divs. 3LMNO) from EU: EU-Spain and Portugal

Groundfish Surveys (2025) and Canadian surveys (Fall 2023 - Spring 2025). NAFO SCR Doc. 25/050 Serial No. N7698.

DFO. (2024). Newfoundland & Labrador Comparative Fishing Analysis – Part 1. In DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/002. (Erratum: August 2024).

DFO. (2025). Newfoundland & Labrador Comparative Fishing Analysis – Part 2. In *DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.* 2025/037.

Durán Muñoz, P., Sacau, M., García-Alegre, A., Román, E. (2020) Cold-water corals and deep-sea sponges by-catch mitigation: Dealing with groundfish survey data in the management of the northwest Atlantic Ocean high seas fisheries. *Marine Policy*, 116, 103712. <https://doi.org/10.1016/j.marpol.2019.103712>

McCallum, Barry R., and Walsh, S. J. (1996). Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971-present. *NAFO SCR Doc.*, 96/50.

Wheeland, L., Trueman, S., Rideout, R. (2023). Coverage of the 2022 Canadian (Newfoundland and Labrador Region) Multi-Species RV Bottom Trawl Survey with notes on Comparative Fishing. NAFO SCR Doc. 23/042.

b) ToR 1.2. Improvements to the Quality Assurance (QA) of data on VME indicators from RV catches

i) Data Quality Checking Procedures (2020-2024)

The data call for the previous KDE analyses (Kenchington *et al.*, 2019) was for the seven VME functional groups, that is Large-Sized Sponges, Sea Pens, Large Gorgonian Corals, Small Gorgonian Corals, Black Corals, Erect Bryozoans, and Sea Squirts (*Boltenia ovifera*). This focus on functional groups, rather than species or taxon, arose from the first iterations of the work where there was uncertainty in the identification of these taxa to lower taxonomic levels such as genus or species, and no photos or subsamples were available to confirm identification subsequently. However, over time greater attention has been given to identification, both at sea and in post-survey protocols. As a result, the more recent data for most VME functional groups now includes data identified to species and/or genus (Murillo *et al.*, 2024; Murillo *et al.*, 2025). Exceptions are for the bryozoans, which are only recorded at that level in all surveys, and the Canadian sponge data which is only recorded as 'Porifera'.

Data from the EU was first provided in 2002, and from 2011-2019, individual VME indicator taxa were identified to the extent possible and provided to NAFO for the species distribution modeling (SDM) work (see Murillo *et al.*, 2024; Murillo *et al.*, 2025). Data from Canada were provided with records as early as 1995 for some functional groups. For the corals (large and small gorgonian corals, sea pens, and black corals), updates provided by Ms. V. Hayes (DFO, NWAFC) in 2024 included identifications to the species level or the lowest taxon that could be assigned with confidence. Such identifications commenced with records in 2000 through to 2022. Therefore, for most VME indicator taxa, the functional group biomass data used for the 2019 KDE analyses was compared with the taxon-specific data provided in 2024 for the SDMs for overlapping time periods. Ideally, the sum of the biomass of the component taxa used for the SDMs should equal the weight provided for the functional group in each trawl set. However, a number of discrepancies were found for most of the functional groups (details in Kenchington *et al.*, 2025). Some of the errors were created at sea (coding errors) while others were in the data handling of both the data providers and the data analysts, primarily in the omission of key taxa that should have been included, but also due to changes made through QC checks by the data provider after 2019. The new data were used in preference to the earlier data sets provided.

In future, a systematic review framework of data provided for the review of the areas closed to protect VME should be in place to avoid, to the extent possible, such mistakes.

References

Kenchington, E., Lirette, C., Murillo, F.J., Hayes, V., Sacau, M. & Gonçalves, P. (2025). Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO Scientific Council Research Document, SCR Doc. 25/036: 1-126.

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- Murillo, F.J., Abalo Morla, S., Downie, A.-L., Lirette, C., Paulin, N., Wang, Z., *et al.* (2025). Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Species Distribution Models of Selected Vulnerable Marine Ecosystem Indicators (Large and Small Gorgonian Corals, Erect Bryozoans and Sea Squirts). NAFO Scientific Council Research Document, SCR Doc. 25/035: 1-62.
- Murillo, F.J., Downie, A.-L., Abalo Morla, S., Lirette, C., Paulin, N., Wang, Z., *et al.* (2024). Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Species Distribution Models of Selected Vulnerable Marine Ecosystem Indicators (Large-Sized Sponges, Sea Pens and Black Corals). NAFO Scientific Council Research Document 24/063, Serial No. N7601. 105 pp. <https://www.nafo.int/Portals/0/PDFs/sc/2024/scr24-063.pdf>

c) ToR 1.3. Update on the methodology to assess the presence of *Pennatula aculeata*

Claude Nozères¹, Ellen Kenchington¹, Laurence De Clippele², Jinshan Xu¹ (1: Canada, 2: UK)

An update from the 2024 WG-ESA meeting was presented on sea pen (superfamily Pennatulioidea) movement patterns observed over several months in images from benthic landers in the Gully canyon. This followed the publication of the report on the image analysis methodology using machine learning, image cataloguing, and BIIGLE web annotations (Nozères *et al.*, 2025). Retraction into the sediment by *Pennatula aculeata* was analyzed for a group in a foreground area. Most images had most sea pens visible and very rarely were they seen as mostly hidden. Group retraction was generally periodic at about 14-day cycles following lunar age, more evident in autumn 2022 (October-December), than in winter-spring 2023 (January-June) when more sea pens remained expanded more often. Environmental variables such as fatty acids from collected sediment traps and sea surface Chl *a* also coincided with higher levels into the spring months. Marine snow, or visible particles in the dark background of images, were counted by machine learning to provide another potential index of available food. While it showed some periodicity, again with mostly higher levels in winter-spring, this pattern was not directly associated with the sea pen group. Random Forest modelling had Chl *a*, fatty acids, and lunar age as among the important positive predictors for expanded sea pens, as a group and for an individual colony. Further analyses are suggested on oceanographic parameters (tidal cycles) and individual sea pen colonies. During the review of sea pens retractions, several instances were also seen of horizontal movements, with colonies, entering, re-positioning, or leaving the field of view. This was seen for both *P. aculeata* and *Balticina finmarchica*, usually by very small colonies. Some rare interactions were also observed, with inadvertent disruptions by larger fishes and crabs in the sea pen fields, and occasional retraction or displacement upon contact of a *Ptillella grandis* by a predatory sea star. Publications are forthcoming for the group retraction patterns by *P. aculeata*, and a separate note on the horizontal movements by individual colonies. While retractions were rare events, they have the potential to affect monitoring of *P. aculeata* density conducted by either image or trawl surveys, and it is recommended to develop predictors of group retractions from seasonal or lunar cycles. Horizontal movements affected relatively few sea pens and were not likely to impact periodic monitoring, though they may become of interest in following long-term patterns of recruitment or changes in sea pen fields.

Reference

- Nozères, C., De Clippele, L.H., Xu, J., and Kenchington, E. (2025). Comparison of *Pennatula aculeata* sea pen abundance at a fixed site over an extended period using machine learning, image annotation, and image cataloguing. Can. Manusc. Rep. Fish. Aquat. Sci. 3300: iv + 34 p. <https://doi.org/10.60825/gce6-8934>.

d) ToR 1.4 Okeanos Explorer work on the Corner Rise Seamounts [COM. Request#6b]

The Corner Rise Seamounts (CRS) are scheduled for re-evaluation of their protection status by NAFO in 2027, requiring updated evidence on the presence and extent of Vulnerable Marine Ecosystems (VMEs). Using video data collected during NOAA's Okeanos Explorer "North-Atlantic Stepping Stones" expedition in 2021, we analyzed coral and sponge diversity across eight CRS seamounts to (1) characterize community composition,

(2) assess environmental influences on assemblage structure, and (3) identify high-density, structure-forming VME habitats based on OSPAR criteria. A total of 112 coral and sponge morphotypes were recorded from 4,655 observations. Assemblages were primarily structured by depth and associated water masses, revealing distinct clusters with characteristic indicator taxa. These results indicate environmental specificity among taxa and suggest dispersal barriers and mechanisms shaping deep-sea community structure. Six high-density coral and sponge habitats exceeded the 25 m² OSPAR threshold for coral gardens, confirming multiple VME habitats down to 2,500 m depth. This study provides a reproducible, video-based approach for identifying VMEs and contributes new scientific information for NAFO's 2027 re-evaluation. It also strengthens the case for maintaining and expanding protections for the southern CRS seamounts, which currently fall only under non-binding WECAFC recommendations. Additional threats, including potential deep-sea mining and climate-driven shifts in species distributions, should also be considered in future management planning. For further information see Beckmann *et al.* (2026).

Reference

Beckmann, L. M., Eveborn, L., Kenchington, E., and Waller, R. (2026). Hotspots beyond borders: quantitative assessment of Vulnerable Marine Ecosystems on the Corner Rise seamounts with implications for conservation planning. *Frontiers in Marine Science* 13:1752067. doi: 10.3389/fmars.2026.1752067

e) ToR 1.5 Update on the centralized data repository using ArcGIS Online [COM. Request#6a]

The Data Subgroup outlined a number of recommendations to advance the development of a centralized data repository using ArcGIS Online to host data and data-products for scientific advice at the November 2024 annual meeting (NAFO, 2024). In preparation for the 2025 WG-ESA meeting, the Data Subgroup continued to advance the work by:

- 1) Identifying additional priority data layers which support the SAI reassessment, contacting the relevant data providers, initiating the acquisition of data layers and metadata, and uploading layers to ArcGIS Online. This included the addition of metadata to data layers that had been previously uploaded to ArcGIS Online to test the platform, but excluded metadata.
- 2) Trialing the Standard Metadata Form as data layers were uploaded to ArcGIS Online.
- 3) Testing the practicality of using the ArcGIS StoryMap, which documented workflows for data preparation and upload to ArcGIS Online, to guide the preparation and upload of data layers.
- 4) Submitting the required documentation to the NAFO Secretariat in April 2025 outlining the costs associated with using ArcGIS Online for the centralized data repository which was approved for the 2026 budget.
- 5) Testing the assignment and use of the available Viewer License to Data Subgroup members.
- 6) Developing a draft template in support of streamlining and standardizing RV trawl data requests.

The progress made during the intersessional period, as detailed above, was presented to the WG-ESA at the meeting in November 2025. Meeting participants provided useful feedback to the Data Subgroup to guide work moving forward.

i) Data Layers

The data layers that had been uploaded to ArcGIS Online were reviewed by meeting participants. It was noted that the initial focus was uploading current data layers that would directly support the upcoming SAI assessment. It was recommended by the Data Subgroup that once this was complete, the focus could then shift to uploading previous versions of these layers to provide a lineage of changes over time. Members did note that in some cases data layers from previous analyses had been found to contain errors after their publication. There was a discussion about how that information could be captured within the data repository to ensure users would be aware of potential issues. The Data Subgroup indicated that it would be possible to add an obvious flag within the metadata description noting that errors had been found in the file and it was not recommended for use moving forward. There was some discussion as to whether erroneous files should be removed from the

data repository, but the general consensus was that all data layers created and published should be retained as they represented the best available products at the time they were generated.

Members were able to review some of the layers through a brief demonstration of the data repository provided by the Data Subgroup. Participants did note that while the year attribute within layer names was useful for discriminating between different versions of the same analysis, it would also be good to capture what SAI reassessment data layers were associated with. To address this, the Data Subgroup proposed the use of tags which would allow members to search data layers by SAI assessment year.

ii) Metadata

Generally, the standard metadata form was found to work well for supporting the upload of data layers to ArcGIS Online. Reviewing samples of the metadata generated for layers uploaded to the data repository prompted some discussion among members about how much detail should be included. One suggestion was that it would be useful to include the units of measurement associated with layers, citing the fishing intensity layers which are computed using many different metrics. There was some additional discussion surrounding the amount of detail included in the metadata, with some members preferring to see more detail and others wanting to be careful to not have the form become too onerous for the data providers. It is expected that the amount of detail required will be an ongoing consideration that may be dependent on the data layer being uploaded.

iii) Workflow Documentation

The Data Subgroup indicated that the ArcGIS StoryMap developed during the 2024 meeting was found to be exceptionally useful for guiding the update of data layers in advance of the 2025 meeting. It was noted by the Data Subgroup that some maintenance will be required as the ArcGIS Online user interface is updated. Considering the cyclical nature that data uploads are expected to follow, it is recommended that the StoryMap continues to be used to guide data management.

iv) Licensing

It was confirmed through an investigation of the August 2025 ESRI Licensing Agreement that the Viewer Licenses are classified as Named User Licenses. As a result, the Data Subgroup indicated that the licenses would have to be assigned to members using their individual email addresses. It was noted that members should not provide email addresses that are already associated with an ArcGIS Online account, as an email address can only be associated with one ArcGIS Online account. The Secretariat would retain all administrative control to assign and revoke Viewer Licenses in line with the Licensing Agreement. To simplify license management, the Data Subgroup proposed the development of some documentation for the Secretariat to reference as needed.

v) RV Trawl Requests

The draft template developed by the Data Subgroup to store RV trawl data in support of streamlining data requests was presented to meeting participants for consideration. It initiated a lengthy discussion surrounding what columns should be included in the template. Specific requests were made to include columns detailing: start and end latitude, longitude, and time, survey season, survey specific gear and species codes, AphiaID, success of set (e.g. valid or null), whether there were associated photos, and possibly indicating what year the record was last updated/revised. There were discussions about what time zone should be associated with time columns, with many participants indicating that UTC would likely be the best to apply to all data sets for consistency. There was some concern about how this would complicate looking into diurnal patterns associated with trawl records, which was noted by the Data Subgroup.

Feedback from data providers (e.g. Instituto Español de Oceanografía [IEO]; Instituto de Investigaciones Marinas [IIM]; Instituto Português do Mar e da Atmosfera [IPMA]; Department of Fisheries and Oceans Newfoundland and Labrador Region [DFO NL]) did indicate that there were some concerns about the column names used within the draft template. Specifically, that the names did not match those used within the underlying databases. It was indicated that this would cause some complications with preparing the data for the template. Furthermore, there was some confusion about specifically what the column headers represented as the various data providers and data sets may collect different types of data that could be considered relevant. It was recommended that additional work be done on defining the column headers in the Data Dictionary to ensure that equivalent data is provided from all data providers. In addition, data providers also raised concerns

about the inclusion of a count (number of specimens of a species) column, given that some species may not be retrieved as whole specimens making counts difficult to reliably generate and could mislead end-users. Members did indicate that while the count column was not commonly used in analyses by the group it had been considered for work conducted on sea pens in the past. As a result, it was suggested that the count column was retained but that additional details be added to the Data Dictionary tab of the template indicating that the counts are unreliable for specimens that are easily damaged during retrieval. Members did note that counts were not regularly reviewed for quality control in the DFO NL data sets.

Further to this, the group discussed how best to upload, store, and maintain, RV trawl data on the ArcGIS Online data repository. Specifically, whether there would be a single data layer that is updated to include each additional year of data as requested, or would each annual request encompass all years of available data that is uploaded as a new data layer on the data repository. Feedback generally supported the latter, indicating that this would ensure that each data layer would be a snapshot of the data in the year it was used and would include any erroneous records that could have fed into the analyses it supported. In addition, requesting the full time series with each data request would ensure that any revisions and/or corrections made by the data providers to past records would be captured within the updated data set. However, concerns were raised about how the Data Subgroup would incorporate edits that data users would have made to previous versions of data sets in post-processing. There was agreement that this would be a problem, with some feedback indicating that it may be possible for data users and providers to offer feedback to one another as changes were made to the original data to ensure that they would be carried forward across years. While this option was supported by meeting participants, some members did make it clear that it could be complicated and that some modifications may ultimately be missed. Another suggestion was to develop an evergreen script that would be updated by the data users each year to consistently apply the same revisions to the data across the time series.

With respect to the timeline and frequency of data requests, meeting participants did indicate that the various surveys are conducted at different times of the year, and the subsequent quality control is performed on an irregular schedule as capacity allows. Canadian participants expressed further concern given the potential for reductions in staff required to support this work, as any changes imposed on data providers would result in additional workload for them. Ultimately members agreed that a flexible timeline should be applied for ongoing data requests. The frequency of data requests that would best support ongoing work was also discussed. While generally the requests are related to the update of VME layers every five years, members did note that interim data requests do come up outside of this cycle. Some members felt that an annual request would be too frequent for the working group's current requirements, but ultimately the group opted to trial conducting an annual data request and determine whether the frequency would need to be modified at a later date. There was some consideration as to who the request should be submitted by, and it was determined that one consistent member of the working group from the Bedford Institute of Oceanography (BIO) would be responsible for submitting data requests.

It was proposed that data requests be made to capture the best data available at the time of data requests. Furthermore, that the requests be broad to ensure as many records as possible (e.g. fish, invertebrates, VME species, litter) are made available by data providers. Members indicated that there are notable differences in the data collected by the EU and the Canadian surveys report (e.g. Canada does not reliably report litter), which was noted by the Data Subgroup and could be captured in the Data Dictionary as a caveat for data users. Data providers also indicated that it was important the requests clearly capture how the data will be used to encourage continued support from management moving forward.

With respect to the data that is provided as part of the data requests, the Data Subgroup did discuss whether it would be suitable for upload to the data repository. However, members did express concern that this pre-processed data could be used inappropriately. This was addressed by indicating that the pre-processed data would be clearly identified and access could be restricted to specific members of the working group. The post-processed versions of these data would be made available for the subsequent analysis by working group members. In terms of compiling the data, it was proposed that the various data providers (e.g. IEO, IIM, IMPA, and DFO NL) submit data in the format of the RV trawl data template. These data would be post-processed by the data requestor (e.g. BIO) and aggregated into a single file that would support subsequent analyses.

Finally, concerns were raised about how credit could be given to acknowledge the work that goes into collecting, processing, and preparing the trawl data to support WG-ESA analyses. Data providers from the EU

did indicate that there is a standardized acknowledgement included in their data requests that is incorporated into any publications generated using these data. There was support among the members to develop a similar mechanism within the Canadian data request forms to acknowledge the collection, processing, and preparation of the underlying data, with additional credit (e.g. co-authorship) extended to the providers if warranted.

vi) Upcoming Work

Based on feedback from meeting participants, the Data Subgroup has identified the following items to address during the intersessional period:

- 1) Incorporate updates into the standard metadata form.
- 2) Continue the upload of relevant data layers to the centralized data repository, prioritizing those associated with the upcoming SAI reassessment.
- 3) Monitor credit usage on the ArcGIS Online data repository.
- 4) Develop documentation for managing the distribution of Viewer Licenses.
- 5) Trial the use of mechanisms to streamline RV trawl data requests, including the update and use of the RV trawl data template.
- 6) Draft the standard acknowledgement text to be used in requests for Canadian RV trawl data.

Reference

NAFO. (2024). Report of the Scientific Council Working Group on Ecosystem Science and Assessment, 12 - 21 November 2024, Halifax, Canada. NAFO SCS Doc. 24/20.

THEME 2: STATUS, FUNCTIONING AND DYNAMICS OF NAFO MARINE ECOSYSTEMS

- 5. Update on recent and relevant research related to status, functioning and dynamics of ecosystems in the NAFO area**
 - a) ToR 2.1. VMEs in the NAFO Regulatory Area: Updated SDM of Selected VME Indicators (Large and Small Gorgonian Corals, Erect Bryozoans and Sea Squirts) [COM. Request#6b]**
 - i) *Species Distribution Modeling of Large and Small Gorgonian Corals, Erect Bryozoans and Sea Squirts in the NAFO Regulatory Area***

Species distribution modeling (SDM) predicts the presence/absence or abundance/biomass of a species or habitat (the response variable) from environmental variables thought to influence it (the predictor variables). SDMs help to inform on the closed area boundaries and have been used to modify the areas of significant concentrations of Large-Sized Sponges and Large Gorgonian Corals produced through kernel density analyses (KDE) in the previous review completed in 2019 (NAFO, 2019).

At the 2024 WG-ESA meeting, maps showing the predicted distributions of Large-Sized Sponges, Sea Pens and Black Corals were presented, along with those for a number of subgroups of Sponges (i.e., sub order Astrophorina, the families Tetillidae and Polymastiidae and sponge grounds (catches above a weight threshold from the kernel density analyses (KDE)) and Sea Pens (i.e., genera *Balticina*, *Funiculina*, *Anthoptilum* and *Pennatula*) (Murillo *et al.*, 2024).

Here we present SDMs for the VME functional groups Large Gorgonian Corals, Small Gorgonian Corals, Erect Bryozoans and Sea Squirts (mostly a single species, *Boltenia ovifera*). SDMs for Large Gorgonian Corals (Knudby *et al.*, 2013), Erect Bryozoans and Sea Squirts (*Boltenia ovifera*) (Kenchington *et al.*, 2019) have previously been incorporated into the NAFO assessment of VMEs (NAFO, 2019), however, the Small Gorgonian Corals have not previously been assessed. For the Erect Bryozoans, we have also modeled the distribution of the Erect Bryozoan VME habitat as determined through use of the kernel density analysis (KDE) threshold established in 2019 using research vessel catches ≥ 0.2 kg of erect bryozoans (Kenchington *et al.*, 2019). This modeling was performed to focus the large area of suitable habitat for erect bryozoans on the smaller areas where they form VMEs. Within the Small Gorgonian Corals we also present models

for *Acanella arbuscula* and *Radicipes gracilis*. These additional models will be used to compare the results of the predicted distributions of individual taxa versus that of their functional group. They also will be used to assess whether the current closed areas and fishing impacts differentially impact these species. We follow the methods applied for the VME functional groups Large-Sized Sponges, Sea Pens and Black Coral (Murillo *et al.*, 2024).

Full details of the biological and environmental data, model fitting, variable importance and evaluation of model performance are presented in Murillo *et al.* (2025). All models generally scored high accuracy across the validation statistics (Murillo *et al.*, 2025). Here, for each model performed we provide maps of the predicted Presences/Absences based on a threshold of Sensitivity=Specificity, showing the areas of extrapolation and uncertainty expressed as the frequency of Presences/Absences from the 10 cross-validation runs and the average probability of the maximum frequency class.

ii) Large Gorgonian Corals

Species distribution models were performed for the large gorgonian coral functional group (Figure 5.1).

iii) Small Gorgonian Corals

Species distribution models were performed for the small gorgonian coral functional group (Figure 5.2) and the small gorgonians *Acanella arbuscula* (Figure 5.3) and *Radicipes gracilis* (Figure 5.4).

iv) Erect Bryozoans

Species distribution models were performed for the erect bryozoan functional group (Figure 5.5) and erect bryozoan VME habitat (Figure 5.6).

v) Sea Squirts

Species distribution models were performed for the Sea Squirt (*Boltenia ovifera*) functional group (Figure 5.7).

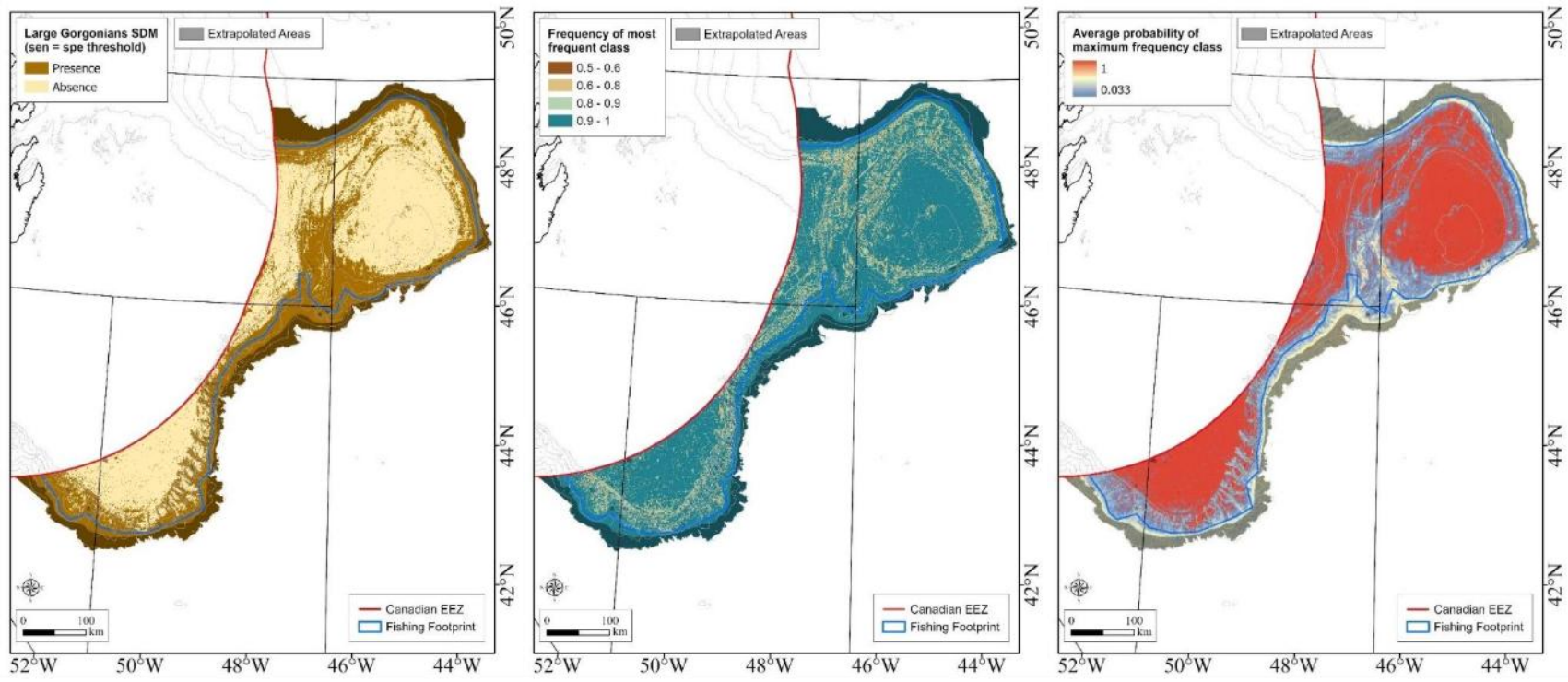


Figure 5.1. Predicted Presences/Absences of Large Gorgonian Coral Functional Group in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs (middle panel) and the average probability of the maximum frequency class (right panel). The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

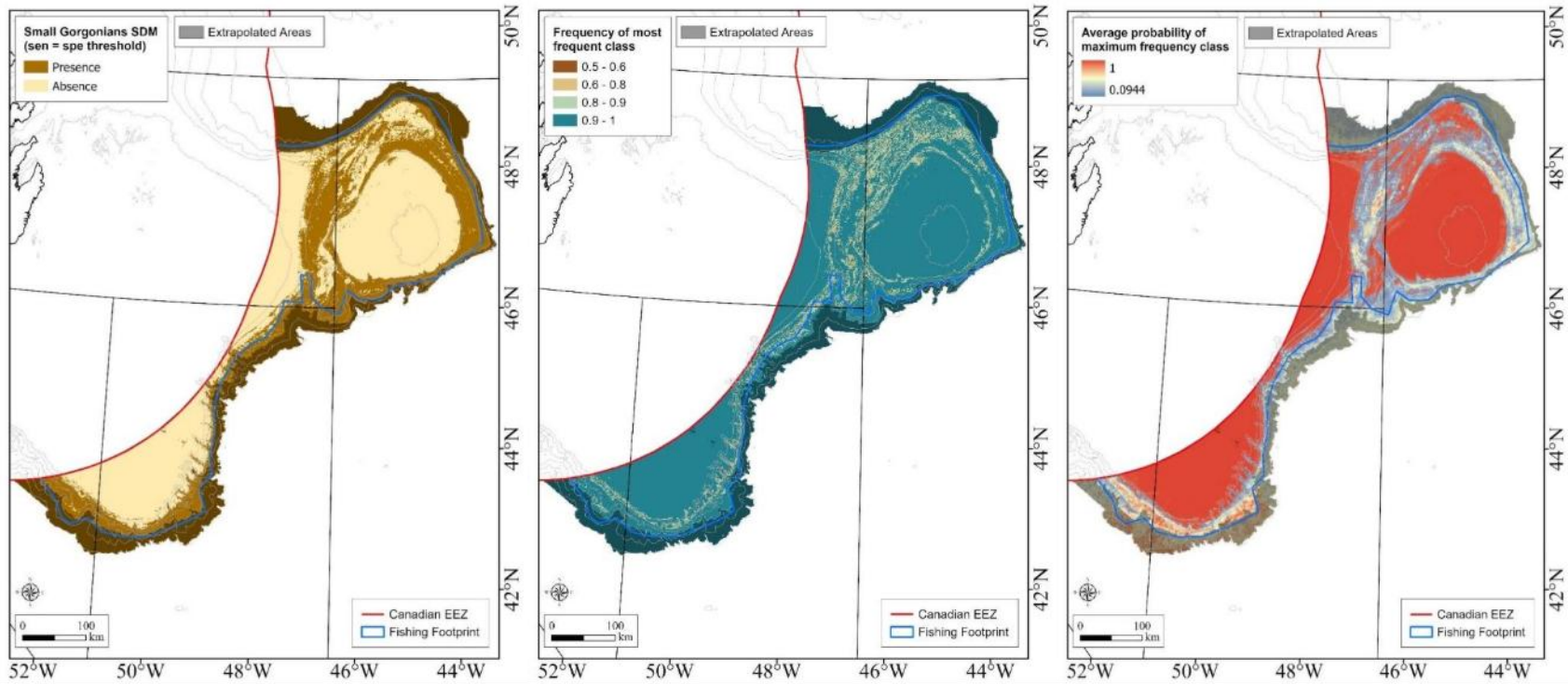


Figure 5.2. Predicted Presences/Absences of Small Gorgonian Coral Functional Group in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs (middle panel) and the average probability of the maximum frequency class (right panel). The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

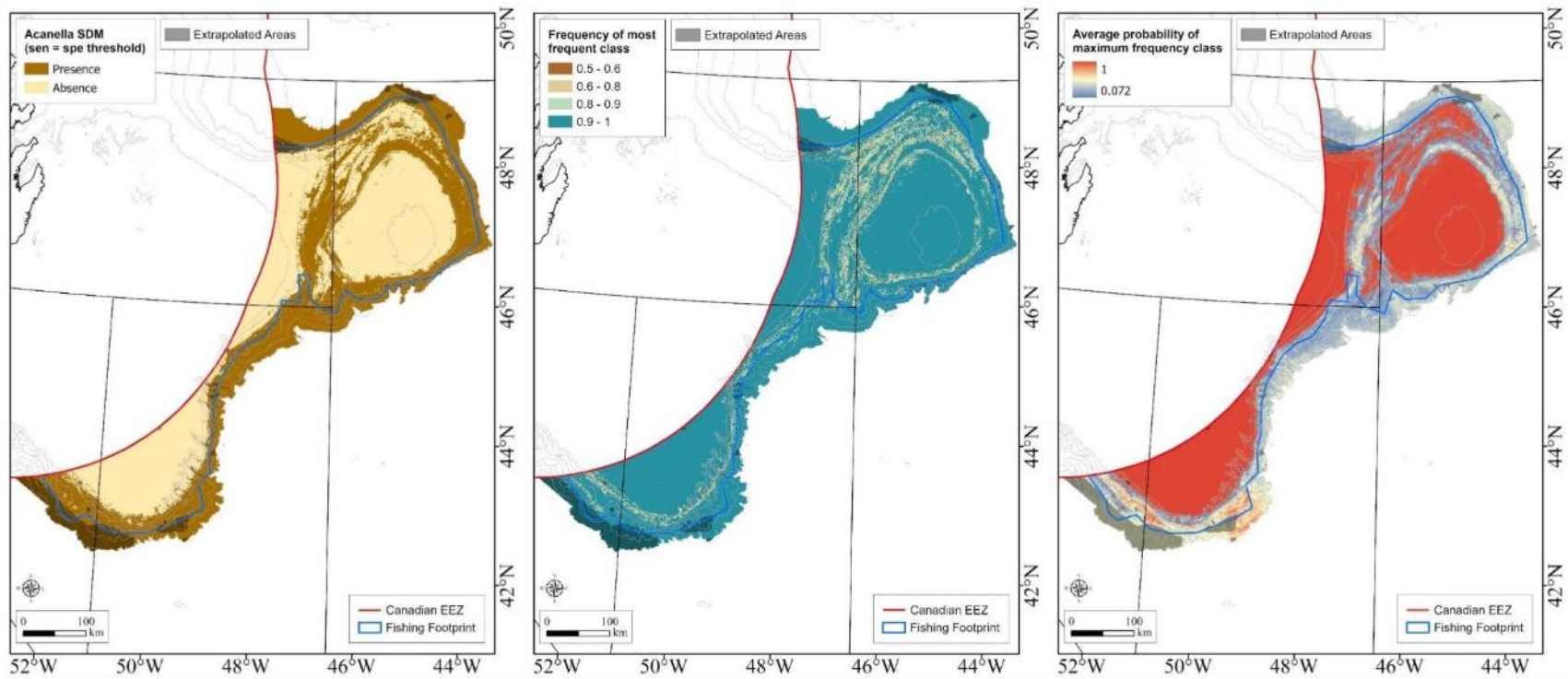


Figure 5.3. Predicted Presences/Absences of the small gorgonian *Acanella arbuscula* in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs (middle panel) and the average probability of the maximum frequency class (right panel). The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

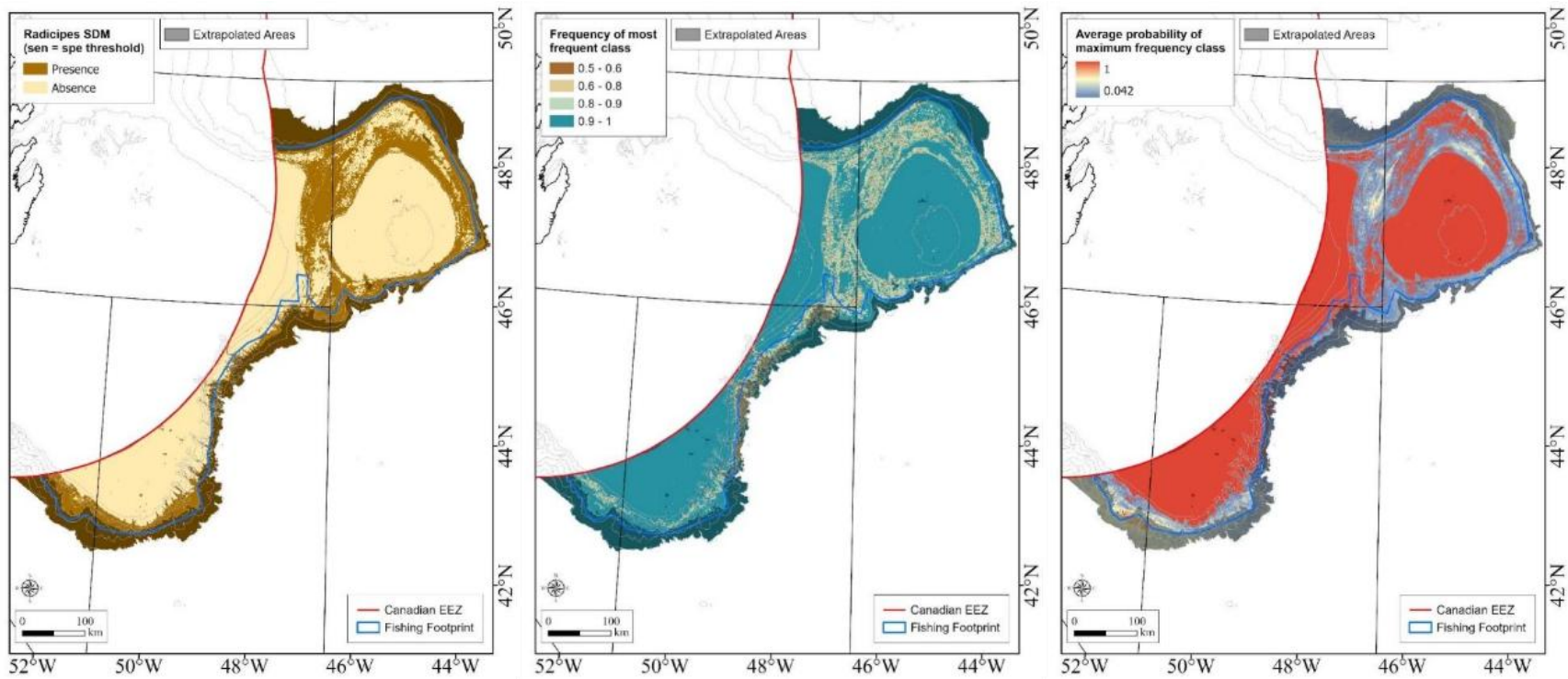


Figure 5.4. Predicted Presences/Absences of the small gorgonian *Radicipes gracilis* in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs (middle panel) and the average probability of the maximum frequency class (right panel). The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

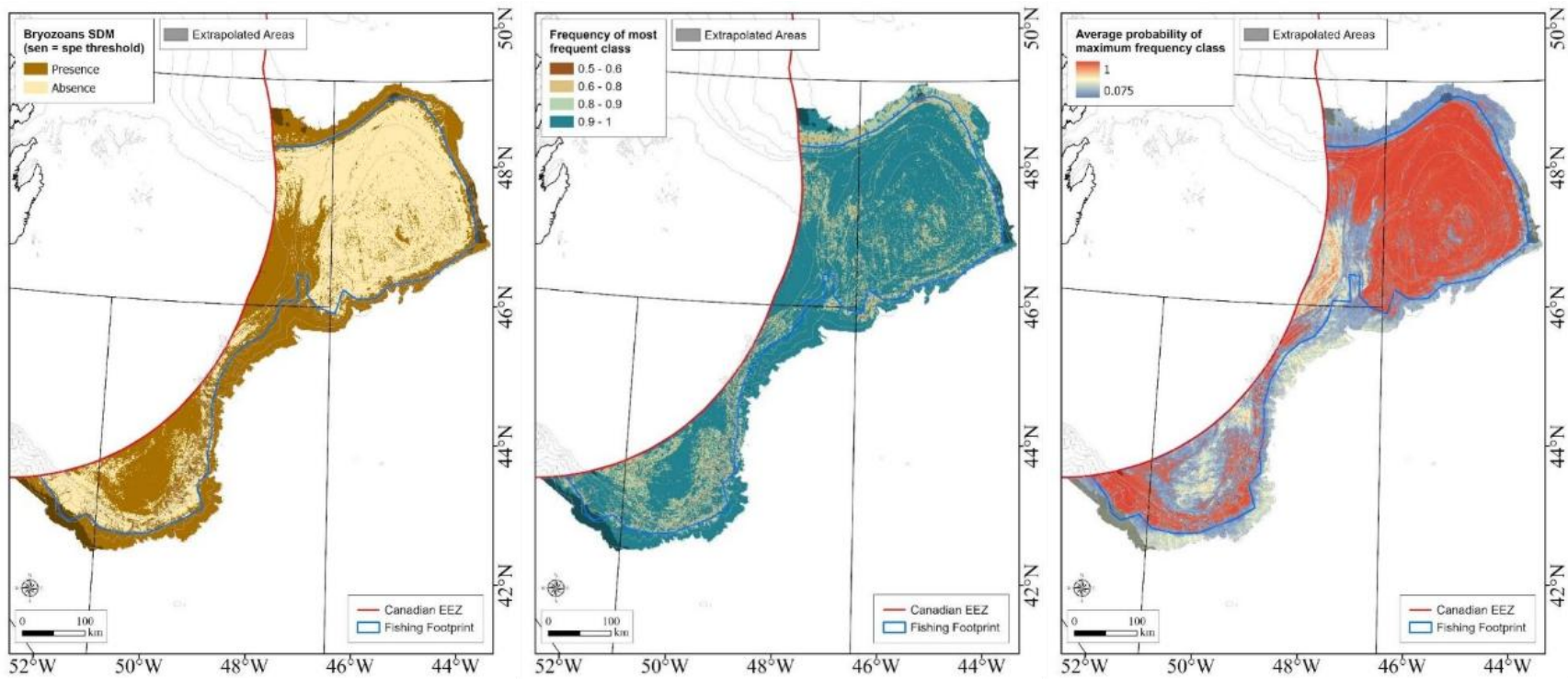


Figure 5.5. Predicted Presences/Absences of Erect Bryozoan Functional Group in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs (middle panel) and the average probability of the maximum frequency class (right panel). The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

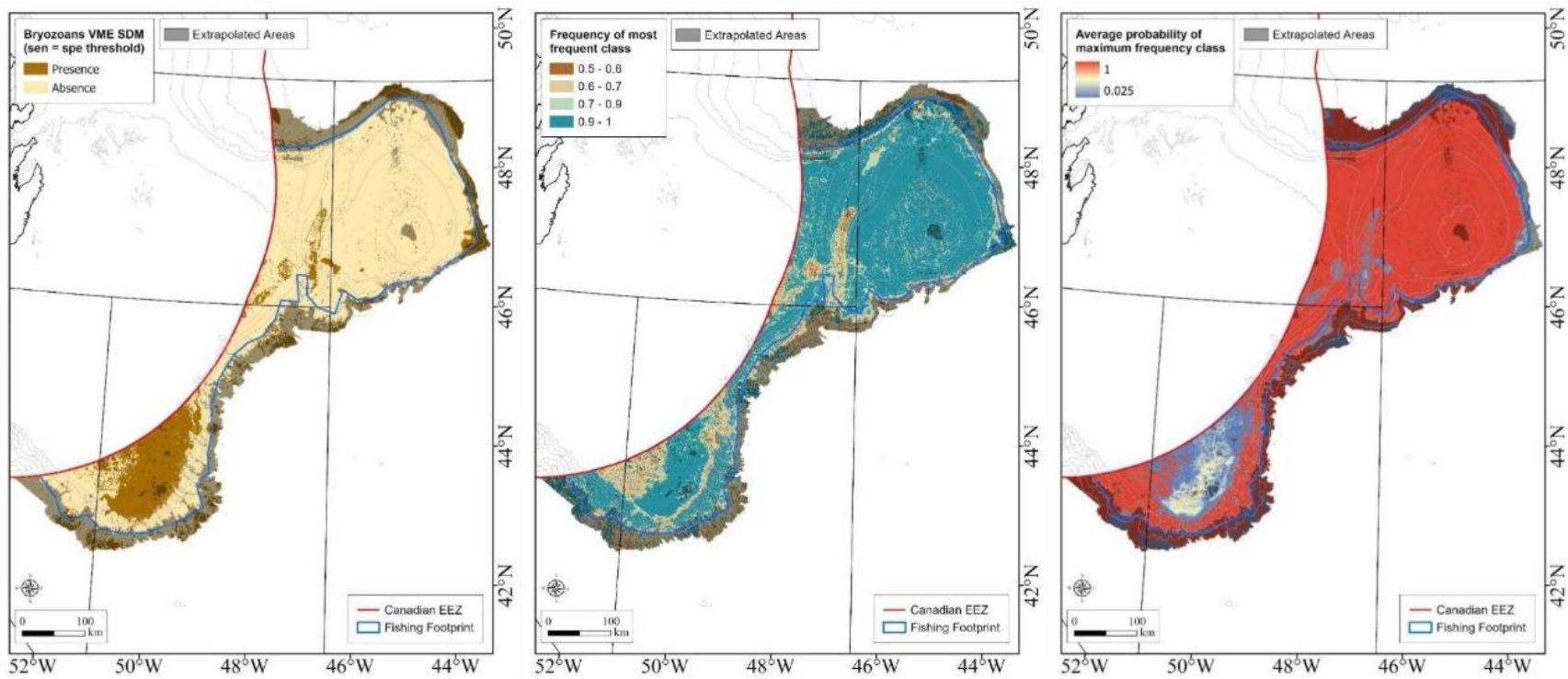


Figure 5.6. Predicted Presences/Absences of Erect Bryozoan VME Habitat in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs (middle panel) and the average probability of the maximum frequency class (right panel). The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

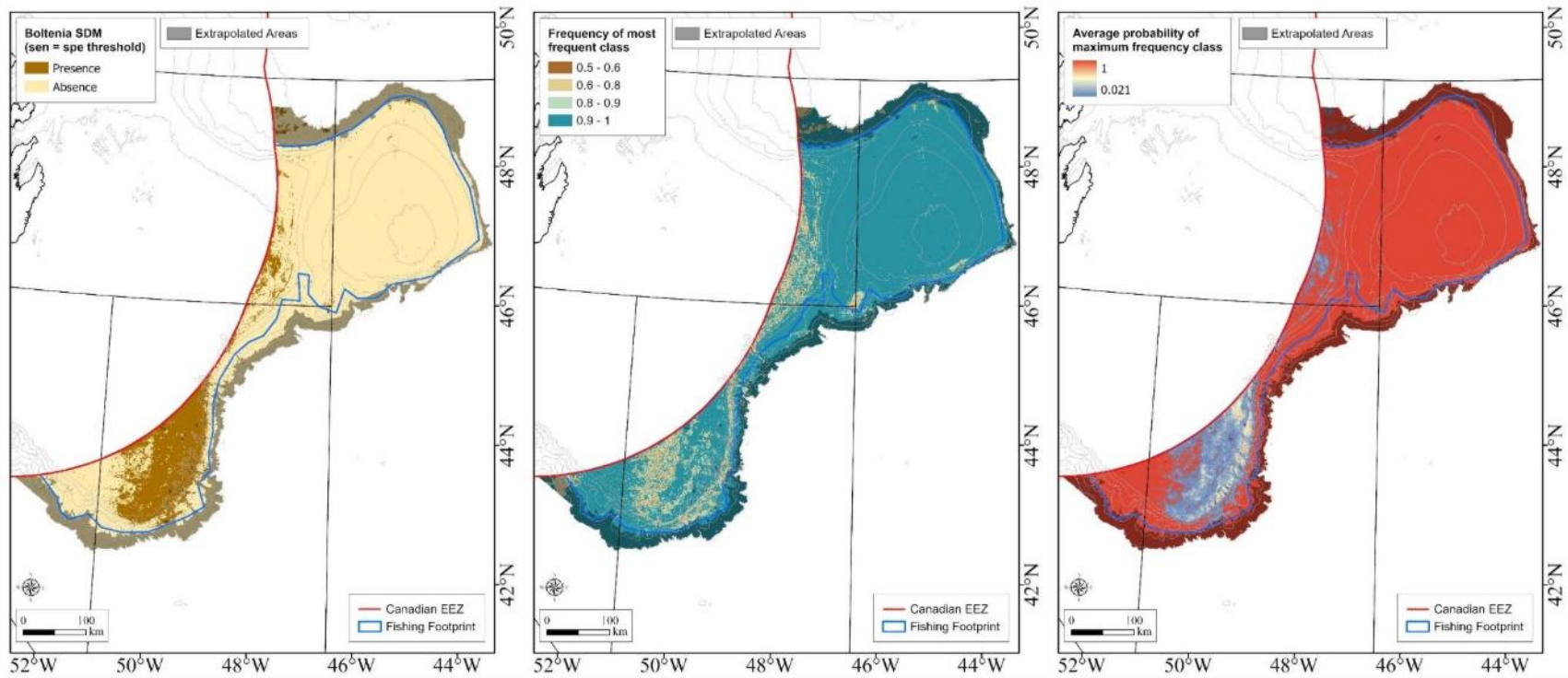


Figure 5.7. Predicted Presences/Absences of Sea Squirt (*Boltenia ovifera*) Functional Group in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs (middle panel) and the average probability of the maximum frequency class (right panel). The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

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- NAFO. (2019). Report of the 12th Meeting of the NAFO SC Working Group on Ecosystem Science and Assessment (WG-ESA) – November 2019. NAFO SCS Doc. 19/25. Serial No. N7027. <https://www.nafo.int/Portals/0/PDFs/sc/2019/scs19-25.pdf>

b) ToR 2.2. VMEs in the NAFO Regulatory Area: Updated Kernel Density Analyses of VME Indicators [COM. Request#6b]

In support of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area, kernel density analyses (KDE) of Large-sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals were undertaken using all available research vessel (RV) survey data (1995–2024) (Kenchington *et al.*, 2025). For Tube-dwelling (Cerianthid) Anemones and Sea Lilies (Crinoids), updated distribution maps were provided, drawing on data from RV trawl surveys, NEREIDA rock dredge samples and NEREIDA underwater imagery.

For the first time, subgroups of some of the VME functional groups had sufficient data to warrant application of the KDE analyses. These included two families and one suborder of sponges (Tetillidae, Polymastiidae, Astrophorina), four sea pen genera (*Balticina*, *Funiculina*, *Pennatula*, and *Anthoptilum*) and two species of small gorgonian coral (*Acanella arbuscula* and *Radicipes gracilis*). These analyses allowed for a visual and quantitative comparison with their functional group VMEs to determine if there is adequate protection for these taxa when the functional group alone is considered. For the majority of the subgroups, there is a large proportion of their VME area that lies outside of their respective VME functional group and therefore should be taken into account when evaluating closed areas and significant adverse impacts on VMEs in the NAFO Regulatory Area. Lastly, a new index is proposed to assist in the quantification of the number of data records contributing to the newly created area as different thresholds are tested in the KDE analyses.

i) Data Sources

Available biomass data for each VME indicator type were obtained from RV trawl surveys conducted by the EU and Canada (Table 5.1), while presence data were obtained from benthic imagery collected through the NEREIDA program (Kenchington *et al.*, 2019) and from NEREIDA project rock and scallop dredges for the mapping of the Tube-dwelling Anemones (Cerianthids) and Sea Lilies (Crinoids) (Kenchington *et al.*, 2019). Only the trawl survey data (Table 5.1) has changed since the last review of closed areas in 2019. These data underwent an extensive quality control review which is detailed in Kenchington *et al.* (2025).

Table 5.1. RV Survey Data from NAFO Contracting Parties (EU and Canada); EU, European Union; DFO, Department of Fisheries and Oceans; NL, Newfoundland and Labrador; IEO, Instituto Español de Oceanografía; IIM, Instituto de Investigaciones Marinas; IPMA, Instituto Português do Mar e da Atmosfera.

Data Source	Period	NAFO Division	Gear	Mesh Size in Cod-end Liner (mm)	Trawl Duration (min)	Average Wingspread (m)
Spanish 3NO Survey (IEO)	2002 - 2024	3NO	Campelen 1800	20	30	24.2 – 31.9
EU Flemish Cap Survey (IEO, IIM, IPMA)	2003 - 2024	3M	Lofoten	35	30	13.89
Spanish 3L Survey (IEO)	2003 - 2024	3L	Campelen 1800	20	30	24.2 – 31.9
DFO NL Multi-species Surveys (DFO)	1995 - 2022	3LNO	Campelen 1800	12.7	15	15 - 20

The data available for each VME Indicator taxon and the time period over which they were collected are summarized in Table 5.2. These were the quality-controlled data going into the analysis. However, the trawling protocols from which the biomass data were collected differ in the type of trawl gear used, the mesh size of the codend liner, wingspread for the trawl and trawl duration (Table 5.1), all of which can affect the catch biomass of the VME indicator taxa. Further, there have been vessel changes in the Canadian survey fleet (DFO, 2024). The Canadian Coast Guard Ship (CCGS) *Wilfred Templeman* was decommissioned in 2008. In 2022, the CCGS *Alfred Needler* and CCGS *Teleost* were replaced with the new Offshore Fisheries Science Vessel sister ships CCGS *John Cabot* and CCGS *Capt. Jacques Cartier* (DFO, 2024), with the CCGS *Alfred Needler* decommissioned in 2023. In addition to changing vessels, minor modifications to the standard Campelen 1800 survey trawl net and footgear were completed in 2020, for use in the survey going forward. Consequently, the impacts of all of these differences on the VME indicator biomass of the catch were statistically evaluated in order to determine which data could be combined and which data should be separately analyzed (Kenchington *et al.*, 2025). For most taxa, only biomass records above a low-level catch threshold were used as input to the KDE (Kenchington *et al.*, 2025).

Table 5.2. Summary of the data inputs for consideration in the KDE analyses. These data record the available data for each VME Indicator taxon. In some cases, subsets of the data were used in the final KDE analyses to account for catchability differences in gear or tow duration (see Results for each VME Indicator taxon).

VME Indicator	Period	No. Records
Large-Sized Sponges	1995 - 2024	5505
Tetillidae	2011 - 2024	225
Polymastiidae	2011 - 2024	686
Astrophorina	2011 - 2024	475
Sea Pens	2005 - 2024	2790
Anthoptilum	2005 - 2024	1396
Balticina	2005 - 2024	740
Funiculina	2006 - 2024	450
Pennatula	2009 - 2024	529
Black Corals	2002 - 2024	418
Large Gorgonian Corals	2000 - 2024	332
Small Gorgonian Corals	2002 - 2024	911
Acanella arbuscula	2002 - 2024	620
Radicipes gracilis	2007 - 2024	162
Erect Bryozoans	2006 - 2024	874
Sea Squirts	2007 - 2024	389

iii) Results

The results of the KDE analyses are detailed in Kenchington *et al.* (2025) with supporting text, tables and figures leading to the selection of the RV catch threshold to define the VMEs. Here, the results for the Large-Size Sponge functional group and the sponge subgroups Tetillidae, Polymastiidae and Astrophorina are provided (Figure 5.8).

The analyses for the **Large-Sized Sponges functional group** were performed on 2244 catches ≥ 0.5 kg (677 Canadian records and 1567 EU-Spanish records). Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. The biomass surface is shown in Figure 5.8 compared with the surface created from the 2019 analysis. The overall locations of the VME polygons are the same and the largest density estimates are also the same (41.12 kg km²). The kernel density distribution identified sponge grounds on the southern portion of Flemish Pass to southwestern Grand Bank, Beothuk Knoll, Sackville Spur and the east and southeast Flemish Cap. Following previously accepted procedures for identifying thresholds (NAFO, 2013), the 100 kg/RV tow density threshold was selected as defining significant concentrations of Large-Sized Sponges (i.e., sponge ground VME). The VME polygons established with this threshold cover an area of 33144.2 km². The threshold encompasses 865 records which is 38.5% of the data. This threshold is the same as that used in the 2019 analysis (Kenchington *et al.*, 2019).

Tetillidae Sollas, 1886, is a family of marine sponges in the order Tetractinellida and class Demospongiae. Tetillids are massive globular sponges, and in the NAFO Regulatory Area (NRA) they are especially common in moderately sheltered areas with the maximum mixed layer depth in the spring < 17 m (Murillo *et al.*, 2024). The total number of records was 225 (Table 5.2) and all were from the EU surveys as Canada only records sponges as Porifera. There was no significant difference among the catch distributions between the Campelen 1800 and Lofoten trawl gears (Kenchington *et al.*, 2025; Appendix Table A2), and so all 225 records were used

in the analyses. A kernel density surface was created, and the highest biomass is found on the southeastern slope of the Tail of Grand Bank and the 0.01 kg threshold was chosen to delimit the Tetillidae VME polygons (Kenchington *et al.*, 2025). Some of the Tetillidae VMEs overlap with the Large-Sized Sponge VMEs determined above (Figure 5.8), but the Tetillidae VME extends further north in Flemish Pass and there are three VME polygons on the Tail of Grand Bank and one on Flemish Cap that are not present in the Large-Sized Sponge VME polygons (Figure 5.8).

Polymastiidae Gray, 1867, is a family of demosponges found in the order Polymastiida. The species occurring in the NAFO Regulatory Area are generally small, with papillae visible. Species distribution models indicated that the Polymastiidae in the NAFO Regulatory Area are found in elevated areas with moderate changes of surface salinity, with mean surface temperatures < 6°C and relatively stable bottom temperature (Murillo *et al.*, 2024). Significant differences in the RV catch biomass due to differences associated with gear type were identified (Kenchington *et al.*, 2025; Appendix Table A2). When all records less than 0.05 kg were removed, there was no significant difference among the catch distributions between the Campelen 1800 and Lofoten trawl gears. Consequently, only records with a biomass ≥ 0.05 kg were used in the KDE analyses (N=238). The highest biomass is found in Flemish Pass with high concentrations along the southeastern slope of the Tail of the Grand Bank and the eastern slope of Flemish Cap. The distribution includes the sponge grounds, but also some higher biomass presences in the shallow waters of Flemish Cap (Kenchington *et al.*, 2025). The bar charts suggest that this taxon is weakly aggregated with each threshold increasing the area, however two potential catch thresholds emerged as potentially indicating the VMEs and the 0.10 kg threshold was ultimately selected for the Polymastiidae VME polygons (Kenchington *et al.*, 2025). There is very little overlap between the Polymastiidae VMEs and the Large-Sized Sponges VMEs determined above (Figure 5.8), with the main area of overlap in Flemish Pass.

Astrophorina is a suborder of large, massive sponges in the class Demospongiae. Astrophorina was formerly named Astrophorida, and classified as an order, but it is now recognised as a suborder of Tetractinellida. Species distribution models for the NAFO Regulatory Area indicate that the Astrophorina are found in depressed areas, with maximum values of primary productivity in summer > 900 mg C m⁻² day⁻¹, minimum surface temperature > 4°C, and stable environment of bottom temperatures (Murillo *et al.*, 2024). The total number of records was 475 (Table 5.2). There was no significant difference among the catch distributions between the Campelen 1800 and Lofoten trawl gears for catches ≥ 0.025 kg (Kenchington *et al.*, 2025; Appendix Table A2), and so 410 records were used in the analyses. The highest biomass is found in Flemish Pass and the southeastern slope of Flemish Cap. The distribution follows that of the sponge grounds (Figure 5.8) which is not surprising as this taxon is the primary constituent of the Large-Sized Sponges VME Functional Group. The 2.5 kg threshold was selected to represent the Astrophorina VME polygons.

The analyses for the **Sea Pen functional group** considered 2790 sea pen records (288 from the Canadian surveys and 2502 from the EU surveys); 577 more data points than were available for the last analysis (Kenchington *et al.*, 2019). When all records less than 0.3 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor the Canadian research vessels (Kenchington *et al.*, 2025; Appendix Table A3). The KDE analyses were performed on 318 catches ≥ 0.3 kg. The 1.5 kg RV catch threshold defined the KDE-VME polygons. Comparison of the KDE-VME polygons obtained from the 2019 KDE analyses (Kenchington *et al.*, 2019) shows a very high degree of congruence with the 2025 analysis (Figure 5.9). Only one VME polygon on the eastern flank of Flemish Cap is slightly larger in the new analysis. The resultant VME polygons cover an area of 9408.6 km² and are found in a horse-shoe formation over Flemish Cap and on the Tail of the Grand Bank (Figure 5.9). They include 189 data points which is 59.4% of the data.

Anthoptilum is a genus of sea pens belonging to the family Anthoptilidae in the phylum Cnidaria. *Anthoptilum grandiflorum* (Verrill, 1879) is common on soft bottoms of Flemish Cap and the Tail of the Grand Bank where they are found at depths of 200 to 1370 m (Altuna and Murillo, 2012) and believed to act as biogenic habitat (Baillon *et al.*, 2014). A second species, *Anthoptilum murrayi* (Kölliker, 1880), has a wide distribution, primarily in the North Atlantic Ocean, but extending into the South Atlantic, and the Indo-Pacific. It has also been recorded in the NAFO Regulatory Area by both EU and Canadian surveys, but only rarely. There were significant differences among the catch series for each survey and differences in the number of small catch weights, likely due to differences associated with gear type, tow length, survey area and sampling protocol. When all records less than 0.1 kg were removed, there was no significant difference among the catch distributions by tow

duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor the Canadian research vessels (Kenchington *et al.*, 2025; Appendix Table A4). The analyses were performed on 387 catches ≥ 0.1 kg. The RV threshold selected is that established with the 0.7 kg catch contour (Figure 5.10). Comparison of the *Anthoptilum* VME polygons with those of the Sea Pen Functional Group (Figure 5.10) shows a high degree of overlap, with most of the Sea Pen Functional Group polygons encompassing those of *Anthoptilum*.

Balticina is a genus of sea pens belonging to the family Balticinidae. *Balticina* was formerly called *Halipteris*, but that name is no longer valid and has been synonymised under *Balticina* Gray, 1870. When all records less than 0.01 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor Canadian research vessels (Kenchington *et al.*, 2025; Appendix Table A5). Therefore, the analyses were performed on 596 catches ≥ 0.01 kg. The highest biomass densities were found on the northeast Flemish Cap and on the Tail of the Grand Bank in NAFO Division 30. The KDE-VME catch threshold was ≥ 0.15 kg (Figure 5.10). The polygons contain 439 data points accounting for 74% of the data records for *Balticina*. The *Balticina* VMEs are generally larger than that of the functional group and important areas on the eastern slope of Flemish Pass are not within the boundaries of the Sea Pen Functional Group (Figure 5.10).

Funiculina quadrangularis (Pallas, 1766) is one of the more common sea pens in the NAFO Regulatory Area, occurring on Flemish Cap, in Flemish Pass and on the Grand Banks at depths of 324-1258 m. It is a tall sea pen in the family Funiculinidae and can exceed 2 m in height. There were 450 records in the initial *Funiculina* data set used for the KDE analyses. However, there were significant differences among the catch series for each survey associated with gear type and tow length (Kenchington *et al.*, 2025; Appendix Table A6). When all records less than 0.05 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor the Canadian research vessel. Therefore, only catches ≥ 0.05 kg were included in the KDE analyses. However, this left very few records for the analyses (N=29) and so although the analysis was performed, it is anticipated that new areas may emerge as more data is provided in future years. The threshold for *Funiculina* VME was 0.10 kg. The highest biomass densities were found on the Tail of the Grand Bank in NAFO Division 30 (Figure 5.10). The VME polygons contain 22 data points accounting for 76% of the data records for *Funiculina*. The *Funiculina* VMEs have distinctive habitats from those of the Sea Pen Functional Group particularly in NAFO Division 30 (Figure 5.10).

Pennatula is a genus of sea pens in the family Pennatulidae. There are over 50 species worldwide, with *Pennatula aculeata* Danielssen, 1860 and *Ptilella grandis* (Ehrenberg, 1834) (formerly known as *Pennatula grandis*) common in and around the NAFO Regulatory Area. There were 529 records in the initial *Pennatula* data set used for the KDE analyses (Table 5.2). However, there were significant differences among the catch series for each survey associated with gear type (Kenchington *et al.*, 2025; Appendix Table A7). When all records less than 0.01 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor Canadian research vessels. Therefore, only catches ≥ 0.01 kg were included in the KDE analyses. The highest biomass densities were found on the Tail of the Grand Bank in NAFO Division 30. The 0.045 kg threshold was seen as defining the *Pennatula* VME polygons (Figure 5.10). There were 159 data points (significant and non-significant catches) within the *Pennatula* VME polygons, representing 72.3% of the data. The *Pennatula* has significant concentrations outside of the area of the Sea Pen functional group, especially in the Flemish Pass (Figure 5.10).

Black corals belong to the cnidarian order Antipatharia. Two species have been identified in the data provided by the Contracting Parties in the NAFO Regulatory area, *Stauropathes arctica* (Lütken, 1871) of the family Schizopathidae, and *Leiopathes cf. expansa* of the family Leiopathidae, although more species have been recorded in the area. Black corals are known for their exceptionally long lifespans, with some colonies having lifespans of 100 to 4500 years, including species of *Leiopathes* (Roark *et al.*, 2009). Antipatharia spp. are listed in Appendix II of CITES, meaning that trade in black corals requires CITES permits to ensure sustainability. Species distributions models show that the Black Coral Functional Group is distributed in a ring around Flemish Cap between about 400 and 600 m depth and in the deep slope waters below 1800 m (Murillo *et al.*, 2024). There were significant differences among the catch series for each survey associated with gear type (Kenchington *et al.*, 2025; Appendix Table A8), therefore, only catches ≥ 0.15 kg/RV tow were included in the

KDE analyses. The analyses were performed on 76 catches ≥ 0.15 kg. The highest biomass densities were found in the Flemish Pass (Figure 5.11). The **Black Coral Functional Group** VME polygons were established with catches ≥ 0.4 kg and contained 39 of the records for this group, representing 51.3% of the data. The location of the VME polygons for the Black Coral Functional Group overlap with those produced in 2019 (Figure 5.11) except for the VME polygon in the Flemish Pass which is further to the south in the present analyses (Figure 5.11). This was examined in detail and arose through the addition of data to the south which included the one significant catch in the 2019 polygon.

The term "gorgonian coral" is commonly associated with species in the cnidarian order Scleralcyonacea that produce a flexible skeleton composed of calcite and the proteinaceous material gorgonin. They are commonly referred to as sea fans and can reach 5 m in height. These species are typically found attached to hard substrate, such as bedrock or a mixture of pebbles, boulders, and cobbles. Their large size and association with hard substrates were factors considered in separating them from the Small Gorgonian Corals (see below). There were significant differences among the catch series for the **Large Gorgonian Coral functional group** for each survey associated with gear type (Kenchington *et al.*, 2025; Appendix Table A9). When all records less than 0.10 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears. Also, there were no differences between research vessels in the Canadian data. Therefore, only catches ≥ 0.10 kg/RV tow were included in the KDE analyses. The analyses were performed on 98 catches ≥ 0.10 kg. The RV catches ≥ 0.7 kg delineated the VME polygons. The VME polygons contain 67 data records, accounting for 68.4% of the data and capture the high density areas in the Flemish Pass (Figure 5.11). The Large Gorgonian Coral VME polygons overlap with those produced in the 2019 analyses (Figure 5.11), at least for the larger polygons. Some of the small VME polygons along the canyon heads on the Tail of the Grand Bank should be considered for protection as one of those has one of the higher density catches (Figure 5.11). The highest biomass densities were found in the Flemish Pass and were very similar in location to those identified in 2019 (Figure 5.11).

Records for the **Small Gorgonian Coral Functional Group** had significant differences among the catch series for each survey associated with gear type (Kenchington *et al.*, 2025; Appendix Table A10). When all records less than 0.02 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears. Further, at this cut-off there were no differences among the vessels used in the Canadian data. Therefore, only catches ≥ 0.02 kg/RV tow were included in the KDE analyses (N= 279). The highest biomass densities were found in NAFO Division 30 on the Tail of the Grand Bank and were very similar in location to those identified in 2019 (Figure 5.12). The 0.065 kg/RV tow was selected as the threshold for identifying the Small Gorgonian Coral VME polygons. The Small Gorgonian Coral VME polygons cover an area of 13379.7 km² and contain 199 data points representing 71.3% of the data. The new KDE polygons match well with those from the 2019 analyses in NAFO Division 30 on the Tail of the Grand Bank (Figure 5.12). However, the new analysis which included 61 more data records in the creation of the KDE surface, identified KDE-VMEs on Flemish Cap and in the Flemish Pass that were not in the previous analyses.

Acanella arbuscula (Johnson, 1862) is a small gorgonian coral belonging to the family Keratoisididae in the order Scleralcyonacea. This species inhabits soft sediments in the northwest Atlantic and has an overall depth range of 150–4800 m. There were significant differences among the catch series for each survey associated with gear type (Kenchington *et al.*, 2025 Appendix Table A11). When all records less than 0.02 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears. Further, at this cut-off there were no differences among the vessels used in the Canadian data. Therefore, only catches ≥ 0.02 kg/RV tow were included in the KDE analyses. The analyses were performed on 204 catches ≥ 0.02 kg. The 0.14 kg threshold was selected to delineate the *Acanella arbuscula* VME polygons. There were 118 data points both above and below the catch threshold falling in those VME polygons, representing 57.8% of the data. They capture the high density areas identified on the Tail of the Grand Bank (Figure 5.12). All of the *Acanella arbuscula* VME polygons fall within the polygons created by the Small Gorgonian Coral Functional Group (Figure 5.12).

Radicipes gracilis (Verrill, 1884) is a small gorgonian coral belonging to the family Chrysogorgiidae in the order Scleralcyonacea. It is found on soft sandy or muddy bottoms at depths from 500 to 3259 metres. There were no significant differences among the catch series for each survey associated with tow duration or gear type (Kenchington *et al.*, 2025 Appendix Table A12), and so all of the data could be used in the analyses. As

there were only four records from the Canadian surveys, and those were all from the same vessel (CCGS *Teleost*) differences among the vessels used in the Canadian data were not evaluated. The analyses were performed on 162 catches. The highest biomass densities were found in NAFO Division 30 on the Tail of the Grand Bank, and on Sackville Spur on Flemish Cap. The 0.004 kg/RV tow threshold was selected to represent the *Radicipes gracilis* VME polygons. There are 76 data points within the *Radicipes gracilis* VME polygons comprising 46.9% of the data. There is overlap with the Small Gorgonian Coral Functional Group VME polygons (Figure 5.12). However, the *Radicipes gracilis* VME polygon in the Flemish Pass extends beyond the functional group polygons with a number of occurrences evident. Although the VME polygon in Division 30 lies partially outside the functional group polygon there, the data points were inside or bordering the functional group polygon.

The VME Indicator listed in the NAFO Conservation and Enforcement Measures (NAFO, 2025) includes only *Eucratea loricata* (Linnaeus, 1758) under the **Erect Bryozoan** VME indicators, however as other species are known to occur in the NRA the functional group level was maintained. There were significant differences among the catch series for each survey associated with gear type (Kenchington *et al.*, 2025; Appendix Table A13). When all records less than 0.02 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears. There were only 12 Canadian records above the threshold, and they were all from the CCGS *Needler*. To examine the vessel effect, all of the Canadian data were used to test the difference between the catches from the CCGS *Needler* and the CCGS *Teleost*, and no significant differences were found. The highest biomass densities were found on the Tail of the Grand Bank and were very similar in location to those identified in 2019 (Figure 5.13). The VME polygons for the Erect Bryozoan Functional Group were established by the 0.2 kg/RV tow threshold and 86 data points fell within the VME polygons, accounting for 48.6% of the data.

Although the sea squirts are listed as the **Sea Squirt functional group**, they are represented by a single species *Boltenia ovifera* (Linnaeus, 1767) in the catches. This is a species of ascidian tunicate in the family Pyuridae. It is a solitary sea squirt with an orange, ball-shaped body up to eight centimetres long and attached by a long stalk to the seabed. The stalk can be two to four times the length of the body. It is commonly called the stalked tunicate. The NAFO Conservation and Enforcement Measures also list *Halocynthia aurantium* (Pallas, 1787), or sea peach, as a VME Indicator for this group, although they have not been identified in the trawl catches. There were significant differences among the catch series for each survey associated with tow duration (Kenchington *et al.*, 2025; Appendix Table A14). When all records less than 0.01 kg were removed, there was no significant difference among the catch distributions. All tows were made with the Campelen 1800 gear. There were no significant differences in catches ≥ 0.01 kg among the Canadian research vessels. There were 369 data points for the analysis above the ≥ 0.01 kg catch threshold. The selected threshold of 0.25 kg/RV tow encompasses 5232.8 km² and captures the high density areas on the Tail of the Grand Bank and the Southeast Shoal (Figure 5.13), and includes 73.2% of the data. In comparison with the VME polygons produced for this VME indicator in 2019, the areas were very similar (Figure 5.13), with the new analyses largely overlapping with the previous one.

Data available for mapping the location of the **Tube-Dwelling Anemones** included 31 records from the EU (2007-2024). There were 6 new RV trawl survey records of the presence of Tube-Dwelling Anemones provided since the last update in 2019. All records were identified to order Ceriantharia, and so the species composition is unknown. Tube-dwelling anemones were observed on several in situ photographic transects across the Flemish Cap (Figure 5.14). The lack of taxonomic details from the photographs and video prevented the identification of these organisms past the subclass level (Ceriantharia). However, these cerianthids were not large, erect species, and do not appear to be *Pachycerianthus borealis* (Verrill, 1873), the only species listed as a VME indicator by NAFO (2025). Dense fields of these cerianthids could occur in the southeast of the Grand Bank in Division 30, north of the 30 Coral Area Closure, where most of the cerianthids were found from the RV surveys. These areas could be particularly important if their bioturbation activities significantly affect infaunal community structure. Elsewhere, they have been shown to enhance local species diversity and abundance in featureless soft-bottom areas (Shepard *et al.*, 1986). Similarly, the data from the RV surveys and NEREIDA rock and scallop dredge samples were mostly identified to subclass (Ceriantharia) and may contain non-VME cerianthid species, although data from the 2007 RV survey on the Grand Bank confirmed the presence of *Pachycerianthus borealis* at 140 m depth (Murillo *et al.*, 2016). Figure 5.14 shows the distribution of the data available for the Tube-Dwelling Anemones.

Data available for mapping the location of **Sea Lilies** included 4 records from Canadian surveys (2015-2017) and 130 records from the EU (2006-2024). There were 33 new RV trawl survey records of the presence of Sea Lilies since the last update in 2019 in addition to 19 records added to the data collected in 2019 and earlier that were added to the updated data sets by the data providers. All records were identified to class Crinoidea. Crinoids are delicate organisms that are not well-sampled by trawl nets although they are represented in the catch (NAFO, 2013). The NEREIDA photographic transects provide in situ evidence for dense aggregations of this VME indicator (Figure 5.14). The stalked crinoid *Rhizocrinus lofotensis* Sars, 1868, formerly known as *Conocrinus lofotensis*, a VME indicator species, was observed in high abundances on the Sackville Spur, but was completely absent from the Flemish Pass area (Kenchington *et al.*, 2019). Other VME indicator taxa are *Gephyrocrinus grimaldii* Koehler & Bather, 1902 and *Trichometra cubensis* (Pourtalès, 1869) (NAFO, 2025). It is difficult to say what the composition of these catches was. Figure 5.14 shows the distribution of the data available for the Sea Lilies.

iv) **Conclusions**

The data available for the kernel density analyses performed in 2025 drew on 2094 more records than the analyses performed in 2019, with 84% of the data provided by the EU due to their more extensive spatial coverage (Table 5.3). The catch weight threshold, or cut-off, to ensure comparable data amongst the surveys was the same for 5 of the 7 VME Indicator groups, with the Sea Pen Functional Group cut-off increasing by 0.1 kg to 0.3 kg/RV tow, and the Black Coral decreasing to 0.15 kg from 0.2 kg/RV tow (Table 5.3). After application of these catch cut-offs, there were 446 new records for the kernel density analyses across the groups (3560 in total).

For the first time, KDE analyses were performed on subgroups of the Large-Sized Sponges, Sea Pens and Small Gorgonian Corals. Corresponding species distribution models were also performed on these taxa (Murillo *et al.*, 2024; Murillo *et al.*, 2025). Before these assessments, there were insufficient data on the subgroups to warrant such analyses. The purpose in doing this was to see whether basing protection decisions on the location of the functional group VMEs afforded unequal protection to component taxa.

For the three subgroups of Large-Sized Sponges (the families Tetillidae and Polymastiidae and the suborder Astrophorina), the analyses showed that each had considerable overlap with the Large-Sized Sponges Functional Group (Figure 5.8), ranging from 38.9% for the Polymastiidae to 69.9% for the Astrophorina (Table 5.4). There were areas in the Flemish Pass, particularly in the north, and on the Tail of the Grand Bank for the Tetillidae and Polymastiidae that were not protected. Further, the Polymastiidae in particular had 17 polygons that did not overlap at all with those of the Large-Sized Sponges Functional Group (Table 5.4).

For the four genera of Sea Pens (*Anthoptilum*, *Balticina*, *Funiculina*, *Pennatula*) the analyses showed that *Anthoptilum* had considerable overlap of its area with the Sea Pen Functional Group (78.6%; Table 5.4). However, for *Balticina*, *Funiculina* and *Pennatula* most of their VME areas were outside of those of the Sea Pen Functional Group (Table 5.4, Figure 5.10). For *Pennatula* there is a large VME polygon in the northern portion of the Flemish Pass that is deeper than the Sea Pen Functional Group VME polygons, as well as one on the eastern slope of the Tail of the Grand Bank (Figure 5.10). Ten *Pennatula* polygons had no overlap with the Sea Pen Functional Group VME polygons (Table 5.4). We note that the KDE analyses of *Funiculina* was produced from a relatively small data set (N=29) and is subject to change as more data are accumulated.

Table 5.3. Number of records from the Canadian and EU research vessel (RV) surveys used in the 2025, 2019 and 2013 assessments of the closed areas, by each of the 7 VME indicator functional groups. Records used for the kernel density analyses are indicated in columns showing records above the RV catch threshold where data could be combined. Sponge=Large-Sized Sponges; SGC=Small Gorgonian Corals; LGC=Large Gorgonian Corals; Bryozoan=Erect Bryozoan.

VME Indicator	Year	Canadian Records	EU Records	Total Records	RV Catch Threshold	Canadian Records \geq Threshold	EU Records \geq Threshold	Total Records \geq Gear Threshold
Sponge	2025	1074	4431	5505	0.5 kg	677	1567	2244
Sponge	2019	975	3415	4390	0.5 kg	618	1207	1825
Sponge	2013	553	2040	2593	0.5 kg	391	763	1154
Sea Pen	2025	288	2502	2790	0.3 kg	32	286	318
Sea Pen	2019	259	1954	2213	0.2 kg	54	376	430
Sea Pen	2013	183	1172*	1355	0.2 kg	35	227	262
SGC	2025	103	808	911	0.02 kg	59	220	279
SGC	2019	106	582	688	0.02 kg	62	156	218
SGC**	2013	87	317	404	0.02 kg	40	45	85
LGC	2025	86	246	332	0.1 kg	29	69	98
LGC	2019	83	200	283	0.1 kg	29	60	89
LGC	2013	42	153	195	0.1 kg	13	45	58
Bryozoan	2025	24	850	874	0.02 kg	12	165	177
Bryozoan	2019	21	768	789	0.02 kg	12	162	174
Bryozoan	2013	-	353***	353	none	-	353	353
Sea Squirts	2025	189	200	389	0.01 kg	188	181	369
Sea Squirts	2019	172	162	334	none	172	162	334
Sea Squirts	2013	-	88	88	none	-	88	88
Black Coral	2025	20	398	418	0.15 kg	6	70	76
Black Coral	2019	20	260	280	0.2 kg	6	38	44
Total	2025	1784	9435	11219		1003	2557	3560
Total	2019	1636	7341	8977		953	2161	3114
Total	2013	865	4123	4988		479	1521	2000

*Misreported as 1127 in NAFO (2013). Totals corrected here. **In 2013 KDE analyses were performed for Divisions 3NO and in 2019 the areas 3LMNO were combined. *** Misreported as 344 records in NAFO (2013). Totals corrected here.

For the two species of Small Gorgonian Corals, *Acanella arbuscula* fell within the VME polygons for the Small Gorgonian Coral Functional Group with very little area outside and all *Acanella arbuscula* VME polygons at least partially overlapping with the Small Gorgonian Coral Functional Group VMEs (Table 5.4, Figure 5.12). For *Radicipes gracilis*, their VME polygon areas overlapped with those of the functional group somewhat (23.8%), but new areas were identified, especially in the Flemish Pass, although only two small polygons do not overlap to some extent with the functional group VME polygons (Table 5.4, Figure 5.12).

Therefore, we conclude that for the majority of the subgroups, there is a large proportion of their VME area that lies outside of their respective VME functional group and therefore should be taken into account when evaluating closed areas and significant adverse impacts on VMEs in the NAFO Regulatory Area. Particular attention should be paid to VME polygons of subgroups that have no overlap with their functional group VMEs (Table 5.4), as these may be distinct populations important to their respective connectivity networks.

v) *Quantifying Cases for Rejecting a KDE Threshold*

One of the evaluation criteria for determining the catch threshold which establishes a VME from the KDE biomass surface is a rapid change in area as the contribution of isolated individuals over a broad area are incorporated (Phase 3 in NAFO, 2013). Cases for rejecting the threshold other than the insufficient data includes, among others, the joining of smaller polygons with little evidence for a continuous distribution within the newly formed area and an increase in area established by creation of new areas of very low density (NAFO, 2013). Previously, the maps of the increase in area and of the points contributing to that increase were visually evaluated using, for example, the maps such as seen in Figure 5 of Kenchington *et al.* (2025) for the Large-Sized Sponges Functional Group evaluations. However, this feature can be quantified as the ratio of the number of additional points falling in the newly created area by the comparative threshold to the area of the newly created area:

$$\frac{\text{Number of additional catch records} > \text{catch threshold 1 falling within } (A2-A1)}{(A2-A1)}$$

where 1 is the biomass catch threshold (kg) being evaluated and 2 is the next successive smaller biomass catch threshold 1 is being compared with, and A is area in km². WG-ESA endorsed adding this calculation to future KDE outputs to assist in the selection of RV catch thresholds representative of VMEs.

Table 5.4. The areas for each of the Large-Sized Sponges, Sea Pen and Small Gorgonian Coral subgroups which overlap with that of their respective functional group taxon are indicated (Common Area). The percentage of the common area of the subgroup area (VME Taxon Area) is also indicated as well as the percentage of the subgroup area lying outside the functional group.

VME Group	VME Group Area (km ²)	VME Taxon	VME Taxon Area (km ²)	Common Area (km ²)	Percent Common Area of VME Taxon Area (%)	VME Taxon Area Outside VME Group Area (km ²)	Percent VME Taxon Area Outside VME Group Area (%)	Number of VME Taxon Polygons Outside of VME Group Area
Large-Sized Sponges	33144.2	Tetillidae	30029.3	16322.8	54.4	13706.5	45.6	5
Large-Sized Sponges	33144.2	Polymastiidae	11851.7	4608.5	38.9	7243.2	61.1	17
Large-Sized Sponges	33144.2	Astrophorina	29197.3	20414.2	69.9	8783.1	30.1	4
Sea Pens	9441.1	Anthoptilum	9305.7	7309.9	78.6	1995.8	21.4	2
Sea Pens	9441.1	Balticina	23141.3	8945.4	38.7	14195.9	61.3	5
Sea Pens	9441.1	Funiculina	2465.6	505.6	20.5	1960.0	79.5	1
Sea Pens	9441.1	Pennatula	10252.2	2899.4	28.3	7352.8	71.7	10
Small Gorgonian Corals	13379.7	Acanella arbuscula	4143.6	4130.7	99.7	13.0	0.3	0
Small Gorgonian Corals	13379.7	Radicipes gracilis	7078.7	1682.0	23.8	5396.7	76.2	2

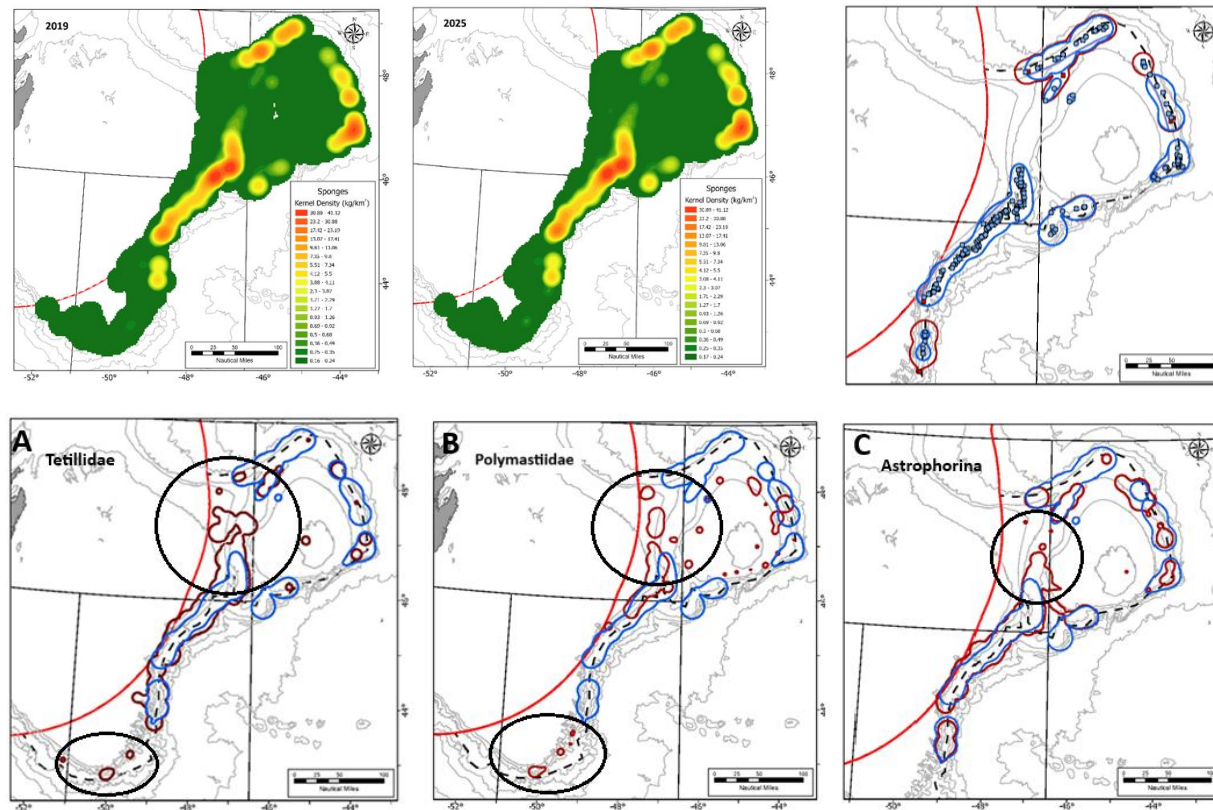


Figure 5.8. Results of the KDE analyses for the Large-Sized Sponges functional group (upper row) showing the 2019 KDE biomass surface, the 2025 KDE biomass surface and the KDE-VME polygons from the 2025 (red) and 2019 (blue) analyses. The KDE-VME polygons for the Tetillidae (A), Polymastiidae (B) and Astrophorina (C) subgroups are shown in red and compared with the 2025 KDE-VME polygons for the Large-Sized Sponges functional group (blue). Areas in each where the subgroup has large areas outside of the functional group are indicated in black.

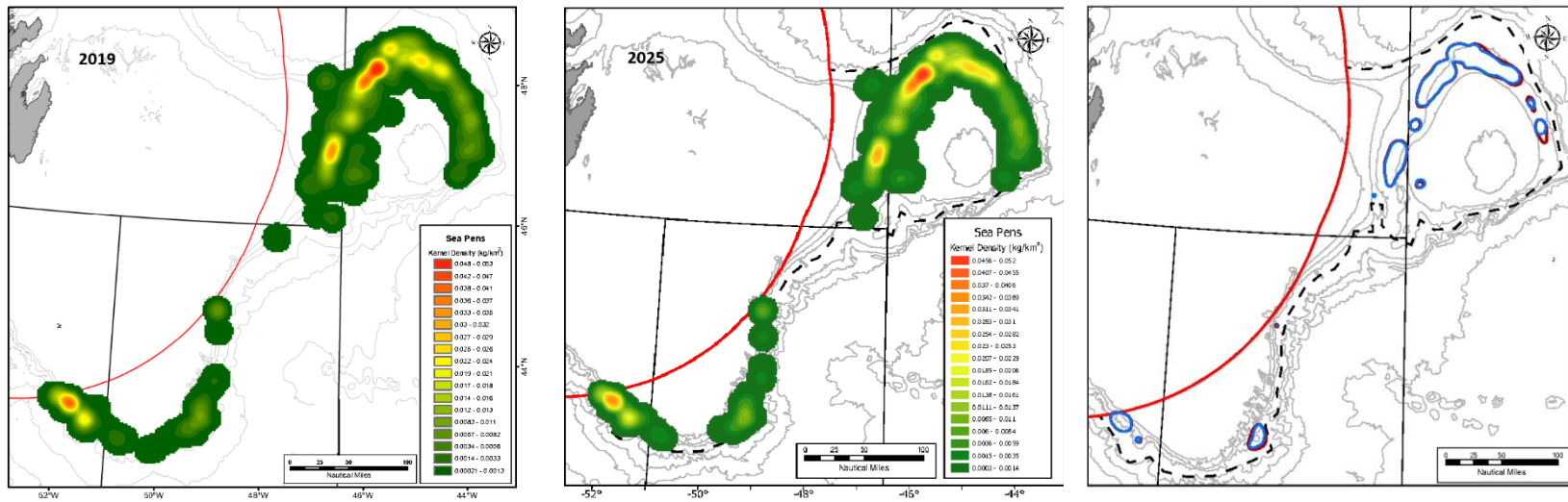


Figure 5.9. Results of the KDE analyses for the Sea Pen functional group showing the 2019 KDE biomass surface, the 2025 KDE biomass surface and the KDE-VME polygons from the 2025 (red) and 2019 (blue) analyses.

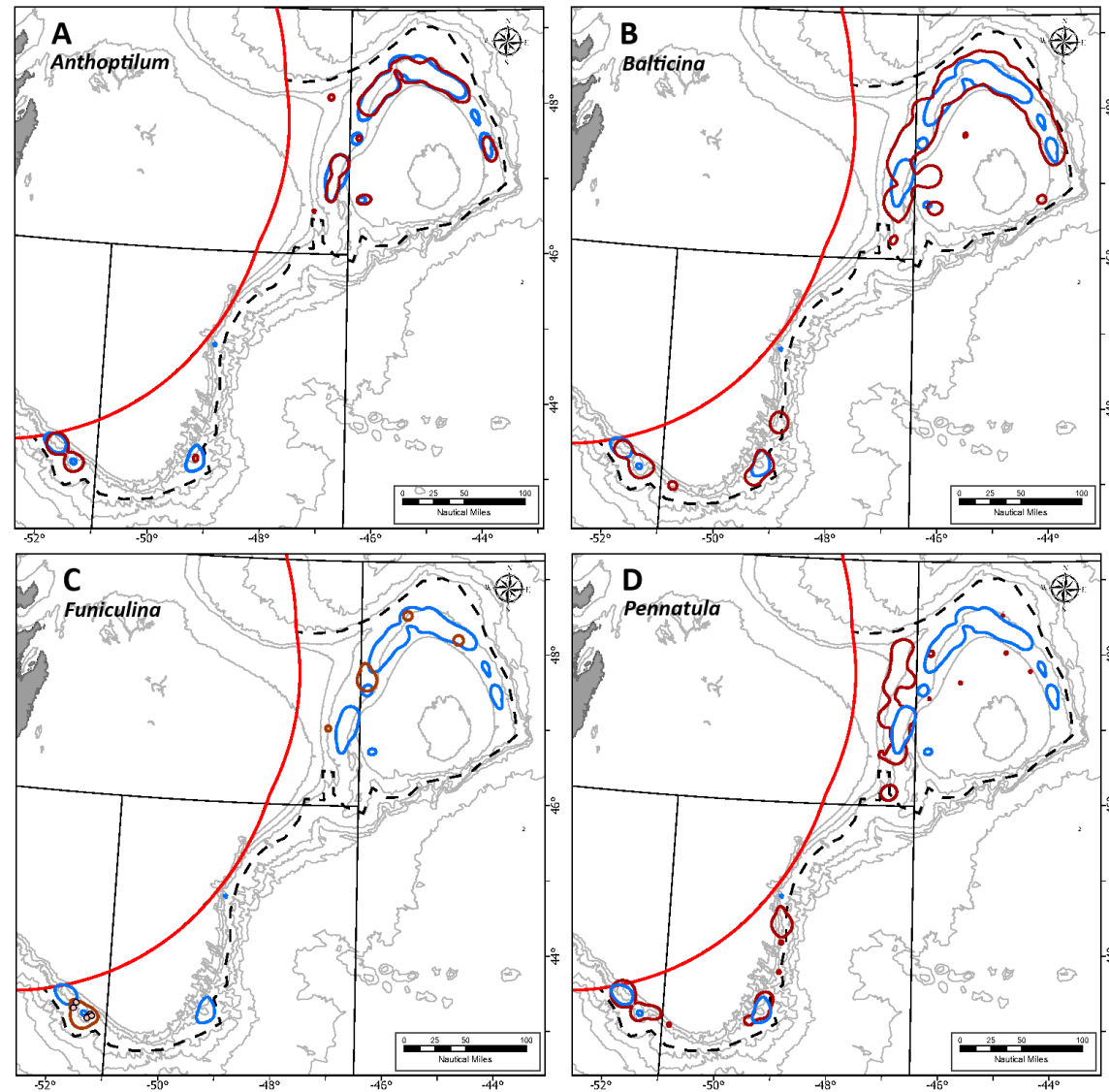


Figure 5.10. The KDE-VME polygons for the *Anthoptilum* (A), *Balticina* (B), *Funiculina* (C) and *Pennatula* (D) subgroups of sea pens are shown in red and compared with the 2025 KDE-VME polygons for the Sea Pen functional group (blue).

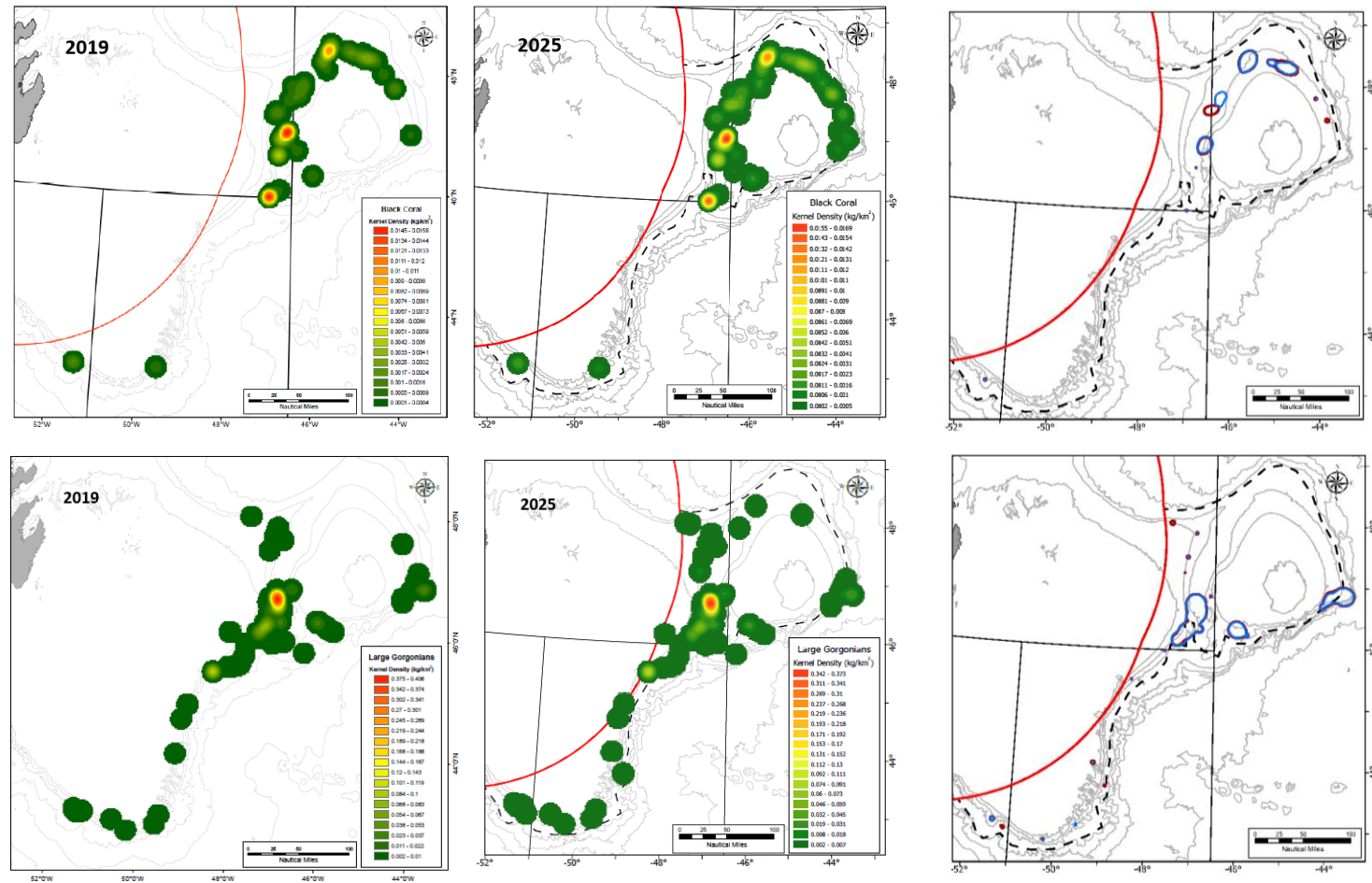


Figure 5.11. Results of the KDE analyses for the Black Coral functional group (upper row) and Large Gorgonian Coral functional group (lower row) showing the 2019 KDE biomass surface, the 2025 KDE biomass surface and the KDE-VME polygons from the 2025 (red) and 2019 (blue) analyses.

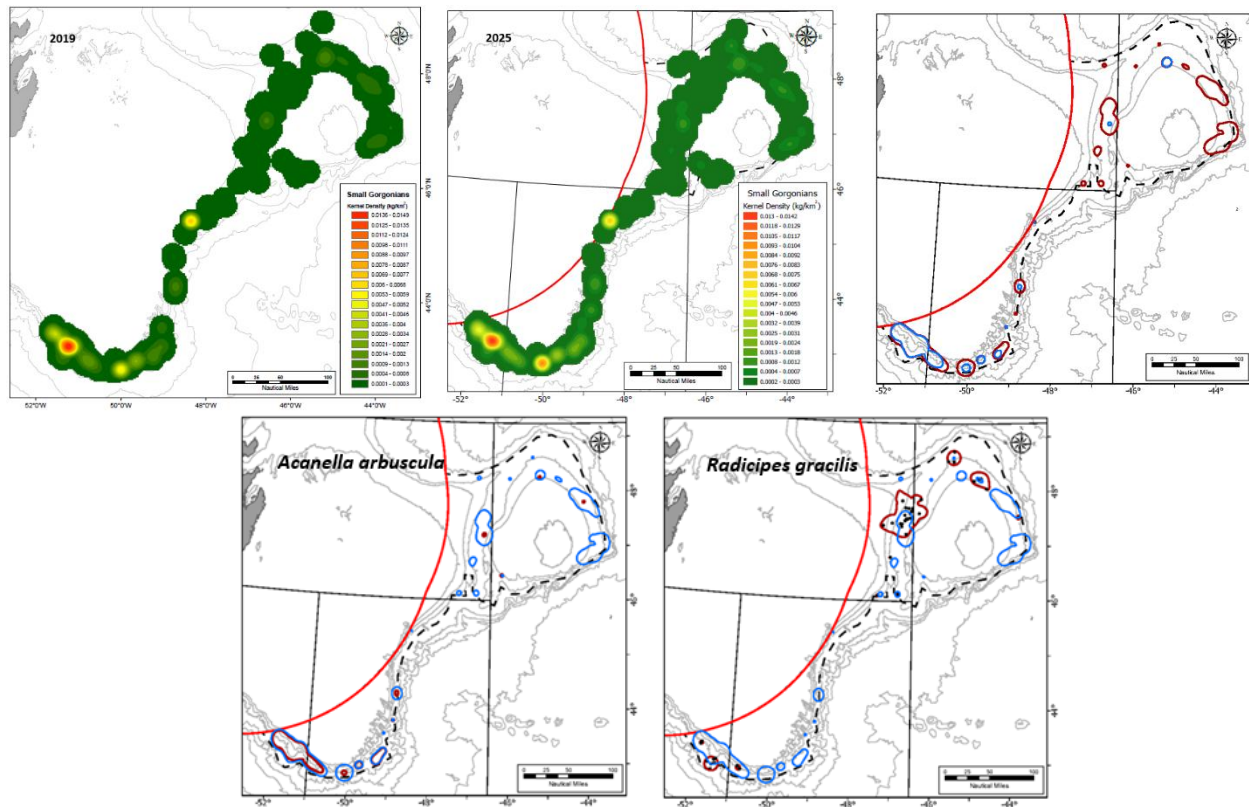


Figure 5.12. Results of the KDE analyses for the Small Gorgonian Coral functional group (upper row) showing the 2019 KDE biomass surface, the 2025 KDE biomass surface and the KDE-VME polygons from the 2025 (red) and 2019 (black) analyses. The KDE-VME polygons for *Acanella arbuscula* and *Radicipes gracilis* (lower row) subgroups are shown in red and compared with the 2025 KDE-VME polygons for the Small Gorgonian Coral functional group (blue). Areas in each where the subgroup has large areas outside of the functional group are indicated in black.

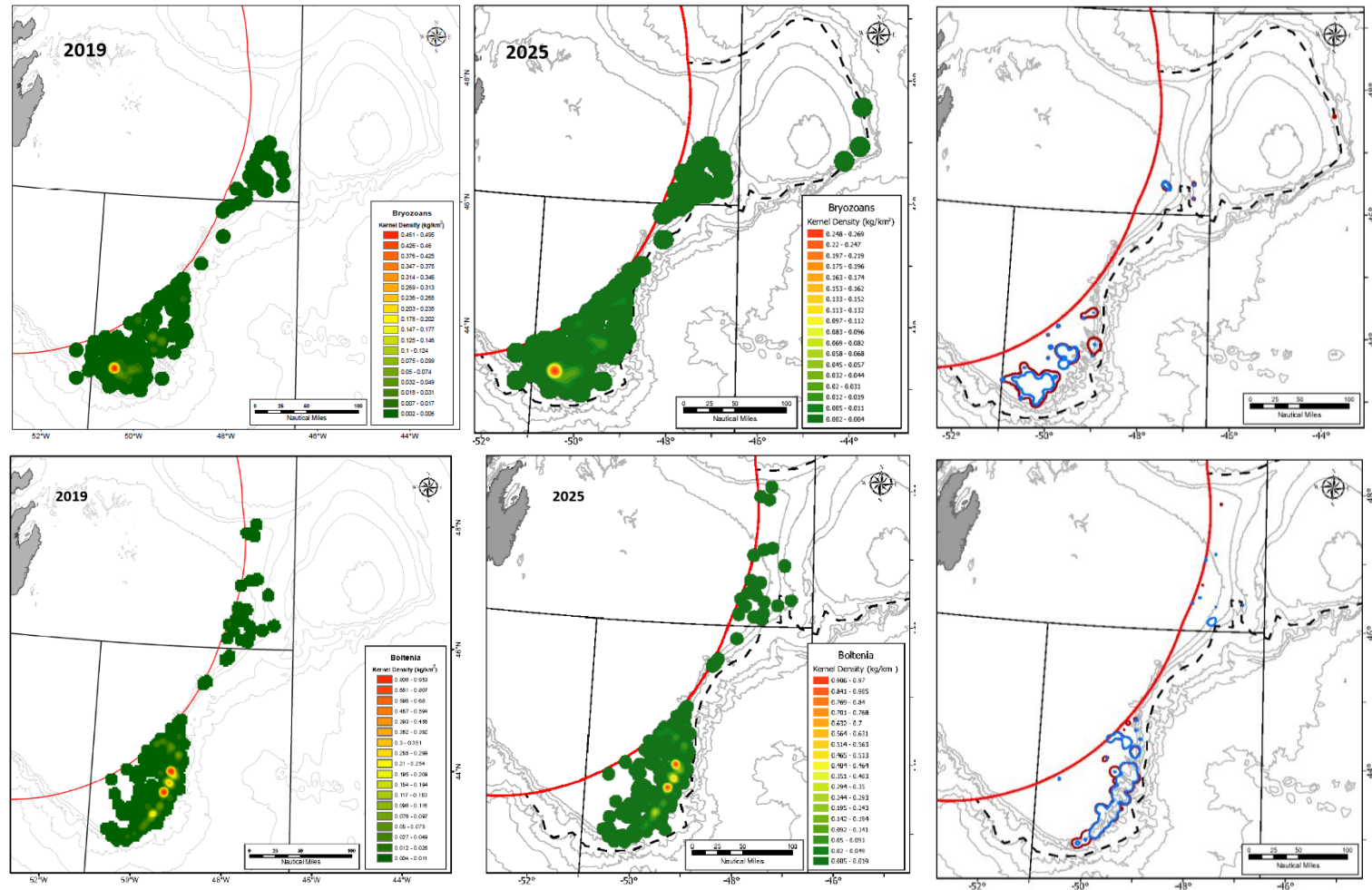


Figure 5.13. Results of the KDE analyses for the Erect Bryozoan functional group (upper row) and Sea Squirt (*Boltenia ovifera*) functional group (lower row) showing the 2019 KDE biomass surface, the 2025 KDE biomass surface and the KDE-VME polygons from the 2025 (red) and 2019 (blue) analyses.

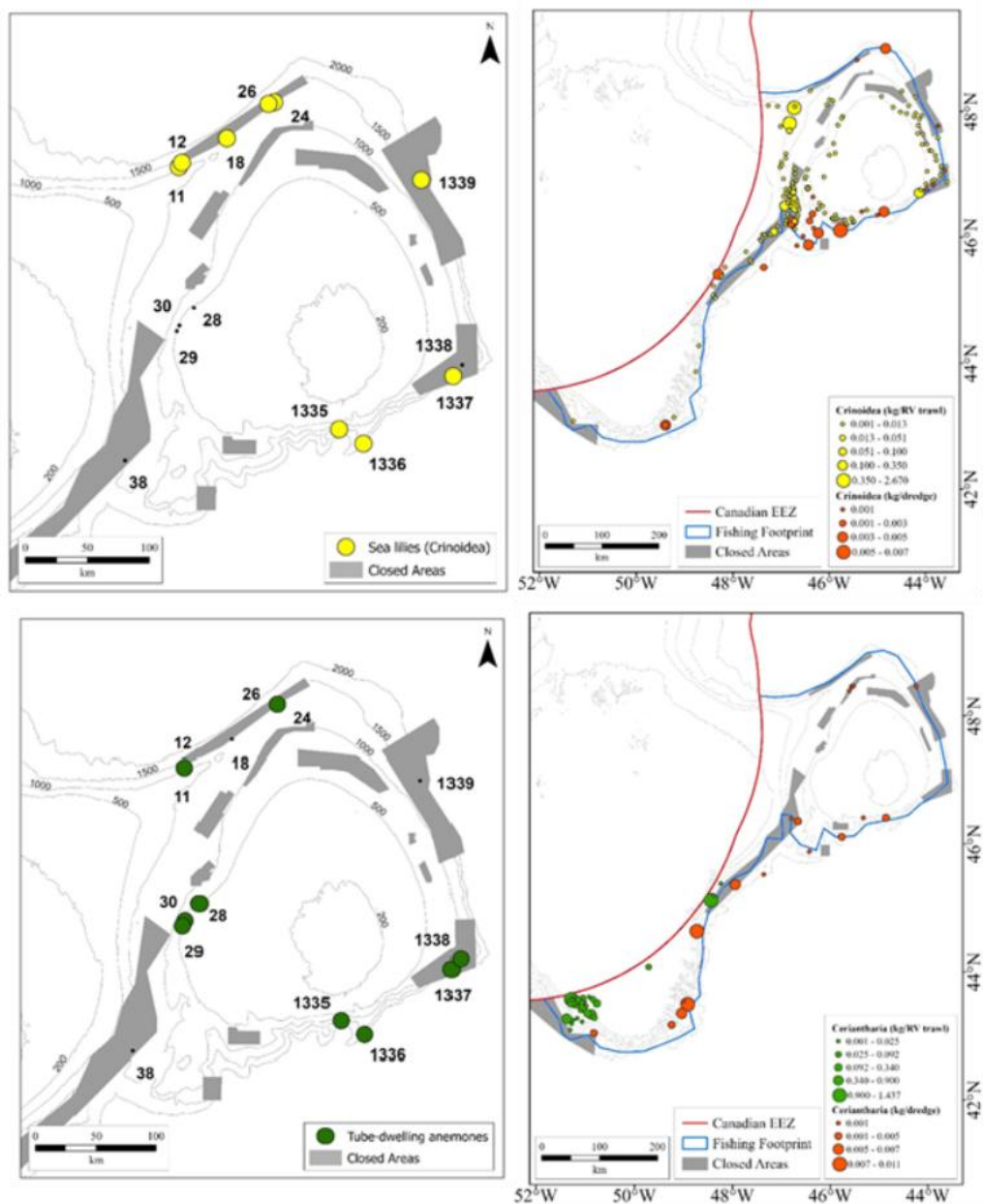


Figure 5.14. **Upper row.** Presence of Sea Lilies on video and photographic transects collected from the Flemish Cap area in 2009 and 2010 (Left). Relative biomass of Crinoidea collected during the NEREIDA surveys between 2009-2010 using a rock dredge (red) and EU-Spain research trawl surveys between 2006-2024 (yellow) (Right). **Lower row.** Presence of Tube-Dwelling (Ceriantharia) Anemones on video and photographic transects collected from the Flemish Cap area in 2009 and 2010. Right panel. Relative biomass of Ceriantharia collected during the NEREIDA surveys between 2009-2010 using a rock dredge (red) and EU-Spain research trawl surveys between 2006-2024 (green).

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c) ToR 2.3. Identification of VMEs in the NAFO Regulatory Area Combining Kernel Density Analyses, SDM and Empirical Data [COM. Request#6b]

Kernel density estimation analyses (KDE) use spatially explicit data to model the distribution of a variable of interest. It is a simple non-parametric neighbour-based smoothing function that relies on few assumptions about the structure of the observed data. It has been used in ecology to identify hotspots, that is, areas of relatively high biomass/abundance. With respect to marine benthic invertebrate species, it was first applied to the identification of significant concentrations of sponges in the NAFO Regulatory Area in 2009 (Kenchington *et al.*, 2009) followed by an application to sea pens (Murillo *et al.*, 2010). Since then, it has been used to identify significant concentrations of corals, sponges and other VME indicators from research vessel (RV) trawl survey catch data in both Canada (Kenchington *et al.*, 2016) and the NRA (NAFO, 2019; Kenchington *et al.*, 2019; Kenchington *et al.*, 2025a).

However, KDE does not take into account environmental variables which can be important determinants of distribution. To address this issue, species distribution models (SDMs), using a common set of environmental variables were performed for the seven VME functional groups (Large-Sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals) (Murillo *et al.*, 2024; Murillo *et al.*, 2025). Subgroups of some of the VME functional groups had sufficient data to warrant application of both the SDM and KDE analyses (Murillo *et al.*, 2024, Murillo *et al.*, 2025, Kenchington *et al.*, 2025a). These included two families and one suborder of sponges (Tetillidae, Polymastiidae, Astrophorina), four sea pen genera (*Balticina*, *Funiculina*, *Pennatula*, and *Anthoptilum*) and two species of small gorgonian coral (*Acanella arbuscula* and *Radicipes gracilis*). The correspondence between the KDE-generated VME polygons and areas of predicted occurrence derived from species distribution models (SDM) was examined and used to modify the polygons to eliminate areas where the taxon was not predicted to occur (as was done previously; NAFO, 2015; NAFO, 2019). Of the 16 VME Indicator taxa, 10 had modifications to one or more of their polygons (Kenchington *et al.*, 2025b). These were reviewed in WG-ESA and here those polygons which were modified are detailed. No modifications were made to the Sea Pen functional group, the sea pen subgroups *Balticina* and *Funiculina*, the Black Coral functional group, the Large Gorgonian Coral functional group and the small gorgonian coral *Acanella arbuscula*. For those groups the KDE-VME polygons are as described elsewhere in this report and in detail in Kenchington *et al.* (2025a).

Lastly, the effectiveness of the closed areas was assessed by examining the proportion of VME polygon area (km²) derived from the kernel density biomass surfaces under protection. These metrics may serve as potential indicators of the status and long-term trends of the VMEs and the management measures in place to protect them, and will be used to inform the ecosystem overview summary sheets.

i) Overlay of Species Distribution Models (SDMs) with VME Polygons from the KDE Analyses

The SDMs predicting the probability of presence for each VME indicator taxon were built using Random Forest classification models (Murillo *et al.*, 2024; Murillo *et al.*, 2025). Random Forest is an ensemble method, where a large number of decision trees (in this case, 500 per model) are built using random subsets of the data (Breiman, 2001; Cutler *et al.*, 2007). Each model was run 10 times and the final model output was based on the most frequently predicted class (presence/absence) across those runs. 'Sensitivity' of the model corresponds to the proportion of observed presences correctly predicted as such while 'Specificity' is the proportion of absences correctly predicted. Binary presence/absence maps were created by using a threshold optimised to ensure that resulting Sensitivity and Specificity are afforded equal weight (Sensitivity=Specificity) to detection of presence and absence, minimising both false-positives and false-negatives to the same degree.

To assess the reliability of those predictions, we generated two types of confidence map layers:

1. Frequency of the dominant class (N/10): This shows how many times the most common class (presence or absence) was predicted out of the 10 runs. For example, a value of 0.6 associated with presence areas, means that presence was predicted in 6 out of 10 runs, but an absence was predicted in the remaining 4.
2. Average probability of the maximum frequency class: This calculates the mean probability of the most frequent class across all 10 runs. This value reflects the model's confidence in its dominant prediction, whether it is presence or absence. Values ranging from 1 to 0 indicate the average probability over all 10 SDM model runs of the most frequent class (either presence or absence), indicating how confident the model is in its dominant prediction. Values close to 1 indicate that the model consistently predicted the same class (presence or absence), reflecting high reliability. Lower values (e.g., 0.37) indicate inconsistency and higher uncertainty, possibly corresponding to transition or environmental extrapolation zones where data is scarce or less representative.

These values help assess the reliability of predictions for conservation decision-making. Importantly, high certainty can apply to both presence and absence predictions. Although both maps are similar, we chose to use the average probability of the maximum frequency class (i.e., presence or absence) from the 10 cross-validation runs to illustrate model uncertainty. Areas with lower average probability within the same class can be







interpreted as areas of higher uncertainty. In the full report (Kenchington *et al.*, 2025b) four maps are presented in two figures to illustrate this uncertainty (e.g., Figures 3 and 4 of Kenchington *et al.*, 2025b). In the first figure the map of average probability of the maximum frequency class is presented as in the SDM reports (Murillo *et al.*, 2024; Murillo *et al.*, 2025). In the same figure the predicted presence area from the SDM with a 30% transparent overlay showing areas where the SDM predicts presence is shown to indicate where the probabilities are associated with predicted presence. In the second figure only the probabilities for when the maximum frequency class = absence in the first map and in an accompanying panel of the figure, only the probabilities for when the maximum frequency class = presence in the second map are shown (Kenchington *et al.*, 2025b). These two figures present the same information in different ways to facilitate decision making.

Additionally, areas of model extrapolation (univariate and combinatorial) were identified to support decision-making. These are regions where the model predicts habitat suitability outside the range of environmental conditions used to train the model, and therefore may yield unreliable or less reliable predictions. Where the KDE-VME polygon reached beyond the spatial extent of the SDMs generally the area was not clipped as there was no basis to do so. In one case the extension was clipped and an explanation provided (Large-Sized Sponges functional group, see below). Some polygons crossed the NAFO Regulatory Area (NRA) into the Canadian EEZ and those were also modified back to the EEZ boundary.

ii) Work Flow

Following previously established procedures (NAFO, 2015) the VME polygons produced from the KDE analyses (Kenchington *et al.*, 2025a) were overlain on these maps to review whether any of the polygons warrant trimming to reflect their predicted habitat distribution. In the last assessment, modifications were made to the Large-Sized Sponges and the Large Gorgonian Coral Functional Groups (Kenchington *et al.*, 2019). The polygons as a group were assessed against the appropriate presence/absence SDM and polygons that merited closer examination flagged. Those were then examined close up using the SDM uncertainty maps along with the underlying data (RV catches) and modifications were proposed. The explanation for the modifications were provided in the accompanying text.

The steps followed to reach a decision on modifications to the KDE VME polygons were:

	<p>Review KDE VME polygons (Kenchington <i>et al.</i>, 2025) with their associated SDMs (Murillo <i>et al.</i>, 2024; 2025)</p> <ul style="list-style-type: none"> • Identify polygons that cross into the Canadian EEZ • Identify polygons that have large overlap with areas of predicted absence
	<p>Zoom in on identified polygons and evaluate uncertainty in the SDM models</p> <ul style="list-style-type: none"> • Identify polygons that overlap with areas where there is a high probability of predicted absence
	<p>Propose modifications to the VME polygons</p> <ul style="list-style-type: none"> • Clip polygon edges to areas where there is a high probability of predicted presence • Clip polygon edges to the border with the Canadian EEZ
	<p>Map the proposed modifications to the VME polygons</p> <ul style="list-style-type: none"> • Map the locations of the VME polygons including ones that have been modified and ones that have not • Calculate the area of each polygon
	<p>Document decisions</p> <ul style="list-style-type: none"> • Document the changes and the rationale followed in making the modifications
	<p>How are decisions made?</p> <ul style="list-style-type: none"> • Decisions are made by balancing empirical evidence with predictive models

iii) Evaluation of the Effectiveness of the NAFO Closed Areas

In order to evaluate the effectiveness of the closed areas, the proportions of the total VME polygon areas located inside and outside the NAFO closed areas, based on the VME polygons delineated in the 2019 and 2025 assessments were calculated. Here we summarize the decisions agreed to in WG-ESA for modification of some of the KDE-VME polygons.

iv) Modifications to the Large-Sized Sponges VME Polygons

Most of the Large-Sized Sponges Functional Group KDE VME polygon areas extended into areas of predicted sponge absence, the exception being the polygons in the vicinity of Area closures 3 and 13 on Beothuk Knoll (Kenchington *et al.*, 2025b). Modifications were made for Area closures 1, 2, 5, 6 and 10 as follows:

Area 1. The Large-Sized Sponges Functional Group KDE VME polygon in the vicinity of Area closure 1 extended into areas of predicted absence (Figure 5.15, Left Panel) on its shallower western boundary. The SDM model for this group did not extend into the deep waters at the eastern boundary of the KDE polygon, and there were no sponge catches at those depths, consequently no information was available for those depths. On the eastern boundary of the KDE, the probability of sponge absence was low adjacent to the area of predicted presence (Figure 5.15, Right Panel). Consequently, the modifications follow the area of predicted presence and extend to the region of high certainty of sponge absence (Figure 5.15) on the eastern boundary. On the western boundary the modification smooths out the area of predicted presence and cuts-off some of the deeper extensions of the polygon, which were created from the search radius of the KDE analyses and not from the presence of sponge in the catch. This was done for this polygon as no independent data were available to confirm sponge presence at depth in those areas in this region.

Area 2. The Large-Sized Sponges Functional Group KDE VME polygon in the vicinity of Area closure 2 extended into areas of predicted absence on its north eastern edge and into the Canadian EEZ on its south western edges

(Figure 5.16, Left Panel). Some of the area of predicted Large-Sized Sponges Functional Group absence had high uncertainty (low probability; Figure 5.16, Right Panel). The modifications were to clip the south western portion of the polygon to the EEZ boundary and to clip the north eastern edge to the region of high certainty of sponge absence (Figure 5.16; Right Panel).

Area 5. The Large-Sized Sponges Functional Group KDE VME polygon in the vicinity of area closure 5 included areas of predicted absence along its eastern edges (Figure 5.17, Left Panel). The lower eastern portion of the polygon extended outside of the spatial extent of the SDM. Figure 5.17 (Right panel) shows that there are areas where the predicted absence is highly uncertain. In some areas the areas of low probability of predicted absence are abutted by areas of predicted presence. This indicates that the model is not performing well at those edges. The modifications were to Area closure 14b and the other following the boundary that the 2019 KDE polygon was clipped to which we can now see has areas of lower probability of sponge absence. As the western boundary of the polygon was not modified in 2019, no changes in this iteration were made to that segment. One polygon including the area of predicted presence and area closure split the lower end of the polygon into two.

Areas 6 and 10. The Large-Sized Sponges Functional Group KDE VME polygon in the vicinity of Area closures 6 and 10 was lobed, with a single polygon capturing both of the two separate polygons established in the 2019 analyses. The polygon extends from Sackville Spur onto the Northwest slope of Flemish Cap. It includes large areas of predicted absence that was predicted with high certainty (Figure 5.18, Right Panel). The modifications separate the single polygon into two. One following the areas of predicted sponge presence running parallel to Sackville Spur and closely abutting Area closure 6 (Figure 5.18). This was similar to the modification made in 2019 (Figure 5.18). The second polygon was created from the lobe that included most of the Area closure 10 (Figure 5.18) and cut from the original polygon at its northern edge following the area of predicted presence. This polygon includes all of the smaller polygon identified in 2019. A third Large-Sized Sponges Functional Group KDE VME polygon was identified both in 2025 and 2019 to the east of Area closure 10 and no modifications were made to that area.

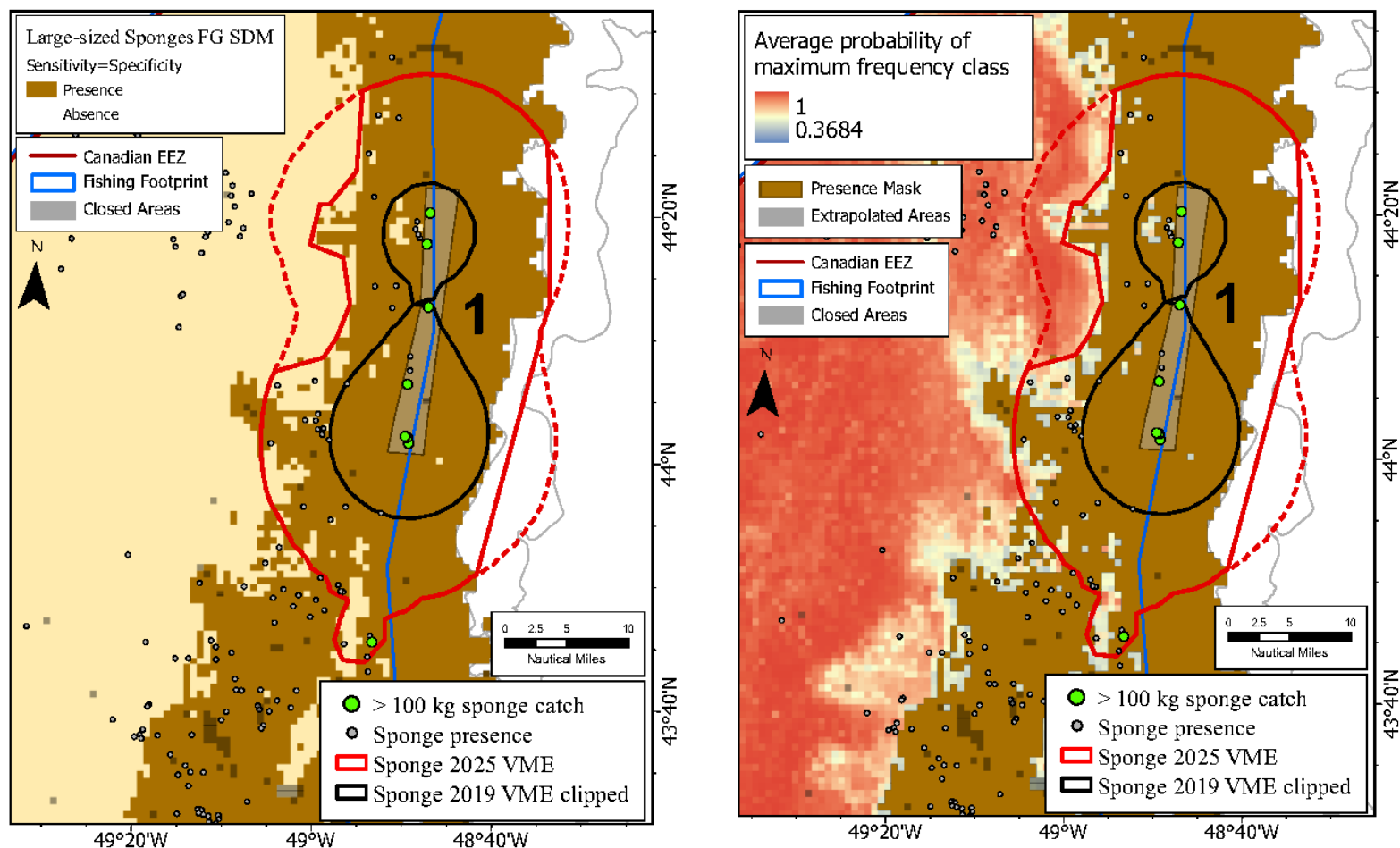


Figure 5.15. Area 1. Left Panel. Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Area 1 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Area 1 in relation to the 2019 accepted KDE VME polygon (solid black line), and showing the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Sized Sponges Functional Group (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown.

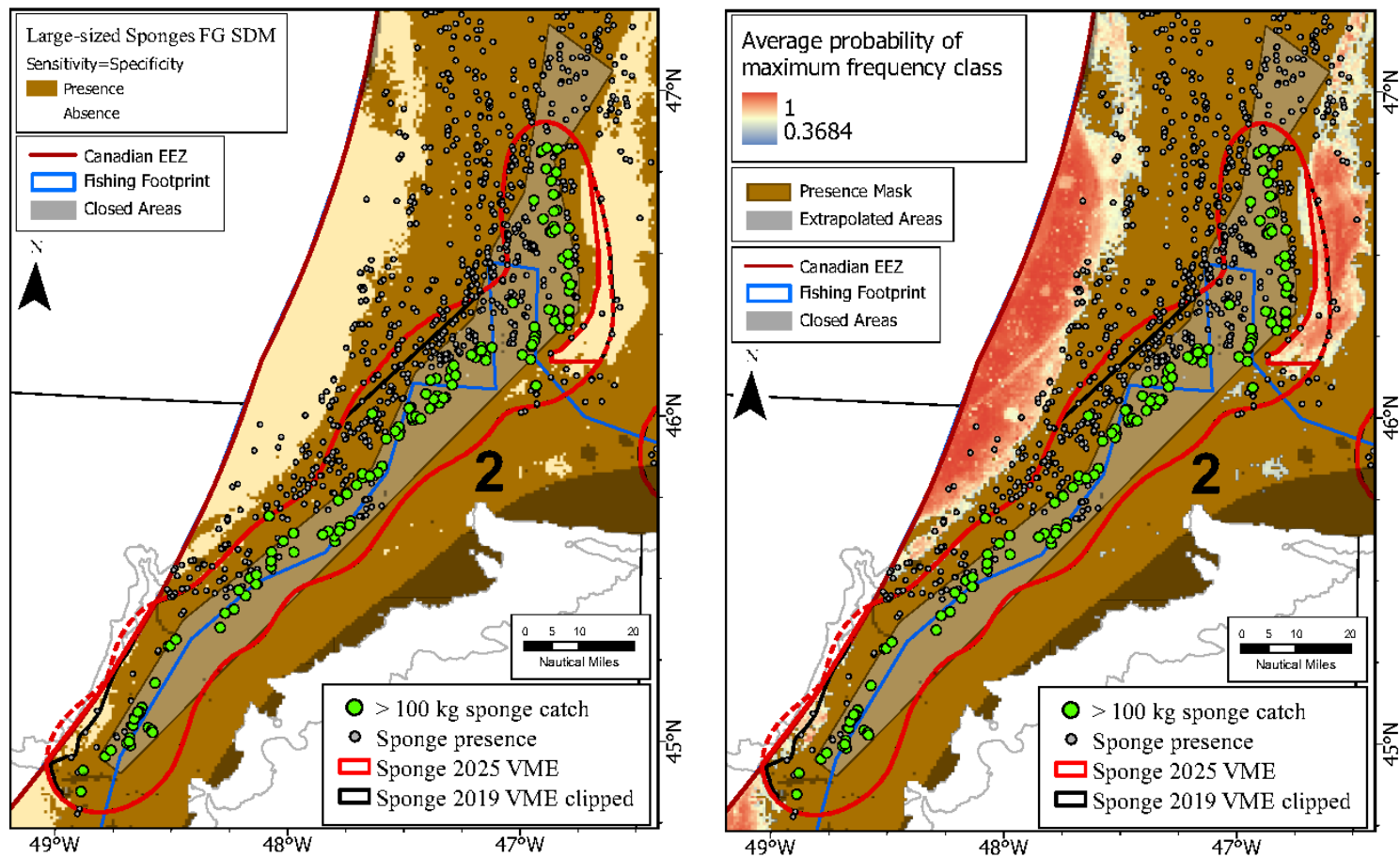


Figure 5.16. Area 2. Left Panel. Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Area 2 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). Right Panel. Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Area 2 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the average probability of the maximum frequency class for absence values from 10 SDM runs for the Large-Sized Sponges Functional Group (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown.

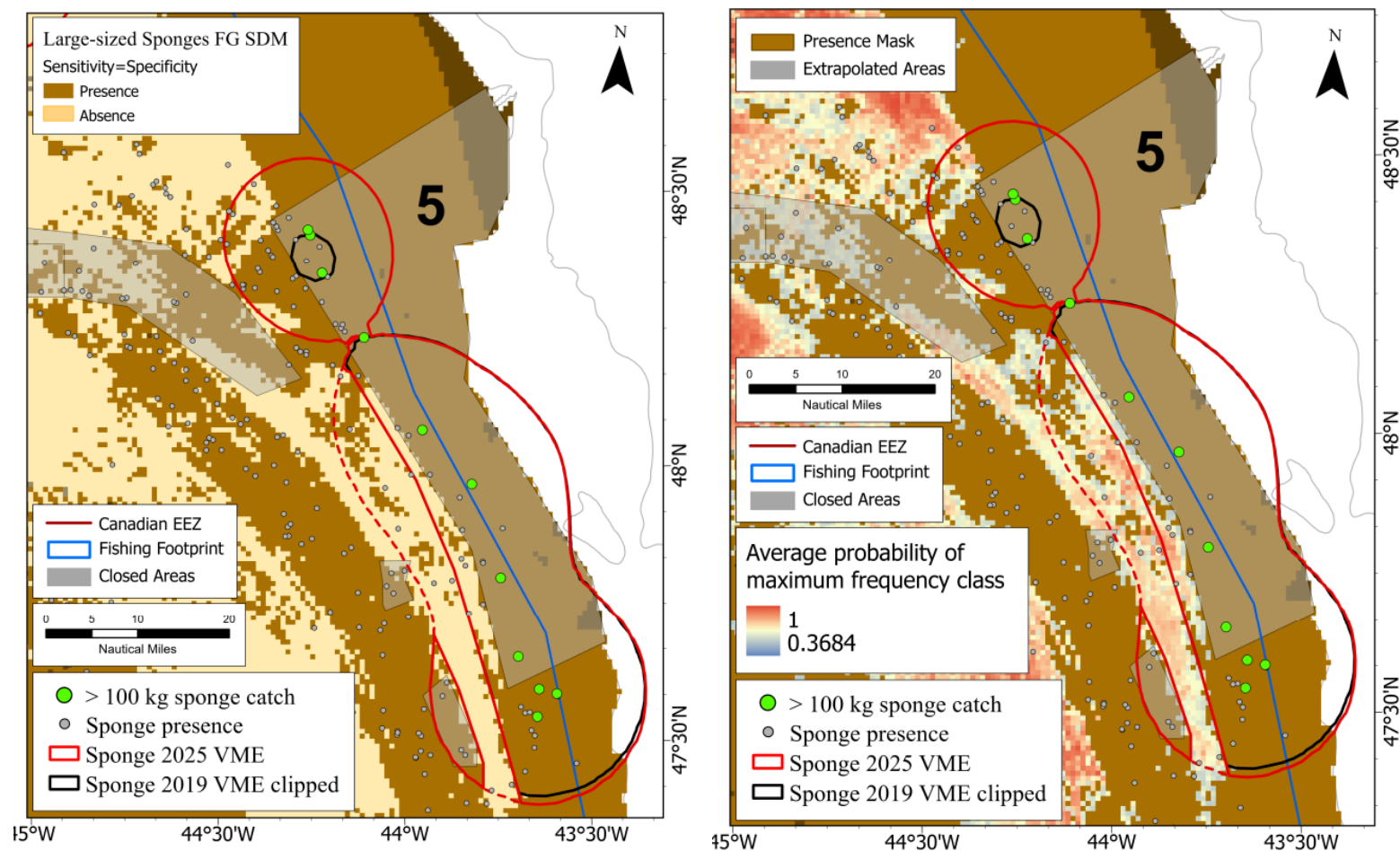


Figure 5.17. Area 5. Left Panel. Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Area 5 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Area 5 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Sized Sponges Functional Group (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown).

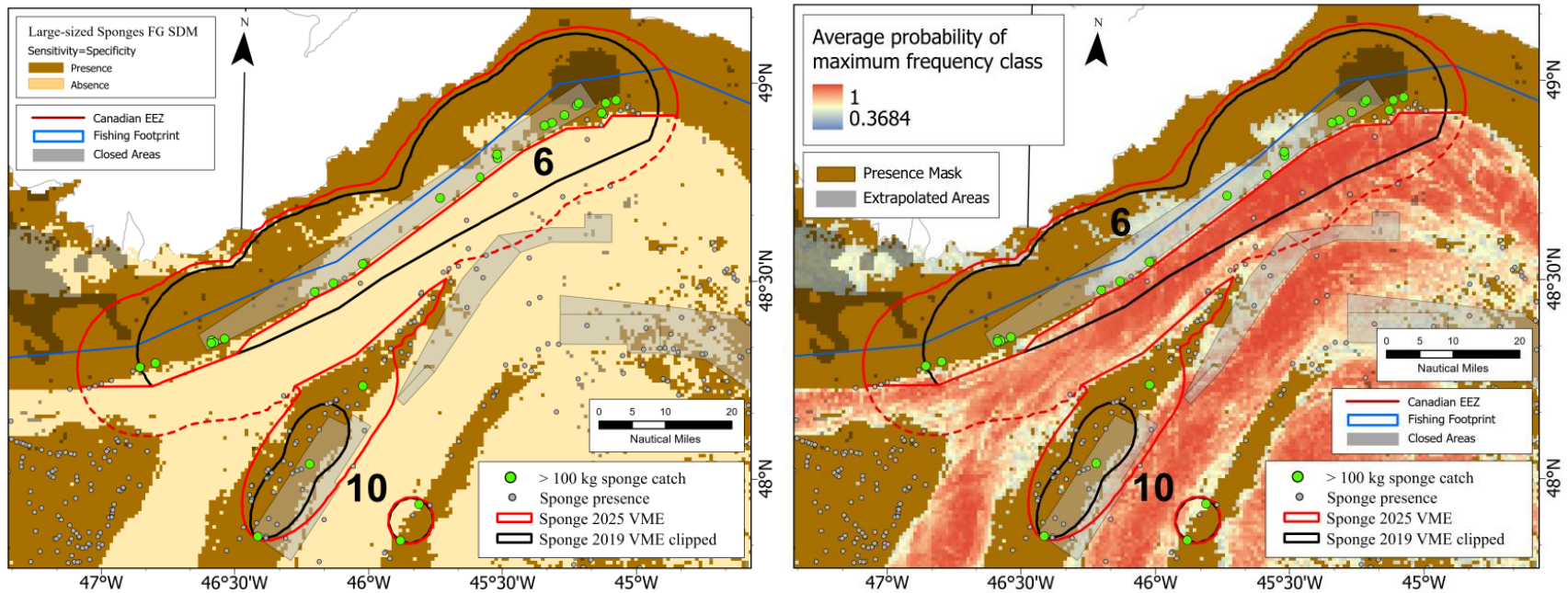


Figure 5.18. Areas 6 and 10. Left Panel. Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Areas 6 and 10 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Large-Sized Sponges KDE VME polygon (red dashed lines) near Areas 6 and 10 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the average probability of the maximum frequency class for absence values from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown).

The modifications would produce nine Large-Sized Sponges Functional Group KDE VME polygons (Figure 5.19).

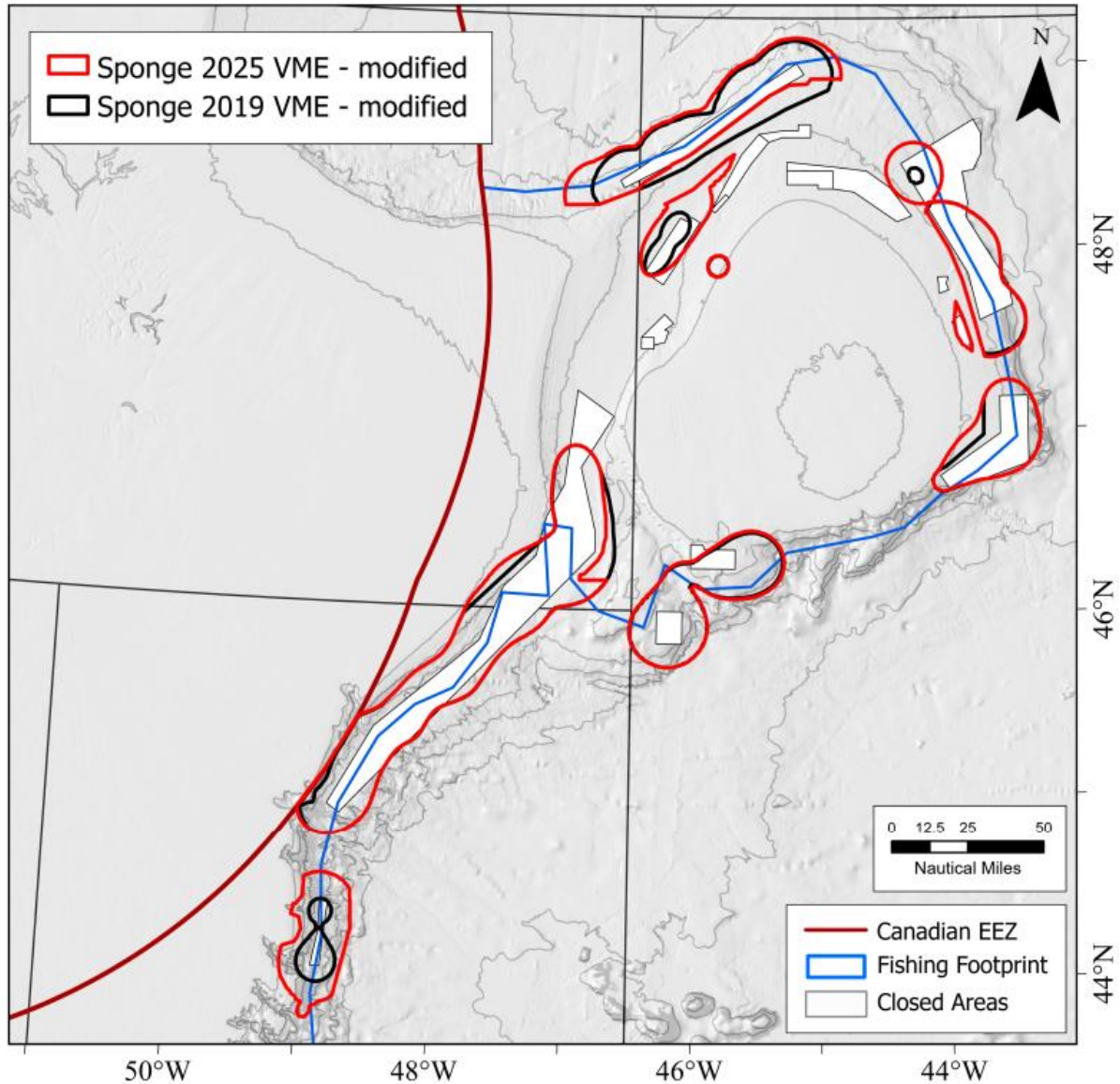


Figure 5.19. Map of the Large-Sized Sponges VME polygons (red line) after consideration of modifications based on the SDM for Large-Size Sponges (Murillo *et al.*, 2024), and in relation to the 2019 accepted KDE VME polygons (black line). Closed areas are indicated in white (NAFO, 2025).

v) *Modifications to the Tetillidae Sponge VME Polygons*

The Tetillidae subgroup of Large-Sized Sponges was not presented in the 2019 review (Kenchington *et al.*, 2019) as there were insufficient data to conduct the KDE analyses at that time. Modifications were made for the large polygon near Areas 1, 2, and 11 and for Area 10 as follows:

Areas 1, 2 and 11. The large convoluted KDE VME polygon for the Tetillidae Sponges crossed into the Canadian EEZ at its western boundary and also transversed areas of high probability of sponge absence (Figure 5.20). The polygon was clipped to the EEZ boundary at those locations and to the approximate area of predicted presence along its western and northern edges (Figure 5.20). No changes were made to the western boundary

at this time as the area in the northwest is fragmented and although the probability of predicted absence is high there are adjacent areas of predicted presence that have a low probability (Figure 5.20) but are nevertheless uncertain. Further, the kappa statistic for the SDM was only fair and the TSS 'good', indicating that model performance could be improved in future with more response data (Murillo *et al.*, 2024).

Area 10. The polygon in the vicinity of Area closure 10 also straddles parts of Area closures 12 and 9 (Figure 5.21). The area of predicted presence is patchy in this region and the adjacent areas of predicted absence are shown with high probability (Figure 5.21; Right Panel). Due to the patchy nature of this area and above noted model performance, we have clipped this polygon to the edges of the areas of predicted presence (Figure 5.21). The modifications would produce 15 Tetillidae Sponge KDE VME polygons (Figure 5.22).

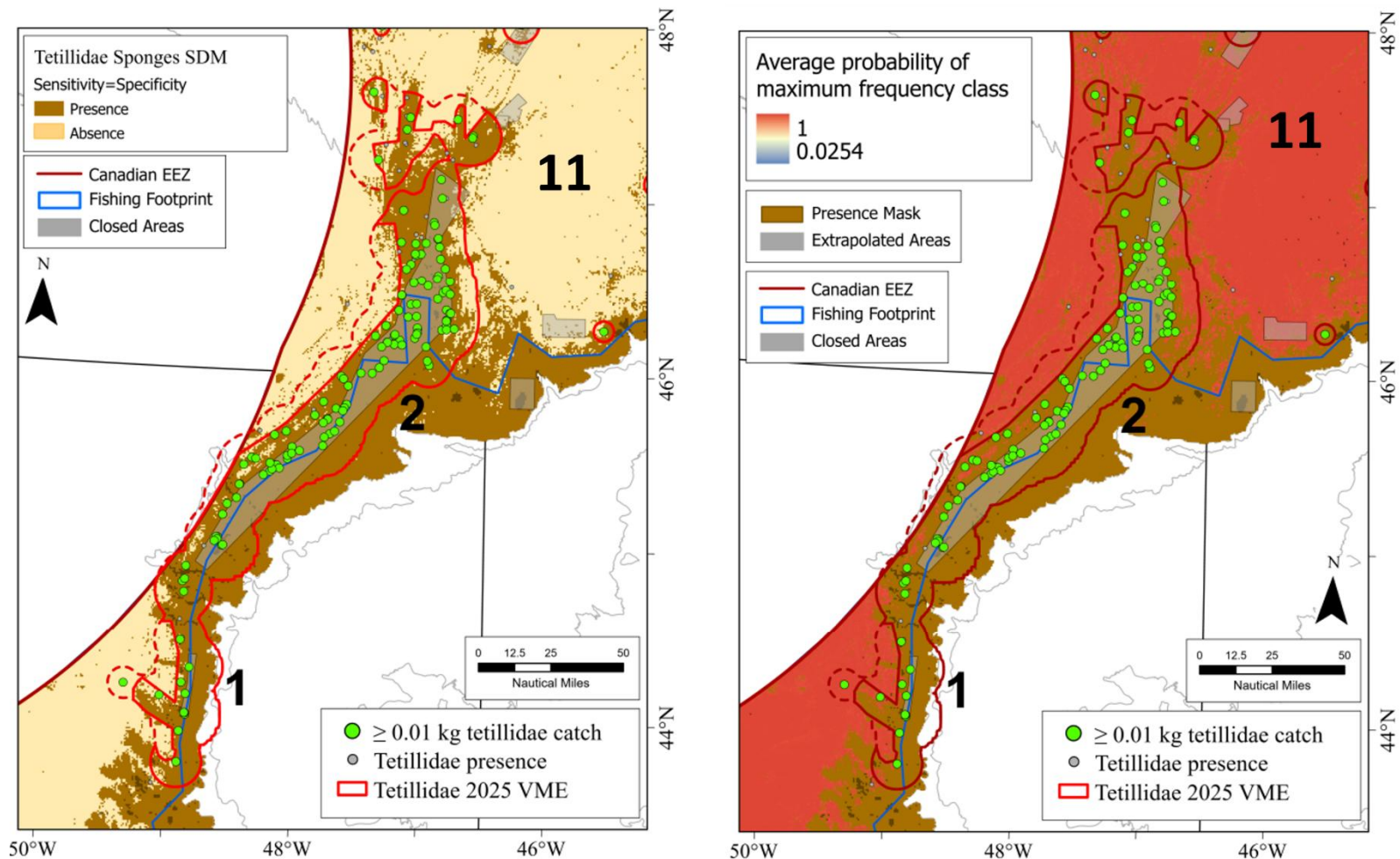


Figure 5.20. Areas 1, 2 and 11. Left Panel. Map of the modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Tetillidae Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) near Areas 1, 2 and 11 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Tetillidae Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.01 kg, the threshold for the KDE analyses, and all other catches with < 0.01 kg are shown.

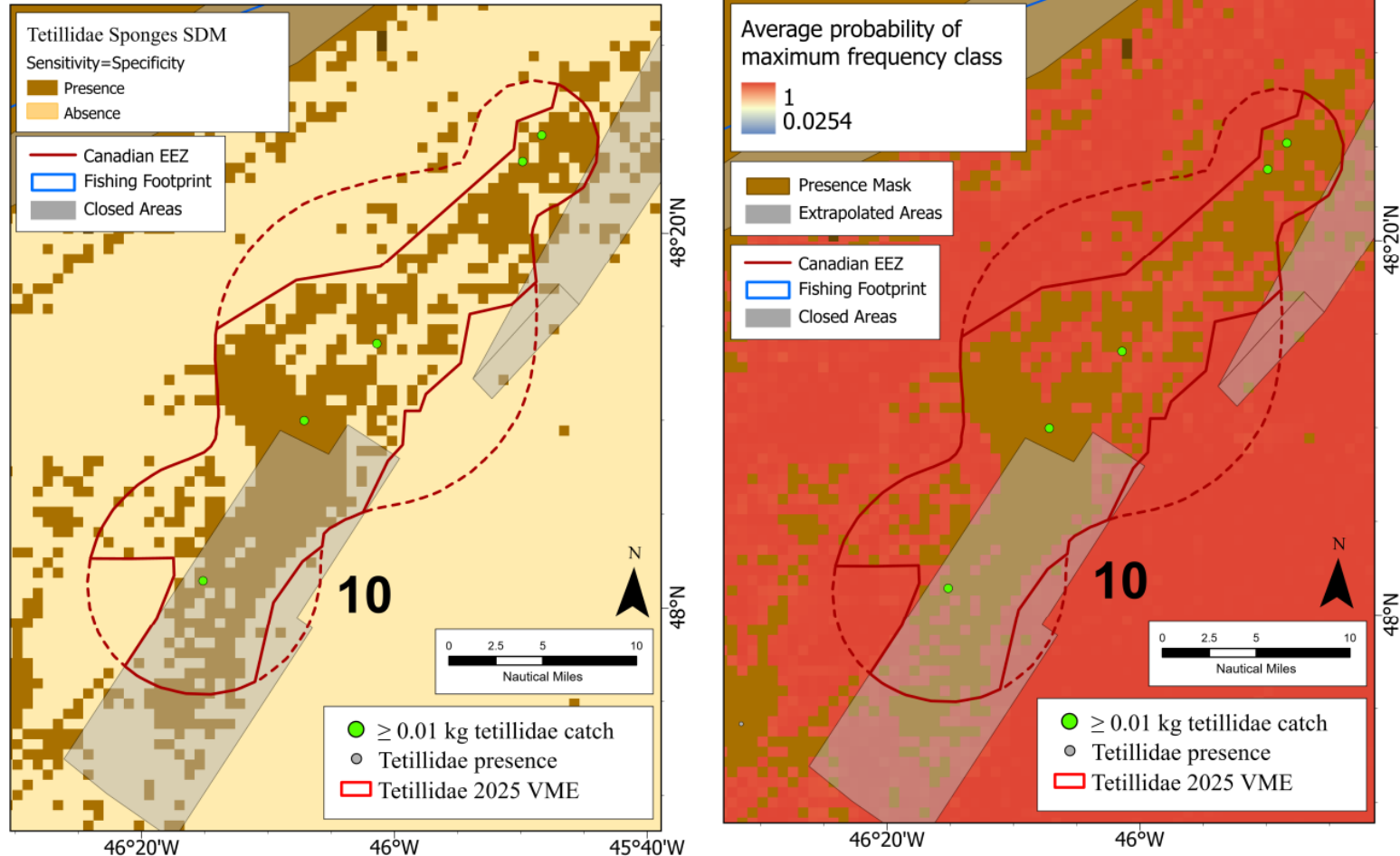


Figure 5.21. Area 10. Left Panel. Map of the modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Tetillidae Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) near Area 10 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Tetillidae Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.01 kg, the threshold for the KDE analyses, and all other catches with < 0.01 kg are shown.

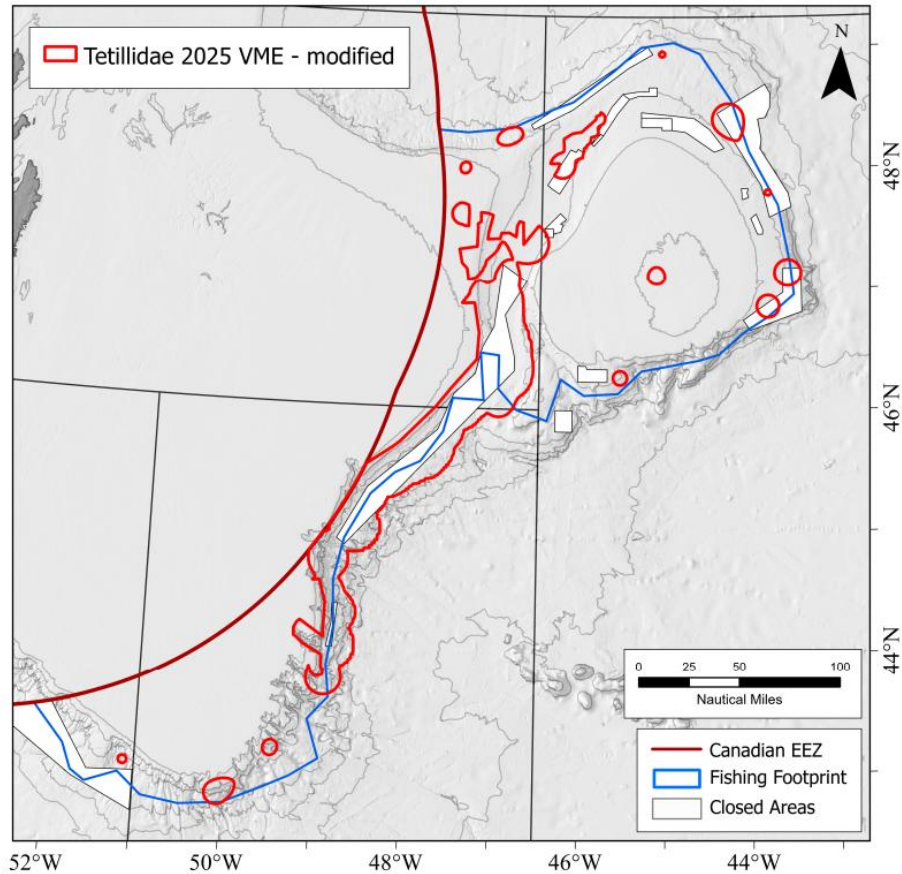


Figure 5.22. Map of the Tetillidae Sponge VME polygons (red outline) after consideration of modifications based on the SDM for Tetillidae Sponges (Murillo *et al.*, 2024). Closed areas are indicated in white (NAFO, 2025).

vi) Modifications to the Polymastiidae Sponge VME Polygons

The Polymastiidae subgroup of Large-Sized Sponges was not presented in the 2019 review (Kenchington *et al.*, 2019) as there were insufficient data to conduct the KDE analyses at that time. Of these, modifications were made to the polygon near Area closures 5 and 14b.

Areas 5 and 14b. The modifications to the Polymastiidae Sponge KDE VME polygon in this region include parts of two closure areas (Area 5 and Area 14b). This polygon was split into two, clipping out the area of predicted absence that is modeled with high probability of absence in that region (Figure 5.23).

The modifications would produce 24 Polymastiidae Sponge KDE VME polygons (Figure 5.24).

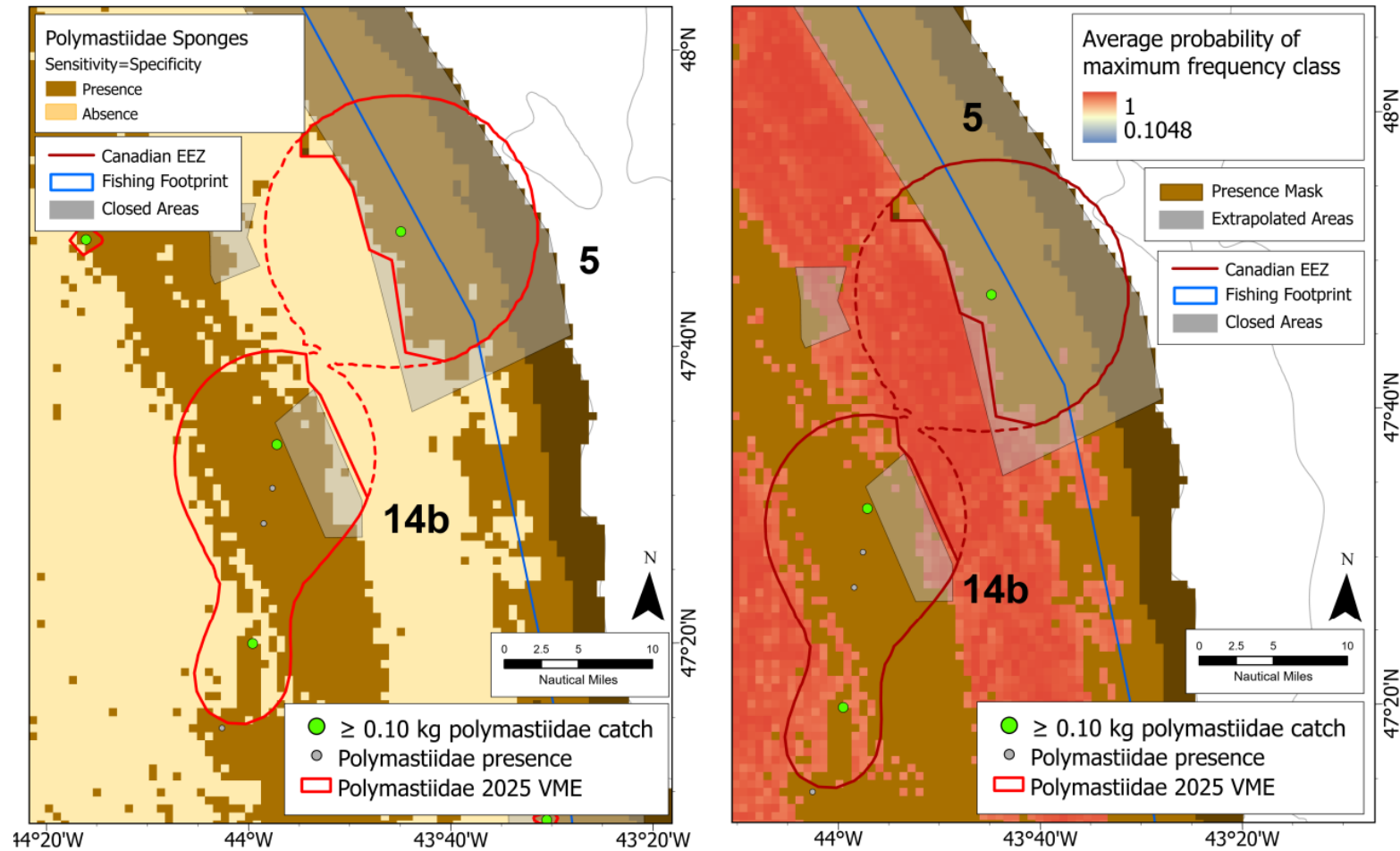


Figure 5.23. Areas 5 and 14b. Left Panel. Map of the modification (solid red line) of the 2025 Polymastiidae Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Polymastiidae Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Polymastiidae Sponge KDE VME polygon (red dashed lines) near Areas 5 and 14b in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Polymastiidae Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.1 kg, the threshold for the KDE analyses, and all other catches with < 0.1 kg are shown.

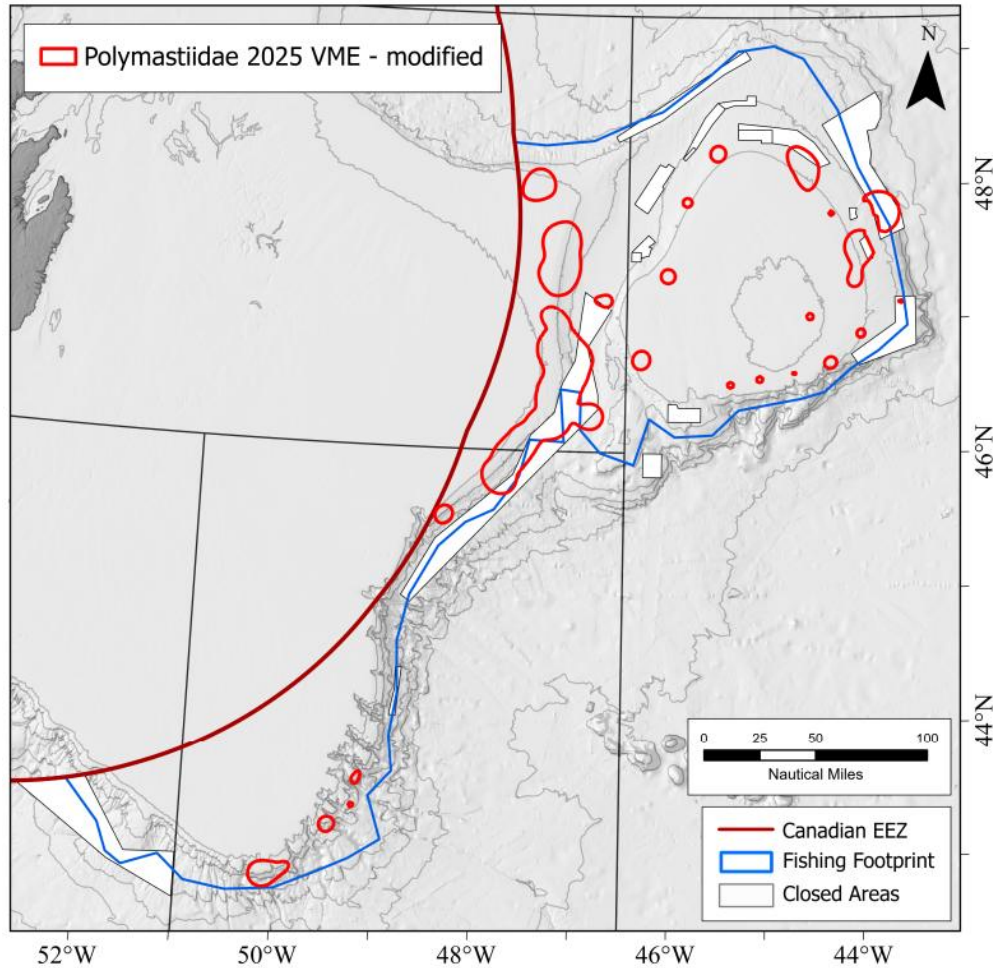


Figure 5.24. Map of the Polymastiidae Sponge VME polygons after consideration of modifications based on the SDM for Polymastiidae Sponges (Murillo *et al.*, 2024). Closed areas are indicated in white (NAFO, 2025).

vii) Modifications to the Astrophorina Sponge VME Polygons

The Astrophorina subgroup of Large-Sized Sponges was not presented in the 2019 review (Kenchington *et al.*, 2019) as there were insufficient data to conduct the KDE analyses at that time. A closer examination was made of the polygons in the vicinity of Area closures 1, 2, 5, 6, 7, and 13.

Area 1. The Astrophorina Sponge KDE VME polygon that encompasses Area 1 was clipped on its northwestern edge to the edge of the predicted presence from the SDM (Figure 5.25). This area of absence was very certain with an associated high probability.

Area 2. The Astrophorina Sponge KDE VME polygon in Flemish Pass overlays the closure Area 2 (Figure 5.26). It extends across the Canadian EEZ at its southwestern boundary but mostly follows areas of predicted sponge presence. Small modifications are suggested as illustrated in Figure 5.26 to exclude areas where the SDM predicts absence with high probability.

Area 5. Two Astrophorina Sponge KDE VME polygons include portions of Area 5 in their extents (Figure 5.27). Both largely overlapped with the area of predicted Astrophorina Sponge presence, but modifications were made to exclude areas where the SDM predicts absence with high probability.

Areas 6 and 10. Two Astrophorina Sponge KDE VME polygons include portions of Area closures 6 and 10 in their extents (Figure 5.28). The one that includes Area 6 has almost half of its extent in the area where the SDM predicts absence with high probability and where there are no smaller catches to indicate recovery potential.

This is an area of heavy fishing activity (Kenchington *et al.* 2019), which may explain the observed distributions. The other polygon captures much of Area closure 10 and some of Area closure 9 and has smaller portions extending into the area where the SDM predicts absence with high probability. Both areas were clipped to the boundary of the predicted presence of sponge from the SDM.

Area 13. The polygon which included large parts of Area closure 13 (Figure 5.29) included some areas where the SDM predicts absence with high probability (Figure 5.29). As for the other polygons, the area was clipped to the boundary of the predicted presence of sponge from the SDM.

The modifications would produce 14 Astrophorina Sponge KDE VME polygons (Figure 5.30).

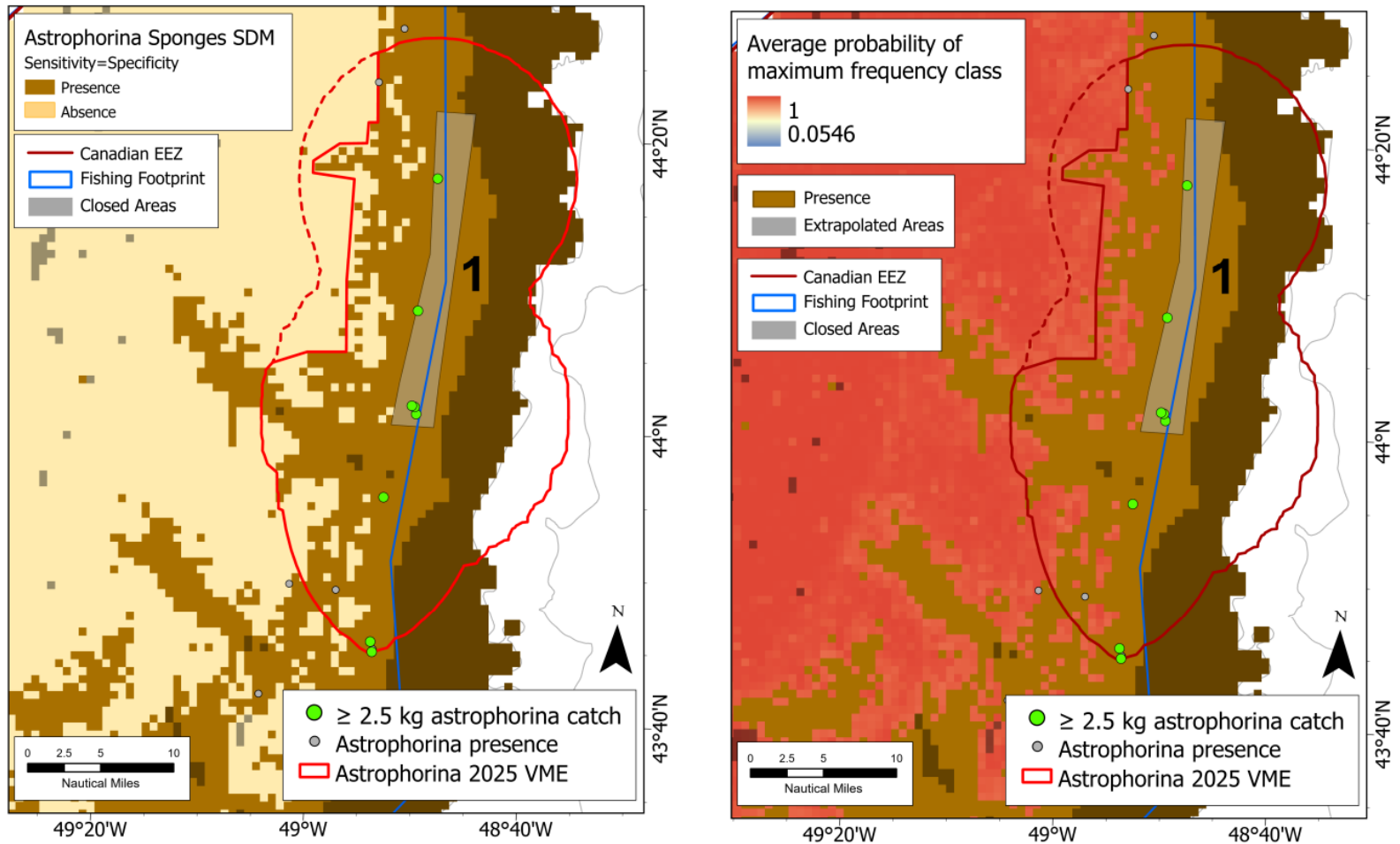


Figure 5.25. Area 1. Left Panel. Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 1 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

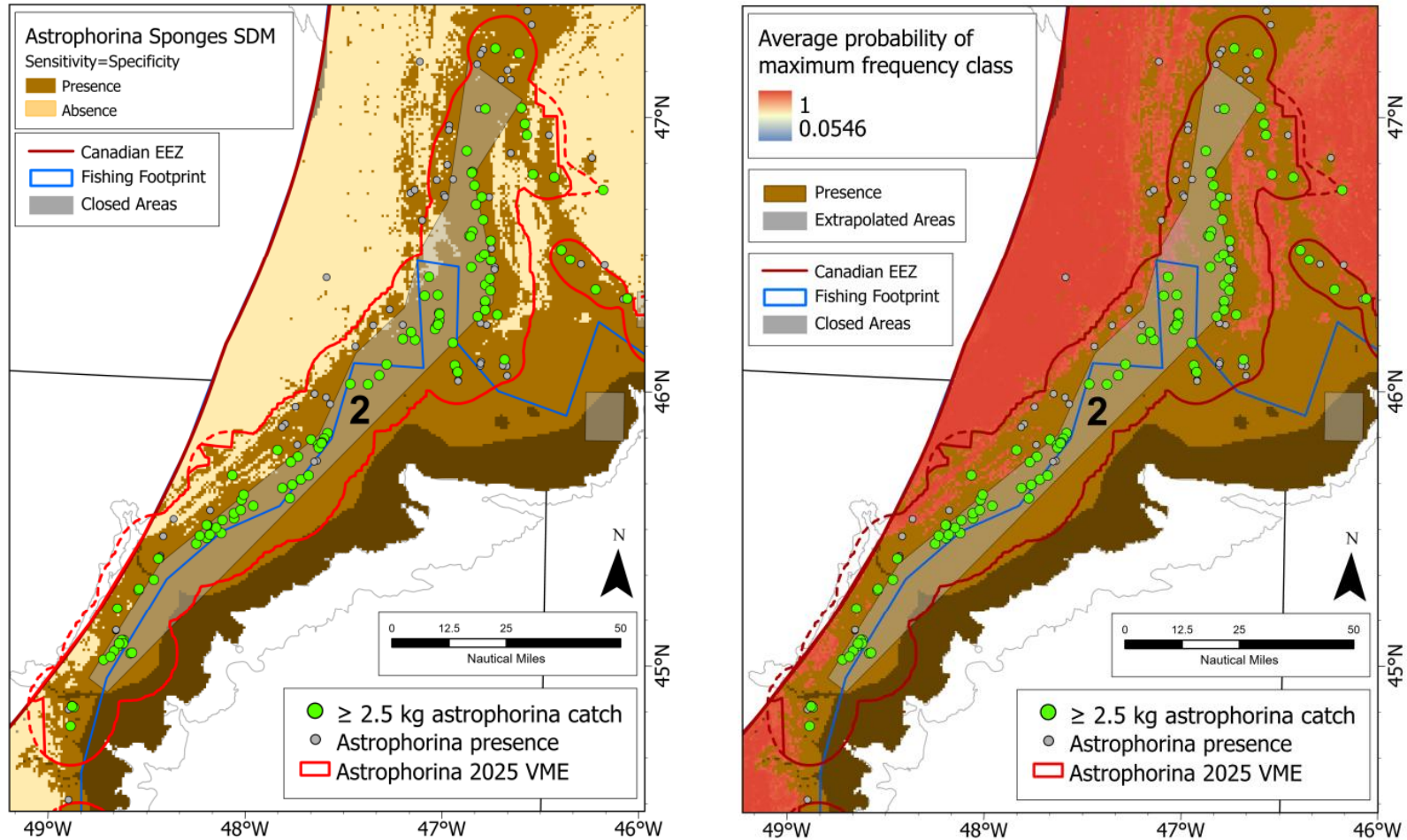


Figure 5.26. Area 2. Left Panel. Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 2 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

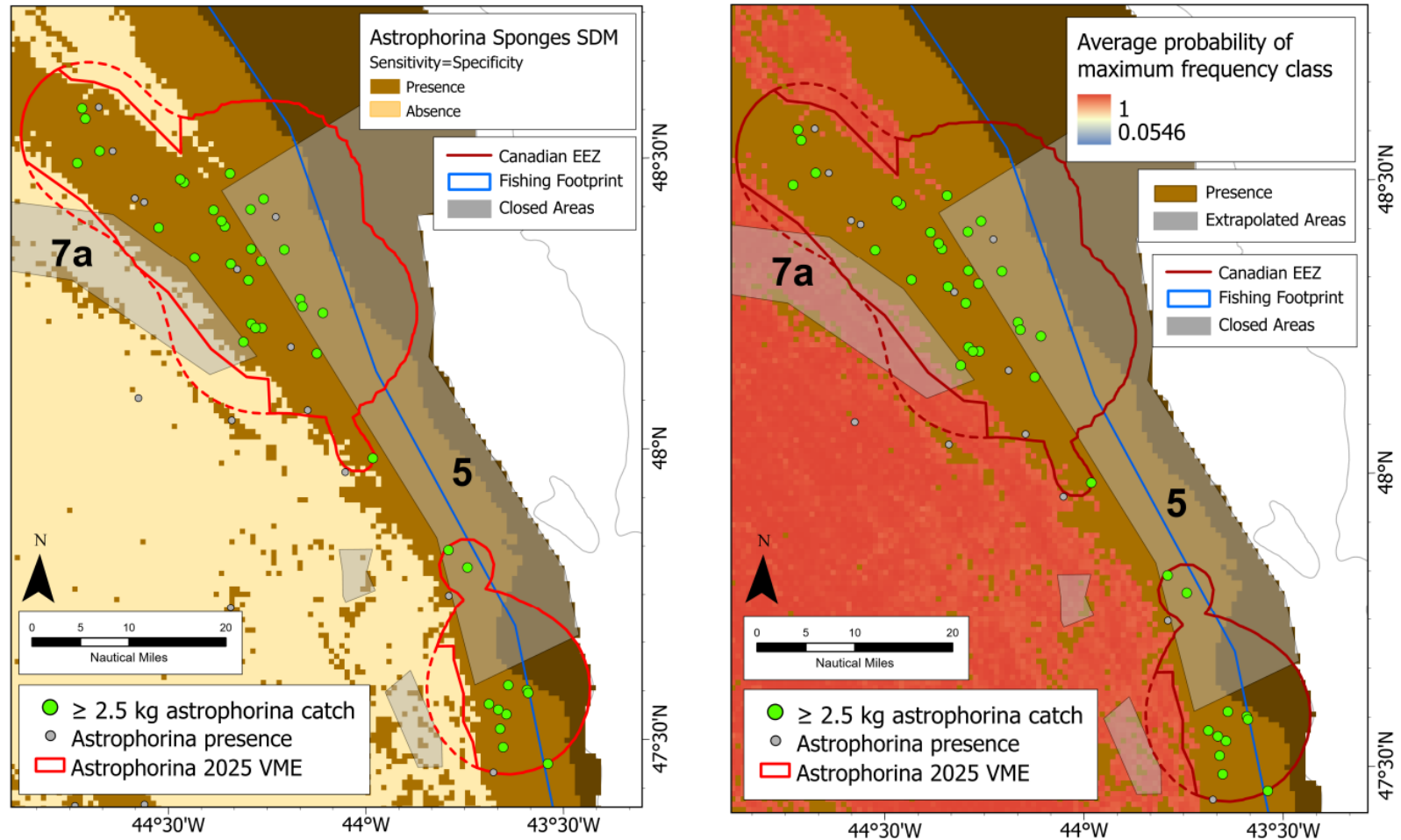


Figure 5.27. Area 5. Left Panel. Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 5 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

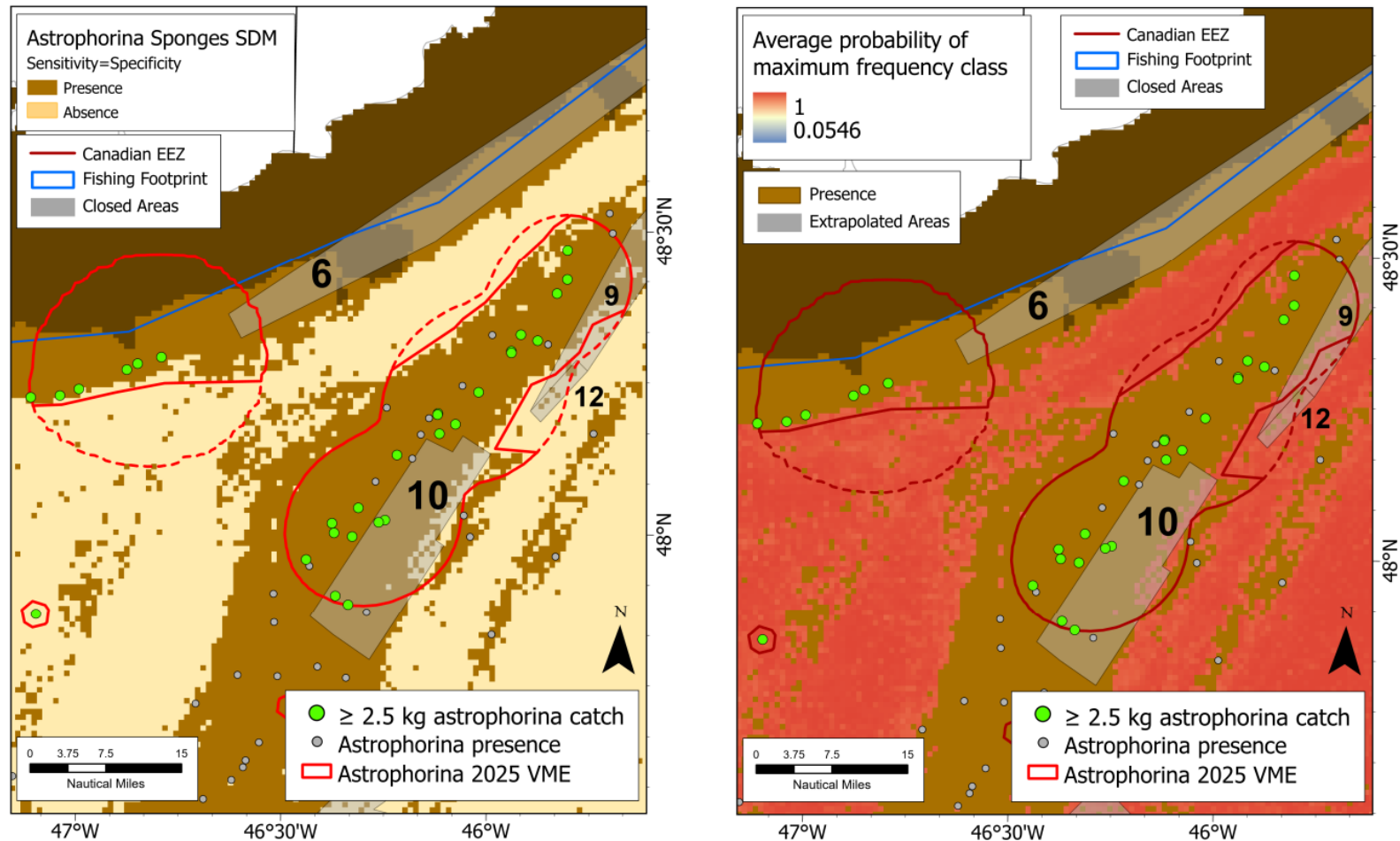


Figure 5.28. Areas 6 and 10. Left Panel. Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Areas 6 and 10 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

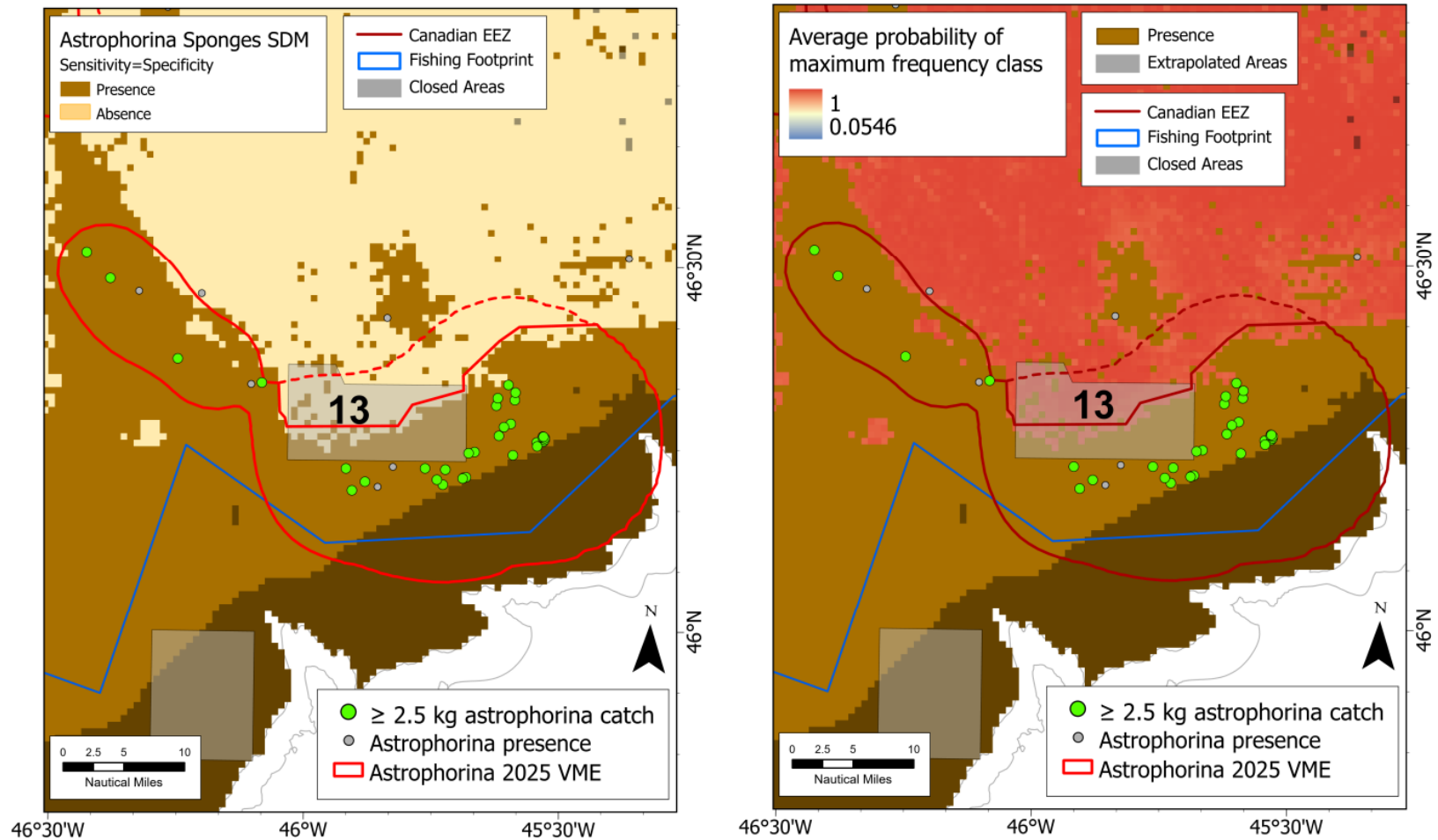


Figure 5.29. Area 13. Left Panel. Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 13 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

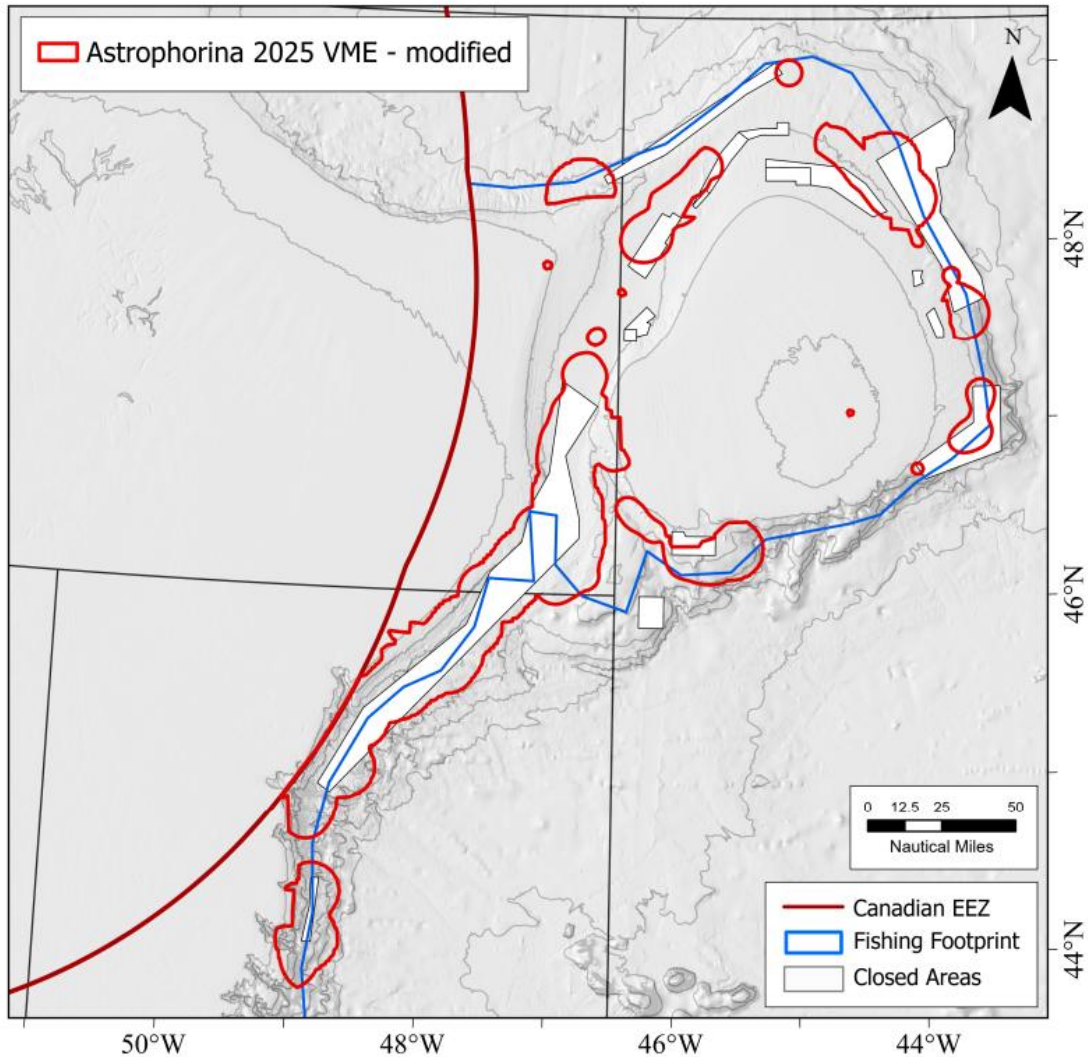


Figure 5.30. Map of the *Astroborina* Sponge VME polygons after consideration of modifications based on the SDM for *Astroborina* Sponges (Murillo *et al.*, 2024). Closed areas are indicated in white (NAFO, 2025).

viii) Modifications to the *Anthoptilum* Sea Pen VME Polygons

The *Anthoptilum* subgroup of Sea Pens was not presented in the 2019 review (Kenchington *et al.*, 2019) as there were insufficient data to conduct the KDE analyses at that time. The area of presence of *Anthoptilum* is predicted with high probability (Figures 35 and 36 in Kenchington *et al.*, 2025b). Modifications for this taxon were made to polygons near the Area closure 30 and near the Area closure 13.

Area 30. The KDE VME polygons for *Anthoptilum* located near the 30 Coral Closure includes an area that overlaps with predicted absence of *Anthoptilum* that is predicted with high probability (Figure 5.31). Three modifications were made for this polygon as shown in Figure 5.31.

Area 13. An *Anthoptilum* KDE VME polygon northwest of Area closure 13 (Figure 5.32) straddles an area that predicts *Anthoptilum* absence with high probability (Figure 5.32). The modification was to create two separate polygons using the boundary of predicted *Anthoptilum* presence to demarcate the new polygons (Figure 5.32).

The modifications produce ten *Anthoptilum* KDE VME polygons (Figure 5.33).

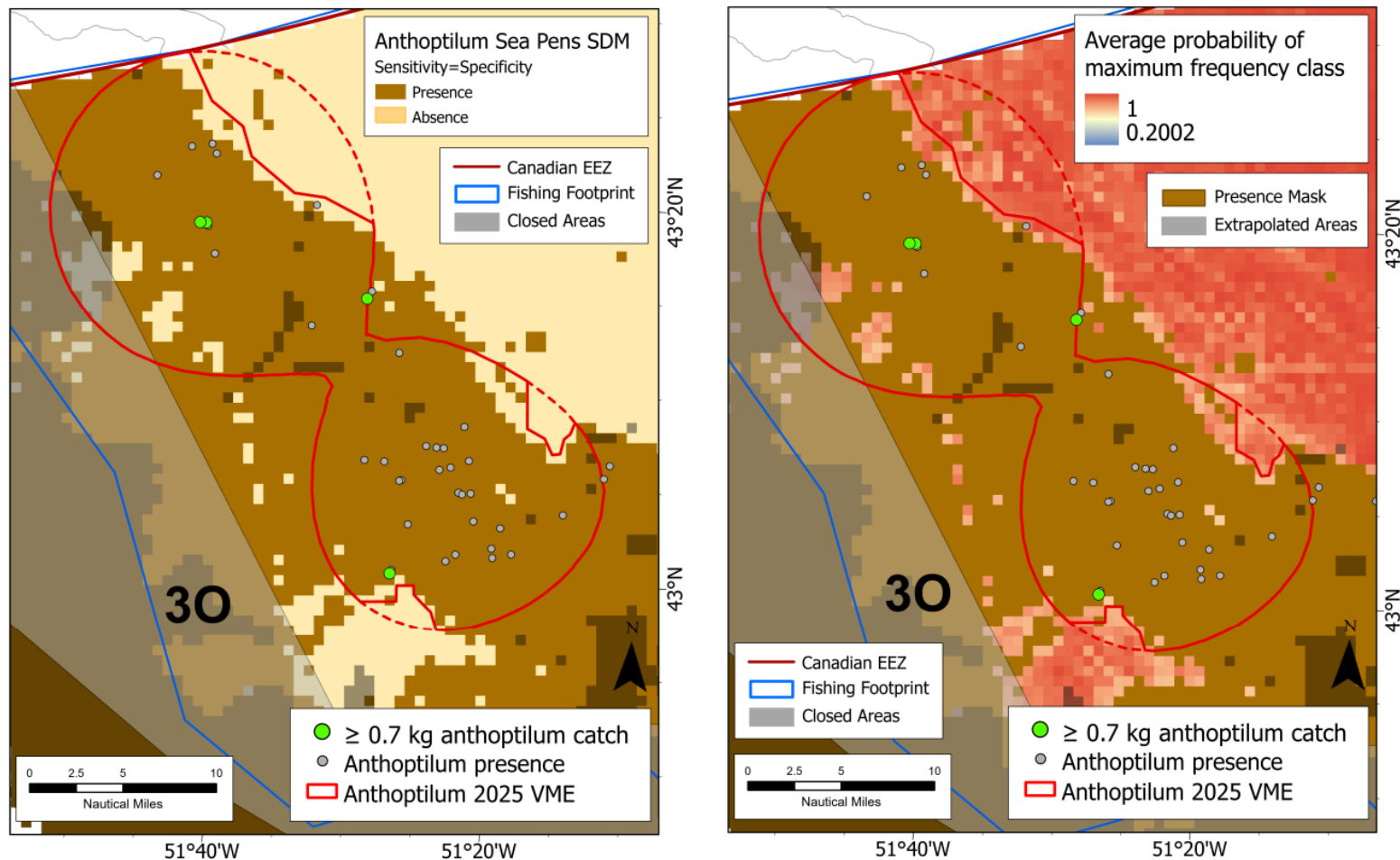


Figure 5.31. Area 30. **Left Panel.** Map of the modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Anthoptilum*). **Right Panel.** Map of the modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) near Area 30 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Anthoptilum* (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.7 kg, the threshold for the KDE analyses, and all other catches with < 0.7 kg are shown.

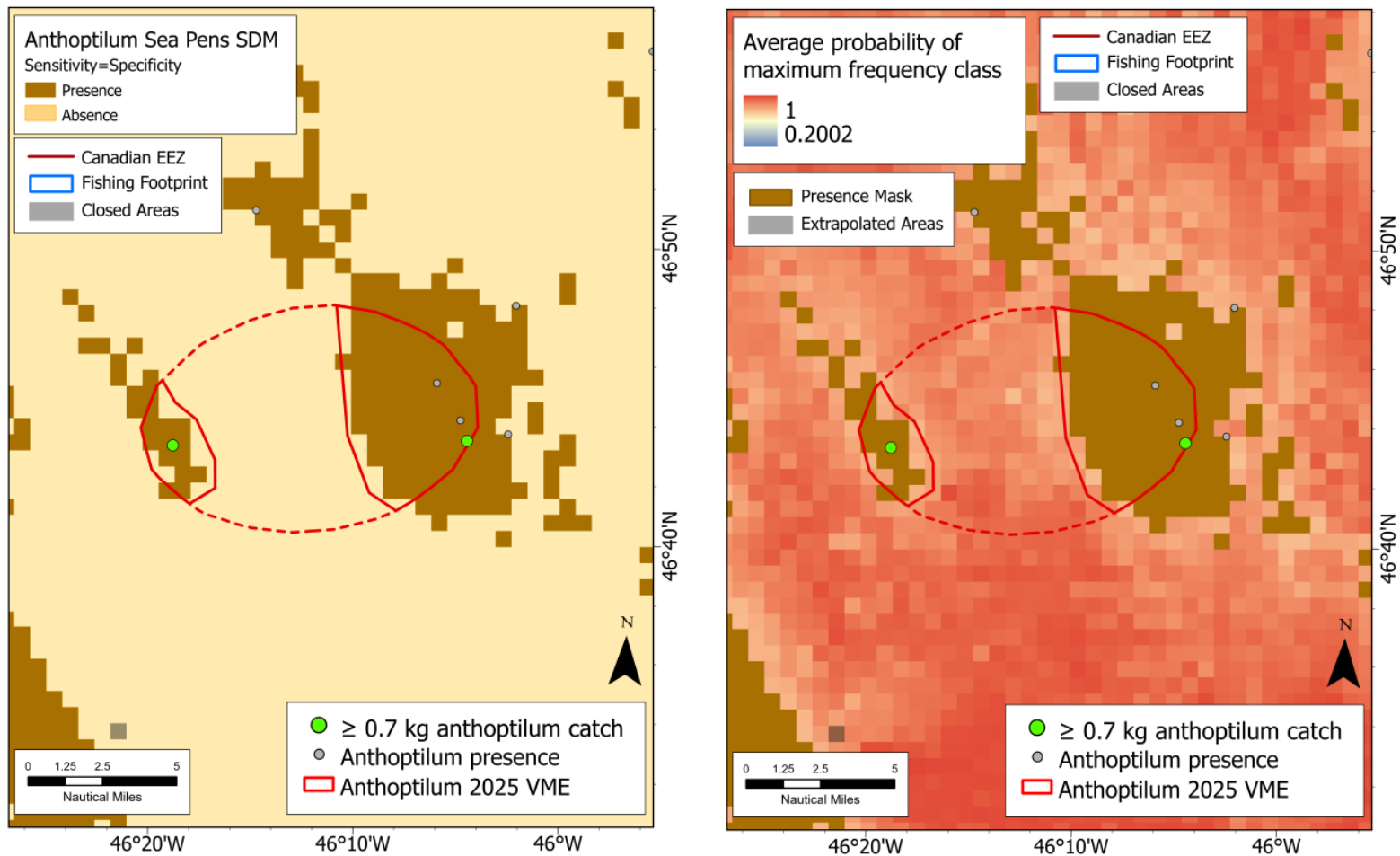


Figure 5.32. Northwest of Area 13. Left Panel. Map of the modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Anthoptilum*). **Right Panel.** Map of the modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) near Area 13 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Anthoptilum* (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.7 kg, the threshold for the KDE analyses, and all other catches with < 0.7 kg are shown.

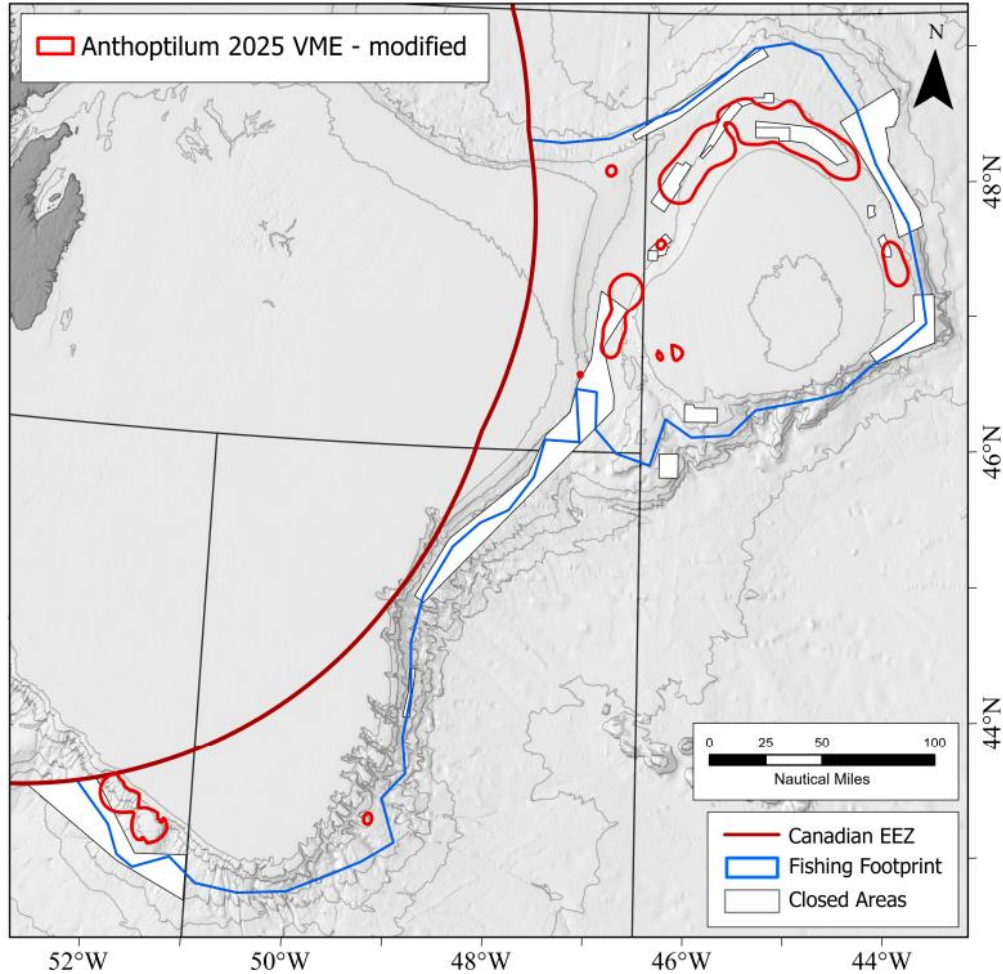


Figure 5.33. Map of the *Anthoptilum* KDE VME polygons after consideration of modifications based on the SDM for *Anthoptilum* (Murillo *et al.*, 2024). Closed areas are indicated in white (NAFO, 2025).

ix) Modifications to the *Pennatula* Sea Pen VME Polygons

The *Pennatula* subgroup of Sea Pens was not presented in the 2019 review (Kenchington *et al.*, 2019) as there were insufficient data to conduct the KDE analyses at that time. The area of presence of *Pennatula* is predicted with high probability (Kenchington *et al.*, 2025b Figures 47 and 48). However, modifications to two polygons were made.

Area 30. The KDE VME polygon for *Pennatula* located near the 30 Coral Closure includes an area that overlaps with predicted absence of *Pennatula* that is predicted with high probability (Figure 5.34). There is also a portion that crosses into the Canadian EEZ. Modifications for this polygon were made to remove the portion in Canadian waters and bring the shallow edge in line with the area of predicted *Pennatula* presence.

Area 1. A *Pennatula* KDE VME polygon that includes part of Area closure 1 (Figure 5.35) straddles an area that predicts *Pennatula* absence with high probability (Figure 5.35). The modification was to clip the western edge to the boundary of predicted *Pennatula* presence (Figure 5.35).

The modifications would produce 14 *Pennatula* KDE VME polygons (Figure 5.36).

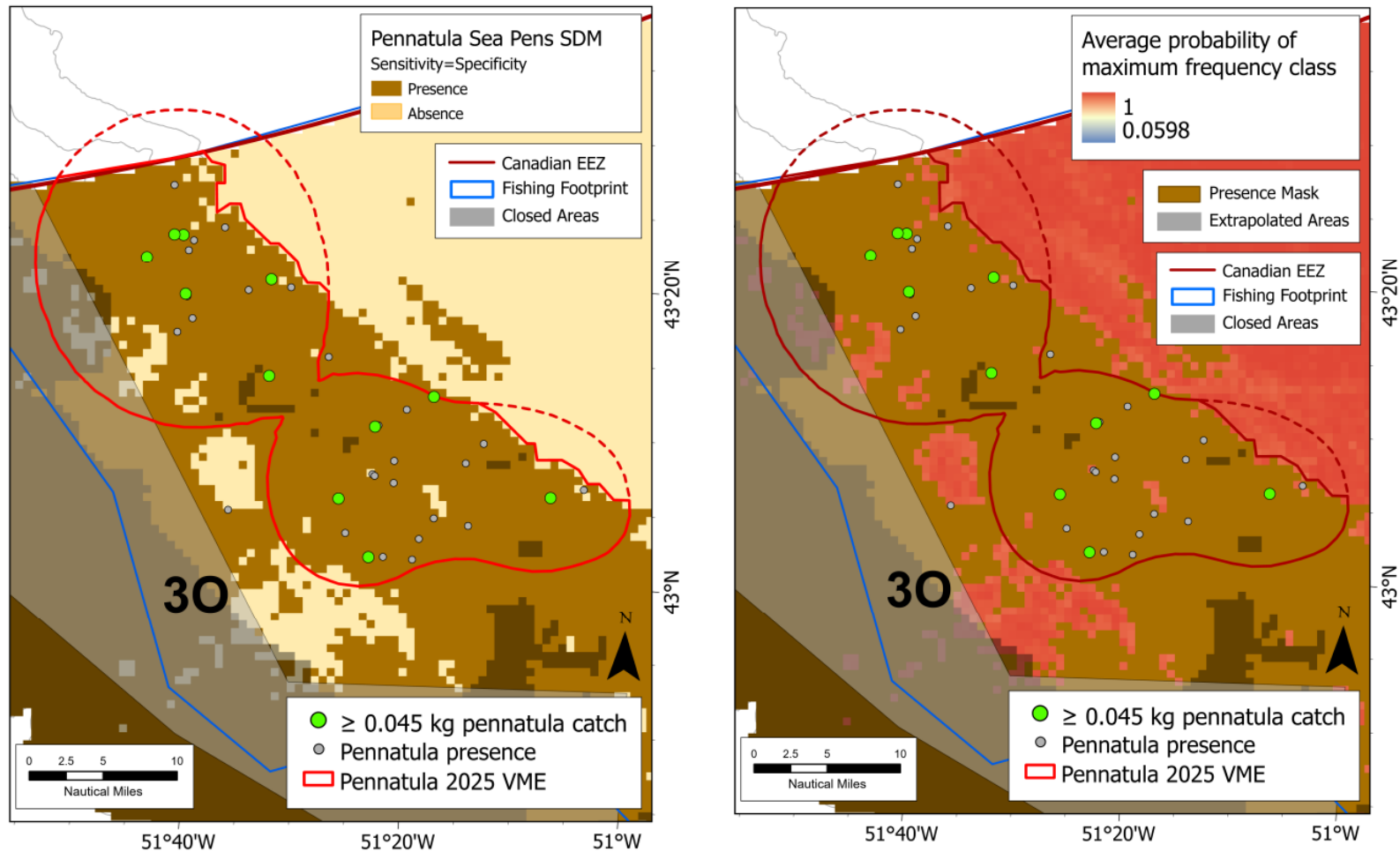


Figure 5.34. Area 30. Left Panel. Map of the modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Pennatula*). **Right Panel.** Map of the modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) near Area 30 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Pennatula* (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.045 kg, the threshold for the KDE analyses, and all other catches with < 0.045 kg are shown.

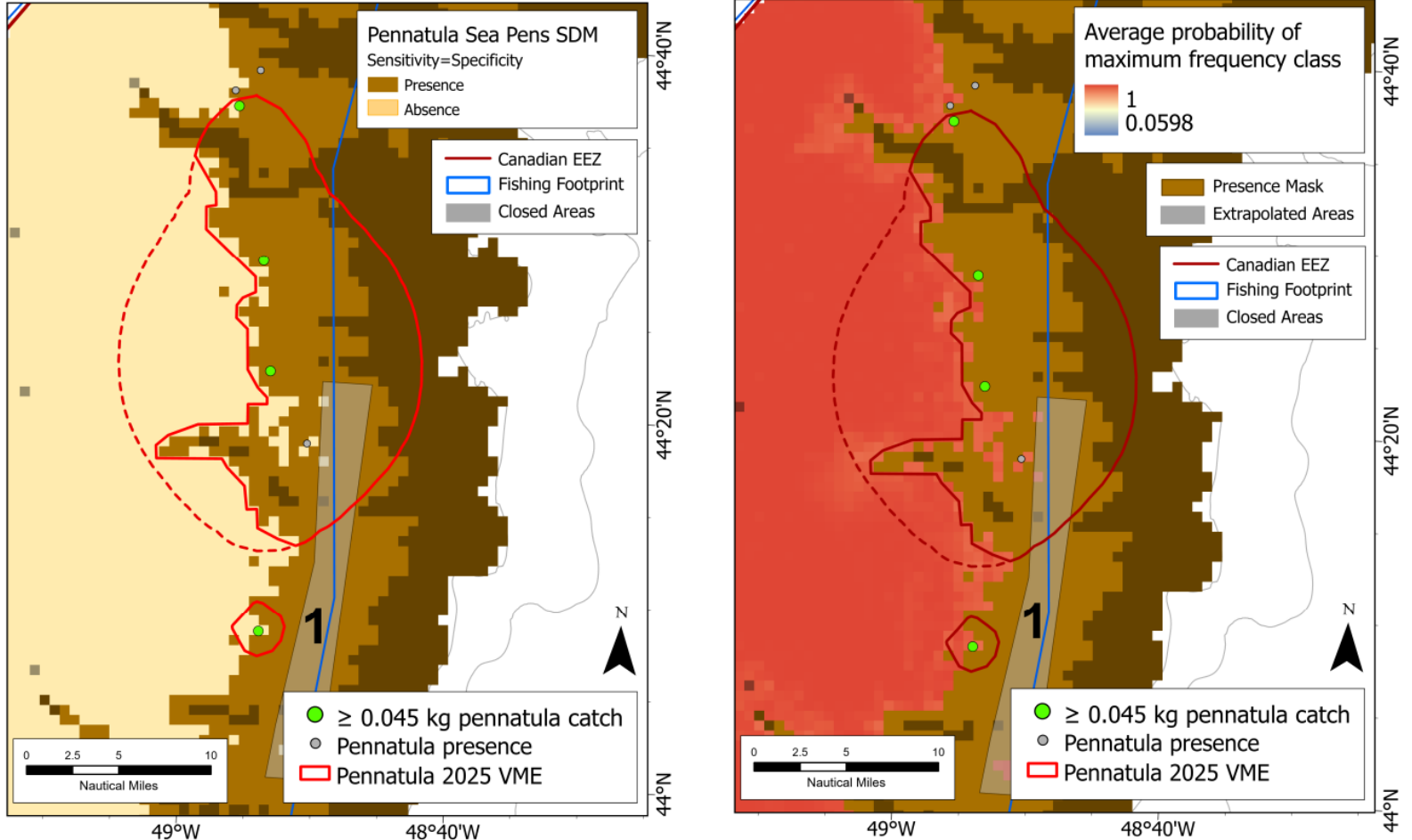


Figure 5.35. Area 1. Left Panel. Map of the modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Pennatula*). **Right Panel.** Map of the modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) near Area 1 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Pennatula* (Murillo *et al.*, 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.045 kg, the threshold for the KDE analyses, and all other catches with < 0.045 kg are shown.

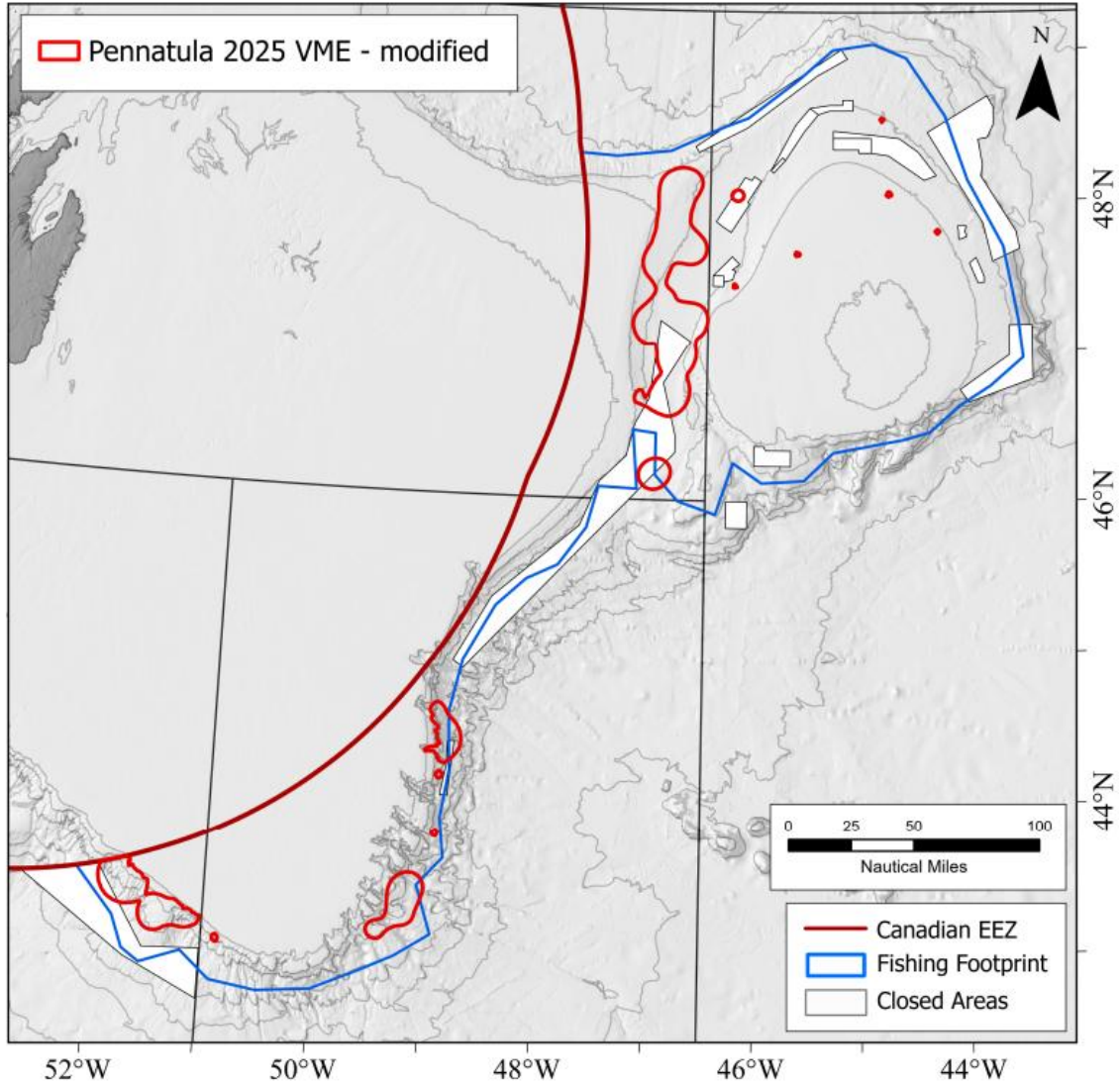


Figure 5.36. Map of the *Pennatula* KDE VME polygons after consideration of modifications based on the SDM for *Pennatula* (Murillo *et al.*, 2024). Closed areas are indicated in white (NAFO, 2025).

x) *Modifications to the Small Gorgonian Coral VME Polygons*

The Small Gorgonian Coral Functional Group (SGC) KDE VME polygons are found in Flemish Pass, on the slopes of Flemish Cap, and on the Nose and Tail of Grand Bank. These polygons all lie largely within the area of predicted Small Gorgonian Coral Functional Group presence from the SDM (Murillo *et al.*, 2025). A modification was made to one KDE VME polygon.

Area 4. A SGC Functional Group KDE VME polygon that includes part of Area closure 4 (Figure 5.37) straddles an area that predicts SGC Functional Group absence with high probability (Figure 5.37). The modification was to clip the western edge to the boundary of predicted SGC presence (Figure 5.37).

The modifications produce 20 Small Gorgonian Coral Functional Group KDE VME polygons (Figure 5.38).

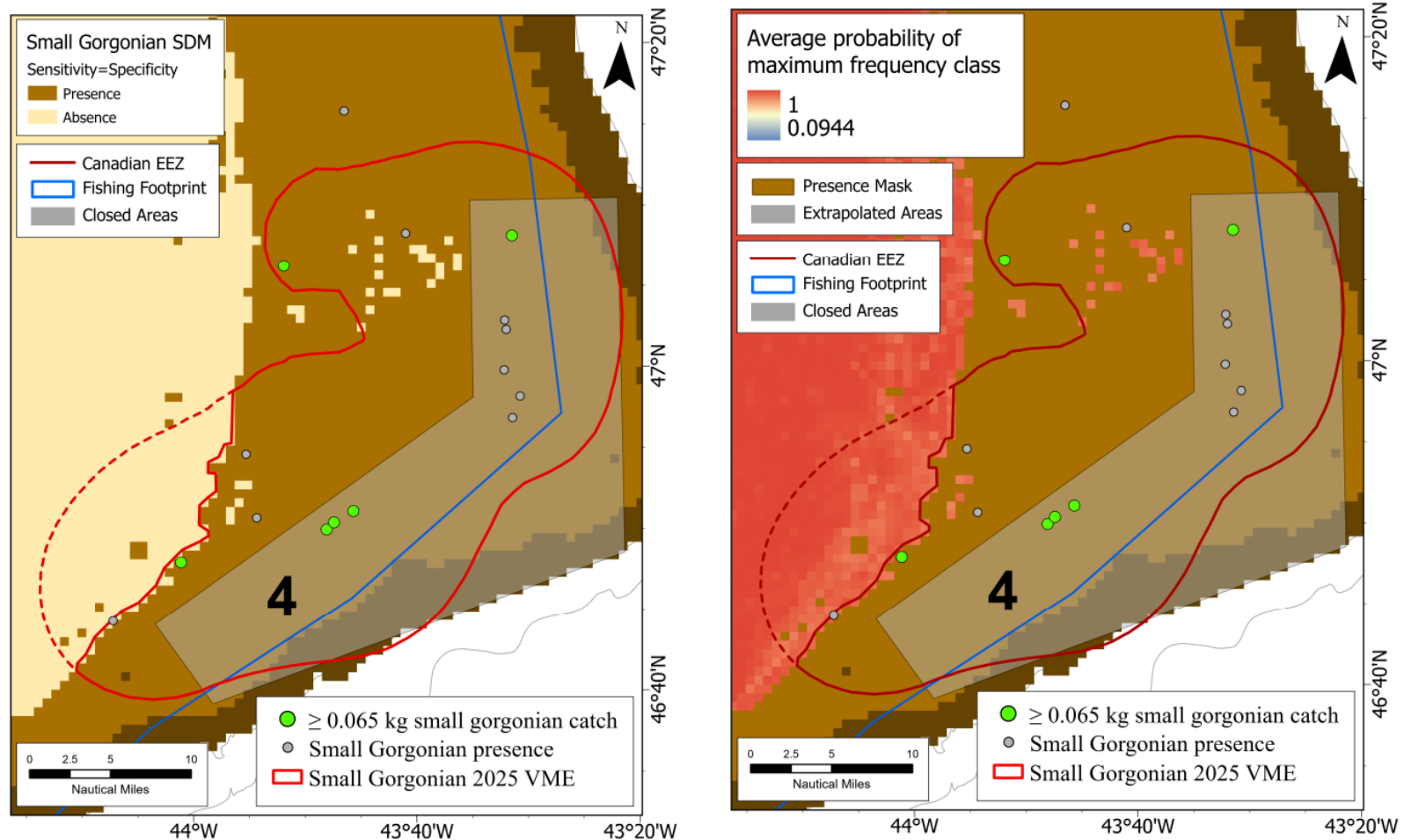


Figure 5.37. **Area 4. Left Panel.** Map of the modification (solid red line) of the 2025 Small Gorgonian Coral Functional Group KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of the Small Gorgonian Coral Functional Group). **Right Panel.** Map of the modification (solid red line) of the 2025 Small Gorgonian Coral Functional Group KDE VME polygon (red dashed lines) near Area 4 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for Small Gorgonian Coral Functional Group (Murillo *et al.*, 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.065 kg, the threshold for the KDE analyses, and all other catches with < 0.065 kg are shown.

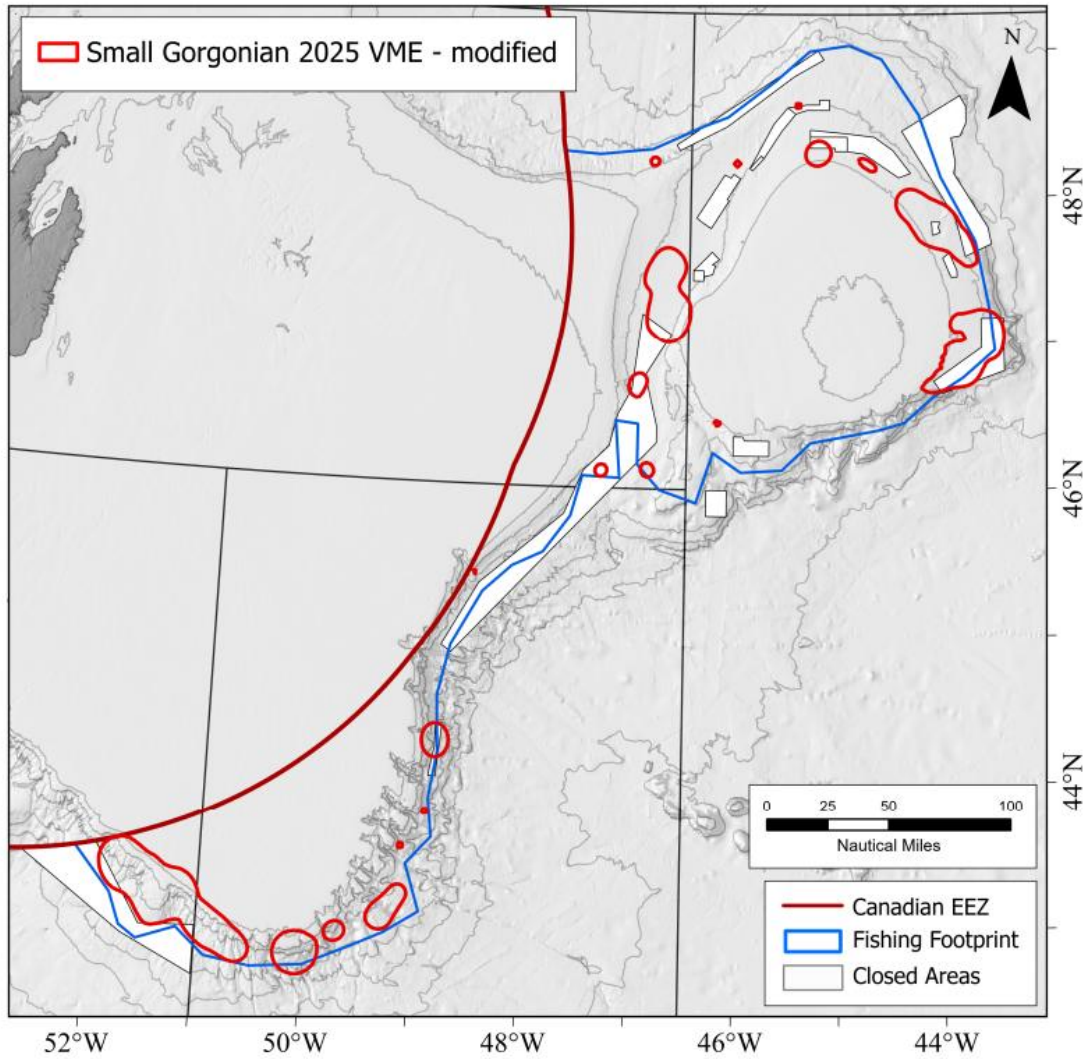


Figure 5.38. Map of the Small Gorgonian Coral Functional Group KDE VME polygons after consideration of modifications based on the SDM for the Small Gorgonian Coral Functional Group (Murillo *et al.*, 2025). Closed areas are indicated in white (NAFO, 2025).

xi) Modifications to the *Radicipes gracilis* VME Polygons

The *Radicipes gracilis* subgroup of Small Gorgonian Corals was not presented in the 2019 review (Kenchington *et al.*, 2019) as there were insufficient data to conduct the KDE analyses at that time. Modifications were made to two *Radicipes gracilis* KDE VME polygons.

Area 2. The southwestern portion of the *Radicipes gracilis* KDE VME polygon near Area closure 2 extends into an area of predicted absence that has high certainty (Figure 5.39). This area has one significant catch but no other smaller catches (Figure 5.39). This polygon was clipped to the area of predicted presence in this area, leaving the significant catch as an isolated point.

Area 8. The *Radicipes gracilis* KDE VME polygon near Area closure 8 extends north into an area of predicted *Radicipes gracilis* absence that is modeled with high certainty. There are areas of predicted presence in this region but they are scattered and may result from fishing activity. One of the areas where *Radicipes gracilis* is predicted to occur contains a significant catch (Figure 5.40). This polygon was clipped to the general area of *Radicipes gracilis* presence.

The modifications would produce 10 *Radicipes gracilis* KDE VME polygons (Figure 5.41).

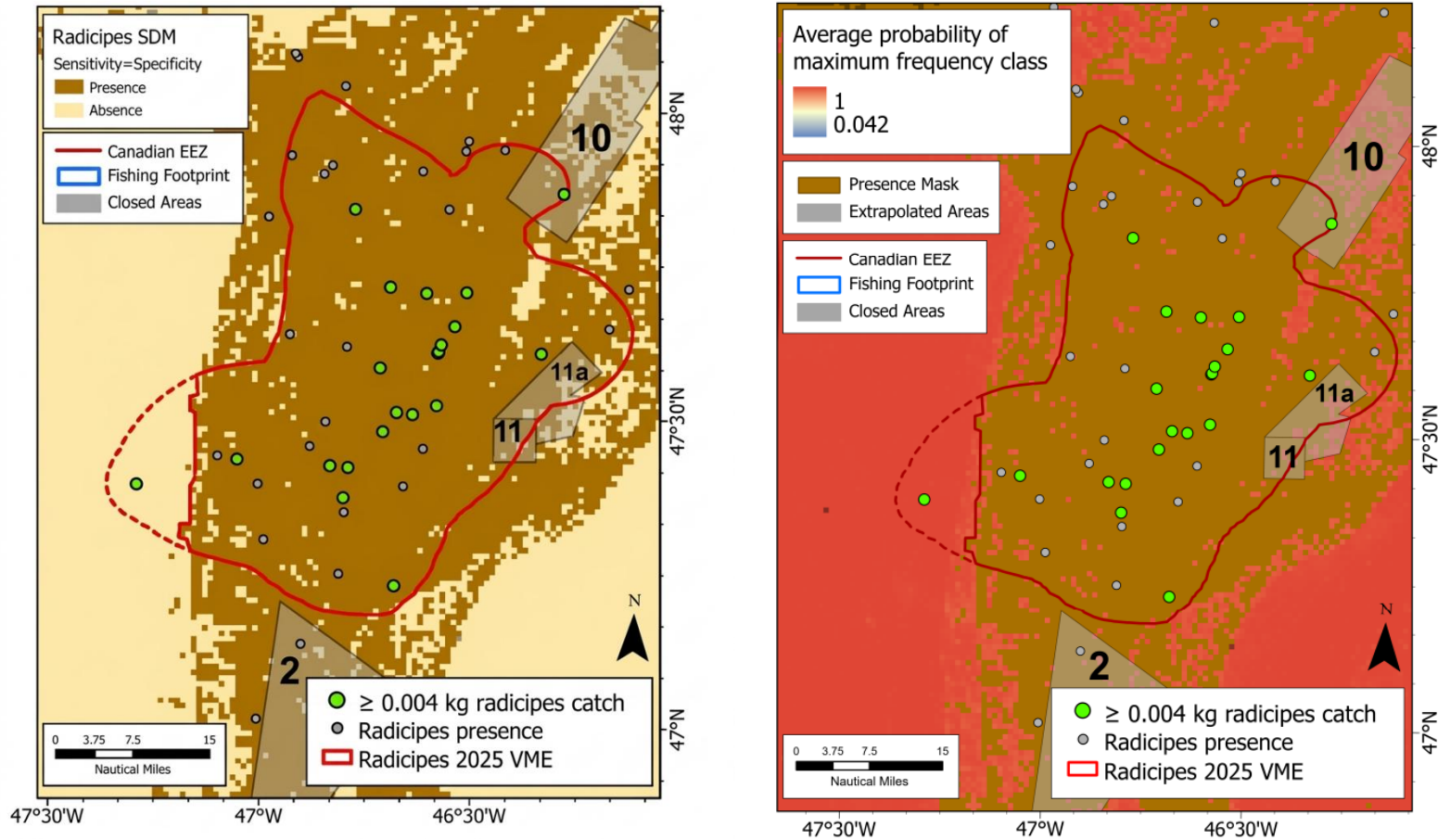


Figure 5.39. Area 2. Left Panel. Map of the modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Radicipes gracilis*). Right Panel. Map of the modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) near Area 2 in relation to the average probability of the maximum frequency class for absence values from 10 SDM runs for *Radicipes gracilis* (Murillo *et al.*, 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.004 kg, the threshold for the KDE analyses, and all other catches with < 0.004 kg are shown.

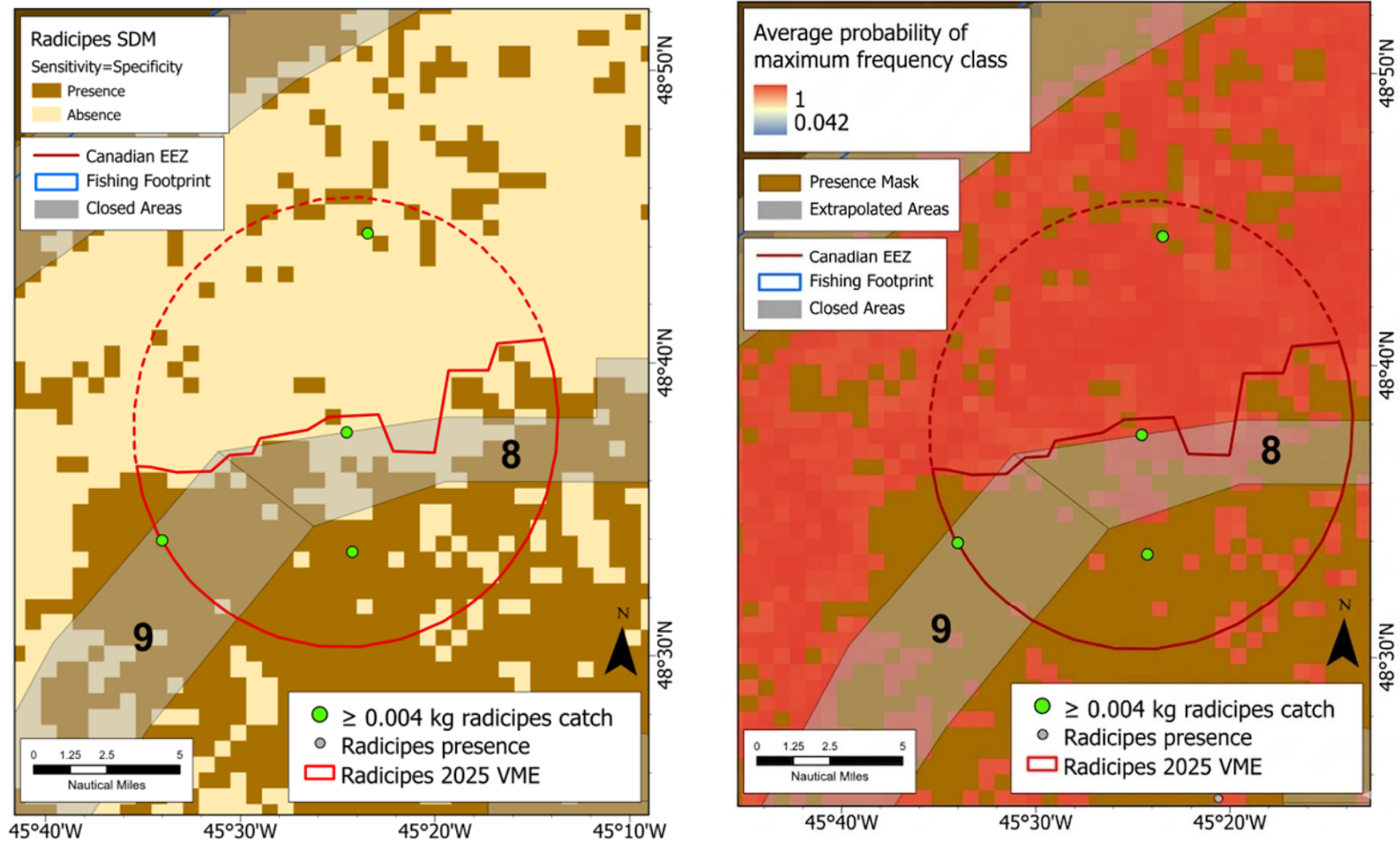


Figure 5.40. Area 8. Left Panel. Map of the modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Radicipes gracilis*). Right Panel. Map of the modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) near Area 8 in relation to the average probability of the maximum frequency class for absence values from 10 SDM runs for *Radicipes gracilis* (Murillo et al., 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.004 kg, the threshold for the KDE analyses, and all other catches with < 0.004 kg are shown.

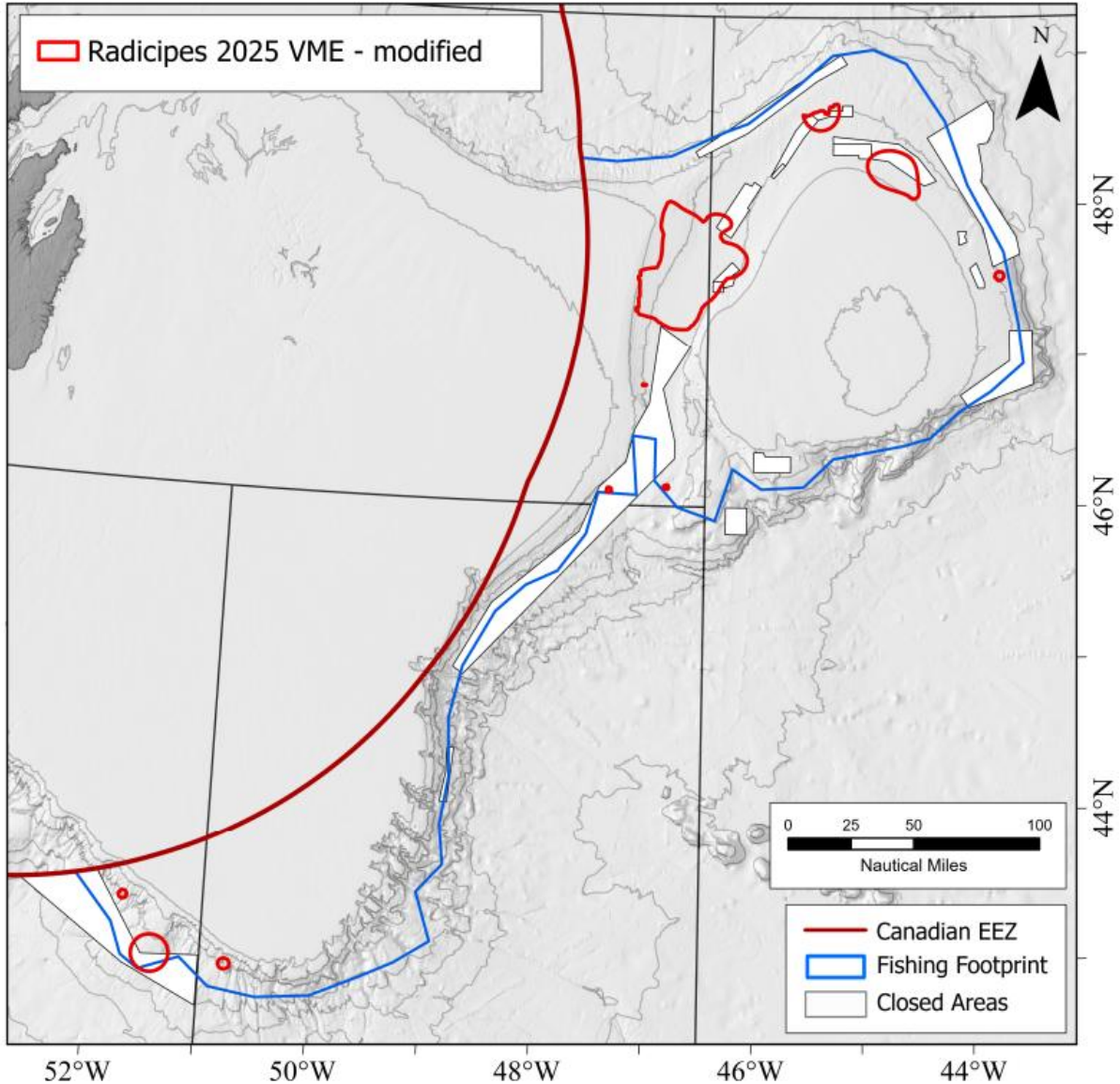


Figure 5.41. Map of the *Radicipes gracilis* KDE VME polygons after consideration of modifications based on the SDM for the *Radicipes gracilis* (Murillo *et al.*, 2025). Closed areas are indicated in white (NAFO, 2025).

xii) Modifications to the Erect Bryozoan VME Polygons

The Erect Bryozoan Functional Group KDE VME polygons are found primarily on the Tail of Grand Bank. These polygons all lie largely within the area of predicted Erect Bryozoan Habitat presence from the SDM (Murillo *et al.*, 2025). Modifications were made to two polygons.

Tail of the Grand Bank. The area of the large Erect Bryozoan VME polygon on the Tail of the Grand Bank that extends into the area of predicted Erect Bryozoan Habitat (Figure 5.42) revealed a mosaic of grid cells predicting presence and absence. Although absence was predicted with high probability, there were three significant catches in this location as well as some smaller catches. The area also had scattering of grid cells with extrapolated environments, rendering the predictions unreliable for those cells. A tongue is left to capture the three significant catches that reach out in a linear direction to the west. Interestingly those catches were taken in 2007 and 2008 and so not used in the SDM where only data between 2011 and 2023 were used, so their occurrence there reinforces the small areas of predicted presence.

Area 1. The Erect Bryozoan VME polygon on the slope of the Grand Bank near Area closure 1 extends on its eastern edge into an area where Erect Bryozoan Habitat is predicted with high certainty to be absent. The modification is to bring the polygon boundary to the edge of the predicted Erect Bryozoan Habitat presence (Figure 5.43).

The modifications would produce 11 Erect Bryozoan Functional Group KDE VME polygons (Figure 5.44).

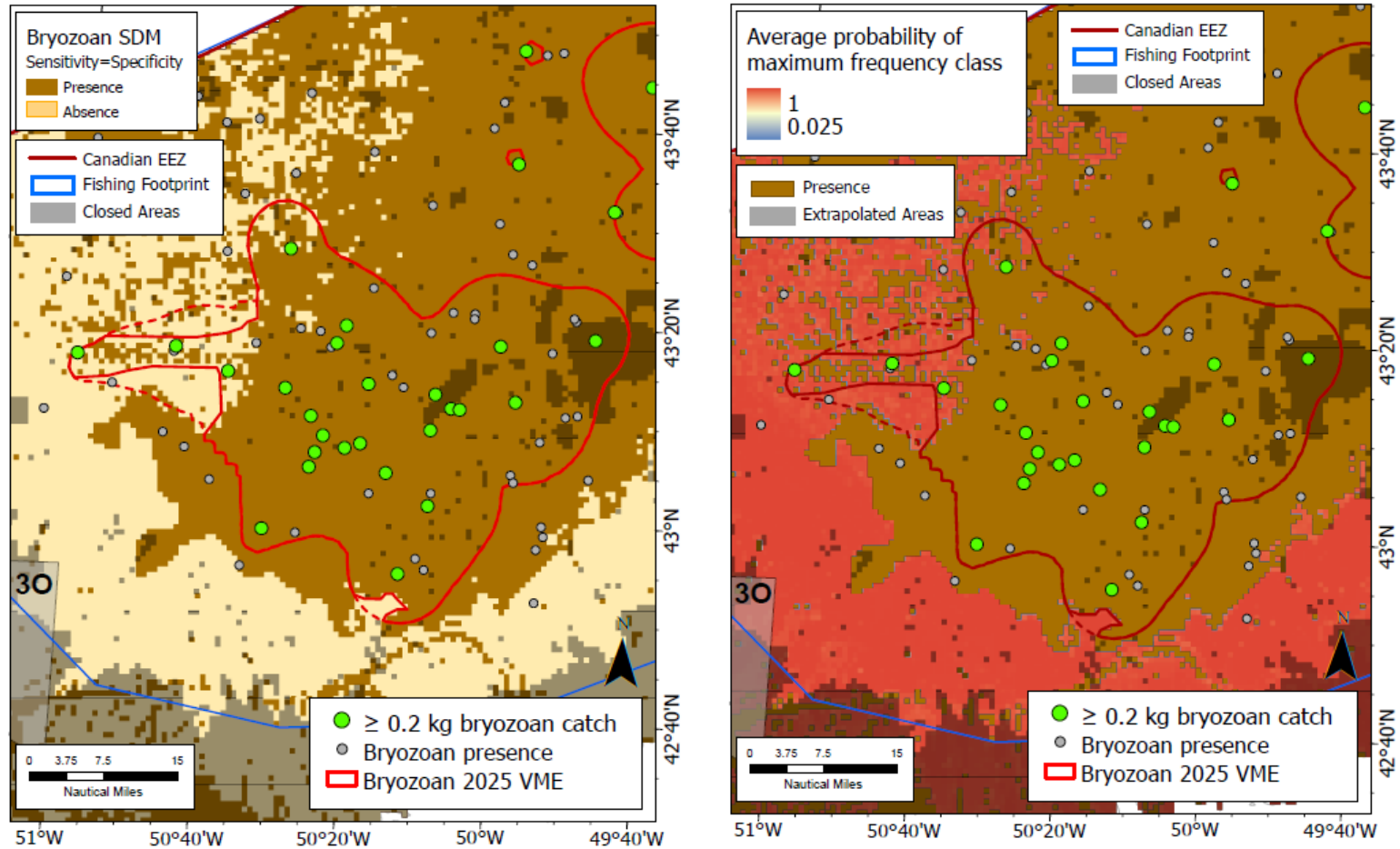


Figure 5.42. Tail of the Grand Bank. Left Panel. Map of the modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of the Erect Bryozoan Habitat). A decision was made not to modify this polygon at this time. **Right Panel.** Map of the modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for Erect Bryozoan Habitat (Murillo *et al.*, 2025). A decision was made not to modify this polygon at this time. Closed areas are indicated in grey shading. Catches of ≥ 0.2 kg, the threshold for the KDE analyses, and all other catches with < 0.2 kg, are shown.

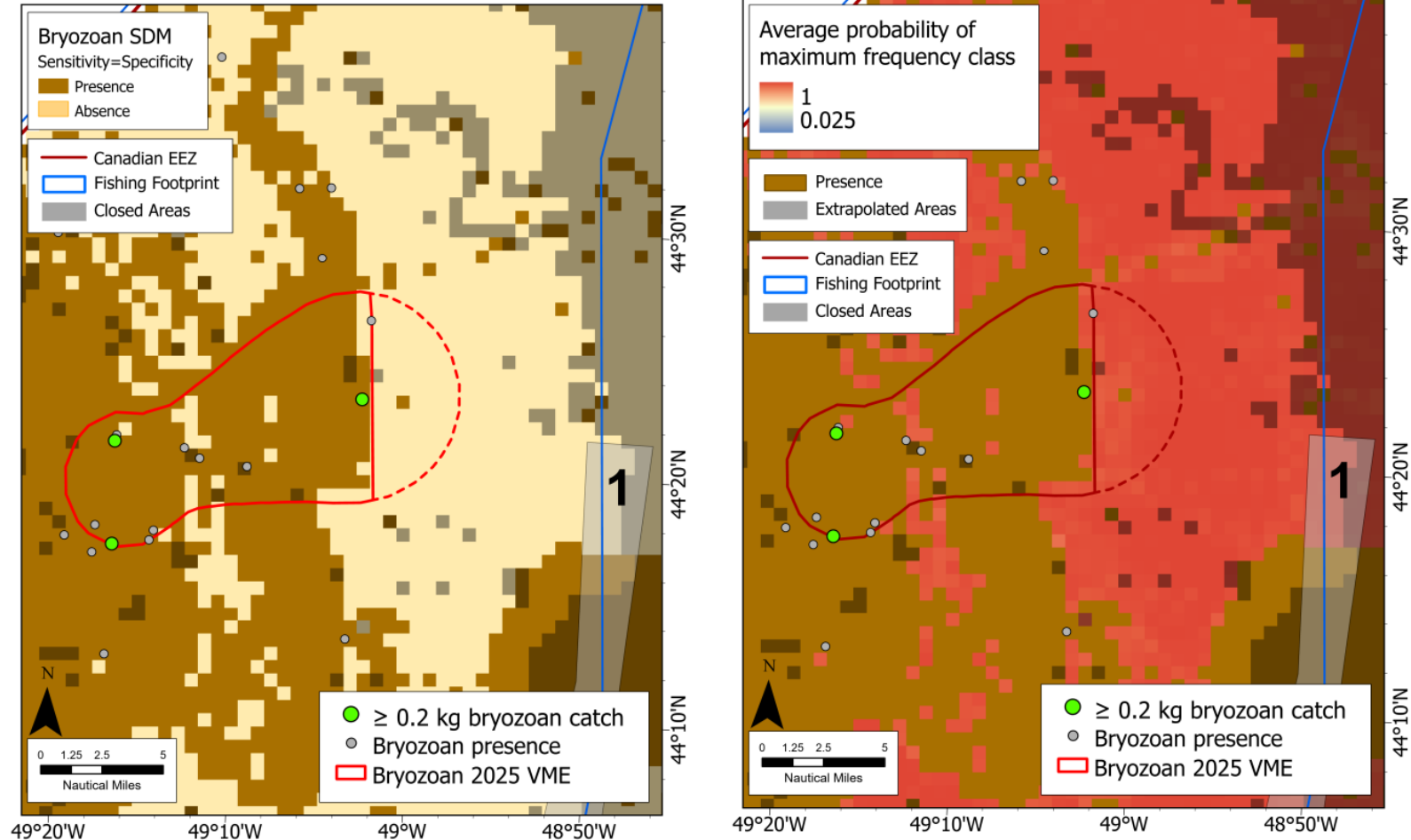


Figure 5.43. Area 1. Left Panel. Map of the modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of the Erect Bryozoan Habitat). **Right Panel.** Map of the modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for Erect Bryozoan Habitat (Murillo *et al.*, 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.2 kg, the threshold for the KDE analyses, and all other catches with < 0.2 kg are shown.

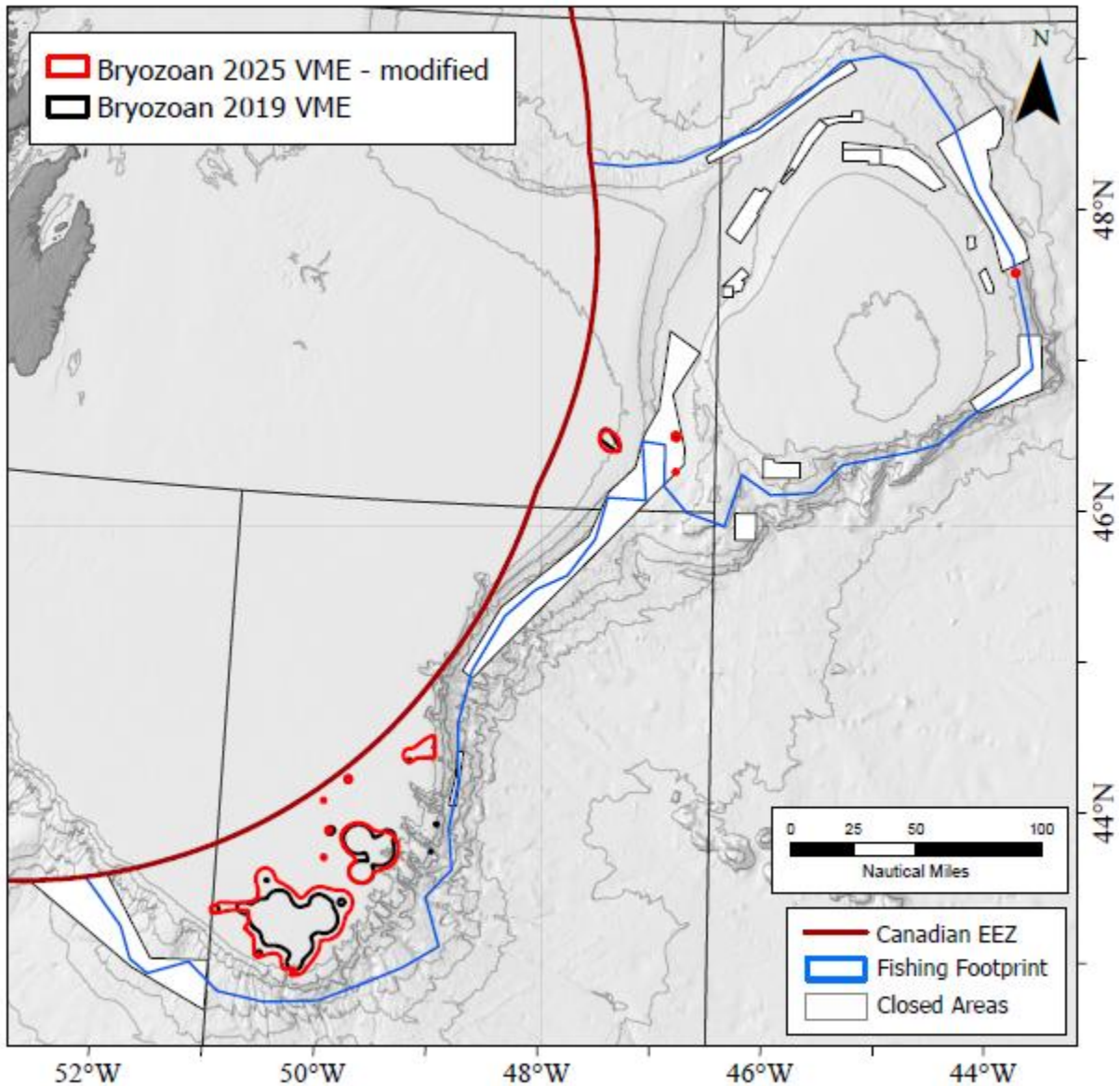


Figure 5.44. Map of the Erect Bryozoan Functional Group KDE VME polygons after consideration of modifications based on the SDM for the Erect Bryozoan Habitat (Murillo *et al.*, 2025), and in relation to the 2019 accepted KDE VME polygons (black line). Closed areas are indicated in white (NAFO, 2025).

xiii) Modifications to the Sea Squirt VME Polygons

The Sea Squirt Functional Group KDE VME polygons are found primarily on the Tail of the Grand Bank (Kenchington *et al.*, 2025b; Figure 78). These polygons all lie largely within the area of predicted Sea Squirt Functional Group presence from the SDM (Murillo *et al.*, 2025) where they are found in areas where there is a high probability of predicted presences. No modifications are suggested based on the SDMs, although polygons close to the Canadian EEZ were examined in close-up and clipped to the EEZ if necessary.

Only one polygon extended into Canadian waters (Figure 5.45), and that was modified to bring the polygon edge in line with the Canadian EEZ.

The modifications would produce 19 Sea Squirrel KDE VME polygons (Figure 5.46).

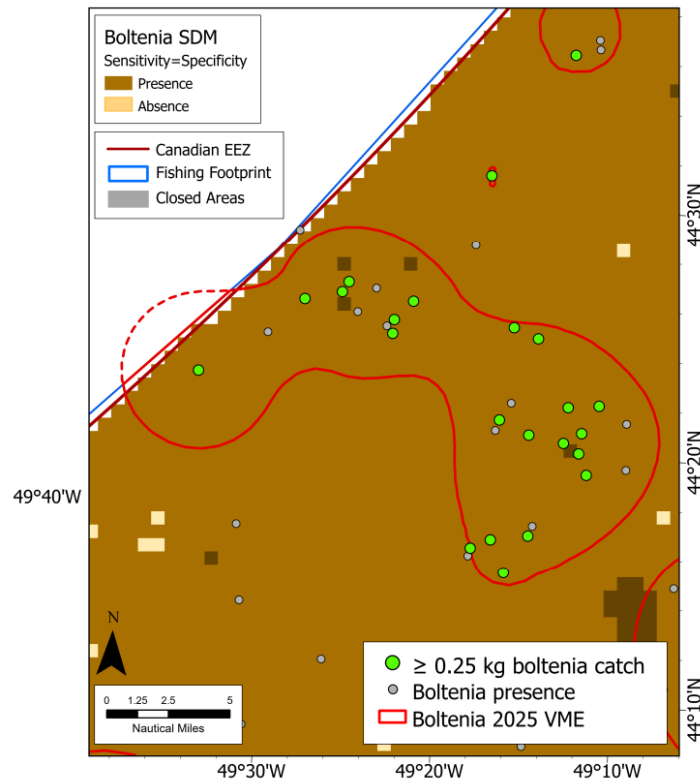


Figure 5.45. Map of the modification (solid red line) of the 2025 Sea Squirrel (*Boltenia*) KDE VME polygon (red dashed lines) to remove portions of the polygon that extended into Canadian waters and showing the underlying SDM (brown area showing predicted presence of the Erect Bryozoan Habitat).

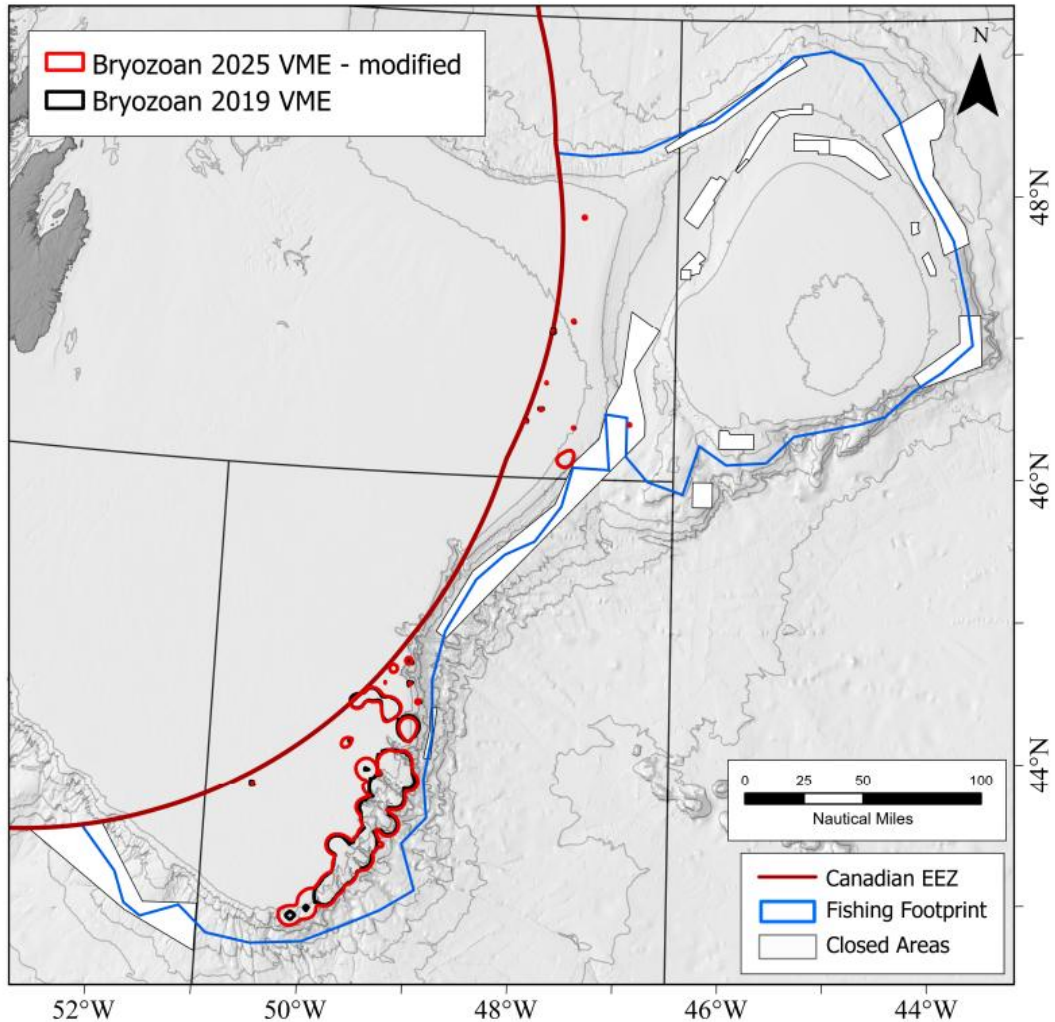


Figure 5.46. Map of the Sea Squirt (*Boltenia*) KDE VME polygons after consideration of modifications detailed above, and in relation to the 2019 accepted KDE VME polygons (black line). Closed areas are indicated in white (NAFO, 2025).

xiv) Discussion

In general, there was an increase in area for all VME Indicators over the area created in 2019 (Table 5.5), with the Large Gorgonian Corals and Black Corals showing the least change. This is despite high similarity in the density threshold selected to delineate the VME polygons. For the Small Gorgonian Corals, the selection of the lower weight threshold (0.065 kg/RV tow) contributed to the large increase in area for that VME indicator. This produced Small Gorgonian Coral KDE VME polygons on the Flemish Cap, which in some cases overlap with the existing closures, increasing their conservation value. Spatially, there was high congruence between the analyses performed in 2019 (Kenchington *et al.*, 2019) and the present analyses, which improved after the modifications were mapped (Figures 5.47, 5.48).

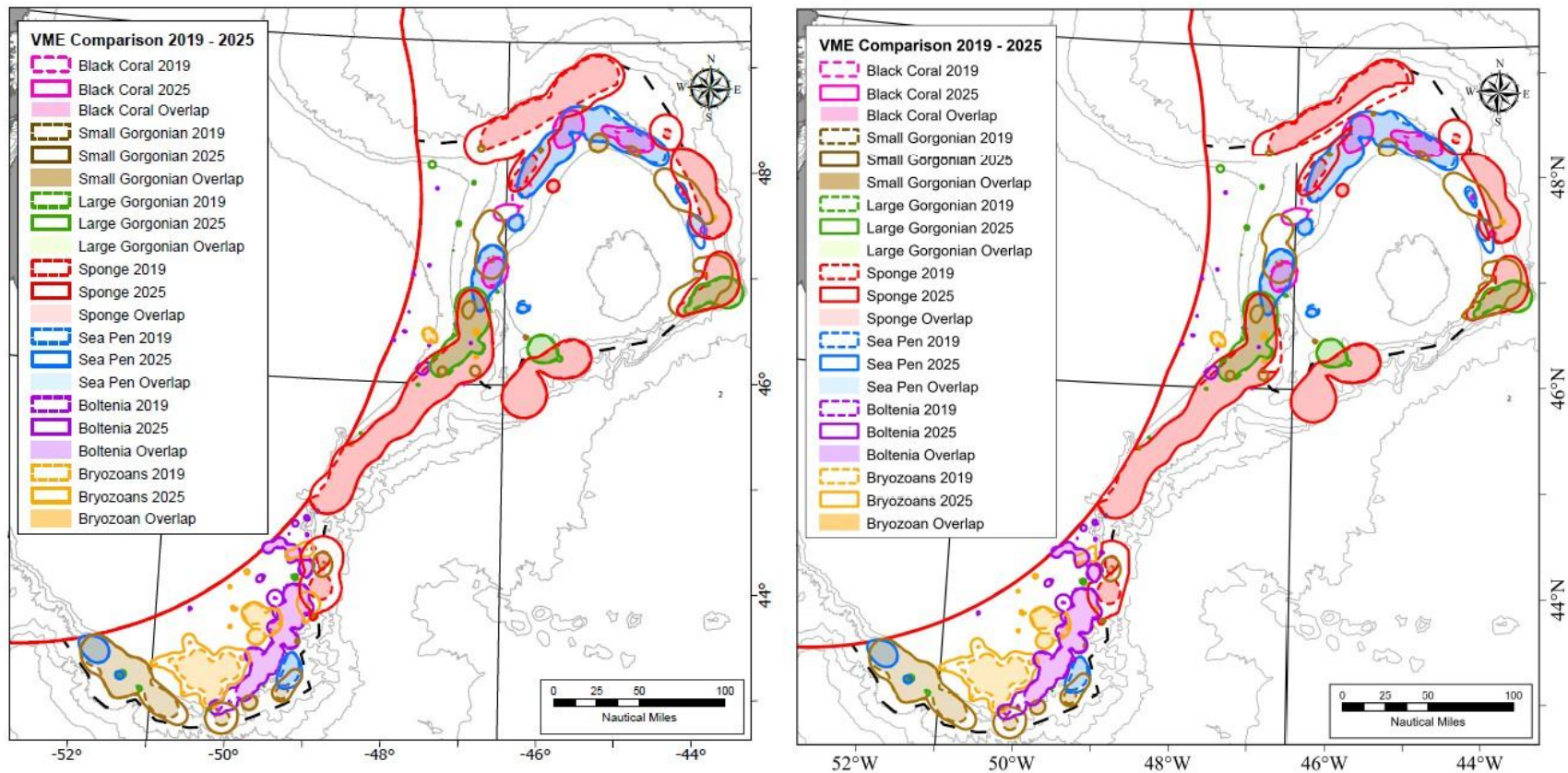


Figure 5.47. Overview map of the location of the KDE VME taxa polygons (Large-Sized Sponges, Sea Pens, Small Gorgonian Corals, Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals) in the NAFO Regulatory Area, colour coded by taxon. For all taxa the clipped polygons determined and accepted from the 2019 analysis are shown in dashed line and compared with those from the 2025 analyses in solid lines. Areas of overlap between the polygons produced in each year are shaded. Dashed black line is the fishing footprint and the red solid line is the Canadian Exclusive Economic Zone. **Left Panel.** 2025 KDE VME taxa polygons without modification. **Right Panel.** 2025 KDE VME taxa polygons modified as in this document.

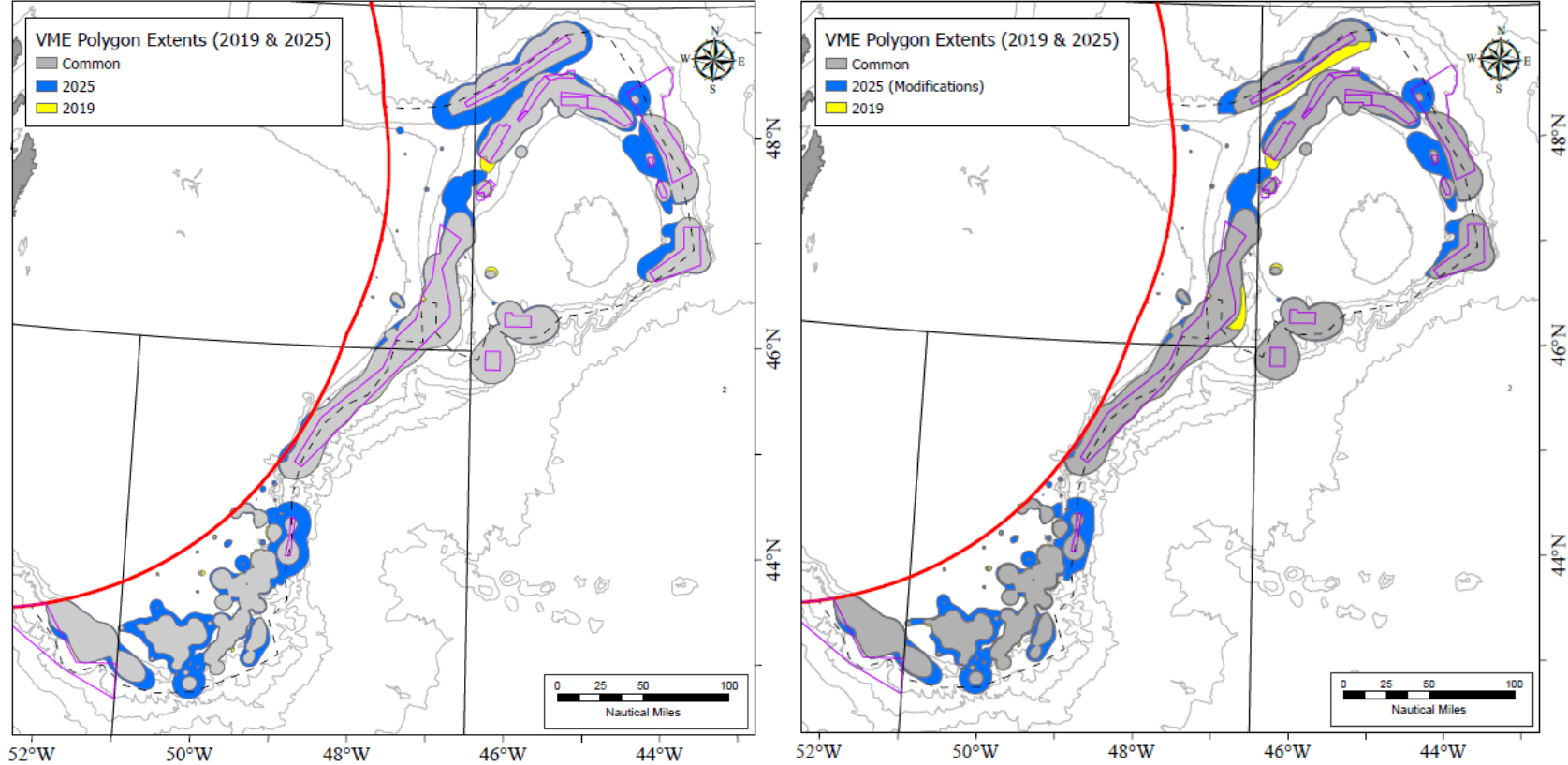


Figure 5.48. Overview map of the location of the combined KDE VME taxa polygons (Large-Sized Sponges, Sea Pens, Small Gorgonian Corals, Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals) in the NAFO Regulatory Area. For all taxa the clipped polygons determined and accepted from the 2019 analysis are shown filled in yellow and compared with those from the 2025 analyses filled in blue. Areas of overlap between the polygons produced in each year are shaded grey. Dashed black line is the fishing footprint and the red solid line is the Canadian Exclusive Economic Zone. **Left Panel.** 2025 KDE VME taxa polygons without modification. **Right Panel.** 2025 KDE VME taxa polygons modified as in this document.

The modifications had very little effect on the total area of VME of the functional groups, although the Large-Sized Sponges area was reduced by 4827 km² (Table 5.5).

Table 5.5. Values of the significant concentration threshold (kg) from research vessel catches and total area (km²) of VME polygons for the years 2013, 2019 and 2025. Area of VME for 2025 is given for the original KDE VME polygons (orig; Kenchington *et al.*, 2025a) and the area taking into account the modifications outlined above (mod). SGC=Small Gorgonian Corals; LGC=Large Gorgonian Corals.

VME Indicator	Research Vessel Catch for Identifying VME Polygons (kg)			Area of VME (km ²)			
	2025	2019	2013	2025 orig	2025 mod	2019	2013
Large-Sized Sponges	100	100	75	33144	28317	24218	19824
Sea Pens	1.5	1.3	1.4	9441	9441	8498	6983
SGC	0.065	0.2	0.15*	13379	13050	4540	307
LGC	0.7	0.6	0.6	5339	5339	5007	3506
Sea Squirts	0.25	0.35	0.3	5233	5212	4077	2193
Erect Bryozoans	0.2	0.2	0.2	6429	5541	3491	6587
Black Corals**	0.4	0.4	-	2894	2894	2631	-

*In 2013 KDE analyses were performed for Divisions 3NO and in 2019 and 2025 the areas 3LMNO were combined. ** KDE analyses on black coral catches were performed for the first time in 2019.

xv) Current Levels of Protection of VMEs

The VME areas inside area closures ('Closed Area Protected') according to the NAFO Conservation and Enforcement Measures (NAFO, 2025), inside the fishing footprint but outside a VME closure ('Unprotected'), and outside the fishing footprint and closed areas ('Conditionally Protected') are shown in Table 5.6 for each of the VME taxa for which KDE analyses were generated (see Kenchington *et al.*, 2019) for illustrations and comparative tables with the 2013 and 2019 results for common taxa). These areas were calculated using the modifications to the KDE VME polygons discussed above.

The levels of protection present at the time of the 2019 analyses are shown in Table 5.7, noting that there have been changes to the closed areas since 2019. Comparison of the percentage of area for each taxon between the present analyses and those performed in 2019 (Table 5.6 and Table 5.7), shows that there have been large increases in the percentage of VME area that is Closed Area Protected in the Sea Pens, Small Gorgonian Corals, and the Black Corals, while there has been little or no change to the percentage of VME area that is Closed Area Protected in the Large-Sized Sponges, Large Gorgonian Corals, Erect Bryozoans and Sea Squirts. The increased protection for the Sea Pens and Black Corals is the result of direct management action whereas the increased protection for the Small Gorgonian Corals has arisen as a result of the new KDE analyses (Kenchington *et al.*, 2025a) identifying new areas on Flemish Cap that overlapped with the Area Closures. In terms of absolute values of area that is Closed Area Protected, there is more VME area protected in 2025 than in 2019. As in 2019, protection for the Erect Bryozoans and the Sea Squirts (*Boltenia*) is almost non-existent. The large percentage (99%+) of their VME areas fall in Unprotected area which means that they are extremely vulnerable to significant adverse impacts of fishing. The greatest protection overall is afforded to the Large-Sized Sponges and Large Gorgonian Corals (Table 5.6).

For the new data on the subgroups, it is clear that taxon-specific protections should be examined for the Polymastiidae sponges, all subgroups of sea pens, but *Funiculina* in particular, and the Small Gorgonian Coral *Acanella arbuscula*.

Table 5.6. Total areas (km²) of VME polygons generated in 2025 that are Closed Area Protected, Conditionally Protected, and Unprotected in NAFO Divisions 3LMNO. The percentage of total area of each treatment is also shown. Areas represent the KDE VME polygons after the modifications were made.

VME Indicator	Total Area of 2025 VME (km ²) after Modifications	Closed Area Protected		Conditionally Protected		Total Protected (Closed Area + Conditionally Protected)			Unprotected	
		Area (km ²)	Percent Total (%)	Area (km ²)	Percent Total (%)	Area (km ²)	Percent (%)	Total	Area (km ²)	Percent Total (%)
Large-Sized Sponges	28317	10620	38	7618	27	18238	64		10079	36
Tetillidae	24071	7220	30	4137	17	11357	47		12713	53
Polymastiidae	11462	2875	25	17	0	2892	25		8570	75
Astrophorina	26704	8807	33	3932	15	12739	48		13965	52
Sea Pens	9441	2824	30	4	0	2828	30		6614	70
Anthoptilum	9012	2341	26	0	0	2341	26		6671	74
Balticina	23141	3903	17	243	1	4146	18		18993	82
Funiculina	2466	306	12	0	0	306	12		2160	88
Pennatula	9619	1372	14	298	3	1670	17		7949	83
Black Corals	2894	1124	39	5	0	1129	39		1764	61
Large Gorgonian Corals	5339	3118	58	336	6	3454	65		1885	35
Small Gorgonian Corals	13050	2106	16	308	2	2414	18		10636	82
Acanella arbuscula	4144	133	3	0	0	133	3		4011	97
Radicipes gracilis	6466	1030	16	0	0	1030	16		5436	84
Erect Bryozoans	5541	31	1	7	0	38	1		5502	99
Sea Squirts	5212	2	0	0	0	2	0		5210	100

Table 5.7. Total area (km²) of VME polygons generated in 2019 that is Closed Area Protected, Conditionally Protected, and Unprotected in NAFO Divisions 3LMNO. The percentage (%) of total area of each treatment is also shown. Note that Area closure 14 was included in this calculation.

VME Indicator	Total Area of 2019 VME (km ²)	Closed Area Protected		Conditionally Protected		Total Protected (Closed Area + Conditionally Protected)		Unprotected	
		Area (km ²)	Percentage of Total (%)	Area (km ²)	Percentage of Total (%)	Area (km ²)	Percent Total (%)	Area (km ²)	Percentage of Total (%)
Large-Sized Sponges	24218	9324	39	6076	25	15400	64	8818	36
Sea pens	8498	1439	17	1	0	1440	17	7057	83
Black corals	2631	456	17	1	0	457	17	2173	83
Large gorgonian corals	5007	2750	55	293	6	3043	61	1964	39
Small gorgonian corals	4540	188	4	0	0	188	4	4352	96
Erect bryozoans	3491	5	0.14	0	0	5	0	3486	99.9
Sea squirts	4077	0	0	18	0	18	0	4059	100

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d) ToR 2.4. Work on modelling the individual sea pens species and their overlaps [COM. Request#6b]

Following from the results on species distribution models (SDMs) used to predict the distribution of the VME functional group for Sea Pens and the individual sea pen genera *Funiculina*, *Balticina*, *Anthoptilum* and *Pennatula* presented in 2024 (NAFO, 2024; Murillo *et al.*, 2024), the current work encompasses further

modelling of the distribution of biomass for the same genera across the NAFO Regulatory Area. These models further investigate the different patterns of distribution observed for the Sea Pens VME at the functional group and individual genus level in the earlier work, including a comparison of the distribution of highest predicted concentrations of biomass for each genus, and the environmental conditions under which these occur.

i) Environmental and sea pen data

Full detail of the environmental data layers and research vessel scientific trawl data used for the current analysis is presented in Murillo *et al.* (2024). The final presence and biomass data used for the two stages of the biomass distribution models for individual sea pen genera included 5704 trawl sets collected 2011-2023. Data used for the presence models for each genus included all sets with presences of the genus and all absence records for Pennatuloidea. Sets where the modelled genus was absent, but Pennatuloidea was recorded, were excluded from genus level models to avoid inclusion of false absences being included (Table 5.8). Biomass models only used records where the genus was present. The biomass data were further log transformed to reduce the effect of the highest biomass samples. Unlike for the KDE analyses above, all records were used and no adjustments were made for catchability differences among the research vessels. For the KDE analyses, small catch weights were generally excluded to correct for this issue.

Table 5.8. Numbers of presence (and positive biomass) and null records (2011-2023) included in the delta models for biomass distribution

Taxon	Presence / Biomass Records	Null Records
<i>Anthoptilum spp.</i>	1199	4430
<i>Balticina spp.</i>	613	4981
<i>Funiculina spp.</i>	374	5216
<i>Pennatula spp.</i>	428	5177

ii) Modelling approach

The distribution of biomass of the four sea pen genera was modelled using a delta model constructed by combining a Random Forest (RF, Breiman, 2001; Cutler *et al.*, 2007) presence/absence (classification) model and log biomass (regression) model. A delta model consists of an initial binary model indicating areas with predicted presence and a continuous biomass model with predictions restricted to areas where the taxon was predicted present. Random Forest is an ensemble ‘statistical modelling’ method, where a large number of decision trees (typically 500-1000) are built using random subsets of the data. Regression trees are used for response variables consisting of continuous data and classification trees for factor variables. In the regression models predictions are based on averages from all trees (Breiman, 2001; Cutler *et al.*, 2007).

The models were built in the free statistical computing software R (v.3.5.1, R Development Core Team, 2018) using the ‘randomForest’ package (Liaw and Wiener, 2002). The models were run using the default settings of the randomForest function, using 500 trees.

Common sets of predictor variables were selected to be used in the presence/absence and log biomass models, respectively. Preliminary models were generated using the full suite of predictor variables to rank variable importance. Following this, an iterative approach was used to conduct model specific variable selection. The variables included as predictors were reduced by inspecting correlations among predictors. The least important variable was removed for variable pairs with correlation scores starting at > 0.70, and iteratively decreased by increments of 0.05, until all remaining predictor variables achieved a VIF < 10. Variables included in this stage in all presence/absence and all log biomass models were tallied and the correlation and VIF steps repeated, but this time prioritising variables by the number of models they were included in (Table 5.9).

Table 5.9. Final common variables included in the biomass models. For detailed description of the variables and their sources see Murillo *et al.* (2024).

Variable	Short code	Unit
Channel Network Base Level 5	CHNETBL5	m
Valley Depth 3	VALD	m
Relative Slope Position 5	RSP5	Index (0-1)
Channel Network Distance 5	CHNETD5	m
Bathymetric Position Index (fine-scale)	BPIF	index
LS-Factor	LSF	index
Eastness (aspect)	EAST	radians
Northness (aspect)	NORTH	radians
Vector Ruggedness Index	VRM	index
Chl <i>a</i> annual max (avg_yr)	MAXCHLA	mg m ⁻³
Chl <i>a</i> annual min (avg_yr)	MINCHLA	mg m ⁻³
Primary Production Summer Min (avg_yr)	PP	mg C m ⁻² day ⁻¹
Surface Temperature (avg) Max	MAXTEMP	°C
Surface Temperature (avg) Min	MINTEMP	°C
Bottom Current Speed (avg) Min	MINCURR	m s ⁻¹
Bottom Salinity (avg) Max	BSAL	N/A
NRA Fishing effort	EFFORT	km km ⁻² year ⁻¹
Survey Series	DATA	N/A

Models were validated using a k-fold cross-validation procedure. For each response variable, the data was randomly subsampled into 10 folds and train sets constructed leaving each fold out in turn, to be used as test data (resulting in a 90/10 percent split). Accuracy measures used to validate the models include the goodness-of-fit statistic R^2 and root mean squared error (RMSE) value. For the purposes of comparison between responses RMSE was normalised to a percentage of the range of observed biomass values for each specific response (NRMSE). Final predictions were achieved by averaging across the 10 model runs.

iii) Results and Discussion

Majority of sea pens captured in the scientific trawls are *Anthoptilum* spp., with the next most abundant being *Balticina* spp., both of which have higher average biomass than the smaller or less robust *Pennatula* spp. and *Funiculina* spp. Consequently, the distribution of the Sea Pens VME functional group biomass is largely driven by the two more frequently captured genera (Figure 5.49). This highlights the importance of mapping the spatial distribution of each genus separately, to identify their core habitats.

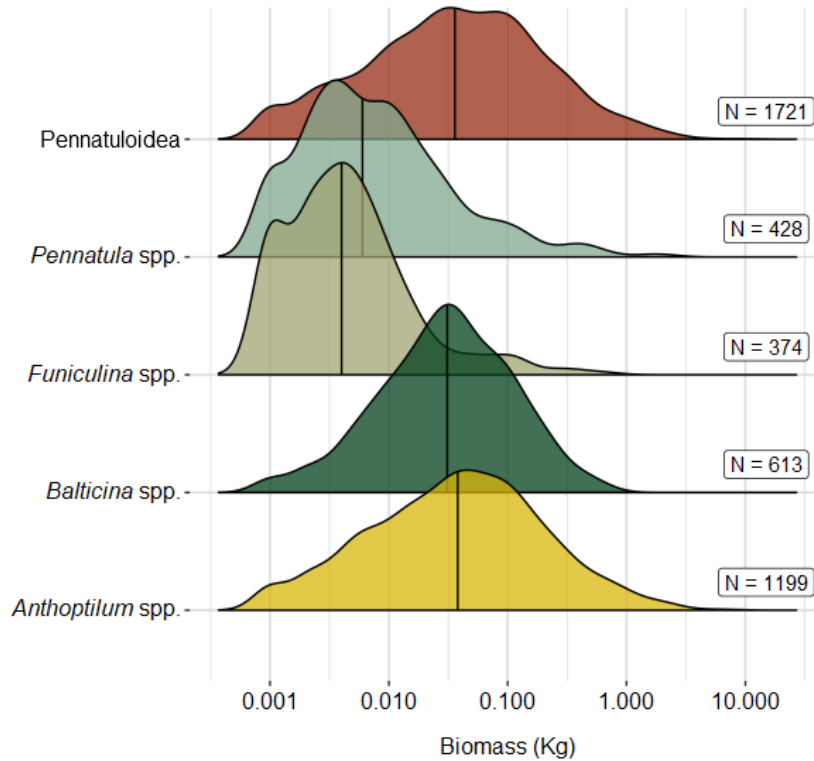


Figure 5.49. Distribution of biomass values for the Sea Pen functional group (Pennatuloidea) overall, and the different sea pen genera.

The model validation statistics for the binary classification models built as part of the hurdle model approach are shown in Table 5.10. All models showed good performance (≥ 0.8 Sensitivity, Specificity, Balanced Accuracy and True Skill Statistic), with *Pennatula* spp. showing highest accuracy overall.

Performance statistics for the regression model part of the hurdle model approach are shown in Table 5.11. Prediction error ranged from 18% of the range of biomass for *Anthoptilum* spp. and *Balticina* spp. to 22% and 23% for *Pennatula* spp. and *Funiculina* spp., respectively. *Anthoptilum* spp. had the highest correspondence of predicted and observed high and low values, with $R^2=0.3$ and *Pennatula* spp. the lowest with $R^2=0.1$. The poorer performance of the biomass models in comparison to the models of occurrence is to be expected with species like sea pens that exhibit patchy populations, not entirely driven by environmental conditions alone. Further, the wet weights of these taxa collected at sea may vary due to differing amounts of water content included in the measure.

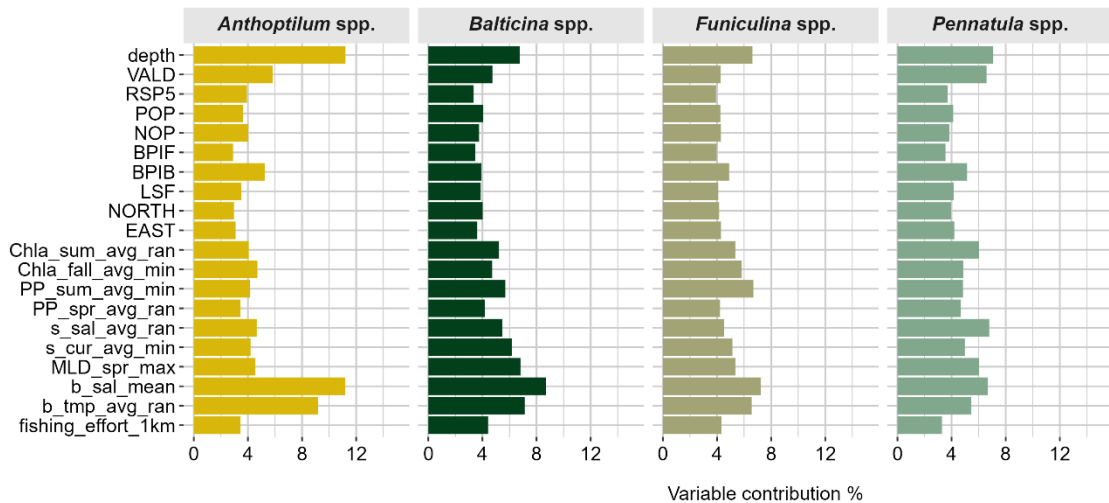
Table 5.10. Validation statistics for the binary classification models. TSS = True Skill Statistic.

	<i>Anthoptilum sp.</i>	<i>Balticina spp.</i>	<i>Funiculina sp.</i>	<i>Pennatula spp.</i>
N	5062	5030	5026	5041
Prevalence	0.21	0.11	0.07	0.08
Accuracy Measure	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Sensitivity	0.79 ± 0.03	0.82 ± 0.03	0.80 ± 0.03	0.83 ± 0.02
Specificity	0.79 ± 0.03	0.82 ± 0.03	0.79 ± 0.03	0.82 ± 0.02
Kappa	0.35 ± 0.06	0.31 ± 0.05	0.29 ± 0.05	0.56 ± 0.04
Balanced Accuracy	0.79 ± 0.03	0.82 ± 0.03	0.80 ± 0.03	0.83 ± 0.02
TSS	0.58 ± 0.06	0.64 ± 0.06	0.59 ± 0.06	0.65 ± 0.04

Table 5.11. Validation statistics for the regression models. RMSE = Root Mean Square Error.

	<i>Anthoptilum sp.</i>	<i>Balticina spp.</i>	<i>Funiculina sp.</i>	<i>Pennatula spp.</i>
N	1077	552	322	374
RMSE	1.40 ± 0.10	1.21 ± 0.09	0.9 ± 0.04	1.20 ± 0.10
Relative RMSE	0.18 ± 0.01	0.18 ± 0.01	0.22 ± 0.01	0.23 ± 0.02
R²	0.29 ± 0.04	0.14 ± 0.07	0.16 ± 0.13	0.10 ± 0.07

Environmental variables structuring the distributions of the sea pen genera were largely similar. Where the importance of environmental drivers (Figure 5.50) and the responses of different genera (Figure 5.51) diverged were with regard to depth, topographic features and mixed layer depth. Fishing intensity was not a very influential variable in the occurrence models and *Balticina spp.*, *Pennatula spp.* and *Funiculina spp.* all showed a slightly positive response to increasing fishing pressure. The positive association of sea pen presence to fishing grounds is expected as many fisheries target seabed that is suitable sea pen habitat. Figure 5.52 Shows the predicted distribution of occurrence for each sea pen genus across the NRA.

**Figure 5.50.** Variable importance for the binary classification models.

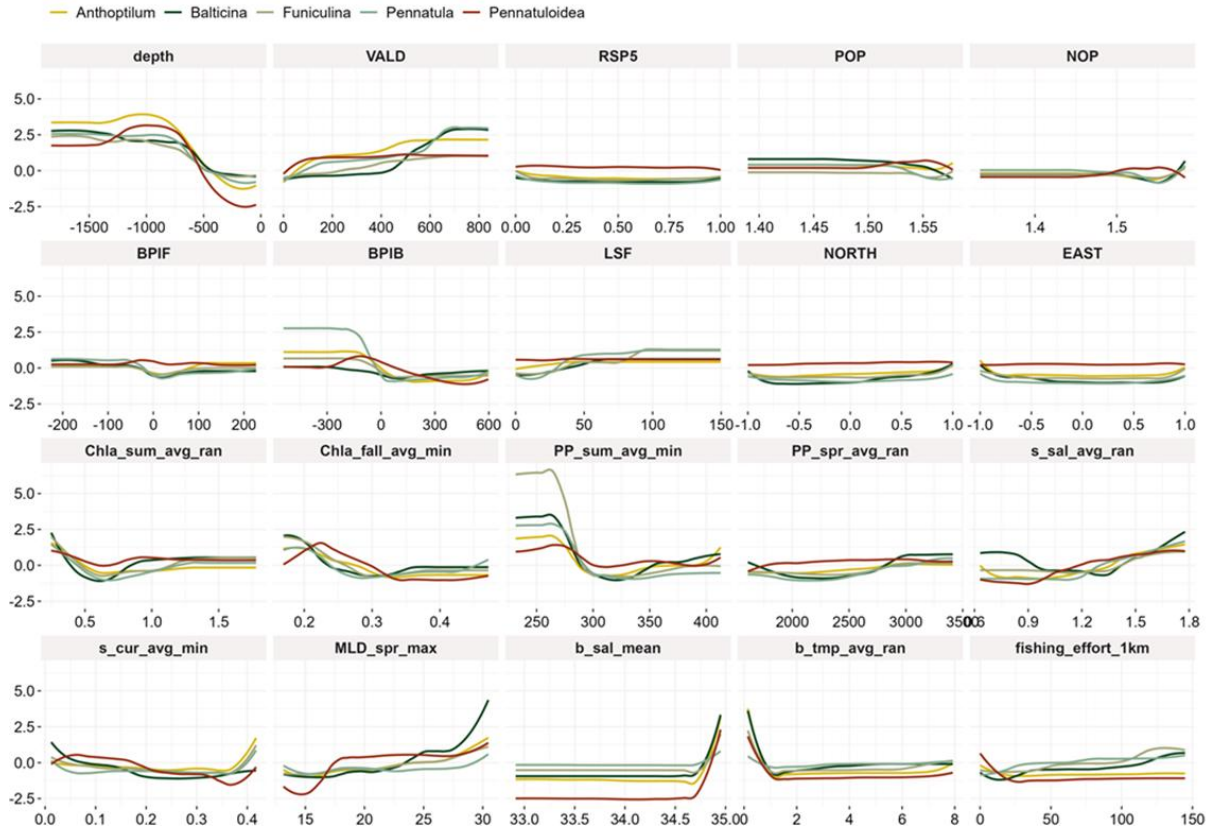


Figure 5.51. Partial response curves for modelled sea pen genera.

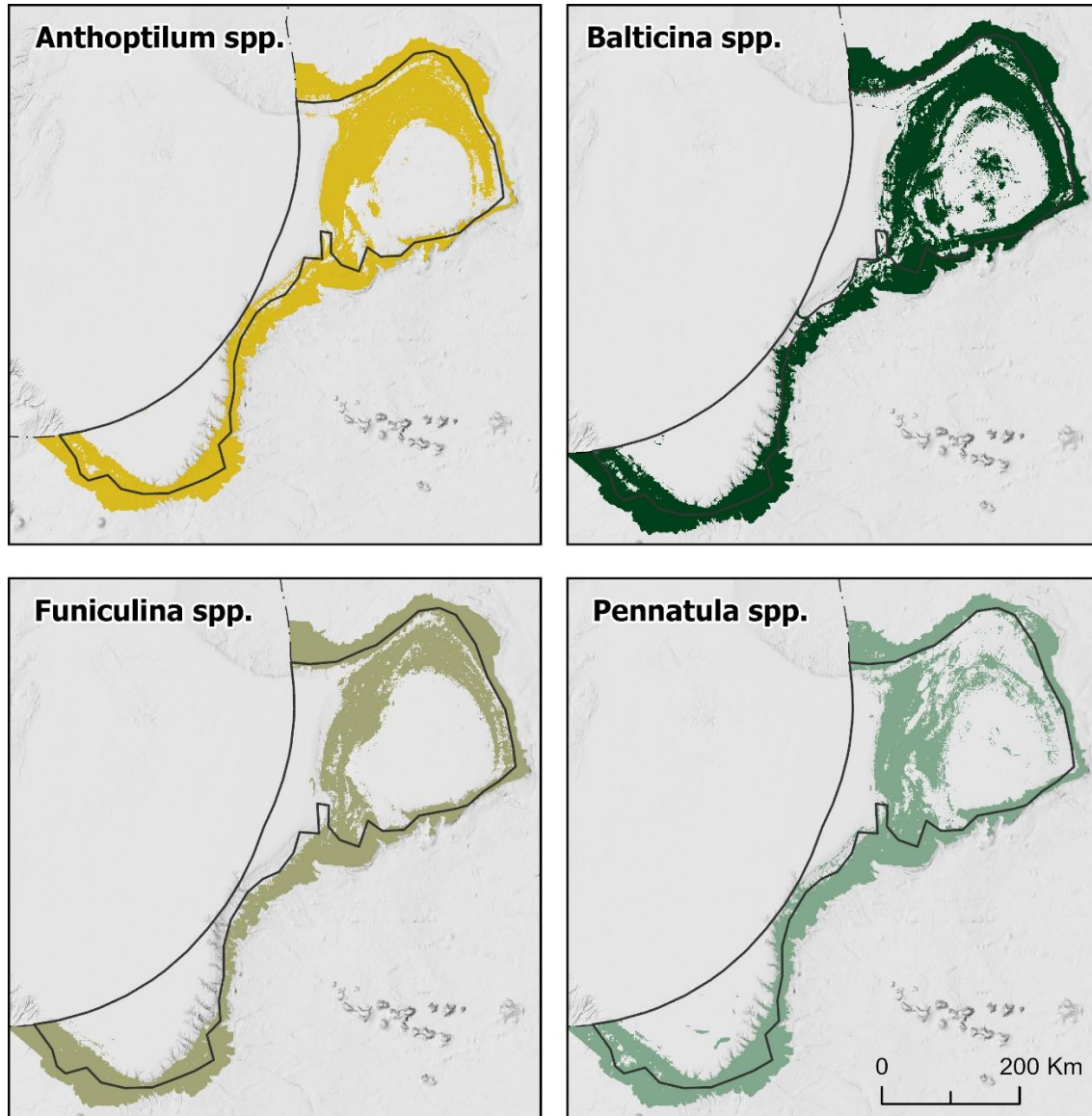


Figure 5.52. Predicted distribution for modelled sea pen genera.

The regression models show a clearer difference in the environmental variables structuring the distributions of biomass between the sea pen genera. The most important variables driving the biomass distribution of *Anthoptilum* spp. are temperature and salinity, whereas for *Balticina* spp. primary production and Chl-a are more important and for *Funiculina* spp. Chl-a and the east-west orientation of the seabed (Figure 5.53 and Figure 5.54). *Pennatula* spp. in contrast is most influenced by topographic features. Fishing intensity became a more important variable than the occurrence models for *Anthoptilum* spp. and *Balticina* spp., with a negative impact on biomass. Figure 5.55 shows the predicted distribution of core areas for each sea pen genus denoted by the areas containing biomass values above the 75th and 90th percentiles of the predicted biomass values across the NRA.

Future work on developing biomass regression models for the sea pens and other VME taxa is required before these surfaces can be used to estimate biomass for use in the assessment of significant adverse impacts of fishing and other applications. The relatively poor performance of the regression models compared with the presence/absence models may be improved through further exploration of the input data. Here, all of the data were used in the models, however for the KDE analyses only data above a certain threshold for each genera

were used (Kenchington et al., 2025) to reduce catchability differences among the different research vessels. Comparison of the sea pen biomass surface relative to surfaces created with focal statistics and kriging would help to identify which surface better represents the true biomass of the sea pen VME.

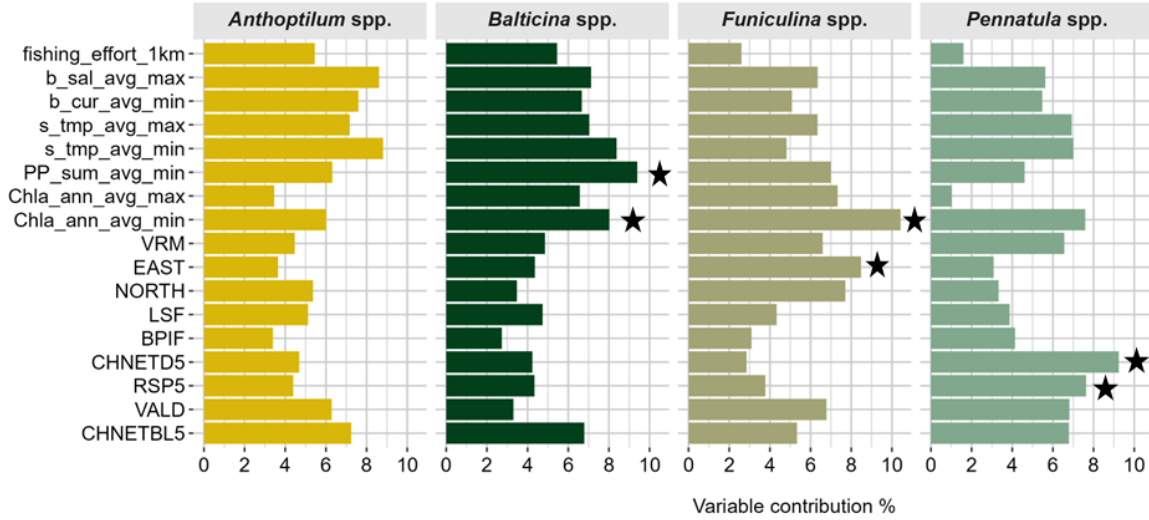


Figure 5.53. Predictor importance for biomass regression models. See Table 5.9 for key to variables. Black stars indicate variables showing the largest differences between genera.

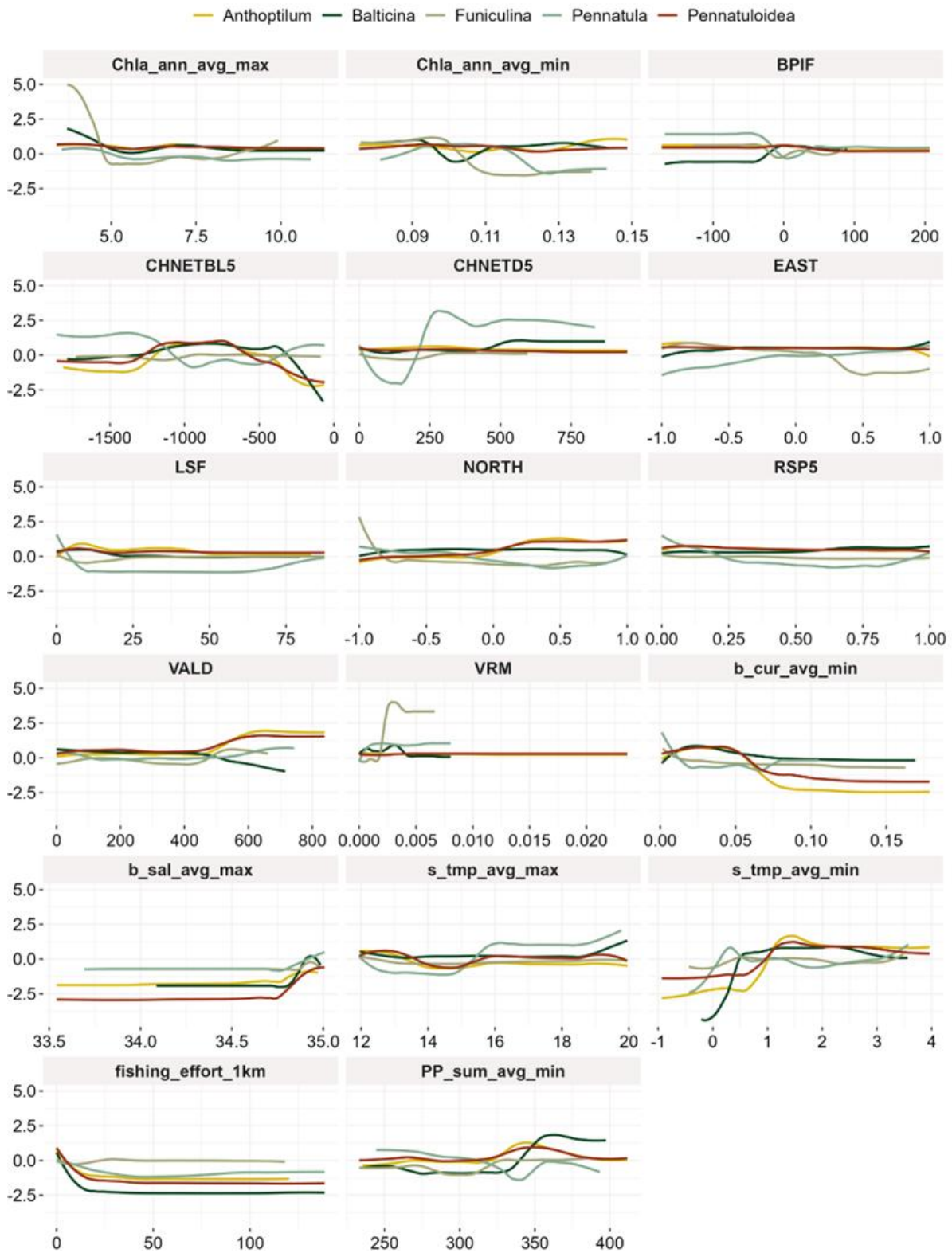


Figure 5.54. Partial response curves for modelled sea pen genera. See Table 5.9 for key to variables.

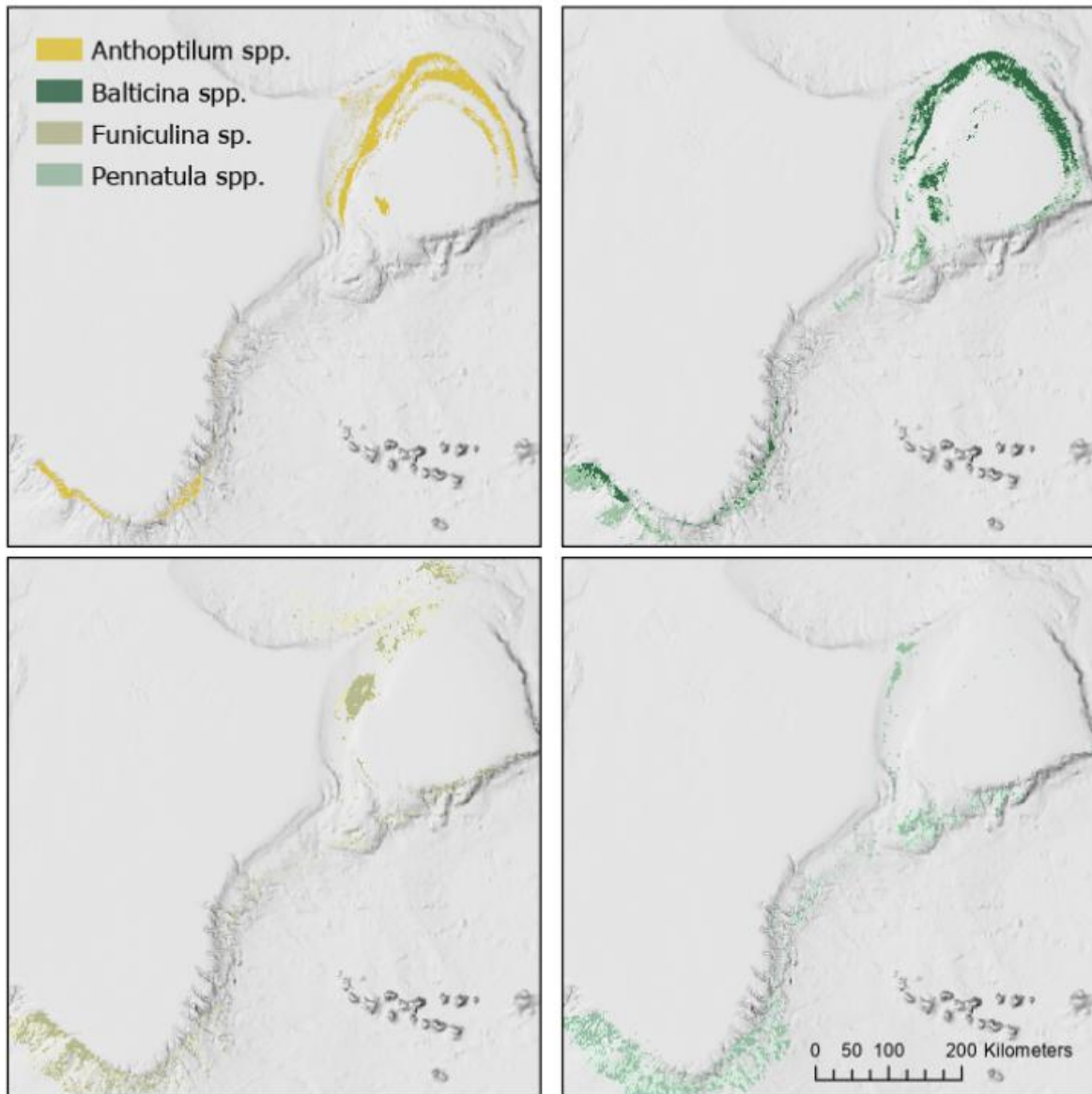


Figure 5.55. Distribution of highest predicted biomass values. Lighter colour denotes values above 75th percentile and the darker colour 90th percentile.

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e) ToR 2.5. High Resolution Climate Projections to 2100 for Use in Species Distribution Modelling of Vulnerable Marine Ecosystem Indicators in the NAFO Regulatory Area [COM. Request#6b]

Oceans are affected by seasonal and year-to-year climate variability as well as long-term climate change. Increasing levels of greenhouse gases in the atmosphere cause global temperatures to increase. As the oceans absorb this heat and carbon dioxide, they become warmer and more acidic, oxygen levels drop, summer sea ice in the Arctic decreases, and marine heatwaves become more frequent. Ocean currents and mixing redistribute the heat and carbon dioxide absorbed at the sea surface to deeper waters causing further changes to marine ecosystems that can be expected to last for decades. Species distribution models (SDMs) predict future species habitats under climate change by correlating known species locations with environmental factors like temperature and salinity (e.g., Beazley *et al.*, 2020; Wang *et al.*, 2022; Busch *et al.*, 2024). These models use current and projected future climate data, alongside chosen climate models and emission scenarios, to map potential species ranges. The outcome is a prediction of habitat suitability, showing areas where a species might persist, shift, or decline, offering crucial data for conservation and management strategies. Further, areas of analogous and novel environments in the future can be identified (Wang *et al.*, 2022).

The Coupled Model Intercomparison Project Phase 6 (CMIP6) represents the latest efforts by a global scientific community to generate climate model projections for high resolution impact studies (Eyring *et al.*, 2016). The CMIP6 models are designed to simulate various components of Earth's climate system, including the atmosphere, oceans, land surface, cryosphere, and carbon system. There are over 100 CMIP6 models from more than 50 modelling groups contributing to the project, though the specific number can vary depending on the specific dataset or model intercomparison being considered. The previous CMIP5 exercise used Representative Concentration Pathways (RCPs) to represent greenhouse gas concentration trajectories, whereas CMIP6 introduces a greater diversity of socio-economic scenarios or Shared Socio-economic Pathways (SSPs) from SSP1-2.6 to SSP5-8.5 (IPCC, 2021). Following previous efforts to drive marine ecosystem models (Tittensor *et al.*, 2019) using a high-resolution representation of the CMIP6 models (Lange, 2019), we seek to improve the precision in an ensemble of physical ocean variables, each of which is adjusted using a single-step statistical downscaling and bias correction.

The CMIP6 models provide SSP-forced climate simulations that are global and free-running (i.e., without data assimilation), but they are performed at relatively large spatial scales (~100 km) and each model has systematic biases compared to observations (e.g., Wang *et al.*, 2023). Biases are often associated with processes that a climate model does not resolve, and when finer scales are required to assess the impact on ocean species, systematic adjustments using downscaling approaches can be useful (e.g., Drenkard *et al.*, 2021). Dynamical downscaling involves a nested regional climate model that uses CMIP6 model output as its boundary conditions, but like global climate models, this method incurs a large computational cost (Drenkard *et al.*, 2021). Although climate models do not assimilate observations, an ocean data assimilation system like the GLObal Ocean ReanalYsis and Simulation (GLORYS12) (Lellouche *et al.*, 2021) performs systematic adjustments that can be applied to climate model output as a parameterization. Thus, an alternative to dynamical downscaling is to train a neural network by taking GLORYS12 as a reference and training a relationship, or mapping, from CMIP6 predictors to corresponding GLORYS12 predictands (Danielson *et al.*, 2025; McKee *et al.*, 2025). Parameterizations obtained using historical data can then be applied to projections to 2100. With the caveat that these parameterizations are fixed in time, local climate change impacts can be assessed at higher resolution and with greater precision across CMIP6 models.

Here, projections from a suite of 22 CMIP6 models (Paulin *et al.*, 2025) were analysed and downscaled using neural networks trained with GLORYS12 predictands for a suite of environmental variables (sea surface

temperature (SST), bottom temperature (BT), sea surface salinity (SSS), bottom salinity (BS), mixed layer depth (MLD), bottom current speed (BCS) and the derived variable bottom stress (τ_b) of interest for species distribution modelling (SDM) (Table 5.12). Simulations from each of four Shared Socio-economic Pathway (SSP) scenarios SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5, and four time periods (P1 (near term): 2020-2039, P2 (mid term): 2040-2059, P3 (mid term): 2060-2079, and P4 (end of century): 2080-2099) were created. These geospatial data products are intended to be used in future species distribution models (SDMs) to assess the impacts of climate change on vulnerable marine ecosystems and area closures in the NAFO Regulatory Area (NRA). Details of the methods used are provided in Paulin *et al.* (2025).

Table 5.12. Water column variables (Max: Maximum; Min: Minimum).

Variable	Abbreviation	Metric	Unit	Native Resolution
Bottom Salinity	BS	Mean, Max, Min, Range	N/A*	1/12° lat/long
Bottom Temperature	BT	Mean, Max, Min, Range	°C	1/12° lat/long
Bottom Current Speed	BCS	Mean, Max, Min, Range	m s ⁻¹	1/12° lat/long
Bottom Stress	BStr (τ_b)	Mean, Max, Min, Range	Pa = kg/m s ⁻¹	1/12° lat/long
Surface Salinity	SS	Mean, Max, Min, Range	N/A*	1/12° lat/long
Surface Temperature	SST	Mean, Max, Min, Range	°C	1/12° lat/long
Mixed Layer Depth	MLD	Mean, Max, Min, Range	m	1/12° lat/long
Summer MLD	MLD _{Su}	Mean, Max, Min, Range	m	1/12° lat/long
Fall MLD	MLD _F	Mean, Max, Min, Range	m	1/12° lat/long
Winter MLD	MLD _W	Mean, Max, Min, Range	m	1/12° lat/long
Spring MLD	MLD _{Sp}	Mean, Max, Min, Range	m	1/12° lat/long

*Salinity is considered unitless because it's defined as a ratio of conductivity, rather than a direct mass measurement.

i) Results

The statistical downscaling for the CMIP6 data showing model performance compared with GLORYS12 products is illustrated in Figure 5.57 for SSP2-4.5, before and after bias corrections, respectively. SSP2-4.5 is often considered a likely or middle-of-the-road scenario (Riahi *et al.*, 2017), possibly reflecting the world's current trajectory of policies and development, but it is not necessarily the most likely scenario for the future, as this depends on future government actions and choices.

Figure 5.58 shows an example of the high-resolution climate change projections for mean sea surface temperature (SST) from the 22 ensemble CMIP6 models for the NAFO study area for the time period 2020-2039 for Shared Socio-economic Pathway (SSP) 1-2.6, and for time period 2080-2099 for Shared Socio-economic Pathway (SSP) 5-8.5. Similar spatial distributions were produced for all of the variables (Table 5.12) and mapped for these same two scenarios in Paulin *et al.* (2025). As there are 44 variables (Table 5.12) each of which was projected under 4 SSPs in each of 4 time periods we have not illustrated all projections here or in Paulin *et al.* (2025), but data will be made available through the NAFO SharePoint for the SDM work planned for 2026.

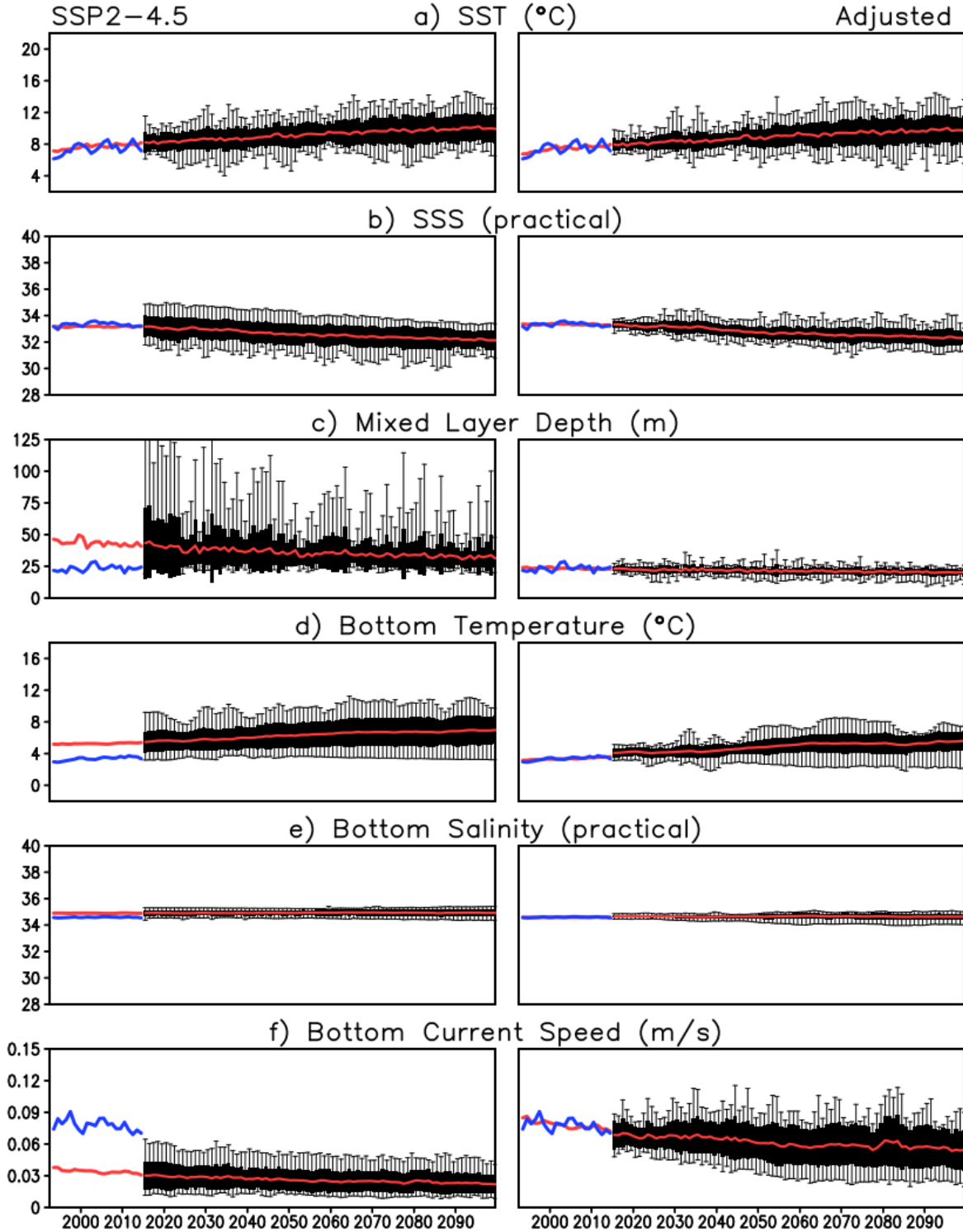


Figure 5.56. Annual averages and standard deviations among SSP2-4.5 model projections of six variables before (left column) and after (right column) AI mapping for the NAFO study area. Blue lines are the GLORYS12 reference. Red lines are the 22 CMIP6 model ensemble average. The black shading indicates one standard deviation above and below the 22-model average and the bars are the two outer model values.

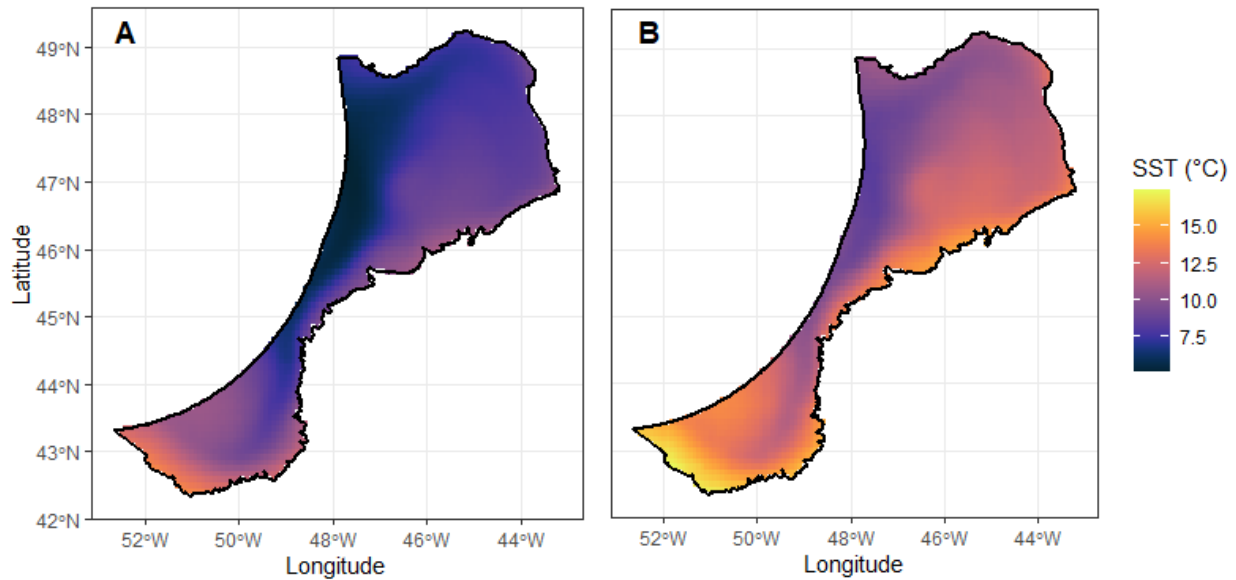


Figure 5.57. The spatial distribution of Mean Sea Surface Temperature (SST) (°C) from the 22 ensemble CMIP6 models for the NAFO study area. **A)** Time period 2020-2039 for Shared Socio-economic Pathway (SSP) 1-2.6. **B)** Time period 2080-2099 for Shared Socio-economic Pathway (SSP) 5-8.5.

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THEME 3: PRACTICAL APPLICATION OF ECOSYSTEM KNOWLEDGE TO FISHERIES MANAGEMENT

6. Update on recent and relevant research related to the application of ecosystem knowledge for fisheries management in the NAFO area.

a) ToR 3.1. Regular Monitoring of Ecosystem Summary Sheets (ESSs) for Divisions 3LNO and 3M [COM. Request#1]

i) Introduction

As part of the implementation of the NAFO Roadmap for an Ecosystem Approach to Fisheries (EAF), Ecosystem Summary Sheets (ESSs) provide a synoptic view of the state of NAFO ecosystems and their management regime, and constitute a tool for strategic assessment, advice and planning. ESSs have been developed for the Grand Bank (3LNO) and Flemish Cap (3M) Ecosystem Production Units (EPUs) (NAFO, 2023) and are intended to undergo regular updates every 5 years. After a delay of one year due to workload, the next regular update of the ESSs for these EPUs is scheduled to be produced by Scientific Council (SC) at its June 2028 meeting.

In the years between regular updates, ecosystem conditions in both EPUs are monitored annually. This interim monitoring is focused on the detection of significant ecological changes, in which case an out-of-schedule ESS update needs to be triggered.

The evaluation of significant ecological changes is focused on an expert judgment examination of: a) trends in ocean climate and oceanographic features, b) trends and structure of the fish community, and c) trends in trophic relationships (e.g. diet composition, stomach content weights).

WG-ESA examined the relevant ecosystem information for the Grand Bank (3LNO) EPU, presented in the context of ecosystem trends across EPUs in the Newfoundland and Labrador Bioregion, and for the Flemish Cap (3M) EPU to determine if significant ecological changes have occurred.

ii) Interim Monitoring of the Grand Bank (3LNO) EPU in the context of ecosystem trends across EPUs in the Newfoundland and Labrador Bioregion

The Newfoundland and Labrador (NL) bioregion constitutes a large marine ecosystem which can be subdivided into four Ecosystem Production Units (EPUs): Labrador Shelf (2GH), Newfoundland Shelf (2J3K), Grand Bank (3LNO), and Southern Newfoundland (3Ps). These EPUs represent relatively well defined functional ecosystems, and are used by NAFO for ecosystem-level summaries and ecosystem management considerations (Pepin *et al.*, 2014; Koen-Alonso *et al.*, 2019).

The focus of the ESS monitoring in the NL bioregion is the Grand Bank (3LNO) EPU, but information on neighbouring EPUs in this bioregion is also examined for broader context on the changes observed.

iii) Ocean climate conditions

The ocean climate in the NL bioregion has shown strong decadal scale changes associated to warm and cold conditions. These changes are well captured and summarized by the NL Climate Index (NLCI) (Cyr and Galbraith, 2021) (Figure 6.1). The NLCI shows that the ocean climate in the late 1980s-early 1990s corresponded to the coldest period on record, while the 1960s and the 2000s were the warmest. With the caveat that data for 2025 are preliminary as some components of the NLCI are not yet available, the data indicates that 2025 has been a warm year, continuing the warm phase that started in 2020 (Figure 6.1). These ocean climate phases have been associated with changes in ecosystem productivity, with warm phases favouring production at the ecosystem level (Cyr *et al.*, 2025).

The long-term variability of the ocean climate in the NL bioregion also appears to be increasing (Figure 6.2), suggesting that the climate phases regulating ecosystem productivity are of shorter duration in recent decades.

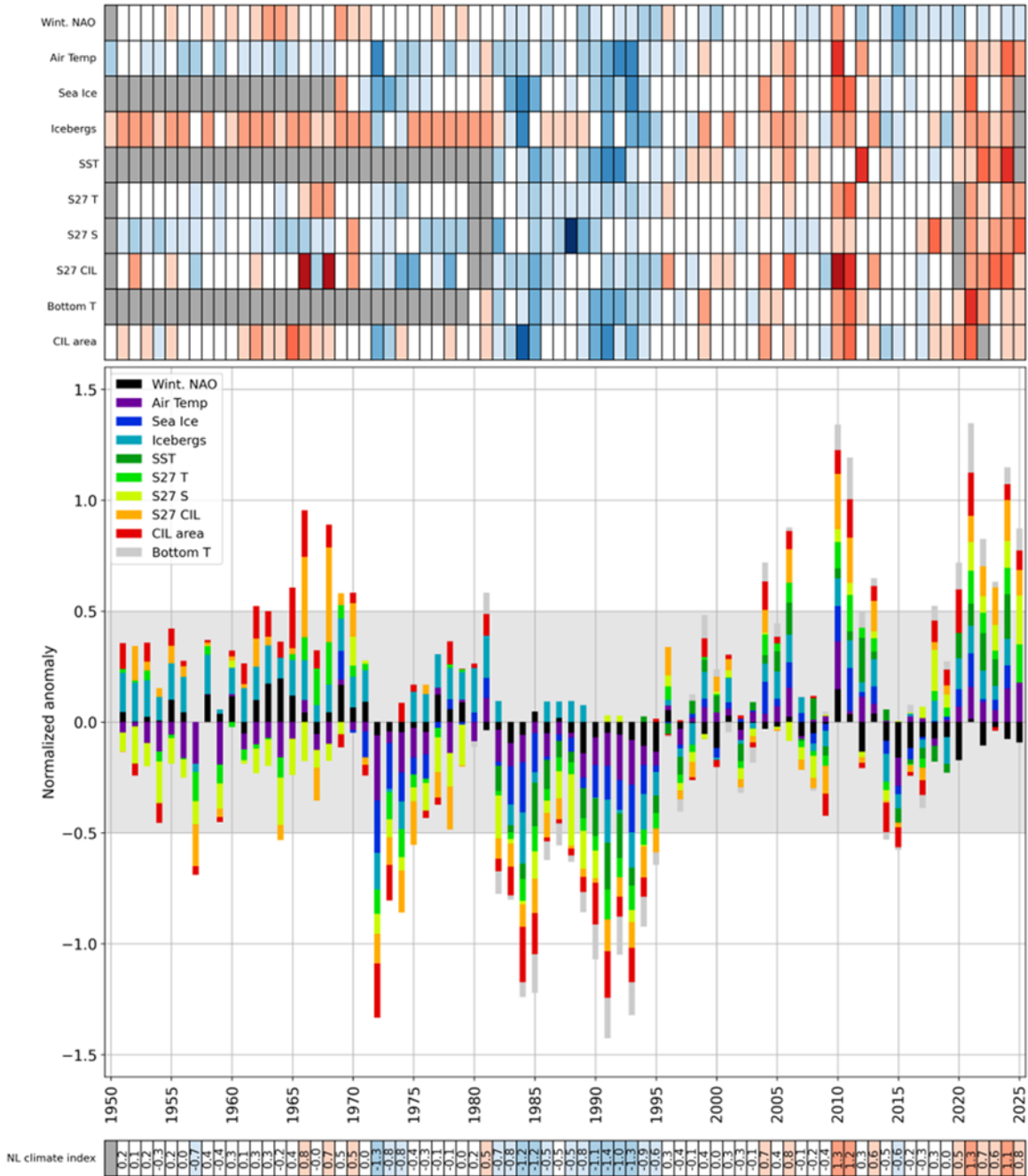


Figure 6.1. Newfoundland and Labrador Climate Index (NLCI). This index summarizes the general ocean climate conditions in the NL Bioregion. The data for 2025 are preliminary as some components of the index are not yet available.

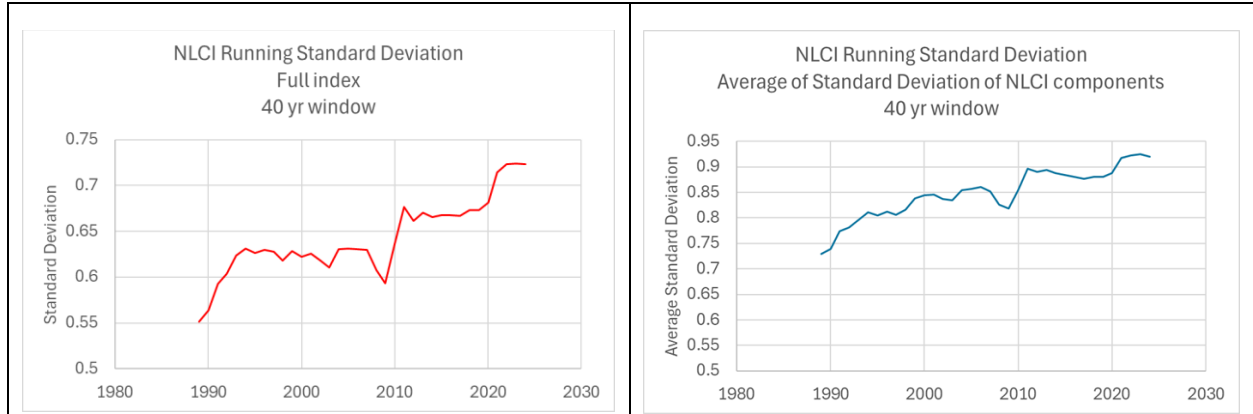


Figure 6.2. Long term trend in the variability of the ocean climate in the NL Bioregion, evaluated through the changes over time of the standard deviation of the NLCI using a 40 years moving window. Left: Standard deviation of the NLCI index using a 40-year moving window; Right: average of the standard deviations of the individual components of the NLCI using a 40-year moving window for each component. These analyses do not include 2025, as the dataset for this terminal year was incomplete at the moment of analysis. Each year in these plots represent the standard deviation (left) or average of the standard deviations (right) calculated for the 40-year window that ends in the year being plotted.

iv) Trends, fish community structure, and trophic interactions

The ecosystems in this bioregion experienced important changes in the 1990s, which involved the collapse of the groundfish community, the collapse of a key prey like capelin (Buren *et al.*, 2019), and the increase in shellfish (dominated by Northern shrimp, *Pandalus borealis*). Even with the increases in shellfish, total biomass never rebuilt to pre-collapse levels. Consistent signals of rebuilding of the groundfish community appeared in the mid-late 2000s, and coincided with modest improvements in capelin (Buren *et al.*, 2019; Murphy *et al.*, 2021), and the beginning of the shellfish decline (NAFO, 2021).

v) Newfoundland Shelf (2J3K)

After the period of high dominance of shellfish during the 1990s and early 2000s, the biomass of the fish community has reverted to a groundfish dominated structure similar to the one observed prior to the ecosystem collapse during the regime shift of the late 1980s and early 1990s (Figure 6.3). While the fish community structure is similar, this does not necessarily imply that the community is reverting back to an identical pre-collapse state.

Within the last decade, total biomass seems to have improved from the low point in the mid-2010s, while the general structure of the community has shown little change in recent years (Figure 6.3). The increase in biomass observed in 2024 is associated with the planktivore functional group and driven by redfish. Ephemeral spikes in redfish biomass are common, so this observation does not necessarily imply a sustained increase in total biomass. The next few years will define the significance of the 2024 observation for the trend in total biomass.

Within this EPU, the diets of key groundfish species, including piscivores like Atlantic cod and Greenland halibut, but also large benthivores like American plaice, show capelin as an important prey, with Northern shrimp gaining importance during the period, this ecosystem was dominated by shellfish (Figure 6.4). Diets from the last decade indicate that capelin was more important in the early 2010s than in recent years, but no major structural changes in diet composition are apparent (Figure 6.4). Diets from 2023-2024 show an improvement in capelin in the diets of several groundfish predators in comparison with the immediately preceding years (Figure 6.4).

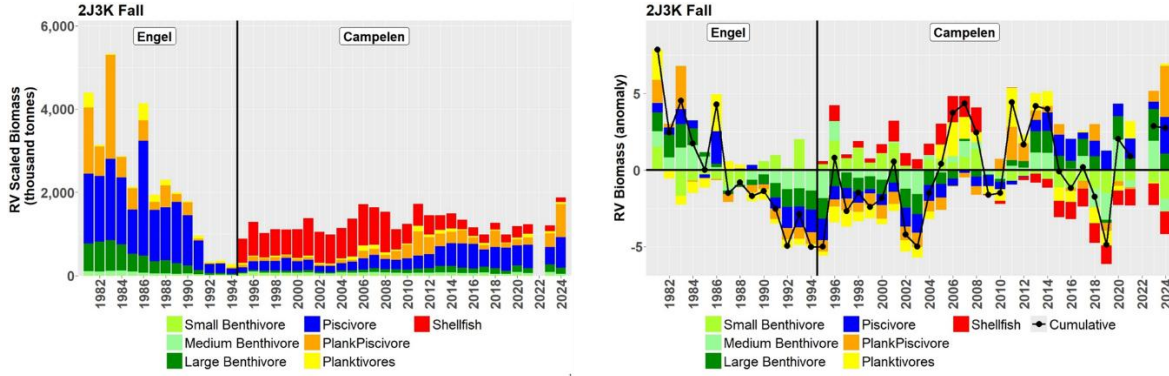


Figure 6.3. Research Vessel (RV) Fall Biomass (left) and Biomass Anomaly (right) of the fish community in the Newfoundland Shelf (2J3K) EPU, discriminated by fish functional group. Engel and Campelen indicate the fishing gear used in each period. The biomass for the Engel period has been scaled so that the order of magnitude of the estimates are comparable between periods. There is no shellfish data available for the Engel period. New RVs and minor modifications in the Campelen gear were introduced to the regular surveys in 2022/2023. While most of the data for this EPU has been converted to the new RV/gear using the available conversion factors, recent analyses indicate that these changes in RV/gear have no measurable impact on the trends and relative magnitudes at the functional group and total ecosystem levels (Munro, pers. comm.).

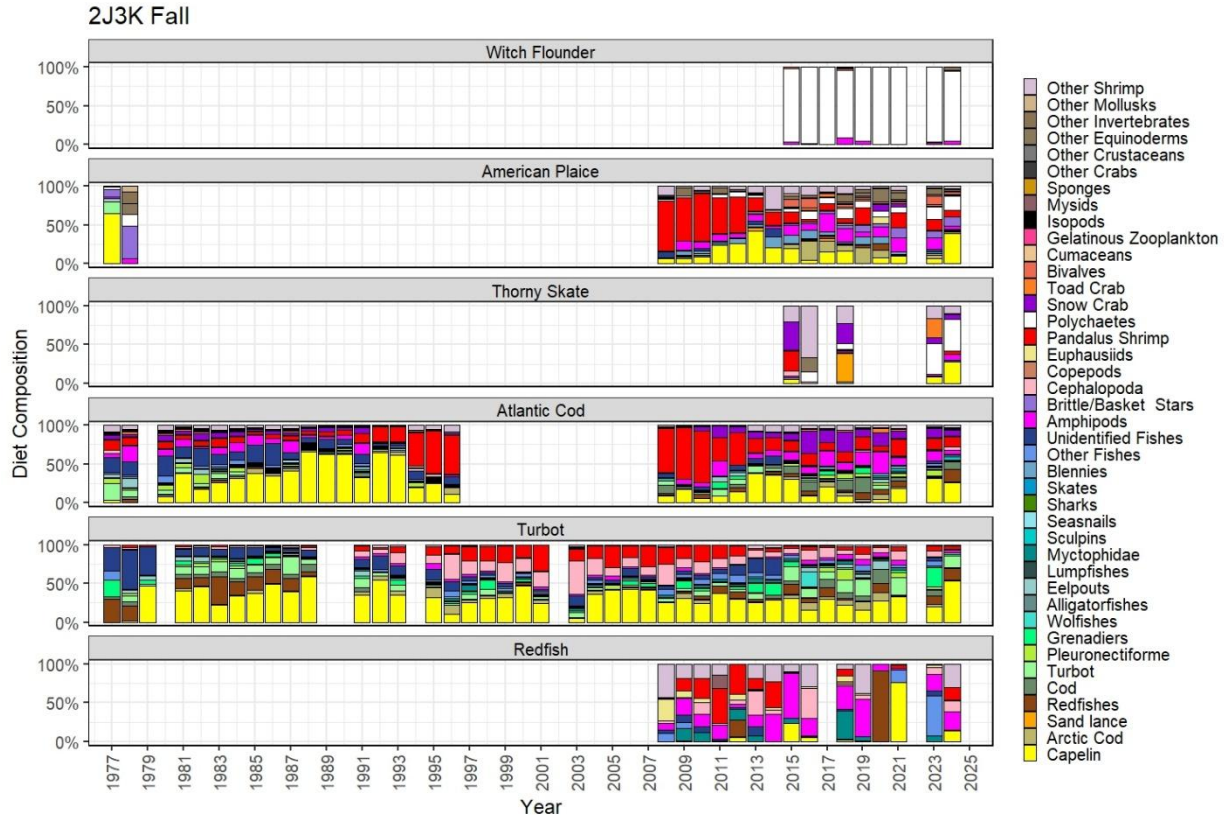


Figure 6.4. Diet composition for key species in the Newfoundland Shelf (2J3K) EPU from stomach contents collected during DFO Fall survey.

vi) Grand Bank (3LNO)

This ecosystem also saw increases in shellfish after the collapse, but the overall ecosystem structure remained groundfish dominated (Figure 6.5). Total biomass increased from the low levels in the early 1990s to post-collapse highs in the early 2010s. During the last decade, clear declines were observed in the mid-2010s in both Spring and Fall surveys, with recent surveys indicating a rebound in total biomass gradually approaching the mid-2010s levels (Figure 6.5). The Spring survey, which includes one more year than the Fall survey, shows biomass around the 2010 levels. The 2024-2025 surveys also show clear improvements in the piscivore and planktivore functional groups (see biomass anomalies in Figure 6.5). These increases are driven by Atlantic cod, capelin, and sandlance.

Within this EPU, the diets of key groundfish species show capelin and sandlance as important prey (Figure 6.6). While both forage fishes are important, capelin appears to increase its importance for some predators in the spring, and sandlance in the fall (Figure 6.6). Diets from the last decade do not appear to indicate any major structural change in diet composition (Figure 6.6).

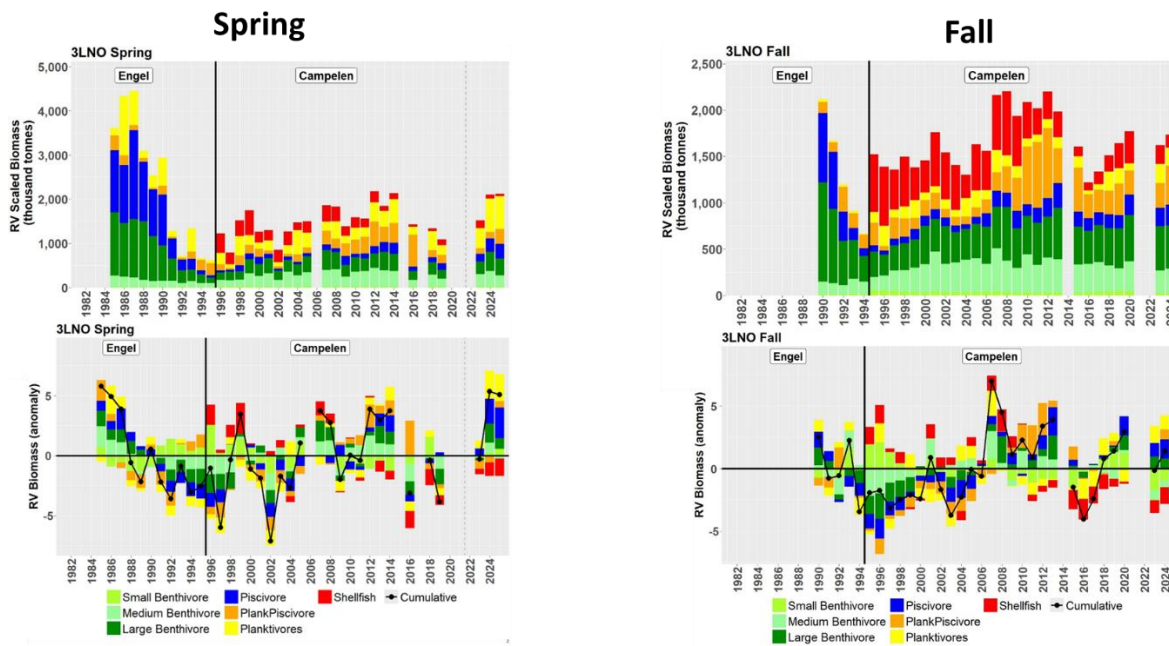


Figure 6.5. Research Vessel (RV) Spring (left column) and Fall (right column) Biomass (top row) and Biomass Anomaly (bottom row) of the fish community in the Grand Bank (3LNO) EPU, discriminated by fish functional group. Engel and Campelen indicate the fishing gear used in each period. The biomass for the Engel period has been scaled so that the order of magnitude of the estimates are comparable between periods. There is no shellfish data available for the Engel period. New RVs and minor modifications in the Campelen gear were introduced to the regular surveys in 2022/2023. While some of the data has been converted to the new RV/gear using the available conversion factors, most of the data, especially for the spring survey, is unconverted. However, recent analyses indicate that these changes in RV/gear have no measurable impact on the trends and relative magnitudes at the functional group and total ecosystem levels, so the use of unconverted data is not a hindrance for this study (Munro, pers. comm.).

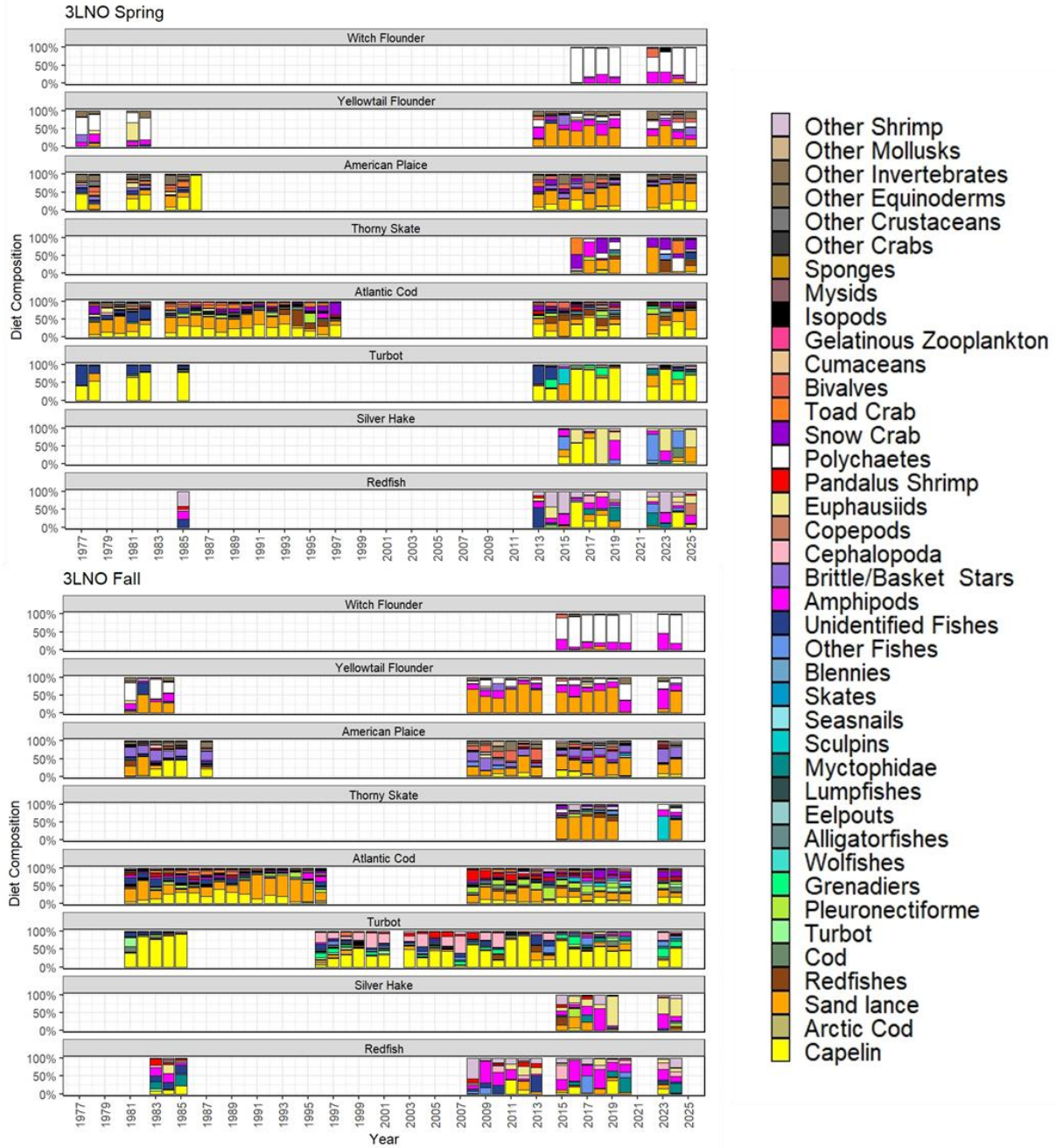


Figure 6.6. Diet composition for key species in the Grand Bank (3LNO) EPU from stomach contents collected during DFO Spring (top) and Fall (bottom) surveys.

vii) Southern Newfoundland (3Ps)

Like other ecosystem units in the NL Bioregion, Southern Newfoundland also saw important declines in total biomass during the early 1990s, but in relative terms this biomass decline was less pronounced (Figure 6.7). However, unlike other EPUs, this ecosystem has not shown clear signals of rebuilding after the declines, apart from transitory spikes in the planktivore functional group driven by redfish. Total biomass in this ecosystem unit has generally oscillated without a trend. During the last decade, and similarly to the other EPUs, reduced levels were observed after the mid 2010s (Figure 6.7). While the data from the most recent years appears to suggest that improvements in total biomass may be occurring, the piscivore functional group continues to show negative anomalies. The signals of improvements are associated to benthivore functional groups.

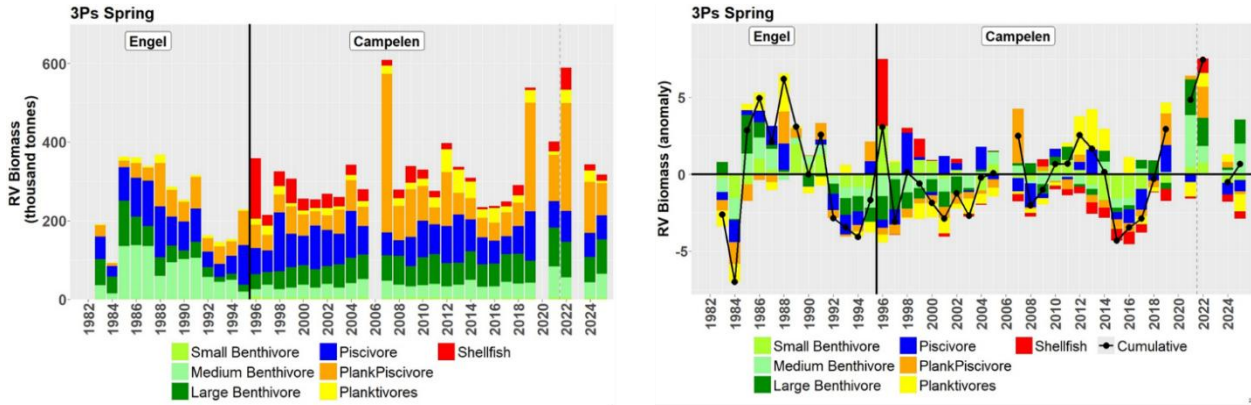


Figure 6.7. Research Vessel (RV) Spring Biomass (left) and Biomass Anomaly (right) of the fish community in the Southern Newfoundland (3Ps) EPU, discriminated by fish functional group. Engel and Campelen indicate the fishing gear used in each period. Unlike the other EPU in the NL Bioregion, the biomass for the Engel period has not been scaled for this EPU, so the magnitude of the estimates is not directly comparable between periods. There is no shellfish data available for the Engel period. The dotted vertical line indicates a change in RV and the introduction of minor modifications in the Campelen gear. The data has not been converted to the new RV/gear. However, recent analyses indicate that these changes in RV/gear have no measurable impact on the trends and relative magnitudes at the functional group and total ecosystem levels, so the use of unconverted data is not a hindrance for this study (Munro, pers. comm.).

One important ecosystem change in this EPU has been observed in the piscivore functional group over the last decade, where silver hake has displaced Atlantic cod as the dominant species (Figure 6.8). The increasing dominance of silver hake, and the high intrusion of spiny dogfish in 2019, both warmer water species, indicate that this community is changing (NAFO, 2021). These changes have been associated with the warming observed in this EPU. Recent analysis indicates that spatial and diet overlap between these species is low (Wheeland, in prep).

Diet information for key groundfish species from this EPU is sparser. Consistent sampling only started in the early 2010s, so long term characterizations of fish diets are difficult. Still, the available data indicates that sandlance is an important prey for several groundfish predators (Figure 6.9). Unlike other ecosystems, fish diets in this EPU appear more variable, suggesting a less stable prey field (Figure 6.9).

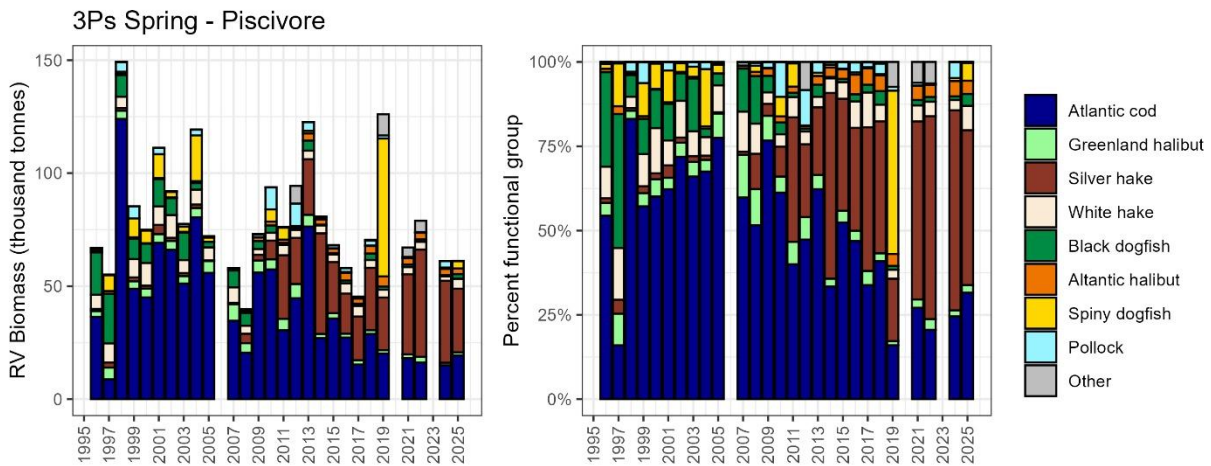


Figure 6.8. Trends in RV Biomass (left) and structure (right) of the piscivore functional group in the Southern Newfoundland (3Ps) EPU (NAFO 2021).

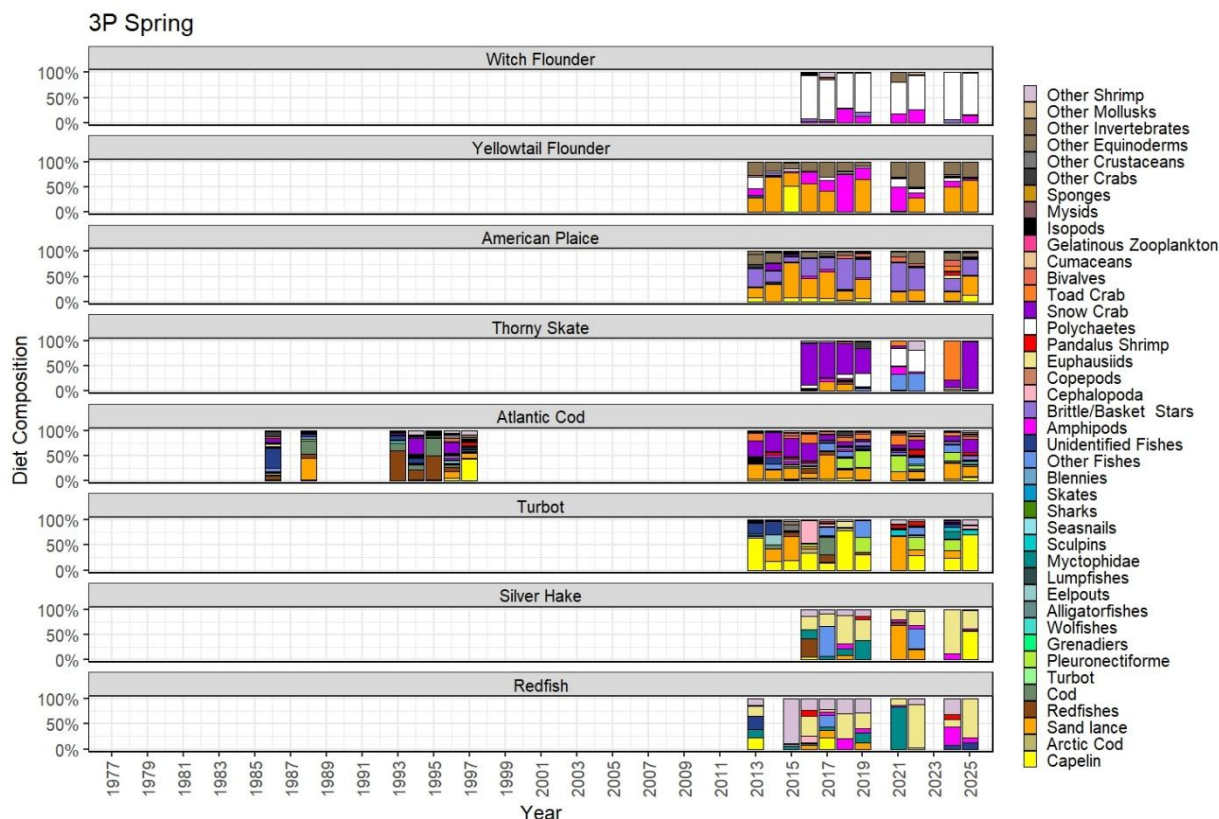


Figure 6.9. Diet composition for key species in the Southern Newfoundland (3Ps) EPU from stomach contents collected during DFO Spring survey.

viii) Comparisons among EPUs

Ecosystem level productivity in the NL Bioregion appears largely bottom-up regulated, with ocean climate phases controlling production at multiple trophic levels (Cyr *et al.*, 2025). Warm phases tend to favour overall ecosystem production, associated with planktivores and groundfish in general, while cold phases are associated with reduced ecosystem level production, but improved production of shellfish components. This suggests that climate phases control ecosystem productivity by shifting the magnitude of the energy flows between the pelagic and benthic energy pathways (Koen-Alonso *et al.*, 2022). In this context, the increasing levels of ocean climate variability would be expected to hinder overall ecosystem productivity, as they would prevent the stabilization of the energy pathways within the ecosystem (e.g., “groundfish production” vs “shellfish production” configurations).

The regime shift in the early 1990s involved the entire fish community. While substantial increases in shellfish were part of the changes, these increases did not compensate for the loss in groundfish (Figure 6.10). These EPUs have sustained significantly lower biomass densities since the collapse (Figure 6.10), indicating that after the regime shift these ecosystems have been experiencing reduced overall production (Koen-Alonso *et al.*, 2022). Within this context of persistent lower productivity, the last decade saw declines in all EPUs in the mid-2010s, but the most recent data indicate positive signals since 2019-2020 (Figure 6.10).

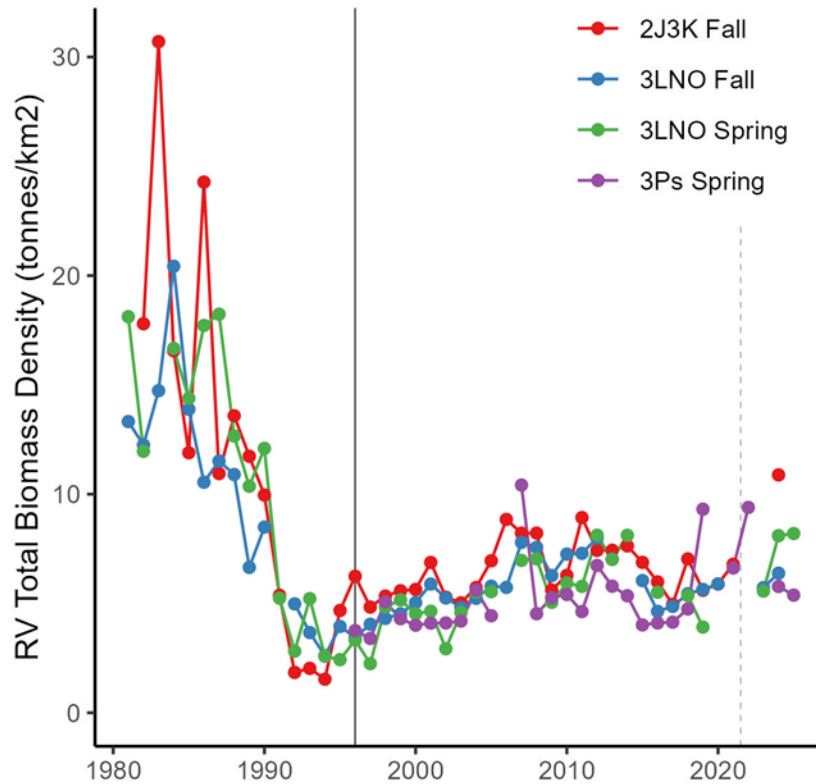


Figure 6.10. Total RV biomass density across EPUs in the NL Bioregion. The vertical filled line indicates the change in fishing gear from Engel to Campelen. Shellfish data are only included for the Campelen period, but this has minor impacts as the substantive increase in shellfish occurred after the gear change. The biomass for the Engel period has been scaled so that the order of magnitude of the estimates are comparable between periods. The dotted vertical line indicates a change in RV and the introduction of minor modifications in the Campelen gear. While some of the data has been converted to the new RV/gear using the available conversion factors, most of the data for 3LNO and 3Ps remains unconverted. However, recent analyses indicate that these changes in RV/gear have no measurable impact on the trends and relative magnitudes at the functional group and total ecosystem levels, so the use of unconverted data is not a hindrance for this study (Munro, pers. comm.).

In terms of community structure, there are clear differences among EPUs (Figure 6.11). While all ecosystems saw increases in shellfish after the collapse, there is a clear north to south gradient in the level of shellfish dominance observed. The fish community in the Newfoundland Shelf (2J3K) EPU was strongly dominated by shellfish after the collapse, while the other two EPUs were never dominated by this functional group, and the Southern Newfoundland (3Ps) EPU saw the weakest shellfish response to the groundfish collapse (Figure 6.11). Other structural differences among EPUs include the higher dominance of benthivores in the Grand Bank (3LNO) in comparison with the other EPUs, and the higher dominance reached by piscivores in the Newfoundland Shelf (2J3K) after this ecosystem unit returned to a groundfish dominated structure (Figure 6.11). Despite the longer-term changes, the general structure of these ecosystem units has remained relatively stable during the last decade (Figure 6.11), but this structural stability does not necessarily imply stability within functional groups, as the case of piscivores in Southern Newfoundland (3Ps) clearly demonstrates (Figure 6.8).

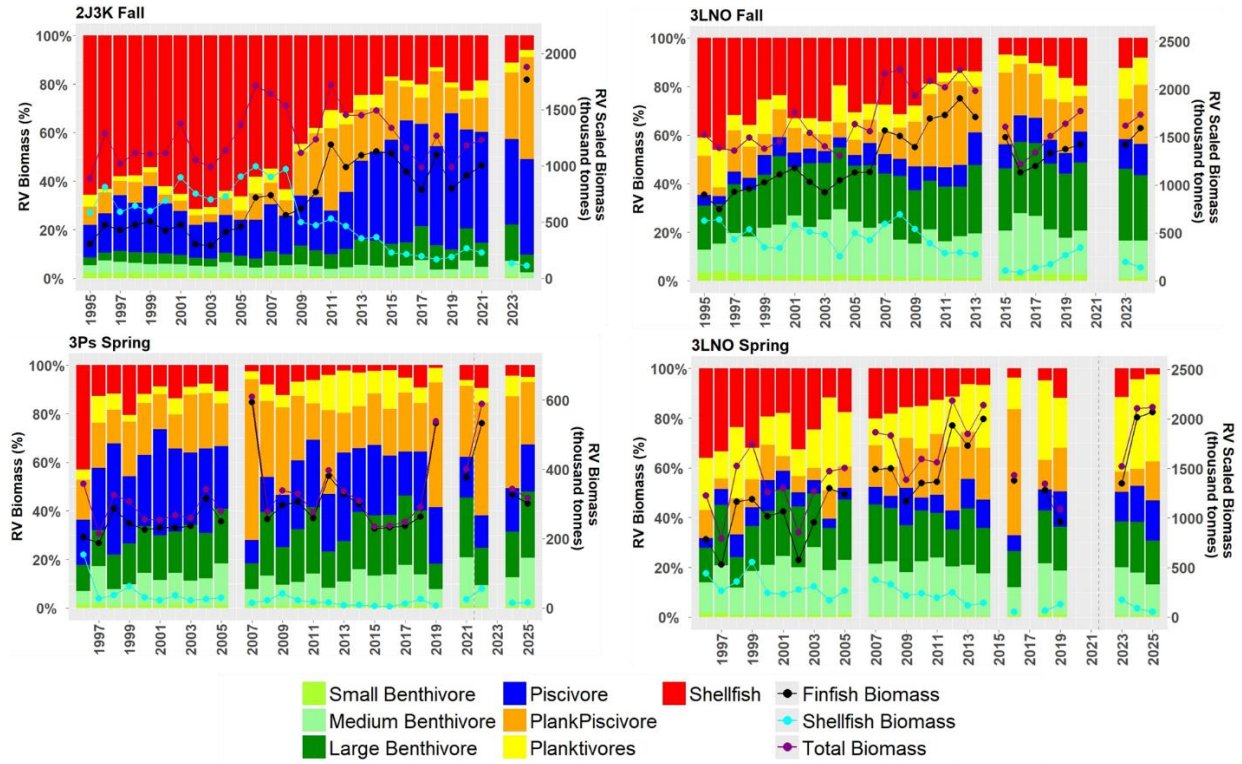


Figure 6.11. Synoptic comparison of the trends (total, finfish, and shellfish biomass) and structure (fish functional groups) of the fish communities after the ecosystem collapse. Top left: Newfoundland Shelf (2J3K) from Fall survey, Right: Grand Bank (3LNO) from Fall (top) and Spring (bottom) surveys, Bottom left: Southern Newfoundland (3Ps) from Spring survey.

From a trophic perspective, the long term signal in the average stomach content weights of Atlantic cod and Greenland halibut (also known as turbot) across EPUs (Figure 6.12) shows a consistent pattern with the trend in total biomass density (Figure 6.10). This relationship is significant (Figure 6.12), and suggests that food availability has been an important and consistent driver of ecosystem change in the NL Bioregion. This observation allows identifying one of the ecological mechanisms at play for the bottom-up control signal from the ocean climate phases. While the overall ecosystem collapse is expected to have resulted from a combination of multiple factors (e.g., high fishing pressure, extreme environmental conditions, the collapse of capelin), the long term association between total biomass density and feeding performance of high trophic level fish predators indicates that bottom-up mechanisms may be behind the persistent low productivity that these ecosystems have been experiencing since the collapse.

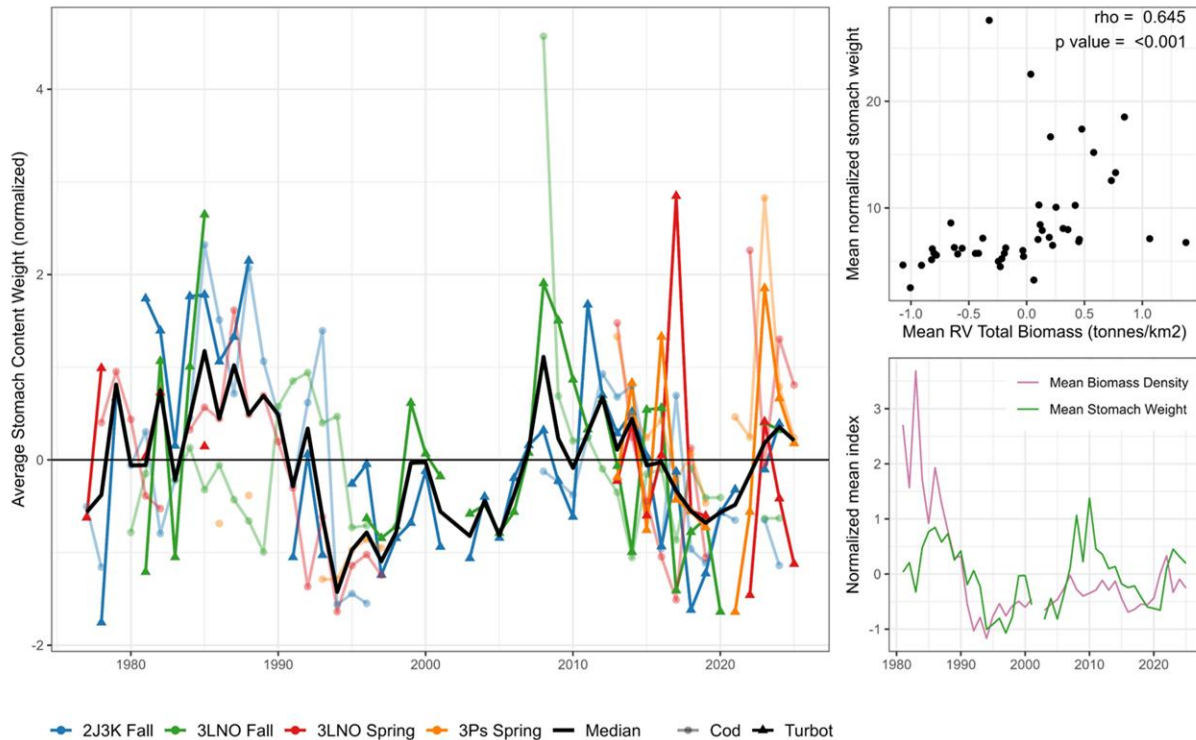


Figure 6.12. Average stomach content weights of Atlantic cod and Greenland halibut (also known as turbot) across the EPU in the NL Bioregion (fish sizes limited to 30-55 cm and excluding empty stomachs to minimize the effects of changes in size distributions and the variability in the determination over time of what constitutes an “empty stomach”) (left), and comparison between average stomach content weights and the average of the total biomass density (Figure 6.10) (bottom right). These two signals are positively and significantly correlated (Spearman correlation) (top right).

ix) Evaluation of significant ecological change

While these ecosystems continue showing changes over time, and these changes need to continue being monitored and assessed on a regular basis, the ecological changes observed since the last update of the ESS for the Grand Bank (3LNO) EPU are in line with already identified patterns and trends for this EPU and the NL Bioregion more generally.

The nature and magnitude of the recently observed changes is not considered to meet the “significant ecological change” criterion required to trigger an update of the 3LNO Ecosystem Summary Sheet out of schedule.

x) Interim Monitoring of the Flemish Cap (3M) EPU

The Flemish Cap bioregion (3M) encompasses a single Ecosystem Production Unit (EPU). This EPU represents a well-defined functional ecosystem, and is used by NAFO for ecosystem-level summaries and ecosystem management considerations (Pepin *et al.*, 2014; Koen-Alonso *et al.*, 2019).

xi) Ocean climate conditions

The Ocean Climate Index for the Flemish Cap (3M) EPU is derived from several temperature series, and provides a general characterization of the ocean climate in this EPU (Cyr and Bélanger, 2024). The ocean climate in this EPU has similar characteristics to the one in the neighbouring NL Bioregion, showing strong decadal changes. After a cold period in the mid-late 2010s, a warm phase started in 2020. This phase continues in 2024 (Figure 6.13).

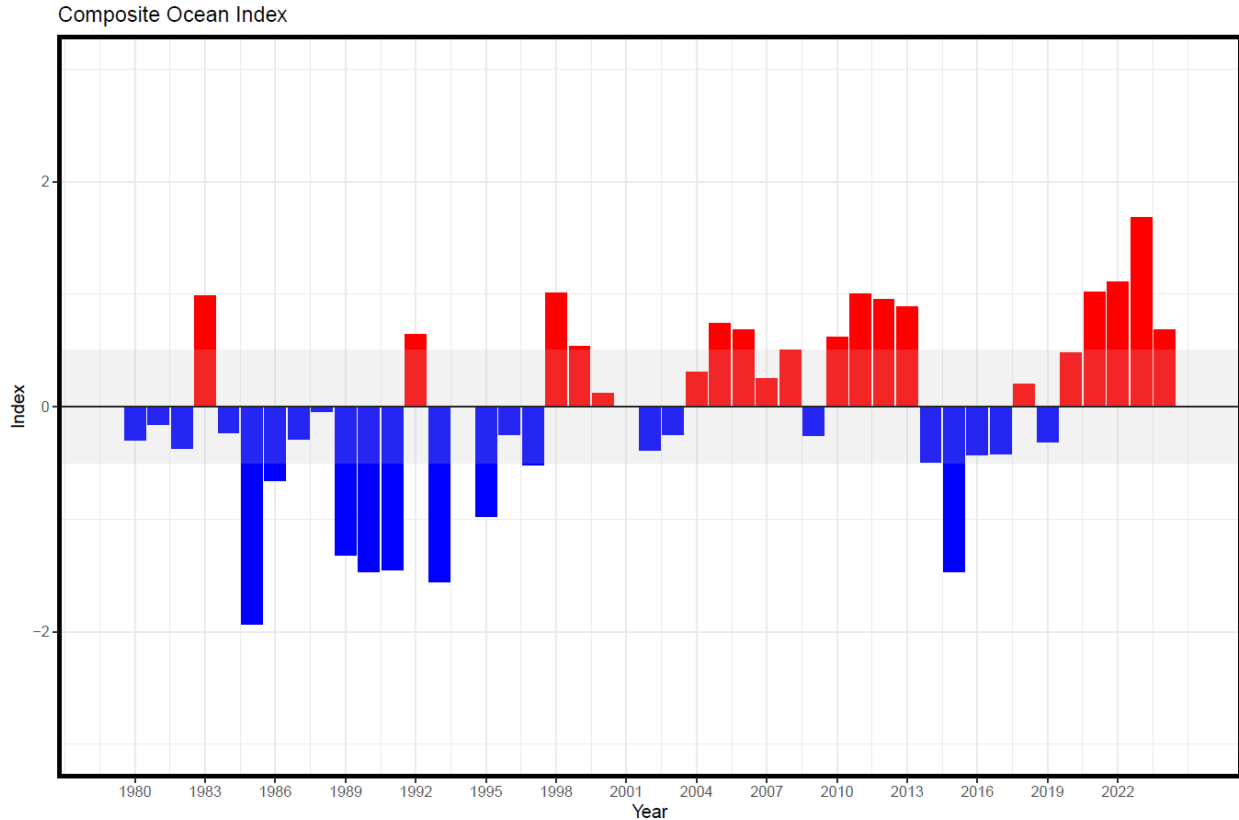


Figure 6.13. Ocean Climate Index for the Flemish Cap (3M) EPU. This index summarizes the general ocean climate conditions in the 3M EPU. The data for 2025 is not yet available.

xii) Trends, fish community structure and trophic interactions

The data used in this section come from the EU Div. 3M survey, which has been carried out since 1988. The survey design changed in 2003, expanding the maximum depth covered from 700 m to 1400 m. Therefore, data for deeper strata are only available since 2003. For consistency purposes, the data used here have been restricted to the shallower strata (up to 700 m) for the entire series. An examination including all data for the 2003-2025 period showed similar general patterns.

Total biomass is around the long-term average, indicating normal productivity conditions. During the 1990s and early 2000s this EPU saw an increase in dominance of shellfish (driven by Northern shrimp, *Pandalus borealis*), and an important increase in total biomass was observed in the mid-2000s driven by planktivores due to high recruitment of redfish (Figure 6.14).

During the last decade, total biomass returned to the long-term average, and community structure has remained stable, with high dominance of piscivores (mainly Atlantic cod) and planktivores (mainly redfish) (Figure 6.15).



Figure 6.14. Research Vessel (RV) Biomass (t) (left) and Biomass Anomaly (right) of the fish community in the Flemish Cap (Div. 3M) EPU, discriminated by fish functional group. Data until 700 m. The data for 2025 are preliminary and are subject to revisions.

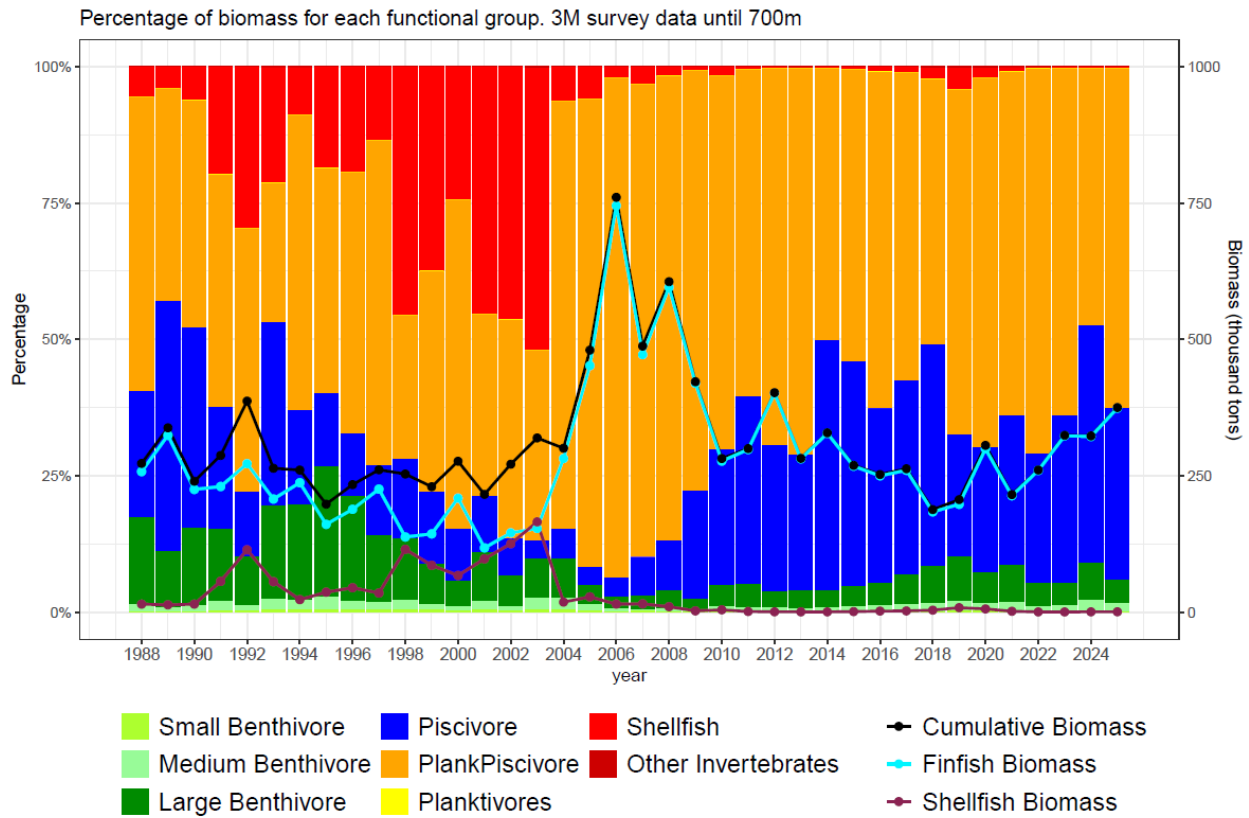


Figure 6.15. Synoptic view of the trends (total, finfish, and shellfish biomass) and structure (fish functional groups) of the fish community in the Flemish Cap (3M) EPU. Data until 700 m. The data for 2025 are preliminary and are subject to revisions.

xiii) Trophic structure

Diet compositions for groundfish species like Atlantic cod, American plaice, witch flounder and Greenland halibut appear generally stable over the last decade (since the decline in shrimp), while roughhead grenadier and redfish diets tended to be more variable (Figure 6.16). Since 2006 the stomach content sampling is done every other year; this increases the uncertainty in diet trends, especially if a species has higher interannual variability in diet composition.

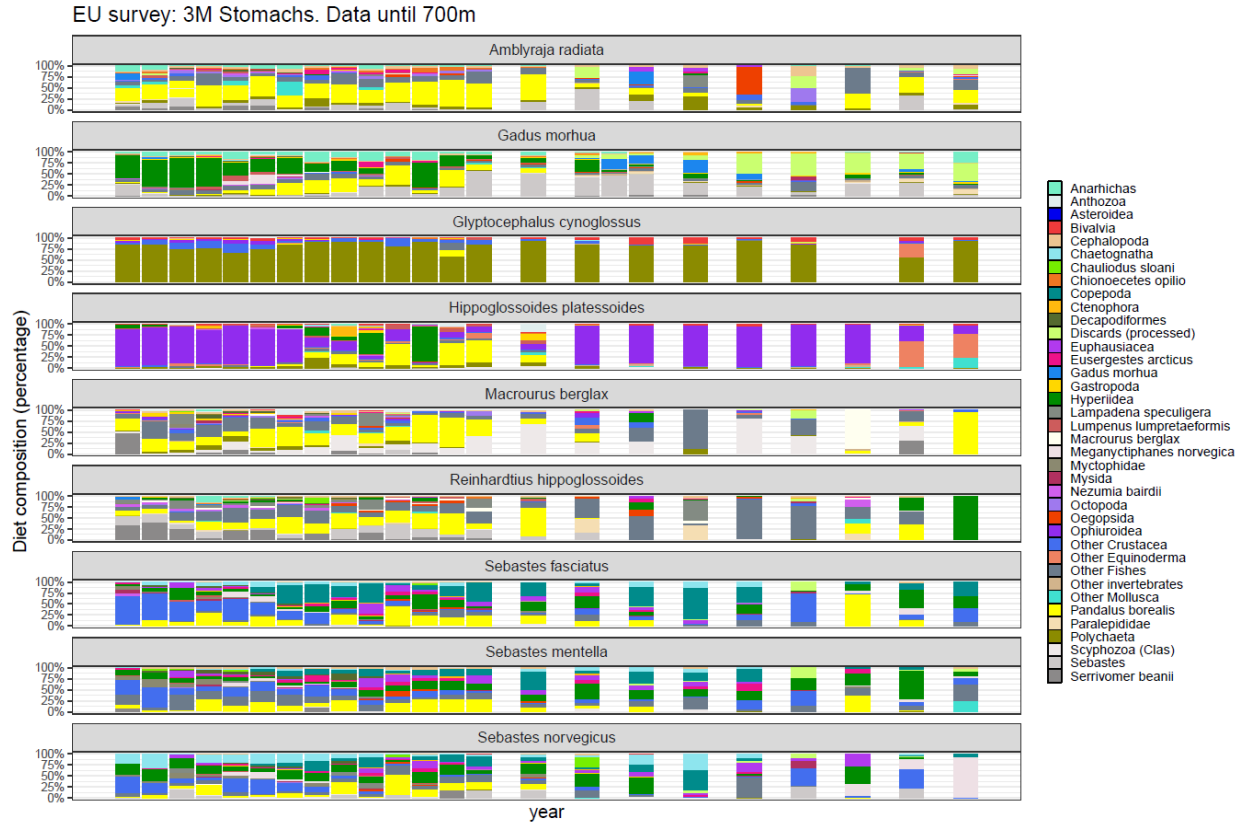


Figure 6.16. Diet composition for key species in the Flemish Cap (3M) EPU from stomach contents collected during EU surveys. Data until 700 m.

In general, the average stomach content of the main predators in the 3M EPU has decline over the years (Figure 6.17, left plot). The long-term signal in the average stomach content weights of these species does not show a consistent pattern with the trend in total biomass density (Figure 6.17, right plots), suggesting that prey availability does not appear be a major driving factor in this ecosystem.

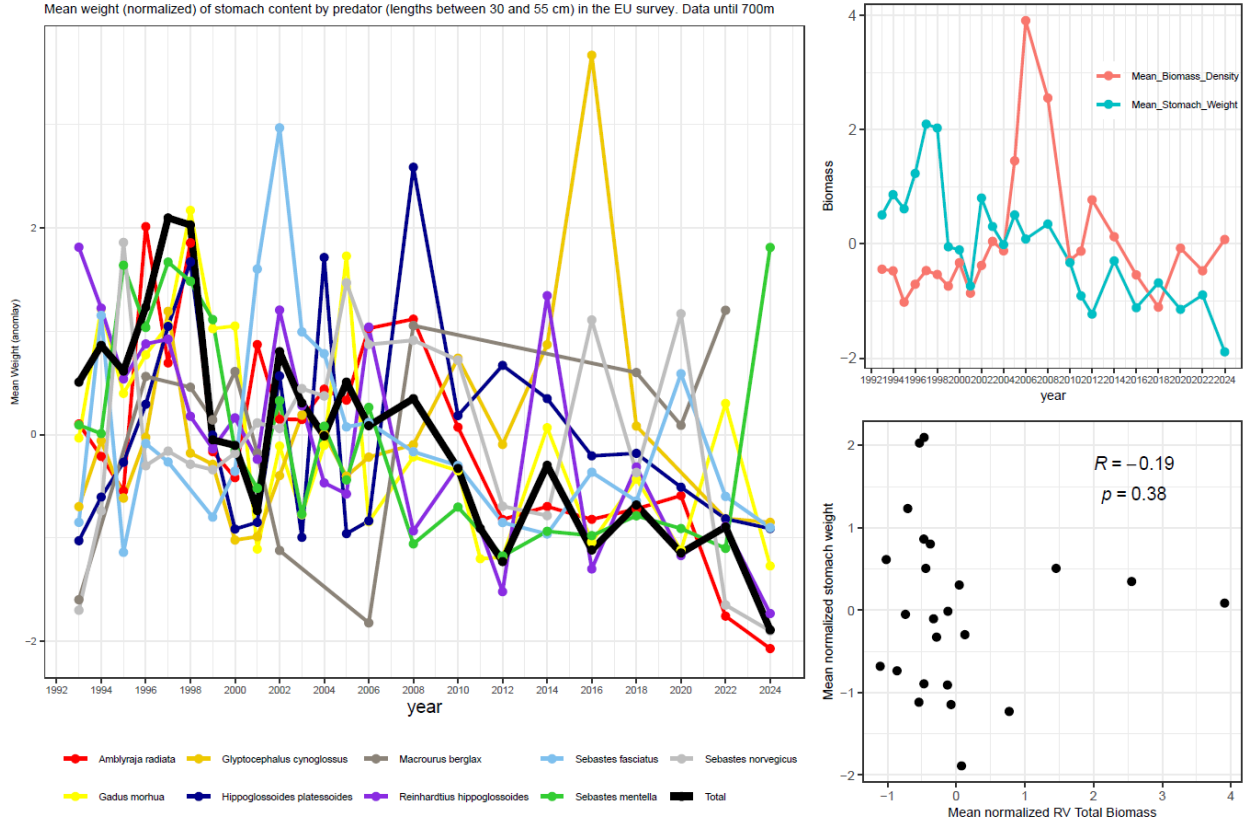


Figure 6.17. Average stomach content weights (standardized) of the main predators in the 3M EPU (fish sizes limited to 30-55 cm and excluding empty stomachs to minimize the effects of changes in size distributions and the variability in the determination over time of what constitutes an “empty stomach”) (left). Data until 700 m. Note that from 2006 the stomach sampling in the survey is every two years. Comparison between average stomach content weights (Figure 6.17 left plot) and the average of the total biomass density (Figure 6.15) is displayed on the right.

Since 2009, the availability of some common forage species (capelin, sand lance, shrimp, redfish juveniles, lantern fish) has been generally lower than in the early 2000s (Figure 6.18). Changes in the mean weight of the stomach content of the predators could be associated with these decreases in biomass. This would imply that reduced availability of these prey has not been compensated by other forage species. The potential implications for stock and community dynamics are not clear at the moment, and require further investigation.

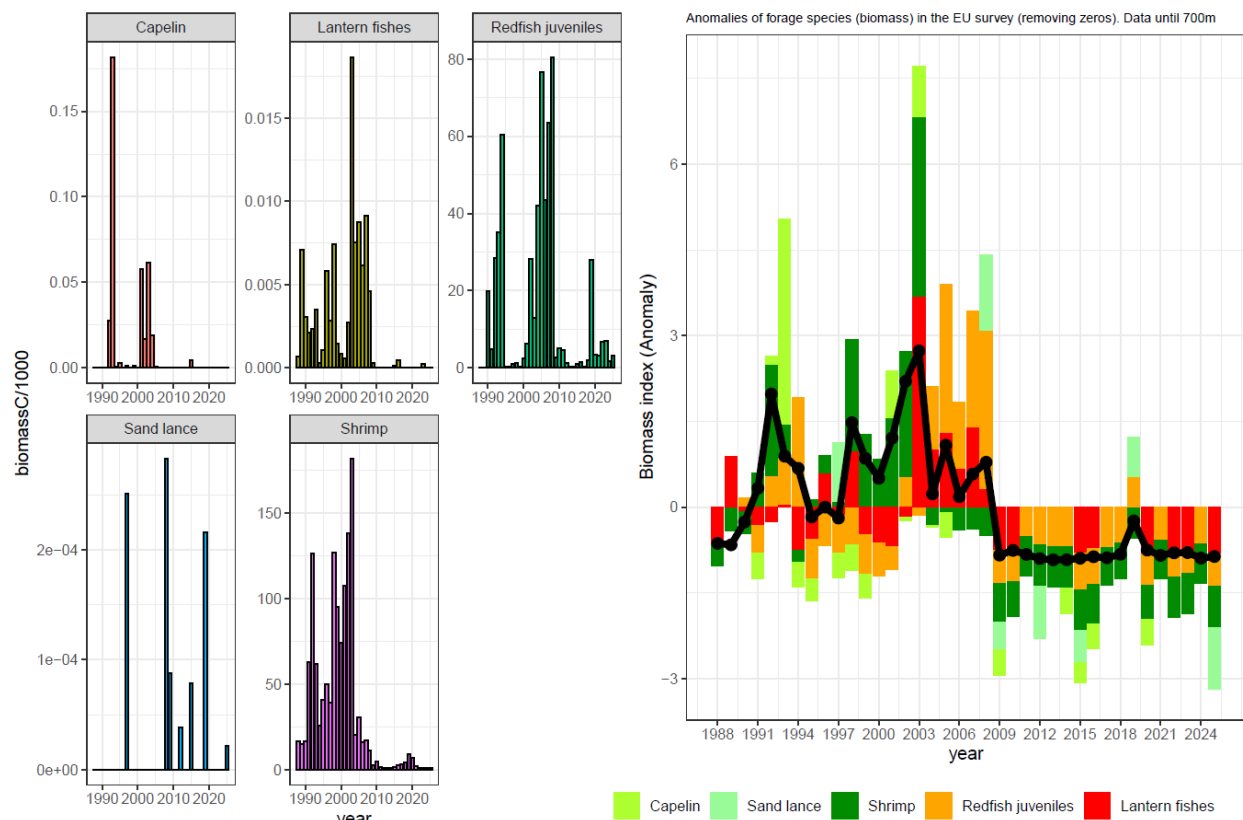


Figure 6.18. Biomass (left) and anomalies of the biomass (right) of the main forage species in the 3M EPU. Data until 700 m.

xiv) Evaluation of significant ecological change

The nature and magnitude of the recently observed changes in the Flemish Cap (3M) EPU are not at this stage considered to meet the “significant ecological change” criterion required to trigger an update of the 3M Ecosystem Summary Sheet out of schedule.

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b) ToR 3.2. Formalization of a full Workplan for the 2028 ESSs update: Analysis of by-catch and discards and proposal for building an ETP species list [COM. Request#1]

As part of the update to the Ecosystem Summary Sheets (ESS), WG-ESA noted that it required an accepted list of species in NAFO which are of Special Concern from a conservation perspective – for example those which are endangered, threatened, and/or protected - in its reporting of incidental catches. Currently, WG-ESA lacks a formal process to categorize species encountered during fishing or survey trawls within the NAFO fishing footprint as species of Special Concern. During the 2025 meeting, a brief summary of the discussions and conclusions from the 2024 WG-ESA meeting was presented, and it was noted that no further progress has been made on the development of a list of Species of Concern.

The group discussed the development of a workplan and the steps involved in defining the terminology, criteria, and methodology for the formulation of a list of species of Special Concern within the NAFO context, leading up to the ESS update in 2027. To support this effort, an informal subgroup has been formed to work on these topics between now and the SC meeting in June 2026, where the proposed steps will be presented and discussed. The SC members in this subgroup are: Patrícia Gonçalves (EU–Portugal), Mark Simpson (Canada), Mariano Koen-Alonso (Canada), and Diana González-Troncoso (EU–Spain).

i) Draft Response to Commission Request 1, Ecosystem Components of Stock Advice

As part of the stock advice, Annex A of the Commission’s request for Scientific Advice provides guidance on the provision of advice. *In relation to Tier 1 of the Roadmap, Scientific Council should provide annually catch information in relation to 2TCI, including recent cumulative catch levels and a scoping of expected cumulative catch levels.*

Interim monitoring of Ecosystem Conditions in the Grand Bank (3LNO) and Flemish Cap (3M) Ecosystem Production Units (EPUs)

The interim monitoring of ecosystem conditions for 2024-2025 indicated that the changes observed in these EPUs are in line with already identified patterns and trends for these ecosystems, and therefore, do not meet the “significant ecological changes” criterion required to trigger an update of the Ecosystem Summary Sheets (ESSs) out of schedule.

The next regular update of the ESSs for the Grand Bank (3LNO) and Flemish Cap (3M) EPUs is scheduled for 2028.

The Ecosystem Designated Expert (EDE) position for the Grand Bank (3LNO) EPU remains vacant. This has implications for the feasibility of the 2028 regular update of the ESS for this EPU.

As part of the implementation of the NAFO Roadmap for an Ecosystem Approach to Fisheries (EAF), Ecosystem Summary Sheets (ESSs) provide a synoptic view on the state of NAFO ecosystems and their management regime, and constitute a tool for strategic assessment, advice and planning. ESSs have been developed for the Grand Bank (3LNO) and Flemish Cap (3M) Ecosystem Production Units (EPUs) (NAFO, 2023), and are intended to undergo regular updates every 5 years. After a delay of one year due to workload, the next regular update of the ESSs for these EPUs is scheduled to be produced by Scientific Council (SC) at its June 2028 meeting.

In the years between regular updates, ecosystem conditions in both EPU are monitored annually. This interim monitoring is focused on the detection of significant ecological changes, in which case an out-of-schedule ESS update needs to be triggered.

The evaluation of significant ecological changes is focused on an expert judgment examination of: a) trends in ocean climate and oceanographic features, b) trends and structure of the fish community, and c) trends in trophic relationships (e.g. diet composition, stomach content weights).

The interim monitoring of ecosystem conditions for 2024-2025 indicated that the changes observed in the Grand Bank (3LNO) and Flemish Cap (3M) EPU are in line with already identified patterns and trends for these ecosystems, and therefore, do not meet the “significant ecological changes” criterion required to trigger an out-of-schedule update of the ESSs.

The Ecosystem Designated Expert (EDE) position for the Grand Bank (3LNO) EPU remains vacant. This has implications for the feasibility of the 2028 regular update of the ESS for this EPU.

c) ToR 3.3. Updates on the Ecosystem Production Potential (EPP)-Total Catch Index (TCI) framework, including primary production estimates to inform EPP models for TCI calculations [COM. Request#1]

i) Introduction

The NAFO Roadmap for an Ecosystem Approach to Fisheries (hereafter Roadmap) is the framework that NAFO is implementing to deliver an ecosystem approach for the management of NAFO fisheries and ecosystems (Koen-Alonso *et al.*, 2019) (Figure 6.19).

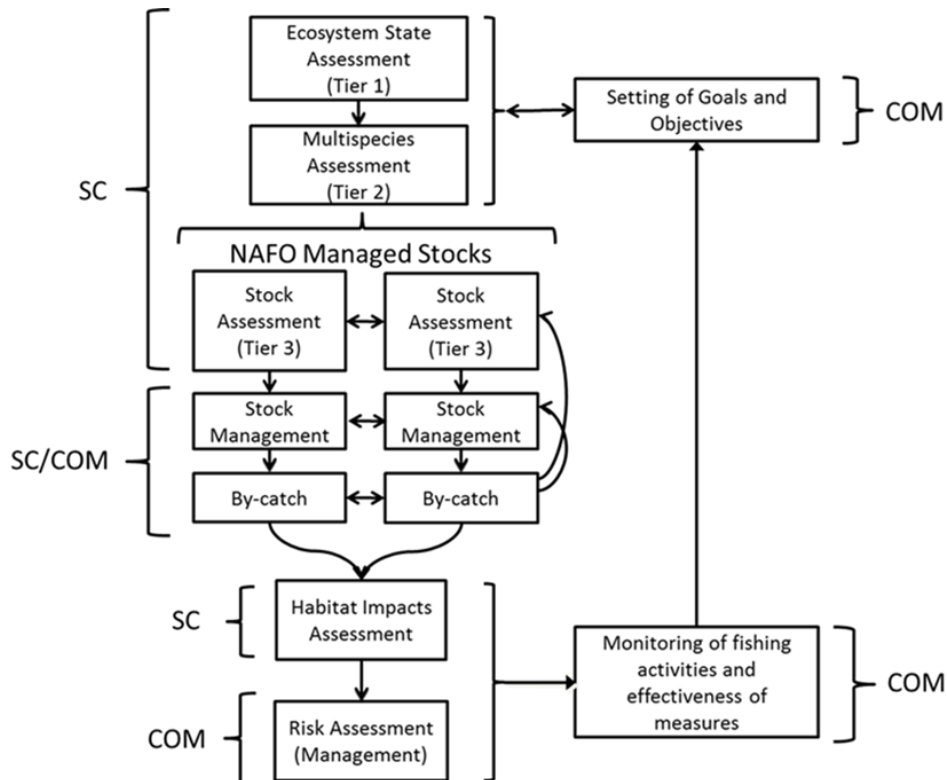


Figure 6.19. Structure of the Roadmap for an Ecosystem Approach to Fisheries, the framework that NAFO is implementing to deliver an ecosystem approach to fisheries management.

Within the Roadmap, sustainability of fisheries catches is achieved through a series of nested assessments aimed at evaluating sustainability at different levels of ecological organization. Tier 1 is focused on

sustainability at the ecosystem level, Tier 2 is focused on sustainability at the multispecies level (e.g. species interactions), and Tier 3 is focused on sustainability at the stock level (i.e. traditional stock-assessment) (Figure 6.19).

The current implementation of Tier 1 includes an ecosystem reference point for aggregated catches that informs on the risk of ecosystem overfishing, and an Ecosystem Summary Sheet that provides an at a glance view of the status and trends in the ecosystem, and on the general performance of the management measures within that ecosystem.

ii) Updates to the analytical framework informing the Risk of Ecosystem Overfishing

The Ecosystem Reference Point adopted by NAFO to inform on the risk of ecosystem overfishing is defined as twice the Total Catch Index (2TCI), where TCI is the 25th percentile of the estimated Fisheries Production Potential (FPP) distribution for a given functional guild in a given Ecosystem Production Unit (EPU) (Koen-Alonso *et al.*, 2022; NAFO, 2022b) (Figure 6.20). Reporting on the risk of ecosystem overfishing has become a standard element of the NAFO stock advice since 2023.

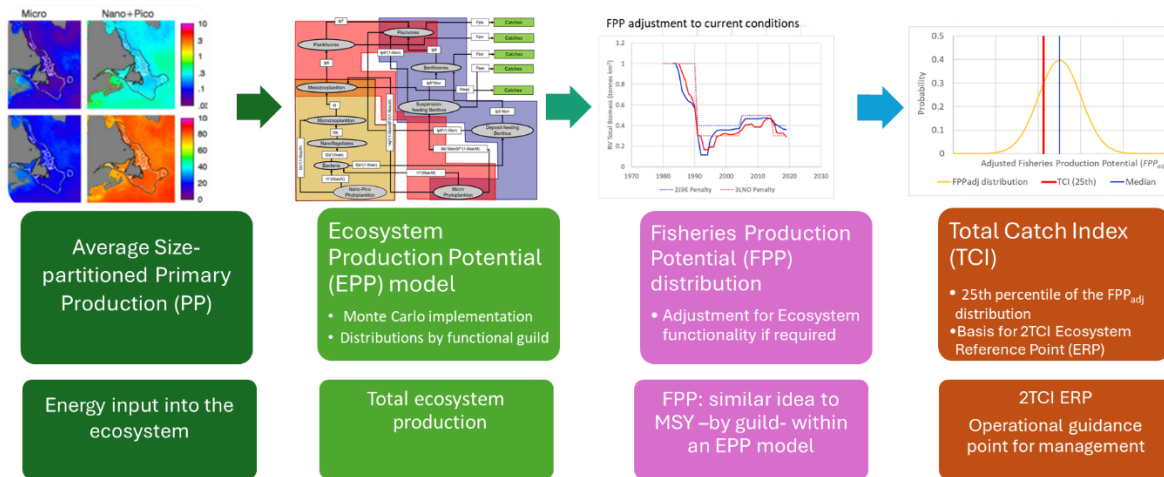


Figure 6.20. Schematic representation of the process used to estimate the Total Catch Index (TCI) for the functional guilds in a given Ecosystem Production Unit

The incorporation of this analysis as part of the regular NAFO Scientific Council (SC) work implies that the inputs for its calculations need to be regularly updated, and the analytical framework reviewed periodically to incorporate any required improvement and/or new understanding. Some key elements to be considered in these updates include a) the average Primary Production (PP) estimates used as input for the Ecosystem Production Potential (EPP) model used to estimate FPP, b) the improvement of the procedures used to scale the EPP output to current ecosystem productivity level, and c) a review of the approach used to partition PP into its microplankton (>20µm), and pico-nanoplankton (<20µm) sources.

In order to implement these updates and reviews on a regular basis, an operational protocol defining the frequency, types of updates (i.e. which data needs updating), the methods to be used to generate the new inputs/outputs, and the sources/research groups responsible for producing them, needs to be developed.

A three-year research project (2025-2028) aimed at addressing these issues is currently ongoing. This project, funded through Fisheries and Oceans (DFO) Competitive Science Research Fund (CSRF), is expected to deliver both the data and framework updates required (Figure 6.21), and the operational protocol to guide the updating process going forward. This project will also produce a 2TCI Checking Tool to facilitate the consideration of the risk of ecosystem overfishing by the NAFO Commission (COM) when discussing the setting of Total Allowable Catches (TACs) for the different stocks managed by NAFO (Figure 6.21). This project is designed to present, discuss, and review its progress through the full integration of its work within the NAFO SC process (i.e. WG-ESA and SC). The initial progress on these updates and improvements is summarized in the sections below.

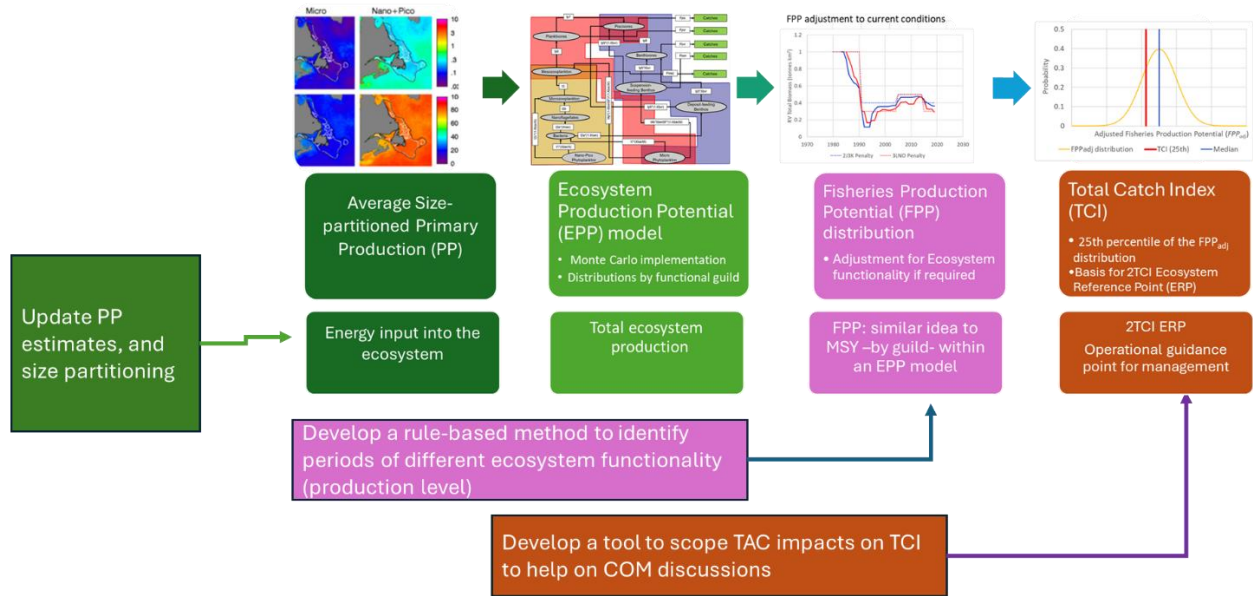


Figure 6.21. Updates and analytical improvements in the EPP-TCI framework to be implemented as part of a 2026-2028 DFO CSRF project (see text). This project will also deliver an operational protocol to standardize and guide updates and improvements of the EPP-TCI going forward.

iii) Primary Production estimates

The adopted EPP-TCI framework uses satellite-derived primary production (PP) estimates derived from the approach described by Platt *et al.* (2008). The current input PP uses the average for 1997-2013 (Koen-Alonso *et al.*, 2013), and there is need to update it. Preliminary work has shown that average PP has not changed in magnitude between the current input period (1997-2013) and more recent years (2014-2024) using global Copernicus products (NAFO, 2024a). While this preliminary analysis was informative about general trends over time, and supported the continued use of the current input for the time being, the absolute magnitude of these estimates was not considered fully reliable. Updated PP estimates from regionally-tailored analyses are still required, and will be required going forward.

To begin addressing this issue, initial estimates from regionally-tailored analyses were produced. Two models that use satellite-derived information were considered for this exercise due to the spatial coverage of the respective analyses. The areas covered by these analyses were:

- Labrador Shelf and northern area of Newfoundland Shelf. Estimates of PP from this region were based on a detailed estimation process that used a regionally-tuned primary production model that considered phytoplankton photosynthetic efficiency as a function of oceanographic regimes defined by phytoplankton community structure and biomass, sea-surface temperature, sea ice, and bathymetry (Devred *et al.*, 2025).
- Southern area of Newfoundland Shelf, most of Grand Bank, and all Flemish Cap. Estimates of PP for these regions were based on a simpler estimation process that considered the seasonality of the parameters of the photosynthesis-irradiance curve based on regional data and a smoothing function, in conjunction with a standard PP model that considered irradiance, chlorophyll-a concentration, and depth (E. Devred and S. Clay, Bedford Institute of Oceanography (BIO), DFO, Dartmouth, ongoing work). This simpler estimation still captures the key processes and parameters that define PP in these regions.

These estimates generally follow and/or improve on the method used for producing the original PP estimates (Platt *et al.*, 2008), and they represent the best currently available estimates of regionally-tailored annual average PP. While the areas considered do not cover 100% of all EPU (Figure 6.22, Table 6.1), their combined spatial coverage is sufficient to produce a reliable average PP by EPU.

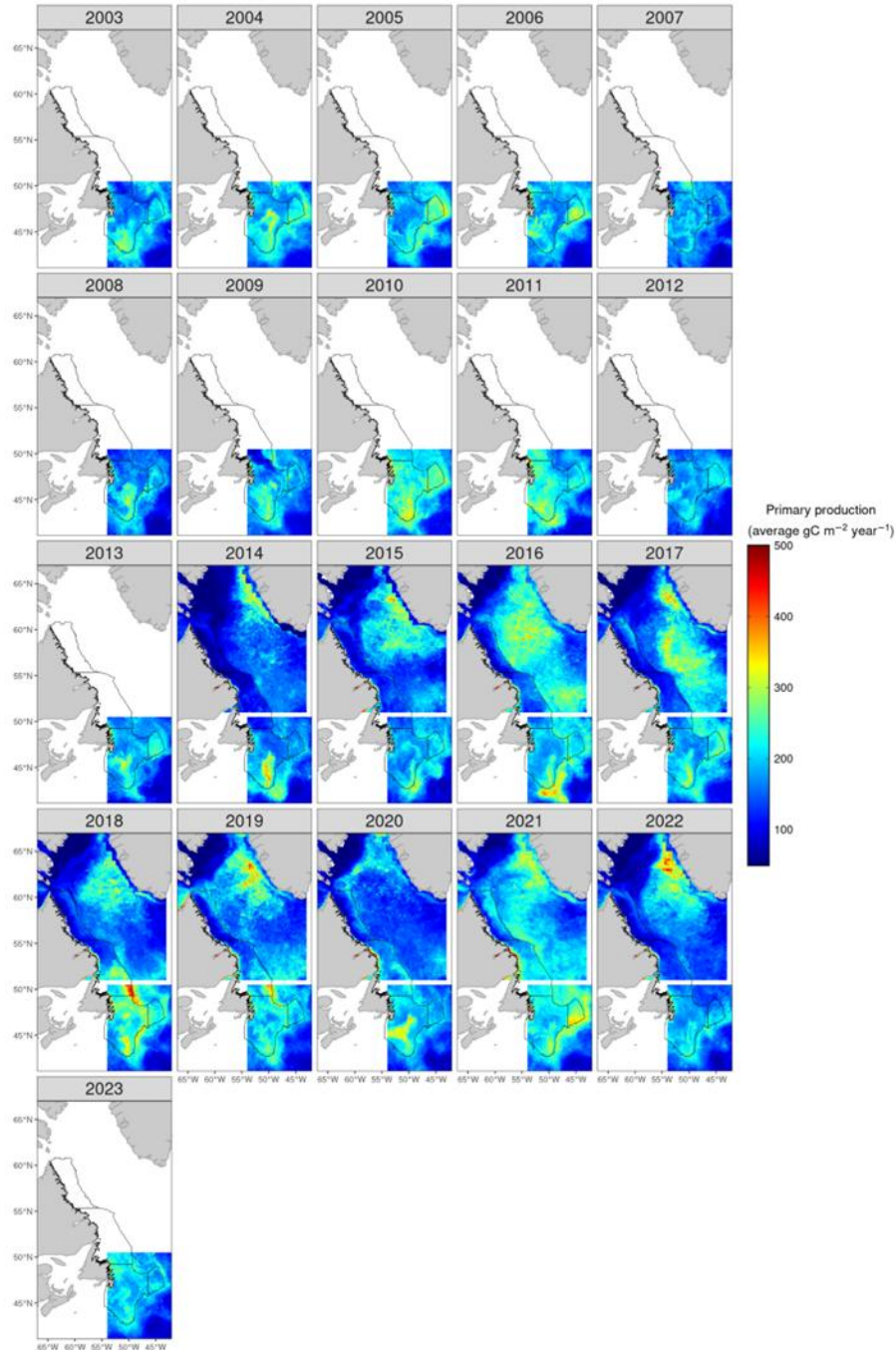


Figure 6.22. Annual estimates of primary production for the Newfoundland-Labrador and Flemish Cap bioregions from regionally tailored analyses. These estimates were integrated and clipped to the EPU to estimate annual average PP estimates by EPU. The more detailed estimation process (Devred *et al.*, 2025) is only available for the northern area for 2014-2022.

These updated regionally-tailored estimates (Figure 6.23), despite their interannual variability, do not show any obvious trend over time. Also, they show no statistically significant differences between PP estimates from the reference period currently in use and more recent years (Table 6.1). Further, the methods used in these updates are expected to provide similar or better estimates of PP than the method used in the original analysis,

and the original estimates are clearly contained within the range of the updated regional PP estimates (Figure 6.23).

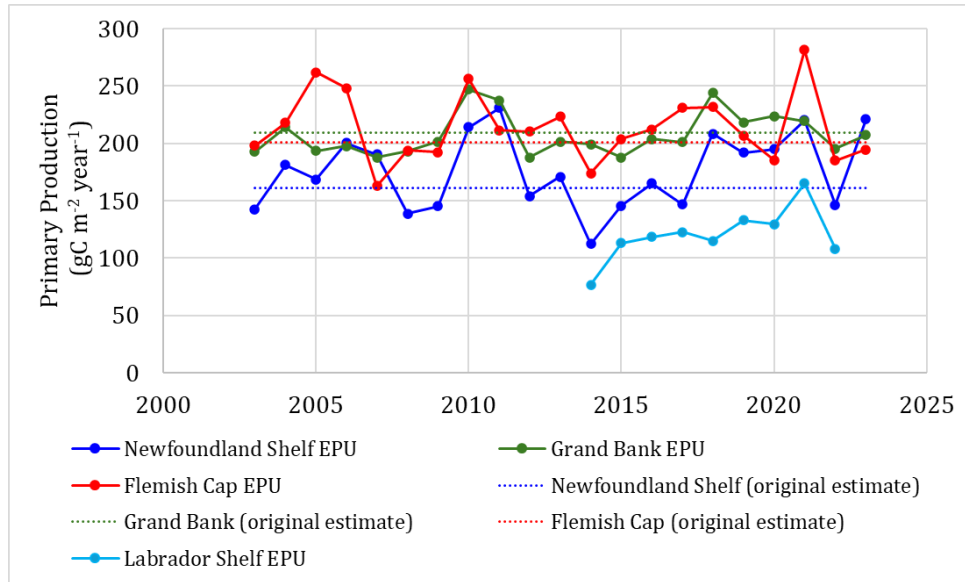


Figure 6.23. Average annual primary production (PP) by Ecosystem Production Unit (EPU) from the updated analyses (solid lines with circle markers) in comparison with average PP currently being used as input for the EPP-TCI analyses for the Newfoundland Shelf (2J3K) EPU, Grand Bank (3LNO) EPU, and Flemish Cap (3M) EPU (dotted horizontal lines).

These results further support the initial conclusion that there has been no major trends over time in PP since the original estimates were produced (NAFO, 2024a), indicating that while updating PP estimates is certainly needed, continued use of the current inputs until the updates and updating protocols are finalized does not represent a risk to the reliability of the advice being produced. Still, as the ice cover in these EPU declines due to climate change, attention should be paid to the potential increase in production due to the increase of open water areas during the year.

These analyses have also produced, for the first time, a regionally-tailored estimate of PP for the Labrador Shelf (2GH) EPU (Figure 6.23, Table 6.1), opening the door for the potential use of the EPP-TCI framework further north. It is also of note that the PP estimate for this EPU is much lower than southern EPU's ones, indicating that the tolerance for fishing pressure in this EPU would be expected to be lower than in the other areas. The ability of tracking PP in the Labrador Shelf (2GH) EPU is particularly relevant going forward, as it would allow tracking the potential impacts of climate change in an EPU that would be expected to be at the forefront of the ecological changes to come as climate change continues to unfold.

Table 6.1. Summary of regionally-tailored Primary Production (PP) estimates by Ecosystem Production Unit (EPU), including tests for evaluating differences between the period used to calculate the original estimates, and more recent years. The original PP values and Coefficient of Variation (CV%) implemented in the Ecosystem Production Potential (EPP) models is also indicated for comparison (Koen-Alonso *et al.*, 2022).

All units are gC.m ⁻² .y ⁻¹	Labrador Shelf (2GH)	Newfoundland Shelf (2J3K)	Grand Bank (3LNO)	Flemish Cap (3M)
Mean PP (start-2013)	NA	176.2	205.0	216.1
Mean PP (2014-end)	120.3	175.3	210.0	210.6
Mean PP (overall)	120.3	175.8	207.4	213.5
CV% (overall)	19.5	18.8	8.8	14.0
t-test: early vs late period (p-value)	NA	0.954	0.542	0.688
% EPU covered by PP models	100	73	97	100
Original estimates (1997-2013 average)		160.9	209.7	200.6
CV% used in EPP model	NA	30	30	30

iv) A 2TCI Checking Tool to facilitate ecosystem overfishing considerations at the COM table

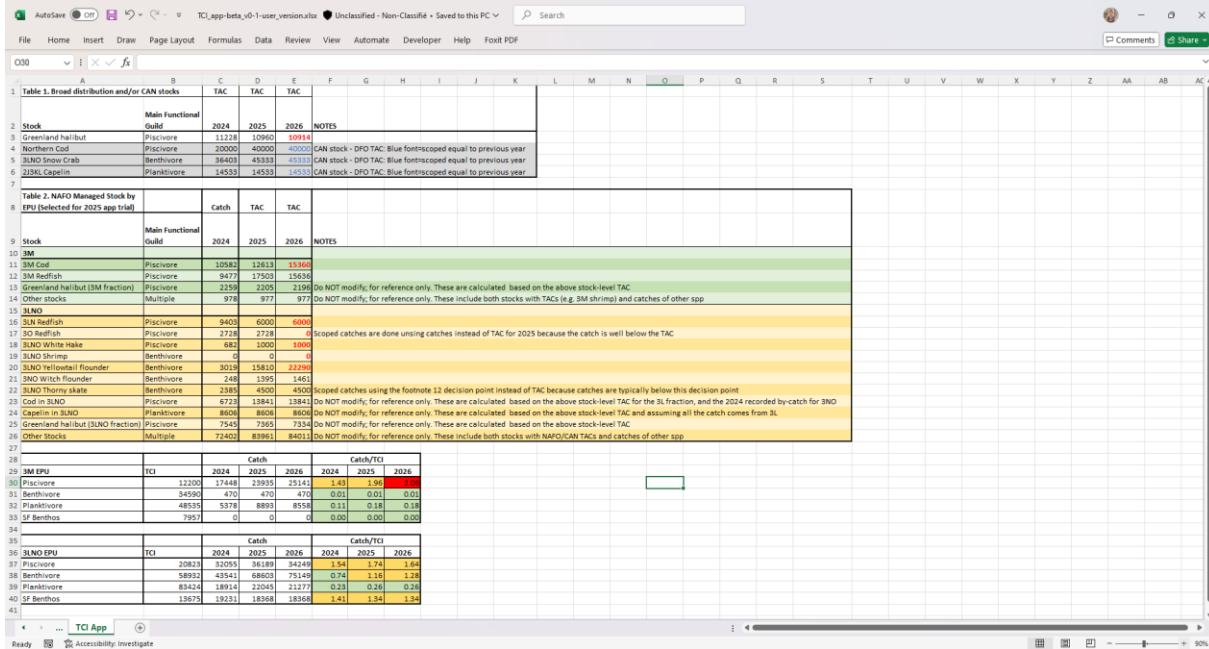
From an operational perspective, the current implementation of the EPP-TCI framework basically involves a) evaluating if the 2TCI ecosystem reference point has been exceeded in previous years, and b) scoping if ongoing catches and the incoming SC stock advice would be expected to drive catches above 2TCI in the current and following year.

A basic assumption of the scoping exercise is that the COM would follow the SC advice. However, this is not always the case. As a consequence of the discussions and negotiations around the COM table, Total Allowable Catches (TACs) for the set of stocks that require TAC decisions in a given year may be set above or below the catch levels indicated in the SC advice and assumed in the scoping exercise. Under these circumstances, the outcome of the scoping exercise becomes more uncertain as the catches assumed in the exercise would differ from the catch levels being adopted by COM. When considering different TAC options, managers do not readily know if the new set of TACs being considered could push catches above 2TCI or not, and hence, they cannot easily consider the impact on the risk of ecosystem overfishing of those decisions.

To address this shortcoming and facilitate the consideration of ecosystem-level impacts of TAC decisions, a 2TCI checking tool is being developed. This tool is intended to facilitate the integration of TCI considerations in the COM discussion. This is achieved by providing a platform where managers can input the TACs being discussed, and the tool would automatically update the scoping exercise, indicating if the new TAC levels under consideration would be expected to drive catches above the 2TCI ecosystem reference point or not. The expectation here is that, by providing a rapid update on the risk of ecosystem overfishing, managers will incorporate this additional dimension to their discussions and decisions as a matter of course.

A preliminary tool with the functionality described above was developed using Microsoft Excel as platform (Figure 6.24a), and distributed among some managers at the 2025 NAFO Annual Meeting for initial testing and feedback. In parallel, the formal development of what is expected will become the final tool was also started, using an R Shiny App as the platform of choice (Figure 6.24b). While functionality and intuitive understanding of the app are central design elements, issues of data security and privacy are also key considerations in the app design and implementation. An initial version of the Shiny App application is intended to be available to managers from all Contracting Parties for the 2026 NAFO Annual meeting for trialing and feedback.

a)



b)

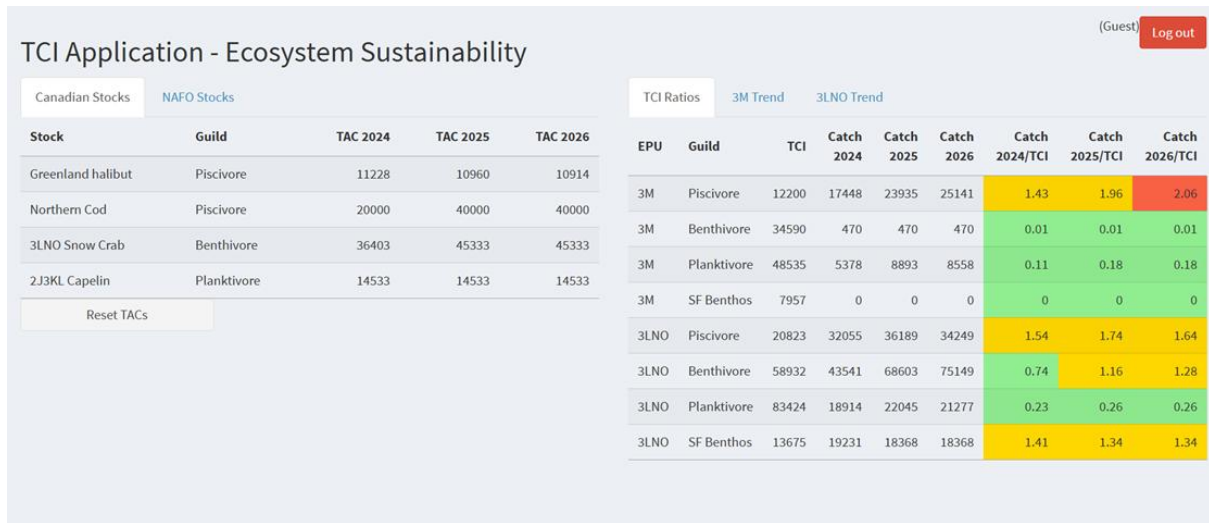


Figure 6.24. Screenshots of the 2TCI Checking Tool under development. a) Preliminary version of the tool implemented in Microsoft Excel that was distributed among some managers at the 2025 NAFO Annual meeting for testing and feedback, b) example of one of the initial designs of the tool being developed as an R Shiny App.

v) **Operational framework for the regular update, review, and communication of 2TCI-related outcomes**

NAFO adopted the EPP-TCI framework, and 2TCI as an Ecosystem Reference Point, in 2022 (NAFO, 2022a). The 2023-2024 management seasons provided initial experiences on how to make these new elements operational

in the SC advice. The Report on Ecosystem Sustainability of Catches was developed and included in the SC June Report in 2023 (NAFO, 2023), and expanded in 2024 to incorporate the scoping exercise to better inform incoming stock-level TAC decisions on the risk of ecosystem overfishing (NAFO, 2024c). Information on TCI was also included in the Stock Summary Sheets (NAFO, 2023). The addition of these elements to the science advice, together with the Ecosystem Summary Sheets (ESSs), constitute the current implementation of the Tier 1 of the NAFO Roadmap for an Ecosystem Approach to Fisheries. At the 2024 NAFO Annual Meeting, the 2TCI-related advice was made an integral component of the standard SC stock advice (NAFO, 2024b), and at the 2025 Annual Meeting both the 2TCI advice and ESSs included in the template for the Commission's annual requests for advice (NAFO, 2025).

With the outcomes of the EPP-TCI framework now embedded in the regular SC stock advice, an operational framework for updating, reviewing, and delivering the corresponding science products becomes necessary. Such a framework should describe an operational protocol defining the frequency, types of updates (i.e. which data need updating), the methods to be used to generate the new inputs/outputs, and the sources/research groups responsible for producing them.

WG-ESA discussed the basic elements of this framework and agreed that while the ongoing process to update PP inputs is a critical piece, other elements of the EPP-TCI framework also need regular review and updates. The basic elements that require regular updates include: PP estimates, size fractionation of PP, and adjustments for ecosystem functionality (penalty factor). WG-ESA also indicated that in addition to these inputs/outputs, structural aspects of the model should also be periodically examined.

In terms of updating frequency, WG-ESA agreed in principle that the schedule for the regular updates could be formally linked with the update of Ecosystem Summary Sheets (~ 5 year cycle). This would mean the ongoing update process should be completed by June 2028. WG-ESA also indicated that any protocol for these scheduled updates should identify a default source/method for those updates to maintain the consistency of the inputs/outputs required by/from the EPP-TCI framework.

WG-ESA, through the support provided by the DFO CSRF project, will develop this formalized protocol for the regular updating of the EPP-TCI framework going forward based on the above considerations. This EPP-TCI updating framework is expected to be integrated into the regular SC workplan. The completion of this framework is planned for the 2027 WG-ESA meeting, in conjunction with the ongoing updating process and the next ESS update.

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d) ToR 3.4. Update on NAFO Roadmap reference document [COM. Request#5]

WG-ESA reviewed the feedback received from managers on the first draft of the Roadmap document tabled by SC at the 2025 WG-EAFFM meeting. On the basis of this feedback, WG-ESA developed a second draft of this document, as well as a draft SC Response to this COM Request (see below). The revised draft of the Roadmap document produced by WG-ESA will be tabled as a working paper at the 2026 SC June Meeting for further consideration and discussion by SC.

Draft SC Response to COM Request 5

The NAFO Roadmap for an Ecosystem Approach to Fisheries (EAF) is the framework NAFO is following to deliver on the NAFO Convention commitment to implement an ecosystem approach for the management of fisheries resources. Although this framework has been described and/or acknowledged in multiple NAFO documents, there is no single, formally adopted document by the Commission (COM) that provides a detailed description of the Roadmap.

The Scientific Council (SC) has produced a document describing the Roadmap. This revised version incorporates the feedback received by managers on the preliminary draft circulated at WG-EAFFM in 2025.

This Roadmap document will be tabled at the 2026 WG-EAFFM meeting for discussion. The expectation is that the document on the Roadmap to be agreed at WG-EAFFM would be formally adopted by COM as the framework guiding NAFO on the implementation of EAF at the 2026 NAFO Annual Meeting.

The NAFO Roadmap for an Ecosystem Approach to Fisheries (EAF) is the framework NAFO is following to deliver on the NAFO Convention commitment to implement an ecosystem approach for the management of fisheries resources. This framework has been described and/or acknowledged in multiple NAFO documents and it has a broad presence and influence on NAFO work. Despite that, there is no NAFO document formally adopted by COM that provides a detailed description of the Roadmap in a single reference document.

To address this, COM requested in 2024 for SC to develop a reference document detailing the Roadmap, with a timeline of 1-3 years for the delivery of the requested document. SC expedited the production of a preliminary draft of the Roadmap document, and tabled it at the 2025 WG-EAFFM meeting to engage and seek feedback from managers on the content and structure of the document.

The preliminary draft document was structured in three sections focused on:

- Policy context. This section described the NAFO Convention and related policy instruments that articulate the concepts and commitment to EAF.
- General structure of the Roadmap. This section provided a conceptual description of the framework based on the summary included in the 2024 WG-EAFFM Report, the 2019 primary publication, and the many descriptions on the Roadmap available across NAFO documents.
- Current implementation. This section provided a summary description of the pieces of the Roadmap already implemented and currently in development, with indications on how these pieces support

NAFO decision-making process (i.e. making explicit the linkages between tools and intended outcomes).

Feedback on this draft document was received at the 2025 WG-EAFFM meeting, as well as through written comments from CPs submitted to SC prior to the 2025 NAFO Annual Meeting. Additional comments and clarifications were gathered during the 2025 NAFO Annual Meeting.

The overall feedback from managers on the preliminary draft document was positive, and included a series of specific suggestions that ranged from content to editorial. The main elements of this feedback were:

- Removal of the “Current implementation” section. The content of this section was deemed useful, but considered to be potentially too dynamic for a framework to be adopted by COM, which is expected to have a degree of stability over time.
- Emphasis on the adaptive nature of the Roadmap. While the draft already included this idea, managers indicated that a more explicit indication that the Roadmap is not intended as a prescriptive approach would be useful.
- Inclusion of a more explicit reference to climate change. The Roadmap already includes and considers climate change, but in light of the recent COM Resolution 2/23 (NAFO/COM Doc. 23-13), managers indicated that a stronger reference to climate change within the documents was warranted.
- Revision of the document to ensure that the quotes of the NAFO Convention fully respect the original text, and intent.

All of the above elements were addressed in the revised version of the document. The implementation section was removed from the document, and its content summarized in SCR 25/049. The other comments were explicitly addressed in the revised version, and the language suggestions put forward by managers were used as basis for some of the edits included in the final document produced by SC.

This Roadmap document will be tabled at the 2026 June SC meeting for discussion and further revision if required, and then tabled at the 2026 WG-EAFFM meeting for discussion. The expectation is that the document on the Roadmap to be agreed at the 2026 WG-EAFFM meeting would be formally adopted by COM as the framework guiding NAFO on the implementation of EAF at the 2026 NAFO Annual Meeting.

References

Koen-Alonso, M., Pepin, P., Fogarty, M. J., Kenny, A., and Kenchington, E. (2019). The Northwest Atlantic Fisheries Organization Roadmap for the development and implementation of an Ecosystem Approach to Fisheries: structure, state of development, and challenges. *Marine Policy*, 100: 342-352.

e) ToR 3.5. Results of the questionnaire to Designated Experts regarding the potential implementation of ecosystem approach (Tiers 2 and 3) in stock assessment

As part of the 2024 WG-ESA meeting, a special session on the approach to implement ecosystem knowledge into tier 2 and tier 3 assessments of the Roadmap and scientific advice was organized. During this session it was identified that a survey for the Designated Experts (hereafter DEs) was the most useful immediate next step. This survey was intended to collect relevant information to identify the stocks whose dynamics show some evidence of relationships with environmental factors, as well as the availability of data and knowledge to support the development of models that can integrate environmental/ecological drivers. The questionnaire for this survey was based on the one by Kulka *et al.* (2022), which details are described in NAFO (2024).

The questionnaire was distributed to all DEs in charge of the stocks assessed by the NAFO Scientific Council. The DEs sent the filled questionnaire before April 1st 2025, covering most of the stocks (Table 6.2). This questionnaire was formed by a list of queries (see the list below), intended to collect information from survey and fishery data, assessment method, previous studies on ecosystem-stock dynamic interactions, previous attempts to include that knowledge into scientific advice, working hypothesis and availability of data to explore those hypotheses, and mayor limitations to conduct the necessary analysis.

List of questions:

1. Length and details of survey and fishery time series for this stock used to examine stock trends (if more than one time series is used for each category then provide information for all series).
2. Please describe the type of assessment method (e.g. type of assessment model, survey-based, catch only) that is used for this stock.
3. Have there been any studies that have demonstrated links between environmental or ecological variables with biological processes that affect productivity of this stock or species?
4. Have there been any attempt to include environmental variables (e.g., climate indicators, oceanographic conditions, ecological factors and/or multispecies links, habitat availability, etc.), quantitatively or qualitatively, in the scientific methods and tools used in the assessment and projections (short-term projections, MSE)? If yes, describe which variables and the approach followed to implement those environmental interactions in the assessment process.
5. If environmental/ecological variables have not been considered in the assessment/MSE yet, why not? Do you have working hypotheses that would be relevant to explore to consider environmental/ecological information? Can you identify potential sources of data to investigate these hypotheses?
6. What are the major limitations that would prevent consideration of environmental variables in the advisory process (e.g., data limitations, lack of monitoring information, survey issues, lack of mechanistic understanding, training, workload)?
7. Any other comments or concerns you may have.

Table 6.2. List of stocks for which the NAFO Designated Experts replied, providing the required information.

Species	NAFO area	Stock
<i>Mallotus villosus</i>	3NO	Capelin 3NO
<i>Hippoglossoides platessoides</i>	3M	American plaice 3M
<i>Pandalus borealis</i>	ICES area 14b	Northern shrimp ICES area 14b
<i>Reinhardtius hippoglossoides</i>	1 inshore	Greenland Halibut 1 inshore
<i>Sebastes sp.</i>	3O	Redfish 3O
<i>Reinhardtius hippoglossoides</i>	0+1	Greenland Halibut 0+1
<i>Pandalus borealis</i>	3LNO	Northern shrimp 3LNO
<i>Pandalus borealis</i>	0A + 1	Northern shrimp 0A+1
<i>Reinhardtius hippoglossoides</i>	2+3KLMNO	Greenland Halibut 2+3KLMNO
<i>Limanda ferruginea</i>	3LNO	Yellowtail flounder 3LNO
<i>Sebastes norvegicus</i>	3M	Golden redfish 3M
<i>Sebastes mentella</i> and <i>S. fasciatus</i>	3M	Beaked redfish 3M
<i>Gadus morhua</i>	3M	Cod 3M
<i>Hippoglossoides platessoides</i>	3LNO	American plaice 3LNO

The information provided by the DEs has been summarized in a single table (Table 6.3), which contains, by stock, a brief summary with the most relevant information provided by the DEs for each of the 7 questions. The relative suitability of the stocks to be considered candidate to progress in the incorporation of ecosystem information in tiers 2 and 3 of the Roadmap to provide scientific advice is represented with a colour scale.

Overall, there are available long time series of scientific surveys informing about stock status and dynamic, and the removals from the commercial fleet are well registered and characterized for even longer periods than

surveys. However, there are some stocks for which the eminently demersal surveys developed in the NAFO area are not appropriate, given the pelagic behavior of the stock (3NO capelin), or doesn't catch the juvenile individuals (Northern shrimp in ICES area 14b). And for a number of stocks there are ageing problems (Greenland halibut 0+1, redfish 30, Northern shrimp 3LNO).

Despite the good coverage of survey and commercial fishery data, there is a relatively high number of stocks assessed using abundance or biomass survey indices trends. Production models are used for another significant number of stocks, and age-structured models are applied to few stocks. Issues with ageing are the main reason for the low number of stocks assessed with age structured assessment models. Using survey indices to assess the stock doesn't preclude using ecosystem information when providing scientific advice, and production models allow the incorporation of ecosystem drivers and running long term simulations. Hence, it is not necessary having an age or age-length structured assessment model to include ecosystem information in the scientific advice. However, having biological processes like growth, maturation, recruitment or natural mortality explicitly modelled (as it can be done in age and age-length based models) allows to explore and model the effects of ecosystem in the population dynamic in a specific way in relation to the aspect of the population productivity of interest.

There is a high number of stocks for which previous studies have showed ecosystem effects in processes driving the productivity of the stock, both at the individual (growth, maturation, natural mortality), and the population level (recruitment). Water temperature is the oceanographic variable most often found as a driver of growth and/or stock distribution (Greenland halibut various stocks: 1 inshore, 0+1 and 2+3KLMNO; 30 redfish, and 3LNO yellowtail flounder), but also predation has been demonstrated to have an effect on a number of stocks (Northern shrimp 0+1 and in cod, redfish and shrimp in 3M).

Despite of the studies mentioned in the previous paragraph, ecosystem effects have been considered in stock assessment very rarely by the NAFO SC, excepting a few stocks for which predation has been modelled in a Gadget multispecies model GadCap (cod, redfish and shrimp in Division 3M), or has been incorporated directly in a single species model (Northern shrimp 0A+1). However, none of these models are currently used for stock assessment. The estimation of natural mortality estimated by the Gadcap model has been used to estimate an average vector of natural mortality in combination with other vectors of natural mortality. This average vector was used as a prior of natural mortality at age for the 3M cod assessment model. In the case of Greenland halibut in 2+3KLMNO, environmental factors are considered qualitatively in the assessment. During the MSE development for this stock, the range of scenarios tested included recruitment or mortality declines mimicking environmental downturns.

In conclusion, there are few stocks for which there have been previous attempts to include this information in the scientific advisory process. However, for many of these stocks, there are working hypotheses that could have been explored. For many cases there is abundant information on the oceanographic conditions as well as stomach content informing about trophic interactions. The reasons for not having included, or not having attempted to include, this information in the scientific advisory process are varied, but the most common are a lack of mechanistic understanding, quantitative functional relationships, lack of time, resources, and expertise to develop the necessary studies to incorporate this information into the advisory process.

Finally, despite the scores obtained for many questions on the questionnaire being relatively low, we believe that the number of stocks with intermediate or high potential for implementing E2A is high. There is a large amount of high-quality information obtained from scientific surveys and commercial catch sampling. This includes a wealth of oceanographic data, stomach contents, and other relevant information. Analytical methods have also improved significantly. For this reason, even for stocks for which no working hypotheses exist, we believe that with sufficient effort, such hypotheses could be identified, and furthermore, the explanatory variables and their relationships with biological and ecological processes could be identified. Therefore, the most important limitation in the NAFO area for the implementation of the ecosystem information in the stock assessment is the lack of resources, personnel, and expertise to conduct the necessary studies.

Despite these significant limitations, a number of stocks have been identified for further progress in the development and implementation of the Roadmap through tiers 2 and 3. These stocks are those in the 3M area: cod, redfish, and shrimp.

Table 6.3. Summary of the information provided by the Designated Experts for the NAFO stocks. The different colours represent a subjective qualification of the adequacy of each stock to be considered as candidate to progress in considering ecosystem information in the scientific advice (tiers 2 and 3 of the NAFO Roadmap). (grey: not so good; orange: intermediate; green: good).

Stock	question 1: survey and fishery data	question 2: assessment method	question 3: previous studies	question 4: attempts	question 5: why not? Hypothesis links	question 6: limitations	question 7: other	Overall score/comment
Capelin 3NO	Spanish bottom trawl survey 1995-2024. Canadian bottom trawl spring survey 1995-2024	'low-priority' stock. No fishing since 1992. Not assessed regularly. Yearly monitoring based on survey.	Studies linking oceanography with distribution and reproductive capacity. Not in NAFO	No attempts	assessment not performed regularly; the survey coverage is not sufficient for the stock	pelagic stock, which is not fully covered by the bottom-trawl surveys	necessity for pelagic trawl-acoustic surveys	Weakness: survey coverage, assessment method. Strength: previous studies
American plaice 3M	USSR/Russia 1972-1993. Canada surveys 1978-1985. EU 1988-2025	Qualitative evaluation of stock survey biomass trends and recruitment indices	The designated expert doesn't know of any study	The designated expert doesn't know of any attempt	The designated expert indicates that there was no need so far	It hasn't been necessary. Lack of mechanistic understanding, training, workload		Weakness: assessment method, lack of mechanistic understanding. Strength: data availability (including oceanographic and stomach content)
Northern shrimp ICES area 14b	Commercial catches from 1978-present. Commercial CPUE from 1980-present. Survey from 2008-2016,2020,2022-present	SPICF	No recent studies. Stomach samples from several fish species, this could be used to better understand predation on this stock.	No attempts	Focus on improving the assessment method. Temperature data is recorded, but it's not been used in the assessment	Short survey time series. Survey does not catch juvenile shrimp. No regular collection of environmental data.		Weakness: short survey time series. No juveniles. No age-length assessment. Strength: Stomach samples from predators.
Greenland Halibut 1 inshore	Fishery timeseries 1904-present. Trawlsurvey1 (1982 to present), Trawl survey2 1990- present, Trawl survey3 (1997 to present), Gillnet survey 2001 to present. CPUE1 (logbook) 2006 to present, CPUE2 (Factory landing slips) 2012 to present.	Evaluation of trends in time series. Attempts with SPICF but not accepted. Planned to test with SAM	Studies on the influence of temperature (and depth) in growth and stock distribution	No incorporation of environmental variables in stock assessment or advice. Previously it was thought there was a link between mean temperature on fykes bank station 2. But there are several issues not solved.	Several working hypothesis. Influence of forage species in Greenland Halibut dynamic. Influence of competitors (cod and greenland shark)	Need of developing all the studies to assess the working hypothesis. Data limitations. High environmental variability in time and space and no proper sampling design	Knowledge about temperature tolerance or general distribution could be added to the sunfishes or starck reports. More information about ecosystem knowledge in NAFO SC documents	Weakness: assessment method. Environmental data. Strength: Working hypothesis and previous studies
Redfish 3O	Canadian spring and autumn bottom trawl surveys 1991-present (abundance, biomass, length, sex, maturity, geoposition, depth, bottom temperature, salinity, EU-Spain bottom trawl survey 1997-present (abundance, biomass, and length). Fishery sampling (Canada, Russia, EU-Spain, and EU-Portugal for 2001 to present)	Survey indices	There are several previous studies connecting oceanographic conditions (temperature, Cl, food availability, etc) with stock productivity	No attempts	Poor understanding of population dynamics. Influence of adjacent populations that is poorly understood. Mix of redfish species with different environmental preferences	No assessment model to connect with environmental variables. Separation of species. Ageing problems. Pelagic behaviour during part of life cycle.		Weakness: assessment method. Ageing problems. Mix of species and populations? Strength: Working hypothesis and previous studies
Greenland Halibut 0+1	SA1: Fishery timeseries 1904-present. Trawlsurvey1 (1982-present), Trawl survey2 (1990-present), Trawl survey3 (1997-present), Gillnet survey (2001-present), CPUE1 (logbook) 2006-present, CPUE2 (Factory landing slips) 2012-present. SA2: Fishery and survey data from 1999 to present.	SPICF since 2024	Studies on the influence of temperature (and depth) in growth and stock distribution	Bottom temperature has been discussed in stock assessments but has not been incorporated	Working hypothesis on the influence of forage species in Greenland Halibut dynamic. Long time series of temperature and forage fish data. Short time series of biological and physical oceanography.	Risk of future limitations in research vessel time		Weakness: No age-length assessment. Strength: Working hypothesis, previous studies
Northern shrimp 3NO	Catch and effort data since 2000. Canada spring trawl survey (1999-2024) and autumn (1996-2024). EU-Spain trawl surveys in the NAFO Regulatory Area 3L since 2003 and in the NRA area 3NO since 1995.	Qualitative evaluation of stock survey biomass trends. However, a new stock assessment model could be accepted this year	Previous studies connecting top-down and bottom-up drivers with shrimp dynamics. Study on population dynamic projections considering environmental drivers	Environmental drivers have not been used in the assessment and advice in a quantitative way. But environmental information and potential effects on the stock dynamics is being presented in the last years.	In the new model that will be proposed in September at the NAFO shrimp meeting, there is a natural mortality (M) component that is estimated by the model.	Time to work on this stock are very limited. The stock in moratorium for over 10 years. Assessment has received little attention in the last 10 years	The 3NO shrimp stock is likely in a transition phase in terms of the assessment model to be used.	Weakness: assessment method??? Strength: Working hypothesis, previous studies, assessment model with environmental drivers
Northern shrimp 0A+1	Survey 1988- ongoing. Fishery: 1970-ongoing	Bayesian Assessment model with logistic stock-recruitment model. Uses CPUE and survey series as biomass indicators, and includes as removals catch data, assumed free of error, as well as a term for predation by Atlantic cod, using available series of cod biomass	Yes, but no specification of what. Needs to be expanded	yes, predation in the assessment model	Data limitation is an issue. Future benchmark, an opportunity to continue improving in considering ecosystem aspects in the scientific advice.	Data limitation. This answer needs to be expanded		Weakness: data limitation. Strength: Working hypothesis, previous studies, assessment model with environmental drivers
Greenland Halibut 2+3KLMNO	Canadian and EU multi-species bottom trawl surveys since the 1980s or 1990s. Commercial fishery data date back to the mid-1970s.	Statistical catch-at-age and a state-space model	Studies on the influence of temperature in stock size and distribution. Colder temperature, decline.	Environmental factors are considered qualitatively in the assessment. During MSE development, scenario testing included recruitment or mortality declines mimicking environmental downturns. Specific causal links between environmental changes have yet to be linked to population processes.	While ocean temperature and prey availability likely influence productivity, these relationships remain unquantified	Incomplete survey coverage, data limitations, and the complexity of modeling large-scale ecological changes. Lack of reliable predictive relationships between environmental variables and stock dynamics. Capacity and time constraints limit the exploration needed to fully understand these interactions.	Stock connectivity between 2+3KLMNO and adjacent areas (0+1) remains a concern. Ageing uncertainties	Weakness: quantitative functional relationship. Capacity and time constraints. Strength: Working hypothesis, previous studies, assessment model and MSE
Yellowtail flounder 3NO	CAN-DOF Spring RV Survey 1985-2024. CAN-DOF Autumn Survey 1990-2024. EU-Spain 3L Survey 2003-2024. EU-Spain 3NO Survey 1997-2024. Catch 1960-2024. No age information for this stock since 1994.	Bayesian surplus production model	Detectable effects of growth, mortality, and temperature on maturation. Range contraction associated with decrease in bottom temperatures. Population dynamics negatively affected by warmer climatological conditions.	No attempts	Evidence of dynamics linked to temperature. Implementation of this in the 3NO IT assessment would be worth exploring	Workload, mechanistic understandings, lack of age-data, and limitations of the current model formulation for direct incorporation of other indicators		Weakness: no age/length assessment, quantitative functional relationship. Capacity and time constraints. Strength: Working hypothesis, previous studies
Golden redfish 3M	USSR/Russia 1972-1993. Canada surveys 1978-1985. EU 1988-2025	Monitoring, survey and catches based	GadCap multispecies model	GadCap multispecies model	GadCap multispecies model	Training, workload		Weakness: quantitative functional relationship. Capacity and time constraints. Strength: Working hypothesis, previous studies, multispecies model
Beaked redfish 3M	USSR/Russia 1972-1993. Canada surveys 1978-1985. EU 1988-2025	MSA	GadCap multispecies model	GadCap multispecies model	GadCap multispecies model	Training, workload		Weakness: quantitative functional relationship. Capacity and time constraints. Strength: Working hypothesis, previous studies, multispecies model
Cod 3M	USSR/Russia 1972-1993. Canada surveys 1978-1985. EU 1988-2025. Commercial data: total catch, length distribution by gear: 1960-2024. ALK: 1988-2023.	Bayesian SCAA model	GadCap multispecies model. No studies relating oceanographic conditions with cod Div. 3M dynamics, but some general studies have linked cold temperature with collapse in early 1990s. Also, the intensity of the anticyclonic gyre in the bank seems to be related with recruitment	GadCap multispecies model	The analysis of the productivity of the bank and its relation to the oceanographic variables should be further explored. How the anticyclonic gyre, in conjunction with temperature and salinity, relate with the primary production and the recruitment of the stock would be interesting to analyze.	Lack of mechanistic understanding, training, workload		Weakness: quantitative functional relationship. Capacity and time constraints. Strength: Working hypothesis, previous studies, multispecies model
American plaice 3NO	CAN-DOF Spring RV Survey 1985-2024. CAN-DOF Autumn Survey 1990-2024. EU-Spain 3L Survey 2003-2024. EU-Spain 3NO Survey 1997-2024. Catch & Catch at age 1960-2024	index-based	Temperature has been linked to growth. Cold temperature may lead to increased starvation	CAN-DOF trawl survey indices are calculated Divisionally to account for spatial differences in environmental and therefore biological parameters. Impact of natural mortality scenarios on current estimates of stock size and trajectory examined at 2021 assessment	Time-varying reference points have been examined, but linkages to drivers of differences have not been made and could be further explored. Known wide thermal tolerance of plaice suggest primary impact of current temperature changes would be through changes in growth. Hypothesis that prey availability and other stressors are coinciding with age-at-maturity leading to high mortality associated with first spawning events.	Lack of accepted assessment model. Lack of conversion factors for CAN-trawl survey data. Workload, data limitations for prey species, lack of mechanistic understandings, information on early life stages		Weakness: assessment method. Strength: Working hypothesis, previous studies.

Reference

NAFO (2024). Report of the Scientific Council Working Group on Ecosystem Science and Assessment, 12 - 21 November 2024, Halifax, Canada. NAFO SCS Doc. 24/20.

f) ToR 3.6. Review of status of coral OECM submission with 2025 updates [COM. Request#6c]

At the WG-EAFFM meeting in 2024 it was agreed that a template for a coral OECM should be developed, to complement the templates already developed for the large sponge VME and seamounts. WG-ESA would take the lead in compiling the relevant material which would include all the existing VME fishery closures for, sea pen, large gorgonian, small gorgonian and black corals, comprising eleven VME fishery closures 7, 7a, 8, 9, 10, 11, 11a, 12, 13, 14a and 14b, as shown in Figures 6.25 and 6.26. This work was presented to SC and WG-EAFFM in 2025. Workload pressures in the Secretariat precluded the possibility of submitting the material to the World Protected Area database in 2025. Given that delay it was decided that the science text should be updated to include the new VMEs that were produced in 2025 for the review of closed areas. Here we provide that updated text for review at SC in 2026 and subsequent endorsement at WG-EAFFM.

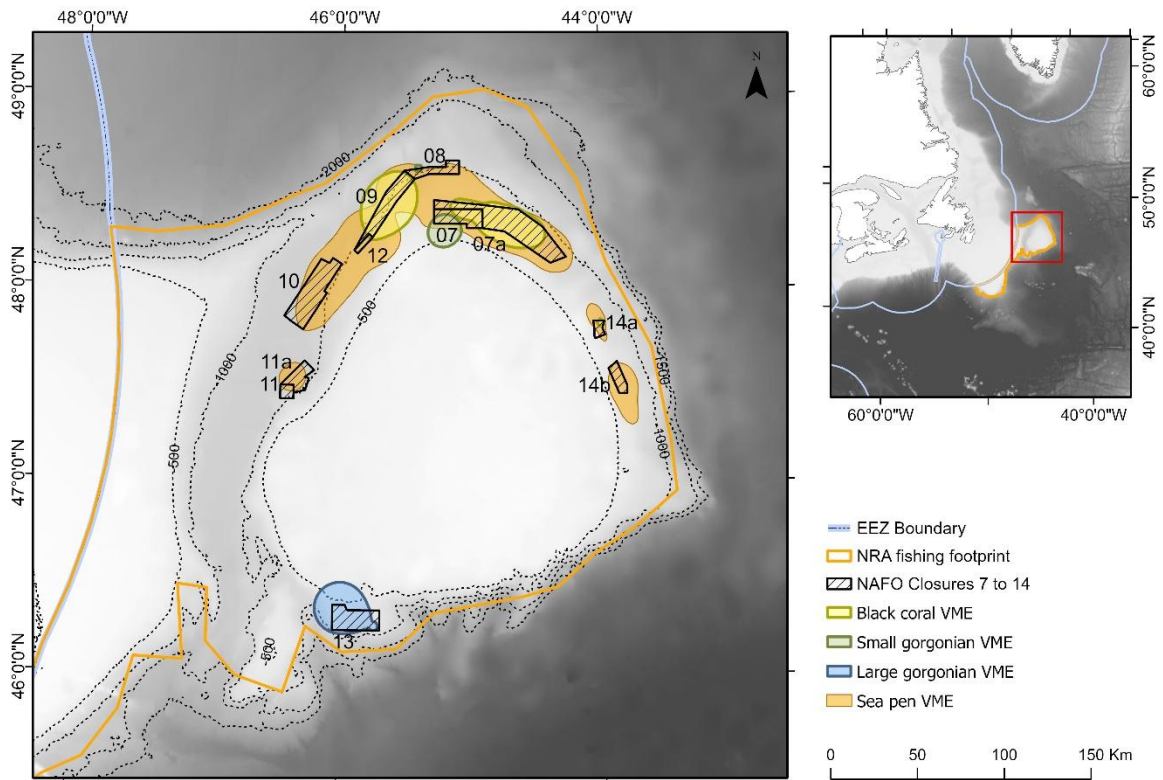


Figure 6.25. The fishery closures which protect sea pen, large gorgonian, small gorgonian and black coral VMEs in the NRA that are to be considered for inclusion in the coral OECM submission. Also, the extent of the corresponding VME polygons is shown. Note, not all of the VME fishery closures and VME polygons are shown on this map – e.g. it excludes large sponge VME and fishery closures which were included in the sponge OECM and which protect large gorgonian coral VME in Flemish Pass (Area 2) and on the southeast slope of Flemish Cap (Area 4).

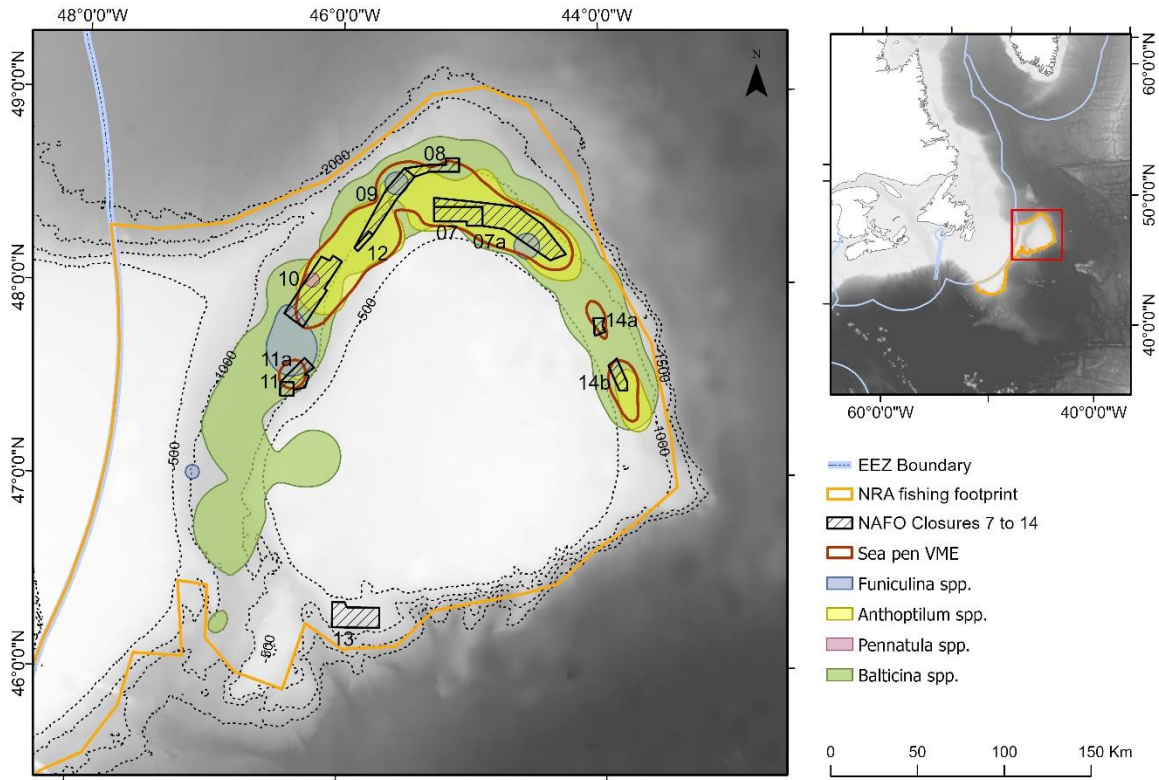


Figure 6.26. The fishery closures which protect subgroups of sea pen VME indicator taxa in the NRA (sea pen *genera* *Funiculina*, *Anthoptilum*, *Pennatula* and *Balticina* VMEs) that are to be considered for inclusion in the coral OECM submission. Also, the extent of the corresponding VME polygons is shown. Note, not all of the VME fishery closures and VME polygons are shown on this map – e.g. it excludes large sponge VME and fishery closures which were included in the sponge OECM and which protect large gorgonian coral VME in Flemish Pass (Area 2) and on the southeast slope of Flemish Cap (Area 4).

Text for the OECM template will be developed, using a combination of information compiled from the Flemish Cap EBSA (Slopes of the Flemish Cap and Grand Bank), descriptions of the ecological significance of the sea pen, large and small gorgonian and black coral VMEs (see below) and text describing the management measures and governance used in support of the sponge and seamount OECMs.

i) Sea Pens

Under suitable conditions, sea pens can form dense aggregations over large areas known as sea pen fields (Kenchington *et al.*, 2014). These fields provide important structure in low-relief sand and mud habitats where there is little physical habitat complexity, creating biogenic habitat for supra-benthic and benthic invertebrates (Humes, 1978; Nygren & Pleijel, 2010; Baillon *et al.*, 2014; De Clippele *et al.*, 2015; Miatta & Snelgrove, 2022; Palummo *et al.* 2025) and demersal fish (Malecha *et al.*, 2005; Boulard *et al.*, 2024; Palummo *et al.* 2025). Seapens can also be a food source for some invertebrates (Birkeland, 1974; Garcia-Matucheski & Muniain, 2011; Stratmann *et al.*, 2024). Sea pen fields can alter near-bottom water current flow, thereby retaining nutrients and entraining plankton and organic particles near the sediment (Tissot *et al.*, 2006). Due to their formation of biogenic habitat, longevity (Murillo *et al.*, 2018) and poor recovery after fishing disturbance (Greathead *et al.*, 2005; Troffe *et al.*, 2005; Heifetz *et al.*, 2009; Malecha & Stone, 2009) sea pens are considered vulnerable marine ecosystems (FAO, 2009). The most common species of sea pens are *Anthoptilum grandiflorum*, *Funiculina quadrangularis*, *Pennatula aculeata*, and *Balticina finmarchica* found in association with mud bottoms (Murillo *et al.*, 2011).

The sea pen, *Anthoptilum* sp. growing on the lower slopes of Flemish Cap, is important for trophic linkages and its removal from a trophic interaction web caused a 2-order extinction cascade (Stratmann *et al.*, 2024) indicating that those sea pen fields are structural species/habitat formers and foundation species in the deep-sea coral and deep-sea sponge habitat. Particle tracking analyses (Wang *et al.*, 2024) revealed that sea pens have the highest degree of connectivity amongst the VMEs in the NAFO Regulatory Area (average number of connections per VME patch: 3.90). VMEs serving as source populations to multiple other patches were prevalent in the sea pen network, in which every VME was a source to at least one other, and the largest VME had downstream connections to all other VMEs.

ii) Gorgonian Corals

Gorgonian corals (order Alcyonacea) include both large and small taxa that are often found in different habitats in the NAFO Regulatory Area. The most common large species include *Paragorgia arborea*, *P. johnsoni*, *Primnoa resedaeformis*, *Paramuricea* spp., and *Keratoisis* sp. These are found growing predominantly on hard substrates. Small gorgonian corals are represented predominantly by *Acanella arbuscula* and *Radicipes gracilis* (Murillo *et al.*, 2011, 2016) which are mostly found on soft sediments in the area.

Gorgonian corals, or sea fans, meet all of the FAO criteria of VMEs (FAO, 2009). They are long-lived, slow-growing, have episodic recruitment and are highly vulnerable to fishing gear (Hourigan *et al.*, 2007). Sherwood and Edinger (2009) aged several species of gorgonians (i.e., *Keratoisis grayi*, *Primnoa resedaeformis*, *Paramuricea* sp., *Acanella arbuscula*, and *Paragorgia arborea*) which ranged in age from a few decades up to 200 years for a subfossil colony of *K. grayi*. *Paragorgia arborea* grew at the fastest radial growth rate of 800 $\mu\text{m} \cdot \text{yr}^{-1}$. Based on known slow growth rates, recovery of gorgonian corals from fishing induced damage will likely take centuries (Fuller *et al.*, 2008). They are structure-forming species creating habitat for a diversity of other invertebrates (Buhl-Mortensen & Mortensen, 2005; Carvalho *et al.*, 2014) and demersal fish species (Baker *et al.*, 2012). Small gorgonian coral biomass showed a positive and significant association with diversity (species density) in the Flemish Cap area when was included as predictor variable in a generalized additive model to explain the total variance of species density (Murillo *et al.*, 2020). Particle tracking analyses (Wang *et al.*, 2024) revealed that the large gorgonian coral VME in closed area 13 (Figure 6.25) connects to three unprotected VMEs on the Tail of Grand Bank and the large gorgonian coral VME in Flemish Pass and protected by the sponge closure in area 2. The small gorgonian coral patch protected on Flemish Cap is highly connected to 6 unprotected small gorgonian coral VMEs on the Tail of Grand Bank (Wang *et al.*, 2024).

iii) Black Corals

Five species of black coral have been documented in the NAFO Regulatory Area: *Stauropathes arctica*, *Sticopathes* sp., *Leiopathes* cf. *expansa*, *Leiopathes* sp., and *Telopathes magna* (Murillo *et al.*, 2011, 2016; Kenchington *et al.*, 2019). Black corals provide substrate for many other invertebrates (Wagner *et al.*, 2012; De Clippele *et al.*, 2019) and can constitute coral forests which enhance both taxonomic and functional diversity of fish (Bosch *et al.*, 2023). They have low rates of growth, fecundity, recruitment, and mortality (Grigg, 1989) and can be very long lived. The oldest recorded living marine invertebrate (4,000 years) is the antipatharian *Leiopathes glaberrima*, a conspecific of species found in the NAFO area. In the Newfoundland Region, black corals were collected at average depths > 1000 m (Wareham & Edinger, 2007). Sherwood and Edinger (2009) determined radial growth rates of 65-31 $\mu\text{m} \cdot \text{yr}^{-1}$, and vertical growth at 1.34 cm. yr⁻¹, respectively, for black corals collected from the Grand Bank. Based on these extremely slow growth rates recovery of deep-sea corals from fishing induced damage will likely take decades to centuries (Fuller *et al.*, 2008). Particle tracking analyses (Wang *et al.*, 2024) revealed that black corals are not well connected, and very few of the eight patches were connected to others. Of the black coral VMEs, the ones protected on Flemish Cap, which are dominated by the species *S. arctica*, are connected to one another, with the VME protected by closed area 09 connected to those VME protected in closed areas 10 and 07/07a (Wang *et al.*, 2024).

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g) ToR 3.7. Draft a scoping document for a potential in-person meeting to explore approaches for further integrating information related to climate change throughout Scientific Council operations [COM. Request#10]

COM Request 10. *The Commission requests the Scientific Council, as workload allows, in consultation with the NAFO Secretariat, to draft a scoping document for a potential in-person meeting to explore approaches for further integrating information related to climate change throughout Scientific Council operations. This scoping document should identify the scientific expertise needed both within and outside Scientific Council and potential financial and workload implications.*

During its November 2025 meeting, WG-ESA hosted a special session open to all Scientific Council (SC) members and one invited expert to begin the process of drafting a scoping document for a potential in-person meeting to explore approaches for further integrating information related to climate change throughout SC operations.

Using a draft scoping document prepared by the NAFO Secretariat as starting point, this special session discussed the intent of the potential in-person meeting, what such a meeting would aim to accomplish, and how it may need to be organized to achieve the identified goals.

The special session concluded that a successful meeting would need to convene climate scientists, oceanographers, ecologists, and fisheries researchers to identify research priorities, collaborative frameworks, and actionable strategies for climate change-informed fisheries and ecosystems management advice in the Northwest Atlantic.

It also recognized that the NAFO Roadmap for an Ecosystem Approach to Fisheries (Roadmap) already includes climate change as one of the elements to be considered within the framework, but implementation remains limited. Therefore, the proposed meeting would need to build upon the Roadmap and previous work with the aim of addressing how climate change considerations can be made operational within the Roadmap.

After exploring options and perspectives, edits to the draft scoping document were proposed to align its content with the conclusions of the special session. The participants also acknowledged the excellent preparatory work done by the NAFO Secretariat in drafting a solid working paper that was extremely useful for setting up a successful conversation at the special session.

The revised draft prepared during the special session will be tabled as a working paper during the 2026 SC June meeting, for further discussion and final edits.

Draft SC Response to COM Request 10

NAFO has resolved to “consider the current and future impacts of climate change on NAFO managed stocks, non-target species, and associated ecosystems in the Convention Area, including, inter alia, as appropriate, in its decision making, and through its work in the Ecosystem Roadmap”.

In collaboration with the NAFO Secretariat, NAFO Scientific Council (SC) developed a scoping document outlining the objectives, structure, and expected outcomes of a proposed meeting. The meeting would focus on establishing a path for the systematic implementation of climate change considerations in the scientific advice, and across the regular operations of SC.

This scoping document will be tabled at the 2026 WG-EAFFM for discussion and presented to COM during the 2026 NAFO Annual meeting.

The NAFO Commission (COM) Resolution 2/23 (NAFO/COM Doc. 23-13) resolved for NAFO to “consider the current and future impacts of climate change on NAFO managed stocks, non-target species, and associated ecosystems in the Convention Area, including, inter alia, as appropriate, in its decision making, and through its work in the Ecosystem Roadmap”.

In 2024, NAFO Scientific Council (SC) indicated that an in-person meeting to explore approaches for further integrating information related to climate change throughout SC operations would be necessary. In collaboration with the NAFO Secretariat, SC developed a scoping document outlining the objectives, structure, and expected outcomes for the proposed meeting. The meeting would focus on establishing a path for the

systematic implementation of climate change considerations in the scientific advice, and across the regular operations of SC.

The scoping document indicates that a successful meeting would need to convene climate scientists, oceanographers, ecologists, and fisheries researchers. The goal would be to identify research priorities, collaborative frameworks, and actionable strategies for climate change-informed fisheries and ecosystems management advice in the Northwest Atlantic. It also recognizes that the NAFO Roadmap for an Ecosystem Approach to Fisheries (Roadmap) already includes climate change as one of the elements to be considered within the framework, but implementation remains limited. Therefore, the proposed meeting would need to build upon the Roadmap and previous work within and outside of NAFO with the aim of addressing how climate change considerations can be made operational within the Roadmap. The scoping document acknowledges the workload required to organize such a meeting, and provides details on the likely costs depending on the number of participants, and meeting location.

This scoping document (Appendix 3) will be tabled at the 2026 WG-EAFFM for discussion and presented to COM during the 2026 NAFO Annual meeting.

h) ToR 3.8. Calculation of biomass for the SAI work [COM. Request#6b]

i) Methodology to Produce Updated Biomass Estimates for Vulnerable Marine Ecosystems in the NAFO Regulatory Area

In support of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area, kernel density analyses (KDE) of Large-sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals were undertaken using all available research vessel survey data (1995 – 2024) (Kenchington *et al.*, 2025a). For the first time, subgroups of some of the VME functional groups had sufficient data to warrant application of the KDE analyses. These included two families and one order of sponges (Tetillidae, Polymastiidae, Astrophorina), four sea pen genera (*Balticina*, *Funiculina*, *Pennatula* and *Anthoptilum*) and two species of small gorgonian coral (*Acanella arbuscula* and *Radicipes gracilis*) (Kenchington *et al.*, 2025a,b). In order to assess significant adverse impacts (SAI) of fishing activity on these VME indicators, it is necessary to produce a spatial layer of biomass for each. As noted previously (Kenchington *et al.*, 2019), the KDE-generated biomass is used to identify areas with a higher density, i.e., "hotspots", where the biomass is more concentrated, and so identify important habitats or vulnerable marine ecosystems. However, KDE does not use null data and KDE biomass is an approximation, not a precise measurement. Therefore, other methods to produce a biomass layer for the VME indicators were developed.

In updating the biomass layers for the assessment of SAI ahead of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems, it was necessary to run ModelBuilder in ArcGIS Pro, which replaces the ESRI ArcMap software. ArcGIS ModelBuilder is a visual programming language for building geoprocessing workflows using different tools within ArcGIS. No changes were needed to functionalize the model in the updated software, however, in reviewing the methodology used previously (Lirette *et al.*, 2020 Appendix 1), it was noted that both EU and Canadian VME indicator catch data were used in 2020, although Cogswell *et al.* (2011) recommended using only the EU data to avoid catchability differences. This prompted a closer examination of how the data were treated in 2020, and some issues were found (Table 6.4).

ii) The workflow developed and used in 2020

Pham *et al.* (2019), who also used only the EU data, advanced the work of Cogswell *et al.* (2011) by applying conversion factors for the two gear types (Lofoten and Campelen 1800) in their "grid-cell approach", to account for catchability differences. The Campelen swept area conversion was applied in the NAFO 3LNO Divisions while the Lofoten swept area conversion was used for the 3M Division, reflecting their different usages in the different surveys. They further calculated that 373 RV Campelen trawl sets or 641 RV Lofoten trawl sets would be required to completely trawl a single 5 km x 5 km grid cell without overlap and used those values to create a total biomass/grid cell that assumed 100% coverage.

In 2020, Lirette *et al.* applied the workflow used by Pham *et al.* (2019) to create updated VME indicator biomass estimates (Figure 6.27) and developed routines in ModelBuilder to automate the process. The first three steps

of the model (Figure 6.27, Table 6.4; Lirette *et al.*, 2020) used the average of the raw catch biomass data to populate empty cells using focal statistics, following Pham *et al.* (2019) and Cogswell *et al.* (2011). In the fourth step, a swept area for each of the two gear types was used to calculate grid cell biomass assuming 100% coverage. These conversions were not made using the actual gear type but drew on the geographic separation of the gears in the EU surveys (which were perfectly valid in Pham *et al.* (2019)). For the Gear field, grid cells located in the NAFO Division 3M were selected and updated to “Lofoten” including those cells intersecting the 3L-3M border. The remaining grid cells, located in the NAFO Divisions 3LNO, were selected and updated to “Campelen”. Unfortunately, by using the Canadian RV data in 2020, two problems were created that were not previously identified.

The Canadian surveys use Campelen gear and fish both in the NAFO Division 3M, and in the NAFO Divisions 3LNO (see Figure A1 in Kenchington *et al.*, 2025a). The standard tow length is 15 min, whereas on the EU surveys the standard tow length is 30 min. Adding the Canadian data to the ModelBuilder in Lirette *et al.* (2020) would have changed the gear to a Lofoten, ignored the shorter tow length and therefore applied an incorrect swept area for tows in Division 3M. For tows in the Divisions 3LNO the gear type would have been correctly applied but the shorter tow length not accounted for in the conversion factor. Pham *et al.* (2019) considered gear type in their work but did not have to consider tow length as they only used EU data. In statistically analyzing catch differences between tow lengths, vessels and gear types, before use in the KDE analyses, Kenchington *et al.* (2025a) confirmed that the different surveys had different catchabilities at the low biomass end of the catch spectrum.

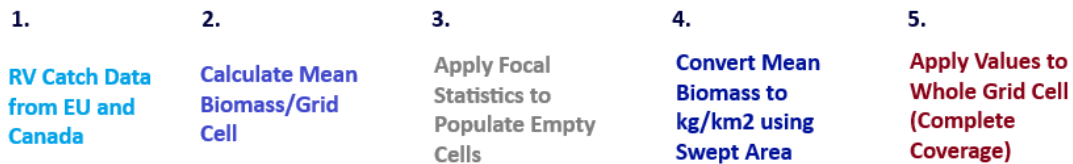


Figure 6.27. Sequential steps (1-5) followed in Lirette *et al.* (2020) to produce biomass surfaces for VME indicator taxa.

WG-ESA evaluated the impact that the selection of data had on the resulting biomass layers by comparing outputs using EU data only and both EU and Canadian data obtained for the period 1995 to 2024. The analysis of Lirette *et al.* (2020) was repeated on each, recognizing that using the EU data only would not have the confounding effects of tow length and gear changes imposed through using the Canadian data. The outputs of the method were reported for their separate steps (Step 2, 3 and 5; Figure 6.27) to examine whether differences were more pronounced in one over others. The various methods of producing biomass layers were discussed and compared to see the impact the method has, as the results using complete coverage of the grid cell, as done in 2020, may not be ecologically realistic at the scale of 25 square km. Lastly, all biomass was converted from EU and Canadian surveys to kg/km² using the swept area of the gear/tow length used, prior to the application of any statistics (Figure 6.28) (Cogswell *et al.*, 2010). Other aspects than the calculation of the biomass per grid cell (i.e., method of separately calculating values inside and outside of the closures) have not changed. The comparisons were made using a grid cell of 5 km x 5 km and for the Large-Sized Sponges. The agreed upon approach will then be used for all of the VME indicators noted above and for two sizes of grid cell, 1 km x 1 km and 5 km x 5 km. Issues related to the use of the smaller grid size were reviewed by Lirette *et al.* (2020) and are not reconsidered here. Essentially the 5 km x 5 km grid is needed to ensure adequate data/grid cell for the focal statistics. It is then reduced to 1 km x 1 km (Lirette *et al.*, 2020).

Table 6.4. Summary of the development of biomass layers for use to assess significant adverse impacts of fishing in NAFO. SDM=Species distribution model; FS=Focal statistics.

Publication	Data Sources	Methods Applied	Issues
Cogswell <i>et al.</i> (2011)	EU data only	Complete Coverage	Different gears not accounted for. FS confounded.
Pham <i>et al.</i> (2019)	EU data only	SDM and Complete Coverage	None
Lirette <i>et al.</i> (2020)	EU and Canadian data	Complete Coverage	Shorter tow length of Canadian data not accounted for. Canadian Campelen tows in 3M changed to Lofoten tows. FS confounded.
This study	EU data only and Canadian and EU data	Various	

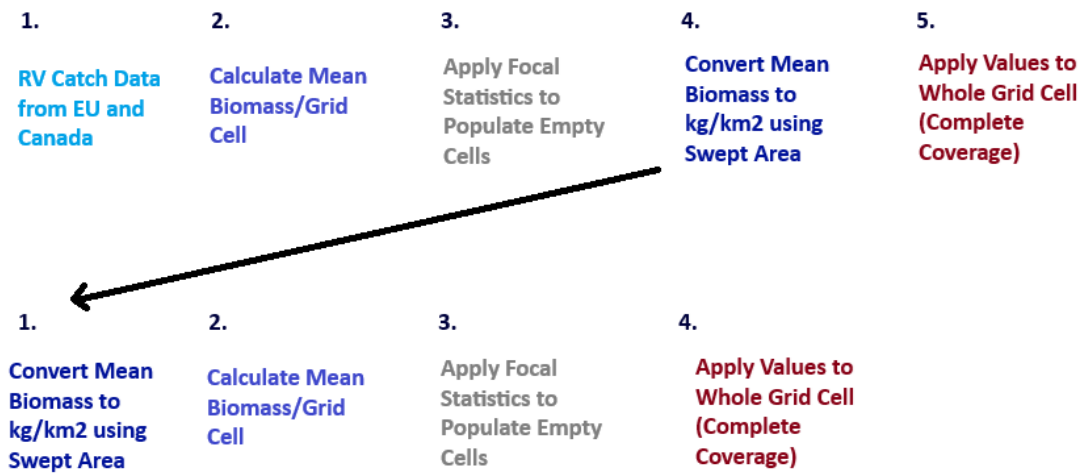


Figure 6.28. Sequential steps (1-5) followed in Lirette *et al.* (2020) to produce biomass surfaces for VME indicator taxa, and the steps applied in Case 3 where all data are converted to kg/km² prior to the analyses.

iii) Data inputs

Data for the Large-Sized Sponges were those compiled for the species distribution analyses (Murillo *et al.*, 2024) and augmented with data from 2024 (Kenchington *et al.*, 2025a), as they had been QA/QC'd for both presences and absences. The data were obtained for the period 1995 to 2024. These data were separated into two groups for analysis (Figure 6.29):

Case 1: included only the EU data (4431 presences, 2774 absences from 2002-2024);

Case 2: included both the EU and Canadian data (5505 presences, 5048 absences from 1995-2024);

and a third case, Case 3, where all data (Case 2) were converted to kg/km² prior to analyses.

iv) Calculation of biomass surfaces

Biomass surfaces produced in 2020 were constructed using an ArcGIS simulation model managed by ArcGIS ModelBuilder, a visual programming language for building geoprocessing workflows in ArcMap. ArcMap is the former main component of Esri's ArcGIS suite of geospatial processing programs, used primarily to view, edit, create, and analyze geospatial data. In this application, ModelBuilder was run in ArcGIS Pro, which replaces their ArcMap software.

For each of the three cases sets five approaches were used to compare the resulting biomass surfaces (Lirette *et al.*, 2025):

- Method 1) **Simple Averaging**, which calculates the average of a set of values by dividing the sum of all values by the total number of values in each grid cell, generating a standard deviation.
- Method 2) **Focal Statistics**, which calculates statistics for input cells within a specified neighborhood around each cell in a raster. This method was used previously (Cogswell *et al.*, 2011; Pham *et al.*, 2019; Lirette *et al.*, 2020) to populate empty cells through several iterations of the tool, performed using the ArcGIS Pro 3.3 Focal Statistics tool in Spatial Analyst ([Focal Statistics \(Spatial Analyst\)—ArcGIS Pro | Documentation](#)). When all cells in the spatial extent were populated, values in previously empty cells were joined to the values in the cells where data were present (as obtained in Method 1), to create full coverage of the spatial extent.
- Method 3) **Swept Area Complete Coverage**, is the method used previously (Figure 6.27) (Pham *et al.*, 2019; Lirette *et al.*, 2020), where for each grid cell the mean biomass was calculated using the output of Method 2, and then converted to kg/km² using swept area for the Lofoten trawl of 39000 m² and 67000 m² for the Campelen trawls and then applied to the total cell area. There are 373 RV Campelen trawl sets or 641 RV Lofoten trawl sets required to completely trawl a single grid cell without overlap (Pham *et al.*, 2019).
- Method 4) **Ordinary Kriging** is a statistical method of spatial interpolation that estimates the value of a variable at unsampled locations based on observed data points. Null values (no VME indicator in haul) are not used. It computes a weighted average of known values in the neighborhood of the point to make predictions. Ordinary Kriging was performed using ArcGIS Pro 3.3 Kriging tool in Spatial Analyst ([Kriging \(Spatial Analyst\)—ArcGIS Pro | Documentation](#)). A kriged biomass raster was created from the kriging which was set to a square cell resolution (a discrete surface was created using 'nearest neighbour' resampling matched to the 25 square km grid (5km x 5 km)). The variance of prediction was mapped showing the predicted error variance, or the uncertainty, of a spatial prediction model at each cell location. Ordinary kriging models were created using all default settings in the Spatial Analyst wizard.
- Method 5) **Species Distribution Modeling (SDM)**. The SDM approach is advantageous for obtaining a continuous biomass surface, allowing predictions in areas beyond the sampled locations based on environmental variables, and thereby capturing the full extent of the sponge grounds (Pham *et al.*, 2019). Here, a random forest (RF) regression model published by Pham *et al.* (2019) was used to predict the distribution of the sponge biomass. The spatial extent of the random forest model was restricted to the 2000 m depth contour (Pham *et al.*, 2019).

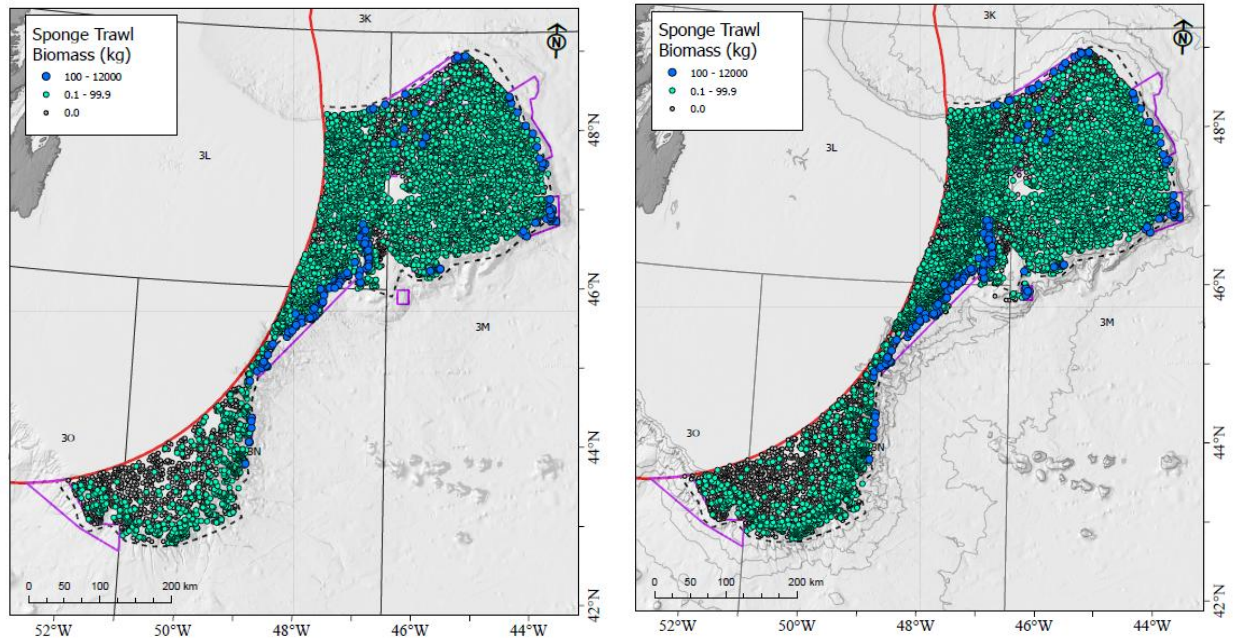


Figure 6.29. Distribution of the research vessel catch data containing Large-Sized Sponges showing catches above and below the 100 kg/RV tow density threshold selected as defining significant concentrations of Large-Size Sponges (Kenchington *et al.*, 2025) as well as null catches. Left panel: EU data only (Case 1). Right panel: EU and Canadian data (Case 2 and Case 3). The fishing footprint is indicated by a dashed black line; closed areas are outlined in purple; Canadian EEZ is indicated in red.

Note that because the application of the swept area conversion factors is not applied until Step 4 (Figure 6.27), for Cases 1 and 2 the maps produced by Methods 1 and 2 (Simple Averaging and Focal Statistics) are confounded by gear type (Case 1) and gear type and trawl length (Case 2) to different extents.

In Methods 1-3, the biomasses inside and outside of the closed areas were separately calculated as in Lirette *et al.* (2020) and then joined. For all methods applied here, the spatial extent was the fishing footprint, plus the closed areas and 2025 Large-Sized Sponges VME polygons (Kenchington *et al.*, 2025) some of which extend beyond the footprint into deeper water. Pham *et al.* (2019) used different spatial extents but compared their methods using a common area (fishing footprint).

Full documentation is presented in Lirette *et al.* (2025). Here key results are presented and discussion within WG-ESA on the way forward is summarized.

v) What was the effect of including the Canadian data in the 2020 biomass estimates?

To evaluate the effect of adding the Canadian data to the analyses in 2020 without accounting for the shorter tow length of the Canadian RV surveys (15 min vs. 30 min for the EU surveys) and the application of the incorrect conversion factor in Division 3M, the same work flow as used in Lirette *et al.* (2020) was applied and the analyses run with and without the Canadian data. Case 1 with EU data only parallels the approach used in Pham *et al.* (2019). Table 6.5 shows the total biomass for the spatial extent calculated using the two data sets. The workflow begins with the calculation of the average biomass per cell (Method 1), then applies focal statistics (Method 2) and then adjusts for gear differences and upscales to complete coverage of the grid cell (Method 3). The final result shows that inclusion of the Canadian data increases the total biomass and the mean biomass/grid cell at each step (Table 6.5). This is also the result found in Cogswell *et al.* (2011). However, the differences are not as large as those seen between the different methods applied in achieving the final biomass layer used (Complete Coverage).

Table 6.5. Biomass (kg) of Large-Sized Sponges for each of two data sets (EU data only (Case 1) and EU and Canadian data (Case 2)). Total Biomass was calculated for the full spatial extent (fishing footprint and closed areas) while means and standard deviations are presented for the grid cell, from the grids comprising the Total Biomass.

Case 1: EU Data Only				
	Method	Total Biomass (kg)	Mean (kg/grid cell)	Standard Deviation (kg/grid cell)
1	Simple Averaging	105,560	32.8	343.4
2	Focal Statistics	678,587	106.1	636.4
3	Complete Coverage ¹	241,624,521	37,789.3	274,757.0
Case 2: EU and Canadian Data				
1	Simple Averaging	144,976	38.8	351.3
2	Focal Statistics	696,103	108.9	606.9
3	Complete Coverage ²	249,967,857	39,094.1	261,303.6

¹Different swept areas for Lofoten and Campelen gears applied in this method.

²Different swept areas for Lofoten and Campelen gears incorrectly applied to Canadian data and no transformation for different tow lengths applied in this method (Lirette *et al.*, 2020).

Spatial differences in the distribution of the biomass were more pronounced (Figure 6.30). The maximum biomass per grid cell was similar between the two data sets but inclusion of the Canadian data seemed to add biomass to grid cells on the Nose and Tail of Grand Bank and on Flemish Cap which had lower biomass when not included. In contrast, the grid cells in Closed Area 6 on Sackville Spur were populated with more cells of higher biomass than when the Canadian data were not included.

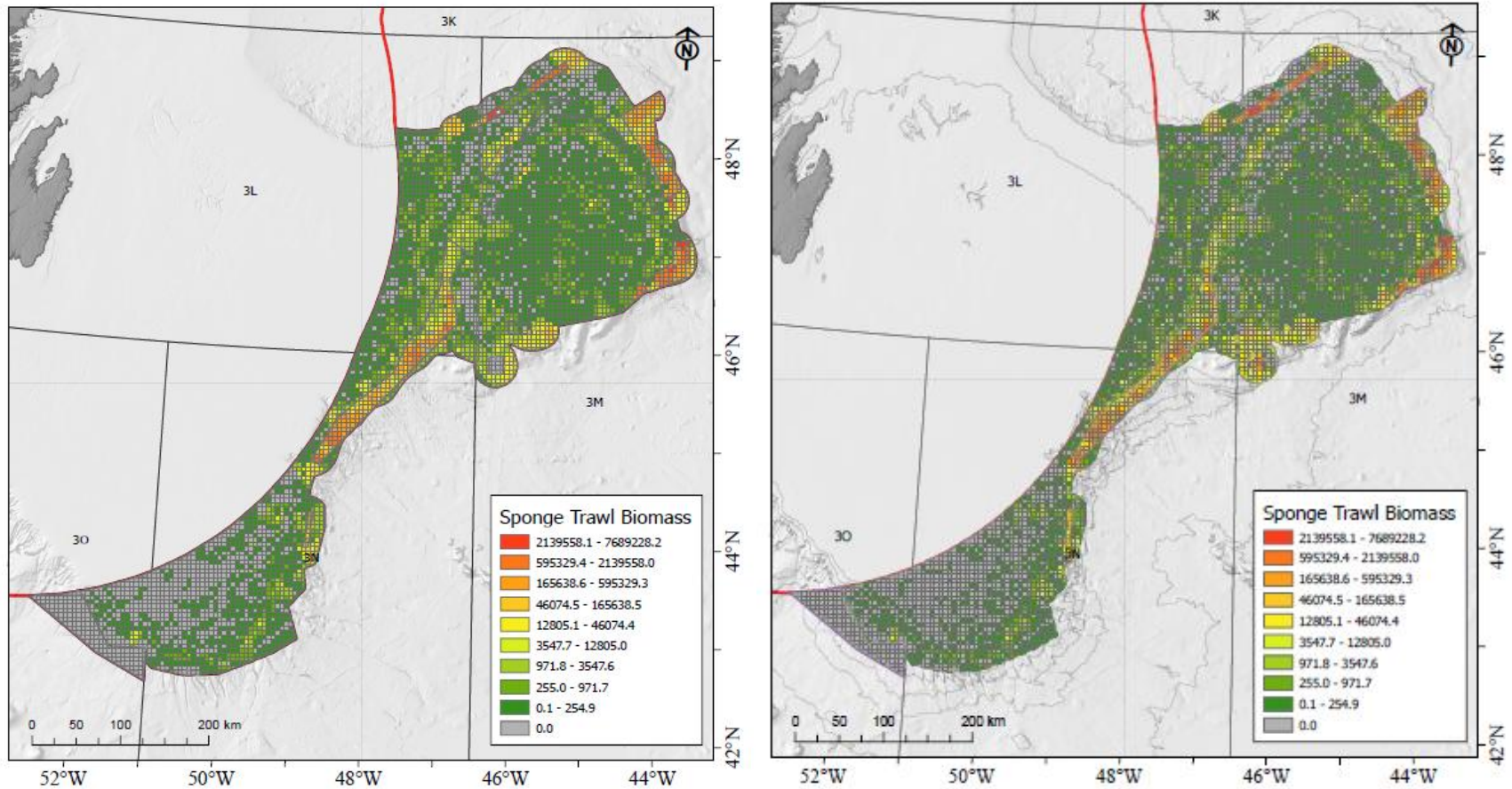


Figure 6.30. Grided mean biomass (kg) surface using swept area complete coverage (Method 3). Left Panel: EU data only. Right Panel: Canadian and EU data. Canadian EEZ is indicated in red.

vi) Application of conversion factors prior to analyses

The application of conversion factors in the Pham *et al.* (2019) publication to account for the two different gear types used by the EU RV fleet (Lofoten and Campelen) was carried over to the 2020 work flow (Lirette *et al.*, 2020 Appendix 1), however, when the Canadian data were added the shorter tow lengths were not similarly accounted for (Table 6.4). Further, the Canadian Campelen tows in 3M were changed to Lofoten tows and converted using that gear swept area calculation. The above results show that inclusion of the Canadian data increases the total biomass and the mean biomass/grid cell at each step of the workflow (Table 6.5) and creates spatial differences in the biomass distribution (Figure 6.30). Therefore, going forward with conversion factors, the Canadian data should use a different conversion factor for the Complete Coverage approach. There is no clear rationale for converting the data at Step 4 of the workflow (Figure 6.27) and this seems to complicate things and generate errors. By doing so the application of the focal statistics is confounded by using biomass from different gears as well as different tow lengths. Here we converted all of the data to kg/km² using the swept area for each gear/tow length combination prior to undertaking the calculations (Figure 6.28). The expectation is that Methods 1 and 2 will have larger total biomass due to the correction factors and that the Complete Coverage will be similar (Table 6.6). WG-ESA confirmed that all conversions to the data should be done as the initial step if applied, however in a second discussion it was confirmed that the VME data are not like fish data and that conversions cannot be applied as longer tows or bigger gears don't necessarily mean more VME in the catch (Kenchington *et al.*, 2025).

Table 6.6. Biomass (kg) of Large-Sized Sponges under four methods of calculation for each of two data sets. Total Biomass was calculated for the full spatial extent (fishing footprint and closed areas) while means and standard deviations are presented for the grid cell from the grids comprising the Total Biomass.

Case 1: EU Data Only				
	Method	Total Biomass (kg)	Mean (kg/grid cell)	Standard Deviation (kg/grid cell)
1	Simple Averaging	105,560	32.8	343.4
2	Focal Statistics	678,587	106.1	636.4
3	Complete Coverage ¹	241,624,521	37,789.3	274,757.0
4	Kriging	312,371	57.6	205.1
Case 2: EU and Canadian Data (Lirette <i>et al.</i>, 2020)				
1	Simple Averaging	144,976	38.8	351.3
2	Focal Statistics	696,103	108.9	606.9
3	Complete Coverage ²	249,967,857	39,094.1	261,303.6
4	Kriging	344,301	63.5	212.3
Case 3: EU and Canadian Data (Conversion factors applied prior to analyses)				
1	Simple Averaging	3,483,265	933.4	8928.0
2	Focal Statistics	17,072,398	2,696.2	15,509.2
3	Complete Coverage	283,223,140	44,728.9	282,163.2
4	Kriging	8,320,942	1,533.5	5165.6

¹Different swept areas for Lofoten and Campelen gears applied in this method.

²Different swept areas for Lofoten and Campelen gears incorrectly applied to Canadian data and no transformation for different tow lengths applied in this method (Lirette *et al.*, 2020).

vii) What is the effect of using different methods to calculate biomass?

The choice of the method to use was discussed in WG-ESA. Pham *et al.* (2019), using only data from the EU surveys, compared the results from two different approaches: the modeling approach which used SDM (Method 5) to produce biomass from random forest regression modeling, and the approach followed in Cogswell *et al.* (2011). Although the data sets are different from those used here, the comparison of results of the SDM and

Complete Coverage methods are expected to follow similar trends. Results from the SDM showed higher biomass estimates both for the spatial extent used and for a common area, i.e. the fishing footprint (Table 6.7).

Table 6.7. Comparison of total biomass estimates published in Pham *et al.* (2019) for two methods of calculation, Species Distribution Modelling and Complete Coverage, using only EU sponge RV catch data collected between 2006–2010.

Method	Total Biomass (kg)	Total Area (km ²)	Total Biomass in Footprint (kg)
Species Distribution Modeling	231,136,000	135,056.82	116,143,000
Complete Coverage ¹	122,465,000	123,307.31	81,169,000

¹Different swept areas for Lofoten and Campelen gears applied in this method.

WG-ESA noted that SDMs can be very useful for extrapolating to areas where there is poor data coverage through its use of environmental predictors. However, the SDM models currently available were created with random forest classification trees and were created to modify the KDE-VME polygons (Kenchington *et al.*, 2025b). For this exercise, random forest regression models are needed if biomass is required. Those are not currently available (but see ToR 2.4 above) and would take some time to produce. It was recommended that in future SDM should be one of the approaches used to compare biomass layers for evaluating significant adverse impacts of fishing.

Regardless of the data used, moving from Simple Averaging to Focal Statistics to Complete Coverage increases the total biomass substantially with each step (Table 6.6, Figures 6.31, 6.32). Of the two interpolation methods examined by Pham *et al.* (2019), SDM estimated considerably more total biomass than the Complete Coverage method, while kriging estimated less. Both of these approaches would take some time to develop and could delay the assessment of significant adverse impacts if selected. The Complete Coverage method is a scalar applied to the focal statistics to move from a density estimate to a total biomass. It brings with it assumptions of whether it is ecologically reasonable to assume 100% coverage at that scale, given that there is high variance in catches within areas of high concentrations of VME indicators (Lirette *et al.*, 2025).

In keeping with the current options two means of obtaining complete spatial coverage, focal statistics or kriging, were compared (Table 6.6, Figures 6.32, 6.33). After some discussion it was agreed that kriging was the more robust method for this application, especially if universal kriging was applied with covariates and cross validation. This method will also allow for the variance associated with the predictions to be illustrated (Figure 6.33) which was valuable in other applications (Kenchington *et al.*, 2025b).

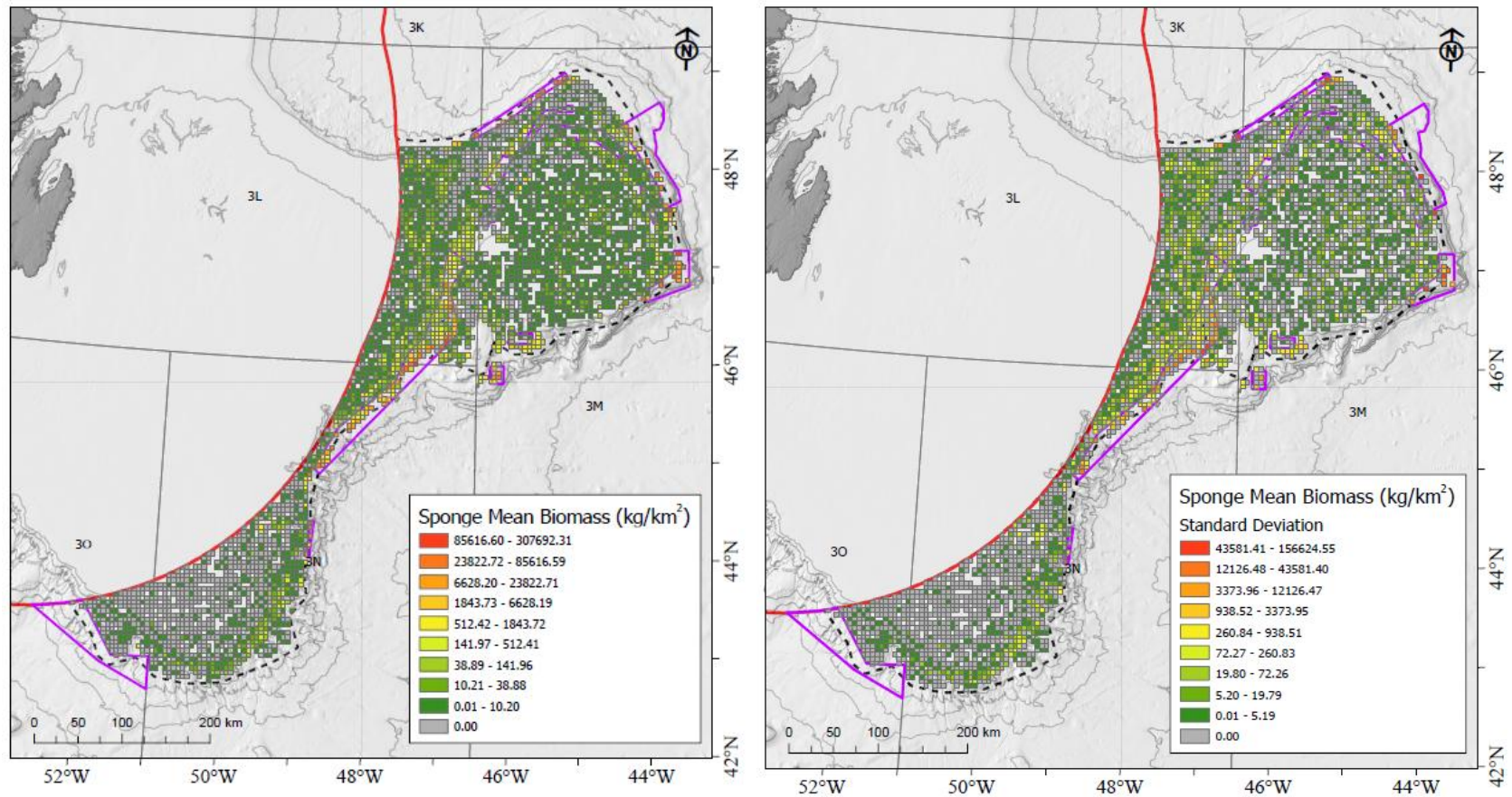


Figure 6.31. Grided biomass surface using transformed EU and Canadian data (Case 3) calculated using simple averaging. Left panel: Mean biomass (kg/grid cell). Right panel: Standard deviation around the mean biomass (kg/grid cell). The fishing footprint is indicated by a dashed black line; closed areas are outlined in purple; Canadian EEZ is indicated in red.

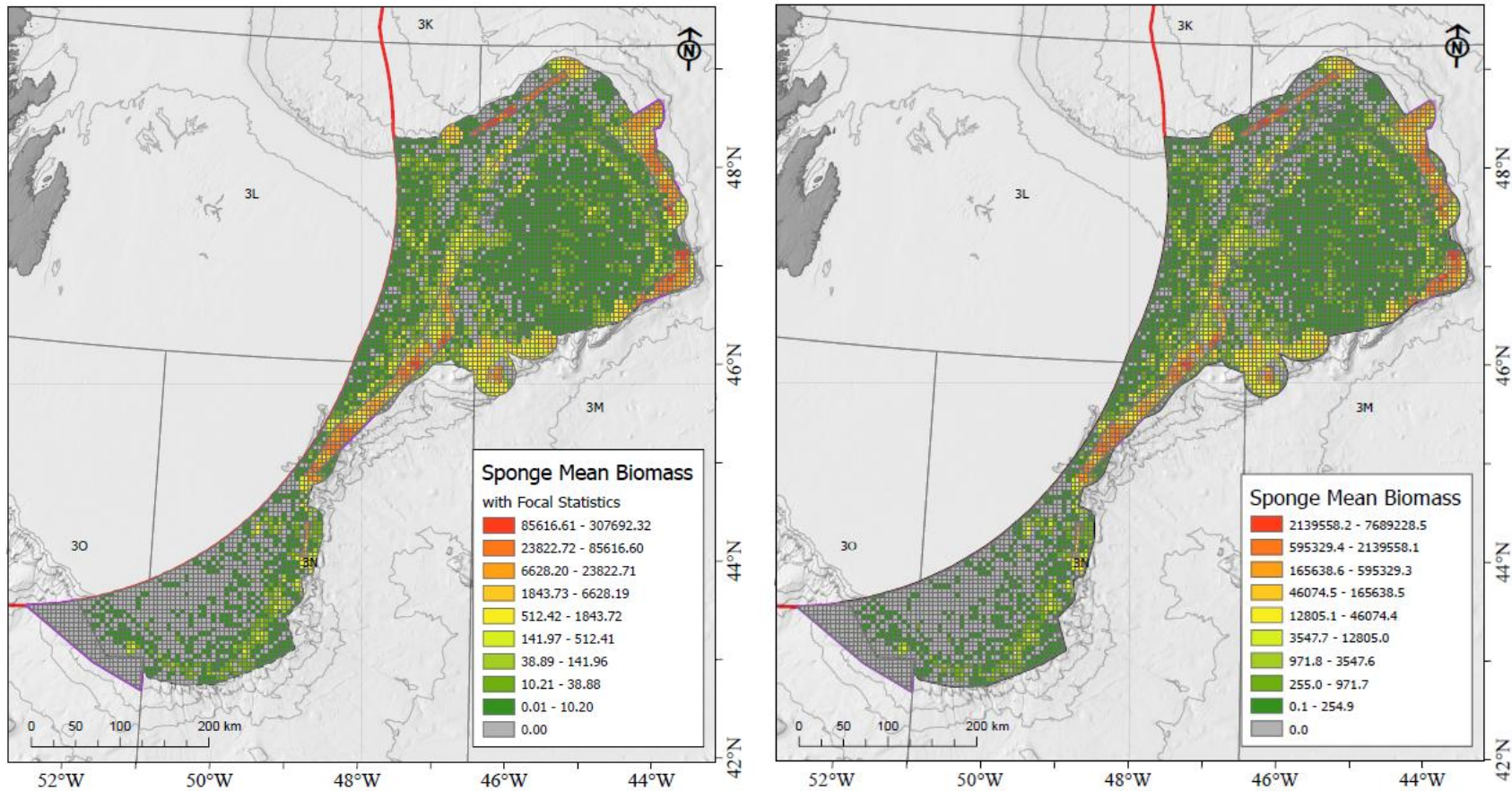


Figure 6.32. Grided mean biomass (kg) surface using transformed EU and Canadian data (Case 3). Left panel: Calculated using focal statistics (Method 2). Right panel: Calculated using swept area complete coverage (Method 3). Canadian EEZ is indicated in red, spatial extent in black.

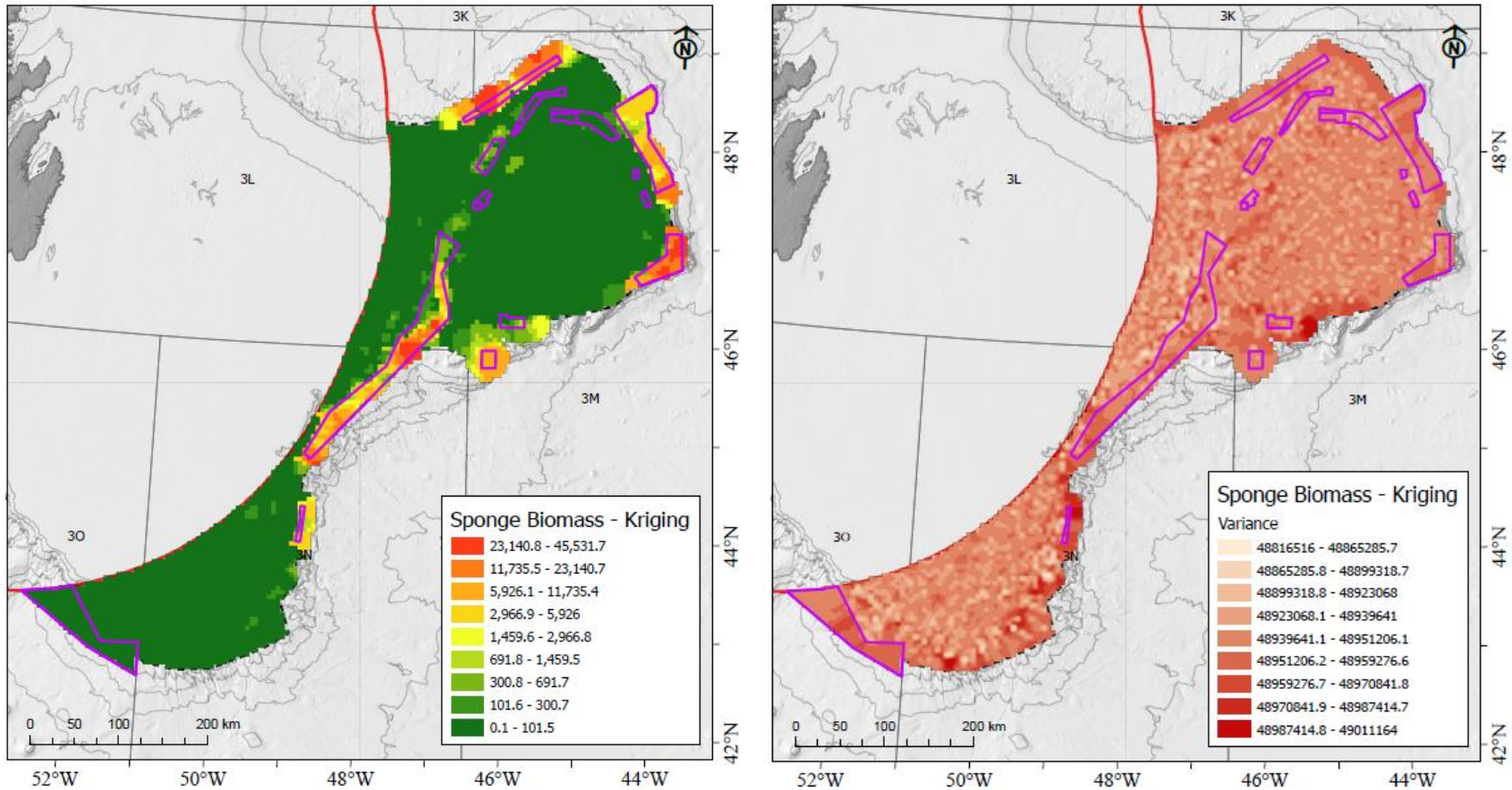


Figure 6.33. Grided biomass surface using EU and Canadian data (Case 3) calculated using kriging. Left panel: Mean biomass (kg). Right panel: Variance of the predictor (kg). Canadian EEZ is indicated in red, closed areas in purple.

viii) **Conclusions**

WG-ESA concluded that a sub-group would be struck to advance this work to prepare grided biomass surfaces by the end of January 2026. All data will be used (Canada and EU) but no conversion factors will be applied. This means that the result will be in kg/RV tow rather than a density measure. As a result, the scalar for Complete Coverage cannot be applied. Focal statistics will be applied so that comparisons can be made between that approach and that obtained by using kriging.

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i) **ToR 3.9. Developing a workplan for the "reassessment of bottom fisheries including SAI" [COM. Request#6b]**

WG-ESA discussed the scope, lead and timing of SAI tasks to be completed to address COM Request #6b. In relation to the habitat impact assessment component of the roadmap (VME and SAI analyses), the Commission requests that Scientific Council “work towards the reassessment of VMEs and impact of bottom fisheries on VMEs for 2027; including potential management options in the reassessment of bottom fisheries”.

An updated review of the VMEs was presented at WG-ESA 2025, which included new KDE analysis and SDMs – SDMs for each of the VME functional types was performed for the 1st assessment in 2014, but was not undertaken for the second assessment in 2020. It was decided in 2024 that the SDMs layers should be updated for 2025 and these were completed and presented at WG-ESA 2025. WG-ESA also identified some critical tasks that must be completed ahead of the overall assessment of SAI, and ahead of the determination of the management options, these are; (i). A finalised set of VME polygons, including VME functional types and new specific VME functional sub-types, (ii). The creation of newly updated VME biomass grid, using revised methods to be determined by a sub-group of WG-ESA, (iii). An updated VMS fishery effort data layer, and (iv). The integration of the VMS and log-book data (see Table 6.8 for a full list of tasks).

Table 6.8. Tasks that must be completed ahead of the overall assessment of SAI and determination of the management options.

Section (sub-section) headings	Lead author	Timing (Task Dependencies)
INTRODUCTION	James/ Andy (section editor)	Section finalised
(i) policy background (to update 2020 text)	James/Andy	By WG-ESA '26
(ii) oceanographic conditions (to update 2020 text)	Miguel	By WG-ESA '26
(iii) ecosystems (to update 2020 text)	Mariano/ Alfonso	By WG-ESA '26
(iv) habitats (to update 2021 text)	Javier/ Anna	By WG-ESA '26
(v) communities – fish, epibenthos, infauna (to update 2020 text)	Javier	By WG-ESA '26
(vi) Description of EPU (to update 2020 text)	Mariano	By WG-ESA '26
VULNERABLE MARINE ECOSYSTEMS (VMEs)	Ellen/ Javier (section editors)	Section finalised in WG-ESA '26
(i) defining, identifying and mapping VMEs incl. SDMs (to update 2020 text, using survey data from 2011 - 2023)	Ellen	By WG-ESA '25 (completed)
(ii) updated VME polygons	Ellen/ Cam	By WG-ESA '25 (completed)
(iii) VME biomass (1 km ² grid using 2011 – 2023 survey data)	Cam/ Ellen	By February '26 (completed for focal statistics approach)
(iv) VME connectivity update (using previous results)	Ellen	By WG-ESA '26
(v) sea pen ABM baseline conditions (using previous results)	Mariano	Between WG-ESA '25 and WG-ESA '26
ASSESSMENT OF FISHERIES	Mar (section editor)	Section finalised in WG-ESA '26
(i) Description of fisheries in the NRA	Mar/ Fernando/Irene	By WG-ESA '26
(ii) VMS filtered data (2010 – 2024)	Anna & NAFO (Andie)	By March '26
(iii) Integrating VMS and logbook (haul by haul) data (2016 – 2024)	Mar/ Irene/ Anna	By WG-ESA '26

(iv) Demersal fisheries (update maps and tables)	Mar/ Irene	By WG-ESA '26
(v) Overlap of demersal fisheries with VMEs (update on 2020 analysis/ text)	Mar/ Irene	By WG-ESA '26
ASSESSMENT OF SAI	James/ Andy (section editors)	Section finalised in WG-ESA '26
(i) Background to the assessment of SAI (update 2020 text)	James/ Andy/ Ellen	By WG-ESA '26
(ii) VME impacts, resilience and recovery (update 2020 text)	Barbara	By WG-ESA '26
(iii) VME SAI impact assessment categories (cut-off values) with maps and tables using 95% thresholds and new thresholds.	James/ Andy	By WG-ESA '26
(iv) Other SAI assessment metrics	Anna/ James (editors)	Section finalised in WG-ESA '26
- fishing (VMS) stability index (recalculated using new data)	Neil/ Anna	By WG-ESA '26
- overlapping VME polygons (recalculated using new data)	James/ Cam	By WG-ESA '26
- overlapping functional polygons (use 2020 results)	James/ Andy	By WG-ESA '26
- VME fragmentation index (recalculated using new data)	Ellen/ Mariano	By WG-ESA '26
- VME closure adequacy 'consistency' index (recalculated using new data)	Mariano	By WG-ESA '26
(v) Overall assessment of SAI	James/ Andy	By WG-ESA '26

Time critical tasks to be completed before WG-ESA 2026 are as follows:

1. **March 2026:** VMS fishery data (2010 – 2024 effort as tracks in km. km⁻². yr⁻¹) - *Anna/ Andie (NAFO)*
2. **February 2026:** Updated VME biomass grid (1km²) using kriging – *Anna/Javier*

j) ToR 3.10. Developing a workplan for the assessment of the "management options" as part of the reassessment of bottom fishing [COM. Request#6b]

The general approach applied in the 2020 assessment (reported in 2021) will be applied again in the 2027 reassessment of VMEs and the impacts of bottom fisheries on VMEs, with the aim of providing the scientific basis for the development and evaluation of potential management options.

The core data layers required will be compiled as part of the SAI assessment and will include; (i) VMS fishery data (2011 – 2024 effort as tracks in km. km⁻². yr⁻¹), (ii) Integrated VMS and log-book data for catch and landings (2016 – 2024), (iii) Updated VME biomass grid (km²), (iv) Updated VME polygons.

WG-ESA further concluded that it would be helpful to include information on the ecological significance of each of the proposed closures. For example; (i) to consider including information on the proposed area climate sensitivity, refugia status and connectivity, (ii) to include relevant information on the long-term fishing patterns in the NRA, e.g. the historic fishing patterns described in Kulka and Pitcher (2001), (iii) to include, if possible, the Canadian snow crab fishery data (e.g. VMS, catch and landings data), which is especially relevant for the Bryozoan and *Boltenia* sp. VMEs on top of the tail of the Grand Bank.

Table 6.9 highlights the specific tasks and timing required to complete the assessment of the management options.

Table 6.9. Tasks, lead authors and timing to complete the assessment for the management options.

Section (sub-section) headings	Lead author	Timing (Task Dependencies)
INTRODUCTION	James/ Andy (section editor)	Section finalised
(i) introduction (to update 2021 text)	Mariano	By March '27
(ii) contributing elements and data used (to update 2021 text)	Mariano/ Mar/ Anna	By March '27
(iii) VME/ fishery options (tables of VME biomass, fishery catches by target species, to include snow crab)	Anna/ Mar/ Mariano	By March '27
(iv) Summary of scientific information relevant to potential management options	Anna/ Mar/ Mariano	By March '27
(v) Additional proposed area attributes (e.g. climate sensitivity, connectivity, historic fishing value)	Anna/Mar/Ellen/ Mariano	By March '27
(vi) summary of management proposals	Mariano/ Mar/ Anna	By March '27

The process and sequence of analysis to be undertaken as part of the SAI, along with the sequence of specific tasks to be undertaken for the management options, is especially important, and is summarised as follows:

1. In the first instance the reassessment of SAI and the management options will focus on the 7 defined and currently mapped VME functional types (VME polygons), as was the case in the 2nd reassessment e.g. (i) sea pen, (ii) black coral, (iii) small gorgonian, (iv) large gorgonian, (v) large sponge, (vi) bryozoan, (vii) *Boltenia* sp.
2. VME polygons for these functional types, which identify significant VME biomass located outside current closures and at risk of SAI, will be delineated and any associated commercial fishing effort and catch levels will be determined.
3. The VME at risk and subject to fishing activity (from **Step 2**) will be assessed to determine potential management options (either as new VME fishery closures and/or adjustments to the boundaries of existing VME fishery closures). This analysis will also include snow crab fishery data, where available.

4. The potential management options determined by **Step 3** will be further assessed to accommodate any newly identified VME subgroup polygons where appropriate (e.g. new genera of sea pens).
5. The potential management options determined by **Step 4** will be further assessed and prioritised with respect to; (i) climate sensitivity, (ii) connectivity, and (iii) historic fishing patterns.

The results of each of these steps, and a final set of proposed management options, will be presented as maps and tables during an intersessional on-line meeting of WG-ESA to be organised no later than March 2027. Proposed management options (proposals for new VME fishery closures or adjustments to existing VME fishery closure boundaries) will be presented to SC in June 2027 and WG-EAFFM in July 2027, where a final set of management options may be agreed on for presentation to the Commission at the 2027 Annual Meeting.

At the 2025 WG-EAFFM meeting (COM-SC Doc. 25-03), early engagement of managers was discussed to help inform potential management options, and WGESA supported the proposal to invite managers to an intersessional WG-ESA meeting in March 2027. This would allow the opportunity for WG-ESA to inform managers of the scientific rationale and process adopted to develop the proposed management options for potential VME fishery closures. An intersessional WG-EAFFM may also be required to further discuss the proposed management options.

k) ToR 3.11. Update on ongoing studies on non-fishing activities in the NRA

An update on ongoing studies of non-fishing activities conducted in the NAFO Regulatory Area was provided, specifically about: i) New data on seabed macrolitter caught during the fishing operations of EU Spain/Portugal Groundfish Surveys (2024) in Divs. 3LMNO; and ii) Methods and objectives of a pilot study on monitoring of polycyclic aromatic hydrocarbon (PAH) metabolites in fish species in Flemish Cap (Div. 3M).

i) New data on seabed macrolitter from EU Spain/Portugal Groundfish Surveys (2024)

New records and densities of seabed macrolitter in the NAFO Regulatory Area (NRA; Divs. 3LMNO) were provided based on opportunistic sampling conducted during the 2024 EU–Spain/Portugal groundfish surveys. These data were collected following the revised protocol for seabed litter collection from EU groundfish surveys, using specific log forms and summary sheets (developed during the NEREIDA project), which were presented at WG-ESA 2024 (Abalo-Morla *et al.*, 2024). It should be noted that sampling effort of seabed macrolitter has apparently increased in recent years, particularly following the review of the protocol as part of the NEREIDA project. A total of 388 valid bottom trawl hauls were analysed, with approximately 238 macrolitter items found in 32.2% of these hauls. Mean densities of macrolitter were 16.6 ± 47.1 items/km⁻² and 52 ± 758 kg/km⁻². Fisheries related litter was the most abundant litter (52.2% of recorded items), followed by plastic (29%), metal (8%), other anthropogenic litter (4%), rubber (3%), organic litter (3%), and glass and ceramics (1%). Using the source-specific indicator items from the OSPAR Commission (2007), following previous studies (García-Alegre *et al.*, 2020; Abalo-Morla *et al.*, 2024), the main sources of seabed macrolitter were identified. Fisheries was found to be the main source of seabed litter (58% of recorded items), followed by galley waste (4%) and operational waste (1%). However, 37% of recorded items were of uncertain source. The results from this study provide an updated information on the distribution of seabed litter in Divs. 3LMNO and will help to improve the current protocol (still in revision) for collecting seabed macrolitter data and to implement best practices in the groundfish surveys conducted in the region. An update from this study is expected to be presented during next WG-ESA meeting, scheduled for November 2026. Above information of seabed macrolitter preliminary data from EU Spain/Portugal groundfish surveys is further detailed in SCR Doc. 25/051.

ii) Monitoring of polycyclic aromatic hydrocarbon (PAH) metabolites in fish species (Flemish Cap pilot study)

During the meeting, the ongoing pilot study on monitoring polycyclic aromatic hydrocarbon metabolites in fish species in Flemish Cap was briefly presented. The objective of this study is to detect these metabolites in the bile of three fish species (Greenland halibut, roughhead grenadier, and witch flounder) in order to assess exposure to, and the biological impact of, contamination (early indicator of PAH contamination). During the 2025 EU Spain/Portugal groundfish survey on the Flemish Cap, gallbladder samples of the aforementioned species were collected from: i) Control areas in north and east Flemish Cap, where no oil and gas activities are

being conducted; and ii) Study areas in west Flemish Cap, where oil and gas activities are present or nearby (*i.e.*: exploration wells). Part of these samples will be analyzed at the Spanish Institute of Oceanography (IEO) in Vigo, in the framework of the collaboration with the Research Group on Marine Pollution (<https://www.csic.es/en/investigation/research-groups/marine-pollution>), using an established protocol of high-performance liquid chromatography (HPLC) coupled with fluorescence detection. This method has proven effective for detecting low concentrations of pollutants. An update from this study is expected to be presented during next WG-ESA meeting, scheduled for November 2026.

Acknowledgements

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THEME 4: OTHER MATTERS

7. Other business

a) ToR 4.1. DSF Project, FAO: Updates on EAFM Symposium, Climate change and other project work relevant to WG-ESA

Tony Thompson presented the conclusions of the FAO Common Oceans Deep-Sea Fisheries (DSF) project's work with its seven partner RFMOs. This included the online precautionary approach workshop held on 15 October 2024, the EAFM symposium at FAO headquarters in March 2025 in Rome and run jointly with NAFO and ICES, and the online climate change workshop summarizing the outcomes of the four climate change consultancies with NAFO, NEAFC, NPFC and SPRFMO held on 14 October 2025. There were overlaps among these three topics regarding uptake and implementation and they were here dealt with together. At these meetings, it was generally accepted that EAFM and the PA should be applied to target stocks, discarded and endangered, threatened and protected (ETP) species, and to the ecosystem as a whole. It was also appreciated that RFMO mandates generally cover only ecological aspects, where social and economic aspects are covered by the contracting parties and invariably define the positions CPs take at RFMO meetings.

The majority of the DSF project workshop participants were from scientific committees, with the balance being made up of managers and industry representatives. These workshops identified that scientists were the main drivers of the EAF, PA and CC work within RFMOs. Principal conclusions were, among other things, the need for more informal science-manager meetings and for the adoption of longer-term guidance to provide clarity and direction to the work of the RFMOs. The DSF Project plans to conclude this work with a single workshop covering all three topics with the suggestions that participants should be drawn from the pool of RFMO managers. The above was thoroughly discussed by WG-ESA.

Many of the WG-ESA participants had attended one or more of the DSF Project workshops, especially the EAFM symposium. They found them useful and supported any follow-up actions by the project and especially the holding of a concluding workshop. However, they felt that the workshop should include representatives from the scientific committees and possibly industry. The reasoning was to provide managers with explanations of the science behind these topics that they require to assist them in their decision-making processes. The group noted that most RFMOs do have elements of long-term targets in their conventions, measures and scientific work, but also felt that the managers main responsibilities lay in the short-term decisions affecting catches and impacts over the following 1-3 years. They however expressed a wish that this should be discussed further so as to acquire a balanced approach that considers both short and long-term targets.

Other comments from the group included:

- Consideration that the DSF Project workshop could be more at the science-management interface level, with participants drawn across all of the project's partners and so be global in scope,
- Promoting longer-term management supported by adopted "guidance" documents,
- Focusing on the development of practical "management" solutions and decisions to address complex ecological interactions,
- To support more global workshops or symposia for scientists,
- To develop consistent communications to highlight the work of RFMOs in contributing to, for example, the Sustainable Development Goals or CBD's Global Biodiversity Framework.

Tony Thompson, on behalf of the DSF Project, thanked WG-ESA for its support and constructive feedback. The project will work with NAFO and the other RFMO partners to organize an appropriate follow-up workshop.

b) ToR 4.2. EAFM Symposium: Update on submission to JNAFS

The NAFO Secretariat (Andrea Perreault) provided an update on the Special JNAFS Issue dedicated to the Symposium on "Applying the ecosystem approach to fisheries management in Areas Beyond National Jurisdiction (ABNJ)". The deadline for submitting articles to the special issue was October 3rd, 2025. As of November 4th, 2025, 7 submissions had been received, with 1 conditionally accepted, 4 under review and 2 about to begin the review process. Additionally, five authors had been given extensions and are expected to submit in early 2026.

c) ToR 4.3. Update on BBNJ Agreement

The NAFO Secretariat (Brynhildur Benediktsdóttir) provided an update on the status of the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement, including the most recent UN meeting attended in August 2025. The Agreement is expected to enter into force at the end of January 2026, and most preparations and arrangements are still underway. It was noted that RFMOs presented at side events on the functioning of their organizations, and that some negotiating delegations had a limited understanding of RFMO decision-making processes and associated timelines. It was emphasized that RFMOs and other international organizations should remain actively involved as the logistical and management aspects of implementing the BBNJ Agreement continue to develop.

8. Date and Place of Next Meeting

The meeting will be held from 10–19 November 2026 in Halifax, Nova Scotia, Canada, unless an invitation to host the meeting is extended by a Contracting Party and accepted by the Organization

9. Adjournment

The co-Chairs thanked the participants for their hard work and cooperation of this year's meeting. The meeting was adjourned at 14:05 on 12 November 2025.

APPENDIX I: AGENDA: NAFO SCIENTIFIC COUNCIL (SC) WORKING GROUP ON ECOSYSTEM SCIENCE AND ASSESSMENT (WG-ESA)

Madrid (Spain), 4-12 November 2025

Details of the meeting ToRs are given in **ANNEX 1**.

Provisional Agenda and Terms of Reference (ToRs)

- 1. Opening by the Chairs, Mar Sacau (EU) and Alfonso Pérez (EU).**
- 2. Appointment of Rapporteur**
- 3. Adoption of Agenda**
- 4. Review of Annual Meeting 2025 outcomes**
- 5. Commission requests for advice on management in 2026 and beyond, requiring input from WG-ESA in 2025 to be presented at the Scientific Council meeting June 2026.**
 - a) COM Request #1 (ANNEX A: Guidance for providing advice on Stocks Assessed).** In relation to Tier 1 of the Roadmap Scientific Council should provide annually catch information in relation to 2TCI, including recent cumulative catch levels and a scoping of expected cumulative catch levels. Ecosystem summary sheets should be monitored annually and updated on a five-year cycle.
 - b) COM Request #6.** In relation to the habitat impact assessment component of the Roadmap (VME and SAI analyses), the Commission requests that Scientific Council to:
 - a. Continue to progress work on the centralized data repository using ArcGIS online to host the data and data-products for scientific advice, in conjunction with the NAFO Secretariat.
 - b. Work towards the reassessment of VMEs and impact of bottom fisheries on VMEs for 2027; including potential management options in the reassessment of bottom fisheries.
 - c. Develop materials on the potential of submitting NAFO coral bottom fishing closed areas as OECMs for discussion at the 2026 WG-EAFFM meeting.
- 6. Commission requests for advice on management in 2026 and beyond, requiring longer term input from WG-ESA.**
 - a) COM Request #5.** In relation to the Ecosystem Roadmap as a whole, the Commission requests the Scientific Council, with input from the WG-EAFFM, to continue work on the development of a reference document detailing the ecosystem roadmap, for completion by the 2026 Annual Meeting.
 - b) COM Request #10.** The Commission requests the Scientific Council, as workload allows, in consultation with the NAFO Secretariat, to draft a scoping document for a potential in-person meeting to explore approaches for further integrating information related to climate change throughout Scientific Council operations. This scoping document should identify the scientific expertise needed both within and outside Scientific Council and potential financial and workload implications.
- 7. Other Business**
- 8. Date and place of next meeting**
- 9. Adjournment**

ANNEX 1. WG-ESA TERMS OF REFERENCE

Please note that this schedule is provisional and subject to changes.

THEME 1: SPATIAL CONSIDERATIONS

ToR 1. Update on identification and mapping of sensitive species and habitats (VMEs) in the NAFO area.

1. Update on VME indicator species data and VME indicator species distribution from EU; EU-Spain Groundfish Surveys and Canadian Surveys (*Bárbara, Sara, Rylan, Mar*)
2. Improvements to the Quality Assurance (QA) of data on VME indicators from RV catches (*Javier*)
3. Update on the methodology to assess the presence of *Pennatula aculeata* (*Claude*)
4. Okeanos Explorer work on the Corner Rise Seamounts [*COM. Request #6b*] (*Lara Maleen*)
5. Update on the centralized data repository using ArcGIS Online [*COM. Request#6a*] (*Lauren, etc*)

THEME 2: STATUS, FUNCTIONING AND DYNAMICS OF NAFO MARINE ECOSYSTEMS

ToR 2. Update on recent and relevant research related to status, functioning and dynamics of ecosystems in the NAFO area.

1. VMEs in the NAFO Regulatory Area: Updated SDM of Selected VME Indicators (Large and Small Gorgonian Corals, Erect Bryozoans and Sea Squirts) [*COM. Request#6b*] (*Javier, Ellen, etc*)
2. VMEs in the NAFO Regulatory Area: Updated Kernel Density Analyses of VME Indicators [*COM. Request#6b*] (*Ellen, Cam, Javier, etc*)
3. Identification of VMEs in the NAFO Regulatory Area Combining Kernel Density Analyses, SDM and Empirical Data [*COM. Request#6b*] (*Ellen, Cam, Javier, etc*)
4. Work on modelling the individual sea pens species and their overlaps [*COM. Request#6b*] (*Anna*)
5. High Resolution Climate Projections to 2100 for Use in Species Distribution Modelling of Vulnerable Marine Ecosystem Indicators in the NAFO Regulatory Area [*COM. Request#6b*] (*Ellen, Zeliang, Cam, etc*)

THEME 3: PRACTICAL APPLICATION OF ECOSYSTEM KNOWLEDGE TO FISHERIES MANAGEMENT

ToR 3. Update on recent and relevant research related to the application of ecosystem knowledge for fisheries management in the NAFO area.

1. Regular Monitoring of Ecosystem Summary Sheets (ESSs) for Divisions 3LNO and 3M [*COM. Request#1*] (*Mariano, Diana, Irene, etc*)
2. Formalization of a full Workplan for the 2028 ESSs update: Analysis of by-catch and discards and proposal for building an ETP species list [*COM. Request#1*] (*Patricia, Mark, Diana, Irene, Javier, Jana*)
3. Updates on the Ecosystem Production Potential (EPP)-Total Catch Index (TCI) framework, including primary production estimates to inform EPP models for TCI calculations [*COM. Request#1*] (*Mariano, STACFEN, etc*)
4. Update on NAFO Roadmap reference document [*COM. Request#5*] (*Mariano*)
5. Results of the questionnaire to Designated Experts regarding the potential implementation of ecosystem approach (Tiers 2 and 3) in stock assessment (*Alfonso*)
6. Review of status of coral OECM submission with 2025 updates [*COM. Request#6c*] (*Ellen, Andy*)
7. Draft a scoping document for a potential in-person meeting to explore approaches for further integrating information related to further integrating information related to climate change throughout Scientific Council operations [*COM. Request#10*] (*NAFO Secretariat, all*)
8. Calculation of biomass for the SAI work [*COM. Request#6b*] (*Ellen, Cam*)
9. Developing a workplan for the "reassessment of bottom fisheries including SAI" [*COM. Request#6b*] (*Andy, all*)
10. Developing a workplan for the assessment of the "management options" as part of the reassessment of bottom fishing [*COM. Request#6b*] (*Andy, all*)

11. Update on ongoing studies on non-fishing activities in the NRA (*Pablo, Sara, Santi, Mar*)

THEME 4: OTHER BUSINESS

1. DSF Project, FAO: Updates on EAFM Symposium, Climate change and other project work relevant to WG-ESA (*Tony Thompson*)
2. EAFM Symposium: Update on submission to JNAFS (*Rick and Andie*)
3. Update on BBNJ Agreement (*Brynhildur*)

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APPENDIX III. DRAFT CLIMATE CHANGE SCOPING DOCUMENT

Scoping Document: Proposed Meeting on Integrating Climate Science into NAFO Scientific Advice

The ocean climate in the NAFO Convention Area changes naturally on decadal time scales (i.e., climate variability) and as a result of global warming (e.g., anthropogenic climate change). In the context of this meeting, *climate change* refers to both definitions. Both climate variability and change are expected to affect NAFO fisheries, especially those located at the cold or warm limit of their range. The outcomes of this meeting will contribute to the implementation of the latest United Nations General Assembly Resolutions on Sustainable Fisheries recommendations regarding climate change and ocean acidification effects on fisheries and marine ecosystems, relevant Convention on Biological Diversity Conference of the Parties decisions, relevant deliberations of the FAO Committee on Fisheries, among other relevant instruments.

This scoping document outlines the objectives, structure, and expected outcomes of a meeting focused on designing an approach to effectively integrate climate change considerations into the scientific advice and regular operations of the Northwest Atlantic Fisheries Organization (NAFO). The meeting will convene climate scientists, oceanographers, biologists, modellers and fisheries researchers, to identify research priorities, collaborative frameworks, and actionable strategies for climate change-informed fisheries and ecosystems management advice in the Northwest Atlantic. Building on the NAFO Roadmap for the Ecosystem Approach to Fisheries (Figure 1) and previous work (Boyce, 2024; Johnson *et al.*, 2025), this meeting will aim to address how climate change considerations can be made operational in the Roadmap's tiered framework.

Meeting Objectives

- Review existing work addressing the impacts of climate change on fisheries and ecosystems across all relevant organizations and jurisdictions.
- Identify how and where climate change considerations can be made operational within the NAFO Roadmap (e.g., Figure 2).
- Identify key impediments that limit the consideration of climate change impacts into NAFO's Tier 1 (ecosystem), Tier 2 (multispecies), Tier 3 (stock-level) and habitat impact (SAI/VME) assessments.
- Develop actionable strategies for integrating climate change considerations across regular NAFO Scientific Council operations.
- Promote cross-disciplinary collaboration among climate scientists, oceanographers, ecologists and fisheries researchers.

Format and Participants

Duration: 5 days in person with hybrid option. Participants will include climate scientists, oceanographers, biologists, ecologists, modellers and fisheries researchers. Keynote speakers and external experts will be invited.

SC shall establish a Steering Committee that will include the chairs of SC, STACFEN and WGESA and an external invited expert, which will be in charge of defining the exact structure and agenda for this meeting. An illustrative agenda on how this meeting could be planned is:

Day 1: Review of existing work addressing the impacts of climate change on NAFO fisheries and ecosystems across all relevant organizations and jurisdictions. Inviting keynote speakers.

Day 2: Breakout groups to brainstorm and identify how and where climate change considerations can be made operational within the NAFO Roadmap.

Day 3/4: Identification of key impediments in Tiers 1, 2, 3 and habitat impact assessments of the Roadmap that limit the consideration of climate change impacts into assessments. Flag current successes, where applicable.

Day 5: Ways forward to integrate climate change science into NAFO scientific advice. Synthesis and recommendations.

Expected Outputs

- Identification of the key elements required for the systematic development of climate change informed scientific advice within the NAFO Roadmap.
- Identifying actionable strategies (action plan), including follow-up projects and/or NAFO working groups, for the systematic implementation of climate change considerations into regular NAFO operations.
- Summary report highlighting key findings and discussions, to be presented to the NAFO Scientific Council.

Budget Overview

The following provides three preliminary budget estimates of the resources required for the five-day meeting, contingent on the location of the meeting.

Category	Estimated Cost (CAD)	Notes
Meeting hosted in Halifax, NS (<25 participants)		
Venue and logistics	\$0	Meeting hosted at the NAFO Secretariat Office
Administrative and coordination support	\$0	
Invited speakers	\$8,000	Support for two invited experts
Contingency (10%)	\$800	Unexpected expenses
Total	\$8,800	
Meeting hosted in Halifax, NS (>25 participants)		
Venue and logistics	\$15,000	Meeting room rental and associated costs
Administrative and coordination support	\$0	
Invited speakers	\$8,000	Support for two invited experts
Contingency (10%)	\$2,300	Unexpected expenses
Total	\$25,300	
Meeting hosted outside of Halifax		
Venue and logistics	\$0	Hosted by CP
Travel support for NAFO administrative and coordination support	\$20,000	Travel, accommodations, and associated costs
Invited speakers	\$8,000	Support for two invited experts
Contingency (10%)	\$2,800	Unexpected expenses
Total	\$30,800	

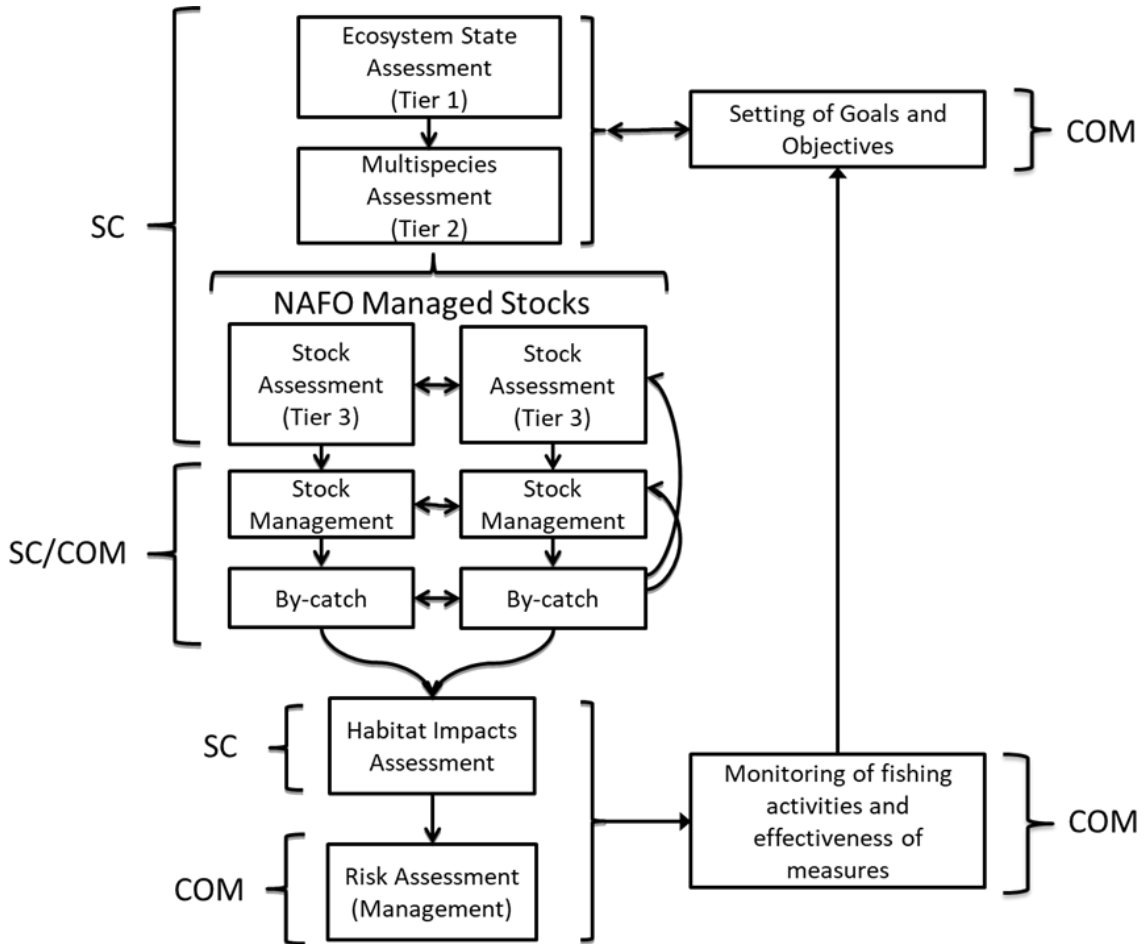


Figure 1. Current template of the NAFO Roadmap for EAF. SC: Scientific Council, COM: Commission. The labelled vertical brackets indicate the leading NAFO body for each Roadmap component (NAFO SC Working Paper 25-022)

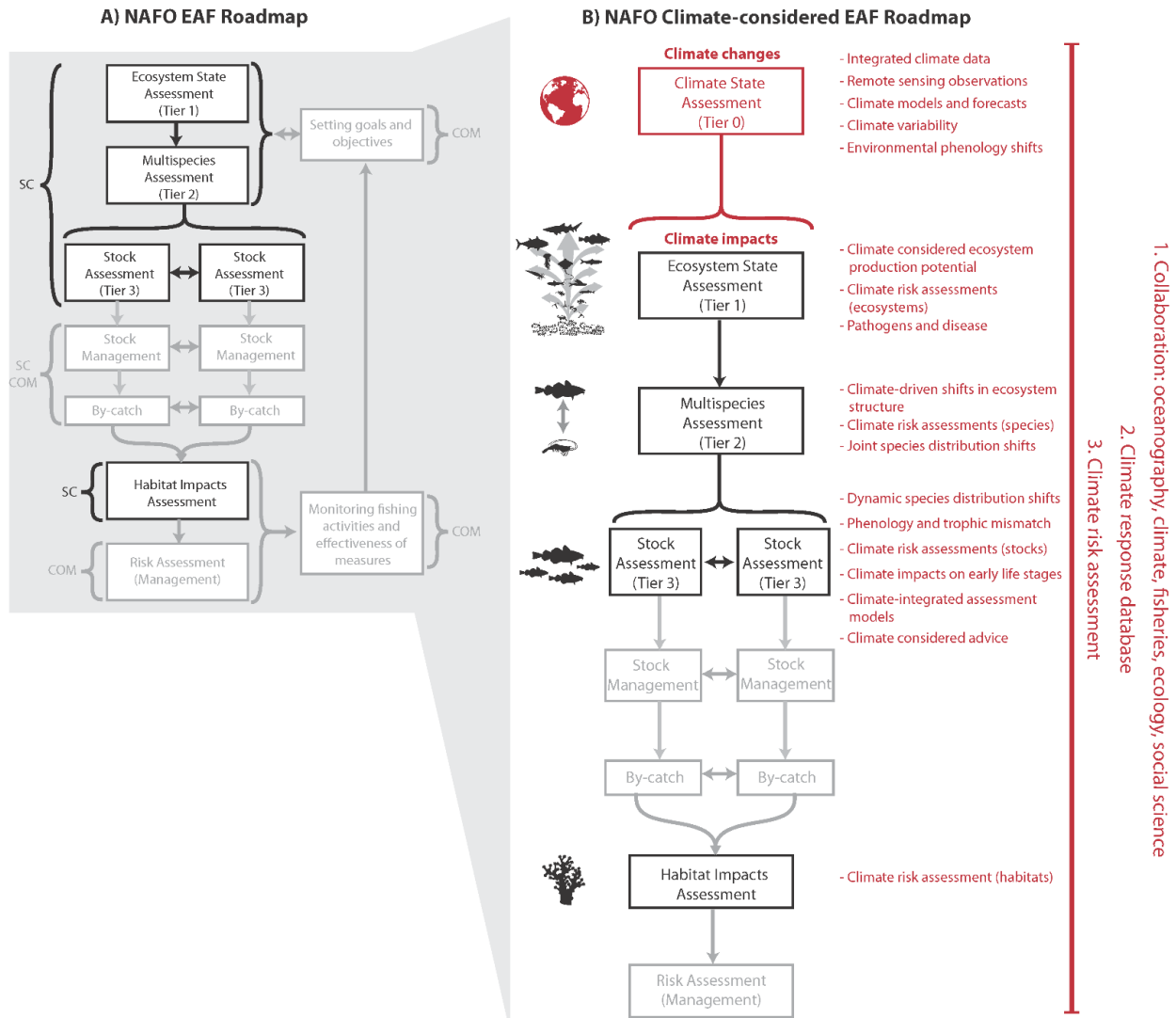


Figure 2. NAFO climate considered EAF roadmap. Current working template of the NAFO Roadmap (A) and steps to enhance its climate readiness (B; red text). SC: Scientific Council; COM: Commission. (NAFO SCR 24-009)

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