Serial No. N7604 NAFO SCS Doc. 24/20

SCIENTIFIC COUNCIL WORKING GROUP ON ECOSYSTEM SCIENCE AND ASSESSMENT – NOVEMBER 2024

Report of the 17th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA)

NAFO Headquarters, Halifax (Canada)
12-21 November 2024

Contents

Recommended Citation

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.

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

12-21 November 2024

1. Opening by the co-Chairs

The NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA) met during 12-21 November 2024 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 08:36 (Halifax Time) on 12 November 2024 by the co-Chairs, Mar Sacau Cuadrado (EU) and Alfonso Pérez (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 Appendix 1. A list of participants is presented in Appendix 2.

2. Appointment of Rapporteur

The NAFO Secretariat (Dayna Bell MacCallum and Jana Aker) 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 (2024)

During 2024, *R/V Vizconde de Eza* carried out three surveys: 1) In Division 3L (Flemish Pass) sampling between 117 - 1482 meters depth, with a total of 95 tows (94 valid); 2) In Division 3M (Flemish Cap) sampling between 128 - 1428 m depth, with a total of 186 tows (181 valid); and 3) In Divisions 3NO (Grand Banks of Newfoundland) sampling between 45 - 1460 m depth with a total of 116 tows (112 valid). In total there were 397 bottom trawl tows, ten of them considered invalid due to technical problems during the fishing operation. 139 hauls out of 387 valid tows have shown zero catches (i.e. no presence) of VME indicator species groups. This represents 35.92% 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 142 of the 387 valid tows (36.7% of the valid tows analyzed), with depths ranging between 45 - 1482 m. There were four significant catches of sponges (≥ 100 kg/tow) in these tows, two of them fell within the VME polygons for sponges. Inside VME closures, sponges were recorded in 3 of the 7 valid tows (43%), one of which had a significant catch of sponges. Large gorgonians were recorded in 9 of the 387 valid tows (2.3% of valid tows analyzed), at mean depths between 228 and 1332 m. There was one significant catch of large gorgonians (≥ 0.6 kg/tow) in these tows, which fell outside the VME polygons for large gorgonians. No large gorgonians were recorded inside VME closures during the EU 2024 surveys. Small gorgonians were recorded in 67 of the 387 valid tows (17.3% of valid tows analyzed), at mean depths between 65 and 1440 m. There were five significant catches of small gorgonians (≥ 0.2 kg/tow) in these tows, two of them fell within the VME polygons for small gorgonians. Inside VME closures, small gorgonians were recorded in 4 of the 7 valid tows (57%), and there was one significant catch, with specimens identified as *Radicipes* sp. and *Acanella arbuscula*.. Sea pens were recorded in 156 of the 387 valid tows (40.3% of valid tows analyzed), at mean depths between 103 and 1482 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. Inside VME closures, sea pens were recorded in 4 of the 7 valid tows (57%), and there were no significant catches of sea pens in these tows. In the set with significant catch, specimens were identified as *Anthoptilum* sp. Black corals were recorded in 49 of the 387 valid tows (12.7% of valid tows analyzed), at mean depths between 212 and 1460 m. There were no significant catches of black corals (≥ 0.4 kg/tow) in these tows. No black corals were recorded inside VME closures or VME polygons for black corals during the EU 2024 surveys. *Boltenia* sp. were recorded in 9 of the 387 valid tows

(2.3% of valid tows analyzed), at mean depths between 50 and 228 m. There were three significant catches of *Boltenia* sp. (≥ 0.35 kg/tow) in these tows, two of them fell within the VME polygons for *Boltenia* sp.. No *Boltenia* sp. were recorded inside VME closures during the EU 2024 surveys. In the sets with significant catch, specimens were identified as *Boltenia ovifera.* Bryozoans were recorded in 32 of the 387 valid tows (8.3% of valid tows analyzed), at mean depths between 112 and 1227 m. There were no significant catches of bryozoans (≥ 0.2 kg/tow) in these tows. Inside VME closures, bryozoans were recorded in 2 of the 7 valid tows conducted inside VME closures (29%), and there were no significant catches of bryozoans in these tows

ii) Canadian Surveys (2023 Fall / 2024 Spring)

In the Fall of 2023 and Spring of 2024, the Canadian Multispecies Surveys, conducted by Fisheries and Oceans Canada, DFO (McCallum and Walsh, 1996), sampled the Grand Bank of Newfoundland (NAFO Divisions 3LNO) between mean depths of 39 - 1404 m, with a total of 134 tows (126 valid). The Fall 2023 sets that fell within the NRA were conducted using the *CCGS Cabot* (35% of all sets, with one unsuccessful set), CCGS 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 that fell within the NRA were conducted using the *CCGS Cabot* (61% of all sets, with four unsuccessful sets), and *MV Calvert* (39% of all sets, with one unsuccessful set). 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 (Divisions 3LNOPs) and fall (Divisions 2HJ3KLNO) multispecies surveys. 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). Comparative fishing data on corals, bryozoans and *Boltenia* sp. (i.e., *Boltenia ovifera*) were insufficient for the development of conversion factors across these surveys. Given that we are unable to inform on the relative catchability of these taxa between the previous vessels and the new vessels using the modified survey trawl, caution should be taken when interpreting the data presented here based on the new vessels. For the CCGS Teleost-Cartier/Cabot comparison (Fall 2021-2022, 2HJ3KL) and CCGS Needler-Cabot comparison (Fall 2021-2022, Fall 3KL), analysis indicated that no significant difference in catchability of sponges, and conversion factors do not need to be applied for these taxa (DFO 2024, in press). Due to operational constraints, data on corals collected during the Fall 2023 & Spring 2024 Canadian surveys were not available for this report and will be presented at WG-ESA in 2025. Results of the 2023 and 2024 combined data (and vessels) showed that sponges were recorded in 121 of the 126 valid tows (96.03% of valid tows analyzed), at mean depths between 48 and 1404 m. There were no significant catches of sponges (≥ 100 kg/tow) in these tows. Inside VME closures, sponges were recorded in all five of the valid tows conducted inside VME closures. *Boltenia* sp. were recorded in 7 of the 126 valid tows (5.56% of valid tows analyzed), at mean depths between 50 and 223 m. There were two significant catches of sea squirts (≥ 0.35 kg/tow) in these tows, both of which fell within the VME polygons for *Boltenia* sp., while no *Boltenia* sp. were recorded inside VME closures. Bryozoans were recorded in 31 of the 126 valid tows (24.6% of valid tows analyzed), at mean depths between 39 and 670 m. There was one significant catch of bryozoans (≥ 0.2 kg/tow), which fell outside both the VME closures and the bryozoan polygons.

Above information of EU, EU-Spain and Canadian surveys, including distribution maps of VME species groups, is further detailed in SCR Doc. 24/064. Following the presentation, WG-ESA participants provided suggestions pertaining to the VME encounters SCR (SCR Doc. 24/064; Abalo-Morla et al., 2024). One of the suggestions was to include an explanation regarding the largely absence of bryozoan records in Divisions 3NO of the EU surveys in order to better understand sources of uncertainty in these records. It was also suggested to include a reference to a complementary SCR document in which an initial investigation of the temporal trends in VME encounters in the NRA was presented. These suggestions were implemented, and the temporal trends were presented in a separate SCR (SCR Doc. 24/065; Command et al., 2024).

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. The study was funded by the European Union NextGenerationEU within the framework of the Agreement between the Ministry of Agriculture, Fisheries and Food and the State Agency of the Spanish National Research Council, M.P. -through the Spanish Institute of Oceanography- to promote fisheries research as a basis for sustainable fisheries management, of the Recovery, Transformation and Resilience Plan of the Government of Spain. 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, VWH, and RC acknowledge DFO-NL personnel and Canadian Coast Guard captain and crew for Canadian data collection.

References:

Abalo-Morla, S., Sacau, M., Neves, B.M., Hayes, V., Command, R. J., and Durán-Muñoz, P. 2024. New preliminary data on VME encounters in NAFO Regulatory Area (Divs. 3LMNO) from EU: EU-Spain and Portugal Groundfish Surveys (2024) and Canadian surveys (Fall 2023 & Spring 2024). NAFO SCR Doc. 24/064 Serial No. N7602.

Command, R.J., Neves, B.M., Abalo-Morla, S., Sacau, M., Hayes, V., Durán-Muñoz, P. (2024). Preliminary temporal trends in VME encounters in NAFO Regulatory Area (Divs.3LMNO) from EU: EU-Spain and Portugal Groundfish Surveys and Canadian RV Surveys (2008-2022). NAFO SCR Doc. 24/065 Serial No. N7603.

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

DFO (In press). Newfoundland & Labrador Comparative Fishing Analysis – Part 2. In DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.

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.

iii) Preliminary temporal trends in VME encounters in NAFO Regulatory Area (Divisions 3LMNO) from EU: EU-Spain and Portugal Groundfish Surveys and Canadian RV Surveys (2008-2022)

In response to feedback from the 16th WG-ESA meeting in 2023, preliminary temporal analysis of VME indicator catches in the NAFO Regulatory Area (Divisions 3LMNO) were presented. This analysis included data from EU, EU-Spain and Portugal, as well as Canadian bottom trawl groundfish surveys for the period of 2008-2022 (and 2023 for the EU data). A total of 5808 valid trawl sets were performed during the EU surveys (1272 sets in Division 3L, 2809 sets in Division 3M, and 1727 sets in Divisions 3NO), while 1871 sets were performed during Canadian surveys. For this exercise, Canadian and EU data were pooled. Given the nuances associated with a temporal analysis of VME catches in the NRA, only summary tables and plots of the proportion of total and significant VME catches accordingly to each year in the NRA, in corresponding VME closures and VME polygons, were presented. Although the data were not statistically assessed, strong temporal patterns were generally not observed, except for a noticeable decreasing trend in the proportion of sponge catches. This trend could be partially attributed to changes in survey behavior in 2018 to avoid closures in Division 3M, following the NAFO recommendation that "*scientific bottom trawl surveys in existing closed areas be avoided if possible and additional work be conducted as soon as possible to further evaluate the implications of excluding RV surveys in closed areas on stock assessment metrics*" (NAFO, 2017). Additionally, several factors were noted to complicate the exploration of data and pose challenges for further trend analyses. These factors include: i) changes in the number and boundaries of VME closures and VME polygons, ii) updates to thresholds for significant catches as new data become available, iii) changes in RV survey behavior, and iv) industrial activities within the NRA (e.g., oil and gas). Overall, during the meeting there was a general agreement that further analysis of the VME catch time series would be valuable, and several recommendations were made. It is expected to further develop out research questions and study design in 2025, with input from other WG participants, for presentation in the 2025 WG-ESA meeting. Above information is further detailed in SCR Doc. 24/065.

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. 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, VWH, and RC acknowledge DFO-NL personnel and Canadian Coast Guard captain and crew for Canadian data collection.

References

Abalo-Morla, S., Sacau, M., Neves, B. M., Hayes, V., Command, R. J., and Durán-Muñoz, P. (2023). New preliminary data on VME encounters in NAFO Regulatory Area (Divs. 3LMNO) from EU: EU-Spain and Portugal Groundfish Surveys (2023) and Canadian surveys (Fall 2022 & Spring 2023). NAFO SCR Doc., 23/055. Serial no. N7485.

Abalo-Morla, S., Sacau, M., Neves, B. M., Hayes, V., Command, R. J., and Durán-Muñoz, P. (2024). New preliminary data on VME encounters in NAFO Regulatory Area (Divs. 3LMNO) from EU: EU-Spain and Portugal Groundfish Surveys (2024) and Canadian surveys (Fall 2023 & Spring 2024). NAFO SCR Doc., 24/064. Serial no. N7602.

Anderson, S. C., Ward, E. J., English, P. A., Barnett, L. A. K., and Thorson, J. T. (2024). sdmTMB: An r package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields. bioRxiv, 2022.03.24.485545. https://doi.org/10.1101/2022.03.24.485545

Kenchington, L. C., E. (2019). Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc., 19/058. Serial no. N7030.

NAFO, 2008. Scientific Council Meeting. NAFO SCS Doc., 08/26. Serial no. N5594.

NAFO, 2009. Report of the Working Group on the Ecosystem Approach to Fisheries Management WGEAFM. NAFO SCS Doc., 09/6. Serial no. N5627.

NAFO, 2013. Report of the 6th Meeting of the NAFO Scientific Council Working Group of Ecosystem Science and Assessment (WG-ESA) [Formerly WGEAFM]. NAFO SCS Doc., 13/24. Serial no. N6277.

NAFO, 2017. Report of the Scientific Council Meeting. NAFO SCS Doc., 17-16 REV. Serial no. N6718.

R Core Team. (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/

b) ToR 1.2. Visual observations from seabed surveys in the Flemish Pass area (NRA) and 3O coral closure (Canadian)

i) Visual observations from seabed surveys in the Flemish Pass area (NRA) and 3O coral closure (Canadian)

Bárbara de Moura Neves[1], Rylan Command[1], Jordan Sutton[1], David Cote[1].

[1]Fisheries and Oceans Canada, Newfoundland and Labrador Region

This presentation focused on two seafloor video surveys: one conducted in the NRA and one in the 3O coral closure (Canadian side). In 2024, Equinor published an Environmental Seabed Survey Program report based on seafloor imagery surveys conducted in 2023 at two sites (named Sitka and Cappahayden) in the NAFO Regulatory Area (NRA). Here, we presented data on corals and sponges based on the report published by Equinor (Equinor 2023 Survey Project No. TE23721001. Equinor Canada Ltd, available at equinor-2023-survey-report.pdf). The Sitka survey took place at ~850 m depth, while Cappahayden was at ~900 m, and both sites fall outside of current NAFO closures and VME polygons. Primary substrate was classified as "fine" for both sites, with sea pens, small gorgonians, soft corals, and cup corals being observed. Neither large gorgonians nor black corals were observed at either site. Sea pens were the most abundant coral, reaching total abundances of >67,000 and densities of >14 colonies.m^{-2} at Sitka, and over 76,000 and densities of >6 colonies.m^{-2} in

Cappahayden. Sponges were rarely observed at both sites. Trawl marks were frequent in Cappahayden, but not at Sitka. The high sea pen densities highlight the importance of these sites as potential VMEs, although these have not been formally assessed. The Sitka site falls within an active oil and gas Exploratory license, while Cappahayden falls within a Significant Discovery license.

The 3O closure survey was conducted as part of DFO Newfoundland and Labrador Region's Marine Conservation Targets (MCT) seafloor surveys associated with the monitoring of Canadian Marine Refuges (i.e., OECMs) and MPAs. A total of 15 stations were surveyed in August of 2024 using a drop camera system deployed between 704-1334 m depth, and preliminary observations about coral distribution were presented. Sea pen fields were identified at some stations (mostly *Pennatula aculeata*), but not all. Cup corals were also commonly observed, while brittle stars were the most common organism observed at some sites. A full video analysis is expected to take place through 2025.

ii) Method to assess the presence of Pennatula aculeata

Claude Nozères[1], Ellen Kenchington[1], Laurence De Clippele[2], Jinshan Xu[1]

[1]Canada
[2] UK

Several sea pen species, including *Pennatula aculeata*, are known to fully withdraw into the seafloor sediment. This behaviour was recently noticed in a time series with photos taken every 30 m from October 2022-July 2023 from a fixed site in The Gully (Nova Scotia, Canada). Because of the large dataset (12,054 photos), three different techniques were explored to evaluate the visible presences of *P. aculeata*. First, a machine learning tool (RootPainter) took eight hours to classify the total area of sea pens visible in a selected clear portion of the photo. Photos with low values of classified area (sum of pixels) suggested periods of withdrawals (absences). Next, a web annotation tool (BIIGLE) was applied manually, providing individual details on each sea pen. As it would take months to annotate all photos, a subset of one photo per week was annoted, which was accomplished in a few hours. The results were broadly similar as machine learning, suggesting periods when most sea pens were expanded or withdrawn. Finally, a photo catalogue (Adobe Lightroom) was used to analyze sea pens across all photos with a multi-step workflow applied over several days. First, an ID number was applied to each sea pen that was clearly visible in the photos, for a total of 57 *P. aculeata* colonies. The photos were then cropped for 22 of the numbered sea pens. Each cropped set was reviewed and tagged with colour labels representing three states: expanded, partially withdrawn, or withdrawn (= absent). The labels were then available as data on individuals and the group. Presences in photos were as high as 22 and as low as 3, at similar periods as seen in the other methods, that is, the end of October, December, and June. Photos with the highest and lowest values in RootPainter and Lightroom were also annotated in BIIGLE for review. Overall, total counts of *P. aculeata* in the clear area of the photo (about 2/3, approximately 5 m^2) could vary ten-fold, from about 5 to over 50. This variability over time could have consequences for monitoring this species in VMEs. Two other sea pen species (*Balticina finmarchica*, *Ptilella grandis*) were also present in the photos; while they did not fully withdraw, their behavior was briefly mentioned, including movement of *B. finmarchica* and predation on the *P. grandis* by a *Hippasteria* sea star. The environmental correlations for the withdrawals have not yet been investigated, although it was suggested water currents like tides might be involved. Increased water turbidity was mentioned as an important factor for *Pennatula* withdrawal in the NE Atlantic. In contrast, sea pens at this site seemed to be expanded in presence of marine snow, though this might need further review. It was mentioned that the observed behavior could be particular for the site or other factors. It would be useful to do other long-term time series observations before suggesting correction factors on counting sea pens using this dataset. The method for counting *P. aculeata* shown here will be published in an upcoming DFO report, with forthcoming analyses to be presented as an update to WG-ESA 2025.

Figure 4.1. Example of a machine learning tool classifying the areas of the image as sea pens (red).

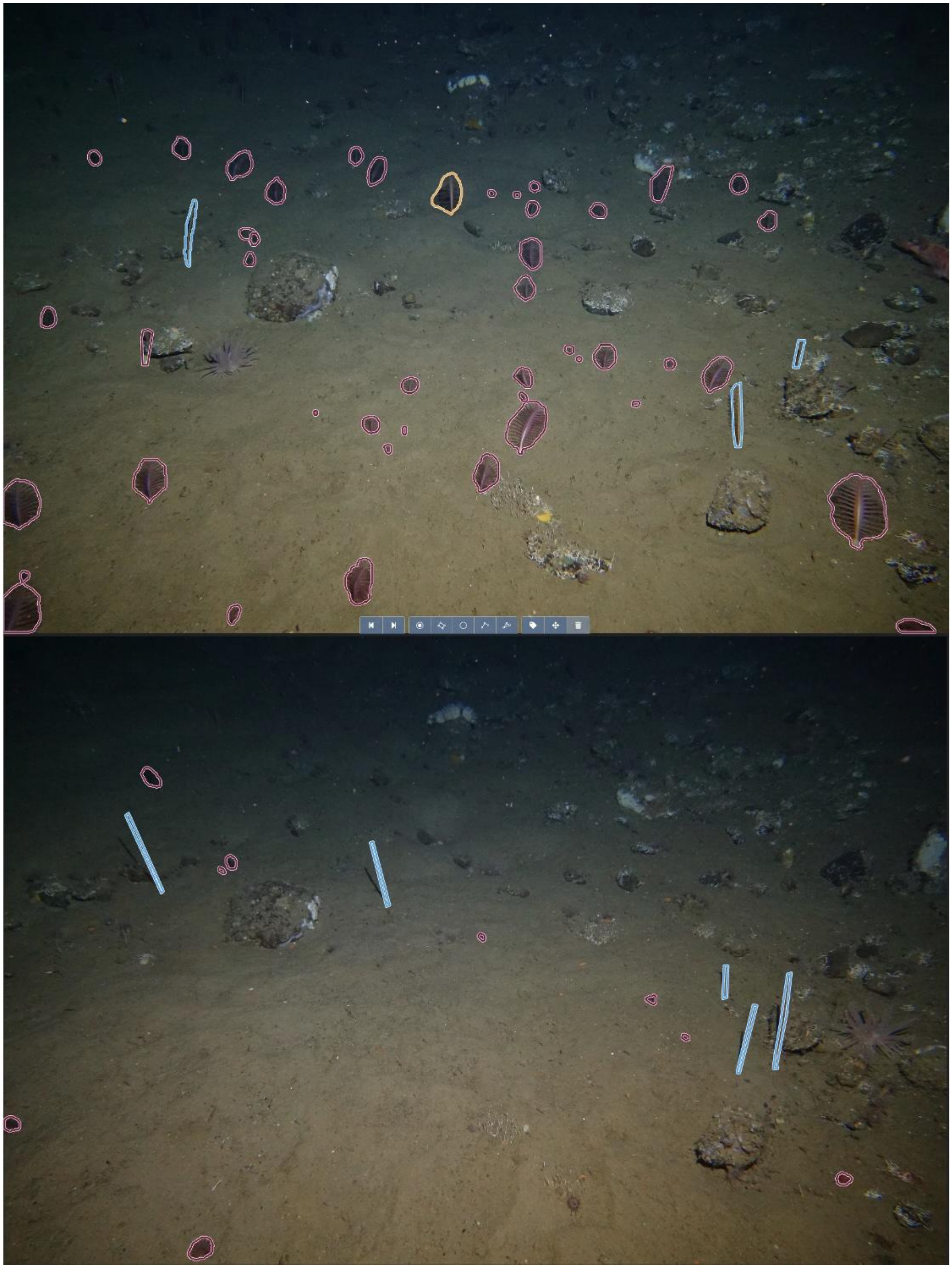

Figure 4.2. Examples of annotated sea pens (red=*Pennatula aculeata*, blue=*Balticina finmarchica*, orange=*Ptilella grandis*) on the BIIGLE web platform, showing a photo with many *P. aculeata* (top) and another photo when very few were visible (bottom).

Figure 4.3. Photo catalogue tagging a sea pen for its state as expanded, partial, or withdrawn.

References

Nozères, C., De Clippele, L. H., Xu, J., and Kenchington, E. 2024. Protocol for counting sea pens at a fixed site over time using machine learning, image annotations, and photo cataloguing. Can. Manuscr. Rep. Fish. Aquat. Sci. **in press**.

c) ToR 1.3. Update on the centralized data repository using ArcGIS online portal (COM Request #6a)

COM Request #6a: *Continue the development of a centralized data repository using ArcGIS online to host the data and data-products for scientific advice, in conjunction with the NAFO Secretariat*

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 2023 annual meeting (NAFO, 2023). These included:

1. Identifying a suite of standard data layers to be included in the repository
2. Proposing suitable metadata standards for hosted layers
3. Informing on the optimal projections to use for data visualization and analysis
4. Developing naming systems and organization structure for hosted layers
5. Documenting proposed workflows as well as outlining roles and responsibilities for data management

In support of this work, the Secretariat provided the Data Subgroup with one ArcGIS Online Creator license to access the existing NAFO ArcGIS Online Portal during the intersessional period. In preparation for the 2024 WG-ESA meeting the Data Subgroup was able to:

1. Upload a subset of standard data layers to the NAFO ArcGIS Online Portal
   - NAFO Regulatory Area
   - NAFO Divisions
   - NAFO Footprint
   - NAFO VME & Seamount Closures
   - Canadian OECMs
   - Gridded Biomass
   - Commercial Catch
   - Standard Polygon & Raster Grids (1 km & 5km)
2. Test the proposed file organization structure, naming system, and privacy settings for layers uploaded to the NAFO ArcGIS Online Portal
3. Draft a preliminary version of a standard metadata form to accompany data layer submissions
4. Develop a website using ArcGIS Hub with an embedded interactive mapping application for WG-ESA members to access, visualize, and download relevant data and data-products hosted on the NAFO ArcGIS Online Portal
5. Use ArcGIS StoryMaps, a web-based communication tool used to create and share interactive content, to document step-by-step instructions for Data Subgroup members to follow when updating and/or modifying the: data layers, ArcGIS website, and interactive mapping application
6. Research and compile preliminary information on license, license management, and storage costs for financial forecasting purposes
7. Moderate initial discussions about how to streamline RV Trawl data requests and store these data

Progress made during the intersessional period, as detailed above, was presented to the WG-ESA at the annual meeting in November 2024. Members were also given a demonstration of the NAFO Data Repository website, administrative tools, and the associated interactive mapping application. Feedback from the WG-ESA indicated good support from the membership to continue work on the data repository, with some items, outlined below, being raised for further consideration by the Data Subgroup.

i) Financial Forecasting

The NAFO Secretariat indicated that they are unable to cover the proposed costs of the centralized data repository without first receiving support from the Commission and Scientific Council. They also informed the WG-ESA that the 2025 budget estimate had been finalized and that any costs associated with the centralized data repository (e.g. licensing and storage costs) had not been included for the upcoming fiscal year. They recommended that the Data Subgroup prepare a more detailed breakdown of the anticipated costs associated with the centralized data repository (e.g. licenses and credits) to share by May 2025 for consideration in the 2026 budget meeting.

ii) Licensing

The NAFO Secretariat expressed that they would need more information on the license-management model to ensure that access to licenses would be in compliance with the ESRI End User Licensing Agreement (EULA). The Secretariat also expressed concern over increased workload to NAFO staff with the added responsibility of managing licenses. The Data Subgroup proposed that the Secretariat acquire one Viewer license ($220 CAD) for use during the intersessional period to allow them to better evaluate and address these concerns, which the Secretariat indicated would be possible to do.

iii) Privacy

Members of WG-ESA did ask for assurance that access to the data hosted on the centralized data repository would be controlled. The Data Subgroup indicated that these considerations had been made and that privacy settings would be managed to ensure internal data could only be accessed by WG-ESA members, and Secretariat staff with licenses purchased for use with the NAFO ArcGIS Online Portal. The Data Subgroup also reiterated that access to a Viewer license during the intersessional period would allow them to further assess appropriate privacy settings.

iv) Data Storage

WG-ESA members discussed the amount of data that should be uploaded to the centralized data repository. Some members hoped to see raw data, intermediate data layers, and data products all uploaded and stored long-term, while others indicated that it may be more reasonable to determine what layers be uploaded, and for how long, on a case-by-case basis. The Data Subgroup and other members of the WG-ESA did highlight that some data like raw VMS pings, for which access is only permitted by request on a project specific basis, would have to be stored in a way which limited access to only those members who had been granted permission.

It was noted that the cost of data storage varies depending on what layers are added and how they will be consumed by users. Specifically, files stored in their native format for direct download by users (e.g. shapefiles, .tiff, .gdb) or as imagery layers (e.g. raster files added for viewing in mapping applications) would be the least expensive. In contrast, feature layers, (e.g. vector files added for viewing in mapping applications), would be more expensive (Table 4.1). Considering this, WG-ESA members discussed the necessity of the mapping application, but felt that it would not only support simple mapping requirements of WG members but also be a useful tool for managers to visualize results of analyses when evaluating management options. The Data Subgroup noted that not all files on the repository would need to be uploaded as feature/imagery layers, and indicated that as work continued it would become easier to forecast costs and identify plans for best managing feature/imagery layers. The Data Subgroup also indicated that there would be no additional cost associated with file storage in the upcoming year. With assistance from WG-ESA members, the Data Subgroup compiled a list of the data layers that would be needed for the SAI reassessment (Table 4.2) to use in calculating storage requirements and associated costs for the Secretariat to consider for the 2026 budget.

Table 4.1. Breakdown of the credit usage for file storage on ArcGIS Online

	Native Layer	**Feature Layer**	**Imagery Layer**
Credits	1.2	2.4	1.2
File Size (mb)	1024	10	1024

Table 4.2. Overview of the data layers required for SAI reassessment and proposals of how the layers would be uploaded to the centralized data repository (e.g. for download, for viewing). (*) indicate groups of associated layers that are expected to be uploaded within File Geodatabases (.gdb).

	Layer Name	**Native Layer for Download**	**Feature/Imagery Layer for Viewing**	**# Layers**
Point	RV Trawl Data	yes (with restricted access)	no	1
	VMS Pings	yes (with restricted access)	no	1
	Logbook Records	yes (with restricted access)	no	1
	Merged VMS-Logbook	yes (with restricted access)	no	1
	VME Presence/Absence/Biomass	yes (with restricted access)	no	7*
Line	VMS Filtered Tracks	yes	no	1
	Logbook Filtered Tracks	yes	no	1
Polygon	VME Closures	yes	yes	1
	Seamount Closures	yes	yes	1
	VME Habitats	yes	yes	7*

	Layer Name	Native Layer for Download	Feature/Imagery Layer for Viewing	# Layers
	Fishing Footprint	yes	yes	1
	NRA	yes	yes	1
	NAFO Divisions	yes	yes	1
	1 km Standard Grid	yes	no	1
	5 km Standard Grid	yes	no	1
	1 km Gridded Biomass - VME Indicators	yes	no	1
	5 km Gridded Biomass - VME Indicators	yes	no	1
	1 km Gridded Biomass - VME Polygons - VME Indicators	yes	no	1
	5 km Gridded Biomass - VME Polygons - VME Indicators	yes	no	1
	1 km Gridded Biomass - VME Closures - VME Indicators	yes	no	1
	5 km Gridded Biomass - VME Closures - VME Indicators	yes	no	1
	VME Functional Polygon - Invertebrate - Bioturbation	yes	yes	4*
	VME Functional Polygon - Fish - Bioturbation	yes	yes	4*
	VME Functional Polygon - Invertebrate - Nutrient Cycling	yes	yes	4*
	VME Functional Polygon - Invertebrate - Habitat Provision	yes	yes	4*
	VME Functional Polygon - Functional Diversity	yes	yes	4*
Raster	1 km standard raster	yes	no	1
	5 km standard raster	yes	no	1
	VME KDE Raster	yes	no	7*
	1 km Gridded Biomass - VME Indicators	yes	yes	7*
	5 km Gridded Biomass - VME Indicators	yes	no	7*
	1 km Gridded Biomass - VME Polygons - VME Indicators	yes	yes	7*
	5 km Gridded Biomass - VME Polygons - VME Indicators	yes	no	7*
	1 km Gridded Biomass - VME Closures - VME Indicators	yes	yes	7*
	5 km Gridded Biomass - VME Closures - VME Indicators	yes	no	7*
	VME Functional KDE Raster - Invertebrate - Bioturbation	yes	no	4*
	VME Functional KDE Raster - Fish - Bioturbation	yes	no	4*
	VME Functional KDE Raster - Invertebrate - Nutrient Cycling	yes	no	4*
	VME Functional KDE Raster - Invertebrate - Habitat Provision	yes	no	4*
	VME Functional KDE Raster - Functional Diversity	yes	no	4*
	Fishing Stability (years fished/cell)	yes	no	1

	Layer Name	Native Layer for Download	Feature/Imagery Layer for Viewing	# Layers
	Fishing Intensity - Merged VMS-Logbook (hrs fished/cell)	yes	no	1
	Fishing Intensity - Merged VMS-Logbook - Cumulative Longliners (hrs fished/cell)	yes	no	1
	Fishing Intensity - Merged VMS-Logbook - By Fishery (hrs fished/cell)	yes	no	?
	Fishing Intensity - VMS Filtered Tracks (km/km2/year/cell)	yes	no	1
	Fishing Intensity - VMS Filtered Tracks - Cumulative Longliners (km/km2/year/cell)	yes	no	1
	Fishing Intensity - VMS Filtered Tracks - By Fishery (km/km2/year/cell)	yes	no	?
	Fishing Intensity - Logbook Filtered Tracks (km/km2/year/cell)	yes	no	1
	Fishing Intensity - Logbook Filtered Tracks - Cumulative Longliners (km/km2/year/cell)	yes	no	1
	Fishing Intensity - Logbook Filtered Tracks - by fishery (km/km2/year/cell)	yes	no	?
	Fishing Intensity - Trawl Tracks Filtered Tracks (km/km2/year/cell)	yes	no	1
	Fishing Intensity - Longlines Filtered Tracks (km/km2/year/cell)	yes	no	1
	Fishing Intensity - Total Catch	yes	no	1
	Fishing Intensity - Total Catch (90th percentile)	yes	no	1
	Fishing Intensity - Total Catch (95th percentile)	yes	no	1
	SDM - Inputs - Physical Variables	yes	no	33*
	SDM - Inputs - Biological Variables	yes	no	44*
	SDM - Inputs - Terrain Variables	yes	no	19*
	SDM Model Outputs for VME species	yes	no	70*

Members also expressed interest in how associated data and data products (e.g. supporting specific SCRs or SAI reassessment cycles) could maintain those linkages in the repository. The Data Subgroup indicated that adding tags to related data layers during upload would allow for this, improving findability of data layers.

There were also questions surrounding the utility of the centralized data repository for hosting scripts and reproducible reporting tools for access by members. The Data Subgroup indicated that there were plans to address how best to incorporate and manage these files as work on the data repository advances.

v) Metadata

The Data Subgroup presented a preliminary draft of the standard metadata form. Feedback indicated that there was support to simplify metadata requirements wherever possible to reduce the burden to data owners when compiling data packages for upload to the centralized repository. It was suggested that as much information as possible be included in the layer “Description” section and that text boxes be added to the standard metadata form to ensure consistent information be provided by data owners. More details on the lineage of the layers was recommended for inclusion in the metadata as part of the “Description” section as well as in the underlying “Lineage” section, which the Data Subgroup supported. The Data Subgroup also asked for feedback on what should be used as the “Publication Date” for layers. There was uncertainty whether this would be the date the layer was finalized by the data owner, the date the associated SCR was published, or the date the layer was uploaded to the centralized repository. WG-ESA members agreed that using the date of upload would be the most suitable as not all layers will be associated with an SCR and the date the layer was finalized could be more difficult to track. Nonetheless, it was recommended that the "Creation Date" also be included if it was available from the data owner. The preliminary draft of the standard metadata form was revised based on this feedback and will be tested as additional layers are added to the data repository (Figure 4.4).

NAFO Repository: Standard Metadata Form

All data layers must have a Standard Metadata Form completed prior to submission to the Data Subgroup. Please populate this form completely and submit it with your data layers for upload to the NAFO Data Repository.

Data Layer Title: Enter layer title	
Is there a publication(s) associated with this data layer?	Yes ☐ No ☐
Description: Enter brief description of layer Temporal Coverage: Enter year(s) Reference(s): Enter relevant publication(s) and/or report(s) Provided By: Enter Name Enter Role Enter Organization Enter Email Update Frequency: Select update interval Previous Versions: Enter previous version(s)	
Bounding Box: West (Left)	Enter in decimal degrees
East (Right)	Enter in decimal degrees
South (Bottom)	Enter in decimal degrees
North (Top)	Enter in decimal degrees
Creation Date (yyyy-mm-dd):	Enter date layer was created by owner
FOR DATA SUBGROUP USE ONLY	
Title of Upload:	Enter title assigned for upload to repository
Topic Category:	Oceans
Terms of Use (Use Limitation):	https://www.nafo.int/Terms
Language:	English
Character Set:	utf8
Publication Date:	Enter date layer was uploaded to repository
Metadata Scope (Hierarchy):	Dataset
Metadata Contact Role:	Resource Provider
Data Subgroup Member:	Enter name of individual performing upload

Figure 4.4. Revised Standard Metadata Form, based on feedback from WG-ESA members, to be tested during the intersessional period.

vi) Accessibility

Some members of the WG-ESA expressed that the centralized data repository should follow the FAIR principles of findability, accessibility, interoperability, and reusability, and that data should be made public wherever possible. Further to this, it was also mentioned that having data and data products be properly credited (e.g. Digital Object Identifiers (DOIs)) would benefit members. One member asked if the portal would be capable of providing access to data on the repository programmatically (e.g. Application Programming Interfaces (APIs)). This feedback was noted by the Data Subgroup to be researched and discussed further with members in future meetings.

vii) Upcoming Work:

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

- Expand the number of standard data layers that are hosted on the centralized data repository, prioritizing those associated with the SAI reassessment
- Trial the use of the Standard Metadata Form and revise as needed
- Trial the suitability of ArcGIS StoryMaps as a tool for documenting data management workflows to ensure business continuity
- Submit a more detailed breakdown of the costs associated with the centralized data repository to the NAFO Secretariat by May 2025
- When available, use the ArcGIS Online Viewer License to advance plans for license management
- Continue progress on streamlining RV trawl requests and standardizing management of these data on the repository

viii) References

NAFO, 2023. Report of the 16th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA), 14 - 23 November 2023, NAFO Headquarters, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 23/25.

d) ToR 1.4 Data management plan for RV trawl data, and standard template for storing RV trawl data in the NAFO-hosted ArcGIS Online portal (COM Request #6a)

COM Request #6a: *Continue the development of a centralized data repository using ArcGIS online to host the data and data-products for scientific advice, in conjunction with the NAFO Secretariat*

i) Data management plan for Research Vessel (RV) trawl data, and standard template for storing RV trawl data in the NAFO-hosted ArcGIS Online portal

In the course of addressing Commission requests and fulfilling its Terms of Reference, WG-ESA uses data from the scientific RV trawl surveys conducted in the NAFO Regulatory Area by Canada and the EU to complete various analyses. Over the years, the RV trawl data has been used in many forms, from full trawl data with biomasses of fish and invertebrates identified to the lowest taxonomic level possible, to total biomasses of groups of taxa indicative of a VME type (e.g., Sponges, Sea Pens, etc.). Discussions in the Working Group over 2021 – 2024 have highlighted the need to develop an agreed standard for preparation and presentation of such data sets.

A data submission protocol, outlined in Figure 4.5, was agreed in 2022 (NAFO, 2022). This included general suggestions for data format, key information to be included in the data provided and metadata to accompany data uploaded to a central data access system, such as an ArcGIS Online data repository, to make data more accessible and discoverable.

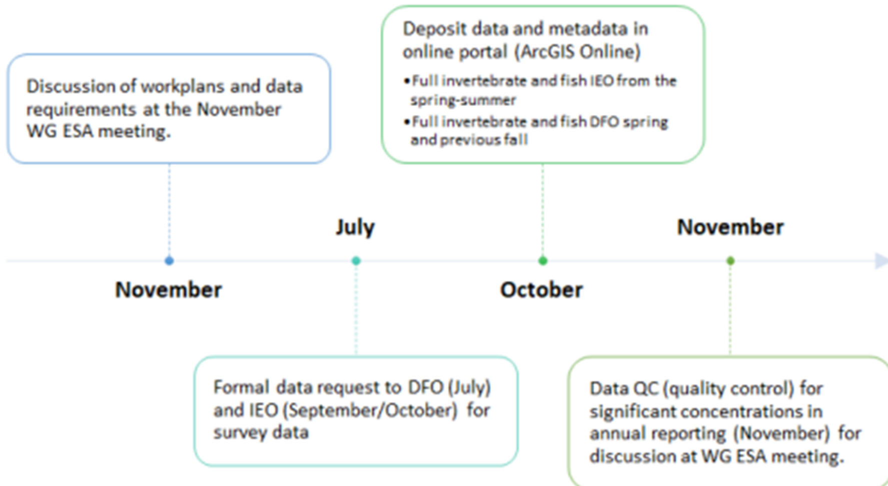

Figure 4.5. Data submission protocol (NAFO, 2022). Action points and timelines for the annual cycle of data collection from the scientific trawl surveys conducted by the EU (Spain, Portugal) and Canada (DFO NL) for use by WG-ESA.

During the 2023 meeting it was acknowledged that the data protocols could not be addressed further at the time of the meeting, as the NAFO-hosted ArcGIS Online portal for WG-ESA was not yet active.

In 2024, a first version of the ArcGIS Online data portal was presented to WG-ESA see section 4.c (i.e. ToR 1.3). This was used as a basis for further discussions on more concrete steps for requesting and delivering the RV trawl data.

ii) Data request process

The data request process for RV trawl data has thus far been informal, with individual WG-ESA members requesting data from the Department of Fisheries and Oceans (DFO) and Instituto Español de Oceanografía (IEO) for specific data analysis on an *ad hoc* basis. Both DFO and IEO have established data request forms, stating the data requested, the planned use, and details of the individuals accessing the data. DFO and IEO will provide the data based on a data agreement addressing the request. The data is provided with the understanding that it will be used solely for the specific purpose and will not be shared outside of the working group.

The WG-ESA data subgroup agreed that to reduce the administrative burden a move to a longer-term data agreement is preferable. WG-ESA suggests a move to a comprehensive data-sharing agreement, made on a five-year rolling basis, with each data provider. This is proposed to be made between the NAFO Secretariat and each institute. Authorization from the respective departments of DFO NL and IEO would be required prior to the implementation of such agreement. The agreement will set terms for the delivery and use of the RV data within the confines of WG-ESA activities. The terms will include:

- Specification of a time period (e.g. 2025-2030) during which data from RV trawls surveys will be delivered by DFO NL and IEO annually on completion of all required Quality Control (QC) steps;
- Specification of the geographical area data will be delivered for (e.g. NAFO Regulatory Area);
- Content, time period covered, and format of data, including the template used for data delivery;
- Specifics of data use, including the types of analysis and advice the data will be used for;
- Statement limiting data access exclusively to WG-ESA members performing analysis that addresses Commission Requests and the WG-ESA ToRs;
- Specifics of how the data is delivered, stored, and distributed to WG-ESA members; and
- Standard data source acknowledgement text that must accompany any presentation or publication of outputs using the data, with prior notification.

The group agreed further information was needed on the practicalities around whether, for the purposes of a data use agreement, the Working Group would be represented by the WG-ESA Chairs or by the NAFO Secretariat. This will be discussed with the Secretariat. The formats of the current DFO and IEO *ad hoc* data-sharing agreements can be used as a basis for the longer-term agreements.

Data will be delivered annually. However, QC of data makes it most practicable for data collected each year to be delivered early in the following year. Whilst this means data available for WG-ESA analyses is one year behind the RV trawl data collection, the data delivered will be fully QC'd, and less likely to be subject to change.

The use restriction statement included in the data agreement will specify the intended use for each type of data. This can, for example, specify:

1) types of statistical analyses (SDM, KDE, etc.),

2) spatial extent of analysis (including Canadian waters),

3) formats and forums where results can be shared (WG-ESA presentations and documents, scientific papers, conference presentations),

4) inclusion of data providers in any potential scientific publications,

5) NAFO Commission request/s that is/are going to be addressed by the group.

iii) Data product specification

The data to be produced under the agreements comprises the full RV trawl contents including catches of both fish and invertebrates, limited to those that have been consistently recorded and deemed reliable for analysis. This is necessary to ensure that the data is trustworthy and of sufficient quality for robust analysis. The main limitations are not related to confidentiality, but rather to ensuring clarity about which data is reliable enough for shared use. These limitations lie both in the quality of the data itself and in the ability to compile and QC it on time. Taxonomic level of the data should be the lowest reliably achievable and AphiaID should be included for invertebrates. The databases of each institute are constantly updated. Errors are identified and corrected, and further inspection of the samples can result in increasing taxonomic detail. Consequently, it is suggested that the full dataset is replaced each year, instead of appending each new year.

Templates are proposed for data and the accompanying metadata. The templates will ensure the data when uploaded on the portal will always be in the same format. The proposed data template fields are listed in Table 4.3.

Table 4.3. Fields included in the proposed RV trawl data delivery template.

Column Name	Description	Data Type	Example
Country	Survey country of origin.	Text	Canada or EU-Spain
Survey_Name	Name of the survey.	Text	Flemish Cap Survey
Vessel	Name of the vessel used for the survey.	Text	R/V Vizconde de Eza
Set	Consecutive numeric identifier assigned to each tow. First tow=1	Integer	1
Valid	Validity of the set.	Text	Yes/No
Gear	Type of gear used for the trawl.	Text	Lofoten or Campelen
NAFO_Division	The NAFO Division the trawling event took place.	Text	3M
Start_Date	Date at the start of the trawl event.	Date	dd-mmm-yyyy "26-JUL-2024"
Time_GMT	Time of the trawl event in Greenwich Mean Time (GMT).	Time	hh:mm:ss - 10:45:28
Year	Year of the trawl event.	Integer	2024
Month	Month of the trawl event.	Integer	7
Day	Day of the trawl event.	Integer	26
Start_Latitude_DD	The latitude at the start of a tow in decimal degrees.	Double	45.293568
Start_Longitude_DD	The longitude at the start of a tow in decimal degrees.	Double	-47.368425
End_Latitude_DD	The latitude at the end of a tow in decimal degrees.	Double	45.315896
End_Longitude_DD	The longitude at the end of a tow in decimal degrees.	Double	-47.345896
Min_Depth_m	The min depth of a trawl in meters.	Double	150
Max Depth_m	The max depth of a trawl in meters.	Double	700
Mean Depth_m	The mean depth of a trawl in meters.	Double	200
Functional_Group	Functional group classification of the species/taxon caught.	Text	Sea Pen
Scientific_Name	Scientific name of the species/taxon caught. Identified, with confidence, to the lowest taxonomic level possible.	Text	*Pennatula aculeata*
AphiaID	Unique identifier for marine species/taxon from the World Register of Marine Species (WoRMS).	Integer	128515
Total_Catch_Weight_kg	Total weight of the catch in kilograms.	Double	3.45

iv) Data delivery method and storage format

WG-ESA proposes that the raw RV trawl data delivered in the above standard template is compiled into a single CSV file. Once the data is compiled, a standard metadata form will be populated and the data package will be uploaded to the NAFO ArcGIS Online data repository. It is recommended that the file be uploaded in its native format (.csv) to be downloaded by users as needed for analysis. Only users who have been granted access to the repository can access and download the data.

Standard metadata forms should be prepared for any data products that result from subsequent analyses of the RV trawl data. The metadata will include a reference to the data agreement and a standard acknowledgement statement specified in the agreement. These should be uploaded and managed on the centralized repository independent of the raw data described above. If the data products are in shapefile or raster format, feature/imagery layers could be generated to allow the data to be viewed in web mapping applications if needed. It is recommended that any code generated to conduct analysis on the raw RV trawl data also be managed using the centralized data repository or a similar platform (e.g. GitHub), which could be access by WG-ESA members through the NAFO data repository website.

Questions that still need to be addressed include the roles of appointed WG-ESA members and the Secretariat in ArcGIS licence management and access, as well as responsibilities for upload of data to the repository. It is suggested that the templates and procedures are tested in 2025 for feedback at WG-ESA.

v) References

NAFO, 2022. Report of the Scientific Council Working Group on Ecosystem Science and Assessment, 15 - 24 November 2022, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 22/25.

NAFO, 2023. Report of the Scientific Council Working Group on Ecosystem Science and Assessment, 14 - 23 November 2023, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 23/25.

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. Update on the review of NAFO VMEs: Species Distribution Models of VME taxa and individual VME Indicators (COM Request #6b)

COM Request #6. *In relation to the habitat impact assessment component of the Roadmap (VME and SAI analyses), the Commission requests that Scientific Council:*

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.

i) Update on the review of NAFO VMEs

The Northwest Atlantic Fisheries Organization (NAFO) Commission has called for a reassessment of the vulnerable marine ecosystems (VMEs) and impact of bottom fisheries on VMEs for 2027, and for work on addressing the impacts of climate change on NAFO ecosystems. Two fundamentally different modeling approaches will be used to predict the distribution of VMEs in the NAFO Regulatory Area: 1) identification of significant concentrations of VME indicator species using geospatial kernel density analyses (KDE) applied to research vessel trawl survey catch data, and 2) species distribution modeling (SDM) which predicts the distribution of a species from a suite of environmental variables thought to influence it. In previous assessments, NAFO has used SDMs to modify the boundaries of the KDE-derived VME polygons to delineate VMEs, if the latter include areas of predicted species absence. With up to 12 additional years of data depending on the analysis, we will update previous KDE and SDMs for 7 VME 'functional groups': Large-sized Sponges, Sea Pens, Large Gorgonian Corals, Small Gorgonian Corals (first SDM), Black Corals, Sea Squirts and Erect Bryozoans. For the Large-Sized Sponges, Sea Pens and Small Gorgonian Corals there are now sufficient data to allow for modelling of subgroups of the data at various levels of taxonomic resolution. These will be compared to models produced for the functional groups to examine differential impacts of bottom fisheries through evaluation of the proportional protection afforded to these subgroups by the existing closed areas. SDMs will be performed under future environmental projections to determine climate refugia and vulnerabilities of the VMEs. This work will be done on the timetable presented in Table 5.1.

Table 5.1. Workplan for provision of vulnerable marine ecosystem (VME) data layers for the reassessment of the VMEs and impact of bottom fisheries on VMEs for 2027, and for work on addressing the impacts of climate change on NAFO ecosystems.

Task	Presentation at WG-ESA Meeting
Species Distribution Models of VME taxa and individual VME Indicators	WG-ESA 2024 WG-ESA 2025
Kernel Density Analyses to Identify VMEs	WG-ESA 2025
Climate Change Models and Identification of Refugia for VMEs	WG-ESA 2026 WG-ESA 2027

ii) Species Distribution Models of VME taxa and individual VME Indicators

Species Distribution Modelling of Large-sized Sponges, Sea Pens and Black Corals in the NAFO Regulatory Area

Species distribution modelling (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). Potential uses of SDMs include 1) explanation, 2) mapping and 3) transfer (Zurell et al., 2020), with the first focused on identifying the main factors driving the species distributions, the second on producing maps of the distribution, and the third on forecasting or projecting the distributions into a different geographic region or time period. The primary objective of the SDMs presented here is for 'Mapping' (Zurell et al., 2020). These models are particularly valuable in areas where the survey vessels do not sample (e.g., rough bottom, cliffs) and for non-aggregating taxa such as the black corals that are present in low frequency. The maps will also be used to evaluate the area between trawl sets to determine if the full vulnerable marine ecosystem (VME) polygon (derived from kernel density analyses which does not consider environmental variables (Kenchington et al., 2019)) is potential habitat, and to modify the boundaries of the VME polygons if they include areas of predicted species absence. The last was previously done to modify the VME polygons for Sponge Grounds and Large Gorgonian Coral VMEs (NAFO, 2019).

Here we present SDMs for the VME functional groups Large-sized Sponges, Sea Pens and Black Corals (mostly a single species *Stauropathes arctica*) (Figures 1-11). Within the Large-sized Sponges we also present models for the sponge grounds (as in Knudby et al., 2013), the sponge families Tetillidae and Polymastiidae (excluding species formerly considered in the genera *Radiella* (e.g., *Radiella hemisphaerica* currently accepted as *Polymastia hemisphaerica*) and Tentorium as they are not VME indicator taxa (NAFO, 2024)), as well as for the Astrophorina, a suborder of massive sponges in the class Demospongiae. We were not able to construct a new model for the glass sponge *Asconema foliatum* as the published data on this species (Murillo et al., 2016; NAFO, 2019) was collected in one year (2007) and were not provided for the analyses herein (see below). Within the Sea Pens, we present models for the genera *Funiculina*, *Balticina*, *Anthoptilum* and *Pennatula* (including *P. grandis* which has been reassigned to the genus Ptilella). These additional models will be used to compare the results of the predicted distributions of individual taxa versus that of their functional group. The later formed the original response data to earlier models as there were insufficient records for individual species, or a lack of confidence in the identifications of early records. The models for the subgroups will also be used to examine differential impacts of bottom fisheries and evaluate the proportional protection afforded to these subgroups by the existing closed areas.

Full details of the biological and environmental data, model fitting, variable importance and evaluation of model performance is presented in Murillo et al. (2024). All models generally scored high accuracy across the validation statistics (Murillo et al., 2024). The binary Presences/Absences maps are based on a threshold of Sensitivity=Specificity, which is the threshold where the chance of correctly predicting a positive or negative observation is the same. Previously, the ratio of Presences/Absences, or Prevalence, was used which produced very similar outputs (Murillo et al., 2024), however a threshold of Sensitivity=Specificity provides a more consistent approach and so will be used for the 2027 review of the closed areas. Another advancement over previous work is the presentation of uncertainty associated with the distributions. This is shown in three distinct ways: 1) inclusion of areas of model extrapolation (predictions outside of the data envelope of the input data) on all maps; 2) maps showing the frequency of Presences/Absences from the 10 cross-validation runs (values close to 1 give confidence in the Presences/Absences identified in the binary maps); and 3) maps of the average probability of the maximum frequency class from the 10 cross-validation runs (e.g., average probability associated to presence and absence areas). 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. Further details on the data distribution and illustration of the average probability of the maximum frequency class are reported in Murillo et al. (2024). The figures here are the ones that are expected to be used for the review of the VMEs at the WG-ESA 2026 meeting in the first instance to clip the VME polygons derived by KDE if needed, and secondly to apply to the assessment of bottom contact fishing activities.

iii) Large-Sized Sponges

Species distribution models were performed for the Sponge Grounds (Figure 5.1), the Large-Sized Sponge Functional Group (Figure 5.2), the sponge families Tetillidae (Figure 5.3) and Polymastiidae (Figure 5.4), and the suborder Astrophorina of the order Tetractinellida, containing the massive geodiid sponges amongst others (Figure 5.5).

iv) Sea Pens

Species distribution models were performed for the sea pen functional group (Figure 5.6) and the sea pen genera *Anthoptilum* (Figure 5.7), *Balticina* (Figure 5.8), *Funiculina* (Figure 5.9) and *Pennatula* (Figure 5.10).

v) Black Corals

Species distribution models were performed for the black coral functional group (Figure 5.11).

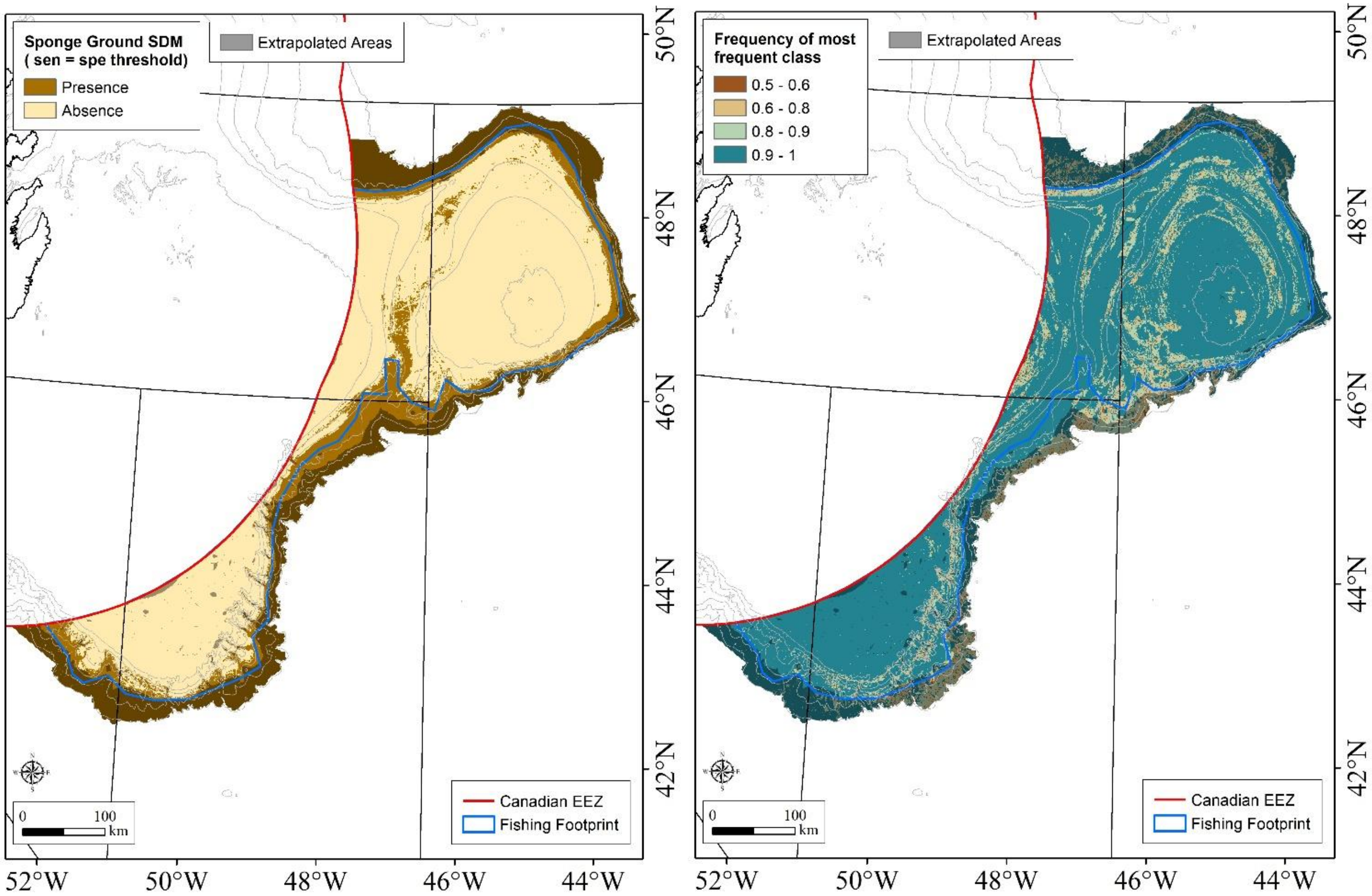

Figure 5.1. Predicted Presences/Absences of sponge ground VMEs in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

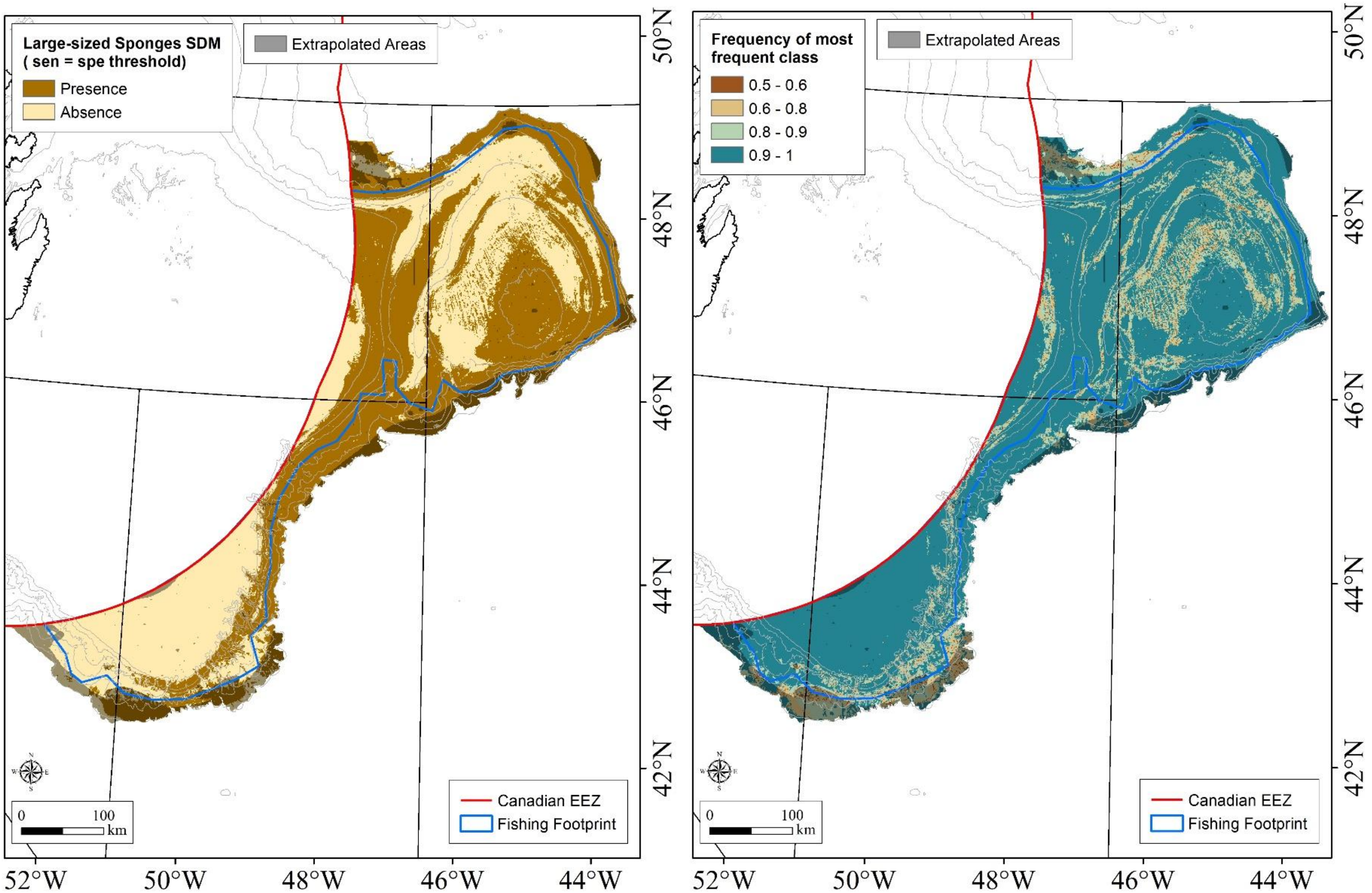

Figure 5.2. Predicted Presences/Absences of the Large-Sized Sponge Functional Group in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

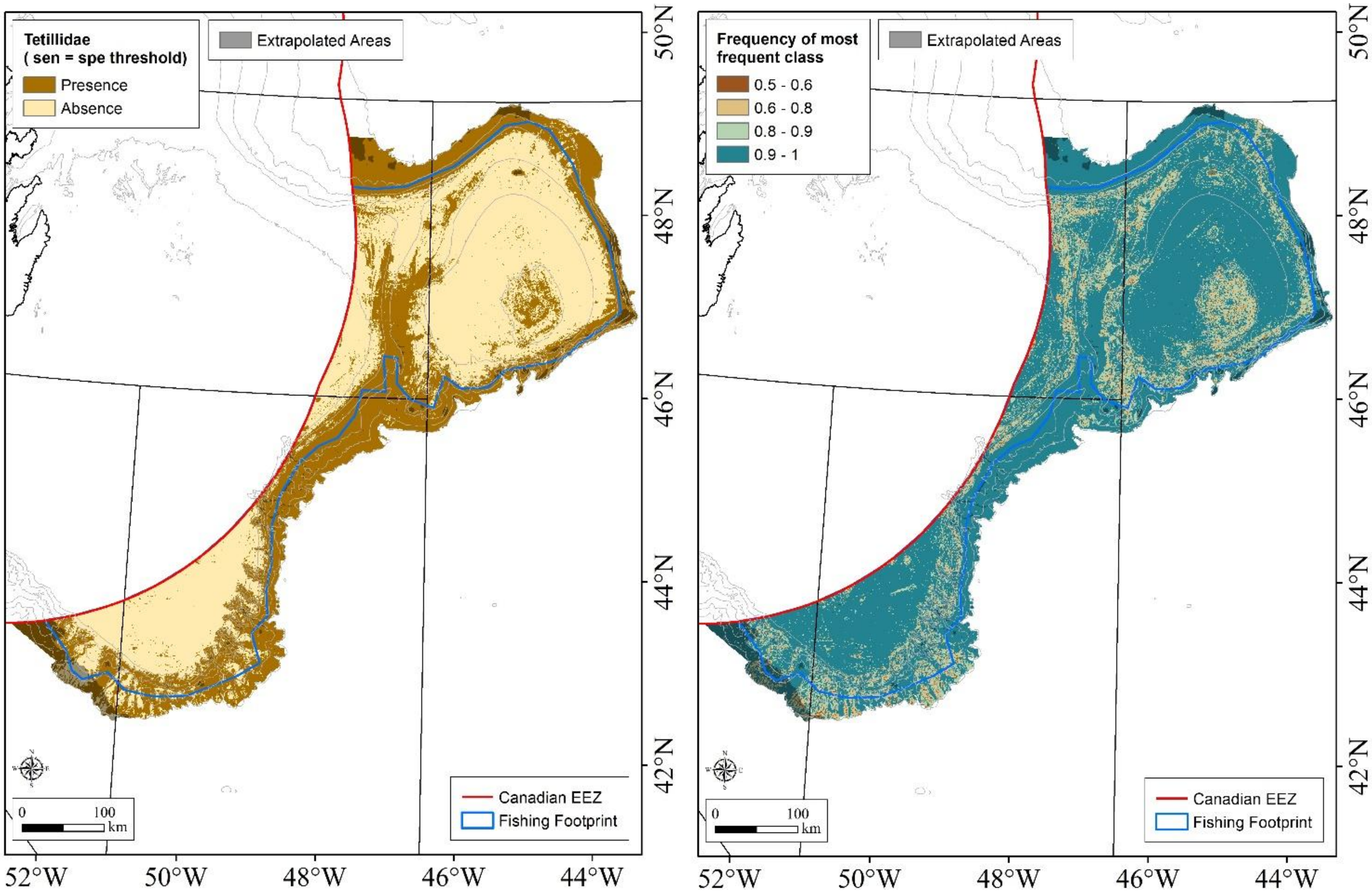

Figure 5.3. Predicted Presences/Absences of the Tetillidae sponges in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

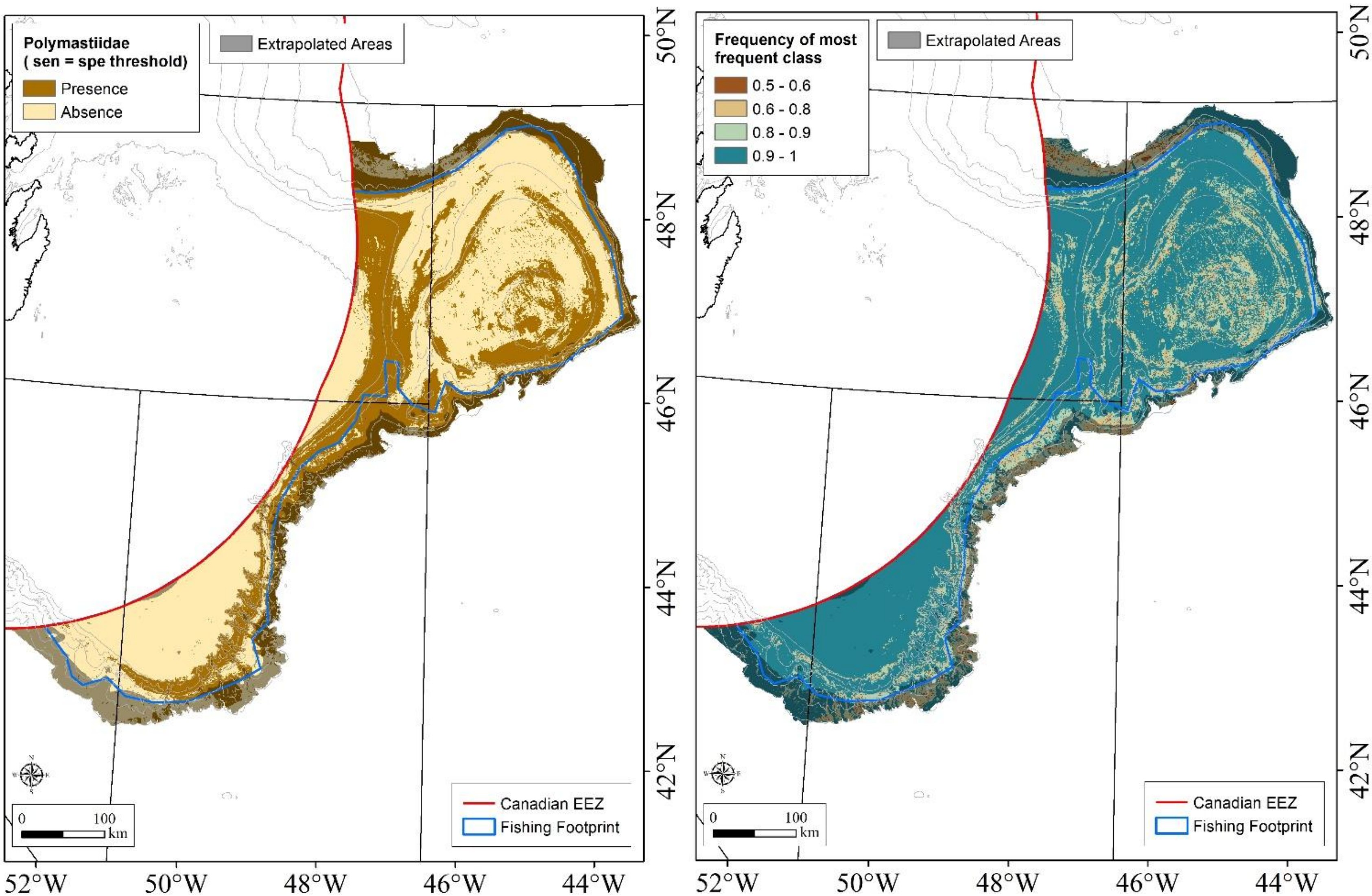

Figure 5.4. Predicted Presences/Absences of the Polymastiidae sponges in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

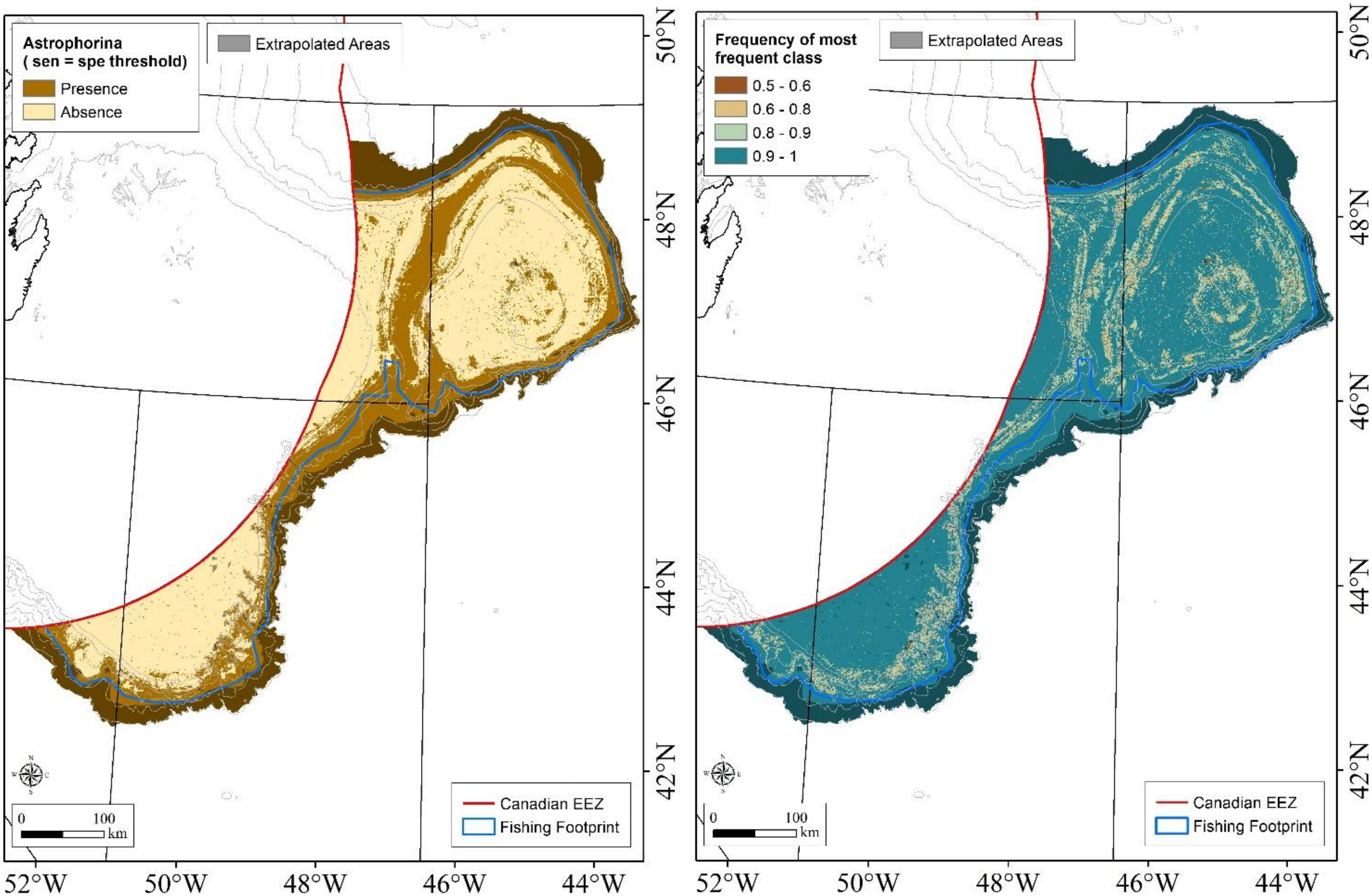

Figure 5.5. Predicted Presences/Absences of the Astrophorina sponges in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

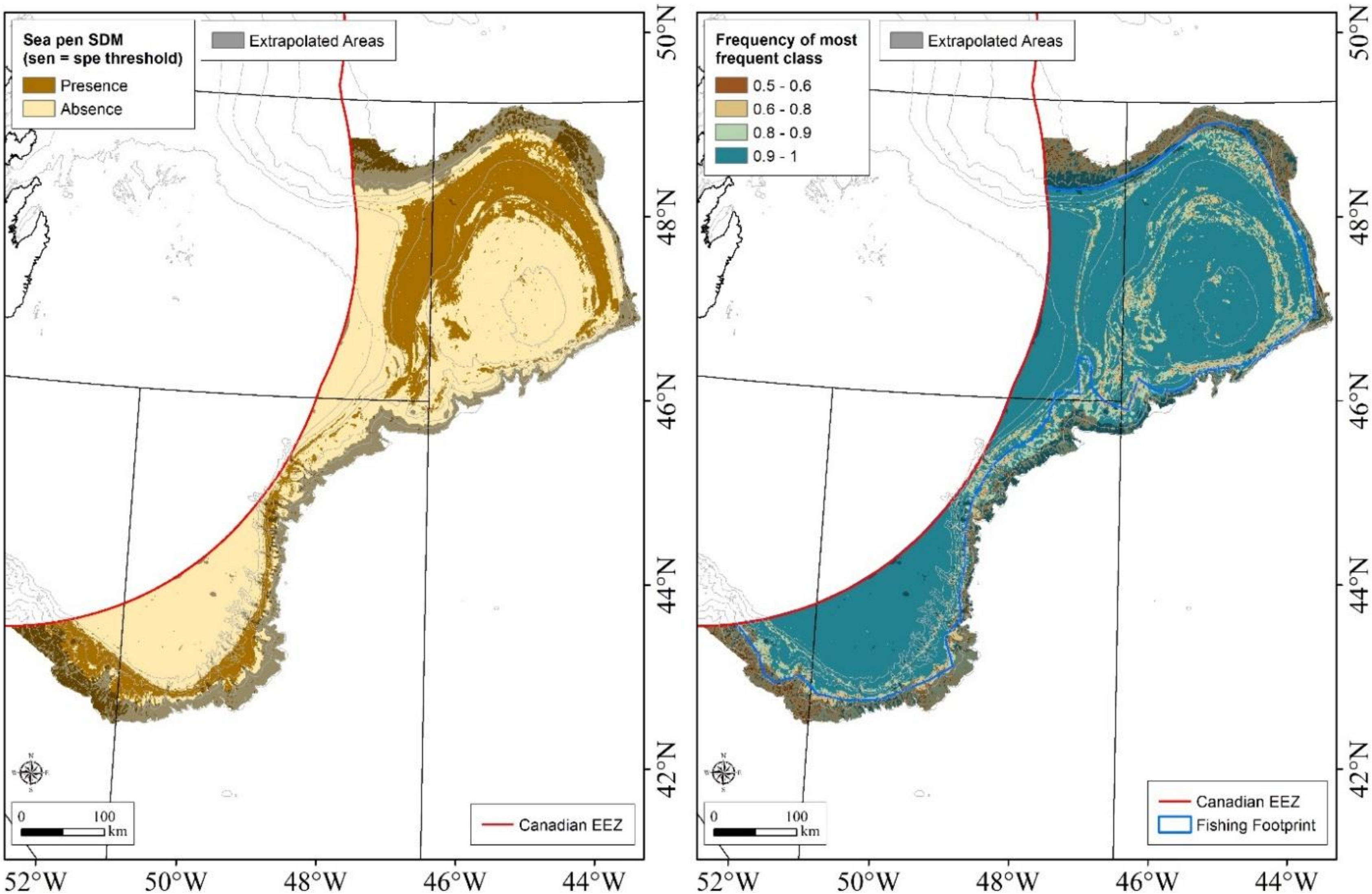

Figure 5.6. Predicted Presences/Absences of the Sea Pen Functional Group in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

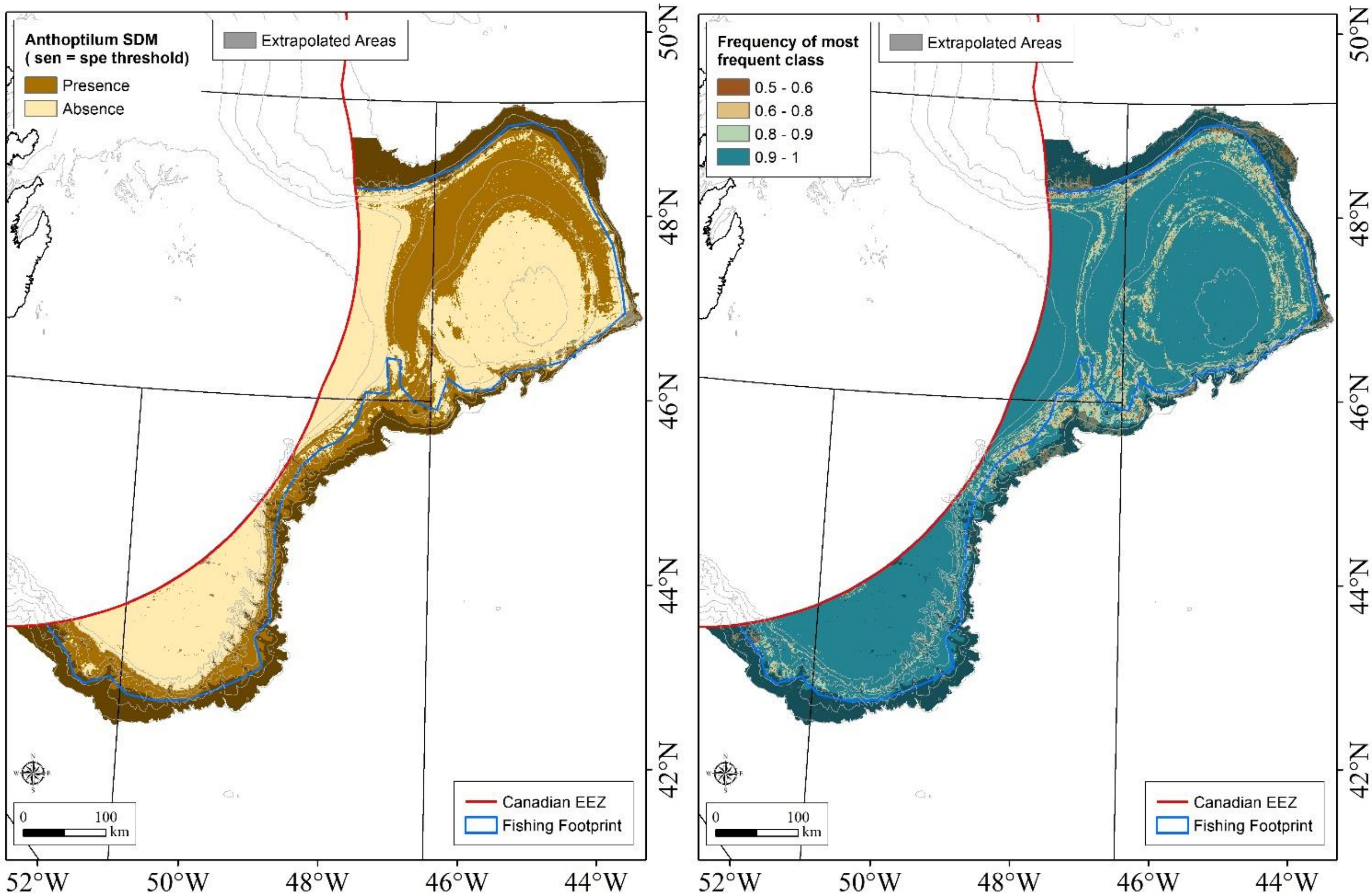

Figure 5.7. Predicted Presences/Absences of *Anthoptilum* spp. in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

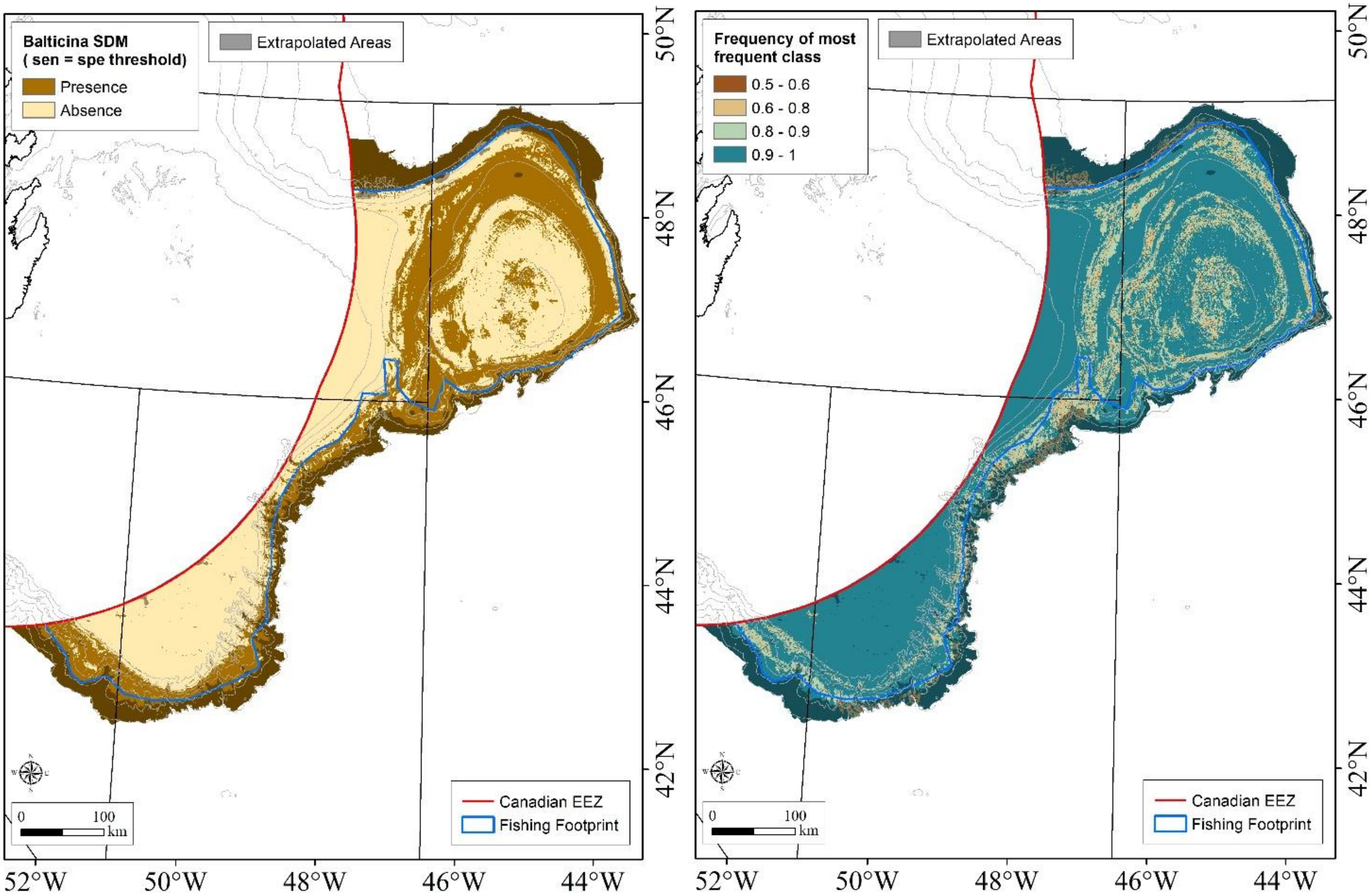

Figure 5.8. Predicted Presences/Absences of *Balticina* spp. in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

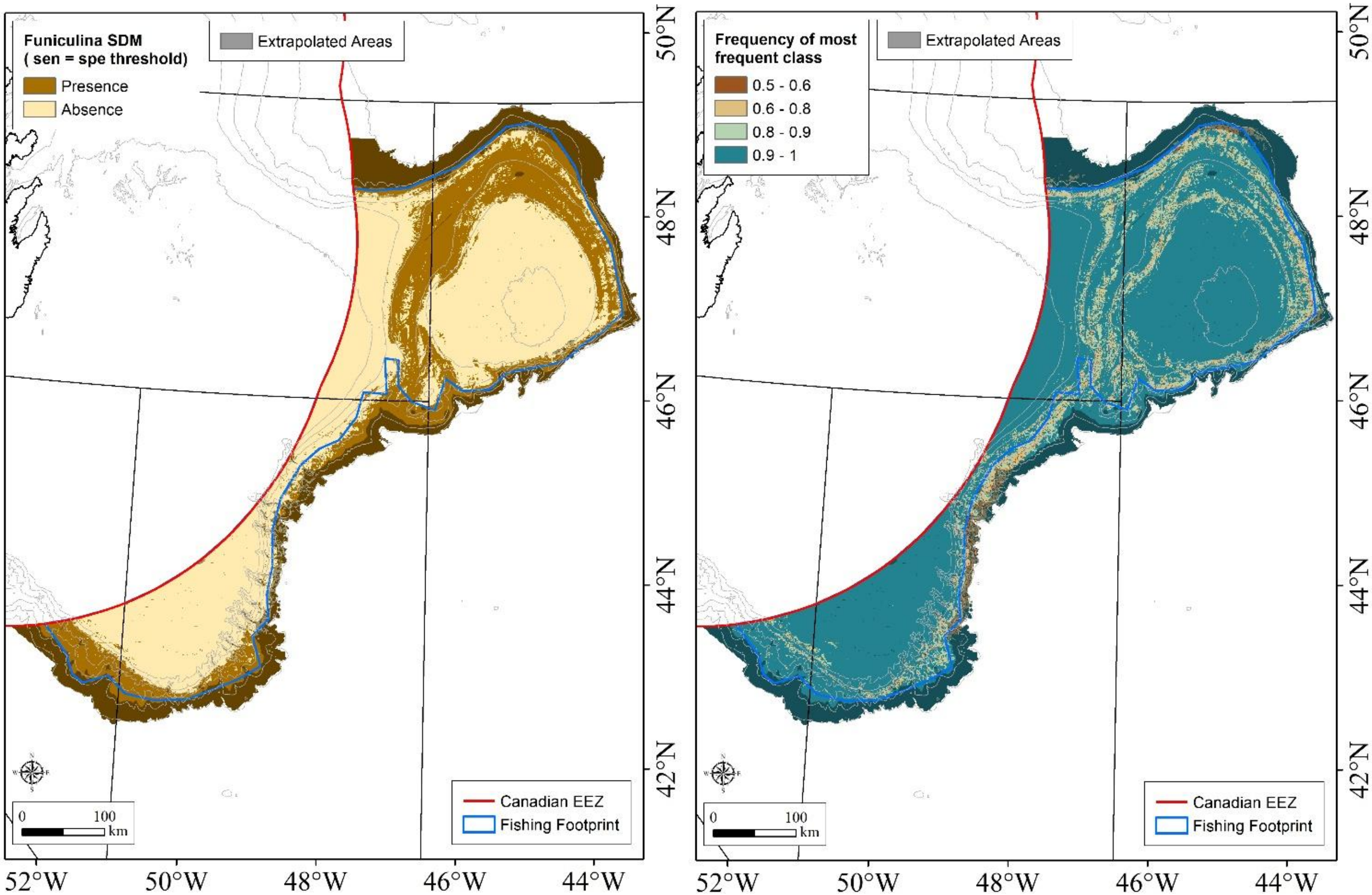

Figure 5.9. Predicted Presences/Absences of *Funiculina* spp. in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

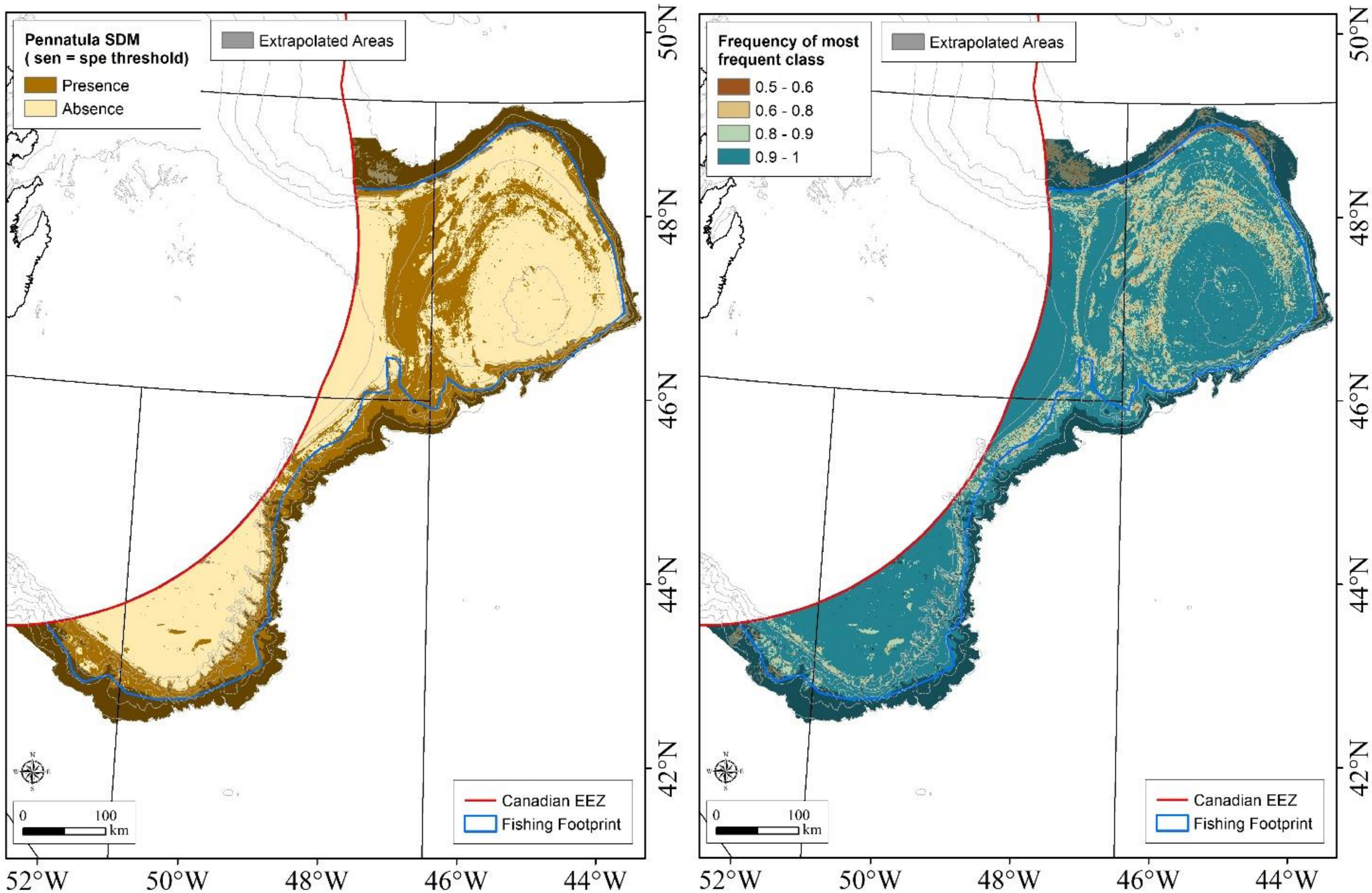

Figure 5.10. Predicted Presences/Absences of *Pennatula* spp. in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

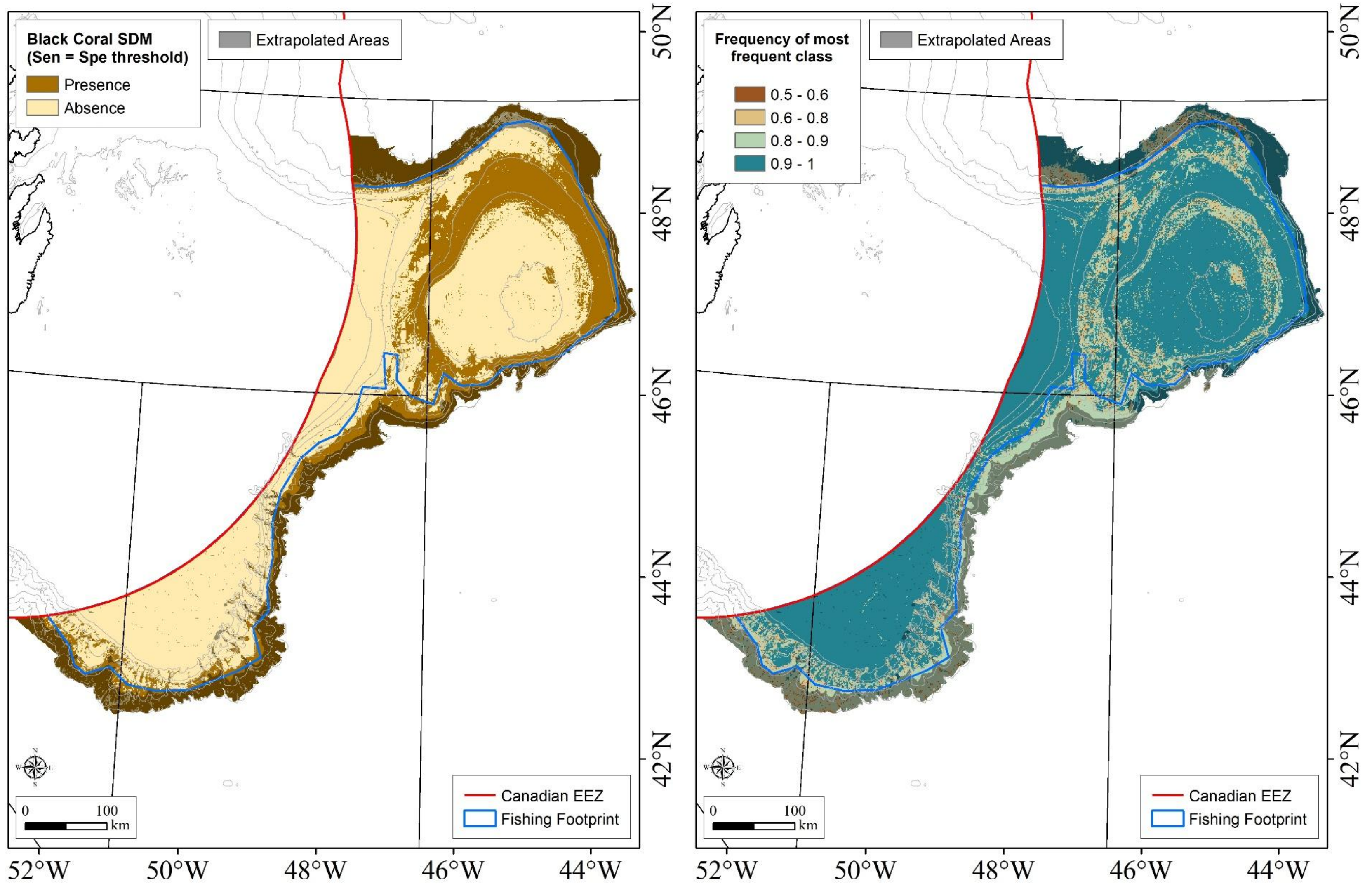

Figure 5.11. Predicted Presences/Absences of the Black Coral Functional Group in the NAFO Regulatory Area (left panel), with associated uncertainty as the frequency of Presences/Absences from the 10 cross-validation model runs. The areas of extrapolation show where the model has predicted into areas outside of the environment for the presence and absence records.

vi) References

Kenchington, E., Lirette, C., Murillo, F.J., Beazley, L., and Downie, A. L. 2019. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 19/058, Serial No. N7030. 68 pp.

Knudby, A., Kenchington, E., and Murillo, F.J. 2013. Modeling the Distribution of Geodia Sponges and Sponge Grounds in the Northwest Atlantic. PLoSONE 8: e82306. doi:10.1371/journal.pone.0082306.

Murillo, F.J., Downie, A.-L., Abalo Morla, S., Lirette, C., Paulin, N., Wang, Z., Devred, E., Clay, S., Sacau, M., Neves, B., Nozères, C., Koen-Alonso, M., Gullage, L., Caetano, M., Gonçalves, P., and Kenchington, E. 2024. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Species Distribution Models of Selected Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 24/063, Serial No. N7601. 105 pp.

Murillo, F.J., Serrano, A., Kenchington, E. and Mora, J. 2016. Epibenthic assemblages of the Tail of the Grand Bank and Flemish Cap (northwest Atlantic) in relation to environmental parameters and trawling intensity. Deep Sea Res. I 109: 99-122.

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

NAFO, 2024. Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures 2024. NAFO/COM Doc. 24-01. Serial No. N7490. https://www.nafo.int/Portals/0/PDFs/com/2024/comdoc24-01.pdf

Zurrell, D., Franklin, J., Konig, C., Bouchet, P.J., Dormann, C.F., Elith, J., Fandos, G., Feng, X., Guillera-Arroita, G., Fuisan, A., Lahoz-Monfort, J.J., Leitao, P.J., Park, D.S., Townsend Peterson, A., Rapacciuolo, G., Schmatz, D.R., Schroder, B., Serra-Diaz, J.M., Thuiller, W., Yates, K.L., Zimmermann, N.E., and Merow, C. 2020. A standard protocol for reporting species distribution models. Ecography (Cop.) 43: 1261-1277.

b) ToR 2.2. Assessment of SAI and reassessment of bottom fisheries impacts: Discussion about lead and timing for completion of the tasks (COM Request #6b)

COM Request #6. *In relation to the habitat impact assessment component of the Roadmap (VME and SAI analyses), the Commission requests that Scientific Council:*

> *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.*

It was agreed at the 2024 NAFO annual meeting that the reassessment of bottom fisheries (including the assessment of SAI) would be required in 2027. This allows more time in 2025 to complete a review of the VMEs which requires an up-date of the SDMs developed and applied in the 1st reassessment, but not up-dated for the 2nd assessment. This task should be completed for presentation at WG-ESA in 2025, including the finalisation of the VME polygon boundaries to be used in the reassessment of bottom fisheries in 2027. WG-ESA also identified some critical tasks that must be completed ahead of the overall assessment of SAI and determination of the management options, e.g. (i). up-dated VME polygons, (ii). up-dated VME biomass grid, (iii). up-dated VMS fishery effort data, (iv). integration of the VMS and log-book data (Table 5.2).

Table 5.2. Critical tasks that must be completed ahead of the overall assessment of SAI and determination of the management options.

Section heading/ tasks	Lead author(s)	Timing
INTRODUCTION	**Andy/James** (section editor)	**Section finalised in WG-ESA '27**
(i) policy background (to up-date 2021 text)	Dani	Between WG-ESA '25 – WG-ESA '27
(ii) oceanographic conditions (to up-date 2021 text)	Miguel	Between WG-ESA '25 – WG-ESA '27
(iii) ecosystems (to up-date 2021 text)	Mariano/ Alfonso	Between WG-ESA '25 – WG-ESA '27
(iv) habitats (to up-date 2021 text)	Javi/Anna	Between WG-ESA '25 – WG-ESA '27
(v) Communities – fish, epibenthos, infauna (to up-date 2021 text)	Javi	Between WG-ESA '25 – WG-ESA '27
(vi) Description of EPUs (to up-date 2021 text)	Mariano	Between WG-ESA '25 – WG-ESA '27
VULNERABLE MARINE ECOSYSTEMS (VMEs)	**Ellen/Javi** (section editor)	**Section finalised in WG-ESA '25**
(i) defining, identifying and mapping VMEs (to up-date 2021 text, using survey data from 2011 - 2023)	Ellen	Between WG-ESA '24 – WG-ESA '25
(ii) up-dated VME polygons	Ellen/Cam	Between WG-ESA '24 – WG-ESA '25
(iii) VME biomass (1 km² grid using 2011 – 2023 survey data)	Cam/ Ellen	Between WG-ESA '24 – WG-ESA '25
(iv) VME connectivity up-date	Ellen	Between WG-ESA '24 – WG-ESA '25
(vi) Sea pen ABM baseline conditions	Mariano	Between WG-ESA '24 – WG-ESA '25
ASSESSMENT OF FISHERIES	**Mar/ ?** (section editor)	**Section finalised in WG-ESA '26**
(i) Description of fisheries in the NRA	Mar/ Fernando	Between WG-ESA '25 – WG-ESA '26
(ii) VMS filtered data (2010 – 2024)	Secretariat/ Anna	By end of May 2025
(iii) Integrating VMS and logbook (haul by haul) data (2016 – 2024)	Mar/Irene/ Anna	Between WG-ESA '25 – WG-ESA '26
(iv) Demersal fisheries (up-date of maps and tables)	Mar/ Fernando	Between WG-ESA '25 – WG-ESA '26
(v) Overlap of demersal fisheries with VMEs (up-date on 2021 analysis/ text)	Mar	Between WG-ESA '25 – WG-ESA '26
ASSESSMENT OF SAI	**Andy/James** (section editors)	**Section finalised in WG-ESA '26**
(i) Background to the assessment of SAI (up-date 2021 text)	Andy/James/ Ellen	Between WG-ESA '25 – WG-ESA '26
(ii) VME impacts, resilience and recovery (review up-date 2021 text)	Barbara	Between WG-ESA '25 – WG-ESA '26
(iii) VME SAI impact assessment categories (cut-off values) with maps and tables	James/Andy	Between WG-ESA '25 – WG-ESA '26
(iv) Other SAI assessment metrics	James/Anna	Between WG-ESA '25 – WG-ESA '26
- fishing (VMS) stability index (up-date on 2021 text)	Neil/James	Between WG-ESA '25 – WG-ESA '26
- overlapping functions index (using 2021 functions polygon data)	Cam/James	Between WG-ESA '25 – WG-ESA '26
- VME fragmentation index (up-date 2021 analysis)	Ellen/Mariano	Between WG-ESA '25 – WG-ESA '26
- VME closure adequacy 'consistency' index (up-date 2021 analysis)	Ellen/Mariano	Between WG-ESA '25 – WG-ESA '26
(v) overall assessment of SAI	Andy/James	WG-ESA '26

c) ToR 2.3. Assessment of SAI and reassessment of bottom fisheries impacts: Provide potential management options as part of the reassessment of bottom fishing (COM Request #6b)

COM Request #6. *In relation to the habitat impact assessment component of the Roadmap (VME and SAI analyses), the Commission requests that Scientific Council:*

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.

The approach applied in 2021, to inform the selection of proposed VME closures, will be undertaken in 2027 as part of the reassessment of bottom fisheries to be completed in 2027. However, WG-ESA concluded that in addition to evaluating the trade-offs between VME biomass, areal extent and fishing opportunities (catch and landings), it would be helpful to include information on the ecological significance of each of the proposed closures. For example;

1. to consider including information on the proposed area climate sensitivity, refugia status and connectivity.
2. to include relevant information on the long-term fishing patterns in the NRA, e.g. the historic fishing patterns in the NRA described in Kulka and Pitcher (2001).
3. 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 5.3 highlights the specific tasks and timing required to complete the assessment of the management options. Work to progress the management options is dependent on the following data sets and analysis having been completed, which is expected to occur in 2025;

1. VMS fishery data (2011 – 2024 effort as tracks in km. km^{-2}. yr^{-1}).
2. Integrated VMS and log-book data (catch and landings).
3. Up-dated VME biomass grid ($1km^2$).
4. Up-dated VME polygons.

Table 5.3. Tasks, lead authors and timing to complete the assessment for the management options.

Section heading/ tasks	Lead author(s)	Timing
Management Options	**Mariano/ Anna**	
(i) Introduction (to up-date 2021 text)	Mariano	Between WG-ESA '26 - WG-ESA '27
(ii) Contributing elements and data used (to up-date 2021 text)	Mariano/Mar/ Anna	Between WG-ESA '26 - WG-ESA '27
(iii) VME/ fishery trade-offs (tables of VME biomass, fishery catches by target species, to include snow crab)	Anna/Mar/Mariano	Between WG-ESA '26 - WG-ESA '27
(iv) Management options (polygons – to up-date 2021 proposals)	Anna/ Mar/Mariano	Between WG-ESA '26 - WG-ESA '27
(v) Additional proposed area attributes (e.g. climate sensitivity, connectivity, historic fishing value)	Anna/Mar/Ellen/ Mariano	Between WG-ESA '26 - WG-ESA '27
(vi) Summary of management proposals.	Mariano/Mar/Anna	Between WG-ESA '26 - WG-ESA '27

References

Kulka, D., W. and Pitcher, D., A., (2001). Spatial and Temporal Patterns in Trawling Activity in the Canadian Atlantic and Pacific. ICES, CM 2001/R:02, pp 55.

d) ToR 2.4. Update on the SAI work (COM Request #6b)

COM Request #6. *In relation to the habitat impact assessment component of the Roadmap (VME and SAI analyses), the Commission requests that Scientific Council:*

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.

Following the reviewers' comments on a scientific paper drafted by WG-ESA members and submitted to the journal "Biological Conservation", revisions to the SAI method have been implemented and the paper revised. Specifically, an issue related to sample bias was addressed, e.g. it was noted there are many more samples in our data set associated with low and very low levels of fishing effort compared to the number of samples which coincide with high fishing effort. In addition, the earlier data set excluded samples from within closed areas, e.g. samples that are associated with no fishing effort in closed areas. Both of these issues have been addressed by compiling a data set of trawl samples located from within the VME polygons, irrespective of associated commercial fishing effort and whether or not they were located within closed areas. A total of seven VME 'functional types' were assessed; (i) small gorgonians, (ii) large gorgonians, (iii) large sponges, (iv) black coral, (v) sea pen (vi), bryozoan (vii), Sea squirts.

A four-parameter logistic function was fitted to the proportional cumulative biomass of VME in relation to fishing effort, using the function shown in Figure 5.12 for small gorgonian biomass.

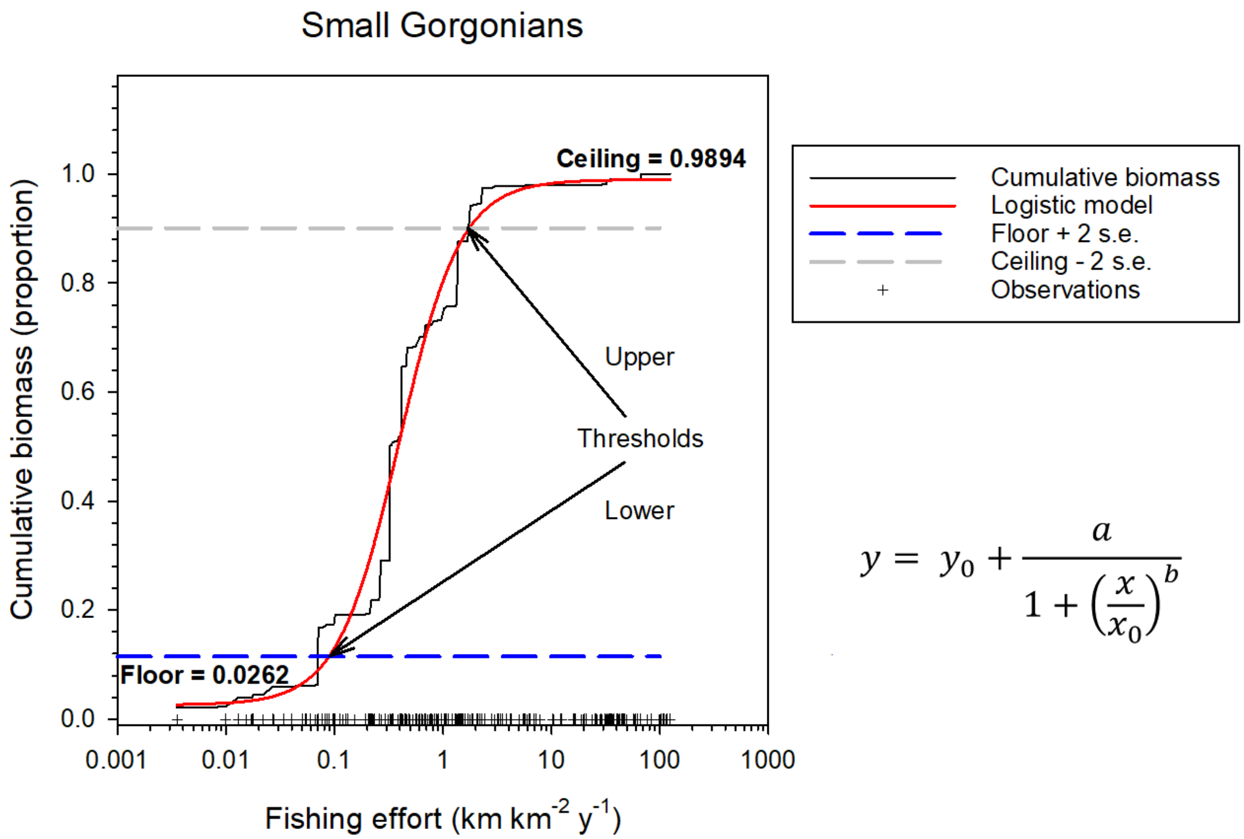

Figure 5.12. Illustrative example of the relationship between cumulative VME biomass in relation to fishing effort. The black line represents the proportional cumulative biomass of small gorgonian in relation to associated fishing effort using sampled biomass. The red line represents a fitted four-parameter logistic function; the dashed blue and grey lines represent the upper and lower estimates of the confidence intervals (+ 2 s.e.) for the 'floor' and 'ceiling' of the functional relationship. Crossed tick marks along the x-axis represent the distribution of observations from which the cumulative biomass and functional relationship was derived. The logistic equation fit to the data is provided for reference.

Where y is the cumulative proportion of VME biomass, x is fishing effort (km·km^{-2}·y^{-1}), and a, b, x0, and y0 are parameters estimated using iterative least squares. The lower (y0) and upper (y0 + a) asymptotes reflect the proportion of the VME taxon protected by closures, and our estimate of the maximum VME loss that can be detected considering the uncertainty in our data, respectively.

Estimates derived from equation (1) allow the identification of the 'floor' and 'ceiling' of VME biomass for each VME type at which the rates of accumulation of VME biomass in relation to fishing effort are low (Figure 5.12). The upper and lower impact thresholds are determined by adding (lower) and subtracting (upper), twice the standard error of the logistic model fit to the floor and ceiling values of the cumulative distribution of VME biomass, respectively. Twice the standard error of estimates of the floor and ceiling represent the upper and lower 95th confidence intervals of the estimates and therefore provides an objective approach to defining the lower and upper impact thresholds based on the quality of the data from which we estimate the functional relationship between the occurrence of fishing activity and areas of high VME concentration. The lower threshold represents the reference point below which VME are essentially unimpacted by current fishing effort, the upper threshold represents the reference point at which VME are recently impacted by bottom trawling activities. The interval of fishing effort between the lower and upper impact thresholds represents the level of fishing effort at which VME are at increasing risk of impact (SAI). Estimates of the fishing effort associated with lower and upper thresholds are determined by solving equation (1) for x using the parameter estimates for each VME.

Revised plots of cumulative VME biomass against ranked fishing effort are shown in Figures 5.12 and 5.13 for large-sized sponges (Porifera), sea pens (Pennatuloidea), sea-squirts (Ascidiacea), bryozoans (Bryozoa), black corals (Antipatharia), and large and small gorgonian corals (Octocorallia).

The up-dated method described here, to identify lower and upper impact thresholds, will be used in the reassessment of bottom fisheries in 2027 to determine the different impact/ risk assessment categories which ate tabulated and mapped.

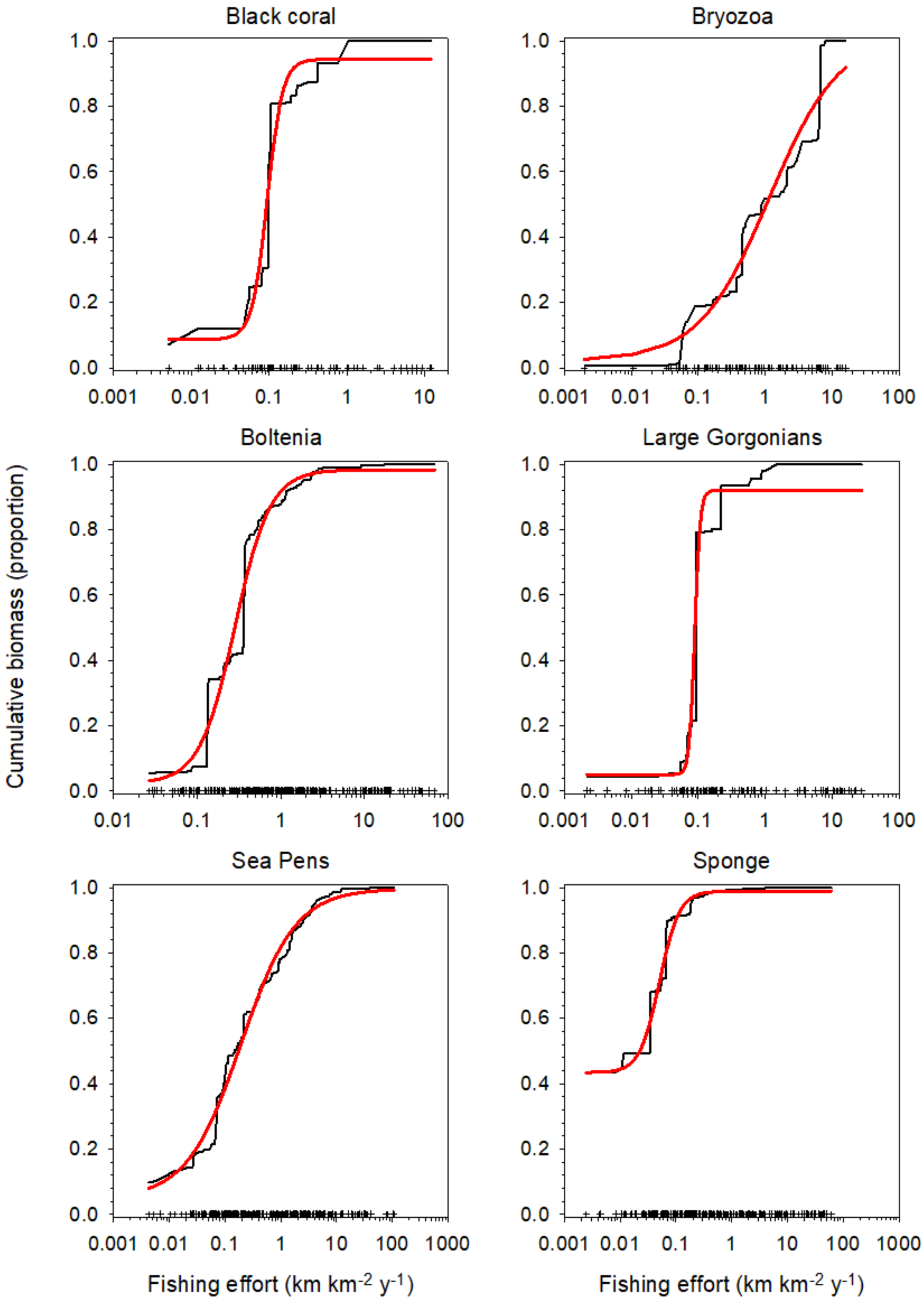

Figure 5.13. Relationship between proportional cumulative VME biomass in relation to fishing effort. The black line represents the proportional cumulative biomass of small gorgonian in relation to associated fishing effort based on our observations; the red line represents the fitted four-parameter logistic function. Crosses along the x-axis represent the distribution of observations.

e) **ToR 2.5. Presentation on the application of dRBS method (dynamic Relative Benthic Status) in SPRFMO: Framework for looking at impact assessments in NAFO (COM Request #6b).**

COM Request #6. *In relation to the habitat impact assessment component of the Roadmap (VME and SAI analyses), the Commission requests that Scientific Council:*

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.

Ashley Rowden, Owen Anderson, and Brad Moore from the National Institute of Water and Atmospheric Research (NIWA), New Zealand, gave a short presentation entitled 'Use of the Relative Benthic Status approach for quantitative benthic impact assessment in SPRFMO'. The presentation summarised information contained in two papers recently presented to the South Pacific Regional Fisheries Management Organisation (SPRFMO), namely 1) A review of information to assist in defining thresholds for Significant Adverse impacts (SAIs) on Vulnerable Marine Ecosystems (SC 12 – DW 07_rev1) and 2) an update to the quantitative benthic impact assessment for New Zealand and Australian bottom fisheries (SC 12 – DW 12_rev1).

Ashley provided a background summary of the identification of VMEs and SAIs used by SPRFMO, and a summary of the Relative Benthic Stats (RBS) measure (Pitcher et a. 2017) used by SPRFMO to estimate the ecosystem state of VMEs in its area. It was noted that different RFMOs use different methods to identify the known or likely presence of VMEs, with SPRFMO identifying VMEs via two methods: (1) through the 'move-on encounter protocol' where the trawl bycatch of VME indicator taxa exceed particular weight thresholds in any one trawl, and the subsequent review process; and (2) through predictive mapping of suitable habitat for VME indicator taxa based on records of such taxa from a variety of sources, most of which data are from outside of the SPRFMO area. With respect to identifying SAIs, it was noted that none of the thresholding approaches used by SPRFMO, NAFO, or ICES correspond to the "Natural variation" or "Maintain function" approaches identified by Hiddink et al (2023a) as ideal for monitoring 'good' versus 'degraded' ecosystem state. The primary method used by SPRFMO to assess SAIs, i.e., RBS, is what Hiddink et al. (2023a) categorise as a "Recovery possible" approach. This approach does not allow for an ecologically "good" state to be distinguished from a "degraded" state, but instead identifies what "state is already degraded at this level, and only preserves the ability to be good in the future".

It was noted that SPRFMO applies a 'quality threshold' borrowed from the Marine Stewardship Council (MSC) to RBS values to denote whether the inferred VMEs are protected from SAIs, which indicates that "B/K [B=biomass/abundance and K=carrying capacity] of 0.8 should be maintained for VMEs. That is, the MSC requirement is that "habitats are not impacted beyond the point at which they could recover to 80% (or more) of their unimpacted level within 5-20 years". However, the previous (2023) use of RBS by SPRFMO did not include the recovery time-frame part of the threshold (i.e., fishing ceased for up to 20 years).

Owen then introduced the update to the quantitative benthic impact assessment for New Zealand and Australian bottom fisheries. The main updates to the assessment included the incorporation of fishing impacts from bottom trawling and bottom longlining for the four years since the last complete assessment; incorporation of recently completed habitat suitability models that allow for status estimation for an additional seven VME indicator taxa; use of an expert elicitation process for revising and updating depletion and recovery parameters for calculating RBS for 17 VME indicator taxa; and a re-assessment of the relationship between modelled habitat suitability and observed abundance.

The key element of the updated assessment, however, was the use of an alternative implementation of Relative Benthic Status (RBS) (dynamic RBS; dRBS) that incorporates a time series of estimates of spatial impacts (rather than a single spatial layer representing average impacts for the period examined as used previously to calculate equilibrium RBS) so that status can be estimated at any point in the time series, including future projections (see Figure 5.14 below). Although the use of this alternative method limits comparison of estimated status from previous assessments, the SPRFMO SC recognised that the approach represents a substantial improvement in the interpretability and potential utility of outputs, where an estimate of status is available for a specific point in time rather than (in equilibrium RBS) for an unspecified time in the future when an equilibrium status has been achieved for a constant level of spatial impact. dRBS also does not require the manipulation and partitioning of historic and future spatial impact levels that were applied to the equilibrium

RBS assessment previously to account for annual variation in historical fishing impacts. The revised inputs and model development have allowed for a more complete and up to date impact assessment that can more clearly highlight taxa and management areas for which status of VME indicator taxa may be below agreed threshold status levels, and the degree to which recovery of status may be possible into the future, including under different fishing effort scenarios. However, there is still a substantial degree of uncertainty associated with the estimated status due to the inherent uncertainty within the input parameters.

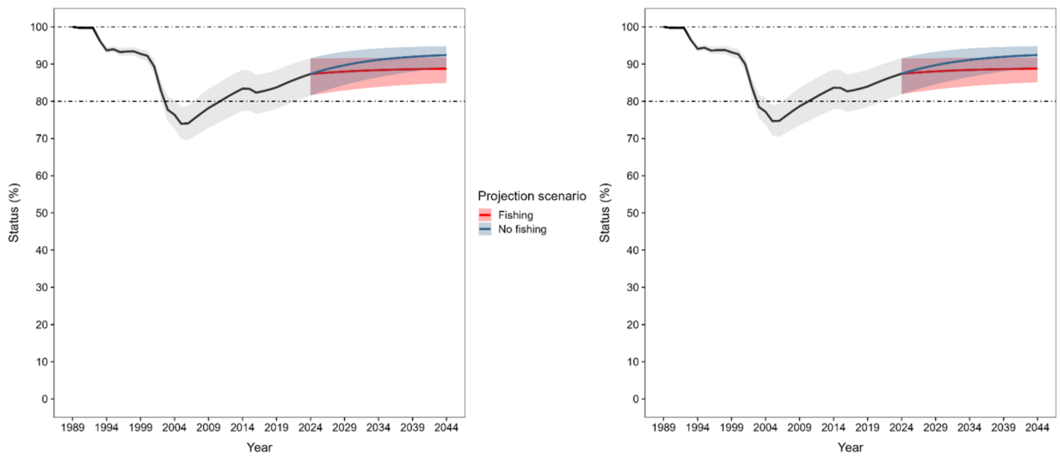

Figure 5.14. Example of the status over time from the dRBS analyses. The plots show that past, present, and projected future status of *Enallopsammia rostrata* (Scleractinia) in the Northwest Challenger Fishery Management Area using ROC-linear transformed habitat suitability index (HSI) values (left) and power mean transformed HSI values (right). From SC 12 – DW 12_rev1.

Brad then presented SPRFMO SC recommendations regarding the next steps in this work, which are: 1) the need to further develop and validate abundance models for VME indicator taxa so that they can be used in future updates of the benthic impact assessment to reduce the need for data transformations, and 2) the need to improve the reliability and estimation of uncertainty for the D and R values that inform the calculation of dRBS, focusing on taxa most at risk from fishing.

The presenters responded to a number of interesting and thoughtful questions from the workshop group, and there was general agreement that future collaboration among science providers to RFMOs is timely and desirable (including through facilitation by FAO). Such collaboration to include co-development of approaches to assess SAIs to VMEs.

f) ToR 2.6. Summary of the information regarding the current and future impacts of climate change on NAFO-managed stocks, non-target species, and associated ecosystems; and identification of any consequential data gaps, research needs and opportunities for productive research. (COM Request #10)

COM Request #10. *Noting the voluntary contribution of the United States to support a consultant to provide feedback on NAFO's processes to address climate change impacts, requests the SC to conduct an analysis of progress and/or outcomes of that work.*

i) Brief summary of Climate Change Consultancy (2023-2024)

In 2023, NAFO adopted a resolution on addressing the impacts of climate change on NAFO fisheries (NAFO, 2023). As a consequence of this resolution, NAFO started to consider how to address climate change impacts in its operations in more comprehensive ways. As part of this process, at its annual meeting in 2023, the Commission (COM) requested Scientific Council to *summarize the information it currently has available regarding the current and future impacts of climate change on NAFO-managed stocks, non-target species, and associated ecosystems and identify any consequential data gaps, research needs and opportunities for productive research.*

Through the Deep-sea Fisheries (DSF) Project, FAO, an expert consultant, Dr. Daniel Boyce, was contracted to summarize knowledge on climate change impacts on fisheries and ecosystems relevant to NAFO, and provide guidance on adaptation and mitigation. This work involved a comprehensive literature review supplemented by analyses of projected climate changes and their likely ecological impacts across the NAFO Convention Area (Boyce, 2024).

The study shows that climate driven changes in stocks and ecosystems are multifaceted, and that there is an urgent need to incorporate climate change into fisheries management. It also highlighted significant environmental signals (e.g. warming surface and bottom temperatures, deoxygenation, acidification, reduced sea ice, etc.) which have important implications for NAFO fisheries and ecosystems. These include projected declines in primary production and changes in phytoplankton communities, and expected changes in fish communities (e.g. species distributions, composition, etc.). Marine biomass declines are expected in the southern part of the NAFO area, where most NAFO fisheries occur, while biomass increases are expected in the Arctic. The analysis also included an evaluation of the climate risk for NAFO stocks, with the results indicating that several of these stocks are at high and moderate climate risk. Forward looking elements of the study included an initial range of possibilities (tools, pathways, etc.) on how climate change could be integrated into NAFO fisheries management in the context of the NAFO Roadmap for an Ecosystem Approach to Fisheries.

This study was discussed by SC at its 2024 June meeting, and served as a basis for the SC response to the corresponding COM request, as well as for a broader conversation on how to address climate change within SC work. A key conclusion of this broader discussion was the need for a dedicated in-person meeting to bring together the multidisciplinary experts required to evaluate the options, and design an approach to integrate climate change considerations throughout Scientific Council operations.

ii) Work on addressing the impacts of climate change on NAFO managed stocks, non-target species, and associated ecosystems

The NAFO Commission has called for work on addressing the impacts of climate change on NAFO ecosystems. As an extension of the workplan for the review of vulnerable marine ecosystems (VMEs) and impact of bottom fisheries on VMEs for 2027 (see ToR 2.1), the WG-ESA Species Distribution Modeling (SDM) subgroup will run SDMs under future environmental projections to determine climate refugia and areas of vulnerability for the VMEs as undertaken by Wang et al. (2022). This work will be first presented at the 2026 meeting of WG-ESA, and potentially extending into 2027.

VME indicator species differ from fish in that as adults they are sessile or sedentary, with limited or no adult movement. Further, individuals can live for decades to millennia, depending on the taxon, and so there is a high probability that individuals present in the NAFO Regulatory Area (NRA) will be alive in 2050 and, in some cases, in 2100. Identifying which VMEs (as represented by KDE polygons; Kenchington et al., 2019) and closed areas are expected to experience changing environmental conditions in future, or conversely, which are not expected to change, can help to prioritize and evaluate protective measures. Further, like their tropical counterparts, deep-sea corals and sponges rely on microbes living within their tissues to survive. Spatio-temporal predictions of host-associated microbiomes for these species are needed to interpret the species response to future conditions. Previous research has highlighted that host-associated microbes may display distribution patterns that are not perfectly correlated with host biogeographies, but also with other factors such as prevailing environmental conditions. Busch et al. (2024a,b) have undertaken this work for the NRA, amongst others, and so will allow for an integrated interpretation of future predictions which more accurately consider the microbiome of these species.

Modeling of future ocean climate typically relies on low resolution models designed to capture large-scale open-ocean properties (IPCC, 2013), the resulting products often being subsequently down-scaled for use in species distribution modeling. Such low-resolution models are inappropriate for capturing shelf-scale processes or for regions with sharp oceanographic boundaries, such as the Canadian Atlantic, where a higher native resolution is required to simulate ocean processes accurately, including under future projections (Stock et al., 2011; Brickman et al., 2016).

Although CMIP6 global models are available for this work, their native resolution is 100 km and they have only been examined for correspondence with observational data for temperature and salinity. Here, a version of the Bedford Institute of Oceanography North Atlantic Model (BNAM) that was developed to simulate climatology for 2046-2065 and 2066-2085 (Brickman et al., 2016), under Intergovernmental Panel on Climate Change Representative Concentration Pathways (RCP) 4.5, an emission-stabilizing scenario, and RCP 8.5, a high emission scenario in which radiative forcing increases through to 2100 (van Vuuren et al., 2011), will be used. The details of this model are below. Averaged annual anomalies for each of the physical oceanographic water column variables, representing the difference between present-day and future conditions, will be extracted from those BNAM simulations and applied to the averaged contemporary climatology layers to obtain projected Random Forest modeled distributions of each variable (Wang et al., 2022). Climate resiliency will be assessed against models built on the same variable sets but under 1990–2023 reference conditions, to allow examination of dynamic relationships among sites in time and space. Areas with projected conditions analogous to those of the reference period, representing potential climate refugia, will be identified.

iii) Overview of oceanographic data from BNAM and CMIP6 models.

1.- BNAM

The BNAM model was developed at Bedford Institute of Oceanography. It is based on Nucleus for European Modelling of the Ocean (NEMO) 2.3 which includes an ocean component OPA and a sea ice module LIM. The model domain was selected to include the North Atlantic Ocean (7°N – 75°N and 100°W – 25°E) with a nominal resolution of 1/12°. The model has a maximum of 50 levels in the vertical, with level thickness increasing from 1 m at the surface to 200 m at a depth of 1250 m and reaching the maximum value of 460 m at the bottom of the deep basins. The maximum depth represented in the model is 5730 m.

BNAM model solutions provide two perspectives:

- Hindcast: A historical simulation from 1990 to 2023 (Wang et al., 2018).

- Climate Projections: Future scenarios under RCP4.5 and RCP8.5 for the periods 2046-2065 and 2066-2085 (Brickman et al., 2016).

Model outputs include monthly mean data for temperature, salinity, current and mixed layer depth.

2.- CMIP6 models

The Coupled Model Inter-comparison Project (CMIP; Meehl et al., 2007; Taylor et al., 2012) has become a core element of national and international assessments of climate change. CMIP6 is the latest modeling effort for simulating and projecting various aspects of climate change. The simulations/projections are based on emissions scenarios from several Shared Socio-economic Pathways (SSPs).

These model results were downloaded from the Earth System Grid Federation (ESGF) (https://esgf-dev1.llnl.gov/). Details about the specific models are available on the ESGF website. The horizontal resolution of most models is approximately 100 km. Two of the models have a higher resolution of 25 km. The atmospheric components of the models have resolutions ranging from 100 to 500 km (Table 5.4).

At the Bedford Institute of Oceanography, scientists have processed and analyzed data from 22 CMIP6 models (Wang et al., 2024a). The analysis focuses on four climate scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) for the period 1950 to 2100. Monthly data for temperature, salinity, current and mixed layer depth are available from these simulations. Ensemble techniques have been demonstrated to improve the performance of CMIP6 models (Wang et al., 2024b), and ensemble mean data are available as well.

Table 5.4. Horizontal resolutions of the 22 CMIP6 models

Earth system model name	Atmosphere: approximate resolution (km)	Ocean: approximate resolution (km)
ACCESS-CM2	250	100
ACCESS-ESM1.5	250	100
AWI-CM 1.1 MR	100	25
CAMS-CSM 1.0	100	100
CanESM5	500	100
CESM2	100	100
CESM2-WACCM	100	100
CMCC-CM2-SR5	100	100
CNRM-CM6-1	250	100
CNRM-CM6-1-HR	100	25
CNRM-ESM2-1	250	100
EC-Earth3	100	100
GISS-E2.1G	250	100
IPSL-CM6A-LR	250	100
MIROC-ES2L	500	100
MIROC6	250	100
MPI-ESM1.2-HR	100	50
MPI-ESM1.2-LR	250	250
MRI-ESM2.0	100	100
NorESM2-LM	250	100
TaiESM 1.0	100	100
UKESM1.0-LL	250	100

iv) Voluntary contribution from USA for Climate Change contract (Climate Change Consultancy 2024-2025)

The chair of the SC, Diana González-Troncoso, presented to the WG-ESA the United States of America voluntary contribution of US$45,000 to support a consultant to conduct work that will build on, and will be informed by, information contained in the FAO-funded climate change consultant's report (Boyce, 2024).

A subgroup with several members of the SC and chaired by Katherine Sosebee (United States of America) has been established to inform and support the consultant in their work. The Terms of Reference (ToRs), initially presented during the September SC meeting (SCS Doc. 24/19), have been developed by the subgroup, and the consultant is in the process of being hired. The consultant will prepare a written report in time for review by the SC at its 2025 June meeting. The subgroup and the consultant may revise the ToRs as needed as work progresses.

Some aspects of the ToRs were discussed during the WG-ESA. First, the topic of the species selected for the study was addressed. The 3M cod was chosen as one of the candidate species, and the second option considered for this study was either the 3LNO yellowtail flounder or 3NO witch flounder. The necessary code and input data are ready to be provided to the consultant upon their hiring. After the completion of WG-ESA, and in a subsequent meeting, SC agreed that the consultant should focus on 3M cod and 3NO witch flounder.

Other topic that was discussed was the projection period. Long-term projections (~2050) were identified as most suitable for assessing the impact of climate change covariates. However, this would not be useful for the task of exploring the effect of climate change in the tactical advice for the selected stocks (for what a 1 to 3 years projections are done). This matter will be further discussed by the subgroup.

A limitation to the projections is the challenge to project climate covariates into the future. On this regard, the results of the models presented by Zeliang Wang (see above) that project temperature, salinity, currents and mixed layer depth into the future (to 2100) are expected to be used by the consultant to make the projections.

Finally, concerns were raised about the time constraint for the consultancy. Given the tight timeline, it is likely that the consultant will have limited capacity to carry out an in-depth analysis. This constraint will need to be factored into discussions between the subgroup and the consultant.

v) WG-ESA session on the climate change studies and scientific advice in NAFO

The presentations on climate change opened a debate among the meeting attendees on the steps that should be taken to be able to address the work needed to estimate the impact of climate change on NAFO fishery resources, VMEs, and ecosystem at large, so that SC can deliver according to NAFO Climate change resolution of September 2023 (NAFO, 2023). Key actions adopted in this resolution include that the current and future impacts of climate change on managed fish stocks, non-target species and associated ecosystems should be considered in decision making and through its work in the NAFO Roadmap (action 1); conservation and management measures should be developed with a view to address the effects of these climate change impacts based on the best available scientific advice on current and future climate impacts (action 2); and examine actions that could be taken to reduce or mitigate the impacts of climate change on management of target, and non-target NAFO managed stocks and ecosystems, as well as fishing activity, including, where appropriate, consideration of the adaptation of NAFO management approaches (action 3).

WG-ESA recognises that it is early to identify specific lines of work that should be developed, as this is a discussion that still needs to be had within the SC. However, together with STACFEN, WG-ESA members consider that this working group is well positioned to play a key role in the development of the work necessary to advise on climate change issues in NAFO.

As described in the presentation on the current and future impacts of climate change, the NAFO managed stocks, non-target species, and associated ecosystems are expected to experience a very different environment in the future. Climate change is a forcing element that drives changes in a wide number of variables that determine the productivity and dynamics of marine populations and ecosystems. While the most obvious are the direct effects, it is conceivable that the most influential and difficult to predict are the indirect effects (Figure 5.15). In order to assess both direct and indirect effects, it will be necessary to develop tools that allow modelling and simulating the dynamics of ecosystems and fisheries with a spatiotemporal resolution that goes beyond what the tools currently available allow. Further, there is a clear and urgent need to develop competence on addressing climate change within the institutions that support NAFO Contracting Parties. Climate change is a long-term and complex problem, and addressing it requires the kind of understanding that can only be developed through sustained and dedicated efforts over time. Short-term and ephemeral scientific activities are not enough.

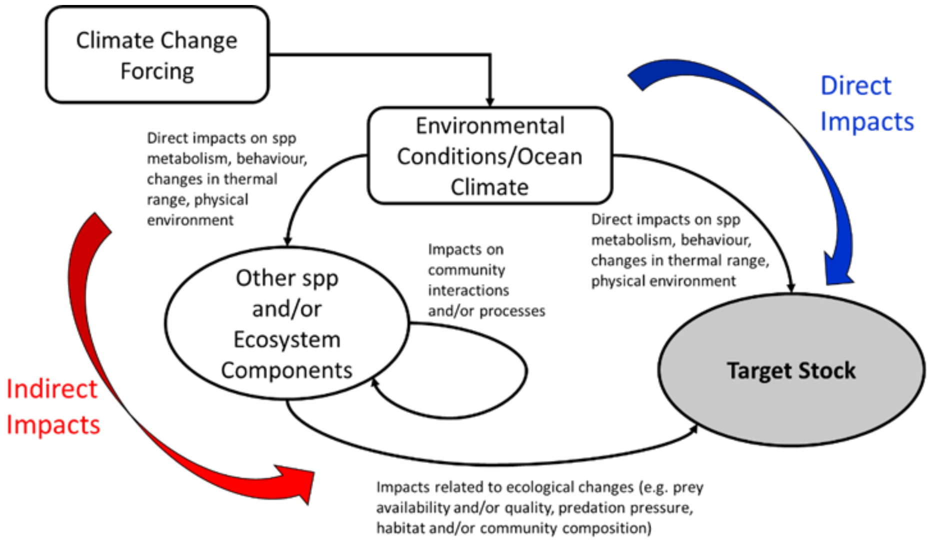

Figure 5.15. Schematic representation of the pathways of effects of climate change impacts on a target stock (or ecosystem component).

One of the issues that WG-ESA anticipates will have to be addressed first is the availability of data to support studies to assess the potential impact that climate change on NAFO fisheries resources, and ecosystems. The type of data generated by BNAM are essential to produce long term simulations that can reliably capture regional expectations under climate change. These data include both historical periods as well as projections of key variables that would allow quantitative modelling of direct and indirect climate change effects on NAFO marine ecosystems.

Another important element to consider is the time window over which the impact of climate change has to be assessed and advised on. Current scientific advice is primarily tactical (short-term), and although assessments of long-term management strategies are made, the objective is to provide advice over a relatively short period of time. While the effect of climate change may have an impact on tactical advice (e.g. increased variability in oceanographic processes can affect short-term stock productivity), climate change-related advice is expected to be, at least initially, primarily strategic (i.e. longer term). This type of advice would be focused on the assessment of the impacts of climate change over relatively long-time horizons (20-50 years), and is intended to anticipate changes that are about to occur, in order to inform management actions to both mitigate the negative impacts on fishing activities and the NAFO ecosystems, as well as to responsibly take advantage of any opportunity that may appear. However, what this strategic advice entails, and how it needs to be produced and delivered remains an open discussion between SC and COM. Some clarity on these issues would be beneficial for identifying specific research directions that need to be developed.

Building on the idea put forward by SC in its 2024 June SC meeting, WG-ESA agreed that, in order to comprehensively address the issues briefly introduced above, a necessary step would be the organization of a symposium attended by relevant experts within NAFO (SC, WG-ESA, STACFEN), as well as from other RFMOs and/or regions where incorporating climate change impacts in the stock and ecosystem advice has already started. Although this symposium would be expected to be focused on the science aspects, it would be advisable to include participation by managers, so that the type of advice that will eventually be required from SC can be scoped (i.e. what is needed vs what is scientifically sensible and technically doable). This event would provide the necessary support to define the strategy to follow, and to generate a climate change workplan for NAFO SC.

vi) References

Boyce, D. G. 2024. Addressing the impacts of climate variability and change on NAFO Fisheries. NAFO SCR Document, 24/009: 86pp.

Brickman, D., Wang, Z., and DeTracey, B. 2016. High Resolution Future Climate Ocean Model Simulations for the Northwest Atlantic Shelf Region. Can. Tech. Rep. Hydrogr. Ocean. Sci. 315, xiv + 143.

Busch, K., Murillo, F.J., Lirette, C., Wang, Z., and Kenchington, E. 2024a. Putative past, present, and future spatial distributions of deep-sea coral and sponge microbiomes revealed by predictive spatio-temporal models. ISME Communications (In press).

Busch, K., Pardy, G., King, M., Lirette, C., Murillo, F.J., and Kenchington, E. 2024b. Marine spatial planning for socio-ecological management of animal-associated microbiomes. Conservation Science and Practice: e13153. https://doi.org/10.1111/csp2.13153

IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Kenchington, E., Lirette, C., Murillo, F.J., Beazley, L., and Downie, A. L. 2019. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 19/058, Serial No. N7030. 68 pp.

Meehl, G. A., Covey, C., Taylor, K. E., Delworth, T., Stouffer, R. J., Latif, M., McAvaney, B., and Mitchell, J. F. B. 2007. THE WCRP CMIP3 Multimodel Dataset: A New Era in Climate Change Research, B. Am. Meteorol. Soc., 88, 1383–1394.

NAFO, 2023. 45th Annual Meeting of NAFO. Addressing the Impact of Climate Change on NAFO Fisheries. NAFO/COM Doc. 23-13

Stock, C. A., Alexander, M. A., Bond, N. A., Brander, K. M., Cheung, W. W. L., Curchitser, E. N., et al. 2011. On the Use of IPCC-Class Models to Assess the Impact of Climate on Living Marine Resources. Prog. Oceanogr. 88, 1–27.

Taylor, K. E., Stouffer, R. J., and Meehl, G. A. 2012. An Overview of CMIP5 and the Experiment Design, B. Am. Meteorol. Soc., 93, 485–498.

Van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., et al. 2011. The Representative Concentration Pathways: An Overview. Clim. Change 109: 5.

Wang, Z., Lu, Y., Greenan, B., Brickman, D., and DeTracey, B. 2018. BNAM: An eddy-resolving North Atlantic Ocean model to support ocean monitoring. Can. Tech. Rep. Hydrogr. Ocean. Sci. 327: vii + 18p.

Wang, S., Murillo, F.J., and Kenchington, E. 2022. Climate-change refugia for the Bubblegum Coral Paragorgia arborea in the Northwest Atlantic. Frontiers in Marine Science 9: 863693 https://doi/10.3389/fmars.2022.863693

Wang, Z., DeTracey, B. Greenan, B., Brickman, D., Cyr, F., Galbraith, P., Steiner, N. and Christian, J. 2024a. Examination of the performance of 22 CMIP6 ESMs on large scale changes in the atmosphere and oceans (North Atlantic, Arctic and North Pacific). Can. Tech. Rep. Hydrogr. Ocean. Sci. 376: v + 49 p.

Wang, Z., Brickman, D., Greenan, B., Christian, J., DeTracey, B., & Gilbert, D., 2024b. Assessment of Ocean Temperature Trends for the Scotian Shelf and Gulf of Maine Using 22 CMIP6 Earth System Models, Atmosphere-Ocean, 62:1, 24-34, DOI: 10.1080/07055900.2023.2264832

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. Update on submitting NAFO seamount and sponge closed areas as OECMs, and developing support materials for coral closures as OECMs (COM Request #6c)

COM Request #6. *In relation to the habitat impact assessment component of the Roadmap (VME and SAI analyses), the Commission requests that Scientific Council:*

c) Develop materials on the potential of submitting NAFO coral bottom fishing closed areas as OECMs for discussion at the 2025 WG-EAFFM meeting.

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 and black corals, comprising eleven VME fishery closures 7, 7a, 8, 9, 10, 11, 11a, 12, 13, 14a and 14b, as shown in Figure 6.1.

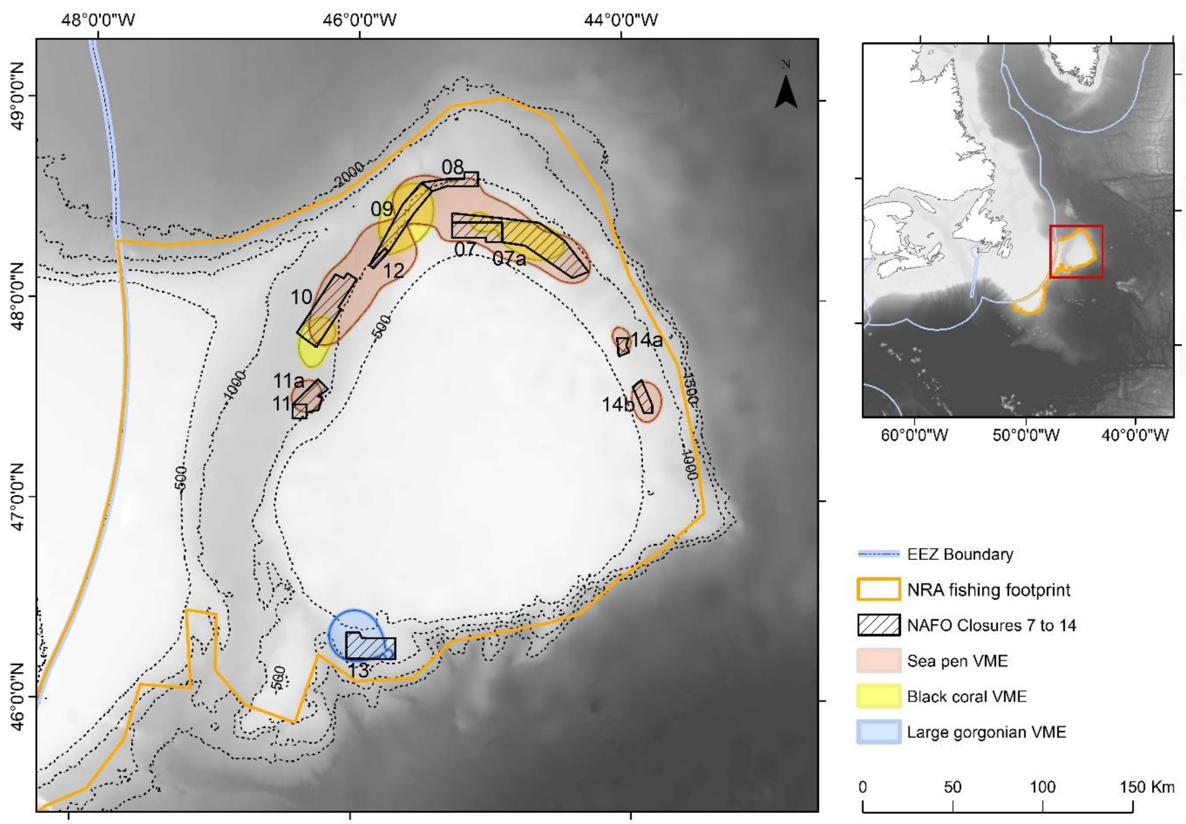

Figure 6.1. VME fishery closures which protect sea pen, large gorgonian and black corals in the NRA to be considered for inclusion in the coral OECM submission. Also, the extent of the corresponding VME polygons are shown. Note, not all of the VME fishery closures and VME polygons are shown on this map – 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 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) and demersal fish (Malecha et al. 2005; Boulard et al. 2024). 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 *Halipteris 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.

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 ornata*, *Primnoa resedaeformis*, *Paramuricea sp*., and *Paragorgia arborea*) which ranged in age from a few decades up to 200 years for a subfossil colony of *K. ornata*. *Paragorgia arborea* grew at the fastest radial growth rate of 800 µm. 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 and Mortensen 2005; Carvalho et al. 2014) and demersal fish species (Baker et al. 2012). Particle tracking analyses (Wang et al. 2024) revealed that the large gorgonian coral VME in closed area 13 (Figure 6.1) 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.

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 magnus* (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 µm.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 the 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 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).

iv) Standardized maps for the Large Sponge and Seamount OECMs.

For consistency, reformatted maps have been produced to replace the maps in the Large Sponge (Figure 6.2) and Seamount (Figure 6.3) OECM templates as shown below:

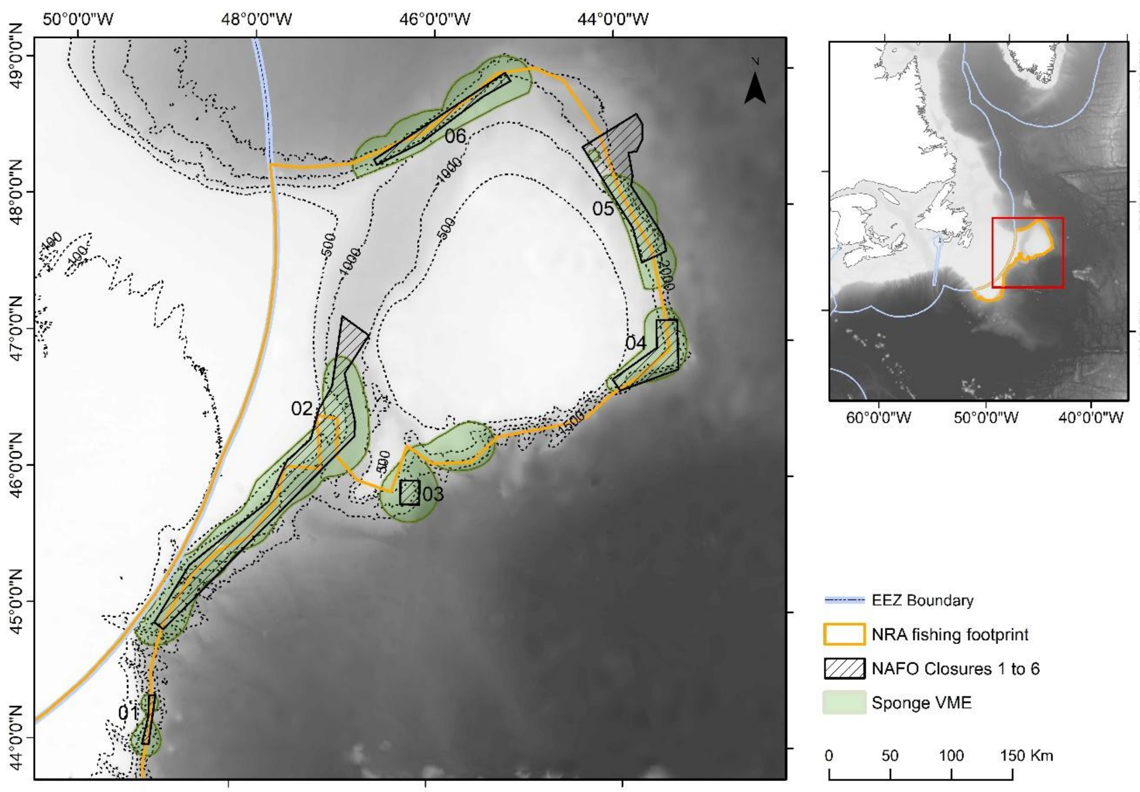

Figure 6.2. VME fishery closures which protect large sponge VME in the NRA for inclusion in the Large-Sized Sponge OECM submission. Also, the extent of the corresponding VME large-sized sponge polygons are shown. Note, not all of the VME fishery closures and VME polygons are shown on this map – e.g. it excludes sea pen, large gorgonian and black coral VME fishery closures included in the proposed coral OECM template.

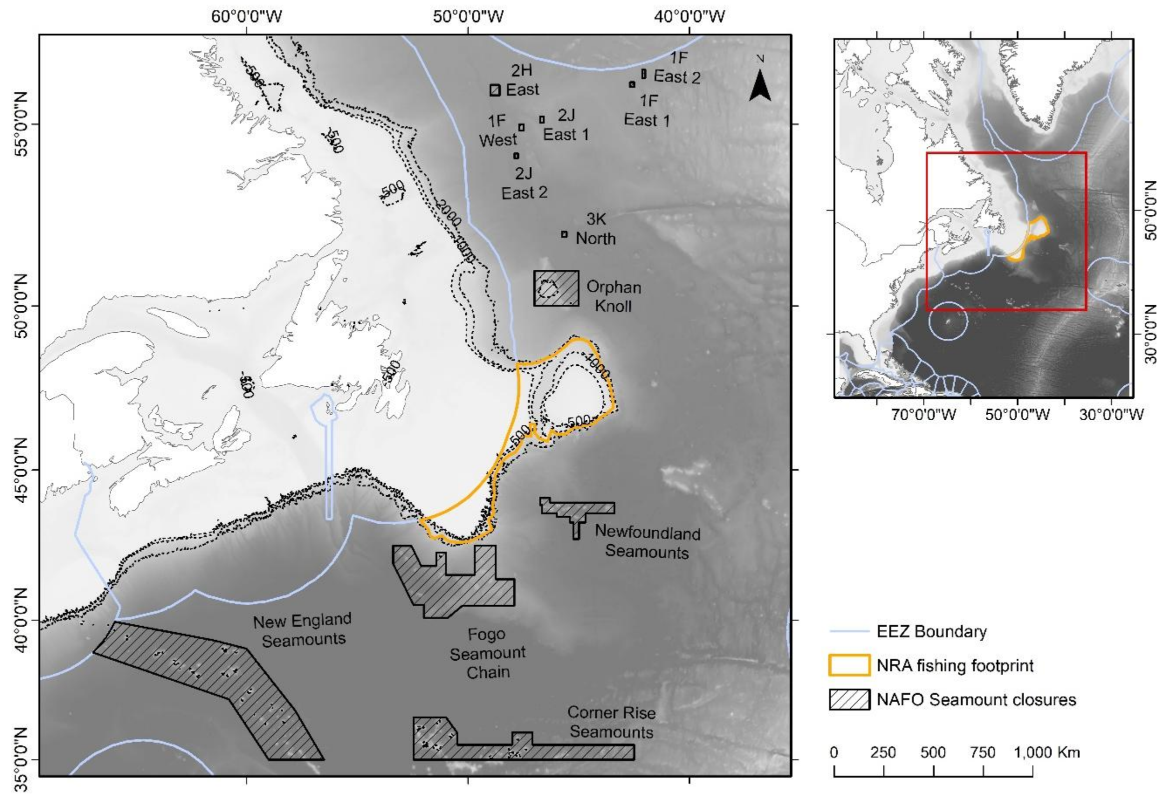

Figure 6.3. Seamount closures which protect Seamount VME for inclusion in the Seamount OECM submission. Note, not all of the VME fishery closures and VME polygons are shown on this.

v) References

Baillon, S., Hamel, J.-F. & Mercier, A. 2014. Diversity, distribution and nature of faunal associations with deep-sea pennatulacean corals in the northwest Atlantic. PLoS One 9(11):e111519.

Baker, K.D., Haedrich, R.L., Fifield, D.A. & Gilkinson, K.D. 2012. Grenadier abundance examined at varying spatial scales in deep waters off Newfoundland, Canada, with special focus on the influence of corals. Journal of Ichthyology 52: 678-689.

Birkeland, C. 1974. Interactions between a sea pen and seven of its predators. Ecological Monographs 44:211–232.

Bosch, N.E., Espino, F., Tuya, F., Haroun, R., Bramanti, L., & Otero-Ferrer, F. 2023. Black coral forests enhance taxonomic and functional distinctiveness of mesophotic fishes in an oceanic island: implications for biodiversity conservation. Scientific Reports. 13: 4963.

Boulard, M., Baker, K., Lawton, P. & Edinger, E. 2024. Local size structure and distribution of demersal fish in relation to sea pens and other benthic habitats in a deep-sea soft-bottom environment. Deep Sea Research Part II : Topical Studies in Oceanography 218 : 105417.

Buhl-Mortensen, L. & Mortensen, P.B. 2005. Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. In: Freiwald, A., Roberts, J.M. (eds) Cold-Water Corals and Ecosystems. Erlangen Earth Conference Series. Springer, Berlin, Heidelberg.

Carvalho, S., Cúrdia, J., Pereira, F., Guerra-García, J.M., Santos, M.N. & Cunha, M.R. 2014. Biodiversity patterns of epifaunal assemblages associated with the gorgonians *Eunicella gazella* and *Leptogorgia lusitanica* in response to host, space and time. Journal of Sea Research 85: 37-47.

De Clippele, L.H., Buhl-Mortensen, P. & Buhl-Mortensen, L. 2015. Fauna associated with cold water gorgonians and seapens. Continental Shelf Research 105:67–78.

De Clippele, L.H., Huvenne, V.A., Molodtsova, T.N., & Roberts, J.M. 2019. The diversity and ecological role of non-scleractinian corals (Antipatharia and Alcyonacea) on scleractinian cold-water coral mounds. Frontiers in Marine Science 6:184.

FAO, 2009. International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Rome, FAO. 73 p.

Fuller, S.D., Murillo Perez, F.J., Wareham, V. & Kenchington, E. 2008. Vulnerable Marine Ecosystems Dominated by Deep-Water Corals and Sponges in the NAFO Convention Area. Serial No. N5524. NAFO Scientific Council Research Document 08/22, 24pp.

García-Matucheski, S. & Muniain, C. 2011. Predation by the nudibranch *Tritonia odhneri* (Opisthobranchia: Tritoniidae) on octocorals from the South Atlantic Ocean. Marine Biodiversity 41:287–297.

Greathead, C.F., Donnan, D.W. & Mair, J.M. 2005. Impact of *Nephrops* sp. trawling on the distribution of the sea pen *Virgularia mirabilis*, *Pennatula phosphorea* and *Funiculina quadrangularis* in Scottish waters. Fisheries Research Services Internal Report No. 02/05. Aberdeen, UK. 18 pp.

Grigg, R.W. 1989. Precious coral fisheries of the Pacific and Mediterranean. In: J.F. Caddy (Ed.), Marine Invertebrate Fisheries: Their Assessment and Management, Wiley, New York, 637-645.

Heifetz, J., Stone, R.P. & Shotwell, S.K. 2009. Damage and disturbance to coral and sponge habitat of the Aleutian Archipelago. Marine Ecology Progress Series 397:295–303.

Hourigan, T. F., Lumsden, S. E., Dorr, G., Bruckner, A.W., Brooke, S. & Stone, R.P. 2007. State of Deep Coral Ecosystems of the United States: Introduction and National Overview, 64 pp.

Humes, A.G. 1978. Lichomolgid copepods (Cyclopoida),with two new species of *Doridicola*, from sea pens (Pennatulacea) in Madagascar. Transactions of the American Microscopical Society 97:524–539.

Kenchington, E., Lirette, C., Murillo, F.J., Beazley, L. & Downie, A.-L. 2019. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO Scientific Council Report 10/058, Serial No. N7030, 68 p.

Malecha, P.W. & Stone, R.P. 2009. Response of the sea whip *Halipteris willemoesi* to simulated trawl disturbance and its vulnerability to subsequent predation. Marine Ecology Progress Series 388:197–206.

Malecha, P.W., Stone, R.P. & Heifetz, J. 2005. Living substrate in Alaska: distribution, abundance and species associations. In: Barnes, P.W., Tomas, J.P., editors. Benthic Habitats and the Effects of Fishing. American Fisheries Society Symposium 41. Bethesda, MD: American Fisheries Society, p 289–299.

Miatta, M. & Snelgrove, P. 2022. Sea pens as indicators of macrofaunal communities in deep-sea sediments: Evidence form the Laurentian Channel Marine Protected Area. Deep Sea Research Part 1: Oceanographic Research Papers 182: 103702.

Murillo, F. J., Durán Muñoz, P., Altuna, A. & Serrano, A. 2011. Distribution of deep-water corals of the Flemish Cap, Flemish Pass, and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): interaction with fishing activities. ICES Journal of Marine Science 68: 319–332.

Murillo, F.J., Serrano, A., Kenchington, E. & Mora, J. 2016. Epibenthic assemblages of the Tail of the Grand Bank and Flemish Cap (northwest Atlantic) in relation to environmental parameters and trawling intensity. Deep Sea Research I 109: 99–122.

Murillo, F.J., MacDonald, B., Kenchington, E., Campana, S., Sainte-Marie, B. & Sacau, M. 2018. Morphometry and growth of sea pen species from dense habitats in the Gulf of St. Lawrence, eastern Canada. Marine Biology Research 14(4): 366-382.

Nygren, A. & Pleijel, F. 2010. Redescription of *Imajimaea draculai*—a rare syllid polychaete associated with the sea pen *Funiculina quadrangularis*. Journal of the Marine Biological Association of the United Kingdom 90: 1441–1448.

Sherwood, O. A. & Edinger, E.N. 2009. Ages and growth rates of some deep-sea gorgonian and antipatharian corals of Newfoundland and Labrador. Canadian Journal of Fisheries and Aquatic Sciences 66: 142-152.

Stratmann, T., Murillo, F.J., Sacau, M., Koen Alonso, M. & Kenchington, E. 2024. Role of Astrophorina sponges (Demospongiae) in food-web interactions at the Flemish Cap (NW Atlantic). Marine Ecology Progress Series 729:99-116.

Tissot, B.N., Yoklavich, M.M., Love, M.S., York, K. & Amend, M. 2006. Benthic invertebrates that form habitat structures on deep banks off southern California, with special reference to deep sea corals. Fishery Bulletin 104:167–181.

Troffe, P.M., Levings, C.D., Piercey, G.B.E. & Keong, V. 2005. Fishing gear effects and ecology of the sea whip (*Halipteris willemoesi* (Cnidaria: Octocorallia: Pennatulacea)) in British Columbia, Canada: preliminary observations. Aquatic Conservation: Marine and Freshwater Ecosystems 15:523–533.

Wang, S., Kenchington, E., Murillo, F.J., Lirette, C., Wang, Z., Koen-Alonso, M., Kenny, A., Sacau, M. & Pepin, P. 2024. Quantifying the effects of habitat fragmentation in deep-sea vulnerable marine ecosystems. Diversity and Distributions 30 (5):e13824.

Wareham, V.E. & Edinger, E.N. 2007. Distributions of deep-sea corals in Newfoundland and Labrador waters. Bulletin of Marine Science 81:289-311.

b) ToR 3.2. Studying the effect of seismic surveying on groundfish fisheries offshore Newfoundland and Labrador, Canada

Corey Morris

Researchers at Fisheries and Oceans Canada have been conducting field investigations regarding the potential impacts of offshore seismic oil and gas surveying on groundfish fisheries since 2021. An overview of that ongoing research was provided to the NAFO WG-ESA workgroup in November 2024. It is known that most fishes depend on the sounds in the ocean, as an important part of their lives, for reproduction, predator-prey dynamics, communication, and more. The impact of noise pollution on commercial fisheries is poorly understood, furthermore, conflicting results in scientific literature that differs among species, locations, and study designs employed, have only increased the need for targeted research. The fishing industry for example have identified a need for realistic research on commercial fishing grounds where there is overlap with seismic surveying, in order to address their regionally specific concerns and species affected. Our research incorporated 3D seismic surveying on commercial fishing grounds, in both deep waters (400-500 m) along the continental slope and shallow water (70-80 m) on the Grand Bank, off the coast of Newfoundland. In 2021, field research identified fish behavioural changes as a result of seismic surveying. Telemetry based movement studies found that witch flounder reduced their movements when the noise level from seismic surveying was louder than the noise generated by a fishing vessel, while Greenland halibut were not measurably affected. Using baited cameras, Atlantic cod appeared to arrive at baited stations sooner in the absence of seismic surveying. Acoustic data collected using a wideband Acoustic Transceiver (WBAT) mounted on the seabed found that fish in the Deep Scattering Layer moved deeper in closer proximity to a seismic surveying vessel. Similar studies were also conducted in 2024, using the same sampling methods, however the analysis of these data is not yet complete. In 2024, baited cameras collected 4500 hours of video data before, after, and at control sites with respect to seismic surveying on the Grand Bank, near Hibernia and Hebron oil and gas platforms. Telemetry research in 2024 in the same areas targeted American Plaice, which were the most abundant species sampled at all shallow water sampling sites. We also deployed several seabed mounted Acoustic Zooplankton Fish Profilers (AZFPs), using high frequency (333 kHz) and low frequency (38kHz) transducers, to monitor fish and zooplankton. A final element of ongoing research on the effects of seismic surveying involves large-scale soundscape evaluation of noise related effects on fisheries. To better understand potential impacts of seismic surveying of fisheries in the Newfoundland and Labrador region, we modelled the ocean soundscape for all of NAFO subdivisions 3KLNO, at a 2 square kilometre grid size, considering noise levels (natural noise, vessel noise, seismic surveying noise) and commercial fishing activity and catch rates (for several fisheries), from 2015 to 2021. Statistical comparisons are ongoing for several fisheries, based on experimental expectations from 2021 and 2024 to evaluate noise level and distance and duration of effect. Combined, this ongoing research is intended to help address some regionally relevant concerns that have been identified by the fishing industry, in collaboration with the oil and gas industry and regulators (Fisheries and Oceans Canada and the

Canada Newfoundland and Labrador Offshore Petroleum Board), regarding the impacts of seismic oil and gas exploration. This research was funded by the Environmental Studies Research Fund (ESRF).

c) ToR 3.3. An integrated numerical framework for Environmental Risk Assessment in marine ecosystems affected by accidental spills

Irene Martins

i) Problematic and goal

The Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances (OPRC-HNS) emerged, in 2000, as the international framework to address pollution incidents caused by chemicals (IMO; Neuparth et al., 2012). However, only three of the twelve EU members that ratified the protocol claimed to have specialized knowledge to respond to HNS spills (IMO; Soares et al., 2020). The behaviour and effects of Hazardous and Noxious Substances (HNS) on the marine environment remain largely unknown and poorly understood (Soares et al. 2020, Cunha et al., 2015), which narrows mitigation actions and suitable responses to HNS spillages at sea. A full preparedness protocol that effectively guides authorities and other intervening agents in case of HNS spills must take into account the specific behaviour of the HNS, its dispersion trajectory and concentration pattern in seawater, and the potential effects on surrounding marine ecosystems. Yet such a complex process should be translated into a simpler framework that would allow straightforward mitigation actions by competent authorities. Building on work previously developed by CIIMAR researchers, the goal of the MODELRISK project was to develop ecosystem models for Atlantic marine ecosystems to predict and quantify the effects of HNS spills on the composition and function of those ecosystems. Due to the ecological relevance and socio-economic importance of its marine ecosystems, the Azores region was used as a case study. Furthermore, the Azores archipelago is located on one of the busiest marine routes of the planet, thus, prone to incidents with HNS spillages.

ii) Workflow

The project's goal was attained by developing a numerical framework that incorporates a database and several different models, specifically: i) the HNS online database previously developed by CIIMAR was augmented to include toxicological data of HNS on marine organisms; ii) the Regional Ocean Modelling System (ROMS) was calibrated for the area within the North Atlantic ocean encompassing the selected deep-sea ecosystems (34.3°/40.8°N, -36°/-28°W); iii) following an hypothetical incident with HNS spill at the summits of the seamount and of the vent field, HNS dispersion trajectories and concentrations were simulated using the OceanDrift from the open source OpenDrift software package; iv) an ecosystem model that includes a food web model of a typical North Atlantic seamount was simulated with the open source AQUATOX model (US- EPA); and v) a food web model of an Atlantic deep-sea hydrothermal vent was simulated with the open source Ecopath with Ecosim model (EwE) (Figure 6.4A).

Based on their different behaviour, four HNS were selected: 4-nonylphenol (4NP), a persistent floater with potential strong effects on pelagic communities; tetrachloroethylene (PCE), a sinker with potential strong effects on benthic communities; aniline (AN), a floater/dissolver with potential strong to medium effects on pelagic and benthic communities; and nitrobenzene (NTB), a sinker/dissolver with potential strong to medium effects on pelagic and benthic communities.

The two selected ecosystems in the Azores oceanic region within the area calibrated for ROMS, were the Seamount 10, due to a lower depth location of the summit (413 m), and the Menez Gwen vent field, also due to a lower depth location (850 m).

Seamounts are hotspots of biodiversity and important habitats for commercial relevant species (e.g., tuna), whereas deep-sea hydrothermal vent field are chemosynthetic fuelled ecosystems sustaining iconic endemic species (e.g., vent mussels).

For each different HNS spill, it was assumed an incident at sea encompassing 100 containers with a volume of 76 m^3 each, which sank to the bottom and reached the summits of Seamount 10 (S10) and Menez Gwen (MG). A total volume of 7600 m^3 (100 containers x 76 m^3) leaked for five days (120 h) from the containers and distributed uniformly around S10 and MG. For each HNS incident, a winter and a summer scenario were simulated.

In both the AQUATOX seamount model and the EwE vent field model, HNS effects were accounted by acute toxicity (LC50). Nonetheless, due to the lack of data regarding the toxicity of the selected HNS on the food web species of both deep-sea ecosystems, in most cases, proxy species had to be considered.

The effects of HNS were simulated assuming the maximum HNS concentrations outputted by the circulation and Lagrangian models at the summit of the seamount and the vent field.

iii) Main findings

According to the ocean circulation and Lagrangian model simulations, the concentrations of HNS are always higher at MG compared to S10, which is related to different circulation patterns affecting the two deep-sea habitats.

From the four considered HNS, PCE (the sinker) attains the highest concentrations at MG, both in winter (PCE=1.180 mgL^{-1}) and summer (PCE= 1.432 mgL^{-1}).

Results regarding the variation of abiotic parameters in the seamount ecosystem model, such as water temperature and salinity, were very well represented. However, nutrients, especially nitrate, were underestimated, possibly due to the fact that the model does not account for the upwelling of deeper nutrient-enriched waters. The seamount food web model accounts for 14 functional groups, amongst which, seven correspond to different fish groups (pelagic fish, demersal fish, mesopelagic fish, tunas, bathypelagic fish, pelagic sharks, deep and benthic sharks and rays), where some correspond to commercially important species (e.g., *Thunnus obesus*). Simulations indicate a GPP (gross primary production) of 42 g O2 d^{-1} (equivalent to 1312.5 mmole O2 d^{-1}), a P/R of 0.88, and a total biomass of 3.83 t DW km^{-2}.

Despite the sinking behaviour of PCE and NTB, in terms of recovery time, it was AN that revealed the longest recovery period (~7 years). This is probably related to specific physico-chemical properties of AN that highly influence its consequent breakdown in the system, with further consumption of dissolved oxygen, leading to anoxic conditions and further mortality. Indeed, although unexpectedly, AQUATOX predicts a decrease in oxygen concentration promoted by the breakdown of the four HNS, which in turn leads to the mortality of biotic groups that are strongly limited by dissolved oxygen concentrations, particularly, at higher depths. Although these results require validation, the indirect effect of pollutants degradation on oxygen depletion with depths cannot be ruled out in case of HNS spills at sea.

According to EwE simulations, the food web structure of the MG hydrothermal field is rather simple, including only three trophic levels, with low predation pressure, with free-living bacteria and vent mussels playing major roles in shaping the ecosystem. Network analysis suggests a system under development that has not yet reached maturity. The simulations of the hypothetical spills of 4NP, AN, and NTB, at the MG, had no observable impacts on the local benthic community. Otherwise, the PCE accidental spill induced concentrations that surpass the acute toxicity levels for two functional groups in the MG trophic web, namely, vent gastropods and vent mussels, with a consequent reduction of 50% in their biomass, which subsequently led to several impacts on higher and lower trophic levels. Nonetheless, according to these preliminary results, the MG ecosystem would recover its initial state after ~ 20 years.

The results of the effects of the four HNS on the two studied deep-sea ecosystems must be regarded cautiously and, at this point, only as a theoretical exercise. In fact, if a protection factor of 100, 1000, 10.000 would be used to set the LC50 as frequently recommended in case of toxicity data gaps (Soares et al., 2020), the effects of the studied HNS on both the seamount and the vent field ecosystems would be much stronger, potentially, leading to the extinction of deep-sea communities. On the other hand, some of these organisms are adapted to extreme environmental conditions, including metal-enriched environments as is the case of the Atlantic deep-sea mussel (*Bathymodiolus* sp.), and have developed mechanisms to cope with such extreme conditions (e.g., metallothioneins) (Company et al., 2007). We do not know if these adaptions would confer them some kind of protection against other type of pollutants.

iv) Final remarks and recommendations

Developing the MODELRISK project allowed us to assemble and calibrate a numerical framework encompassing several different models, from circulation and Lagrangian dispersion models, to toxicology, food web and ecosystem models of Atlantic deep-sea ecosystems, to respond to HNS accidental spills at Sea. While innovative and timely, the presented framework requires further calibration and validation before it can be used as a decision-support tool in spill response. Most of the current limitations of the MODELRISK framework rely on knowledge gaps (Figure 6.4B), namely:

- The absence of a numerical tool that describes the chemical transformations of HNS in the water column (horizontally and vertically), while describing their dispersion (the first version of a model that describes pollutants fate in the water has just been released- ChemicalDrift by OpenDrift - Aghito et al., 2023);
- Available ecosystem models are not, in general, appropriate to simulate chemosynthetic ecosystems and habitats (i.e., where energy is not produced by photosynthesis);
- There is a deep knowledge gap regarding chronic and acute toxicity of the most frequently transported HNS on marine and deep-sea species;
- Available knowledge regarding the ecology and physiology of some marine species and most deep-sea species is rather limited.

Hence, we recommend that future research may tackle the aforementioned points. Subsequently, modellers can improve the calibration, verification and, ultimately, the validation of the MODELRISK framework, allowing it to be used as a support tool in HNS spill response at Sea.

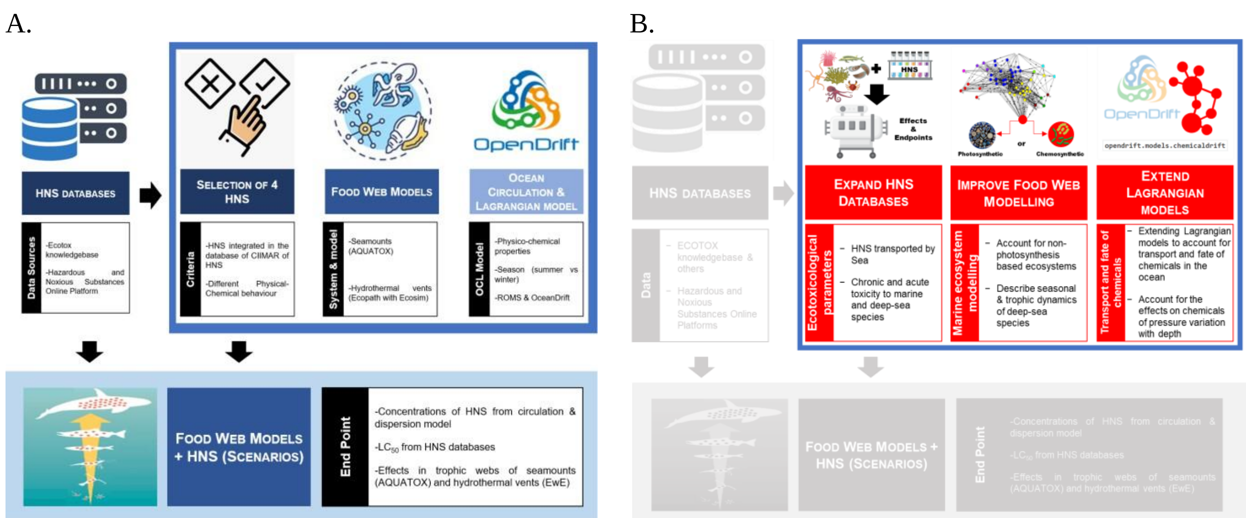

Figure 6.4. A. Workflow; B. Recommended research efforts to tackle the limitations identified.

v) References

Aghito, M., et al., Calgaro, L., Dagestad, K-F. et al. (2023). ChemicalDrift 1.0: an open-source Lagrangian chemical-fate and transport model for organic aquatic pollutants. Geosci. Model Dev. 16(9): p. 2477-2494.

Company, R., Serafim, A., Cousson, R. et al. (2007). Adaptation of the antioxidant defence system in hydrothermal-vent mussels (*Bathymodiolus azoricus*) transplanted between two Mid- Atlantic Ridge sites. Marine Ecology 28(1): p. 93-99.

Cunha, I., Moreira, S., Santos, M.M. (2015). Review on hazardous and noxious substances (HNS) involved in marine spill incidents-An online database. Journal of Hazardous Materials 285: 509- 516.

Neuparth, T., Moreira, S.M., Santos, M.M., Reis-Henriques, M.A. (2012). Review of oil and HNS accidental spills in Europe: Identifying major environmental monitoring gaps and drawing priorities. Marime Pollution Bulletin, 64, 1085-1095.

Soares, J., Fernandes, R., Brito, D., Oliveira, H., Neuparth, T., Martins, I., Santos, M.M. (2020). Environmental risk assessment of accidental marine spills: A new approach combining an online dynamic Hazardous and Noxious substances database with numerical dispersion, risk and population modelling. Science of the Total Environment 715: 136801.

d) ToR 3.4. Update on seabed macrolitter on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO): Sources, drivers of distribution and reviewed protocol for groundfish surveys

An update on seabed macrolitter in NAFO Regulatory Area was provided, building on the information presented during the Scientific Council in June 2024 (Abalo-Morla et al., 2024). The update included a reviewed protocol for data collection during the EU groundfish surveys, as well as results from the analysis on the sources and drivers of the spatial distribution of seabed macrolitter in the NRA.

i) Reviewed protocol for data collection in the EU groundfish surveys.

Given the need for standardized protocols to collect data on seabed macrolitter and ensure high-quality information, a revised protocol was proposed based on the revision and improvement of the previous methodology used by the IEO during its groundfish surveys in the NRA. The aim of this revised protocol is to establish common criteria for the surveys across different divisions, promoting a "common practice" and enabling standardized data recording. The review of the available data and information led to the development of a standardized master file, that includes all updated categories and specific codes for records collected by the IEO in the NRA to date. This standardized master file, it has been an essential first step for subsequent data analysis and it is crucial for the correct categorisation of sampled items. Additionally, as part of the revised protocol an improved seabed macrolitter data collection form was developed and tested during the EU groundfish in 2024. Furthermore, a visual guide for seabed macrolitter data collection, designed to assist in categorizing litter items onboard, and a decalogue of good practices for scientific bottom trawl surveys are in preparation.

ii) Update on seabed macrolitter: Sources and drivers of distribution.

Data collected from EU groundfish surveys (Divisions 3LMNO: 2018-2023 period) was analyzed. A total of 1936 valid hauls were examined, with 528 macrolitter items found in 16.7% of these hauls. Using the source-specific indicator items from the OSPAR Commission (2007), following García-Alegre et al. (2020), the main sources of seabed macrolitter were identified. The primary source was fisheries (44.8% of recorded items); followed by non-operational galley waste from shipping, fisheries and offshore activities (3.9% of recorded items); and operational waste from shipping and offshore activities (3.2 % of recorded items). Significant differences in density of items were found among Divisions for all sources except non-operational waste. To elucidate the drivers of seabed macrolitter distribution, the data was analyzed separately for different trawl gear types (Campelen 1800 in Divisions 3LNO; Lofoten in Division 3M). Environmental variables that could influence seabed macrolitter distribution were considered. Overall, the GAM models explained only a small portion of the variability, with limited predictive power. The best models for both areas considered only presence data and explained approximately 11% of the variability in standardized item abundance. Important variables influencing the spatial distribution of seabed macrolitter included slope, depth, bottom sea current speed, roughness, and sediment texture. Slope was significant in Divisions 3LNO, while bottom trawl fishing effort and sediment texture were significant in Division 3M. Despite the low explanatory power of the models, these results provide preliminary insights into the distribution of seabed macrolitter, though accurate modelling remains challenging.

iii) References

Abalo-Morla S, Palas Otero S, Román-Marcote E, Durán Muñoz P, Pérez P, Sacau M (2024) Preliminary results on seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO). NAFO SCR Doc. 24/046. Serial No. N7553

García-Alegre A., Román-Marcote E., Gago J., González-Nuevo G., Sacau M., Durán Muñoz P. (2020). Seabed litter distribution in the high seas of the Flemish Pass area (NW Atlantic). Scientia Marina 84(1). https://doi.org/10.3989/scimar.04945.27A

OSPAR (2007). Monitoring of Marine litter in the OSPAR Region. Publication No. 306/2007. London, United Kingdom, 74 pp.

e) ToR 3.5. Regular Monitoring of Ecosystem Summary Sheets (ESSs) for Divisions 3LNO and 3M (COM Request #1)

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.*

i) Introduction

The Ecosystem Summary Sheets (ESSs) for the Grand Bank (Divs. 3LNO) and Flemish Cap (Div. 3M) Ecosystem Production Units (EPUs) are scheduled for a regular update in 2027, unless changes in these ecosystems warrant an earlier update. The evaluation of these changes is done through an annual interim monitoring process. Due to changes in the Scientific Council workplan for 2025-2027, that involves a higher workload for the WG-ESA during those years, WG-ESA requested SC to consider requesting the Commission (COM) to delay the next update of the ESSs to 2028.

The ESS interim monitoring is aimed at detecting significant ecological changes. The evaluation is focused on: 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). Based on these elements, an expert judgment examination is conducted to determine if significant ecological change has occurred, and an out-of-schedule ESS update needs to be triggered.

WG-ESA examined the relevant ecosystem information for the Grand Bank (Divs. 3LNO) EPU, presented in the context of ecosystem trends across EPUs in the Newfoundland and Labrador Bioregion, and for the Flemish Cap (Div. 3M) EPU.

ii) Interim Monitoring of the Grand Bank (Divs. 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) (Fig. 6.5). 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 2024 are preliminary as some components of the NLCI are not yet available, the current data indicates that 2024 was a warm year, continuing the warm phase that started in 2020 (Figure 6.5). These ocean climate phases have been associated with changes in ecosystem productivity, with warm phases favouring production at the ecosystem level (see section 6(j) in this report).

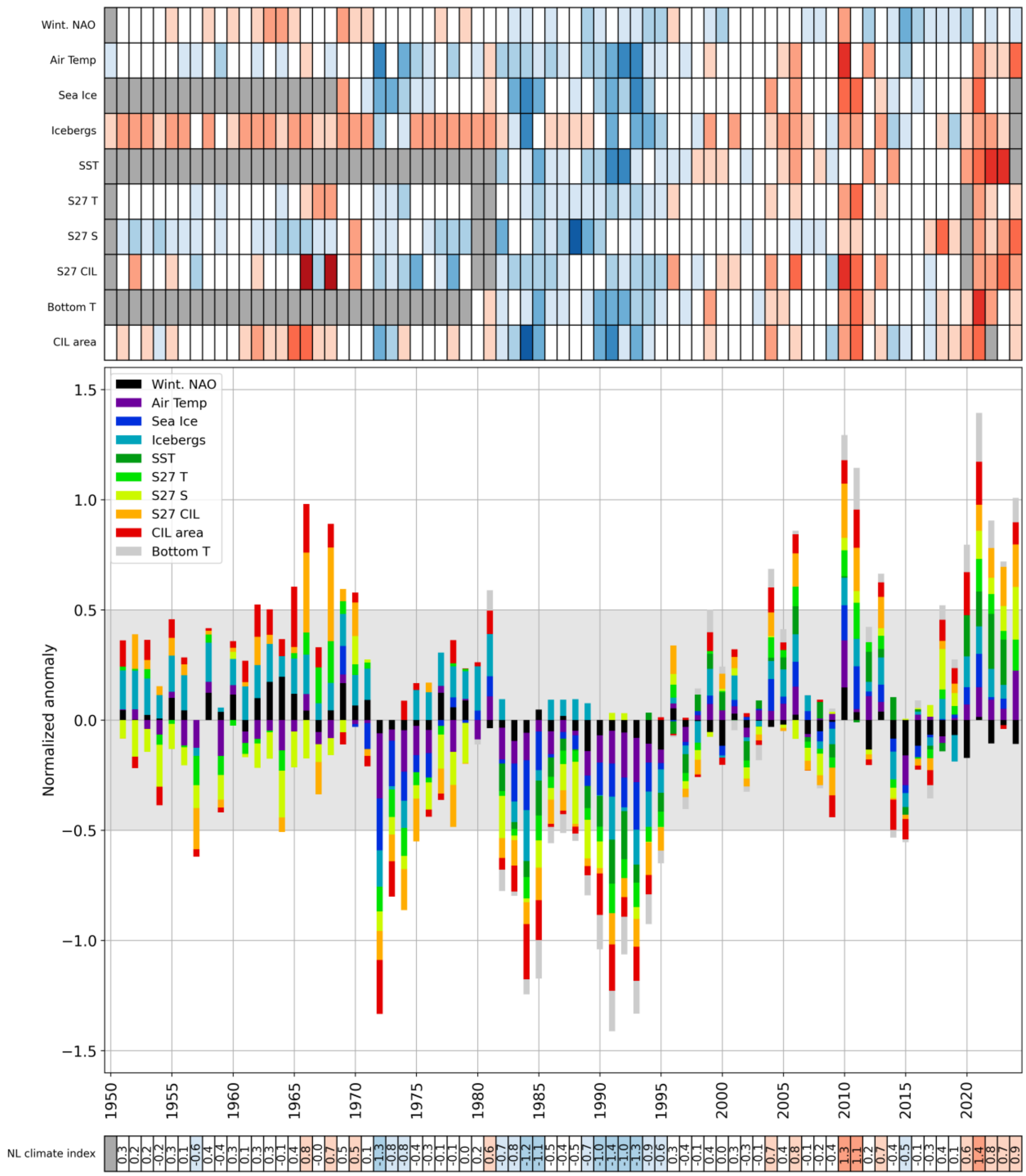

Figure 6.5. Newfoundland and Labrador Climate Index (NLCI). This index summarizes the general ocean climate conditions in the NL Bioregion. The data for 2024 are preliminary as some components of the index are not yet available.

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 forage species like capelin (Buren et al., 2019), and the increase in shellfish (dominated by *Pandalus* shrimp). 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).

Newfoundland Shelf (Divs. 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 6.6). 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 6.6).

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 *Pandalus* shrimp gaining importance during the period this ecosystem was dominated by shellfish. 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. Diets from 2023 show an improvement in capelin in Atlantic cod in comparison with the immediately preceding years (Figure 6.7).

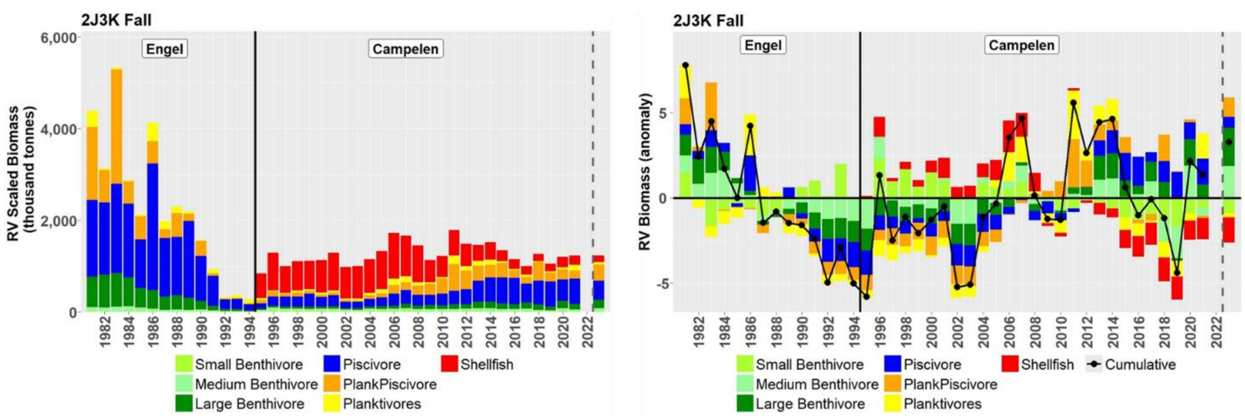

Figure 6.6. Research Vessel (RV) Fall Biomass (left) and Biomass Anomaly (right) of the fish community in the Newfoundland Shelf (2J3K) EPU, discriminated by fish functional group. Engel and Campelen indicate the fishing gear used in each period. The biomass for the Engel period has been scaled so that the order of magnitude of the estimates are comparable between periods. There is no Shellfish data available for the Engel period. 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. Conversion factors at the ecosystem level are still in development, but using unconverted data is generally considered acceptable for order of magnitude analyses.

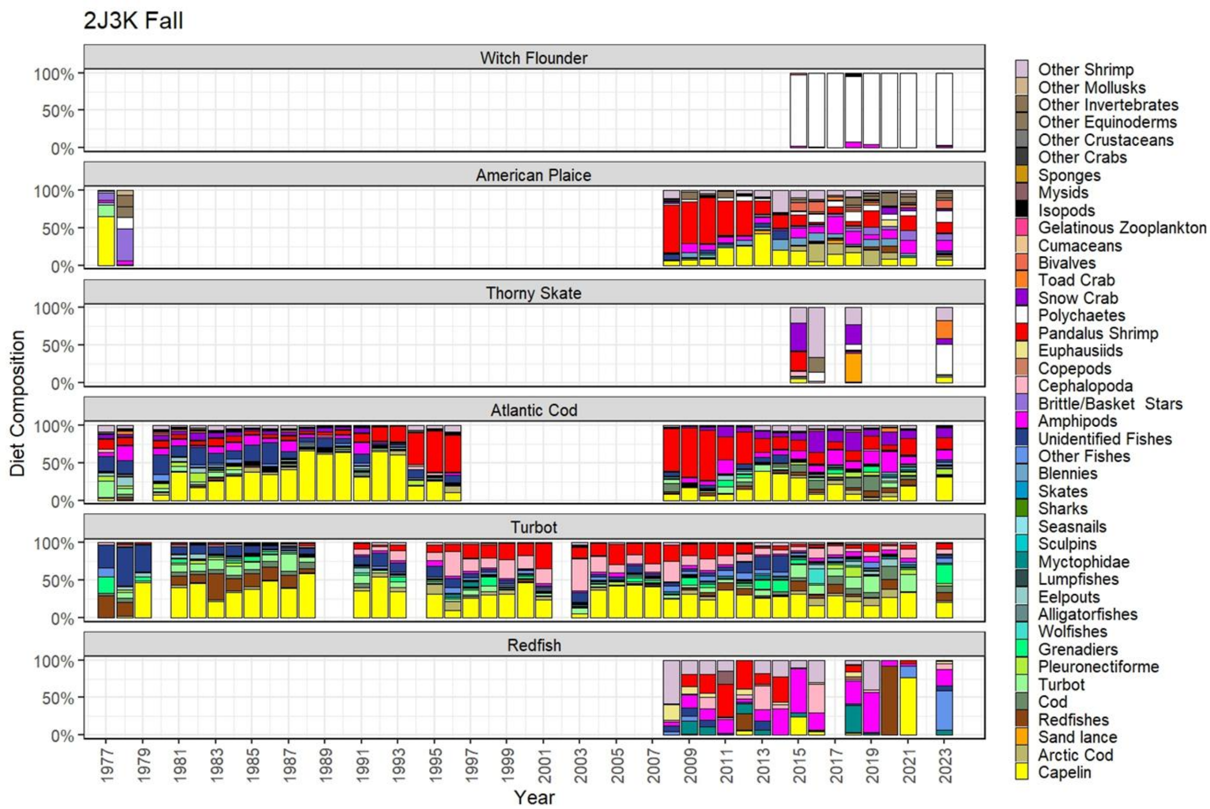

Figure 6.7. Diet composition for key species in the Newfoundland Shelf (2J3K) EPU from stomach contents collected during DFO Fall survey.

Grand Bank (Divs. 3LNO)

This ecosystem also saw increases in shellfish after the collapse, but the overall ecosystem structure remained groundfish dominated (Figure 6.8). 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 6.8). The Spring survey, which includes one more year than the Fall survey, shows biomass around the 2010 levels. The 2024 Spring survey also shows clear increases in the piscivore and planktivore functional groups. These increases are driven by Atlantic cod and capelin in the northern portion of the EPU (Div. 3L).

Within this EPU, the diets of key groundfish species show capelin and sandlance as important prey. While both forage fishes are important, capelin appears to increase its importance for some predators in the spring, and sandlance in the fall. Diets from the last decade do not appear to indicate any major structural change in diet composition. The 2024 spring diets show modest improvements in capelin dominance in several predators (Atlantic cod, American plaice and redfish) (Figure 6.9).

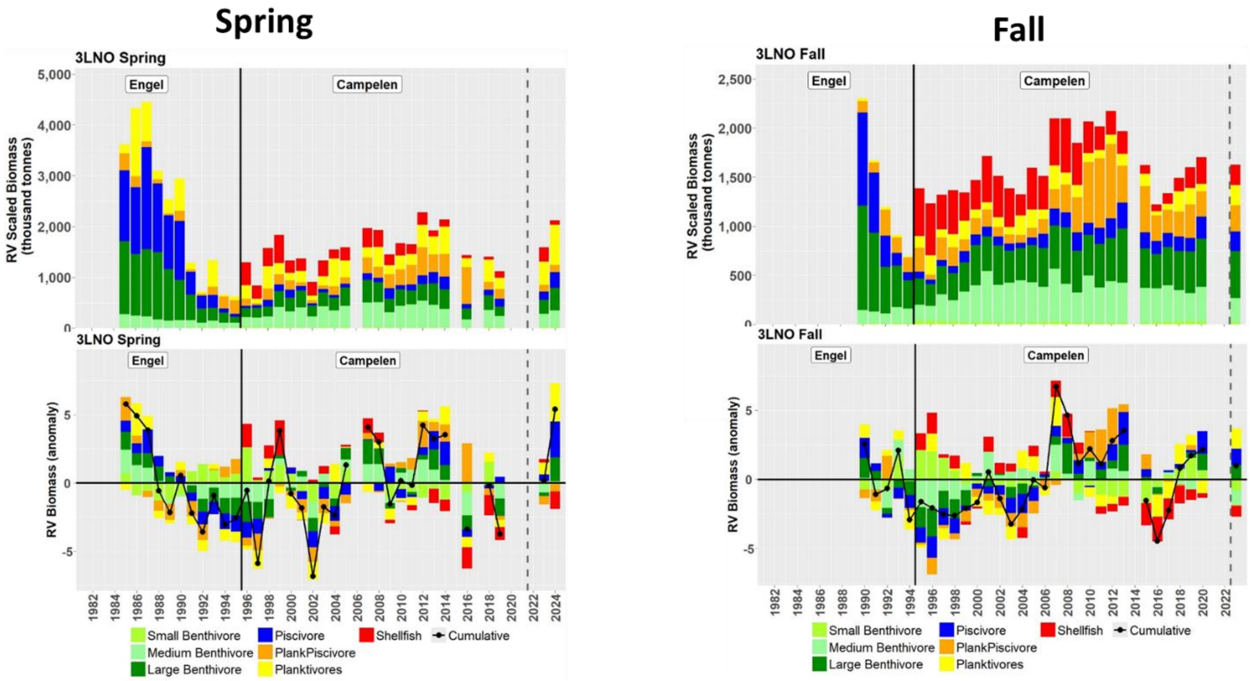

Figure 6.8. Research Vessel (RV) Spring (left column) and Fall (right column) Biomass (top row) and Biomass Anomaly (bottom row) of the fish community in the Grand Bank (3LNO) EPU, discriminated by fish functional group. Engel and Campelen indicate the fishing gear used in each period. The biomass for 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. The dashed 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. Conversion factors at the ecosystem level are still in development, but using unconverted data is generally considered acceptable for order of magnitude analyses.

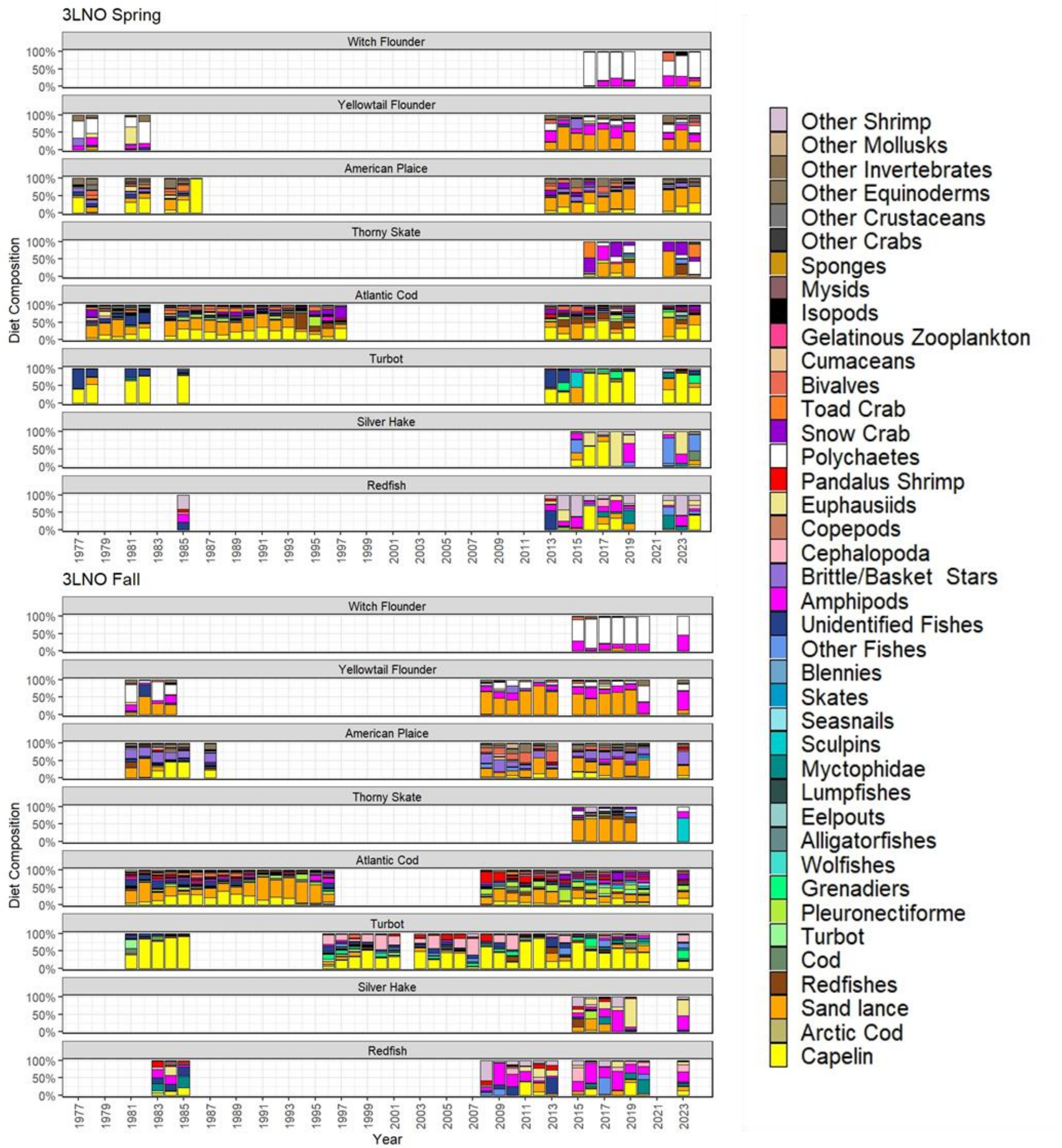

Figure 6.9. Diet composition for key species in the Grand Bank (Divs. 3LNO) EPU from stomach contents collected during DFO Spring (top) and Fall (bottom) surveys.

Southern Newfoundland (Div. 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 6.10). However, unlike other EPUs, this ecosystem has not shown clear signals of rebuilding after the declines, apart from transitory spikes in the plankpiscivore 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 6.10). The last data available appears to suggest that improvements in total biomass may be occurring, but the lack of recent surveys has prevented a proper evaluation of this signal.

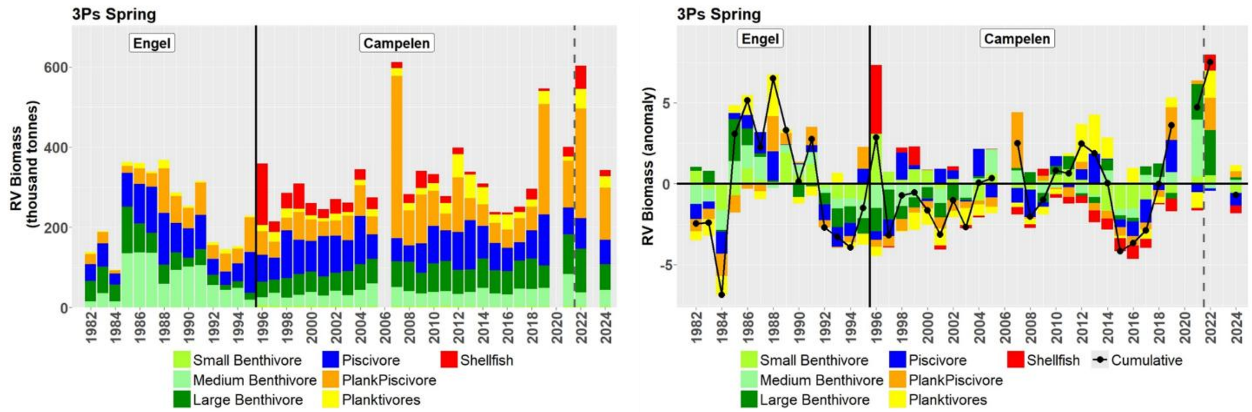

Figure 6.10. Research Vessel (RV) Spring Biomass (left) and Biomass Anomaly (right) of the fish community in the Southern Newfoundland (Div. 3Ps) EPU, discriminated by fish functional group. Engel and Campelen indicate the fishing gear used in each period. Unlike the other EPUs in the NL Bioregion, the 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 dashed 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. Conversion factors at the ecosystem level are still in development, but using unconverted data is generally considered acceptable for order of magnitude analyses.

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 6.11). The increasing in dominance of silver hake, and the high intrusion of spiny dogfish in 2019, both warmer water species, indicate this community is changing (NAFO, 2021). These changes have been associated with the warming observed in this EPU. Recent analyses indicate 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. Unlike other ecosystems, fish diets in this EPU appear more variable, suggesting a less stable prey field (Figure 6.12).

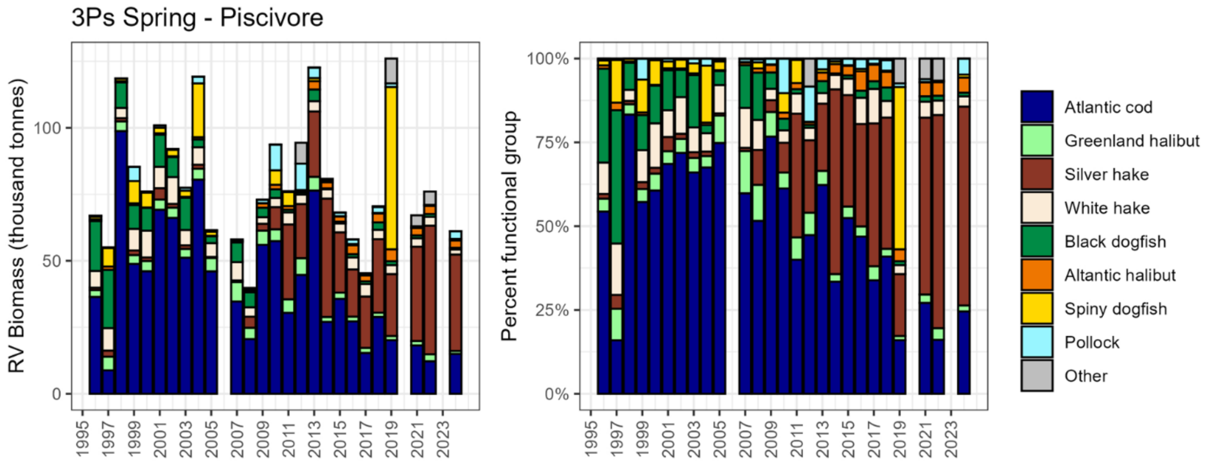

Figure 6.11. Trends in RV Biomass (left) and structure (right) of the piscivore functional group in the Southern Newfoundland (Div. 3Ps) EPUs.

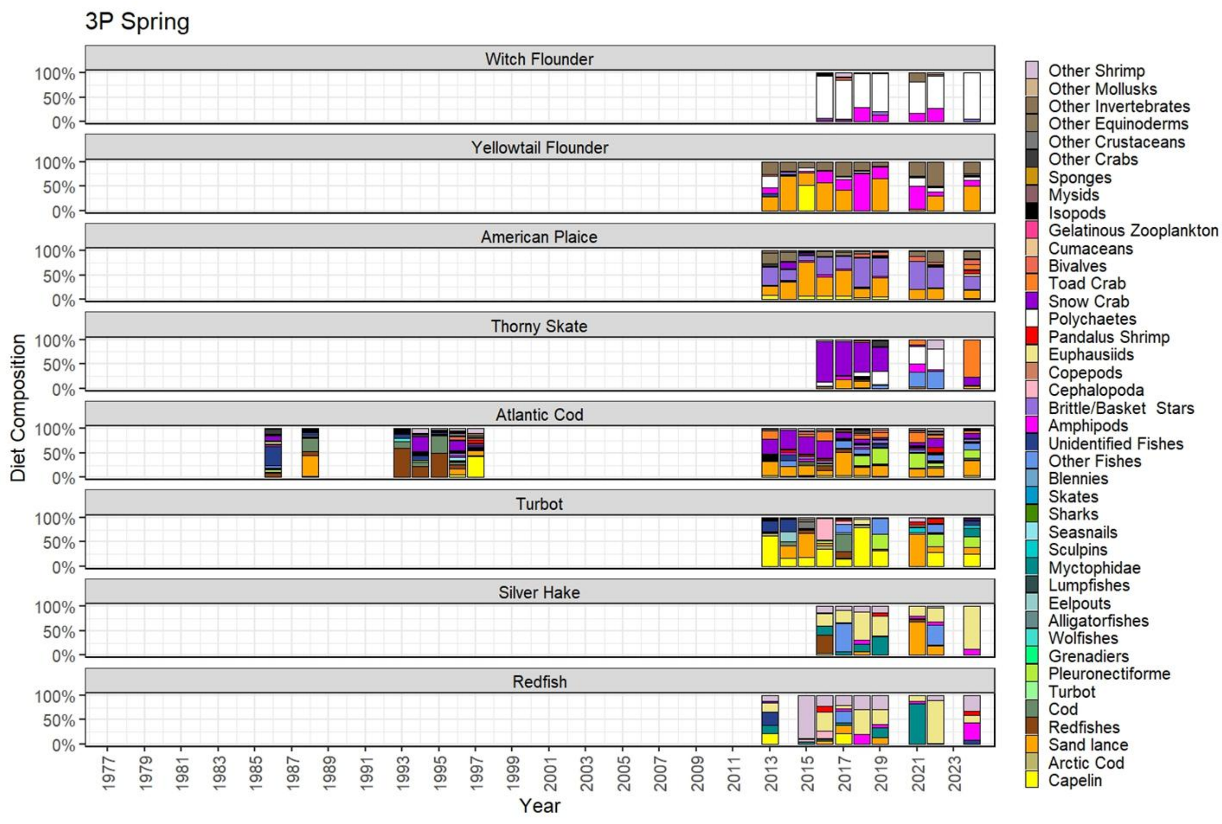

Figure 6.12. Diet composition for key species in the Southern Newfoundland (3Ps) EPU from stomach contents collected during DFO Spring survey.

v) Comparisons among EPUs

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 6.13). These EPUs have sustained significantly lower biomass densities since the collapse, indicating that after the regime shift these ecosystems have been experiencing reduced 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 available data indicate positive trends since 2019-2020.

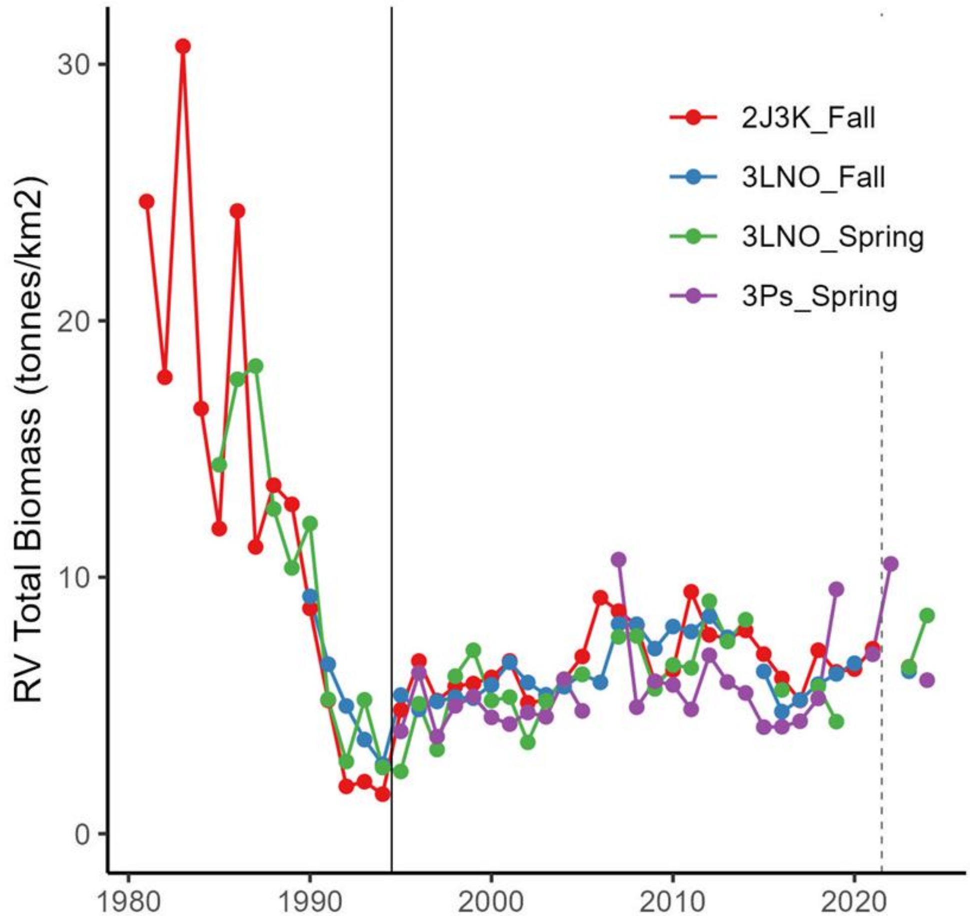

Figure 6.13. Total RV biomass density across EPUs in the NL bioregion. The vertical filled line indicates the change in fishing gear from Engel to Campelen. Shellfish data is only included for the Campelen period, but this has minor impacts as the substantive increase in shellfish occurred after the gear change. The biomass for the Engel period has been scaled so that the order of magnitude of the estimates are comparable between periods (except for 3Ps). The dashed 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. Conversion factors at the ecosystem level are still in development, but using unconverted data is generally considered acceptable for order of magnitude analyses.

In terms of community structure, there are clear differences among EPUs (Figure 6.14). 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 (Divs. 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 (Div. 3Ps) EPU saw the weakest shellfish response to the groundfish collapse. Another 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 (Divs. 2J3K) after this ecosystem unit returned to a groundfish dominated structure

(Figure 6.14). Despite the longer term changes, the general structure of these ecosystem units has remained relatively stable during the last decade (Figure 6.14), but this structural stability does not necessarily imply stability within functional groups, as the case of piscivores in Southern Newfoundland (Div. 3Ps) clearly demonstrates (Figure 6.11).

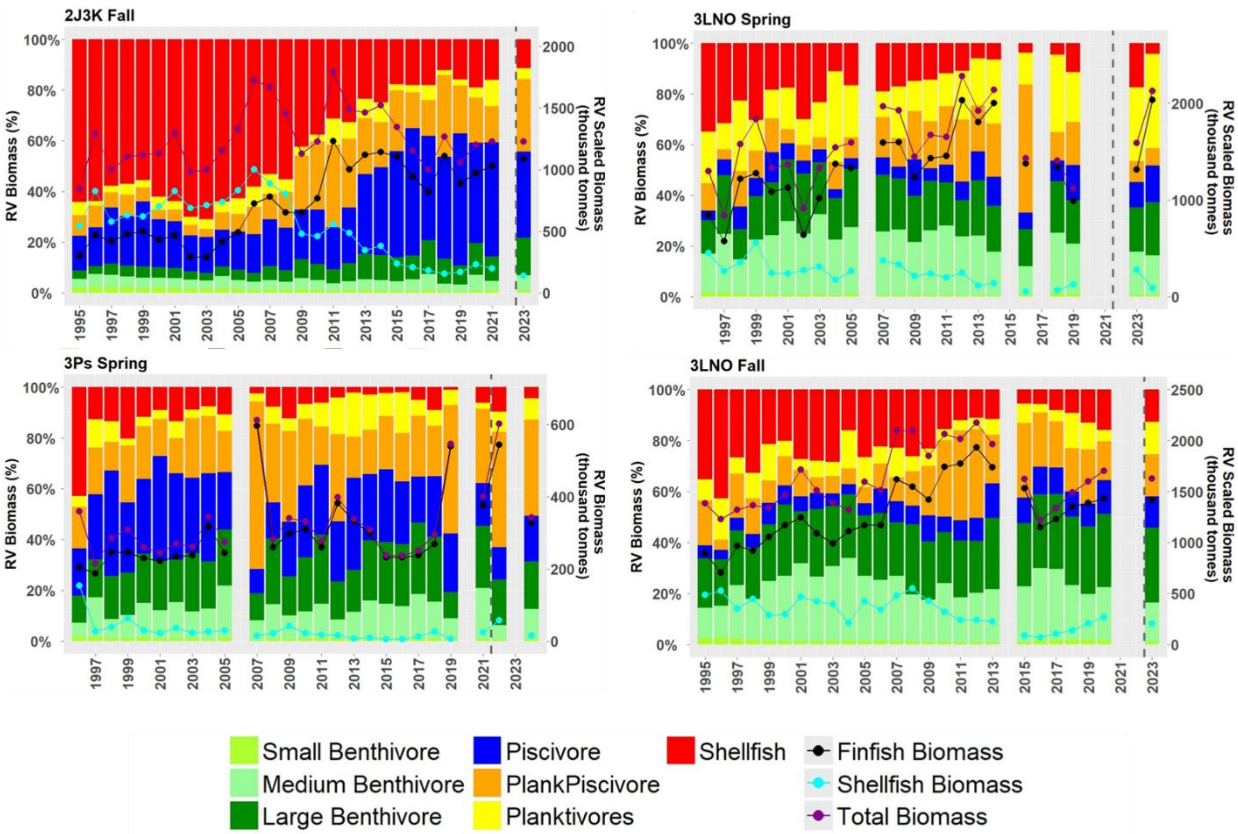

Figure 6.14. Synoptic comparison of the trends (total, finfish, and shellfish biomass) and structure (fish functional groups) of the fish communities after the ecosystem collapse. Top left: Newfoundland Shelf (Divs. 2J3K) from Fall survey, Right: Grand Bank (Divs. 3LNO) from Spring (top) and Fall (bottom) surveys, Bottom left: Southern Newfoundland (Div. 3Ps) from Spring survey.

From a trophic perspective, the long-term signal in the average stomach content weights of Atlantic cod and Greenland halibut (aka Turbot) across EPUs (Figure 6.15) shows a consistent pattern with the trend in total biomass density (Figure 6.13). This relationship is significant (Figure 6.15), and suggests that food availability has been an important and consistent driver of ecosystem change in the NL Bioregion. 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.

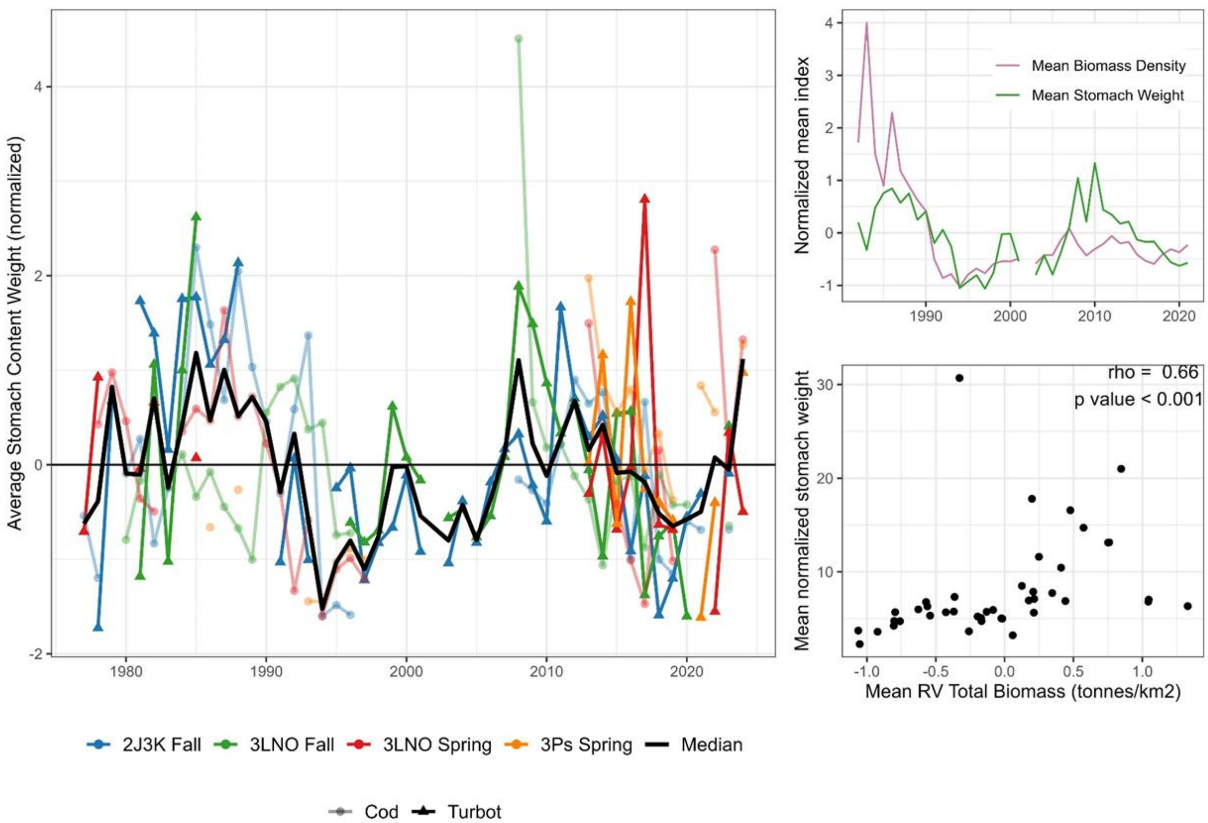

Figure 6.15. Average stomach content weights of Atlantic cod and Greenland halibut (aka turbot) across the EPUs in the NL Bioregion (fish sizes limited to 30-55 cm and excluding empty stomachs to minimize the effects of changes in size distributions and the variability in the determination over time of what constitutes an "empty stomach") (left). Comparison between average stomach content weights (Figure 6.15) and the average of the total biomass density (Figure 6.13) (right). These two signals are positively and significantly correlated (Spearman correlation).

vi) 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 (Divs. 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 are not at this stage considered to meet the "significant ecological change" criterion required to trigger an update of the 3LNO Ecosystem Summary Sheet out of schedule.

vii) Interim Monitoring of the of the Flemish Cap (Div. 3M) EPU

The Flemish Cap bioregion (Div. 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).

viii) Ocean climate conditions

The Ocean Climate Index for the Flemish Cap (Div. 3M) EPU is derived from several temperature series, and provide a general characterization of the ocean climate in this EPU (Cyr and Bélanger, 2024). The ocean climate in the Flemish Cap 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, with years 2023 and 2022 ranking respectively as the warmest and second warmest years since the time series started.

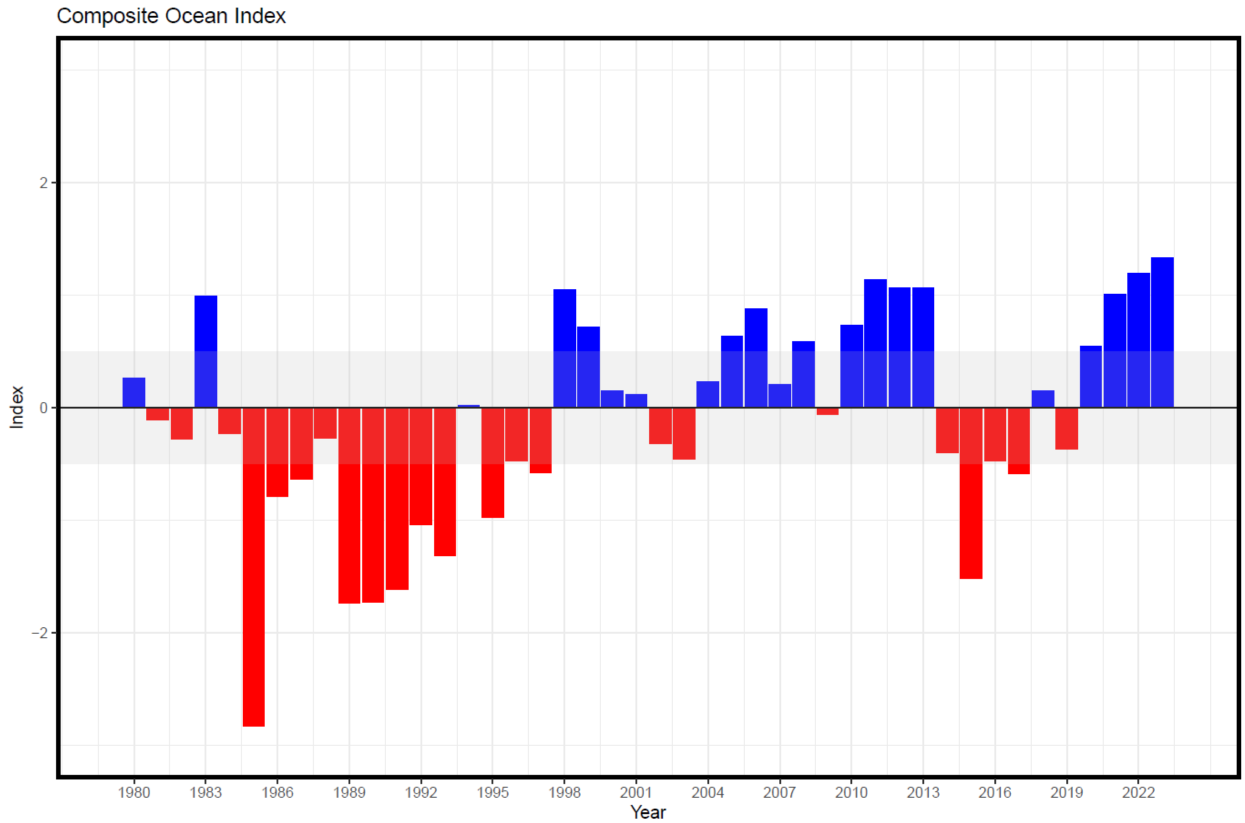

Figure 6.16. Ocean Climate Index for the Flemish Cap (Div. 3M) EPU. This index summarizes the general ocean climate conditions in the 3M EPU. The data for 2024 is not yet available.

ix) Trends, fish community structure and trophic interactions

The data used in this section come from the EU Div. 3M survey, that 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 2003-2024 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 *Pandalus* shrimp), and an important increase in total biomass was observed in the mid 2000s driven by plankpiscivores due to high recruitment of redfish (Figure 6.17).

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 plankpiscivores (mainly redfish) (Figure 6.18).

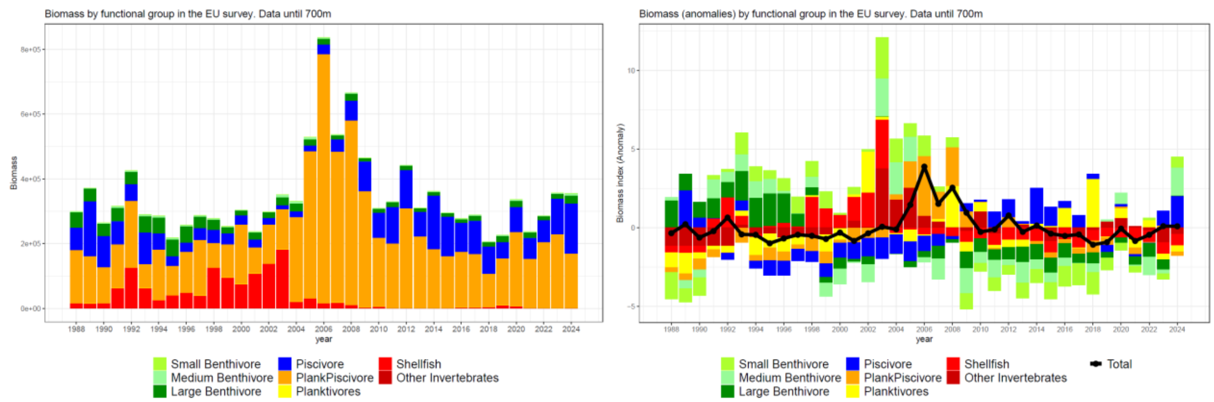

Figure 6.17. Research Vessel (RV) Biomass (t) (left) and Biomass Anomaly (right) of the fish community in the Flemish Cap (Div. 3M) EPU, discriminated by fish functional group. Data until 700 m. The data for 2024 are preliminary and are subject to revisions.

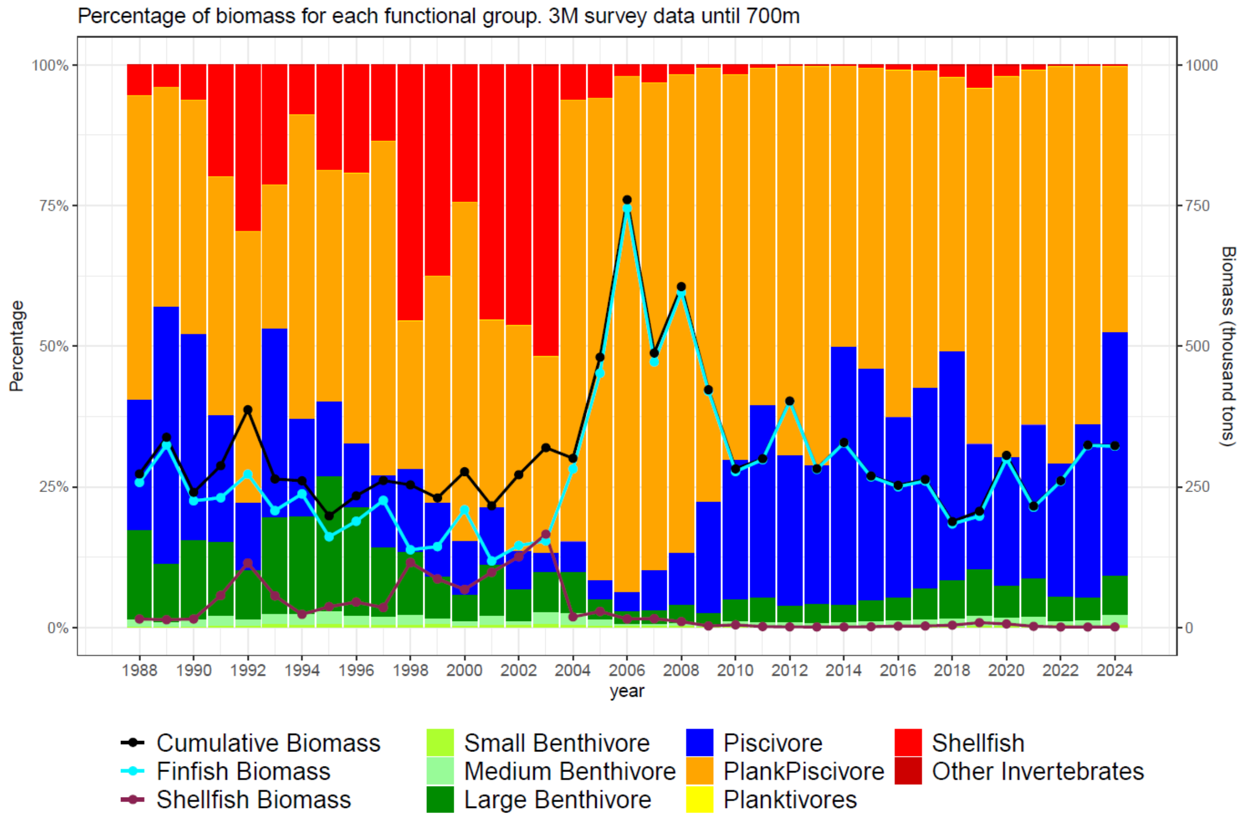

Figure 6.18. Synoptic view of the trends (total, finfish, and shellfish biomass) and structure (fish functional groups) of the fish community in the Flemish Cap (Div. 3M) EPU. Data until 700 m. The data for 2024 are preliminary and are subject to revisions.

x) 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 6.19). 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.

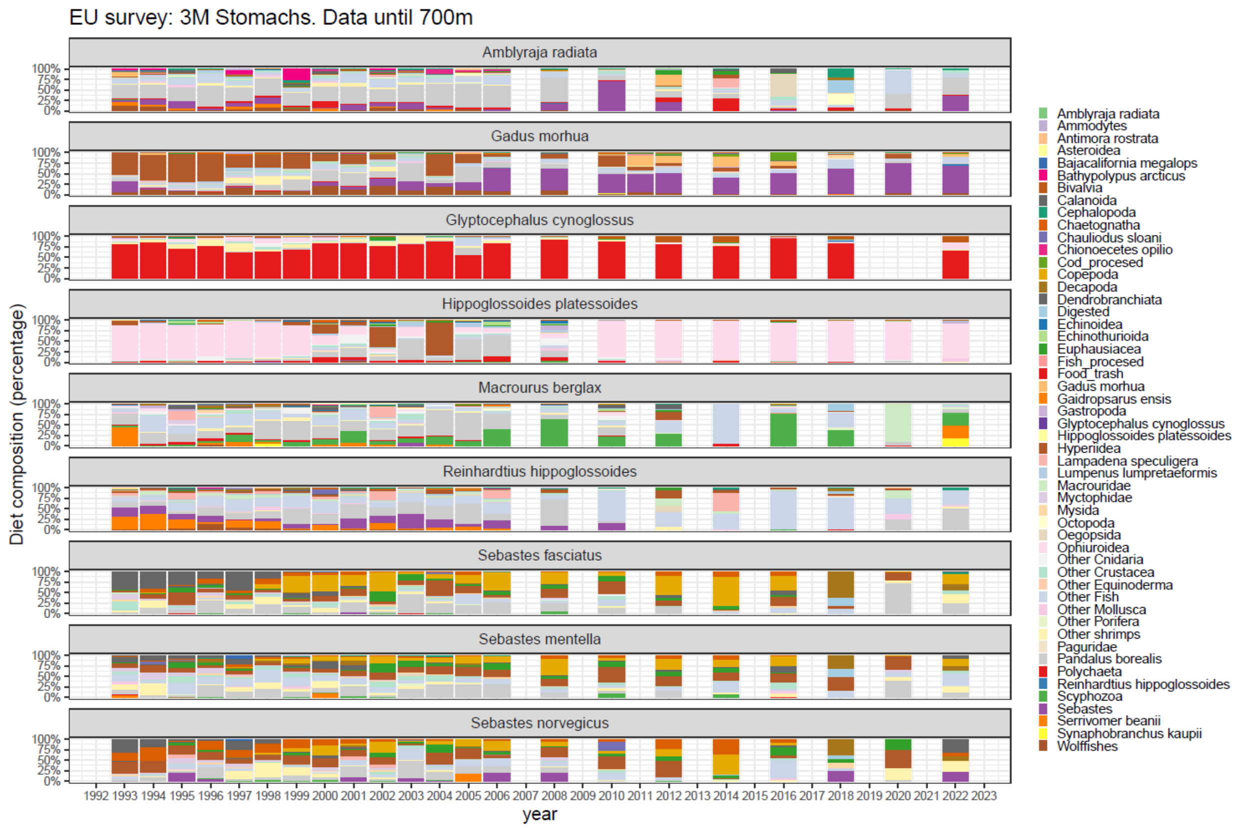

Figure 6.19. Diet composition for key species in the Flemish Cap (3M) EPU from stomach contents collected during EU surveys. Data until 700 m.

In general, the average stomach content of the main predators in the 3M EPU has decline over the years (Figure 6.20, 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 6.20, right plots), suggesting that prey availability does not appear be a major driving factor in this ecosystem.

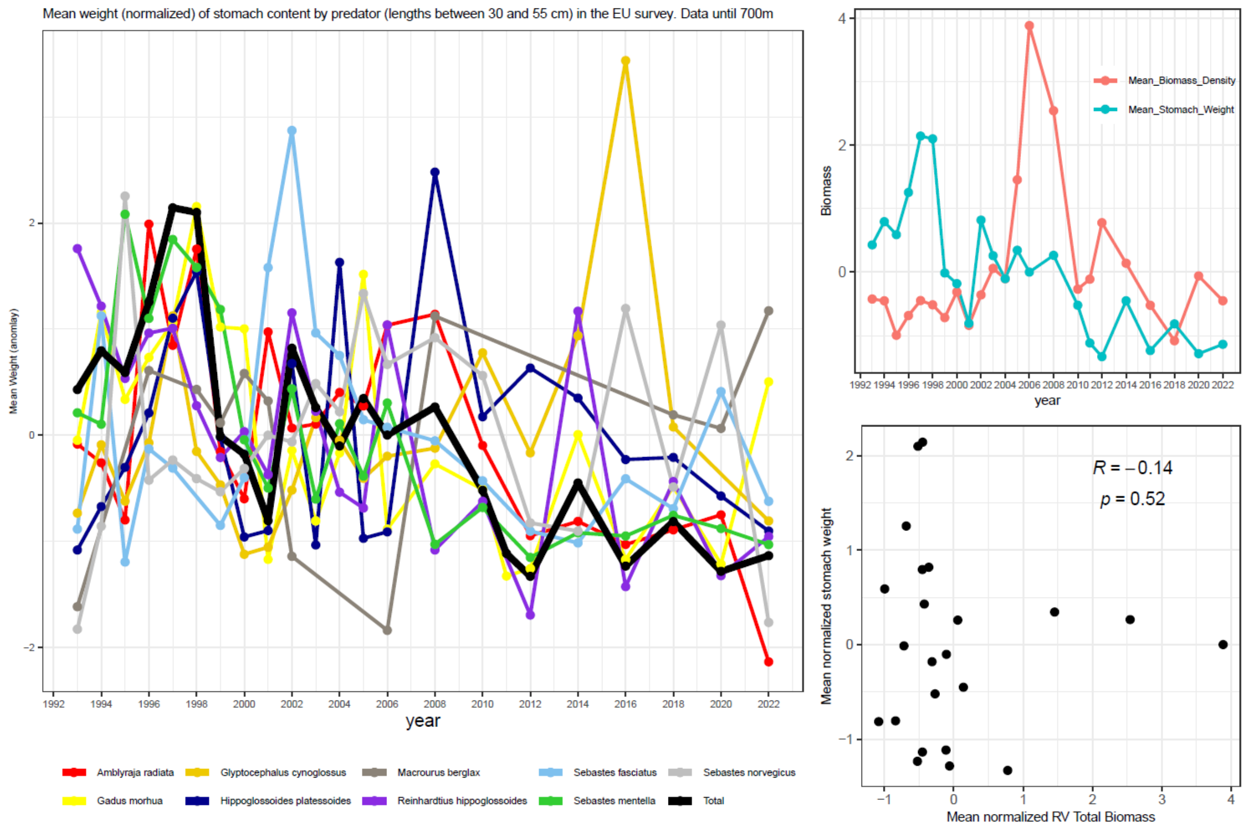

Figure 6.20. Average stomach content weights (standardized) of the main predators in the 3M EPU (fish sizes limited to 30-55 cm and excluding empty stomachs to minimize the effects of changes in size distributions and the variability in the determination over time of what constitutes an "empty stomach") (left). Data until 700 m. Take into account that from 2006 the stomach sampling in the survey is every two years. Comparison between average stomach content weights (Figure 6.20 left plot) and the average of the total biomass density (Figure 6.18).

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 6.21). 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.

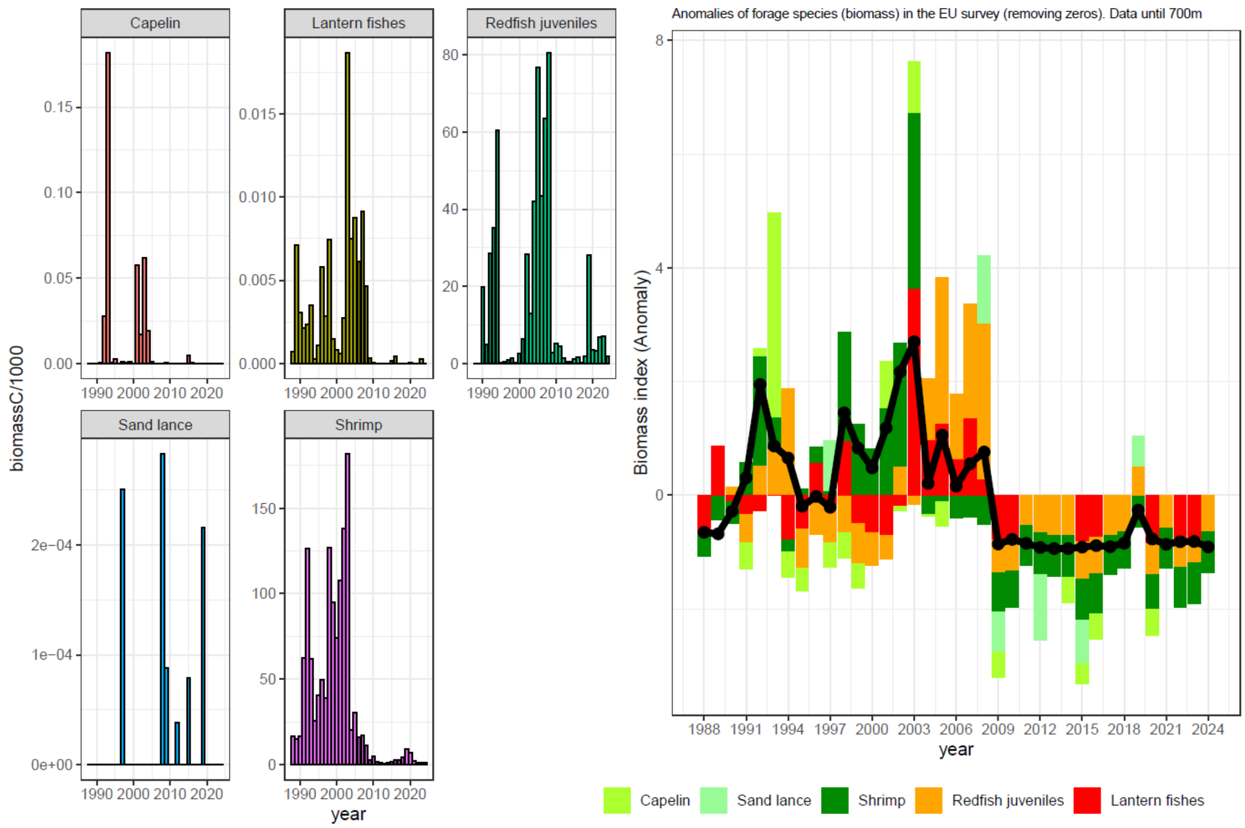

Figure 6.21. Biomass (left) and anomalies of the biomass (right) of the main forage species in the 3M EPU. Data until 700 m.

xi) Evaluation of significant ecological change

The nature and magnitude of the recently observed changes in the Flemish Cap (Div. 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.

xii) References

Buren, A. D., Murphy, H. M., Adamack, A. T., Davoren, G. K., Koen-Alonso, M., Montevecchi, W. A., Mowbray, F. K., et al. 2019. The collapse and continued low productivity of a keystone forage fish species. Marine Ecology Progress Series, 616: 155-170.

Cyr, F., and Bélanger, D. 2024. Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS) – 2023 update. NAFO SCR Document, 24/012: 21pp.

Cyr, F., and Galbraith, P. S. 2021. A climate index for the Newfoundland and Labrador shelf. Earth System Science Data, 13: 1807-1828.

Koen-Alonso, M., Pepin, P., Fogarty, M., and Gamble, R. 2022. Review and Assessment of the Ecosystem Production Potential (EPP) model structure, sensitivity, and its use for fisheries advice in NAFO. NAFO SCR Document, 22/002: 1-52.

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.

Murphy, H. M., Adamack, A. T., and Cyr, F. 2021. Identifying possible drivers of the abrupt and persistent delay in capelin spawning timing following the 1991 stock collapse in Newfoundland, Canada. ICES Journal of Marine Science, 78: 2709-2723.

NAFO, 2021. Report of the 14th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA), 16-25 November 2021. NAFO SCS Document, 21/21: 181pp.

Pepin, P., Higdon, J., Koen-Alonso, M., Fogarty, M., and Ollerhead, N. 2014. Application of ecoregion analysis to the identification of Ecosystem Production Units (EPUs) in the NAFO Convention Area. NAFO SCR Document, 14/069: 1-13.

f) ToR 3.6. Formalization of a full Workplan for the 2027 ESSs update: Analysis of by-catch and discards and proposal for building an ETP species list. (COM Request #1)

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.*

The Ecosystem Summary Sheets (ESS) for the Grand Bank (Divs. 3LNO) and Flemish Cap (Div. 3M) Ecosystem Production Units (EPUs) are currently scheduled for an update in 2027. This means that WG-ESA needs to complete this update in its November 2026 meeting to be able of presenting the updated ESSs at the 2027 June meeting of the Scientific Council.

Considering that the SAI-VME has been delayed by a year, this means that both the update of the ESSs and the SAI-VME would need to be completed at the November 2026 WG-ESA meeting. This would represent a significant workload for WG-ESA. Therefore, WG-ESA requests SC to consider delaying by one year the ESSs updates to allow for a better distribution of the workload involved. This would mean that the ESSs update will be presented to SC in June 2028.

WG-ESA also wants to reiterate that the Ecosystem Designated Expert (EDE) position for the Grand Bank (Divs. 3LNO) EPU remains vacant, and the EDE position for the Flemish Cap (Div. 3M) EPU is only covered on an interim basis. This situation creates important difficulties in advancing with the ESSs updates as intended, and may impede completing the updates in the timelines indicated above.

The current workplan for updating the Ecosystem Production Potential (EPPs) is currently focused on three components of the ESSs. These components are a) the improvement of the estimation of incidental catches and discards, b) the consideration of Threatened, Endangered, and Protected (ETP) species and how these concepts can be used to inform the report on catches, and c) the update of framework and input values for the calculation of the Total Catch Index (TCI).

Current progress on incidental catches and ETP species considerations are detailed in the sections below. Progress on the review and update of the EPP framework, its Primary Production (PP) inputs, and TCI calculation is summarized in section 6(g) of this report, as this work also has implications for the information required by the Commission (COM) from Scientific Council (SC) as part of COM Request #1 (regular stock advice).

i) Incidental Catches and Discards

One of the elements that needs improvement in the update of the ESSs is the treatment of by-catch and discards. The issues identified with the analysis of by-catch and discards include the need for improving the sources of data used, and the potential confusion arising from the terminology used, as the term by-catch has specific definitions within NAFO in relation to regulatory and compliance processes.

The objective of this analysis in the context of the ESSs is to evaluate the likely impact of incidental catches in fishing operations at the ecosystem level, irrespective of regulatory issues. Therefore, WG-ESA considered a change in terminology to a) provide a scientifically consistent classification of the catches that is not impacted by regulatory considerations, and b) avoid any potential confusion in terminology can create unintended consequences.

The main change in terminology and definitions is the replacement of the term “by-catch” for “incidental catch”, where the identification of the target species in a haul would align with the standard NAFO definition (the species that dominates the catch in biomass), with the additional qualifier that a target species needs to be a NAFO managed species. The remaining species in the haul would be considered “incidental catch”.

There are a number of data sources that can be used for the incidental catch and discards analysis (i.e. daily catch reports (DCR), logbooks (HxH), observer reports, or CESAG data). After a discussion and consideration of these different sources, WG-ESA agreed that the core source of data for this type of analysis, as it contains the most complete information and with a higher resolution despite the errors described in previous analyses, is the logbook information (haul by haul data).

The updated analysis will quantify the catches by fishery -defined by target species-, using the haul by haul data, as described in Figure 6.22. Anything that is not a target species will be considered as incidental catch. This incidental catch will be further classified between regulated species and other species. The group of other species will be classified between ETPs and non-ETPs (see discussion on ETPs below). And finally, the ETPs category will be divided between VMEs and other ETPs. The flow chart in Figure 1 will be used in this classification. The retained and discarded components for each category will also be considered in the analysis.

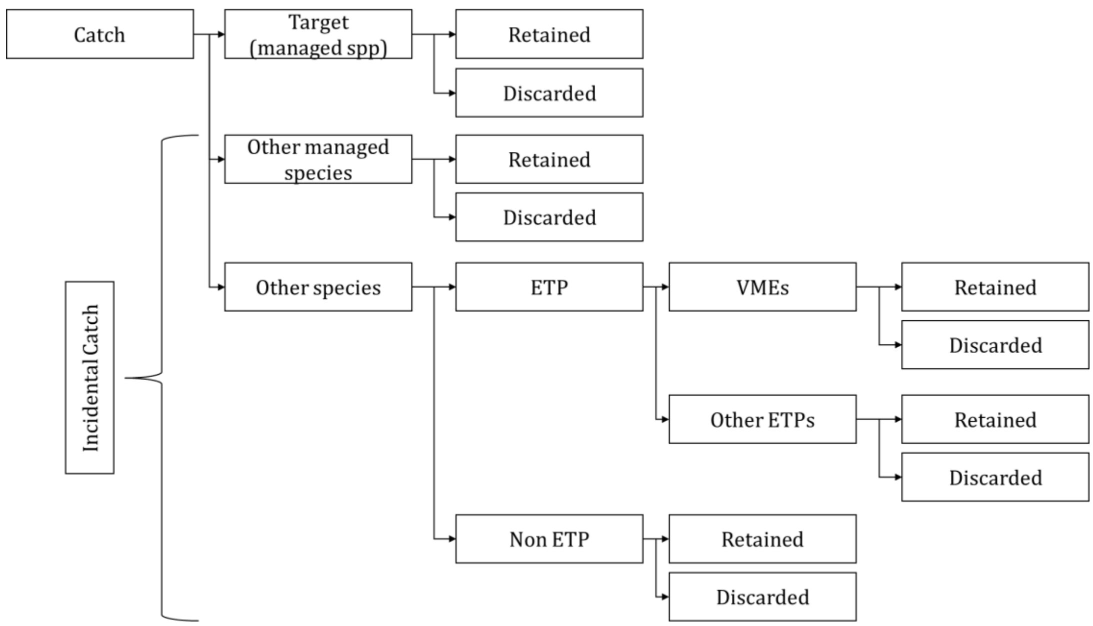

Figure 6.22. Flow chart to be used in the analysis of incidental catches and discards. ETP refers to Endangered, Threatened, and Protected species, and it is used here as a shorthand general terminology but not intended to reflect any specific regulatory framework (see next section). VME refers to Vulnerable Marine Ecosystem indicator taxa.

ii) Threatened, Endangered, and Protected (ETP) species

As part of the update of the Ecosystem Summary Sheets (ESS) WG-ESA has to improve its consideration of Endangered, Threatened and Protected (ETP) species in its reporting on incidental catches. At the current time WG-ESA does not have a process to categorize species encountered in fishing or survey trawls in the NAFO fishing footprint as ETP species. During this meeting, presentations by Patrícia Gonçalves (EU-Portugal) and Mark Simpson (Canada) provided an overview of some existing ranking schemes used by the International Union for Conservation of Nature (global list), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Canadian Species at Risk Act (Canadian list), the National Oceanic and Atmospheric Administration (USA list), Greenland and the World Wildlife Fund. Issues in the development of a NAFO-specific list of ETP species and their implications were raised and discussed. It was recognized that NAFO requires a scientifically sound rules-based decision-making system of all taxon encountered during fishing and survey activity, which accounts for the different spatial-temporal scales of the species of interest, and also accounts for the different life histories of the catch. It was suggested to adopt a stepwise approach, potentially prioritizing species with life histories which make them particularly vulnerable or sensitive to these activities, as well as species that are important for ecosystem functioning within NAFO.

Looking forward to the completion of the ESS update, it was resolved that further investigation of the existing ETP lists would be conducted. This would involve reviewing methodologies and potential applications to the

NAFO context, as well as comparing these lists with the NAFO Observer haul database and the NAFO Haul by Haul database. Where possible, incremental steps will be identified in the development of a priority species list. Focus will be placed on the type of taxa that are likely to be impacted by fishing to potentially inform on additional protection measures that may be required; and in that context highlight species that are more likely to be susceptible from additional mortality such as those long lived, low fecundity types of species. Coinciding with the update of the ESS every 5 years, it was proposed to review this list of species and update it if necessary. Included in the overarching issues that have been identified are:

1) concern regarding labelling of ETP species given the potential legal implications of terms such as endangered, threatened and protected by some NAFO Contracting Parties (CPs); and

2) the need for Science to consult with CP's in the development of this list to ensure acceptance of the proposals. The development of this list can build on existing NAFO resolutions, such as the resolution to "Reduce Sea Turtle Mortality in NAFO Fishing Operations" (NAFO/FC Doc. 06/7) and "Measures to Conserve Greenland Sharks" (NAFO/COM Doc. 22-15). To avoid the use of ETP nomenclature, suggestions have been made to refer to "special species" or "species of concern" to encompass the intent of the ETP list while avoiding triggering unintended legal processes within CPs. Finally, it was suggested that those species which are actively managed by NAFO and/or those which are covered through VME and SAI analyses will not be included in this list, as these species already have targeted processes within the NAFO to managed fishing impacts and conservation requirements.

As part of the discussions, it was noted that it would be valuable for the CESAG data to include all species for the Convention Area. The CESAG method is currently intended for NAFO managed species (COM-SC Doc. 17-08), however, upon request, the Secretariat has been including all species in the CESAG data where possible (COM-SC Doc. 20-02). However, for those Contracting Parties providing data for the CESAG method via part 4 of the estimation methodology as outlined in Annex 1 of COM-SC Doc 17-08, the data are limited to the NAFO managed species. WG-ESA also noted that the Terms of Reference allows for CESAG to consider and identify potential refinements of the Catch Estimate Strategy including the incorporation of haul-by-haul data within the strategy (COM-SC Doc. 17-09) and noting the improvements to the haul-by-haul reporting requirements, it may be beneficial to review the current method. The co-Chair of CESAG, Katherine Sosebee (United States of America) noted that the need for a potential meeting of CESAG will be raised at the upcoming NAFO Efficiency Working Group meeting.

g) ToR 3.7. Update on Primary Productivity Estimates to inform EPP models for TCI calculations (COM Request #1)

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.*

i) Introduction

The 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). This framework has been formally summarized within NAFO by the COM-SC Working Group on the Ecosystem Approach Framework to Fisheries Management (WG-EAFFM) (NAFO, 2024b), and this summary description has been adopted by the NAFO Commission (NAFO, 2024a).

As a management framework, the Roadmap integrates the impacts of a changing environment and ecosystem productivity to define sustainable exploitation levels for fish stocks, with the impacts that fishing has on stocks, ecosystems, and habitats (Figure 6.23).

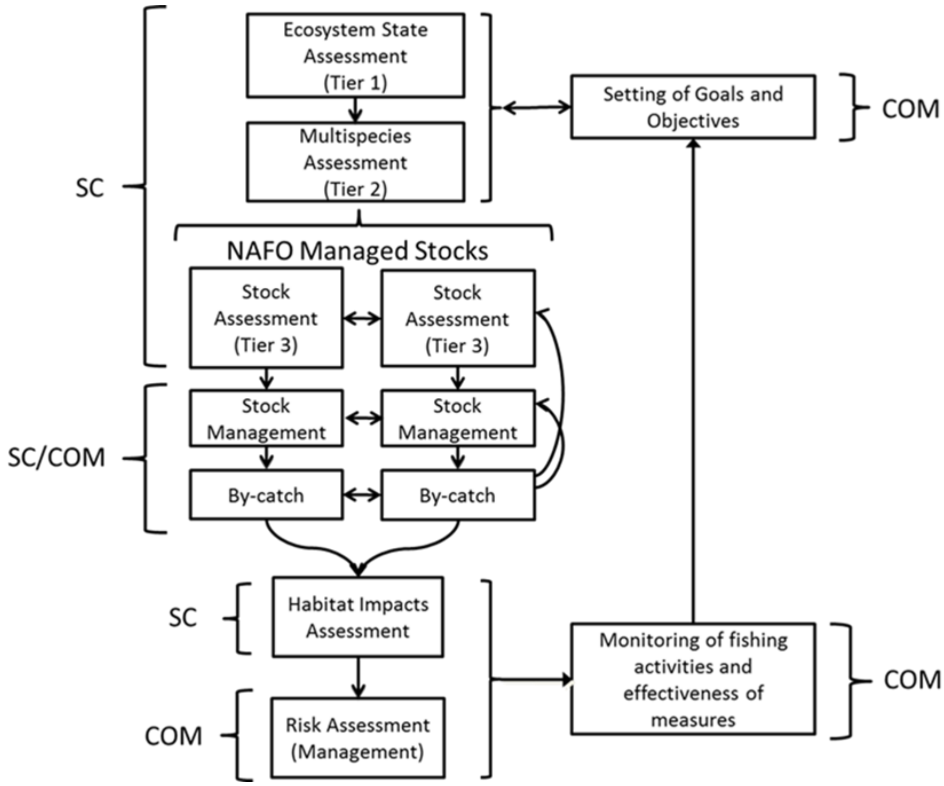

Figure 6.23. Structure of the Roadmap for an Ecosystem Approach to Fisheries, the framework that NAFO is implementing to deliver an ecosystem approach to fisheries management.

Within the Roadmap, sustainability of fisheries catches is achieved through a nested series of assessments aimed at evaluating sustainability at different levels of organization. Within these assessments, 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 6.23).

The current implementation of Tier 1 includes two distinct elements. These elements are an ecosystem reference point for aggregated catches by functional guild within an ecosystem that informs on the risk of ecosystem overfishing, and an Ecosystem Summary Sheet that provides an at glance view of the status and trends of multiple ecological features, as well as the general performance of management measures within the ecosystem.

The ecosystem reference point that informs on the risk of ecosystem overfishing was adopted by NAFO in 2022 (NAFO, 2022a). It 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). In 2024 NAFO added the reporting on 2TCI to the annex on guidance for providing advice on stocks assessed, making the reporting on the risk of ecosystem overfishing a standard element of the regular stock advice (NAFO, 2024a).

The inclusion of the reporting on 2TCI as part of the regular stock advice requires the underlying TCI to be regularly updated. Some key elements in this process include a) the update of 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 (>20m), and pico-nanoplankton (<20m) sources.

ii) Updating Primary Production input

The current PP values used as input for the EPP model for the Newfoundland Shelf (Divs. 2J3K), Grand Bank (Divs. 3LNO), and Flemish Cap (Div. 3M) EPUs correspond to the average for the 1997-2013 period (Koen-Alonso et al., 2013). These estimates were derived from satellite information following the Nearest-Neighbour Method (NNM) of primary production estimation (Platt et al., 2008).

Due to workload and operational issues, these estimates of PP have yet to be updated. However, and until this update can be conducted, it is important to verify if PP has substantially changed since the values currently in use were estimated. In order to evaluate if there have been significant changes on PP over time between the current reference period (1997-2013) and more recent years, a comparison of the trends in PP using two readily available products was conducted. Both of these products are available from the Copernicus Marine Service (https://marine.copernicus.eu/), and provide estimates of PP from either satellite observations or from a model hindcast of PP. These products are:

1) Global Ocean Colour (Copernicus-GlobColour), Bio-Geo-Chemical, L4 (monthly and interpolated) from Satellite Observations (1997-ongoing) (https://doi.org/10.48670/moi-00281).
    - This product resembles more closely the type of approach used in the current estimates, but it is a global product, not a regionally validated one, and it is known to produce slightly lower values for the Atlantic Ocean.
2) Global Ocean Biogeochemistry Hindcast (https://doi.org/10.48670/moi-00019).
    - This product is based on a modelling exercise and lacks data assimilation, making it less reliable for the estimation of absolute values.

The outputs of both products were integrated to produce values in the same units as the current PP inputs for the EPP model to facilitate comparisons.

While both of these products have limitations that prevent using them in a straightforward way for generating an updated PP input for the EPP model, they still provide useful information on relative temporal changes in PP at the EPU level. A visual examination of these trends indicates that there seem to be no major changes in PP between the current reference period (1997-2013) and most recent years (Figure 6.24).

The comparison of the averages between the reference period and most recent years within each one of these products shows no significant differences in most cases, with the only exception being the Flemish Cap (Div. 3M) EPU in one of these products (Table 6.1). This difference would indicate a reduction on PP in this EPU in recent years. However, this difference only appears in one of the products for this EPU, and all other EPUs in both products show no differences in average PP over time, suggesting that this significant difference may be more of an artifact of this series than an indication of an actual difference in PP.

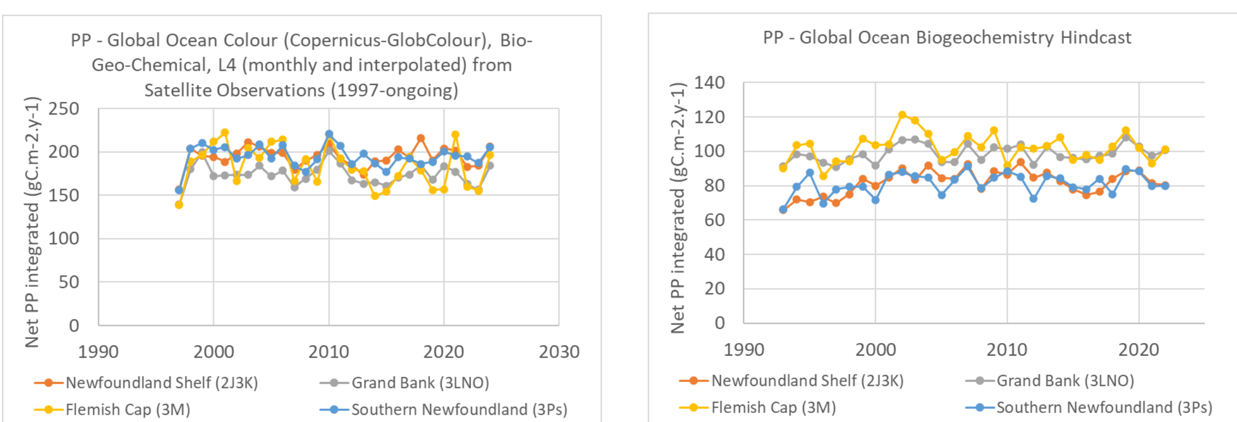

Figure 6.24. Trends in Primary Production (PP) from two Copernicus Marine Service products (see text for details). These products are being considered for the evaluation of changes in PP over time.

Table 6.1. Summary of Primary Production estimates from two Copernicus Marine Service products, including results from statistical tests comparing the 1997-2013 and 2014-end of series, and the currently used PP inputs for comparison. The range of 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).

Product	Global Ocean Colour (Copernicus-GlobColour), Bio-Geo-Chemical, L4 (monthly and interpolated) from Satellite Observations (1997-ongoing). Period: 1997-2024 Note: Data-based product			Global Ocean Biogeochemistry Hindcast Period: 1993-2022 Note: Model-based product (no data assimilation)		
Link	https://doi.org/10.48670/moi-00281			https://doi.org/10.48670/moi-00019		
PP units are in gC.m^{-2}.y^{-1}	Newfoundland Shelf (2J3K)	Grand Bank (3LNO)	Flemish Cap (3M)	Newfoundland Shelf (2J3K)	Grand Bank (3LNO)	Flemish Cap (3M)
Mean (1997-2013)	192.8	174.8	190.6	84.6	99.1	104.0
Mean (2014-end of series)	196.3	171.6	172.1	81.6	99.2	100.7
t-test (p-value)	0.473	0.525	0.045	0.227	0.950	0.304
Coefficient of Variation (CV%) for the full series	6.4	7.4	13.2	8.8	5.0	8.0
Original Estimates (1997-2013)	160.9	209.7	200.6	160.9	209.7	200.6
CV% in EPP model	30	30	30	30	30	30
Range in EPP model	15-430	15-430	15-430	15-430	15-430	15-430

Considering that the EPP model implementation includes a 30% Coefficient of Variation (CV%) for PP, the type of differences observed in these data products indicates that the model implementation provides sufficient coverage for the temporal variability emerging from these products. In fact, the 30% was initially used based on the interannual variation of the original PP estimates. Overall, these results indicate that no significant bias would be expected if the current input values continue to be used until new estimates are available.

Next steps on this process include the production of regional estimates of PP using satellite-derived information. This process is expected to be conducted with the collaboration of regional experts on remote sensing estimation of PP. Contacts to establish these collaborations have been made, and the necessary work is currently being planned.

iii) Improving of the procedures used to scale the EPP output to current ecosystem productivity level

The current process to scale the EPP output to current ecosystem productivity level relies on comparisons of the current total biomass estimated from Research Vessel (RV) surveys, with a period where the EPU can be considered to have been fully functional. This comparison is then used to derive a schema that coarsely reflects generalized productivity periods based on expert judgement (Koen-Alonso et al., 2022). The Independent Review Panel of international scientific experts that reviewed the complete EPP-TCI framework indicated that this process of scaling could be improved through the implementation of a rule-based method to minimize subjectivity in identifying productivity periods (NAFO, 2022b).

As part of the review and update of the EPP-TCI framework, aimed to be completed for the next update of the Ecosystem Summary Sheets, this element of the framework is intended to be examined, and improved if possible.

iv) Review of the approach used to partition PP into its microplankton, and pico-nanoplankton sources

The EPP model requires the PP input to be partitioned into microplankton (>20µ), and pico-nanoplankton (<20µ). The current proportions used for this partition were derived from analyses of phytoplankton taxonomic composition information that allowed to estimate size fractionated primary production (Uitz et al., 2009; Uitz et al., 2010; Pan et al., 2011).

Since the size structure of the phytoplankton community is expected to be impacted by climate change, and different phytoplankton size fractions differentially feed into the ecosystem energy pathways (Koen-Alonso et al., 2022), it is important to monitor and update this input if necessary.

There are ongoing discussions to explore both empirical and analytical approaches to evaluate changes in size-partitioned PP. These approaches require additional resources and capacity to be pursued. If the necessary resources and capacity are available, the size-partitioning of PP will be included in the review and update of the EPP-TCI framework, aimed to be completed for the next update of the Ecosystem Summary Sheets.

v) Update of the scoping exercise to evaluate the risk of ecosystem overfishing in 2024-2025

In June 2024, the SC advice on 2TCI included the scoping of the catches for 2024-2025, and how these catches were expected to relate to the 2TCI Ecosystem Reference Point. This scoping assumed that Total Allowable Catch (TAC) decisions by COM would align with the SC advice. Under these circumstances, the expectation was that while catches would get close to the 2TCI Ecosystem Reference Point in some cases, they would still remain below (NAFO, 2024c).

Since the SC advice was produced, some of the assumed conditions changed. Canada re-opened the Northern Cod (Divs. 2J3KL) commercial fishery, and some of the TAC decisions by COM were above the SC advice. These changes could impact the conclusions that catches in 2024 and 2025 are expected to remain close but below 2TCI. In order to evaluate if this conclusion still holds, an update of the scoping exercise was conducted by including the actual TAC decisions, and updating the cod catch expectations in Div. 3L to reflect the re-opening of the Northern cod fishery. The updated scoping exercise still indicates that catches are expected to remain below 2TCI in 2024-2025, but piscivore guild catches are getting closer to the 2TCI Ecosystem Reference Point in 2024 in both the Grand Bank (Divs. 3LNO) and Flemish Cap (Div. 3M) EPUs, and are expected to continue increasing towards 2TCI in 2025 in the case of the Flemish Cap (Div. 3M) EPU (Figure 6.25).

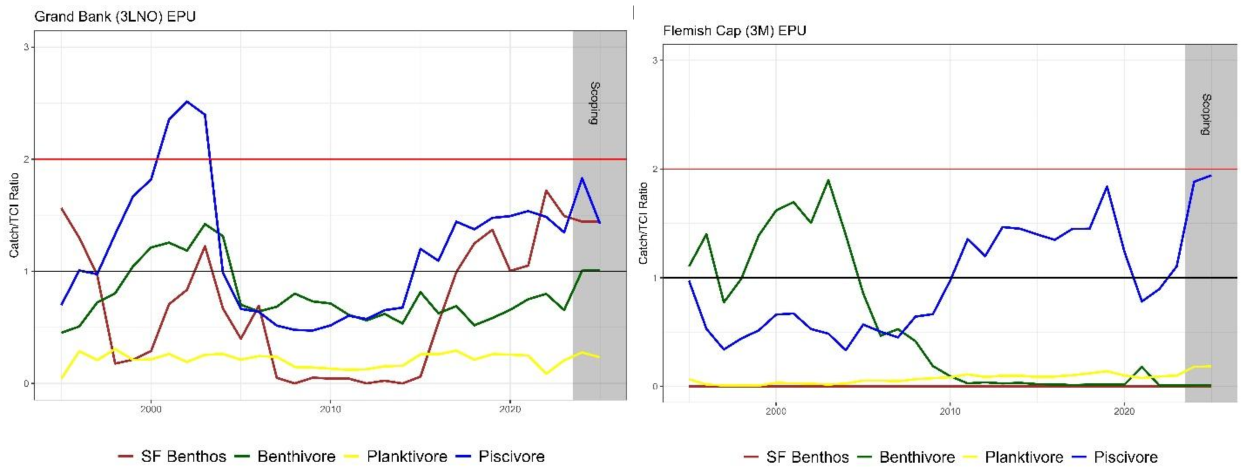

Figure 6.25. Updated scoping exercise of the Catch/TCI Ratio for the Grand Bank (3LNO) and Flemish Cap (Div. 3M) EPUs, including the increased cod catch related to the re-opening of the Northern Cod (Divs. 2J3KL) commercial fishery, and the actual TACs adopted by COM during the 2024 Annual Meeting.

The inclusion of information of risk of ecosystem overfishing is a new element of the management discussion around setting TACs. This was first implemented in 2023, and the addition of the scoping procedure was included in 2024 for the first time. The 2024 experience indicates that while the scoping using the SC advice is useful, it does not necessarily provide an indication of how close to (or above) 2TCI catches can get if COM decides to adopt TACs above the SC advice. One way to address this issue could be the development of a tool that could allow COM to check how different TAC values may affect the scoped Catch/TCI Ratio. This tool could dynamically inform the discussion on TACs as COM considers alternative options. Developing such a tool is something that COM may want to consider.

vi) References

Koen-Alonso, M., Fogarty, M., Pepin, P., Hyde, K., and Gamble, R. 2013. Ecosystem production potential in the Northwest Atlantic. NAFO SCR Document, 13/075: 1-13.

Koen-Alonso, M., Pepin, P., Fogarty, M., and Gamble, R. 2022. Review and Assessment of the Ecosystem Production Potential (EPP) model structure, sensitivity, and its use for fisheries advice in NAFO. NAFO SCR Document, 22/002: 1-52.

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.

NAFO, 2022a. Report of the NAFO Commission and its Subsidiary Bodies (STACTIC and STACFAD), 44th Annual Meeting of NAFO, 19-23 September 2022, Porto, Portugal. NAFO COM Document, 22/27: 168pp.

NAFO, 2022b. Report of the Scientific Council Meeting, 03 -16 June 2022. NAFO SCS Document, 22/18: 241pp.

NAFO, 2024a. Report of the NAFO Commission and its Subsidiary Bodies (STACTIC and STACFAD). 46th Annual Meeting of NAFO, 23-27 September 2024, Halifax, Canada. NAFO COM Document, 24/25: 154pp.

NAFO, 2024b. Report of the NAFO Joint Commission–Scientific Council Working Group on Ecosystem Approach Framework to Fisheries Management (WG-EAFFM) Meeting, 05-07 August 2024, Bergen, Norway. NAFO COM-SC Document, 24/02: 18.

NAFO, 2024c. Report of the Scientific Council Meeting, 31 May - 13 June 2024, Halifax, Nova Scotia. NAFO SCS Document, 24/16REV: 250.

Pan, X., Mannino, A., Marshall, H. G., Filippino, K. C., and Mulholland, M. R. 2011. Remote sensing of phytoplankton community composition along the northeast coast of the United States. Remote Sensing of Environment, 115: 3731-3747.

Platt, T., Sathyendranath, S., Forget, M.-H., White, G. N., Caverhill, C., Bouman, H., Devred, E., et al. 2008. Operational estimation of primary production at large geographical scales. Remote Sensing of Environment, 112: 3437-3448.

Uitz, J., Claustre, H., Gentili, B., and Stramski, D. 2010. Phytoplankton class-specific primary production in the world's oceans: Seasonal and interannual variability from satellite observations. Global Biogeochemical Cycles, 24.

Uitz, J., Claustre, H., Griffiths, F. B., Ras, J., Garcia, N., and Sandroni, V. 2009. A phytoplankton class-specific primary production model applied to the Kerguelen Islands region (Southern Ocean). Deep Sea Research Part I: Oceanographic Research Papers, 56: 541-560.

h) ToR 3.8. Update on the work towards developing operational objectives for the protection of VMEs and biodiversity in the NRA

A summary of discussions held at WG-EAFFM in 2024, based upon on a draft working paper (COM-SC EAFFM-WP 24-07) on a framework for potential Goals (based on the NAFO Convention Principles), Objectives, Targets and Indicators, was presented at WG-ESA. It was noted that work on developing 'operational objectives' had been tasked to the co-chairs of EAFFM that will undertake e.g.:

1. a review of the applicability of the Convention General Principles as 'goals' to inform the development of operational objectives.
2. identification of additional relevant elements.
3. the initial development of objectives on what NAFO is presently doing in practice.

WG-ESA discussed potential benefits of developing further the operational objectives from a science perspective, specifically in relation to the development of targets and indicators to implement different elements of the NAFO EAF Roadmap. However, it was decided not to devote any time to this task, because; a) SC assigned this activity a low priority, and b) WG-EAFFM had not requested WG-ESA for specific input into the process.

i) ToR 3.9. Develop Table of Contents for the NAFO Roadmap reference document (COM Request #5)

COM Request #5. *In relation to the Ecosystem Roadmap as a whole, the Commission requests that the Scientific Council develop a reference document detailing the ecosystem roadmap, for completion in the next 1-3 years.*

i) Introduction

The Roadmap for an Ecosystem Approach to Fisheries (Roadmap) is the framework that NAFO is implementing to deliver an ecosystem approach for the management of NAFO fisheries and ecosystems (Figure 6.26).

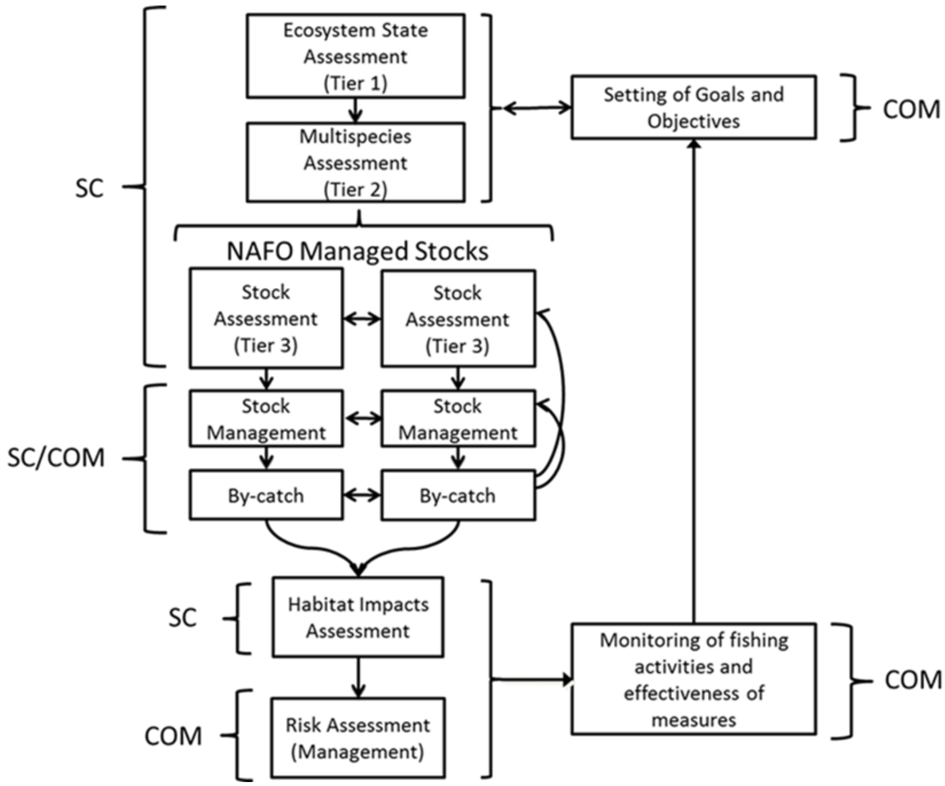

Figure 6.26. Structure of the Roadmap for an Ecosystem Approach to Fisheries, the framework that NAFO is implementing to deliver an ecosystem approach to fisheries management.

While the Roadmap is described across multiple NAFO documents -e.g. see some relevant links in Koen-Alonso (2022), and described as a whole in a scientific publication (Koen-Alonso et al., 2019), there is no formally adopted NAFO document that provides a comprehensive description of the Roadmap in a single document.

This shortcoming has started to be addressed by formally summarizing the Roadmap in the 2024 report of the COM-SC Working Group on the Ecosystem Approach Framework to Fisheries Management (WG-EAFFM) (NAFO, 2024b), and this summary description has also been adopted by the NAFO Commission (NAFO, 2024a). Still, the need for a formal NAFO document providing a comprehensive description of the Roadmap remains. This need prompted the Commission (COM) to request Scientific Council (SC) in its COM Request #5:

"*In relation to the Ecosystem Roadmap as a whole, the Commission requests that the Scientific Council develop a reference document detailing the ecosystem roadmap, for completion in the next 1-3 years*."

WG-ESA considered the development of this document, including the level of detail it is expected to contain, and the target audience for it. After some discussion, WG-ESA concluded that this detailed Roadmap document should be focused on an internal audience (i.e. NAFO members), and describe the Roadmap elements with enough resolution to provide both NAFO managers and scientists with sufficient guidance not only to understand the Roadmap, but to support related planning and auditing processes.

WG-ESA agreed that the detailed document should expand on the already adopted summary (NAFO, 2024b), and along the general lines described in the existing primary publication (Koen-Alonso et al., 2019). The content of this document is expected to be structured as follows:

1. **Description of linkages to NAFO Convention principles**
2. **Basic Roadmap framework structure** (components that are generally stable over time)
    a. ***Concepts*** (Science driven)
        i. Respects the organizational structure of natural ecosystems
        ii. Integrates impacts of ecosystem on fishing, and impacts of fishing on ecosystem
        iii. Focused of key ecological processes and scales:
            1. Sustainability at multiple levels of organization (1-3 tiers)
            2. Integrates environmental drivers and climate change.
            3. Considers impacts on target stocks (catch) and community (by-catch)
            4. Integrates impacts/conservation of benthic communities (VMEs)
        iv. Modular structure
    b. ***Implementation in NAFO operations*** (adaptive to existing organizational structure)
        i. Integrates existing and new NAFO operational elements (SC and COM)
        ii. Considers NAFO management cycle
        iii. Identifies NAFO bodies involved (lead and supporting)
3. **Specific applications** (components that are expected to evolve over time)
    a. Details on how specific elements are currently implemented (e.g. VMEs, SAI, EPP/TCI)

While the deadline for finalizing this document is 2027, WG-ESA agreed to expedite efforts for its completion. If substantive progress can be made, an update of this ongoing work will be presented at the NAFO 2025 SC June meeting.

ii) References

Koen-Alonso, M. 2022. Supporting material for the independent scientific review of the estimation of fisheries production potential and total catch indices, and their adequacy for their proposed used within the NAFO Roadmap. NAFO SCR Document, 22/003: 1-5.

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.

NAFO, 2024a. Report of the NAFO Commission and its Subsidiary Bodies (STACTIC and STACFAD). 46th Annual Meeting of NAFO, 23-27 September 2024, Halifax, Canada. NAFO COM Document, 24/25: 154pp.

NAFO, 2024b. Report of the NAFO Joint Commission–Scientific Council Working Group on Ecosystem Approach Framework to Fisheries Management (WG-EAFFM) Meeting, 05-07 August 2024, Bergen, Norway. NAFO COM-SC Document, 24/02: 18.

j) ToR 3.10. Brainstorming session on the approach to implement ecosystem knowledge into the single species stock assessment and scientific advice on management strategies.

i) Introduction

In 2021 WG-ESA held a discussion session on the implementation of Tier 2 within the NAFO Roadmap for an Ecosystem Approach to Fisheries (Roadmap) (NAFO, 2021, pages 117-134, section "Work to develop models that support implementation of tier 2 of the EAFM Roadmap"). The goals of that session were to continue the development of Tier 2 by establishing a clear understanding of what a Tier 2 model is, and what is required for its development and application within the Roadmap.

Within the Roadmap, the sustainability of fisheries harvest rates is informed through a series of nested assessments (Tiers 1 to 3) that focus on sustainability at different levels of ecological organization (Koen-Alonso et al., 2019). While Tiers 1 and 3 deal with assessments at the ecosystem and stock levels respectively, Tier 2 is centred in the assessment of multispecies interactions, with special focus on the emerging trade-offs from these interactions. During the 2021 session, it was agreed that Tier 2 models should have the lowest possible complexity (e.g. minimum realistic models or Models of Intermediate Complexity for Ecosystem approach, MICE). It was also stressed that Tier 2 provides a bridge between large-scale ecosystem properties (e.g. ecosystem productivity) and the individual stock status and trends. Accordingly, Tier 2 assessments can provide support for both strategic and/or tactical decisions. An important conclusion, and very relevant for the session of the present WG-ESA meeting, is that, tier 2 models, in addition to species interactions, should be developed with the aim of including environmental/ecological variables as driving forces affecting the productivity of the stocks when this knowledge is available (e.g. water temperature, ocean climate effects in general, climate change impacts, etc.).

The 2021 session also identified a series of applications for Tier 2 models. Some of these were, for example, the evaluation of trade-offs between fisheries, the responses of managed stocks to external drivers (i.e. environmental and/or other stocks), informing stock-assessment models/advice (e.g. trends in natural mortality, consumption models for the estimation of predation mortality), and construction of ecosystem-informed precautionary approach frameworks (e.g. Reference Points) and/or ecosystem-informed Management Strategy Evaluation (MSE) frameworks and MPs.

The 2021 discussion session also established that what defines the assessment level (i.e. Tier 2 or 3) is not the type of model used (i.e. multispecies vs single species) but the scope of the assessment. A multispecies model could be used for the provision of tactical advice on a specific stock (i.e. Tier 3 assessment level), and an expanded single species model (e.g. one that includes ecosystem/environmental indices as external drivers) can be used to inform how changes in prey and/or predators are expected to influence one or many managed stocks (i.e. Tier 2 assessment level).

A number of multispecies models, either developed or in development, were also presented to exemplify the variety of models and modelling approaches that can support Tier 2 applications. Among those tier 2 models there were presented a Northern shrimp surplus production model including spatiotemporal drivers; a Grand Banks flatfish model including competition between yellowtail flounder and American plaice; and a Flemish Cap multispecies Gadget age-length based model (GadCap) including trophic interactions between cod, redfish and shrimp used as operating model in a multispecies MSE Gadget-FLR framework. These examples showed the usefulness of multispecies models as assessment tools that can be used to assess and manage a group of interacting stocks, taking into account the trade-offs when considering a range of different management options (NAFO 2021). These developments showed that work on applications relevant for Tier 2 is already in progress, and in some cases, well advanced. However, the incorporation of the outputs from these models into scientific advice is still pending.

Building on the 2021 work, a second discussion session "From Ecosystem to Assessment (E2A)", was organized during the 2024 WG-ESA meeting. The 2024 session aimed at exploring the incorporation of ecosystem information into assessment models and Management Procedures (MPs) to account for environmental/ecological conditions in the provision of tactical and strategic advice.

To achieve this goal, oceanographers, fisheries ecologists and stock assessors need to work together. In NAFO, these three groups of scientists are represented mainly within STACFEN, WG-ESA and SC respectively. Therefore, one overarching goal of the 2024 session was to provide a meeting point for an initial discussion between scientists from these different disciplines and NAFO SC bodies. The objective of this multidisciplinary session was to brainstorm on which stocks are the most promising for incorporating environmental/ecological information into their assessments, who are the scientists that could do it, and the logistical elements that would need to be considered.

ii) Examples and opportunities

The 2024 discussion session began with a series of presentations that showed 1) the potential of oceanographic variables (physical, chemical and biological) to explain the spatiotemporal variation in the productivity of marine ecosystems and fishery resources; 2) the approaches being developed within ICES to implement EAFM; 3) the development of a Tier 2 model in the Flemish Cap (Div. 3M) Ecosystem Production Unit (EPU), and 4) an overview of options for advancing the incorporation of ecosystem information into assessment models and MPs within NAFO. Brief summaries of these presentations are provided below:

Environmental Control on the Productivity of the NW Atlantic Ecosystem (Frederic Cyr)

Sustainable fisheries management requires an understanding of the links between environmental conditions and fish populations, especially in the context of climate change. From this perspective, identifying the phases in which ocean climate fluctuations and changes in ecosystem productivity coincide could provide a powerful tool to help inform fisheries management. Using more than 70 years of climate and fisheries data, this study shows that Newfoundland and Labrador (NL) ecosystem productivity, from primary producers to piscivorous fish, changes in relative synchronicity with the climate of the northern hemisphere over interannual to decadal time scales. This broad correspondence between climate and lower and higher trophic levels has not previously been documented in the Northwest Atlantic to this extent in the context of fisheries. This work advances ideas for incorporating environmental knowledge into fisheries management on the NL shelves or in other regions facing similar dynamics.

Overview of the Biogeochemical Oceanographic Conditions in the Northwest Atlantic in 2023 (Gary Maillet)

This presentation reviewed the spatial and temporal variability in biogeochemical indices derived from satellite observations (spring and fall bloom timing and intensity) and in situ measurements of oceanographic variables (nitrate and chlorophyll-a concentration, and zooplankton abundance and biomass) across NAFO Subareas 2, 3 and 4 with an emphasis on the year 2023. Nitrate inventories on the Grand Bank and in Southern Newfoundland decreased to near-normal levels in 2023 but remained unchanged elsewhere compared to the previous year. Chlorophyll inventories were variable across the zone without any strong departure from the climatological mean. Spring and fall bloom timing were later and earlier than normal, respectively, on the Scotian Shelf and the Georges Bank, while bloom intensity reached record-high levels in the Gulf of St. Lawrence in both spring and fall. Zooplankton biomass and copepod abundance were mainly near to below normal across the zone for the second consecutive year. For regions from the Grand Bank to the north, this represents a decline compared to the near to above-normal levels observed during the 2016- 2021 period. The abundance of large *Calanus finmarchicus* copepods was near to above normal with no negative anomalies in any of the regions for the first time in twelve years. The abundance of smaller, but more abundant, *Pseudocalanus* spp. copepods remained high on the Grand Bank and Newfoundland Shelf, where above-normal levels have been recorded almost consistently since 2013. The abundance of non-copepod zooplankton was primarily above normal from the Grand Bank to the north, and near normal from the Scotian Shelf to the south, continuing a trend that started around the mid-2010s.

Feco, other Ecological Reference Points, MSE, and integration at ICES (Jacob Bentley)

Decision-makers have committed to delivering an ecosystem approach to fisheries management, with ICES recognising Ecosystem-Based Fisheries Management (EBFM) as the primary approach. EBFM operates on a spectrum, acknowledging that marine ecosystems are dynamic, interconnected social-ecological systems influenced by species interactions, habitat conditions, and environmental variability. Progress is being made in the Northeast Atlantic to integrate ecosystem-informed science into fisheries advice, both implicitly (as best available science evolves) and explicitly (through Ecosystem Overviews and ecological reference points). ICES' Framework for Ecosystem-Informed Science and Advice (FEISA) supports this transition, offering feasible options such as ecological reference points (e.g., Feco), ecosystem-informed Management Strategy Evaluation (MSE), and multispecies reference points. However, barriers to progress remain, including knowledge and capacity limitations, institutional inertia, deep uncertainty (e.g., climate change), and a lack of political impetus or support networks. Overcoming these challenges requires iterative, risk-based approaches that account for knowledge gaps, incremental steps aligned with available evidence, and the development of methods to translate diverse knowledge into actionable science and advice. To advance EBFM, there is a need for ambitious, ecosystem-focused scientific questions, adoption of existing EBFM frameworks (e.g., FEISA), implementation of ecosystem-informed mechanisms (e.g., predation information), and greater alignment between government science, policy teams, and stakeholders, supported by long-term institutional commitment.

Development and outputs of a Tier 2 multispecies model in the Flemish Cap (Alfonso Pérez-Rodríguez)

Since late 1980s, the demersal community of Flemish Cap (NAFO area 3M) has experienced large variations (including the collapse) in the abundance and population structure of its main fishing resources: cod Gadus morhua, redfish *Sebastes* sp. and shrimp *Pandalus borealis*, with alternation in their dominant role in the ecosystem. The work developed in two consecutive EU projects, GadCap and SC05 "Multispecies Fisheries

Assessment for NAFO" allowed and modelling the interactions between the main commercial stocks in the Flemish Cap and their respective fisheries and to explore alternative management strategies from a multispecies approach.

The EU project GadCap dealt with the development of a GADGET multispecies model for the Flemish Cap cod, redfish and shrimp, as part of the NAFO roadmap for the EAF. The effect of fishing, trophic interactions (including cannibalism) and water temperature in the dynamic of these three major fishing resources were modelled. The results highlighted the interdependent dynamic of these stocks, and reveals strong interactions between recruitment, fishing and predation (including cannibalism), with marked changes in their relative importance by species-age-length over time. These drivers have marked changes in their relative importance by species, age, and length over time, producing a transition from a traditional redfish-cod dominated system in the early 1990s, to an intermediate shrimp-other fish species state by late 1990s, and in turn back to something close to the initial state by late 2000s. It was concluded that the dynamic of the Flemish Cap cod, redfish and shrimp stocks is strongly interconnected, with predation mortality being a main driver of changes in population size and age/length structure over time. The role of cannibalism in cod and redfish was found of major relevance when the abundance of large and old individuals is higher (Pérez-Rodríguez et al, 2017).

The EU SC05 project *"Multispecies Fisheries Assessment for NAFO"*, contributed to the development of the multispecies approach in the NAFO area. As a first goal the multispecies model GadCap (Pérez-Rodríguez et al. 2017) was updated. A main goal of the SC05 project was contributing to the development of the NAFO roadmap for an EAF exploring alternatives to incorporate the multispecies approach into the fisheries advice process. As first output of this project was the estimation of natural mortality from the multispecies model GadCap and the consideration during the 3M cod Benchmark (NAFO, 2018). Second, the multispecies model GadCap was used for the development of a multispecies MSE framework (msMSE) integrating GadCap as operating model within an a4a-MSE framework. A high number of combinations of HCRs for the three stocks were tested with the msMSE framework. Long term simulations were run considering multiple combinations of fishing mortality for cod, redfish and shrimp. The results showed the influence that variable fishing strategies on predators (cod and redfish) would have on the prey stocks (shrimp, redfish, but also cannibalism in cod). It was especially evident the impact that different fishing strategies on cod would have in the productivity of shrimp and redfish. Additionally, as an exploratory exercise, a two-stage hockey stick HCR for cod was simulated, with the intention of testing the effect of reducing an excessive predation capacity from cod when the stock is at very high biomass levels (Pérez-Rodríguez et al, 2022).

<u>*Options and opportunities for the integration of ecosystem information in Tiers 2 and 3 of the NAFO Roadmap for EAF (Alfonso Pérez Rodriguez)*</u>

The incorporation of ecosystem information into Tiers 2 and 3 of the Roadmap needs to build upon the existing structures and practices within SC. In this context, two potential avenues could be explored for the next steps in advancing the consideration of environmental/ecological conditions in the provision of tactical and strategic advice. These options are not mutually exclusive, but given the limited resources available, they may not be possible to pursue everything at once.

The first option is to focus the efforts on identifying the stocks with the best potential for incorporating environmental/ecological drivers that could be influential on the scientific advice process (data availability, significant effect in stock productivity, etc.). The second option is to focus the efforts on identifying how and where to incorporate environmental drivers into Tier 2 and 3 models, and the approach to follow for using the outputs in the production of tactical and strategic scientific advice (i.e. the general mechanics of the process).

a) <u>Identification of candidate stocks</u>

Three different ways could be explored as a way forward:

1) A survey of SC Designated Experts (DEs) for NAFO-managed stocks to evaluate the degree of implementation of ecosystem information in NAFO stock assessments, identify the stocks for which any kind of approach has been attempted before, and determine the specific stocks for which there is potential to explore the inclusion of environmental/ecological drivers in the stock-assessment and subsequent advice, either quantitatively or qualitatively. The questionnaire used by Kulka et al. (2022, Appendix 1, page 35) was suggested as a starting point.

2) Use of the information in the "Biological and environmental interactions" section of the Stock Summary Sheets (SSSs) (e.g., SC 2024) to identify candidate stocks. At the moment, this section contains very summarized information and cannot be directly used to identify relevant drivers that could inform the discussion on catch levels, nor to conclude which stocks are good candidates to start incorporating ecosystem information in their assessments. This approach would require a prior expansion of the content and details included in this SSS section.

3) Create a prioritization criteria list to set the order of preference of the stocks to work with. A priority list in line with the proposal by Marshall *et al.* (2019), could be used as a starting point, where the stock status, the ecosystem importance (trophic linkages), variability in processes affecting stock productivity (recruitment, growth, etc.), habitat associations (potential effect on catchability) and other factors are taken into account.

b) Approaches to incorporate ecosystem information into Tier 2 and 3

While any actual implementation would obviously require identifying the stock where the implementation will be done, there may be merit in identifying the general mechanics and key issues that need to be considered when incorporating environmental/ecological drivers into Tier 2 and 3 models and advice. Some potential approaches and key issues are presented below.

Although the relationships between environmental/ecological drivers and the processes that define the dynamics and productivity of a stock will be studied from observed data, i.e. the historical period, the results from these studies can be used to analyse that historical period or to inform predictions/projections of future states of the stock. This also implies that the type of questions and applications to be considered will be different depending on whether they deal with the historical period or with short, medium or long projections.

In the assessment of the status of a stock in the historical period, it is very common to use age-structured assessment models for data-rich stocks. In these models, it is usual that natural mortality is assumed to be the same for all ages, or to be variable by age, but in both cases constant over time. In these cases, if the assessed stock is an important prey for an abundant predator in the ecosystem, this would be an indication of the need to develop a multispecies model, or to make some estimate of prey consumption that can be translated into an estimate of predation mortality to be used in the assessment model, instead of the usual assumption of constant natural mortality. This would be a way of integrating the results of a Tier 2 model into a single-species assessment model (Tier 3).

Although the data collected in scientific and commercial surveys generally constitute quality data, it is likely that these data are influenced by environmental/ecological factors that are seldom considered in the construction of the input data products used for the assessment. Temporal or spatiotemporal modelling is becoming more common to produce input data for stock assessment, in which environmental variables (water temperature, depth, latitude, etc.) or ecological variables (abundance of a certain predator or competitor) are considered. For example, the biomass index in a scientific survey can be estimated by taking the tow data which is modelled using a spatiotemporal model with environmental variables (e.g. ICES, 2023). The recruitment in the last years of the historical period is another element where significant improvement can be made by incorporating ecosystem information. The uncertainty in the value of recruitment is high in these years due to the limited information for these cohorts. Depending on the age at which fish enters the fishable biomass, this can be highly relevant for the short-term projections used in the provision of advice on recommended catches. Incorporating environmental variables in the estimation of recruitment can be a way of improving these estimates and reduce uncertainty (ICES, 2020).

If instead of an age-structured model a size- and age-structured model is used, such as Gadget (Begley and Howell 2004) or SS3 (Methot and Wetzel, 2013), the growth models that determine weight at age, as well as the maturation models that determine the proportion of mature individuals at age, can be improved by including environmental variables that modify model output values in terms of weight and proportion of mature individuals at age.

However, it is in the short-term projections used to provide tactical advice, or in the long-term projections used to provide strategic advice, where the need for incorporating ecosystem information is likely the greatest. In short-term projections, models with temporal correlation, density-dependent effects and/or the effect of environmental/ecological variables can be used to determine the value of annual recruitment, weight at age (which can be linked to the proportion of mature at age) and natural mortality, which can be determined by projections with a multi-species model or can be incorporated on a short-term forecast simulation model (e.g. short term projections for Barents Sea capelin accounting for cod predation, ICES, 2020). In long-term projections used to assess the performance of alternative MPs and provide strategic advice to managers, it is becoming more common to use MSE environments including operating models (OMs) in which the processes that define the dynamics and productivity of the stock (recruitment, natural mortality, growth and maturation) are influenced by environmental and ecological variables. These MSE environments also include observation models in which the effect of environmental factors on observation error can be simulated.

While these examples and considerations illustrate some possibilities for incorporating environmental/ecological drivers into Tier 2 and 3 models, and their use in informing tactical and strategic advice, it is expected that the specific applications will be tailored to the needs of the stock, the assessment and advice method, the data, and the human resources available to carry out the work. This means that concrete implementations will be stock-specific processes, but as this type of work progresses, approaches that are more generally applicable and effective are likely to be identified.

iii) Brainstorming session

The 2024 session aimed at exploring the incorporation of ecosystem information into assessment models and MPs to account for environmental/ecological conditions in the provision of tactical and strategic advice. This involves considering implementation in Tiers 2 and 3 assessment levels.

In this context, it is relevant to highlight that what defines and assessment tier is not the model used (e.g. multispecies or single-species) but the scope of application. For this reason, from a modelling perspective, the boundary between a tier 2 and a tier 3 model is blurry (Figure 6.27).

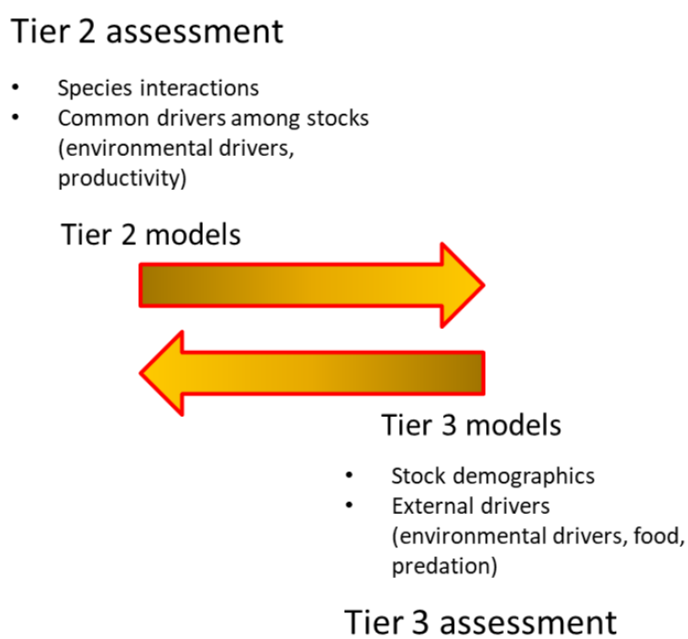

Figure 6.27. Taken from NAFO (2021). Schematic representation of the relationships between Tiers 2 and 3 as assessment levels, versus the role of Tier 2 (e.g. multispecies) and Tier 3 (e.g. stock-assessment) models within these assessment levels. From a model structure perspective, the boundary between tier 2 and tier 3 models can be a fuzzy one; what effectively defines the Tier is the scope of the assessment being conducted.

A clear outcome of the discussion was the acknowledgment that a multidisciplinary approach is needed; oceanographers (STACFEN), fisheries ecologists (WG-ESA), and stock assessors (SC) need all to be involved. Oceanographers provide knowledge on the environmental conditions impacting the stocks and ecosystems, fisheries ecologists identify linkages among stocks and between them and environmental drivers, and stock assessors integrate the emerging knowledge into the assessment models and process. Collaborative work among these three groups of scientists is a must for an effective and successful incorporation of ecosystem information in the provision of tactical and strategic advice.

WG-ESA also highlighted that the case studies currently being planned in relation to the incorporation of climate change impacts on NAFO stocks (ToR 2.7, COM Request #10) represent an implementation of the type of applications being considered here for the integration of environmental/ecological drivers in stock-assessment models. While these climate change case studies may be more limited in the scope of options that could be explored due to the short-term duration of the consultancy supporting this work, the results will nonetheless be informative for the discussion on incorporating ecosystem information into tactical and strategic advice, and complementary to the work being done in WG-ESA on this topic.

The 2021 discussion session (NAFO, 2021) concluded that the first step in developing a Tier 2 model is putting together an "ecological case" to justify the need for the Tier 2 model. This ecological case needs to provide a) a rationale for the interactions to be included in the model, b) a credible expectation of relevance for the managed stocks (i.e. the modelled interactions are expected to be dynamically influential), and c) some empirical evidence supporting the rational and expectation of relevance.

Building upon this idea, WG-ESA identified a survey of DEs as the most useful immediate next step. This survey is 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 to be used for this survey was based on the one used by Kulka et al (2022), and its details are provided below:

iv) Survey to DEs on the incorporation of ecosystem information in the stock-assessment process

Instructions

- This questionnaire is to be responded by the **Designated Expert** (**DE)** responsible for the stock, which will be the person to be contacted for any follow-up that may be required. In preparing the responses, the DE can contact any/all members of the assessment team as needed.
- Responses can be structured in paragraph or point form, whatever works best for the respondent.
- Please be brief but include all details that you think may be relevant to our understanding of the incorporation of **environmental/ecological variables** into the assessment.
    - **Environmental/Ecological variables** can consist of climate change indicators, oceanographic variables (e.g., temperature, salinity, upwelling, current or transport indices), ecological factors (e.g., abundance of potential prey, predators, competitors, natural mortality estimates), metrics of physical or biological habitat availability, or other variables that can affect the productivity (e.g., growth, mortality, recruitment) or availability (e.g., distribution, catchability) of the stock being assessed.
- If relevant, specify whether the environmental variables are considered to be useful from a tactical and/or strategical perspective.
- Include any documentation that you think may enhance our understanding of the environmental variables used and their incorporation into the assessment.
- The deadline for submission of responses to this questionnaire is April 1st, 2025. The completed questionnaire is to be returned to Alfonso Pérez-Rodríguez (alfonso.perez@ieo.csic.es).
- Once you submit the completed questionnaire, Dr. Alfonso Pérez-Rodríguez might need a follow-up interview by teleconference with you. This teleconference session would be used to elaborate on the written responses and allow for clarification of points where appropriate.
- After the teleconference session, Dr. Alfonso Pérez-Rodríguez will make any necessary additions or edits to the responses to the questionnaire and will send you a final version for validation.

Questionnaire

Responsible scientist, biologist or analyst: Name
Stock identification: Stock
Bioregion:
EPU:
NAFO area: Region
Due date for return of completed questionnaire: April 1st 2025

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.

v) References

Begley, J., and Howell, D. 2004. An overview of Gadget, the Globally applicable Area Disaggregated General Ecosystem Toolbox. ICES CM 2004/FF:13.

ICES. 2023. Benchmark workshop on Northern Shelf cod stocks (WKBCOD). ICES Scientific Reports. 5:37. 425 pp. https://doi.org/10.17895/ices.pub.22591423

ICES. 2020. Arctic Fisheries Working Group (AFWG). ICES Scientific Reports. 2:52. 577 pp. http://doi.org/10.17895/ices.pub.6050

Koen-Alonso, M; Pepin, P; Kenny, A.; 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.

Kulka, D.W., Thompson, S., Cogliati, K., Olmstead, M., Austin, D., and Pepin, P. 2022. An Accounting of Integration of Environmental Variables in Fishery Stock Assessments in Canada. Canadian Technical Report of Fisheries and Aquatic Science 3473: viii + 79 p.

Marshall, K. N., Koehn, L. E., Levin, P. S., Essington, T. E., & Jensen, O. P. 2019. Inclusion of ecosystem information in US fish stock assessments suggests progress toward ecosystem-based fisheries management. ICES Journal of Marine Science, 76, 1–9. https://doi.org/10.1093/icesj ms/fsy152

Methot, R.D., Wetzell, C.R., 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fish. Res. 142, 86–99

NAFO, 2018. Estimates of natural predation and residual mortality for the Flemish Cap cod. NAFO SCR Doc. 18/025.

NAFO, 2021. Report of the 14th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA). NAFO SCR Doc. 21/21

NAFO, 2024. Report of the Scientific Council Meeting. 31 May-13 June 2024. NAFO SCS Doc. 24/16.

Pérez-Rodríguez, A., D. Howell, M. Casas, F. Saborido-Rey, and A. Avila-de Melo. 2017. Dynamic of the Flemish Cap commercial stocks: use of a Gadget multispecies model to determine the relevance and synergies among predation, recruitment, and fishing. Canadian Journal of Fisheries and Aquatic Sciences 74:582-597.

Pérez-Rodríguez, A., Umar, I., Goto, D., Howell, D., Mosqueira, I., and González-Troncoso, D. 2022. Evaluation of harvest control rules for a group of interacting commercial stocks using a multispecies MSE framework. Canadian Journal of Fisheries and Aquatic Sciences, 79: 1–45.

THEME 4: OTHER MATTERS

7. Other business

a) ToR 4.1. Update presentation on the work on carbon sediment content in Canada, protected area overlays and early work on trawling distribution

Graham Epstein, Susanna D. Fuller, Sophia C. Johannessen, Emily Rubidge, Dipti Hingmire, Lauren Gullage, Paul G. Myers, Angelica Peña, Clark Pennelly, Melissa Turner & Julia K. Baum

The conservation of seabed sediments has the capacity to significantly contribute to climate change mitigation as these habitats globally contain around 7 times the carbon sequestration and approximately 200 times the carbon stock of all coastal vegetated blue carbon habitats combined (i.e. saltmarsh, seagrass, mangrove & kelp). In contrast, the disturbance of seafloor sediments from mobile bottom fishing and other anthropogenic disturbances can result in significant losses of organic carbon stocks, with the potential to limit carbon burial and alter the oceanic carbon sink. While there is significant uncertainty in the magnitude of carbon remineralisation from different disturbances and under a range of environmental settings, identifying those areas at highest risk can allow selection of priority areas for further research, precautionary fisheries management and/or protection. Our research led to the production of the first national predictive map of organic carbon in seabed sediments on Canada's continental margin, estimating that the top 30 cm contains 10.9 Gt, which is equivalent to around 100 times that of all Canadian seagrass beds and saltmarshes, or half of that in all Canada's forest vegetation. Large spatial variation was identified with high carbon areas centered around muddy sediments in depositional zones such as fjords, troughs, inlets, channels and bays. Canada's marine conserved area (MCA) network is rapidly expanding and aims to integrate climate change mitigation by protecting coastal vegetated habitats. Seabed sediments have not been considered, but we argue that their protection could bring similar or greater benefits. We show that Canada's MCAs (designated and proposed) currently encompass only 19.6% of seabed carbon stocks and 19.5% of high carbon areas. We identify an additional set of high-priority areas for future research and potential proactive protection based on carbon stocks, proxies for lability, and ecological/biological significance. Finally, by combining data on predicted carbon stocks and mean annual fishing effort, we estimate that mobile bottom fishing disturbs on average 32.0 Mt of organic carbon per year in Canada's Atlantic and 2.1 Mt in the Pacific. Shrimp trawling was the largest contributor to this disturbance, but clam and scallop dredging had highest disturbances per unit effort. By combing these results with data on sediment composition and oceanographic conditions, we construct a measure of the relative-risk for carbon remineralisation, identifying those fisheries and seabed areas where changes in fisheries management or gear adaptations could be most impactful for seabed carbon. While further research is still necessary, these analyses could be used to implement ecosystem-based fisheries management frameworks that include precautionary climate change mitigation measures for the seabed. As NAFO make progress on implementing the ecosystem approach to fisheries management, including through the review of significant adverse impacts on VMEs, considering carbon sediment sequestration in soft sediment areas could be an additional consideration. While the recent report on NAFO and climate change impacts on fisheries did not consider the seafloor ecosystem, future discussions could include fishing impacts on seafloor carbon sequestration, particularly in areas where high concentrations of carbon overlap with known VME areas, most relevant to seapen fields.

b) ToR 4.2. UN Convention on Biological Diversity (CBD) Conference of the Parties 16 (COP 16) outcomes + Updates on BBNJ Agreement

Daniela Diz reported on the main outcomes of the UN Convention on Biological Diversity (CBD) 16th Conference of the Parties (COP 16) which took place in Cali, Colombia from 21 November to 2 November 2024, with respect to the marine and coastal biodiversity agenda items. In this context, two decisions were adopted by COP 16, namely: Further work on ecologically or biologically significant marine areas (EBSAs) (CBD/COP/16/L.8), and conservation and sustainable use of marine and coastal biodiversity and of island biodiversity (CBD/COP/16/L.17)[1].

i) Further work on ecologically or biologically significant marine areas

After eight years of negotiations, through this EBSA decision, the CBD COP has adopted new modalities for the modification of descriptions of EBSAs and the description of new areas as per the annex to the decision (see Figure 7.1 below for a flowchart of the current process as it applies to areas beyond national jurisdiction (ABNJ)). The new process provides for a more dynamic way to update EBSA descriptions or for the description of new EBSAs in light of new scientific information.

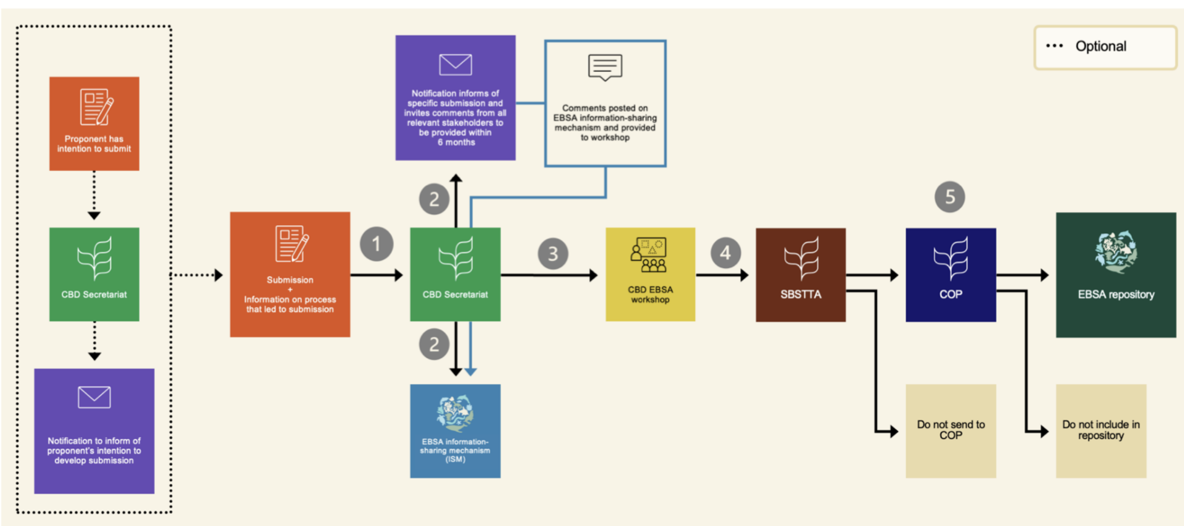

Figure 7.1. Process for modification or new description of EBSAs in areas beyond national jurisdiction in accordance with the Annex of the CBD EBSA decision. © CBD/COP/16/INF/11

The EBSA decision specifies that for ABNJ the proponents of such submissions to the CBD Secretariat would be only States, individually or collectively, including through competent intergovernmental organizations, which is the case of NAFO (para 3 of the Annex to CBD/COP/16/L.8).

[1] The text of this L.doc was slightly modified in the last plenary session of the COP, and the amended text (in the format of an adopted decision) is not yet available on the CBD website at the time of writing (20 Nov 2024).

For the Northwest Atlantic, seven areas have been described as meeting the EBSA criteria in 2014 through a CBD regional workshop, which NAFO Secretariat and NAFO scientists participated in (UNEP/CBD/EBSA/WS/2014/2/4). The seven areas are the following:

1. Labrador Sea Deep Convection Area
2. Seabird Foraging Zone in the Southern Labrador Sea
3. Orphan Knoll
4. Slopes of the Flemish Cap and Grand Bank
5. Southeast Shoal and Adjacent Areas on the Tail of the Grand Bank
6. New England and Corner Rise Seamounts
7. Hydrothermal Vent Fields

CBD COP 12 considered the outcomes of that workshop and listed these seven areas as meeting the EBSA criteria in the NW Atlantic into table 6 of the annex of decision XII/22 (2014).

The new modalities that were adopted by COP 16 did not amend the EBSA criteria, which continue to be the same.[2] As per the COP 16 new modalities, the reasons for modification of an EBSA description in ABNJ are the following:

(i) Newly available or accessible knowledge, including knowledge, innovations and practices of indigenous peoples and local communities, on features associated with the area;
(ii) Change in the ecological or biological features of the area;
(iii) Scientific errors identified in the description (Para. 2(a) of the Annex to CBD/COP/16/L.8).

The reasons must be provided in the submission to modify an EBSA.

During the discussions, WG-ESA members noted that there is no major new information at NAFO that could justify the modification of the seven EBSAs in the Northwest Atlantic at the moment.

ii) Conservation and sustainable use of marine and coastal biodiversity and of island biodiversity

With respect to the marine and coastal biodiversity decision, two areas were highlighted as of potential interest for NAFO, namely: a request for a biodiversity beyond national jurisdiction (BBNJ) workshop; and a list of new areas for work under the Convention.

On the former, paragraph 11 of the document CBD/COP/16/L.17 requested the Executive Secretary of the CBD to continue cooperation with the UN Division for Ocean Affairs and the Law of the Sea (DOALOS) and with organizations with competence in marine areas beyond national jurisdiction to convene an expert workshop on opportunities for specific areas of scientific and technical work, including cross-sectoral areas of work conducted under the CBD to contribute to the conservation and sustainable use of marine biodiversity in ABNJ. It was noted that NAFO's expertise in this field would provide a valuable contribution to the workshop. It was also noted that with respect to the BBNJ Agreement, there are currently 14 Parties to the Agreement and 60 is the number needed for the treaty to enter into force, and that sessions of the Preparatory Commission has been scheduled by the UN General Assembly to take place in 2025 to advance the work that needs to be adopted by the first COP of the Agreement once it is into force.

In relation to the new areas of work under the CBD, it was noted that several areas have been listed in the Annex to the marine and coastal biodiversity decision as areas that merit further attention by future COPs in order to help implement the Kunming-Montreal Global Biodiversity Framework (CBD decision 15/4 (2022)). These new areas of work will benefit from further implementation guidance developed under the Convention or elsewhere, as well as further recommendations by future COPs. It was noted that the work of NAFO in several of these areas may be an important contribution to this work. Some of these areas include the following topics, inter alia:

(a) Active and passive restoration in the marine environment;

[2] Namely, uniqueness or rarity; special importance for life-history stages of species; importance for threatened, endangered, or declining species and/or habitats; vulnerability, fragility, sensitivity, or slow recovery; biological productivity; biological diversity; naturalness. The EBSA criteria was adopted by CBD decision IX/20 (2008), and is contained in Annex I of this decision.

(b) Marine protected areas (MPAs) and other effective area-based conservation measures (OECMs);

(c) Minimisation of human-wildlife conflict in marine areas in particular regarding threatened, endangered and vulnerable species;

(d) To assess, monitor and conserve genetic diversity of marine species;

(e) To improve understanding of marine biodiversity across mesopelagic, deep-sea and benthic ecosystems and linkages between them;

(f) To assess, prevent, mitigate or minimize individual and cumulative impacts of all types of pollution;

(g) To enhance the use of nature-based solutions and ecosystem-based approaches across marine ecosystems;

(h) To map, monitor, restore and effectively manage marine and coastal ecosystems that contribute to climate change mitigation and adaptation;

(i) To conserve and sustainably use biodiversity associated with sea ice, and to improve understanding of the impacts of rapidly decreasing sea ice on marine and coastal ecosystems;

(j) To improve integration of the multiple values of biodiversity across marine and coastal areas into planning and decision-making.

iii) References

CBD/COP/16/L.8 (2024), Further work on ecologically or biologically significant marine areas.

CBD/COP/16/L/17 (2024), Conservation and sustainable use of marine and coastal biodiversity and of island biodiversity.

CBD decision IX/20 (2008), Marine and coastal biodiversity

CBD decision XII/22 (2014), Marine and coastal biodiversity: ecologically or biologically significant marine areas (EBSAs).

UNEP/CBD/EBSA/WS/2014/2/4 (2014), Report of the North-west Atlantic Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas

c) ToR 4.3. Update on EAFM Symposium

Tony Thompson, the Deep-sea Fisheries project (FAO) symposium co-coordinator, provided an overview of the progress made on the EAFM symposium. The symposium website is hosted by the NAFO Secretariat on a webpage with the link www.eafm-symposium.nafo.int. The symposium is being organised by the FAO DSF project, NAFO and ICES. The symposium is three days and will include the scientific, management and implementation aspects of the ecosystem component of EAFM. The output will be a short guidance document that identify the EAFM topics of relevance to the deep-sea RFMOs and CCAMLR together with the responsibilities of their scientific and management committees to move these topics forward to better implement EAFM. In addition, papers from the symposium will be published in the NAFO Journal of Northwest Atlantic Fishery Science. Each day will include two keynote addresses, and three sessions each having three presentations. Each session and each day will end with discussions. The final symposium session will be a panel format to develop the final output. Speakers have been provisionally identified for 27 of 31 slots. Suggestions were received for WG-ESA and will be considered for inclusion in the programme.

8. Date and Place of Next Meeting

The next WG-ESA meeting is scheduled for 04-13 November 2025, in Halifax, Canada.

9. Adjournment

The co-Chairs thanked the participants for their hard work and cooperation of this year's meeting. The meeting was adjourned at 09:40 on 21 November 2024.

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

NAFO Headquarters, Halifax, 12-21 November 2024

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 2024 outcomes**
5. **Commission requests for advice on management in 2025 and beyond, requiring input from WG-ESA in 2024 to be presented at the Scientific Council meeting June 2025.**

    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.

    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:

    a. Continue the development of a 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 2025 WG-EAFFM meeting.

6. **Commission requests for advice on management in 2025 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 that the Scientific Council develop a reference document detailing the ecosystem roadmap, for completion in the next 1-3 years.

    b) **COM Request #10.** Noting the voluntary contribution of the United States to support a consultant to provide feedback on NAFO's processes to address climate change impacts, requests the SC to conduct an analysis of progress and/or outcomes of that work.

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. There is flexibility and some items are still pending confirmation.

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. Temporal trends on VME catches (*Bárbara/Sara/Mar*)
2. Visual observations from seabed surveys in the Flemish Pass area (NRA) and 3O coral closure (Canadian) (*Bárbara*)
3. Update on the centralized data repository using ArcGIS online portal [*COM. Request#6a*]. (*Neil, Lauren, etc*)
4. Data management plan for RV trawl data, and standard template for storing RV trawl data in the NAFO-hosted ArcGIS Online portal [*COM. Request#6a*] (*Anna, all*)

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. Update on the review of NAFO VMEs: Species Distribution Models of VME taxa and individual VME Indicators [*COM. Request#6b*] (*Ellen, Cam, Javier Murillo, Bárbara, Anna, Sara, Claude Nozeres, etc*)
2. Assessment of SAI and reassessment of bottom fisheries impacts: Discussion about lead and timing for completion of the tasks [*COM. Request#6b*] (*All*)
3. Assessment of SAI and reassessment of bottom fisheries impacts: Provide potential management options as part of the reassessment of bottom fishing [*COM. Request#6b*] (*All*)
4. Update on the SAI work [*COM. Request#6b*] (*Andy*)
5. Presentation on the application of dRBS method (dynamic Relative Benthic Status) in SPRFMO: Framework for looking at impact assessments in NAFO [*COM. Request#6b*] (*Ashley Rowden, Owen Anderson, Bradley*)
6. Summary of the information regarding the current and future impacts of climate change on NAFO-managed stocks, non-target species, and associated ecosystems; and identification of any consequential data gaps, research needs and opportunities for productive research [COM. Request #10] (*Mariano*) and Voluntary contribution from USA for Climate Change contract [COM. Request #10] (*Diana, all*)

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. Update on submitting NAFO seamount and sponge closed areas as OECMs, and developing support materials for coral closures as OECMs [*COM. Request #6c*] (*Andy, Ellen, Daniela, Brynhildur, etc*)
2. Studying the effect of seismic surveying on groundfish fisheries offshore Newfoundland and Labrador, Canada (*Corey Morris*).

3. An integrated numerical framework for Environmental Risk Assessment in marine ecosystems affected by accidental spills (*Irene Martins*)
4. Update on seabed macrolitter on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO): Sources, drivers of distribution and reviewed protocol for groundfish surveys (*Santi/Sara/Pablo/Esther/Mar*).
5. Regular Monitoring of Ecosystem Summary Sheets (ESSs) for Divisions 3LNO and 3M [*COM. Request#1*] (*Mariano, Diana*)
6. Formalization of a full Workplan for the 2027 ESSs update: Analysis of by-catch and discards and proposal for building an ETP species list. [*COM. Request#1*] (*Patricia, Mark, Diana, Javier Murillo, Jana*)
7. Update on Primary Productivity Estimates to inform EPP models for TCI calculations [*COM. Request#1*] (*Mariano, STACFEN, etc*)
8. Update on the work towards developing operational objectives for the protection of VMEs and biodiversity in the NRA (*Andy*)
9. Develop Table of Contents for the NAFO Roadmap reference document [*COM. Request#5*] (*Mariano*)
10. Brainstorming session on the approach to implement ecosystem knowledge into the single species stock assessment and scientific advice on management strategies. (*Alfonso, all*)

THEME 4: OTHER MATTERS

1. Update presentation on the work on carbon sediment content in Canada, protected area overlays and early work on trawling distribution (*Graham Epstein and Susanna Fuller*)
2. UN Convention on Biological Diversity (CBD) Conference of the Parties 16 (COP 16) outcomes + Updates on BBNJ Agreement (*Daniela Diz*)
3. Update on EAFM Symposium (*Tony Thompson*).

APPENDIX II. LIST OF PARTICIPANTS

Name	Affiliation	E-mail
CHAIRS		
Perez, Alfonso	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	alfonso.perez@ieo.csic.es
Sacau Cuadrado, Mar	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	mar.sacau@ ieo.csic.es
CANADA		
Command, Rylan*	Fisheries and Oceans Canada, St. John's, NL	rylan.command@dfo-mpo.gc.ca
Cyr, Frederic*	Fisheries and Oceans Canada, St. John's, NL	Frederic.Cyr@dfo-mpo.gc.ca
Gullage, Lauren*	Fisheries and Oceans Canada, St. John's, NL	lauren.gullage@dfo-mpo.gc.ca
Hamilton, Charmain	Fisheries and Oceans Canada	Charmain.Hamilton@dfo-mpo.gc.ca
Hatefi, Fatemeh*	Fisheries and Oceans Canada, St. John's, NL	fatemeh.hatefi@dfo-mpo.gc.ca
Hayes, Vonda*	Fisheries and Oceans Canada, St. John's, NL	vonda.hayes@dfo-mpo.gc.ca
Hedges, Kevin*	Fisheries and Oceans Canada, Winnipeg, MB	kevin.hedges@dfo-mpo.gc.ca
Kenchington, Ellen	Fisheries and Oceans Canada, Dartmouth, NS	ellen.kenchington@dfo-mpo.gc.ca
Koen-Alonso, Mariano	Fisheries and Oceans Canada, St. John's, NL	mariano.koen-alonso@dfo-mpo.gc.ca
Krohn, Martha*	Fisheries and Oceans Canada, Ottawa, ON	martha.krohn@dfo-mpo.gc.ca
Lang, Shelley*	Fisheries and Oceans Canada	Shelley.Lang@dfo-mpo.gc.ca
Lirette, Camille	Fisheries and Oceans Canada, Dartmouth, NS	camille.lirette@dfo-mpo.gc.ca
Maillet, Gary*	Fisheries and Oceans Canada, St. John's, NL	Gary.Maillet@dfo-mpo.gc.ca
Morris, Corey*	Fisheries and Oceans Canada	Corey.Morris@dfo-mpo.gc.ca
Munro, Hannah*	Fisheries and Oceans Canada, St. John's, NL	hannah.munro@dfo-mpo.gc.ca
Murillo-Perez, Francisco Javier	Fisheries and Oceans Canada, Dartmouth, NS	javier.murillo-perez@dfo-mpo.gc.ca
Neves, Bárbara*	Fisheries and Oceans Canada, St. John's, NL	barbara.neves@dfo-mpo.gc.ca
Nozères, Claude	Fisheries and Oceans Canada, Dartmouth, NS	Claude.Nozeres@dfo-mpo.gc.ca
Ollerhead, Neil	Fisheries and Oceans Canada, St. John's, NL	neil.ollerhead@dfo-mpo.gc.ca
Perreault, Andrea*	Fisheries and Oceans Canada, St. John's, NL	Andrea.Perreault@dfo-mpo.gc.ca
Regular, Paul*	Fisheries and Oceans Canada, St. John's, NL	paul.regular@dfo-mpo.gc.ca
Rideout, Rick*	Fisheries and Oceans Canada, St. John's, NL	rick.rideout@dfo-mpo.gc.ca

Simpson, Mark	Fisheries and Oceans Canada, St. John's, NL	mark.simpson@dfo-mpo.gc.ca
Wang, Zeliang*	Fisheries and Oceans Canada, Dartmouth, NS	zeliang.wang@dfo-mpo.gc.ca
Wheeland, Laura*	Fisheries and Oceans Canada, St. John's, NL	laura.wheeland@dfo-mpo.gc.ca
EUROPEAN UNION		
Abalo, Sara*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	sara.abalo@ieo.csic.es
Cabrero, Agueda*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	agueda.cabrero@ieo.csic.es
Caetano, Miguel*	Instituto Português do Mar e da Atmosfera, Lisbon, Portugal	mcaetano@ipma.pt
Durán Muñoz, Pablo*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	pablo.duran@ieo.csic.es
Garrido, Irene*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	irene.garrido@ieo.csic.es
Gonçalves, Patricia*	Instituto Português do Mar e da Atmosfera, Lisbon, Portugal	patricia@ipma.pt
González-Costas, Fernando*	Instituto Español de Oceanografía, Vigo (Pontevedra), Spain	fernando.gonzalez@ieo.csic.es
González-Troncoso, Diana	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	diana.gonzalez@ieo.csic.es
González, Gonzalo*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	gonzalo.gonzaleznuevo@ieo.csic.es
Martins, Irene*	CIIMAR (Interdisciplinary Centre of Marine and Environmental Research) – Portugal	imartins@ciimar.up.pt
Merino Buisac, Adolfo*	European Commission. Directorate-General for Maritime Affairs and Fisheries. Unit C.3 – Scientific advice and data collection	adolfo.merino-buisac@ec.europa.eu
Otero, Pablo*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	pablo.otero@ieo.csic.es
Palas, Santiago*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	santiago.palas@ieo.csic.es
Román, Esther*	Instituto Español de Oceanografía (COV-IEO), CSIC, Spain	Esther.roman@ieo.csic.es
JAPAN		
Taki, Kenji*	Japan Fisheries Research and Education Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, 236-8648, Japan	takisan@fra.affrc.go.jp
RUSSIAN FEDERATION		
Fomin, Konstantin*	Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk.	fomin@pinro.ru
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND		
Bell, James*	CEFAS, Lowestoft Laboratory, Lowestoft, UK	james.bell@cefas.gov.uk

Downie, Anna	CEFAS, Lowestoft Laboratory, Lowestoft, UK	anna.downie@cefas.gov.uk
Kenny, Andrew	CEFAS, Lowestoft Laboratory, Lowestoft, UK	andrew.kenny@cefas.gov.uk
UNITED STATES OF AMERICA		
Mencher, Elizabethann*	National Marine Fisheries Service, Office of International Affairs and Seafood Inspection, NOAA, USA	elizabethann.mencher@noaa.gov
Sosebee, Katherine*	National Marine Fisheries Service, NEFSC, USA	katherine.sosebee@noaa.gov
INVITED GUESTS		
Anderson, Owen*	National Institute of Water and Atmospheric Research (NIWA), New Zealand	Owen.Anderson@niwa.co.nz
Moore, Bradley*	National Institute of Water and Atmospheric Research (NIWA), New Zealand	Bradley.Moore@niwa.co.nz
Rowden, Ashley*	National Institute of Water and Atmospheric Research (NIWA), New Zealand	Ashley.Rowden@niwa.co.nz
Epstein, Graham*	University of Victoria	grahamepstein@uvic.ca
Bentley, Jacob*	Natural England, United Kingdom	Jacob.Bentley@naturalengland.org.uk
Thompson, Tony*	Food and Agriculture Organization	Anthony.thompson@fao.org
OBSERVERS		
Diz, Daniela*	Deep Sea Conservation Coalition	d.diz@hw.ac.uk
Fuller, Susanna	Oceans North, Halifax Office, Halifax, NS, Canada	susannafuller@oceansnorth.ca
Luckhurst, Brian	Sargasso Sea Commission	brian.luckhurst@gmail.com
Rayner, Gemma	Oceans North, Halifax Office, Halifax, NS, Canada	grayner@oceansnorth.ca
NAFO SECRETARIAT		
Benediktsdóttir, Brynhildur	NAFO Secretariat, Halifax, NS, Canada	bbenediktsdottir@nafo.int
Aker, Jana	NAFO Secretariat, Halifax, NS, Canada	jaker@nafo.int
Bell MacCallum, Dayna	NAFO Secretariat, Halifax, NS, Canada	dbell@nafo.int

*Virtual participation