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SCIENTIFIC COUNCIL WORKING GROUP ON ECOSYSTEM SCIENCE AND ASSESSMENT – NOVEMBER 2022

Report of the 15th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA)

By WebEx
15-24 November 2022

Contents

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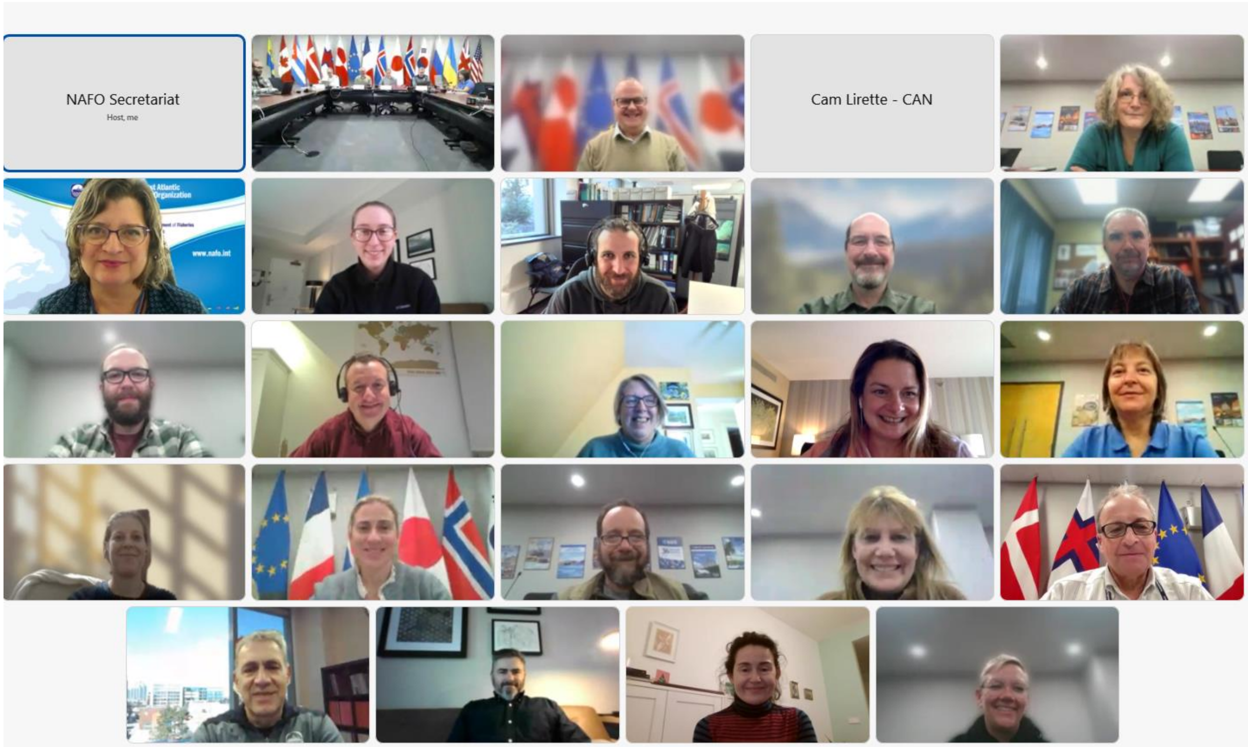

WG-ESA Meeting Participants
15-24 November 2022

From left to right:

Top row: *NAFO Secretariat, NAFO Boardroom*, Andrew Kenny (co-Chair), Cam Lirette, Anna Downie
Second row: Alexis Pacey, Lauren Gullage, Javier Murillo-Perez, Mark Simpson, Rick Rideout
Third row: Robert Deering, Adolfo Merino Buisac, Ellen Kenchington, Daniela Diz, Diana González-Troncoso
Fourth row: Irene Garrido Fernández, Mar Sacau- Cuadrado, Mariano Koen-Alonso, Martha Krohn, Fred Kingston
Fifth row: Tom Blasdale, Neil Ollerhead, Patricia Gonçalves, Karen Dwyer
Missing from photo: Hugues Benoît, Karen Cogliati, Bárbara Neves, Paul Regular, Vonda Wareham-Hayes, Sara Abalo Morla, Ricardo Alpoim, Miguel Caetano, Pablo Durán Muñoz, Ignacio Granell, Alfonso Perez-Rodriguez, Kenji Taki, Temur Tairov, Elizabethann Mencher, susanna Fuller, Tony Thompson, Dayna Bell MacCallum, Ricardo Federizon.

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

15-24 November 2022

1. Opening by the co-Chairs

The NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA) met during 15-24 November 2022 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 09:00 (Halifax Time) on 15 November 2022. The co-Chairs, Andrew Kenny (UK) and Mar Sacau Cuadrado (EU) welcomed participants.

Andrew Kenny 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. ToR 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 Scientific Council Coordinator 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

i) EU and EU- Spain Groundfish Surveys (2022)

Due to logistical issues during 2022, R/V Vizconde de Eza only carried out two surveys, one in Division 3M (Flemish Cap, EU-Spain and EU-Portugal) sampling between 128 - 1470 m, with a total of 183 tows (182 valid; 1 no valid) and other in Divisions 3NO (Grand Banks of Newfoundland, EU-Spain) sampling between 40 - 1460 m depth with a total of 114 tows (113 valid; 1 no valid). In total there were 297 bottom trawl tows, two of them considered invalid due to technical problems during the fishing operation. 110 hauls out of 295 valid tows have shown cero catches (i.e. no presence) of VME indicator species groups. This represents the 37.3% of the total valid hauls. A brief description of the survey methodology can be found in Durán Muñoz *et al.* (2020). **Sponges** were recorded, with non-significant concentrations (< 100 kg/tow), in 81 of the 295 valid tows (27.5% of the valid tows analyzed), with depths ranging between 128 - 1460 m. One of the valid tows was found to have a significant concentration of sponges (≥ 100 kg/tow). **Large gorgonians** were recorded, with non-significant concentrations (< 0.6 kg/tow), in 9 of the 295 valid tows (3% of valid tows analyzed), with depths ranging between 607- 1405 m. One of the valid tows had a significant concentration of large gorgonians (≥ 0.6 kg/tow). **Small gorgonians** were recorded, with non-significant concentrations (< 0.2 kg/tow), in 39 of the 295 valid tows (13.2% of valid tows analyzed), with depths ranging between 482- 1470 m. One of the valid tows had a significant concentration of small gorgonians (≥ 0.2 kg/tow). **Sea pens** were recorded, with non-significant concentrations (<1.3 kg/tow), in 101 tows (34.2% of valid tows analyzed), with depths ranging between 221 - 1470 m. One tow with significant concentration (≥ 1.3 kg/tow) was recorded. **Black corals** were recorded, with non-significant concentrations (< 0.4 kg/tow), in 18 tows (6.1% of valid tows analyzed), with depths ranging between 281 - 1336 m. One tow with significant concentration (≥ 0.4 kg/tow) was recorded. **Sea squirts** *(Boltenia ovifera*) was recorded, with non-significant concentrations (< 0.35 kg/tow), in 1 tow (0.3% of valid tows analyzed), at a depth of 562 m. Three tows with significant concentrations (≥ 0.35 kg/tow) were recorded. **Bryozoans** were recorded, with non-significant concentrations (< 0.2 kg/tow), in 25 tows (8.5% of valid tows analyzed), with depths ranging between 49 - 1377 m. Two tows with significant concentrations (≥ 0.2 kg/tow) were recorded.

ii) Canadian Surveys (2022 Spring)

In the Spring of 2022, the Canadian Multispecies Surveys, conducted by Fisheries and Oceans Canada (SCR Doc. 96-050), sampled the Grand Bank of Newfoundland (NAFO Divs. 3LNO) between mean depths of 45 - 727 m, with a total of 59 tows (58 valid; 1 invalid). A new vessel was used to conduct 85% of the 2022 Canadian sets reported here, and comparability in catchability between this new vessel and previous vessels has not yet been assessed. **Sponges** were recorded in 34 of the 58 valid tows (58.6%), with mean depths ranging between 105 - 727 m. There were no tows with significant concentrations of sponges (≥ 100 kg/tow) in these tows. **Large gorgonians** were recorded in 5 of the 58 valid tows (8.6% of total tows analyzed), at mean depths of 197 and 717 m. There was one tow with significant concentration of large gorgonians (≥ 0.6 kg/tow), outside of the large gorgonians VME polygons. **Small gorgonians** were recorded with non-significant concentrations in 1 valid tow (1.7 % of total tows analyzed), from a mean depth of 727 m. That concentration was significant (> 0.2 kg/tow) and found within the small gorgonians VME polygon. **Sea pens** were recorded in 12 of the 58 valid tows (20.7% of total tows analyzed), with mean depths ranging between 118 - 727 m. No tows with significant concentrations of sea pens (≥ 1.3 kg/tow) were recorded within the NRA. No **black corals** were recorded during the DFO 2022 Spring surveys. **Sea squirts** *(Boltenia ovifera)* were recorded in 5 of the 58 valid tows (8.6% of total tows analyzed), with mean depths ranging between 45 - 208 m. Of these, a total of two tows had significant concentrations of *Boltenia* (≥ 0.35 kg/tow), both of which were found inside the *Boltenia* VME polygon. These significant concentrations were: 0.565 kg and 0.601 kg. No **bryozoans** were recorded during the DFO 2022 Spring surveys.

Above information, including distribution maps of VME species groups, is further detailed in SCR Doc. 22/054 (Sacau *et al*. 2022).

iii) Acknowledgements

The collection of the EU-Spain and EU-Portugal Groundfish Surveys used in this paper has been funded by the EU through the European Maritime and Fisheries Fund (EMFF) within the National Program of collection, management and use of data in the fisheries sector and support for scientific advice regarding 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 (MS; SAM & PDM) and the European Union cannot be held responsible for any use that may be made of the information contained therein. BMN and VWH acknowledge DFO-NL personnel and Canadian Coast Guard captain and crew for Canadian data collection.

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b) ToR 1.2. Summary of 3O Marine Refuge ROV expedition (Canada)

In 2022, Canada conducted an offshore expedition that video-surveyed seafloor habitats in the 3O closure (Marine Refuge, Canadian EEZ). The expedition took place between August 8-19th, 2022 aboard industry vessel *Atlantic Condor*, using the work-class remotely operated vehicle (ROV) Magnum 74 (Oceaneering). While the expedition also surveyed a number of sites in Nova Scotia and Newfoundland waters, this presentation focused on two ROV dives conducted inside of the 3O closure due to its relevance to NAFO. Two locations were selected for two ROV dives based on: 1) reasonable distance to other stations surveyed during the expedition, 2) location of a 2007 ROV video survey, 3) recovery of experimental arrays deployed in 2007 (metal frames with rocks and kitchen sponges acting as substrate for larval settlement), and 4) location of scientific trawl surveys conducted in the area. The first dive (M-13) took place at the 2007 ROV location. In 2007, a video-survey of the area took place using the ROV ROPOS, and included areas both inside and outside of the current closure. At the time of that survey the area had not yet been closed to fisheries. The 2022 survey plan therefore aimed at locating and collecting the experimental arrays and surveying both areas inside and outside of the closure, providing for an opportunity for both before-after, inside-outside comparisons. The survey took place at ~600 m depth. Experimental arrays were found and successfully recuperated. Other than a small gorgonian (*Acanthogorgia armata*) growing on one of the array's rocks, there was no much growth even 15 years after the arrays were deployed. The video survey showed abundant corals (large gorgonians like *Keratoisis* sp.) and small gorgonians (likely *Acanthogorgia armata*) growing on boulders, and abundant Redfish (*Sebastes* sp.). We could not yet draw a picture of patterns inside vs. outside of the closure or before/after. The second dive (M-14) had a design focused on following the track of a trawl survey conducted by Fisheries and Oceans Canada in 2011. The design had a zig-zag pattern and aimed at crossing the trawl path to assess patterns in benthic diversity. Despite the small distance to M-13 (<1 km), the seafloor here was flat, with a few instances of hard bottoms noted. The site was less diverse than the site surveyed during dive M13, with not many corals (mostly *Flabellum* cup corals, some sea pens and the small gorgonian *Acanella arbuscula*), but still abundant Redfish (*Sebastes* sp.). Redfish exhibited a behavior of stirring the sediment to the point of making turbidity too high and the dive needed to be aborted. Video analysis is expected to be initiated in the Winter of 2023.

c) ToR 1.3 Use of Passive Acoustics to Quantify Fish Biodiversity and Habitat Use

Vazella pourtalesii is a relatively large sponge (up to 50 cm) that can form dense biogenic habitats (Figure 4.1) and locally enhances invertebrate biodiversity (Hawkes et al., 2019). It is considered a vulnerable marine ecosystem indicator (SCR Doc. 08-022). Fourteen fish species in trawl catches have been found to be significantly associated with these sponge grounds, including commercially important silver hake, redfish, haddock and northern shortfin squid (Hawkes et al., 2019). Since fish may use these sponge grounds for feeding, spawning, and nursery areas there is a need to collect more information on fish use of this key benthic VME habitat in order to support decision-making following an ecosystem approach.

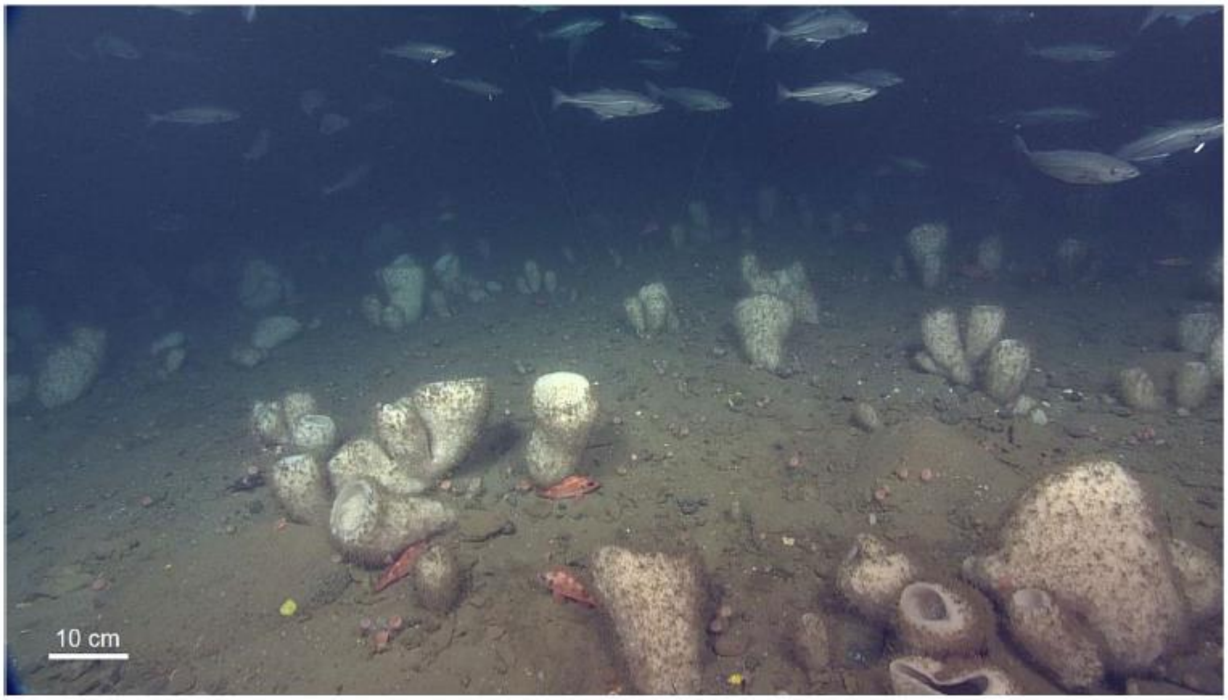

Figure 4.1. Sponge grounds formed by *Vazella pourtalesii* in the Sambro Bank Sponge Conservation Area, Emerald Basin, NS. Depth is 155 m. A school of pollock is swimming over the sponges and redfish are seen on the seabed taking shelter at the sponge bases.

The Department of Fisheries and Oceans (Drs. J. Xu and E. Kenchington), in collaboration with the University of Edinburgh (Dr. L. H. De Clippele) through the iAtlantic EU Horizon 2020 project, and the Ocean Tracking Network (Dr. F. Whoriskey), successfully deployed three benthic landers in the Sambro Bank Sponge Conservation Area from September 2021 to May 2022 (Kenchington et al., 2021). The landers were placed in areas of high and low sponge density and in an area where dead sponges were observed, and were equipped with a variety of instrumentation, including passive acoustic devices (SoundTraps (Ocean Instruments, Auckland, New Zealand), AMAR (autonomous multichannel acoustic recording device)), OTN acoustic receivers, and a camera system developed at the Bedford Institute of Oceanography (K. Phelan). Over 3 TB of passive acoustic data and 25,987 photos as well as CTD measurements including 2-D current and temperature, sedimentation and particulate organic matter, and OTN tagged species occurrence data were collected.

The health and biodiversity of the sponge grounds will be assessed using passive acoustic recordings. Passive acoustic monitoring was put forward as a non-invasive monitoring technique for Other Effective Area-Based Conservation Measures (OECMs) at a recent CSAS meeting (Neves et al., 2020; DFO, 2021). Acoustic landscapes, or soundscapes, are composed of biological, geophysical and anthropogenic sounds, and in some environments, such as tropical coral reefs, biological components dominate the soundscape. Desiderà et al. (2019) found a strong relationship between taxonomic and acoustic diversity as measured by richness, diversity and community similarity indices, and acoustic communities showed stronger differences between sites and a higher discriminating potential. Biological sound emissions will be catalogued using combined acoustic and photo recordings (Mouy et al., 2018), allowing for the sounds emitted by the fish to be associated with their behaviours (e.g. mating, scaring off predators, territorial protection). The pollock are believed to spawn in the fall and so the timing of the lander deployments may enable spawning behaviour to be captured. Acoustic indices will be calculated to evaluate the use of sound as a biodiversity and health indicator of the *Vazella* sponge grounds (Desiderà et al., 2019; Pieretti and Danovaro, 2020; Dimoff et al., 2021). The fish sound repertoire will be organized into a dichotomous tree based on acoustic characteristics (Amorim, 2006) for use as a biodiversity indicator for resource monitoring and management.

In October 2022, the three landers were redeployed; one at the high density sponge site on Sambro Bank, and two in rich sea pen fields in the Gully MPA. If successfully recovered, the 2022-2023 deployments will allow comparisons between the two VME habitat types (sponge and sea pen) as well as temporal replication at the sponge site. The end date of the project is 29 March 2024. The iAtlantic project is funded by the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 818123.

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d) ToR 1.4. Standardized GIS data layers (Com. Request #6.b)

COM. Request #6b. *Support the Secretariat in creating standardized data layers (using GIS), and products with supporting documentation (including metadata) for periodic reassessment purposes required to support the implementation of the NAFO Roadmap towards an Ecosystem Approach.*

WG-ESA has produced numerous summarised data products and GIS layers, both as results of analyses and for use in further analytical steps. Many of these data sets and layers are used by several members of the Working Group in regular assessments and need to be updated or reproduced for new analyses. Other data and layers are compiled for the provision of recurrent advice on VME closures every few years. The appropriate documentation of data collation and production steps, versioning, and sharing within the Working Group was identified as a priority area for development to ensure comparability and continuity in data products. Consequently, the NAFO Working Group on Ecosystem Science and Assessment (WG-ESA) established a Data Subgroup at its 14th meeting in November 2021 (NAFO, 2021). The subgroup focussed on four main agenda items:

1. discuss and provide recommendations for a list of standard GIS data products and draft procedures for associated documentation including metadata;
2. review lessons learnt concerning inconsistencies in data used in analyses across the working group;
3. discuss possible solutions to data continuity through developing and maintaining a NAFO geodatabase; and
4. plan how to prepare new fishing effort and integrated fishing effort/ log-book data incorporating shrimp fishery data for the reassessment of VME closures by 2023.

After discussion in break-out sessions, the Data subgroup made a number of recommendations to further those issues that were adopted by WG-ESA in plenary (NAFO, 2021), specifically:

Standard data products

- *that trawl data products for at least 1) full fish and invertebrate trawl data, 2) VME biomass data and 3) functional group biomass data by trawl are compiled as documented and annually updated entries in a spatial database.*
- *as a first step, the procedure demonstrated for the above products is followed for other data products and the geodatabases or map packages are made available via NAFO. A regular time interval, suited to the assessments the group is asked to do, should also be agreed for the update of the polygon and biomass grid products.*
- *an SCR document is supplied to record the methodology for production of 1) VMS only fishing effort layers covering annual and mean effort from 2010 onwards; 2) Fishing effort layers based on logbook-VMS combination data covering annual and mean effort from 2019 onwards, and 3) distribution of annual catches of commercially caught fish species from 2019 onwards, and that these layers are made available through a geodatabase.*

Data documentation, storage and access

- *that NAFO explore the feasibility of using ArcGIS Online/ ArcGIS Enterprise, or another spatial data portal, as a means to manage, visualize and share the core ecosystem data layers and derived products used by SC.*

Lessons learned from data inconsistencies

- *that in also recognises the future a decision is made on what importance of ensuring data spatial analysis method is most suitable to the data being used, and the same methods are consistently applied without change in approach used each time (including rounding errors) unless otherwise agreed by the whole group.*[1]

[1] This wording exactly follows the recommendation as found in NAFO (2021), however, the text is not clear. The intent of this recommendation was to support the recommendations under 'Standard data products' based on a review of actual discrepancies identified in previous WG-ESA work.

Following the 2021 WG-ESA meeting, the Data Subgroup worked intersessionally through monthly virtual meetings to assemble metadata and data products in agreed upon formats and to discuss specifics of the 2021 agenda items.

At the 15th WG-ESA meeting held in November 2022, the Data Subgroup presented their work to the meeting. They were able to advance the 2021 recommendations in a number of ways.

Standard Data Products

GIS Metadata Standards

Metadata documents the details of a data resource and includes Descriptive, Administrative and Structural elements. Descriptive metadata in its basic form includes details of the author, date created, date modified and file size. Geospatial metadata describes maps, Geographic Information Systems (GIS) files, imagery, and other location-based data resources. Administrative metadata facilities the management of resources. It can include elements such as technical, preservation, rights, and use. Structural metadata, generally used in machine processing, describes relationships among various parts of a resource, such as used in modeling different data sources.

There are four main functional categories of metadata standards that should be considered: Structure, Content, Value and Format. Structure standards, or schemas, describe a labeling, tagging or coding system used for recording cataloging information or structuring descriptive records. A metadata schema establishes and defines data elements and the rules governing the use of data elements to describe a resource. Content standards help to guide the input data into the element set. Common examples of these input rules include the formatting of names (e.g., Last, First), omitting initial articles in a title, and when to capitalize. Value standards, or controlled vocabularies, limit choices to established lists of terms or codes. Format standards are the technical specifications for how to encode the metadata for machine readability, processing, and exchange among systems. These specifications are collectively referred to as "data formats" or "encoding standards" and common examples include CSV, XML, and RDF. A set of International Standards for metadata has been developed and published by the ISO[2], the International Organization for Standardization.

The Data Subgroup endorsed the use of the metadata content standard **ISO 19115**, Geographic information — Metadata, and the implementation specification **ISO 19139** Geographic information — Metadata — XML schema implementation. Full ISO 19115 and ISO 19139 metadata for an item are generated in ArcGIS Pro which allows you to edit and export metadata in this format, and validate it using the standard's XML Schemas[3].

Scientific Survey Trawls

Scientific trawl data has been used in many forms, from full trawl data with biomasses of fish and invertebrates identified to the highest taxonomic level possible, to total biomasses of taxa indicative of a VME type (e.g., Sponges, Sea Pens etc.). The procedures behind preparation of this data are documented in the working group reports and some in SCR documents, but there is no agreed standard for preparation and presentation of such data sets.

WG-ESA agreed to follow the data submission protocol outlined in Figure 4.2. Both DFO and IEO have data requisition forms that must be filled in before the data can be accessed. Typically, those data requests have been completed by individual WG-ESA members. As WG-ESA moves to place the data in a central access system, the protocols for requesting the data may be streamlined. For example, the request could be made by the Chair of WG-ESA or by a member of the NAFO Secretariat. Further consideration of this issue will be given

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[2] https://www.iso.org/standards.html

[3] https://pro.arcgis.com/en/pro-app/latest/help/metadata/create-iso-19115-and-iso-19139-metadata.htm

once other parts of the data submission cycle have been tested. Each agency (DFO, IEO) has a contact person within WG-ESA through whom the data has traditionally been requested (V. Hayes, M. Sacau in 2022). The contact person is responsible for processing the data request, providing the associated metadata, uploading it to the shared portal and relaying any concerns or caveats with the data that could affect analyses to the data requester.

The Data Subgroup agreed that the trawl survey data should be collated in a standard GIS database format every year with appropriate metadata. The metadata schema should include acknowledgement text of use of the data as deemed appropriate by the data providers. The current data formats which provide location, cruise information, date of collection, species, biomass, abundance etc. should be augmented to include:

- *WoRMS AphiaID (https://www.marinespecies.org/aphia.php?p=webservice)*
- *Confidence Score for confidence in identification (H, M, L).*

All survey data should be provided, including trawl sets that did not record VME indicators. Sets that were incomplete should also be included but clearly identified. Such sets may not be useful for stock assessments but can contain useful information on VME presence.

To facilitate reporting on recurrent terms of reference such as the annual reporting of the location of the significant concentrations of VME indicators from the previous year's scientific surveys, it was agreed that for 2023, R Markdown would be explored as a means of standardizing reporting and assisting in data QC. R Markdown uses R script to produce high quality documents, reports, presentations and dashboards (https://rmarkdown.rstudio.com/).

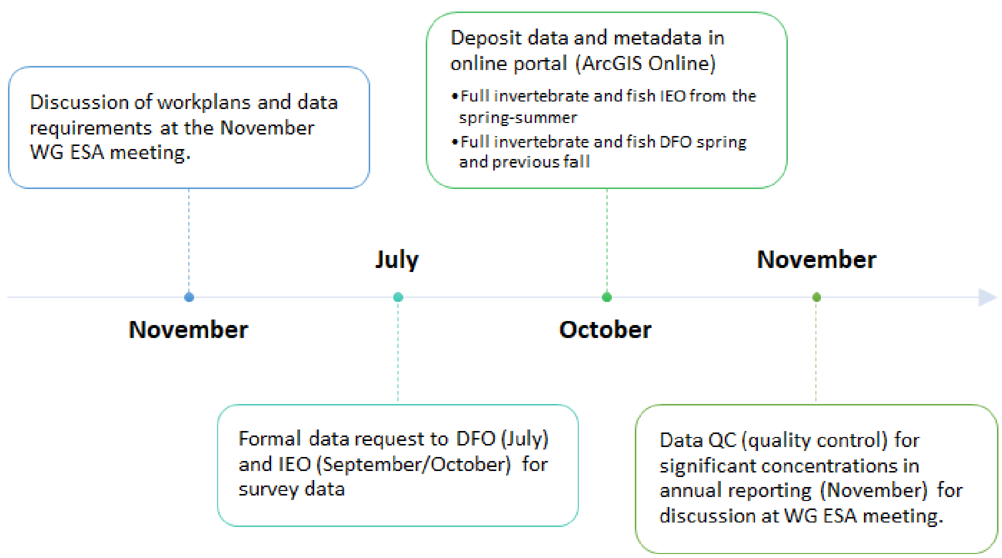

Figure 4.2. Data submission protocol. Action points and timelines for the annual cycle of data collection from the scientific trawl surveys conducted by the EU (Spain, Portugal) and Canada (DFO NL) for use by WG-ESA.

VME-related Data

Through the intersessional period, the data and metadata on VMEs from the most recent review of the closed areas (Kenchington et al., 2019), from the production of the biomass grids (Lirette et al., 2020) and from the work on ecosystem functions (Kenchington et al., 2020) have been organized into GIS projects that included geodatabases, map, layer files and SCR docs. These thematic databases are ready to upload to the shared data portal once established. Rasters for each of the species distribution models (SDMs) used to evaluate the kernel density-produced polygons (Kenchington et al., 2019) will be added to the data inventories intersessionally. SDMs are used to clip the VME polygons in some cases and have recently been used in the habitat fragmentation work. It was agreed that the VME-related databases would be updated on a 5 year cycle to keep current with the work being done on significant adverse impacts (SAI).

VMS Data

Details of the use of VMS data are found under ToR 2. COM. Request #6a. Exploring different ways to use length of track, depth and directional changes to further improve the accuracy of our fishing effort. Details for the standard data products include:

- *VMS tracks from pings filtered to 0.5-5 knots with year, primary fishing gear and target fishery included in the attributes (derived from daily catches)*
- *VMS tracks from pings filtered by haul start and end times from vessel logbooks combined with coordinates from the logbooks (where available) and with year, fishing gear and catches by haul to include the species managed by NAFO.*

After further analyses, testing and agreement on appropriate thresholds for filtering the data, attribute columns will be added for additional data:

- *Haul depth range by gear type / fishery / division*
- *Lines that cross high slopes*
- *Comparisons of fisheries based on logbook filtered data.*

These will be included in a thematic database that is updated annually by the NAFO Secretariat, appending the most recent year's tracks. Timelines for action points for the submission protocols similar to those developed for the scientific survey data (Figure 1) will be developed.

Fishing Effort Rasters

Fishing effort rasters will be produced using the 1 km cell size and a base grid matching the VME biomass raster data (see above). Effort will be calculated as the total length of VMS track within a 1 km^2 neighbourhood using for each of longlines and trawls:

- *Yearly/average effort (km/km^2/year) from 2010 onwards based on speed-filtered VMS tracks*
- *Yearly / Average effort (km/km^2/year) 2016 onwards based on logbook filtered VMS tracks*
- *Fishing footprint by year and over full timeseries for each above*
- *Number of years fishing present.*

These will be included in a thematic database prepared by WG-ESA members from the VMS data supplied by the NAFO Secretariat and updated annually by appending the most recent year's annual layers and the mean layers including the latest year. A SCR documenting the procedures associated with the production of these rasters will be produced next year (2023).

Fishing Catch Rasters

Fishing catch rasters will be produced using the 1 km cell size and a base grid matching the VME biomass raster data and fishing effort raster data (see above). Data will be presented as:

- *Distribution of catch per unit effort (kg/km trawled)*
- *Based on haul by haul catches associated with logbook filtered VMS tracks*
- *Calculated as the mean of catch per length of VMS track (kg/km trawled) within a 1km^2 neighbourhood*
- *Yearly / Average of 2016 onwards by species*

These will be included in a set of thematic databases prepared by WG-ESA members and updated annually by appending the most recent year's annual layers and the mean layers including the latest year.

Spatial Analysis Methods

Raster data is any pixelated (or gridded) data where each pixel is associated with a specific geographical location. The value of a pixel can be continuous (e.g., depth) or categorical (e.g., inside or outside a closed area). Vector data is comprised of individual points stored as pairs of geographic coordinates that indicate a physical location. Vector data includes points, lines and polygons. WG-ESA uses both types of data for its work but in the past has not been consistent in its application, resulting in small differences in results for the same quantity produced by different groups (Lirette et al., 2021; NAFO, 2021). Raster analysis is quick and simple to use for scripted calculations including multiple variables and loops, which makes it more easily programmable and repeatable. However some data have detailed boundaries, e.g. the VME polygons and especially the closed areas, where rasterization, especially at a lower spatial resolution loses boundary detail and makes calculations, especially those of area less precise. At a 1 km raster cell size over the NRA the differences are mostly minimal, and it was previously agreed that we can accept and caveat variability less than 1% of the total and deal with the discrepancy by rounding values up to set number of significant figures, where the difference disappears, when reporting numbers (NAFO, 2021).

The Data Subgroup agreed that all gridded data for rasters will be presented with a cell resolution of 1 km. When vector data for a polygon shape needs to be extracted from the raster data surface, the position of the grid cell centroid shall be used to determine whether or not a grid cell is included within or outside of the polygon as shown in Figure 4.3. If the centroid of the grid cell falls on or within the perimeter of the polygon the full contents of that grid cell are included in the calculations. Conversely if the centroid of the grid cell falls outside of the polygon perimeter, it is excluded. In the past different approaches were used, including partitioning the amount of data according to the proportion of the grid cell bisected by the polygon perimeter. In this way consistent values will be presented for polygon characteristics. The immediate relevance of this work applies to the determination of the proportions of the area and biomass under various protection levels in the Ecosystem Summary Sheets.

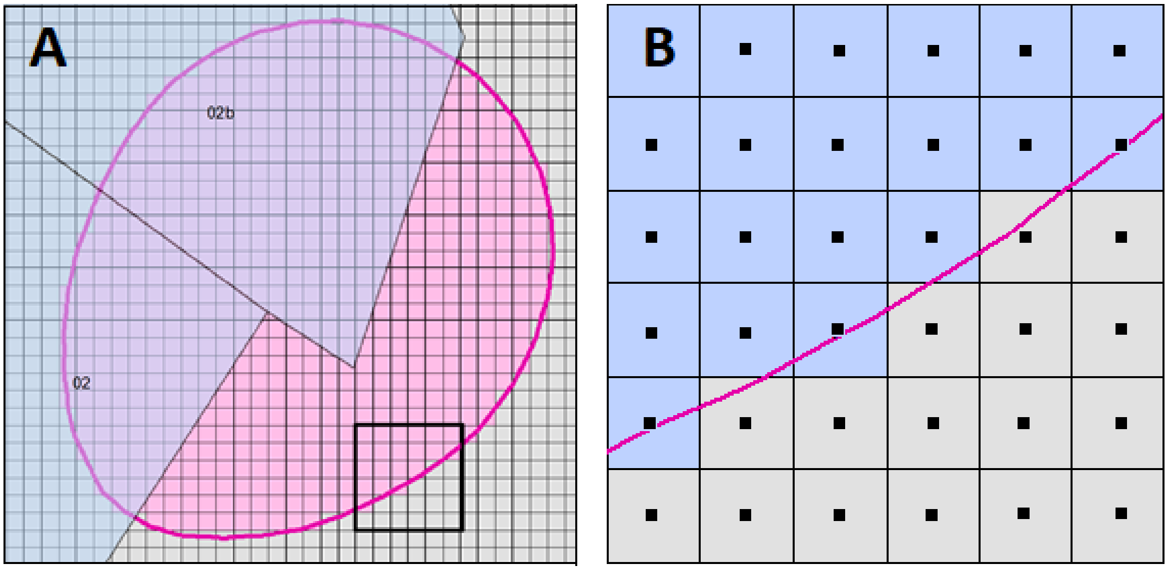

Figure 4.3. A) Illustration of the overlay of a polygon with a grid layer. Such overlays occur bet the VME polygons and the gridded biomass surfaces in recent work. B) Enlargement of the inset shown in A) in black outline showing how the decision to include the data in the grid cell in the estimate for the polygon is made. Grid cells with a centroid (black square) falling within the polygon perimeter are included in the data extraction for the polygon (blue cells) while those whose centroid lies outside of the polygon perimeter are excluded (grey cells).

Centralized Data Repository for WG-ESA Members: ArcGIS Online

ArcGIS Online[4] is a tool to share GIS data with others across organisations as web layers hosted in Esri's cloud. This particular data repository was chosen by the Data Subgroup and recommended by WG-ESA for a trial subscription. It is a secure site and accessible by invitation only for a low annual fee. In ArcGIS Online, when you publish a shapefile that contains metadata or a file geodatabase that contains feature classes and tables with metadata, that metadata is included in the hosted feature layer, and you can view each layer's metadata on the feature layer's item page in ArcGIS Online. Other features include the ability to produce web maps, web apps, StoryMaps and embedding maps in web pages, all of which will be useful for disseminated the work of WG-ESA on the NAFO website.

The NAFO Secretariat agreed to explore the costs of hosting an ArcGIS Online portal by the end of 2022, to take advantage of the current budget. Pending financial review and feasibility **WG-ESA recommended** *that the NAFO Secretariat set up a pilot ArcGIS Online Private Group for testing and proof of concept by June 2023.* The VME databases have been completed and could be uploaded to test the system. Once established, the Data Subgroup will review the effectiveness and functionality of the system and provide feedback to the 2023 WG-ESA meeting. If it proves not to be cost effective or fit for purpose the subgroup will investigate alternatives.

[4] https://www.arcgis.com/index.html

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Kenchington, E., C. Lirette, F.J. Murillo, L. Beazley & A. L. Downie, 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.

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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 Re-assessment of previously recommended closures of 7a, 11a, 14a and 14b COM. Request #6a.

COM. Request #6a. *Complete the re-assessment of its previously recommended closures of 7a, 11a, 14a and 14b, incorporating catch and effort data for fisheries of shrimp from 2020 and 2021 into the fishing impact assessments. This work is needed for the 2023 WG-EAFFM meeting*.

In 2020 WG-ESA was requested to deliver an expert assessment of potential VME management options based on a re-assessment of existing VME closures and evaluation of risk of significant adverse impact. The assessment considered possible trade-offs between appropriate conservation measures (VME fishery closures) and the possible consequences to bottom-contact fisheries, with the aim to reduce the risk of SAI and improve the protection of VMEs while limiting any potential losses to fishers in the NRA. The effects of existing and suggested VME closures on fisheries were evaluated through a relative proportion of: 1) overall fishing effort ($km.km^{-2}.year^{-1}$) based on trawl fisheries in the NRA between 2010-2019; 2) the average fishery specific catch biomass per distance of trawling ($kg.km^{-1}$) between 2016-2019; 3) cumulative total fishing effort in years fished between 2010-2019 and; 4) cumulative total fishing effort in years fished between 2010-2019 for the main target species Cod, Redfish, Greenland halibut and Skate, in the NRA occurring in the existing and suggested closures. The assessment resulted in proposals for ten extensions to existing closures, the creation of three new closures and modifications to one previous closure, Area 14. A review of the suggested additional closures by expert groups with diverse scientific and fisheries management expertise (SCS Doc. 20/23; SCS Doc. 21/14REV), lead to six of the proposed extensions and the modification to Area 14 being adopted by the Commission, and these came into effect in January 2022 (NAFO/COM Doc. 22-01, Figure 5.1a).

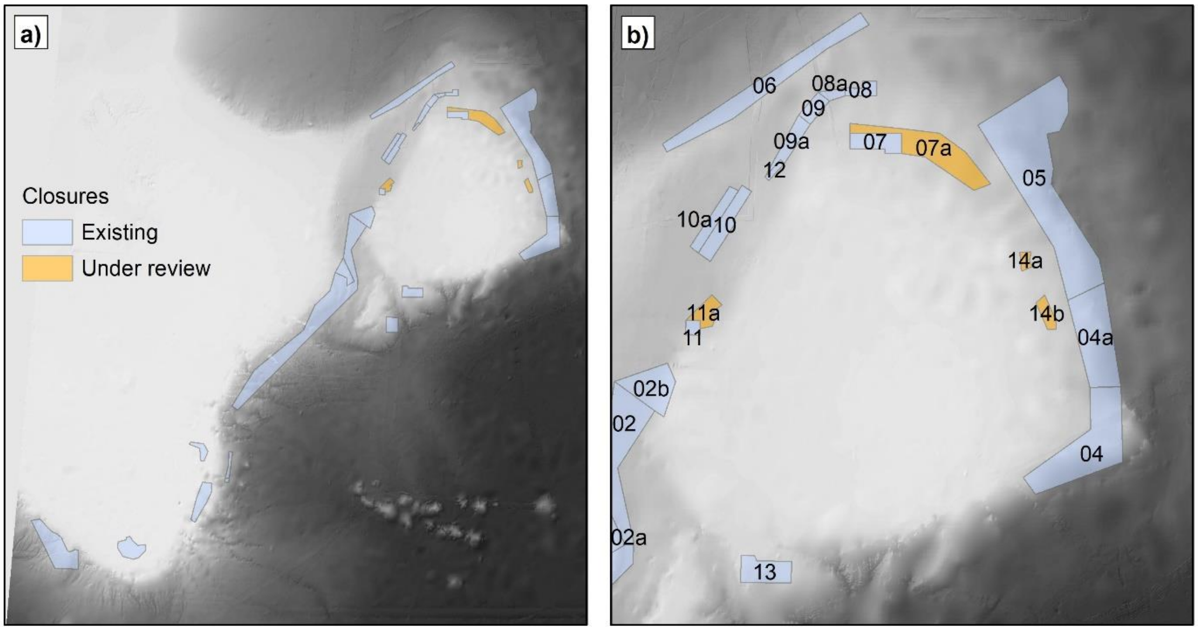

Figure 5.1. (a) Location of fisheries closures in the NRA. (b) Close-up view of the location of the four closure extensions/modifications being re-assessed in 2023 (shown in orange).

Four of the new closure modifications: Area closure 7a (an eastward extension of Area Closure 7), Area closure 11a (a north-eastward extension of Area Closure 11) and Area closures 14a and 14b (re-establishment of a modified Area Closure 14), all established to provide greater protection for sea pens and black corals, were established on a temporary basis pending reassessment in 2023 (Figure 5.1b). The temporary nature of these closures was to allow an up-dated analysis of potential shrimp fisheries operating in these areas using more recent fisheries data from 2020 and 2021, as prior to this period the shrimp fishery was under a moratorium. The re-assessment requested by the Commission was to include an updated analysis of the consequences to fisheries in these new closures, specifically incorporating the most recent catch and effort data from the shrimp fishery.

The updated assessment by WG-ESA in 2022 concentrated on the consequences of 7a, 11a, 14a and 14b specifically on fishing activities and catches for the newly reopened shrimp fishery. Analysis was done using two datasets:

- *The average annual effort ($km.km^{-}.year^{-1}$) for all trawls from tracks derived from VMS pings filtered by speed to 0.5-5 knots over 2010-2021.*
- *The distribution of average catch per distance trawled ($kg.km^{-1}$) by fish species based on tracks with associated catches derived from haul-by-haul catches combined with VMS pings based on start and end fishing times of hauls recorded in commercial vessel logbooks over 2020-2021.*

The spatial distribution of overall fishing effort ($km.km^{-2}.year^{-1}$) from all trawl fisheries in the NRA updated to cover 2010-2021 was included for comparison with the previous assessment covering 2010-2019. Similarly, the total catch biomass per distance of trawling ($kg.km^{-1}$) and the spatial extent of trawl catches derived from haul-by-haul logbook data were updated to cover 2020-2021, the years the shrimp fishery operated. Catch species specific spatial extent of catches and the catch biomass per distance of trawling ($kg.km^{-1}$) is only reported for the shrimp fishery, as per the Commission request. The shrimp fishery was determined on the basis of shrimp being included in catches. The simple rule is appropriate because hauls where shrimp is reported and landed are almost entirely consisting of shrimp, and any other species caught have a minimum contribution to the total catch of those hauls (Figure 5.2.).

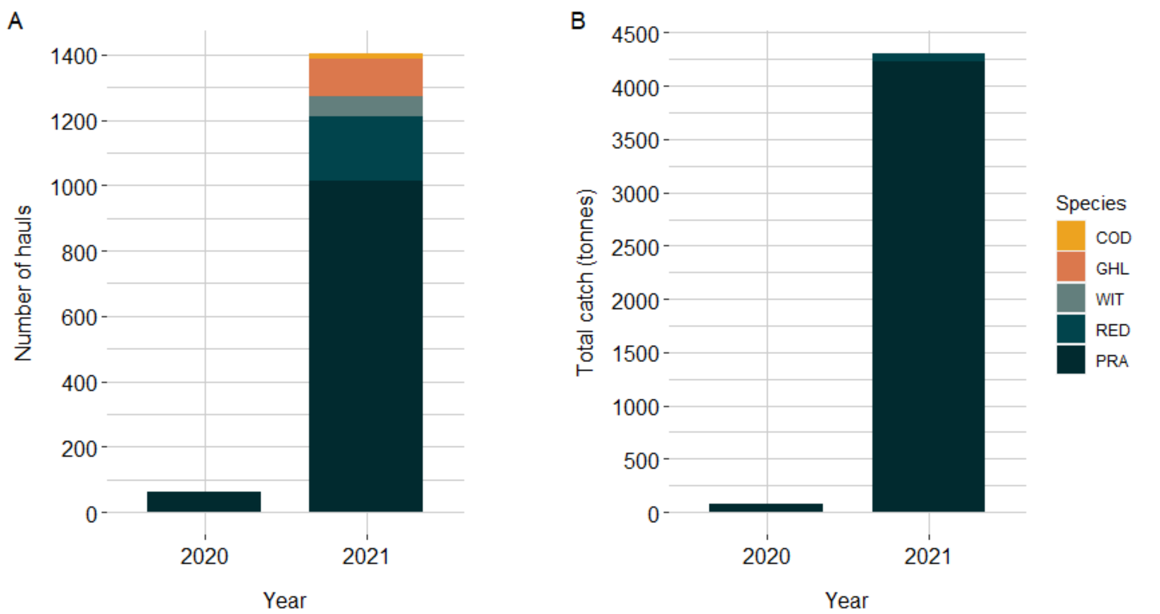

Figure 5.2. Breakdown of the number of hauls each species was recorded in (a) and total catch in tonnes (b) by species in the shrimp fishery dataset made up of hauls from logbook data with any shrimp catches associated with VMS data.

The impact of the closures under re-assessment on fisheries is summarised in table 5.1. Overall, less than 0.7% of the 98,671 km^2 that has been fished by any trawl gear between 2010-2021 (as determined by the speed filtered VMS data) overlaps with closures 7a, 11a, 14a and 14b and less than 0.05% of the average effort (km.km^{-2} year^{-1}) occurs in these closures. Based on the haul-by-haul logbook filtered data for the period 2020-2021, a total of 42,866 km2 over the entire NRA were fished and resulted in an associated catch. Total catch per effort ranged from 0.02 to 37,905 kg km^{-1}. Only 73 km^2 overlapped with the closures under review (0.17% of total area with catches), with total catch per effort ranging from 37 to 383 kg.km^{-1}, amounting to 0.09% of total catch.

The shrimp fisheries in 2020-2021 covered 2,575 km^2 and reported haul-by haul catches ranging between 5-14,601 kg. Catches per distance trawled ranged from 0.1-2,704 kg.km^{-1}. Of the closures under review, only Area Closure 7a has a partial overlap with shrimp fisheries. Continuance of this closure would result in a 0.8% loss of the area fished for shrimp and 0.5% loss of average total catch as reported in 2020-2021 (Table 5.1). However, despite the very low proportion of shrimp catches observed in Area Closure 7a, the overlap and catches of shrimp reported here may be artificially inflated. The estimates include what appears to be an anomalous trawl track, which makes a 90-degree change in direction to cross Area 7a in a northerly orientation perpendicular to other shrimp trawls (see Figureb). The part of the track crossing the closure may not represent true fishing effort and the associated catch should potentially be assigned into the part of the track that conforms to the direction taken by other shrimp trawls located outside of the closure.

The analysis indicates that there is no discernible overlap between the re-assessed closures and the shrimp fishery. This implies that these 4 closures would result in no discerable losses in catch for the shrimp fishery.

Table 5.1. Proportion of fishing effort from 2010-2021 and the effort and and catches of the shrimp fishery 2020-2021 in NRA occurring in the re-assessed VME fishery Closures 7a, 11a, 14a and 14b.

	% of total in NRA				
	Closure 7a*	**Closure 11a**	**Closure 14a**	**Closure 14b**	**Total**
All trawls 2010-2021 (Speed filtered VMS)					
Fished area (km2)	0.5%	0.1%	0.03%	0.03%	0.66%
Effort (km/km2/year)	0.04%	0.01%	0.003%	0.001%	0.05%
Shrimp trawls 2020-2021* (Logbook filtered)					
Fished area (km2)	0.8%	0%	0%	0%	0.80%
Catch (kg/km)	0.5%	0%	0%	0%	0.50%
All trawls 2020-2021 (Logbook filtered)					
Fished area	0.14%	0.03%	0%	0%	0.17%
Total catch	0.08%	0.01%	0%	0%	0.09%

* The values for fished area and catch for shrimp include what appears to be an anomalous trawl track which crosses Area 7a in a northerly orientation perpendicular to other shrimp trawls (see Figureb), including this trawl may artificially inflate the estimates.

a) b)

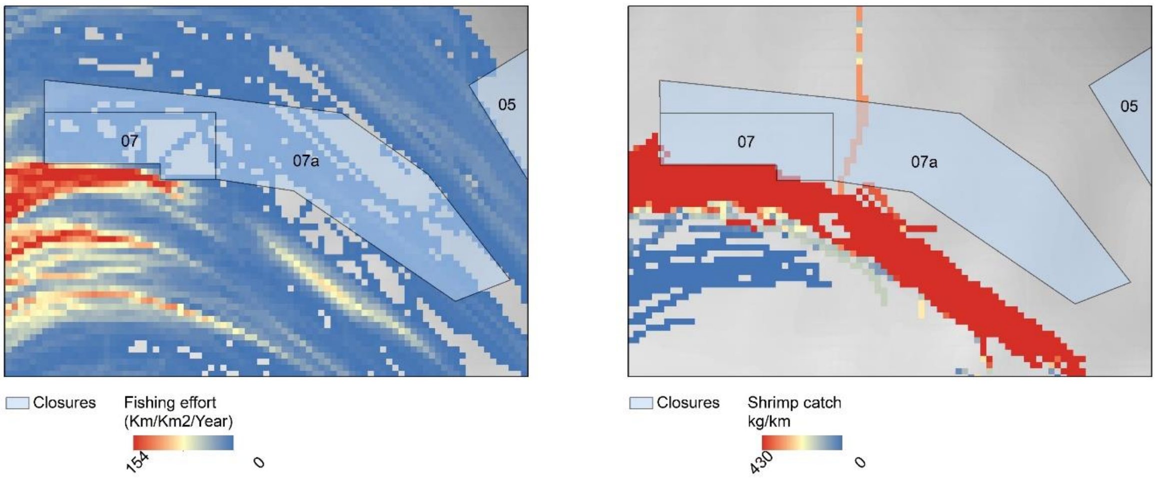

Figure 5.3. Overlap of Area Closures 7 and 7a with (a) Average yearly effort (km.km^{-2} year^{-1}) from 2010-2021 by trawl fisheries; and (b) mean shrimp catch (kg.km^{-1}) from 2020-2021.

a) b)

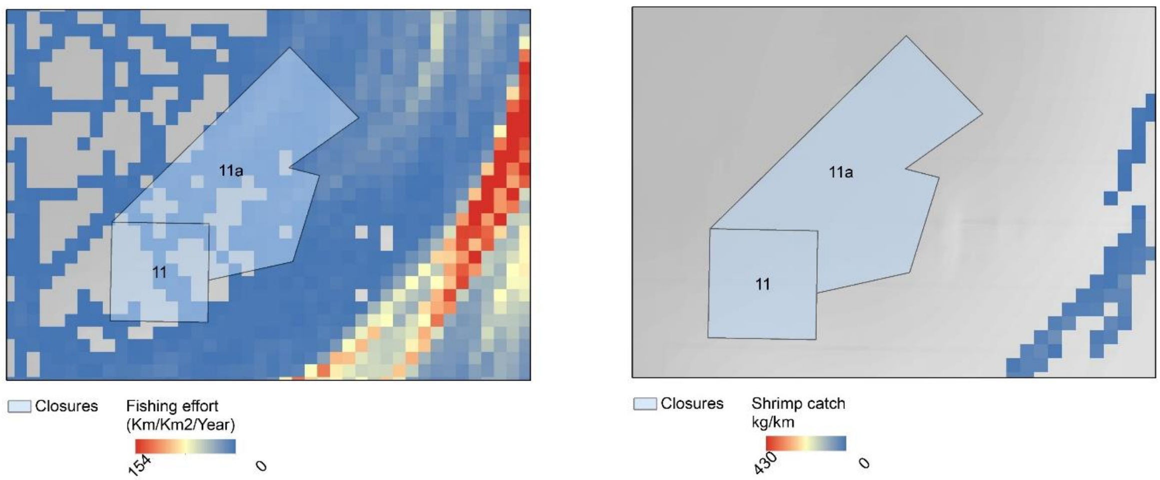

Figure 5.4. Overlap of Area Closures 11and 11a with (a) Average yearly effort (km km^{-2} year^{-1}) from 2010-2021 by trawl fisheries; and (b) mean shrimp catch (kg km^{-1}) from 2020-2021.

a) b)

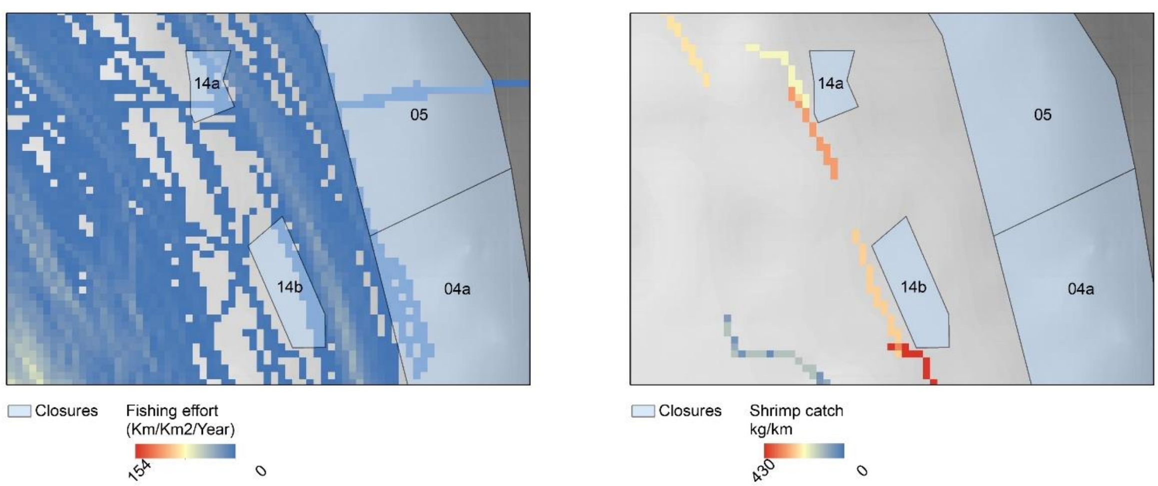

Figure 5.5. Overlap of Area Closures 14a and 14b with (a) Average yearly effort (km km-2 year-1) from 2010-2021 by trawl fisheries; and (b) mean shrimp catch (kg km-1) from 2020-2021.

b) **ToR 2.2. Exploring different ways to use length of track, depth and directional changes to further improve the accuracy of our fishing effort layers (Com. Request #6.b).**

Com. Request #6.b *Support the Secretariat in creating standardized data layers (using GIS), and products with supporting documentation (including metadata) for periodic reassessment purposes required to support the implementation of the NAFO Roadmap towards an Ecosystem Approach.*

Exploring different approaches to use length of track, depth and directional changes to further improve the accuracy of our fishing effort layers

Vessel monitoring system (VMS) data are used to generate tracks of fishing activity that are used in the development of effort and biomass layers used in WG-ESA analyses. These data are speed filtered to include only those tracks between 0.5 and 5 knots and are then clipped to the fishing footprint. To better depict fishing fleet behaviour, an exploration of other potential filtering approaches was undertaken. Utilizing knowledge of normal trawl fleet behavior, track data was filtered according to maximum fishing depth, directional changes, duration, and depth range. These filters were applied incrementally and the fraction of the data removed at each step was documented.

Maximum fishing depth filter

The current VMS track layer within the fishing footprint includes data from 2010 to 2021 and represents over 4.15 million kilometres of fishing effort. The first filter applied clipped the tracks to exclude those in areas where depths were below 1,500 m. Spanish commercial trawl fishery data collected between 1992 and 2021 by the Scientific Observers was used to determine the 1,500 m threshold as this represented the maximum trawl depth likely to be observed. The fishing footprint was reduced by approximately 6,400 km, or 0.2%, as a result of this filter (Figure 5.6).

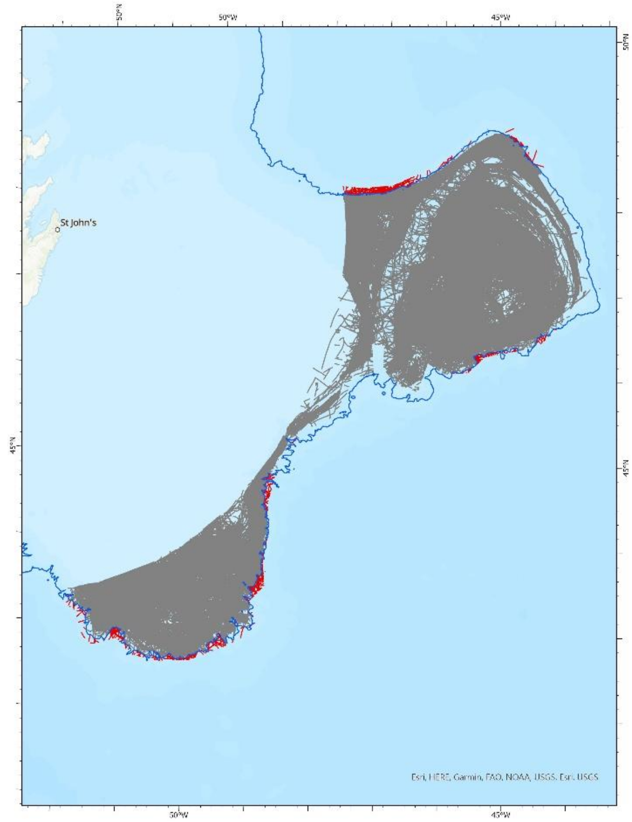

Figure 5.6. 1,500m maximum depth filtered data layer. Red indicates the tracks that were removed at this filtering step.

Turn Analysis and Track Length Filtering

An analysis of observer data for the Spanish commercial trawl fleet indicated that the longest expected haul duration would be approximately 12 to 13 hours. Using a nominal fishing speed of 3 knots, multiplied by the expected maximum 13 hours duration, an approximate maximum trawl length of 75 km was calculated. An analysis of the track length frequency distribution showed approximately 11% of the tracks were over the 75 km threshold, however those tracks represented 36% of the total kilometers of effort, with some tracks as long as 850 km.

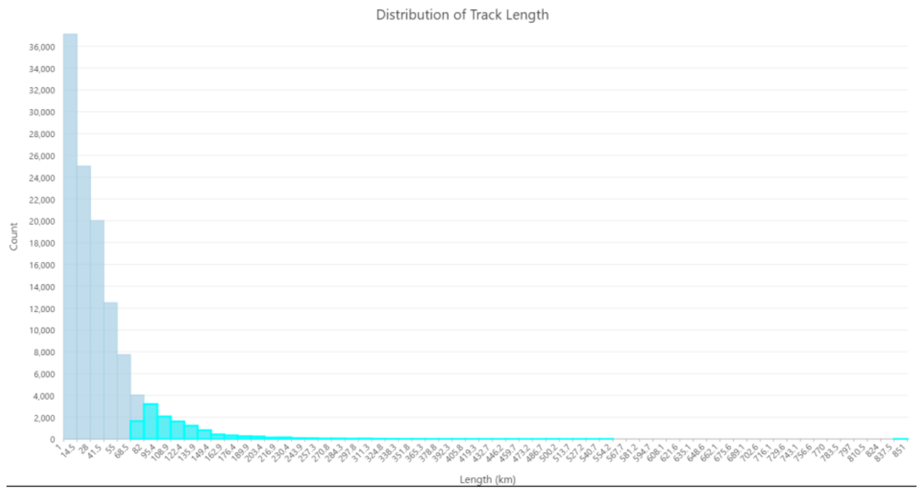

Figure 5.7. Track length frequency distribution. The cyan region represents those tracks longer than 75km

An inspection of these longer tracks frequently demonstrated a repeated pattern of long straight segments along the bathymetric contours alternating with shorter segments at markedly different bearings, sometimes nearing 180° to the previous segment. It is likely that this pattern represents long segments of fishing activity followed by abrupt changes in bearing as vessels turn, before beginning resuming fishing activity. These tracks were considered to represent continuous activities as the vessel did not go beyond the 0.5 to 5 knot speed thresholds as they transitioned.

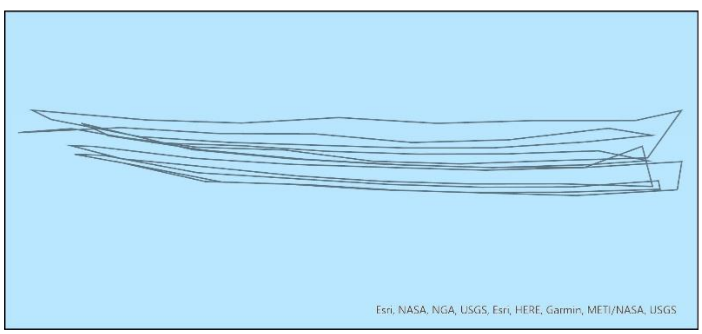

Figure 5.8. Sample long track demonstrating the pattern of alternating long and short segments.

An analysis of the track bearings was conducted to split the tracks into segments to indicate a likely change in activity. This track-splitting analysis not only enabled the discrimination between these activities but also allowed for the retention of fishing effort that would have otherwise been excluded as a result of the length and depth range filters.

The VMS tracks were broken into segments by creating separate line features between consecutive VMS pings along the track. Tracks were subsequently split where the segments demonstrated a significant change in direction from one segment to the next. A decision rule was established to define a turn as a change in bearing of more than 45° to the left or right from the previous segment. Figure 5.8 illustrates the splitting process and Figure 5.9 shows two sample segments from the VMS track layer before and after the turn analysis.

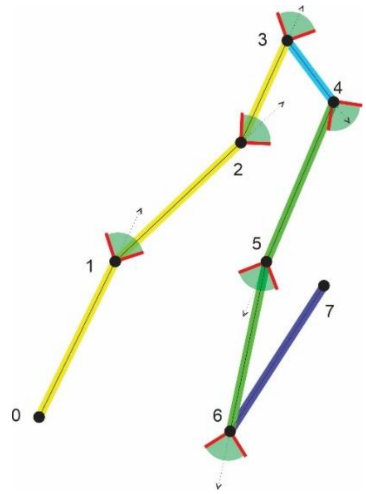

Figure 5.9. The track was constructed from 8 VMS pings and is comprised of 7 segments. The green zone indicates the region 45 ° to the left and right of the bearing of each segment. A turn is identified and the track is split anywhere the second segment of each segment pair falls outside this region. In this example, the original track will be split into 4 segments, 1-3, 3-4, 4-6, and 6-7.

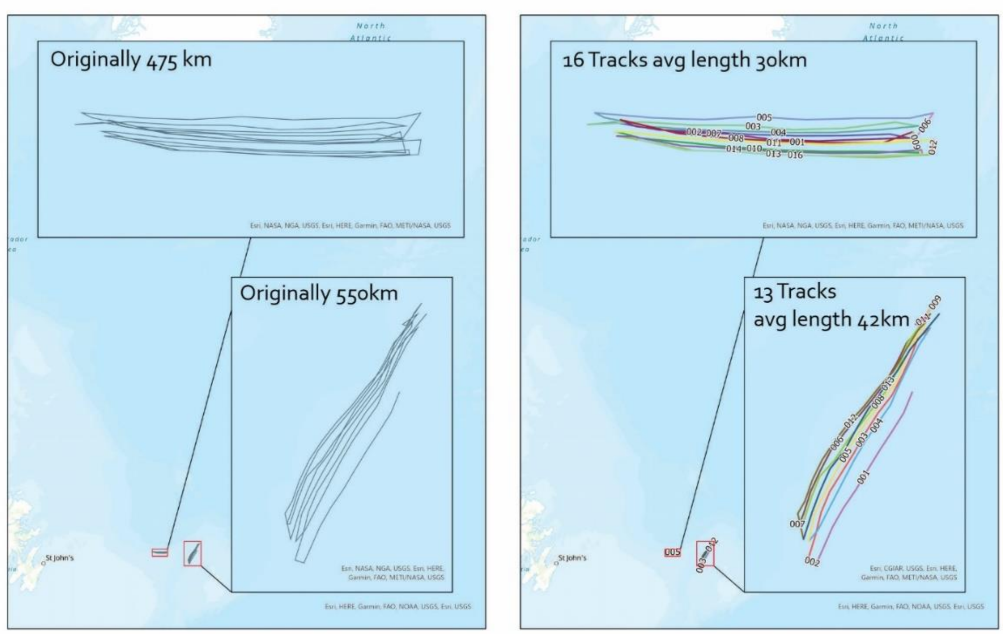

Figure 5.10. Sample tracks extracted from the database before and after turn processing.

Once the tracks had been processed using the turn analysis, length filtering was applied to remove all tracks exceeding 75 km in length. This filtering led to a further reduction of approximately 100,000 km, or 2.4%, of fishing effort.

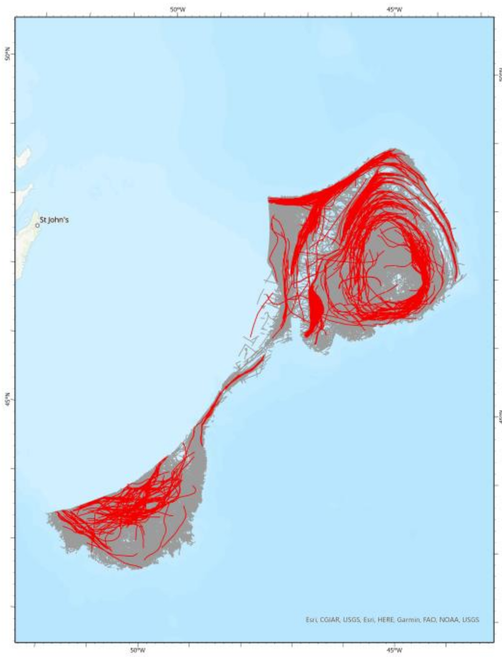

Figure 5.11. 75km maximum length filtered data layer. Red indicates the tracks that were removed at this filtering step.

Depth Range Filtering

Observer data from Spanish trawl fisheries indicated that trawl depth ranges, defined as the difference in the depths observed at the start and end of a tow, were not likely not exceed 250m. Start and end of tow depths were determined using the GEBCO bathymetric dataset (2022). When applied, this depth range filter removed approximately 270,000 km, or 6.7%, of the effort (Figure 5.11).

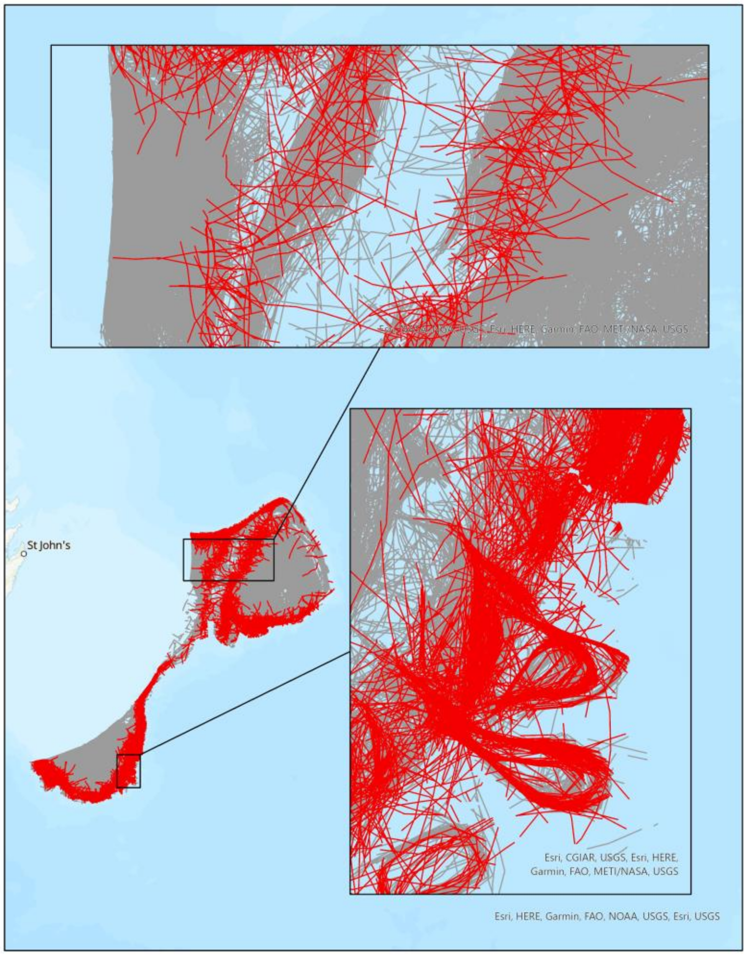

Figure 5.12. 250m maximum trawl depth range filtered data layer. Red indicates the tracks that were removed at this filtering step.

Future work

Discussions around this work provided guidance on next steps to advance these analyses. The current approach applied single thresholds for the maximum depth, track length and depth ranges the entire track dataset which consisted of data for various species and gear types, over a large spatial extent. Next steps would explore developing different filtering thresholds for selected combinations of species caught, gear, depth ranges and NAFO division. The development of the different thresholds would ensure that the filtering more accurately reflects the characteristics of each fishing scenario. It was also suggested that a comparison between the logbook and VMS fishing footprint with the filters applied would be important in validating this work. Work will also continue on the turn analysis to perform a comparison with the logbook data to confirm that the longer segments identified in this analysis are actually depicting fishing activity and not some other behavior. Additional exploratory work will be conducted around the possible use of other approaches and analytical techniques to filter tracks.

c) Tor 2.3. Quantifying the effects of habitat fragmentation in deep-sea Vulnerable Marine Ecosystems

Indices of Habitat Fragmentation Applied to the VMEs in the NRA

An index of habitat configuration that incorporates habitat area and nearest neighbour distances (PX; Gustafson and Parker, 1994) was applied to the distributions of seven deep-sea vulnerable marine ecosystem (VME) benthic invertebrate habitat types in the high-seas area of the northwest Atlantic. This work built on previous work undertaken by WG-ESA to incorporate connectivity and habitat configuration into the assessment and recommendations for closed area protection of the VMEs (NAFO, 2021). In 2021, more realistic connections among the closed areas and among the VME habitats were evaluated based on connectivity modeling using 3-D Lagrangian particle tracking models (Wang et al., 2021a; NAFO, 2021). At that meeting, unlikely connections were eliminated and PX was recalculated using minimum straight line distances. That work showed that PX, when applied to the new closures, appeared sensitive to their spatial configuration.

Here, we further the development of that work by replacing Euclidean distances between likely connections among VME habitats with distances determined from 3-D Lagrangian particle tracking (LPT) models parameterized with relevant biological traits of the VME indicator taxa (Wang et al., 2023). Recognizing that scattered individuals of VME indicators may be able to subsidize recruitment to downstream VMEs we evaluated the proportion of suitable habitat over the NRA, as determined from species distribution models (Kenchington et al., 2019), and assessed what portion of that suitable habitat was potentially modified by fishing activity, during the period 2010 to 2018 inclusive (reducing the probability of VME Indicator presence), both throughout the NRA and within 20 km of the VMEs.

The seven VME taxa (large-size sponges, sea pens, large and small gorgonian corals, black corals, sea squirts and erect bryozoans) differed in the size and number of their VMEs (Table 1; Wang et al., 2021a). LPT modeling showed that black coral, large gorgonian corals and bryozoans had the greatest proportion of 'unconnected' VMEs (Table 1) with 50%, 33% and 29% of their VMEs respectively not acting as a source population for another VME. Such VMEs may be self-recruiting and/or be a sink habitat. Alternatively, the connections may not have been detected in the LPT models. The models were constructed using averaged currents but connections might have appeared if individual years were examined (e.g., Wang et al., 2021b). Further, as recruitment in these species is very episodic, connectivity to 'unconnected' habitat patches may also occur through anomalous events which are difficult to model. Sea pens, sponges and small gorgonian corals all had highly connected habitat patches suggesting that habitat fragmentation may be more disruptive to their persistence than for those with a higher proportion of unconnected patches.

The PX values for each taxon (Table 5.2), calculated from the single minimum distance observed across all LPT modeling scenarios is larger when the habitat patch is surrounded by larger and/or closer habitat patches, and decreases as the habitat patches become smaller and/or more sparse (Gustafson and Parker, 1994). This produced a strong correlation between PX and the ratio of suitable habitat occupied by the VMEs ($P < 0.000$, $R^2_{Adj} = 0.927$), consistent with expectation. PX was largest for the sponges (Table 5.2) consistent with the large and closely-spaced VMEs, with minimum connection distances ranging from 56 to 422 km. Sea squirts also had a higher PX value (72.9) reflecting the closer spacing of the VMEs on the Tail of Grand Bank, and shorter connection distances of 52 to 774 km. Conversely, PX was low for the small gorgonian corals, bryozoans and black corals (Table 5.2). The small gorgonian corals had the smallest PX (3.3) arising from large connection distances (106 to 1783 km) and smaller and fewer VMEs (Table 5.2).

The potential for VMEs to receive larval subsidies from outside the VMEs, that is from individuals scattered throughout the suitable habitat matrix, was inferred by the proportion of suitable habitat that was subjected to bottom-contact fishing disturbance (Table 5.2). The proportion of suitable habitat within the study area landscape ranged from 14.2% for sea squirts to 48.8% for bryozoans. Sea squirts may be more reliant on connections among VMEs to sustain their populations. Within the suitable habitat area, environmental conditions supporting the formation and size of VMEs were more variable. The ratio of the 'area of VME: area of suitable habitat' in the habitat matrix, ranged from 0.043 for the black coral to 0.444 for the large-sized sponges, indicative of the relative ability of the landscape to support VMEs for the different taxa (Table 5.2).

The levels of bottom contact fishing activities, occurring within the suitable habitat area as a whole, and within 20 km of the VMEs, were used to evaluate the likelihood of the VMEs receiving larvae from the habitat matrix at two spatial scales. The amount of fishing within 20 km of the VME edges also provided an indication of whether fishing may have modified the shape of the VME, although the data is not spatially resolved to the degree necessary to evaluate such effects quantitatively. The amount of fishing disturbance in the suitable habitat area of the habitat matrix was poorest for the sea squirts with 68.05% of the suitable habitat having been disturbed between 2010 and 2018 (Table 5.2). Sponges had the least proportion of suitable habitat showing fishing disturbance, due to the deeper location of the habitat relative to fishing activity. Large gorgonian corals also showed relatively less disturbance across the predicted suitable habitat, also in part due to the depth of the VMEs. The proportion of the buffered area around the VMEs that experienced fishing disturbance may indicate whether subsidies from the area immediately adjacent to the VMEs are likely. Most taxa had a high proportion of the VME area immediately surrounding the patches showing fishing disturbance and assumed habitat modification, ranging from 18.76 to 74.08% (Table 5.2). Sponges were quite low with only 18.76% of the area disturbed (Table 5.2). Conversely, a very high proportion of the suitable area within 20 km of the VMEs was disturbed in bryozoans and sea squirts (74.08% and 71.88% respectively). All taxa except for the black corals, had at least one VME on Grand Bank close to the Canadian Exclusive Economic Zone such that a portion of the 20 km area surrounding the VME extended into Canadian waters where fishing effort was not included. This would deflate the proportion of disturbance for those taxa, however for the deeper living sponges and large gorgonian corals that area, being shallower, would likely be unsuitable habitat.

Table 5.2. VME characteristics and effect of the systematic removal of the individual VMEs on PX for each of seven deep-sea benthic invertebrate groups considered to be VME indicators ranked by mean response of PX (across different particle tracking models) to simulated habitat fragmentation. Mean values for the simulation effects were calculated across each LPT model scenario using the minimum distance in each. Unconnected VMEs are those not acting as a source population for another patch. SGC=Small Gorgonian Corals; LGC=Large Gorgonian Corals.

Taxon	No. of VMEs	No. of Unconnected VMEs within the Landscape	PX	Mean Percent Decline in PX in Simulations	Ratio of Area of VME: Area of Suitable Habitat from SDM	Proportion of Suitable Habitat Disturbed by Fishing Activity (%)	Proportion of Area around VME Disturbed by Fishing (%)
Black Corals	8	4	9.8	22.6	0.043	31.67	56.75
Sponges	9	1	155.3	20.4	0.444	16.93	18.76
SGC	9	1	3.3	18.8	0.063	48.88	46.80
LGC	12	4	18.6	16.3	0.076	25.28	48.82
Sea pens	11	0	53.1	14.0	0.130	44.44	56.96
Bryozoans	17	5	50.3	7.0	0.053	47.66	74.08
Sea Squirts	18	3	72.9	6.8	0.215	68.05	71.88

Simulating Habitat Fragmentation to Assess the Relative Importance of VMEs in their Networks

Artificial landscapes that mimicked habitat fragmentation processes while controlling for the size and shape of patches in the landscape were generated through systematic removal of VMEs. The LPT algorithms were informed by biological traits of spawning time and pelagic larval duration when known, further increasing the degree of realism in the models.

Mean values for the simulation effects were calculated for each VME removal across each LPT model scenario for each taxon, using the minimum distance in each (Wang et al., 2023). All taxa showed declines in PX in response to the simulations. The percent decline of PX compared with the baseline model of no removals for each LPT scenario was also averaged and showed that PX for the black coral responded the most to changes due to loss of whole habitats (22.6% decline in PX), followed by sponges and small gorgonian corals, with the sea squirts and bryozoans the least affected but still showing a 6.8% and 7% decline in PX with the simulated habitat removals (Table 5.2). The mean percent decline in PX was significantly and negatively correlated with the number of connected patches ($P < 0.0024$, $R^2_{Adj} = 0.838$), indicating that the fewer the habitat patches the greater the impact fragmentation through loss of whole habitats will have on habitat configuration, consistent with theoretical expectation (Hanski, 2001). WG-ESA recommended that the percent decline in PX (Table 5.3) be used for weighting the relative importance of the VMEs in the assessment of significant adverse impacts (SAIs).

Jenks natural breaks classification was applied to the mean percent PX decline values for all VMEs (N = 84) to optimally identify breaks after evaluating all possible partitions. The Goodness of Variance Fit (GVF) was used to evaluate results with 2 to 8 classifications, a range deemed useful for interpreting our results for management actions, and the total squared deviation of the k optimized classes was compared to that of k classes of equal numbers for the selected classification scheme. Selection of the best scheme was based on GVF and an arbitrary minimum of >6 samples in a class in order to have some confidence in the variance calculations. Classification into three partitions achieved 92.8% GVF, compared with 78.7% GVF for two partitions and 96.2% GVF for four. Thereafter GVF approached an asymptote with small incremental increases but with some classes have ≤ 5 sampling points. From a consideration of sample size in each class the solutions with 2 and 3 classes were the only ones that met the *a priori* criteria. A 3-class system was chosen as it had much higher GVF than the 2-class partitions. The deviation squared was much reduced in the Jenks breaks (Class 1: 58.81-88.75%; Class 2: 18.57-48.98%; Class 3: 0-16.35%) compared to division of the data into three equal sized classes (d2 = 3,258.78 vs. 18,557.98). The placement of each habitat patch into its class according to the three-class Jenks scheme is shown in Table 5.3.

The three classes of percent decline in PX, identified through the simulations, indicate their relative importance to the maintenance of the habitat configuration, assuming that distance is correlated to colonization. Habitat patches in the Class 1 bin are the most influential, those in Class 2 have a moderate influence on PX while those in Class 3 have little to no measurable effect on PX should they be removed from the system. This last class does not mean that those patches are unimportant to the overall habitat configuration, and collectively there is a strong negative relationship between PX and the total number of habitat patches as noted above. In most cases the largest number of habitat patches in each taxon were in Class 3, the exception being for the black coral where most habitat patches were Class 2 (Table 5.3). For the large-sized sponges, sea pens, large gorgonian corals and black corals, the habitat patches in Classes 1 and 2 currently are protected from disturbance by bottom-contact fishing by closed areas (Table 5.3). For the sponges and black corals all but one habitat patch each had some level of protection. However, the amount of the habitat that was unprotected is very high for most taxa with the sponges and large gorgonian corals having the greatest proportion of the habitat area protected with the 2019 area closures (Table 5.3), while the other taxa had over 80% of their habitat patches unprotected and therefore vulnerable to fishing disturbance reducing habitat quality (Table 5.2).

The results of the assessment of the impacts of habitat fragmentation on the VME habitats in the NAFO Regulatory Area (NRA) emphasize the importance of maintaining the number of habitat patches in each VME habitat in order to preserve the overall habitat configuration and connectivity network that sustains it. The current distribution and configuration of the remnant populations of VMEs in the NRA are vulnerable to habitat fragmentation disrupting connectivity pathways. For large-sized sponges, sea pens, large gorgonian corals and black corals the VMEs in Classes 1 and 2 that appear to be vital to maintaining the connectivity networks all currently have some degree of protection through areas closed to bottom contact fishing protect (Table 5.3). However, at present there is little to no protection for habitats of small gorgonian corals, bryozoans or sea squirts in the NRA within the fishing footprint, including habitats in those classes (NAFO, 2022). The results indicate that the highest priority should be given to protecting small gorgonian VMEs SGC1, 3, 4 and 5, bryozoan VMEs BR1 and BR2 and sea squirt (tunicate) VME TU1 (Table 5.3, Figure 5.13).

Table 5.3. Simulation Results. The mean effect of VME removal on PX for each of the VMEs for each of the seven deep-sea benthic invertebrate groups considered to be VME indicators. VMEs are ranked by response of mean PX percent decline (across different particle tracking models) to simulated habitat fragmentation and colour-coded by class determined by application of Jenks natural breaks classification. Class 1 (dark blue): 58.81-88.75%; Class 2 (light blue): 18.57-48.98%; Class 3 (grey): 0-16.35%. Patch numbers (e.g., S1) reflect patch area with "1" being the largest area (see Wang et al. (2021a) for areas of each VME). *Indicates that the VME is currently partially protected from area closures prohibiting bottom-contact fishing (NAFO, 2022).

Large-Sized Sponges		Sea Pens		Large Gorgonian Corals		Small Gorgonian Corals		Bryozoans		Sea Squirts		Black Corals	
Habitat Patch	Percent Decline in PX	Habitat Patch	Percent Decline in PX	Habitat Patch	Percent Decline in PX	Habitat Patch	Percent Decline in PX	Habitat Patch	Percent Decline in PX	Habitat Patch	Percent Decline in PX	Habitat Patch	Percent Decline in PX
S1*	45.3	SP1*	86.6	LGC1*	88.7	SGC4	61.9	BR1	70.7	TU1	87.9	BC1*	49.0
S5*	34.0	SP6*	46.1	LGC9*	83.7	SGC3	58.8	BR2	29.2	TU2	10.1	BC3*	43.9
S4*	33.5	SP2*	6.3	LGC3*	12.3	SGC5	21.7	BR4	14.0	TU8	9.2	BC8*	37.8
S6*	33.0	SP3	4.3	LGC2*	10.7	SGC1	18.6	BR6	1.5	TU3	7.2	BC4*	26.5
S2*	16.4	SP9	4.2	LGC4	0.0	SGC6*	3.1	BR5	1.3	TU5	0.5	BC2*	23.5
S3*	16.2	SP5*	2.3	LGC5	0.0	SGC7	3.0	BR7	0.8	TU4	0.3	BC5	0.0
S7*	4.2	SP8*	2.3	LGC6	0.0	SGC2*	2.0	BR8	0.1	TU9	0.1	BC6*	0.0
S9*	0.8	SP7	0.9	LGC7	0.0	SGC8	0.0	BR9	0.1	TU10	0.1	BC7*	0.0
S8	0.1	SP4	0.7	LGC8	0.0	SGC9	0.0	BR11	0.1	TU11	0.1		
		SP10*	0.0	LGC10	0.0			BR12	0.1	TU6	0.0		
		SP11	0.0	LGC11*	0.0			BR13	0.1	TU7	0.0		
				LGC12	0.0			BR14	0.1	TU12	0.0		
								BR17	0.1	TU13	0.0		
								BR3	0.0	TU14	0.0		
								BR10*	0.0	TU15	0.0		
								BR15	0.0	TU16	0.0		
								BR16*	0.0	TU17	0.0		
										TU18	0.0		

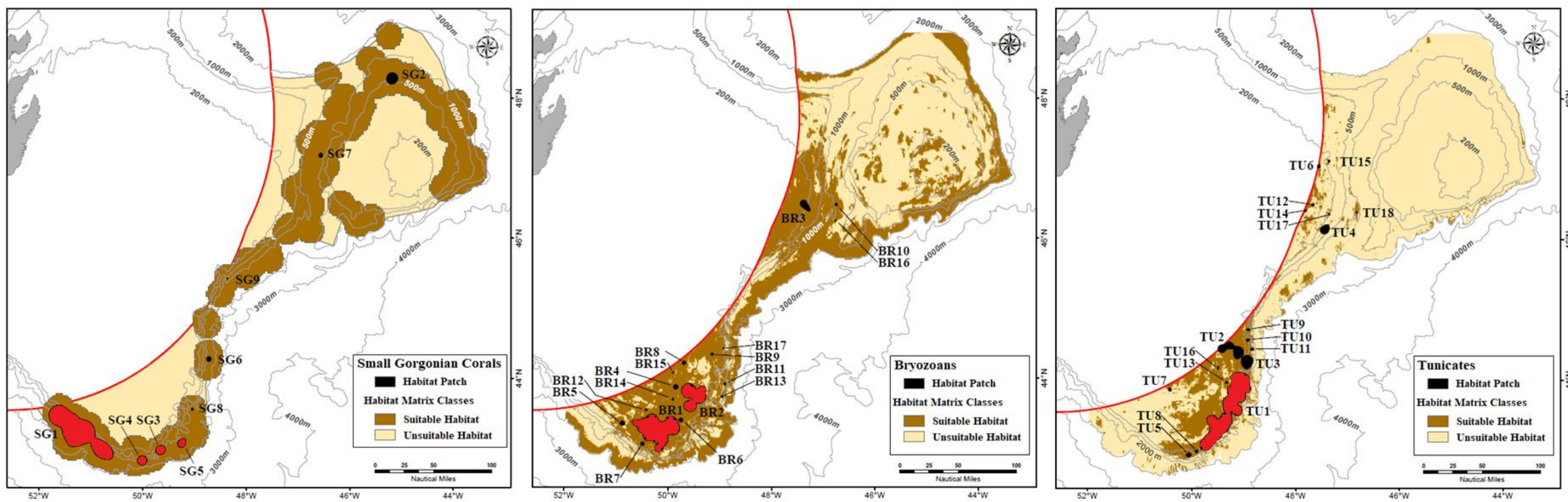

Figure 5.13. Location of (left to right) the Small Gorgonian Coral, Erect Bryozoan and Sea Squirt (Tunicates) VMEs (habitat patches) in red fill that are critical to maintaining connectivity among their VME habitat networks and for which there is currently no protection from bottom contact fishing (Table 5.4). The habitat matrix divided into suitable and unsuitable habitat is indicated. Map projection: NAD 83 UTM 22N.

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d) ToR 2.4. Spatial extent question related to the KDE calculations

In support of the 2020 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area, kernel density analyses (KDE) of the biomass of Large-sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals were undertaken using all available research vessel survey data (1995 – 2019). The results of those analyses were compared with those previously conducted in 2013 reviewed by the NAFO Working Group on Ecosystem Science and Assessment (WG-ESA) at its 12th meeting in November 2019. At that meeting, members of WG-ESA queried the appropriateness of confining the analyses to the NRA and requested that additional analyses be conducted prior to the next review of the closed areas to determine the effect of including data from Canadian waters in identifying the VME polygons in the NRA. Here we present the results of that comparison using data from the Newfoundland and Labrador bioregion (Figure 5.14).

The data from the different surveys were compiled for the same time periods as in the 2019 analyses so that there was no additional data from the NRA and all new data came from Canadian waters. Previously, the data were analysed for differences between gear types, and for some species removal of the smallest catches was required in order to remove that effect. That same data treatment was applied herein. The parameters for the KDE analyses were also held the same as in 2019 (search radius, cell size, biomass intervals) in order to control for differences due to other than the change in geographic coverage. In 2013 the fewer data required the search radii in the KDE analyses to be adjusted so that continuous biomass surfaces could be created. However, in 2019 the default parameters (determined from the spatial extent of the data) were used, which in future will create even further stability to the results. For that reason, we retained the KDE parameters used in 2019 in the 2022 analyses. The number of new records was considerable for all VME Indicator groups, and for Sea Squirts increased by an order of magnitude. Full details of the analyses are reported in the accompanying Scientific Council Report (Kenchington et al., 2022) and are not repeated here.

Of the seven VME Indicator groups evaluated, there was no change in the RV catch threshold used to delineate VMEs in three (Sea Pens, Large Gorgonian Corals, Erect Bryozoans) (Table 5.4). The thresholds were larger for two groups (Large-sized Sponges, and Sea Squirts) and smaller for two others (Small Gorgonian Corals and Black Corals). For the Large-sized Sponges (Figure 5.15) and Sea Squirts (Figure 5.16), the different thresholds did not translate to large changes in the VME polygons in the NRA. For the Black Corals, which remain rare in terms of record numbers, the new threshold increased a previously identified VME polygon and created two new VMEs, all in Flemish Pass (Figure 5.17). For Small Gorgonian Corals the new threshold was the same as that found in 2013 and that was considered in 2019 (Table 5.4). The new threshold, being lower than the current threshold for identification of VMEs in the NRA identified two new areas on the eastern slope of Flemish Cap and connected three smaller VMEs on the slope of the Tail of Grand Bank (Figure 5.18). Those new areas are small compared with the 1377% increase in area found between the 2013 and 2019 KDE analyses for this taxon (Kenchington et al., 2019).

Conclusions

Taken together, the results of the new analyses did not greatly change the delineation of VME polygons in the NRA despite the large increase in data and the inclusion of new environmental spaces (e.g., records from shallower shelf areas). This was not entirely unexpected by the technical experts, although the degree of stability was not anticipated (no change to 3 of the 7 VME Indicator groups). This is because hotspots are identified by the local data neighbourhood (Kenchington et al., 2022). Under similar species compositions and environments, the largest catches would be expected to be similar, as well as the biomass thresholds defining the habitats. Testing that theoretical expectation with empirical evidence provides stronger support for the ecological relevance of the habitats. Additional data within the NRA as seen in the comparison of thresholds between 2013 and 2019, has a greater effect than increasing the geographic coverage because it affects the number of records in the local data neighbourhood. This was shown to be the case especially for those taxa that had low numbers of biomass records (Kenchington et al., 2019). Further, these analyses show that should future KDE analyses be conducted to re-assess the VME habitats (the next reporting to UNGA is scheduled for

2026), change of the spatial extent from the NRA to the EPU should not have large impacts on the identificaton of the VME.

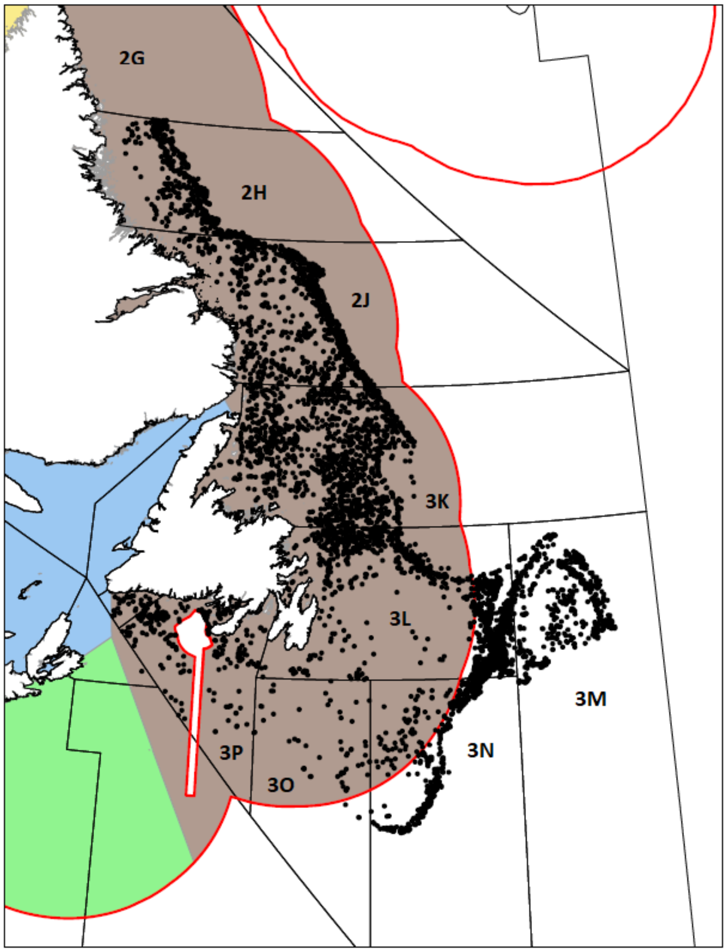

Figure 5.14. The biogeographic zones identified by DFO (DFO, 2009) showing the location of the Newfoundland and Labrador Shelves zone (brown). Data from within Canada for this study were restricted to this zone. Location of survey data showing presence of sponges are shown (black closed circles) to illustrate the full data extent into the NAFO Regulatory Area. NAFO Divisions within the biogeographic zone and the NRA are labelled. Red lines show the exclusive economic zones of Canada, Greenland and St. Pierre and Miquelon. Map projection: NAD 83 UTM 22N.

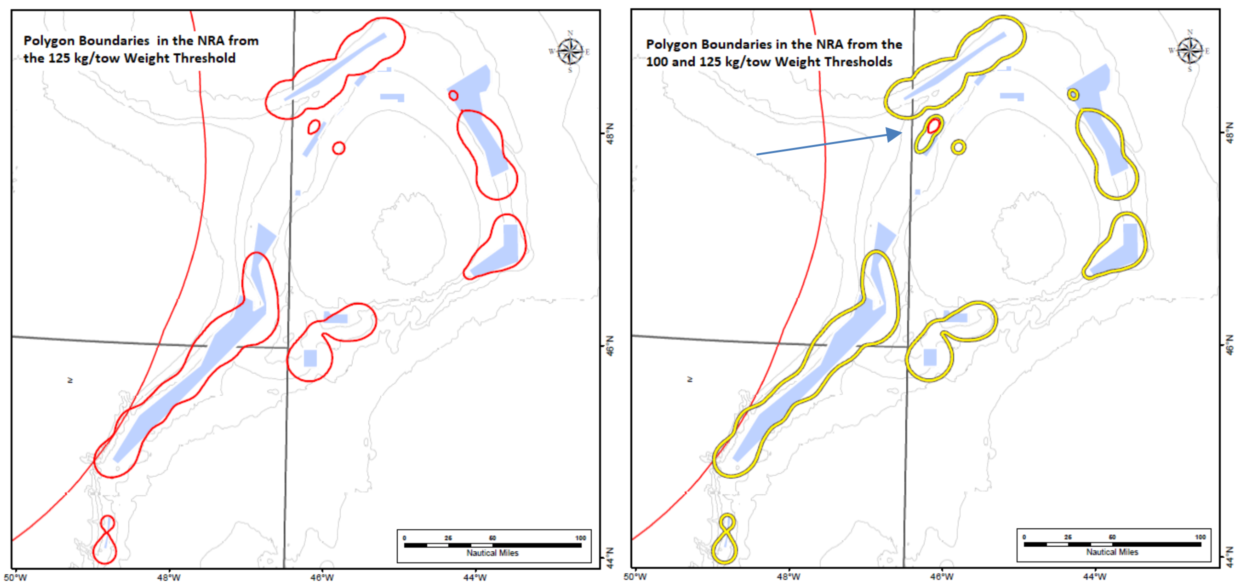

Figure 5.15. Comparison of the *Large-sized Sponge* VME polygons using the 125 kg threshold (red outline) with the sponge VME polygons established previously with the 100 kg threshold (yellow outline) (NAFO, 2019). Closed areas in place in 2019 are shown with blue shading for comparing with previous work (Kenchington et al., 2019; NAFO, 2019). The blue arrow points to the only difference in area identified when using the full data set as opposed to only the data from the NRA. Map projection: NAD 83 UTM 22N.

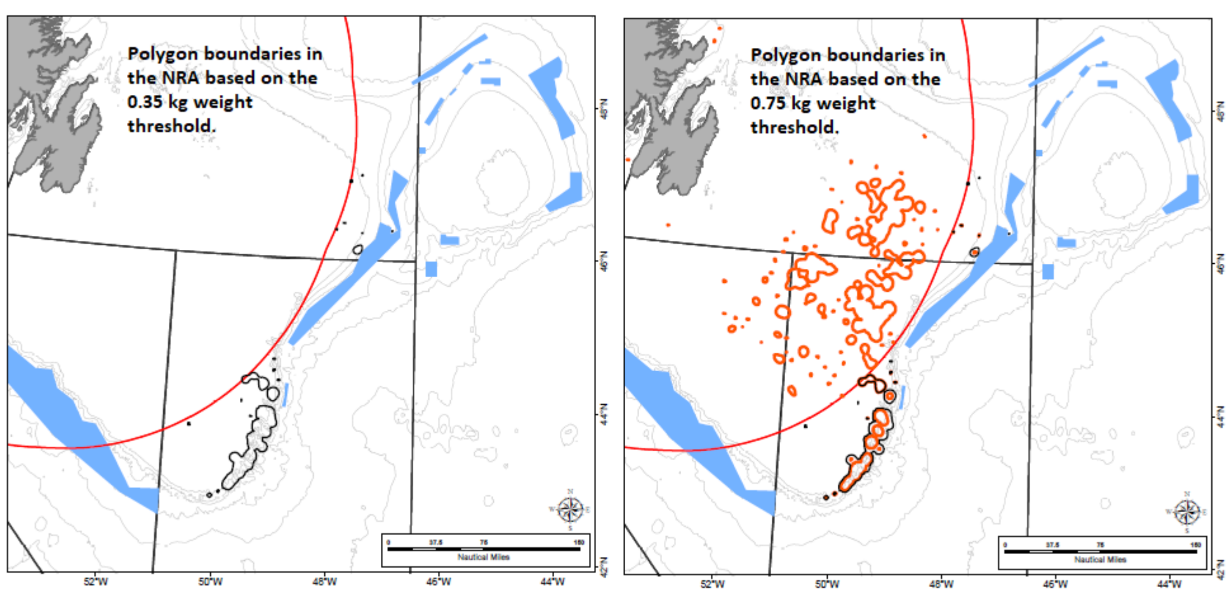

Figure 5.16. Comparison of the *Sea Squirt (Boltenia)* VME polygons using the previously established threshold 0.35 kg threshold (black outline; NAFO, 2019) and the new 0.75 kg threshold (red outline). Closed areas in place in 2019 are shown with blue shading for comparing with previous work (Kenchington et al., 2019; NAFO, 2019). Map projection: NAD 83 UTM 22N.

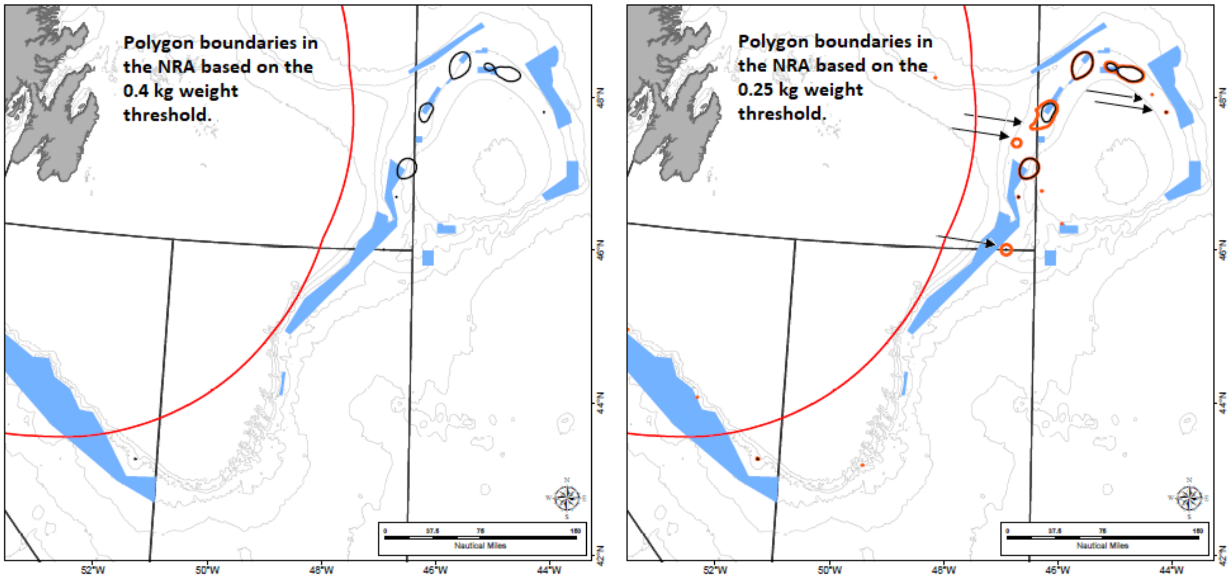

Figure 5.17. Comparison of the Black Coral VME polygons using the previously established threshold 0.4 kg threshold (black outline; NAFO, 2019) and the new 0.25 kg threshold (red outline). Closed areas in place in 2019 are shown with blue shading for comparing with previous work (Kenchington et al., 2019; NAFO, 2019). The arrows point to the larger differences in area identified when using the full data set as opposed to only the data from the NRA. Map projection: NAD 83 UTM 22N.

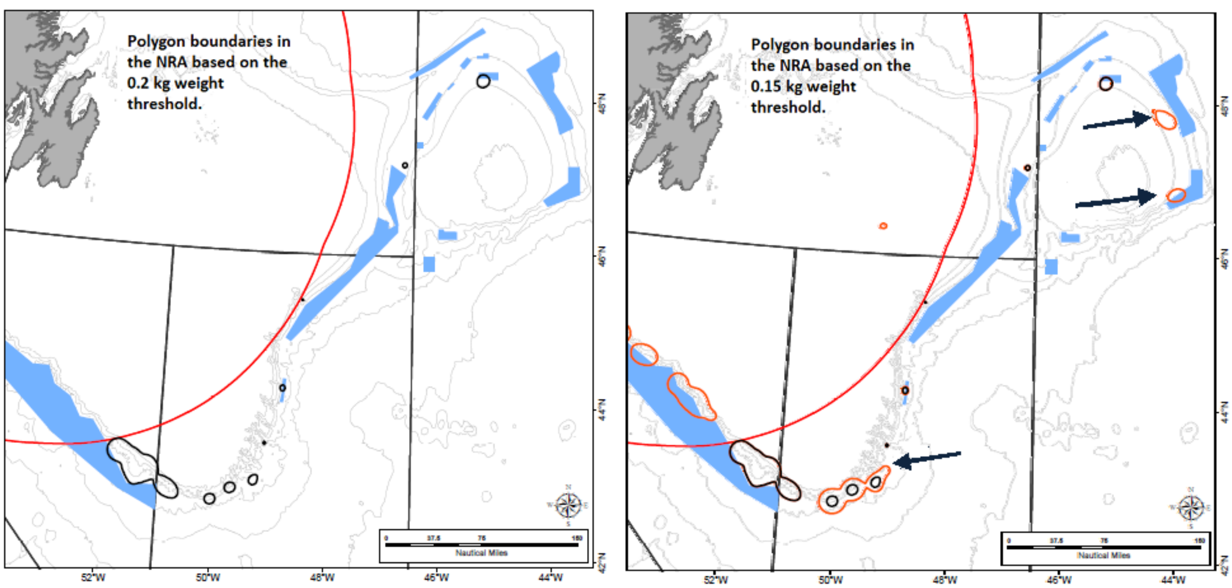

Figure 5.18. Comparison of the *Small Gorgonian Coral* VME polygons using the previously established threshold 0.2 kg threshold (black outline; NAFO, 2019) and the new 0.15 kg threshold (red outline). Closed areas in place in 2019 are shown with blue shading for comparing with previous work (Kenchington et al., 2019; NAFO, 2019). The arrows point to the difference in area identified when using the full data set as opposed to only the data from the NRA. Map projection: NAD 83 UTM 22N.

Table 5.4. Comparison of RV catch thresholds produced from the KDE analyses conducted herein in 2022, and previously in the 2019 and 2013 assessments of the closed areas, by VME indicator group.

VME Indicator	Year of Analyses	Number of Records in Analyses	RV Catch Threshold for Delineating VME polygons	Implications of 2022 Analyses for VME in the NRA
Large-sized Sponge	2022	5449	125 kg	Contracted area for small VME polygon on northern Flemish Cap
Large-sized Sponge	2019	1825*	100 kg	
Large-sized Sponge	2013	1154	75 kg	
Sea Pen	2022	815	1.3 kg	No Change
Sea Pen	2019	430	1.3 kg	
Sea Pen	2013	262	1.4 kg	
Small Gorgonian Coral	2022	421	0.15 kg	Two new areas on the eastern slope of Flemish Cap and connected three smaller VMEs on the slope of the Tail of Grand Bank
Small Gorgonian Coral	2019	218	0.2 kg	
Small Gorgonian Coral	2013	85	0.15 kg	
Large Gorgonian Coral	2022	323	0.6 kg	No Change
Large Gorgonian Coral	2019	89	0.6 kg	
Large Gorgonian Coral	2013	58	0.6 kg	
Erect Bryozoans	2022	391	0.2 kg	No Change
Erect Bryozoans	2019	174	0.2 kg	
Erect Bryozoans	2013	343**	0.2 kg	
Sea Squirts	2022	1340	0.75 kg	Change largely in the edge effects of the 2019 polygons; some of the isolated single record VMEs on the Nose and Tail are lost
Sea Squirts	2019	334	0.35 kg	
Sea Squirts	2013	88	0.3 kg	
Black Coral	2022	62	0.25 kg	Expands one previous VME and creates two new VMEs in Flemish Pass
Black Coral	2019	44	0.4 kg	

*Misreported as 1797 records in Kenchington et al. (2019). **In 2013 the data were only from the EU-Spanish 3NO and 3L surveys (NAFO, 2013) and so no gear catch threshold was applied.

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e) ToR 2.5 Cerianthid Ecological Roles

Cerianthids (Cnidaria: Anthozoa) are vulnerable marine ecosystem (VME) indicators. Yet, few studies have investigated their ecological role in particular in relation to sediment macrofauna in soft sediment areas. This presentation focused on the development of a research project examining the relationship between cerianthids and macrofauna diversity and sediment fluxes in Hebron Fjord (Labrador, Northwest Atlantic), where cerianthids have been observed in high densities at some locations. Sediment samples were collected in cerianthid and non-cerianthid sites, located <1 km apart, at ~ 250 m depth. Samples were collected from sediment push-cores using the ASTRID remotely operated vehicle (ROV) aboard CCGS *Amundsen* in September 2022. A total of 22 push-cores were collected (11 at each site), 16 of which were sampled for macrofauna analysis and the others for a nutrient cycling study. Sediment samples for macrofauna were sliced at 0-2 cm, 2-5 cm, and 5-10 cm deep in the core and preserved in 10% buffered formalin. Macrofauna will be sieved in 500 µm mesh sieves, sorted, and identified to the lowest taxonomic level. This project is part of a collaboration between DFO-NL, Memorial University, and Dalhousie University, and part of graduate students projects, and will hopefully contribute to increase our knowledge of cerianthid ecosystem functions.

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. Implementation of Tiers 1 and 2 of the EAFM Roadmap (Com. Requests #5a and 5b).

Com. Request 5 a and b: *The Commission requests that the Scientific Council continue to work on tiers 1 and 2 of the Roadmap, specifically to:*

a. Include on a regular basis summary information on TCI in stock summary sheets (including indications of other NAFO managed stocks within the corresponding guild) and ecosystem summary sheets.

b. Work to support WG-EAFFM in exploring:

i. Management considerations for occasions in which the 2TCI ecosystem reference point were to be exceeded, similar to those when exceptional circumstances are triggered within MSE.

ii. Effective methods to communicate TCI-related information to the Commission, in particular for when 2TCI is, or expected to be exceeded.

i) Com. Request 5.a: Include on a regular basis summary information on TCI in stock and ecosystem summary sheets

Stock Summary Sheets (SSSs) are updated by SC when a full assessment on the stock is conducted. This means that some SSSs are updated annually, while others are updated at a lower frequency. For this reason, in order to include updated TCI-related information on SSSs, TCI updates need to be produced on an annual basis. These updates need to be carried out at the SC June meeting using the most updated data on catches so these updates match the information used in the stock-assessments as close as possible. Furthermore, stocks like Greenland halibut, which is managed using a Harvest Control Rule (HCR), do not have SSSs; including TCI-related information would require that a full SSS be developed in the first place. From this perspective, an initial observation is that, regardless of the management regime, it would be advisable that all stocks managed by NAFO to have a SSS.

In terms of providing TCI information on a the regular basis, the differences in scheduled assessments among stocks, and the nominally multiannual schedule for the update of Ecosystem Summary Sheets (ESSs), implies that regular provision of complete TCI information requires a stand-alone reporting that covers all relevant EPUs. This type of comprehensive summary reporting is discussed and presented under ToR 3.1b (see below).

TCI reporting on a SSS needs to be focused on the functional guild to which the stock belongs, and since some stock areas expand over more than a single Ecosystem Production Unit (EPU), this summary TCI reporting would require reporting for all EPUs that the managed stock inhabits.

Incorporation of this information in the SSS can be done by adding a TCI-specific information in the SSS narrative, as well as complementing it by adding a row in the main summary table of the SSS.

At present, SSSs include a section on "Biological and environmental interactions" and this is the section where some form of TCI information has been included in the past. In recent years, this section has also included a brief narrative describing the current state of the fish community. After examining some alternatives, WG-ESA concluded that a standard text summarizing the state of the fish community is needed in the "Biological and environmental interactions" section, but the TCI-related information requires a stand-alone section in the SSS narrative.

A draft of the proposed structure and narratives using the 3M cod stock as an example is provided below [italicized and bracketed text is new or modified text from the 2022 3M Cod SSS]:

> **Biological and environmental interactions**
>
> Redfish, shrimp and smaller cod are important prey items for cod. Recent studies indicate strong trophic interactions between these species in the Flemish Cap.
>
> [*A 2022 summary of the state of the fish community in the Flemish Cap (3M) EPU indicated that this ecosystem has not experienced sustained reductions in overall productivity observed in other EPUs. With the exception of a short-lived increase in 2005-2009, total biomass has remained fairly stable over time despite the changes in individual stocks.*]
>
> **[*Ecosystem sustainability of catches*]**
>
> [*3M cod is included in the piscivores guild of the Flemish Cap (3M) Ecosystem Production Unit (EPU). Other NAFO managed stocks in this EPU within the piscivores guild are 3M Redfish and 2+3KLMNOPs Greenland Halibut. The Catch/TCI level for this guild in the Flemish Cap (3M) EPU is below the 2TCI ecosystem reference point (3M Piscivore Catch/TCI=0.82) indicating a low risk of ecosystem overfishing.]*

Similar narratives would need to be developed for other stocks and EPUs for SC consideration and inclusion in the SSS at the 2023 SC June meeting.

The inclusion of a row in the main table of the SSS to reflect ecosystem information was also debated by WG-ESA, and while the idea was found valuable and useful, the specific structure and information for this row remains a matter of discussion due to the difficulties on assigning colors to the assessment. At present, while the TCI framework has been adopted, only 2TCI has been formally recognized as an ecosystem reference point. This means that the characterization of high risk of ecosystem overfishing based on catches exceeding 2TCI is accepted by NAFO managers, but the distinction of medium and low risk based on catches below TCI and between 1 and 2 TCI remains within the realm of science advice. This implies that only green and red colors would need to be used in this table. With this potential caveat in mind, one simple option is to add a second line in the "Eliminate overfishing" row, and add TCI information there. For example, the 3M Cod Table could look like:

Convention objectives	Status	Comment/consideration
Restore to or maintain at B_{MSY}	🟡	Stock above B_{lim} in 2022. B_{MSY} is unknown
Eliminate overfishing	🟢	Stock level: $F < F_{lim}$ in 2021
	🟢	Ecosystem level: catches below 2TCI in relevant EPUs
Apply Precautionary Approach	🟢	F_{lim} and B_{lim} defined
Minimise harmful impacts on living marine resources and ecosystems	🟡	VME closures in effect, no specific measures
Preserve marine biodiversity	⚪	Cannot be evaluated

🟢 OK
🟡 Intermediate
🔴 Not accomplished
⚪ Unknown

Regarding the incorporation of TCI-related information in the Ecosystem Summary Sheets (ESSs), this type of information was already included in the original ESS design. The updated ESSs produced by WG-ESA (see ToR 3.1c) include a revised presentation of this information to align the ESSs with the TCI framework and 2TCI ecosystem reference point adopted by NAFO at its 2022 Annual Meeting.

ii) Com. Request 5.b.i: Support WG-EAFFM on management considerations for 2TCI as analogous to Exceptional Circumstances, and improving communication on TCI-related information

Management considerations for occasions in which the 2TCI ecosystem reference point were to be exceeded, similar to those when exceptional circumstances are triggered within MSE.

The experience gained through the 2022 WG-EAFFM workshop on the implementation of Tier 1 showed that, at least at the present time, management discussions and decisions towards preventing a high risk of ecosystem overfishing were better served by the provision of TCI information in a non-prescriptive way, and allowing the existing negotiation mechanisms within COM to incorporate the TCI-related information and integrate it into the overall discussions on setting TACs.

Furthermore, the analyses on catch levels in relation to TCI have indicated that catches exceeding 2TCI are clearly associated with negative ecosystem outcomes (i.e. declining trends in functional guilds), and that the frequency of these high catch levels has been low in the last 25 years. Since the early 2000s there have been no sustained catches exceeding 2TCI, but catches have in occasions approached 2TCI in recent years clearly indicating that the risk of exceedance cannot be dismissed.

In this context, the event of exceeding 2TCI is analogous to the concept of Exceptional Circumstances in the context of Management Strategy Evaluation. This implies that management systems need to be prepared for it, but the expectation is that these actions would be rarely invoked. Furthermore, regular monitoring of catches in relation to TCI should provide early warnings that a 2TCI exceedance event may be likely, and early management measures could be adopted to prevent this from happening.

The TCI framework adopted by NAFO identifies 2TCI as an ecosystem reference point, and catches above this reference point are associated with a high risk of ecosystem overfishing. The analyses underpinning this framework also identified catches between 1 and 2 TCI as posing an intermediate risk of ecosystem overfishing, and catches below TCI as having a low risk of ecosystem overfishing. While the intermediate and low risk of ecosystem overfishing levels have not been formally adopted by NAFO as part of its management framework, they still represent useful characterizations of risk from a science perspective, as they can be used to organize actions conducive to prevent a high risk of ecosystem overfishing.

These actions can be seen as emerging from a series of science and management considerations. A working set of these considerations include:

Science considerations

1) *Reasons for exceeding 2TCI. An increased likelihood of exceeding 2TCI could be related to:*
   a) *Stock assessment misspecification: stocks assessments projecting single species yields that fail to properly consider ecosystem constraints (can stock assessment be updated/improved? Do some assessments need to be conducted earlier?), and/or*
   b) *Ecosystem productivity misspecification: ecosystem productivity has improved and it is above the baseline level used in the TCI calculation (can TCI estimates be examined and updated? Is there other reason, like unusually high recruitment, that can explain the excess productivity?).*
2) *Horizon for negative impacts. How long catches exceeding 2TCI could be reasonably tolerated before impacts would be expected? (quantitatively addressing this question likely require a complex, MSE-type of modelling exercise).*
3) *Status and trends of the stocks involved. Are some stocks declining and other increasing? Are some stocks near* B_{lim} *and others way above? (this would inform the stock level risks likely associated to the 2TCI exceedance).*
4) *Interactions among stocks. What are the interactions among the stocks involved? Would a change in one be expected to impact another? (quantitatively addressing this question would require Tier 2 type of modelling; developing relevant Tier 2 models can inform this but also stock interactions questions on their own right; developing Tier 2 assessments as part of the Roadmap would be expected to inform this consideration).*
5) *Incoming TACs. Do the stocks involved have already agreed TACs for the incoming years? How do these TACs accumulate? (this would allow to map scenarios around the expected 2TCI exceedance event).*

Management considerations

1) *Timing of advice in relation to action. Should actions be taken immediately (i.e. only stocks that are coming up for decisions on the year that a likely 2TCI exceedance is identified) or can be staggered over time?*
2) *Horizon of persistence of 2TCI excess. How long catches are expected to be over 2TCI? Is this horizon tolerable? (from a manager's perspective this involves not just the ecological tolerance examined by SC, but also potential socio-economic impacts, both present -reductions now- and future ones -reduced future productivity due to 2TCI exceedance-).*
3) *Trade-offs among stocks. The TCI analysis provides no information on how to prioritize stocks within a guild, therefore, in the absence of additional analysis, a value judgement by managers on how to prioritize stocks for management actions would be required. What is the best way to prioritize stocks from a management perspective (e.g. conservation status, economic relevance, other)? (developing Tier 2 models/assessments could inform this consideration, but these models cannot be developed on demand, they require planning in advance and targeted resources).*
4) *Process to evaluate/integrate information. The evaluation of exceptional circumstances is often implemented using a structured protocol that involve a sequence of specific steps and actors involved (e.g. type of analyses to be performed, NAFO bodies involved, decision tree, integration within NAFO management cycle). How such a protocol looks like from a manager's perspective? What would the necessary steps be? (addressing this consideration requires an iterative process between scientists and managers to identify the most effective architecture, key steps, and assignation of roles and responsibilities).*

Constructing an effective protocol to respond to a likely exceedance of 2TCI would require a systematic examination of these considerations, plus a workplan to develop the additional pieces of science and/or management support tools that may be required. However, given the expected low frequency of these events, careful consideration needs to be given to the value proposition of the work involved. On the science side, complex modelling efforts may be better invested in developing Tier 2 models of broader scope instead of targeted algorithmic solutions to balance TAC allocations (i.e. tools in the spirit of the illustrative spreadsheet used for the 2022 WG-EAFFM Workshop). On the management side, regular examination of the Catch/TCI trends can provide sufficient early warnings of trends approaching 2TCI to allow those trends to be managed with minor TAC adjustments over a number of years, and hence, avoiding both the need for sudden/major readjustments of TACs, and the associated difficult negotiations that would be expected to come with them.

In this context, the risk classification structured around “less than 1 TCI” (low risk of ecosystem overfishing), “between 1 and 2 TCI” (intermediate risk of ecosystem overfishing), and “above 2TCI” (high risk of ecosystem overfishing) provides a practical framework for examining and organizing actions based on the above science and management considerations. In very simple terms, if catches are “between 1 and 2 TCI” science needs to examine more closely the trends in catches and trends of relevant stocks and be prepared to focus attention on them and the corresponding EPU productivity, while managers need to start considering tempering actions that would keep increasing the aggregated catches.

While these observations and considerations by themselves do not constitute a structured protocol for addressing a 2TCI exceedance, they are expected to provide a useful starting point for a discussion between scientists and managers at WGEAFFM on how best to structure such protocol, the elements it needs to contain, and the work and resources required for making it operational.

iii) Com. Request 5.b.ii: Effective methods to communicate TCI-related information to the Commission, in particular for when 2TCI is, or expected to be exceeded

In line with the science and management considerations detailed in the previous section, and following up on the need for an annual stand-alone reporting on TCI described in ToR3.1b, WG-ESA developed a summary report on “Sustainability of Catches at the Ecosystem Level”. This report constitutes an initial attempt to provide a concise and clear reporting on TCI information that includes both, the Catch/TCI ratios that provide an *at glance* perspective of the level of risk of ecosystem overfishing at the EPU scale, and detailed plots that highlight the main species in the catch for each guild by EPU. The report was designed to only include detailed catch by species for the Flemish Cap (3M) and Grand Bank (3LNO) EPUs because these two EPUs are the ones containing most of the stocks and areas under direct NAFO management, and the goal of the report is to provide information useful for NAFO management discussions, while avoiding overloading managers with information that may not be directly useful for potential TAC negotiations.

Notwithstanding this design feature of the report, and considering that this is the first time the report has been produced, complementary detailed information for the Newfoundland Shelf (2J3K) EPU has also been generated.

This report needs to be considered as a proof of concept towards developing effective tools to communicate TCI-related information to managers. It is intended to address both, the requirement to include TCI-related information in the regular reporting from SC to COM, and to serve as test case for the discussion with WG-EAFFM on effective ways of communicating this type of results.

The “Roadmap Tier 1: Summary Report on Sustainability of Catches at the Ecosystem Level” is included below:

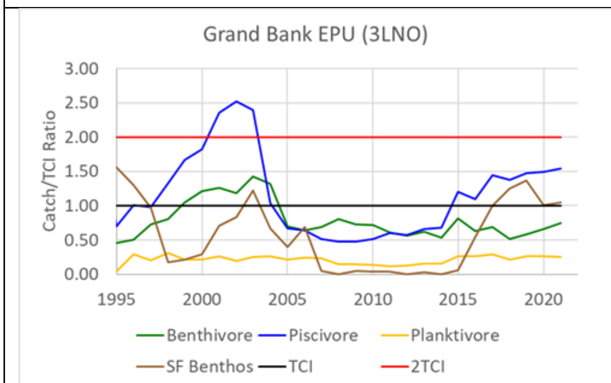
Roadmap Tier 1: Summary Report on Sustainability of Catches at the Ecosystem Level

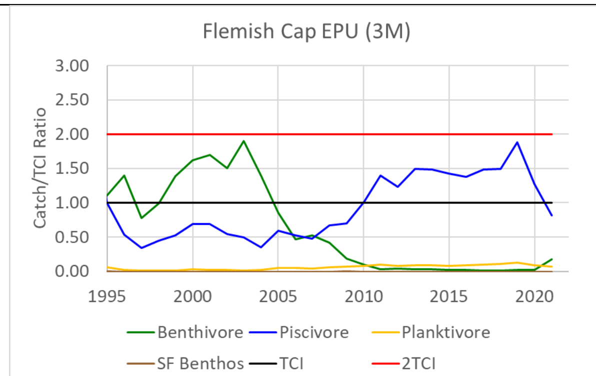
Since 2005 all Ecosystem Production Units (EPUs) evaluated (3M, 3LNO and 2J3K) have shown aggregate catch levels by functional guild which are consistent with the productivity of the EPUs and the prevention of high risk of ecosystem overfishing.

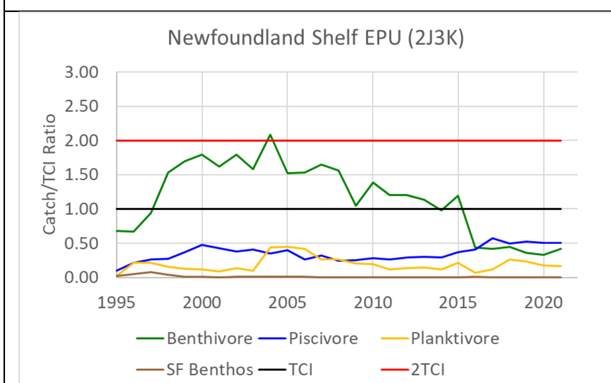
Approach:

Total Catch Index (TCI): This index is an indicator of the level of aggregated catch for a given functional guild (aggregate of species) that is consistent with the current productivity of the ecosystem (ecosystem sustainability). The comparison of aggregate catches with TCI is informative of the risk of ecosystem overfishing.

NAFO has adopted 2TCI as an ecosystem reference point to inform on ecosystem overfishing (EO).







Risk of ecosystem overfishing:

Catch > 2TCI: high risk of ecosystem overfishing

Catch between 1 and 2 TCI: intermediate risk of ecosystem overfishing

Catch < TCI: low risk of ecosystem overfishing

Summary:

During 1960-1995 all the Ecosystem Production Units (EPUs) evaluated had experienced sustained catch levels consistent with ecosystem overfishing.

Since 2005 aggregated catches for all functional guilds have been below the 2TCI ecosystem reference point across all EPUs.

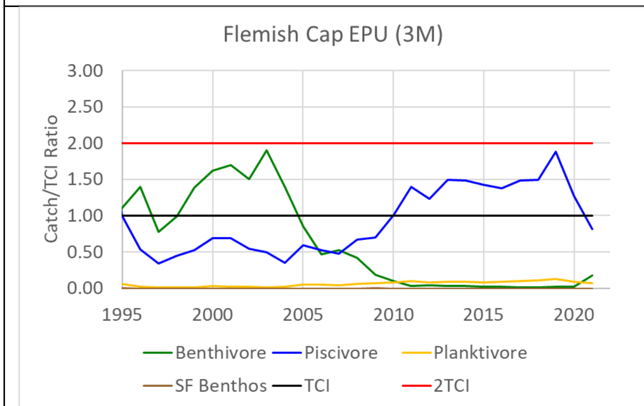
The catch levels for 2021 indicate a low risk of ecosystem overfishing on the Flemish Cap (3M) EPU and the Newfoundland Shelf (2J3K) EPU, and intermediate risk of ecosystem overfishing in the Grand Bank (3LNO) EPU.

All catch levels are consistent with preventing a high risk of ecosystem overfishing.

Details by EPU

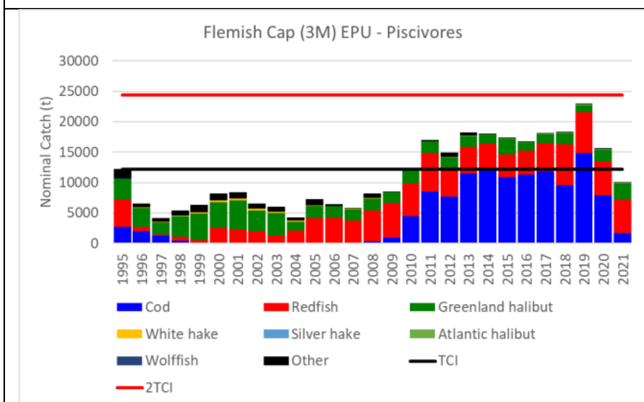
NAFO-managed stocks predominantly inhabit the Flemish Cap (3M) and Grand Bank (3LNO) EPUs, and typically belong to the Piscivore, Benthivore and Planktivore functional guilds. Details on catch composition in relation to TCI for these focal EPUs is provided below to complement stock-assessment information, and further assist NAFO management discussions on appropriate TAC levels than can consider the risk of ecosystem overfishing (EO).

Flemish Cap (3M) Ecosystem Production Unit (EPU)



Overview

Catches for all functional guilds are below 2TCI, indicating that current fishing levels are consistent with preventing a high risk of ecosystem overfishing.

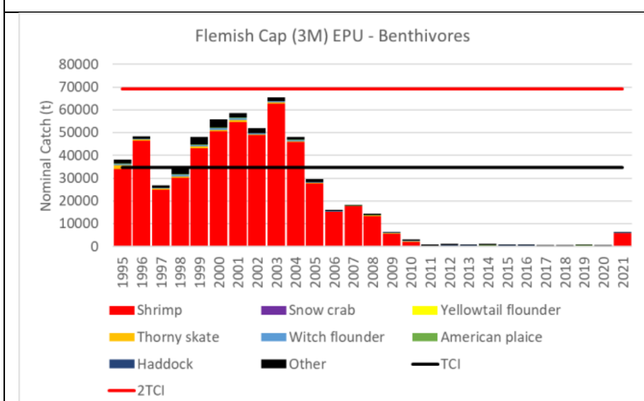


Piscivores Guild: low risk of EO

Current 2TCI=24kt

Catches are dominated by redfish, Greenland halibut and Atlantic cod.

Redfish (3M), Greenland halibut (2+3KLMNO) and Atlantic cod (3M) stocks are managed by NAFO.

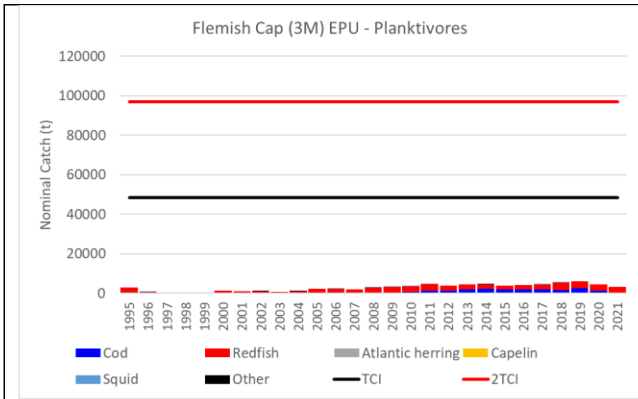


Benthivores Guild: low risk of EO

Current 2TCI=69kt

Catches are dominated by shrimp.

Shrimp (3M) stock is managed by NAFO.



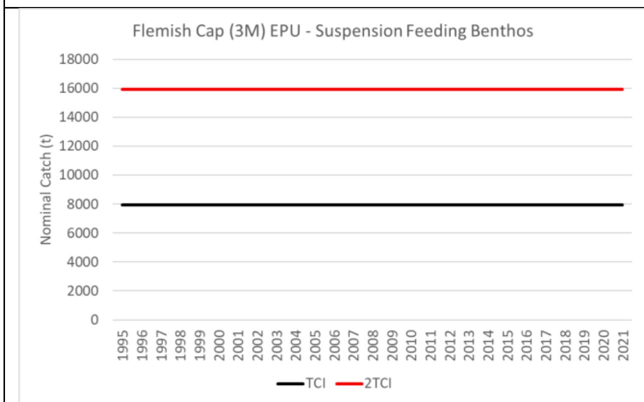
Planktivore Guild: low risk of EO

Current 2TCI=97kt

There are no fisheries directed to planktivores in this EPU.

Catches are dominated by younger ages of Atlantic cod and redfish.

A fraction of Atlantic cod and redfish catches is mapped to this functional guild to account for the planktivore production of these stocks during the early part of their life histories.

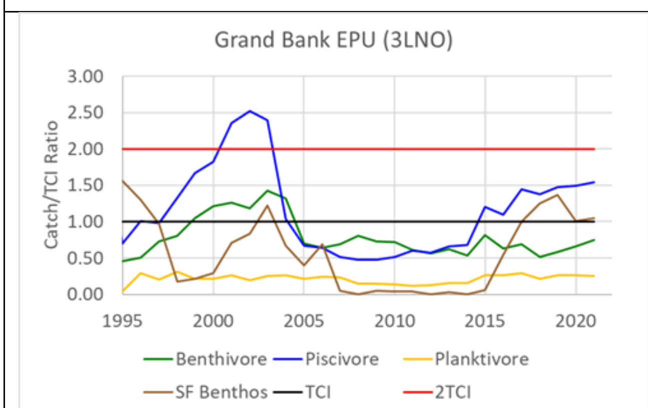


Suspension Feeding Benthos Guild: low risk of EO

Current 2TCI=159kt

There are no fisheries directed to Suspension Feeding Benthos in this EPU.

Grand Bank (3LNO) Ecosystem Production Unit (EPU)

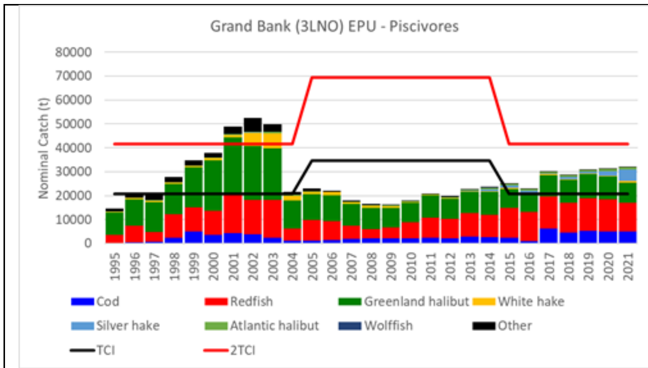


Overview

Catches for all functional guilds are below 2TCI, indicating that current fishing levels are consistent with preventing a high risk of ecosystem overfishing.

Catches for Piscivores and Suspension Feeding Benthos are between 1 and 2 TCI, indicating an intermediate risk of ecosystem overfishing.

Catches for Benthivores and Planktivores are below TCI, indicating a low risk of ecosystem overfishing.



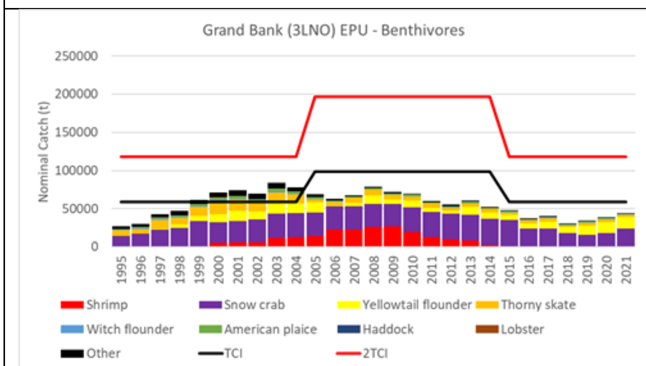
Piscivores Guild: intermediate risk of EO

Current 2TCI=42kt

Catches are dominated by redfish, Greenland halibut and Atlantic cod.

Redfish (3LN and 3O stocks), Greenland halibut (2+3KLMNO) and Atlantic cod (3NO -moratorium-) stocks are managed by NAFO, while the Atlantic cod (2J3KL -moratorium, Stewardship fishery only-) stock is managed by Canada.

Catches of silver hake are noticeably increasing since 2018, likely linked to ecosystem changes related to warming trends.

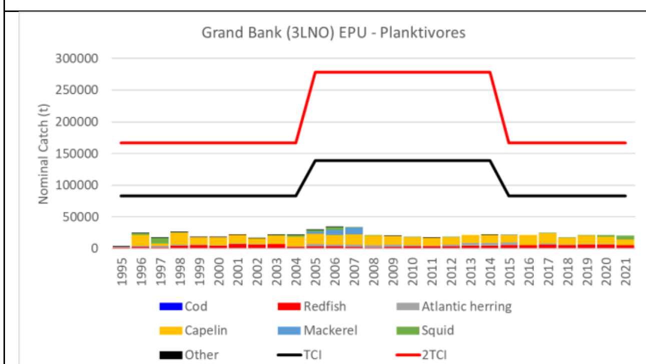


Benthivores Guild: low risk of EO

Current 2TCI=118kt

Catches are dominated by yellowtail flounder and snow crab.

Yellowtail flounder (3LNO) is managed by NAFO, while the snow crab (3L inshore, 3LNO offshore) assessment units are managed by Canada.



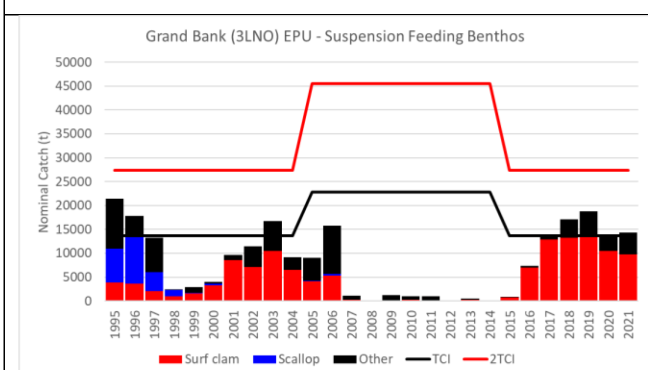
Planktivore Guild: low risk of EO

Current 2TCI=167kt

Catches are dominated by capelin (2J3KL).

Capelin (2J3KL) is a stock managed by Canada.

A fraction of Atlantic cod and redfish catches is mapped to this functional guild to account for the planktivore production of these stocks during early part of their life histories.



Suspension Feeding Benthos Guild: intermediate risk of EO

Current 2TCI=27kt

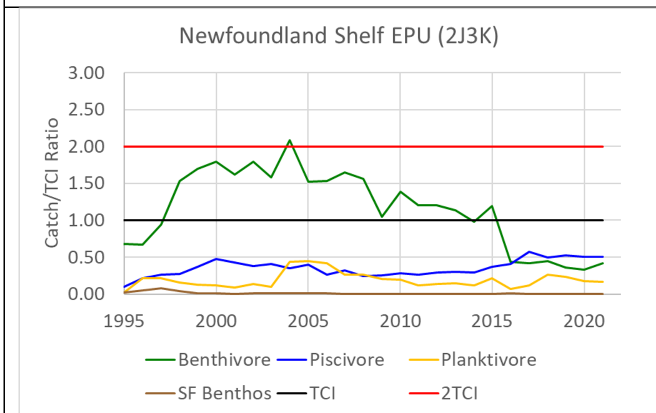
Catches are dominated by surf clam.

The surf clam fishery is managed by Canada.

As indicated above, the "Roadmap Tier 1: Summary Report on Sustainability of Catches at the Ecosystem Level" was designed to contain detailed information for only the Flemish Cap (3M) and Grand Bank (3LNO) EPUs, however, this being a case test for the utility and effectiveness of this report, a complementary piece with identically structured detailed catches for the Newfoundland Shelf (2J3K) EPU was also produced. This piece is not intended to be included in the regular reporting on TCI, but it was deemed relevant to have it available for the discussion on utility and effectiveness of the report.

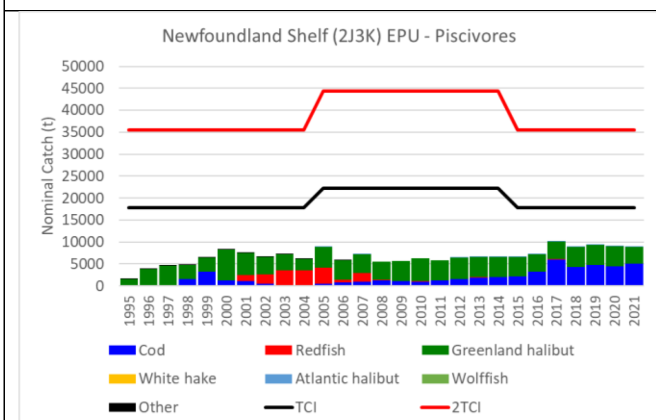
The complementary catch details for the Newfoundland Shelf (2J3K) EPU is provided below:

Newfoundland Shelf (2J3K) Ecosystem Production Unit (EPU)



Overview

Catches for all functional guilds are below 2TCI, indicating that current fishing levels are consistent with preventing a high risk of ecosystem overfishing.

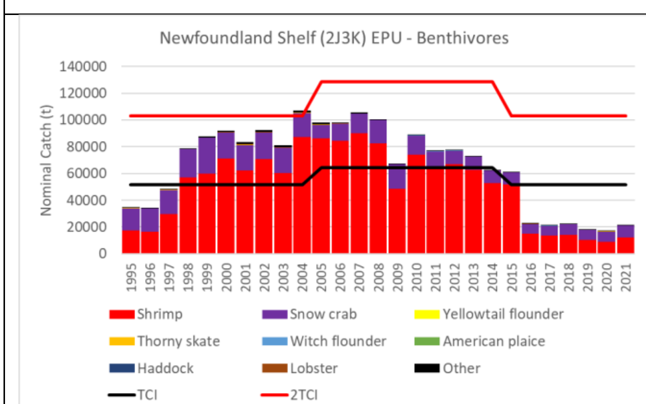


Piscivores Guild: low risk of EO

Current 2TCI=35kt

Greenland halibut and Atlantic cod.

Greenland halibut (2+3KLMNO) stock is managed by NAFO, while the Atlantic cod (2J3KL -moratorium, Stewardship fishery only-) stock is managed by Canada.

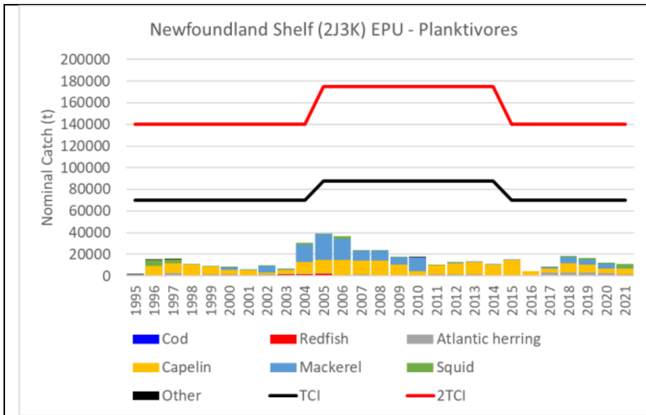


Benthivores Guild: low risk of EO

Current 2TCI=103kt

Catches are dominated by shrimp and snow crab.

Shrimp (SF6 management area) and snow crab (2HJ and 3K assessment units) are managed by Canada.



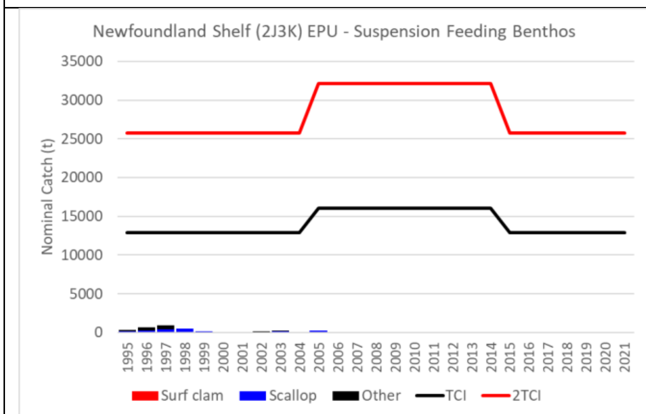
Planktivore Guild: low risk of EO

Current 2TCI=140kt

Catches are dominated by capelin (2J3KL).

Capelin (2J3KL) is a stock managed by Canada.

A fraction of Atlantic cod and redfish catches is mapped to this functional guild to account for the planktivore production of these stocks during early part of their life histories.



Suspension Feeding Benthos Guild: low risk of EO

Current 2TCI=26kt

There are no fisheries directed to Suspension Feeding Benthos in this EPU.

b) ToR 3 3.1. Development of the Grand Bank (3LNO) and Flemish Cap (3M) Ecosystem Summary Sheets (ESSs) (Com. Request 5.c).

Com. Request 5.c: *Complete the development of the 3LNO ecosystem summary sheet (ESS), advance as much as possible the development of the 3M ESS, and continue working, if capacity allows, toward undertaking a joint Workshop with ICES (International Council for the Exploration of the Sea) on reporting on North Atlantic ecosystems.*

The NAFO convention commits the organization to apply an ecosystem approach to fisheries management in the Northwest Atlantic that includes safeguarding the marine environment, conserving its marine biodiversity, minimizing the risk of long term or irreversible adverse effects of fishing activities, and taking account of the relationship between all components of the ecosystem. To fulfill this commitment, NAFO is implementing its Roadmap for an Ecosystem Approach to Fisheries (EAF).

The NAFO Roadmap requires integrating information beyond single-species, providing managers with an integrative perspective at the ecosystem level, as well as how the suite of management measures performing at that scale. The development of Ecosystem Summary Sheets (ESSs) are one element of this process. Analogous to current Stock Summary Sheets, which provide a synoptic view of the status, trends and management processes for individual target stocks, ESSs are intended to provide a synoptic perspective on the state of NAFO ecosystems and their management regime, and constitute a tool for strategic assessment, advice, and planning.

The structure of ESSs distinguishes between ecological features and management measures, aligning the summary information with the general principles adopted by NAFO in Chapter III of its convention. The current structure of ESSs is the result of input from SC and WG-EAFFM. The assessment focuses on average state (S – Status) and trend (T – Trend) over the last 5 years (Tables 6.1 and 6.2), but without losing the long-term perspective.

Table 6.1. Colour scheme for the Ecological Features of the ecosystem summary sheet and the corresponding criteria for assignment to each category for the status and trends. Contributing elements time series should be standardized to zero mean and unit standard deviation relative to an appropriate reference period.

	Ecological Features	
	Status	**Trend**
Green	The state over the last 5 years is consistent with conditions observed/estimated during high productivity/high resilience periods. (mean > 0.5 SD)	The trend over the last 5 years indicates consistent improving of the state/condition. (trend > 1 SD/5 y or >20% increase in state)
Yellow	The state over the last 5 years is consistent with conditions observed/estimated during average productivity/average resilience periods.	The trend over the last 5 years does not indicate any consistent change of the state/condition.
Red	The state over the last 5 years is consistent with conditions observed/estimated during low productivity/low resilience periods. (mean < -0.5 SD)	The trend over the last 5 years indicates consistent deterioration of the state/condition. (trend < -1 SD/5 y or >-20% decline in state)
Grey	Unknown - insufficient data to assess or assessment pending.	Unknown - insufficient data to assess or assessment pending.

Table 6.2. Colour scheme for the Management Measures of the ecosystem summary sheet and the corresponding criteria for assignment to each category for the status and trends.

	Management Measures	
	Status	**Trend**
Green	Good. Current management measures are delivering the desired results.	Good. Management measures over the last 5 years are improving conditions; moving towards/maintaining the desired results.
Yellow	Uncertain. Current management measures appear to have limited ability to deliver the desired results.	Uncertain. Management measures over the last 5 years are not improving conditions; no clear movement towards achieving the desired results.
Red	Poor. Current management measures appear insufficient to deliver the expected results or no management measure is in place.	Poor. Management measures over the last 5 years are not effective or no management measure is in place; conditions are moving away/deteriorating from the desired results.
Grey	Unknown - insufficient data to assess or assessment pending.	Unknown - insufficient data to assess or assessment pending.

Completion of the Grand Bank (3LNO) and Flemish Cap (3M) Ecosystem Summary Sheets

The completion of the ESSs included the update of information for the Grand Bank (3LNO) ESS, and the full development of the Flemish Cap (3M) ESS.

Information on the physical environment and lower trophic levels was obtained from STACFEN products (Bélanger *et al.* 2022, Cyr *et al.* 2022), while the other elements were compiled and/or produced from a diversity of sources, including data from Canadian and EU surveys, haul-by-haul data reported to NAFO, and a range of publications and information from NAFO and Fisheries and Oceans Canada (DFO), among others. Information on oil and gas was updated using information from the Canada-Newfoundland Labrador Offshore Energy Board (C-NLOEB) (http://www.cnlopb.ca), while metrics and summaries on non-NAFO Fisheries and non-NAFO VME protection have been developed based on information from DFO and the International Commission for the Conservation of Atlantic Tunas (ICCAT) for stocks in or migrating through the EPUs. A complete description of the information sources and analyses used to complete the ESSs is provided in Deering *et al.* (2022) and González-Troncoso *et al.* (2022).

In completing the ESSs, WG-ESA noted that NAFO does not have a list of species of conservation concern (invertebrates, fishes, marine mammals, sea birds, etc.) that can be used to focus monitoring of incidental mortality and/or other types of operational interactions. Developing such a list would be a necessary step to improve tracking, reporting, and assessment of this type of impact of fisheries operations.

In this context, the discussion of which species to consider led to strikethrough some text related to wolffishes in the 3M ESS for SC consideration. These species are of concern in Canada, and hence, where treated as such in the 3LNO ESS, but there is not equivalent classification for these species in 3M.

Ecosystem Summary Sheets are tentatively scheduled to be updated every 3-5 years, but a precise schedule has not been set. The updating schedule needs to be decided considering both, a reasonable time-frame from the data perspective, as well as SC and WG-ESA capacity to do the work. Furthermore, SC created two Ecosystem Designated Expert (EDE) positions in June 2022 to ensure the stability of the production and update of the Grand Bank (3LNO) and Flemish Cap (3M) Ecosystem Summary Sheets, but only one of these positions has been filled.

WG-ESA approved the appointment of Diana González-Troncoso as EDE for the Flemish Cap (3M) EPU, but the EDE position for the Grand Bank (3LNO) EPU remains vacant. No Contracting Party has provided an expert to fill this position.

The completed Ecosystem Summary Sheets for the Grand Bank (3LNO) and Flemish Cap (3M) EPUs are provided below:

3LNO Ecosystem Summary Sheet

The Grand Bank (3LNO) EPU is currently experiencing low productivity conditions, with total biomass well below pre-collapse levels (pre 1990s). Current reduced productivity appears associated to bottom-up processes. Some ecosystem indicators are showing improvements in recent years. Ongoing warming trends together with increases in warm water species suggest that this ecosystem may be starting to undergo important structural changes. VME protection in this EPU has improved between 2019 and 2021, but only two VME types out of seven are well protected. Overall catch levels are consistent with current ecosystem productivity and the prevention of ecosystem overfishing as defined by 2TCI .

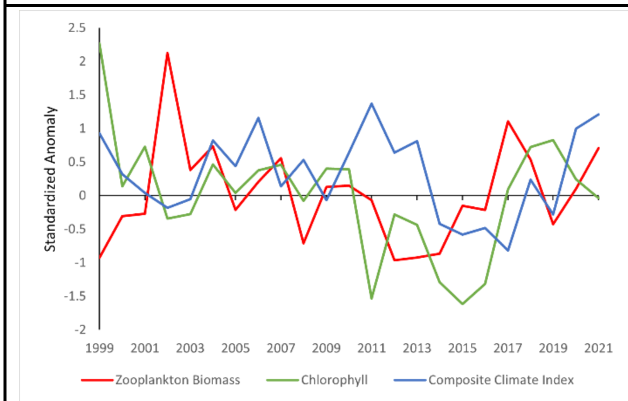
ECOLOGICAL FEATURES					
Convention Principle					**Comment**
A	**Ecosystem status and trends (long-term sustainability)**		**S**	**T**	**Summary of multiple trends/state**
	1	Physical Environment			Ocean climate index above normal conditions in 2020-2021 with 2021 being the second highest value since 1999. Clear increasing trend over the last 5 years, from below normal conditions to above normal.
	2	Primary Productivity			Chlorophyll at normal level in 2021, recovered from a prolonged below normal state in 2013-2017. Indices are dominated by cyclic changes with no clear trend.
	3	Secondary Productivity			Zooplankton biomass above normal in 2021, recovered from below normal levels in 2011-2014. Indices are dominated by cyclic changes with no clear trend.
	4	Fish productivity			Total finfish and shellfish biomass in 2020 increased since the lows in 2015-2016. Total biomass still below levels observed in 2010-2014, and remains well below pre-collapse levels. Average weight of individuals by functional group in the survey has declined since the late 2000s and remains below normal for many functional groups.
	5	Community composition			Shellfish has increased in dominance in 2015-2020 after clear declines in previous years, but piscivores have yet to regain their pre-collapse dominance. There is an increase in warm water species like silver hake and Atlantic halibut.
B	**Ecosystem productivity level and functioning**		**S**	**T**	**Summary of multiple trends/state**
	1	Current Fisheries Production Potential			Total biomass density declined from ~40-50% to ~30% of the estimated pre-collapse (pre-1990s) level between 2014-2016. Some indications of improvement in 2019-2020, but no clear trend yet. More recent information is limited due to lack of surveys.
	2	Status of key forage components			Reduced levels of capelin and shrimp, and near average levels of sandlance.
	3	Signals of food web disruption			Diet variable, declining trend in stomach content weights, with below normal levels since 2013.
E	**State of biological diversity**		**S**	**T**	**Summary of multiple trends/state**
	1	Status of VMEs			Area and biomass of VMEs are considered to be at similar levels since the start of their assessments. Differences in estimates in the 2016-2021 period are due to improvements in the evaluation methods and availability of data.

			S	T	Comment
	2	Status of non-commercial species			Based on 22 non-commercial species selected from the multispecies surveys, 60% of the species are above 20% of their historical maximum. This has increased from around 50% in 2016.
MANAGEMENT MEASURES					
Convention Principle					**Comment**
C/D	**Apply Precautionary Principle**		**S**	**T**	**Summary of metrics on level of management action**
	1	Aggregate catches and risk of ecosystem overfishing (2TCI ecosystem reference point)			All catches are below 2TCI, but with Piscivore and Suspension Feeding Benthos catches above TCI. Piscivore catches have been increasing since 2015.
	2	Multispecies and/or environmental interactions			No explicitly consideration of species interactions and/or environmental drivers.
	3	Production potential of single species			Only 66% of NAFO managed stocks (8 out of 12) are in condition of supporting fisheries; some stocks have declining trends or status unknown due to lack of recent survey information and/or absence of reference points.
D/E	**Minimize harmful impacts of fishing on ecosystems**		**S**	**T**	**Summary of metrics on level of management action**
	1	Level of protection of VMEs			All VMEs with some level of protection, but only two out of seven with good level of protection. Protection has improved between 2019 and 2022. Fishing with bottom contacting gears does not intrude in closed areas.
	2	Level of protection of exploited species			Ecosystem reference point to inform on ecosystem overfishing (2TCI) has been adopted. LRPs or HCRs are available for 80% of managed stocks but some stocks only have survey-based LRPs. No multispecies assessments are in place.
D/F	**Assess significance of incidental mortality in fishing operations**		**S**	**T**	**Summary of metrics on level of management action**
	1	Discard level across fisheries			Total discards for the NRA show a significant increase in 2018-2021. While the greatest tonnage occurs in the yellowtail flounder fishery, most fisheries show increasing trends in discards. In terms of percentage of total catch from a fishery, the reported discards relative to total catch in 2016-2021 was less than 5% for the main fisheries (redfish, yellowtail flounder, Greenland halibut, thorny skate). However, Atlantic halibut and white hake fisheries had high discard levels (15-50%) in 2016-2018.
	2	Incidental catch of depleted and/or protected species, or other species of conservation interest			Incidental catch of wolffishes in 3LNO fisheries in 2016-2021 in the NRA was low (less than 1% of survey biomass), oscillating without trend around a value of 33 t per year. Incidental catch of Greenland sharks in the NRA during the same period oscillated without trend around a value of 60 t per year. Special protection measures for this species are in place.

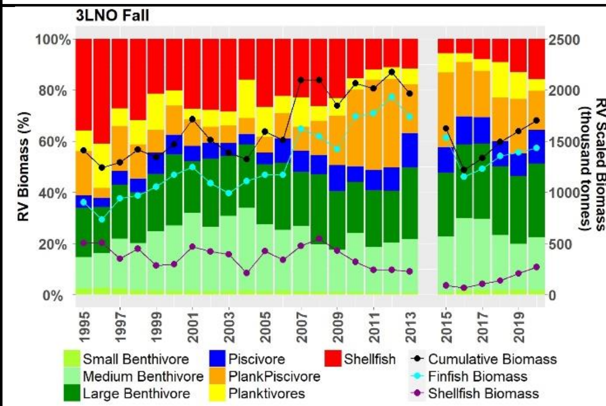
OTHER CONSIDERATIONS (outside mandate of NAFO Convention)					
Human Activities other than fisheries			**S**	**T**	**Comment**
	1	Oil and gas activities			As of 2022, there are four offshore production fields on the Grand Bank and intense exploration activities along the Flemish Pass, eastern shelf break, and oceanic areas off the eastern shelf break. The total area for 3KLMNO of licenses[5] has increased 16.3-fold from 2014 to 2021. There have been 12 reported incidents between 2015 and 2022, with a major oil spill in 2018, and one in 2019 that extended into the NRA. A proposed development project in the Flemish Pass overlaps with fishing grounds. It is expected, based on current exploration leases and development projections, that oil and gas exploration activities will continue to increase in the NRA.
	2	Pollution			The most recent information (up to 2017) indicates that there is low occurrence and density of litter in 3L and fisheries are the primary source from both NAFO-managed and non-NAFO managed fisheries. Data for more recent years has been collected in the EU surveys but has yet to be analyzed. Standardized protocols for litter data collection have been implemented in the EU surveys.
Fisheries not managed by NAFO			**S**	**T**	**Comment**
		Non-NAFO fisheries (coastal states and other RFMOs)			Among the fisheries managed by Canada in this EPU, 70% are currently supporting fisheries, and 46% have Limit Reference Points. Lack of recent survey information represents a challenge for stock-assessments. Swordfish and tuna fisheries operate in this EPU under ICCAT jurisdiction.
		Level of protection of VMEs (coastal states and other RFMOs)			Only coral and sponge VMEs are considered for protection under Canadian regulations. Among the VMEs present and covered by these regulations most have some level of protection, and one is unprotected.

[5] License types: Exploration, Significant Discovery and Production

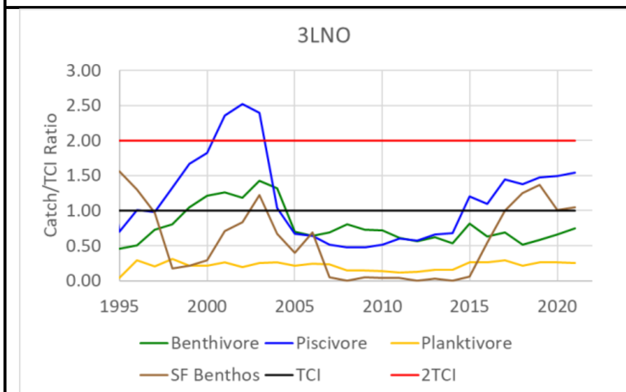
PHYISICAL ENVIRONMENT AND LOWER TROPHIC LEVELS



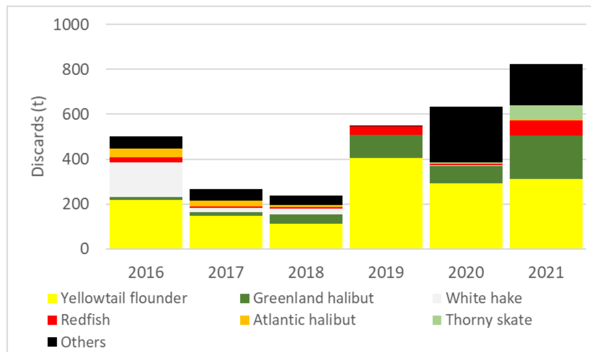
FISH COMMUNITY COMPOSITION AND BIOMASS



ECOSYSTEM AGGREGATED CATCHES



DISCARDS



Selected indicators to illustrate the 3LNO EPU status. Upper left-hand panel shows anomalies of the 3LNO subset of the NL Climate Index, chlorophyll-a, and zooplankton biomass index. Upper-right panel shows the relative composition of the fish community by functional groups from Canadian 3LNO fall survey. Lower left-hand panel shows the nominal total catch by functional guilds scaled relative to the corresponding Total Catch Index (TCI: black line; 2TCI: red line). The lower-right panel shows the tonnage of discards (total weight of all species) in each fishery from NAFO haul-by-haul catch reports and therefore include catches in the NRA only.

ECOLOGICAL FEATURES

Ecosystem Status and Trends

The last 5 years have been characterized by improved levels of nutrients and phytoplankton indices, as well as total zooplankton biomass with respect to earlier years. Small-sized copepods have significantly increased in abundance but the larger, lipid-rich taxa that are preferred prey of forage fish have been below normal in 2013-2020. After 2013-2014, total fish biomass declined and lost the gains built-up since the mid-1990s. After the lows around 2016-2017 the biomass of both finfish and shellfish has been improving but has yet to reach the early 2010s level. The piscivore functional group has not regained its pre-collapse dominance, with its proportion in biomass in the community remaining steady since 2015. Ongoing warming trends together with increases in warm water species like silver hake and Atlantic halibut suggest that this ecosystem may be starting to undergo structural changes.

Ecosystem productivity level and functioning

The Grand Bank continues experiencing low productivity conditions. After the regime shift in the late 1980s and early 1990s, this ecosystem never regained its pre-collapse biomass level. Improved conditions between the mid-2000s and early 2010s allowed a build-up of total biomass up to ~40-50% of the pre-collapse level. This productivity was associated to good environmental conditions for groundfish, and modest increases in forage species, principally capelin. Since 2013, reduced levels of capelin and shrimp, and near average levels of sandlance, have been observed; the biomass of these forage species are not showing a clear trend. A reduction in total biomass density to ~30% of pre-collapse levels occurred after 2013-2014. Some indications of improvement can be seen in 2019-2020, but no clear trend yet. More recent information is limited due to lack of research surveys. Although variable, diet composition of key predators suggests reduced contributions of forage species, and average stomach content weights of cod and Greenland halibut have shown declines, suggesting poor foraging conditions.

State of biological diversity

Biological diversity is a multi-faceted concept. Out of its many dimensions, assessment of its state is being limited to Vulnerable Marine Ecosystems (VMEs) and the number of non-commercial fish species considered depleted due to availability of appropriate analyses. Although identification and delineation of VMEs is being done, it is difficult to assess their status given the absence of a defined baseline and the unquantified impacts from historical fishing activities. In this context, area and biomass of VMEs are considered to be at similar levels since the start of their assessments in 2016. Differences in estimates in the 2016-2021 period are due to improvements in the evaluation methods and data. Based on 22 non-commercial fish species selected from the multispecies surveys, 60% of the species are above 20% of their historical maximum. This has increased from around 50% in 2016.

MANAGEMENT MEASURES

Precautionary Principles

The NAFO Roadmap addresses sustainability of fishing at three nested levels of ecosystem organization: ecosystem, multispecies and stock levels. At the present time, only considerations at the ecosystem and stock levels are in place. All catches are below the 2TCI ecosystem reference point, indicating that catch levels are consistent with current ecosystem productivity and the prevention of ecosystem overfishing. However, piscivore and suspension feeding benthos catches are above TCI. Piscivore catches have been increasing since 2015. Only 65% of the NAFO managed stocks in the Grand Bank are in conditions of supporting fishing, and some stocks have declining trends or status unknown due to lack of recent survey information. Impacts of either species interactions or environmental drivers are not currently being considered in the provision of stock advice or management.

Minimize harmful impacts of fishing on ecosystems

Minimization of harmful impacts of fishing on benthic communities has been focused on the protection of VMEs. Many coral and sponge VMEs in the Grand Bank are currently protected with dedicated closures, but the 3O coral closure provides no effective protection for the identified VMEs in that area. Closures protect 95% of sponge VME, 38% of sea pen VME, and 87% of large gorgonian coral VME biomass in 3LNO, however only 23% of black coral VME biomass is currently protected by closures for other taxa. Only 2% or less of small gorgonian corals, sea squirts and erect bryozoans VME biomass are protected.

At the ecosystem level, Total Catch Indices (TCI) for functional guilds in this EPU have been developed and an ecosystem reference point (2TCI) has been adopted to inform on the risk of ecosystem overfishing. At the stock level, 80% of managed stocks have LRPs or HCRs, although some LRPs are based on survey indices. At this time, there are no multispecies assessments to inform on trade-offs among fisheries.

Assess significance of incidental mortality in fishing operations

Total discards have shown significant increases in 2018-2021, peaking at ~800 t in 2021. Total discards were highest in the yellowtail flounder fishery, but have been increasing in other fisheries too. As a fraction of total catches, the reported discards in 2016-2021 were less than 5% for the main fisheries (redfish, yellowtail flounder, Greenland halibut, thorny skate). However, Atlantic halibut and white hake fisheries had high discard levels (15-50%) in 2016-2018.

Generally, the incidental catch of wolffish in 3LNO fisheries in 2016-2021 was low (less than 1% of survey biomass), oscillating without trend around 33 t per year. Incidental catches of Greenland sharks oscillated around 60 t per year for the same period. Special protection measures for Greenland shark were adopted in 2022.

OTHER CONSIDERATIONS

Human activities other than fishing

As of 2022, there are four offshore production fields on the Grand Bank and intense exploration activities along the eastern shelf break, oceanic areas off the shelf break, and Flemish Pass. The total area for 3KLMNO of licenses[6] has increased 16.3-fold from 2014 to 2021. There have been 12 reported incidents between 2015 and 2022, with a major oil spill in 2018, and one in 2019 that extended into the NRA. A proposed development project in the Flemish Pass overlaps with fishing grounds. It is expected, based on current exploration leases and development projections, that oil and gas exploration activities will continue to increase in the NRA.

The most recent information (up to 2017) indicates that there is low occurrence and density of litter in 3L and fisheries are the primary source from both NAFO-managed and non-NAFO managed fisheries. Data for more recent years has been collected in the EU surveys but has yet to be analyzed. Standardized protocols for litter data collection have been implemented in the EU surveys.

Fisheries not managed by NAFO

Among the fisheries managed by Canada in this EPU, 70% are currently supporting fisheries, and 46% have LRPs. Lack of recent survey information represents a challenge for stock-assessments. Swordfish and tuna fisheries operate in this EPU under ICCAT jurisdiction.

Only coral and sponge VMEs are considered for protection under Canadian regulations (classified as Significant Benthic Areas - SiBAs). Among the VMEs present and covered by these regulations most have some level of protection (large and small gorgonians, and sea pens), and one is unprotected (sponges).

References

Cyr, F., P. S. Galbraith, C. Layton, D. Hebert, N. Chen, and G. Han. 2022. Environmental and Physical Oceanographic Conditions on the Eastern Canadian shelves (NAFO Sub-areas 2, 3 and 4) during 2021. NAFO SCR Doc. 22/020. 64p.

Bélanger, D. and F. Cyr. 2022. Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS). NAFO SCR Doc. 22/021. 17p.

Deering, R. L. Gullage, N. Ollerhead, and M. Koen-Alonso. 2022. Supporting analysis and information for the completion of the Grand Bank (3LNO) EPU Summary Sheet. SCR Doc. 22/XX. XXp.

[6] License types: Exploration, Significant Discovery and Production

3M Ecosystem Summary Sheet

The Flemish Cap (3M) EPU is currently experiencing normal productivity conditions, with total biomass around the long-term level. VME protection in this EPU has improved between 2019 and 2021 with three out of five VME types well protected. Overall catch levels are consistent with current ecosystem productivity and the prevention of ecosystem overfishing as defined by 2TCI .

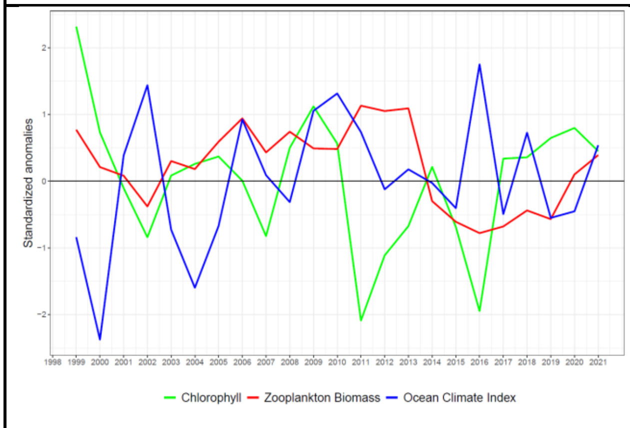
ECOLOGICAL FEATURES					
Convention Principle					**Comment**
A	**Ecosystem status and trends (long-term sustainability)**		**S**	**T**	**Summary of multiple trends/state**
	1	Physical Environment			Ocean climate index at normal conditions in 2020-2021, after a 5 year period below normal (2015-2019). Clear increasing trend over the last 5 years, from below normal conditions to normal.
	2	Primary Productivity			Chlorophyll at normal level in 2021, after being above normal in 2019-2020. Indices stable at or above normal since 2017.
	3	Secondary Productivity			Zooplankton biomass generally oscillating within the normal range in 2019-2021. Indices are dominated by cyclic changes with no clear trend.
	4	Fish productivity			Total biomass returned to average levels, after a peak in biomass in 2004-2010 driven by redfish recruitment. Shellfish remains low since the decline in shrimp. Average weight of individuals by functional group in the survey returned to normal range after increases between 2010 and 2017.
	5	Community composition			Community composition has remained relatively stable since 2010.
B	**Ecosystem productivity level and functioning**		**S**	**T**	**Summary of multiple trends/state**
	1	Current Fisheries Production Potential			Total biomass returned to average levels, after a peak in biomass in 2004-2010 driven by redfish recruitment.
	2	Status of key forage components			Reduced levels of shrimp and juvenile redfish.
	3	Signals of food web disruption			Diet composition appears generally stable over the last decade (since the decline in shrimp). Stomach content weights have been above normal since 2014. However levels are now declining back to normal levels.
E	**State of biological diversity**		**S**	**T**	**Summary of multiple trends/state**
	1	Status of VMEs			Area and biomass of VMEs are considered to be at similar levels since the start of their assessments. Differences in estimates in the 2016-2021 period are due to

			S	T	
					improvements in the evaluation methods and availability of data.
	2	Status of non-commercial species			Based on 28 non-commercial species selected from the EU survey, 60% of the species have been above 20% of their historical maximum in 2012-2021. This indicator has decreased from around 80% in 2004-2009, but remains above the 40% level observed in 1992-2002.
MANAGEMENT MEASURES					
Convention Principle					**Comment**
C/D	**Apply Precautionary Principle**		**S**	**T**	**Summary of metrics on level of management action**
	1	Aggregate catches and risk of ecosystem overfishing (2TCI ecosystem reference point)			All catches have been below 2TCI since 1995. Piscivore catches are below 1 TCI in 2021, having been between 1 and 2 TCI during 2011-2020.
	2	Multispecies and/or environmental interactions			A multispecies model with cod, shrimp and redfish has been developed for this EPU. However, it has yet to be incorporated into scientific advice. No explicit consideration of species interactions and/or environmental drivers are currently being used.
	3	Production potential of single species			66% of NAFO managed stocks (four out of six) are in condition of supporting fisheries; some stocks have declining trends.
D/E	**Minimize harmful impacts of fishing on ecosystems**		**S**	**T**	**Summary of metrics on level of management action**
	1	Level of protection of VMEs			Three out of five VME types with good level of protection, with the exception being sea pens and small gorgonians. Protection has improved between 2019 and 2022. Fishing with bottom contacting gears does not intrude in closed areas.
	2	Level of protection of exploited species			Ecosystem reference point to inform on ecosystem overfishing (2TCI) has been adopted. LRPs or HCRs are available for 50% of managed stocks but one stock only has survey-based LRPs.
D/F	**Assess significance of incidental mortality in fishing operations**		**S**	**T**	**Summary of metrics on level of management action**
	1	Discard level across fisheries			Total discards in 3M showed a significant increase (>10-fold) between 2019 and 2021. While the greatest tonnage occurs in the Greenland halibut fishery, increases are observed in other fisheries. In terms of percentage of total catch from a fishery, the reported discards relative to total catch in the 2016-2021

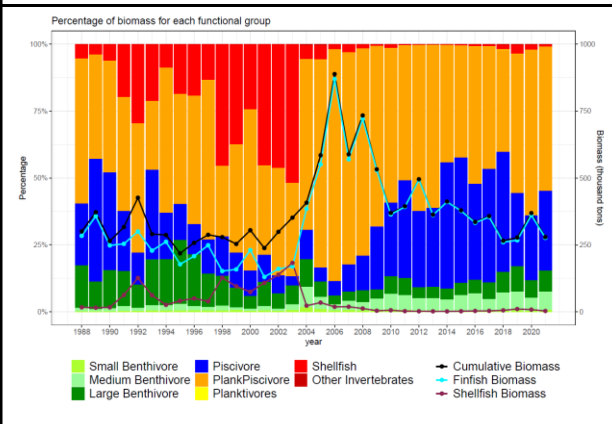
					was less or equal to 5% for the main fisheries (cod, redfish and Greenland halibut). Reporting of discards in minor fisheries is highly variable.
	2	Incidental catch of depleted and/or protected species, or other species of conservation interest			~~Incidental catch of wolffishes in 3M fisheries in 2016-2021 was low (less than 1% of survey biomass), but showed an increasing trend, doubling its magnitude during this period to reach 35 t per year in 2020-2021.~~ Incidental catch of Greenland sharks during 2016-2021 ~~also~~ showed increases, going from values at or below 15 t in 2016-2019 to around 24 t in 2020-2021. Special protection measures for this species are in place.
OTHER CONSIDERATIONS (outside mandate of NAFO Convention)					
Human Activities other than fisheries			**S**	**T**	**Comment**
	1	Oil and gas activities			As of 2022, there is intense exploration activities along the Flemish Pass. The total area for 3KLMNO of licenses[7] has increased 16.3-fold from 2014 to 2021. There have been 12 reported incidents between 2015 and 2022 in the Grand Bank, with an oil spill extending into the NRA in 2019. There is anticipated development of the Bay du Nord oil field in the Flemish Pass. This project overlaps with VME areas, a VME closure, and fishing grounds. It is expected, based on current exploration leases and development projections, that oil and gas exploration activities will continue to increase in the NRA.
	2	Pollution			There is no information of the occurrence of litter in 3M. Data has been collected in the EU surveys but has yet to be analyzed. Standardized protocols for litter data collection have been implemented in the EU surveys.
Fisheries not managed by NAFO			**S**	**T**	**Comment**
		Non-NAFO fisheries (coastal states and other RFMOs)			Swordfish and tuna fisheries operate in this EPU under ICCAT jurisdiction.
		Level of protection of VMEs (coastal states and other RFMOs)			Not applicable.

[7] License types: Exploration, Significant Discovery and Production

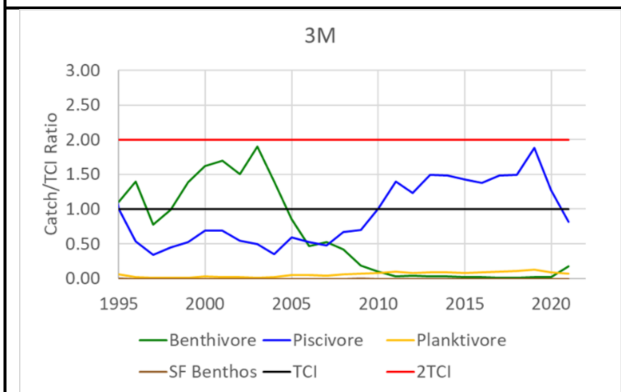
PHYISICAL ENVIRONMENT AND LOWER TROPHIC LEVELS



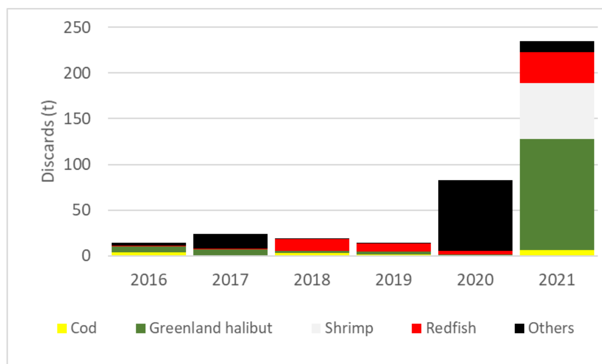
FISH COMMUNITY COMPOSITION AND BIOMASS



ECOSYSTEM AGGREGATE CATCHES



DISCARDS



Selected indicators to illustrate the 3M EPU status. Upper left-hand panel shows anomalies of the 3M subset of the NL Climate Index, chlorophyll-a, and zooplankton biomass index. Upper-right panel shows the relative composition of the fish community by functional groups from EU 3M survey. Lower left-hand panel shows the nominal total catch by functional guilds scaled relative to the corresponding Total Catch Index (TCI: black line; 2TCI: red line). The lower-right panel shows the tonnage of discards (total weight of all species) in each fishery from NAFO haul-by-haul catch reports.

ECOLOGICAL FEATURES

Ecosystem Status and Trends

Ocean climate index is at normal conditions in 2020-2021, after a 5 year period below normal (2015-2019). Clear increasing trend over the last 5 years, from below normal to normal conditions. Chlorophyll-a was at normal level in 2021, after being above normal in 2019-2020, this index has been stable at or above normal since 2017. Zooplankton biomass generally oscillating within the normal range in 2019-2021; this index has been dominated by cyclic changes with no clear trend.

Total fish biomass from the EU survey has been stable through all the period analyzed, despite values above normal in 2004-2009. Fishes have increased their dominance in the community since 2004, with a low proportion of shellfish in the ecosystem. The piscivore functional group experienced low biomass in late 1990s and beginning of 2000s, but since 2009 the level is at or above the level of the beginning of the series.

Average weight of individuals by functional group in the survey returned to normal range after increases between 2010 and 2017.

Ecosystem productivity level and functioning

The Flemish Cap (3M) EPU is experiencing normal productivity conditions. Total biomass returned to average levels, after a peak in biomass in 2004-2010 driven by redfish recruitment. In terms of key forage species, reduced levels of shrimp and juvenile redfish have been observed in this EPU since 2009. However, diet composition appears generally stable over the last decade (since the decline in shrimp) and stomach content weights have been above normal since 2014, but have been returning to normal levels in recent years.

State of biological diversity

Biological diversity is a multi-faceted concept. Out of its many dimensions, assessment of its state is being limited to Vulnerable Marine Ecosystems (VMEs) and the number of non-commercial fish species considered depleted due to availability of appropriate analyses. Although identification and delineation of VMEs is being done, it is difficult to assess their status given the absence of a defined baseline and the unquantified impacts from historical fishing activities. In this context, area and biomass of VMEs are considered to be at similar levels since the start of their assessments in 2016. Differences in estimates in the 2016-2021 period are due to improvements in the evaluation methods and data. Based on 28 non-commercial species selected from the EU survey, 60% of the species have been above 20% of their historical maximum in 2012-2021. This indicator has decreased from around 80% in 2004-2009, but remains above the 40% level observed in 1992-2002.

MANAGEMENT MEASURES

Precautionary Principles

The NAFO Roadmap addresses sustainability of fishing at three nested levels of ecosystem organization: ecosystem, multispecies and stock levels. At the present time, only considerations at the ecosystem and stock levels are in place. Catches for all functional guilds have been below the 2TCI ecosystem reference point since 1995, indicating that overall catches have been generally consistent with current ecosystem productivity and the prevention of ecosystem overfishing. Catches of piscivores have been between 1 and 2 TCI during 2011-2020 but declined below TCI in 2021. Among NAFO managed stocks, 66% (four out of six) are in condition of supporting fisheries, but some stocks are showing declining trends. Impacts of either species interactions or environmental drivers are not currently being considered in the provision of advice or management.

Minimize harmful impacts of fishing on ecosystems

Minimization of harmful impacts of fishing on benthic communities has been focused on the protection of VMEs. Many coral and sponge VMEs in the Flemish Cap are currently protected with dedicated closures. Closures protect 94% of sponge VME, 59% of sea pen VME, 95% of large gorgonian coral VME, and 76% of black coral VME biomass, but only 8% of small gorgonians VME biomass is currently protected in this EPU.

At the ecosystem level, Total Catch Indices (TCI) for functional guilds in this EPU have been developed and an ecosystem reference point (2TCI) has been adopted to inform on the risk of ecosystem overfishing. At the stock level, 50% of managed stocks have LRPs or HCRs, although some LRPs are based on survey indices. A multispecies model with cod, shrimp and redfish has been developed for this EPU. However, it has yet to be used in management. At this time, there are no multispecies assessments in place to inform on trade-offs among fisheries.

Assess significance of incidental mortality in fishing operations

Total discards showed a significant increase (>10-fold) between 2019 and 2021, going from ~13 t to ~235 t. While the greatest tonnage occurs in the Greenland halibut fishery, increases are observed in all fisheries. In terms of percentage of total catch from a fishery, the reported discards relative to total catch in the 2016-2021 was less or equal to 5% for the main fisheries (cod, redfish and Greenland halibut). Reporting of discards in minor fisheries (e.g. roundnose grenadier, witch flounder) are highly variable and with many reporting no discards.

Incidental catch of Greenland sharks during 2016-2021 also showed increases, going from values at or below 15 t in 2016-2019 to around 24 t in 2020-2021. Special protection measures for this species are in place.

OTHER CONSIDERATIONS

Human activities other than fishing

As of 2022, there is intense exploration activities along the Flemish Pass. The total area for 3KLMNO of licenses[8] has increased 16.3-fold from 2014 to 2021. There have been 12 reported incidents between 2015 and 2022 in the Grand Bank, with an oil spill extending into the NRA in 2019. There is anticipated development of the Bay du Nord oil field in the Flemish Pass. This project overlaps with VME areas, a VME closure, and fishing grounds. It is expected, based on current exploration leases and development projections, that oil and gas exploration activities will continue to increase in the NRA.

There is no information of the occurrence of litter in 3M. Data has been collected in the EU surveys but has yet to be analyzed. Standardized protocols for litter data collection have been implemented in the EU surveys.

Fisheries not managed by NAFO

Swordfish and tuna fisheries operate in this EPU under ICCAT jurisdiction.

References

Cyr, F., P. S. Galbraith, C. Layton, D. Hebert, N. Chen, and G. Han. 2022. Environmental and Physical Oceanographic Conditions on the Eastern Canadian shelves (NAFO Sub-areas 2, 3 and 4) during 2021. SCR Doc. 22/020. 64p.

Bélanger, D., and F. Cyr. 2022. Environmental indices for NAFO subareas 0 to 4 in support of the Standing Committee on Fisheries Science (STACFIS). SCR Doc. 22/021. 17p.

González-Troncoso, D., I. Garrido, C. González, L. Gullage, D. Belanger, F. Cyr and M. Koen-Alonso. 2022. Supporting analysis and information for the completion of the Flemish Cap (3M) EPU Summary Sheet. NAFO SCR Doc. 22/055.

c) ToR 3.2. Potential impact of activities other than fishing in the Convention Area (Com. Request #12)

Com Request 3.2: *The Commission requests Secretariat and the Scientific Council with other international organizations, such as the FAO and ICES to inform the Scientific Council's work related to the potential impact of activities other than fishing in the Convention Area. This would be conditional on CPs providing appropriate additional expertise to Scientific Council".*

i) Update on oil and gas activities

The issue of the potential impacts of activities other than fishing, is a matter of continuing concern in NAFO (NAFO, 2018, 2019, 2020, 2021). This year (NAFO, 2022a), SC reiterated its prior advice that *"there are a number of activities occurring in the NRA (especially oil and gas) which appear to have significant spatial overlap with NAFO bottom fisheries, NAFO closures and VMEs, and have the potential to impact fisheries resources and the ecosystem. These activities have increased in recent years"*. As documented in the scientific literature, routine oil and gas activities can have detrimental environmental effects during each of the main

[8] License types: Exploration, Significant Discovery and Production

phases of exploration, production, and decommissioning (Cordes *et al.*, 2016). Environmental effects include impacts from routine operational activities such as drilling waste and produced water discharges (Neff *et al.,* 2011; Neff *et al.,* 2014), accidental discharges and spills (e.g. Cordes *et al.,* 2016), long-term impacts on deep-sea corals (e.g., Girard and Fisher, 2018) and impacts on deep-sea sponges and their associated habitats (Vad *et al.,* 2016).

The spatial information presented during the 15th WG-ESA was obtained through a review of publicly available data sources[9], including a report (Equinor, 2020) on a development project located in the Flemish Cap ("Bay du Nord Development Project").

Spatial location of oil and gas activities and potential conflicts

The updated map of the geographical location of oil and gas activities in NAFO Divs. 3LNM is presented in Figure 6.1. New spatial data (licences and wells) was available this year. In comparison with the information assessed previously reported by the WG-ESA (Durán Muñoz and Sacau, 2021; NAFO, 2021), there are two new "Exploration Wells" in Division 3L, one of them located inside NAFO fishing grounds. In the map, the yellow star indicates the location of the proposed production installation within the "Bay du Nord Development Project" in the Flemish Pass (outlined in blue). Some of the exploration and proposed production activities related to this project, appear to have significant spatial overlap with NAFO bottom fisheries (Division 3L and 3M), VMEs (Division 3M) and NAFO closure No 10 (Division 3M):

- *<u>Overlap and potential conflicts between oil and gas activities and NAFO fisheries</u> (e.g. reduction of fishing opportunities, ecosystem impacts, etc.), particularly in Division 3M, in the northern part of the project area where there is overlap between a "Significant Discovery Licence" (and their associated wells) and NAFO fishing grounds (see Figure 6.1), in an area where the Greenland halibut bottom trawl fishery takes place[10] (NAFO, 2020).*
- *<u>Overlap and potential conflicts between oil and gas activities, VMEs and VME Area closure No 10</u> (e.g. impacts on VMEs). It is worth noting that the overlap with VMEs and closed areas in Division 3M has increased substantially in recent years (Figure 6.2) due to both the increase in the number of licenses (i.e. "Significant Discovery Licenses") and the expansion of Area closure No 10, implemented by NAFO (NAFO, 2022b). Moreover, there has also been an increase in the number of "Exploration Wells" within the project area, and some of them are located inside fishing grounds, VMEs or a VME closed area (Figure 6.2).*

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[9] Available data was collected mainly from the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) and the Impact Assessment Agency of Canada (IAAC).

[10] Detailed maps of the footprint of the Greenland halibut trawl fishery (GHL-OTB-3LMNO) are available in the 2020 WG-ESA report.

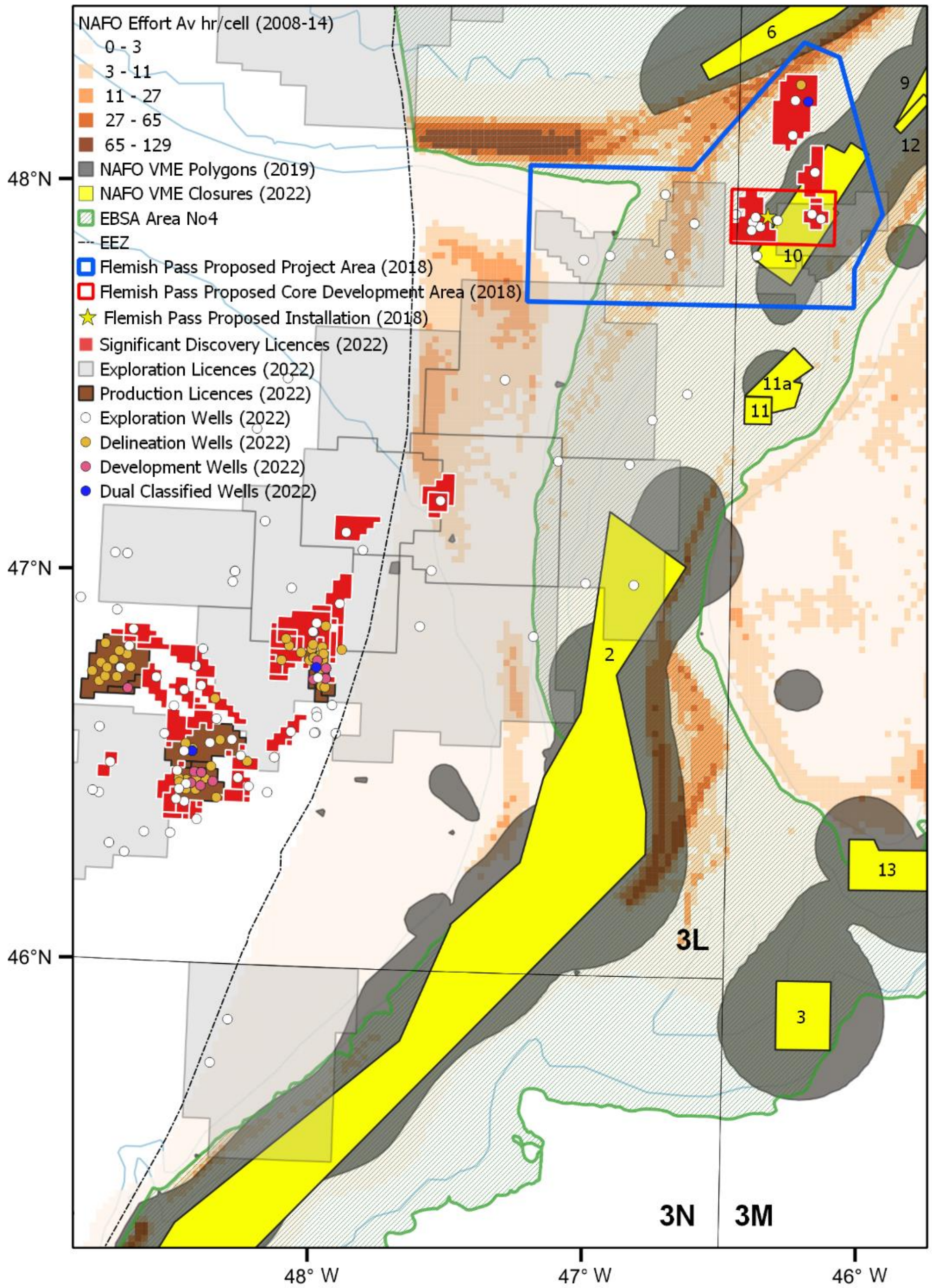

Figure 6.1. Updated map showing the geographical location of oil and gas activities in NAFO Divs. 3LNM. The map shows the potential conflict areas between different users of the marine space (e.g. oil and gas vs. fisheries) and between users and the marine environment (oil and gas vs. VMEs). The yellow star indicates the location of the proposed production installation within the "Bay du Nord Development Project" in the Flemish Pass (outlined in blue). The available spatial information on oil and gas activities (licences and wells) – at the reporting date, November 2022 – is noted in brackets (2022). Sources: NAFO, C-NLOPB and CBD.

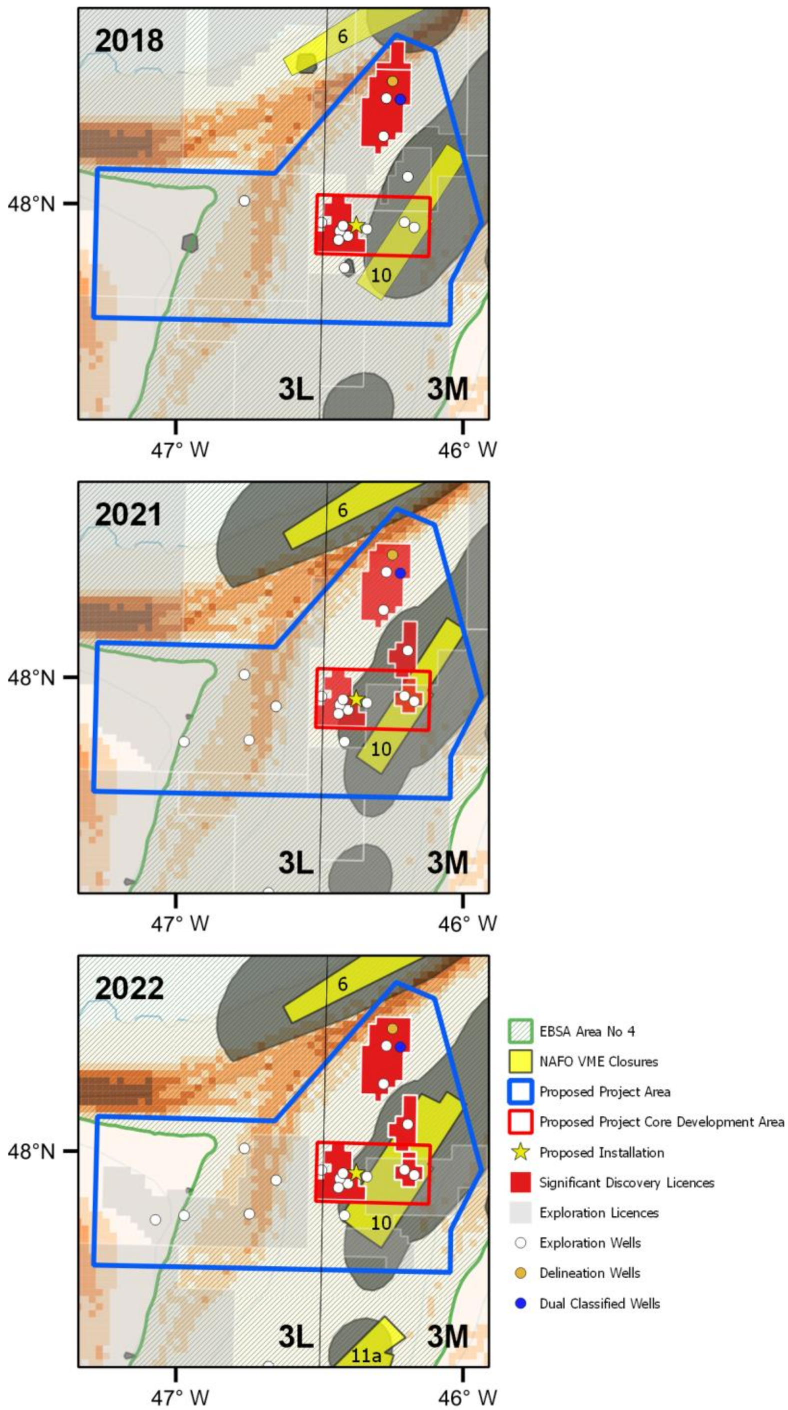

Figure 6.2. "Bay du Nord Development Project". Evolution over time of the degree of overlap between oil and gas activities, VMEs and VME Area closure No. 10 (2018 -2022). There has been an increase in overlap due to both the increase in the number of "Significant Discovery Licenses" and the expansion of Area closure No 10. In addition, the number of "Exploration Wells" within the project area has also increased.

Another issue of concern is the overlap between oil and gas activities and NAFO groundfish surveys (e.g. restriction of sampling area and depth) and its potential effects on survey indices (e.g. abundance and biomass) and VMEs monitoring. Figure 6.3 shows the survey strata (Doubleday, 1981; Bishop, 1994) potentially affected by the oil and gas project in Division 3L (strata 731, 732, 733, 734, 745, 746 and 747; depths from 367 to 1280m) and Division 3M (strata 528, 529, 530, and 532; depths from 732 to 1463m). The location of survey hauls (EU and EU-Spain surveys) during the period 1988-2021 is also presented.

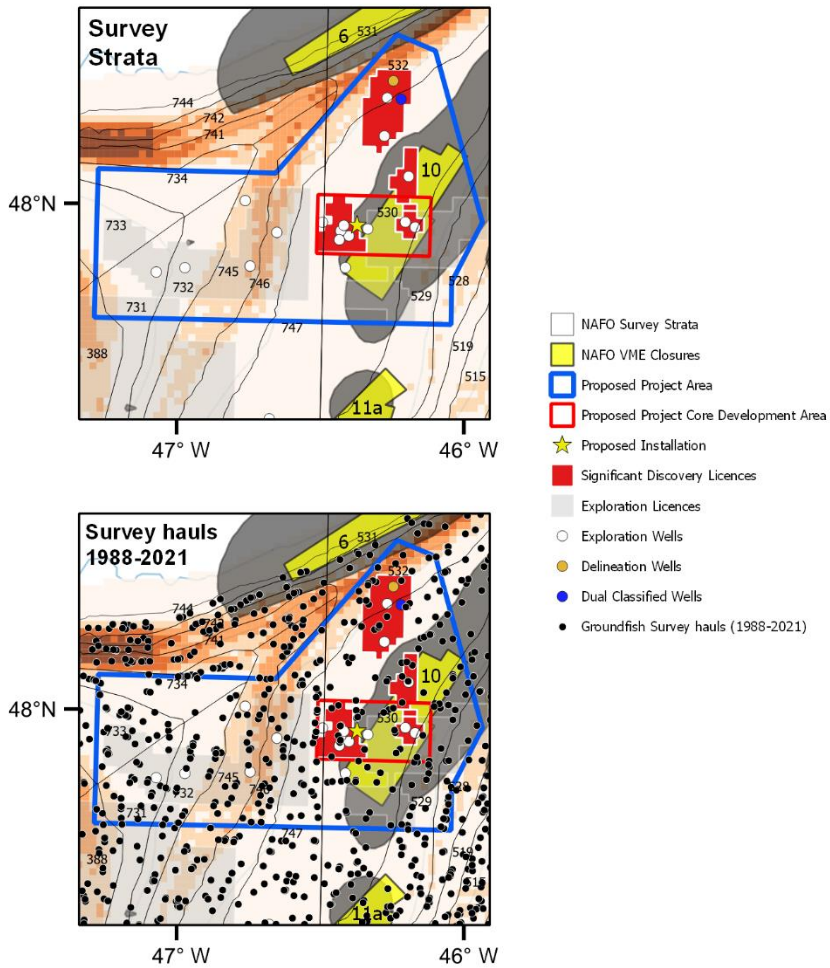

Figure 6.3. "Bay du Nord Development Project". The map shows the potential conflicts between oil and gas activities and groundfish surveys conducted in Divisions 3L and 3M, based on survey stratification and data from EU and EU-Spain surveys (start position of survey hauls, period 1988-2021).

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d) ToR 3.3. Evaluation of impacts related to scientific trawl surveys on VMEs (Com. Request #3)

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

ToR 3.3. Evaluation of impacts related to scientific trawl surveys on VMEs (COM Request #3).

> **Com. Request #3:** *The Commission requests that Scientific Council continue its evaluation of the impact of scientific trawl surveys on VME in closed areas and the effect of excluding surveys from these areas on stock assessments.*

WG-ESA reviewed all available analyses from relevant Canadian and EU surveys on the impacts of excluding bottom-trawl surveys from VME closed areas, as well as the impacts these surveys may have on these VMEs. Based on this review, WG-ESA concluded that the evidence does not support a blanket exclusion of research surveys from all protected areas. Impacts from research surveys are not generally considered to cause long-term harm to VMEs as the recurrence time for the surveys is expected to allow sufficient time for VMEs to recover. Notwithstanding this general conclusion, scientific trawls do damage VMEs, and it is good scientific practice to maximize effort to a) avoid, minimize and/or compensate for these impacts, and b) maximize the collection of VME data when these trawls take place. WG-ESA develop a guidance framework to assist survey planning and design to mitigate impacts on VMEs.

The Commission requested that Scientific Council (SC) continues its evaluation of the impact of scientific trawl surveys on VME in closed areas and the effect of excluding surveys from these areas on stock assessments.

Following up on the SC response to COM from June 2022 on this topic, WG-ESA reviewed the work previously carried out by Canada and the EU to examine the issue of scientific surveys with bottom contacting gears sampling in protected/VME areas. Brief summaries of these analyses are included below:

Canada's framework and its application to surveys in the Gulf of St. Lawrence

The establishment of protected marine areas in Canada and worldwide has accelerated in recent decades. Data from large scale bottom-contacting marine surveys (typically bottom-trawl) are often used to identify protected areas, resulting in a substantial spatial overlap between them. In protected areas with defined benthic conservation objectives, scientific sampling with bottom-contacting gear is often viewed as inconsistent with those objectives. Meanwhile, the large-scale surveys provide data critical to inform science-based decision making related to the conservation of harvested marine resources, species of conservation concern and macro-faunal communities in the broader ecosystem. This situation generates a need to evaluate and balance risks associated with a diversity of conservation objectives. In 2018, Fisheries and Oceans Canada's (DFO) developed its national Framework to support decisions on authorizing scientific surveys with bottom-contacting gears in protected areas with defined benthic conservation objectives to guide the evaluation of ongoing recurrent scientific activities (surveys), within protected areas. The Framework evaluates four main elements: 1) the potential impact of recurring survey activities within protected areas, 2) potential mitigation measures to reduce their impact, 3) benefits of survey activities to the management of protected areas and 4) potential consequences to the scientific understanding and management of species and communities in the broader ecosystem caused by excluding sampling in protected areas. This framework was applied in 2019 to 15 protected areas and eight recurring marine resource and ecosystem surveys of the Gulf of St. Lawrence in a formal review process. The evaluation indicated that recurring surveys are unlikely to hinder the achievement of benthic and demersal conservation objectives in most of the protected areas, but was less certain for survey activities in designated sponge conservation areas given gaps in the available information. Two mitigation measures have since been applied: a reduction of the number of surveys operating in certain coral and sponge areas, and a gear change that has cut by more than half the footprint of a major trawl survey. A retrospective analysis indicated that the broader scale monitoring of certain taxa would likely be compromised by exclusion of some surveys from a number of protected areas. Meanwhile all multi-species surveys were found to collect some information that could support scientific understanding and evidence-based decision making within the protected areas, at least in the short term. Based on the review, a multisectorial working group involving scientists and managers (fishery and protected areas) formulated recommendations to senior DFO management to maintain bottom-contracting survey activities in the protected areas, conditional on simple annual reporting and a defined list of conditions under which a re-evaluation would be undertaken. These recommendations were adopted and have been in effect since 2021.

Application to Newfoundland-Labrador surveys

A network of protected areas has been created by Canada to guard sensitive benthic taxa and critical fish habitat from anthropogenic activities such as the potential damaging effects of commercial fishing with bottom trawls and other bottom-contacting gears. Here we followed Fisheries and Oceans Canada's 2018 framework to advise on the risks posed to sensitive benthic taxa by bottom-contacting scientific surveys relative to the consequences of not having data collected in those protected areas by scientific surveys. We included both Canadian and NAFO protected areas. Analyses demonstrated that the footprint of Canadian surveys is magnitudes lower than that of commercial bottom trawl fishing, and suggested that ongoing research activities that use bottom-contacting gears within the protected areas should not hinder the conservation objectives of those closures. In addition, the loss of survey data within the protected areas could create problematic biases in terms of oceanographic data as well as general ecosystem and single-stock indices used to provide broad scale science advice. Despite these findings, the recommendation was still made to explore potential mitigation measures when possible. However, these mitigation measures should not only reduce the potential impacts of bottom-contacting surveys but also do so without compromising newly collected data relative to existing time series. While switching to less intrusive surveying methods (cameras, acoustics, eDNA) could reduce the impacts on sensitive benthic taxa, none of these methods are currently able to replace bottom-trawl surveys in a multispecies context and would disrupt many of the data time series that DFO relies on for the provision of science advice. More applicable mitigation measures currently being employed in Canadian NL surveys include small movements of fishing set locations to place them outside of protected areas, selecting alternate set locations to replace sets positioned within protected areas, reducing the number of sets allocated to strata that overlap with protected areas, and reducing the duration of fishing sets within protected areas. While it was recognized that monitoring benthic taxa within protected areas would best be done by replacing bottom-contacting gears with less intrusive options (e.g. camera technology), it was also recognized that this could compromise the ability to evaluate closure objectives not specifically related to benthic taxa.

Application to EU surveys in the NRA

In 2009, the Fisheries Commission established several coral and sponge protection closures areas to bottom fisheries within the NAFO Regulatory Area that were applied in 2010. Three random-stratified bottom trawl surveys are performed by the EU annually in the NAFO Regulatory Area: Spanish Div. 3NO (Spring), Spanish and Portuguese in Div. 3M (Summer) and Spanish Div. 3L (Summer). SC was asked to evaluate the impact of surveys on VMEs in closed areas in the NRA and the effects of excluding surveys from these areas on stock assessments. Analyses indicate that removal of survey sampling within the closed areas have a significant impact and potentially biases the abundance and biomass indices of certain species, particularly Greenland halibut and roughhead grenadier. It is especially pronounced at some ages/lengths for these and other species. The application of the Canadian Framework to EU and Canadian scientific surveys in closed areas in the NRA indicated that for sea pens, which have a shorter lifespan than large gorgonians and sponges, survey recurrence times would reasonably allow recovery in the closed areas. For large gorgonians and sponges the conclusions were not as clear due to the lack of information about longevity of some of the coral and sponge species. Reducing the trawling time in EU surveys from 30 to 20 minutes within closed areas would not jeopardize the survey operations, while considerably increasing the recurrence time to around 1500 years, allowing for sufficient time for sea pens to recover, and measurably improving the conditions for recovery of the longer-lived VME species.

General observations and conclusions

The surveys analyzed are the basic source of fisheries independent data to produce the management advice. However, trawl surveys are known to impact benthic species and habitats by causing immediate harm or mortality. These effects can also be cumulative over time. The potential for these sensitive species to recover is determined by biological parameters such as low productivity, extreme longevity (from 100s to >1000s of years), as well as the long period of time over which some of these habitats develop. Considering recurrence time allows evaluating if the time between trawl impacts is sufficiently long in relation to these parameters to assume that recovery of the habitat is possible. If this time is long enough, then the impact of the survey can thought to be less harmful.

The impacts of surveys and fisheries on VMEs differs by orders of magnitude. While bottom-contacting scientific sampling gears can have similar damaging impacts on vulnerable benthic taxa as commercial fishing gears per unit of effort, the difference in overall impact stems from the orders of magnitude difference between fishing and surveys effort.

A review of the analyses carried out for Canadian and EU surveys across multiple ecosystems did not support a blanket exclusion of research surveys from all protected areas. Survey recurrence times in relation to expected recovery times suggest that bottom-contacting science surveys do not pose a major long-term threat to benthic ecosystems. On the other hand, the review of excluding closed areas from the surveys indicated that survey indices would be impacted and in some cases biased, making them unreliable for scientific advice. These surveys also play a role in monitoring conservation objectives of the protected areas. While bottom-contacting surveys are not the best option for monitoring vulnerable benthic taxa, when these surveys occur efforts must be made to improve sampling protocols to maximize the information gathered from these surveys in relation to benthic taxa in protected areas. Although the surveys analyzed here may not pose a serious long-term threat to benthic taxa, mitigation measures should still be considered to minimize harm. Such measures could include moving sets outside the VME closed areas if possible, avoiding areas of particularly high density of VMEs within the closed areas, shortening the survey time within the closed areas, reducing the number of sets in the stratum within the closed areas and/or compensating for survey impacts by enlarging the closed areas and removing fishing effort from VMEs. An example framework to apply these measures is provided in Figure 6.4. This could be considered when developing a survey plan.

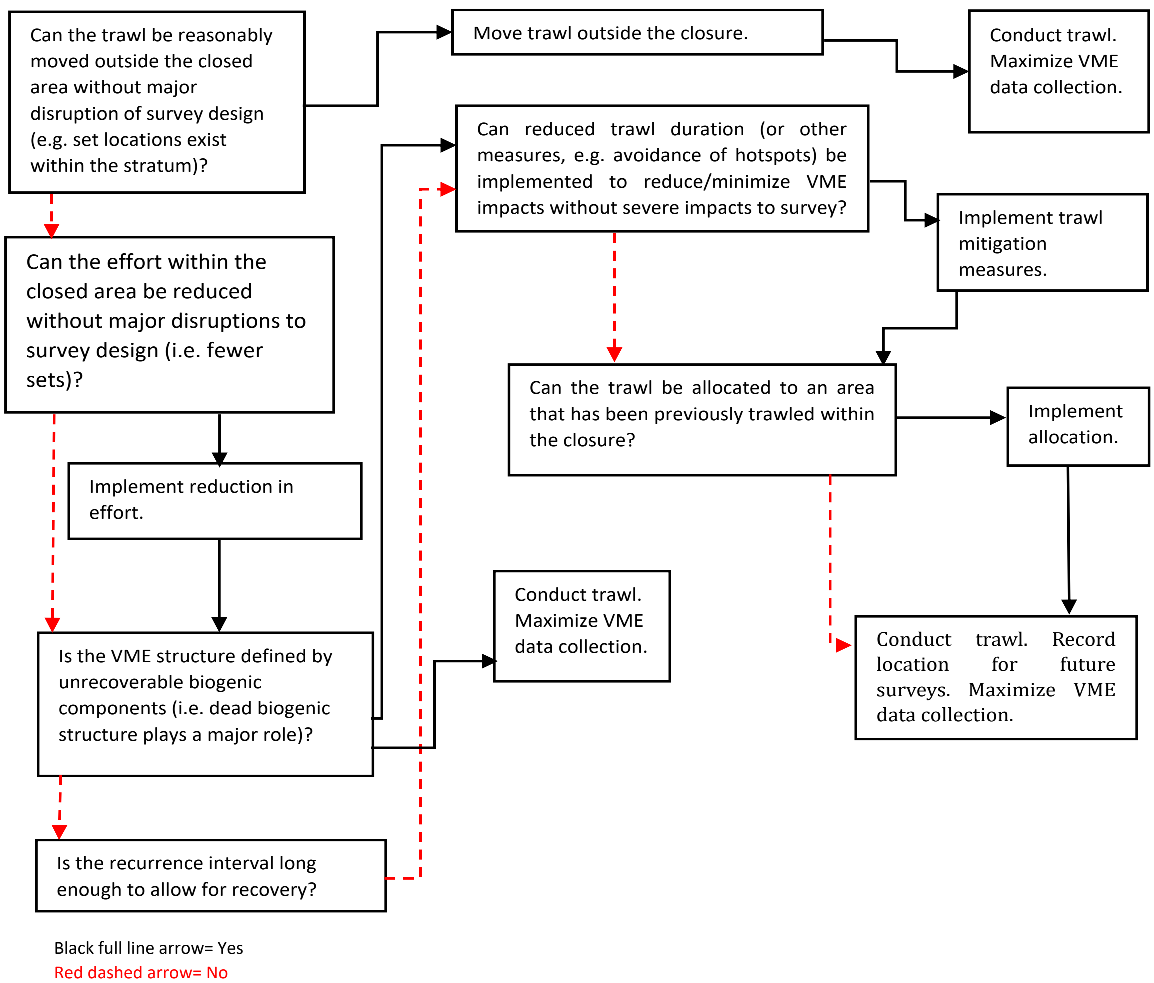

Figure 6.4. Framework to assist the planning and design of scientific bottom-trawl surveys to mitigate impacts from surveys on VME closed areas.

e) ToR 3.4. Continue working towards developing operational objectives for the protection of VMEs and biodiversity in the NRA (Com. Request #6.c)

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

c) continue working with WG-EAFFM towards developing operational objectives for the protection of VMEs and biodiversity in the NRA.

The implementation of the NAFO ecosystem roadmap necessitates developing long-term plans with clear priorities and objectives, in addition to having the means to monitor and assess progress towards those goals and objectives as part of a management processes or frameworks (Tunnicliffe, *et al.,* 2020). An example of such a management framework was presented to WG-ESA as shown in Figure 6.5, which introduces a hierarchy of terms that are commonly used to track organisational performance, including those related to marine biodiversity conservation, e.g. through the setting of goals, objectives, targets and indicators (Table 6.3). The framework requires defining priorities, thereby focusing the organization and stakeholders on how activities and operational resources are allocated. Furthermore, the priorities can guide formulation of objectives which are understandable by all participants.

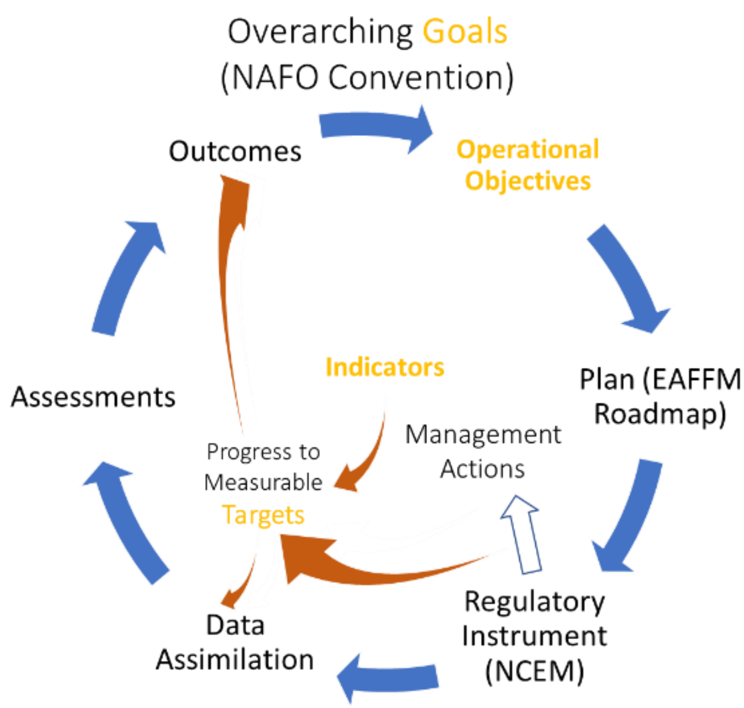

Figure 6.5. Adapted from Tunnicliffe et al., 2020, a simplified representation of a management process or framework setting goals and objectives that can proceed to implementation of policy and management actions, indicating the role of NAFO plans and regulations in developing a strategic approach and overseeing outcomes through measurable targets and the application of indicators.

The principle of setting environmental goals and objectives is demonstrated in several international fora, e.g. UN SFA, CBD, UN Conference on Sustainable Development. However, significant challenges remain on agreement of the specific indicators to assess performance relative to the targets and objectives set in these agreements – and this is also a challenge for the principals outlined on the NAFO Convention.

Table 6.3. Definition of terms typically used track organisational performance with respect to management processes and frameworks. After C. Ehler, (2014)

Term	Definition
Goal	A statement of general direction or intent. Goals are high level statements of the desired outcomes to be achieved.
Objective	A specific statement of desired outcomes that represent the achievement of a goal.
Target	An interim point on the way to an outcome and eventually to a long-term management goal.
Indicator	A quantitative or qualitative statement or measured parameter that can be used to measure the effects of specific management actions over time.

Examples of goals associated with the protection of marine resources, including biodiversity, are those given in the first global integrated marine assessment conducted by the United Nations (Inniss & Simcock, 2017) e.g. "maintain long-term sustainability, as well as local and immediate enhancement of human well-being within the carrying capacity of the biophysical system", and in the text of the NAFO Convention e.g. "apply an ecosystem approach to fisheries management… that safeguards the marine environment, conserves its biodiversity, minimizes the risk of long term or irreversible adverse effects of fishing activities…" (NAFO, 2017). Specifically, in relation to ecosystem-based fishery management, Link (2010) proposes 5 goals that are clearly relevant to the work of NAFO, and which map well onto the primary elements (and Tiers) of the NAFO ecosystems roadmap and the principals of the NAFO Convention as shown in Table 6.4.

Table 6.4. The relationship between EBFM goals as identified by Link (2010) and the primary elements (and Tiers) of the NAFO ecosystem roadmap and the NAFO Convention principals.

EBFM Goals	NAFO Ecosystem Roadmap	NAFO Convention Principles
Prevent overfishing	Tiers 1 to 3	b, c, f
Protect critical, sensitive species and habitats	VME closures & by-catch measures	d, i
Conserve biodiversity	VME closures	d, e. i
Maintain trophic resilience	Tiers 1-2 & VME closures	d, e, i
Maximise societal benefits (subject to the previous goals).	Tier 3 & all elements	a, b

In addressing Commission Request #6c and working with WG-EAFFM towards developing operational objectives for the protection of VMEs and biodiversity in the NRA – the focus of discussions in WG-ESA was in relation to the work undertaken on the identification and mapping of VME (SCS 19/25) and the assessment of SAI (SCS 20/23). Furthermore, potential NAFO biodiversity objectives should take into account the principles set out in the Convention of Biological Diversity, specifically Principle 6 which states "ecosystems must be managed within the limits of their functioning" (CBD, 2004). Indeed, establishing targets related to the current metrics used in NAFO to assess SAI and prevent ecosystem overfishing were considered appropriate starting points for setting operational objectives, but it was also acknowledged that this does not represent everything that could be included and of relevance in ensuring positive biodiversity outcomes, e.g. the SAI metrics do not consider the protection of PET species such as sharks, seabirds, marine mammals, or other non-VME related bycatch species.

WG-ESA agreed the framework definitions as outlined in Table 6.3, which are internationally recognised by the Intergovernmental Oceanographic Committee of UNESCO (Ehler, 2014). They follow a logical hierarchy of terms that could be used to define and track the implementation of operational objectives for the protection of biodiversity and prevention of ecosystem overfishing in the NRA as proposed in Table 6.5, but further discussion and analysis will be required to establish suitable targets (or reference values) to achieve low risk of SAI. Accordingly, WG-ESA considered that providing details of the current operational indicators in the framework outlined in Table 6.5 was not appropriate at this stage, since the framework has yet to be formerly approved by SC.

Table 6.5. Proposed operational objectives for the protection of biodiversity and prevention of ecosystem overfishing in the NRA

***Overarching Goal*[11]**	***Goal*[12]**	***Objective*[13]**	***Target*[14]**	***Indicator*[15]**
Apply an ecosystem approach to fisheries management and safeguard the marine ecosystems in the NRA	Protect and conserve biodiversity and ecosystem integrity and functioning in the NRA	Protect and conserve biodiversity at levels that can maintain 'baseline' ecosystem-integrity, structure, and function.	Achieve low risk of SAI	Risk level of SAI
	Prevent ecosystem overfishing	Maintain ecosystem-level fishing pressure at sustainable levels	Achieve low risk of ecosystem overfishing	TCI
NAFO Convention Text		NAFO Convention Article II – Objective: Long-term conservation and sustainable use of fishery resources.	Article III – General Principles: (e) take due account of the need to preserve marine biological diversity, (b) adopt measures based on the best scientific advice available	

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[11] Statement of intent – from the NAFO Convention text.

[12] Desired outcome.

[13] Specific desired outcome.

[14] A measurable point on the way to an outcome, for TCI these targets have been set and for VME we have the proportion of biomass protected.

[15] A measured parameter used to assess the effects of management actions against targets and objectives – e.g. TCI and VME biomass.

CBD (2004). Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Seventh Meeting. UNEP/CBD/COP/DEC/VII/11. Kuala Lumpur, 9-20 and 27 February 2004. https://www.cbd.int/doc/decisions/cop-07/cop-07-dec-11-en.pdf

THEME 4: OTHER MATTERS

7. Other business

a) The FAO ABNJ Deep-Seas Fisheries Project

Fred Kington, NAFO ES, introduced the FAO ABNJ Deep-Sea Fisheries (DSF) project and explained that it follows on from the FAO Deep-sea project that was executed from 2014-2019.

Tony Thompson, FAO, elaborated on the DSF Project that was developed cooperatively with deep-sea fisheries stakeholders to support sustainable bottom fisheries and eliminate significant adverse impacts. The project partners include all seven RFMOs managing bottom fisheries, ICES, ICFA and SIODFA industry groups, and NOAA from the USA. The project will hold its inception workshop in January 2023 where details of the initial work plan and reporting obligations will be discussed.

Initial work areas of the DSF Project, most relevant to WG-ESA, include recording impacts on deepwater sharks, mapping VMEs, mapping deepsea fisheries, review of the implementation for the DSF Guidelines, rapid stick assessments, and the review of various frameworks. The early work of the DSF project will generally focus on data collection methodologies.

Deep-Ocean Observing Strategy (DOOS) working group on Science Translation

The DSF project presented an initiative proposed by DOOS so that WG-ESA could give guidance to the DSF Project on the relevance of this to both RFMOs generally and to the DSF Project. The initiative was for DOOS to survey the use of deep ocean observation platforms by RFMOs in the course of undertaking their science work. This would serve to inform RFMOs of the variety of deep-sea observations systems currently deployed and inform DOOS of the current use of such systems. It is hoped that the sharing of information on what is available and matching the needs of RFMOs will improve sustainable fisheries and reduce impacts.

The work plan is that the DOOS working group will undertake the work and compile the review, and the DSF Project will use its network to facilitate the process with RFMOs.

The WG-ESA participants felt that the review by DOOS would be useful and encourage it to focus on systems that were in regular use in other regions, i.e. moved beyond the experimental and exploratory stage, and should include platforms that record physical, chemical, and biologically data sets, including images and video. This could include, for example, permanent or semi-permanent deployments and instruments attached to fishing gear. The emphasis should be on deep-ocean systems, say below 200 m. The recording of catches made by fishing gears was seen as both less useful and more difficult to quantify in the context of this DOOS review. The DSF Project thanked WG-ESA for their guidance.

b) FAO/NAFO Symposium on ecosystem production models (and the NAFO roadmap).

Tony Thompson made a further presentation on the suggestion of holding a symposium (workshop, conference) on ecosystem production models that allow for the estimation of total fish production from primary production inputs. This can be compared with harvested fish yields to determine if ecosystem overfishing has or is occurring. NAFO has pioneered this approach following the development of its ecosystem roadmap and the adoption of a total catch index threshold at its 2022 annual meeting in Porto, Portugal. Tony Thompson explained that the outcomes of the symposium would be the introduction of an ecosystem approach to fisheries that could be applied in different regions and be used to assess the effects of ecosystem change, including climate change, on ecosystems health including ecosystem overfishing.

The matter was discussed among participants and the following was tentatively agreed:

- *The format would be a hybrid symposium (with presentations) and workshop (focused discussion/analysis sessions) format.*
- *A framework will be developed to guide the meeting and provide focus. This will include the estimation of fish production from primary production (or similar) that could be used to provide a total catch index to just ecosystem overfishing. The incorporation of this into management action will form part of the framework.*
- *The NAFO road map with be used as a focus, but recognizing the same objectives may be achieved in different ways on different regions.*
- *The symposium will be global in scope with an ABNJ focus.*
- *The symposium will be organized by FAO DSF Project and NAFO (with the DSF project undertaking the majority of the workload). Additional organizing partners from the north Atlantic will be explored in the near future. Financial arrangements will be agreed when the organizing partners are decided.*
- *The technical aspects of the meeting will be governed by a steering committee to be decided by the organizing partners.*
- *The symposium is expected to be held in 2024.*

c) Potential implications and opportunities for NAFO of the Convention on Biological Diversity Post-2020 Global Biodiversity Framework

The Parties to the UN Convention on Biological Diversity (CBD), at the time of the 2022 WG-ESA meeting, the post-2020 Global Biodiversity Framework (GBF) (CBD/Post2020/OM/2022/1/2; CBD/WG2020/4/4)) was still under negotiations. The GBF aims to replace the CBD's Strategic Plan for Biodiversity 2011-2020, including Aichi Biodiversity Targets (CBD decision X/2 (2010)). As part of the negotiations, the GBF draft text will be considered by the Open Ended Working Group (OEWG) – a body established by the CBD Conference of the Parties (COP) to support the preparation of the framework (CBD decision 14/34 (2018)) – at its fifth meeting in Montreal from 3-5 December 2022. The outcomes of the OEWG-5 meeting will then be considered by CBD COP 15 taking place in Montreal from 7-19 December 2022 and if agreed upon, adopted by a COP decision. [16]

The CBD is an international treaty that aims at the conservation of biodiversity, the sustainable use of its components and the fair and equitable access and benefit sharing regarding the utilization of genetic resources (CBD, Art 1). The CBD applies to terrestrial and marine biodiversity, including to areas beyond national jurisdiction (ABNJ) as follows (CBD, Art 4):

a) In the case of components of biological diversity, such as marine genetic resources, the CBD provisions apply to areas within the limits of its national jurisdiction; and

b) In the case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control of its Parties, the provisions apply within the area of national jurisdiction or beyond the limits of national jurisdiction.

Given the jurisdictional scope and objectives of the CBD, NAFO can play an important role in contributing to the achievement of several GBF targets and the overall framework, especially given the synergies among relevant provisions of UN Convention on the Law of the Sea (e.g. UNCLOS, Arts 119 and 194(5)), UN Fish

[16] The GBF was adopted by CBD COP 15 on 19 December 2022. See CBD/COP/15/L.25 (18 Dec 2022).

Stocks Agreement (e.g. UNFSA, Art 5(g)) and the NAFO Convention (e.g. 8th preambular para, and Arts II and III (d) and (e))[17] with the CBD Convention.

Some GBF targets to be achieved by 2030 (CBD/COP/15/L.25 (2022), para 31) can be of particular interest for NAFO and WG-ESA work, especially:

a) Target 1 on ensuring integrated biodiversity-inclusive spatial planning and/or effective management processes addressing sea-use change to bring the loss of areas of high biodiversity importance, including ecosystems of high ecological integrity, close to zero.

b) Target 2 on ensuring effective restoration of degraded marine ecosystems with a view to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity.

c) Target 3 on ensuring that at least 30% of marine areas, especially areas important for biodiversity and ecosystem functions and services are effectively conserved and managed through ecologically representative, well-connected and equitably governed systems of marine protected areas (MPAs) and other effective area-based conservation measures (OECMs)[18] and integrated into wider seascapes.

d) Target 4 on ensuring management measures to recover and conserve species, especially threatened species.

e) Target 5 on ensuring that the use, harvesting and trade of wild species is sustainable, safe and legal, preventing overexploitation, minimizing impacts on non-target species and ecosystems, and applying the ecosystem approach.

f) Target 7 on reducing pollution risks and the negative impact of pollution from all sources to levels that are not harmful to biodiversity and ecosystem functions and services, considering cumulative effects.

g) Target 8 on minimising the impact of climate change and ocean acidification on biodiversity and increasing its resilience through mitigation and adaptation, including through nature-based solution and/or ecosystem-based approaches.

h) Target 14 on ensuring the full integration of biodiversity and its multiple values into environmental impact assessments (EIAs) within and across all levels of government and across all sectors.

While the main means of implementation of the GBF is through the development or update of National Biodiversity Strategy and Plans (NBSAPs), CBD Parties have recognised the important role of enhanced collaboration, cooperation and synergies between the CBD, other biodiversity-related conventions and other relevant multilateral agreements and international organisations and processes, including at the regional level (CBD/COP/15/L.25 (2022), para 24). In this context, the work of the WG-ESA and NAFO on the ecosystem approach to fisheries can be of significant importance for the implementation of GBF Targets 4 (species) and 5 (fisheries). Similarly, the ongoing efforts to identify OECMs can be particularly relevant to the implementation of target 3 (MPAs/OECMs), as well as the assessment of significant adverse impacts (SAIs) on vulnerable marine ecosystems (VMEs) in relation to Targets 1 and 14 (EIAs). Furthermore, the ongoing WG-

[17] These provisions refer to *inter alia*: the conservation of living marine resources (UNCLOS, Art. 119); the protection and preservation of the marine environment (UNCLOS, Arts 192, 194(5)); the protection of marine biodiversity (UNFSA, Art 5(g)); the application of the ecosystem approach, safeguarding the marine environment, and conserving its marine biodiversity (NAFO Convention, 8th preambular para, and Art II); preservation of marine biodiversity (NAFO Convention, Art III (d) and (e)).

[18] The definition of OECM is contained in para 2 of CBD decision 14/8 (2018) as: "A geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio-economic, and other locally relevant values"

ESA research and work related to better understanding ecosystem functions and services and ecological connectivity can contribute to the implementation of Targets 1 (MSP), 2 (restoration), 3 (MPA/OECM), 8 (climate change/ ocean acidification and nature-based solutions), and 14 (EIAs).

An opportunity to further develop closer links between the work of NAFO on these fronts could be further explored in the context of the upcoming update of the CBD programme of work (PoW) on marine and coastal biodiversity in support of GBF implementation (CBD/COP/15/L.15, para 4). In this context, the CBD Secretariat has been requested to compile submissions from Parties, other Governments, and relevant organisations (such as NAFO) to develop a strategic review and analysis of the PoW and to prepare a draft update of the plan, which is expected to be adopted by COP 16 in 2024. In this sense, the best practices by NAFO on a number of the issues highlighted above could be shared and further opportunities for enhancing synergies across different policy and legal instruments and governance regimes could be pursued.

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1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (2167 UNTS 3). Concluded 4 August 1995. Entered into force 11 November 2001. (Fish Stocks Agreement or UNFSA).

CBD decision 14/34 (2018)

CBD decision X/2 (2010)

CBD/COP/15/L.25 (2022)

CBD/Post2020/OM/2022/1/2 (2022)

CBD/WG2020/4/4 (2022)

d) Reflections on the interface between the BBNJ Agreement and NAFO

The United Nations Convention on the Law of the Sea (UNCLOS) is meant to provide, *inter alia*, a legal order for the seas and oceans to facilitate the equitable and efficient utilization of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment (UNCLOS, preambular para). In its Part XII on the protection and preservation of the marine environment, it sets an obligation for States to adopt necessary measures to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life (UNCLOS, Art 194(5)). This obligation directly relates to vulnerable marine ecosystems (VMEs), and protective measures including not only sectoral measures such as VME closures to fisheries, but also cross-sectoral measures such as marine protected areas (MPAs) or other effective area-based conservation measures (OECMs).

However, UNCLOS did not establish a process for establishing these area-based management tools (ABMTs) at the global level. Such an implementation gap was identified several years ago by the UN General Assembly (UNGA), through an Ad Hoc Open-ended Working Group to study issues related to the conservation and sustainable use of marine biodiversity of areas beyond national jurisdiction (UNGA A/61/65 (2006). In 2015 a Preparatory Committee was established under the auspices of the UNGA to develop an international legally binding instrument under UNCLOS (UNGA Resolution 69/292 (2015)). In 2017, the UNGA decided to convene an intergovernmental conference (IGC) to elaborate the text of such instrument addressing four main elements as a package: ABMTs, including MPAs; environmental impact assessments (EIAs); marine genetic resources (MGRs), including questions on the sharing of benefits; and capacity building and the transfer of marine technology (UNGA Resolution 72/249 (2017)). A fifth session of the IGC was convened in August 2022, which had its work suspended and will resume from 20 February to 3 March 2023 (UNGA A/CONF.232/2023/L.1 (2022)), when the Agreement may be finalised for adoption.

The first part of IGC-5 made progress on several fronts, especially on the ABMT Part of the draft Agreement. However, several issues remain to be resolved in the second part of the conference, including with respect to:

- *Cross-cutting issues related to the institutional bodies of the Agreement such as the Scientific and Technical Body (STB), dispute settlement mechanisms, principles and approaches;*
- *EIAs: thresholds, decision-making modalities;*
- *MGRs: monetary benefits, intellectual property rights, digital sequence information;*
- *Capacity building and technology transfer: mandatory or voluntary nature of such obligations.*

With respect to ABMTs, the interface between NAFO and the BBNJ Agreement could enhance opportunities for synergies on issues such as OECMs by facilitating cross-sectoral cooperation. The latest draft text of the Agreement defines ABMT as: “a tool including a marine protected area, for a geographically defined area through which one or several sectors or activities are managed with the aim of achieving particular conservation and sustainable use objectives in accordance with this Agreement” (UNGA A/CONF.232/2022/CRP.13/Add 1 (2022), Art.1 (3)). It is not clear if this definition could encompass OECMs that do not have an explicit and express conservation or sustainable use objective such as VME closures, but that in accordance with the OECM definition under the CBD,[19] could achieve biodiversity conservation outcomes. Nonetheless, under draft Art 19 (on decision-making), the Agreement confers its Conference of the Parties (COP) with the possibility to take decisions on measures complementary to and compatible with those adopted by sectoral bodies (UNGA A/CONF.232/2022/CRP.13/Add 1 (2022), Art.19 (1) (b)), such as NAFO. While it will be for the COP to decide on what these measures may constitute, coordinated efforts across sectors to ensure biodiversity conservation outcomes arising from NAFO VME closures could be a possibility under this provision, including in the context of OECMs. It is important to note however, that the BBNJ

[19] CBD decision 14/8 (2018), para 2.

Agreement will be applicable solely to areas beyond national jurisdiction (ABNJ) with respect to ABMTs. It is still to be decided whether or not activities within national jurisdiction with potential impacts on biodiversity beyond national jurisdiction would fall under the scope of the Agreement with respect to EIAs.

On EIAs, NAFO's work and expertise on the assessment of significant adverse impacts (SAIs) on VMEs could add value to the BBNJ Agreement in several ways, including by sharing expertise and knowledge about methods to measure SAI thresholds, ecological functions and services, connectivity patterns and avoidance of SAIs. Therefore, the relationship between the BBNJ Agreement STB (once established) and NAFO scientific bodies (SC and relevant WGs, such as WG-ESA) can offer an opportunity for better assess cumulative pressures (including from other sectors) to marine biodiversity, ecosystems and ecosystem functions and services in the NAFO regulatory area.

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UNGA A/CONF.232/2023/L.1 (2022)

UNGA Resolution 69/292 (2015)

UNGA Resolution 72/249 (2017)

e) Update from the Executive Secretary on, MoU with the Sargasso Sea Commission + ICES revision of MoU

Concerning the **proposed MOU between the NAFO Secretariat and the Secretariat of the Sargasso Sea Commission (SSSC)**, the Executive Secretary recalled that the WG-EAFFM meeting of August 2022 agreed on a draft final text for this proposed MOU and had recommended that "the Commission support the finalization of an MOU between NAFO and the Sargasso Sea Commission Secretariats". However, during the Annual Meeting, the SSSC informed that it had some last-minute changes to the 'final' text, following a 'legal scrubbing' by one of its Members. The text of these changes, received from the SSSC, was distributed to the Working Group – these changes were of a technical nature and should not affect the substance of the previous final text. Consequently, the Executive Secretary was of the opinion that this MoU could shortly be signed. However, the co-Chair of the WG-EAFFM (Liz Mencher – USA) said that she thought that some amendments to the text proposed by this SSC Member (i.e. the USA) were missing from this text. She said she will try to clarify this with her colleagues and then inform the Executive Secretary. In the meantime the Executive Secretary was going to check this issue with the SSSC.

Concerning **the possible revision of NAFO's MOU with ICES**, the Executive Secretary noted that the justification for considering such a revision is the following:

- *The MOU was agreed before the 2007 amendments to the NAFO Convention, in which the objectives of NAFO were changed, in particular to add the phrase "… to safeguard the marine ecosystems to which these resources are found". The first preambular paragraph of the MOU does not reflect this, so at least this needs updating, even if the more 'operative' provisions of this MOU are still valid and complete.*
- *In NAFO's 2018 Performance Review Report, in the section on "Scientific capacity and adequacy of resources" (pp. 42-43), under the title of "Outsourcing", it was suggested (although not part of the recommendations per se) that "benefits could arise with cooperation with ICES; and*
- *In light of the SC concerns about its heavy workload, including the discussion at this year's Annual Meeting, possibly a closer cooperation with ICES may help to partially address some of these concerns.*

Concerning the work of WG-ESA, the Executive Secretary added that cooperation with ICES could already fit within WG-ESA's Terms of Reference (ToR), including ToR 3.1 – regarding North Atlantic ecosystems and ToR 3.2 – impacts of activities other than fishing. Also later in this meeting, there is scheduled a joint session with the ICES Working Group Fisheries Benthic Impact and Trade-offs (WG-FBIT).

In this context, the NAFO Secretariat met virtually with ICES (Alan Haynie (ICES General Secretary) and Lotte Clausen (Head of Advice Department)) in October 2022 to explore the possibility of updating the MOU. ICES also indicated that they were willing to explore updating the MOU. Both sides agreed that each of us would consult internally and meet again as soon as possible with some interested members of NAFO's Scientific Council, including the Scientific Council Executive. The Chair of the Scientific Council indicated that she agreed that this initiative was timely and would try to participate at this next meeting. The WG-ESA co-Chair (Andrew Kenny) also expressed his support for this initiative. He added that the following areas related to WG-ESA's work could be explored with ICES during these discussions:

- *Mapping and methodology (including working with the ICES Working Group on Deep Water Ecology (WG-DEC);*
- *Ecosystem overviews;*
- *Impacts of fishing on deep water habitats;*
- *Progress on the NAFO Roadmap, including work on TCI limits; and*
- *The impact of activities other than fishing.*

Potential NAFO OECMs, discussion as input to WG-EAFFM sub-group on NAFO OECMs.

Background

The Convention on Biodiversity (CBD) Decision 14/8, adopted in 2018 (CBD, 2018), is the foundational document for OECMs (Other Effective area-based Conservation Measures). A new 10-year strategy for nature conservation has been agreed as part of the United Nations Convention on Biological Diversity (CBD). The strategy requires that governments and other regulatory bodies protect and conserve at least 30% of coastal and marine areas by 2030 – the so called "30 by 30" target – to maintain healthy oceans, support ecosystem resilience against climate change, and improve food security. The CBD recognizes that both MSP initiatives and area-based fishery management measures/ tools (ABFM/Ts) can play an important role in protecting biodiversity, and that if such benefits can be demonstrated and sustained, they have the potential to make a significant contribution to meeting the "30 by 30" target.

Accordingly, the IUCN-CEM Fisheries Expert Group (FEG) in collaboration with the FAO and CBD convened an expert meeting on OECMs in the marine capture fishery sector, Rome, Italy in 2019. This meeting culminated in a report first published in 2020 and then again with revisions in 2021 (Garcia et al, 2021) that proposes a systematic set of actions that would be needed to identify and use OECMs in the marine capture fisheries sector – the report is commonly referred to as the OECMs guidelines document.

The OECMs guidelines for the fisheries sector were then applied to several 'real world' case study examples of area-based fishery management measures during a workshop jointly convened by ICES and the IUCN-CEM FEG in 2021 on Testing OECM Practices and Strategies (WKTOPS, see ICES, 2021). Six case studies from the North Atlantic were evaluated, differing in size, biodiversity features, types of measures in place, jurisdictional authority, and expected biodiversity benefits. All six areas were found to meet subsets of the CBD Criteria and Sub-criteria for OECMs, and none were strongly at variance with any Criteria. The measures evaluated included permanent area closures, closures to specific gears or fisheries for particular stocks, and licensed uses of an area for aquaculture. All case studies were found to produce outcomes consistent with the intent of OECMs. However, WKTOPS noted that each case study had enabling conditions that were important for the effectiveness of the measures in delivering biodiversity outcomes to date. Also, some case studies documented noteworthy biodiversity benefits although the spatial measure was not adopted with the intent of producing the biodiversity outcome. Consequently, context is important to OECM evaluations.

Of specific relevance to NAFO, the VME fishery closures (notably sponge VME) and Seamounts closures (notably the Corner Rise Seamounts) were evaluated against the CBD OECM criteria at the workshop and both categories of ABFM in NAFO were assessed to be suitable candidate OECMs.

In a fisheries context, OECMs are established, spatially defined management and/or conservation measures other than protected areas that produce positive, long-term and in situ biodiversity outcomes, in addition to the intended fishery outcomes. However, considerable confusion abounds with regard to which measures qualify as OECMs, why fisheries agencies should take the time to identify them, and how fisheries management will benefit from the OECM identification process.

Accordingly, the FAO convened and expert group to review a 'handbook' compiled by the FAO on fisheries OECMs (FAO, 2022). The handbook describes the key characteristics of Fisheries OECMs and outlines a basic process for identifying, evaluating, and reporting in order to encourage global recognition of the role that fisheries management plays in biodiversity conservation. To this end, the handbook poses questions that could be considered and provides examples showing how area-based management tools (ABMT) used in some fisheries can be evaluated to determine whether they qualify as Fisheries OECMs.

For example, guided by the criteria laid out in Decision 14/8, the FAO handbook focuses on describing a specific subset of fisheries ABMTs that have potential as Fisheries OECMs. If the area where biodiversity benefits occur is geographically delineated, with clear boundaries (GPS or latitude/longitude coordinates) and if there is evidence that the fisheries management measures in place have led or will lead to long-term biodiversity outcomes, then the ABMT is likely to be aligned with the OECM criteria. By contrast, fisheries ABMTs that do not occur in a fixed, prescribed area may not readily meet OECM criteria. Such ABMTs include move-on rules and real-time closures (which are variable in time and space). Similarly, ring-fencing – in which potentially damaging fisheries are kept within a prescribed space – is not likely to be aligned with OECM criteria, since the area supporting the biodiversity that benefits from the measure has no outer boundaries or are so extensive; that the area with the biodiversity outcome cannot therefore be fully described or mapped.

The FAO "handbook" notes that both the VME and seamount fishery closures are amongst the ABMTs most aligned with the OECM criteria.

Next Steps

The consideration of NAFO ABFMs as candidate OECMs is being led by WG-EAFFM in accordance with the existing guidelines and FAO handbook for their evaluation. A presentation of the work undertaken so far (summariesed here), and the processes outlined in the FAO handbook will be presented to WG-EAFFM in 2023.

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f) Project on bottom trawling and carbon sequestration

Summary of Epstein et al., 2022 publications on mobile bottom fishing and seabed sediment carbon

Subtidal marine sediments are one of the planet's primary carbon stores and strongly influence the oceanic sink for atmospheric CO_2. By far the most widespread human activity occurring on the seabed is bottom trawling/dredging for fish and shellfish. A global first-order estimate suggested mobile demersal fishing activities may cause 0.16–0.4 Gt of organic carbon (OC) to be remineralised annually from seabed sediment carbon stores (Sala et al., 2021). There are, however, many uncertainties in this calculation.

Using a qualitative and quantitative literature review, we suggest that under certain environmental settings mobile demersal fishing would reduce OC in seabed stores due to lower production of flora and fauna, the loss of fine flocculent material, increased sediment resuspension, mixing and transport and increased oxygen exposure. Reductions would be offset to varying extents by reduced faunal bioturbation and community respiration, increased off-shelf transport and increases in primary production from the resuspension of nutrients. Studies which directly investigated the impact of demersal fishing on OC stocks had mixed results. A finding of no significant effect was reported in 61% of 49 investigations; 29% reported lower OC due to fishing activities, with 10% reporting higher OC. Patterns in the environmental and experimental characteristics between different outcomes were largely indistinct. More evidence is urgently needed to accurately quantify the impact of anthropogenic physical disturbance on seabed carbon in different environmental settings and to incorporate full evidence-based carbon considerations into global seabed management.

Even so, best available evidence indicates that fishing disturbance of seabed sediment carbon provides conditions conducive to remineralisation and recent modelling studies indicate that the level of loss and/or remineralisation may be significant, therefore until the fate of carbon is better understood, protection of the most important and/or intensively disturbed carbon sinks represents sensible precautionary policy. Using spatial modelling of best available datasets relating to seabed carbon stocks and fishing disturbance in the UK Exclusive Economic Zone (EEZ), we estimate the cumulative disturbance of OC by mobile bottom fishing to be 109 Mt per year.

Areas with high carbon stocks and disturbance are geographically restricted enabling identification of potential priority areas for precautionary carbon management and/or future research. By targeting areas with the highest 1%, 5% and 10% of carbon values, while also accounting for fisheries displacement, we examined three management levels ranging from 3–12% of the area of the EEZ. These areas encompass between 7–29% of organic carbon stocks. If all mobile bottom fishing disturbance in priority areas was eliminated it would reduce seabed carbon disturbance across the EEZ by 27–67%. Eliminating this fishing effort would be estimated to affect fisheries landings worth between £55m and £212m per year. In contrast, if all mobile bottom fishing was displaced from priority areas to other areas within the study region, our modelling predicts net reductions of organic carbon disturbance between 11% and 22%. To offset the carbon and financial impacts of fisheries displacement, complementary management will be necessary to protect more carbon, including gear modifications to reduce seabed disturbance, overall effort reductions, and incentives to switch to alternative fishing methods.

Seabed protection is predominantly undertaken through the establishment of marine protected area (MPA) networks. Although MPAs are now widespread, with ~8% of the global ocean under a protected area designation, their conservation objectives and legislation are often limited in scope and many damaging activities still persist, which may leave even nominally protected carbon stores at risk. In total, only around 3% of the global ocean is fully or highly protected from fishing impacts and other damaging and disturbing human activities. This has led to calls to increase the level of protection afforded to current MPAs, to derive a climate change mitigation benefit from the additional protection of seabed organic carbon stocks.

The UK has one of the most extensive networks of MPAs in the world to protect marine life, consisting of 374 MPAs covering 38% of EEZ. Using the UKEEZ as a case study, we show that full protection of the MPA network would offer limited carbon benefit, due to below average organic carbon stocks and low disturbance from mobile fishing gears when compared to the entire UK seabed. Although closing entire MPA networks to mobile bottom fishing would have many co-benefits due to the biodiversity focus of MPAs, and their placement often selected to minimise economic impact and fisheries disturbance, this problem is likely to be applicable to many parts of the global ocean.

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APPENDIX 1: AGENDA: NAFO SCIENTIFIC COUNCIL (SC) WORKING GROUP ON ECOSYSTEM SCIENCE AND ASSESSMENT (WG-ESA)

Provisional Agenda and Terms of Reference (ToRs)

Details of the meeting ToRs and specific agenda items including timings are given in **ANNEX 1** and **ANNEX 2**, respectively (see below).

Provisional Agenda and Terms of Reference (ToRs)

1. Opening by the Chairs, Andrew Kenny (UK) and Mar Sacau (EU)

2. Appointment of Rapporteur

3. Adoption of Agenda

4. Review of Annual Meeting 2022 outcomes

5. Commission requests for advice on management in 2023 and beyond, requiring input from WG-ESA in 2022 to be presented at the Scientific Council meeting June 2023.

a) Commission Request #3. The Commission requests that Scientific Council continue its evaluation of the impact of scientific trawl surveys on VME in closed areas and the effect of excluding surveys from these areas on stock assessments.

b) Commission Request #5. The Commission requests that the Scientific Council continue to work on tiers 1 and 2 of the Roadmap, specifically to:

a. Include on a regular basis summary information on TCI in stock summary sheets (including indications of other NAFO managed stocks within the corresponding guild) and ecosystem summary sheets.

b. Work to support WG-EAFFM in exploring:

- *i. Management considerations for occasions in which the 2TCI ecosystem reference point were to be exceeded, similar to those when exceptional circumstances are triggered within MSE.*
- *ii. Effective methods to communicate TCI-related information to the Commission, in particular for when 2TCI is, or expected to be exceeded.*

c. Complete the development of the 3LNO ecosystem summary sheet (ESS), advance as much as possible the development of the 3M ESS, and continue working, if capacity allows, toward undertaking a joint Workshop with ICES (International Council for the Exploration of the Sea) on reporting on North Atlantic ecosystems.

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

a. Complete the re-assessment of its previously recommended closures of 7a, 11a, 14a and 14b, incorporating catch and effort data for fisheries of shrimp from 2020 and 2021 into the fishing impact assessments. This work is needed for the 2023 WG-EAFFM meeting.

b. Support the Secretariat in creating standardized data layers (using GIS), and products with supporting documentation (including metadata) for periodic reassessment purposes required to support the implementation of the NAFO Roadmap towards an Ecosystem Approach.

c. Continue working with WG-EAFFM towards developing operational objectives for the protection of VMEs and biodiversity in the NRA.

d) Commission Request #12. The Commission requests Secretariat and the Scientific Council with other international organizations, such as the FAO and ICES to inform the Scientific Council's work related to the potential impact of activities other than fishing in the Convention Area. This would be conditional on CPs providing appropriate additional expertise to Scientific Council.

6. Review Recommendations

7. Other Business

a) Updates from the Executive Secretary on, MoU with the Sargasso Sea Commission.

b) The ABNJ Deep-Seas Fisheries Project.

c) FAO/NAFO Symposium on ecosystem production models (and the NAFO roadmap)

d) Potential implications for NAFO of the Convention on Biological Diversity (CBD) Post-2020 Global Biodiversity Framework.

e) Highlights on Biodiversity of Areas Beyond National Jurisdiction (BBNJ)

f) FAO OECM handbook meeting

g) Project on quantification, conservation and management of Canada´s seabed sediment carbon stores.

h) Date and place of next meeting

8. Adjournment

ANNEX 1. WG-ESA TERMS OF REFERENCE

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.*
2. *Summary of 3O Marine Refuge ROV expedition (Canada).*
3. *VME/fish habitat use using benthic landers.*
4. *Standardized GIS data layers **(COM. Request#6b).***

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. *Agree plan to complete the re-assessment of closures of 7a, 11a, 14a and 14b, incorporating catch and effort data for fisheries of shrimp from 2020 and 2021 into the fishing impact assessments. This work is to be completed by the 2023 Scientific Council meeting (**COM. Request #6a**).*
2. *Exploring different ways to use length of track, depth and directional changes to further improve the accuracy of our fishing effort layers (**COM. Request #6a**).*
3. *Quantifying the effects of habitat fragmentation in deep-sea vulnerable marine ecosystems.*
4. *Spatial extent question related to KDE calculations.*
5. *Workplans for next VME and SAI reassessments.*

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. *The Commission requests that the Scientific Council continue to work on tiers 1 and 2 of the Roadmap (**COM. Request #5)**, specifically to:*

   a. *Include on a regular basis summary information on TCI in stock summary sheets (including indications of other NAFO managed stocks within the corresponding guild) and ecosystem summary sheets.*
   b. *Work to support WG-EAFFM in exploring:*
      i. *Management considerations for occasions in which the 2TCI ecosystem reference point were to be exceeded, similar to those when exceptional circumstances are triggered within MSE.*
      ii. *Effective methods to communicate TCI-related information to the Commission, in particular for when 2TCI is, or expected to be exceeded.*
   c. *Complete the development of the 3LNO ecosystem summary sheet (ESS), advance as much as possible the development of the 3M ESS, and continue working, if capacity allows, toward undertaking a joint Workshop with ICES (International Council for the Exploration of the Sea) on reporting on North Atlantic ecosystems.*

2. *The Commission requests Secretariat and the Scientific Council with other international organizations, such as the FAO and ICES to inform the Scientific Council's work related to the potential impact of activities other than fishing in the Convention Area. This would be conditional on CPs providing appropriate additional expertise to Scientific Council (**COM. Request #12**).*
3. *The Commission requests that Scientific Council continue its evaluation of the impact of scientific trawl surveys on VME in closed areas and the effect of excluding surveys from these areas on stock assessments (**COM. Request #3).***
4. *Continue working towards developing operational objectives for the protection of VMEs and biodiversity in the NRA (**COM. Request #6c).***

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