Northwest Atlantic Fisheries Organization

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SC WG ON THE ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT – DECEMBER 2011

Report of the 4th Meeting of the NAFO Scientific Council Working Group on Ecosystem Approaches to Fisheries Management (WGEAFM)

NAFO Headquarters, Dartmouth, Canada

30 November -10 December 2011

Introduction

The NAFO Scientific Council (SC) Working Group on Ecosystem Approaches to Fisheries Management (WGEAFM) operates within a set of long-term Themes and Terms of Reference (ToRs) which are being systematically addressed by WGEAFM over several meetings. These Themes and ToRs build on the "*Roadmap for Developing an Ecosystem Approach to Fisheries for NAFO*" (WGEAFM Report, NAFO SCS 10/19). In addition, WGEAFM also provides guidance to SC on specific ecosystem-related issues and requests from NAFO Fisheries Commission (FC).

To date, the work of WGEAFM can be described under two non-mutually exclusive contexts:

1. work intended to advance the "Roadmap for the development of and ecosystem approach to fisheries (EAF) for NAFO" ("Roadmap to EAF", for short).
2. work intended to address specific requests from Scientific Council (SC) and/or Fisheries Commission (FC).

In this context, at the 2011 June Meeting in Braunschweig, Germany, SC approved that work during the 4th WGEAFM meeting to be focused on:

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

> *It is expected that additional analyses from the NEREIDA project and surveys will become available; these new studies will be presented and discussed under this ToR.*

ToR 2. *Based on available biogeographic and ecological information, identify appropriate ecosystem-based management areas.*

> *Updates and new analysis related to ecoregion delineation and ecosystem-level unit identification work (e.g. incorporation of taxomomic layers, variations in ecoregion boundaries over time) are expected to be presented and discussed under this ToR.*

ToR 3. *Update on recent and relevant research related to status, functioning and dynamics of ecosystems in the NAFO area.*

> *Work under this ToR will be focused in the exploration of methods to estimate fisheries production potential at the scale of the ecosystem-level units identified during the 3rd WGEAFM meeting. These analysis are expected to include fisheries production potential models (see ToR4c in the WGEAFM Report), but they may also explore other modelling avenues (e.g. aggregate biomass models).*

During the 2011 NAFO Annual Meeting, FC put forward 19 requests to SC. From these requests, 6 has been forwarded by the SC chair to WGEAFM for consideration during it 2011 meeting. These FC Requests were:

10. *On the Flemish Cap, there seems to be a connection between the most recent decline of the shrimp stock, the recovery of the cod stock and the reduction of the redfish stock. The Fisheries Commission requests the Scientific Council to provide an explanation on the possible connection between these phenomena. It is also requested that SC advises on the feasibility and the manner by which these three species are maintained at levels capable of producing a combined maximum sustainable yield, in line with the objectives of the NAFO Convention.*

15. *As per the recommendation outlined in the report of the Working Group of Fishery Managers and Scientists on Vulnerable Marine Ecosystems adopted in September 2011, the Fisheries Commission requests the Scientific Council to produce a detailed list of VME indicator species and possibly other VME elements.*

16. *Given the progress made by Scientific Council on the development of the GIS model for the evaluation of bycatch thresholds for sponges as requested by Fisheries Commission in its 2010 Annual Meeting, and mindful of the need for further refining this modelling framework, as well as exploring its potential utility for its application to other VME-defining species, Fisheries Commission requests the Executive Secretary to provide to the Scientific Council anonymous VMS data in order to further develop the current sponge model as requested by the Fisheries Commission in 2010 and to assess the feasibility of developing similar models for other VME-defining species(e.g. corals).*

17. *Fisheries Commission requests the Scientific Council to make recommendations for encounter thresholds and move on rules for groups of VME indicators including sea pens, small gorgonian corals, large gorgonian corals, sponge grounds and any other VME indicator species that meet the FAO Guidelines for VME and SAI. Consider thresholds for 1) inside the fishing footprint and outside of the closed areas and 2) outside the fishing footprint in the NRA, and 3) for the exploratory fishing area of seamounts if applicable.*

18. *Noting Article 4bis - Assessment of bottom fishing of the NAFO Conservation and Enforcement measures. " The Scientific Council, with the co-operation of Contracting Parties, shall identify, on the basis of best available scientific information, vulnerable marine ecosystems in the Regulatory Area and map sites where these vulnerable marine ecosystem are known to occur or likely to occur and provide such data and information to the Executive Secretary for circulation to all Contracting Parties".*

The Fisheries Commission requests the Scientific Council to produce a comprehensive map of the location of VME indicator species and elements in the NRA as defined in the FAO International Guidelines for the Management of Deep Sea Fisheries in the High Seas. This includes canyon heads and spawning grounds and any other VME not protected by the current closures to protect coral and sponge. This will be used by Contracting Parties to complete impact assessments

19. *As stated in the "Reassessment of the Impact of NAFO Managed Fisheries on known or Likely Vulnerable Marine Ecosystems" (NAFO FC WP 11/24), the Scientific Council in collaboration with the Working Group of Fishery Managers and Scientists on Vulnerable Marine Ecosystem will conduct a reassessment of NAFO bottom fisheries by 2016 and every 5 years thereafter. In preparation for reassessments, the Fisheries Commission requests the Scientific Council to develop a workplan for completing the initial reassessment and identifying the resources and information to do so.*

Terms of Reference for the 4th NAFO SC WGEAFM meeting

The above FC requests, together with the agreed topics under the "Roadmap to EAF" were amalgamated in the final ToRs for the 4th WGEAFM Meeting. It is worth mentioning that the FC requests fell nicely within the scope of the WGEAFM long-term ToRs, suggesting that the structure of these long-term ToRs, and the topics they cover, appear to be well fitted to address NAFO requirements on ecosystem-related issues and management, providing a useful platform from where to build an Ecosystem Approach to Fisheries for the organization. The final ToRs for the 4th WGEAFM Meeting were:

Theme 1: Spatial considerations

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

ToR 1.1. Update on NEREIDA-related analyses and results

ToR 1.2. [FC Request # 15] Produce a detailed list of VME indicator species and possibly other VME elements.

ToR 1.3. [FC Request # 18] Development of a comprehensive map of the location of VME indicator species and elements in the NRA as defined in the FAO International Guidelines for the Management of Deep Sea Fisheries in the High Seas. This includes canyon heads and spawning grounds and any other VME not protected by the current closures to protect coral and sponge.

ToR 2. Based on available biogeographic and ecological information, identify appropriate ecosystem-based management areas.

ToR 2.1. [Roadmap to EAF] Update on ecoregion analyses (Scotian Shelf).

ToR 2.2. [Roadmap to EAF] Development of framework for an integrated ecoregion analysis for the entire Northwest Atlantic.

Theme 2: Status, functioning and dynamics of NAFO marine ecosystems.

ToR 3. Update on recent and relevant research related to status, functioning and dynamics of ecosystems in the NAFO area.

ToR 3.1. [Roadmap to EAF] Initiate the evaluation of fisheries production potential at the ecosystem level by considering a) Fisheries Production Potential Models, b) other models/approaches, and c) other research that can be of relevance to understand the ecosystem productivity of NAFO ecosystems.

ToR 3.2. [FC Request # 10] Provide an explanation on the possible connection between the recent decline of the shrimp stock, the recovery of the cod stock, and the reduction of the redfish stock in the Flemish Cap ecosystem, as well as advice on the feasibility and the manner by which these three species could be maintained at levels capable of producing a combined maximum sustainable yield.

Theme 3: Practical application of ecosystem knowledge to fisheries management

ToR 4. Update on recent and relevant research related to the application of ecosystem knowledge for fisheries management in the NAFO area.

ToR 4.1. [FC Requests # 16 & 17]. Implement and/or further refine the existing GIS simulation/modelling framework, in conjunction with the VMS data supplied by the NAFO Secretariat [FC Request #16], to make recommendations on encounter thresholds and move on rules for groups of VME indicators including sea pens, small gorgonian corals, large gorgonian corals, sponge grounds and any other VME indicator species that meet the FAO Guidelines for VME and SAI. Consider thresholds for 1) inside the fishing footprint and outside of the closed areas and 2) outside the fishing footprint in the NRA, and 3) for the exploratory fishing area of seamounts if applicable.

ToR 5. Methods for the long-term monitoring of VME status and functioning.

ToR 5.1. [FC Request # 19] In preparation for the reassessment of NAFO bottom fisheries by 2016 and every 5 years thereafter, develop a workplan for completing the initial reassessment and identifying the resources and information to do so.

Theme 4: Specific requests

ToRs 6+. As generic ToRs, these are place-holders intended to be used when addressing expected additional requests from Scientific Council.

NOTE: All FC requests have been incorporated under already exisiting ToRs, so there is no need to address them under this generic ToR

ToR 1.1. Update on NEREIDA-related analyses and results

1.1.1. Box corer samples

Overall a total of 40 box corer (BC) samples from a total of 368 have been processed to date (Figure 1.1.1.1). The Sackville Spur closed area was selected during the NEREIDA meeting in Vigo (Oct. 2010) as the first case study from which Box Corer samples should be processed (6 of them inside the closed area and 9 outside) to investigate differences in benthic community structure. A manuscript describing the results from this study has been accepted with minor changes into the ICES Journal of Marine Science publication*: "An evaluation of benthic community structure in and around the Sackville Spur closed area (Northwest Atlantic) in relation to the protection of vulnerable marine ecosystems"*. A summary of the findings is presented in Section 1.1.5 below.

In addition, a similar assessment to the one carried out in Sackville Spur area is expected to be completed within North Flemish Pass (Closed Area 2) before the end of March 2012. Twenty five BC samples have been processed (9 of them inside the closed area and 16 inside).

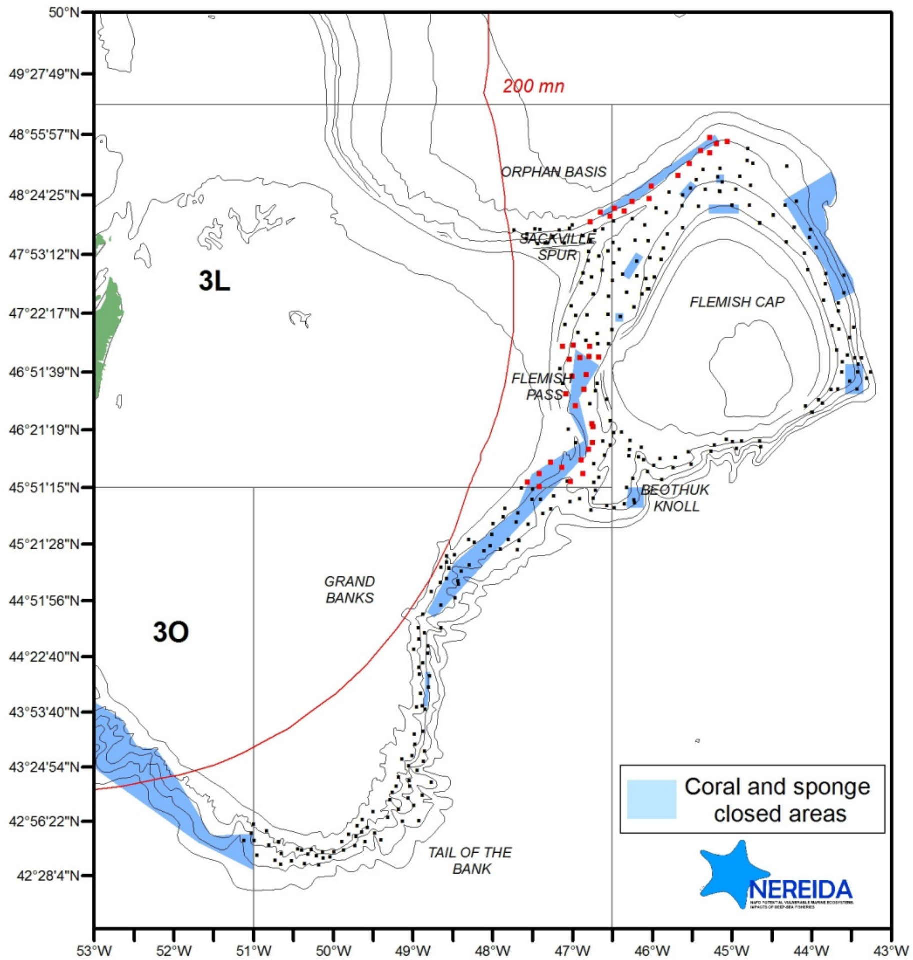


Figure 1.1.1.1 Location map of box core samples. Those indicated in red have been processed.

1.1.2. Rock dredge samples

All 94 Rock Dredge samples have been processed by faunal group (Figure 1.1.2.1). Identification of Echinoderm and Cnidarian (except sea anemones) taxa to the lowest possible level has been completed. Molluscs and Porifera continue to be processed along with other less abundant taxonomic groups. It is expected to finish the processing of all groups before the end of 2014.

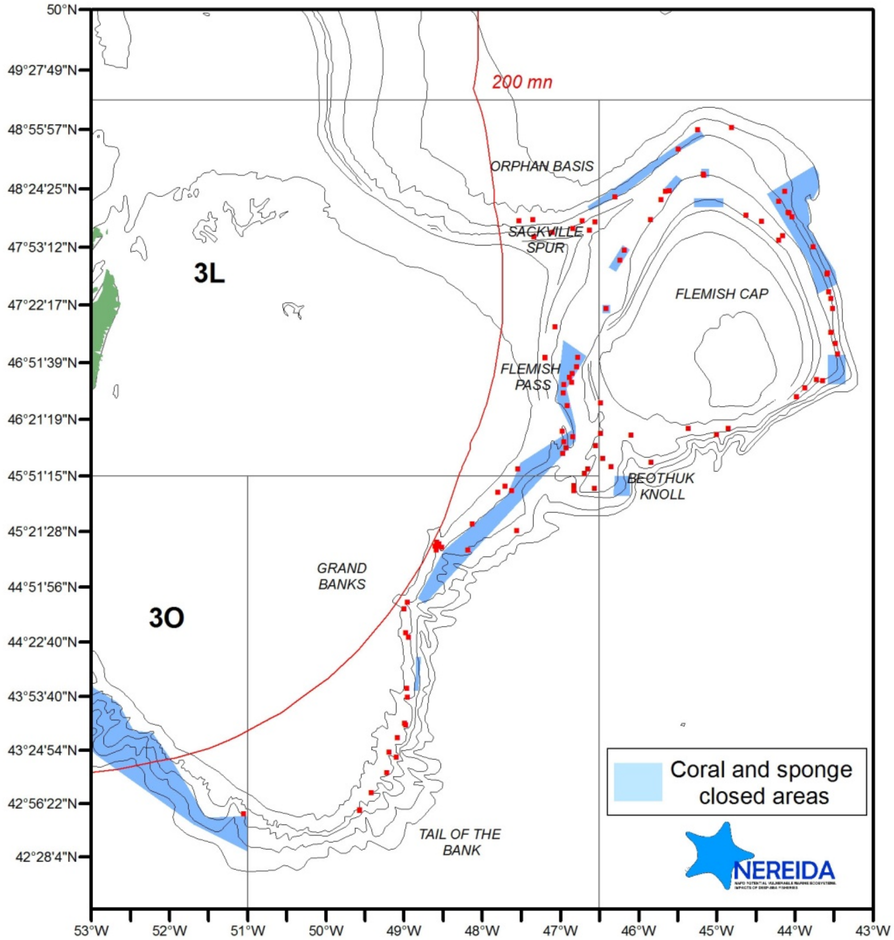


Figure 1.1.2.1 Location map of Rock Dredge samples.

Sponge identification requires the preparation of spicule slides to study their shape and size under the microscope. This process is time consuming and at present over 1000 spicule slides have been prepared for the specimen identification. A record of sponge and spicule photographs of sampled specimens during NEREIDA surveys is being prepared. In addition, Sponge Identification Sheets are being finalised in PDF format. This valuable work is intended to increase our knowledge of, and ability to identify sponge specimens.

Two reference collections with invertebrate 'voucher' specimens have also been created; one is stored in Vigo (Spain) and the other in Halifax (Canada). A common database is intended to store all the information regarding the invertebrate specimens collected during all the NEREIDA surveys.

Biomass records from all 94 successful Rock Dredge trawls are being processed in an attempt to investigate the distribution of epibenthic biomass across the survey area, and how this relates to major geomorphological features and environmental conditions. Work on this is expected to be completed by March 2011.

1.1.3. Geology

Geologists working in the NEREIDA project have carried out a classification of the geological features of the surveyed area. A classification (specific to the survey area) has been proposed (Table 1.1.3.1) and mapped (Figure 1.1.3.1), which is intended to provide a summary of the geological context for interpreting the biological data derived from box core and rock dredge samples. The classification does not, it self, take into account factors such as water depth, local gradient, bottom-water temperature or bottom sediment type. However, many of the meso-topographic features may have a local influence on nearbed circulation patterns and variations in sediment type.

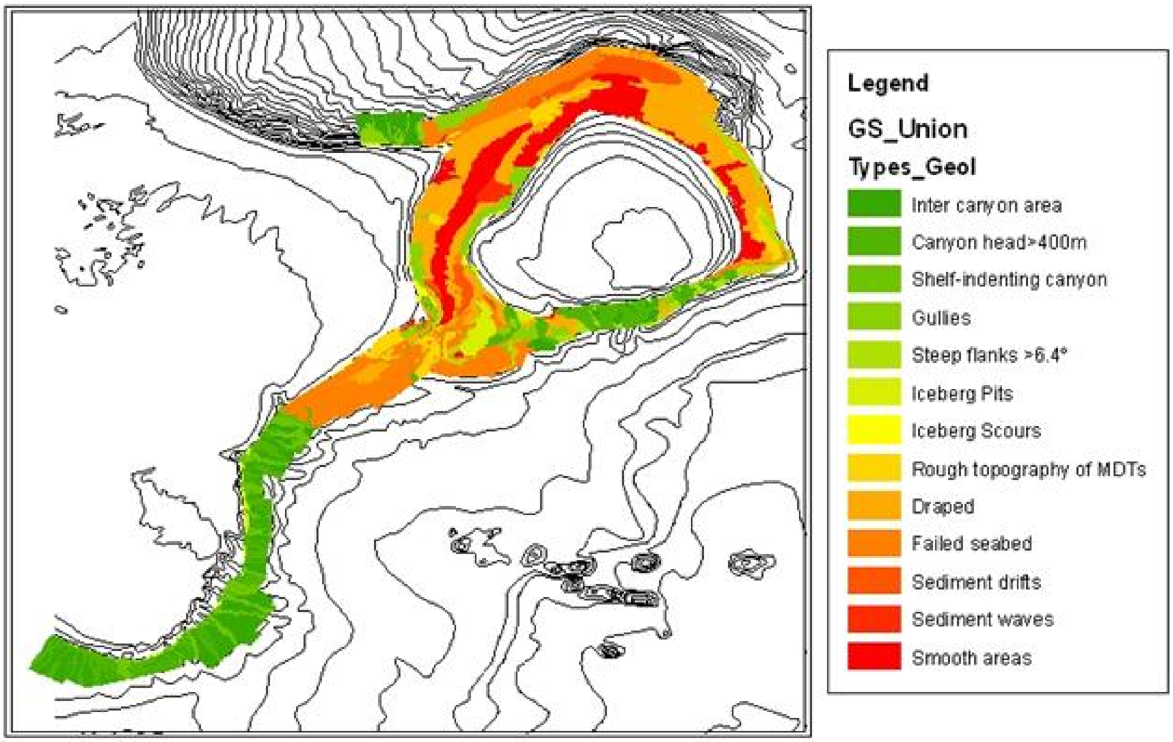


Figure 1.1.3.1. The distribution of classified meso-topographic features.

The classification is based primarily on the interpretation of multibeam bathymetric data and TOPAS sub-bottom profiler data. Locally, backscatter data was also used.

Table 1.1.3.1. Classification of meso-topographic feature types	
1.	Gullies
2.	Shelf-indenting canyons
3.	Canyons that head at > 400 m water depth
4.	Inter-canyon ridges
5.	Sediment waves
6.	Steep flanks > 6.4º
7.	Failed seabed
8.	Mass transport deposits with rough topography
9.	Thick sediment drape over irregular seafloor
10.	Smooth areas without evidence of erosion
11.	Sediment drift
12.	Areas with abundant iceberg scours in flat area
13.	Areas with abundant iceberg pits in flat areas

1.1.4. Sackville Spur and Flemish Cap Digital Still Analysis

During a 2009 Fisheries and Oceans mission on CCGS Hudson, a Natural Resources Canada (NRCAN) 4k drop camera was deployed to capture high resolution geo-referenced digital stills at locations in the Flemish Pass and locations within the Sackville Spur closed area. The digital stills from both locations have been analyzed by counting organisms within each of 12 grid cells applied to each image. A Microsoft Access data entry form was created for the task which allows the user to create and maintain a taxonomic list as well as assign a count of individuals in each cell during the analysis of the images. Each newly identified organism was “clipped” from the image and stored with its assigned name to await taxonomic verification (Megan Best, F. Javier Murillo, Kevin MacIsaac).

The order of analysis within each benthic transect was randomized to avoid bias in analysis. Upon completion of the analysis, vetting of the taxonomic nomenclature and quality control and assurance of the data, the image locations and their associated taxonomic data were plotted in ArcGIS 10. ArcGIS was also used to create interpolated surfaces (via krigging) derived from NEREIDA temperature, salinity and oxygen data, as well as surfaces for percent silt, clay and sand. This data, in conjunction with depth, aspect and slope derived from NEREIDA multibeam was extracted to each image for all transects at each location. It is hoped that in conjunction with a full taxonomic accounting of benthic images at each location, an analysis describing the influence of abiotic and biotic factors controlling distribution of both recognized VME taxa and associated species can be described in a manuscript to be prepared for the next NEREIDA workshop.

1.1.5. Sackville Spur Closed Area Box Core simple analysis

As part of the NEREIDA programme a detailed study of box core samples taken in and around the Sackville Spur have been analysed to characterise the macrofaunal assemblage. The principal aim of the research was to acquire evidence to either support or oppose the continued closure of the Sackville Spur to bottom-contact fishing gear. Analyses centred upon the infauna extracted from Box Core samples inside and outside the Sackville Spur closed area. Patterns in the data revealed at least three distinct faunal assemblages (Figure 1.1.5.1).

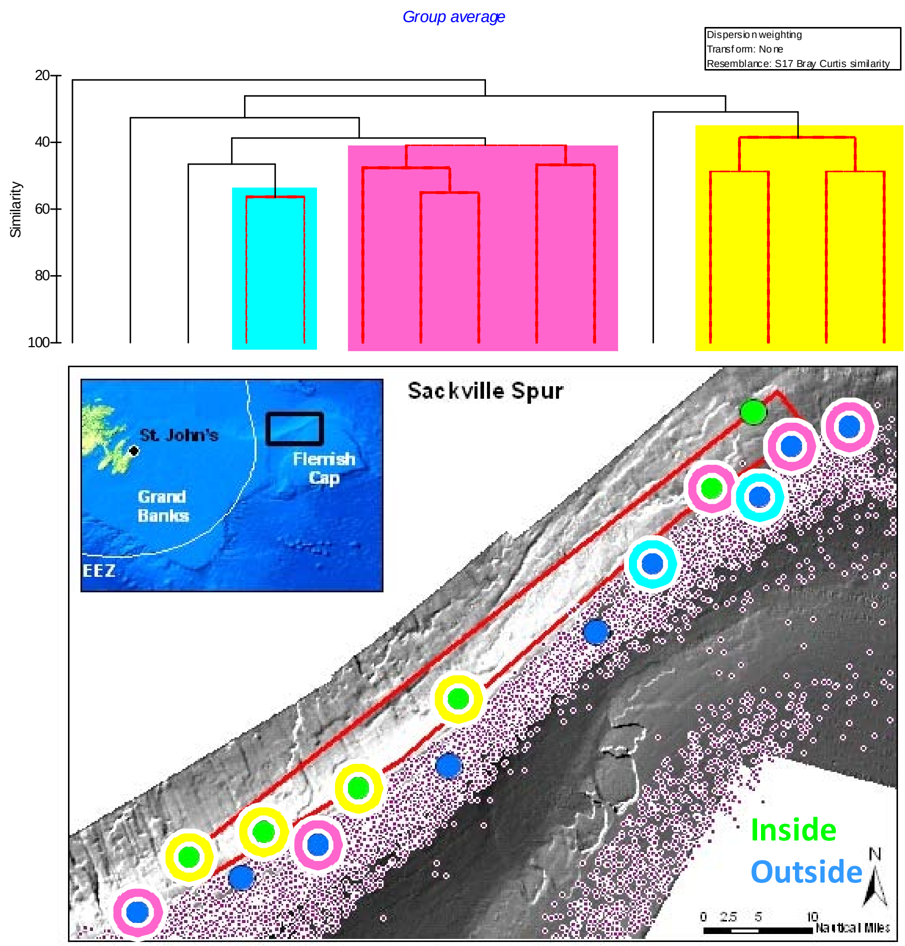


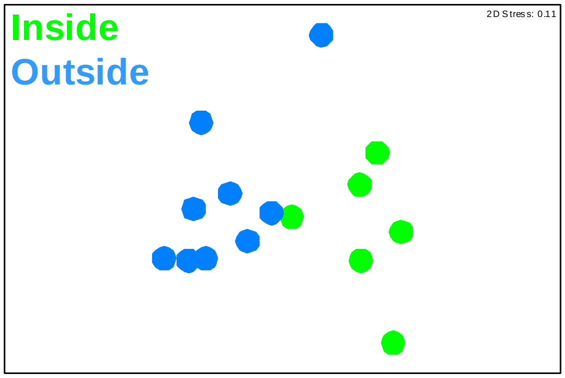
Figure 1.1.5.1. Top: Dendrogram illustrating the similarity between samples from the Sackville Spur, with three statistically distinct assemblages highlighted. Bottom: Spatial arrangement of distinct assemblages identified in the dendrogram above in relation to the Sackville Spur closed area (red box) and the historical (1992-2006) fishing footprint (small dots).

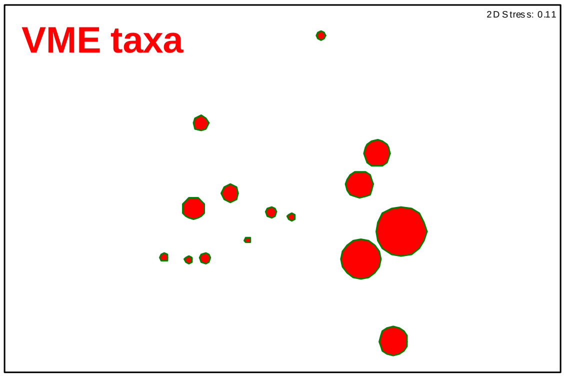
In addition to these distinct assemblages, differences in assemblage composition also exist between the assemblage living inside the closed area and that living outside. Assemblages inside the closed area were characterized by a greater proportion of taxa considered indicative of VMEs. The relative contribution of each major taxon to the difference between assemblages inside and outside the closed area is presented in Table 1.1.5.1.

The single environmental variable which best explains the observed patterns in total faunal community structure is depth. A combination of three variables – depth, sediment temperature and % silt – showed a higher correlation with the complete faunal dataset than depth alone. The single environmental variable showing the highest correlation with VME community structure is fishing effort; no combination of variables showed a higher correlation with VME community structure. Based on the above findings, the recommendation is to continue enforcing the closure of the Sackville Spur closed area, to protect the VMEs within. Future work will centre around similar analyses of Box Core samples from the Flemish Pass closed area, as well as investigating patterns in biomass (from Rock Dredge samples) across the whole NEREIDA survey area.

Table 1.1.5.1. Left: Relative contribution of each taxon to the dissimilarity between macrofaunal assemblages living inside and outside the Sackville Spur closed area. Taxa are ordered in decreasing order of combined contribution, and each cell is colour-coded on a colour scale to reflect the relative contribution of each taxon to the whole assemblage (red = high, yellow = medium, green = low). Taxa indicative of VMEs are in bold. Right: MDS plots illustrating the degree of similarity between samples coded by location in relation to closed area (top) and sized in proportion to the relative abundance of VME indicative taxa (bottom).

Taxa	Inside	Outside
Polychaeta	3.21	4.01
Nematoda	3.24	1.16
Ophiuroidea	3.22	0.26
Gastropoda	1.33	2.11
Nemertea	1.31	1.75
Bivalvia	0.87	1.79
Aplacophora	1.17	1.44
Hydrozoa	2.00	0.11
Demospongiae	1.87	0.11
Malacostraca	0.95	0.78
Scaphopoda	0.17	1.56
Crinoidea	1.33	0.11
Sipunculida	1.16	0.16
Maxillopoda	0.47	0.82
Holothuroidea	1.18	0.04
Ascidiacea	0.83	0.33
Anthozoa	0.15	0.73
Porifera	0.77	0.00
Pycnogonida	0.67	0.00
Ostracoda	0.00	0.37
Priapulida	0.17	0.11
Asteroidea	0.17	0.00
Cnidaria	0.17	0.00
TOTAL	26.41	17.75





1.1.6. Next NEREIDA Workshop

It is scheduled that next NEREIDA workshop will be held in Vigo during the 28-29th February 2012. Current status of the project, coordination of activities and new publication opportunities will be discussed during this meeting.

1.1.7. Areas with significant concentrations of sponges and corals outside of the current Fishery Closure Areas

During the years 2008 and 2009, the NAFO WGEAFM identified significant concentrations of corals and sponges in the NAFO Regulatory Area (Divisions 3LMNO) from bottom groundfish trawl surveys (NAFO 2008, NAFO 2009). In 2010 NAFO closed 11 areas within its fishing footprint to protect coral and sponge dominated VMEs based upon the significant catches presented in 2008 and 2009 (NAFO 2010a).

During the 4th NAFO WGEAFM meeting new coral and sponge data were presented based upon new groundfish trawl surveys, namely; coral data for the period 2008 - 2010; and sponge data for the period 2009 – 2010 (Figure 1.1.7.1, more details in Murillo et al. 2011).

The new data assessed, together with the significant catches of corals and sponges not protected by current fishery closures in 2010 (Figure 1.1.7.2), indicates the presence of significant concentrations of VME indicator species in densities in excess of the current encounter thresholds (see Murillo et al. 2011). Specifically there is one area of significant sea pen catches (Figure 1.1.7.2, **Area 1**), one area of significant sponge catches (Figure 1.1.7.2, **Area 2**), one area of significant large gorgonian catches (Figure 1.1.7.2, **Area 3**), and one area of significant small gorgonian catches Figure 1.1.7.2, **Area 4**). More detail of these areas, including the fishing track (VMS) data from 2010, is presented in Figures 1.1.7.3 to 1.1.7.6.

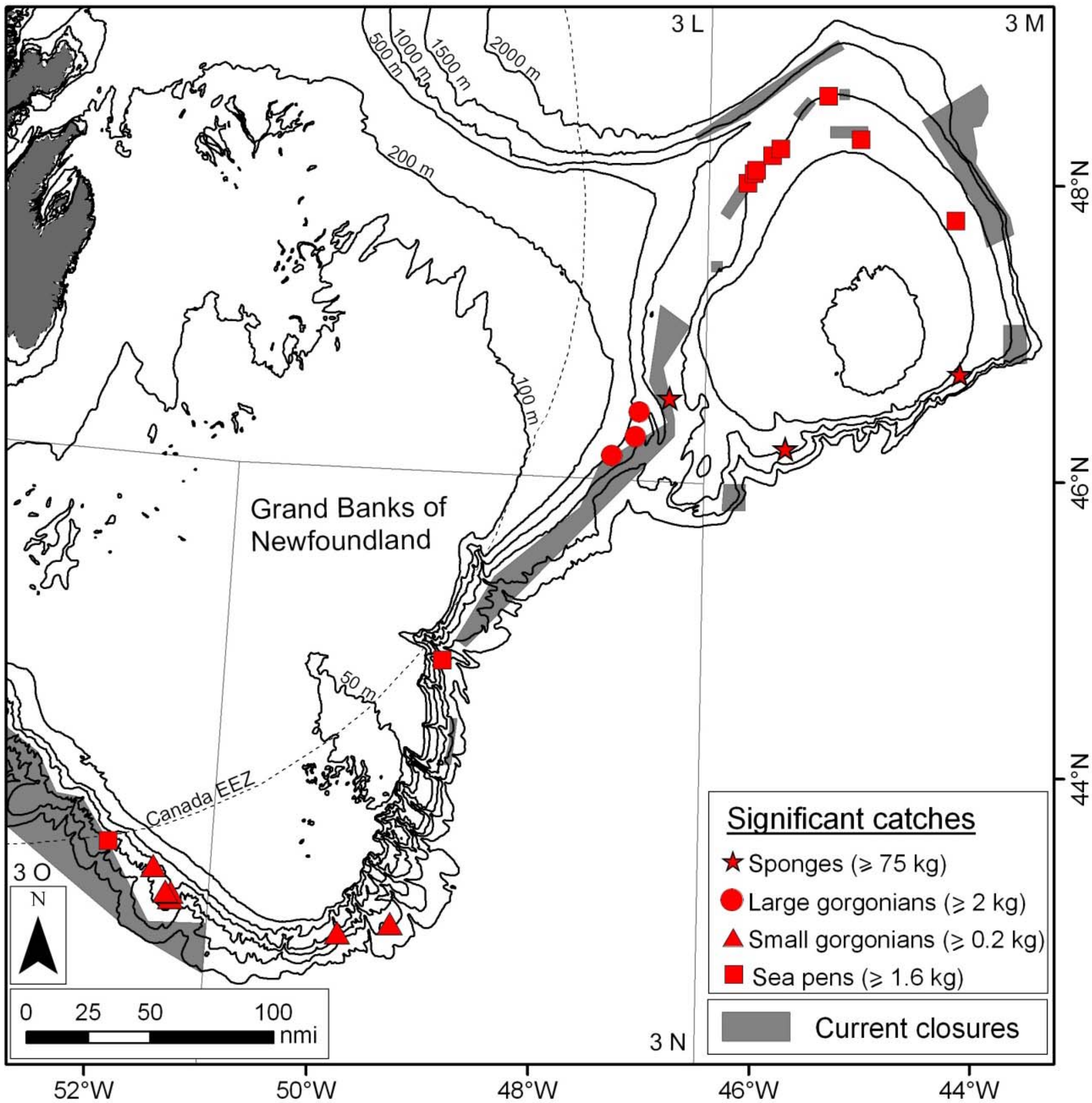


Figure 1.1.7.1. Distribution of significant catches of deep-water corals (2008-2010 period) and sponges (2009-2010 period) outside of the current closed areas based on recent research vessel survey data (Murillo et al. 2011).

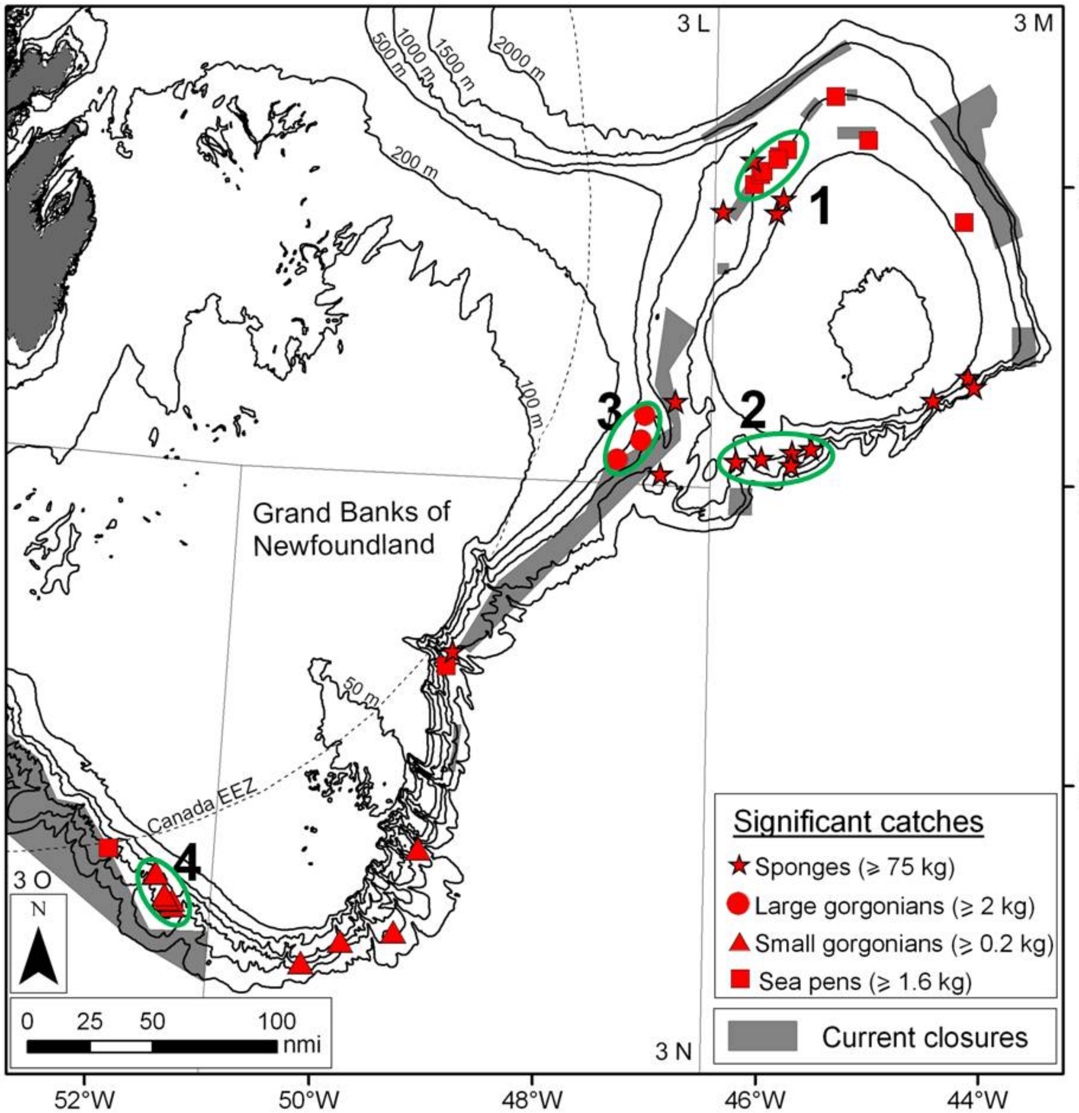


Figure 1.1.7.2. Distribution of significant catches of deep-water corals and sponges outside of the current closed areas based on all the research vessel survey data. The figure also shows the areas (1 to 4) where new data reveals significant concentrations of VME taxa.

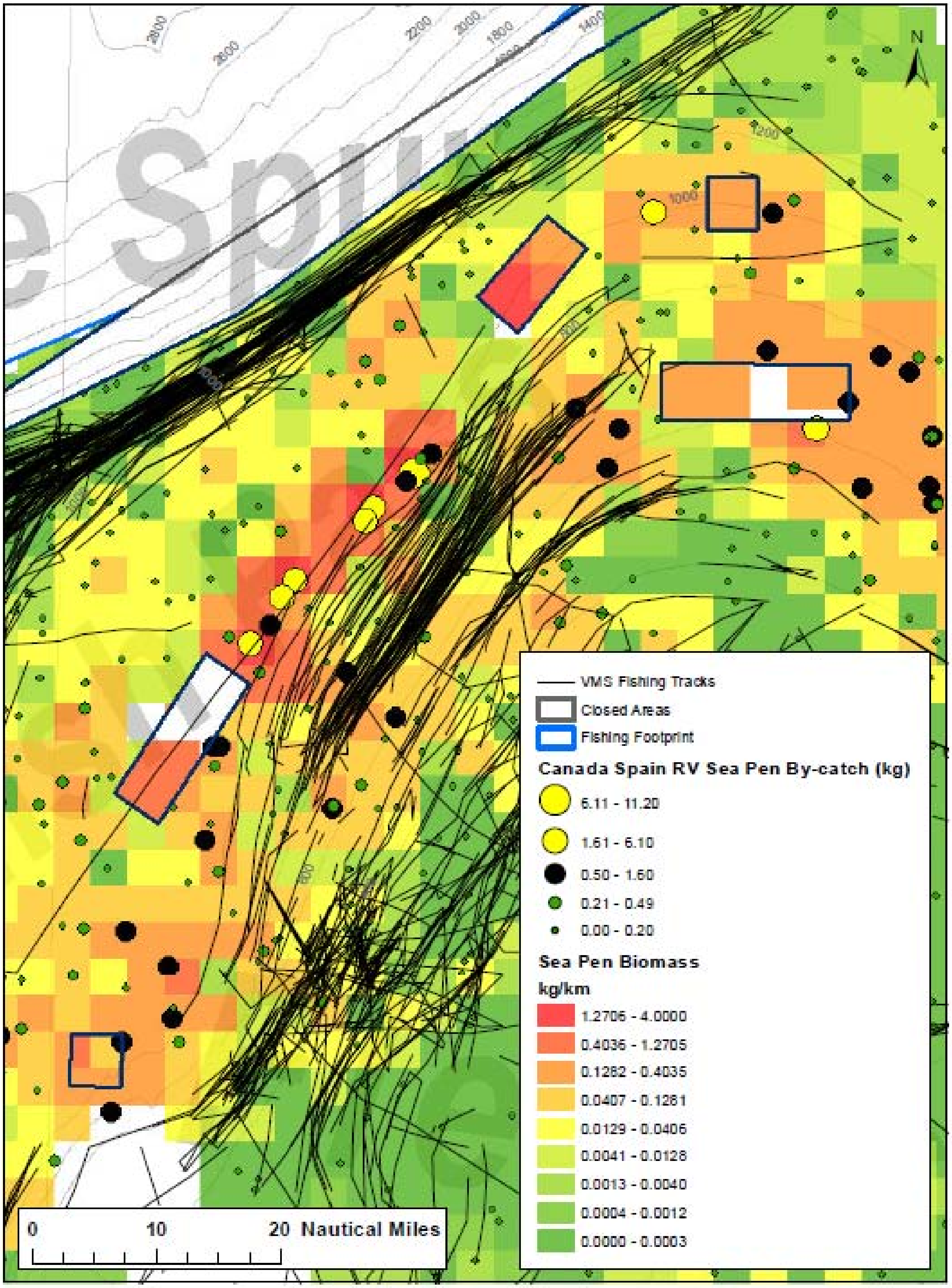


Figure 1.1.7.3. Map showing the interaction between RV sea pen biomass (grid cells) and VMS fishing tracks in **Area 1**. Yellow circles represent significant sea pen catches (NAFO 2008). Black circles represent sea pen bycatch between 0.5 and 1.6 kg. The 0.5 kg weight threshold was considered as a good indicator of the higher sea pens concentrations in the study area (NAFO 2010b).

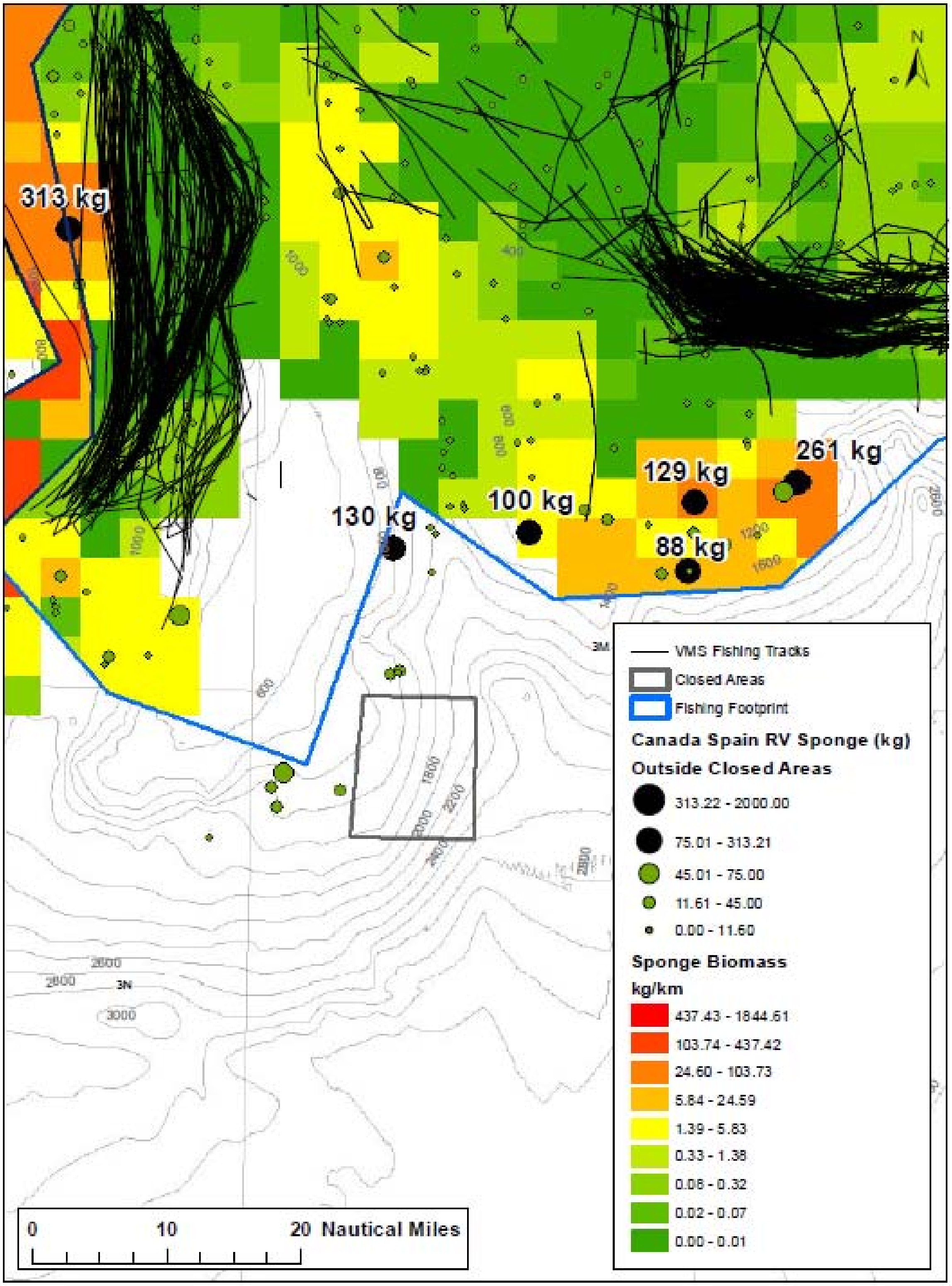


Figure 1.1.7.4. Map showing the interaction between RV sponge biomass (grid cells) and VMS fishing tracks in **Area 2**. Black circles represent significant sponge catches (NAFO 2009).

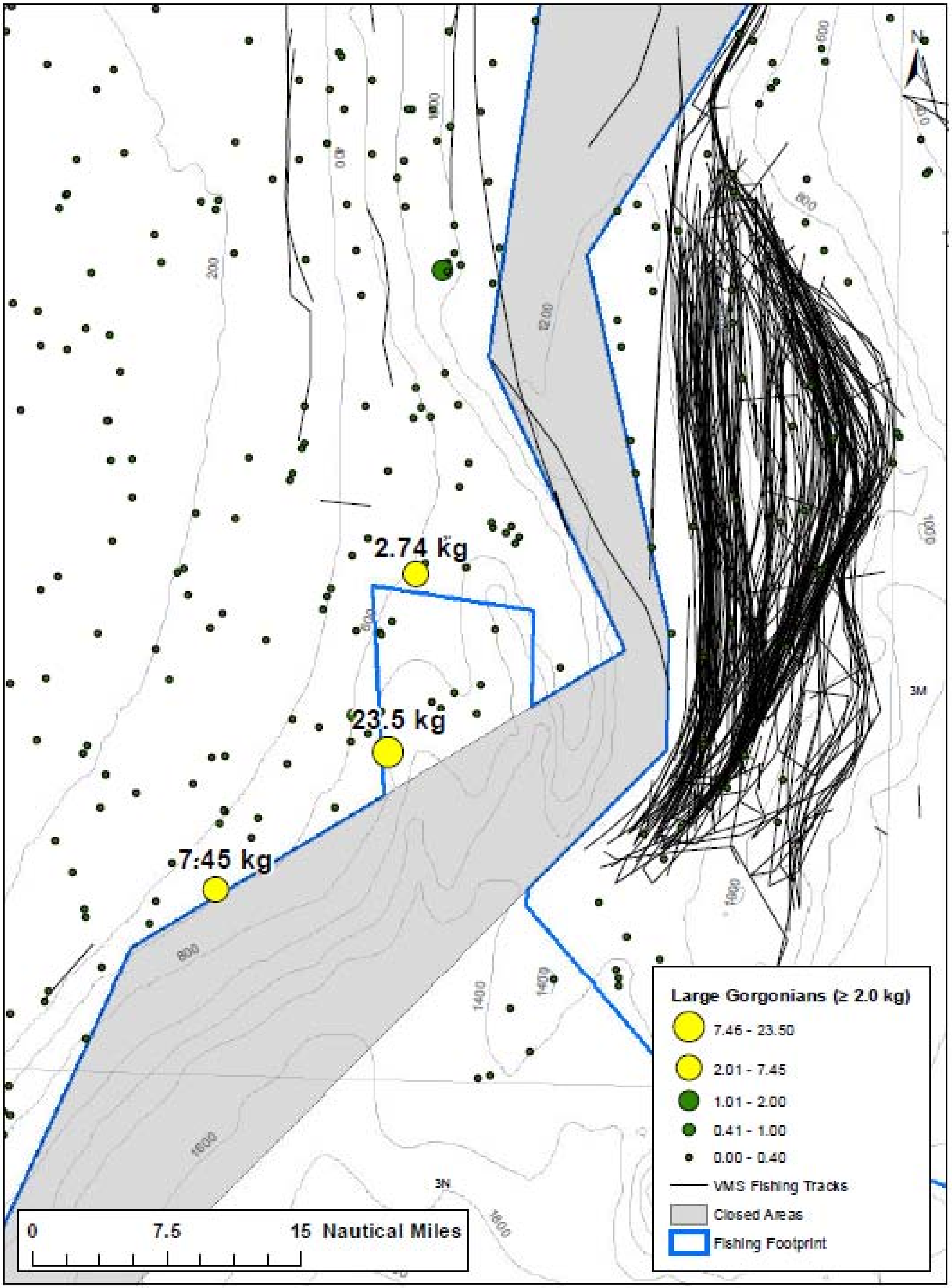


Figure 1.1.7.5. Map showing the interaction between significant large gorgonians catches (yellow circles) and VMS fishing tracks in **Area 3**.

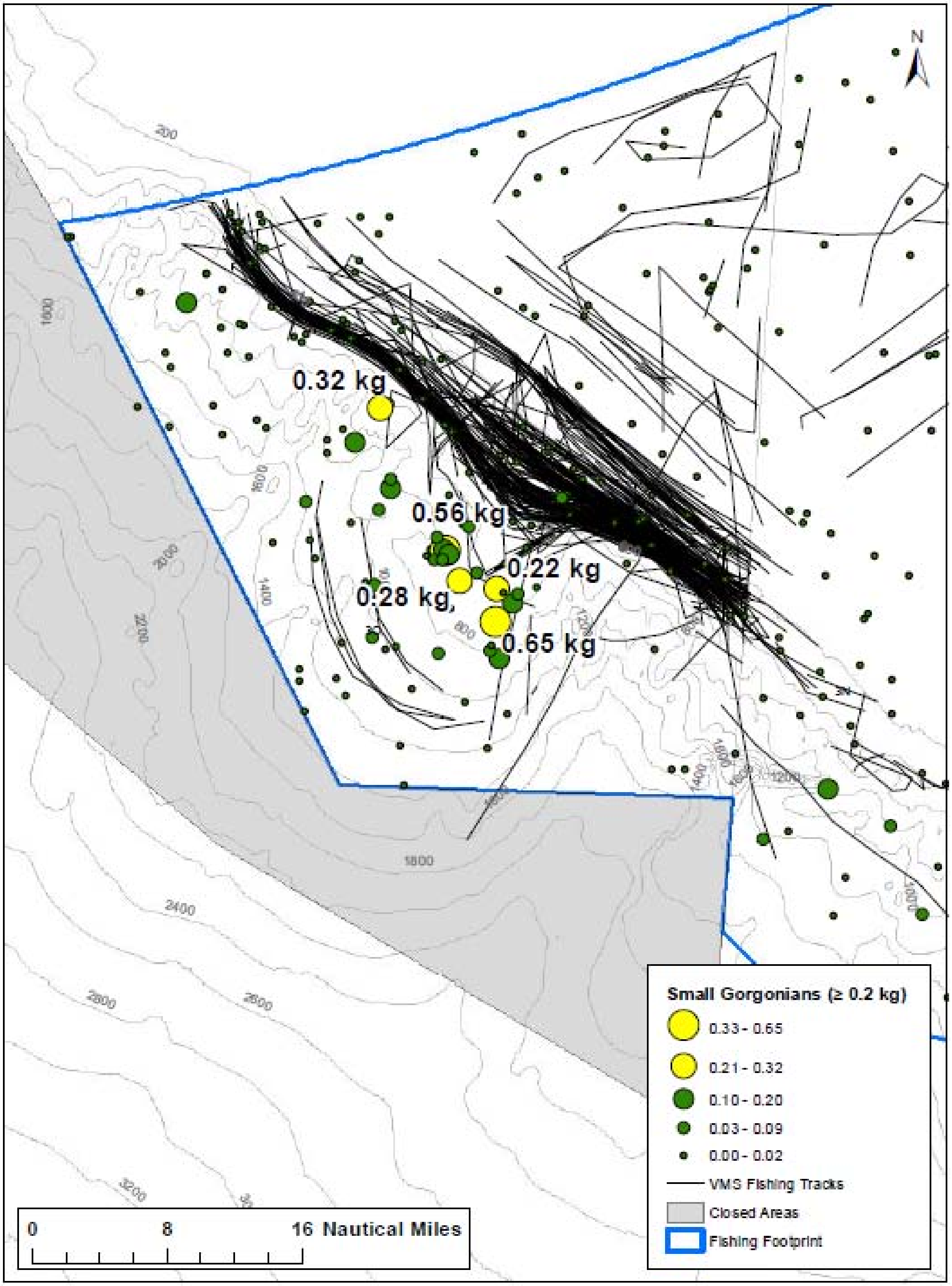


Figure 1.1.7.6. Map showing the interaction between significant small gorgonians catches (yellow circles) and VMS fishing tracks in **Area 4**.

WGEAFM recommends that SC consider this new evidence (presented here and in Murillo et al. 2011) on significant concentration of VME indicator species for the possible designation of new fishery closure areas which are adjacent to existing closed areas to help protect these large densities of VME species.

WGEAFM notes there was a general concern about the potential environmental impacts of marine research on VMEs (OSPAR 2008) as reported in Murillo et al. (2011). Although in the NAFO NRA VMEs are generally avoided by the groundfish surveys (E. Roman, pers. comm.), some records of indicator species suggest that surveys are causing some disturbance, particularly, in those grounds less used by the commercial fishery. In such areas, e.g. VME closed areas, and areas of high risk of VME encounters (see Section 4, ToR 4 in this report), scientific activities could represent the main disturbance factor on sensitive habitats. This needs to be taken into account in order to establish sampling guidelines to prevent adverse effects on sensitive areas.

WGEAFM recommends that SC considers an appropriate response to mitigate for the potential scientific survey impacts on identified and mapped VMEs in the NAFO NRA. This could take the form of advising against the use of any survey bottom-contact fishing gears in VME fishery closed areas.

1.1.8. Other relevant initiatives

1.1.8.1 Biogeographic zones, Ecoregions and Ecologically and Biologically Significant Areas.

Classification of the oceans can occur at a variety of spatial and temporal scales and is dependent on the objectives of the classification scheme. For purposes of managing fishing activities within an ecologically contextualized framework these boundaries will range from biogeographic zones, to ecoregions at the larger scale, to ecologically and biologically significant areas (EBSA) and other management areas at the smaller scale. The boundaries defined for these areas may or may not coincide with current national / international, or regional fisheries management boundaries. Biogeographic zones and ecoregions are generally large areas whose overall biophysical characteristics are more similar and adherent within than between adjacent areas, while at the smaller spatial scale EBSAs are defined as those areas for which the ecological or food-web consequences of severe perturbation are greater that an equal perturbation in most other areas or for most other species within the larger ecoregion or biogeographic zone.

EBSAs are therefore identified by evaluating candidate areas against a set of criteria including; uniqueness, aggregation, fitness consequences, and naturalness. Uniqueness refers to the rarity of a particular area, both its physical structure and associated fauna (canyons, highly topographically complex areas). Aggregation here refers to areas where species of significance to the encompassing ecoregion aggregate more than other areas. Fitness consequences of an areas relates to the degree to which the area is essential to the overall dynamics of significant species (spawning, juvenile rearing, adult refugia etc.). Finally naturalness refers to the degree to which the candidate area has been subjected to human activities over its history. Evaluation of candidate areas can occur only within the context of an encompassing ecoregion or biogeographic zone, that is candidate areas can only be ranked in significance relative to other areas within the boundaries of an encompassing zone.

The schematic presented in Figure 1.1.8.1.1. gives a simple pictorial overview of these concepts. Here we also introduce the implicit notions of recoverability and vulnerability. From this it is apparent that candidate areas that rank high in terms of the evaluation criteria, are highly vulnerable to perturbation and have inherently low recoverability would receive the highest relative EBSA rankings, and would require the highest degree of risk aversion relative to human activities. Areas that score low on evaluation criterion scale, are not vulnerable and or show high recoverability potential would receive a lower overall EBSA ranking. Examples of areas that would receive high scores include aggregations of hard corals or other highly structured communities in areas of low natural perturbation and growth potential. Areas that score low include populations that inhabit highly energetic areas with high growth potential.

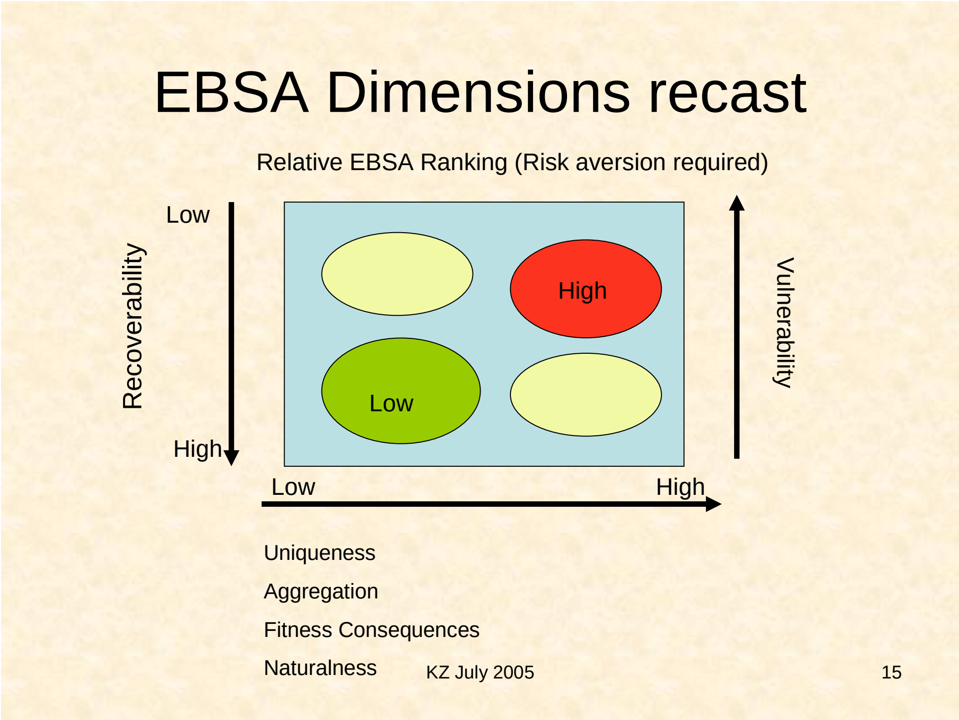
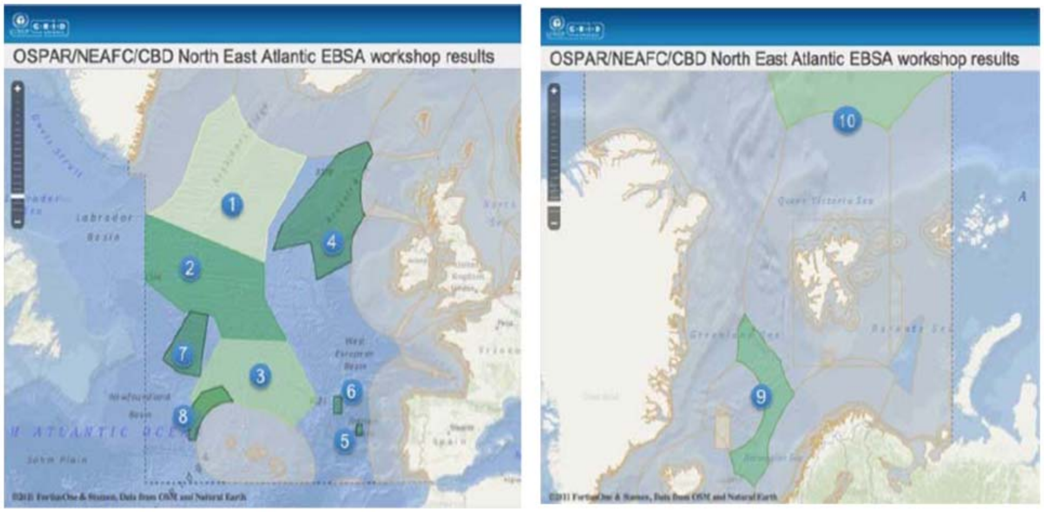


Figure 1.1.8.1. 1. Criteria for identifying and ranking EBSAs

1.1.8.2 1st EBSA (Ecologically, Biologically and Sensitive Areas) workshop for the NE Atlantic

The UN Convention on Biological Diversity (CBD), as a result of a Decision (X/29) taken at the10th Conference of the Parties (COP) on Marine and Coastal Biological Diversity, is implementing a process of designating EBSAs in high sea areas. The first high seas region to be considered, and to trail the process, is the North East Atlantic. A joint workshop was convened by OSPAR/NEAFC/CBD to progress this objective in September 2011. The conclusion of the workshop was the proposal for 10 candidate EBSAs in the high sea area of the NE Atalntic region (beyond national EEZ 200nm limits) – see Figure 1.1.8.2.1.



1. Reykjanes Ridge south of Iceland EEZ
2. Charlie-Gibbs Fracture Zone and Sub-Polar Frontal Zone of the Mid-Atlantic Ridge
3. Mid-Atlantic Ridge north of the Azores
4. The Hatton and Rockall Banks and the Hatton-Rockall Basin
5. Around Pedro Nunes and Hugo de Lacerda Seamounts – IBA MA04
6. North east Azores-Biscay Rise – IBA MA03
7. Evlanov Seamount region
8. North-west of Azores EEZ
9. The Arctic Front – Greenland/Norwegian Seas
10. The Arctic Ice habitat – multiyear ice, seasonal ice and marginal ice zone

10 Candidate EBSAs were proposed....

Figure 1.1.8.2.1. Proposed candidate EBSAs for the NE Atlantic.

WGEAFM noted that there are no inherent incompatibilities between the CBD criteria (COP IX/20) for designating EBSAs and the FAO criteria for designating VMEs, reinforcing the case the two sets of criteria are compatible. However, it was noted that the candidate EBSAs proposed for the NE Atlantic are much larger in spatial scale than those considered elsewhere (notably in Canada). The proposed spatial extent of the EBSAs appears to be more in line with the designation of ecoregions and not specific seabed features, habitats or species which was the original intention of the EBSA defining criteria.

The proposed candidate EBSAs are undergoing a process of review by ICES and NEAFC before being formally submitted for consideration and approval by CBD CoP in October 2012.

1.1.8.3. Proposed extension to Coral Closure Box presented to NAFO by the Sierra Club

WGEAFM took notice of the Sierra Club proposal submitted to NAFO at the 2011 Annual Meeting, where it requested NAFO to consider the extension of the Coral Closure Box based on recent coral distribution data, as well as historical information (1950s and 1960s) on the use of that area by haddock as overwintering ground.

WGEAFM reviewed the information content of the proposal, and concluded that the data sources cited, especially on haddock (e.g. Templeman and Hoder 1964a, 1964b), would be useful when the NAFO closed areas are revisited in the coming years. Highlighting patterns of use no longer observed today (haddock numbers in the Grand Bank have been low in recent decades) could be an important element in the discussion of context and objectives for closed areas. Although this last topic was by no means exhausted at the discussion session that took place at WGEAFM, it was clear that the idea of an historical perspective when defining closed areas can be quite important. The absence of a species from a place where it was abundant in the past may simply be the consequence of local depletion/extirpation, and may not necessarily warrant closing the area without a careful examination of the recovery potential of the species in question. However, in the context of potential multidecadal cycles in ecosystems, the observation of low levels over long periods of time may be just part of a multidecadal dynamic pattern, and protecting areas known to be important for a species, even if that species has not been abundant for a long time, may become critical with a change in the long term phase for that area. In the case of haddock in the Grand Bank, it was not possible to assess this type of considerations at the WGEAFM meeting, so WGEAFM did not advance this discussion beyond the general recognition that historical perspectives need to be considered when setting up objectives, and hence boundaries, for closed areas.

The information on coral distribution mentioned in the Sierra Club proposal (Edinger et al. 2007) is already incorporated in WGEAFM analyses. On this regard, and in the context of candidate VME areas, **WGEAFM re-iterates** its original 2008 recommendation (NAFO SCS Doc 08/10) that the shallower boundary for the coral box closed area to be raised up to 200m depth.

1.1.9. References

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ToR 1.2. [FC Request # 15] Produce a detailed list of VME indicator species and possibly other VME elements

1.2.1. Introduction and review of previous work

The United Nations General Assembly Resolution 61/105 calls upon "States to take action immediately, individually and through regional fisheries management organizations and arrangements, and consistent with the precautionary approach and ecosystem approaches, to sustainably manage fish stocks and protect vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals, from destructive fishing practices, recognizing the immense importance and value of deep sea ecosystems and the biodiversity they contain".

To provide States and Regional Fisheries Management Organizations with guidance for implementing Resolution 61/105, FAO sponsored an Expert Consultation in Bangkok, Thailand in September 2007 which resulted in a set of "International Guidelines for the Management of Deep-Sea Fisheries in the High Seas" (FAO 2009) – hereafter referred to as the FAO Guidelines. In this context, vulnerability is assessed with respect to species and habitats that come into contact with bottom-contact fishing gears.

It is important to reiterate that vulnerability is not based on physical characteristics alone. The FAO Guidelines, following the UNGA resolution, explicitly refer to interactions that cause significant adverse impacts: "Significant adverse impacts are those that compromise ecosystem integrity (i.e. ecosystem structure or function) in a manner that: (i) impairs the ability of affected populations to replace themselves; (ii) degrades the long-term natural productivity of habitats; or (iii) causes, on more than a temporary basis, significant loss of species richness, habitat or community types. Impacts should be evaluated individually, in combination and cumulatively." The FAO Guidelines view non-significant or temporary impacts as those that allow ecosystem recovery to occur in less than 20 years. However, "if the interval between the expected disturbance of a habitat is shorter than the recovery time, the impact should be considered more than temporary" (FAO 2009).

Vulnerable Marine Ecosystems (VMEs) can be identified by such properties as functional significance, uniqueness, fragility, structural complexity and the life-history traits of component species that produce a slow recovery to disturbance. These traits are expanded upon in the FAO Guidelines which also provide examples of species groups, communities and habitat-forming species which may contribute to forming vulnerable marine ecosystems. With respect to life history traits of component species that make up vulnerable marine ecosystems, identifying traits include "(i) maturation at relatively old ages; (ii) slow growth; (iii) long life expectancies; (iv) low natural mortality rates; (v) intermittent recruitment of successful year classes; and (vi) spawning that may not occur every year".

NAFO has closed areas to protect VMEs in accordance with the FAO Guidelines. All or parts of the Fogo Seamounts, Orphan Knoll, Corner Seamounts, Newfoundland Seamounts, and New England Seamounts have been closed to bottom-contact fishing gear. In these cases, the *topographical feature*, that is the seamount or seamount chain, represents the vulnerable marine ecosystem. The Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM) has previously (NAFO 2008a) provided justification for including seamounts as VME with respect to traits referred to above and in the FAO Guidelines. It also identified canyon heads as VME elements.

NAFO has further closed 12 areas within its fishing footprint to protect coral and sponge dominated VMEs. These were identified by life history traits and recovery to disturbance trajectories of component species by the WGEAFM (NAFO 2008a) on the basis of a NAFO Scientific Council Research Document (Fuller et al. 2008). Significant concentrations of these taxa were identified by a cumulative catch distribution method for corals (NAFO 2008b) and quantitative spatial analysis method for sponges (Kenchington et al. 2009, NAFO 2009). This latter method exploited the aggregation properties of this taxon which underpins their role as ecosystem engineers, providing structural complexity and altering the physical habitat through their presence. The broader habitats formed by these taxa are referred to as sea pen fields, gorgonian forests and sponge grounds and host a wide range of associated species (Klitgaard 1995, Brodeur 2001, Klitgaard and Tendal 2004, Buhl-Mortensen and Mortensen 2005, Metaxas and Davis 2005, Bell 2008).

Fuller et al. (2008) also identified tube dwelling anemone fields (Ceriantharia) as habitat which should be considered as a VME following similar justification as for the sea pen fields.

Black corals (Antipatharia) are the only benthic taxon identified thus far in the NRA (Fuller et al. 2008) which were identified under the FAO Guidelines criterion of uniqueness/rarity: " – an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include: habitats that contain endemic species; habitats of rare, threatened or endangered species that occur only in discrete areas; or nurseries or discrete feeding, breeding, or spawning areas". Black corals occur at low density in the NRA and elsewhere in the northwest Atlantic and are believed to be one of the longer lived corals in the area (Fuller et al. 2008). In considering the areas to close to protect coral and sponge habitats, the NAFO Working Group of Fisheries Managers and Scientists noted the occurrence of black coral and adjusted boundaries for the sponge grounds and gorgonian forests to maximize their protection. However, with new information on the regional distributions of Antipatharia (Kenchington et al. 2010, Murillo et al. 2011a, 2011b) and data collected through NEREIDA in the NRA, it appears that the taxon is not spatially restricted. We provide further comment on this below (see 1.2.2).

The WGEAFM previously outlined a four step process that it used to identify VMEs for mobile organisms (fish) (NAFO 2008a). They reviewed taxa known to occur in the NRA (N=219, listed in NAFO 2008a) and on seamounts (Vinnichenko 1997) with respect to the uniqueness/rarity, functional significance of the habitat and life history traits identified in the FAO Guidelines (NAFO 2008a). This produced an initial list of 27 "Tier 1" species which fit one of more of these criteria and so were believed to be the best candidates to help identify areas suitable for consideration as potential vulnerable marine ecosystems. The 27 Tier 1 species were examined in more detail and resulted in a reduced list (”Tier 2") of 21 species that were considered to be indicators of vulnerable marine ecosystems, or had discrete areas or habitats "that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species (FAO 2009)". Six of these Tier 2 species have distributions highly associated with seamounts: *Beryx splendens, B. decadactylus. Hoplostethus atlanticus, H. mediterraneus, Polyprin americanus* and *Epigonus telescopus.* Two areas were identified as critical spawning grounds for *Lamna nasus* and *Mallotus villosus* respectively. One was identified as a rare species with a higher concentration reported in the NRA than elsewhere (*Centroscymnus coelolepis*). Nine species were included using the rationale of "Restricted areas of high concentration in the Grand Banks and NRA", two with "Distribution restricted to slopes, core concentrations in the NRA" and one with "Highest concentrations along the slope, Restricted areas of high concentration in the Grand Banks and NRA".

For the Grand Banks and Flemish Cap section of the NRA, maps for Tier 2 species were produced. These maps were based on Canadian RV survey data for the period 1995-2004 and the EU survey for the period 1988-2007 and illustrated average abundance following Kulka (1998). From these species-specific maps, the areas containing approximately 90% of the entire abundance were extracted. These multiple maps were then overlaid to produce a single map depicting the most relevant areas for the selected species (NAFO 2008a Figure 18). There was very little overlap in distribution, with only a few areas proving critical to more than 2 species and no areas in common with 5.

The FAO Guidelines also call for monitoring and assessments of low-productivity fish species caught in deep sea fisheries (which have the same life-history traits as those detailed above for identifying components of vulnerable marine ecosystems). General principles for the management of deep sea fisheries, including target and non-target species, are set forth in the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. The WGEAFM did not comment explicitly on whether any of the 21 Tier 2 species that they listed were monitored or assessed.

We have investigated this and note that Scientific Council provides advice on 18 stocks in the NRA, 3 of which were identified by the WGEAFM as vulnerable marine ecosystem indicators and so therefore are managed through stock assessments: redfish 3LN, 3O, 3M; roughhead grenadier 2+3; white hake 3NO.

The request of the Fisheries commission was to provide a list of VME indicator species and other vulnerable marine ecosystem elements. We interpret this to mean *additional* examples of species groups, communities and habitat-forming species and elements which may contribute to forming vulnerable marine ecosystems. Consequently we will not repeat the work of the previous WGEAFM report (NAFO 2008a) and supporting documents (Fuller et al. 2008), which is reiterated herein, but will revisit the cases made for black coral, Cerianthid anemones and "other benthic taxa" listed in their report where we feel new information is available for assessment. We will consider *additional* species groups, communities and habitat-forming species and elements which may contribute to forming VMEs in the context of *additional* to the seamounts, corals and sponges already protected by NAFO.

List I provides a detailed list of VME indicator species (benthic invertebrates, fish, marine mammals and sea turtles) known to occur in the NRA. For completeness, this list also includes VME indicator fish species associated with seamounts. NEREIDA data are being analyzed and more species are expected to be added to the list in the coming years.

List II provides a detailed list of the VME and Potential VME elements considered and known to occur in the NRA.

1.2.2. Potential benthic invertebrate Vulnerable Marine Ecosystem indicators

1.2.2.1. VME indicator species based on functional significance, fragility, and the life-history traits of component species that produce a slow recovery to disturbance.

In order to provide a systematic assessment of whether there are additional benthic invertebrate species, communities or habitat-forming species in the NRA that should be considered VME indicators, a list of traits was produced against which the taxa known to occur in the NRA could be evaluated. Known taxon lists were created from records from Spanish/EU bottom trawl groundfish surveys and from rock dredge records from the NEREIDA project. Samples are still being processed so more taxa could be added to the list in the coming years, however for this assessment approximately 500 taxa were considered. The traits against which these were assessed are indicated in Table 1.2.2.1.1. Benthic invertebrate megafaunal taxa were classified initially into broad taxonomic groupings and considered against the criteria. Those which appeared to have potential for meeting the criteria were crinoids, tube anemones, large sea anemones, erect hydrozoans, erect bryozoans, large sea squirts (Ascidians), large sea stars (Brisingidae), sea urchins, brittle stars, large holothurians, large gastropods and barnacles. Each of those groups was assessed against the criteria listed in Table 1.2.2.1.1 to the extent possible using relevant literature. In many cases biological traits were inferred from other similar species. Of these, only three different groups were considered to be indicators of VMEs. These are the crinoids, the erect bryozoans and the large sea squirts.

Table 1.2.2.1.1. Biological traits for vulnerable marine ecosystem components used to evaluate the benthic invertebrate taxa known to occur in the NAFO regulatory area and the faunal groups which possess those traits. Traits reflect the three pillars of the FAO Guidelines (FAO 2009): Vulnerability, Recoverability and Ecosystem Function.

Biological Traits Relevant to FAO Guidelines	**Faunal Group**		
	Crinoids	**Erect Bryozoans**	**Large Sea Squirts**
Fragility, Vulnerability and Recoverability			
fragility	yes	yes	yes
height off bottom > 5 cm	yes (stalked)	yes	yes
lifespan (> 20 yr)	yes	some cases	?
slow growth rates	no	?	?
late age of maturity	?	?	?
irregular or episodic recruitment	?	?	?
poor regeneration ability (> 20 years)	no	?	yes
low fecundity	?	?	no
Significant Role in Ecosystem (Function)			
structural engineer	X	X	X
predator			
bioturbator			
carbon sequester			
benthic pelagic coupling			
benthic production			

1.2.2.1.1. Crinoids. Phylum Echinodermata. Class Crinoidea

Crinoids are fragile organisms that in some cases live attached to the sea bottom by a stalk that raises them off the sea floor (Figure 1.2.2.1.1.1) and consequently are vulnerable to bottom-contact fisheries. Although limited information exists about their longevity or growth rates, Roux (1976) estimated mean age in a population of *Endoxocrinus wyvillethomsoni* as greater than 15 years, with some individuals older than 20 years, and Messing, (unpublished data, in Messing et al. 2007) indicated a longevity exceeding 20 yr for *Cenocrinus asterinus* in 215 m depth.

Some species are highly aggregated in deep water (Conan et al. 1981) and they can provide refuge and substrata for a wide variety of small fishes and invertebrates (Lissner and Benech 1993 and Puniwai 2002 cited in Tissot et al. 2006). Direct evidence of fish predation on stalked crinoids is likewise rare, as the deep-water habitats of living stalked crinoids make observations difficult (Baumiller 2008) however, submersible observations provide some evidence that fishes do interact with these crinoids (Conan et al. 1981, Messing et al. 1988, Baumiller et al. 1991) as well as other invertebrates (Baumiller et al. 1999).

Some species of unstalked crinoids form dense aggregations or beds. In the Mediterranean *Leptometra phalangium* is a dominant species on the shelf break and appears to be critical habitat to juvenile and spawning benthopelagic fish (Colloca et al. 2004, Ordines and Massutí 2009). The crinoid beds are heavily damaged by trawling and recovery does not take place at least within a season (Smith et al. 2000). However, unstalked crinoids are one of only a few taxa that had significantly higher abundance five to ten years after trawling on New Zealand and Australian seamounts (Williams et al. 2010). It was suggested that this may have resulted from protection in natural refuges inaccessible to trawls followed by a rapid recolonization of cleared substrate (Williams et al. 2010).

***Conclusion*:** The fragility, long lifespan, and capacity to provide habitat for other organisms when they are aggregated to form beds make crinoids VME indicator species.

Comments on presence of crinoid VME in the NRA

Data from Spanish/EU groundfish surveys (2007-2010 data), rock dredge samples (NEREIDA Project 2009-2010) and a proportion of the *in situ* images (NERIDA Project 2009-2010) were reviewed and 3 species of crinoid that could be VME indicators were identified (Table 1.2.2.1.1.1). From the groundfish surveys only 11 records were found each with only 1 – 6 individuals per trawl. These were located mainly around Flemish Cap between 600 and 1200 m depth. The 94 valid rock dredge samples which were taken from approximately 500 to 2000 m depth provided 24 records with crinoids. The maximum abundance was 41 individuals in a single dredge. The most important concentrations were observed through video images in the 2010 NEREIDA-Canadian ROPOS Survey along the East of Flemish Cap, where high densities of the stalked crinoid *Gephyrocrinus grimaldii* were observed together with several structure-forming sponges at 2148 m depth (Figure 1.2.2.1.1.1). These data are still being processed and may provide indication of crinoid VME areas within the NRA.

Figure 1.2.2.1.1.1. *Gephyrocrinus grimaldii*, East of Flemish Cap (NAFO 3M Div.). Photo courtesy of DFO (NEREIDA project).

Beds of unstalked crinoids (Table 1.2.2.1.1.1) have not been observed in the NRA, although more data on these may emerge as the NEREIDA data are analyzed in the coming year.

Table 1.2.2.1.1.1. Examples of crinoids known to occur in the NRA considered VME indicator species.

TAXON	FAMILY	Morphology	VME Indicator
Gephyrocrinus grimaldii	Hyocrinidae	Stalked	yes
Conocrinus lofotensis	Bourgueticrinidae	Stalked	potentially
Trichometra cubensis	Antedonidae	Not stalked	potentially

1.2.2.1.2. Erect Bryozoans. Phylum Bryozoa.

Erect bryozoans form ramified structures in a variety of marine environments that can be ecologically important in providing substrata for epizoans and hiding places for motile organisms, including ophiuroids and small fish (Smith et al. 2001). Although most bryozoans are short-lived and studies of growth rate and colony age in large erect bryozoan species are few, some colonies can reach twenty years old (Smith et al. 2001). Fenestrate or reteporiform cheilostomate bryozoans are some of the erect bryozoans that constitute hard structures (Figure 1.2.2.1.2.1) and are popularly known as lace corals (Hayward and Ryland 1996).

Figure 1.2.2.1.2.1. Reteporiform bryozoan. Tail of the Grand Banks of Newfoundland, (NAFO 3N Div.). Photo courtesy of IEO. Note the other species associated with it.

Their fragility and exposure above the bottom means that bottom trawling of the seabed can damage bryozoan beds. Saxton (1980) and Bradstock and Gordon (1983) recorded the effects of the systematic destruction by trawlers of the bryozoan beds in Tasman Bay, New Zealand, which provided habitat for juvenile snapper and tarakihi. It was also noted that the abundance of juvenile fish subsequently declined (Saxton 1980). These bryozoan beds had not recovered 10 years later and the loss was believed to be permanent (Jones 1992). However less dense aggregations have been shown to be relatively unaffected by trawling, with large interannual variability in recruitment greater than impact effects (Henry et al. 2006).

Conclusion: Based on their life history traits and empirical evidence on their vulnerability to bottom trawling we recommend that the conservation unit be **bryozoan beds**, rather than less dense aggregations of these species.

Comments on presence of erect bryozoan VME in the NRA

Spanish/EU groundfish survey bycatch data revealed that in some areas of the NRA (Tail of the Grand Banks of Newfoundland) it is common to find the erect bryozoan *Eucratea loricata* together with others bryozoans including some with reteporiform shape. This species forms a tall, dense clump (Figure 1.2.2.1.2.2), commonly around 10 cm, but up to 25 cm tall, buff or light-brown, resembling a miniature poplar tree (Ryland and Hayward 1991). The catches found in 2007 ranged from 0.001 to 1.45 kg per 30 minute research trawl. All the catches were shallower than 100 m depth. The catches found do not seem to be representative of bryozoan beds, but in order to make a complete assessment more research in the area with visual ground truthing is required.

Figure 1.2.2.1.2.2. *Eucratea loricata*. Tail of the Grand Banks of Newfoundland, (NAFO 3N Div.). Photo courtesy of IEO.

Table 1.2.2.1.2.1. Examples of erect bryozoans known to occur in the NRA and with the potential to form beds or dense aggregations. This group has not been fully processed and other species are known to occur but they have not yet been identified.

TAXON	FAMILY
Eucratea loricata	Eucrateidae

1.2.2.1.3. Large Sea squirts. Phylum Chordata. Class Ascidiacea

Boltenia ovifera and other large species such as *Halocynthia aurantium* are often found in groups where they form significant habitat (Figure 1.2.2.1.3.1). Kenchington et al. (2007) identified *Boltenia ovifera* as one of a number of species which significantly declined in the Bay of Fundy, Canada over a 30 year period and attributed this decline to the cumulative impacts of trawling in the area. In the North Pacific, they are known to provide habitat to small juvenile red king crab (*Paralithodes camtschaticus*) (McMurray et al. 1984, Stevens and Kittaka 1998). Some sea squirts (i.e. *Boltenia ovifera*) support other invertebrate fauna attached to the stems and holdfasts.

Figure 1.2.2.1.3.1. *Boltenia ovifera*, Bay of Fundy, Canada. Photo courtesy of Mike Strong and Maria Buzeta-Innes, DFO.

Comments on presence of large sea squirt VME in the NRA.

Two species of large sea squirt were identified from the data sources (Table 1.2.2.1.3.1). Spanish/EU groundfish survey bycatch data (2007-2010) revealed fifty records of *Boltenia ovifera* from the Tail of the Grand Banks between 50 and 320 m depth. More than 75 % of the catches were lower than 1 kg and 10 individuals; however a catch of 4.55 kg (65 individuals, Figure 1.2.2.1.3.2) was recorded at 200 m depth. The large catch of *B. ovifera* which may constitute the location of a VME indicated by this species was found at: 43°21'50.4''N 49°25'19.2''W (start of tow) 43°23'09''N 49°24'17.4''W (end of tow). There were only a few individuals of *Halocynthia aurantium* present in these data.

Figure 1.2.2.1.3.2. *Boltenia ovifera*, Tail of the Grand Banks of Newfoundland, (NAFO 3N Div.). Photo courtesy of IEO.

Table 1.2.2.1.3.1**.** Examples of large sea squirts known to occur in the NRA considered VME indicator species.

TAXON	FAMILY
Boltenia ovifera	Pyuridae
Halocynthia aurantium	Pyuridae

1.2.2.1.4. Tube-dwelling Anemones. Phylum Cnidaria. Order Ceriantharia

Justification to include tube dwelling anemone fields (Ceriantharia) as habitat which should be considered as VME were provided in Fuller et al. (2008). We present new information about their presence in the NRA based on Spanish/EU groundfish surveys and preliminary data from the NEREIDA project.

From the period analyzed (2007-2010) no tube dwelling anemone fields have been observed and only two single records of tube-dwelling anemones (*Pachycerianthus borealis* Table 1.2.2.1.4.1) were registered in the Tail of the Grand Banks based on Spanish/EU groundfish surveys and around 20 records of other small Ceriantharia species with a maximum of 11 small specimens (11 g) taken in one sample station based in rock dredges from the NEREIDA Project (2009-2010).

These sampling gears do not provide accurate estimates of the abundance of these organisms, because bottom trawls are expected to have a low catchability for them, as they can burrow in the sediments when disturbed. Rock dredges are used for sampling hard bottoms and these tube dwelling anemones form dense aggregations on sandy or muddy bottoms.

At this time for the area studied (NRA, Divs. 3LMNO, 50-1500 m) no tube dwelling anemone fields have been observed but analysis of the *in situ* photographic images and video collected during NEREIDA is necessary to complete this assessment.

Table 1.2.2.1.4.1. Examples of tube dwelling anemones known to occur in the NRA and with potential to form fields or dense aggregations. This group has not been fully processed and other species are known to occur but they have not yet been identified.

TAXON	FAMILY
Pachycerianthus borealis	Cerianthidae

1.2.2.2. Vulnerable Marine Ecosystem indicators based on uniqueness/rarity, fragility, and the life-history traits of component species that produce a slow recovery to disturbance

Based on data from Spanish/EU groundfish surveys (2007-2010 period), rock dredge samples (NEREIDA Project) and preliminary analysis of images from the NEREIDA-Canadian photographic surveys (2009-2010) no other rare/endemic species have been identified in the NRA. NEREIDA data are currently being analyzed and new information may emerge in the coming years.

1.2.2.2.1. Black Corals. Phylum Cnidaria. Order Antipatharia

As noted above, black corals meet the vulnerability and recoverability criteria for vulnerable marine ecosystems as described in the FAO Guidelines. However, because they are solitary and rare they have little impact on ecosystem functioning. They are broadly distributed at low density in the northwest Atlantic and so do not meet the uniqueness/rarity criterion of habitats of rare, threatened or endangered species that occur only in discrete areas. If they were removed from the fishing footprint of the NRA they would still persist along the continental slopes of Canada (Kenchington et al. 2010). Figure 1.2.2.2.1.1 illustrates the records of black coral per 10 x 10 nautical mile cell sizes based in Spanish/EU groundfish surveys (2006-2010), NEREIDA Project (2009-2010) and NEREIDA-Canadian 2010 ROPOS survey superposed with the current closures in the NRA (Divs. 3LMNO). While broadly distributed, black corals are more prevalent in four areas near the current closured areas. These higher density areas could be considered for further protection given the iconic nature of these species (Fuller et al. 2008) based on their extraordinary life-history traits.

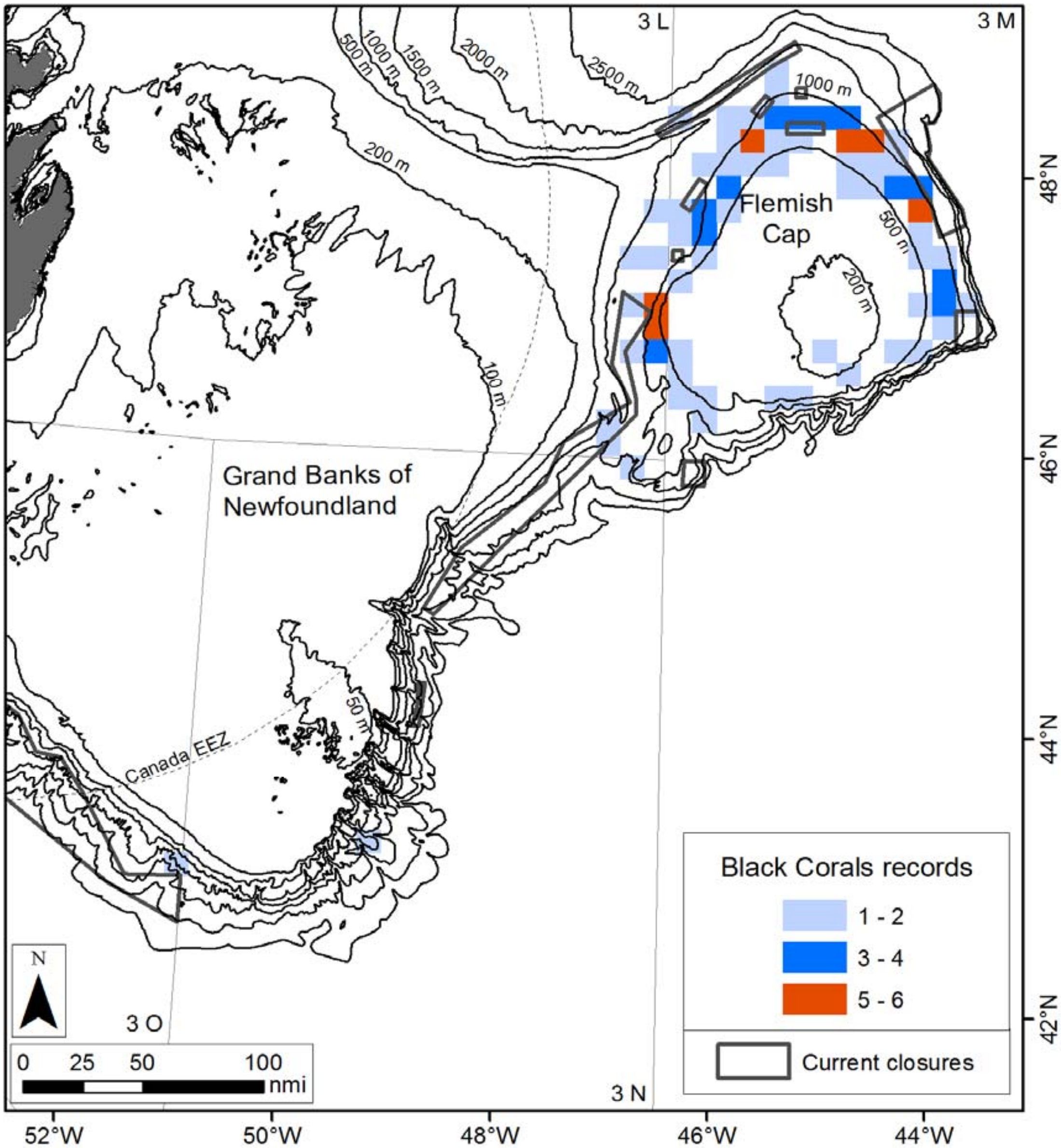

Figure1.2.2.2.1.1**.** Map of Black Corals records in the NRA (Divs. 3LMNO) per 10 x 10 nautical mile cell sizes based in Spanish/EU groundfish surveys (2006-2010), NEREIDA Project (2009-2010), and NEREIDA-Canadian 2010 ROPOS Survey superimposing the current closed areas.

1.2.3. Fish, aquatic mammals, and sea turtles as potential Vulnerable Marine Ecosystem indicators

In proposing candidate VMEs in 2008, WGEAFM considered how fish species fit into the FAO criteria for defining VMEs, and identified numerous fish species that fit these criteria. WGEAFM re-examined these species to see if they still qualify, and also considered whether other fish, aquatic mammals, and sea turtles should be added. Shellfish were not considered at this stage. WGEAFM noted that the purpose of the exercise in 2008 was to identify candidate VME **areas**, and that the current exercise is focused on defining VME indicator **species**.

The original (2008) process involved several steps. From the original five criteria outlined in the FAO Guidelines, three were selected as being suitable for individual fish species: (i) uniqueness or rarity, (ii) functional significance of the habitat, and (iv) life history traits. For the uniqueness or rarity criterion, factors such as NAFO moratoria on fishing, and COSEWIC designations for populations that enter the NRA were considered. For a full description of the process involved in selecting the list of VME species of fish, including the actual list and criteria, see pages 30-34 of the 2008 WGEAFM report (SCS 08/10).

A similar procedure to determine a list of species was used at the current meeting. A list of 50 of the most commonly occurring fish species from research vessel survey data in the NRA was examined, along with the list of marine mammals and sea turtles known to occur in the general area.

Fish species were selected for consideration as VME indicators if they met one of four criteria: under NAFO moratorium, COSEWIC (2011) designation as Special Concern, Threatened or Endangered (as of October 2011), present on seamounts, or the FAO criteria for life history traits of species that make recovery difficult. Following this initial selection, a more detailed examination of the status and situation of these species within the NRA was performed; this examination included a more focused assessment of the FAO criteria, as well as other information like the presence of these species as by-catch in fisheries. As a consequence of this additional reviewing step, the species in the list of potential VME indicator species in the NRA were qualified as VME indicator species or not (Table 1.2.3.1). Those accepted species were included in **List I**.

In the specific case of aquatic mammals and sea turtles, the procedure essentially involved the examination of the COSEWIC status of the species known or likely to occur in the NRA (Table 1.2.3.2). The scale of movement of any of these species is certainly far larger than the NRA itself, so their consideration as VME indicator species is more related to conservation concerns for their respective populations. Marine mammals and sea turtles have life history traits that make recovery difficult when depleted.

WGEAFM noted that some species which qualify as VME indicators are commercial species, and some stocks are at fishable levels. For the current FC request to identify a list of VME indicator species, WGEAFM considered that such a list of fish/mammal species (see **List I**) would likely require different management/conservation measures than a list of other VME indicator species such as corals and sponges. For example, the encounter protocols and threshold values applied to the corals and sponges are not likely to be applicable in the same way to mobile species, which in some cases are covered by existing quota and/or by-catch management rules. Nonetheless, WGEAFM considered important to highlight that species that have a history of exploitation, may very well posses characteristics that make them VME indicator species.

Table 1.2.3.1. List of potential fish VME indicator species. **i – v** = FAO VME species criteria, only (i) uniqueness or rarity, (ii) functional significance of the habitat, and (iv) life history traits were deemed applicable for mobile species; **Inc** = species considered to be VME indicator species in the NRA. In addition to seamount specific species, 16 additional fish species have been identified as VME indicators in the NRA, and 14 of these have sufficient data for them to be mapped.

Common name	**i**	**ii**	**iii**	**iv**	**v**	**Inc**	**Scientific name**	**Mapped**	**Initial rationale for inclusion**	**Final rationale for inclusion/ exclusion**
redfish, deep water	n	n		y		**In**	*Sebastes mentella*	*	*COSEWIC designation, threatened, life history*	*Distribution restricted to slopes or specific areas, core concentrations in the NRA*
redfish,golden (marinus)	n	n		y		**In**	*Sebastes marinus*	*	*COSEWIC designation, threatened, life history*	*Distribution restricted to slopes or specific areas, core concentrations in the NRA*
redfish, Acadian	n	n		y		**In**	*Sebastes faciatus*	*	*COSEWIC designation, threatened, life history*	*Distribution restricted to slopes or specific areas, core concentrations in the NRA*

American Plaice	n	n		n			*Hippo-glossoides platessoides*	*	*NAFO moratorium, COSEWIC designation threatened*	*Ample distribution, no critical concentrations in NRA*
cod, Atlantic	n	n		n			*Gadus morhua*	*	*NAFO moratorium in 3NO, COSEWIC designation endangered*	*Ample distribution, no critical concentrations in NRA, Good population in 3M*
witch flounder	n	n		n			*Glyptocephalus cynoglossus*	*	*NAFO moratorium*	*Ample distribution, no critical concentrations in NRA*
Capelin	y	y		n		**In**	*Mallotus villosus*	*	*NAFO moratorium*	*Critical spawning grounds in the Southeast Shoal for 3NO stock*
dogfish, black	n	n		y		**In**	*Centroscyllium fabricii*	*	*Sensitive life history traits*	*Restricted areas of high concentration on the GB and in the NRA*
grenadier, roundnose	n	n		y		**In**	*Coryphaenoides rupestris*	*	*Designated [endangered, COSEWIC], life history*	*Restricted areas of high concentration on the GB and in the NRA*
grenadier, roughhead	n	n		y		**In**	*Macrourus berglax*	*	*Designated [special concern, COSEWIC], life history*	*Restricted areas of high concentration on the GB and in the NRA*
deep sea cat shark	n	n		y		**In**	*Apristuris profundorum*	*	*Sensitive life history traits*	*Restricted areas of low concentration on the GB and in the NRA*
hake, white (common)	n	n		y		**In**	*Urophycis tenuis*	*	*low abundance, under review by COSEWIC*	*Restricted areas of high concentration on the GB and in the NRA*
wolffish, striped	y	n*		?		**In**	*Anarhichas lupus*	*	*Designated [special concern, COSEWIC & SARA]*	*Restricted areas of high concentration on the GB and in the NRA*
wolffish, broadhead	y	n*		?		**In**	*Anarhichas denticulatus*	*	*Designated [threatened, COSEWIC & SARA]*	*Restricted areas of high concentration on the GB and in the NRA*
skate,smooth	y	y		y		**In**	*Malacoraja senta*	*	*Final assessment stage, COSEWIC*	*Restricted areas of high concentration on the GB and in the NRA, potential for local populations*
wolffish, spotted	y	n*		?		**In**	*Anarhichas minor*	*	*Designated [threatened, COSEWIC & SARA]*	*Restricted areas of high concentration on the GB and in the NRA*

halibut (Atlantic)	y	n		n			*Hippoglossus hippoglossus*		*Designated [not at risk, COSEWIC]*	*Ample distribution, no critically low concentrations in NRA*
mako, shortfin	y	n		y			*Isurus oxyrinchus*		*Designated [threatened, COSEWIC]*	*Ample distribution, pelagic, no critically low concentrations in NRA*
porbeagle	y	n		y		**In**	*Lamna nasus*		*Designated [endangered, COSEWIC]*	*Pupping grounds in the NRA and other parts of the Grand Bank*
skate, spinytail	n	n		y		**In**	*Bathyraja spinicauda*	*	*Sensitive life history traits*	*Highest concentrations along the slope, Restricted areas of high concentration on the GB and in the NRA*
shark, Portuguese	y	?		y		**In**	*Centroscymnu s coelolepis*		*Sensitive life history and, presence in seamounts*	*A globally rare species but with high frequency of records in the NRA, also present in seamounts*
shark,basking	n	n		y			*Cetorhinus maximus*		*Designated [special concern, COSEWIC], life history*	*Ample distribution*
Alfonsino	y	y		n		**In**	*Beryx splendens*		*Present on seamounts*	*Distribution and concentrations highly associated to seamounts*
Beryx decadactylus	y	y		n		**In**	*Beryx decadactylus*		*Present on seamounts*	*distribution and concentrations highly associated to seamounts*
Orange roughy	y	y		y		**In**	*Hoplostethus atlanticus*		*Present on seamounts*	*distribution and concentrations highly associated to seamounts*
Hoplostethus mediterraneus	y	y		y?		**In**	*Hoplostethus mediterraneus*		*Present on seamounts*	*distribution and concentrations highly associated to seamounts*
Wreckfish	y	y		y?		**In**	*Polyprin americanus*		*Present on seamounts*	*distribution and concentrations highly associated to seamounts*
Cardinalfish	y	y		y?		**In**	*Epigonus telescopus*		*Present on seamounts*	*distribution and concentrations highly associated to seamounts*

Table 1.2.3.2. List of potential aquatic mammals and sea turtles as VME indicator species that can be found in Atlantic waters.

Common name	**Scientific name**	**COSEWIC designation**	**Distribution in NW Atlantic**	**Presence in NRA**	**Include as VME?**
Bowhead Whale	*Balaena mysticetus*	Special Concern	northern - occasional in south	unlikely	
Minke Whale	*Balaenoptera acutorostrata*	Not at Risk	Everywhere	Yes	
Sei Whale	*Balaenoptera borealis*	Data Deficient	Everywhere	Yes	Y
Blue Whale	*Balaenoptera musculus*	Endangered	Everywhere	likely	Y
Fin Whale	*Balaenoptera physalus*	Special Concern	Everywhere	Yes	Y
Gray Whale	*Eschrichtius robustus*	Extirpated			
North Atlantic Right Whale	*Eubalaena glacialis*	Endangered	likely offshore on Grand Banks	likely	Y
Humpback Whale	*Megaptera novaeangliae*	Not at Risk	Everywhere	Yes	
Sperm Whale	*Physeter macrocephalus*	Not at Risk	Everywhere	Yes	
Sowerby's Beaked Whale	*Mesoplodon bidens*	Special Concern	Offshore	Yes	Y
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not at Risk	occasional	Possible - offshore	
True's Beaked Whale	*Mesoplodon mirus*	Not at Risk	occasional	Possible - offshore	
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not at Risk	Offshore	Yes	
Beluga	*Delphinapterus leucas*	Endangered stocks	northern - occasional in south	unlikely	
Short-Beaked Common Dolphin	*Delphinus delphis*	Not at Risk	Everywhere	likely	
Long-finned Pilot Whale	*Globicephala melas*	Not at Risk	Everywhere	Yes	
Risso's Dolphin	*Grampus griseus*	Not at Risk	occasional	Possible	
Northern Bottlenose Whale	*Hyperoodon ampullatus*	Endangered/Special Concern	Slope edge	Yes	Y
Atlantic White-sided Dolphin	*Lagenorhynchus acutus*	Not at Risk	Everywhere	Yes	
White-Beaked Dolphin	*Lagenorhynchus albirostris*	Not at Risk	Everywhere	Yes	
Narwhal	*Monodon monoceros*	Special Concern	northern - occasional in south	unlikely	
Killer Whale	*Orcinus orca*	Special Concern	Everywhere	likely	Y
Harbour Porpoise	*Phocoena phocoena*	Special Concern	Everywhere	Yes	Y

Striped Dolphin	*Stenella coeruleoalba*	Not at Risk	occasional	Possible	
Bottle-Nosed Dolphin	*Tursiops truncatus*	Not at Risk	Everywhere	likely	
Hooded Seal	*Cystophora cristata*	Not at Risk	Everywhere	Yes	
Bearded Seal	*Erignathus barbatus*	Data Deficient	Nearshore	unlikely	
Gray Seal	*Halichoerus grypus*	Not at Risk	Scotian shelf/nearshore	unlikely	
Harp Seal	*Pagophilus groenlandica*	Not at Risk	Everywhere	Yes	
Harbour Seal	*Phoca vitulina*	Not at Risk	Nearshore	unlikely	
Ringed Seal	*Pusa hispida*	Not at Risk	Nearshore	unlikely	
Polar Bear	*Ursus maritimus*	Special Concern	northern+ Labrador	unlikely	
Leatherback turtle	*Dermochelys coriacea*	Endangered	Everywhere	likely	Y

1.2.4. Potential VME (non biological) elements

1.2.4.1. Canyons

As noted previously, the Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM) provided justification for including seamounts as VME elements with respect to traits referred to above and in the FAO Guidelines as well as canyon heads, spawning areas and other knolls (NAFO 2008a).

NEREIDA work has allowed the identification of new canyons along the south of Flemish Cap and the redefinition of those which previously were identified by the WGEAFM. The WGEAFM previously identified canyons using the 200 m depth contour as the upper limit, whereas NEREIDA geologists have identified two different types of canyons based in the location of the canyon head: 1) shelf-indenting canyons; canyons with heads that indent the shelf of the Grand Banks and 2) canyons that head at > 400 m water depth; canyons with heads on the upper slope. As NEREIDA work was not able to map the Division 3O outside the Canadian EEZ, the previously identified canyons of this area (Jukes and Whitbourne canyons) are maintained. The map with the new canyons is presented in Figure 1.2.4.1.1.

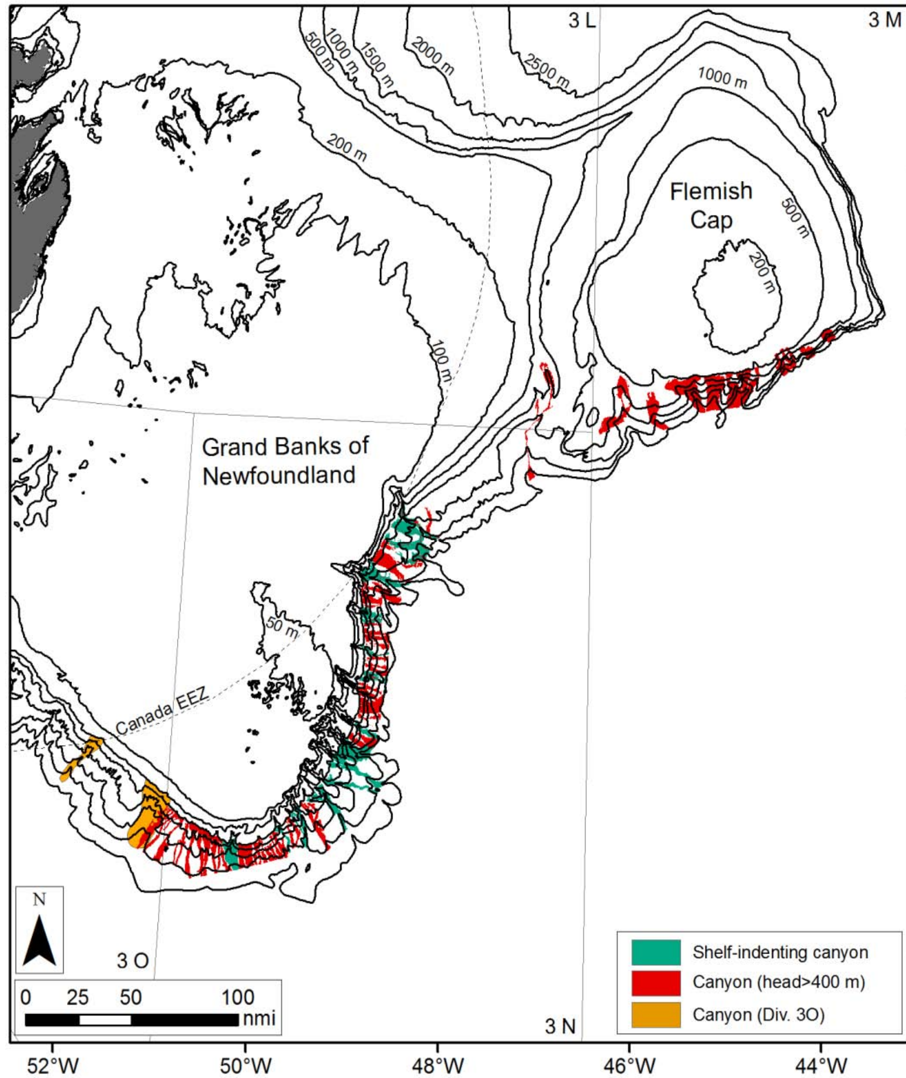

Figure 1.2.4.1.1. Map of canyons in the NRA (Divs. 3LMNO).

1.2.4.2. Steep flanks

Submerged edges and slopes are recognized geological features that potentially support vulnerable species groups or communities such as corals and sponges (FAO 2009), and so could be considered potential VME elements.

NEREIDA work has allowed the geologists to identify areas of steep seafloor on the continental slope commonly with sub-parallel intervals of slopes >6.4° alternating with less steep intervals. These areas could be potential VME elements and are represented in the Figure 1.2.4.2.1. They occur around Flemish Cap and on smaller bedrock highs such as Beothuk Knoll and “Hudson prong”.

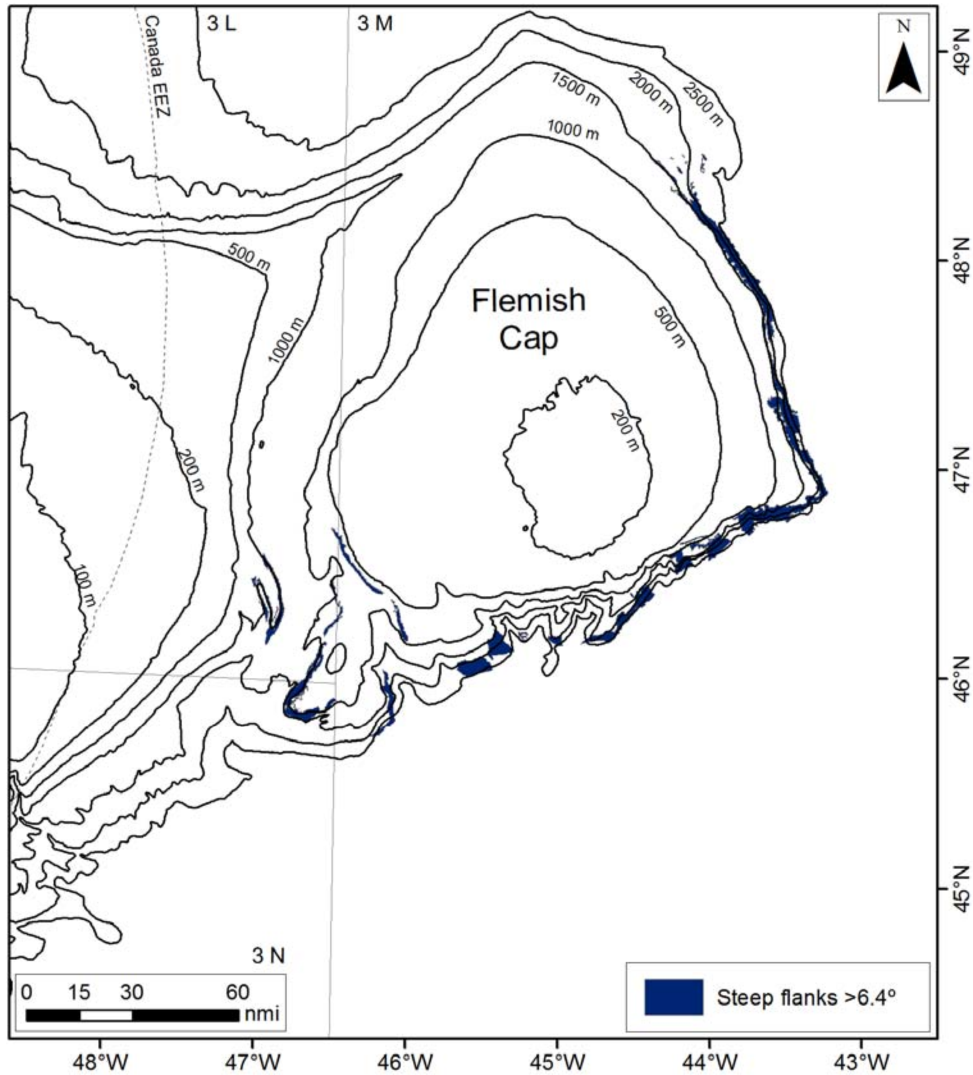

Figure 1.2.4.2.1. Map of the Steep flanks >6.4° in the NRA (Divs. 3 LM).

1.2.4.3. Seamounts. The Fogo Seamounts.

The Fogo Seamounts are located on oceanic crust in the central North Atlantic Ocean, southwest of the Grand Banks of Newfoundland and form a broad zone of volcanoes that parallels the transform margin (Figure 1.2.4.3.1). This zone is narrowest in the northwest and widens to 200 km in the southeast. This pattern differs from the narrow linear arrangement of a typical seamount channel, such as the Newfoundland and New England Seamounts (Pe-Piper et al. 2007).

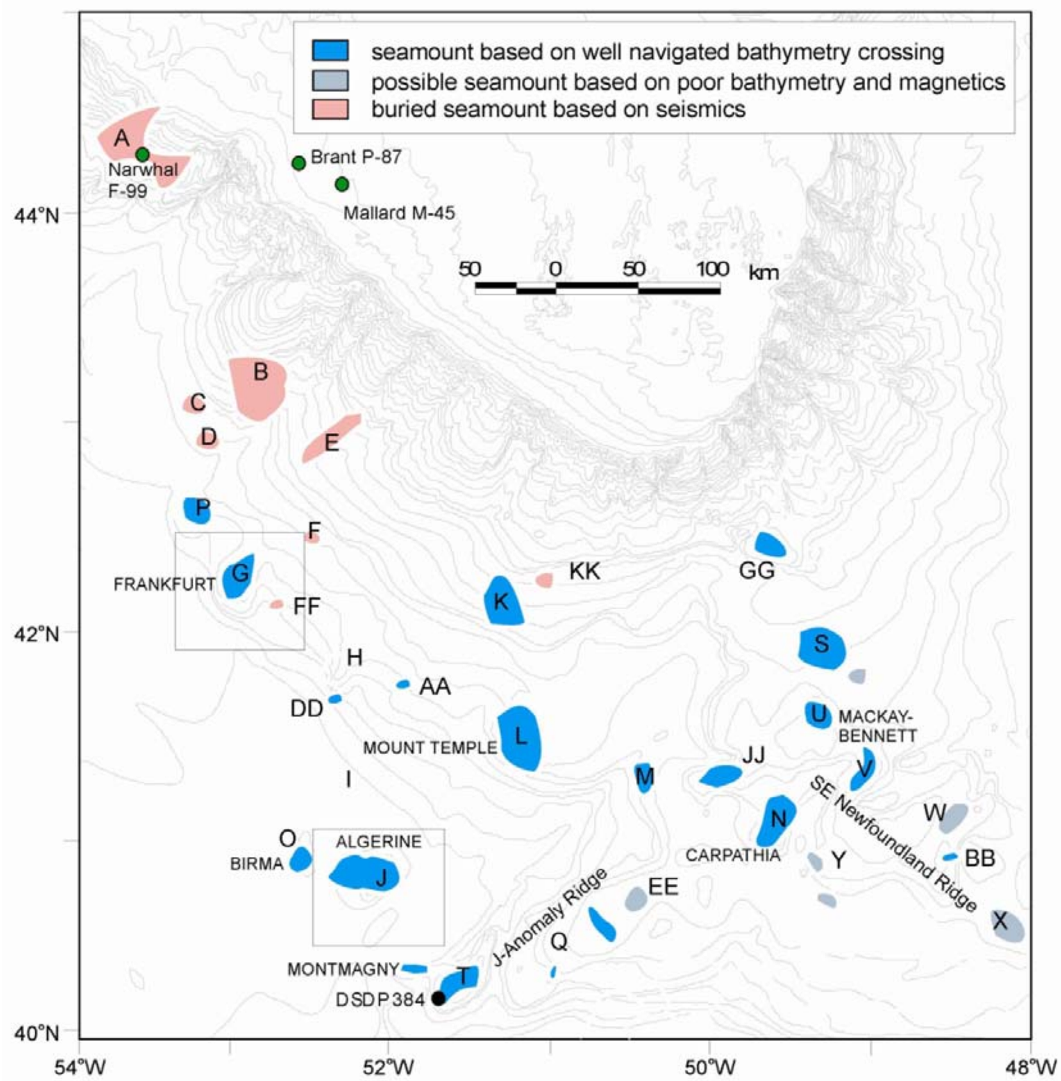

Figure 1.2.4.3.1. Map of the Fogo Seamounts and other seamounts south of the Tail of the Banks. Modified from Pe-Piper et al. (2007). Largest seamounts have official names (after the ships that came to the aid of the Titanic). Other geological seamounts may be buried or are otherwise low features. Letter codes refer to Table 2 of GSC Open File 5182 which lists sources of data. The locations of the Fogo Seamounts current closures are also indicated.

Since January 1, 2007, two areas to protect the Fogo Seamounts were closed to all bottom fishing activities (NAFO 2010). At this point only a small part of the area was closed (Figure 1.2.4.3.1) and several seamounts remained outside of the closures. Most of the seamounts are deeper than 2000 m depth and outside of the current fishery footprint, so interactions with fishery activities and seamounts at this moment is quite improbable.

WGEAFM notes that given new information on distribution of Fogo Seamounts is available (Pe-Piper et al. 2007) it should be highlighted to SC that these new areas be taken into consideration when reviewing seamounts closures in 2014 (NAFO 2012).

1.2.5. References

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List I. List of VME indicator species (benthic invertebrates, fish, aquatic marine mammals, and sea turtles) in the NAFO Regulatory Area.

Benthic Invertebrates

Common name	**Taxon**	**Family**	**Phyllum**
Large-sized sponges	*Iophon piceum*	Acarnidae	Porifera
	Stelletta normani	Ancorinidae	
	Stelletta sp.	Ancorinidae	
	Stryphnus ponderosus	Ancorinidae	
	Axinella sp.	Axinellidae	
	Phakellia sp.	Axinellidae	
	Esperiopsis villosa	Esperiopsidae	
	Geodia barretti	Geodiidae	
	Geodia macandrewii	Geodiidae	
	Geodia phlegraei	Geodiidae	
	Mycale (Mycale) lingua	Mycalidae	
	Thenea muricata	Pachastrellidae	
	Polymastia spp.	Polymastiidae	
	Weberella bursa	Polymastiidae	
	Weberella sp.	Polymastiidae	
	Asconema foliatum	Rossellidae	
	Craniella cranium	Tetillidae	
Stony corals	*Lophelia pertusa*	Caryophylliidae	Cnidaria
	Solenosmilia variabilis	Caryophylliidae	
	Enallopsammia rostrata	Dendrophylliidae	
	Madrepora oculata	Oculinidae	

Small gorgonians	*Anthothela grandiflora*	Anthothelidae	Cnidaria
	Chrysogorgia sp.	Chrysogorgiidae	
	Radicipes gracilis	Chrysogorgiidae	
	Metallogorgia melanotrichos	Chrysogorgiidae	
	Acanella arbuscula	Isididae	
	Acanella eburnea	Isididae	
	Swiftia sp.	Plexauridae	
	Narella laxa	Primnoidae	
Large gorgonians	*Acanthogorgia armata*	Acanthogorgiidae	Cnidaria
	Iridogorgia sp.	Chrysogorgiidae	
	Corallium bathyrubrum	Coralliidae	
	Corallium bayeri	Coralliidae	
	Keratoisis ornata	Isididae	
	Keratoisis sp.	Isididae	
	Lepidisis sp.	Isididae	
	Paragorgia arborea	Paragorgiidae	
	Paragorgia johnsoni	Paragorgiidae	
	Paramuricea grandis	Plexauridae	
	Paramuricea placomus	Plexauridae	
	Paramuricea spp.	Plexauridae	
	Placogorgia sp.	Plexauridae	
	Placogorgia terceira	Plexauridae	
	Calyptrophora sp.	Primnoidae	
	Parastenella atlantica	Primnoidae	
	Primnoa resedaeformis	Primnoidae	
	Thouarella grasshoffi	Primnoidae	
Sea pens	*Anthoptilum grandiflorum*	Anthoptilidae	Cnidaria
	Funiculina quadrangularis	Funiculinidae	
	Halipteris cf. *christii*	Halipteridae	
	Halipteris finmarchica	Halipteridae	
	Halipteris sp.	Halipteridae	
	Kophobelemnon stelliferum	Kophobelemnidae	
	Pennatula aculeata	Pennatulidae	
	Pennatula grandis	Pennatulidae	
	Pennatula sp.	Pennatulidae	
	Distichoptilum gracile	Protoptilidae	
	Protoptilum sp.	Protoptilidae	
	Umbellula lindahli	Umbellulidae	
	Virgularia cf. mirabilis	Virgulariidae	

Black corals	*Stichopathes* sp.	Antipathidae	Cnidaria
	Leiopathes cf. *expansa*	Leiopathidae	
	Leiopathes sp.	Leiopathidae	
	Plumapathes sp.	Myriopathidae	
	Bathypathes cf. patula	Schizopathidae	
	Bathypathes sp.	Schizopathidae	
	Paranthipathes sp.	Schizopathidae	
	Stauropathes arctica	Schizopathidae	
	Stauropathes cf. *punctata*	Schizopathidae	
Tube-dwelling anemones	*Pachycerianthus borealis*	Cerianthidae	Cnidaria
Erect bryozoans	*Eucratea loricata*	Eucrateidae	Bryozoa
Sea lilies	*Trichometra cubensis*	Antedonidae	Echinodermata
	Conocrinus lofotensis	Bourgueticrinidae	
	Gephyrocrinus grimaldii	Hyocrinidae	
Sea squirts	*Boltenia ovifera*	Pyuridae	Chordata
	Halocynthia aurantium	Pyuridae	

Fish

Common name	**Scientific name**	
redfish, beaked (deepwater)	*Sebastes mentella*	
redfish,golden (marinus)	*Sebastes marinus*	
Redfish, Acadian	*Sebastes faciatus*	
Capelin	*Mallotus villosus*	
dogfish,black	*Centroscyllium fabricii*	
grenadier, roundnose	*Coryphaenoides rupestris*	
grenadier, roughhead	*Macrourus berglax*	
deep sea cat shark	*Apristuris profundorum*	
hake, white (common)	*Urophycis tenuis*	
wolffish, striped	*Anarhichas lupus*	
wolffish,broadhead	*Anarhichas denticulatus*	
skate,smooth	*Malacoraja senta*	
wolffish, spotted	*Anarhichas minor*	
porbeagle	*Lamna nasus*	
skate, spinytail	*Bathyraja spinicauda*	
shark, Portuguese	*Centroscymnus coelolepis*	
Alfonsino	*Beryx splendens*	(seamount species)
Beryx decadactylus	*Beryx decadactylus*	(seamount species)
Orange roughy	*Hoplostethus atlanticus*	(seamount species)

Hoplostethus mediterraneus	*Hoplostethus mediterraneus*	(seamount species)
Wreckfish	*Polyprin americanus*	(seamount species)
Cardinalfish	*Epigonus telescopus*	(seamount species)

Aquatic mammals and sea turtles

Common name	**Scientific name**
North Atlantic Right Whale	*Eubalaena glacialis*
Sei Whale	*Balaenoptera borealis*
Blue Whale	*Balaenoptera musculus*
Fin Whale	*Balaenoptera physalus*
Killer Whale	*Orcinus orca*
Harbour Porpoise	*Phocoena phocoena*
Northern Bottlenose Whale	*Hyperoodon ampullatus*
Sowerby's Beaked Whale	*Mesoplodon bidens*
Leatherback sea turtle	*Dermochelys coriacea*

List II. VME and Potential VME elements in the NAFO Regulatory Area

- Seamounts;
  - Fogo Seamounts (Divs. 3O, 4Vs)
  - Newfoundland Seamounts (Divs. 3MN)
  - Corner Rise Seamounts (Divs. 6GH)
  - New England Seamounts (Divs. 6EF).
- Canyons;
  - Shelf-indenting canyon; Tail of the Grand Banks of Newfoundland (Div. 3N).
  - Canyons with head > 400 m depth; South of Flemish Cap and Tail of the Grand Banks of Newfoundland (Divs. 3MN).
  - Canyons with heads > 200 m depth; Tail of the Grand Banks of Newfoundland (Div. 3O).
- Knolls.
  - Orphan Knoll (Div 3K).
  - Beothuk Knoll (Divs. 3 LMN).
- Spawning grounds; Southeast Shoal, Tail of the Grand Banks of Newfoundland (Div. 3 N).
- Steep flanks > 6.4º; South and Southeast of Flemish Cap. (Divs. 3 LM).

ToR 1.3. [FC Request # 18] Development of a comprehensive map of the location of VME indicator species and elements in the NRA as defined in the FAO International Guidelines for the Management of Deep Sea Fisheries in the High Seas. This includes canyon heads and spawning grounds and any other VME not protected by the current closures to protect coral and sponge.

1.3.1. Introduction

The need to assess whether fishing activities have a significant adverse impact on vulnerable marine ecosystems was first noted in Paragraph 83 of the United Nations General Assembly resolution 61/105 which calls upon RFMOs to: "(*a*) To assess, on the basis of the best available scientific information, whether individual bottom fishing activities would have significant adverse impacts on vulnerable marine ecosystems, and to ensure that if it is assessed that these activities would have significant adverse impacts, they are managed to prevent such impacts, or not authorized to proceed". At the 64th session of the GA, resolution 64/72 Paragraph 119 calls upon "regional fisheries management organizations … to take the following urgent actions in areas beyond national jurisdiction: (a) Conduct the assessments called for in paragraph 83 (*a*) of resolution 61/105, consistent with the Guidelines, and ensure that vessels do not engage in bottom fishing until such assessments have been carried out;".

Further guidance on these assessments was provided by FAO (2009) in their International Guidelines for the Management of Deep-Sea Fisheries in the High Seas:

> **47.** Flag States and RFMO/As should conduct assessments to establish if deep-sea fishing activities are likely to produce significant adverse impacts in a given area. Such an impact assessment should address, *inter alia*:
>
> **i.** type(s) of fishing conducted or contemplated, including vessels and gear types, fishing areas, target and potential bycatch species, fishing effort levels and duration of fishing (harvesting plan);
>
> **ii.** best available scientific and technical information on the current state of fishery resources and baseline information on the ecosystems, habitats and communities in the fishing area, against which future changes are to be compared;
>
> **iii.** identification, description and mapping of VMEs known or likely to occur in the fishing area;
>
> **iv.** data and methods used to identify, describe and assess the impacts of the activity, the identification of gaps in knowledge, and an evaluation of uncertainties in the information presented in the assessment;
>
> **v.** identification, description and evaluation of the occurrence, scale and duration of likely impacts, including cumulative impacts of activities covered by the assessment on VMEs and low productivity fishery resources in the fishing area;
>
> **vi.** risk assessment of likely impacts by the fishing operations to determine which impacts are likely to be significant adverse impacts, particularly impacts on VMEs and low-productivity fishery resources; and
>
> **vii.** the proposed mitigation and management measures to be used to prevent significant adverse impacts on VMEs and ensure longterm conservation and sustainable utilization of low-productivity fishery resources, and the measures to be used to monitor effects of the fishing operations.
>
> **48.** Risk assessments referred to in paragraph 47 (vi) above should take into account, as appropriate, differing conditions prevailing in areas where DSFs are well established and in areas where DSFs have not taken place or only occur occasionally.

1.3.2 Maps of <u>benthic habitat</u> VME indicator species

This ToR addresses the mapping component of item **iii** of Paragraph 47 of the FAO Guidelines which calls for identification, description and mapping of VMEs known or likely to occur in the fishing area. The process of identifying and mapping VMEs within NAFO began in 2008 through the Working Group on the

Ecosystem Approach to Fisheries Management (WGEAFM). This process is ongoing and new information is provided elsewhere in this report (ToR 1.2). In order to facilitate the rapid communication of the desired map product to the FC we have prepared 8 maps.

The first map (Figure 1.3.2.1) includes all areas currently closed to protect significant concentrations of corals and sponges and seamount habitats in the NRA. The content in this map has been approved by the Fisheries Commission (FC) and the closed areas are as those that are listed in the 2012 NAFO conservation and enforcement measures (CEMs, NAFO 2012).

The second map (Figure 1.3.2.2) includes all areas currently closed to protect significant concentrations of corals and sponges in the NRA (Divs. 3LMNO). It also includes the location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia) inside and outside of the closed areas. The content in this map has been approved by the Scientific Council (SC) and the closed areas are as those that are listed in the 2012 NAFO conservation and enforcement measures (CEMs, NAFO 2012).

The third map (Figure 1.3.2.3) includes the same information that the second map (Figure 1.3.2.2) but the location of significant research vessel trawl catches of corals and sponges inside of the closed areas have been taken out.

The fourth map (Figure 1.3.2.4) includes all of the information presented in the third map plus the location of the canyon heads, spawning areas and knolls endorsed as areas known to support vulnerable species, communities, or habitats by the SC *but not explicitly closed to fishing through the CEMs* (some canyon heads or parts of canyons fall into areas closed to protect significant concentrations of corals and sponges). We refer to these areas as potential VME elements. The WGEAFM used the 200 m isobath to delineate the upper limit of the canyons found in the NRA while the lower limit varied but generally was determined by the 2000 m isobath. Fifteen canyons occur along the continental shelf edge in the NRA, with the highest density along the eastern edge of the southern Grand Bank.

The fifth map (Figure 1.3.2.5) includes all of the areas presented in the third map and adds the candidate VME areas put forth by the WGEAFM (NAFO 2008a) and endorsed by the SC. These were assessed using the information on potential coral/sponge habitat, spawning grounds, and topographical features

A final map (Figure 1.3.2.6) includes all of the information content in the fifth map (Figure 1.3.2.5) all endorsed by SC and some acted upon by FC, and adds the new information contained in this report on the new locations of significant research vessel trawl catches of corals and sponges outside of the closed areas for the period 2008-2010 (Murillo et al. 2011) and other VME indicator species (update of black corals records and new VME indicator species) and potential VME elements (see ToR 1.2). The next two maps (Figures 1.3.2.7 and 1.3.2.8) are a magnification of this map for the Flemish Cap area (NAFO Divisions 3LM), and for the Tail of the Banks (NAFO Divisions 3NO), respectively.

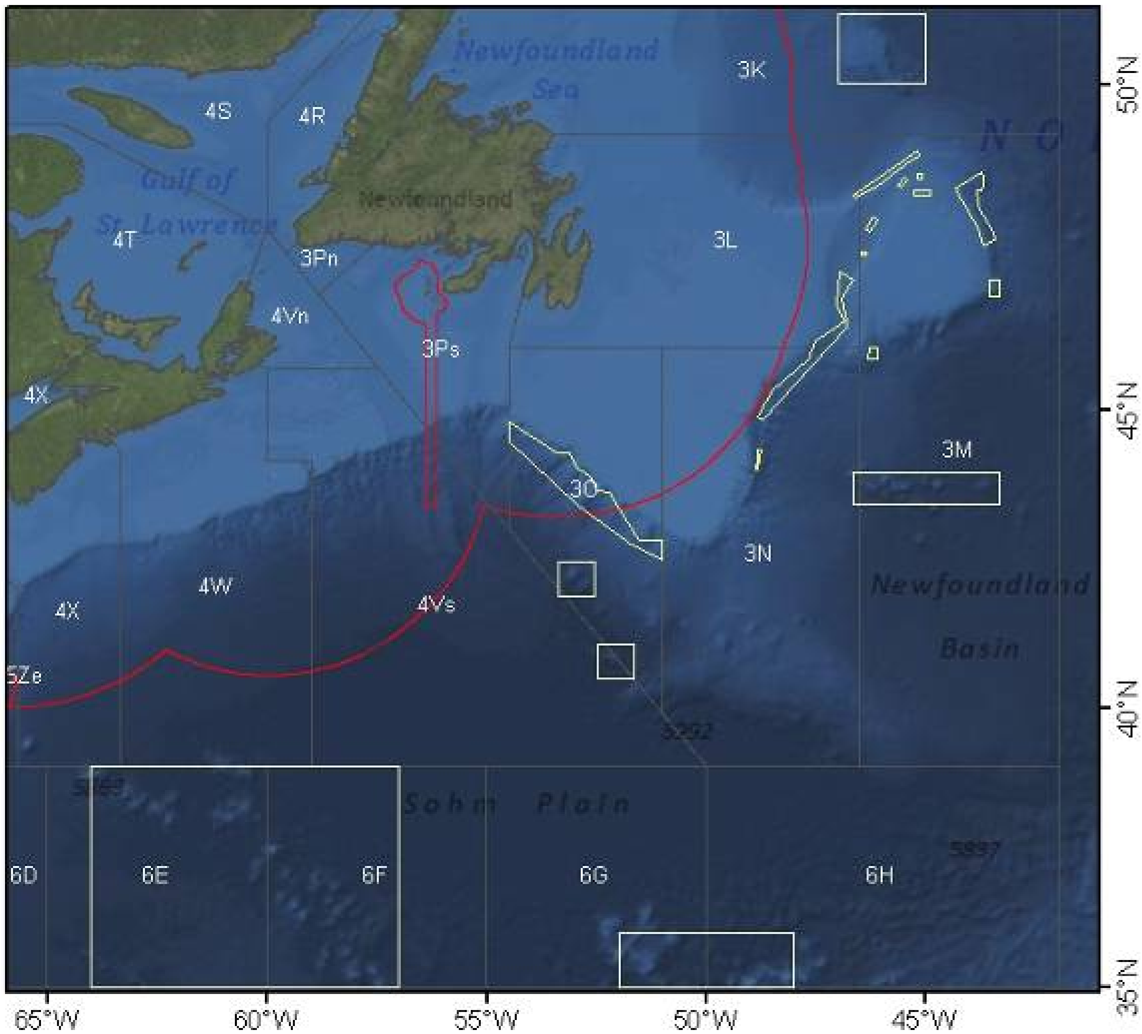

Figure 1.3.2.1. Map of all areas currently closed to bottom fishing to protect significant concentrations of corals and sponges and seamount habitats in the NRA.

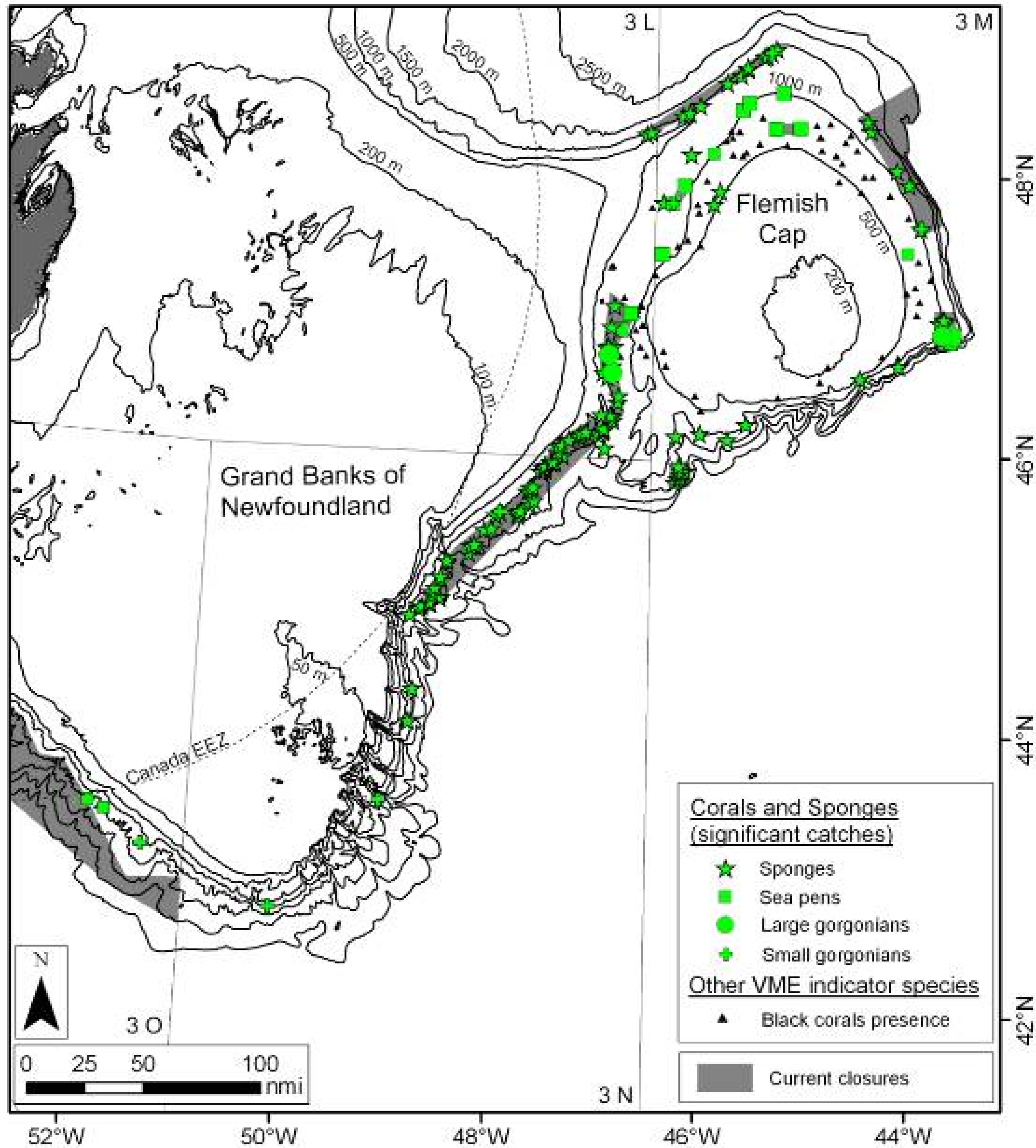

Figure 1.3.2.2. Map of all areas currently closed to protect significant concentrations of corals and sponges in the NRA (Divs. 3LMNO). The location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia), previously identified by the WGEAFM (NAFO 2008a, 2009) inside and outside of the closed areas are also indicated.

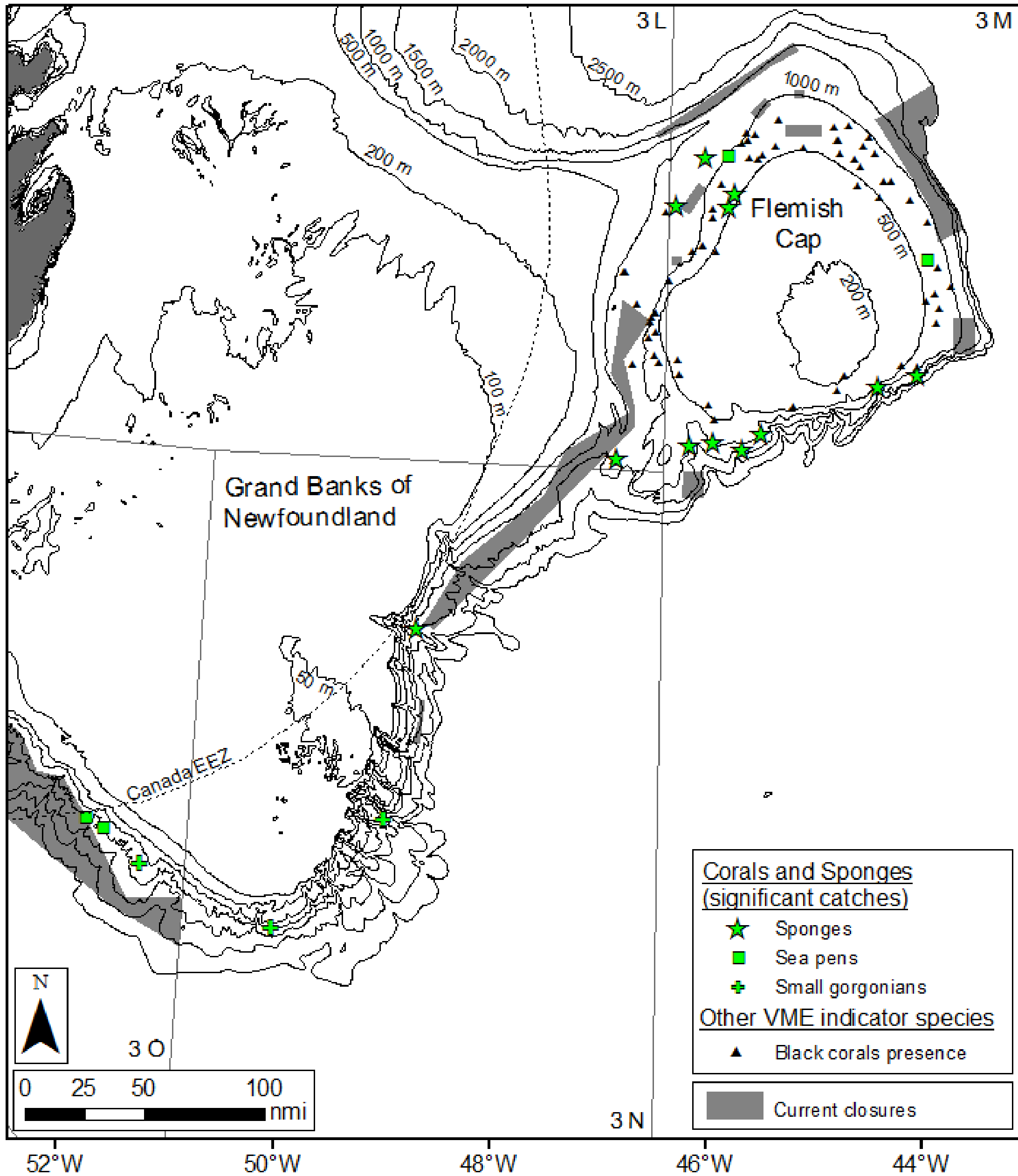

Figure 1.3.2.3. Map of all areas currently closed to protect significant concentrations of corals and sponges in the NRA (Divs. 3LMNO). The location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia), previously identified by the WGEAFM (NAFO 2008a, 2009) outside of the closed areas are also indicated.

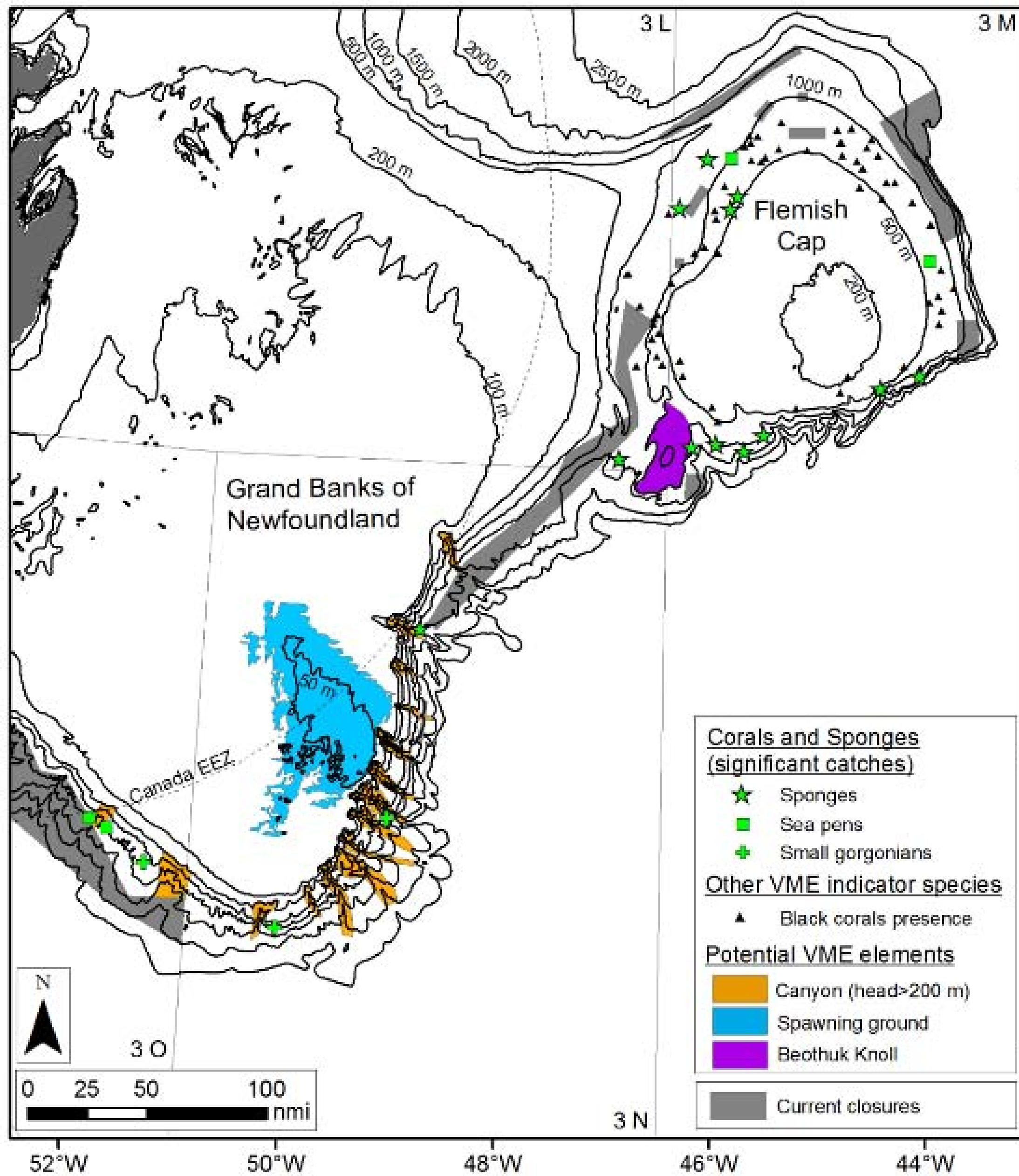

Figure 1.3.2.4. Map of all areas currently closed to protect significant concentrations of corals and sponges in the NRA (Divs. 3LMNO). The location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia) outside of the closed areas together with the location of potential VME elements, previously identified by the WGEAFM (NAFO 2008a, 2008b, 2009), are also indicated.

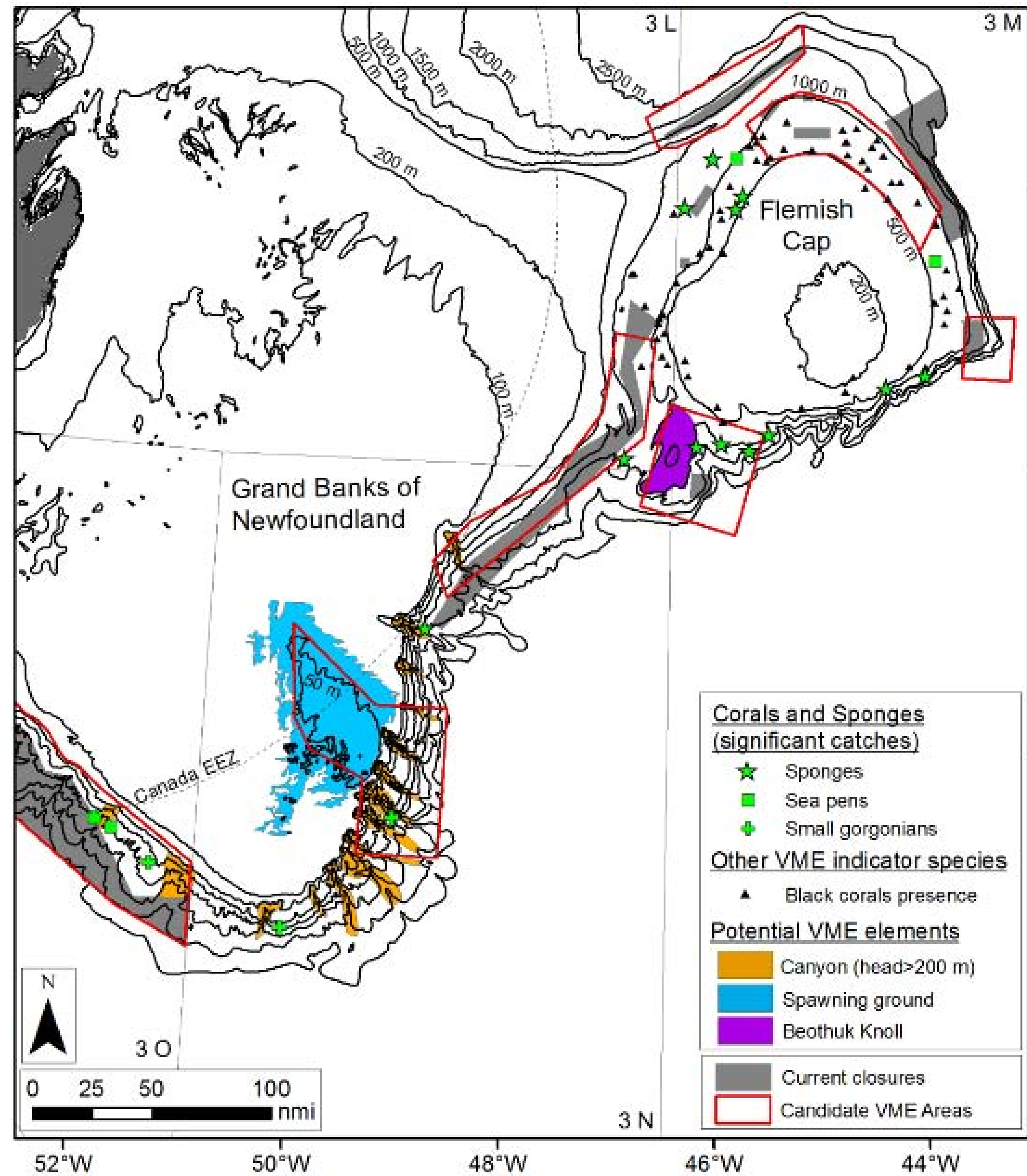

Figure 1.3.2.5. Map of all areas currently closed to protect significant concentrations of corals and sponges in the NRA (Divs. 3LMNO). The location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia) outside of the closed areas together with the location of potential VME elements and candidate VME areas, previously identified by the WGEAFM (NAFO 2008a, 2008b, 2009), are also indicated.

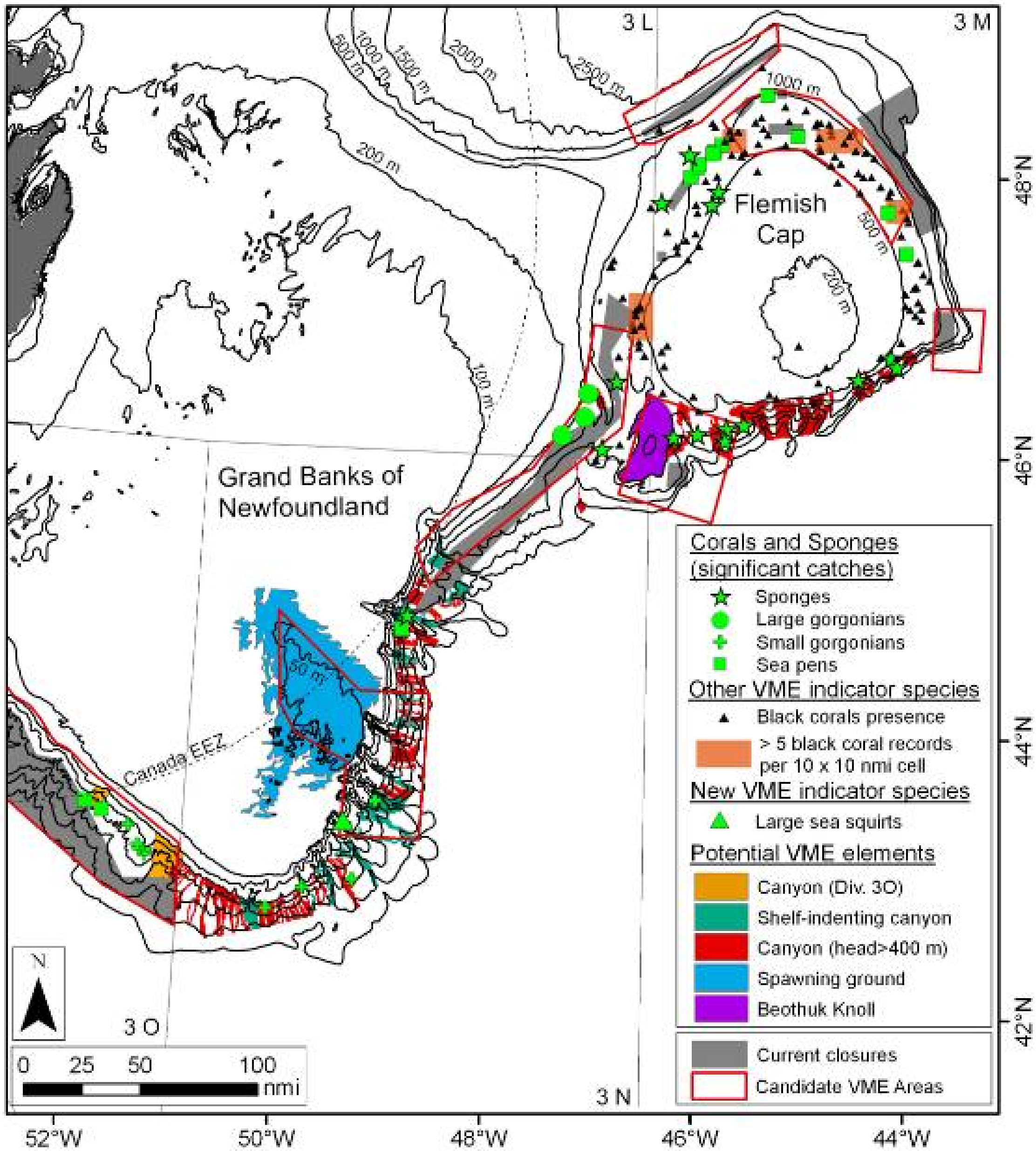

Figure 1.3.2.6. Map of all areas currently closed to protect significant concentrations of corals and sponges in the NRA (Divs. 3LMNO). The location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia) outside of the closed areas, location of potential VME elements and candidate VME areas, previously identified by the WGEAFM (NAFO 2008a, 2008b, 2009), together with new information on the locations of significant research vessel trawl catches of corals and sponges outside of the closed areas for the period 2008-2010 (Murillo et al. 2011), and VME indicator species and elements, are indicated (see ToR 1.2).

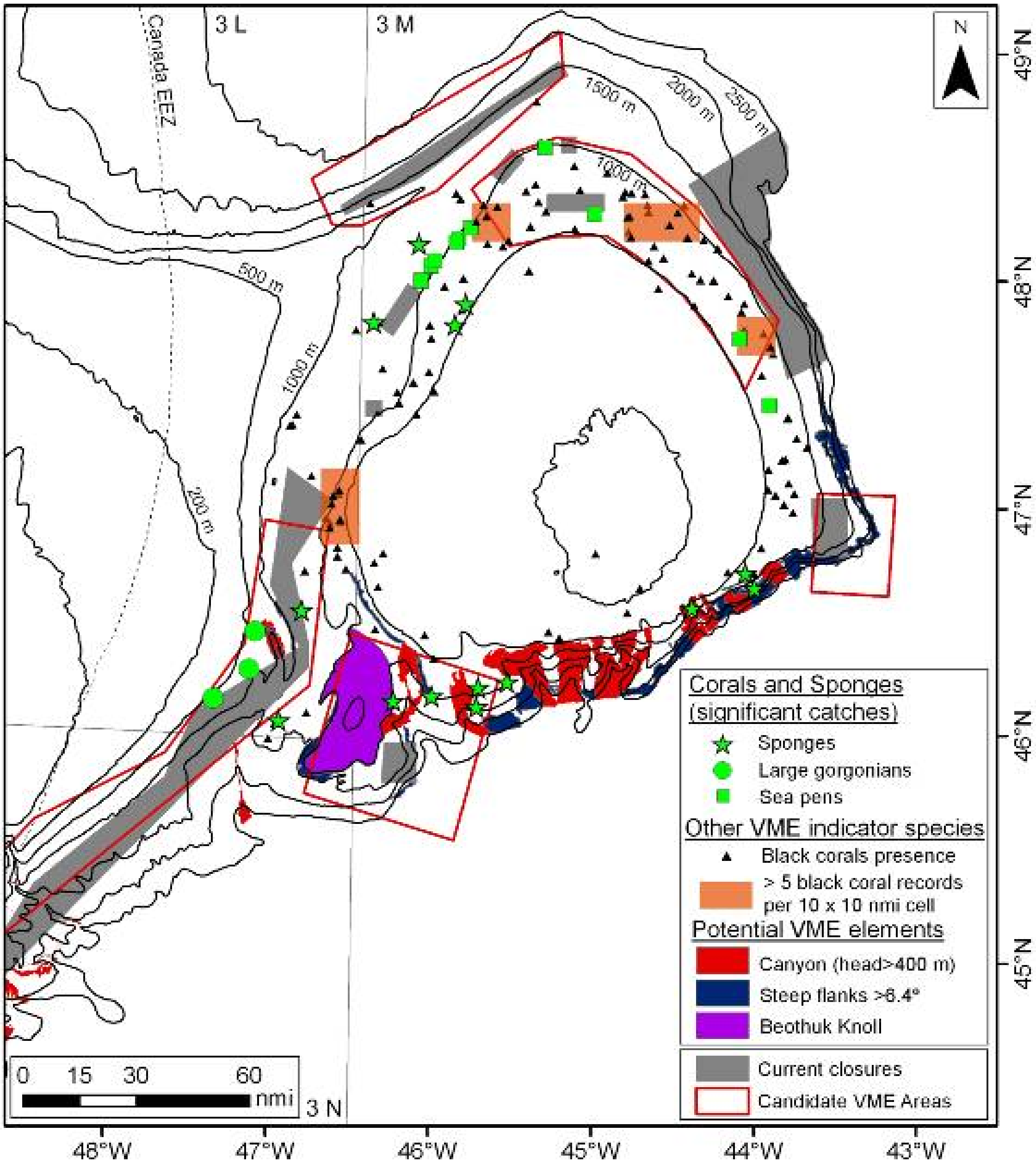

Figure 1.3.2.7. Map of all areas currently closed to protect significant concentrations of corals and sponges in the Divisions 3LM of the NRA. The location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia) outside of the closed areas, location of potential VME elements and candidate VME areas, previously identified by the WGEAFM (NAFO 2008a, 2008b, 2009), together with new information on the locations of significant research vessel trawl catches of corals and sponges outside of the closed areas for the period 2008-2010 (Murillo et al. 2011), and VME indicator species and elements, are indicated (see ToR 1.2).

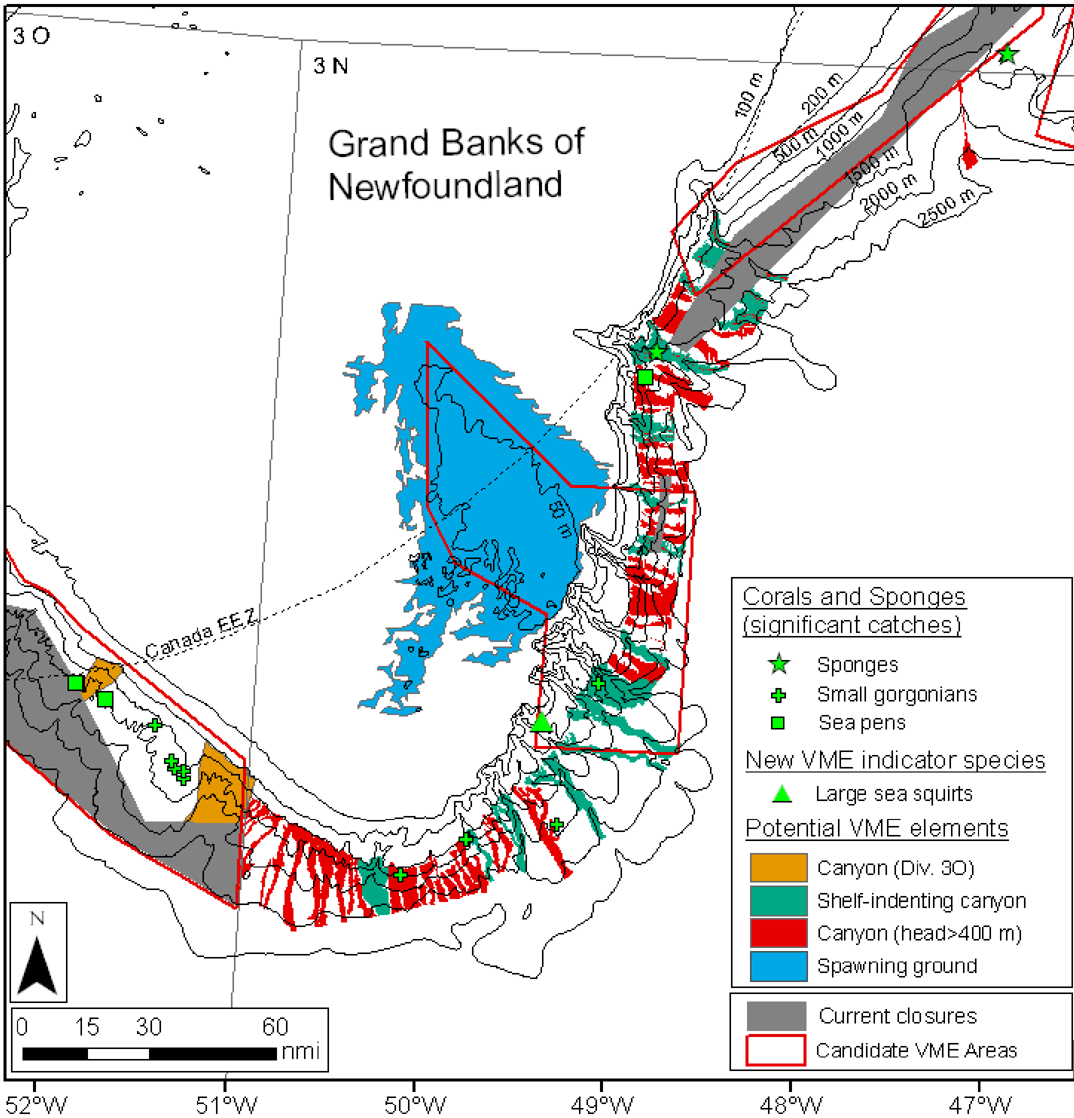

Figure 1.3.2.8. Map of all areas currently closed to protect significant concentrations of corals and sponges in the Divisions 3NO of the NRA. The location of significant research vessel trawl catches of these species groups and presence of black corals (Antipatharia) outside of the closed areas, location of potential VME elements and candidate VME areas including fish distributions, previously identified by the WGEAFM (NAFO 2008a, 2008b, 2009), together with new information on the locations of significant research vessel trawl catches of corals and sponges outside of the closed areas for the period 2008-2010 (Murillo et al. 2011), and VME indicator species and elements, are indicated (see ToR 1.2).

1.3.3 Maps of <u>demersal fish</u> VME indicator species

In total sixteen fish species met the criteria (not including seamount specific species) to qualify as VME indicator species (see Table 1.2.3.1) and the distribution of those species were mapped within the NRA and immediate surrounding area with the exception of the portuguese shark and deepsea cat shark as their densities and number of records was not sufficient for plotting.

The data derived from two surveys a) Canadian Campelen shrimp trawl survey which covered the Grand Bank out to 1500 m including the Flemish Pass and b) the Spanish Lophoten demersal trawl survey which covered the Flemish Cap out to 1500 m. The Campelen series encompassed data from 1995 to 2009 and the Lophoten series encompassed data from 1988 to 2009.

Abundance (numbers caught per standard tow) associated with each individual set for each species was used to map the distribution. Potential mapping (SPANS GIS, Anon. 2003) was used to transform the point data (number per tow for individual fishing sets) to surfaces reflecting the distribution of the species. Details of the point to surface transformation method are available in Kulka et al (1996) and Kulka (1998).

Each map (Figures 1.3.3.1 and 1.3.3.2) was created based on 15 equal areas with different densities of fish occurred within the extent of the distribution of the species. Each area grouped similar densities of fish (#/tow) such that green areas are low abundance grading to red – highest abundance. The grey areas are locations surveyed where none of the species was found (zero catch).

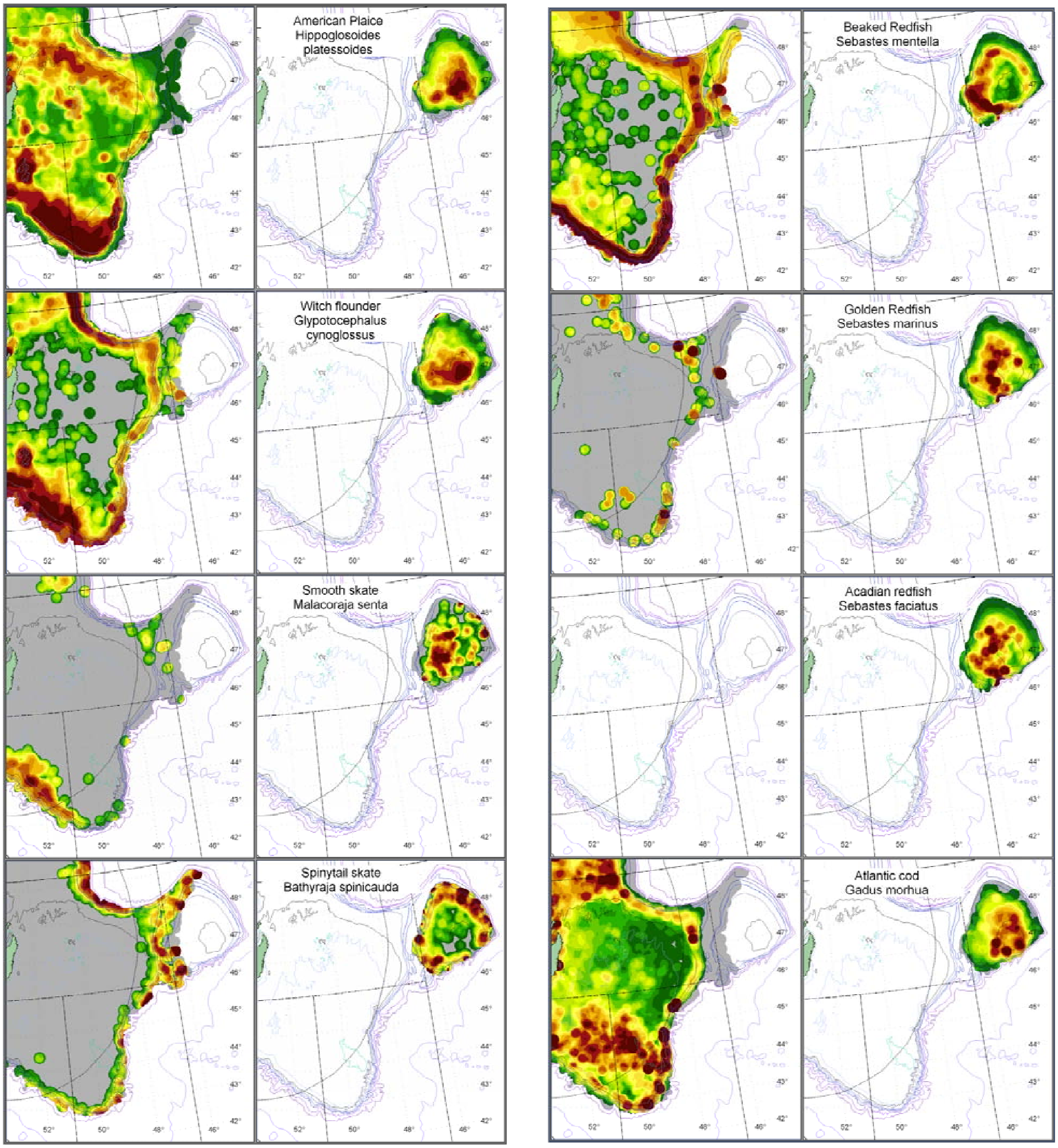

Figure 1.3.3.1. Distribution maps of potential VME indicator fish species, note, those marked with * are not potential VME indicator species; American plaice*, Witch flounder*, Smooth skate, Spinytail skate, Beaked redfish, Golden redfish, Acadian redfish and Atlantic cod*.

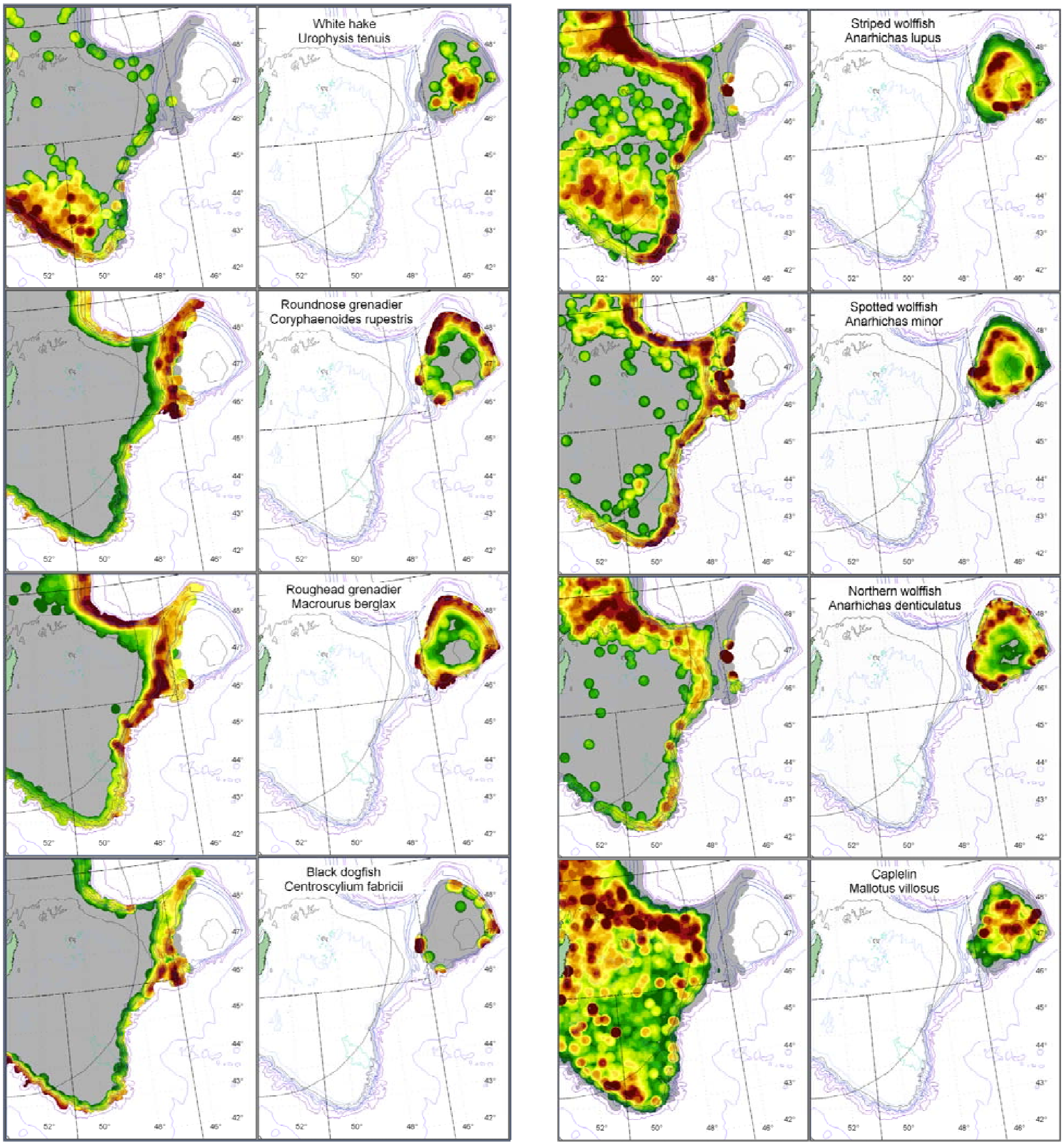

Figure 1.3.3.2. Distribution maps of potential VME indicator fish species, White hake, Roundnose grenadier, Roughead grenadier, Black dogfish, Striped wolffish, spotted wolffish, Northern wolffish, Capelin.

1.3.4 References

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NAFO. 2008b. Report of the NAFO SC Working Group on Ecosystem Approach to Fisheries Management (WGEAFM). Meeting, 26-30 May 2008, Dartmouth, Canada. Serial No. N5511. NAFO SCS Doc. 08/10, 70 pp.

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NAFO. 2012. NAFO Conservation and Enforcement Measures. Serial No. N6001. NAFO/FC Doc. 12/1, 100 pp.

ToR 2. Based on available biogeographic and ecological information, identify appropriate ecosystem-based management areas.

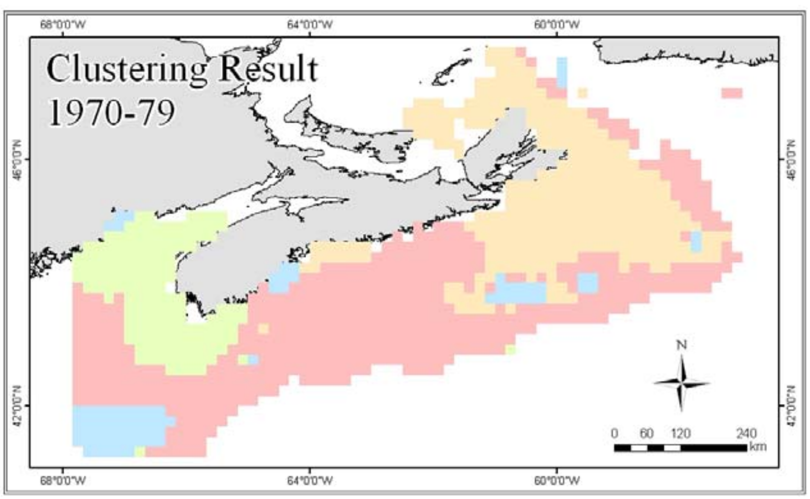
ToR 2.1. [Roadmap to EAF] Update on ecoregion analyses (Scotian Shelf).

2.1.1. Preliminary Analysis of the Temporal Variablity of Scotian Shelf Ecoregions

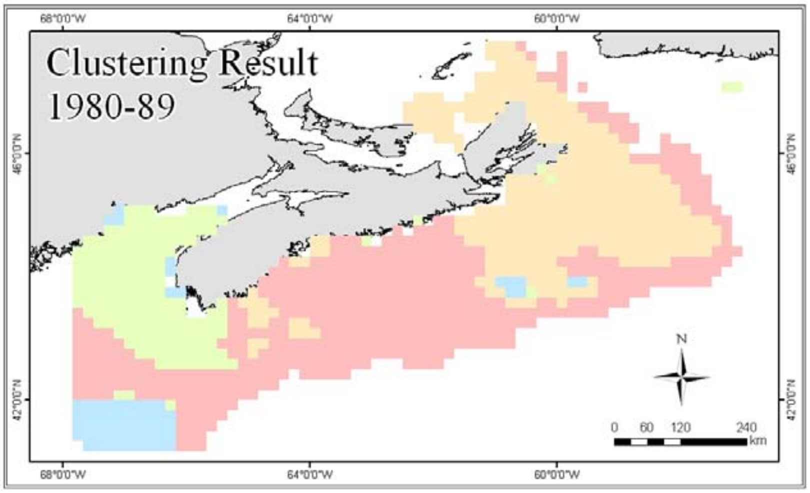
Zwanenburg et al. (2010) delineated ecoregions on the Scotian Shelf. Since the utility of these regions depends on their spatial and temporal stability, the data used to delineate these regions were time disaggregated and used in an initial exploration of their spatial and temporal stability. Four decadal periods (1970 to 2010) were arbitrarily chosen for these exploratory analyses; also the analyses were restricted to examining the physical data layers. The overall intention of this work is to compare the consistency of Scotian Shelf subunits (10x10 squares in this instance) relative to the long term multivariate characteristics for each subunit derived from the time collapsed analysis.

Using Principal Components Analysis (PCA) and hierarchical clustering ecoregions were identified for each decadal time period between 1970 and 2010 based on surface and bottom salinity, surface and bottom temperature, surface and bottom Sigma-T as well as mixed layer depth. Data were converted to raster format with a 10min x 10min cell size, in keeping with the 2010 analysis. Rasters were standardized (mean = 0 , s.d. = 1) and the resulting PCA scores were clustered using a k-means algorithm. The number of clusters was optimized using the Calinksi-Harabasz (CH) statistic (Legendre, 2001).

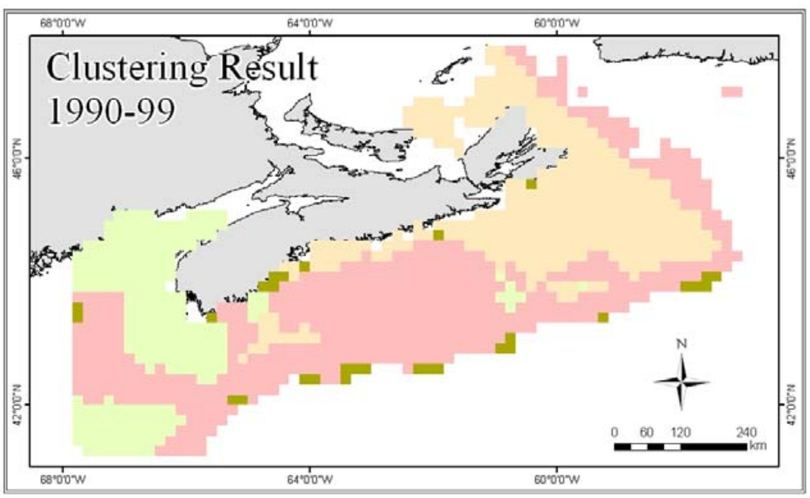
Figures 2.1.1.1-4 show the results of the time disaggregated PCA / cluster analysis. Overall, the patterns at this level of aggregation are similar between each of the four decadal time periods examined. The major clusters are present in each decade with some variability in the boundaries. These analyses differ from the time collapsed view in that they identify fewer clusters and thus lose some of the detailed resolution of the physical space. Future work will include developing methods to quantify the stability of the clusters between time periods relative to the time collapsed view (using the long-term view as the expression of average conditions and then comparing the multivariate characteristics of each subunit to that average). We will also determine how consistently the biological layers map into the regions.



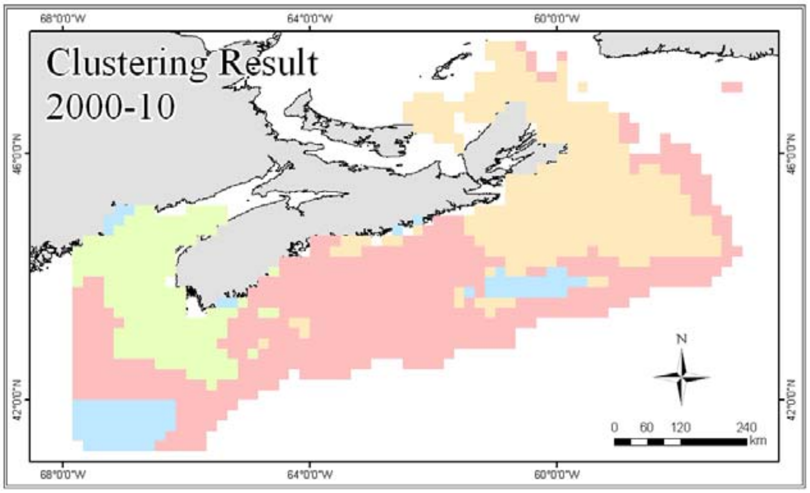
Figures 2.1.1.1. Results from the ecoregion analysis delineation for the Scotian Shelf in the 1970-79 period. This analysis only included physical data layers



Figures 2.1.1.2. Results from the ecoregion analysis delineation for the Scotian Shelf in the 1980-89 period. This analysis only included physical data layers



Figures 2.1.1.3. Results from the ecoregion analysis delineation for the Scotian Shelf in the 1990-99 period. This analysis only included physical data layers.



Figures 2.1.1.4. Results from the ecoregion analysis delineation for the Scotian Shelf in the 2000-10 period. This analysis only included physical data layers.

ToR 2.2. [Roadmap to EAF] Development of framework for an integrated ecoregion analysis for the entire Northwest Atlantic.

Researchers from the Northwest Atlantic Fisheries Centre outlined an on-going project that aims to assess the robustness of regional ecosystem units on the Newfoundland and Labrador Shelf and proposed the development of a workshop that aims to provide a venue for the integration of all data used in the identification of ecoregions in the NRA. Pepin et al. (2010) investigated the influence of data resolution and complexity on the correspondence between ecoregions on the Newfoundland-Labrador Shelf defined using various subsets of information. They concluded that various additional data could serve to establish the robustness of their findings:

- Taxonomic information is needed to assess the representativeness of the boundaries between ecoregions;
- A time-series approach to the definition of ecoregions is required to determine the persistence boundaries during periods of ecosystem changes to maximize the value of ecoregions as a long term base from which to develop management advice;
- Application to data-poor areas, such as the coast of Labrador, based on the relationships established for the NL shelf to further extend the information base for the provision of advice.

Several issues need to be considered to assess the robustness and applicability of ecoregion definition schemes:

- What species should be included or should layer(s) based on regional community analyses be developed?
- How to define appropriate time blocks to investigate the possible role of changes in environmental conditions?
- How should one deal with changes in approaches used to sample different analytical layers?
- What interpolation methods should be applied in data-poor regions?

Similar issues exist in other regions of the NRA and researchers also aim to evaluate the importance of these factors and issues on their data sets. To address some of these matters in a coordinated manner across the NRA, researchers from DFO (NL) proposed to lead a subset of WG members to integrate the available information into a harmonized analysis that would be completed during a workshop prior to the WG meeting in 2013. This analysis would include information from Hudson/Davis Strait to the mid-Atlantic Bight. The WG recognized that the definition of ecoregions that may represent management or advisory subunits of the region is still flexible and that the development of objective quantitative criteria that can be applied to a broad geographic area represented a significant challenge. This would involve consideration of the hierarchical description of scales, from the broader biogeographic zones, to ecosystems and ecoregions, with consideration of EBSAs, VMEs and areas of high concentration or aggregation. In addition, differences in scale-dependency across and along the continental shelves and slopes of variables used to characterize ecoregions would have to be addressed in the design of any analytical approach(es) to be applied over an extensive geographic scale. The WG also identified important issues to be addressed in order to combine data from different regions, which include but are not restricted to:

- Differences in data types among regions (e.g. trawl surveys – ship/gear effects);
- Standardization of different data types among sources;
- Changes over time;
- How to deal with taxonomic differences by using species distribution abundance data vs. aggregate measures of complexity (e.g. community structure, evenness, species diversity) vs. analytical scores from multivariate analyses performed on data from different survey sources.

These can all affect the stability of boundaries between and the robustness of areas identified as ecoregions. What choices are made in developing the analytical approach taken in combining the information could be affected by the smoothing effects of broadly distributed taxa or by the potential erosion of biological structure as a result of the potential effects of fishing pressure and activity. These issues are to be addressed through online and face-to-face discussions among members of the researchers involved in the analyses. The WG noted also that most variables are represented as temporally averaged spatial fields, largely because of the limited availability of some data. Spatial patterns in potential variability of some variables (e.g. sea surface temperature, bottom temperature, sea surface chlorophyll, trawl survey biomass and diversity) could be added as additional or alternate layers to provide some indices of the stability in regional features.

Members of the WG agreed that coordination and planning of the project would be handled by researchers at the Northwest Atlantic Fisheries Centre, with participation of researchers from the Bedford Institute of Oceanography, Woods Hole (US) and the Instituto Español de Oceanografía and the Instituto de Investigaciones Marinas (Spain) [the latter pending Delegate approval]. The timelines for the project and planning are:

- January to July 2012: Extension NL model to include the continental shelf off Labrador and Hudson and Davis Straits and apply to data from regions further north to establish the northern boundary of the NL shelf ecoregion;
- August 2012 – December 2012: Temporal stability of the NL shelf, Grand Banks ecoregions (present results to WGEAFM Dec 2012);
- Starting in mid-2012 onward: we will develop ToRs and define analyses required for a joint Canada-US-Spain working group meeting or workshop (to be held in Autumn 2013 prior to WG meeting, and present results in December 2013);
- Final Project Report produced by April 2014;
- Summary of results to be presented at the 2014 NAFO WGEAFM meeting.

2.3. References

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Pepin, P., Cuff, A., Koen-Alonso, M. and Ollerhead, N. 2010. Preliminary analysis for the delineation of marine ecoregions on the Newfoundland and Labrador Shelves. NAFO SCR Doc. 10/72.

Zwanenburg, K., Horsman, T., and Kenchington, E. 2010. Preliminary analysis of biogeographic units on the Scotian Shelf. NAFO SCR Doc. 10/06.

ToR 3.1. [Roadmap to EAF] Initiate the evaluation of fisheries production potential at the ecosystem level by considering a) Fisheries Production Potential Models, b) other models/approaches, and c) other research that can be of relevance to understand the ecosystem productivity of NAFO ecosystems.

3.1.1. Fisheries Production Potential (FPP) models

WGEAFM was provided with an outline of the Fishery Production Potential (FPP) model and the approach for their application in the NRA by M. Forgarty (US). The model represents foodweb structure along a linear chain of many trophic levels, from primary producers to top predators, with recognition that variations in the complexity of lower trophic levels can affect the potential energy flow to forage fish and top predators. In essence, the potential extractable biomass will be dependent on the overall level of primary productivity and the composition of the phytoplankton, the fraction of new versus regenerated production, and the mean trophic level of the catch. The current models take into consideration parameter uncertainty, spatial variation in phytoplankton distribution and environmental drivers within the region of interest (estimation), etc., to provide a probability distribution of production potential and allow an assessment of the sensitivity of projections. Currently, the model is based on climatological averages for the regions where they have and are being applied but the intention is to take into account inter-annual or long-term trends in environmental and biological variables that drive predictions.

Outcomes and predictions from application of the FPP model were viewed favourably by the WGEAFM as they provide first order estimates of the link between ecosystem productivity and potential fishery yield within the NRA. Basic data and information were provided to M. Fogarty for the Flemish Cap, and Newfoundland and Scotian Shelves to allow preliminary comparisons among regions throughout much of the NRA (deep ocean basins were excluded) during the later part of the meeting.

Some concerns were raised about changes in phytoplankton composition that may have taken place from 1960 – 2010 (Head and Pepin, 2010a), as well as spatial variations in the relative abundance of picoplankton, dinoflagellates and diatoms (Head and Pepin, 2010b) and their possible influence on model projections. There was agreement that a subgroup of WGEAFM participants would work toward combining the information available from regions throughout the NRA during the coming year in an attempt to provide a more comprehensive representation of lower trophic level productivity over a broad geographic range. As well, the potential influence of other sources of uncertainty would be explored.

3.1.2. Aggregate biomass production models for the Newfoundland-Labrador Shelf and Flemish Cap

The implementation of the "Roadmap to EAF" requires the estimation of total fisheries production potential for the identified candidate ecosystem-level production units. The previous section detailed the progress made on this topic using Fisheries Production Potential (FPP) models. As a complement to that approach, and as part of a multimodel strategy, aggregate biomass production models were also explored.

The general areas considered in this exercise were the Newfoundland-Labrador shelf, and the Flemish Cap. In terms of production units, WGEAFM has previously defined two operational units in the Newfoundland-Labrador shelf; these units correspond to the Labrador and Northeastern Newfoundland shelf (NAFO Divs. 2GHJ3K), and the Grand Bank proper (NAFO Divs. 3LNO), recognizing that the northern area in the Grand Bank (nominally NAFO Div. 3L) functions as a transition zone between these two units. The Flemish Cap (NAFO Div. 3M) was defined as a single production unit.

Based on the above considerations, and constrained by the available data, aggregate biomass production models were put together as follows:

> **Newfoundland-Labrador shelf**. These models used data from Canadian Fall surveys. The series modeled were:
>
> > Campelen gear. 1995-2010. All fish species plus shrimp and snow crab are included.
> >
> > > ***NAFO Divs. 2J3KLNO***
> > >
> > > ***NAFO Divs. 2J3K***
> > >
> > > ***NAFO Divs. 2J3KL***
> > >
> > > ***NAFO Divs. 3LNO***

Engels gear. 1981-1994. Only fish species are considered (note: during this period, shrimp biomass was low, so its absence may not represent a major shortcoming).

NAFO Divs. 2J3KL

Flemish Cap (NAFO Div. 3M). A single model was put together using data from EU surveys for the period 1988-2010.

NAFO Div. 3M

The corresponding catches for each one of these areas and periods were taken from NAFO catch databases (NAFO STATLANT 21A), or more refined catch estimates whenever possible.

All models were based on a discrete logistic formulation of the form:

$$B_{i,t+1} = B_{i,t} + r_i B_{i,t}\left(1 - \frac{B_{i,t}}{K_i}\right) - C_{i,t}$$

where B_i is the aggregate biomass, r_i is the intrinsic growth rate, K_i is the carrying capacity, and C_i is the aggregate fisheries catch.

Parameter estimation was done by defining total production as $P_{i,t} = B_{i,t+1} - B_{i,t} + C_{i,t}$, which allows re-writing the above logistic formulation as:

$$P_{i,t} = r_i B_{i,t} - \frac{r_i}{K_i} B_{i,t}^2$$

This last equation is a linear one, and hence, its parameters can be estimated using multiple linear regression analysis.

Models were fitted to the data following the procedure outlined above by assuming a 1:1 relationship between RV total biomass indices and actual biomass (i.e. catchability equal 1), and a process error structure. The assumption on catchability is an important one, especially because the Campelen gear used in Newfoundland and Labrador since 1995 has a much smaller mesh size than the Engels gear used previously. This assumption also prevents absolute comparisons, not only between pre and post collapse period on the Newfoundland shelf, but also between these areas and the Flemish Cap.

Overall, these models fitted the time series relatively well despite their simplicity (Figure 3.2.1). Given the many assumptions involved, it is not yet prudent to rely on the current results to provide system-wide estimates of production for quantitative advice; a closer examination of model behaviour and exploration of the impact of the assumptions is required. Nonetheless, the results are certainly promising, and in conjunction with FPP models, these exercises could provide a reliable way for defining acceptable operational estimates for overall fisheries production.

Another important observation from this analysis is the emerging relationship between maximum sea ice area extent and the residuals from these models (Figure 3.2.1). Sea ice is an important physical feature in the Newfoundland-Labrador shelf, and its dynamics has been linked to the triggering of the phytoplankton spring bloom (Wu et al. 2007). Ongoing studies are also linking the dynamics and characteristics of sea ice with bottom up driven regulatory processes in this ecosystem (A. Buren, unpublished data). In this context, the pattern emerging between model residuals and maximum sea ice extent is suggestive. The correlation can be detected at the entire 2J3KLNO scale, but it seems stronger in the northern areas (2J3KL, 2J3K) than in the south (3LNO), and is clearly absent in the Flemish Cap (3M). Furthermore, even though other confounding effects may be at play (e.g. fish only vs fish plus shrimp and crab; differences in catchability between gears), this correlation in 2J3KL appears to be stronger in the most recent period (post-collapse), than prior to the system collapse (Figure 3.2.1). Overall, these relationships appear to be hinting at a bottom up signal influencing production at a system-wide scale in the Newfoundland-Labrador shelf.

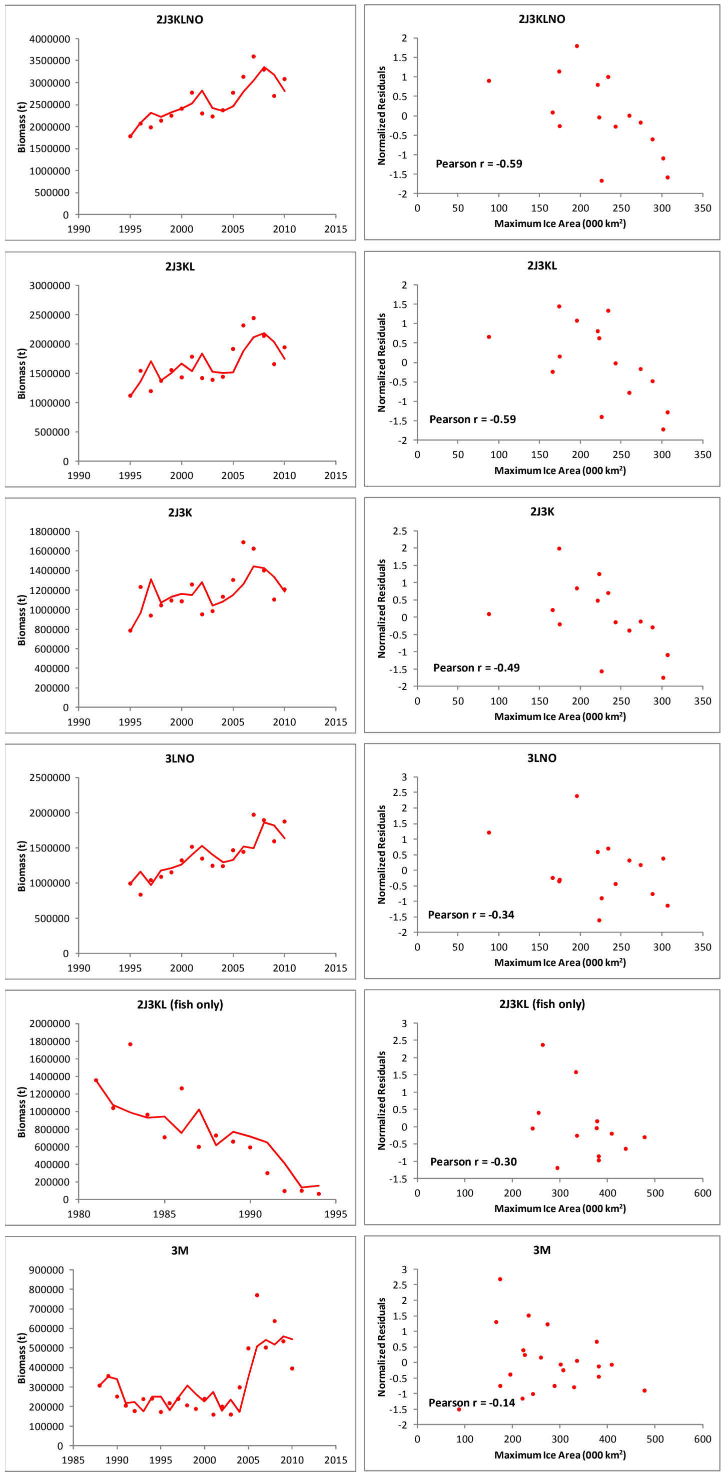

Figure 3.2.1. Aggregate biomass production models for the Newfoundland-Labrador and Flemish Cap production areas. Left panels show the observed (dots) and predicted (line) value for each one of the areas and periods considered. Right panels show the scatter-plots between the corresponding model residuals (normalized), and the estimated maximum sea ice area extent in the Newfoundland-Labrador shelf.

3.1.3. Estimating marine mammal consumption

The food consumption by marine mammals in the Northwest Atlantic, and its potential impact on fish stocks, has always been an intensely debated issues. Therefore, if we are to a comprehensive view of overall fish production potential, we also need to address the issue of marine mammal consumption in that context. Estimates of food consumption by marine mammals will not only contribute to discriminate between facts and speculation, they will also serve as input for parameterizing FPP models.

The amount of biomass consumed by marine mammals was estimated using bioenergetics models. These models assume that the energy requirements of a population can be estimated and that the marine mammal obtains the energy required. Estimating prey consumption requires information on population size, energetic requirements, diet composition, and distribution of feeding effort, as well as size classes and energy density of the prey (Hammill and Stenson 2000, Stenson and Hammill 2004).

Here, we model fish consumption by Northwest Atlantic harp seals, taking into account seasonal changes in feeding and variability in seal abundance, distribution, and diet composition. All possible sources of uncertainty are incorporated into the estimates.

Prey consumption by harp seals in 2J3KL was estimated by:

$$C_{jt} = \sum_{s=1}^{s=S} \sum_{a=1}^{a=A} \sum_{i=1}^{i=I} N_{it} E_i D_{ias} P_{jas}$$

where:

C_{jt} = Consumption of prey species j in year t.

N_{it} = No. of seals in age class i in year t.

E_i = Annual gross energy required by a seal aged i.

D_{ias} = Prop.of the total annual energy obtained by a seal aged i in area a during season s.

P_{jas} = Prop. of prey species j in the diet of seals in area a during season s.

I = Total no. of age classes, currently 13 (ages 0 - 11 and 12+).

A = Total no. of areas.

S = Total no. of seasons, currently 2 (Winter and Summer)

Changes in abundance of Northwest Atlantic harp seals over time were estimated using a population model that incorporates annual estimates of human removals throughout their range and age specific pregnancy rates, and periodic independent estimates of pup production obtained from surveys. Uncertainty (mean and standard deviation in the numbers in each age group (0 through 11 and12+) for each year was estimated from the population trajectories and incorporated into the consumption model. Harp seal abundance declined during the 1950s and 1960s to a little less than 2 million seals in 1971. Since then, it has increased steadily to approximately 8.3 million (95% CI=7,300,000-9,000,000) in 2008. In recent years it is estimated to have declined slightly due to increased mortality of young due to poor ice conditions and lower reproductive rates (Hammill et al. 2011).

Age-specific energy requirements were calculated using a simple allometric equation based on body mass:

$GEI_i = GP_i * (AF*293 *BM_i^{0.75}) /ME$

where:

GEI_i = Daily gross energy intake (kjoules/day) at age i,

GP, = Growth premium (i.e. the additional energy required by young seals < age 6).

AF = Daily activity factor

BM_i = Body mass (in kg) at age i

ME = metabolizable energy

Because of seasonal changes in body size and energy consumption, monthly growth curves were used. These were based upon average body size of harp seals sampled between 1979 and 2004. They were not adjusted for interannual changes in condition.

Harp seals are highly migratory and our knowledge of their seasonal distribution is primarily based on historical catch data, tag returns and anecdotal reports. More recently, studies of harp seal movements using satellite telemetry have improved our understanding of seasonal distributions significantly. Northwest Atlantic harp seals summer in the Canadian Arctic and/or West Greenland. During the fall and early winter, seals move southward along the Labrador coast. One component of this population remains off the east coast of Newfoundland/southern Labrador (i.e. 2J3KL) while the other moves into the Gulf of St. Lawrence in December. In the late spring, the animals return to the Arctic. Annual changes in ice conditions or food availability likely affect the seasonal movements of the population. The proportion of energy obtained from various areas was assumed to be equal to the seasonal residency in that area.

The diet of harp seals was estimated using reconstructed wet weights of stomach contents from animals collected in various areas between 1986 and 2007. Prey lengths and weights were estimated from hard parts using part length – total length and part length – and/or length – weight regression equations. Reconstructed wet weights were converted to energy densities using published energy values for each prey species. Diets were found to vary between years as well as with season and area. A multiple regression technique was used to estimate annual diets. Fatty acid signatures were also used to estimate diets integrated over longer time periods. There were significant differences in the proportion of each prey species in the diet determined by the various methods. The different methods of estimating diet did not change the estimates of total biomass but did result in significant differences in the consumption estimates for individual prey species.

Total prey consumption by harp seals in 2J3KL during 2008 was estimated to be approximately 4.2 million metric tonnes. However, this estimate was imprecise with 95% CI being 3.2 million – 5.4 million tonnes. Approximately 80% was obtained from 2J3K with less than 20% from 3L.

Fecundity of harp seals has been declining since the 1980s. The proportion of mature females that give birth each year has also become highly variable in recent years, ranging from over 70% in 2008 to less than 30% in 2011 (Stenson and Wells 2011). This appears to be due primarily to density dependent changes associated with increased abundance and interannual variation in environmental conditions. This decline in pregnancy rates appears to be associated with similar density dependent reductions in growth and condition. If so, this suggests that current energy requirements and the resulting consumption are overestimated.

3.1.4. References

Hammill, M. O. and G. B. Stenson. 2000. Estimated prey consumption by harp seals (*Phoca groenlandica*), grey seals (*Halichoerus grypus*), harbour seals (*Phoca vitulina*) and hooded seals (*Cystophora cristata*) in Atlantic Canada. J. Northw. Atl. Fish. Sci.26:1-23.

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Wu Y, Peterson IK, Tang CCL, Platt T, Sathyendranath S, and Fuentes-Yaco C, 2007. The impact of sea ice on the initiation of the spring bloom on the Newfoundland and Labrador Shelves. Journal of Plankton Research 29:509-514.

ToR 3.2. [FC Request # 10] Provide an explanation on the possible connection between the recent decline of the shrimp stock, the recovery of the cod stock, and the reduction of the redfish stock in the Flemish Cap ecosystem, as well as advice on the feasibility and the manner by which these three species could be maintained at levels capable of producing a combined maximum sustainable yield.

Addressing this ToR in full would require developing and validating multispecies models. This type of modelling exercise is among the identified constituent elements of the “Roadmap to EAF”, but work on this topic is only of its initial stages; with the current level of support its development is expected to require multiple meetings to be completed. However, results form ongoing work, as well as some preliminary modelling explorations, can provide some useful insights in the functioning of the Flemish Cap fish community in general, and the interactions between cod, shrimp and redfish in particular. These results include analysis of trends and feeding habits of the main demersal species in the Flemish Cap, an initial attempt at modelling consumption of redfish by cod, and a preliminary exploration of the dynamics of the trophic system composed by cod, shrimp and redfish using a simple predator-prey Lotka-Volterra model.

3.2.1. Common trends in biomass time series and feeding habits of the main demersal species of Flemish Cap.

Important changes have been observed in the biomass of the species of the demersal community of the Flemish Cap in the period 1988-2008. Figure 3.2.1.1 shows the index of biomass from the EU Research Vessel (RV) survey of those species that appeared over the entire 1988-2008 period with a proportion higher than 0.5% of the total RV survey biomass (Species Group I). Figure 3.2.1.2 shows the same index but for those species which appeared in less than 15 years in the EU survey (Species Group II).

In Group I (17 species), the decline of cod (*Gadus morhua*) from 150,000 tons (t) in 1989 to its collapse in 1995 was followed by important changes in the RV biomass of other demersal species. The more notable cases were the Northern shrimp *Pandalus borealis*, that experienced an unprecedented increase with the maximum value in 2002, and the Greenland halibut *Reinhardtius hippoglossoides* which showed a peak of 30,000 t in 1998. Other species that showed a relatively important increase in biomass coincident with the decline of cod were the three wolffish species (*Anarhichas denticulatus*, *A. lupus* and *A. minor*), and the thorny skate (*Amblyraja radiata*). Most of these species experienced a decline in biomass indexes at the end of the 1990s, however, the Northern shrimp stayed at high levels until 2007, coincident with the increase in two of the three redfish species, *Sebastes marinus* and *S. fasciatus*, from less than 25,000 t to more than 300,000 t in both cases. Since 2006, the cod stock started a recovery trend, while redfish species showed a declining pattern.

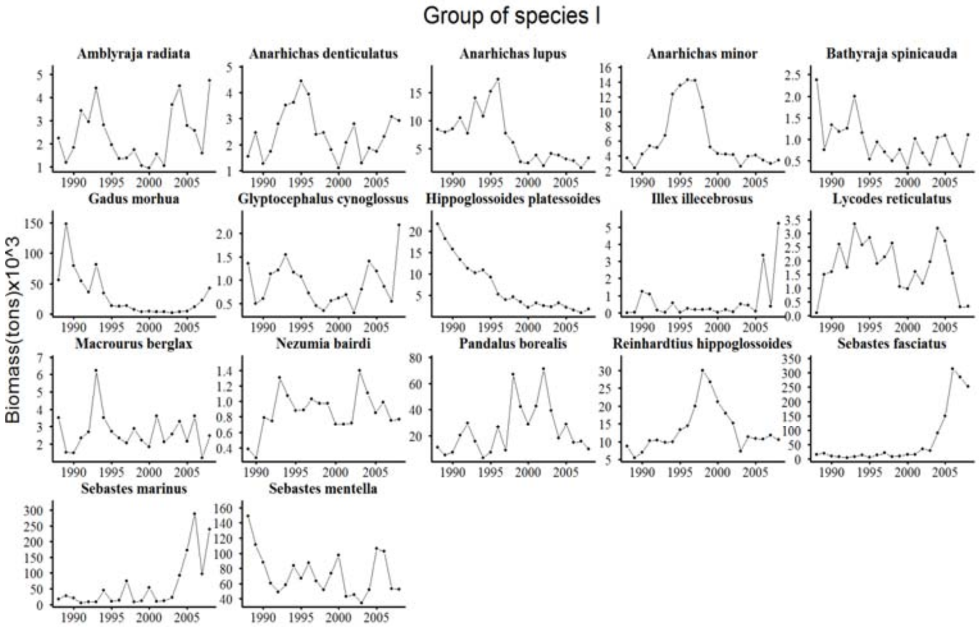


Figure 3.2.1.1. RV Biomass Index for species that represented more than 0.5% of the total RV biomass and were recorded over the entire 1988-2008 period in the Flemish Cap EU surveys.

In Group II (14 species), important variations were also observed. Some species like *Notacanthus chemnitzii* and *Synaphobranchus kaupi*, experienced notable declines in biomass in the early to mid-1990s, whereas others such as *Gaidropsarus ensis* and *Urophycis chesteri* followed an opposing trend, with biomass highest in the later part of the time-series. *Lycodes vahli* and *L. esmarki* biomasses were highest during the 1990s whereas those of other species like *Malacoraja senta* and *Coryphaenoides rupestris*, peaked in the early and late years of the study period.

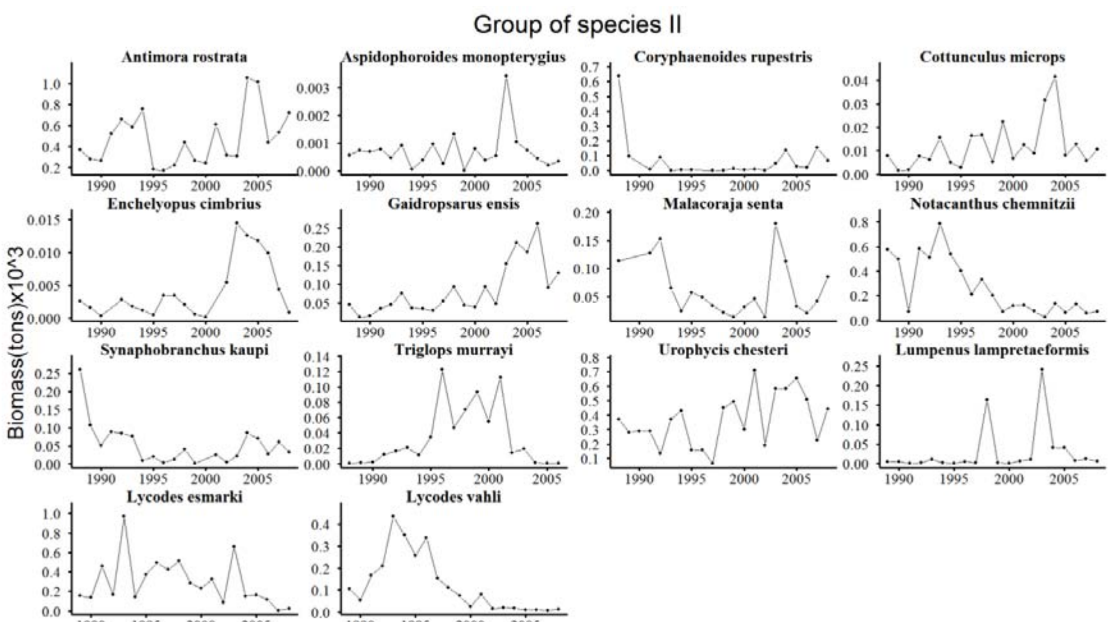


Figure 3.2.1.2. RV Biomass Index for species that represented more than 0.5% of the total RV biomass and were recorded over the entire 1988-2008 period in the Flemish Cap EU surveys.

Pérez-Rodríguez et al (2011a) used Dynamic Factor Analysis (DFA) to look for common trends in the biomass time series within these two species groups. When no explanatory variables were considered in the analysis, DFA results indicated the existence of multiple common trends which explained the trajectories of collection of species within Group I (three common trends) and Group II (two common trends) (Table 3.2.1.1). The number of common trends was reduced when explanatory variables were included in the analysis. These explanatory variables appeared consistently important, suggesting that environmental conditions (represented in the analysis by a running mean of the NAO index), as well as predation and fishing mortality, are significant drivers of the Flemish Cap fish community. The influence of the NAO on each species was as expected for 26 of the 31 species, based on their temperature preference in relation to the bottom temperature of the study area in the Flemish Cap (Table 3.2.1.1). The NAO was incorporated as the average value in a time window between *t-4* and *t-7*, and hence the environmental influence found on this analysis can be interpreted as the environmental effect acting during the recruitment stage. The abundance of predator species was not only important, but also its coefficients consistently showed the negative sign expected from a predation-related variable; suggesting that predation by large piscivorous fishes strongly affects not only the juveniles of Sebastes spp. (in agreement with Lilly (1983) suggestion), but the structure and dynamics of the entire demersal assemblage in the Flemish Cap. After including these explanatory variables in the DFA analysis, the remaining common trend was very similar between both groups of species (r= 0.98, p-value<0.01), strongly suggesting that the dynamics of the main demersal species in the Flemish Cap (Groups I and II) are interconnected, and can be summarized by few common patterns.

Contemporary with the changes in the indices of biomass described above, important variations in the feeding habits of the main fish demersal species of Flemish Cap were also observed, with some trends common to most species (Pérez-Rodríguez et al, 2011b). Most biological species were split into size classes based in clear diet differences with fish size (the denomination "1" after the species name indicates the smaller sizes and "2" the larger ones, if no denomination is used, then all sizes of the species were considered as a single "trophic" species), resulting in different trophic species. The analysis of diet revealed that since mid-late 1990s most trophic species experienced an increased importance of shrimp in the diet, regardless of trophic guild. Parallel to this, there was a decline in the proportion of prey species that have been traditionally the most important ones (Figure 3.2.1.3), as occurred with hyperiids in both cod trophic species, and Greenland halibut 1, ophiuroids and other benthic invertebrates in American plaice, Arctic eelpout, and the spotted and Atlantic wolffish 1 and 2; or copepods and other pelagic invertebrate preys in the redfish trophic species, specially in the larger ones. Later on, in the early 2000's, the species forming the piscivorous trophic guild (i.e. the largest trophic species of cod, Greenland halibut and wolffishes) experienced a very important increase in Sebastes sp. prey consumption since early 2000s.

Table3.2.1.1. Outputs from the DFA model fitting with and without explanatory variables for Species Groups I and II.

	DFA Without explanatory variables			**DFA With explanatory variables**					
	Factor Loadings			**Factor Loadings**	**Coefficients (Significance)**				
Species	**Trend 1**	**Trend 2**	**Trend 3**	**Trend 1**	**NAO**	**AFI**	**Piscivorous**	**Average[1]**	**Preference[2]**
Group I									
Reinhardtius hippoglossoides	-0.189	0.065	**-0.238**	**-0.236**	0.32	0.277	0.439 (*)	2.25	Colder
Pandalus borealis	-0.179	-0.186	-0.196	-0.177	-0.262	0.622 (*)	0.365	5.2	Warmer
Nezumia bairdi	0.037	0.102	-0.169	-0.145	0.534 (**)	0.517 (*)	-0.569 (**)	5.5	Warmer
Anarhichas minor	-0.058	**0.416**	-0.065	-0.071	1.004 (***)	0.384 (*)	-0.204	1.825	Colder
Sebastes marinus	**0.29**	0.02	-0.04	-0.047	-0.218	-1.207 (***)	-0.383 (*)	5	Warmer
Sebastes fasciatus	**0.318**	0.002	-0.035	-0.038	-0.291 (**)	-1.273 (***)	-0.448 (***)	5.55	Warmer
Lycodes reticulatus	-0.047	0.099	-0.024	-0.022	0.463 (*)	0.796 (**)	-0.136	1.3	Colder
Anarhichas denticulatus	0.126	**0.386**	-0.002	-0.011	0.605 (*)	-0.027	-0.338	2.8	Colder
Illex illecebrosus	**0.246**	0.043	0.015	-0.008	-0.285	-0.846 (**)	-0.028		Warmer
Macrourus berglax	-0.003	0.037	0.015	0.038	0.447 (*)	0.511	-0.515 (*)	2.75	Colder
Amblyraja radiata	0.195	-0.024	0.072	0.072	-0.079	0.088	-0.441	6	Warmer
Glyptocephalus cynnoglossus	**0.206**	0.06	0.105	0.103	0.028	-0.193	-0.478 (*)	4	Warmer
Anarhichas lupus	-0.033	**0.323**	0.136	0.125	0.830 (***)	0.51 (**)	-0.259 (*)	1.8	Colder
Sebastes mentella	-0.023	0.003	0.159	0.16	0.205	-0.659 (*)	-0.276	0	Colder
Bathyraja spinicauda	0.006	-0.017	**0.211**	**0.221**	0.172	0.154	-0.398 (*)	0.9	Colder
Gadus morhua	0.016	-0.01	**0.272**	**0.244**	-0.241	-0.298	0.311 (*)	4.75	Warmer
Hippoglossoides platessoides	-0.086	0.008	**0.296**	**0.287**	0.077	0.138	0.037	1	Colder

Group II								
Triglops murrayi	0.084	**-0.232**	**-0.211**	0.579 (**)	0.63 (**)	0.244		Colder
Cottunculus microps	-0.15	-0.067	-0.126	0.145	0.583 (*)	-0.32	2	Colder
Lumpenus lampretaeformis	-0.12	-0.025	-0.098	-0.042	0.329	-0.065	1.25	Colder
Gaidropsarus ensis	**-0.252**	-0.022	-0.096	-0.159	-0.51 (**)	-0.555 (**)	1.25	Colder
Urophycis chesteri	**-0.214**	0.025	-0.078	-0.268	-0.028	-0.094	5.65	Warmer
Enchelyopus cimbrius	**-0.26**	0.044	-0.058	-0.188	-0.042	-0.594 (**)		Warmer
Lycodes esmarki	0.147	-0.133	-0.037	0.602 (**)	0.876 (**)	-0.131	2	Colder
Aspidophoroides monopterygius	-0.111	0.057	-0.026	-0.097	0.552	-0.082	0.75	Colder
Antimora rostrata	-0.099	-0.024	0.025	-0.291	-0.147	-0.311	3.35	Colder
Lycodes vahli	**0.333**	-0.145	0.098	0.838 (***)	0.634 (**)	-0.29 (*)	2.75	Colder
Coryphaenoides rupestris	-0.061	**0.28**	0.198	-0.063	-0.361	-0.376	4	Warmer
Malacoraja senta	-0.008	**0.253**	**0.21**	-0.36	0.414	0.096	5.5	Warmer
Notacanthus chemnitzii	**0.267**	0.061	**0.232**	0.414 (*)	0.383	-0.225	3	Colder
Synaphobranchus kaupi	-0.024	**0.321**	**0.264**	-0.152	-0.246	-0.247	5.5	Warmer

Those species with absolute factor loadings higher than 0.2 were considered to be importantly influenced by the trend. (***; p-value≤0.001;t-value>3.85) (**; p-value≤0.01; 2.85<t-value<3.85); (*; p-value≤0.05; 2.09<t-value<2.85).
1. Average value of the temperature range for each species. Obtained from Scott & Scott (1988).
2. Temperature preference in relation to the average bottom temperature in Flemish Cap in the period 1988-2008.

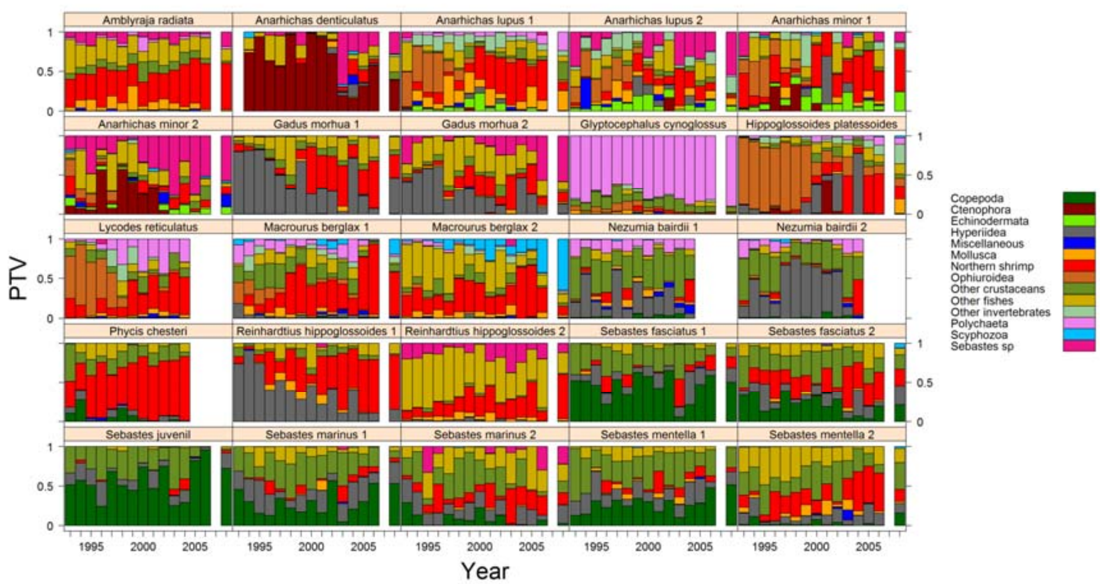


Figure 3.2.1.3. Diet composition of fish species in Group I in the Flemish Cap over the 1993-2008 period. Diet composition is expressed as percentage of prey categories over the total volume of the stomachs (PTV).

Non-parametric Multidimensional Scaling (MDS) was used to map the diets of all trophic species over time in a three dimensional trophic space (Pérez-Rodríguez et al, 2011b). This analysis showed that trophic species occupied fairly well defined areas on this 3D trophic space. The changes in the MDS coordinate for each trophic species on each one of the three MDS axes over time were analyzed for common trends between trophic species using DFA. DFA results indicated that the general patterns in diet described above are well captured by the common trends found along the MDS axes. Furthermore, the abundance of prey species, intra-guild competition, and bottom water temperature emerged as important explanatory variables. On the other hand, the MDS-defined trophic space showed a clear shrink over time, with the different trophic species getting closer (i.e. higher similarity) as we move from 1993-1997, 1998-2002 and 2003-2008 (Pérez-Rodríguez et al, 2011b).

These results suggest a relationship between the observed changes in the demersal community and feeding habits variations. The oceanographic conditions, fishing activity and piscivorous predators biomass were found as main drivers of the observed changes in the biomass trajectories of the demersal community of Flemish Cap since 1998 (although a residual trend still remained in both groups I and II). On the other hand, changes in feeding habits were found to be due to shifts in the abundance of prey and competitor populations. Thus, the decline in cod stock biomass was followed by the increase in shrimp and a later on, in the early 2000s by a sudden increase of redfish populations. In turn, this led to an increase of these prey in the cod diet.

3.2.2. Estimation of redfish consumption by cod in the period 1993-2010.

A preliminary attempt to estimate the redfish consumption by cod was done using a bioenergetic approach developed by Temming & Herrmann (2009). Fish growth (considered as variation in weight) is dependent on two antagonistic processes, anabolism and catabolism.

$$\frac{dW}{dt} = Anabolism - Catabolism = EW_t^m - kW_t^n \qquad (1)$$

Where *W* is weight, *t* is time, and *E* and *k* are the constants representing the numerical strengths of the anabolic and catabolic processes, *n* is the catabolic exponent (n=1), and *m* is the allometric coefficient of consumption with fish weight. In previous experimental studies with cod and whiting it was determined that m=0.8.

Hence, from the whole amount of food ingested by a fish, there is a part that will be allocated to catabolism; it is called the maintenance ration while the remaining portion will be invested in fish growth (Figure 3.2.2.1). If fish consumption is below the maintenance ration, fish weight will decrease. On the contrary, when food intake is higher than the maintenance ration fish starts to growth (increases fish weight) in a proportional way to consumption. This proportionality is defined by the *K3* parameter, which is the slope of the Growth-Food intake relationship.

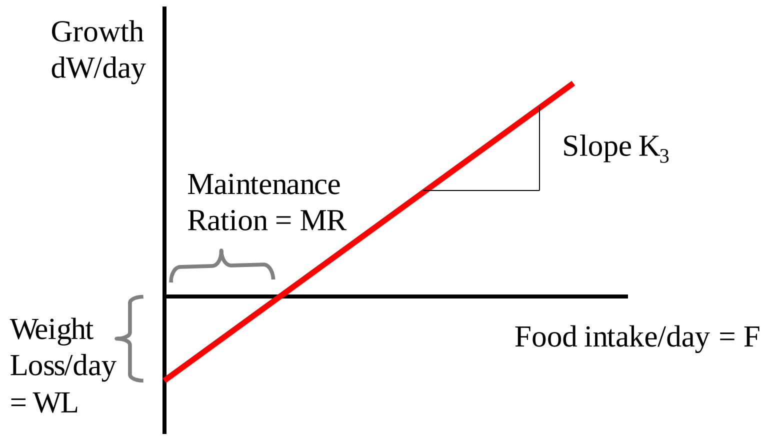


Figure 3.2.2.1. This figure shows some important concepts of the conceptual framework of bioenergetic models (Adapted from Temming & Herrmann, 2009). The relationship between food intake and growth (slope *K3*) is assumed to be linear.

From Figure 3.2.2.1 it can be said that:

$$\frac{dW}{dt} = (K_3 \times F) - WL \qquad (2)$$

From equations 1 and 2:

$$E \times W_t^m = K_3 \times F \qquad (3)$$

$$F = \frac{1}{K_3} \times E \times W_t^m \qquad (4)$$

The constant that determine the strength of metabolism may be defined by means of the parameters from the generalized von Bertalanffy growth function (*GBGF*), W_∞ and *K*:

$$E = 3 \times K \times W_{\infty}^{1-m} \tag{5}$$

Hence, from equation 4 and 5, fish consumption may be defined by means of:

$$F = \frac{1}{K_3} \times 3 \times K \times W_{\infty}^{1-m} \times W_t^m \tag{6}$$

In the present preliminary study, in the absence of an alternative *m* value, the *m*=0.8 value was assumed. From growth feeding studies, *K3* spans between 0.55 (when good food) and 0.35 (bad food). Following the example of Temming and Herrmann, the 0.55 value was utilized. *K* and W_{∞} where obtained by fitting the *GBGF* to each cohort age-weight relationship:

$$W_t = W_{\infty}\left[\left(1 - e^{\left(\left(\frac{3D}{-b}\right) \times K \times (t - t_0)\right)}\right)^{\frac{b}{D}}\right] \tag{7}$$

where b=3 and $D = b \times (1 - m) = 3 \times 0.2 = 0.6$.

Due to the relatively reduced range of ages available for each cohort (usually contained in the range between 2 and 8 years old) in comparison to the actual range in cod lifespan, when the *GBGF* was fitted by cohort group the values obtained for t_0 and W_{∞} were extremely variable and were out of the ranges acceptable based in the biological knowledge for these species. As a compromise solution, fixed values were assigned to t_0 and W_{∞} based on the biological knowledge: t_0=0 and W_{∞}=14,000g, i.e. we assume that when weight is 0 age is also 0, and that the maximum weight is 14 kg. Hence, finally the only parameter to be estimated in both the equations 6 and 7 was *K* from the *GBGF*, i.e. the growth rate. Since $W\infty$ is known to vary between cohorts depending on the growth history, two other different W_{∞} were employed to do consumption estimations (W_{∞}=10,000g and W_{∞}=8,000g). This would permit checking for the importance of variability between cohorts in this parameter for differences in consumption.

With t_0=0 and W_{∞}=14,000g, fitted *K* values for the different cohorts showed a marked increase since early-mid 1990s (Figure 3.2.2.2), which is consistent with the observed increase in size at age since the early 1990's cohorts (Pérez-Rodríguez et al., accepted ms).

Once the growth curves were fitted to each cohort, the amount of food (in grams) that needs to be consumed by a fish between age *x*-1 and *x* to achieve the observed weight at age *x* was estimated. These values were then translated from cohort to actual years. The consumption by individual cods weighing between 0 and 200 grams was used as an index of the relative changes in consumption for the entire weight range. This index of consumption showed a marked decline in consumption before the collapse (Figure 3.2.2.3). However, following the collapse of cod in the mid 1990s, a sudden increase in consumption is observed (Figure 3.2.2.3), which is a reflection of the changes observed in *K*, and ultimately the observed changes in growth (Pérez-Rodríguez et al., accepted ms).

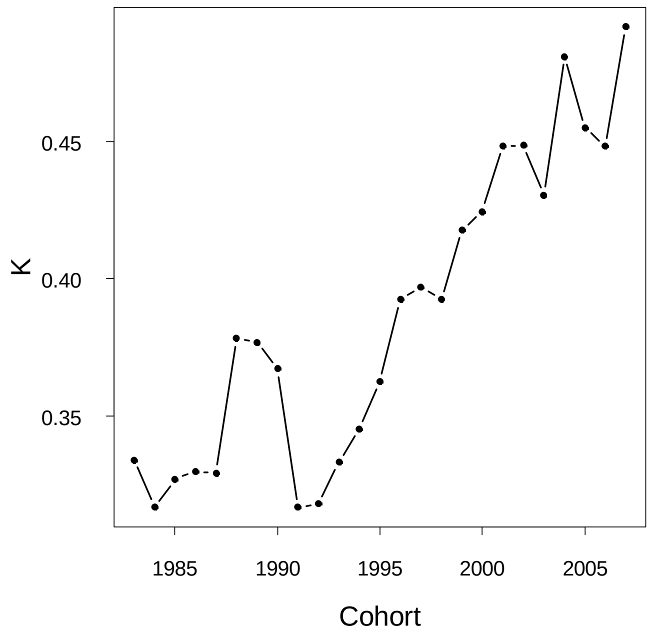


Figure 3.2.2.2. Estimated *K* values from the *GBGF* fitted for each cohort when assuming *t0*=0 and *W*∞=14,000g.

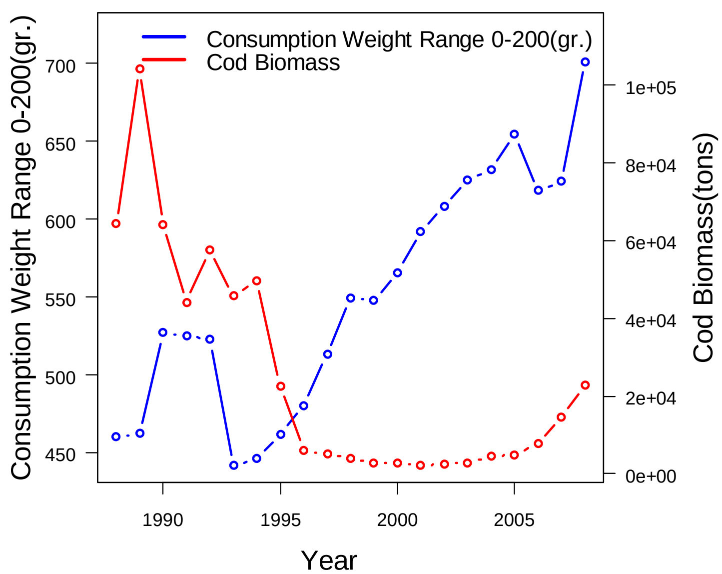


Figure 3.2.2.3. Total Flemish Cap cod stock biomass (González-Troncoso & Vázquez, 2011) and an index of total annual consumption by cod (individuals between 0-200 grams).

Next, the mean weight at age, as well as the abundance at age (González-Troncoso & Vázquez, 2011), were employed for the estimation of the annual total consumption by the entire Flemish Cap cod stock. Due to the high degree of similarity between both time series (Figure 3.2.2.4), it may be suggested that that total consumption has been mainly determined by the size of the stock (Pearson=0.98, *p-value*<0.001). These preliminary results suggest that total annual food consumption by cod has been around three times the estimated total cod stock biomass. Figure 3.2.2.4 also shows that, despite there exist some variations in total consumption when different values are given to W_∞, these differences are relatively small in comparison to changes over time. Hence, differences in W_∞ between cohorts may be expected to have a marginal effect and would not importantly alter the consumption curve from the presented in Figure 3.2.2.4.

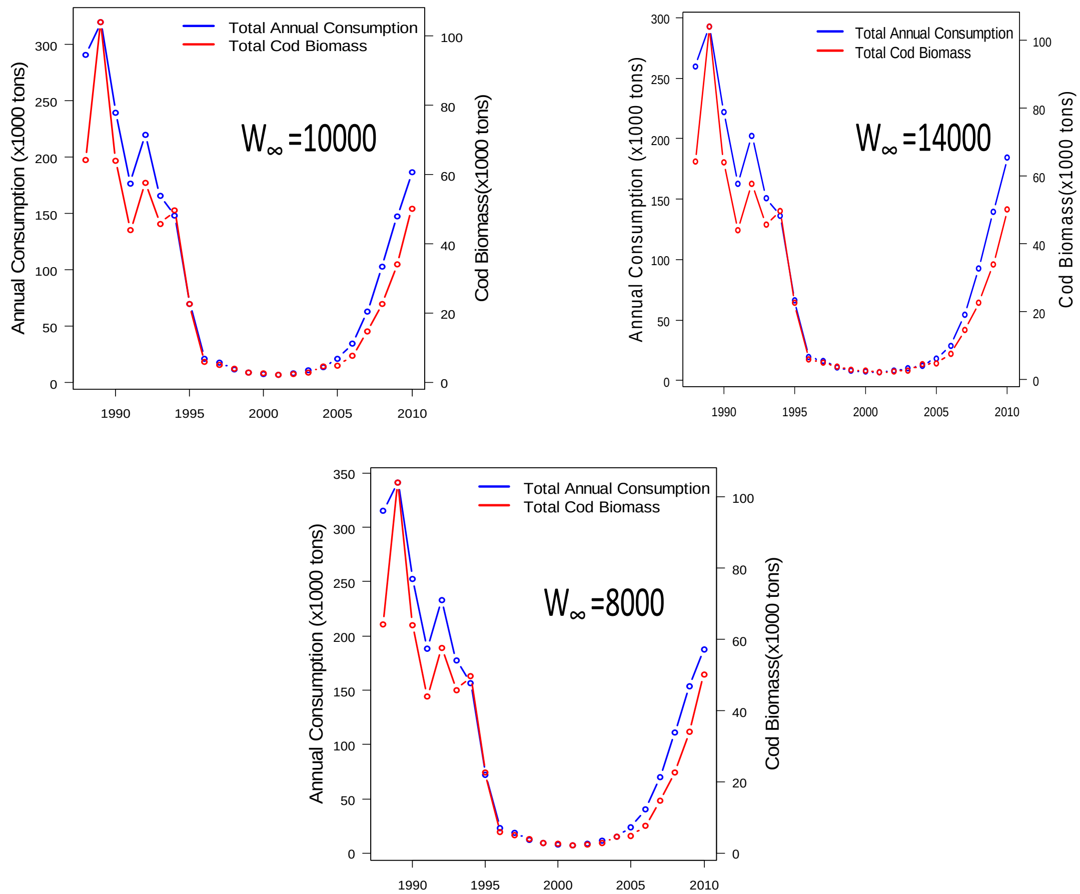


Figure 3.2.2.4. Total annual food consumption estimates by the Flemish Cap cod stock obtained by considering different W_∞ in the *GBGF* are shown with the population biomass for the cod stock.

Once the total consumption was estimated, this consumption must be allocated among the different prey species. To do this, the stomach content information for the Flemish Cap cod, available since 1993 to 2008, was employed. As no feeding habits information was available for 2007, 2009 and 2010, the average diet composition in 2006 and 2008 was employed. Next, the percentage of each prey over the total volume of stomach content analyzed was estimated for each 5 cm size class.

In this preliminary analysis we were focused on the consumption of redfish by cod. Figure 3.2.2.5 shows the estimated average annual consumption by an individual cod between 40 and 75 cm together with the total beaked redfish biomass estimated with XSA (Ávila de Melo et al, 2011). The individual redfish consumption by cod showed a similar pattern than beaked redfish biomass, however, in the early 2000s the increase in the consumption by individual was higher than the increase in redfish biomass.

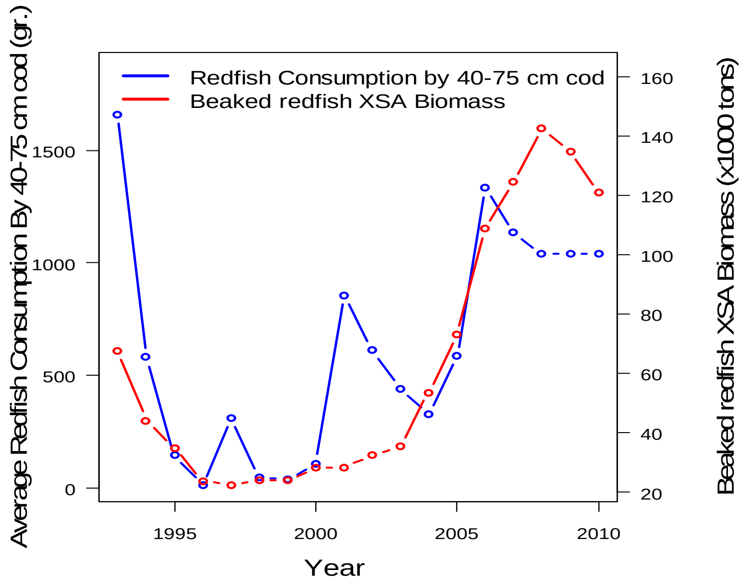


Figure 3.2.2.5. Total beaked redfish biomass (Ávila de Melo et al, 2011) is shown in conjunction with the average consumption for an individual cod in the range 40-75 cm.

The redfish biomass consumed by the whole Flemish Cap cod stock was estimated as the product of average biomass consumed every year by an average individual at every age and the total abundance of individuals by age in the Flemish Cap cod (González-Troncoso & Vázquez, 2011). Total redfish consumption increased drastically since 2006, and in 2008 beaked redfish XSA biomass showed a marked decline (Figure 3.2.2.6).

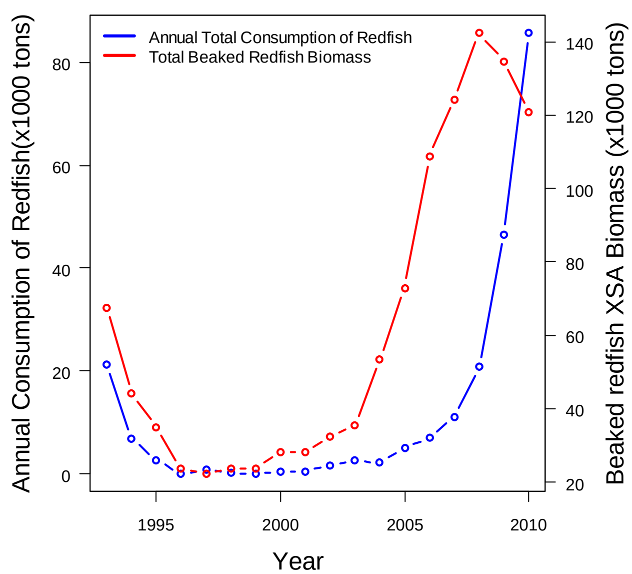


Figure 3.2.2.6. Estimated total beaked redfish biomass, and estimated annual redfish biomass consumed by the cod stock in the Flemish Cap.

However, interannual biomass changes are expected to occur as response not only to mortality and recruitment processes, but growth is also expected to have an important influence. To consider the potential influence of this factor, the number of redfish consumed by cod was also estimated. Furthermore, previous analyses suggested that juvenile-sized redfish were the main size consumed by cod (Lilly 1983, Paz and Casas 1994), so it was assumed that all individual redfish consumed by cod were 15 cm size. On average, a 15cm redfish individuals weighs 516g (estimated using the average size-weight relationship for redfish species; $Weight=0.166Length^{2.97}$, p-value<0.001). Using this average redfish weight, the total number of juvenile redfish individuals consumed by cod was estimated from the total redfish biomass consumed. The estimated numbers of redfish consumed per year were compared with the estimated annual changes in redfish abundance. These changes in abundance were approximated by the difference in XSA numbers between the year *t* and *t-1* (X_t-X_{t-1}) (Figure 3.2.2.7). These two series showed a negative correlation (Pearson=-0.49), as it would be expected if predation by cod was affecting the level of redfish abundance. However, it is more interesting to note that the negative changes in redfish abundance (i.e. loses) are observed in years when the cod stock was at high abundance level (i.e. before the 1995 collapse, and after 2006). If only those years of high cod abundance are considered, the correlation between cod consumption and redfish abundance loses becomes -0.82.

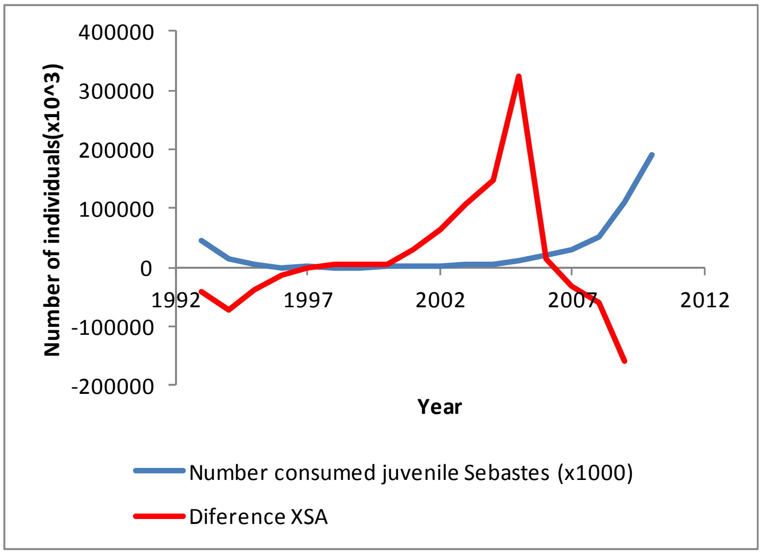


Figure 3.2.2.7. Total number of redfish consumed by cod, and the difference between consecutive years in redfish XSA abundance (X_t-X_{t-1}) in the Flemish Cap.

This observation may suggest that cod has a direct and negative impact on the dynamics of the redfish stocks when cod is present at high densities. However, when cod is at low densities, the expected positive effect (i.e. predation release) of a low predator density on the redfish stock is not as clear (e.g. Figure 3.2.2.8). It seems that the absence of predation only means the absence of a negative effect, but not necessarily a clearly positive one. Significant increases in the redfish stock would need other drivers, like proper oceanographic and secondary production conditions for successful recruitment events, and not just a reduction in predation.

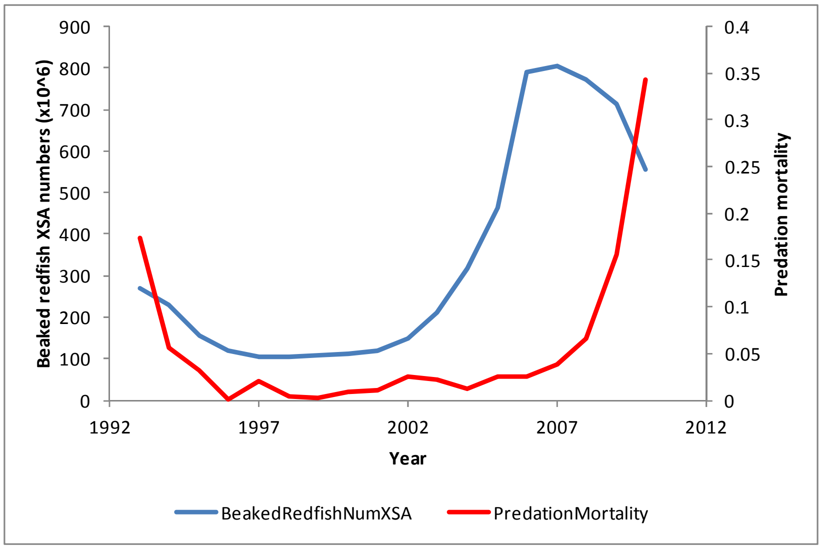


Figure 3.2.2.8. XSA estimated abundance of beaked redfish (Ávila de Melo et al, 2011), and estimated predation mortality produced by the cod.

It is important to note that the XSA-based numbers used for these preliminary analyses include only beaked redfish (*Sebastes mentella* and *S. fasciatus*; Ávila de Melo, pers.comm.), while the estimates of redfish consumption by cod include all three *Sebastes* species (*S. mentella*, *S. fasciatu*s and *S. marinus*). Hence some differences may arise if *S. marinus* would be also considered in the XSA exercise. However, since indices of biomass from EU surveys for *S. marinus* and *S. fasciatus* have been very similar over the study period considered (Figure 3.2.1.1), it can be expected that the overall patterns and relationships described here would remain valid. However, this difference would influence downwards the illustrative predation mortality estimates depicted in Figure 3.2.2.8.

Although these consumption analyses are informative in terms of developing an understanding of the potential effects of cod on redfish, the quantitative aspects should only be considered as preliminary results; more work and additional explorations and refinements on this analysis are required before quantitative results can be considered reliable. Some examples of additional work that needs to be considered include:

- Incoporation of prey quality through different *K3* values depending on the prey.
- Incorporation of available information on changes in diet within a year.
- Fractioning growth within the year in four seasons.
- Further considerations of variability in *W*∞ among cohorts.
- Inclusion of information of variability in age at maturation over time due to its effect on energy allocation.
- Exploration of the effect of a variable allometric coefficient of consumption *m*.
- If possible, develop XSA estimations of biomass and abundance for all three *Sebastes* species.
- Incorporation of recent stomach content data available for year 2010.

3.2.3. Preliminary exploration of the cod-shrimp-redfish trophodynamic system in the Flemish Cap

A preliminary exploration of the joint dynamics of cod, shrimp, and redfish in the Flemish Cap was conducted by implementing the most simple trophodynamic model possible that includes these three components (Figure 3.2.3.1).

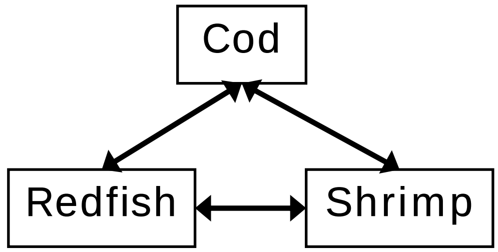


Figure 3.2.3.1 Graphical depiction of the 3-spp model implemented. This generic representation shows the interactions between components.

The actual model implementation was based on a discrete version of the generalized predator-prey Lotka-Volterra formulation of the form:

$$B_{i,t+1} = B_{i,t} + r_i B_{i,t}\left(1 - \frac{B_{i,t} + \sum_J \alpha_{ij} B_{j,t}}{K_i}\right) - C_{i,t}$$

where B_i, r_i, and K_i are the stock biomass, intrinsic growth rate, and carrying capacity for species i, α_{ij} represents the *per capita* interaction effect of species j on species i, and C_i is fishing catch. The sub-index t indicates time-dependent variables for year t.

Given the sign conventions used in the above equation, it is expected α_{ij} to be negative if the effect of j on the biomass of i is positive (e.g. i is a predator of j), and positive if the effect of j on the biomass of i is negative (e.g. i is a predator/competitor of j).

Based on this discrete generalized Lotka-Volterra equation, net biomass production for a given species i in year t ($P_{i,t}$) can be modeled as:

$$P_{i,t} = B_{i,t+1} - B_{i,t} + C_{i,t}$$

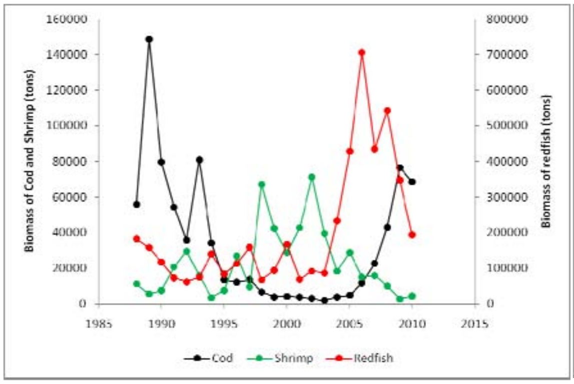
or

$$P_{i,t} = r_i B_{i,t} - \frac{r_i}{K_i} B_{i,t}^2 - \sum_J \frac{r_i}{K_i} \alpha_{ij} B_{i,t} B_{j,t}$$

This last production equation is a linear one, so we can estimate its parameters using standard multiple regressions, as long as we have time series for all stock biomasses and the fisheries catches. In the case of the model implemented here, the solution involves a system of three equations, one per species.

If we consider the most common representation of the observation equation, $I_i = q_i B_i$, where I_i is the observed index (e.g. RV biomass index), and q_i is the scaling factor that relates actual biomass with the observed index for species i, and then we assume that q_i=1, we can used the RV biomass indices for these species to estimate the parameters in the linearized production equations. The assumption q_i=1 is a major one, and hence, any results obtained from its application should only be considered preliminary ones.

Following these procedures, assuming q_i=1, and using EU RV survey indices for cod, shrimp, and redfish in the Flemish cap, as well as NAFO catch statistics for these species in the study area (Figure 3.2.3.2), the parameters of this 3-spp model were estimated using linear multiple regressions.



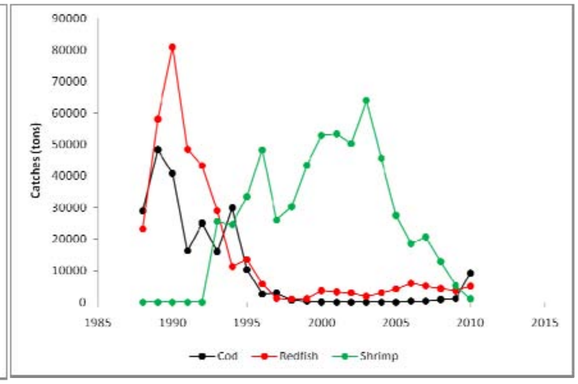


Figure 3.2.3.2. RV biomass indices and fisheries catches for cod, shrimp and redfish in the Flemish Cap.

Although the estimated model parameters values are expected to be conditioned to the q_i=1 assumption, the results obtained were quite acceptable for an initial and preliminary exploration. Both the order of magnitude of most parameters, as well as the signs from the interaction coefficient were in reasonable agreement with prior expectations, with the only exception of a rather large estimate for the intrinsic growth rate of shrimp (Table 3.2.3.1). The signs of the estimated interaction coefficients were in full agreement with available information and expectations; both shrimp and redfish have a positive effect on cod (both are known and important prey for cod, see Figure 3.2.1.3), while cod, as a predator, has a negative effect on both shrimp and redfish; redfish which is also a predator of shrimp, also has a negative effect on shrimp, while shrimp, as a prey, has a positive effect on redfish (Table 3.2.3.1).

Table 3.2.3.1. Estimated parameters for the discrete generalized Lotka-Volterra model. These estimates are conditioned to the assumption of q_i=1. At the present time these parameter values must be regarded as preliminary.

Cod		Redfish		Shrimp	
r_{cod}	0.486	$r_{redfish}$	0.268	r_{shrimp}	3.600
K_{cod}	80,066	$K_{redfish}$	231,789	K_{shrimp}	78,910
$\alpha_{cod-redfish}$	-0.132	$\alpha_{redfish-cod}$	2.430	$\alpha_{shrimp-cod}$	0.781
$\alpha_{cod-shrimp}$	-2.142	$\alpha_{redfish-shrimp}$	-16.627	$\alpha_{shrimp-redfish}$	0.050

In addition to these reasonably valued estimated parameters, the actual fit of the model to the data was remarkably good given the assumptions and limitations of this exercise (Figure 3.2.3.3). Expected values for cod, shrimp, and redfish were generated using the estimated parameters, and assuming a process error structure (i.e. model predictions are based on the observed value in the previous year; the model only predicts the next year). In general, predicted values tracked reasonably well the observations, but in the case of shrimp, there were some years were the model predicted negative biomasses. This clearly indicates that the model fit is not fully satisfactory; this particular biological implausibility may very well be related to the q_i=1 assumption. Residuals from this model were acceptable but not ideal; normalized residuals were, with only one exception, clearly bounded between -3 and 3 standard deviations, but there seems to be some patterns over time, specially in the case of redfish (Figure 3.2.3.4). In any case, these results are promising, but warrant caution in the use of any quantitative prediction from this model.

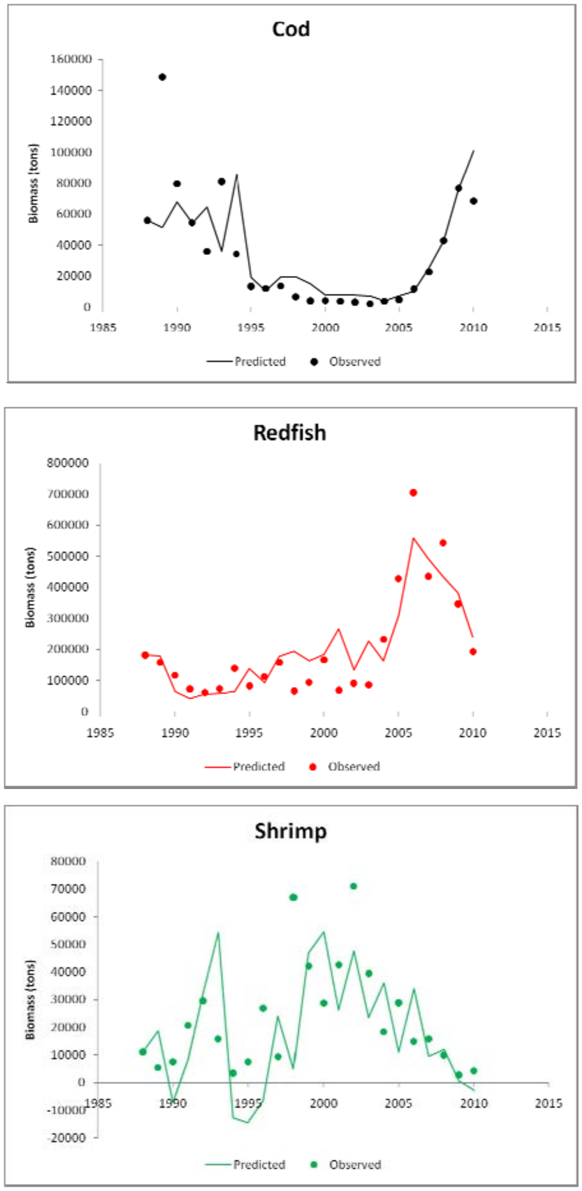


Figure 3.2.3.3. Observed and model predicted RV biomasses for cod, redfish, and shrimp in the Flemish Cap.

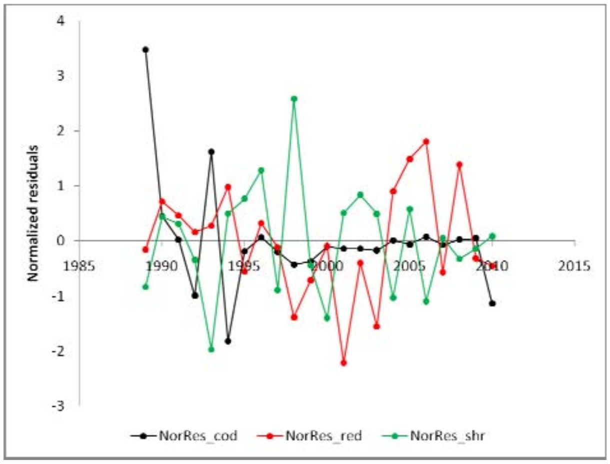


Figure 3.2.3.4. Normalized residuals for the cod, redfish, and shrimp series in the 3-spp Lotka-Volterra model for cod-redifish-shrimp system in the Flemish Cap.

Further explorations with this model provided some interesting observations. In order to investigate alternative scenarios of single species and multispecies maximum sustainable yields (SSMSY and MSMSY respectively), the fishing capture term in the original model formulation (C_i) was replaced by F_iB_i, where F_i represents a fishing mortality level for the species *i*. With fishing terms redefined in this way, and together with the estimated parameters, the 3 equation model was numerically solved for equilibrium under specific yield scenarios. These scenarios were:

- MS. The fishing mortalities for all species were varied to maximize the overall system yield (i.e. the combined yield for cod, redfish, and shrimp).
- SScod. The fishing mortalities for all species were varied to maximize the cod yield.
- SSredfish. The fishing mortalities for all species were varied to maximize the redfish yield.
- SSshrimp. The fishing mortalities for all species were varied to maximize the shrimp yield.

The results from these MSY explorations indicate that most scenarios render comparable overall catch levels, the exception being SSshrimp which renders less than the others in terms of total catch. The MS scenario provides the most overall catch, but this is achieved with a catch distribution by species where the shrimp catch level is quite low in comparison with the yield from the SSshrimp scenario. Even more dramatic, the achievement of the goals of SScod and SSredfish require no shrimp catches, and both of these SS scenarios have an overall catch which is slightly lower than the MS scenario. Finally, maximizing the yield for shrimp requires catches of cod and redfish far lower that the values in the MS, SScod or SSredfish scenarios. Figure 3.2.3.5 summarizes all these comparisons among MSY scenarios.

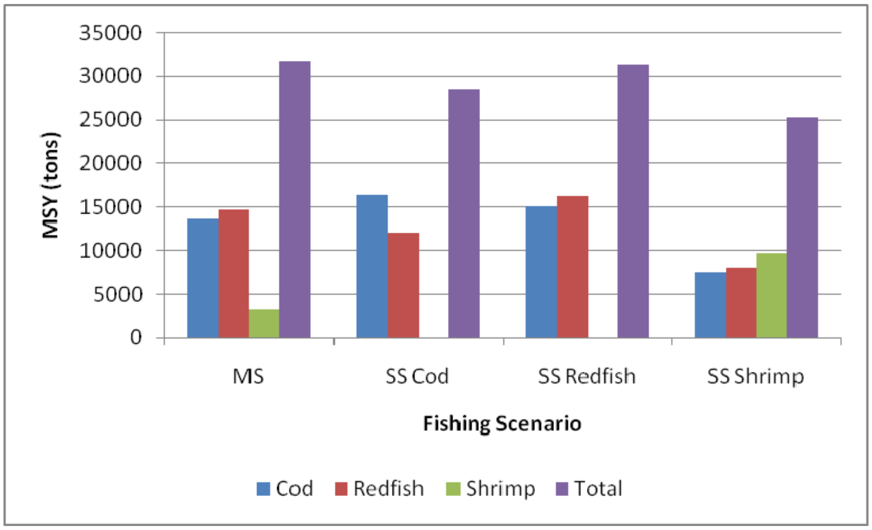


Figure 3.2.3.5. Comparative MSY values for the four scenarios explored.

Furthermore, all these MSY scenarios generate distributions of equilibrium biomasses which are dramatically different from the one of the unexploited system (Figure 3.2.3.6), and in the case of the SScod and SSredfish scenarios, the achievement of their respective MSY goals require the absence of shrimp from the system (i.e. collapsing the 3-spp system into a 2-spp system). A similar observation emerges from the equilibrium biomasses in the unfished system. In this case, the equilibrium biomass for shrimp is a negative biomass. This results is clearly indicating a problem in the model, however, an unfished system with a very large cod population and no shrimp, is exactly what we could have expected for this system if we consider the history of this system. This system was dominated by cod, and shrimp was not an historically important species in the Flemish Cap; shrimp suddenly appear in significant number and increase in biomass in the mid 1990s. This oddity in the model is not a satisfactory result, and certainly can be the consequence of the many assumptions and restrictions imposed by the model structure and the parameter estimation process. Nonetheless, it may also be a hint that the model, in all its simplicity, is capturing an important feature of the Flemish Cap system; shrimp may not be an structurally important species in this ecosystem, and its large abundances in the past decade are just a transient feature of a heavily perturbed system.

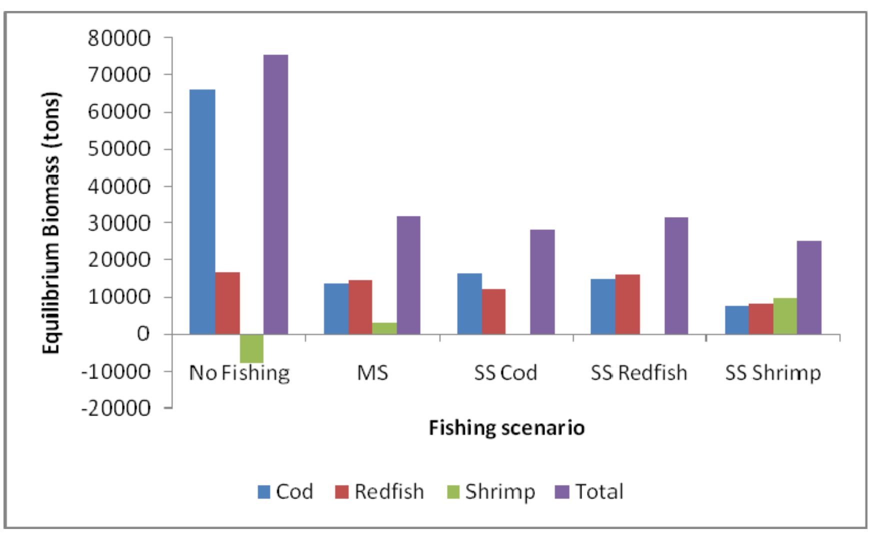


Figure 3.2.3.6. Equilibrium biomasses for cod, redfish, shrimp, and all combined (total) under no fishing, and the four MSY fishing scenarios described in the text.

Finally, and just as an exploration in misguided wishful thinking, we explore what would happen if the fishing mortalities for the target species obtained in each one of the SSMSY scenarios were applied simultaneously. We compare the actual model predictions under this "parallel SS management scenario", with the expectations from each one of the original SSMSY scenarios. This comparison clearly shows that a parallel implementation of SSMSY strategies would render lower yields than expected under the individual SSMSY scenarios (Figure 3.2.3.7), and for cod and redfish, also lower than what would be obtained under the MS scenario (Figure 3.2.3.5). This naïve exploration suggests a potentially important insight, a true MSMSY management could provide better yields (although not for all species) than independent SSMSY strategies.

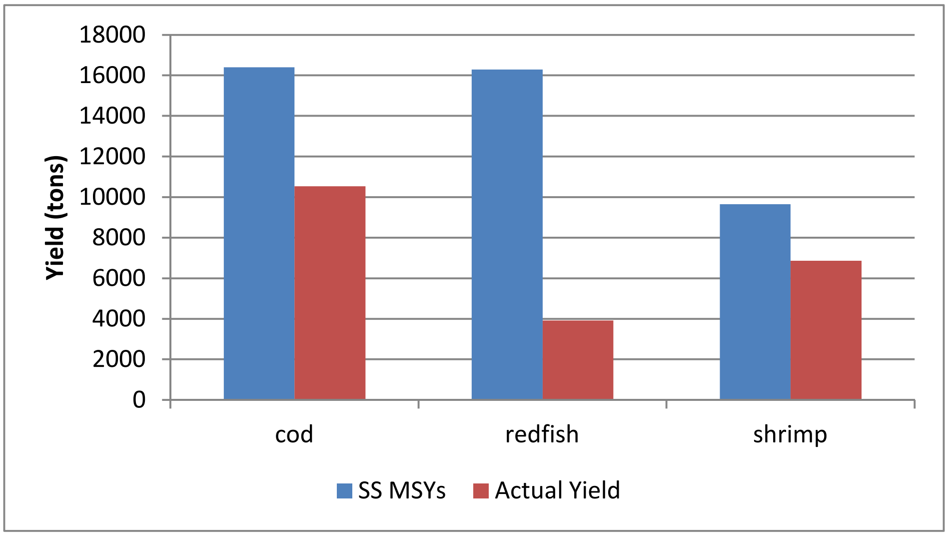


Figure 3.2.3.7. Comparison of the yields obtained in each one of the original SSMSY scenarios, with the expected yields resulting from applying the Fmsy values estimated in each one of the SSMSY scenarios simultaneously.

In summary, this modeling exercise, although it does not provide reliable quantitative values given all its assumptions and potential shortcomings, still provides important insights in the relationships among cod, redfish, and shrimp in the Flemish Cap. It clearly shows that a simultaneous maximization of the yields for the three species appears unfeasible from a biological perspective, there is a clear trade-off between the yields of cod and redfish, and the yield of shrimp; more yield on the shrimp side requires low yields for the fishes. On the other side, maximal yields for the fish species can only be realized at very low shrimp population levels. There is also a trade-off to be achieved between the two fish species; maximizing the yield of one of them requires assuming less than maximum yields for the other. Attempting to provide fine details for these trade-offs exercises is clearly beyond the capacity of this model in its current configuration, but achieving a combined MSY level for all of them will require not just a better model to address the issue of biological plausibility, it would also require addressing at the management table the question of how these necessary trade-offs will be discussed and agreed upon.

3.2.4. References

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ToR 4.1. [FC Requests # 16 & 17]. Implement and/or further refine the existing GIS simulation/modelling framework, in conjunction with the VMS data supplied by the NAFO Secretariat [FC Request #16], to make recommendations on encounter thresholds and move on rules for groups of VME indicators including sea pens, small gorgonian corals, large gorgonian corals, sponge grounds and any other VME indicator species that meet the FAO Guidelines for VME and SAI. Consider thresholds for 1) inside the fishing footprint and outside of the closed areas and 2) outside the fishing footprint in the NRA, and 3) for the exploratory fishing area of seamounts if applicable.

Sea pen fields, large and small gorgonian coral stands and sponge grounds are important structure-forming taxa indicative of vulnerable marine ecosystems (VMEs) in the NAFO regulatory area (NRA) (Fuller et al. 2008). Significant concentrations of these have been identified and subsequently protected through area closures in accordance with paragraph 66 of the FAO International Guidelines for the Management of Deep-Sea Fisheries in the High Seas (FAO 2009). However significant concentrations of these taxa remain unprotected within the fishing footprint of the NRA and in deep water along the continental slopes outside of the fishing footprint. The United Nations Sustainable Fisheries Resolutions (61/105, 64/72) state that RFMOs should have an appropriate protocol in place for how fishing vessels should respond to encounters with VMEs in the course of fishing operations (FAO 2009). This involves defining what constitutes evidence of an encounter with a vulnerable marine ecosystem (UNGA 64/72, para 119 (c)). Specifically, the guidance is:

67. States and RFMO/As should have an appropriate protocol identified in advance for how fishing vessels in DSFs should respond to encounters in the course of fishing operations with a VME, including defining what constitutes evidence of an encounter. Such protocol should ensure that States require vessels flying their flag to cease DSFs fishing activities at the site and report the encounter, including the location and any available information on the type of ecosystem encountered, to the relevant RFMO/A and flag State.

68. In designing such protocols and defining what constitutes an encounter, States and RFMO/As should take into account best available information from detailed seabed surveys and mapping, other relevant information available for the site or area, and other conservation and management measures that have been adopted to protect VMEs pursuant to paragraphs 70 and 71. (FAO 2009)

In 2010 NAFO set the encounter thresholds for all coral and for sponge as:

For both existing and new fishing areas, an encounter with primary VME indicator species is defined as a catch per set (e.g. trawl tow, longline set, or gillnet set) of more than 60 kg of live coral and/or 800 kg of live sponge. These thresholds are set on a provisional basis and may be adjusted as experience is gained in the application of this measure (NAFO 2011a).

At the 2011 Annual General Meeting, NAFO voted to reduce the sponge encounter threshold to 400 kg outside of the fishing footprint, and to 600 kg inside of the fishing footprint but outside of the closed areas (NAFO 2012). This was done in a precautionary framework without specific scientific support for the threshold levels. FC further requested of the Scientific Council:

17. *Fisheries Commission requests the Scientific Council to make recommendations for encounter thresholds and move on rules for groups of VME indicators including sea pens, small gorgonian corals, large gorgonian corals, sponge grounds and any other VME indicator species that meet the FAO Guidelines for VME and SAI. Consider thresholds for 1) inside the fishing footprint and outside of the closed areas and 2) outside the fishing footprint in the NRA, and 3) for the exploratory fishing area of seamounts if applicable.*

This report is in response to this request of the Fisheries Commission for advice.

The VME indicator taxa (associated with sea pen fields, large and small gorgonian coral stands and sponge grounds) are all highly aggregating. This property was exploited in the quantitative analyses of Kenchington et al. (2010a) and Murillo et al. (2010) who were able to identify a research vessel catch level (referred to as a threshold) which corresponded to a dense aggregation of sponges and sea pens respectively. In principle, the same approach could be used to identify when a commercial vessel has encountered such an aggregation. However, progress in establishing commercial by-catch values which would constitute evidence of an encounter has been hampered by the lack of commercial by-catch data. This has been discussed previously and compensated for by the development of a GIS-based simulation model (Kenchington et al. 2010a,b, Cogswell et al. 2010, Cogswell et al. 2011) which estimates commercial catches under various management scenarios. The model constructs a biomass layer derived from the research vessel catches; uses simulated trawl start and end positions and/or VMS data (Cogswell et al. 2011) to reflect commercial fishing; and calculates the biomass removed from under each fishing line to estimate commercial by-catch.

The model was first applied in 2010 to the sponge grounds in the NRA, using simulated trawl lines with effort-weighted start and end positions (NAFO 2010). The simulated trawls were not allowed to cross into the closed areas and were constrained to within the fishing footprint. That model application provided a fishery assessment framework for evaluating where large catches could still be obtained outside of the closed areas and what proportion of the catches would be affected by altering by-catch thresholds. For example, advice was given in this context: Reducing the encounter threshold for sponges from 800 kg to 50 kg would only affect 5.5% of trawls (94.5% of fishing would be unaffected) and those encounters could be avoided as catches > 50 kg are concentrated in just two areas in Flemish Pass outside of the closed areas. Based on that analysis the WGEAFM recommended that the encounter threshold for sponges fished with bottom trawl gear be reduced from 800 kg to between 30 and 50 kg per tow. However, the Scientific Council (SC) was reluctant to endorse the WGEAFM report (NAFO 2011b) and raised a number of issues regarding this approach which we have addressed here and in Cogswell et al. (2011).

SC felt that the straight line, effort-weighted simulated tows used in the model were not characteristic of "real" fishing practices and that using the simulated lines would produce unrealistic results. This was a known issue (Kenchington et al. 2010a) however at the time there was no way to test this effect. However at the request of the FC (request #16 – see above), NAFO provided VMS data from 2010 (Cogswell et al. 2011). Cogswell et al. (2011) utilized a 2010 ground fish fishing effort layer, a Spanish/EU only biomass surface layer for both sponges and sea pens, and a recent revision to closed area #5 (NAFO, 2012) for model runs designed to address FC request #17. Using these new Model input layers, Cogswell et al. (2011) compared and contrasted model outputs using the two measures of fishing effort and showed that the simulated trawls produced very similar results to the VMS data over most of the by-catch range, with the former over-representing the very small catches and the latter the very large ones.

SC further noted that the model did not link specific thresholds to biological or ecological criteria (NAFO 2011b). This was identified also in the WGEAFM report (NAFO 2010). The model as presented was to guide managers towards precautionary decision making and to allow them to assess the potential impact of different threshold choices on the fishing industry. Lastly, SC disagreed with the application of the model in that the model was applied to an area outside of the closed areas to protect sponges as well as within the fishing footprint. The consequences of this are that the catch biomass range is reduced and the highest catches may no longer be indicative of sponge grounds. This is further exacerbated by fishermen avoiding sponge grounds resulting in effort-weighted catches further narrowing the catch biomass range. However, as we now have confidence in the use of the simulated straight-lines used to mimic fishing effort, the model outputs can be considered valid should managers wish to evaluate fishing measures in that context.

As a result of these issues, we have taken a different approach in our application of the model to address the concerns of the SC. In order to provide ecological relevance to the threshold level we follow the same approach that we used to detect the significant concentrations or aggregations of sponges and sea pens that led to the implementation of the closed areas (Kenchington et al. 2010a,b, Cogswell et al. 2010, Murillo et al. 2010). The "threshold" for the identification of sponge grounds/sea pen fields was estimated by recording when the area occupied by catches was greater than or equal to a threshold value, suddenly increased. This identifies the transition from the dense aggregations of these animals to the widespread occurrence of isolated individuals or small aggregations. Instead of using research vessel tows, we imposed 2000 random trawl start and end positions of commercial trawl length (13.8 nm see Cogswell et al. 2011) over the sponge/sea pen biomass layer derived from research vessel survey catch (Cogswell et al. 2011). This provides the commercial tow equivalent of the research vessel "threshold" catches used to identify sponge grounds and sea pen fields. Randomization of the tows (as opposed to positioning using weightings for fishing effort) is necessary in order to produce tows that cross the sponge grounds and sea pen fields which are to some extent avoided by the fleet. The threshold value would apply anywhere a commercial vessel encountered such habitats with similar species composition, both *1) inside the fishing footprint and outside of the closed areas* and *2) outside the fishing footprint in the NRA*, where these habitats occur.

Having used the model to identify a commercial encounter threshold indicative of the VME feature we then apply it as we did in the 2010 WGEAFM report (NAFO 2010) to assess the impact of that threshold on the 2010 fishing activities using the 2010 VMS data provided by NAFO.

Thus far we have not addressed significant adverse impacts (SAI) of fishing on the aggregations. The model outputs themselves are not influenced by gear selectivity or gear efficiency (catchability (q)) and SAI effects have no impact on the identification of aggregations using the area-occupied approach described above. This is because applying q across all areas would only proportionally change the catch values used to identify the significant aggregations. However, in order to assess immediate and cumulative impacts of encounters, gear efficiency and incidental mortality become important factors which influence recovery. We review the literature for these issues and present new information from the NEREIDA research program for the species in the NAFO regulatory area.

NAFO uses move-on rules to mitigate "encounters" with small fish and bycatch of commercial species. When considering encounter thresholds for coral and sponge they also applied a move-on rule: with associated procedural directions (NAFO 2012).

"The vessel master shall cease fishing and move away at least 2 nautical miles from the endpoint of the tow/set in the direction least likely to result in further encounters. The captain shall use his best judgment based on all available sources of information",

As for the encounter thresholds, the move away distance has not been scientifically determined. The information on sponge biomass distribution used in our model can be used to inform captains on the "direction least likely to result in further encounters". We also explore various options for move-away rules which would support the conservation objective of preventing further damage to the VME.

Here we present data for sponge grounds and sea pen fields that we feel provide a first scientific basis for commercial encounter protocols and move-on rules for those taxa *1) inside the fishing footprint and outside of the closed areas* and *2) outside the fishing footprint in the NRA*. In doing so we discuss significant adverse impacts of bottom-contact gear on these taxa and other issues related to our results. If our approach is accepted by SC the same methodology could be applied to the small and large gorgonian corals in future.

4.1.1. Sponge Grounds

4.1.1.1 GIS-Simulation of Commercial By-catch (Encounter) Thresholds Indicative of Sponge Grounds in the NAFO Regulatory Area (NRA)

Both the research vessel survey data used to estimate sponge biomass and fishing effort (by definition) fall within the fishing footprint. Consequently, we must make assumptions about sponge grounds outside of the fishing footprint in exploratory fishing areas on the slopes of the Flemish Cap and Grand Banks (seamounts are dealt with elsewhere). The assumption made is that the sponge grounds are the same or similar to the *Geodia*-dominated sponge grounds found in the fishing footprint and along the Canadian slope (Kenchington et al. 2010b, Fuller 2011, Murillo et al. 2011). These include aggregations of other large structure forming sponge species (ICES 2009) including glass sponges such as *Asconema* spp. Preliminary viewing of NEREIDA *in situ* seabed imagery suggests that there may be such sponge grounds outside of the fished area, and we know that there are some unprotected sponge grounds within the NRA.

This simulation uses 2000 randomly placed and oriented straight line simulation trawls of median commercial tow length (13.8 nm) (see Cogswell et al. 2011). All lines generated by this method have a random start location and a randomly chosen heading between 0 and 360 degrees, at 1 degree intervals. In addition, lines were not restricted from crossing into closed areas so that the data could be collected on the appropriate thresholds for commercial vessels that encounter the sponge grounds, most of which have been protected by the closed areas (see explanation above). The extent of our analysis is limited to the footprint of the

Spanish/EU research vessel 5 x 5 km cell sponge biomass surface (Cogswell et al. 2011) (Figure 4.1.1.1.1) which is used to estimate the commercial catches. We use only the Spanish/EU research vessel data for estimating the sponge biomass layer (Cogswell et al. 2011). This is because the Canadian research vessel data is restricted spatially and is derived from tows of a shorter duration than the Spanish/EU vessels (15 min vs. 30 min.). By using only the Spanish/EU data we avoid worsening spatial bias through scaling the Canadian data in order to standardize it (Cogswell et al. 2011).

The simulated commercial sponge catch was calculated from the 5 x 5 km gridded Spanish/EU research vessel survey sponge biomass layer and then used to create a smoothed sponge density layer (Figure 4.1.1.1.2) interpolated using the kernel density function with a search radius of 25 km (Kenchington et al. 2010a,b). This smoothing is necessary so that equal density polygons can be drawn around the area occupied by successive weight thresholds (following Kenchington et al. (2010 a,b) and Cogswell et al. (2010)). This density layer identified "hot spots" in locations similar to those in the research vessel sponge density layer used to identify the closed areas (Figure 4.1.1.1.2 compares the kernel density outputs from both the simulated trawl catch and research vessel by-catch). The major difference is in the relative densities and spread of the locations (due largely to the length of simulated commercial trawls (25.6 km) compared to the research vessel trawl length (2.8 km)) and particularly so in the area south of Sackville Spur on Flemish Cap.

Polygons of equal density were drawn around successive catch weights of sponge and the area occupied by each polygon was calculated. The "threshold" for the identification of sponge grounds was estimated by recording when the area occupied by catches greater to or equal to a threshold value, suddenly increased. This identified the transition from the dense aggregations of these animals to the widespread occurrence of isolated individuals or small aggregations. Figure 4.1.1.1.3 illustrates the relative change in area occupied by successive density polygons for 42 catch weight thresholds between 0.01 and 35,000 kg. Initially the area increases dramatically as the number of data points are small and the core of the sponge grounds are not yet established (Kenchington et al. 2010a). The relative increase in area (Figure 4.1.1.1.3) has its first threshold at catches greater than 10,000 kg where there is a relative increase of 1.5 times the area (the increase in area going from 35,000 to 15,000, and 15,000 to 10,000 kg are not shown but were even larger at 154 and 3 times respectively). Beyond this, the next largest change in area between successive catch thresholds occurred between catches of 3,000 and 2,000 kg (2.2 x) (Figure 4.1.1.1.3). Catches of this size reflect sponge grounds dominated by the massive ball sponges of the genus *Geodia*. The next largest change in area occurs between 300 and 200 kg. Catches of 300 kg or more occupy an area of 24,914 km^2 while catches of 200 kg or more occupy an area 1.5 times larger (36,548 km^2). The locations of the simulated commercial catches greater than or equal to 300 kg are illustrated in Figure 4.1.1.1.4 in relation to the closed areas. These catches correspond to the VME sponge grounds for both *Geodia*- and *Asconema*- dominated habitats. We also examined the next threshold which is between 200 kg and 100 kg (1.4 times change in area), however this is established by only 5 points which is not considered to be a robust result (Kenchington et al. 2010a). Following the procedures used previously to identify significant concentrations of sponge from research vessel trawl survey catches, the threshold of 300 kg/13.8 nm trawl taken by a commercial vessel would indicate a significant concentration of sponge and could be used as the threshold for identifying an encounter by commercial vessels. Figure 4.1.1.1.5 illustrates a typical *Geodia*-dominated sponge catch near this 300 kg threshold limit.

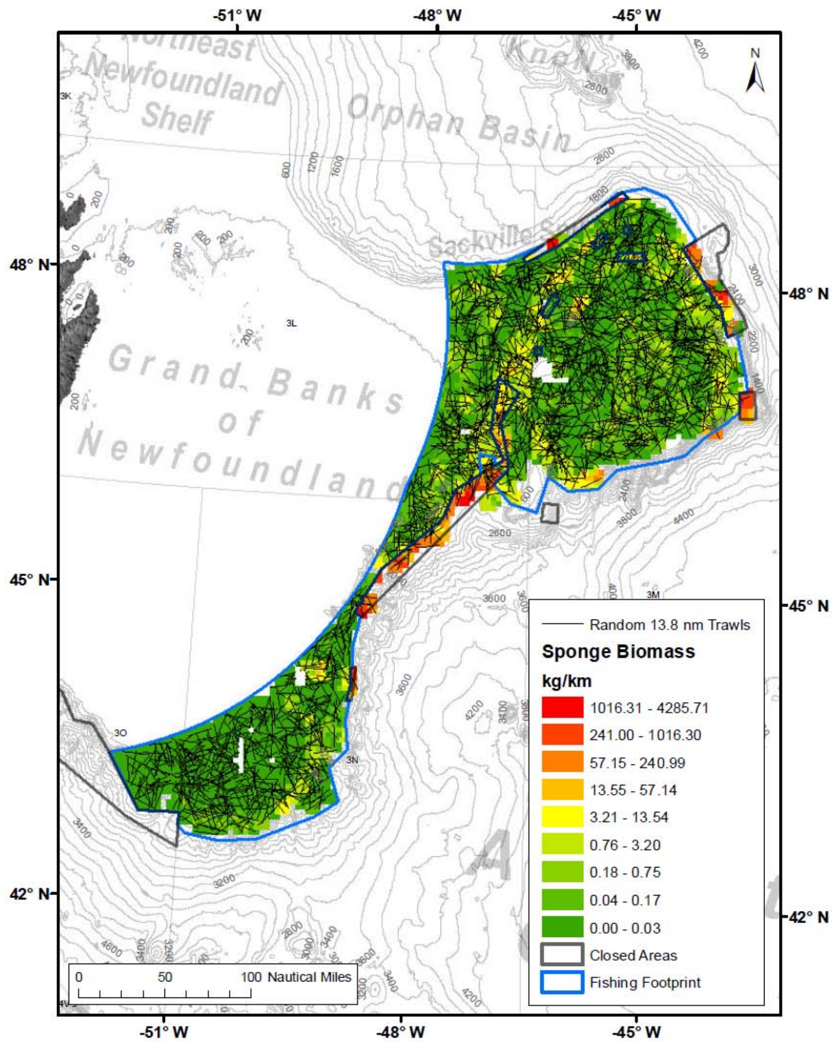

Figure 4.1.1.1.1. Simulated trawls (n=2000) with random start locations and orientation. Each trawl is of standard length (13.8 nm) and falls within the 5 x 5 km cell sponge biomass surface for the NRA.

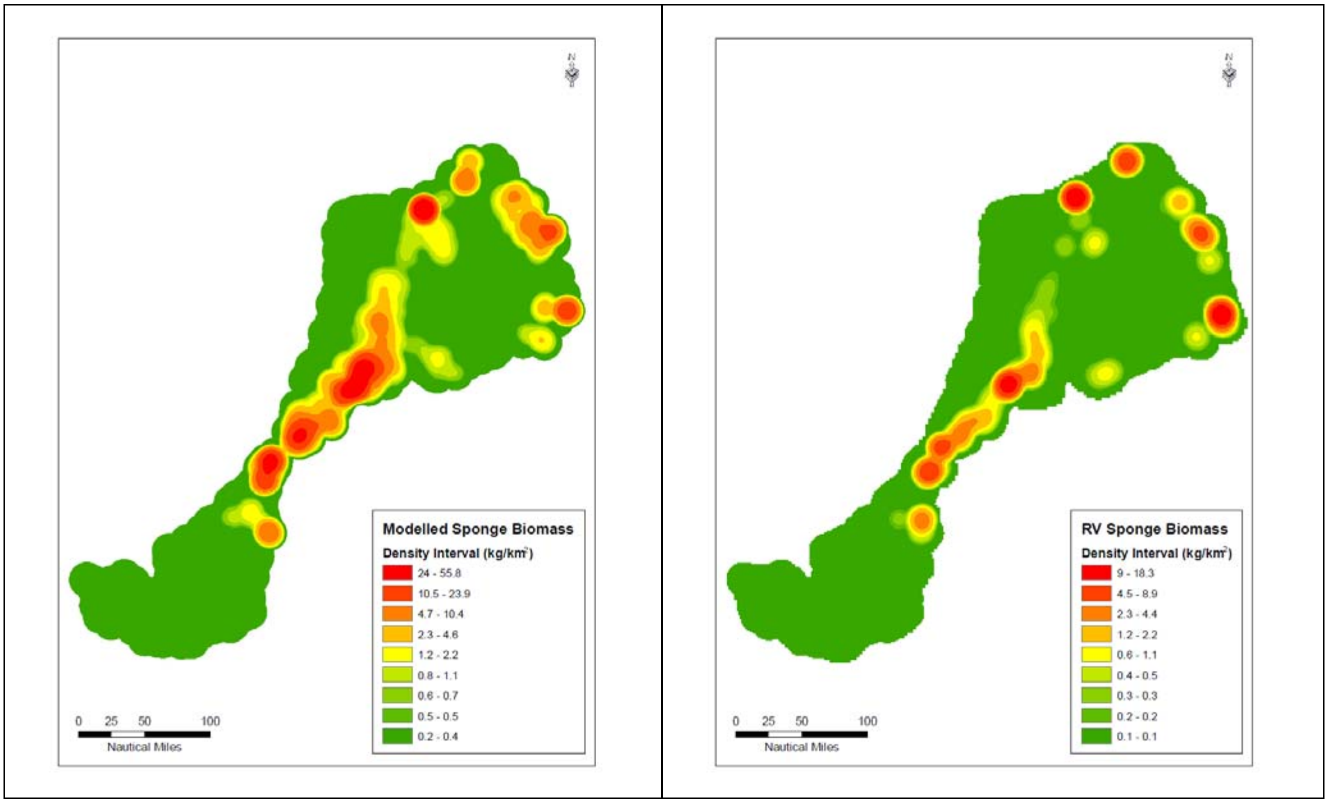

Figure 4.1.1.1.2. Sponge biomass (displayed using a geometric distribution in kg/km^2) in the NRA estimated from simulated commercial trawls with random start locations and orientation (left) and from Spanish/EU research vessel catches (right). Note maximum density values cannot be compared between the two methods.

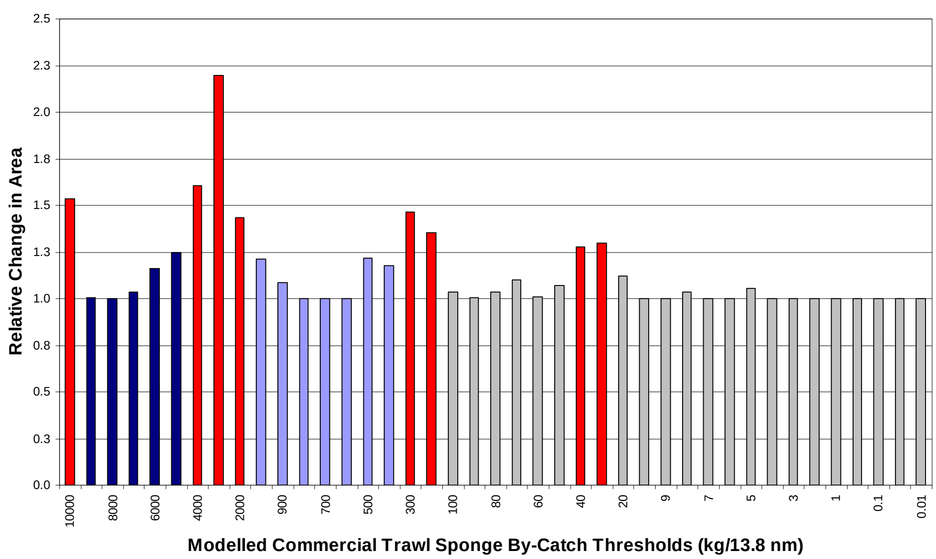

Figure 4.1.1.1.3. Relative change in area occupied between successive catch thresholds from ≥10,000 kg to ≥ 0.01 kg. Dark blue bars correspond to the core of the *Geodia*-dominated sponge grounds. Light blue bars correspond to the VME sponge grounds for both *Geodia*- and *Asconema*- dominated habitats. The red bars indicate the levels where the greatest difference in area occupied occurred between successive catch weight values (greater than 1.3 times the area of the previous threshold).

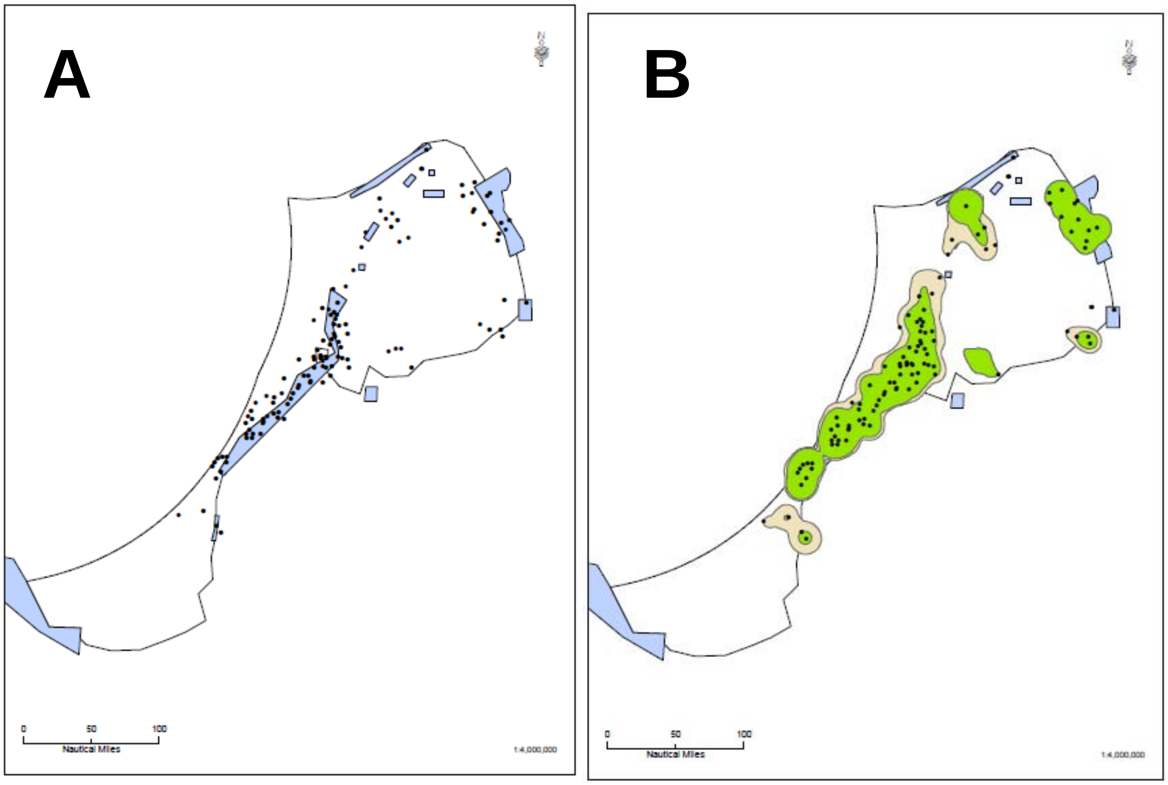

Figure 4.1.1.1.4. A) Location of the simulated commercial catches in the NRA ≥ 300 kg in relation to the current closed areas in the NRA (blue polygons). B) Polygons depicting the area occupied by simulated commercial catches in the NRA ≥300 kg (inner green coloured polygon) and ≥200 kg (outer beige coloured polygon). This represents a 1.5 times increase in area.

Figure 4.1.1.1.5. Photograph of a catch of 268 kg taken from the Tail of the Grand Banks in 2007 illustrating the numbers of sponge represented by this weight. Most sponges belong to the Geodiidae (Photo courtesy of F. J. Murillo, IEO-Vigo)

Kenchington et al. (2011) examined the ≥ 40 kg sponge catch threshold identified in the analysis and concluded that the lower threshold of 40 kg may capture non-VME sponge taxa, although it may be appropriate for lighter weight VME species such as *Asconema* spp. At present there is insufficient data to develop a threshold by sponge species or family which might be lower for these lighter weight VME sponges. This may be something to look at in the future as more data become available. However, lowering the encounter threshold to 200 kg would clearly protect some of those sponges.

4.1.1.2 Anticipated Impact on the Commercial Fishery of Using 300 kg Encounter Thresholds

The simulation model was run using 2000 randomly selected commercial trawls from data falling within the 95% confidence interval of the 2010 VMS data (see Cogswell et al. (2011) for description of all input layers). Fishing in 2010 was restricted to within the fishing footprint and outside of the closed areas. The model utilized the sponge biomass raster with a cell size of 5 x 5 km which is large enough to average approximately three Spanish/EU RV sponge records per cell.

According to this model the current sponge encounter threshold of 600 kg of live sponge from within the fishing footprint would have been encountered only once by commercial trawlers with the 2010 fishing effort distribution (Table 4.1.1.2.1). Lowering the threshold to 300 kg or 40 kg as identified through our analyses would impact 0.65% and 3.9% of the catches respectively. Catches of 300 kg or greater are expected to come from the two locations illustrated in Figure 4.1.1.2.1 following the 2010 fishing effort pattern, although there is potential for such catches to come from other areas with a change from the 2010 effort pattern (Figure 4.1.1.1.4). In particular the area between the closed areas in Flemish Pass and Beothuk Knoll were not fished in 2010 (see Cogswell et al. 2012) and this is one area where such catches could occur.

Table 4.1.1.2.1. The number and percent of simulated groundfish trawls catching sponge at various encounter threshold levels. The shaded cells indicate the current sponge encounter threshold inside the fishing footprint (600 kg) as well as the thresholds identified in this analysis (300 kg and 40 kg).

Threshold (kg per tow)	No. Filtered VMS Trawls	% Filtered VMS Trawls ≥ Threshold	Threshold (kg per tow)	No. Filtered VMS Trawls	% Filtered VMS Trawls ≥ Threshold
800	0	0	80	44	2.2
700	0	0	70	48	2.4
600	1	0	60	55	2.8
500	1	0	50	63	3.2
400	5	0.3	40	78	3.9
300	11	0.6	20	89	4.5
200	23	1.2	10	127	6.4
100	35	1.8	1	260	13.0
90	38	1.9	0.1	869	43.5

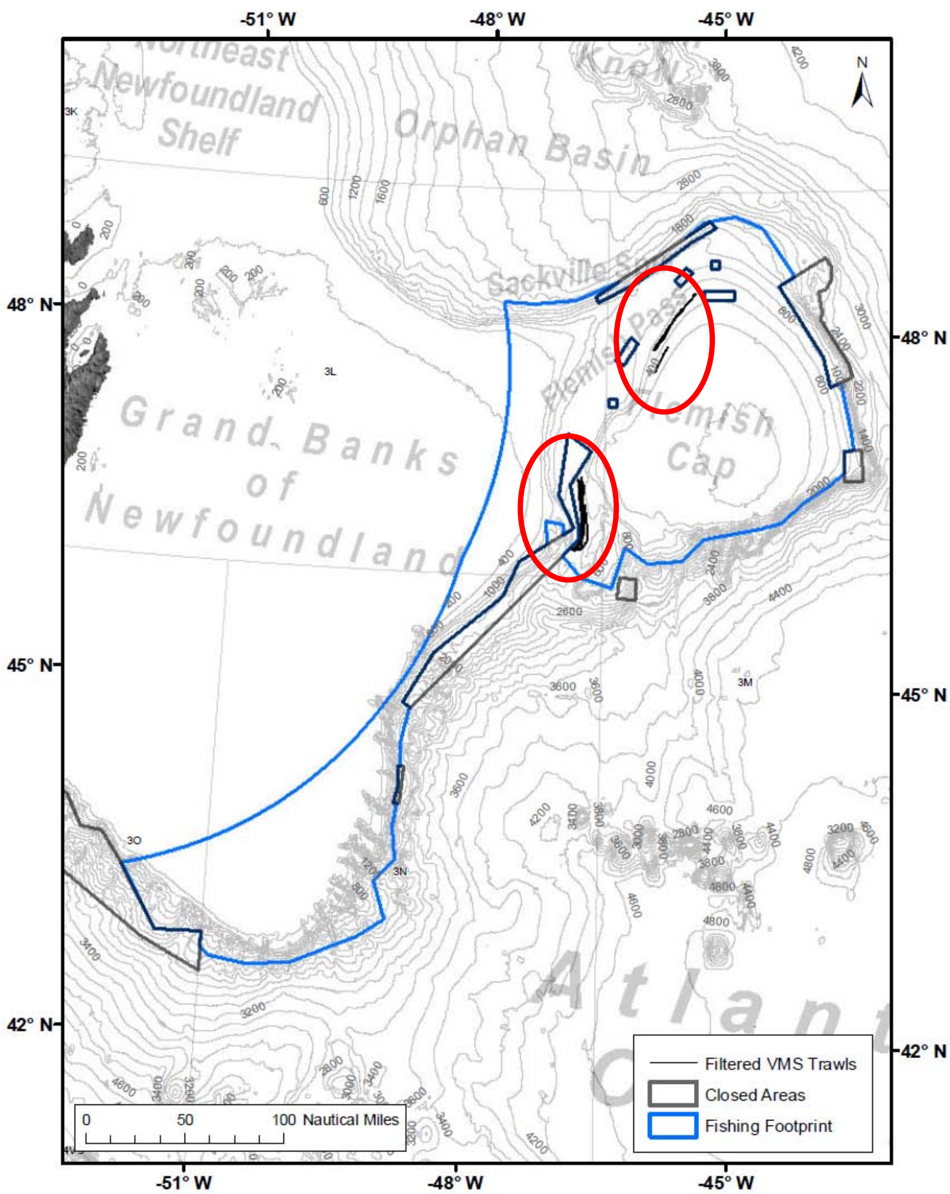

Figure 4.1.1.2.1. Location (red circles) of commercial trawls (black lines) expected to have caught ≥ 300 kg of sponge in 2010 (data from filtered VMS data set detailed in Cogswell et al. 2011).

4.1.1.3 Assessment of Significant Adverse Impact of Bottom-Contact Gear on Sponges

Kenchington et al. (2011) examined the potential for significant adverse impact (SAI) on sponges of fishing within the fishing footprint and outside of the closed areas in the NRA by identifying areas where VMS 2010 fishing and sponges co-occurred. Figure 4.1.1.3.1 illustrates this interaction by first highlighting in red, cells that contain simulated commercial catch values in excess of 300 kg/ 13.8 nm tow (the proposed threshold value), and then by highlighting cells with greater than 40 kg of simulated commercial by-catch at varying levels of effort using other colours. This method clearly shows areas with potential for significant adverse impact to sponges by showing where high commercial by-catch is likely.

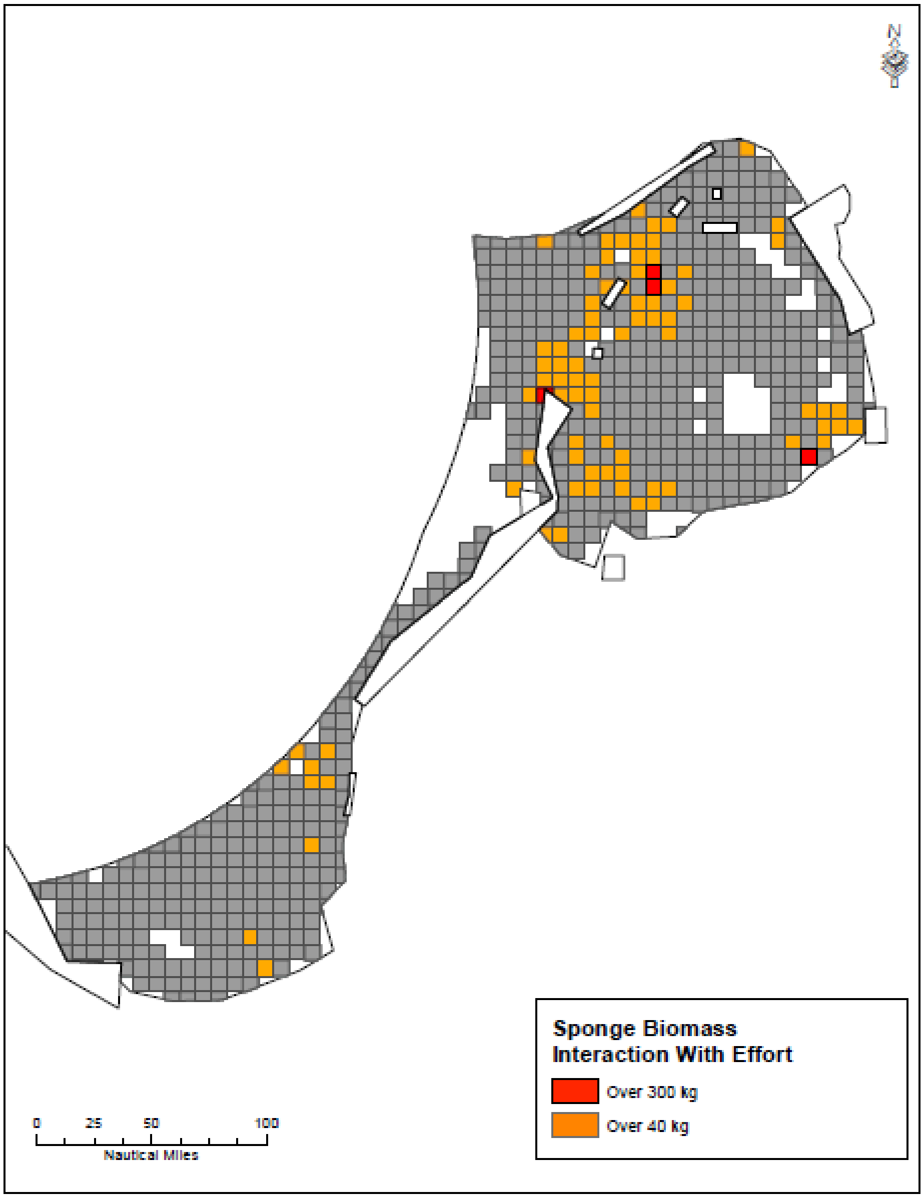

Figure 4.1.1.3.1. The interaction between the 2010 commercial fishing effort and sponge biomass is highlighted with cells with simulated commercial by-catch in excess of 300 kg in red and 40 kg in orange. Grey cells represent areas where the simulated commercial by-catch values are less than 40 kg or where there was no effort. These colored squares (red and orange) therefore represent potential high risk of sponge encounters and where fishing may cause significant adverse impacts to sponge grounds.

4.1.1.3.1 Gear Efficiency and Incidental Mortality on Sponges

The literature reports a wide range of gear efficiencies for large sponges which is summarized in Kenchington et al. (2011). They provide evidence from regional data that estimate gear efficiency for sponge for both the Campelen and Lofoten trawl gear in the NRA is on the order of 2%, however the literature report values of up to 70% for large sponges in other areas. Kenchington et al. (2011) also reviewed the literature for incidental mortality and found it to be high with 55% to 95% of large sponges reported detached from the sea bed and 32% to 60% of attached sponges being damaged. In one case recovery occurred within a year, but generally, and in the few cold water studies recovery has not occurred within a year and is expected to take decades. Larval retention is likely high and increases the importance of maintaining sufficient densities of sponges within each sponge ground. These conclusions on the significant adverse impact of fishing on sponges would favour the 40 kg threshold as gear efficiency may be as low as 5% with high incidental mortality, however, the reason for not going to that level is due to the species composition. The areas with those species include non-VME taxa (see discussion above).

4.1.1.4 Move-on Rules for Sponges

Kenchington et al. (2011) provide area-specific move-on rules which move effort away from known sponge grounds. Sponge grounds are localized in narrow bands along the slope of the Grand Banks and Flemish Cap and they extend to deep waters. WGEAFM therefore propose a move on rule that would require the vessel to move from its position to shallower areas where no sponge grounds are expected to occur. This rule would have to be applied through consideration of other VME species so as not to displace effort to other areas.

The move on rule would require the vessel to move from its position to shallow water ≤ 700 m in Slope Area 1, to ≤ 1000 m in Slope Area 2, to ≤ 950 m in Slope Area 3, to ≤ 1050 m in Slope Area 4 or to ≤ 1250 m in the Sackville Spur Area 5 (Table 4.1.1.4.1). If one rule were to be implemented for all areas it would be: the vessel is required to move to shallower water ≤ 700m. Given the average slope of the continental slope in these areas (θ) (calculated from multibeam bathymetery from the NEREIDA surveys see Kenchington et al. 2011) and the maximum sponge depth of 2000 m, the maximum move on distance would equate to b(2000 – 700)/tan θ. This is the average distance from an “encounter” at the deepest part of the sponge grounds with a movement decision to go in the direction of shallow water. The maximum move on distance in the NRA would be 18.1 km or 9.8 nm in the shortest direction of shallower water. This would occur in Slope Area 1 on the Nose and Tail of the Grand Bank.

Table 4.1.1.4.1. Minimum and maximum depth ranges for sponge grounds on the continental slopes of the NRA with a maximum move on distance based on average slope and a starting point of 2000 m, the maximum depth of the sponge grounds.

Slope Area	**Shallow End of Sponge Depth Range (m)**	**Average Slope over Depth Range of Sponge Grounds**	**Estimated Maximum Distance to Move km (nm)**
1 GB Nose & Tail	700	4.112	18.1 (9.8)
2 Beothuk Knoll	1000	5.011	11.4 (6.2)
3 SE Flemish Cap	950	4.198	14.3 (7.7)
4 E Flemish Cap	1050	3.861	14.1 (7.6)
5 Sackville Spur	1250	3.516	12.2 (6.6)

4.1.2 Sea Pen Fields

Sea pens are colonial organisms belonging to the order Pennatulacea. The generalized sea pen body plan takes the form of a rigid, erect stalk (the rachis) with one or more polyps raised into the water column, and a bulbous "root" or peduncle at its base which anchors it in the soft sediments of the sea floor (Williams 1995). All belong to the family Pennatulaceae (sea pens) with the longer species sometimes referred to also as sea whips. NAFO, following the guidelines of the FAO (FAO 2009), have identified sea pens as key structural components of soft-bottom vulnerable marine ecosystems in the Regulatory Area (Fuller et al. 2008, NAFO 2008a,b, Murillo et al. 2010). Aggregations of sea pens, known as "fields", provide important structure in low-relief sand and mud habitats where there is little physical habitat complexity. These fields provide refuge for small planktonic and benthic invertebrates (Birkeland 1974), which in turn may be preyed upon by fish (Krieger 1993). They also alter water current flow, thereby retaining nutrients and entraining plankton near the sediment (Tissot et al. 2006). Sea pens fields belong to the Initial OSPAR List of Threatened and/or Declining Species and Habitats (OSPAR 2003).

NAFO Scientific Council (2008a) made recommendations for closing areas to protect deep sea corals, including sea pens. An extensive database from Canada and Spain/EU of 7,279 research vessel survey trawl records from NAFO Divisions 3LMNO covering a depth range of 31-1491 m were used to locate key concentrations of sea pens using the cumulative catch distribution to identify aggregations (NAFO 2008a). This was followed by the application of GIS modelling (Kenchington et al. 2010a) to identify significant concentrations using kernel density analysis (Murillo et al. 2010).

There is a high diversity of sea pens in Atlantic Canada and surrounds compared with other coral orders. Murillo et al. (2011) list 11 sea pen species from the NAFO Regulatory Area (NRA), and the NAFO Coral Identification Guide (Kenchington et al. 2009), which included only the more common taxa, lists 5 sea pen species and 2 other genera. However, the dominant sea pen taxa observed in the surveys are *Anthoptilum grandiflorum*, *Halipteris finmarchica* and *Pennatula aculeata* (Murillo et al. 2010). The first two are whip-like sea pens and the last is a smaller fleshy species; all of the common sea pens in the NRA fall into one or other of these morphologies.

At present, different coral groups do not have different encounter thresholds, despite their very different morphologies and biomass. The encounter threshold of 60 kg of live coral is very high for the smaller corals such as the sea pens and it is for this reason that we have chosen to include them, along with the sponges, in this first full assessment of encounter protocols and SAI. Full details are found in Kenchington et al. (2012).

4.1.2.1 GIS-Simulation of Commercial By-catch (Encounter) Thresholds Indicative of Sea Pen Fields in the NAFO Regulatory Area (NRA)

The layers used by the model to predict commercial sea pen by-catch under varying scenarios remain largely unchanged from those used for describing the model layers to estimate commercial trawl sponge by-catch. The only exceptions are the simulated trawl lines generated for each scenario and the sea pen biomass layer used to calculate by-catch for each simulated line. The former random trawl lines drawn for the sponge by-catch analyses had to be regenerated to allow for the different spatial footprint of the sea pen biomass raster.

The sea pen data set consists of 3063 records from Canadian (N=1051) and Spanish/EU (N=2012) research vessel trawls from 2002 to 2010. Of these, 2,245 records represent null data points where no sea pen by-catch was observed (Figure 4.1.2.1.1). Further, of the 818 research trawls recording sea pens, ~92% were found in water depths greater than or equal to 300 m (Figure 4.1.2.1.1). That sea pen distribution is easily discernable as a horseshoe around Flemish Cap and a narrow band hugging the slope on the southeast Grand Banks and above the 3O closure (Figure 4.1.2.1.1).

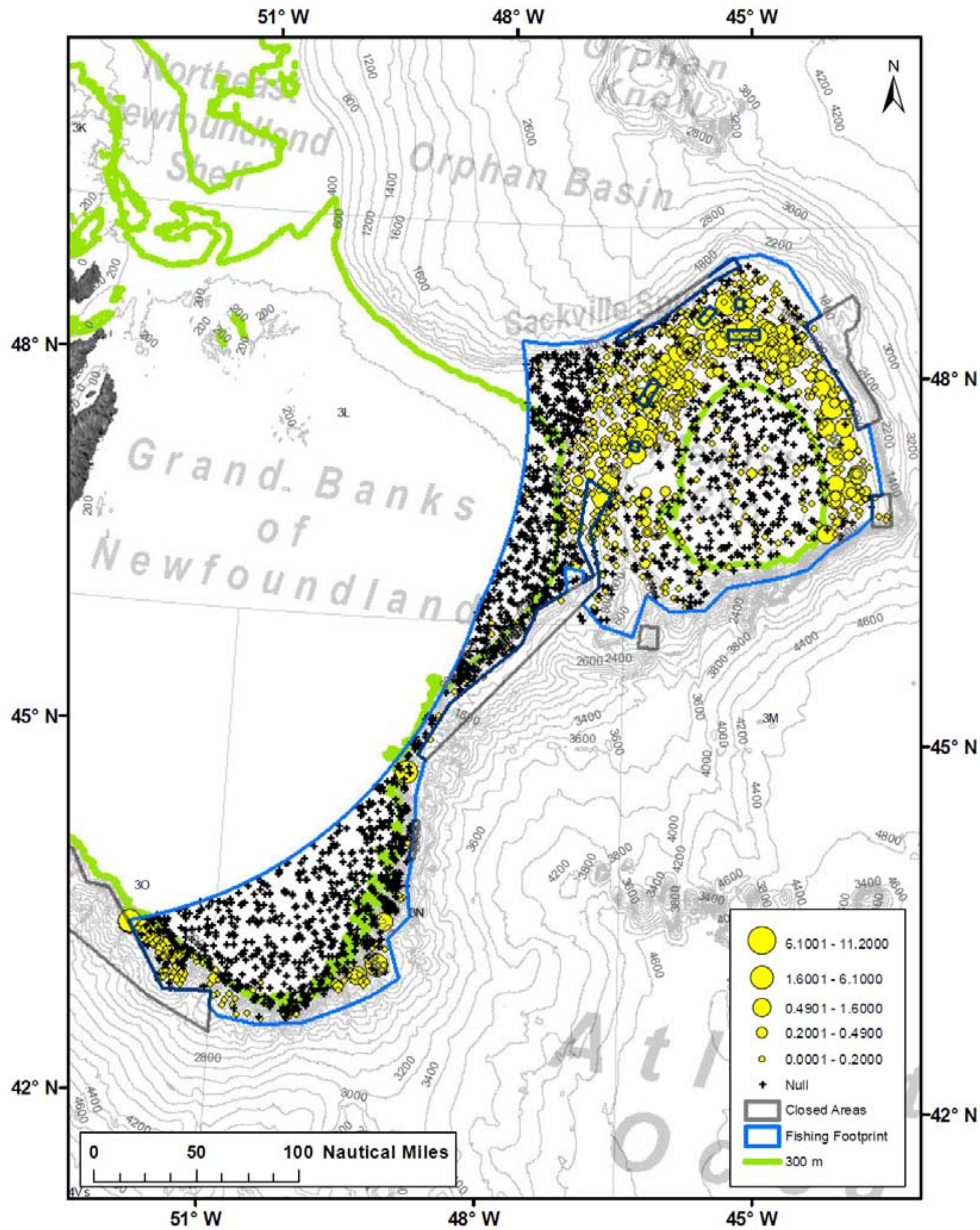

Figure 4.1.2.1.1. The distribution of sea pen by-catch (yellow circles) and null sets (black cross) in relation to the 300 m contour (green line) in the NAFO Regulatory Area.

The sea pen biomass layer created for the model scenarios described below were created in a similar manner as the sponge by-catch raster, that is with 5 x 5 km cells and using only the Spanish/EU research vessel data (Cogswell et al. 2011). Canadian data was not used in the analysis to avoid introducing spatial bias through standardization methods as discussed above. The resultant sea pen biomass layer used for the GIS modelling is illustrated in Figure 4.1.2.1.2 and referred to as the 5 x 5 km sea pen biomass surface.

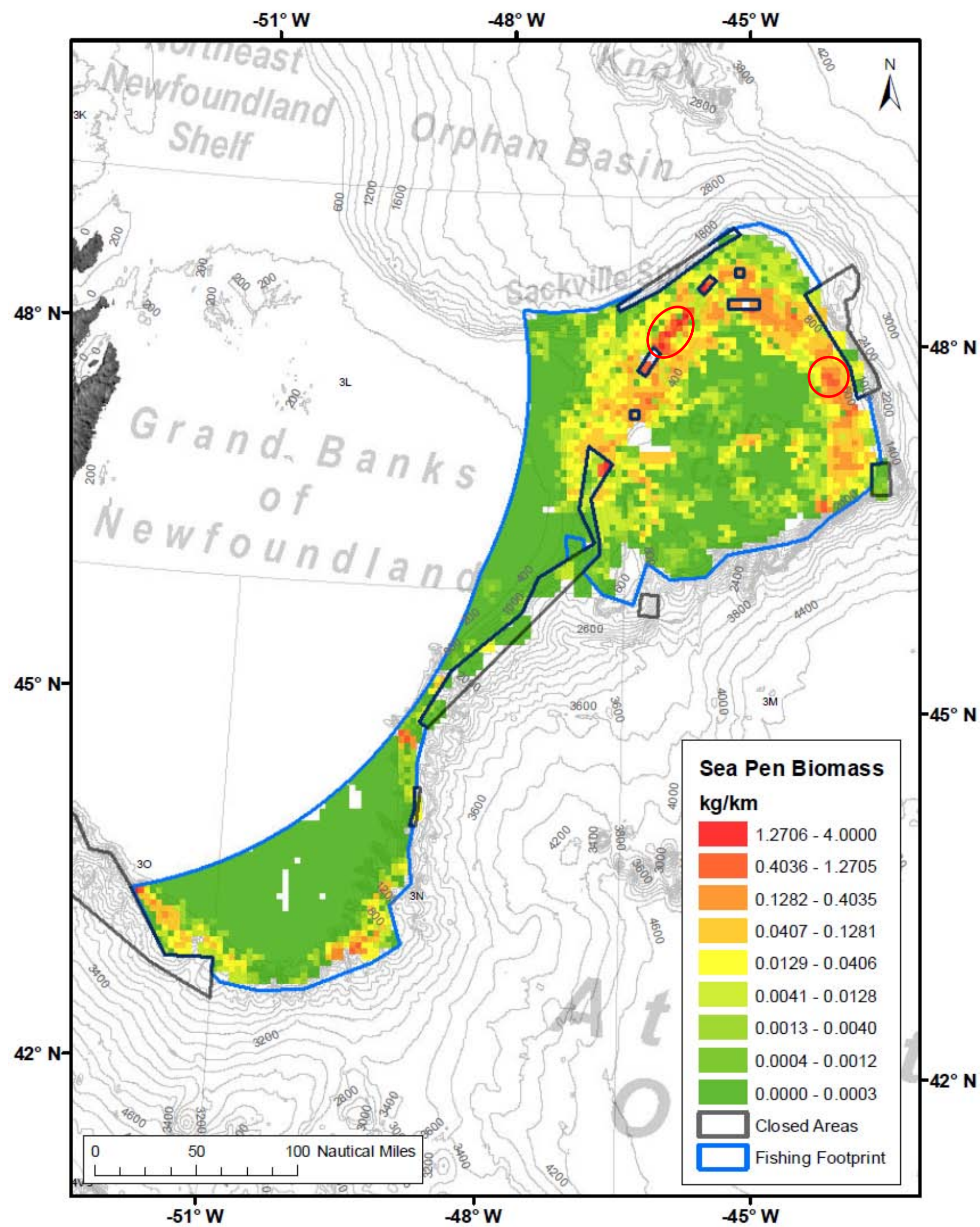

Figure 4.1.2.1.2. The sea pen biomass layer used to calculate simulated by-catch. This figure can also be used to identify the potentially high risk encounter areas of sea pens inside the fishing footprint but outside the closed areas, e.g. high risk areas identified by red ellipses.

As for the analysis of sponge by-catch, this simulation uses 2000 randomly placed and oriented straight line simulation trawls of standard commercial tow length (13.8 nm) (Figure 4.1.2.1.3). All lines generated by this method have a random start location and a randomly chosen heading between 0 and 360 degrees, at 1 degree intervals. Lines were not restricted from crossing into a closed area, but were limited to within the footprint of the Spanish/EU research vessel 5 x 5 km grid sea pen biomass surface (Figure 4.1.2.1.3). These lines are meant to mimic the research vessel random trawl stations with commercial length trawls to reproduce the protocol for sea pen field identification established previously (Kenchington et al. 2009, Cogswell et al. 2010, Murillo et al. 2010) only using commercial trawl threshold values. This is the same model application used for identifying sponge grounds.

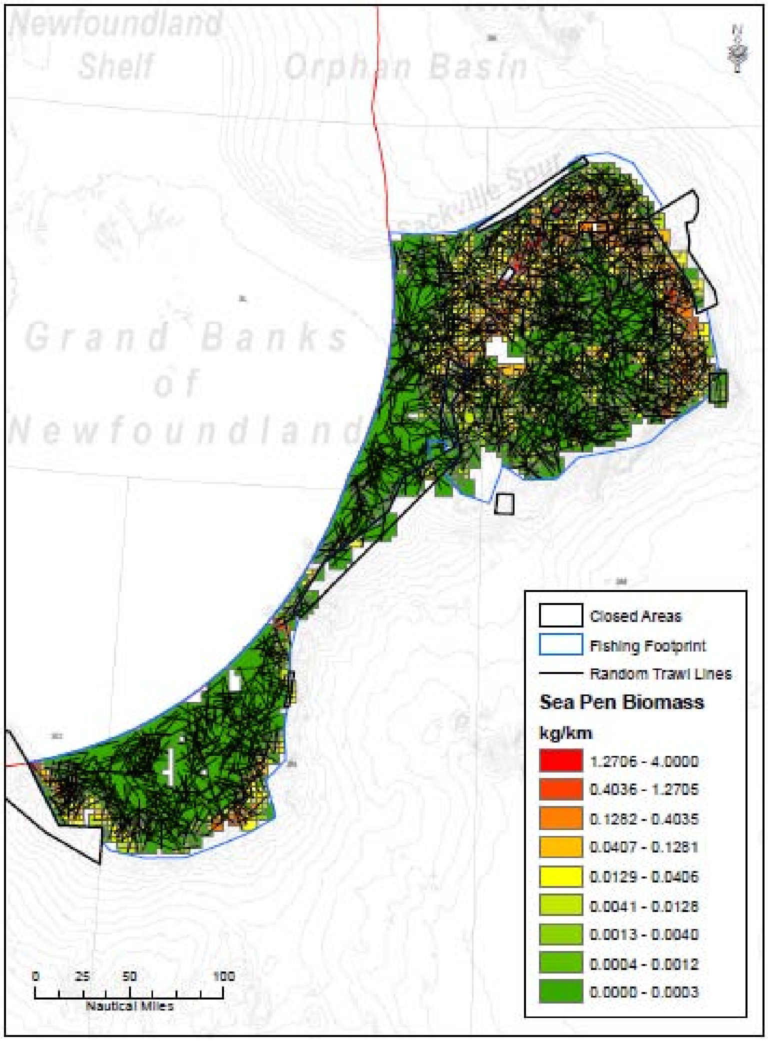

Figure 4.1.2.1.3. Simulated trawls (n=2000) with random start locations and orientation. Each trawl is of standard length (13.8 nm) and falls within the 5 x 5 km sea pen biomass surface for the NRA.

The simulated commercial sea pen by-catch was used to create a sea pen biomass layer interpolated using the kernel density algorithm with a search radius of 25 km (Figure 4.1.2.1.4) (Kenchington et al. 2010a), and polygons were drawn around the area occupied by successive weight thresholds following Kenchington et al. (2010a) and Kenchington et al. (2010b). This biomass layer identified "hot spots" in locations similar to those in the research vessel sea pen interpolated biomass layer used to identify the closed areas however the high density locations are more prominent in the modeled data from the simulated trawls.

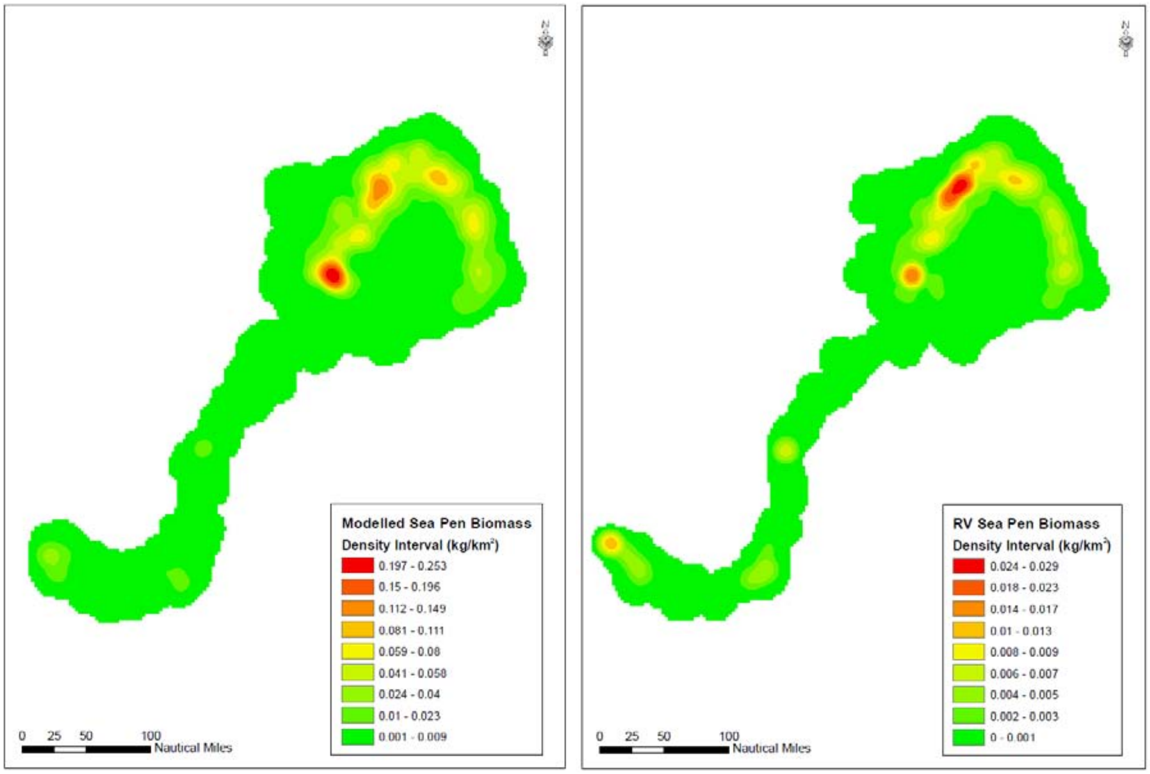

Figure 4.1.2.1.4. Modelled sea pen biomass (kg/km^2) in the NRA estimated from simulated commercial trawls with random start locations and orientation (left) and from Spanish/EU research vessel catches (right). Note maximum density values cannot be compared between the two methods.

Figure 4.1.2.1.5 illustrates the area occupied by the calculated density polygons for 26 catch weight thresholds between 0.001 and 30 kg. In this series the largest change between successive categories occurs between 7 and 6 kg. Catches of 7 kg or more occupy an area of 5,000 km^2 while catches of 6 kg or more occupy an area 2.6 times larger (13,088 km^2). This threshold was established with 12 data points from the research vessel survey and so is considered to be a reliable indicator of sea pen fields (note sometimes aerial expansion can be created through only a few data points which we would not consider to be a robust estimator of the habitat area). The difference in area occupied by these catches is illustrated in Figure 4.1.2.1.6. Most of the catches ≥7 kg occurred outside of the current closed areas. A threshold of 7 kg equates to about 198 individuals of the short and fleshy species (based on mean individual weights of 220 *P. borealis*) and to about 583 of the sea whips (based on mean of individual weights of 306 *Anthoptilum grandiflorum*) (E. Kenchington, unpublished data). Figure 4.1.2.1.7 illustrates a mixed species catch of 388 sea pens weighing 5.7 kg taken from a research vessel trawl on Flemish Cap.

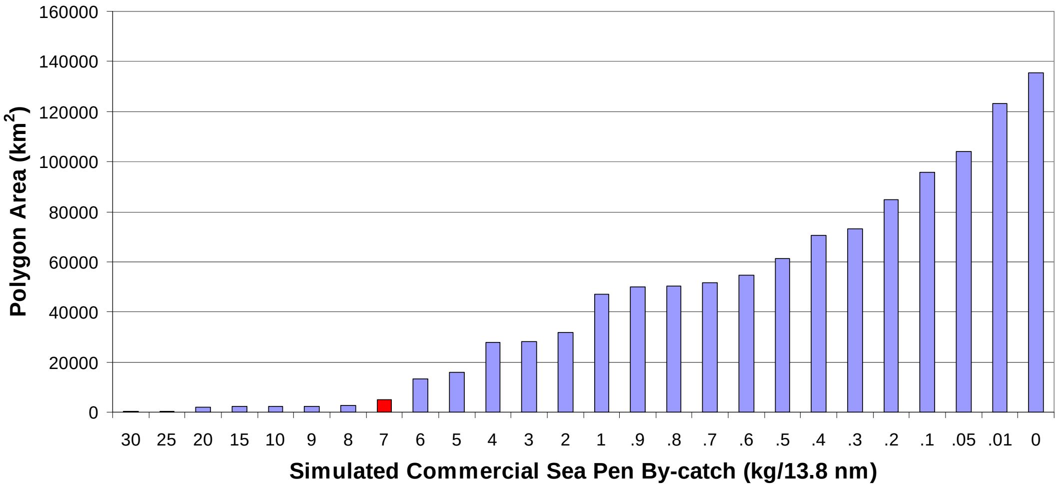

Figure 4.1.2.1.5. Area (km^2) occupied by tows with decreasing sea pen catch weight from ≥30 kg to >0 kg. The red bar indicates the levels where the greatest difference in area occupied occurs between successive catch weight values.

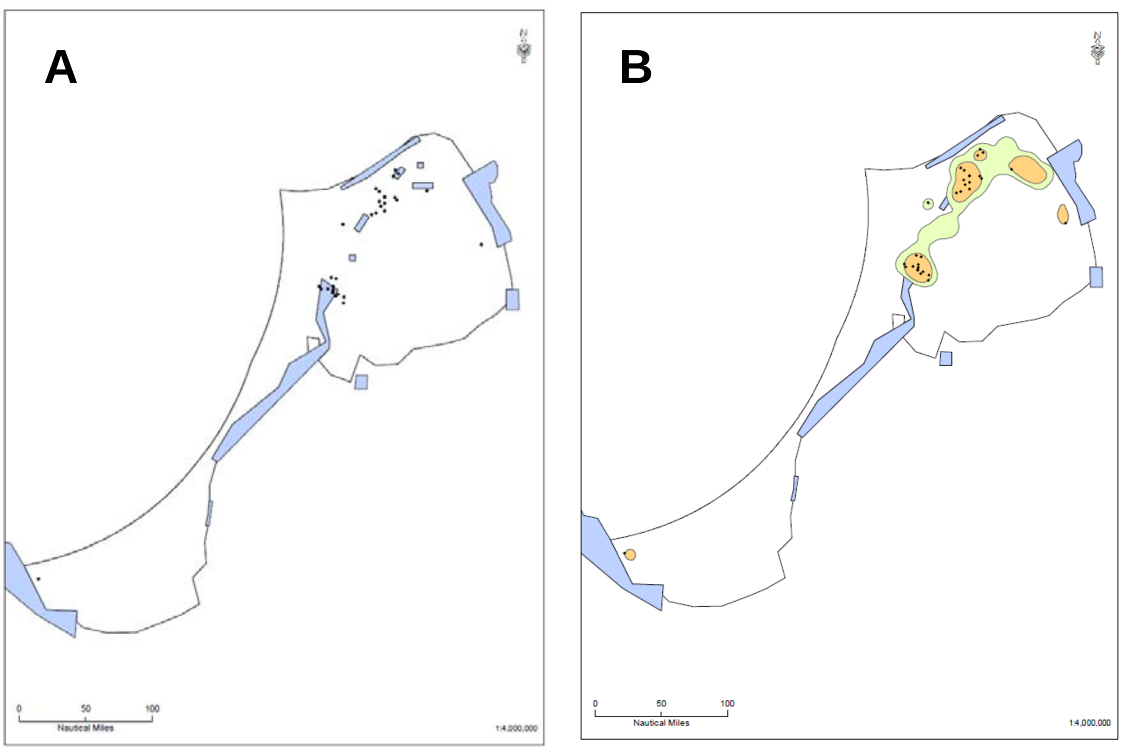

Figure 4.1.2.1.6. A) Location of simulated commercial catches with ≥7 kg of sea pen by-catch. Locations of the closed areas in the NRA are indicated as shaded light blue areas. B) Polygons depicting the area occupied by simulated commercial sea pen catches in the NRA ≥7 kg (inner darker orange coloured polygon) and ≥6 kg (outer lighter green coloured polygon). This represents a 2.6 times increase in area between the thresholds.

Figure 4.1.2.1.7. Photograph of a 5.7 kg catch of sea pens of mixed composition taken from Flemish Cap. *Halipteris finmarchica* (n=15, 0.55 kg), *Anthoptilum* sp. (n=363, 5.11kg), (*Funiculina quadrangularis* (n=8, 0.032kg), *Umbellula lindahli* (n=1, 0.017 kg), *Distichoptilum gracile* (n= 1, 0.008 kg) also present but not visible). (photo courtesy of F. J. Murillo, IEO-Vigo).

4.1.2.2 Anticipated Impact on the Commercial Fishery of Using a 7 kg Encounter Threshold

The simulation model was run using 2000 randomly selected commercial trawls from data falling within the 95% confidence interval of the 2010 VMS data (see Cogswell et al. 2011 for description of all input layers). Fishing in 2010 was restricted to within the fishing footprint and outside of the closed areas (Figure 4.1.2.2.1). The model utilized the sea pen biomass raster detailed above, and produced a highly skewed cumulative catch distribution as seen in the research vessel sea pen catch data (NAFO 2008a).

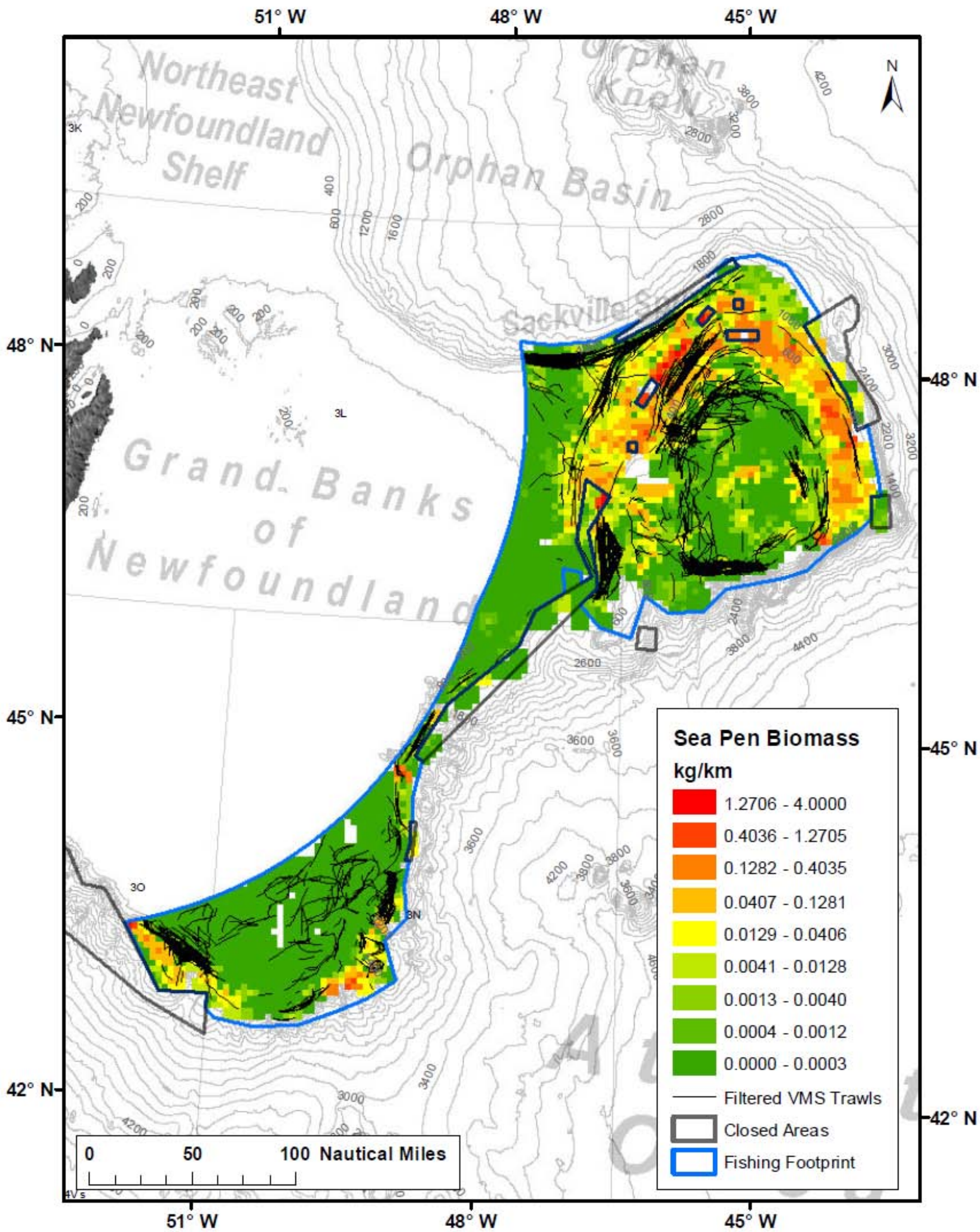

Figure 4.1.2.2.1. Location of 2000 randomly selected VMS trawl lines from the filtered 2010 fishing effort distribution superimposed over sea pen biomass as determined from Spanish/EU research vessel survey data.

Table 4.1.2.2.1. The number and percent of groundfish trawls catching sea pens at various encounter threshold levels. Trawl lines were randomly selected from VMS data falling within the 95% CI of the mean of that data. The shaded row indicates the proposed sea pen encounter threshold.

Threshold (kg per tow)	No. Filtered VMS Trawls	% Filtered VMS Trawls ≥ Threshold
16	2	0.1
15	5	0.3
14	6	0.3
13	6	0.3
12	6	0.3
11	6	0.3
10	6	0.3
9	8	0.4
8	8	0.4
7	8	0.4
6	15	0.8
5	17	0.9
4	26	1.3
3	41	2.1
2	72	3.6
1	129	6.5

According to this model the current sea pen encounter threshold of 60 kg of live coral would rarely if ever be caught. Reducing the encounter threshold to 7 kg would affect only 0.4 % of trawl sets fishing with the 2010 fishing effort distribution (Table 4.1.2.2.1). Following the fishing effort pattern of 2010, catches ≥ 7 kg are found in three locations (Figure 4.1.2.2.2). Two of these are on Flemish Cap and one just south of the Flemish Pass closed area. There are 8 VMS trawls, and the mean trawl length is 31 nm, with the shortest 13 and the longest 58 nm. Therefore the trawl length accounts for some of the values being so high. Figure 4.1.2.2.3 shows a close-up of 6 VMS tracks near the sea pen closed areas on Flemish Cap. Research vessel sea pen by-catch is high in adjacent unfished areas.

There are two morphologies of sea pens in the NRA. One group is short and fleshy with *Pennatula aculeata* being the most common, and the other group is long and thin and sometimes referred to as sea whips. *Anthoptilum grandiflorum* and *Halipteris finmarchica* are the most common of the second form. Figures 4.1.2.2.4 and 4.1.2.2.5 show that most of the 2010 fishing effort above the proposed threshold of 7 kg would impact the long thin species, or sea whips.

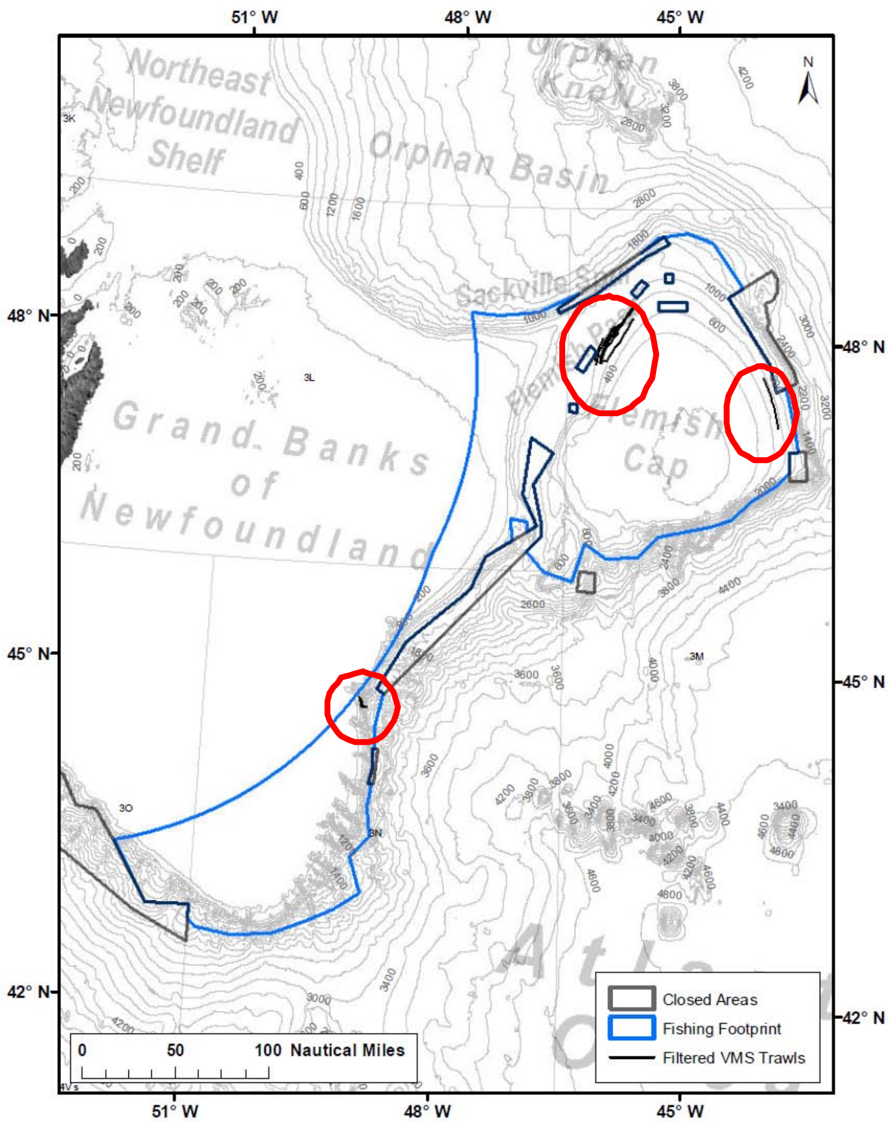

Figure 4.1.2.2.2. Location (red circles) of commercial trawls (black lines) expected to have caught ≥ 7 kg of sea pens in the NRA in 2010 (data from filtered VMS data set detailed in Cogswell et al. 2011).

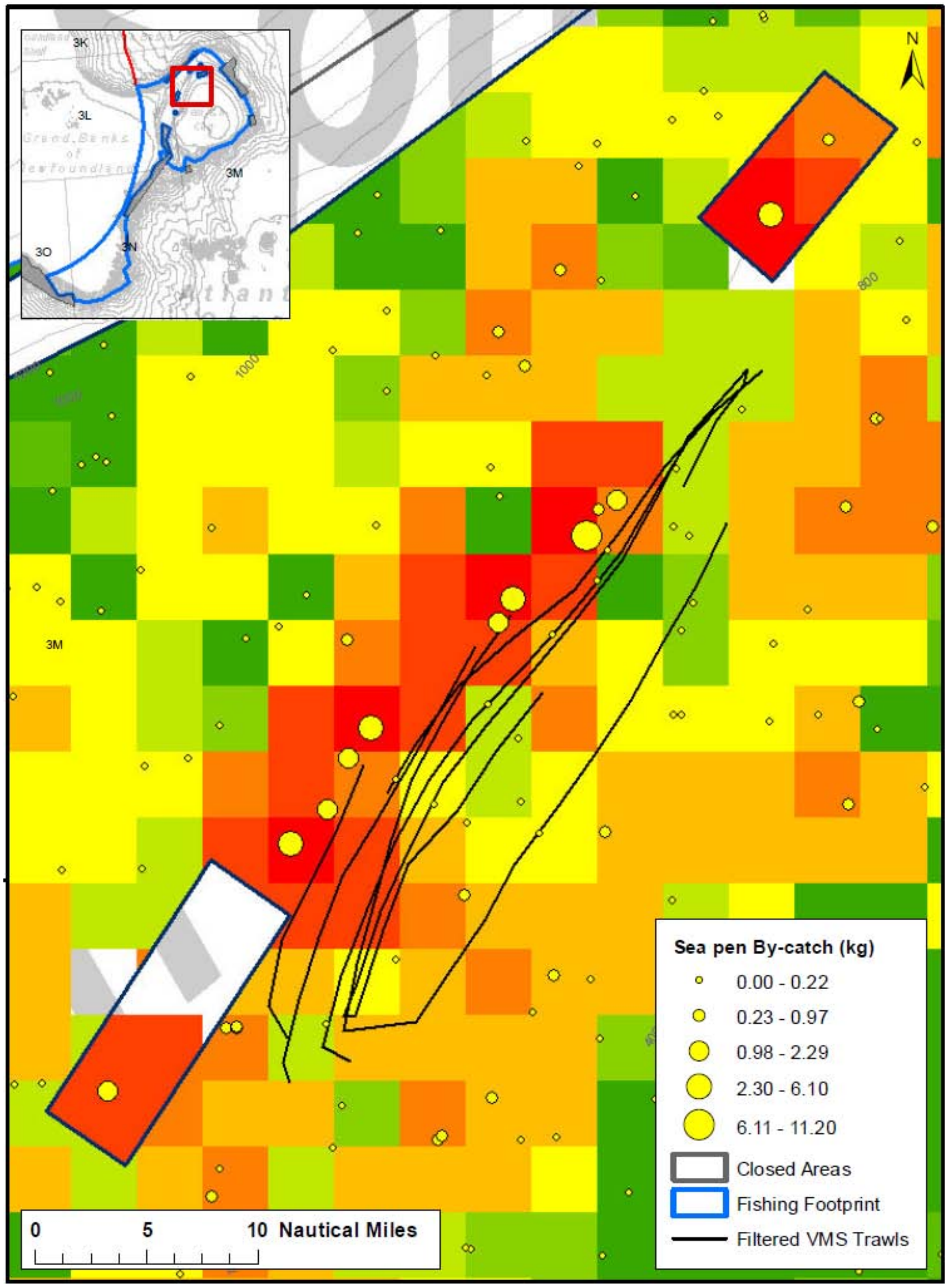

Figure 4.1.2.2.3. Location of the 6 commercial trawls (black lines) expected to have caught ≥ 7 kg of sea pens in the NRA in 2010 (data from filtered VMS data set detailed in Cogswell et al. 2011). The 5 x 5 km grid sea pen biomass surface is shown along with individual research vessel catches.

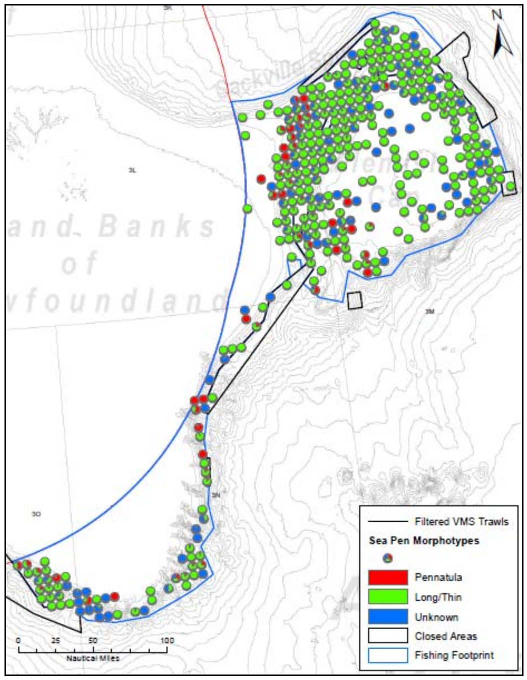

Figure 4.1.2.2.4. Relative proportion of short fleshy sea pens (*Pennatula* spp.) and long thin sea whips in the NRA as determined from research vessel surveys.

Figure 4.1.2.2.5. Close up of the area with greatest effort above the proposed sea pen threshold of 7 kg. The relative proportion of short fleshy sea pens (*Pennatula* spp.) and long thin sea whips in the NRA as determined from research vessel surveys is illustrated. Size of the circle represents the size of the catch (biomass). Location of commercial trawls (black lines) expected to have caught ≥ 7 kg of sea pens in the NRA in 2010.

4.1.2.3 Assessment of Significant Adverse Impact (SAI) of Bottom-Contact Gear on Sea Pens

Murillo et al. (2011) reported Pennatulaceans in 36% of 910 research vessel survey tows in the NRA. Quantitative assessment of significant adverse impact of bottom-contact gear on sea pens in this area requires information on gear efficiency and selectivity in order to assess the nature of removals (see Kenchington et al. 2011 for more details). Figure 4.1.2.3.1 highlights areas outside of the closed areas where significant interactions between fishing and sea pens may have occurred by identifying only cells where simulated commercial sea pen by-catch above 7 kg occurred in areas that were fished in 2010.

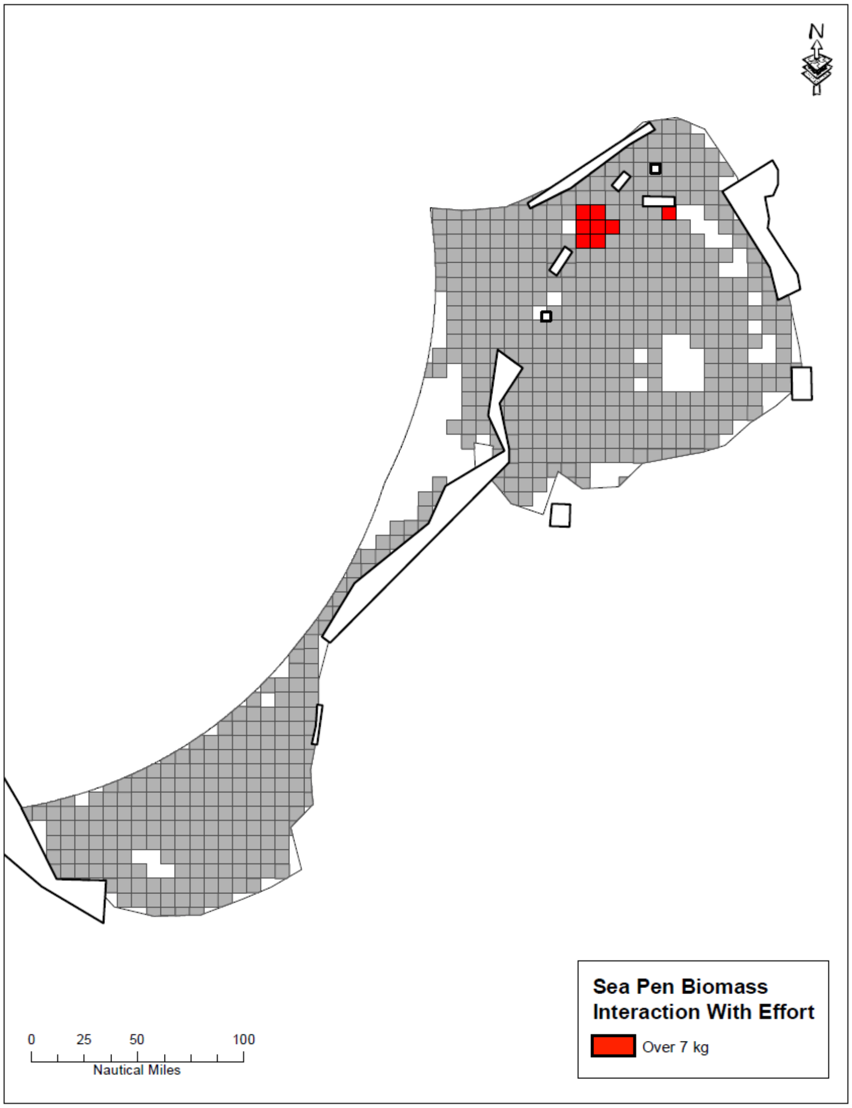

Figure 4.1.2.3.1. This interaction map highlights cells where fishing effort overlaps with simulated commercial by-catch in excess of 7 kg. These are areas where significant adverse impact of fishing on sea pens has the highest probability of occurring.

Information on incidental damage and recovery from trawling informs the magnitude of the impact on the population. Sea pens have flexible axial rods and some species are able to re-anchor in the sediment if they are dislodged, however, mobility can be limited and species specific (Malecha and Stone 2009). The low catch threshold proposed for these species corresponds to a much higher catch in terms of numbers of individuals. A threshold of 7 kg equates to about 198 individuals of the short and fleshy species and about 583 of the larger sea whips. Removals of these numbers of individuals will cause population-level impacts, possibly altering recruitment dynamics.

As well, long-term success of injured or dislodged sea pens can be relatively low. When compounded by large scale effects (i.e. population level) with low survival the result is a relatively high risk of SAI to sea pen populations, particularly with isolated communities.

4.1.2.3.1 Gear Efficiency and Incidental Mortality on Sea Pens

Kenchington et al. (2011) provide a literature review of issues related to gear efficiency, selectivity, incidental mortality and recoverability for sea pens and provide regional data to place in context with studies elsewhere. They conclude that gear efficiency for sea pens is low (less than 10% in their study and as low as 0% in the literature), incidental mortality can be high, ranging from 40 to 50% in the literature over time frames of up to one year post trawl. This means that a catch of 7 kg could cause incidental mortality to an additional 3.5 kg of sea pen on the sea floor. Recovery is not well studied but recruitment may occur annually or every few years but can be spatially unpredictable and patchy. There is some evidence that cumulative impacts may cause local depletion of sea pen fields.

4.1.2.4 Move-on Rules for Sea Pens

Kenchington et al. (2011) determine the maximum distance that a vessel would have to move after an encounter (either shallower or deeper), by calculating the centroid of each significant area polygon (Murillo et al. 2010) in ARCGIS. These area-specific move-on distances range from 4 km to 20 km or 2.4 to 10.7 nm. However, the effectiveness of such movements may be to force the vessel from the fishery and so more thought should go into this issue due to the close proximity of the sea pen fields to the fishery in some areas (Figure 4.1.2.2.5**)**

4.1.3 Assessing Significant Adverse Impacts

Understanding the scale and frequency with which a particular area of seabed (such as a VME) will be impacted by fishing is essential for implementing an ecosystem approach and assessing Significant Adverse Impacts (SAI) on marine ecosystems. WGEAFM was requested by Fisheries Commission to investigate options and approaches for undertaking an SAI of fisheries. The output of this may also provide some useful direction and input to the preparation of evidence required to support the assessment of fisheries required by 2016 as described under ToR 5.1.

Framework

Following discussions in WGEAFM we propose 5 principal steps, all of which would require evaluation through a framework underpining a potential Significant Adverse Impacts (SAI) assessment of fisheries on VMEs. The 5 proposed steps of the SAI framework (see below) are equally applicable to areas of both low and high fishing pressure or fishing intensity:

1. Define trawled (or directly observed) removals (by catch) of VME species (determined from research vessel surveys).
2. Estimate trawled (unobserved) direct *in situ* damage and/or habitat modification/destruction which could potentially impact life history stages of species within VMEs.
3. Estimate trawled (unobserved) indirect *in situ* impacts which increase VME species mortality due to stress/disease etc.
4. Determine which VME species (if any) are minimally impacted by fishing activities.
5. Assess the likelihood and process of recolonisation (which is a function of the resilience of the ecosystem and includes species introduced through, *inter alia*, motile scavengers, passive and active translocation by the fishing gears, and the frequency and intensity of fishing efforts through time, etc…).

The approach to evaluate each of these steps was considered by a sub-group of WGEAFM. Two approaches were proposed, neither are exclusive of one another, indeed both approaches are most likely to be required to achieve an acceptable level of confidence in any assessment of SAI. An evaluation of these steps should enable a robust assessment of significant adverse impacts. The first approach would involve a thorough review of the literature with regard to each component, and the second would involve evaluating current empirical evidence and identifying gaps that could be filled through further studies and the refocusing or stratification of existing RV surveys. It is hoped that in addition to a review of literature and empirical data, considerations of this ToR from Scientfic Council during the June 2012 meeting, would also be incorporated into a document (to be presented at the next WGEAFM meeting in December 2012) detailing the way forward for assessing SAI and its integration into the fisheries assessment process as highlighted in ToR 5.1.

Literature Review and Modelling Approach

A more thorough understanding of the capture efficiencies and impacts of different fishing gears can, in part, be achieved through a more detailed review of relevant literature. In addition, the absence of direct observations of 'unobserved' impacts can potentially be estimated by applying various appropriate models with explicit assumptions. Kenchington et al. (2011) have undertaken this step for sea pens and sponge grounds.

Empirical Approach

This approach utilises fishing vessel VMS data, R/V survey and VME (benthic habitat and species) data, to evaluate steps 1-5 of the SAI (described above).

VMS data

The VMS layer is a useful tool to demonstrate the current interactions between the fishery and identified seabed VME habitats and species. It is proposed that the VMS data be extracted for the dates it is available and evaluated and/or compared between successive years in attempt to track long term variability in fishing spatial intensity that may result in potential impacts on VMEs. 2010 VMS data reveals a pattern of spatial coherence and consistency over time. It is also evident, given what is known of the limited recoverability of some benthic VME species, that interactions between known centres of VME concentrations (gathered through surveys) and fishing effort occurs on an extremely limited basis.

Integrating Fishing Intensity, Habitat and VME indicator species data (R/V and NEREIDA data)

The RV survey and NEREIDA data cover a full range of habitats subject to varying levels of fishing intensity in the NAFO Regulatory Area. It is therefore proposed to examine the variations in VME species biomass (as bycatch) derived from both the RV and NEREIDA surveys, and to compare these gradients to the observed variations in fishing intensity over time for the same areas. This will enable the full range of values for specific (area based) seabed habitats (see ToR 1.1) and VME species biomass to be evaluated and quantified against a full range of fishing intensities.

The assessment of SAIs therefore depends on quantifying the initial (direct and indirect) impacts of fishing, in combination with an evaluation of the recovery potential of the impacted system. For example, the worst case or most significant fishery impact, will be associated with a significant removal of VME biomass (including VME indicator species) in combination with very little or no potential for recovery (e.g. low resilience). By contrast, the least significant impact would be expected to occur in those situations with a low level of initial (direct) damage or removal of VME biomass followed by the relatively rapid recolonisation, growth and recovery of VME species (e.g. high resilience).

To assess this for the NAFO regulatory area WGEAFM proposes to analyse the VMS data to categorize the spectrum of fishing intensity as four levels for a given VME type (see Figure 4.1.3.1), namely; **i.** no fishing (control), **ii**. low intensity, **iii**. moderate intensity and **iv**. high intensity. The time (in years) corresponding to each level of fishing intensity for all parts of the seabed to be impacted in a given area can therefore be calculated. This essentially provides a probabilistic estimate of the total amount of time available for benthic recolonisation (or available for recovery) before the next fishing disturbance event occurs. Clearly the lower intensity of fishing effort will result in a higher probability of an increase in time between disturbance events for a given area of seabed and *vice versa*. Therefore, if the VME has high resilience (e.g. high potential for recolonisation and growth) then a higher biomass may be expected for a given fishing intensity compared to a system of low resilience. This difference will be tested using currently available data sets as described in Figure 4.1.3.1. The break-through (and innovation) in this approach is to define and compare the gradients in benthic/habitat biomass for different fishing pressures in different areas. Such comparisons would help to define the proportion and type of seabed responsible for a given amount of fishery yield and could therefore support a more adaptive spatial management approach to fisheries management.

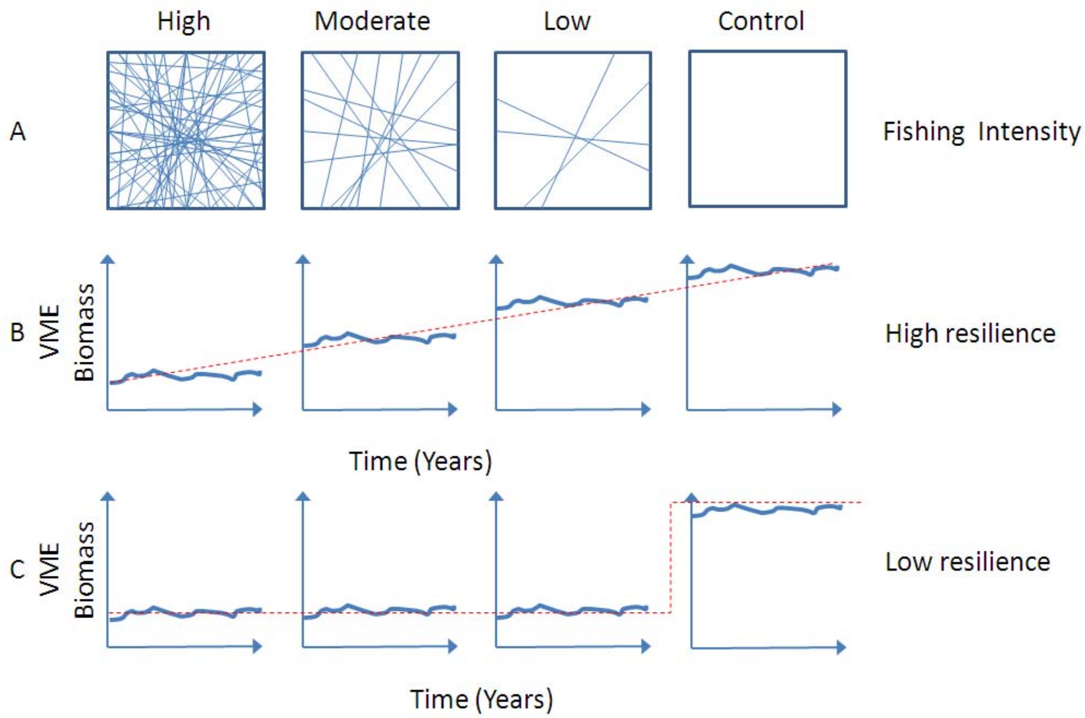

Figure 4.1.3.1. The analysis of VMS and VME biomass data for the NAFO regulatory area to evaluate specific VME SAIs. The levels of fishing intensity should be consistent from year to year although the actual trawl tracks will vary. This implies that all areas of seabed subject to a defined intensity of fishing will, at some calculable time, be impacted. The difference will be that high intensity areas will result in all areas being impacted in a short period of time (a few years) whereas a low intensity area will result in all areas being impacted over a long period of time (many decades).

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ToR 5.1. [FC Request # 19] In preparation for the reassessment of NAFO bottom fisheries by 2016 and every 5 years thereafter, develop a workplan for completing the initial reassessment and identifying the resources and information to do so.

5.1.1. Context

In the September 2011 Meeting, Fisheries Commission (FC) requested Scientific Council (SC) the following:

19. *As stated in the "Reassessment of the Impact of NAFO Managed Fisheries on known or Likely Vulnerable Marine Ecosystems" (NAFO FC WP 11/24), the Scientific Council in collaboration with the Working Group of Fishery Managers and Scientists on Vulnerable Marine Ecosystem will conduct a reassessment of NAFO bottom fisheries by 2016 and every 5 years thereafter. In preparation for reassessments, the Fisheries Commission requests the Scientific Council to develop a workplan for completing the initial reassessment and identifying the resources and information to do so.*

This request fundamentally changes the previously perceived notion that fisheries assessments were to be produced by contracting parties, then submitted to NAFO for their evaluation and, on the basis of this evaluation, make a decision about the future of the assessed fisheries. It was under this notion that WGEAFM developed flowcharts to better understand and outline the process currently in place in NAFO in reference to fisheries assessments. The first chart indicated the decision process leading to when a fisheries assessment would be required, and the second chart outlined the process currently defined by Fisheries Commission for fisheries assessments. (2010 WGEAFM Report, NAFO SCS 10/24). On the basis of the current request, now the onus of producing these fisheries assessments is on Scientific Council and the FC Working Group of Fishery Managers and Scientists on Vulnerable Marine Ecosystem (WGFMS). Therefore, the workplan required by this request, and the identification of resources needed, would involve the following:

1) Design a template for the structure of the Fisheries Assessment
2) Describe the content and/or analysis involved in each one of its components
3) Identify the different groups within NAFO and/or contracting parties that should contribute to the different components of the assessment.
4) Identify the data, including format and/or any pre-processing required, that contracting parties must provide to carry out the assessment
5) Develop a timeline to carry out the necessary work that would allow the assessment to be ready by the September Meeting in 2016.
6) Identify all the resources required to carry out the work on time, including data, but also any additional analytical capabilities, coordination support, travel needs, and/or qualified personnel that may not be currently tasked and/or allocated to NAFO-related activities.

At the present time, WGEAFM is the first group that has discussed this request, and its potential implications. Further discussion and elaboration of concepts, components, requirements, and feasibility is expected to take place at SC, and WGFMS. The goal of WGEAFM when addressing this request is simply to provide an initial general layout for discussion, as well as focusing on those topics that are within the scope of the expertise within WGEAFM.

5.1.2. Fisheries Assessments, Integrated Ecosystem Assessments, and the "Roadmap to EAF"

5.1.2.1. Required components of a Fisheries Assessment in NAFO

The components of a fisheries assessment within NAFO, as agreed by FC in September 2010, following input from SC, are as follows (NCEM Chapter 2/19, and Part V of Annex I.E.):

1) Type(s) of fishing conducted or contemplated, including vessels and gear types, fishing areas, target and potential bycatch species, fishing effort levels and duration of fishing (harvesting plan);
2) Best available scientific and technical information on the current state of fishery resources and baseline information on the ecosystems, habitats and communities in the fishing area, against which future changes are to be compared;
3) Identification, description and mapping of VMEs known or likely to occur in the fishing area;
4) Identification, description and evaluation of the occurrence, scale and duration of likely impacts, including cumulative impacts of activities covered by the assessment on VMEs;
5) Data and methods used to identify, describe and assess the impacts of the activity, the identification of gaps in knowledge, and an evaluation of uncertainties in the information presented in the assessment;
6) Risk assessment of likely impacts by the fishing operations to determine which impacts on VMEs are likely to be significant adverse impacts;
7) The proposed mitigation and management measures to be used to prevent significant adverse impacts on VMEs, and the measures to be used to monitor effects of the fishing operations.

5.1.2.2. Ecosystem Assessments

Traditional stock assessments did not explicitly consider the ecological contexts of individual fish populations. The only implicit recognition of connections to the wider ecosystem was through the examination of stock and recruitment relationships. Exploited stocks were implicitly considered to be closed self-perpetuating systems whose exploitation was managed by limiting removals to below that which could be replaced by recruitment and growth. As our understanding matured, we recognized that fish populations were components of complex systems that are interconnected at a variety of spatial and temporal scales, and these complex systems are themselves interconnected. Equally important, our understanding of exploitation has also matured in that we now recognize that incentives for fisheries comprise an array of cultural, social and economic motivations ranging from subsistence to fishing as a market-driven extraction of fish as commodities. Today we recognize that a exploited stock can no longer be assessed as an isolated entity; it needs to be assessed in the complex and variable context of the ecosystems being exploited and of the social and economic human systems that exploit them (Figure 5.1.1).

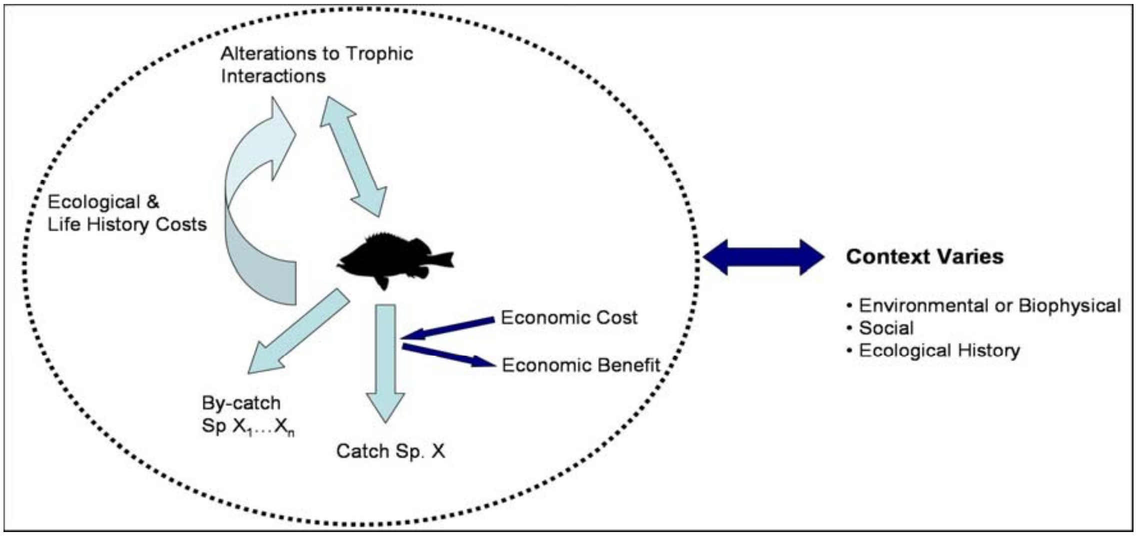

Figure 5.1.1. Conceptual depiction of the ecological and human costs and benefits associated with the exploitation of a fish population in a variable ecological and social context.

Recognizing these complexities, and the need to consider them in management, has led to the development of Integrated Ecosystem Assessments (IEA), which have been defined as: "*a synthesis and quantitative analysis of information on relevant physical, chemical, ecological, and human processes in relation to specified ecosystem management objectives*" (Levin et al. 2009*).* Integrated Ecosystem Assessments are designed to meet multiple objectives and they can be considered as a tool, a product, and a process. They are a tool that uses integrated analysis and ecosystem modeling for synthesis. IEAs are product for managers and stakeholders who rely on scientific support for policy and decision making. Finally, IEAs are a process including the identification of management objectives by managers and stakeholders, the development of quantitative assessments, and the evaluation of alternative management strategies. As a whole, IEAs should not be viewed as a replacement of single-sector and/or single-species management; instead, they should be considered as a necessary supplement that highlights potential conflicts among human activities, as well as potential inconsistencies between human goals and ecosystem states and/or processes. To implement an EAF successfully, therefore, it is not only necessary to have a suite of indicators that accurately portray the "state" of various ecosystem components, but it is also critical to have indicators that describe changes in the level of different manageable human activities.

5.1.2.3. Fisheries Assessments and the "Roadmap to EAF"

NAFO SC is currently engaged in the process of developing, and implementing the "Roadmap to EAF" (WGEAFM Report, NAFO SCS 10/19). This process involves developing an Integrated Ecosystem Assessment structure for NAFO, on the basis of three operational steps: 1) definition of spatial management units, 2) definition of ecosystem state and functional processes, and 3) development of management tools and examination of exploitation trade-offs (Figure 5.1.2).

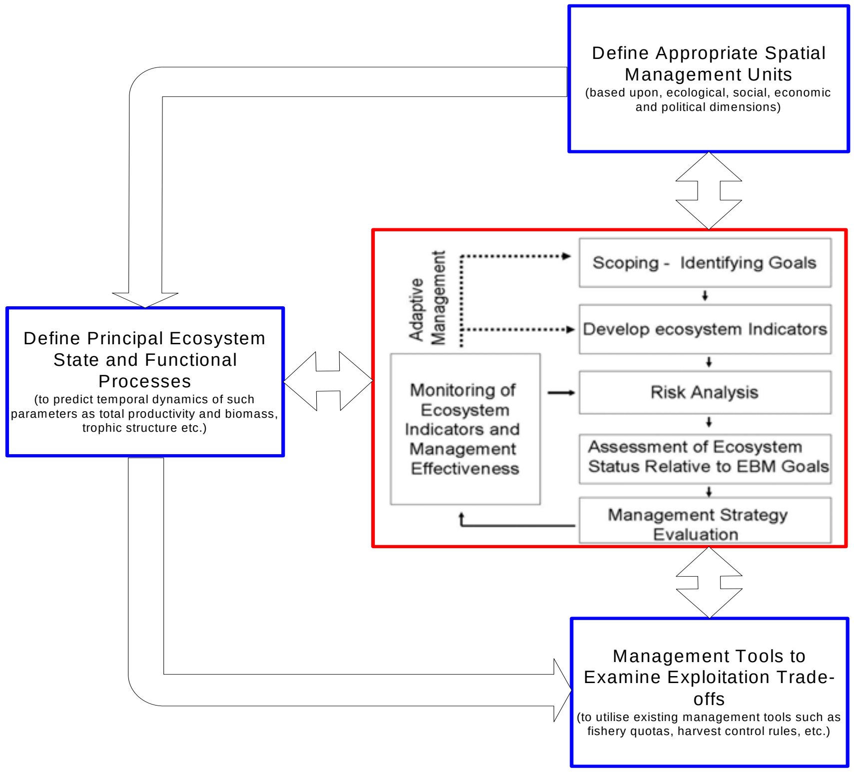

Figure 5.1.2. The relationship between the 3 practical steps in moving towards the implementation of an ecosystem approach to fisheries management (blue boxes) and the steps required to deliver effective holistic integrated ecosystem assessments (IEA) shown in the red box (from WGEAFM Report, NAFO SCS 10/19).

In terms of ecosystem state and function, the “Roadmap to EAF” considers that overall ecosystem productivity is dependent on ecosystem state, so ecosystem sustainability would require state-dependent ecosystem fishery production to be allocated among target species considering species interactions, which implies that trade-offs among fisheries need to be identified. Since all the above considerations may not fully capture species-specific biological and life history features, stock sustainability needs to be evaluated on the basis of single-species assessments.

If we examine the list of components of a Fisheries Assessment (see section 5.1.2.1. above) from the perspective of the “Roadmap to EAF” (WGEAFM Report, NAFO SCS 10/19), it is possible to map many of these components onto the very structure of the “Roadmap to EAF”. This suggests that the basic template for putting together Fisheries Assessments can be drawn from the current structure of the “Roadmap to EAF”. In this context, Figure 5.1.3. provides an schematic representation of a possible structure for Fisheries Assessments in NAFO.

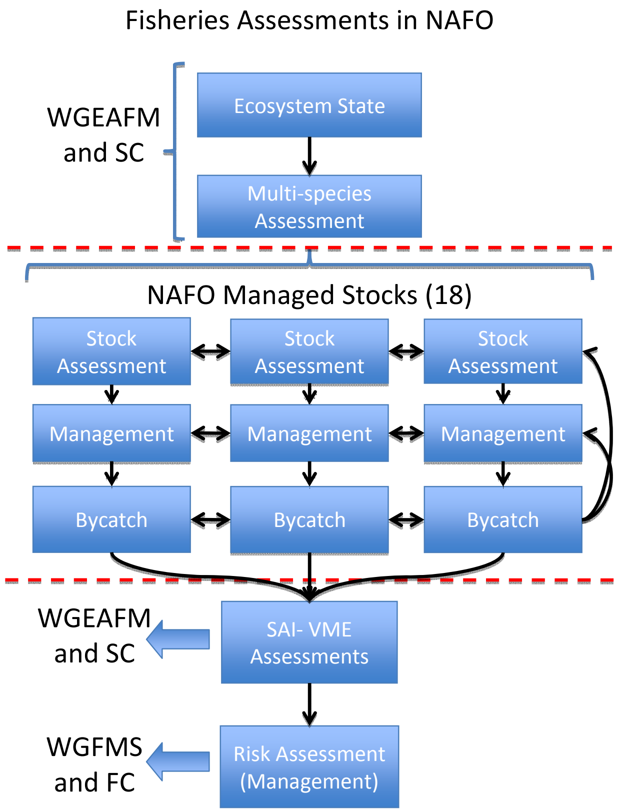

Figure 5.1.3. Schematic representation of a possible structure to develop Fisheries Assessments in NAFO.

The high level components (top 2 boxes in Figure 5.1.3) are consistent with the "Roadmap to EAF" in relation to incorporate sustainability at the ecosystem level (i.e. state-dependent ecosystem productivity), and multispecies interactions, which allow considering trade-offs between fisheries and multispecies sustainability. By considering these elements, the Fisheries Assessment will be incorporating some of the ecosystem and community information required under item 2) of the list of fisheries assessment components (NCEM, Part V of Annex I.E.), while providing a common ecosystem-level umbrella under which individual stock information can be presented (items 1 and 2 in NCEM, Part V of Annex I.E.). The three boxes for each individual stock would be providing information on the state of those resources, as well as details for the individual fisheries, management practices, and description of by-catch issues. In this case, the box of by-catch also includes by-catch of VME species. These stock-specific boxes are covering elements in items 1, 2 and 4 of the list of fisheries assessment components (NCEM, Part V of Annex I.E.). The information of by-catch of VME-species feeds down to the Significant Adverse Impact (SAI) on VME box, where it is integrated. Although evaluation of SAIs can be applied to target (fish) species, many of the seven items in the list of components of fisheries assessments specified above refer to VMEs. For example, item 3 refers to mapping of VMEs, and it would also be incorporated into the SAI box. Considerable progress has been made at the current WGEAFM meeting on mapping VMEs, as well as to advance on ways to evaluate SAIs (see ToR 4.1.). Items 4 and 5 of the list of components of fisheries assessments are the "nuts and bolts" of the assessment of SAIs for SC to consider, along with Item 6. Managers would be expected to play a role in Items 6 and 7.

The structure depicted in Figure 5.1.3 can be used as a template to actually implement in practice the Roadmap to EAF. Such implementation would require to develope a closed loop based on that structure by incorporating both monitoring and objective setting steps (Figure 5.1.4).

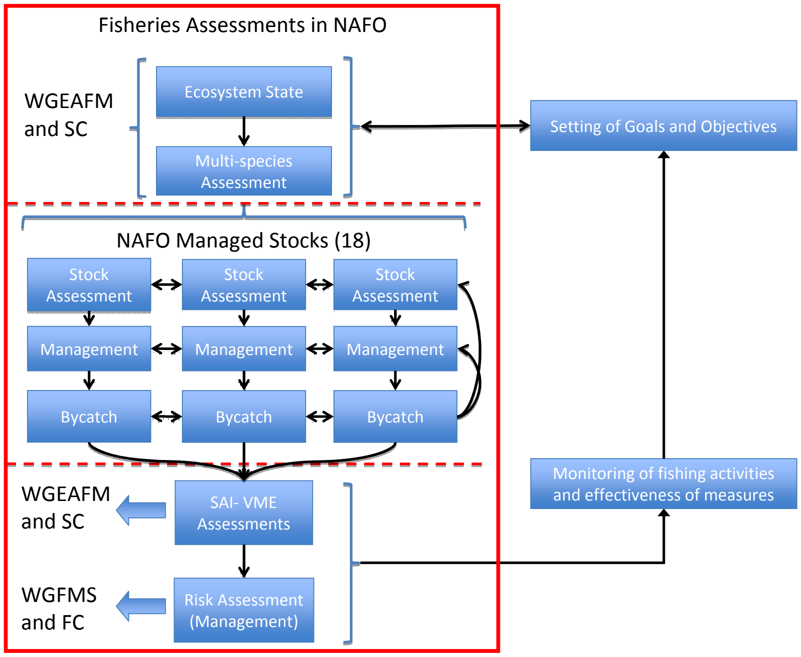

Figure 5.1.4. A conceptual description of the implementation of the "Roadmap to EAF" based on the suggested structure for Fisheries Assessments. The red box shows the proposed structure to develop Fisheries Assessments in NAFO.

There are a couple of important observations to be made regarding fisheries assessments and the proposed structure to develop them. First, this proposed structure is centered on the ecosystem unit; this means that NAFO needs to develop ecosystem assessment for each identified ecosystem-level management unit. Based on WGEAFM results to date, the candidate units that minimally need to be considered by 2016 are the Grand Bank proper (but considering the influence of the Northern NL shelf), and the Flemish Cap, because it is in these two areas where NAFO actually regulates active fisheries.

The other important consideration is the fact that fisheries assessments are exactly that, assessments, and we need to accept that some of the boxes identified in Figure 5.1.3 may not be fully developed by 2016, and/or the management considerations emerging from them implemented. These incomplete components of the assessment would be identified as gaps, showing where work is needed as we move towards a complete implementation of the "Roadmap to EAF".

5.1.3. Resources and information needed.

WGEAFM considered the type of information required for the assessments, as well as the resources needed to conduct them. For data requirements, it was concluded that better catch data is required, including accurate information on directed species, by-catch, and catches with VME indicator species (whether above or below the threshold). The current data collection form for exploratory fisheries should provide the necessary fishery data, provided it is collected from all tows in the NRA, i.e. it is critical to have this type of information from ongoing fisheries in the footprint in order to conduct the assessments

It will also be important to have accurate maps of fishing effort (VMS data from NAFO), as well as good research vessel information (e.g. Nereida, trawl surveys). The onus will still be on CPs to continue to provide this information in a timely fashion, to meet any assessment timelines established. Data are often lacking on the impacts of fishing gear on benthic habitats, and studies in this area will be important to determine risks to VMEs. Ongoing support for programs (Nereida, DFO Ecosytem Research Initiative) currently providing data and analyses will also be critical. WGEAFM discussed the existing FC data protocol for exploratory fisheries, noting that this type of information will be required from all commercial fisheries to ensure that accurate fisheries assessments can be carried out. A data collection form, based on the one for exploratory fisheries, is proposed and presented at the end of this section.

WGEAFM noted that human resources will also be needed to complete the work required for fisheries assessments. This will include, among others, ecologists, benthic scientists, stock assessment biologists and at-sea observers. It is vital that NAFO CPs consider the workloads involved in the assessment process and commit to providing these resources.

5.1.4. Management measures

The risk assessment component is the final box in the above diagram (Figure 5.1.3), and based on previous FC information, it is expected that this component would be dealt with the FC's WG of Fisheries Managers and Scientists on VMEs. The main objective of the WG is to make recommendations to the FC on the effective implementation of measures to prevent significant adverse impacts on vulnerable marine ecosystems.

The current ToRs for this group, as established by FC in September 2011, state:

In responding to requests for advice and recommendations from the Fisheries Commission, the Working Group shall:

Consider the advice of Scientific Council to Fisheries Commission; evaluate associated risks; and make recommendations on mitigation strategies and measures to avoid significant adverse impacts on vulnerable marine ecosystems, drawing on relevant international guidance.

Review area closures, fisheries impact assessments and other measures outlined in the NAFO Conservation and Enforcement Measures (NCEMs) with specific timelines.

Therefore, any specific management measure to be implemented, as well as assessing the risks involved in different strategies needs to be developed in the context of WGFMS.

It is important to highlight at this point that the requirements from fisheries assessments, even though are heavily focused in addressing impacts on VMEs, they also address the overall sustainability of the exploited resources. This means that fisheries assessments include the actual stock assessments, in addition to any SAI on VMEs that the fisheries may be producing. Furthermore, it is in terms of this sustainability of exploited stocks where multispecies analysis feed into the process, allowing species interactions to be explored. This eventually would allow evaluation and advice on trade-offs i.e. it will not be possible for all fished species to be at levels allowing MSY catches. Examples of multispecies modeling were considered at the current meeting (e.g. Flemish Cap cod, redfish, shrimp – see ToR 3.2). At present SC uses a multispecies assessment model for shrimp in Subarea 0+1, which includes predation of cod on shrimp.

5.1.5. References

Levin, P.S., M. J. Fogarty, S.A. Murawski, D. Fluharty. 2009. Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean. PloS Biology. Vol.7 (1) e1000014. pp. 23-28.

Fishery Data Collection Form

A. Fishing Trip Information

Flag state		Vessel Name		Call sign		Date of encounter (ddmmyy)	

B. Gear and Fishing Information (use separate form for each gear).

Fishing Gear (e.g. trawl, gill net, hook and line, etc)		Gear Details:	Gear type (e.g. bottom trawl, set gill net, etc.)	
			Gear size (groundrope length, panel length, etc.)	
			Other details (cod end mesh size, # of hooks, etc.)	

		hr	min			degrees		minutes		meters
Tow or Set Start:	GMT Time:			Latitude	N				Depth	
				Longitude	W					
Tow or Set End:	GMT Time:			Latitude	N				Depth	
				Longitude	W					

C. Catch Information *Don't leave blank. Indicate zero catch if necessary.

Live Corals total weight in the haul (kg)*		Live Sponges total weight in the haul (kg)*	

Organisms identified to the lowest taxonomic unit as possible** Include fish and invertebrates	Biological Samples taken?		Biological samples of Vulnerable Indicator Species taken?		Total Weight (kg) in catch	Weight is esti--mate or actual? Tick one.	
	yes	no	yes	no		Act.	Est.

D. Comments

**Refer to Annex I of the FAO International Guidelines for the Management of Deep-Sea Fisheries in the High Seas. Also, use NAFO Coral and Sponge Identification Guides as appropriate.

CORALS

Page	Name	kg
	Soft corals (Alcyonacea)	
C1	Anthomastus spp.	
C2	Duva florida	
C3	Gersemia rubiformis	
C4	Other Nephtheidae	
	Black corals (Antipatharia)	
C5	Stauropathes arctica	
C6	Stichopathes spp.	
	Stony corals (Scleractinia)	
C7	Lophelia pertusa	
C8	Desmophyllum dianthus	
C9A	Flabellum alabastrum	
C9B	Flabellum angulare	
C9C	Flabellum macandrewi	
	Branching corals ((Alcyonacea)	
C10	Acanella spp.	
C11	Acanthogorgia armata	
C12	Keratoisis ornata	
C13	Paramuricea spp.	
C14A	Paragorgia arborea	
C14B	Paragorgia johnsoni	
C16	Primnoa resedaeformis	
C17	Radicipes gracilis	
	Sea pens (Pennatulacea)	
C18	Anthoptilum spp.	
C19	Funiculina quadrangularis	
C20	Halipteris finmarchica	
C21	Ombellula spp.	
C23	Pennatula sp.	
C23A	Pennatula aculaeta	
C23B	Pennatula phosphorea	
C23C	Pennatula borealis	
	TOTAL LIVE WEIGTH	

SPONGES

Page	Name	kg
	Solid/Massive	
S1	Biemna variantia	
S2	Forcepia (Forcepia) thielei	
S3	Geodia spp.	
S4	Hamacantha (Hamacantha) carteri	
S5	Melonanchora elliptica	
S6	Mycale (Mycale) lingua	
S7	Spongionella pulchella	
S8	Stelletta spp.	
S9	Stryphnus ponderosus	
S10	Suberites ficus	
S11	Thenea muricata	
S12	Thenea spp.	
	Leaf/Vase-Shaped	
S13	Iophon piceum	
S14	Phakellia spp.	
S15	Vazella pourtalesi	
	Round with Projections	
S16	Craniella cranium	
S17	Histodermella sp.	
S18	Polymastia spp.	
S19	Radiella hemisphaerica	
	Thin-Walled, Complex	
S20	Asconema foliata	
S21	Chonelasma sp.	
S22	Euplectella spp.	
	Stalked	
S23	Asbestopluma sp.	
S24	Chondrocladia spp.	
S25	Cladorhiza spp.	
S26	Rhizaxinella sp.	
	Other	
S27	Stylocordyla borealis	
S28	Cliona sp.	
S29	Haliclona spp.	
S30	Homaxinella sp.	
S31	Hymedesmia sp.	
S32	Quasillina brevis	
S33	Sycon sp.	
S34	Tentorium semisuberites	
S35	Spicule clumps	
	TOTAL LIVE WEIGHT	

See NAFO Coral and Sponge Guides for pictures. Guides can be downloaded from http://www.nafo.int/publications/frames/science.html or acquired from the NAFO Secretariat (info@nafo.int).

Other businesses

a) Report of the 2nd ICES - WGNARS meeting in Dartmouth, Canada

The ICES Working Group on the Northwest Atlantic Regional Sea (WGNARS), met at the Bedford Institute of Oceanography, Dartmouth, Canada, on February 8-10, 2011. The final report of this meeting is available as ICES CM 2011/SSGRSP:01 at the ICES website. Mariano Koen-Alonso, co-chair of NAFO SC WGEAFM attended to this meeting.

Within the ICES structure, WGNARS is one of the expert groups under the Steering Group on Regional Seas Programme (SSGRSP), which in turns report to the Science Committee (SCICOM). WGNARS and SSGRSP are currently developing the science to support future advice on marine resource management, and are expected to eventually develop more close linkages to the ICES Advisory Committee (ACOM). WGNARS is co-chaired by Steve Cadrin, University of Massachussets, and Catherine Johnson, Fisheries and Oceans Canada.

WGNARS long term objective is to develop an integrated ecosystem assessment (IEA) of the Northwest Atlantic Ocean, but in the short term its work is focused on developing scientific support for the development of ecosystem approaches to management in the region.

During its second meeting, WGNARS addressed issues related to a) ecosystem approaches frameworks, where among other topics the history and activities of NAFO SC WGEAFM was presented, b) socio-economic components of IEAs, c) spatial planning, d) ecosystem indicators and climate/environmental drivers, e) thresholds and indicators, and f) signal propagation on the shelf and slope.

When comparing WGNARS and NAFO SC WGEAFM, it is clear that both groups have similar general goals (e.g. development of IEAs as a key element of ecosystem approaches), but also differ in terms of the background and expertise of their memberships, as well as their needs to provide tailored advice for specific requests. WGNARS work does not provide advice to any specific management organization, while WGEAFM work is linked to the needs for advice within NAFO structure and timelines. Some other differences included: a) WGNARS deals with a wide spectrum of human activities, while WGEAFM is bounded by the fisheries-specific mandate of NAFO, b) WGNARS work is focused on shelf and coastal systems, while WGEAFM work involves shelf and deep-sea systems, c) WGNARS membership includes social scientists and is addressing socio-economic aspects of ecosystem approaches, while WGEAFM lacks this expertise and it is not actively working on these aspects, and d) WGNARS membership is mainly composed by North American scientists (USA and Canada), while WGEAFM membership is more reflective of NAFO contracting parties (i.e. USA, and Canada, but also Spain, Portugal, Russia, and UK), and hence, operational and functional issues may be affected by different sets of constraints for each working group.

In terms of coordination between ICES WGNARS and NAFO WGEAFM, both working groups can complement each other in several aspects, as well as develop close collaborations in others. With the intent of maintaining close linkages, avoiding duplication of efforts, and promoting collaborations and positive feedbacks between the two groups, ICES WGNARS and NAFO WGEAFM co-chairs proposed that, as an initial step for developing these collaborations, efforts should be made to ensure that the chairs and/or co-chairs of both working groups can attend to each other's meetings, as well as to include them in each other's mailing lists. As both working groups evolve, more formal linkages between them may need to be explored sometime in the future.

NAFO SC took notice of the activities of ICES WGNARS at its 2011 June meeting, and endorsed the proposed mechanisms to explore and promote linkages and communication between ICES WGNARS and WGEAFM. As part of this process, Catherine Johnson, co-chair of ICES WGNARS, attended the 4th NAFO WGEAFM meeting. The 3rd ICES WGNARS is schedule to take place 6-8 March, 2012 at Falmouth, MA, and Mariano Koen-Alonso would be attending this meeting as NAFO WGEAFM co-chair.

b) Election of WGEAFM Chairs

NAFO SC working groups do not have a regulated schedule for the replacement/renewal of their chairs. In the case of WGEAFM, the current co-chairs, Mariano Koen-Alonso (Canada) and Andrew Kenny (UK), were elected to those positions at the 1st WGEAFM meeting (26-30 May, 2008, Dartmouth, Canada). Since more than 3 years have elapsed since their initial designation, WGEAFM reviewed the co-chairs situation and proposed to renew the incumbent appointments.

Documents reviewed and/or produced during this meeting

From the work presented and discussed at this meeting, WGEAFM review and endorsed the following to be produced as SCR documents:

Cogswell, A., E. Kenchington, C. Lirette, F.J. Murillo, G. Campanis, N. Campbell, and N. Ollerhead. 2011. Layers utilized by an ArcGIS model to approximate commercial coral and sponge by-catch in the NAFO Regulatory Area. NAFO SCR Doc. 11/72.

Murillo, F.J., E. Kenchington, M. Sacau, D.J.W. Piper, V. Wareham, and A. Muñoz. 2011. New VME indicator species (excluding corals and sponges) and some potential VME elements of the NAFO Regulatory Area. NAFO SCR Doc. 11/73.

Murillo, F.J., Wareham, V., Sacau, M., Román, E., and Durán Muñoz, P. 2011. New data on deep-water corals and sponges from Spanish/EU and Canadian bottom trawl groundfish surveys in the NAFO Regulatory Area (Divs. 3LMNO): 2008-2010 period. NAFO SCR Doc. 11/74.

Kenchington, E., F.J. Murillo, A. Cogswell, and C. Lirette. 2011. Development of encounter protocols and assessment of significant adverse impact by bottom trawling for sponge grounds and sea pen fields in the NAFO Regulatory Area. SCR Doc. 11/75.

Pérez-Rodríguez, A; Koen-Alonso, M.; González, C. and Saborido-Rey, F. 2011. Analysis of common trends in the feeding habits of main demersal fish species on the Flemish Cap. NAFO SCR Doc. 11/77.

Next Steps

a) Date and place for next meeting

It was proposed that the 5th WGEAFM meeting to take place in November 21-30, 2011 at the NAFO Secretariat in Dartmouth, Canada.

b) ToRs for next meeting

WGEAFM proposes that its 5th meeting should continue addressing the the long-term ToRs described as:

<u>Theme 1: Spatial considerations</u>

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

ToR 2. Based on available biogeographic and ecological information, identify appropriate ecosystem-based management areas.

<u>Theme 2: Status, functioning and dynamics of NAFO marine ecosystems.</u>

ToR 3. Update on recent and relevant research related to status, functioning and dynamics of ecosystems in the NAFO area.

<u>Theme 3: Practical application of ecosystem knowledge to fisheries management</u>

ToR 4. Update on recent and relevant research related to the application of ecosystem knowledge for fisheries management in the NAFO area.

ToR 5. Methods for the long-term monitoring of VME status and functioning.

Theme 4: Specific requests

ToRs 6+. As generic ToRs, these are place-holders intended to be used when addressing expected additional requests from Scientific Council.

More specifically, work during the 5th WGEAFM meeting is proposed to be focused on:

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

It is expected that updates from the NEREIDA project as well as other surveys will become available; these new studies will be presented and discussed under this ToR. Other elements to be discussed may include modeling VME distribution using habitat characteristics, as well as analyses of distribution of benthic communities.

ToR 2. Based on available biogeographic and ecological information, identify appropriate ecosystem-based management areas.

It is expected to that updated analyses considering temporal variability of ecoregions will be presented and discussed under this ToR. Advances on the integration of databases for the Northwest Atlantic integrated ecoregion analysis are also expected to be discussed here.

ToR 3. Update on recent and relevant research related to status, functioning and dynamics of ecosystems in the NAFO area.

It is expected to continue working on Fisheries ProductionPotential (FPP) models, as well as modeling of multispecies systems, and estimations of food consumption.

ToR 4. Update on recent and relevant research related to the application of ecosystem knowledge for fisheries management in the NAFO area.

It is expected that work under this ToR would include a literature review on parameterizations for SAI analyses, as well as a brainstorming session on the details and caveats of using VMS data for SAI analysis.

In addition to the work focused on the ToRs indicated above, WGEAFM would also be expected to dedicate time to address specific ToRs related to SC and/or FC requests.

If time allows, any study not pertaining to the focal ToRs indicated above, but still of relevance for addressing WGEAFM long-term ToRs may also be presented and discussed.

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