Northwest Atlantic Fisheries Organization

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SCIENTIFIC COUNCIL MEETING – JUNE 2011

Report of the 3rd Meeting of the NAFO Scientific Council Working Group on Ecosystem Approaches to Fisheries Management (WGEAFM)

NAFO Headquarters, Dartmouth, Canada

1-10 December 2010

Introduction

The NAFO WGEAFM currently operates within a set of long term Themes and Terms of Reference that were approved by NAFO Scientific Council (SC) in June 2010 and will be systematically addressed by the group over several meetings. These Themes and ToRs build on the "*Roadmap for Developing an Ecosystem Approach to Fisheries for NAFO*" proposed by WGEAFM in its 2nd meeting (Vigo, 1-5 February 2010). In addition, WGEAFM also provides guidance to SC on specific ecosystem-related issues and requests from Fisheries Commission.

The 3rd meeting of WGEAFM delineates ecoregions and ecosystem units in the NW Atlantic, focusing particularly on the Newfoundland and Labrador Shelf, the Flemish Cap and the Scotian Shelf and their associated slope regions. Seamounts, being geophysical features on the abyssal plains, also received special attention at this meeting. In future meetings, and assuming that personnel and data are available, it is hoped to extend the coverage to include shelf seas around western Greenland and also additional features such as canyons. It is recognized that work on the eastern seaboard of the USA, and especially on George's Bank, has shown significant advances in over the last 5 or so years. Though not directly comparable to the NAFO area, expertise available at this meeting elaborated on these advances and allowed for a cross fertilization of ideas and concepts.

In addition to the above work, the WGEAFM also provides the scientific information and guidance to Scientific Council required to address three ecosystem-related requests from Fisheries Commission made in September 2010. Of assistance here is the roadmap developed by WGEAFM in their earlier meetings that has arisen from their work on developing an Ecosystem Approach for Fisheries Management that is consistent with NAFO's aims and objectives.

This meeting, more than previous meetings, has benefited from the participation of scientific experts from other research groups/projects who have shared their spatial data. This collaboration has benefited the group and greatly enhanced the quality and applicability of the output. It is hoped that the expansion of the group continues for the benefit of all contracting Parties concerned in their efforts to promote sustainable fisheries and maintain diverse and healthy ecosystems. The timing of this meeting, being held in early December, has assisted in this wider participation. The timing is beneficial for another reason, as it allows for the early planning of responses to requests from Scientific Council, many of which were formulated in September by Fisheries Commission.

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

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

The Fisheries Commission Request # 13 from the September 2010 FC meeting states:

> *"Mindful of the NEREIDA mission, the international scientific effort led by Spain to survey the seafloor in the NAFO Regulatory Area,*
>
> *Recognizing that the Coral and Sponge Protection Zones closed to bottom fishing activities for the protection of vulnerable marine ecosystems as defined in Chapter 1 Article 16 Paragraph 3 is in place until December 31, 2011,*
>
> *Mindful of the call for review of the above measures based on advice from the Scientific Council, Fisheries Commission requests that Scientific Council review any new scientific information on the areas defined in Chapter 1 Article 16 Paragraph 3 which may support or refute the designation of these areas as vulnerable marine ecosystems. In the event that new information is not available at the time of the Fisheries Commission meeting in September 2011, prepare an overview of the type of information that will be available and the timeline for completion."*

This request was deemed adequately covered by ToR 1 (Update on identification and mapping of sensitive species and habitats in the NAFO area) under Theme 1(Spatial considerations), and hence, it has been addressed as ToR1a.

ToR 1a *(to address FC Request # 13)*. Considering the work emerging from the NEREIDA project, review any new scientific information which may support or refute the designation of the areas defined in Chapter 1 Article 16 Paragraph 3 as vulnerable marine ecosystems. In the event that new information is not available at the time of the Fisheries Commission meeting in September 2011, prepare an overview of the type of information that will be available and the timeline for completion.

1a. NEREIDA results: Sackville Spur Closed Area and Flemish Cap (south, east & north east)

1a.1. Introduction

This section summarises the new information available to support the designation of areas defined in Chapter 1 Article 16 Paragraph 3 as Vulnerable Marine Ecosystems. The Sackville Spur closed area was selected as a case study in order to assess the original closed area selection criteria. In addition, qualitative descriptions of new survey results from the southern and eastern Flemish Cap conducted on the 2010 CCGS *Hudson* NEREIDA Cruise are presented.

1a.2. General description of the Sackville Spur Closed Area (Area 6)

The Sackville Spur is a sediment drift feature that forms a northeastward extension of the Grand Banks continental slope between the 500 and 1100 m isobaths (Kennard et al. 1990). It marks the southeastern margin of the 3000-m deep Orphan Basin The Labrador Current (LC) is the major hydrodynamic force on Sackville Spur, affecting both sedimentation patterns and biological community structure. The sponge grounds identified in this area are dependent on the current regime as the sponges here are sessile filter feeders and are susceptible to smothering if deposition is too strong and starving of there is insufficient food supply.

According to Kennard et al. (1990), "Reflection seismic data suggest that current-influenced deposition, associated predominantly with bottom-sediment reworking by the deeper offshore component of the LC, has been active over the uppermost part of the spur since Late Miocene to Early Pliocene time. The initiation of deep LC flow at this time is marked by a distinctive angular unconformity near the base of the spur drift deposit. Following this erosional event, deposition caused rapid progradation of the spur to the northeast. The latest phase of the spur's evolution is characterized by (*i*) intermittent erosion with concomitant large-scale submarine sliding; (*ii*) smaller scale mass-flow deposition; and (*iii*) a distinctive southeastward shift of its depocentre toward the Flemish Pass." The late Quaternary construction of the shallow part of Sackville Spur was strongly influenced by glaciation, with deposition of glacial till to water depths of 650 m (Huppertz and Piper, 2009). Although modern icebergs scour only to water depths of < 200 m, late Quaternary ice scours consist of two size populations, extending to water depths of ~500 m and ~ 700 m respectively (Piper and Pereira, 1992). The large submarine slides on the southeast side of Sackville Spur have been further investigated by Piper and Campbell (2004) and are thought to have been triggered by occasional large earthquakes. On the steeper northern flank of Sackville Spur, probably multiple landslides have removed seafloor strata leaving a step like pattern of multiple headscarps. The age of the youngest landslide event is uncertain, but the available Nereida box cores suggest that there is a mid to late Holocene (at least < 7 ka) sediment drape over the entire area. Nereida multibeam data show a large fresh-looking retrogressive failure on the northwest flank of Flemish Pass (again with at least a mid to late Holocene drape); the steep northern flank of Sackville Spur probably failed at the same time.

Surface grain size data from Nereida box cores show that in water depths of 1150-1325 m, percentage sand (>63 µm) ranges from 9 to 19% and % silt (63-4 µm) ranges from 51-62 %. Two samples (111 and 114) at 1404 and 1574 m have 15% and 5% sand respectively and lower silt content (45-47%) than in shallower water. A rather similar pattern is seen in core samples 50 km to the west (Tripsanas et al. 2008), where cores from 800-1250 m water depth have a thin (~ 20 cm) surface layer of muddy sand, the base of which is dated at ~ 7 ka, the time of the initiation of the modern Labrador Current. One core (NWF-83) from 1543 m recovered at least 1 m of mud above an 8 ka marker. Holocene sedimentation rates then decrease again in water depths > 2000 m. These data might be interpreted to mean that the Labrador Current is reworking and winnowing the seabed to a water depth of about 1300 m and beyond that depth there is a zone of enhanced deposition of winnowed fine sediment, that would be referred to as an incipient mounded sediment drift in the geological literature (Faugères et al. 1999).

Most of the sponge species found within fishing depths in the North Atlantic are relatively common and widespread. Over much of their distribution they occur as isolated individuals, however, in some locations, where environmental conditions are favorable, they form dense, multi-species communities and these sponge grounds (Figure 1a.1) require protection.

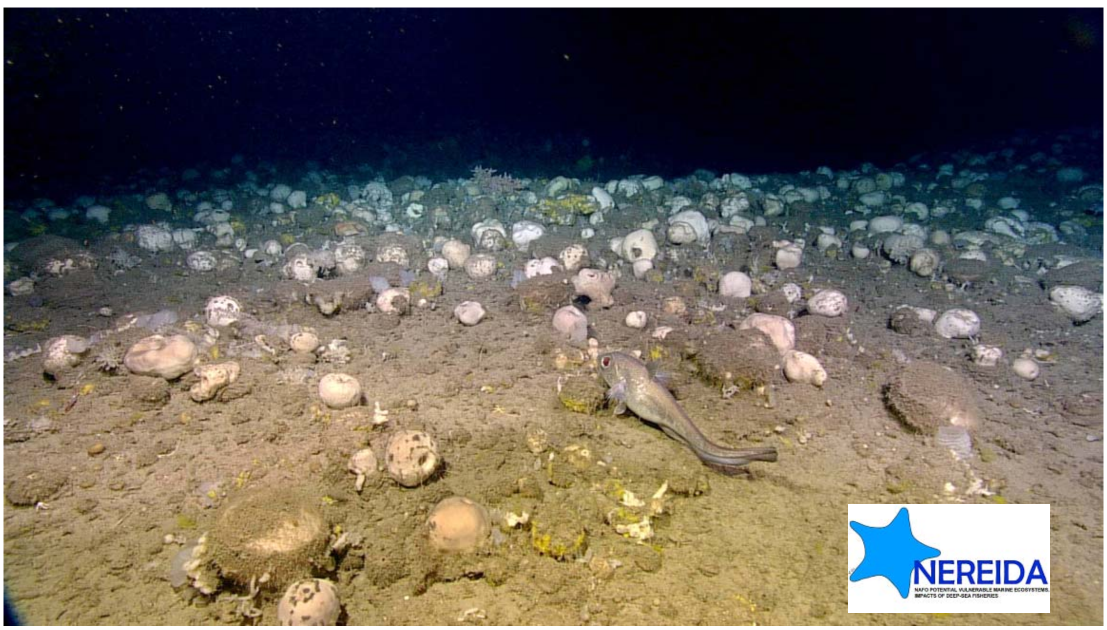


Figure 1a.1. Sponge Grounds, dominated by large, structure-forming species of *Geodia*, from the northeast slope of Flemish Cap photographed with ROPOS (Remotely Operated Platform for Ocean Science) as part of the CCGS *Hudson* 2010 NEREIDA survey.

Both the NAFO WGEAFM (Kenchington et al. 2009, NAFO 2009) and ICES WGDEC (2009) identified significant concentrations of sponges, i.e., sponge grounds, in the Sackville Spur area. The Sackville Spur Sponge Grounds are dominated by the large habitat structure-forming species of the genus *Geodia* (Figure 1a.1). These large sponges take decades to achieve their size and so sponges are at risk of significant adverse impacts due to fishing (ICES 2009). In order to protect the Sackville Spur Sponge Grounds, NAFO put a closure in place (Figure 1a.2, NAFO CEM 2010). As of January 1st, 2010, and until December 31st, 2011, the polygon defined by the points in Table 1a.1 will be closed on an interim basis to all bottom fishing activities. The Sackville Spur Closed Area is number 6 of 11 closures put in place to protect coral and sponge in the NAFO Regulatory Area (NRA) (Figure 1a.2). Area 6 is defined by connecting the coordinates in Table 1a.1 (as illustrated in Figure 1a.2).

Table 1a.1. Coordinates defining the NAFO closed area on Sackville Spur to protect Sponges from Bottom Fishing Activities (NAFO CEM 2010).

Area	Description	Point No.	Latitude	Longitude
		6.1	48°18'51.12"N	46°37'13.44"W
		6.2	48°28'51.24"N	46°08'33.72"W
		6.3	48°49'37.2"N	45°27'20.52"W
		6.4	48°56'30.12"N	45°08'59.99"W
6	Sackville Spur	6.5	49°00'9.72"N	45°12'44.64"W
		6.6	48°21'12.24"N	46°39'11.16"W
		11.2	47°30'1.44"N	46°21'23.76"W
		11.3	47°30'1.44"N	46°27'33.12"W
		11.4	47°25'48"N	46°27'33.12"W

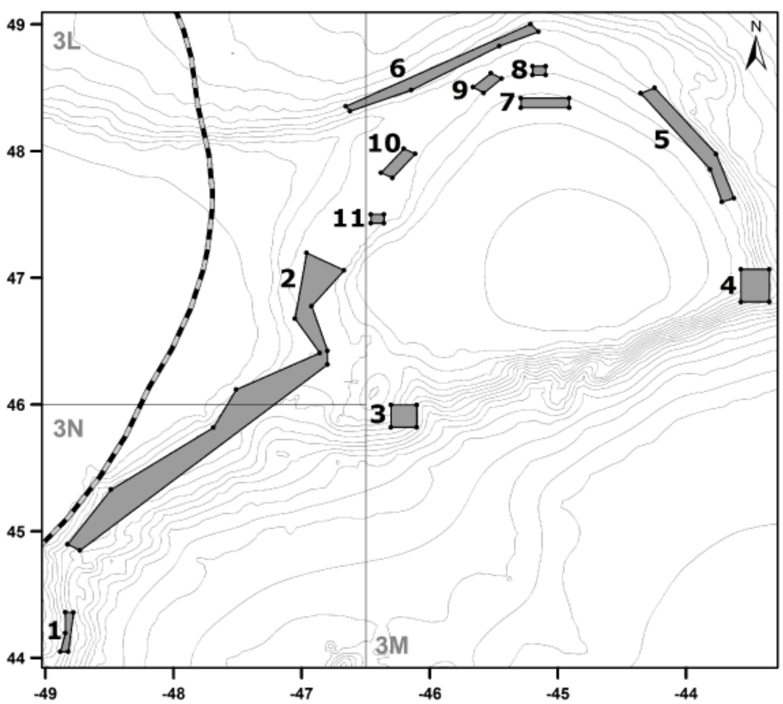


Figure 1a.2. Location of NAFO areas closed to bottom fishing to protect coral and sponge in the NRA. Area 6 is the Sackville Spur closure (Table 1a.1).

1a.2.1. Benthic fauna from Rock Dredge sampling in the Sackville Spur

Nineteen valid rock dredges were carried out during NEREIDA 0609 survey on board *Research Vessel Miguel Oliver*, owned and operated by the Secretaría General del Mar (see Figure 1a.3). During this survey, sampling was carried out within the Sackville Spur closed area.

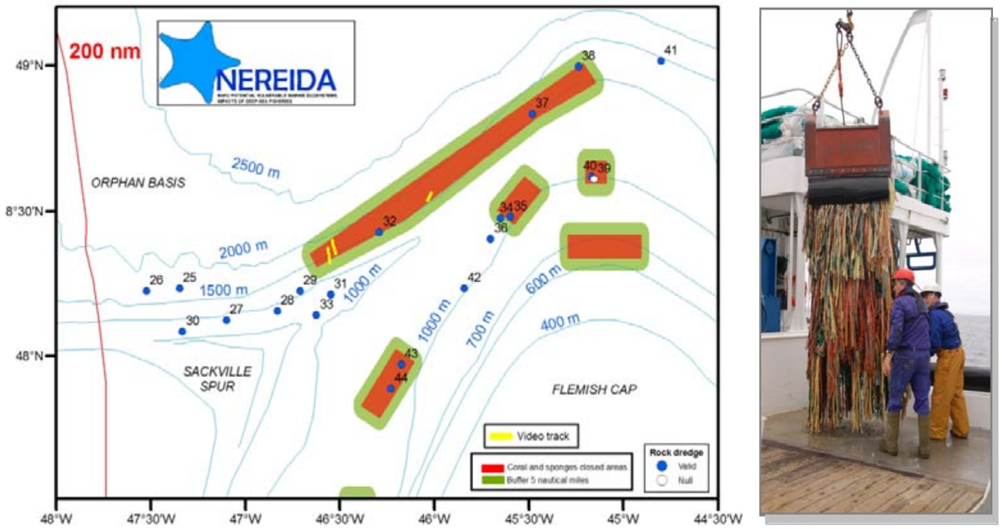


Figure 1a.3. Rock dredge sampling locations (NEREIDA 0609 survey)

Two of the 19 rock dredges (RD) were completed inside the Sackville Spur closed area (i.e. RD 32 and RD 37) and one inside the five nautical mile (nm) buffer which was arbitrarily drawn to identify samples that were near the closed area and likely to contain similar biota (i.e. RD 38). Table 1a.2 shows the locations and depths of all rock dredges conducted within the Sackville Spur closed area (see Figure 1a.4).

Table 1a.2. Sackville Spur rock dredges sampling locations.

SAMPLES	LATITUDE N (Decimal degrees)	LONGITUDE W (Decimal degrees)	AREA	DEPTH(meters)
DR32 SHOT	48.441362	46.249588	5 nm buffer	1273
DR32 BOTTOM	48.426898	46.291487	5 nm buffer	1264
DR32 HOLD	48.424188	46.297395	5 nm buffer	1294
DR37 SHOT	48.869510	45.459530	Sackville Spur	1538
DR37 BOTTOM	48.832943	45.483825	Sackville Spur	1360
DR37 HOLD	48.829753	45.482985	Sackville Spur	1347
DR38 SHOT	49.033452	45.243063	5 nm buffer	1965
DR38 BOTTOM	48.995192	45.238018	5 nm buffer	1575
DR38 HOLD	48.993242	45.230705	Sackville Spur	1561
DR29 SHOT	48.246500	46.712000	Outside buffer	970
DR29 BOTTOM	48.224833	46.711333	Outside buffer	863
DR29 HOLD	48.219333	46.712167	Outside buffer	851
DR31 SHOT	48.221167	46.647500	Outside buffer	869
DR31 BOTTOM	48.212000	46.548333	Outside buffer	878
DR31 HOLD	48.210167	46.541667	Outside buffer	880
DR41 SHOT	49.004000	44.738000	Outside buffer	1948
DR41 BOTTOM	49.014333	44.801333	Outside buffer	1885
DR41 HOLD	49.015000	44.807167	Outside buffer	1879

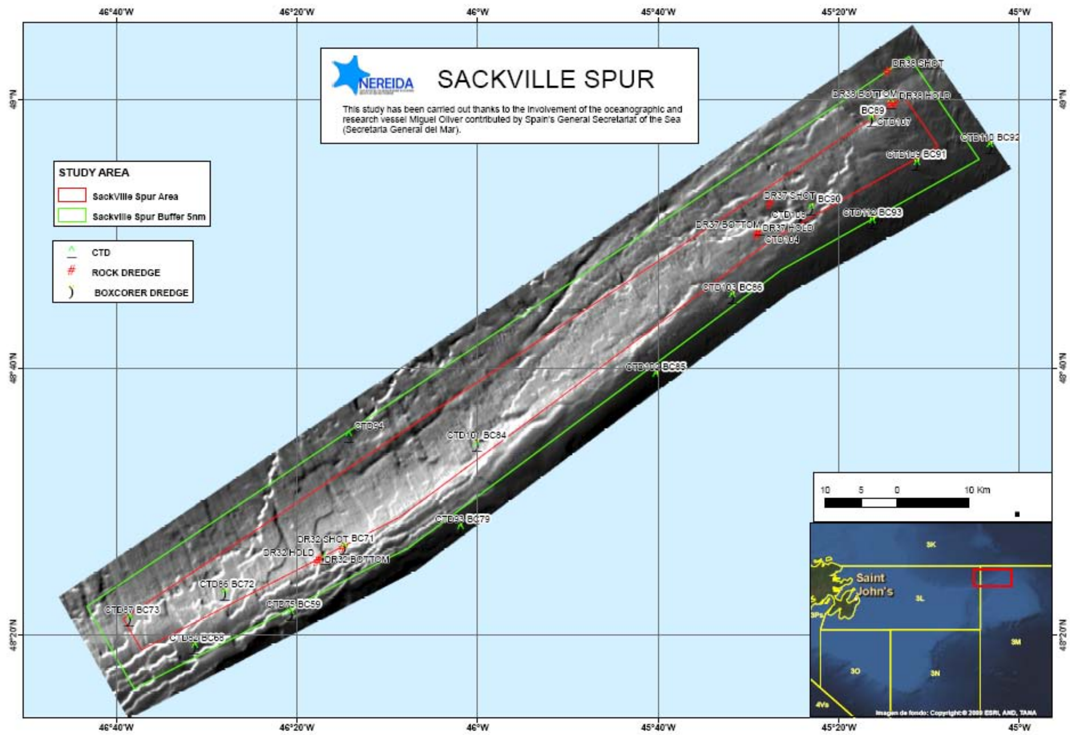


Figure 1a.4. Sackville Spur closed areas (red) and 5 nm buffer (green). Red dots represent locations of rock dredge sampling sites.

During the NEREIDA 0609 survey invertebrate abundances were estimated at 3,849 specimens with a total wet weight of 12.631 kg. See Table 1a.3 for invertebrate abundances, taxon counts, and wet weights (Figure 1a.5) broken down by areas:

Sackville Spur closed area (red): RD 32 and RD 37

5 nm buffer (green): RD 38

Closer areas outside the buffer (blue): RD 29, RD 31 and RD 41

Table 1a.3. Wet weight, abundance and estimated taxon counts for all invertebrates sampled by rock dredge within and adjacent the Sackville Spur area.

AREA	ROCK DREDGE	WET WEIGHT (kg)	ABUNDANCE	ESTIMATED NUMBER OF TAXA
Sackville Spur area	32	5.746	159	22
	37	2.501	69	22
5nm buffer	38	1.269	18	10
Outside buffer	29	0.074	251	15
	31	0.004	8	4
	41	0.114	144	27

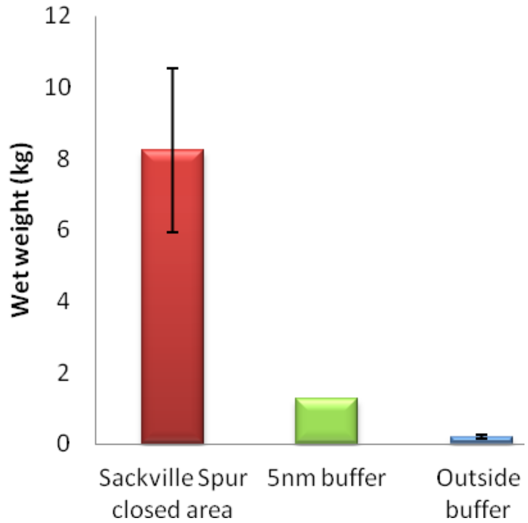


Figure 1a.5. Total wet weight of organisms sampled with the rock dredge from the three spatial areas of Table 1a.3. Note that these weights are not standardized for the number of dredges, although they include Standard Deviation error bars.

1a.2.2. Benthic fauna from *in situ* photographic transects in the Sackville Spur

The Canadian Coast Guard Vessel *Hudson* conducted *in situ* benthic photographic transects in the Sackville Spur area in 2009. The 4K camera system (4KCam) which was used for the surveys was built by the Geological Survey of Canada (GSCA) in 2008. It consists of a 4000m depth capable digital still camera system enclosed in a rugged aluminum roll cage (Figure 1a.13). A Canon Rebel Eos Ti 12 megapixel camera housed in a pressure case was triggered by a near bottom mechanical switch/acoustic pinger to take vertical still photos illuminated by two Canon flashes. To simplify the operations a nonconductor hydrostatic wire was used to lower and raise the camera via a ship winch. Subsea positioning was achieved using an ORE Trackpoint II USBL system. The VladCam Bullet HD video camera was a separate system that ran autonomously and was developed by GSCA in 2009 with 2000m depth capabilities. A Sony HD-SR12 camcorder powered internally and recording to memory sticks was mounted inside a pressure case. The VladCam was mounted to the side of the 4K camera roll cage in a vertical view and a “state of the art” high intensity LED Matrix light (Deep Sea Light & Power) was angled to provide constant illumination of the bed. When near the bed the high colour temperatures of this light (6000° K) allowed for true colour high definition video of the benthic flora and fauna. This system was not live view so was set to record at the surface then quickly downloaded on recovery and backed up on hard drives. A small autonomous SeaBird pressure/temperature recorder was also attached to the 4K cage for this mission. Each photo is approximately 0.42 square meters in area.

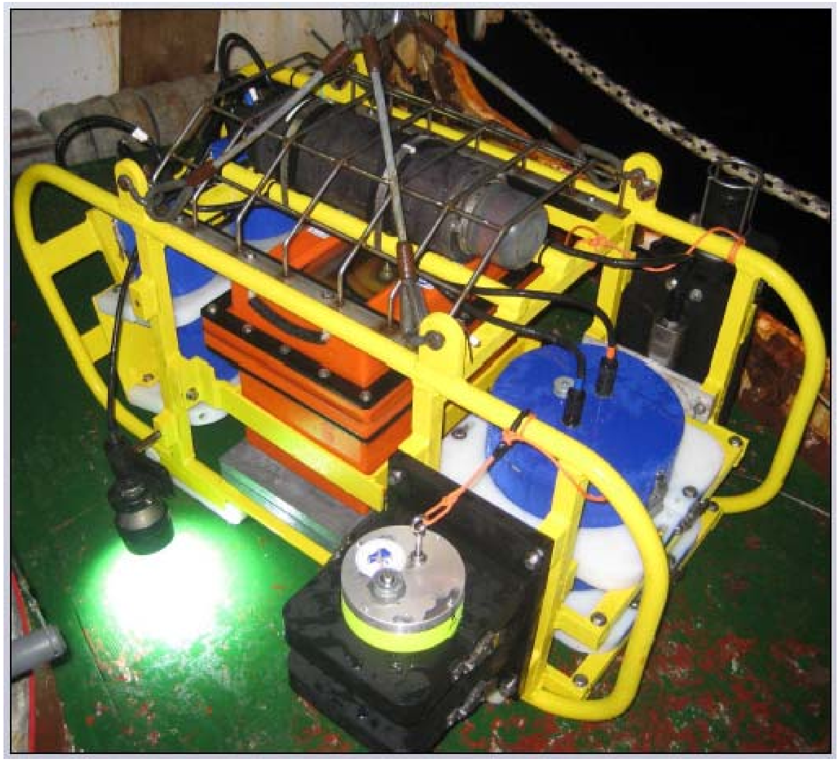


Figure 1a.13. The 4K camera system (4KCam) used to conduct the in situ benthic surveys in the Sackville Spur area was built by the Geological Survey of Canada (GSCA).

Six transect lines were completed in the Sackville Spur area. Two transect lines (Con 11 and Con 12, Figure 1a.14, Table 1a.4) were planned to run from the shallow water to the deep water, perpendicular to the slope and extending from an unfished area to a fished area. They were situated near large catches of sponge from the EU/Spanish trawl surveys (2005-2007). One of these two transects (Con 11), in going from deep to shallow, passed out of the Sackville Spur Closed Area 6. The third transect line (Con 18) was planned to follow a depth contour in order to assess directional effects of currents on sponge density.

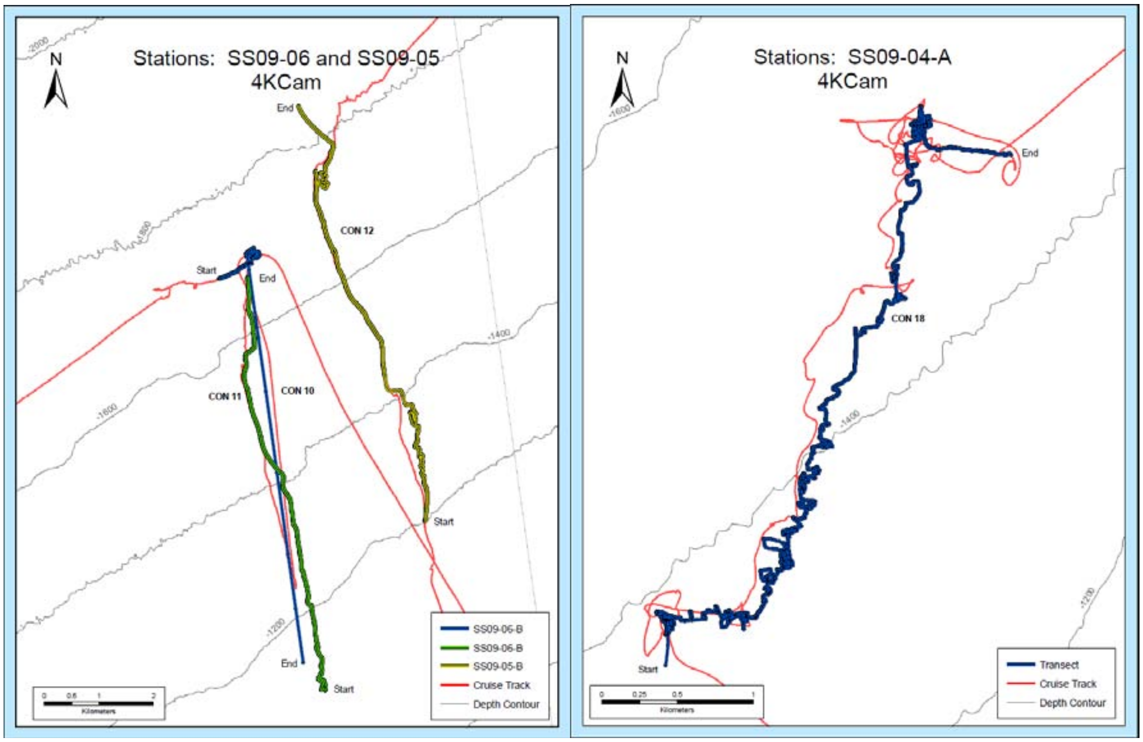


Figure 1a.14. Location of the three benthic transect lines in the Sackville Spur Closed Area 6 for which the photographs have been analyzed for species abundance. Red lines indicate the position of CCGS *Hudson* while thicker lines mark the camera transit.

Table 1a.4. Location, length and number of photos taken and analyzed on each of three transect lines in the vicinity of the Sackville Spur Closed Area.

Event	Start Latitude (DD)	Start Longitude (DD)	End Latitude (DD)	End Longitude (DD)	Transect Length (m)	Depth Range (m)	Total No. Photos (No. Analyzed)
SS-09-06 Con 11	48.319940	-46.55428	48.37352	-46.56174	8986	1103 -1542	183 (167)
SS-09-05 Con 12	48.353154	-46.52246	48.40004	-46.53897	12046	1312 -1724	215 (172)
SS-09-04-A Con 18	48.535330	-46.03735	48.56270	-46.01667	14132	1377-1477	128 (99)

The position of these three transect lines is indicated in Figure 1a.15 relative to the closed area and a 5 km buffer zone around it, and to the rock dredge samples (Section 2.1). A total of 526 photos were taken on these three lines (Table 1a.5), however some of these were taken close to one another and some did not sit properly on the bottom. A subset of photos (N=438) was analyzed with no photo closer than 10 m to its' neighbour. In addition, approximately 17 hours of video was shot on these six plus one additional transect in the closed area. Video data has not yet been analyzed.

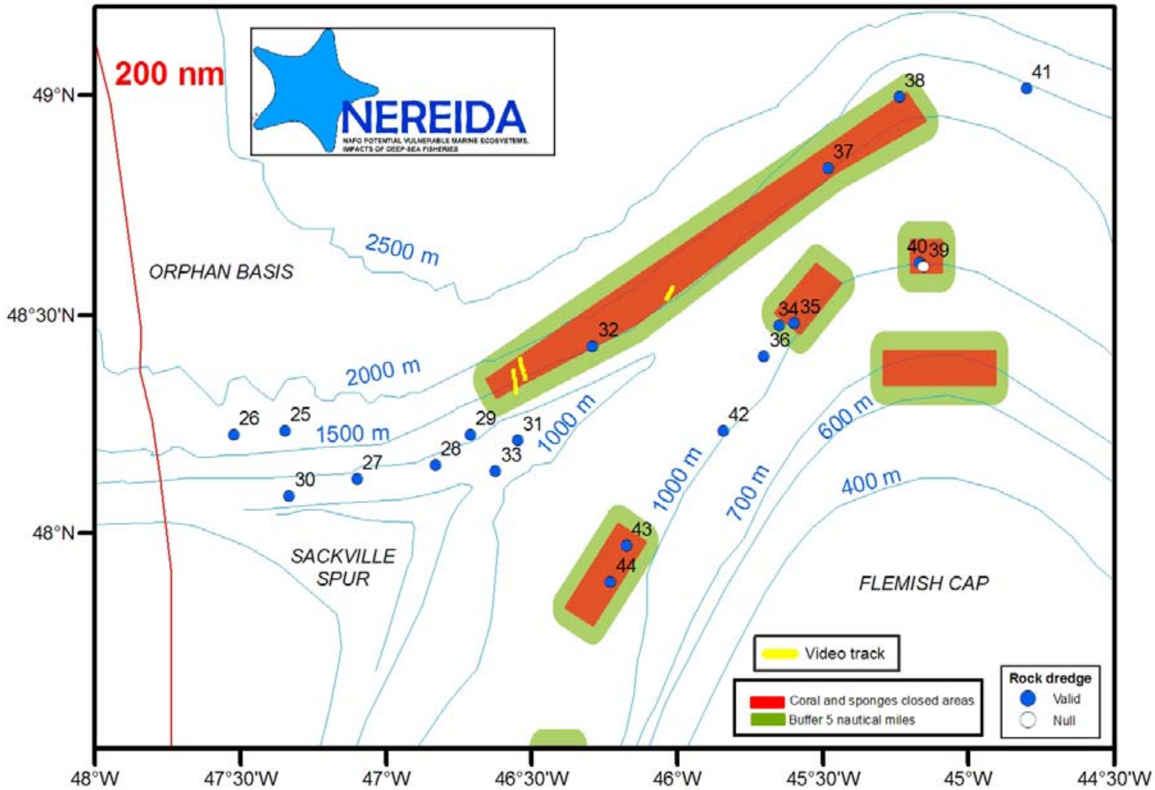


Figure 1a.15. Position of the three benthic photographic transect lines (yellow) completed with the 4KCam from CCGS Hudson in 2009 as part of the NEREIDA project. Blue dots indicate the position of rock dredge samples (see previous section).

Three transect lines, conducted in the northeastern portion of the Sackville Spur Closure Area 6 have not yet been processed. Their position and information on the numbers of photos on each line are provided in Figure 1a.16 and Table 1a.5. It is expected that these will be analyzed by March 2011 at which time a full analysis of these data will be conducted.

Table 1a.5. Location, length and number of photos taken on each of three transect lines in the Sackville Spur Closed Area

Event	Start Latitude (DD)	Start Longitude (DD)	End Latitude (DD)	End Longitude (DD)	Transect Length (m)	Number of Photos
SS-09-02-A Con 24	48.801516	-45.522337	48.827511	-45.527662	13652	183
NSS09-03-B Con 25	48.763496	-45.634056	48.773416	-45.620149	6666	31
NSS09-03 Con 26	48.790528	-45.585539	48.816504	-45.542352	15648	81

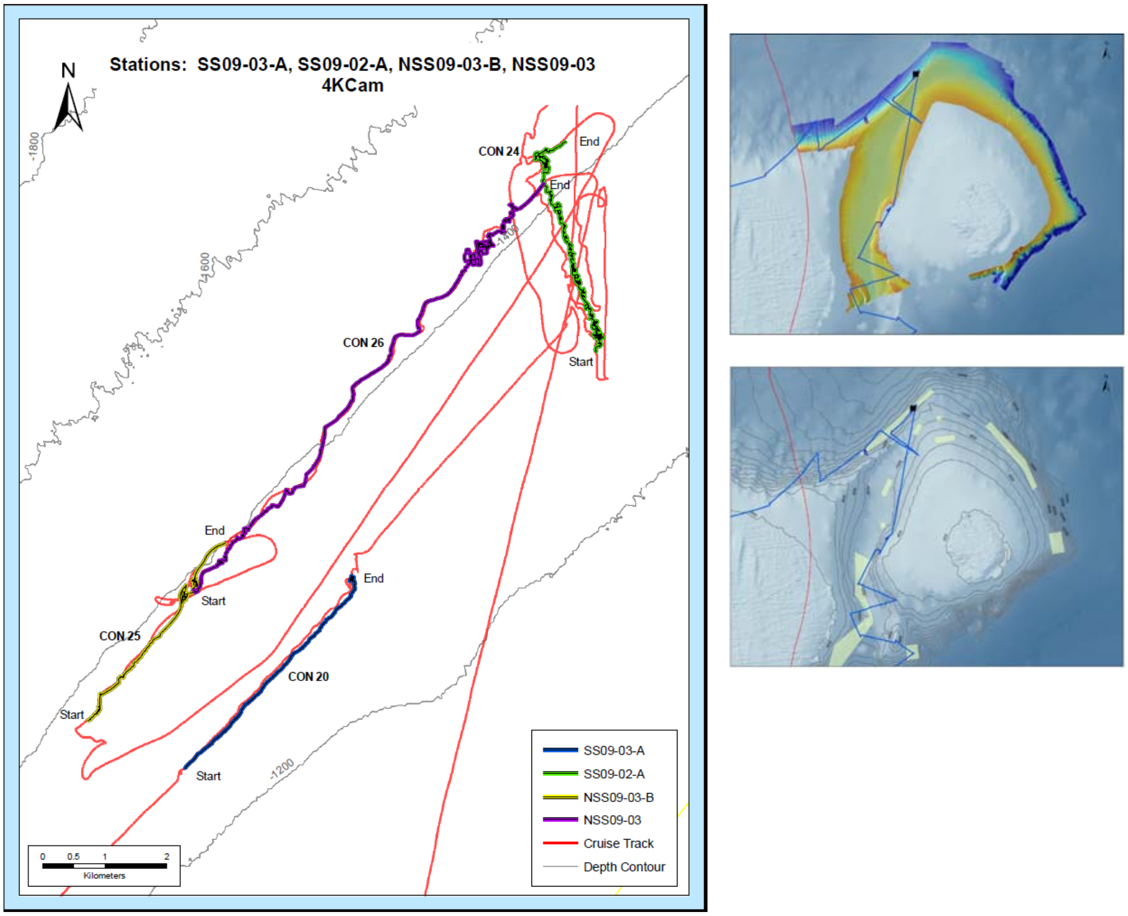


Figure 1a.16. Location of the three benthic transect lines (left) in the northeastern portion of the Sackville Spur Closed Area 6 (right, black box) for which the photographs have not yet been analyzed for species abundance. Red lines on left indicate the position of CCGS *Hudson* while thicker lines mark the camera transit. Con 20 was a video survey line only.

1a.2.2.1. Biodiversity in the Sackville Spur

The Sackville Spur Sponge Grounds is a very diverse area, with nine phyla observed in the photographs from the 3 transect lines detailed in Figure 1a.16and Table 1a.5 above. Most phyla were observed both within the Sackville Spur Closed Area 6 and in the 5 km buffer zone outside of it (Figure 1a.15), with three exceptions: Ecotoprocta, Nermertea and Protozoa were not seen outside of the closed area (Table 1a.6). A total of 348 taxa were observed (Table 1a.6), with 333 seen inside the closed area and 86 outside. Some of this discrepancy in the number of taxa inside and outside of the closure is due to unequal sampling. The majority of the photographs were taken inside the Closed Area (N= 362) with only 16% falling outside of it (N=69). Further, the species accumulation curves for each of the lines were not saturated, although they were approaching the asymptote. This means that this list is not exhaustive for each transect line and further sampling would have identified more taxa. Nevertheless, the three transect lines together did produce a saturated taxon accumulation curve and so these data may be used to describe the fauna of the closed area in a general sense. Both areas showed evidence of biogenic habitat created by depressions, silt accumulation, burrows, tubes and filaments, although this was more common inside the closed area than outside (Table 1a.7).

Table 1a.6. Number of taxa by phylum for the three transect lines detailed in Table 1a.1 combined and for the portion of those lines inside and outside of the Closed Area 6.

Phylum	Total Number of Taxa Observed	Inside	Outside
Unidentified	141	141	29
Porifera	77	77	9
Cnidaria	40	30	20
Echinodermata	34	33	9
Mollusca	19	17	11
Arthropoda	18	18	5
Ectoprocta	6	6	
Annelida	5	4	1
Chordata	4	3	1
Brachiopoda	2	2	1
Nemertea	1	1	
Protozoa	1	1	

Table 1a.7. Number of observations of biogenic habitat and boulders for the three transect lines detailed in Table X1 for the portion of those lines inside and outside of the Closed Area 6.

Substrate	Inside	Outside
Boulders	1	
Castings	151	46
Silt balls	100	
Tracks	57	
Amphipod Filaments	94	63
Tubes Type 1	145	1
Tubes Type 2	144	12

Many taxa could not be identified from the photographs, which is one of the problems with photo-identification. Of the 348 taxa, 141 (40.5%) could not be identified and will contain some redundancy in identification. In general, these were small organisms that did not provide sufficient information in their features to be classified to a phylum. Of the identified taxa, the Porifera were the most diverse with 77 taxa observed (Table 1a.6).

Biodiversity, expressed as the number of taxa observed, shows a strong pattern with depth from the surface (Figure 1a.17). Between 1100 and 1300 m the number of taxa is relatively constant. However below 1300 m there is an increase in biodiversity with depth. This seems to continue to about 1600 m (Figure 1a.17, Con 12) where it stays the same or is slightly reduced. Within a narrower depth band, this relationship is not as strong (Figure 1a.18).

Figure 1a.19 shows this relationship between biodiversity and distance along the transect line in graphs where the photos are arranged in context of their relative position along the transect lines. The relationship between this distance and depth is positive and strong for all three transects (not shown) and so this distance is a proxy for water depth below the surface.

The increase in biodiversity with depth is not simply a function of depth. Figure 1a.20 illustrates the linear relationship between biodiversity (excluding sponge taxa) and the abundance of sponges (Porifera). As first approximation, a linear regression was applied to each dataset and the model equations are provided. All regressions explained a significant proportion of the variance in the data. These relationships are very strong and positive in the data from all three transect lines, including Con 18 where depth ranged only by 100 m. Therefore we conclude that the sponge grounds appear to be responsible for the biodiversity in the Sackville Spur area and, if the underline relationship is well represented by these linear equations, we could expect that if the sponge grounds are lost, biodiversity could be reduced by 50% or more to 20 taxa or less (see intercepts of lines in Figure 1a.20). The Porifera taxa which could be identified below the phylum level are indicated in Table 1a.8.

Table 1a.8. Sponge taxa identified from photos from the transect lines on Sackville Spur.

Asconema ~ foliata	*Phakelia ~ ventillabrum*
Cladorhiza concrescens	*Polymastia* spp.
Cladorhizidae (F.) spp.	Axinellidae (F.) spp.
Geodia ~ barretti	*Stylocordyla* spp.
Geodia sp.	*Tetilla cranium*
Oceanapia spp.	
Pachastrellidae (F.) sp. 1	
Phakelia ~ robusta	

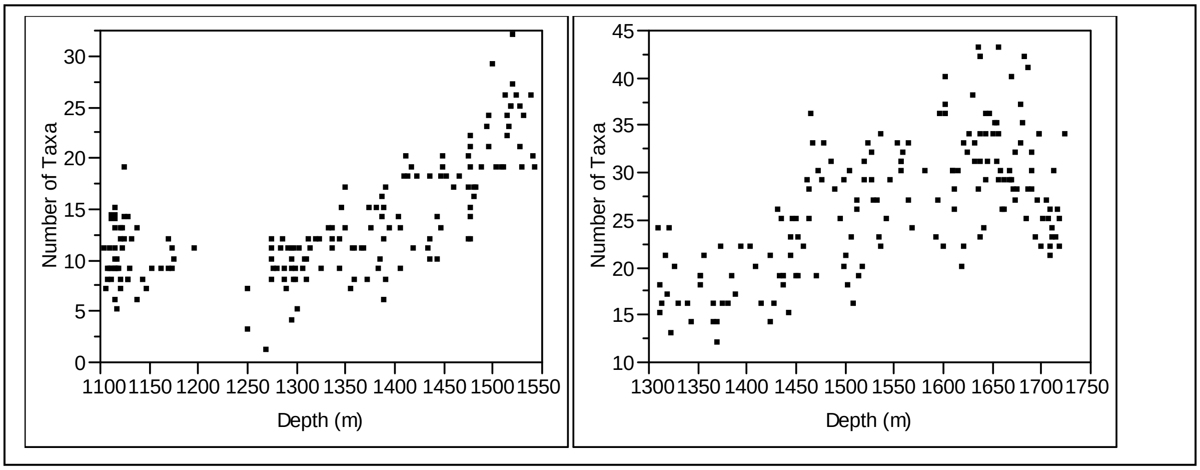


Figure 1a.17. Relationship between depth and the number of taxa observed from photographs taken along the two transect lines on Sackville Spur which run up slope from deep to shallow water (Figure 1a.14, left). Con 11 is depicted on the left, Con 12 on the right.

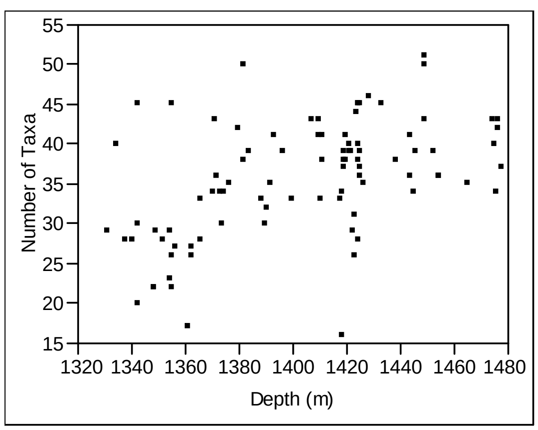


Figure 1a.18. Relationship between depth and the number of taxa observed from photographs taken along the transect line on Sackville Spur which ran along a depth contour from west to east (Con 18, Figure 1a.14, right).

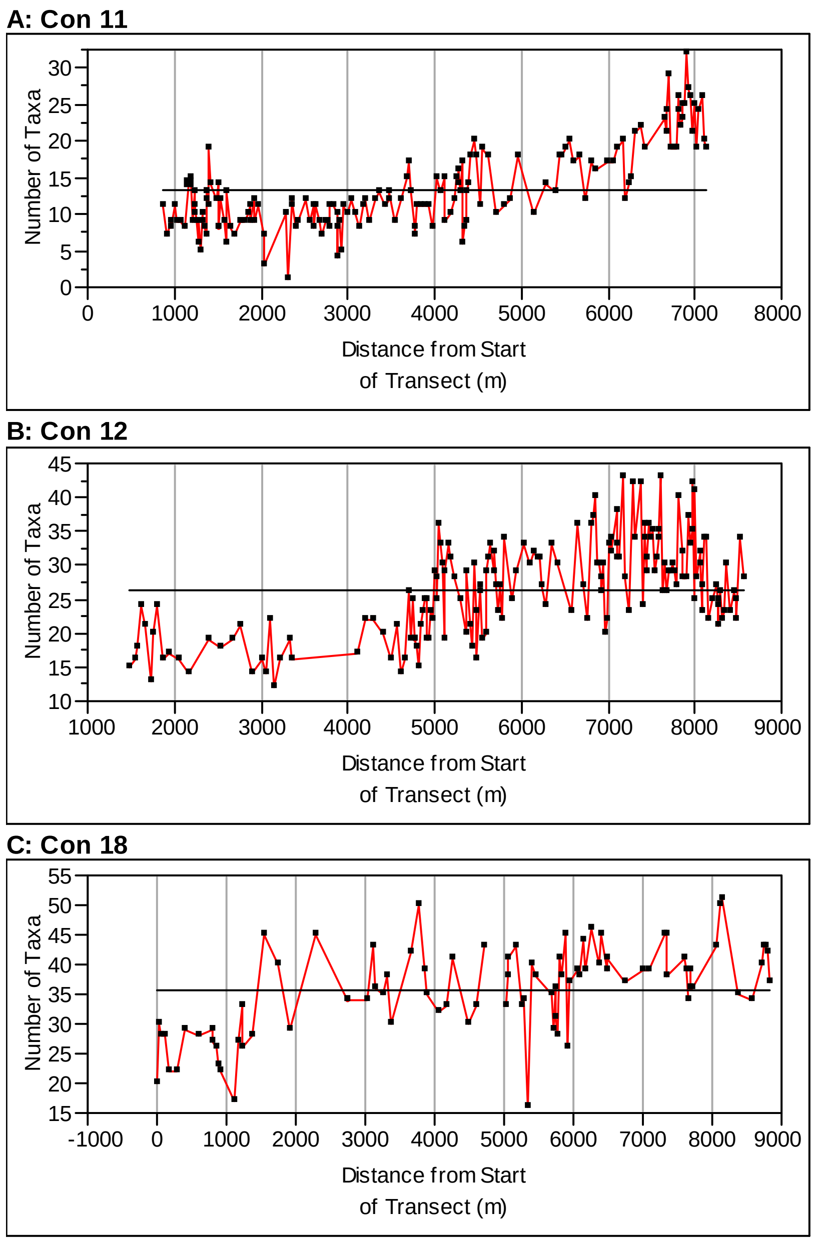
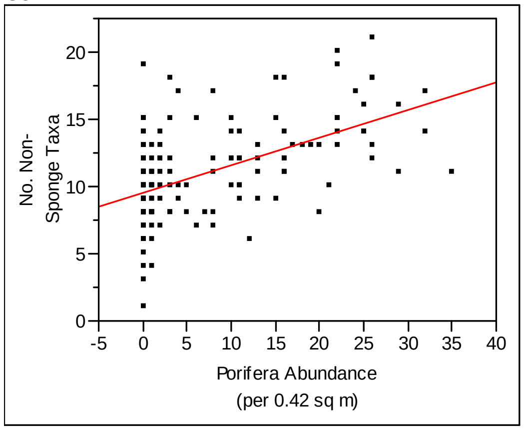


Figure 1a.19. A, B: The number of taxa in relation to the distance from the start of the transect line in the shallow water to the end in the deeper water. C: The number of taxa in relation to the distance from the start of the transect line running from west to east at between 1377 and 1477 m depth.

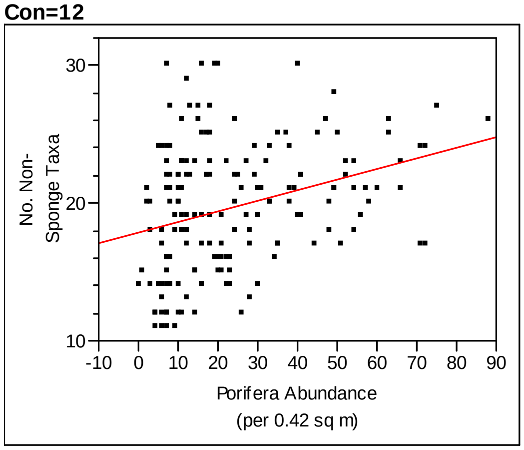
Con=11



Linear Fit

No. Non-Sponge Taxa = 9.5514295 + 0.2047507 Porifera Abundance (per 0.42 sq m)

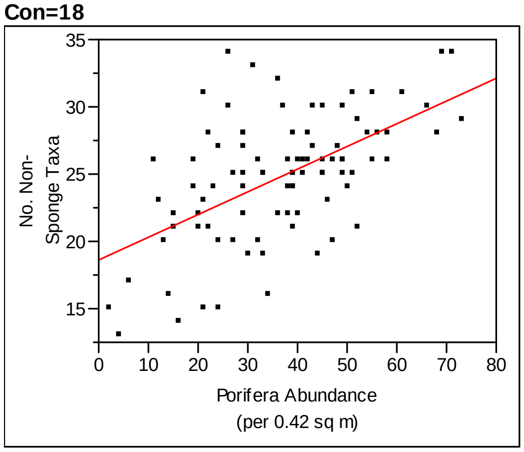
Con=12



Linear Fit

No. Non-Sponge Taxa = 17.858224 + 0.0765881 Porifera Abundance (per 0.42 sq m)

Con=18



Linear Fit

No. Non-Sponge Taxa = 18.608104 + 0.1687218 Porifera Abundance (per 0.42 sq m)

Figure 1a.20. The positive relationship between the abundance of sponge (Porifera) and the total number of taxa observed (Biodiversity) excluding sponge taxa. For each of the three transects on Sackville Spur (Figure 1a.14). A linear regression was applied to each dataset and the model equations are provided. All regressions explained a significant proportion of the variance in the data.

A generalized linear model (GLM) was applied to this data to determine the relative effects of sponge abundance (Porifera), water depth and their interaction in determining the Number of Non-Sponge Taxa (i.e., species richness or biodiversity). These two factors are not linearly related (Figure 1a.21).

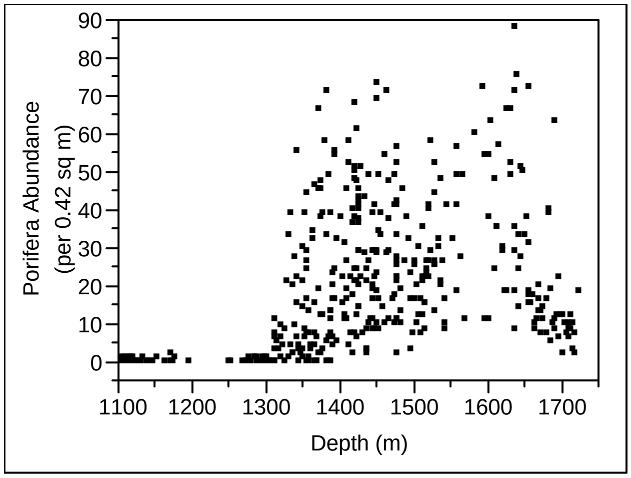


Figure 1a.21. Relationship between Depth and Porifera Abundance, the independent variables in the GLM analysis.

The GLM was run with the Number of Non-sponge Taxa following a Poisson distribution and used the log link function. We compared the full model that had both factors (sponge abundance and depth) and their interaction with reduced versions of itself, one that just had the two factors and, one minimal model that only had Porifera Abundance. There were significant differences between the full model, and its reduced versions. The greatest difference was found between the full and minimal models (Table 1a.9). The full model fit was also the one that had a well behaved residuals structure (Figure 1a.22). This analysis shows that both depth and sponge abundance are important determinants of the increased biodiversity.

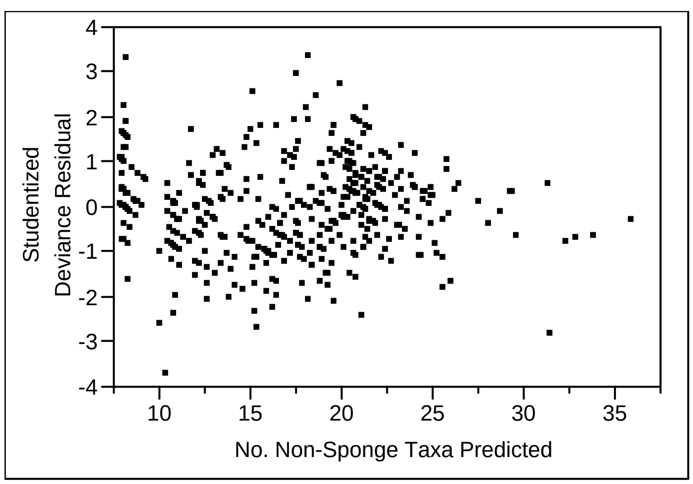


Figure 1a.22. Studentized deviance residual by the predicted variable, the Number of Non-Sponge Taxa.

Table 1a.9. Generalized Linear Model Fit of the Number of Non-Sponge Taxa using a Poisson distribution and logarithmic link function (N=430).

Comparison between full and minimal models

Model	-LogLikelihood	Chi Square	DF	P-value
Difference	381.946	763.89	3	<.0001
Full (depth+sponge+depth*sponge)	1219.15			
Minimal (sponge)	1601.09			

<u>Details of the Full (depth+sponge+depth*sponge) GLM model fit</u>

Goodness Of Fit Statistic	ChiSquare	DF	P-value
Pearson	453.72	426	0.17
Deviance	455.08	426	0.16

Effect Tests

Source	DF	Chi Square	P-value
Porifera Abundance (per 0.42 sq m)	1	376.33	<.0001
Depth (m)	1	68.70	<.0001
Depth (m)*Porifera Abundance (per 0.42 sq m)	1	112.83	<.0001

Parameter Estimates

Term	Estimate	Std Error	Chi Square	P-value	Lower CL	Upper CL
Intercept	1.54	0.13	145.11	<.0001	1.29	1.79
Porifera Abundance (per 0.42 sq m)	0.01	0.001	376.33	<.0001	0.01	0.02
Depth (m)	0.001	8.9068e-5	68.70	<.0001	0.001	0.001
(Depth (m) - 1430.61) * (Porifera Abundance (per 0.42 sq m) - 19.9349)	-4.6521e-5	4.4844e-6	112.83	<.0001	-5.535e-5	-3.777e-5

1a.2.2.2. Comparison of benthic community composition inside and outside of the Sackville Spur Closed Area

One of the three transect lines (Con 11) crossed from the Closed Area into the Fished Area of Sackville Spur. This transect contained 98 photos from within the Closed Area and 69 from Outside. The species accumulation curves for each of these areas were not asymptotic (Figure 1a.23), indicating that increased sampling effort would identify more species in each of the areas. Therefore this section deals with the nominal diversity of this area which is expected to be an underestimate of the actual biodiversity of the area.

Inside Closed Area (N=97) **Outside Closed Area (N=69)**

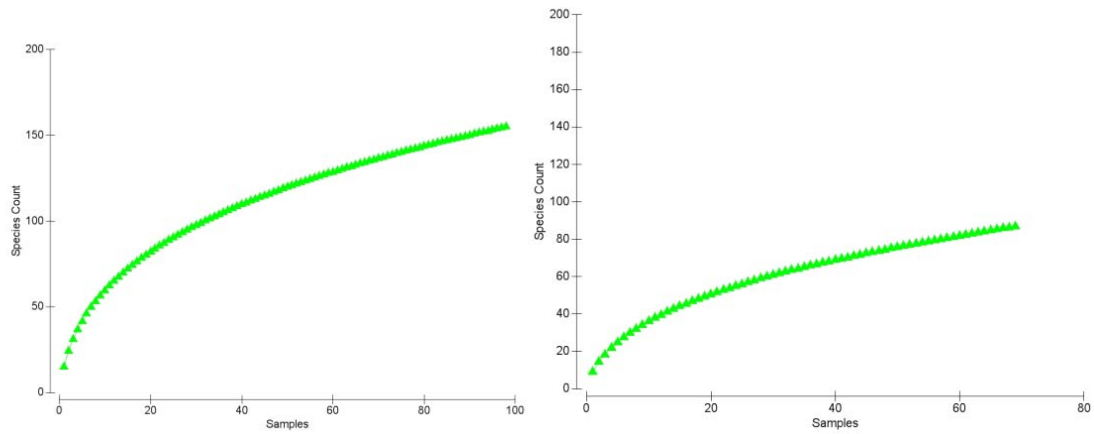


Figure 1a.23. Species accumulation curves for Con 11, a benthic photo-transect line running from deep to shallow water on Sackville Spur. The left panel shows the curve for photos from inside the Sackville Spur Closed Area, while the right panel shows the curve for photos from outside the Closed Area. Note small differences in the scales of the X and Y axes.

The abundance data for this transect were both log10- and presence/absence-transformed and a Bray-Curtis similarity matrix was constructed for each transformation using PRIMER software. These matrices were visualized using a MDS ordination plot in 2 dimensions, with samples labelled according to whether they were inside or outside of the Closed Area (Figure 1a.24). Both visualizations show that the two areas are not very similar to one another. Analyses of Similarity (ANOSIM) of both data sets produced a highly significant effect of Area (levels: Inside or Outside) with P-values < 0.001 and explaining 85.5% and 68.4% of the variance in the data respectively.

The similarity within and dissimilarity between the two areas was compared for both types of transformation of the data using the SIMPER routine in PRIMER (Table 1a.10). In both cases there was greater dissimilarity between the areas than similarity within.

Table 1a.10. Similarity of benthic communities inside and outside of the Sackville Spur Closed Area.

Transformation	Average % Similarity Inside Closed Area	Average % Similarity Outside Closed Area	Average % Dissimilarity between Inside and Outside Closed Area
Log-10 Abundance	41.16	53.98	83.14
Presence - Absence	38.80	39.83	77.83

The taxa list contributing most to the dissimilarity between the areas was large in both cases. For the log10-transformed data 55 taxa contributed to 90% of the dissimilarity (Table 1a.8), while for presence/absence data 81 taxa contributed to this level of dissimilarity. Clearly these differences are at the community level and not merely a redistribution of a few species.

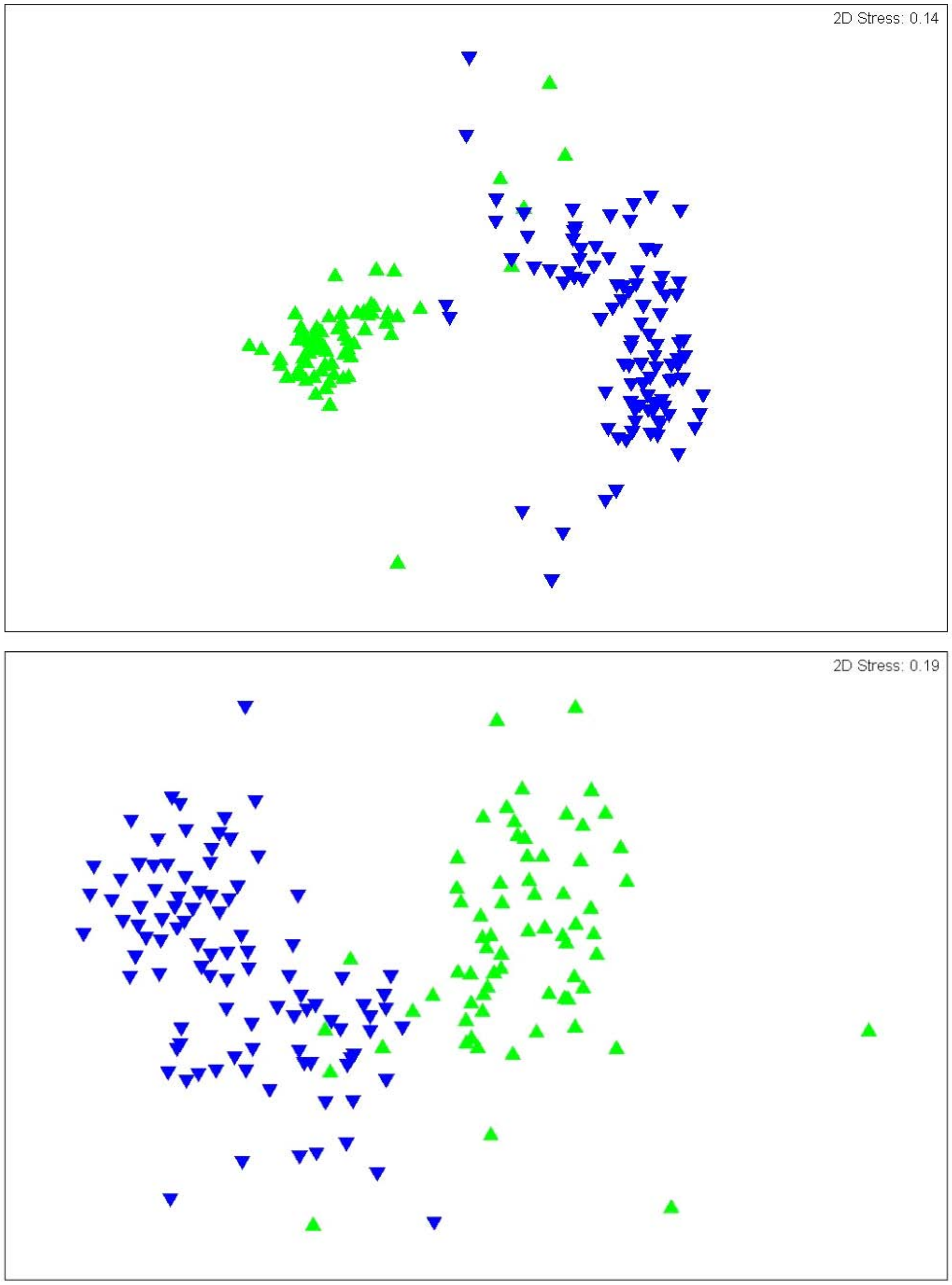


Figure 1a.24. MDS ordination of Bray-Curtis similarity of benthic communities inside (blue) and outside (green) the Sackville Spur Closed Area. Top: Abundance data Log10-transformed. Bottom: Presence-absence data.

Table 1a.11. Taxa contributing to 90% of the 83% dissimilarity in log10-transformed abundance of benthic taxa found Inside and Outside of the Sackville Spur Closed Area.

Taxa	Outside Average Abundance	Inside Average Abundance	Average Dissimilarity	Diss/SD	Contribution %	Cumulative %
Amphipoda (O.) _ Polychaeta (C.) spp.	5.55	0.11	18.01	2.25	21.66	21.66
Holothuroidea (C.) sp. 1	0.08	2.84	9.06	2.02	10.89	32.55
Ophiacantha anomala	0.72	2.12	4.98	1.73	5.99	38.54
Porifera (P.) sp. 12	0	1.23	3.67	1.19	4.41	42.95
Eurycope sp. 1	1.32	1.08	2.64	1.19	3.17	46.12
Unidentified 5	0.96	0.9	2.54	1.22	3.05	49.17
Unidentified 58	0	0.72	2.12	0.82	2.55	51.72
Porifera (P.) spp.	0.01	0.64	1.86	0.86	2.24	53.96
Rhizocrinus lofotensis	0.02	0.58	1.8	1	2.17	56.12
Dentalium spp.	0.45	0.08	1.47	0.87	1.77	57.9
Porifera (P.) sp. 18	0	0.51	1.34	0.73	1.61	59.51
Unidentified 21	0.3	0.25	1.31	0.78	1.58	61.09
Ophiuroidea (C.) spp.	0	0.4	1.24	0.68	1.49	62.57
Boreomysis spp.	0.34	0.08	1.2	0.78	1.44	64.02
Porifera (P.) sp. 17	0	0.46	1.18	0.64	1.42	65.44
Ophiomusium lymani	0.12	0.3	1.07	0.78	1.29	66.73
Porifera (P.) sp. 8	0.01	0.37	1.07	0.63	1.28	68.01
Polynoidae (F.) spp.	0.24	0.17	1.03	0.7	1.24	69.25
Unidentified 25	0.13	0.28	1.03	0.75	1.24	70.49
Unidentified 24	0.16	0.13	0.87	0.61	1.04	71.53
Hydrozoa (C.) sp. 1	0.26	0	0.83	0.51	1	72.53
Unidentified 48	0	0.27	0.81	0.59	0.97	73.5
Porifera (P.) sp. 68	0	0.29	0.79	0.64	0.95	74.45
Unidentified 3	0.23	0.01	0.76	0.54	0.91	75.36
Actiniaria (O.) sp. 2	0.24	0	0.74	0.42	0.89	76.25
Bivalvia (C.) spp.	0.04	0.18	0.69	0.49	0.83	77.09
Unidentified 4	0.21	0	0.67	0.53	0.8	77.89
Brachiopoda (P.) spp.	0.01	0.17	0.62	0.52	0.75	78.63
Nemertea (P.) spp.	0.12	0.08	0.61	0.54	0.73	79.37
Nephtheidae (F.) sp. 1	0.03	0.22	0.61	0.49	0.73	80.1
Unidentified 17	0.11	0.08	0.56	0.53	0.68	80.77
Ophiuroidea (C.) sp. 1	0.08	0.11	0.49	0.47	0.59	81.37
Unidentified 61	0	0.16	0.47	0.42	0.56	81.93
Ophiuroidea (C.) sp. 2	0	0.16	0.42	0.4	0.51	82.44
Phakelia ~ ventillabrum	0	0.15	0.39	0.43	0.47	82.91
Unidentified 1	0.03	0.11	0.39	0.44	0.47	83.38
Buccinidae (F.) sp. 2	0.08	0.05	0.39	0.42	0.46	83.85
Ectoprocta (P.) sp. 1	0	0.13	0.36	0.4	0.44	84.28
Actiniaria (O.) sp. 4	0.12	0	0.36	0.42	0.43	84.71
Porifera (P.) sp. 5	0.01	0.08	0.34	0.3	0.41	85.12
Unidentified 2	0.11	0	0.33	0.34	0.39	85.52
Geodia sp.	0	0.13	0.32	0.41	0.38	85.9
Pentacrinus sp. 1	0.01	0.07	0.31	0.3	0.37	86.27
Ectoprocta (P.) spp.	0	0.12	0.3	0.39	0.36	86.63

Unidentified 8	0.07	0.04	0.3	0.36	0.36	86.99
Unidentified 23	0.09	0	0.29	0.37	0.35	87.34
Porifera (P.) sp. 9	0	0.08	0.28	0.29	0.34	87.68
Nephtheidae (F.) sp. 3	0.03	0.08	0.28	0.37	0.34	88.02
Gastropoda (C.) spp.	0	0.07	0.28	0.32	0.33	88.35
Nephtheidae (F.) sp. 2	0.04	0.07	0.27	0.34	0.32	88.67
Cladorhizidae (F.) spp.	0.07	0.01	0.26	0.35	0.31	88.99
Aporrhais occidentalis	0.03	0.05	0.26	0.34	0.31	89.3
Bathysiphon spp.	0	0.09	0.25	0.3	0.3	89.6
Astarte sp.	0.07	0	0.24	0.29	0.29	89.89
Unidentified 27	0.05	0.01	0.21	0.28	0.25	90.14

1a.3. NEREIDA 0609 Survey Rock Dredge Samples

Table 1a.12 shows the total catch and percentage based on wet weight and abundance of the different phyla of invertebrates captured in NEREIDA 0609 survey.

Table 1a.12. Total catch and percentage based on wet weight and abundance of the different phyla

	WET WEIGHT		ABUNDANCE	
TAXON	kg	%	NUMBER	%
PORIFERA	9.524	75.40	193	5.01
CNIDARIA	1.466	11.61	301	7.82
ANNELIDA	0.530	4.20	2,620	68.07
MOLLUSCA	0.754	5.97	509	13.22
ECHINODERMATA	0.234	1.85	115	2.99
SIPUNCULA	0.041	0.32	38	0.99
ARTHROPODA	0.037	0.29	48	1.25
ASCIDIACEA	0.036	0.29	8	0.21
BRYOZOA	0.005	0.04	5	0.13
NEMERTINA	0.004	0.03	12	0.31
TOTAL	12.631		3,849	

Sponges, mainly from the family Geodiidae (Figure 1a.25), dominated the deeper rock dredge sites of the northern parts of Flemish Cap and Flemish Pass/Sackville Spur (i.e. RD32, RD37 and RD38).

Figure 1a.25. Examples of Geodiidae sponges collected from rock dredge sites RD32, RD37, and RD38.

Other sponges were documented in rock dredges, such as species from the genera *Tentorium* and *Stylocordyla*, and the family Cladorhizidae and Euplectellidae (see Figure 1a.26).

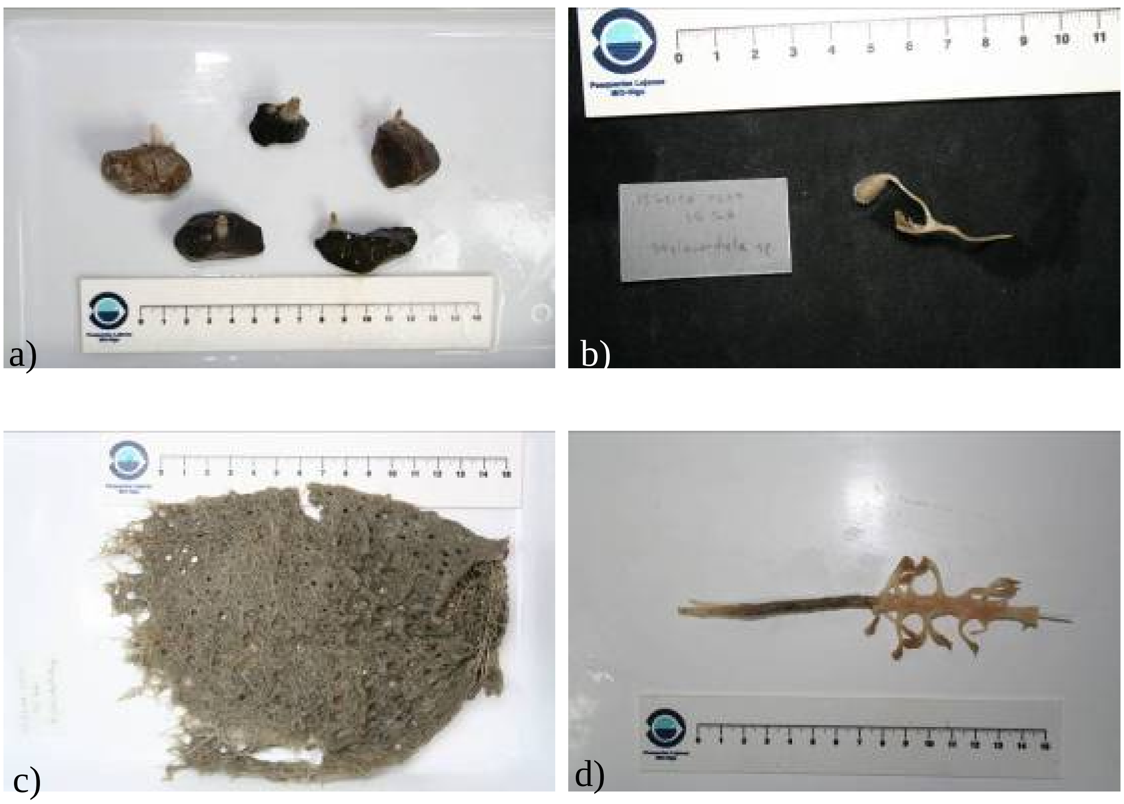


Figure 1a.26. Examples of other sponges sampled with rock dredge included; a) *Tentorium* sp.; b) *Stylocordyla* sp.; c) Euplectellidae indet., and d) Cladorhizidae indet.

For the entire NEREIDA 0609 survey, the second dominant group in terms of wet weight was the cnidarians, primarily sea anemones belonging to the family Hormathiidae. Most of these samples were documented in Flemish Pass and on Flemish Cap, with no records within the Sackville Spur closed area. Soft corals, such as *Duva florida*, were observed attached to different rocks.

Other anthozoa found include soft corals (*Anthomastus* sp. and *Drifa* sp.), gorgonians (*Acanella arbuscula*), sea pens (*Virgularia mirabilis*, *Pennatula aculeata*, *Anthoptilum* sp., *Protoptilum* sp. and *Halipteris finmarchica*), and antipatharian (*Stauropathes arctica*). Hydrozoa were also captured, mainly the genera *Cladocarpus, Aglaophenia,* and *Tamarisca* (Figure 1a.27).

Figure 1a.27. Cnidarians sampled during NEREIDA 0609 survey include, a) *Actinauge* sp.; b) *Duva florida*; c) *Acanella arbuscula*; d) *Pennatula aculeata*; e) *Stauropathes arctica*; and f) *Cladocarpu*s sp.

For the entire NEREIDA 0609 survey, the next dominant phylum was the annelids (Figure 1a.28). This phylum had the greatest biomass. It was the most important in terms of abundance due to the large number of polychaetes, mainly Eunicidae and Sabellidae, sampled in the rock dredge site immediately adjacent to the Sackville Spur closure (i.e. RD29), as well as other sites located further west of the closure (i.e., RD26, RD27, RD28 and RD30). Most sites sampled soft sediment substrates, which may account for this dominance.

Eunicidae family was represented mainly by *Onuphis opalina* and *Maldani sarsii* polychaetes sampled from the Sackville Spur-outside of the closure area (i.e. RD29). Other families sampled include: Chaetopteridae, Ampharetidae, Lumbrineridae, Polynoidae, Terebellidae, Nephtyidae, Goniadidae, Nereididae, and Dorvilleidae.

Figure 1a.28. Polychaetes sampled during NEREIDA 0609 survey; a) *Maldane sarsii*; b) *Eunice pennata*; c) Sabellidae indet.; and d) Polynoidae indet.

For the NEREIDA survey molluscs had 6% dominance for biomass and 13% in terms of abundance. It is important to note the presence of the several species of bivalves *Astarte* sp., *Nuculana* sp., and gastropods *Buccinum* sp. and *Colus* sp. (see Figure 1a.29).

Figure 1a.29. Molluscs captured during NEREIDA 0609 survey. a) *Astarte* sp., and b) *Buccinum* sp.

Echinoderms had little representation in this survey and yielded only 2-3% in terms of wet weight and abundance. The main species found were the asteroids *Ceramaster granularis*, *Madiaster bairdi*, *Hippasteria phrygiana*, *Pseudarchaster* sp., ophiuroids *Gorgonocephalus lamarckii, Ophiomusium limany,* sea urchin *Brisaster fragilis,* and sea cucumber *Psolus* sp. (see Figure 1a.30).

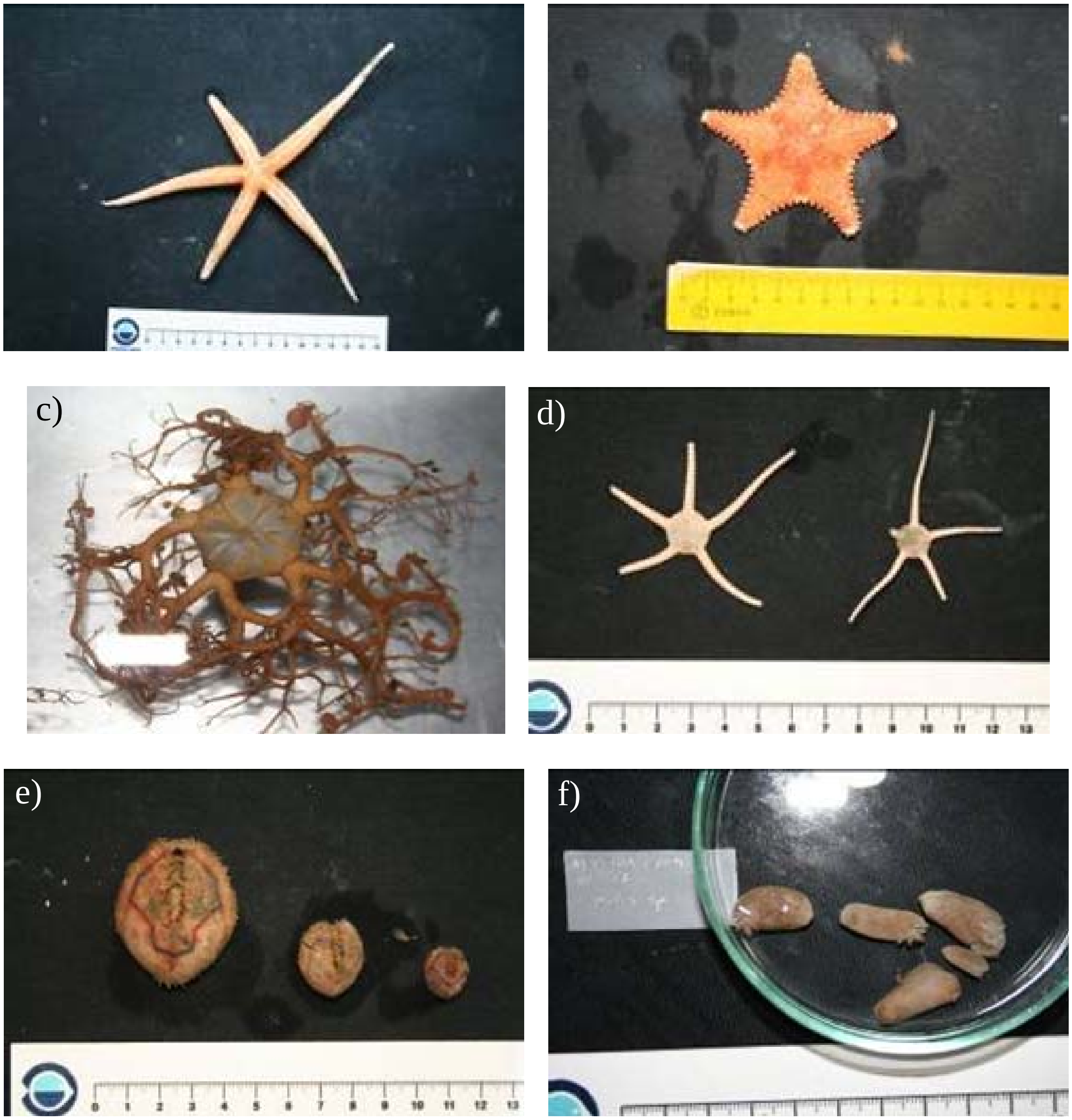


Figure 1a.30. Echinoderms sampled during NEREIDA 0609 survey; a) *Zoroaster fulgens*; b) *Hippasteria phrygiana*; c) *Gorgonocephalus lamarckii*; d) *Ophiomusium lymani*; e) *Brissaster fragilis*; f) *Psolus* sp.

Other organisms were sampled in smaller quantities and only accounted for 1% of dominance in terms of biomass and 3% with respect to abundance. Species sampled include the phyla Arthropoda, Bryozoa, Chordata, Sipuncula, and Nemertea.

Most rock dredge sites sampled were conducted on soft substrates with few rocks collected (i.e. RD29, RD28, RD27, RD26). Most rocks showed no signs of invertebrate colonization. However, some rock samples did contain epifauna that were dominated by hydroids, bryozoans, anemones, and juvenile *Duva florida* (see Figure 1a.31).

Figure 1a.31. Rock sample collected in RD28 showing diverse epifauna.

1a.4. Flemish Cap dives conducted on the 2010 CCGS Hudson NEREIDA Cruise

In July 2010 a 28 day multi-disciplinary Canadian research cruise was conducted utilizing the Remotely Operated Platform for Oceanographic Science (ROPOS).

Target areas for study included; The Gully Marine Protected Area on Scotian Shelf, Flemish Cap, and the Orphan Knoll Seamount. Five dives were conducted at three general areas on Flemish Cap: south, east, and northeastern edges. Site selection was based primarily on NERIEDA survey data (geological and biological) collected in 2009, as well as proximity to current NAFO closures. The purpose was to collect information on corals and sponges from areas that could not be samples with the research vessel trawls because of bottom topography to both 1) provide further description of the NAFO closed areas using *in situ* benthic surveys and 2) provide baseline data for areas outside of the NAFO fishing footprint for evaluating Exploratory Fishing requests.

All dive transects moved upslope to maximize HD video from the forward and downward facing cameras of the remotely operated vehicle ROPOS. Conductivity, Temperature and Depth (CTD) casts, McLane water pump samples, as well as push cores were also collected at all dive sites.

1a.4.1. Flemish Cap South

Two dives were successfully completed on Flemish Cap south (Dive R1335, R1336; Figure 1a.32). The primary objective of Dive R1335 was to investigate a steep ridge. Dive commenced at 1840 m and concluded at 875 m. Samples collected included corals (*Acanella*, and living and dead *Desmophyllum dianthus*), sponges (vase and encrusting), and rocks (bedrock, sedimentary, and glacial-derived samples). Visual observations documented vertical bedrock faces with abundant solitary cup corals and encrusting sponges.

The second site on Flemish Cap south was dive R1336. The primary objective of this dive was to investigate a large steep incision, which appeared as though it might have been initiated by a soft-sediment slump. Dive commenced at 2900 m and concluded at 2224 m. Diverse assemblages of corals and sponges were observed. Coral specimens collected included gorgonian corals (*Chrysogorgia* spp., *Swiftia* sp., *Narella laxa*, and Isididae spp.), soft corals (*Anthomastus* spp.), scleractinians (*Desmophyllum dianthus*), and pennatulaceans (*Pennatula* cf. *inflata*). Sponge specimens collected included; unique glass sponges (Hexactinellida: stalked, vase, and ruffle types), Geoiidae sponges, and carnivorous sponges (Cladorhizidae). Rock samples indicated the presence of igneous rock, basalt, and glacially transported or ice-rafted debris.

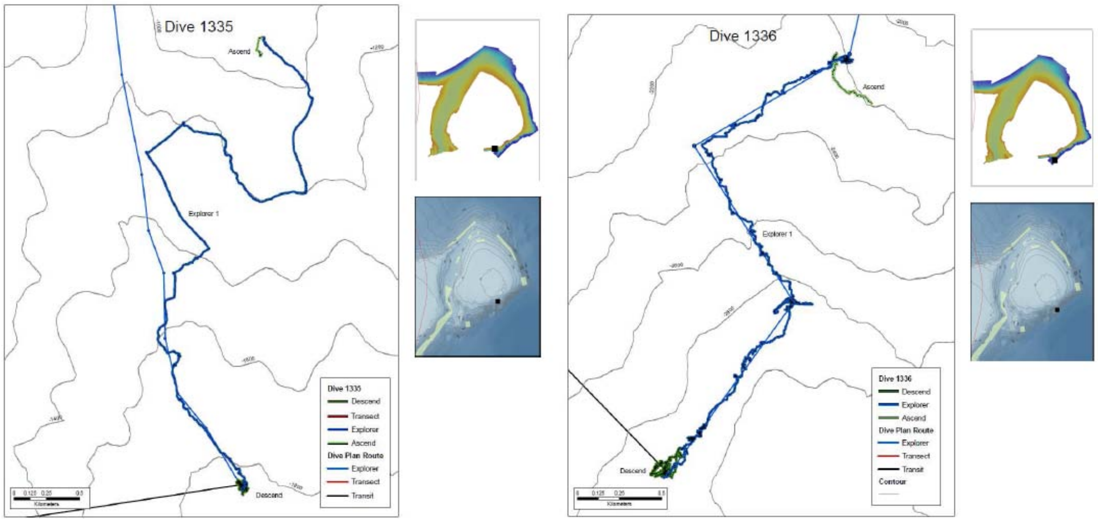


Figure 1a.32. Location of ROPOS benthic transects on Flemish Cap south (Dive R1335 left, R1336 right) conducted on the CCGS *Hudson* 2010 NEREIDA mission. Heavy blue lines are the actual survey tracks on bottom. Insets show the general location of the dive transects relative to the Flemish Cap and to the closed areas on Flemish Cap.

1a.4.2. Flemish Cap East (Closed Area 4)

The next target area focused on the eastern portion of Flemish Cap. Two dives were successfully completed (Dive R1337, R1338; Figure 1a.33). The primary objective of dive R1337 (Figure 1a.34) was to investigate geological features identified in the NEREIDA 2009 multibeam data. Dive commenced at 2195 m and concluded at 1020 m. Vertical outcrops composed of sedimentary bedrock with unbedded igneous rock were observed. Large gorgonian concentrations, *Primnoa resedaeformis* intermixed with other coral species, and large fan sponges were also observed, but sampling was restricted due to the vertical bathymetry. Coral specimens collected included gorgonian corals (*Paramuricea* sp., *Acanthogorgia* sp., *Parastenella atlantica*, *Keratoisis* spp.), soft corals (*Duva florida*, *Drifa* spp.). Sponge specimens collected included large fan-shaped specimens.

The primary objective of the second dive R1338 on eastern portion of Flemish Cap was to investigate trawling impacts. In 2007, an EU research vessel collected 1000 kg of *Geodia* spp. sponge at this dive site. Dive commenced at 1053 m and concluded at 1074 m. Trawl scars were light and difficult to distinguish. Observations of trawl impacts included linear marks in substrate, displaced rocks, and knocked over or tipped coral colonies. In general anecdotal observations of benthic communities, composed of corals (i.e., *Anthomastus* sp., *Pennatula* spp.) and sponges (i.e., *Asconoma foliate*), were sparse compared to initial start of dive and other locations surveyed on Flemish Cap. Further analysis of the data is required to determine if a statistical difference exists. Evidence of other fishing activities was also observed (i.e., lost gear).

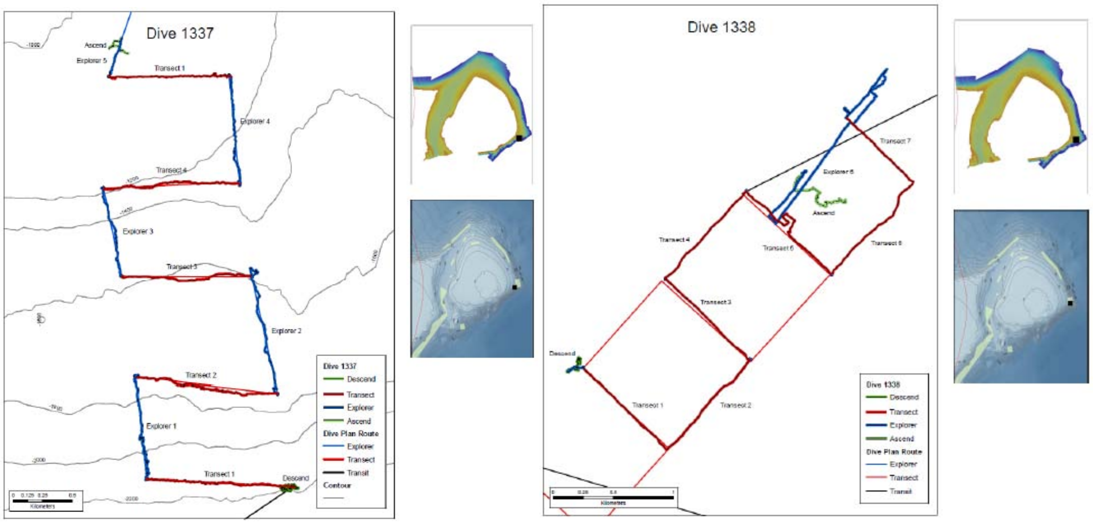


Figure 1a.33. Location of ROPOS benthic transects on the eastern slope of Flemish Cap (Dive R1337 left, R1338 right) conducted on the CCGS *Hudson* 2010 NEREIDA mission. Heavy blue and red lines are the actual survey tracks on bottom. Red lines run along a depth contour while blue lines run perpendicular to depth isobaths. Insets show the general location of the dive transects relative to the Flemish Cap and to the closed areas on Flemish Cap.

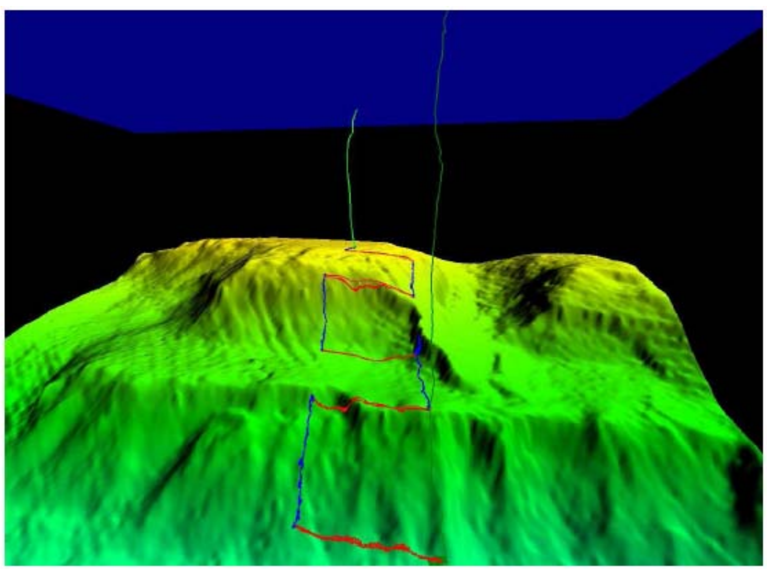


Figure 1a.34. Location of ROPOS benthic transects on the eastern slope of Flemish Cap (Dive R1337) in relation to the three dimensional depth contours provided by the multibeam bathymetric data from the NEREIDA survey.

1a.4.3. Flemish Cap Northeast Prong (Closed Area 5)

The finally target area for Flemish Cap focused on the northeast prong (Figure 1a.35). The primary objective of dive R1339 was to investigate benthic communities within and adjacent to the NAFO closure (Closed Area 5). The dive commenced at 2463 m in deep water outside of the closure and concluded at 1363 m just inside the lower bathymetric boundary of the closure. Geology included thinly bedded sedimentary bedrock outcrops with slopes covered in loose sand, gravel, cobbles, and boulders. This dive was the most interesting in terms of abundance and community diversity of both corals and sponges.

In general, observed communities transitioned from deep to shallower depths commencing with concentrations of corals dominated by Isididae (bamboo) at ~2450 m, to corals (Ellisellidae) intermixed with sponges (Phakellia sp., Geoida spp.) at ~2000 m, followed by extensive concentrations of sponges dominated by Geoida spp. at 1500 m, and concluding the dive with diverse communities composed of sponges, corals (Isididae, Gorgonians) and other benthic groups (e.g. Bryozoans) at ~1300 m. Specimens collected included corals (Ellisellidae sp., Keratoisis spp.), and sponges (Geoida spp., Phakellia sp., Hertwigla sp., Hexactinellida).

Initial dive results suggest that the lower bathymetric boundary of this NAFO closure should be extended into deeper water to the 2500 m contour until a more detailed analysis can be conducted.

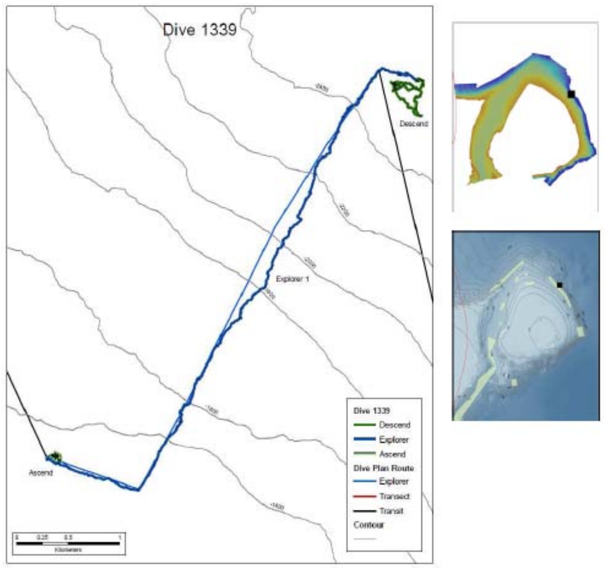


Figure 1a.35. Location of ROPOS benthic transects on the eastern slope of Flemish Cap (Dive R1339) near the northeast prong, conducted on the CCGS *Hudson* 2010 NEREIDA mission. Heavy blue line is the actual survey tracks on bottom. Insets show the general location of the dive transects relative to the Flemish Cap and to the closed areas on Flemish Cap.

1a.5. Corner Rise Seamounts

In September 2010, Scientific Council provided advice on vulnerable marine ecosystems (VMEs) on the seamounts (item 9, FC Doc. 09/17; NAFO, 2009) to the Fisheries Commission. The preliminary work on this response to the FC request was done at the WGEAFM meeting in February, 2010, and the final version of the response was developed at the June 2010 and September 2010 SC meetings, including replies to additional questions posed by FC at the latter meeting. The limited historical data from various studies and fisheries on seamounts, both in the NAFO area and worldwide, were used in developing the SC response. In September of 2010, FC extended the closures of the six identified seamount areas in the NRA, to all bottom fishing activities, until Dec. 31, 2014.

At the current meeting, WGEAFM was presented with additional material on the Corner Rise Seamounts, focused mainly on reported information from Russian research and commercial fisheries. This information added to and addressed some inaccuracies in the material used to provide responses pertaining to seamounts. It was noted that much of the USSR/Russian fishery activity previously documented on the Corner Rise Seamounts was conducted with pelagic trawls, and that the use of bottom trawls were only reported in 1977, and only on Kukenthal peak. Observations from Russian fishers were that the use of pelagic trawls was avoided close to the tops and slopes of seamounts due to a high risk of damage or loss of fishing gear. No Russian fishing activity has been reported on Yakutat seamount, and trawl damage observed in that area was therefore likely caused by other fisheries.

Additional information on alfonsino was reviewed by WGEAFM. Compared with most other deepwater fishes, alfonsino have a relatively short lifespan (up to 14 years) and the species is characterized by higher growth and reproductive rates. Therefore alfonsino may be more resilient to fishing than many other deepsea seamount species.

However, the typically small stock size which characterizes seamount populations, as well as alfonsino aggregation behaviour, makes this species vulnerable to an intensive fishery. As a result pulse fishing for alfonsino is usually observed on the seamounts. It was also observed that juveniles are distributed in the 0-600 m water layer and they are absent between 600-1000 m depth, where commercial fishing for mature alfonsino takes place. However, WGEAFM noted that the response by SC in September, that some seamounts are known to aggregate juvenile fish, is still valid (SCS 10/21, p 13.).

In summary, WGEAFM concluded that the new information had relevance to some specific points in the SC responses to FC requests for advice on seamounts, but that the main conclusions in the previous SC responses were acceptable and did not require modification. The additional data provided will be included in the body of knowledge available for any future advice. Given that the fisheries for deepwater species on the Corner Rise seamounts are currently not regulated, it could be useful if SC eventually was able to develop recommendations concerning the conservation and management measures for deepwater species, although biological data available from many of the seamount areas and species are likely not adequate for this purpose at present.

WGEAFM took the opportunity, on this first attendance of a Russian scientist to one its meetings, to fully recognize the importance of having a broad range of sources and expertise to address its ToRs and specific requests. The working group valued these additional contributions on this topic, and extended an open invitation to scientists with specific expertise (e.g. on deepsea species and seamounts) to participate in future WGEAFM meetings.

1a.6. Conclusions

- Recently acquired quantitative sample data from the Sackville Spur closed area (Area 6) clearly highlights the importance of the sponge ground in contributing to a very diverse benthic community – this evidence supports the appropriateness of maintaining it as a closed area.
- NAFO fishing footprint data for the Sackville Spur (collated between 1987 to 2007) reveals the fishing pressure to be mainly confined to depths above 1,200 m; e.g. 28% at 1,000 m, 26% at 1,100, 22% at 900 m, with only occasional records of fishing having occurred below 1,300 m. Whilst this evidence supports the assertion that other factors (probably natural) are most likely causing the abrupt increase in sponges observed at depths around 1,300m, fishing effects can not be completely ruled out.
- A further investigation of depth related gradients in sponge densities on the Sackville Spur using cores is being considered as a possible survey objective for the Canadian survey programme in 2011. The aim of this would (in part) help to determine the historic extent of sponges on the Spur, through an analysis of possible sponge spicules present in cores from different depths.
- 19 geological/seabed classes were identified covering the whole NEREIDA area and these have been assigned to the biological sample locations to facilitate the classification of seabed habitats/biotopes for the NEREIDA area.
- A further 20 box core samples have been selected from the Flemish Cap area to be considered for sample processing and analysis in 2011.
- The data from the Sackville Spur box core samples will be further analysed and trends in the infauna macrofauna quantified for this area and integrated with existing epifauna data.
- Further funding will be explored by the NEREIDA consortium to allow all sample and data analysis to be completed to address a number of priority questions.
- NAFO FC is reviewing the VME closed areas around the Flemish Cap in 2011, taking into account new information available. NEREIDA has made substantive progress analyzing data for the Sackville Spur closed area but comprehensive information for the remaining areas will not be available this year. Given the large quantity of information and data collected, and the fact that funding for some project participants is currently not available beyond 2011, NEREIDA suggests that a suitable deadline for a review of the remaining closed areas would be 2014. However, this will be conditional on the procurement of additional funding. This particularly applies to scientists participating from Spain and the UK.

- Flemish Cap south and east areas are also very diverse, supporting a mixture of sponges and corals naturally protected from fishing by the geological and topographical features of the seabed in these areas comprising rocky outcrops and overhangs.
- Flemish Cap northeast (NAFO Area 5 closure), as stated above, supports large concentrations of structure forming communities of corals and sponges. Communities were dominated by corals from the Family Isididae, and sponges from the Family Geodiidae-similar to those found in the Sackville Spur closure (Area 6). Initial results from the Hudson 2010 ROPOS cruise suggest that the lower bathymetric boundary of NAFO Area 5 closure is not protecting diverse and abundant coral and sponge communities found in deeper waters. Therefore, the WGEAFM recommends the lower boundary of NAFO Area 5 closure be extended to the 2500 m contour until a more detailed analysis can be conducted.

Based upon the above findings WGEAFM are confident in asserting that the original rationale and basis for identifying and establishing closed areas to protect significant populations of VME sponges and corals was appropriate, and that the closed areas be maintained pending further analysis of site specific survey data.

1a.7. References

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ToR 1b *(towards Roadmap for EAF)*. Delineation of ecoregions in the NAFO area.

1b. Delineation of ecoregions in the NAFO Area

1b.1. Introduction

A necessary element for developing an Ecosystem Approach to Fisheries is to identify the region in space that, in practice, bounds the ecosystem that is intended to be managed in an integrated way. This step is one of the key elements identified in the "Roadmap for EAF" and, as starting point to address it, WGEAFM devoted efforts to delineate ecoregions within the NAFO area. In previous meetings, WGEAFM discussed the work done on this topic in the US Northeast Continental Shelf ecosystems, and began exploring and expanding that type of approach in other NAFO areas (NAFO 2008, NAFO 2010). This work continued during this meeting, including the application of this approach to two areas, the Newfoundland-Labrador shelf and Flemish Cap, where it has not been applied yet.

1b.2. Delineation of ecoregions in the Newfoundland and Labrador Shelves

The Newfoundland and Labrador Shelves have been identified as one of the twelve major marine biogeographic units by Fisheries and Oceans Canada (DFO 2009). Within WGEAFM, previously discussed work regarding ecoregion identification and delineation includes the US Northeast Atlantic Continental Shelf, and the Canadian Scotian Shelf (NAFO 2008, 2010, Fogarty and Keith, 2009, Zwanenburg et al. 2010). Using similar methods as previous studies (Fogarty and Keith, 2009, Zwanenburg et al., 2010), the ongoing work on ecoregion identification and delineation was extended to the Canadian Newfoundland and Labrador (NL) shelves based on biological and physical datasets collected from 1995 – 2007 (Pepin et al., 2010).

The analyses were based on the synthesis of spatially explicit and interpolated data using multivariate approaches (Principal Components – PCA) and K-means clustering. The data gathered were generally similar to those of other regions, but limitations in the spatial extent and resolution of information varied greatly among the variables considered in the analysis. Data consisted of bathymetry (Bathy), sea surface (SST) and bottom (BT) temperatures, chlorophyll *a* (Chl-a), primary production (PP), zooplankton biomass, demersal surveys (biomass, diversity - Shannon Evenness Index- and richness -number of species-), nekton surveys (biomass, diversity and richness), and data on deep-sea cold water corals (presence/absence, diversity, richness). The cell size of the interpolated surfaces was dependent on the spatial distribution of samples from the original datasets, ranging from 2 km to 20 km. To maintain consistency between the raster and vector datasets, all surfaces were converted to a 20 km grid using the aggregate tool in ArcGIS (ESRI, 2008). Zooplankton, nekton, demersal, and bottom temperature raster datasets were all interpolated using ordinary kriging. The coral datasets were not originally interpolated because of the large number of observations that recorded no coral catch. Therefore the coral raster datasets were actually mean values within each 20 km x 20 km cell based on a focal mean based on a 3x3 cell window was calculated for each no data cell in order to fill in these gaps and create a continuous surface. All the data were standardized to a mean of 0 and standard deviation of 1.

To evaluate the influence of different combinations of variables, six (6) different PCA runs were carried out to determine the robustness of the ecoregion patterns identified. This assessment essentially involved the comparison of runs where different data layers were include or excluded from the analysis. The PCA results based on the first four principal components, which explained ~80% of the variance, were used in a k-means clustering procedure to classify the data and the optimal number of clusters as determined by the Calinksi-Harabasz (CH) statistic (Legendre, 2001).

Physical variables (i.e. primary production, sea surface temperature, and bathymetry) dominated the signal on the first two principal components in three (3) of the runs in which they were included. In runs based principally on the data for dermersal surveys and corals (one including, one excluding bottom temperature), the first principal component (PC) is dominated by coral percent presence, diversity, and richness, while the second PC represents the influence of demersal biomass, diversity, and bottom temperature, with biomass correlated with bottom temperature and in opposition to diversity. A PCA run which had all the variables included except sea surface temperature, primary production, and bathymetry, and yielded the same general pattern as those based on the coral and demersal variables.

The spatial distribution of clusters revealed that there are some common outcomes to all analyses that differ in the spatial extent of the different clusters identified from the analysis among PCA runs (Figures 1b.1-4). The clustering results of two PCA runs (one with only nekton and zooplankton datasets removed; the other with nekton, zooplankton, and coral datasets removed) clustered the NL shelf and the southeast shoal as different clusters

(Figures 1b.1 and 1b.4). In contrast, PCA runs to assess the influence of demersal and coral variables in the presence and absence of bottom temperature clustered them as having similar attributes (Figures 1b.2 and 1b.3). The contrast among all PCA runs highlights the influence of the physical variables in determining the difference between these two areas in clustering results. In all runs, the northern Grand Bank remained its own class separate from the NL shelf and the Southeast Shoal. The "patchy" class along the edge of the clustering results of all PCA runs, except in a run that excluded coral variables (Fig. 4), occurred on the continental slope, and is most likely caused by the different spatial scales of coral habitats relative to those describing the physical features of the environment and the temporally averaged distribution of demersal fish and phytoplankton.

A critical aspect of these analyses comes from the relatively simplistic description of the biological variables using biomass, diversity and richness that resulted in the northeast Newfoundland Shelf and the southeast Shoal appearing to have the same attributes. Although the two areas are similar in their general metrics, the species found in each part of the continental shelf differ substantially. This raises a cautionary aspect to the definition of ecoregions using summary variables. Creating GIS layer(s) that reflect metrics of taxonomic similarity (or dissimilarity) could serve to add an important element in the definition of ecoregions that would include aspects of ecosystem structure that reflects the patterns of biodiversity across the region of interest.

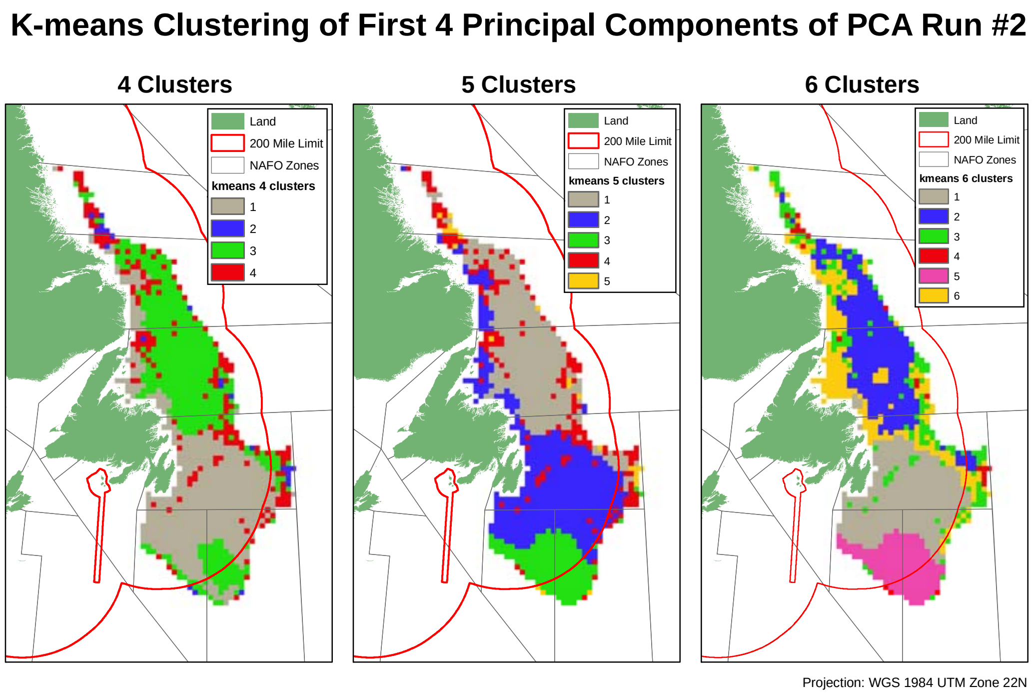

Figure 1b.1. Maps of k-means clustering results for the Newfoundland and Labrador shelves based on the first four principal components of PCA run #2. This run includes demersal surveys (biomass, diversity and richness), corals, SST, Chl-a, Bathy, BT, and PP, while it excludes nekton and zooplankton datasets. According to the CH statistic the optimal number of clusters for this analysis is five (5) (middle pannel).

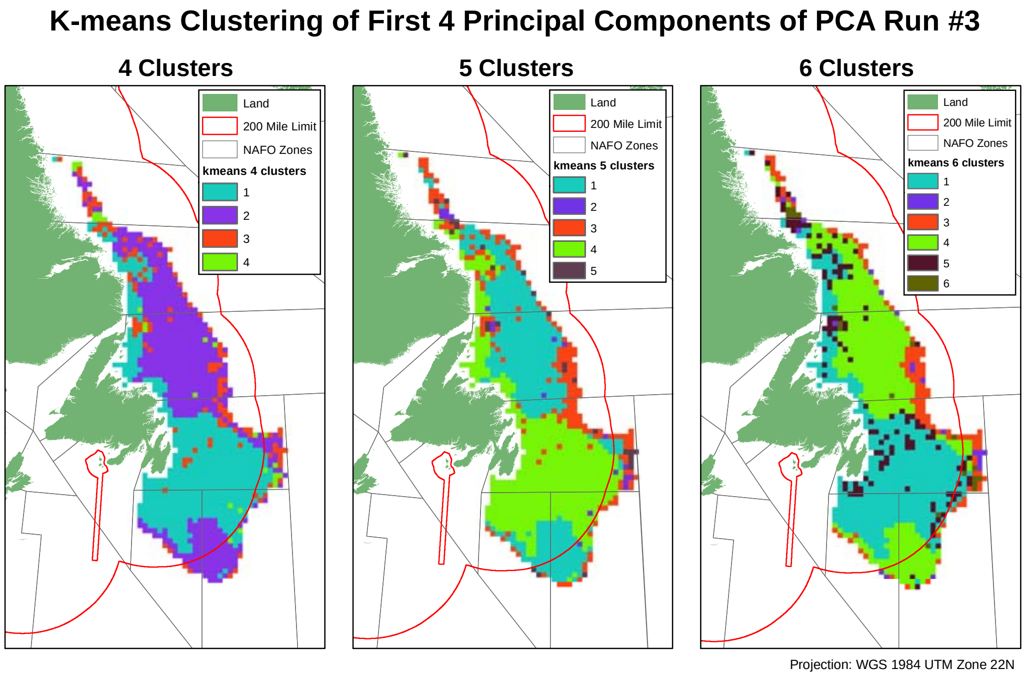

Figure 1b.2. Maps of k-means clustering results for the Newfoundland and Labrador shelves based on the first four principal components of PCA run #3. This run includes demersal surveys (biomass, diversity and richness), corals, Chl-a, BT, while it excludes nekton, zooplankton, PP, Bathy, and SST datasets. According to the CH statistic the optimal number of clusters for this analysis is six (6) (right pannel).

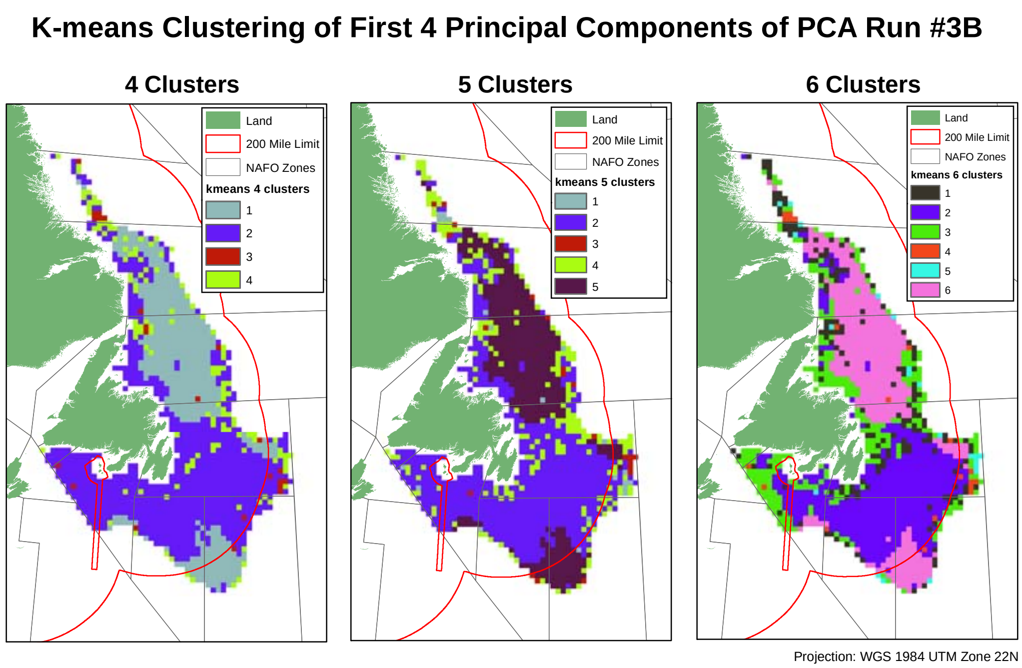

Figure 1b.3. Maps of k-means clustering results for the Newfoundland and Labrador shelves based on the first four principal components of PCA run #3B. This run includes demersal surveys (biomass, diversity and richness), corals, and Chl-a, while it excludes nekton, zooplankton, PP, Bathy, BT, and SST datasets. According to the CH statistic the optimal number of clusters for this analysis is six (6) (right pannel).

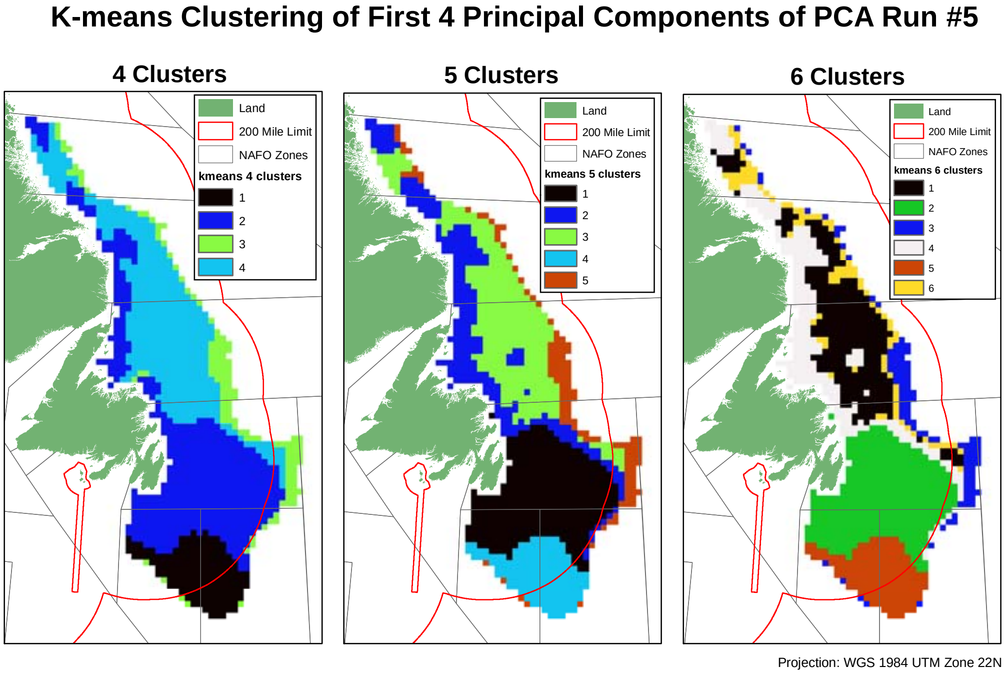

Figure 1b.4. Maps of k-means clustering results for the Newfoundland and Labrador shelves based on the first four principal components of PCA run #5. This run includes demersal surveys (biomass, diversity and richness), Chl-a, BT, SST, Bathy and PP, while it excludes corals, nekton, and zooplankton datasets. According to the CH statistic the optimal number of clusters for this analysis is five (5) (middle pannel).

1b.3. Delineation of ecoregions in the Flemish Cap

In the Flemish Cap (NAFO regulatory area 3M), no previous studies dealing with the identification of major ecosystem subunits (ecoregions) has been carried out. In the present work (Pérez-Rodriguez et al. 2010), an attempt to study the ecoregions subdivision of Flemish Cap was undertaken by applying the same methodology used in the Newfoundland Shelf (Pepin et al., 2010). Both physical and biological variables were used to define homogenous areas. Bathymetry data were derived from the GEBCO dataset. Sea surface temperature, chlorophyll *a*, and primary production data were acquired from satellite derived imagery. Demersal biomass, diversity (Shannon's index), and richness data were estimated from data collected on European Union surveys conducted in July on the Flemish Cap from 1988 – 2008. Bottom temperature data were also provided by this survey.

These data were processed using ArcGIS software in order to make them spatially comparable. The demersal biological indices and the bottom temperature data were interpolated using the inverse distance weighted algorithm in order to create continuous surfaces that match the continuous coverage of the remotely sensed imagery. All surfaces were spatially resampled to a common 20 km grid in order to match observations from each variable. The 20 km cell size was selected to maintain consistency with previous ecoregions analysis on the North-east US Continental Shelf (Fogarty and Keith, 2009), Scotian Shelf (Zwanenburg et al., 2010), and the NL Shelves (Pepin et al., 2010). Finally, the data were standardized [(x – mean (x)) / sd] to make them numerically comparable.

The high dimensionality of this database was reduced by means of a principal components analysis (PCA). The first four principal components (PC) containing the bulk of the variance were used as input variables in a k-means clustering using the algorithm of Legendre (2001). Different runs were carried out considering a number of clusters ranging from 2 to 6. The algorithm used to perform the clustering provides a statistical measure (Calinski-Harabasz statistic), which provides a measure to determine the optimal number of clusters.

The chlorophyll *a* annual average and the cumulative primary production exhibited a patchy pattern throughout the Flemish Cap. The annual mean sea surface temperature showed a decreasing gradient from the west to the east related with the front formed by the Labrador and the North Atlantic currents southern and eastern the Flemish Cap

(Gil et al, 2004). The biological variables presented marked patterns with the bathymetry (Figure 1b.5). The biomass was observed to be at its highest values in the area comprised between 200 and 400 m, while the richness and diversity values increased with depth. There were abrupt changes in neighbouring bottom temperature values as a result of the inter-annual variability. Despite this variability, the mean bottom temperature gradually increased by depth and reached its maximum at 250m (Figure 1b.5).

The first four principal components of the PCA analysis explained 88% of the total variance. The first PC loadings (35% explained variance) were dominated by the biological variables (demersal biomass, diversity, and richness). The demersal biomass presented a positive influence while the diversity and richness exhibited an important negative affect; reflecting the opposite trend showed in Figure 1b.5. The second PC (28% explained variance) was mainly influenced by the physical variables (except chlorophyll *a*). The bathymetry showed a positive affect, while the sea surface temperature, bottom temperature, and primary production exhibited negative loadings. The third PC was determined mainly by the bottom temperature and the demersal biomass, both with positive loadings, while the fourth PC was mainly influenced by the demersal biomass (negative loading).

The first four PCs were employed in the k-means clustering algorithm. The Calinski-Harabasz statistic results indicated that optimal clustering occurred when the data were grouped into two clusters. The mapped result (Figure 1b.6) illustrated that this division generally separated the central-south, shallower areas (cluster 2) from the northern deeper parts (cluster 1) of the Flemish Cap. This subdivision is in agreement with the observed pattern in the biological variables, which dominated the first PC. Cluster 1 represents the higher portion of the biomass of the bank, while cluster 2 contains the higher Shannon's diversity and richness values.

Based on these results, it can be concluded that the Flemish Cap contains two ecoregions. This subdivision emerges as result of the relationship between the biological variables and the bathymetry.

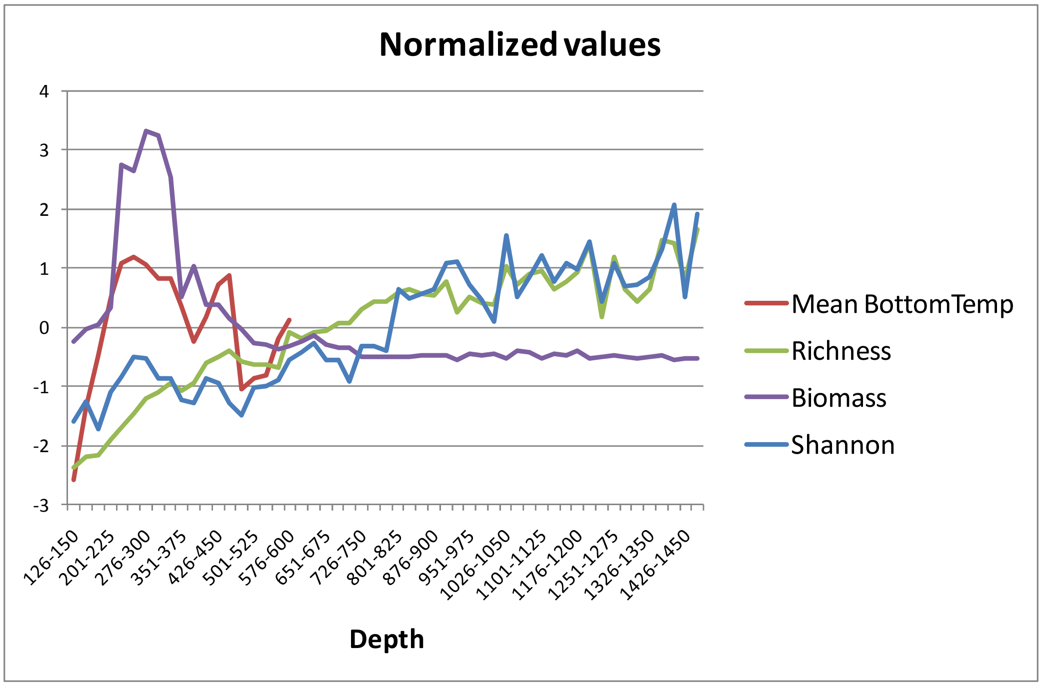

Figure 1b.5. The normalized values by depth range of the bottom temperature and the biological variables employed in the analysis.

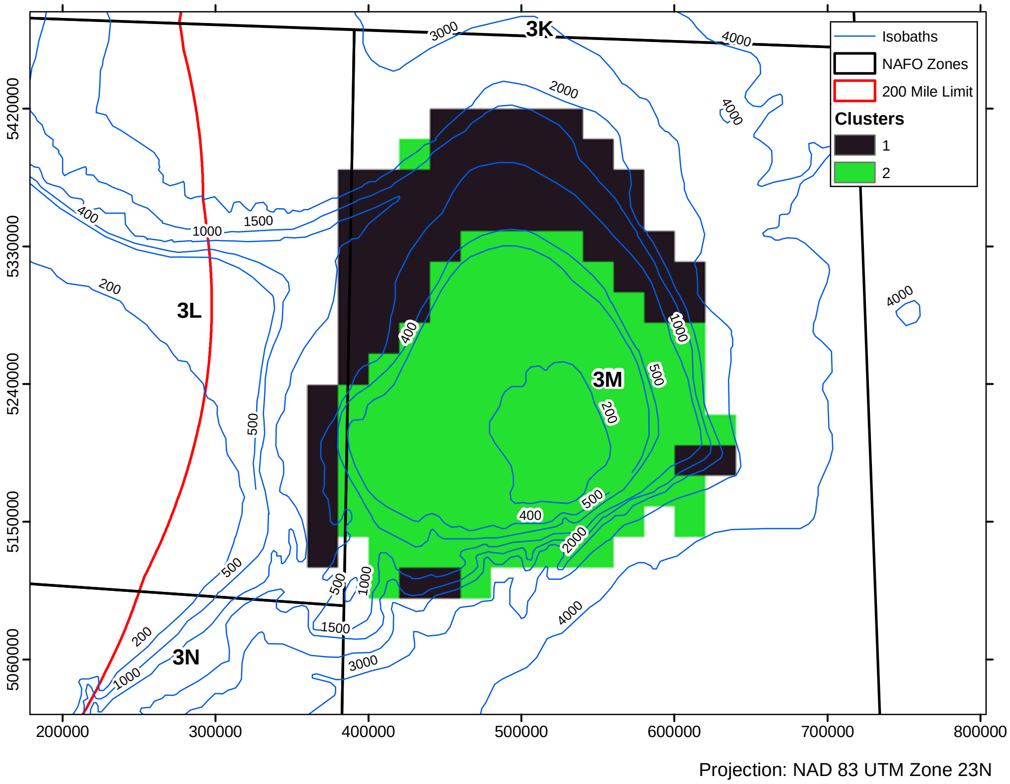

Figure 1b.6. Map of the k-means clustering results with 2 clusters.

1b.4. Delineation of ecoregions in the Scotian Shelf

The delineation of ecosystem subunits (i.e. ecoregions) on the Scotian Shelf was first examined by Zwanenburg et al. (2010). This paper implemented hierarchical agglomerative clustering as implemented using PRIMER (V.6) to cluster the results of the principal components analysis (PCA). In order to control how the algorithm defined clusters and the number of clusters in the results, the authors implemented different thresholds of similarity. However, this work has not provided any measure to suggest the optimal number of clusters that the datasets contain. To provide an approach consistent with the revised work by Fogarty et al. (2010) and Pepin et al. (2010), a k-means clustering procedure was used to classify the data and the optimal number of clusters as determined by the Calinksi-Harabasz (C-H) statistic (Legendre, 2001).

The principal component scores provided by the authors of the Scotian Shelf analysis included only the following physical variables: Bottom Temperature, Bottom Temperature Span, Sea Surface Temperature, Sea Surface Temperature Span, Mixed-layer Depth, Mixed-layer Depth, and Bathymetry. The principal component scores with both the physical and biological variables will be analyzed in the near future.

The optimal number of clusters in the Scotian Shelf dataset was six (6) and is illustrated in Figure 1b.7. There are several main clusters in the eastern Scotian Shelf, one in the western Scotian Shelf, a cluster representing the continental slope, one cluster at the outer reaches of the Bay of Fundy, and one cluster split between the Sable Island bank and the Bay of Fundy. There are obvious similarities when comparing the cluster groupings resulting from k-means clustering and the hierarchical agglomerative clustering (Figure 1b.8), specifically the clusters of Sable Island bank, eastern Scotian Shelf, and western Scotian Shelf. The main differences between the two results occur along the continental slope and the Bay of Fundy area. In general, k-means cluster groupings simplify the number of clusters along the continental slope and the Bay of Fundy area.

The working group and the authors of the initial Scotian Shelf Ecoregions project (Zwanenburg et al., 2010) concluded that the six (6) clusters provided a good representation of the underlying physical variables. The k-means result simplified the high number of groupings resulting from the initial hierarchical agglomerative clustering approach. The lower number of groupings from the k-means clustering analysis was deemed more practical for the definition of ecosystem units compared to the higher number of groupings from the hierarchical agglomerative clustering results.

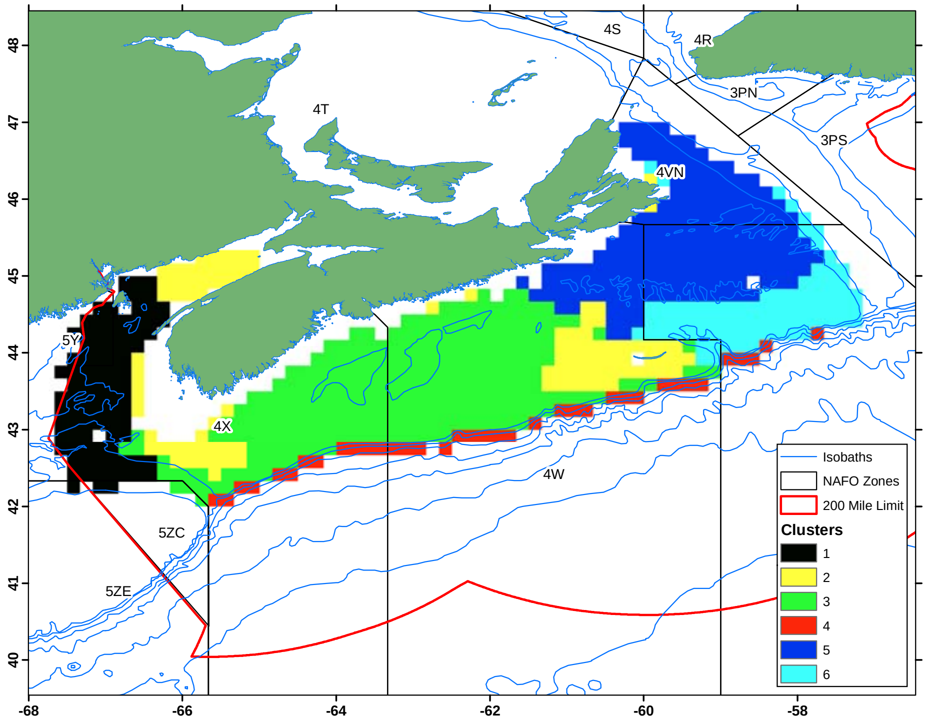

Figure 1b.7. Scotian Shelf cluster groupings resulting from k-means clustering of the first four principal component scores of the physical variables only.

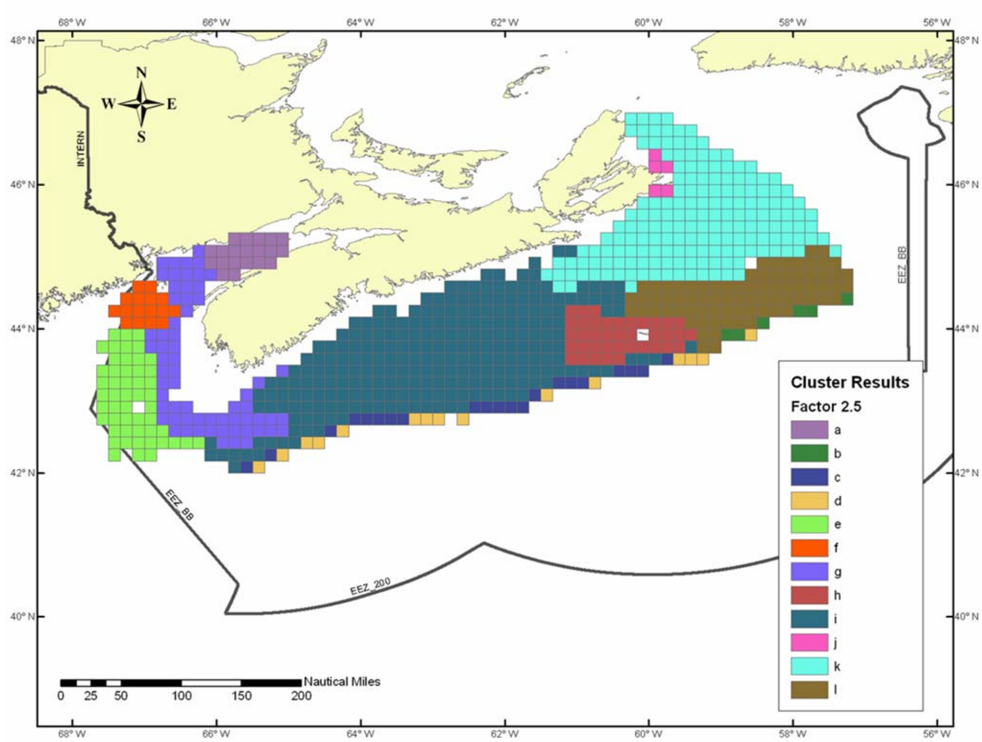

Figure 1b.8. Scotian Shelf cluster groupings resulting from hierarchical clustering of the principal component scores of the physical variables only (Zwanenburg et al., 2010).

1b.5. Delineation of ecoregions in the Northeast US continental Shelf

A presentation *via* Webex and conference call on this topic was given by Mike Fogarty, NFSC, NOAA (Fogary et al. 2010). This presentation included not only an update of the work done on ecoregion delineation, but also the use of this information to identify candidate management units for ecosystem-based fisheries management. A summary of this work is provided in **ToR2a.5**.

1b.6. Conclusions

In general terms, WGEAFM concluded that ecoregion analyses presented at the meeting, even though further refinements and improvements can (and will) be done, still provides a robust basis for the discussion and identification of ecosystem-level units to be used for the initial development and implementation of the "roadmap to EAF" (see **ToR 2a**).

Some key aspects of the analysis that were identified as needed to further strengthen the ecoregion delineation results and the identification of ecosystem-level units were:

Taxonomy: The current ecoregion analyses do not contain information on the identity of the species included in the calculation of layers of biomass, richness and diversity. One consequence of this lack of taxonomic information is, for example, the classification of the Newfoundland shelf and Southeast Shoal into the same cluster for some of the analyses done for the NL region. Although expert knowledge of these systems can often be used to detect some of the most obvious issues, it was considered important to devise a way to summarize taxomic information in one (or few) layers and incorporate this type of data in the ecoregion delineation analysis. This could be particularly useful in cases where more than one stock for a given species may be present within a given region.

Time variability: At the present time, all ecoregion delineation analyses are based on data layers that condensate multiple years; this makes sense because there is an expectation that these regions should be relatively stable over time. However, little change does not mean "no change", and if the potential impacts of climate change are considered, it is reasonable to expect that changes in the location and extent of these ecoregions, and consequently the ecosystem-level units that they conform, will occur. In this context, exploring the variability of the ecoregions over time, at least in those cases where the data allow producing temporally tagged layers, could provide valuable insights, as well as reference states, to study how to incorporate these potential spatial changes in the development and implementation of ecosystem approaches to fisheries. In this context, the incorporation of taxonomic information discussed above is also particularly important since climate change is expected to affect the distribution ranges of species.

Delineation of ecoregions at the Northwest Atlantic spatial scale: Even though the scales at which current ecoregion analyses are deemed appropriate for the identification of ecosystem-level units in the context of developing ecosystem approaches to fisheries, it is also important to explore if these units would emerge from a single analysis merging all regions. Such an analysis, in conjunction with the current studies, would potentially provide valuable information to further understand the hierarchical structure of ecosystem organization both within and across spatial units at the scale of Large Marine Ecosystems (LME) (Sherman and Alexander, 1986), as well as to provide a Northwest Atlantic scale perspective to serve as a reference to study large scale impacts of climate change on ecological systems. An analysis of these characteristics would require dedicated efforts to standardize data sources; finding ways to meaningfully merge data from regular research vessel (RV) fish surveys, which typically differ in many ways across regions (vessels, gears, season, etc) is expected to be challenge, but without this type of information, the results would be expected to essentially reflect major environmental latitudinal patterns and oceanographic characteristics.

WGEAFM agreed that these additional analyses and considerations need to be explored, and they will be done depending on the availability of resources to do the research, but these additional elements are not perceived as critical "bottlenecks" to advance in the identification of ecosystem-level units, and to keep developing further the "Roadmap to EAF". It is expected that, when the results become available, they would be incorporated into the EAF under development.

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

ToR 2a *(towards Roadmap for EAF).* Integration of available ecoregion information towards the identification of potential ecosystem-level management units in the NAFO area.

2a. Identification of candidate ecosystem units in the NAFO Area

2a.1. Introduction

In the context of Ecosystem Approaches to Fisheries, the definition of ecosystem-level management units needs to consider both ecological processes as well as many operational and regulatory constraints, also including social and economic aspects of the fisheries expected to be managed within an integrated framework.

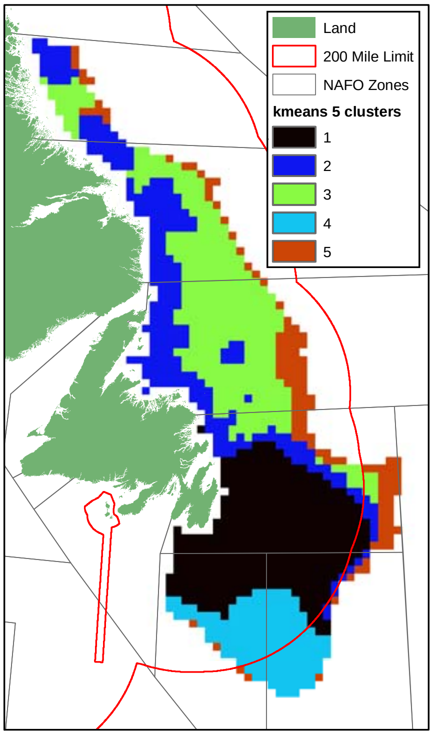
The delineation of ecoregions (ToR 1b) provides the basic underpinnings to identify areas that can be considered candidate ecosystem units at an ecologically functional level. Since ecosystems are intrinsically open systems, any process that defines precise boundaries for them is expected to be an approximation even in the best of cases. When these boundaries are also expected to meaningfully capture aspects to be of use for the sustainable use of marine resources, some balance between ecological accuracy and management practicality needs to be negotiated and achieved.

At the present time, the efforts made by WGEAFM are intended to define candidate ecosystem units that are mainly ecologically functional entities (i.e. ecological production units), but also keeping in mind that integrated ecosystem assessments and management plans would be expected to be developed for these regions in the future. So, even though management aspects in the NAFO context were not directly addressed so far, the process of identifying ecosystem units had these management aspects as a background for the analyses. As such, the candidate ecosystem units identified here will be used by WGEAFM as initial templates for the development of tools and analyses required for the implementation of the “Roadmap to EAF”. It is to be expected that some of these ecosystem units could change as we move forward with the development of EAF, and more detailed analyses and studies become available.

2a.2. Definition of ecosystem units in the Newfoundland and Labrador shelves

All multivariate analyses of the NL ecoregions essentially yielded the same general results: two narrow transitional areas (one coastal, one at the shelf slope) were identified along major parts of the continental shelf with three major areas on the shelf (Northeast Newfoundland, northern Grand Bank, and Southeast Shoal). The analysis that most clearly demonstrated this pattern was based on the use of physical variables, phytoplankton data and demersal surveys but which excluded nekton, zooplankton and coral variables. This analytical result had the lowest spatial separation of data cells within clusters (Figure 2a.1) as a result of the elimination of the influence of small scale of coral habitats that would have resulted in the greater separation of at least one cluster. Removal of coral variables from the analysis does not result in the loss of their importance in the transitional ecoregions because the enhanced definition of these as clusters in the analysis results in the inclusion of coral sites within both the coastal and slope transitional areas.

5 Clusters



Major areas:

Newfoundland Shelf (cluster 3)

Northern Grand Banks (cluster 1)

Southeast Shoal (cluster 4)

Transitional areas:

Coastal transitional area (cluster 2)

Slope water (cluster 5)

Figure 2a.1. Principal ecoregions in the Newfoundland region as determined from K-means clustering of the first four principal components of an analysis that include surface and bottom temperatures, bathymetry, chlorophyll a and primary production as well as variables from demersal surveys (biomass, richness and diversity).

Overall, coastal and slope transitional areas had intermediate biomass estimates from demersal surveys but high demersal diversity and high biomass and diversity of corals. The Newfoundland Shelf and Southeast Shoal have similar levels of demersal biomass and diversity but differ in terms of their communities and temperature environments while the Grand Banks have low demersal biomass but a diversity similar to that of the Southeast Shoal. The Grand Banks also come into direct contact with the cold intermediate layer (T < 0°C) because of their shallow depth.

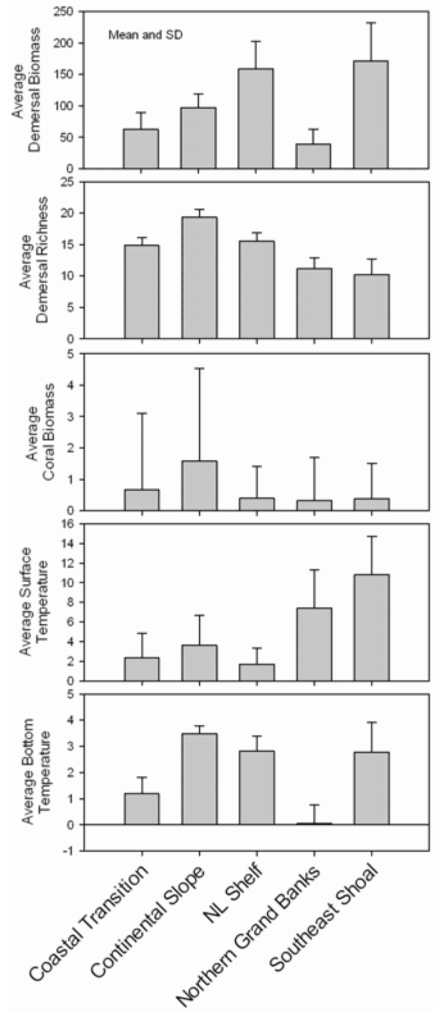


Figure 2a.2. Contribution of variables to the different ecoregions identified in run #5 for the Newfoundland and Labrador shelves. This run included surface and bottom temperatures, bathymetry, chlorophyll a and primary production as well as variables from demersal surveys (biomass, richness and diversity).

Ecoregions identify areas with similar environmental characteristics based on relatively simple characterizations of physical and biological elements of a region. However, differences in the spatial scales of variation among variables may result in the classification of parts of the area as distinct ecoregions but which are essentially part of larger ecosystem units and influenced by similar drivers. For example, the transitional areas along the coast and continental slope clearly have distinct ecological features from the remainder of the continental shelf but their proximity to the major shelf ecoregions is likely to imply that they would be subject to similar environmental drivers (e.g. strength of the Labrador Current, wind and weather pattern, North Atlantic oscillation).

In order to integrate the available ecoregion information towards the identification of potential ecosystem-level units in the NAFO area, NL researchers proposed that the coastal and slope transitional areas be combined with adjacent shelf regions. These portions of the larger ecosystem units should have special considerations in the provision of advice because of the distinct communities which occur in those ecoregions. They went on to propose that the northern Grand Banks and Southeast Shoal (3LNO), and adjacent transitional areas be combined into a single ecosystem unit, as well as combining 2GH3K into a second ecosystem unit, recognizing that the northern Grand Banks (nominally NAFO Div. 3L) represents an area of transition and energy flux between the northern (2GH3K) and southern (3NO) portions of the region. Because the extent and variability of the flux between ecosystem units is unknown, further research will be required to determine its importance of the 3L region to the dynamics of each of the ecosystem units on either side. Furthermore, the location and size of the northern boundary of the combined northern Grand Banks and Southeast Shoal ecoregions will require careful assessment of the oceanographic features and biological considerations (e.g. migratory routes) that could serve to define the nature, breadth and variability of the boundary.

WGEAFM agreed that this should result in the definition of two (2) major ecosystem units in the NL area (2GH3K; 3LNO) with the clear recognition that the transitional areas within those areas must be treated with special consideration in estimating productivity or in the provision of advice concerning possible management actions (e.g. the implementation of networks of MPAs).

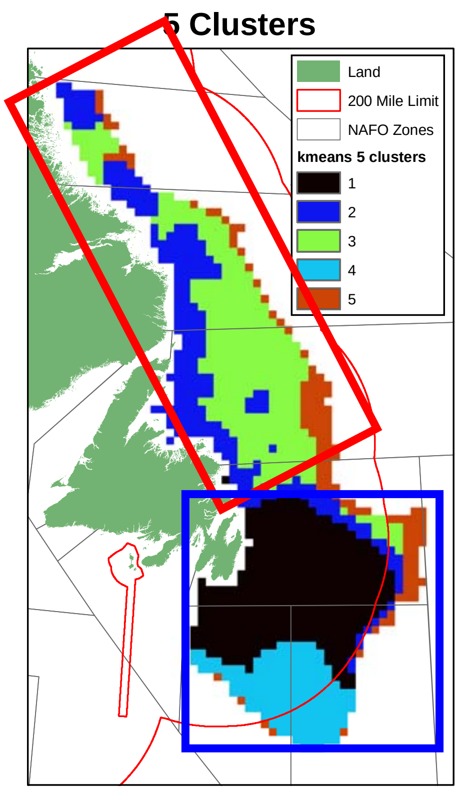


Figure 2a.3. Amalgamation of ecoregions into two candidate ecosystem units for the NL shelves: Newfoundland Shelf and Grand Banks.

2a.3. Definition of ecosystem units in the Flemish Cap

Previous studies on the Flemish Cap (NAFO regulatory area 3M) have pointed to this region as a relatively isolated area in relation to the Newfoundland shelf from a population dynamic perspective. The Flemish Pass, characterized by depths in excess of 1400 m, hinder the migration to and from the Grand Bank for demersal fish species which usually don't inhabit the deepest areas such as Atlantic cod *Gadus morhua* (Templeman 1963, Konstantinov, 1970; De Cardenas-Gonzalez 1996). From an oceanographic and hydrological point of view the shallow water of the

Flemish Cap present some distinctive characteristics owed to the proximity of large-scale oceanic circulation around the Bank, including the Labrador Current (LC) and North Atlantic Current (NAC) (Maillet et al, 2005).

The study of the major ecosystem subunits existing in the Flemish Cap presented in this report has shown that two ecoregions can be differentiated in the base of the main physical and general biological indexes, representing patterns related with productivity and demersal fish community structure. The shallower ecoregion (shelf-upper continental slope ecoregion) could be hypothesized to be the one responding to the isolation of the cap, while the deepest one (off-shelf ecoregion) inhabited by fish species which could connect the Flemish Cap with the surrounding deep sea areas.

On the other hand, it is known that in Flemish Cap the distribution of fish species with depth overlap in variable degree (Figure 2a.4). This overlapping generates a chain of interactions from the shallowest to the deepest areas, although species in the extreme of this chain rarely interact. More research is needed in order to improve and define more precisely the actual knowledge in relation to these issues as well as the degree on interconnection between species characteristics from these two ecoregions.

However with the available knowledge and from an ecosystem approach to management point of view, the Flemish Cap can be considered as a whole and unique ecosystem unit, with two subareas which can present strong interconnections in terms of energy and matter transferences.

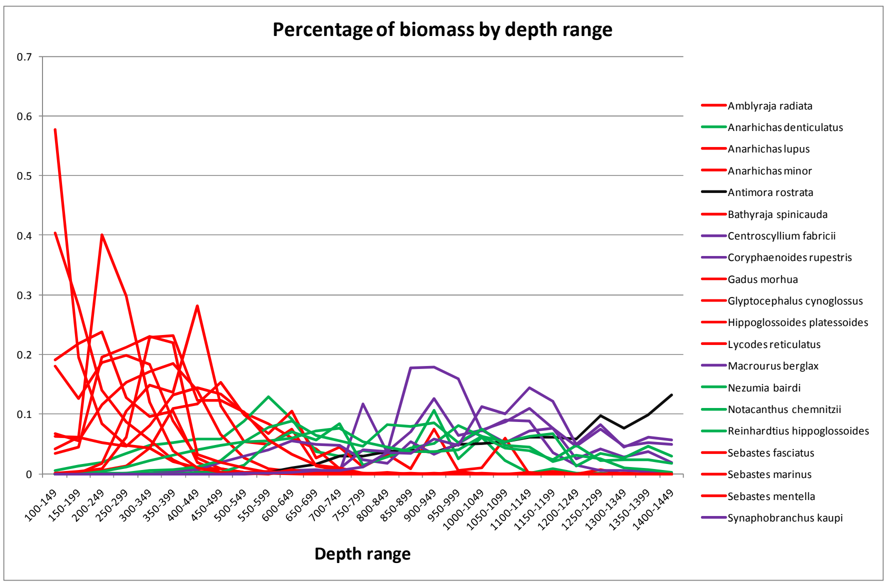


Figure2a.4. For each species, the proportion of biomass by depth range over the total biomass is shown. The species presented in this figure cover the 99% of total fish biomass caught in the period from 1988-2008. In red color the species which presented the major proportion in the depth range of the shelf-upper continental slope ecoregion. In purple color, the ones with the higher presence in the lower continental slope ecoregion. In green color the species with similar presence in both ecoregions.

2a.4. Definition of ecosystem units in the Scotian Shelf

Delineation of spatial management units is prerequisite to establishment of an effective ecosystem approach to management of human activities in marine ecosystems. Biogeographic classification is often considered fundamental for marine spatial planning and can serve as a framework for a number of uses, from assessment and monitoring to marine protected areas network design.The delineation of ecosystem subunits (i.e. ecoregions) for the Scotian Shelf was first examined by Zwanenburg et al. (2010). Multivariate analyses of long-term biophysical data from the Scotian Shelf showed a relatively consistent subdivision of the area into regions of similarity / dissimilarity henceforth ecoregions. These analyses were; however, not constrained and resulted in an arbitrary (and large) number of regions. The approach was later refined by estimating the optimal number of clusters for the dataset (see

ToR 1b.4). Results of these analyses indicated that Scotian is optimally divided into 6 ecoregions (Figure 1b.7). This does; however not mean that the more detailed sub-division of the area might not have utility in management but merely that the larger areas are likely to have at least initial utility for a large number of human activities. The finer subdivisions may have use when “fine-tuning” specific activities in

A cursory comparison of demersal fish assemblage structure (Zwanenburg and Jaureguizar unpublished MS), in general shows a reasonable match to the regions defined by the physical attributes of the Scotian Shelf (Figure 2a.5) This affords some confidence that these regions serve as functional units and thus may provide utility as management units. The optimized clustering, in particular, also identifies a single but spatially separated region for the Bay of Fundy and its coastal approaches and the shallow areas of Sable Island bank. This similarity is reflected in analyses of demersal fish assemblage structures (Figure 2a.5, Zwanenburg and Jaureguizar unpublished MS).

Based on these analyses it appears that the Shelf may be usefully subdivided broadly into eastern and western portions (this has been known for some time), although the boundary between Eastern and Western Scotian Shelves appears somehow fluid. Another subdivision, which separates the western approaches to the Gulf of Maine and the approaches to the Bay of Fundy from the Western shelf might be considered. There also appears to be utility in considering the Shelf Slope as separate from the shelf proper. Finally the Bay of Fundy (and perhaps the shallow portions of Sable Island bank) have significant affinity and might be considered as a region in themselves. The division of the Eastern Shelf into inshore / near shore and offshore section is not obviously reflected in the fish assemblage structure. Similarly the Scotian Shelf–side slope of the Laurentian Channel does not cluster out in this analysis as it did in the assemblage analysis.

These conclusions are quite preliminary and require significantly more analyses in terms of refining both the boundaries of the regions and their biophysical characteristics. The current outlines do; however provide a reasonable starting point for categorizing the shelf and making some preliminary decisions about probable physical conditions and faunal compositions that human acitivities would expect to encounter for each of the regions.

The current analyses have been conducted with time aggregated data in that it assumes that the long-term average physical structure is indicative of the physical structure at any given period of time. This has yet to be determined and is of significant importance given the highly dynamic nature of the Scotian Shelf in general. Given such dynamics it is important to determine the temporal stability of ecoregion boundaries as it relates to their utility as management units, this work is ongoing.

In summary, given the spatial extent and scale of the Scotian Shelf as a whole, and to the effect of exploring future steps associated with the development of the “Roadmap to EAF” (e.g. fisheries production potential models), this region would be minimally described in terms of two distinct ecosystem-level units, the Eastern and Western Scotian shelves, but additional work is required to define the best location for the boundary between these ecosystem-level units. In terms of the “Roadmap to EAF” these exercises are expected to be of use for understanding the connections and relationships between the different elements in the framework, but since this region is within Canadian waters, management of these ecosystem units is actually under the national jurisdiction of a contracting party.

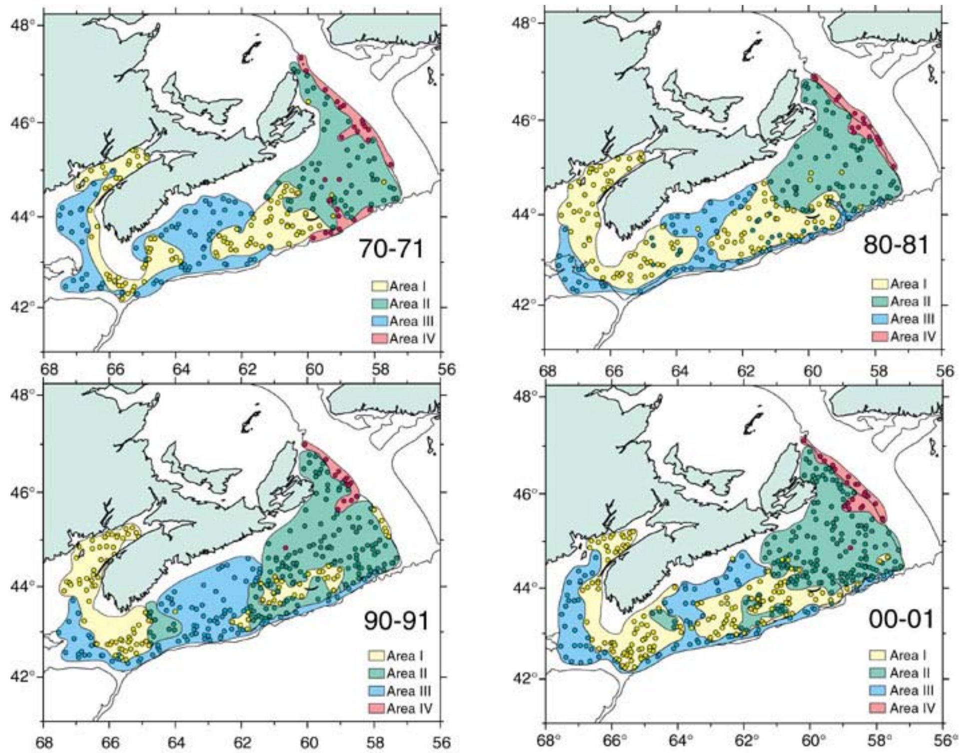


Figure 2a.5. Demersal fish assemblages derived from standardized summer trawl survey data (1970 – 2001, Zwanenburg and Jaureguizar unpublished MS)

2a.5. Spatial Considerations for Ecosystem-Based Fishery Management on the Northeast U.S. Continental Shelf

The objective identification of spatial management units is a critical pre-requisite for the development of strategies for marine Ecosystem-Based Management (EBM). Although many definitions of EMB have been advanced, virtually all share at least three common elements: (1) the recognition that humans are an integral part of the ecosystem, (2) a focus on the inter-relationships among ecosystem components, the physical environment, and human communities and (3) a commitment to establishing spatial management units based on ecological rather than political boundaries. It will be essential to consider the interplay between ecological production processes and human connections to the sea in defining appropriate spatial management units.

Potential spatial units for marine Ecosystem-Based Fishery Management (EBFM) on the Northeast Continental Shelf of the United States were examined. In this context, Ecosystem-Based Fisheries Management (EBFM) is one component of EBM and it will be necessary to devise strategies that are ultimately consistent with the more comprehensive mandates of the latter to consider the full spectrum of ecosystem goods and services provided by marine systems as well as tradeoffs among ocean use sectors. One of the fundamental ways in which marine EBM will differ from more conventional fishery management approaches is in the development of integrated management plans for defined ecological regions rather than for individual species/stocks. Although a general regulatory and legal framework for EBM in the United States has not yet been established, progress on EBFM is currently possible under existing mandates, hence the focus on this component at this stage. The recent establishment of a National Ocean Policy for the United States, which identifies marine EBM as its guiding principle and the role of Marine and Coastal Spatial Planning (MCSP) as an essential tool for its implementation, will serve as an important impetus for implementing full EBM.

The definition of ecological production units of the Northeast U.S. Continental Shelf was revisited with a focus on the requirements for EBFM. Previous analyses for this region have principally applied qualitative and subjective methods in specifying subregions based on general considerations of physical structure and productivity. This approach was formalized to provide an objective definition of the boundaries of ecological production units for the shelf system in a way that can be re-evaluated periodically to test for environmentally-driven changes in the extent of the individual subsystems. This may become a critical issue in the face of climate change. Next a process was specified in which once the larger-scale spatial management units are identified, finer levels of spatial detail may be identified and integrated into the management plan for an ecologically-defined management region. Considerations at this stage include the need to identify areas requiring special protection either because of the occurrence of vulnerable species or habitats, or the importance of areas defined by biomass and/or species diversity levels. These biological considerations are then viewed through the lens of spatially-defined human connections to the sea incorporating information on time spent in different fishing locations for vessels and crews defined by port of origin, vessel size, and gear type. Levels of concordance among this diverse set of considerations and the implications for choices of spatial management units were evaluated. The overall approach is explicitly hierarchical with a set of nested spatial considerations coming into play to meet specified management objectives. In all instances, it is recognized that proposed units are open and interconnected through water mass movements, migratory behavior of organisms, and spatial fishing patterns and processes crossing production unit borders.

To proceed, a set of physiographic, oceanographic and biotic (lower trophic level) variables to provide a basis for identification of ecological production units on the Northeast Continental Shelf was assembled. The physiographic variables considered in this analysis include bathymetry and surficial sediments. The physical oceanographic and hydrographic measurements include sea surface temperature, annual temperature span and temperature gradients. The biotic measurements considered include satellite-derived estimates of chlorophyll *a* and primary production, and chlorophyll gradients. The gradient metrics are included to capture frontal zone positions.

Principal components analysis was employed to examine the multivariate structure of the data and as a prelude to classification of ecological production units. Then K-means cluster analysis was used on the principal component scores to define the spatial units. The clusters represent major ecological production units on the shelf including (1) Eastern Gulf of Maine- Scotian Shelf, (2) Western-Central Gulf of Maine (3) Inshore Gulf of Maine, (4) Georges Bank-Nantucket Shoals (5) Intermediate Mid-Atlantic Bight (6) Inshore Mid-Atlantic Bight and (7) Continental Slope (Cape Hatteras to Georges Bank) (see Figure 2a.6). Then it was developed a revised set of ecological subareas as potential management regions in which nearshore regions are considered special zones nested within the adjacent shelf regions. A similar strategy is suggested for the continental slope region. The consolidatation strategy results in four principal regions for consideration of potential management units (Figure 2a.7).

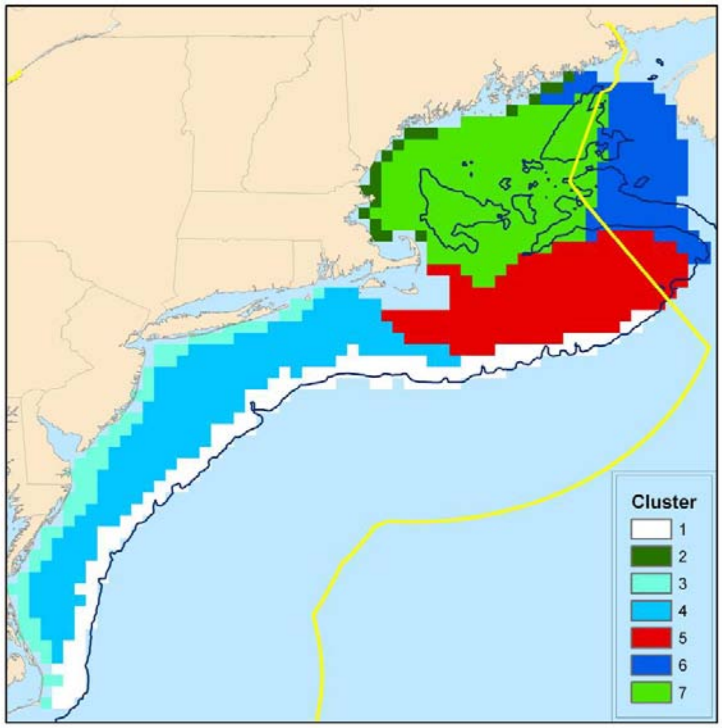


Figure 2a.6. Designation of principal ecological zones on the Northeast U.S. Continental Shelf Large Marine Ecosystem based on a cluster analysis of principal component scores for a set of physiographic, hydrographic and lower trophic level variables.

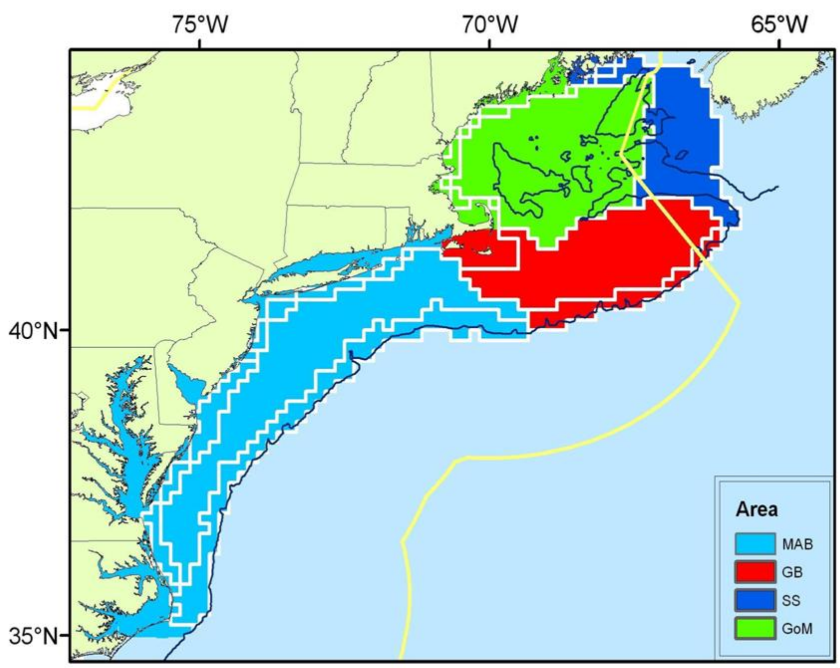


Figure 2a.7. Proposed ecological production units as potential management boundaries following consolidation of nearshore and continental slope ecological zones with adjacent continental shelf areas.

2a.6. Conclusions

Regarding the identification of candidate ecosystem-level units, the results emerging from the ecoregion analyses appear to be provide a consistent set of observations across the different areas:

> ***Scale***: Ecoregion analyses as implemented here typically delineate units at spatial scales considered to be of a finer resolution than what is expected for an entire ecosystem-level functional unit (e.g. management stocks often extend to more than one ecoregion, ecotone areas like coastal and shelf break regions are delineated as ecoregions). Therefore, ecosystem-level [production] units are typically defined by amalgamating the ecoregions that emerge from the analysis. Another important scale-dependent aspect is the recognition that some ecosystem features, like coral reefs or sponge grounds, are defined at much smaller spatial scales than the ecological production unit; there is a hierarchical structure in the spatial arrangement of ecosystem features and properties that is relevant not just from a functional perspective, but it is also important when designing integrated management plans.
>
> ***Areas of special consideration***: Even though ecosystem-level units are identified *via* consolidation of ecoregions, the internal spatial structure of the ecosystem as represented by these ecoregion subunits provides valuable information that needs to be considered when developing management plans. For example, ecoregional structure within an ecosystem-level unit potentially provides a natural template for the design of networks of MPAs, as well as identify areas that may require special management considerations (e.g. coastal zone, shelf break, but also VME-defining features).
>
> ***Transition areas***: Boundaries between identified ecosystem units are not necessarily clear-cut or precisely defined. In some cases, entire regions can be described as transition areas between ecosystem units. For example, even though two ecosystem units has been identified in the NL region (Newfoundland Shelf and Grand Banks), the northern part of the Grand Banks (nominally NAFO Div. 3L) is considered a transition area between these units. Similarly, the northern boundary between the NL and the Arctic is potentially a transition area, but more studies are need to better understand that particular boundary. Another region that still requires future work is the Scotian Shelf. This region appears to contain two ecosystem units (Eastern and Western Scotian Shelf), but the exact location of the boundary between them is still a matter of investigation. Equally important is how to best integrate the Scotian Shelf-Gulf of Maine ecosystem unit identified in the Northeast US Continental Shelf analysis with the results from the Scotian Shelf analysis.
>
> ***Open borders and fluxes***: In all cases, and regardless how narrow or wide, precise or diffuse, a boundary between ecosystem units appears to be, it must be explicitly recognized that borders between ecosystem units are open, and fluxes and exchanges through these boundaries will occur, and hence, need to be explicitly addressed. Ecosystem-level units, in the context of its application for ecosystem approaches to fisheries as sketched in the "Roadmap to EAF", are defined as ecological production units, but interconnections between these units do exist, and their importance needs to be evaluated, specially so in those cases where wide transition areas may exist. Another important aspect related to the fluidity of borders is in relation to climate change; the current delineation of candidate ecosystem units, as well as the magnitude of the fluxes and interactions between them may be affected as environmental and oceanographic conditions are altered by the advent of climate change. In this later context, a better understanding on how these boundaries change over time, and how they respond to specific changes in environmental drivers will be needed.

Based on current analysis, a minimum of eight ecosystem-level units have been preliminary identified in the NAFO area. From north to south, these areas are the Newfoundland Shelf, the Grand Banks, the Flemish Cap, the Eastern and Western Scotian Shelves, the Gulf of Maine, Georges Bank and Mid-Atlantic Bight. Some of these units fall entirely within national jurisdictions, while others include areas inhabited by stocks managed under NAFO. These ecosystem-level units will provide the initial spatial template required for further development of the "Roadmap to EAF", which includes the study of fisheries production potential at the ecosystem level (see **ToR4c**).

2a.7. References

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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.

This ToR was not addressed during this meeting.

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.

The work developed under this ToR includes activities directed to address FC requests, as well as activities directed to advance the "Roadmap to EAF".

The Fisheries Commission Request # 14 from the September 2010 FC meeting states:

> *"Noting the response from the Scientific Council in June 2010 regarding simulation modeling in a GIS framework: "To apply this model to the NRA, an agreed upon set of gear descriptions and tow duration/lengths for each fishing fleet segment would need to be created. Further estimation of retention efficiencies of the different commercial gears and indirect effects of fishing will be needed to model effects of serious adverse impacts.*
>
> *The Fisheries Commission requests that the Scientific Council: 1) acquire the requisite data and apply the model to the extent possible to the NRA, and 2) consider whether the SASI model used by the US New England Fisheries Council should be incorporated into the aforementioned GIS framework as a means of integrating significant adverse impacts into the approach."*

This request was deemed adequately covered by ToR 4 (Update on recent and relevant research related to the application of ecosystem knowledge for fisheries management in the NAFO area) under Theme 3 (Practical application of ecosystem knowledge to fisheries management), and hence, its two components have been addressed in ToRs 4a and 4b.

ToR 4a *(to address FC request #14.1)*. Considering the simulation modeling in a GIS framework that was first discussed at the WGEAFM meeting in Vigo, and later refined as part of a DFO process in Canada (Kenchington et al. 2010), acquire the requisite data and apply the model to the extent possible to the NRA.

4a. Encounter Thresholds: Sponges fished with otter trawl gear in the NRA

4a.1. Introduction

To meet the expectations of the United Nations General Assembly (UNGA) resolution 61/105, NAFO has implemented a series of sponge and coral concentration closed areas within its jurisdiction designed to prevent significant adverse impacts on VMEs (NAFO CEM 2010- Article 16 - Coral and Sponge Protection Zones). At present there are eleven areas closed to protect coral and sponge in the NAFO Regulatory Area (NRA) in addition to the Div. 3O closure to protect coral. However, the UNGA resolution also calls upon regional fisheries management organizations to require vessels to cease bottom fishing in areas if vulnerable marine ecosystems (VMEs) are encountered so that appropriate measures can be adopted in respect of the relevant site (UNGA Res. 61/105 article 83). This becomes particularly important should the slopes of the NRA outside of the fishing footprint (NAFO, 2009a) be fished under exploratory fisheries, as it is expected that vulnerable marine ecosystems (VME) will be present there. In order to implement this resolution an operational definition of an encounter is required.

NAFO has established conservation measures using encounter protocol provisions. An encounter is defined through the use of bycatch thresholds which were not scientifically based but established as interim measures until more scientifically-based estimates could be provided. The following is taken from the 2010 NAFO CEM Article 5bis - Interim Encounter Provision:

> *"Definition of an Encounter – is an encounter, above threshold levels as set out in paragraph 3, with indicator species of coral identified as antipatharians, gorgonians, cerianthid anemone fields, lophelia, and sea pen fields or other VME elements. Any encounter with a VME indicator species or merely detecting the presence of an element itself is not sufficient to identify a VME. That identification should be made on a case-by-case basis through assessment by relevant bodies.*
>
> *3) 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 800kg 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."*

Thus for sponges, an encounter is defined as any bycatch of live sponge greater than 800 kg. There are a number of problems with the NAFO encounter thresholds other than the level, not least of which are that no tow duration is defined, all gears are treated the same and there is no use of species information although it is recognized in the official definition that there are a number of VME taxa (NAFO, 2010).

The difficulty with this definition lies in establishing a quantity greater than a "presence" and sufficient enough to identify a VME. If commercial sponge bycatch data were available, it might be possible to look at the catch distribution in the same manner that was used to identify significant concentrations of sponge from research vessel bycatch (NAFO, 2009b). That is, to identify aggregations through the use of spatial analysis. However, such data is not available, necessitating a modeling approach. Here we present the results of the GIS model prepared for sponges. If requested, the model could be applied to the three coral VME taxa: Small and Large Gorgonians, and Sea Pens. In keeping with the view that encounter protocols should be gear/taxon specific we examine **sponge** bycatch thresholds applicable to the **groundfish fishery** only. This fishery is prosecuted with a variety of **bottom trawl** gears and is the largest single fishery in the NRA.

4a.2. Methods

The model as described by Kenchington et al. (2010) has been updated and improved in this application and the details of the methods used to evaluate sponge bycatch threshold levels are found in a supporting research document (Cogswell et al. 2010). In essence the model uses a map of sponge biomass produced from research vessel survey bycatch from the Canadian and EU surveys and superimposes on it simulated commercial trawl catches. The commercial sponge bycatch is then calculated by estimating the sponge biomass under the simulated line. The commercial trawl lines were all approximately 27.8 km which is equal to the median distance fished from 1052 tows from various vessels fishing groundfish from 2005-2010. This distance was calculated by multiplying the tow duration, which was provided, by a towing speed of 3 knots. To place the trawl lines in areas as representative of actual fishing effort as possible the random start positions were weighted by fishing effort and the direction of the tow was in the direction of maximum effort.

There are a number of assumptions and limitations to the model we have presented. First, the standard trawl lengths from which the by-catch is estimated are all straight lines. Use of start and end positions combined with tow duration might allow for a more accurate determination of trawl length, but this was not possible with the data currently available. Second, there is an issue of retention efficiency of sponge by-catch. Ideally, biomass estimates used to create the sponge biomass raster would be gathered through visual and other ground truthing methods. By-catch from research vessel surveys underestimates actual sponge biomass because of: benthic obstructions (e.g., rocks, etc…) that can "shelter" sponge as the trawl travels over the rough bottom and more importantly through fragmentation when sponge impacts the fishing gear and is torn or shredded. Kenchington et al. (2010) describe null sets for coral in research vessel trawls in the Eastern Arctic that actually did catch coral but did not retain it. This was determined by the placement of linney bags outside the gear to catch material passing through the meshes. The sponges are also susceptible to breakage and passing through the meshes. However, retention will increase as the net fills. These factors will influence real commercial bycatch data. In our modeled bycatch estimates we assume 100% retention of sponge over the trawl line (this is 100% retention of sponge biomass calculated from a layer that is less than the actual sponge on the bottom as described above). Therefore the real commercial bycatch is expected to be less than that produced from our model and the amount of sponge on the bottom is expected to be more than that represented by the research vessel bycatch.

This model does not evaluate the biological significance of the removals. Nor does it make an assessment of significant adverse impact to the ecosystem. In order to do that more information on species composition would be required. Given that the major sponge grounds in the fished areas have already been identified and protected (NAFO, 2009b), areas with larger sponge biomass are unlikely to be from intact sponge grounds but may be fragments of former sponge grounds damaged by fishing, or aggregations of smaller sponge species.

The model provides a 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 bycatch thresholds. In a precautionary framework it makes sense to reduce the threshold values towards smaller values, especially if only a small area and/or proportion of the catches would be affected.

4a.3. Results and Discussion

The running average of the simulated sponge bycatch run under the fishing scenario where weighted-random-simulated trawl lines were excluded from all coral and sponge closed areas on Flemish Cap and the southeast Grand Banks, (including the 3O closure) began to stabilize after about 800 lines were generated (Figure 4a.1). We conclude therefore that the 1500 simulations used to characterize this fishing scenario provide a good basis for drawing conclusions on sponge bycatch. The locations of these simulated trawl lines are illustrated in Figure 4a.2.

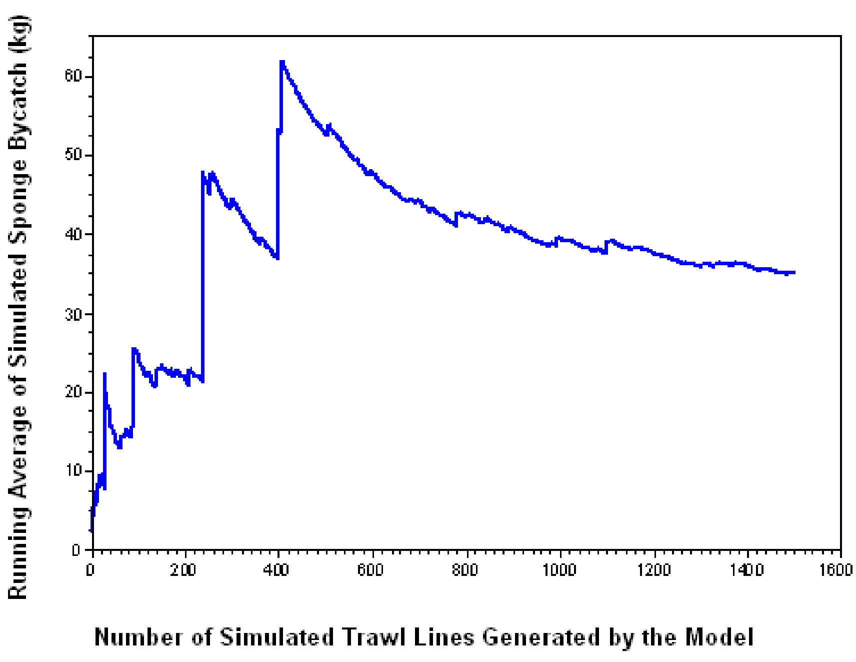

Figure 4a.1. The running average of the simulated sponge bycatch from 1500 weighted-random-simulated groundfish trawls excluded from all coral and sponge closed areas on Flemish Cap and the southeast Grand Banks, including the 3O closure with trawl sponge bycatch generated using the modified sponge biomass raster (excluding research vessel survey bycatch from within the closed areas).

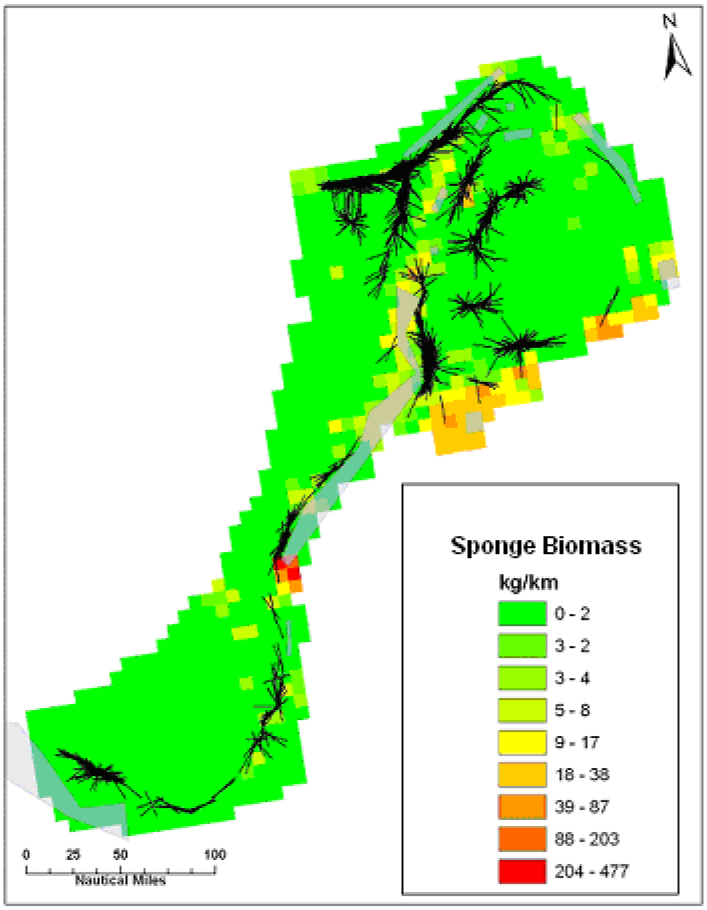

Figure 4a.2. Location of 1500 weighted-random-simulated groundfish trawls (black lines) excluded from all coral and sponge closed areas on Flemish Cap and the southeast Grand Banks, including the 3O closure. Closed areas are indicated by the gray shading. The simulated trawl lines are shown over sponge biomass, where green indicates small amounts of sponge (0-2 kg/km) and red indicates higher sponge biomass (204-477 kg/km).

4a.4. Evaluation of Potential Encounter Protocol Thresholds for Sponges in the NRA

As described above, the GIS model was used to simulate sponge bycatch from a modeled groundfish fishery with the coral and sponge closure areas in place, which is the current restriction on the fishery. Those outputs were used to evaluate the effect of various encounter threshold options on the fishery.

The simulated commercial sponge cumulative bycatch distribution follows a similar distribution pattern to the research vessel sponge bycatch (NAFO, 2009), with large numbers of small catches and a few very large catches. Twenty-seven percent of the sponge catches were less than 1 kg/27.8 km while 64% were less than 10 kg/27.8 km (Table 4a.1).

Table 4a.1. The number and percent of simulated groundfish trawls catching sponge at various encounter threshold levels. Shaded values indicate the range recommended by WGEAFM.

Encounter threshold bycatch weight (kg)	Number of simulated trawls that caught the encounter threshold weight or greater	Percent of simulated trawls that caught the encounter threshold weight or greater
800	6	0.4
700	7	0.5
600	10	0.7
500	15	1.0
400	26	1.7
300	37	2.5
200	44	2.9
100	58	3.9
90	62	4.1
80	67	4.5
70	73	4.9
60	77	5.1
50	82	5.5
40	113	7.5
30	169	11.3
20	284	18.9
10	546	36.4
5	911	60.7
1	1092	72.8
0.1	1301	86.7

The current encounter threshold for sponges is 800 kg and our model suggests that very few groundfish trawls (0.4%) would ever encounter this level under the current fishing effort patterns (Table 4a.1). All six of the simulated catches > 800 kg came from one location (Figure 4a.3), along the slope of the Grand Banks, near the Canadian EEZ. Reducing the encounter threshold for sponges 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 (Figure 4a.3).

When considering lower encounter threshold values below 50 kg it is important to look at the effect of the area that would be influenced. Figure 4a.4 shows the location of simulated groundfish trawls catching > 50, 40, 30, 20, 10, and 5 kg of sponge in the NRA. Reducing the level to 40 kg would start to influence fishing in the area near Sackville Spur while reducing to 30 kg would start to affect the slope waters around the southwest of Flemish Cap and Beothuk Knoll.

We compared the locations of the simulated catches greater than 50 kg with the areas identified as having significant concentrations of sponge in the spatial analyses of the research vessel (RV) bycatch used to delineate the closed areas (Figure 4a.5). Of the three areas with the greatest aggregations of simulated lines, two also were areas where significant concentrations of sponge were taken in the RV surveys. Those two areas were identified in the NAFO WGEAFM report as containing significant concentrations of sponge but were not included in the spatial closures that were ultimately implemented (Figure 4a.6). The third area did not have high RV catches and the simulated catches were achieved by fishing across larger homogenous areas of medium bycatch (9-17 kg/km) to accumulate larger catches (Figure 4a.3).

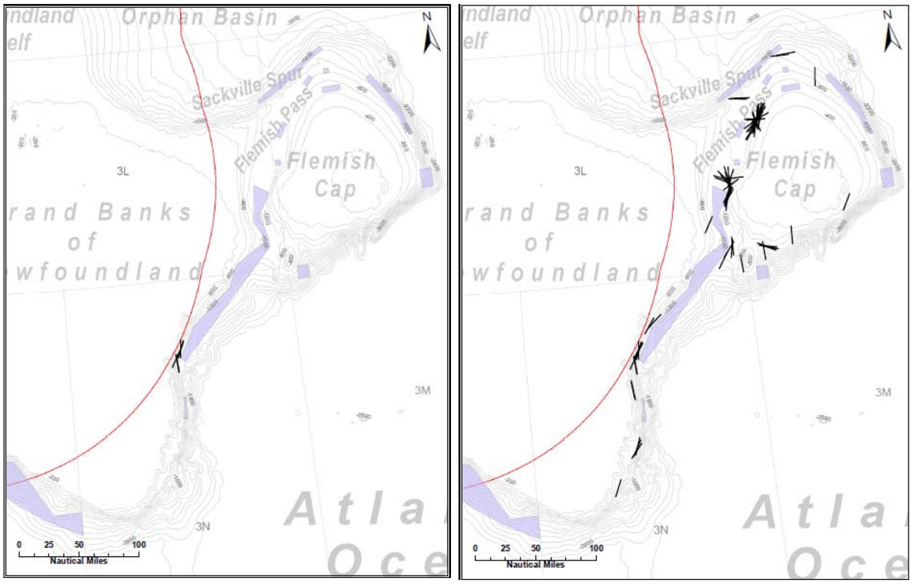

Figure 4a.3. Location of simulated groundfish trawls catching > 800 kg (left) and > 50 kg (right) of sponge in the NRA.

Data on species composition would help to determine the significant adverse impact of the threshold levels. For example, a single (large) specimen of *Geodia barretti*, caught off Greenland (Figure 4a.7) was 55 cm in width and weighed 38.46 kg (M. Best, pers. comm.). Therefore reducing the encounter threshold to 50 kg might involve the collection of only a few sponges if the catch composition is comprised of large, massive structure forming species such as *Geodia* spp. Conversely, 50 kg could represent much larger numbers of less massive sponges which might also be vulnerable marine ecosystem components and represent a greater adverse impact.

Based on the model results, the WGEAFM recommends that the encounter threshold for sponges fished with bottom trawl gear be reduced from 800 kg to between 30 and 50 kg per tow. This is unlikely to have a large effect on the commercial fishery within the fishing footprint and would serve as a more effective sponge conservation measure in unfished areas under an exploratory fishery. This range was selected because it is the range after which there is a large increase in the proportion of the fishery affected with lowering threshold (Figure 8). Figure 4 indicates the areas where the model predicts that such encounters would occur for each of the levels proposed. Part of the validation would be to see whether reports from the commercial fishery align spatially with Figure 4 projections. **The WGEAFM further recommends that commercial fishery data on coral and sponge bycatch be obtained so that these modelled results can be directly compared with commercial catches.**

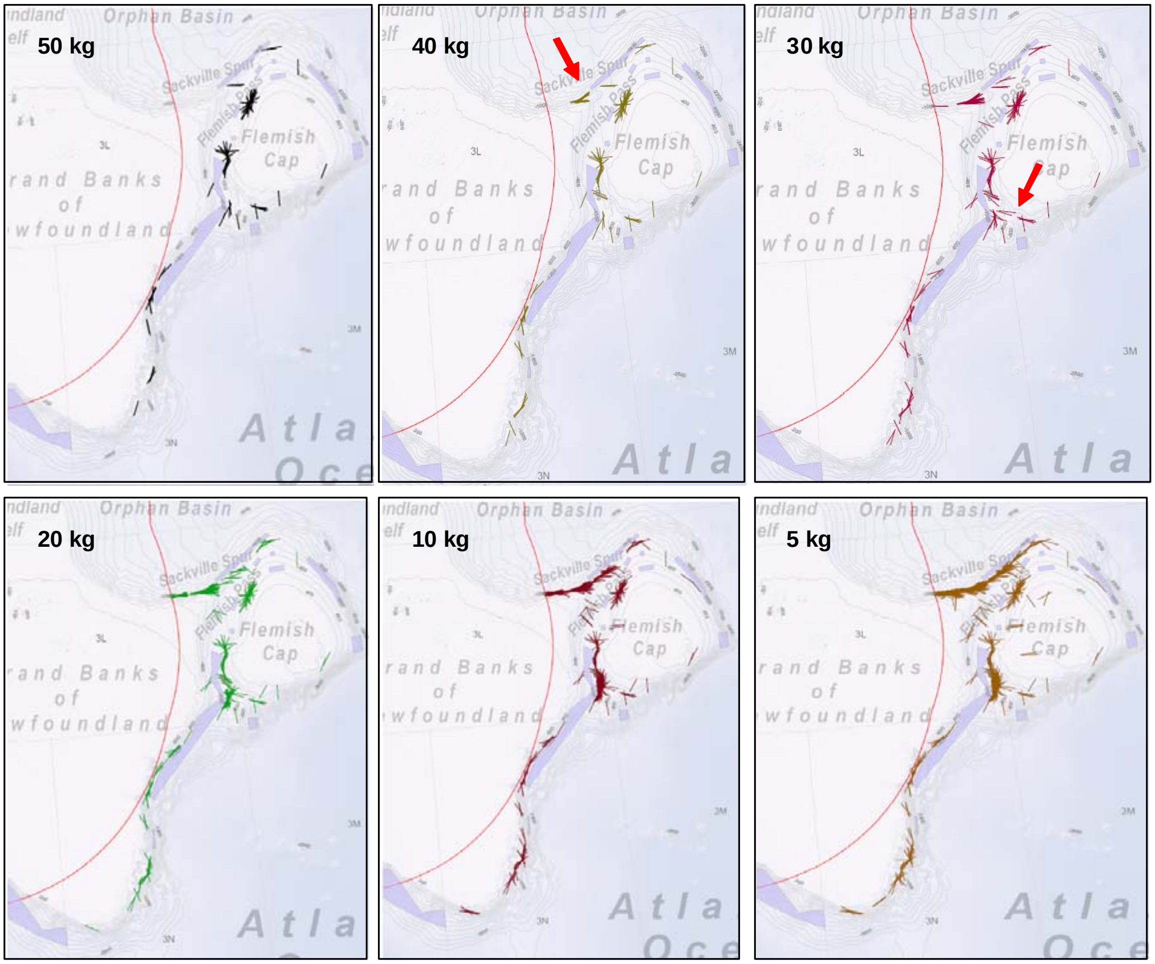

Figure 4a.4. Location of simulated groundfish trawls catching > 50, 40, 30, 20, 10, and 5 kg of sponge in the NRA. Red arrows on the 40 and 30 kg panels indicate where new areas are formed relative to the 50 kg panel.

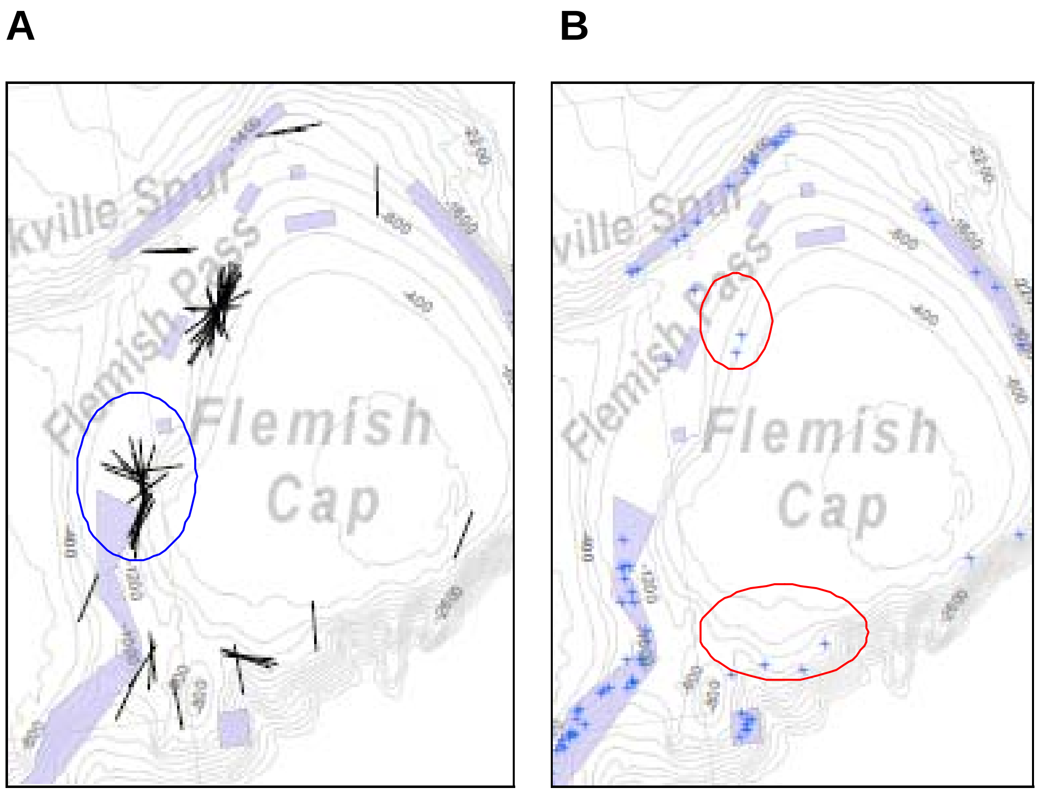

Figure 4a.5. Panel A shows the location of simulated trawl lines which caught more than 50kg of sponge. Panel B shows the location of actual research vessel (RV) trawl catches that caught more than 75 kg of sponge, the value used to identify sponge grounds ("significant catches") in NAFO (2009b). The blue circle on panel A indicates an area where simulated trawl lines with more than 50 kg sponge bycatch were concentrated AND where there were no large RV catches. The red circles on panel B indicate an area where simulated trawl lines with more than 50 kg sponge bycatch were concentrated AND where there were large RV catches (> 75kg) identified but not protected by area closures.

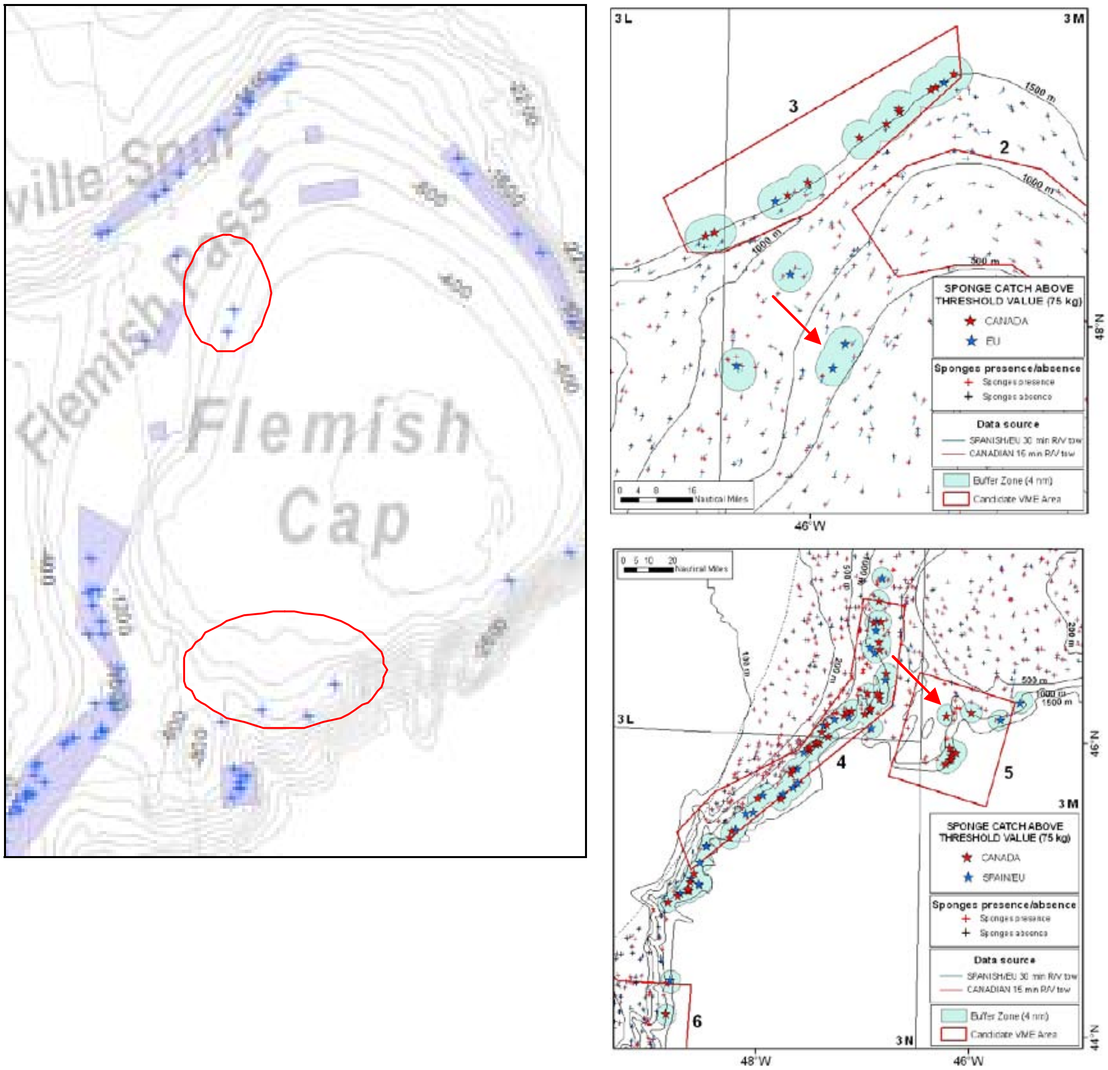

Figure 4a.6. Left: The location of actual research vessel (RV) trawl catches that caught more than 75 kg of sponge, the value used to identify sponge grounds ("significant catches") in NAFO (2009b). The red circles indicate an area where simulated trawl lines with more than 50 kg sponge bycatch were concentrated AND where there were large RV catches (> 75kg) identified but not protected by area closures (shaded grey polygons). Right: Figure 10 (upper) and Figure 11 (lower) from NAFO (2009b) with red arrows indicating location of significant concentrations of sponges not protected by the closed areas and corresponding to the areas circled on the left side panel.

Figure 4a.7. A single specimen of *Geodia barretti*, 38.46 kg and 55 cm width, caught off Greenland (Photo courtesy of M. Best, DFO).

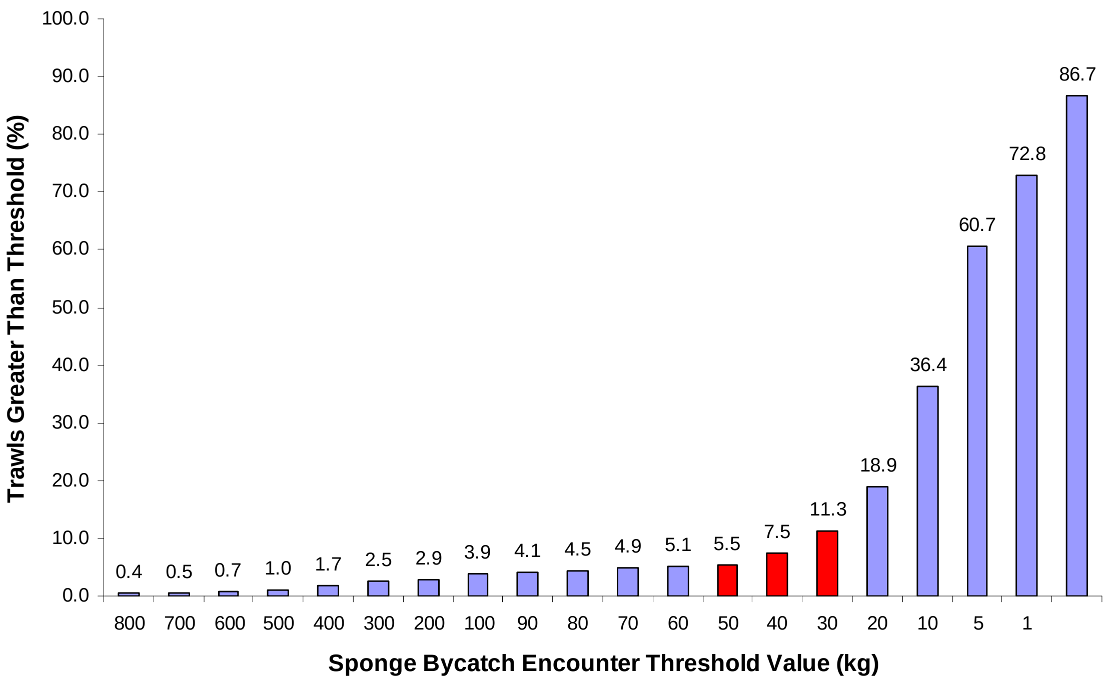

Figure 4a.8. Graphical representation of Table 4a.1 showing the proportion of simulated trawls with sponge catches greater than the sponge bycatch encounter threshold. Red bars indicate the area where the proportion of the trawls begins to increase more relative to other changes with decreasing threshold.

4a.5. References

Cogswell, A., E. Kenchington, C. Lirette, B. Brodie, G. Campanis, A. Cuff, A. Perez, A. Kenny, N. Ollerhead, M. Sacau, V. Wareham. 2010. Evaluating Sponge Encounter Thresholds through GIS Simulation of the Commercial Groundfish Fishery in the NAFO Regulatory Area. NAFO Scientific Council Research Document 10/71.

Kenchington, E., A. Cogswell, C. Lirette, J. Rice. 2010. A GIS Simulation Model for Estimating Commercial Sponge Bycatch and Evaluating the Impact of Management Decisions. DFO Canadian Scientific Advisory Secretariat Research Document 2010/040. vi + 39 pp.

NAFO. 2009a. Delineation of existing bottom fishing areas in the NAFO Regulatory Area. Serial No. N5676 NAFO Scientific Council Summary Document 09/21, 9 pp.

NAFO. 2009b. Report of the NAFO Scientific Council Working Group on Ecosystem Approach to Fisheries Management (WGEAFM) in Response to Fisheries Commission Request 9b and c. Serial No. N5627 NAFO Scientific Council Summary Document 09/6.

NAFO. 2010. Report of the NAFO Scientific Council Working Group on Ecosystem Approach to Fisheries Management (WGEAFM). Serial No. N5627 NAFO Scientific Council Summary Document 10/19.

ToR 4b *(to address FC request #14.2).* Consider whether the SASI model used by the US New England Fisheries Council should be incorporated into the aforementioned GIS framework as a means of integrating significant adverse impacts into the approach.

4b1. Comparison between SASI and the GIS framework developed by WGEAFM

The Swept Area Seabed Impact model (SASI) was developed by the New England Fisheries Management Council (NEFMC) Habitat Plan Development Team to 1) assess fishing impacts on Essential Fish Habitat and 2) to develop new spatial fishery management measures (e.g. habitat closed areas) on the Northeast US Continental Shelf.

Briefly put, SASI quantifies adverse impacts of fishing by combining, in a geo-referenced framework, fishing effort information with the vulnerability of the particular habitat to that particular type of fishing effort (i.e. gear). Fishing effort is standardized to a common currency (area swept) which takes in consideration the actual contact of the gear with the bottom, while vulnerability is typified considering the geology of the bottom, the shear stress to which habitats are exposed, as well as suite of habitat components.

Full documentation of this model is available at NEFMC (2010), while a detailed summary description of the model development and application can be found in the ICES 2010 Report from the Working Group on Fish Ecology (ICES 2010). In addition to these sources, WGEAFM assessment of this model benefited from a presentation on the topic by Brad Harris, University of Massachusetts, and Dave Preble, NEFMC, members of the SASI development team.

On the other hand, the GIS framework developed by WGEAFM (Cogswell et al. 2010, Kenchington et al. 2010) was intended to simulate by-catch of sponges in commercial fishing operations based of the distribution of sponges in the NRA and the distribution and characteristics of the fishing operations. This work (see previous section) provides an avenue to improve management tools for the protection of VMEs (e.g. thresholds to be used in encounter protocols).

WGEAFM compared both approaches, and concluded that the SASI model and the aforementioned GIS framework are designed to address different questions, and so there is no simple means of integrating the two models into a single computational environment. Equally important, there is no particular advantage of trying to do so; each model is addressing valid questions in their own right. Upon reviewing the SASI methodology and structure, WGEAFM considered that even though in its current parameterization and configuration SASI is not directly applicable to the assessment of significant adverse impacts in the NRA, the general framework it provides and the possibilities for customization of that framework show promise for future use in the NRA. Such explorations would require a detailed examination and adaptation of some of the basic matrices used in SASI (e.g. vulnerabilities), so they can reflect the nature of the ecosystems in the NRA. SASI was developed for application in a (comparatively) shallow shelf system, while fishing operations in the NRA often involve fishing at much larger depths and on shelf break habitats.

Despite their differences, one of the spatial data inputs is common to both approaches (e.g. fishing effort rasters provided by the NAFO Secretariat) and use of this in the SASI model may be possible. Other data layers used by SASI might be available from the NEREIDA project for portions of the the NRA, however use of those data would have to be discussed by NEREIDA project members, not all of whom work within NAFO. However, further work would be required to adapt those data to the formats required to run the model (or adapt the model to the data). For example, SASI presently uses only X,Y geological data based on physical seabed samples, while portions of the NAFO region has broad scale multi-beam acoustic information available through NEREIDA.

Additionally, there are fundamental differences between the relatively high energy continental shelf ecosystems for which SASI was developed and the much deeper lower energy systems in the NAFO area. As such the SASI vulnerability assessment would need to be expanded to include the significant biological features found in the deep waters of the NAFO area. In this context, and with initial goal of exploring the possibility of future applications of SASI-like frameworks in the NRA, Brad Harris was invited to join WGEAFM.

In summary, SASI addresses a different set of questions than the GIS framework developed by WGEAFM, and hence, there is no particular benefit in merging both approaches into a single application. SASI structure provides another tool to explore significant adverse impacts, but its current configuration/parameterization is not directly applicable to the NRA, however, the possibility of developing a SASI-like a tool for the NRA will be explored further by WGEAFM in future meetings through the inclusion in the WGEAFM membership of a SASI expert like Brad Harris, University of Massachusetts.

4b.2. References

Cogswell, A., E. Kenchington, C. Lirette, B. Brodie, G. Campanis, A. Cuff, A. Perez, A. Kenny, N. Ollerhead, M. Sacau, V. Wareham. 2010. Evaluating Sponge Encounter Thresholds through GIS Simulation of the Commercial Groundfish Fishery in the NAFO Regulatory Area. NAFO Scientific Council Research Document 10/71.

ICES. 2010. Report of the Working Group on Fish Ecology (WGFE), 6–10 September 2010, Sète, France. ICES CM 2010/SSGEF:24. 90 pp.

Kenchington, E., A. Cogswell, C. Lirette, J. Rice. 2010. A GIS Simulation Model for Estimating Commercial Sponge Bycatch and Evaluating the Impact of Management Decisions. DFO Canadian Scientific Advisory Secretariat Research Document 2010/040. vi + 39 pp.

ToR 4c *(towards Roadmap for EAF).* Detailed description of the modelling approach being developed for the US Northeast Continental Shelf ecosystems towards estimating fisheries production potential from primary production data, and discussion on its application to other areas.

4c.1. Context

Implementing the “Roadmap to EAF” requires developing the capability of estimating fisheries production potential at the level of the ecosystem-units identified in ToR 2a. Although addressing this issue was not a primary goal for this meeting, it was considered valuable to kick-start its discussion in preparation for a more thorough consideration of the topic in future meetings. As initial step, the work done in the Eastern US Continental Shelf was presented.

4c.2. Fishery Production Potential on the Northeast Continental Shelf of the United States

Attempts to define the fishery production potential of marine systems based on energy flow considerations have an extensive history (Ryther 1969). Bottom-up control of fish production has now been demonstrated in many regions of the world ocean (Ware 2000), supporting the general approach of tracing pathways involved in the translation of primary production to fishery yields. The Northeast Continental Shelf of the United States has supported important commercial fisheries for several centuries (Murawski et al. 1997). Investigations into the determinants of fishery production potential of this region were initiated with the seminal studies of Clarke (1946) on Georges Bank. Energy budgets for this system have since been progressively expanded and refined (Cohen et al. 1982; Sissenwine et al. 1984; Steele et al. 2007; Link et al. 2006, 2008).

The fishery production potential for a region is a function of the amount of primary production elaborated, the fraction of this production retained and available to higher trophic levels, the transfer efficiency between successive trophic levels, and the number of trophic levels through which energy must be transferred. We assumed a retention rate of 0.9 to reflect advective loss from the continental shelf margin as a result of entrainment by rings and eddies. In our analysis, we recognize two pathways for transfer of primary production in the system -- the classical grazing food chain tracing the fate of new primary production, principally by diatoms, and production involving transfer through the microbial food web originating with nanoplankton production. The former involves grazing by mesozooplankton and filtering of diatom production by benthic invertebrates, particularly bivalves. The latter pathway entails consumption of nanoplankton by heterotrophic bacteria and feeding of microzooplankton on bacteria. Carnivorous zooplankton prey on microzooplankton in this representation. The microbial pathway therefore involves two or more trophic transfer steps before reaching mesozooplankton as a bridge to higher trophic levels.

We employed satellite-derived estimates of primary production for the region using the Ocean Productivity and Light (OPAL) model (K. Hyde NEFSC, personal communication). Estimates of transfer efficiencies between successive trophic levels were based on information in the literature for the microbial food web and on direct estimates from network models derived for this system (Link et al. 2006). For the microbial food web, we assumed that 50% of the nanoplankton is consumed by heterotrophic bacteria (Ware 2000). The gross growth efficiency of bacteria was taken to be 33% and the assimilation fraction to be 80% (Link et al. 2006). The transfer efficiency of from bacteria to microzooplankton was taken to be 0.25 (Ware 2000).

For the grazing food chain, we partitioned the system into transfer from net phytoplankton to mesozooplankton and macrobenthic invertebrates and transfer from mesozooplankton to higher trophic levels. An emerging generalization is that the transfer efficiency from the first to second trophic level is approximately 20% while the transfer efficiency between successive higher trophic levels is on the order of 10-15% (e.g. Lalli and Parsons 1997). For our data, the estimated transfer from net phytoplankton to secondary producers is 18.8 % and for all higher trophic levels it is 13.2% based on Ecopath results for this system

Estimated fishery production potential using this general approach is known to be particularly sensitive to the transfer efficiencies employed (e.g. Miller 2004). We therefore explored the consequences of uncertainty in transfer efficiencies based on the observed range in the North American studies cited above. Monte Carlo simulations were conducted with transfer efficiencies between the first and second trophic levels and between successive higher trophic levels drawn from Beta distributions with mean and variances specified by the unweighted averages of the North American studies as described above. Parameters of the Beta Distribution were determined by iteration (Johnson and Kotz 1995).

Under an MSY harvest policy, the estimated mean trophic level for all species for which MSY reference points are currently available would be approximately 3.1. We consider this to be a minimum estimate because reference points for a number of high level predators are not currently available and therefore not incorporated. Mean trophic level exceeded this benchmark during the period of distant water fleet activity. We explored predicted production levels over a range of mean trophic levels of 3.0 to 3.25 to encompass a probable span of trophic levels under an MSY harvest policy. Our estimate of system-wide production under this range is 4.8-6.2 million mt.

We are ultimately interested in translating production to estimates of sustainable catch from the system (representing commercial and recreational landings and discards). Quantitative guidelines for ecosystem exploitation rates have not yet been established. We explored possible exploitation levels ranging from 0.25 to 0.35. For a mean trophic level of the catch of 3.1 and an ecosystem exploitation rate of 0.3, the predicted catch level (landings plus discards) from the system as a whole is 1.855 million tons (fish and invertebrates). For a mean trophic level of the catch of 3.2 and an ecosystem exploitation rate of 0.3, the predicted equilibrium catch level is 1.55 million tons.

4c.3. Discussion

WGEAFM had an initial discussion on the development and implementation of fisheries production potential models, based on the experience gained in their application to the Northeast US Continental Shelf. It was concluded that these models appear to be a good starting point worthy of exploration in other NAFO ecosystem units, but it was also recognized that other models may also be of use for exploring basic overall ecosystem production (e.g. aggregate biomass production models). Based on this initial discussion, it appears that the basic data sources should be available, at least for the recent past, but a more careful examination of all required data sources is needed. It was also pointed out that, given the sensitivity of these models to key parameters (e.g. transfer efficiencies), and the lack of field estimates for many of these type of parameters, a significant effort needs to be put in the development of modeling tools and exercises to properly incorporate the impact of uncertainties in model outputs. The development of some kind of validation strategy for this type of models was considered a key element for their reliable application in the provision of fisheries advice. WGEAFM considered that the exploration of these models, and the general topic of basic fisheries production potential in the identified ecosystem units, is a logical next step in the development of the “Roadmap to EAF”.

4c.4. References

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

The Fisheries Commission Request # 15 from the September 2010 FC meeting states:

> *"Recognizing the initiatives on vulnerable marine ecosystems (VME) through the work of the WGFMS, and with a view to completing and updating fishery impact assessments, the Scientific Council is requested to provide the Fisheries Commission at its next annual meeting in 2011: 1) guidance on the timing and frequency of fishing plans/assessments for the purpose of evaluating significant adverse impacts on VMEs; 2) a framework for developing gear/substrate impact assessments to facilitate reporting amongst the contracting parties."*

This request was deemed adequately covered by ToR 5 (Methods for the long-term monitoring of VME status and functioning) under Theme 3 (Practical application of ecosystem knowledge to fisheries management), and hence, its two components have been addressed in the following ToRs 5a and 5b.

ToR 5a *(to address FC request #15.1)*. In the context of the work done on vulnerable marine ecosystems (VME) by the FC Working Group of Fisheries Managers and Scientists (WGFMS) and WGEAFM, and with a view to completing and updating fishery impact assessments, provide guidance on the timing and frequency of fishing plans/assessments for the purpose of evaluating significant adverse impacts on VMEs.

In order to provide guidance on timing and frequency of fishing plans/assessments, WGEAFM constructed the following flowcharts to better understand and outline the process currently in place in NAFO re fisheries assessments. The first chart indicates the decision process leading to when a fisheries assessment would be required (based on the existing procedures outlined in the NAFO Conservation and Enforcement Measures) (Figure 5a.1). At present, there are three circumstances where an assessment would be required. A fourth (bottom right part of the flowchart) is suggested if/when periodic assessments of fishing activities are required (e.g. on a multi-year basis). This would address the question of frequency for existing and/or unassessed fisheries.

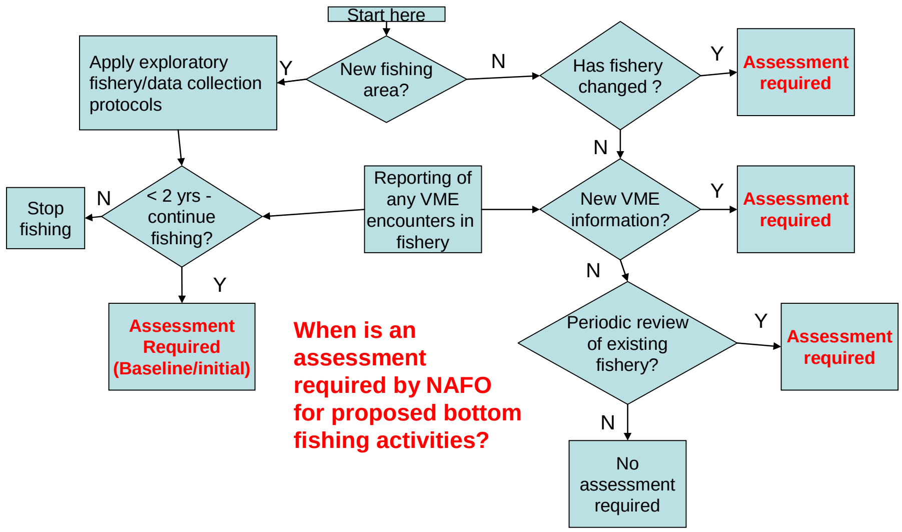

Figure 5a.1. Flowchart describing the decision process leading to when a fisheries assessment would be required (based on the existing procedures outlined in the NAFO Conservation and Enforcement Measures).

The second chart outlines the process currently defined by Fisheries Commission for fisheries assessments. Boxes highlighted in green outline the components that Scientific Council would need to consider (Figure 5a.2).

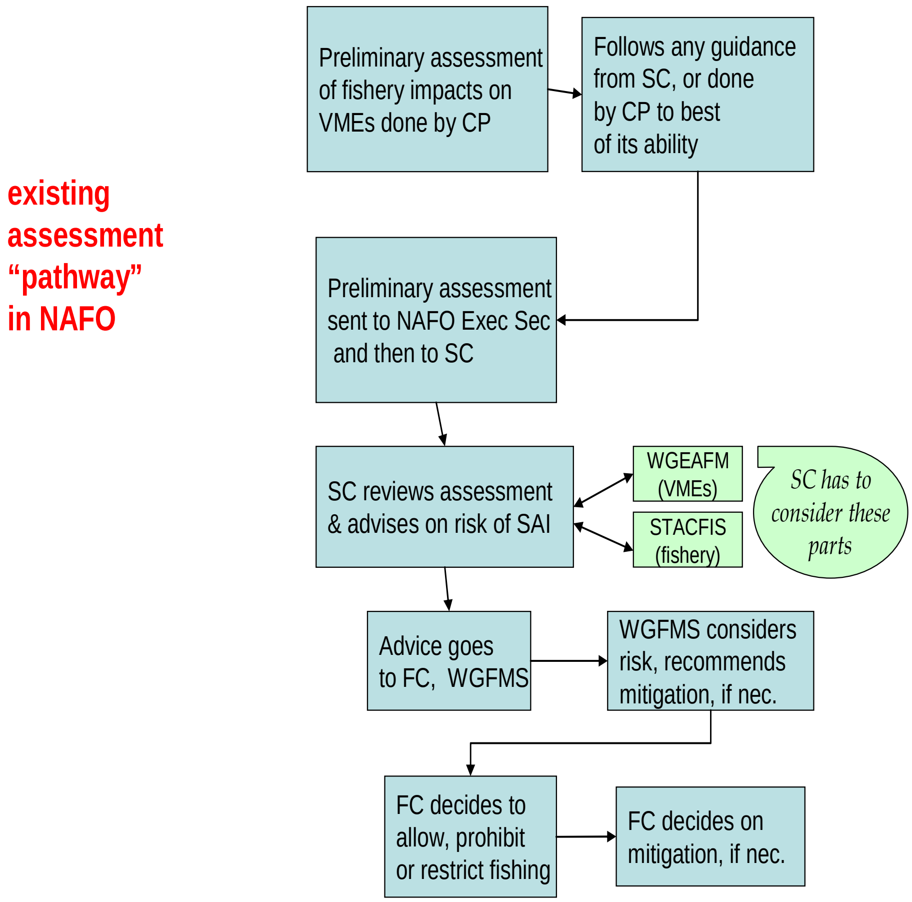

Figure 5a.2. Flowchart describing the process currently defined by Fisheries Commission for fisheries assessments.

The components of a fisheries assessment within NAFO, as agreed by FC in September 2010, following input from SC, are as follows:

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.

WGEAFM noted that no assessments have yet been submitted following this format, given that it had just been adopted by FC. Once assessments are received, it will be possible to evaluate and provide feedback on the content. On the question of timing, there are several steps in the current assessment pathway, involving SC, FC and its Working Groups. Given the current schedule of meetings for SC and FC, assessments would have to be submitted several months before decisions were required. For example, SC and/or its WGs would require time to review the assessment, and then FC/WGFMS would evaluate risks, decide on any required mitigation measures, and decide if a fishery was to proceed. This would be required for any fishery requiring an assessment for a Jan. 1 opening date, with FC making its decision in late September of the previous year. Under such a schedule, an assessment would have to be submitted by a Contracting Party about 8-9 months in advance of anticipated fishing.

During discussion of the process and timelines, the following observations were made:

- There is no provision currently for initial assessment of an existing fishery, unless changes occur in the fishery, or VMEs are observed.
- Frequency of assessments is now determined by new information (e.g changes in the fishery, presence of VMEs). Perhaps a regular multi-year assessment schedule could be developed.
- VME by definition has a broader application than just the current closed areas.
- SC needs data from fisheries to address questions on whether VME have been detected during fishing, and to evaluate if significant changes in fishery have occurred.
- There should be an established process for reporting and reviewing possible VME encounters
- How would the exploratory fishery protocol be evaluated re any decision to allow fishing (up to 2 years)? This should be subject to the same assessment procedures as fishing in a new area.

ToR 5b *(to address FC request #15.2)*. Within the context described above, provide guidance on a framework for developing gear/substrate impact assessments to facilitate reporting amongst the contracting parties.

WGEAFM considered the idea of a framework for such impact assessments, but could not provide a comprehensive approach at this time, noting that this would require considerably more information and expertise. However, there were a number of items that WGEAFM considered to be useful in this regard. One of the most important data sources in conducting impact assessments will be documentation of physical characteristics of the fishing gear. To evaluate potential impacts, it is important that descriptions of fishing methods be reported. This should include details such as target species, net or bottom longline types and how they are set ; net dimensions or bottom line lengths and types / number of hooks; trawl-door type, size and weight; footrope type and dimensions; ground gear (bobbins, rock-hopper gear, etc), range in fishing height off bottom; door-spread and net opening; and factors affecting gear selectivity (mesh size, tickler chains, etc.). WGEAFM noted that the data collection form currently approved for use in NAFO exploratory fisheries requires much of the basic information on fishing gear to be reported, but emphasized that detailed information as outlined above would be most useful. This would allow more detailed maps of fishing effort by gear type to be constructed.

Another useful aspect would be to map areas where known damage to fishing gear has occurred in previous fisheries, in both research and commercial fishing tows. Reporting damage on a tow by tow basis (e.g. in terms of low, medium, or high degree of trawl damage) would allow such information to be included in models examining fishing gear impacts.

Theme 4: Specific requests

ToR 6. Explore options for developing a FAO 3-letter alpha codes for corals and sponges

Scientific Council requested in October 2009 that the NAFO representative to the Coordianted Working Party on Fisheris Statistics (CWP, Ricardo Federizon, NAFO Secretariat) discuss the inclusion of 3-letter codes for corals and sponges in the ASFIS list of species codes (http://www.fao.org/fishery/collection/asfis/en)at the February 2010 CWP meeting to be held in Hobart, Australia, during February 2010. After some informal discussions with CWP, in was decided that this issue was not appropriate for the agenda of this CWP meeting. However, it was identified that the correct procedure to adopt new 3-letter codes to the ASFIS list was by recommendation from a competent group to the FAO Fisheries Statistics and Information Service (FIPS).

The ASFIS list of codes was initially developed to allow for the easy recording of commercial fish species, and in 2000 contained 1 700 species that covered the main finfish and shellfish species required for statistical reporting of catches worldwide. However, since then, there have been many requests to include species of a more local interest. In March of 2010, around 20-30 corals and sponges were added following a request from CCAMLR. The list currently stands at some 10 900 species (http://www.fao.org/fishery/collection/asfis/en).

The group reviewed the 3-letter codes currently assigned to the coral and sponge species already included in the ASFIS database. However, it was quickly seen that the codes poorly and inconsistently related to the scientific names and because of this it was felt that they would be difficult to use and likely prone to recording error. For example, the following codes do not follow a consistent abbreviation rational: COL (*Corallium rubrum*, Sardinia coral), CEL (*Corallium elatius*, Momo, boke magai, misu coral), and QGA (*Spongia agaricina*, Elephant ear sponge). Common names rarely help. Also of note is that a 3-letter code can have 26^3 = 17 576 combinations, and that nearly 11 000 have been already assigned. This means that future codes will increasingly link to the names of the species they are being assigned to. Because of this, the group was of the opinion that the development of 3-letter ASFIS codes for corals and sponges in the northwest Atlantic would not be helpful for the purposes of easy and accurate recording.

It was proposed that a new form be developed that utilized existing recording forms and information contained within the NAFO coral[1] and sponge[2] guides. The only existing relevant NAFO recording form is the Exploratory Data Collection Form reproduced in Annex XXV of the NAFO Control and Enforcement Measures (NCEM). It is proposed that this is used as the first part of the recording form, as it contains important information on gear, position, depth, etc., in combination with a second part that asks for accurate identification and links to the guides. A draft of a possible form layout, that could be printed on both sides of a sheet of recording paper, would look like (see over page):

6.1. References

Kenchington, E., M. Best, A. Cogswell, K. MacIsaac, F. J. Murillo-Perez, B. MacDonald, V. Wareham, S. D. Fuller, H. I. Ø. Jørgensbye, V. Sklya, and A. B. Thompson. 2009. Coral Identification Guide NAFO Area. *Sci. Coun. Studies*, **42**: 1-35. doi:10.2960/S.v42.m1

Best, M., E. Kenchington, K. MacIsaac, V. E. Wareham, S. D. Fuller, and A. B. Thompson. 2010. Sponge Identification Guide NAFO Area. *Sci. Coun. Studies*, **43**: 1-35. doi:10.2960/S.v43.m1

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).

ToR 7. Presentation of the NAFO sponge guide.

The United Nations General Assembly Resolution 61/105 (UNGA, 2006) calls upon Regional Fisheries Management Organizations (RFMOs), such as NAFO, to identify vulnerable marine ecosystems (VMEs) in the high seas and to adopt protective measures for those in danger of significant adverse impact from fishing gear. The Fisheries and Agriculture Organization (FAO) of the United Nations has responded to this request by preparing technical guidelines to assist States and RFMOs in formulating and implementing the appropriate measures for the management of deep-sea fisheries (FAO, 2008). The FAO Guidelines provide examples of species groups, communities and habitat-forming species that are documented or considered sensitive and potentially vulnerable to fishing activities in the high-seas. These include sponges, deep-water corals, and hydroids.

However, not all sponge species meet the criteria of VME components suggested by the FAO. Fuller *et al*. (2008) discuss the large number of sponge species that are known from the North Atlantic and describe three general groups which should be considered VME:

- Hexactinellid patches (*Vazella pourtalesi*), found to date on the Scotian Shelf in soft sediment areas;
- *Geodia* spp. found along the shelf edge, in gravel or hard bottom areas; and
- *Thenea* sp. generally found in soft bottom, and growing on spicule mats.

These groupings were endorsed by the NAFO Working Group on the Ecosystem Approach to Fisheries Management and by the NAFO Scientific Council (NAFO 2008a, b). ICES (2009) later reviewed the North Atlantic sponge taxa against the FAO (2008) criteria to determine which should be considered as vulnerable marine ecosystem components. They produced an expanded list of 25 sponge species which are habitat-forming and can be considered indicators of sponge VMEs in the North Atlantic. These are species that form the sponge grounds, which is the conservation unit in this area (as opposed to a particular species), and host a variety of associated smaller sponge species that contribute to the biodiversity of the habitat (Boutillier *et al*., 2010).

Unfortunately, there is very little data on sponge species distribution in the NRA as no identification guide has been created that would facilitate this reporting. Because the habitat-forming taxa are large and of considerable weight, research vessel bycatch tended to be highly skewed towards large numbers of very small sponge bycatch, with a few very large catches that were indicative of sponge grounds (Kenchington *et al*., 2009a). Management decisions have proceeded on the reasonable assumption that protecting sponge grounds would infer protection to both the habitat-forming taxa and the smaller associated taxa. However, more detailed information would be very useful in evaluating the VME status of the sponge areas. Consequently a Sponge Identification Guide has been prepared for the NAFO Regulatory Area (NRA). It follows the format of the Coral Identification Guide (Kenchington *et al*., 2009b) and includes 33 sponge taxa known to occur in the NRA (e.g., Figure 7.1), 1 habitat-forming taxon (*Vazella pourtalesi*) known to occur on the Scotian Shelf (Kenchington *et al*., 2010) but which may occur in the NRA, and one sponge-derived habitat, i.e., sponge spicule mats (Best *et al*., 2010).

It was recognized that sponges as a group can be very difficult to identify, due to their malleability and variation within members of even the same species. Accurate identification to species often requires microscopic analysis of spicules, therefore several taxa are represented at the genus level to avoid incorrect reporting (for example, *Geodia* spp. represents at least 3 known species in the genus *Geodia*). It was also recognized that most of the intended users will use pictures to identify the taxa as they appear on deck, and will also wish to minimize reading time associated with identification. The guide therefore uses clear photos taken on-deck or laboratory photos (versus underwater photos), and illustrates those features which help to distinguish the taxon using current taxonomic descriptors. The taxa represented in the guide are organized according to morphology or body type, as this tends to be more intuitive than organizing them taxonomically. Thus, there are 6 morphology groups defined, representing a total of 35 sponge taxa. It is recognized that the taxa list is almost certainly incomplete, as sponge expertise in the area is developing. Thus, the guide is intended to be a ‘living’ document, where pages can easily be added and updated as knowledge of sponges in the NRA improves.

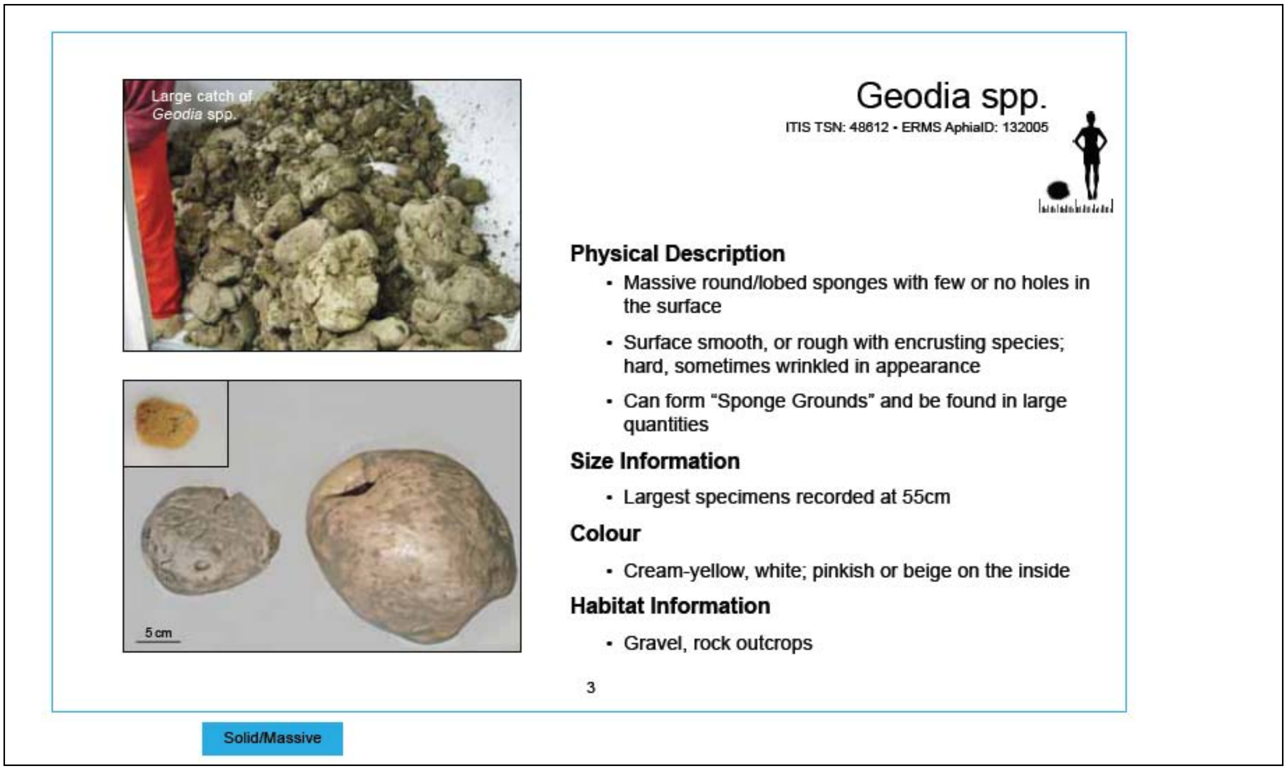

Figure 7.1. An example of a page from the NAFO Sponge Identification Guide (Best *et al*., 2010) describing *Geodia* spp., one of the habitat-forming taxa in the NRA.

7.1. References

Best, M., E. Kenchington, K. MacIsaac, V.E. Wareham, S.D. Fuller & A.B. Thompson. 2010. Sponge Identification Guide: NAFO Area. NAFO Scientific Council Studies, 43:1-49. doi:10.2960/S.v43.m1

Boutillier, J., E. Kenchington & J. Rice. 2010. A Review of the Biological Characteristics and Ecological Functions Served by Corals, Sponges and Hydrothermal Vents, in the Context of Applying an Ecosystem Approach to Fisheries. *DFO Canadian Scientific Advisory Secretariat Research Document* 2010/048. iv+36 p.

FAO. 2008. Report of the Technical Consultation on International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Rome, 4–8 February and 25-29 August 2008. FAO Fisheries and Aquaculture Report, No. 881, Rome, FAO. 42 pp. ftp://ftp.fao.org/docrep/fao/011/i0605t/i0605t00.pdf

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

ICES. 2009. Report of the ICES/NAFO Joint Working Group on Deep Water Ecology (WGDEC). ICES CM 2009/ACOM:23, 94pp.

Kenchington, E., A. Cogswell, C. Lirette & F.J. Murillo-Perez. 2009a. The Use of Density Analyses to Delineate Sponge Grounds and Other Benthic VMEs from Trawl Survey Data. Serial No. N5626. NAFO Scientific Council Research Document 09/6, 18pp.

Kenchington, E., C. Lirette, A. Cogswell, D. Archambault, P. Archambault, H. Benoit, D. Bernier, B. Brodie, S. Fuller, K. Gilkinson, M. Levesque, D. Power, T. Siferd, M. Treble & V. Wareham. 2010. Delineating Coral and Sponge Concentrations in the Biogeographic Regions of the East Coast of Canada Using Spatial Analyses. *DFO Canadian Scientific Advisory Secretariat Research Document* 2010/041. iv + 207 pp.

Kenchington, E., M. Best, A. Cogswell, K. MacIsaac, J. Murillo-Perez, B. MacDonald, V. Wareham, S. D. Fuller, H. I. Ø. Jørgensbye Hansen, V. Sklyar & A. B. Thompson, 2009b. Coral Identification Guide NAFO Area. Scientific Council Studies, 42: 1-18. doi:10.2960/S.v42.m1.

NAFO. 2008a. Report of the NAFO Scientific Council Working Group on Ecosystem Approach to Fisheries Management (WGEAFM). Serial No. N5592. NAFO SCS Doc. 08/24, 19pp.

NAFO. 2008b. Scientific Council Meeting, 22-30 October 2008, Copenhagen, Denmark. Serial No. N5594. NAFO SCS Doc. 08/26, 32pp.

UNGA. 2006. United Nations General Assembly Resolution 61/105. http://daccessdds.un.org/doc/UNDOC/GEN/N06/500/73/PDF/N0650073.pdf?OpenElement

ToR 8. Review of the NAFO poster on Ecosystem-based Management

The NAFO Secretariat asked the group to review ideas for a poster that depicts NAFOs ecosystem approach. The poster would explain, in general terms, how NAFO is developing and implementing its ecosystem approach objectives, and be directed at a more general audience for use at shows or on the website. Several valuable suggestions were forthcoming that will allow the Secretariat to develop a draft poster. This draft poster may be sent informally to various group members for review.

ToR 9. Data sharing agreement

Data has been provided in a raw or minimally processed format by several CPs or scientific projects/groups to the working group (DFO, EU surveys, NEREIDA project, and NAFO Secretariat). These data have been provided to the WGEAFM so they can address their ToRs, and for no other purpose. Summary results derived from these data sets, either alone or in combination with other data sets, may appear in this or subsequent WG EAFM reports. Scientific Council may also refer to these summary results in their reports for the purpose of providing advice to Fisheries Commission.

Documents reviewed and/or produced during this meeting

Three SCR documents were reviewed, endorsed by WGEAFM, and produced at this meeting. These documents are:

> Cogswell, A., E. Kenchington, C. Lirette, B. Brodie, G. Campanis, A. Cuff, A. Perez, A. Kenny, N. Ollerhead, M. Sacau, V. Wareham. 2010. Evaluating Sponge Encounter Thresholds through GIS Simulation of the Commercial Groundfish Fishery in the NAFO Regulatory Area. NAFO Scientific Council Research Document 10/71.
>
> 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.
>
> Pérez-Rodríguez, A., Cuff, A., Ollerhead, N., Pepin, P., and Koen-Alonso, M. 2010. Preliminary analysis towards the delineation of marine ecoregions in the Flemish Cap, Northwest Atlantic. NAFO SCR Doc. 10/73.

WGEAFM also reviewed and endorsed the production of the following NAFO Sponge Identification Guide (see ToR 7):

> Best, M., E. Kenchington, K. MacIsaac, V.E. Wareham, S.D. Fuller & A.B. Thompson. 2010. Sponge Identification Guide: NAFO Area. NAFO Scientific Council Studies, 43:1-49. doi:10.2960/S.v43.m1

Next Steps

a) Date and place for next meeting

It was proposed that the 4th WGEAFM meeting to take place in November 30-December 09, 2011 at the NAFO Secretariat in Darmouth, Canada.

b) ToRs for next meeting

WGEAFM proposes that its 4th meeting should continue addressing the the long-term ToRs described as:

Theme 1: Spatial considerations

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.

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.

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 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 4th 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 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 this report), but they may also explore other modelling avenues (e.g. aggregate biomass models). These studies have been placed under ToR3 (instead of ToR4, as it was during the 3rd WGEAFM meeting) because, unlike the case of the Northeast US continental Shelf, there is very little base work on this topic available for the other areas, and thinking of the application of these studies in a management context seems premature at the present time, but it would represent one additional step forward in the process of developing the "Roadmap to EAF".*

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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