Northwest Atlantic Fisheries Organization

Serial No. N5627 NAFO SCS Doc. 09/6

SCIENTIFIC COUNCIL MEETING – JUNE 2009

Report of the Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM)

CONTENTS

Response to Fisheries Commission Request 9 b

1. Request

9. Recognizing the initiatives on vulnerable marine ecosystems (VME), and with a view to completing fishery impact assessments at the earliest possible date, Fisheries Commission requests the Scientific Council to:

a) Provide, as soon as possible in 2008, delineations, if any, of significant concentrations of corals in the NAFO Regulatory Area, by species, for the identification of VMEs. This should include the size and catch characteristics of corals obtained respectively from commercial fishing vessels and fisheries research vessels and the assessment of significant adverse impacts, with a particular focus on those species which involve interactions with commercial fisheries. The data should include absence/presence of corals as well as density.

b) Provide, by June 30, 2009, delineations, if any, of significant concentrations of sponges in the Regulatory Area by species, including the size and catch characteristics of sponges obtained respectively from commercial fishing vessels and fisheries research vessels, with a particular focus on those species which involve interactions with commercial fisheries. The data should include absence/presence of sponges as well as density.

c) With respect to corals and sponges in canyons denoted in the Scientific Council's response on the area denoted as "Southern Flemish Pass to Eastern Canyons", provide detailed information as soon as practicable or at least a report on progress by June 30, 2009, with a particular focus on those species which involve interactions with commercial fisheries.

The NAFO Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM) met through correspondence to address Item 9 b.

2. Response to Item 9 b: Sponge-dominated Vulnerable Marine Ecosystems

Annex 1 of the FAO Guidelines for Management of Deep-Sea Fisheries in the High Seas (FAO 2008) provides examples of species groups, communities and habitat-forming species which may contribute to forming *vulnerable marine ecosystems* (VMEs). These include "*some types of sponge dominated communities*". The guidelines also describe characteristics of VMEs to aid in their definition, including morphological and life-history traits amongst others.

The joint NAFO/ICES Working Group on Deepwater Ecology (WGDEC) further considered the types of sponges that were sensitive to fishing impact through their 2009 Terms of Reference F (ICES 2009), in order to begin the task of operationalizing the FAO Guidelines for management purposes:

"Term of Reference (f): Define and map sponge associations based on taxonomic information and survey data. Assess the association of sponge grounds with fish and other fauna. Provide a summary of sensitivity of different sponge species to impact and disturbance. Assess priorities areas for sponge distribution data and target areas for future surveys."

Building on previous work by WGDEC (ICES 2007) and by the NAFO WGEAFM (NAFO 2008a,b), the experts at WGDEC produced a list of 25 sponge species that can be considered as structure-forming in certain environments, and indicators of sponge dominated vulnerable marine ecosystems. Most of the sponge species found within fishing depths in the North Atlantic occur as isolated individuals over much of their distribution; however, in some locations environmental conditions permit the formation of dense, multi-species communities, referred to as sponge grounds (cf. ICES 2009).

The foundation for these sponge grounds are often the large, erect sponges which can fill a trawl when such habitats are encountered (ICES 2009). This upright structure makes them especially vulnerable to the impacts of bottom tending gear (Freese et al. 1999, Freese 2001). The most critical damage from this type of gear comes from dislodgement and crushing. When sponges are broken at their base and free floating or turned over through crushing, they are unable to recover (ICES 2009). Sponges brought on deck and returned to the sea cannot reattach and the air in their bodies causes them to float and prevents the functioning of their water exchange system (ICES 2009). Klitgaard and Tendal (2004) suggest that the dominant species on these sponge grounds are slow growing and take at least several decades to reach the sizes commonly observed.

WGEAFM was tasked with delineating "significant concentrations of sponges in the Regulatory Area *by species*"**.** However, WGDEC (ICES 2009) recommended using these large structure-forming species as indicators, and endorsed a habitat-based approach to management, shifting conservation efforts to the sponge grounds as opposed to individual sponge species. OSPAR Commission (2005) uses this approach through the recognition of "sponge aggregations" as habitats on their list of threatened and declining species and habitats. This is very practical in the context of fisheries management as it means that the weight of sponge catch can be used as an indicator of sponge grounds. While information on species composition might be desirable, it is not essential to the establishment of conservation measures for VMEs in the North Atlantic. Consequently the WGEAFM has adopted the WGDEC recommendations and followed a habitat-based approach to addressing Item 9 b.

Furthermore, the specific request form FC indicates that the focus of the response should be given to those species which have interactions with commercial fisheries. By taking a habitat-based approach this particular aspect of the request needs to be interpreted as sponge aggregations which have interactions with commercial fisheries. Since detailed and consistent quantitative information is only available from research surveys, and since the WGEAFM approach is trying to identify sponge grounds in the NRA, it is reasonable to expect that the sponge grounds locations and their corresponding characteristics identified from this analysis are essentially what a fishing vessel may encounter during its commercial operations. There is no reason to believe that commercial fishing vessels will encounter anything different than that observed in research surveys.

Table 1 provides a subset of 9 species from the WGDEC report (ICES 2009) which are known to either dominate or co-dominate sponge grounds at fishing depths in the Northwest Atlantic. These are the structure-forming species which contribute to the VME status of sponge grounds. Those sponge species from the WGDEC list which are associated with the dominant species on the sponge grounds and are abundant but with low biomass, were not listed again here. Most of the dominant species presented in Table 1 occur in the NAFO Regulatory Area (NRA), or are represented by congeneric species such as *Thenea levis* and *T. valdiviae* (S.D. Fuller, pers. comm.), and those not yet documented have distributions that would suggest that they may occur there.

Table 1. Large-sized (>5 cm maximum dimension) sponge species frequently reported from sponge grounds in the Northwest Atlantic. The nature of occurrence is different from one species to another: D = dominating on the ground; M = one of several dominating species on the ground (from ICES 2009). *indicates taxa known to occur in the NRA.

TAXON	SUBSTRATE	SIZE (ADULT)	ASSOCIATED WITH DENSE GROUNDS	GROWTH FORM
HEXACTINELLIDA				
Pheronema carpenteri (Thomson, 1869)	Mud	25 cm	D	Barrel-shaped, thick-walled
Asconema setubalense Kent, 1870 *	Gravel, stones	60 cm	M	Funnel-shaped, thin-walled
Vazella pourtalesi (Schmidt, 1870)	Mud	10 cm	D	Barrel-shaped, thin-walled
DEMOSPONGIAE				
Geodia barretti (Bowerbank,1858)*	Gravel, stones	50 cm (100 cm)	D, M	Globular, often irregular
Geodia macandrewi Bowerbanki, 1858*	Gravel, stones	45 cm	D, M	Globular, often faintly flattened
Geodia mesotriaena (Hentschel, 1929)	Gravel, stones	15 cm	M	Spherical
Geodia phlegraei (Sollas, 1880)*	Gravel, stones	20 cm	M	Globular to funnel-shaped
Stryphnus ponderosus (Bowerbank, 1866)*	Gravel, stones	50 cm	D, M	Lumpy, often irregular
Thenea muricata (Bowerbank, 1858)*	Mud, sand	20 cm	D	Spherical

2.1. Defining Significant Concentrations of Sponges

The WGEAFM agreed that a process is required to define what weight of sponge catch from the trawl surveys constitutes ‘evidence of a sponge-dominated VME’ (as opposed to an insignificant encounter). In previously considering the term “significant” for delineating concentrations of coral in the NRA, the WGEAFM developed a protocol using plots of the cumulative catch weight distribution from the groundfish trawl surveys (NAFO 2008a,b). The distribution of cumulative catch weights was highly skewed, with most trawls catching small quantities, and only small numbers of trawls with larger catches. The objective of that analysis was to identify catch weight thresholds for each taxon which could be considered to be ‘evidence of a VME’, and then selecting those sets where these threshold weights were exceed and use this information to map the location of significant catches. This approach was independently used by the South Pacific Regional Fisheries Management Organization (SPRFMO; Penney et al. 2008) to evaluate commercial data for implementing encounter protocols.

The WGEAFM was unable to select a threshold for significant concentrations of coral using biological criteria, but opted to use the upper 97.5 quantile as a standard (2.5% of the catches were above this value) based on the customary use of this level in statistical analyses (NAFO 2008a,b). However, they argued that for some taxa there may be good reasons to choose lower thresholds and advocated the 90% quantile for their large gorgonian taxon on the basis that these corals are particularly vulnerable to breakage and so the data are likely biased at the small catch end of the distribution by pieces of coral rather than whole colonies.

Faced with a similar challenge, Penney and colleagues (2008) remarked that in the absence of scientific rationale:

"The choice of what weight percentile to use as a threshold for determining evidence of a VME is essentially a management choice, amounting to choosing what percent of tows should qualify as VMEs, based on the data analyzed. This choice needs to be made between the extremes of presence / absence (any occurrence of a vulnerable species in a catch would be considered to be evidence of a VME) and high weight thresholds (only the largest recorded vulnerable species by-catch weights would qualify as evidence of VMEs)."

However, with the absence of any specified definition, or management objective, for 'evidence of a VME', they used a more conservative value (50% quantile = median) than proposed by WGEAFM.

Since its last report on coral, the WGEAFM has considered further the problem of how to choose the appropriate threshold using a biological basis. The cumulative catch weight distribution takes the shape that it does because of the nature of sponge and coral grounds. Both taxa have the ability to form dense aggregations but are otherwise broadly distributed at low density. When a trawl encounters a dense aggregation the catch is consequently very much higher than when fishing on low density areas. It was noted that when the position of the significant concentrations of coral were plotted by the WGEAFM (NAFO 2008a,b) they were grouped into 'key locations', that is, the high catches were spatially aggregated. This was not surprising as it supports the notion that these catches are in fact 'evidence of a VME'.

Here, we present additional analyses that incorporate this spatial dimension to assist in the selection of appropriate catch thresholds to delineate the sponge VMEs. Specifically, we developed a protocol for extracting the area of sponge grounds occupied at different threshold values (Kenchington et al. 2009). If the sponges are highly aggregated in dense concentrations we would expect to see a large change in area as the area expands to include the lower weight thresholds. Further, we would expect that the weight threshold delineating the sponge grounds would be consistent over the NRA and also when considering different data sources, provided that coverage is sufficient.

2.1.1. Data Sources

A total of 1062 trawls with sponge records from four R/V survey programmes fell in the NRA outside of Canada's EEZ (Divs. 3LMNO) and form the basis of the analysis presented here. Details of the programmes are;

1. DFO NL Multi-species Surveys (R/V Campelen 1800 Bottom Trawl): 1995-2008 (NRA. Divs. 3LMNO): 257 records of sponge between 40 and 1494 m, standardized 15 min tow. Provided by Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre (NAFC), St. John's, NL;

2. Spanish 3NO Survey (R/V Campelen 1800 Bottom Trawl): 2002-2008 (Divs. 3NO): 230 records of sponge covering the 'Tail' of the Grand Banks (NRA) between 40 and 1500 m, unstandardized 30 min tow. Provided by the Instituto Español de Oceanografía (IEO);

3. EU Flemish Cap Survey (R/V Lofoten Bottom Trawl): 2003-2008 (Div. 3M): 423 records of sponge covering all the Flemish Cap (NRA) between 130 and 1450 m, unstandarized 30 min tow. Provided by IEO;

4. Spanish 3L Survey (R/V Campelen 1800 Bottom Trawl): 2003-2004 and 2006-2007 (Div. 3L): 152 records of sponge covering the 'Nose' of the Grand Banks and Flemish Pass (NRA) between 110 and 1450 m, unstandardized 30 min tow. Provided by IEO.

In all surveys, sponges were not identified to species level, although all large catches were identified as belonging to the species listed in Table 1. In DFO surveys where only a few were caught, sponge was weighed directly; however, large catches were estimated to the nearest 100 or 1000 kg to expedite the process. Prior to 2005, absence of sponge could be a genuine absence or it could be that small catches were not weighed. A similar process was followed during the Spanish/EU R/V trawl surveys and sponge data collated for the years 2002-2008. After 2005 in the Spanish 3NO survey, and after 2006 in the EU Flemish Cap survey and in the Spanish 3L surveys, all the sponge records were weighed. Prior to this, small catches were not weighed with the same criteria as for the Canadian data.

Consequently, only the records with sponge presence were considered prior to 2005-2006, while null data from the later years was used in mapping.

The location of these trawls is illustrated in Figure 1 and shows good spatial coverage of the NRA (Divs. 3LMNO).

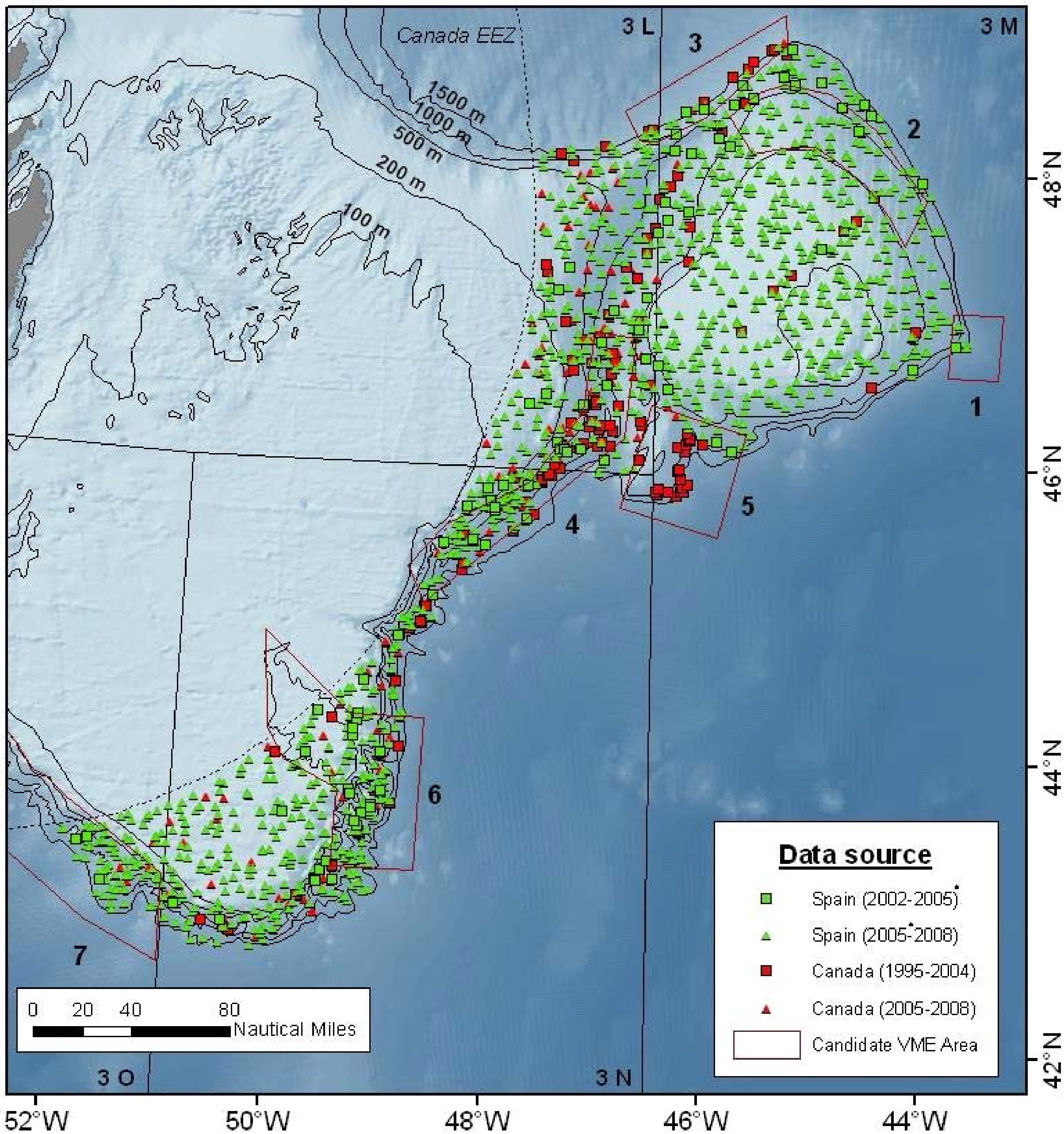


Figure 1. Location of trawls containing sponges from the Canadian (red: 1995 – 2008, N=257) and Spanish/EU (green: 2002-2008, N=805) R/V trawl surveys in the NAFO Regulatory Area (Divs. 3LMNO). Triangles for both represent the subset of data used to calculate cumulative catch distributions (see below). Candidate VME areas are numbered as used by the NAFO SC and outlined in red. *Spanish data from 2005 Platuxa survey was used to calculate cumulative catch distributions and are included in the trawls marked by the green triangles. Data from the 2005 EU Flemish Cap survey used a different sponge sampling protocol and so were not used in that analysis and are represented by the green squares.

2.1.2. Comparing Sponge Catches Between Surveys

The Canadian survey trawls are of fifteen minutes duration while the Spanish/EU trawls are of thirty minutes. In order to use these two data sets together it must first be established whether the sponge catch rates are significantly different between the two. Since 2005 both surveys followed a similar sponge sampling protocol. A Kolmogorov-Smirnov test for the Canadian and Spanish/EU Data was performed, considering all the sponges weights, greater than 0.1, 0.5, 1 and 10 kg for each data set

Sponge catch weight greater than 0.5 kg was not significantly different between the Canadian and Spain/EU surveys (Table 2). This is consistent with what was observed for corals (NAFO 2008a,b) and relates to the size of the coral and sponge grounds relative to the short trawl lengths of both surveys. In order to present the most robust data for the analyses, only the sponge catch greater than 0.5 kg from both surveys was used for calculation of the cumulative frequency distribution.

Table 2. Comparison of the distribution of sponge catch from the Canadian 15 minute RV trawls and the Spanish/EU 30 minute RV trawls by Kolmogorov-Smirnov (K-S) test for different sponge weight catch (Numbers of data (N)) for the 2005-2008 period.

	KS	P
Total Weight (N_{Can}=132, $N_{Spain/EU}$=718)	0.369	< 0.001
> 0.1 kg (N_{Can}=124, $N_{Spain/EU}$=463)	0.180	0.003
> 0.5 kg (N_{Can}=104, $N_{Spain/EU}$=311)	0.062	0.928
> 1 kg (N_{Can}=86, $N_{Spain/EU}$=245)	0.084	0.763
> 10 kg (N_{Can}=34, $N_{Spain/EU}$=100)	0.083	0.995

2.2. Conceptual Description and Comparison of the Methods used for Threshold Identification

Two alternative methods were applied to identify significant threshold values. These were a recently developed GIS-based method (Kenchington et al. 2009) and the cumulative distribution approach previously used for the analysis of coral data (NAFO 2008a,b). Both methods are similar in that they exploit the aggregated distribution of corals and sponges to identify trawl catch weight thresholds indicative of coral beds or sponge grounds.

If there are discontinuities in density, as could be expected between areas with low density of individuals or small groups of individuals and areas with large concentrations of individuals forming grounds or beds, then these discontinuities will be reflected in a cumulative distribution curve. Under these circumstances, the catch weight distribution will appear bimodal with a gap between the high and low density catch weights (Figure 2a), that is, little or no medium sized catches. The corresponding cumulative distribution curve will have long step separating the data from these two density distributions (Figure 2b). If these long steps can be observed in real data, then thresholds that represent natural discontinuities in the data can be identified. These thresholds are expected to be a better reflection of the underlying ecology of the species in question. However, care must be taken because long steps at very high values could also reflect sampling limitations and/or the discrete nature of coral beds and sponge grounds. In this context, it could be expected that gaps identified at lower threshold levels are more likely to reflect actual biological thresholds, than large gaps between extremely large values. If these long steps are not evident, then customary statistical reference points can be used (e.g. 97.5 percentile, median), but probably a more sensible approach would be to use the point of maximum curvature in the cumulative distribution, which represents a point of maximum change of the curve (Stirling and Zakynthinaki 2008). Both statistical reference points and the point of maximum curvature are ultimately reflective of biological properties of the data, however, they do not directly relate to the question of whether the trawl catch was taken from a sponge ground. Spatial information is not directly utilized.

If the essence of the above rationale is represented in a geographic context, it could be expected that the area occupied by actual sponge grounds or coral beds would be much smaller than the area covered by both isolated individuals and the sponge grounds or coral beds together. The largest catches should all come from the sponge grounds, particularly as the R/V tows are short and so large catches resulting from accumulation of isolated individuals over many kilometres are not a factor. Furthermore, if coverage is calculated using increasing/decreasing threshold values, then changes in area covered would be expected to behave in a similar way as the steps in a cumulative distribution. A large decrease/increase in area covered between two subsequent threshold values could be a reflection of the change between the area of distribution of all individuals, including the scattered isolated ones and the area covered by actual grounds. The added value of the geographical analysis comes from seeing changes in distribution and area directly on the map, which can be an extremely useful aid in defining the biological significance of a given threshold. This geographic approach also potentially provides a sort of "magnifying glass" for the large jumps expected to be associated with biologically meaningful changes in threshold values, which can make easier the identification of these, often elusive, ecologically relevant thresholds.

A) FREQUENCY DISTRIBUTION **B) CUMULATIVE DISTRIBUTION**

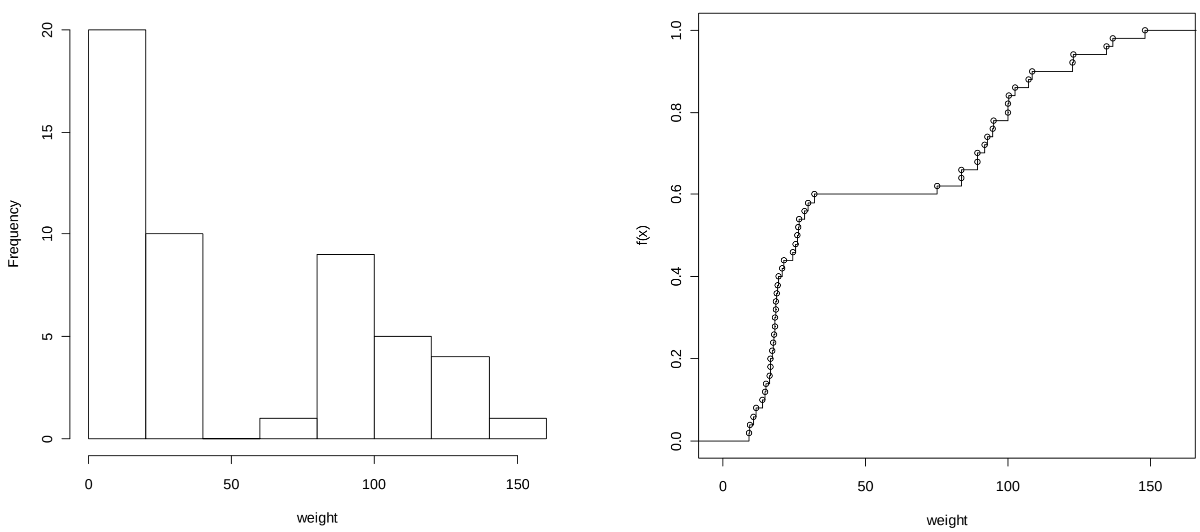


Figure 2. Hypothetical example to illustrate the use of the cumulative distribution to detect natural discontinuities in catch/density data. Here simulated data were randomly drawn from two different distributions, one with low mean value to mimic the distribution of isolated individuals (low density) and the other one with a larger mean value to mimic the densities from coral beds or sponge grounds (high density) (Figure 2a). The gap between the two distributions emerges in the cumulative distribution as a long step (Figure 2b). The length of this step is related to the difference between the two distributions; this specific value has been explicitly chosen here to help illustrating the type of shape expected in the cumulative distribution when there is a very clear difference between the density/weight associated with isolated or small groups of individuals versus dense aggregations. In real data, these longer steps in the distribution are not necessarily as clear as depicted in this illustrative example.

2.2.1. GIS Analyses

ArcGIS 9.2 (ESRI Canada Limited) was used to facilitate the process of creating a density map of sponge distribution along the Eastern Grand Banks and Flemish Pass/Cap area. Full details of this method can be found in Kenchington et al. (2009). The sponge data were plotted using the UTM projected coordinate system (Zone 23N) to avoid distorting the data surfaces. The ultimate goal was to map sponge density and subsequently determine the area of polygons that follow density contours that fully encompass points associated with specific weight thresholds. In preliminary assessments the area around trawl locations were drawn by hand and the area calculated, but this was found to be subjective. To make the process more objective, a model was developed to standardize this procedure (Kenchington et al. 2009).

Model Builder, an ArcGIS 9.2 utility, was used to create the majority of steps necessary to create the polygons from which total area was determined. Figure 3 is a schematic of the model indicating the various steps and tools required to produce a series of outputs. The "Kernel" Density tool (Figure 3A) creates a density raster output (Figure 3B) by defining a circular neighbourhood (search radius – Figure 3C) around each cell. For the R/V data this was 2939.7 m x 2939.7 m or approximately 8.64 km^2. The tool then sums the total weight found within the search radius and divides that number by the area around each cell resulting in a running average of features per unit area.

A 25 km search radius was selected as it recognized distinct geographic features and optimal for this area (Kenchington et al. 2009). Ardron et al. (2007) used a 10 km search radius to perform density analysis on the by-catch of coral and sponge off the coast of British Columbia, Canada but this was found to be too small for the NRA, resulting in many fragmented areas (Kenchington et al. 2009).

The final steps of the model (Figure 3D-I), creates output contours of the density data in 0.1 kg/km^2 increments (Figure 3E), selects only contour values greater than 0 (Figure 3G) and then converts those selected contour lines into polygons (Figure 3I). The contour value of 0.1 kg/km^2 was used because this interval can be used to create polygons which adequately represent the entire extent of sponge distribution. A 20 km nearest neighbour measure was used to avoid excessive aerial expansion due to distant single points (Kenchington et al. 2009).

The data were combined, log 10 (x+1) transformed, binned into equal 0.3 log units and the inverse log of those taken for plotting the cumulative catch curve (see Figure 4 below). The categories were: ≥3980 kg, ≥1994, ≥999, ≥500, ≥250, ≥125, ≥62, ≥31, ≥15, ≥7, ≥3, ≥1 kg. The area for each of these thresholds was then extracted (Kenchington et al. 2009).

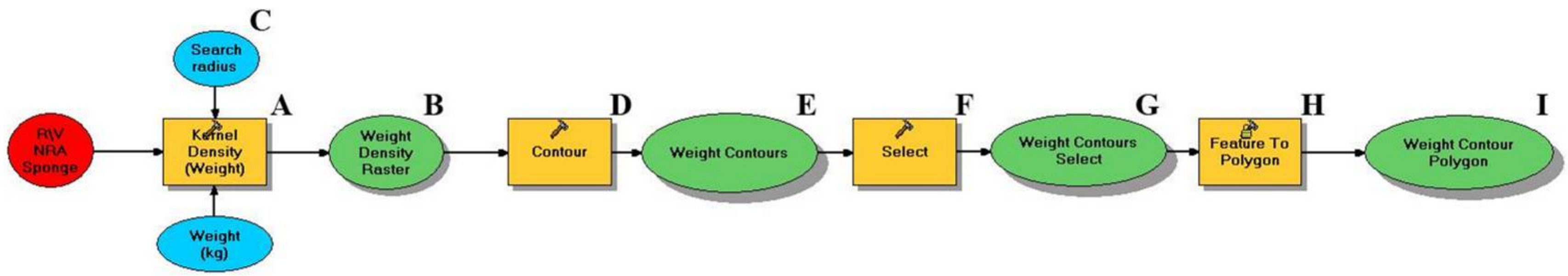


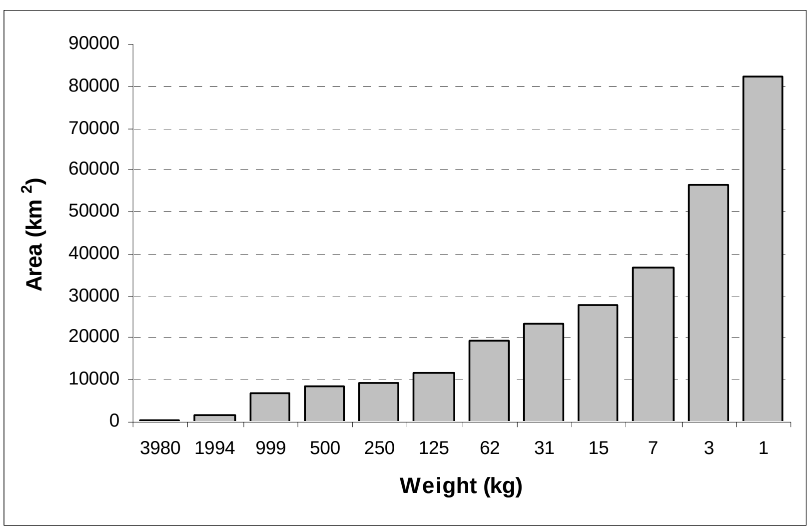
Figure 3. The graphic output model created in ArcGIS 9.2 used to describe sponge density in the NRA. The red circle represents the input data; orange boxes represent the ArcGIS tool utilized; blue ovals represent the adjustable variables for the tools to which they are attached; green ovals represent the output derived from each tool.

2.2.1.1. Sponge Area-Catch Threshold Relationships

Figure 4 shows the area occupied by each of the sponge weight thresholds from the combined Canadian and Spanish/EU data sets. Other than the initial increase in area as the largest catches are mapped, the first large increase in area occurs between catches of 125 and 62 kg. This increase marks the area where the sponge grounds are delineated. Smaller catches between 62 and 1 kg show exponential increase which may represent catches from former sponge grounds which have been fished down or just the widespread occurrence of isolated individuals.

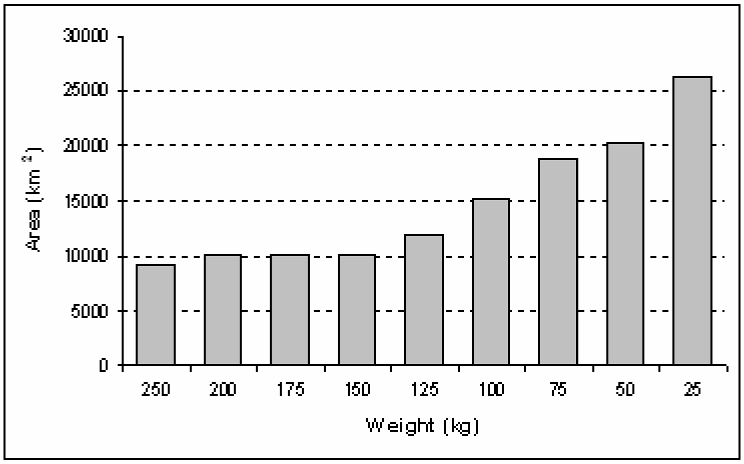
In order to refine the catch weight which corresponds with a sponge ground for mapping purposes, the data were broken into 25 kg weight bins between 25 and 200 kg, with the 250 kg bin added for perspective (Figure 5). It is clear that between 250 kg and 150 kg the area occupied changes very little despite the addition of trawls. The first large increase in area occurs between 125 kg and 100 kg (area increase of 3136 km^2), with another large increase between 100 and 75 kg (area increase of 3784 km^2). Figure 6 further illustrates this by showing the change in area per trawl for each of the 19 weight thresholds illustrated in Figures 4 and 5. These values were calculated by dividing the increase in area in going from one category to the next by the number of additional trawls added in going from one category to the next. High values mean that additional trawls greatly increased the area occupied, while small values mean that additional trawls did not greatly affect the area occupied, that is, they largely fell within the previously defined area. It can readily be seen that there is a large change in going from 125-150 kg (Code 9), 100-125 kg (Code 10) and 75-100 kg (Code 11). These categories are indicated by black bars on Figure 6.

In order to select the appropriate threshold value the location of the catches over 100 kg, between 75 and 100 kg, and between 50 and 75 kg were plotted on a map. Ten of the 11 trawls greater than 75 kg but less than 100 kg fell among the 100 kg and greater trawls, that is, they were clearly part of the sponge grounds. This was not the case for the trawl locations of catches between 50 and 75 kg. Those trawls were in new locations and quite widespread. The use of a 20 km nearest neighbour distance in establishing the area polygons prevented this large aerial increase from appearing in the graphics. If a 30 km nearest neighbour distance had been used we would have seen little effect at 75 kg but a much more dramatic effect at 50 kg thresholds. Consequently the 75 kg weight threshold is the best indicator of the sponge grounds in the NRA.



Code	Weight (kg)	Area (km^2)	N tows
1	3980	505	7
2	1994	1743	21
3	999	6731	37
4	500	8623	61
5	250	9186	73
9	125	11896	93
12	62	19204	118
14	31	23432	155
16	15	28042	195
17	7	36895	264
18	3	56690	352
19	1	82516	501

Figure 4. Area occupied by trawls with decreasing catch weight from 3980 kg to 1 kg calculated using the GIS density rasters described in the text.



Code	Weight (kg)	Area (km^2)	N tows
5	250	9186	73
6	200	10143	87
7	175	10143	88
8	150	10143	89
9	125	11896	93
10	100	15032	102
11	75	18816	113
13	50	20368	130
15	25	26371	168

Figure 5. Area occupied by trawls with decreasing catch weight from 25 kg to 250 kg calculated using the GIS density rasters described in the text.

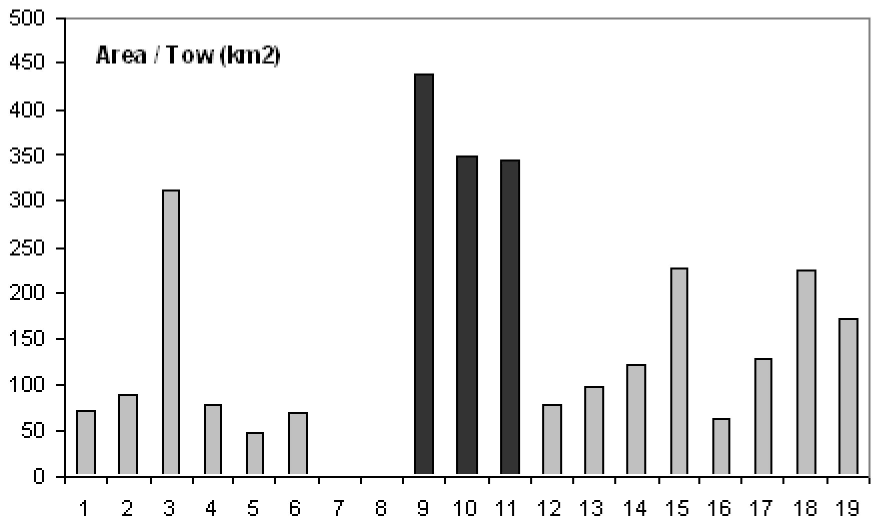
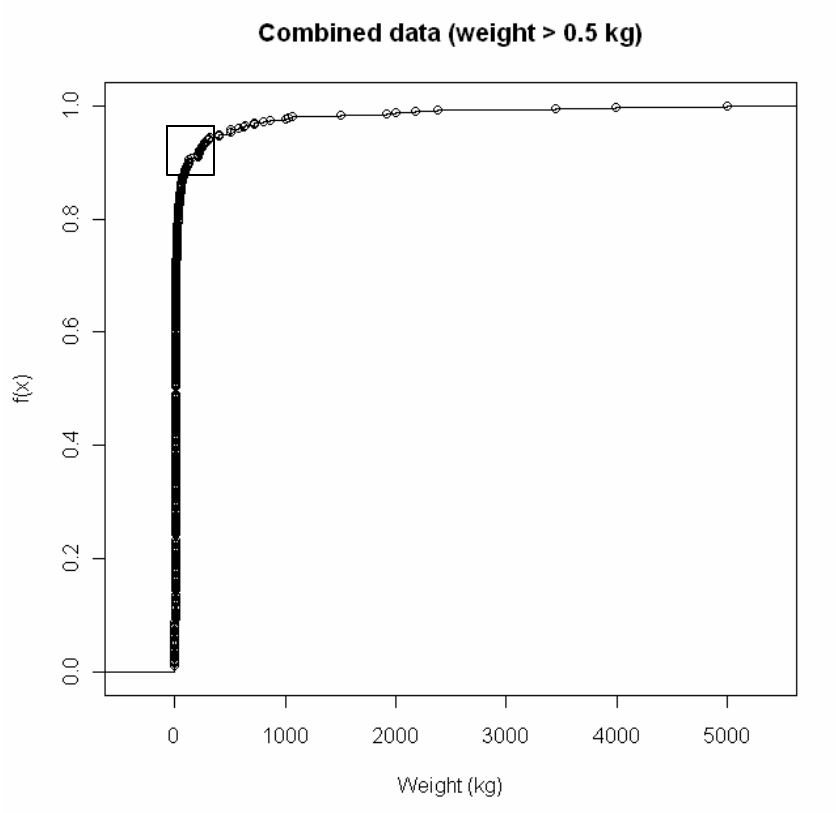


Figure 6. The area occupied per tow (km^2) for each of 19 sponge catch weight categories listed in Figures 4 and 5 (see Codes). Black bars highlight categories referred to in the text. These values were calculated by dividing the increase in area in going from one category to the next by the number of additional tows added in going from one category to the next.

2.2.2. Determination of Significant Concentrations of Sponges Using Cumulative Catch Distributions

Canadian and Spanish/EU R/V survey data for the NRA (Divs. 3LMNO) were analyzed using only data collected from 2005 to 2008. The location of these trawls is indicated in Figure 1. For both data sets some of the large catch over 100 kg were not weighed but estimated, either by subsampling or in some cases by visual estimation.

The distribution of sponges is highly skewed and covers a wide range (from 0.5 kg to 5000 kg), but the median catch is fairly low with a value of 3.5 kg. Very large catches constitute sparse events at the upper tail of the curve (Figure 7). Since the full cumulative distribution does not show any obvious (i.e. potentially biologically meaningful) long step, a more pragmatic approach to threshold identification was required. The 97.5% quantile, comparable with the coral work, is 953.13 kg. The median value was much lower at 3.5 kg. Given the large discrepancy between the two measures WGEAFM felt an alternate measure was required. WGEAFM opted for the point of maximum curvature (Stirling and Zakynthinaki 2008) because it potentially provides more meaningful characteristics in the selection of a threshold value. Estimating this point requires an analytical description of the cumulative distribution (i.e. fitting the data to a model and using the fitted model equation to analytically calculate the point of maximum curvature). Although this can be done, due to time limitations and the essentially coarse and discrete nature of many aspects of the analysis, it was considered that a simpler visual approximation to this point would suffice for identifying a reasonable threshold. Although Figure 7 does not provide a clear position for the point of maximum curvature, it allows defining a general region where this point is expected to be located. This region, encompassing sponge weights between 10 and 300 kg, was plotted in Figure 8. The examination of this section of the cumulative distribution suggests that the point of maximum curvature should be located somewhere between 50 and 125 kg which closely correspond to the range of catch thresholds for sponge grounds obtained from the spatial analysis approach. Furthermore, this close-up view reveals some "longer steps" in the curve which could also suggest biologically relevant thresholds points. The first one of these relatively longer steps occurs at a value of 75kg (Figure 8).



N = 415		
	Weight quantiles	
100%	maximum	5000
99.5 %		3370.58
99%		2151.38
97.5 %		953.13
95%		430.00
90%		124.46
85%		52.52
80%		25.81
75%	quartile	16.10
50%	median	3.50
25%	quartile	1.25
20%		0.97
15%		0.85

Figure 7. Cumulative catch distribution of sponges from combined R/V Spanish surveys (30 min tows) and Canadian surveys (15 min tows). The values of catch weight are presented as quantiles. The box represents the general area of the point of maximum curvature.

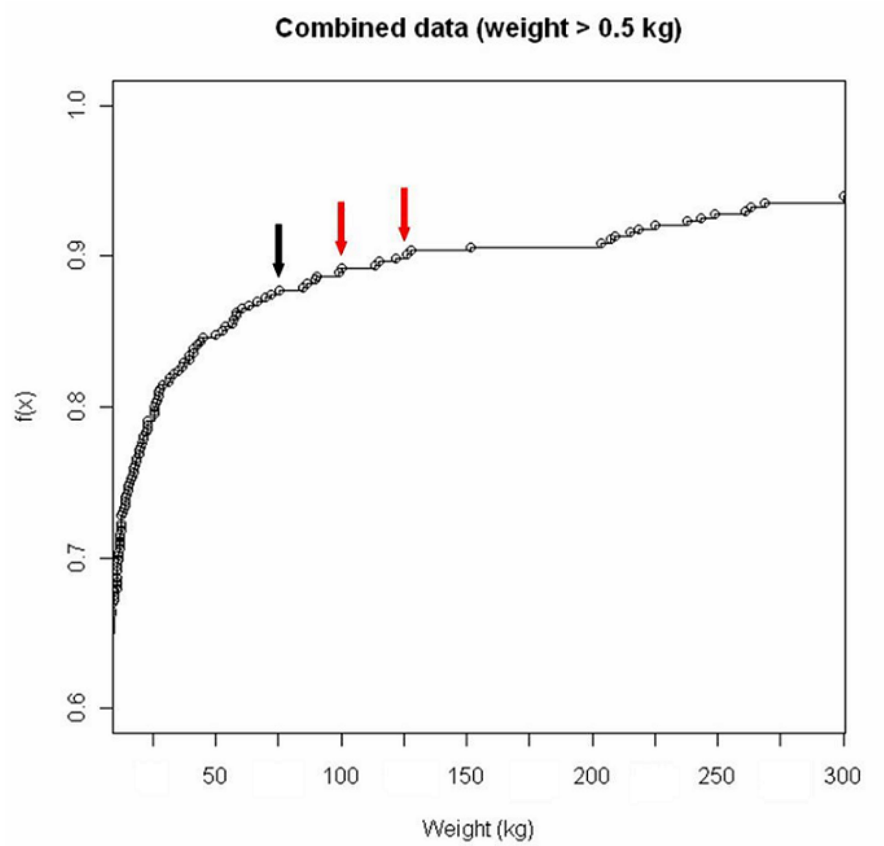


Figure 8. Cumulative distribution of sponges (Figure 7) zoomed in to show the section between 10 and 300 kg from R/V Spanish/EU surveys (30 min tows) and Canadian surveys (15 min tows). The black arrow indicates the first clearly long step in the general region where the point of maximum curvature is expected to be located; this point correspond to a value of 75 kg and coincides with one of the thresholds identified by the spatial analysis. Red arrows represent the 100 kg and 125 kg thresholds also indicated from the spatial analyses. Note that all three threshold points identified by the spatial analysis (75, 100 and 125 kg) correspond to relatively longer steps in the cumulative distribution. This match between methods strengthens the notion that these values correspond to natural discontinuities in the data. The apparent flattening of the curve relative to Figure 7 is due to a different aspect ratio, with the x-axis stretched more than the y-axis.

2.2.3. Summary of Sponge Weight Thresholds Using Spatial and Cumulative Distribution Approaches

Potential thresholds to define significant concentrations of sponges are summarized in Table 3. Quantiles are extracted from the cumulative distribution, while the spatial analyses incorporate a direct neighborhood concept (i.e. biologically meaningful) for the selection. Based on all the available information and the combined results from the different analyses, the WGEAFM recommends using the 75 kg threshold for mapping trawl locations indicating significant concentrations of sponges (sponge grounds). This value clearly and consistently emerges from both analytical approaches taken and, among all potential thresholds, is considered by WGEAFM a reasonably precautionary one.

Table 3. Summary of potential thresholds to define significant concentrations of sponges.

VALUE (KG/RV TRAWL)	REMARKS
3.5	50% quantile of cumulative distribution; median value (statistical/biological relevance); used by SPRFMO for similar taxa
75-125	Approximation to the region of the point of maximum curvature of cumulative distribution as well as first “clearly longer steps” in this distribution (statistical/ biological relevance)
124.5	90% quantile of cumulative distribution; used by WGEAFM for large gorgonian corals (NAFO 2008a,b)
953.1	97.5% quantile of cumulative distribution; upper limit of s.d. around the mean (statistical/biological relevance, outliers); used by WGEAFM for seapens and small gorgonian corals (NAFO 2008a,b)
100	Estimation of bed area using spatial analyses (Figures 4 and 5)
75-125	Estimation of bed area using spatial analyses (Figure 6)

2.3. Delineating Significant Concentrations of Sponges in the NAFO Regulatory Area (Divs. 3LMNO)

Using a 75 kg weight threshold to define significant concentrations of sponges from the R/V surveys catches, their locations were plotted (Figure 9). All the geographical information was referenced to the WGS 1984 UTM Zone 23N. Bathymetric contours were exported from GEBCO Digital Atlas for approximate depth reference, however, these are not totally precise.

Among the four candidate VME areas originally identified by the WGEAFM on the main basis of presence of sponge habitat (areas 1, 3, 4, and 5, following the NAFO numbering on Figure 9), all have emerged from this analysis as containing significant catch of sponges (Figure 9).

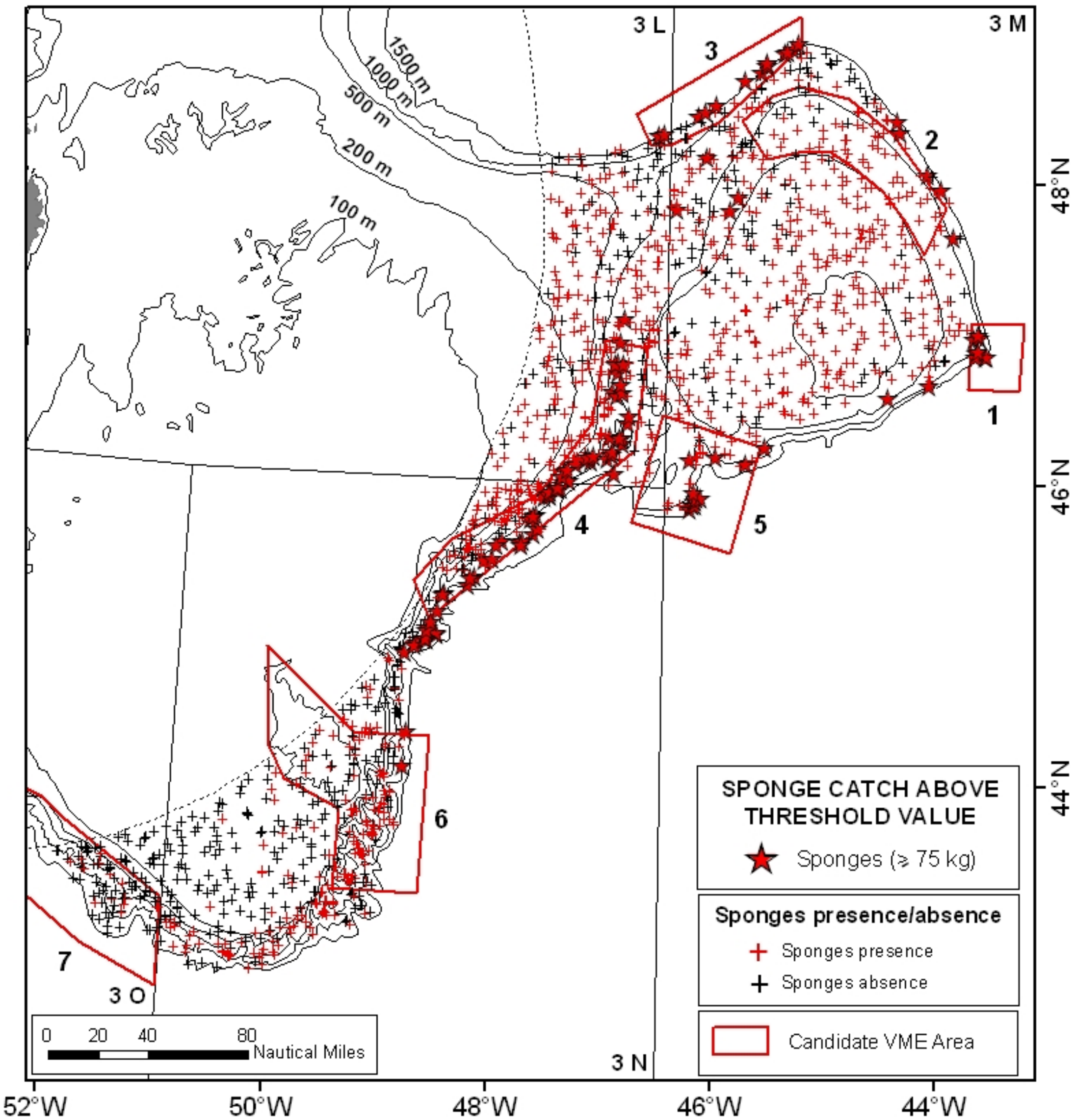


Figure 9. Significant catch of sponges determined from research vessel survey data. The numbers refer to the NAFO numbering of the candidate VME locations.

Figures 10-12 show a close-up of each area where significant concentrations of sponges were identified. Locations of significant catches of sponge are shown with a 4 nm radial buffer following the same approach used for delimiting the coral concentrations in the NRA (NAFO 2008a). The start and end of the trawl positions are indicated in Table 4 by area. Trawls occurring within a candidate VME (cVME) and those outside the area but nearby were grouped together. Trawl locations and their buffers were not grouped into key locations as was done for the coral, as there are various options on how to do this. The WGEAFM does agree that the 4 nm buffer is important for the conservation of the sponge grounds. However, the circular configuration of the zone makes it difficult to provide co-ordinates.

Area1: Flemish Cap East

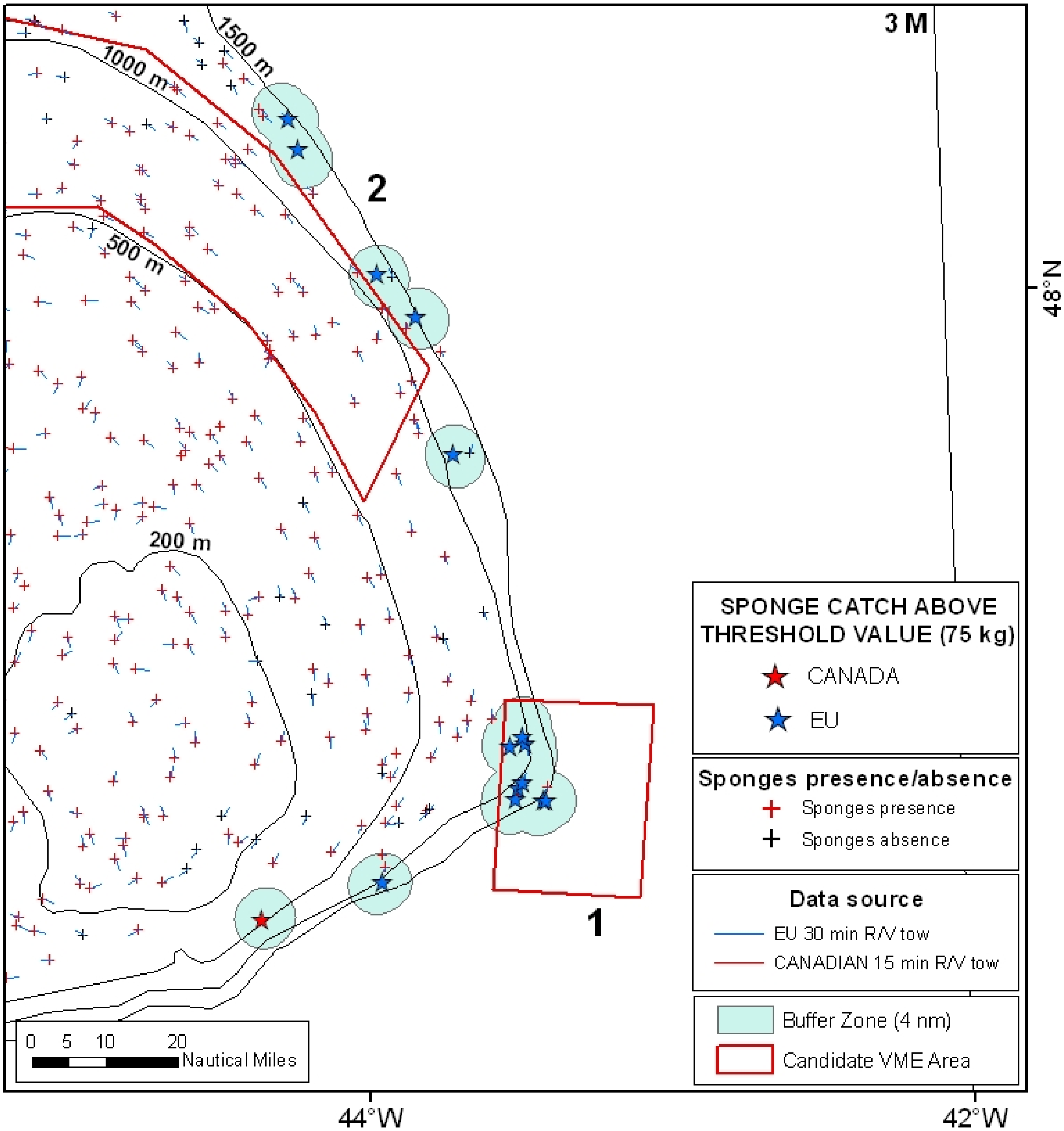


Figure 10. Significant catches of sponges and buffer zones in the Flemish Cap East.

Area3: Sackville Spur

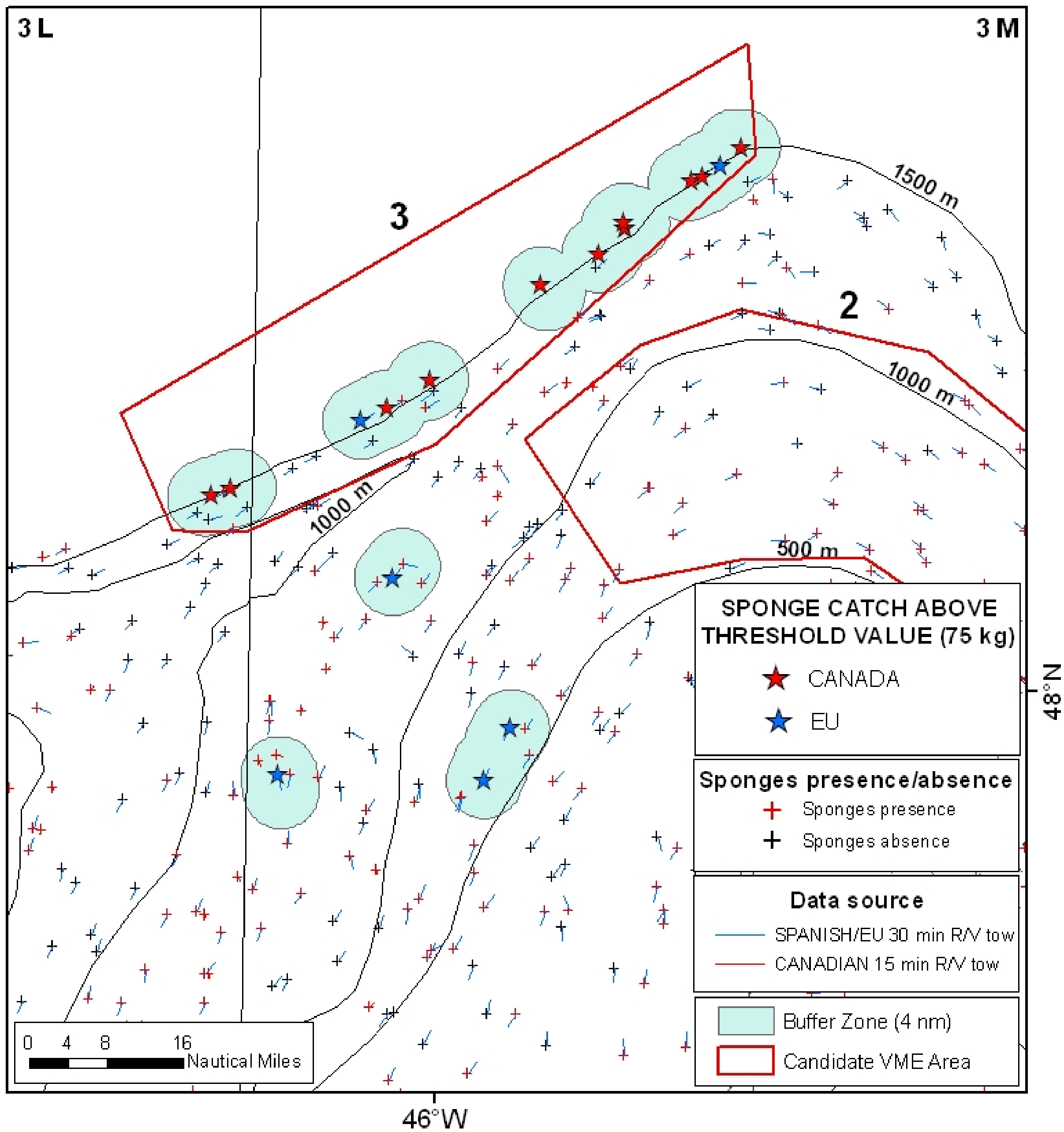


Figure 11. Significant catches of sponges and buffer zones in the Sackville Spur.

Areas 4 and 5: Southern Flemish Pass to Eastern Canyons and Beothuk Knoll

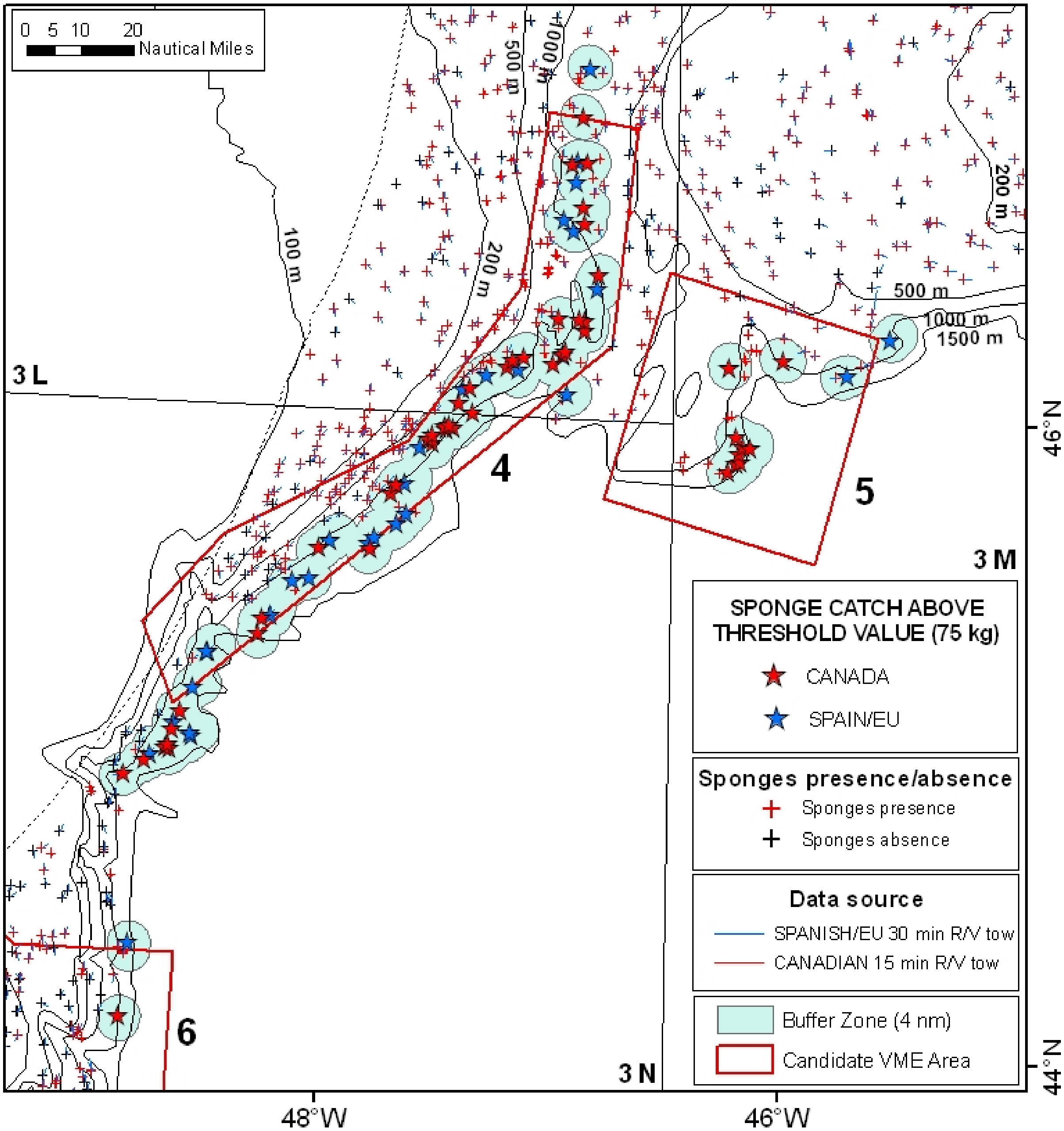


Figure 12. Significant catches of sponges and buffer zones in the Flemish Pass to Eastern Canyons and Beothuk Knoll.

Table 4. Start and end positions of trawls with significant concentrations of sponges (≥ 75 kg) in the NRA (Divs. 3LMNO). Trawls occurring within a candidate VME area (cVME) and those outside the area but nearby were grouped together.

cVME Area or Vicinity	N	Survey	Start position		End position	
			Latitude	Longitude	Latitude	Longitude
1-2	1-2.1	DFO-CAN	46° 35' 35" N	44° 21' 00" W	46° 36' 00" N	44° 20' 24" W
	1-2.2	SPAIN-EU	48° 25' 50" N	44° 14' 16" W	48° 26' 54" N	44° 15' 57" W
	1-2.3	SPAIN-EU	48° 21' 38" N	44° 12' 24" W	48° 20' 20" N	44° 11' 25" W
	1-2.4	SPAIN-EU	48° 04' 23" N	43° 56' 20" W	48° 03' 44" N	43° 55' 55" W
	1-2.5	SPAIN-EU	47° 58' 25" N	43° 48' 26" W	47° 57' 57" N	43° 47' 55" W
	1-2.6	SPAIN-EU	47° 39' 28" N	43° 41' 21" W	47° 38' 45" N	43° 40' 59" W
	1-2.7	SPAIN-EU	47° 00' 19" N	43° 28' 25" W	47° 01' 49" N	43° 28' 30" W
	1-2.8	SPAIN-EU	46° 59' 17" N	43° 27' 38" W	46° 57' 36" N	43° 27' 37" W
	1-2.9	SPAIN-EU	46° 59' 00" N	43° 30' 52" W	46° 59' 44" N	43° 30' 41" W
	1-2.10	SPAIN-EU	46° 53' 55" N	43° 28' 26" W	46° 55' 23" N	43° 27' 59" W
	1-2.11	SPAIN-EU	46° 53' 14" N	43° 29' 17" W	46° 52' 01" N	43° 30' 59" W
	1-2.12	SPAIN-EU	46° 51' 38" N	43° 30' 01" W	46° 50' 55" N	43° 31' 17" W
	1-2.13	SPAIN-EU	46° 51' 30" N	43° 24' 20" W	46° 51' 12" N	43° 25' 17" W
	1-2.14	SPAIN-EU	46° 51' 28" N	43° 23' 45" W	46° 50' 39" N	43° 25' 42" W
	1-2.15	SPAIN-EU	46° 40' 36" N	43° 57' 00" W	46° 40' 08" N	43° 58' 12" W
3	3.1	DFO-CAN	48° 57' 00" N	45° 13' 12" W	48° 57' 00" N	45° 14' 13" W
	3.2	DFO-CAN	48° 54' 00" N	45° 19' 19" W	48° 54' 29" N	45° 18' 25" W
	3.3	DFO-CAN	48° 53' 35" N	45° 21' 00" W	48° 53' 17" N	45° 22' 01" W
	3.4	DFO-CAN	48° 49' 12" N	45° 31' 48" W	48° 48' 47" N	45° 32' 35" W
	3.5	DFO-CAN	48° 48' 36" N	45° 31' 41" W	48° 49' 01" N	45° 30' 43" W
	3.6	DFO-CAN	48° 48' 36" N	45° 31' 41" W	48° 48' 18" N	45° 32' 35" W
	3.7	DFO-CAN	48° 45' 43" N	45° 35' 42" W	48° 46' 12" N	45° 34' 48" W
	3.8	DFO-CAN	48° 42' 29" N	45° 44' 53" W	48° 41' 42" N	45° 43' 59" W
	3.9	DFO-CAN	48° 32' 24" N	46° 02' 17" W	48° 32' 06" N	46° 03' 11" W
	3.10	DFO-CAN	48° 29' 24" N	46° 08' 53" W	48° 29' 06" N	46° 09' 47" W
	3.11	DFO-CAN	48° 20' 42" N	46° 33' 18" W	48° 20' 49" N	46° 32' 17" W
	3.12	DFO-CAN	48° 19' 59" N	46° 36' 18" W	48° 19' 41" N	46° 37' 19" W
	3.13	SPAIN-EU	48° 55' 11" N	45° 16' 27" W	48° 54' 43" N	45° 18' 31" W
	3.14	SPAIN-EU	48° 28' 02" N	46° 13' 06" W	48° 28' 48" N	46° 10' 52" W
	3.15	SPAIN-EU	48° 11' 41" N	46° 07' 44" W	48° 12' 50" N	46° 06' 17" W
	3.16	SPAIN-EU	47° 56' 05" N	45° 48' 56" W	47° 54' 42" N	45° 50' 07" W
	3.17	SPAIN-EU	47° 50' 50" N	46° 24' 58" W	47° 49' 11" N	46° 24' 37" W
	3.18	SPAIN-EU	47° 50' 34" N	45° 53' 01" W	47° 51' 55" N	45° 52' 15" W
4	4.1	DFO-CAN	46° 57' 07" N	46° 56' 13" W	46° 57' 36" N	46° 56' 49" W
	4.2	DFO-CAN	46° 48' 47" N	46° 54' 29" W	46° 48' 11" N	46° 54' 54" W

	4.3	DFO-CAN	46° 48' 25" N	46° 58' 41" W	46° 47' 42" N	46° 58' 19" W
	4.4	DFO-CAN	46° 40' 23" N	46° 55' 19" W	46° 40' 19" N	46° 54' 18" W
	4.5	DFO-CAN	46° 37' 19" N	46° 55' 01" W	46° 37' 30" N	46° 56' 06" W
	4.6	DFO-CAN	46° 27' 43" N	46° 50' 42" W	46° 27' 00" N	46° 50' 24" W
	4.7	DFO-CAN	46° 19' 30" N	47° 01' 19" W	46° 18' 54" N	47° 01' 59" W
	4.8	DFO-CAN	46° 19' 12" N	46° 55' 41" W	46° 18' 29" N	46° 55' 23" W
	4.9	DFO-CAN	46° 18' 54" N	46° 54' 25" W	46° 19' 30" N	46° 53' 49" W
	4.10	DFO-CAN	46° 17' 06" N	46° 54' 11" W	46° 17' 42" N	46° 54' 00" W
	4.11	DFO-CAN	46° 13' 19" N	46° 59' 24" W	46° 12' 29" N	46° 59' 31" W
	4.12	DFO-CAN	46° 12' 36" N	47° 00' 00" W	46° 13' 19" N	46° 59' 42" W
	4.13	DFO-CAN	46° 11' 53" N	47° 10' 37" W	46° 12' 36" N	47° 10' 23" W
	4.14	DFO-CAN	46° 11' 17" N	47° 13' 23" W	46° 11' 53" N	47° 12' 47" W
	4.15	DFO-CAN	46° 10' 41" N	47° 02' 31" W	46° 11' 24" N	47° 02' 35" W
	4.16	DFO-CAN	46° 10' 01" N	47° 14' 49" W	46° 09' 11" N	47° 15' 07" W
	4.17	DFO-CAN	46° 05' 53" N	47° 25' 05" W	46° 06' 18" N	47° 24' 11" W
	4.18	DFO-CAN	46° 04' 00" N	47° 27' 43" W	46° 03' 25" N	47° 26' 24" W
	4.19	DFO-CAN	46° 01' 23" N	47° 24' 07" W	46° 00' 47" N	47° 24' 47" W
	4.20	DFO-CAN	45° 58' 48" N	47° 30' 11" W	45° 59' 13" N	47° 29' 24" W
	4.21	DFO-CAN	45° 58' 37" N	47° 31' 12" W	45° 59' 06" N	47° 30' 43" W
	4.22	DFO-CAN	45° 58' 23" N	47° 28' 55" W	45° 58' 55" N	47° 28' 05" W
	4.23	DFO-CAN	45° 58' 05" N	47° 31' 01" W	45° 58' 41" N	47° 30' 29" W
	4.24	DFO-CAN	45° 56' 49" N	47° 34' 37" W	45° 57' 25" N	47° 33' 54" W
	4.25	DFO-CAN	45° 55' 59" N	47° 35' 31" W	45° 55' 12" N	47° 35' 35" W
	4.26	DFO-CAN	45° 55' 12" N	47° 34' 30" W	45° 54' 36" N	47° 34' 48" W
	4.27	DFO-CAN	45° 47' 13" N	47° 43' 41" W	45° 47' 49" N	47° 43' 05" W
	4.28	DFO-CAN	45° 45' 47" N	47° 45' 11" W	45° 45' 07" N	47° 45' 47" W
	4.29	DFO-CAN	45° 35' 17" N	47° 50' 24" W	45° 34' 30" N	47° 51' 07" W
	4.30	DFO-CAN	45° 34' 59" N	48° 03' 54" W	45° 34' 37" N	48° 04' 41" W
	4.31	DFO-CAN	45° 21' 18" N	48° 18' 25" W	45° 20' 49" N	48° 19' 12" W
	4.32	DFO-CAN	45° 18' 36" N	48° 19' 30" W	45° 17' 53" N	48° 19' 30" W
	4.33	DFO-CAN	45° 03' 18" N	48° 39' 00" W	45° 03' 29" N	48° 40' 01" W
	4.34	DFO-CAN	44° 59' 53" N	48° 41' 06" W	45° 00' 29" N	48° 40' 05" W
	4.35	DFO-CAN	44° 56' 53" N	48° 41' 53" W	44° 56' 13" N	48° 42' 00" W
	4.36	DFO-CAN	44° 56' 35" N	48° 42' 29" W	44° 55' 48" N	48° 42' 29" W
	4.37	DFO-CAN	44° 56' 13" N	48° 41' 31" W	44° 55' 23" N	48° 41' 42" W
	4.38	DFO-CAN	44° 54' 00" N	48° 47' 53" W	44° 53' 35" N	48° 48' 54" W
	4.39	DFO-CAN	44° 51' 11" N	48° 53' 24" W	44° 50' 53" N	48° 54' 11" W
	4.40	SPAIN-EU	47° 06' 20" N	46° 54' 31" W	47° 06' 54" N	46° 55' 15" W
	4.41	SPAIN-EU	46° 49' 00" N	46° 57' 22" W	46° 47' 31" N	46° 57' 31" W
	4.42	SPAIN-EU	46° 45' 05" N	46° 57' 22" W	46° 46' 32" N	46° 57' 22" W
	4.43	SPAIN-EU	46° 37' 49" N	47° 00' 39" W	46° 36' 33" N	46° 59' 26" W
	4.44	SPAIN-EU	46° 35' 50" N	46° 57' 51" W	46° 36' 40" N	46° 57' 51" W
	4.45	SPAIN-EU	46° 25' 03" N	46° 51' 11" W	46° 26' 26" N	46° 51' 47" W

	4.46	SPAIN-EU	46° 12' 18" N	47° 00' 05" W	46° 13' 47" N	47° 00' 05" W
	4.47	SPAIN-EU	46° 09' 30" N	47° 12' 05" W	46° 08' 26" N	47° 12' 18" W
	4.48	SPAIN-EU	46° 08' 23" N	47° 20' 35" W	46° 08' 48" N	47° 19' 08" W
	4.49	SPAIN-EU	46° 05' 35" N	47° 26' 37" W	46° 06' 34" N	47° 25' 03" W
	4.50	SPAIN-EU	46° 05' 05" N	46° 58' 37" W	46° 05' 26" N	46° 58' 04" W
	4.51	SPAIN-EU	45° 54' 31" N	47° 37' 47" W	45° 55' 48" N	47° 36' 41" W
	4.52	SPAIN-EU	45° 47' 31" N	47° 41' 46" W	45° 48' 35" N	47° 40' 13" W
	4.53	SPAIN-EU	45° 41' 52" N	47° 41' 03" W	45° 42' 56" N	47° 39' 49" W
	4.54	SPAIN-EU	45° 40' 02" N	47° 43' 24" W	45° 39' 04" N	47° 44' 54" W
	4.55	SPAIN-EU	45° 37' 14" N	47° 49' 16" W	45° 38' 33" N	47° 48' 29" W
	4.56	SPAIN-EU	45° 36' 32" N	48° 01' 17" W	45° 37' 25" N	47° 59' 26" W
	4.57	SPAIN-EU	45° 36' 16" N	47° 50' 34" W	45° 34' 52" N	47° 50' 29" W
	4.58	SPAIN-EU	45° 29' 18" N	48° 06' 18" W	45° 29' 00" N	48° 08' 12" W
	4.59	SPAIN-EU	45° 28' 36" N	48° 10' 37" W	45° 27' 46" N	48° 11' 46" W
	4.60	SPAIN-EU	45° 22' 04" N	48° 16' 05" W	45° 23' 23" N	48° 15' 29" W
	4.61	SPAIN-EU	45° 14' 52" N	48° 32' 17" W	45° 16' 02" N	48° 31' 05" W
	4.62	SPAIN-EU	45° 14' 46" N	48° 32' 49" W	45° 15' 46" N	48° 31' 30" W
	4.63	SPAIN-EU	45° 07' 55" N	48° 35' 51" W	45° 08' 34" N	48° 34' 19" W
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	4.65	SPAIN-EU	44° 59' 13" N	48° 36' 10" W	44° 59' 53" N	48° 34' 19" W
	4.66	SPAIN-EU	44° 58' 47" N	48° 35' 56" W	44° 57' 37" N	48° 37' 12" W
	4.67	SPAIN-EU	44° 55' 08" N	48° 46' 30" W	44° 56' 25" N	48° 45' 50" W
5	5.1	DFO-CAN	46° 10' 48" N	46° 15' 07" W	46° 11' 31" N	46° 15' 11" W
	5.2	DFO-CAN	46° 12' 07" N	46° 00' 25" W	46° 12' 36" N	46° 01' 23" W
	5.3	DFO-CAN	45° 57' 47" N	46° 13' 01" W	45° 57' 00" N	46° 12' 36" W
	5.4	DFO-CAN	45° 55' 48" N	46° 10' 55" W	45° 56' 35" N	46° 10' 37" W
	5.5	DFO-CAN	45° 55' 41" N	46° 09' 00" W	45° 56' 31" N	46° 08' 53" W
	5.6	DFO-CAN	45° 54' 36" N	46° 12' 07" W	45° 54' 11" N	46° 13' 05" W
	5.7	DFO-CAN	45° 52' 59" N	46° 11' 49" W	45° 52' 30" N	46° 12' 36" W
	5.8	DFO-CAN	45° 52' 41" N	46° 13' 01" W	45° 52' 19" N	46° 13' 55" W
	5.9	DFO-CAN	45° 51' 11" N	46° 15' 11" W	45° 51' 25" N	46° 14' 13" W
	5.10	SPAIN-EU	46° 16' 10" N	45° 31' 46" W	46° 17' 15" N	45° 30' 14" W
	5.11	SPAIN-EU	46° 09' 28" N	45° 43' 20" W	46° 09' 05" N	45° 44' 54" W
6	6.1	DFO-CAN	44° 05' 35" N	48° 51' 36" W	44° 04' 59" N	48° 51' 47" W
	6.2	SPAIN-EU	44° 19' 33" N	48° 49' 57" W	44° 18' 04" N	48° 49' 59" W

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Response to Fisheries Commission Request 9c

1. Request

Recognizing the initiatives on vulnerable marine ecosystems (VME), and with a view to completing fishery impact assessments at the earliest possible date, Fisheries Commission requests the Scientific Council to:

a) Provide, as soon as possible in 2008, delineations, if any, of significant concentrations of corals in the NAFO Regulatory Area, by species, for the identification of VMEs. This should include the size and catch characteristics of corals obtained respectively from commercial fishing vessels and fisheries research vessels and the assessment of significant adverse impacts, with a particular focus on those species which involve interactions with commercial fisheries. The data should include absence/presence of corals as well as density.

b) Provide, by June 30, 2009, delineations, if any, of significant concentrations of sponges in the Regulatory Area by species, including the size and catch characteristics of sponges obtained respectively from commercial fishing vessels and fisheries research vessels, with a particular focus on those species which involve interactions with commercial fisheries. The data should include absence/presence of sponges as well as density.

c) With respect to corals and sponges in canyons denoted in the Scientific Council's response on the area denoted as "Southern Flemish Pass to Eastern Canyons", provide detailed information as soon as practicable or at least a report on progress by June 30, 2009, with a particular focus on those species which involve interactions with commercial fisheries.

The NAFO Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM) met through correspondence to address Item 9c.

2. Response to Item 9c: Corals and Sponges in the "Southern Flemish Pass to Eastern Canyons"candidate VME area

WGEAFM responses to items 9a and 9b already contain the fundamentals to address this request (NAFO 2008c, 2009). Item 9c is asking for information on one specific candidate VME area, and focusing the attention to any detailed information on corals and sponges in canyons within that particular candidate VME. Therefore, this report is essentially an integration of the results from the WGEAFM responses to items 9a and 9b, but geographically focused on one specific candidate VME. The area in question is denoted as "Southern Flemish Pass to Eastern Canyons" and it is labeled as candidate VME 5 in the original WGEAFM Report (NAFO 2008a) and as candidate VME 4 in the subsequent Scientific Council Report (NAFO 2008b).

This area was originally identified as candidate VME based on the presence of large gorgonians and large catches of sponges. Complementary support was provided by the presence of vulnerable fish species like striped wolffish, redfish, spiny tailed skate, northern wolfish, black dogfish and deep sea cat shark (see Fig. 18 in NAFO 2008a).

Further WGEAFM work delineated key locations of corals and sponges (NAFO 2008c, 2009). As part of these analyses, key locations for both corals and sponges were identified within the "Southern Flemish Pass to Eastern Canyons" candidate VME area (Fig. 1). These key locations involved large gorgonians in the case of corals, but around the northern boundary of the candidate VME some key locations of pennatulaceans were also identified (Fig. 1) (NAFO 2008c). In the case of sponges, key locations (Fig. 1) were based on dense and structure-forming multi-species aggregations called sponge grounds (ICES 2009, NAFO 2009).

This particular candidate VME only includes one canyon, the Carson Canyon, and from it only its head region is actually within the area. In this particular region only key locations of sponges were found (Fig. 1).

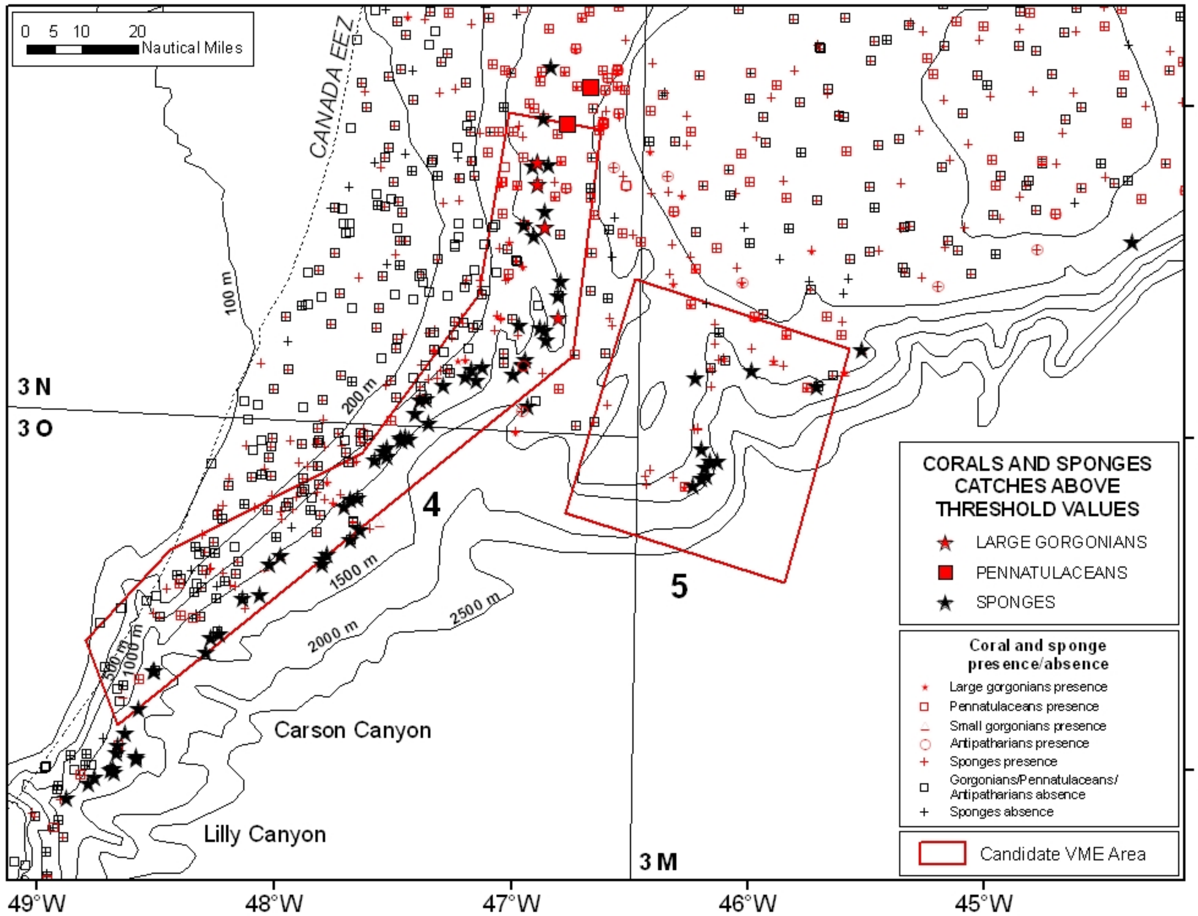

Figure 1. Key locations of corals and sponges in the "Southern Flemish Pass to Eastern Canyons" candidate VME (area 4) [key locations for the "Beothuk Knoll" candidate VME (area 5) are also shown]. This numbering scheme follows the Scientific Council Report (NAFO 2008b).

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