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Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators

by

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Abstract

In support of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area, kernel density analyses (KDE) of Large-sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals were undertaken using all available research vessel survey data (1995 – 2024). For Tube-dwelling (Cerianthid) Anemones and Sea Lilies (Crinoids), updated distribution maps were provided, drawing on data from research vessel trawl surveys, NEREIDA rock dredge samples and NEREIDA underwater imagery.

For the first time, subgroups of some of the VME functional groups had sufficient data to warrant application of the KDE analyses. These included two families and one order of sponges (Tetillidae, Polymastiidae, Astrophorina), four sea pen genera (*Balticina*, *Funiculina*, *Pennatula* and *Anthoptilum*) and two species of small gorgonian coral (*Acanella arbuscula* and *Radicipes gracilis*). These analyses allowed for a visual and quantitative comparison with their functional group VMEs to determine if there is adequate protection for these taxa when the functional group alone is considered. For the majority of the subgroups, there is a large proportion of their VME area that lies outside of their respective VME functional group and therefore should be taken into account when evaluating closed areas and significant adverse impacts on VMEs in the NAFO Regulatory Area. Lastly, a new index is proposed to assist in the quantification of the number of data records contributing to the newly created area as different thresholds are tested in the KDE analyses.

The KDE polygons produced herein will be overlain on their respective species distribution models in a separate document to determine whether any of the polygons should be clipped given their predicted distributions. Therefore the VME polygons produced here are not considered the final VME polygons for the 2027 review of the closed areas.

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Previously Adopted Definitions (NAFO, 2013)

Vulnerable Marine Ecosystem (VME). Under the structure-forming criterion, a VME is a regional habitat that contains VME indicator species at or above significant concentration levels. These habitats are structurally complex, characterized by higher diversities and/or different benthic communities, and provide a platform for ecosystem functions/processes closely linked to these characteristics. The spatial scale of these habitats is larger than the footprint of a higher concentration observation. NAFO has used quantitative methods to objectively define areas that contain VME indicator species at or above significant concentration levels, termed VME polygons. These areas are not simply defined by the individual tows above the threshold value but also by all of the smaller catches within the delimited polygon. These smaller catches may represent recruitment, or smaller species in the VME functional indicator group. These larger areas are the VMEs proper unless post-hoc considerations suggest otherwise. VMEs occur throughout the NRA and their spatial arrangement may be important to recruitment processes and to overall ecosystem function (Wang et al., 2024).

VME indicator species. These are species that met one or more of the FAO Guidelines criteria (FAO, 2009) and may indicate the possible presence of VMEs. Their simple presence is not an automatic indication of a VME, but when found in significant aggregations with conspecifics, or other VME indicator species, they can constitute a VME. NAFO has approved a list of taxa that qualify as VME indicator species in Part VI of Annex I.E. of the Conservation and Enforcement Measures (NAFO, 2025).

Higher concentration observations of VME indicator species (a.k.a. "Significant concentrations"). These are specific locations where there are individual records of VME indicator species at densities at or above a threshold value that, for that specific VME functional indicator species, is associated with the formation of highly aggregated groups of that species. These higher concentration locations have, in part, been used to delineate VME closures referred as "Vulnerable Marine Ecosystem Area Closures" in the NCEM Article 17, which are closed to bottom fishing activities (NAFO, 2025).

Introduction

Kernel density estimation (KDE) utilizes spatially explicit data to model the distribution of a variable of interest. It is a simple non-parametric neighbour-based smoothing function that relies on few assumptions about the structure of the observed data. It has been used in ecology to identify hotspots, that is, areas of relatively high biomass/abundance. With respect to marine benthic invertebrate species, it was first applied to the identification of significant concentrations of sponges in the NAFO Regulatory Area (NRA) in 2009 (Kenchington et al., 2009) followed by an application to sea pens (Murillo et al., 2010). Since then, it has been used to identify significant concentrations (VMEs) of corals, sponges and other VME indicators from research vessel (RV) trawl survey catch data in both Canada (Kenchington et al., 2016) and in the NRA (NAFO, 2013; Kenchington et al., 2014; Kenchington et al., 2019; Kenchington et al., 2022).

Here, KDE biomass surfaces for seven VME functional indicator taxa were created: Large-Sized Sponges, Sea Pens, Small Gorgonian Corals, Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals, and the RV catch threshold that delineates the VME polygons determined and compared to previous analyses (Kenchington et al., 2019). For the Large-Sized Sponges, Sea Pens and Small Gorgonian Corals, species distribution models (SDMs) (Murillo et al., 2024; Murillo et al., 2025) identified subgroups of these taxa where sufficient data had been collected to allow modeling. Data for the sponges of the sub-order Astrophorina, the families Tetillidae and Polymastiidae, the sea pen genera *Balticina*, *Funiculina*, *Anthoptilum* and *Pennatula*, and the small gorgonian corals *Acanella arbuscula* and *Radicipes gracilis* were reviewed and the KDE applied where sufficient data were available (noting that KDE analyses do not use null data).

Previously, KDE of the biomass of Large-Sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals were undertaken to examine the effect of spatial extent on the selection of the KDE research vessel catch threshold used to identify the locations of the significant concentrations of VME indicators (Kenchington et al., 2022). Results (threshold values, location of significant areas) from confining the analyses to the NRA were compared with those produced when data from Canadian waters were included and examined. It was concluded that changes in the spatial extent of VME polygons in the NRA were not affected by the inclusion of data from Canadian waters. However, greater precision of VMEs in the NRA through use of KDE is expected to occur through increased data from that area, as the analysis is driven by the local data neighbourhood. Here, the spatial extent was that of the NRA and data from Canadian waters were not considered.

For two VME indicator groups (Tube-dwelling Anemones (Cerianthids) and Sea Lilies (Crinoids)), updated distribution maps are provided, drawing on up-to-date data from the RV trawl surveys, and the "NAFO Potential Vulnerable Marine Ecosystem-Impacts of Deep-sea Fisheries" NEREIDA project, which was funded by the European Union (EU) through NAFO. NEREIDA rock dredge samples and NEREIDA underwater imagery were reviewed and mapped (Kenchington et al., 2019).

Methods

Data Sources

Available biomass data for each VME indicator type were obtained from research vessel trawl surveys conducted by the EU and Canada (Table 1), while presence data were obtained from benthic imagery collected through the NEREIDA program (Kenchington et al., 2019) and from NEREIDA project rock and scallop dredges for the mapping of the Tube-dwelling Anemones (Cerianthids) and Sea Lilies (Crinoids) (Kenchington et al., 2019). Only the trawl survey data (Table 1) has changed since the last review of closed areas in 2019.

Table 1. Research Vessel Survey Data from NAFO Contracting Parties (EU and Canada); EU, European Union; DFO, Department of Fisheries and Oceans; NL, Newfoundland and Labrador; IEO, Instituto Español de Oceanografía; IIM, Instituto de Investigaciones Marinas; IPMA, Instituto Português do Mar e da Atmosfera.

Data Source	Period	NAFO Division	Gear	Mesh Size in Cod-end Liner (mm)	Trawl Duration (min)	Average Wingspread (m)
Spanish 3NO Survey (IEO)	2002 - 2024	3NO	Campelen 1800	20	30	24.2 – 31.9
EU Flemish Cap Survey (IEO, IIM, IPMA)	2003 - 2024	3M	Lofoten	35	30	13.89
Spanish 3L Survey (IEO)	2003 - 2024	3L	Campelen 1800	20	30	24.2 – 31.9
DFO NL Multi-species Surveys (DFO)	1995 - 2022	3LNO	Campelen 1800	12.7	15	15 - 20

The trawling protocols from which the biomass data were collected differ in the type of trawl gear used, the mesh size of the cod-end liner, wingspread for the trawl and trawl duration (Table 1), all of which can affect the catch biomass of the VME indicator taxa. Further, there have been vessel changes in the Canadian survey fleet (DFO, 2024). The Canadian Coast Guard Ship (CCGS) *Wilfred Templeman* was decommissioned in 2008. In 2022, the CCGS *Alfred Needler* and CCGS *Teleost* were replaced with the new Offshore Fishery Science Vessel sister ships CCGS *John Cabot* and CCGS *Capt. Jacques Cartier* (DFO, 2024), with the CCGS *Alfred Needler* decommissioned in 2023 (Table 2). In addition to changing vessels, minor modifications (described in Wheeland et al., 2023) to the standard Campelen 1800 survey trawl net and footgear (Walsh et al. 2009) were completed in 2020, for use in the survey going forward. Consequently, the impacts of all of these differences on the VME indicator biomass of the catch were evaluated in order to determine which data could be combined and which data should be separately analyzed (see Analyses, below).

Table 2. Canadian Coast Guard Ship (CCGS) vessels contributing to the vulnerable marine ecosystem indicator (VME) database with details on the size, years and number of records by vessel.

Vessel	Length (m)	Gross Tonnage	Years in Database for VME	Number of Records
CCGS *Wilfred Templeman*	50.3	925.0	1995-2008	142
CCGS *Teleost*	63.0	2,405.0	1996-2018	287
CCGS *Alfred Needler*	50.3	958.9	2005-2022	617
CCGS *John Cabot*	63.4	2,672.0	2022	28

Data Quality Control

Data Anomalies (1995-2019)

The data call for the previous KDE analyses (Kenchington et al., 2019) was for the seven VME functional groups, that is Large-Size Sponges, Sea Pens, Large Gorgonian Corals, Small Gorgonian Corals, Black Corals, Erect Bryozoans, and Sea Squirts (*Boltenia ovifera*). This focus on functional groups, rather than species or taxon, arose from the first iterations of the work where there was uncertainty in the identification of these taxa to lower taxonomic levels such as genus or species, and no photos or subsamples were available to confirm identification subsequently. However, over time greater attention has been given to identification, both at sea and in post-survey protocols. As a result, the more recent data for most VME functional groups now includes data identified to species and/or genus (Murillo et al., 2024; Murillo et al., 2025). Exceptions are for the bryozoans, which are only recorded at that level in all surveys, and the Canadian sponge data which is only recorded as 'Porifera'.

As indicated in Table 1, data from the EU was first provided in 2002, and from 2011-2019, individual VME indicator taxa were identified to the extent possible and provided to NAFO for the species distribution modeling (SDM) work (see Murillo et al., 2024; Murillo et al., 2025). Data from Canada were provided with records as early as 1995 for some functional groups (Table 1). For the corals (large and small gorgonian corals, sea pens, and black corals), updates provided by Ms. V. Hayes (DFO, NWAFC) in 2024 included identifications to the species level or the lowest taxon that could be assigned with confidence. Such identifications commenced with records in 2000 through to 2022. Therefore, for most VME indicator taxa, the functional group biomass data used for the 2019 KDE analyses can be compared with the taxon-specific data provided in 2024 for the SDMs for overlapping time periods. Ideally, the sum of the biomass of the component taxa used for the SDMs should equal the weight provided for the functional group in each trawl set. However, a number of discrepancies were found and are discussed below for each functional group.

Large-Size Sponge Functional Group. The data from 1995 to 2019 received and initially reviewed for use in the previous KDE analyses (Kenchington et al., 2019) included 4390 sponge records (975 from the Canadian surveys and 3415 from the EU surveys); note that after testing for gear and other differences only data from 1825 catches ≥ 0.5 kg (618 Canadian records and 1207 EU records) were input to the KDE (Kenchington et al., 2019). As Canada only identified sponges as Porifera, no further comparisons can be made to detect errors in those data, however, the EU provided taxon-specific sponge data from 2011-2019 for use in SDM (Murillo et al., 2024) which were used to validate the data previously used for the KDE analyses.

Of the total number of records, biomass data matched perfectly for the years 2012 and 2015. However, 235 records showed discrepancies between data provided for the 2019 KDE analyses and that provided for species distribution modeling from the EU surveys (Murillo et al., 2024) (Table 3). The majority of those sponge records with discrepancies (172) showed differences of 1 kg or less which are unlikely to influence the analyses, however 16 records differed by more than 10 kg and 2 of those by more than 100 kg (Table 3). Closer inspection of those data showed that the differences were greatest in 2014 where 184 anomalous records were found. Those differences were attributed to three errors: 1) duplicate data were sent by the data providers (109 records affected); 2) the taxon 'Porifera' was omitted in the summated data sent by the data providers (74 records); 41 of these records added to sponge biomass while 33 new records were created where the catch only contained data recorded as 'Porifera'; and 3) one data entry error.

Table 3. Summary of the number of mismatched records between the EU 2011-2019 data used for the previous KDE analyses for the Large-Size Sponge Functional Group and the data provided for the 2024 species distribution modelling, by weight and year.

Discrepancies between: .001 and 1 kg = 172 1 and 5 kg =32 5 and 10 kg = 15 10 and 20 kg = 8 20 and 50kg = 3 50 and 100kg = 3 Over 100kg = 2	

Year	Count in Year
2011	3
2013	10
2014	184
2016	2
2017	15
2018	13
2019	8

For the 16 records that were >10 kg, the errors were in part due to an error in not including ‘Astrophorida’ (N=6) or ‘Porifera’ (N=7) in the biomass sum for the group taxon in 2019 (Table 4). In three cases, duplicate records were included in the biomass summation and in another three cases coding errors were discovered. The errors were only identified because of access to the taxon-specific data from the EU and could only be evaluated for the EU data provided for the 2011-2019 survey years. Potential errors in data provided by Canada and the EU from 2002-2010 cannot be similarly reviewed. Some of the errors were created at sea (coding errors) while others were in the data handling of both the data providers and the data analysts, primarily in the omission of key taxa that should have been included. In future a systematic review framework of data provided for the review of the areas closed to protect VME should be in place to avoid, to the extent possible, such mistakes.

The locations of the erroneous Large-Sized Sponge data identified from this review are shown in Figure 1. In addition to these errors in the biomass of the Large-Size Sponge Functional Group, three differences in the position of the trawl sets were identified through mapping of the trawl locations used in the 2019 KDE analyses (Kenchington et al., 2019) and those provided for the SDM work (Murillo et al., 2024). Two of the records PLA14126 and PLA16083 were flagged for review as they were outside of the fishing footprint, while the third was very close to the Canadian border (Table 5, Figure 2). Correcting the positions put the records in line with the closed areas and SDMs (Murillo et al., 2024).

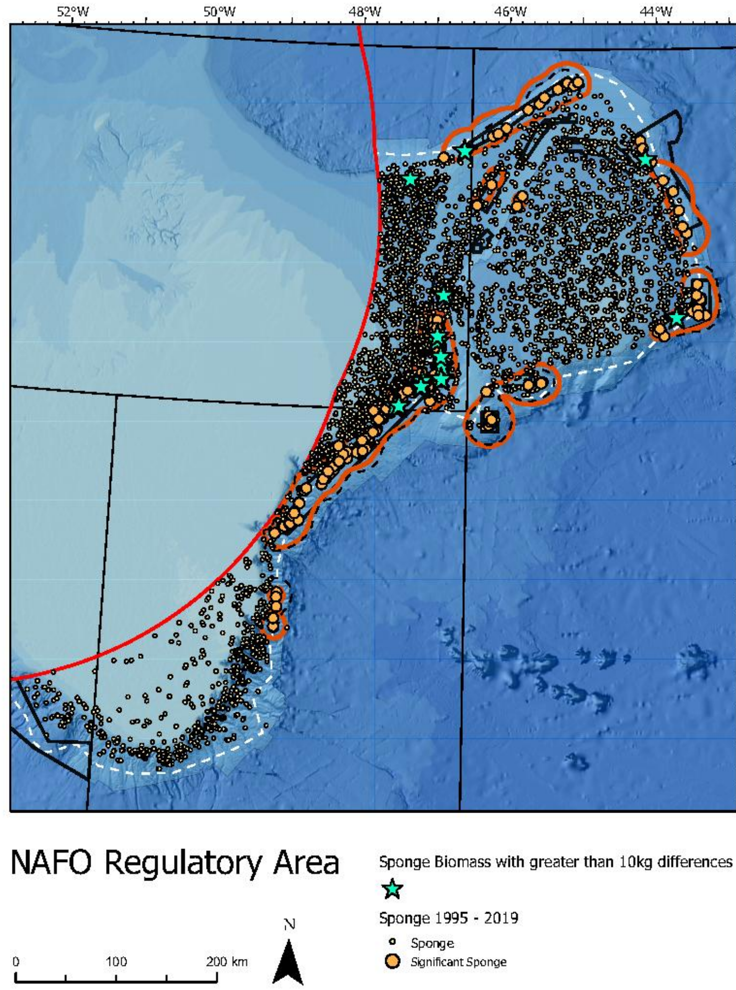


Figure 1. Location of the 16 data records discrepancies of > 10 kg between the EU 2011-2019 data used for the previous KDE analyses (Kenchington et al., 2019) for the Large-Size Sponge Functional Group and the data provided for the 2024 species distribution modelling (Murillo et al., 2024).

Table 4. Summary of the mismatched records of > 10 kg between the EU 2011-2019 data used for the previous KDE analyses for the Large-Size Sponge Functional Group and the data provided for the 2024 species distribution modelling, by year. Shaded values were retained for the analysis in the corrected data set.

Year	Trawl ID	Summed Sponge Biomass from 2024 SDM Data (Kg)	Sponge Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
2014	FN3L14098	423.155	804.969	-381.814	Duplicate records removed; ‘Porifera’ data added
2014	CAFC14114	3197.900	3253.266	-55.366	Duplicate records removed
2014	CAFC14082	13.300	26.600	-13.300	Duplicate records removed
2014	FN3L14088	459.776	448.326	11.450	‘Porifera’ data added
2014	FN3L14058	16.760	0.002	16.758	‘Porifera’ data added
2014	FN3L14087	1395.096	1377.820	17.276	‘Porifera’ data added
2014	FN3L14008	20.273	1.257	19.016	‘Porifera’ data added
2014	FN3L14002	511.700	454.500	57.200	‘Porifera’ data added
2014	FN3L14096	312.321	185.788	126.533	‘Porifera’ data added
2017	FN3L17069	26.559	16.490	10.069	‘Astrophorida’ data added
2017	FN3L17091	33.526	17.699	15.827	‘Astrophorida’ data added
2017	FN3L17092	49.150	32.864	16.286	‘Astrophorida’ data added
2017	FN3L17095	264.886	204.305	60.581	‘Astrophorida’ data added
2018	FN3L18092	76.551	36.751	39.80	‘Astrophorida’ data added; Coding error corrected by data provider
2018	FN3L18098	41.899	0.049	41.85	Coding error corrected by data provider
2019	FN3L19095	135.226	103.216	32.01	‘Astrophorida’ data added; Coding error corrected by data provider

Table 5. Co-ordinates of the 3 data records with positional errors between the EU 2011-2019 data used for the previous KDE analyses (Kenchington et al., 2019) for the Large-Size Sponge Functional Group and the data provided for the 2024 species distribution modelling (Murillo et al., 2024), by year. Shaded values were retained for the analysis in the corrected data set.

Year	Trawl ID	Start Latitude (DD) Used in 2019 KDE Analyses	Start Longitude (DD) Used in 2019 KDE Analyses	Start Latitude (DD) from 2024 SDM Data	Start Longitude (DD) from 2024 SDM Data	Biomass (Kg)
2014	FN3L14028	47.3045	-47.679167	47.3045	-46.679167	0.002
2014	PLA14126	44.0135	-48.681667	45.0135	-48.681667	42.997
2016	PLA16083	43.13083333	-48.88266667	44.130833	-48.882667	0.040

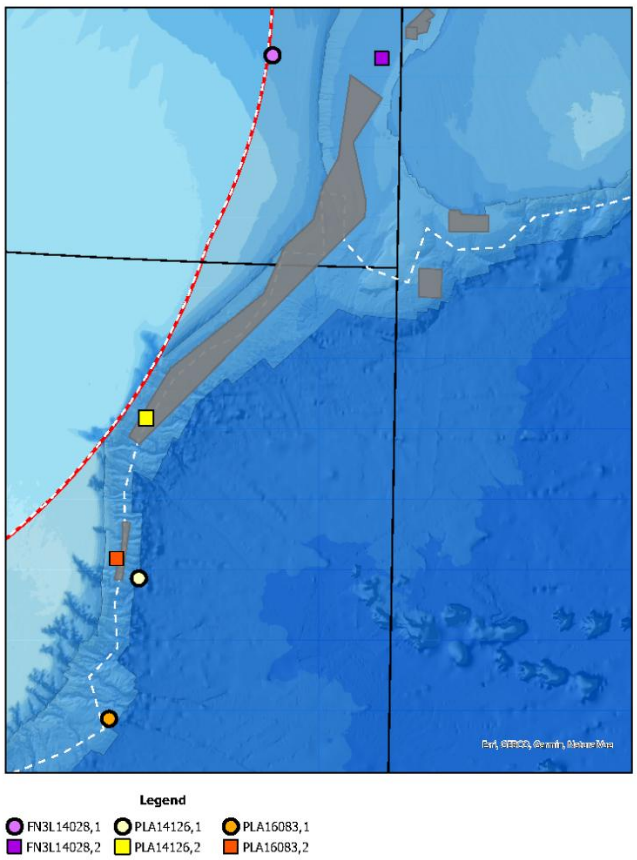


Figure 2. Location of the 3 data records with positional errors between the EU 2011-2019 data used for the previous KDE analyses (Kenchington et al., 2019) for the Large-Size Sponge Functional Group (circles) and the data provided for the 2024 species distribution modelling (Murillo et al., 2024) (squares). Shaded areas represent areas closed to protect corals and sponges; white dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Sea Pen Functional Group. The data from 1995 to 2019 received and initially reviewed for use in the previous KDE analyses (Kenchington et al., 2019) included 2213 sea pen records (259 from the Canadian surveys and

1954 from the EU surveys); note that after testing for gear and other differences only data from 403 catches ≥ 0.2 kg were input to the 2019 KDE (Kenchington et al., 2019). Records for the genera *Anthoptilum* and *Balticina* (formerly *Halipteris*) first appeared in 2005 from the Canadian surveys when survey identification codes for sea pens were first introduced, while *Funiculina* was not recorded until 2006 and *Pennatula* in 2005. The EU surveys also began recording sea pens in 2005, and details for individual sea pen taxa became available in 2011. This chronology is reflected in the numbers of records with taxon names reported in each year (Murillo et al., 2024). These 2213 records used in the previous KDE analyses were compared with the EU and Canadian data at the mission/set level with those provided for the SDM (Murillo et al., 2024) for the corresponding timeframe. Of the 2213 records, 3 did not match (Table 6). Those three records, used in the 2019 KDE analyses had an incorrect mission number (biomass and position were matched) and those were corrected. Six records were present in the data provided for the modeling work but were not present in the data set provided for the previous 2019 KDE analyses. Those records were added to the corrected database (Table 6).

Table 6. Summary of the mismatched records of mission/set between the data used for the previous KDE analyses for the Sea Pen Functional Group and the data provided for the 2024 species distribution modelling. Shaded values indicate sets that were mislabelled in the 2019 analyses but have been corrected for the present analyses. Data in the second column were used in the KDE analyses herein.

Mission/Set Code (Biomass kg) Used in 2019 KDE Analyses	Mission/Set Code (Biomass kg) [Taxon] from 2024 SDM Data
CAFC15078 (0.211)	CAFC15117 (0.211)
CAFC15072 (0.141)	CAFC15177 (0.141)
PLA14120 (0.026)	PLA14121 (0.026)
	NED2009905064 (0.11)
	CAFC14046 (0.014) [Halipteris christii]
	CAFC14075 (0.028) [Halipteris christii]
	CAFC14122 (0.106) [Halipteris christii]
	CAFC14125 (0.03) [Halipteris christii]
	CAFC15022 (0.109) [Anthoptilum spp]

Table 7. Summary of the number of mismatched records between the data used for the previous KDE analyses for the Sea Pen Functional Group and the data provided for the 2024 species distribution modelling, by weight and survey.

Biomass Interval	Total Records	EU Records	Canadian Records
< 0.001 kg	2	1	1
0.001 and 0.005 kg	17	12	5
0.005 and 0.01 kg	9	4	5
0.01 and 0.05 kg	35	4	31
0.05 and 0.1 kg	12	1	11
0.1 and 0.5 kg	8	3	5
0.5 and 1 kg	2	1	1
> 1 kg	1	1	0

Table 8. Summary of the mismatched records of > 0.2 kg between the EU (2011-2019) and Canadian (2005-2019) data used for the previous KDE analyses for the Sea Pen Functional Group and the data provided for the 2024 species distribution modelling, by year. Shaded values were retained for the analysis in the corrected data set.

Year	Trawl ID	Summed Sea Pen Biomass from 2024 SDM Data (Kg)	Sea Pen Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
EU Trawl Survey Data					
2014	CAFC14015	2.344	2.342	0.002	'Pennatula aculeata' added
2014	CAFC14065	0.977	0.976	0.001	'Kophobelemnon stelliferum' added
2014	CAFC14027	0.756	0.762	-0.006	Duplicate record removed, 'Pennatula aculeata' added
2014	CAFC14060	0.535	0.519	0.016	'Halipteris christii' added
2014	CAFC14006	0.166	0.332	-0.166	Duplicate record removed
2014	CAFC14069	0.202	0.112	0.09	'Halipteris christii' added
2014	FN3L14101	0.005	1.061	-1.056	'Pennatula aculeata/Phosphorea' removed; coding error corrected by data provider
2015	CAFC15093	0.688	0.109	0.579	'Anthoptilum spp' added
2015	PLA15062	0.184	0.342	-0.158	Duplicate 'PENNATULA GRANDIS' record removed
2015	PLA15067	0.285	0.320	-0.035	Duplicate 'PENNATULA GRANDIS' record removed
2015	PLA15068	1.506	1.531	-0.025	Duplicate 'PENNATULA GRANDIS' record removed
2015	FN3L15048	1.034	1.028	0.006	'FUNICULINIA SP.' added
Canadian Trawl Survey Data					
2009	TEL2009899011	0.9391	1.0334	-0.0943	Corrected by data provider
2007	TEL2007751025	0.360	0.8	-0.44	Corrected by data provider
2010	NED2010933018	0.1226	0.65	-0.5274	Corrected by data provider
2007	TEM2007771042	0.2726	0.3888	-0.1162	Corrected by data provider
2007	TEL2007752008	0.2987	0.34	-0.0413	Corrected by data provider
2010	NED2010943027	0.2465	0.322	-0.0755	Corrected by data provider
2006	TEL2006683029	0.270	0.3	-0.03	Corrected by data provider
2011	NED2011404027	0.33915	0.290	0.04915	Corrected by data provider
2005	TEL2005608016	0.270	0.273	-0.003	Corrected by data provider
2007	TEL2007751026	0.264	0.265	-0.001	Corrected by data provider
2005	TEL2005609001	0.240	0.254	-0.014	Corrected by data provider
2009	NED2009915008	0.224	0.246	-0.022	Corrected by data provider
2012	NED2012425017	0.199	0.209	-0.010	Corrected by data provider
2009	TEL2009895013	0.0248	0.201	-0.1762	Corrected by data provider
2015	TEL2015142075	0.320	0.160	0.160	Corrected by data provider

Table 9. Trawl identification codes and associated biomass for 14 RV trawl sets not included in the previous 2019 Black Coral KDE analyses but listed with the 2024 updated files submitted by the data providers.

Year	Trawl ID	Biomass (Kg)	Taxon Code
2011	CAFC11048	0.001	Antipatharia
2011	CAFC11055	0.009	Antipatharia
2011	CAFC11056	0.001	Antipatharia
2011	CAFC11121	0.007	Stauropathes arctica
2014	CAFC14018	0.006	Antipatharia
2016	CAFC16015	0.066	Antipatharia
2016	CAFC16016	0.008	Antipatharia
2016	CAFC16021	0.016	Antipatharia
2016	CAFC16022	0.003	Antipatharia
2016	CAFC16048	0.019	Antipatharia
2016	CAFC16049	0.001	Antipatharia
2016	CAFC16054	0.020	Antipatharia
2016	CAFC16059	0.001	Antipatharia
2016	PLA16047	0.002	Antipatharia

Table 10. Summary of the mismatched records between the EU (2006-2019) and Canadian (2002-2019) data used for the previous KDE analyses for the Black Coral Functional Group and the data provided for the 2024 species distribution modelling. Shaded values were retained for the new KDE analysis in the corrected data set.

Year	Trawl ID	Country	Summed Black Coral Biomass from 2024 SDM Data (Kg)	Black Coral Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
2014	TEL2010979060	Canada	6.05	6.00	0.05	'Leiopathes cf. expansa' added
2014	CAFC14091	EU	0.038	0.034	0.004	'Antipatharia' added

Table 11. Trawl identification codes and associated biomass for 8 RV trawl sets not included in the previous 2019 Large Gorgonian Coral KDE analyses but listed with the 2024 updated files submitted by the data providers.

Year	Trawl ID	Biomass (Kg)	Taxon Code
2014	CAFC14027	0.004	Acanthogorgiidae
2014	CAFC14154	0.006	Acanthogorgiidae
2014	CAFC14157	0.006	Acanthogorgiidae
2014	CAFC14163	0.002	Acanthogorgiidae
2014	CAFC14167	0.002	Acanthogorgiidae
2014	FN3L14003	0.006	Acanthogorgia
2014	FN3L14005	0.002	Acanthogorgia
2014	FN3L14087	0.007	Acanthogorgia

Table 12. Details of duplicate records from the Canadian RV surveys identified in the data used in 2019 for the Large Gorgonian Coral KDE analyses.

Vessel	Trip	Set	Year	Start Lat (DD)	Start Long (DD)	Gear	Wt (kg)
Teleost	142	62	2015	48.14	-47.5133	61	0.07
Teleost	142	62	2015	48.14	-47.5133	61	0.07
Teleost	142	63	2015	48.18167	-47.4317	61	0.01
Teleost	142	63	2015	48.18167	-47.4317	61	0.01
Teleost	142	77	2015	46.37	-47.0983	61	1.12
Teleost	142	77	2015	46.37	-47.0983	61	1.12

Comparing the biomass between the data sets, 86 records were found to have differences in biomass of .001kg or higher; 27 from the EU surveys and 59 from the Canadian surveys. However, only data ≥ 0.2 kg were used in the previous KDE analyses. Those records included 12 records from the EU surveys and 15 records from the Canadian surveys (Table 8). The errors in the EU data ≥ 0.2 kg were due to duplicate records (N=5), missing taxa (N=7) and one coding error. Changes to the Canadian data were made through QC checks by the data provider and were used in preference to the earlier data sets provided.

For biomass < 0.2 kg errors in the EU data were mostly attributed to duplicate records (N=8), to missing taxa (N=6) and to one rounding error; those were all corrected. Changes to the Canadian data were made through QC checks by the data provider and were used in preference to the earlier data sets provided.

Black Coral Functional Group. The data available for checking for data anomalies were from 2000 to 2019 (294 records, 20 from the Canadian surveys and 274 from the EU surveys). Records for the Black Corals first appeared in 2002 from the Canadian surveys where *Stauropathes arctica* was recorded (Wareham and Edinger 2007). The EU surveys began recording black corals in 2006, and details for individual black coral taxa became available in 2011, as for other VME indicator species. The previous KDE data for Black Corals for the same timeframe held 280 black coral records. Therefore 14 records were not included in the previous analyses but are now available (Table 9). For the 280 records in common, all biomass matched except for two records where taxa had been omitted in 2019 that should have been included, and those were corrected (Table 10).

Large Gorgonian Coral Functional Group. The data available for checking for data anomalies were from 2000 to 2019. The data set analysed in 2019 had 283 records, however the comparative data sets for the same time frame supplied for the SDM analyses had 291 records. Examination of the discrepancy showed that 8 records were not included in 2019 (Table 11). Those records were all from 2014 and have been added to the corrected database. Records for the Large Gorgonian Corals first appeared in 2000 from the Canadian surveys where *Paragorgia arborea* was recorded. The EU surveys began recording Large Gorgonian Corals in 2006, and details for individual taxa became consistently available after 2011. For the 283 records in common, all biomass matched but three tows from the Canadian RV surveys in 2015 appear to have been duplicated (Table 12). The duplicate records were removed for the current analyses.

Small Gorgonian Coral Functional Group. The data available for checking for data anomalies were from 2002 to 2019. The data set analysed in 2019 had 688 records, however the comparative data sets for the same time frame supplied for the SDM analyses had 699 records. A review of the component taxa for this functional group (Murillo et al., 2025) concluded that the 'ISIDIDAE' and 'Octocorallia sp. (SUBCLASS)' records should be removed, although they were included in the 2019 analyses. There were 20 Isididae (all EU records) and 22 Octocorallia sp. (SUBCLASS) (all Canadian records) which were removed from the taxa dataset. Further, most recent updates had an additional 25 records that were not present in the 2019 KDE analyses (Table 13). Those records were included in the present analyses. Biomass comparisons in the common data set between 2019 and the updated data found 11 cases where the biomass differed. In ten of those cases 'Radicipes gracilis' or 'RADICIPES SP' was missing from the 2019 data and added in. In one case the data provider updated the biomass (Table 14).

Table 13. Details of records from the 2024 data updates that were not included in the 2019 KDE analyses.

Year	Trawl ID	Biomass (kg)	Taxon
2015	NED2015460017	0.08	Acanella arbuscula
2007	TEL2007751016	0.01	Radicipes gracilis
2007	TEL2007751026	0.04	Radicipes gracilis
2009	TEL2009895015	0.0008	Radicipes gracilis
2009	TEL2009899013	0.001	Radicipes gracilis
2014	CAFC14002	0.001	Radicipes gracilis
2014	CAFC14009	0.001	Radicipes gracilis
2014	CAFC14059	0.005	Radicipes gracilis
2014	CAFC14060	0.002	Radicipes gracilis
2014	CAFC14070	0.002	Radicipes gracilis
2014	CAFC14090	0.001	Radicipes gracilis
2014	CAFC14110	0.001	Radicipes gracilis
2014	CAFC14154	0.001	Radicipes gracilis
2014	FN3L14031	0.022	Radicipes
2014	FN3L14032	0.001	Radicipes
2014	FN3L14033	0.001	Radicipes
2014	FN3L14034	0.001	Radicipes
2014	FN3L14036	0.001	Radicipes
2014	FN3L14039	0.062	Radicipes
2014	FN3L14040	0.010	Radicipes
2014	FN3L14046	0.002	Radicipes
2014	FN3L14047	0.001	Radicipes
2014	FN3L14062	0.001	Radicipes
2015	FN3L15067	0.005	Anthothelidae
2016	FN3L16045	0.001	Anthothelidae

Table 14. Summary of the mismatched records between the data used for the previous KDE analyses for the Small Gorgonian Coral Functional Group and the data provided for the 2024 species distribution modelling. Shaded values were retained for the new KDE analysis in the corrected data set.

Year	Trawl ID	Summed Small Gorgonian Coral Biomass from 2024 SDM Data (Kg)	Small Gorgonian Coral Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
2012	FN3L12051	0.075	0.087	-0.012	Data corrected by data provider
2014	CAFC14024	0.007	0.006	0.001	'Radicipes gracilis' added
2014	CAFC14027	0.036	0.034	0.002	'Radicipes gracilis' added
2014	CAFC14031	0.004	0.002	0.002	'Radicipes gracilis' added
2014	CAFC14094	0.002	0.001	0.001	'Radicipes gracilis' added
2014	CAFC14143	0.002	0.001	0.001	'Radicipes gracilis' added
2014	CAFC14146	0.005	0.004	0.001	'Radicipes gracilis' added
2014	FN3L14029	0.002	0.001	0.001	'RADICIPES SP' added
2014	FN3L14030	0.042	0.002	0.040	'RADICIPES SP' added
2014	FN3L14038	0.022	0.002	0.020	'RADICIPES SP' added
2014	FN3L14053	0.005	0.004	0.001	'RADICIPES SP' added

Erect Bryozoan Functional Group. The data available for checking for data anomalies were from 2006 to 2019. Comparison of the data used in 2019 with that used for the 2025 species distribution modelling identified 15 duplicate records and 2 missing records in the 2019 data set (Table 15). Those data were corrected, and the final data set included 874 erect bryozoan records.

Table 15. Summary of the mismatched records between the data used for the previous KDE analyses for the Erect Bryozoan Functional Group and the data provided for the 2024 species distribution modelling. Shaded values were retained for the new KDE analysis in the corrected data set.

Year	Trawl ID	Summed Erect Bryozoan Biomass from 2024 SDM Data (Kg)	Erect Bryozoan Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
2016	TEL2016170053	0.01		0.01	Data corrected by data provider
2016	TEL2016170063	0.01		0.01	Data corrected by data provider
2017	PLA17012	3.66	3.66		Duplicate record removed
2017	PLA17005	0.33	0.33		Duplicate record removed
2017	PLA17011	0.144	0.144		Duplicate record removed
2017	PLA17070	0.056	0.056		Duplicate record removed
2017	PLA17085	0.051	0.051		Duplicate record removed
2017	PLA17014	0.038	0.038		Duplicate record removed
2017	PLA17041	0.024	0.024		Duplicate record removed
2017	PLA17003	0.02	0.02		Duplicate record removed
2017	PLA17008	0.02	0.02		Duplicate record removed
2017	PLA17083	0.008	0.008		Duplicate record removed
2017	PLA17095	0.006	0.006		Duplicate record removed
2017	PLA17004	0.005	0.005		Duplicate record removed
2017	PLA17006	0.003	0.003		Duplicate record removed
2017	PLA17002	0.003	0.003		Duplicate record removed
2017	PLA17086	0.002	0.002		Duplicate record removed

Sea Squirt (*Boltenia ovifera*) Functional Group. The data available for checking for data anomalies were from 2007 to 2019. Comparison of the data used in 2019 with that used for the 2025 species distribution modelling, identified 3 missing records in the 2019 data set and one biomass change (Table 16). Those data were corrected, and the final data set included 389 Sea Squirt Functional Group records.

Table 16. Summary of the mismatched records between the data used for the previous KDE analyses for the Sea Squirt (*Boltenia ovifera*) Functional Group and the data provided for the 2024 species distribution modelling. Shaded values were retained for the new KDE analysis in the corrected data set.

Year	Trawl ID	Summed Sea Squirt (*Boltenia ovifera*) Biomass from 2024 SDM Data (Kg)	Sea Squirt (*Boltenia ovifera*) Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
2018	PLA18056	0.018		0.018	Data corrected by data provider
2015	PLA15062	0.018		0.018	Data corrected by data provider
2015	PLA15061	0.015		0.015	Data corrected by data provider
2019	TEL2007771073	0.160	0.32	0.160	Data corrected by data provider

Tube-Dwelling (Cerianthid) Anemones. Three records of Tube-Dwelling (Cerianthid) Anemones for 2016 were provided by the data providers in their most recent updates that were absent from the 2019 mapping for this functional group, and one record was removed (Table 17). The corrected data have been mapped along with the new data records (see Results below).

Table 17. Summary of the mismatched records between the data used for the previous KDE analyses for the Tube-Dwelling (Cerianthid) Anemones Functional Group and the data provided for the 2024 species distribution modelling. Shaded values were retained for the new KDE analysis in the corrected data set.

Year	Trawl ID	Summed Tube-Dwelling (Cerianthid) Anemones Biomass from 2024 SDM Data (Kg)	Tube-Dwelling (Cerianthid) Anemones Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
2016	PLA16021	0.662		0.662	Data corrected by data provider
2016	PLA16025	0.661		0.661	Data corrected by data provider
2016	PLA16031	0.01		0.01	Data corrected by data provider
2018	FN3L18017		0.124	0.124	Data corrected by data provider

Sea Lilies (Crinoids). Nineteen records of Sea Lilies (Crinoids) that were not included in the previous mapping (Kenchington et al., 2019) were reported from the EU surveys for the period 2011 to 2016 in their most recent update of the data while six records from 2012 that were used were invalidated (Table 18). The corrected data have been mapped along with the new data records (see Results below).

Table 18. Summary of the mismatched records between the data used for the previous KDE analyses for the Sea Lilies Functional Group and the data provided for the 2024 species distribution modelling. Shaded values were retained for the new KDE analysis in the corrected data set.

Year	Trawl ID	Summed Sea Lily Biomass from 2024 SDM Data (Kg)	Sea Lily Biomass Used in 2019 KDE Analyses (Kg)	Biomass Difference (Kg)	Comment
2011	PLA11025	0.001		0.001	Data corrected by data provider
2012	FN3L12032	0.010		0.010	Data corrected by data provider
2012	CAFC12076		0.050	0.050	Data corrected by data provider
2012	CAFC12079		0.002	0.002	Data corrected by data provider
2012	CAFC12131		0.030	0.030	Data corrected by data provider
2012	CAFC12132		0.005	0.005	Data corrected by data provider
2012	CAFC12135		0.010	0.010	Data corrected by data provider
2012	CAFC12149		0.010	0.010	Data corrected by data provider
2013	CAFC13063	0.001		0.001	Data corrected by data provider
2013	CAFC13069	0.001		0.001	Data corrected by data provider
2013	CAFC13126	0.001		0.001	Data corrected by data provider
2013	CAFC13136	0.001		0.001	Data corrected by data provider
2013	CAFC13152	0.001		0.001	Data corrected by data provider
2013	CAFC13172	0.001		0.001	Data corrected by data provider
2013	CAFC13180	0.002		0.002	Data corrected by data provider
2016	CAFC16098	0.001		0.001	Data corrected by data provider
2016	CAFC16109	0.001		0.001	Data corrected by data provider
2016	CAFC16139	0.001		0.001	Data corrected by data provider
2016	CAFC16144	0.001		0.001	Data corrected by data provider
2016	CAFC16180	0.001		0.001	Data corrected by data provider
2016	FN3L16001	0.001		0.001	Data corrected by data provider
2016	FN3L16062	0.002		0.002	Data corrected by data provider
2016	FN3L16063	0.001		0.001	Data corrected by data provider
2016	FN3L16099	0.252		0.252	Data corrected by data provider
2016	PLA16076	0.001		0.001	Data corrected by data provider

Data Quality Checking Procedures (2020-2024)

Upon receipt of data from the data providers and with the assistance of the World Register of Marine Species (WoRMS) taxon match tool (https://www.marinespecies.org/aphia.php?p=match), full taxon classification was added to the dataset and taxa records were assigned to their VME functional group. Those assignments were further reviewed by taxonomic experts, to ensure that taxa were not missing from the biomass summaries. To prepare the data for the KDE analyses, for each VME functional group, trawl sets were grouped, and the biomass summed. Data were then mapped to identify potential errors in the positional information provided, and the depths of the records were checked to determine whether the taxon was expected to occur at the location provided. Any suspicious records were collated and sent back to the data providers for further review and consensus on what the corrected data should be. The numbers of data records for each VME Indicator taxon used herein are provided in Table 6. Note that the final number of records used in the KDE analyses may differ depending on the results of the data comparison tests (see Analyses below) and are reported on in the Results.

Data Quality Checking Procedures for the Subgroups of Large-Sized Sponges, Sea Pens and Small Gorgonian Corals

Species distribution models were run for some VME subgroups within the Large-Sized Sponges, Sea Pens, and Small Gorgonian Corals. At the 2024 WGESA meeting it was suggested that the KDE analyses also be performed on the VME Indicator subgroups (listed in Table 19). The quality checking of those data was performed and documented as in Murillo et al. (2024, 2025) with the additional EU data from 2024 reviewed as noted above.

Table 19. Summary of the data inputs for consideration in the KDE analyses. These data record the available data for each VME Indicator taxon. In some cases, subsets of the data were used in the final KDE analyses to account for catchability differences in gear or tow duration (see Results for each VME Indicator taxon).

VME Indicator	Period	No. Records
Large-Sized Sponges	1995 - 2024	5505
Tetillidae	2011 - 2024	225
Polymastiidae	2011 - 2024	686
Astrophorina	2011 - 2024	475
Sea Pens	2005 - 2024	2790
Anthoptilum	2005 - 2024	1396
Balticina	2005 - 2024	740
Funiculina	2006 - 2024	450
Pennatula	2009 - 2024	529
Black Corals	2002 - 2024	418
Large Gorgonian Corals	2000 - 2024	332
Small Gorgonian Corals	2002 - 2024	911
Acanella arbuscula	2002 - 2024	620
Radicipes gracilis	2007 - 2024	162
Erect Bryozoans	2006 - 2024	874
Sea Squirts	2007 - 2024	389

Analyses

The data were drawn from three different combinations of gear type and trawling duration (Table 1). All catch weight distributions were highly right-skewed due to large numbers of small catches with few very large catches as is characteristic of highly aggregating species (Kenchington et al., 2014). To assess whether the different survey data should be used separately or in combination for each VME indicator taxon, we applied non-parametric statistics to the catch biomass from each of the three gear/duration data sets using all of the biomass data and to only those data above arbitrarily-selected weight classes. Because each of the surveys covered different and largely non-overlapping spatial extent natural differences in biomass are confounded in this approach and could enhance or mask differences between gears and/or trawl duration. This effect is most likely to affect tests involving gear comparison as the Lofoten gear was used almost exclusively on the Flemish Cap while the Campelen trawls were deployed in the Flemish Pass and on Grand Bank. Comparison of trawl duration effects between the surveys using Campelen gear cover a similar spatial extent and so are less likely to be confounded by geospatial differences in catchability. Two-sample Kolmogorov-Smirnov (KS) tests using only data collected with the Campelen gear were performed to evaluate the influence of trawl duration (15 min vs. 30 min), a proxy of trawl length. When no significant differences were found, the data sets were combined and tested against the Lofoten gear data, to evaluate the influence of the gear type following Kenchington et al. (2014). Tukey-Kramer HSD tests were used to compare mean VME Indicator biomass among the catches of the four Canadian survey vessels. As the analyses of the sponge, sea pen and small gorgonian coral subgroups used only EU data, KS tests were only performed to test the effect of trawl gear type.

The primary tool used previously to quantitatively determine significant concentrations of VMEs is the non-parametric kernel density estimation (KDE) analysis. As applied here, this analysis identifies "hotspots" in catch biomass distribution. Using the output kernel biomass density surfaces, polygons were drawn around successively smaller catch values and the area occupied by each polygon was calculated (Kenchington et al., 2014; Kenchington et al., 2019). The catch value associated with the largest change in area between successive values, after the initial establishment of each VME area, is considered to be the VME, distinguishing habitat-forming dense aggregations from the broader occurrence of individuals as identified through rule-based decisions (NAFO, 2013). Kernel Density (KDE) analyses were performed in ArcGIS Pro v.3.3.2's Model Builder where VME research vessel trawl biomass point data, taken from the start positions of the trawl sets, were used to create a density surface ('Kernel Density' toolset in the 'Spatial Analyst' toolbox). Following protocols established in 2019 the default parameters (determined from the spatial extent of the data) were used, to provide further stability to the reported results. Once the kernel density surface was produced, it was used to estimate the area covered by the original data points at selected biomass threshold levels along the kernel contours. This calculation was repeated for successively decreasing biomass threshold values at intervals reported for each taxon. These values were collected into a table and exported to an Excel spreadsheet for reporting. The analyses were performed using a NAD 83 UTM 23N projection.

Decision Rules Adopted by NAFO (2013) for Identifying VME Thresholds

"When applied to a highly aggregating species the area occupied by polygons created by successively smaller catch weights follows a repeated pattern: Phase 1: rapid increase in area as the areas with the highest biomass are established; Phase 2: little change in the area occupied by successively smaller catch weights due to the aggregative nature of the species; Phase 3: a rapid change in area as the contribution of isolated individuals over a broad area are incorporated. Phases 2 and 3 may occur more than once in a profile. When interpreting the catch weight defining the significant concentrations a number of criteria are simultaneously considered: 1) identification of the catch weights which show the largest change in area after the initial establishment of the habitat areas; 2) consideration of the number of data points contributing to the change in area between successive catch thresholds; 3) examination of the spatial relationship of the polygons greater and less than the potential threshold using GIS and the position of the new data points. In this last step area can increase by the joining of two or more high density polygons. If this occurs the evidence for connecting the areas (i.e., number of points between the smaller areas) is reviewed. The threshold is considered to be valid when there is increase in area through a reasonable number of widely spaced data points. Cases for rejecting the threshold other than insufficient data include: 1) joining of smaller polygons with little evidence for a continuous distribution within the newly formed area; 2) a gradual increase in area with every new polygon added, creating a situation where no one successive change in area is especially larger or smaller than others (this indicates that there is no aggregation); 3) an increase in area established by creation of new areas of very low density; 4) no large increase in area. Lastly, once the catch weight for defining the significant concentrations is established each VME area is evaluated by reviewing all of the data records (including null values) around each VME to evaluate whether the area is extensive enough to qualify as a VME." (NAFO, 2013).

Results

Large-Size Sponge Functional Group

Significant concentrations of Large-Size Sponges have been determined previously in the NRA using kernel density analyses and an evaluation of the expansion of the area covered by successive density polygons (NAFO, 2013). These analyses have been updated using all available data from the RV trawl surveys. Specifically, data from the Spanish 3NO survey (2002-2024), EU Flemish Cap Survey (2003-2024), the Spanish 3L Survey (2003-2024) and the DFO-NL Multi-species Surveys (1995-2022) were assessed. These data sources yielded 5,505 sponge records (1074 from the Canadian surveys and 4431 from the EU surveys); 1115 more data points than were available for the last analysis (Kenchington et al., 2019).

As noted previously, there were significant differences among the catch series for each survey and differences in the number of small catch weights, likely due to differences associated with gear type, tow length, survey area and sampling protocol. When all records less than 0.5 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears (Appendix Table A1). A significant effect of vessel was found within the Canadian data for catches ≥ 0.5 kg (Appendix Table A1). Those differences were between the CCGS *Teleost*, and all three of the other vessels (Appendix Table A1). Further examination of the location of the trawl sets (Appendix Figures A1, A2), showed that the CCGS *Teleost* was fishing in the deeper water on Flemish Cap relative to the other vessels. The large catches from CCGS *Teleost* were from those deep sponge grounds and were fished prior to 2011 (Appendix Figure A3); Tukey-Kramer HSD tests showed that there was no difference in the catch biomass among vessels after 2011, when the locations fished were more similar. Therefore, the significant differences in catch biomass between the CCGS *Teleost* and each of the CCGS *Alfred Needler*, CCGS *Wilfred Templeman*, and CCGS *John Cabot* are due to the CCGS *Teleost* fishing in the deep water sponge grounds on Flemish Cap prior to 2011 (Appendix Figure A3) and not to catchability differences as shown by the non-significant difference in catch biomass among the Canadian fleet post-2011 (Appendix Table A1).

The analyses were performed on 2244 catches ≥ 0.5 kg (677 Canadian records and 1567 EU-Spanish records). Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 25 km; Contour Interval = 0.01; Cell size default = 3097.9 m. The biomass surface is shown in Figure 3 compared with the surface created from the 2019 analysis. The overall locations of the VME polygons are the same and the largest density estimates are also the same (41.12 kg km^2).

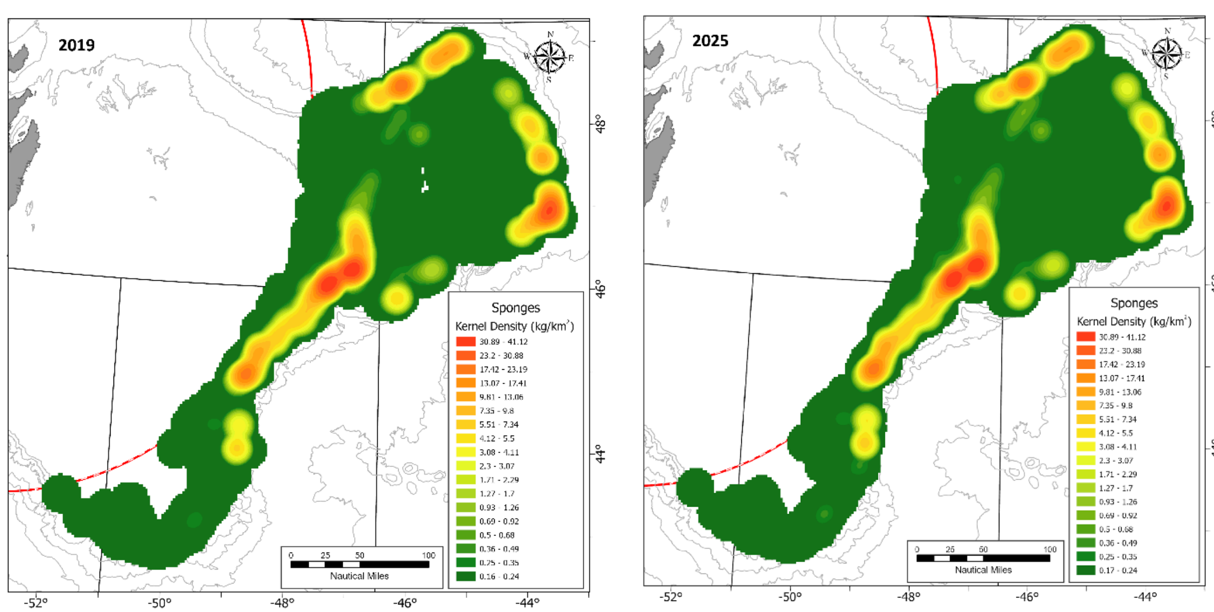


Figure 3. Kernel density biomass surface of Large-Size Sponges in the NAFO Regulatory Area. Left Panel: Surface created in 2019 for closed area assessments; Right Panel: Surface created in 2025 for current closed area re-assessments.

The kernel density distribution identified sponge grounds on the southern portion of Flemish Pass to southwestern Grand Bank, Beothuk Knoll, Sackville Spur and the east and southeast Flemish Cap (Figure 3). The change in area of polygons created with successively smaller catch weight thresholds (Table 20, Figure 4) showed typical patterns with very large changes in area seen as the VME areas are being established. The 200 kg/RV tow density threshold emerged was the first catch level where there is a large increase in area (40.6%)

once the initial sponge grounds are delineated (Table 20, Figure 4), indicating a potential catch threshold. However, it was only established with 6 additional points (Table 20), whereas the 100 kg/RV tow density threshold was established with 24 additional data points and had a similar increase in area (39.2%; Table 20). Both potential thresholds were visually inspected (Figure 5). In moving from a threshold of 200 kg/RV tow to 175 kg, sponge grounds on the eastern slope of Flemish Cap are created. However, in the threshold of 100 kg/RV tow, all of the sponge grounds on the eastern slope of Flemish Cap are connected and capture the high density areas (Figures 3, 5). Only the extension of the Sackville Spur polygon at its southwestern extension includes lower density areas, but as this is in an area of fishing, this may represent thinning.

Following previously accepted procedures for identifying thresholds (NAFO, 2013), the 100 kg/RV tow density threshold was selected as defining significant concentrations of Large-Size Sponges (i.e., sponge ground VME). The VME polygons established with this threshold cover an area of 33144.2 km^2 and were determined by an additional 24 trawl set observations ≥ 100 kg (see Table 20). The threshold encompasses 865 records which is 38.5% of the data. This threshold is the same as that used in the 2019 analysis (Kenchington et al., 2019).

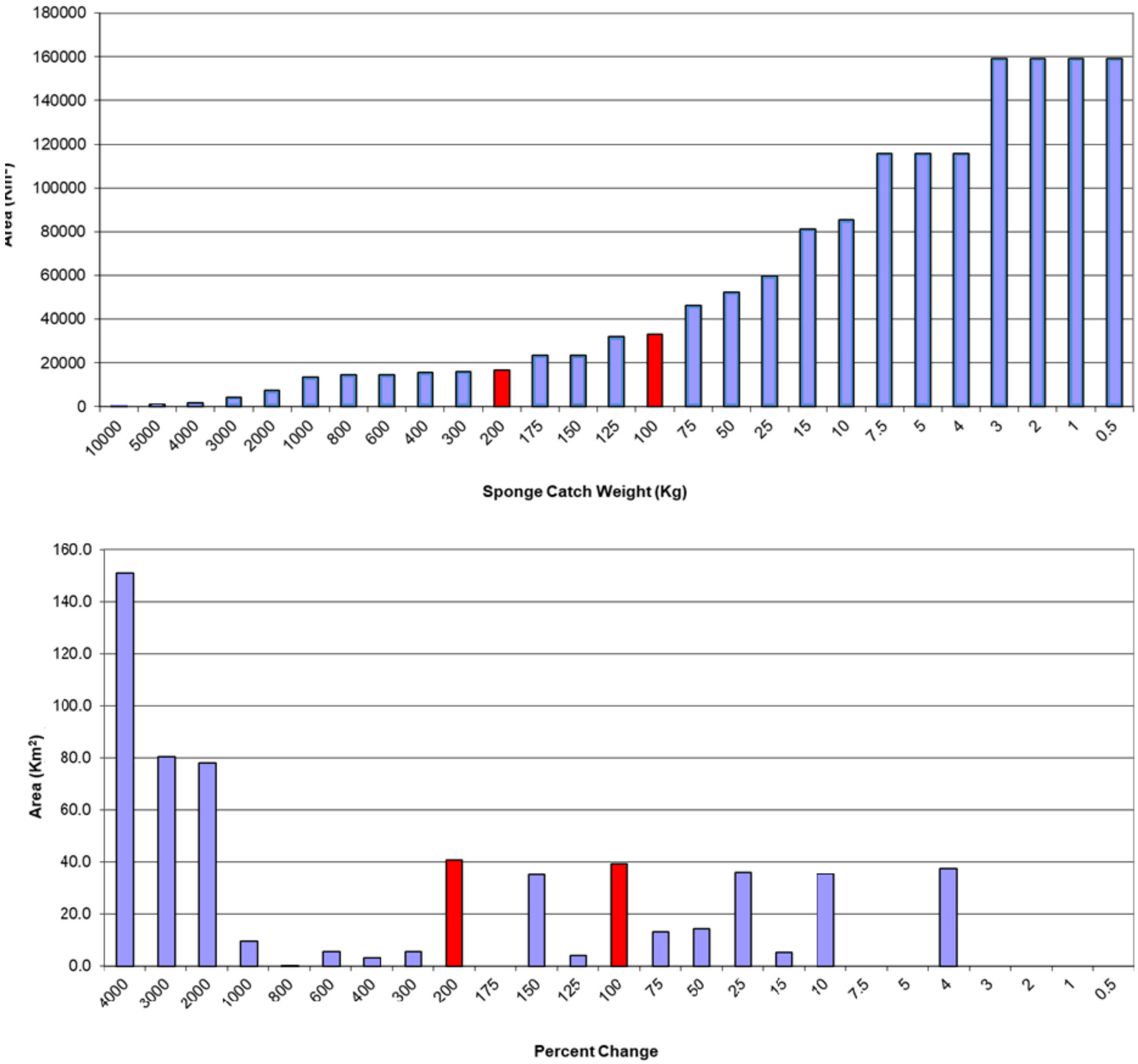


Figure 4. Bar graphs of the polygon area established by successively smaller research vessel sponge catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

The significant and non-significant catches within the VME polygons for the Large-Size Sponge Functional Group are shown in Figure 6. Comparison of the VME polygons obtained from the 2019 KDE analyses (Kenchington et al., 2019) show a high degree of congruence with the 2025 analysis with four VME polygons not changing their configuration (Figure 7). Three changes are noted: 1) the linking of the Sackville Spur VME polygon with the VME located south of the Sackville Spur closed area in what appears to be a lightly fished area (Figure 7). This is a small area, but in 2019 was thought to have special environmental or physical conditions enhancing sponge biomass, which could constitute VMEs. In the new analyses that area has data linking it to the Sackville Spur grounds (Figures 6, 7), with many smaller catches, possibly thinned by fishing (see Kenchington et al., 2019) present (Figure 6); 2) The establishment of a new sponge VME north of the VME polygon on the eastern wall of Flemish Cap (Figures 6, 7); 3) The combining of two smaller VME polygons on the southern wall of Flemish Pass on the Tail of Grand Bank (Figures 6, 7), supported by a number of smaller catches in the shallower portions of the polygon (Figure 6). Of the significant catches ≥ 100 kg, most fall within the closed areas put in place in 2025 to protect VMEs (Figure 8).

Table 20. The area of Large-Size Sponge VME polygons based on successively smaller research vessel catch weight thresholds (kg). The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Large-Size Sponge Functional Group Catch Threshold (Kg)	Total Number of Observations in Polygons	Number of Observations > Weight Threshold in Polygon	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
10000	5	2		37.2	3029.0
5000	63	9	7	1163.5	42.8
4000	70	13	4	1662.0	150.8
3000	130	23	10	4168.1	80.5
2000	311	37	14	7523.6	78.2
1000	504	69	32	13405.0	9.5
800	521	77	8	14676.7	0.2
600	526	91	14	14712.4	5.2
400	535	118	27	15475.3	3.2
300	537	134	16	15966.1	5.2
200	570	164	30	16794.3	40.6
175	662	170	6	23610.0	0.0
150	662	175	5	23610.0	35.0
125	839	184	9	31869.1	4.0
100	865	206	22	33144.2	39.2
75	1212	230	24	46139.5	13.2
50	1403	270	40	52213.4	14.3
25	1552	365	95	59685.5	36.2
15	1953	459	94	81314.4	5.1
10	2017	588	129	85470.7	35.3
7.5	2212	701	113	115610.7	0.0
5	2212	876	175	115610.7	0.0
4	2212	998	122	115610.7	37.7
3	2244	1145	147	159166.0	0.0
2	2244	1381	236	159166.0	0.0
1	2244	1776	395	159166.0	0.0
0.5	2244	2244	468	159166.0	

As identified in the 2019 KDE analyses, there is a small polygon on Flemish Cap with only two significant catches (Figures 6, 7). These likely have another sponge species composition, which may include *Asconema foliata*, also a VME indicator taxon (see species distribution model in NAFO, 2019a).

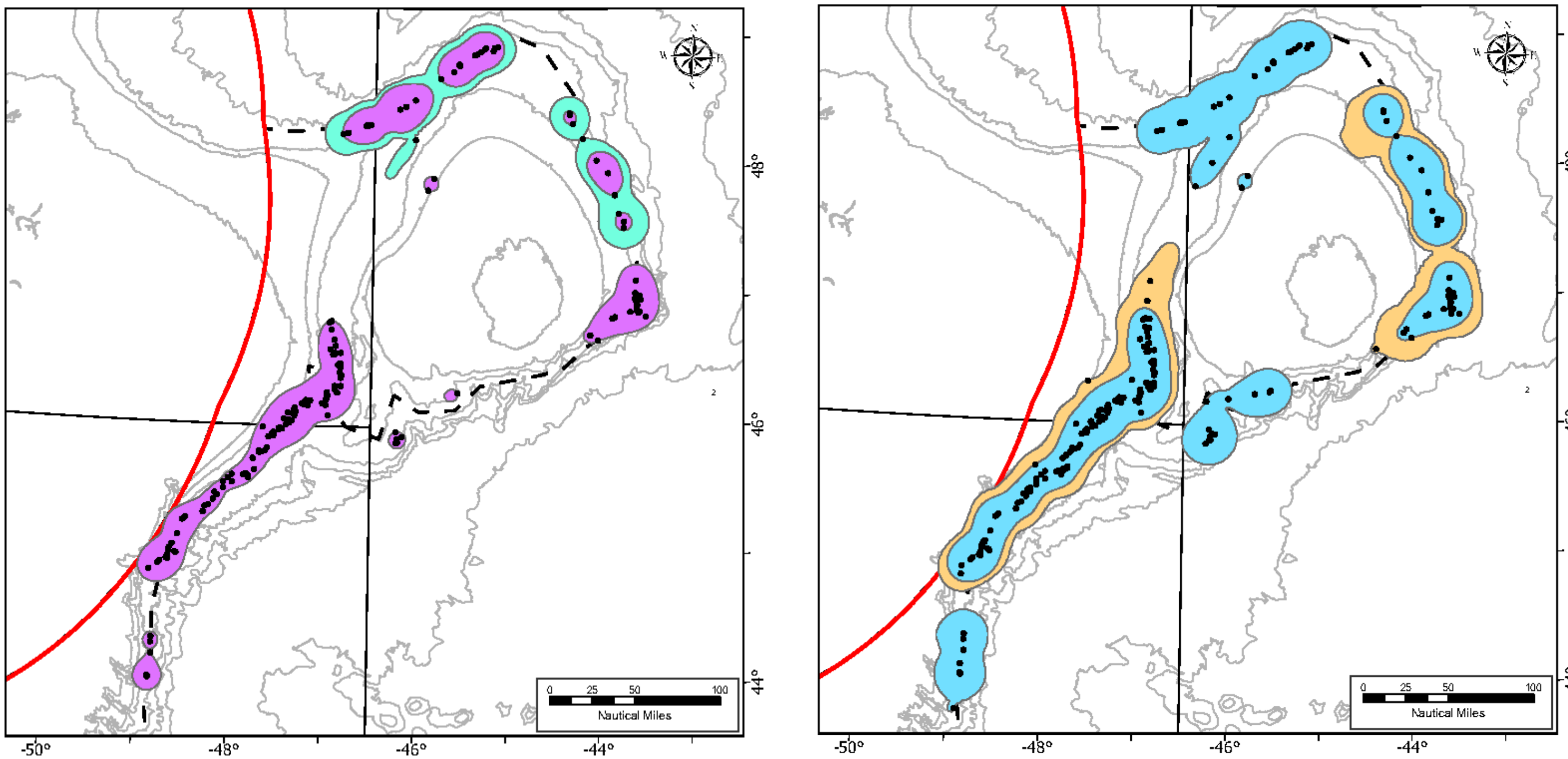


Figure 5. Comparison of the area covered by catches ≥ 200 kg (purple) and catches ≥ 175 kg (turquoise) (left panel); the area covered by catches ≥ 100 kg (blue) and catches ≥ 75 kg (brown) (right panel). The locations of trawl sets ≥ the lowest threshold in each panel are shown. Arrows highlight small VME polygons discussed in the text. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

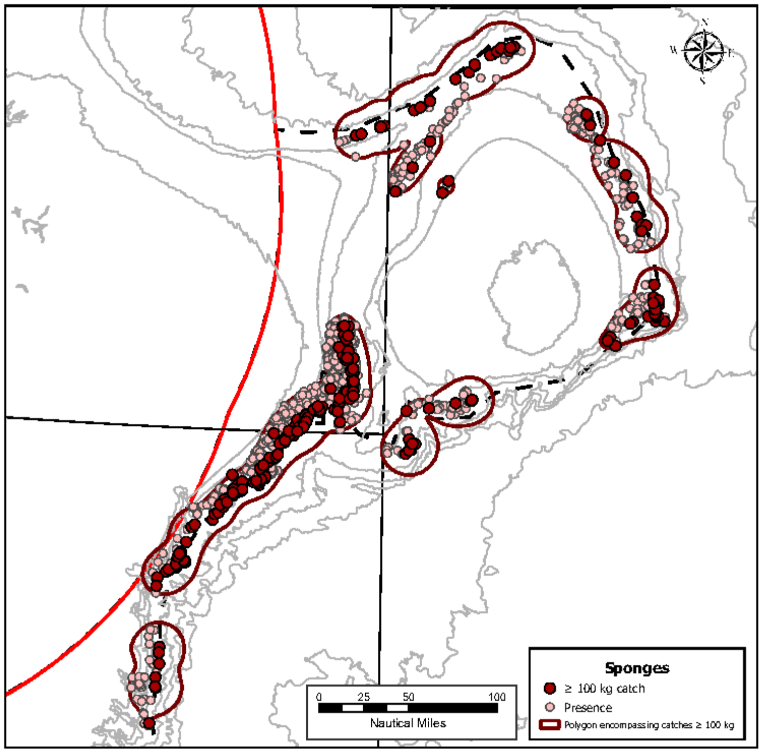


Figure 6. Illustration of the Large-Size Sponge VME polygons (red outline), catches ≥ 100 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

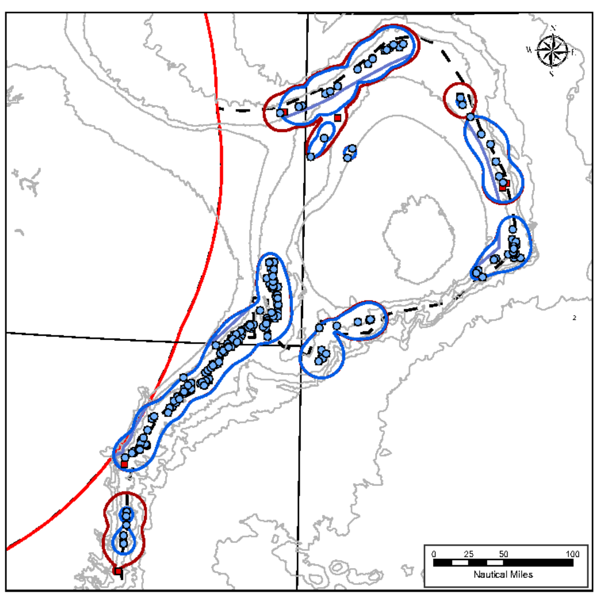


Figure 7. Comparison of the 2019 sponge VME polygons using the 100 kg threshold (blue outline) with the sponge VME polygons established in the new 2025 analysis (red outline). Where the red outline is not visible it is underneath the blue outline. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

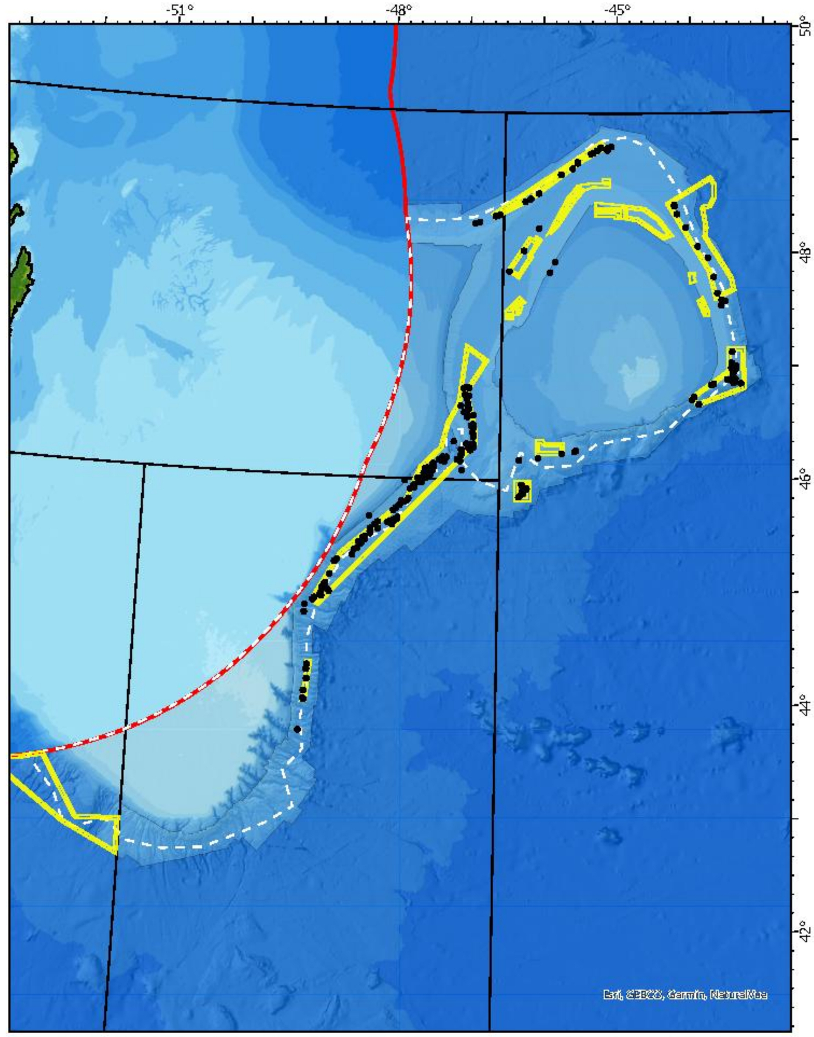


Figure 8. Illustration of the sponge VME catches ≥ 100 kg (solid black circles) in relation to the closed areas in place to protect VMEs in 2025 (NAFO, 2025). Yellow outline indicates VME spatial closures. White dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Tetillidae Sponges

Tetillidae Sollas, 1886 is a family of marine sponges in the order Tetractinellida and class Demospongiae. Tetillids are massive globular sponges, and in the NRA they are especially common in moderately sheltered areas with the maximum mixed layer depth in the spring < 17 m (Murillo et al., 2024). Response variables for the species distribution model of Tetillidae included data recorded as '*Craniella*', '*CRANIELLA* SP', '*Craniella* spp' and 'Tetillidae' (Murillo et al., 2024). In addition to those 211 records, 14 additional records of the same at-sea coding were provided by the EU from the 2024 surveys. The total number of records was 225 (Table 19). There was no significant difference among the catch distributions between the Campelen 1800 and Lofoten trawl gears (Appendix Table A2), and so all 225 records were used in the analyses. A kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 20.4 km; Contour Interval = 0.000025; Cell size default = 2449 m. The KDE biomass surface is shown in Figure 9. The highest biomass is found on the southeastern slope of the Tail of Grand Bank.

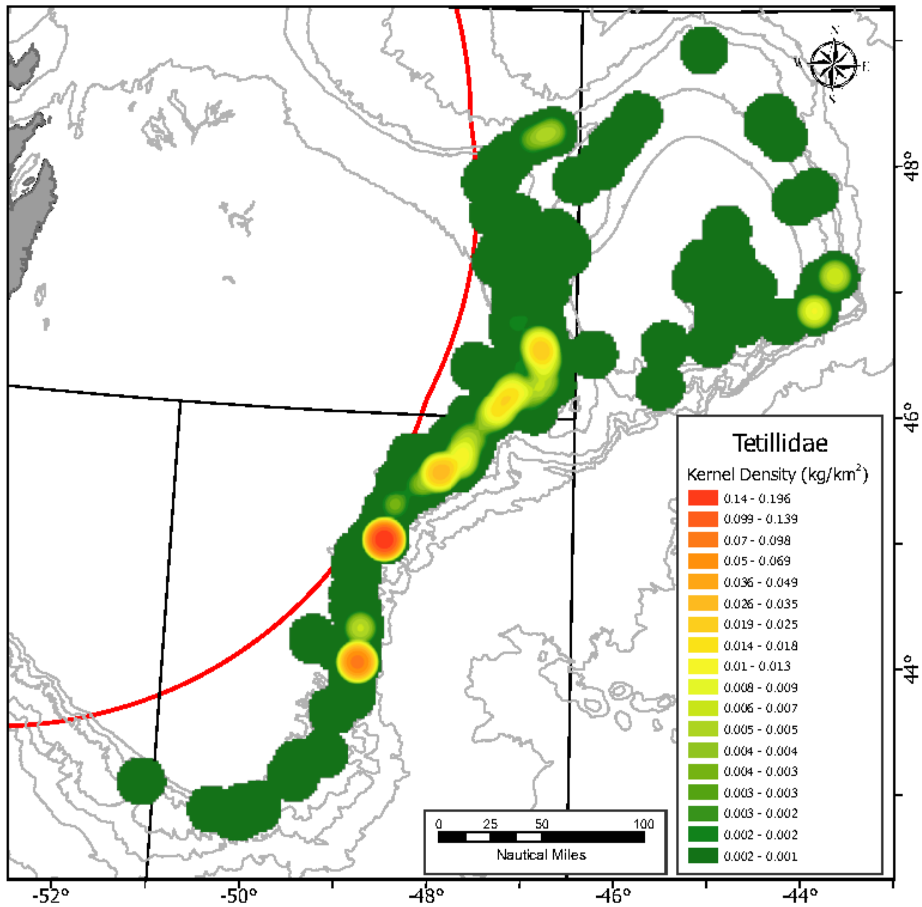


Figure 9. Kernel density biomass surface of Tetillidae sponges in the NAFO Regulatory Area.

The bar charts show evidence of aggregation (Figure 10). Three potential catch thresholds emerged from the analyses: 2 kg, 0.5 kg and 0.01 kg (Figure 10, Table 21). Examination of the first catch threshold of 2 kg/RV tow, showed that the increase in area in moving to 1 kg was created through the addition of 7 points which linked some locations in Flemish Pass and added a new location on Sackville Spur (Figure 11A). The next threshold, between 0.5 kg and 0.2 kg was created with 22 additional data points (Table 21). The 0.5 kg contour linked the polygons created by the 1 kg contour in Flemish Pass (Figure 11B). The 0.1 kg and smaller thresholds to 0.025 kg/RV tow identified new areas in Flemish Pass and on the Tail of Grand Bank (Figure 11C). New areas continued to be identified with the 0.1 kg, 0.05 kg and 0.025 kg thresholds (Figure 11C); however, there were a number of significant catches that were represented by a single catch, especially on the eastern slope of Flemish Pass. Comparing the 0.01 kg threshold with that of 0.005 kg (Figure 11D), identified a 149% increase in area created by 24 additional data points spread through the newly created area (Table 21, Figure 11D). Consequently, the 0.01 kg threshold was chosen to delimit the Tetillidae VME polygons.

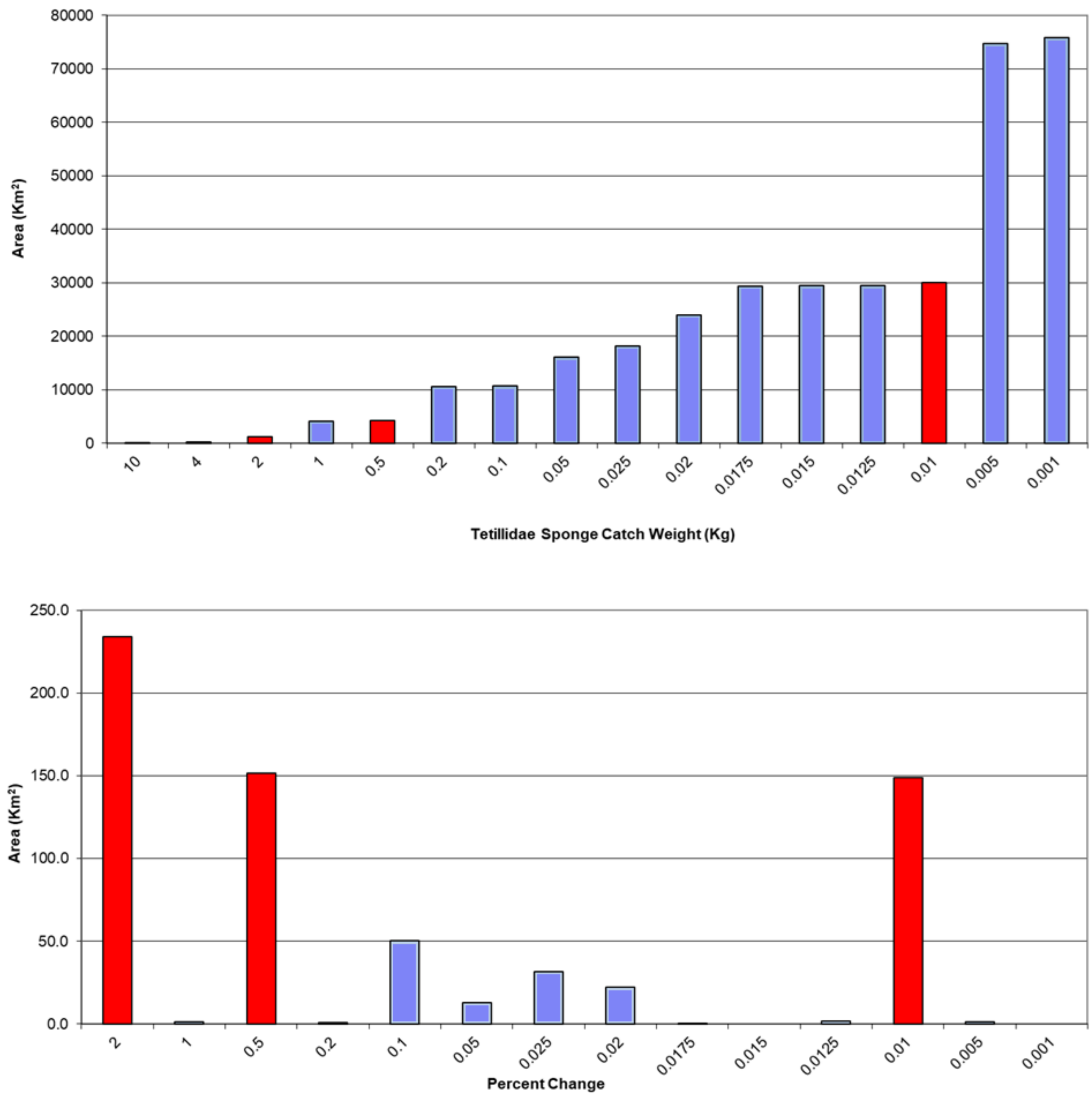


Figure 10. Bar graphs of the polygon area established by successively smaller research vessel Tetillidae sponge catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

The locations of the Tetillidae sponge VME polygons are shown in Figure 12, along with the individual significant (≥ 0.01 kg) and non-significant catches within the VMEs. Some of the Tetillidae VMEs overlap with the Large-Size Sponge VMEs determined above (Figure 13), but the Tetillidae VME extends further north in Flemish Pass and there are three VME polygons on the Tail of Grand Bank and one on Flemish Cap that are not present in the Large-Size Sponge VME polygons (Figure 13).

Table 21. The area of Tetillidae sponge VME polygons based on successively smaller research vessel catch weight thresholds (kg). The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Tetillidae Sponge Catch Threshold (Kg)	Total Number of Observations in Polygons	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
10	3	3		3.1	10269.5
4	13	8	5	323.1	288.6
2	29	12	4	1255.3	234.0
1	75	19	7	4192.2	1.2
0.5	76	28	9	4243.2	151.5
0.2	138	50	22	10671.4	0.8
0.1	141	66	16	10754.1	50.2
0.05	167	89	23	16157.4	12.8
0.025	177	120	31	18223.3	31.7
0.02	186	131	11	23991.8	22.4
0.0175	195	136	5	29368.5	0.5
0.015	199	142	6	29521.5	0.0
0.0125	199	147	5	29521.5	1.7
0.01	201	160	13	30029.3	149.0
0.005	224	184	24	74768.7	1.4
0.001	225	225	41	75832.2	

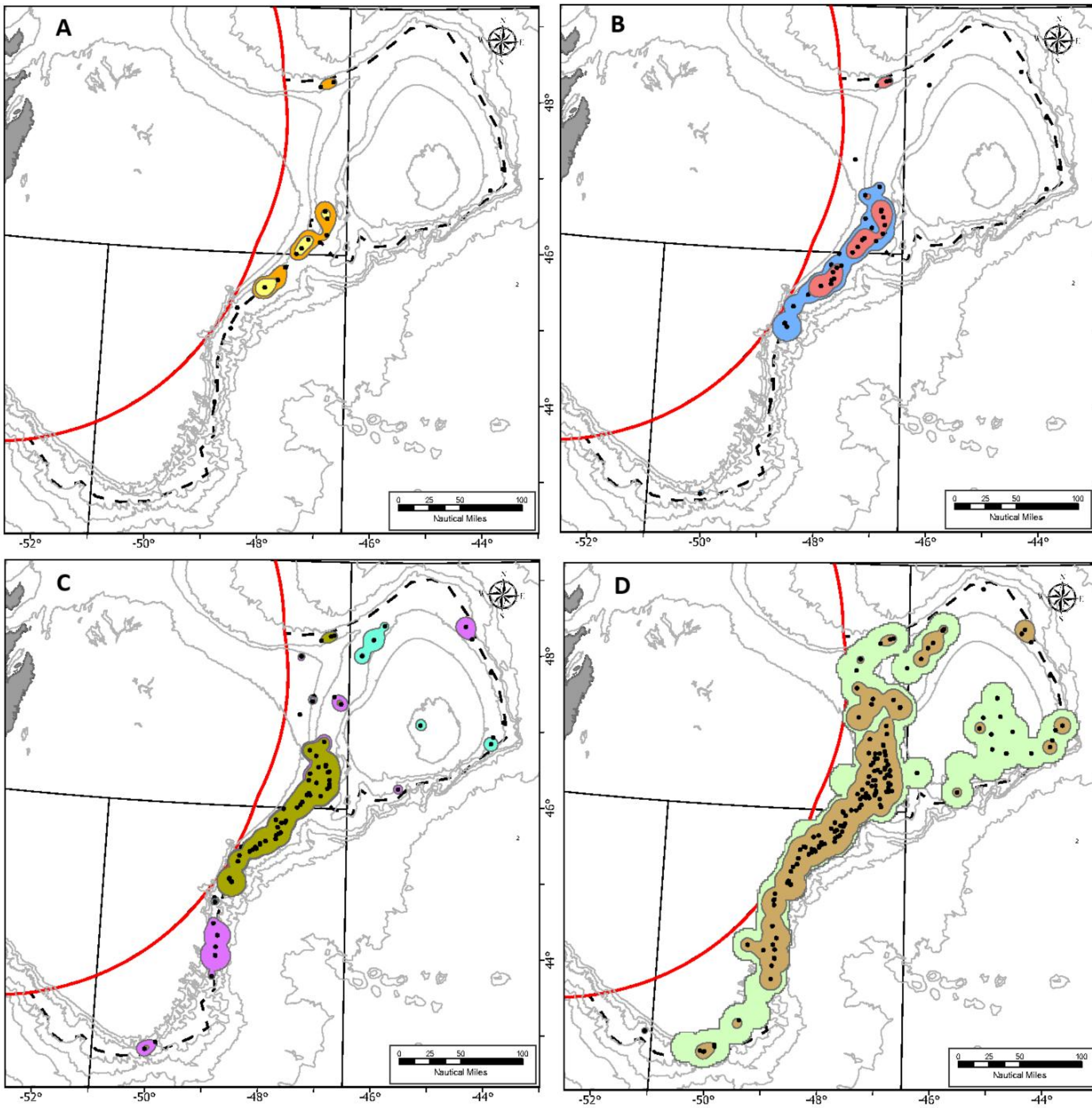


Figure 11. Comparison of the areas covered by Tetillidae catches A) ≥ 2 kg (yellow) and catches ≥ 1 kg (orange); B) the areas covered by catches ≥ 0.5 kg (salmon) and catches ≥ 0.2 kg (blue); C) the areas covered by catches ≥ 0.1 kg (olive), by catches ≥ 0.05 kg (pink), and catches ≥ 0.025 kg (turquoise), and D) the areas covered by catches ≥ 0.01 kg (brown) and catches ≥ 0.005 kg (green). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Dashed black line is the NAFO fishing footprint.

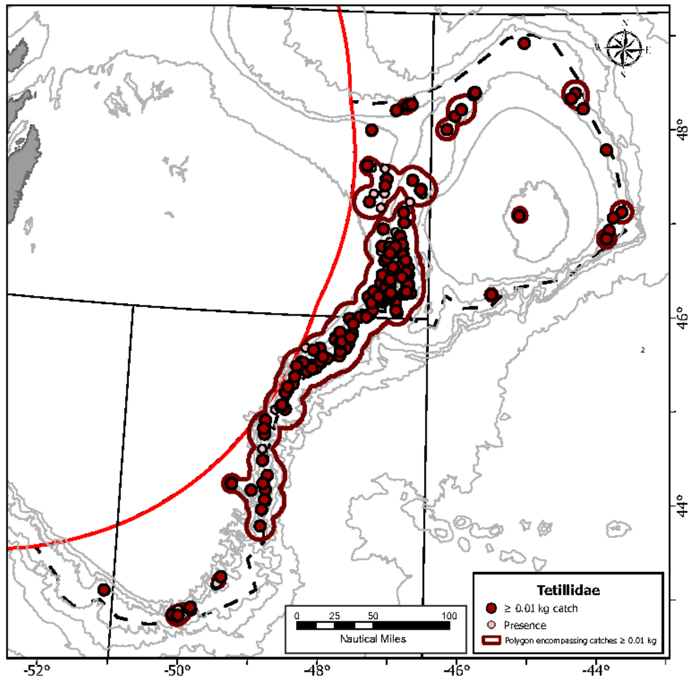


Figure 12. Illustration of the Tetillidae sponge VME polygons (red outline), catches ≥ 0.01 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

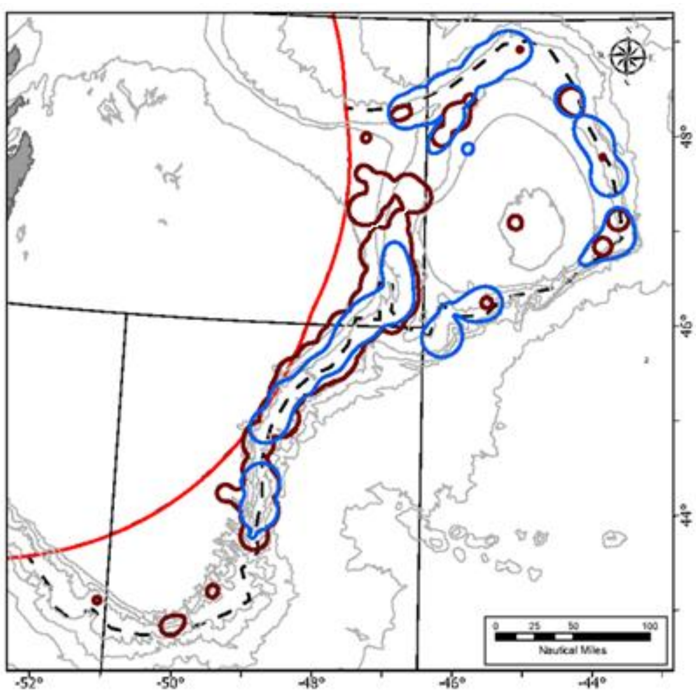


Figure 13. Comparison of the Tetillidae sponge VME polygons (red outline) with the Large-Size Sponge VME polygons analyzed above (blue outline). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Polymastiidae Sponges

Polymastiidae Gray, 1867 is a family of demosponges found in the order Polymastiidae. The species occurring in the NAFO Regulatory Area are generally small with papillae visible. Species distribution models indicated that the Polymastiidae in the NAFO Regulatory Area are found in elevated areas with moderate changes of surface salinity, with mean surface temperatures < 6°C and relatively stable bottom temperature (Murillo et al., 2024). As for the SDM work (Murillo et al., 2024) Polymastiidae formerly considered in the genera *Radiella* [e.g., *Radiella hemisphaerica* currently accepted as *Polymastia hemisphaerica*] and *Tentorium* were excluded, as they are not VME indicator taxa (NAFO, 2025). All data records of Polymastiidae were recorded as 'Polymastiidae' and included 686 records for the KDE analyses, including data submitted for the 2024 surveys. Significant differences in the research vessel catch biomass due to differences associated with gear type were identified (Appendix Table A2). When all records less than 0.05 kg were removed, there was no significant difference among the catch distributions between the Campelen 1800 and Lofoten trawl gears (Appendix Table A2). Consequently, only records with a biomass ≥ 0.05 kg were used in the KDE analyses (N=238).

A kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 18.8 km; Contour Interval = 0.0001; Cell size default = 2256.6 m. The KDE biomass surface is shown in Figure 14. The highest biomass is found in Flemish Pass with high concentrations along the southeastern slope of the Tail of Grand Bank and the eastern slope of Flemish Cap. The distribution includes the sponge grounds, but also some higher biomass presences in the shallow waters of Flemish Cap (Figure 14).

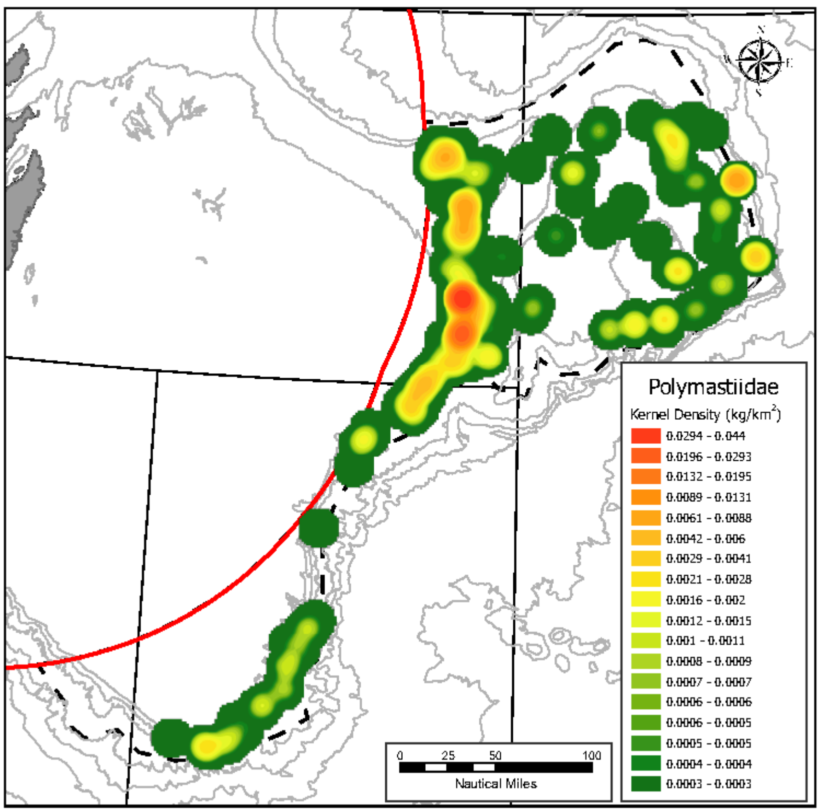


Figure 14. Kernel density biomass surface of Polymastiidae sponges in the NAFO Regulatory Area.

Table 22. The area of Polymastiidae sponge VME polygons based on successively smaller research vessel catch weight thresholds (kg). The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Polymastiidae Sponge Catch Threshold (Kg)	Total Number of Observations in Polygons	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
1	17	10		339.9	293.9
0.5	52	19	9	1339.1	205.5
0.3	114	43	24	4091.2	52.8
0.2	145	65	22	6250.6	37.1
0.15	165	79	14	8572.4	38.3
0.1	180	114	35	11851.7	72.0
0.075	215	159	45	20382.0	36.3
0.06	228	197	38	27773.4	16.1
0.05	238	238	41	32237.6	

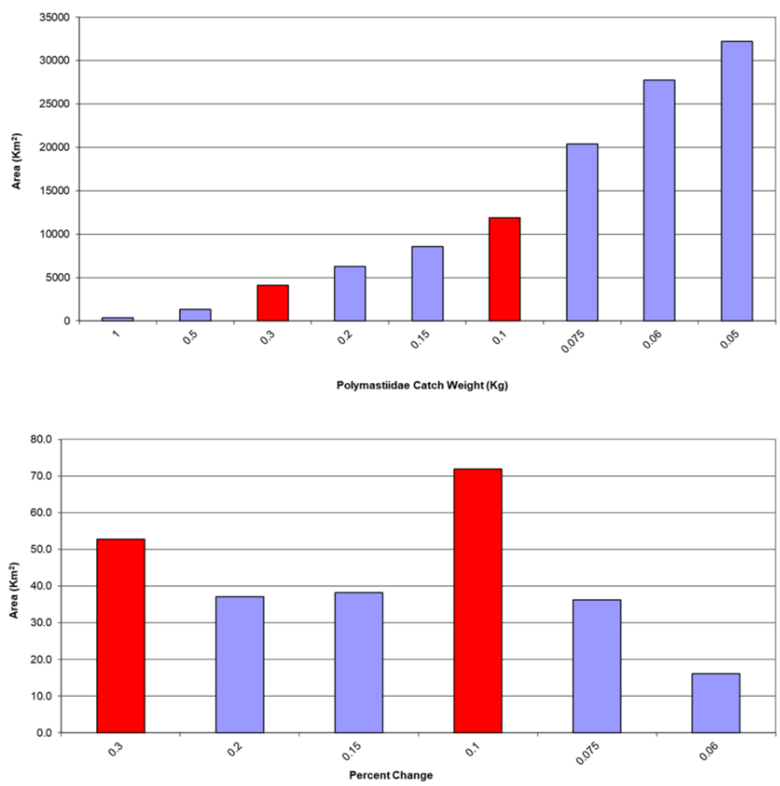


Figure 15. Bar graphs of the polygon area established by successively smaller research vessel Polymastiidae sponge catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

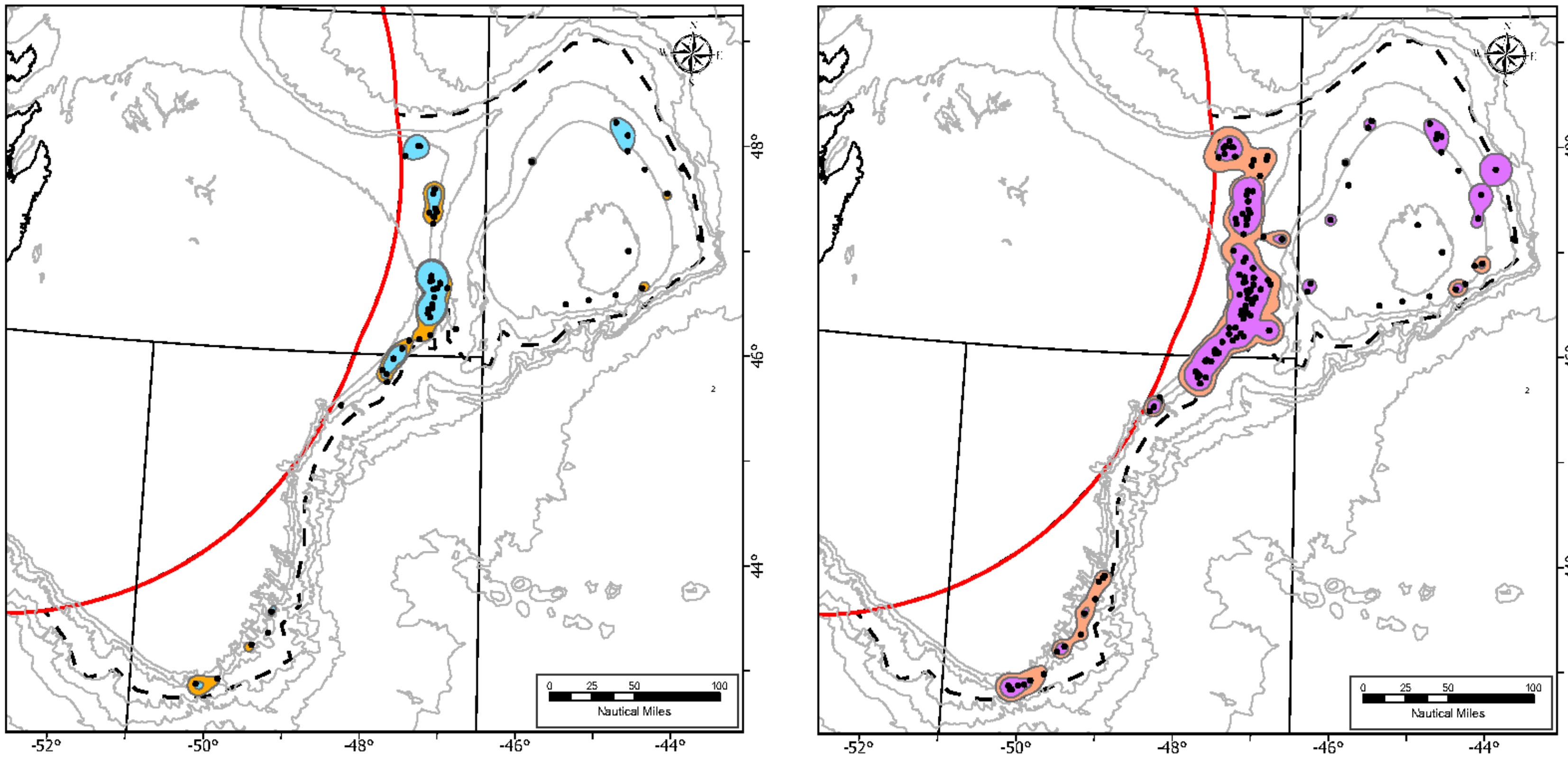


Figure 16. Comparison of the areas covered by Polymastiidae catches ≥ 0.3 kg (blue) and catches ≥ 0.2 kg (orange) (left panel); the areas covered by catches ≥ 0.10 kg (purple) and catches ≥ 0.075 kg (salmon). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

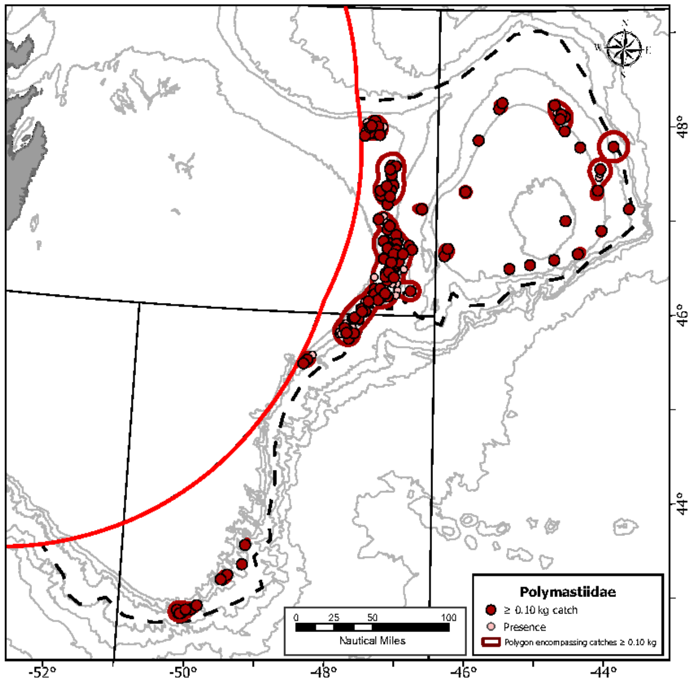


Figure 17. Illustration of the Polymastiidae sponge VME polygons (red outline), catches ≥ 0.10 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

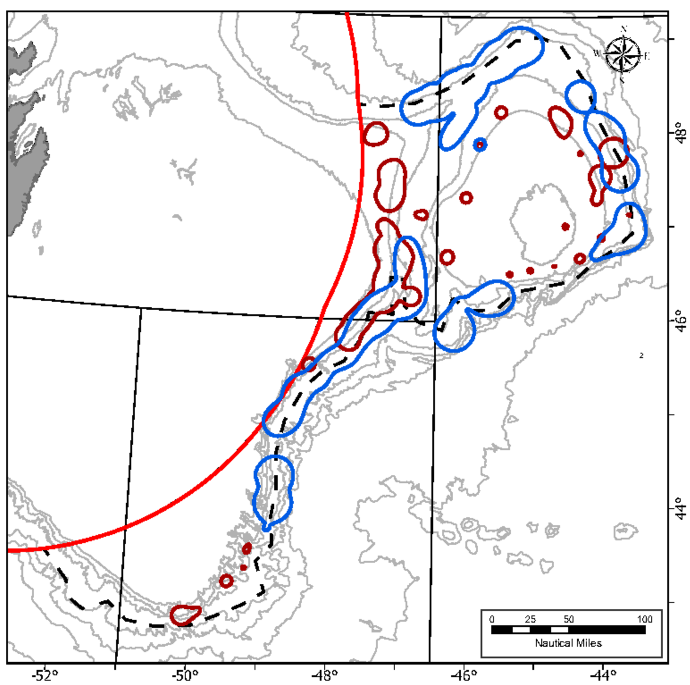


Figure 18. Comparison of the Polymastiidae sponge VME polygons (red outline) with the Large-Size Sponge VME polygons analyzed above (blue outline). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

The bar charts suggest that this taxon is weakly aggregated with each threshold increasing the area, however two potential catch thresholds emerged as potentially indicating the VMEs (Table 22, Figure 15): 0.30 kg and 0.10 kg/RV tow. Examination of the first catch threshold of 0.30 kg/RV tow, showed that the increase in area in moving to 0.20 kg was created through the addition of 24 points which linked some locations in Flemish Pass (Figure 16). The increase in area at 0.20 kg appears well supported by data, particularly in the northern part of Flemish Pass and it carves out a new area on the Tail of Grand Bank (Figure 16). The next threshold, between 0.10 kg and 0.075 kg was created with 35 additional data points (Table 22) that also appear to support the areal increase. Thus, both thresholds could be justified, although the percent change in area between thresholds is much higher (72%) with the 0.10 kg/RV tow catch thresholds. Consequently the 0.10 kg threshold was selected for the Polymastiidae VME polygons.

The locations of the Polymastiidae sponge VME polygons are shown in Figure 17, along with the individual significant (≥ 0.10 kg) and non-significant catches within the VMEs. The non-significant catches fill the polygons among the significant ones and there are 180 records within the VME polygons representing 75.6% of the data (Table 22). There are a number of isolated single catches occurring on Flemish Cap and these may be remnants of more extensive distribution that has been damaged through fishing (fishing was an important determinant of the distribution in the species distribution model for this group (Murillo et al., 2025)).

There is very little overlap between the Polymastiidae VMEs and the Large-Size Sponge VMEs determined above (Figure 18), with the main area of overlap in Flemish Pass.

Astrophorina Sponges

Astrophorina is a suborder of large, massive sponges in the class Demospongiae. Astrophorina was formerly named Astrophorida and classified as an order, but it is now recognised as a suborder of Tetractinellida (Morrow & Cárdenas, 2015). Species distribution models for the NAFO Regulatory Area indicate that the Astrophorina are found in depressed areas, with maximum values of primary productivity in summer > 900 mg C m^{-2} day^{-1}, minimum surface temperature > 4°C, and stable environment of bottom temperatures (Murillo et al., 2024). Those species distribution models for the Astrophorina used the at-sea identifications for 'Ancorinidae', 'Astrophorida', 'Astrophorina', 'ASTROPHORINA (ASTROPHORIDA)', 'Geodia', 'GEODIA SP.', 'Geodia spp', 'Geodiidae', 'Isops spp.', 'Poecillastra compressa', 'STELLETA SP', 'STELLETA SPP', 'Stelletta', 'Stryphnus', 'Stryphnus sp.', 'STRYPHNUS SPP', 'Thenea', 'Thenea levis', 'THENEA MURICATA', 'THENEA SP', and 'Thenea spp.'. The total number of records was 475 (Table 17). There was no significant difference among the catch distributions between the Campelen 1800 and Lofoten trawl gears for catches ≥ 0.025 kg (Appendix Table A2), and so 410 records were used in the analyses.

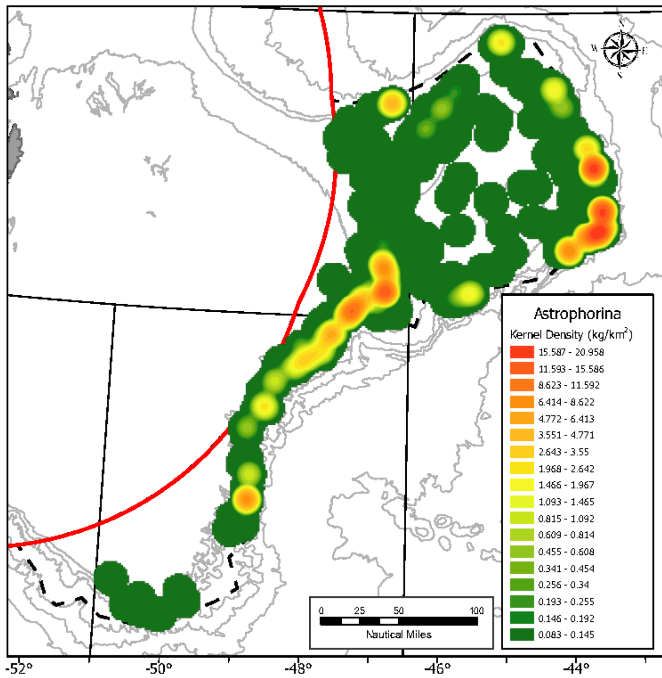


Figure 19. Kernel density biomass surface of Astrophorina sponges in the NAFO Regulatory Area.

A kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 19.5 km; Contour Interval = 0.0005; Cell size default = 2334.7 m. The KDE biomass surface is shown in Figure 19. The highest biomass is found in Flemish Pass and the southeastern slope of Flemish Cap. The distribution follow that of the sponge grounds (Figure 19) which is not surprising as this taxon is the primary constituent of the Large-Size Sponge VME Functional Group.

The bar charts suggest that this taxon is aggregated, and three potential catch thresholds emerged as potentially indicating the VMEs (Table 23, Figure 20): 50 kg, 20 kg and 2.5 kg. The model results below 0.2 kg are not reliable and are considered invalid. In ArcGIS Pro, the polygon data are stored as a 'feature class' inside a geodatabase, with information on the position of the data and other attributes (e.g., biomass). Polygon features are created on a specified layer for each closed boundary formed by selected line polygon features (here kernel density contour intervals[1]). A cluster tolerance determines whether the selected geometry forms a boundary[2]. The default x,y tolerance is 0.001 meters. Changing this parameter's value may cause failure or unexpected results. This can also happen if the data naturally fall outside of this tolerance. This has occurred here with the very small catches that occur at large distances from the polygons created with larger thresholds (Table 23; Figure 22). We originally produced polygons using a contour of 0.005 and the model failed at the 5 kg polygon threshold. We reran the model using a 0.0005 contour interval and were able to get tighter delineation of the sponge grounds (although with no substantial changes to polygon area). Even at that contour interval there was model failure at 0.1 kg, when the points were too dispersed, and addition of lower threshold polygons fell outside of the tolerance. This rendered the large area increase at the 0.2 kg threshold invalid (Table 23; Figure 22). However, with the 0.0005 contour interval we were able to confidently assess the threshold for Astrophorina VME as the failure of the model occurred below the potential thresholds considered.

[1] https://pro.arcgis.com/en/pro-app/latest/tool-reference/data-management/feature-to-polygon.htm
[2] https://pro.arcgis.com/en/pro-app/latest/help/data/geodatabases/overview/feature-class-basics.htm#GUID-69FA8570-7C64-4213-B822-68716CD9E764

Table 23. The area of Astrophorina sponge VME polygons based on successively smaller research vessel catch weight thresholds (kg). The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs. NR=Not Reliable.

Astrophorina Sponge Catch Threshold (Kg)	Total Number of Observations in Polygons	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
1000	36	16		996.3	200.1
250	86	39	23	2989.9	137.8
100	148	61	22	7111.1	34.5
50	205	83	22	9565.1	55.6
20	245	120	37	14883.5	34.9
10	264	150	30	20081.6	5.8
7.5	277	170	20	21243.0	22.1
5	303	192	22	25927.8	12.6
2.5	325	243	51	29197.3	34.6
1	352	275	32	39296.2	4.4
0.5	359	294	19	41011.8	18.1
0.3	370	314	20	48450.0	8.1
0.2	378	331	17	52371.4	83.2 (NR)
0.1	407	349	18	95943.5	NR
0.05	410	382	33	101036.5	NR
0.025	410	410	28	101036.5	NR

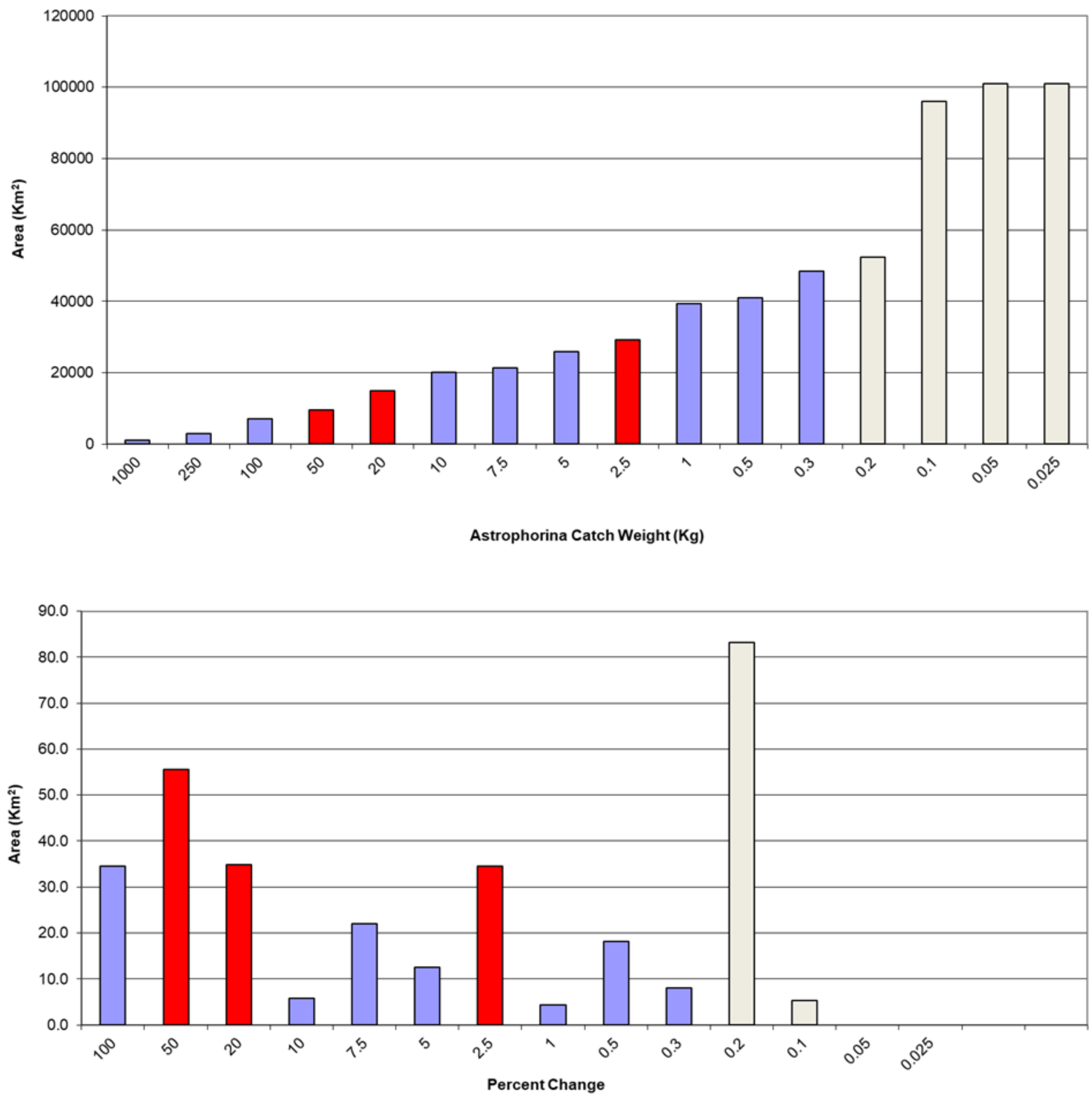


Figure 20. Bar graphs of the polygon area established by successively smaller research vessel Astrophorina sponge catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined. Grey bars indicate invalid results and were not considered.

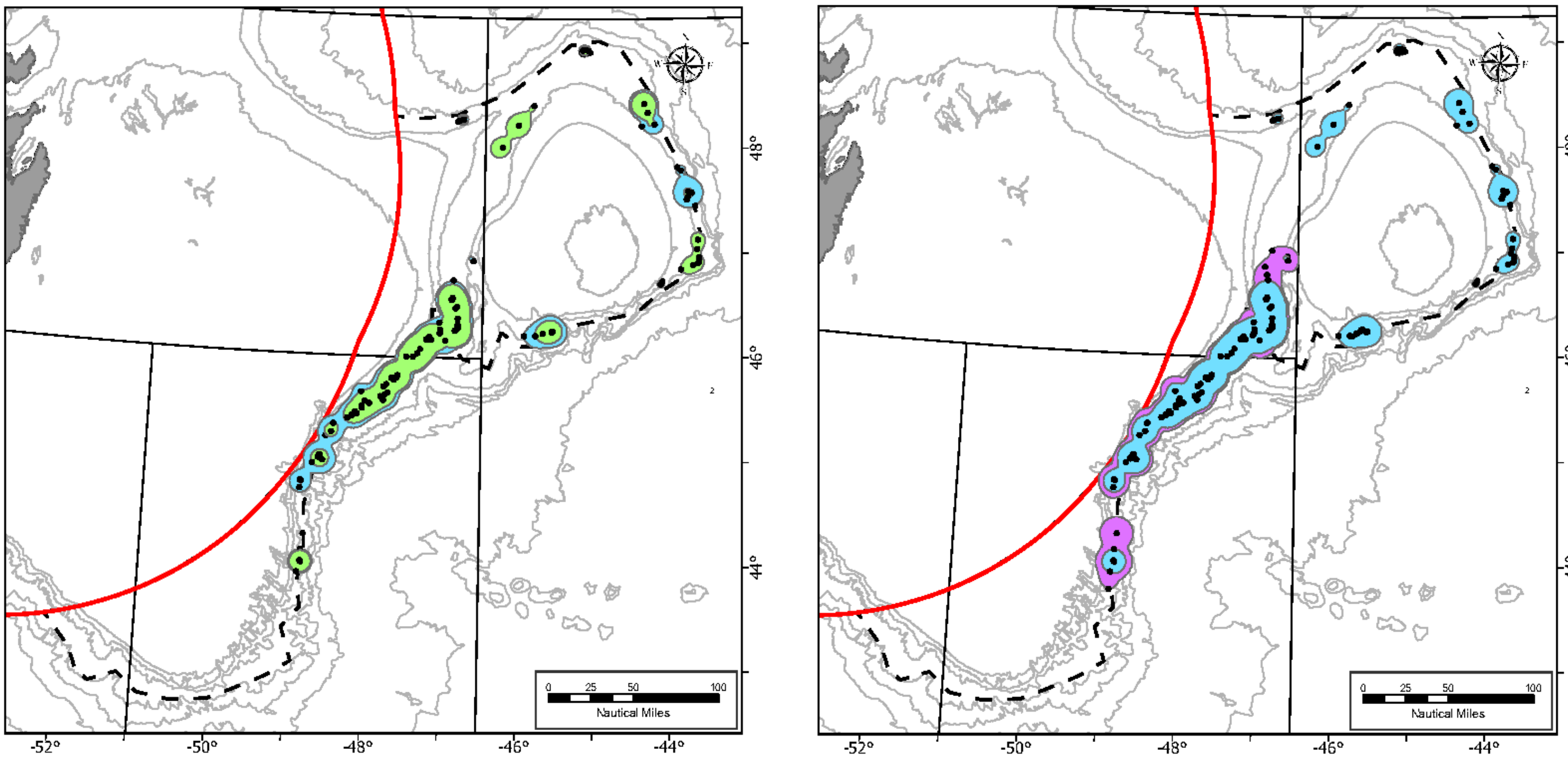


Figure 21. Comparison of the areas covered by Astrophorina catches ≥ 50 kg (green) and catches ≥ 20 kg (blue) (left panel); the areas covered by catches ≥ 20 kg (blue) and catches ≥ 10 kg (purple). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

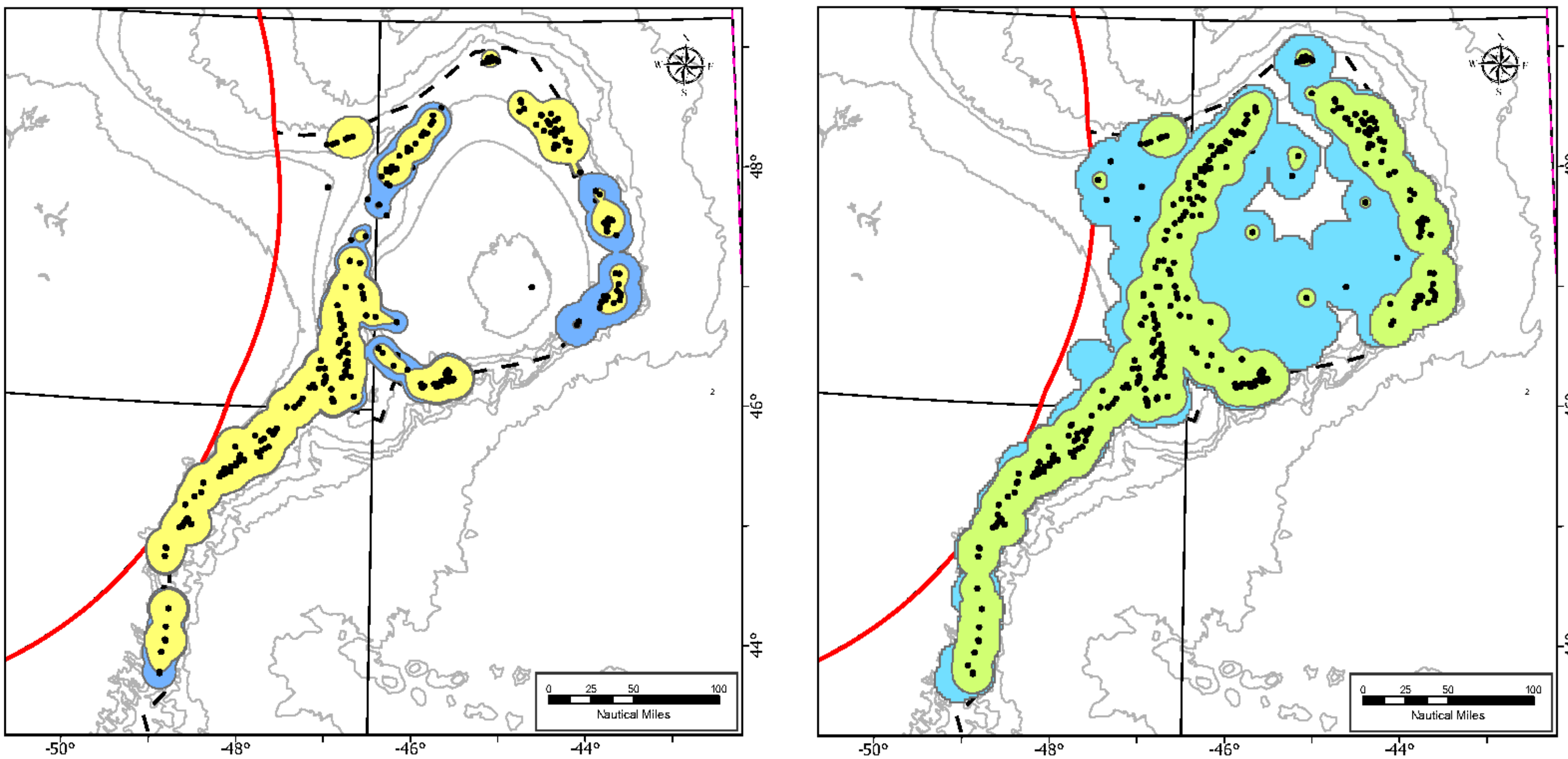


Figure 22. Comparison of the areas covered by Astrophorina catches ≥ 2.5 kg (yellow) and catches ≥ 1 kg (blue) (left panel); the areas covered by catches ≥ 0.20 kg (green) and catches ≥ 0.10 kg (turquoise) (right panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

Examination of the first catch threshold of 50 kg, showed that the increase in area in moving to 20 kg was created through the addition of 37 points which carved out new areas on the eastern slope of the Tail of Grand Bank and in the Beothuk Knoll region (Figure 21). The increase in area from the 20 kg to the 10 kg threshold expanded the existing polygons, particularly in Flemish Pass with good support from the data and extension into new area on the Tail of Grand Bank. At 2.5 kg, the major sponge areas are established and moving to the 1 kg polygon increased the area by 34.6% (Figure 22). The 2.5 kg was selected to represent the Astrophorina VME polygons, although these areas may be reduced when overlain on the species distribution model for this taxon (Murillo et al., 2024).

The locations of the Astrophorina sponge VME polygons are shown in Figure 23, along with the individual significant (≥ 2.5 kg) and non-significant catches within the VMEs, together accounting for 79.3% of the data records. The non-significant catches fill the polygons among the significant ones along the shallower extents but there were no data from the deeper extents of the polygons in most cases. There is a high degree of overlap between the Astrophorina VMEs and the Large-Size Sponge VMEs determined above (Figure 24), as expected since the Astrophorina form a substantial biomass component of the Large-Size Sponge VMEs.

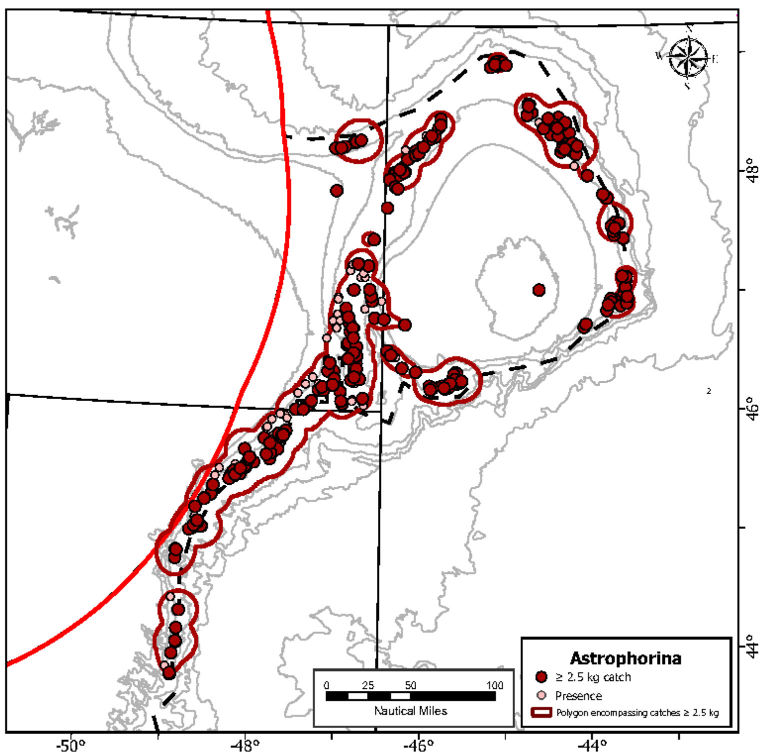


Figure 23. Illustration of the Astrophorina sponge VME polygons (red outline), catches ≥ 2.5 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

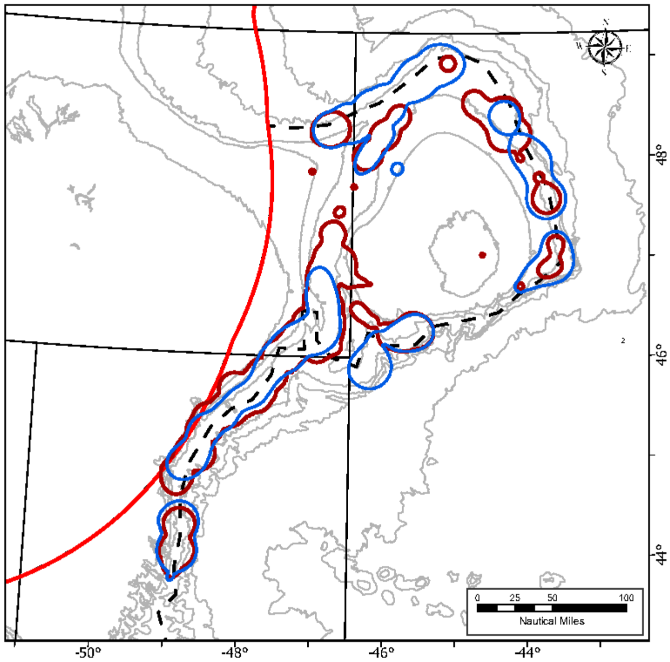


Figure 24. Comparison of the Astrophorina sponge VME polygons (red outline) with the Large-Size Sponge VME polygons analyzed above (blue outline). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Sea Pen Functional Group

Significant concentrations of Sea Pens have been determined previously in the NRA using kernel density analyses and an evaluation of the expansion of the area covered by successive density polygons (NAFO, 2019a). These analyses have been updated using all available data from the RV trawl surveys. Specifically, data from the Spanish 3NO survey, EU Flemish Cap Survey, the Spanish 3L Survey and the DFO-NL Multi-species Surveys were assessed. These data sources yielded 2790 sea pen records (288 from the Canadian surveys and 2502 from the EU surveys); 577 more data points than were available for the last analysis (Kenchington et al., 2019).

As noted previously, there were significant differences among the catch series for each survey and differences in the number of small catch weights, likely due to differences associated with gear type, tow length, survey area and sampling protocol. When all records less than 0.3 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor the Canadian research vessels (Appendix Table A3).

The analyses were performed on 318 catches ≥ 0.3 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 22.2 km; Contour Interval = 0.0001; Cell size default = 2661.25 m. The biomass surface is shown in Figure 25 compared with the surface created from the 2019 analysis. The overall locations of the VME polygons are similar although more extensive in 2019 at the lower densities, while the largest density estimates are the same (approximately 0.5 kg km^2).

The bar charts (Figure 26) suggest that this taxon is aggregated, and one potential catch threshold emerged as potentially indicating the Sea Pen Functional Group VMEs (Table 24, Figure 27): 1.5 kg. There are 11 additional points in moving to the 1.25 kg threshold, but most of those lie in the polygons created by the 1.5 kg threshold, with less data support for the extensive areas created by linking the 1.5 kg polygons (Figure 27). The selected VME polygons cover an area of 9408.6 km^2 and are found in a horse-shoe formation over Flemish Cap, and on the Tail of Grand Bank (Figure 27). They include 189 data points which is 59.4% of the data.

The location of the Sea Pen Functional Group VME polygons along with the significant (≥ 1.5 kg) and non-significant catches (< 1.5 kg) contained within them are shown in Figure 28. Comparison of the VME polygons obtained from the 2019 KDE analyses (Kenchington et al., 2019) show a very high degree of congruence with the 2025 analysis (Figure 29). Only one VME polygon on the eastern flank of Flemish Cap is slightly larger in the new analysis.

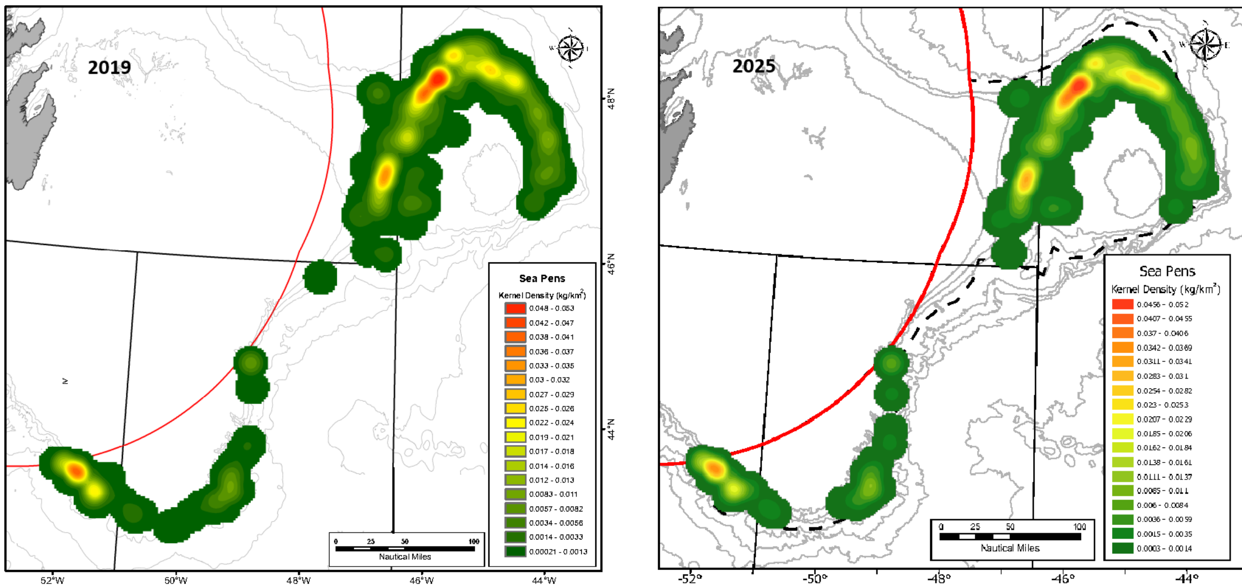


Figure 25. Kernel density biomass surface of Sea Pens in the NAFO Regulatory Area. Left Panel: Surface created in 2019 for closed area assessments; Right Panel: Surface created in 2025 for current closed area re-assessments.

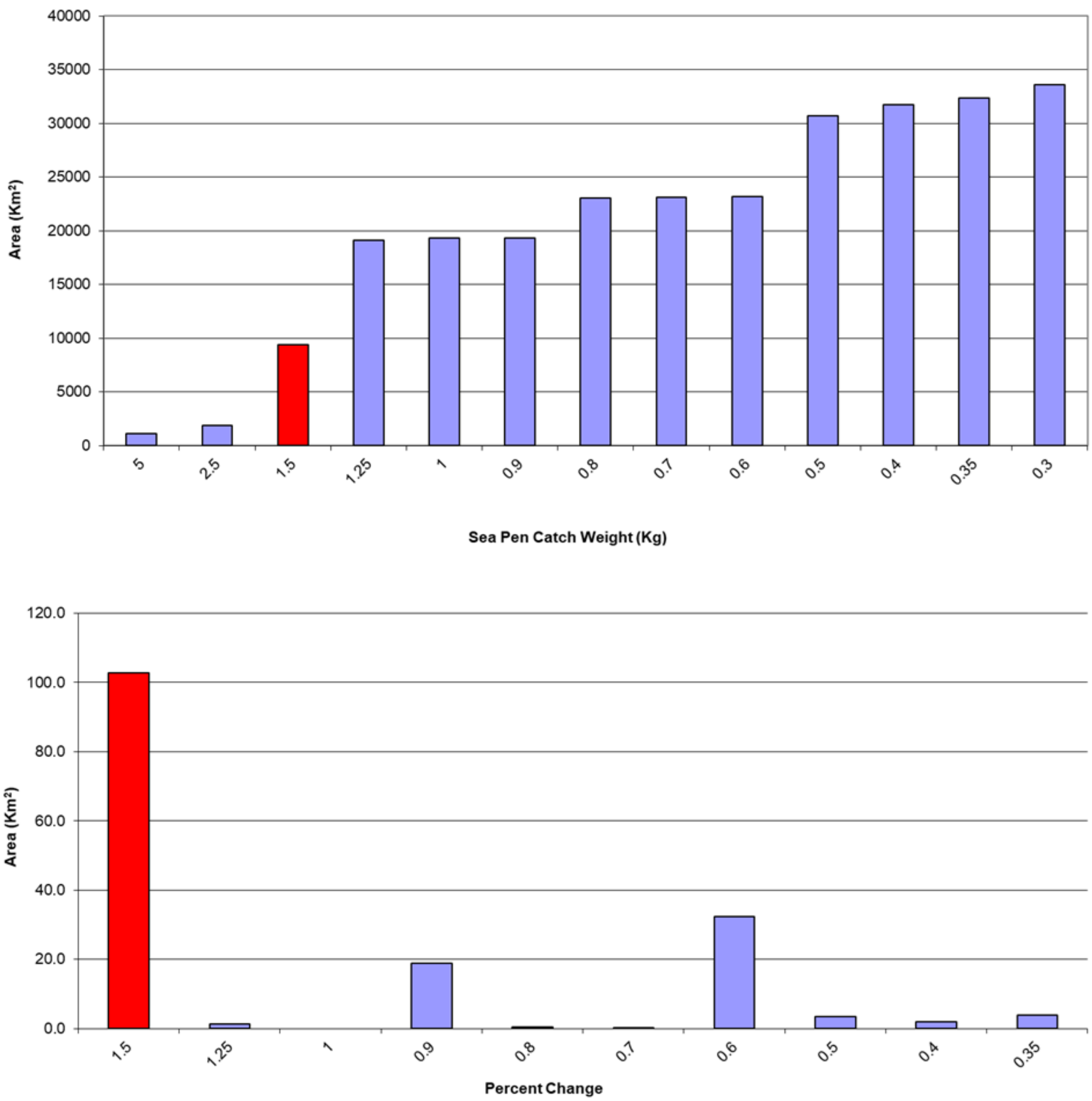


Figure 26. Bar graphs of the polygon area established by successively smaller research vessel Sea Pen catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

Table 24. The area of Sea Pen Functional Group VME polygons based on successively smaller research vessel catch weight thresholds (kg). The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Sea Pen Functional Group Catch Threshold (Kg)	Total Number of Observations in Polygons	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
5	36	6		1102.1	71.3
2.5	55	13	7	1888.1	398.3
1.5	189	46	33	9408.6	102.9
1.25	271	57	11	19086.5	1.4
1	277	83	26	19344.6	0.0
0.9	277	94	11	19344.6	19.0
0.8	292	111	17	23011.5	0.4
0.7	295	128	17	23092.7	0.3
0.6	297	150	22	23170.3	32.4
0.5	310	182	32	30673.3	3.5
0.4	315	229	47	31734.1	1.9
0.35	316	272	43	32335.8	4.0
0.3	318	318	46	33623.7	

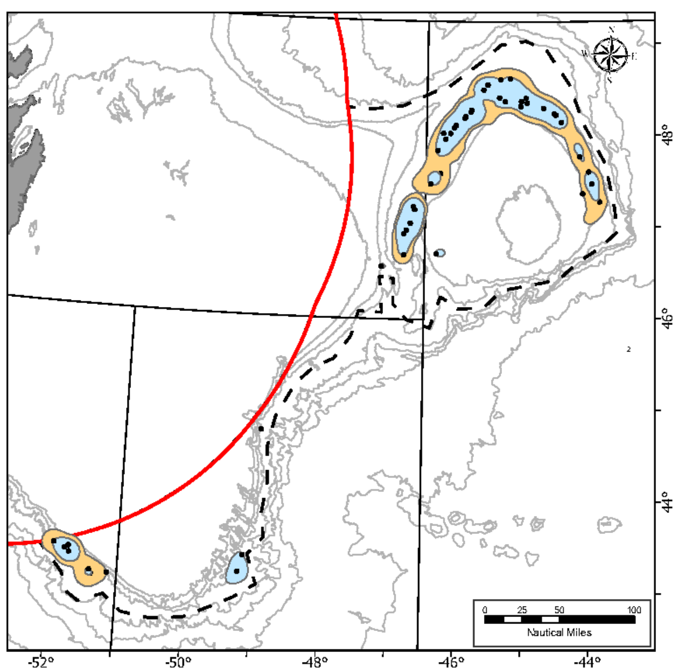


Figure 27. Comparison of the area covered by catches ≥ 1.5 kg (blue) and catches ≥ 1.25 kg (tan). The location of trawl sets ≥ the 1.25 kg threshold are shown. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

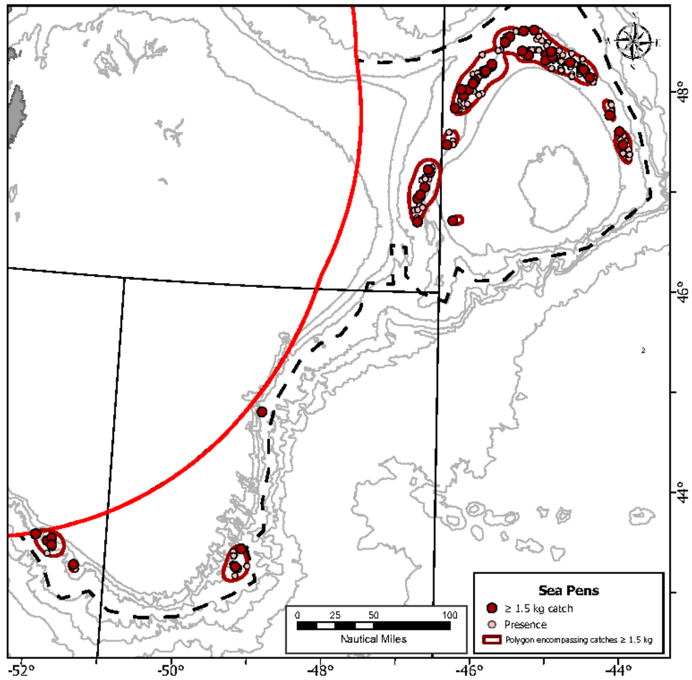


Figure 28. Illustration of the Sea Pen Functional Group VME polygons (red outline), catches ≥ 1.5 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

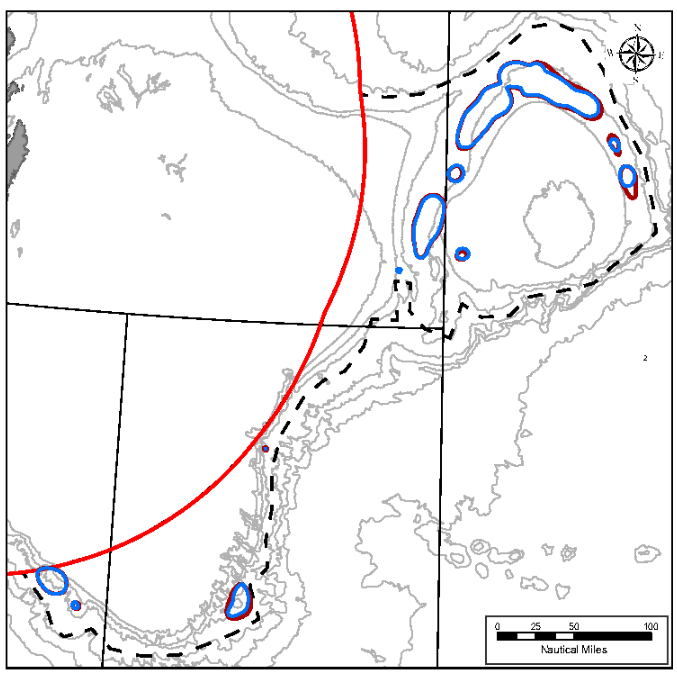


Figure 29. Comparison of the 2019 Sea Pen Functional Group VME polygons (blue outline) with the Sea Pen Functional Group VME polygons established in the new 2025 analysis (red outline). Where the red outline is not visible it is underneath the blue outline. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Anthoptilum Sea Pens

Anthoptilum is a genus of sea pens belonging to the family Anthoptilidae in the phylum Cnidaria. *Anthoptilum grandiflorum* (Verrill, 1879) is common on soft bottoms of Flemish Cap and the Tail of Grand Bank where they are found at depths of 200 to 1370 m (Altuna and Murillo, 2012) and believed to act as biogenic habitat (Baillon et al., 2014). A second species, *Anthoptilum murrayi* Kölliker, 1880, has a wide distribution, primarily in the North Atlantic Ocean, but extending into the South Atlantic, and the Indo-Pacific. It has also been recorded in the NAFO Regulatory Area by both EU and Canadian surveys, but only rarely. The most important variables for predicting the presence of *Anthoptilum* spp. were averaged mean bottom salinity, bathymetry, valley depth, broad scale bathymetric position index, and averaged minimum surface salinity (Murillo et al., 2024). The SDMs indicated that *Anthoptilum* spp. are typically located in depressed areas at depths more than 500 meters, with an optimum depth band around 700-1250 m depth, mean bottom salinity > 34.7, valley depth > 400 m, and low fall chlorophyll *a* concentration. Whilst the effect of bottom trawling effort is of lower importance in the model in comparison to the environmental conditions the probability of presence increases at lower fishing effort (Murillo et al., 2024).

For the KDE analyses of *Anthoptilum*, 1396 records were obtained from 2005 to 2024 for the EU and Canadian surveys under the identifications 'Anthoptilum', 'Anthoptilum grandiflorum', 'ANTHOPTILUM GRANDIFLORUM', 'ANTHOPTILUM MURRAYI', 'Anthoptilum murrayi', 'ANTHOPTILUM SP', 'Anthoptilum sp.', and 'Anthoptilum spp', with the majority of the records listed as 'Anthoptilum' (Murillo et al., 2024).

There were significant differences among the catch series for each survey and differences in the number of small catch weights, likely due to differences associated with gear type, tow length, survey area and sampling protocol. When all records less than 0.1 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor the Canadian research vessels (Appendix Table A4).

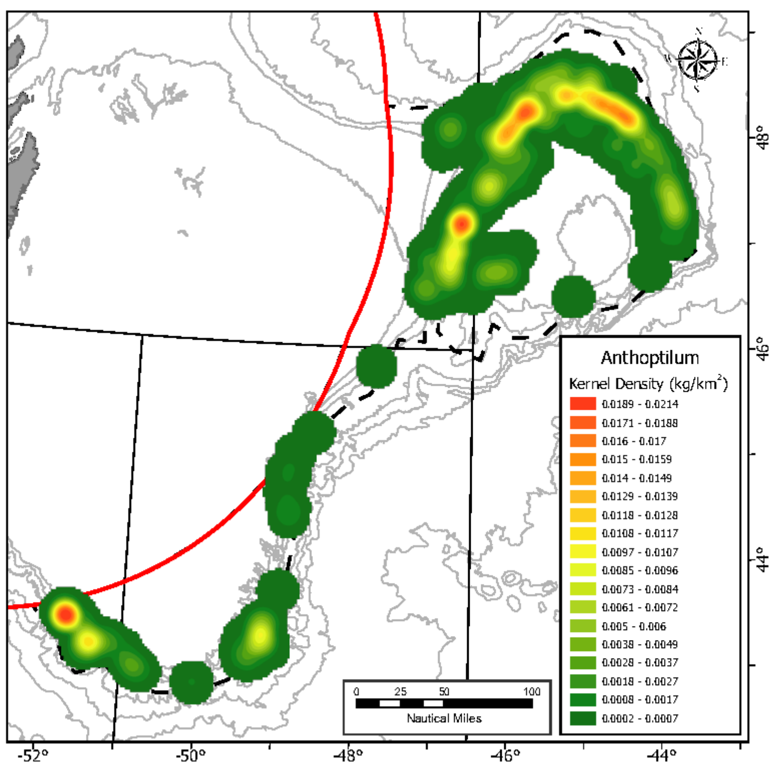


Figure 30. Kernel density biomass surface of *Anthoptilum* sea pens in the NAFO Regulatory Area.

The analyses were performed on 387 catches ≥ 0.1 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 21.5 km; Contour Interval = 0.0001; Cell size default = 2580.5 m. The biomass surface is shown in Figure 30.

Three potential catch thresholds emerged from the KDE analyses: 0.7 kg, 0.5 kg, and 0.35 kg (Table 25, Figure 31). Each showed an increase in area of 34-37% created through a reasonable number of data points (Table 25). The spatial configurations of each threshold and its next smaller threshold are shown in Figures 32 and 33. The 34.4% increase in area in moving from the 0.7 kg contour to the 0.6 kg contour was created through 11 additional points and enlarged some of the polygons on Flemish Cap and on the Tail of Grand Bank with modest data support (Figure 32). Conversely, 21 additional points were included moving from the 0.5 kg contour to the 0.4 kg contour (Figure 32). This increase in area was largely due to connecting polygons on the western slope of Flemish Cap, but there were few data falling in the enlarged area (Figure 33). A similar situation was seen between the 0.35 kg and 0.3 kg polygons (Figure 34) where large area is created in Flemish Pass with little data support. Therefore, the threshold selected is that established with the 0.7 kg catch contour (Figure 32).

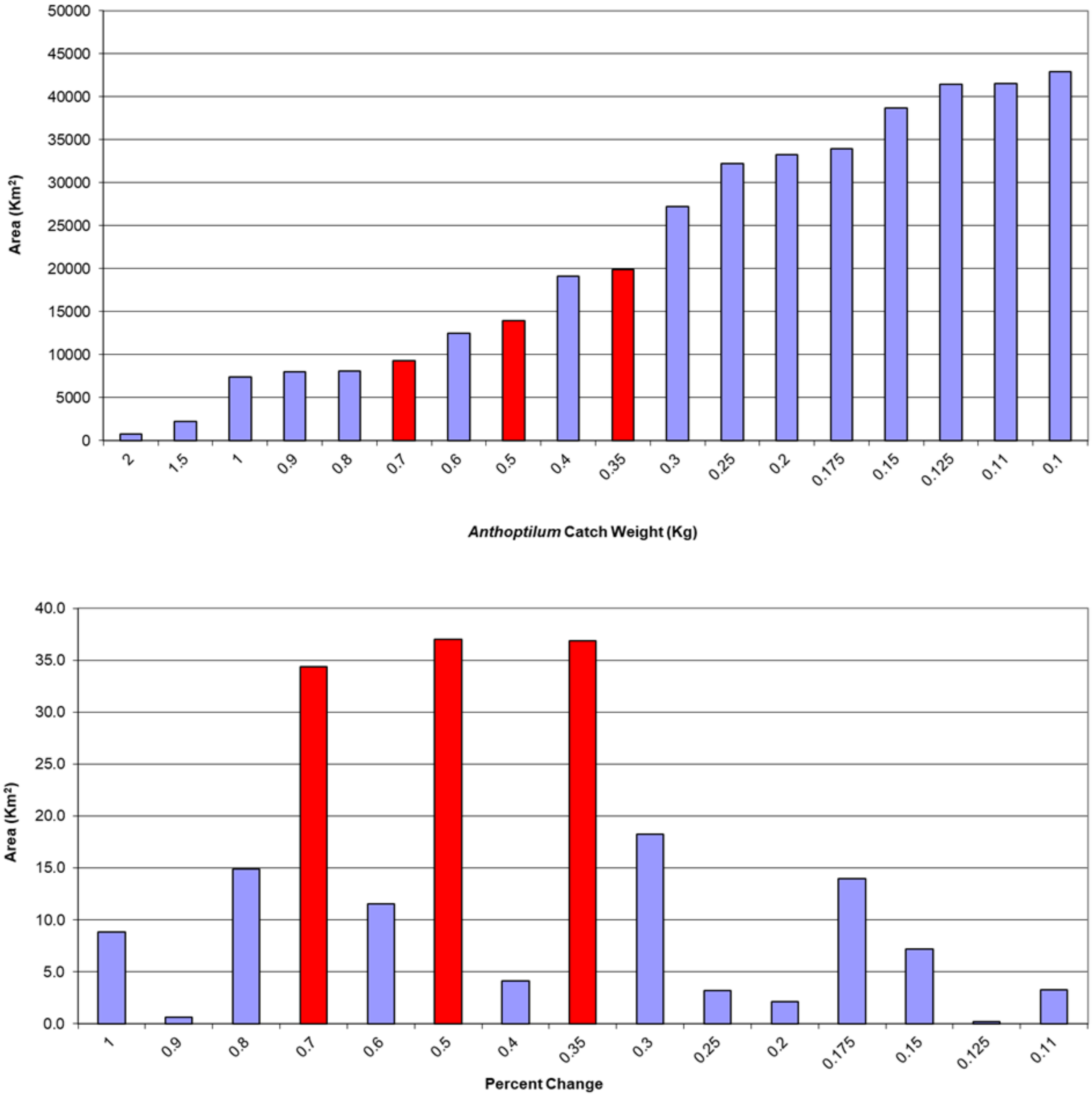


Figure 31. Bar graphs of the polygon area established by successively smaller research vessel *Anthoptilum* sea pen catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

Figure 34 shows the distribution of catches ≥ 0.7 kg and the non-significant catches within the VME polygons established for *Anthoptilum*. Comparison of the *Anthoptilum* VME polygons with those of the Sea Pen Functional Group (Figure 35) shows a high degree of overlap, with most of the Sea Pen Functional Group polygons encompassing those of *Anthoptilum*.

Table 25. The area of *Anthoptilum* sea pen VME polygons based on successively smaller research vessel catch weight thresholds (kg). The area and number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

***Anthoptilum* Sea Pen Catch Threshold (Kg)**	**Total Number of Observations in Polygons**	**Number of Observations in Polygon > Weight Threshold**	**Additional Observations Per Interval > Weight Threshold**	**Area of Polygon (km²)**	**Percent Change in Area Between Successive Thresholds**
2	40	9		803.5	173.5
1.5	66	15	6	2197.9	236.3
1	149	29	14	7392.1	8.8
0.9	181	35	6	8045.7	0.6
0.8	183	42	7	8096.2	14.9
0.7	198	52	10	9305.7	34.4
0.6	250	63	11	12506.2	11.6
0.5	260	76	13	13954.6	37.0
0.4	307	97	21	19123.0	4.1
0.35	318	114	17	19907.3	36.9
0.3	353	135	21	27244.9	18.3
0.25	367	166	31	32226.4	3.2
0.2	371	208	42	33260.3	2.1
0.175	372	228	20	33962.7	14.0
0.15	379	272	44	38703.3	7.2
0.125	384	314	42	41478.6	0.2
0.11	385	351	37	41562.5	3.3
0.1	387	387	36	42922.7	

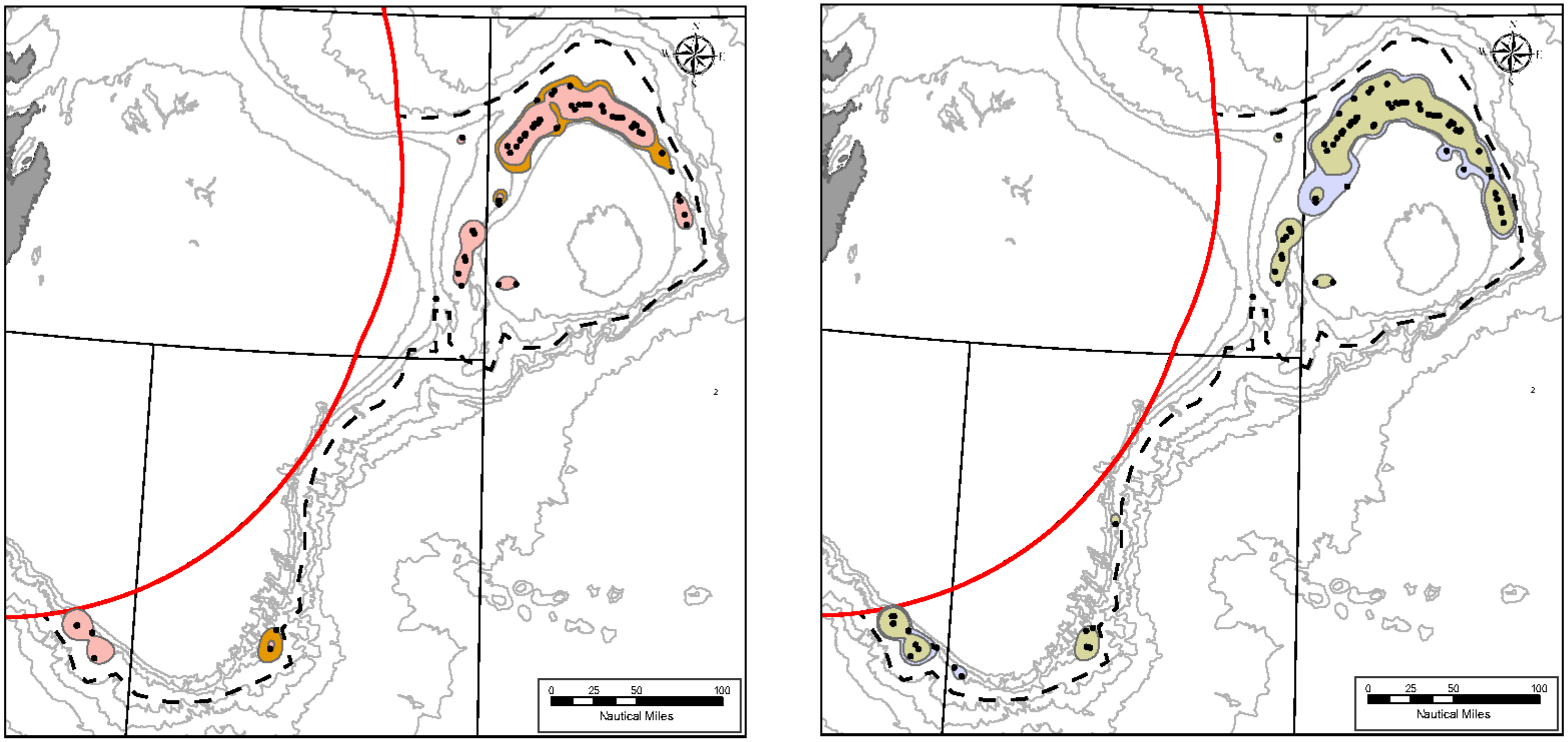


Figure 32. Comparison of the areas covered by *Anthoptilum* sea pen catches ≥ 0.7 kg (salmon) and catches ≥ 0.6 kg (orange) (left panel); the areas covered by catches ≥ 0.5 kg (olive) and catches ≥ 0.4 kg (mauve) (right panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

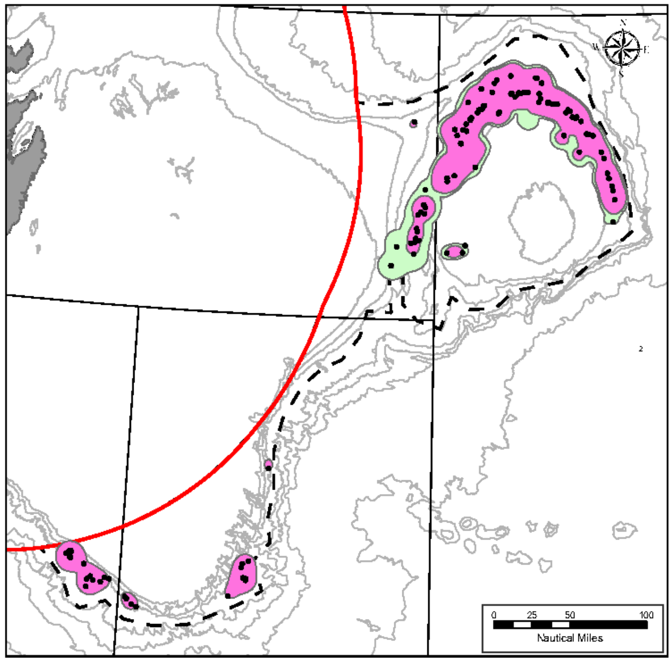


Figure 33. Comparison of the areas covered by *Anthoptilum* sea pen catches ≥ 0.35 kg (pink) and catches ≥ 0.3 kg (green). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

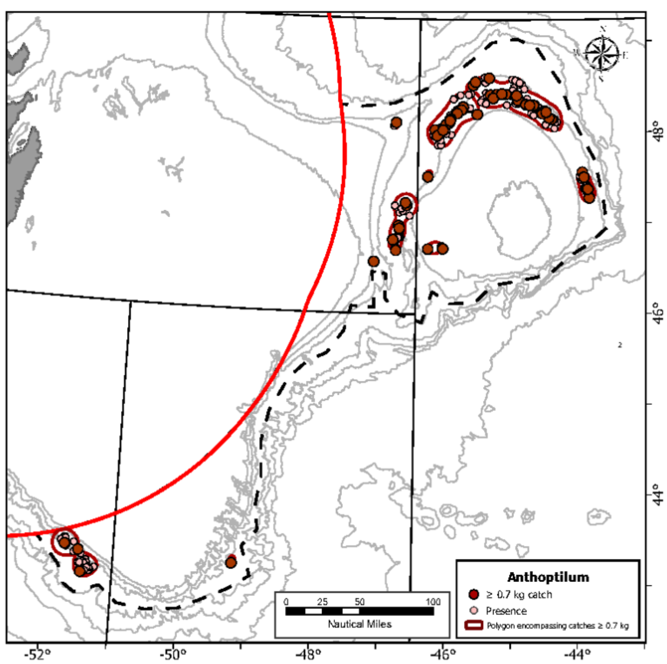


Figure 34. Illustration of the *Anthoptilum* sea pen VME polygons (red outline), catches ≥ 0.7 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

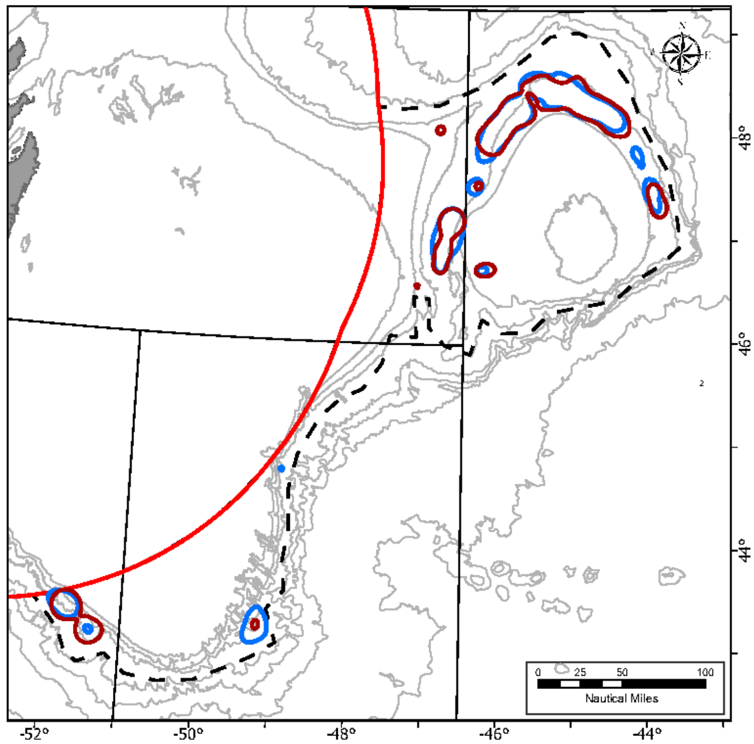


Figure 35. Comparison of the Sea Pen Functional Group VME polygons (blue outline) with the *Anthoptilum* sea pen VME polygons (red outline), both established in the new 2025 analysis. Where the red outline is not visible it is underneath the blue outline. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

***Balticina* Sea Pens**

Balticina is a genus of sea pens belonging to the family Balticinidae. *Balticina* was formerly called *Halipteris*, but that name is no longer valid and has been synonymised under *Balticina* Gray, 1870. The records for this genus were compiled from the following at-sea identifications: 'Balticina finmarchica (=Halipteris)', 'Halipteridae', 'Halipteris cf. christii', 'Halipteris christii', 'HALIPTERIS FINMARCHICA', and 'Halipteris finmarchica', with 86% of those recorded as 'Halipteris finmarchica' and 'HALIPTERIS FINMARCHICA' (Murillo et al., 2024). *Balticina finmarchica* (Sars, 1851) is found in the shallower waters on Flemish Cap, and less so in Flemish Pass and on Grand Bank (Altuna and Murillo, 2012). It occurs at depths of 320–1370 m. A second species, *Balticina christii* (Koren & Danielssen, 1848) is also found on the top of the Flemish Cap, between 169 and 290 m depth, and was first tentatively recorded in 2011 (Murillo et al., 2011). The most important variables for predicting the presence of *Balticina* spp. were averaged mean bottom salinity, averaged bottom temperature range, maximum mixed layer depth in spring, bathymetry, averaged minimum surface current speed and averaged minimum fall chlorophyll concentration (Murillo et al., 2024). The SDMs indicated that *Balticina* spp. are typically located in areas with mean bottom salinity > 34.7, low temperature variability with average bottom temperature range < 1°, high spring mixed layer depth (> 22 m), low surface current speeds and low fall chlorophyll *a* concentration (Murillo et al., 2024).

There were 740 records in the initial *Balticina* data set used for the KDE analyses, with 95% listed as *B. finmarchica*. However, there were significant differences among the catch series for each survey associated with gear type and tow length (Appendix Table A5). When all records less than 0.01 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor Canadian research vessels (Appendix Table A5). Therefore, only catches ≥ 0.01 kg were included in the KDE analyses. The analyses were performed on 596 catches ≥ 0.01 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 22.4 km; Contour Interval = 0. 00001; Cell size default = 2,684.9 m. The biomass surface is shown in Figure 36. The highest biomass densities were found on the northeast Flemish Cap and on the Tail of Grand Bank in NAFO Division 3O.

Table 26. The area of *Balticina* sea pen VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

***Balticina* Sea Pen Catch Threshold (Kg)**	**Total Number of Observations in Polygons**	**No. of Observations in Polygon > Weight Interval**	**Additional Observations Per Interval > Weight Threshold**	**Area of Polygon (km²)**	**Percent Change in Area Between Successive Thresholds**
0.4	110	14		2539.0	282.5
0.25	279	33	19	9712.6	23.8
0.2	314	48	15	12022.0	92.5
0.15	439	80	32	23141.3	23.0
0.125	484	98	18	28469.7	0.9
0.112	490	118	20	28734.4	5.3
0.1	502	137	19	30268.0	4.6
0.09	511	156	19	31660.1	6.3
0.08	516	175	19	33660.5	11.0
0.07	532	205	30	37348.0	14.1
0.06	552	228	23	42604.9	22.3
0.05	573	267	39	52100.7	0.0
0.045	573	285	18	52100.7	0.6
0.04	579	318	33	52428.1	1.5
0.035	581	345	27	53199.2	9.1
0.03	587	396	51	58020.7	0.0
0.025	587	434	38	58020.7	1.5
0.02	588	478	44	58867.3	0.2
0.0175	589	498	20	58971.9	18.0
0.015	592	532	34	69584.6	5.2
0.012	596	566	34	73201.7	0.0
0.01	596	596	30	73201.7	

Two potential thresholds emerged from the examination of the area encompassed by successively smaller density contours (Table 26, Figure 37): 0.15 kg and 0.06 kg. In progressing from 0.4 to 0.2 kg new areas were carved out. The same also occurred at the 0.15 kg threshold but the new area was relatively small and on the Tail of Grand Bank (Figure 38). Of the 18 additional points added in moving from 0.15 kg to 0.125 kg, few were outside of the polygons established with the 0.15 kg threshold. The 0.06 kg density contour expanded the polygons that were established at the 0.15 kg threshold and linked neighbouring polygons on the Tail of Grand Bank and on Flemish Cap, with few of the additional 39 data points added with the 0.05 kg contour falling in the new area (Figure 38). Some new areas, all relatively small, were created. Either of these could be considered the threshold, although the 0.15 kg threshold has a slightly higher areal increase and occurred first (Table 26). We examined the difference between the 0.15 kg and 0.06 kg thresholds to examine the spatial data support for the lower threshold (Figure 39) and found that the polygons established with the 0.06 kg threshold were not supported by many additional data points from that of the 0.15 kg threshold (Figure 39). The exception is two areas in the shallower portion of Flemish Cap and one on the Tail of Grand Bank that were not detected with the 0.15 kg threshold. We chose a conservative approach to identifying the VMEs for *Balticina* sea pens given that this is the first time that this analysis has been performed and recommend the 0.15 kg threshold. That threshold captures the largest density areas on both Flemish Cap and the Tail of Grand Bank (Figure 36). Examination of both thresholds considering the species distribution models for this species (Murillo et al., 2024) is recommended to determine if the polygons in the shallower part of Flemish Cap fall within the area of predicted distribution.

The distribution of the data ≥ 0.15 kg threshold and of non-significant catches within the *Balticina* VME polygons established by the threshold is shown in Figure 40. The polygons contain 439 data points (Table 26) accounting for 74% of the data records for *Balticina*. Figure 41 compares the VMEs for the Sea Pen Functional Group with those of *Balticina*. The *Balticina* VMEs are generally larger than that of the functional group and important areas on the eastern slope of Flemish Pass are not within the boundaries of the Sea Pen Functional Group (Figure 41).

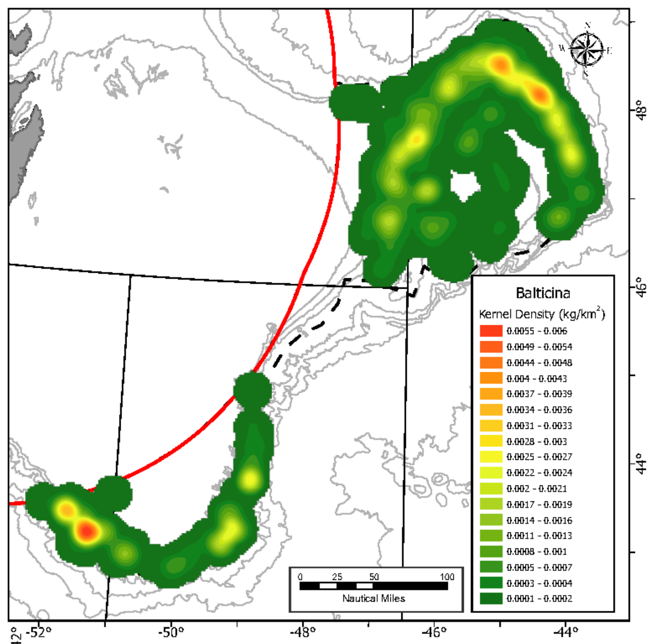


Figure 36. Kernel density biomass surface of *Balticina* sea pens in the NAFO Regulatory Area.

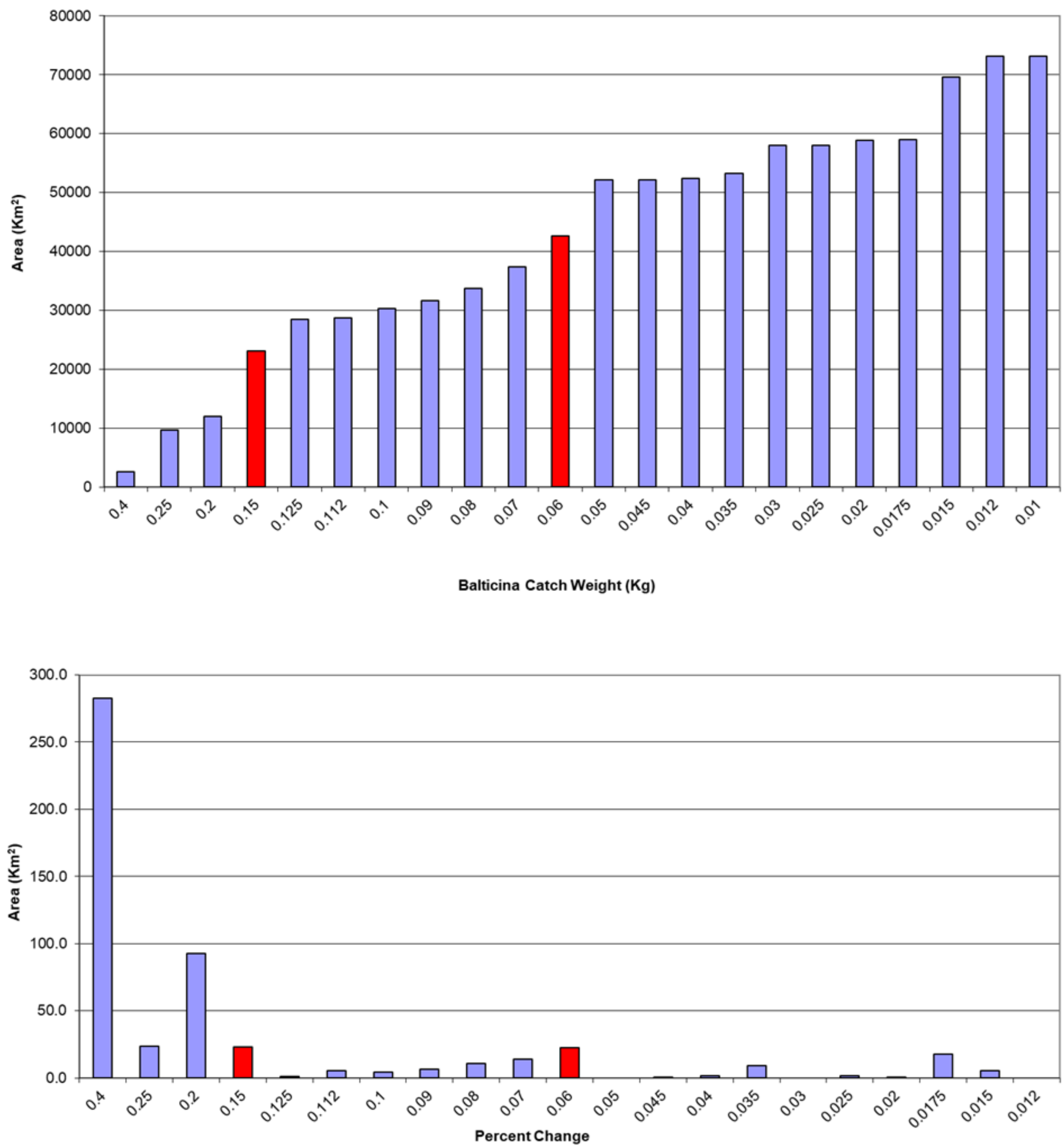


Figure 37. Bar graphs of the polygon area established by successively smaller research vessel *Balticina* sea pen catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

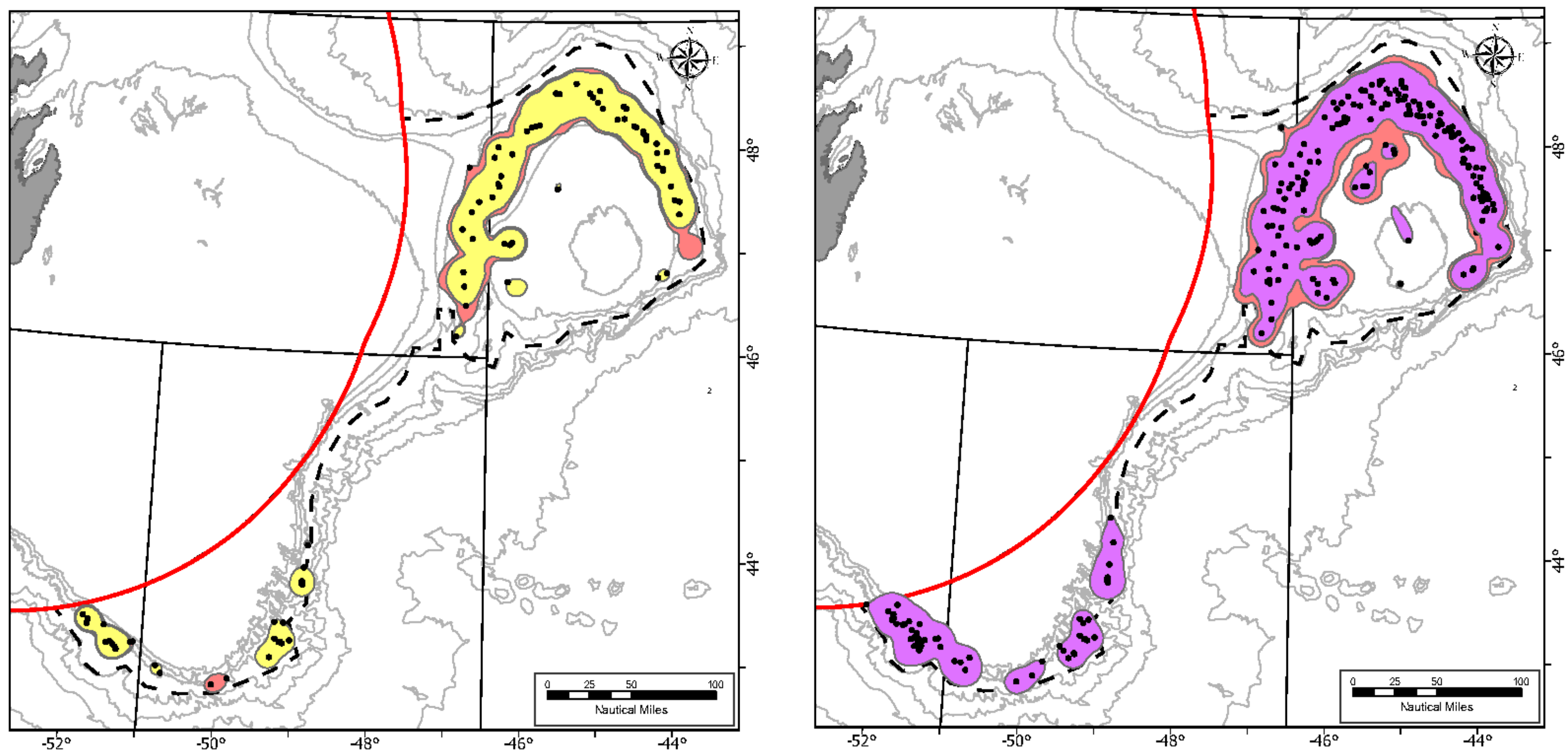


Figure 38. Comparison of the areas covered by *Balticina* sea pen catches ≥ 0.15 kg (yellow) and catches ≥ 0.125 kg (salmon) (left panel); catches ≥ 0.06 kg (purple) and catches ≥ 0.05 kg (salmon) (right panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

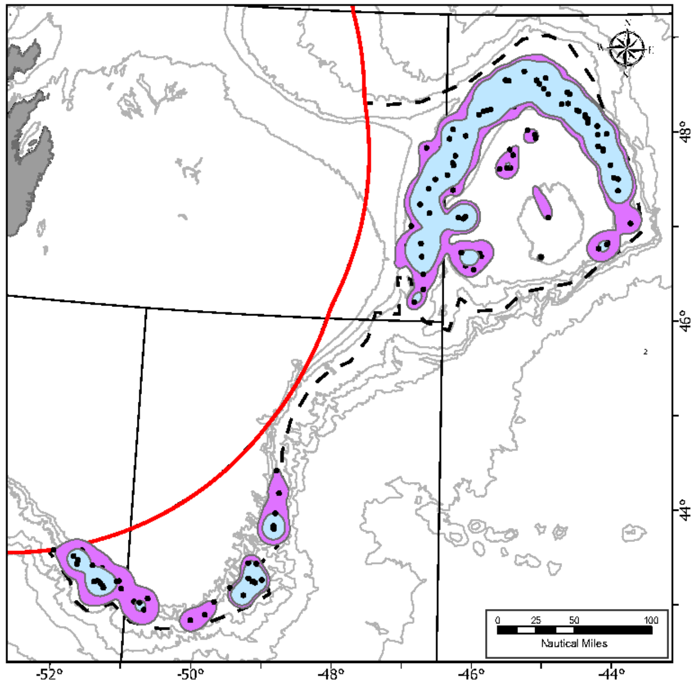


Figure 39. Comparison of the areas covered by *Balticina* sea pen catches ≥ 0.15 kg (blue) and ≥ 0.06 kg (purple). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

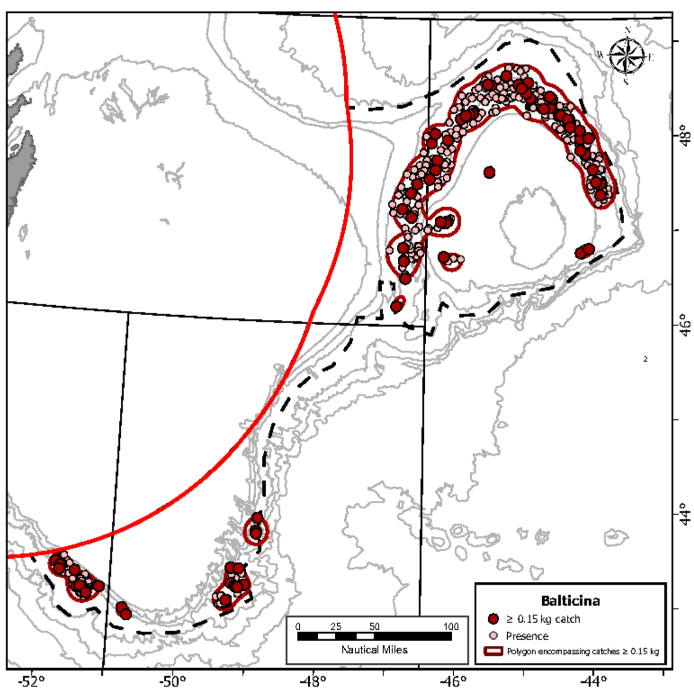


Figure 40. Illustration of the *Balticina* VME polygons (red outline), catches ≥ 0.15 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

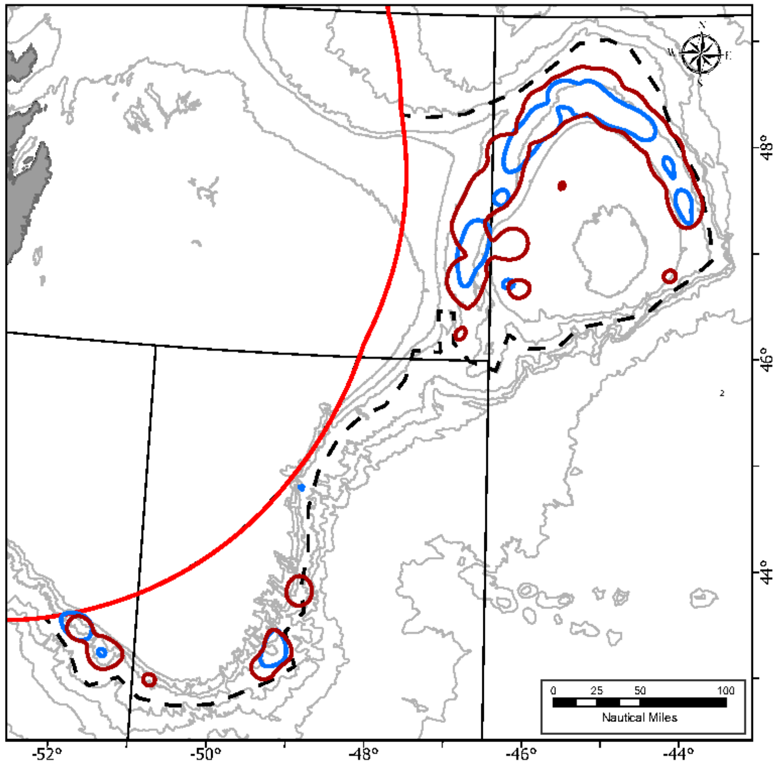


Figure 41. Comparison of the Sea Pen Functional Group VME polygons (blue outline) with the *Balticina* sea pen VME polygons (red outline), both established in the new 2025 analysis. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

***Funiculina* Sea Pens**

Funiculina quadrangularis (Pallas, 1766) is one of the more common sea pens in the NAFO Regulatory Area, occurring on Flemish Cap, in Flemish Pass and on the Grand Banks at depths of 324-1258 m (Altuna and Murillo, 2012). It is a tall sea pen in the family Funiculinidae and can exceed 2 m in height. A second species, *Funiculina armata* Verrill, 1879, or armoured sea pen, has been reported from the northwest Atlantic, specifically in Hudson Canyon (Smithsonian Institution, National Museum of Natural History, Record ID nmnhinvertebratezoology_53563) and could be present in the NAFO Regulatory Area, although it has not been reported thus far.

The most important variables for predicting the presence of *Funiculina* spp. were the averaged minimum summer primary productivity, averaged mean bottom salinity, averaged bottom temperature range, channel network base level (effectively a coarse scale representation of bathymetry), averaged minimum fall chlorophyll a concentration, and maximum mixed layer depth in spring (Murillo et al., 2024). The SDMs indicate that *Funiculina* spp. are typically located in areas with low summer primary productivity, mean bottom salinity > 34.7, low temperature variability with average bottom temperature range < 1°, base depths > 500 m, and low fall chlorophyll a concentration (Murillo et al., 2024). The likelihood of occurrence increases with higher spring mixed layer depths.

For the KDE analyses of *Funiculina*, taxon names in the data records were 'F. quadrangularis', 'FUNICULINA QUADRANGULARIS' and 'Funiculina'. It is highly likely that the KDE for this genus is representative of a single species, *F. quadrangularis*.

There were 450 records in the initial *Funiculina* data set used for the KDE analyses. However, there were significant differences among the catch series for each survey associated with gear type and tow length

(Appendix Table A6). When all records less than 0.05 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor the Canadian research vessel (Appendix Table A6). Therefore, only catches ≥ 0.05 kg were included in the KDE analyses. However, this left very few records for the analyses (N=29) and so although the analysis was performed, it is anticipated that new areas may emerge as more data is provided in future years. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 20.1 km; Contour Interval = 0. 0001; Cell size default = 2,406.1 m. The biomass surface is shown in Figure 42. The highest biomass densities were found on Tail of Grand Bank in NAFO Division 3O.

Only one potential threshold emerged as a potential *Funiculina* VME (0.10 kg) from the examination of the area encompassed by successively smaller density contours (Table 27, Figures 43 and 44). In progressing from 0.1 to 0.07 kg the area around the large polygon in NAFO Division 3O (Figure 44) was greatly increased by 48% with additional data supporting the increase, suggesting that the threshold was valid.

The distribution of the data ≥ 0.10 kg threshold and of non-significant catches within the *Funiculina* VME polygons established by the threshold is shown in Figure 45. The polygons contain 22 data points (Table 27) accounting for 76% of the data records for *Funiculina*. Figure 46 compares the VMEs for the Sea Pen Functional Group with those of *Funiculina*. The *Funiculina* VMEs have distinctive habitats from those of the Sea Pen Functional Group particularly in NAFO Division 3O (Figure 46).

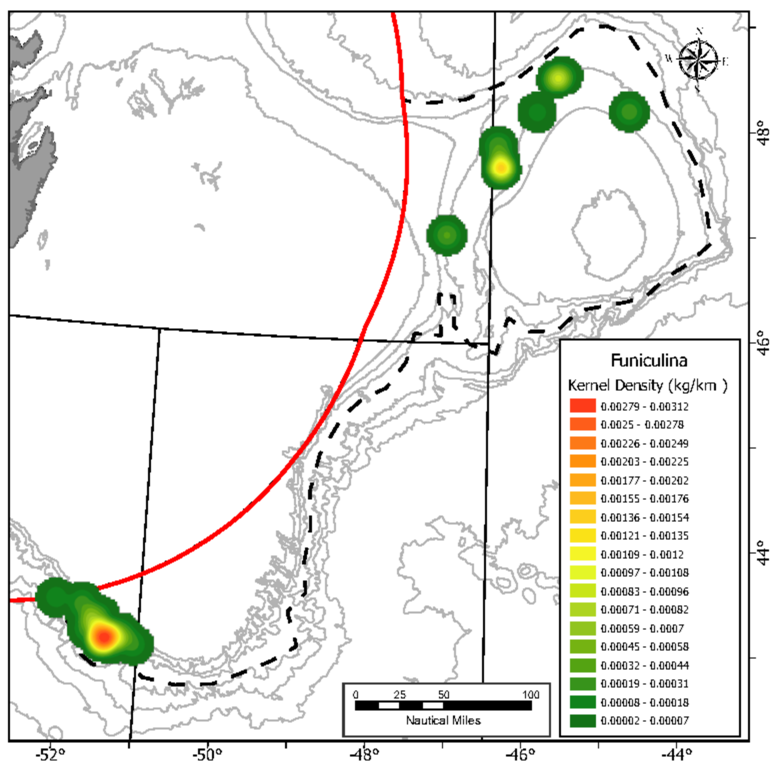


Figure 42. Kernel density biomass surface of *Funiculina* sea pens in the NAFO Regulatory Area.

Table 27. The area of *Funiculina* sea pen VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

***Funiculina* Sea Pen Catch Threshold (Kg)**	**Total Number of Observations in Polygon**	**Number of Observations in Polygon > Weight Threshold**	**Additional Observations Per Interval > Weight Threshold**	**Area of Polygon (km^2)**	**Percent Change in Area Between Successive Thresholds**
0.3	3	3		163.41	622.0
0.12	12	8	5	1179.86	96.0
0.11	21	13	5	2312.78	6.6
0.1	22	16	3	2465.64	48.3
0.07	27	20	4	3655.96	5.5
0.055	28	24	4	3856.50	2.5
0.05	29	29	5	3952.73	

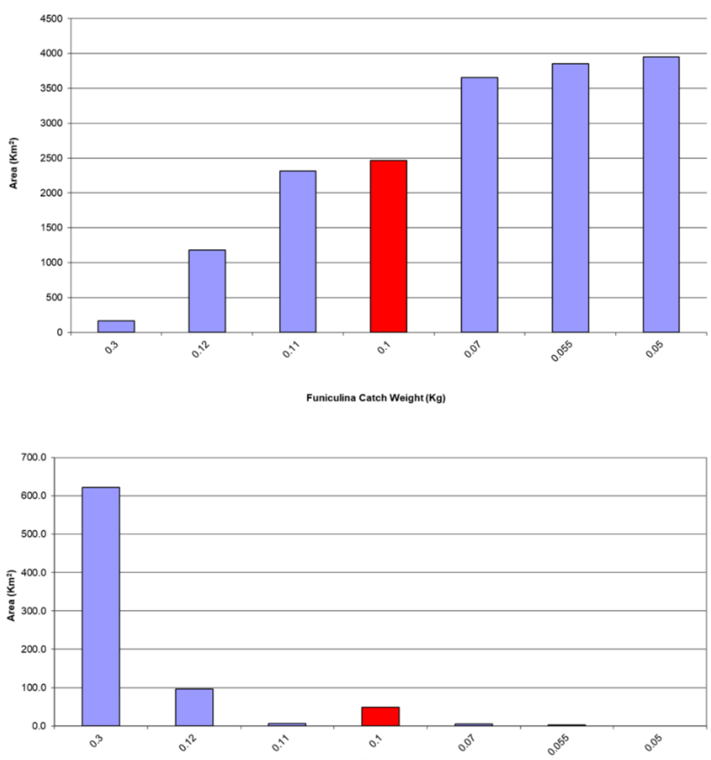


Figure 43. Bar graphs of the polygon area established by successively smaller research vessel *Funiculina* sea pen catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

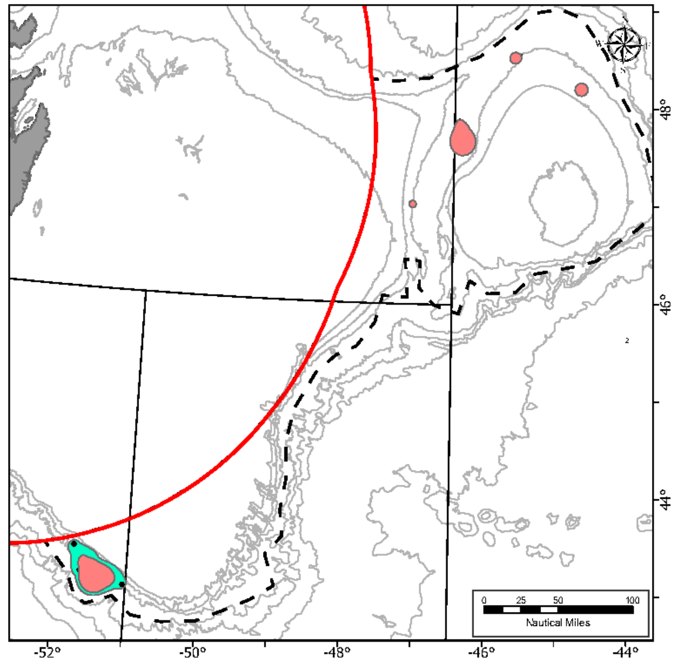


Figure 44. Comparison of the areas covered by *Funiculina* sea pen catches ≥ 0.1 kg (rose) and catches ≥ 0.07 kg (green). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

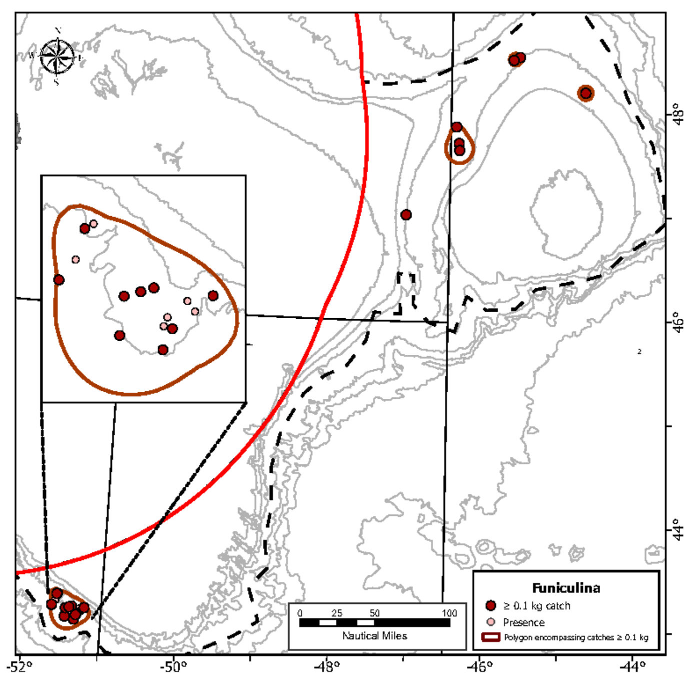


Figure 45. Illustration of the *Funiculina* VME polygons (red outline), catches ≥ 0.1 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

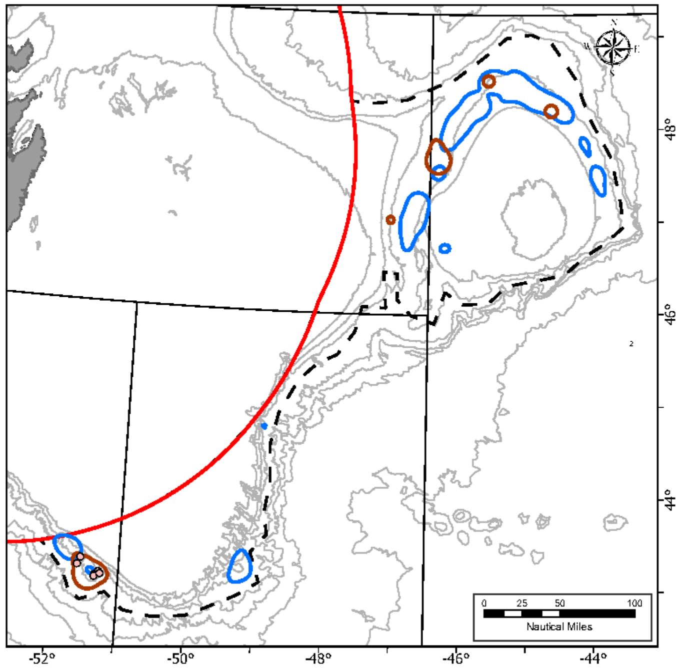


Figure 46. Comparison of the Sea Pen Functional Group VME polygons (blue outline) with the *Funiculina* sea pen VME polygons (red outline), both established in the new 2025 analysis. Where the red outline is not visible it is underneath the blue outline. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

***Pennatula* Sea Pens**

Pennatula is a genus of sea pens in the family Pennatulidae. There are over 50 species worldwide, with *Pennatula aculeata* Danielssen, 1860 and *Ptilella grandis* (Ehrenberg, 1834) (formerly known as *Pennatula grandis*) common in and around the NAFO Regulatory Area (Altuna and Murillo, 2012; Murillo et al., 2018). *Pennatula phosphorea* Linnaeus, 1758 was preliminarily reported in the area (Murillo et al., 2008). Subsequent examination showed that those specimens belong to *P. aculeata* (Murillo et al., 2011; Altuna and Murillo, 2012). *P. aculeata* has been reported from depths of 302–1214 m, while *Ptilella grandis* occurs over a similar depth range of 324–1246 m (Altuna and Murillo, 2012). Both genera are included under *Pennatula* spp. for this analysis.

The most important variables for predicting the presence of *Pennatula* spp. In the NAFO Regulatory Area were bathymetry, averaged surface salinity range, valley depth, averaged mean surface temperature, averaged mean bottom salinity, and averaged range of summer chlorophyll a concentration (Murillo et al., 2024). The SDMs indicated that *Pennatula* spp. are typically located in depressed areas at depths > 500 meters, with optimum depths occurring at > 700 m. Likelihood of presence increased in areas with variable surface salinity, mean bottom salinity > 34.7, and low summer chlorophyll *a* concentration (Murillo et al., 2024).

For the KDE analyses *Pennatula* included records for 'Pennatula', 'Pennatula aculeata', 'PENNATULA ACULEATA/PHOSPHOREA', 'Pennatula grandis', 'PENNATULA GRANDIS', 'Ptilella grandis (=Pennatula)', 'Pennatula phosphorea', and 'Pennatula sp.'. There were 529 records in the initial *Pennatula* data set used for the KDE analyses. However, there were significant differences among the catch series for each survey associated with gear type (Appendix Table A7). When all records less than 0.01 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears, nor Canadian research vessels (Appendix Table A7). Therefore, only catches ≥ 0.01 kg were included in the KDE analyses. The analyses were performed on 220 catches ≥ 0.01 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius =

20.2 km; Contour Interval = 0. 00001; Cell size default = 2,423.7 m. The biomass surface is shown in Figure 47. The highest biomass densities were found on the Tail of Grand Bank in NAFO Division 3O.

Table 28. The area of *Pennatula* sea pen VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

***Pennatula* Sea Pen Catch Threshold (Kg)**	**Total Number of Observations in Polygon**	**Number of Observations in Polygon > Weight Threshold**	**Additional Observations Per Interval > Weight Threshold**	**Area of Polygon (km²)**	**Percent Change in Area Between Successive Thresholds**
0.3	47	12		1051.9	720.7
0.1	137	30	18	8632.5	4.0
0.07	148	44	14	8978.3	14.2
0.045	159	60	16	10252.2	58.7
0.035	193	77	17	16265.5	20.6
0.025	202	104	27	19610.7	4.7
0.02	208	123	19	20530.0	6.9
0.017	215	140	17	21945.4	4.8
0.014	216	166	26	22988.0	0.0
0.113	216	183	17	22988.0	4.8
0.011	218	194	11	24083.6	3.6
0.01	220	220	26	24940.6	

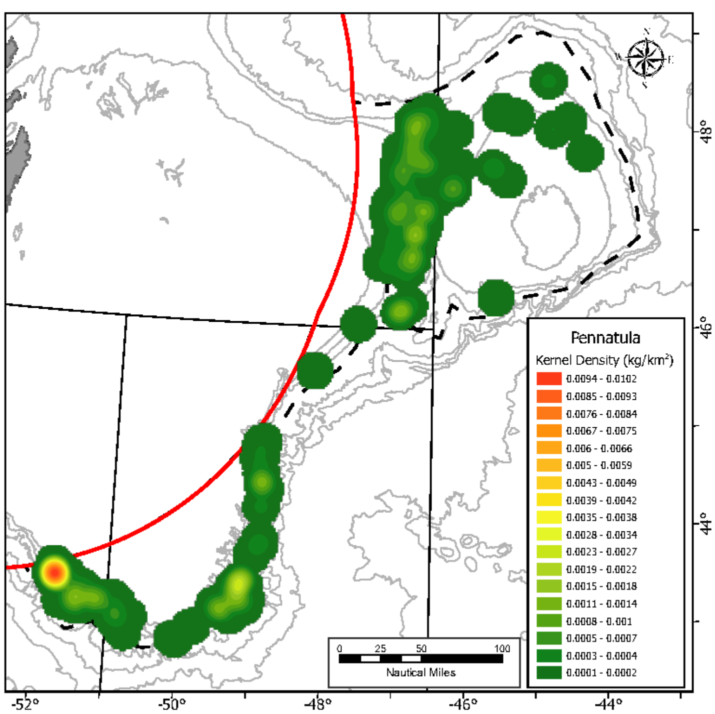


Figure 47. Kernel density biomass surface of *Pennatula* sea pens in the NAFO Regulatory Area.

Two potential thresholds emerged from the analyses (Table 28, Figure 48). The greatest change in area, after the establishment of the initial polygons occurs at the 0.045 kg threshold where the areal increase to the 0.35 kg threshold is 58.7%. This increase in area is created with 17 additional data points greater than or equal to the threshold (Table 28, Figure 49). The next potential threshold is 0.35 kg, however the increase in area in moving to the 0.025 kg threshold (20.6%) is created by the joining of smaller polygons with little evidence for a continuous distribution within the newly formed area (Figure 49). Therefore the 0.045 kg was seen as defining the *Pennatula* VME polygons. There were 159 data points (significant and non-significant catches) within the *Pennatula* VME polygons, representing 72.3% of the data (Figure 50).

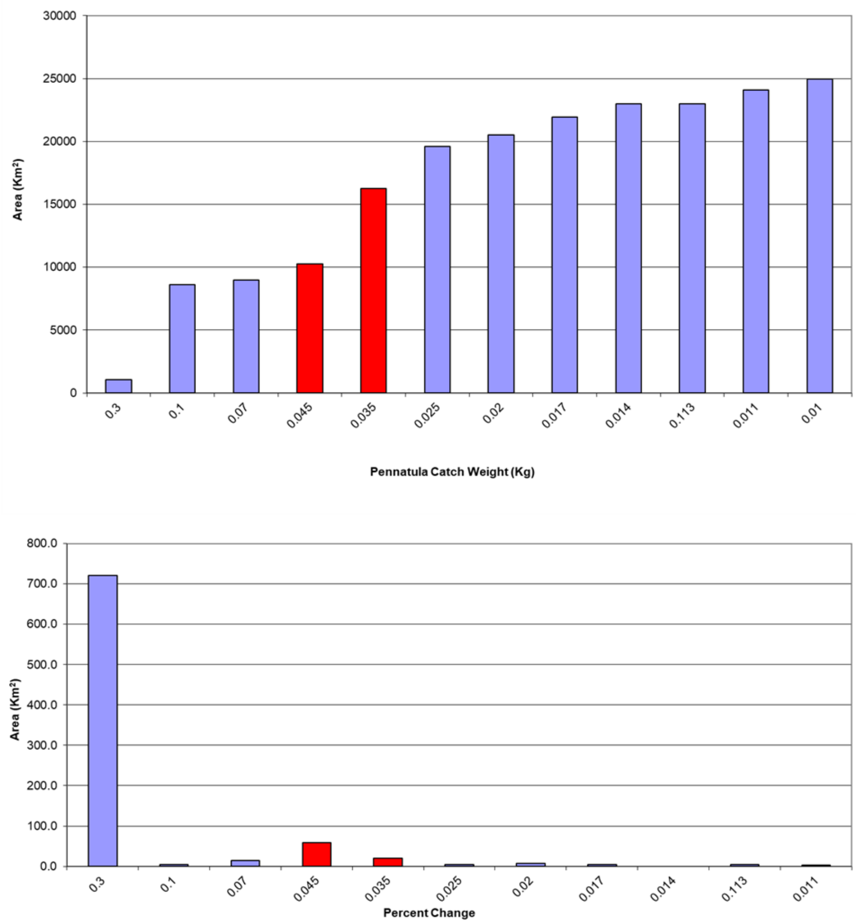


Figure 48. Bar graphs of the polygon area established by successively smaller research vessel *Pennatula* sea pen catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

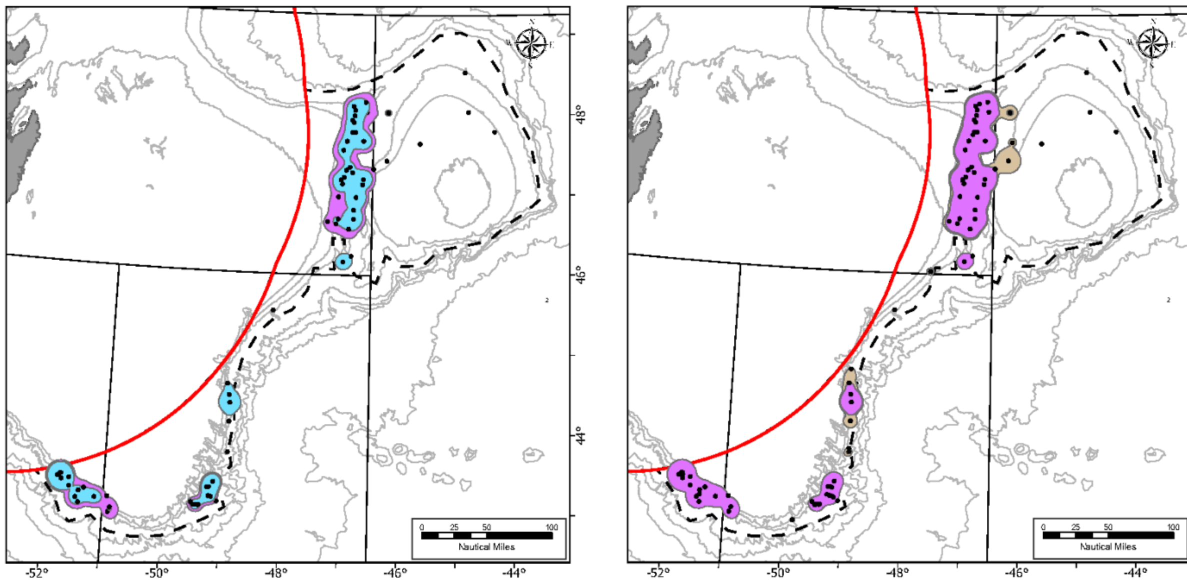


Figure 49. Comparison of the areas covered by *Pennatula* sea pen catches ≥ 0.045 kg (blue) and catches ≥ 0.035 kg (purple) (left panel), and catches ≥ 0.035 kg (purple) and catches ≥ 0.025 kg (brown) (right panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

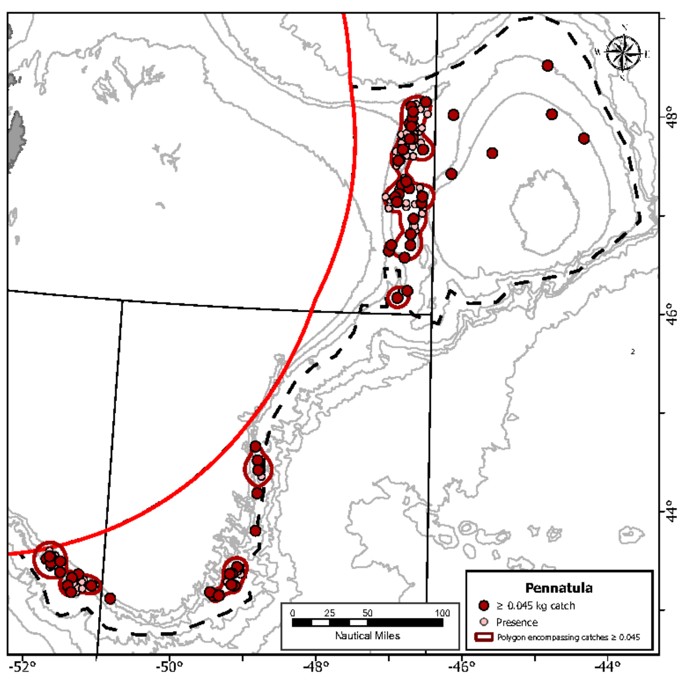


Figure 50. Illustration of the *Pennatula* VME polygons (red outline), catches ≥ 0.045 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

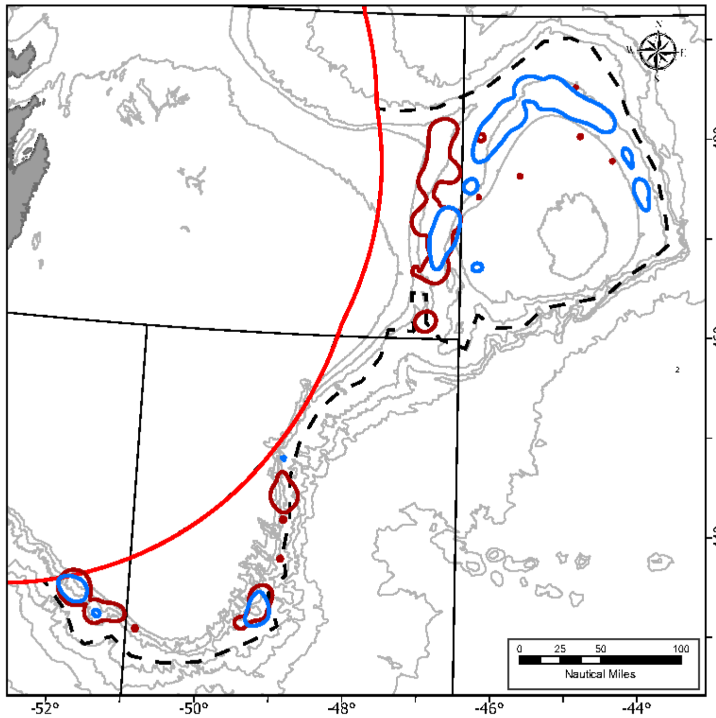


Figure 51. Comparison of the Sea Pen Functional Group VME polygons (blue outline) with the *Pennatula* sea pen VME polygons (red outline), both established in the new 2025 analysis. Where the red outline is not visible it is underneath the blue outline. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Black Coral Functional Group

Black corals belong to the cnidarian order Antipatharia. Two species have been identified in the data provided by the Contracting Parties in the NAFO Regulatory area, *Stauropathes arctica* (Lütken, 1871) of the family Schizopathidae, and *Leiopathes cf. expansa* of the family Leiopathidae, although more species have been recorded in the area (NAFO, 2019a; NAFO, 2025). Black corals are known for their exceptionally long lifespans, with some colonies having lifespans of 100 to 4500 years, including species of *Leiopathes* (Roark et al., 2009). Antipatharia spp. are listed in Appendix II of CITES, meaning that trade in black corals requires CITES permits to ensure sustainability. Species distributions models show that the Black Coral Functional Group is distributed in a ring around Flemish Cap between about 400 and 600 m depth and in the deep slope waters below 1800 m (Murillo et al., 2024). The data for the VME Black Coral Functional Group were compiled from those identified at sea as 'Antipatharia', 'Antipatharia sp. (ORDER)', 'Stauropathes arctica', 'STAUROPATHES ARCTICA', and 'Leiopathes cf. expansa', and included records for the functional group but with no taxon name or biomass provided. The majority of records with taxon names were of *Stauropathes arctica*.

There were significant differences among the catch series for each survey associated with gear type (Appendix Table A8). When all records less than 0.15 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears (Appendix Table A8). There were only 6 Canadian records above the threshold, and 5 of those were from the CCGS *Teleost* and the other from the CCGS *Wilfred Templeman*. A KS test found no significant difference (P=0.34) although with so few data it had no influence on the analyses. Therefore, only catches ≥ 0.15 kg/RV tow were included in the KDE analyses. The analyses were performed on 76 catches ≥ 0.15 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 19.9 km; Contour Interval = 0.

0001; Cell size default = 2,385.98 m. The biomass surface is shown in Figure 52. The highest biomass densities were found in Flemish Pass and were very similar in location to those identified in 2019 (Kenchington et al., 2019).

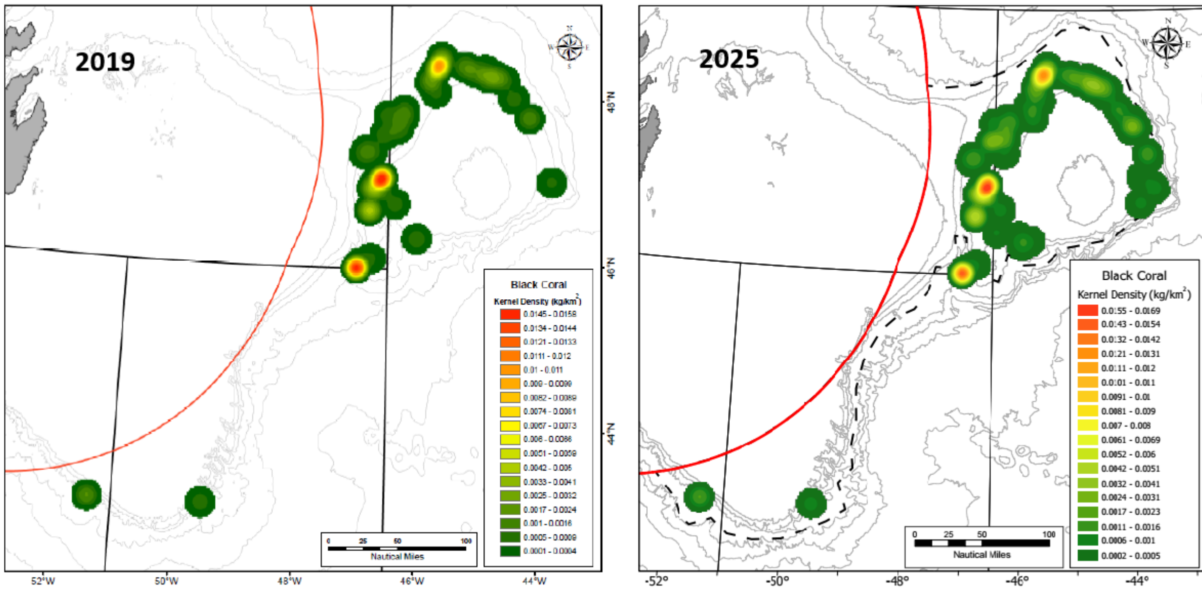


Figure 52. Kernel density biomass surfaces of the Black Coral Functional Group in the NAFO Regulatory Area comparing results from 2019 and 2025.

Table 29. The area of Black Coral Functional Group VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Black Coral Functional Group Catch Threshold (Kg)	Total Number of Observations in Polygon	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
1.5	8	4		71.8	1018.4
1	19	9	5	803.4	117.0
0.5	30	17	8	1743.2	66.0
0.4	39	25	8	2893.5	54.3
0.32	47	32	7	4464.3	27.0
0.3	53	38	6	5670.5	16.0
0.23	62	47	9	6578.7	34.2
0.2	69	55	8	8828.6	3.0
0.17	71	64	9	9094.1	22.1
0.16	74	72	8	11101.0	1.7
0.15	76	76	4	11287.8	

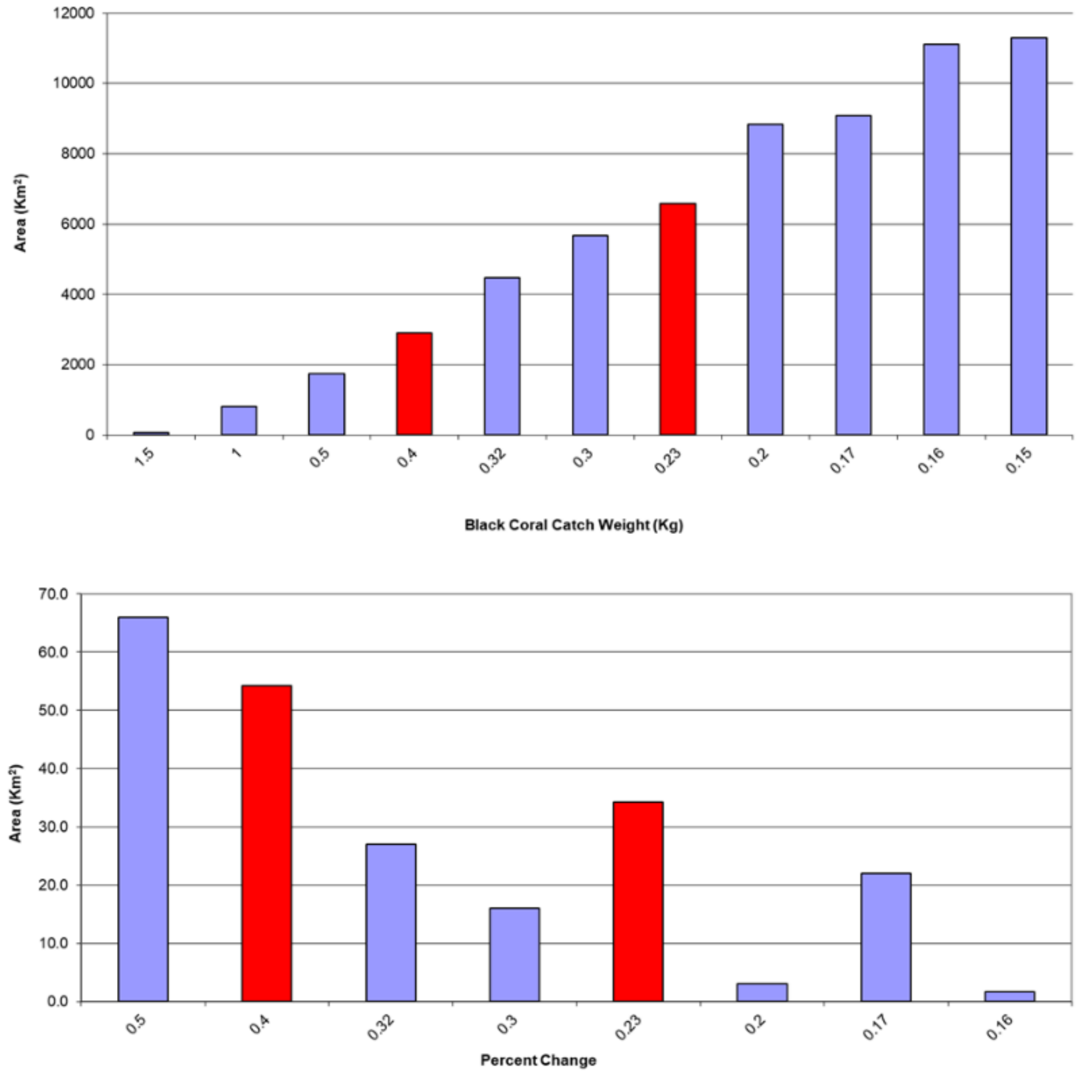


Figure 53. Bar graphs of the polygon area established by successively smaller research vessel Black Coral Functional Group catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

Two potential thresholds emerged from the KDE analyses (Table 29, Figure 53), the 0.4 kg/RV tow and the 0.23 kg/RV tow. The thresholds higher than 0.4 kg identify new areas and so were not considered. At the 0.4 kg threshold the area increased by 54.3% and was established with 7 additional data points (Table 15). As this is the first large increase in area after establishing the core areas this threshold was selected over the 0.23 kg/RV tow threshold which showed a smaller increase in area with similar data support (Table 29, Figure 54). In selecting the 0.4 kg/RV tow density contour we highlight that there are 5 catches above this threshold that occur as isolated points. In this case we recommend considering those points as VME given that this is only the second time these analyses were performed and the data used is relatively small.

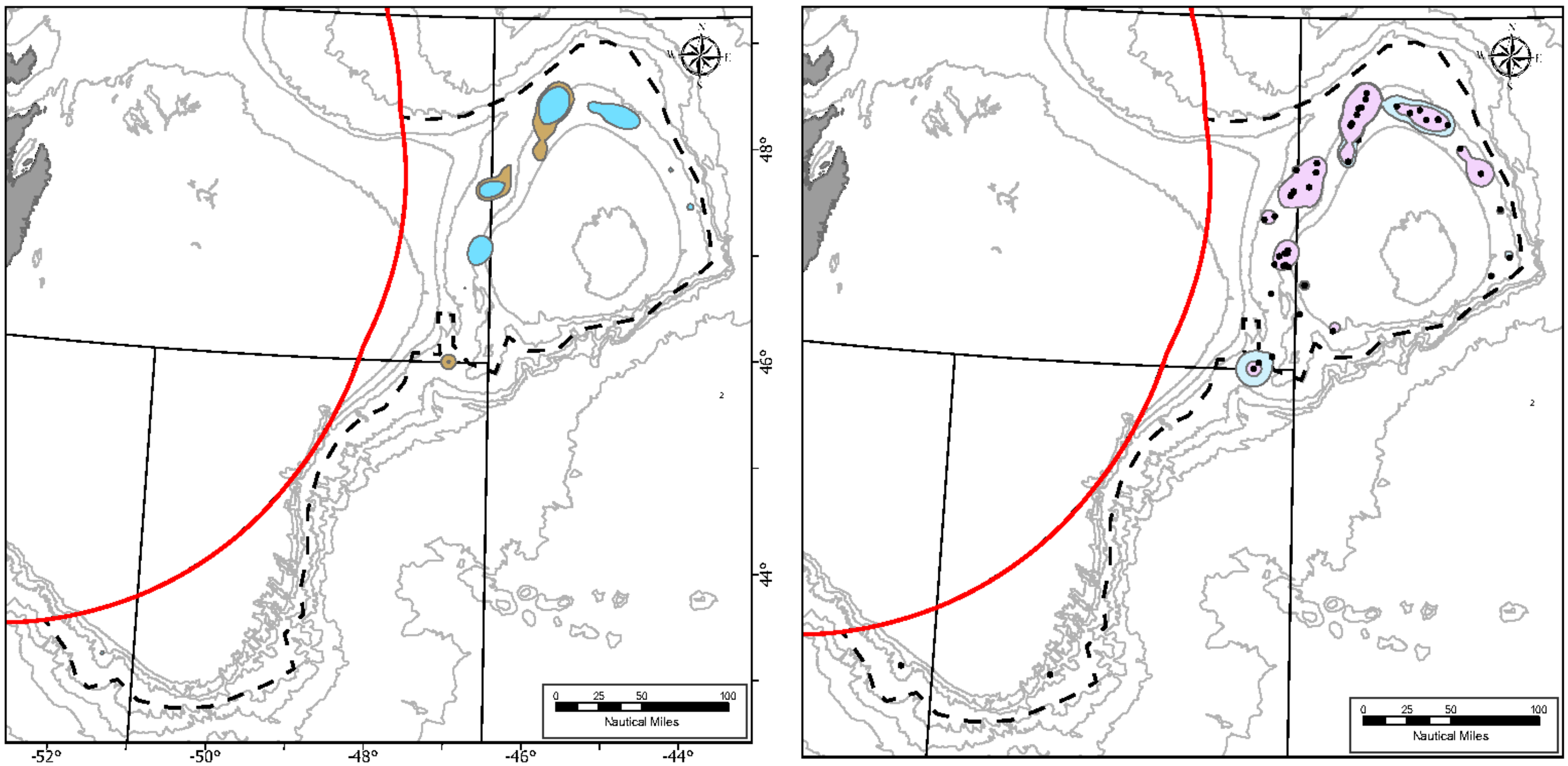


Figure 54. Comparison of the areas covered by Black Coral Functional Group catches ≥ 0.40 kg (blue) and catches ≥ 0.32 kg (brown) (left panel); and catches ≥ 0.23 kg (mauve) and catches ≥ 0.20 kg (blue) (right panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

The Black Coral Functional Group VME polygons established with catches ≥ 0.4 kg contained 39 of the records for this group representing 51.3% of the data (Table 27, Figure 55). The location of the VME polygons for the Black Coral Functional Group overlap with those produced in 2019 (Figure 56) except for the VME polygon in the Flemish Pass which is further to the south in the present analyses (Figure 56).

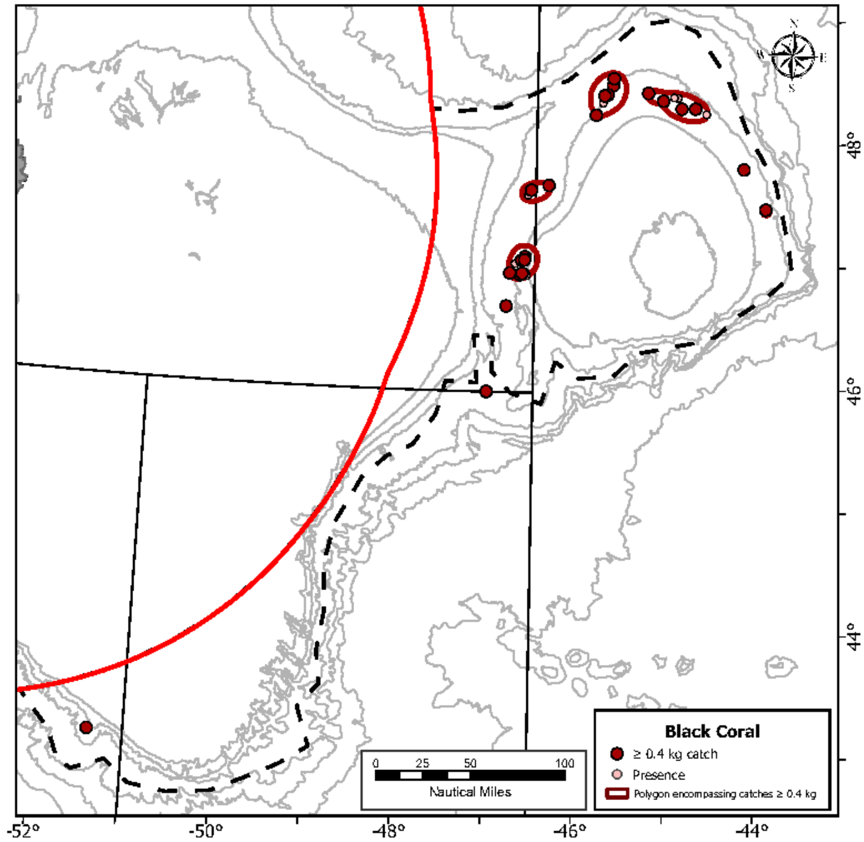


Figure 55. Illustration of the Black Coral Functional Group VME polygons (red outline), catches ≥ 0.4 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

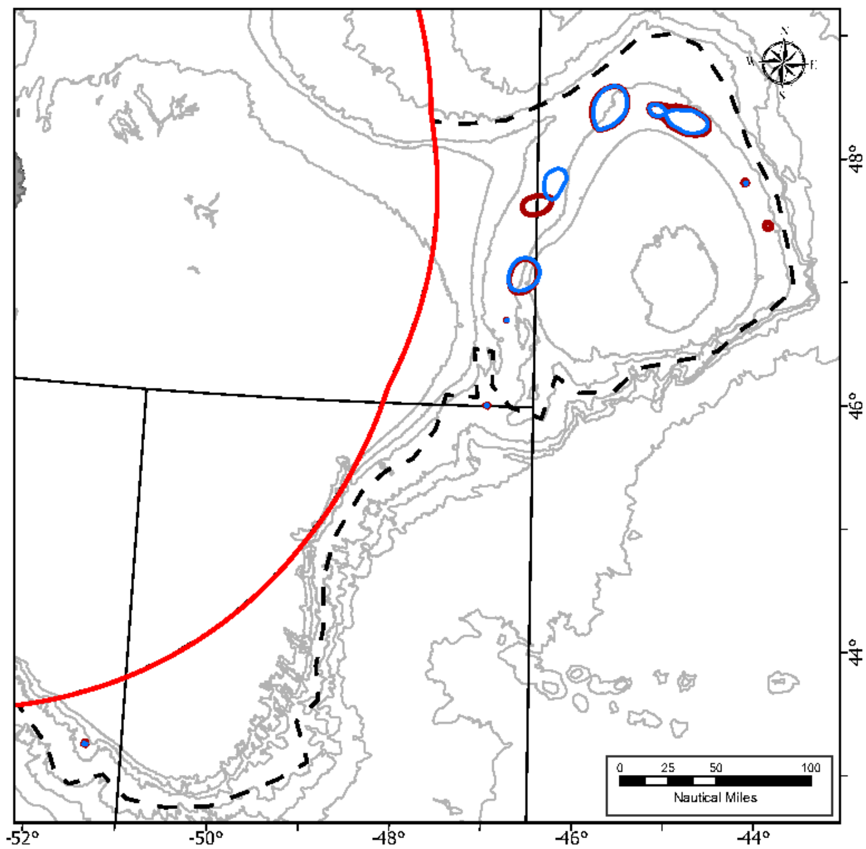


Figure 56. Comparison of the 2019 Black Coral Functional Group VME polygons (blue outline) with the Black Coral Functional Group VME polygons established in the new 2025 analysis (red outline). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Large Gorgonian Coral Functional Group

The term "gorgonian coral" is commonly associated with species in the cnidarian order Scleralcyonacea that produce a flexible skeleton composed of calcite and the proteinaceous material gorgonin. They are commonly referred to as sea fans and can reach 5 m in height. These species are typically found attached to hard substrate, such as bedrock or a mixture of pebbles, boulders, and cobbles. Species distribution models indicated that the presence of Large Gorgonian Corals was associated with areas with a mean spring primary productivity > 1200 mg C m^{-2} day^{-1}, a range of bottom salinity > 0.1, and in sheltered locations on elevations to 600 m with rugged terrain (Murillo et al., 2025). Their large size and association with hard substrates were factors considered in separating them from the Small Gorgonian Corals (see below).

For the KDE analyses the Large Gorgonian Coral Functional Group included records for 'Acanthogorgia', 'Acanthogorgia armata', 'ACANTHOGORGIA SP.', 'Acanthogorgia sp.', 'Acanthogorgiidae', 'Keratoisis', 'Keratoisis cf. flexibilis', 'Octocorallia sp. (SUBCLASS)', 'Paragorgia', 'PARAGORGIA ARBOREA', 'Paragorgia arborea', 'Paragorgia arborea', 'Paragorgia spp', 'Paramuricea placomus', 'Paramuricea', 'PARAMURICEA SP', 'Paramuricea sp.', 'Paramuricea sp.', 'Primnoa resedaeformis', 'Primnoa resedaeformis', and 'PRIMNOIDAE', as well as ones just listed under the functional group. One taxon, 'ISIDIDAE' which was represented by one record was not included as this could also be a small gorgonian coral. The taxon names indicate that at least four genera are present, *Acanthogorgia*, *Keratoisis*, *Paragorgia*, *Paramuricea* and *Primnoa*.

There were significant differences among the catch series for each survey associated with gear type (Appendix Table A9). When all records less than 0.10 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears (Appendix Table A9). Also, there were no differences between research vessels in the Canadian data. Therefore, only catches ≥ 0.10 kg/RV tow were included in the KDE analyses. The analyses were performed on 98 catches ≥ 0.10 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 20.2 km; Contour Interval = 0. 0001; Cell size default = 2,426.36 m. The biomass surface is shown in Figure 52. The highest biomass densities were found in Flemish Pass and were very similar in location to those identified in 2019 (Kenchington et al., 2019).

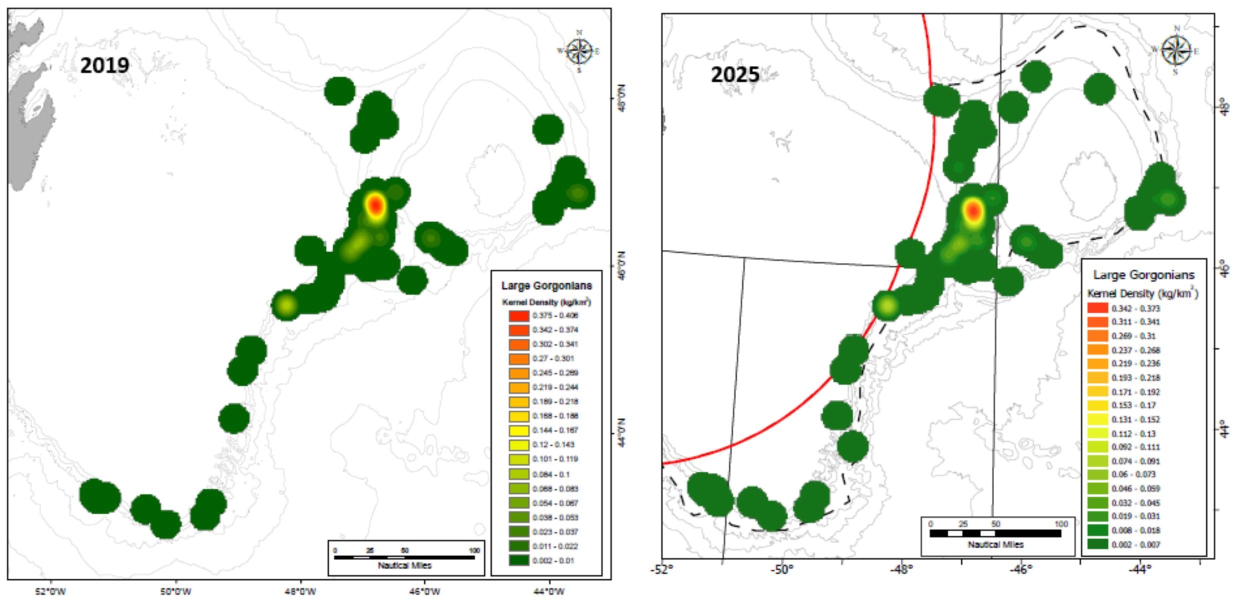
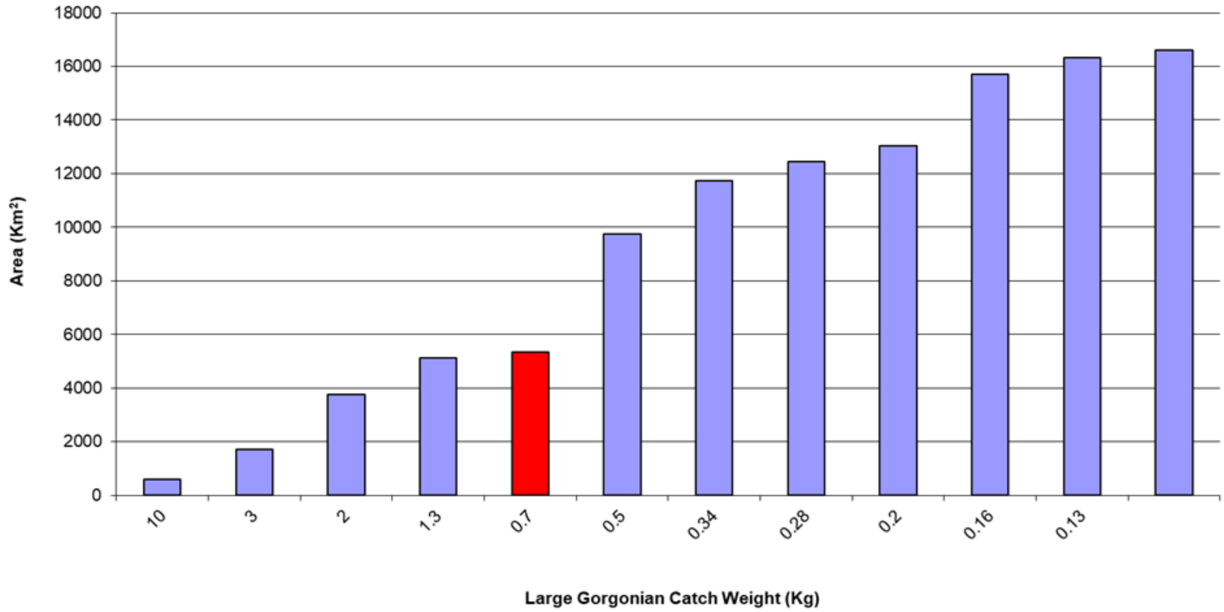


Figure 57. Kernel density biomass surfaces of the Large Gorgonian Coral Functional Group in the NAFO Regulatory Area comparing the surface created in 2019 with that created in 2025.

The KDE analyses identified one clear threshold for the Large Gorgonian Coral Functional Group (Table 30, Figure 58). The catches ≥ 0.7 kg delineated the VME polygons. There was an 82.8% increase in area going from the 0.7 kg contour to the 0.5 kg contour (Table 30, Figure 59), which was established with 7 additional points. These VME polygons contain 67 data records, accounting for 68.4% of the data (Figure 60) and capture the high density areas in Flemish Pass seen in the KDE surface (Figure 57). The Large Gorgonian Coral VME polygons overlap with those produced in the 2019 analyses (Figure 61), at least for the larger polygons. Some of the small VME polygons along the canyon heads on the Tail of Grand Banks should be considered for protection as one of those has one of the higher density catches (Figure 57).



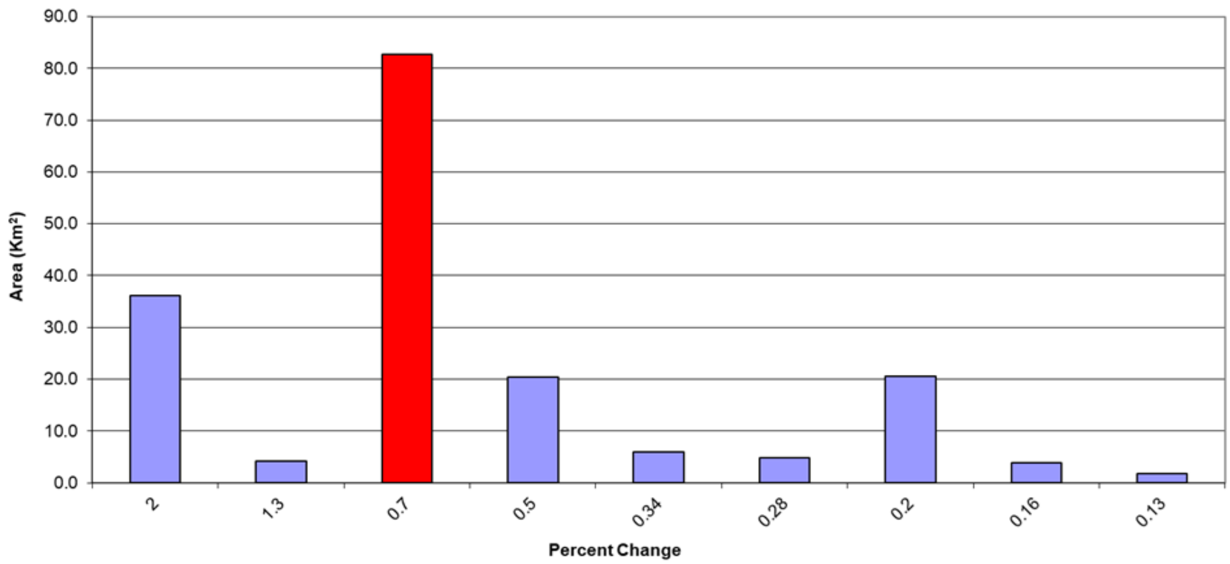


Figure 58. Bar graphs of the polygon area established by successively smaller research vessel Large Gorgonian Coral Functional Group catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

Table 30. The area of Large Gorgonian Coral Functional Group VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Large Gorgonian Coral Functional Group Catch Threshold (Kg)	Total Number of Observations in Polygon	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
10	14	8		590.6	191.3
3	39	17	9	1720.2	118.9
2	51	26	9	3765.1	36.1
1.3	63	35	9	5126.0	4.2
0.7	67	44	9	5338.8	82.8
0.5	76	51	7	9757.6	20.4
0.34	82	60	9	11746.5	5.9
0.28	88	69	9	12443.9	4.8
0.2	91	76	7	13039.8	20.5
0.16	93	84	8	15717.8	3.8
0.13	96	92	8	16320.8	1.8
0.1	98	98	6	16619.1	

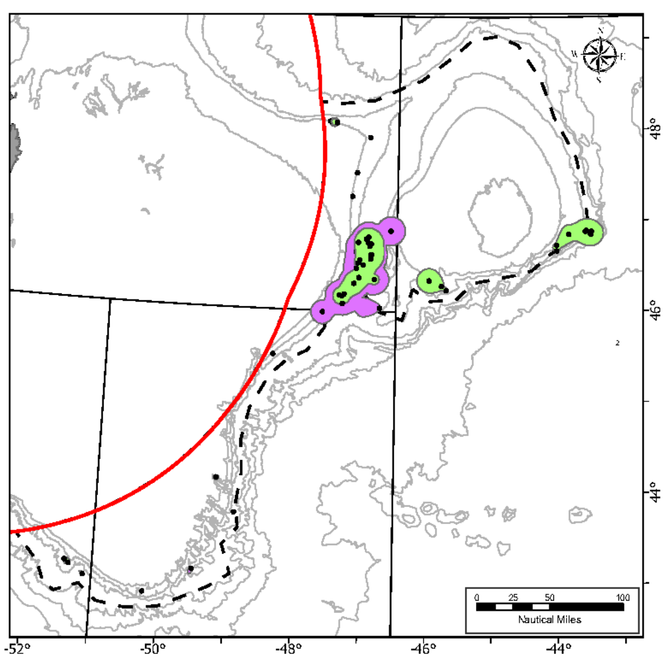


Figure 59. Comparison of the areas covered by Large Gorgonian Coral Functional Group catches ≥ 0.70 kg (green) and catches ≥ 0.50 kg (purple). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

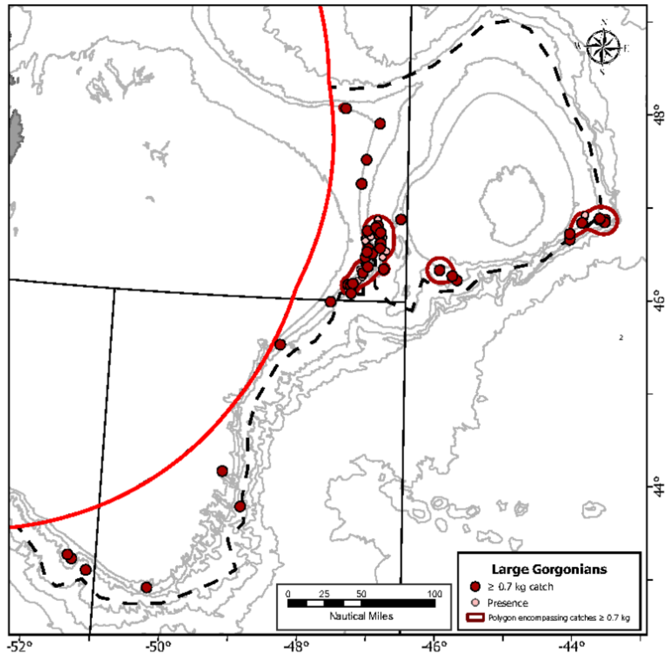


Figure 60. Illustration of the Large Gorgonian Coral Functional Group VME polygons (red outline), catches ≥ 0.7 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

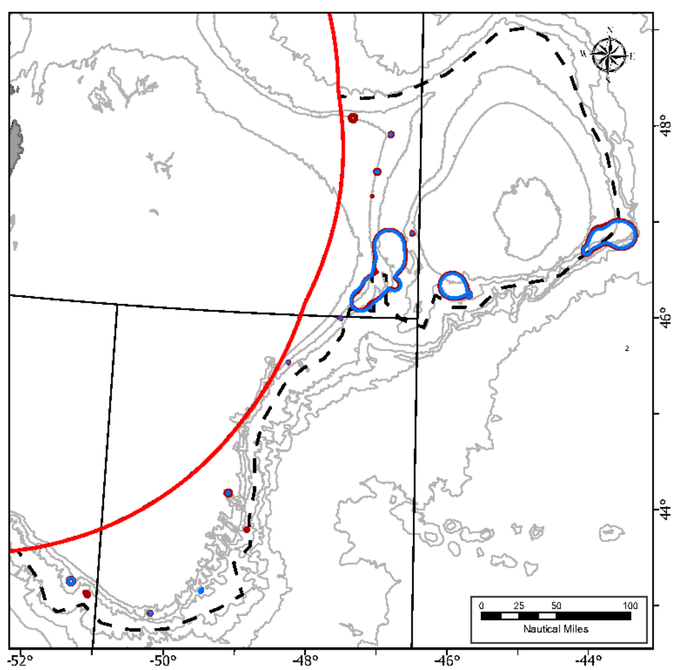


Figure 61. Comparison of the 2019 Large Gorgonian Coral Functional Group VME polygons (blue outline) with the Large Gorgonian Coral Functional Group VME polygons established in the new 2025 analysis (red outline). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Small Gorgonian Coral Functional Group

Records for the Small Gorgonian Coral Functional Group included 'Acanella', 'Acanella arbuscula', 'ACANELLA ARBUSCULA', 'Anthothela', 'Anthothelidae', 'Anthothela grandiflora', 'Radicipes', 'Radicipes gracilis', 'RADICIPES SP', 'Radicipes sp.', 'Radicipes spp' as well as records provided for the functional group with no lower level taxon name (Murillo et al., 2025). Two taxa, 'Octocorallia sp. (SUBCLASS)' and 'Isididae' were excluded as they could include species from the Large Gorgonian Coral Functional Group (Murillo et al., 2025).

There were significant differences among the catch series for each survey associated with gear type (Appendix Table A10). When all records less than 0.02 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears (Appendix Table A10). Further, at this cut off there were no differences among the vessels used in the Canadian data. Therefore, only catches ≥ 0.02 kg/RV tow were included in the KDE analyses. The analyses were performed on 279 catches ≥ 0.02 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 22.1 km; Contour Interval = 0. 0001; Cell size default = 2,656.7 m. The biomass surface is shown in Figure 62. The highest biomass densities were found in NAFO Division 3O on the Tail of Grand Bank and were very similar in location to those identified in 2019 (Kenchington et al., 2019).

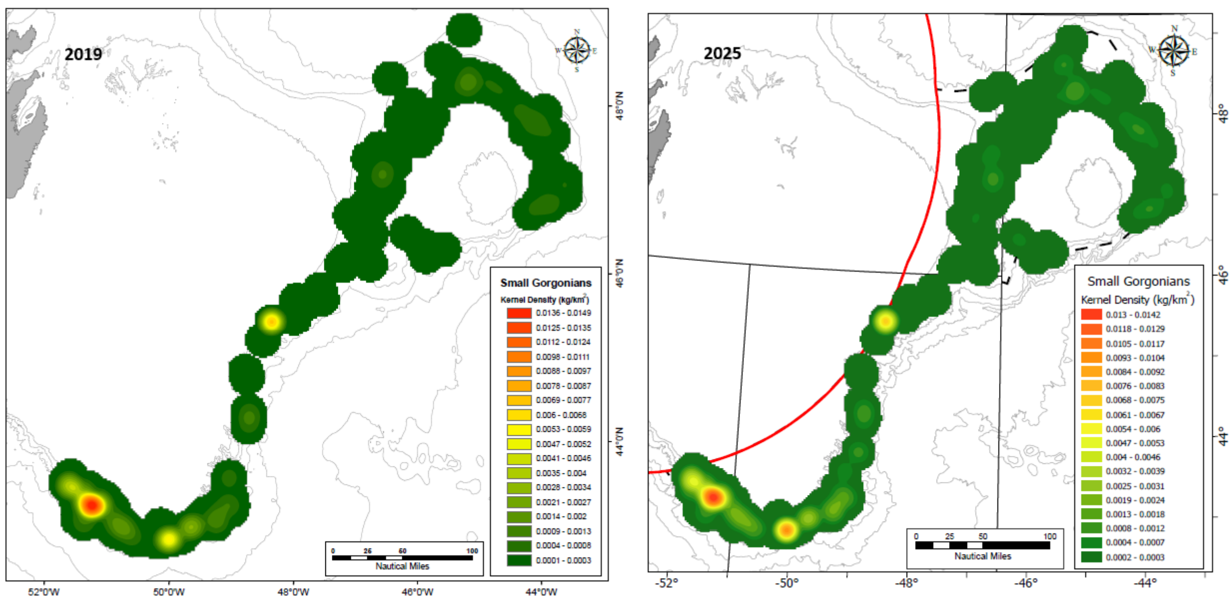


Figure 62. Kernel density biomass surfaces of the Small Gorgonian Coral Functional Group in the NAFO Regulatory Area comparing the surface created in 2019 with that created in 2025.

The areal increase with each catch interval (Table 31, Figures 63, 64) identified new areas through to the 0.065 kg/RV tow catch threshold. In moving from the 0.065 kg to the 0.05 kg density contour there was a 56.1% increase in area, established with 29 additional data points. This change was considered robust, and the 0.065 kg/ RV tow was selected as the threshold for identifying the Small Gorgonian Coral VME polygons.

Table 31. The area of Small Gorgonian Coral Functional Group VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Small Gorgonian Coral Functional Group Catch Threshold (Kg)	Total Number of Observations in Polygon	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
1	42	7		333.8	391.9
0.5	70	11	4	1641.8	109.4
0.3	106	18	7	3437.9	55.5
0.2	132	32	14	5345.8	22.9
0.15	154	46	14	6572.0	8.9
0.125	158	55	9	7157.5	14.6
0.1	168	70	15	8199.3	23.5
0.08	182	85	15	10126.7	32.1
0.065	199	104	19	13379.7	56.1
0.05	227	133	29	20881.1	24.0
0.04	247	157	24	25897.2	7.6
0.035	251	172	15	27877.7	13.2
0.03	260	195	23	31550.3	8.0
0.025	270	220	25	34089.5	4.5
0.022	274	238	18	35608.6	0.4
0.021	275	247	9	35763.4	36.6
0.02	279	279	32	48867.8	

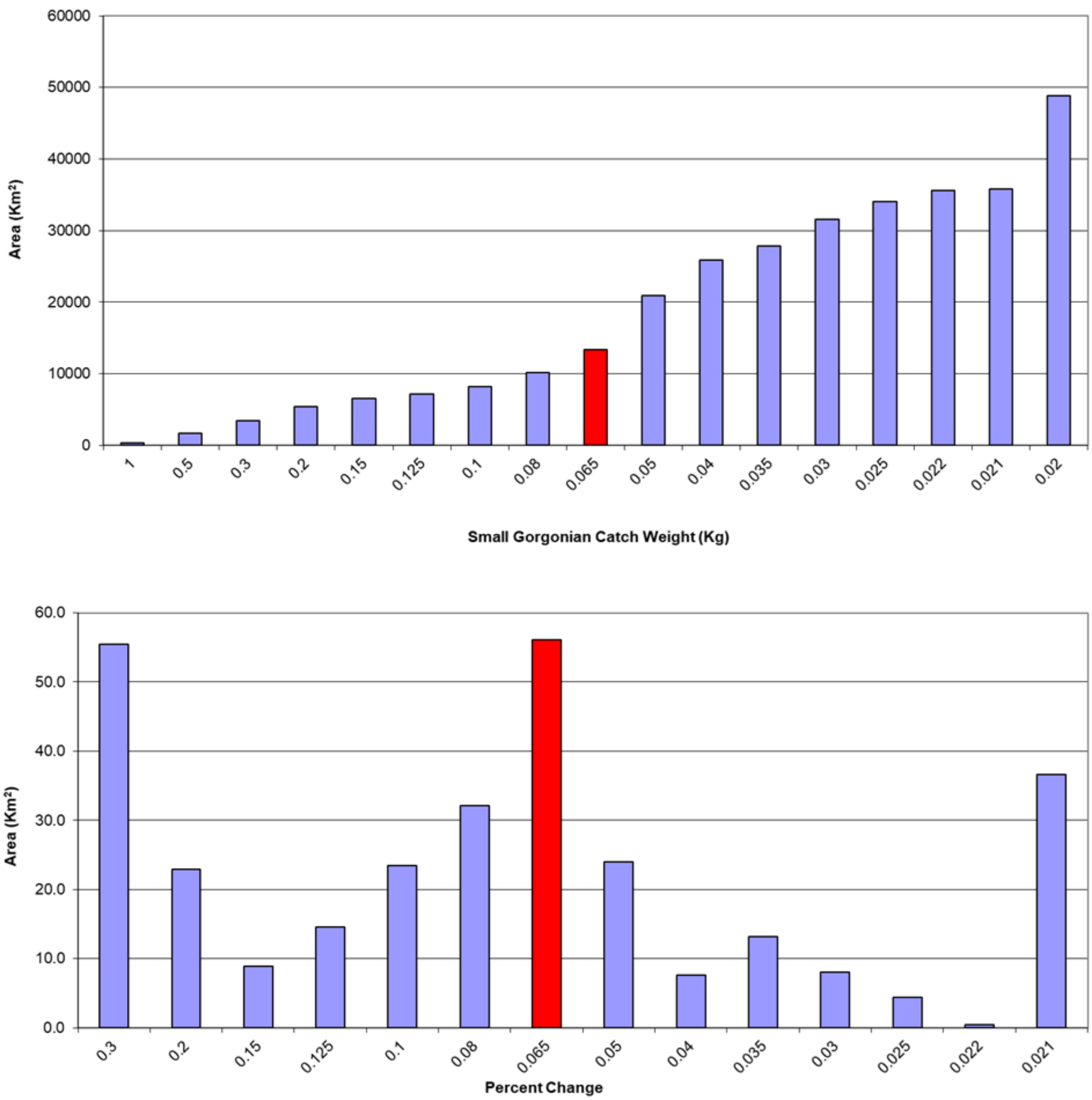


Figure 63. Bar graphs of the polygon area established by successively smaller research vessel Small Gorgonian Coral Functional Group catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

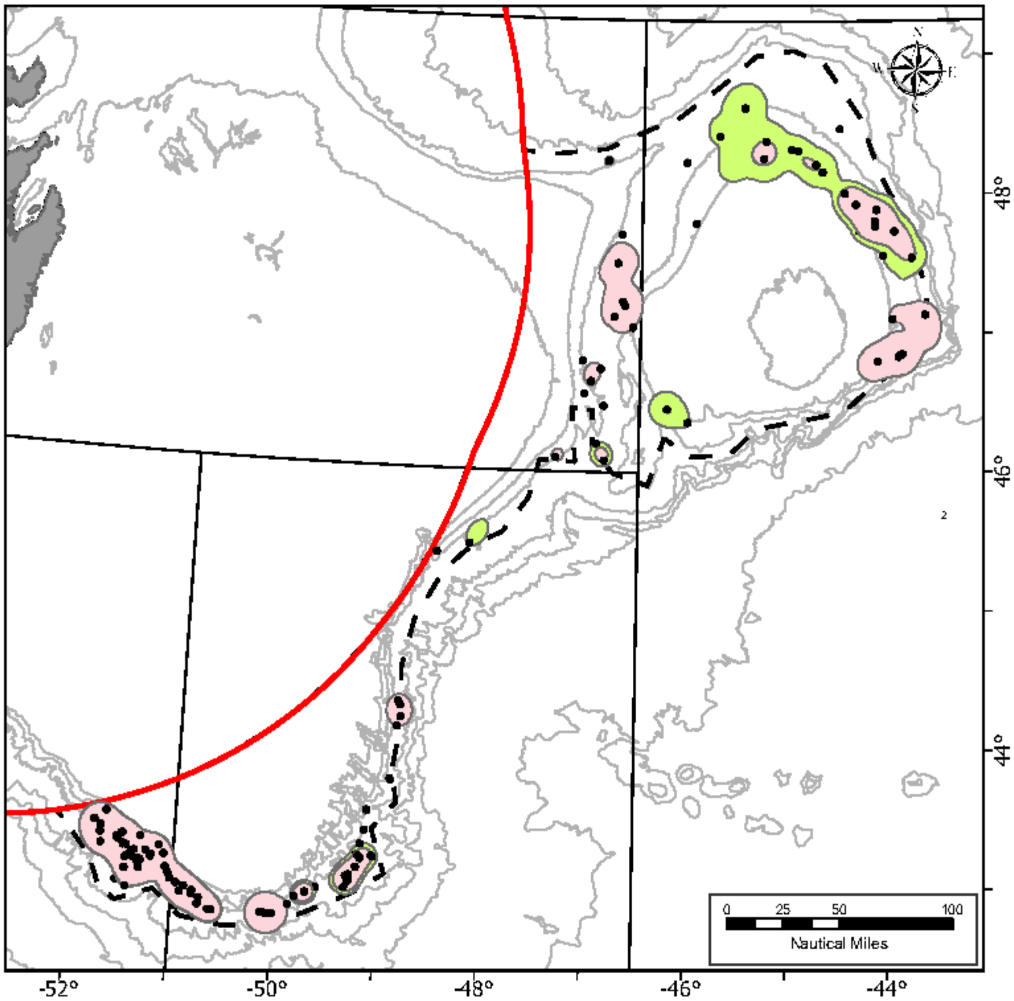


Figure 64. Comparison of the areas covered by Small Gorgonian Coral Functional Group catches ≥ 0.065 kg (pink) and catches ≥ 0.05 kg (green). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

The Small Gorgonian Coral VME polygons cover an area of 13379.7 km² and contain 199 data points representing 71.3% of the data (Table 31, Figure 65). The new KDE polygons match well with those from the 2019 analyses in the Division 3O region on the Tail of Grand Bank (Figure 66), however, the new analysis which included 61 more data records in the creation of the KDE surface, identified areas on Flemish Cap and in Flemish Pass that were not in the previous analyses.

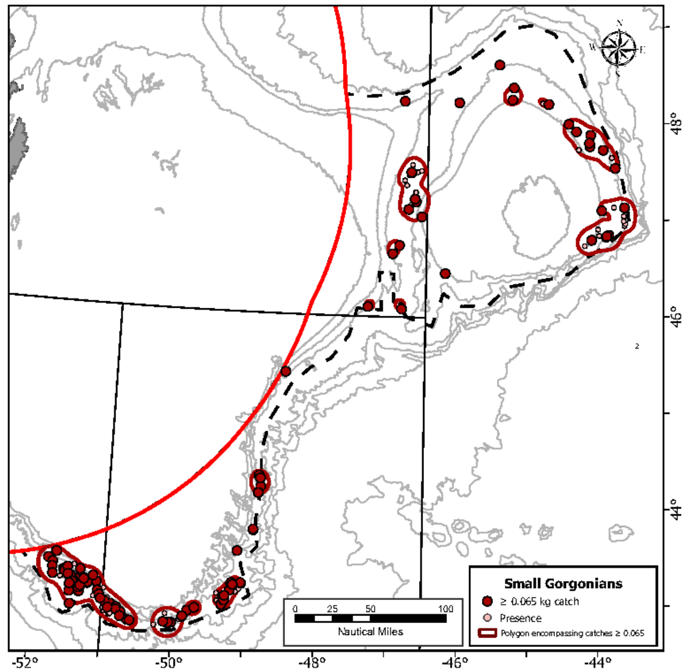


Figure 65. Illustration of the Small Gorgonian Coral Functional Group VME polygons (red outline), catches ≥ 0.065 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

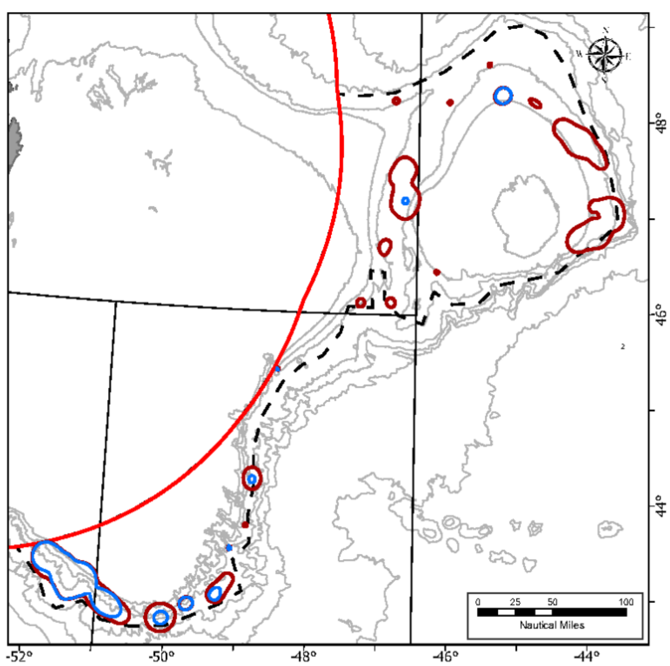


Figure 66. Comparison of the 2019 Small Gorgonian Coral Functional Group VME polygons (blue outline) with the Small Gorgonian Coral Functional Group VME polygons established in the new 2025 analysis (red outline). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

***Acanella arbuscula* Corals**

Acanella arbuscula (Johnson, 1862) is a small gorgonian coral belonging to the family Keratoisididae in the order Scleralcyonacea. This species inhabits soft sediments in the northwest Atlantic and has an overall depth range of 150–4800 m. Records for *Acanella arbuscula* were recorded as 'Acanella', 'Acanella arbuscula' or 'ACANELLA ARBUSCULA'. Data for these taxa were recorded from 2002 to 2024.

There were significant differences among the catch series for each survey associated with gear type (Appendix Table A11). When all records less than 0.02 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears (Appendix Table A11). Further, at this cut off there were no differences among the vessels used in the Canadian data. Therefore, only catches ≥ 0.02 kg/RV tow were included in the KDE analyses. The analyses were performed on 204 catches ≥ 0.02 kg. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 21.31 km; Contour Interval = 0. 00001; Cell size default = 2,555.7 m. The biomass surface is shown in Figure 67. The highest biomass densities were found in NAFO Division 3O on the Tail of Grand Bank.

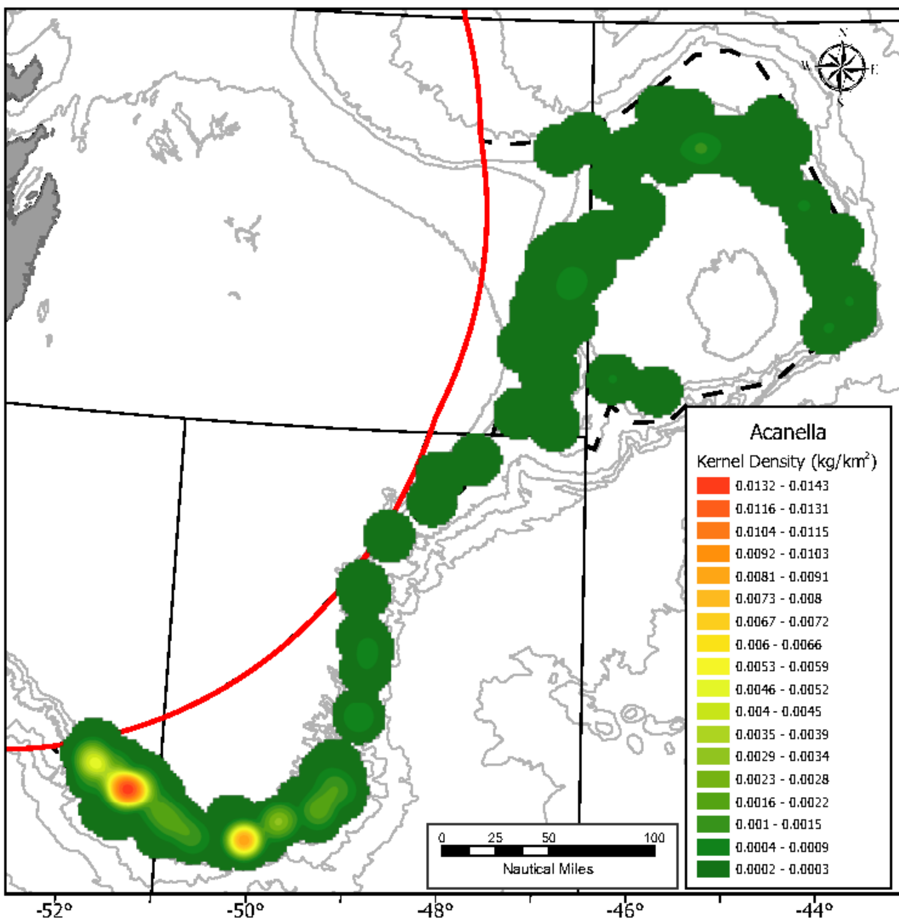


Figure 67. Kernel density biomass surface of *Acanella arbuscula* in the NAFO Regulatory Area.

Table 32. The area of *Acanella arbuscula* VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Acanella arbuscula **Catch Threshold (Kg)**	**Total Number of Observations in Polygon**	**Number of Observations in Polygon > Weight Threshold**	**Additional Observations Per Interval > Weight Threshold**	**Area of Polygon (km²)**	**Percent Change in Area Between Successive Thresholds**
1	32	6		291.2	483.8
0.4	61	12	6	1699.9	95.9
0.28	94	22	10	3330.8	23.9
0.17	114	31	9	4127.3	0.4
0.14	118	42	11	4143.6	32.9
0.1	131	55	13	5508.5	0.0
0.08	131	64	9	5508.5	38.4
0.065	146	77	13	7623.6	22.9
0.055	155	88	11	9369.4	8.2
0.05	157	99	11	10142.0	26.5
0.04	166	112	13	12826.0	9.2
0.035	170	124	12	14001.5	22.8
0.03	177	141	17	17190.3	24.8
0.025	193	163	22	21449.2	0.0
0.022	194	174	11	21457.9	42.6
0.02	204	204	30	30605.4	

Two potential thresholds emerged from the examination of the kernel density analyses (Table 32, Figure 68), the 0.14 kg /RV tow and the 0.08 kg/ RV tow. The 0.08 threshold added 13 additional points in moving to the 0.065 threshold but none of these were in the newly created areas (Figure 69) and so this threshold was not supported by any data. The 0.14 kg threshold added 13 additional points as well but included two data points in the new area created on the Tail of Grand Bank (Figure 69). Therefore the 0.14 kg threshold was selected to delineate the *Acanella arbuscula* VME polygons. There were 118 data points both above and below the catch threshold falling in those VME polygons, representing 57.8% of the data (Figure 70). They capture the high density areas identified on the Tail of Grand Bank (Figure 67). All of the *Acanella arbuscula* VME polygons fall within the polygons created by the Small Gorgonian Coral Functional Group (Figure 71).

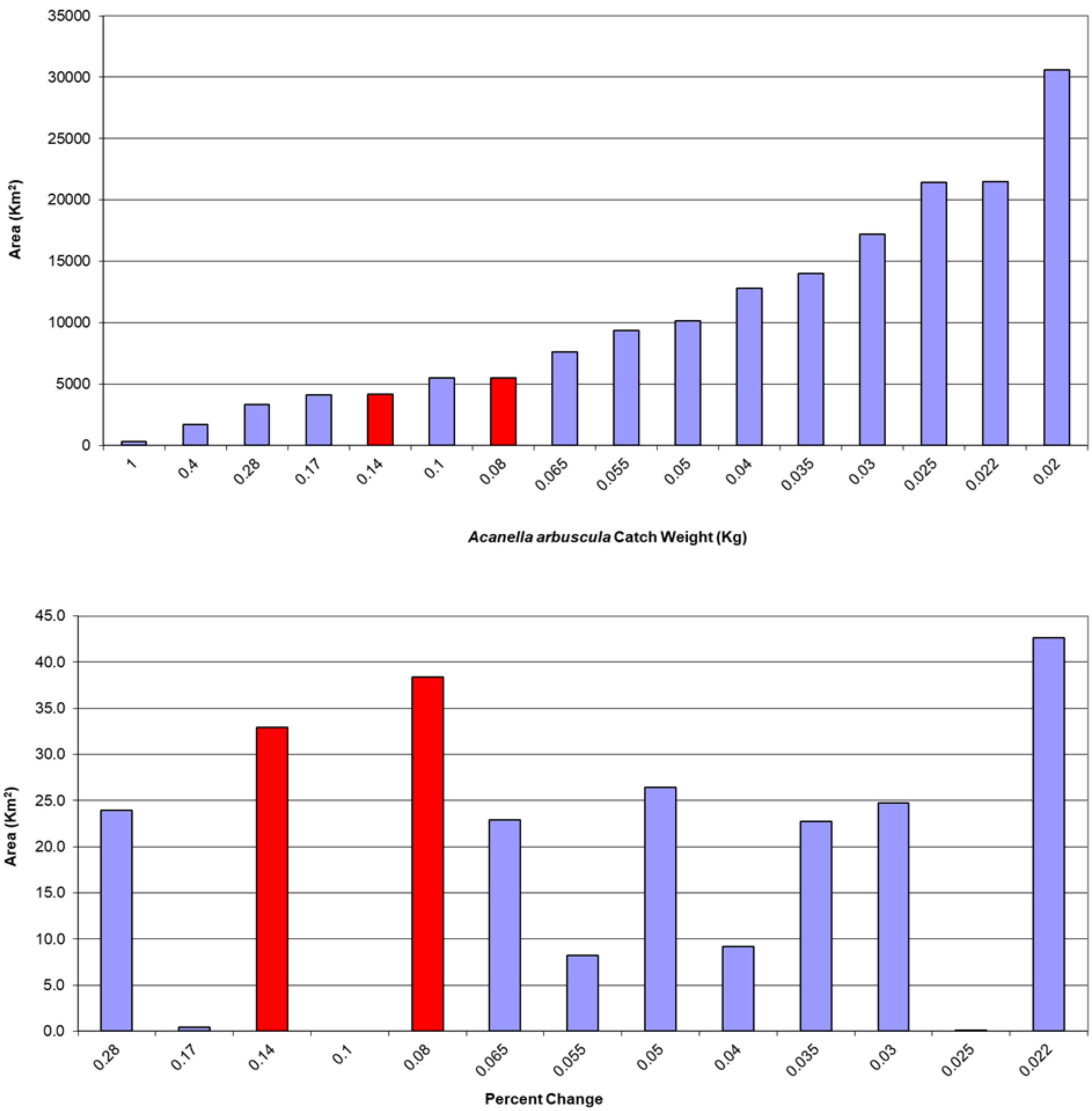


Figure 68. Bar graphs of the polygon area established by successively smaller research vessel *Acanella arbuscula* catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

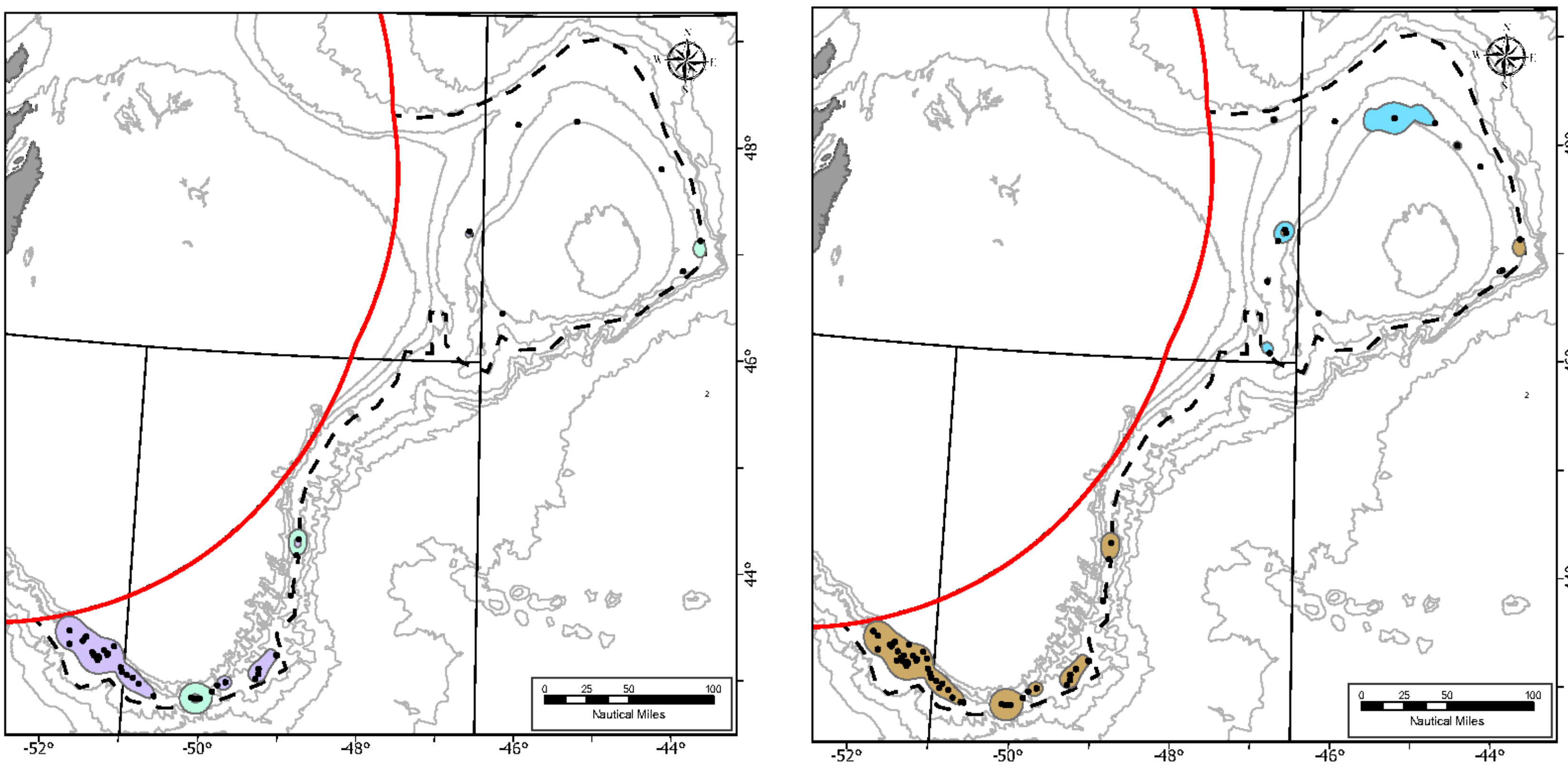


Figure 69. Comparison of the areas covered by *Acanella arbuscula* catches ≥ 0.14 kg (purple) and catches ≥ 0.10 kg (turquoise) (left panel); catches ≥ 0.08 kg (gold) and catches ≥ 0.065 kg (blue) (right panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

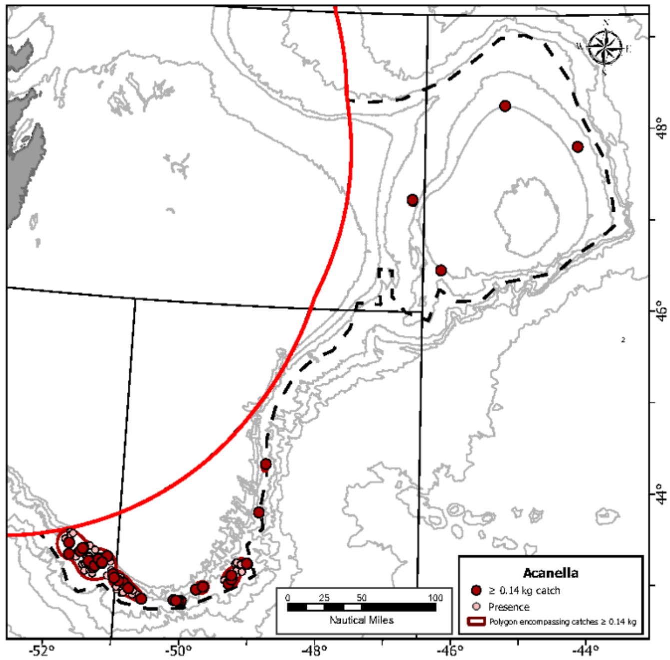


Figure 70. Illustration of the *Acanella arbuscula* VME polygons (red outline), catches ≥ 0.14 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

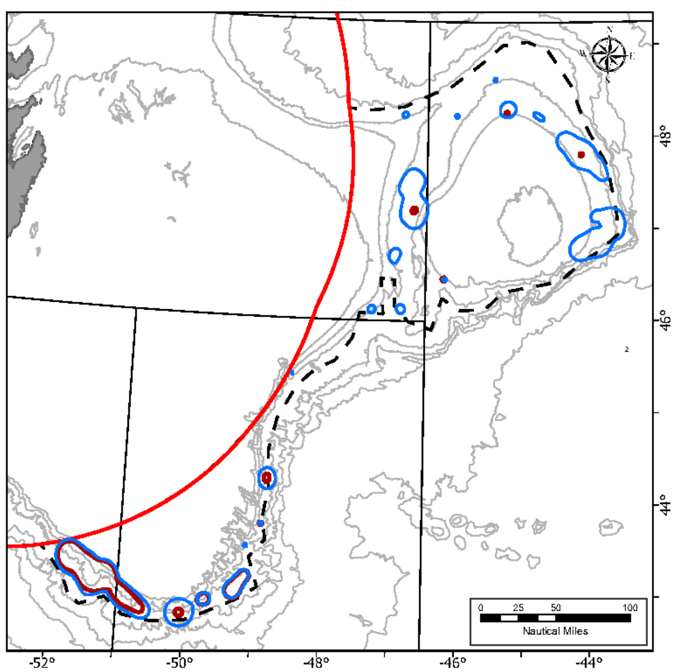


Figure 71. Comparison of the *Acanella arbuscula* VME polygons (red outline) with the Small Gorgonian Coral Functional Group VME polygons (blue outline) established in the new 2025 analysis. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

***Radicipes gracilis* Corals**

Radicipes gracilis (Verrill, 1884) is a small gorgonian coral belonging to the family Chrysogorgiidae in the order Scleralcyonacea. It is found on soft sandy or muddy bottoms at depths from 500 to 3259 metres. Records for *Radicipes gracilis* were recorded as 'Radicipes', 'Radicipes gracilis', 'RADICIPES SP', 'Radicipes sp.' and 'Radicipes spp'. Data for these taxa were recorded from 2007 to 2024.

There were no significant differences among the catch series for each survey associated with tow duration or gear type (Appendix Table A12), and so all of the data could be used in the analyses. As there were only four records from the Canadian surveys, and those were all from the same vessel (CCGS *Teleost*) differences among the vessels used in the Canadian data were not evaluated. The analyses were performed on 162 catches. Following previously established methods and assessment criteria, a kernel density surface was created, and the area of successive density polygons calculated. KDE parameters were: Search Radius = 21.6 km; Contour Interval = 0. 000001; Cell size default = 2,596.3 m. The biomass surface is shown in Figure 72. The highest biomass densities were found in NAFO Division 3O on the Tail of Grand Bank, and on Sackville Spur on Flemish Cap.

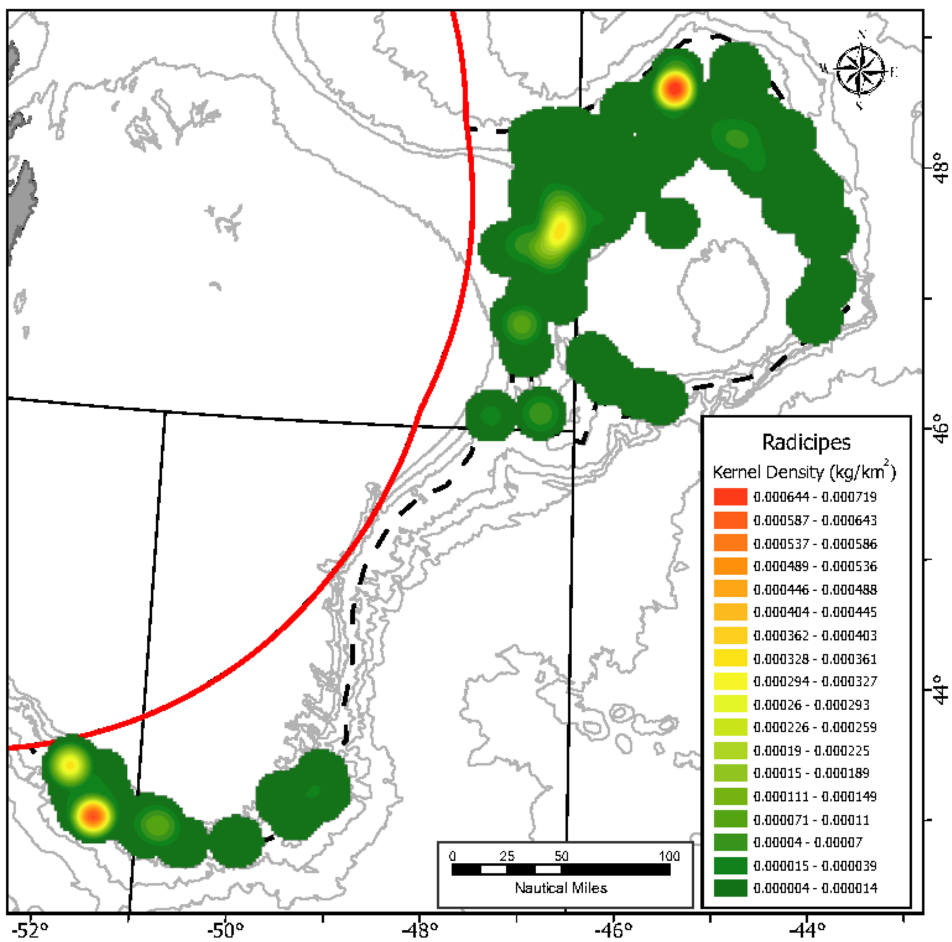


Figure 72. Kernel density biomass surface of *Radicipes gracilis* in the NAFO Regulatory Area.

Table 33. The area of *Radicipes gracilis* VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Radicipes gracilis **Catch Threshold (Kg)**	**Total Number of Observations in Polygon**	**Number of Observations in Polygon > Weight Threshold**	**Additional Observations Per Interval > Weight Threshold**	**Area of Polygon (km²)**	**Percent Change in Area Between Successive Thresholds**
0.1	3	3		11.8	10719.5
0.04	23	10	7	1278.2	115.3
0.02	40	18	8	2752.4	2.4
0.01	43	26	8	2817.5	52.8
0.006	53	33	7	4304.4	64.5
0.004	76	44	11	7078.7	67.9
0.003	100	57	13	11885.6	50.4
0.002	137	94	37	17870.3	67.9
0.0008	162	162	68	30000.5	

Examination of the results from the KDE analysis (Table 33, Figures 72,73) showed two potential thresholds for the VME polygons for *Radicipes gracilis*, 0.006 kg/RV tow and 0.004 kg/RV tow. The change in area in moving from the 0.006 kg density contour to the 0.004 kg was 64.5% and there were 11 additional points incorporated (Table 33). The areas show similar spatial coverage although at 0.004 kg there is a polygon enlargement on Flemish Cap which appears well supported (Figure 74). The next potential threshold was 0.004 kg and there was a 67.9% increase in area in moving to the 0.003 kg KDE contour. That increase in area was supported by 13 additional data points and much of the area was in NAFO Division 3O (Figure 74). As this change in area is greater than the first threshold examined, was well supported by the data and included the area on Flemish Cap that was not highlighted in the 0.006 kg contours, the 0.004 kg/RV tow threshold was selected to represent the *Radicipes gracilis* VME polygons.

There are 76 data points within the *Radicipes gracilis* VME polygons comprising 46.9% of the data (Figure 75). There is overlap with the Small Gorgonian Coral Functional Group VME polygons (Figure 76), however the *Radicipes gracilis* VME polygon in Flemish Pass extends beyond the functional group polygons with a number of occurrences evident. Although the VME polygon in Division 3O lies partially outside the functional group polygon there, the inset to Figure 76 shows that the data points were inside or bordering the functional group polygon.

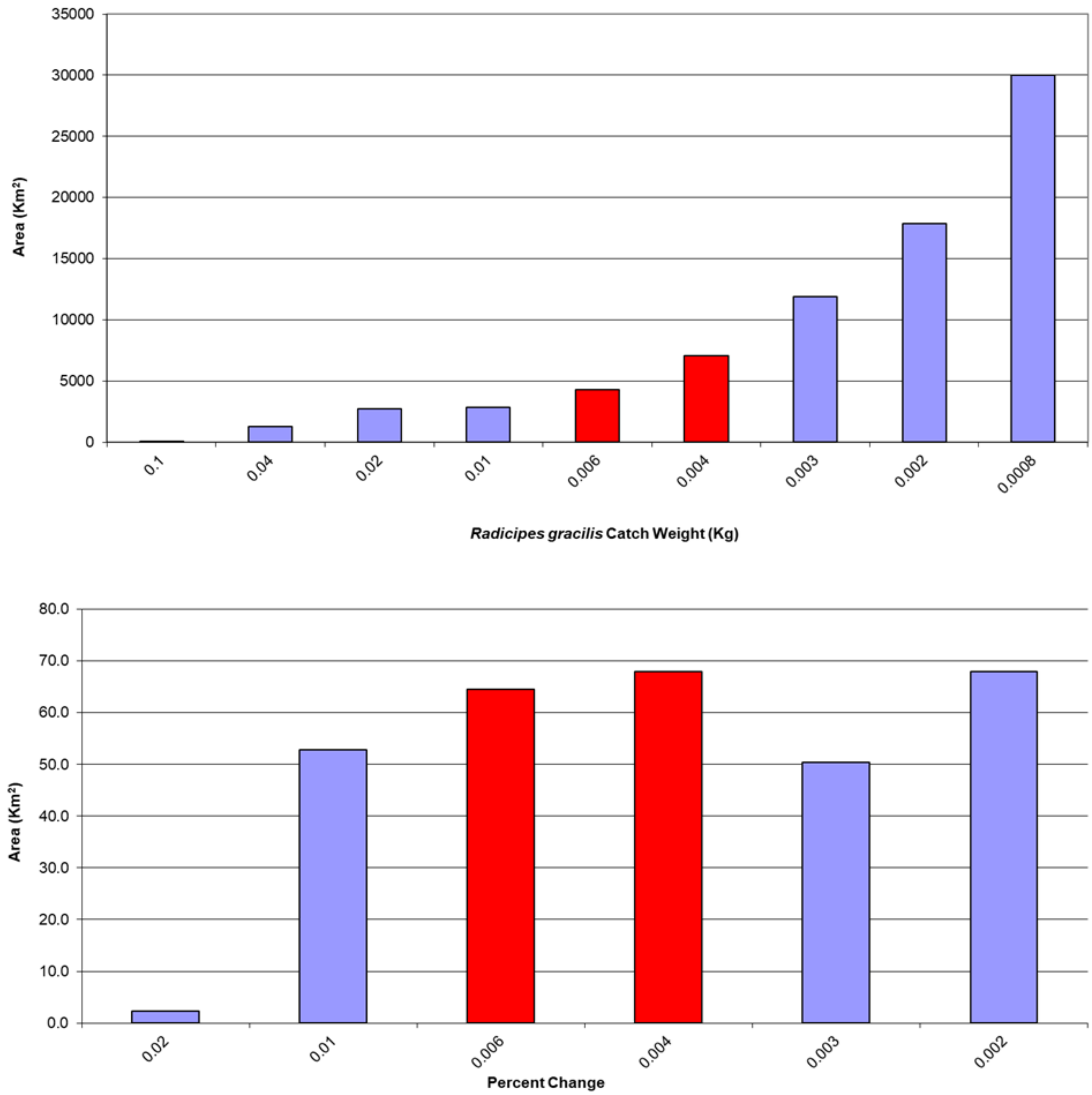


Figure 73. Bar graphs of the polygon area established by successively smaller research vessel *Radicipes gracilis* catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

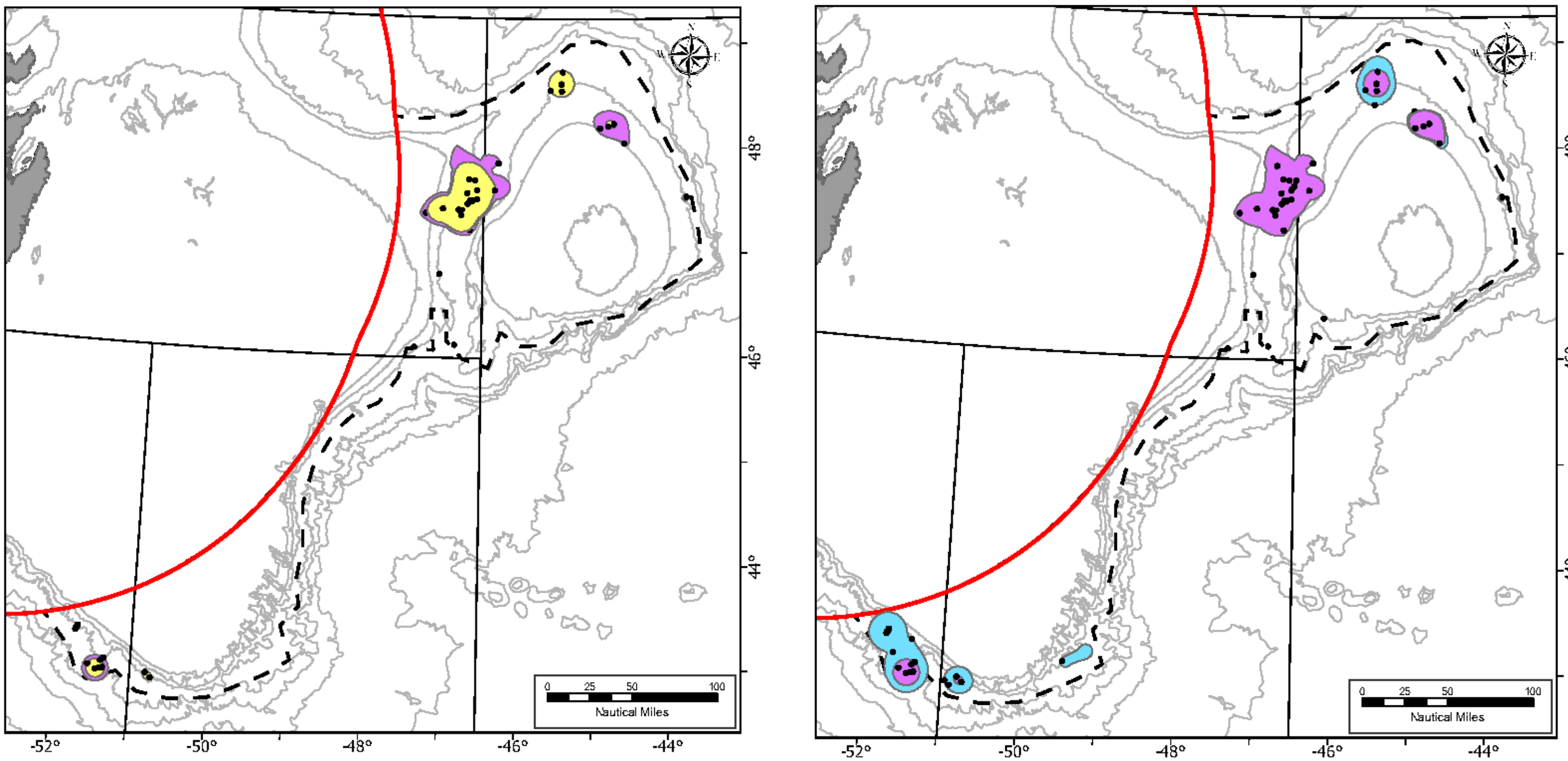


Figure 74. Comparison of the areas covered by *Radicipes gracilis* catches ≥ 0.006 kg (yellow) and catches ≥ 0.004 (purple) (left panel); catches ≥ 0.004 kg (purple) and catches ≥ 0.003 kg (blue) (right panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

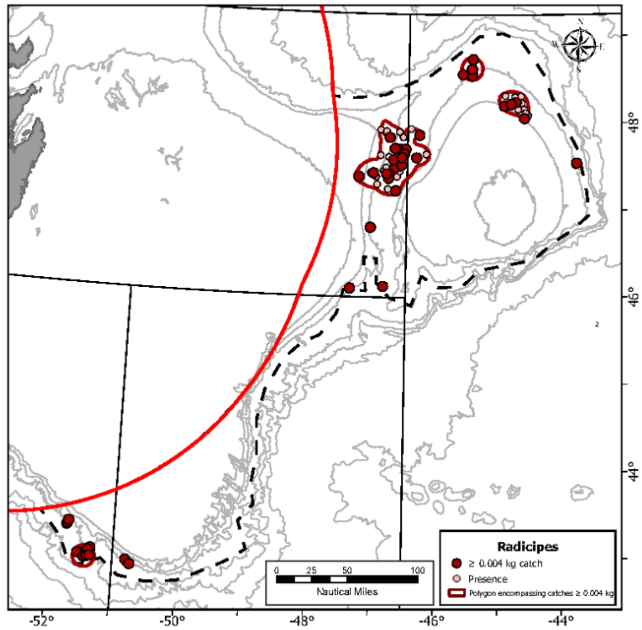


Figure 75. Illustration of the *Radicipes gracilis* VME polygons (red outline), catches ≥ 0.004 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

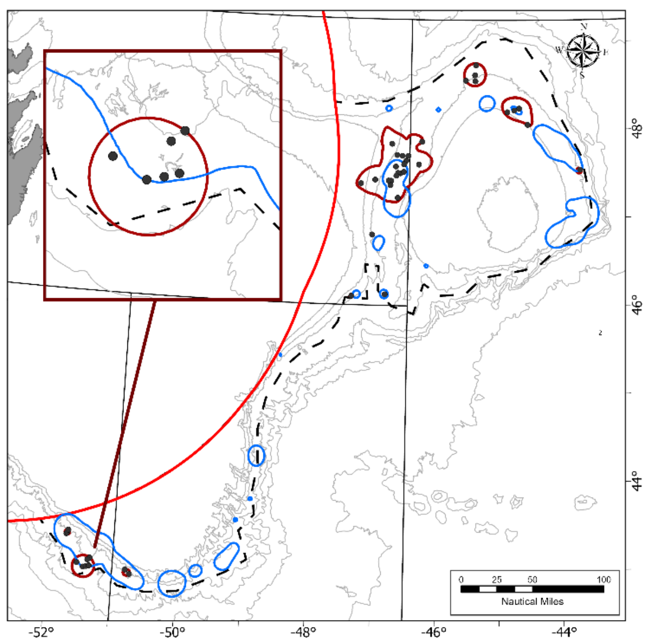


Figure 76. Comparison of the *Radicipes gracilis* VME polygons (red outline) with the Small Gorgonian Coral Functional Group VME polygons (blue outline) established in the new 2025 analysis. Black circles show location of catches above the catch threshold used to establish the VMEs. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone. Inset shows *Radicipes gracilis* points above the threshold falling inside or bordering the Small Gorgonian Coral Functional Group VME polygon. Inset shows location of data points in 3O in close-up view.

Erect Bryozoans Functional Group

These records were compiled from those identified at sea as 'BRYOZOA', and 'Bryozoa', and also included the data for the functional group but with no taxon name provided. Five records listed as 'BRYOZOAN ECT. OR ENT.' were excluded (see Murillo et al., 2025). The VME Indicator listed in the NAFO Conservation and Enforcement Measures (NAFO, 2025) is *Eucratea loricata* (Linnaeus, 1758).

There were significant differences among the catch series for each survey associated with gear type (Appendix Table A13). When all records less than 0.02 kg were removed, there was no significant difference among the catch distributions by tow duration with the Campelen 1800 gear, nor between the Campelen 1800 and Lofoten trawl gears (Appendix Table A13). There were only 12 Canadian records above the threshold, and they were all from the CCGS *Needler*. To examine the vessel effect, all of the Canadian data were used to test the difference between the catches form the CCGS *Needler* and the CCGS *Teleost*, and no significant differences were found (Appendix Table A13). KDE parameters were: Search Radius = 17.1 km; Contour Interval = 0. 00005; Cell size default = 2,055.52 m. The biomass surface is shown in Figure 77. The highest biomass densities were found on the Tail of Grand Bank and were very similar in location to those identified in 2019 (Figure 77).

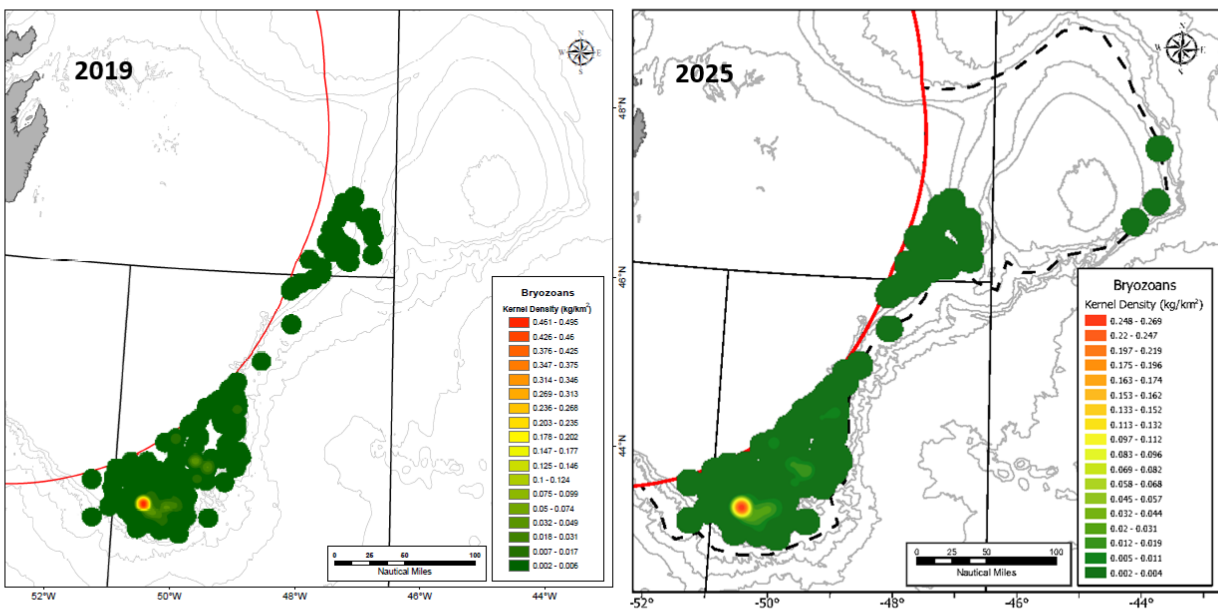


Figure 77. Kernel density biomass surface of the Erect Bryozoan Functional Group in the NAFO Regulatory Area comparing the surface created in 2019 with that created in 2025.

Examination of the KDE analyses for the Erect Bryozoan Functional Group showed one strong candidate for the VME catch threshold (Table 34, Figure 78), the 0.2 kg/RV tow. In moving from the 0.2 kg density contour to the 0.13 kg density contour there was a 62.2% increase in area, supported by 12 additional points (Table 34, Figure 79). This change in area was robust and so the threshold was accepted. The VME polygons for the Erect Bryozoan Functional Group contains 86 data points accounting for 48.6% of the data (Figure 80). The VME areas are very similar in location to those assessed in 2019 (Figure 81).

Table 34. The area of the Erect Bryozoan Functional Group VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Erect Bryozoan Functional Group Catch Threshold (Kg)	Total Number of Observations in Polygon	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
2.5	24	8		1335.1	27.2
1	31	16	8	1698.2	116.0
0.6	48	23	7	3668.7	24.3
0.3	67	34	11	4559.2	41.0
0.2	86	43	9	6429.4	62.2
0.13	106	55	12	10425.5	19.3
0.1	118	71	16	12435.5	13.1
0.07	125	84	13	14064.2	31.6
0.06	143	95	11	18502.9	11.2
0.05	152	108	13	20569.1	3.9
0.04	159	120	12	21361.4	18.5
0.03	167	140	20	25311.5	18.3
0.023	177	155	15	29939.3	0.0
0.02	177	177	22	29939.3	

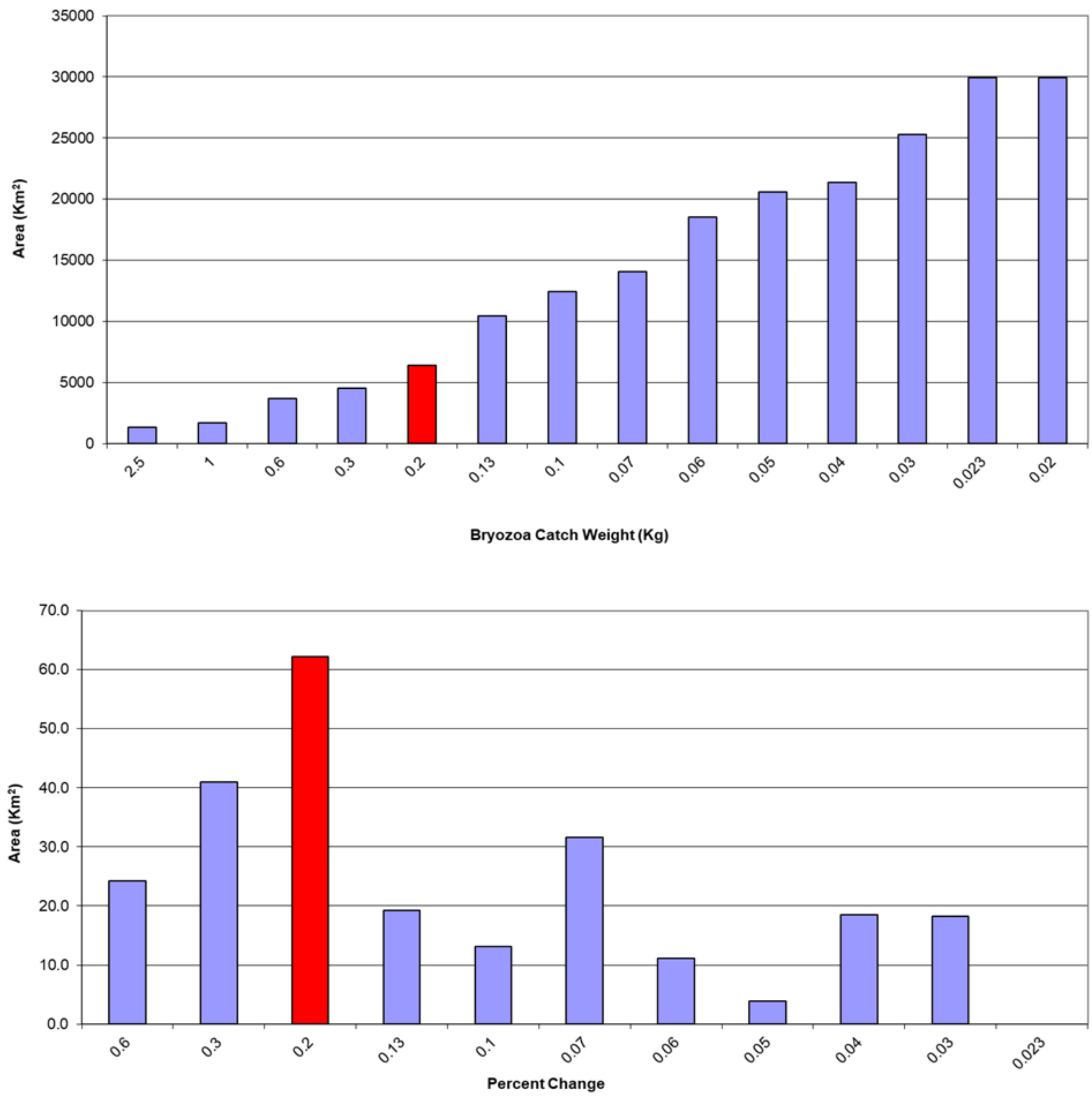


Figure 78. Bar graphs of the polygon area established by successively smaller research vessel Erect Bryozoan Functional Group catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

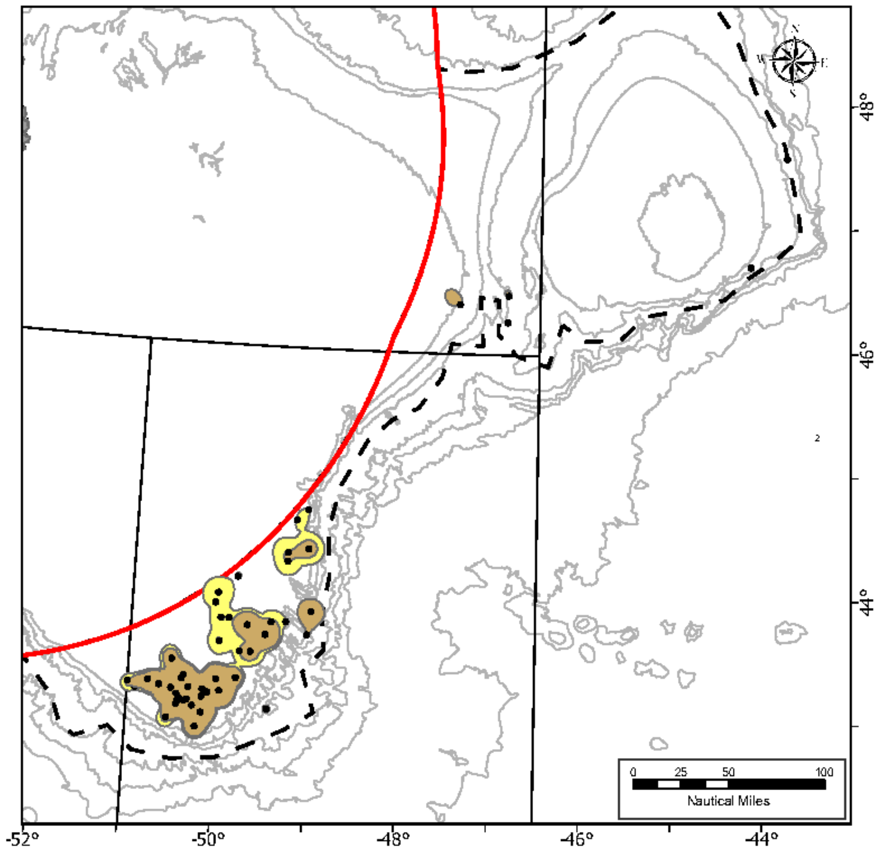


Figure 79. Comparison of the areas covered by Erect Bryozoan Functional Group catches ≥ 0.20 kg (brown) and catches ≥ 0.13 (yellow) (left panel). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

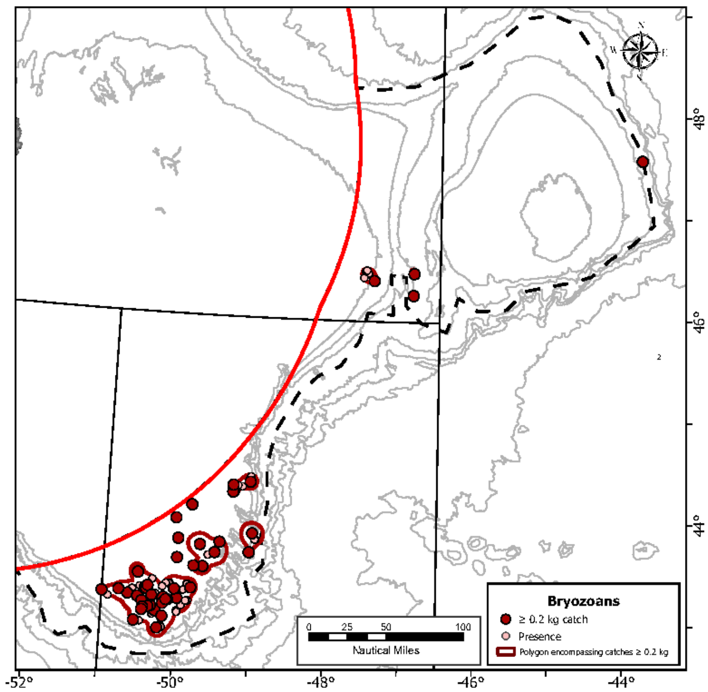


Figure 80. Illustration of the Erect Bryozoan Functional Group VME polygons (red outline), catches ≥ 0.20 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

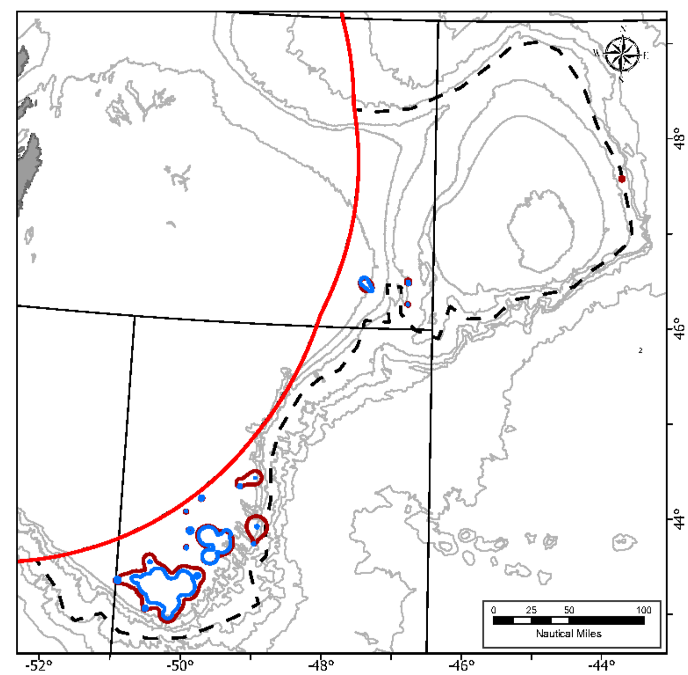


Figure 81. Comparison of the 2019 Erect Bryozoan Functional Group VME polygons (blue outline) with the Erect Bryozoan Functional Group VME polygons (red outline) established in the new 2025 analysis. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Sea Squirts Functional Group

Although the sea squirts are listed as a functional group, they are represented by a single species *Boltenia ovifera* (Linnaeus, 1767), a species of ascidian tunicate in the family Pyuridae. It is a solitary sea squirt with an orange, ball-shaped body up to eight centimetres long and attached by a long stalk to the seabed. The stalk can be two to four times the length of the body. It is commonly called the stalked tunicate. Records for *Boltenia ovifera* were recorded as 'BOLTENIA OVIFERA', 'BOLTENIA SP.', and 'TUNICATE, SESSILE' along with records provided under the Sea Squirts Functional Group (Murillo et al., 2025). The NAFO Conservation and Enforcement Measures also list *Halocynthia aurantium* (Pallas, 1787), or sea peach, as a VME Indicator for this group (NAFO, 2025), although they have not been identified in the trawl catches.

There were significant differences among the catch series for each survey associated with tow duration (Appendix Table A14). When all records less than 0.01 kg were removed, there was no significant difference among the catch distributions. All tows were made with the Campelen 1800 gear. There were no significant differences in catches ≥ 0.01 kg among the Canadian research vessels (Appendix Table A14).

There were 369 data points for the analysis above the ≥ 0.01 kg catch threshold. KDE parameters were: Search Radius = 10.1 km; Contour Interval = 0. 0001; Cell size default = 1,217.88 m. The biomass surface is shown in Figure 82. The highest biomass densities were found on the Tail of Grand Bank and were very similar in location to those identified in 2019 (Figure 82).

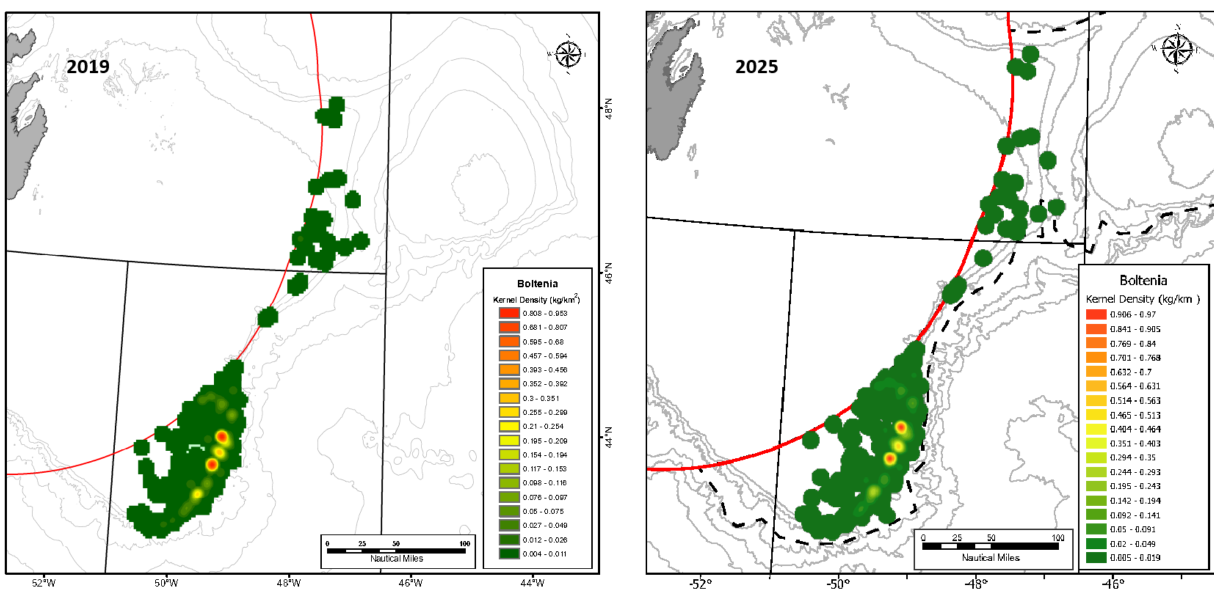


Figure 82. Kernel density biomass surface of the Sea Squirts Functional Group in the NAFO Regulatory Area comparing the surface created in 2019 with that created in 2025.

The results from the KDE analyses identified the 0.25 kg/RV tow as the catch threshold for the Sea Squirts (*Boltenia ovifera*) Functional Group VME polygons (Table 35, Figures 83, 84). The thresholds building to the 0.25 kg density contours identified new areas on the Tail of Grand Bank. The greatest increase in area was seen in moving from the 0.25 kg to the 0.20 kg density contours, where there was a 45.8% increase in area supported by 29 additional data points (Table 35). The selected threshold encompasses 5232.8 km^2 and captures the high density areas on the Tail of Grand Bank and the Southeast Shoal (Figures 82, 84).

There were data points inside of the Sea Squirts Functional Group VME polygons, representing 73.2% of the data (Figure 85). In comparison with the VME polygons produced for this VME indicator in 2019, the areas were very similar (Figure 86), with the new analyses largely overlapping with the previous one but extending the VME polygon to the south.

Table 35. The area of the Sea Squirts Functional Group VME polygons based on successively smaller research vessel catch weight thresholds (kg). The number of observations used to define each polygon and the percent change in area and the number of additional observations between successive thresholds are provided. The shaded rows represent catch thresholds investigated as potential VMEs.

Sea Squirts Functional Group Catch Threshold (Kg)	Total Number of Observations in Polygon	Number of Observations in Polygon > Weight Threshold	Additional Observations Per Interval > Weight Threshold	Area of Polygon (km²)	Percent Change in Area Between Successive Thresholds
6	44	10		206.1	176.3
3.5	78	23	13	569.6	51.8
2	103	40	17	864.4	4.5
1.5	112	54	14	903.1	145.2
1	185	71	17	2214.5	7.0
0.9	190	81	10	2368.7	29.0
0.6	222	97	16	3054.9	2.2
0.5	229	109	12	3122.3	33.3
0.4	251	122	13	4160.9	3.8
0.35	255	137	15	4320.7	19.5
0.3	267	154	17	5162.9	1.4
0.25	270	167	13	5232.8	45.8
0.2	298	196	29	7631.7	0.4
0.15	302	212	16	7662.2	12.6
0.1	313	246	34	8624.6	9.7
0.08	323	268	22	9463.4	24.7
0.05	344	293	25	11796.4	16.4
0.03	360	335	42	13725.3	43.4
0.01	369	369	34	19685.7	

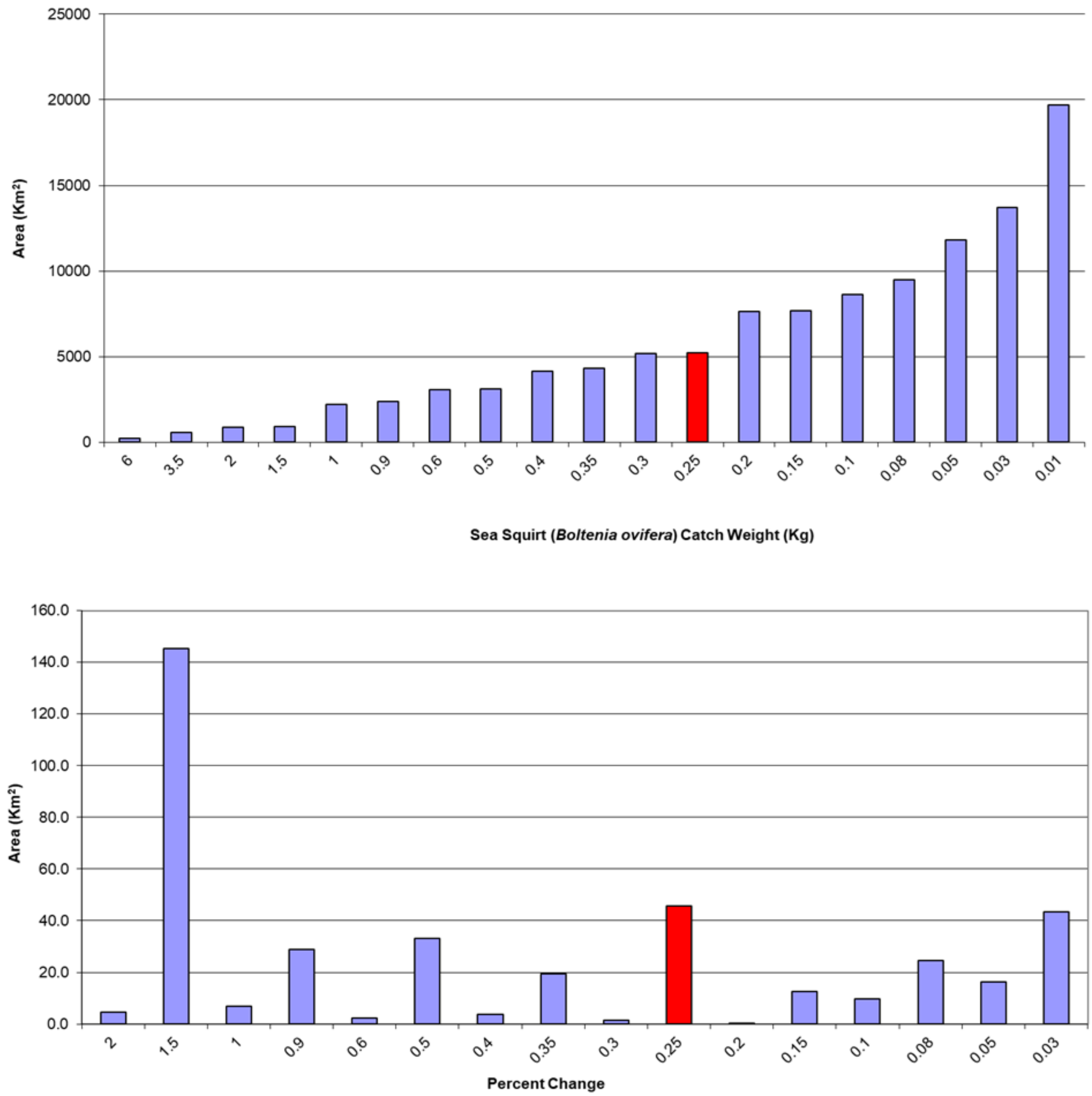


Figure 83. Bar graphs of the polygon area established by successively smaller research vessel Sea Squirts Functional Group catch weight thresholds (upper panel) and of the percent change in area created between successively smaller research vessel catch weight thresholds (lower panel). Red bars indicate potential VME polygon thresholds examined.

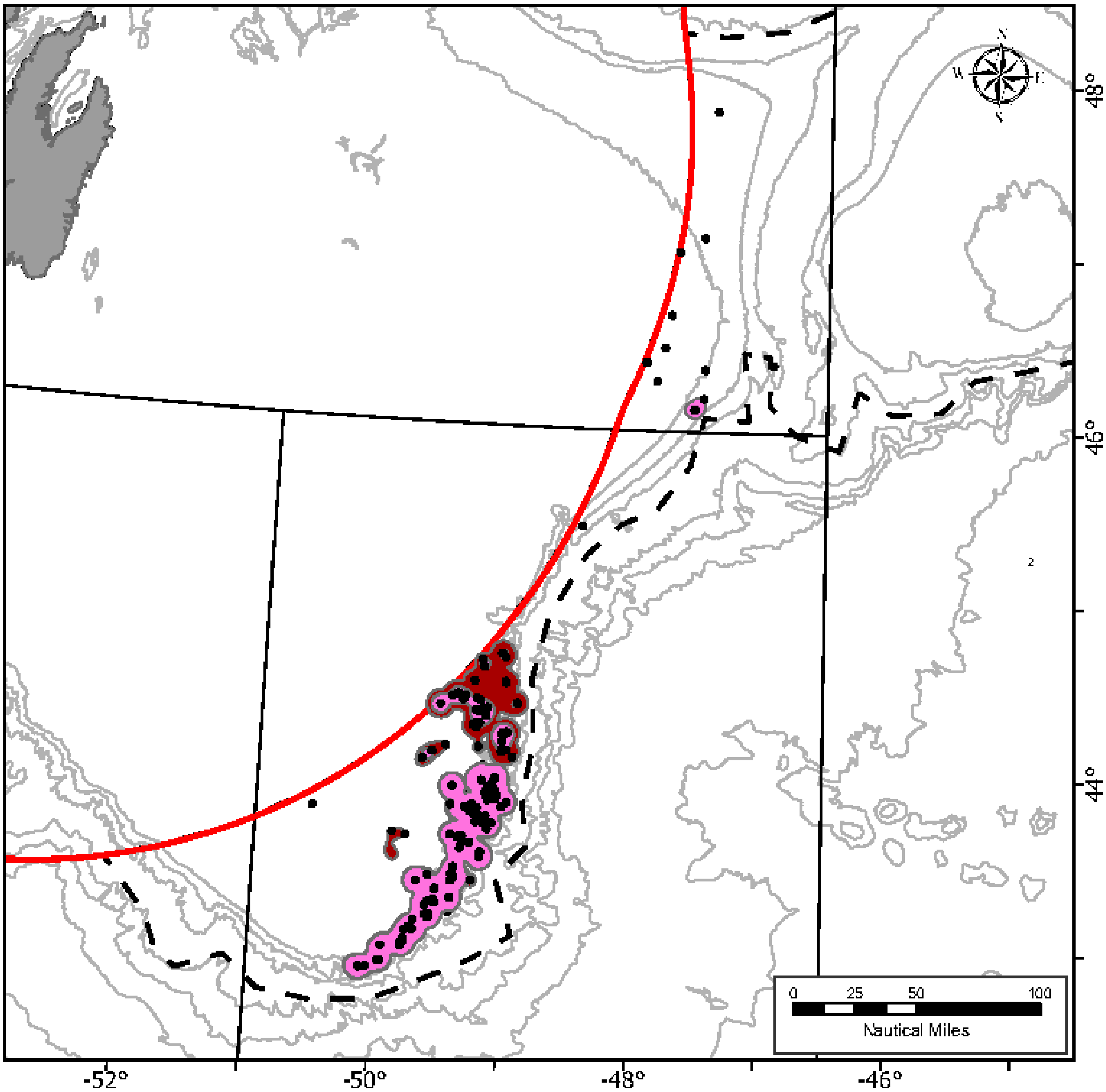


Figure 84. Comparison of the areas covered by Sea Squirts Functional Group catches ≥ 0.25 kg (pink) and catches ≥ 0.20 (red). The location of trawl sets ≥ the lowest threshold for the two intervals in each panel are shown. Solid red line represents the Canadian Exclusive Economic Zone. Black dashed line is the NAFO fishing footprint.

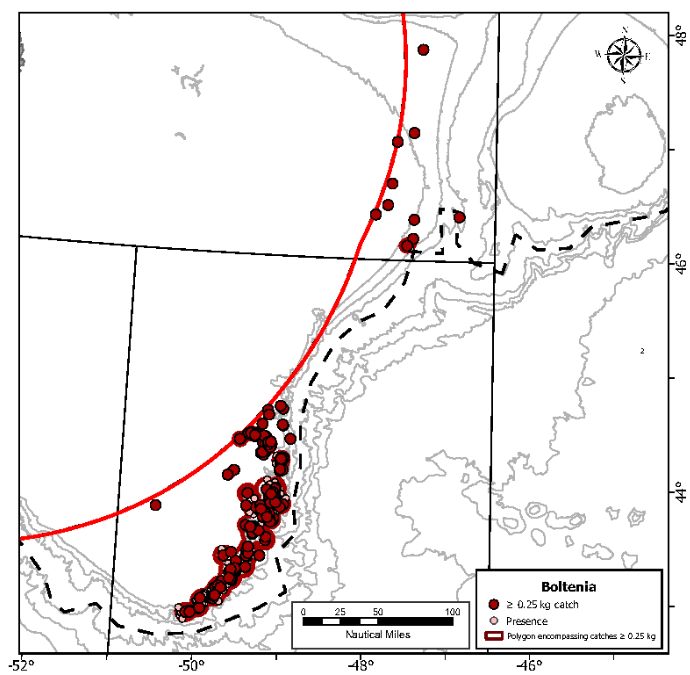


Figure 85. Illustration of the Sea Squirts Functional Group VME polygons (red outline), catches ≥ 0.25 kg (solid red circles) and catches within the VME polygons but at lower catch weights (solid pink circles). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

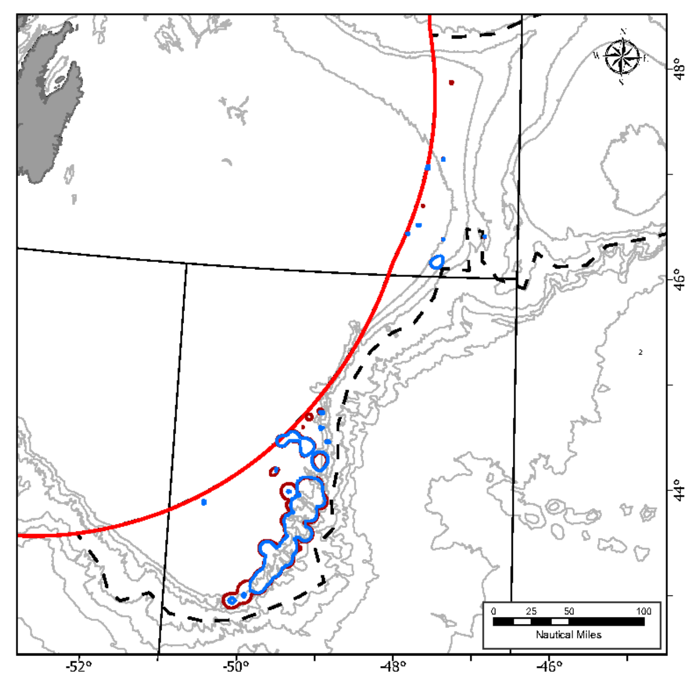


Figure 86. Comparison of the 2019 Sea Squirts Functional Group VME polygons (blue outline) with the Sea Squirts Functional Group VME polygons (red outline) established in the new 2025 analysis. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Tube-Dwelling (Cerianthid) Anemones

Data available for mapping included 31 records from the EU (2007-2024). There were 6 new RV trawl survey records of the presence of Tube-Dwelling Anemones provided since the last update in 2019. All records identified to order – Ceriantharia, and so the species composition is unknown. Tube-dwelling anemones were observed on several *in situ* photographic transects across the Flemish Cap (Figure 87). The lack of taxonomic details from the photographs and video prevented the identification of these organisms past the subclass level (Ceriantharia). However, these cerianthids were not large, erect species, and do not appear to be *Pachycerianthus borealis* (Verrill, 1873), the only species listed as a VME indicator by NAFO (2025). Dense fields of these cerianthids could occur in the southeast of the Grand Bank in Division 3O, north of the 3O Coral Area Closure, where most of the cerianthids were found from the RV surveys. These areas could be particularly important if their bioturbation activities significantly affect infaunal community structure. Elsewhere they have been shown to enhance local species diversity and abundance in featureless soft-bottom areas (Shepard et al., 1986). Similarly the data from the RV surveys and NEREIDA rock and scallop dredge samples were mostly identified to subclass (Ceriantharia) and may contain non-VME cerianthid species, although data from the 2007 RV survey on the Grand Bank confirmed the presence of *Pachycerianthus borealis* at 140 m depth (Murillo et al., 2016). Figure 87 shows the distribution of the data available for the Tube-Dwelling Anemones.

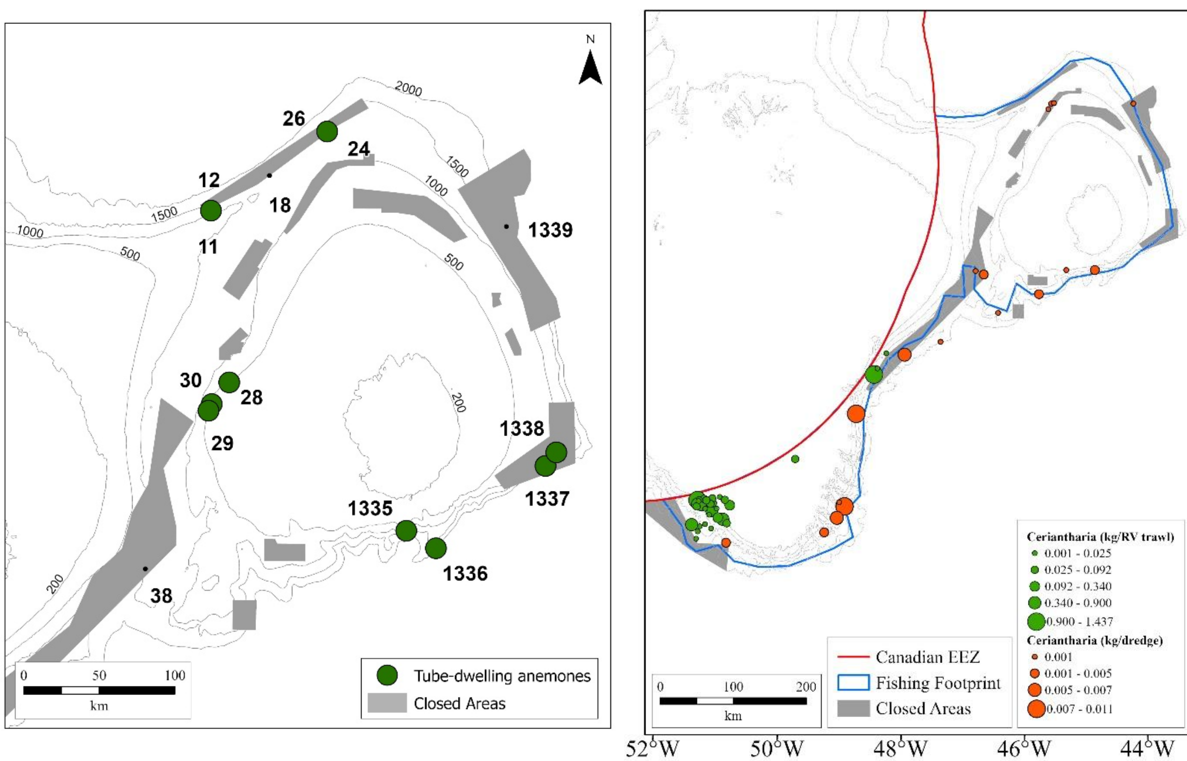


Figure 87. Left panel. Presence of Tube-Dwelling (Ceriantharia) Anemones on video and photographic transects collected from the Flemish Cap area in 2009 and 2010. Right panel. Relative biomass of Ceriantharia collected during the NEREIDA surveys between 2009-2010 using a rock dredge (red) and EU-Spain research trawl surveys between 2006-2024 (green).

Sea Lilies (Crinoids)

Data available for mapping included 4 records from Canadian surveys (2015-2017) and 130 records from the EU (2006-2024). There were 33 new RV trawl survey records of the presence of Sea Lilies since the last update in 2019 in addition to 19 records added to the data collected in 2019 and earlier that were added to the updated data sets by the data providers. All records were identified to class – Crinoidea. Crinoids are delicate organisms that are not well-sampled by trawl nets although they are represented in the catch (NAFO, 2013). The NEREIDA photographic transects provide *in situ* evidence for dense aggregations of this VME indicator (Figure 88). The stalked crinoid *Rhizocrinus lofotensis* Sars, 1868 formerly known as *Conocrinus lofotensis*, a VME indicator species, was observed in high abundances on the Sackville Spur, but was completely absent from the Flemish Pass area (Kenchington et al., 2019). Other VME indicator taxa are *Gephyrocrinus grimaldii* Koehler & Bather, 1902 and *Trichometra cubensis* (Pourtalès, 1869) (NAFO, 2025). It is difficult to say what the composition of these catches were. Figure 88 shows the distribution of the data available for the Sea Lilies.

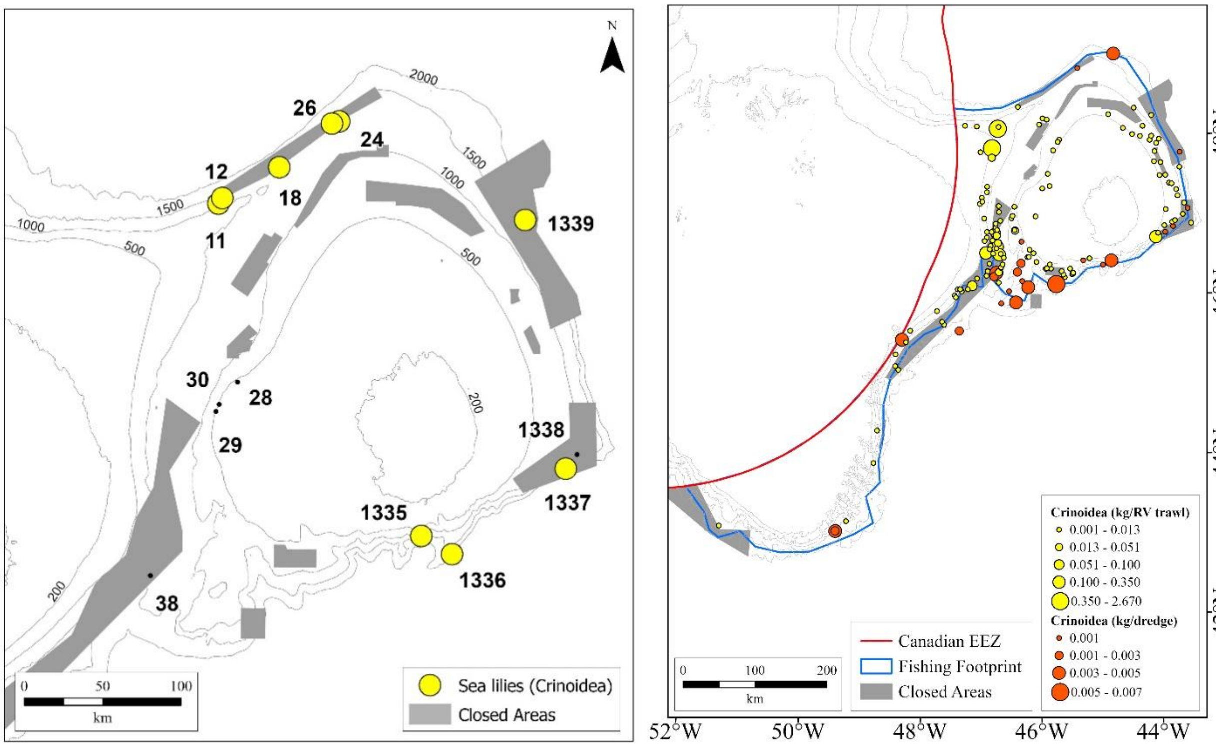


Figure 88. Left panel. Presence of Sea Lilies on video and photographic transects collected from the Flemish Cap area in 2009 and 2010. Right panel. Relative biomass of Crinoidea collected during the NEREIDA surveys between 2009-2010 using a rock dredge (red) and EU-Spain research trawl surveys between 2006-2024 (yellow).

Discussion

In support of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area, kernel density analyses (KDE) of Large-sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals were undertaken using all available research vessel survey data from both Canada and the EU (1995 – 2024).

The data available for the kernel density analyses performed in 2025 drew on 2094 more records than the analyses performed in 2019, with 84% of the data provided by the EU due to their more extensive spatial coverage (Table 36). The catch weight threshold, or cut-off, to ensure comparable data amongst the surveys was the same for 5 of the 7 VME Indicator groups, with the Sea Pen Functional Group cut off increasing by 0.1 kg to 0.3 kg/RV tow and the Black Coral decreasing to 0.15 kg from 0.2 kg/RV tow (Table 36). After application of these catch cut-offs, there were 446 new records for the kernel density analyses across the groups (3560 in total).

Table 36. Number of records from the Canadian and EU research vessel (RV) surveys used in the 2025, 2019 and 2013 assessments of the closed areas, by each of the 7 VME indicator functional groups. Records used for the kernel density analyses are indicated in columns showing records above the RV catch threshold where data could be combined. Sponge=Large-Sized Sponges; SGC=Small Gorgonian Corals; LGC=Large Gorgonian Corals; Bryozoan=Erect Bryozoan.

VME Indicator	Year	Canadian Records	EU Records	Total Records	RV Catch Threshold	Canadian Records ≥ Threshold	EU Records ≥ Threshold	Total Records ≥ Gear Threshold
Sponge	2025	1074	4431	5505	0.5 kg	677	1567	2244
Sponge	2019	975	3415	4390	0.5 kg	618	1207	1825
Sponge	2013	553	2040	2593	0.5 kg	391	763	1154
Sea Pen	2025	288	2502	2790	0.3 kg	32	286	318
Sea Pen	2019	259	1954	2213	0.2 kg	54	376	430
Sea Pen	2013	183	1172*	1355	0.2 kg	35	227	262
SGC	2025	103	808	911	0.02 kg	59	220	279
SGC	2019	106	582	688	0.02 kg	62	156	218
SGC**	2013	87	317	404	0.02 kg	40	45	85
LGC	2025	86	246	332	0.1 kg	29	69	98
LGC	2019	83	200	283	0.1 kg	29	60	89
LGC	2013	42	153	195	0.1 kg	13	45	58
Bryozoan	2025	24	850	874	0.02 kg	12	165	177
Bryozoan	2019	21	768	789	0.02 kg	12	162	174
Bryozoan	2013	-	353***	353	none	-	353	353
Sea Squirts	2025	189	200	389	0.01 kg	188	181	369
Sea Squirts	2019	172	162	334	none	172	162	334
Sea Squirts	2013	-	88	88	none	-	88	88
Black Coral	2025	20	398	418	0.15 kg	6	70	76
Black Coral	2019	20	260	280	0.2 kg	6	38	44
Total	2025	1784	9435	11219		1003	2557	3560
Total	2019	1636	7341	8977		953	2161	3114
Total	2013	865	4123	4988		479	1521	2000

*Misreported as 1127 in NAFO (2013). Totals corrected here. **In 2013 KDE analyses were performed for Divisions 3NO and in 2019 the areas 3LMNO were combined. *** Misreported as 344 records in NAFO (2013). Totals corrected here.

Evaluation of KDE Performance on Subgroups of Large-Size Sponges, Sea Pens, and Small Gorgonian Corals

For the first time, KDE analyses were performed on subgroups of the Large-Size Sponge, Sea Pens and Small Gorgonian Corals. Corresponding species distribution models were also performed on these taxa (Murillo et al., 2024; Murillo et al., 2025). Before these assessments, there were insufficient data on the subgroups to warrant such analyses. The purpose in doing this was to see whether basing protection decisions on the location of the functional group VMEs afforded unequal protection to component taxa.

For the three subgroups of Large-Size Sponges (the families Tetillidae and Polymastiidae and the suborder Astrophorina) the analyses showed that each had considerable overlap with the Large-Size Sponge Functional Group (Figure 89), ranging from 38.9% for the Polymastiidae to 69.9% for the Astrophorina (Table 37). There were areas in Flemish Pass, particularly in the north, and on the Tail of Grand Bank for the Tetillidae and Polymastiidae that were not protected (Figure 89). Further, the Polymastiidae in particular had 17 polygons that did not overlap at all with those of the Large-Size Sponge Functional Group (Table 37).

For the four genera of Sea Pens (*Anthoptilum*, *Balticina*, *Funiculina*, *Pennatula*) the analyses showed that *Anthoptilum* had considerable overlap of its area with the Sea Pen Functional Group (78.6%; Table 37). However, for *Balticina*, *Funiculina* and *Pennatula* most of their VME areas were outside of those of the Sea Pen Functional Group (Table 37, Figure 90). For *Pennatula* there is a large VME polygon in the northern portion of Flemish Pass that is deeper than the Sea Pen Functional Group VME polygons, as well as one on the eastern slope of the Tail of Grand Bank (Figure 90D). Ten *Pennatula* polygons had no overlap with the Sea Pen Functional Group VME polygons (Table 37). We note that the KDE analyses of *Funiculina* was produced from a relatively small data set (N=29) and is subject to change as more data are accumulated.

For the two species of Small Gorgonian Corals, *Acanella arbuscula* fell within the VME polygons for the Small Gorgonian Coral Functional Group with very little area outside and all *Acanella arbuscula* VME polygons at least partially overlapping with the Small Gorgonian Coral Functional Group VMEs (Table 37, Figure 91). For *Radicipes gracilis*, their VME polygon areas overlapped with those of the functional group somewhat (23.8%), but new areas were identified, especially in Flemish Pass, although only two small polygons do not overlap to some extent with the functional group VME polygons (Table 37, Figure 91).

Therefore, we conclude that for the majority of the subgroups, there is a large proportion of their VME area that lies outside of their respective VME functional group and therefore should be taken into account when evaluating closed areas and significant adverse impacts on VMEs in the NAFO Regulatory Area. Particular attention should be paid to VME polygons of subgroups that have no overlap with their functional group VMEs (Table 37) as these may be distinct populations important to their respective connectivity networks.

Table 37. The areas for each of the Large-Sized Sponge, Sea Pen and Small Gorgonian Coral subgroups which overlap with that of their respective functional group taxon are indicated (Common Area). The percentage of the common area of the subgroup area (VME Taxon Area) is also indicated as well as the percentage of the subgroup area lying outside the functional group.

VME Group	VME Group Area (km^2)	VME Taxon	VME Taxon Area (km^2)	Common Area (km^2)	Percent Common Area of VME Taxon Area (%)	VME Taxon Area Outside VME Group Area (km^2)	Percent VME Taxon Area Outside VME Group Area (%)	Number of VME Taxon Polygons Outside of VME Group Area
Large-Sized Sponges	33144.2	Tetillidae	30029.3	16322.8	54.4	13706.5	45.6	5
Large-Sized Sponges	33144.2	Polymastiidae	11851.7	4608.5	38.9	7243.2	61.1	17
Large-Sized Sponges	33144.2	Astrophorina	29197.3	20414.2	69.9	8783.1	30.1	4
Sea Pens	9441.1	*Anthoptilum*	9305.7	7309.9	78.6	1995.8	21.4	2
Sea Pens	9441.1	*Balticina*	23141.3	8945.4	38.7	14195.9	61.3	5
Sea Pens	9441.1	*Funiculina*	2465.6	505.6	20.5	1960.0	79.5	1
Sea Pens	9441.1	*Pennatula*	10252.2	2899.4	28.3	7352.8	71.7	10
Small Gorgonian Corals	13379.7	*Acanella arbuscula*	4143.6	4130.7	99.7	13.0	0.3	0
Small Gorgonian Corals	13379.7	*Radicipes gracilis*	7078.7	1682.0	23.8	5396.7	76.2	2

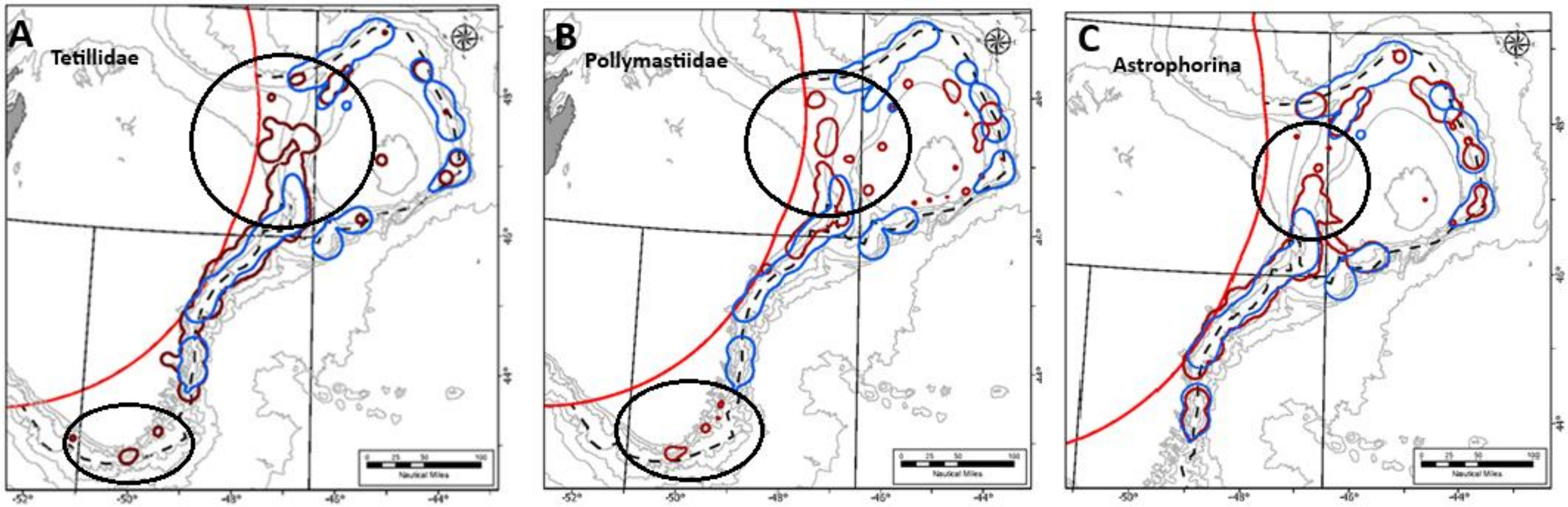


Figure 89. Comparison of the VME polygons for the subgroups (red outline) of Large-Size Sponges compared with the Large-Size Sponge Functional Group VME polygons (blue outline). A) Tetillidae; B) Polymastiidae; C) Astrophorina. Black circles highlight areas where the VME polygons for the subgroups differ from that of the functional group. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

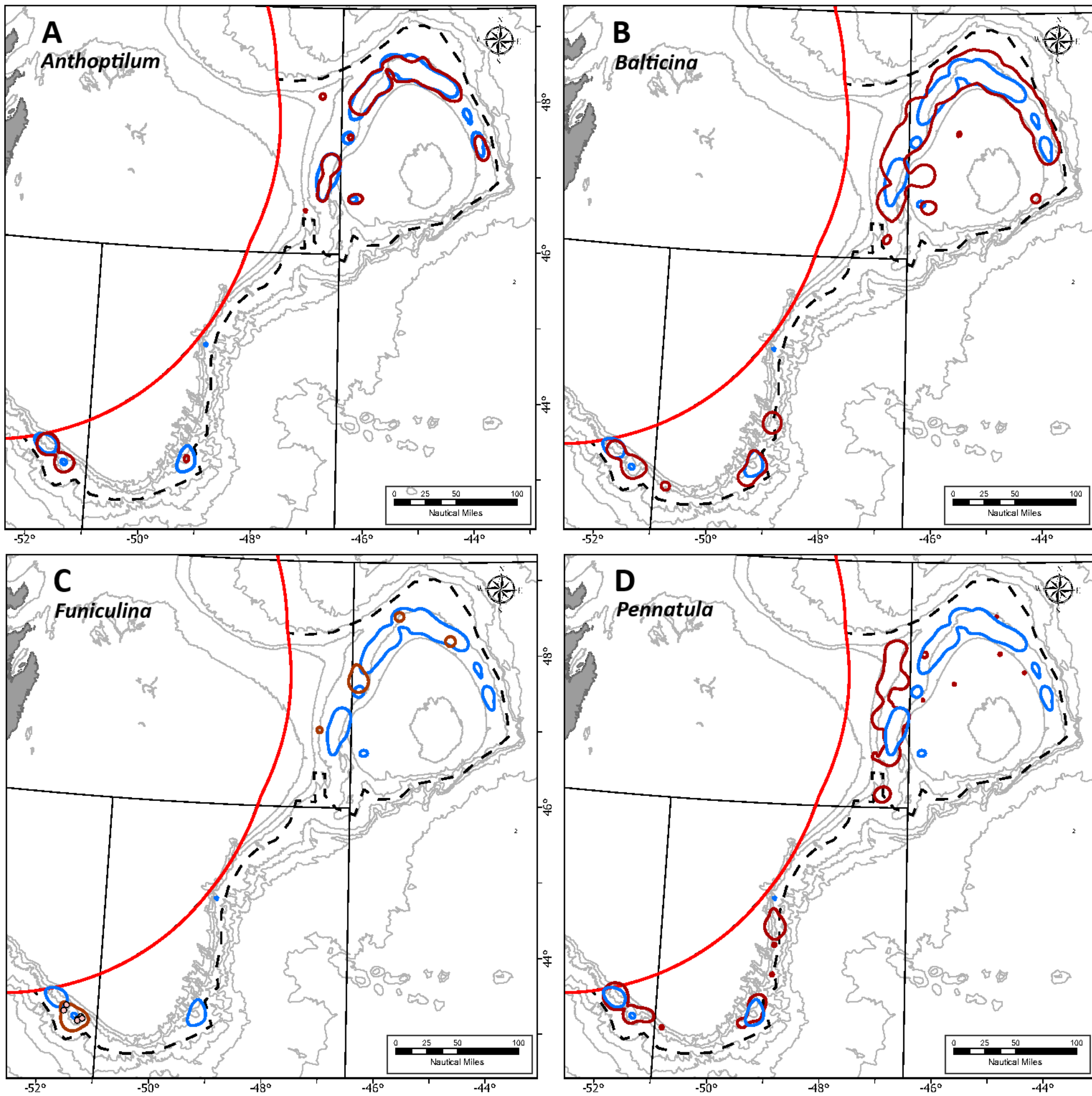


Figure 90. Comparison of the VME polygons for the subgroups (red outline) of Sea Pens compared with the Sea Pen Functional Group VME polygons (blue outline). A) *Anthoptilum*; B) *Balticina*; C) *Funiculina*; D) *Pennatula*. Black circles highlight areas where the VME polygons for the subgroups differ from that of the functional group. Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

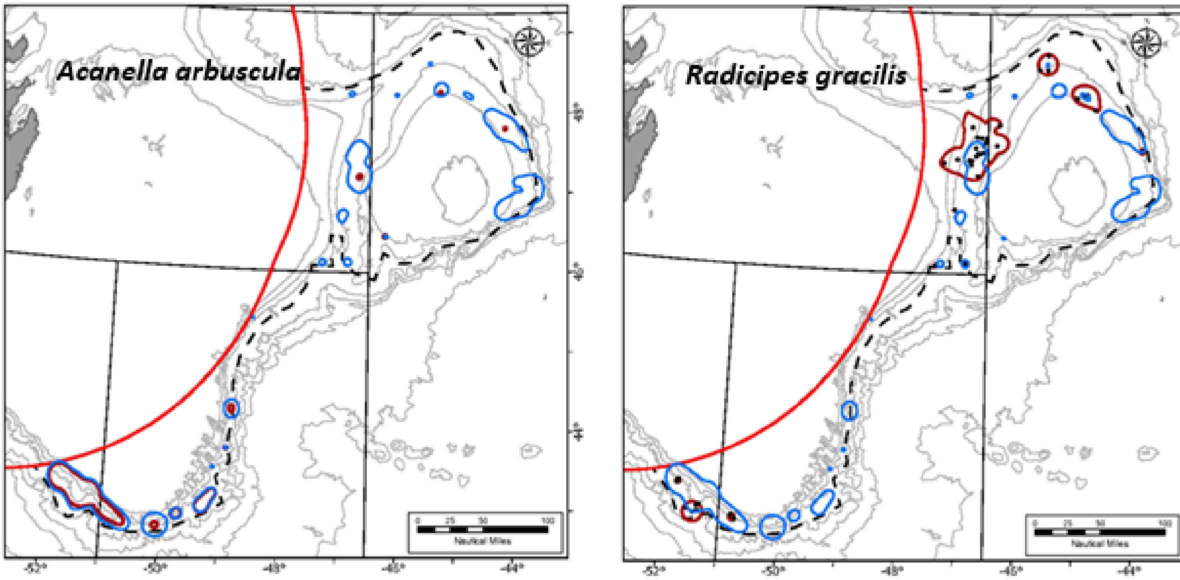


Figure 91. Comparison of the VME polygons for the subgroups (red outline) of Small Gorgonian Corals compared with the Small Gorgonian Corals Functional Group VME polygons (blue outline). A) *Acanella arbuscula* (left panel); B) *Radicipes gracilis* (right panel). Black dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Quantifying Cases for Rejecting a KDE Threshold

One of the evaluation criteria for determining the catch threshold which establishes a VME from the KDE biomass surface is a rapid change in area as the contribution of isolated individuals over a broad area are incorporated (Phase 3 in NAFO, 2013). Cases for rejecting the threshold other than insufficient data includes, amongst others, the joining of smaller polygons with little evidence for a continuous distribution within the newly formed area and an increase in area established by creation of new areas of very low density (NAFO, 2013). The polygons are derived from the density contours established by the KDE analyses as seen in the first figures under each of the VME taxa evaluated (e.g., Figure 3 for the Large-Size Sponge Functional Group). For each catch threshold the contours are selected and outlined, creating the polygons for each catch interval examined (Kenchington et al., 2014; Kenchington et al., 2019). Kernel Density calculates the density of point features around each output raster cell and a smoothly curved surface is fitted over each point. The surface value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the Search Radius distance from the point. The density at each output raster cell is calculated by adding the values of all the kernel surfaces where they overlay the raster cell center. Therefore, it is possible to have density values which were produced from the sum of small catches (below the threshold) with no catches greater than or equal to the threshold catch weight. An example of that occurring is seen in Figure 11D on the Tail of Grand Bank where there are no Tetillidae sponge catch records falling in the density contour for catches ≥ 0.005 kg.

Previously, the maps of the increase in area and of the points contributing to that increase were visually evaluated using, for example, the maps such as seen in Figure 5 for the Large-Size Sponge Functional Group evaluations. However, this feature can be quantified as the ratio of the number of additional points falling in the newly created area by the comparative threshold to the area of the newly created area:

$$\frac{\text{Number of additional catch records > catch threshold 1 falling within (A2-A1)}}{\text{(A2-A1)}}$$

where 1 is the biomass catch threshold (kg) being evaluated and 2 is the next successive smaller biomass catch threshold 1 is being compared with, and A is area in km^2. In the examples shown in Figure 92 the selected threshold is evaluated against other potential thresholds using this ratio. For *Pennatula*, the chosen threshold of catches ≥ 0.045 (vs. catches ≥ 0.035) had a higher ratio than the comparative threshold catches ≥ 0.035 (vs. catches ≥ 0.025) (Table 28). This shows that the second threshold examined increased the area based on few observations compared with the selected threshold, and therefore the increase in area was not robust. This was the case for most of the taxa and supports the contention that this ratio could be a useful means of quantifying the data support for the areal expansion in the KDE analyses. For *Anthoptilum*, three potential thresholds were evaluated (Table 25) and the decision was to select the more conservative threshold (catches ≥ 0.7 kg). The ratio shows that this threshold was well-supported by the data in the expansion area compared with the next lower threshold (Figure 92), however the third threshold examined had similar support for the increase in area. However, as that threshold was much lower in the series (Table 25; catches ≥ 0.35 kg), other decision rules came into play and it was not considered further, i.e., identification of the catch weights which show the largest change in area after the initial establishment of the habitat areas. For the Polymastiidae two thresholds were reviewed and the data support for the higher threshold had a much higher ratio than for the accepted threshold but in this case, both were considered robust and other factors were evaluated. The KDE did not perform well for this group and so this new ratio could have been used to arbitrate between the choices. Across the sea pens the selected catch threshold was larger than the comparative catch thresholds and there was a general pattern of the ratio being smaller than that of the selected threshold. For the sponges, the selected threshold was smaller than the comparative threshold and so the comparative threshold was often as high or higher. This is because the new areas being carved out at the higher thresholds were well supported by the data, as they should be.

This information was not directly used in the evaluation of the selection of the VME thresholds herein but is proposed as a means of evaluating thresholds in future applications. It is recommended that this ratio be evaluated in concert with the spatial distribution of the data (e.g., Figure 11D) as the distribution of the data in the newly created area is not addressed by this ratio. We suggest that future KDE analyses include this ratio in their summary tables to further assist in the identification of the RV catch threshold to use in delineating the VME polygons.

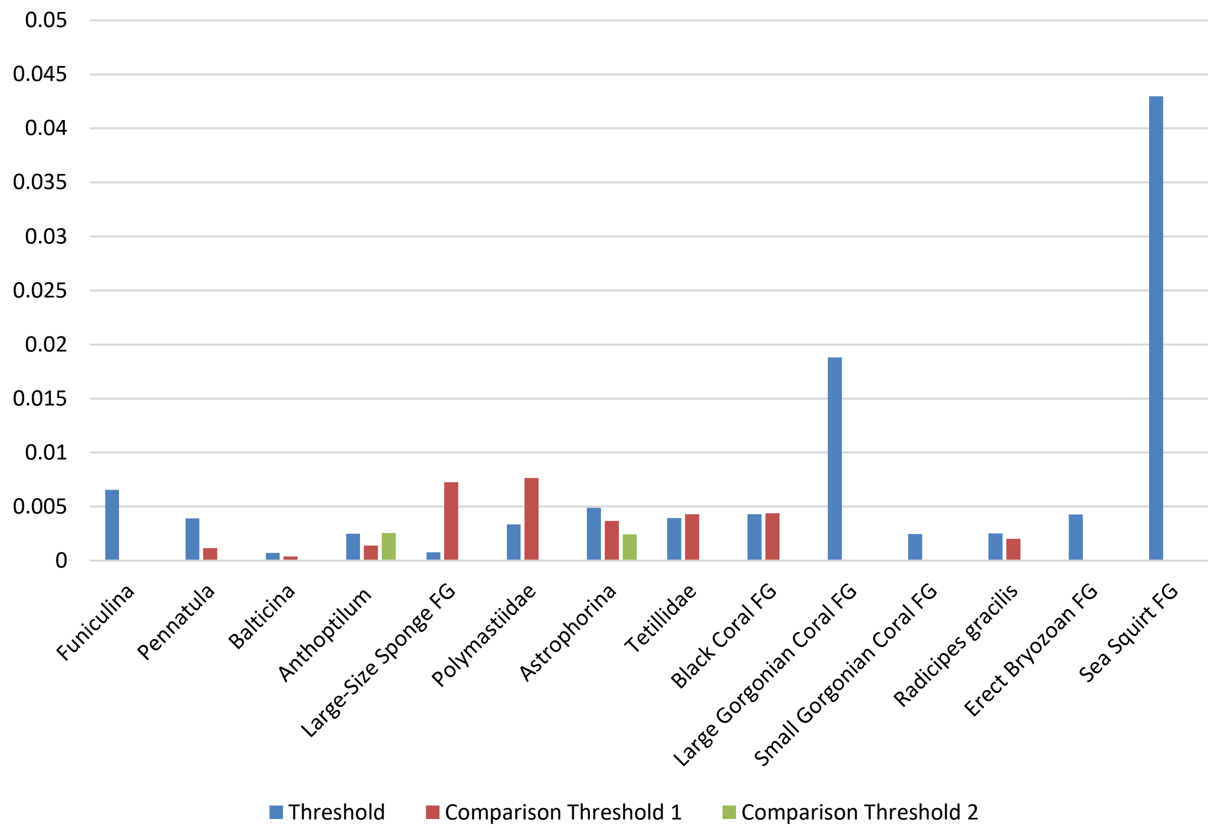


Figure 92. Examination of the ratio of the number of additional points in the expanded area between threshold levels to the area of the expanded area for the selected catch threshold and for the comparative threshold if one was evaluated. FG=VME Functional Group. The ratio for *Acanella arbuscula* was 0.1225 but was not plotted to maintain the scale for the smaller ratios.

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Appendix

Table A1. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and comparisons for all pairs of vessels in the Canadian data using Tukey-Kramer HSD tests, using different subsets of the Large-Size Sponge biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min Campelen 30 min	All Data	1074 2083	0.101	<0.0001
Campelen 15 min Campelen 30 min	GTE 0.010 kg	1073 1822	0.066	<0.0001
Campelen 15 min Campelen 30 min	GTE 0.050 kg	973 1487	0.043	0.0002
Campelen 15 min Campelen 30 min	GTE 0.100 kg	907 1319	0.032	0.02
Campelen 15 min Campelen 30 min	GTE 0.500 kg	677 914	0.023	0.36
Campelen 1800 Lofoten	GTE 0.500 kg	1591 653	0.026	0.09
Test	**Data Threshold**			**P**
Teleost/Cabot	GTE 0.500 kg			0.18
Teleost/Needler				<0.0001
Teleost/Templeman				<0.0001
Templeman/Cabot				1.00
Templeman/Needler				1.00
Needler/Cabot				1.00
Teleost/Cabot	GTE 0.500 kg and Year GTE 2011			0.63
Teleost/Needler				0.08
Needler/Cabot				1.00

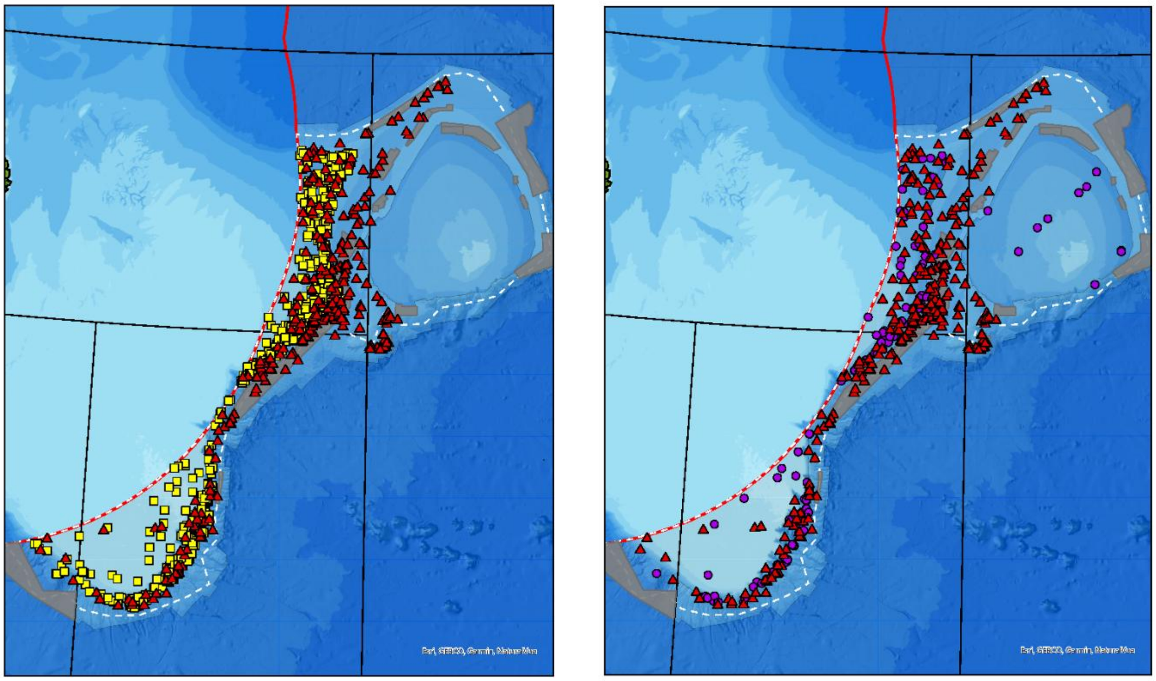

Figure A1. Location of data for the Large-Sized Sponge Functional Group provided by Canada by survey vessel. CCGS *Teleost*: red triangles; CCGS *Alfred Needler*: yellow squares; CCGS *Wilfred Templeman*: purple circles. Shaded areas represent areas closed to protect corals and sponges; white dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

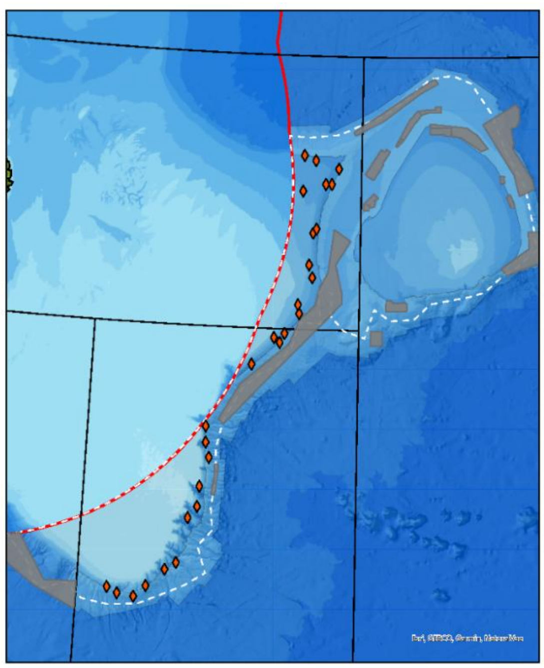

Figure A2. Location of data for the Large-Sized Sponge Functional Group provided by Canada with the CCGS *John Cabot*. Shaded areas represent areas closed to protect corals and sponges; white dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

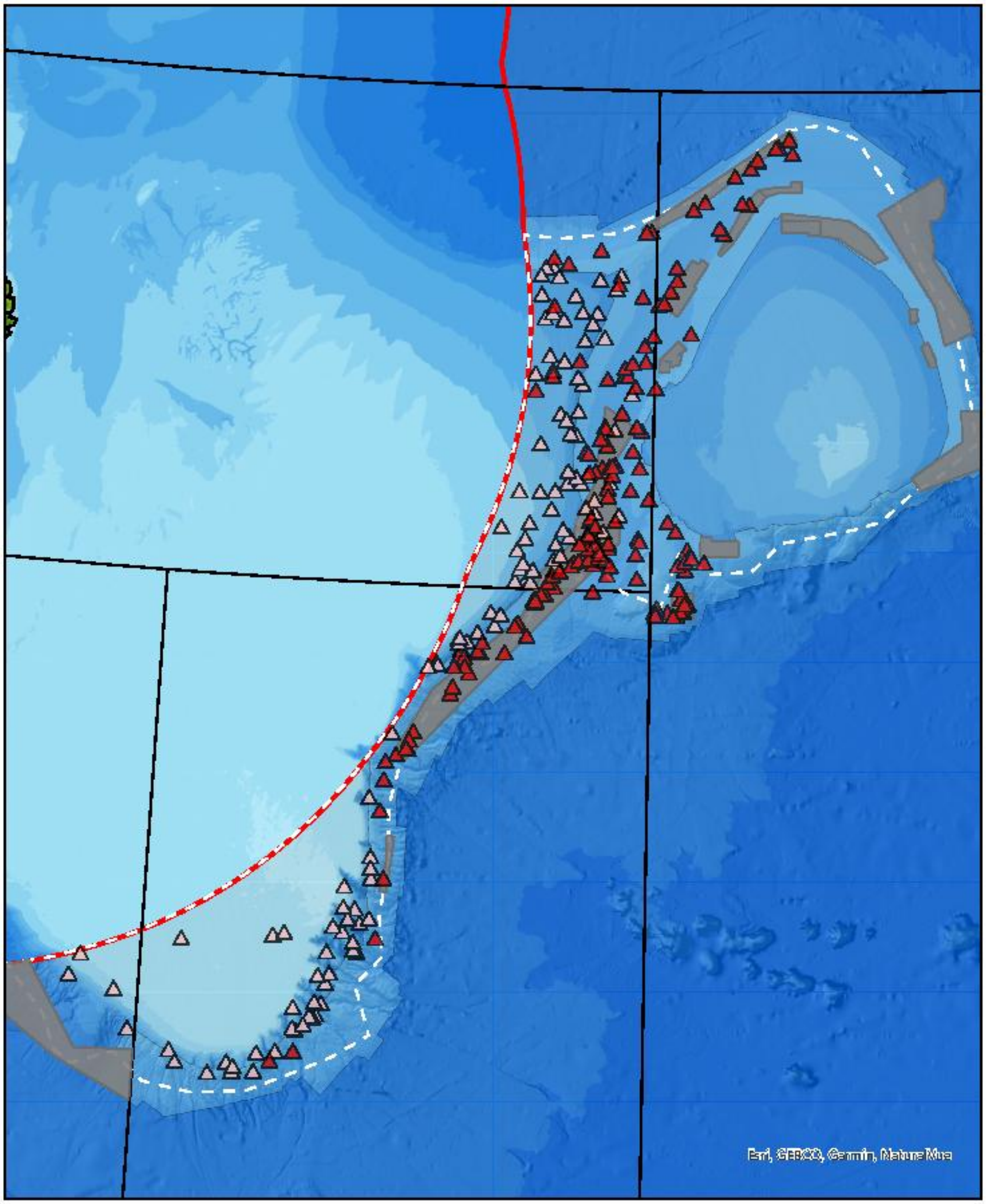

Figure A3. Location of data for the Large-Sized Sponge Functional Group provided by Canada with the CCGS *Teleost* showing the location of the trawl stations from 1996 to 2011 (red triangles) and from 2011 to 2018 (pink triangles). Shaded areas represent areas closed to protect corals and sponges; white dashed line represents the NAFO fishing footprint; solid red line represents the Canadian Exclusive Economic Zone.

Table A2. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between Large-Size Sponge subgroup biomass trawl gear type (Campelen vs. Lofoten). Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Tetillidae				
Campelen 1800	All Data	194	0.083	0.09
Lofoten		31		
Polymastiidae				
Campelen 1800	All Data	471	0.097	< 0.0001
Lofoten		214		
Campelen 1800	GTE 0.050 kg	188	0.080	0.10
Lofoten		49		
Astrophorina				
Campelen 1800	All Data	254	0.074	0.01
Lofoten		221		
Campelen 1800	GTE 0.025 kg	213	0.068	0.05
Lofoten		197		

Table A3. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the Sea Pen biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min	All Data	288	0.098	<0.0001
Campelen 30 min		1091		
Campelen 15 min	GTE 0.010 kg	282	0.071	<0.0001
Campelen 30 min		808		
Campelen 15 min	GTE 0.20 kg	58	0.047	0.80
Campelen 30 min		134		
Campelen 1800	GTE 0.20 kg	192	0.070	0.02
Lofoten		300		
Campelen 1800	GTE 0.25 kg	150	0.067	0.06
Lofoten		249		
Campelen 1800	GTE 0.30 kg	109	0.034	0.86
Lofoten		209		
Test	**Data Threshold**			**P**
Teleost/Cabot	GTE 0.30 kg			0.81
Teleost/Needler				0.59
Needler/Cabot				0.60

Table A4. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the *Anthoptilum* sea pen biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min	All Data	137	0.074	0.0007
Campelen 30 min		589		
Campelen 15 min	GTE 0.010 kg	125	0.044	0.23
Campelen 30 min		446		
Campelen 1800	GTE 0.010 kg	571	0.067	< 0.0001
Lofoten		541		
Campelen 1800	GTE 0.050 kg	293	0.063	0.01
Lofoten		332		
Campelen 1800	GTE 0.10 kg	165	0.048	0.35
Lofoten		222		
Test	**Data Threshold**			**P**
Needler/Cabot	GTE 0.10 kg			0.81
Teleost/Cabot				0.87
Needler/Templeman				0.88
Teleost/Templeman				0.93
Teleost/Needler				0.99
Templeman/Cabot				1.00

Table A5. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the *Balticina* sea pen biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min Campelen 30 min	All Data	63 229	0.089	0.02
Campelen 15 min Campelen 30 min	GTE 0.01 kg	59 173	0.044	0.76
Campelen 1800 Lofoten	GTE 0.01 kg	232 364	0.036	0.41
Test	**Data Threshold**			**P**
Needler/Cabot	GTE 0.01 kg			0.93
Teleost/Cabot				0.87
Needler/Templeman				0.92
Teleost/Templeman				0.81
Teleost/Needler				0.97
Templeman/Cabot				1.00

Table A6. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the *Funiculina* sea pen biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min Campelen 30 min	All Data	37 187	0.15	< 0.0001
Campelen 15 min Campelen 30 min	GTE 0.01 kg	25 50	0.15	0.07
Campelen 1800 Lofoten	GTE 0.01 kg	75 31	0.18	0.002
Campelen 1800 Lofoten	GTE 0.05 kg	24 5	0.20	0.23
CCGS Teleost CCGS Needler	GTE 0.05 kg	7 1	0.19	0.94

Table A7. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), using different subsets of the *Pennatula* sea pen biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min Campelen 30 min	All Data	61 372	0.09	0.003
Campelen 15 min Campelen 30 min	GTE 0.01 kg	42 164	0.09	0.05
Campelen 1800 Lofoten	GTE 0.01 kg	206 14	0.04	0.84
Test	**Data Threshold**			**P**
Needler/Teleost Teleost/Templeman Needler/Templeman	GTE 0.01 kg			0.45 0.91 0.35

Table A8. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), using different subsets of the Black Coral Functional Group biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min Campelen 30 min	All Data	20 54	0.26	< 0.0001
Campelen 15 min Campelen 30 min	GTE 0.010 kg	20 23	0.13	0.44
Campelen 1800 Lofoten	GTE 0.010 kg	43 244	0.09	0.03
Campelen 1800 Lofoten	GTE 0.015 kg	35 224	0.11	0.01
Campelen 1800 Lofoten	GTE 0.020 kg	33 208	0.11	0.004
Campelen 1800 Lofoten	GTE 0.10 kg	19 92	0.18	0.001
Campelen 1800 Lofoten	GTE 0.15 kg	18 58	0.14	0.05
Campelen 1800 Lofoten	GTE 0.20 kg	17 38	0.10	0.702

Table A9. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the Large Gorgonian Coral Functional Group biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min Campelen 30 min	All Data	86 117	0.17	< 0.0001
Campelen 15 min Campelen 30 min	GTE 0.05 kg	44 48	0.15	0.03
Campelen 15 min Campelen 30 min	GTE 0.10 kg	29 44	0.09	0.62
Campelen 1800 Lofoten	GTE 0.10 kg	73 25	0.06	0.91
Test	**Data Threshold**			**P**
Teleost/Cabot	GTE 0.10 kg			0.99
Teleost/Needler				0.90
Teleost/Templeman				0.95
Templeman/Cabot				0.93
Templeman/Needler				0.82
Needler/Cabot				1.00

Table A10. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the Small Gorgonian Coral Functional Group biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min	All Data	103	0.18	< 0.0001
Campelen 30 min		463		
Campelen 15 min	GTE 0.01 kg	95	0.14	< 0.0001
Campelen 30 min		216		
Campelen 15 min	GTE 0.02 kg	60	0.09	0.08
Campelen 30 min		150		
Campelen 1800	GTE 0.02 kg	210	0.05	0.43
Lofoten		69		
Test	**Data Threshold**			**P**
Teleost/Cabot	GTE 0.02 kg			1.00
Teleost/Needler				0.09
Teleost/Templeman				0.72
Templeman/Cabot				0.98
Templeman/Needler				0.78
Needler/Cabot				0.88

Table A11. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the *Acanella arbuscula* small gorgonian coral biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min	All Data	93	0.18	< 0.0001
Campelen 30 min		330		
Campelen 15 min	GTE 0.01 kg	87	0.14	< 0.0001
Campelen 30 min		162		
Campelen 15 min	GTE 0.02 kg	54	0.09	0.13
Campelen 30 min		111		
Campelen 1800	GTE 0.02 kg	165	0.08	0.15
Lofoten		39		
Test	**Data Threshold**			**P**
Teleost/Cabot	GTE 0.02 kg			1.00
Teleost/Needler				0.15
Teleost/Templeman				0.39
Templeman/Cabot				0.92
Templeman/Needler				1.00
Needler/Cabot				0.89

Table A12. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), using different subsets of the *Radicipes gracilis* small gorgonian coral biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min	All Data	4	0.05	0.93
Campelen 30 min		94		
Campelen 1800	All Data	98	0.10	0.10
Lofoten		64		

Table A13. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, between trawl gear type (Campelen vs. Lofoten), and Canadian research vessel, using different subsets of the Erect Bryozoan Functional Group biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test. Note the test for the effect of research vessel on the Canadian data was performed on all data although only data from the CCGS Needler was present in catches ≥ 0.2 kg.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min	All Data	24	0.11	< 0.0001
Campelen 30 min		721		
Campelen 15 min	GTE 0.01 kg	23	0.11	0.002
Campelen 30 min		248		
Campelen 15 min	GTE 0.02 kg	12	0.06	0.54
Campelen 30 min		162		
Campelen 1800	GTE 0.02 kg	174	0.05	0.71
Lofoten		3		
CCGS Teleost	All Data	5	0.26	0.09
CCGS Needler		19		

Table A14. Results of non-parametric Kolmogorov-Smirnov two sample tests examining differences between tow duration with Campelen 1800 trawl gear, and between Canadian research vessels, using different subsets of the Sea Squirt Functional Group biomass data. Shaded rows indicate data threshold at which no significant differences were found for the particular test.

Test	Data Threshold	No. Records	KS	P
Campelen 15 min	All Data	189	0.07	0.04
Campelen 30 min		200		
Campelen 15 min	GTE 0.01 kg	188	0.04	0.58
Campelen 30 min		181		
Test	**Data Threshold**			**P**
Needler/Templeman	GTE 0.01 kg			0.91
Teleost/Needler				0.89
Teleost/Templeman				1.00