Serial No. N7693 NAFO SCR Doc. 25/047

SCIENTIFIC COUNCIL MEETING –NOVEMER 2025

Identification of Vulnerable Marine Ecosystems in the NAFO Regulatory Area Combining Kernel Density Analyses, Species Distribution Modeling and Empirical Data

by

E. Kenchington[1], C. Lirette[1], M. Sacau[2], F.J. Murillo[1], and Z. Wang[1]

[1]Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, NS, Canada.

[2]Instituto Español de Oceanografía (COV-IEO), CSIC, Vigo, Spain.

KENCHINGTON, E., LIRETTE, C., SACAU, M., MURILLO, F.J., & WANG, Z. 2025. Identification of Vulnerable Marine Ecosystems in the NAFO Regulatory Area Combining Kernel Density Analyses, Species Distribution Modeling and Empirical Data. *NAFO Scientific Council Research Document*, SCR Doc. 25/047: 1-105.

Abstract

In support of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area (NRA), kernel density estimation analyses (KDE) of Large-Sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals were undertaken in 2025 using all available research vessel survey biomass data (1995 – 2024). In addition, subgroups of some of the VME functional groups had sufficient data to warrant application of 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*). For each of these VME functional groups and subgroups, updated species distribution models (SDMs) were also performed using a common suite of environmental indicators. These SDMs produced predicted distributions and associated uncertainty. Here, the SDM models are used to determine whether the VME polygons from the KDE analyses fall into areas of predicted taxon presence. Where such was not the case, adjustments to the polygon areas are proposed based on SDM results, following previously established protocols for polygon trimming. In 2019, adjustments were made to the Large-Sized Sponges and Large Gorgonian Corals. The effectiveness of the closed areas was assessed by examining the proportion of the final VME polygon areas protected for each VME indicator functional group and subgroup. The results of those analyses were compared with those previously conducted in 2019.

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Introduction

Kernel density estimation analyses (KDE) uses 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 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 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, 2019; Kenchington et al., 2019; Kenchington et al., 2025).

However, KDE does not take into account environmental variables which can be important determinants of distribution. To address this issue, species distribution models (SDMs), using a common set of environmental variables were performed for the seven VME functional groups (Large-sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals) (Murillo et al., 2024, Murillo et al., 2025). Subgroups of some of the VME functional groups had sufficient data to warrant application of both the SDM and KDE analyses (Murillo et al., 2024, Murillo et al., 2025, Kenchington et al., 2025). 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*). The correspondence between the KDE-generated VME polygons and areas of predicted occurrence derived from species distribution models (SDM) was examined, and used to modify the polygons to eliminate areas where the taxon was not predicted to occur (as was done previously; NAFO, 2015, 2019).

Lastly, the effectiveness of the closed areas was assessed by examining the proportion of VME polygon area (km^2) derived from the kernel density biomass surfaces under protection. These metrics may serve as potential indicators of the status and long-term trends of the VMEs and the management measures in place to protect them, and will be used to inform the ecosystem overview summary sheets.

Methods

Overlay of Species Distribution Models (SDMs) with VME Polygons from the KDE Analyses

The SDMs predicting the probability of presence for each VME indicator taxon were built using Random Forest classification models (Murillo et al., 2024; Murillo et al., 2025). Random Forest is an ensemble method, where a large number of decision trees (in this case, 500 per model) are built using random subsets of the data (Breiman, 2001; Cutler et al., 2007). Each model was run 10 times and the final model output was based on the most frequently predicted class (presence/absence) across those runs. 'Sensitivity' of the model corresponds to the proportion of observed presences correctly predicted as such while 'Specificity' is the proportion of absences correctly predicted. Binary presence/absence maps were created by using a threshold optimised to ensure that resulting Sensitivity and Specificity are afforded equal weight (Sensitivity=Specificity) to detection of presence and absence, minimising both false-positives and false-negatives to the same degree.

To assess the reliability of these predictions, we generated two types of confidence map layers:

1. Frequency of the dominant class (N/10): This shows how many times the most common class (presence or absence) was predicted out of the 10 runs. For example, a value of 0.6 associated with presence areas, means that presence was predicted in 6 out of 10 runs, but an absence was predicted in the remaining 4.
2. Average probability of the maximum frequency class: This calculates the mean probability of the most frequent class across all 10 runs. This value reflects the model's confidence in its dominant prediction, whether it is presence or absence. Values ranging from 1 to 0 indicate the average probability over all 10 SDM model runs of the most frequent class (either presence or absence), indicating how confident the model is in its dominant prediction. Values close to 1 indicate that the model consistently predicted the same class (presence or absence), reflecting high reliability. Lower values (e.g., 0.37) indicate inconsistency and higher uncertainty,

possibly corresponding to transition or environmental extrapolation zones where data is scarce or less representative. These values help assess the reliability of predictions for conservation decision-making. Importantly, high certainty can apply to both presence and absence predictions.

Although both maps are similar, we chose to use the average probability of the maximum frequency class (i.e., presence or absence) from the 10 cross-validation runs to illustrate model uncertainty. Areas with lower average probability within the same class can be interpreted as areas of higher uncertainty. We present 4 maps in two figures to illustrate this uncertainty (e.g., Figures 3 and 4). In the first figure the map of average probability of the maximum frequency class is presented as in the SDM reports (Murillo et al., 2024; Murillo et al., 2025). In the same figure we show the predicted presence area from the SDM with a 30% transparent overlay showing areas where the SDM predicts presence to indicate where the probabilities are associated with predicted presence (right panel in this figure). In the second figure we show only the probabilities for when the maximum frequency class = absence in the first map (left panel) and only the probabilities for when the maximum frequency class = presence in the second map (right panel). These two figures present the same information in different ways to facilitate decision making.

Additionally, areas of model extrapolation (univariate and combinatorial) were identified to support decision-making. These are regions where the model predicts habitat suitability outside the range of environmental conditions used to train the model, and therefore may yield unreliable or less reliable predictions. Where the KDE-VME polygon reached beyond the spatial extent of the SDMs generally the area was not clipped as there was no basis to do so.

Following previously established procedures (NAFO, 2015) the VME polygons produced from the KDE analyses (Kenchington et al., 2025) were overlain on these maps to review whether any of the polygons warrant trimming to reflect their predicted habitat distribution. In the last assessment, modifications were made to the Large-Size Sponge and the Large Gorgonian Coral Functional Groups (Kenchington et al., 2019). The steps followed to reach a decision on modifications to the KDE VME polygons were:

	Review KDE VME polygons (Kenchington et al., 2025) with their associated SDMs (Murillo et al., 2024; 2025) • Identify polygons that cross into the Canadian EEZ • Identify polygons that have large overlap with areas of predicted absence
	Zoom in on identified polygons and evaluate uncertainty in the SDM models • Identify polygons that overlap with areas where there is a high probability of predicted absence
	Propose modifications to the VME polygons • Clip polygon edges to areas where there is a high probability of predicted presence • Clip polygon edges to the border with the Canadian EEZ
	Map the proposed modifications to the VME polygons • Map the locations of the VME polygons including ones that have been modified and ones that have not • Calculate the area of each polygon
	Document decisions • Document the proposed changes and the rationale followed in making the modifications
	How are decisions made? • Decisions are made by balancing empirical evidence with predictive models

Evaluation of the Effectiveness of the NAFO Closed Areas

In order to evaluate the effectiveness of the closed areas, we examined the proportions of the total VME polygon areas located inside and outside the NAFO closed areas, based on the VME polygons delineated in the 2019 and 2025 assessments. For the area-based calculations we used tools within the ArcGIS Pro Analysis Toolbox:

- the 'Erase' tool was applied to erase the VME polygon area overlapped with the closure areas.
- the 'Clip' tool was then used to was used to extract the sections of the closure areas that intersected with the VME polygons.

The resulting area depicts the proportion of the VME closed to fishing, and represents the 'Closed Area Protected' area of Figure 1. The 'Erase' tool was then used to erase the closed area from the VME, and the Clip tool was used to clip this area by the fishing footprint, resulting in the VME area inside the fishing footprint but outside the closure ('Unprotected'; Figure 1) and outside the fishing footprint and closed areas ('Conditionally Protected'; Figure 1).

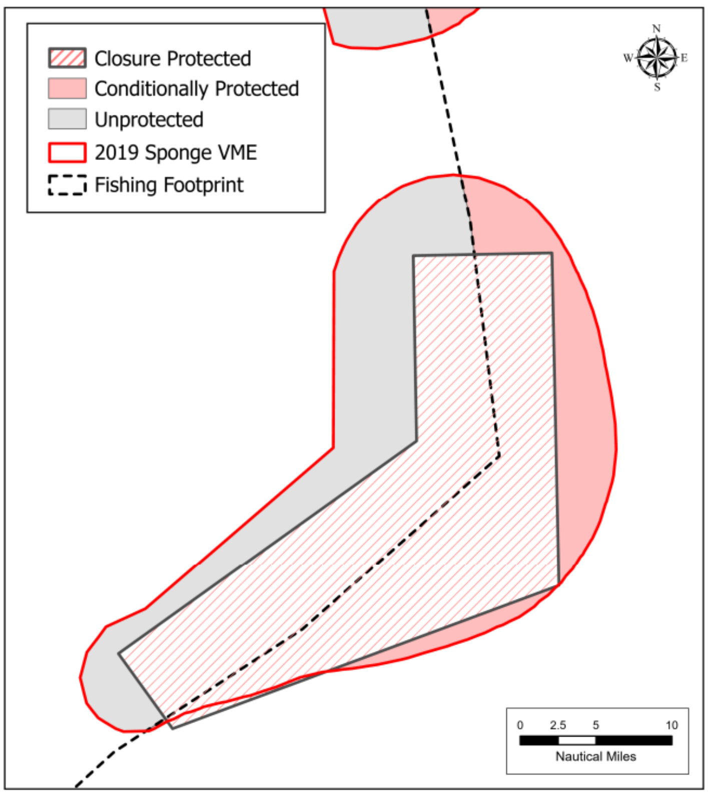


Figure 1. Example of the different levels of protection of VME in the NRA. The area of VME inside the closure is considered 'Closed Area Protected' (red thatched polygon with black outline); the VME area outside the fishing footprint and closed area 'Conditionally Protected' (red shaded polygon), and the VME area outside the closed area and inside the fishing footprint 'Unprotected' (grey shaded polygon). Note that the area outside the VME but inside the closed area (small white area in southwest portion of the polygon) is not included in the calculations as it is outside the sponge VME. The boundary of the fishing footprint is represented by the dashed black line.

Results

Large-Sized Sponges

Figure 2 illustrates the 2025 KDE VME polygons for the Large-Size Sponge Functional Group (Kenchington et al., 2025) superimposed on the SDM for the Large-Size Sponge Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). This functional group was one that was previously modified in 2019 (clipped) using the SDM to trim the KDE polygons (Kenchington et al., 2019). In order to be consistent in determining which KDE polygon boundaries should be modified, the 2019 clipped KDE VME polygons for the Large-Size Sponge Functional Group were overlain with those of 2025 (Figure 2). Murillo et al. (2024) also presented models for sponge grounds for comparison. Five KDE polygons for the Large-Size Sponge Functional Group were identified for potential modifications and labelled using the number of the nearest existing area closures (Areas 1, 4, 5, 6 and 10) (Figure 2). These were area closures that were previously modified in 2019 or that showed extensive area of predicted taxon absence within their boundaries. Where decisions were made previously not to modify the boundary, as for example in northeastern portion of the large polygon in Flemish Pass.

Figure 3 shows 2025 and clipped 2019 KDE VME polygons for the Large-Size Sponge Functional Group superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). The figure is also shown with the SDM presence/absence map underlain in order to help distinguish which is the maximum frequency class in each area. In Figure 4 the probabilities for the absence (left panel) and presence (right panel) classes are separately shown to distinguish the two areas of maximum probability. This map of uncertainty in the SDM models is a new introduction into the assessments. It can guide the decision making through assessment of the probability of the taxon presence or absence in areas proposed for trimming. For example, the area of predicted absence between areas 6 and 10 in Figure 2, is shown to have a high probability of absence in Figure 3 and Figure 4, bolstering a decision to make modifications in that area.

Proposed Modifications to the Large-Sized Sponge VME Polygons

Most of the Large-Size Sponge Functional Group KDE VME polygon areas extended into areas of predicted sponge absence, the exception being the polygons in the vicinity of closed areas 3 and 13 on Beothuk Knoll (NAFO, 2025). Modifications are proposed for Areas 1, 2, 4, 5, 6 and 10 as follows:

Area 1. The Large-Size Sponge Functional Group KDE VME polygon in the vicinity of area closure 1 (NAFO, 2025) extended into areas of predicted absence (Figure 5, Left Panel) on its shallower western boundary. The SDM model for this group did not extend into the deep waters at the eastern boundary of the KDE polygon, and there were no sponge catches at those depths, consequently no information was available for those depths. On the eastern boundary of the KDE the probability of sponge absence was low adjacent to the area of predicted presence (Figure 5, Right Panel). Consequently, the proposed modifications follow the area of predicted presence and extend to the region of high certainty of sponge absence (Figure 5) on the eastern boundary. On the western boundary the proposed modification smooths out the area of predicted presence and cuts off some of the deeper extensions of the polygon which were created from the search radius of the KDE analyses and not from the presence of sponge in the catch.

Area 2. The Large-Size Sponge Functional Group KDE VME polygon in the vicinity of area closure 2 (NAFO, 2025) extended into areas of predicted absence on its north eastern edge and into the Canadian EEZ on its south western edges (Figure 6, Left Panel). Some of the area of predicted Large-Size Sponge Functional Group absence had high uncertainty (low probability; Figure 6, Right Panel). The proposed modifications were to clip the south western portion of the polygon to the EEZ boundary and to clip the north eastern edge to the region of high certainty of sponge absence (Figure 6; Right Panel).

Area 4. The Large-Size Sponge Functional Group KDE VME polygon in the vicinity of area closure 4 (NAFO, 2025) included areas of predicted absence on its north eastern edge (Figure 7, Left Panel). However, the closer examination of this area of predicted absence was associated with high uncertainty (low probability of absence) (Figure 7, Right Panel). Consequently, no modifications were made to this polygon. A number of catches below the KDE threshold of 100 kg per research vessel trawl occur in this general area of predicted Large-Size Sponge Functional Group presence (Figure 7).

Area 5. The Large-Size Sponge Functional Group KDE VME polygon in the vicinity of area closure 5 (NAFO, 2025) included areas of predicted absence along its eastern edges (Figure 8, Left Panel). The lower eastern portion of the polygon extended outside of the spatial extent of the SDM. Figure 8 (Right panel) shows that there are areas where the predicted absence is highly uncertain. In some areas the areas of low probability of predicted absence are abutted by areas of predicted presence. This indicates that the model is not performing well at those edges. The suggested modifications are to split the lower end of the polygon into two. One polygon including the area of predicted presence and area closure 14b (NAFO, 2025) and the other following the boundary that the 2019 KDE polygon was clipped to which we can now see has areas of lower probability of sponge absence. As the western boundary of the polygon was not modified in 2019, we have not proposed any changes in this iteration to that segment.

Areas 6 and 10. The Large-Size Sponge Functional Group KDE VME polygon in the vicinity of area closures 6 and 10 (NAFO, 2025) was lobed, with a single polygon capturing both of the two separate polygons established in the 2019 analyses (Figure 9). The polygon extends from Sackville Spur onto the Northwest slope of Flemish Cap. It includes large areas of predicted absence that was predicted with high certainty (Figure 9, Right Panel). The proposed modifications are to separate the single polygon into two. One following the areas of predicted sponge presence running parallel to Sackville Spur and closely abutting area closure 6 (Figure 9). This was similar to the modification made in 2019 (Figure 9). The second polygon was created from the lobe that included most of the area closure 10 (Figure 9) and cut from the original polygon at its northern edge flowing the area of predicted presence. This polygon includes all of the smaller polygon identified in 2019. A third The Large-Size Sponge Functional Group KDE VME polygon was identified both in 2025 and 2019 to the east of Area 10 and no modifications are proposed to that area.

Table 1. The area occupied by each of the Large-Size Sponge Functional Group KDE VME Polygons after making the proposed modifications.

Large-Size Sponge Functional Group KDE VME Polygon Label	Polygon Area (km^2)
Area 1 Mod	2497.02
Area 2 Mod	9725.67
Areas 3 and 13 No Mod	3846.60
Area 4 No Mod	2518.11
Area 5 Mod 1	3609.45
Area 5 Mod 2	145.72
Area 6 - 10 Mod 1	4449.60
Area 6 - 10 Mod 2	1395.95
Flemish Cap No Mod	128.49
Total Area:	28316.60

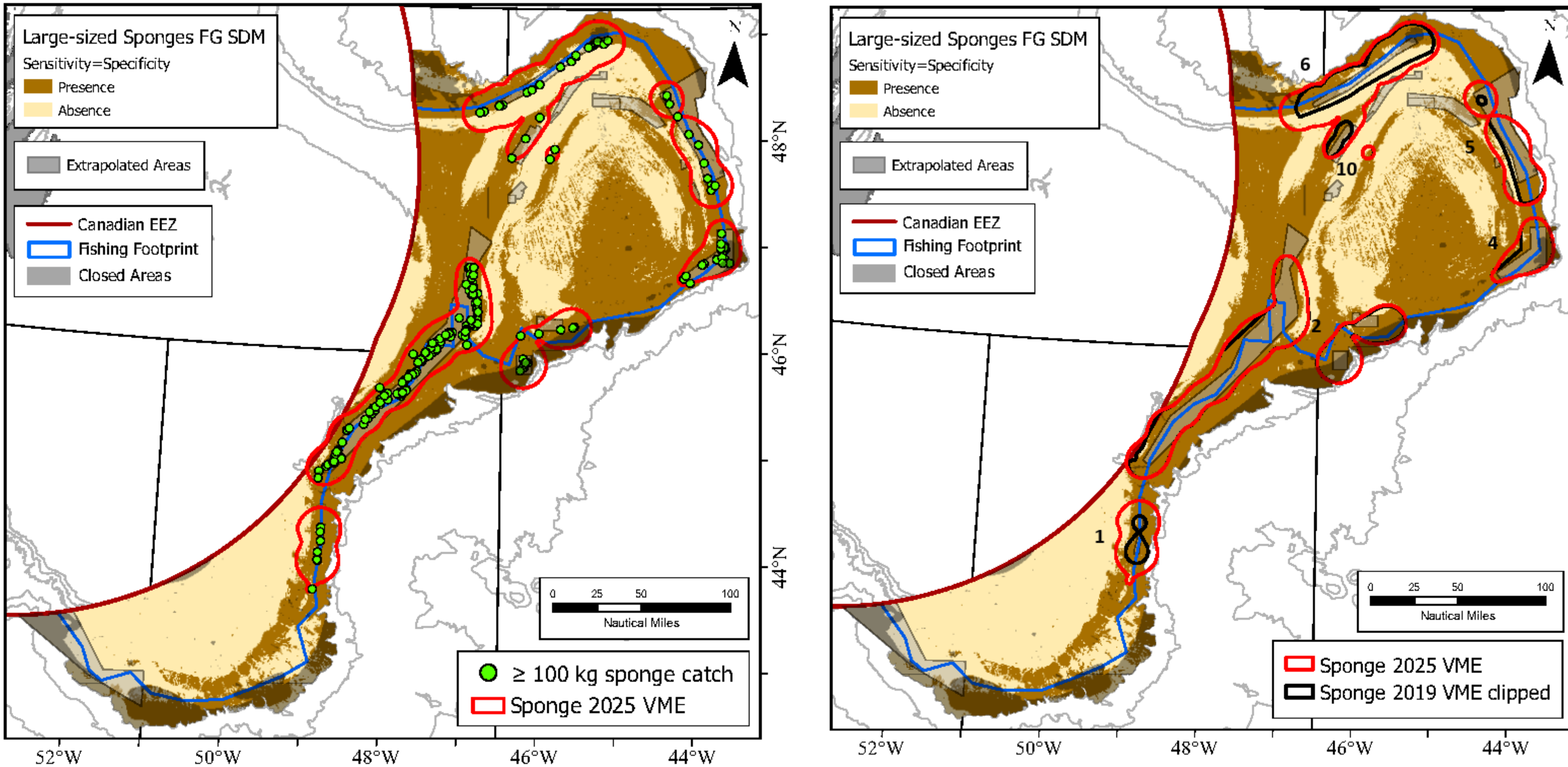


Figure 2. **Left Panel.** The 2025 Large-Size Sponge Functional Group KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Large-Size Sponge Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 100 kg are indicated. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large-Size Sponge Functional Group KDE VME polygons superimposed on the SDM for the Large-Size Sponge Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications.

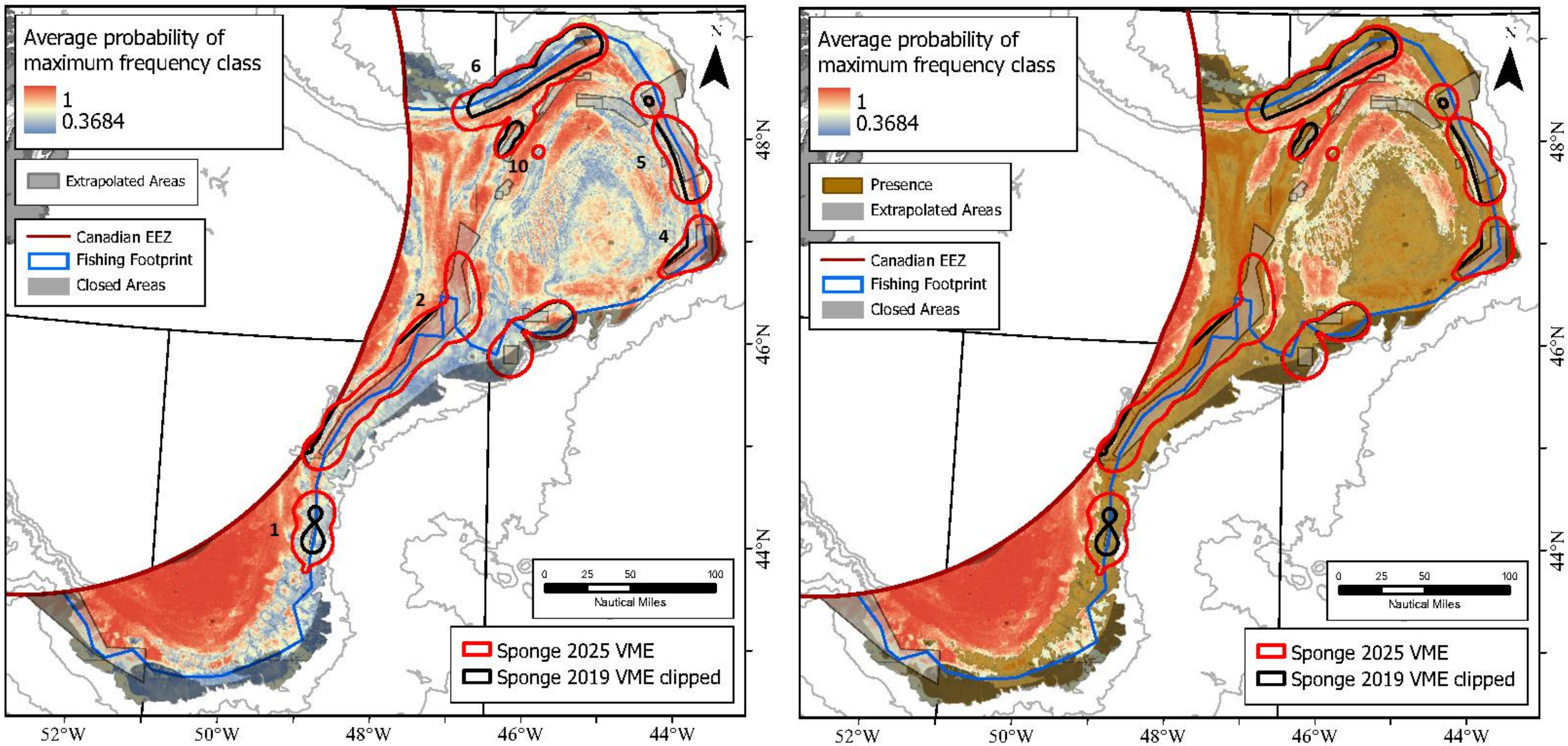


Figure 3. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large-Size Sponge Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for potential modifications. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large-Size Sponge Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Large-Size Sponge Functional Group which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Large-Size Sponge Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

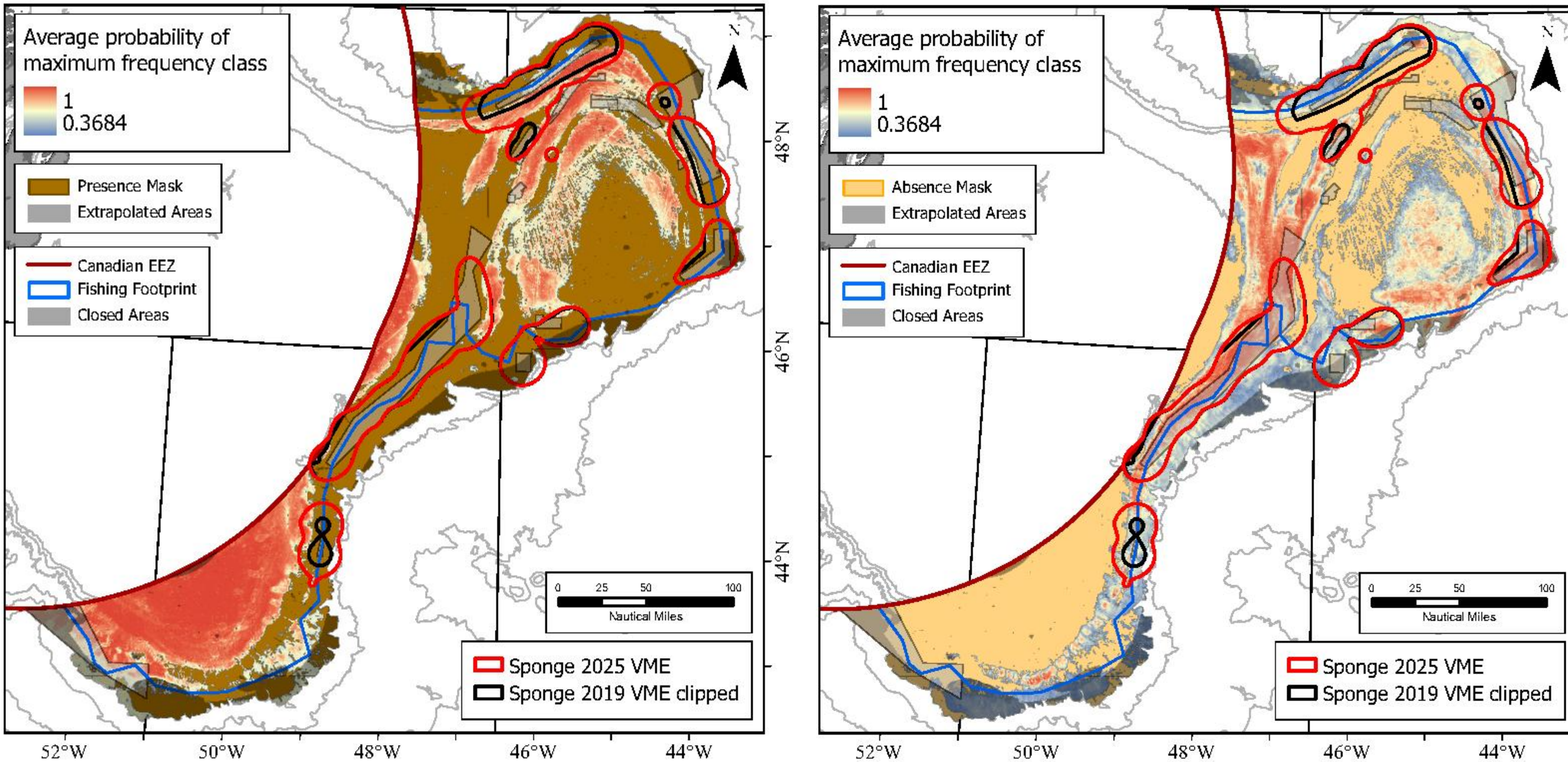


Figure 4. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large-Size Sponge Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large-Size Sponge Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024).

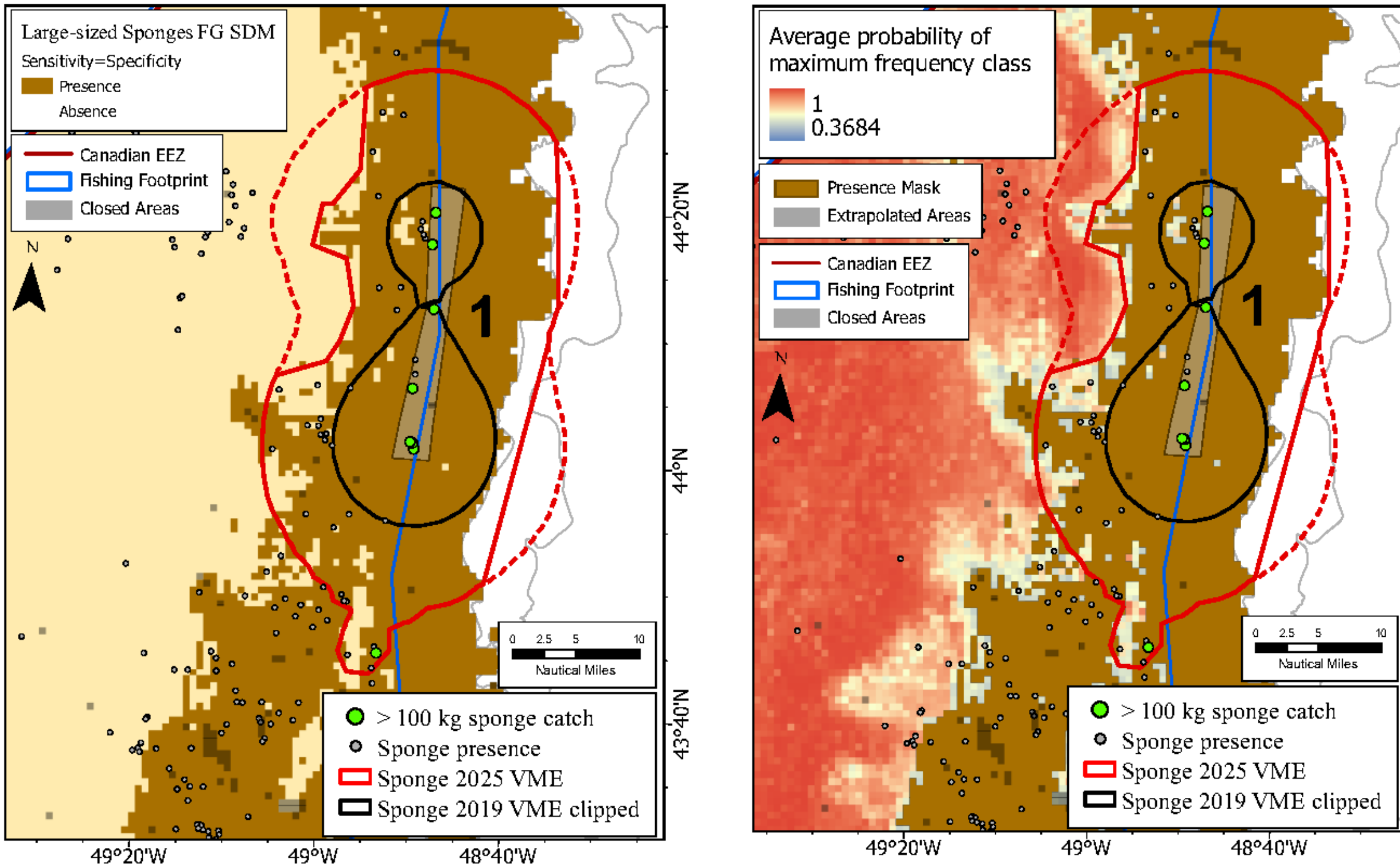


Figure 5. **Area 1. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Area 1 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Area 1 in relation to the 2019 accepted KDE VME polygon (solid black line), and showing the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown.

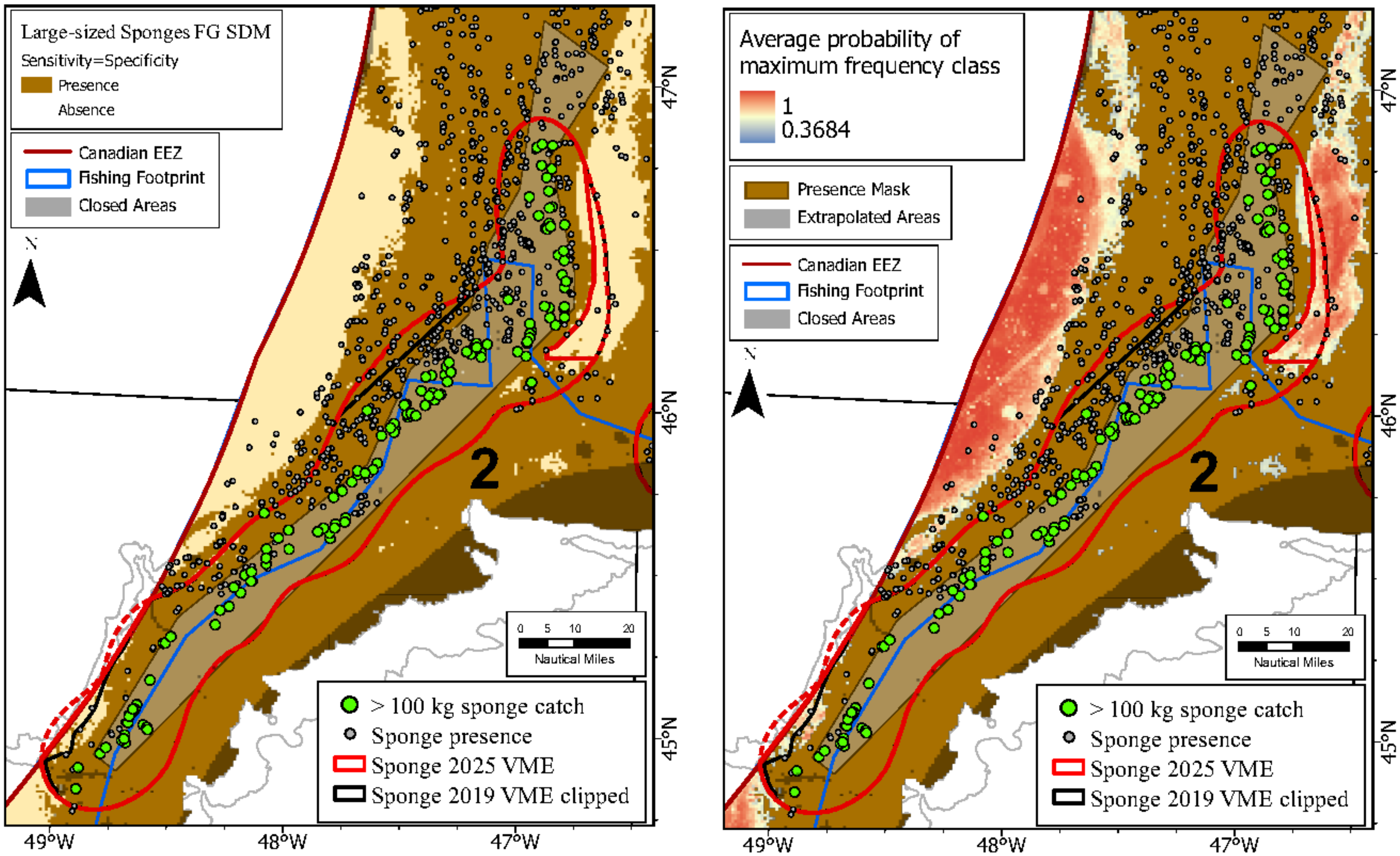


Figure 6. **Area 2. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Area 2 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Area 2 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown.

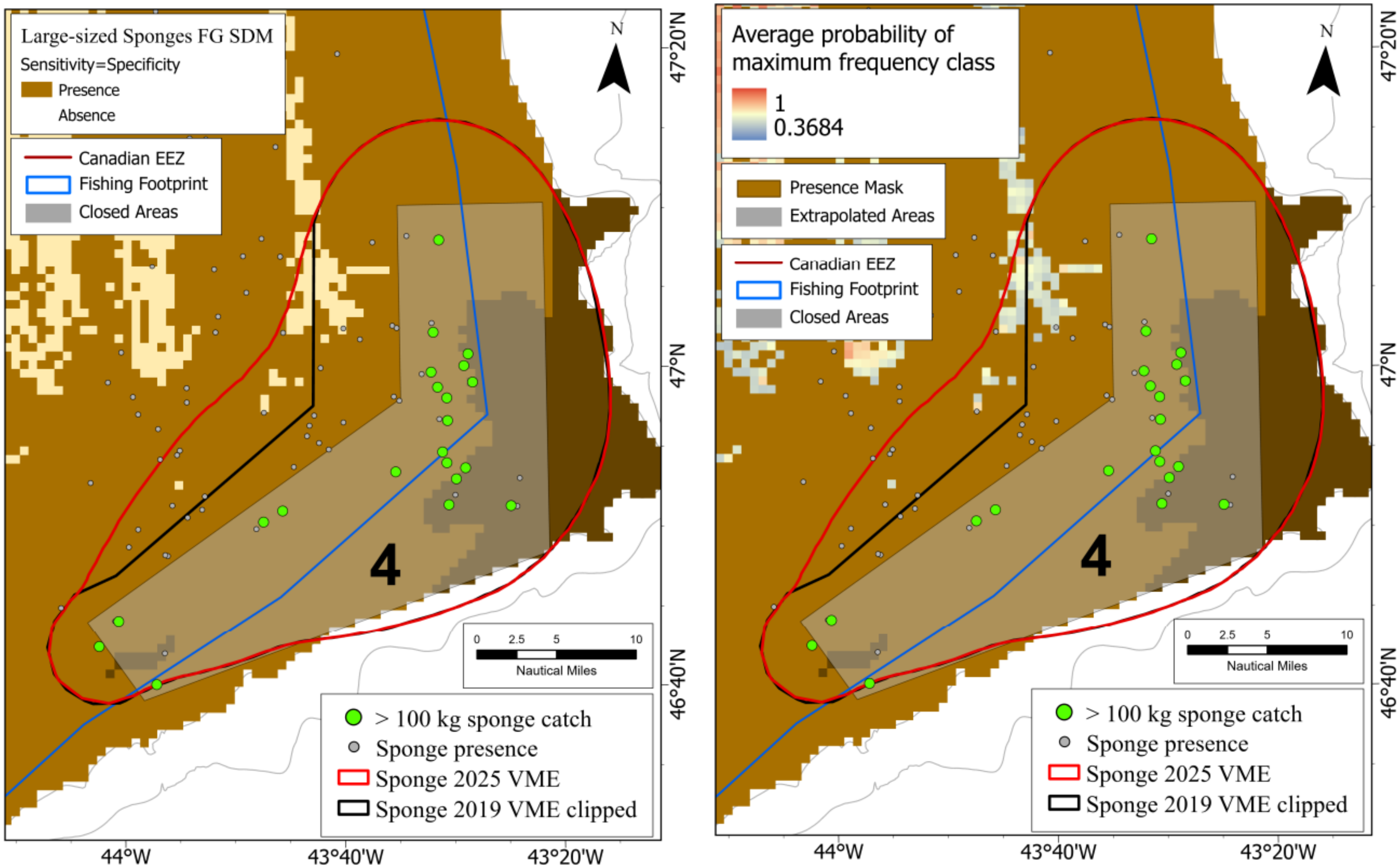


Figure 7. **Area 4. Left Panel.** Map of the 2025 Large-Sized Sponge KDE VME polygon (solid red line) near Area 4 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the 2025 Large-Sized Sponge KDE VME polygon (solid red line) near Area 4 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown.

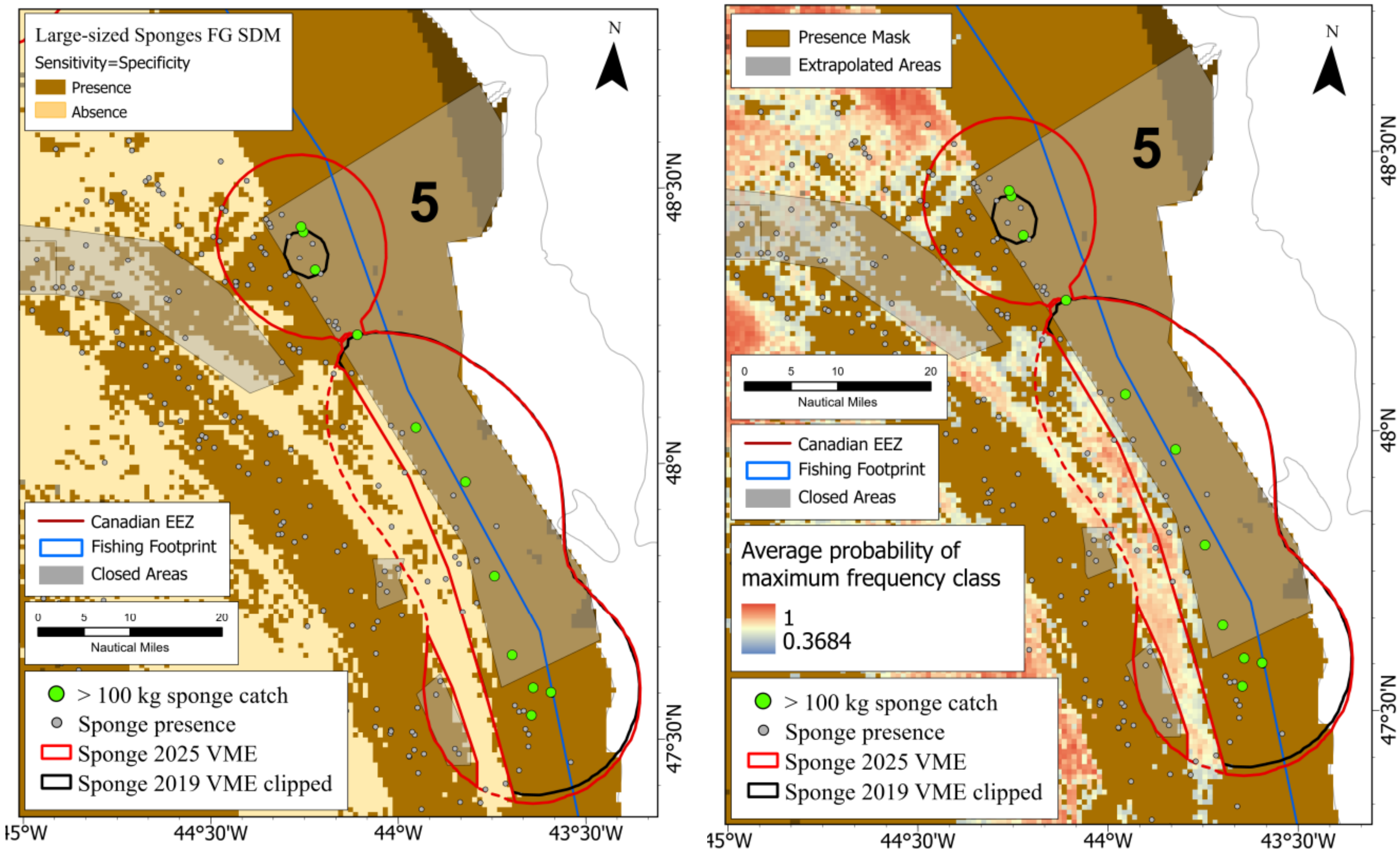


Figure 8. **Area 5. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Area 5 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Area 5 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown).

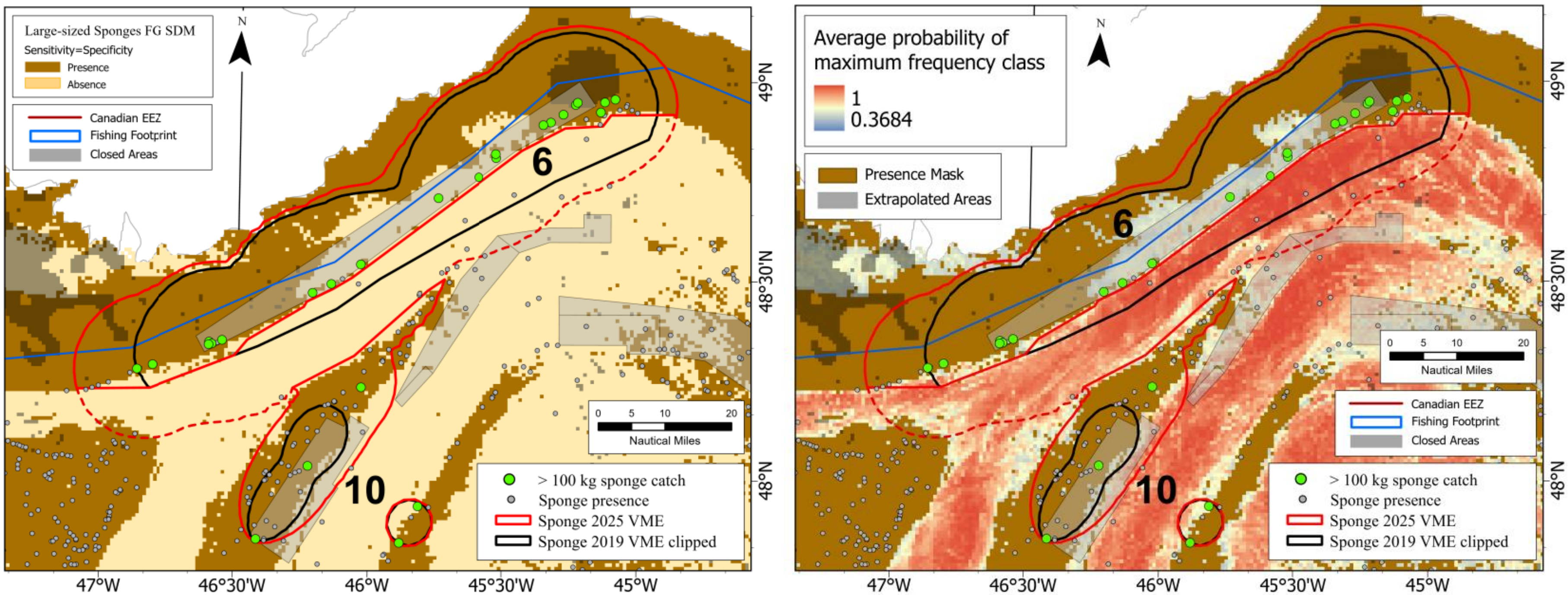


Figure 9. **Areas 6 and 10. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Areas 6 and 10 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the underlying SDM (brown area showing predicted presence of Large-Sized Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Large-Sized Sponge KDE VME polygon (red dashed lines) near Areas 6 and 10 in relation to the 2019 accepted KDE VME polygon (solid black line) and showing the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large-Size Sponge Functional Group (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 100 kg, the threshold for the KDE analyses, and all other catches with < 100 kg are shown).

The proposed modifications would produce nine Large-Size Sponge Functional Group KDE VME polygons (Figure 10). Those polygons ranged in size from 145.72 km^2 to 9725.67 km^2 (Table 1).

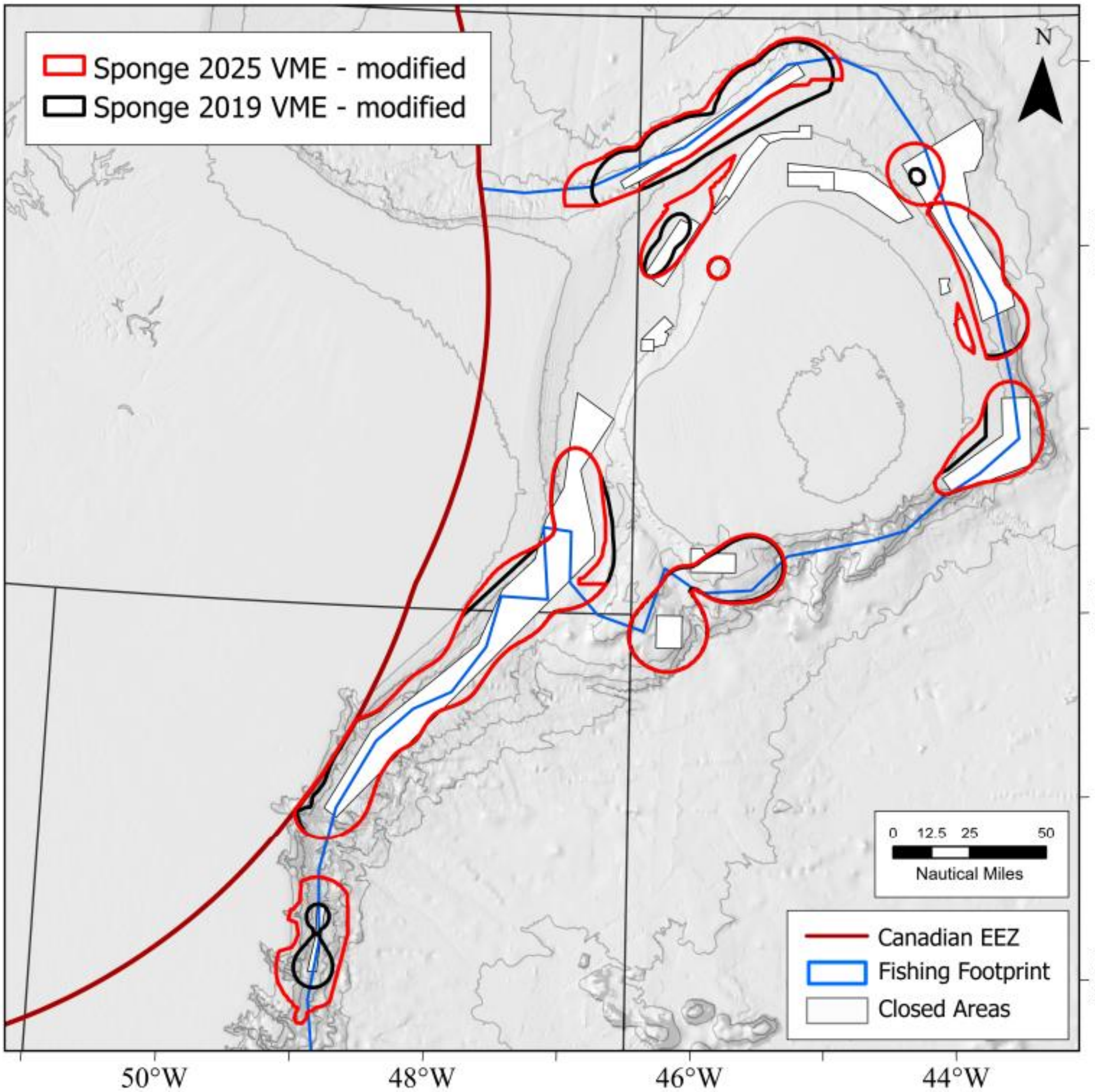


Figure 10. Map of the proposed Large-Size Sponge VME polygons (red line) after consideration of modifications based on the SDM for Large-Size Sponges (Murillo et al., 2024), and in relation to the 2019 accepted KDE VME polygons (black line). Closed areas are indicated in white (NAFO, 2025).

Tetillidae

The Tetillidae subgroup of Large-Size Sponges was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. The 2025 KDE VME polygons for the Tetillidae Sponges (Kenchington et al., 2025) superimposed on the SDM for the Tetillidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024) is shown in Figure 11. Fourteen KDE VME polygons for the Tetillidae Sponges were identified with one being very large and the others relatively smaller (Figure 11). Of these, two polygons are proposed for potential modifications and labelled using the number of the nearest area closures (Areas 1/2/11 and Area 10) (Figure 11).

Figure 12 shows 2025 KDE VME polygons for the Tetillidae Sponges superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Tetillidae Sponges (Murillo et al., 2024). The figure is also shown with the SDM presence/absence map underlain in order to help distinguish which is the maximum frequency class in each area. In Figure 13 the probabilities for the absence (left panel) and presence (right panel) classes are separately shown to distinguish the two areas of maximum probability.

Proposed Modifications to the Tetillidae Sponge VME Polygons

Most of the Tetillidae Sponge KDE VME polygon areas extended into areas of predicted sponge absence, the exception being the polygons in the vicinity of closed areas 3 and 13 on Beothuk Knoll (NAFO, 2025). Modifications are proposed for the large polygon near Areas 1, 2, and 11 and for Area 10 as follows:

Areas 1, 2 and 11. The large convoluted KDE VME polygon for the Tetillidae Sponges crossed into the Canadian EEZ at its western boundary and also transversed areas of high probability of sponge absence (Figure 14). It is proposed that the polygon be clipped to the EEZ boundary at those locations and to the approximate area of predicted presence along its western and northern edges (Figure 14). No changes are proposed to the western boundary at this time as the area in the northwest is fragmented and although the probability of predicted absence is high there are adjacent areas of predicted presence that have a low probability (Figure 13) but are nevertheless uncertain. Further, the kappa statistic for the SDM was only fair and TSS 'good', indicating that model performance could be improved in future with more response data (Murillo et al., 2024).

Area 10. The polygon in the vicinity of Area 10 also straddles parts of Area 12 and Area 9 (Figure 15). The area of predicted presence is patchy in this region and the adjacent areas of predicted absence are shown with high probability (Figure 15; Right Panel). Due to the patchy nature of this area and above noted model performance we have clipped this polygon to the edges the areas of predicted presence (Figure 15).

The proposed modifications would produce 15 Tetillidae Sponge KDE VME polygons (Figure 16). Those polygons ranged in size from 20.54 km^2 to 19824.45 km^2 (Table 2).

Table 2. The area occupied by each of the Tetillidae Sponge KDE VME polygons after making the proposed modifications.

Tetillidae Sponge KDE VME Polygon Label	Polygon Area (km^2)
Area 2 Poly1 - Mod	19824.45
Area 10 - Mod	1002.47
Area 5 Poly 1 - No Mod	747.81
GB Tail Poly 1 - No Mod	505.67
Area 4 Poly 1 - No Mod	462.50
Area 4 Poly 2 - No Mod	330.86
Sackville Spur Poly 1 - No Mod	292.16
Area 2 Poly2 - Mod	260.85
FC Poly1 - No Mod	194.86
GB Tail Poly 2 - No Mod	152.97
FC South Poly 1 - No Mod	130.25
Sackville Spur Poly 2 - No Mod	77.24
GB Tail Poly 3 - No Mod	46.53
Area 5 Poly 2 - No Mod	21.37
FC North Poly1 - No Mod	20.54
Total Area:	24070.52

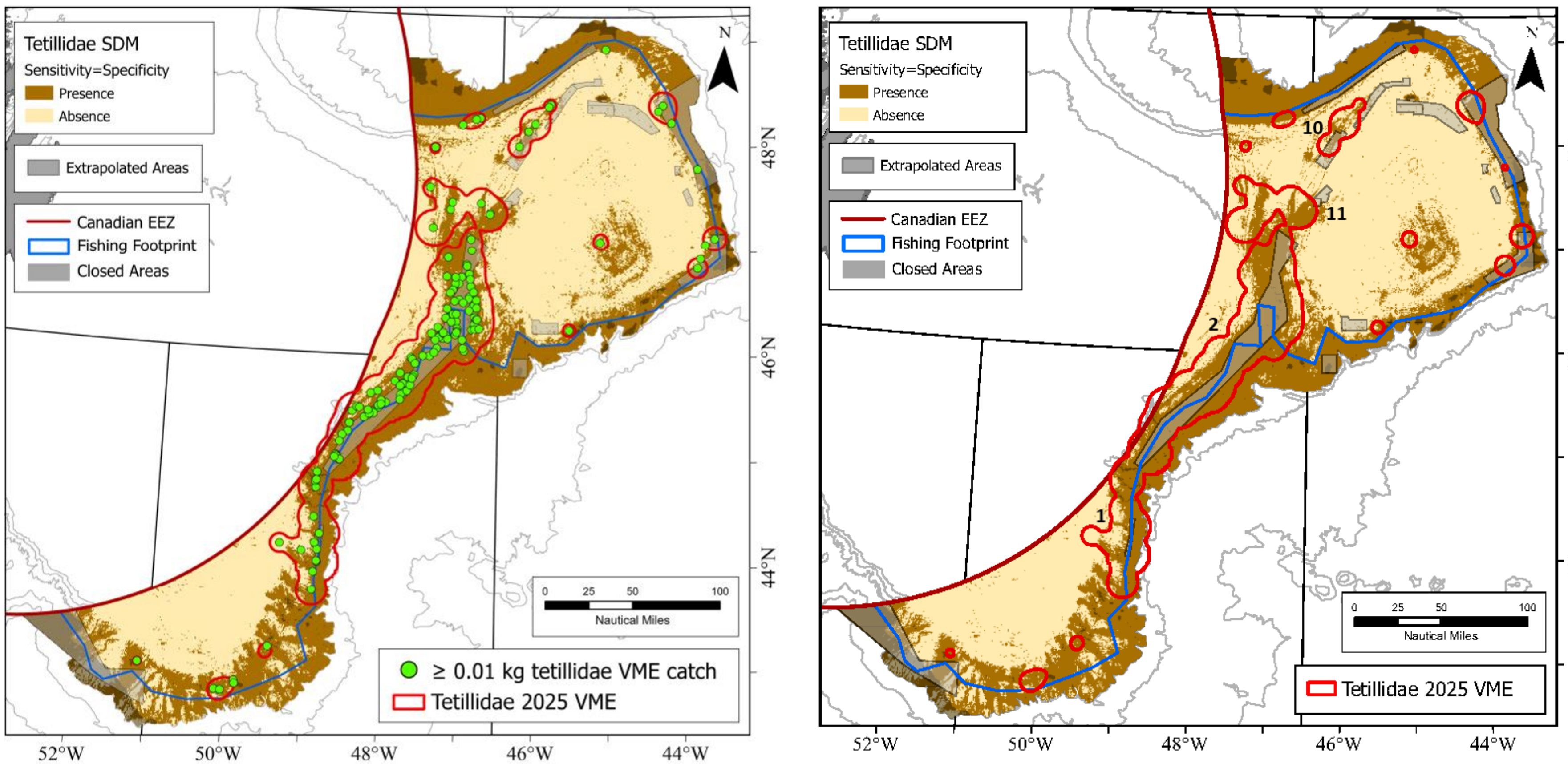


Figure 11. **Left Panel.** The 2025 Tetillidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for Tetillidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 0.01 kg are indicated. **Right Panel.** The 2025 Tetillidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Tetillidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications.

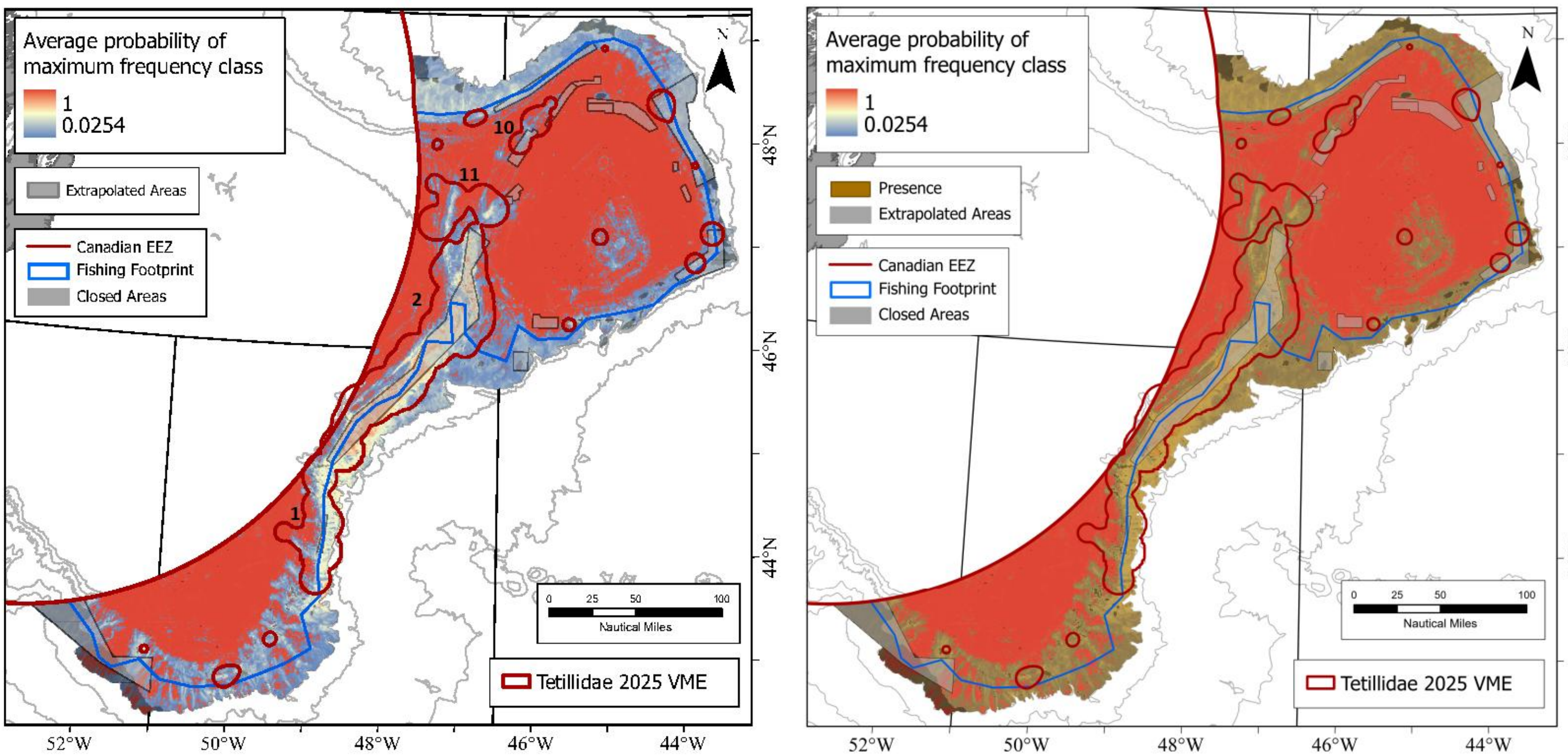


Figure 12. **Left Panel.** The 2025 Tetillidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Tetillidae Sponge (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for potential modifications. **Right Panel.** The 2025 Tetillidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Tetillidae Sponge which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Tetillidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

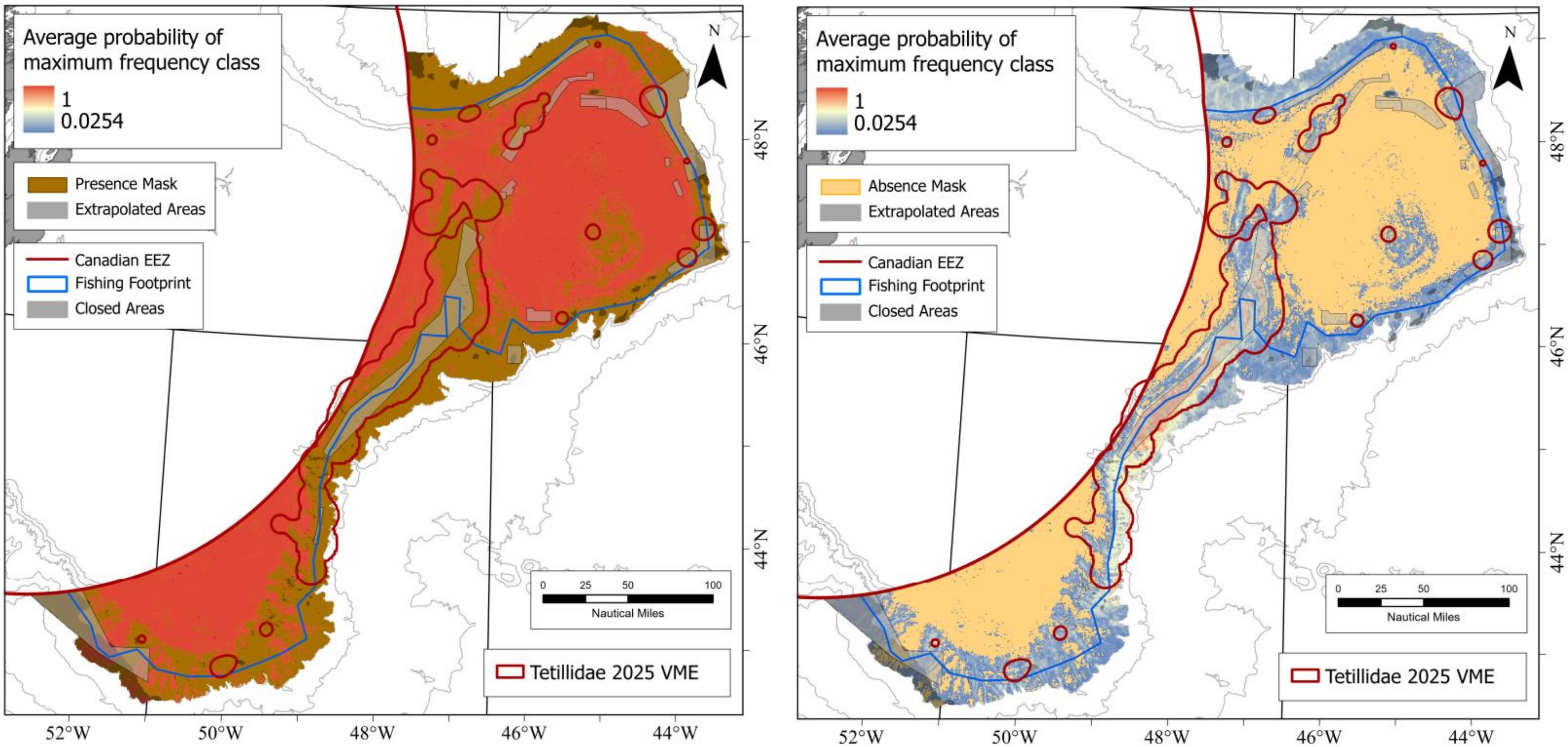


Figure 13. **Left Panel.** The 2025 Tetillidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Tetillidae Sponge (Murillo et al., 2024). **Right Panel.** The 2025 Tetillidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Tetillidae Sponge (Murillo et al., 2024).

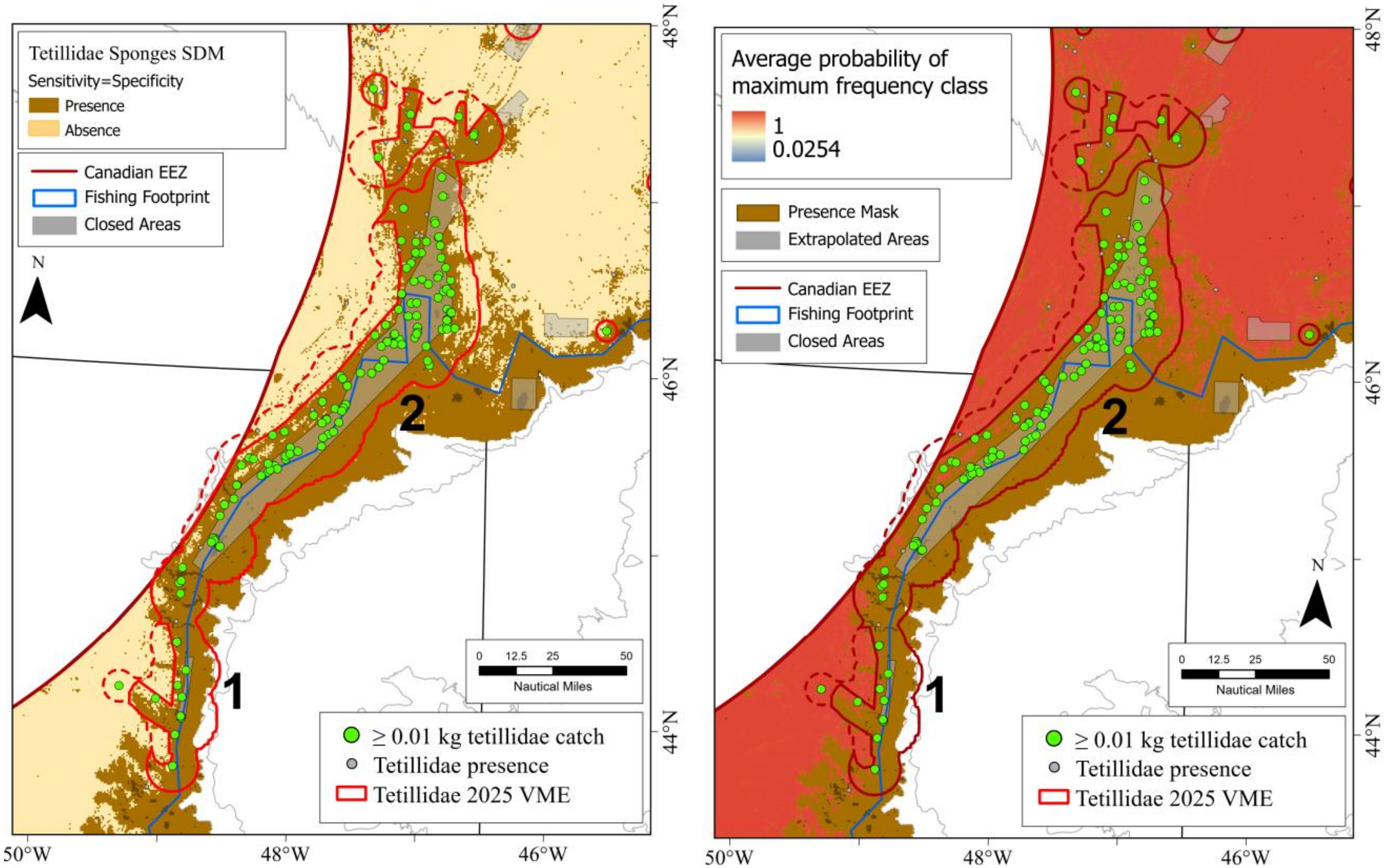


Figure 14. **Areas 1, 2 and 11. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Tetillidae Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) near Areas 1, 2 and 11 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Tetillidae Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.01 kg, the threshold for the KDE analyses, and all other catches with < 0.01 kg are shown.

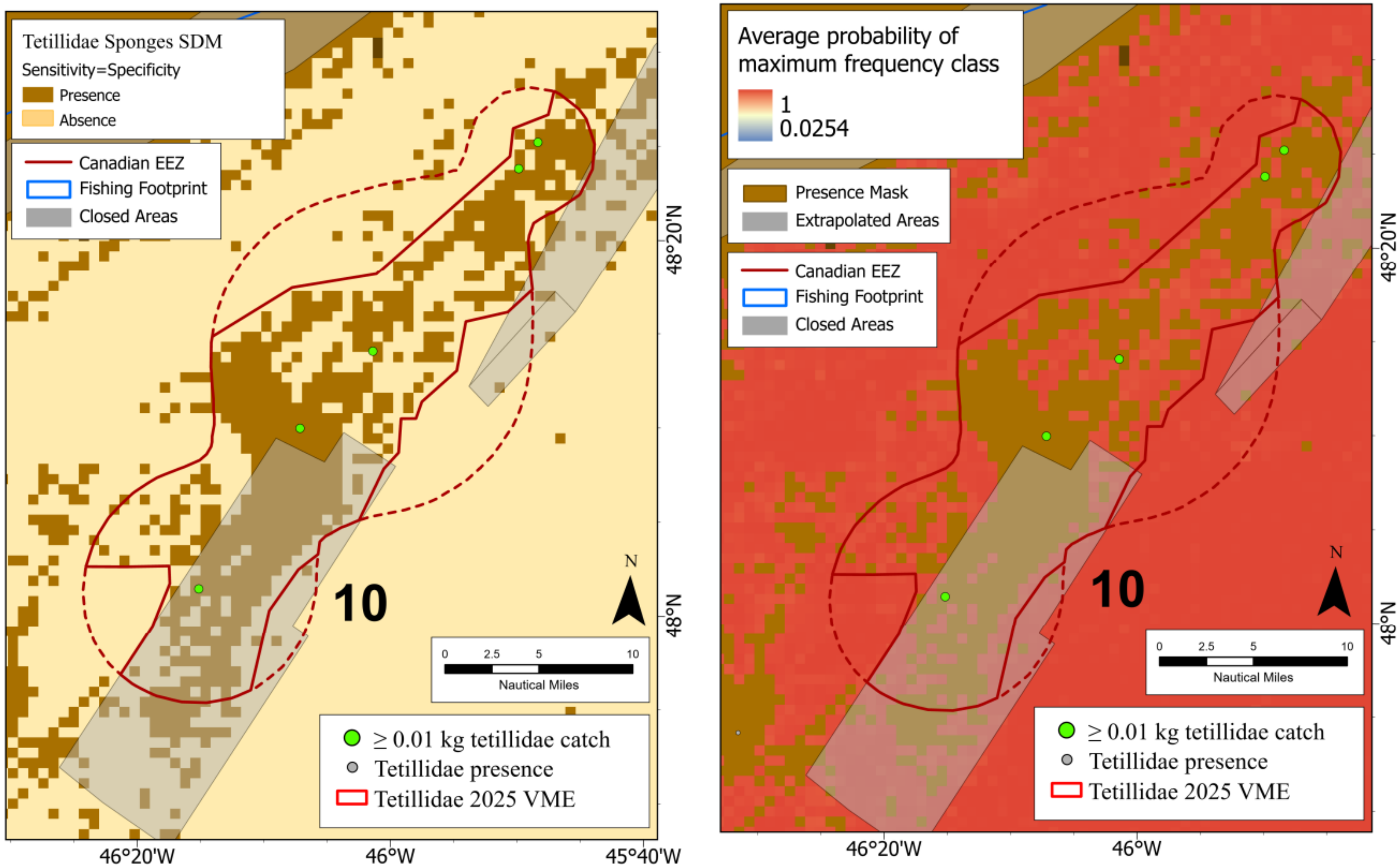


Figure 15. **Area 10. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Tetillidae Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Tetillidae Sponge KDE VME polygon (red dashed lines) near Area 10 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Tetillidae Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.01 kg, the threshold for the KDE analyses, and all other catches with < 0.01 kg are shown.

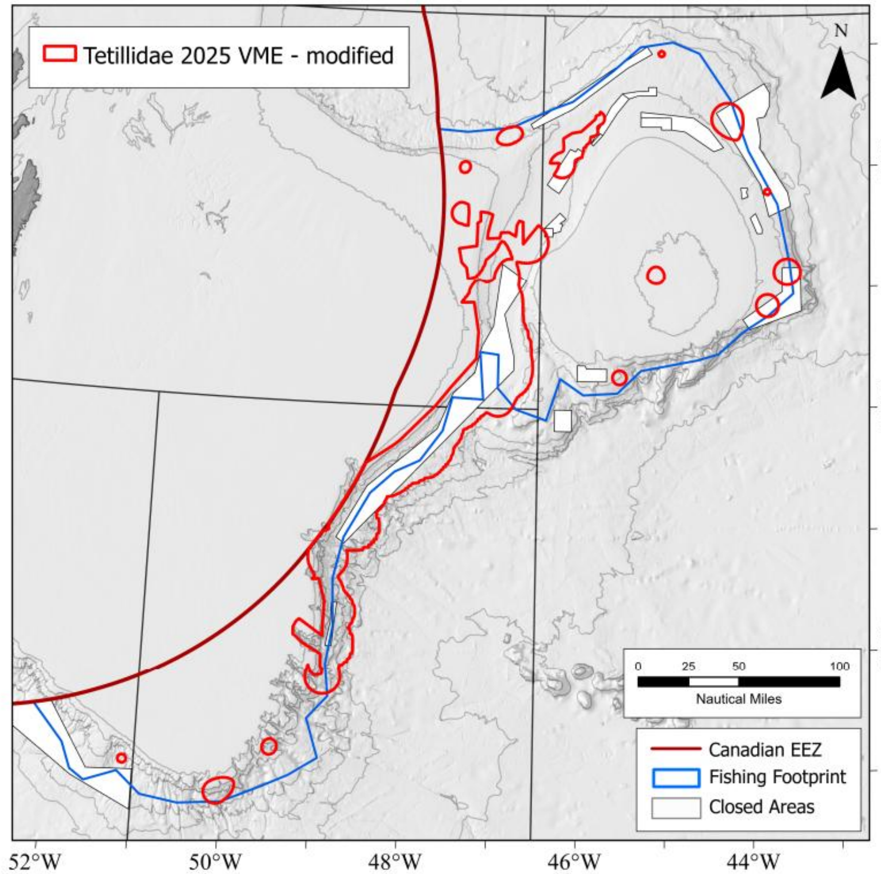


Figure 16. Map of the proposed Tetillidae Sponge VME polygons (red outline) after consideration of modifications based on the SDM for Tetillidae Sponges (Murillo et al., 2024). Closed areas are indicated in white (NAFO, 2025).

Polymastiidae

The Polymastiidae subgroup of Large-Size Sponges was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. The 2025 KDE VME polygons for the Polymastiidae Sponges (Kenchington et al., 2025) superimposed on the SDM for the Polymastiidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024) is shown in Figure 16. Twenty-three KDE VME polygons for the Polymastiidae Sponges were identified with one being large and the others relatively smaller (Figure 17). Of these, the VME polygon that includes parts of Area 5 and Area 14b on the eastern slope of Flemish Cap is proposed for modification. There is a high probability of predicted absence between the two lobes of the polygon (Figures 18, 19) along with a low probability of predicted presence (Figure 19; Right Panel).

Proposed Modifications to the Polymastiidae Sponge VME Polygons

Areas 5 and 14b. The proposed modifications to the Polymastiidae Sponge KDE VME polygon that includes parts of two closure areas (Area 5 and Area 14b) was split into two, clipping out the area of predicted absence that is modeled with high probability of absence in that region (Figure 20).

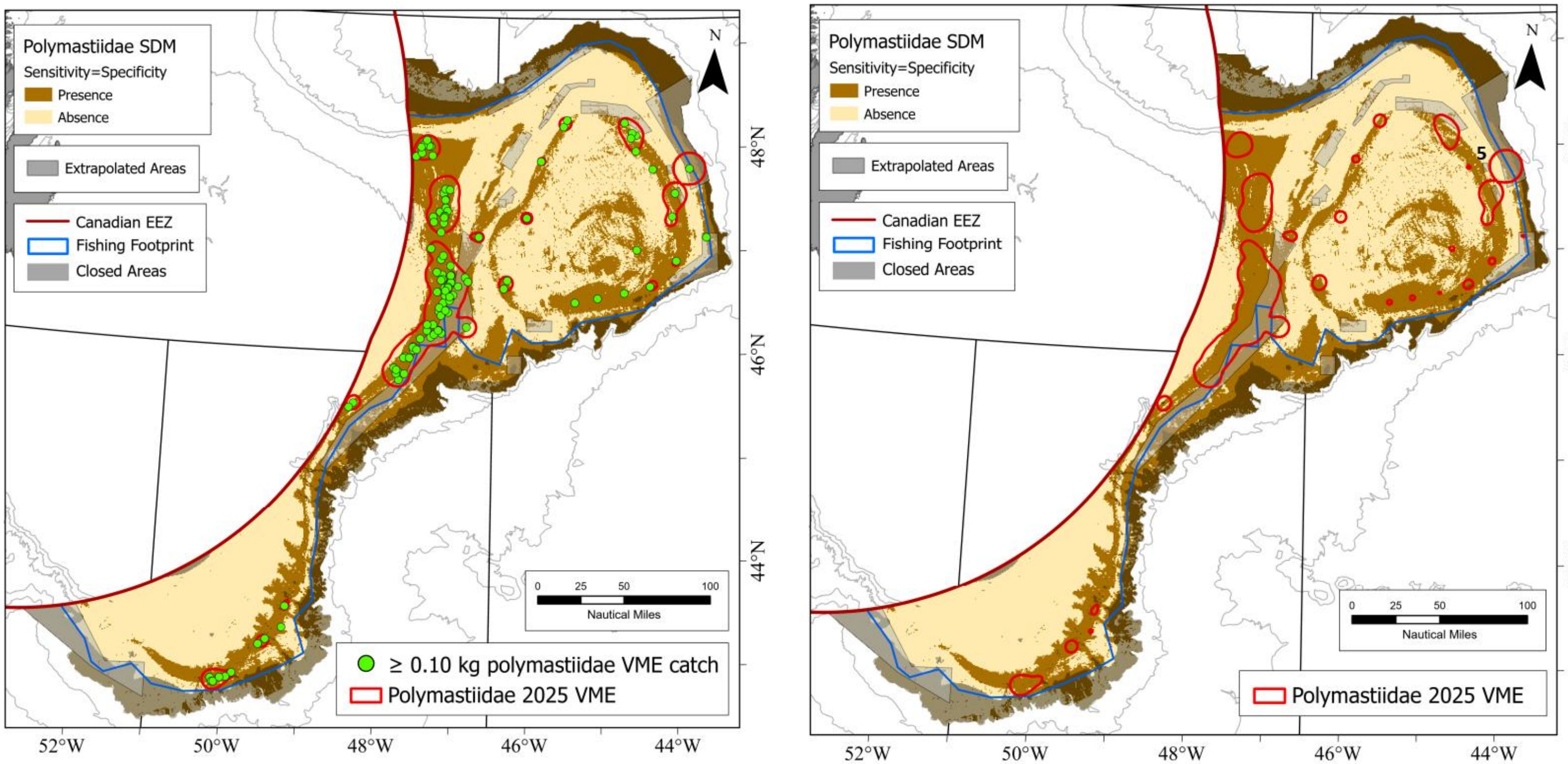


Figure 17. **Left Panel.** The 2025 Polymastiidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for Polymastiidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 0.1 kg are indicated. **Right Panel.** The 2025 Polymastiidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Polymastiidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications.

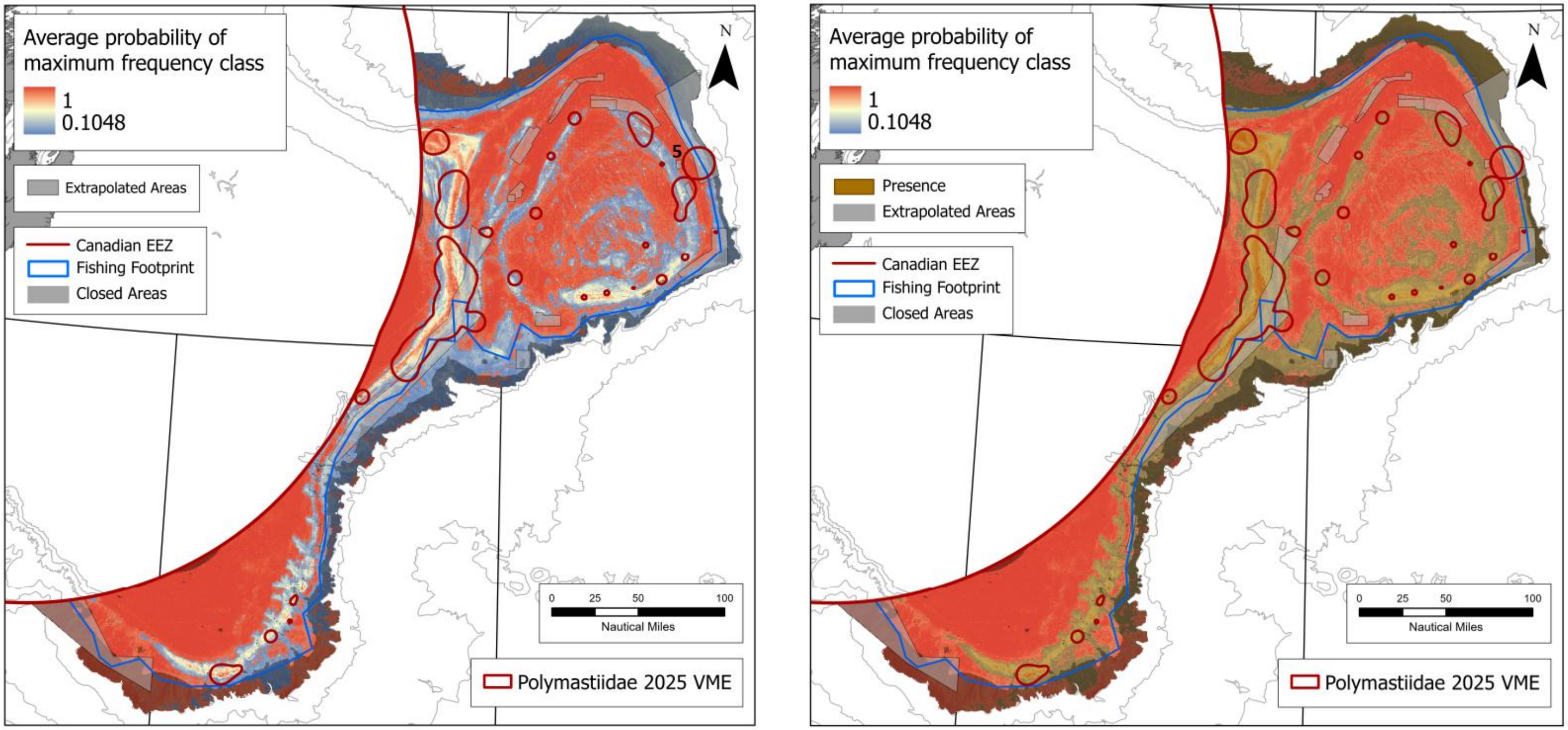


Figure 18. **Left Panel.** The 2025 Polymastiidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Polymastiidae Sponge (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for potential modifications. **Right Panel.** The 2025 Polymastiidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Polymastiidae Sponge which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Polymastiidae Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

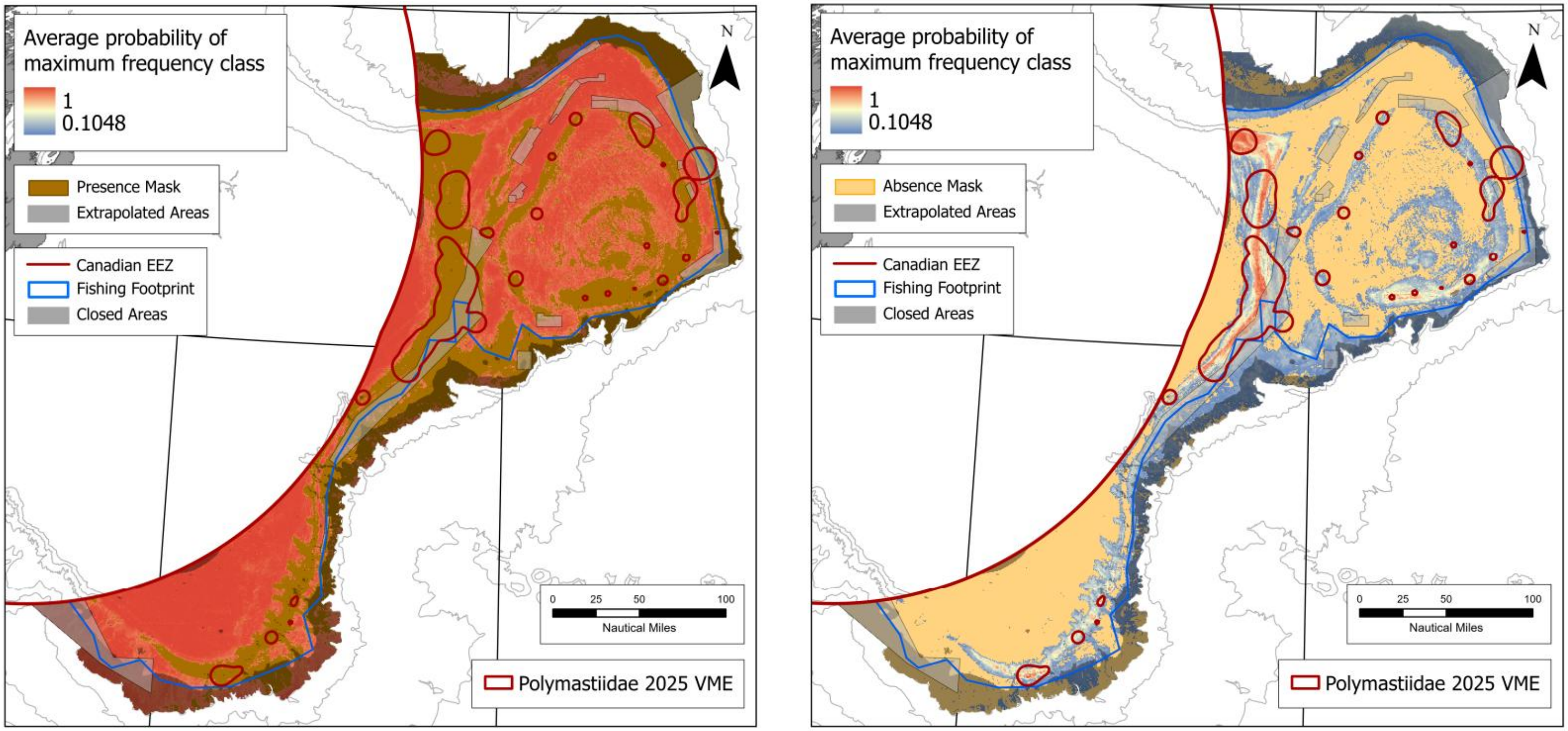


Figure 19. **Left Panel.** The 2025 Polymastiidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Polymastiidae Sponge (Murillo et al., 2024). **Right Panel.** The 2025 Polymastiidae Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Polymastiidae Sponge (Murillo et al., 2024).

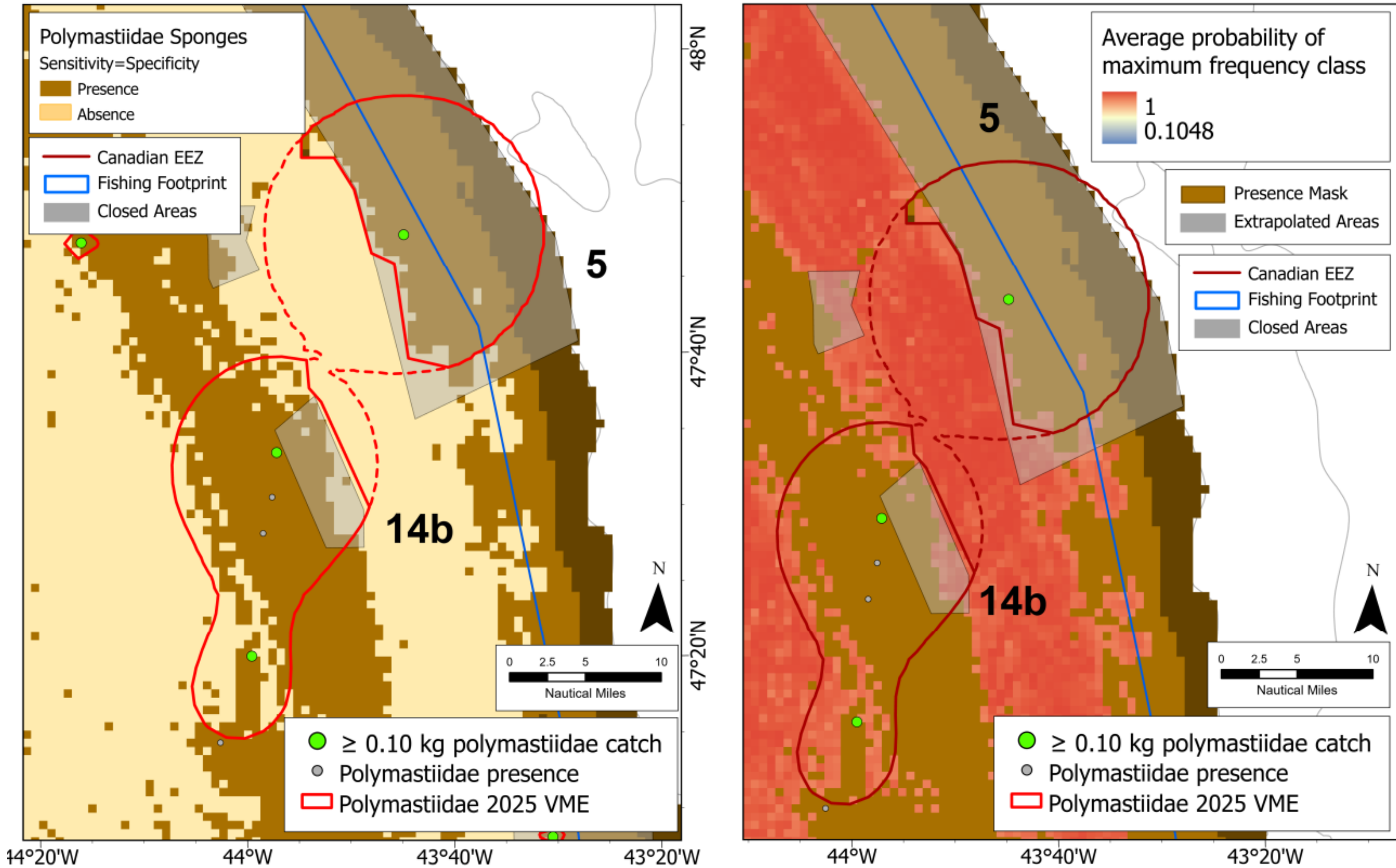


Figure 20. Areas 5 and 14b. Left Panel. Map of the proposed modification (solid red line) of the 2025 Polymastiidae Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Polymastiidae Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Polymastiidae Sponge KDE VME polygon (red dashed lines) near Areas 5 and 14b in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Polymastiidae Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.1 kg, the threshold for the KDE analyses, and all other catches with < 0.1 kg are shown.

The proposed modifications would produce 24 Polymastiidae Sponge KDE VME polygons (Figure 21). Those polygons ranged in size from 3.4 km^2 to 5653.85 km^2 (Table 3).

Table 3. The area occupied by each of the Polymastiidae Sponge KDE VME polygons after making the proposed modifications.

Polymastiidae Sponge KDE VME Polygon Label	Polygon Modified	Polygon Area (km^2)
Area 2 Poly1	No	5653.85
Sackville Spur Poly1	No	1705.32
Area 14b Poly1	Yes	688.55
Area 7a Poly1	No	640.12
Area 5 Poly1	Yes	602.59
Sackville Spur Poly2	No	554.90
GB Tail Poly1	No	515.39
FC SW Poly1	No	173.31
Slope Poly1	No	170.83
FC North Poly1	No	127.74
GB Tail Poly2	No	125.25
Area 2 Poly2	No	107.44
FC W Poly1	No	106.67
FC S Poly1	No	76.30
GB Tail Poly3	No	51.47
FC W Poly2	No	42.54
FC S Poly2	No	36.14
FC Poly1	No	21.16
FC S Poly3	No	18.55
FC S Poly4	No	17.37
GB Tail Poly4	No	10.14
FC E Poly1	No	8.96
Area 4 Poly1	No	3.93
FC S Poly5	No	3.40
Total Area:		**11461.92**

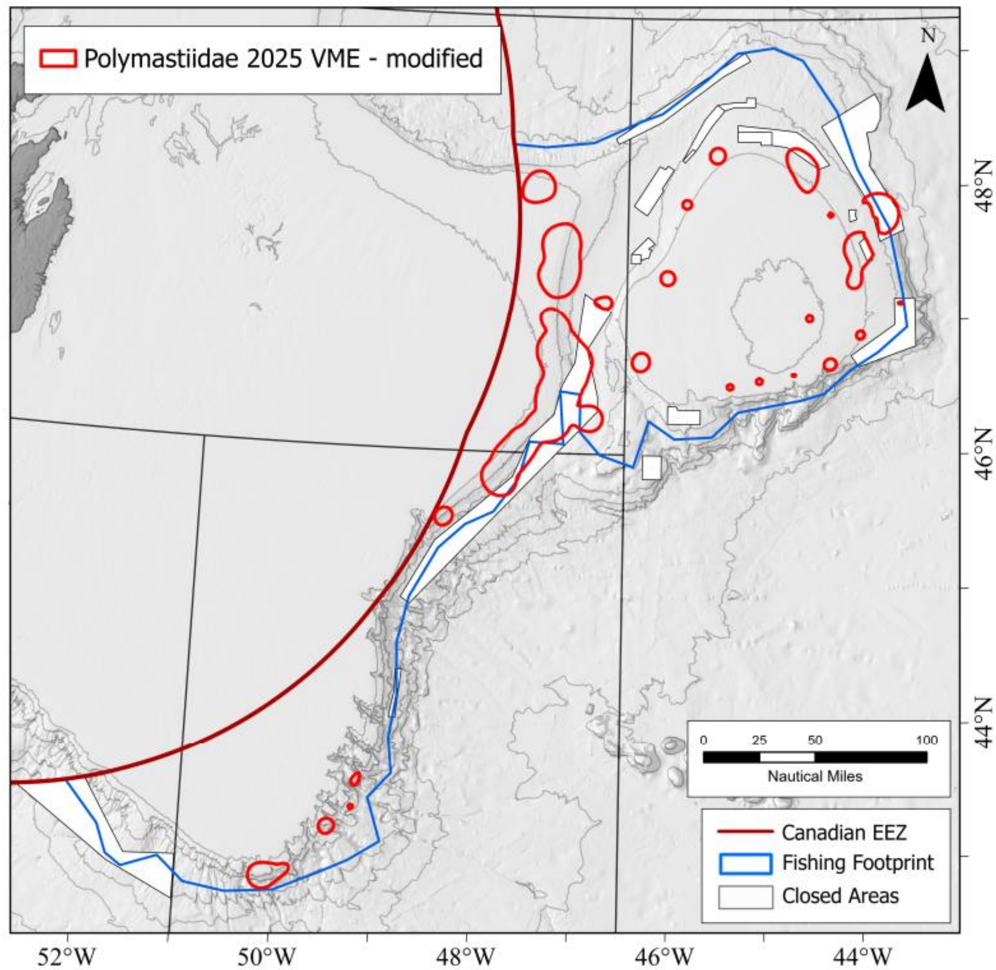


Figure 21. Map of the proposed Polymastiidae Sponge VME polygons after consideration of modifications based on the SDM for Polymastiidae Sponges (Murillo et al., 2024). Closed areas are indicated in white (NAFO, 2025).

Astrophorina

The Astrophorina subgroup of Large-Size Sponges was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. The 2025 KDE VME polygons for the Astrophorina Sponges (Kenchington et al., 2025) superimposed on the SDM for the Astrophorina Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024) is shown in Figure 22. Most of the KDE VME polygons fall within the area of predicted sponge presence (Figure 22). However some of them extend into areas of predicted absence (Figures 23, 24). Closer examination of 6 of the polygons was deemed useful for determining whether modifications were needed or not. These are the polygons in the vicinity of Areas 1, 2, 5,6,7 and 13.

Proposed Modifications to the Astrophorina Sponge VME Polygons

Area 1. The Astrophorina Sponge KDE VME polygon that encompasses Area 1 was clipped on its northwestern edge to the edge of the predicted presence from the SDM (Figure 25). This area of absence was very certain with an associated high probability.

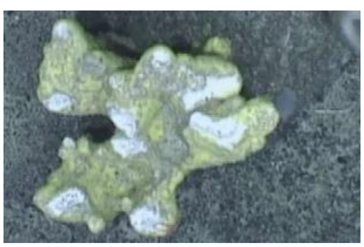
Area 2. The Astrophorina Sponge KDE VME polygon in Flemish Pass overlays the closure Area 2 (Figure 26). It extends across the Canadian EEZ at its southwestern boundary but mostly follows areas of predicted sponge presence. Small modifications are suggested as illustrated in Figure 24 to exclude areas where the SDM predicts absence with high probability.

Area 5. Two Astrophorina Sponge KDE VME polygons include portions of Area 5 in their extents (Figure 27). Both largely overlapped with the area of predicted Astrophorina Sponge presence, but proposed modifications were made to both 24 to exclude areas where the SDM predicts absence with high probability.

Areas 6 and 10. Two Astrophorina Sponge KDE VME polygons include portions of Areas 6 and 10 in their extents (Figure 28). The one that includes Area 6 has almost half of its extent in the area where the SDM predicts absence with high probability and where there are no smaller catches to indicate recovery potential. This is an area of heavy fishing activity (Kenchington et al. 2019) which may explain the distributions. The other polygon captures much of Area 10 and some of Area 9 and has smaller portions extending in to the area where the SDM predicts absence with high probability. Both areas were clipped to the boundary of the predicted presence of sponge from the SDM model.

Area 13. The polygon which included large parts of Area 13 (Figure 29) included some areas where the SDM predicts absence with high probability (Figure 29). As for the other polygons the area was clipped to the boundary of the predicted presence of sponge from the SDM model.

Table 4. The area occupied by each of the Astrophorina Sponge KDE VME polygons after making the proposed modifications.



Astrophorina Sponge KDE VME Polygon Label	Polygon Modified	Polygon Area (km^2)
Area 2 Poly1	Yes	14934.29
Area 5 Poly1	Yes	2855.49
Area13 Poly1	Yes	2142.40
Area1 Poly1	Yes	2058.83
Area 10 Poly1	Yes	1857.56
Area6 Poly1	Yes	884.52
Area5 Poly2	Yes	801.07
Area4 Poly1	No	793.32
Area6 Poly2	No	203.50
FlemishPass Poly1	No	95.03
Area4 Poly2	No	38.02
Sackville Spur Poly1	No	17.65
FlemishPass Poly2	No	13.56
FlemishCap Poly1	No	9.13
Total Area:		**26704.36**

The proposed modifications would produce 14 Astrophorina Sponge KDE VME polygons (Figure 30). Those polygons ranged in size from 9.13 km^2 to 14934.29 km^2 (Table 4).

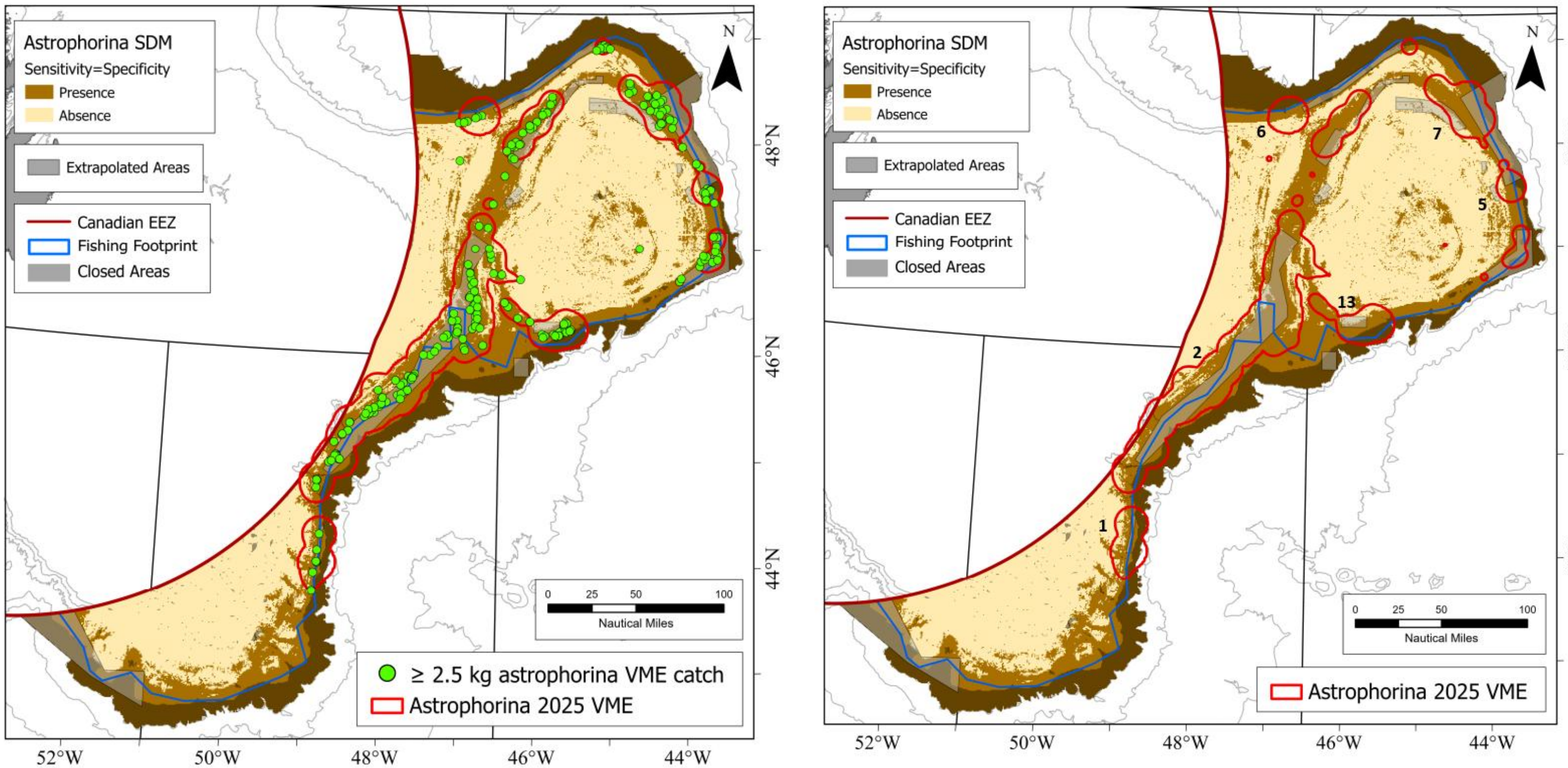


Figure 22. **Left Panel.** The 2025 Astrophorina Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for Astrophorina Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 2.5 kg are indicated. **Right Panel.** The 2025 Astrophorina Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Astrophorina Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications.

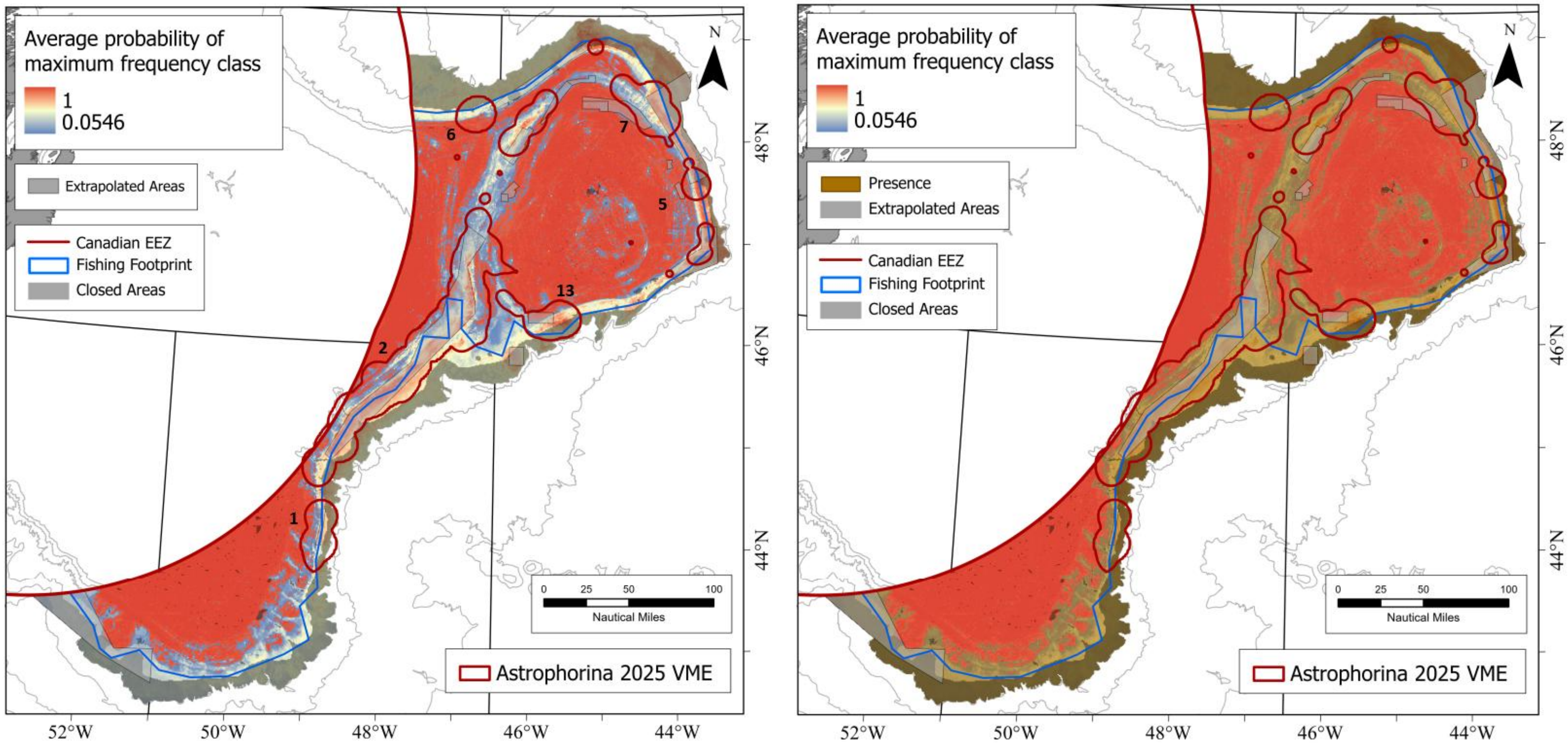


Figure 23. Left Panel. The 2025 Astrophorina Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Astrophorina Sponge (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for potential modifications. **Right Panel.** The 2025 Astrophorina Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Astrophorina Sponge which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Astrophorina Sponge created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

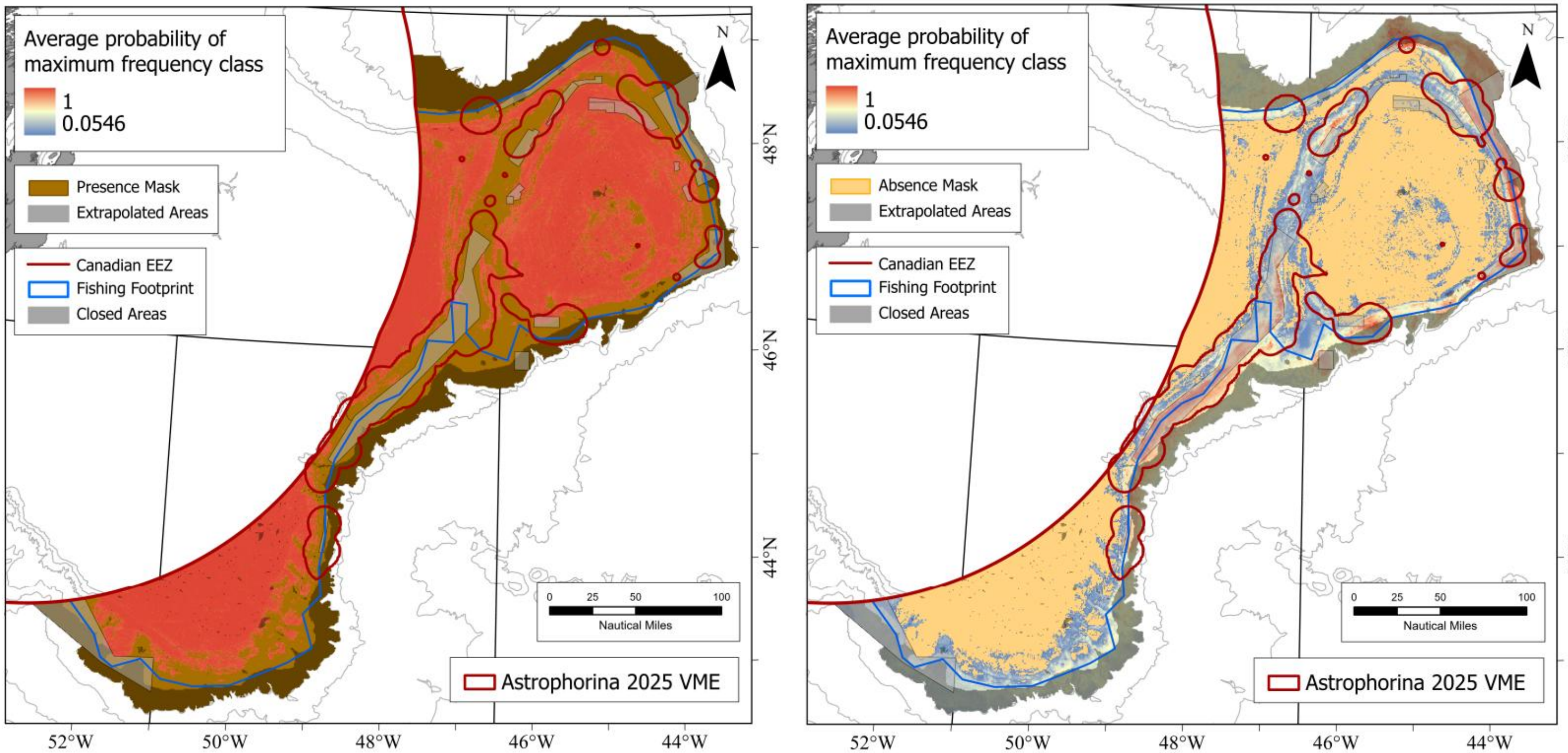


Figure 24. **Left Panel.** The 2025 Astrophorina Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponge (Murillo et al., 2024). **Right Panel.** The 2025 Astrophorina Sponge KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Astrophorina Sponge (Murillo et al., 2024).

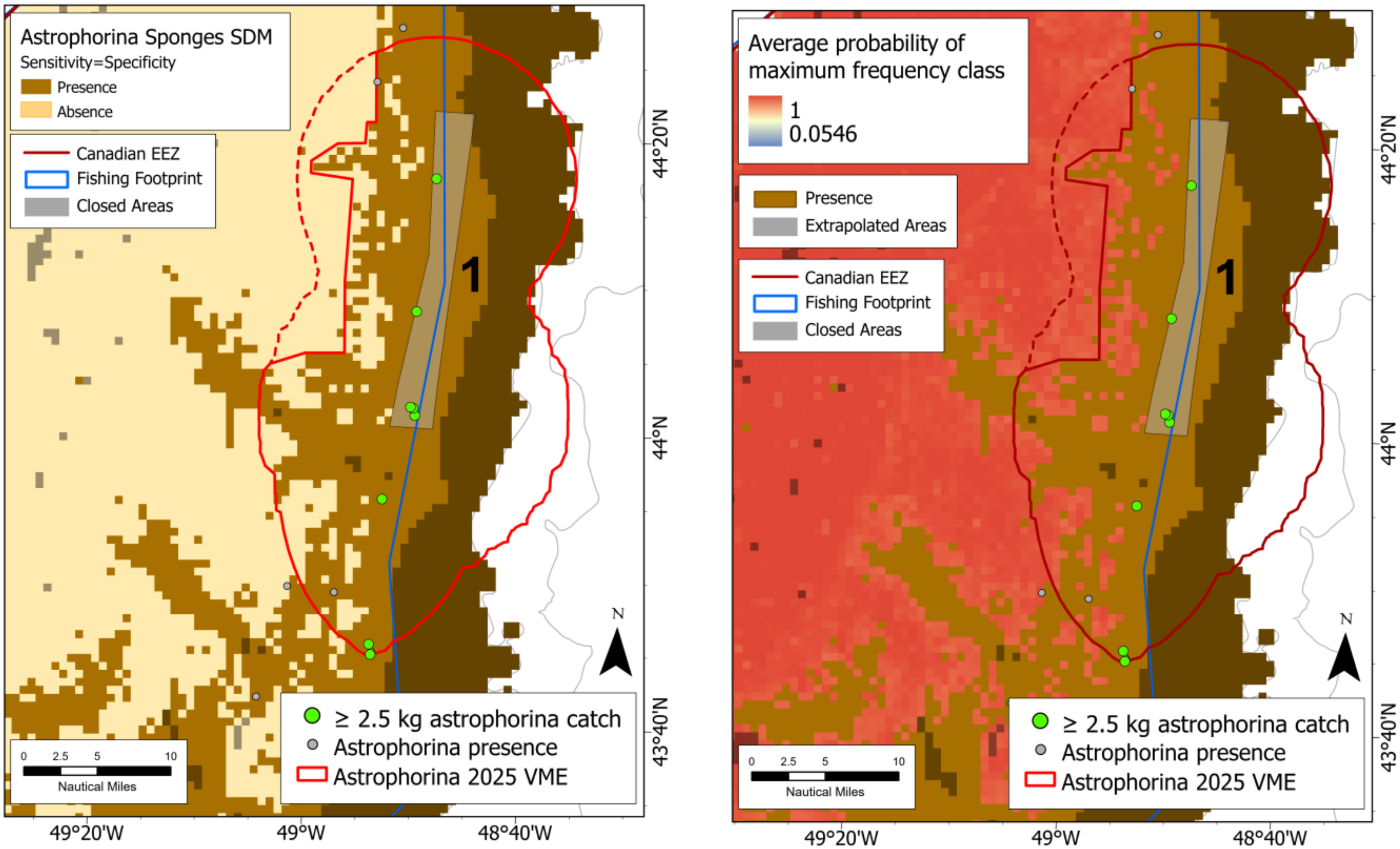


Figure 25. **Area 1. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 1 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

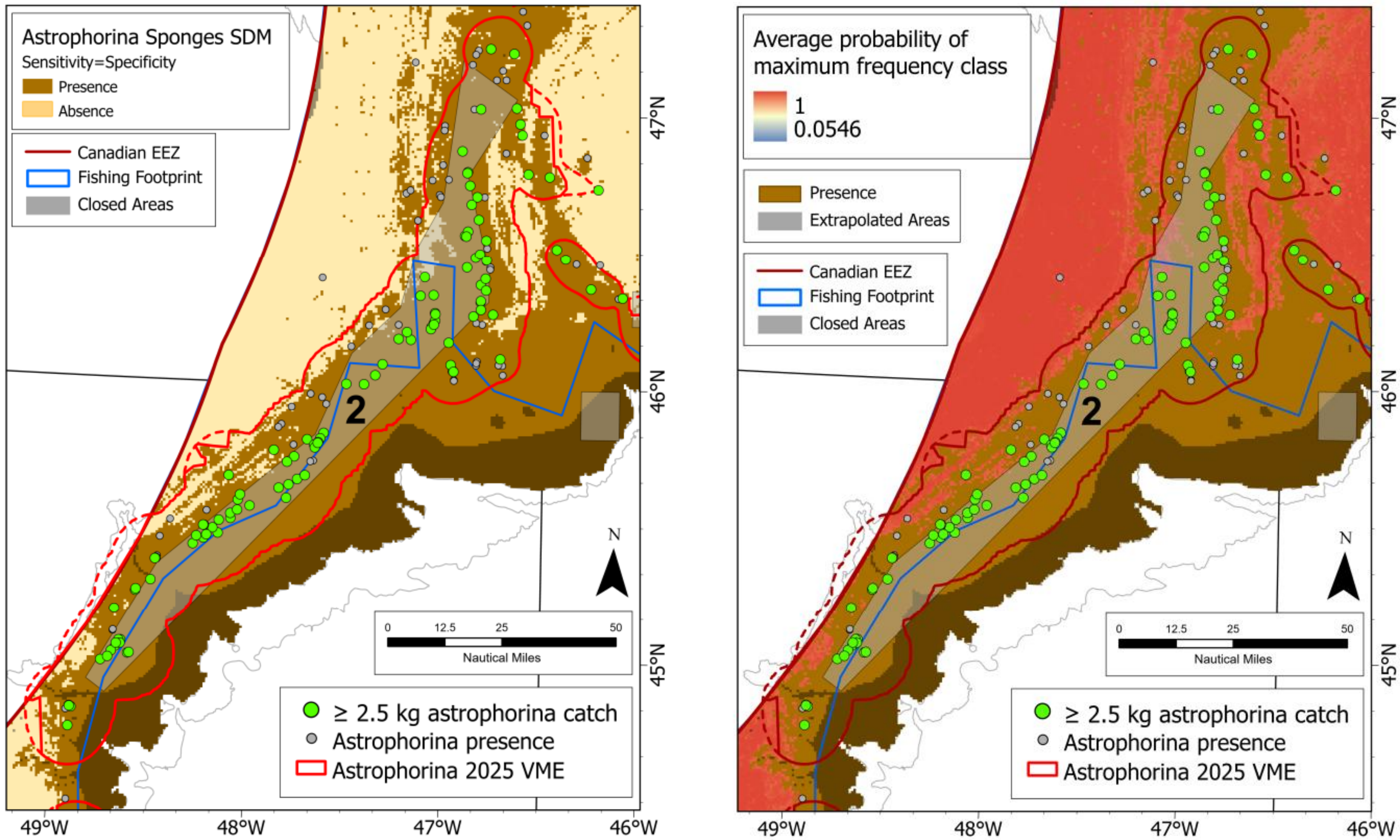


Figure 26. **Area 2. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 2 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

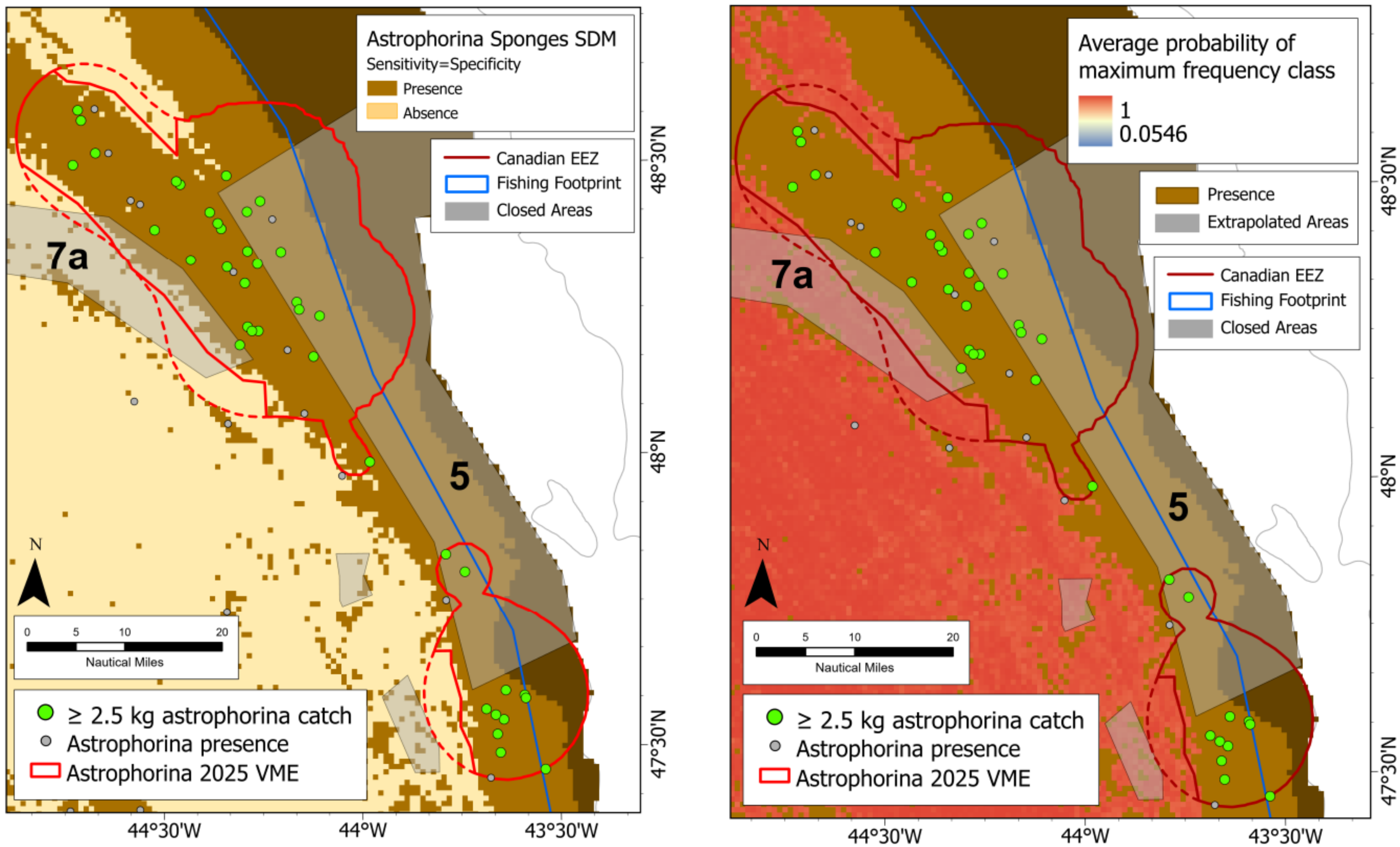


Figure 27. **Area 5. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 5 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

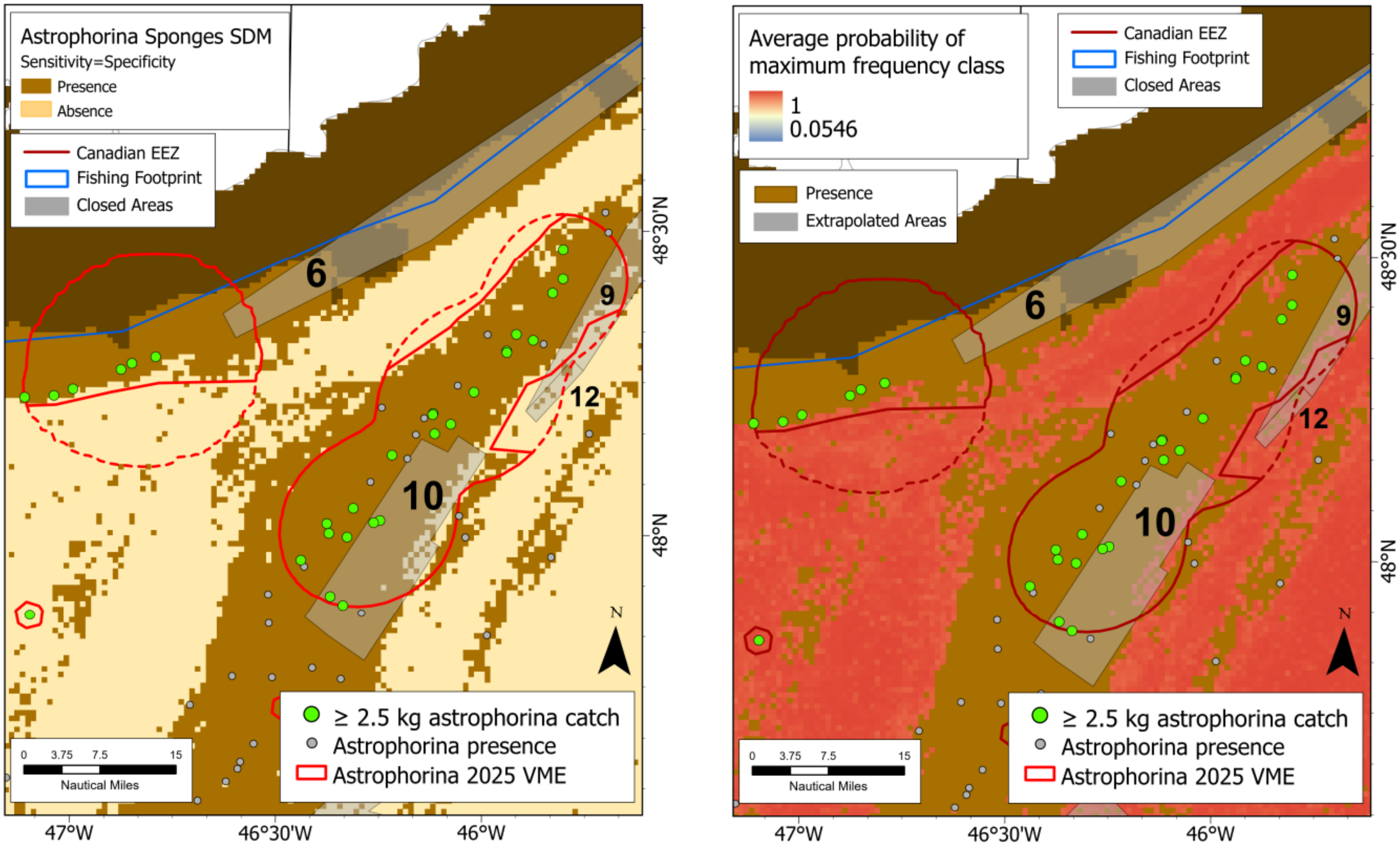


Figure 28. Areas 6 and 10. Left Panel. Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Areas 6 and 10 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

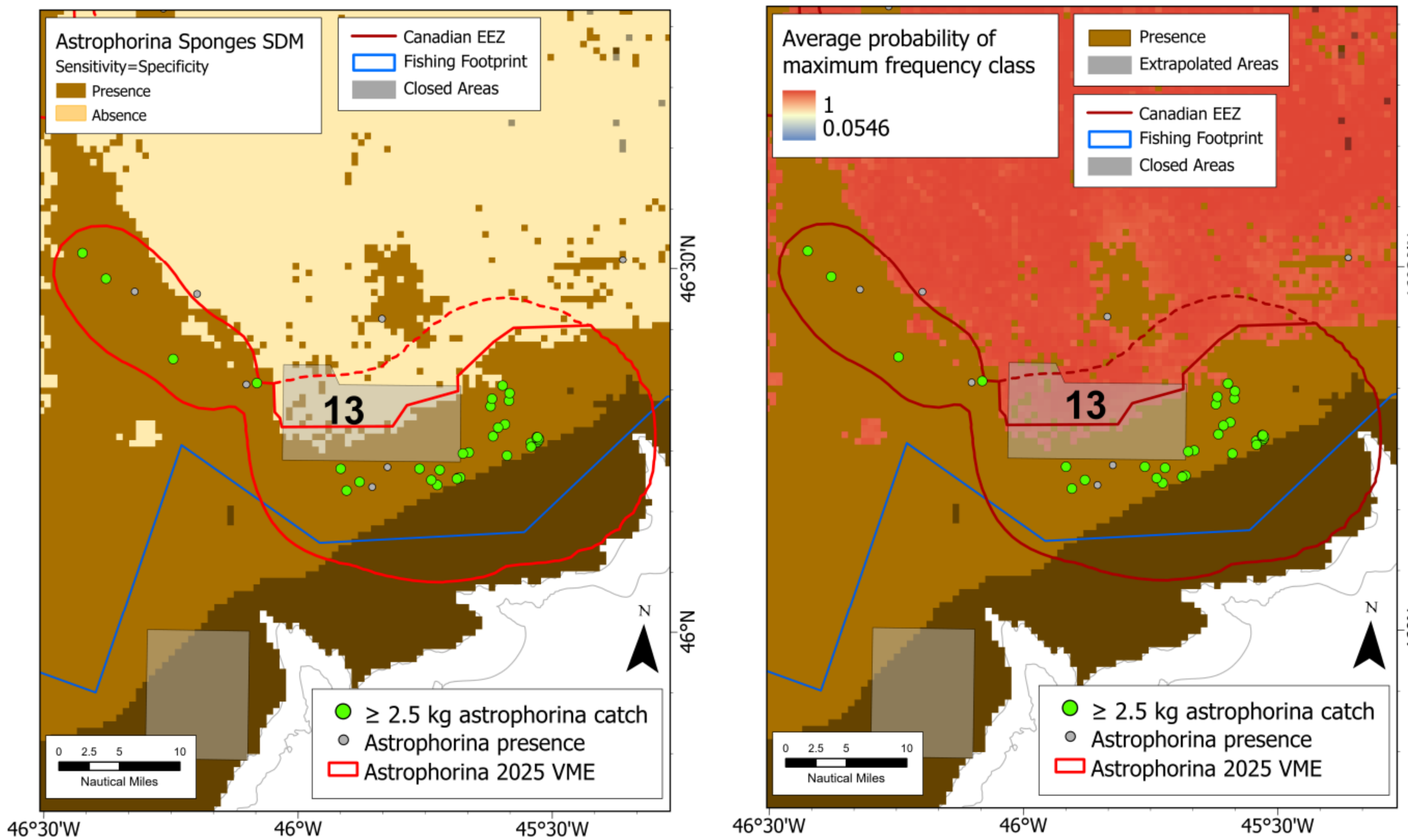


Figure 29. **Area 13. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of Astrophorina Sponges). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Astrophorina Sponge KDE VME polygon (red dashed lines) near Area 13 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Astrophorina Sponges (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 2.5 kg, the threshold for the KDE analyses, and all other catches with < 2.5 kg are shown.

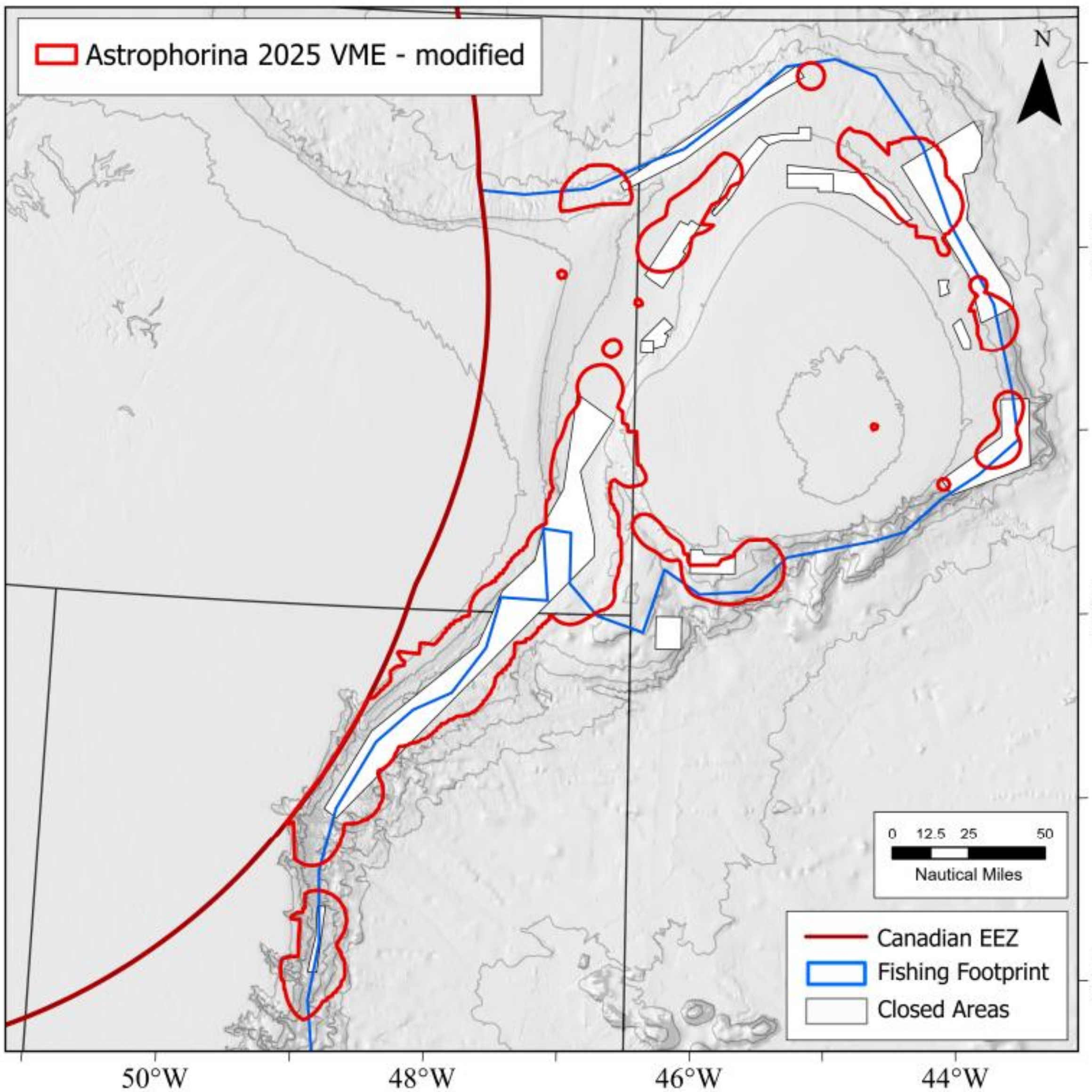


Figure 30. Map of the proposed Astrophorina Sponge VME polygons after consideration of modifications based on the SDM for Astrophorina Sponges (Murillo et al., 2024). Closed areas are indicated in white (NAFO, 2025).

Sea Pens

Figure 31 illustrates the 2025 KDE VME polygons for the Sea Pen Functional Group (Kenchington et al., 2025) superimposed on the SDM for the Sea Pen Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). All of the KDE VME polygons fall within the predicted distribution of Sea Pen presence (Figure 31). This distribution follows a horse-shoe arrangement as has previously been noted (Kenchington et al., 2025).

The area of presence of the Sea Pen Functional Group is predicted with high probability (Figures 32 and 33) and so no modifications are proposed for this functional group.

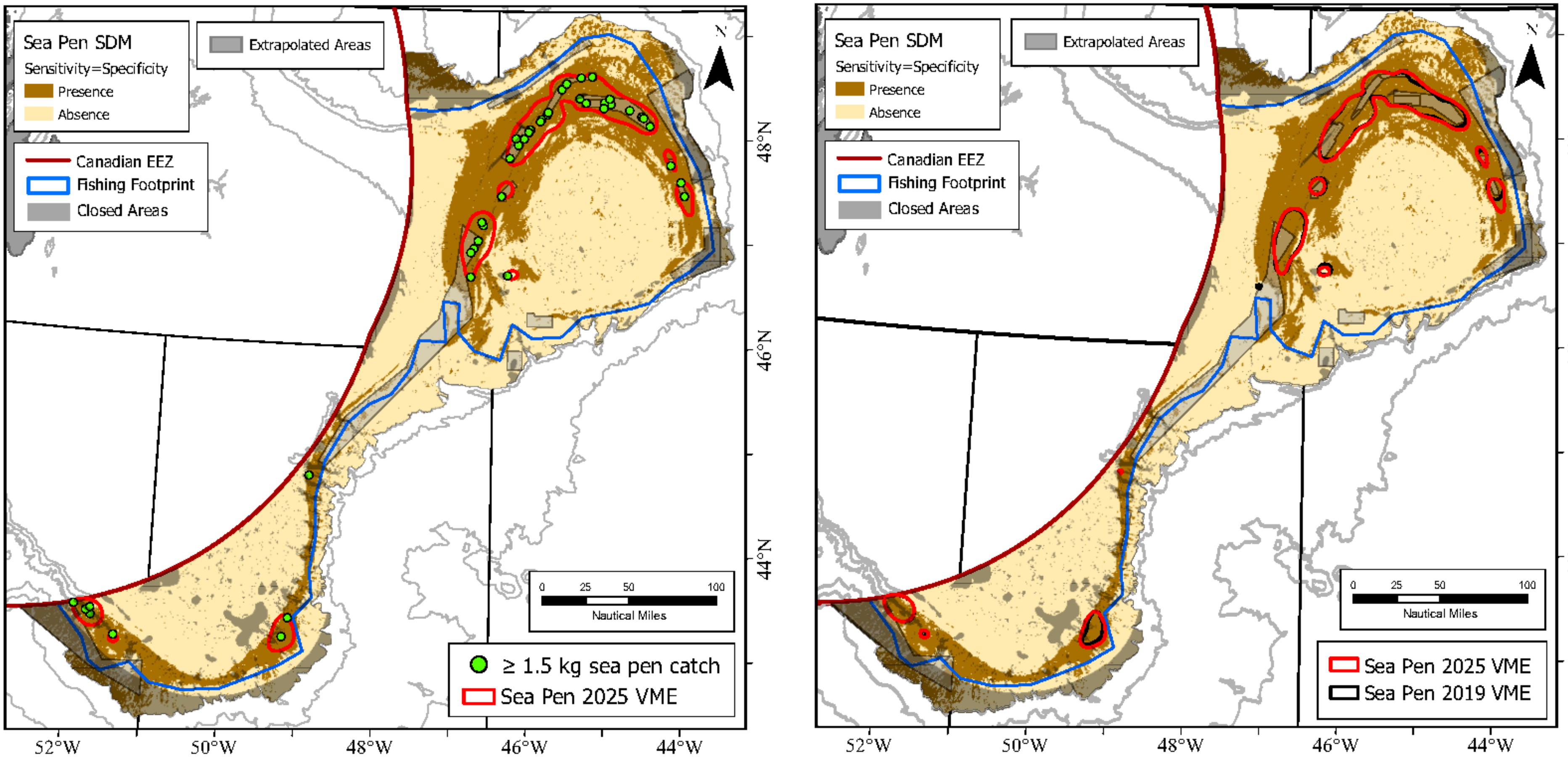


Figure 31. **Left Panel.** The 2025 Sea Pen Functional Group KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Sea Pen Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 1.5 kg are indicated. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Pen Functional Group KDE VME polygons superimposed on the SDM for the Sea Pen Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

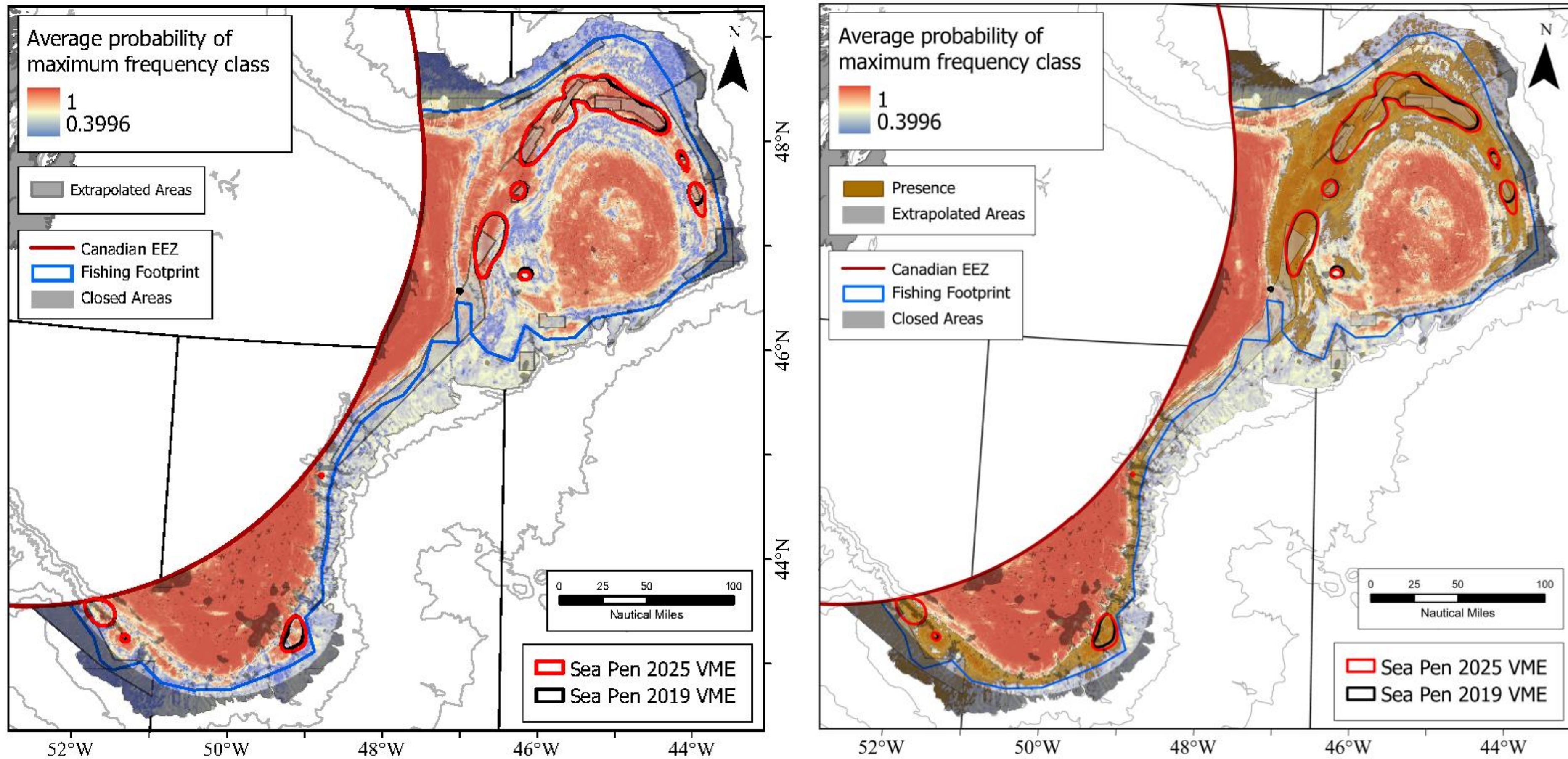


Figure 32. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Pen Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Sea Pen Functional Group (Murillo et al., 2024). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Pen Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Sea Pen Functional Group which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Sea Pen Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

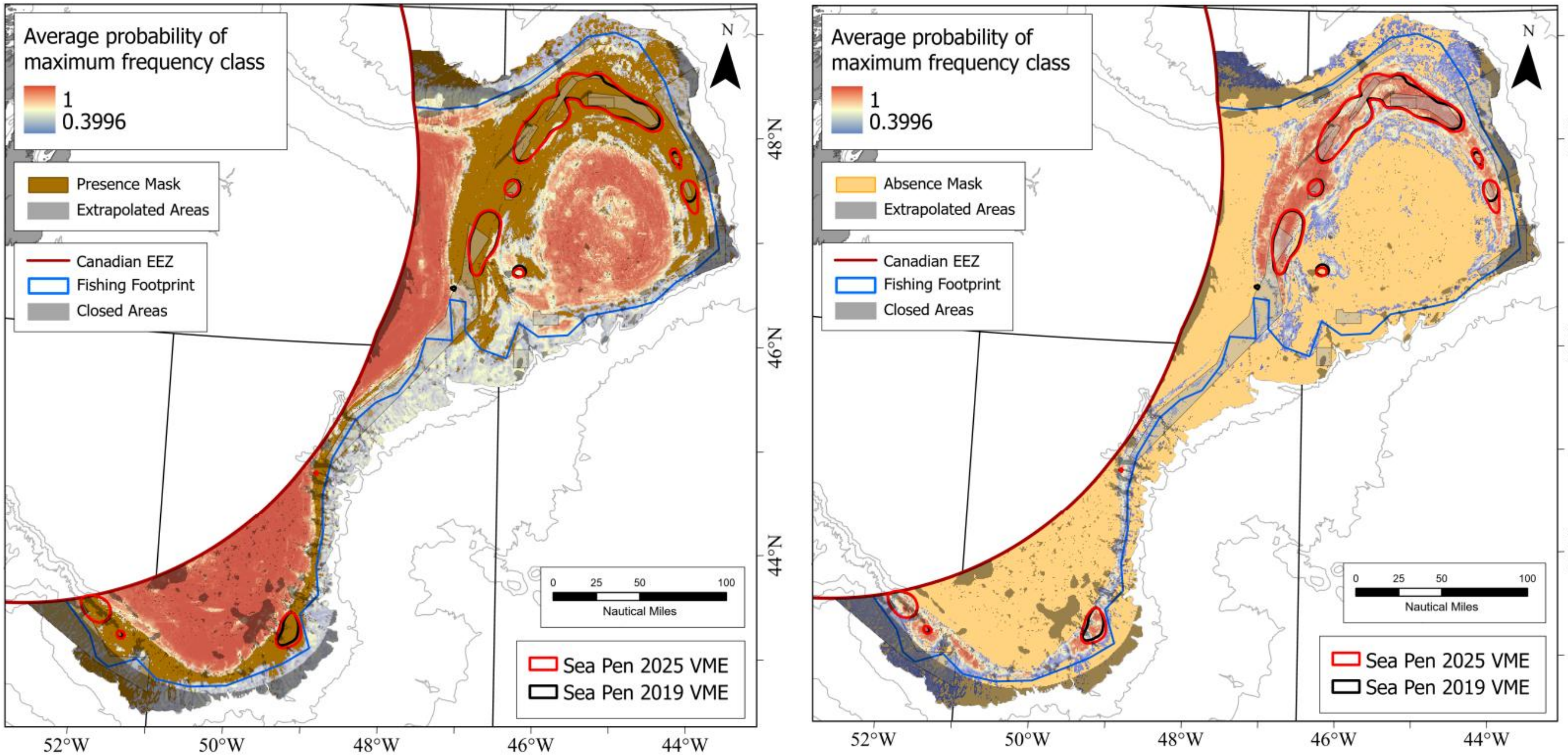


Figure 33. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Pen Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Sea Pen Functional Group (Murillo et al., 2024). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Pen Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Sea Pen Functional Group (Murillo et al., 2024).

Anthoptilum

The *Anthoptilum* subgroup of Sea Pens was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. Figure 34 illustrates the 2025 KDE VME polygons for *Anthoptilum* (Kenchington et al., 2025) superimposed on the SDM for *Anthoptilum* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). All of the KDE VME polygons fall largely within the predicted distribution of *Anthoptilum* presence (Figure 34). Their distribution follows a horse-shoe arrangement as has previously been noted for the Sea Pen Functional Group described above.

The area of presence of *Anthoptilum* is predicted with high probability (Figures 35 and 36). We propose minor modifications for this taxon, one near the Area 3O closure and the other near the Area 13 closure.

Proposed Modifications to the *Anthoptilum* Sea Pen VME Polygons

Area 3O. The KDE VME polygons for *Anthoptilum* located near the 3O Coral Closure includes area that overlaps with predicted absence of *Anthoptilum* that is predicted with high probability (Figure 37). Three modifications are proposed for this polygon as seen in Figure 37.

Area 13. An *Anthoptilum* KDE VME polygon northwest of Area 13 (Figure 35) straddles an area that predicts *Anthoptilum* absence with high probability (Figure 38). The proposed modification is to create two separate polygons using the boundary of predicted *Anthoptilum* presence to demarcate the new polygons (Figure 38).

Table 5. The area occupied by each of the *Anthoptilum* KDE VME polygons after making the proposed modifications.

***Anthoptilum* KDE VME Polygon Label**	**Polygon Modified**	**Polygon Area (km^2)**
FC North Poly1	No	5680.54
Area 3O Poly1	Yes	1315.33
Area 2 Poly1	No	1251.05
Area 14b Poly1	No	519.69
FC West Poly 1	Yes	77.05
Sackville Spur Poly 1	No	50.99
GB Tail Poly1	No	48.35
Area 11a Poly1	No	39.19
FC West Poly 2	Yes	21.00
Area 2 Poly2	No	9.19
Total Area:		9012.39

The proposed modifications would produce ten *Anthoptilum* KDE VME polygons (Figure 39). Those polygons ranged in size from 9.19 km^2 to 5680.54 km^2 (Table 5).

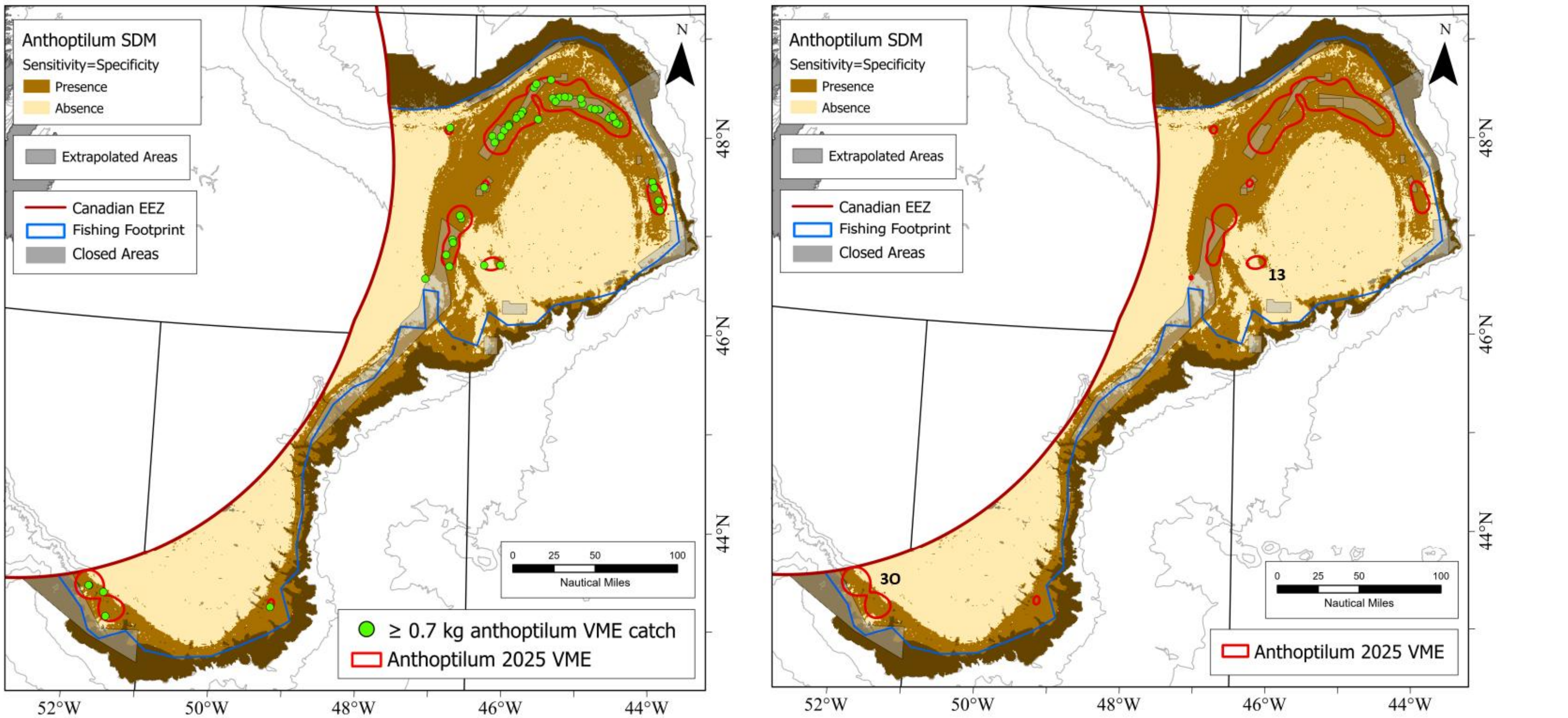


Figure 34. **Left Panel.** The 2025 *Anthoptilum* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Anthoptilum* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 0.7 kg are indicated. **Right Panel.** The 2025 *Anthoptilum* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Anthoptilum* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications.

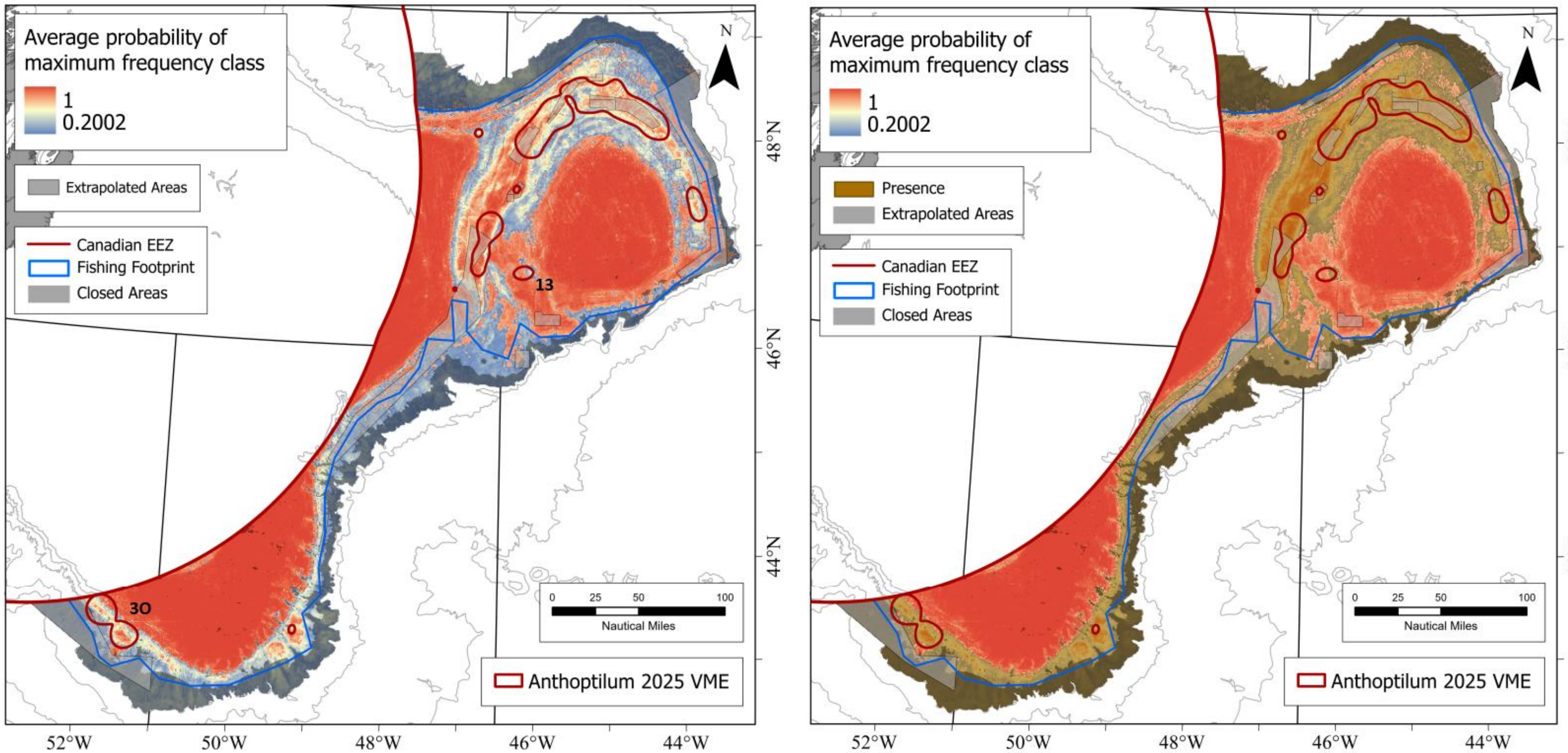


Figure 35. Left Panel. The 2025 *Anthoptilum* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Anthoptilum* (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for potential modifications. **Right Panel.** The 2025 *Anthoptilum* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Anthoptilum* which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the *Anthoptilum* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

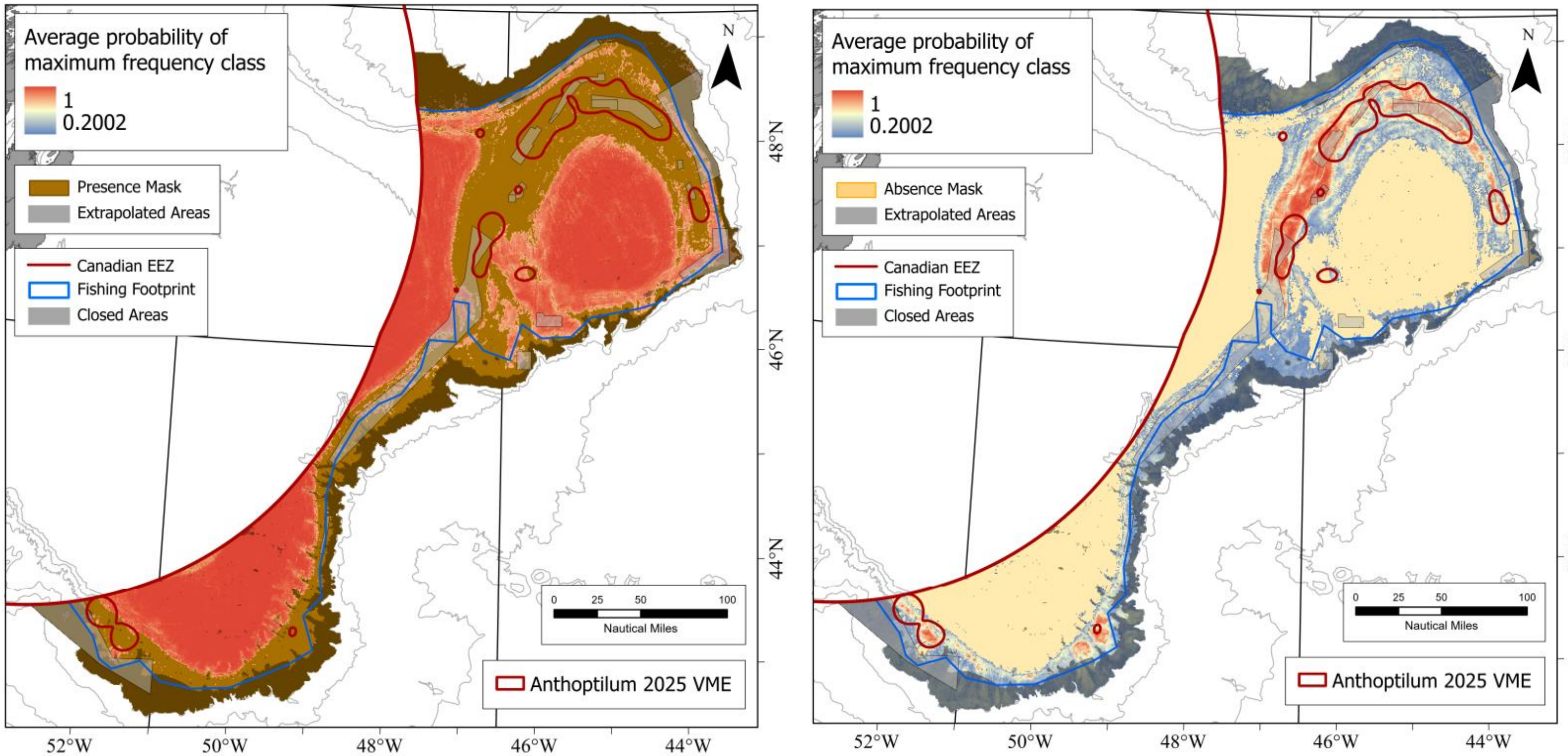


Figure 36. **Left Panel.** The 2025 *Anthoptilum* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Anthoptilum* (Murillo et al., 2024). **Right Panel.** The 2025 *Anthoptilum* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for *Anthoptilum* (Murillo et al., 2024).

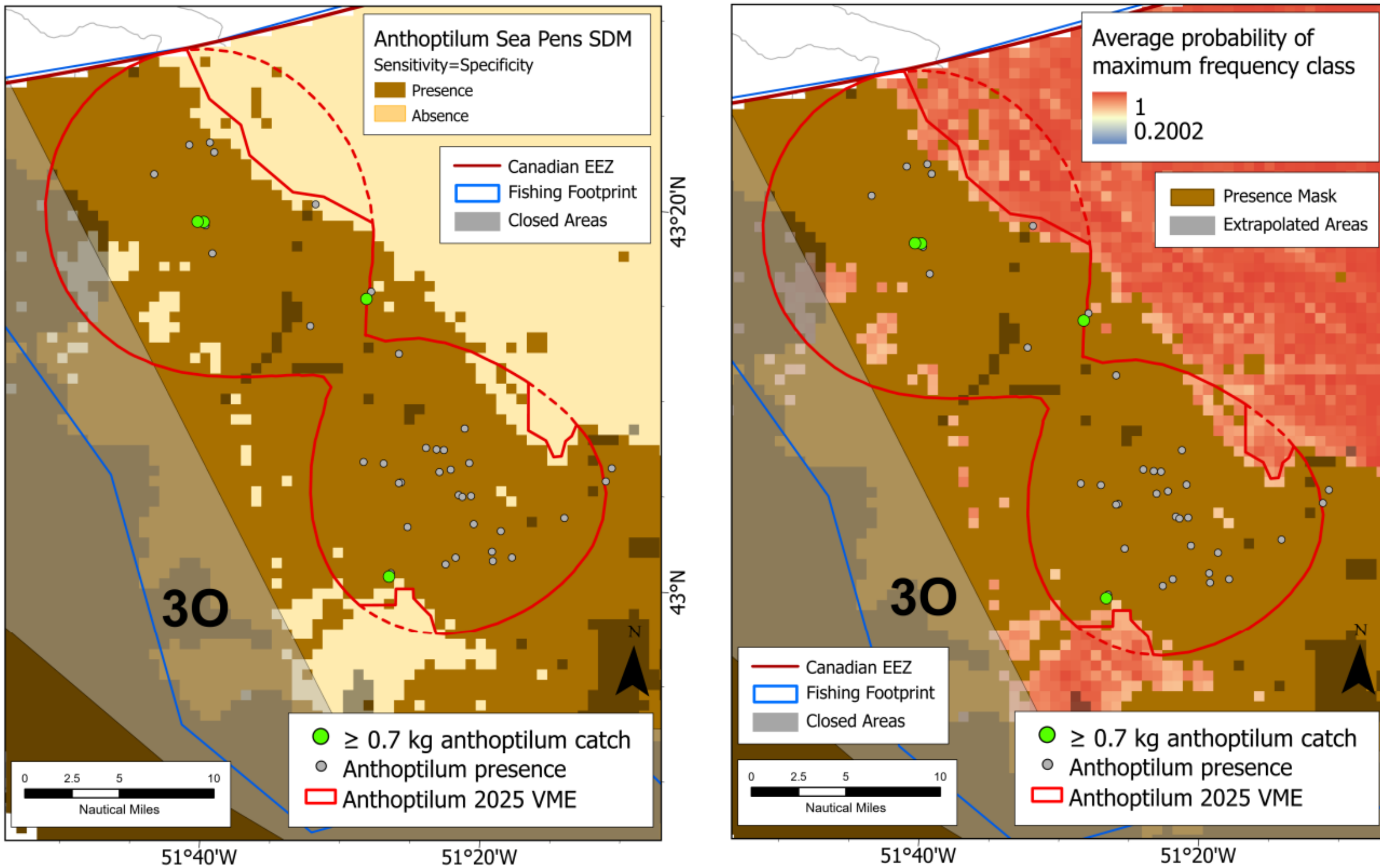


Figure 37. **Area 3O. Left Panel.** Map of the proposed modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Anthoptilum*). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) near Area 3O in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Anthoptilum* (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.7 kg, the threshold for the KDE analyses, and all other catches with < 0.7 kg are shown.

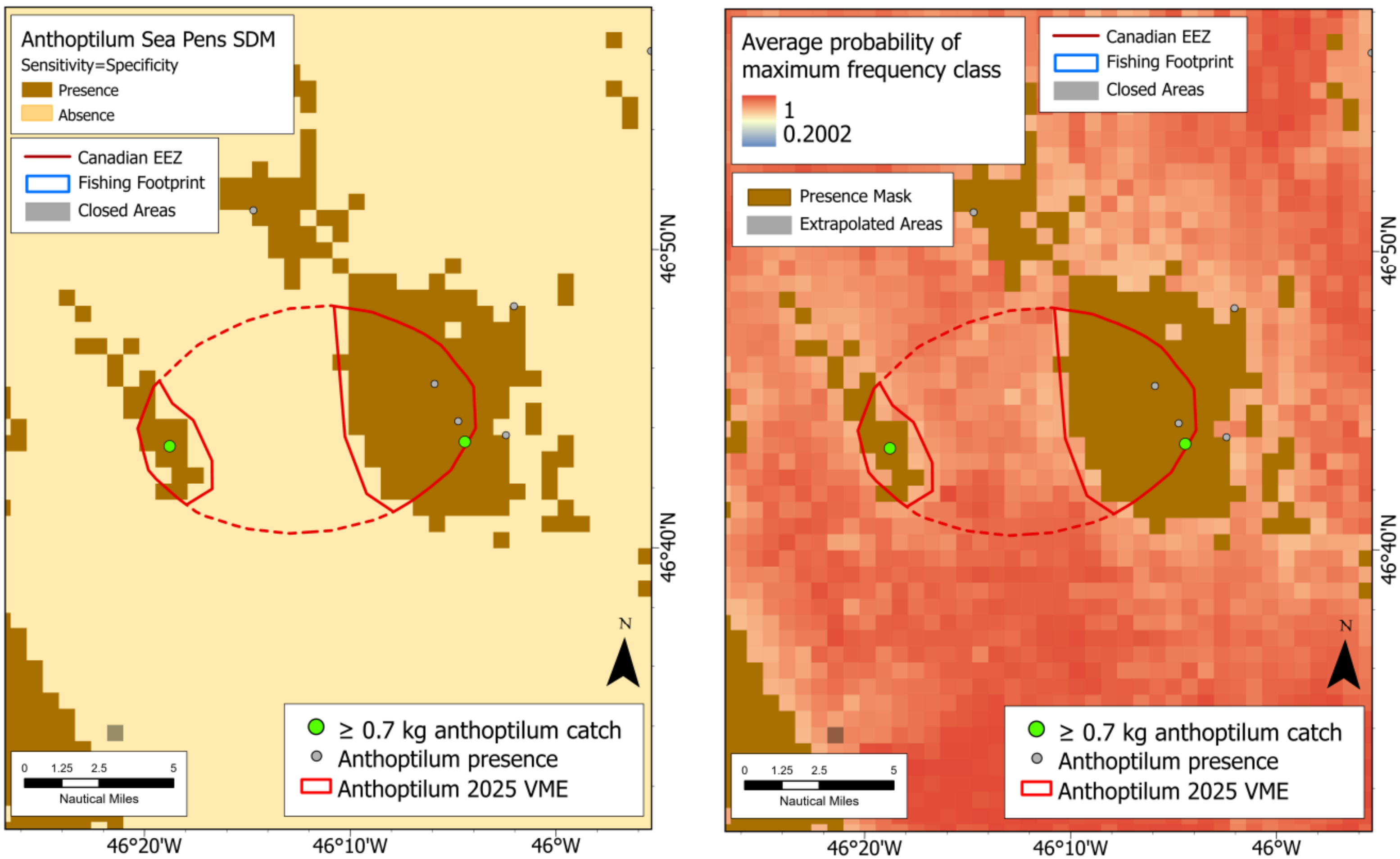


Figure 38. **Area 13. Left Panel.** Map of the proposed modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Anthoptilum*). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 *Anthoptilum* KDE VME polygon (red dashed lines) near Area 13 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Anthoptilum* (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.7 kg, the threshold for the KDE analyses, and all other catches with < 0.7 kg are shown.

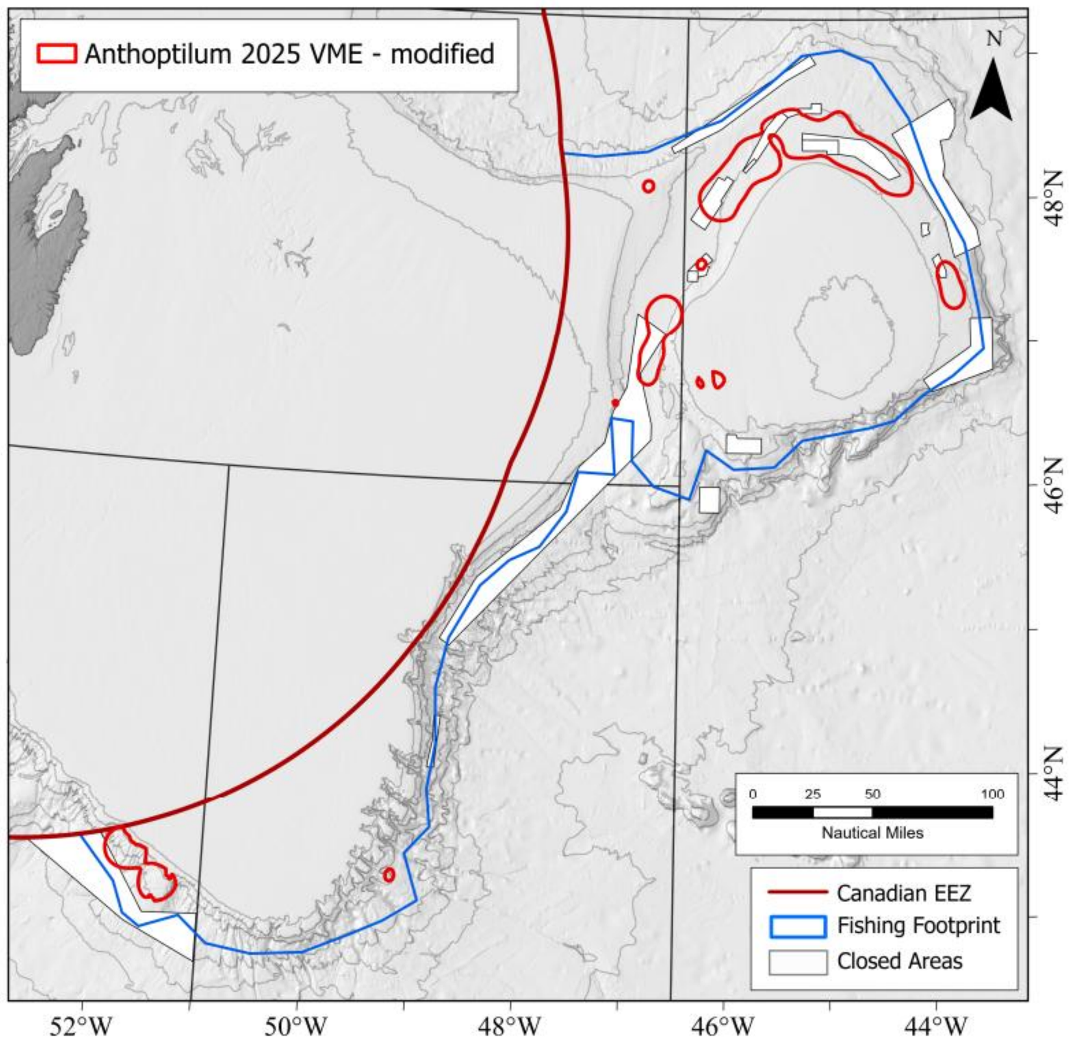


Figure 39. Map of the proposed *Anthoptilum* KDE VME polygons after consideration of modifications based on the SDM for *Anthoptilum* (Murillo et al., 2024). Closed areas are indicated in white (NAFO, 2025).

Balticina

The *Balticina* subgroup of Sea Pens was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. Figure 40 illustrates the 2025 KDE VME polygons for *Balticina* (Kenchington et al., 2025) superimposed on the SDM for *Balticina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). All of the KDE VME polygons fall within the predicted distribution of *Balticina* presence (Figure 40). Their distribution follows a horse-shoe arrangement as has previously been noted for the Sea Pen Functional Group described above. The area of presence of *Balticina* is predicted with high probability (Figures 41 and 42). We propose no further modifications to these KDE VME polygons.

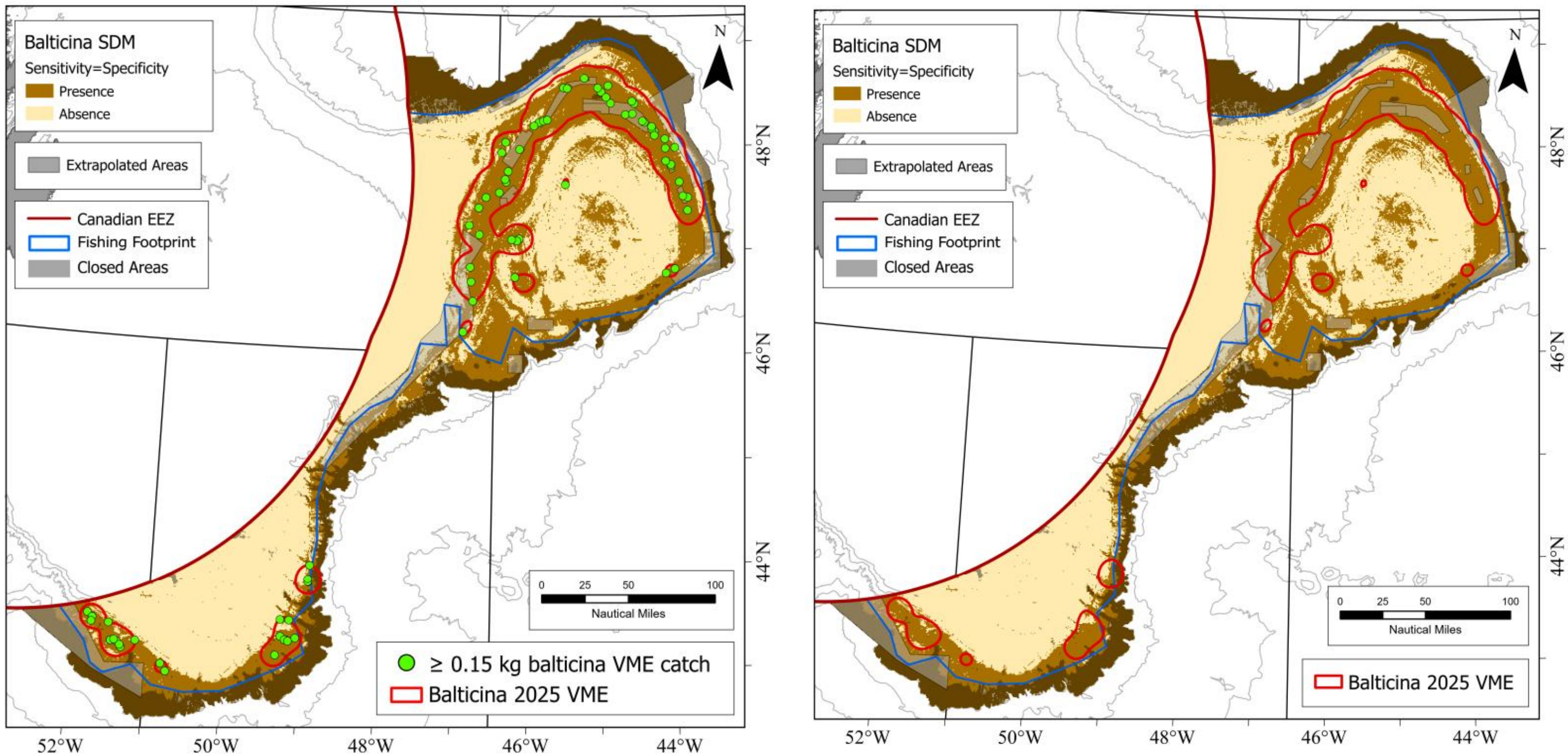


Figure 40. **Left Panel.** The 2025 *Balticina* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Balticina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 0.15 kg are indicated. **Right Panel.** The 2025 *Balticina* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Balticina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

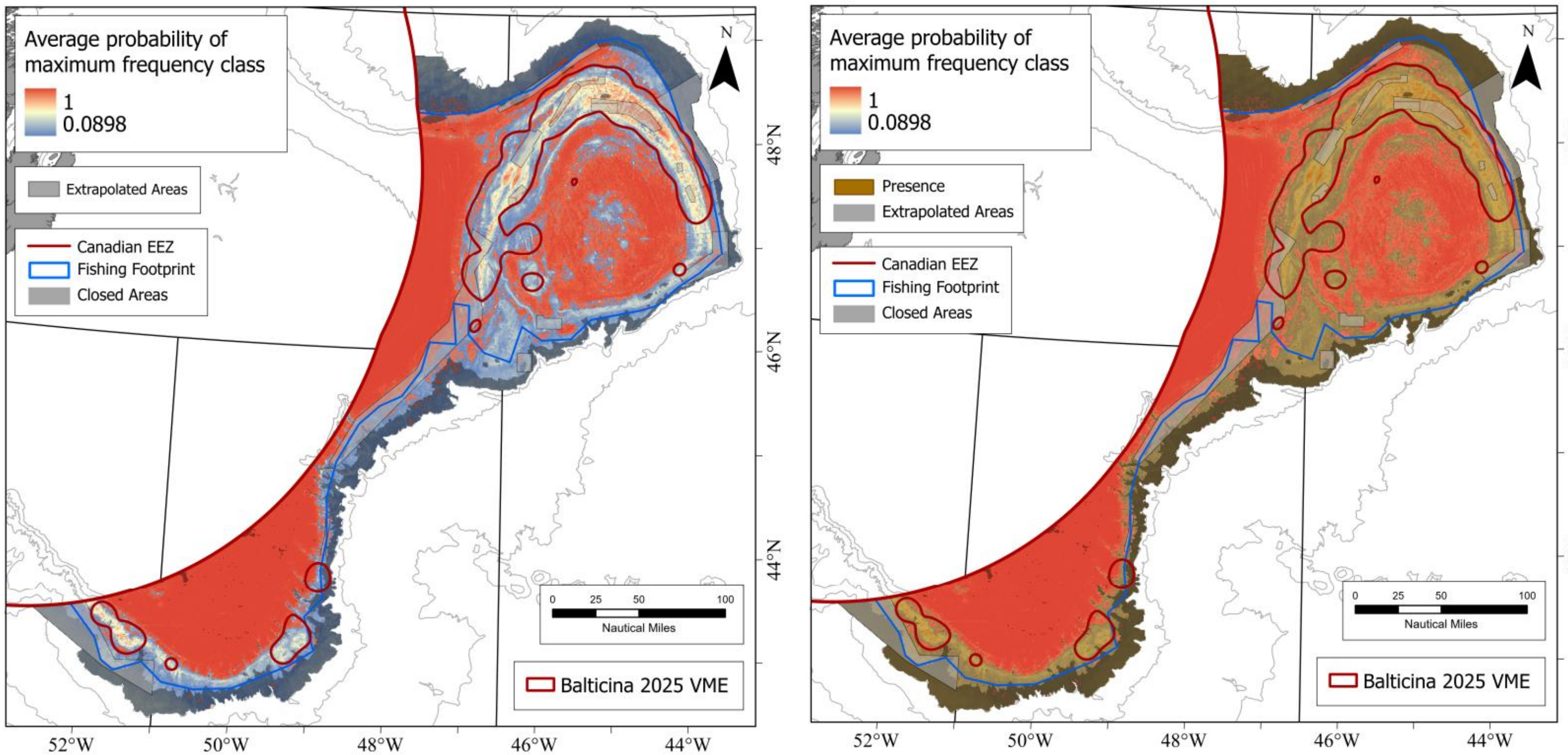


Figure 41. **Left Panel.** The 2025 *Balticina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Balticina* (Murillo et al., 2024). **Right Panel.** The 2025 *Balticina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Balticina* which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for *Balticina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

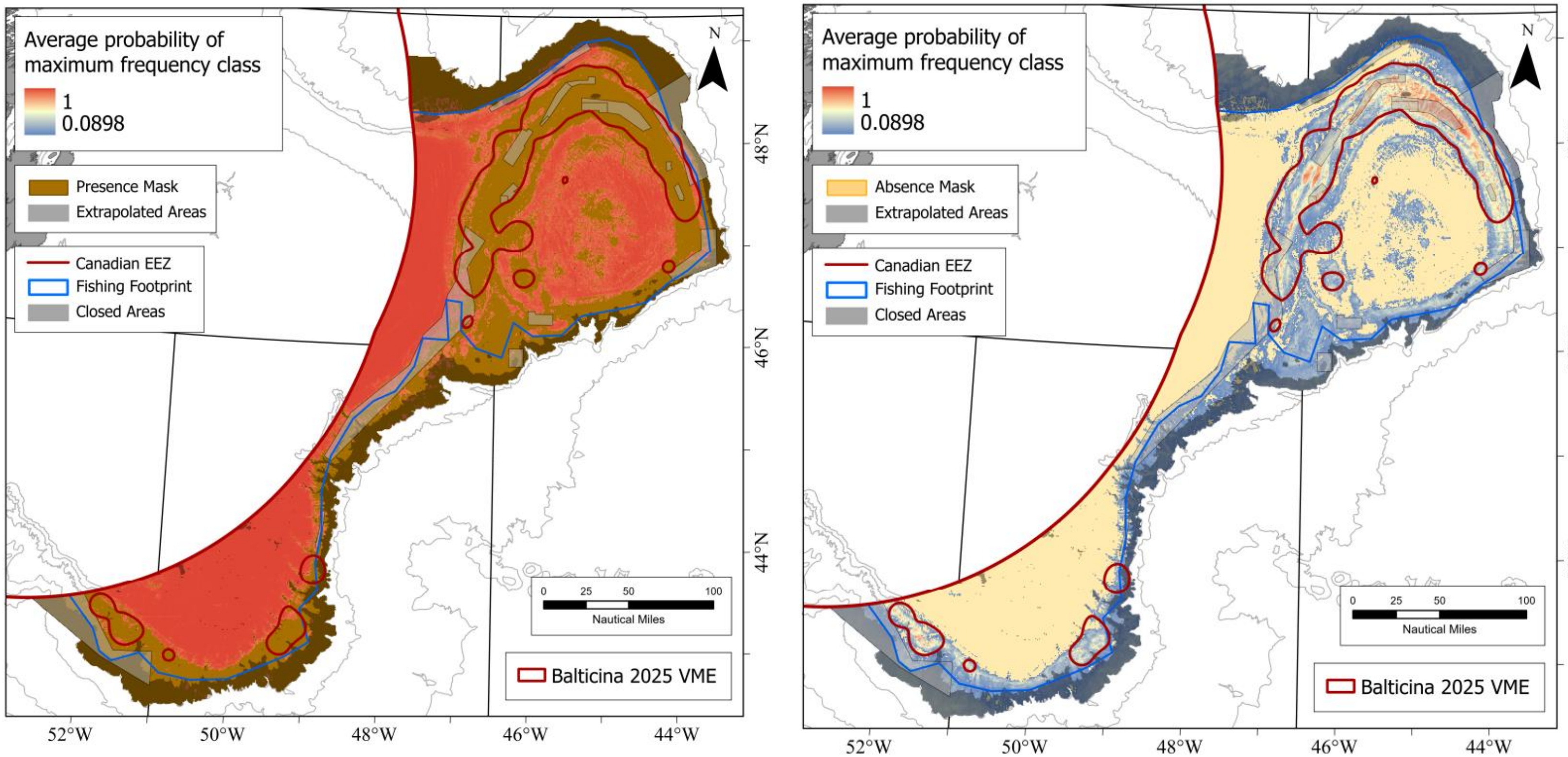


Figure 42. **Left Panel.** The 2025 *Balticina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Balticina* (Murillo et al., 2024)**.** **Right Panel.** The 2025 *Balticina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for *Balticina* (Murillo et al., 2024)**.**

Funiculina

The *Funiculina* subgroup of Sea Pens was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. Figure 43 illustrates the 2025 KDE VME polygons for *Funiculina* (Kenchington et al., 2025) superimposed on the SDM for *Funiculina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Only a few relatively small KDE VME polygons for *Funiculina* were identified and they all fall within the predicted distribution of *Funiculina* presence (Figure 43). The area of presence of *Funiculina* is predicted with high probability (Figures 44 and 45). We propose no further modifications to these KDE VME polygons.

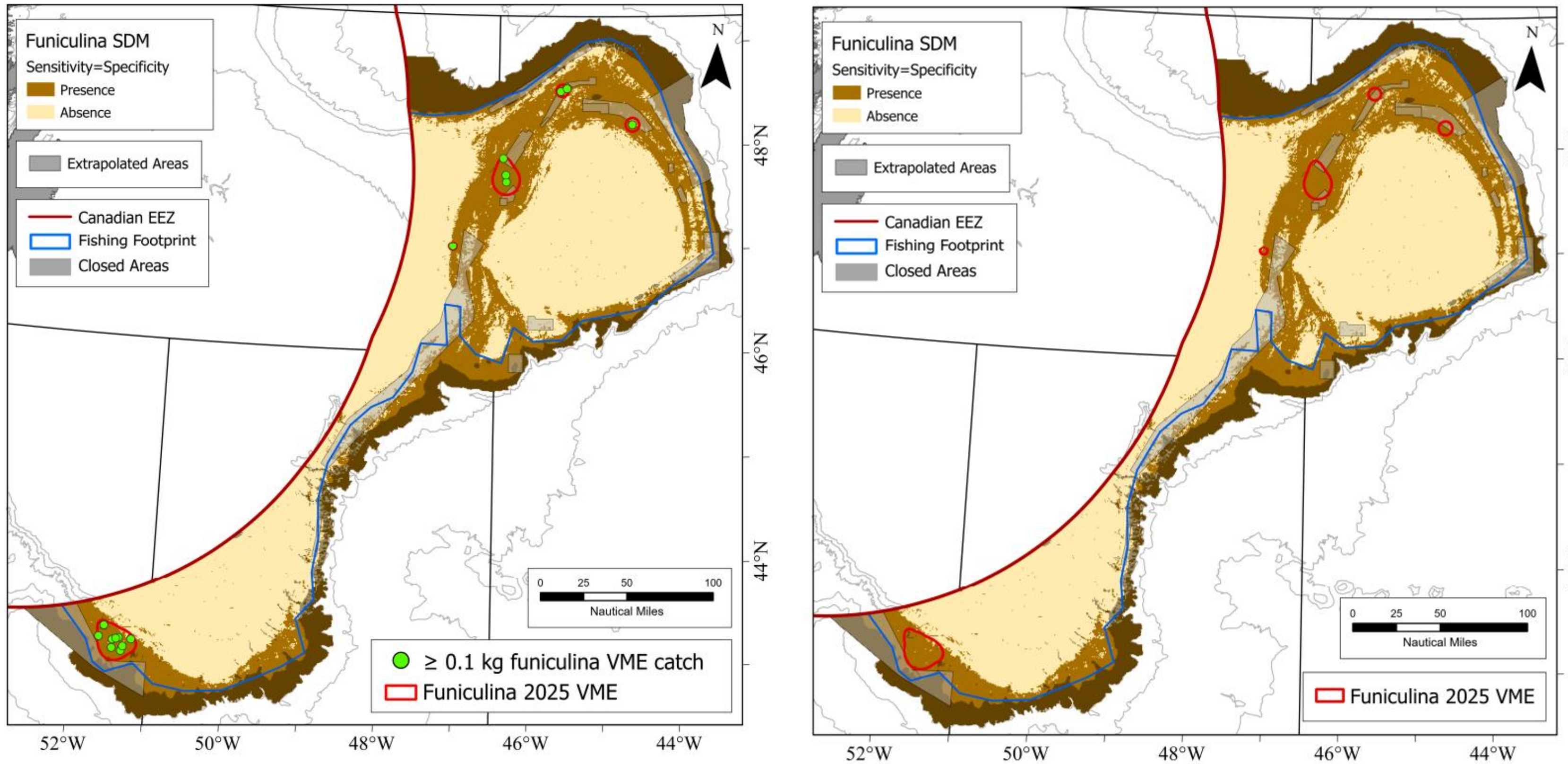


Figure 43. **Left Panel.** The 2025 *Funiculina* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Balticina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 0.1 kg are indicated. **Right Panel.** The 2025 *Funiculina* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Funiculina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

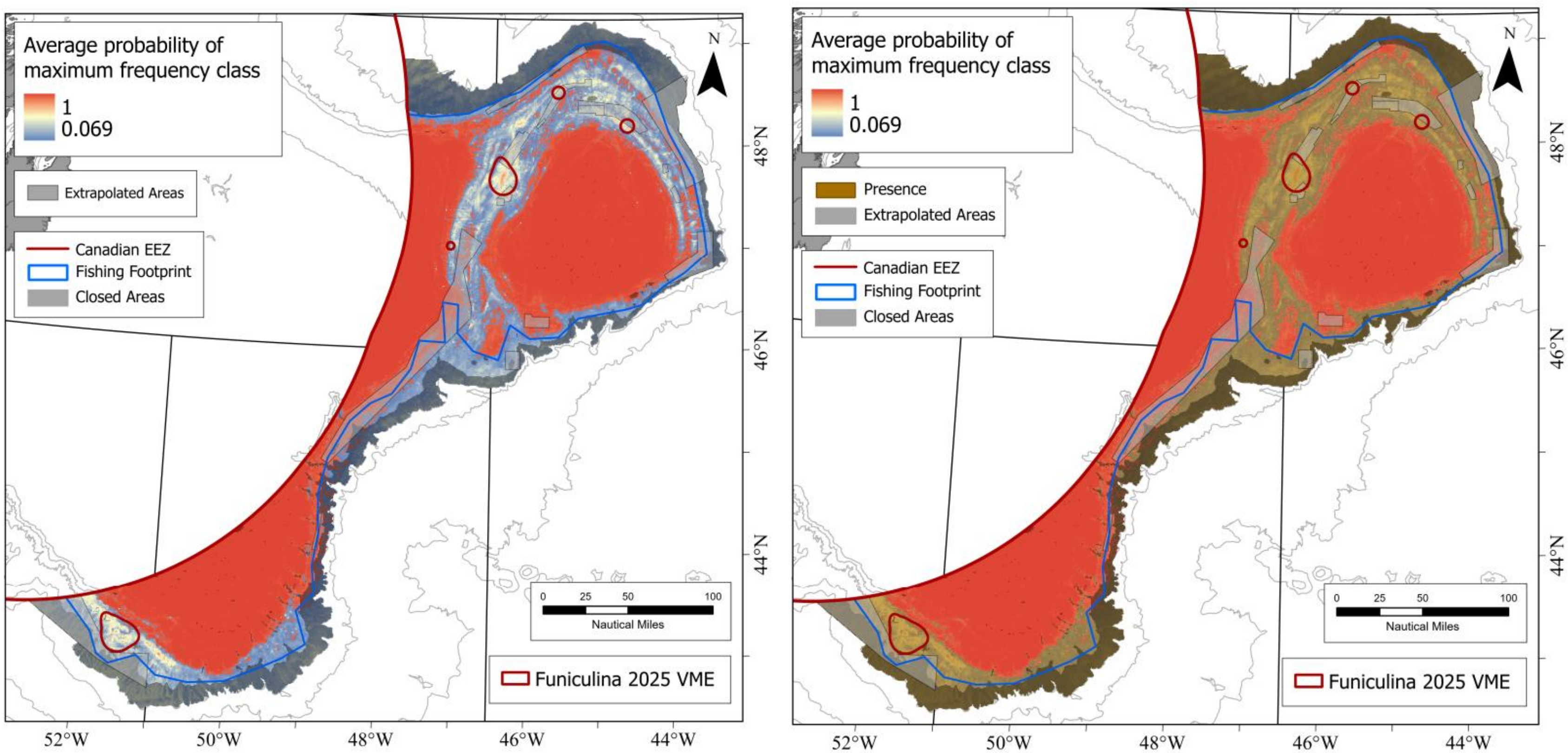


Figure 44. **Left Panel.** The 2025 *Funiculina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Funiculina* (Murillo et al., 2024). **Right Panel.** The 2025 *Funiculina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Funiculina* which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for *Funiculina* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

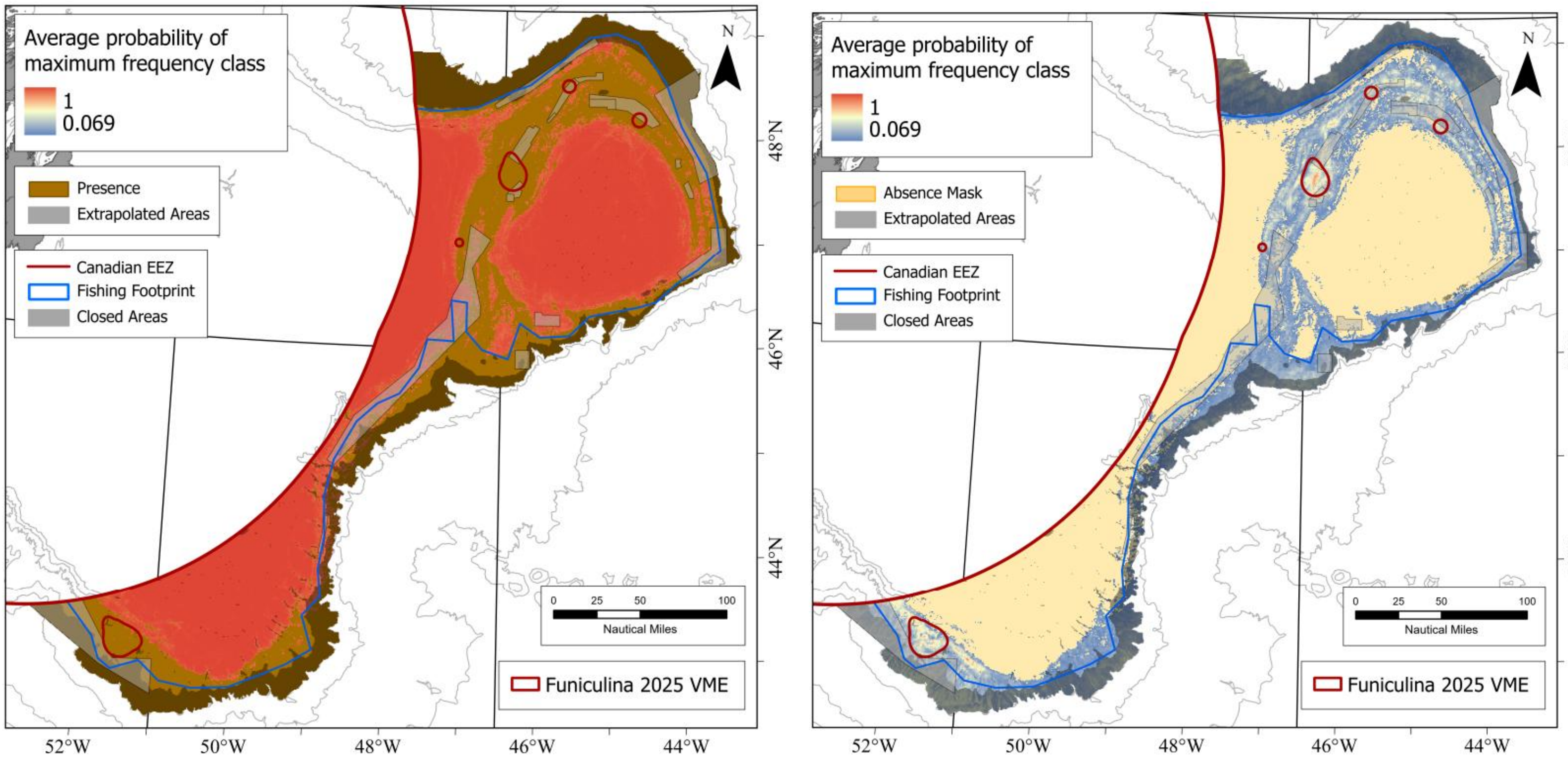


Figure 45. **Left Panel.** The 2025 *Funiculina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Funiculina* (Murillo et al., 2024). **Right Panel.** The 2025 *Funiculina* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for *Funiculina* (Murillo et al., 2024).

Pennatula

The *Pennatula* subgroup of Sea Pens was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. Figure 46 illustrates the 2025 KDE VME polygons for *Pennatula* (Kenchington et al., 2025) superimposed on the SDM for *Pennatula* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Most of the KDE VME polygons for *Pennatula* fall within the predicted distribution of *Pennatula* presence (Figure 46). The area of presence of *Pennatula* is predicted with high probability (Figures 47 and 48). However near Area 3O the polygon crosses the Canadian EEZ and includes some area of predicted absence. The polygon near Area 1 also crosses into an area where absence is predicted with high certainty. Therefore we propose modification to those two polygons.

Proposed Modifications to the *Pennatula* Sea Pen VME Polygons

Area 3O. The KDE VME polygon for *Pennatula* located near the 3O Coral Closure includes area that overlaps with predicted absence of *Pennatula* that is predicted with high probability (Figure 49). There is also a portion that crosses into the Canadian EEZ. Modifications are proposed for this polygon as seen in Figure 49 to remove the portion in Canadian waters and bring the shallow edge in line with the area of predicted *Pennatula* presence.

Area 1. A *Pennatula* KDE VME polygon that includes part of Area 1 (Figure 50) straddles an area that predicts *Pennatula* absence with high probability (Figure 50). The proposed modification is to clip the western edge to the boundary of predicted *Pennatula* presence (Figure 50).

Table 6. The area occupied by each of the *Pennatula* KDE VME polygons after making the proposed modifications.

***Pennatula* KDE VME Polygon Label**	**Polygon Modified**	**Polygon Area (km²)**
Area 2 Poly1	No	5626.92
Area 3O Poly1	Yes	1760.51
GB Tail Poly1	No	1033.73
Area 1 Poly1	Yes	636.37
Area 2 Poly2	No	419.23
Area 10 Poly1	No	55.70
Area 1 (Near) Poly2	No	19.36
GB Tail Poly2	No	18.92
GB Tail Poly 3	No	14.15
FC Poly1	No	10.05
FC Poly2	No	7.77
FC Poly3	No	6.25
FC East Poly1	No	5.99
FC North Poly1	No	4.39
Total Area:		**9619.35**

The proposed modifications would produce 14 *Pennatula* KDE VME polygons (Figure 51). Those polygons ranged in size from 4.39 km² to 5626.92 km² (Table 6).

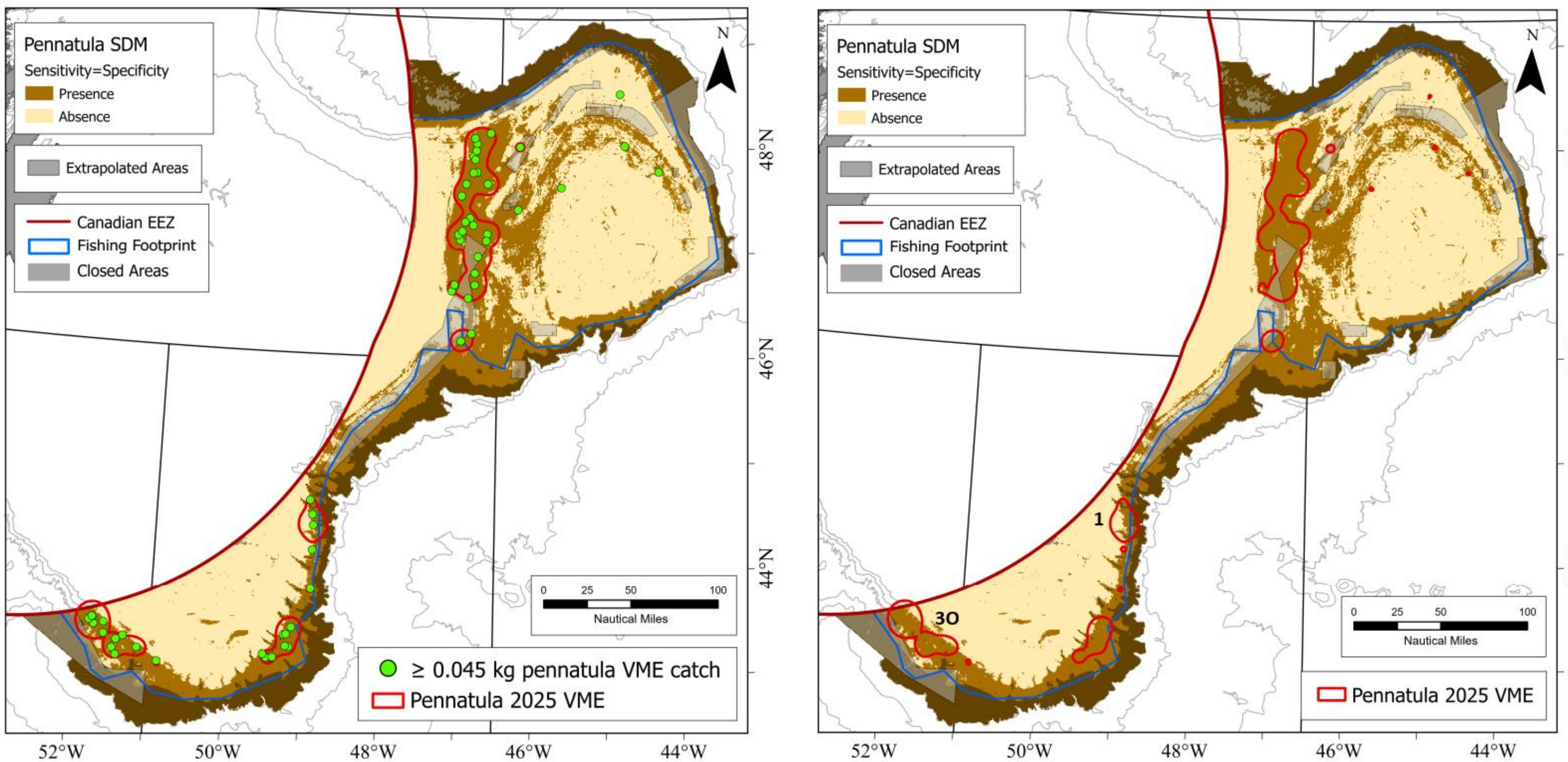


Figure 46. **Left Panel.** The 2025 *Pennatula* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Pennatula* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 0.045 kg are indicated. **Right Panel.** The 2025 *Pennatula* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Pennatula* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications.

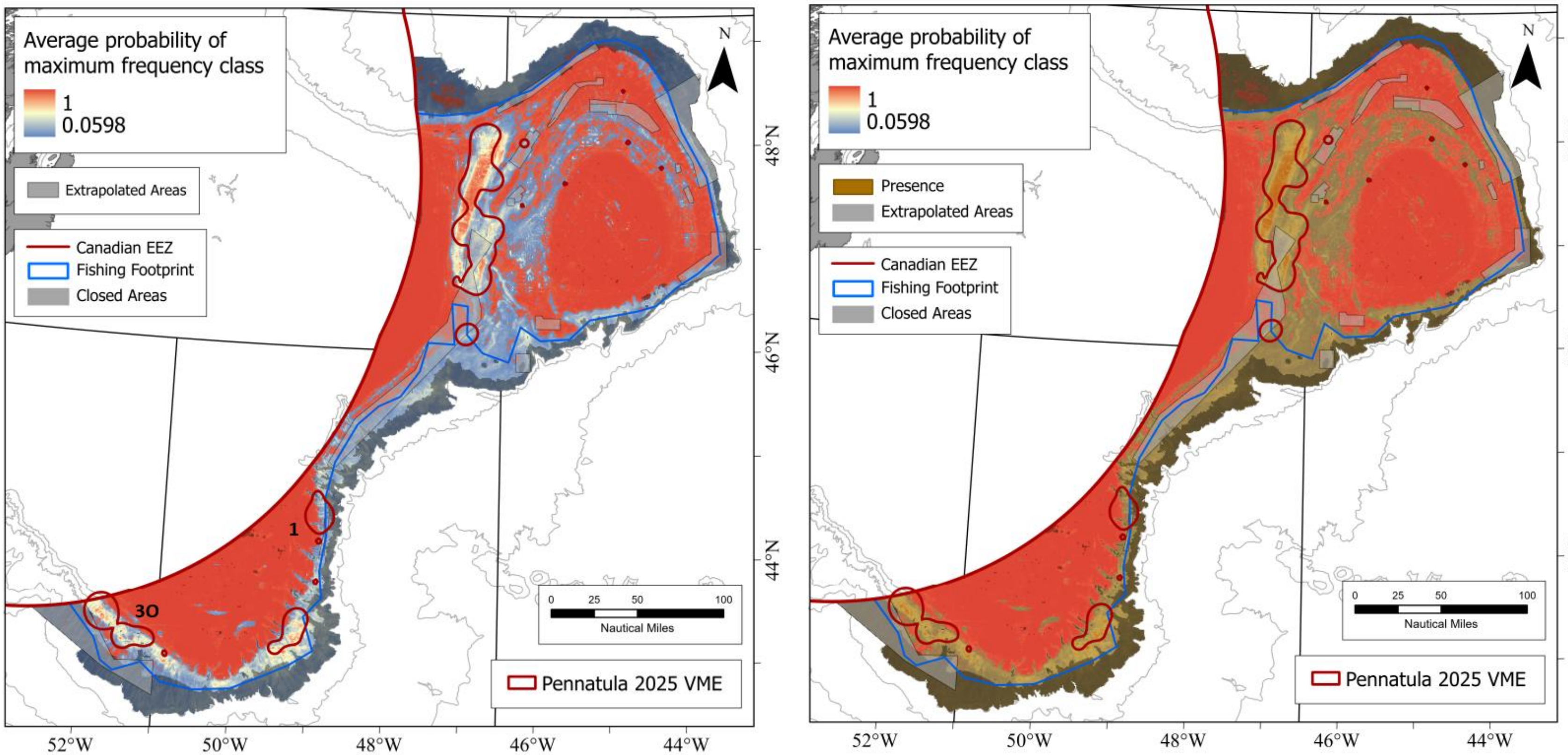


Figure 47. **Left Panel.** The 2025 *Pennatula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Pennatula* (Murillo et al., 2024). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for potential modifications. **Right Panel.** The 2025 *Pennatula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Pennatula* which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for *Pennatula* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

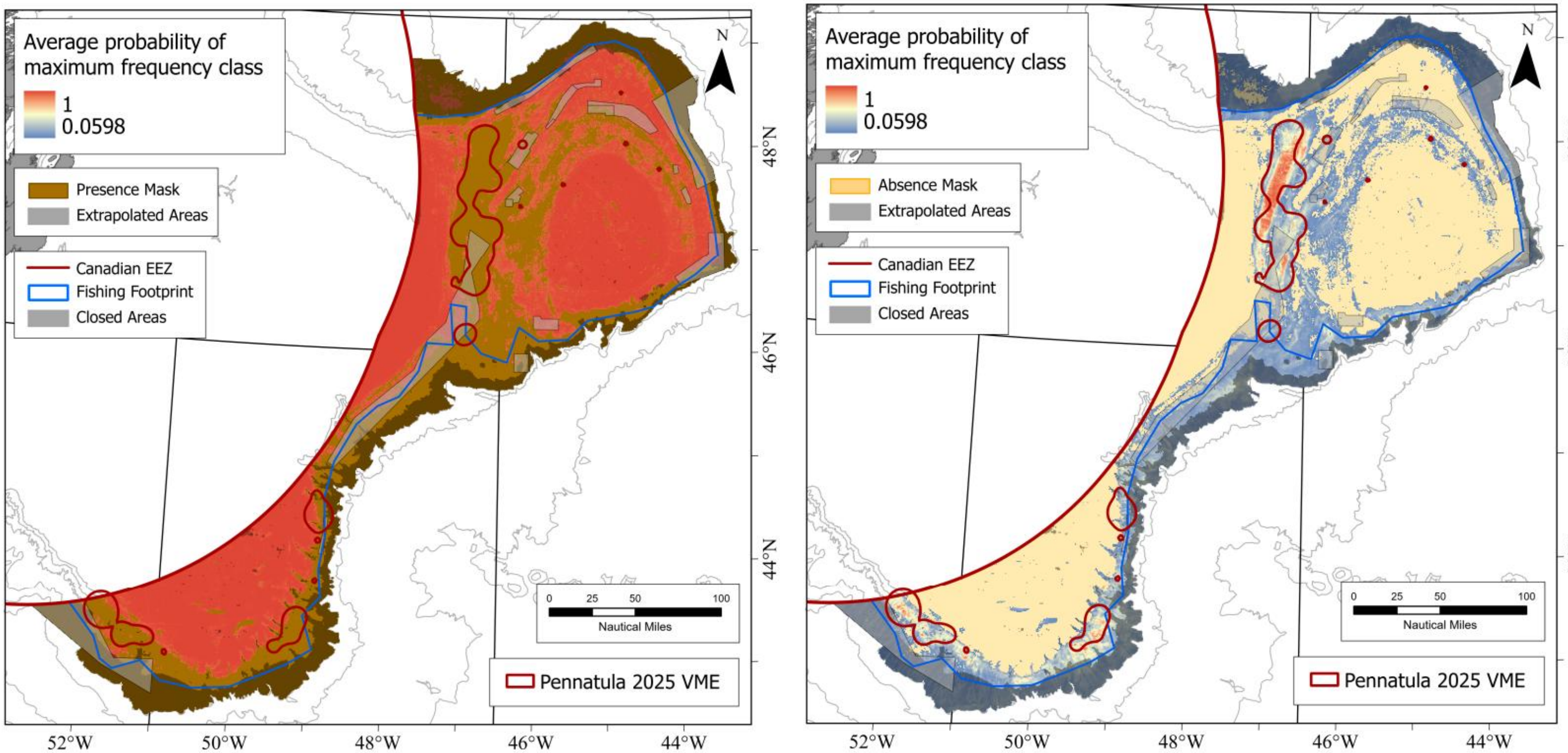


Figure 48. **Left Panel.** The 2025 *Pennatula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Pennatula* (Murillo et al., 2024). **Right Panel.** The 2025 *Pennatula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for *Pennatula* (Murillo et al., 2024).

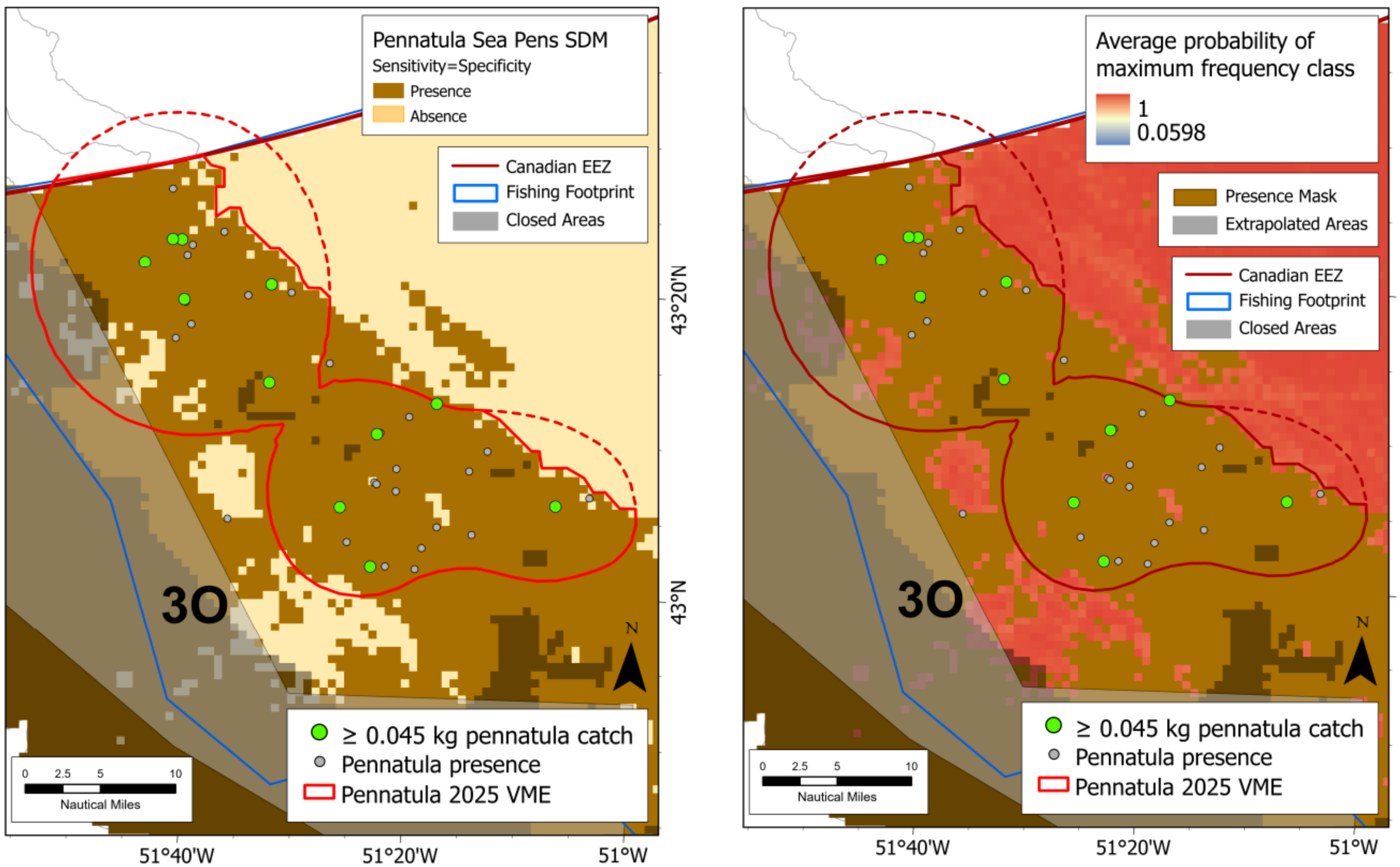


Figure 49. **Area 3O. Left Panel.** Map of the proposed modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Pennatula*). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) near Area 3O in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Pennatula* (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.045 kg, the threshold for the KDE analyses, and all other catches with < 0.045 kg are shown.

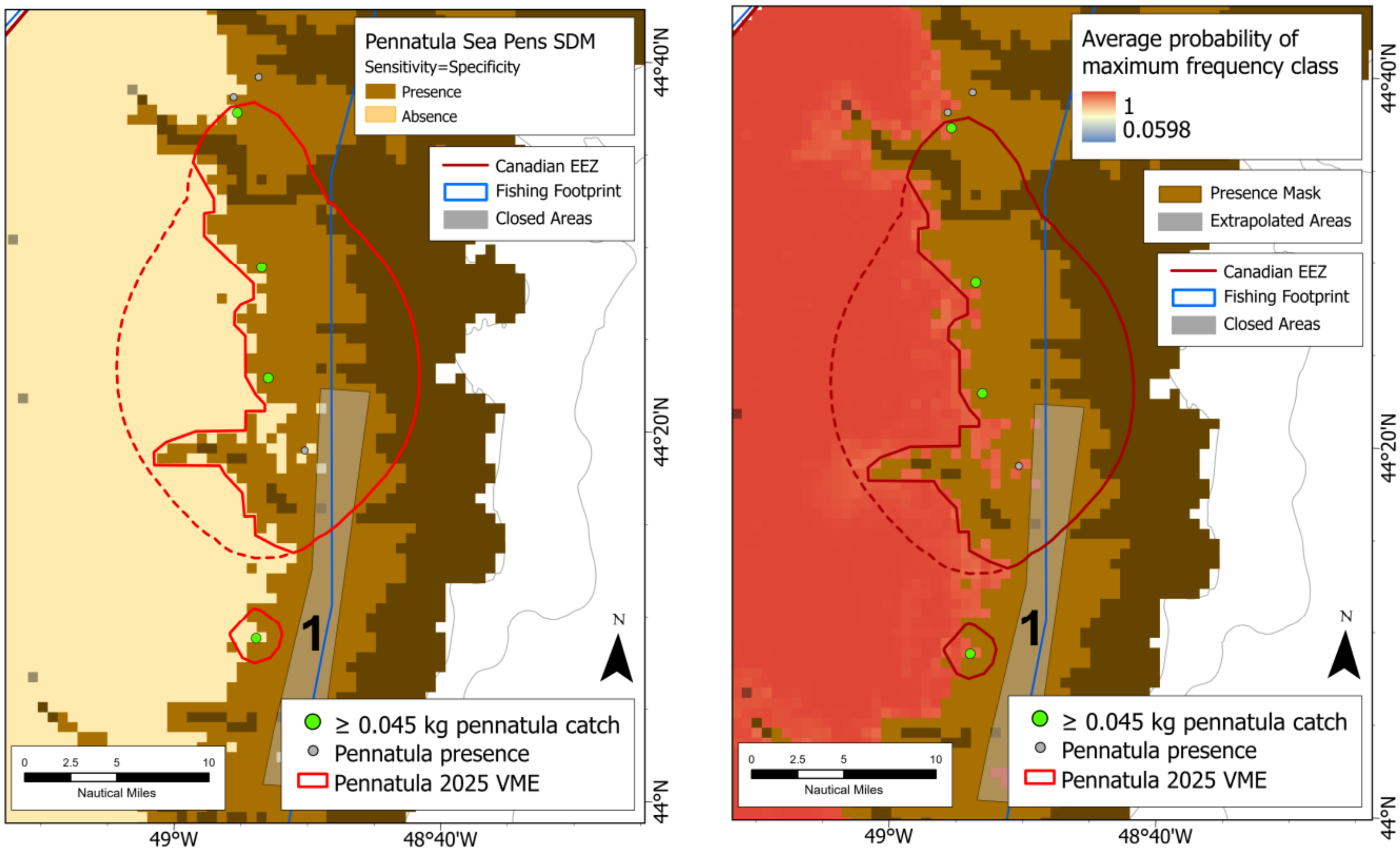


Figure 50. **Area 1. Left Panel.** Map of the proposed modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Pennatula*). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 *Pennatula* KDE VME polygon (red dashed lines) near Area 1 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Pennatula* (Murillo et al., 2024). Closed areas are indicated in grey shading. Catches of ≥ 0.045 kg, the threshold for the KDE analyses, and all other catches with < 0.045 kg are shown.

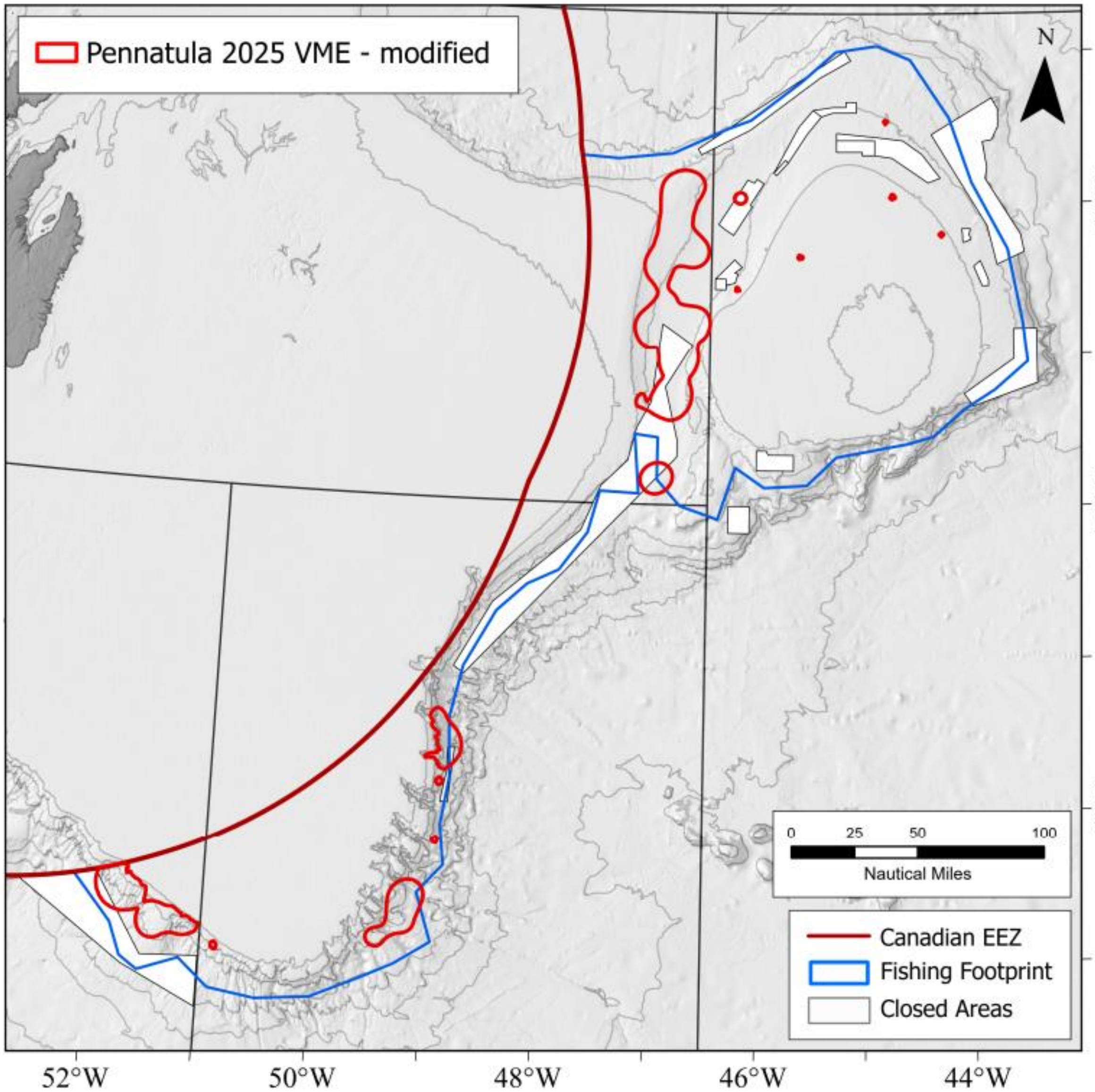


Figure 51. Map of the proposed *Pennatula* KDE VME polygons after consideration of modifications based on the SDM for *Pennatula* (Murillo et al., 2024). Closed areas are indicated in white (NAFO, 2025).

Black Corals

The Black Coral Functional Group KDE VME polygons are mostly found on the slopes of Flemish Cap, with small polygons in Flemish Pass and on Grand Bank near the 3O Coral Closure (Figure 52). These polygons all lie largely within the area of predicted Black Coral Functional Group presence from the SDM (Murillo et al., 2024). These VME polygons lie in areas of variable probability of black coral presence (Figures 53 and 54) but there is very little overlap with areas of high probability of black coral absence. Therefore we have not suggested any modifications to the Black Coral Functional Group KDE VME polygons.

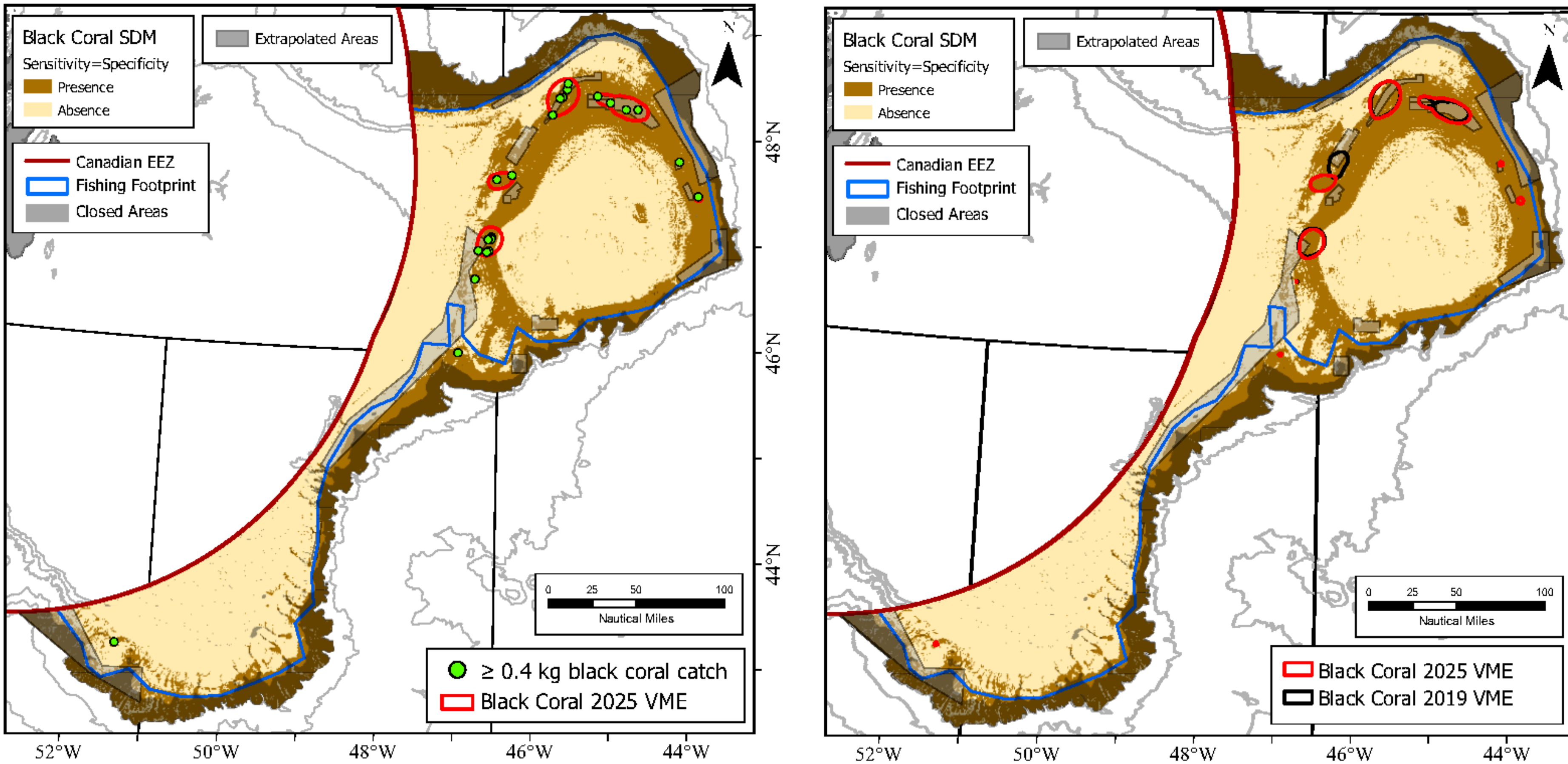


Figure 52. **Left Panel.** The 2025 Black Coral Functional Group KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Black Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024). The location of research vessel survey catches greater than or equal to 0.4 kg are indicated. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Black Coral Functional Group KDE VME polygons superimposed on the SDM for the Black Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

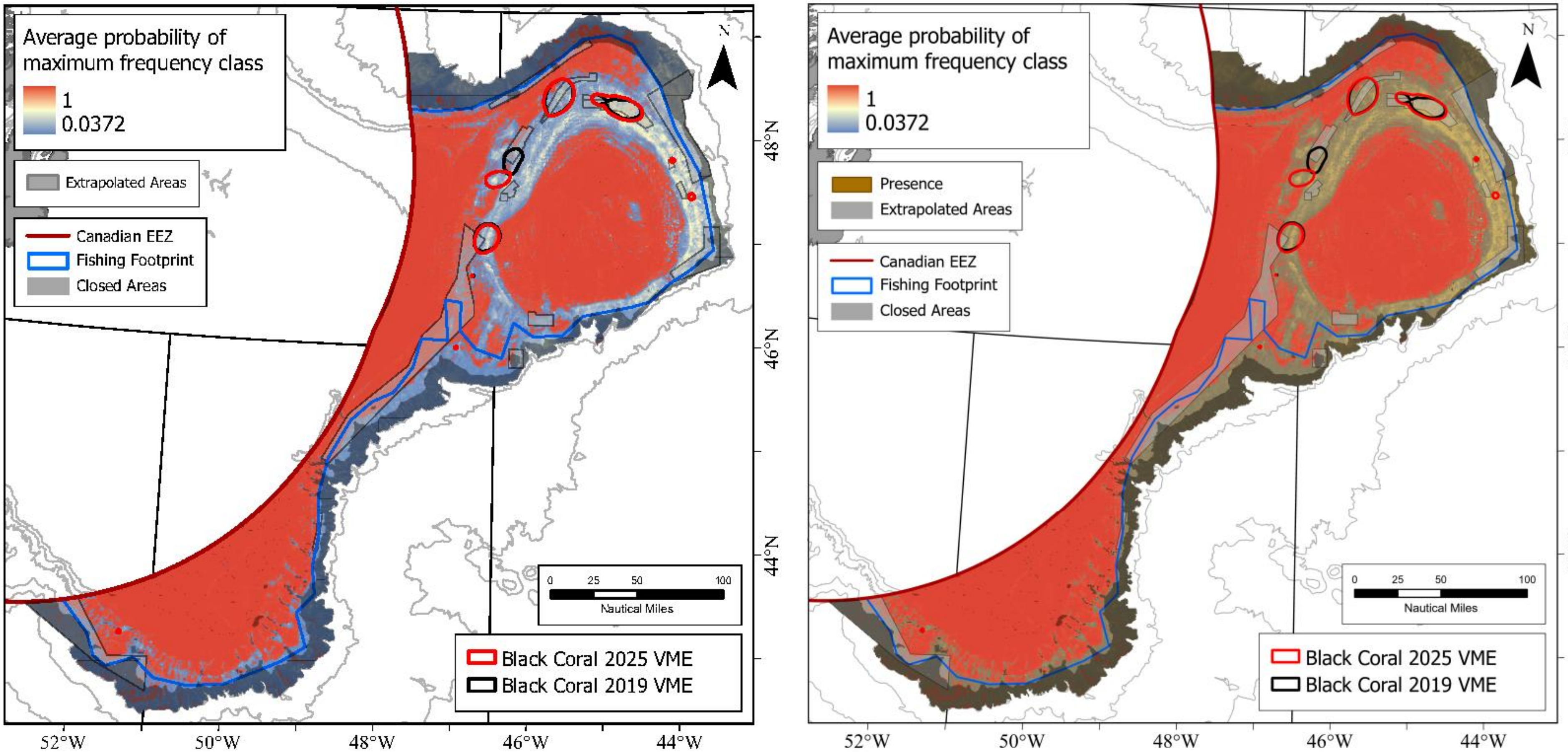


Figure 53. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Black Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Black Coral Functional Group (Murillo et al., 2024). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Black Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Black Coral Functional Group which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Black Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2024).

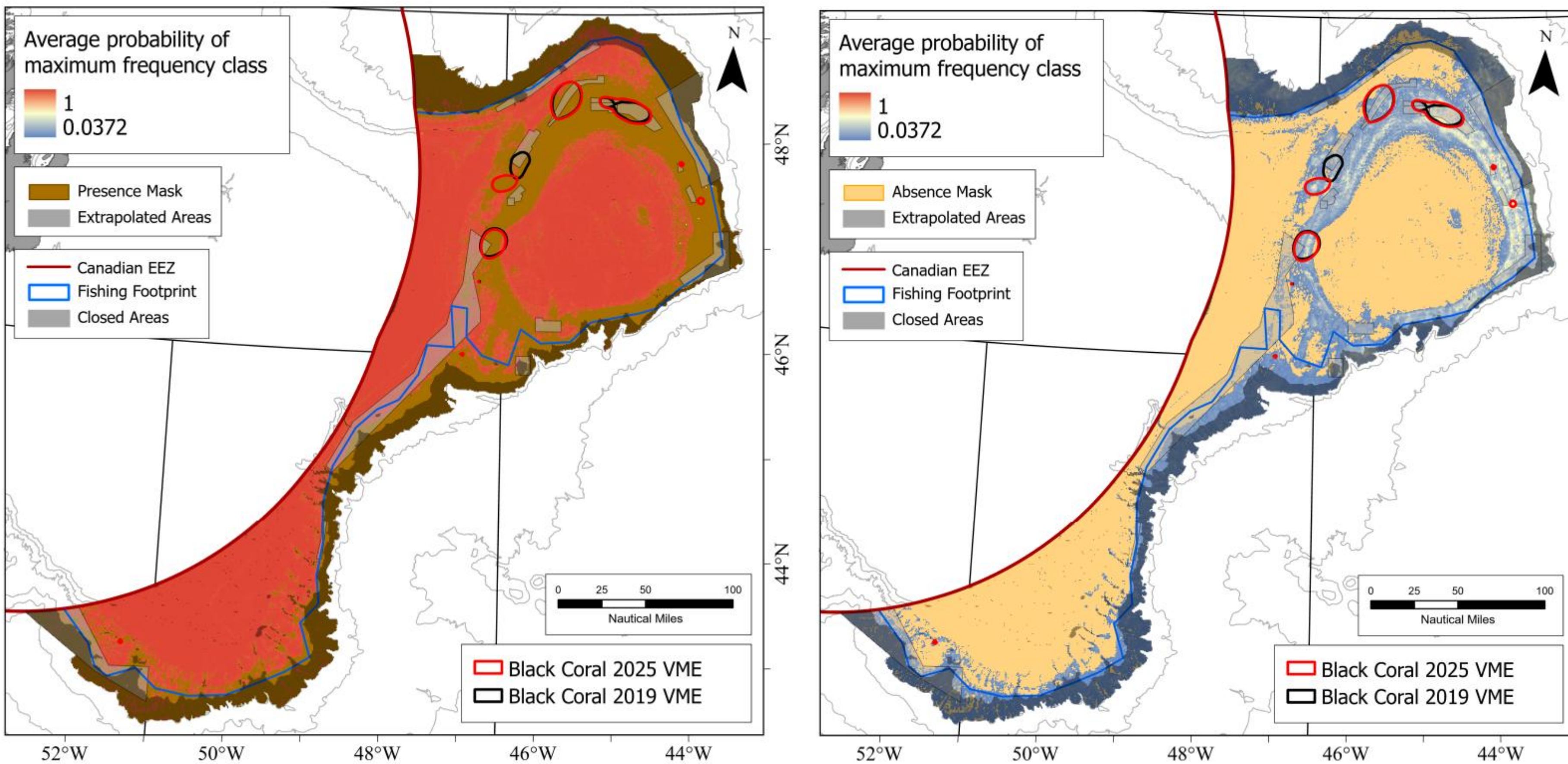


Figure 54. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Black Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Black Coral Functional Group (Murillo et al., 2024). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Black Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Black Coral Functional Group (Murillo et al., 2024).

Large Gorgonian Corals

The Large Gorgonian Coral Functional Group KDE VME polygons are mostly found in Flemish Pass and on the slopes of Flemish Cap, with small polygons on the Nose and Tail of Grand Bank (Figure 55). These polygons all lie largely within the area of predicted Large Gorgonian Coral Functional Group presence from the SDM (Murillo et al., 2025). These VME polygons lie in areas of variable probability of large gorgonian coral presence (Figures 56 and 57) but there is very little overlap with areas of high probability of large gorgonian coral absence. Therefore we have not suggested any modifications to the Large Gorgonian Coral Functional Group KDE VME polygons. In 2019, a small modification to Area 2 was made to bring the polygon edge to the boundary for the closed area as it fell in an area of predicted absence. The new SDM (Murillo et al., 2025) has much less overlap with areas of predicted absence.

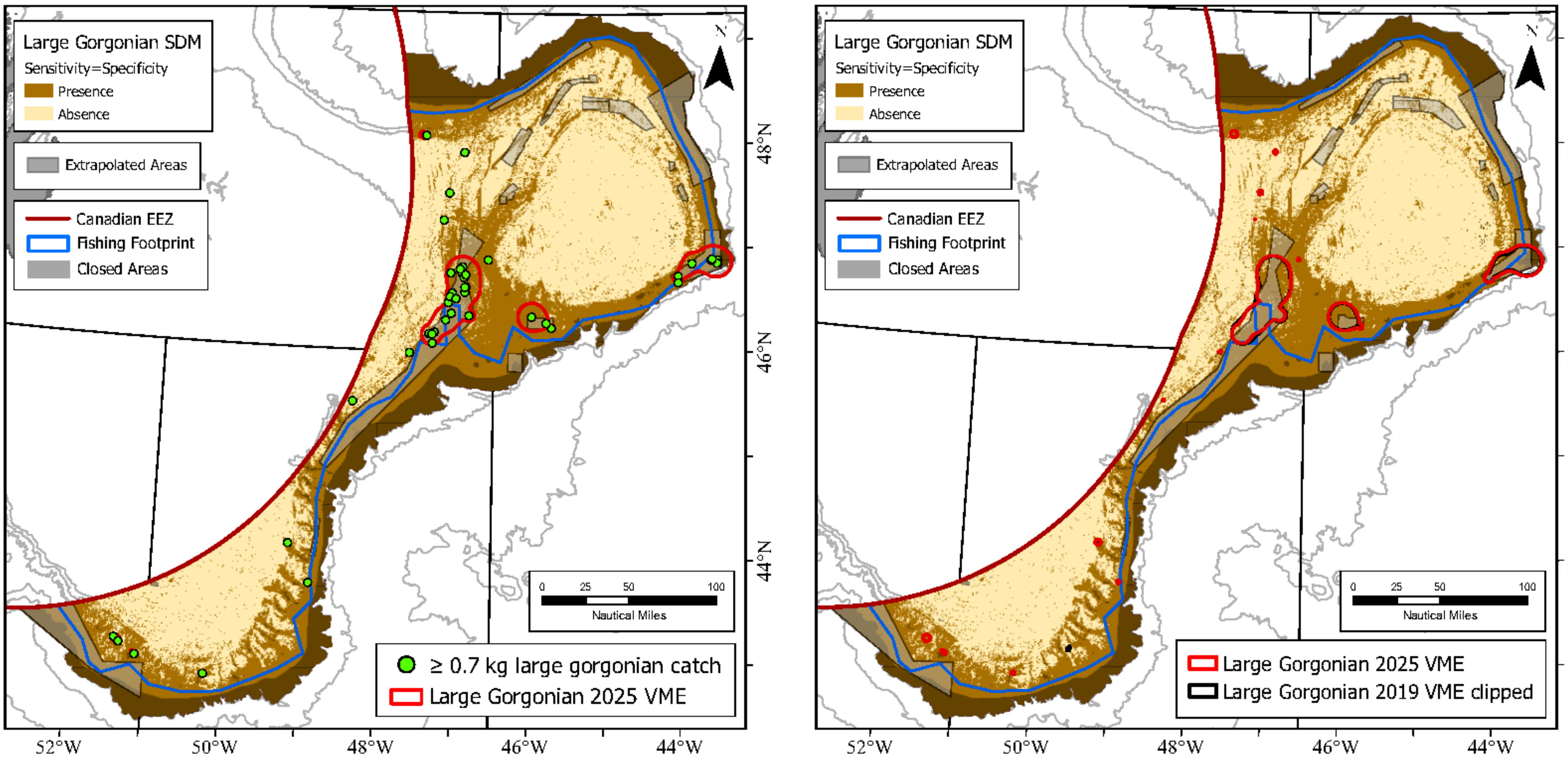


Figure 55. **Left Panel.** The 2025 Large Gorgonian Coral Functional Group KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Large Gorgonian Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). The location of research vessel survey catches greater than or equal to 0.7 kg are indicated. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large Gorgonian Coral Functional Group KDE VME polygons superimposed on the SDM for the Large Gorgonian Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

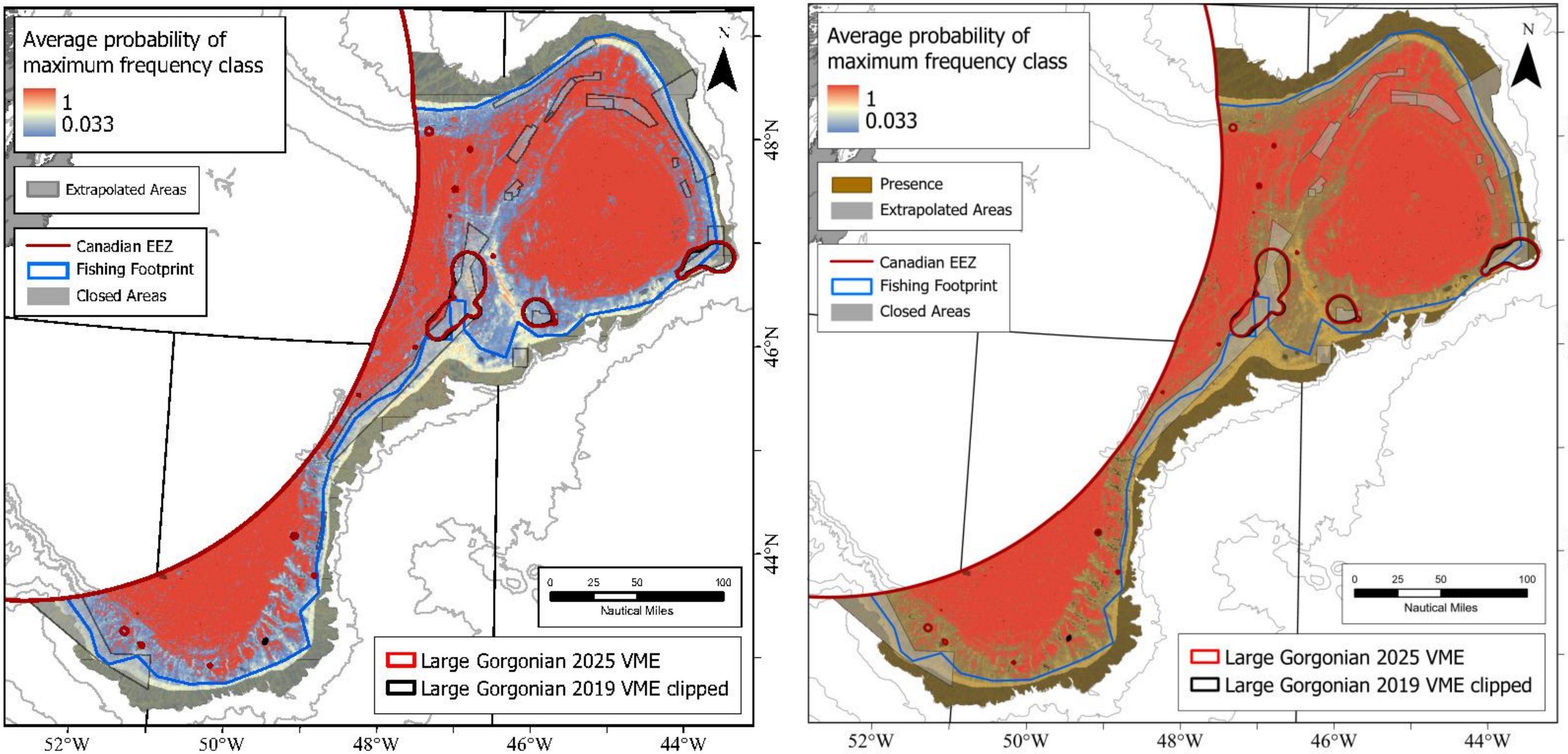


Figure 56. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Large Gorgonian Coral Functional Group (Murillo et al., 2025). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Large Gorgonian Coral Functional Group which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Black Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

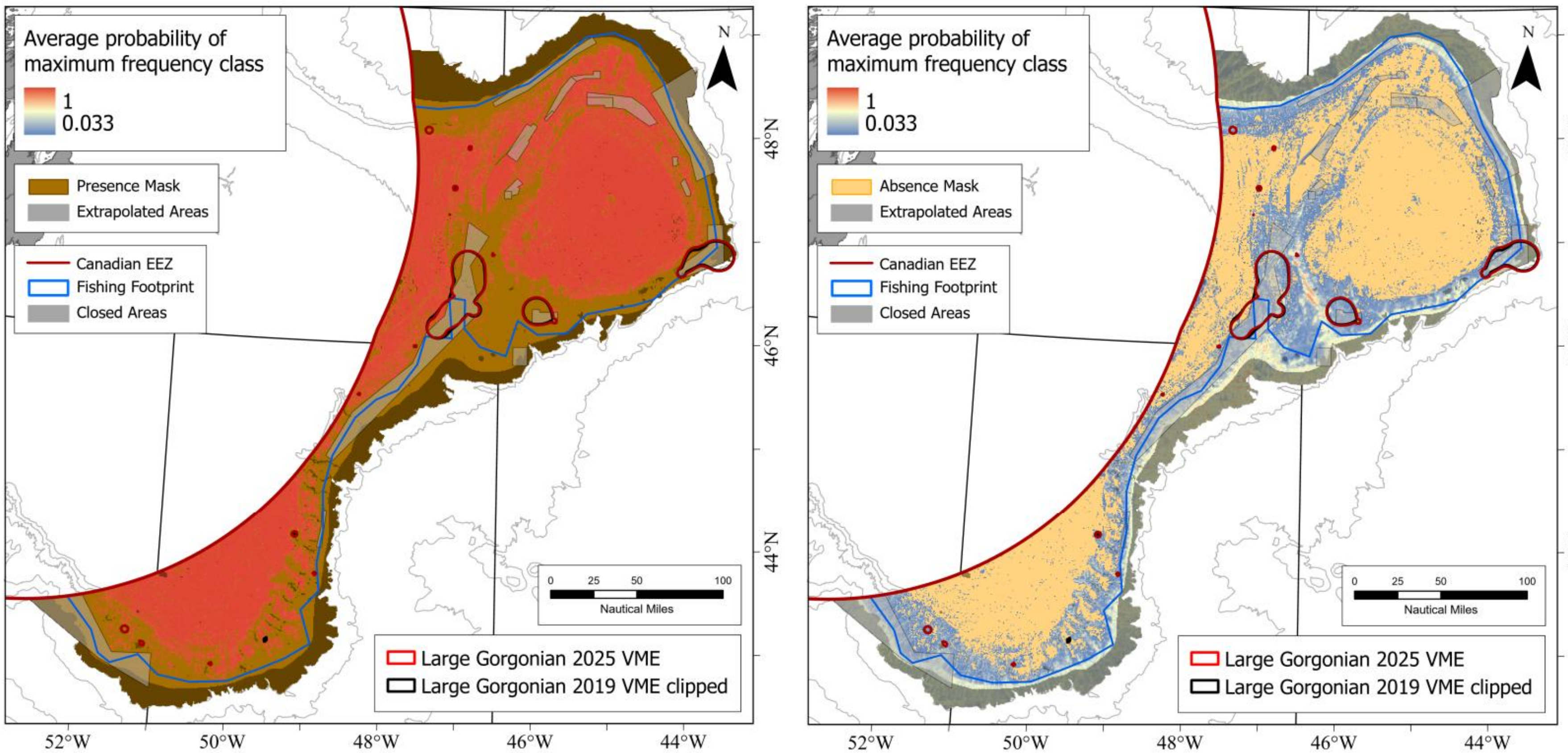


Figure 57. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Large Gorgonian Coral Functional Group (Murillo et al., 2025). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Large Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Large Gorgonian Coral Functional Group (Murillo et al., 2025).

Small Gorgonian Corals

The Small Gorgonian Coral Functional Group (SGC) KDE VME polygons are found in Flemish Pass, on the slopes of Flemish Cap, and on the Nose and Tail of Grand Bank (Figure 58). These polygons all lie largely within the area of predicted Small Gorgonian Coral Functional Group presence from the SDM (Murillo et al., 2025). These VME polygons lie in areas of variable probability of small gorgonian coral presence (Figures 59 and 60) but there is very little overlap with areas of high probability of small gorgonian coral absence. The only exception is a polygon near Area 4 which extends at its southwestern edge into shallower water on Flemish Cap where there is a high probability of Small Gorgonian Coral Functional Group absence (Figures 59 and 60). We propose modifications to that KDE VME polygon.

Proposed Modifications to the Small Gorgonian Coral VME Polygons

Area 4. A SGC Functional Group KDE VME polygon that includes part of Area 4 (Figure 61) straddles an area that predicts SGC Functional Group absence with high probability (Figure 61). The proposed modification is to clip the western edge to the boundary of predicted SGC presence (Figure 61).

Table 7. The area occupied by each of the Small Gorgonian Coral (SGC) Functional Group KDE VME polygons after making the proposed modifications.

SGC KDE VME Polygon Label	Polygon Modified	Polygon Area (km²)
Area 3O Poly1	No	4337.73
Area 4 Poly1	Yes	2165.96
Area 2 Poly1	No	1880.76
Area 14a 5 Poly1	No	1788.88
GB Tail Poly1	No	888.50
GB Tail Poly2	No	606.17
Area 1 Poly1	No	410.47
Area 7 Poly1	No	282.57
Area 2 Poly1	No	183.84
GB Tail Poly3	No	182.65
Flemish Pass Poly1	No	85.64
Flemish Cap North Poly1	No	74.89
Area 2 Poly3	No	65.67
Sackville Spur Poly1	No	32.80
Flemish Pass Poly2	No	13.32
GB Tail Poly4	No	12.20
GB Tail Poly5	No	11.94
Flemish Cap South Poly1	No	11.28
Area 8 Poly1	No	11.26
GB Slope Poly1	No	3.36
Total Area:		**13049.90**

The proposed modifications would produce 20 Small Gorgonian Coral Functional Group KDE VME polygons (Figure 62). Those polygons ranged in size from 3.36 km^2 to 4337.73 km^2 (Table 7).

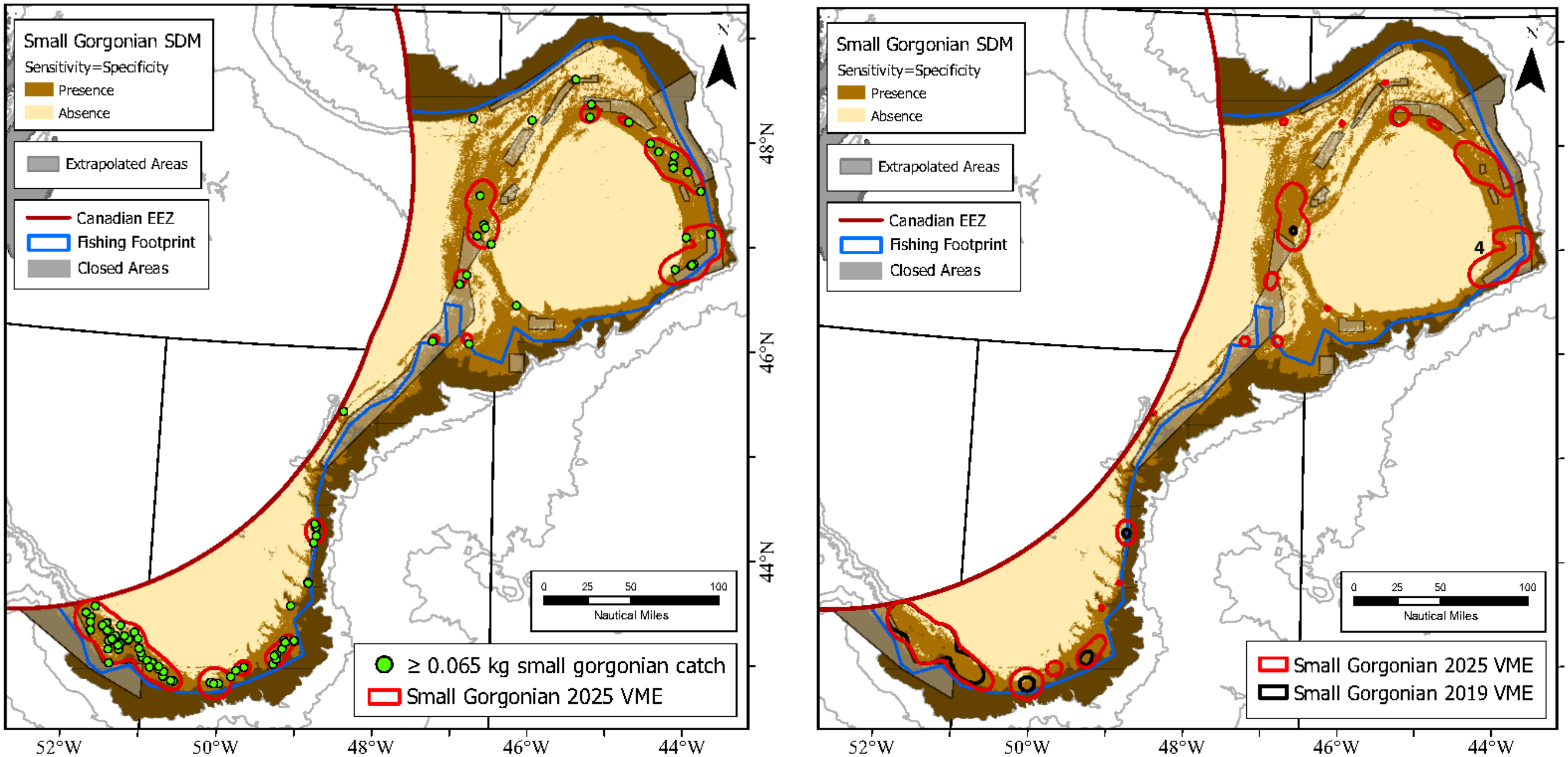


Figure 58. **Left Panel.** The 2025 Small Gorgonian Coral Functional Group KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Small Gorgonian Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). The location of research vessel survey catches greater than or equal to 0.065 kg are indicated. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Small Gorgonian Coral Functional Group KDE VME polygons superimposed on the SDM for the Small Gorgonian Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). The number indicates the Vulnerable Marine Ecosystem Area Closure referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serves to identify the 2025 KDE VME polygon that warrants further examination for potential modification.

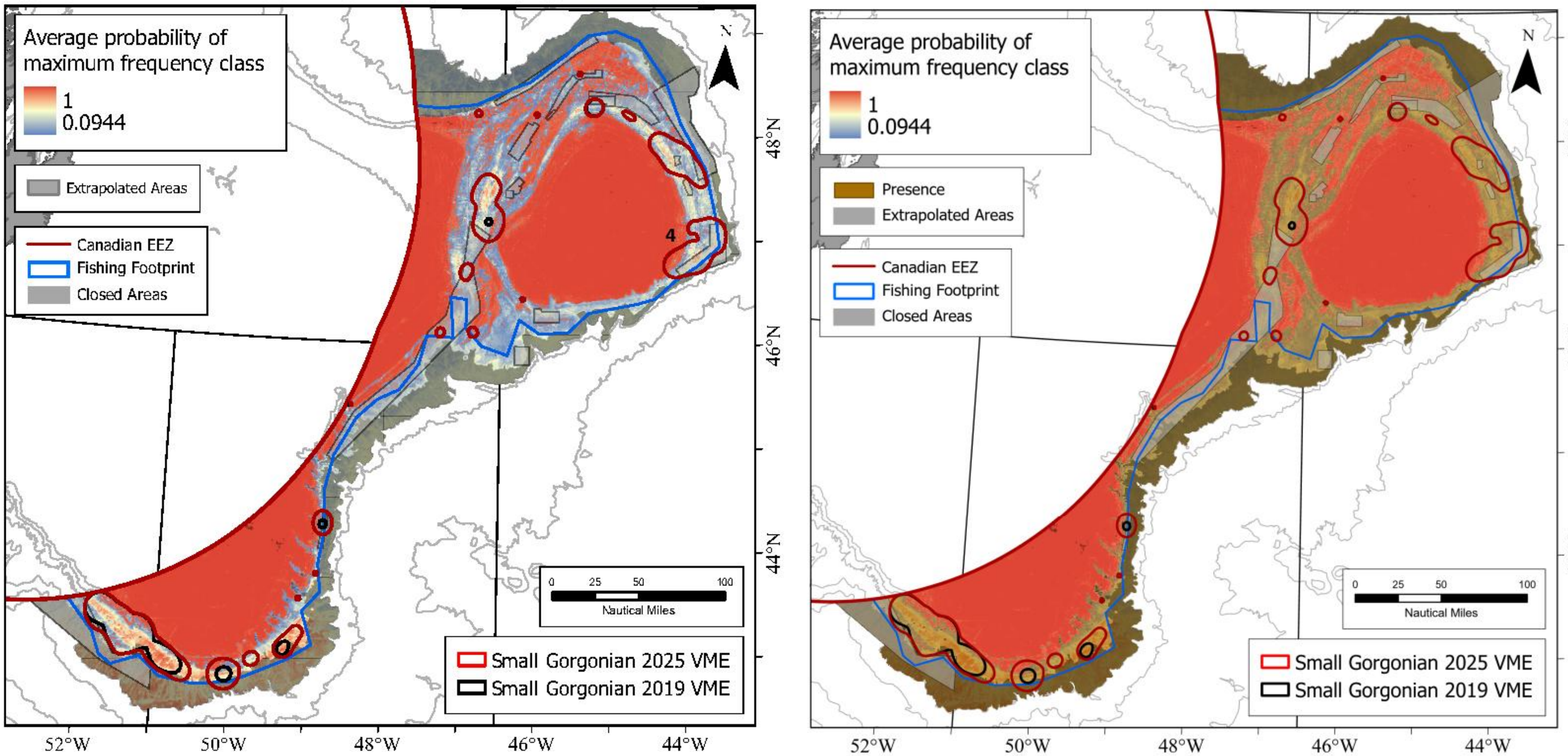


Figure 59. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Small Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Small Gorgonian Coral Functional Group (Murillo et al., 2025). The number indicates the Vulnerable Marine Ecosystem Area Closure referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serves to identify the 2025 KDE VME polygon that warrants further examination for potential modification. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Small Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Small Gorgonian Coral Functional Group which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Small Coral Functional Group created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

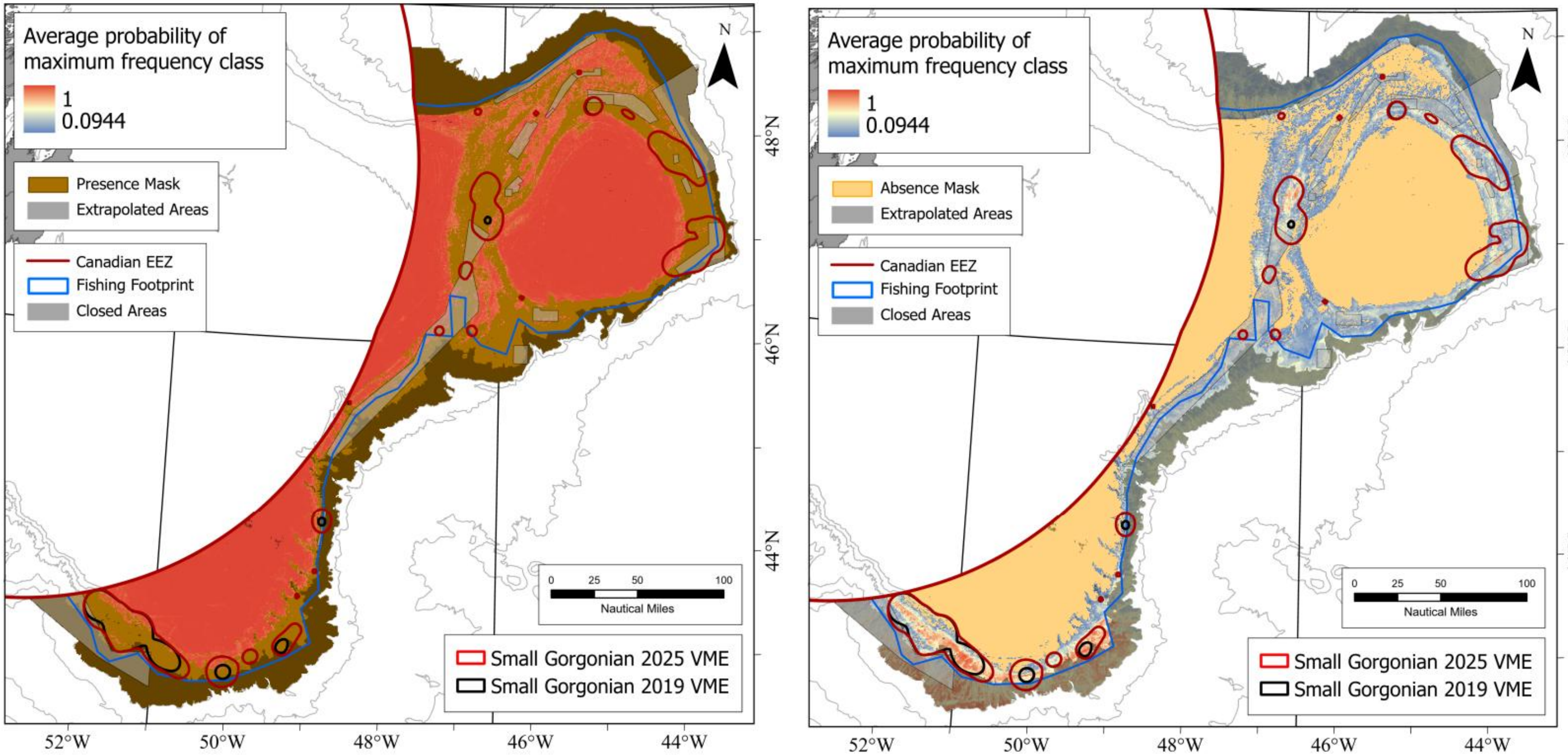


Figure 60. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Small Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Small Gorgonian Coral Functional Group (Murillo et al., 2025). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Small Gorgonian Coral Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Small Gorgonian Coral Functional Group (Murillo et al., 2025).

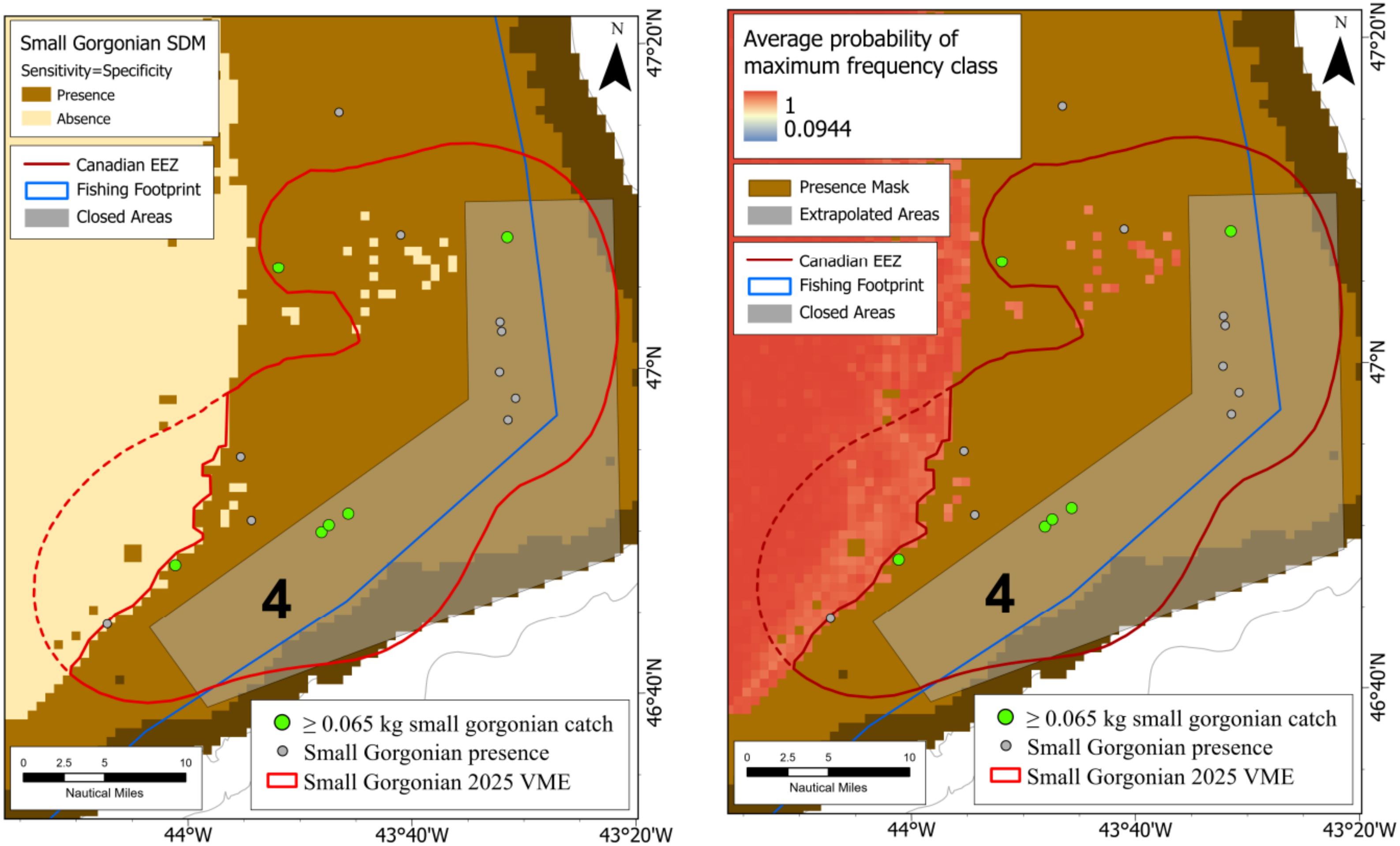


Figure 61. **Area 4. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Small Gorgonian Coral Functional Group KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of the Small Gorgonian Coral Functional Group). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Small Gorgonian Coral Functional Group KDE VME polygon (red dashed lines) near Area 4 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for Small Gorgonian Coral Functional Group (Murillo et al., 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.065 kg, the threshold for the KDE analyses, and all other catches with < 0.065 kg are shown.

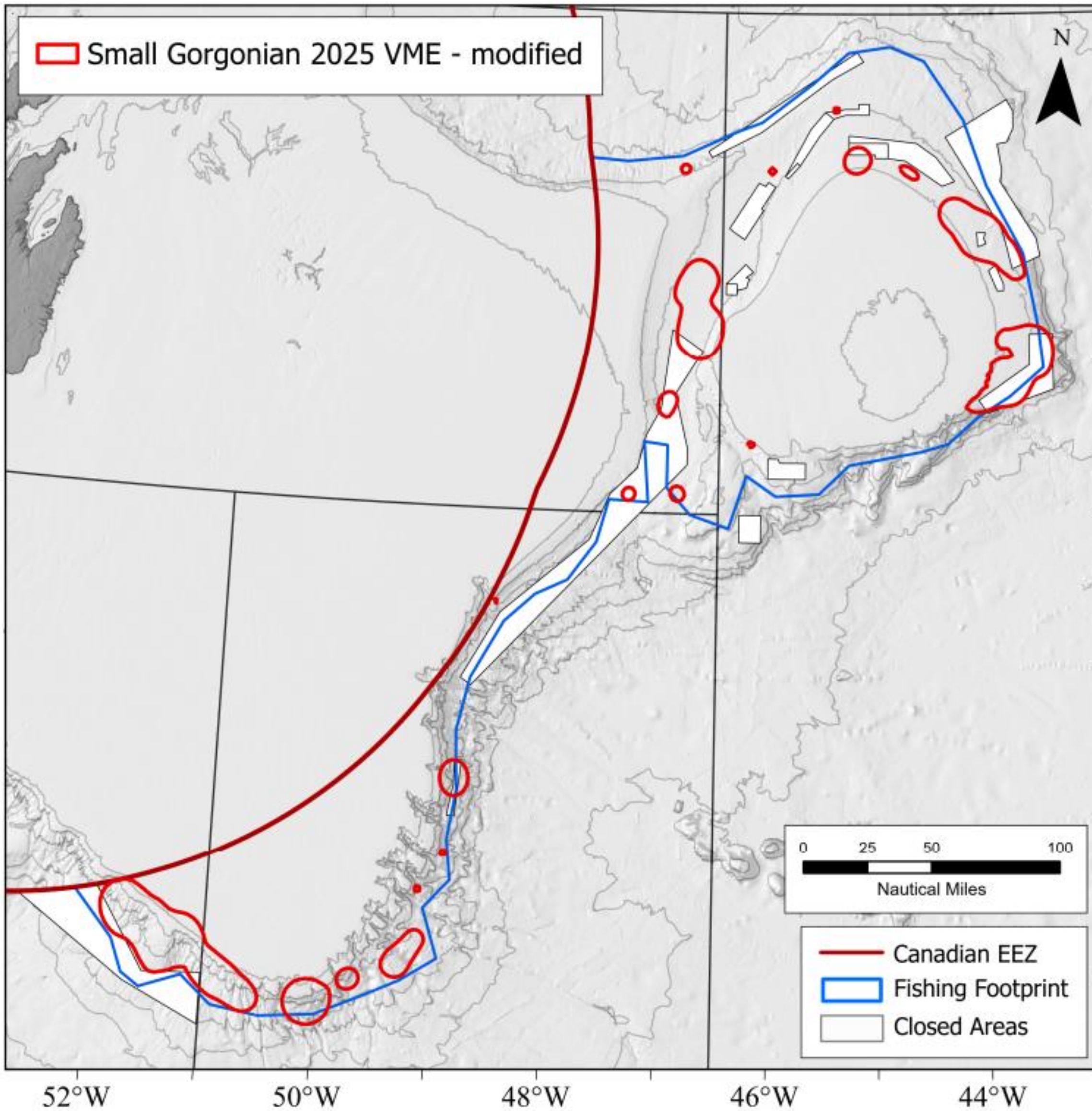


Figure 62. Map of the proposed Small Gorgonian Coral Functional Group KDE VME polygons after consideration of modifications based on the SDM for the Small Gorgonian Coral Functional Group (Murillo et al., 2025). Closed areas are indicated in white (NAFO, 2025).

Acanella arbuscula

The *Acanella arbuscula* subgroup of Small Gorgonian Corals was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. The *Acanella arbuscula* KDE VME polygons (Kenchington et al., 2025) are found primarily on the Tail of Grand Bank (Figure 63). These polygons all lie largely within the area of predicted *Acanella arbuscula* presence from the SDM (Murillo et al., 2025). These VME polygons lie in areas of high probability *Acanella arbuscula* presence (Figures 64 and 65) and there is very little overlap with areas of high probability of *Acanella arbuscula* absence. Consequently we do not propose modifications to the *Acanella arbuscula* KDE VME polygons.

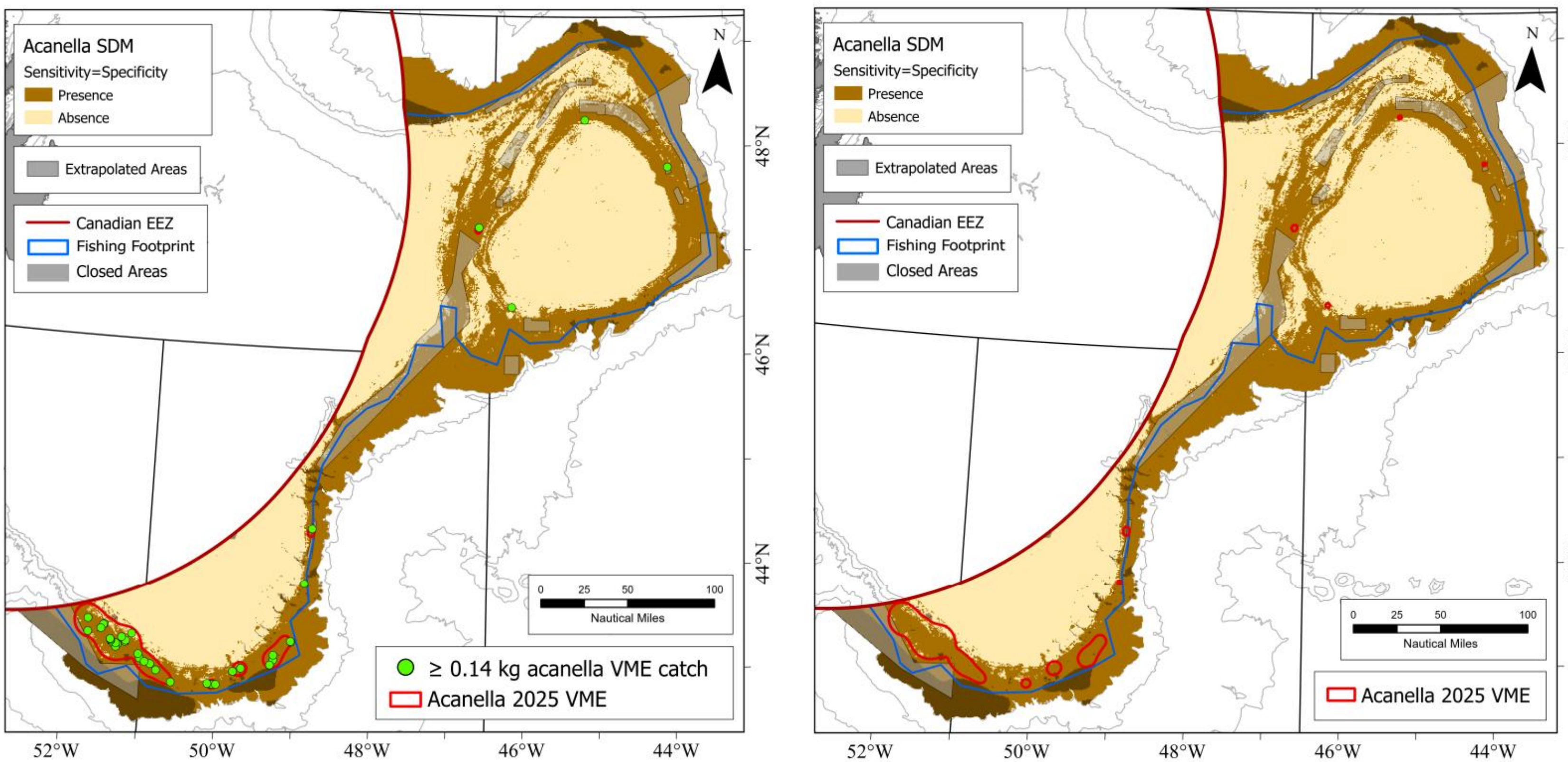


Figure 63. **Left Panel.** The 2025 *Acanella arbuscula* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Acanella arbuscula* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). The location of research vessel survey catches greater than or equal to 0.14 kg are indicated. **Right Panel.** The 2025 *Acanella arbuscula* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Acanella arbuscula* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

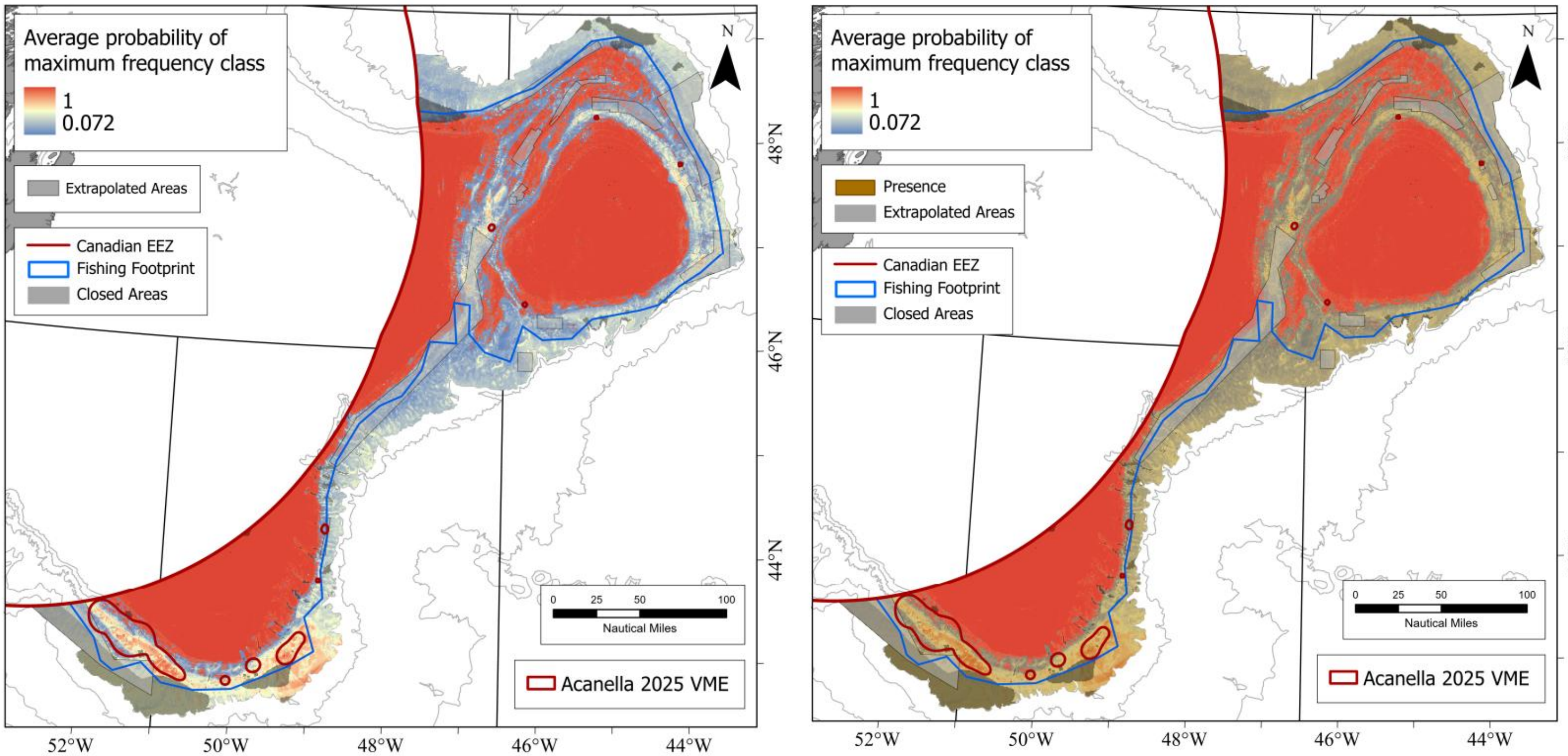


Figure 64. **Left Panel.** The 2025 *Acanella arbuscula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Acanella arbuscula* (Murillo et al., 2025). **Right Panel.** The 2025 *Acanella arbuscula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the *Acanella arbuscula* which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for *Acanella arbuscula* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

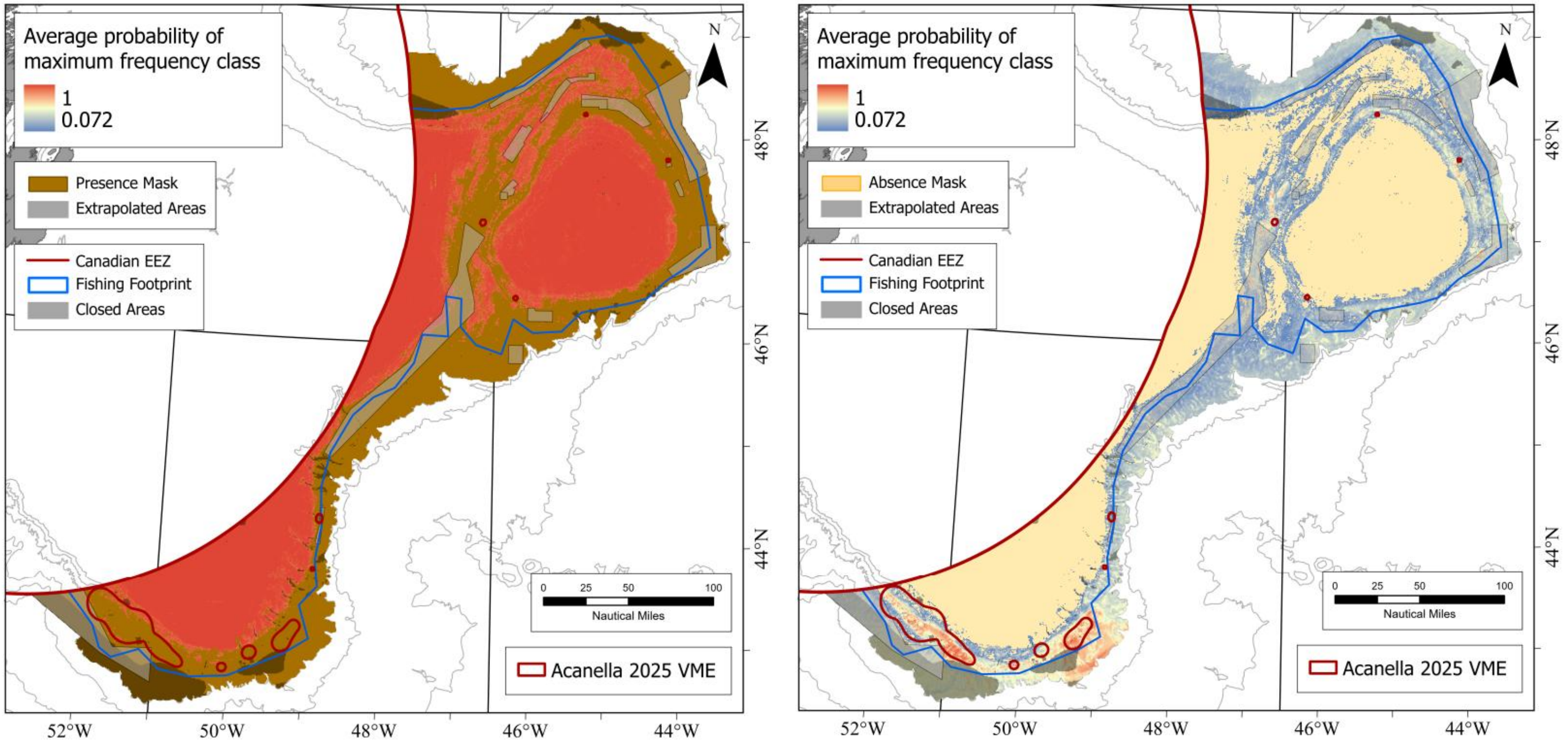


Figure 65. **Left Panel.** The 2025 *Acanella arbuscula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Acanella arbuscula* (Murillo et al., 2025). **Right Panel.** The 2025 *Acanella arbuscula* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for *Acanella arbuscula* (Murillo et al., 2025).

Radicipes gracilis

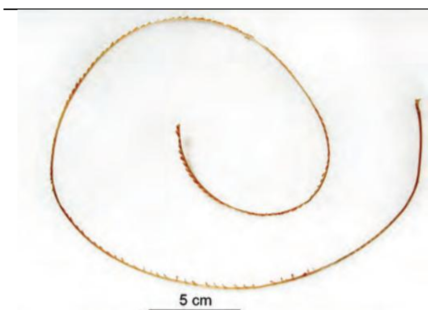
The *Radicipes gracilis* subgroup of Small Gorgonian Corals was not presented in the 2019 review (Kenchington et al., 2019) as there were insufficient data to conduct the KDE analyses at that time. The *Radicipes gracilis* KDE VME polygons (Kenchington et al., 2025) are found on the Tail of Grand Bank, in Flemish Pass and on the slopes of Flemish Cap (Figure 66). These polygons all lie largely within the area of predicted *Radicipes gracilis* presence from the SDM (Murillo et al., 2025). However, two polygons, one near Area 2 and the other near Area 6 (Figure 66) have portions of their area extending into areas of high probability of *Radicipes gracilis* absence (Figures 67 and 68). Consequently we propose modifications to those two *Radicipes gracilis* KDE VME polygons.

Proposed Modifications to the *Radicipes gracilis* VME Polygons

Area 2. The southwestern portion of the *Radicipes gracilis* KDE VME polygon near Area 2 extends into an area of predicted absence that has high certainty (Figure 69). This area has one significant catch but no other smaller catches (Figure 69). We propose to clip this polygon to the area of predicted presence in this area, leaving the significant catch as an isolated point.

Area 8. The *Radicipes gracilis* KDE VME polygon near Area 8 extends north into an area of predicted *Radicipes gracilis* absence that is modeled with high certainty. There are areas of predicted presence in this region but they are scattered and may result from fishing activity. One of the areas where *Radicipes gracilis* is predicted to occur contains a significant catch (Figure 70). We propose to clip this polygon to the general area of *Radicipes gracilis* presence.

Table 8. The area occupied by each of the *Radicipes gracilis* KDE VME polygons after making the proposed modifications.



***Radicipes gracilis* KDE VME Polygon Label**	**Polygon Modified**	**Polygon Area (km²)**
Flemish Pass Poly1	Yes	4489.30
Area 7a Poly1	No	935.92
Area 3O Poly1	No	598.19
Area 8 9 Poly1	Yes	303.84
GB Tail Poly1	No	53.62
Flemish Cap East Poly1	No	32.82
GB Tail Poly2	No	29.37
Area 2 Poly1	No	10.85
Flemish Pass Poly2	No	9.51
Flemish Pass Poly3	No	2.38
Total Area:		6465.80

The proposed modifications would produce 10 *Radicipes gracilis* KDE VME polygons (Figure 71). Those polygons ranged in size from 2.38 km^2 to 4489.30 km^2 (Table 8).

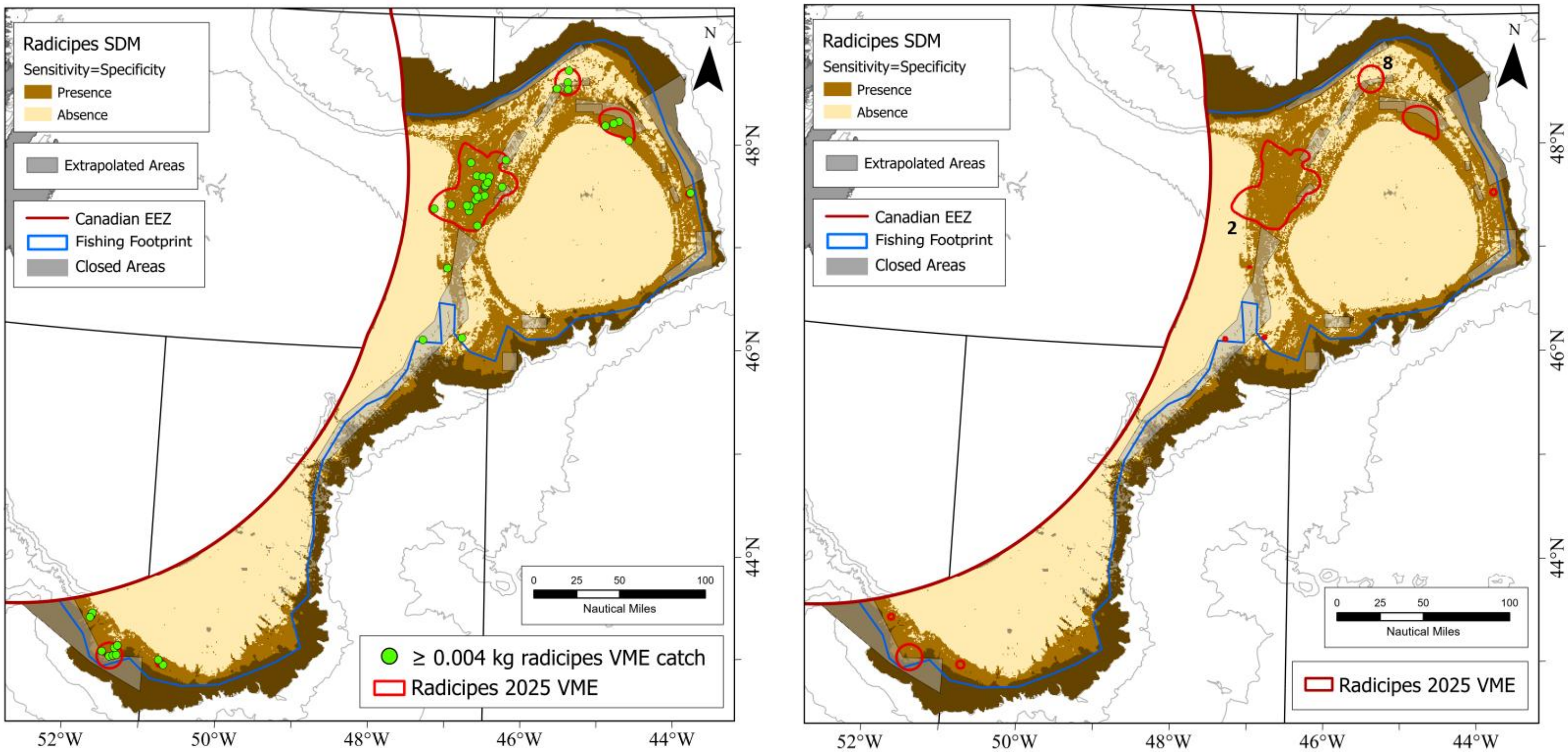


Figure 66. **Left Panel.** The 2025 *Radicipes gracilis* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Radicipes gracilis* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). The location of research vessel survey catches greater than or equal to 0.004 kg are indicated. **Right Panel.** The 2025 *Radicipes gracilis* KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for *Radicipes gracilis* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications.

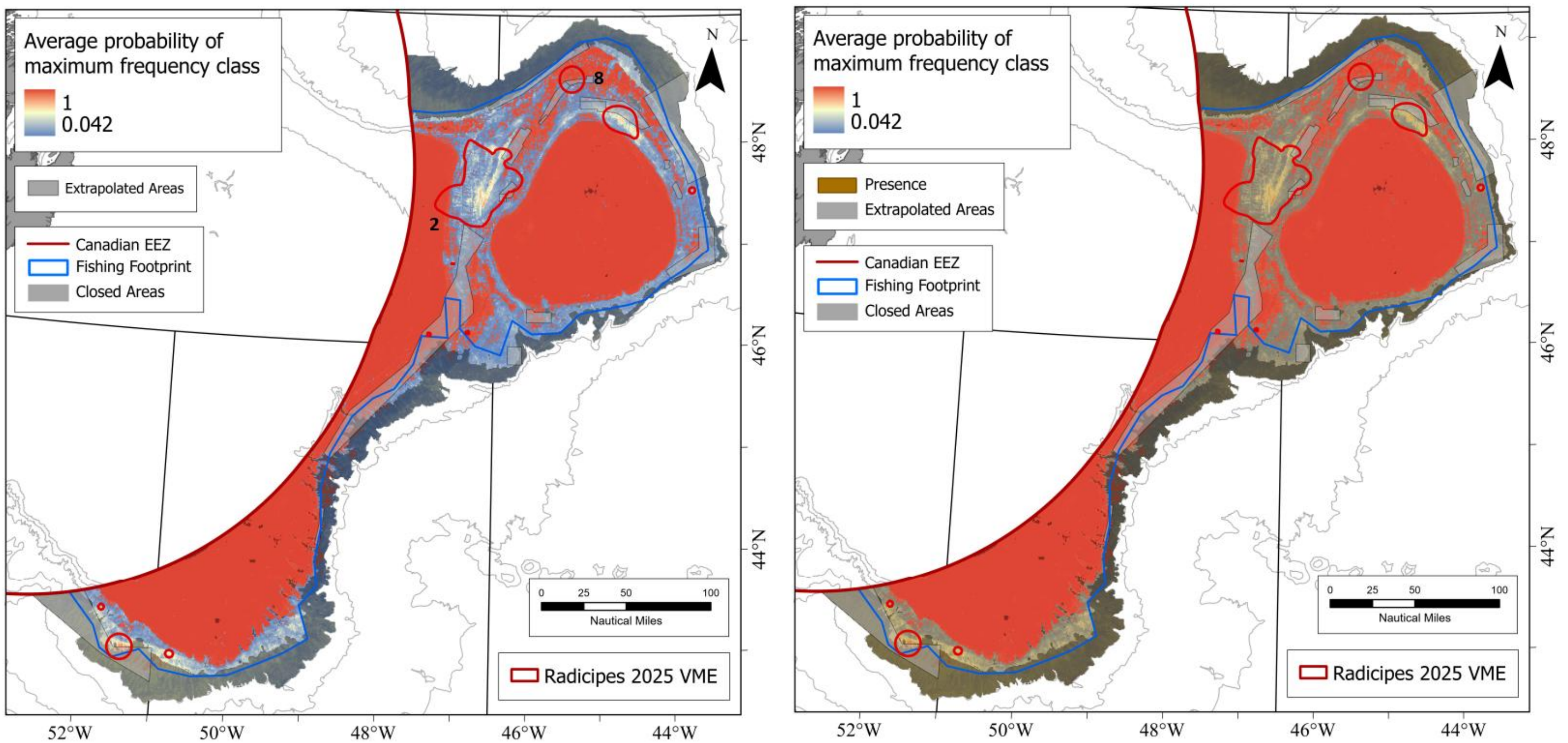


Figure 67. **Left Panel.** The 2025 *Radicipes gracilis* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Radicipes gracilis* (Murillo et al., 2025). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for potential modifications. **Right Panel.** The 2025 *Radicipes gracilis* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for *Radicipes gracilis* which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for *Radicipes gracilis* created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

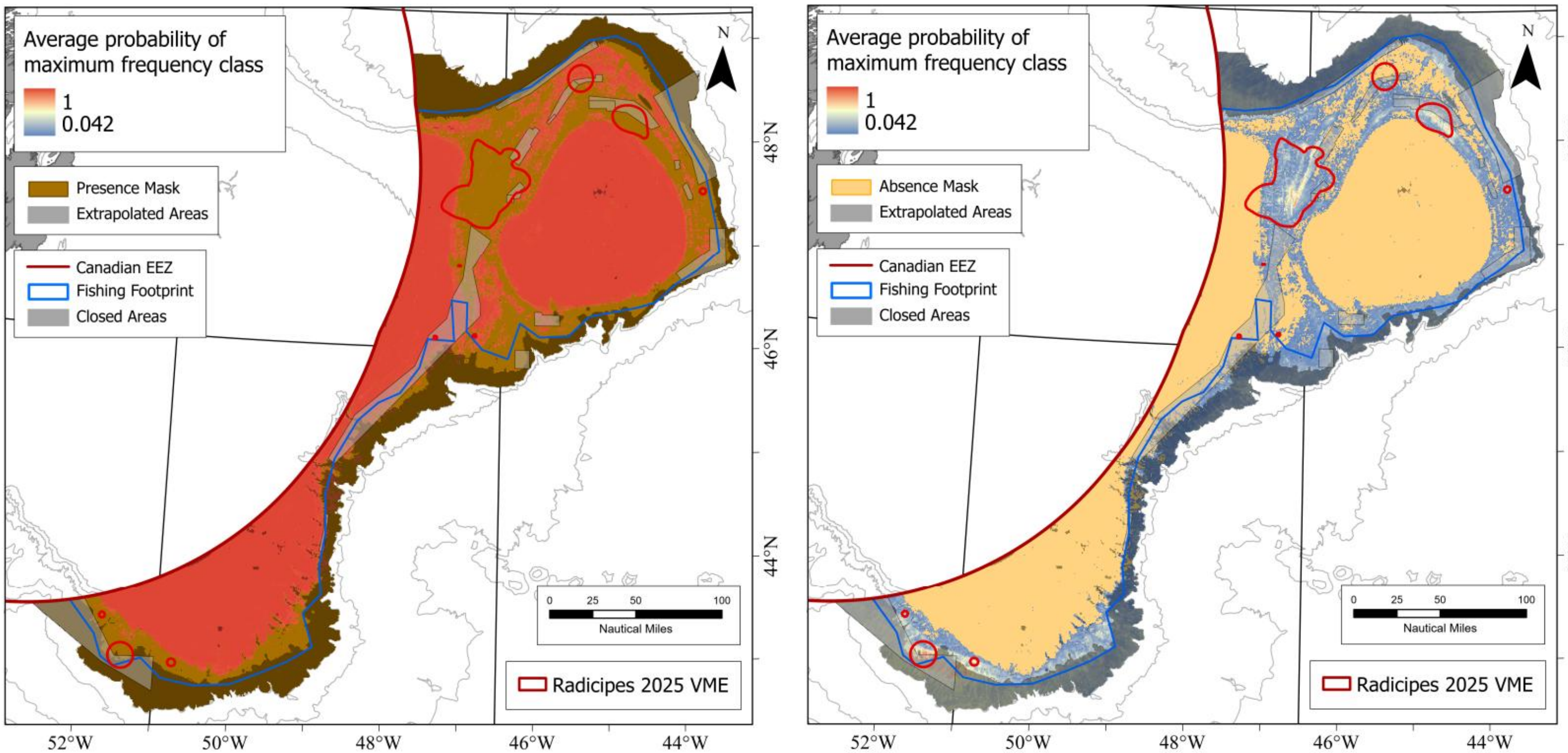


Figure 68. **Left Panel.** The 2025 *Radicipes gracilis* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Radicipes gracilis* (Murillo et al., 2025). **Right Panel.** The 2025 *Radicipes gracilis* KDE VME polygons (Kenchington et al., 2025) superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for *Radicipes gracilis* (Murillo et al., 2025).

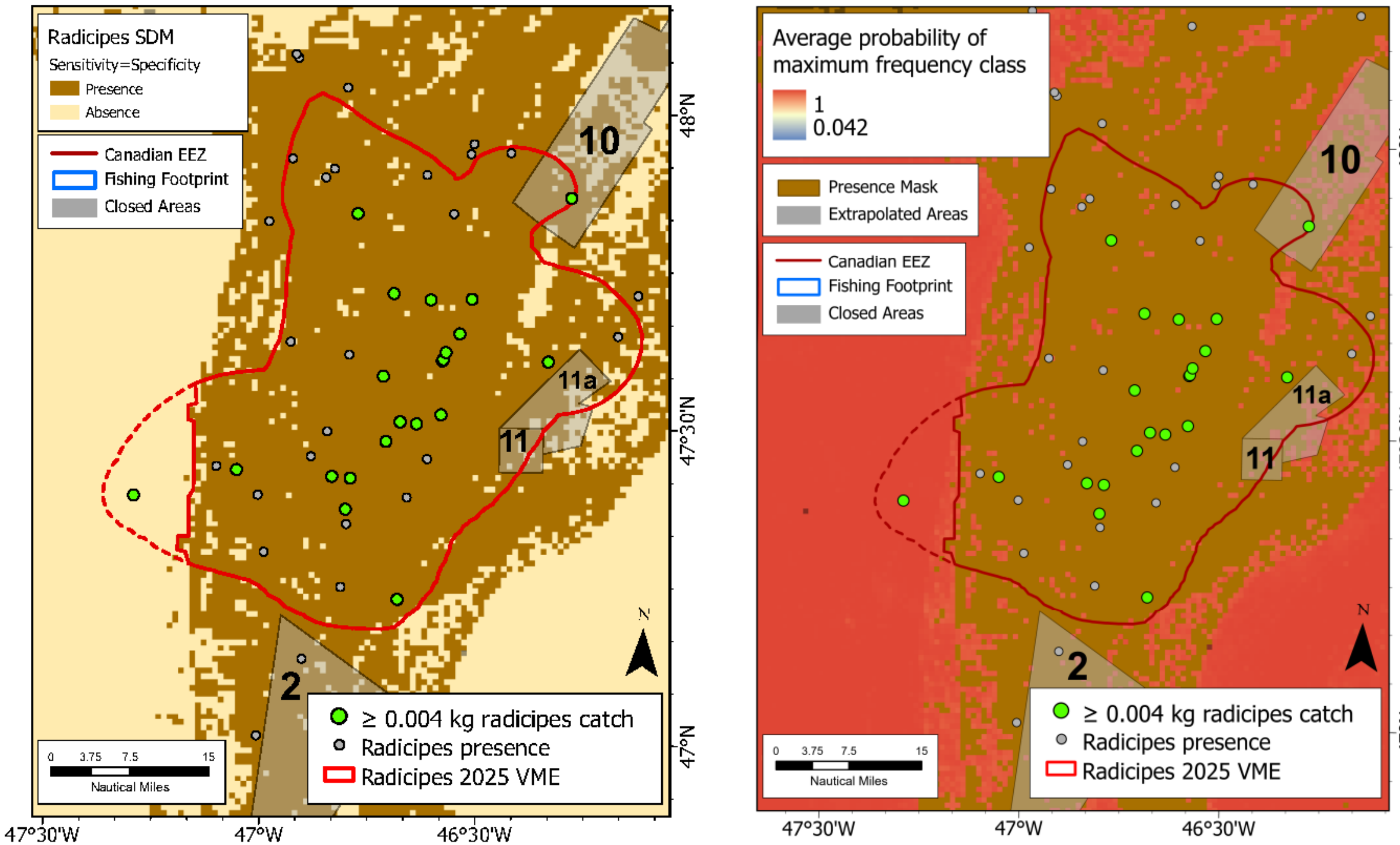


Figure 69. **Area 2. Left Panel.** Map of the proposed modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Radicipes gracilis*). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) near Area 2 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Radicipes gracilis* (Murillo et al., 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.004 kg, the threshold for the KDE analyses, and all other catches with < 0.004 kg are shown.

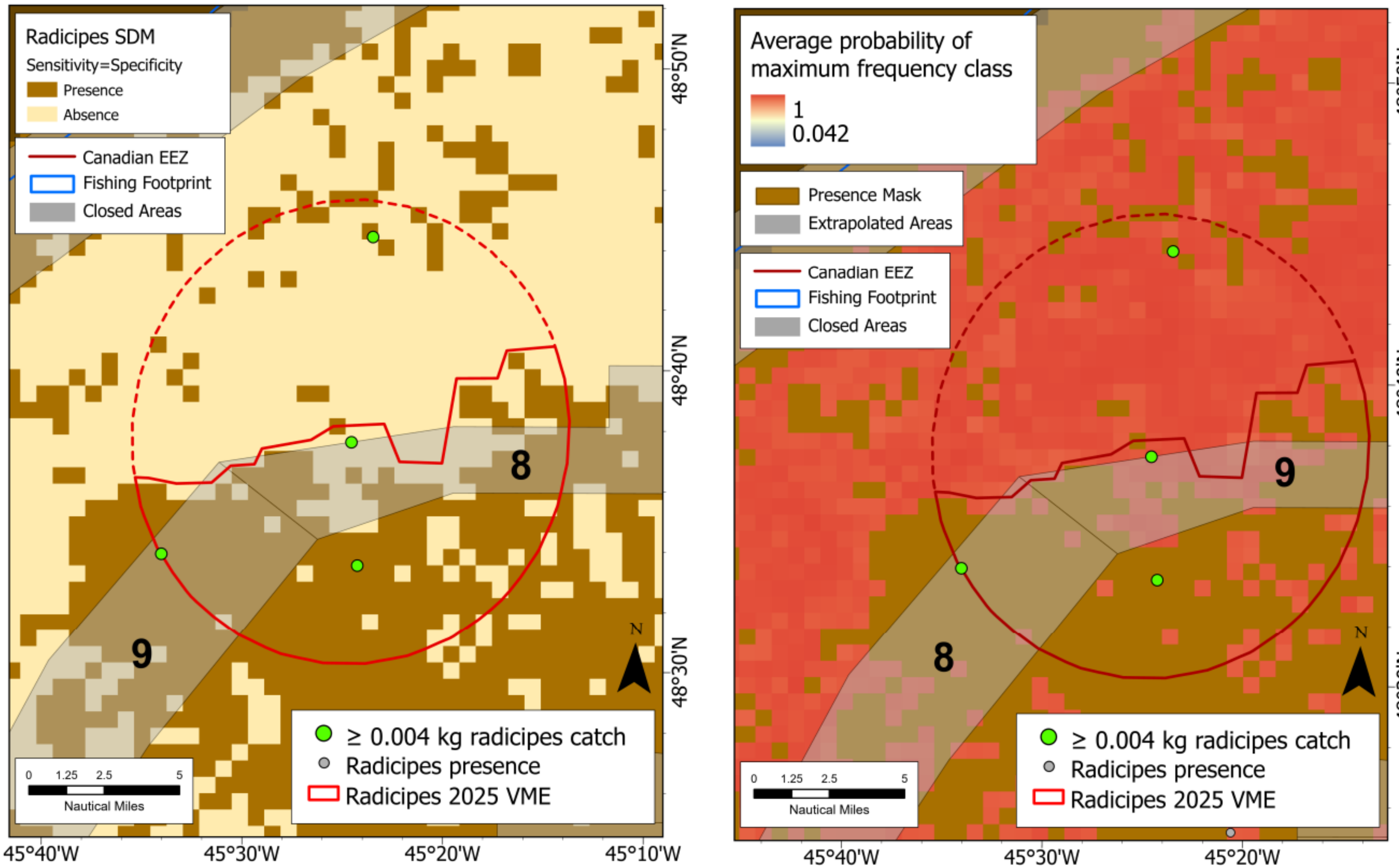


Figure 70. **Area 8. Left Panel.** Map of the proposed modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of *Radicipes gracilis*). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 *Radicipes gracilis* KDE VME polygon (red dashed lines) near Area 8 in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for *Radicipes gracilis* (Murillo et al., 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.004 kg, the threshold for the KDE analyses, and all other catches with < 0.004 kg are shown.

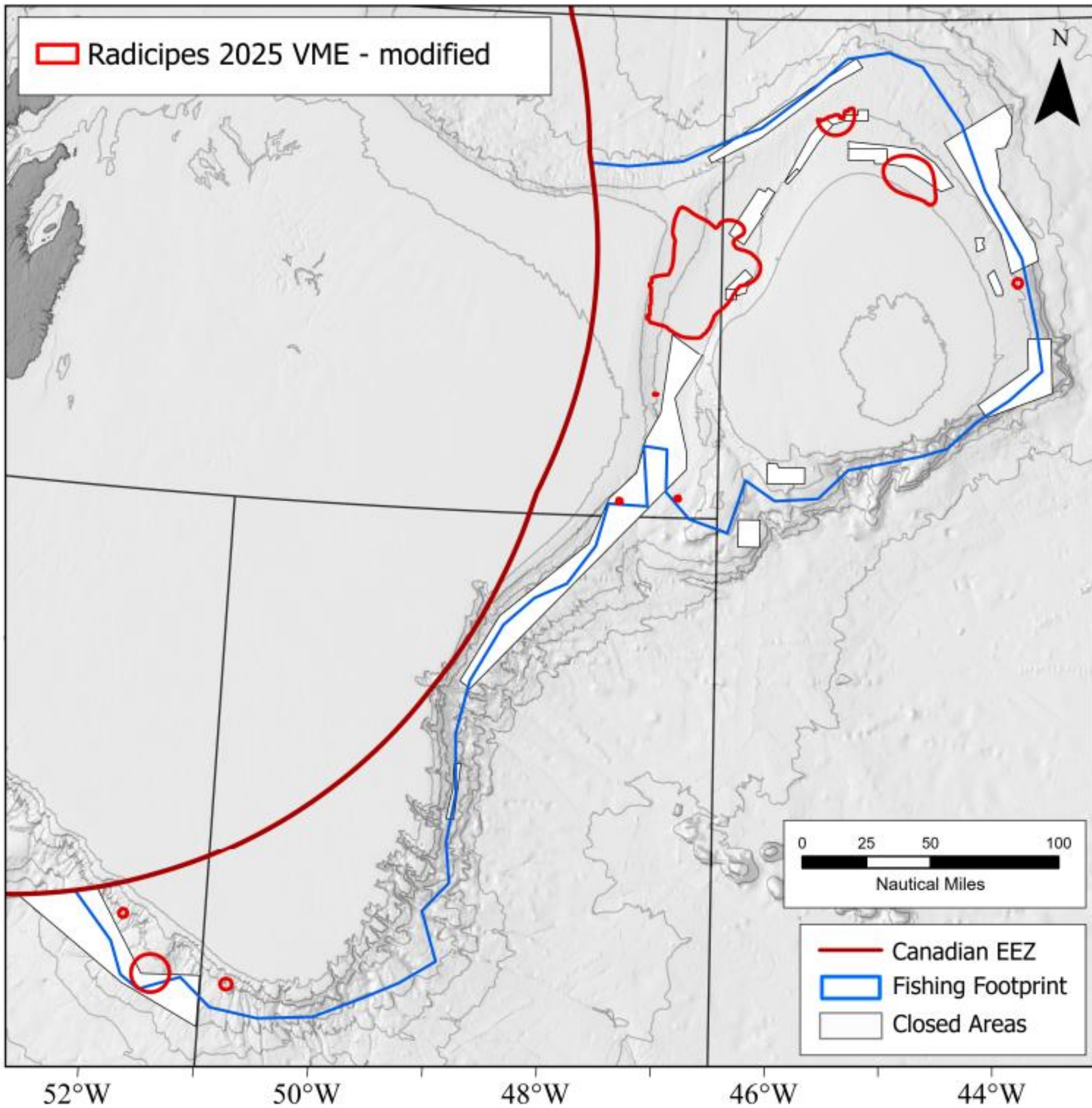


Figure 71. Map of the proposed *Radicipes gracilis* KDE VME polygons after consideration of modifications based on the SDM for the *Radicipes gracilis* (Murillo et al., 2025). Closed areas are indicated in white (NAFO, 2025).

Erect Bryozoans

The Erect Bryozoan Functional Group KDE VME polygons are found primarily on the Tail of Grand Bank (Figure 72). These polygons all lie largely within the area of predicted Erect Bryozoan Habitat presence from the SDM (Murillo et al., 2025). In this area the largest of the polygons extends into area of predicted Erect Bryozoan Habitat absence while a smaller polygon on the eastern slope near Area 1 is mostly in an area where Erect Bryozoan Habitat absence is predicted with high probability (Figures 73 and 74). South of this polygon there is another polygon lying entirely within the area of predicted Bryozoan Habitat absence. This polygon was formed from two significant catches. (Figures 72-74). We propose to remove that VME polygon and retain the two data points as significant catches. Further examination of the remaining two polygons was undertaken.

Proposed Modifications to the Erect Bryozoan VME Polygons

Tail of Grand Bank. The area of the large Erect Bryozoan VME polygon on the Tail of Grand Bank that extends into the area of predicted Erect Bryozoan Habitat (Figure 75) revealed a mosaic of grid cells predicting presence and absence. Although absence was predicted with high probability, there were three significant catches in this location as well as some smaller catches. The area also had scattering of grid cells with extrapolated environments, rendering the predictions unreliable for those cells. A tongue is left to capture the three significant catches that reach out in a linear direction to the west. Interestingly those catches were taken in 2007 and 2008 and so not used in the SDM where only data between 2011 and 2023 were used, so their occurrence there reinforces the small areas of predicted presence.

Area 1. The Erect Bryozoan VME polygon on the slope of Grand Bank near Area 1 extends on its eastern edge into an area where Erect Bryozoan Habitat is predicted with high certainty to be absent. The proposed modification is to bring the polygon boundary to the edge of the predicted Erect Bryozoan Habitat presence (Figure 76).

Table 9. The area occupied by each of the Erect Bryozoan Functional Group KDE VME polygons after making the proposed modifications.

Erect Bryozoan Functional Group KDE VME Polygon Label	**Polygon Modified**	**Polygon Area (km^2)**
GB Tail Poly1	Yes	3764.58
GB Tail Poly2	No	1242.24
Area 1 (Near) Poly2	Yes	264.97
GB Nose Poly1	No	178.07
Area 2 Poly1	No	25.91
GB Tail Poly3	No	16.84
FC East Poly1	No	15.77
GB Tail Poly4	No	10.73
Area 2 Poly2	No	8.13
GB Tail Poly5	No	6.90
GB Tail Poly6	No	6.57
Total Area:		5540.71

The proposed modifications would produce 11 Erect Bryozoan Functional Group KDE VME polygons (Figure 77). Those polygons ranged in size from 6.57 km^2 to 4044.60 km^2 (Table 9).

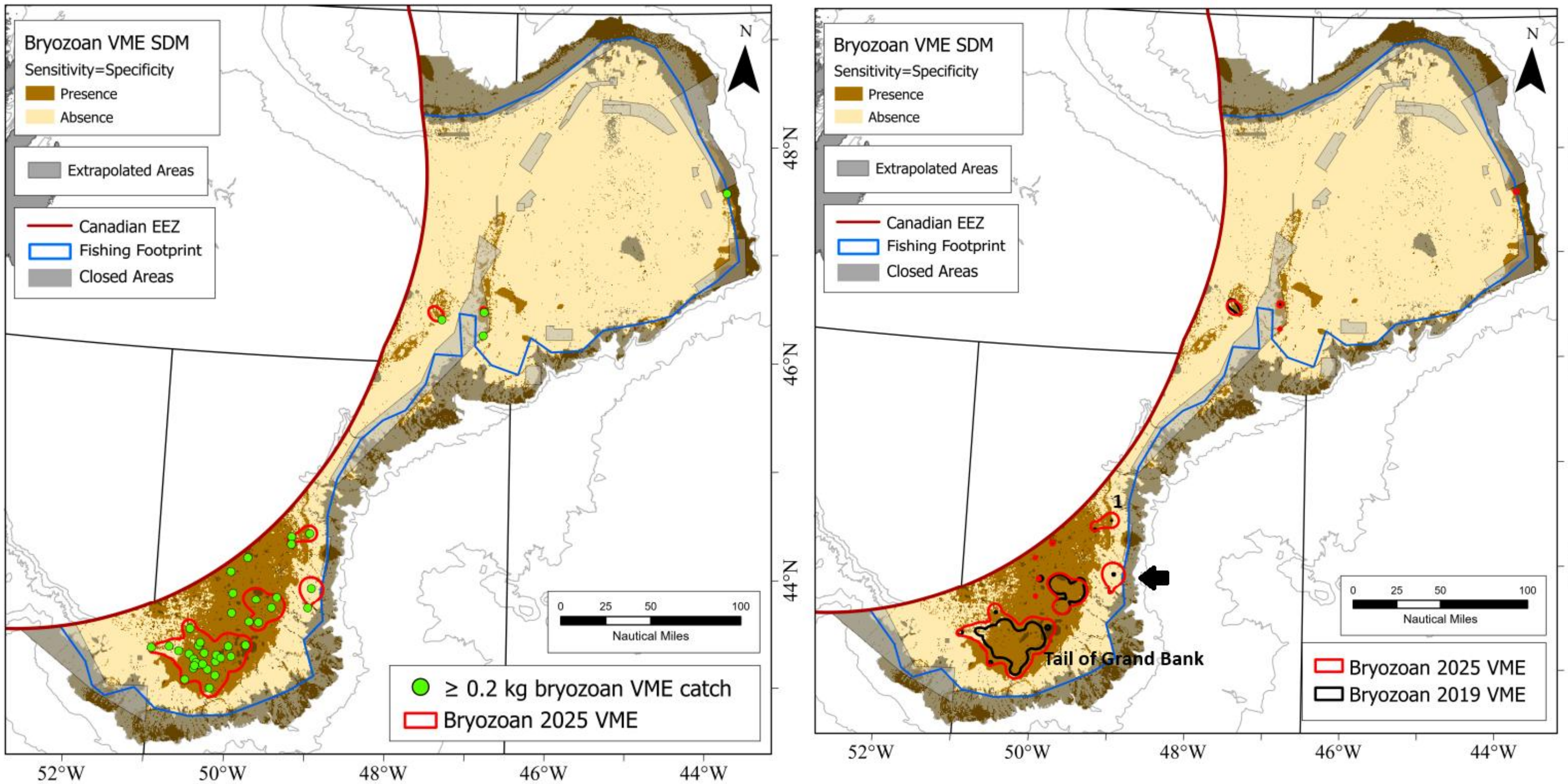


Figure 72. **Left Panel.** The 2025 Erect Bryozoan Functional Group KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Erect Bryozoan Habitat created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). The location of research vessel survey catches greater than or equal to 0.2 kg are indicated. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Erect Bryozoan Functional Group KDE VME polygons superimposed on the SDM for the Erect Bryozoan Habitat created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications. The arrow points to the Erect Bryozoan Functional Group KDE VME polygon falling in the area of predicted absence (see text).

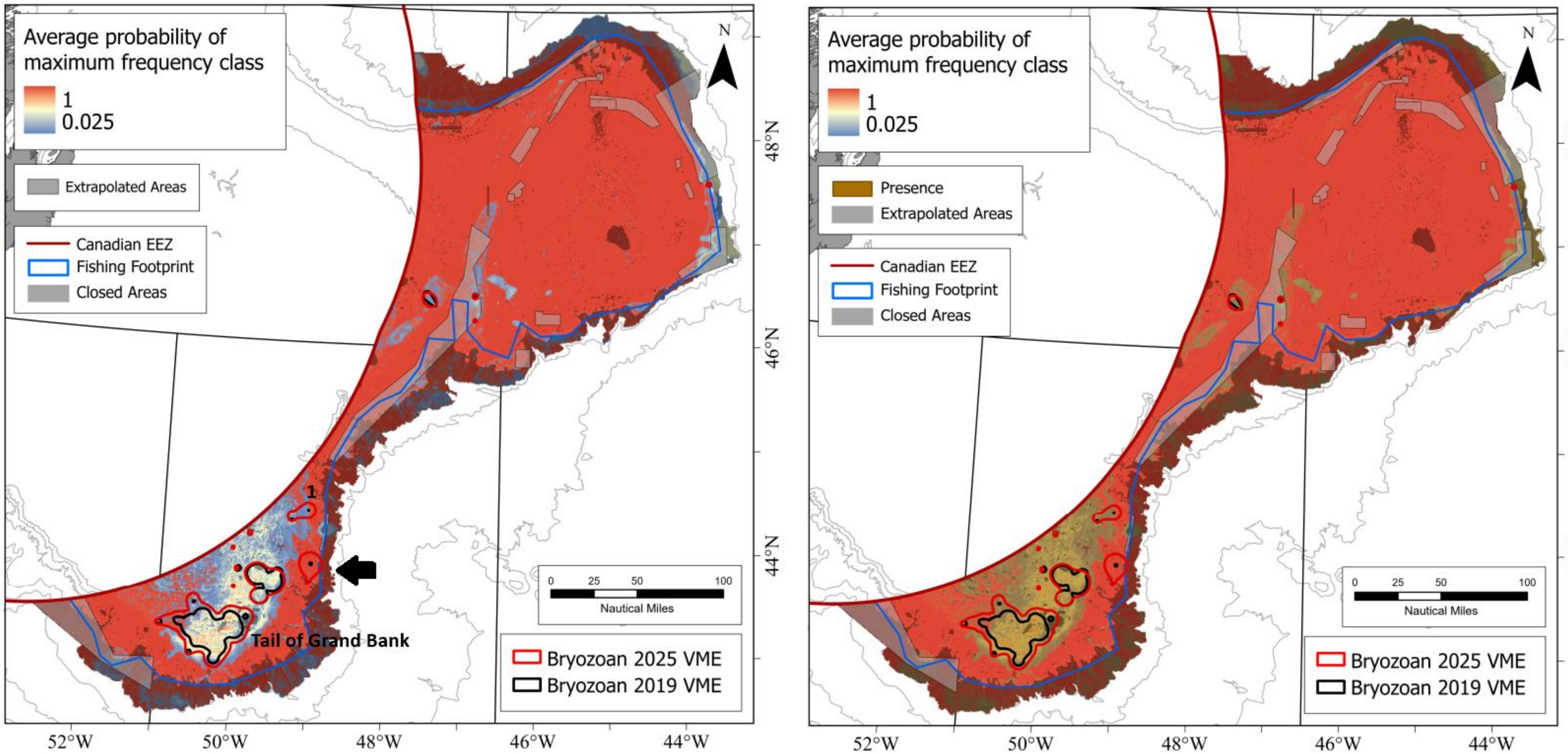


Figure 73. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Erect Bryozoan Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Erect Bryozoan Habitat (Murillo et al., 2025). Numbers indicate the Vulnerable Marine Ecosystem Area Closures referenced in Article 17.3 of the NAFO Conservation and Enforcement Measures (NAFO, 2025) and serve to identify the 2025 KDE VME polygons that warrant further examination for modifications. The arrow points to the Erect Bryozoan Functional Group KDE VME polygon falling in the area of predicted absence (see text). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Erect Bryozoan Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Erect Bryozoan Habitat which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Erect Bryozoan Habitat created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

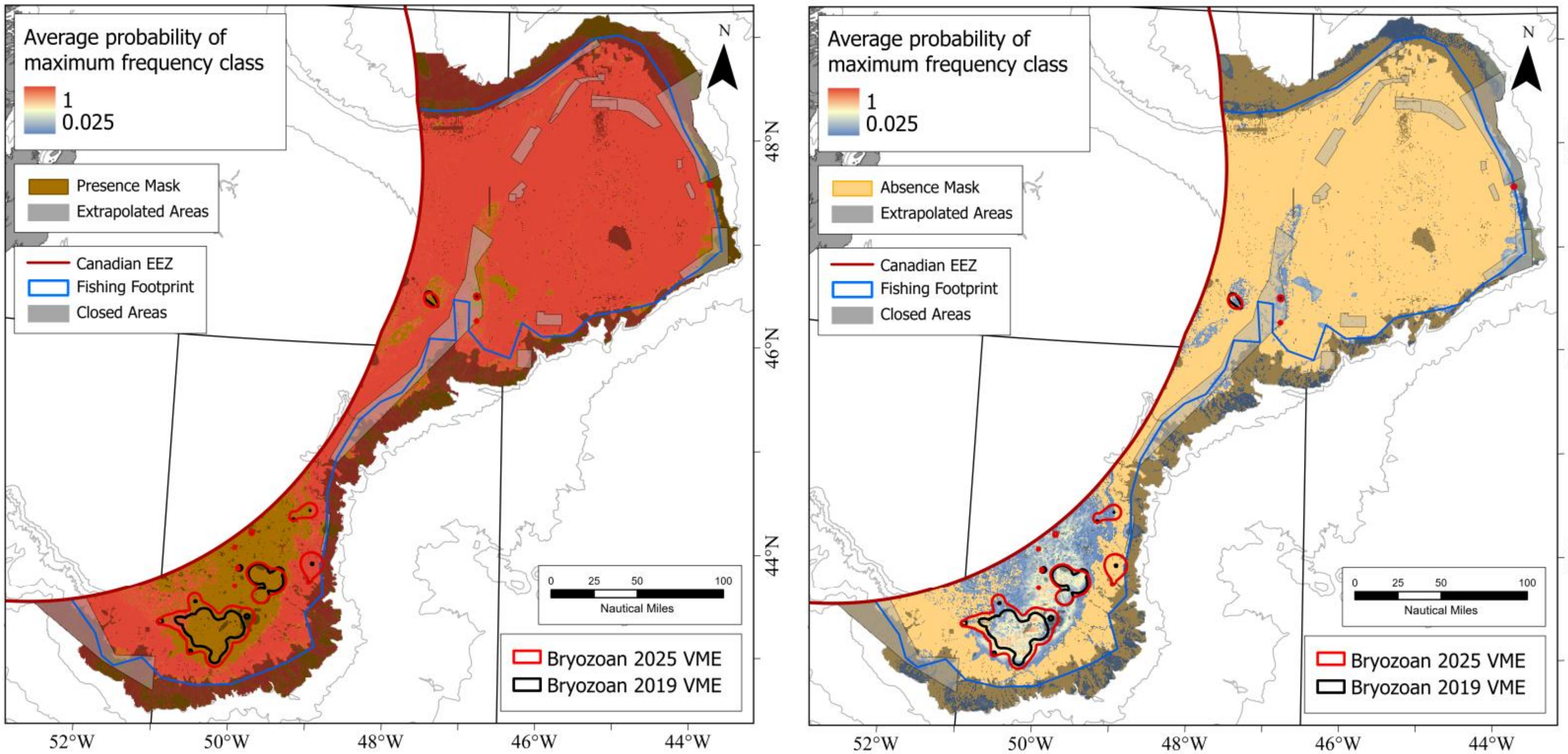


Figure 74. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Erect Bryozoan Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Erect Bryozoan Habitat (Murillo et al., 2025). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Erect Bryozoan Functional Group KDE VME polygons superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Erect Bryozoan Habitat (Murillo et al., 2025).

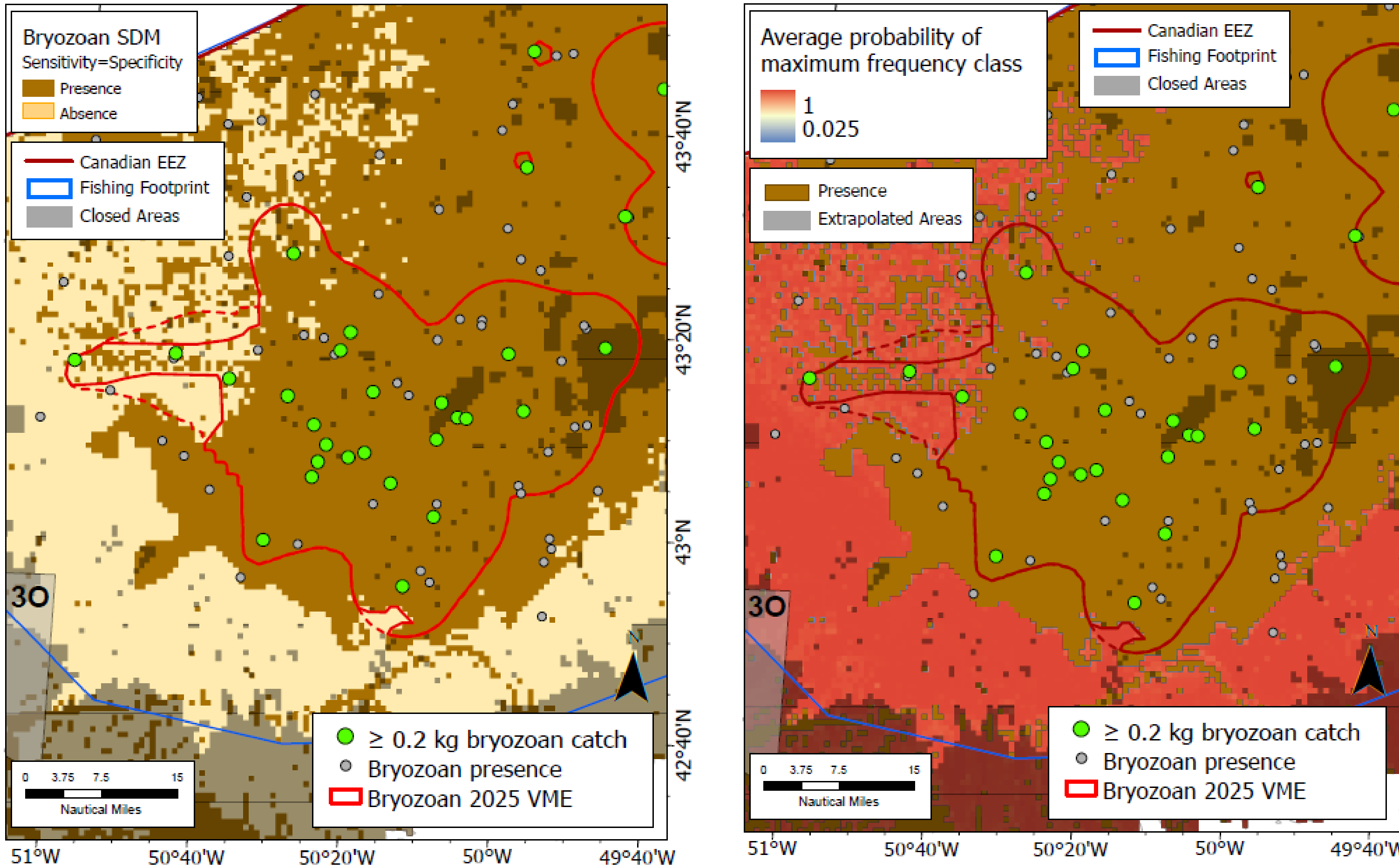


Figure 75. Tail of Grand Bank. Left Panel. Map of the proposed modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of the Erect Bryozoan Habitat). A decision was made not to modify this polygon at this time. **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for Erect Bryozoan Habitat (Murillo et al., 2025). A decision was made not to modify this polygon at this time. Closed areas are indicated in grey shading. Catches of ≥ 0.2 kg, the threshold for the KDE analyses, and all other catches with < 0.2 kg are shown.

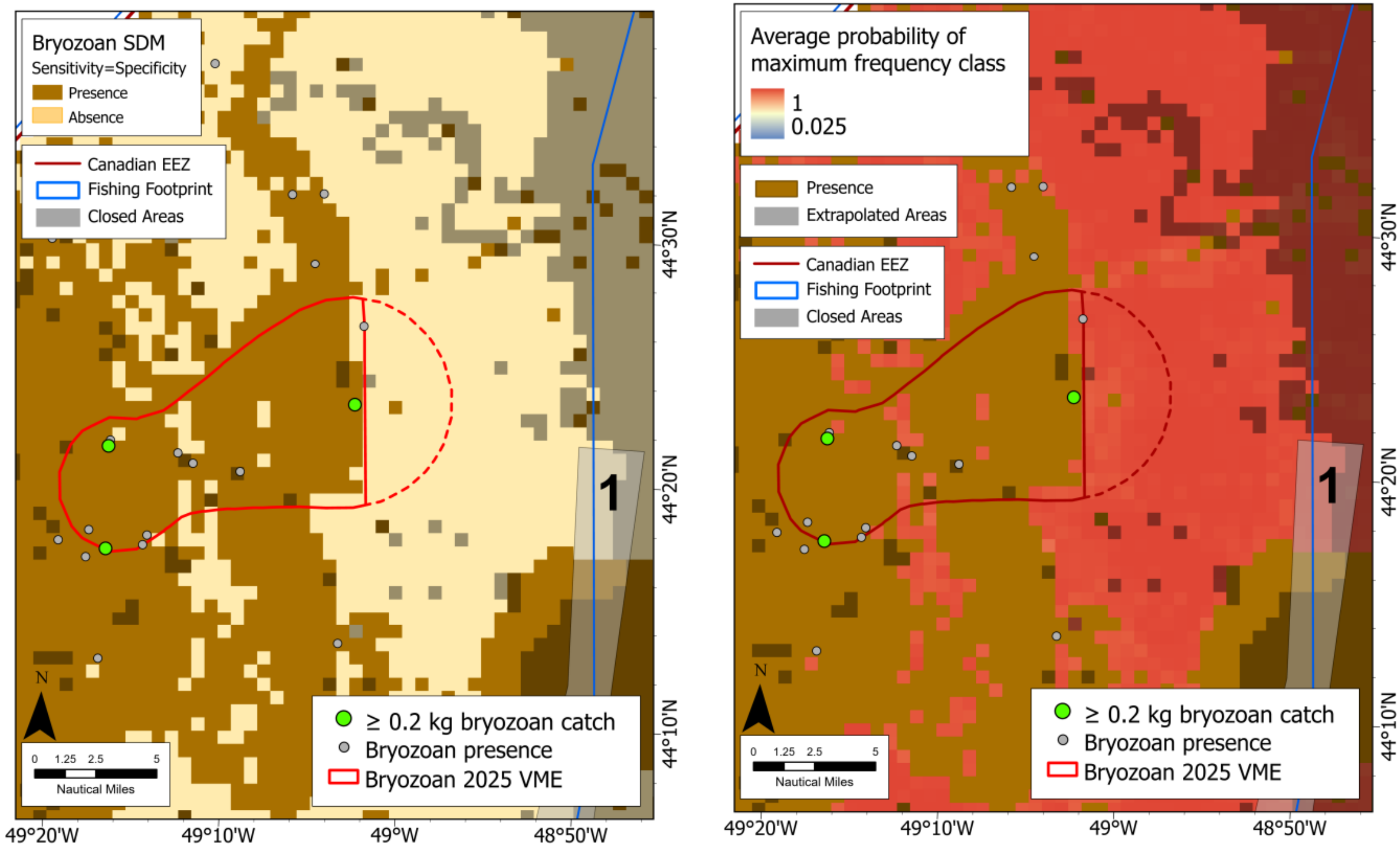


Figure 76. **Area 1. Left Panel.** Map of the proposed modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) and showing the underlying SDM (brown area showing predicted presence of the Erect Bryozoan Habitat). **Right Panel.** Map of the proposed modification (solid red line) of the 2025 Erect Bryozoan Functional Group KDE VME polygon (red dashed lines) in relation to the average probability of the maximum frequency class for **absence values** from 10 SDM runs for Erect Bryozoan Habitat (Murillo et al., 2025). Closed areas are indicated in grey shading. Catches of ≥ 0.2 kg, the threshold for the KDE analyses, and all other catches with < 0.2 kg are shown.

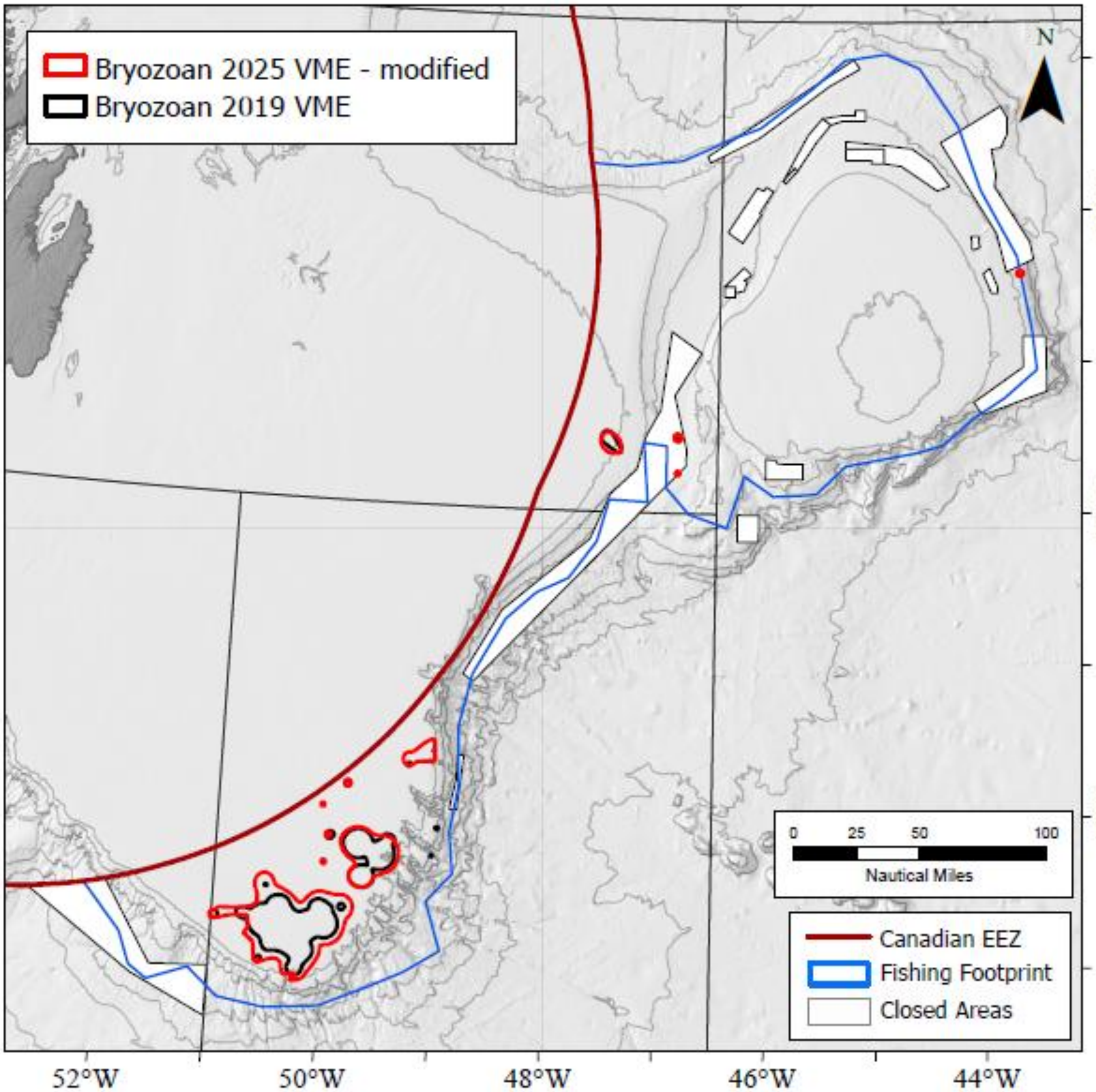


Figure 77. Map of the proposed Erect Bryozoan Functional Group KDE VME polygons after consideration of modifications based on the SDM for the Erect Bryozoan Habitat (Murillo et al., 2025), and in relation to the 2019 accepted KDE VME polygons (black line). Closed areas are indicated in white (NAFO, 2025).

Sea Squirts

The Sea Squirt Functional Group KDE VME polygons are found primarily on the Tail of Grand Bank (Figure 78). These polygons all lie largely within the area of predicted Sea Squirt Functional Group presence from the SDM (Murillo et al., 2025) where they are found in areas where there is a high probability of predicted presences (Figures 79 and 80). No modifications are suggested based on the SDMs although polygons close to the Canadian EEZ were examined in close-up and clipped to the EEZ if necessary.

Proposed Modifications to the Sea Squirt VME Polygons

Only one polygon extended into Canadian waters (Figure 81) and that was modified to bring the polygon edge in line with the Canadian EEZ.

The proposed modifications would produce 19 Sea Squirt KDE VME polygons (Figure 82). Those polygons ranged in size from 0.51 km^2 to 4280.38 km^2 (Table 10).

Table 10. The area occupied by each of the Sea Squirt KDE VME polygons after making the proposed modifications.

Sea Squirt KDE VME Polygon Label	Polygon Modified	Polygon Area (km^2)
GB Tail Poly1	No	4280.38
GB Tail Poly2	Yes	471.00
GB Tail Poly3	No	199.43
GB Nose Poly1	No	132.05
GB Tail Poly4	No	48.00
GB Tail Poly5	No	29.98
GB Tail Poly6	No	20.40
GB Tail Poly7	No	7.68
Sackville Spur Poly1	No	4.61
GB Nose Poly2	No	3.19
GB Nose Poly3	No	2.70
GB Tail Poly8	No	2.40
Area 2 Poly1	No	2.39
GB Nose Poly4	No	2.02
GB Tail Poly9	No	1.75
GB Nose Poly5	No	1.24
GB Nose Poly6	No	1.22
GB Nose Poly7	No	1.03
GB Tail Poly10	No	0.51
Total Area:		5211.96

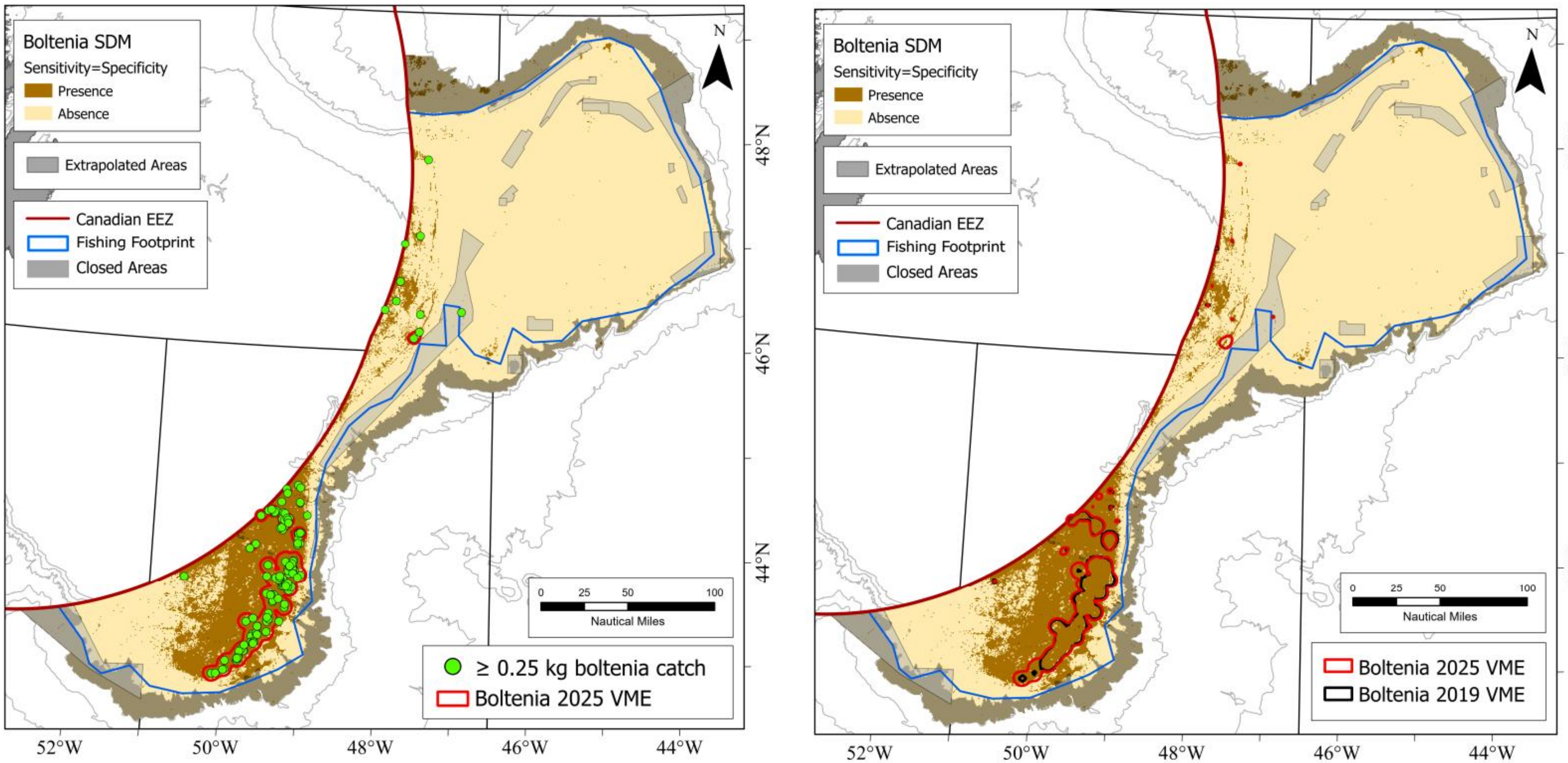


Figure 78. **Left Panel.** The 2025 Sea Squirt (*Boltenia*) KDE VME polygons (Kenchington et al., 2025) superimposed on the SDM for the Sea Squirt (*Boltenia*) created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025). The location of research vessel survey catches greater than or equal to 0.25kg are indicated. **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Squirt (*Boltenia*) KDE VME polygons superimposed on the SDM for the Sea Squirt (*Boltenia*) created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

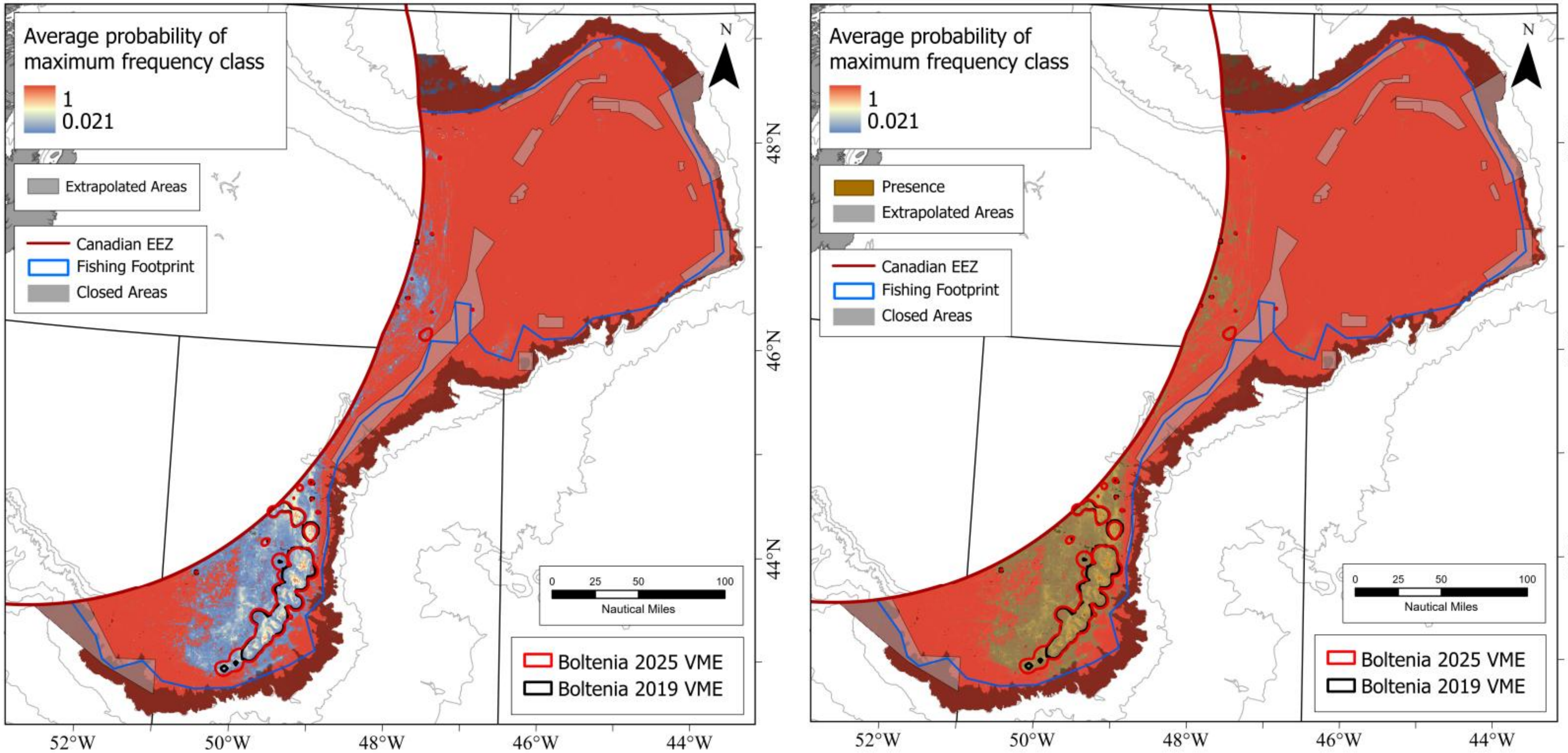


Figure 79. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Squirt (*Boltenia*) KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Sea Squirt (*Boltenia*) (Murillo et al., 2025). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Squirt (*Boltenia*) KDE VME polygons superimposed on the average probability of the maximum frequency class (presence or absence) from 10 SDM runs for the Sea Squirt (*Boltenia*) which itself is superimposed with a 30% transparent overlay showing areas where the SDM predicts presence for the Sea Squirt (*Boltenia*) created with a threshold optimised to ensure that resulting Sensitivity=Specificity (Murillo et al., 2025).

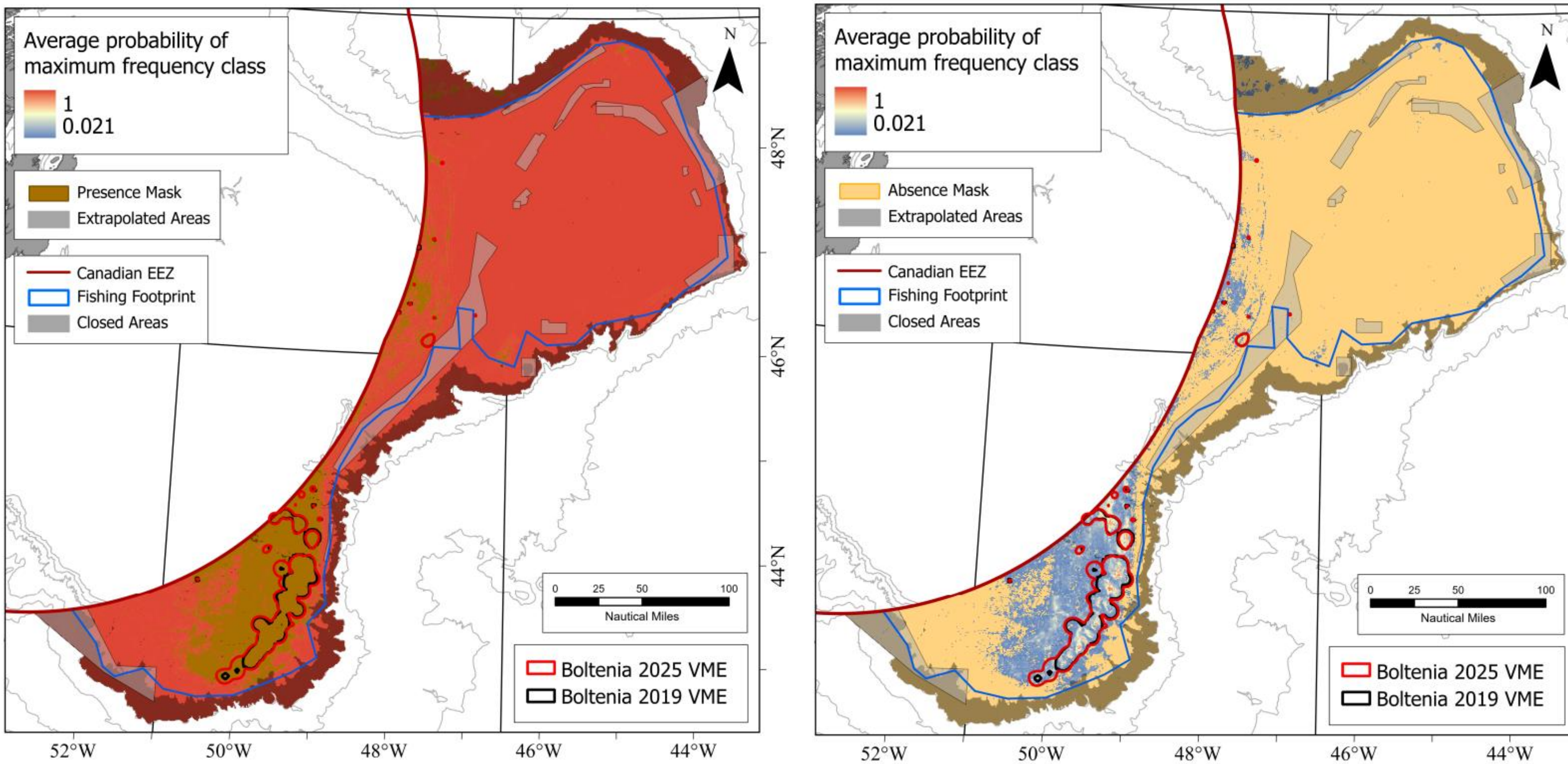


Figure 80. **Left Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Squirt (*Boltenia*) KDE VME polygons superimposed on the average probability of the maximum frequency class for **absence values** from 10 SDM runs for the Sea Squirt (*Boltenia*) (Murillo et al., 2025). **Right Panel.** The 2025 (Kenchington et al., 2025) and 2019 clipped (Kenchington et al. 2019) Sea Squirt (*Boltenia*) KDE VME polygons superimposed on the average probability of the maximum frequency class for **presence values** from 10 SDM runs for the Sea Squirt (*Boltenia*) (Murillo et al., 2025)

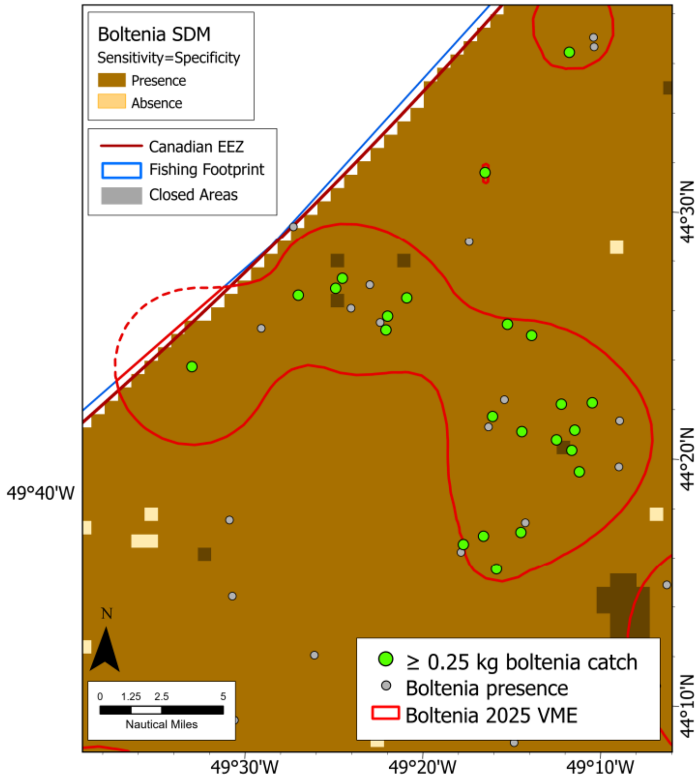


Figure 81. Map of the proposed modification (solid red line) of the 2025 Sea Squirt (*Boltenia*) KDE VME polygon (red dashed lines) to remove portions of the polygon that extended into Canadian waters and showing the underlying SDM (brown area showing predicted presence of the Erect Bryozoan Habitat).

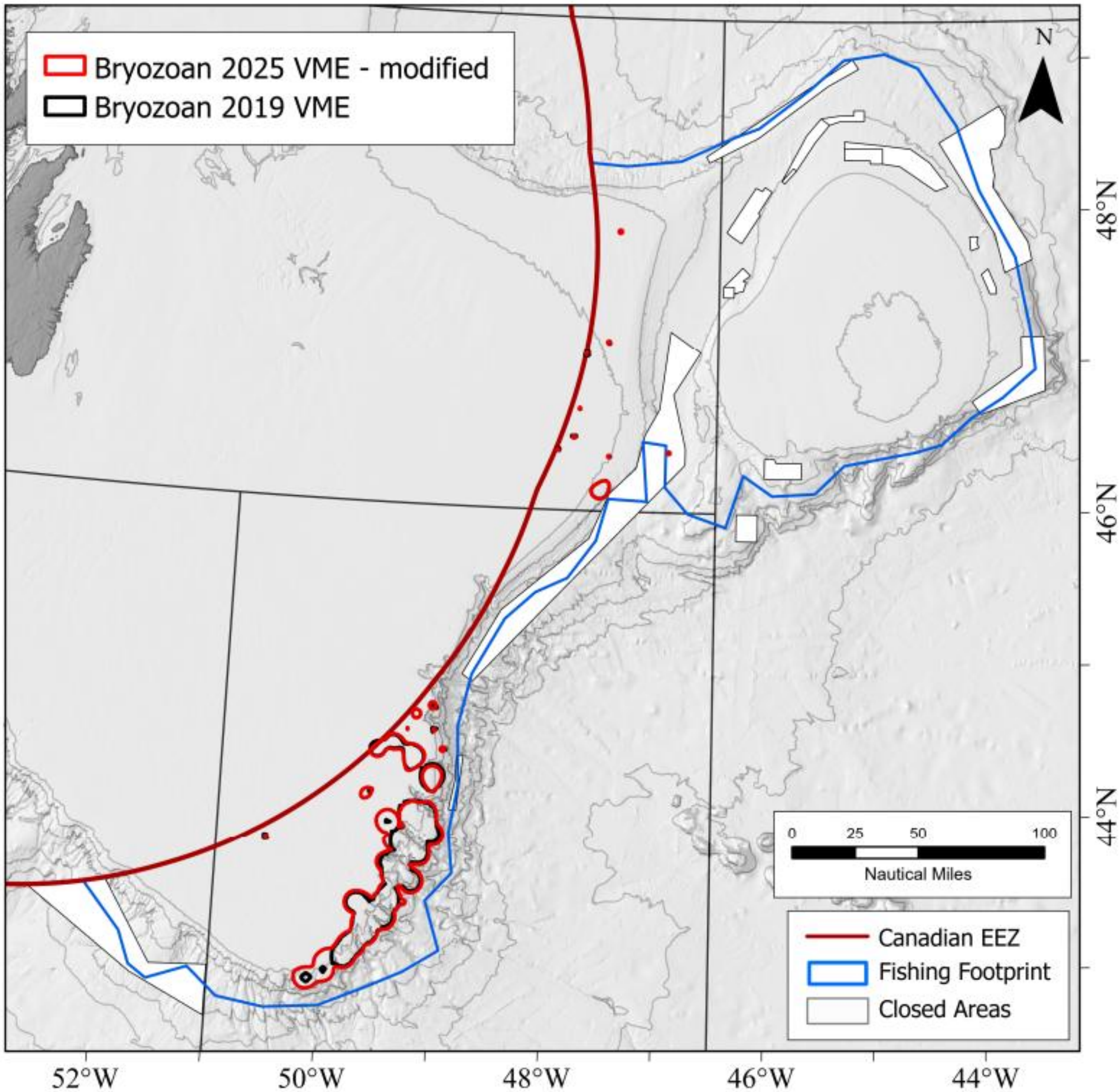


Figure 82. Map of the proposed Sea Squirt (*Boltenia*) KDE VME polygons after consideration of modifications detailed above, and in relation to the 2019 accepted KDE VME polygons (black line). Closed areas are indicated in white (NAFO, 2025).

Discussion

In general, there was an increase in area for all VME Indicators over that created in 2019 (Table 11), with the Large Gorgonian Corals and Black Corals showing the least change. This is despite high similarity in the density threshold selected to delineate the VME polygons. For the Small Gorgonian Corals the selection of the lower weight threshold (0.065 kg/RV tow) contributed to the large increase in area for that VME indicator. This produced Small Gorgonian Coral KDE VME polygons on Flemish Cap which in some cases overlap with the existing closures, increasing their conservation value. Spatially there was high congruence between the analyses performed in 2019 (Kenchington et al., 2019) and the present analyses which improved after the proposed modifications were mapped (Figures 83, 84).

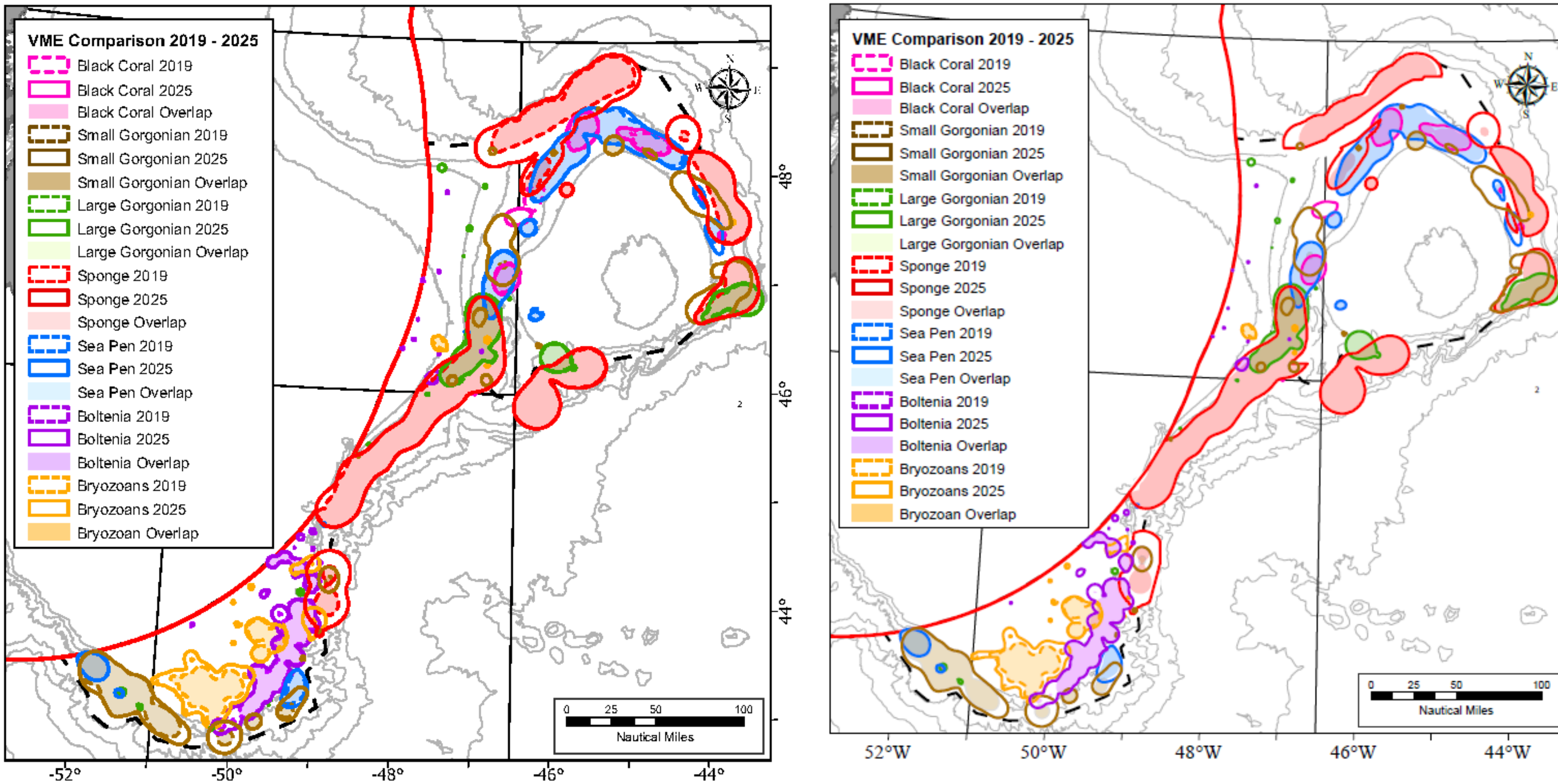


Figure 83. Overview map of the location of the KDE VME taxa polygons (Large-Sized Sponges, Sea Pens, Small Gorgonian Corals, Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (*Boltenia ovifera*), and Black Corals) in the NAFO Regulatory Area, colour coded by taxon. For all taxa the clipped polygons determined and accepted from the 2019 analysis are shown in dashed line and compared with those from the 2025 analyses in solid lines. Areas of overlap between the polygons produced in each year are shaded. Dashed black line is the fishing footprint and the red solid line is the Canadian Exclusive Economic Zone. **Left Panel.** 2025 KDE VME taxa polygons without modification. **Right Panel.** 2025 KDE VME taxa polygons modified as proposed in this document.

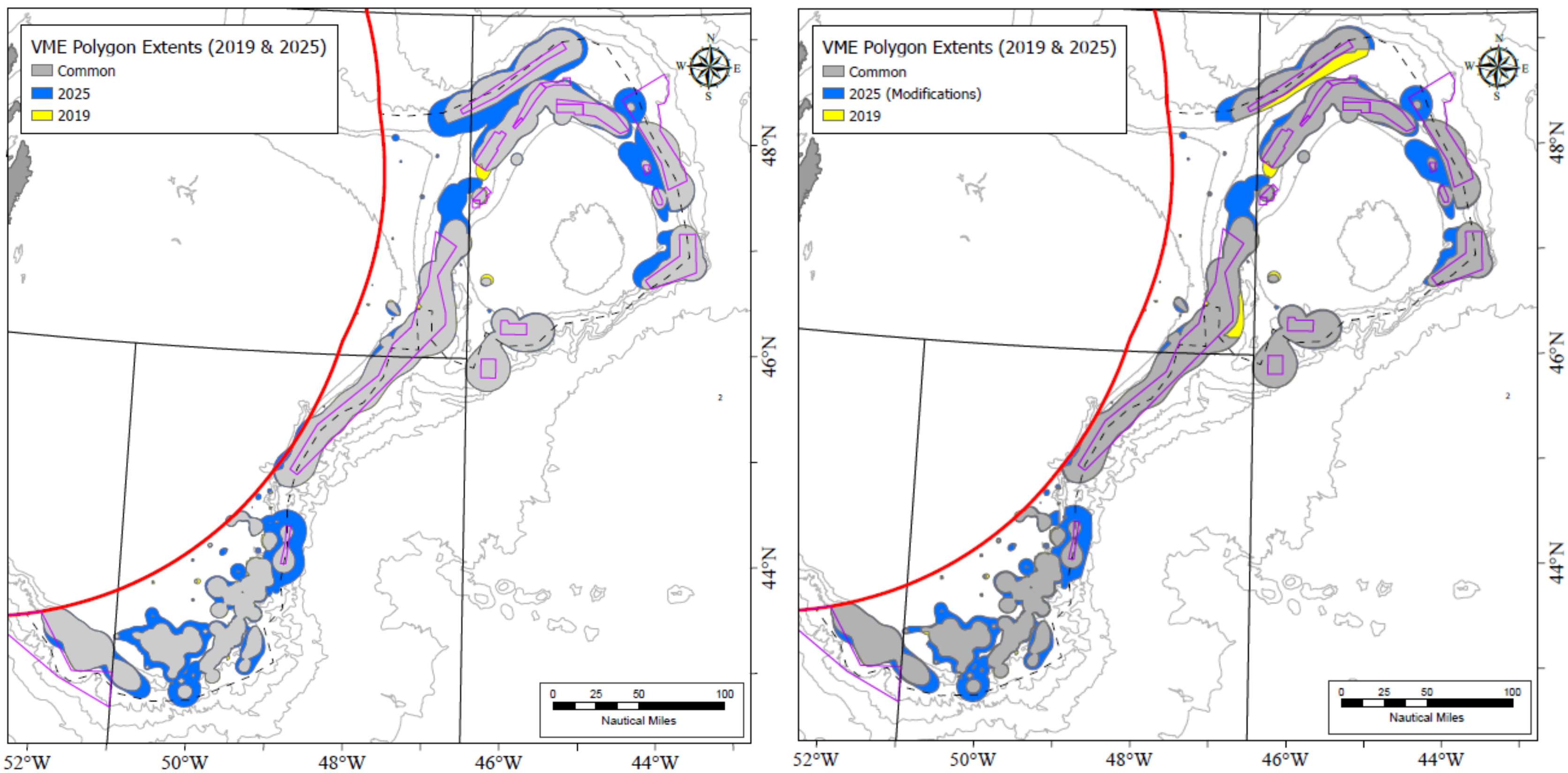


Figure 84. Overview map of the location of the combined KDE VME taxa polygons (Large-Sized Sponges, Sea Pens, Small Gorgonian Corals, Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (Boltenia ovifera), and Black Corals) in the NAFO Regulatory Area. For all taxa the clipped polygons determined and accepted from the 2019 analysis are shown filled in yellow and compared with those from the 2025 analyses filled in blue. Areas of overlap between the polygons produced in each year are shaded grey. Dashed black line is the fishing footprint and the red solid line is the Canadian Exclusive Economic Zone. **Left Panel.** 2025 KDE VME taxa polygons without modification. **Right Panel.** 2025 KDE VME taxa polygons modified as proposed in this document.

The proposed modifications had very little effect on the total area of VME of the functional groups, although the Large-Sized Sponge area was reduced by 4827 km^2 (Table 11).

Table 11. Values of the significant concentration threshold (kg) from research vessel catches and total area (km^2) of VME polygons for the years 2013, 2019 and 2025. Area of VME for 2025 is given for the original KDE VME polygons (orig) and the area taking into account the modifications proposed above (mod). SGC=Small Gorgonian Corals; LGC=Large Gorgonian Corals.

VME Indicator	**Research Vessel Catch Threshold (kg) for Identifying VME Polygons**			**Area of VME (km^2)**			
	2025	**2019**	**2013**	**2025 orig**	**2025 mod**	**2019**	**2013**
Large-Sized Sponges	100	100	75	33144	28317	24218	19824
Sea Pens	1.5	1.3	1.4	9441	9441	8498	6983
SGC	0.065	0.2	0.15*	13379	13050	4540	307
LGC	0.7	0.6	0.6	5339	5339	5007	3506
Sea Squirts	0.25	0.35	0.3	5233	5212	4077	2193
Erect Bryozoans	0.2	0.2	0.2	6429	5541	3491	6587
Black Corals**	0.4	0.4	-	2894	2894	2631	-

*In 2013 KDE analyses were performed for Divisions 3NO and in 2019 and 2025 the areas 3LMNO were combined. ** KDE analyses on black coral catches were performed for the first time in 2019.

Current Levels of Protection of VMEs

The VME areas inside area closures ('Closed Area Protected') according to the NAFO Conservation and Enforcement Measures (NAFO, 2025), inside the fishing footprint but outside a VME closure ('Unprotected'), and outside the fishing footprint and closed areas ('Conditionally Protected') are shown in Table 12 for each of the VME taxa for which KDE analyses were generated (see Kenchington et al., 2019 for illustrations and comparative tables with the 2013 and 2019 results for common taxa). These areas were calculated using the proposed modifications to the KDE VME polygons discussed above.

The levels of protection present at the time of the 2019 analyses are shown in Table 13, noting that there have been changes to the closed areas since 2019. Comparison of the percentage of area for each taxon between the present analyses and those performed in 2019 (Table 12 and Table 13), shows that there has been large increases in the percentage of VME area that is Closed Area Protected in the Sea Pens, Small Gorgonian Corals, and the Black Corals, while there has been no or little change to the percentage of VME area that is Closed Area Protected in the Large-Sized Sponges, Large Gorgonian Corals, Erect Bryozoans and Sea Squirts. The increased protection for the Sea Pens and Black Corals are the result of direct management action whereas the increased protection for the Small Gorgonian Corals has arisen as a result of the new KDE analyses (Kenchington et al., 2025) identifying new areas on Flemish Cap that overlapped with the Area Closures. In terms of absolute values of area that is Closed Area Protected, there is more VME area protected in 2025 than in 2019. As in 2019, protection for the Erect Bryozoans and the Sea Squirts (*Boltenia*) in almost non-existent. The large percentage (99%+) of their VME areas fall in Unprotected area which means that they are extremely vulnerable to significant adverse impacts of fishing. The greatest protection overall is afforded to the Large-Sized Sponges and Large Gorgonian Corals (Table 12).

For the new data on the subgroups, it is clear that taxon-specific protections should be examined for the Polymastiidae sponges, all subgroups of sea pens but *Funiculina* in particular, and the Small Gorgonian Coral *Acanella arbuscula*.

Table 12. Total areas (km²) of VME polygons generated in 2025 that are Closed Area Protected, Conditionally Protected, and Unprotected in NAFO Divisions 3LMNO. The percentage of total area of each treatment is also shown. Areas represent the KDE VME polygons after the proposed modifications were made.

VME Indicator	Total Area of 2025 VME (km²) after Proposed Modifications	Closed Area Protected		Conditionally Protected		Total Protected (Closed Area + Conditionally Protected)		Unprotected	
		Area (km²)	Percent Total (%)	Area (km²)	Percent Total (%)	Area (km²)	Percent Total (%)	Area (km²)	Percent Total (%)
Large-Sized Sponges	28317	10620	38	7618	27	18238	64	10079	36
Tetillidae	24071	7220	30	4137	17	11357	47	12713	53
Polymastiidae	11462	2875	25	17	0	2892	25	8570	75
Astrophorina	26704	8807	33	3932	15	12739	48	13965	52
Sea Pens	9441	2824	30	4	0	2828	30	6614	70
Anthoptilum	9012	2341	26	0	0	2341	26	6671	74
Balticina	23141	3903	17	243	1	4146	18	18993	82
Funiculina	2466	306	12	0	0	306	12	2160	88
Pennatula	9619	1372	14	298	3	1670	17	7949	83
Black Corals	2894	1124	39	5	0	1129	39	1764	61
Large Gorgonian Corals	5339	3118	58	336	6	3454	65	1885	35
Small Gorgonian Corals	13050	2106	16	308	2	2414	18	10636	82
Acanella arbuscula	4144	133	3	0	0	133	3	4011	97
Radicipes gracilis	6466	1030	16	0	0	1030	16	5436	84
Erect Bryozoans	5541	31	1	7	0	38	1	5502	99
Sea Squirts	5212	2	0	0	0	2	0	5210	100

Table 13. Total area (km²) of VME polygons generated in 2019 that is Closed Area Protected, Conditionally Protected, and Unprotected in NAFO Divisions 3LMNO. The percentage (%) of total area of each treatment is also shown. Note that Area 14 was included in this calculation.

VME Indicator	Total Area of 2019 VME (km²)	Closed Area Protected		Conditionally Protected		Total Protected (Closed Area + Conditionally Protected)		Unprotected	
		Area (km²)	Percentage of Total (%)	Area (km²)	Percentage of Total (%)	Area (km²)	Percent Total (%)	Area (km²)	Percentage of Total (%)
Large-sized sponges	24218	9324	39	6076	25	15400	64	8818	36
Sea pens	8498	1439	17	1	0	1440	17	7057	83
Black corals	2631	456	17	1	0	457	17	2173	83
Large gorgonian corals	5007	2750	55	293	6	3043	61	1964	39
Small gorgonian corals	4540	188	4	0	0	188	4	4352	96
Erect bryozoans	3491	5	0.14	0	0	5	0	3486	99.9
Sea squirts	4077	0	0	18	0	18	0	4059	100

Acknowledgements

EK, CL, FJM and ZW participation was through Fisheries and Oceans, Canada's Competitive Science Research Fund Project "Distribution modeling of Vulnerable Marine Ecosystems (VME) in the Northwest Atlantic Fisheries Organization".

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