Northwest Atlantic Fisheries Organization

Serial No. N7696 NAFO SCR Doc. 25/048

SCIENTIFIC COUNCIL MEETING – NOVEMBER 2025

Methodology to Produce Updated Biomass Estimates for Vulnerable Marine Ecosystems in the NAFO Regulatory Area

by

C. Lirette, E. Kenchington, F.J. Murillo

Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada.

LIRETTE, C., KENCHINGTON, E., & MURILLO, F.J. 2025. Methodology to Produce Updated Biomass Estimates for Vulnerable Marine Ecosystems in the NAFO Regulatory Area. *NAFO Scientific Council Research Document*, SCR Doc. 25/048: 1-21.

Abstract

Biomass surfaces for the vulnerable marine ecosystem (VME) indicators are required in order to evaluate impacts of fishing (significant adverse impacts; SAI) and the effectiveness of the closed areas. Here we explore data treatment and analytical approaches to produce biomass surfaces using data from research vessel catches of the Large-Size Sponge VME indicator at the resolution of 25 square km (5 km x 5 km grid cell). Data from both the EU and Canada were used as was done in 2020, and with EU data only. We point out issues with previous approaches for use of the different gear types and tow lengths, assess the impacts of those issues, and suggest a means to resolve them going forward. Total biomass and the average biomasses and standard deviations per grid cell were calculated and compared in different ways: 1) Simple Averaging; 2) Focal Statistics; 3) Swept Area Complete Coverage; 4) Ordinary Kriging; and 5) Species Distribution Modeling. The results of those approaches were tabulated for discussion in WG-ESA of the approach to be used in producing the final set of biomass surfaces for the full suite of VME indicators.

Contents

Introduction

In support of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems (VMEs) in the NAFO Regulatory Area, kernel density analyses (KDE) of Large-sized Sponges, Sea Pens, Small and Large Gorgonian Corals, Erect Bryozoans, Sea Squirts (Boltenia ovifera), and Black Corals were undertaken using all available research vessel survey data (1995 – 2024) (Kenchington et al., 2025). For the first time, subgroups of some of the VME functional groups had sufficient data to warrant application of the KDE analyses. These included two families and one order of sponges (Tetillidae, Polymastiidae, Astrophorina), four sea pen genera (*Balticina*, *Funiculina*, *Pennatula* and *Anthoptilum*) and two species of small gorgonian coral (*Acanella arbuscula* and *Radicipes gracilis*) (Kenchington et al., 2025). In order to assess significant adverse impacts (SAI) of fishing activity on these VME indicators, it is necessary to produce a spatial layer of biomass for each. As noted previously (Kenchington et al., 2019), the KDE-generated biomass is used to identify areas with a higher density, i.e., "hotspots", where the biomass is more concentrated, and so identify important habitats or vulnerable marine ecosystems. However, KDE does not use null data and KDE biomass is an approximation, not a precise measurement. Therefore, other methods to produce a biomass layer for the VME indicators were developed.

In updating the biomass layers for the assessment of SAI ahead of the 2027 NAFO review of the closed areas to protect vulnerable marine ecosystems, it was necessary to run ModelBuilder in ArcGIS Pro, which replaces the ESRI ArcMap software. ArcGIS ModelBuilder is a visual programming language for building geoprocessing workflows using different tools within ArcGIS. No changes were needed to functionalize the model in the updated software, however, in reviewing the methodology used previously (Lirette et al., 2020 Appendix 1), it was noted that both EU and Canadian VME indicator catch data were used in 2020, although Cogswell et al. (2011) recommended using only the EU data to avoid catchability differences. This prompted a closer examination of how the data were treated in 2020, and some issues were found (Table 1).

The workflow developed and used in 2020

Pham et al. (2019), who also used only the EU data, advanced the work of Cogswell et al. (2011) by applying conversion factors for the two gear types (Lofoten and Campelen 1800) in their "grid-cell approach", to account for catchability differences. The Campelen swept area conversion was applied in the NAFO areas 3LNO while the Lofoten swept area conversion was used for the area 3M, reflecting their different usages in the different surveys. They further calculated that 373 RV Campelen trawl sets or 641 RV Lofoten trawl sets would be required to completely trawl a single 5 km x 5 km grid cell without overlap and used those values to create a total biomass/grid cell that assumed 100% coverage.

In 2020, Lirette et al. applied the workflow used by Pham et al. (2019) to create updated VME indicator biomass estimates (Figure 1) and developed routines in ModelBuilder to automate the process. The first three steps of the model (Figure 1, Table 1; Lirette et al., 2020) used the average of the raw catch biomass data to populate empty cells using focal statistics, following Pham et al. (2019) and Cogswell et al. (2011). In the fourth step, a swept area for each of the two gear types was used to calculate grid cell biomass assuming 100% coverage. These conversions were not made using the actual gear type but drew on the geographic separation of the gears in the EU surveys (which were perfectly valid in Pham et al. (2019)). For the Gear field, grid cells located in the 3M NAFO Division were selected and updated to "Lofoten" including those cells intersecting the 3L-3M border. The remaining grid cells, located in the 3NLO NAFO Divisions, were selected and updated to "Campelen". Unfortunately, by using the Canadian RV data in 2020, two problems were created that were not previously identified.

The Canadian surveys use Campelen gear and fish both in the 3M NAFO Division, and in the 3NLO NAFO Divisions (see Figure A1 in Kenchington et al., 2025). The standard two length is 15 min, whereas on the EU surveys the standard tow length is 30 min. Adding the Canadian data to the ModelBuilder in Lirette et al. (2020) would have changed the gear to a Lofoten, ignored the shorter tow length and therefore applied an incorrect swept area for tows in Division 3M. For tows in the 3NLO NAFO Divisions the gear type would have been correctly applied but the shorter tow length not accounted for in the conversion factor. Pham et al. (2019)

considered gear type in their work but did not have to consider tow length as they only used EU data. In statistically analyzing catch differences between tow lengths, vessels and gear types, before use in the KDE analyses, Kenchington et al. (2025) confirmed that the different surveys had different catchabilities at the low biomass end of the catch spectrum.

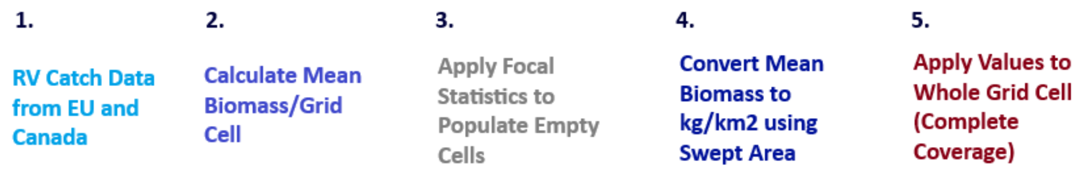


Figure 1. Sequential steps (1-5) followed in Lirette et al. (2020) to produce biomass surfaces for VME indicator taxa.

Here, we evaluated the impact that the selection of data had on the resulting biomass layers by comparing outputs using EU data only and both EU and Canadian data obtained for the period 1995 to 2024. We repeated the analyses of Lirette et al. (2020) on each, recognizing that using the EU data only would not have the confounding effects of tow length and gear changes imposed through using the Canadian data. We separated the outputs of the method into their separate steps (Step 2, 3 and 5; Figure 1) to examine whether differences were more pronounced in one over others. We then looked at various methods of producing biomass layers and compared them to see the impact the method has, as the results using complete coverage of the grid cell, as done in 2020, may not be ecologically realistic at the scale of 25 square km. Lastly, we converted all biomass from EU and Canadian surveys to kg/km^2 using the swept area of the gear/tow length used, prior to the application of any statistics (Figure 2) (Cogswell et al., 2010). Other aspects than the calculation of the biomass per grid cell (i.e., method of separately calculating values inside and outside of the closures) have not changed. The comparisons were made using a grid cell of 5 km x 5 km and for the Large-Size Sponges. The agreed upon approach will then be used for all of the VME indicators noted above and for two sizes of grid cell, 1 km x 1 km and 5 km x 5 km. Issues related to the use of the smaller grid size were reviewed by Lirette et al. (2020) and are not reconsidered here.

Table 1. Summary of the development of biomass layers for use to assess significant adverse impacts of fishing in NAFO. SDM=Species distribution model; FS=Focal statistics.

Publication	Data Sources	Methods Applied	Issues
Cogswell et al. (2011)	EU data only	Complete Coverage	Different gears not accounted for. FS confounded.
Pham et al. (2019)	EU data only	SDM and Complete Coverage	None
Lirette et al. (2020)	EU and Canadian data	Complete Coverage	Shorter tow length of Canadian data not accounted for. Canadian Campelen tows in 3M changed to Lofoten tows. FS confounded.
This study	EU data only and Canadian and EU data	Various	

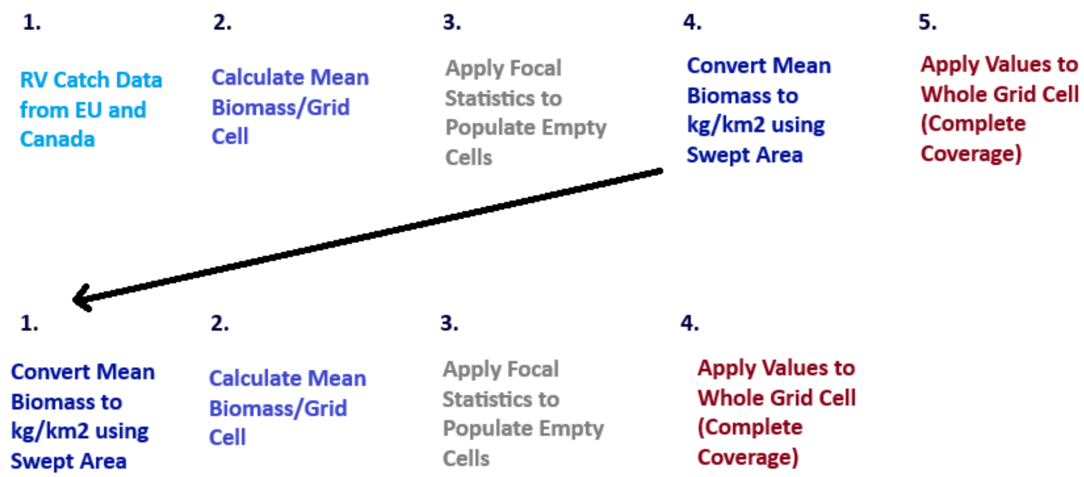


Figure 2. Sequential steps (1-5) followed in Lirette et al. (2020) to produce biomass surfaces for VME indicator taxa, and the steps applied in Case 3 where all data are converted to kg/km^2 prior to the analyses.

Methods

Data inputs

Data for the Large-Size Sponges were those compiled for the species distribution analyses (Murillo et al., 2024) and augmented with data from 2024 (Kenchington et al., 2025), as they had been QA/QC'd for both presences and absences. The data were obtained for the period 1995 to 2024. These data were separated into two groups for analysis (Figure 3):

Case 1: included only the EU data (4431 presences, 2774 absences from 2002-2024);

Case 2: included both the EU and Canadian data (5505 presences, 5048 absences from 1995-2024);

and a third case, Case 3, where all data (Case 2) were converted to kg/km^2 prior to analyses.

Calculation of biomass surfaces

Biomass surfaces produced in 2020 were constructed using an ArcGIS simulation model managed by ArcGIS ModelBuilder, a visual programming language for building geoprocessing workflows in ArcMap. ArcMap is the former main component of Esri's ArcGIS suite of geospatial processing programs, used primarily to view, edit, create, and analyze geospatial data. In this application, ModelBuilder was run in ArcGIS Pro, which replaces their ArcMap software.

For each of the three cases sets five approaches were used to compare the resulting biomass surfaces:

Method 1) **Simple Averaging**, which calculates the average of a set of values by dividing the sum of all values by the total number of values in each grid cell, generating a standard deviation.

Method 2) **Focal Statistics**, which calculates statistics for input cells within a specified neighborhood around each cell in a raster. This method was used previously (Cogswell et al., 2011; Pham et al., 2019; Lirette et al., 2020) to populate empty cells through several iterations of the tool, performed using the ArcGIS Pro 3.3 Focal Statistics tool in Spatial Analyst (Focal Statistics (Spatial Analyst)—ArcGIS Pro | Documentation). When all cells in the spatial extent were populated, values in previously empty cells were joined to the values in the cells where data were present (as obtained in Method 1), to create full coverage of the spatial extent.

Method 3) **Swept Area Complete Coverage**, is the method used previously (Figure 1; Pham et al., 2019; Lirette et al., 2020), where for each grid cell the mean biomass was calculated using the output of Method 2, and then converted to kg/km^2 using swept area for the Lofoten trawl of 39000 m^2 and 67000 m^2 for the Campelen trawls and then applied to the total cell area. There are 373 RV Campelen trawl sets or 641 RV Lofoten trawl sets required to completely trawl a single grid cell without overlap (Pham et al., 2019).

Method 4) **Ordinary Kriging** is a statistical method of spatial interpolation that estimates the value of a variable at unsampled locations based on observed data points. Null values (no VME indicator in haul) are not used. It computes a weighted average of known values in the neighborhood of the point to make predictions. Ordinary Kriging was performed using ArcGIS Pro 3.3 Kriging tool in Spatial Analyst (Kriging (Spatial Analyst)—ArcGIS Pro | Documentation). A kriged biomass raster was created from the kriging which was set to a square cell resolution (a discrete surface was created using 'nearest neighbour' resampling matched to the 25 square km grid (5km x 5 km)). The variance of prediction was mapped showing the predicted error variance, or the uncertainty, of a spatial prediction model at each cell location. Ordinary kriging models were created using all default settings in the Spatial Analyst wizard.

Method 5) **Species Distribution Modeling (SDM)**. The SDM approach is advantageous for obtaining a continuous biomass surface, allowing predictions in areas beyond the sampled locations based on environmental variables, and thereby capturing the full extent of the sponge grounds (Pham et al., 2019). Here, a random forest (RF) regression model published by Pham et al. (2019) was used to predict the distribution of the sponge biomass. The spatial extent of the random forest model was restricted to the 2000 m depth contour (Pham et al., 2019).

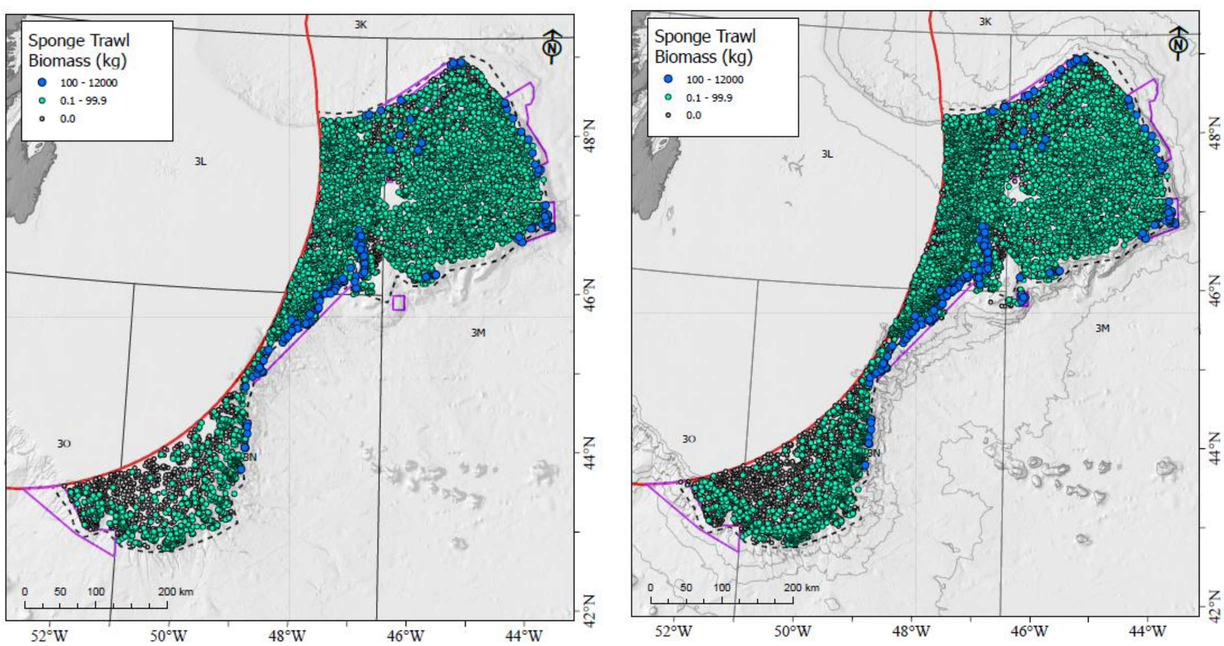


Figure 3. Distribution of the research vessel catch data containing Large-Size Sponges showing catches above and below the 100 kg/RV tow density threshold selected as defining significant concentrations of Large-Size Sponges (Kenchington et al., 2025) as well as null catches. Left panel: EU data only (Case 1). Right panel: EU and Canadian data (Case 2 and Case 3). The fishing footprint is indicated by a dashed black line; closed areas are outlined in purple; Canadian EEZ is indicated in red.

Note that because the application of the swept area conversion factors are not applied until Step 4 (Figure 1), for Cases 1 and 2 the maps produced by Methods 1 and 2 (Simple Averaging and Focal Statistics) are confounded by gear type (Case 1) and gear type and trawl length (Case 2) to different extents.

In Methods 1-3, the biomasses inside and outside of the closed areas were separately calculated as in Lirette et al. (2020) and then joined. For all methods applied here, the spatial extent was the fishing footprint, plus the closed areas and 2025 Large-Size Sponge VME polygons (Kenchington et al., 2025) some of which extend beyond the footprint into deeper water. Pham et al. (2019) used different spatial extents but compared their methods using a common area (fishing footprint).

Results and Discussion

What was the effect of including the Canadian data in the 2020 biomass estimates?

To evaluate the effect of adding the Canadian data to the analyses in 2020 without accounting for the shorter tow length of the Canadian RV surveys (15 min vs. 30 min for the EU surveys) and the application of the incorrect conversion factor in division 3M, we applied the same work flow as used in Lirette et al. (2020) and ran the analyses with and without the Canadian data. Case 1 with EU data only parallels the approach used in Pham et al. (2019). Table 2 shows the total biomass for the spatial extent calculated using the two data sets. The workflow begins with the calculation of the average biomass per cell (Method 1), then applies focal statistics (Method 2) and then adjusts for gear differences and upscales to complete coverage of the grid cell (Method 3). The final result shows that inclusion of the Canadian data increases the total biomass and the mean biomass/grid cell at each step (Table 2). This is also the result found in Cogswell et al. (2011). However, the differences are not as large as those seen between the different methods applied in achieving the final biomass layer used (Complete Coverage).

Table 2. Biomass (kg) of Large-Size Sponges for each of two data sets (EU data only (Case 1) and EU and Canadian data (Case 2). Total Biomass was calculated for the full spatial extent (fishing footprint and closed areas) while means and standard deviations are presented for the grid cell, from the grids comprising the Total Biomass.

Case I:	**EU Data Only**			
	Method	**Total Biomass (kg)**	**Mean (kg/grid cell)**	**Standard Deviation (kg/grid cell)**
1	Simple Averaging	105,560	32.8	343.4
2	Focal Statistics	678,587	106.1	636.4
3	Complete Coverage[1]	241,624,521	37,789.3	274,757.0
Case 2:	**EU and Canadian Data**			
1	Simple Averaging	144,976	38.8	351.3
2	Focal Statistics	696,103	108.9	606.9
3	Complete Coverage[2]	249,967,857	39,094.1	261,303.6

[1]Different swept areas for Lofoten and Campelen gears applied in this method.
[2]Different swept areas for Lofoten and Campelen gears incorrectly applied to Canadian data and no transformation for different tow lengths applied in this method (Lirette et al., 2020).

Spatial differences in the distribution of the biomass were more pronounced (Figure 4). The maximum biomass per grid cell was similar between the two data sets but inclusion of the Canadian data seemed to add biomass to grid cells on the Nose and Tail of Grand Bank and on Flemish Cap which had lower biomass when not included. In contrast, the grid cells in Closed Area 6 on Sackville Spur were populated with more cells of higher biomass than when the Canadian data were not included.

What is the effect of using different methods to calculate biomass?

Pham et al. (2019), using only data from the EU surveys, compared the results from two different approaches: the modeling approach which used SDM (Method 5) to produce biomass from random forest regression modeling, and the approach followed in Cogswell et al. (2011). Although the data sets are different from those used here, the comparison of results of the SDM and Complete Coverage methods are expected to follow similar trends. Results from the SDM showed higher biomass estimates both for the spatial extent used and for a common area, i.e. the fishing footprint (Table 3).

Table 3. Comparison of total biomass estimates published in Pham et al. (2019) for two methods of calculation, Species Distribution Modeling and Complete Coverage, using only EU sponge RV catch data collected between 2006–2010.

Method	Total Biomass (kg)	Total Area (km^2)	Total Biomass in Footprint (kg)
Species Distribution Modeling	231,136,000	135,056.82	116,143,000
Complete Coverage[1]	122,465,000	123,307.31	81,169,000

[1]Different swept areas for Lofoten and Campelen gears applied in this method.

The effect of the different methods for obtaining a biomass surface is shown in Table 4 for the EU data set. Simple Averaging (Method 1) produces the lowest biomass estimates which is not surprising given the number of empty cells used in the calculation (Figure 5). However, this method provides a standard deviation which shows higher values where average biomass is higher, such as in the closed areas. This reflects the patchiness of the sponge grounds at the 5 km x 5 km grid scale. The application of the Focal Statistics method (Method 2) to populate the empty cells produces considerably higher biomass (Table 4) and amplifying that increased biomass through the Complete Coverage approach (Method 3) further increases total biomass (Table 4; Figure 6). Although the spatial extents analyzed are different, and there were many more data records used in our analyses, the Complete Coverage method produced a total biomass of 241,624,521 kg (Table 4), which is more than twice that produce by Pham et al. (2019) using the same method but data from different time frames (Table 3) and more similar to their results from Species Distribution Modeling. Interestingly, the use of ordinary kriging to produce a biomass surface (Method 4) produced results intermediate between Simple Averaging (Method 1) and Focal Statistics (Method 2), neither of which consider the effect of gear type (Table 4). Spatially, kriging had relatively low variance except for in the deep waters of the slopes, where variance was high (Figure 7). Further, kriging does not use the 0 values and so none appear on the kriged surface (Figure 7) where the lowest biomass is 0.1 kg. Kriging forced complete presence of sponge, albeit at low density for most of the area, and accentuated the high biomass in the closed areas (Figure 7).

Table 4. Biomass (kg) of Large-Size Sponges under four methods of calculation using only data from the EU (Case 1). Total Biomass was calculated for the full spatial extent (fishing footprint and closed areas) while means and standard deviations are presented for the grid cell from the grids comprising the Total Biomass.

Case I:	**EU Data Only**			
	Method	**Total Biomass (kg)**	**Mean (kg/grid cell)**	**Standard Deviation (kg/grid cell)**
1	Simple Averaging	105,560	32.8	343.4
2	Focal Statistics	678,587	106.1	636.4
3	Complete Coverage[1]	241,624,521	37,789	274,757.0
4	Kriging	312,371	57.6	205.1

[1]Different swept areas for Lofoten and Campelen gears applied in this method.

Table 5. Biomass (kg) of Large-Size Sponges under four methods of calculation using data from the EU and Canada (Case 2). Total Biomass was calculated for the full spatial extent (fishing footprint and closed areas) while means and standard deviations are presented for the grid cell from the grids comprising the Total Biomass.

Case 2:	**EU and Canadian Data**			
1	Simple Averaging	144,976	38.8	351.3
2	Focal Statistics	696,103	108.9	606.9
3	Complete Coverage[1]	249,967,857	39,094.1	261,303.6
4	Kriging	344,301	63.5	212.3

[1] Different swept areas for Lofoten and Campelen gears incorrectly applied to Canadian data and no transformation for different tow lengths applied in this method (Lirette et al., 2020).

Similar results between the methods were seen when both the EU and Canadian data were used as transformed in Lirette et al. (2020), that is, without accounting for the shorter tow lengths of the Canadian surveys (Table 5, Figures 8, 9, 10). Kriging produced results intermediate between Simple Averaging and Focal Statistics.

Over both data sets, Total biomass of Large-Size Sponges over the spatial extent was much greater (more than 200,000,000 kg) using the Complete Coverage method than for any of the other methods evaluated (Tables 4, 5). The Simple Averaging method produced the lowest total biomass as expected with the large number of small catches and data gaps. Kriging produced about half the total biomass that Focal Statistics did. Focal statistics calculates a value for each cell based on a neighborhood of cells, while kriging is a geostatistical method that uses a model of spatial autocorrelation to predict values at unsampled locations and provides a measure of uncertainty. The key differences are that focal statistics is a deterministic operation on a raster, using a defined neighborhood and statistic (mean) for every cell, while kriging uses statistical modeling of relationships between data points, not just their proximity, to generate both a prediction surface and a map of prediction errors. Kriging is most appropriate when there is a spatially correlated distance or directional bias in the data as seen in the sponge grounds following depth contours. Within the kriging family, a number of different methods exist including but not limited to, ordinary kriging, universal kriging, and simple kriging. For this report, we chose ordinary kriging as the method of spatial interpolation as it assumes that the mean is unknown prior to modelling and approximately constant (stationary) only in the local neighbourhood of each estimation point and not over the entire data domain (Li and Heap, 2008; Li and Heap, 2014). Thus, use of ordinary kriging with a local search neighbourhood accounts for trends in the data (Li and Heap, 2008). Consequently, the biomass produced through Kriging (Method 4) may have more ecological relevance. However, it would be expected to be more similar to the results produced by Species Distribution Models (Method 5) (Murillo et al., 2024) which was not the case. Pham et al. (2019) found a much larger biomass produced through SDM than through the Complete Coverage method (Table 3), whereas Kriging as applied here produced a lower biomass (Tables 4, 5).

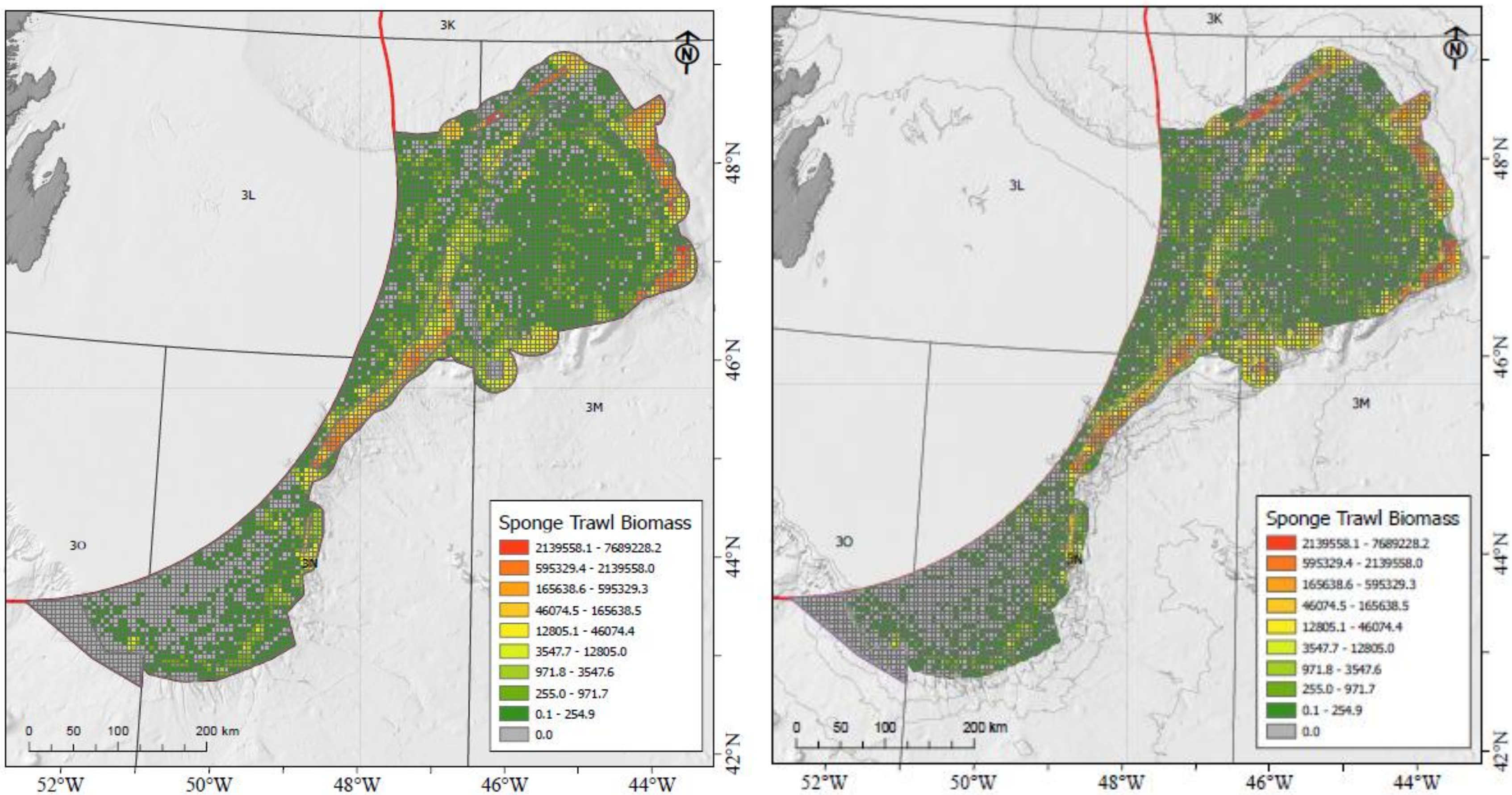


Figure 4. Grided mean biomass (kg) surface using swept area complete coverage (Method 3). Left Panel: EU data only. Right Panel: Canadian and EU data. Canadian EEZ is indicated in red.

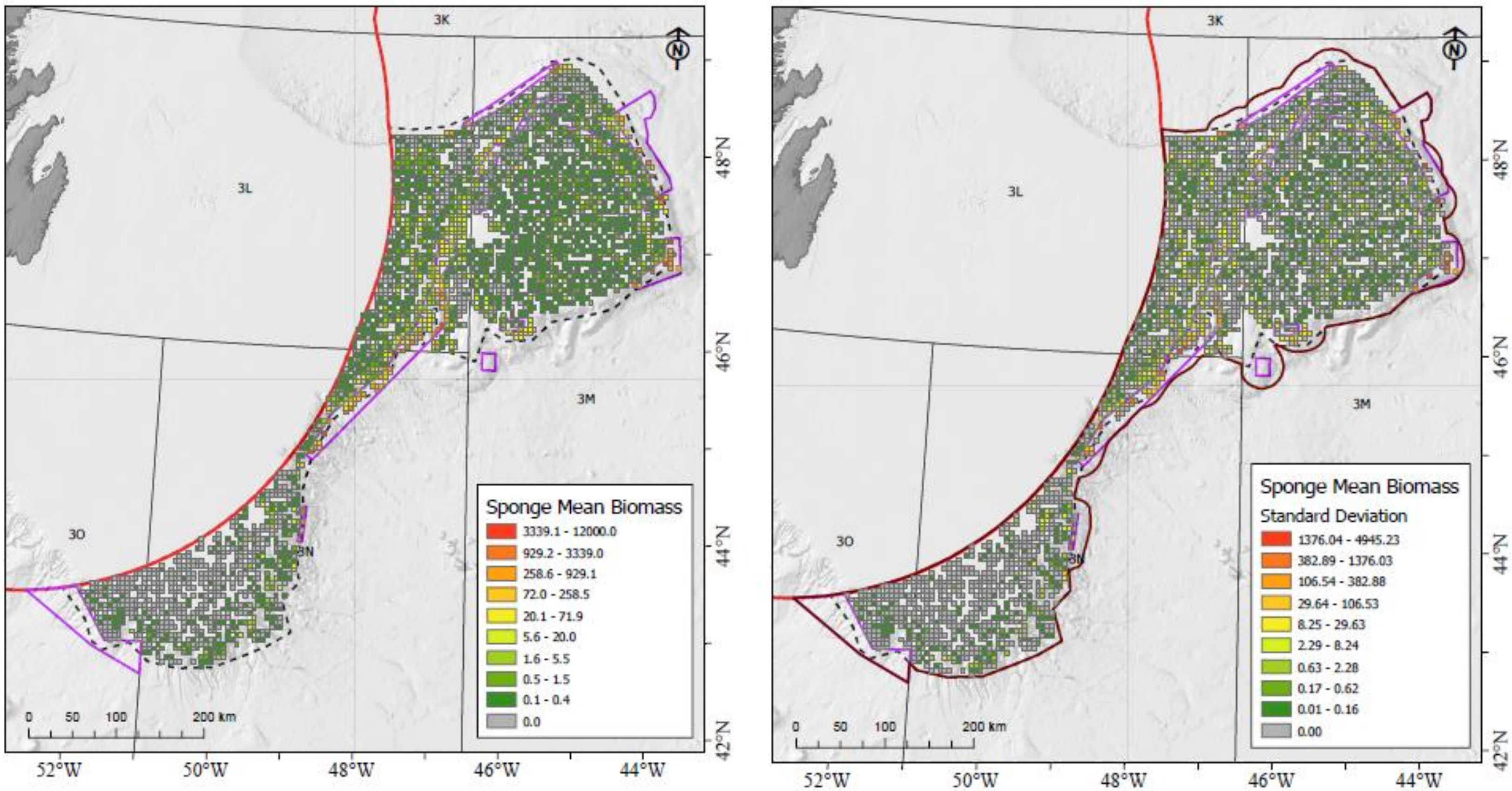


Figure 5. Grided biomass surface using EU data calculated using simple averaging. Left panel: Mean biomass (kg/grid cell). Right panel: Standard deviation around the mean biomass (kg/grid cell). The fishing footprint is indicated by a dashed black line; closed areas are outlined in purple; Canadian EEZ is indicated in red.

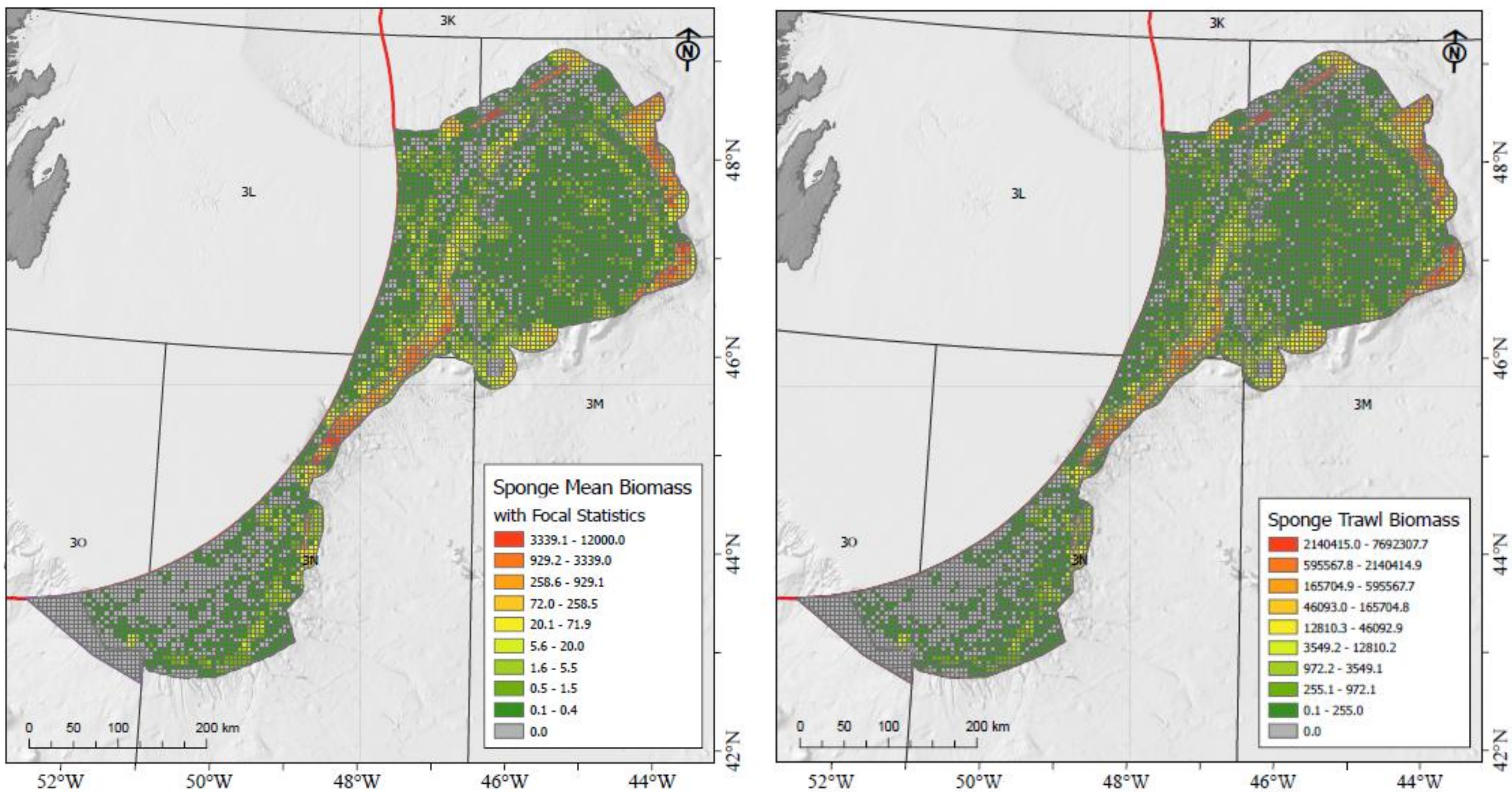


Figure 6. Grided mean biomass (kg) surface using EU data. Left panel: Calculated using focal statistics (Method 2). Right panel: Calculated using swept area complete coverage (Method 3). Canadian EEZ is indicated in red.

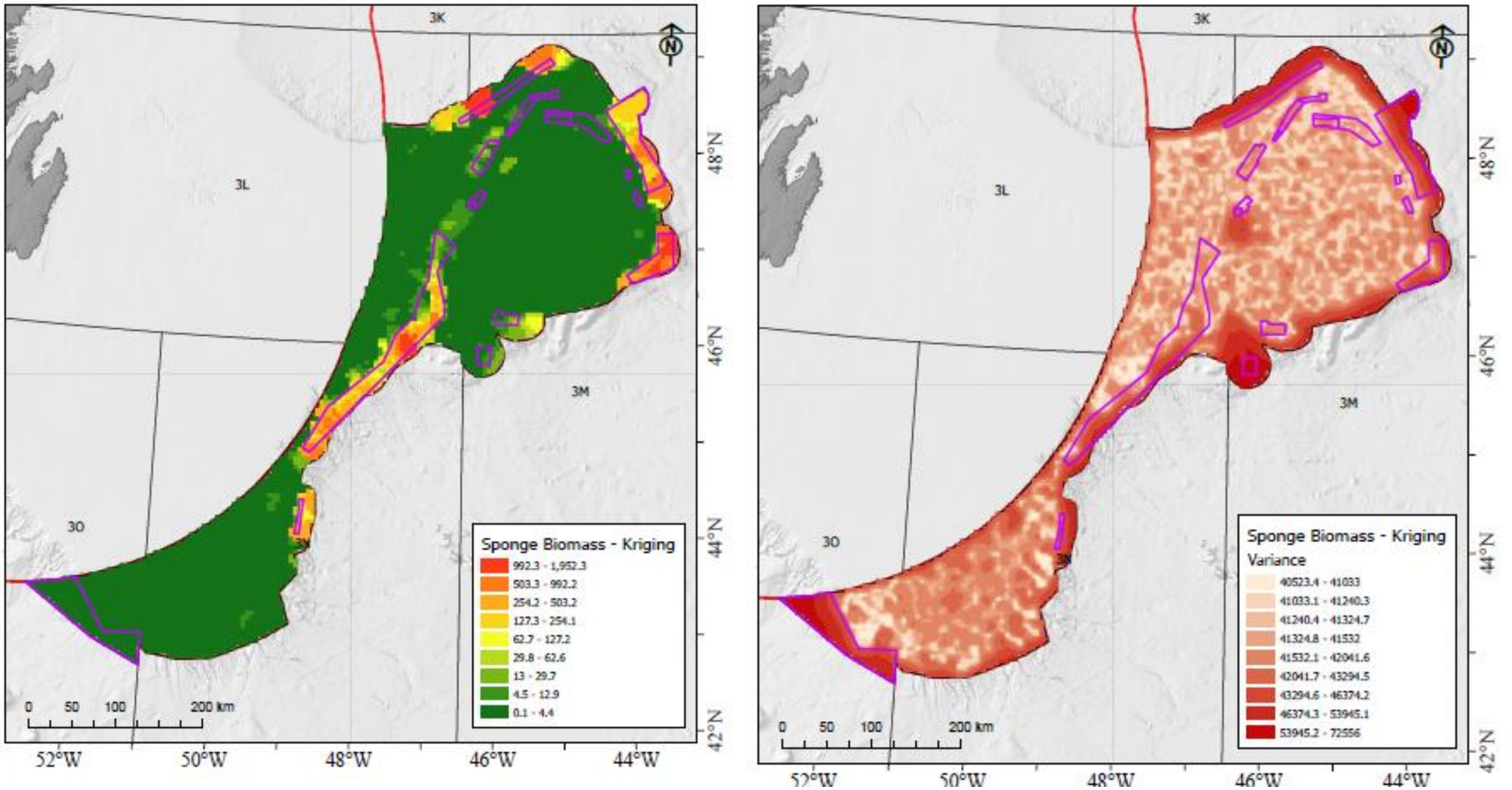


Figure 7. Grided biomass surface using EU data calculated using kriging. Left panel: Mean biomass (kg). Right panel: Variance of the predictor (kg). Canadian EEZ is indicated in red, closed areas in purple.

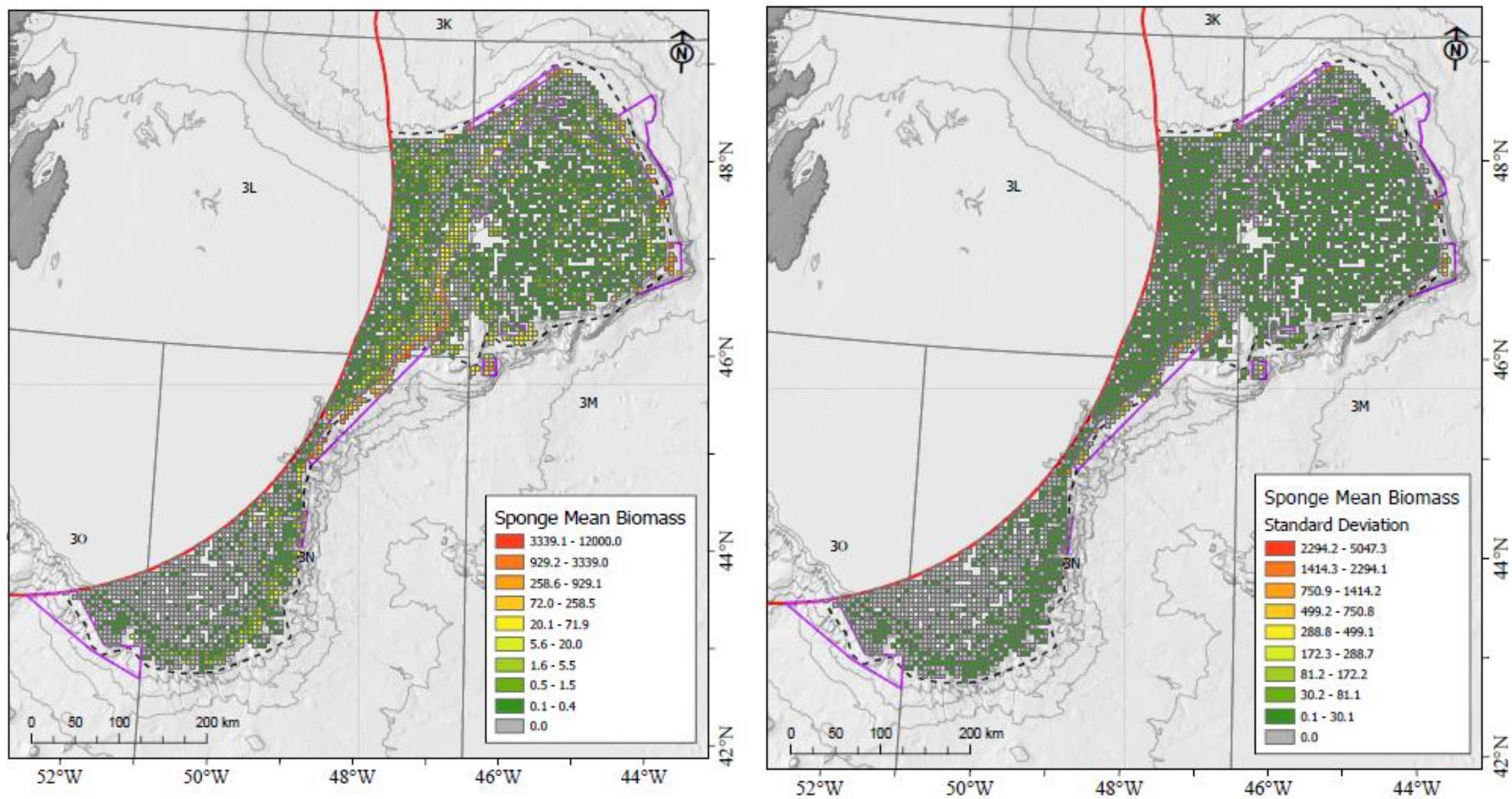


Figure 8. Grided biomass surface using EU and Canadian data calculated using simple averaging. Left panel: Mean biomass (kg/grid cell). Right panel: Standard deviation around the mean biomass (kg/grid cell). The fishing footprint is indicated by a dashed black line; closed areas are outlined in purple; Canadian EEZ is indicated in red.

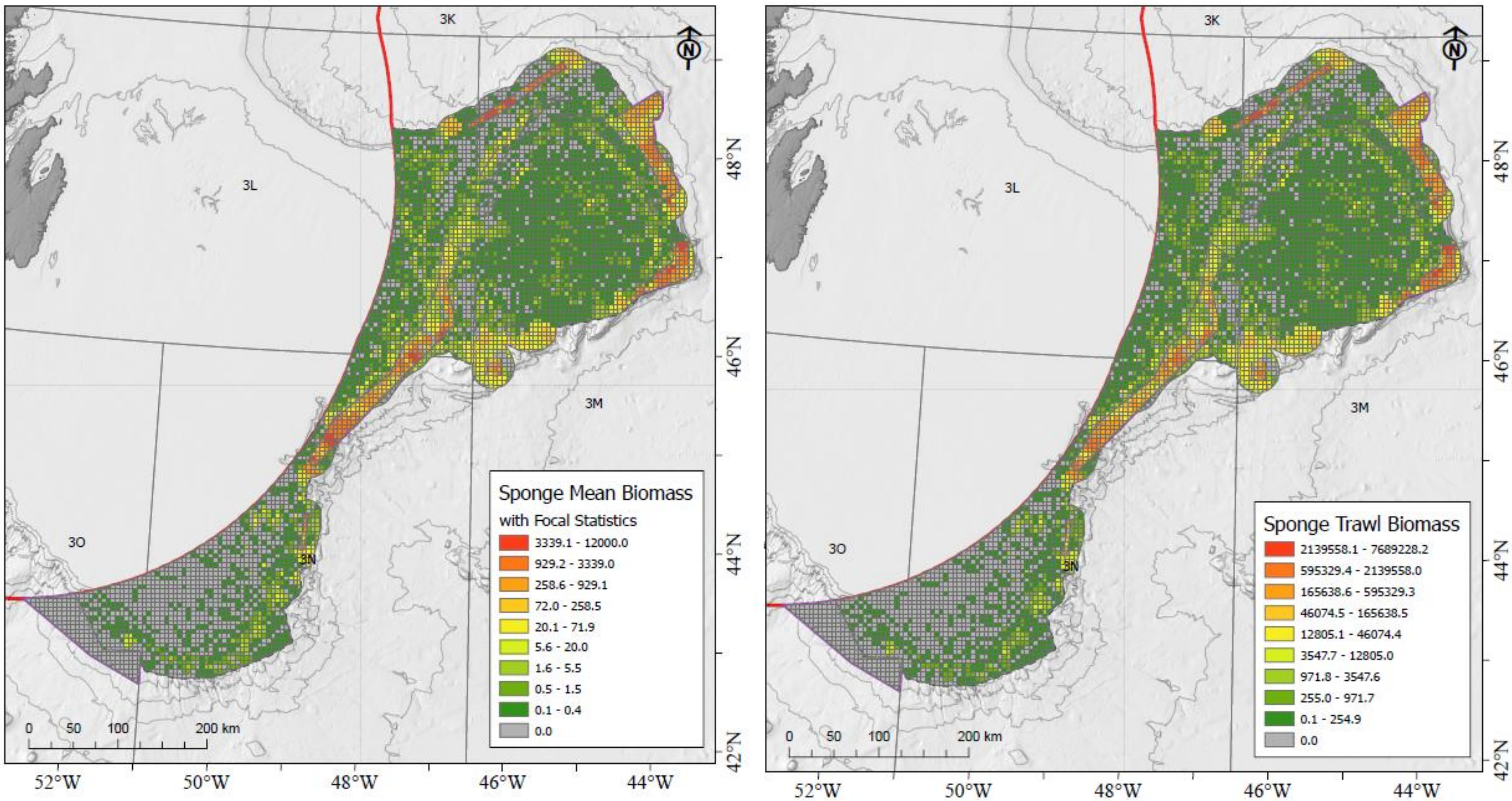


Figure 9. Grided mean biomass (kg) surface using EU and Canadian data. Left panel: Calculated using focal statistics (Method 2). Right panel: Calculated using swept area complete coverage (Method 3). Canadian EEZ is indicated in red.

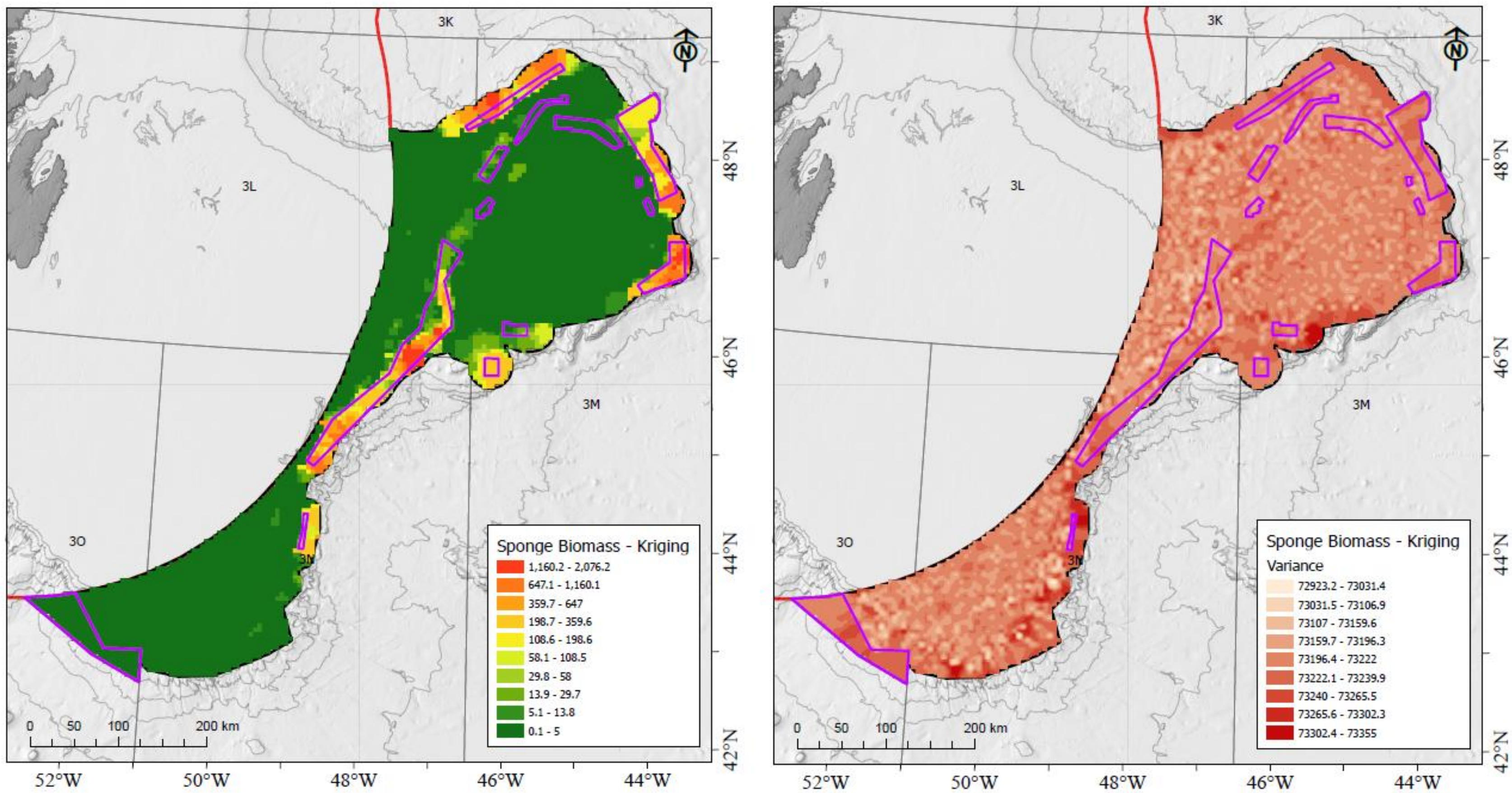


Figure 10. Grided biomass surface using EU and Canadian data calculated using kriging. Left panel: Mean biomass (kg). Right panel: Variance of the predictor (kg). Canadian EEZ is indicated in red, closed areas in purple.

Application of conversion factors prior to analyses

The application of conversion factors in the Pham et al. (2019) publication to account for the two different gear types used by the EU RV fleet (Lofoten and Campelen) was carried over to the 2020 work flow (Lirette et al., 2020 Appendix 1), however, when the Canadian data were added the shorter tow lengths were not similarly accounted for (Table 1). Further, the Canadian Campelen tows in 3M were changed to Lofoten tows and converted using that gear swept area calculation. The above results show that inclusion of the Canadian data increases the total biomass and the mean biomass/grid cell at each step of the workflow (Table 2) and creates spatial differences in the biomass distribution (Figure 4). Therefore, going forward, the Canadian data should use a different conversion factor for the Complete Coverage approach. There is no clear rationale for converting the data at Step 4 of the workflow (Figure 1) and this seems to complicate things. By doing so the application of the focal statistics is confounded by using biomass from different gears as well as different tow lengths. Here we convert all of the data to kg/km^2 using the swept area for each gear/tow length combination prior to undertaking the calculations. The expectation is that Methods 1 and 2 will have larger total biomass due to the correction factors and that the Complete Coverage will be similar.

Table 6. Biomass (kg) of Large-Size Sponges under four methods of calculation for each of two data sets. Total Biomass was calculated for the full spatial extent (fishing footprint and closed areas) while means and standard deviations are presented for the grid cell from the grids comprising the Total Biomass.

	Method	Total Biomass (kg)	Mean (kg/grid cell)	Standard Deviation (kg/grid cell)
Case I:	**EU Data Only**			
1	Simple Averaging	105,560	32.8	343.4
2	Focal Statistics	678,587	106.1	636.4
3	Complete Coverage[1]	241,624,521	37,789.3	274,757.0
4	Kriging	312,371	57.6	205.1
Case 2:	**EU and Canadian Data (Lirette et al., 2020)**			
1	Simple Averaging	144,976	38.8	351.3
2	Focal Statistics	696,103	108.9	606.9
3	Complete Coverage[2]	249,967,857	39,094.1	261,303.6
4	Kriging	344,301	63.5	212.3
Case 3:	**EU and Canadian Data (Conversion factors applied prior to analyses)**			
1	Simple Averaging	3,483,265	933.4	8928.0
2	Focal Statistics	17,072,398	2,696.2	15,509.2
3	Complete Coverage	283,223,140	44,728.9	282,163.2
4	Kriging	8,320,942	1,533.5	5165.6

[1]Different swept areas for Lofoten and Campelen gears applied in this method.
[2]Different swept areas for Lofoten and Campelen gears incorrectly applied to Canadian data and no transformation for different tow lengths applied in this method (Lirette et al., 2020).

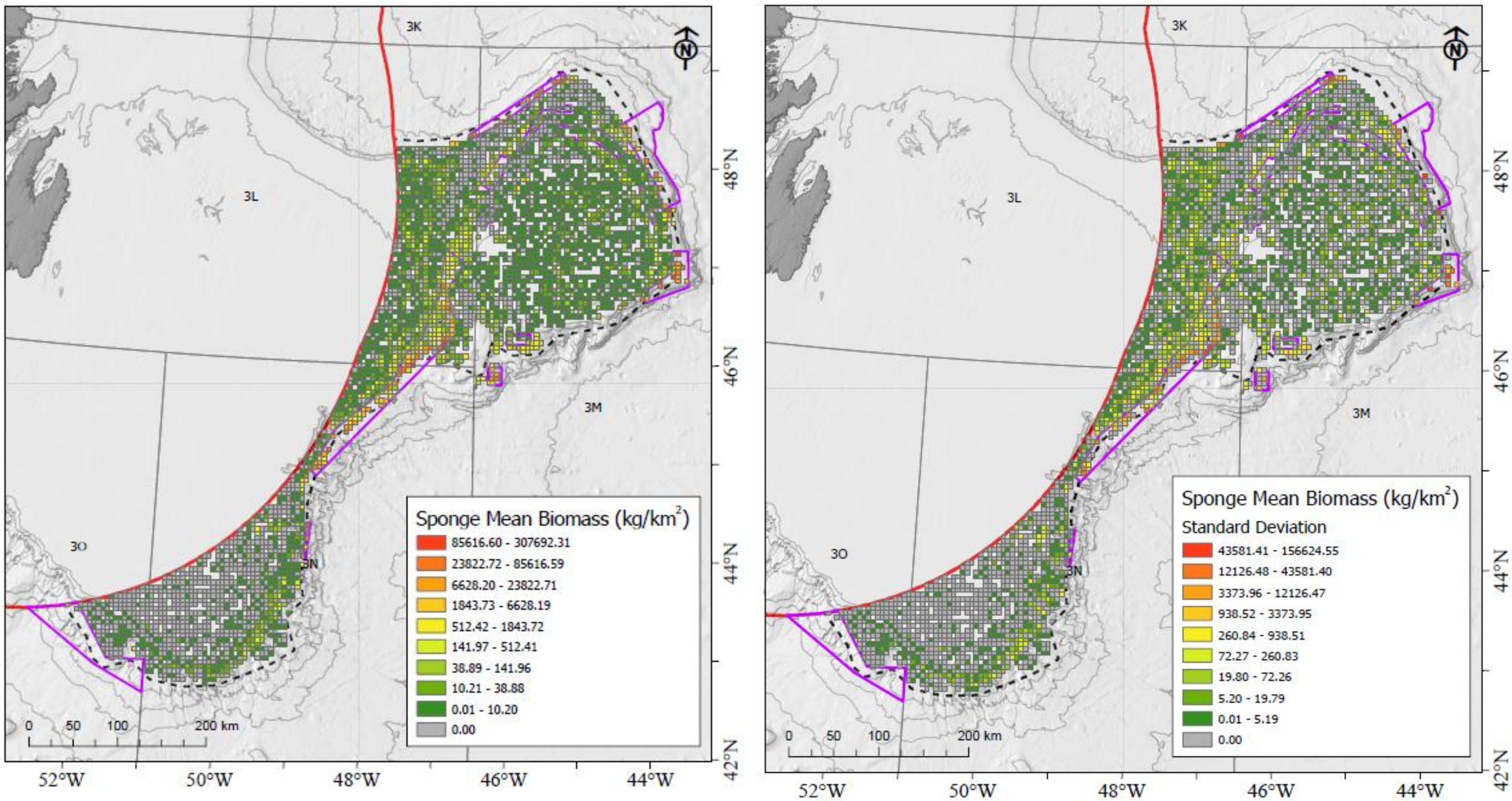


Figure 11. Grided biomass surface using transformed EU and Canadian data (Case 3) calculated using simple averaging. Left panel: Mean biomass (kg/grid cell). Right panel: Standard deviation around the mean biomass (kg/grid cell). The fishing footprint is indicated by a dashed black line; closed areas are outlined in purple; Canadian EEZ is indicated in red.

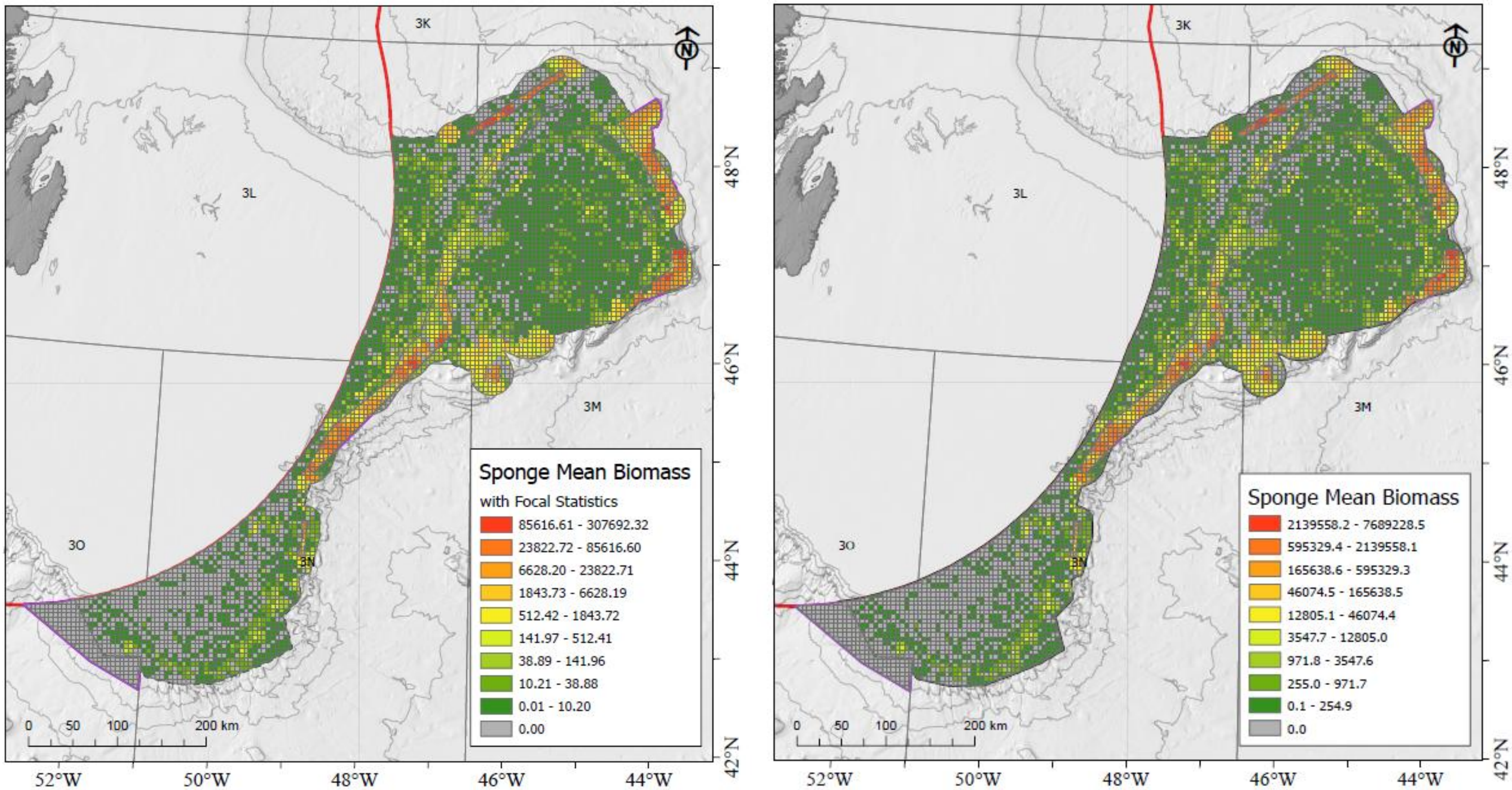
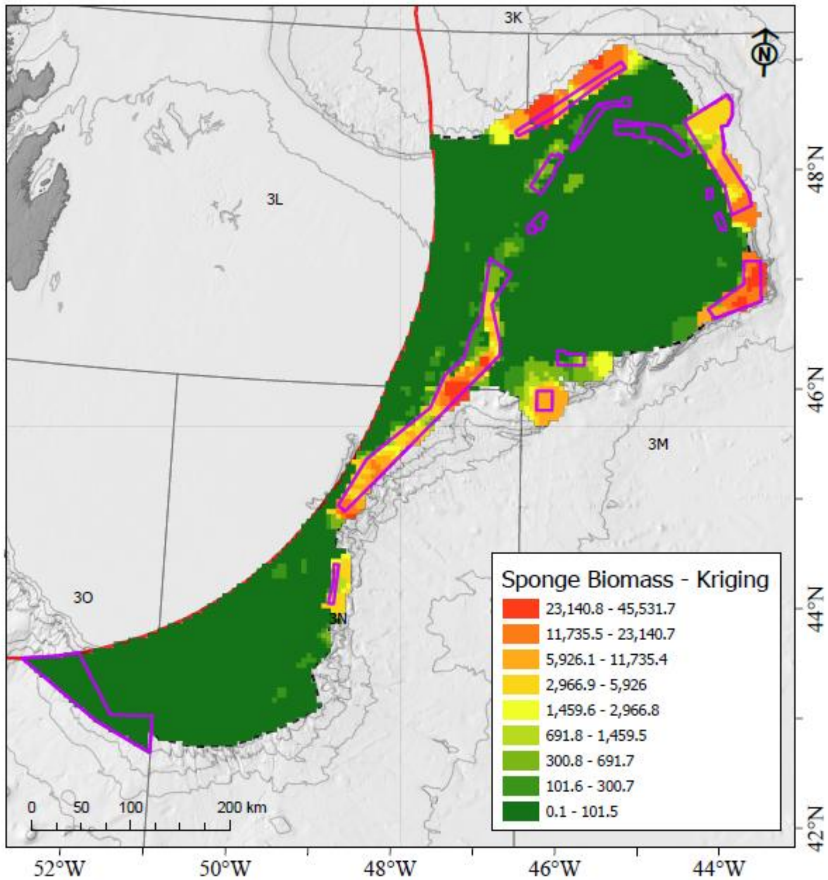


Figure 12. Grided mean biomass (kg) surface using transformed EU and Canadian data (Case 3). Left panel: Calculated using focal statistics (Method 2). Right panel: Calculated using swept area complete coverage (Method 3). Canadian EEZ is indicated in red, spatial extent in black.



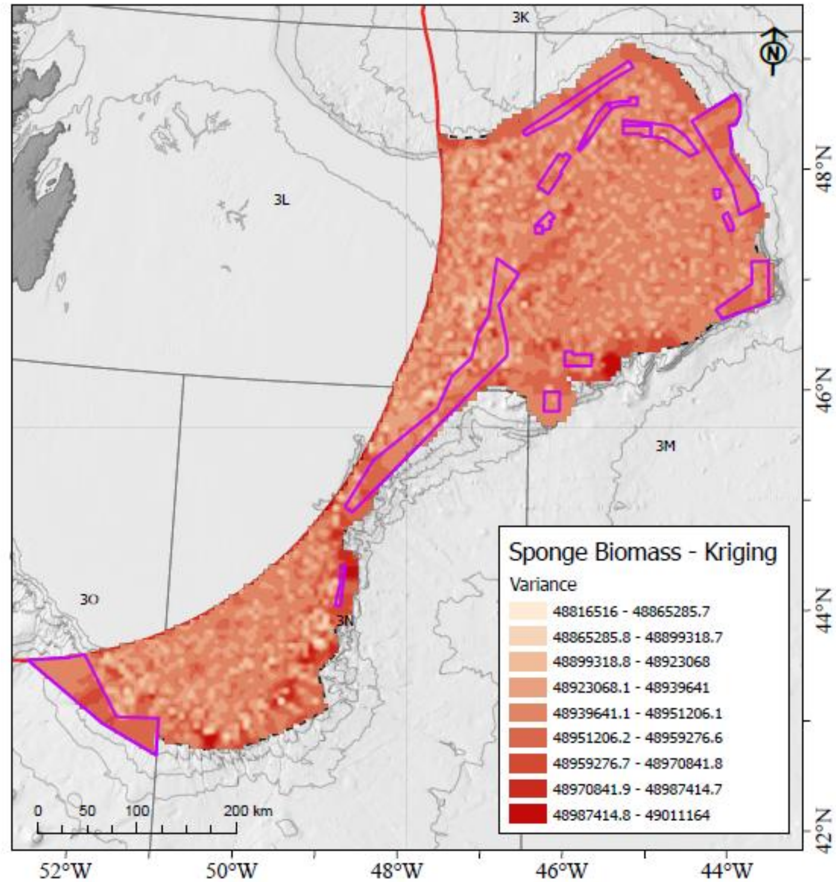


Figure 13. Grided biomass surface using EU and Canadian data (Case 3) calculated using kriging. Left panel: Mean biomass (kg). Right panel: Variance of the predictor (kg). Canadian EEZ is indicated in red, closed areas in purple.

Conclusions

The errors found in the biomass layers created in 2020 (Lirette et al., 2020) were introduced by using the Canadian data without appropriate conversions. Applying the Complete Coverage method which was used at the time to the current data set, the effect of adding the Canadian data was to increase the total biomass by 8,343,336 kg, with most of that greater biomass accruing in the closed areas (e.g., Area 6, Sackville Spur) (Figure 4). This would not likely have a large impact on the SAI analyses conducted in 2020 using that data.

In going forward, we recommend that the data be converted to kg/km^2 prior to applying any statistics as was done in 2010 (Cogswell et al., 2010). The choice of the method to use requires WG-ESA consensus. Regardless of the data used, moving from Simple Averaging to Focal Statistics to Complete Coverage increases the total biomass substantially with each step. Of the two interpolation methods examined, SDM estimated considerably more total biomass than the Complete Coverage method as demonstrated by Pham et al. (2019), while kriging estimated less. Both of these approaches would take some time to develop and could delay the assessment of significant adverse impacts by one year if selected.

Staying within the previous workflow (Figure 2), the question is whether it is reasonable to assume 100% coverage in upscaling the biomass measures produced by Focal Statistics? This step greatly increases the total biomass (Table 6) by a substantial amount (>240,000,000 kg) but does not change the relative distribution of the biomass over that produced by Focal Statistics.

References

Cogswell, A., Kenchington, E., Lirette, C., Murillo, F.J., Campanis, G., Campbell, N., and Ollerhead, N. 2011. Layers Utilized by an ArcGIS Model to Approximate Commercial Coral and Sponge By-catch in the NAFO Regulatory Area. NAFO SCR Doc. 11/72, 50 pp. https://www.nafo.int/Portals/0/PDFs/sc/2011/scr11-072.pdf

Cogswell, A., Kenchington, E., Lirette, C., Brodie, B., Campanis, G., Cuff, A., Perez, A., Kenny, A., Ollerhead, N., Sacau, M., and Wareham, V. 2010. Evaluating Sponge Encounter Thresholds through GIS Simulation of the Commercial Groundfish Fishery in the NAFO Regulatory Area. NAFO SCR Doc. 10/71, 26 pp.

Kenchington, E., Lirette, C., Murillo, F.J., Hayes, V., Sacau, M. and Gonçalves, P. 2025. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 25/036, 126 pp.

Kenchington, E., Lirette, C., Murillo, F.J., Beazley, L., and Downie, A. L. 2019. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 19/058, 68 pp.

Li, J., and Heap, A.D. 2014. Spatial interpolation methods applied in the environmental sciences: A review. Environmental Modelling & Software 53: 173-189.

Li, J., and Heap, A.D. 2008. A Review of Spatial Interpolation Methods for Environmental Scientists. Geoscience Australia, Record 2008/23, 137pp.

Lirette, C., Kenchington, E., Murillo, F.J., Downie, A.-L., and Kenny, A. 2020. Biomass Estimates for Vulnerable Marine Ecosystems in the NAFO Regulatory Area. NAFO SCR Doc. 20/072, 46 pp.

Murillo, F.J., Downie, A.-L., Abalo Morla, S., Lirette, C., Paulin, N., Wang, Z., et al. 2024. Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Species Distribution Models of Selected Vulnerable Marine Ecosystem Indicators (Large-Sized Sponges, Sea Pens and Black Corals). NAFO SCR Doc. 24/063, 105 pp. https://www.nafo.int/Portals/0/PDFs/sc/2024/scr24-063.pdf

Pham, C.K., Murillo, F.J., Lirette, C., Maldonado, M., Colaco, A., Ottaviani, D., and Kenchington, E. 2019. Removal of deep-sea sponges by bottom trawling in the Flemish Cap area: conservation, ecology and economic assessment. Scientific Reports, 9: 15843. https://doi.org/10.1038/s41598-019-52250-1