Kernel Density Analyses of Coral and Sponge Catches from Research Vessel Survey Data for Use in Identification of Significant Benthic Areas

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KERNEL DENSITY ANALYSES OF CORAL AND SPONGE CATCHES FROM RESEARCH VESSEL SURVEY DATA FOR USE IN IDENTIFICATION OF SIGNIFICANT BENTHIC AREAS

by

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ABSTRACT

Kenchington, E., Lirette, C., Murillo, F.J., Beazley, L., Guijarro, J., Wareham, V., Gilkinson, K., Koen Alonso, M., Benoît, H., Bourdages, H., Sainte-Marie, B., Treble, M., Siferd, T. 2016. Kernel Density Analyses of Coral and Sponge Catches from Research Vessel Survey Data for Use in Identification of Significant Benthic Areas. Can. Tech. Rep. Fish. Aquat. Sci. 3167: viii+207p.

Kernel density estimation (KDE) utilizes spatially explicit data to model the distribution of a variable of interest. It is a simple non-parametric neighbour-based smoothing function that relies on few assumptions about the structure of the observed data. It has been used in ecology to identify hotspots, that is, areas of relatively high biomass/abundance, and in 2010 was used by Fisheries and Oceans Canada to delineate significant concentrations of corals and sponges. The same approach has been used successfully in the Northwest Atlantic Fisheries Organization (NAFO) Regulatory Area. Here, we update the previous analyses with the catch records from up to 5 additional years of trawl survey data from Eastern Canada, including the Gulf of St. Lawrence. We applied kernel density estimation to create a modelled biomass surface for each of sponges, small and large gorgonian corals, and sea pens, and applied an aerial expansion method to identify significant concentrations of these taxa. We compared our results to those obtained previously and provided maps of significant concentrations as well as point data co-ordinates for catches above the threshold values used to construct the significant area polygons. The borders of the polygons can be refined using knowledge of null catches and species distribution models of species presence/absence and/or biomass.

RÉSUMÉ

Kenchington, E., Lirette, C., Murillo, F.J., Beazley, L., Guijarro, J., Wareham, V., Gilkinson, K., Koen-Alonso, M., Benoît, H., Bourdages, H., Sainte-Marie, B., Treble, M., Siferd, T. 2016. Analyses des noyaux de densité des prises de coraux et d'éponges à partir des données des relevés par navire de recherche aux fins d'utilisation dans la détermination de zones benthiques importantes. Can. Tech. Rep. Fish. Aquat. Sci. 3167: viii+207p.

L'estimation de la densité par la méthode du noyau utilise des données spatialement explicites pour modéliser la distribution d'une variable d'intérêt. Il s'agit d'une simple fonction de lissage non paramétrique fondée sur la proximité qui repose sur quelques hypothèses quant à la structure des données observées. Elle a été utilisée en écologie pour déterminer des zones névralgiques, c'est-à-dire des zones où la biomasse ou l'abondance sont relativement élevées, et, en 2010, elle a été utilisée par Pêches et Océans Canada pour délimiter les concentrations importantes de coraux et d'éponges. La même approche a été utilisée avec succès dans la zone réglementaire de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO). Dans le présent document, nous mettons à jour les analyses précédentes avec les registres des prises représentant jusqu'à cinq années de données supplémentaires tirées des relevés au chalut dans l'Est du Canada, y compris dans le golfe du Saint-Laurent. Nous avons appliqué l'estimation de la densité par la méthode du noyau afin de créer une surface de biomasse modélisée pour chacune des éponges, des petites et grandes gorgones et des pennatules, et appliqué une méthode d'expansion aérienne pour déterminer les concentrations importantes de ces taxons. Nous avons comparé nos résultats avec ceux obtenus antérieurement, et fourni des cartes des concentrations importantes ainsi que des coordonnées de données ponctuelles pour les prises dépassant les valeurs de seuil utilisées pour construire les zones polygones importantes. Les limites des polygones peuvent être affinées à l'aide de la connaissance des captures nulles et des modèles de répartition de la présence ou de l'absence des espèces ou de la biomasse.

INTRODUCTION

Kernel density estimation (KDE) utilizes spatially explicit data to model the distribution of a variable of interest. It is a simple non-parametric neighbour-based smoothing function that relies on few assumptions about the structure of the observed data. It has been used in ecology to identify hotspots, that is, areas of relatively high biomass/abundance. With respect to marine benthic invertebrate species, it was first applied to the identification of significant concentrations of sponges in the Northwest Atlantic Fisheries Organization (NAFO) Regulatory Area in 2009 (Table 1). Since then it has been used to identify significant concentrations of corals and sponges from research vessel trawl survey catch data in both Canada (Kenchington et al., 2010) and in the NAFO Regulatory Area (Kenchington et al., 2014). Here we present an updated analysis of Kenchington et al. (2010) which adds new research vessel (RV) survey data collected from 2009 to 2015 for four benthic taxa: Sponges (Porifera), Sea Pens (Pennatulacea), Large Gorgonian Corals and Small Gorgonian Corals (Alcyonacea, formerly classed as Gorgonacea).

Table 1. Annotated Reference List of the Use of Kernel Density Analysis in the Northwest Atlantic.

Year	Publication Reference	Annotation Regarding KDE
2009	Kenchington, E., A. Cogswell, C. Lirette & F.J. Murillo-Perez. The Use of Density Analyses to Delineate Sponge Grounds and Other Benthic VMEs from Trawl Survey Data. Serial No. N5626. *NAFO Scientific Council Research Document* 09/6, 18pp.	KDE concept was explained and applied to Canadian RV sponge catch data from 1995 to 2008 in the NAFO Regulatory Area (Flemish Cap, Nose and Tail of Grand Bank). A model created with Model Builder in ArcGIS 9.2 was presented to semi-automate the process and the effects of various search radii were examined.
2010	Kenchington, E., C. Lirette, A. Cogswell, D. Archambault, P. Archambault, H. Benoit, D. Bernier, B. Brodie, S. Fuller, K. Gilkinson, M. Levesque, D. Power, T. Siferd, M. Treble & V. Wareham. Delineating Coral and Sponge Concentrations in the Biogeographic Regions of the East Coast of Canada Using Spatial Analyses. *DFO Canadian Scientific Advisory Secretariat Research Document* 2010/041. iv + 207 pp.	KDE analysis was applied to Canadian RV coral and sponge catch in each of the five biogeographic zones of eastern Canada, including the Gulf of St. Lawrence and Hudson Strait. Modifications to the model were made that were designed to automate the manual steps of selecting the contour polygons that most tightly encompass the subset of points within a given weight threshold.
2010	Murillo, F.J., E. Kenchington, C. Gonzalez & M. Sacau. The use of density analyses to delineate significant concentrations of Pennatulaceans from trawl survey data. Serial No. N5753. NAFO Scientific Council Research Document 10/07,7 pp.	KDE was applied to sea pens in the NAFO 3LMNO Divisions. Data from Canada and the EU were combined.

2012	Kenchington, E., T. Siferd & C. Lirette, 2012. Arctic Marine Biodiversity: Indicators for Monitoring Coral and Sponge Megafauna in the Eastern Arctic. *DFO Canadian Scientific Advisory Secretariat Research Document* 2012/003: vi + 44p.	Geospatial metrics using coral and sponge habitat derived from KDE were presented. These were constructed from individual patches (e.g., mean patch area and shape). The spatial relationship among patches, or patch configuration was also quantified using nearest-neighbour and other statistics capturing information on the relative position of the patches within the survey landscape.
2014	Kenchington, E., F.J. Murillo, C. Lirette, M. Sacau, M. Koen-Alonso, A. Kenny, N. Ollerhead, V. Wareham & L. Beazley, 2014. Kernel density surface modelling as a means to identify significant concentrations of vulnerable marine ecosystem indicators. *PLoS ONE* 9(10): e109365. doi:10.1371/journal.pone.0109365	KDE was applied to four VME indicator taxa: large-sized sponges, sea pens, small and large gorgonian corals in the NAFO Regulatory Area. Independent assessments of the VMEs so identified were made using underwater images, benthic sampling with other gear types (dredges, cores), and/or species distribution models of probability of occurrence, as available.

MATERIALS AND METHODS

Details of KDE

For each biogeographic region in Eastern Canada (DFO, 2009), for which trawl survey data were available, we used kernel density estimation (KDE) to create a modelled biomass surface for each coral and sponge indicator taxon, using the start positions of each research vessel (RV) trawl tow. Details of the analysis are provided in Appendix 1. The biomass was not standardized as previous analyses have shown that there is no relationship between biomass and tow length (Kenchington et al., 2014; Murillo et al., 2016). Instead, biomass was analysed as kg/tow.

Evaluation of Optimum Search Radius

Kernel estimators smooth out the contribution of each data point over a specified local neighbourhood. The extent of that contribution is determined by the shape of the kernel function used, and the search radius or bandwidth which acts as a smoothing function. The latter is particularly influential as, if it is too small, then the surface can be under-smoothed creating discontinuities with sharp peaks and troughs and noisy density estimates; if too large it can be over-smoothed, blurring hotspots (Bowman, 1984).

The analysis fits a circle around each data point (here, around each trawl catch position; Figure 1). We used an optimum search radius to define the circle, based on the ARCGIS v.10 SPATIAL ANALYSIS KERNEL DENSITY tool's default calculations (note these calculations are different in version 10.2), which is the shortest of the width or height of the data spatial extent (a rectangle encompassing all of the data used in the analysis), divided by 30. The rectangle must be larger than the default radius to ensure that the whole density surface is created. In most cases the width was the shortest extent. In order to reduce arbitrary and suboptimal choices about the amount of smoothing, we applied this commonly used optimal bandwidth. It is designed to minimize the estimated mean square error. However, if the surface was highly discontinuous we increased the search radius above the default value, while if it was continuous but with data spread at low density, we lowered the search radius. Both were done in order to examine the effect of smoothing produced by those changes. We have not explored the use of an adaptive kernel algorithm to compare the effect of the bandwidth (Brunsdon, 1995). In this technique the parameters which control the surface estimation are adjusted over geographic space, allowing for local variations in the density of observations. This approach limits the influence of a single record to a small spatial extent when the density of points is high, through the use of a small bandwidth. Conversely, in areas where density is lower, the kernel is geographically larger and the influence of a single data point is greater. This could give a more precise surface for each analysis but would still differ over time as new data are incorporated. Another established method for determining an optimal bandwidth, that is cross validation, results in small bandwidths with large sample sizes, and so was not pursued for this application (Bowman, 1984).

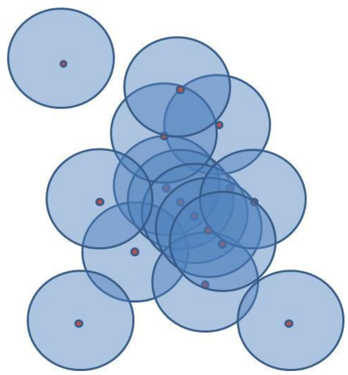

Figure 1. An illustration of the application of the optimum search radius (blue circles) to hypothetical data points (red closed circles) representing research vessel trawl start of tow locations.

Production of Kernel Density Surface

Once the search radius was established, a curve was fit centered over each data point (biomass of the species of interest in the RV catch) in all directions such that the surface value is highest at the location of the point and decreases outwards in all directions to reach zero at the search radius distance to define a circular neighbourhood for each point observation (Figure 2; Appendix 1). We used a Gaussian (normal) function in fitting the decay curve. In this way biomass is predicted for the area covered by the circle. When two or more circles overlap (Figure 1), the kernel function sums their values over the overlap area (Figure 3). A quadratic kernel density function was then used to fit a smooth curve over each data point in ARCGIS v.10.2 (ESRI Canada Limited, Toronto, Ontario) using the appropriate Universal Transverse Mercator (UTM) projected coordinate system North American Datum 1983 Zone for each area. This kernel surface sums the values under each Gaussian curve to produce a smooth surface (Figure 3). The null data do not influence this summation.

A grid is then placed over the surface and the value of the kernel surface at the midpoint of each grid cell is extracted. The cell size (resolution) of this grid was also based on the study area rectangle, and used the shorter measure of either the width or height of the output extent that goes just beyond the distance of the kernel density surface, divided by 250. Each cell kernel value in the grid is the KDE biomass value divided by the search neighbourhood area. If two search circles are used to create the KDE biomass then the divisor is the area of both circles combined. This will standardize the KDE value. The effect of this is to produce lower values where there is less data to support the prediction than when there are multiple intersections. The kernel surface is by default displayed on this gridded surface which is subsequently smoothed using bilinear interpolation (Figure 4) to create a smooth surface from the gridded raster. This final surface was used to identify hotspots in the data so that significant concentrations could be distinguished from the broader distribution of the species. The surface represents relative biomass in that the data were not meant to be true or actual biomass values. We know that catchability differed among species and that the trawls were not good benthic samplers of these organisms (e.g., Kenchington et al., 2011).

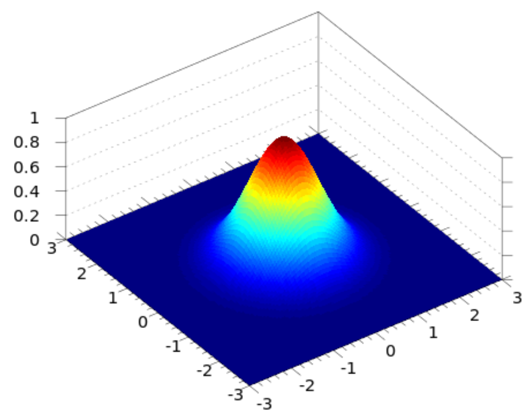

Figure 2. A Gaussian curve fit in two dimensions (From Wikimedia Commons, the free media repository). When applied in KDE the peak of the curve is centered over the data point and the base of the curve is delineated by the optimum search radius circle.

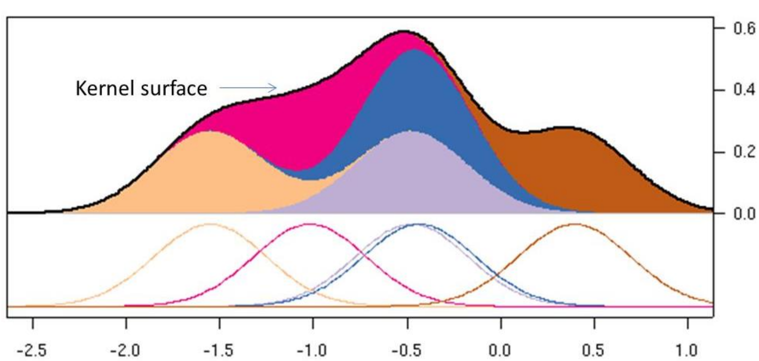

Figure 3. An illustration of how the kernel surface is created through summing the values under each curve in areas of overlapping search radii. Note that where data are not overlapping such as at the extreme right, the kernel surface takes the form of the underlying Gaussian surface.

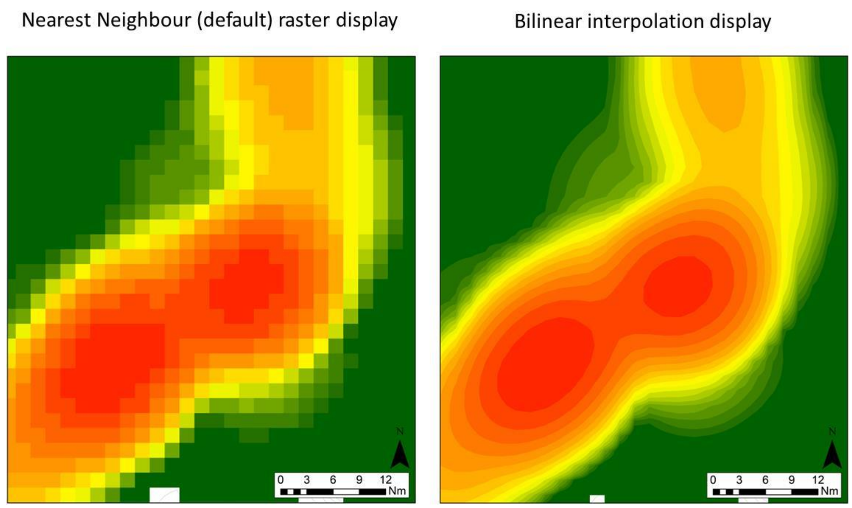

Figure 4. An example of how a KDE gridded surface is smoothed using bilinear interpolation.

Use of KDE Surface to Identify Hotspots

Once the smoothed KDE surface (Figure 4) was produced, contours were placed over its surface. These contours were finely spaced (10^{-4} – 10^{-7} kg intervals) (Figure 5) and reported for each analysis. Each contour line was then converted to a density polygon in ARCGIS. An iterative tool called DENSITY POLYGON DISSOLVER was then applied (Appendix 1). This tool selected the contour polygon which most tightly encompassed the subset of points within a given biomass threshold value and outputted the area occupied by the polygon.

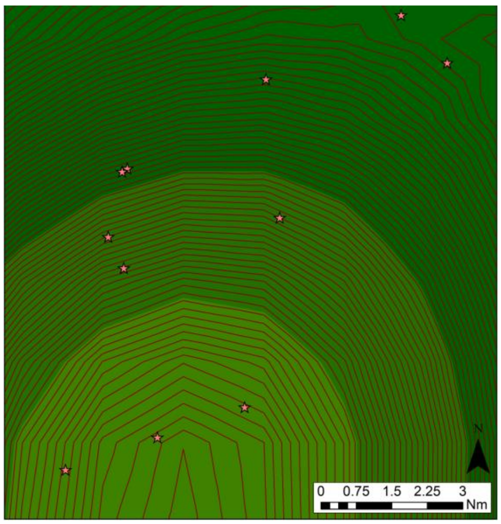

Figure 5. An illustration of contour lines fitted to the KDE surface. Stars represent original data points.

For each benthic taxon, we then produced histograms of the area occupied by successively decreasing biomass values (Figure 6). Typically, for these benthic species that form habitats through dense aggregations, the threshold-area curves initially showed a slow increase in total area as the threshold values decrease. This slow increase in area reflects the fact that the arbitrary thresholds keep “mapping out” the areas that contain the dense aggregations (i.e., better delineating the areas of high density, where density may decrease near their boundaries, while also starting to incorporate smaller new aggregation areas with relatively lower densities). After this initial “phase” of slow increase in area, the threshold-area curves showed a rapid and sharp increase in area as the thresholds keep decreasing; this rapid increase in area is associated with thresholds values that are beginning to capture isolated/non-aggregating individuals of the species represented by small catch values in the data. Finally, as the thresholds reached their lowest values, the area covered often stabilizes again, reflecting the entire distribution of the species in the study area. The selection of weight bins does not have a large effect on the results within the dense aggregations. This is because the area can only increase (never decrease) with decreasing weight. For example, placing another weight bin at 190 kg in Figure 6 would mean that the bar would have to fall between the area produced by the 200 and 175 kg bins. Where bin selection does make a difference is in the area of rapid change. For example, placing a bin of 30 kg between 50 and 25 kg in Figure 6 could reduce the degree of change in area depending on where the data fell relative to the bin. This type of fine tuning of the polygon was not pursued given that the original data was not precise to meter accuracy and that the catch could have been taken anywhere along the tow length which was approximately 1 km on average.

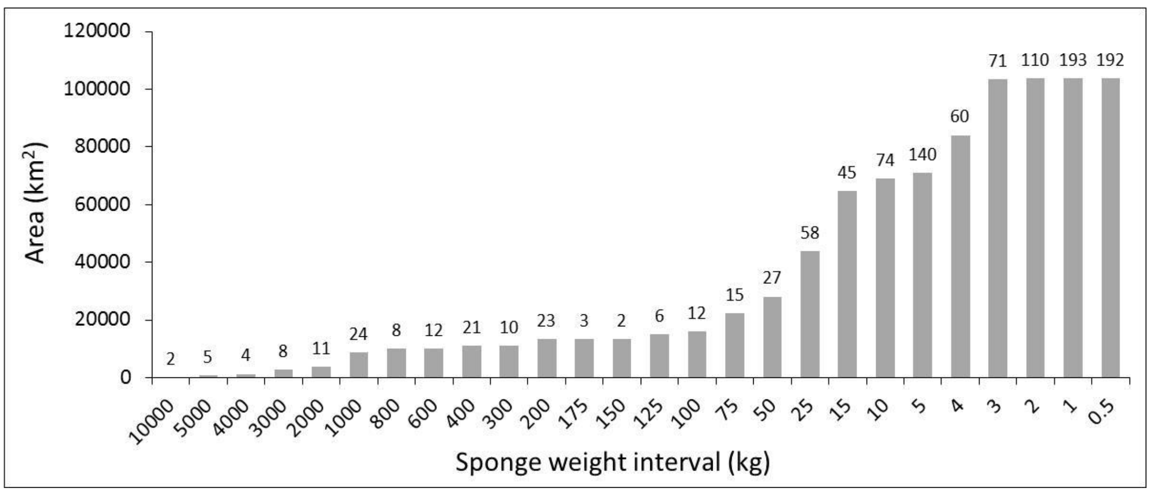

Figure 6. The area occupied by successive weight thresholds of sponges. The numbers of additional data points contributing to each weight bin are displayed above the bars on the histogram.

Consequently, when interpreting the catch weight defining the significant concentrations a number of criteria are *simultaneously* considered: 1) identification of the catch biomass which showed the largest change in area after the initial establishment of the aggregations; 2) consideration of the number of data points contributing to those changes in area between successive catch thresholds; 3) examination of the spatial relationship of the polygons created by biomass thresholds greater and lesser than the potential threshold using GIS, and 4) the position of the new data points relative to previously established polygons. These two last criteria were the spatial component to criterion 2 and are necessary as polygon area can increase by the joining of two or more high density polygons. If this occurs the evidence for connecting the areas (i.e., number of points between the smaller areas) was reviewed. In this instance the threshold was considered to be valid when there was an increase in area through a reasonable number of widely spaced data points. Cases for rejecting the threshold other than insufficient data included: 1) joining of smaller polygons with little evidence for a continuous distribution within the newly formed area; 2) a gradual increase in area with every new polygon added, creating a situation where no one successive change in area is especially larger or smaller than others (this indicated that there is no aggregation); 3) an increase in area established by creation of new areas of very low density; and 4) no large increase in area. This decision framework was followed herein. For each analysis two independent assessments were made on the threshold determination. In the majority of cases they came to the same conclusion following the guidelines. When different thresholds were initially selected (i.e., for the Eastern Arctic large and small gorgonian coral catches with Campelen trawls performed on over-smoothed surfaces) agreement was reached through discussion.

Polygons Delineating Significant Concentrations

Using KDE as described above, areas with significant biomass concentrations of the target species groups were identified. Within these polygons all of the catches above the delimiting threshold were included, but the areas also contained smaller catches. This is expected as those could represent recruitment, areas thinned by bottom contact fishing gears or observation errors. Consequently, the conservation unit is the polygon area rather than the individual research vessel tows. In some cases, those areas can be refined upon closer examination of the null data which does not influence the KDE but is very useful in a post-hoc assessment (see Discussion).

Application of KDE to Research Vessel Trawl Catch Data

We applied KDE, as described above to areas within each of the Department of Fisheries and Ocean's (DFO's) Biogeographic Regions (DFO, 2009) in eastern Canada for which trawl survey data were available. This was so that our results could be directly compared with those produced in 2010 (Kenchington et al., 2010). In order to facilitate the interpretation of our results we have included information on the data sources in the Results section. For each region we followed the data selection decisions outlined in Kenchington et al. (2010). That included the set of species codes from the surveys to include in each taxon (i.e., group of species) analyzed, and time period. In the former analyses, *Radicipes* spp. was considered to be a large gorgonian coral based on its size. Here we have placed it with the small gorgonian corals, based on its biomass, following Kenchington et al. (2014). We first reproduced the results of that earlier study, and then we re-ran the analyses with the additional data. Some small errors were discovered in the data and were corrected. For each taxon and region we looked at the effect of different search radii on the KDE surface, using the default search radius as well as radii above and below the default values. This differs from our previous analyses where a fixed 25 km search radius was applied for all regions/taxa. The new analyses using optimal search radii in most cases will improve the accuracy of the KDE surface. Nevertheless, there remains subjectivity in the selection of thresholds. For some species groups managers and others may which to be more precautionary and consider the full distribution or parts thereof. We note that corals and sponges are not the target species in the research vessel surveys and that trawls are not the best samplers of these taxa. Consequently, we do not view the biomass surfaces as true estimates of biomass, but rather as relative biomass for each fishing gear type and taxon combination.

RESULTS

Scotian Shelf Biogeographic Zone

In this biogeographic zone there were too few records to apply KDE to the small gorgonian corals and so that analysis was omitted. Our analyses were conducted on sponges, sea pens and large gorgonian corals within the Scotian Shelf Biogeographic Zone. The species that comprised each taxon are provided in Beazley et al. (2016a).

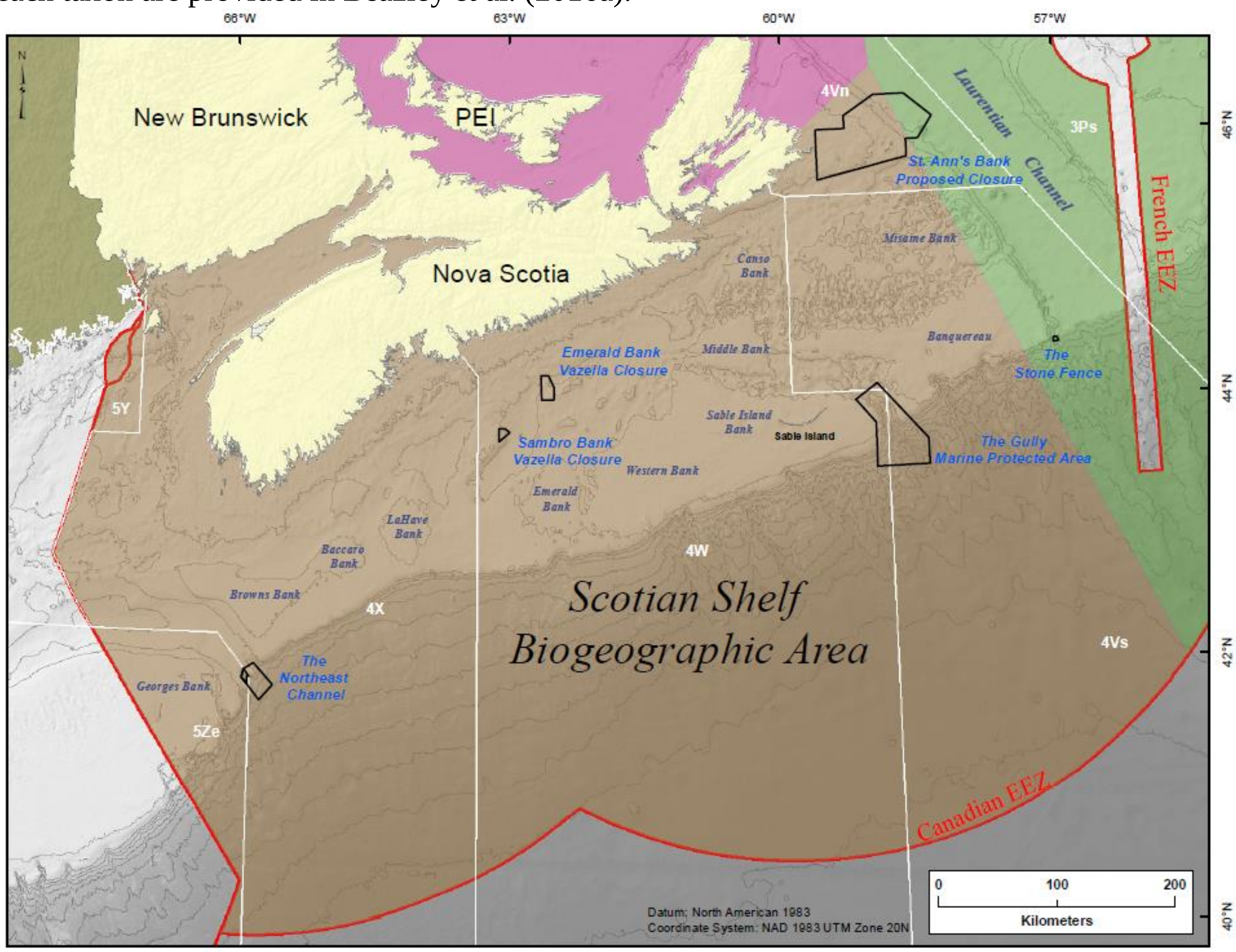

Figure 7. Map showing the area of the Scotian Shelf Biogeographic Zone (DFO, 2009), with place names, areas closed or proposed to be closed to protect benthic species and habitats, and the Canadian and French Exclusive Economic Zones (EEZ; red line).

Sponges (Porifera)

Data Sources and Distribution

The data available for the analyses of sponges in the Scotian Shelf Biogeographic Zone covered 30 surveys conducted over 15 years from 2001 to 2015. There were 1102 records with sponge catch and 1815 records of catches with no sponges from the same surveys. This represented nearly 3x the number of presence records that were available for the previous analyses (Kenchington et al., 2010). All surveys that were used in this time series were conducted with

Western IIA trawls with tow locations chosen following a stratified random design (Frank, 2004; Kulka et al., 2006; Chadwick et al., 2007). A large area off southwest Nova Scotia was excluded from the survey area due to rough bottom (Figure 8). Consistent reporting of invertebrate catch protocols in these surveys was not practised until 2005 and so null data from before that year were not included. The data were extracted from the Maritimes Region Virtual Data Centre (VDC). In this biogeographic zone, the data were restricted to the shelf and upper slope with most of the area in deeper water extending out to the Exclusive Economic Zone (EEZ) not surveyed (Figure 8). Within the surveyed area, the sponges had a scattered distribution but appeared more frequently on Georges and Browns Banks (Figure 8).

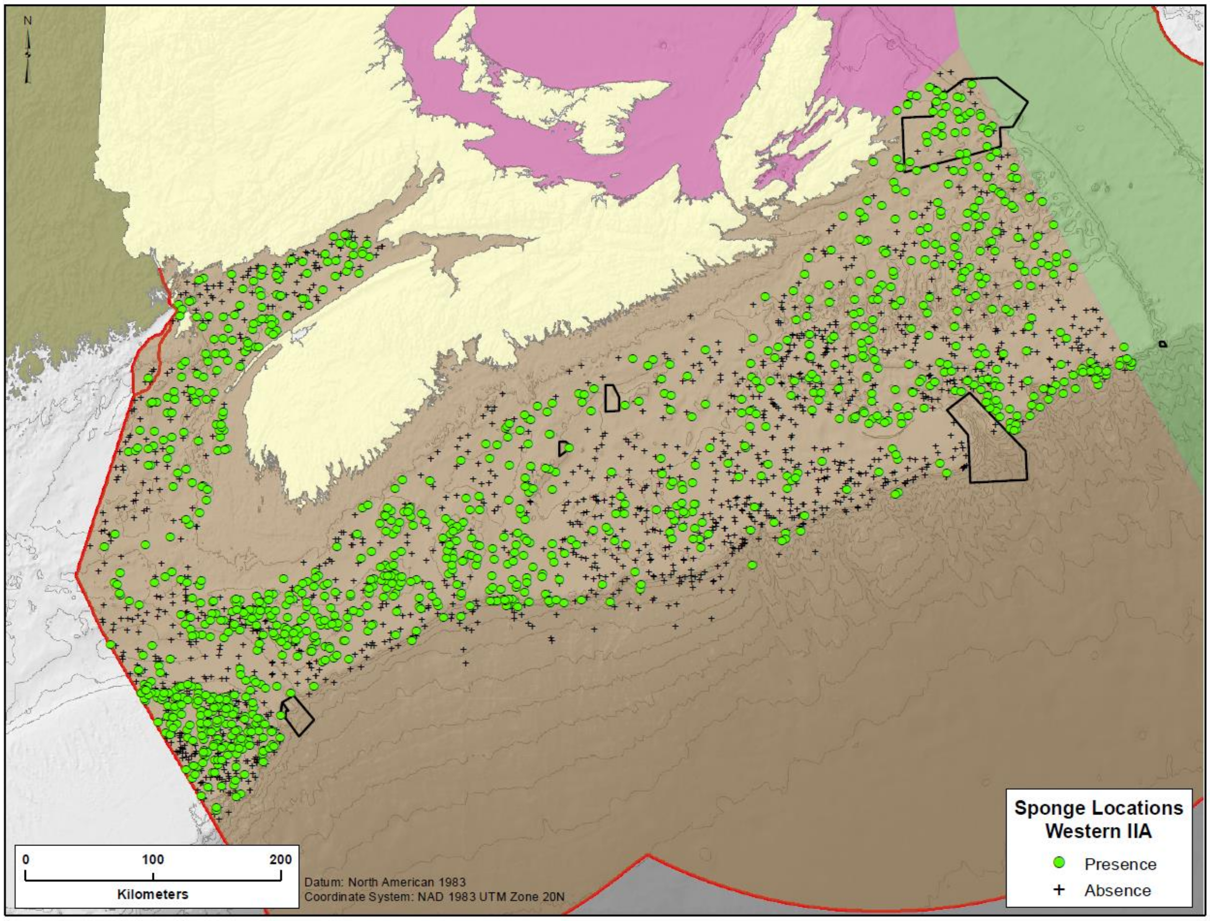

Figure 8. Distribution of sponges from DFO research vessel survey catches using a Western IIA trawl. The Northeast Channel Coral Conservation Area, the Gully Marine Protected Area, the *Vazella* Sensitive Benthic Area and the St. Ann's Bank Proposed Closed Area are depicted in outline (see Fig. 7). Green circles indicate sponge presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 18.921 km. We compared that KDE surface with those produced by using 10 km and 25 km search radii. The default search radius produced a good fit to the data (Figure 9) while the 10 km radius under-smoothed and the 25 km over-smoothed the data (Figure 10). The default search radius was used in the preparation of the KDE surface. The default grid size was 2.64 km^2. Contours placed over the KDE surface were finely spaced at 0.00001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

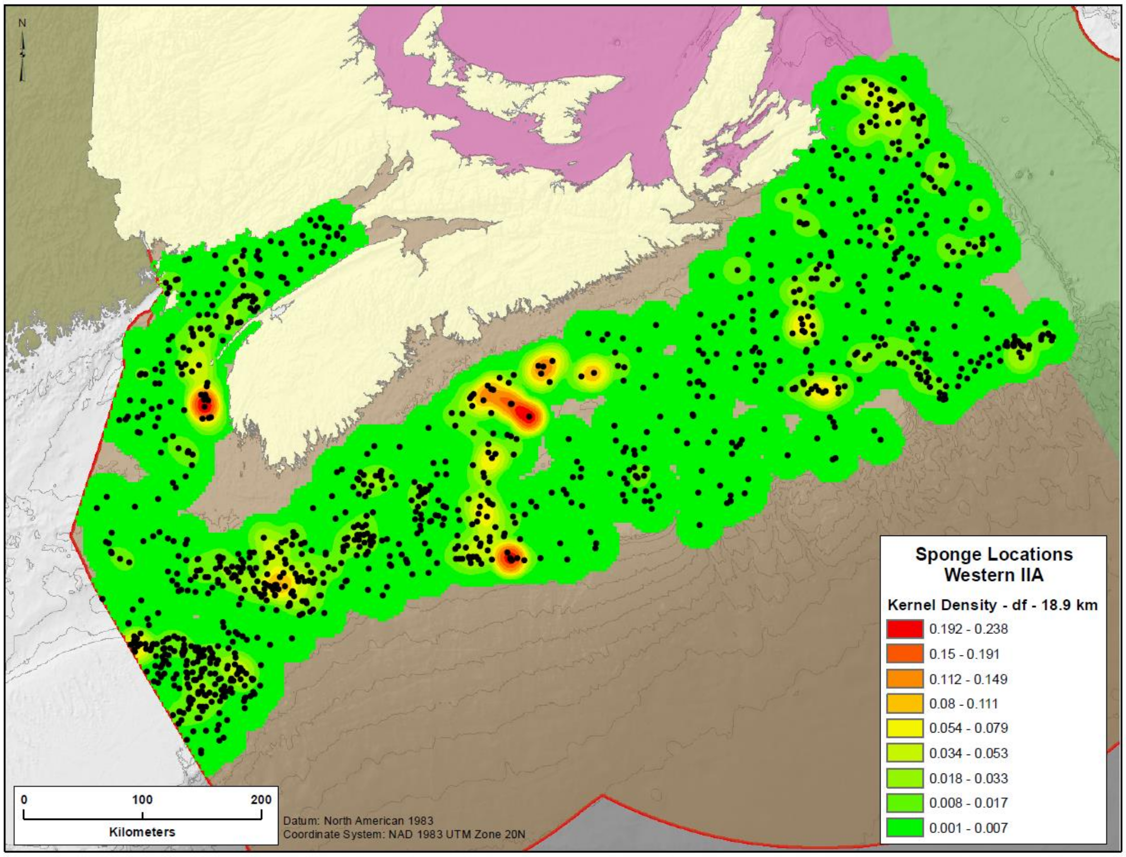

Figure 9. KDE surface of sponge biomass produced with the default (df) search radius (18.921 km). Tow locations with sponge catch used in the analysis are indicated in black.

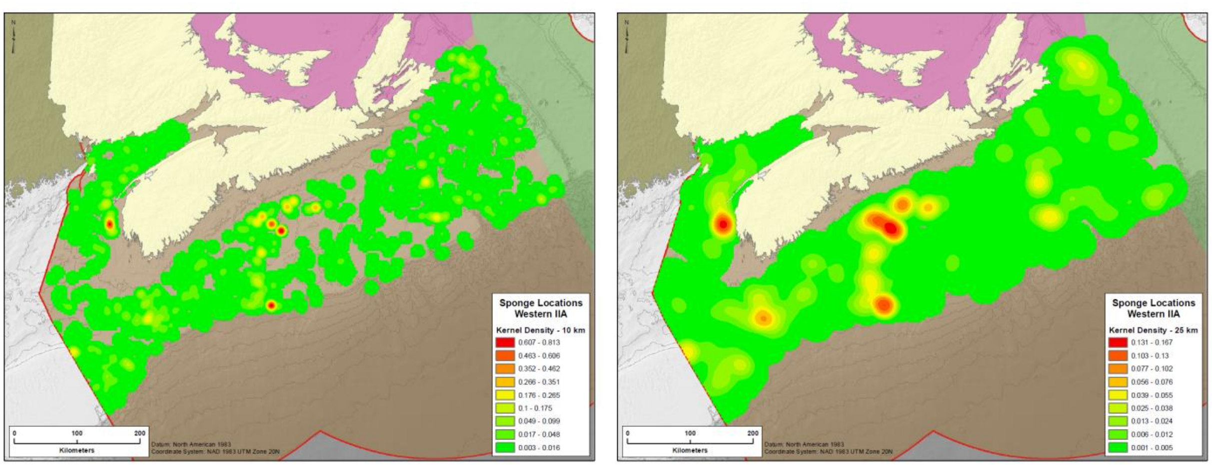

Figure 10. KDE analyses conducted with a 10 km (left) and 25 km (right) search radius. The former is under-smoothed and the latter over-smoothed.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sponge weight threshold is provided in Table 2 and illustrated in Figure 11. The first large increase in area was found between 10 and 8 kg where area increased 241% (Table 2). However that areal expansion was only supported by 3 additional points and examination of the spatial area occupied by the polygons showed that there was a large distance between the catches. The next largest increase in area was seen between 3 and 2 kg (Figure 12). That change was supported by 58 additional data points and was considered to be the threshold delineating significant concentrations of sponges. The areas occupy 12,873 km^2.

Table 2. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
50	3	-	30	2482
30	7	4	764	34
25	10	3	1026	5
20	14	4	1078	4
15	17	3	1125	13
10	24	7	1268	241
8	27	3	4317	4
7	33	6	4475	61
6	47	14	7212	8
5	52	5	7782	20
4	62	10	9327	38
3	79	17	12873	99
2	137	58	25631	81
1	272	135	46390	61
0.5	400	128	74723	74
0.1	733	333	129900	11
0.05	879	146	144200	21
0.01	1071	192	173906	

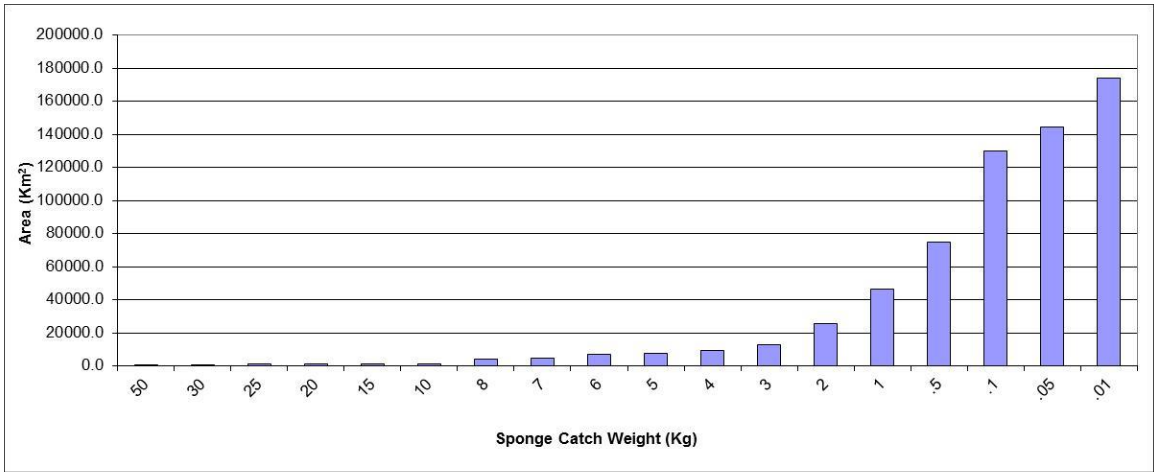

Figure 11. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

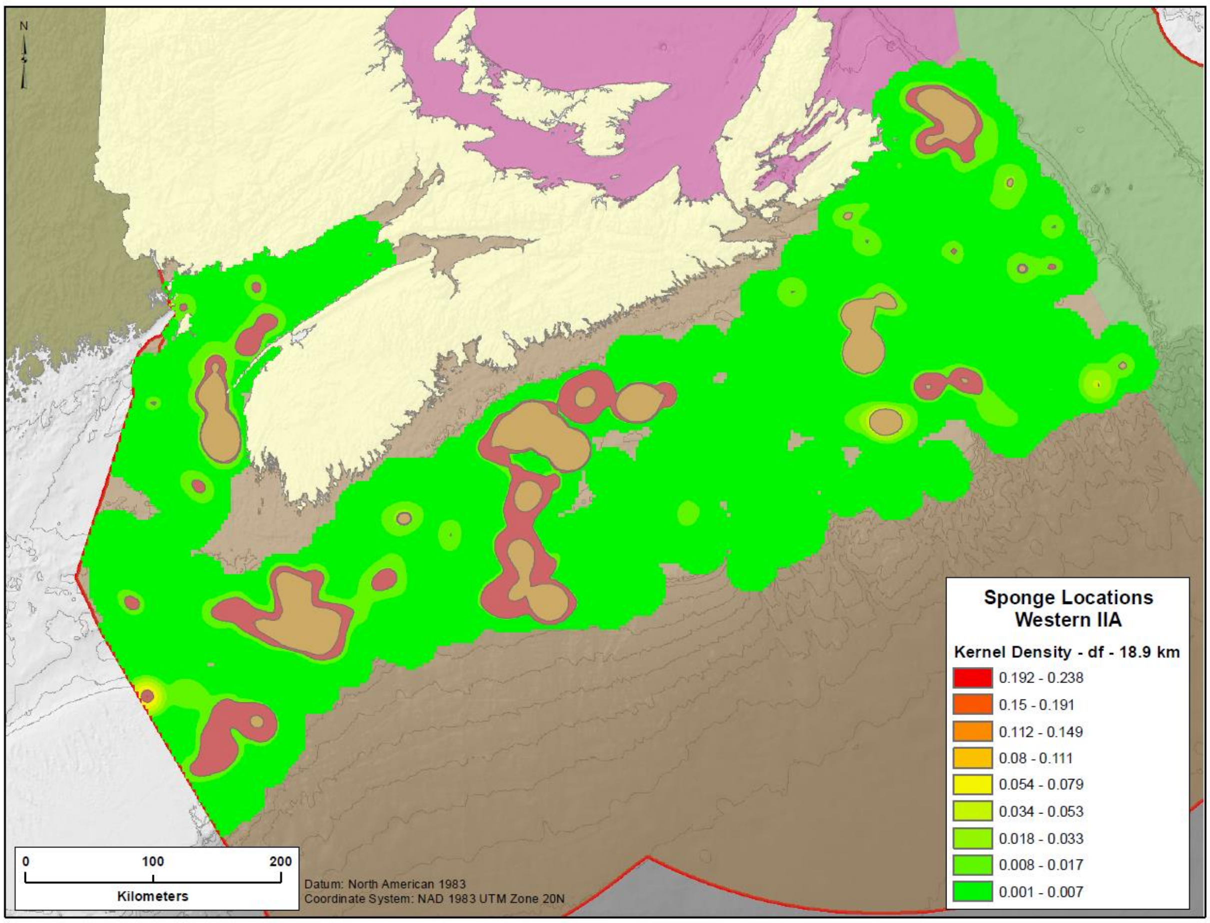

Figure 12. Location of polygons encompassing the ≥3 kg RV catches (light purple) and the ≥2 kg RV catches (darker purple), showing the 99% increase in area (Table 2) and overlain on the KDE biomass surface produced with the default (df) search radius.

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of sponges are shown in Figure 13 and the locations of the RV survey tows that defined those polygons are provided in Table 3. In both Figure 13 and Table 3 sponge catches dominated by the glass sponge *Vazella pourtalesi* were plotted separately from tows where the catch was only recorded as Porifera. In Figure 14, the results of this study are compared to those produced in Kenchington et al. (2010). The areas identified were very similar.

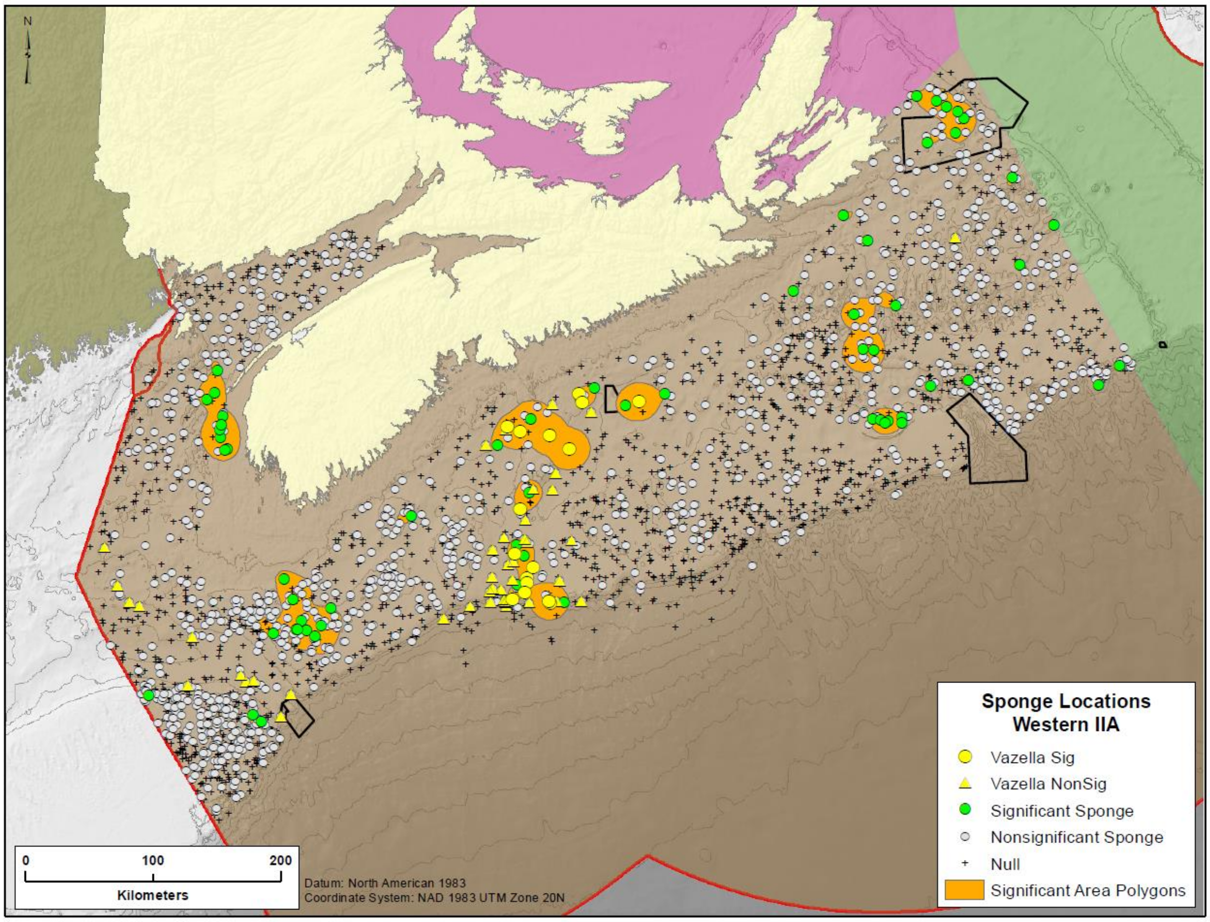

Figure 13. Location of the polygons identifying significant sponge aggregations relative to the broader distribution of sponges and areas closed or proposed to be closed to protect benthic species and habitats (see Fig. 7) in the Scotian Shelf Biogeographic Zone. *Vazella pourtalesi* is identified separately from Porifera in the database and catches that contributed to the identification of the polygons are indicated as significant (Table 3), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

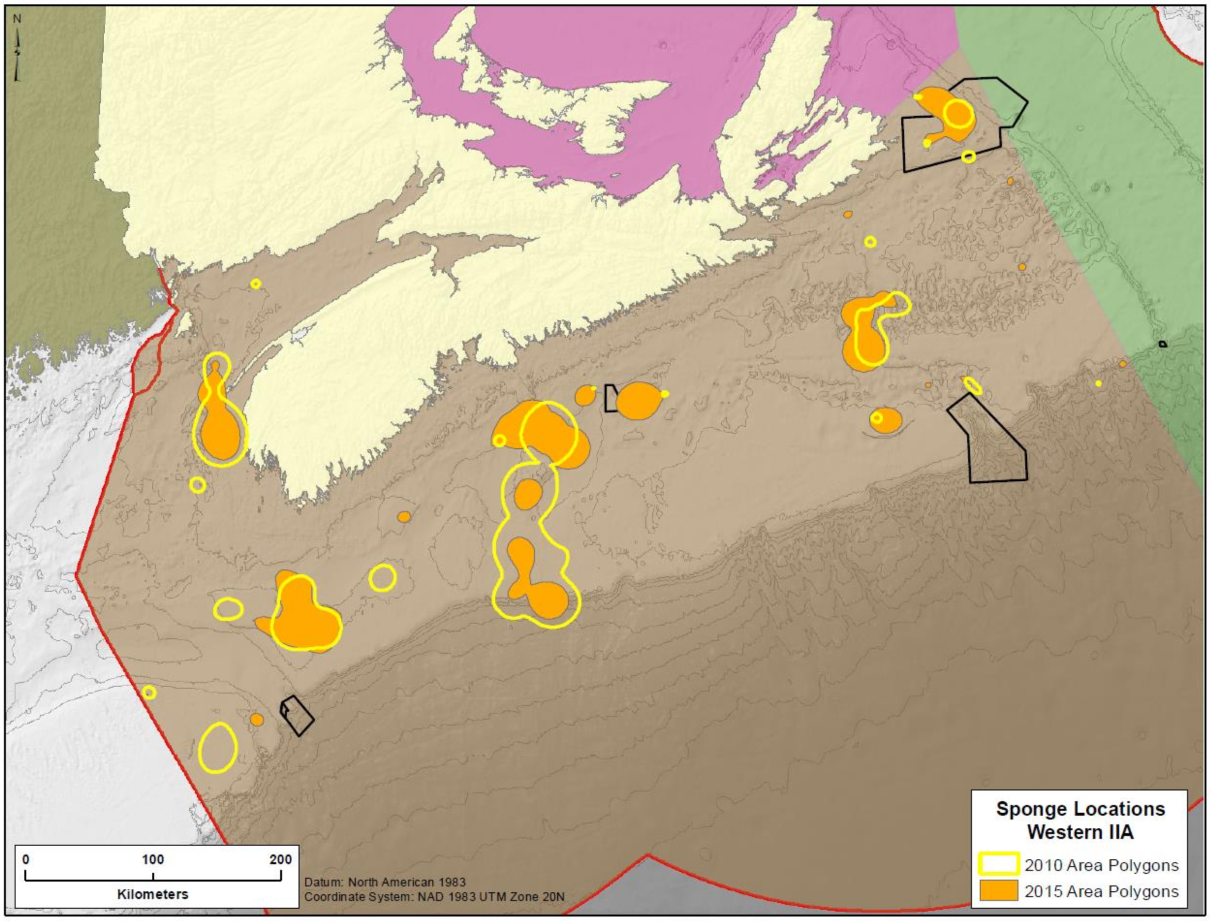

Figure 14. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (gold/orange polygons). Areas closed or proposed to be closed to protect benthic species and habitats are indicated in outline (see Fig. 7).

Table 3. Scotian Shelf Biogeographic Zone: Details of the Location of Research Vessel Sponge Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)	*Vazella pourtalesi*
2011	NED2011025004	43.89233	-63.02217	43.86383	-63.01400	85.54	Yes
2008	TEM2008830046	43.91683	-66.42050	43.93383	-66.45367	56.00	
2010	NED2010027086	42.81667	-63.21633	42.81483	-63.17633	50.18	Yes
2013	NED2013022174	44.22183	-62.33667	44.20483	-62.36750	36.25	Yes
2013	NED2013028032	44.09600	-63.39900	44.08833	-63.43733	32.89	
2002	NED2002037002	43.98917	-63.21050	43.96683	-63.18483	30.50	
2012	NED2012022003	43.98733	-63.21633	43.97217	-63.18200	30.18	Yes
2014	NED2014018144	44.21833	-62.89400	44.19300	-62.91200	29.89	Yes

2014	NED2014101002	44.01417	-63.50150	44.02283	-63.46267	28.10	Yes
2009	NED2009027095	44.31217	-62.77817	44.31500	-62.73833	27.41	
2009	NED2009027051	43.96833	-66.43217	43.94883	-66.43317	24.80	
2002	NED2002037026	43.57433	-63.41150	43.59717	-63.38750	23.63	
2011	NED2011025151	44.55517	-60.12833	44.55133	-60.16817	23.22	
2014	NED2014002020	42.08183	-67.00633	42.05683	-66.98317	20.89	
2010	NED2010027041	44.22683	-66.50350	44.20967	-66.51933	16.48	
2005	TEL2005605004	43.13517	-63.46150	43.14550	-63.42283	15.85	
2011	NED2011025171	44.27550	-62.92933	44.25983	-62.96267	15.10	Yes
2010	NED2010002071	42.81800	-63.21933	42.81800	-63.18550	14.07	Yes
2014	NED2014018133	44.04300	-59.91267	44.03767	-59.95533	13.63	
2010	NED2010027029	42.64917	-65.57917	42.62650	-65.57883	13.20	
2014	NED2014018170	46.27350	-59.29717	46.26983	-59.26817	12.64	
2009	NED2009027032	42.58783	-65.62533	42.58917	-65.66450	12.42	
2002	NED2002040055	44.22383	-57.83533	44.23867	-57.86467	11.76	
2008	TEM2008830088	42.80617	-63.19967	42.80700	-63.16333	10.15	Yes
2013	NED2013022161	44.03400	-59.93950	44.02667	-59.97900	8.90	
2010	NED2010027025	42.94317	-65.75833	42.91350	-65.75883	8.85	
2009	NED2009027055	44.38950	-66.47750	44.41550	-66.45700	8.09	
2002	NED2002037023	43.20967	-63.53100	43.23367	-63.50700	7.96	
2002	NED2002040090	46.14550	-59.02533	46.13917	-58.98400	7.66	
2013	NED2013022020	42.58883	-65.61250	42.60867	-65.62433	7.28	
2008	TEM2008830034	42.61817	-65.39367	42.63500	-65.42650	7.17	
2008	TEM2008830037	42.80150	-65.66717	42.77783	-65.68583	7.10	
2009	NED2009027052	44.07083	-66.41117	44.05133	-66.41117	7.04	
2014	NED2014101003	43.46317	-63.49967	43.44117	-63.52533	6.95	Yes
2012	NED2012022047	42.54067	-65.44567	42.52550	-65.48000	6.65	
2008	TEM2008830148	46.31767	-59.49067	46.33050	-59.45233	6.55	
2002	NED2002037066	43.83617	-66.35067	43.86583	-66.34567	6.53	
2010	NED2010027194	44.19683	-62.47483	44.17617	-62.49933	6.53	
2013	NED2013022221	46.04650	-59.11817	46.07517	-59.11133	6.47	
2011	NED2011025212	45.70767	-58.57083	45.69283	-58.60700	6.28	
2010	NED2010002058	44.27450	-59.47833	44.25317	-59.44783	6.18	
2012	NED2012002048	41.92900	-65.92983	41.94883	-65.95917	6.16	
2011	NED2011025176	44.98017	-60.80200	45.00383	-60.77667	6.14	
2014	NED2014101001	44.04283	-63.62967	44.05483	-63.59433	6.11	Yes
2008	TEL2008805011	44.05033	-59.97933	44.05267	-59.93967	6.10	
2010	NED2010002015	44.80217	-60.20467	44.82550	-60.18667	6.07	
2008	TEM2008830138	45.98867	-59.40467	45.96383	-59.41567	6.05	
2015	NED2015002026	41.97467	-66.01317	41.94850	-65.99750	5.80	
2009	NED2009027149	46.19417	-59.08733	46.17750	-59.05267	5.74	
2008	TEL2008805002	44.26983	-62.08433	44.26800	-62.04383	5.20	
2011	NED2011025047	43.82917	-66.37133	43.81000	-66.36883	5.20	

2010	NED2010027030	42.58017	-65.53017	42.57150	-65.55367	5.02	
2007	TEL2007745030	44.17983	-66.57283	44.19250	-66.55133	4.99	
2012	NED2012022069	44.00583	-66.41950	44.02833	-66.40000	4.90	
2010	NED2010027008	43.15467	-63.54933	43.13150	-63.57317	4.80	Yes
2007	TEL2007745068	42.97783	-63.43167	42.97683	-63.39267	4.65	Yes
2014	NED2014018084	42.87550	-63.45250	42.87383	-63.48000	4.53	Yes
2007	TEL2007745069	43.05600	-63.37300	43.08517	-63.37000	4.35	Yes
2006	NED2006030088	42.80267	-63.20167	42.80733	-63.16200	4.32	
2012	NED2012022191	45.36217	-58.18117	45.35517	-58.14167	4.24	
2010	NED2010027085	42.94750	-63.43117	42.96433	-63.41883	4.20	Yes
2012	NED2012022051	42.55450	-65.84350	42.58300	-65.85050	4.04	
2010	NED2010027173	44.06483	-59.77283	44.05400	-59.81167	3.97	
2008	TEM2008830087	42.83067	-63.56183	42.82750	-63.52383	3.95	Yes
2007	TEM2007686014	44.30617	-59.11133	44.33483	-59.10267	3.85	
2002	NED2002040095	45.31683	-60.04567	45.29200	-60.02333	3.84	
2007	TEL2007745118	44.06217	-60.05633	44.06550	-60.09667	3.70	
2010	NED2010002030	45.09617	-58.54033	45.12483	-58.52650	3.70	
2002	NED2002040076	46.23167	-59.19667	46.24933	-59.23117	3.67	
2010	NED2010027157	45.49567	-60.27600	45.51700	-60.25800	3.61	
2013	NED2013022009	43.40300	-64.55233	43.41833	-64.53350	3.58	
2007	TEM2007686089	42.80517	-63.07400	42.80383	-63.11350	3.50	
2013	NED2013022016	42.74450	-65.30483	42.74633	-65.34333	3.43	
2007	TEL2007745124	44.84883	-59.78833	44.82033	-59.78950	3.20	
2005	TEL2005605085	43.91250	-63.72250	43.93467	-63.69300	3.10	
2013	NED2013028150	44.02300	-59.78100	44.03250	-59.74300	3.05	
2009	NED2009002041	44.53950	-60.02250	44.56867	-60.01667	3.04	
2010	NED2010002054	44.34767	-57.61850	44.35233	-57.57833	3.02	
2013	NED2013022103	42.93117	-63.52100	42.92267	-63.55717	3.01	

Sea Pens (Pennatulacea)

Data Sources and Distribution

The data available for analysis of sea pens in the Scotian Shelf Biogeographic Zone was collected over 14 years from 2002 to 2015. There were 129 records with sea pen catch and 2245 records of catches with no sea pens from the same surveys. In contrast there were only 46 records available for the previous analysis (Kenchington et al., 2010). All surveys that were used in this time series were conducted with Western IIA trawls with tow locations chosen following a stratified random design (Frank, 2004; Kulka et al., 2006; Chadwick et al., 2007). A large area off southwest Nova Scotia was excluded from the survey area due to rough bottom (Figure 15). Consistent reporting of invertebrate catch protocols in these surveys was not practiced until 2005 and so null data from before that year were not included. The data were extracted from the Maritimes Region Virtual Data Centre (VDC). In this biogeographic zone, the data were restricted to the shelf and upper slope with most of the area in deeper water extending out to the

EEZ not surveyed (Figure 15). Within the surveyed area, the sea pens were distributed on the inner Eastern Scotian Shelf and along the Stone Fence area (Figure 15).

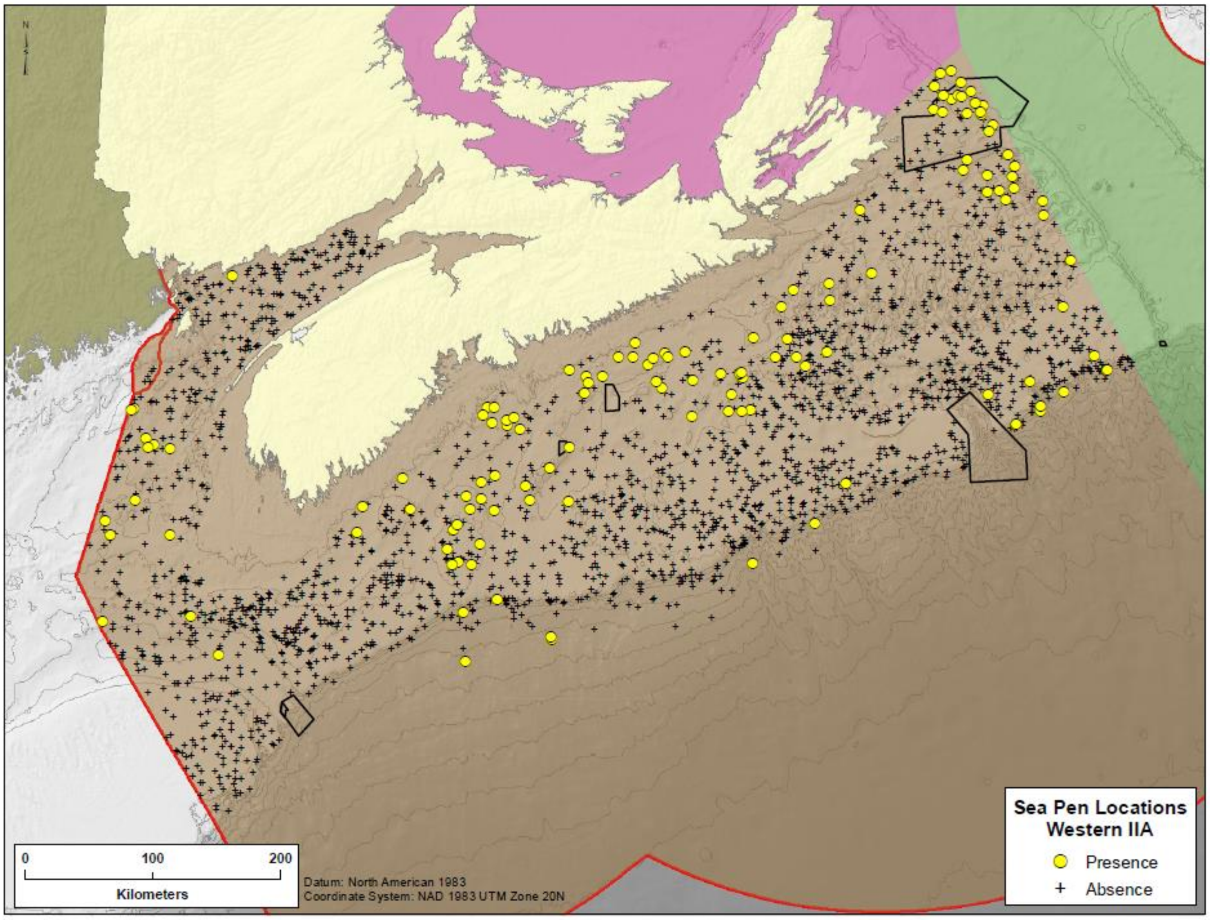

Figure 15. Distribution of sea pens from DFO research vessel survey catches using a Western IIA trawl. The Northeast Channel Coral Conservation Area, the Gully Marine Protected Area, the *Vazella* Sensitive Benthic Area and the St. Ann's Bank Proposed Closed Area are depicted in outline (see Fig. 7). Yellow circles indicate sea pen presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 15.399 km. We compared that KDE surface with those produced by using 10 km and 20 km search radii. The default search radius produced a good fit to the data (Figure 16) while the 10 km radius under-smoothed and the 20 km over-smoothed the data (Figure 17). The default search radius was used in the preparation of the KDE surface. The default grid size was 2.29 km^2. Contours placed over the KDE surface were finely spaced at 0.000001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

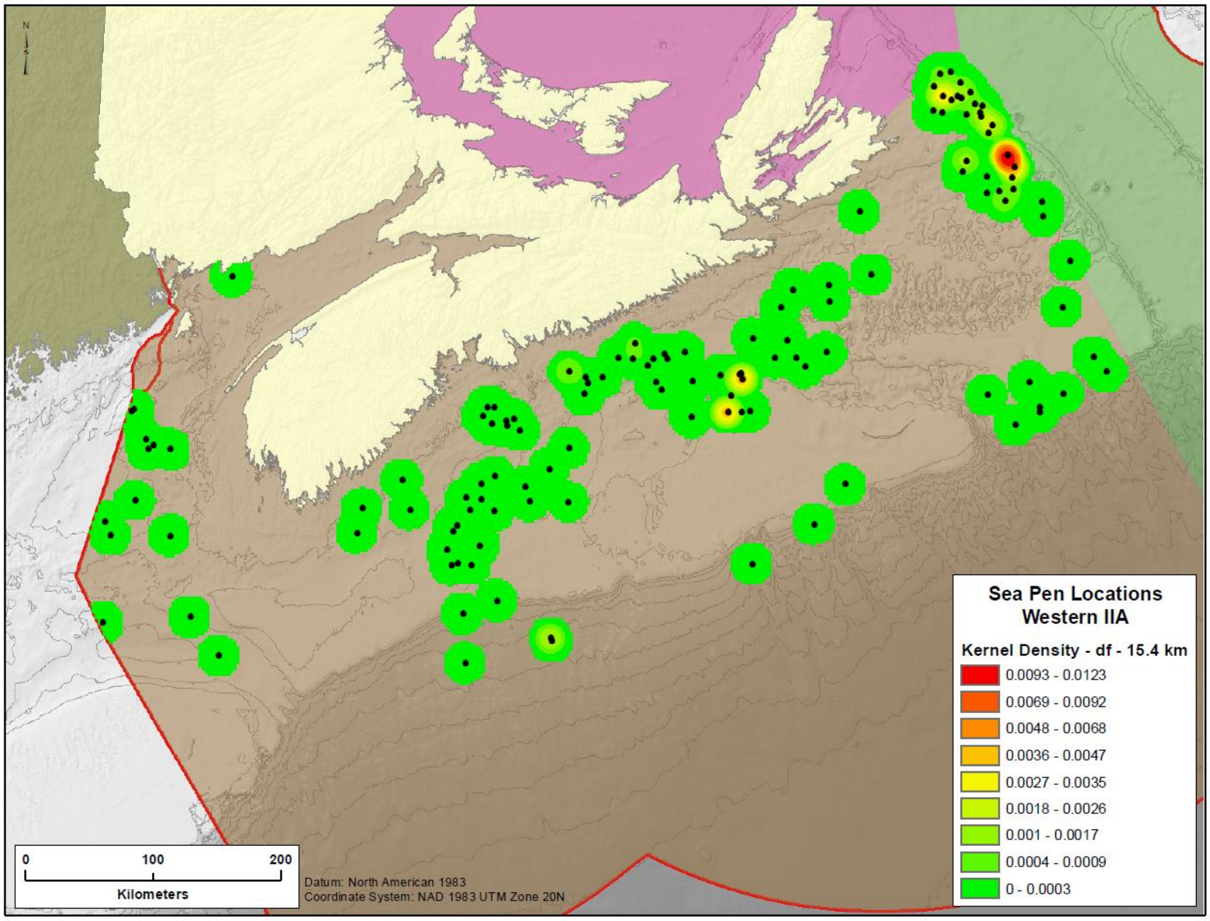

Figure 16. KDE surface of sea pen biomass produced with the default (df) search radius (15.399 km). Tow locations with sea pen catch used in the analysis are indicated in black.

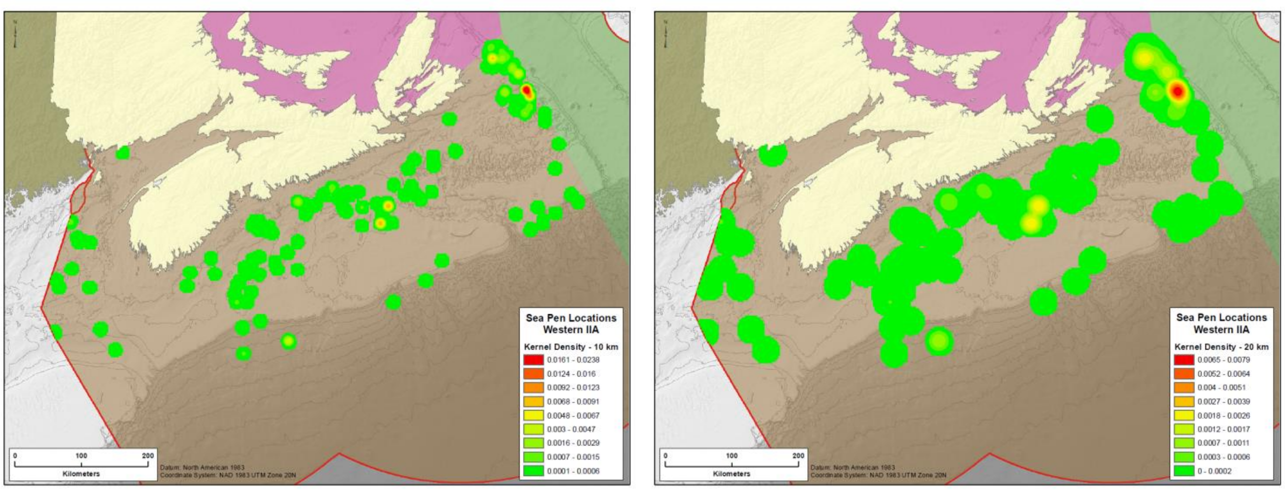

Figure 17. KDE analyses conducted with a 10 km (left) and 20 km (right) search radius. The former is under-smoothed and the latter over-smoothed.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sea pen weight threshold is provided in Table 4 and illustrated in Figure 18. The first large increase in area was found between 0.2 and 0.1 kg where area increased 638% (Table 4). However, that areal expansion was only supported by 7 additional points and examination of the spatial area occupied by the polygons showed that the key areas highlighted in the KDE were not captured. The next largest percent change in area occurred in going from 0.01 to 0.001 kg (Figure 19). This change was well supported by 54 additional data points and was accepted as the threshold. The areas occupy 9,039 km^2.

Table 4. Comparative Sea Pen Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sea Pens is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
2	1	-	21	693
1	4	3	167	2
0.75	5	1	171	14
0.5	6	1	195	80
0.2	10	4	352	638
0.1	17	7	2598	55
0.05	29	12	4020	125
0.01	75	46	9039	166
0.001	129	54	24011	693

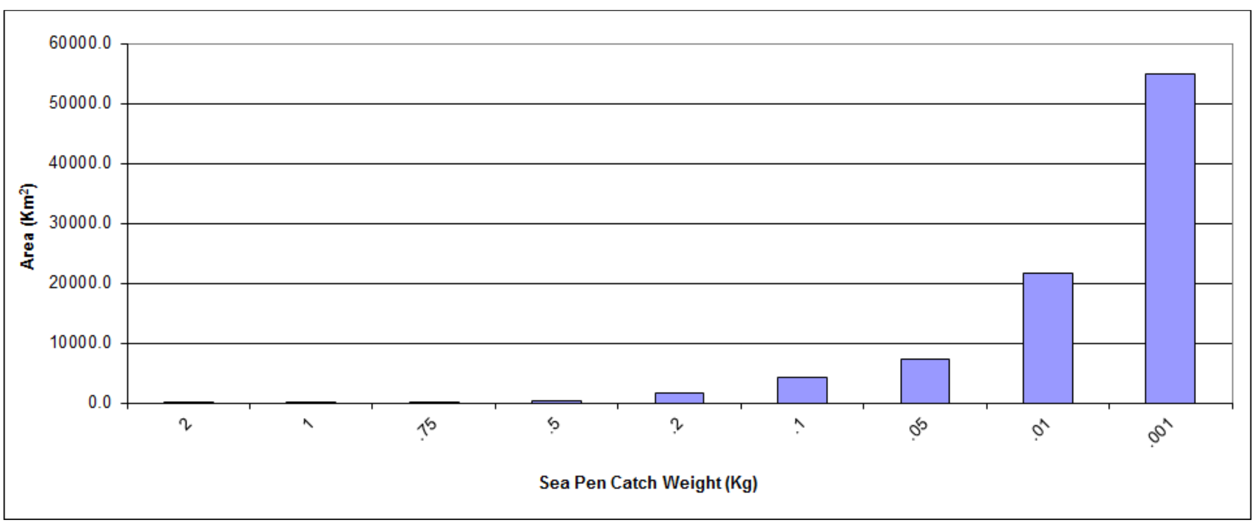

Figure 18. Barplot of polygon area (km^2) associated with sea pen weight thresholds (kg).

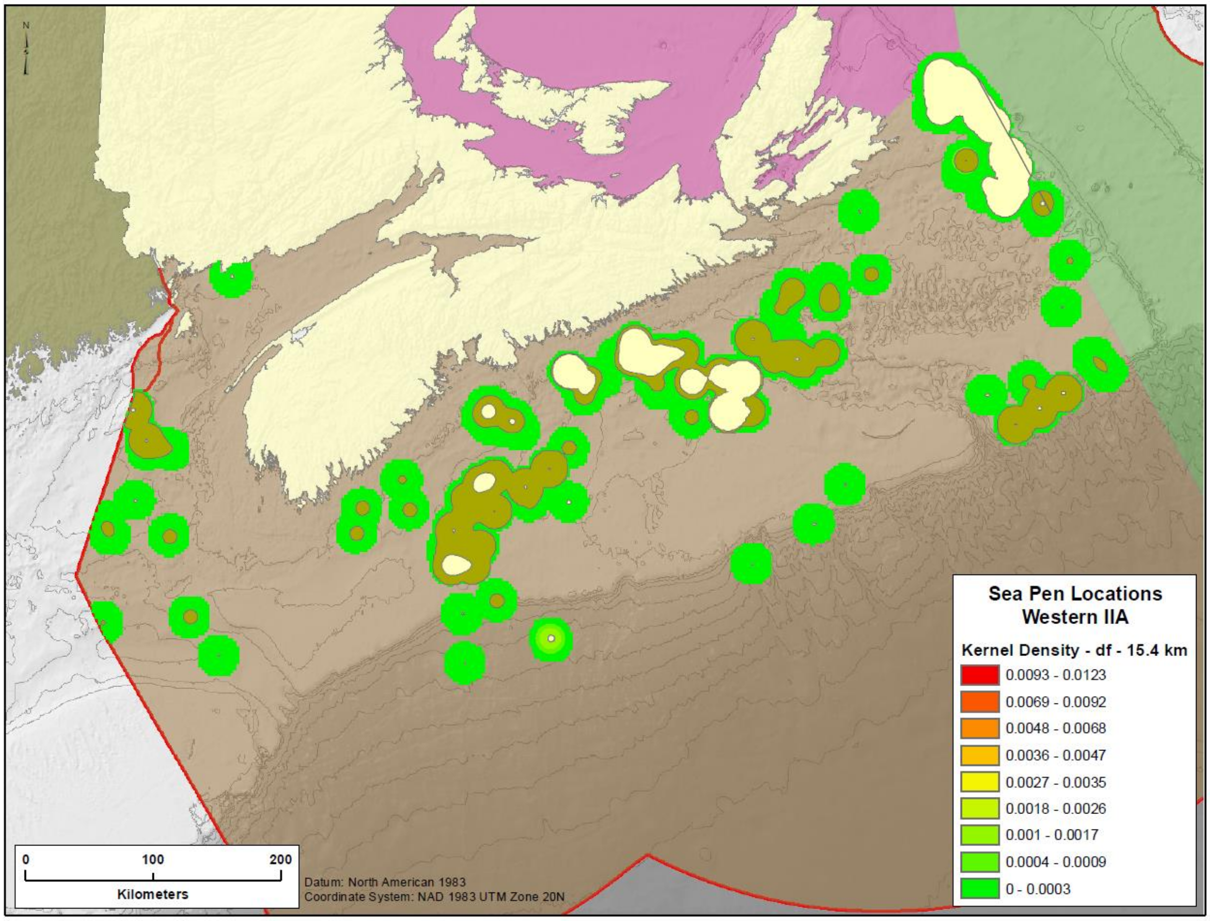

Figure 19. Location of polygons encompassing the ≥ 0.01 kg (pale cream) and ≥ 0.001 kg (olive) sea pen catches, showing the 166% increase in area (Table 4). The polygons are overlain on the KDE sea pen biomass surface produced with the default (df) search radius.

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of sea pens are shown in Figure 20 and the locations of the survey tows that defined those polygons are provided in Table 5. In Figure 21, the results of this study were compared to those produced in Kenchington et al. (2010).

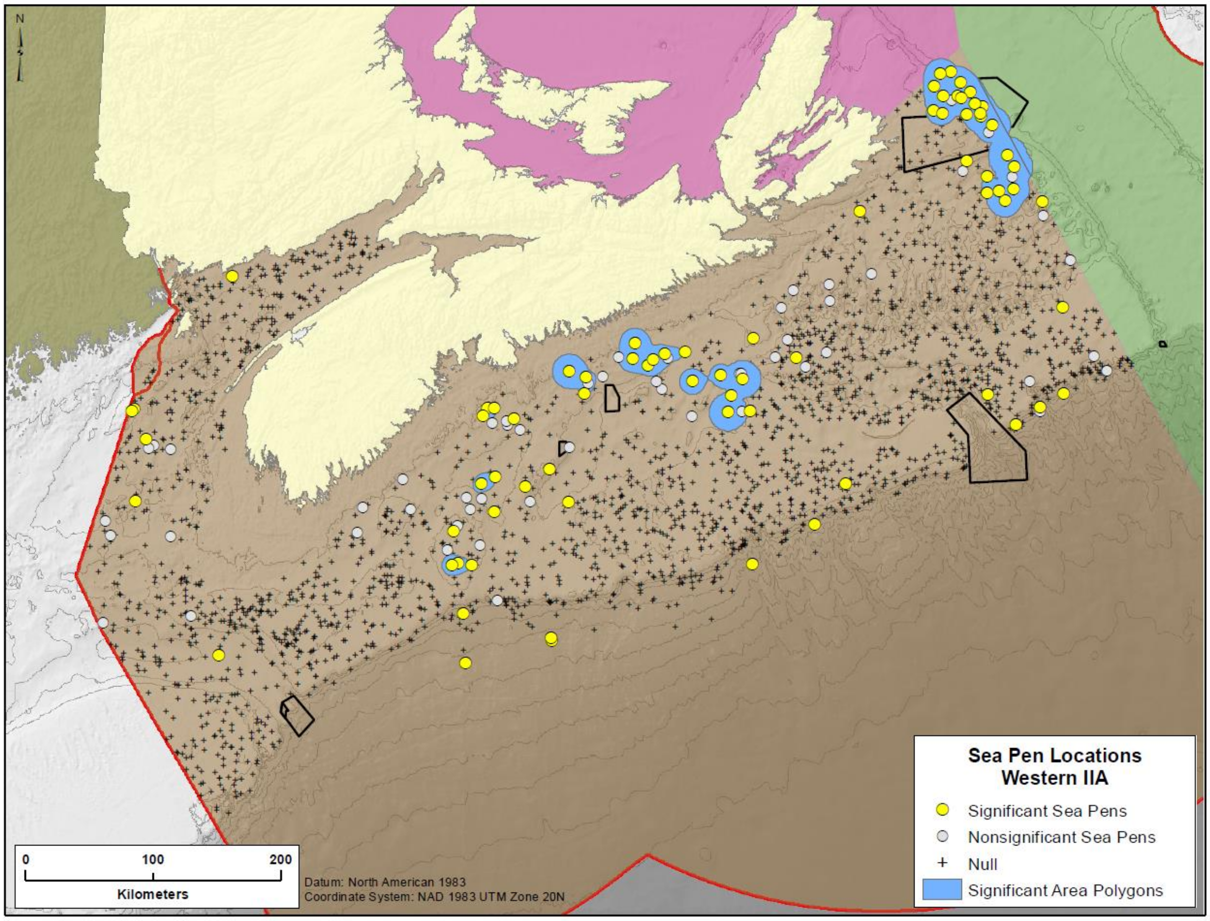

Figure 20. Location of the polygons identifying significant sea pen aggregations relative to the broader distribution of sea pens and areas closed or proposed to be closed to protect benthic species and habitats (see Fig. 7) in the Scotian Shelf Biogeographic Zone. Catches that contributed to the identification of the polygons are indicated as significant (Table 5), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

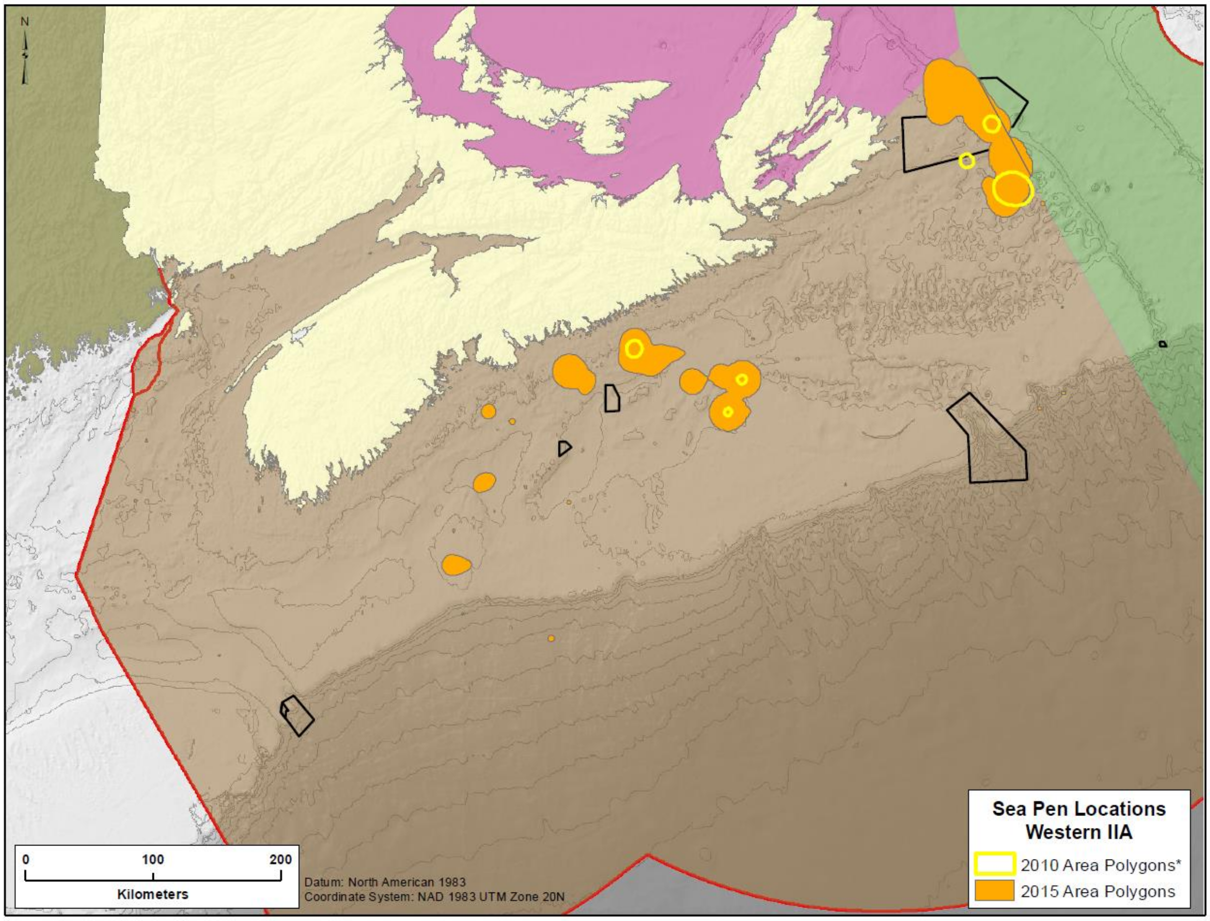

Figure 21. Comparison of the location of the significant concentrations of sea pens identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (gold/orange polygons). Areas closed or proposed to be closed to protect benthic species and habitats are indicated in outline (see Fig. 7).

Table 5. Scotian Shelf Biogeographic Zone: Details of the Location of Research Vessel Sea Pen Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sea Pen Weight (kg)
2012	NED2012022183	45.86450	-58.60300	45.84933	-58.56750	2.560
2014	NED2014018190	45.78183	-58.54517	45.78733	-58.50800	1.140
2008	TEL2008805004	44.13217	-61.47050	44.11200	-61.50200	1.000
2008	TEL2008805005	44.36333	-61.31783	44.33483	-61.32483	1.000
2011	NED2011025206	46.30867	-59.22450	46.31817	-59.26517	0.791
2007	TEL2007745156	46.08533	-58.73683	46.10350	-58.76900	0.500
2010	NED2010027235	42.55233	-63.19467	42.53867	-63.26900	0.418

2009	NED2009027153	45.84567	-59.01867	45.84250	-59.05333	0.286
2012	NED2012022145	44.43217	-63.01983	44.42367	-63.05767	0.236
2012	NED2012022180	46.15383	-58.84900	46.12867	-58.82717	0.224
2012	NED2012022186	45.54900	-58.65483	45.56067	-58.61800	0.172
2011	NED2011025205	46.28517	-59.04067	46.26383	-59.01150	0.122
2007	TEM2007686047	45.63017	-58.55867	45.65600	-58.54150	0.120
2010	NED2010027123	46.46217	-59.24517	46.44367	-59.21400	0.106
2013	NED2013028006	46.30117	-59.07783	46.27983	-59.04967	0.106
2006	NED2006036002	44.62450	-62.37233	44.63933	-62.34317	0.105
2012	NED2012022179	46.32667	-58.94800	46.30450	-58.92217	0.104
2011	NED2011025204	46.39517	-59.03783	46.37583	-59.00600	0.095
2010	NED2010027231	42.37450	-64.00817	42.38367	-64.18600	0.074
2009	NED2009027097	44.35283	-61.81300	44.35100	-61.77183	0.072
2013	NED2013022007	43.05850	-64.15167	43.06383	-64.11467	0.072
2009	NED2009027096	44.52100	-62.39700	44.53067	-62.35917	0.062
2008	TEM2008775075	44.08467	-67.27617	44.11167	-67.26050	0.060
2010	NED2010027216	43.05567	-61.25917	43.10650	-61.28400	0.058
2008	TEM2008830083	42.72067	-64.03517	42.73150	-64.00000	0.056
2003	NED2003042035	46.22017	-58.83250	46.20217	-58.80017	0.056
2012	NED2012022209	44.17650	-58.18350	44.16100	-58.20517	0.054
2009	NED2009027098	44.39467	-61.53267	44.39450	-61.49133	0.052
2013	NED2013022194	43.97467	-58.66300	43.95950	-58.69667	0.050
2012	NED2012022197	44.77633	-58.14083	44.75950	-58.17383	0.043
2002	NED2002037030	43.06100	-63.95900	43.05767	-63.91883	0.040
2010	NED2010027226	42.52917	-63.18400	42.55483	-63.11567	0.040
2011	NED2011025207	46.18850	-59.23483	46.15917	-59.23183	0.040
2011	NED2011025173	44.51350	-62.19333	44.52433	-62.15550	0.040
2011	NED2011025268	43.60367	-60.33983	43.59333	-60.37750	0.039
2010	NED2010027004	43.74450	-63.21617	43.71517	-63.21667	0.037
2010	NED2010027061	44.07017	-67.29750	44.04883	-67.32567	0.037
2013	NED2013022226	46.37800	-59.30717	46.37067	-59.34833	0.036
2006	NED2006030067	43.87417	-67.14517	43.89717	-67.13450	0.035
2012	NED2012022148	44.64933	-61.20617	44.62150	-61.21800	0.032
2013	NED2013022216	45.51967	-60.11050	45.51200	-60.15133	0.032
2008	TEM2008775078	45.04833	-66.37000	45.06417	-66.33200	0.026
2010	NED2010027005	43.61750	-63.44850	43.58883	-63.44967	0.026
2010	NED2010027074	42.37967	-66.35217	42.37700	-66.31300	0.024
2012	NED2012022146	44.47267	-62.24967	44.46350	-62.28867	0.024
2013	NED2013022008	43.29967	-64.14050	43.32833	-64.13683	0.023
2009	NED2009027099	44.24850	-61.43083	44.27500	-61.41533	0.022
2009	NED2009027159	45.52833	-58.27817	45.54550	-58.24450	0.022
2012	NED2012022147	44.55000	-62.08333	44.53333	-62.11667	0.022
2013	NED2013022004	43.63950	-63.87533	43.61383	-63.85700	0.022

2009	NED2009027100	44.13800	-61.25083	44.10883	-61.24733	0.020
2006	NED2006036001	44.38583	-62.85750	44.39517	-62.81800	0.020
2009	NED2009027148	46.20450	-59.32583	46.18317	-59.29850	0.018
2008	TEL2008805006	44.50267	-60.78400	44.53050	-60.80333	0.016
2009	NED2009027154	45.72550	-58.81683	45.73700	-58.77717	0.016
2013	NED2013022225	46.47267	-59.13733	46.48883	-59.17250	0.016
2010	NED2010027129	45.61900	-58.71017	45.59817	-58.73667	0.016
2011	NED2011025174	44.55633	-61.88483	44.55583	-61.84417	0.016
2011	NED2011025257	44.08950	-58.42083	44.06917	-58.42100	0.015
2010	NED2010027003	44.09233	-63.56250	44.10933	-63.53917	0.015
2003	NED2003036133	43.32883	-60.65517	43.33433	-60.61650	0.014
2009	NED2009027005	44.17050	-63.82133	44.19033	-63.79217	0.014
2009	NED2009027155	45.61200	-58.83167	45.58900	-58.85650	0.014
2010	NED2010027124	46.17183	-58.85917	46.15067	-58.83867	0.014
2010	NED2010027002	44.17233	-63.75867	44.14617	-63.77700	0.014
2013	NED2013028040	43.44400	-63.74350	43.41400	-63.75233	0.014
2010	NED2010027064	43.44067	-67.21517	43.42033	-67.24300	0.014
2013	NED2013022003	44.11383	-63.86967	44.09217	-63.89600	0.014
2011	NED2011025172	44.26900	-62.87367	44.28250	-62.83783	0.014
2013	NED2013022223	46.23983	-58.90150	46.25867	-58.93433	0.012
2010	NED2010027006	43.68600	-63.74383	43.69750	-63.77983	0.012
2002	NED2002037029	43.07533	-64.08850	43.05467	-64.11733	0.010
2009	NED2009027008	43.51000	-63.02600	43.53117	-62.99883	0.010
2008	TEL2008805016	44.19017	-58.92650	44.17350	-58.88967	0.010
2007	TEL2007745157	46.17000	-58.99167	46.18667	-59.02533	0.010

Large Gorgonian Corals

Data Sources and Distribution

The data available for analysis of large gorgonian corals in the Scotian Shelf Biogeographic Zone was collected over 14 years from 2002 to 2015. There were 62 records with large gorgonian coral catch and 1907 records of catches with none of those corals from the same surveys. In contrast, only 33 records were available to the previous analysis (Kenchington et al., 2010). All surveys that were used in this time series were conducted with Western IIA trawls with tow locations chosen following a stratified random design (Frank, 2004; Kulka et al., 2006; Chadwick et al., 2007). A large area off southwest Nova Scotia was excluded from the survey area due to rough bottom (Figure 22). Consistent reporting of invertebrate catch protocols in these surveys was not practised until 2005 and so null data from before that year were not included. Catch weights of large gorgonian corals can be unreliable as they are fragile and easily break. The data were extracted from the Maritimes Region Virtual Data Centre (VDC). In this biogeographic zone, the data were restricted to the shelf and upper slope with most of the area in deeper water extending out to the EEZ not surveyed (Figure 22). Within the surveyed area, the large gorgonian corals were distributed on the continental slopes and along the Stone Fence area (Figure 22).

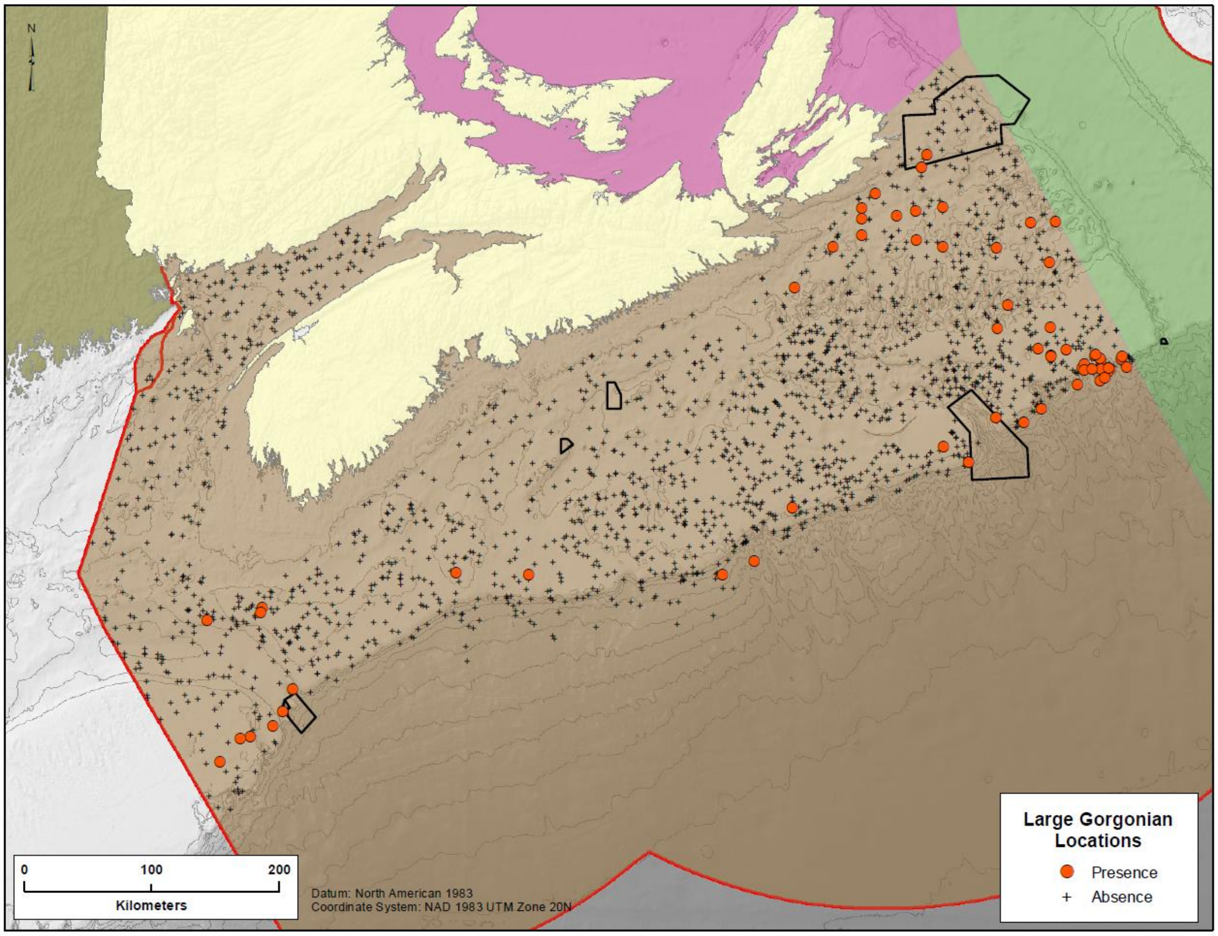

Figure 22. Distribution of large gorgonian corals from DFO research vessel survey catches using a Western IIA trawl. The Northeast Channel Coral Conservation Area, the Gully Marine Protected Area, the *Vazella* Sensitive Benthic Area and the St. Ann's Bank Proposed Closed Area are depicted in outline (see Fig. 7). Coloured circles indicate large gorgonian coral presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 15.825 km. We compared that KDE surface with those produced by using 10 km and 20 km search radii. The 10 km radius produced a good fit to the data (Figure 23) as did the default value (Figure 24), while the 20 km over-smoothed the data (Figure 24). The 10 km search radius was used in the preparation of the KDE surface as this did not create extensive extrapolation around singletons. The grid size was 2.30 km^2. Contours placed over the KDE surface were finely spaced at 0.00001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

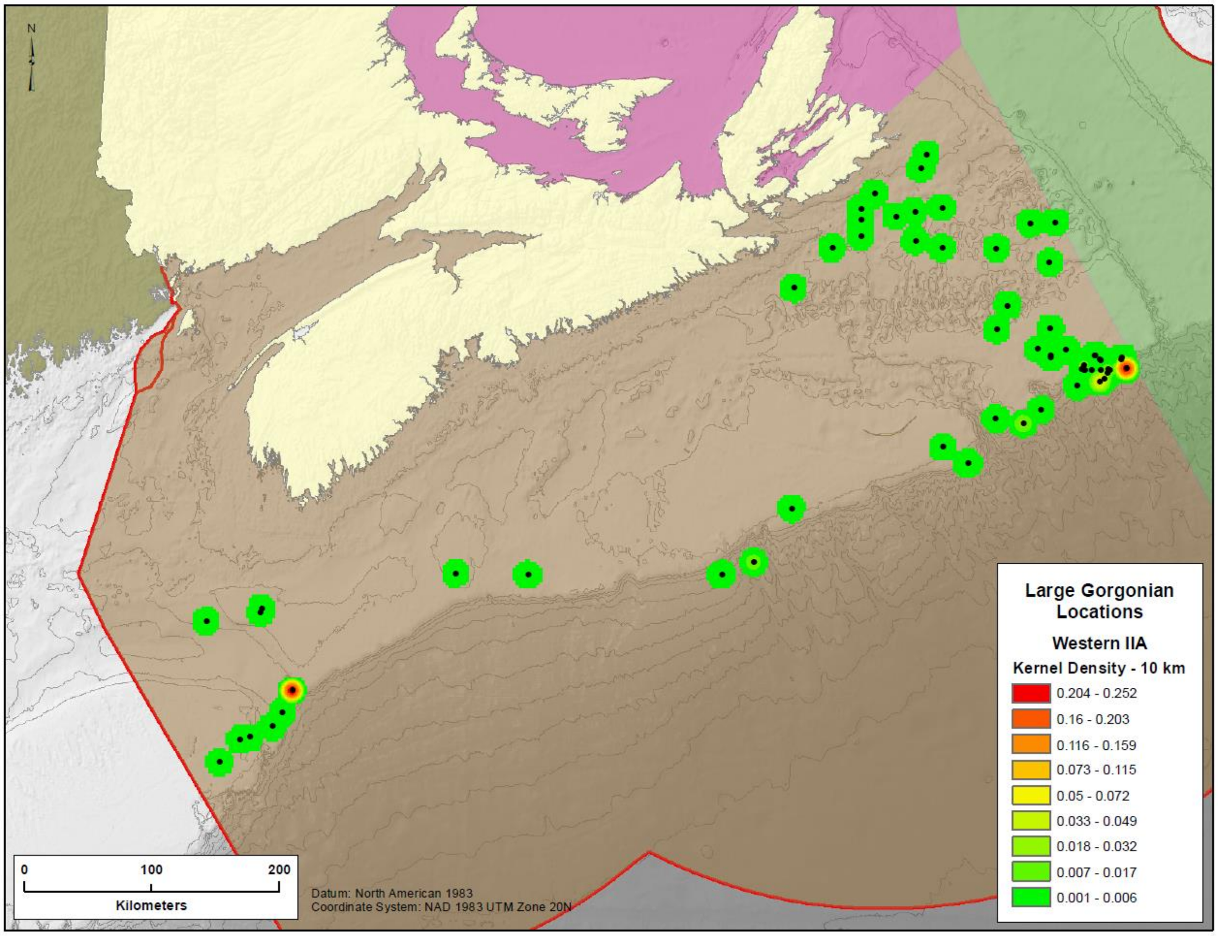

Figure 23. KDE surface of large gorgonian coral biomass produced with the 10 km search radius. Locations of research vessel tow data points are indicated with black points.

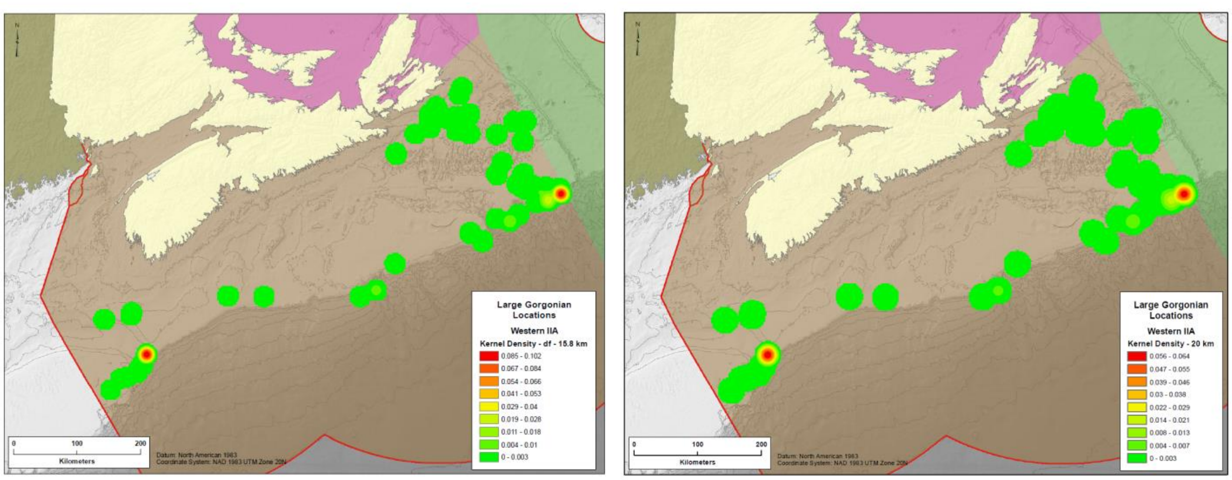

Figure 24. KDE analyses conducted with a default (df) 15.825 km (left) and 20 km (right) search radius.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each large gorgonian weight threshold was provided in Table 6 and illustrated in Figure 25. The first large increase in area was found between 0.3 and 0.1 kg where area increased 107% (Table 6). That areal expansion was supported by only 7 additional points and so was not well supported. We then looked at the polygons produced by the 0.01 and 0.001 kg thresholds. The increase in area was well supported by 16 additional data points and the 0.01 kg threshold was adopted. The areas occupy 1,528 km^2 (Table 6).

Table 6. Comparative Large Gorgonian Coral Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Large Gorgonian Corals is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
5	3	-	5	42
2	4	1	7	1
1	5	1	7	6748
0.5	8	3	464	0
0.3	10	2	464	107
0.1	17	7	961	4
0.05	22	5	995	54
0.01	45	23	1528	106
0.001	61	16	3149	

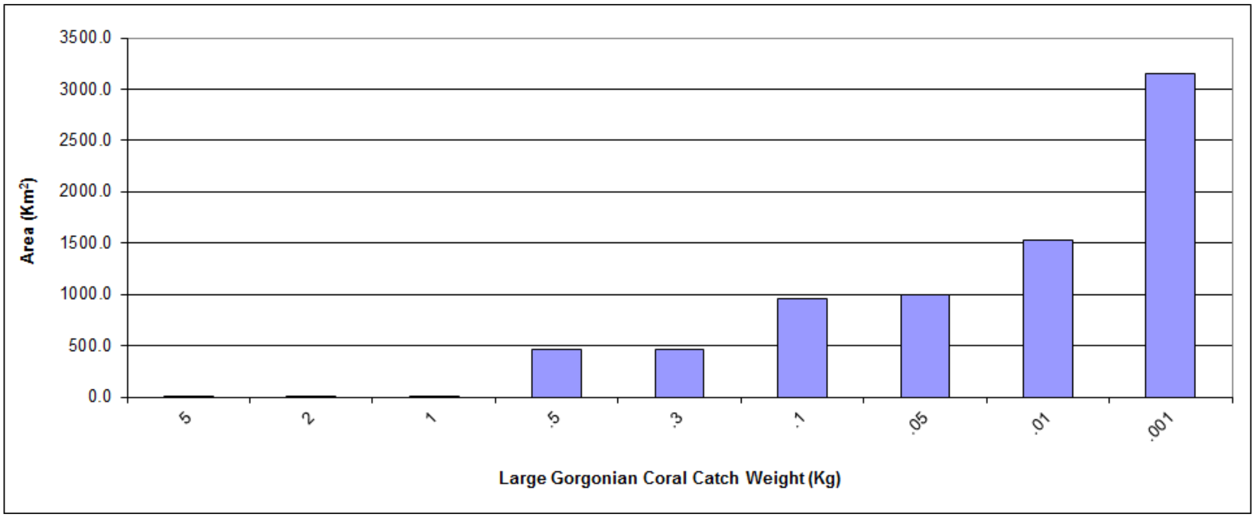

Figure 25. Barplot of polygon area (km^2) associated with large gorgonian coral weight thresholds (kg).

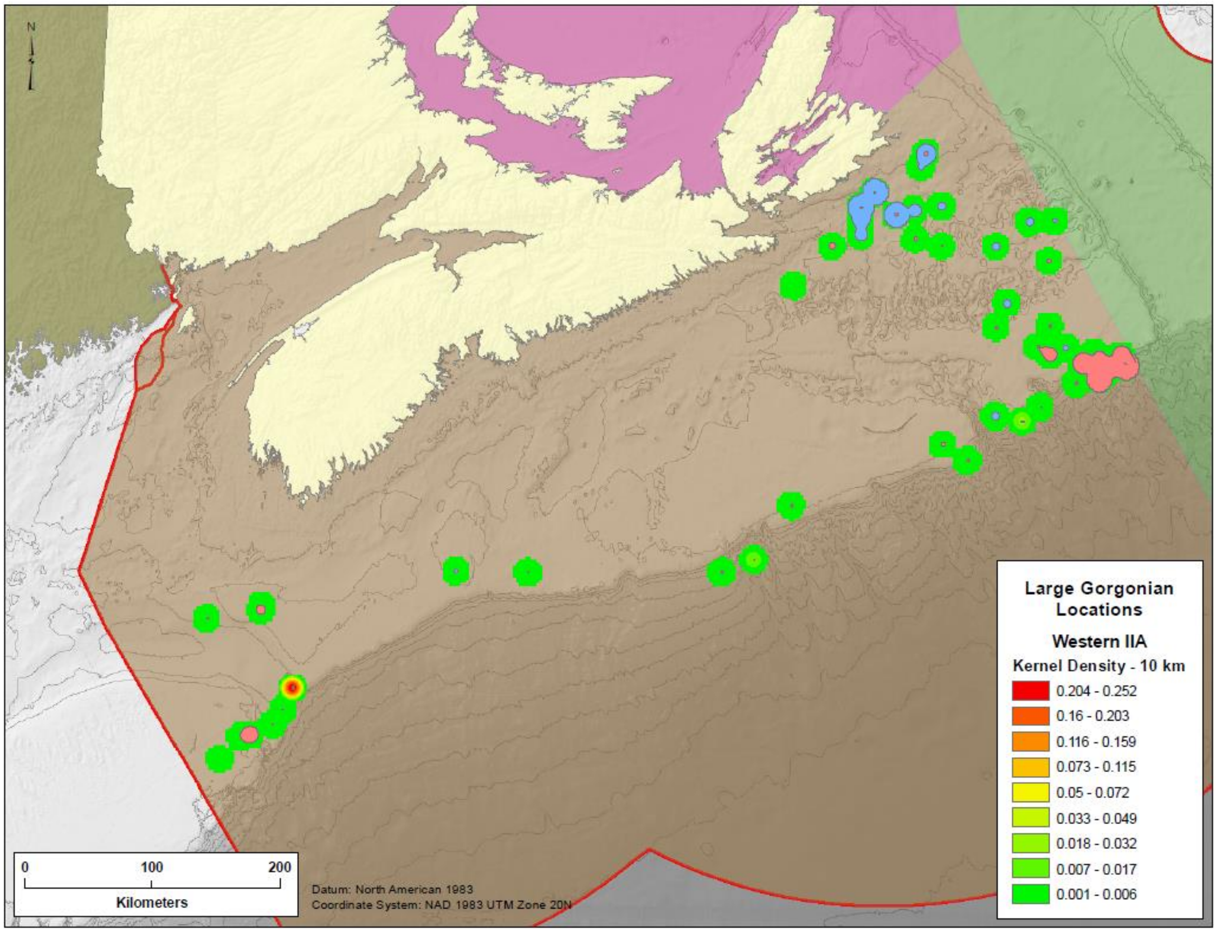

Figure 26. Location of polygons encompassing the ≥0.01 kg (pink) and ≥0.001 kg (blue) large gorgonian coral catches, showing the increase in area (Table 6). The polygons are overlain on the KDE large gorgonian biomass surface produced with a 10 km search radius.

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of large gorgonian corals are shown in Figure 27 and the locations of the survey tows that defined those polygons are provided in Table 7. In Figure 28, the results of this study were compared to those produced in Kenchington et al. (2010).

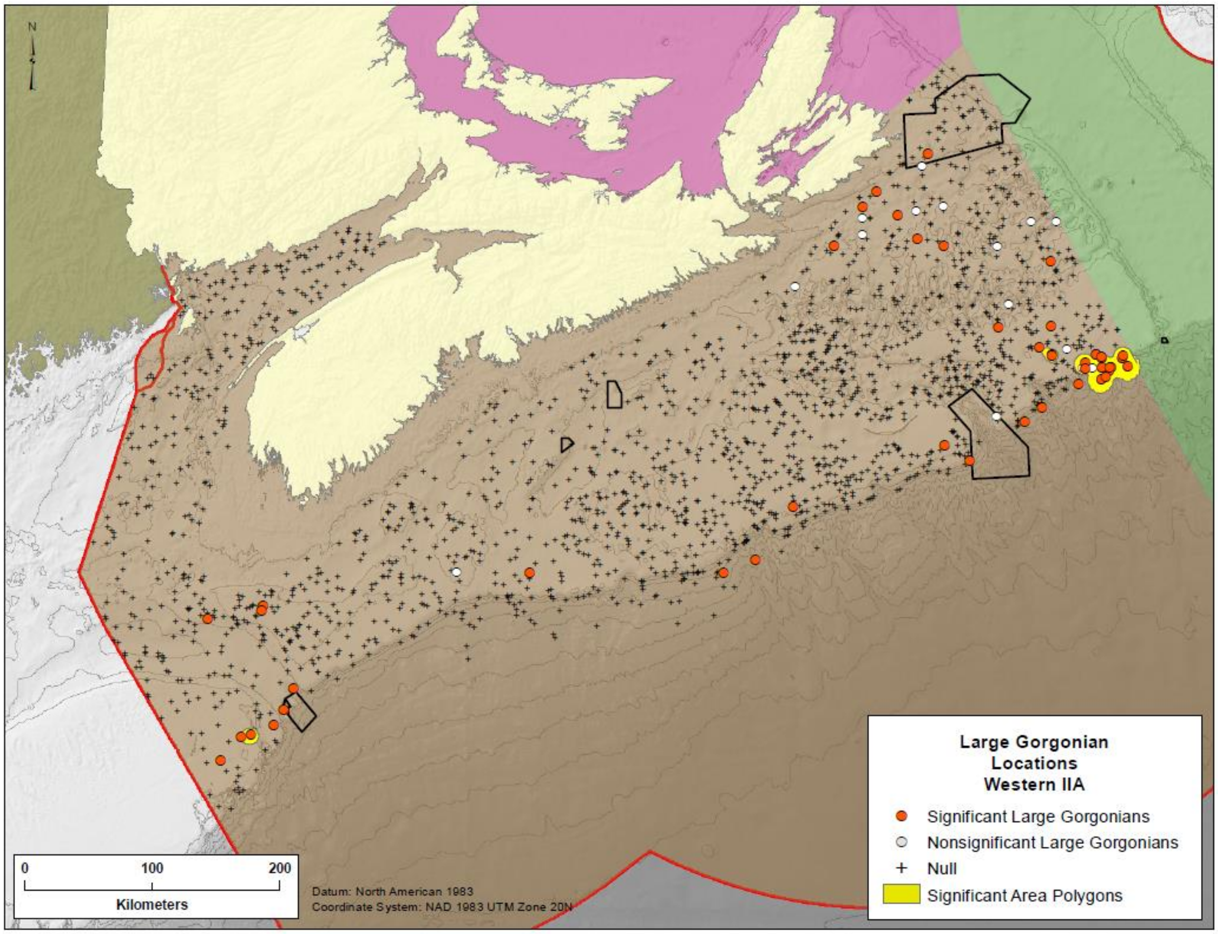

Figure 27. Location of the polygons identifying significant large gorgonian coral aggregations relative to the broader distribution of large gorgonian corals and areas closed or proposed to be closed to protect benthic species and habitats (see Fig. 7) in the Scotian Shelf Biogeographic Zone. Catches that contributed to the identification of the polygons are indicated as significant (Table 7), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

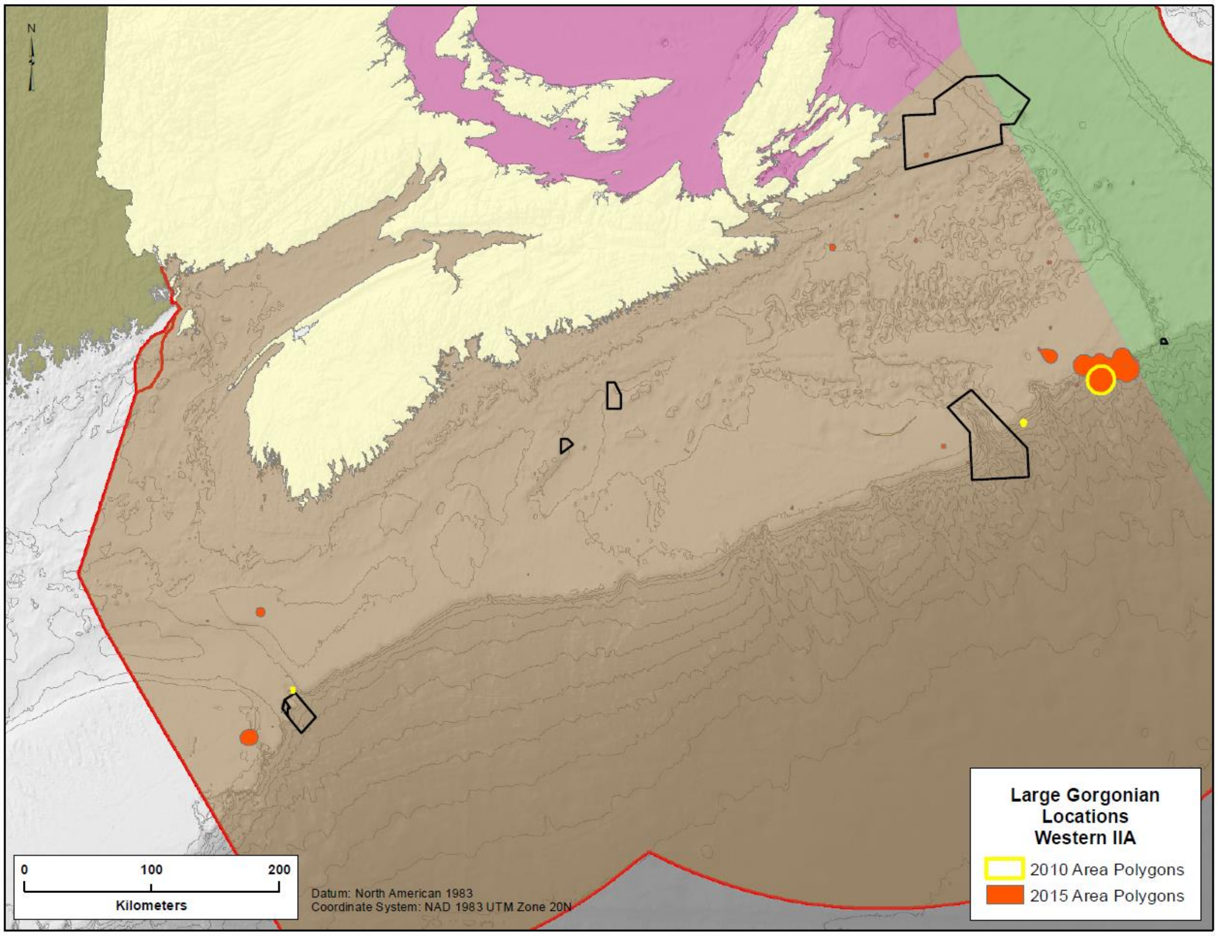

Figure 28. Comparison of the location of the significant concentrations of large gorgonian corals identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (orange polygons). Areas closed or proposed to be closed to protect benthic species and habitats are indicated in outline (see Fig. 7).

Table 7. Scotian Shelf Biogeographic Zone: Details of the Location of Research Vessel Large Gorgonian Coral Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Large Gorgonian Coral Weight (kg)
2007	TEL2007745058	42.13483	-65.66050	42.14050	-65.62250	27.109
2011	NED2011025229	44.30500	-57.56900	44.29133	-57.59083	26.025
2002	NED2002040055	44.22383	-57.83533	44.23867	-57.86467	6.000
2006	NED2006036061	43.96300	-58.60717	43.94900	-58.64150	2.170
2010	NED2010027216	43.05567	-61.25917	43.10650	-61.28400	1.494

2011	NED2011025232	44.34567	-57.98333	44.31733	-57.99350	0.850
2005	TEL2005633050	44.30533	-57.73167	44.28350	-57.75667	0.570
2011	NED2011025230	44.38333	-57.60183	44.38083	-57.64567	0.538
2009	NED2009027179	44.28350	-57.75800	44.25483	-57.76333	0.460
2015	NED2015002023	41.97783	-65.74633	41.95100	-65.72617	0.326
2012	NED2012022164	45.62250	-59.96500	45.64050	-59.93233	0.203
2009	NED2009027036	42.67533	-65.98717	42.66850	-65.96267	0.160
2007	TEL2007745068	42.97783	-63.43167	42.97683	-63.39267	0.140
2015	NED2015002027	41.79417	-66.04533	41.76650	-66.05217	0.129
2013	NED2013022216	45.51967	-60.11050	45.51200	-60.15133	0.112
2003	NED2003042066	44.05333	-58.42500	44.03817	-58.42500	0.110
2005	TEL2005633051	44.37150	-57.81367	44.37900	-57.85317	0.105
2005	NED2005034051	44.38050	-57.82000	44.38617	-57.85917	0.096
2015	NED2015002030	41.61183	-66.32217	41.58350	-66.31433	0.082
2011	NED2011025231	44.30683	-57.82133	44.28467	-57.84917	0.078
2014	NED2014018158	45.45783	-59.75917	45.46767	-59.72067	0.059
2012	NED2012022162	45.22467	-59.31400	45.23583	-59.28817	0.052
2013	NED2013022190	44.62067	-58.29100	44.60100	-58.26067	0.041
2013	NED2013022200	44.31000	-57.74550	44.32467	-57.72200	0.041
2013	NED2013022154	44.63100	-58.81617	44.64333	-58.85267	0.040
2014	NED2014018206	44.31233	-57.97950	44.33933	-57.96883	0.035
2011	NED2011025238	44.47817	-58.42183	44.48633	-58.46133	0.032
2011	NED2011025237	44.42700	-58.30400	44.45067	-58.33000	0.032
2015	NED2015002024	41.87467	-65.83533	41.89600	-65.86450	0.030
2014	NED2014018205	44.20783	-58.06183	44.18967	-58.06650	0.029
2015	NED2015002028	41.77850	-66.13650	41.75083	-66.14500	0.028
2013	NED2013022191	44.41517	-58.30017	44.38583	-58.30483	0.028
2009	NED2009027042	42.60000	-66.49667	42.60550	-66.45800	0.026
2005	NED2005034015	45.87867	-59.43333	45.88833	-59.40933	0.025
2008	TEL2008805062	43.42867	-60.88283	43.43967	-60.85833	0.020
2003	NED2003042049	44.24117	-57.79067	44.26433	-57.76750	0.018
2012	NED2012022161	45.28167	-59.57750	45.28217	-59.61800	0.017
2012	NED2012022192	45.07983	-58.26033	45.05050	-58.26583	0.016
2012	NED2012022159	45.25500	-60.40933	45.23233	-60.38317	0.016
2003	NED2003042069	43.82617	-59.39150	43.80850	-59.42300	0.016
2005	NED2005034052	44.40733	-57.86833	44.40767	-57.90867	0.015
2013	NED2013022029	42.70733	-65.97600	42.68733	-66.00483	0.012
2009	NED2009027178	44.36950	-57.61650	44.36817	-57.65700	0.012
2003	NED2003042068	43.70533	-59.15883	43.69167	-59.19383	0.010
2010	NED2010027218	42.97150	-61.56617	42.99050	-61.53467	0.010

Newfoundland and Labrador Shelves Biogeographic Zone

In this biogeographic zone our analyses were conducted on sponges, sea pens and large and small gorgonian corals. Note that this area extends onto the Scotian Shelf, which allows for both slopes of the Laurentian Channel to be considered as one unit. The species that comprised each taxon used for the analyses are provided in Guijarro et al. (2016).

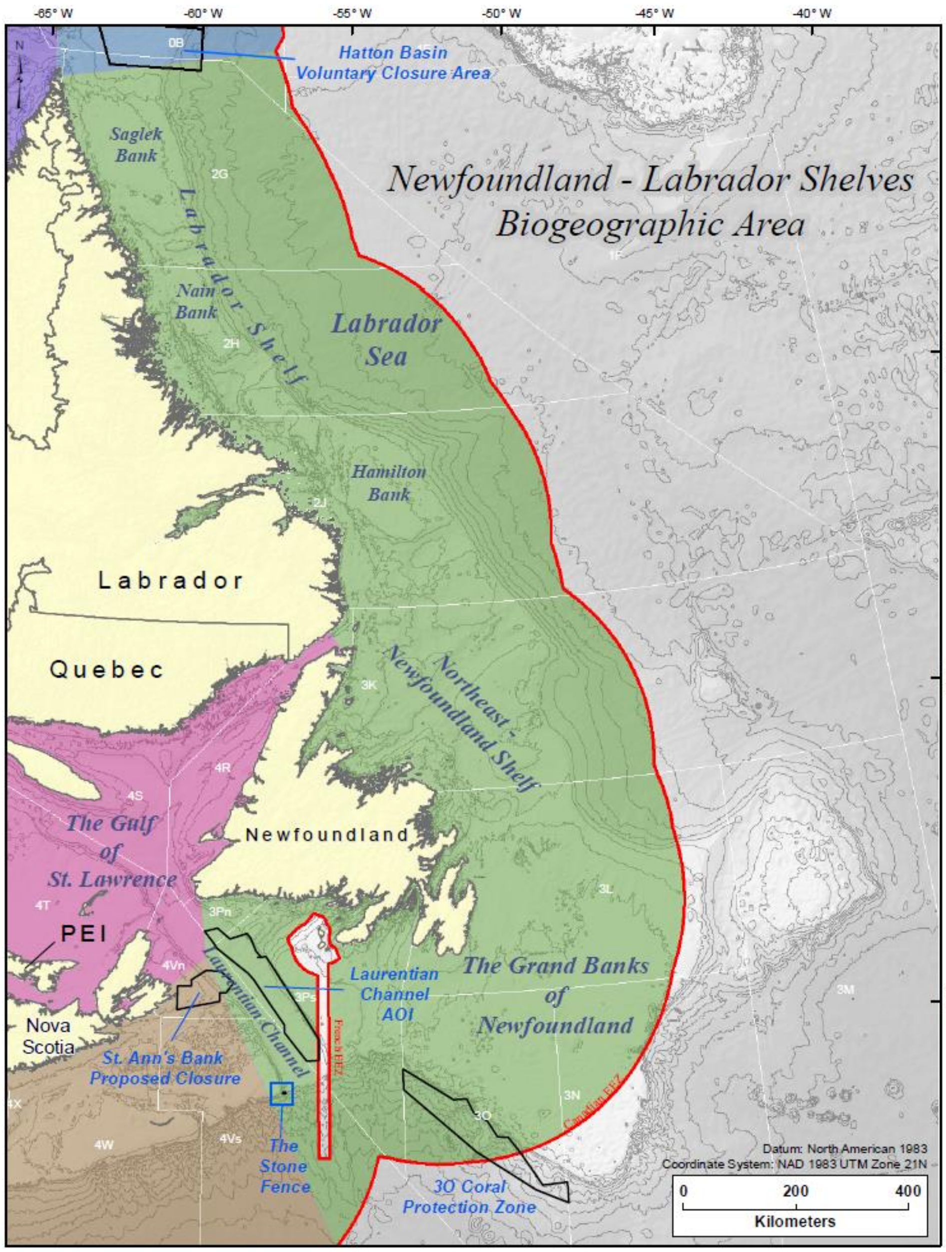

Figure 29. Map showing the area of the Newfoundland and Labrador Shelves Biogeographic Zone in green (DFO, 2009), with some place names, areas closed or proposed to be closed to protect benthic species and habitats, and the Canadian and French Exclusive Economic Zones (EEZ; red line).

Sponges (Porifera)

Data Sources and Distribution

The data available for the analysis of sponges in the Newfoundland and Labrador Shelves Biogeographic Zone came from 3 DFO administrative regions (Newfoundland and Labrador, Maritimes, and Quebec) conducted over 21 years from 1995 to 2015.

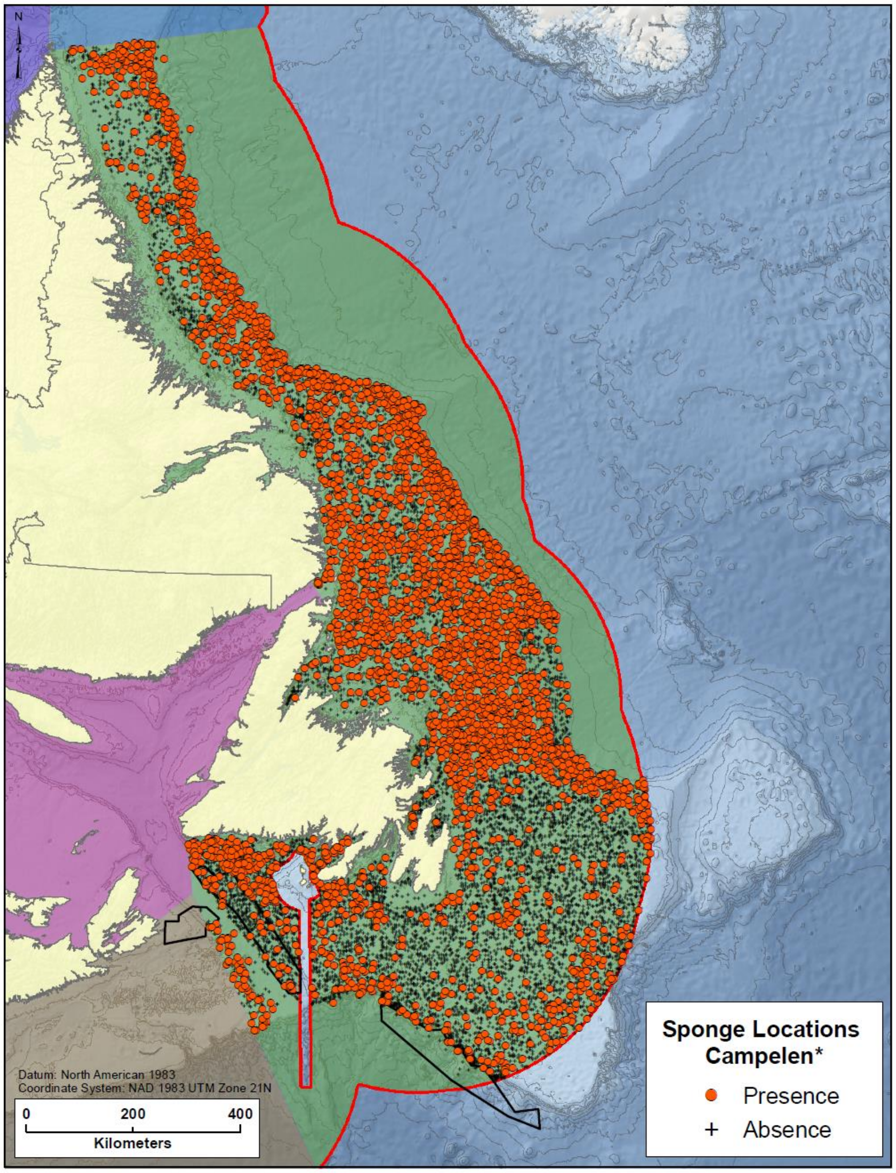

Figure 30. Distribution of sponges from DFO research vessel survey catches mostly* using a Campelen trawl. The 3O Coral Closure, the St. Ann's Bank Proposed Closed Area and the Laurentian Channel Proposed Closed Area are depicted in outline (see Fig. 29). Coloured circles indicate sponge presence in the catch and black crosses indicate verified null records. *A Western IIA trawl was used on the Nova Scotia side of the Laurentian Channel.

There were 4184 records with sponge catch (98% from the Newfoundland and Labrador Region of DFO) and 12,275 records of catches with no sponges from the same surveys. This represented 2463 more presence records than were available for the previous analyses (Kenchington et al., 2010). All surveys that were used in this time series were conducted with a Campelen trawl except for those from Maritimes Region that used a Western IIA trawl. For all surveys, tow locations were chosen following a stratified random design (Kulka et al., 2006; Chadwick et al., 2007). Within the surveyed area, the sponges were broadly present over most of the continental shelves and slopes but were less common on The Grand Banks of Newfoundland and on the northern Labrador Shelf (Figure 30).

Evaluation of Search Radii

The default search radius for the KDE was 35.9563 km. We compared that KDE surface with that produced by using a 25 km search radius, as the default search radius over-smoothed the data (Figure 31). The 25 km search radius was adopted for the preparation of the KDE surface in order to give tighter fit around the polygon boundaries. The grid size was 4.6939 km^2. Contours placed over the KDE surface were finely spaced at 0.0005 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons. The final KDE surface is shown in Figure 32 in relation to the tow positions that caught sponges.

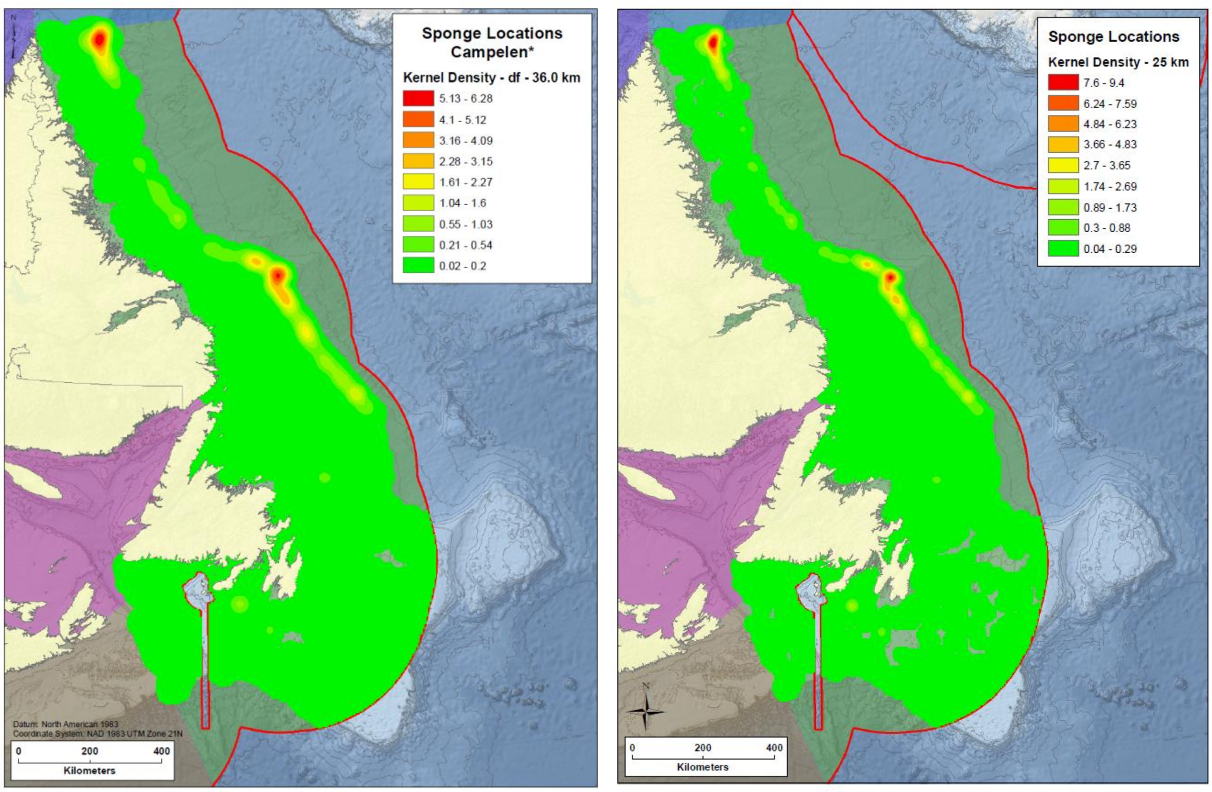

Figure 31. KDE surface of sponge biomass produced with the default (df) search radius (36 km) (left) and 25 km (right) search radius. The former is over-smoothed.

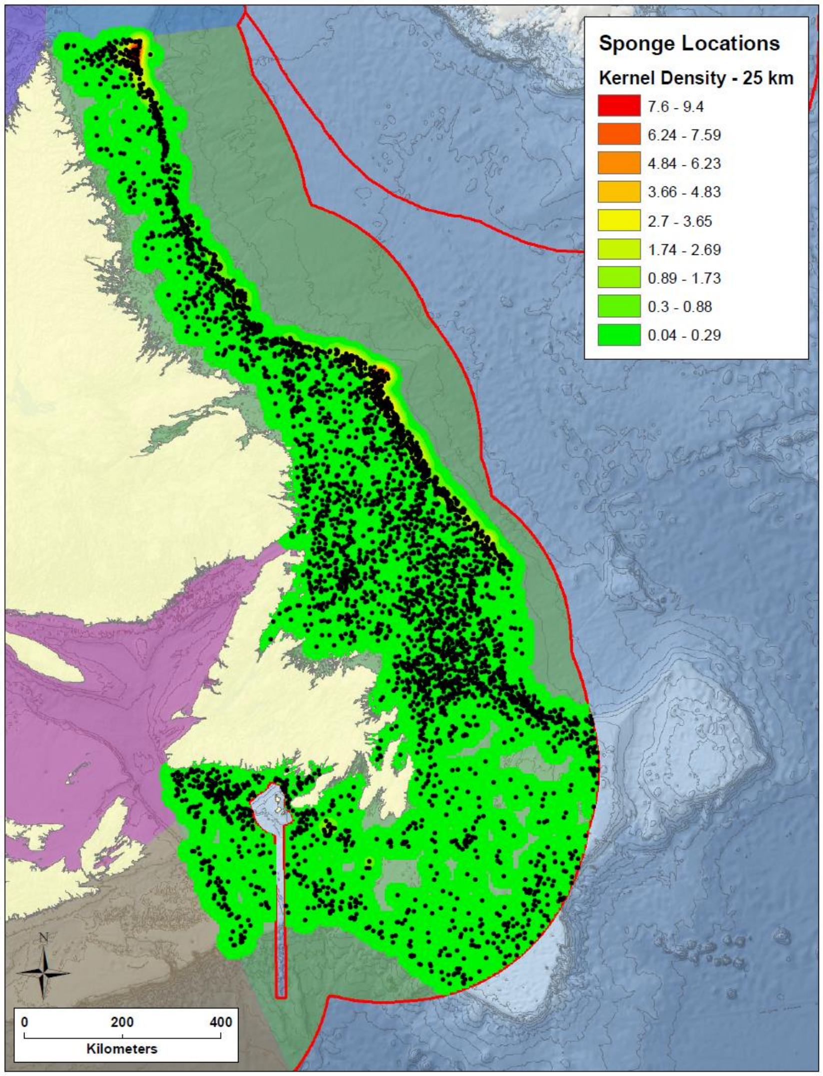

Figure 32. KDE analyses conducted with a 25 km search radius. Tow positions with sponge catch are depicted by black closed circles.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sponge weight threshold is provided in Table 8 and illustrated in Figure 33. The first large increase in area was found between 400 and 300 kg where area increased 95% (Table 8). However, that increase was an expansion of the core areas established with the higher weight thresholds. In fact, there was very little change in area between thresholds of 100 kg and 60 kg, despite 55 additional points being incorporated (Table 8), suggesting that the sponge grounds were still being mapped out within that range. In contrast, the areas occupied by the 40 kg and 30 kg catch polygons (Figure 34) showed that the change in area going to 30 kg was due to new areas being created on the continental shelf. Likely the species were different on the continental slope from those on the shelf. Figure 34 shows the area occupied by polygons produced by 200 kg, 40 kg and 30 kg catches. Consequently we selected 40 kg as the catch threshold for delimiting the sponge grounds in this region. The areas occupy 43,854 km^2. However the polygon on the shelf identified by the 30 kg threshold might be considered as an area for further evaluation (Figure 34). If the species composition of that area is different from that of the slopes it could also be considered a significant polygon.

Table 8. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
1000	5	-	1286	55
750	11	6	1993	205
500	32	21	6086	5
400	39	7	6407	95
300	55	16	12485	62
200	98	43	20256	42
100	179	81	28838	9
90	190	11	31528	1
80	198	8	31735	1
70	218	20	32080	1
60	234	16	32327	0
50	265	31	32341	36
40	292	27	43854	47
30	341	49	64308	24
20	431	90	79528	92
10	645	214	152844	72
5	1066	421	263565	68
1	2453	1387	442818	

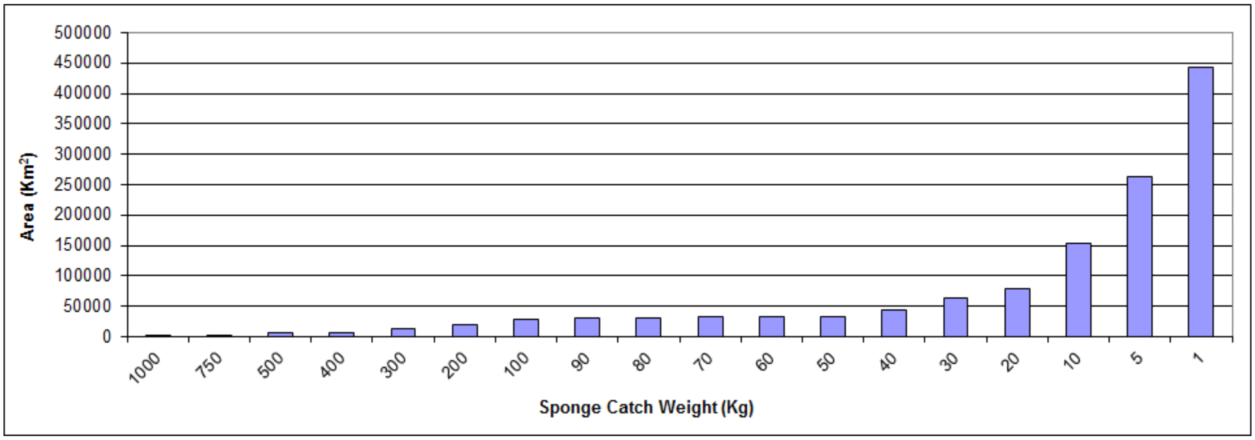

Figure 33. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

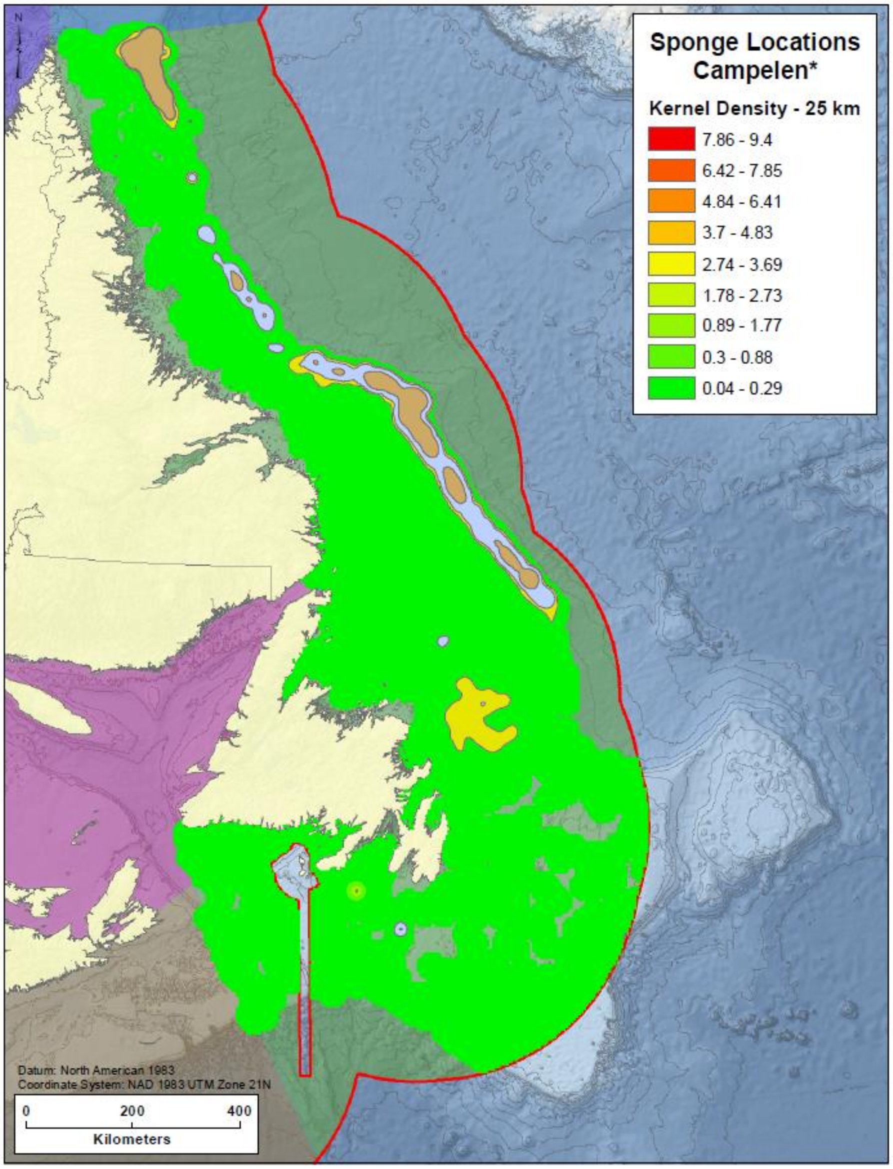

Figure 34. Location of polygons encompassing the ≥200 kg catches (light brown), the ≥40 kg catches (light purple), and the ≥30 kg catches (gold), showing the increase in area (Table 8) produced by the latter threshold in establishing areas on the continental shelf. The polygons are overlain on the KDE biomass surface produced with the 25 km search radius.

Location of the Dense Aggregations

The locations of areas that indicate significant concentrations of sponges are shown in Figure 35 and the locations of the survey tows that defined those polygons are provided in Table 9. The polygons capture sponge grounds along the Labrador Slope and each of the polygons is well supported (Figure 35 right panel) at its shallow border. In Figure 36, the results of this study are compared to those produced in Kenchington et al. (2010).

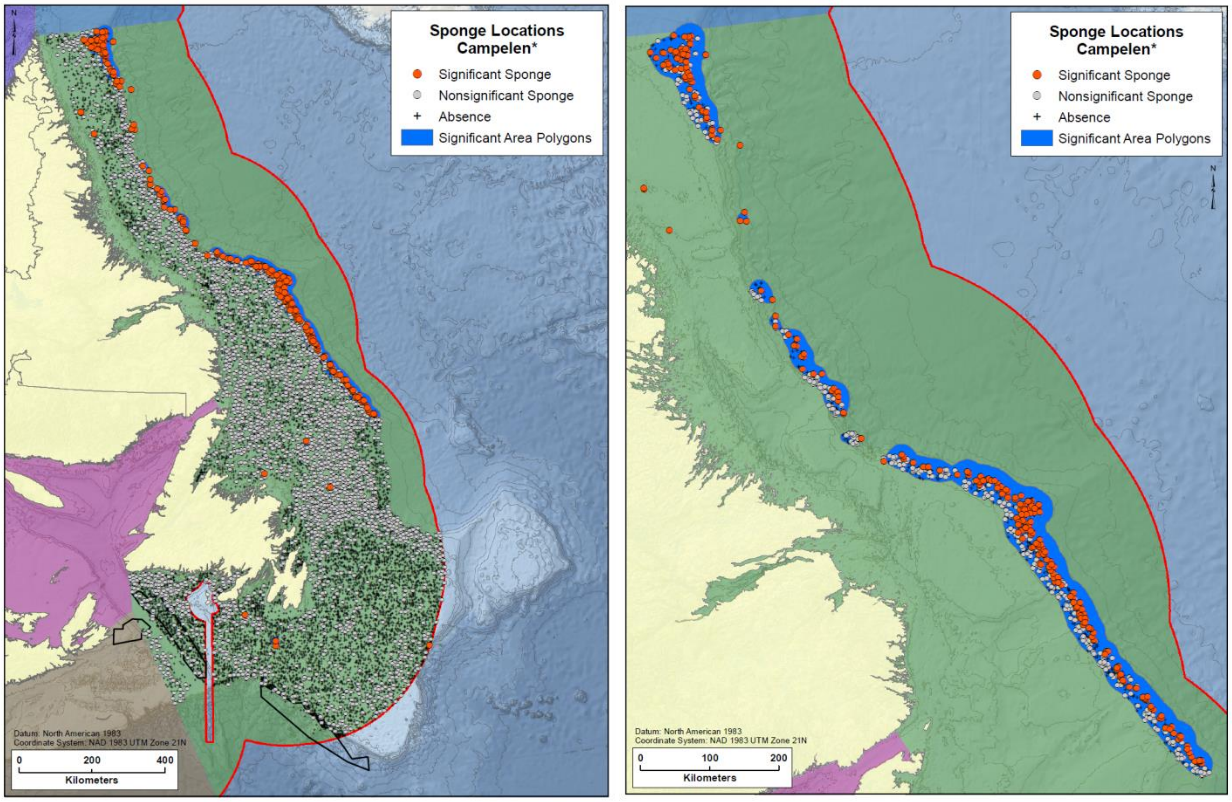

Figure 35. Location of the polygons identifying significant sponge aggregations relative to the broader distribution of sponges and areas closed or proposed to be closed to protect benthic species and habitats (see Fig. 29) in the Newfoundland and Labrador Shelves Biogeographic Zone. Catches that contributed to the identification of the polygons are indicated as significant (Table 9), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross. The left panel shows the full distribution while the right panel shows a close-up of the polygons on the Labrador Slope with all records inside each polygon illustrated.

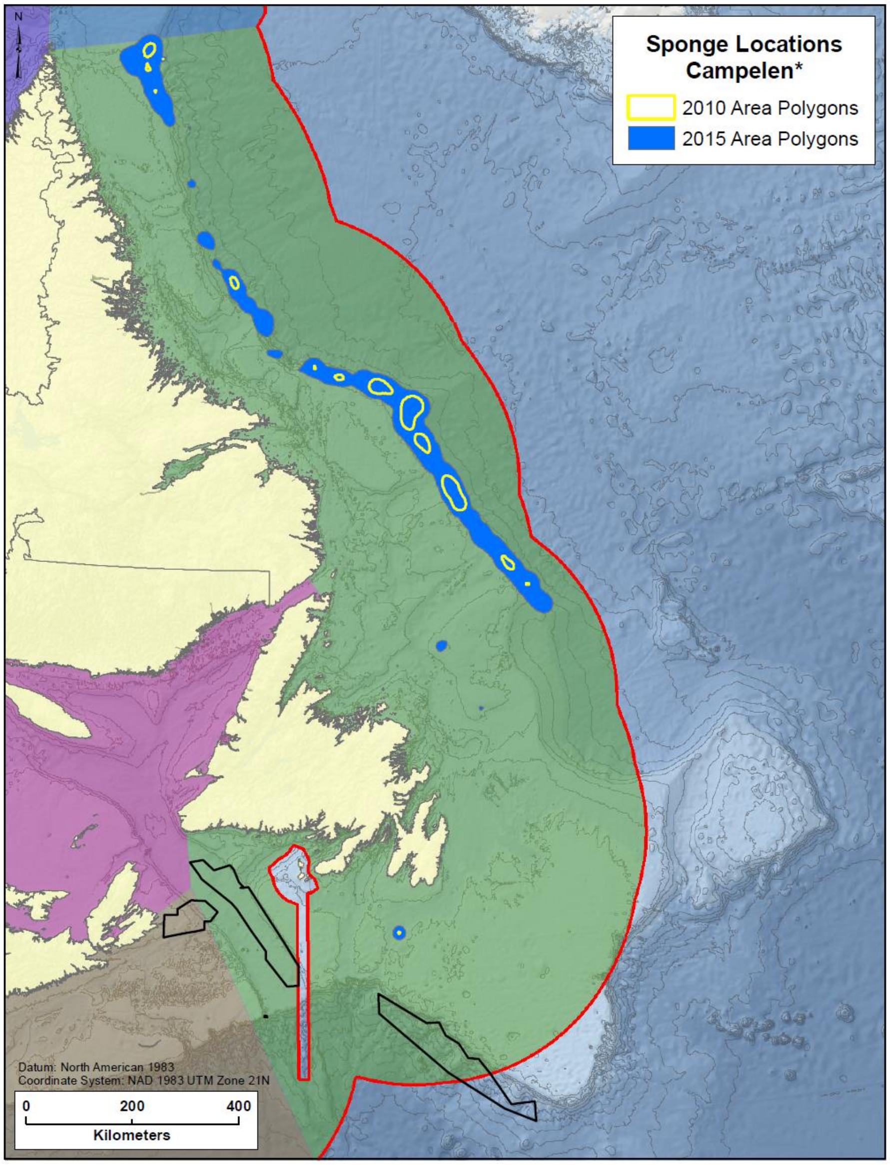

Figure 36. Comparison of the location of the significant concentrations of sponge identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (blue polygons). Areas closed or proposed to be closed to protect benthic species and habitats are indicated in outline (see Fig. 29).

Table 9. Newfoundland and Labrador Shelves Biogeographic Zone: Details of the Location of Research Vessel Sponge Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)
2011	BAL2011106067	60.47233	-61.28593	60.45592	-61.27250	1226.29
2008	BAL2008103072	60.75800	-61.21000	60.74800	-61.21200	1200.00
2008	BAL2008103070	60.37500	-61.25000	60.39500	-61.24300	1043.21

2010	BAL2010105080	60.64632	-61.32495	60.63208	-61.31115	1010.30
1997	TEL1997053051	60.81167	-61.19500	60.81167	-61.19500	1000.00
2012	NED2012415019	46.52000	-55.00000	46.53167	-55.00000	823.68
2008	BAL2008103071	60.61617	-61.27033			800.00
2006	BAL2006101084	60.64300	-61.43300	60.65000	-61.45700	800.00
2010	BAL2010105077	60.22763	-61.09982	60.24343	-61.11322	795.61
2010	TEL2010978067	51.59833	-50.09667	51.59000	-50.08500	779.52
2009	TEL2009896013	54.69000	-52.85833	54.69667	-52.84333	750.00
2010	BAL2010105079	60.57203	-61.37953	60.55917	-61.35598	745.62
2007	TEL2007753044	55.03333	-53.65833	55.02167	-53.65667	602.75
2009	BAL2009104061	60.04833	-61.00250	60.03750	-60.98633	600.00
2014	TEL2014135048	54.78833	-52.98500	54.78500	-52.96500	599.22
2001	TEL2001361039	54.72167	-52.77667	54.71167	-52.79000	591.80
2007	TEL2007753045	55.08167	-53.98833	55.07000	-53.97833	580.90
2007	BAL2007102056	60.02500	-60.99200	60.03500	-61.00200	579.65
2009	BAL2009104068	60.60733	-61.39233	60.61993	-61.38900	550.00
1996	TEL1996039053	54.78167	-52.95667	54.79000	-52.97333	550.00
2012	AQV2012107062	59.84260	-60.77070	59.85222	-60.78702	538.66
2004	TEL2004539034	55.09167	-53.97000	55.08000	-53.97333	521.20
2004	TEL2004539092	52.00000	-50.66000	52.01000	-50.67167	519.05
2005	TEL2005611034	53.93500	-52.54500	53.92500	-52.53667	514.01
2014	TEL2014136024	54.21833	-52.83833	54.20667	-52.82667	500.00
1997	TEL1997053054	60.63667	-61.29667	60.65167	-61.29667	500.00
2006	BAL2006101075	60.48300	-61.30000	60.49700	-61.30800	500.00
1999	TEL1999084043	60.40000	-61.25667	60.41167	-61.26167	500.00
2006	TEL2006681062	54.72667	-52.91500	54.71500	-52.92833	500.00
2001	TEL2001361036	54.11167	-52.74667	54.10000	-52.73833	500.00
2001	TEL2001361038	54.41167	-53.17000	54.39833	-53.16167	500.00
2005	TEL2005542020	51.57667	-50.10000	51.56667	-50.09167	500.00
2005	TEL2005611039	54.63833	-52.74500	54.62667	-52.75167	487.60
2013	TEL2013121046	54.78833	-52.98333	54.79167	-53.00167	465.83
2001	TEL2001361037	54.15667	-52.70833	54.17000	-52.71333	446.65
2007	TEL2007753043	54.94667	-53.53500	54.94833	-53.54833	436.70
2001	TEL2001361041	54.68333	-53.08333	54.67167	-53.09667	400.00
2006	TEL2006681061	54.76000	-52.92667	54.76667	-52.94333	400.00
2001	TEL2001361040	54.78000	-52.91500	54.77167	-52.90000	400.00
2012	AQV2012107078	60.21723	-61.11555	60.20432	-61.11498	396.73
2013	AQV2013108084	60.43920	-61.74747	60.43775	-61.77600	395.16
2012	AQV2012107084	60.80692	-61.25992	60.81952	-61.25648	394.07
2013	AQV2013108081	60.59977	-61.40927	60.59807	-61.38543	374.32
1996	TEL1996023021	54.54167	-53.13167	54.54667	-53.11000	368.40
1996	TEL1996039052	54.66333	-53.10500	54.67500	-53.11333	360.00
2010	BAL2010105084	60.58233	-61.91133	60.59050	-61.93028	357.72

2004	TEL2004539035	55.06833	-54.02833	55.05500	-54.03333	350.00
2009	TEL2009896019	55.21167	-54.33000	55.22000	-54.34333	338.95
2009	TEL2009896006	54.12000	-52.68333	54.11000	-52.67500	320.25
2004	TEL2004539093	51.85667	-50.46500	51.86833	-50.47500	320.00
2012	TEL2012108030	54.21667	-52.84167	54.20833	-52.83000	318.30
2010	BAL2010105061	59.90217	-60.86700	59.89300	-60.85767	311.97
2011	TEL2011096039	54.73000	-52.75833	54.71833	-52.76000	305.82
2009	TEL2009896015	54.84833	-53.27333	54.84167	-53.25667	300.00
2014	TEL2014136051	53.23000	-51.99667	53.21667	-51.98833	300.00
2012	TEL2012109033	53.43167	-51.99500	53.44333	-51.99667	293.55
1996	TEM1996188012	45.86000	-53.95667	45.86500	-53.97500	275.88
2005	TEL2005611040	54.62667	-52.96000	54.61667	-52.96000	265.70
1998	TEL1998072071	55.44833	-55.80333	55.44500	-55.81833	257.60
2003	TEL2003509014	53.23333	-52.00000	53.24500	-52.01167	256.00
2013	AQV2013108080	60.55852	-61.25612	60.57257	-61.25610	253.71
2012	TEL2012108037	53.56667	-52.12000	53.55833	-52.10000	253.19
1998	TEL1998073076	54.34833	-52.96667	54.36167	-52.96833	250.00
2006	TEL2006681063	54.45500	-53.00167	54.44333	-53.00833	250.00
2012	AQV2012107076	60.12607	-61.14112	60.13403	-61.16133	249.20
2009	TEL2009897037	52.27667	-50.92833	52.26667	-50.91500	246.20
2014	TEL2014135040	55.07667	-53.98000	55.06833	-53.97333	242.00
1996	TEL1996037053	60.58333	-60.78333	60.58500	-60.80833	239.53
2013	TEL2013121041	54.38000	-52.93333	54.39000	-52.94000	238.60
2007	TEL2007753050	55.23833	-54.94667	55.23833	-54.93167	235.70
2013	TEL2013121044	54.44833	-53.08333	54.45833	-53.09500	235.33
2003	TEL2003457036	54.58000	-53.27000	54.59333	-53.26833	230.75
2010	TEL2010975021	56.20833	-57.25500	56.20333	-57.24333	224.30
2011	TEL2011096028	53.91833	-52.50833	53.90667	-52.50500	219.90
2009	TEL2009896018	55.08500	-54.13667	55.09000	-54.15500	219.45
2014	TEL2014135047	54.95833	-53.46333	54.96667	-53.46500	217.93
2011	TEL2011096014	53.17000	-51.94667	53.16000	-51.93833	216.96
2014	TEL2014137036	51.70667	-50.31167	51.69833	-50.29500	215.80
2008	TEL2008820013	53.38667	-52.06333	53.39833	-52.07167	215.50
2001	TEL2001362015	51.89000	-50.45667	51.87833	-50.44500	215.20
2002	TEL2002415045	53.50167	-52.14000	53.49000	-52.13000	214.55
2014	TEL2014137037	51.60833	-50.10833	51.61667	-50.12000	212.28
2008	TEL2008820010	53.07833	-51.79667	53.09167	-51.80667	210.40
2007	TEL2007753009	53.03500	-51.75000	53.04333	-51.75500	207.90
2014	KIN2014109082	60.29810	-61.14847	60.30688	-61.15910	203.70
2012	TEL2012107071	54.76000	-53.16667	54.76500	-53.18833	200.63
2010	TEL2010975026	56.50167	-57.83500	56.49667	-57.84667	200.00
2014	TEL2014136040	53.78333	-52.43167	53.77167	-52.41833	200.00
2014	TEL2014136038	54.09000	-52.71333	54.10000	-52.71333	200.00

2012	TEL2012107067	55.13667	-54.03333	55.13000	-54.02000	200.00
2007	BAL2007102079	60.61200	-61.27000	60.62500	-61.27500	200.00
1999	TEL1999085055	56.95000	-58.24667	56.96000	-58.25833	200.00
2006	TEL2006681060	54.73333	-53.12500	54.72333	-53.11333	200.00
2000	TEL2000340078	54.19167	-52.80167	54.20167	-52.82667	200.00
1999	TEL1999086073	54.10833	-52.68333	54.12167	-52.69000	200.00
2003	TEL2003509016	53.34833	-51.95667	53.33667	-51.94833	200.00
2000	TEL2000340098	53.08667	-51.80667	53.09500	-51.81833	200.00
2000	TEL2000340067	54.52500	-53.11500	54.51333	-53.11833	200.00
2011	TEL2011096013	53.10500	-51.83500	53.09000	-51.82333	193.84
2010	TEL2010975020	56.15000	-57.26000	56.14333	-57.25500	178.40
1996	TEL1996039046	53.98833	-52.57333	54.00000	-52.57833	177.50
1999	TEL1999086042	54.86000	-53.13500	54.86333	-53.15500	177.20
2010	TEL2010975047	57.56500	-59.12667	57.55667	-59.11167	175.11
1997	TEL1997054021	56.71833	-58.07667	56.73000	-58.08667	175.00
2013	TEL2013121051	55.07000	-53.71833	55.06167	-53.70333	174.33
1996	TEL1996037056	60.45333	-61.77500	60.45000	-61.80167	173.44
2011	TEL2011097035	55.07500	-53.80000	55.06667	-53.78833	171.41
2013	AQV2013108082	60.57968	-61.58652	60.57465	-61.55745	170.98
1997	TEL1997055050	54.08333	-52.70833	54.07167	-52.69667	170.35
2011	TEL2011097032	55.16167	-54.30000	55.16167	-54.28167	169.65
2014	TEL2014136022	54.62500	-53.15333	54.63667	-53.14667	165.25
2012	TEL2012107069	54.97833	-53.67000	54.97333	-53.65500	162.11
2011	TEL2011096027	53.87000	-52.58167	53.86000	-52.57500	158.70
2008	TEL2008820011	53.25833	-51.91333	53.27000	-51.92000	157.00
2007	BAL2007102070	60.62300	-61.70800	60.62300	-61.68000	156.94
2011	BAL2011106056	59.85215	-60.78207	59.86042	-60.79050	156.40
2014	TEL2014135039	55.18833	-54.29667	55.18167	-54.28500	156.40
2013	TEL2013121043	54.49167	-53.24167	54.50167	-53.24333	155.50
2011	TEL2011096037	54.52000	-53.23167	54.50667	-53.22333	152.30
2013	AQV2013108063	59.84552	-60.69705	59.85598	-60.71150	151.68
2002	TEL2002415038	52.27833	-50.94167	52.26833	-50.92667	150.00
1996	TEL1996023019	54.74500	-53.08000	54.73667	-53.06167	150.00
2006	TEL2006681068	53.92333	-52.53333	53.91333	-52.52333	150.00
2003	TEL2003457041	55.10167	-53.84500	55.10667	-53.82833	150.00
2007	BAL2007102054	59.77300	-60.67000	59.76200	-60.65300	150.00
2014	TEL2014136052	53.22833	-51.90667	53.21833	-51.89500	150.00
2010	TEL2010975031	56.75667	-58.07000	56.76333	-58.05333	150.00
2009	BAL2009104055	59.77233	-60.66683	59.76133	-60.65083	150.00
2003	TEL2003509048	54.68000	-52.99167	54.66833	-53.00000	143.20
2012	TEL2012109041	52.39333	-51.19500	52.40167	-51.20500	142.30
1999	TEL1999086067	54.42333	-53.06833	54.41333	-53.06000	140.95
2013	TEL2013121040	54.27667	-52.78000	54.28667	-52.78667	139.53

2011	TEL2011094025	56.26500	-57.26333	56.27833	-57.26167	133.90
2014	KIN2014109060	59.84283	-60.69052	59.85405	-60.70373	133.62
2013	TEL2013122021	52.73833	-51.53833	52.72833	-51.53000	131.18
2003	TEL2003509013	53.14667	-51.96500	53.13500	-51.95833	129.75
2014	TEL2014136026	54.30333	-53.15667	54.31000	-53.17000	126.81
1997	TEL1997053055	60.57667	-61.51167	60.58833	-61.50167	126.65
2010	TEL2010977038	53.95333	-52.55833	53.96667	-52.56167	123.93
2009	TEL2009896007	54.23500	-52.87167	54.22667	-52.85667	122.10
2013	TEL2013122017	53.21500	-51.89167	53.20667	-51.87667	120.00
2009	TEL2009896012	54.51667	-52.96500	54.52667	-52.95500	118.35
2012	TEL2012108029	54.21500	-52.75500	54.20500	-52.74333	117.69
1999	TEL1999086084	53.29500	-52.02667	53.28500	-52.02167	117.30
1996	TEL1996039045	53.93500	-52.53000	53.94667	-52.53333	116.75
1999	TEL1999086068	54.63667	-52.87500	54.64500	-52.86000	116.45
2004	TEL2004537005	56.50833	-57.64167	56.51833	-57.64333	116.40
2001	TEL2001361024	53.36333	-52.07667	53.35000	-52.07000	115.00
2010	BAL2010105035	58.28460	-61.43172	58.28708	-61.45308	114.85
2001	TEL2001362020	51.73333	-50.25833	51.72333	-50.24333	114.60
1996	TEL1996037059	60.25667	-61.26000	60.27000	-61.26667	112.35
2012	TEL2012110039	51.26667	-49.85000	51.26000	-49.83500	111.60
1997	TEL1997055041	54.93167	-53.43500	54.93667	-53.45333	108.65
2011	BAL2011106066	60.34152	-61.21635	60.35422	-61.22807	108.11
1999	TEL1999088028	51.26333	-49.72000	51.27333	-49.73167	107.65
2014	TEL2014137038	51.37500	-49.94833	51.38500	-49.94833	107.09
2006	TEL2006681065	54.18667	-52.92333	54.19833	-52.93500	106.50
2003	TEL2003509059	55.17500	-54.55333	55.16667	-54.53833	106.50
1996	TEL1996039066	55.09833	-53.87833	55.09333	-53.89167	106.30
1996	TEL1996036066	57.44833	-58.84333	57.45333	-58.85333	105.40
2011	TEL2011096009	52.77500	-51.47000	52.76333	-51.45167	103.10
2013	TEL2013121042	54.38333	-53.24667	54.39333	-53.25833	102.88
1997	TEL1997055067	53.28500	-51.91667	53.29667	-51.92333	102.80
2005	TEL2005611023	52.97667	-51.78333	52.96667	-51.77167	102.00
1997	TEL1997055044	54.63667	-53.05500	54.64833	-53.05000	102.00
2006	TEL2006679020	56.31500	-57.36500	56.32500	-57.36500	101.85
1999	TEL1999086031	55.28667	-55.32167	55.28000	-55.30167	101.70
2001	TEL2001361012	52.46667	-51.23167	52.47500	-51.24333	101.50
2003	TEL2003509047	54.70667	-52.76000	54.72000	-52.76167	101.45
1996	TEL1996039044	53.89667	-52.60000	53.90333	-52.61500	101.15
2010	TEL2010978064	52.02167	-50.66333	52.01167	-50.65167	100.98
1997	TEL1997055042	54.82000	-53.27833	54.83000	-53.29333	100.80
2012	AQV2012107083	60.70608	-61.21222	60.69643	-61.21550	100.40
2007	TEL2007755041	51.56500	-50.14833	51.56000	-50.13500	100.00
2001	TEL2001361010	52.43167	-51.23667	52.44167	-51.24500	100.00

2000	TEL2000340068	54.41667	-53.16667	54.43000	-53.16500	100.00
2006	TEL2006681066	54.19500	-52.82500	54.20667	-52.83500	100.00
1997	TEL1997053026	60.28667	-61.28667	60.29500	-61.31333	100.00
2012	TEL2012107072	54.68333	-53.08000	54.67333	-53.09333	100.00
2012	TEL2012110040	51.32500	-49.91333	51.31500	-49.90333	98.83
1999	TEL1999086043	54.85167	-53.44333	54.84833	-53.42500	98.75
2006	TEL2006680017	57.24167	-58.76833	57.25167	-58.75833	98.20
1997	TEL1997054062	55.42667	-55.77000	55.43833	-55.77167	97.05
2001	TEL2001361029	53.78000	-52.52833	53.79833	-52.50333	96.60
1999	TEL1999087048	52.45167	-51.25833	52.46167	-51.27000	95.95
2005	BAL2005100038	58.79200	-62.12300	58.80000	-62.13500	95.06
2013	TEL2013120006	56.72167	-58.13333	56.71000	-58.13167	93.81
1997	TEL1997055043	54.60667	-53.15833	54.59500	-53.16000	93.00
2010	TEL2010977037	53.92667	-52.61500	53.93833	-52.61167	91.38
1997	TEL1997055046	54.50833	-53.22167	54.52167	-53.22333	91.00
1999	TEL1999085028	58.46667	-59.70333	58.45500	-59.70167	88.80
2008	TEL2008821010	52.15333	-50.71500	52.14167	-50.70667	87.00
2004	TEL2004539027	54.40000	-52.97000	54.41167	-52.97000	86.40
2012	AQV2012107081	60.51368	-61.52357	60.51998	-61.53758	84.85
1999	TEL1999086114	52.93333	-51.76000	52.94333	-51.76667	84.60
2010	TEL2010977018	53.17167	-51.91667	53.18333	-51.92167	83.98
2006	TEM2006707067	49.55833	-51.65167	49.56167	-51.66833	82.05
1999	TEL1999085029	58.45500	-59.54500	58.45833	-59.56667	80.00
2014	TEL2014136023	54.37167	-52.93000	54.38333	-52.93333	79.51
2012	TEL2012107073	54.61667	-53.04667	54.60333	-53.04833	79.15
1999	TEL1999086028	55.39833	-55.76500	55.39667	-55.78333	78.30
1998	TEL1998071027	59.43667	-59.78167	59.44833	-59.77500	77.10
2010	TEL2010975033	57.00333	-58.44000	56.99500	-58.42500	76.46
1997	TEL1997054029	56.24667	-57.31500	56.25667	-57.32333	76.30
1998	TEL1998071010	58.56667	-59.59500	58.57667	-59.61000	75.80
2007	TEL2007753038	54.50167	-52.99833	54.49667	-53.01500	75.05
2003	TEL2003509020	53.83500	-52.53500	53.84667	-52.53667	75.00
1996	TEL1996039048	54.18000	-52.97333	54.19000	-52.98833	75.00
2006	TEL2006681049	55.08667	-53.82167	55.09833	-53.83333	75.00
1998	TEL1998071034	59.62833	-60.51167	59.64000	-60.51333	75.00
1998	TEL1998073079	54.08500	-52.82500	54.07333	-52.81500	74.15
2014	TEL2014135046	54.90000	-53.56833	54.90833	-53.58333	73.35
2001	TEL2001362011	52.15167	-50.81333	52.16333	-50.82167	73.25
2001	TEL2001397015	50.73500	-52.46000	50.73167	-52.47833	72.60
2010	TEL2010977030	53.44500	-52.12833	53.43167	-52.12000	72.45
2008	BAL2008103048	59.74500	-60.68000	59.75700	-60.69200	72.14
2008	TEL2008818026	57.10667	-58.76167	57.09667	-58.75667	71.25
2011	TEL2011096008	52.53167	-51.31167	52.54167	-51.32167	71.20

1996	TEL1996036018	56.00500	-57.13167	56.00667	-57.11000	69.70
2008	TEL2008821009	52.10833	-50.74167	52.09833	-50.73000	69.40
1999	TEL1999084023	59.55167	-60.52000	59.56500	-60.52500	67.35
1996	TEL1996037060	60.38167	-61.40500	60.39500	-61.40833	66.62
2010	TEL2010976032	54.40500	-52.97500	54.41667	-52.97167	66.49
2007	BAL2007102081	60.80700	-61.66000	60.81700	-61.67500	65.63
2002	TEL2002415037	52.13167	-50.76500	52.14167	-50.77667	65.40
2011	BAL2011106055	59.61822	-60.50757	59.62790	-60.52223	64.94
1997	TEL1997056070	51.25333	-49.74000	51.24333	-49.72667	64.60
2005	BAL2005100073	60.49300	-61.44300	60.48000	-61.43700	64.60
1996	TEM1996198070	49.97167	-54.11500	49.98333	-54.11000	63.32
1997	TEL1997053060	59.62333	-60.28833	59.62833	-60.28833	63.05
2011	TEL2011096038	54.44500	-53.09333	54.43667	-53.07333	61.76
1998	TEL1998074042	51.85333	-50.49167	51.86167	-50.50333	60.70
2003	TEL2003509054	55.08833	-53.82333	55.10000	-53.83333	60.60
1996	TEL1996023015	55.03000	-54.05500	55.03500	-54.06500	60.00
1995	TEM1995177107	45.47667	-48.57833	45.48333	-48.56333	59.41
2013	AQV2013108086	60.57042	-62.23882	60.57502	-62.26290	59.18
1996	TEL1996039054	54.69000	-53.18000	54.70167	-53.18500	58.80
1999	TEL1999086074	53.97667	-52.81000	53.98667	-52.82167	58.75
2003	TEL2003509046	54.37833	-52.96333	54.36833	-52.95167	58.40
1996	TEL1996036028	56.28833	-57.40000	56.29500	-57.41667	58.35
2007	TEL2007752034	52.42333	-51.24000	52.43167	-51.24667	57.95
2009	BAL2009104069	60.80050	-61.36567	60.80000	-61.33817	56.68
1997	TEL1997053029	60.39000	-61.71167	60.39167	-61.73833	55.75
2010	TEL2010977039	53.95667	-52.78167	53.94667	-52.76833	55.65
1999	TEL1999086083	53.38333	-52.00167	53.37500	-51.98833	55.00
2006	BAL2006101024	58.80800	-62.13200	58.79500	-62.12800	55.00
2013	TEL2013121054	55.07000	-54.08333	55.07667	-54.10167	54.80
1996	TEL1996040033	51.97000	-50.61000	51.97833	-50.61500	54.70
2003	TEL2003457052	55.27667	-55.23167	55.28167	-55.25167	54.70
1998	TEL1998072022	56.56000	-58.10167	56.56333	-58.11833	54.45
2010	TEL2010977031	53.52000	-52.18500	53.51000	-52.17667	53.75
2009	TEL2009897062	51.43000	-49.98000	51.42000	-49.97000	53.20
2010	BAL2010105055	59.49500	-60.36617	59.50500	-60.38000	52.83
1999	TEL1999086069	54.44000	-53.01500	54.45167	-53.00667	52.70
2011	TEL2011096026	53.76667	-52.41833	53.75667	-52.40833	52.28
2009	TEL2009897016	53.71333	-52.44167	53.70333	-52.42667	51.00
2009	BAL2009104070	60.60117	-61.57650	60.59217	-61.55600	50.89
2014	KIN2014109089	60.57313	-61.88760	60.57918	-61.90172	50.85
2013	TEL2013122022	52.55833	-51.30000	52.54667	-51.29000	50.56
2002	TEL2002415040	52.77833	-51.50333	52.76833	-51.49167	50.00
1998	TEL1998073081	54.01667	-52.65833	54.00333	-52.65333	50.00

2006	TEL2006681067	54.13333	-52.76667	54.14500	-52.77500	50.00
1999	TEL1999085085	55.99167	-57.12000	55.98500	-57.10000	50.00
2009	BAL2009104065	60.36383	-61.55050	60.36250	-61.52450	50.00
2009	BAL2009104071	60.41367	-61.87533	60.40650	-61.85317	50.00
2010	TEL2010977011	52.56000	-51.30000	52.54833	-51.29000	49.35
1996	TEL1996036072	56.85833	-58.24500	56.86833	-58.25333	49.00
1997	TEL1997056039	52.11667	-50.76167	52.12833	-50.76333	48.60
2014	KIN2014109081	60.27243	-61.14712	60.26552	-61.13567	47.65
2005	TEL2005611033	53.72833	-52.50667	53.72000	-52.49500	47.50
2005	TEL2005611018	52.29500	-51.07333	52.30333	-51.08667	47.45
1998	TEL1998072018	56.86333	-58.30500	56.87333	-58.31333	46.25
2002	TEL2002415044	53.23000	-51.91000	53.21833	-51.89833	45.75
2008	TEL2008817001	55.35000	-55.54000	55.34667	-55.52167	45.50
2012	TEL2012109034	53.26167	-51.99833	53.27167	-52.01000	45.46
1998	TEL1998072069	55.36667	-56.21833	55.36833	-56.24000	44.85
2005	TEL2005611032	53.68333	-52.36667	53.68000	-52.34833	44.85
1996	TEL1996039022	52.47500	-51.24833	52.48500	-51.26000	44.45
2012	TEL2012107068	54.99833	-53.57833	55.00833	-53.57500	44.04
2006	TEL2006682025	52.55500	-51.29833	52.54500	-51.28667	44.00
2004	TEL2004536015	55.66333	-56.72833	55.65500	-56.72000	43.90
2008	TEL2008821008	51.72500	-50.39500	51.73500	-50.40667	43.85
2003	TEL2003510031	51.65000	-50.23667	51.64167	-50.22500	43.60
2000	TEM2000319003	45.73167	-53.96167	45.72333	-53.97333	43.55
2005	TEL2005611020	52.57000	-51.27167	52.56167	-51.25667	43.20
2014	TEL2014137039	51.26833	-49.75667	51.27833	-49.75500	41.80
2004	TEL2004539012	52.93833	-51.75333	52.92667	-51.74500	41.45
2004	TEL2004539008	52.37000	-51.18833	52.38000	-51.20167	40.85
2010	TEL2010976020	55.28167	-55.21333	55.28667	-55.22500	40.85
2002	TEL2002415029	51.23000	-49.71833	51.22000	-49.71000	40.10
2007	TEL2007755042	51.47000	-49.97833	51.46333	-49.96000	40.00
2006	BAL2006101082	60.50200	-62.07200	60.51200	-62.09300	40.00

Sea Pens (Pennatulacea)

Data Sources and Distribution

The data available for the analysis of sea pens in the Newfoundland and Labrador Shelves Biogeographic Zone came from 3 DFO administrative regions (Newfoundland and Labrador, Maritimes, and Quebec) conducted over 13 years from 2003 to 2015, and from Spanish surveys of a portion of Grand Bank (Kenchington et al., 2010). There were 1033 records with sea pen catch (95% from NL and Labrador Region of DFO) and 5119 records of catches with no sea pens from the same surveys. This compares with the 403 records with sea pen catches available for the previous analyses (Kenchington et al., 2010). All surveys that were used in this time series were conducted with a Campelen trawl except for those from Maritimes Region that used a Western IIA trawl. For all surveys, tow locations were chosen following a stratified random design (Chadwick et al., 2007). Within the surveyed area, the sea pens were present largely on the continental slopes and were less common on the shelf (Figure 37).

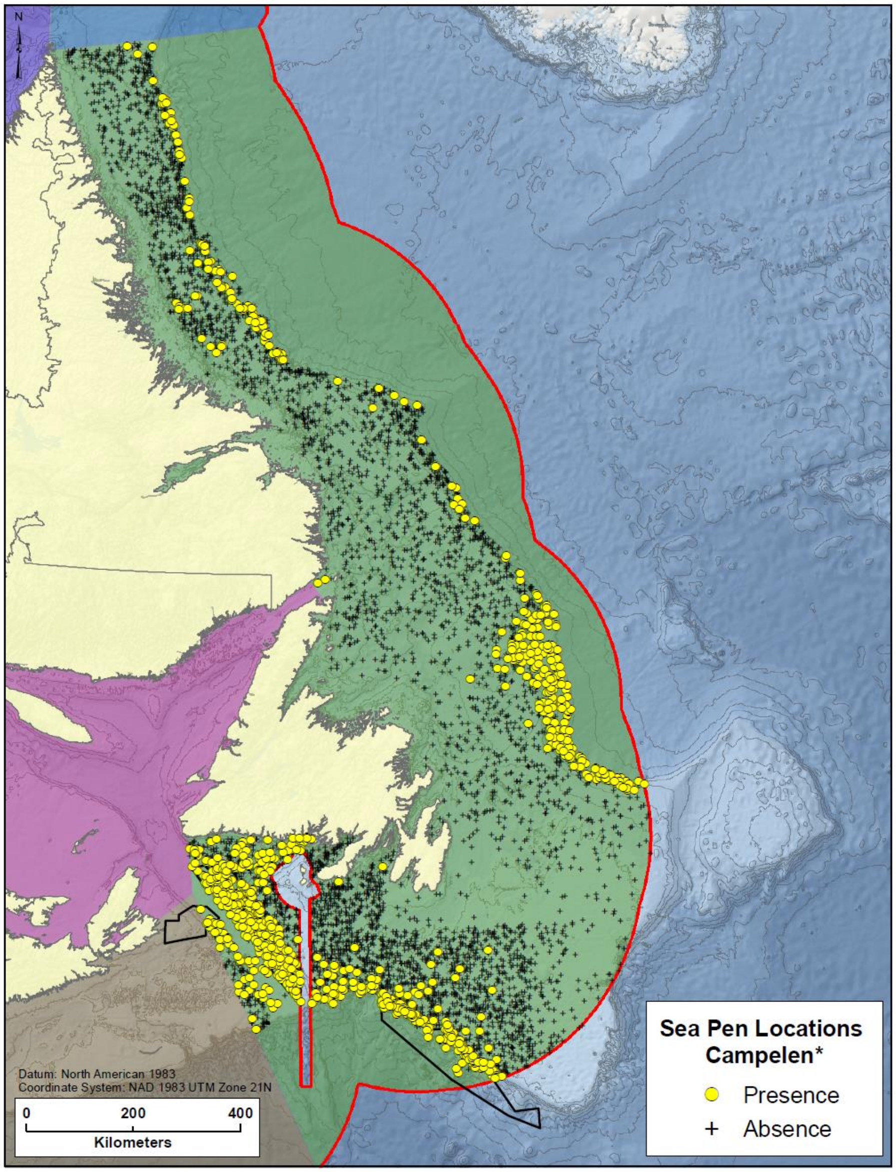

Figure 37. Distribution of sea pens from DFO research vessel survey catches mostly* using a Campelen trawl. The 3O Coral Closure, the St. Ann's Bank Proposed Closed Area and the Laurentian Channel Proposed Closed Area are depicted in outline (see Fig. 29). Yellow circles indicate sea pen presence in the catch and black crosses indicate verified null records. *A Western IIA trawl was used on the Nova Scotia side of the Laurentian Channel.

Evaluation of Search Radii

The default search radius for the KDE was 32.1644 km. We compared that KDE surface with one produced by using a 25 km search radius, as the default search radius over-smoothed the data (Figure 38). The 25 km search radius was adopted for the preparation of the KDE surface as this did not change the continuity of the surface but did tighten the contour spacing. The grid size was 4.3263 km^2. Contours placed over the KDE surface were finely spaced at 0.00001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons. The final KDE surface is shown in Figure 39 in relation to the tow positions that caught sea pens.

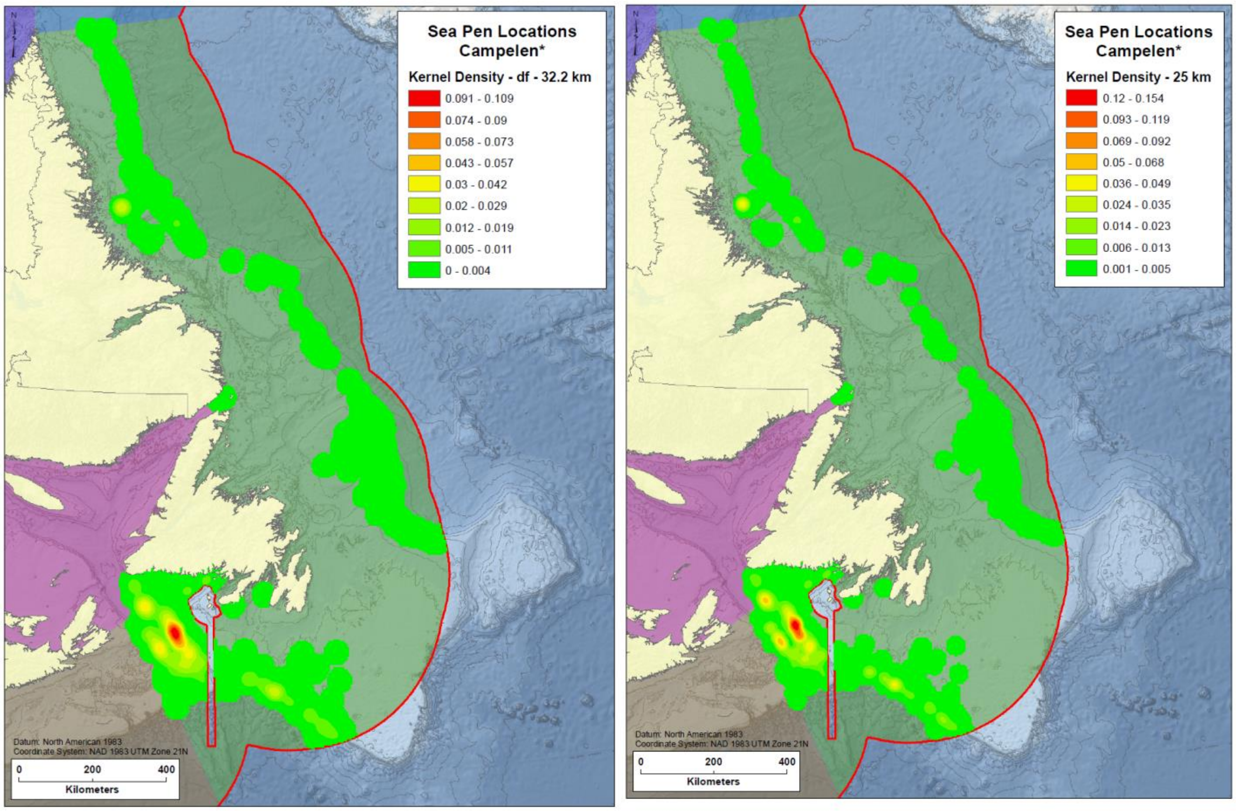

Figure 38. KDE surface of sea pen biomass produced with the default (df) search radius (32.2 km) (left) and 25 km (right) search radius. The former is over-smoothed in the area of higher concentration.

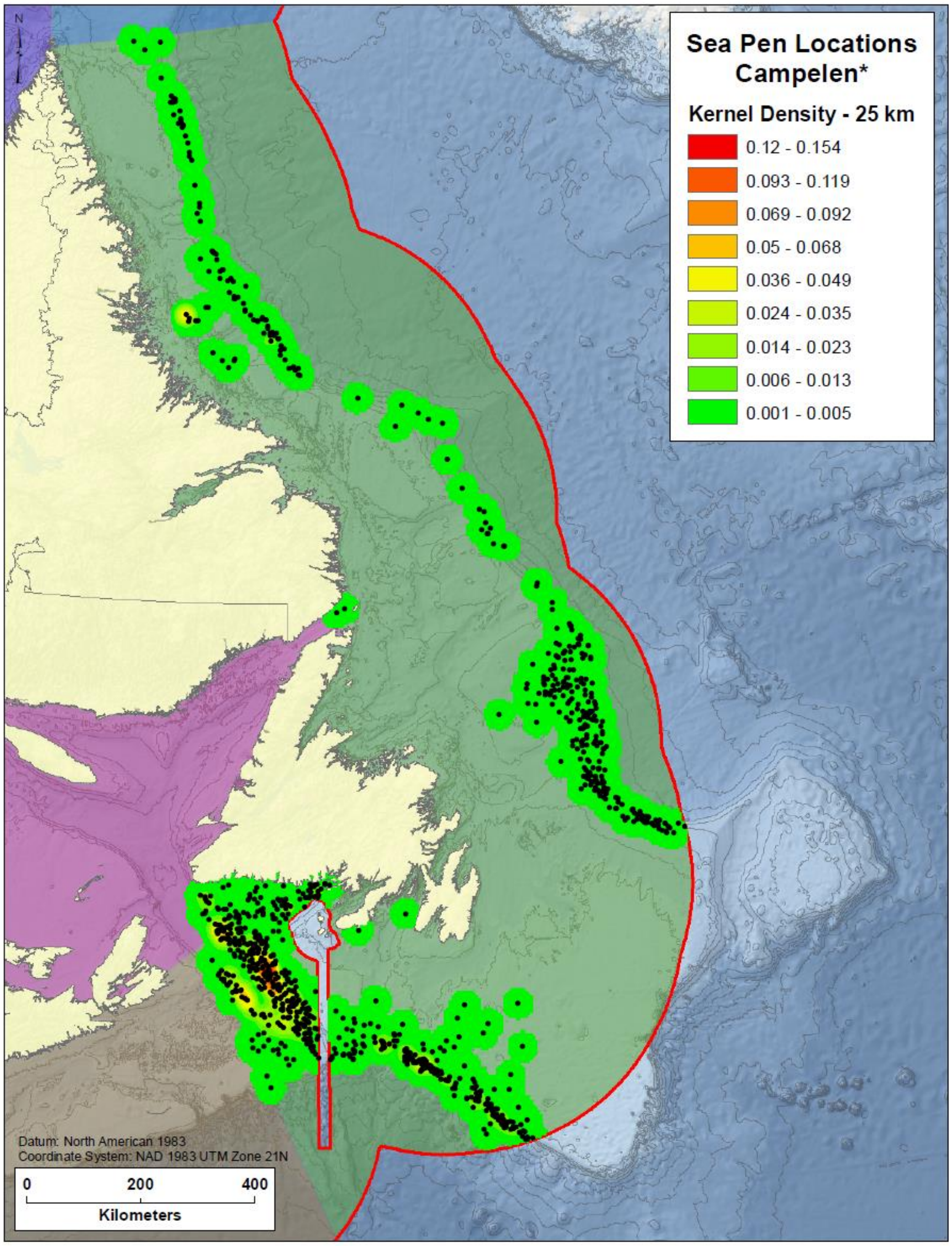

Figure 39. KDE analyses conducted with a 25 km search radius. Tow positions with sea pen catch are depicted by black closed circles.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sea pen weight threshold is provided in Table 10 and illustrated in Figure 40. The first large increase in area was found between 2 and 1 kg where area increased 146% (Table 10, Figures 40, 41). That increase was supported by 61 additional points (Table 10), and 2 kg was selected as the threshold for the analyses. The areas occupy 14,193 km^2.

Table 10. Comparative Sea Pen Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sea Pens is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
10	12	-	4948	30
5	27	15	6435	73
4	36	9	11112	9
3	56	20	12083	17
2	86	30	14193	146
1	147	61	34902	0
0.9	155	8	34902	4
0.8	163	8	36412	5
0.7	175	12	38156	1
0.6	194	19	38578	3
0.5	209	15	39668	20
0.4	240	31	47510	16
0.3	289	49	54885	28
0.2	346	57	70308	21
0.1	493	147	85246	40
0.05	639	146	119294	40
0.001	985	346	167142	0
0.005	1000	15	167142	

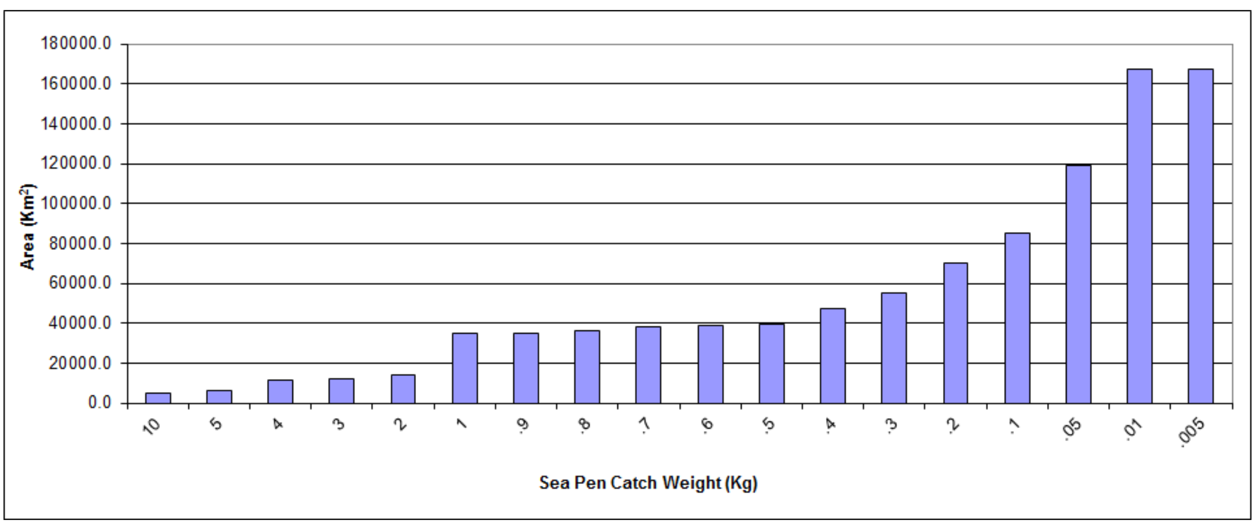

Figure 40. Barplot of polygon area (km^2) associated with sea pen weight thresholds (kg).

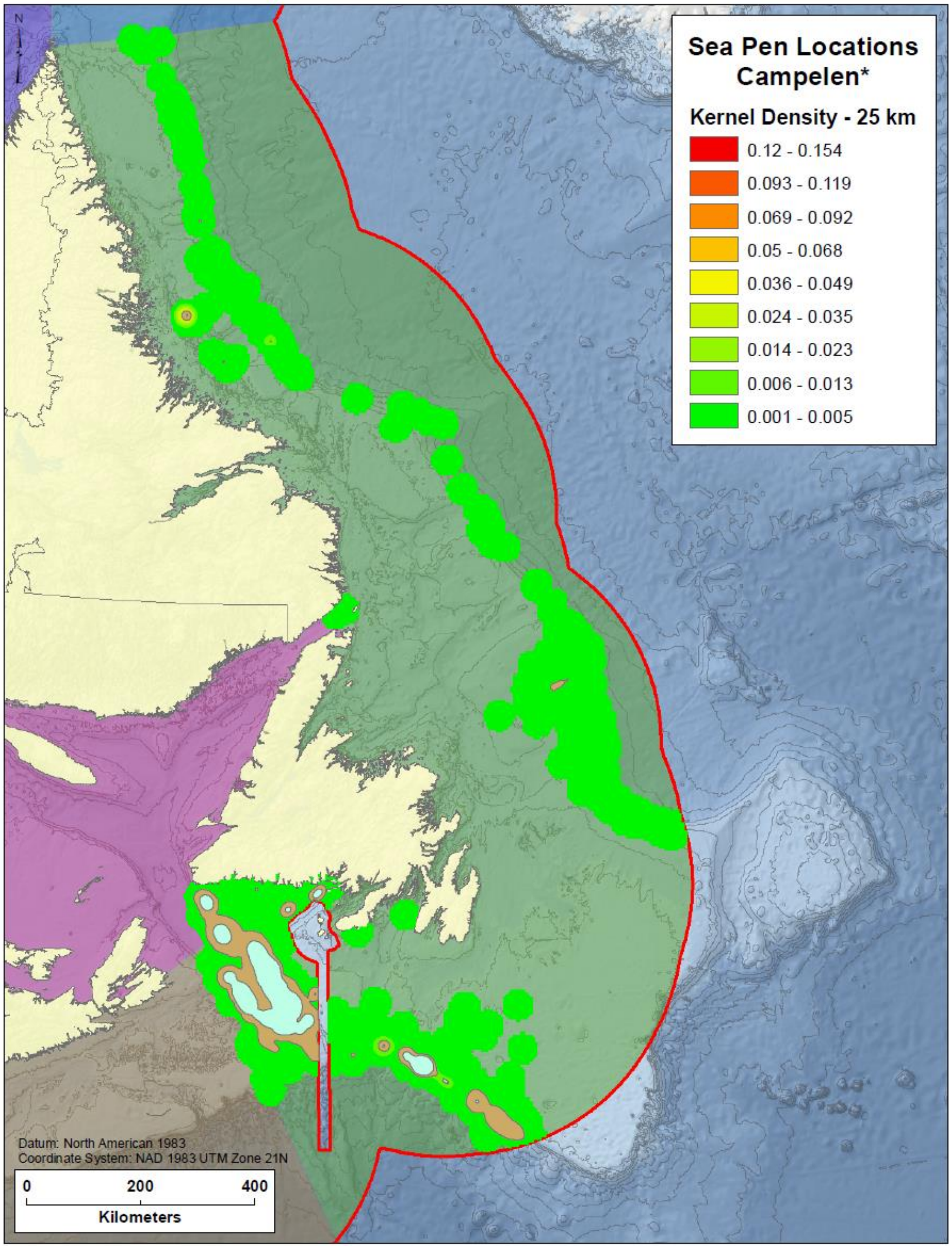

Figure 41. Location of polygons encompassing the ≥2 kg catches (light blue) and the ≥1 kg catches (brown), showing the 146% increase in area (Table 10) produced by the latter threshold. The polygons are overlain on the KDE biomass surface produced with the 25 km search radius.

Location of the Dense Aggregations

The locations of areas that indicate significant concentrations of sea pens are shown in Figure 42 and the locations of the survey tows that defined those polygons are provided in Table 11. Almost all of the sea pen fields area located in the south of the biogeographic zone, in the Laurentian Channel and adjacent slopes. In Figure 43, the results of this study are compared to those produced in Kenchington et al. (2010).

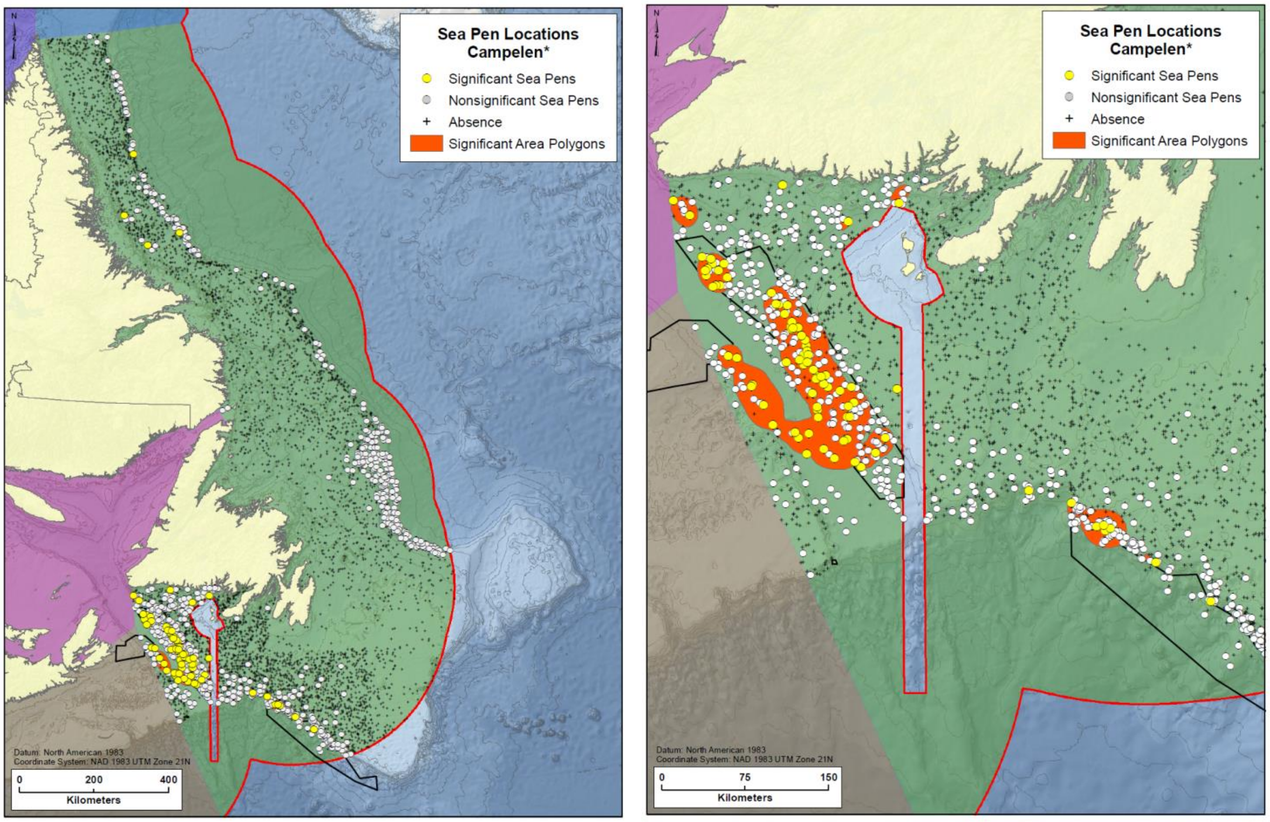

Figure 42. Location of the polygons identifying significant sea pen aggregations relative to the broader distribution of sea pens and areas closed or proposed to be closed to protect benthic species and habitats (see Fig. 29) in the Newfoundland and Labrador Shelves Biogeographic Zone. Catches that contributed to the identification of the polygons are indicated as significant (Table 11), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross. A close up of the area in the Laurentian Channel is shown in the panel to the right.

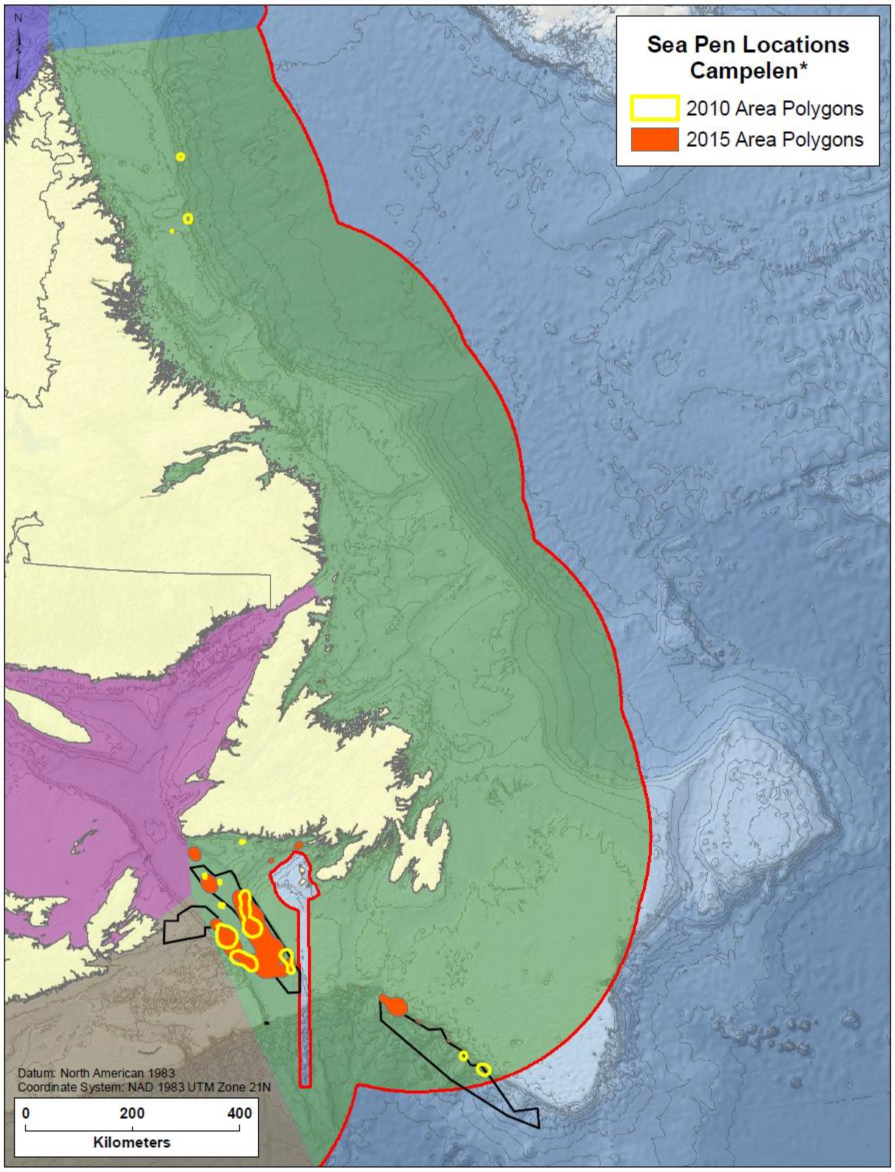

Figure 43. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (orange polygons). Areas closed or proposed to be closed to protect benthic species and habitats are indicated in outline (see Fig. 29).

Table 11. Newfoundland and Labrador Shelves Biogeographic Zone: Details of the Location of Research Vessel Sea Pen Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sea Pen Weight (kg)	Gear Type
2010	NED2010931042	46.22500	-57.52000	46.21500	-57.53000	40.00	Campelen
2013	NED2013022211	45.74617	-58.00417	45.77033	-58.02667	30.62	Western IIA

2014	TEL2014134050	56.51333	-60.00500	56.50333	-59.98667	28.60	Campelen
2010	NED2010931044	45.96667	-57.38500	45.95500	-57.38833	24.40	Campelen
2009	NED2009027158	45.90567	-58.14283	45.88283	-58.11650	21.22	Western IIA
2009	NED2009903065	46.14833	-57.54667	46.14167	-57.54000	19.50	Campelen
2010	NED2010931041	46.27333	-57.53167	46.27333	-57.55000	17.36	Campelen
2009	NED2009903066	45.98000	-57.39167	45.97000	-57.37833	13.00	Campelen
2010	NED2010942015	44.69333	-54.11833	44.68833	-54.12833	10.65	Campelen
2010	NED2010002043	45.31233	-57.18950	45.29150	-57.16433	10.36	Western IIA
2012	NED2012022182	46.13517	-58.42833	46.15217	-58.46317	10.22	Western IIA
2015	NED2015451089	45.65167	-57.04167	45.64333	-57.04000	10.20	Campelen
2014	TEL2014130040	46.18500	-57.50833	46.17333	-57.49833	9.59	Campelen
2010	NED2010931092	45.04000	-54.96833	45.03000	-54.97667	9.40	Campelen
2008	TEM2008830153	45.58317	-57.89633	45.56067	-57.87167	8.65	Western IIA
2011	NED2011402026	46.70667	-58.53833	46.69667	-58.52833	8.10	Campelen
2010	NED2010931043	46.03333	-57.43333	46.02167	-57.42667	8.10	Campelen
2005	NED2005656107	46.48167	-57.77333	46.49500	-57.77167	7.60	Campelen
2011	NED2011402036	46.15167	-57.49333	46.16167	-57.50000	7.50	Campelen
2010	NED2010931047	45.76500	-56.96500	45.75500	-56.95333	6.70	Campelen
2008	TEM2008835015	44.71333	-54.05667	44.72167	-54.04833	6.40	Campelen
2007	TEM2007758057	46.37000	-57.62000	46.37333	-57.60333	5.55	Campelen
2010	NED2010002041	45.47883	-57.60100	45.46000	-57.58467	5.49	Western IIA
2007	TEM2007686041	45.52283	-57.64250	45.51583	-57.68083	5.45	Western IIA
2012	NED2012416075	46.70500	-58.58833	46.70500	-58.60500	5.38	Campelen
2013	NED2013431047	46.30833	-57.57500	46.29500	-57.57167	5.36	Campelen
2008	TEM2008826058	45.95500	-57.40667	45.96667	-57.40167	5.10	Campelen
2011	NED2011403054	44.73167	-54.21000	44.72667	-54.22000	4.92	Campelen
2005	NED2005656075	45.48167	-56.60500	45.47833	-56.62333	4.70	Campelen
2010	NED2010002042	45.39167	-57.31283	45.37383	-57.28617	4.54	Western IIA
2014	TEL2014130030	46.87667	-58.63500	46.87500	-58.65000	4.42	Campelen
2014	TEL2014134015	56.13500	-57.59000	56.12667	-57.60667	4.38	Campelen
2007	TEM2007686039	45.34950	-57.50700	45.36150	-57.54317	4.35	Western IIA
2011	NED2011402050	45.36000	-56.71833	45.37000	-56.72833	4.20	Campelen
2014	TEL2014130031	46.83500	-58.69333	46.83500	-58.71333	4.10	Campelen
2008	TEM2008826055	45.65333	-57.01333	45.66667	-57.01667	4.05	Campelen
2007	TEL2007745155	46.11767	-58.32483	46.14483	-58.34483	3.95	Western IIA
2015	NED2015451076	46.37667	-57.70167	46.38333	-57.71167	3.92	Campelen
2007	TEM2007758048	46.78167	-58.70167	46.78000	-58.68500	3.90	Campelen
2013	NED2013431032	47.26167	-58.91333	47.26167	-58.90167	3.86	Campelen
2013	NED2013431038	46.82500	-58.56000	46.82167	-58.54833	3.82	Campelen
2011	NED2011401062	46.92000	-58.65333	46.92833	-58.64333	3.77	Campelen
2007	TEM2007759043	45.24833	-56.88167	45.24333	-56.89833	3.75	Campelen
2009	NED2009903060	46.35833	-57.68667	46.35167	-57.69167	3.75	Campelen
2015	NED2015451090	45.47167	-57.04333	45.46500	-57.04000	3.72	Campelen

2008	TEM2008826056	45.73500	-57.03000	45.74167	-57.04667	3.70	Campelen
2011	NED2011401035	47.23167	-57.03000	47.22833	-57.04333	3.50	Campelen
2011	NED2011402048	45.45667	-57.08000	45.44833	-57.06667	3.50	Campelen
2012	NED2012419025	44.09000	-52.96000	44.08500	-52.95000	3.41	Campelen
2010	NED2010932044	44.42167	-53.55833	44.41833	-53.54167	3.40	Campelen
2008	TEM2008826057	45.84333	-57.44500	45.84667	-57.46333	3.40	Campelen
2007	TEM2007759036	45.70833	-57.38667	45.70833	-57.37000	3.30	Campelen
2009	NED2009902077	46.88167	-58.49667	46.88333	-58.47833	3.30	Campelen
2014	NED2014018189	45.89117	-58.15417	45.91567	-58.17683	3.26	Western IIA
2008	TEM2008826024	46.82167	-58.71333	46.81000	-58.71500	3.20	Campelen
2013	NED2013431043	46.64833	-57.93500	46.65667	-57.94500	3.00	Campelen
2007	TEM2007759033	46.07167	-57.54833	46.06500	-57.51833	2.95	Campelen
2014	TEL2014130041	45.89500	-57.26833	45.90667	-57.28000	2.83	Campelen
2011	NED2011402022	46.55333	-57.84667	46.56000	-57.86000	2.72	Campelen
2015	NED2015451083	46.09000	-57.75000	46.08167	-57.74833	2.70	Campelen
2007	TEM2007686040	45.51600	-57.48517	45.54400	-57.48467	2.70	Western IIA
2004	TEL2004537065	55.80667	-58.92667	55.80000	-58.94500	2.55	Campelen
2008	TEM2008826032	46.41500	-57.69167	46.41833	-57.77333	2.55	Campelen
2013	NED2013433004	44.93000	-54.49167	44.92167	-54.50500	2.52	Campelen
2011	NED2011401061	46.92833	-58.75833	46.93833	-58.74833	2.50	Campelen
2011	NED2011402049	45.28333	-56.95333	45.27667	-56.94000	2.50	Campelen
2011	NED2011402053	45.87833	-56.46667	45.87000	-56.45333	2.50	Campelen
2008	BAL2008103004	57.99167	-59.71350	58.00050	-59.73050	2.49	Campelen
2009	NED2009913029	44.74000	-54.13167	44.72833	-54.12500	2.46	Campelen
2005	NED2005656108	46.55833	-57.87833	46.56333	-57.89333	2.40	Campelen
2010	NED2010931033	46.77000	-58.45500	46.77333	-58.43667	2.40	Campelen
2009	NED2009903067	45.98833	-57.29000	45.98000	-57.27500	2.38	Campelen
2014	TEL2014130035	46.55000	-57.74333	46.54333	-57.75833	2.34	Campelen
2007	TEM2007759034	45.92000	-57.31500	45.91333	-57.28500	2.30	Campelen
2013	NED2013431039	46.69000	-58.62167	46.68500	-58.61167	2.29	Campelen
2011	NED2011401058	47.37833	-59.11500	47.37167	-59.09833	2.27	Campelen
2015	NED2015451011	47.38333	-56.42500	47.37667	-56.41833	2.22	Campelen
2007	TEM2007759035	45.86000	-57.12667	45.85833	-57.11000	2.20	Campelen
2011	NED2011402047	45.64667	-57.38000	45.63667	-57.37167	2.20	Campelen
2010	NED2010931046	45.73167	-57.39000	45.72000	-57.38833	2.20	Campelen
2007	TEM2007759031	46.11333	-57.59500	46.11167	-57.61333	2.15	Campelen
2007	TEM2007758031	47.52000	-57.81333	47.51333	-57.79833	2.15	Campelen
2012	NED2012417011	46.36333	-57.67833	46.37333	-57.67000	2.10	Campelen
2010	NED2010930065	45.89500	-56.99500	45.88333	-56.98833	2.07	Campelen
2012	NED2012417004	45.97833	-57.34667	45.97000	-57.33333	2.00	Campelen
2011	NED2011402035	46.09333	-57.50500	46.08500	-57.49333	2.00	Campelen

Large Gorgonian Corals

Data Sources and Distribution

The data available for the analysis of large gorgonian corals in the Newfoundland and Labrador Shelves Biogeographic Zone came from 2 DFO administrative regions (Newfoundland and Labrador, and Maritimes) conducted over 13 years from 2003 to 2015, and from Spanish surveys of a portion of Grand Bank (Kenchington et al., 2010). Details of the species constituting this taxon used for our analyses can be found in Guijarro et al. (2016).

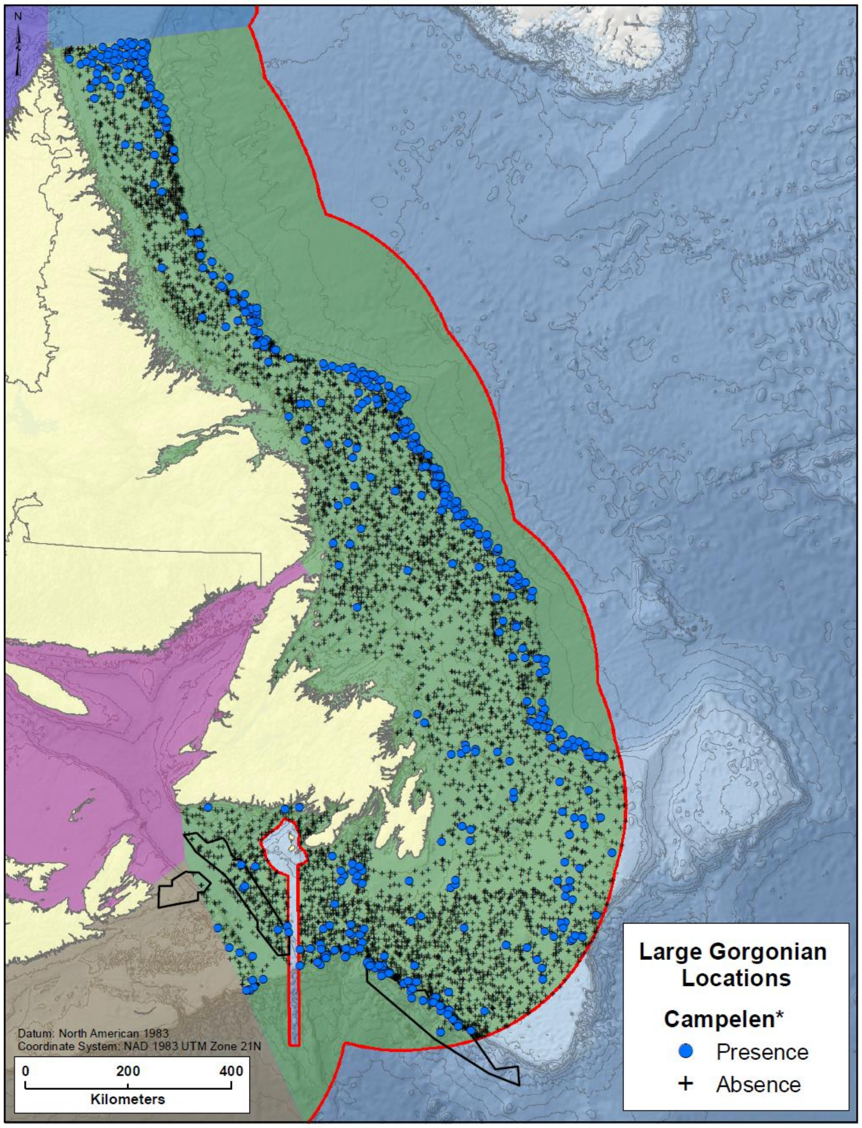

Figure 44. Distribution of large gorgonian corals from DFO research vessel survey catches mostly* using a Campelen trawl. The 3O Coral Closure, the St. Ann's Bank Proposed Closed Area and the Laurentian Channel Proposed Closed Area are depicted in outline (see Fig. 29). Blue circles indicate large gorgonian coral presence in the catch and black crosses indicate verified null records. *A Western IIA trawl was used on the Nova Scotia side of the Laurentian Channel.

There were 530 records with large gorgonian corals (98% from Newfoundland and Labrador Region of DFO) and 5988 records of catches with no large gorgonian corals from the same surveys. This compares with the 199 records with large gorgonian coral catches available for the previous analyses (Kenchington et al., 2010). All surveys that were used in this time series were conducted with a Campelen trawl except for those from Maritimes Region that used a Western IIA trawl. For all surveys, tow locations were chosen following a stratified random design (Kulka et al., 2006; Chadwick et al., 2007). Within the surveyed area, the large gorgonian corals were present largely on the continental slopes and were less common on the shelf (Figure 44).

Evaluation of Search Radii

The default search radius for the KDE was 35.1014 km. We compared that KDE surface with that produced by using a 25 km search radius, as the default search radius over-smoothed the data (Figure 45). The 25 km search radius was adopted for the preparation of the KDE surface. The grid size was 4.6939 km^2. Contours placed over the KDE surface were finely spaced at 0.00005 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons. The final KDE surface is shown in Figure 46 in relation to the tow positions that caught large gorgonian corals.

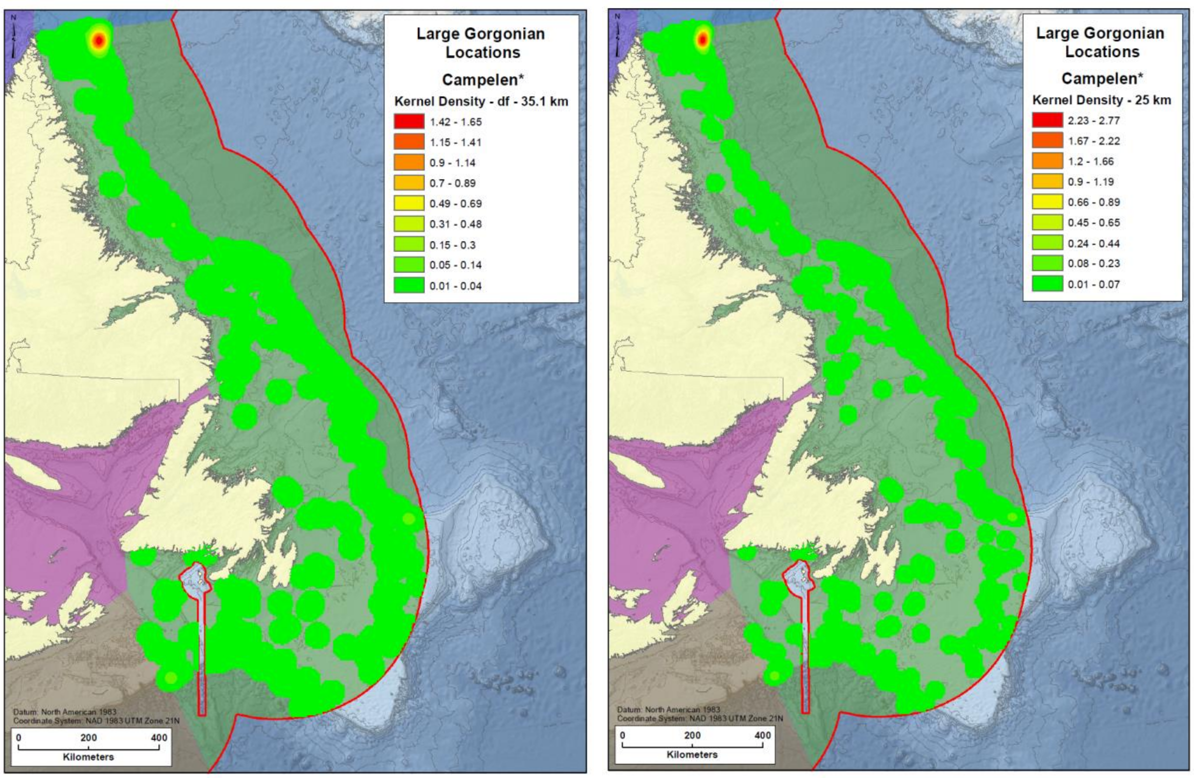

Figure 45. KDE surface of large gorgonian coral biomass produced with the default (df) search radius (35.1 km) (left) and 25 km (right) search radius. The former is over-smoothed in the area of higher concentration.

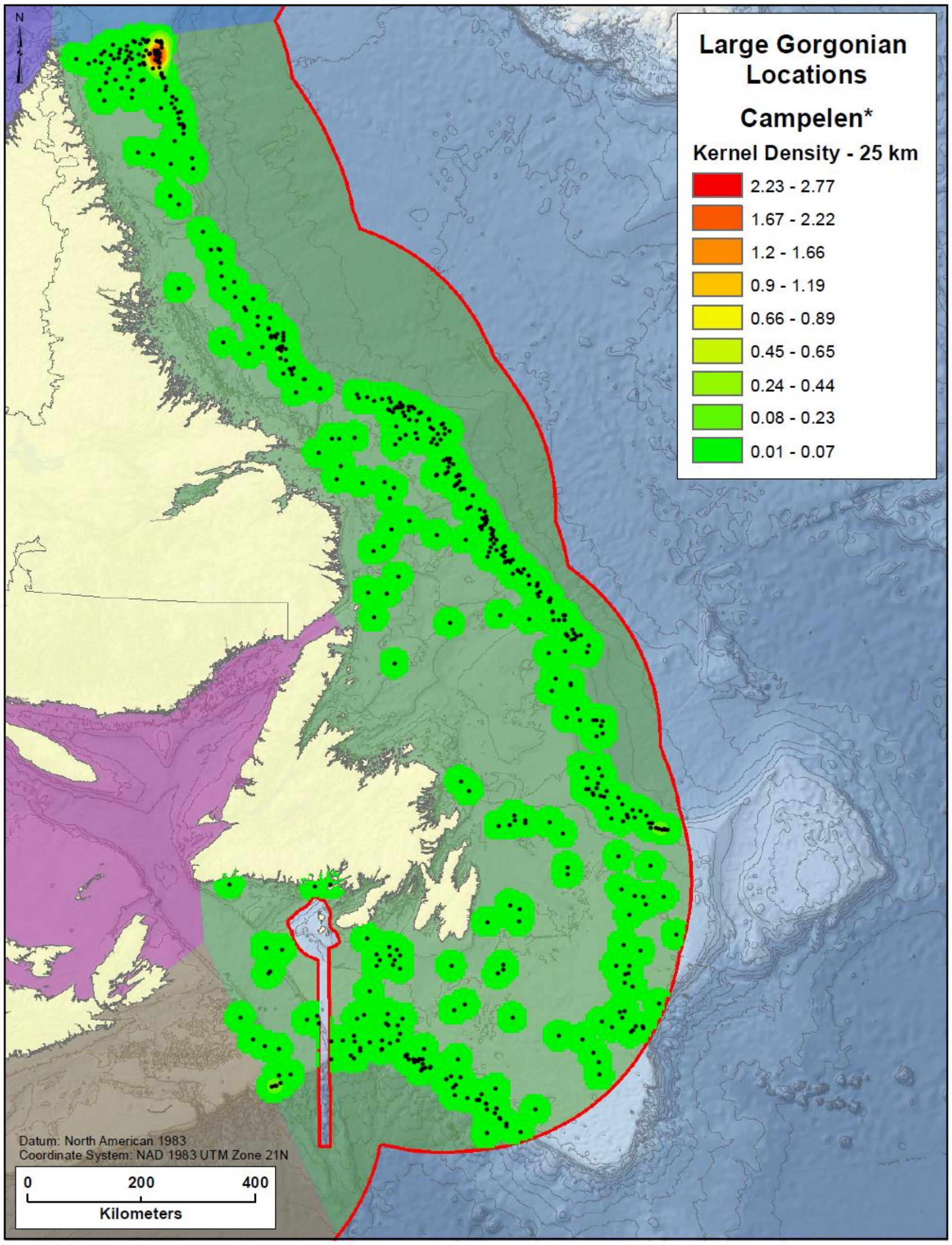

Figure 46. KDE analyses conducted with a 25 km search radius. Tow positions with large gorgonian coral catch are depicted by black closed circles.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each large gorgonian coral weight threshold is provided in Table 12 and illustrated in Figure 47. The first large increase in area was found between 1 and 0.5 kg where area increased 73% (Table 12, Figures 47, 48). That increase was supported by 39 additional points (Table 12), and 1 kg was selected as the threshold for the analyses. The areas occupy 16,303 km^2.

Table 12. Comparative Large Gorgonian Coral Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Large Gorgonian Corals is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
100	8	-	1076	34
50	12	4	1438	150
20	23	11	3589	48
10	32	9	5309	65
5	41	9	8780	23
3	50	9	10788	36
2	64	14	14688	11
1	81	17	16303	73
0.5	120	39	28129	38
0.4	135	15	38917	16
0.3	154	19	45206	41
0.2	199	45	63920	35
0.1	266	67	86586	9
0.07	298	32	94510	27
0.05	340	42	120380	14
0.03	387	47	137459	4
0.01	455	68	142975	0
0.001	488	33	142975	

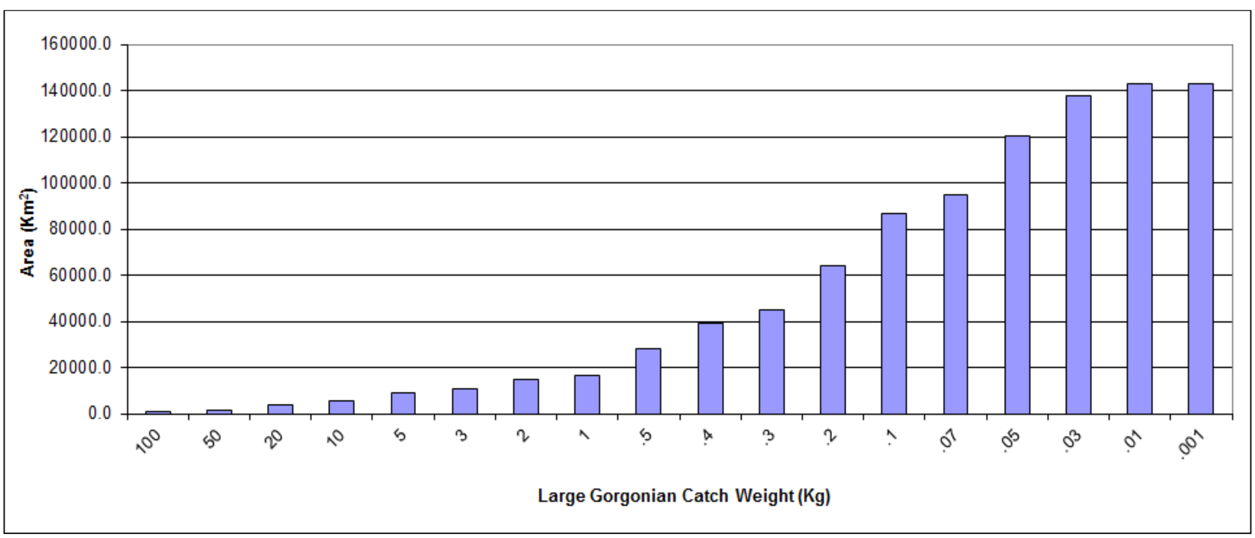

Figure 47. Barplot of polygon area (km^2) associated with large gorgonian coral weight thresholds (kg).

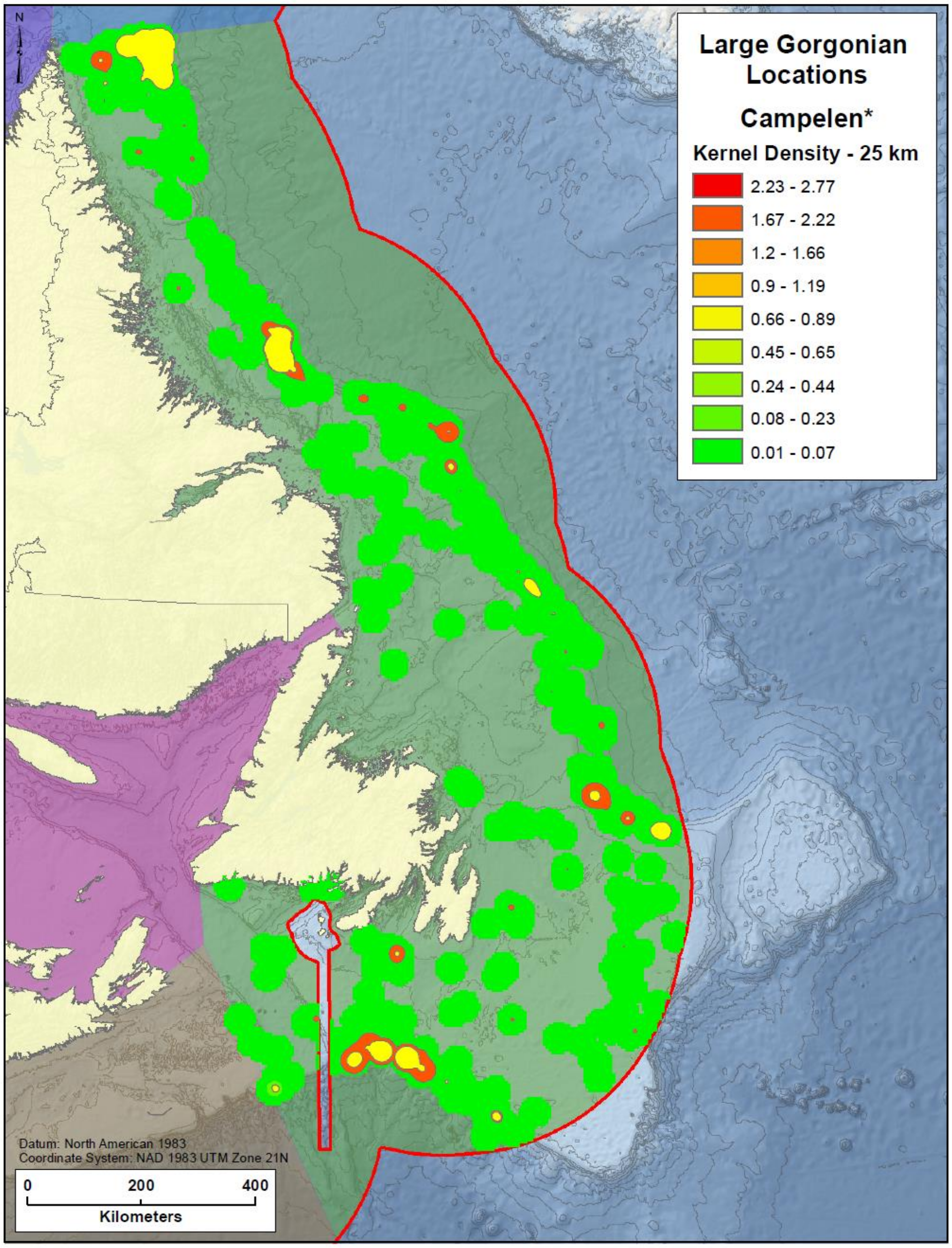

Figure 48. Location of polygons encompassing the ≥1 kg catches (yellow) and the ≥0.5 kg catches (red-brown), showing the 73% increase in area (Table 12) produced by the latter threshold. The polygons are overlain on the KDE biomass surface produced with the 25 km search radius.

Location of the Dense Aggregations

The locations of areas that indicate significant concentrations of large gorgonian corals are shown in Figure 49 and the locations of the survey tows that defined those polygons are provided in Table 13. In Figure 50, the results of this study are compared to those produced in Kenchington et al. (2010).

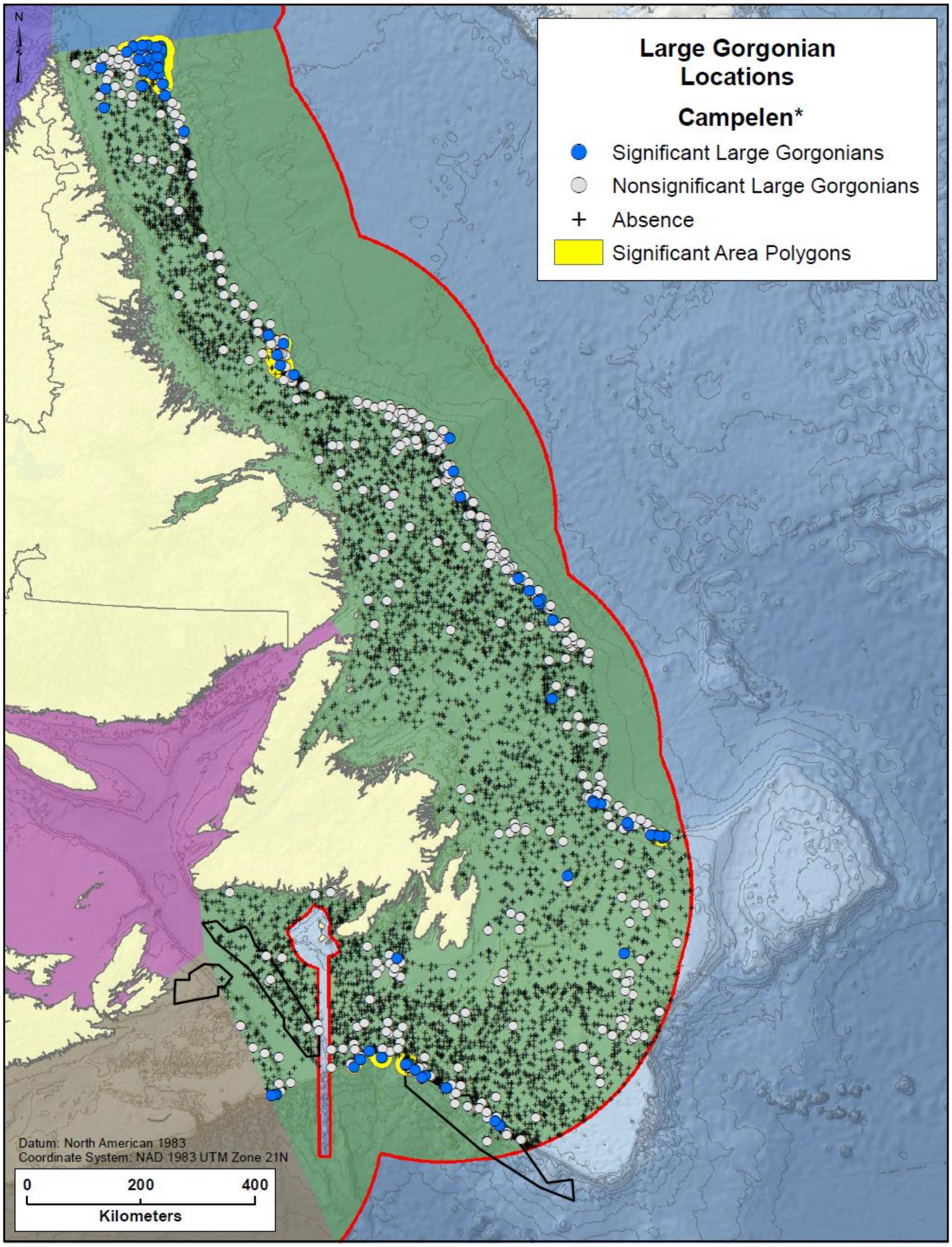

Figure 49. Location of the polygons identifying significant large gorgonian corals relative to the broader distribution of large gorgonian corals and areas closed or proposed to be closed to protect benthic species and habitats (see Fig. 29) in the Newfoundland and Labrador Shelves Biogeographic Zone. Catches that contributed to the identification of the polygons are indicated as significant (Table 13), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

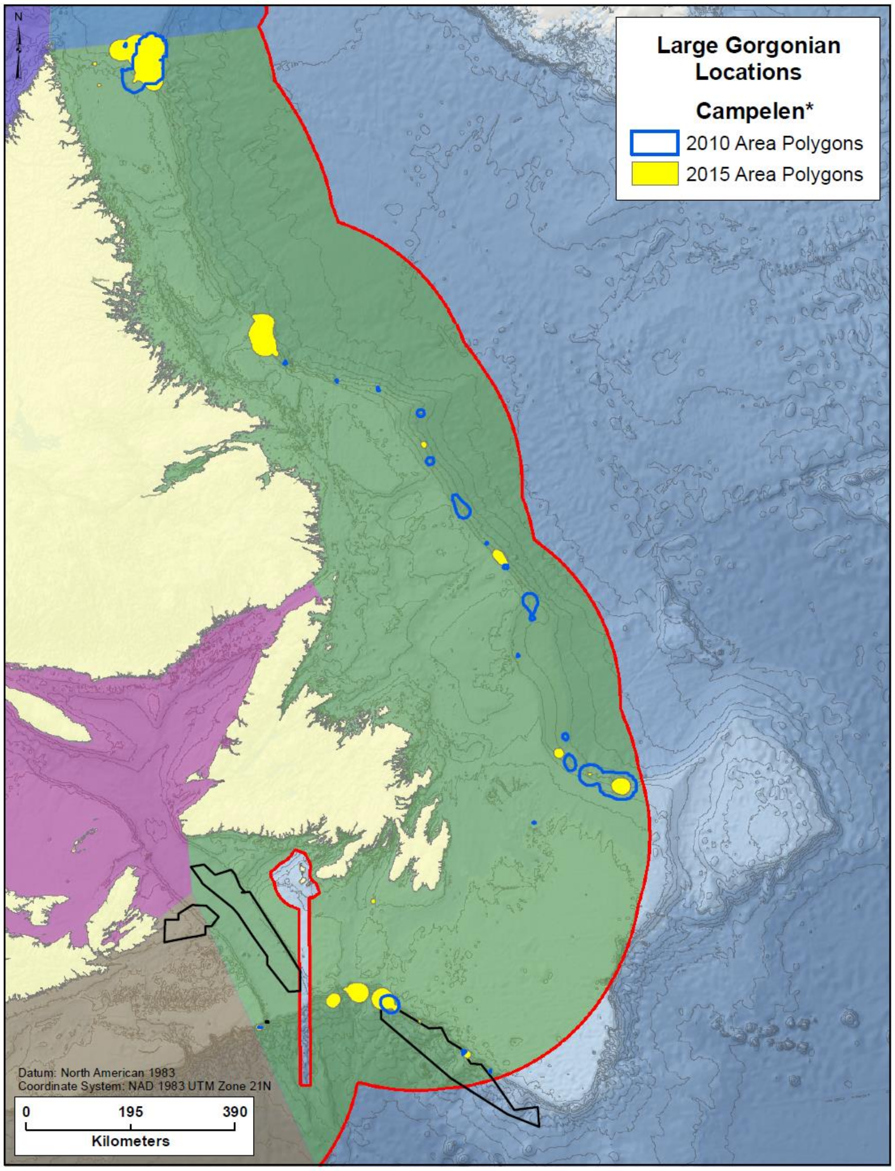

Figure 50. Comparison of the location of the significant concentrations of large gorgonian corals identified in Kenchington et al. (2010) (blue outline) and those identified in this study (yellow polygons). Areas closed or proposed to be closed to protect benthic species and habitats are indicated in outline (see Fig. 29).

Table 13. Newfoundland and Labrador Shelves Biogeographic Zone: Details of the Location of Research Vessel Large Gorgonian Coral Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Large Gorgonian Coral Weight (kg)
2013	AQV2013108080	60.55852	-61.25612	60.57257	-61.25610	866.90

2011	BAL2011106067	60.47233	-61.28593	60.45592	-61.27250	412.65
2010	BAL2010105080	60.64632	-61.32495	60.63208	-61.31115	307.02
2008	BAL2008103072	60.75817	-61.21017	60.74900	-61.21183	200.00
2010	BAL2010105079	60.57203	-61.37953	60.55917	-61.35598	173.85
2008	BAL2008103070	60.37483	-61.25067	60.39567	-61.24267	156.67
2012	AQV2012107083	60.70608	-61.21222	60.69643	-61.21550	154.39
2006	BAL2006101073	60.49333	-61.39000	60.50333	-61.40000	150.00
2007	3LCANZEE07009	48.09950	-48.28667	48.09767	-48.24733	66.25
2012	AQV2012107084	60.80692	-61.25992	60.81952	-61.25648	58.67
2006	NED2006036055	44.38183	-57.34517	44.38483	-57.39633	54.20
2006	BAL2006101075	60.48333	-61.30000	60.49667	-61.30833	50.19
2007	BAL2007102079	60.61200	-61.27067	60.62500	-61.27517	40.00
2013	TEL2013119019	55.86500	-57.33333	55.87500	-57.34500	35.70
2010	BAL2010105085	60.68282	-62.30657	60.68615	-62.33322	35.00
2011	NED2011409009	44.83667	-54.46333	44.84500	-54.45000	33.40
2010	BAL2010105077	60.22763	-61.09982	60.24343	-61.11322	32.00
2010	TEL2010975017	56.02500	-57.43833	56.01167	-57.43833	25.00
2012	NED2012022203	44.36533	-57.45100	44.35150	-57.47183	23.95
2007	BAL2007102080	60.77350	-61.22000	60.78600	-61.22483	22.05
2013	AQV2013108082	60.57968	-61.58652	60.57465	-61.55745	21.14
2009	BAL2009104069	60.80050	-61.36567	60.80000	-61.33817	20.73
2011	BAL2011106071	59.79310	-62.87933	59.80647	-62.87872	20.11
2008	3LCANZEE08011	48.15467	-48.55483	48.17267	-48.57883	19.00
2013	NED2013432041	44.93667	-55.01667	44.92833	-55.01667	16.88
2007	BAL2007102081	60.80583	-61.65950	60.81717	-61.67567	14.55
2009	NED2009904037	44.81000	-55.64167	44.80667	-55.66000	13.70
2010	NED2010931088	44.95667	-55.00667	44.96333	-54.99833	12.10
2013	AQV2013108081	60.59977	-61.40927	60.59807	-61.38543	11.14
2010	NED2010027138	44.38250	-57.37967	44.37583	-57.40217	11.04
2010	BAL2010105082	60.81687	-61.83453	60.80713	-61.85832	10.86
2006	TEL2006682045	50.44667	-50.59500	50.46000	-50.59667	10.00
2010	BAL2010105055	59.49500	-60.36617	59.50500	-60.38000	9.77
2012	AQV2012107085	60.77850	-61.71733	60.78015	-61.74267	9.44
2010	BAL2010105078	60.35708	-61.43043	60.37093	-61.45083	9.00
2010	TEL2010978063	52.16167	-50.92667	52.16167	-50.91500	8.96
2008	TEL2008820016	53.71167	-52.53000	53.72333	-52.53833	8.40
2006	TEM2006707032	48.75667	-49.81000	48.74500	-49.80167	8.25
2010	BAL2010105084	60.58233	-61.91133	60.59050	-61.93028	6.06
2009	3LCANZEE09022	48.34967	-49.06700	48.36133	-49.09267	6.00
2010	NED2010931089	45.06000	-55.27667	45.07333	-55.27833	5.23
2008	3LCANZEE08010	48.11067	-48.23950	48.11350	-48.20350	4.80
2006	BAL2006101084	60.64333	-61.43333	60.65000	-61.45667	4.61
2015	NED2015452053	44.92333	-55.49333	44.93333	-55.50167	4.11

2009	BAL2009104068	60.60733	-61.39233	60.61993	-61.38900	4.00
2005	BAL2005100066	60.18167	-61.72167	60.19333	-61.73833	3.75
2014	TEL2014137018	51.98833	-50.73833	52.00000	-50.74833	3.50
2004	TEL2004539008	52.37000	-51.18833	52.38000	-51.20167	3.40
2013	TEL2013123041	51.67500	-50.39333	51.68333	-50.39833	3.36
2009	NED2009913026	44.82333	-54.49333	44.83167	-54.49500	3.29
2007	TEM2007760037	43.87167	-52.58833	43.88000	-52.60000	2.96
2009	BAL2009104061	60.04833	-61.00250	60.03750	-60.98633	2.86
2012	NED2012420097	48.78333	-49.82833	48.77333	-49.82333	2.81
2006	BAL2006101077	60.17000	-61.78833	60.18167	-61.79000	2.80
2009	TEL2009895020	48.39167	-49.07167	48.38833	-49.05833	2.75
2012	NED2012424030	44.63667	-54.07000	44.63500	-54.08667	2.68
2007	TEL2007755037	51.94833	-50.71500	51.95833	-50.72833	2.63
2010	TEL2010975021	56.20833	-57.25500	56.20333	-57.24333	2.53
2005	TEM2005618061	44.82667	-54.49167	44.83333	-54.47667	2.52
2010	TEL2010979032	48.73167	-49.66333	48.74167	-49.67667	2.50
2005	TEL2005611039	54.63833	-52.74500	54.62667	-52.75167	2.42
2008	BAL2008103074	60.77600	-62.12500	60.77533	-62.14283	2.25
2010	NED2010930014	46.51500	-54.61833	46.50167	-54.61833	2.22
2005	TEM2005627035	44.73333	-54.28833	44.73333	-54.27167	2.02
2012	NED2012424033	44.43500	-53.62000	44.43833	-53.63000	1.96
2009	TEL2009894002	44.61333	-54.13167	44.61167	-54.11333	1.83
2012	NED2012424044	43.78833	-52.48167	43.78667	-52.49500	1.79
2009	TEL2009898039	48.12167	-48.36167	48.12000	-48.38000	1.79
2014	KIN2014109090	60.79007	-61.38135	60.79203	-61.41993	1.62
2007	3LCANZEE07008	48.14517	-48.42867	48.14133	-48.39350	1.54
2009	BAL2009104070	60.60117	-61.57650	60.59217	-61.55600	1.53
2011	BAL2011106073	60.38985	-63.08163	60.39235	-63.10705	1.46
2011	BAL2011106068	60.40958	-61.71427	60.41343	-61.69083	1.43
2009	TEL2009896006	54.12000	-52.68333	54.11000	-52.67500	1.40
2007	BAL2007102082	60.74200	-61.90500	60.75500	-61.90983	1.36
2008	TEL2008817011	55.71333	-56.97167	55.71833	-56.99167	1.35
2011	BAL2011106072	60.07970	-62.89383	60.09428	-62.89113	1.32
2010	TEL2010978064	52.02167	-50.66333	52.01167	-50.65167	1.30
2014	TEL2014134016	56.33833	-57.66667	56.32667	-57.65167	1.24
2006	TEM2006707011	47.65000	-50.58167	47.64333	-50.56833	1.03
2008	TEM2008838013	46.36000	-49.45333	46.35833	-49.43667	1.00

Small Gorgonian Corals

Data Sources and Distribution

The data available for the analysis of small gorgonian corals in the Newfoundland and Labrador Shelves Biogeographic Zone came from 2 DFO administrative regions (Newfoundland and Labrador, and Maritimes) conducted over 13 years from 2003 to 2015, and from Spanish surveys of a portion of Grand Bank (Kenchington et al., 2010). The species comprising this taxon and used in our analyses are detailed in Guijarro et al. (2016).

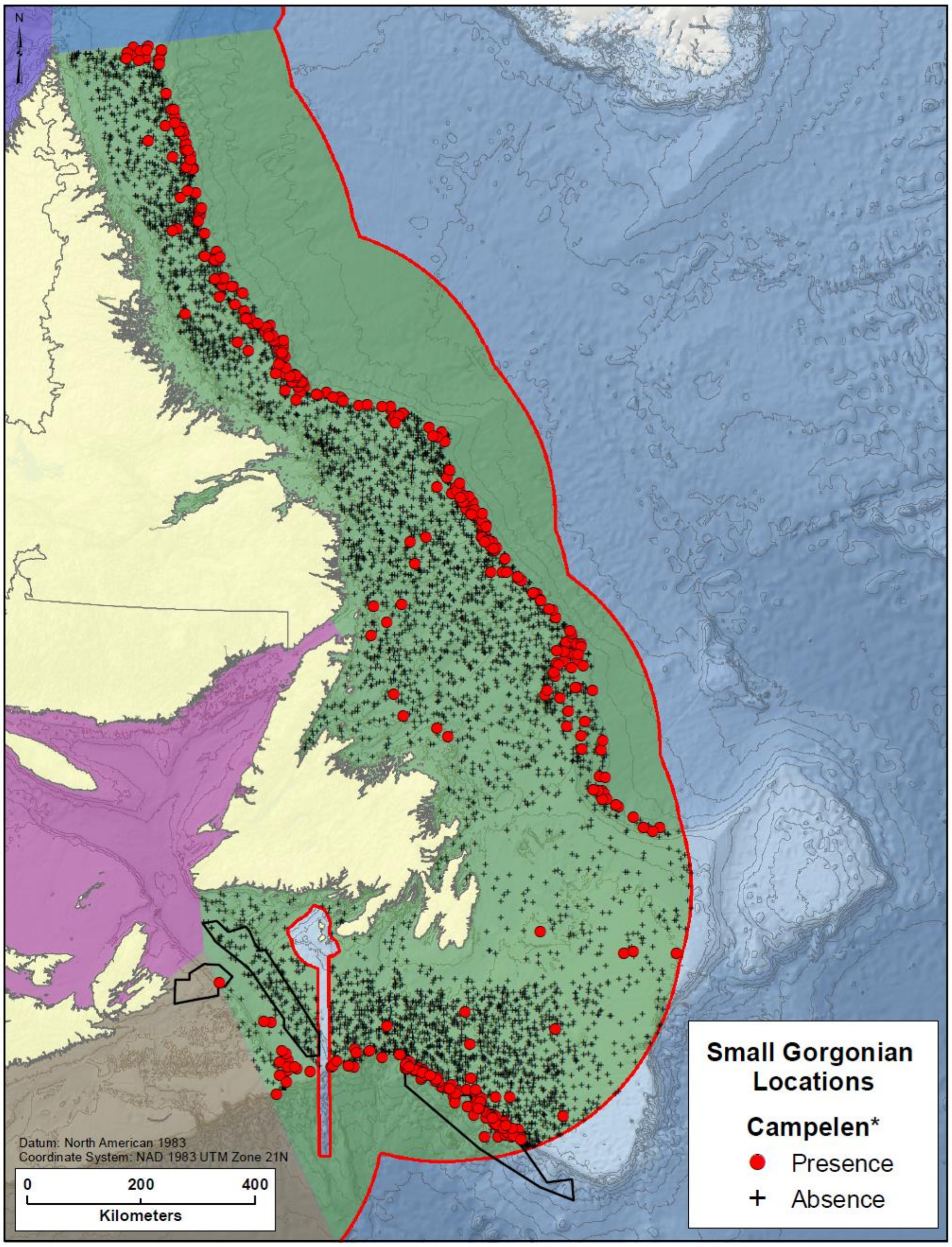

Figure 51. Distribution of small gorgonian corals from DFO research vessel survey catches mostly* using a Campelen trawl. The 3O Coral Closure, the St. Ann's Bank Proposed Closed

Area and the Laurentian Channel Proposed Closed Area are depicted in outline (see Fig. 29). Red circles indicate small gorgonian coral presence in the catch and black crosses indicate verified null records. *A Western IIA trawl was used on the Nova Scotia side of the Laurentian Channel.

There were 396 records with small gorgonian corals (96% from Newfoundland and Labrador Region of DFO) and 5261 records of catches with no small gorgonian corals from the same surveys. This compares with the 152 records with small gorgonian coral catches available for the previous analyses (Kenchington et al., 2010). All surveys that were used in this time series were conducted with a Campelen trawl except for those from Maritimes Region that used a Western IIA trawl. For all surveys, tow locations were chosen following a stratified random design (Kulka et al., 2006; Chadwick et al., 2007). Within the surveyed area, the small gorgonian corals were present largely on the continental slopes and were less common on the shelf (Figure 51).

Evaluation of Search Radii

The default search radius for the KDE was 32.1346 km. We compared that KDE surface with that produced by using a 25 km search radius, as the default search radius over-smoothed the data (Figure 52). The 25 km search radius was adopted for the preparation of the KDE surface as it didn't affect the continuity of the surface in the high distribution areas and provided tighter contours for the analyses. The grid size was 4.3263 km^2. Contours placed over the KDE surface were finely spaced at 0.000001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons. The final KDE surface is shown in Figure 53 in relation to the tow positions that caught small gorgonian corals.

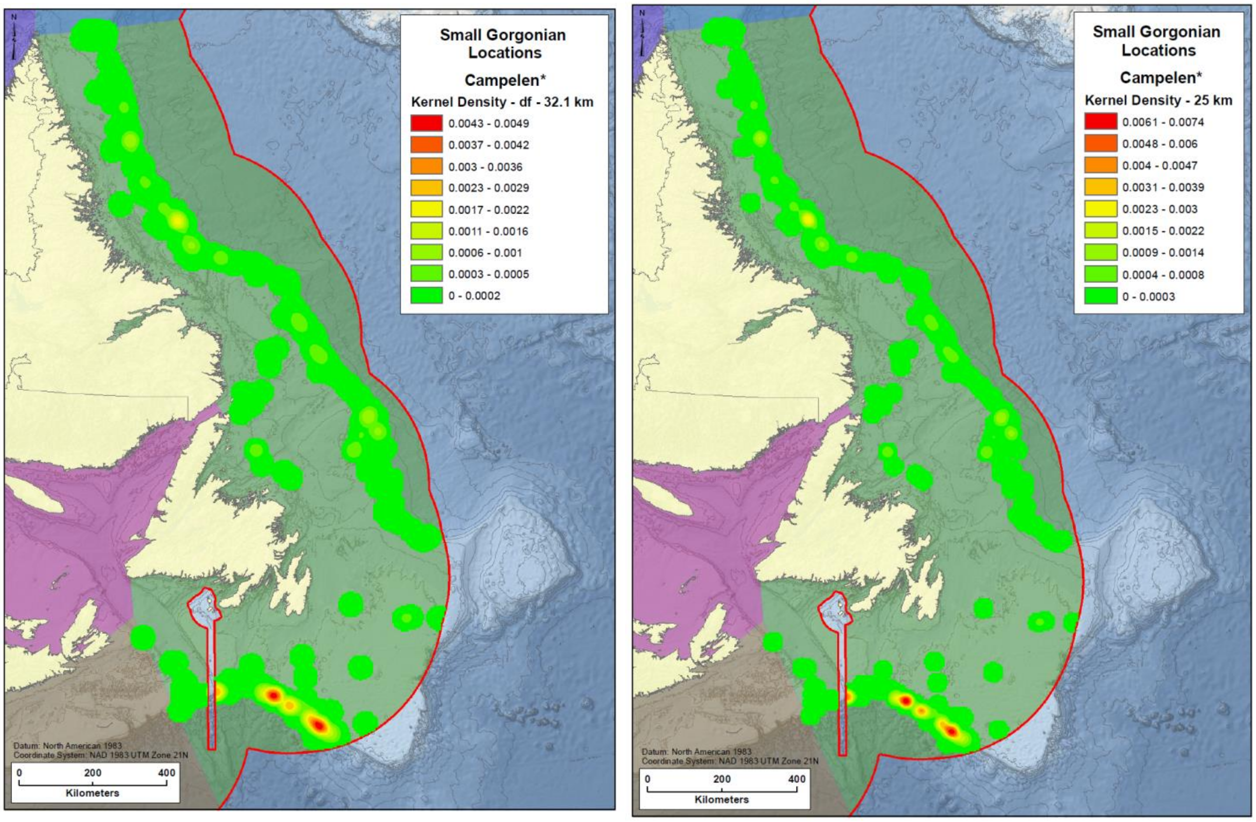

Figure 52. KDE surface of small gorgonian coral biomass produced with the default (df) search radius (32.1 km) (left) and 25 km (right) search radius. The former is over-smoothed in the area of higher concentration.

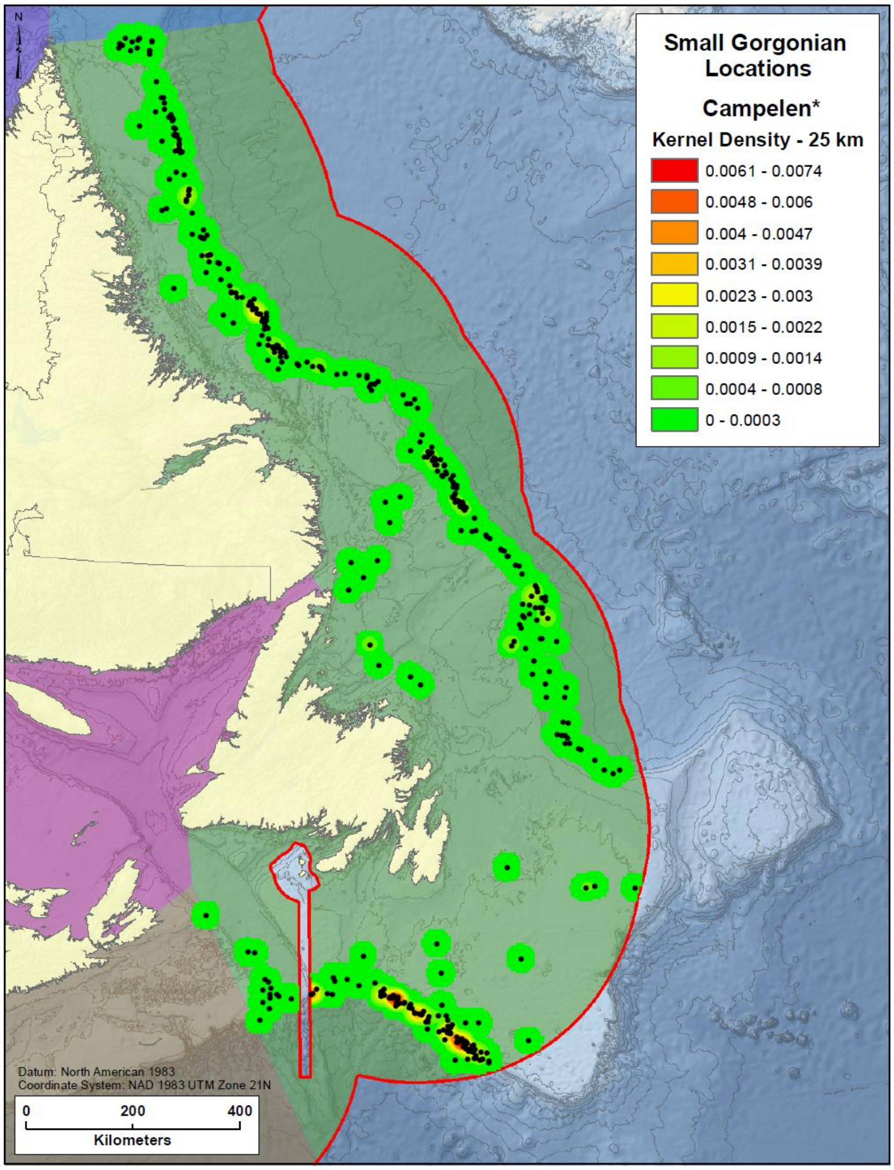

Figure 53. KDE analyses conducted with a 25 km search radius. Tow positions with small gorgonian coral catch are depicted by black closed circles.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each small gorgonian coral weight threshold is provided in Table 14 and illustrated in Figure 54. The first large increase in area was found between 0.2 and 0.1 kg where area increased 126% (Table 14, Figures 54, 55). That increase was supported by 27 additional points (Table 14), and 0.2 kg was selected as the threshold for the analyses. The areas occupy 5,626 km^2.

Table 14. Comparative Small Gorgonian Coral Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Small Gorgonian Corals is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
1	7	-	461	255
0.7	12	5	1640	133
0.5	19	7	3815	47
0.2	43	24	5626	126
0.1	70	27	12716	16
0.08	82	12	14734	37
0.07	92	10	20254	42
0.05	130	38	28824	38
0.03	169	39	39714	33
0.02	203	34	52914	49
0.01	301	98	79086	3
0.005	320	19	81393	55
0.001	389	69	126178	

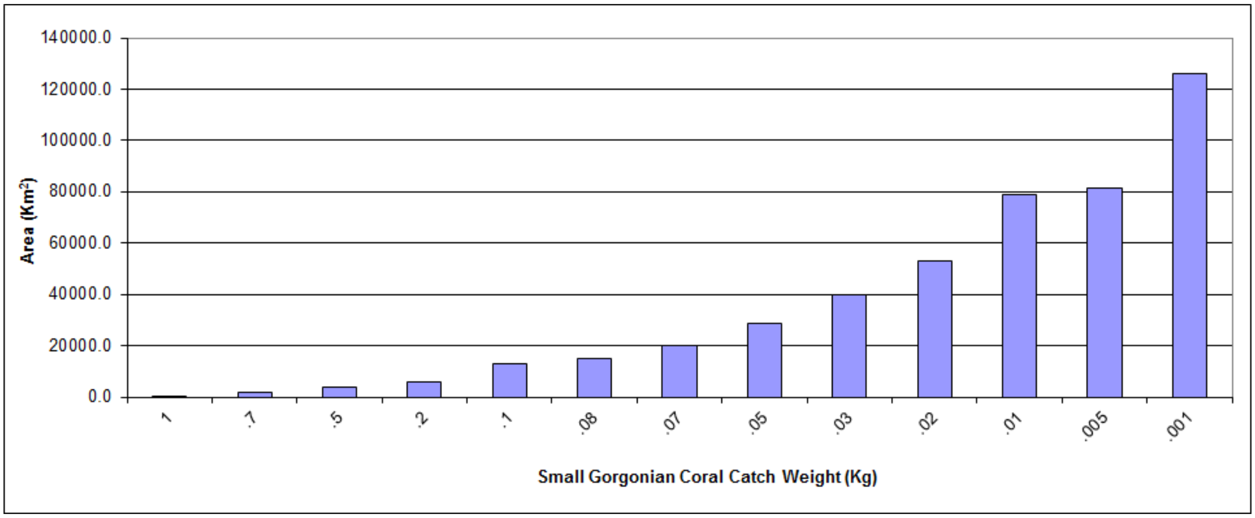

Figure 54. Barplot of polygon area (km^2) associated with small gorgonian coral weight thresholds (kg).

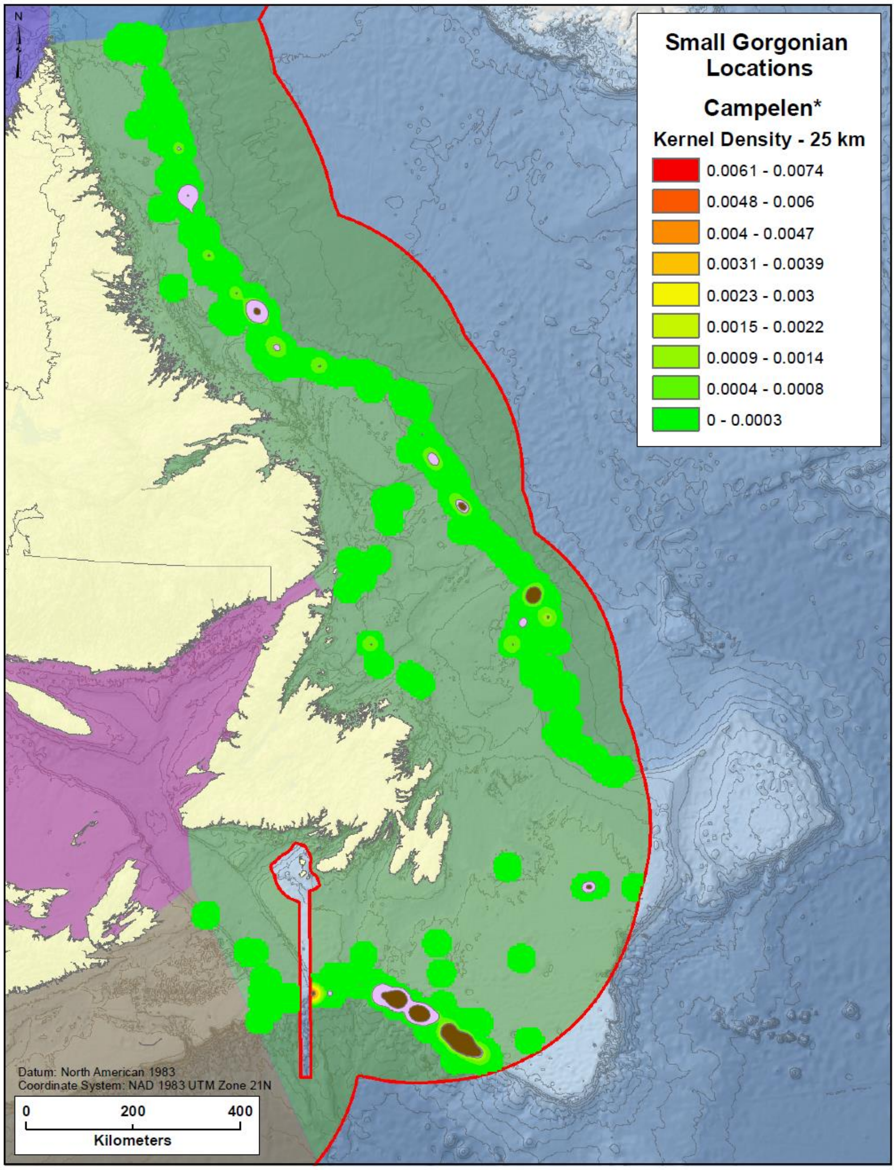

Figure 55. Location of polygons encompassing the ≥0.2 kg catches (dark brown) and the ≥0.1 kg catches (purple), showing the increase in area (Table 14) produced by the latter threshold. The polygons are overlain on the KDE biomass surface produced with the 25 km search radius.

Location of the Dense Aggregations

The locations of areas that indicate significant concentrations of small gorgonian corals are shown in Figure 56 and the locations of the survey tows that defined those polygons are provided in Table 15. Most of the high concentrations of small gorgonian corals are located in the south of the biogeographic zone, in the Laurentian Channel and adjacent slopes. In Figure 57, the results of this study are compared to those produced in Kenchington et al. (2010).

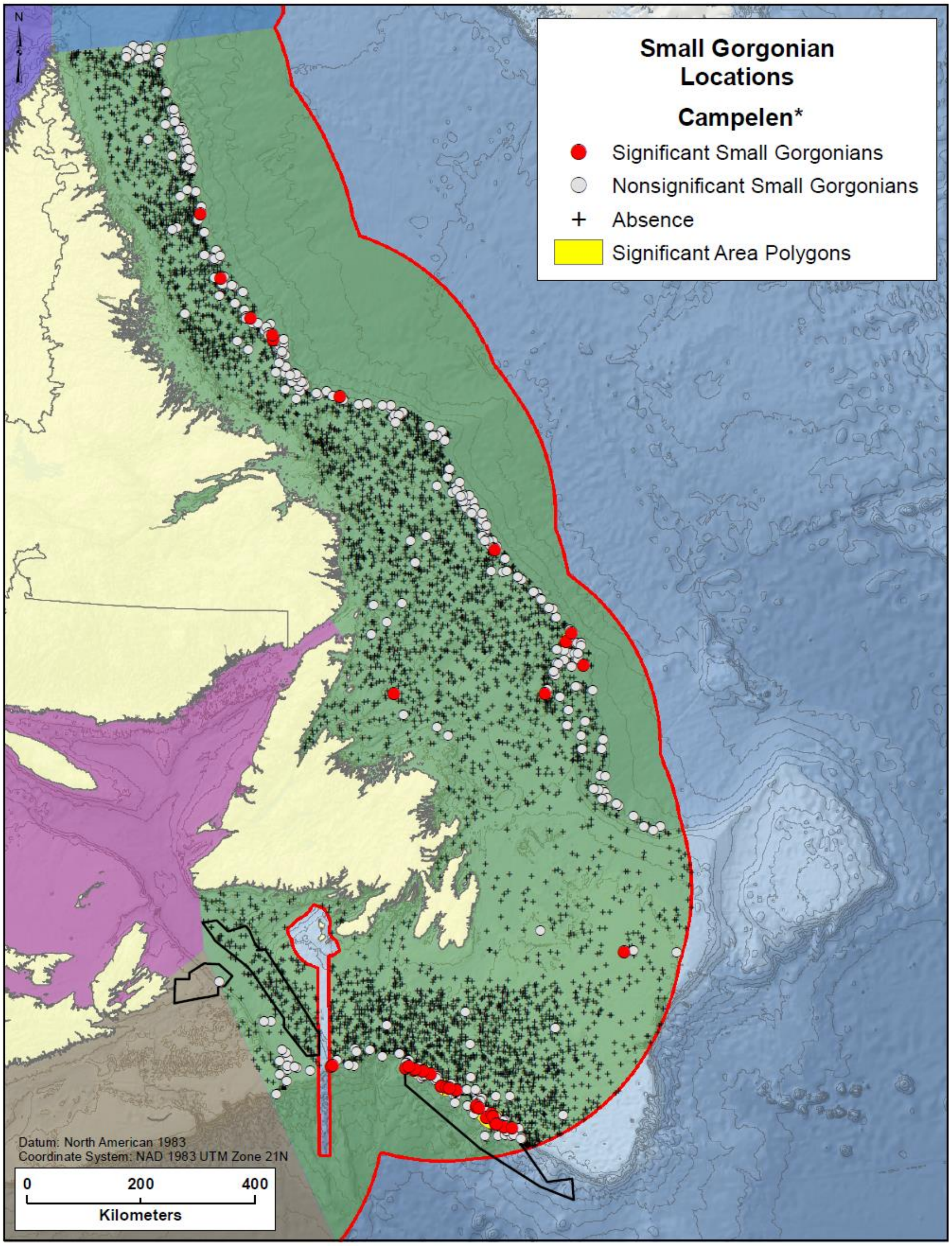

Figure 56. Location of the polygons identifying significant small gorgonian coral aggregations relative to the broader distribution of small gorgonian corals and areas closed or proposed to be closed to protect benthic species and habitats (see Fig. 29) in the Newfoundland and Labrador Shelves Biogeographic Zone. Catches that contributed to the identification of the polygons are indicated as significant (Table 15), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

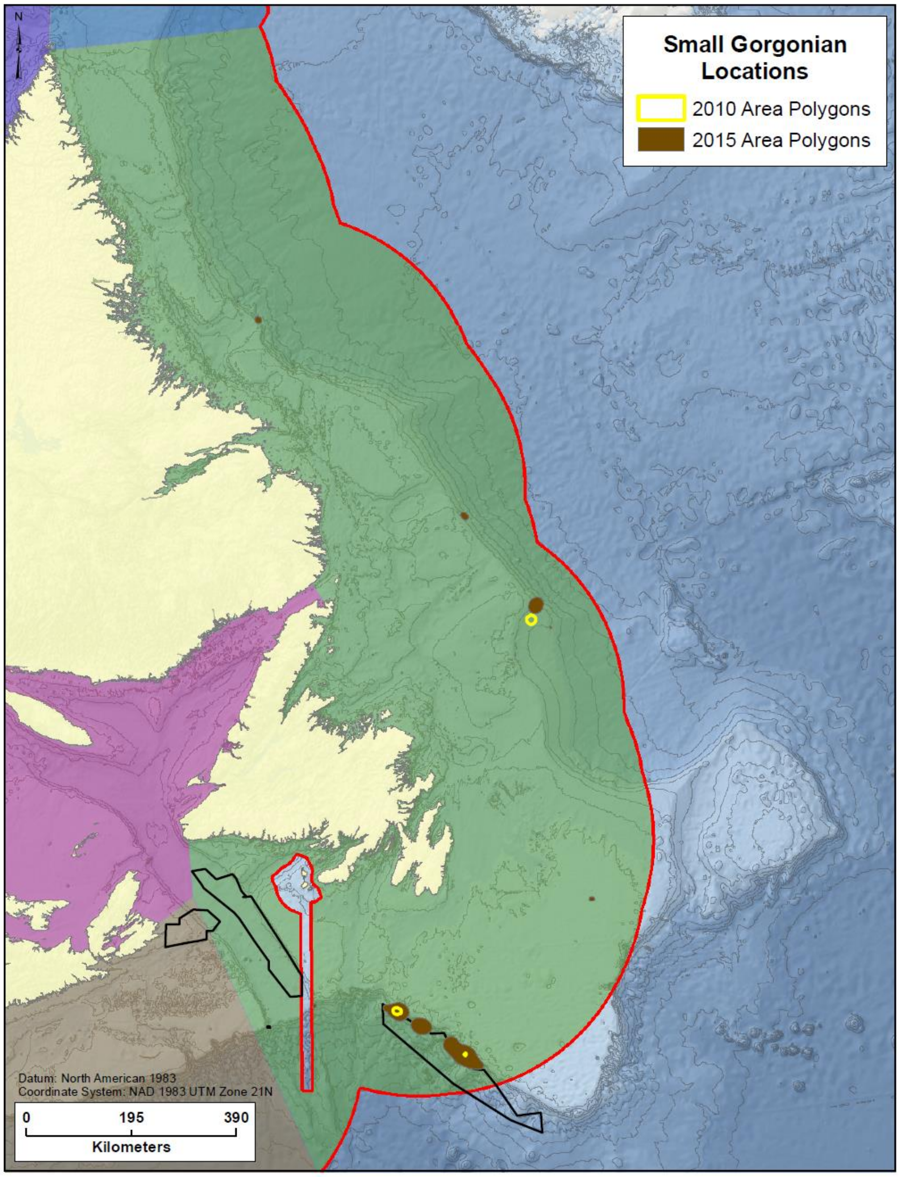

Figure 57. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (brown polygons). Areas closed or proposed to be closed to protect benthic species and habitats are indicated in outline (see Fig. 29).

Table 15. Newfoundland and Labrador Shelves Biogeographic Zone: Details of the Location of Research Vessel Small Gorgonian Coral Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Small Gorgonian Coral Weight (kg)
2005	NED2005656066	44.82667	-56.10333	44.83000	-56.09333	2.80
2010	NED2010942015	44.69333	-54.11833	44.68833	-54.12833	2.60

2009	TEL2009894010	43.93167	-52.77667	43.94167	-52.78667	1.75
2005	TEM2005619047	43.93667	-52.62833	43.94000	-52.64167	1.45
2008	TEL2008817027	56.26667	-57.53500	56.27500	-57.54833	1.40
2015	NED2015453013	44.45667	-53.72000	44.46500	-53.73000	1.18
2008	TEM2008836018	43.85667	-52.58167	43.84667	-52.58833	1.05
2011	NED2011409013	44.69333	-54.12167	44.68667	-54.13167	0.98
2011	BAL2011106018	58.21113	-59.75405	58.22243	-59.74613	0.83
2005	TEM2005588009	51.30833	-50.11667	51.30000	-50.11167	0.76
2012	NED2012417093	44.42833	-53.53500	44.43500	-53.52500	0.71
2009	TEL2009894001	44.76167	-54.49833	44.76833	-54.51500	0.70
2013	NED2013438018	44.43500	-53.60667	44.43833	-53.59000	0.64
2014	TEL2014138042	50.91833	-49.74333	50.92667	-49.73167	0.60
2011	NED2011403066	44.13333	-52.96500	44.13500	-52.98167	0.60
2007	TEM2007760031	44.69500	-54.11333	44.69667	-54.10167	0.56
2008	TEM2008827044	43.74333	-52.22500	43.74833	-52.23833	0.52
2012	NED2012419025	44.09000	-52.96000	44.08500	-52.95000	0.50
2010	NED2010932067	44.07833	-52.91667	44.07167	-52.90167	0.50
2007	TEL2007755066	50.52000	-50.75167	50.53167	-50.75333	0.45
2009	NED2009905023	43.76333	-52.39333	43.77500	-52.40333	0.44
2010	NED2010947022	50.67167	-54.47500	50.67667	-54.49167	0.40
2010	NED2010932044	44.42167	-53.55833	44.41833	-53.54167	0.40
2013	TEL2013119001	55.36833	-55.69667	55.37333	-55.70833	0.39
2015	NED2015453027	43.98167	-52.64500	43.97667	-52.63167	0.38
2008	TEL2008817028	56.33833	-57.57333	56.34667	-57.58667	0.37
2013	NED2013433010	44.09667	-52.98333	44.09000	-52.99833	0.31
2009	NED2009905022	43.82333	-52.56667	43.82833	-52.58000	0.29
2007	TEM2007771025	44.72667	-54.30833	44.72667	-54.32000	0.28
2011	TEL2011096011	52.84333	-51.72667	52.83500	-51.71333	0.26
2007	TEM2007771027	44.37500	-53.38833	44.36833	-53.37167	0.26
2008	TEM2008827040	43.93167	-52.61167	43.92500	-52.59833	0.23
2014	TEL2014139048	43.82167	-52.54833	43.82500	-52.53000	0.23
2005	TEM2005627035	44.73333	-54.28833	44.73333	-54.27167	0.22
2008	TEM2008835019	44.64333	-53.95000	44.64000	-53.96333	0.21
2013	NED2013433008	44.45167	-53.70833	44.45000	-53.69667	0.20
2008	TEM2008835013	44.76667	-54.42667	44.75833	-54.41333	0.20
2008	TEM2008838013	46.36000	-49.45333	46.35833	-49.43667	0.20
2006	TEL2006680016	57.21500	-59.07000	57.22667	-59.08167	0.20
2006	TEL2006679029	56.60000	-58.18833	56.61000	-58.20167	0.20
2013	TEL2013123039	51.43333	-49.95833	51.42333	-49.94500	0.20
2007	TEM2007759046	44.80667	-56.14500	44.80500	-56.16167	0.20
2007	TEM2007759077	44.78500	-54.43000	44.78333	-54.41667	0.20

Gulf Biogeographic Zone

The Gulf Biogeographic Zone, located in the Gulf of St. Lawrence, encompasses 4 DFO administrative regions, although the majority of data come from two; the Gulf Region in the south which extends from the New Brunswick-Quebec border to the northern tip of Cape Breton, and the Quebec Region in the north, within the borders of the province of Quebec (Figure 58). In the south the surveys were conducted using Western IIA trawl gear. In the north, the surveys were conducted with Campelen trawls, and consistent invertebrate catch reporting did not start until 2006. Previously, Kenchington et al. (2010) demonstrated that these two gear types should be analyzed separately, and that the records from the southern Gulf collected prior to 2003 were temporally distinct from latter surveys, particularly for the sponges, which showed evidence of having been in a decline whether through fishing or other factors. Our analyses here were conducted on sponges and sea pens by gear type within the Gulf Biogeographic Zone. Data from the Gulf Region and some from the Maritimes Region were used for the Southern Portion and data from Quebec Region with some from Newfoundland and Labrador Region were used for the Northern Portion. The species that comprised each taxon analysed are provided in Murillo et al. (2016). Nozères et al. (2015) provide a comprehensive review of the biodiversity of this region.

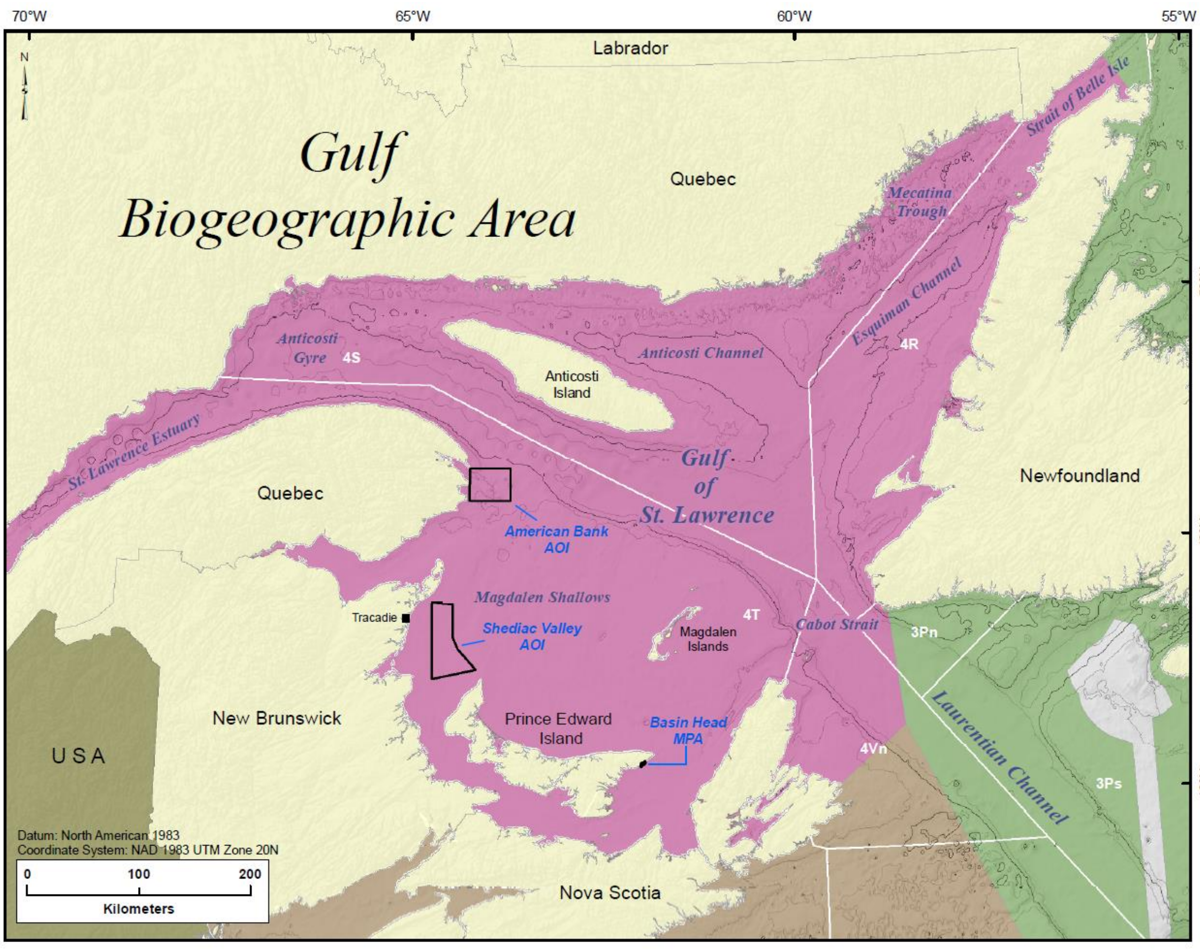

Figure 58. Map showing the area of the Gulf Biogeographic Zone (DFO, 2009), with place names.

Southern Portion of the Gulf Biogeographic Zone

Sponges (Porifera)

Data Sources and Distribution

The data available for the analyses of sponges in the southern portion of the Gulf Biogeographic Zone covered 12 years from 2003 to 2014. Data were from two DFO administrative regions (Gulf and Maritimes), with most of the data (98%) from the Gulf Region. There were 1238 records with sponge catch and 814 records of catches with no sponges from the same surveys. All surveys that were used in this time series were conducted with Western IIA trawls with tow locations chosen following a stratified random design (Kulka et al., 2006; Chadwick et al., 2007). Within the surveyed area, the sponges had a wide distribution and were caught in most tows (Figure 59).

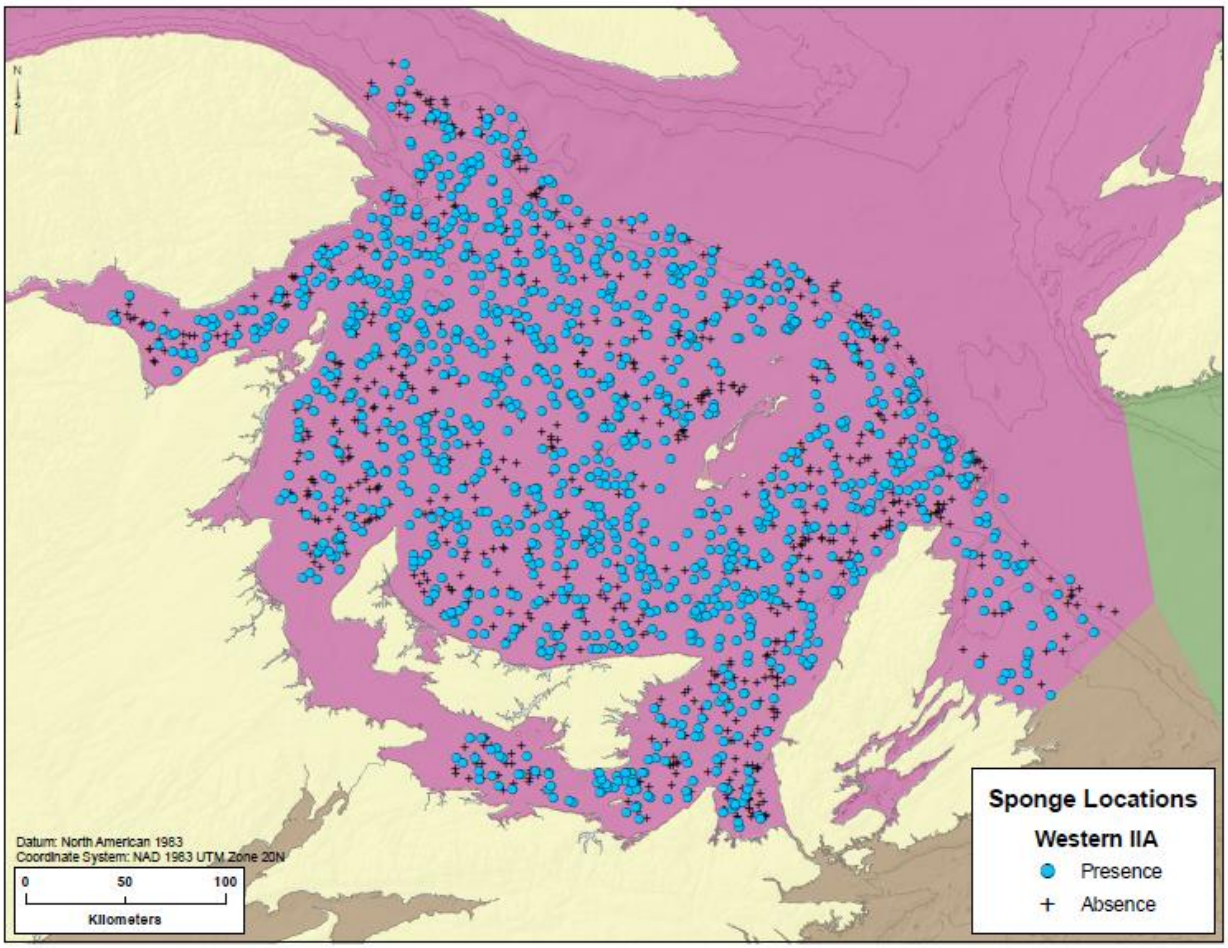

Figure 59. Distribution of sponges from DFO research vessel survey catches in the southern portion of the Gulf Biogeographic Zone sampled using a Western IIA trawl. Blue circles indicate sponge presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 12.73517 km. We compared that KDE surface with those produced by using 10 km and 15 km search radii. The default search radius produced a good fit to the data (Figure 60) while the 10 km radius under-smoothed, particularly in the area near Cape Breton, and the 15 km over-smoothed the data (Figure 61).

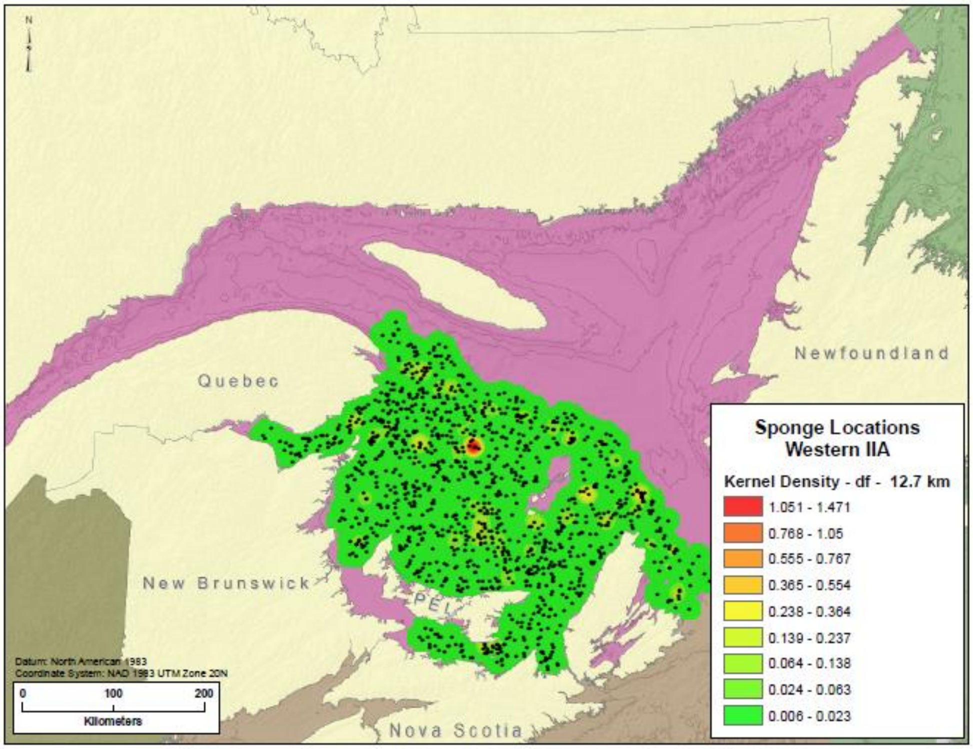

Figure 60. KDE surface of sponge biomass produced with the default (df) search radius (12.7 km). Tow locations with sponge catch used in the analysis are indicated in black.

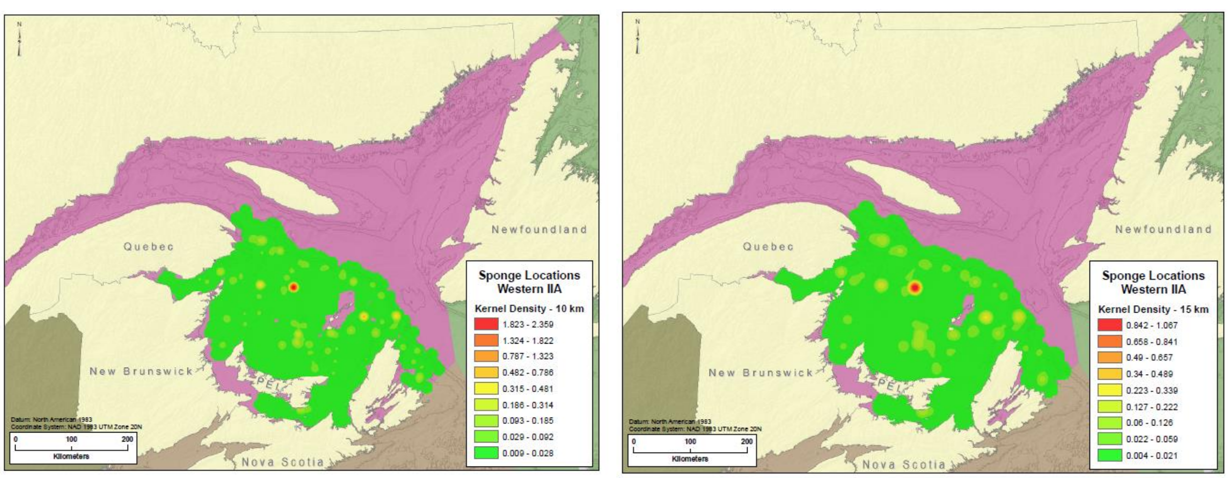

Figure 61. KDE analyses conducted with a 10 km (left) and 15 km (right) search radius. The former is under-smoothed and the latter over-smoothed.

The default search radius was used in the preparation of the KDE surface. The default grid size was 2.2786 km^2. Contours placed over the KDE surface were finely spaced at 0.0001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sponge weight threshold is provided in Table 16 and illustrated in Figure 62. The first large increase in area was found between 7 and 6 kg where area increased 135% (Table 16). However that areal expansion was only supported by 4 additional points and examination of the spatial area occupied by the polygons showed that there were a number of small isolated catches causing the area to increase. The next largest increase in area was seen between 5 and 4 kg (Table 16, Figures 62, 63). That change was supported by 7 additional data points but the expansion was around established areas to a greater extent than the previous threshold. We looked at the change in area between the 3kg and 2kg thresholds (Figure 63) and that was a clear expansion of the type that we would identify with a threshold, except for the fact that the 3kg polygons just identified isolated points over the 4 kg polygons. Taken together, 5 kg was considered to be the threshold delineating significant concentrations of sponges. The areas occupy 328 km^2.

Table 16. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
50	2	-	4	226
20	6	4	13	82
15	9	3	24	96
10	15	6	48	30
9	18	3	62	54
8	21	3	96	30
7	25	4	125	135
6	29	4	293	12
5	35	6	328	444
4	42	7	1781	8
3	53	11	1927	192
2	89	36	5631	110
1	184	95	11801	168
0.5	315	131	31682	122
0.1	703	388	70198	11
0.05	860	157	78195	10
0.01	1135	275	85733	0
0.001	1238	103	85733	

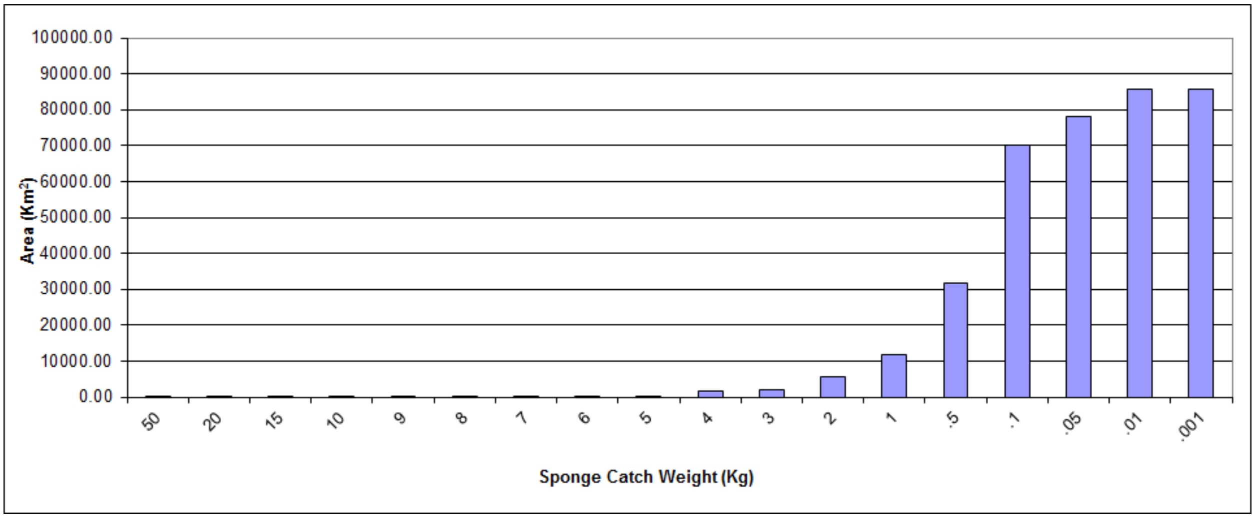

Figure 62. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

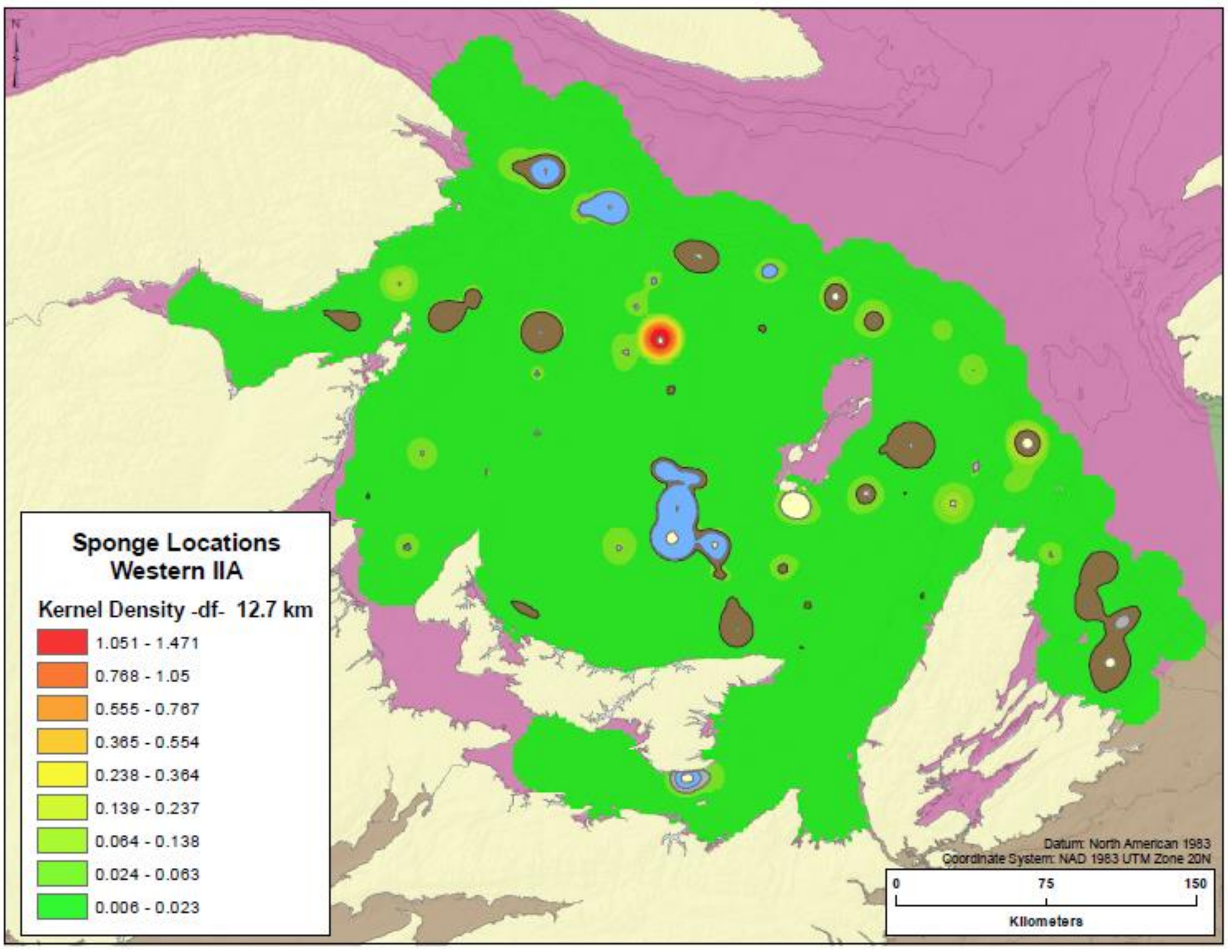

Figure 63. Location of polygons encompassing the ≥5 kg catches (cream), ≥4 kg catches (blue), ≥3 kg catches (light grey) and ≥2 kg catches (brown), showing the increase in area (Table 16) and overlain on the KDE biomass surface produced with the default (df) search radius. The ≥5 kg (cream) polygons were selected to represent the significant concentrations of sponges.

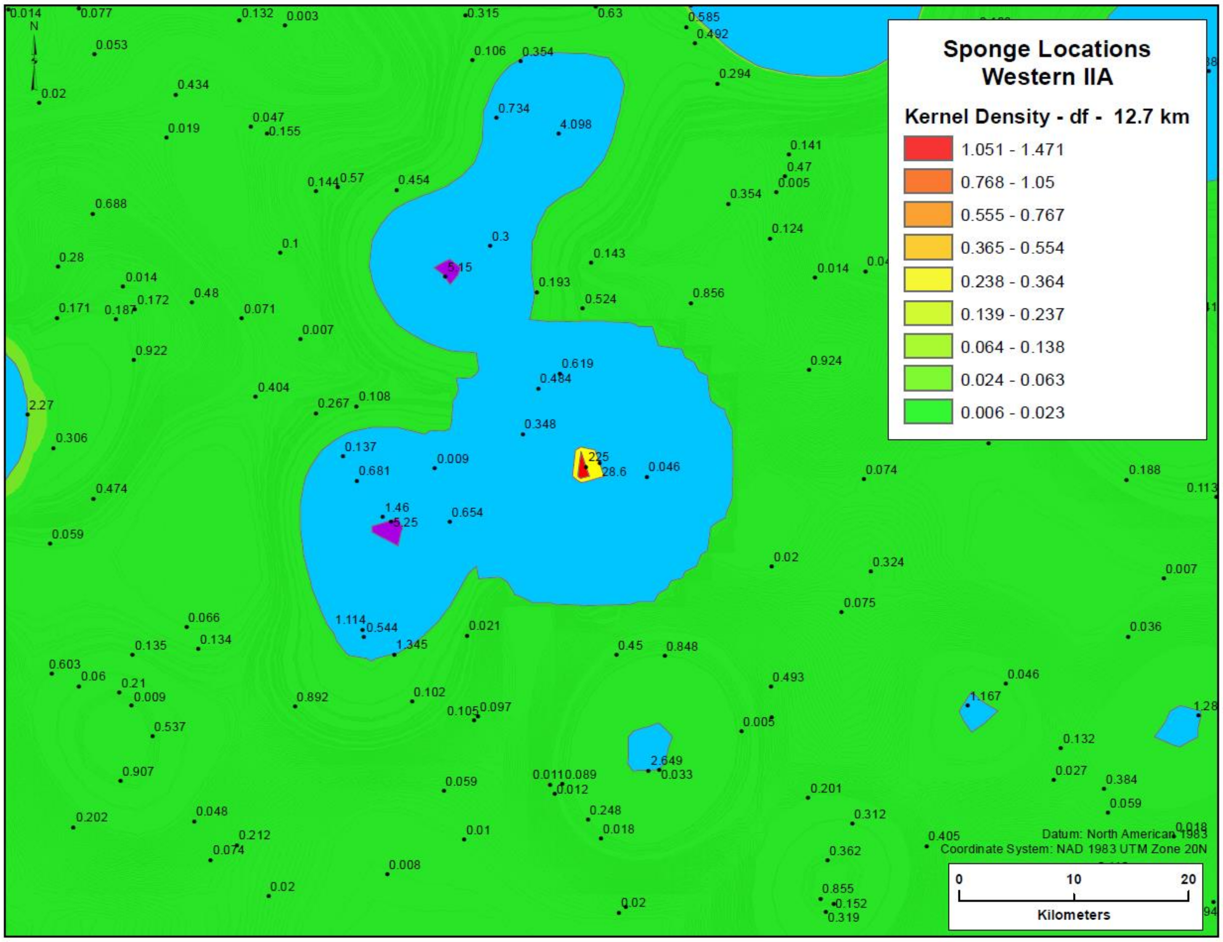

Figure 64. Polygons established using threshold values of ≥50 kg (red), ≥20 kg (yellow), ≥5 kg (purple) and ≥1 kg (blue) overlain on the KDE biomass surface created using the default (df) search radius. Catch weights are labelled for each tow location.

The KDE surface created a high density area (Figures 63, 64) west of the Tracadie, New Brunswick area. In this case a single high catch of 225 kg was taken but it had very low catches surrounding it (Figure 64). We verified that catch, and it is accurate, filling 9 buckets with sponge. The KDE surface would have spread the biomass out from that peak over the circle creating a modelled high biomass density area that was larger than that of the nearest neighbour catches. This can happen if there is no "sponge ground" habitat and is a good location to compare KDE results with those of species distribution models (Murillo et al., 2016) to see whether this catch could have supported higher biomass in the broader area. We note that the high catch is still incorporated into the significant areas (Table 17, Figure 64) but is not visible on the map at the scale we have shown them (Figure 63).

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of sponges are shown in Figure 65 and the locations of the survey tows that defined those polygons are provided in Table 17. In Figure 66, the results of this study are compared to those produced in Kenchington et al. (2010).

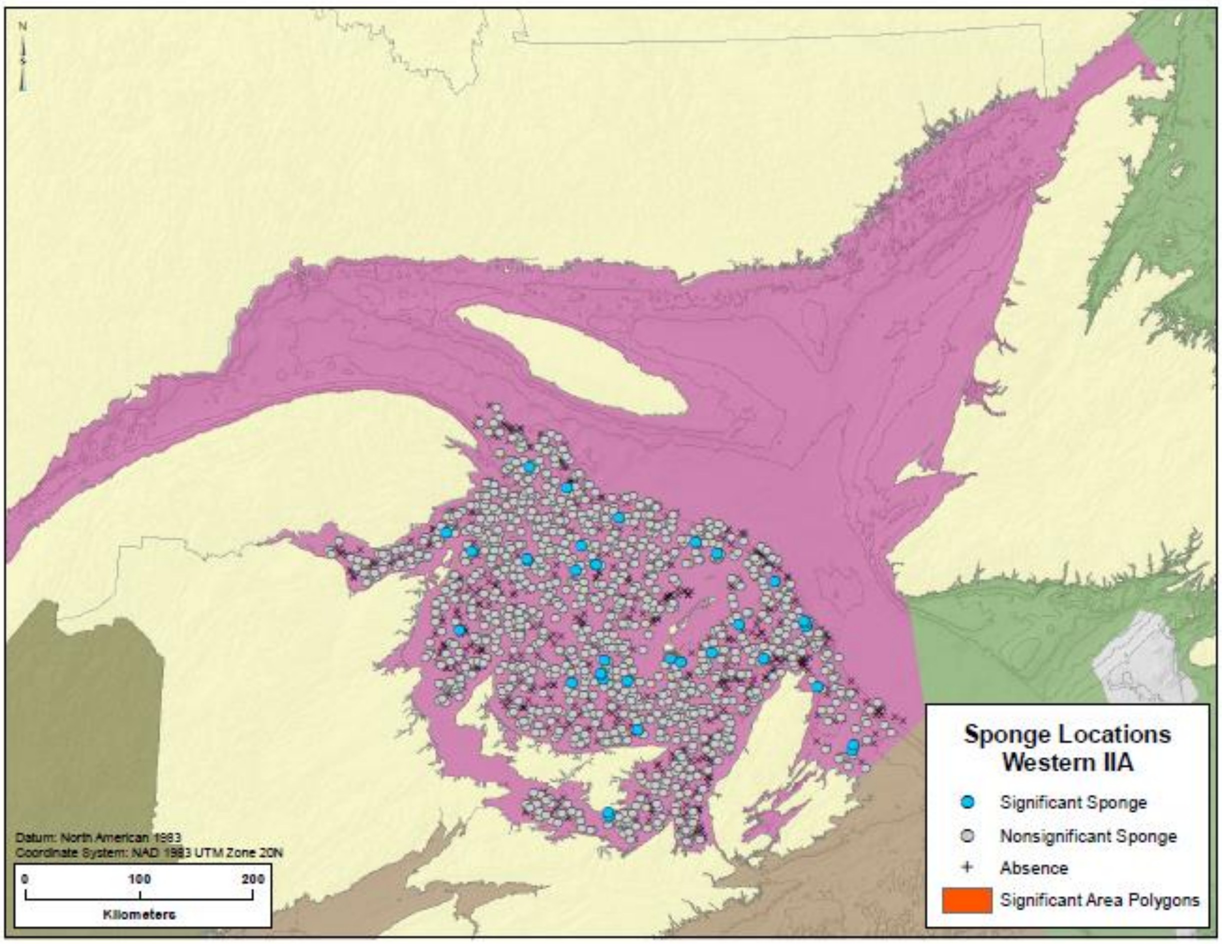

Figure 65. Locations of the significant sponge catches relative to the broader distribution of sponges in the southern portion of the Gulf Biogeographic Zone. Catch locations that contributed to the identification of the polygons are indicated as significant (Table 17), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross. The polygons are very small and not visible in this map.

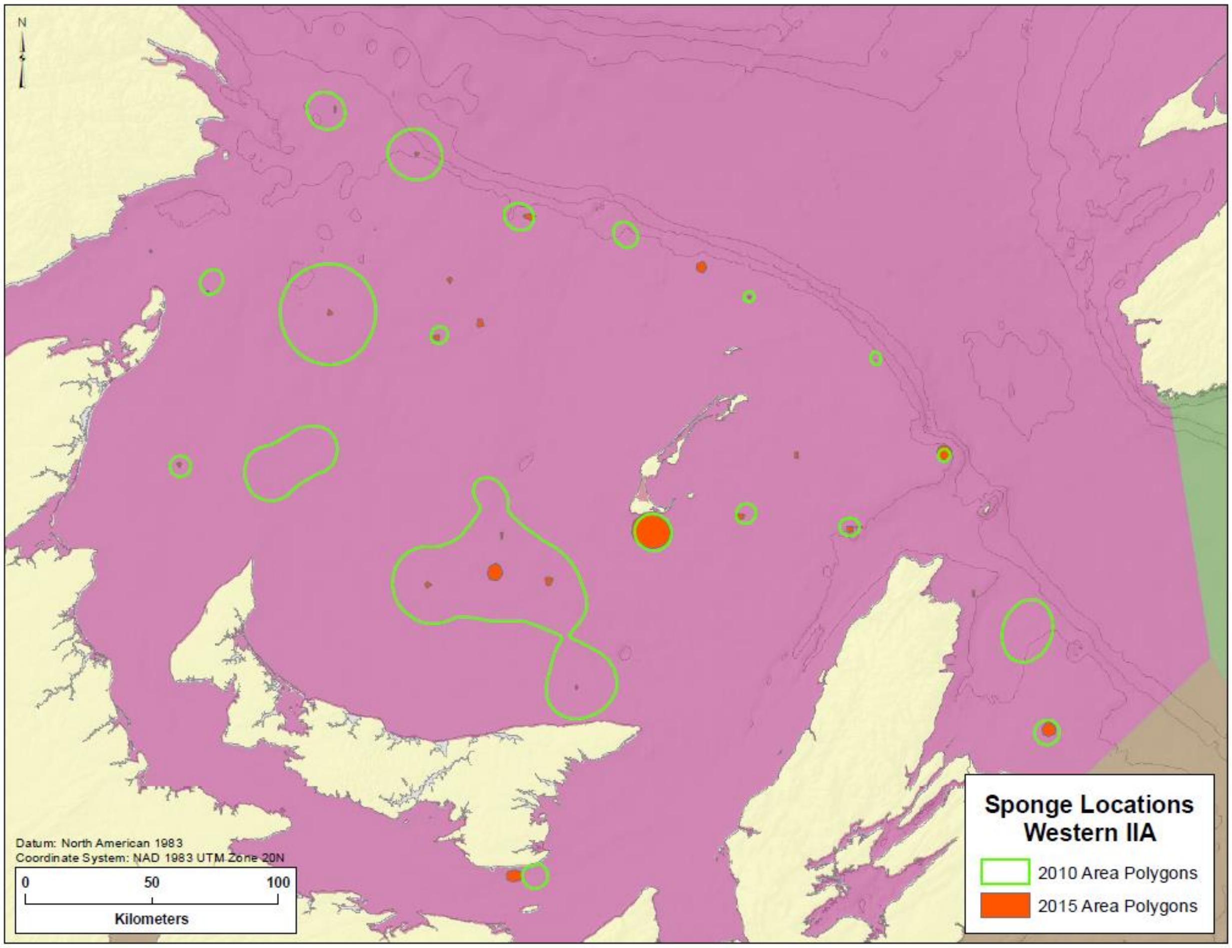

Figure 66. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (green outline) and those identified in this study (orange polygons).

Table 17. Southern Portion of the Gulf Biogeographic Zone: Details of the Location of Research Vessel Sponge Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)
2009	TEL2009992129	47.89625	-62.79942	47.90767	-62.78667	225.000
2010	TEL201074145	47.41075	-61.13158	47.42200	-61.14583	57.202
2010	TEL201074065	47.89917	-62.78342	47.88950	-62.80050	28.600
2009	TEL2009992052	47.14492	-62.69417	47.15700	-62.70750	24.500
2005	TEL2005507093	47.93220	-63.59120	47.93033	-63.63483	23.202
2006	TEL2006678034	47.41130	-60.35780	47.42800	-60.38567	21.023
2014	TEL2014433089	48.13917	-64.55250	48.12950	-64.56933	19.230
2003	TEL2003352023	47.15580	-61.92430	47.13333	-61.91017	18.940
2005	NED2005542093	47.93970	-63.60180	47.93433	-63.64333	16.788
2006	TEL2006678071	48.49900	-63.12730	48.51067	-63.15300	13.734

2005	TEL2005507146	47.97870	-61.36330	47.97517	-61.33300	13.462
2003	TEL2003352019	47.13570	-60.86070	47.13783	-60.90167	13.151
2006	TEL2006678077	48.66370	-63.58030	48.64167	-63.55167	11.892
2012	TEL2012205042	47.41933	-60.37742	47.43033	-60.37267	11.100
2003	TEL2003352043	46.97250	-63.06820	46.98283	-63.02817	10.200
2007	TEL2007745167	46.39017	-59.88217	46.40550	-59.84633	9.650
2008	TEL2008815186	47.19070	-61.45580	47.16300	-61.47233	9.645
2007	TEL2007749183	46.59280	-62.30870	46.58433	-62.28083	9.385
2014	TEL2014433066	45.94250	-62.66075	45.94033	-62.67700	8.924
2005	NED2005542141	47.74180	-60.70870	47.76900	-60.70633	8.167
2012	TEL2012205058	48.06983	-61.62025	48.07183	-61.63600	8.000
2013	TEL2013318037	45.91625	-62.64692	45.91250	-62.66767	7.750
2003	TEL2003352040	47.02100	-62.73970	47.02250	-62.69683	7.619
2008	TEM2008830142	46.43017	-59.86483	46.45000	-59.83100	7.250
2005	TEL2005507069	47.37680	-64.37530	47.38867	-64.35050	7.070
2008	TEL2008815156	46.97680	-62.42750	46.94783	-62.41633	6.928
2005	NED2005542096	48.00120	-64.24250	48.02033	-64.25033	6.761
2004	NED2004446019	46.99120	-62.70530	46.98767	-62.66250	6.288
2004	TEL2004434032	47.12550	-61.81270	47.09883	-61.82967	6.150
2008	TEL2008815049	47.03330	-62.74400	47.00717	-62.76667	5.994
2010	TEL201074044	47.37942	-60.36458	47.36700	-60.35367	5.848
2007	TEL2007749130	48.26700	-62.51830	48.25717	-62.54617	5.479
2010	NED2010027116	46.90200	-60.23867	46.91733	-60.20233	5.350
2004	TEL2004434094	47.85320	-63.02720	47.83700	-63.06150	5.250
2009	TEL2009992130	48.04550	-62.96333	48.05783	-62.97567	5.150

Sea Pens (Pennatulacea)

Data Sources and Distribution

Data were from two DFO administrative regions, with 92% of the catches from the Gulf Region and the remainder from Maritimes Region. There were 272 records with sea pen catch and 1779 records of catches with no sea pens from the same surveys. All surveys that were used in this time series were conducted with Western IIA trawls with tow locations chosen following a stratified random design (Kulka et al., 2006; Chadwick et al., 2007). Within the surveyed area, the sea pens were located along the Laurentian Channel (Figure 67). Details of the species codes that were used for the analyses are provided in Murillo et al. (2016).

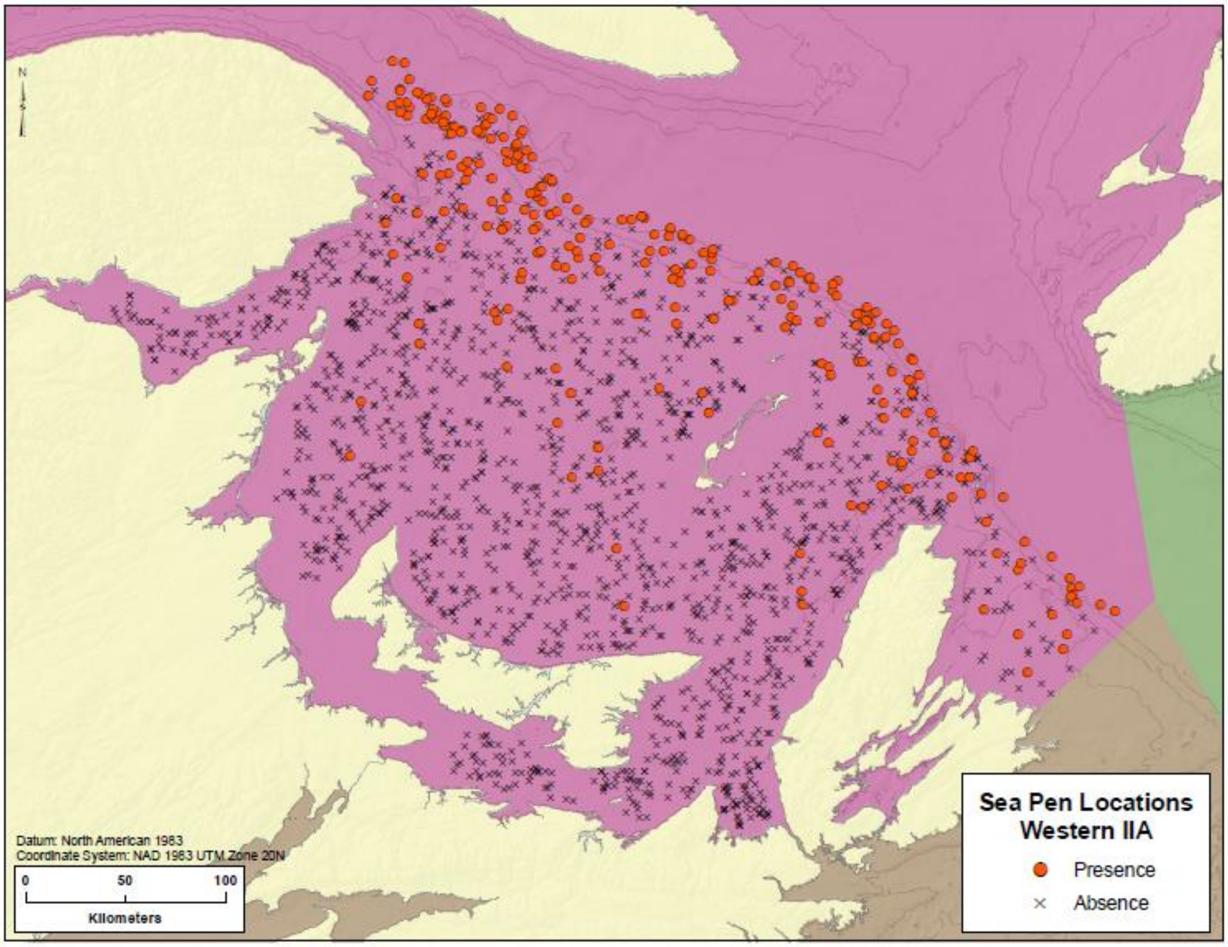

Figure 67. Distribution of sea pens from DFO research vessel survey catches using a Western IIA trawl. Red circles indicate sea pen presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 10.1877 km. We compared that KDE surface with one produced by using a 15 km search radius. The default search radius produced a good fit to the data (Figure 68) however it was under-smoothed particularly in the area around Cape Breton and along the edge of the Laurentian Channel; the 15 km radius was a better fit with a more continuous surface needed for contouring, and was used in the preparation of the KDE surface (Figure 69). The grid size was 1.6273 km^2. Contours placed over the KDE surface were finely spaced at 0.0001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

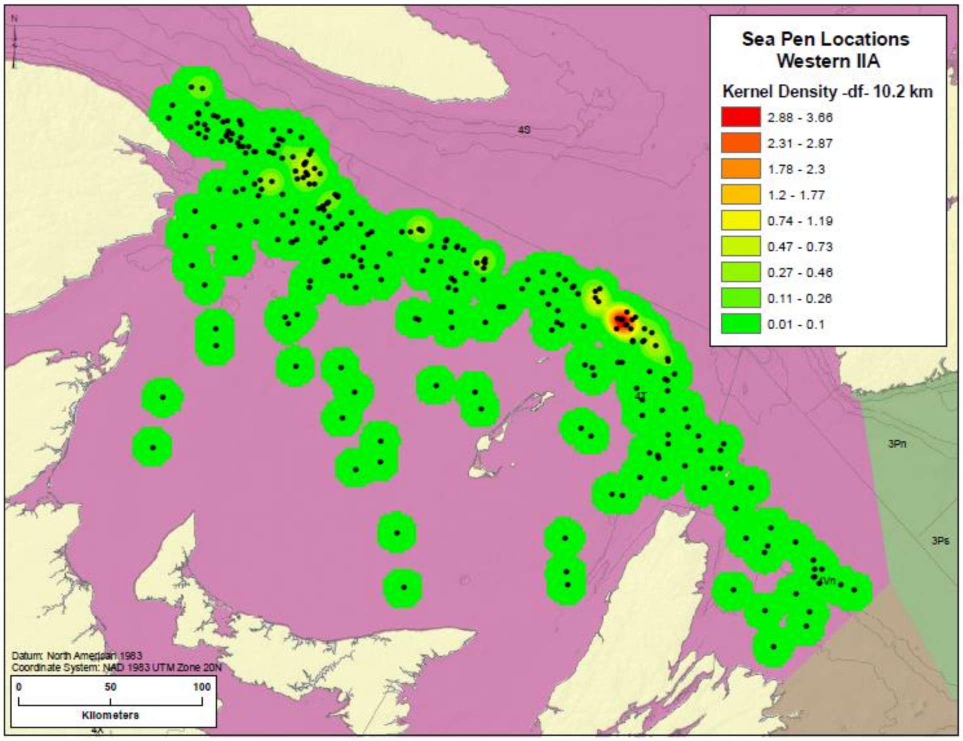

Figure 68. KDE surface of sea pen biomass produced with the default (df) search radius (10.2 km). Tow locations with sea pen catch used in the analysis are indicated in black.

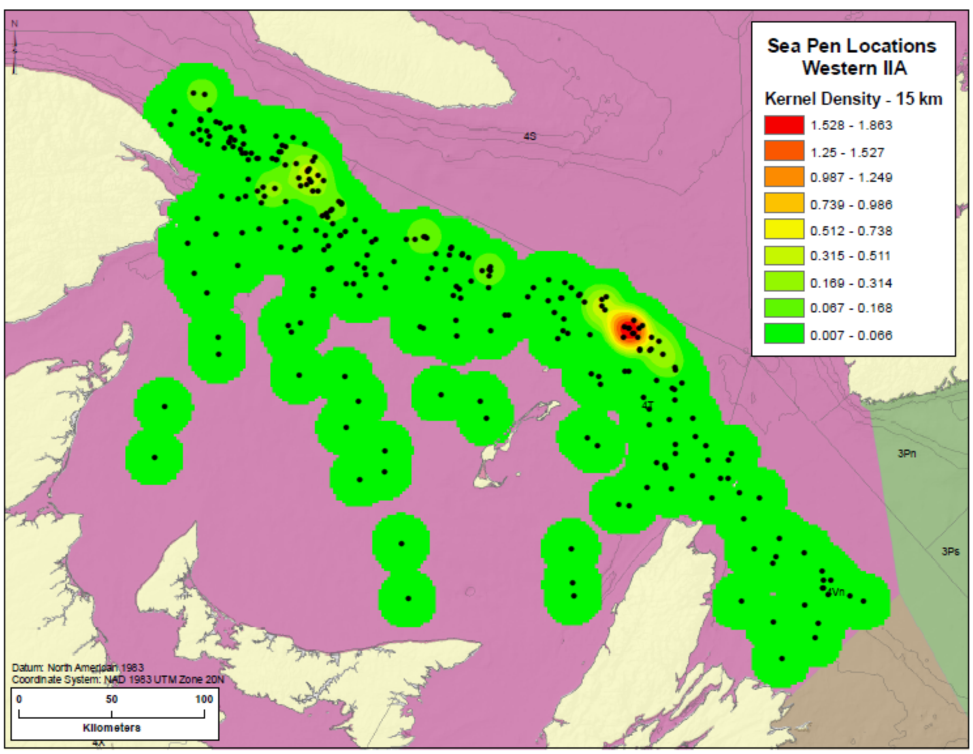

Figure 69. KDE analyses conducted with a 15 km search radius. Tow locations with sea pen catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sea pen weight threshold is provided in Table 18 and illustrated in Figure 70. The first large increase in area was found between 15 and 10 kg where area increased 97% (Table 18). That areal expansion was supported by 8 additional points but examination of the spatial area occupied by the polygons showed that only two of those points expanded the area. The next largest increase in area (60%) was seen between 10 and 5 kg (Figure 71). That change was supported by 10 additional data points and introduced a new area in the northwest. Successively smaller thresholds built incrementally on those areas. Consequently we selected 10 kg as the threshold value. The areas occupy 1,900 km^2.

Table 18. Comparative Sea Pen Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sea Pens is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
100	1	-	18	2427
70	5	4	465	50
40	9	4	696	1
20	12	3	704	37
15	19	7	964	97
10	27	8	1900	60
5	37	10	3039	29
2	50	13	3927	52
1	68	18	5984	43
0.7	78	10	8577	35
0.5	89	11	11570	7
0.3	101	12	12401	3
0.2	116	15	12721	34
0.1	138	22	16986	13
0.075	152	14	19156	6
0.05	174	22	20220	27
0.025	205	31	25635	16
0.01	239	34	29638	

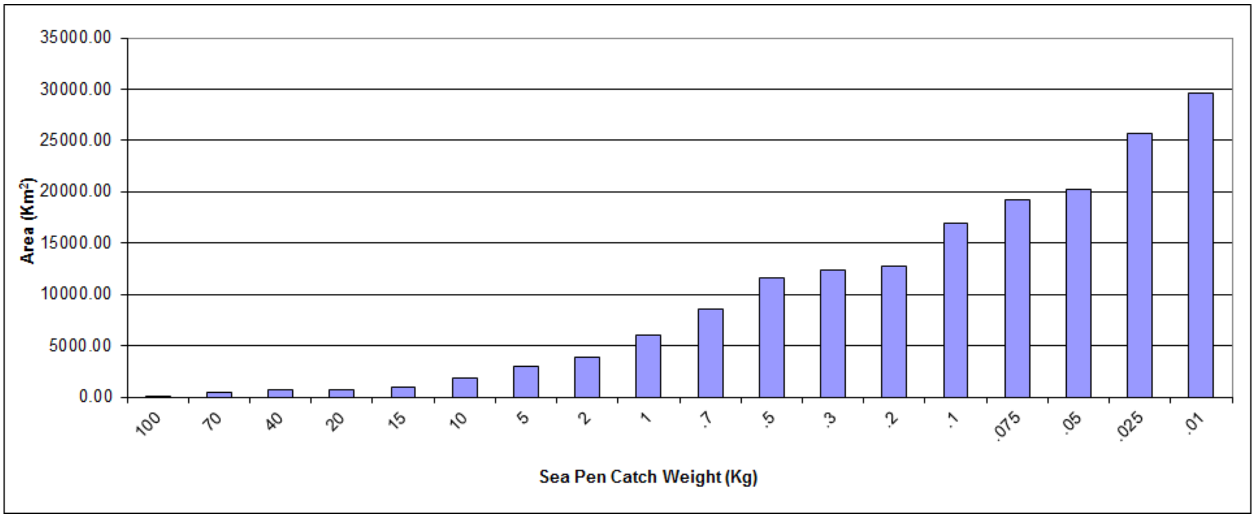

Figure 70. Barplot of polygon area (km^2) associated with sea pen weight thresholds (kg).

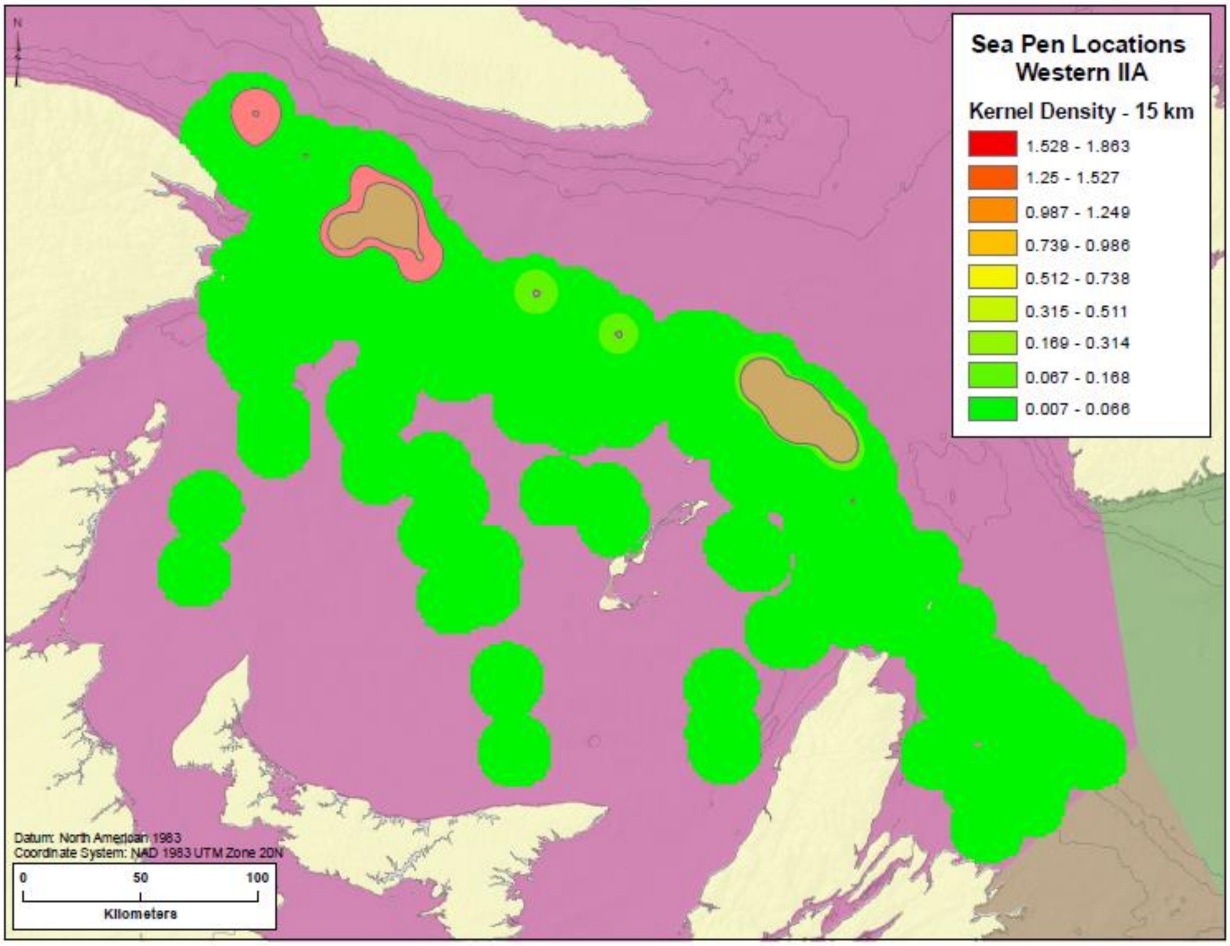

Figure 71. Location of polygons encompassing the ≥10 kg catches (brown) and the ≥5 kg catches (pink), showing the increase in area (Table 18) and overlain on the KDE biomass surface produced with the 15 km search radius.

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of sea pens are shown in Figure 72 and the locations of the survey tows that defined those polygons are provided in Table 19. In Figure 73, the results of this study are compared to those produced in Kenchington et al. (2010).

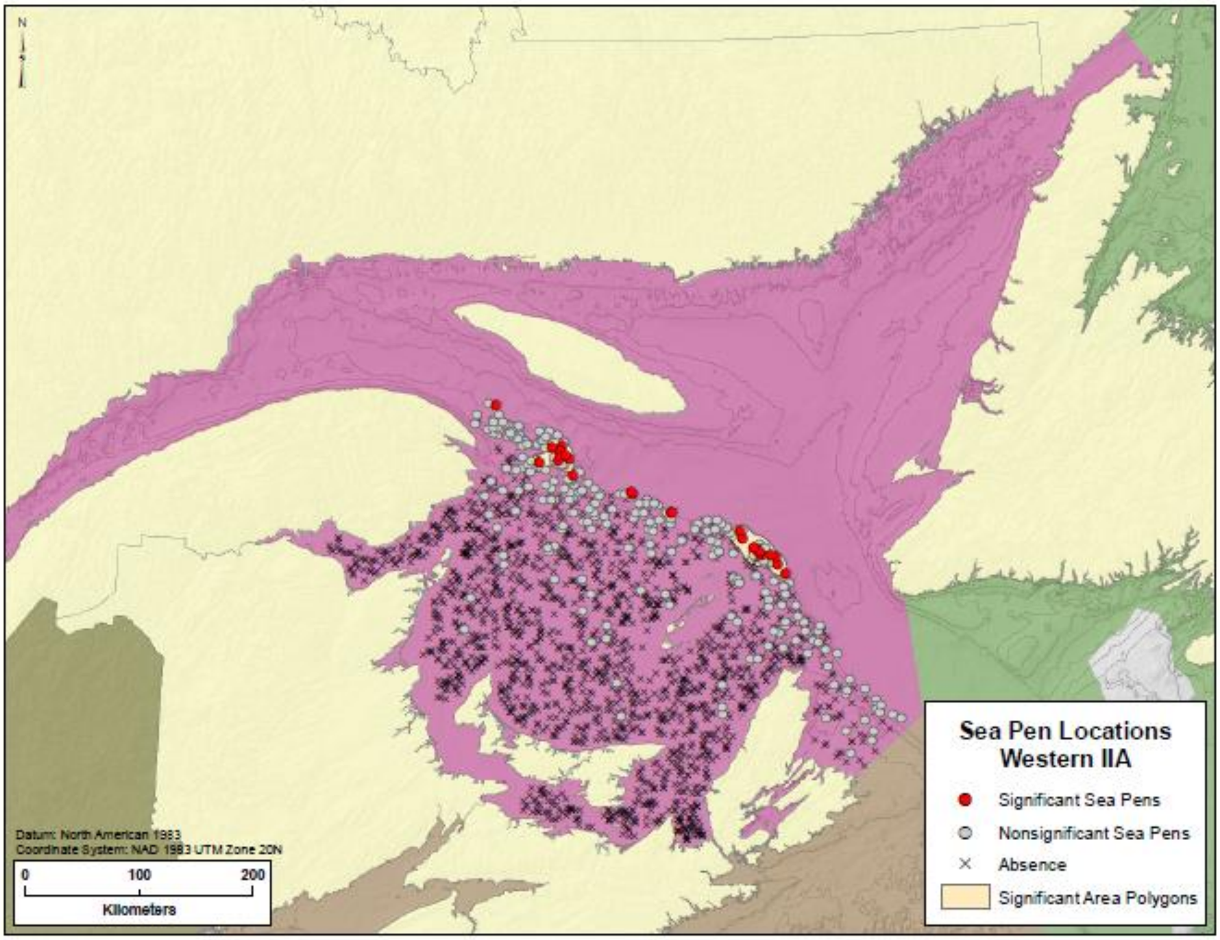

Figure 72. Locations of the polygons identifying significant sea pen aggregations relative to the broader distribution of sea pens in the southern portion of the Gulf Biogeographic Zone. Catch locations that contributed to the identification of the polygons are indicated as significant (Table 19), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

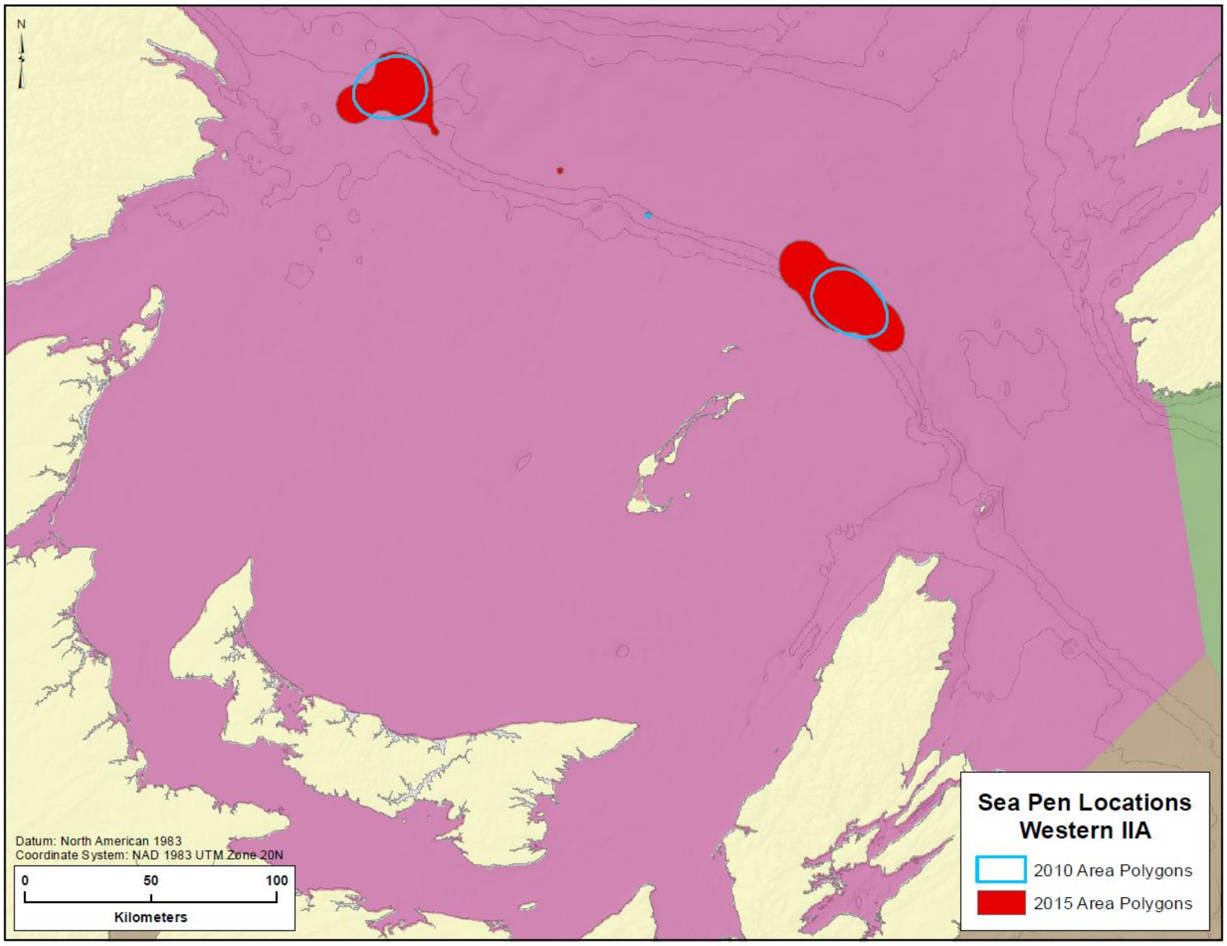

Figure 73. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (blue outline) and those identified in this study (red polygons).

Table 19. Southern Portion of the Gulf Biogeographic Zone: Details of the Location of Research Vessel Sea Pen Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sea Pen Weight (kg)
2010	TEL2010074142	47.95108	-60.85550	47.96133	-60.87133	108.000
2008	TEL2008815169	47.98270	-60.88820	47.96717	-60.85200	99.432
2009	TEL2009992136	47.97992	-60.88933	47.97317	-60.87100	85.400
2012	TEL2012205054	47.98875	-60.91942	47.98100	-60.90100	78.900
2009	TEL2009992038	48.06825	-61.05358	48.06350	-61.03383	76.100
2011	TEL2011194119	47.95542	-60.85925	47.96583	-60.87467	50.700
2004	TEL2004434054	47.84470	-60.64680	47.86700	-60.67500	48.200
2006	TEL2006678074	48.67850	-63.45450	48.70350	-63.47867	46.011
2007	TEL2007749034	47.93620	-60.82550	47.95517	-60.85883	42.470
2014	TEL2014433036	48.12125	-61.07600	48.11167	-61.05850	30.300

2006	TEL2006678075	49.13220	-63.97530	49.16067	-63.97317	24.215
2006	TEL2006678166	47.91000	-60.67100	47.90150	-60.64400	20.563
2003	TEL2003352082	48.77320	-63.20230	48.79333	-63.23283	19.787
2007	TEL2007749136	48.27500	-61.88280	48.26300	-61.84350	19.342
2012	TEL2012205066	48.44375	-62.36142	48.45000	-62.37767	18.600
2007	TEL2007749122	48.69730	-63.21720	48.67533	-63.19167	17.394
2008	TEL2008815118	48.79770	-63.29550	48.78067	-63.26167	17.300
2005	TEL2005507122	48.76400	-63.20780	48.74200	-63.17883	15.819
2013	TEL2013318127	48.71483	-63.09617	48.72700	-63.10583	15.400
2013	TEL2013318145	47.93517	-60.72133	47.94417	-60.73983	13.500
2007	TEL2007749033	47.78280	-60.56070	47.75950	-60.53850	12.651
2004	TEL2004434073	48.43270	-62.34070	48.43267	-62.29683	12.458
2010	TEL2010074094	48.72308	-63.20008	48.73433	-63.21517	12.200
2005	TEL2005507123	48.57450	-63.04380	48.54933	-63.02183	11.968
2014	TEL2014433013	48.74192	-63.13892	48.75300	-63.14667	10.500
2013	TEL2013318137	48.28900	-61.87942	48.28367	-61.86067	10.300
2006	TEL2006678104	48.81220	-63.17600	48.78283	-63.16700	10.142

Northern Portion of the Gulf Biogeographic Zone

Sponges (Porifera)

Data Sources and Distribution

The data available for the analyses of sponges in the northern portion of the Gulf Biogeographic Zone covered 10 years from 2006 to 2015. Data were from two DFO administrative regions (Quebec and Newfoundland and Labrador), with most of the data (99%) from the Quebec Region. Prior to 2006 there was not consistent/thorough reporting of taxonomic information, which explains the start year of the data series. There were 1158 records with sponge catch and 615 records of catches with no sponges from the same surveys. All surveys that were used in this time series were conducted with Campelen trawls with tow locations chosen following a stratified random design (Chadwick et al., 2007) and were implemented as detailed in Bourdages et al. (2015). Within the surveyed area, the sponges were present throughout and in the majority of tows (Figure 74).

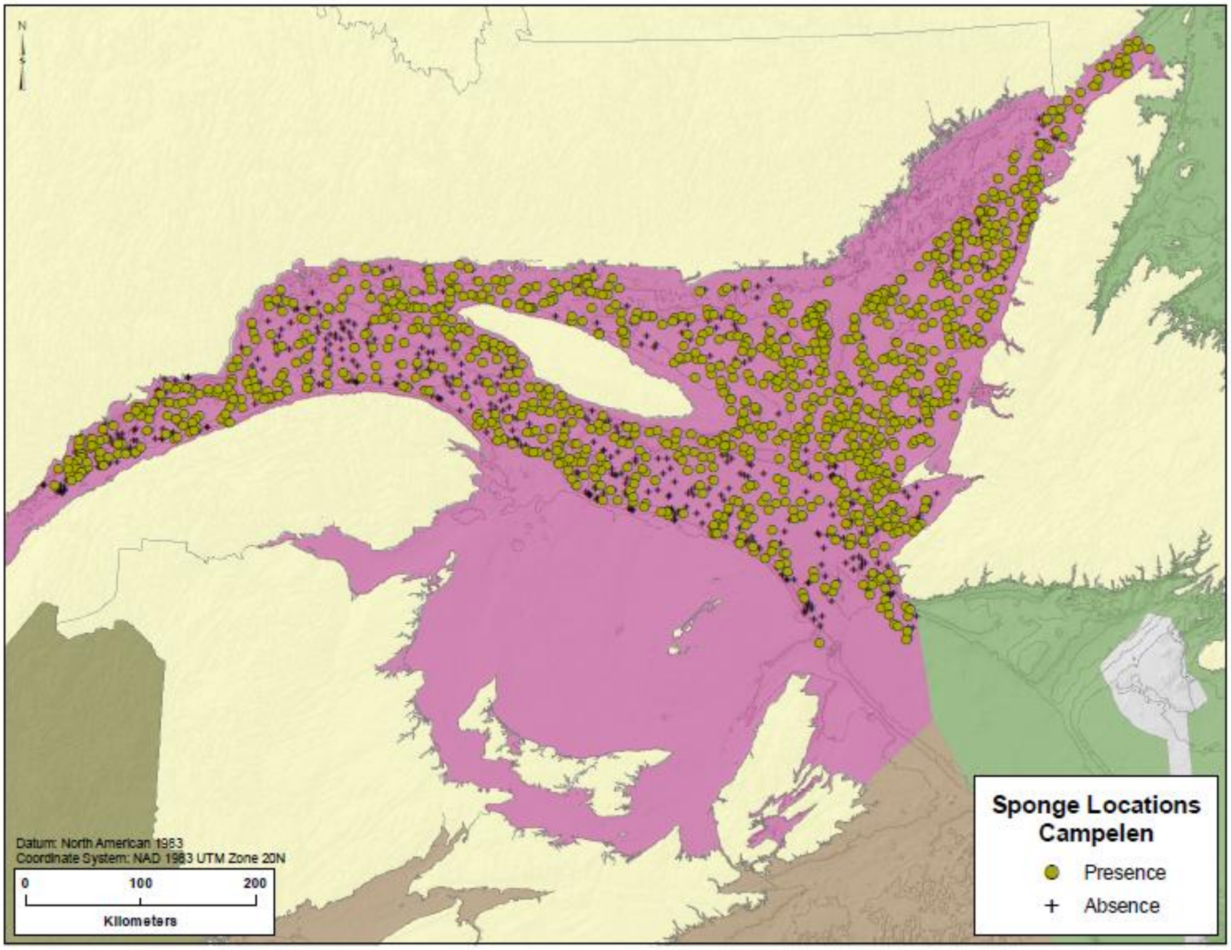

Figure 74. Distribution of sponges from DFO research vessel survey catches in the northern portion of the Gulf Biogeographic Zone sampled using a Campelen trawl. Olive circles indicate sponge presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 17.3731 km. We compared that KDE surface with those produced by using 15 km and 20 km search radii. The default search radius produced a good fit to the data (Figure 75) while the 15 km radius was very similar to the default value but did under-smooth, creating gaps in the surface. The 20 km search radius over-smoothed the data particularly in the area north of Cape Breton, Nova Scotia (Figure 76). The default search radius was used in the preparation of the KDE surface. The default grid size was 2.294 km^2. Contours placed over the KDE surface were finely spaced at 0.0001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

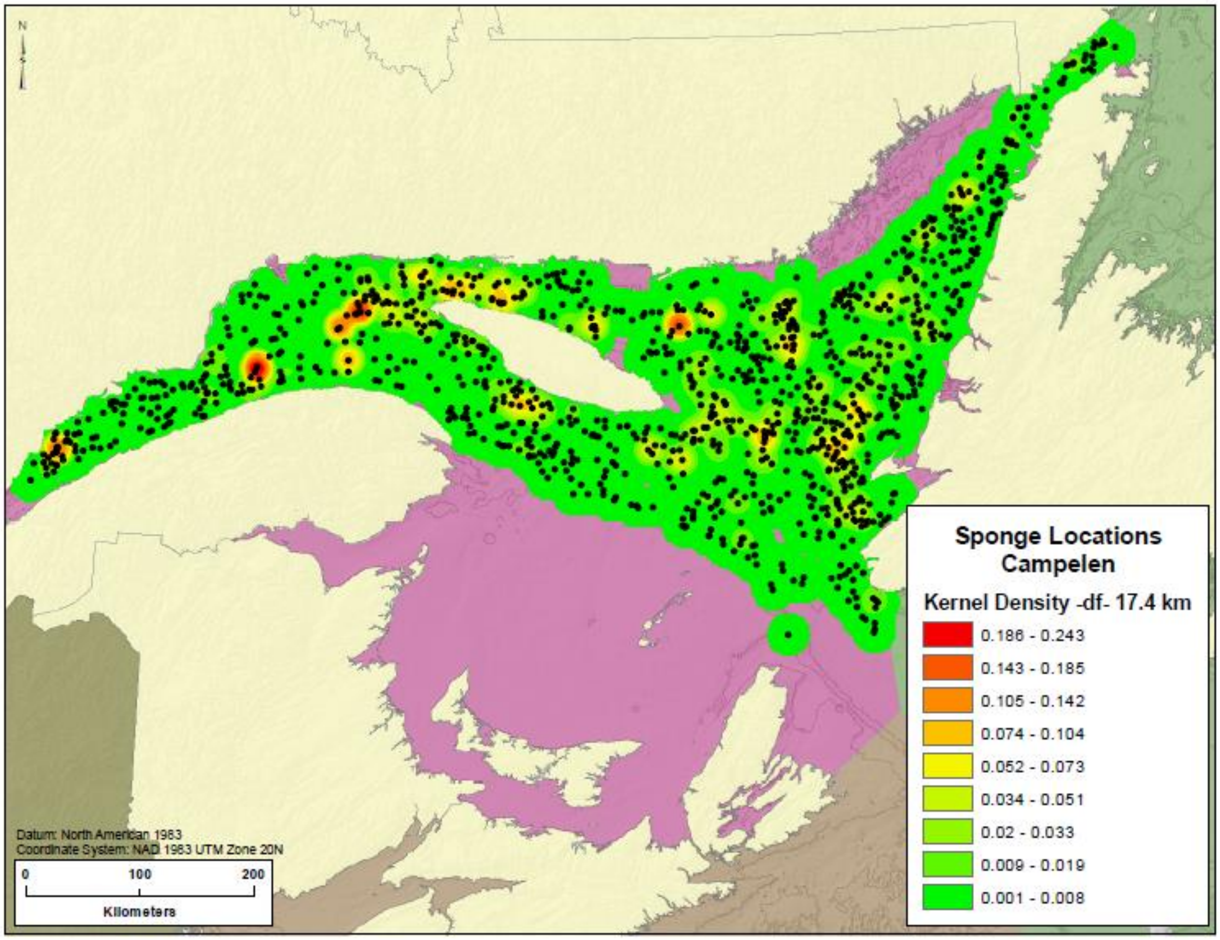

Figure 75. KDE surface of sponge biomass produced with the default (df) search radius (17.4 km). Tow locations with sponge catch used in the analysis are indicated in black.

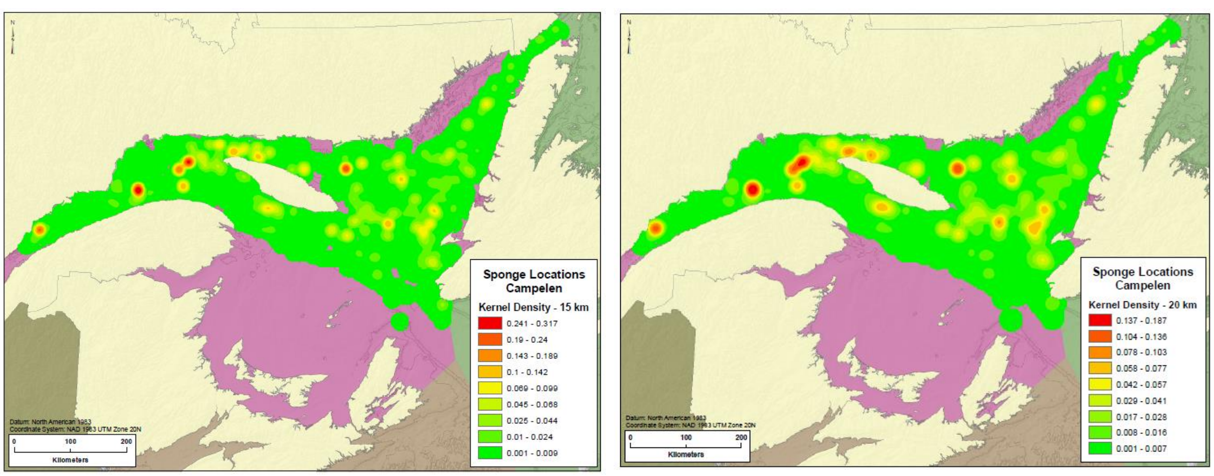

Figure 76. KDE analyses conducted with a 15 km (left) and 20 km (right) search radius. The former is under-smoothed and the latter over-smoothed.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sponge weight threshold is provided in Table 20 and illustrated in Figure 77. The larger thresholds map out the sponge areas to 8 kg then from 7 kg to 2 kg the changes are predominately through expansion of the existing areas, grouping close ones and expanding out others. The first large increase in area was found between 2 and 1 kg where area increased 120% (Table 20). That change was supported by 111 additional data points and the selection of 2 kg as the threshold was well supported for delineating significant concentrations of sponges (Figure 78). The areas occupy 21,528 km^2.

Table 20. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
50	2	-	4	497
20	8	6	27	1674
15	16	8	473	222
10	27	11	1520	88
8	34	7	2855	52
7	40	6	4339	40
6	48	8	6066	18
5	57	9	7150	44
4	80	23	10268	34
3	107	27	13717	57
2	143	36	21528	120
1	254	111	47365	4
0.9	271	17	49213	3
0.8	288	17	50881	10
0.7	320	32	55849	2
0.6	348	28	57061	14
0.5	367	19	65074	13
0.4	410	43	73813	4
0.3	449	39	76854	30
0.2	530	81	100086	5
0.1	663	133	104778	8
0.08	714	51	113286	0
0.06	761	47	113659	10
0.04	823	62	125222	0
0.02	908	85	125262	1
0.01	977	69	125990	0
0.005	1027	50	125990	

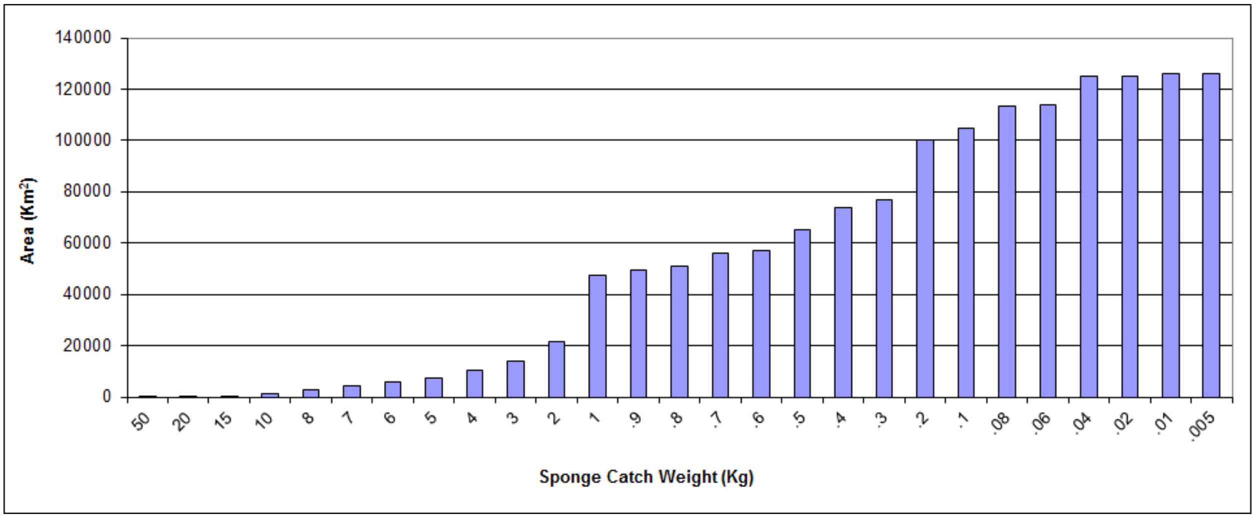

Figure 77. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

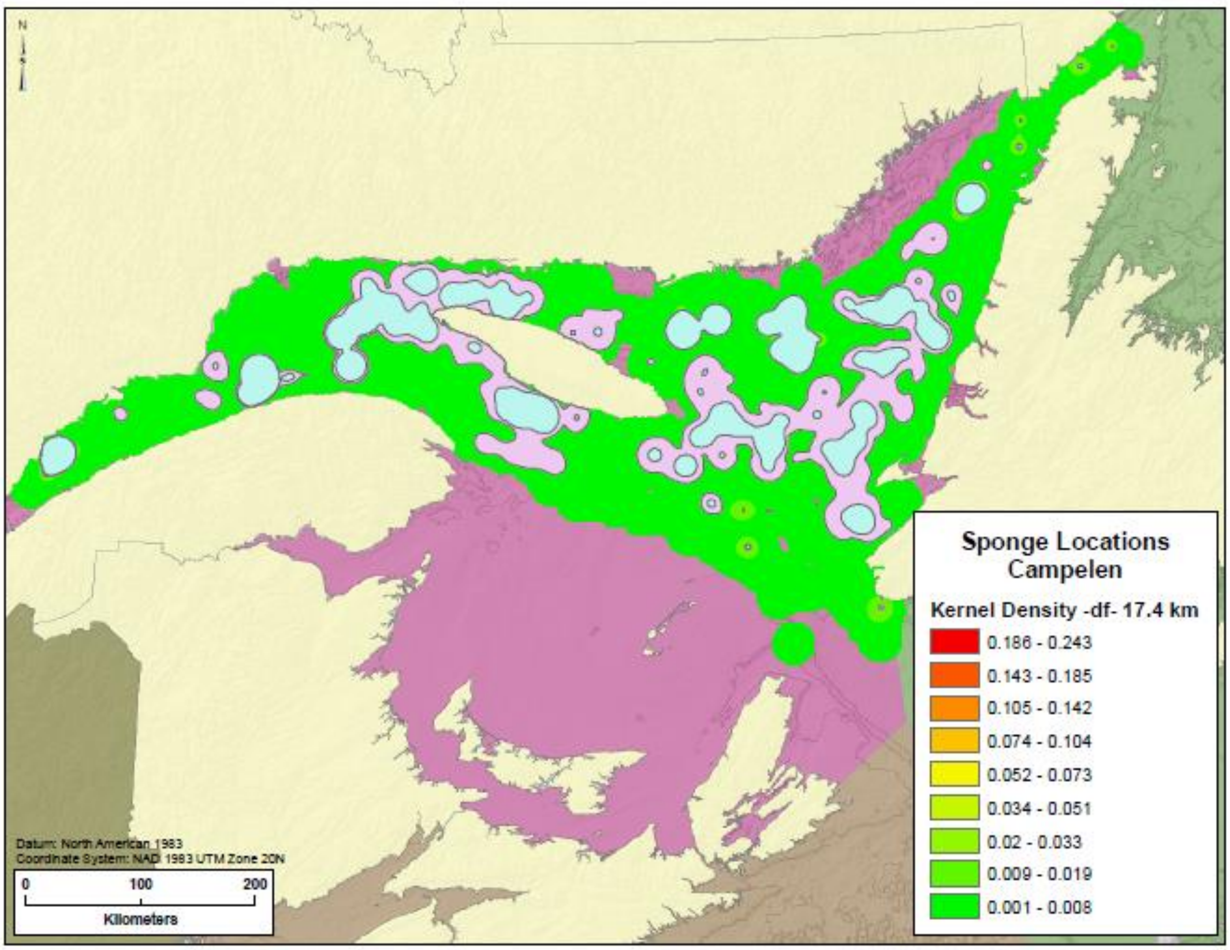

Figure 78. Location of polygons encompassing the ≥2 kg catches (blue) and the ≥1 kg catches (light pink), showing the increase in area (Table 20) and overlain on the KDE biomass surface produced with the default (df) search radius.

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of sponges are shown in Figure 79 and the locations of the survey tows that defined those polygons are provided in Table 21. In Figure 80, the results of this study are compared to those produced in Kenchington et al. (2010).

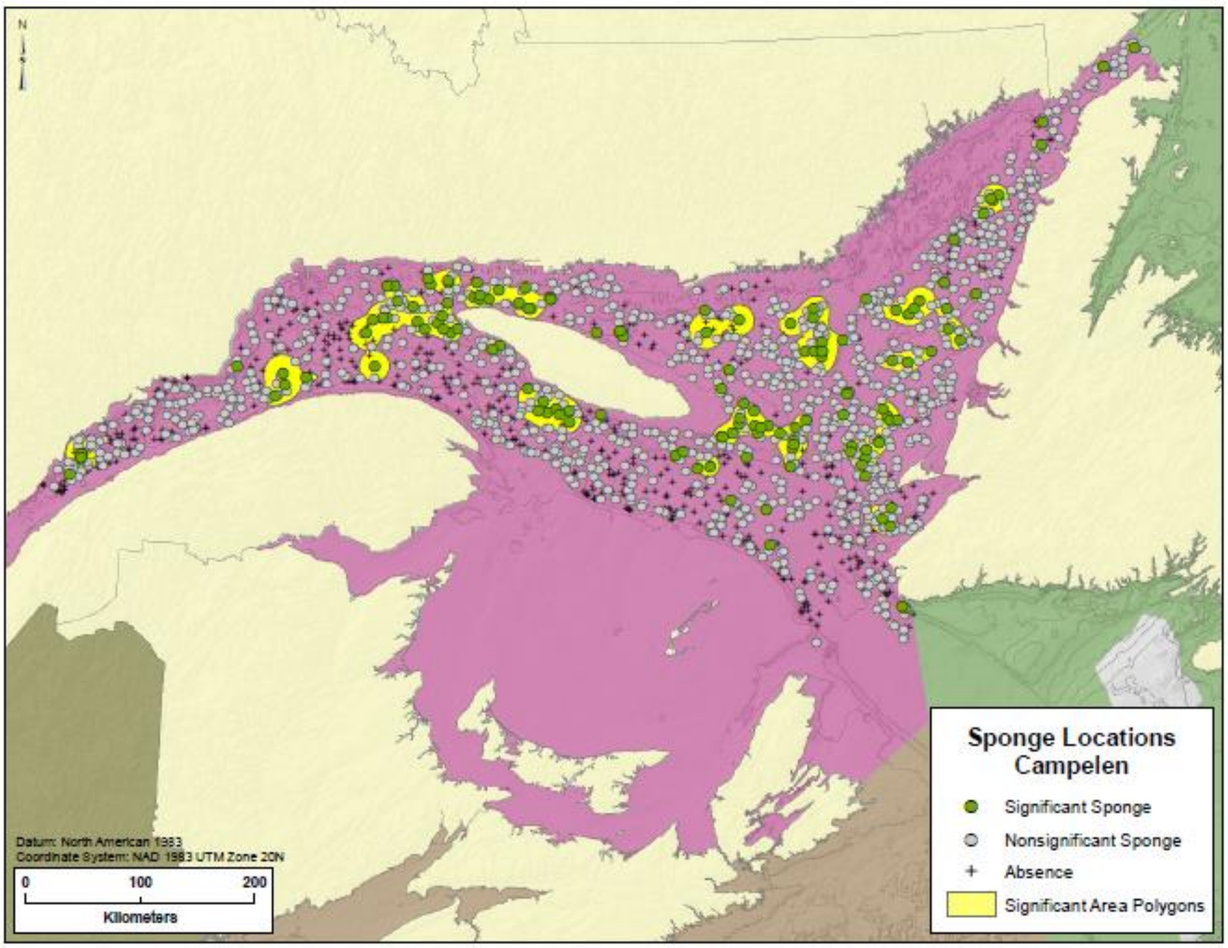

Figure 79. Locations of the significant sponge areas relative to the broader distribution of sponges in the northern portion of the Gulf Biogeographic Zone. Catch locations that contributed to the identification of the polygons are indicated as significant (Table 21), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

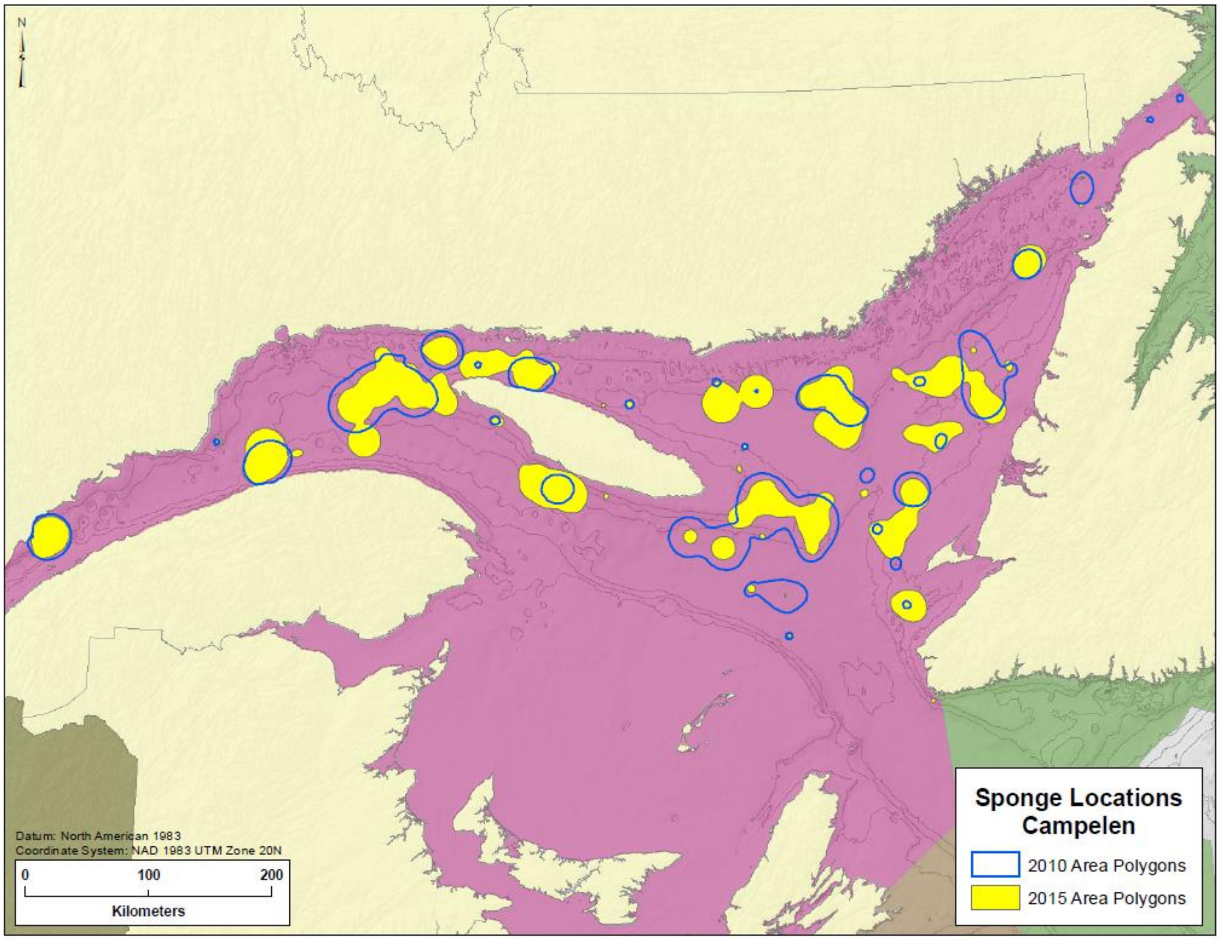

Figure 80. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (blue outline) and those identified in this study (yellow polygons).

Table 21. Northern Portion of the Gulf Biogeographic Zone: Details of the Location of Research Vessel Sponge Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)
2015	TEL2015012142	49.36667	-66.57750	49.36017	-66.59300	70.90
2012	TEL2012009171	49.73467	-61.47317	49.73633	-61.45400	56.32
2006	TEL2006003184	49.70117	-65.59417	49.70333	-65.57550	43.91
2011	TEL2011008186	49.83217	-65.34467	49.83700	-65.35900	41.18
2010	TEL2010007111	49.44900	-65.47517	49.44650	-65.49483	29.05
2007	TEL2007004172	48.63867	-68.90083	48.64617	-68.88600	25.30
2008	TEL2008005106	48.85317	-60.47033	48.86517	-60.46817	22.35
2008	TEL2008005181	49.81883	-65.39083	49.82400	-65.40850	20.60
2008	TEL2008005171	49.92367	-63.60450	49.91800	-63.58717	18.20
2006	TEL2006003156	49.81733	-61.07583	49.81783	-61.09550	17.99
2010	TEL2010007164	50.05833	-63.99183	50.05600	-63.97733	17.30

2007	TEL2007004143	50.12100	-64.61000	50.11617	-64.59067	17.10
2010	TEL2010007166	50.00900	-64.29550	50.00800	-64.31000	16.43
2008	TEL2008005139	48.67850	-61.46333	48.67617	-61.44550	15.60
2010	TEL2010007060	49.02700	-59.34233	49.03700	-59.33217	15.57
2012	TEL2012009022	49.51900	-60.09833	49.52650	-60.10967	15.22
2010	TEL2010007065	48.82950	-59.45333	48.81833	-59.46233	14.96
2010	TEL2010007067	48.70350	-59.62117	48.71533	-59.61633	14.94
2007	TEL2007004201	49.11500	-63.39967	49.10783	-63.38433	13.64
2012	TEL2012009145	49.91833	-65.02883	49.91833	-65.04333	12.90
2007	TEL2007004108	48.76467	-61.86250	48.76617	-61.88083	12.75
2012	TEL2012009033	49.91100	-58.88467	49.91850	-58.87217	12.23
2006	TEL2006003024	48.21767	-59.45800	48.22967	-59.46400	12.10
2013	TEL2013010141	50.08167	-63.67500	50.08667	-63.65667	11.38
2007	TEL2007004181	49.27033	-66.53917	49.27433	-66.52117	11.10
2010	TEL2010007162	49.99550	-64.23383	49.99750	-64.24983	11.05
2008	TEL2008005173	49.96083	-63.74633	49.96367	-63.76617	10.40
2012	TEL2012009026	49.81900	-60.17450	49.80667	-60.17917	9.95
2008	TEL2008005089	50.66300	-57.91983	50.67517	-57.92367	9.45
2012	TEL2012009036	50.37317	-58.41283	50.37883	-58.39550	9.28
2012	TEL2012009200	48.64033	-68.89817	48.64583	-68.88517	8.88
2006	TEL2006003133	49.14600	-63.28767	49.14617	-63.26883	8.35
2010	TEL2010007151	49.12667	-63.50167	49.13167	-63.51500	8.29
2006	TEL2006003175	49.80533	-64.97317	49.80533	-64.95383	8.16
2006	TEL2006003043	49.08050	-59.38900	49.08550	-59.37183	7.91
2008	TEL2008005170	50.00933	-63.36500	50.00267	-63.34833	7.65
2008	TEL2008005038	48.79917	-59.78450	48.81167	-59.78867	7.40
2012	TEL2012009020	49.02133	-60.31317	49.00900	-60.31883	7.37
2015	TEL2015012212	48.91133	-61.32550	48.91150	-61.30583	7.24
2008	TEL2008005154	49.43150	-61.21967	49.41967	-61.21283	7.05
2012	TEL2012009076	49.23050	-59.79033	49.23833	-59.78033	6.74
2010	TEL2010007163	49.98900	-64.11433	49.98850	-64.13517	6.60
2008	TEL2008005165	49.74450	-62.49300	49.75567	-62.48583	6.29
2012	TEL2012009176	49.73117	-62.80300	49.73583	-62.82083	6.23
2006	TEL2006003101	48.66200	-60.51967	48.66933	-60.50317	6.22
2012	TEL2012009032	49.80650	-59.01700	49.79983	-59.03317	6.10
2006	TEL2006003147	49.77500	-60.46317	49.78183	-60.46933	6.02
2014	TEL2014011037	50.69183	-57.84083	50.69117	-57.86300	6.02
2010	TEL2010007050	49.59117	-58.42000	49.58683	-58.42117	5.94
2010	TEL2010007018	49.55500	-60.29117	49.54833	-60.27900	5.82
2008	TEL2008005167	49.72917	-62.53317	49.71667	-62.53000	5.70
2010	TEL2010007066	48.77500	-59.60617	48.78400	-59.59367	5.54
2013	TEL2013010002	49.03183	-63.12983	49.03983	-63.14517	5.40
2014	TEL2014011187	50.10817	-64.83250	50.10817	-64.81150	5.28

2006	TEL2006003099	48.80250	-60.48167	48.81417	-60.47617	5.17
2007	TEL2007004203	49.12200	-63.13367	49.13167	-63.14550	5.10
2007	TEL2007004113	48.93450	-61.19883	48.93367	-61.17983	5.05
2012	TEL2012009087	48.64900	-59.67167	48.63667	-59.67850	4.99
2007	TEL2007004031	48.56483	-59.62850	48.55250	-59.62917	4.82
2011	TEL2011008189	49.73033	-64.57283	49.72983	-64.55433	4.81
2009	TEL2009006074	49.84917	-59.17783	49.85067	-59.19100	4.80
2008	TEL2008005137	49.09533	-63.24883	49.09967	-63.26283	4.75
2008	TEL2008005166	49.71183	-62.48700	49.72400	-62.48133	4.60
2008	TEL2008005215	48.59717	-68.91133	48.58817	-68.92533	4.58
2006	TEL2006003039	48.75767	-59.79083	48.76933	-59.78450	4.50
2007	TEL2007004165	49.39367	-67.12450	49.40233	-67.11100	4.48
2012	TEL2012009094	48.15400	-59.36833	48.14667	-59.38400	4.42
2009	TEL2009006019	48.32717	-60.81800	48.31583	-60.82367	4.40
2007	TEL2007004087	48.74383	-61.02883	48.73750	-61.01150	4.40
2009	TEL2009006158	49.10817	-60.93283	49.10267	-60.94500	4.40
2014	TEL2014011011	49.05033	-59.86217	49.04367	-59.87967	4.39
2007	TEL2007004086	48.91867	-60.62267	48.92900	-60.60883	4.33
2015	TEL2015012193	49.74533	-62.52133	49.75800	-62.52550	4.27
2014	TEL2014011009	48.98117	-60.75700	48.97133	-60.76833	4.23
2010	TEL2010007038	50.68167	-57.93800	50.67333	-57.93083	4.23
2012	TEL2012009023	49.55200	-60.17950	49.54583	-60.16450	4.21
2010	TEL2010007156	49.80150	-64.72217	49.79083	-64.72200	4.19
2009	TEL2009006199	49.18367	-66.65767	49.18633	-66.63950	4.15
2006	TEL2006003173	50.13067	-64.62250	50.11850	-64.61517	4.10
2010	TEL2010007158	49.96333	-65.21950	49.95800	-65.23783	4.09
2009	TEL2009006120	49.62117	-63.97400	49.62567	-63.99350	3.95
2009	TEL2009006050	49.67900	-58.55167	49.66783	-58.56283	3.95
2014	TEL2014011189	49.99150	-63.35700	49.98717	-63.34483	3.93
2013	TEL2013010166	48.80117	-61.78333	48.80033	-61.80300	3.91
2007	TEL2007004085	48.96433	-60.43467	48.97683	-60.43317	3.76
2009	TEL2009006138	50.14083	-64.86200	50.15317	-64.86500	3.75
2012	TEL2012009182	49.95783	-64.61733	49.97150	-64.61300	3.70
2013	TEL2013010164	49.28017	-61.30250	49.28650	-61.31233	3.65
2006	TEL2006003185	49.80333	-65.51633	49.80117	-65.49750	3.65
2008	TEL2008005145	48.98350	-60.93017	48.98500	-60.91167	3.65
2014	TEL2014011161	48.63783	-68.90450	48.63067	-68.91567	3.64
2014	TEL2014011188	50.12117	-64.26033	50.11917	-64.27367	3.62
2010	TEL2010007167	49.92283	-63.62533	49.90150	-63.60467	3.61
2006	TEL2006003176	49.74600	-64.88317	49.74800	-64.89750	3.56
2012	TEL2012009016	48.83467	-60.47467	48.82267	-60.47650	3.53
2008	TEL2008005061	50.04833	-58.57500	50.04217	-58.59333	3.50
2008	TEL2008005175	50.01983	-64.21733	50.02367	-64.19933	3.45

2011	TEL2011008008	48.66667	-61.61350	48.66267	-61.59467	3.36
2014	TEL2014011073	48.98933	-59.30500	49.00300	-59.30600	3.27
2012	TEL2012009083	48.81867	-59.45300	48.80883	-59.46450	3.16
2011	NED2011401056	47.52500	-59.24500	47.51500	-59.23500	3.12
2010	TEL2010007184	49.00867	-61.10683	49.01767	-61.09350	3.11
2014	TEL2014011019	49.55933	-60.09133	49.55433	-60.11133	3.09
2011	TEL2011008194	49.19200	-63.44800	49.19467	-63.43067	3.05
2007	TEL2007004049	49.84267	-58.56233	49.85267	-58.57767	3.03
2011	TEL2011008187	49.74850	-64.65567	49.76050	-64.66300	3.00
2007	TEL2007004077	49.62183	-60.08417	49.62200	-60.06467	3.00
2006	TEL2006003187	50.08100	-65.26133	50.08117	-65.24583	2.90
2008	TEL2008005097	49.63233	-59.83517	49.64517	-59.83433	2.90
2007	TEL2007004173	48.47150	-69.01883	48.47950	-69.00350	2.88
2015	TEL2015012008	49.56117	-60.09150	49.55733	-60.10833	2.85
2012	TEL2012009072	49.50483	-58.78350	49.49317	-58.79100	2.82
2011	TEL2011008115	49.08967	-62.76200	49.08667	-62.74600	2.82
2010	TEL2010007155	49.85167	-64.67500	49.84667	-64.69500	2.78
2007	TEL2007004064	51.76500	-55.99517	51.75900	-56.01517	2.74
2006	TEL2006003140	48.92600	-60.89517	48.92983	-60.87983	2.71
2008	TEL2008005086	51.24067	-57.22417	51.25317	-57.21933	2.70
2009	NED2009902068	47.53500	-59.27333	47.52667	-59.25833	2.68
2006	TEL2006003152	49.89817	-61.48833	49.89817	-61.47183	2.68
2014	TEL2014011089	48.31033	-59.34767	48.32283	-59.35183	2.64
2006	TEL2006003141	48.97967	-60.85600	48.97283	-60.87200	2.64
2010	TEL2010007053	49.45350	-59.25150	49.45417	-59.23150	2.62
2007	TEL2007004063	51.63733	-56.40533	51.64800	-56.39733	2.50
2010	TEL2010007152	49.30000	-63.63000	49.29333	-63.61000	2.44
2012	TEL2012009146	50.07450	-65.35817	50.07533	-65.33917	2.30
2008	TEL2008005014	48.04867	-60.78450	48.04183	-60.76867	2.30
2006	TEL2006003143	49.04300	-61.09617	49.05567	-61.09800	2.30
2011	TEL2011008029	49.84700	-58.96083	49.83667	-58.97450	2.30
2007	TEL2007004061	51.06100	-57.26967	51.04767	-57.27683	2.26
2009	TEL2009006045	48.98267	-59.22017	48.97217	-59.23300	2.25
2009	TEL2009006068	50.56067	-58.03900	50.56683	-58.02150	2.25
2012	TEL2012009201	48.60700	-68.90883	48.61433	-68.89283	2.21
2008	TEL2008005111	48.40600	-61.22217	48.41450	-61.20883	2.20
2007	TEL2007004081	49.21550	-59.81050	49.20450	-59.81833	2.20
2010	TEL2010007025	49.94750	-59.52100	49.93600	-59.52950	2.17
2009	TEL2009006049	49.43783	-59.06967	49.42750	-59.08333	2.15
2011	TEL2011008117	48.90683	-61.31300	48.90167	-61.29550	2.09
2015	TEL2015012211	49.16733	-61.04583	49.17217	-61.05717	2.08
2009	TEL2009006080	49.89183	-60.17033	49.89317	-60.15100	2.05
2012	TEL2012009137	49.59983	-64.06417	49.59367	-64.04750	2.03

2011	TEL2011008188	49.75717	-64.48533	49.76367	-64.50167	2.03
2008	TEL2008005058	49.93800	-58.19167	49.95000	-58.18467	2.00
2008	TEL2008005229	49.33800	-66.28983	49.33450	-66.30850	2.00

Sea Pens (Pennatulacea)

Data Sources and Distribution

Data were from two DFO administrative regions conducted from 2004 to 2015, with 99% of the catches from the Quebec Region and the remainder from Newfoundland and Labrador Region. There were 1098 records with sea pen catch and 808 records of catches with no sea pens from the same surveys. All surveys that were used in this time series were conducted with Campelen trawls with tow locations chosen following a stratified random design (Chadwick et al., 2007) and were implemented as detailed in Bourdages et al. (2015). Within the surveyed area, the sea pens were located along the Laurentian Channel and at the head of the Esquiman Channel (Figure 81).

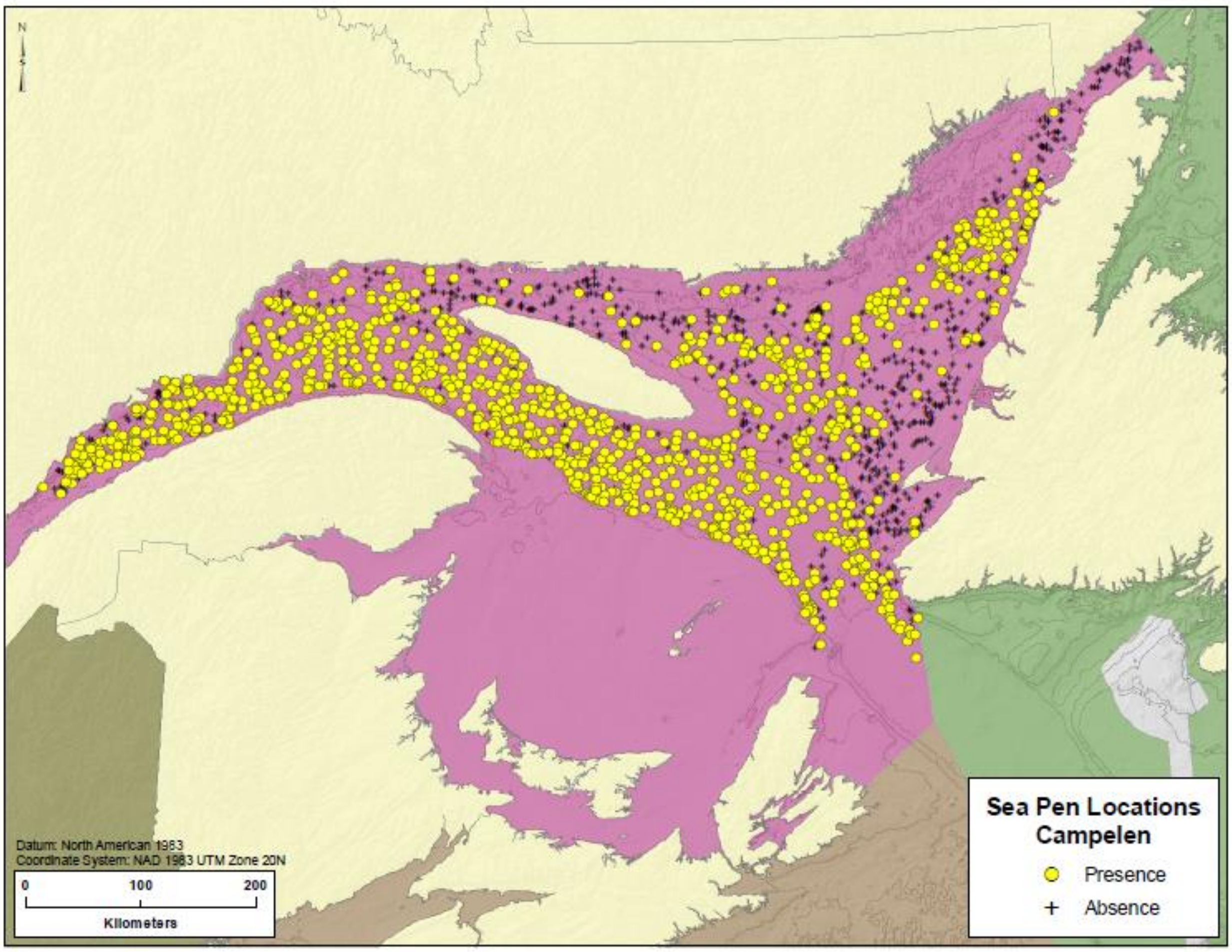

Figure 81. Distribution of sea pens from DFO research vessel survey catches using a Campelen trawl. Yellow circles indicate sea pen presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 15.7580 km. We compared that KDE surface with one produced by using a 10 and 20 km search radius. The default search radius produced a good fit to the data (Figure 82). The 20 km search radius over-smoothed the data and expanded the spatial extent over the slope of the Laurentian Channel to the south, where there were no data (Figure 83). The 10 km search radius under-smoothed the data, creating a patchy surface north and northwest of Anticosti Island.

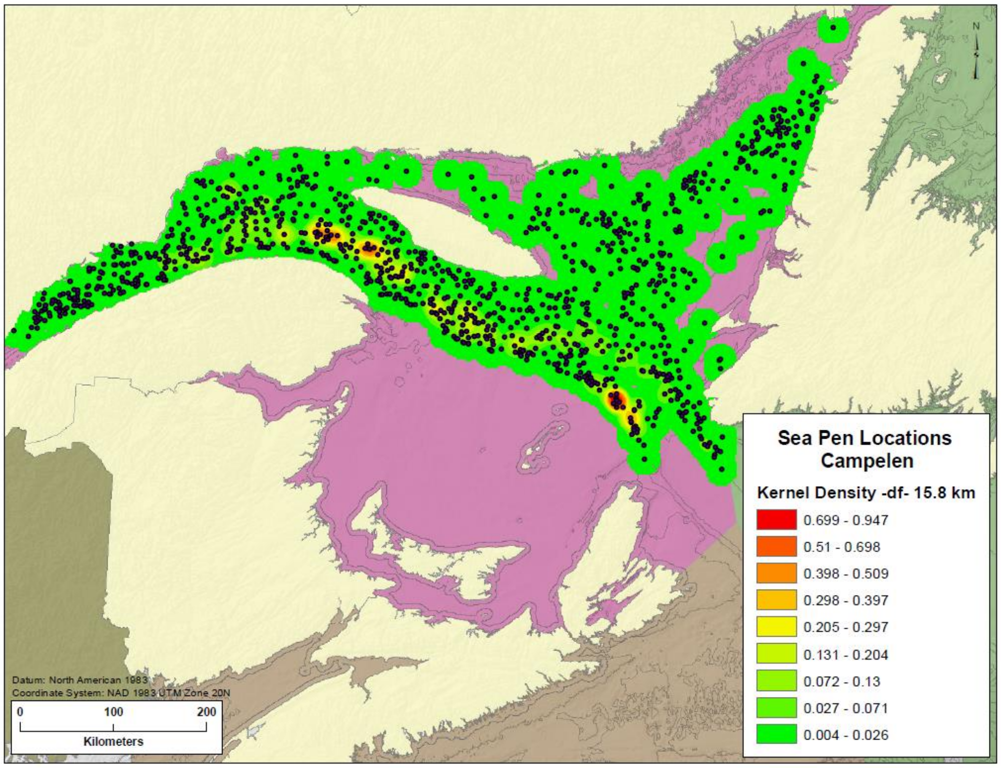

Figure 82. KDE surface of sea pen biomass produced with the default (df) search radius (15.8 km). Tow locations with sea pen catch used in the analysis are indicated in black.

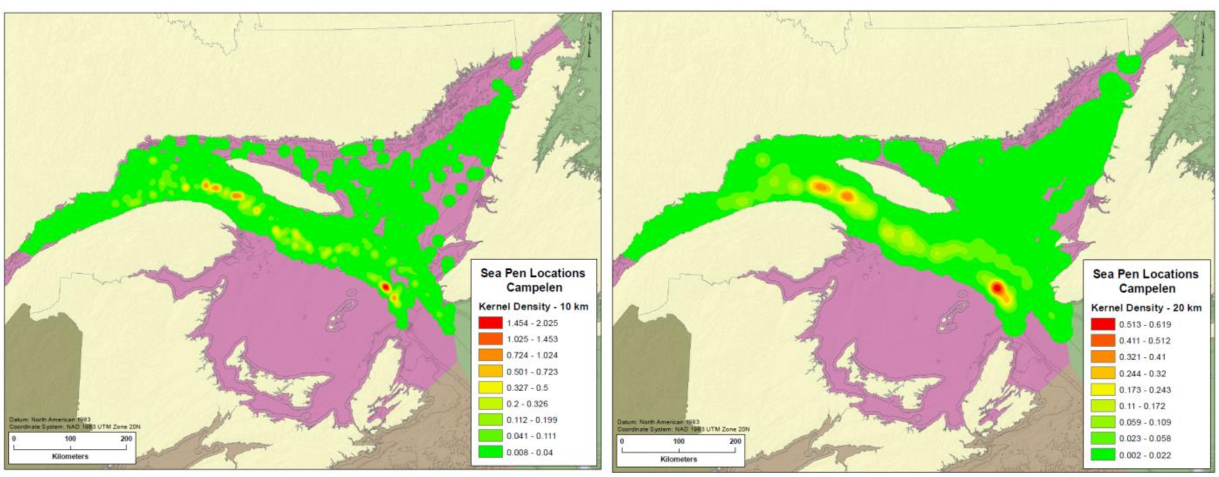

Figure 83. KDE analyses conducted with a 10 km (left) and 20 km (right) search radius. The former is under-smoothed and the latter over-smoothed.

The default search radius was used in the preparation of the KDE surface (Figure 82). The grid size was 2.1093 km^2. Contours placed over the KDE surface were finely spaced at 0.0001 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sea pen weight threshold is provided in Table 22 and illustrated in Figure 84. The first large increase in area was found between 4 and 3 kg where area increased 55% (Table 22). That areal expansion was supported by 34 additional points and examination of the spatial area occupied by the polygons showed that this threshold was applicable (Figure 85). Larger threshold values mapped out the distribution then remained relatively stable to these increments. Consequently we selected 4 kg as the threshold value. The areas occupy 14,995 km^2 and stretches along the Laurentian Channel.

Table 22. Comparative Sea Pen Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sea Pens is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
50	7	-	220	89
30	13	6	415	683
20	21	8	3252	4
15	30	9	3396	49
10	45	15	5076	51
7	63	18	7645	31
6	75	12	9991	9
5	90	15	10926	37
4	109	19	14995	55
3	143	34	23200	9
2	191	48	25285	30
1	263	72	32947	11
0.8	291	28	36645	2
0.6	319	28	37352	2
0.4	360	41	38188	34
0.2	441	81	51172	16
0.1	535	94	59162	19
0.05	629	94	70692	15
0.01	825	196	81092	

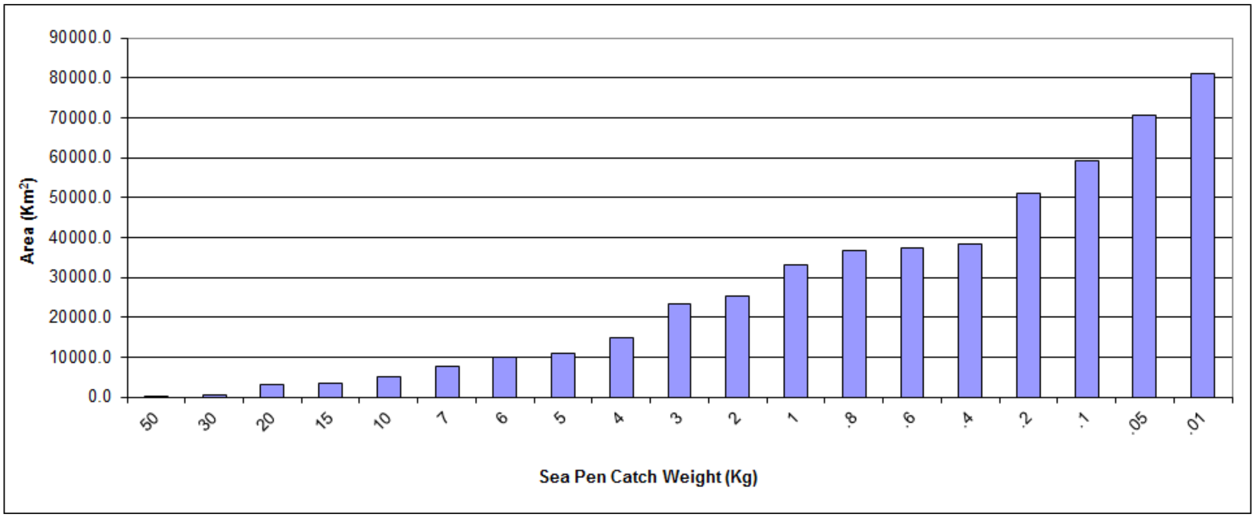

Figure 84. Barplot of polygon area (km^2) associated with sea pen weight thresholds (kg).

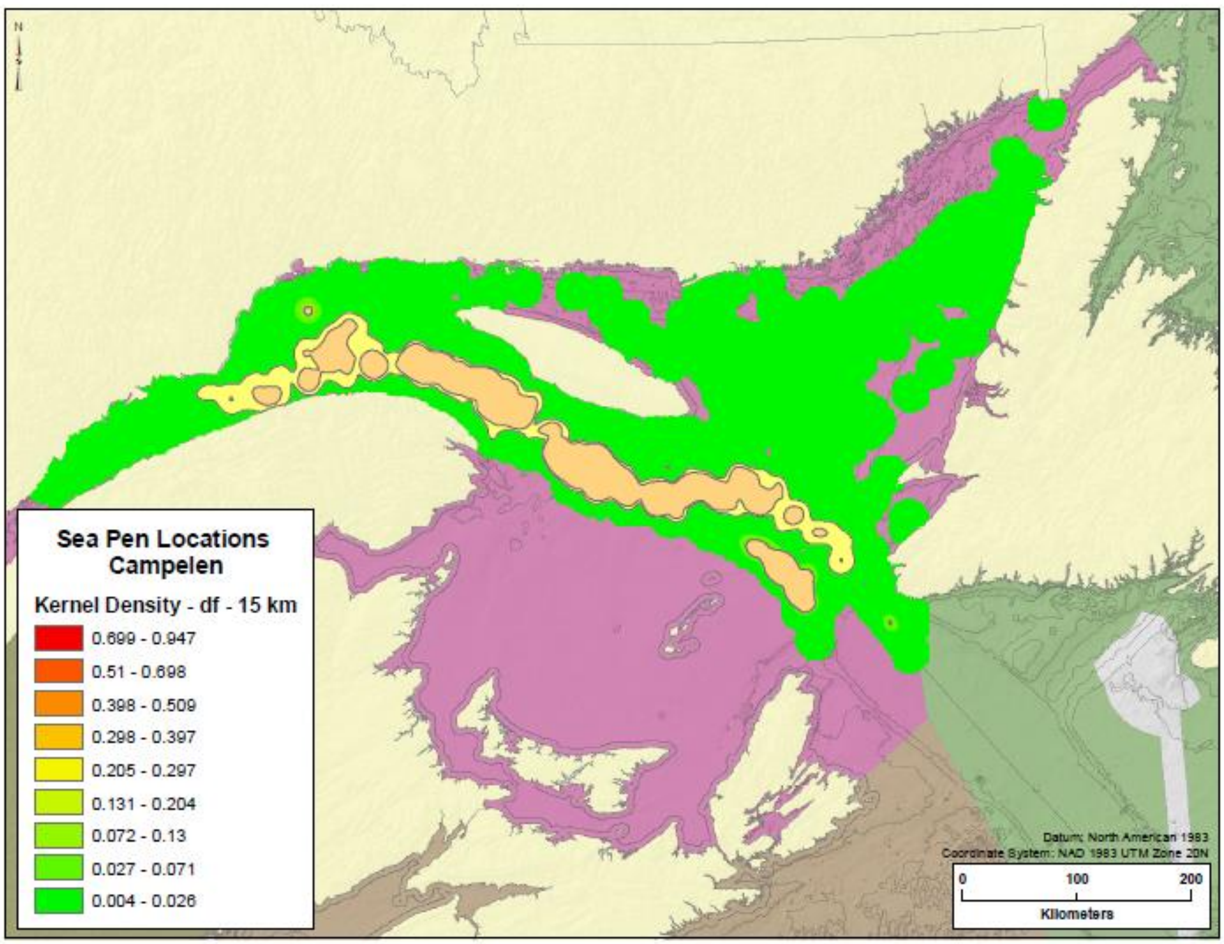

Figure 85. Location of polygons encompassing the ≥4 kg catches (orange) and the ≥3 kg catches (yellow), showing the increase in area (Table 22) and overlain on the KDE biomass surface produced with the default (df) search radius.

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of sea pens are shown in Figure 86 and the locations of the survey tows that defined those polygons are provided in Table 23. In Figure 87, the results of this study are compared to those produced in Kenchington et al. (2010). The polygons for the sea pens have expanded in the current analysis over that produced in 2010, despite the use of a smaller search radius in the current evaluation. This is likely due to the additional data used in the analysis. The same general areas are highlighted from the broader distribution but the additional data results in the previous polygons being connected. The 2010 polygons all lie within the new polygons, with the exception of one north of the Gaspé Peninsula that straddles two of the new polygons (Figure 87).

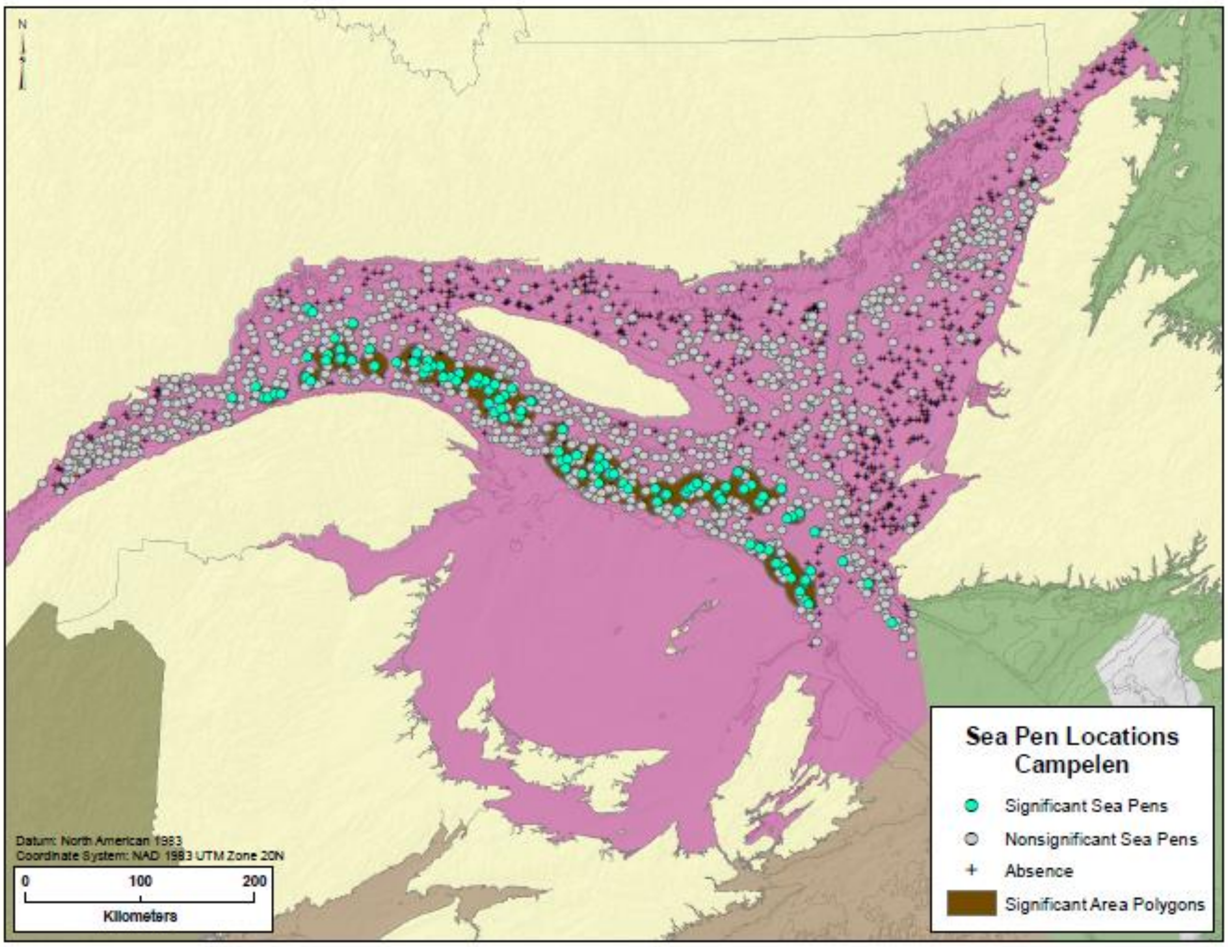

Figure 86. Locations of the significant sea pen areas relative to the broader distribution of sea pens in the northern portion of the Gulf Biogeographic Zone. Catch locations that contributed to the identification of the polygons are indicated as significant (Table 23), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

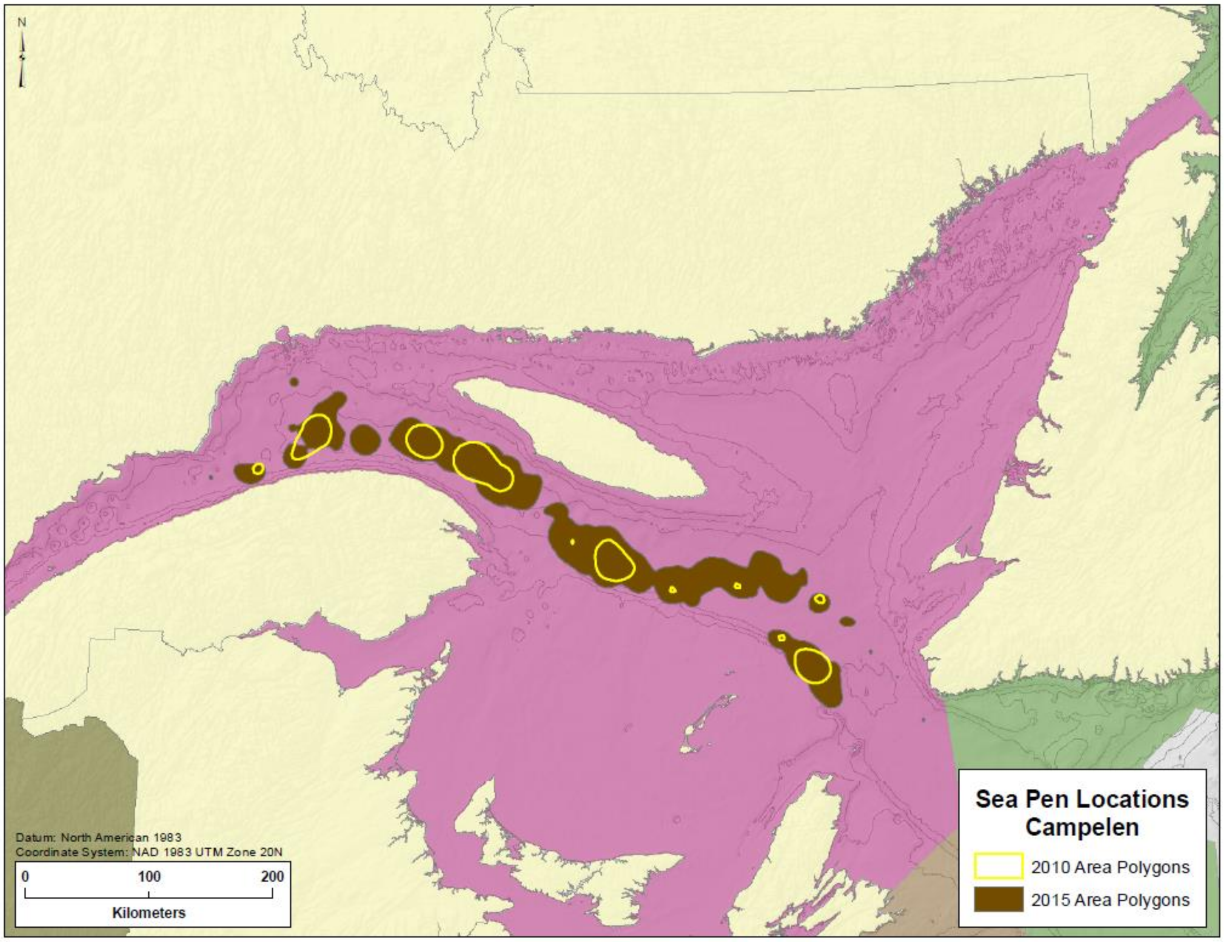

Figure 87. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (brown polygons).

Table 23. Northern Portion of the Gulf Biogeographic Zone: Details of the Location of Research Vessel Sea Pen Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sea Pen Weight (kg)
2015	TEL2015012096	47.87083	-60.64533	47.88300	-60.65600	128.520
2008	TEL2008005238	49.33050	-64.27450	49.31733	-64.27633	93.100
2013	TEL2013010068	47.68083	-60.45133	47.66783	-60.44500	85.430
2010	TEL2010007110	49.48433	-64.98183	49.47983	-64.96450	80.400
2010	TEL2010007108	49.45100	-64.68600	49.45150	-64.70633	68.280
2012	TEL2012009135	49.33850	-64.13800	49.32817	-64.14983	67.981
2012	TEL2012009110	47.84017	-60.61800	47.85017	-60.62867	63.904
2009	TEL2009006167	49.45500	-64.78167	49.45517	-64.76283	49.450
2010	TEL2010007111	49.44900	-65.47517	49.44650	-65.49483	48.670
2015	TEL2015012125	49.10983	-63.71917	49.09733	-63.72467	45.333
2013	TEL2013010176	48.79100	-63.26050	48.79983	-63.27517	40.613

2011	TEL2011008095	47.90183	-60.71850	47.89367	-60.70283	36.714
2007	TEL2007004018	47.83667	-60.60500	47.82800	-60.59150	30.350
2008	TEL2008005122	48.54283	-62.78617	48.55067	-62.80150	27.960
2009	TEL2009006100	48.75767	-62.79217	48.76317	-62.81050	24.400
2004	TEL2004001137	48.39500	-62.09117	48.39750	-62.10800	24.100
2012	TEL2012009108	47.59817	-60.38400	47.61117	-60.38383	23.200
2014	TEL2014011180	49.86267	-66.30883	49.85683	-66.32567	21.372
2006	TEL2006003219	49.19483	-63.97217	49.18967	-63.95550	20.850
2011	TEL2011008164	49.27500	-64.08667	49.27000	-64.08500	20.515
2008	TEL2008005135	49.16467	-64.09983	49.16100	-64.08200	20.050
2006	TEL2006003177	49.54733	-64.97450	49.54917	-64.95583	19.850
2010	TEL2010007107	49.40417	-64.45617	49.41250	-64.47117	19.560
2013	TEL2013010080	48.44917	-61.99067	48.45200	-62.00883	17.900
2008	TEL2008005120	48.55183	-62.49133	48.55900	-62.50683	17.244
2008	TEL2008005012	47.78283	-60.55283	47.79283	-60.56550	16.750
2012	TEL2012009124	48.49717	-62.44300	48.50583	-62.45733	16.227
2010	TEL2010007003	48.69083	-62.71167	48.69450	-62.72983	16.050
2012	TEL2012009114	48.38833	-60.89667	48.39667	-60.90983	15.347
2006	TEL2006003124	49.22467	-63.90917	49.21150	-63.90517	15.150
2010	TEL2010007191	48.47150	-61.76500	48.48183	-61.77850	14.700
2012	TEL2012009102	47.89817	-59.94483	47.90000	-59.96233	14.260
2004	TEL2004001140	48.01433	-60.90850	48.00650	-60.89350	13.800
2012	TEL2012009129	48.61900	-62.98300	48.62683	-62.99900	13.210
2007	TEL2007004017	47.75233	-60.39017	47.75833	-60.40467	12.550
2013	TEL2013010178	48.70667	-62.77000	48.70667	-62.79167	12.185
2013	TEL2013010085	49.07117	-63.72267	49.07367	-63.70200	12.111
2010	TEL2010007109	49.39200	-64.88533	49.38817	-64.90433	12.040
2012	TEL2012009118	48.44800	-61.37800	48.46067	-61.37933	12.010
2010	TEL2010007198	48.71817	-63.22967	48.70983	-63.21450	11.800
2009	TEL2009006165	49.33000	-64.20333	49.33333	-64.22333	11.550
2007	TEL2007004189	49.44217	-64.80533	49.43217	-64.79383	11.200
2009	TEL2009006108	48.74367	-63.15783	48.73617	-63.14200	11.000
2006	TEL2006003181	49.51683	-66.04100	49.52150	-66.02417	10.600
2009	TEL2009006023	48.28017	-60.43117	48.27950	-60.41250	10.000
2007	TEL2007004190	49.34083	-64.49033	49.34750	-64.50767	9.950
2012	TEL2012009119	48.50583	-61.51883	48.51067	-61.53750	9.710
2013	TEL2013010177	48.76150	-63.04433	48.77333	-63.05567	9.543
2010	TEL2010007143	49.14517	-67.16300	49.15450	-67.15200	8.440
2011	TEL2011008094	47.75567	-60.39183	47.74233	-60.39800	8.430
2010	TEL2010007144	49.15433	-66.79017	49.15617	-66.77083	8.390
2015	TEL2015012119	48.66633	-63.17333	48.65917	-63.15283	8.288
2013	TEL2013010067	47.56633	-60.35767	47.55833	-60.34300	8.110
2008	TEL2008005121	48.61833	-62.62333	48.61133	-62.60867	7.974

2008	TEL2008005229	49.33800	-66.28983	49.33450	-66.30850	7.700
2013	TEL2013010109	49.16400	-66.73500	49.15717	-66.75167	7.527
2009	TEL2009006199	49.18367	-66.65767	49.18633	-66.63950	7.500
2013	TEL2013010086	49.18550	-63.59483	49.17650	-63.59067	7.487
2014	TEL2014011145	49.47350	-65.01417	49.46250	-65.02633	7.412
2013	TEL2013010069	47.83600	-60.31933	47.85000	-60.32150	7.350
2015	TEL2015012110	48.45933	-61.98600	48.45367	-61.96683	7.251
2006	TEL2006003103	48.40933	-61.34517	48.41783	-61.35800	7.050
2012	TEL2012009120	48.48983	-61.72817	48.48567	-61.71067	7.050
2012	TEL2012009155	49.76250	-65.75367	49.76550	-65.73550	6.847
2007	TEL2007004198	49.28133	-63.82600	49.27283	-63.81300	6.700
2012	TEL2012009112	48.13233	-60.26233	48.14133	-60.27467	6.670
2011	TEL2011008169	49.49567	-64.83317	49.49650	-64.85267	6.554
2010	TEL2010007112	49.46850	-66.05883	49.47067	-66.07750	6.550
2012	TEL2012009157	49.48267	-65.74700	49.48367	-65.72833	6.492
2006	TEL2006003214	49.30400	-66.23400	49.30867	-66.21633	6.450
2015	TEL2015012111	48.49500	-62.12300	48.49067	-62.10217	6.323
2013	TEL2013010103	49.36900	-64.56333	49.36500	-64.58450	6.310
2009	TEL2009006126	49.56633	-65.54250	49.56817	-65.52367	6.300
2006	TEL2006003178	49.46917	-65.21850	49.47717	-65.20333	6.150
2011	NED2011401057	47.39500	-59.41000	47.38667	-59.39833	6.000
2012	TEL2012009125	48.62767	-62.66183	48.63450	-62.67750	5.976
2006	TEL2006003125	49.32417	-64.02700	49.32500	-64.04650	5.950
2013	TEL2013010076	48.51850	-61.68250	48.52917	-61.66983	5.890
2010	TEL2010007113	49.64967	-65.97767	49.63983	-65.98867	5.800
2006	TEL2006003182	49.56067	-65.89783	49.55017	-65.91017	5.800
2011	TEL2011008167	49.36617	-64.64700	49.36717	-64.66550	5.629
2015	TEL2015012116	48.65483	-62.80317	48.66783	-62.79483	5.561
2014	TEL2014011140	49.33600	-64.49167	49.32817	-64.50900	5.504
2011	TEL2011008099	48.24983	-60.51683	48.26033	-60.50400	5.377
2006	TEL2006003126	49.37383	-64.23667	49.38300	-64.24917	5.350
2013	TEL2013010100	49.49283	-65.88333	49.47917	-65.88583	5.330
2012	TEL2012009104	47.71517	-59.66083	47.70400	-59.65150	5.271
2009	TEL2009006012	48.00267	-60.80267	47.99517	-60.78883	5.100
2015	TEL2015012106	48.50250	-61.28917	48.50350	-61.26917	5.060
2007	TEL2007004088	48.51800	-60.98500	48.51383	-60.96717	5.000
2015	TEL2015012104	48.42800	-60.84617	48.42617	-60.86817	4.960
2015	TEL2015012105	48.49533	-61.07317	48.50167	-61.09150	4.930
2010	TEL2010007106	49.10217	-64.02617	49.09500	-64.01133	4.920
2015	TEL2015012107	48.54200	-61.62533	48.53950	-61.60450	4.907
2009	TEL2009006101	48.66133	-62.77867	48.66700	-62.79633	4.650
2009	TEL2009006014	48.05133	-61.01450	48.04467	-60.99967	4.600
2013	TEL2013010084	49.05933	-63.90617	49.07017	-63.91933	4.587

2012	TEL2012009113	48.24167	-60.58400	48.24733	-60.60033	4.538
2011	TEL2011008176	49.23900	-66.89000	49.24033	-66.87167	4.511
2014	TEL2014011150	49.49767	-66.29817	49.49267	-66.27933	4.511
2006	TEL2006003108	48.32850	-61.85867	48.33717	-61.87200	4.400
2011	TEL2011008011	48.48367	-60.63383	48.49400	-60.64700	4.390
2008	TEL2008005134	49.12017	-63.94483	49.11383	-63.92900	4.350
2009	TEL2009006130	49.84917	-66.25333	49.83633	-66.25733	4.350
2011	TEL2011008173	49.20050	-66.58417	49.20317	-66.56567	4.312
2007	TEL2007004188	49.43350	-64.85133	49.42450	-64.83717	4.300
2008	TEL2008005109	48.62050	-61.14600	48.62533	-61.16417	4.100
2014	TEL2014011131	48.61767	-62.60883	48.62067	-62.58967	4.062
2008	TEL2008005126	48.96700	-63.21200	48.97467	-63.22683	4.050

Overview of the Gulf Biogeographic Zone

Sponges (Porifera)

Sponges were widely distributed in the Gulf Biogeographic Zone being present in 63% of the survey tows used in the analyses (Figure 88).They were distributed throughout most of the region. The locations of the polygons suggest that there are many more significant areas in the northern portion of the Gulf than in the south (Figure 89). The locations of the significant polygons in the north show consistency with the previous analyses of Kenchington et al. (2010), especially for the areas around Anticosti Island and in the estuary (Figure 89). However, in the southern portion of the region there were fewer and smaller polygons identified in the current analyses. The reason for this is not certain. In part, this could be due to the use of the optimal search radius of 12.7 km in the current analysis, as opposed to the 25 km fixed search radius used in the previous analyses. However, this was not seen with the sea pens (see below) that had a smaller search radius as well (15.8 km). We suspect that the data distribution (referred to as the population density) is the reason for this difference. The distribution of the data influences the kernel surface and the additional data likely had more impact on the broadly distributed sponges than it did on the more concentrated sea pens. Also, the result may represent real degradation. It had previously been shown that in the southern portion of the Gulf Biogeographic Zone, the sponge biomass had been reduced between the periods 1990-2002 and 2003-2009 (Figure 90 and Kenchington et al., 2010). We conducted a comparative analysis of the sponge biomass data from 2009-2014, to assess further loss of sponges that could be responsible for the reduction of area in the significant polygons (Figure 90). We removed a single high catch (225 kg, Table 17) in order to better visualize changes in biomass, and used the same colour scales and search radius (25 km) as used earlier. We notice that the loss of sponges over the Magdalene Shallows has continued to occur, but with a lesser difference than was observed between 1990-2002 and 2003-2009.

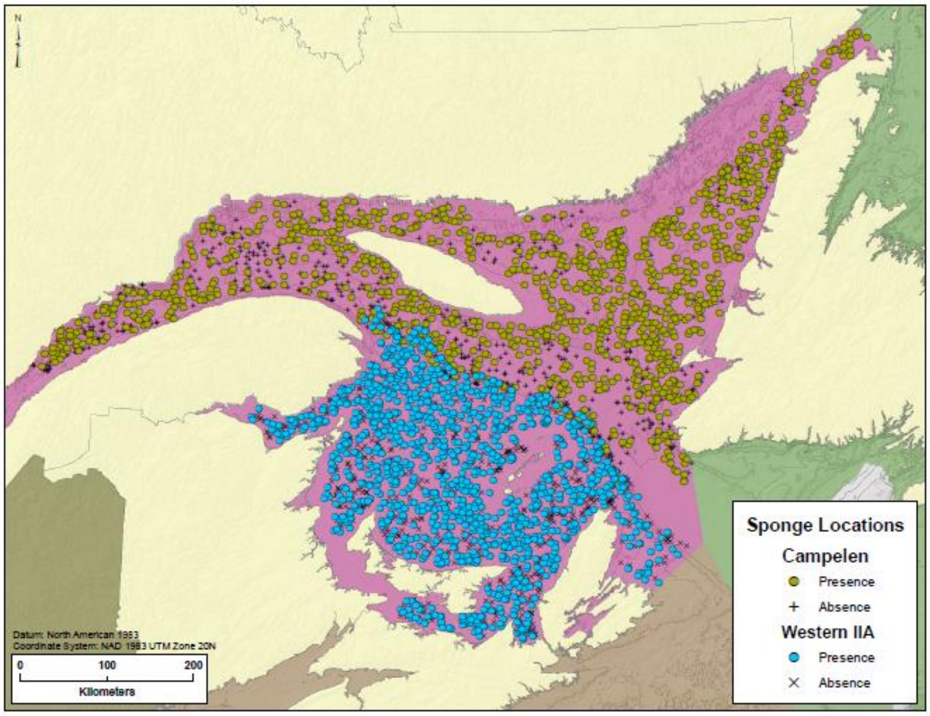

Figure 88. Distribution of sponges from DFO research vessel survey catches using Campelen (olive circles) and Western IIA (blue circles) trawls. Black crosses indicate verified null records.

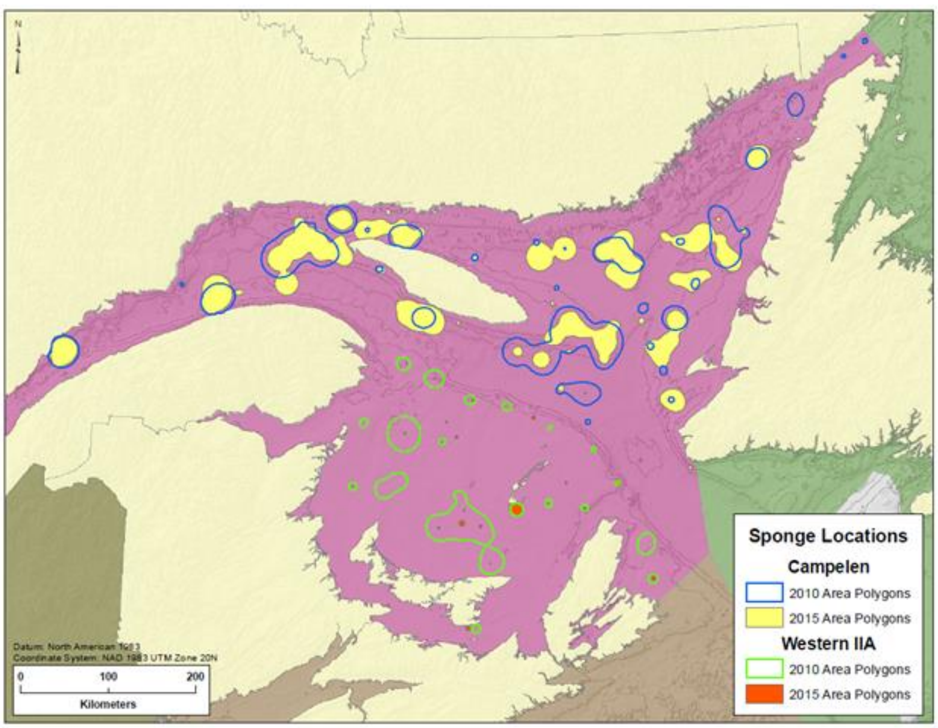

Figure 89. Comparison of the location of the significant concentrations of sponges in the Gulf Biogeographic Zone identified in Kenchington et al. (2010) (outlines) and those identified in this study (polygons).

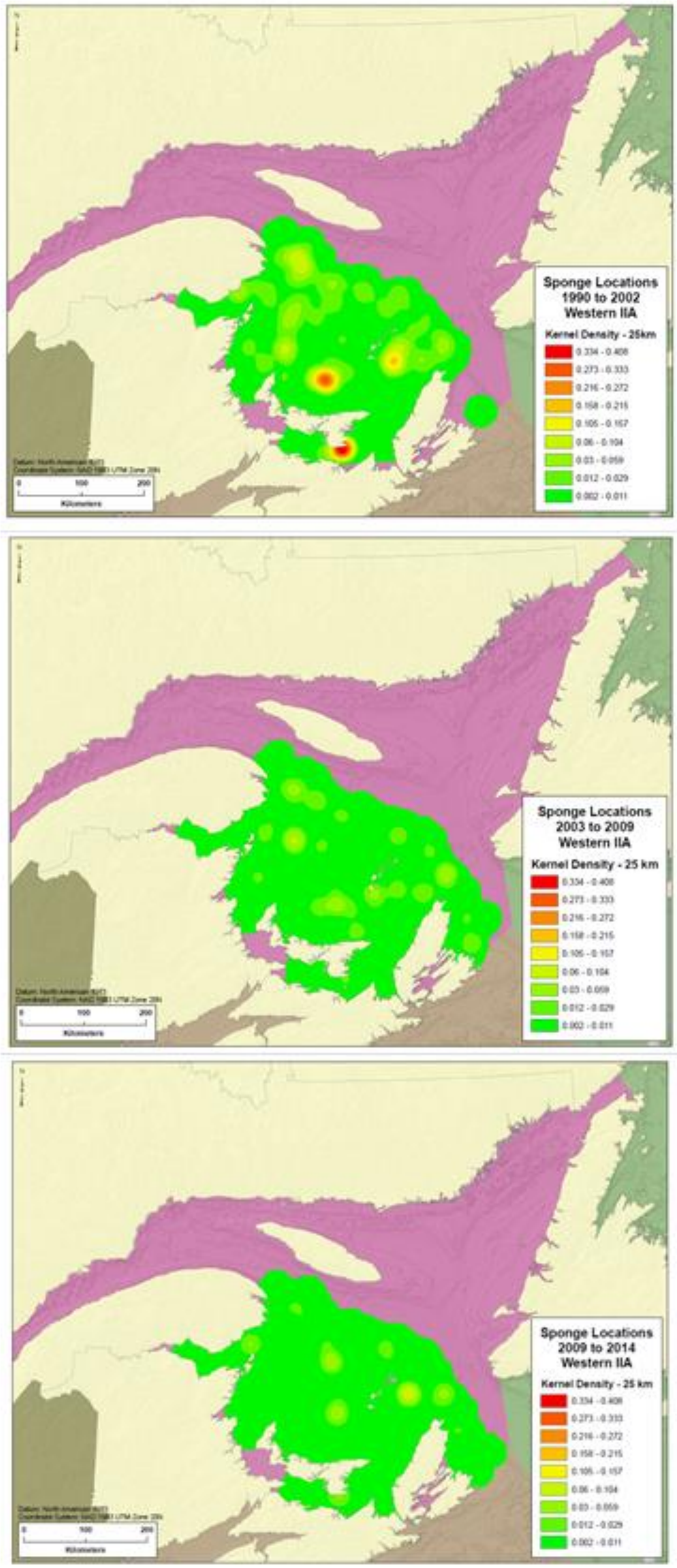

Figure 90. Kernel density surface maps of sponge biomass collected with a Western IIA trawl for three time frames from 1990 to 2014. A search radius of 25 km as used in order to compare the results of Kenchington et al. (2010),shown in the upper (1990-2002) and middle (2003-2009) panels, to the newer data (2009-2014). The scale and colour settings for the maps were set at those produced for the 1990 to 2002 dataset (upper panel), in order to show the relative decrease in sponge biomass over the timeframe. *Note that the 25 km search radius applied to the most recent data (lower panel) differs from the search radius used in our above analyses which was optimized. Also, for the 2009 to 2014, the single large catch of 225 kg (Table 17) was removed prior to creating the surface so as to better visualize changes over the broader distribution.

Sea Pens (Pennatulacea)

Sea pens were distributed in the Gulf of St. Lawrence Estuary, along the Laurentian Channel and north to the deeper waters of the Anticosti and Esquiman Channels in the Gulf Biogeographic Zone (Figure 91). They were largely absent from the Magdalen Shallows (see Figure 58 for place names). The locations of the polygons indicating significant areas lie along the Laurentian Channel (Figure 92).The polygons identified in the Kenchington et al. (2010) report were similar to those identified herein for the Western IIA trawls; however our current analyses identified a greater area using data from the Campelen trawls than was previously identified. The general location of the latter is similar, however the present analyses expands and connects the previously identified polygons (Figure 92).

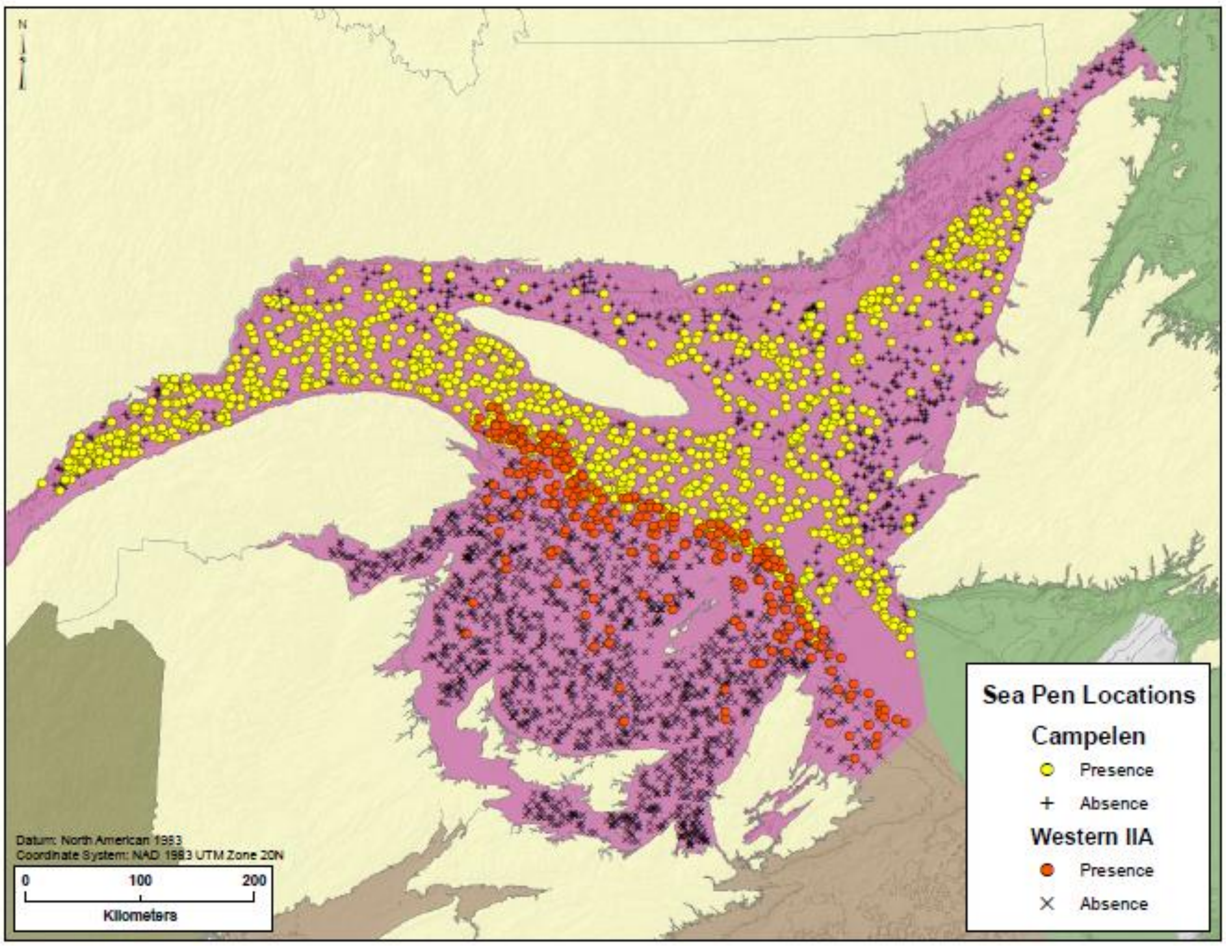

Figure 91. Distribution of sea pens from DFO research vessel survey catches using Campelen (yellow circles) and Western IIA (red circles) trawls. Black crosses indicate verified null records.

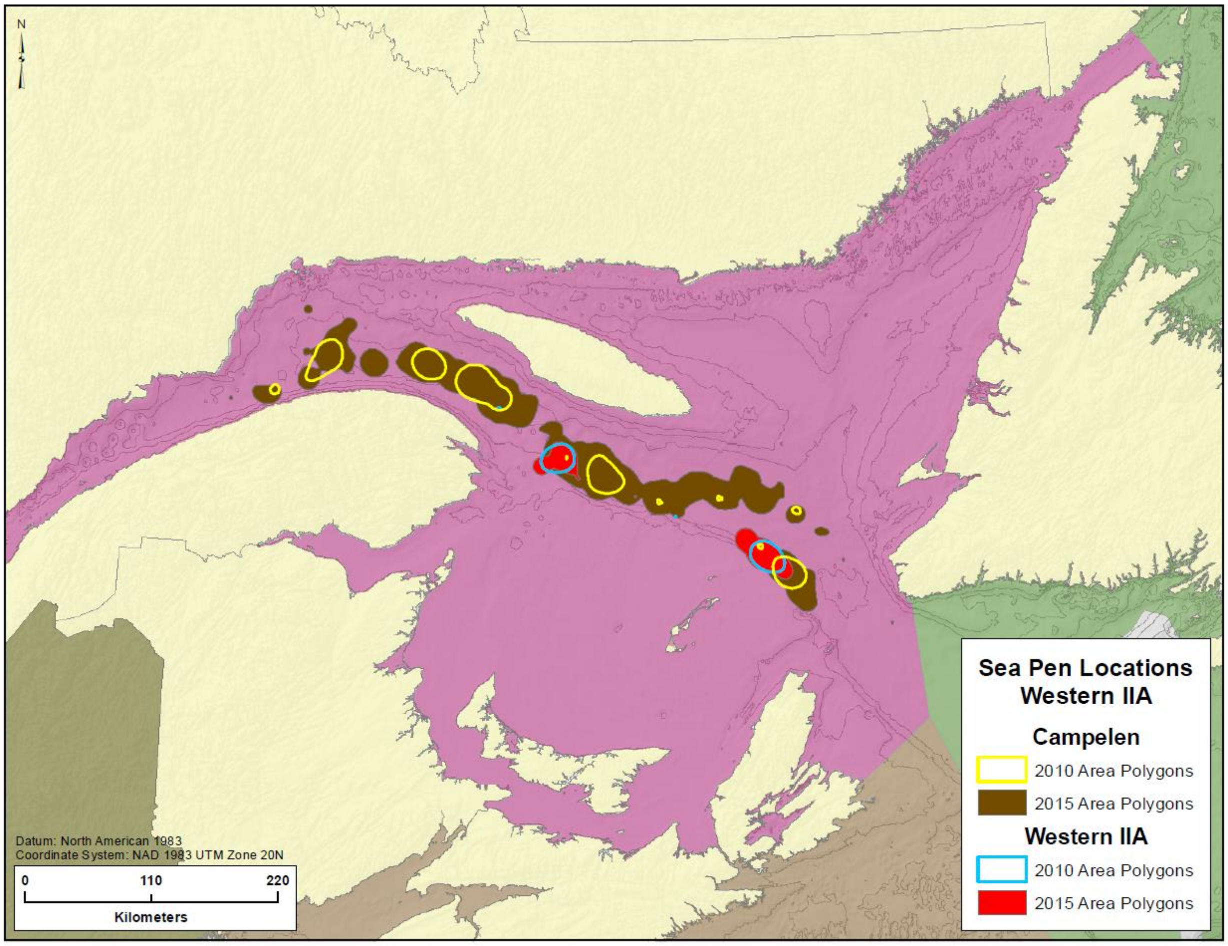

Figure 92. Comparison of the location of the significant concentrations of sea pens in the Gulf Biogeographic Zone identified in Kenchington et al. (2010) (outlines) and those identified in this study (polygons) with the two different trawl gears.

Hudson Bay Complex Biogeographic Zone

In this biogeographic zone there were too few records to apply KDE to the large or small gorgonian corals or to sea pens. Our analyses were conducted on sponges within Hudson Strait and Ungava Bay in the Hudson Bay Complex Biogeographic Zone (Figure 93).

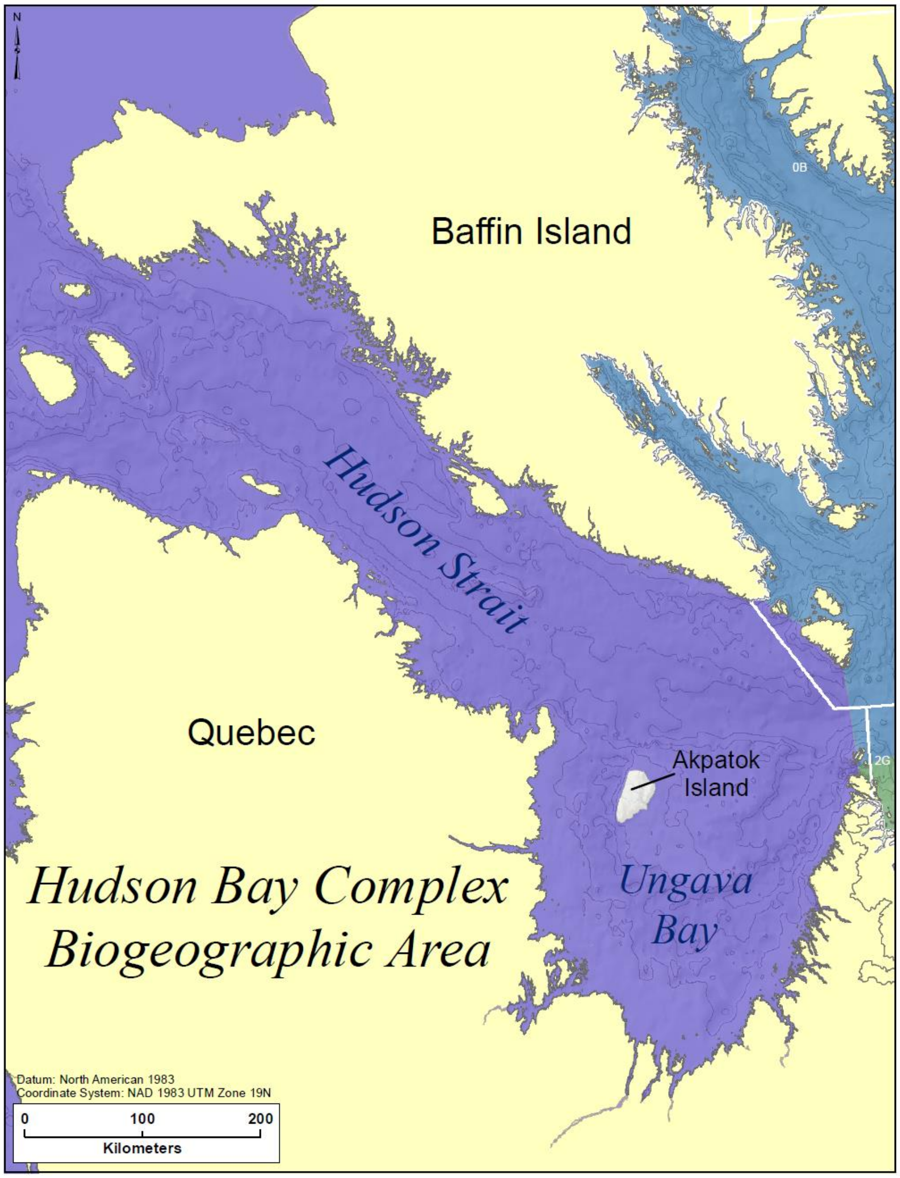

Figure 93. Map showing the area of the eastern portion of the Hudson Bay Complex Biogeographic Zone (DFO, 2009), with place names.

Sponges (Porifera)

Data Sources and Distribution

The data available for the analyses of sponges in the Hudson Bay Complex Biogeographic Zone were restricted to the Hudson Strait and Ungava Bay area in the eastern portion of the Zone. Data used in the analyses were from DFO/industry shrimp surveys conducted from 2007 to 2013 using Cosmos trawls. Specifically surveys were conducted in 2007, 2009, 2011 and 2013 with the full spatial extent only covered in 2009, as the other surveys were in the Ungava Bay area at the eastern extent of the data spatial range (see DFO, 2008; Kenchington et al., 2010 for more details of these surveys). There were 229 records with sponge catch and 109 records of catches with no sponges from the same surveys. This represented 57 more presence records with this gear type than were available for the previous review (Kenchington et al., 2010). In the previous assessment of this area, KDE was not performed on the data because of the small weights of the catches and assumed similarity of species composition to the sponge grounds dominated by Geodiidae on the slopes to the east (Kenchington et al., 2010). However, we have conducted the analysis to assist in the detection of sponge aggregations in Hudson Strait. Within the surveyed area, the sponges were distributed broadly and occurred over the entire depth range (Figure 94).

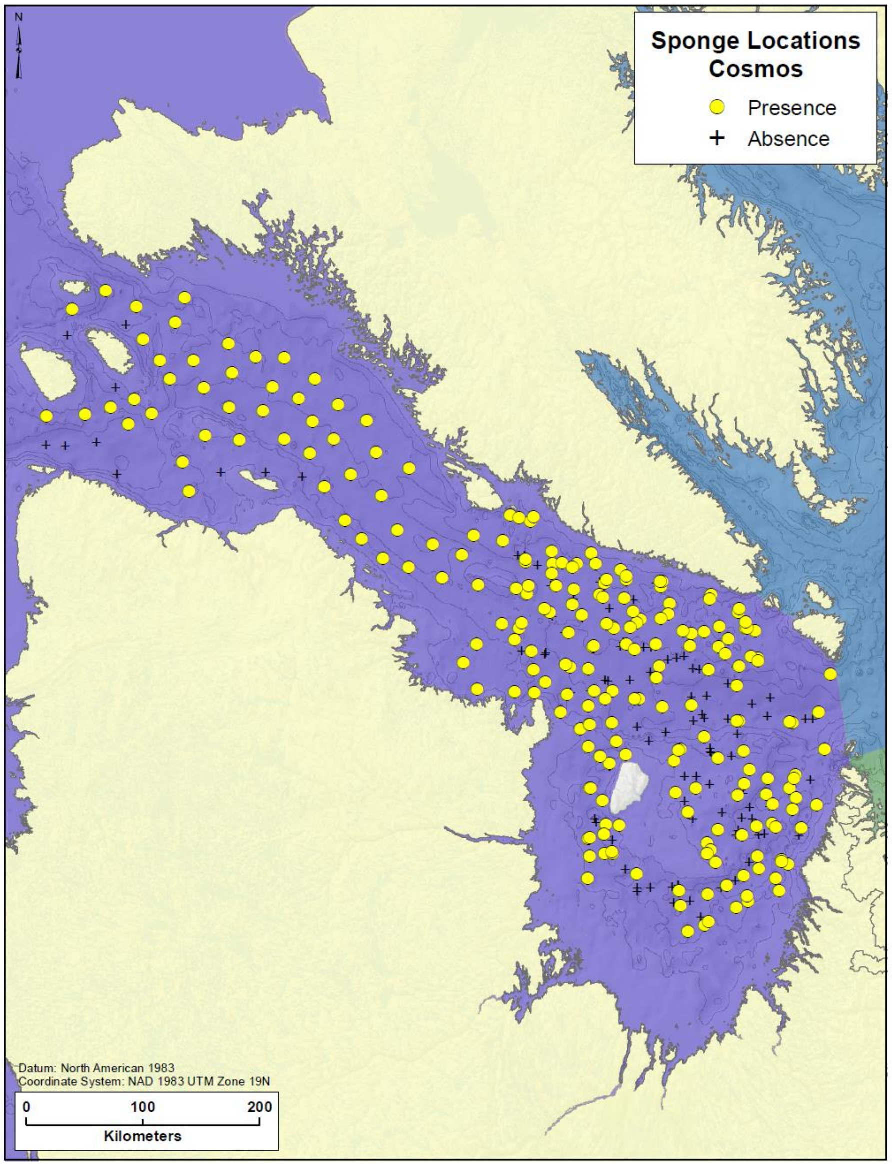

Figure 94. Distribution of sponges from DFO/industry research vessel survey catches using a Cosmos shrimp trawl. Yellow circles indicate sponge presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii

The default search radius for the KDE was 18.291 km. We compared that KDE surface with that produced by using a 25 km search radius. The default search radius produced a number of gaps in the surface while the 25 km radius over-smoothed the data but produced a continuous surface for modelling (Figure 95). The 25 km search radius was used in the preparation of the KDE surface. The default grid size was 2.46 km^2. Contours placed over the KDE surface were finely spaced at 0.000005 kg intervals in order to get as close as possible to the tow locations when constructing the bounding polygons.

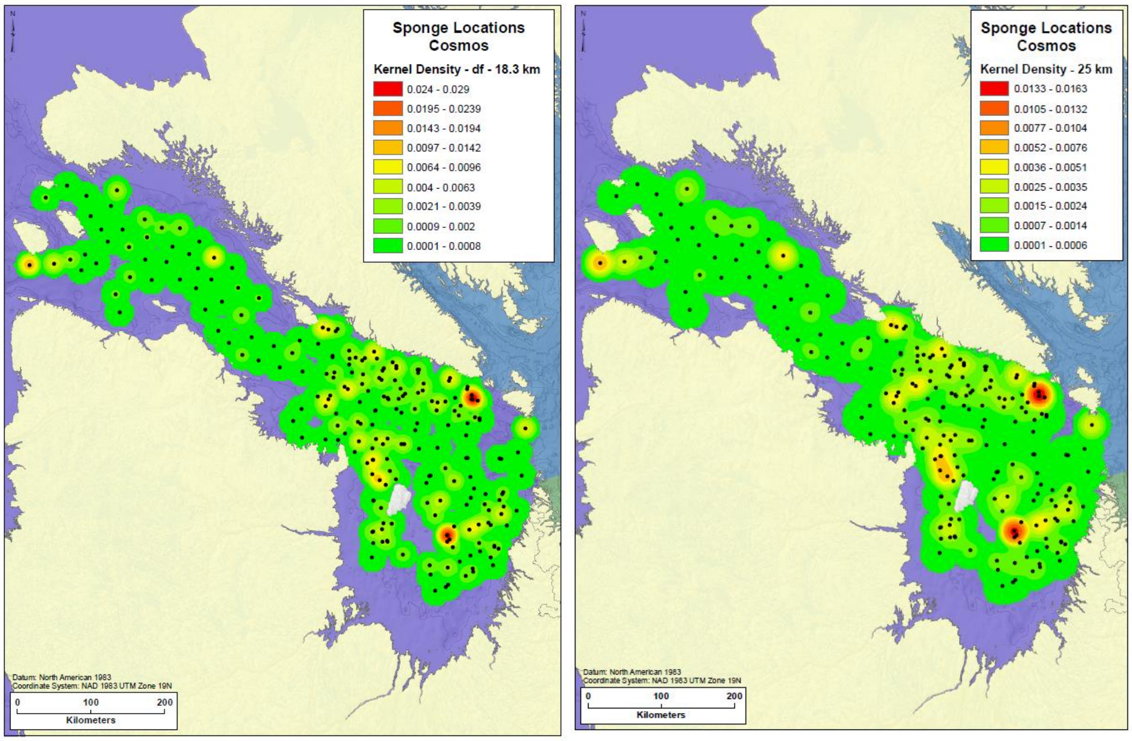

Figure 95. KDE surface of sponge biomass produced with the default (df) search radius (18.291 km) (left) and a 25 km search radius (right). Tow locations with sponge catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations

The area surrounding each sponge weight threshold is provided in Table 24 and illustrated in Figure 96. The first large increase in area was found between 2 and 1 kg where area increased 521% (Table 24, Figures 96, 97). That change was supported by 11 additional data points and was considered to be the threshold delineating significant concentrations of sponges (Table 24). The areas occupy 757 km^2 (Figure 97). This threshold is just on the cusp of the aerial expansion phase and we considered the next large areas of increase at 0.8 and 0.7 kg (Table 24, Figure 96), however their low weight and the identification of areas around single points suggested that these lower thresholds were not identifying significant habitat areas.

Table 24. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
4	3	-	46	207
3	6	3	143	430
2	16	10	757	521
1	27	11	4697	44
0.9	31	4	6765	31
0.8	36	5	8874	48
0.7	43	7	13095	57
0.6	54	11	20535	12
0.5	62	8	22999	39
0.4	74	12	31902	27
0.3	94	20	40670	21
0.2	120	26	49349	61
0.1	156	36	79289	9
0.075	167	11	86273	9
0.05	186	19	94214	12
0.025	202	16	105153	18
0.01	220	18	123788	0
0.005	227	7	123788	

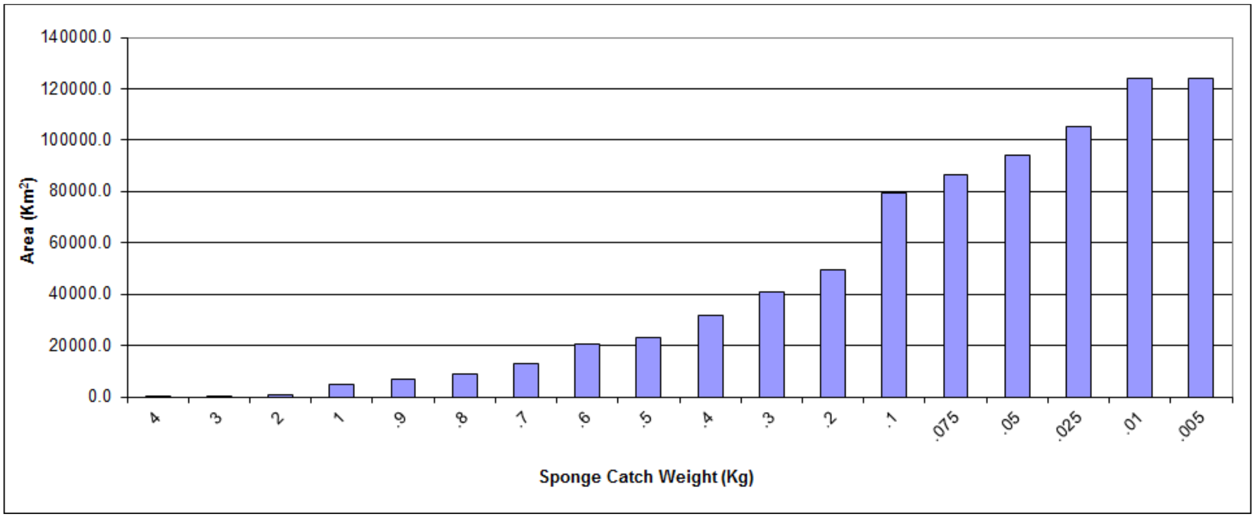

Figure 96. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

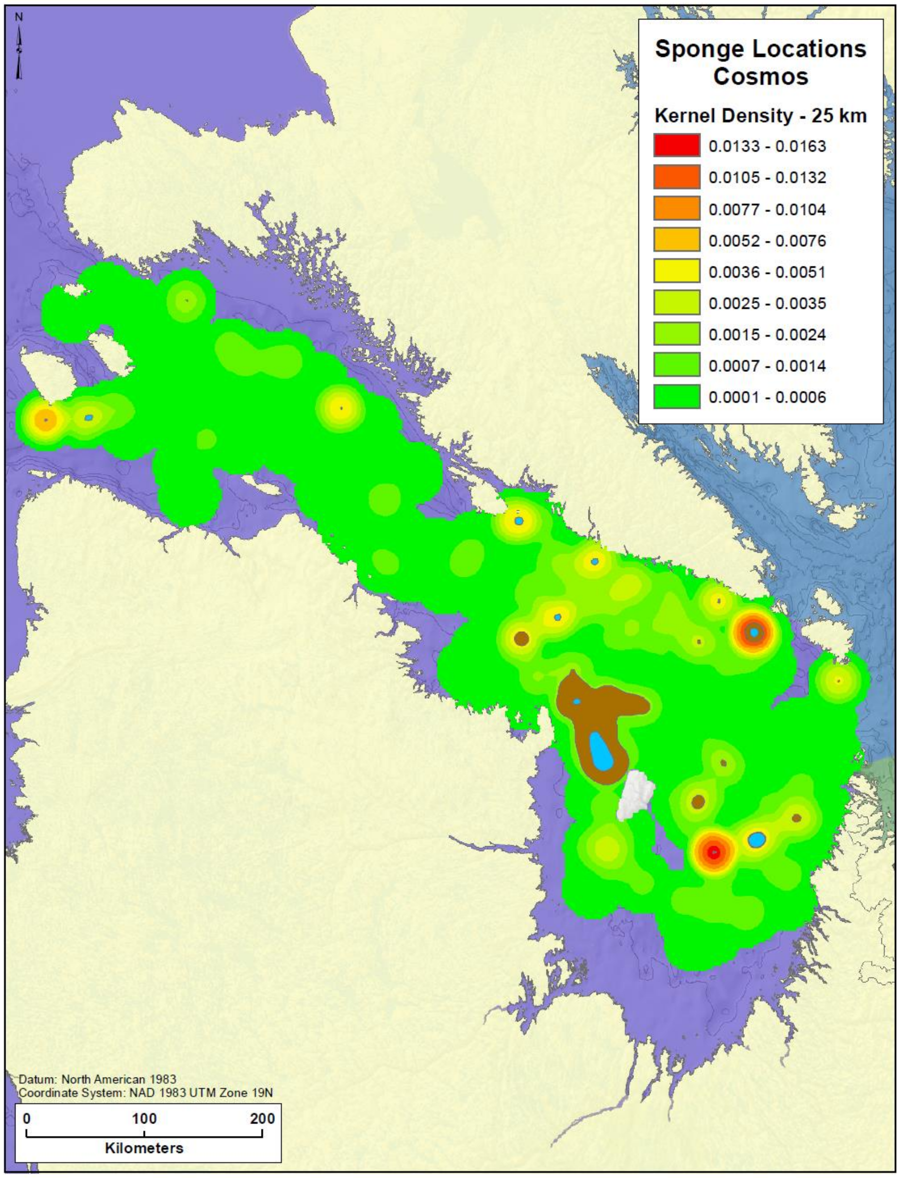

Figure 97. Location of polygons encompassing the ≥2 kg catches (blue) and the ≥1 kg catches (brown), showing the 521% increase in area (Table 24) and overlain on the KDE biomass surface produced with the 25 km search radius.

Location of the Dense Aggregations

The locations of areas that indicated significant concentrations of sponges are shown in Figure 98 and the locations of the survey tows that defined those polygons are provided in Table 25. Sponge identification to species level has been ongoing in the Hudson Strait and Eastern Arctic Regions since 2011. The species composition of the sponges represented in the significant catches from 2011 (Table 25) is provided in Table 26. These sponges include structure forming larger taxa such as *Dendoricella flabelliformis*, *Mycale lingua*, *Thenea*, *Forcepia forcipula* and *Hemigellius arcofer* and also rare taxa such as the calcareous sponges which have only been identified in the region from the Hudson Strait to date.

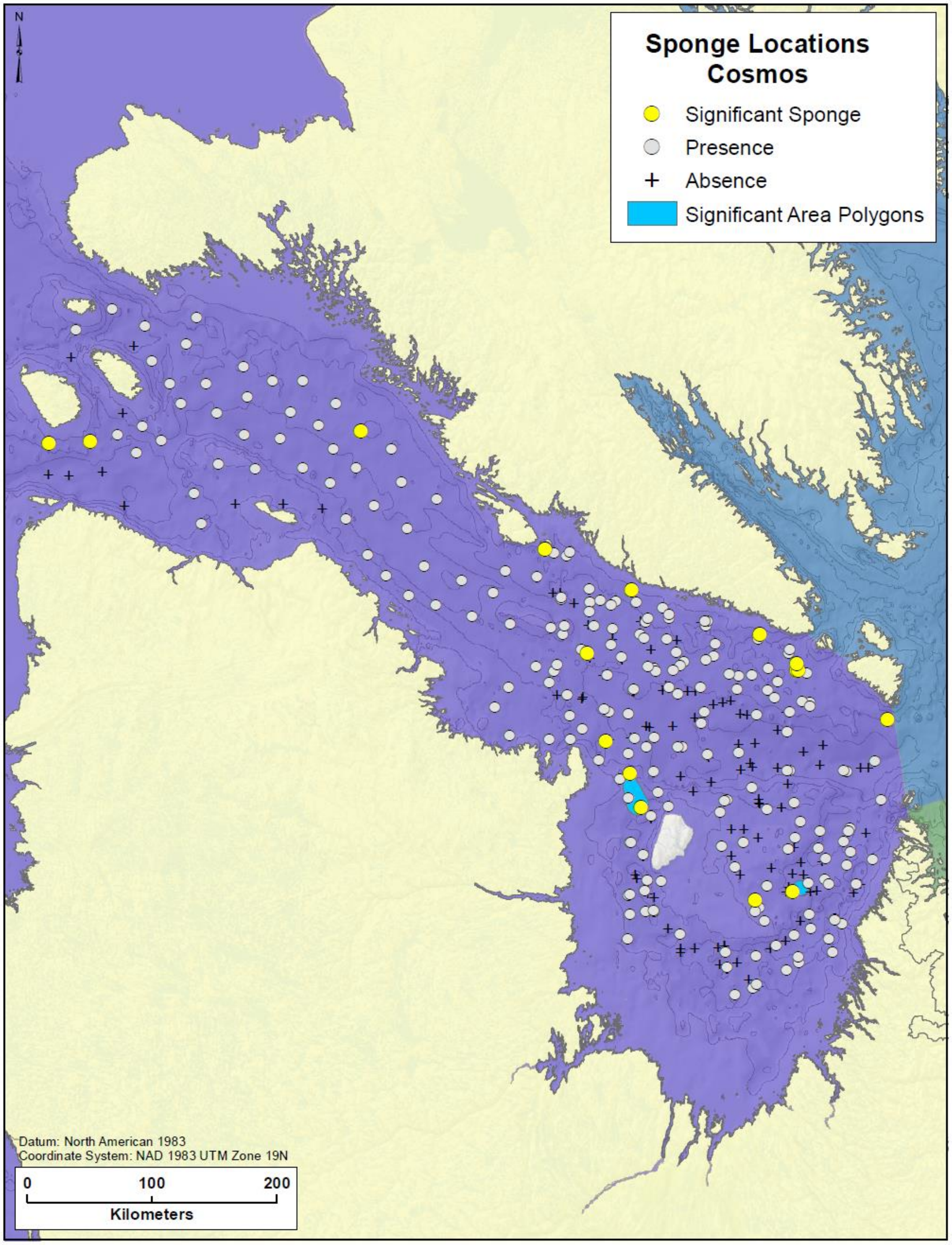

Figure 98. Location of the polygons identifying significant sponge aggregations relative to the broader distribution of sponges in Hudson Strait. Porifera catches that contributed to the identification of the polygons are indicated as significant (Table 25), while those not used to define the polygons are indicated as presence. Null data (absence) is indicated by the black cross.

Table 25. Hudson Bay Complex Biogeographic Zone, Hudson Strait and Ungava Bay: Details of the Location of Research Vessel Sponge Catches used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)
2011	PAA2011117102	59.95787	-66.96861	59.96161	-66.94982	8.754
2009	PAA2009007119	62.97383	-77.95183	62.96467	-77.95167	4.613
2009	PAA2009007056	61.64667	-66.23383	61.65683	-66.23550	4.221
2011	PAA2011117045	61.59906	-66.23395	61.59450	-66.25588	3.404
2009	PAA2009007045	60.63767	-68.60300	60.64683	-68.59017	3.252
2009	PAA2009007147	63.29083	-73.04150	63.28367	-73.02450	3.147
2009	PAA2009007091	62.49350	-70.06833	62.49317	-70.08883	2.781
2009	PAA2009007046	60.88850	-68.76117	60.89517	-68.77450	2.754
2011	PAA2011117069	61.74660	-69.40123	61.73596	-69.40771	2.545
2007	PAA2007007037	62.20333	-68.72517	62.20305	-68.74778	2.542
2011	PAA2011117046	61.86658	-66.76842	61.85627	-66.76769	2.479
2007	PAA2007007073	61.21032	-64.91152	61.21210	-64.89832	2.444
2007	PAA2007007038	61.11483	-69.11263	61.11278	-69.08972	2.224
2007	PAA2007007010	61.59747	-66.21477	61.58678	-66.21282	2.184
2007	PAA2007007062	60.01433	-66.42883	60.01767	-66.42550	2.112
2009	PAA2009007120	63.02850	-77.30883	63.01783	-77.30433	2.055

Table 26. Lab Identification of Sponge Species from Sets with Significant Catches (Table 25) from Hudson Strait in 2011.

Mission Number and Set*	**Sponge Weight (kg)**	**Species Identified**
PAA2011117102	8.754	*Hemigellius arcofer*
PAA2011117045	3.404	*Thenea* sp.*; *Polymastia uberrima*; *Weberella bursa*; *Mycale lingua*; *Forcepia forcipula*; Calcarea spp.**; *Tedania suctoria*; *Iophon piceum*; *Lissodendoryx indistincta*; *Tentorium semisuberites*
PAA2011117046	2.754	*Lissodendoryx indistincta*; Calcarea spp.**
PAA2011117069	2.545	*Dendoricella flabelliformis**; *Mycale lingua*; *Forcepia forcipula**

*Largest individual specimens recorded from the region (including Eastern Arctic). **Rare in surveys. Every calcareous sponge we have recorded has been from Hudson Strait.

Eastern Arctic Biogeographic Zone

In this biogeographic zone (Figure 99) there were records for all of the 4 taxa: sponges, sea pens, large and small gorgonian corals. In this region, up to three sampling gears are used in the surveys (Kenchington et al., 2010), that is, Campelen, Alfredo and Cosmos trawls. As in previous analyses we have performed separate KDE analyses on each trawl/taxon as the gears operate in different regions, with potentially different species compositions, and have different catchabilities. Details of the species comprising each taxon can be found in Beazley et al. (2016b).

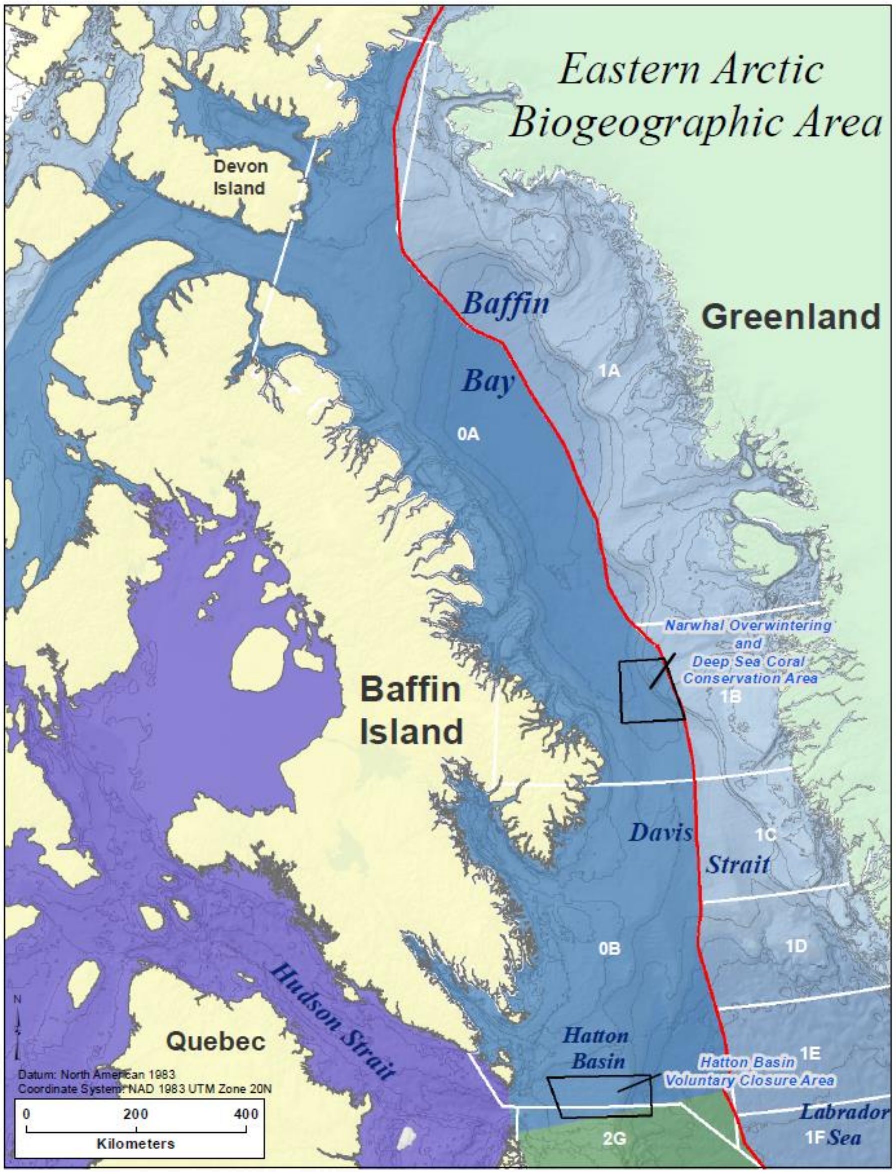

Figure 99. Map showing the area of the surveyed portion (NAFO Div. 0A, 0B) of the Eastern Arctic Biogeographic Zone (DFO, 2009), with place names, NAFO Divisions, areas closed to protect benthic species and habitats, and the Canadian Exclusive Economic Zone (EEZ; red line).

Sponges (Porifera)

Alfredo Trawl Data Sources and Distribution

The data available for the analyses of sponges in the Eastern Arctic Biogeographic Zone were restricted to the lower Baffin Bay and Davis Strait area. Data used in the analyses were from surveys conducted from 1999 to 2014 using Alfredo trawls. There were 663 records with sponge catch and 177 records of catches with no sponges from the same surveys. Within the surveyed area, the sponges were distributed broadly and occurred over the slopes and deeper water, being less common on the shelf east of Lancaster Sound (Figure 100).

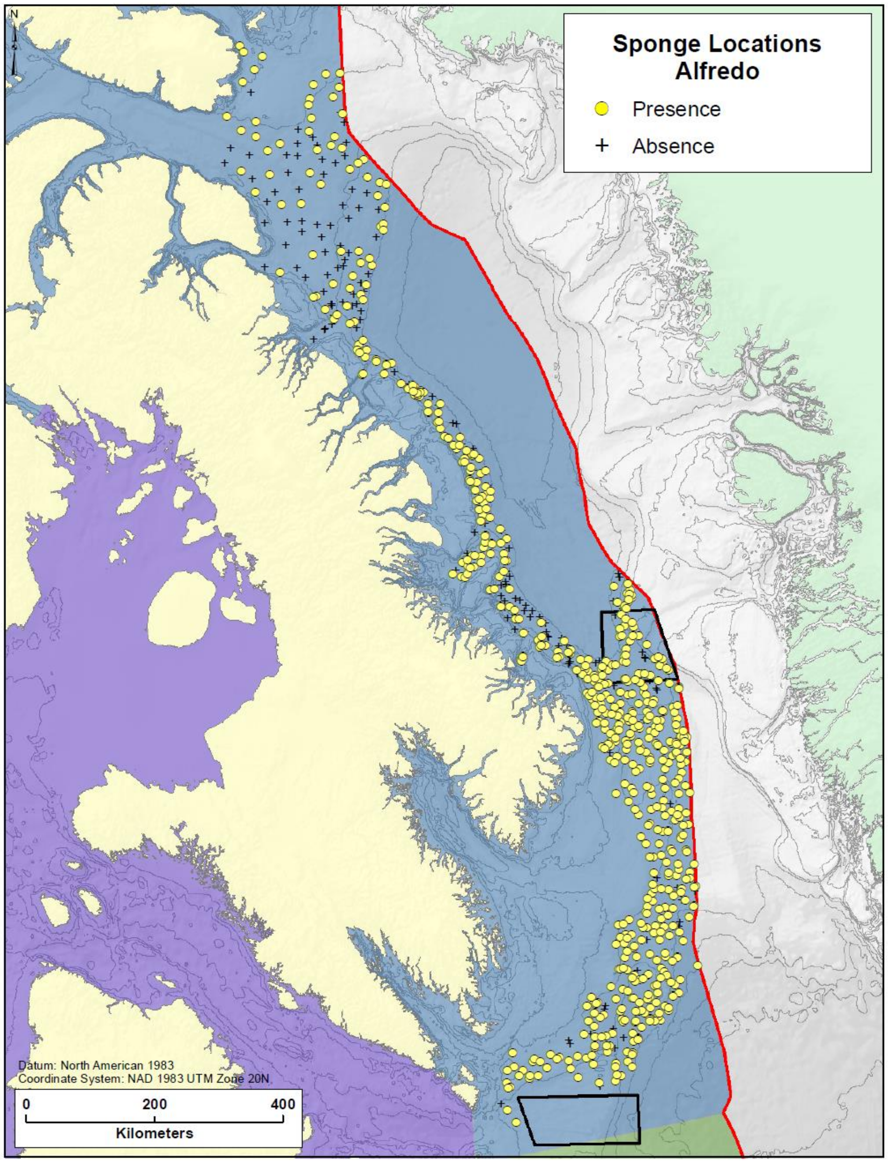

Figure 100. Distribution of sponges from DFO research vessel survey catches using Alfredo trawls. Yellow circles indicate sponge presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Alfredo Trawl Data

The default search radius for the KDE was 24.4148 km. We compared that KDE surface with one produced by using a 20 km search radius, rather than larger radii, as the coverage was continuous with the default values. The results were very similar and we chose to use the default as it provided a more continuous surface in the northern part of the spatial extent of the data

(Figure 101). The default grid size was 3.22 km^2. Contours placed over the KDE surface were spaced at 0.0001 kg intervals when constructing the bounding polygons.

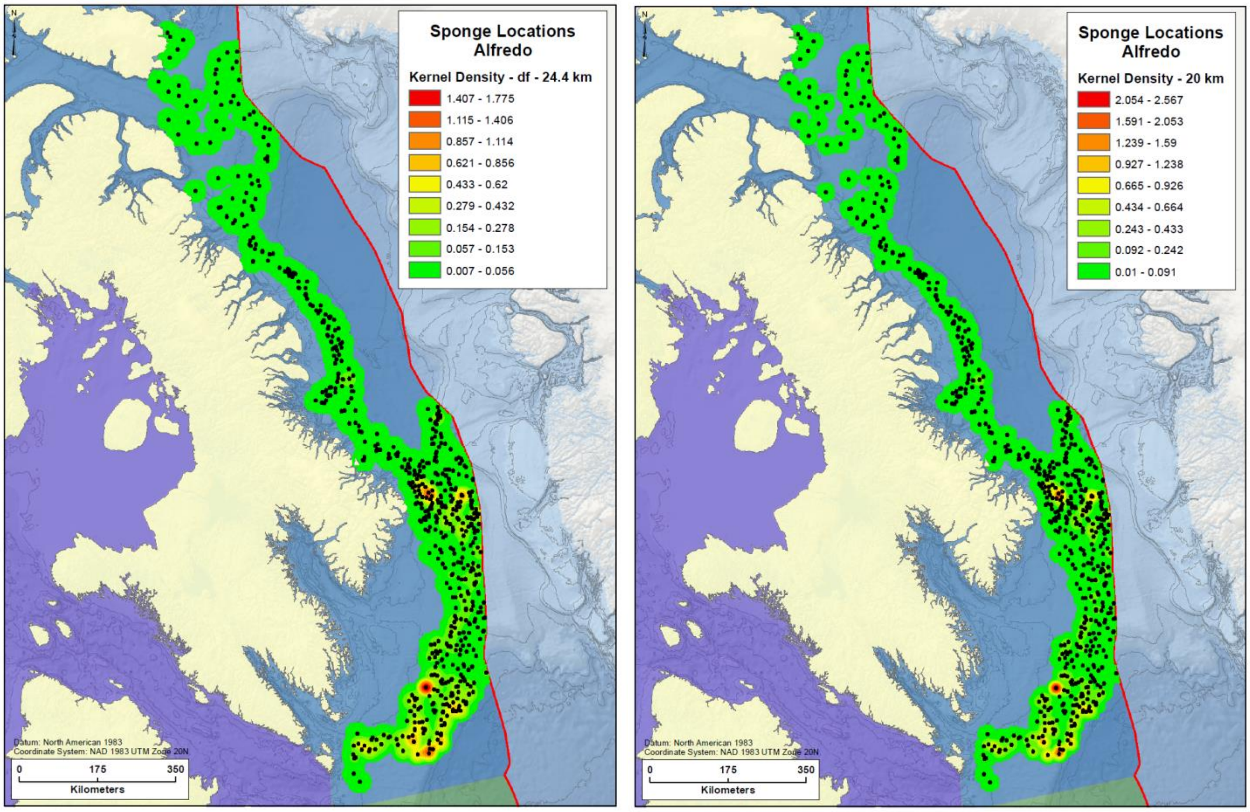

Figure 101. KDE surface of sponge biomass produced with the default (df) search radius (24.4 km) (left) and a 20 km search radius (right). Tow locations with sponge catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Alfredo Trawl Data

The area surrounding each sponge weight threshold is provided in Table 27 and illustrated in Figure 102. The first large increase in area after the mapping out of the sponge grounds was found between 80 and 60 kg where area increased 79% (Table 27, Figures 102, 103). That change was supported by 14 additional data points and was considered to be the threshold delineating significant concentrations of sponges (Table 27). The areas occupy 10,198 km^2 (Table 27).

Table 27. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
400	4	-	824	174
200	10	6	2255	332
100	34	24	9734	5
80	44	10	10198	79
60	58	14	18297	6
50	67	9	19306	21
40	81	14	23351	27
30	102	21	29740	54
20	127	25	45656	1
15	148	21	45988	23
10	179	31	56384	15
7	197	18	64648	10
5	215	18	71029	9
4	228	13	77359	3
3	259	31	79702	4
2	281	22	83030	11
1	332	51	92503	3
.7	352	20	94957	4
0.5	380	28	98702	9
0.3	413	33	107736	17
0.2	450	37	126496	7
0.1	498	48	135602	9
0.05	535	37	147490	4
0.01	602	67	152842	0
0.005	608	6	152842	1
0.001	624	16	154958	0
0.0005	624	0	154958	

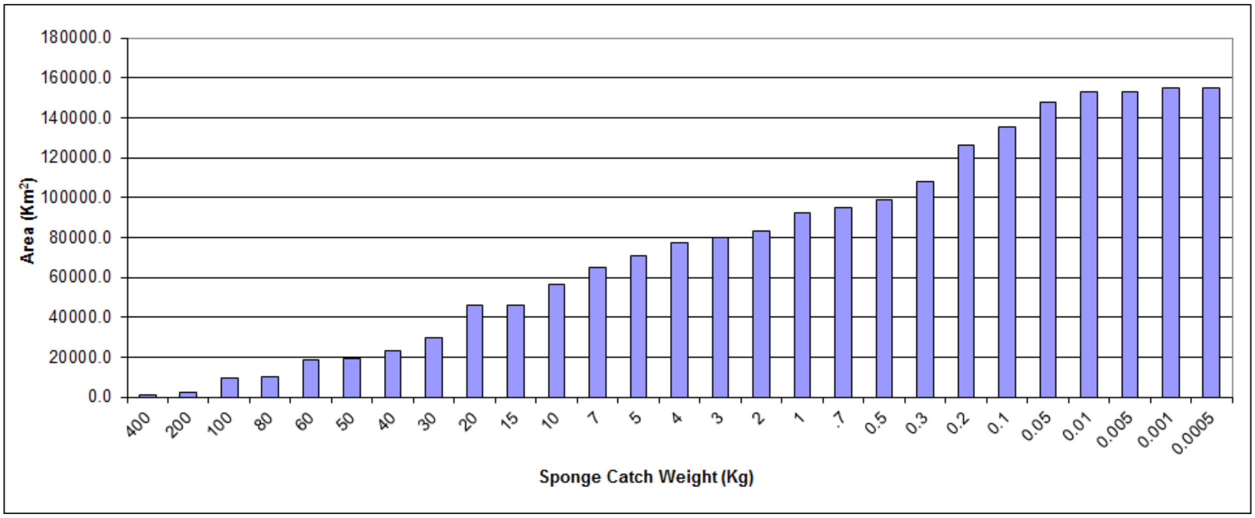

Figure 102. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

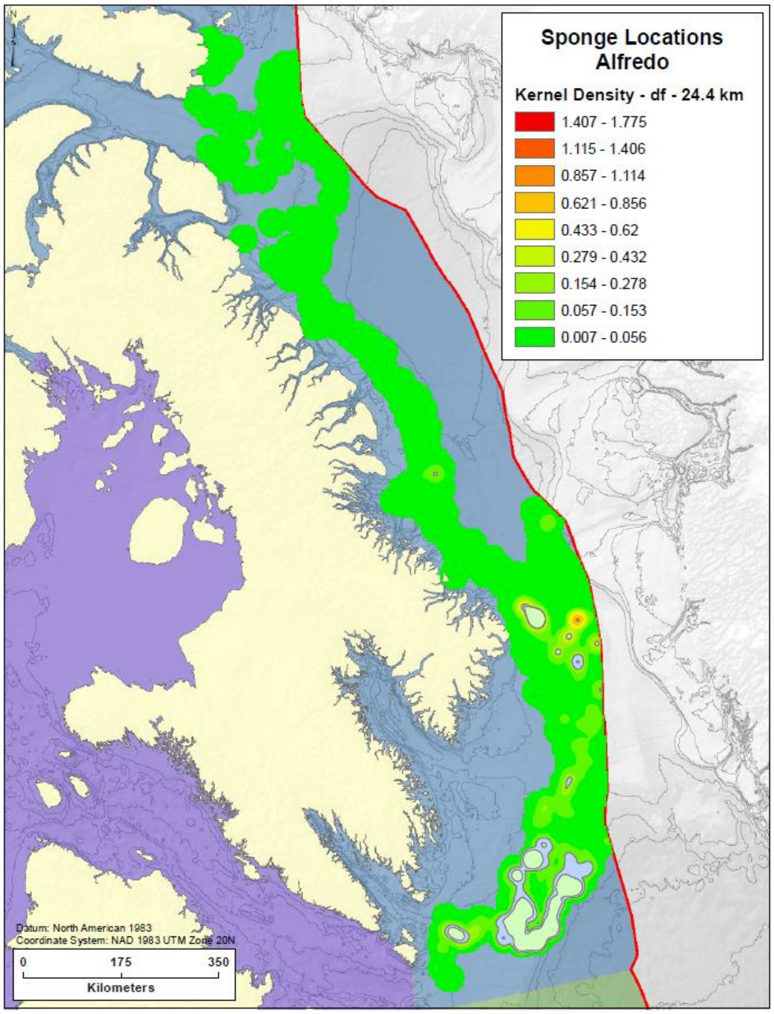

Figure 103. Location of polygons encompassing the ≥80 kg catches (light gray) and the ≥60 kg catches (blue), showing the increase in area (Table 27) and overlain on the KDE biomass surface produced with the default (df) search radius.

Location of the Dense Aggregations from Alfredo Trawl Data

The locations of areas that indicated significant concentrations of sponges are shown in Figure 104 and the locations of the survey tows that defined those polygons are provided in Table 28. Figure 105 shows the locations of the significant area polygons determined from this study in comparison with those produced in the 2010 report (Kenchington et al., 2010). The same general areas are recognized but there is more extensive area identified northeast of Hatton Basin. The largest sponge biomass is outside of the voluntary closed area put in place by industry but no data were collected within the closed area to examine it in more detail. In this area species distribution modelling may be very insightful.

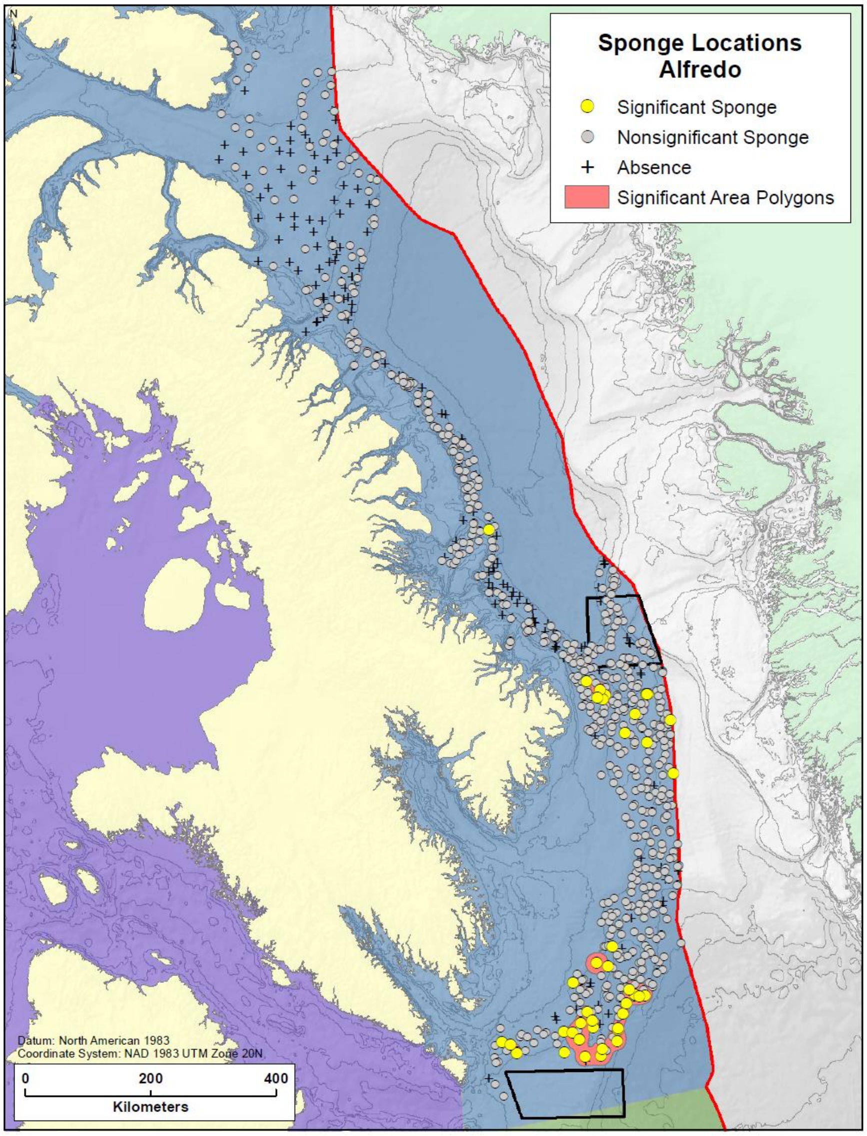

Figure 104. Location of the polygons identifying significant sponge aggregations relative to the broader distribution of sponges in the Eastern Arctic. Sponge catches that contributed to the identification of the polygons are indicated as significant (Table 28), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

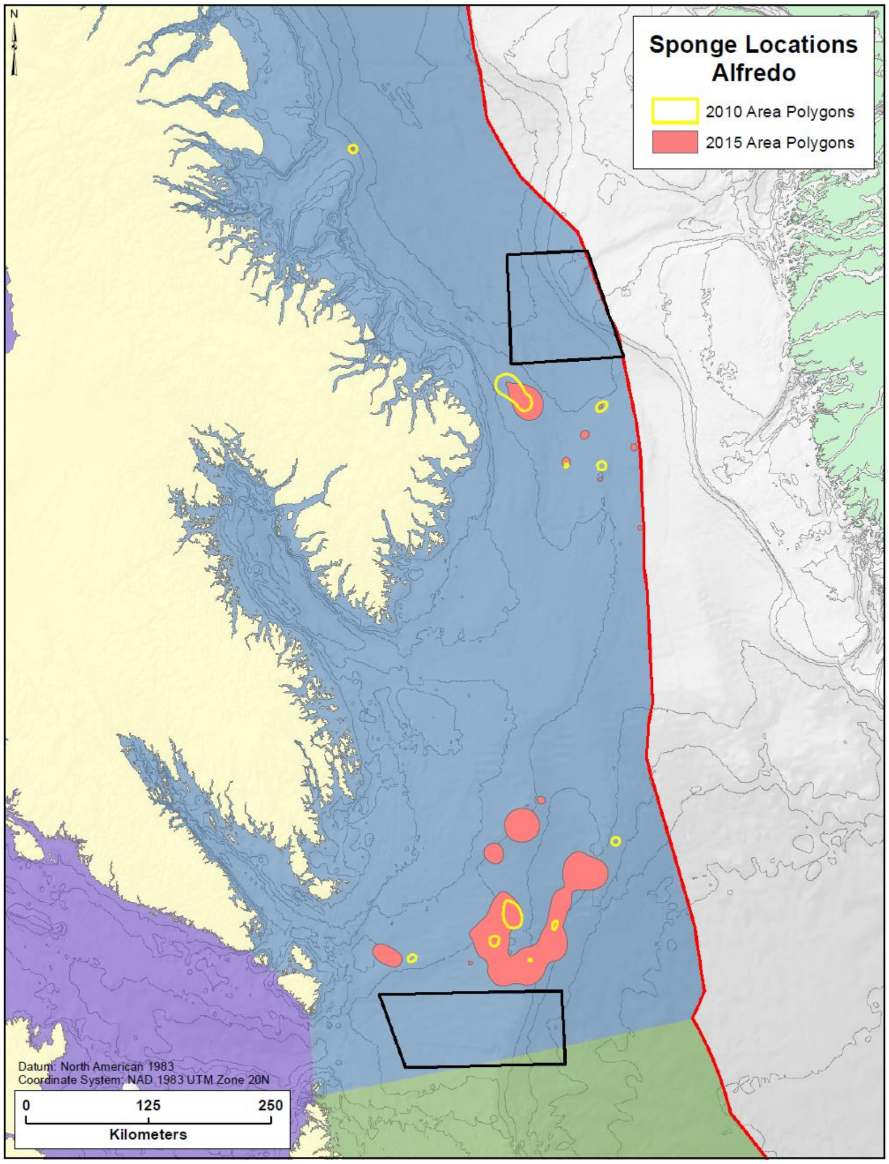

Figure 105. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (salmon polygons).

Table 28. Eastern Arctic Biogeographic Zone, Davis Strait: Details of the Location of Research Vessel Sponge Catches from Alfredo Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)
2014	PAA2014007142	63.02763	-60.67272	63.01992	-60.62243	1088.322
2013	PAA2013008137	61.70485	-60.65048	61.71987	-60.65288	528.998
2012	PAA2012007155	66.91700	-60.16643	66.89253	-60.15118	419.700

2013	PAA2013008136	61.68727	-61.12232	61.68443	-61.08505	413.100
2014	PAA2014007134	61.89890	-60.13640	61.86890	-60.13235	399.425
2000	PAA2000002017	61.79000	-60.59000	61.77000	-60.60000	350.000
2011	PAA2011117121	61.94133	-61.27989	61.92167	-61.26488	301.500
2008	PAA2008007067	67.06183	-60.64783	67.03675	-60.63187	250.000
2011	PAA2011117022	62.52859	-59.20289	62.54439	-59.23940	233.150
2013	PAA2013008056	61.87438	-63.37695	61.85992	-63.40908	215.750
2013	PAA2013008135	61.76735	-61.72832	61.74850	-61.70205	172.950
2012	PAA2012007194	66.82927	-58.50340	66.83135	-58.56127	168.224
2010	PAA2010009115	66.84350	-59.99717	66.82003	-59.98455	168.050
2011	PAA2011117023	62.55180	-59.52723	62.57452	-59.53568	162.900
2014	PAA2014007092	66.14090	-58.61472	66.16238	-58.64475	153.424
2010	PAA2010009161	66.55412	-58.96755	66.53023	-58.98213	152.750
2000	PAA2000002026	61.94000	-61.27000	61.92000	-61.25000	150.000
2011	PAA2011117114	61.90894	-63.63715	61.92445	-63.59632	140.579
2006	PAA2006008011	66.92167	-60.18567	66.94050	-60.21500	133.450
2013	PAA2013008052	62.04287	-61.47677	62.02062	-61.50008	132.364
2011	PAA2011117037	61.75708	-63.17784	61.74090	-63.18217	131.768
2013	PAA2013008045	62.98347	-60.30927	62.95920	-60.31075	126.473
2014	PAA2014007004	66.78685	-60.09917	66.76540	-60.11338	124.100
2010	PAA2010009155	66.81430	-58.45597	66.80987	-58.39535	123.850
2011	PAA2011117124	62.17897	-61.21684	62.20351	-61.21690	123.826
2000	PAA2000002033	62.33000	-61.00000	62.35000	-61.00000	120.000
2014	PAA2014007088	66.82693	-58.49283	66.82817	-58.55197	117.793
2013	PAA2013008147	62.62903	-59.67562	62.60567	-59.68063	115.396
2011	PAA2011117132	63.24716	-60.16543	63.26452	-60.19422	107.525
2011	PAA2011117119	62.06004	-61.74539	62.03883	-61.72220	107.149
2013	PAA2013008145	62.43510	-59.78475	62.41438	-59.77095	104.750
2008	PAA2008007049	66.82817	-58.47145			100.000
2000	PAA2000002028	62.11000	-60.85000	62.12000	-60.86000	100.000
2000	PAA2000002030	62.20000	-60.86000	62.23000	-60.88000	100.000
2011	PAA2011117028	62.28608	-59.91905	62.26182	-59.91587	98.903
1999	PAA1999001012	66.82000	-60.28000	66.84000	-60.28300	98.590
2014	PAA2014007124	62.52203	-59.39858	62.54528	-59.40400	94.400
1999	PAA1999001004	66.29000	-59.36000	66.31000	-59.36200	90.500
2011	PAA2011117169	65.66646	-57.76882	65.64293	-57.76118	88.852
2000	PAA2000002016	62.09000	-60.10000	62.06000	-60.12000	88.250
2013	PAA2013008047	62.76543	-61.43020	62.74237	-61.44598	87.950
2010	PAA2010009168	66.42807	-57.70140	66.40437	-57.71060	85.943
2006	PAA2006008044	69.23160	-64.35775	69.24890	-64.39367	83.124
2013	PAA2013008141	62.05390	-60.09182	62.03137	-60.09517	83.030

Campelen Trawl Data Sources and Distribution

The data available for the analyses of sponges in the Eastern Arctic Biogeographic Zone as sampled with Campelen trawls were restricted to the Davis Strait area (Figure 106). The sponges were widespread throughout the data extent but more frequent in deeper water. Data used in the analyses were from surveys conducted from 2005 to 2014. There were 711 records with sponge catch and 862 records of catches with no sponges from the same surveys.

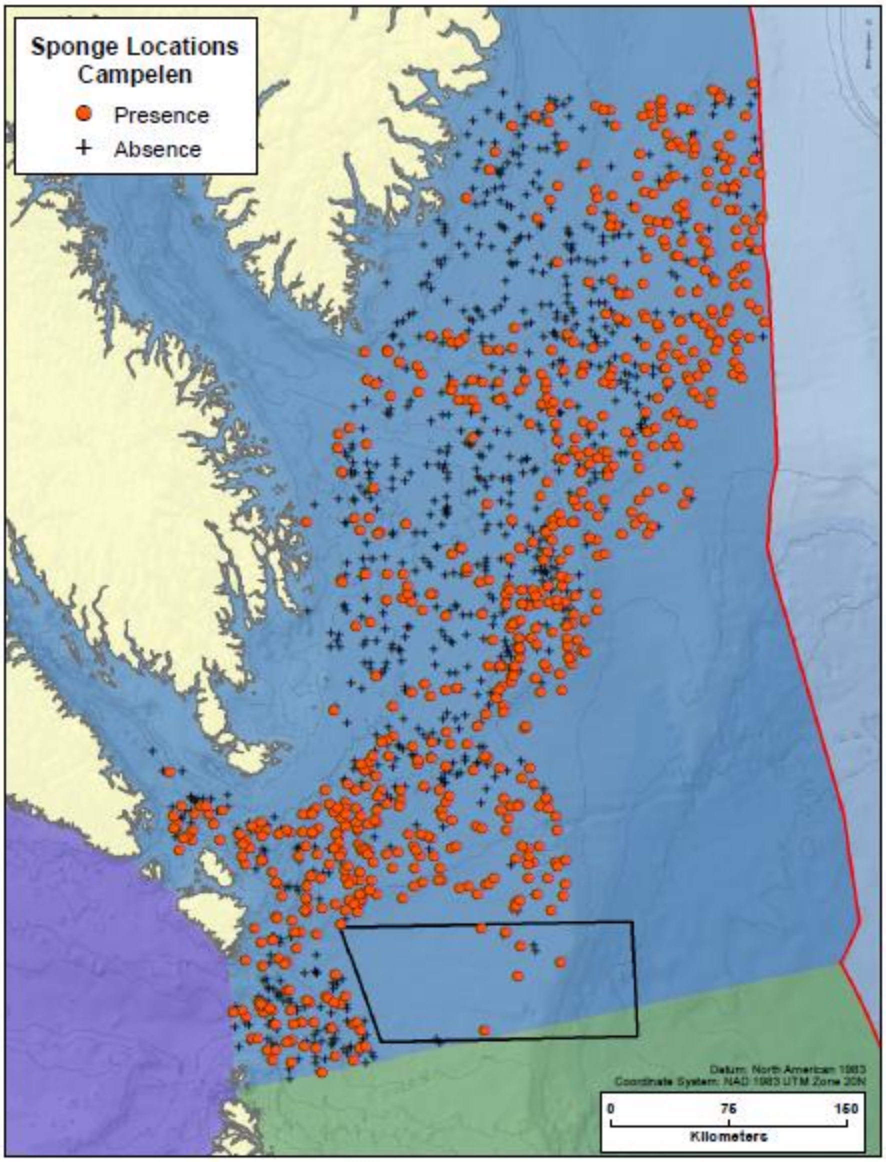

Figure 106. Distribution of sponges from DFO research vessel survey catches using Campelen trawls. Red circles indicate sponge presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Campelen Trawl Data

The default search radius for the KDE was 12.6874 km. We compared that KDE surface with one produced by using a 20 km search radius, which provided a more continuous surface for the analyses (Figure 107). The 20 km search radius was used and the default grid size was 1.65 km^2. Contours placed over the KDE surface were finely spaced at 0.0005 kg intervals when constructing the bounding polygons.

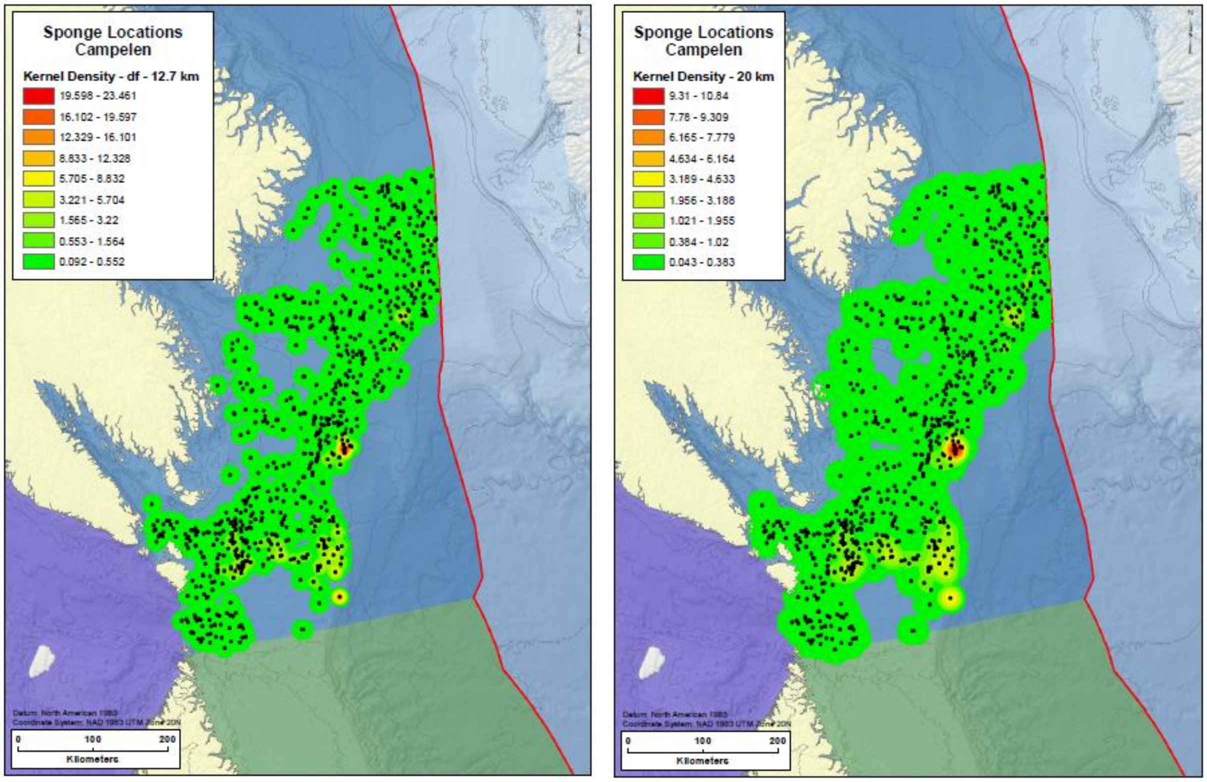

Figure 107. KDE surface of sponge biomass produced with the default (df) search radius (12.7 km) (left) and a 20 km search radius (right). Tow locations with sponge catch from Campelen trawls used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Campelen Trawl Data

The area surrounding each sponge weight threshold is provided in Table 29 and illustrated in Figure 108. The first large increase in area after the mapping out of the sponge grounds was found between 20 and 10 kg where area increased 55% (Table 29, Figures 108, 109). That change was supported by 54 additional data points and was considered to be the threshold delineating significant concentrations of sponges (Table 30). The areas occupy 29,672 km^2 (Table 29). We also reviewed the 30 kg threshold as it had a similar aerial expansion at 42%, however there was not as much change in going from 30 to 20 kg as there was going from 20 to 10 kg (Figure 109).

Table 29. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
1000	4	-	393	435
500	13	9	2100	149
200	24	11	5235	164
100	52	28	13839	4
70	63	11	14327	5
50	81	18	15005	12
40	95	14	16812	24
30	124	29	20851	42
20	159	35	29672	55
10	213	54	46013	1
8	224	11	46339	5
5	249	25	48632	0
4	270	21	48640	6
3	294	24	51628	3
2	324	30	53371	3
1	378	54	54921	0
0.75	395	17	55089	4
0.5	429	34	57340	2
0.25	473	44	58684	2
0.1	510	37	59833	1
0.075	515	5	60499	0
0.05	520	5	60499	

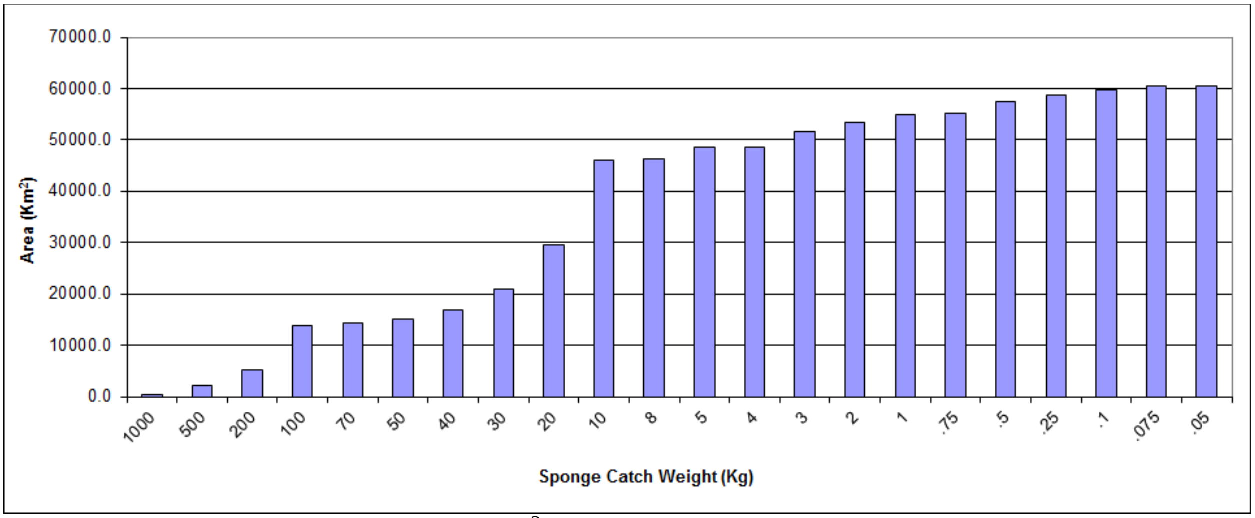

Figure 108. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

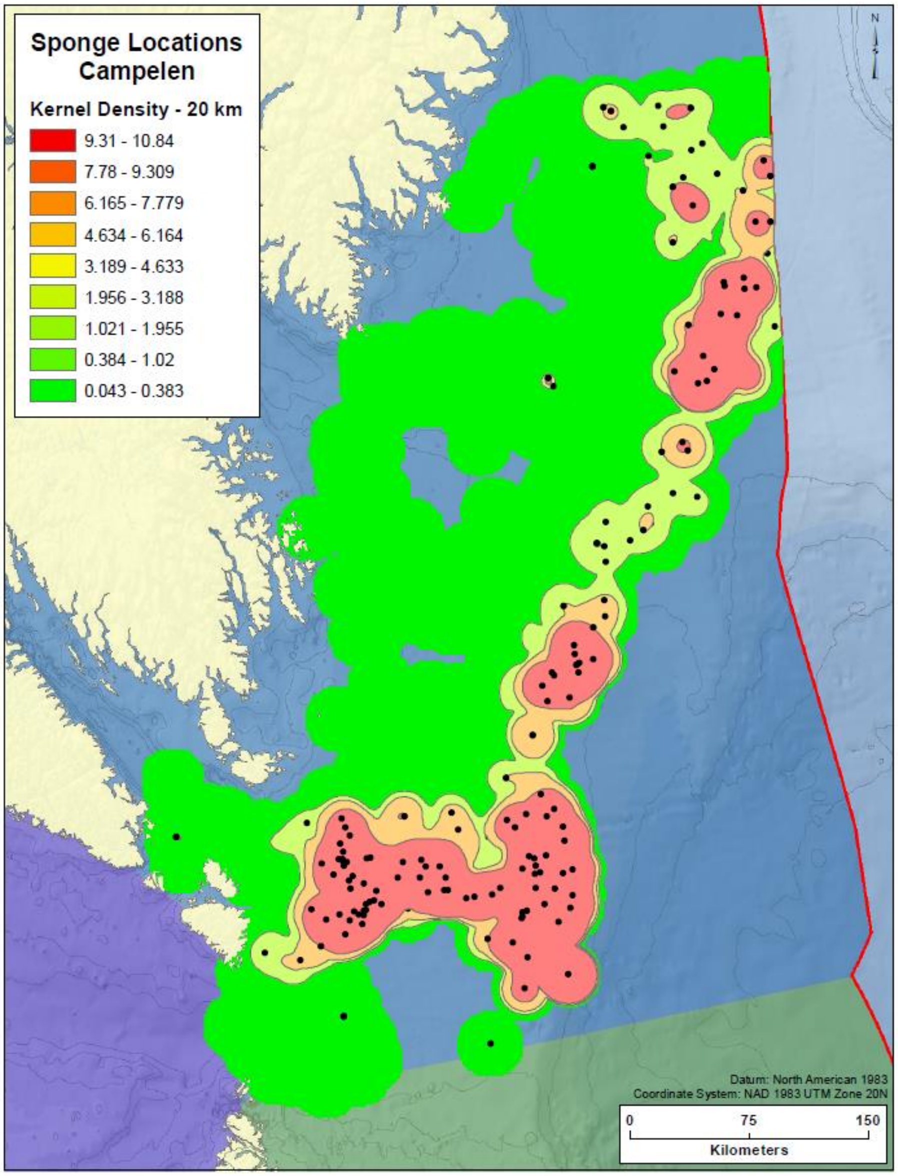

Figure 109. Location of polygons encompassing the ≥30 (salmon), ≥20 (light pink) and ≥10 (light green) kg catches showing the increase in area (Table 29) and overlain on the KDE biomass surface produced with the 20 km search radius. The 20 kg threshold was used to define the significant areas of sponge with the Campelen gear.

Location of the Dense Aggregations from Campelen Trawl Data

The locations of areas that indicated significant concentrations of sponges are shown in Figure 110 and the locations of the survey tows that defined those polygons are provided in Table 30. The locations identified through this study are in the same areas as those reported in 2010 (Kenchington et al., 2010) and follow the continental slope (Figure 111) where large massive sponges have been observed *in situ*.

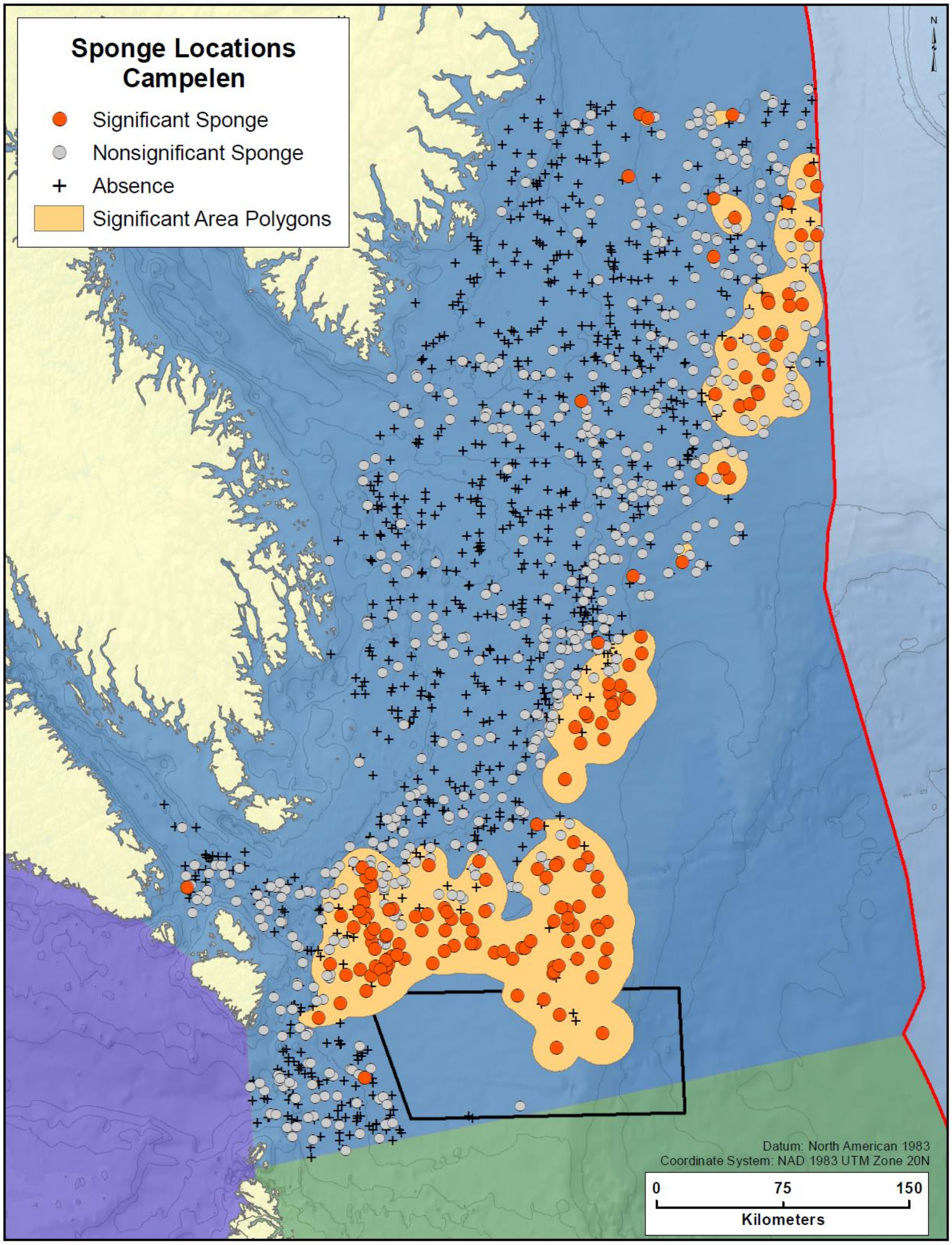

Figure 110. Location of the polygons identifying significant sponge aggregations relative to the broader distribution of sponges in the Eastern Arctic. Sponge catches with Campelen trawls that contributed to the identification of the polygons are indicated as significant (Table 30), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

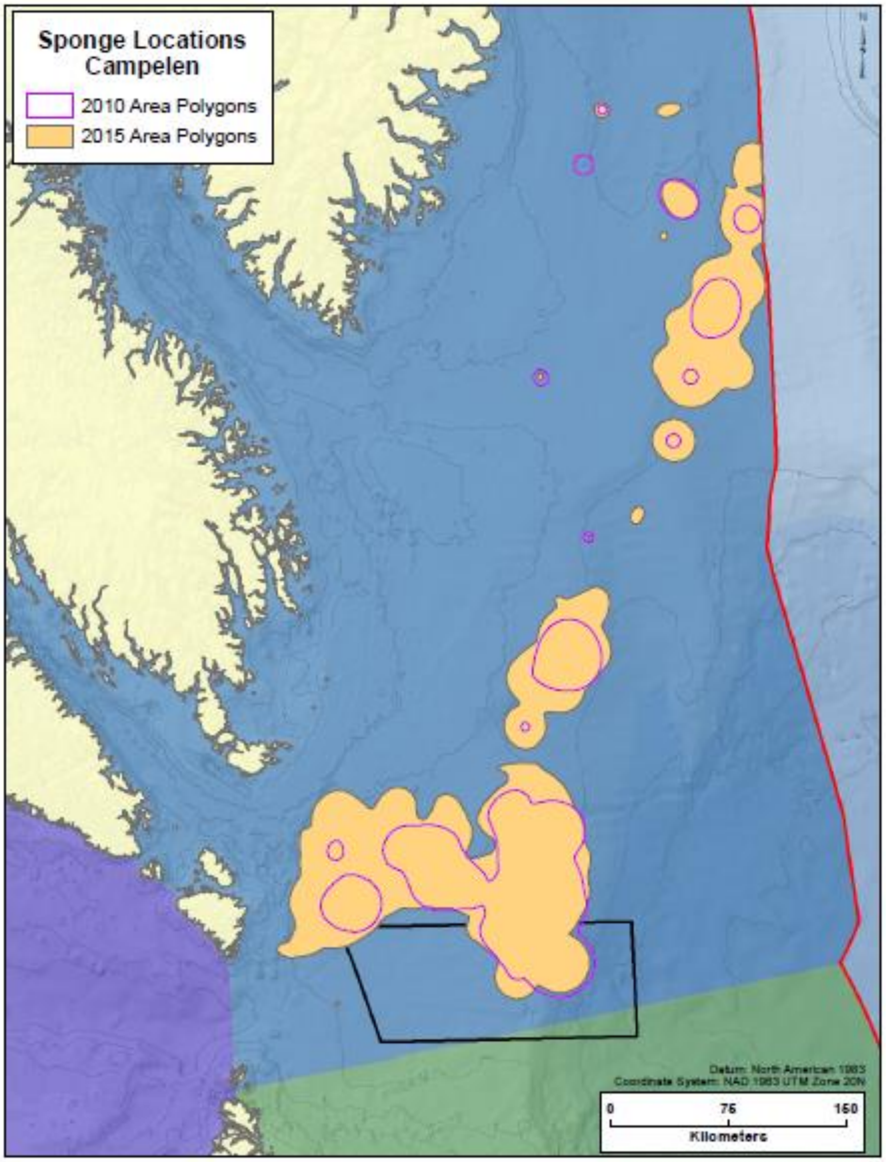

Figure 111. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (purple outline) and those identified in this study (orange polygons).

Table 30. Eastern Arctic Biogeographic Zone, Davis Strait: Details of the Location of Research Vessel Sponge Catches using Campelen Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)
2006	BAL2006101090	61.27300	-60.87200	61.27667	-60.89833	2000.000
2005	BAL2005100220	63.03700	-60.60300	62.02333	-60.61500	1500.000
2008	BAL2008103076	61.57200	-60.96000	61.56383	-60.97267	1027.120
2008	BAL2008103095	62.98200	-60.61300	62.97133	-60.62733	1000.000
2007	BAL2007102104	63.02300	-60.64200	63.01467	-60.66667	900.000

2009	BAL2009104254	63.02933	-60.62983	63.02150	-60.65283	800.000
2005	BAL2005100236	61.76300	-60.99300	61.76000	-60.97000	800.000
2007	BAL2007102083	61.64000	-61.33200	61.64133	-61.36017	550.700
2008	BAL2008103158	64.58500	-58.89800	64.57167	-58.91033	504.130
2008	BAL2008103078	61.76700	-62.27500	61.76817	-62.25767	500.000
2007	BAL2007102210	61.63000	-63.33700	61.63333	-63.30933	500.000
2008	BAL2008103096	63.13800	-60.66300	63.15117	-60.67317	500.000
2006	BAL2006101097	62.03000	-60.86200	62.04000	-60.87667	500.000
2010	BAL2010105263	63.05415	-60.42313	63.06728	-60.41015	305.973
2006	BAL2006101102	61.76500	-62.31700	61.77167	-62.29000	300.000
2006	BAL2006101095	61.77000	-61.22700	61.78167	-61.22667	300.000
2007	BAL2007102089	61.90200	-62.37200	61.89250	-62.39350	300.000
2007	BAL2007102100	62.91200	-61.07200	62.90267	-61.09333	300.000
2010	BAL2010105282	61.67685	-61.12683	61.68637	-61.10273	255.099
2010	BAL2010105280	61.86642	-60.77252	61.85375	-60.78200	250.830
2008	BAL2008103077	61.65000	-60.81300	61.64317	-60.82500	225.940
2005	BAL2005100237	61.46300	-61.51000	61.45333	-61.52833	200.000
2007	BAL2007102086	61.72800	-61.96000	61.72100	-61.98600	200.000
2005	BAL2005100234	61.89300	-61.22000	61.88167	-61.20167	200.000
2012	AQV2012107094	61.84818	-60.89045	61.85788	-60.90613	191.127
2010	BAL2010105180	61.68970	-63.07025	61.67440	-63.06718	156.751
2007	BAL2007102209	61.59800	-63.72800	61.60650	-63.70600	156.460
2007	BAL2007102152	64.59200	-58.77700	64.57883	-58.79383	155.190
2009	BAL2009104255	62.83983	-60.74117	62.83317	-60.72283	151.788
2013	AQV2013108142	61.51842	-63.50073	61.52433	-63.48210	151.226
2006	BAL2006101096	61.95200	-61.29000	61.96333	-61.27833	150.000
2007	BAL2007102211	61.57700	-63.30000	61.58217	-63.27933	150.000
2005	BAL2005100184	65.59200	-58.81200	65.60167	-58.83500	144.000
2011	BAL2011106177	63.08680	-60.64975	63.07665	-60.66527	130.000
2011	BAL2011106081	61.72250	-60.78743	61.73640	-60.79367	129.525
2013	AQV2013108280	61.75342	-62.51582	61.76013	-62.49653	125.000
2008	BAL2008103175	65.47300	-57.97300	65.45867	-57.97267	120.000
2005	BAL2005100235	61.84800	-61.23000	61.83500	-61.21833	120.000
2007	BAL2007102150	64.25500	-59.15500	64.24067	-59.15100	117.330
2007	BAL2007102125	63.70700	-60.31800	63.69383	-60.32867	115.520
2010	BAL2010105276	61.77282	-61.64453	61.77517	-61.61680	110.891
2010	BAL2010105275	61.83857	-62.30048	61.84452	-62.27562	110.205
2005	BAL2005100112	61.92800	-62.81500	61.91333	-62.81500	108.920
2005	BAL2005100226	62.63300	-61.20800	62.62333	-61.19000	102.000
2010	BAL2010105181	61.70067	-63.21193	61.69040	-63.23290	101.521
2008	BAL2008103179	66.15000	-59.87200	66.16317	-59.87717	101.240
2013	AQV2013108281	61.73862	-61.74940	61.73373	-61.73178	100.013
2007	BAL2007102149	64.20700	-59.09000	64.19417	-59.10650	100.000

2006	BAL2006101089	61.20200	-61.38800	61.21333	-61.38000	100.000
2006	BAL2006101241	61.94200	-63.58000	61.95333	-63.56833	100.000
2006	BAL2006101091	61.37700	-61.34500	61.39000	-61.33833	100.000
2008	BAL2008103094	62.98700	-60.95000	63.00067	-60.94683	100.000
2005	BAL2005100232	62.11300	-61.45200	62.10500	-61.47500	97.200
2008	BAL2008103161	64.96500	-58.53300	64.95317	-58.54783	90.370
2008	BAL2008103080	61.93800	-62.58500	61.93300	-62.56583	90.000
2012	AQV2012107128	61.63120	-63.56428	61.63842	-63.55283	81.892
2013	AQV2013108275	62.21497	-60.97392	62.20260	-60.96267	80.968
2014	KIN2014109227	65.10053	-58.03595	65.09007	-58.05082	76.533
2013	AQV2013108147	61.85337	-63.64582	61.85857	-63.62120	76.337
2014	KIN2014109322	61.64850	-63.39537	61.65008	-63.37752	75.566
2010	BAL2010105279	62.11082	-60.87435	62.09663	-60.87160	75.000
2009	BAL2009104267	61.95067	-61.09050	61.94483	-61.11550	72.000
2013	AQV2013108145	61.77457	-63.44222	61.77690	-63.42167	70.626
2012	AQV2012107129	61.59720	-63.44695	61.58620	-63.45150	68.445
2012	AQV2012107112	61.83763	-62.60432	61.82493	-62.60127	67.450
2005	BAL2005100188	65.70200	-59.07200	65.68833	-59.06167	65.000
2010	BAL2010105278	62.17430	-61.06937	62.16078	-61.06268	62.030
2014	KIN2014109327	61.98615	-63.52990	61.98562	-63.55547	60.755
2012	AQV2012107093	61.87795	-61.37597	61.88265	-61.35173	60.061
2008	BAL2008103160	64.95200	-58.31800	64.93917	-58.33333	60.020
2006	BAL2006101226	61.70800	-63.15300	61.70000	-63.13167	60.000
2010	BAL2010105283	61.60972	-61.39430	61.62113	-61.37622	55.316
2013	AQV2013108148	61.94148	-63.53653	61.93975	-63.56218	55.122
2010	BAL2010105119	65.81220	-57.79882	65.82828	-57.82098	54.748
2011	BAL2011106082	61.85785	-61.16688	61.86450	-61.19130	54.351
2007	BAL2007102205	61.92800	-63.48500	61.92600	-63.51267	52.900
2006	BAL2006101124	65.12500	-58.46000	65.13667	-58.44333	51.440
2011	BAL2011106209	61.65390	-63.24807	61.64677	-63.27683	51.082
2013	AQV2013108146	61.82147	-63.45443	61.82335	-63.43530	50.534
2009	BAL2009104265	61.71700	-62.05250	61.71833	-62.07983	50.000
2007	BAL2007102207	61.90700	-63.51700	61.91933	-63.52300	50.000
2007	BAL2007102136	64.65500	-60.86700	64.64183	-60.86883	49.900
2013	AQV2013108278	61.83920	-62.87523	61.84065	-62.89378	48.564
2006	BAL2006101123	65.09700	-58.19800	65.11000	-58.18667	48.240
2014	KIN2014109326	61.94608	-63.24693	61.95503	-63.26385	46.505
2007	BAL2007102163	65.84200	-60.16500	65.82850	-60.16733	45.000
2012	AQV2012107091	61.59868	-61.40358	61.61232	-61.40747	44.250
2009	BAL2009104142	61.80667	-63.27900	61.80083	-63.30233	43.450
2014	KIN2014109228	65.16237	-58.18915	65.15158	-58.20615	43.130
2012	AQV2012107130	61.62578	-63.27643	61.61315	-63.27718	41.164
2011	BAL2011106085	61.90190	-62.53327	61.91340	-62.54883	40.713

2009	BAL2009104143	61.95217	-63.20067	61.94017	-63.20650	40.000
2006	BAL2006101092	61.48700	-61.80500	61.48833	-61.83333	40.000
2007	BAL2007102103	62.96800	-60.91800	62.95883	-60.94200	40.000
2007	BAL2007102170	65.46500	-57.77800	65.45433	-57.78567	40.000
2011	BAL2011106211	61.64957	-63.28268	61.63992	-63.29675	39.818
2013	AQV2013108282	61.63312	-61.39322	61.62663	-61.37905	39.428
2012	AQV2012107162	61.93382	-63.54263	61.92348	-63.52807	38.172
2005	BAL2005100109	62.17300	-63.55300	62.16500	-63.53500	38.170
2005	BAL2005100096	61.91700	-63.78800	61.96167	-63.79667	38.000
2009	BAL2009104094	61.44767	-63.78283	61.44517	-63.80683	37.920
2013	AQV2013108143	61.68915	-63.25678	61.69895	-63.23732	37.330
2005	BAL2005100111	62.18500	-62.79300	62.18167	-62.82167	36.720
2011	BAL2011106083	61.93805	-61.22777	61.93783	-61.25597	36.613
2005	BAL2005100219	63.23300	-60.41200	63.22000	-60.41833	35.800
2014	KIN2014109328	62.07612	-63.45265	62.07938	-63.42868	35.703
2008	BAL2008103162	64.91800	-58.97300	64.90717	-58.98767	35.630
2006	BAL2006101249	62.04800	-65.54200	62.04500	-65.57167	35.490
2013	AQV2013108187	65.14513	-58.46183	65.15052	-58.43057	35.478
2010	BAL2010105190	61.05393	-63.50533	61.06978	-63.51442	35.332
2008	BAL2008103178	66.14000	-58.75200	66.15167	-58.73650	35.310
2006	BAL2006101119	64.73700	-58.80700	64.74167	-58.78333	35.000
2006	BAL2006101100	62.15700	-61.54500	62.16667	-61.52833	35.000
2007	BAL2007102141	64.65700	-59.20500	64.64283	-59.20250	35.000
2014	KIN2014109296	62.82545	-61.01403	62.81982	-61.03055	34.981
2010	BAL2010105179	61.84830	-63.41650	61.84480	-63.44587	33.307
2011	BAL2011106214	62.03220	-63.56828	62.01968	-63.59543	32.994
2007	BAL2007102203	62.12200	-63.51000	62.11000	-63.49433	32.730
2013	AQV2013108144	61.76610	-63.13112	61.77300	-63.11617	32.023
2010	BAL2010105182	61.65632	-63.90457	61.64277	-63.90173	32.000
2008	BAL2008103086	62.18700	-61.31800	62.17367	-61.32000	31.780
2009	BAL2009104229	64.65683	-58.67217	64.64450	-58.67283	31.170
2007	BAL2007102171	65.72300	-57.72200	65.73667	-57.71233	30.000
2006	BAL2006101099	62.29800	-61.13300	62.30833	-61.15667	30.000
2011	BAL2011106178	63.12572	-60.52065	63.14502	-60.51268	29.620
2005	BAL2005100218	63.29500	-60.25200	63.28167	-60.25333	29.400
2005	BAL2005100175	64.83000	-58.56300	64.81500	-58.57167	29.060
2013	AQV2013108150	62.01840	-63.53528	62.03017	-63.52385	28.817
2012	AQV2012107092	61.73517	-61.70585	61.74272	-61.68183	28.460
2014	KIN2014109323	61.68208	-63.28177	61.67958	-63.26197	27.872
2014	KIN2014109220	66.17215	-59.96897	66.16020	-59.96252	27.868
2005	BAL2005100094	61.74000	-63.40200	61.74833	-63.37667	26.590
2014	KIN2014109325	61.81207	-63.27278	61.82170	-63.25645	26.500
2011	BAL2011106181	63.38635	-60.25640	63.40647	-60.24525	26.476

2006	BAL2006101118	64.64500	-58.66700	64.65833	-58.65333	26.000
2013	AQV2013108279	61.66170	-62.75550	61.66228	-62.73485	25.695
2005	BAL2005100231	62.17700	-61.33800	62.16333	-61.34667	25.600
2011	BAL2011106176	62.92792	-60.75652	62.92450	-60.78548	25.338
2009	BAL2009104141	61.64617	-63.29183	61.64800	-63.26717	25.000
2007	BAL2007102090	61.95800	-62.61500	61.95383	-62.64250	25.000
2008	BAL2008103111	63.36000	-60.77200	63.36733	-60.75050	25.000
2007	BAL2007102085	61.94300	-62.15800	61.94000	-62.17867	24.490
2014	KIN2014109251	64.74195	-58.52618	64.72930	-58.53008	24.428
2008	BAL2008103151	63.77200	-59.72200	63.77100	-59.75267	24.100
2005	BAL2005100229	62.39800	-61.54300	62.40000	-61.51500	24.000
2007	BAL2007102084	61.82800	-60.87800	61.83100	-60.90700	23.760
2011	BAL2011106084	61.72997	-62.61718	61.72807	-62.64845	22.665
2014	KIN2014109158	62.20405	-62.22047	62.21132	-62.19990	22.500
2006	BAL2006101120	64.89500	-58.40300	64.90833	-58.40667	22.500
2005	BAL2005100114	62.10800	-62.14200	62.12167	-62.13500	21.780
2008	BAL2008103153	64.20800	-59.42200	64.19517	-59.42967	21.300
2005	BAL2005100185	65.38700	-59.11800	65.37333	-59.11000	21.200
2012	AQV2012107174	63.06620	-60.46115	63.08075	-60.45282	21.000
2013	AQV2013108149	62.08545	-63.44520	62.09708	-63.43630	20.981
2008	BAL2008103176	65.65500	-58.11700	65.64233	-58.09933	20.880
2009	BAL2009104262	61.91633	-62.94850	61.92867	-62.94400	20.000
2009	BAL2009104268	61.68450	-61.85283	61.68267	-61.88050	20.000
2007	BAL2007102213	61.36800	-64.02200	61.35883	-64.04500	20.000
2006	BAL2006101239	62.14200	-63.45300	62.13500	-63.42833	20.000

Cosmos Trawl Data Sources and Distribution

The data available for the analyses of sponges caught with Cosmos trawls in the Eastern Arctic Biogeographic Zone were largely restricted to the slope along Baffin Island north of the Cape Dyer area (Figure 112). Data used in the analyses were from surveys conducted from 2006 to 2012 using Cosmos trawls. There were 167 records with sponge catch and 62 records of catches with no sponges from the same surveys. Within the surveyed area, the sponges were distributed broadly and occurred over the entire range except for the shallowest stations (Figure 112).

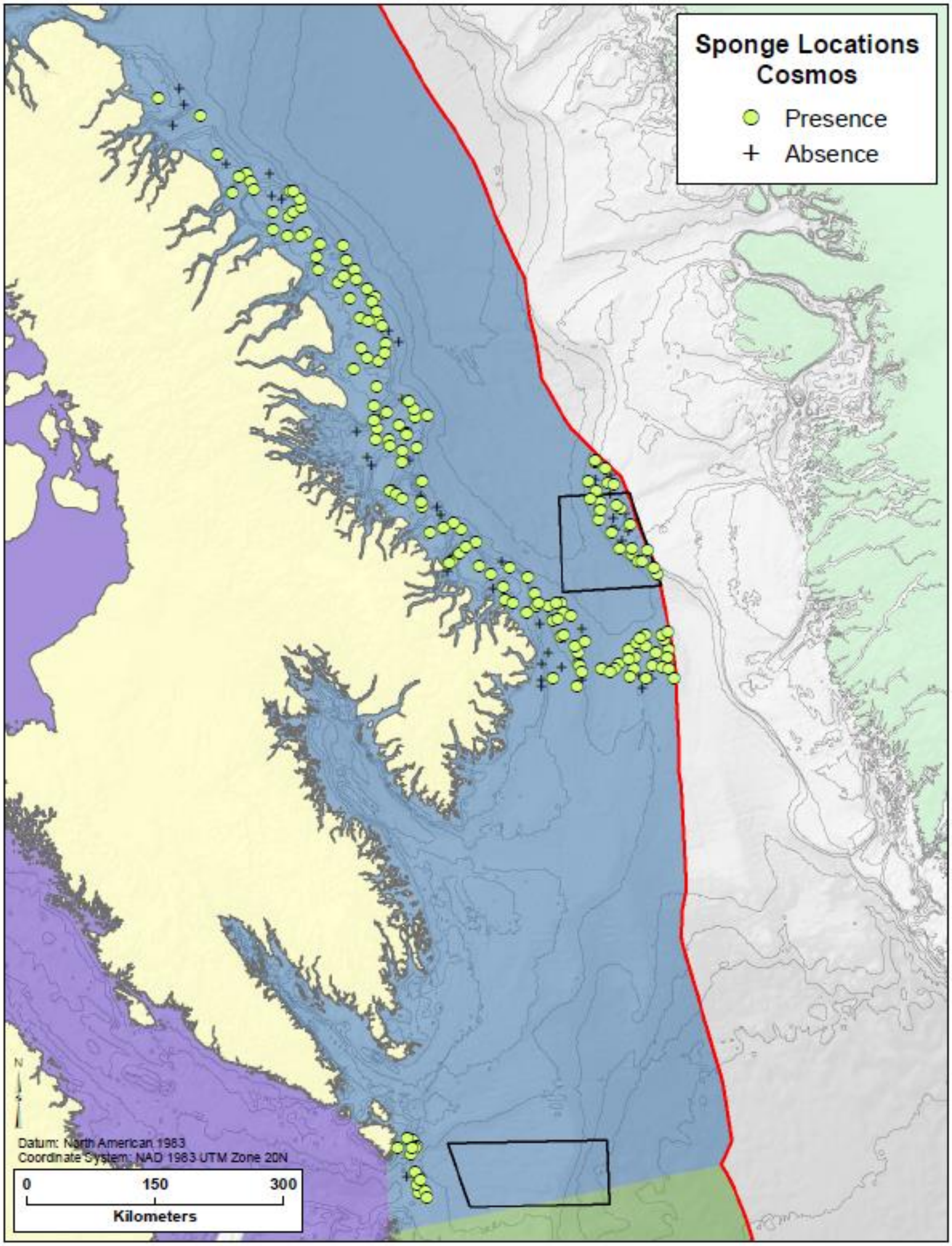

Figure 112. Distribution of sponges from DFO research vessel survey catches using Cosmos trawls. Green circles indicate sponge presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Cosmos Trawl Data

The default search radius for the KDE was 20.092 km. We compared that KDE surface with one produced by using a 25 km search radius. The results were very similar (Figure 113) and we chose to use the 25 km radius as it gave a more continuous surface in the northern most part of the spatial extent (Figure 113). The default grid size was 2.65 km^2. Contours placed over the KDE surface were spaced at 0.0005 kg intervals when constructing the bounding polygons.

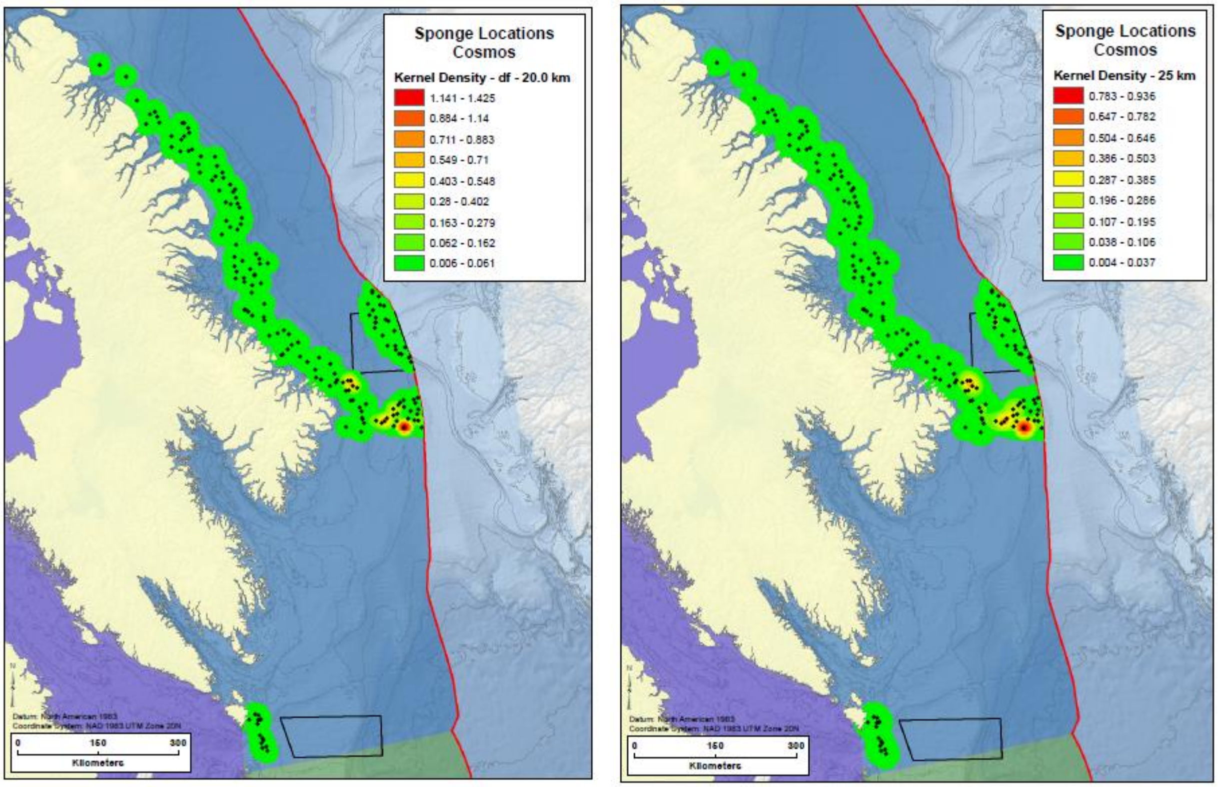

Figure 113. KDE surface of sponge biomass produced with the default (df) search radius (20 km) (left) and a 25 km search radius (right). Tow locations with sponge catch from Cosmos trawls used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Cosmos Trawl Data

The area surrounding each sponge weight threshold is provided in Table 31 and illustrated in Figure 114. The first large increase in area occurs between 40 and 10 kg where area increased 198% (Table 31, Figures 114, 115). That change was supported by 5 additional data points and 40 kg was considered to be the threshold delineating significant concentrations of sponges (Table 32). The areas occupy 1924 km^2 (Table 31). We also reviewed the 2 kg threshold as the next largest aerial expansion at 92%, however it did not identify new areas, only single isolated catches.

Table 31. Comparative Sponge Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sponges is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
100	5	-	983	96
40	10	5	1924	198
10	15	5	5742	0
7	22	7	5758	19
5	26	4	6835	19
2	33	7	8130	92
1	44	11	15579	13
0.5	57	13	17594	14
0.3	65	8	20111	25
0.2	78	13	25153	52
0.1	97	19	38327	17
0.05	110	13	44937	13
0.01	139	29	50590	

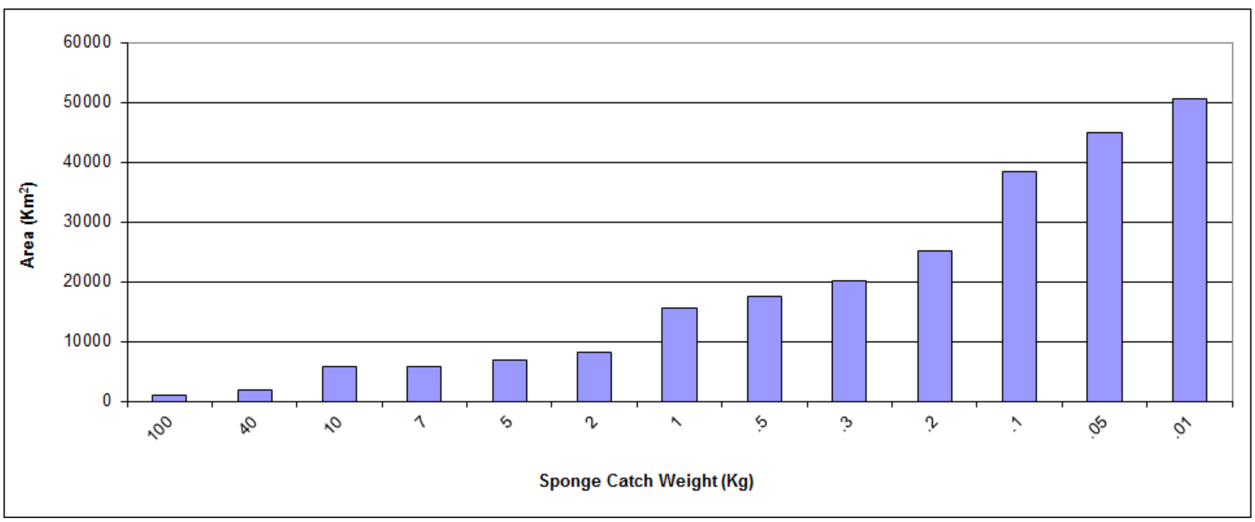

Figure 114. Barplot of polygon area (km^2) associated with sponge weight thresholds (kg).

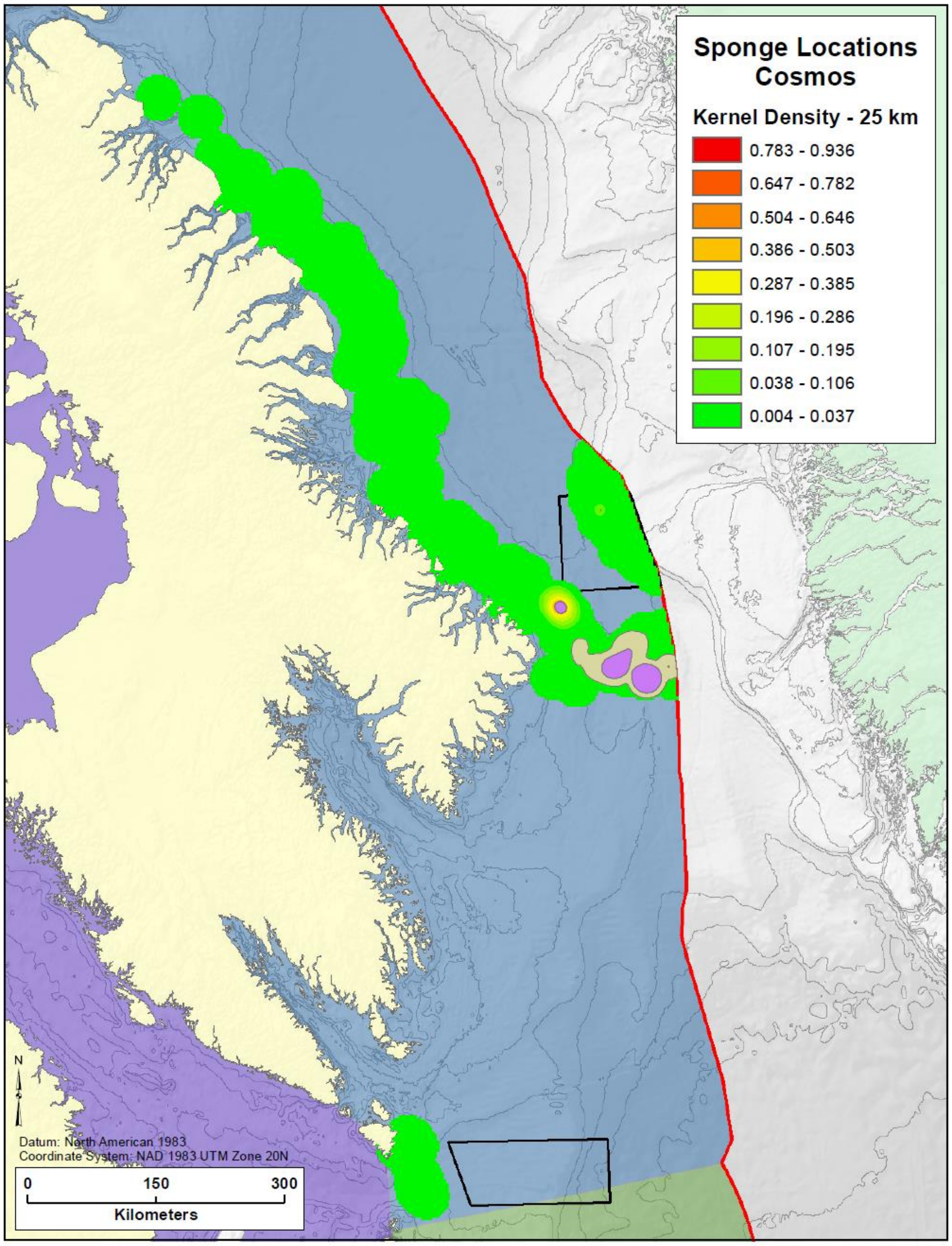

Figure 115. Location of polygons encompassing the ≥40 (purple), and ≥10 kg (light gray) catches showing the increase in area (Table 31) and overlain on the KDE biomass surface produced with the 25 km search radius. The 40 kg threshold was used to define the significant areas of sponge with the Cosmos gear.

Location of the Dense Aggregations from Cosmos Trawl Data

The locations of areas that indicated significant concentrations of sponges are shown in Figure 116 and the locations of the survey tows that defined those polygons are provided in Table 32. Figure 117 compares the results of this analysis with those obtained in 2010 (Kenchington et al., 2010).

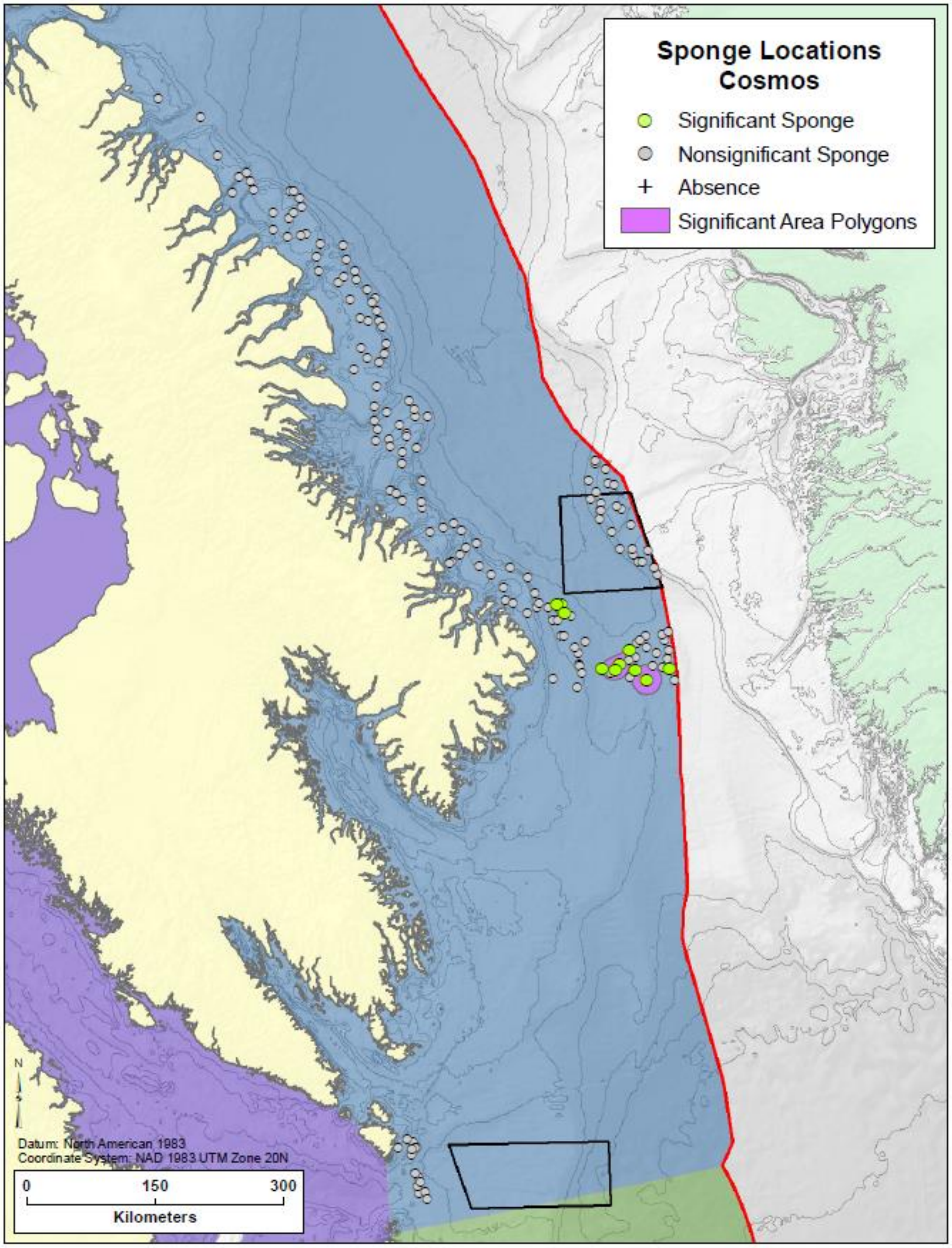

Figure 116. Location of the polygons identifying significant sponge aggregations relative to the broader distribution of sponges in the Eastern Arctic. Sponge catches with Cosmos trawls that contributed to the identification of the polygons are indicated as significant (Table 32), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

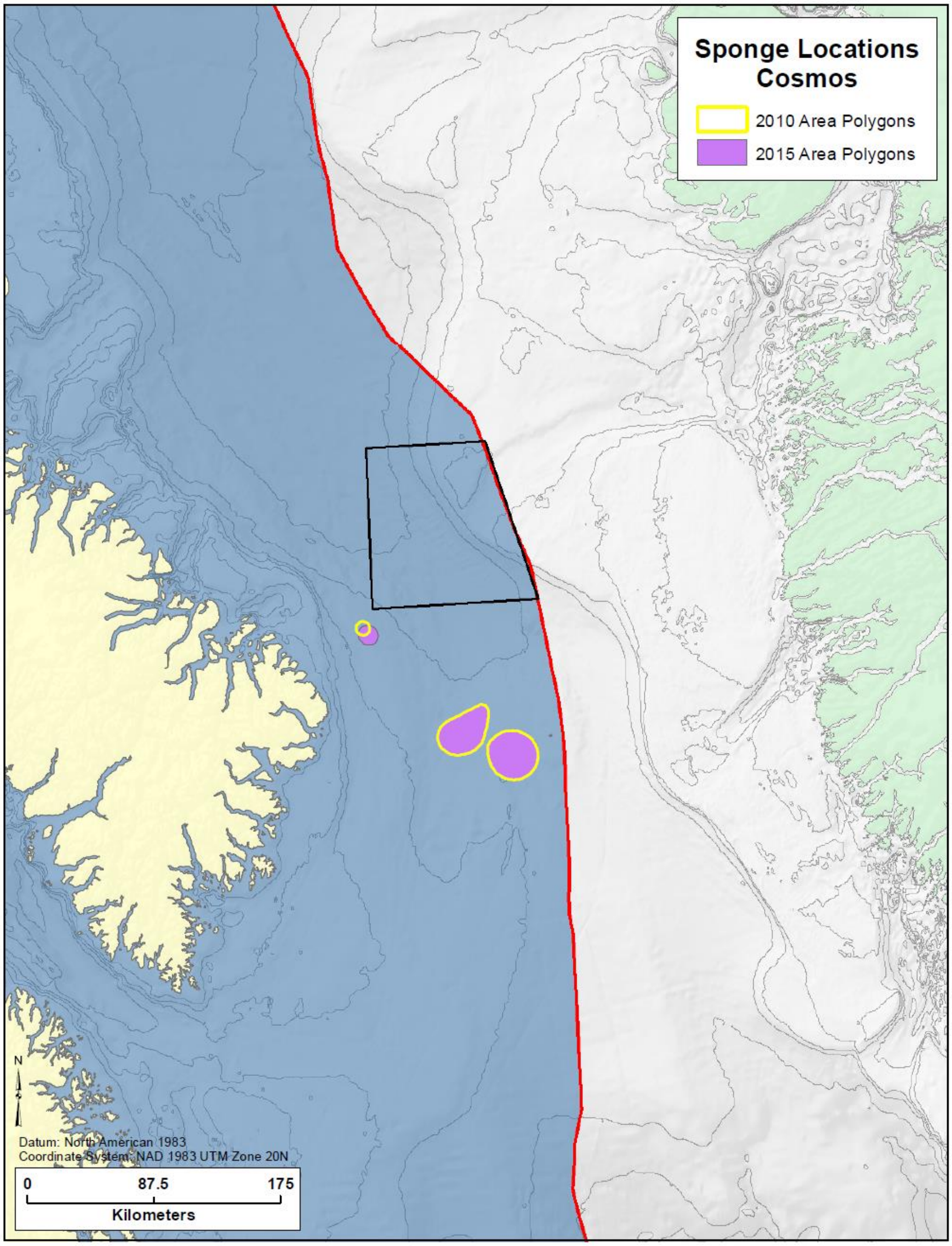

Figure 117. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (purple polygons).

Table 32. Eastern Arctic Biogeographic Zone, Davis Strait: Details of the Location of Research Vessel Sponge Catches with Cosmos Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sponge Weight (kg)
2006	PAA2006005100	66.29000	-58.42350	66.29617	-58.40617	603.800
2006	PAA2006005093	66.41777	-59.23245	66.40853	-59.22227	195.900
2010	PAA2010009104	67.03782	-60.50720	67.02837	-60.50612	168.100
2008	PAA2008007066	67.13367	-60.71033	67.12432	-60.69650	147.600
2008	PAA2008007048	66.61433	-58.83467	66.62427	-58.82730	139.400
2008	PAA2008007035	66.47083	-59.12767	66.45945	-59.11825	76.500
2006	PAA2006005092	66.43463	-59.57798	66.42828	-59.55770	70.315
2006	PAA2006005089	67.12583	-60.56483	67.11567	-60.56217	53.145
2010	PAA2010009167	66.39263	-57.82317	66.38230	-57.81568	43.121
2008	PAA2008007040	66.40765	-58.71933	66.39547	-58.71592	40.850

Overview of Sponge KDE Polygons

The three different gears collectively cover the fishing grounds in the Davis Strait area. When the polygons from the separate analyses are overlain there is good congruence between areas where the surveys overlapped (Figure 118).

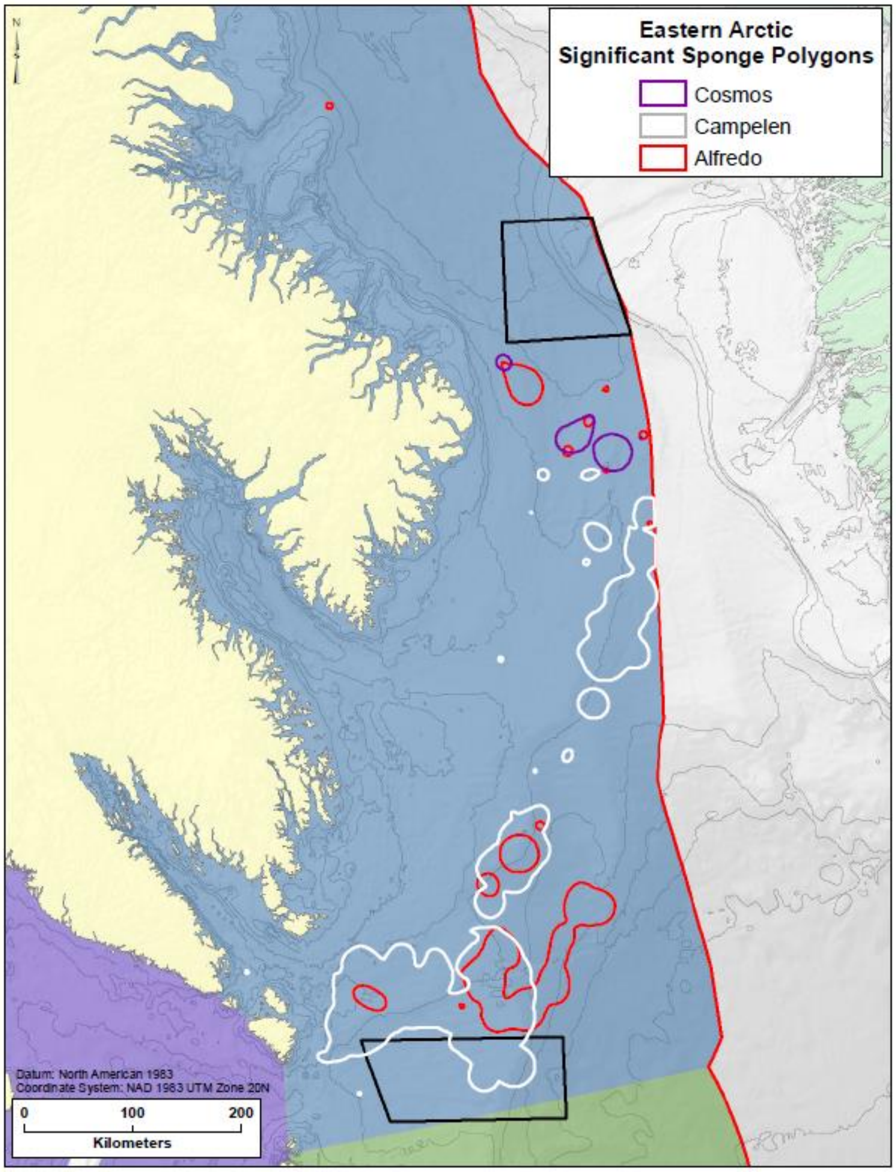

Figure 118. Location of significant concentrations of sponges identified through KDE analyses for each of 3 gear types (Cosmos, Campelen and Alfredo trawls).

Sea Pens (Pennatulacea)

Alfredo Trawl Data Sources and Distribution

Data were from DFO research vessel trawl surveys conducted from 1999 to 2014 by the Central and Arctic Region. There were 316 records with sea pen catch and 470 records of catches with no sea pens from a subset of the surveys conducted from 2006 to 2014. Within the surveyed area, the sea pens were located throughout but were less common on the shelf area in the south (Figure 119).

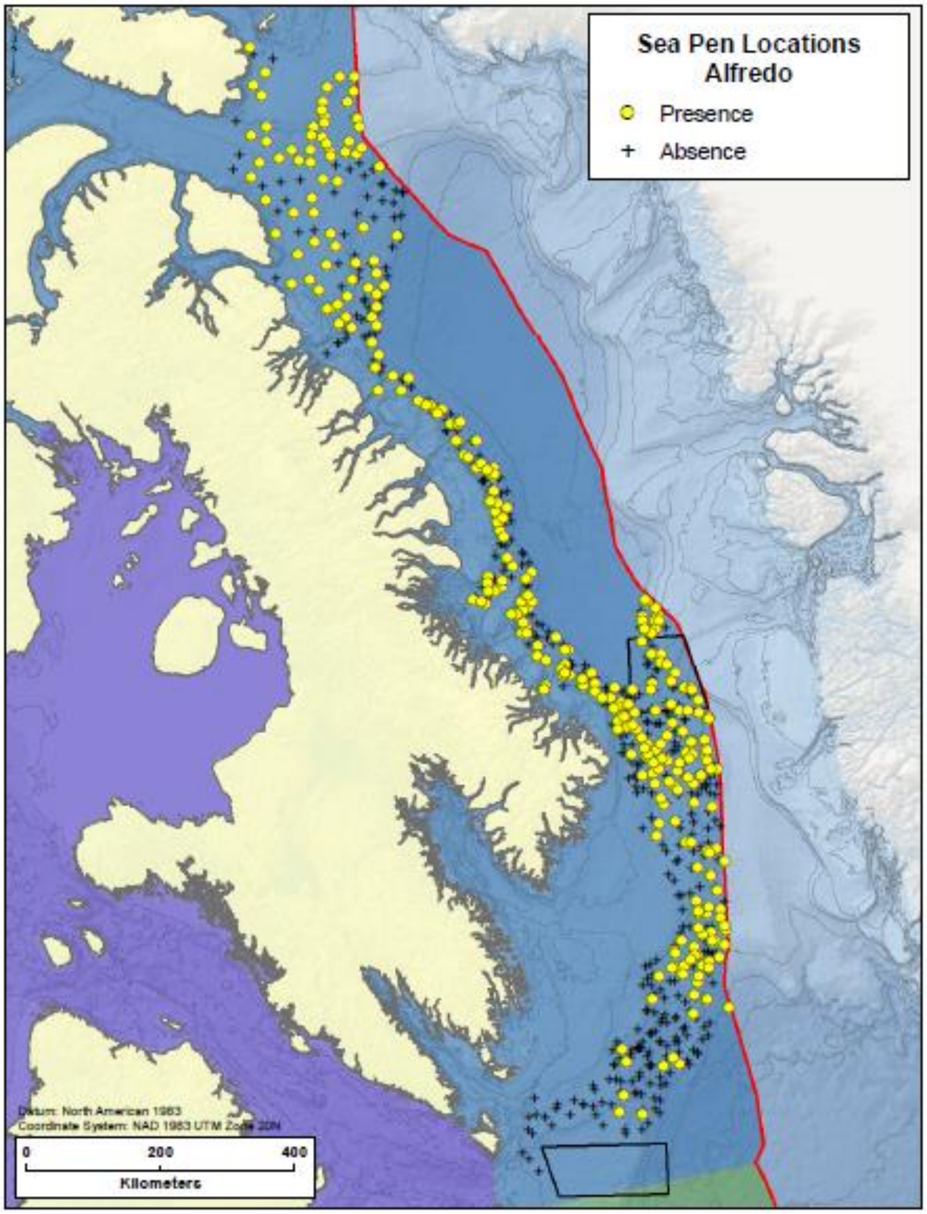

Figure 119. Distribution of sea pens from DFO research vessel survey catches using an Alfredo trawl. Yellow circles indicate sea pen presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Alfredo Trawl Data

The default search radius for the KDE was 23.7374 km and it produced a good surface given the data distribution (Figure 120). We compared that KDE surface with one produced by using a 20 km search radius. The default search radius produced a better fit to the data (Figure 120) as the 20 km search radius under-smoothed the data and created larger gaps in the surface in the north (Figure 120). Consequently we used the default value for the analyses. The default grid size was 3.12 km^2. Contours placed over the KDE surface were spaced at 0.000001 kg intervals when constructing the bounding polygons.

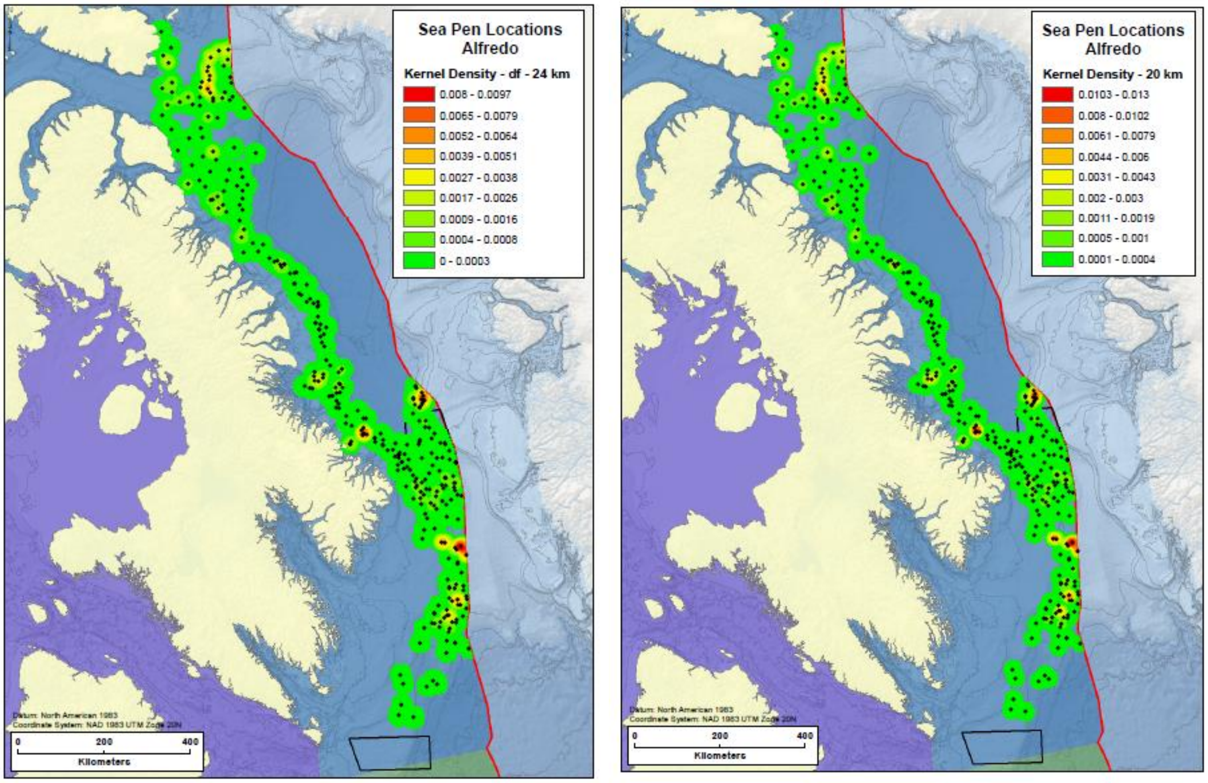

Figure 120. KDE surface of sea pen biomass produced with the default (df) search radius (24 km; left) and a 20 kg search radius (right). Tow locations with sea pen catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Alfredo Trawl Data

The area surrounding each sea pen weight threshold is provided in Table 33 and illustrated in Figure 121. An increase in area was found between 0.3 and 0.2 kg where area increased 87% (Table 33). That areal expansion was supported by 19 additional points and was very similar to the largest increase of 95% found going from 0.2 to 0.1 kg. In going from 0.3 to 0.2 kg new areas were included, while in going from 0.2 to 0.1 kg, which was supported by 32 additional points, there was more of a tendency to expand existing areas. This was particularly true in the area east of Cumberland Sound (Figure 122). Consequently we selected 0.2 kg as the threshold value. The areas occupy 13,823 km^2 (Table 33).

Table 33. Comparative Sea Pen Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sea Pens is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
3	3	-	587	170
1	14	11	1582	200
0.7	22	8	4745	56
0.3	41	19	7384	87
0.2	60	19	13823	95
0.1	92	32	26993	28
0.07	114	22	34605	36
0.05	132	18	47074	22
0.03	166	34	57364	41
0.02	202	36	81048	11
0.01	244	42	89683	31
0.005	271	27	117520	31
0.001	309	38	154522	

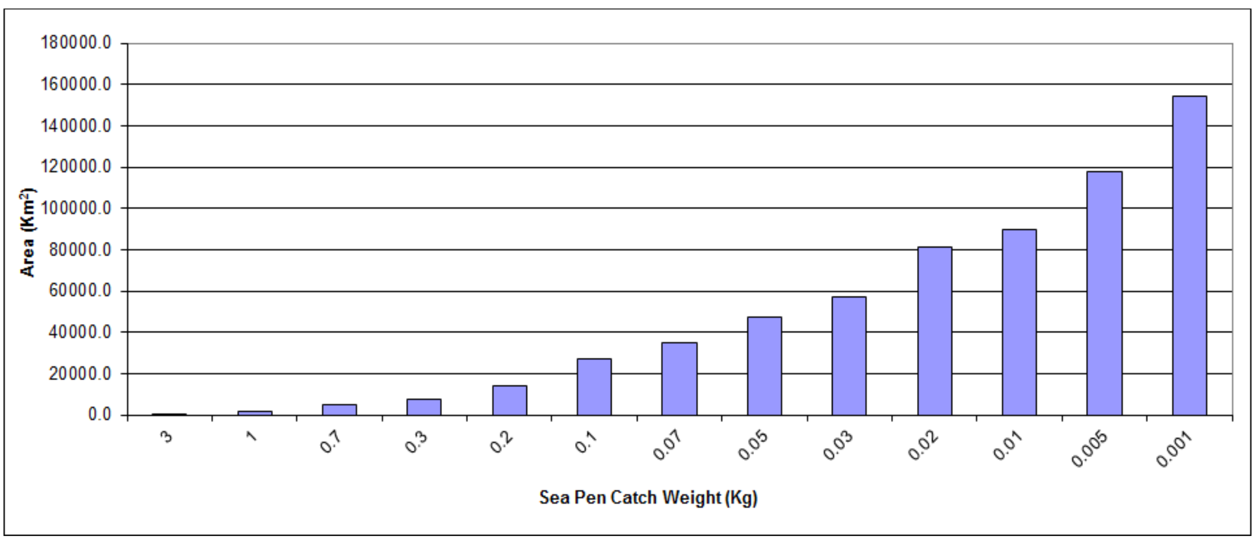

Figure 121. Barplot of polygon area (km^2) associated with sea pen weight thresholds (kg).

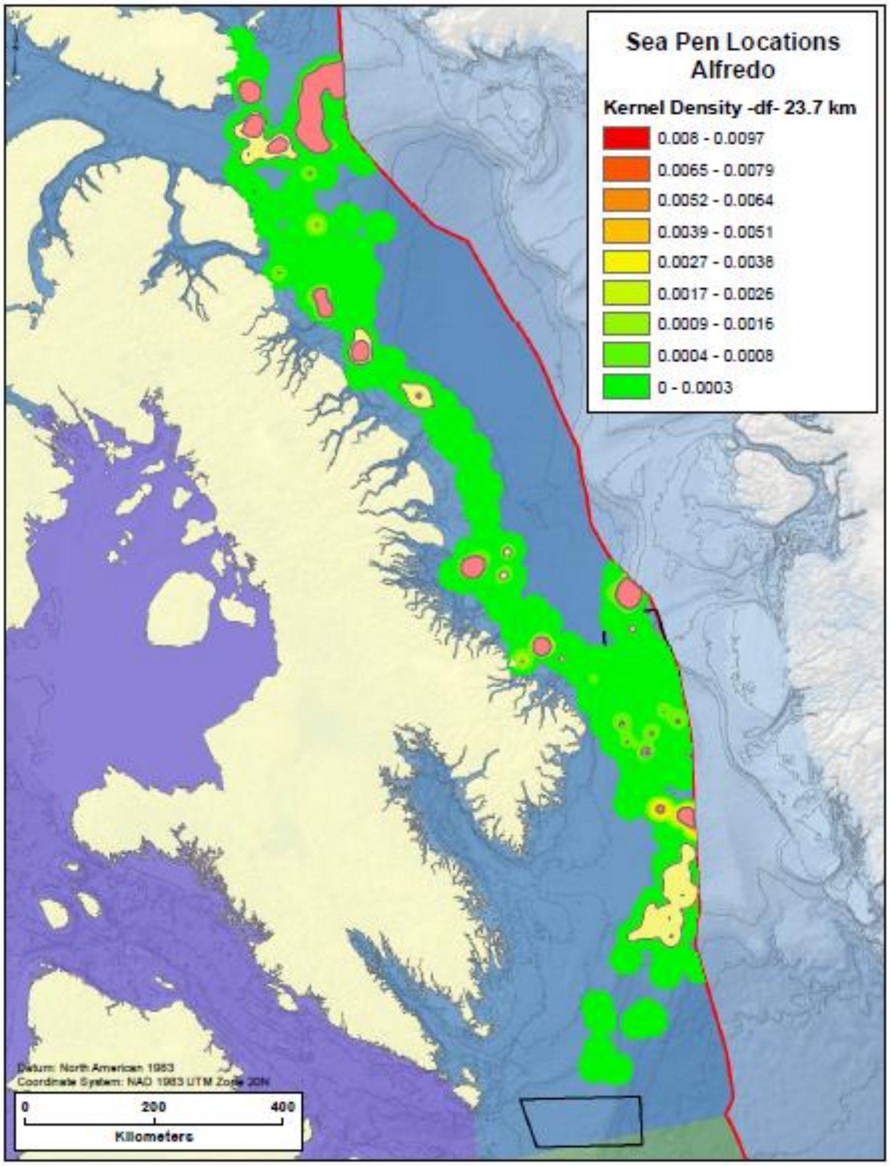

Figure 122. Location of polygons encompassing the ≥0.2 kg catches (pink) and the ≥0.1 kg catches (cream), showing the increase in area (Table 33) and overlain on the KDE biomass surface produced with the default (df) search radius.

Location of the Dense Aggregations from Alfredo Trawl Data

The locations of areas that indicated significant concentrations of sea pens are shown in Figure 123 and the locations of the survey tows that defined those polygons are provided in Table 34. In Figure 124, the results of this study are compared to those produced in Kenchington et al. (2010). The surveys have covered more area in the northern part of the range since the last assessment and therefore new sea pen areas have been identified there (Figure 124).

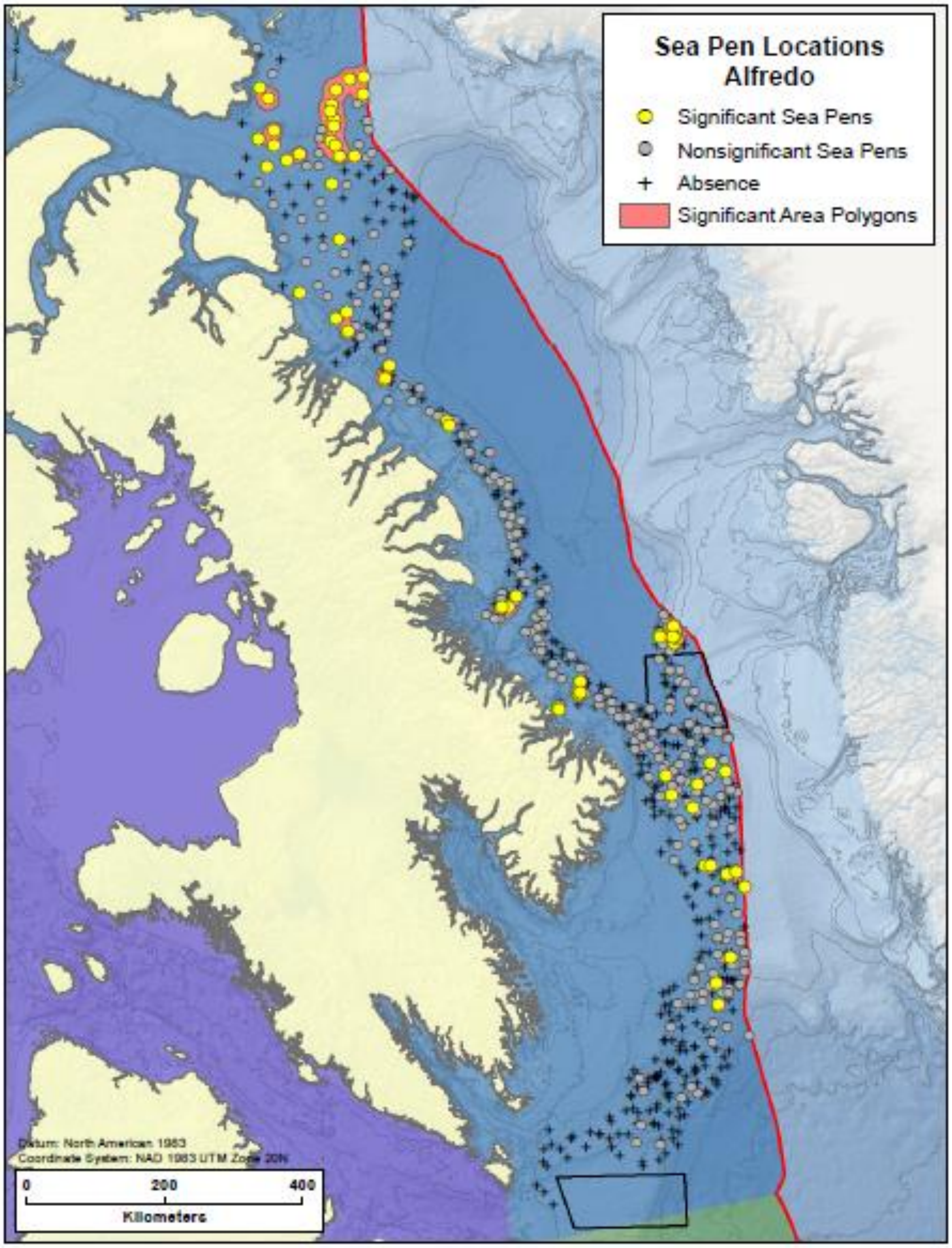

Figure 123. Locations of the significant sea pen areas relative to the broader distribution of sea pens in the Davis Strait –Baffin Bay area. Catch locations that contributed to the identification of the polygons are indicated as significant (Table 34), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

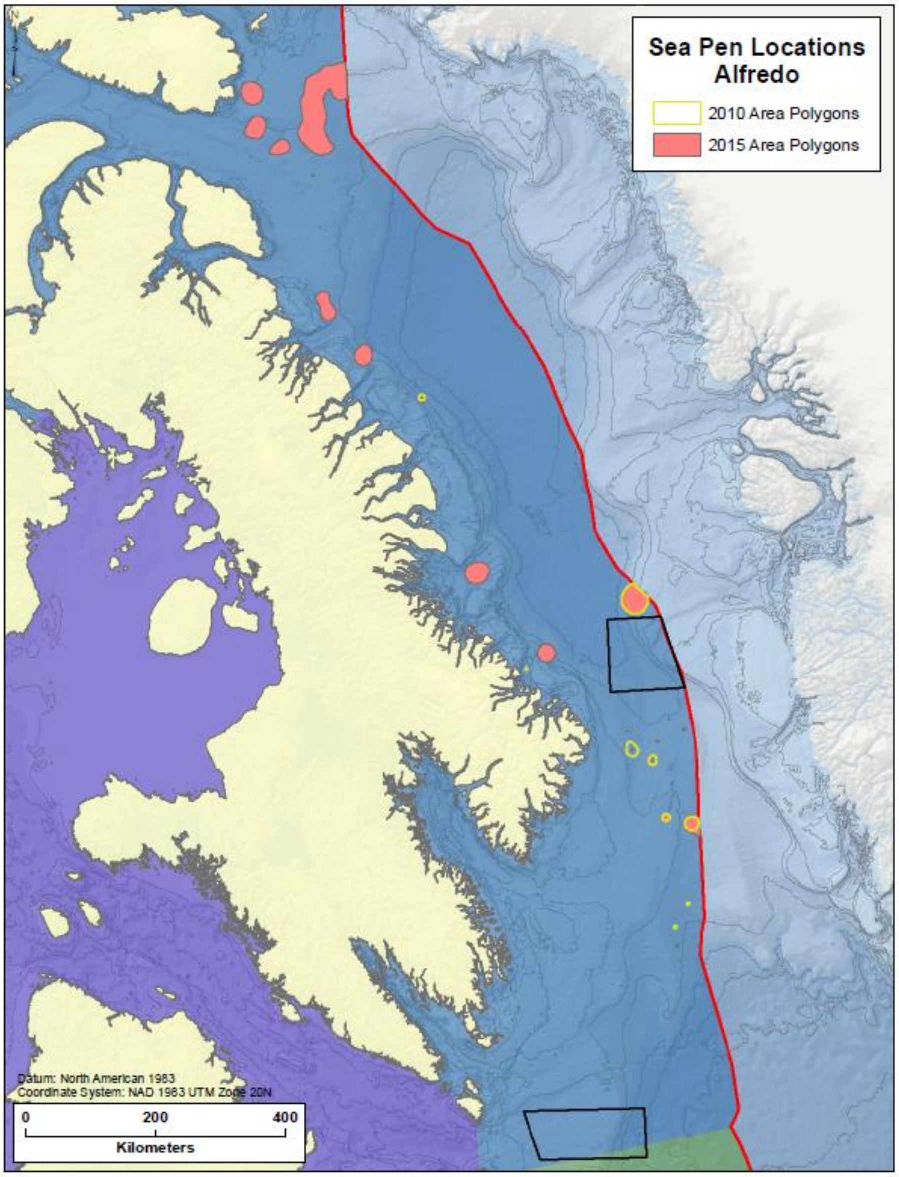

Figure 124. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (pink polygons).

Table 34. Eastern Arctic Biogeographic Zone: Details of the Location of Research Vessel Sea Pen Catches with Alfredo Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sea Pen Weight (kg)
2000	PAA2000002	65.38000	-57.95000	65.37000	-57.91000	5.000
2012	PAA2012007	67.81010	-62.79388	67.82403	-62.81360	3.201
2011	PAA2011007	65.19384	-57.71988	65.17259	-57.69835	3.150
2000	PAA2000002	64.28000	-58.32000	64.26000	-58.31000	3.000
2010	PAA2010009	74.65587	-75.00450	74.66215	-75.05523	2.385
2000	PAA2000002	65.49000	-58.92000	64.00000	-58.76000	2.000
2000	PAA2000002	63.97000	-58.78000	65.47000	-58.91000	2.000
2006	PAA2006008	68.55854	-59.37512	68.57033	-59.36755	1.790
2008	PAA2008007	68.46967	-59.43933	68.49353	-59.42368	1.782
2000	PAA2000002	65.48000	-58.73000	65.48000	-58.66000	1.500
2000	PAA2000002	65.36000	-58.24000	65.35000	-58.19000	1.500
2010	PAA2010009	75.30722	-75.25663	75.32952	-75.21998	1.386
2012	PAA2012007	74.84357	-75.02408	74.86072	-75.05397	1.132
2010	PAA2010009	75.53365	-73.96020	75.53740	-73.86885	1.119
2012	PAA2012007	74.98952	-78.48975	74.96445	-78.46423	1.051
2012	PAA2012007	68.88413	-65.37500	68.87165	-65.42833	0.960
2012	PAA2012007	73.40008	-73.70258	73.37697	-73.70988	0.900
2008	PAA2008007	68.62585	-59.45592	68.64652	-59.42268	0.883
2010	PAA2010009	75.47390	-74.69687	75.48268	-74.61155	0.815
2012	PAA2012007	74.58103	-74.74010	74.59807	-74.79483	0.805
2010	PAA2010009	74.93317	-75.05700	74.94053	-75.02583	0.800
2010	PAA2010009	75.10010	-75.32772	75.12150	-75.37388	0.769
2010	PAA2010009	75.33230	-73.86925	75.30960	-73.83802	0.710
2014	PAA2014007	68.88805	-65.61208	68.86973	-65.65382	0.696
2012	PAA2012007	67.78205	-62.84420	67.76097	-62.80668	0.680
2014	PAA2014007	71.73143	-70.83840	71.71362	-70.78648	0.600
2012	PAA2012007	72.25118	-72.64468	72.23482	-72.58478	0.596
2012	PAA2012007	75.01362	-75.30227	75.02585	-75.34005	0.583
2008	PAA2008007	67.59070	-63.52675	67.56693	-63.53820	0.441
2012	PAA2012007	74.61217	-77.83188	74.59587	-77.91213	0.411
2012	PAA2012007	74.40155	-76.32752	74.38072	-76.34735	0.408
2010	PAA2010009	68.49103	-59.51873	68.51490	-59.51288	0.397
2012	PAA2012007	72.49310	-72.85548	72.50843	-72.79293	0.384
2012	PAA2012007	74.08485	-74.53025	74.09380	-74.61137	0.366
2012	PAA2012007	67.58938	-63.51998	67.56548	-63.52448	0.364
2010	PAA2010009	74.48638	-74.43188	74.50177	-74.46012	0.354
2012	PAA2012007	72.64118	-75.02295	72.63848	-74.94125	0.335

2014	PAA2014007	67.80163	-62.78588	67.78265	-62.75893	0.331
1999	PAA1999001	68.49000	-59.94000	68.51000	-59.94200	0.330
2014	PAA2014007	71.19832	-68.02155	71.18180	-67.96880	0.324
1999	PAA1999001	68.53000	-59.94000	68.55000	-59.92500	0.320
2014	PAA2014007	69.02915	-65.11960	69.01260	-65.16563	0.302
2013	PAA2013008	63.69600	-58.77515	63.67358	-58.79937	0.296
2008	PAA2008007	66.27150	-59.17333	66.24912	-59.17898	0.294
2010	PAA2010009	66.55412	-58.96755	66.53023	-58.98213	0.288
2012	PAA2012007	74.25942	-76.87812	74.26850	-76.80220	0.281
1999	PAA1999001	68.40000	-59.48000	68.42000	-59.46800	0.280
1999	PAA1999001	71.25000	-68.14000	71.26000	-68.14800	0.280
2012	PAA2012007	66.70117	-59.99098	66.72455	-59.99708	0.280
2012	PAA2012007	72.39897	-73.27557	72.41617	-73.32800	0.278
2012	PAA2012007	66.82925	-58.50355	66.83135	-58.56127	0.274
2012	PAA2012007	74.14480	-77.74493	74.12582	-77.68670	0.257
2006	PAA2006008	66.43538	-59.84717	66.44628	-59.85102	0.252
2010	PAA2010009	66.70383	-58.03158	66.68167	-58.03720	0.243
2006	PAA2006008	67.93475	-62.78317	67.94400	-62.80317	0.240
2006	PAA2006008	68.45698	-59.35718	68.49567	-59.36267	0.240
2012	PAA2012007	74.44627	-78.43235	74.44770	-78.51802	0.221
2012	PAA2012007	74.42153	-77.62690	74.42537	-77.71058	0.220
2012	PAA2012007	75.10380	-79.05275	75.08118	-79.08113	0.209
2010	PAA2010009	74.51815	-73.74495	74.49935	-73.74788	0.203
2014	PAA2014007	71.90353	-70.75372	71.88498	-70.69808	0.201

Campelen Trawl Data Sources and Distribution

Data were from DFO research vessel trawl surveys conducted from 2005 to 2014 by the Central and Arctic Region. There were 67 records with sea pen catch and 1508 records of catches with no sea pens from the same surveys. Within the surveyed area, the sea pens were not very common. Catches were located at the northern- and southernmost areas of the survey extent (Figure 125).

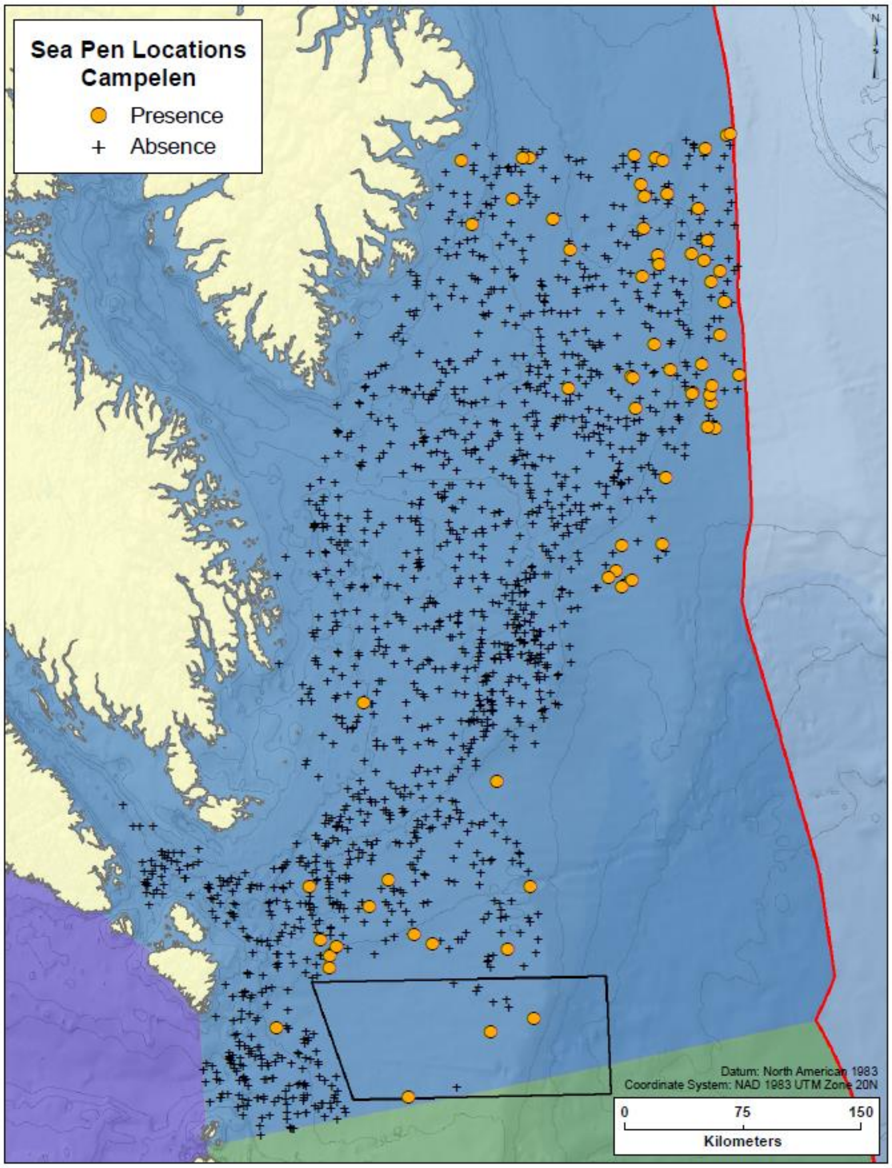

Figure 125. Distribution of sea pens from DFO research vessel survey catches using a Campelen trawl. Orange circles indicate sea pen presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Campelen Trawl Data

The default search radius for the KDE was 9.8064 km and it produced a good surface given the data distribution (Figure 126). We compared that KDE surface with one produced by using a 20 km search radius. The 20 km search radius over-smoothed the data but created a better surface for the analysis with fewer gaps (Figure 126). Consequently we used the 20 km search radius for the analyses. The default grid size was 1.31 km^2. Contours placed over the KDE surface were spaced at 0.0000005 kg intervals when constructing the bounding polygons.

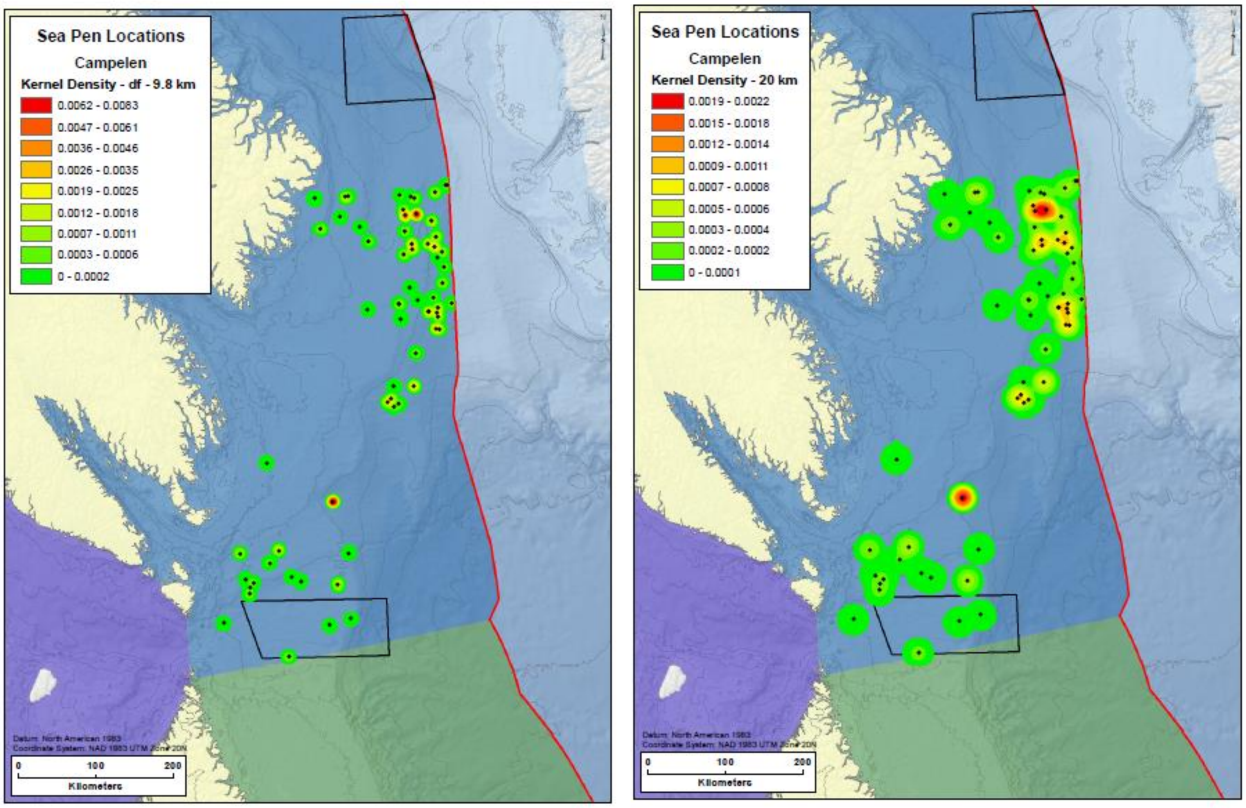

Figure 126. KDE surface of sea pen biomass produced with the default (df) search radius (9.8 km; left) and a 20 km search radius (right). Tow locations with sea pen catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Campelen Trawl Data

The area surrounding each sea pen weight threshold is provided in Table 35 and illustrated in Figure 127. The sea pen fields are mapped out as the weight threshold falls from 0.7 to 0.1 kg. In going from 0.1 to 0.08 kg there is a large increase in area, supported by only 6 additional points, indicating that the 0.1 kg threshold delineates the habitat (Figure 128). This threshold covers an area of 1,694 km^2.

Table 35. Comparative Sea Pen Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sea Pens is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
0.7	2	-	85	571
0.2	8	6	573	196
0.1	23	15	1694	145
0.08	29	6	4158	14
0.05	35	6	4736	103
0.04	44	9	9601	7
0.02	48	4	10286	13
0.01	56	8	11616	2
0.001	61	5	11814	

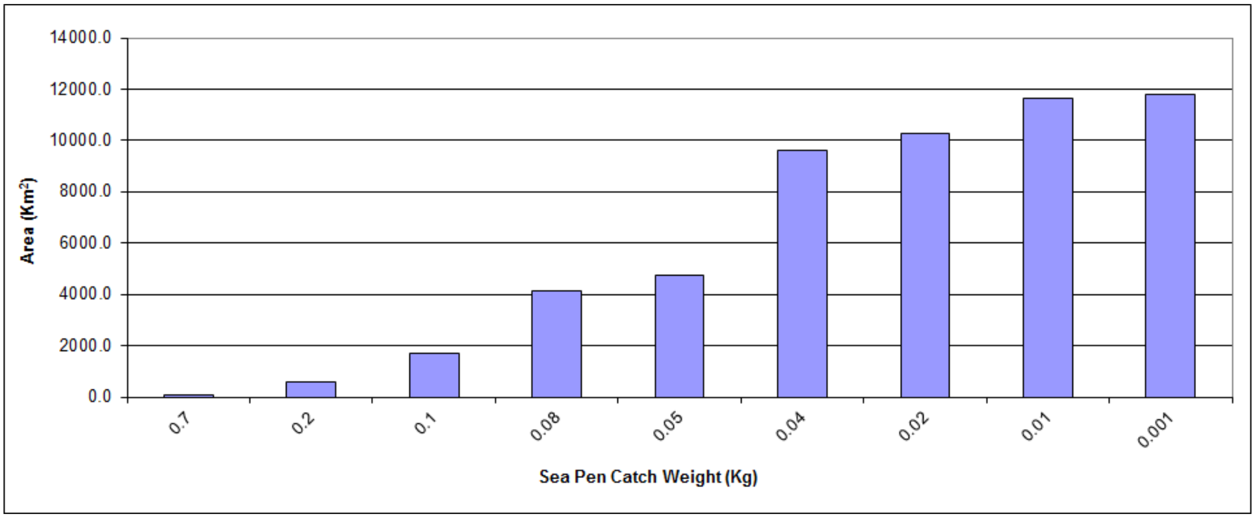

Figure 127. Barplot of polygon area (km^2) associated with sea pen weight thresholds (kg).

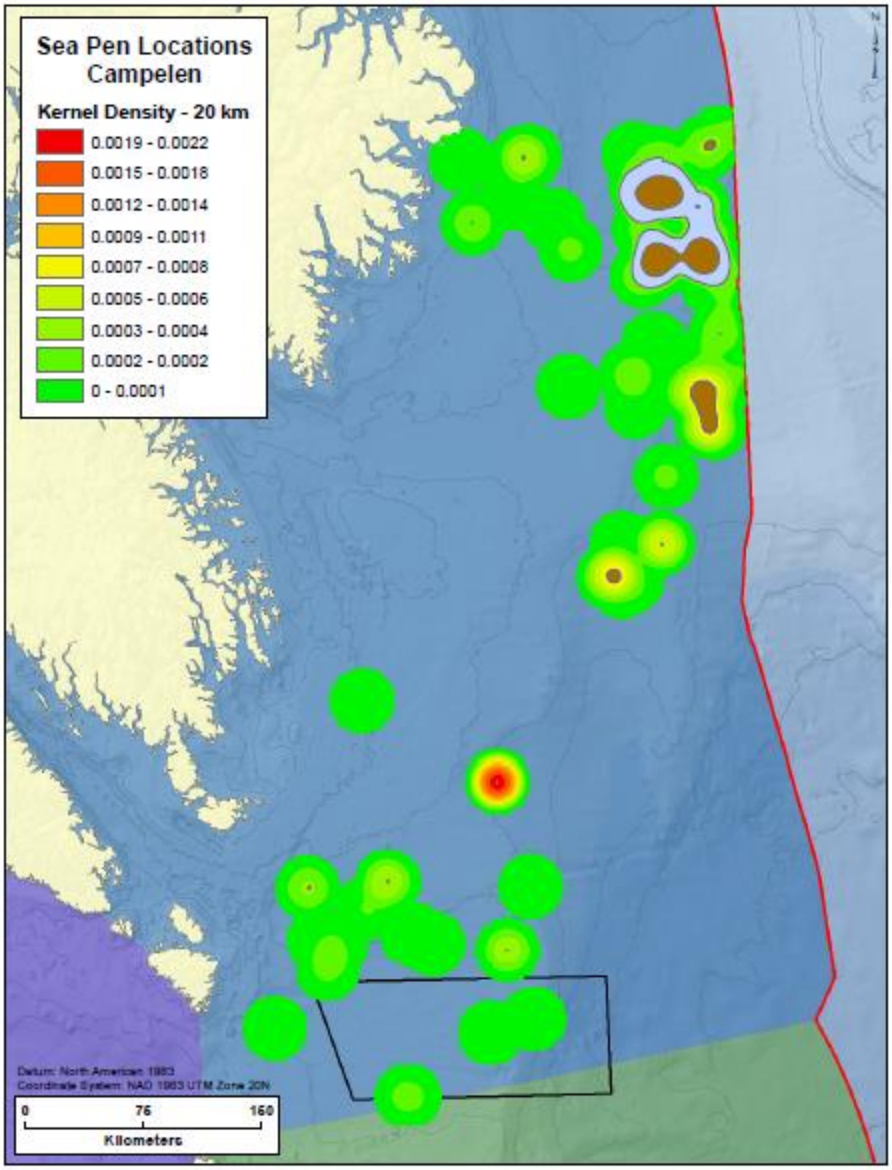

Figure 128. Location of polygons encompassing the ≥0.1 kg catches (brown) and the ≥0.08 kg catches (light purple), showing the increase in area (Table 35) and overlain on the KDE biomass surface produced with the 20 km search radius.

Location of the Dense Aggregations from Campelen Trawl Data

The locations of areas that indicated significant concentrations of sea pens are shown in Figure 129 and the locations of the survey tows that defined those polygons are provided in Table 36. In Figure 130, the results of this study are compared to those produced in Kenchington et al. (2010). The areas identified in the current and previous analyses are very similar in location (Figure 130).

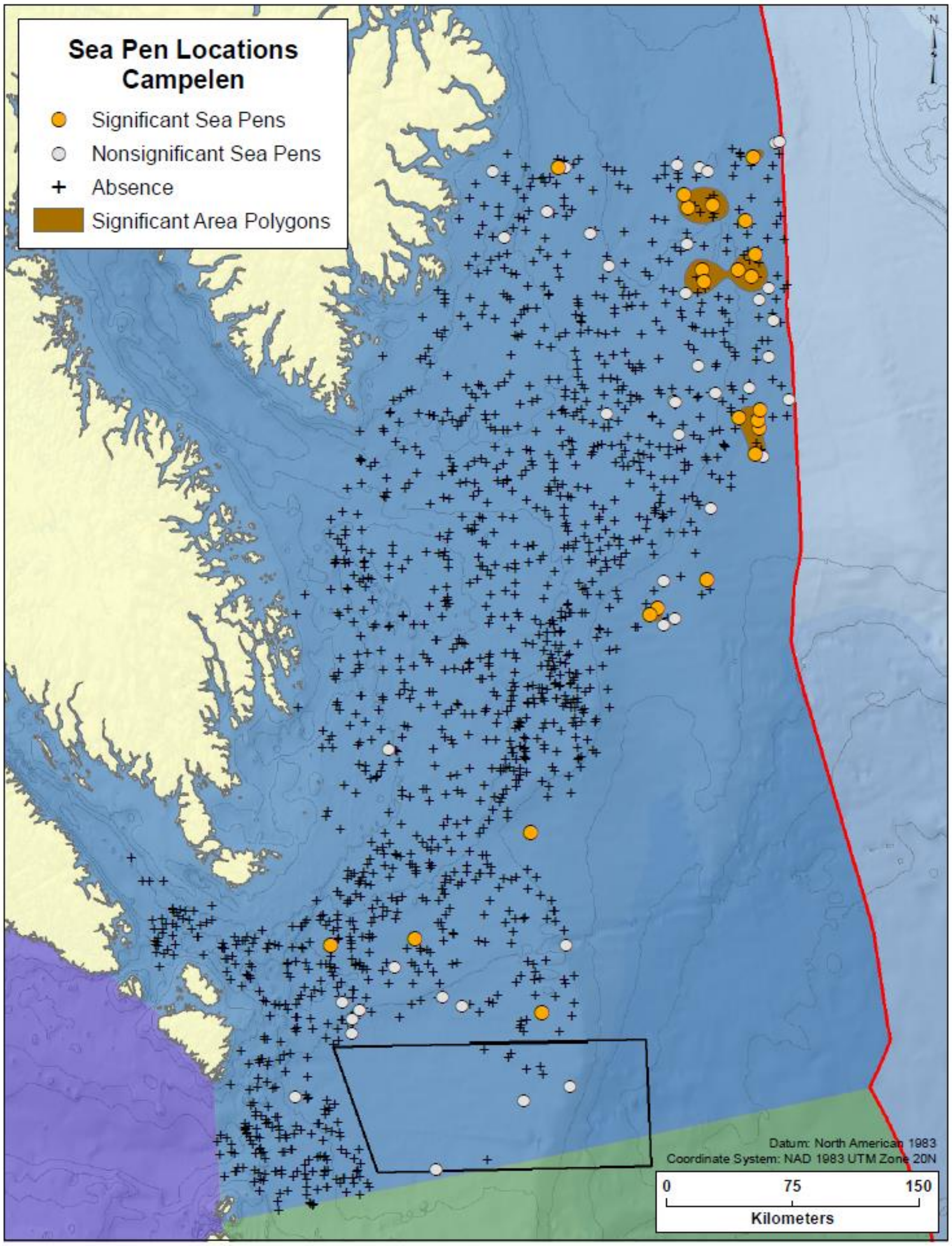

Figure 129. Locations of the significant sea pen areas relative to the broader distribution of sea pens in the Davis Strait –Southern Baffin Bay area. Catch locations with Campelen trawls that contributed to the identification of the polygons are indicated as significant (Table 36), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

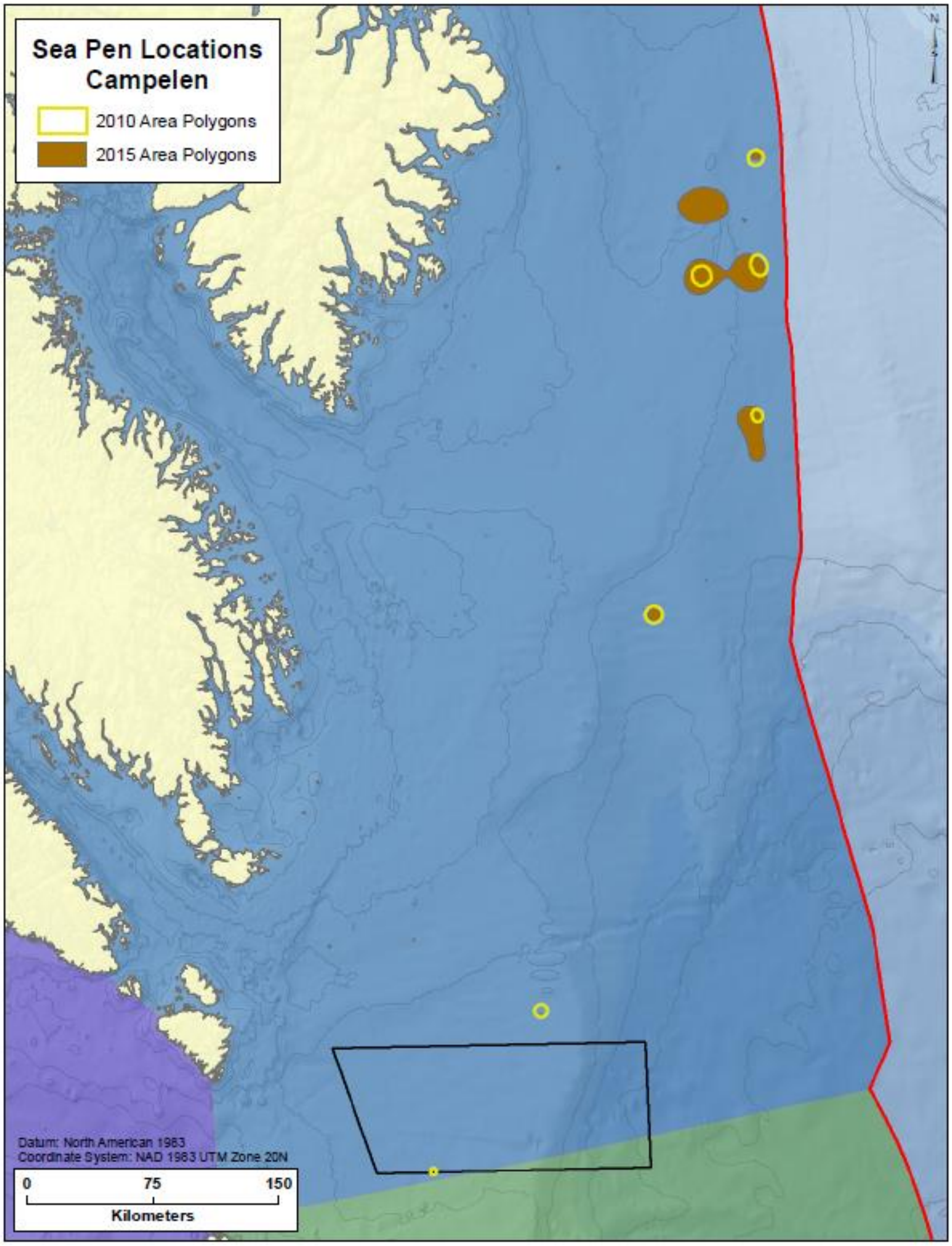

Figure 130. Comparison of the location of the significant concentrations identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (brown polygons).

Table 36. Eastern Arctic Biogeographic Zone: Details of the Location of Research Vessel Sea Pen Catches with Campelen Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sea Pen Weight (kg)
2007	BAL2007102099	62.63017	-61.22600	62.64233	-61.24167	0.840
2014	KIN2014109223	65.93757	-58.62283	65.92753	-58.60342	0.720
2013	AQV2013108198	65.92978	-58.94392	65.91648	-58.95840	0.450
2012	AQV2012107187	63.94058	-59.00437	63.95277	-58.99335	0.250
2014	KIN2014109225	65.53643	-58.18128	65.52528	-58.17115	0.250
2012	AQV2012107189	64.58932	-58.30567	64.60140	-58.29512	0.246
2005	BAL2005100184	65.59167	-58.81167	65.60167	-58.83500	0.230
2008	BAL2008103151	63.77083	-59.72167	63.77100	-59.75267	0.200
2013	AQV2013108180	64.79022	-58.47428	64.80283	-58.46762	0.181
2008	BAL2008103173	65.53050	-58.80200	65.51800	-58.79050	0.180
2009	BAL2009104263	62.07617	-62.58033	62.08583	-62.56100	0.160
2010	BAL2010105124	66.17960	-60.61675	66.16695	-60.62358	0.150
2014	KIN2014109224	65.58023	-58.35412	65.56937	-58.33823	0.150
2005	BAL2005100212	63.80833	-59.61667	63.80333	-59.58833	0.140
2010	BAL2010105117	65.84233	-58.20957	65.83007	-58.22080	0.140
2006	BAL2006101094	61.67167	-61.16167	61.68500	-61.15667	0.137
2008	BAL2008103176	65.65467	-58.11733	65.64233	-58.09933	0.130
2013	AQV2013108179	64.72523	-58.23185	64.73892	-58.23940	0.110
2007	BAL2007102154	64.82800	-58.20467	64.81433	-58.21133	0.110
2005	BAL2005100176	64.77167	-58.24500	64.76833	-58.21500	0.100
2005	BAL2005100193	66.17333	-58.04667	66.16500	-58.02167	0.100
2009	BAL2009104144	62.03883	-63.54367	62.02917	-63.54467	0.100
2011	BAL2011106144	65.99653	-58.98448	66.00747	-58.96613	0.100

Cosmos Trawl Data Sources and Distribution

Data were from DFO research vessel trawl surveys conducted from 2006 to 2012 by the Central and Arctic Region. There were 57 records with sea pen catch and 171 records of catches with no sea pens from the same surveys. Within the surveyed area, the sea pens were located throughout but were less common or absent on the shelf areas (Figure 131).

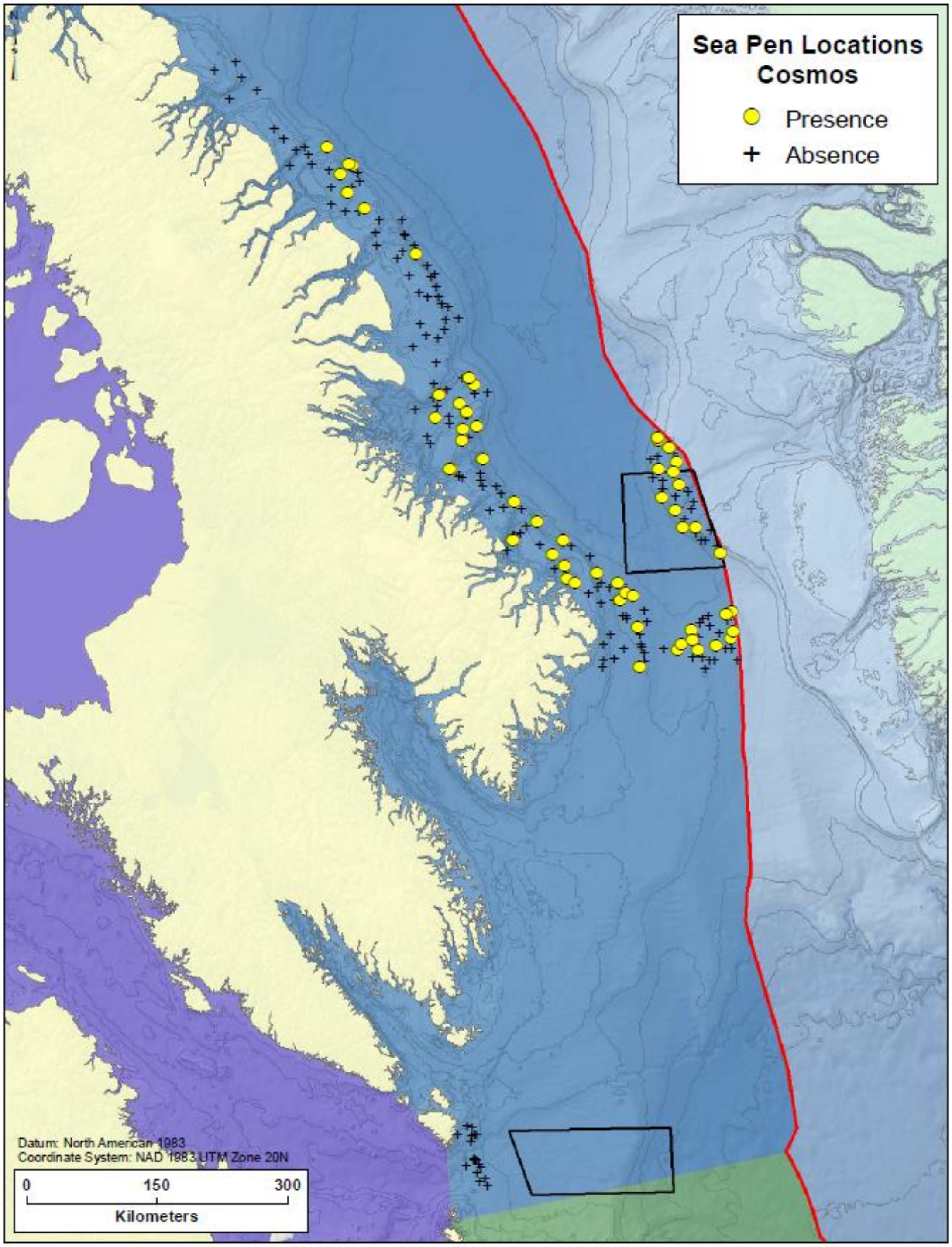

Figure 131. Distribution of sea pens from DFO research vessel survey catches using a Cosmos shrimp trawl. Yellow circles indicate sea pen presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Cosmos Trawl Data

The default search radius for the KDE was 15.5599 km and it produced a good surface given the data distribution (Figure 132). We compared that KDE surface with one produced by using a 20 km search radius. The 20 km search radius produced a better fit to the data (Figure 132) and a smoother surface for the analyses. Consequently we used the 20 km search radius for the analyses. The default grid size was 2.11 km^2. Contours placed over the KDE surface were spaced at 0.000001 kg intervals when constructing the bounding polygons.

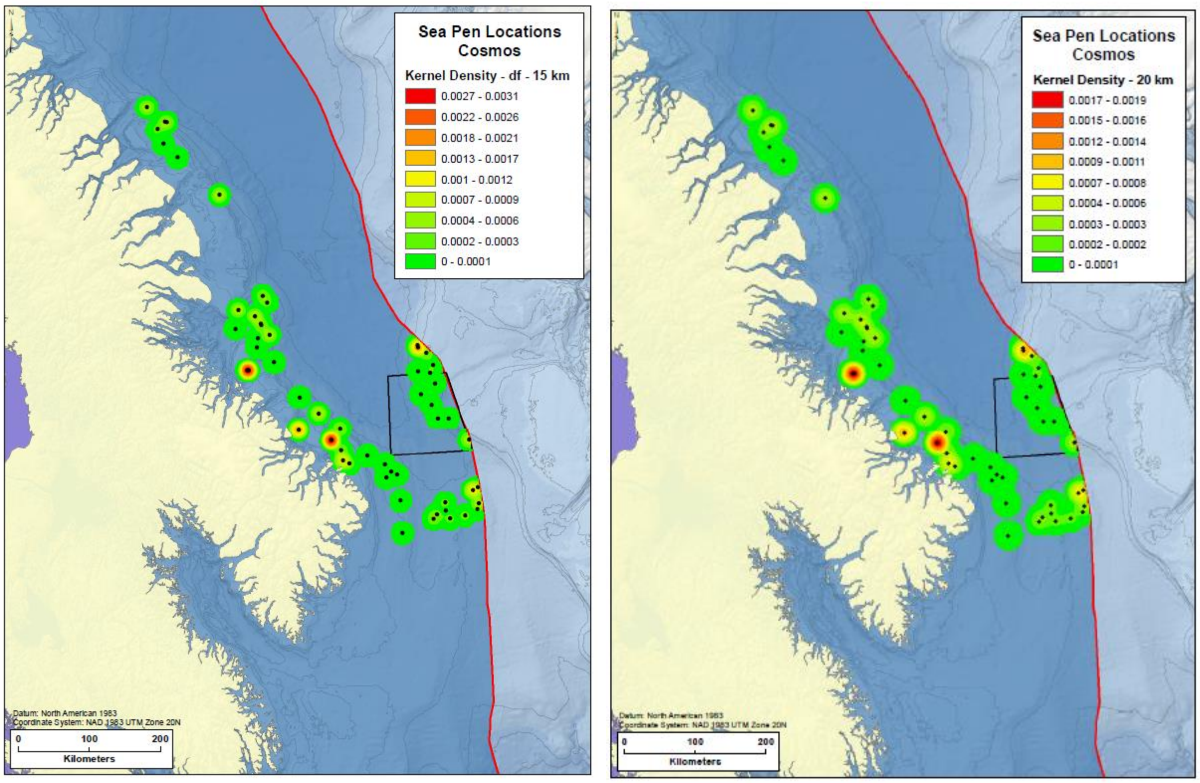

Figure 132. KDE surface of sea pen biomass produced with the default (df) search radius (15 km; left) and a 20 km search radius (right). Tow locations with sea pen catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Cosmos Trawl Data

The area surrounding each sea pen weight threshold is provided in Table 37 and illustrated in Figure 133. The data for this species group caught with this gear type is sparse. The analysis identified the 0.1 kg weight threshold as one identifying the sea pen concentrations (Figure 134), however that biomass is low and *in situ* data should be collected to determine if the identified areas, totaling 718 km^2, are sea pen fields.

Table 37. Comparative Sea Pen Biomass Polygon Areas Derived from the KDE Analyses. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Sea Pens is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
0.6	2	-	1	1502
0.2	6	4	19	3626
0.1	15	9	718	301
0.07	20	5	2879	42
0.04	29	9	4085	17
0.02	38	9	4790	59
0.01	44	6	7619	14
0.005	47	3	8703	78
0.001	57	10	15515	

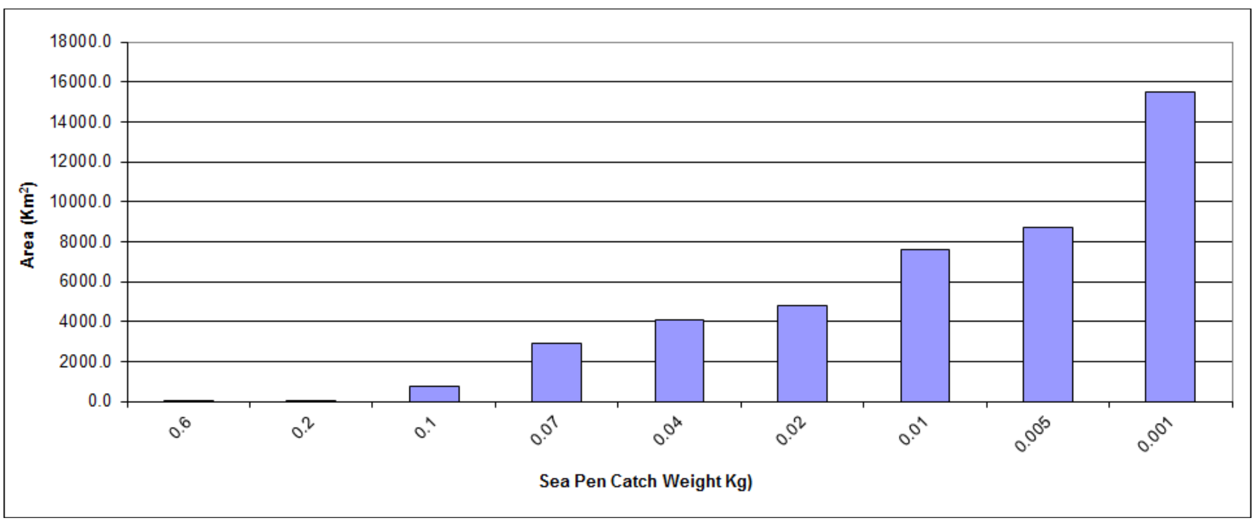

Figure 133. Barplot of polygon area (km^2) associated with sea pen weight thresholds (kg).

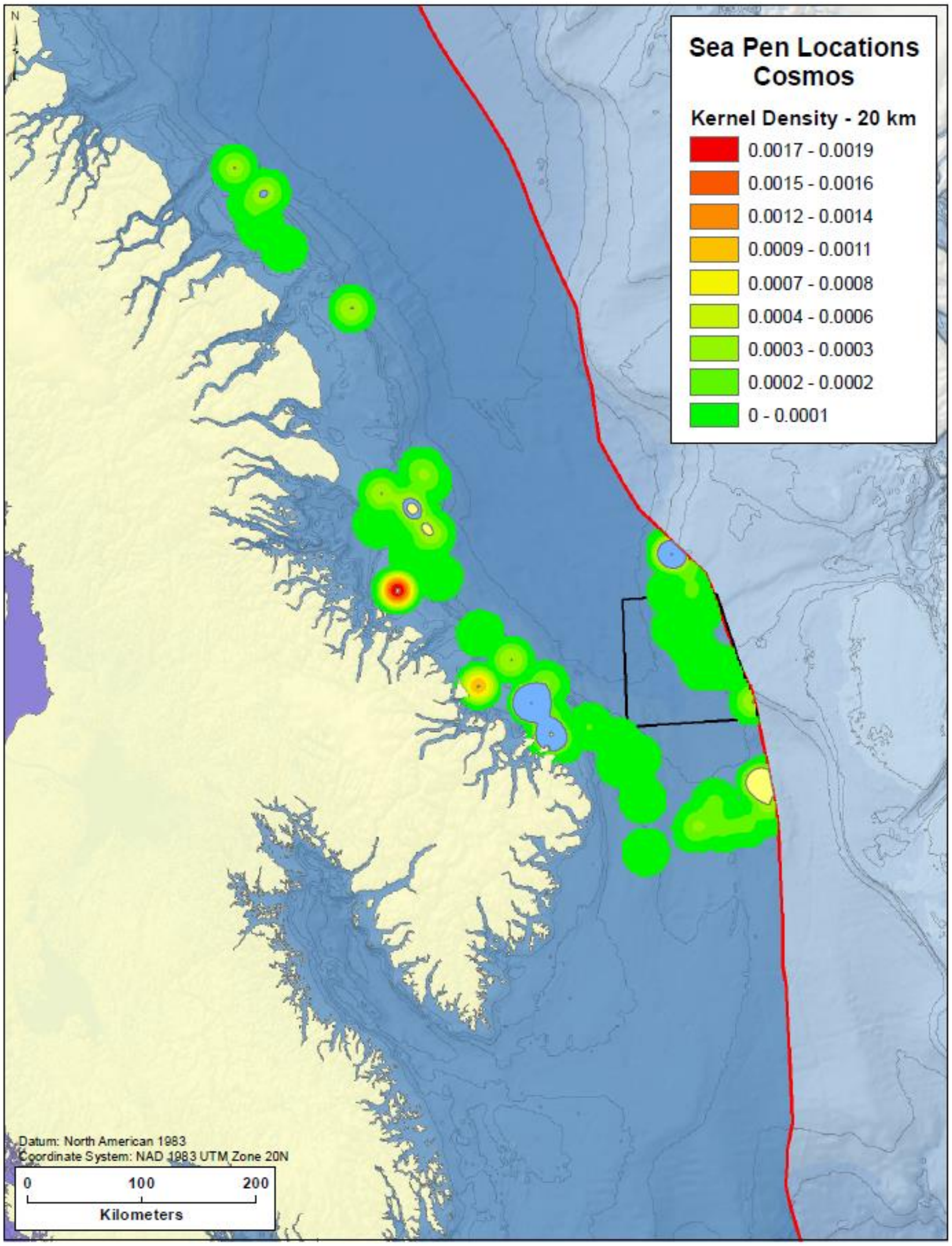

Figure 134. Location of polygons encompassing the ≥0.1 kg catches (light cream) and the ≥0.07 kg catches (blue), showing the increase in area (Table 37) and overlain on the KDE biomass surface produced with the 20 km search radius.

Location of the Dense Aggregations from Cosmos Trawl Data

The locations of areas that indicated significant concentrations of sea pens are shown in Figure 135 and the locations of the survey tows that defined those polygons are provided in Table 38. In Figure 136, the results of this study are compared to those produced in Kenchington et al. (2010).

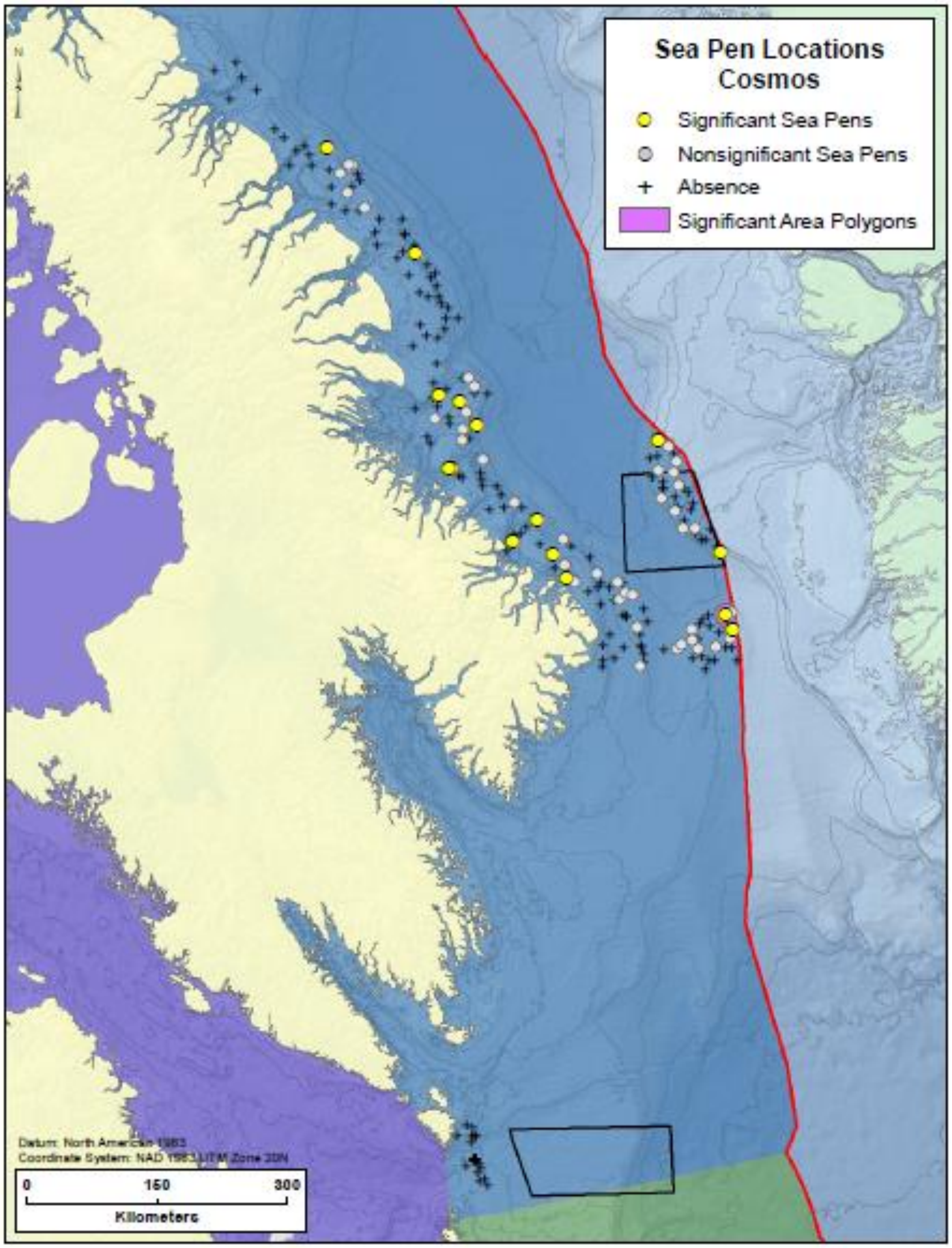

Figure 135. Locations of the significant sea pen areas relative to the broader distribution of sea pens in the Davis Strait –Southern Baffin Bay area. Catch locations that contributed to the identification of the polygons are indicated as significant (Table 38), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

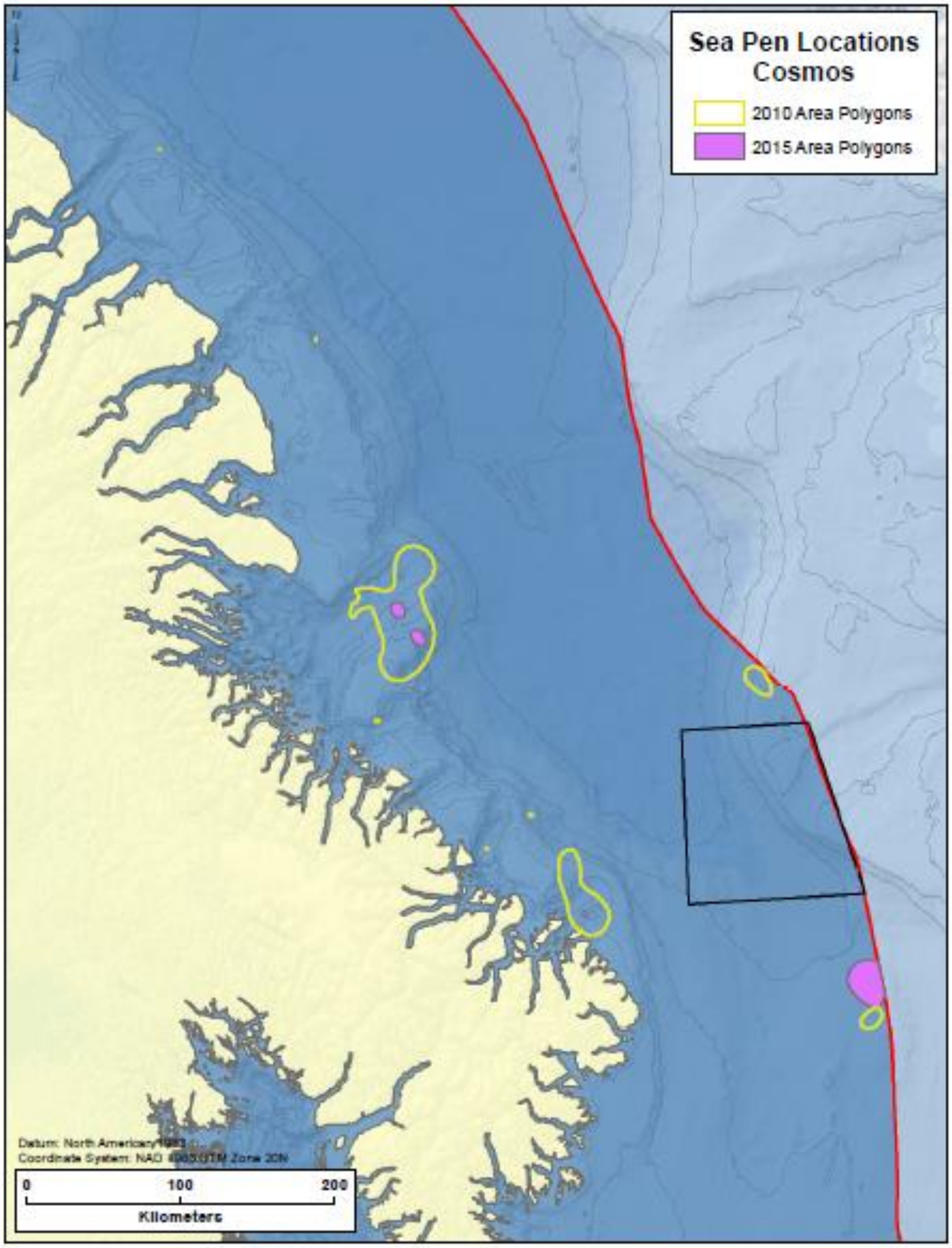

Figure 136. Comparison of the location of the significant concentrations of sea pens identified in Kenchington et al. (2010) (yellow outline) and those identified in this study (pink polygons).

Table 38. Eastern Arctic Biogeographic Zone: Details of the Location of Research Vessel Sea Pen Catches with Cosmos Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Sea Pen Weight (kg)
2008	PAA2008007178	67.45488	-62.43787	67.44733	-62.41765	0.780
2008	PAA2008007168	68.31975	-65.24255	68.31313	-65.26900	0.603
2008	PAA2008007177	67.58698	-63.51835	67.59750	-63.51365	0.424
2008	PAA2008007002	68.58700	-59.41783	68.59717	-59.40950	0.382
2010	PAA2010009157	66.74613	-57.92630	66.73622	-57.93393	0.240
2008	PAA2008007179	67.19417	-62.06750	67.20033	-62.09008	0.217
2008	PAA2008007169	68.32315	-65.29628	68.32547	-65.26808	0.184
2008	PAA2008007183	67.79115	-62.84827	67.78270	-62.83172	0.137
2006	PAA2006005056	70.51923	-66.58125	70.51262	-66.56238	0.129
2006	PAA2006005065	69.00732	-65.07908	69.01463	-65.09782	0.122
2006	PAA2006005021	69.07450	-65.68300	69.06700	-65.69900	0.118
2010	PAA2010009147	67.38282	-57.92137	67.39148	-57.93733	0.114
2006	PAA2006005068	68.77447	-64.55833	68.78333	-64.54683	0.112
2008	PAA2008007043	66.57533	-57.77705	66.58362	-57.76262	0.105
2006	PAA2006005042	71.54143	-69.67102	71.53887	-69.63908	0.104

Overview of Sea Pen KDE Polygons

The three different gears collectively cover the fishing grounds in the Davis Strait area. There is only a small area where the surveys overlapped and there the polygons were close to one another (Figure 137).

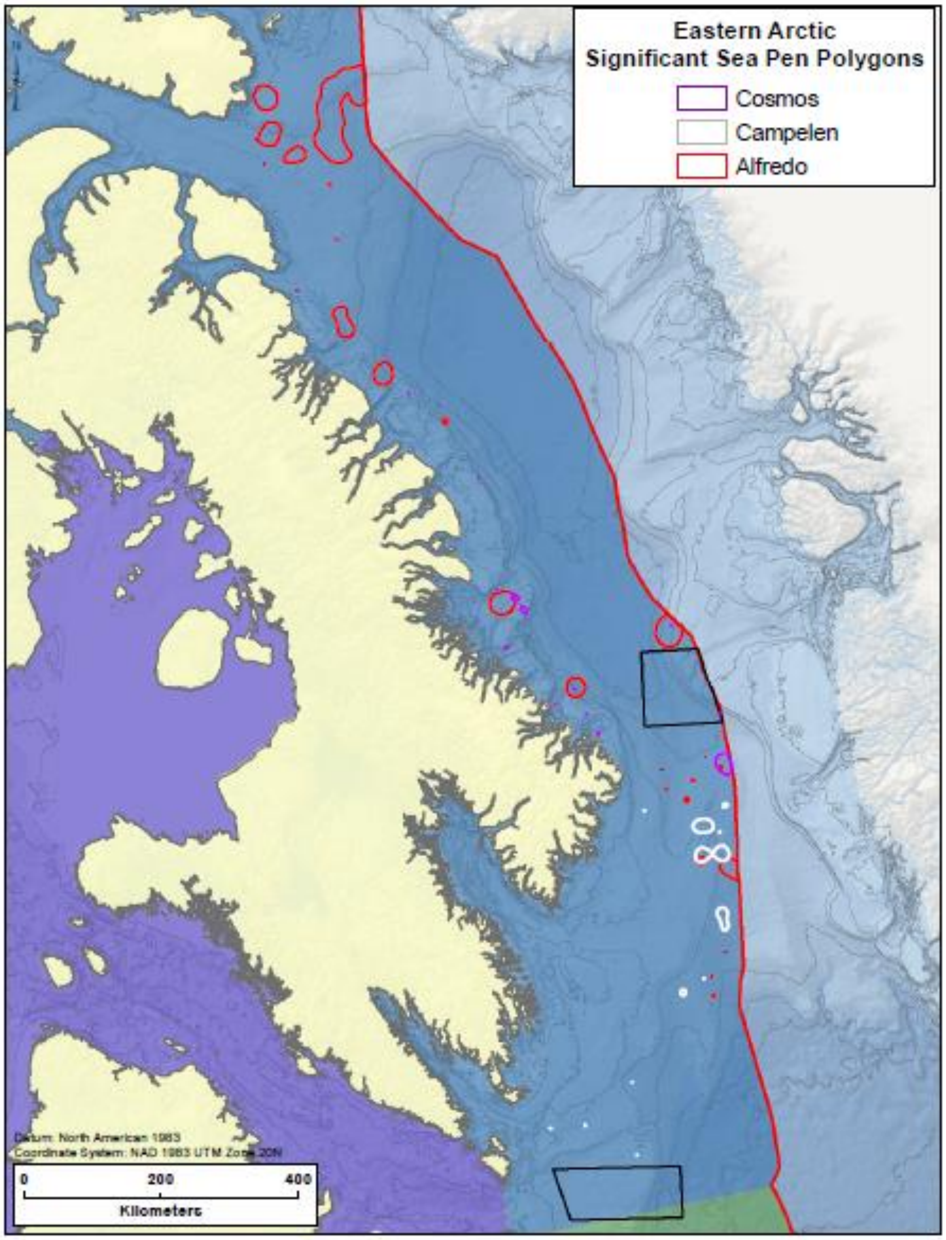

Figure 137. Location of significant concentrations of sea pens identified through KDE analyses for each of 3 gear types (Cosmos, Campelen and Alfredo trawls).

Large Gorgonian Corals

Alfredo Trawl Data Sources and Distribution

The data used for the analyses of large gorgonian corals in the Eastern Arctic Biogeographic Zone were from surveys conducted from 1999 to 2014 using Alfredo trawls. There were 39 records with large gorgonian coral catch and 733 records of catches with no large gorgonian corals from the same surveys. Within the surveyed area, the large gorgonian corals were patchily distributed, being most common in the southernmost part of the survey area (Figure 138).

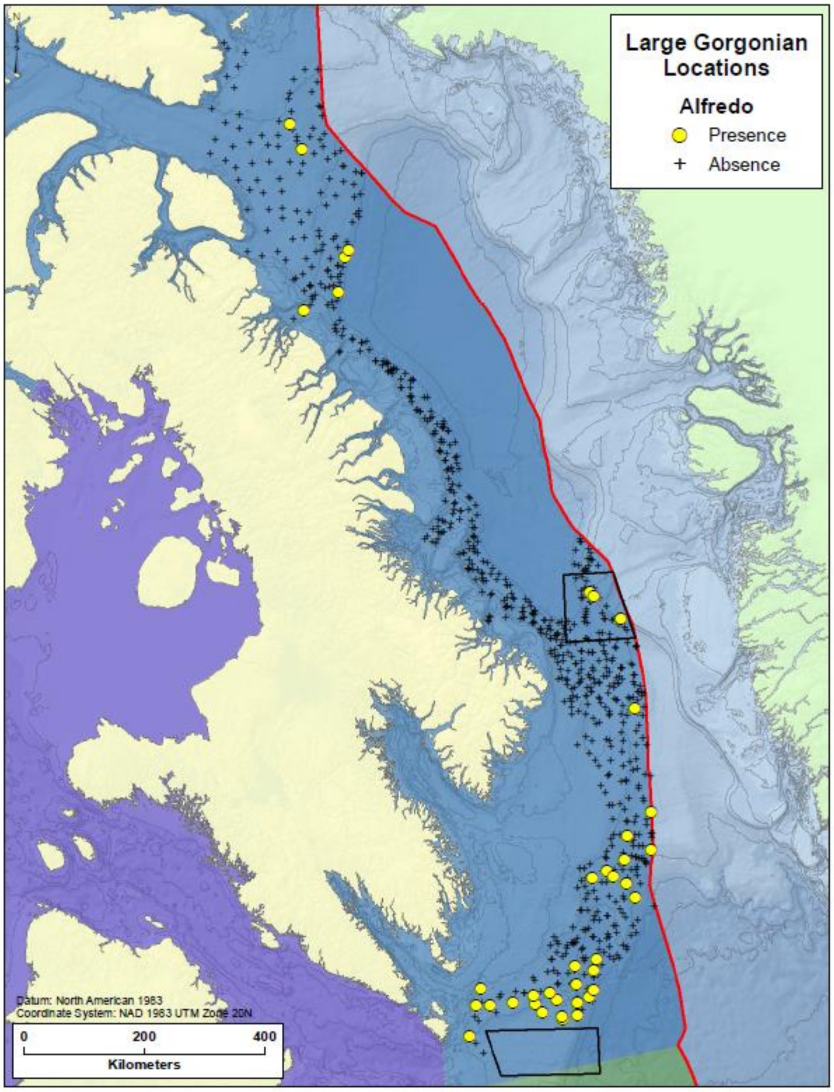

Figure 138. Distribution of large gorgonian corals from DFO research vessel survey catches using Alfredo trawls. Yellow circles indicate large gorgonian coral presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Alfredo Trawl Data

The default search radius for the KDE was 19.9742 km. We first looked at the effect of a single large catch of 2000 kg on the KDE surface using the default search radius and running the analysis with and without that datum (Figure 139). This catch is located in the Narwhal and Coral Closed Area and has been confirmed by *in situ* images. Running the analysis on the different data sets will have small influences on the positions of the polygons but those are relatively minor. We observed this directly through repeating analyses after correcting for erroneous data. The 25 km search radius (Figure 139) over-smoothed the data and did not substantially change the continuity of the surfaces so the default search radius using all data was used in the analysis. The default grid size was 2.8057 km^2. Contours placed over the KDE surface were spaced at 0.0001 kg intervals when constructing the bounding polygons.

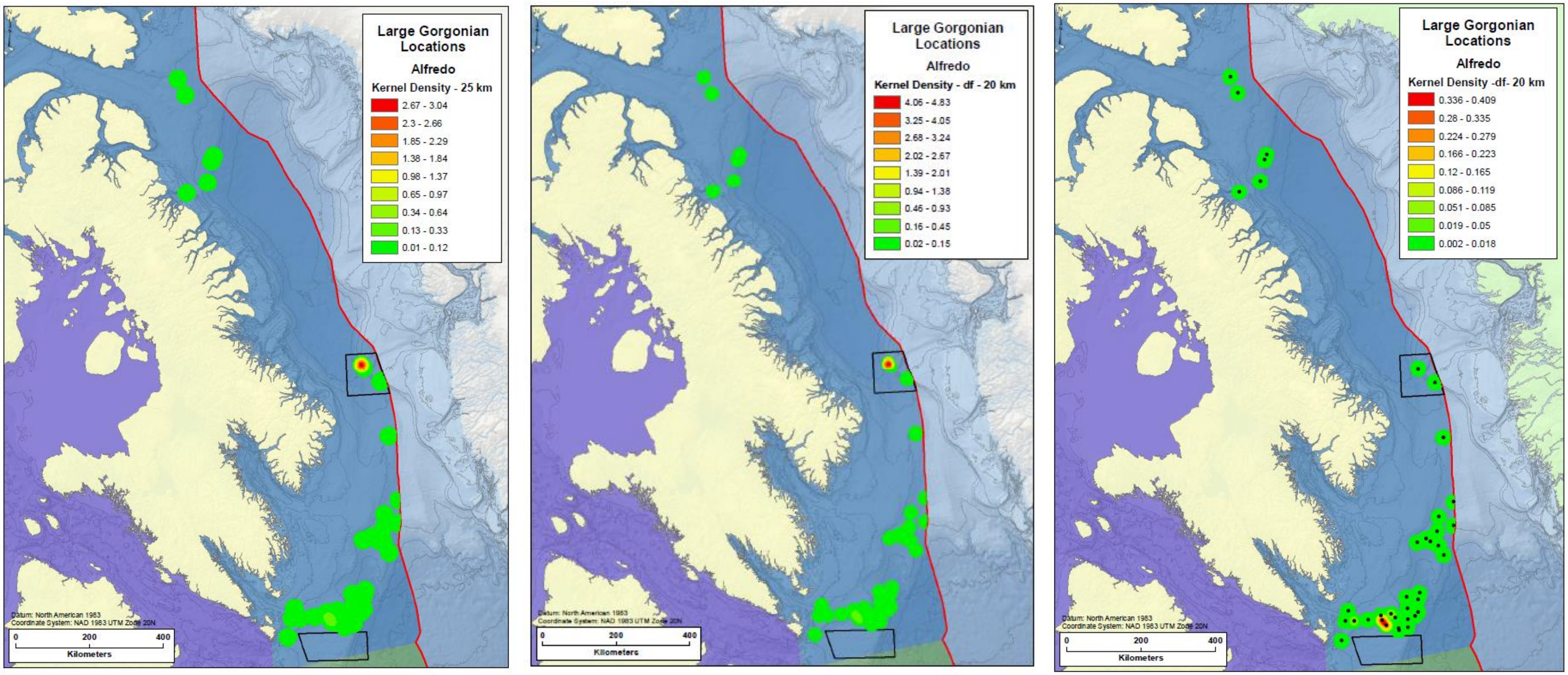

Figure 139. KDE surface of large gorgonian coral biomass produced with the 25 km search radius using all Alfredo trawl catch data (left), default (df) search radius (20 km) using all catch data (middle), and a 20 km search radius (right) excluding the 2000 kg catch in the Narwhal and Coral Closed Area. Tow locations with large gorgonian catch used in the analysis are indicated in black (right).

Selection of the Polygons Delineating Dense Aggregations from Alfredo Trawl Data

The area surrounding each large gorgonian coral weight threshold is provided in Table 39 and illustrated in Figure 140. The first large increase in area was found between 1 and 0.5 kg where area increased 120% (Table 39, Figures 140, 141). That change was supported by only 3 additional data points but few points defined all of the potential thresholds (Table 39). We considered 1 kg to be the threshold delineating significant concentrations of large gorgonian corals (Table 39). The areas occupy 2,135 km^2 (Table 39).

Table 39. Comparative Large Gorgonian Coral Biomass Polygon Areas Derived from the KDE Analyses with Alfredo Trawl Catches. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Large Gorgonian Coral is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
15	5	-	238	778
5	7	2	2088	2
1	11	4	2135	120
0.5	14	3	4694	36
0.3	19	5	6383	25
0.1	22	3	7996	20
0.03	26	4	9633	3
0.01	27	1	9958	0
0.002	27	0	9958	

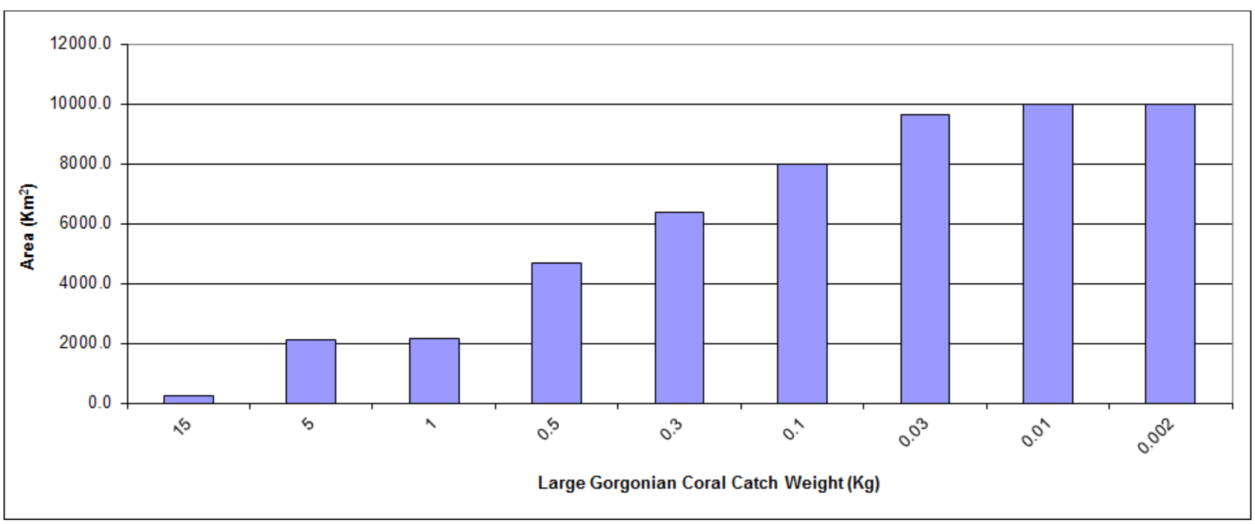

Figure 140. Barplot of polygon area (km^2) associated with large gorgonian coral weight thresholds (kg).

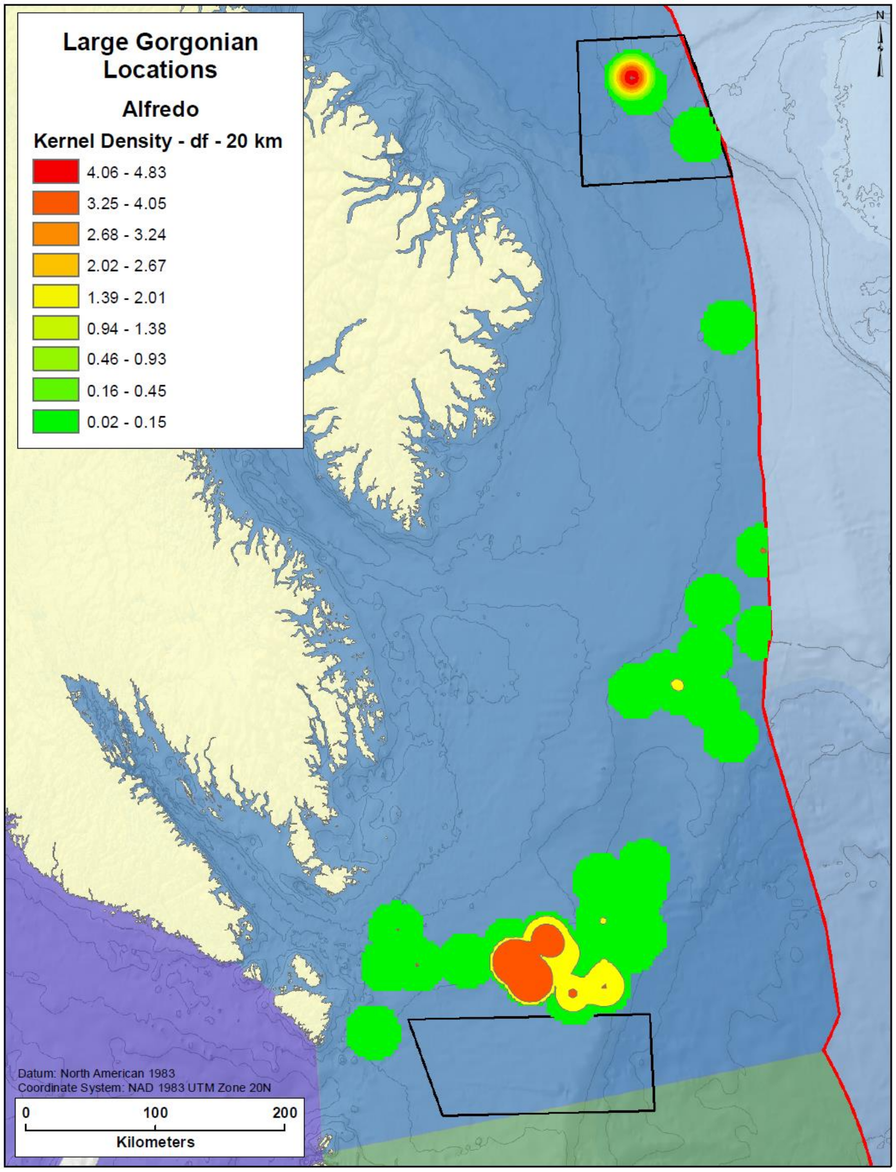

Figure 141. Location of polygons encompassing the ≥1 kg catches (orange) and the ≥0.5 kg catches (yellow), showing the increase in area (Table 39) and overlain on the KDE biomass surface produced with the default (df) 20 km search radius.

Location of the Dense Aggregations from Alfredo Trawl Data

The locations of areas that indicated significant concentrations of large gorgonian corals are shown in Figure 142 and the locations of the survey tows that defined those polygons are provided in Table 40. Significant area polygons were not determined in the 2010 report (Kenchington et al., 2010) as there were too few data.

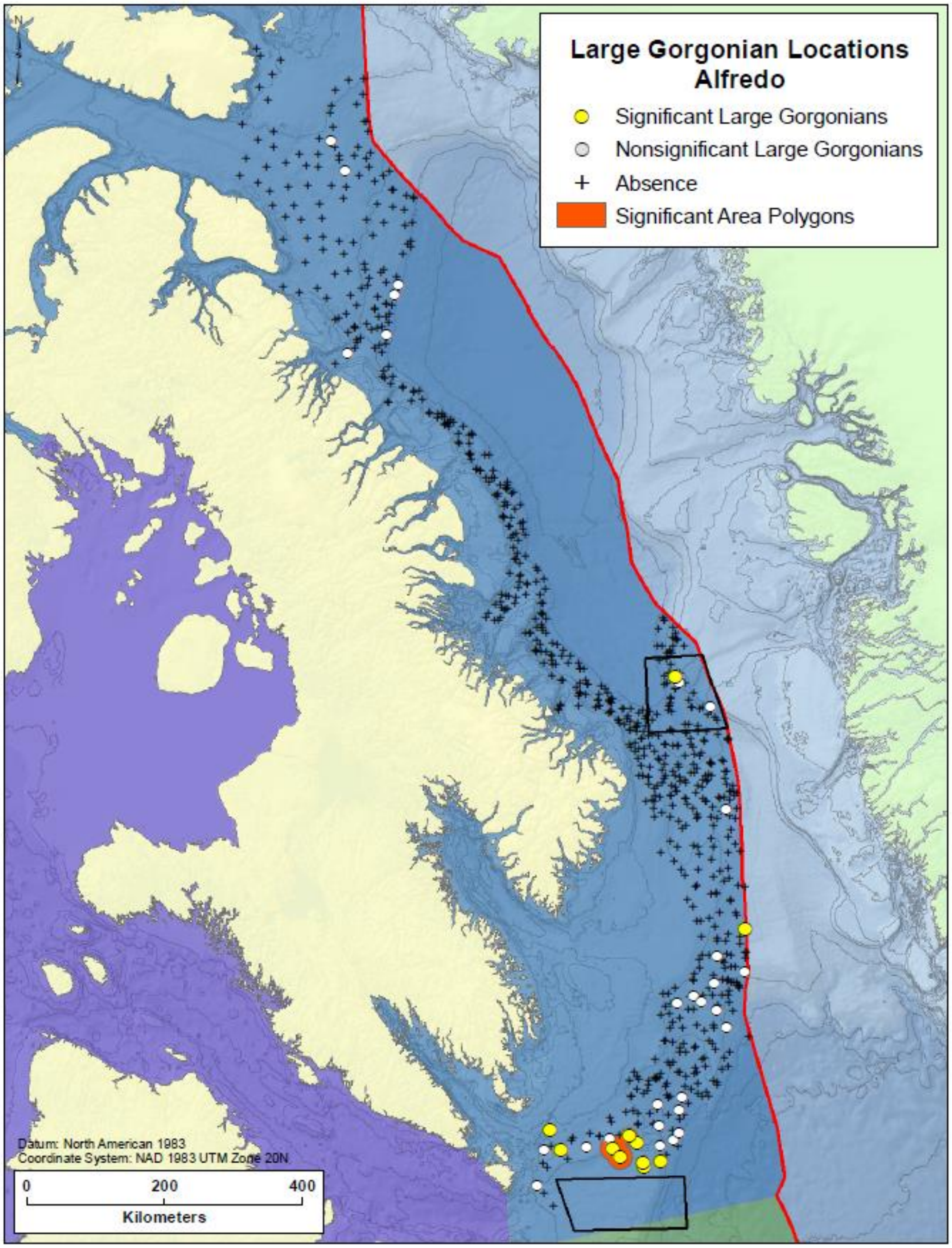

Figure 142. Location of the polygons identifying significant large gorgonian coral aggregations relative to the broader distribution of large gorgonian corals in the Eastern Arctic. Large gorgonian coral catches that contributed to the identification of the polygons are indicated as significant (Table 40), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

Table 40. Eastern Arctic Biogeographic Zone, Davis Strait: Details of the Location of Research Vessel Large Gorgonian Coral Catches from Alfredo Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Large Gorgonian Coral Weight (kg)
1999	PAA1999001	67.98000	-59.51000	67.96000	-59.49500	2000.000
2011	PAA2011007	61.88867	-61.93881	61.87287	-61.97377	139.800
2013	PAA2013008	61.76735	-61.72832	61.74850	-61.70205	120.250
2013	PAA2013008	61.87438	-63.37695	61.85992	-63.40908	19.800
2013	PAA2013008	62.04287	-61.47677	62.02062	-61.50008	19.550
2013	PAA2013008	61.70485	-60.65048	61.71987	-60.65288	6.400
2011	PAA2011007	61.94133	-61.27989	61.92167	-61.26488	5.100
2013	PAA2013008	62.11742	-63.68068	62.12995	-63.72565	2.498
2014	PAA2014007	64.65027	-57.82775	64.66595	-57.87232	1.900
2013	PAA2013008	61.68727	-61.12232	61.68443	-61.08505	1.809
2011	PAA2011007	61.63815	-61.10504	61.63938	-61.14792	1.720

Campelen Trawl Data Sources and Distribution

The data used for the analyses of large gorgonian corals caught with Campelen trawls in the Eastern Arctic Biogeographic Zone were restricted to the Davis Strait area. There were 120 records with large gorgonian coral catch from surveys conducted between 2005 and 2014, and 1455 records of catches with no large gorgonian corals from the same surveys. Within the surveyed area, the corals were concentrated around and in the volunteer closure area (Figure 143).

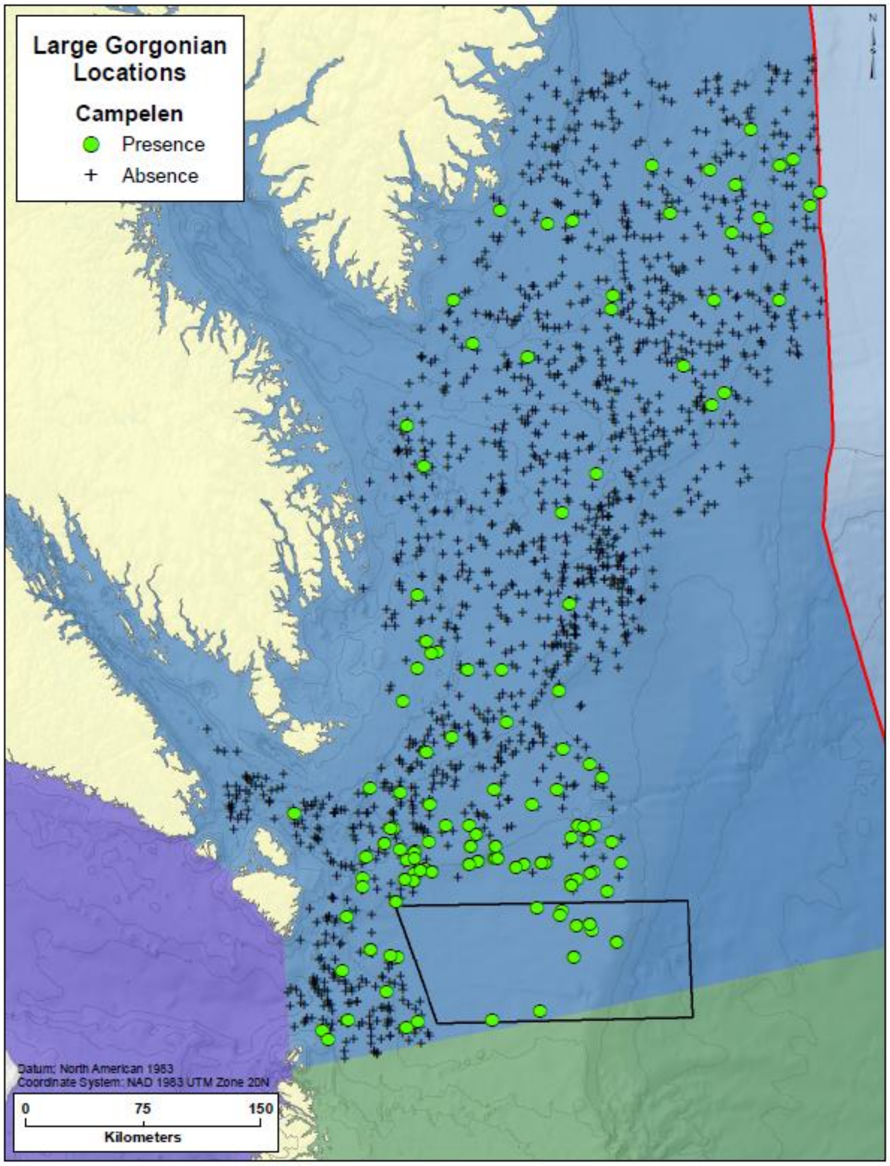

Figure 143. Distribution of large gorgonian corals from DFO research vessel survey catches using Campelen trawls. Green circles indicate large gorgonian coral presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Campelen Trawl Data

The default search radius for the KDE was 11.1608 km. We compared that KDE surface with one produced by using a 20 km search radius as the coverage was not continuous with the default values. The larger search radius allowed us to use a continuous surface for the southern- and northernmost part of the spatial extent (Figure 144). By using this larger search radius the polygons will be larger than those produced from the smaller default value due to the over-smoothing, however, given that these are very fragile and long-lived species that buffer created around the data points as a result will be conservative for the delimitation of the areas. The default grid size was 1.50 km^2. Contours placed over the KDE surface were spaced at 0.0001 kg intervals when constructing the bounding polygons.

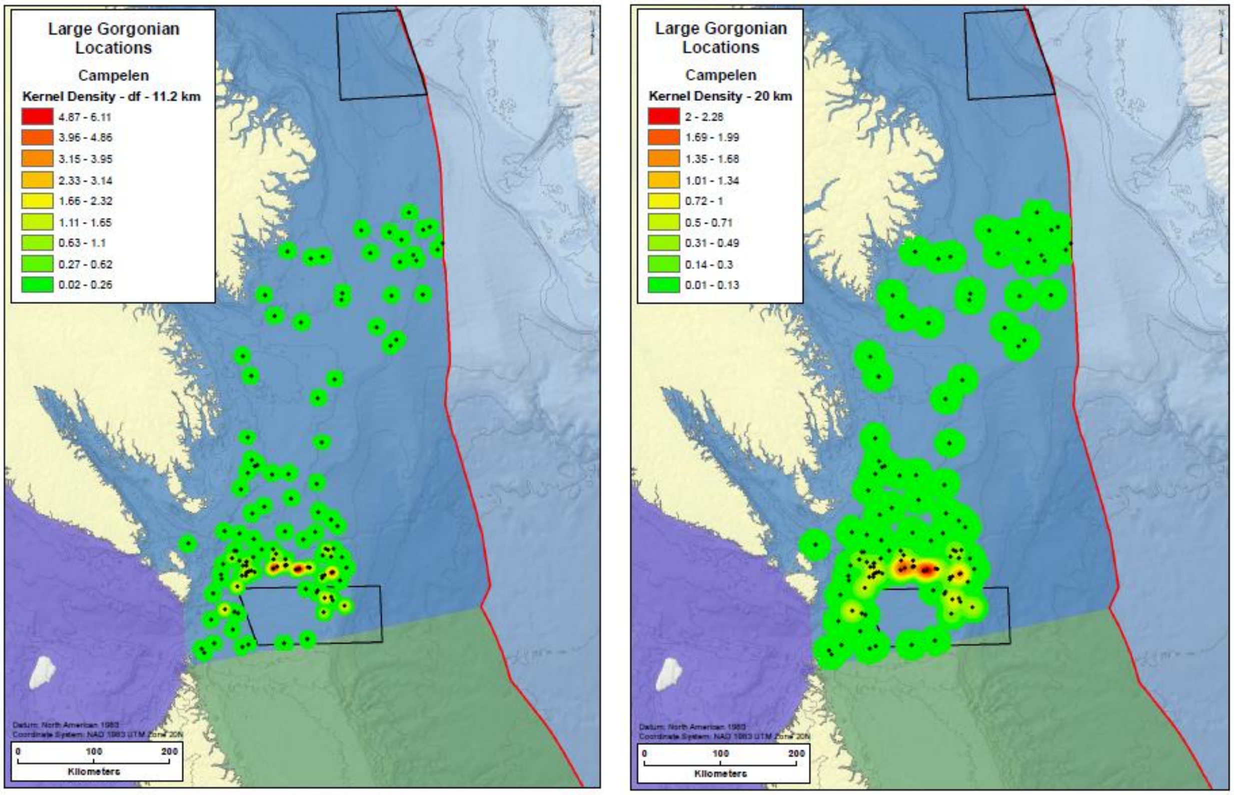

Figure 144. KDE surface of large gorgonian coral biomass produced with the default (df) search radius (11.2 km) (left) and a 20 km search radius (right). Tow locations with large gorgonian coral catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Campelen Trawl Data

The area surrounding each large gorgonian coral weight threshold is provided in Table 41 and illustrated in Figure 145. The first large increase in area after the mapping out of the large gorgonian corals was found between 30 and 10 kg where area increased 108% (Table 41, Figures 145, 146). That change was supported by 11 additional data points and was considered to be the threshold delineating significant concentrations of large gorgonian corals (Table 41). The areas occupy 4,878 km^2 (Table 41).

Table 41. Comparative Large Gorgonian Coral Biomass Polygon Areas Derived from the KDE Analyses with Campelen Trawl Catches. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Large Gorgonian Coral is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
300	6	-	133	3041
100	17	11	4181	17
30	29	12	4878	108
10	40	11	10171	22
1	48	8	12358	27
0.5	61	13	15725	38
0.1	78	17	21761	10
0.05	89	11	23889	1
0.01	91	2	24012	

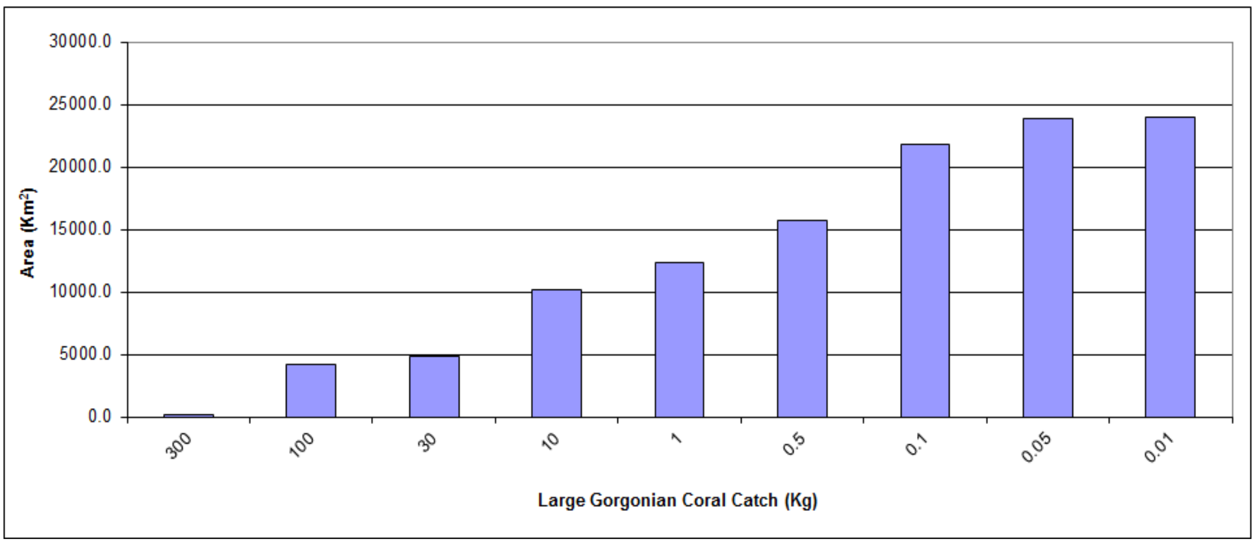

Figure 145. Barplot of polygon area (km^2) associated with large gorgonian coral weight thresholds (kg).

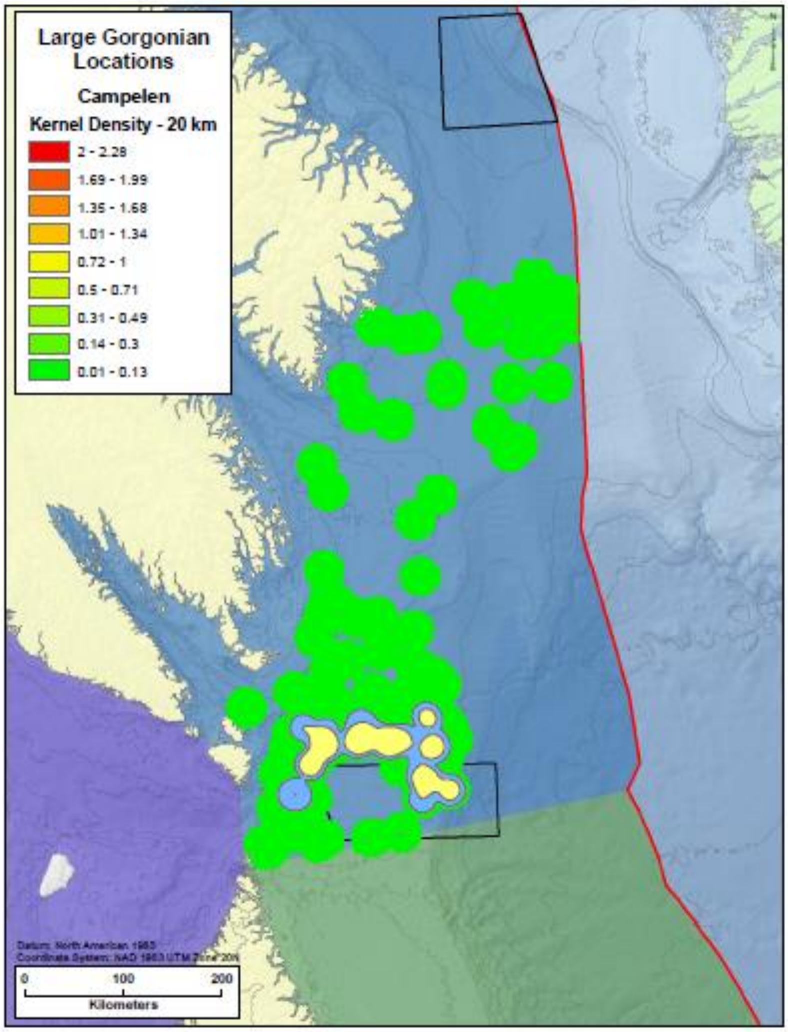

Figure 146. Location of polygons encompassing the ≥30 kg catches (yellow) and the ≥10 kg catches (blue) of large gorgonian corals, showing the increase in area (Table 41) and overlain on the KDE biomass surface produced with the 20 km search radius.

Location of the Dense Aggregations from Campelen Trawl Data

The locations of areas that indicated significant concentrations of large gorgonian corals are shown in Figure 147 and the locations of the survey tows that defined those polygons are provided in Table 42. Figure 148 shows the locations of the significant area polygons determined from this study in comparison with those produced in the 2010 report (Kenchington et al., 2010). The same general areas are recognized but there is more extensive area identified north of Hatton Basin that was revealed with the additional survey data and analysis. The significant concentrations of large gorgonian coral biomass are found both inside and outside of the volunteer closed area put in place by industry.

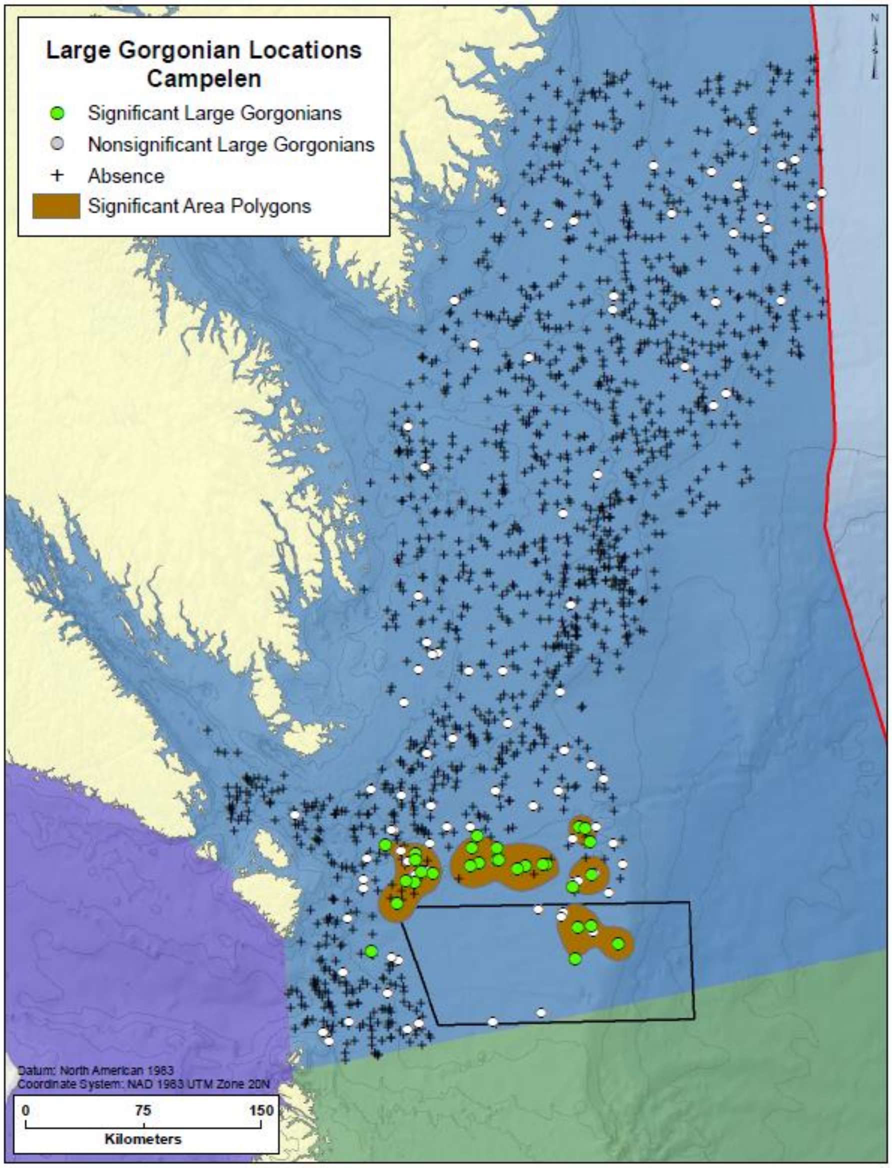

Figure 147. Location of the polygons identifying significant large gorgonian coral aggregations relative to the broader distribution of large gorgonian coral in the Eastern Arctic. Large gorgonian coral catches that contributed to the identification of the polygons are indicated as significant (Table 42), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

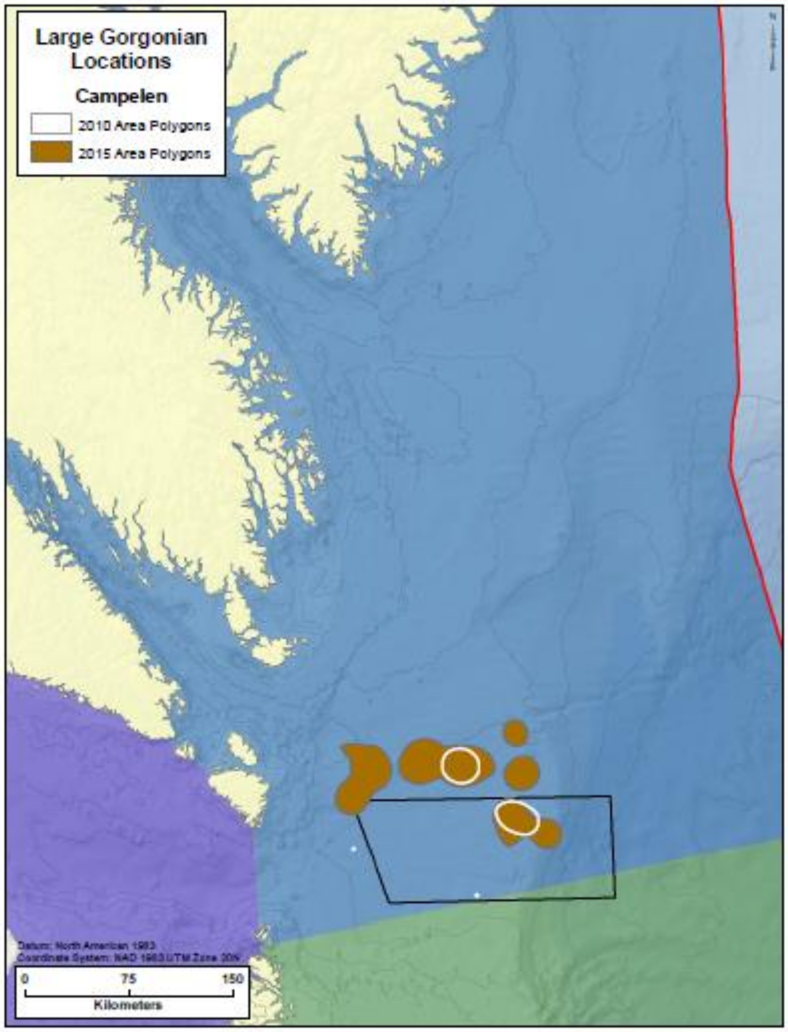

Figure 148. Comparison of the location of the significant concentrations of large gorgonian corals identified in Kenchington et al. (2010) (white outline) and those identified in this study (brown polygons).

Table 42. Eastern Arctic Biogeographic Zone, Davis Strait: Details of the Location of Research Vessel Large Gorgonian Coral Catches from Campelen Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Large Gorgonian Coral Weight (kg)
2006	BAL2006101094	61.67167	-61.16167	61.68500	-61.15667	500.059
2007	BAL2007102086	61.72750	-61.95933	61.72100	-61.98600	500.030
2011	BAL2011106084	61.72997	-62.61718	61.72807	-62.64845	409.940
2009	BAL2009104265	61.71700	-62.05250	61.71833	-62.07983	385.490
2013	AQV2013108280	61.75342	-62.51582	61.76013	-62.49653	375.440
2012	AQV2012107126	61.24570	-63.79993	61.24343	-63.82497	300.000
2006	BAL2006101091	61.37667	-61.34500	61.39000	-61.33833	260.000
2013	AQV2013108142	61.51842	-63.50073	61.52433	-63.48210	240.900
2006	BAL2006101090	61.27333	-60.87167	61.27667	-60.89833	225.000
2013	AQV2013108281	61.73862	-61.74940	61.73373	-61.73178	175.150
2010	BAL2010105181	61.70067	-63.21193	61.69040	-63.23290	139.060
2006	BAL2006101089	61.20167	-61.38833	61.21333	-61.38000	120.146
2011	BAL2011106085	61.90190	-62.53327	61.91340	-62.54883	103.300
2013	AQV2013108147	61.85337	-63.64582	61.85857	-63.62120	101.720
2006	BAL2006101096	61.95167	-61.29000	61.96333	-61.27833	100.000
2008	BAL2008103078	61.76683	-62.27483	61.76817	-62.25767	100.000
2009	BAL2009104141	61.64617	-63.29183	61.64800	-63.26717	100.000
2012	AQV2012107092	61.73517	-61.70585	61.74272	-61.68183	90.100
2010	BAL2010105283	61.60972	-61.39430	61.62113	-61.37622	82.470
2007	BAL2007102087	61.76883	-62.29983	61.76300	-62.32533	76.000
2010	BAL2010105180	61.68970	-63.07025	61.67440	-63.06718	57.740
2005	BAL2005100239	61.38500	-61.18500	61.37333	-61.17167	50.000
2011	BAL2011106082	61.85785	-61.16688	61.86450	-61.19130	41.101
2009	BAL2009104142	61.80667	-63.27900	61.80083	-63.30233	39.670
2012	AQV2012107112	61.83763	-62.60432	61.82493	-62.60127	38.240
2011	BAL2011106083	61.93805	-61.22777	61.93783	-61.25597	35.635
2011	BAL2011106208	61.76455	-63.27865	61.75598	-63.31055	32.220
2010	BAL2010105275	61.83857	-62.30048	61.84452	-62.27562	32.000
2014	KIN2014109322	61.64850	-63.39537	61.65008	-63.37752	31.360

Small Gorgonian Corals

Alfredo Trawl Data Sources and Distribution

The data used for the analyses of small gorgonian corals in the Eastern Arctic Biogeographic Zone were from surveys conducted from 2006 to 2014 using Alfredo trawls. There were 88 records with small gorgonian coral catch and 684 records of catches with no small gorgonian corals from the same surveys. Within the surveyed area, the small gorgonian corals were distributed only in the deeper water in the southernmost part of the surveyed area (Figure 149).

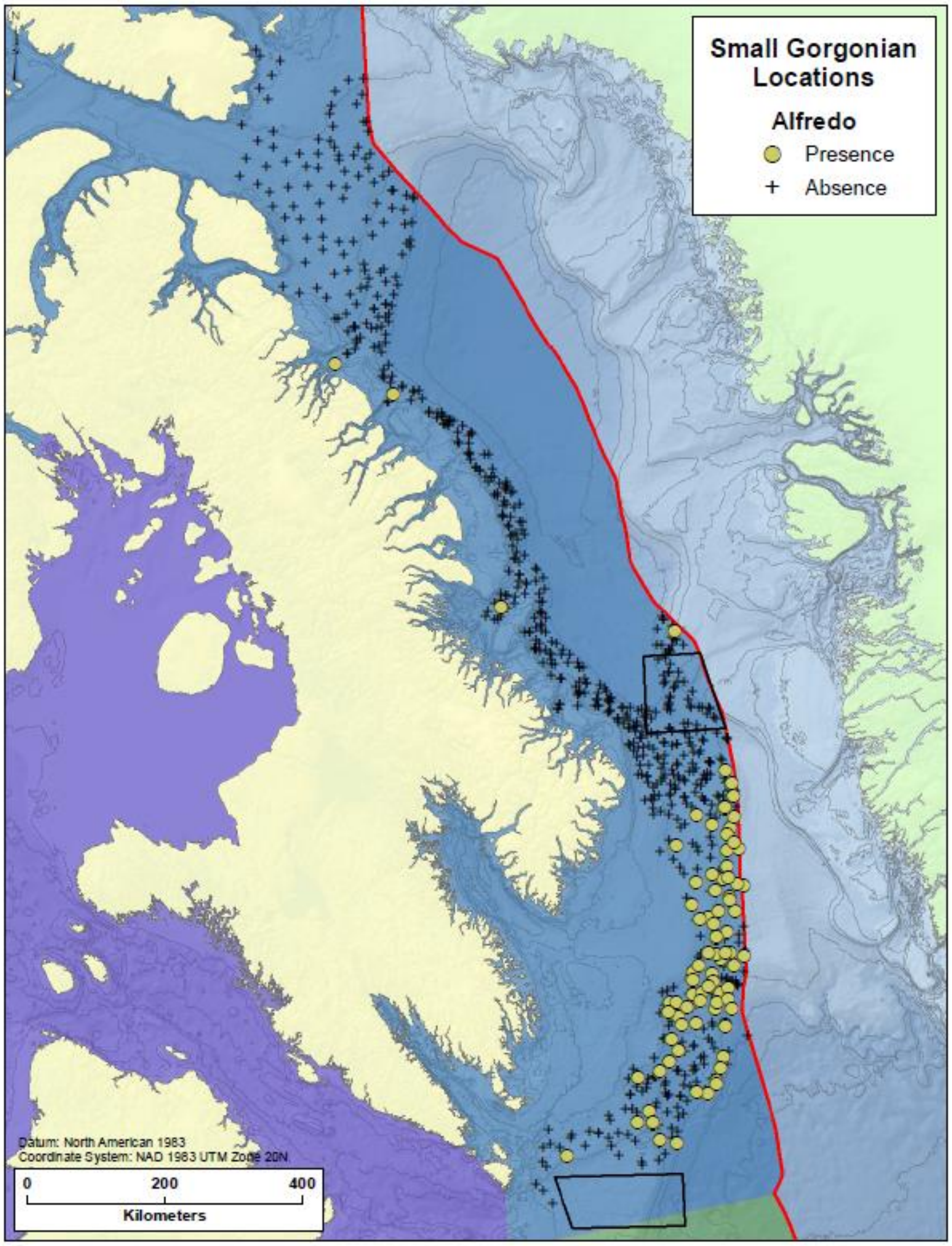

Figure 149. Distribution of small gorgonian corals from DFO research vessel survey catches using Alfredo trawls. Olive circles indicate small gorgonian coral presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Alfredo Trawl Data

The default search radius for the KDE was 19.8061 km. This search radius produced a discontinuous surface in the southernmost part of the data extent, while the 25 km search radius over-smoothed the data but did create a better surface for analysis (Figure 150). This will result in larger polygons around the data points than would be created with the default value. However, we used the 25 km search radius in order to perform the analysis and recognize that the fit will not be as tight. The default grid size for this search radius was 2.73 km^2. Contours placed over the KDE surface were finely spaced at 0.0000005 kg intervals when constructing the bounding polygons.

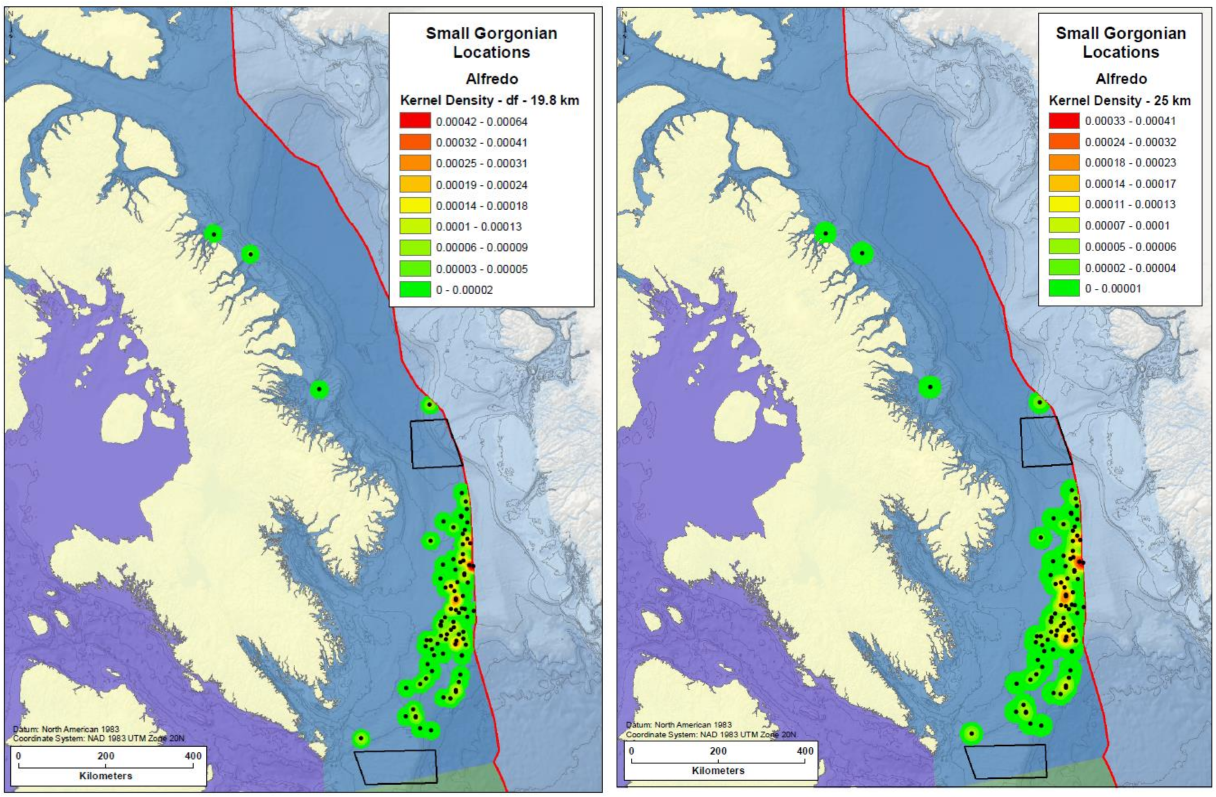

Figure 150. KDE surface of small gorgonian coral biomass produced with the default (df) search radius (19.8 km) (left) and a 25 km search radius (right). Tow locations with small gorgonian coral catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Alfredo Trawl Data

The area surrounding each small gorgonian coral weight threshold is provided in Table 43 and illustrated in Figure 151. The first large increase in area after the mapping out of the small gorgonian coral beds was found between 0.02 and 0.01 kg where area increased 153% (Table 43, Figures 151, 152). That change was supported by 12 additional data points and was considered to be the threshold delineating significant concentrations of small gorgonian coral (Table 43). The areas occupy 5,125 km^2 (Table 43).

Table 43. Comparative Small Gorgonian Coral Biomass Polygon Areas Derived from the KDE Analyses with Alfredo Trawl Catches. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Small Gorgonian Coral is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
0.1	1	-	23	329
0.07	3	2	97	3015
0.05	10	7	3010	25
0.03	16	6	3759	36
0.02	22	6	5125	153
0.01	34	12	12940	71
0.005	51	17	22138	24
0.003	73	22	27560	33
0.001	86	13	36576	

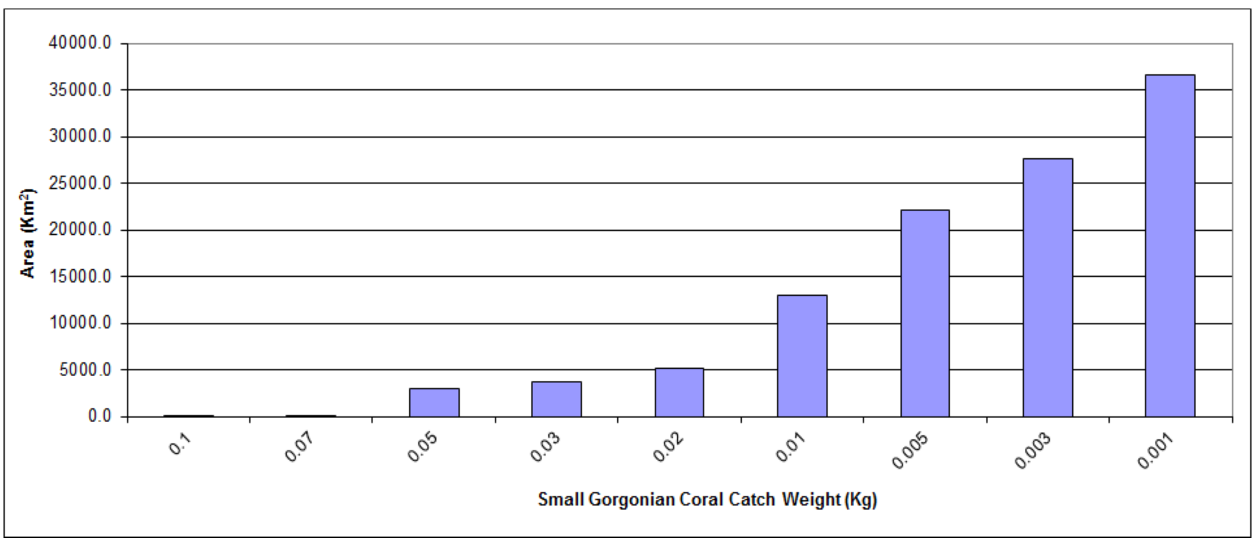

Figure 151. Barplot of polygon area (km^2) associated with small gorgonian coral weight thresholds (kg).

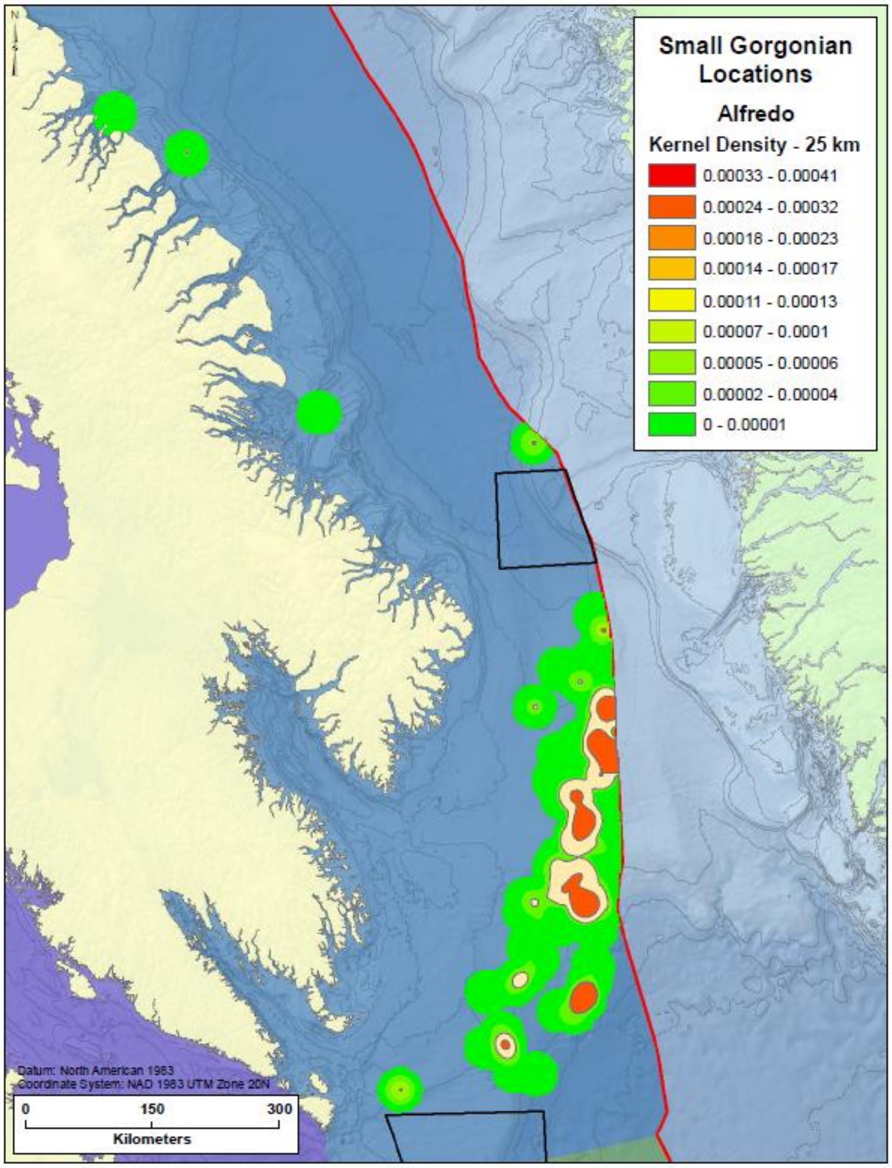

Figure 152. Location of polygons encompassing the ≥0.02 kg catches (red) and the ≥0.01 kg catches (light pink) of small gorgonian corals, showing the increase in area (Table 43) and overlain on the KDE biomass surface produced with the 25 km search radius.

Location of the Dense Aggregations from Alfredo Trawl Data

The locations of areas that indicated significant concentrations of small gorgonian corals are shown in Figure 153 and the locations of the survey tows that defined those polygons are provided in Table 44. There were insufficient data to run this analysis in 2010 (Kenchington et al., 2010) and so no comparison can be made with those earlier results.

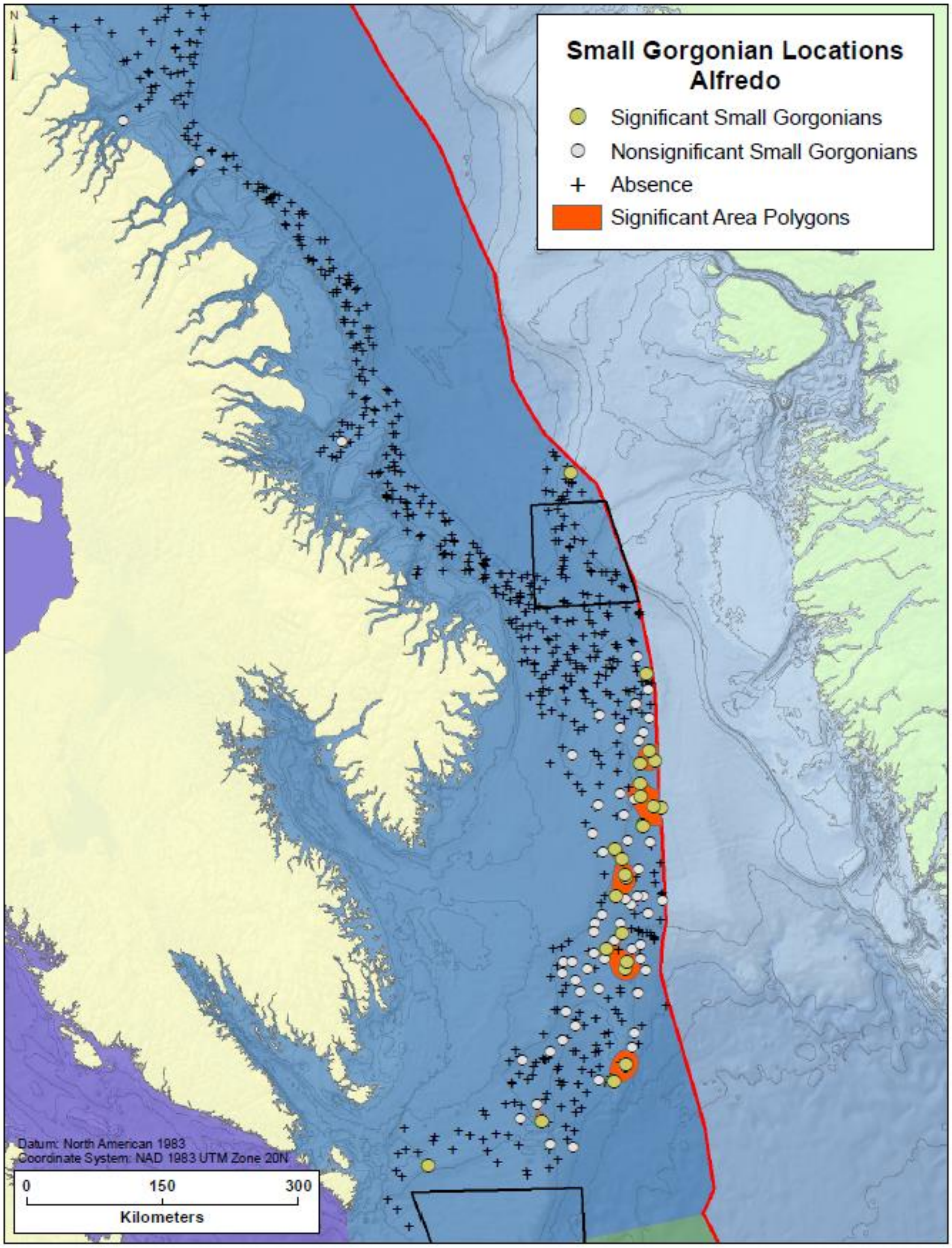

Figure 153. Location of the polygons identifying significant small gorgonian coral aggregations relative to the broader distribution of small gorgonian coral in the Eastern Arctic. Small gorgonian coral catches that contributed to the identification of the polygons are indicated as significant (Table 44), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

Table 44. Eastern Arctic Biogeographic Zone, Davis Strait: Details of the Location of Research Vessel Small Gorgonian Coral Catches from Alfredo Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Small Gorgonian Coral Weight (kg)
2011	PAA2011007005	65.19384	-57.71988	65.17259	-57.69835	0.240
2013	PAA2013008005	64.52757	-58.66903	64.55183	-58.66767	0.104
2013	PAA2013008157	63.62998	-58.82358	0.00000	0.00000	0.081
2011	PAA2011007144	64.81870	-58.86771	64.84048	-58.88082	0.076
2014	PAA2014007155	65.31822	-58.17720	65.33980	-58.20542	0.069
2011	PAA2011007169	65.66646	-57.76882	65.64293	-57.76118	0.066
2014	PAA2014007150	64.35795	-58.92525	64.37662	-58.88850	0.064
2013	PAA2013008158	63.69600	-58.77515	63.67358	-58.79937	0.053
2011	PAA2011007021	62.69001	-58.94275	62.66701	-58.95473	0.052
2014	PAA2014007156	65.76307	-57.89552	65.78340	-57.86378	0.052
2013	PAA2013008159	63.97803	-58.84367	63.95478	-58.85777	0.051
2013	PAA2013008035	63.84002	-59.20585	63.81870	-59.18218	0.044
2013	PAA2013008008	65.02363	-58.17635	65.04692	-58.16848	0.044
2013	PAA2013008009	65.21562	-57.90177	65.21527	-57.95778	0.040
2011	PAA2011007037	61.75708	-63.17784	61.74090	-63.18217	0.037
2013	PAA2013008010	65.44800	-58.18323	65.46518	-58.20398	0.035
2014	PAA2014007151	64.56132	-58.68083	64.54835	-58.70443	0.033
2014	PAA2014007161	66.52778	-57.81260	66.50298	-57.79922	0.029
2011	PAA2011007032	62.17080	-60.78182	62.14774	-60.77752	0.026
2006	PAA2006008069	68.55854	-59.37512	68.57033	-59.36755	0.025
2013	PAA2013008006	64.71255	-58.72272	64.73360	-58.69530	0.022
2011	PAA2011007022	62.52859	-59.20289	62.54439	-59.23940	0.021
2013	PAA2013008011	65.65702	-58.14032	65.67890	-58.12725	0.021

Campelen Trawl Data Sources and Distribution

The data used for the analyses of small gorgonian corals in the Eastern Arctic Biogeographic Zone were from surveys conducted from 2005 to 2014 using Campelen trawls. There were 91 records with small gorgonian coral catch and 1484 records of catches with no small gorgonian corals from the same surveys. Within the surveyed area, the small gorgonian corals were distributed broadly over the slopes and deeper water (Figure 154).

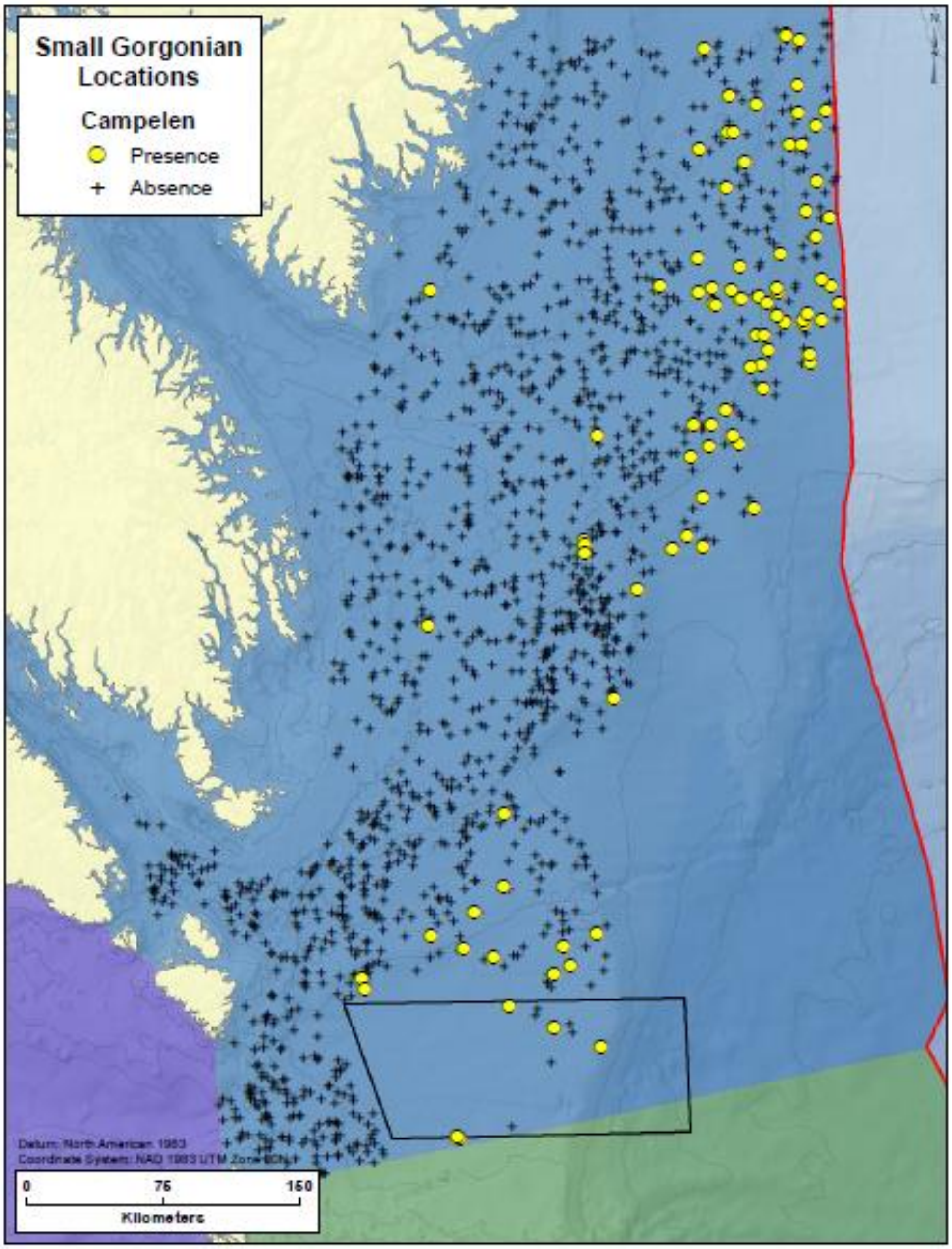

Figure 154. Distribution of small gorgonian corals from DFO research vessel survey catches using Campelen trawls. Yellow circles indicate small gorgonian coral presence in the catch and black crosses indicate verified null records.

Evaluation of Search Radii from Campelen Trawl Data

The default search radius for the KDE was 8.7501 km. This search radius produced a discontinuous surface over most of the data extent, while the 20 km search radius over-smoothed the data but did create a better surface for analysis (Figure 155). Consequently we used the 20 km search radius in order to perform the analysis but acknowledge that the polygons produced will be somewhat larger due to the over-smoothing effect. The default grid size for the 20 km search radius was 1.1963 km^2. Contours placed over the KDE surface were finely spaced at 0.0000005 kg intervals when constructing the bounding polygons.

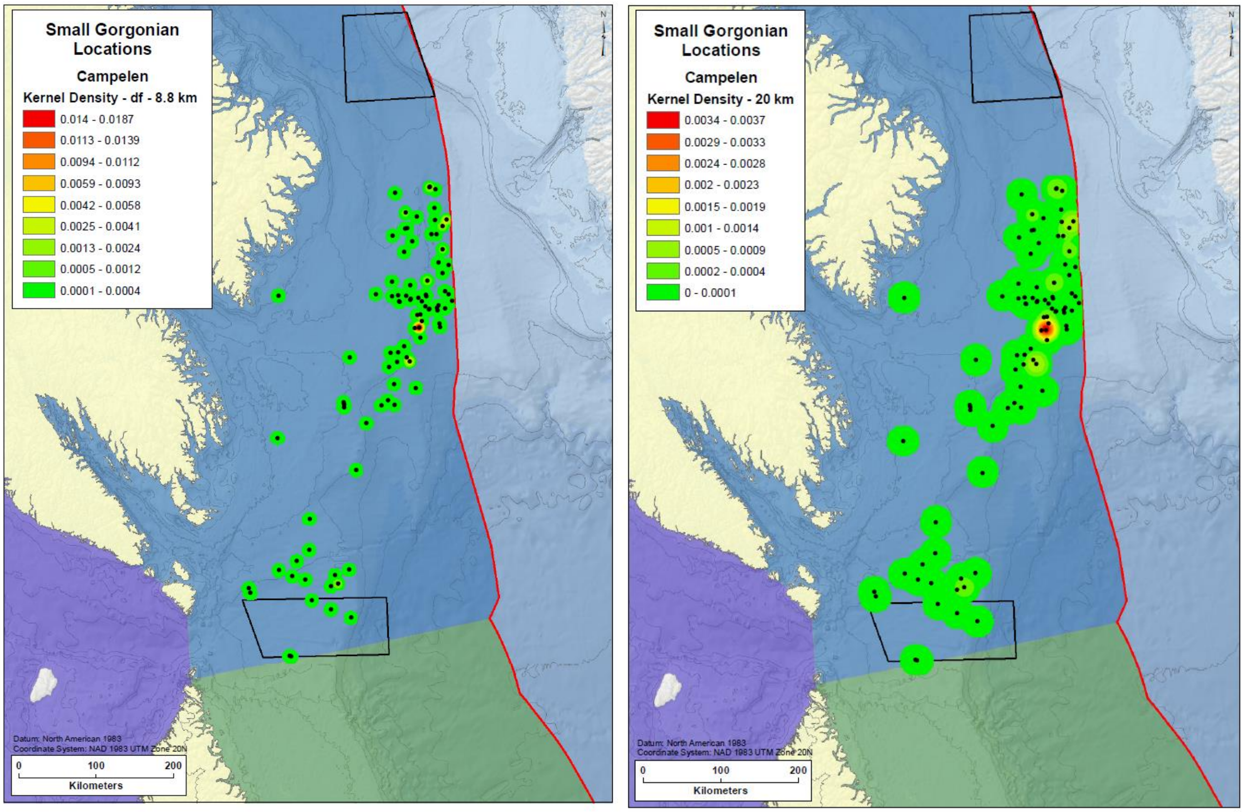

Figure 155. KDE surface of small gorgonian coral biomass produced with the default (df) search radius (8.8 km) (left) and a 20 km search radius (right). Tow locations with small gorgonian coral catch used in the analysis are indicated in black.

Selection of the Polygons Delineating Dense Aggregations from Campelen Trawl Data

The area surrounding each small gorgonian coral weight threshold is provided in Table 45 and illustrated in Figure 156. The first large increase in area after the mapping out of the small gorgonian coral beds was found between 0.02 and 0.01 kg where area increased 167% (Table 45, Figures 156, 157). That change was supported by 15 additional data points and was considered to be the threshold delineating significant concentrations of sponges (Table 45). The areas occupy 2,452 km^2 (Table 45).

Table 45. Comparative Small Gorgonian Coral Biomass Polygon Areas Derived from the KDE Analyses with Campelen Trawl Catches. Additional Data and Percent Change is relative to the Next Weight Threshold. The Threshold Selected to Delineate Dense Aggregations of Small Gorgonian Coral is Boxed.

Weight Threshold (kg)	Number of Points in Polygon	Number of Additional Points	Polygon Area (km^2)	Percent Change in Area
0.3	2	-	1	16638
0.1	6	4	119	646
0.05	11	5	891	64
0.03	16	5	1457	68
0.02	21	5	2452	167
0.01	36	15	6550	37
0.003	49	13	8967	27
0.001	71	22	11357	31
0.0002	78	7	14886	

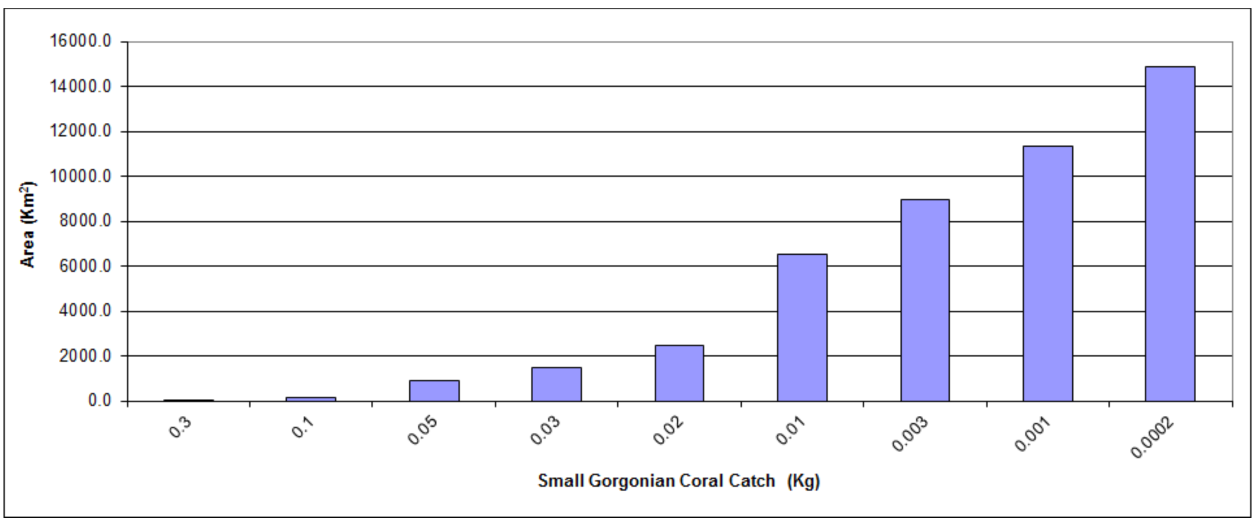

Figure 156. Barplot of polygon area (km^2) associated with small gorgonian coral weight thresholds (kg).

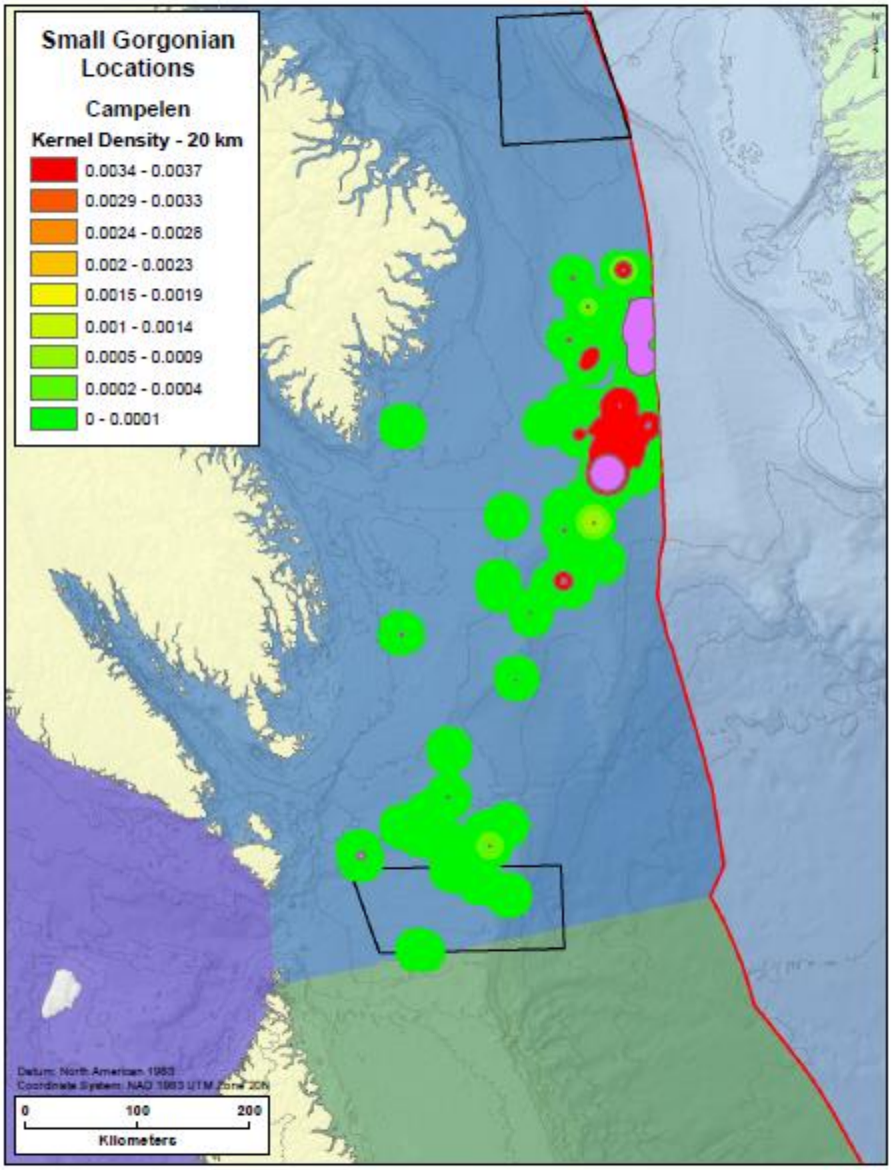

Figure 157. Location of polygons encompassing the ≥0.02 kg catches (purple) and the ≥0.01 kg catches (red), showing the increase in area (Table 45) and overlain on the KDE biomass surface produced with the 20 km search radius.

Location of the Dense Aggregations from Campelen Trawl Data

The locations of areas that indicated significant concentrations of small gorgonian corals are shown in Figure 158 and the locations of the survey tows that defined those polygons are provided in Table 46. Compared with the analysis done in 2010 (Kenchington et al., 2010) the areas are in the same general location and the current analysis has identified both new areas and increased the size of previous areas (Figure 159), although as noted some of that increase is due to over-smoothing.

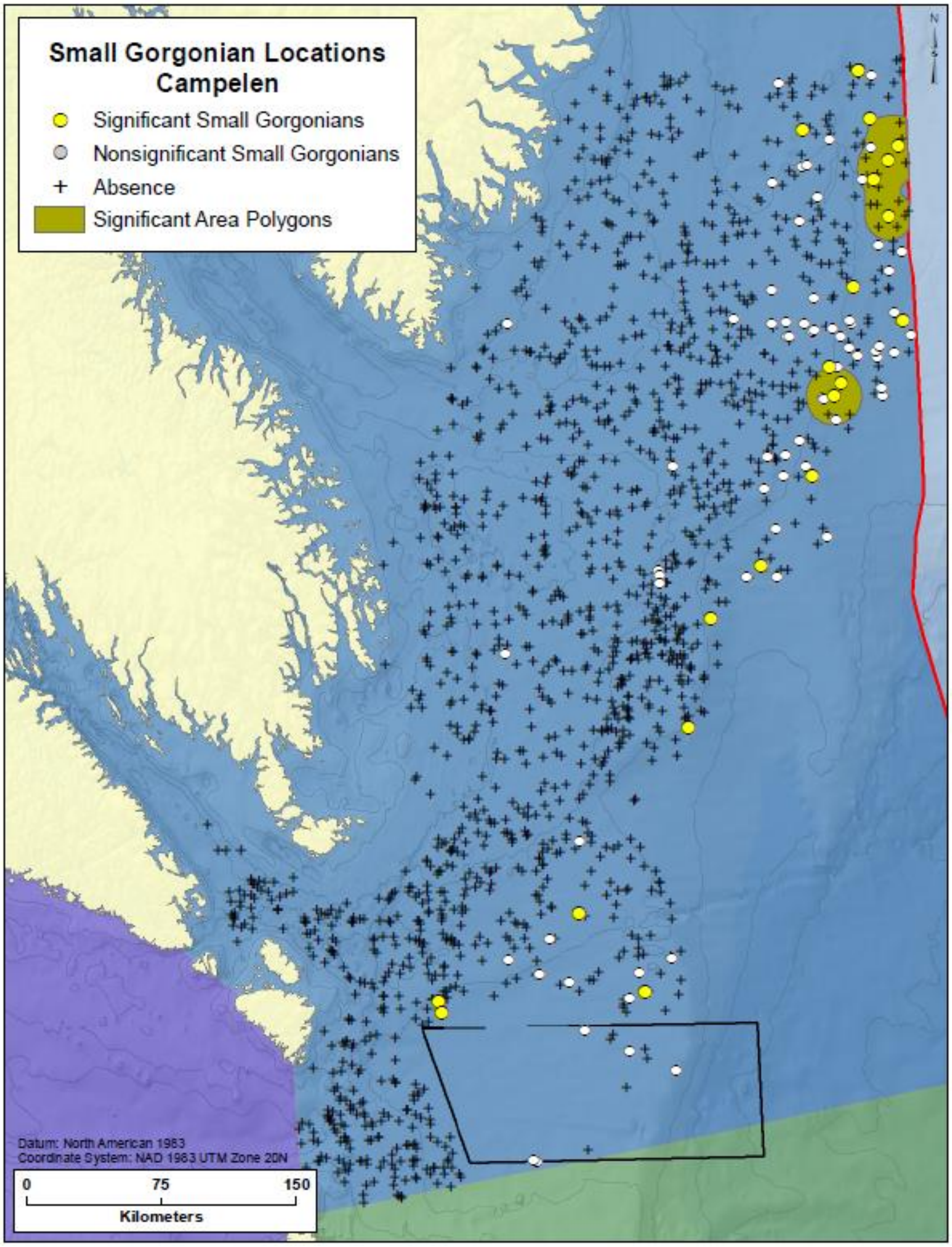

Figure 158. Location of the polygons identifying significant small gorgonian coral aggregations relative to the broader distribution of small gorgonian coral in the Eastern Arctic. Small gorgonian coral catches that contributed to the identification of the polygons are indicated as significant (Table 46), while those not used to define the polygons are indicated as nonsignificant. Null data (absence) is indicated by the black cross.

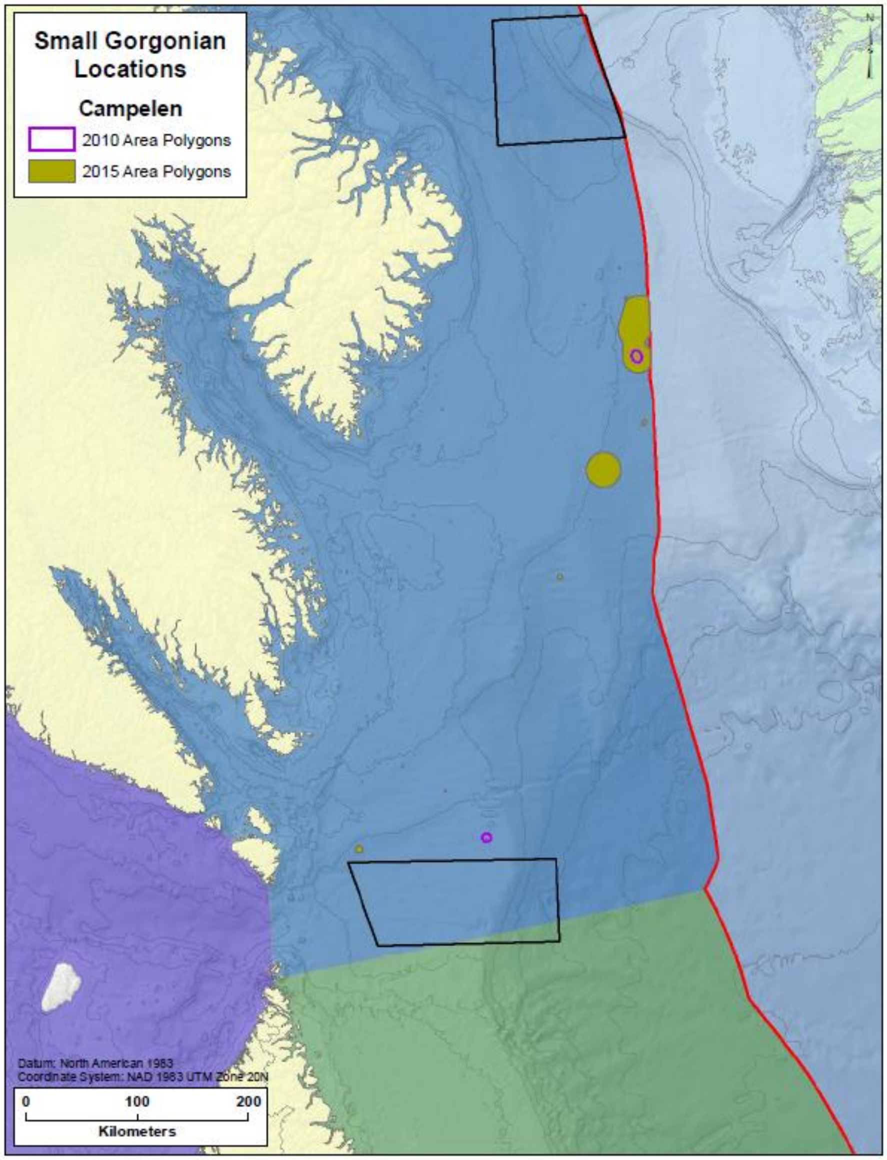

Figure 159. Comparison of the location of the significant concentrations of Campelen trawl-caught small gorgonian corals identified in Kenchington et al. (2010) (purple outline) and those identified in this study (olive polygons).

Table 46. Eastern Arctic Biogeographic Zone, Davis Strait: Details of the Location of Research Vessel Small Gorgonian Coral Catches from Campelen Trawls used to identify the Significant Area Polygons. *Set number is the last 3 digits of the string.

Year	Mission Number and Set*	Start Lat. (DD)	Start Long. (DD)	End Lat. (DD)	End Long. (DD)	Small Gorgonian Coral Weight (kg)
2007	BAL2007102152	64.59100	-58.77683	64.57883	-58.79383	1.500
2007	BAL2007102149	64.20617	-59.09017	64.19417	-59.10650	0.340
2010	BAL2010105119	65.81220	-57.79882	65.82828	-57.82098	0.270
2009	BAL2009104210	65.74317	-57.92983	65.75450	-57.94433	0.140
2006	BAL2006101094	61.67167	-61.16167	61.68500	-61.15667	0.122
2006	BAL2006101124	65.12500	-58.46000	65.13667	-58.44333	0.110
2013	AQV2013108197	66.20552	-58.20248	66.21768	-58.19113	0.090
2008	BAL2008103175	65.47283	-57.97383	65.45867	-57.97267	0.080
2013	AQV2013108198	65.92978	-58.94392	65.91648	-58.95840	0.070
2006	BAL2006101119	64.73667	-58.80667	64.74167	-58.78333	0.050
2010	BAL2010105150	64.66138	-58.68850	64.66753	-58.66127	0.050
2008	BAL2008103095	62.98217	-60.61400	62.97133	-60.62733	0.040
2008	BAL2008103151	63.77083	-59.72167	63.77100	-59.75267	0.040
2010	BAL2010105120	66.20172	-58.20583	66.19037	-58.21910	0.040
2008	BAL2008103117	63.51667	-60.31050			0.039
2008	BAL2008103176	65.65467	-58.11733	65.64233	-58.09933	0.030
2013	AQV2013108196	65.95875	-58.10960	65.96787	-58.12153	0.025
2006	BAL2006101101	62.07000	-61.84833	62.07833	-61.82667	0.020
2006	BAL2006101121	64.95000	-57.91000	64.96167	-57.90500	0.020
2007	BAL2007102210	61.63050	-63.33600	61.63333	-63.30933	0.020
2007	BAL2007102211	61.57683	-63.29967	61.58217	-63.27933	0.020

Overview for Large and Small Gorgonian Corals in the Eastern Arctic

The two different gears collectively cover the fishing grounds in the Davis Strait area. When the polygons from the separate analyses are overlain there is good congruence between areas where the surveys overlapped (Figure 160).

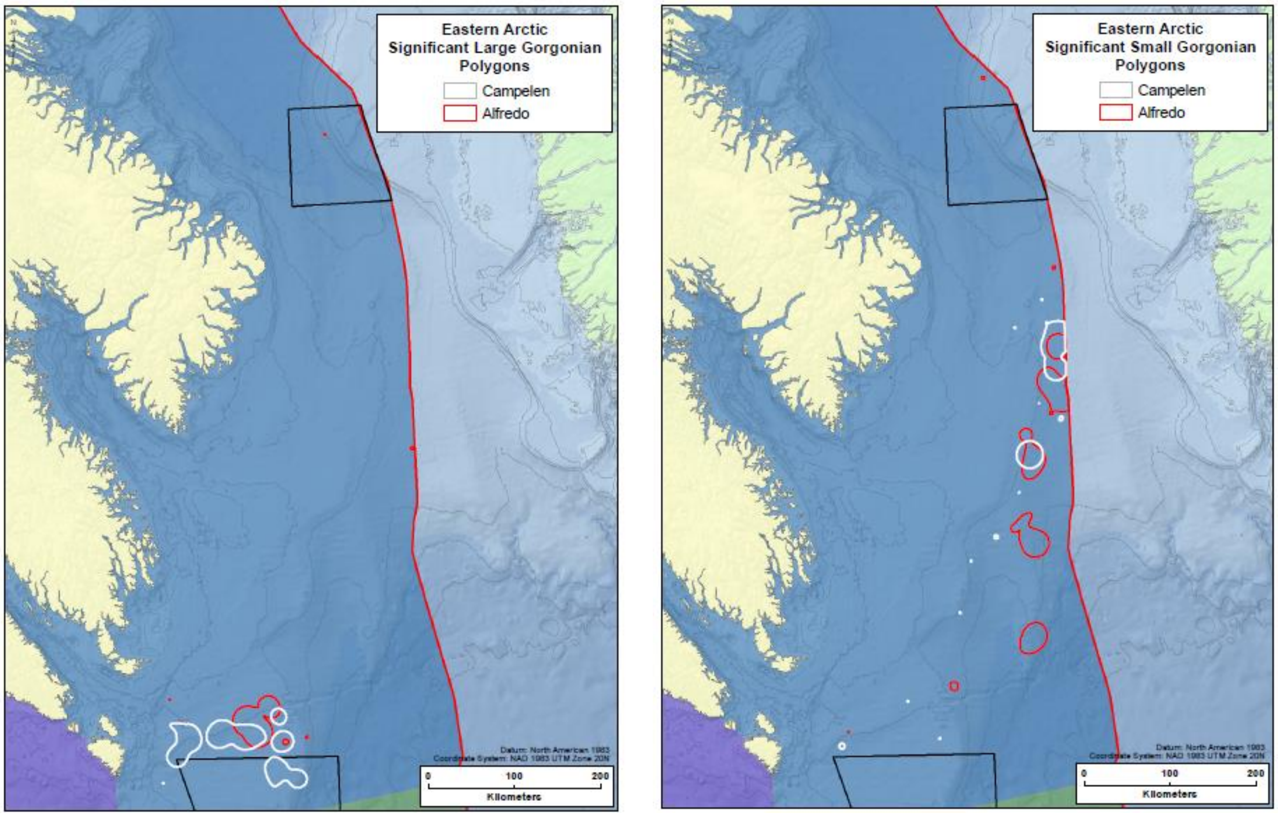

Figure 160. Location of significant concentrations of large (left panel) and small (right panel) gorgonian corals identified through KDE analyses for each of 2 gear types (Campelen and Alfredo trawls).

DISCUSSION

Canada is legally obligated to take action in response to the United Nations General Assembly (UNGA) Resolution 61/105 and other international agreements to identify and protect sensitive benthic marine species and habitats. In 2009, Fisheries and Oceans Canada (DFO) developed the Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas. Guided by the Sustainable Fisheries Framework, which provides the basis for ensuring Canadian fisheries are conducted in a manner that supports marine conservation and sustainable resource use consistent with the Fisheries Act, Oceans Act, and Species at Risk Act, the Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas called for the development of an Ecological Risk Analysis Framework to analyze the impacts of commercial, recreational, and Aboriginal fisheries on sensitive benthic habitat and species both within and outside Canada's 200 nautical mile exclusive economic zone. The policy outlined a two-step process for identifying Sensitive Benthic Areas: 1) determination of ecological or biological significance of the area, and 2) determination of the sensitivity of the area to proposed or ongoing fishing activity. The policy specifically highlights the need for improved knowledge on the location and type of benthic species, particularly in frontier areas, i.e., areas where no current fishing activity takes place and little or no available information on the benthic habitat, communities, or species. Due to the high level of uncertainty, frontier areas receive a higher level of risk aversion in order to reduce the potential impacts of fishing activities.

Significant Benthic Areas are defined in DFO's Ecological Risk Assessment Framework (ERAF) as "significant areas of cold-water corals and sponge dominated communities", where significance is determined "through guidance provided by DFO-lead processes based on current knowledge of such species, communities and ecosystems" (http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/risk-ecolo-risque-eng.htm). The selection of species groups used in these analyses were governed by those performed in the previous analyses (Kenchington et al., 2010) where the corals and sponges identified as vulnerable marine ecosystem (VME) indicators in the Northwest Atlantic Fisheries Organization (NAFO; NAFO, 2014) were the focus of the Canadian review. Other corals that are not considered to be VME indicators, such as the nephtheid soft corals, black corals and the stony cup coral *Flabellum* spp. were not considered herein, but can be relevant to conservation in different contexts. Equally, other species groups considered by NAFO to be VME indicators, that is, erect bryozoans, large sea squirts, Crinoidea, and tube dwelling anemones (NAFO, 2014), were not considered here, and not all of those groups are amenable to this analytical approach as they aggregate on spatial scales smaller than the trawl distance of approximately 1 km, or are non-aggregating.

Our analyses were conducted within biogeographic zones as an attempt to work with similar species compositions. This is particularly relevant when the data are not fully ascribed to species and can include species compositions with different morphologies and biomass. For this reason, the threshold values for a taxon (e.g., sponges) derived from the same survey gear can differ amongst the different biogeographic zones (e.g., comparing thresholds with Campelen gear for sponges across biogeographic regions). This is an expected result and is particularly relevant when shelf systems such as Hudson Strait are compared with regions with continental slope fauna. This will also influence the results within regions where both shelf and slope fauna with widely divergent species morphologies and biomass may occur. This arises primarily with sponges in the Newfoundland and Labrador and Eastern Arctic biogeographic regions. There, large massive sponge grounds (Knudby et al., 2013) occur on the slopes (these are not found in the Scotian Shelf Biogeographic Zone), and smaller more delicate species are found on the shelves. KDE will put an emphasis on the heavier, highly aggregated slope species. This issue is not so relevant to the gorgonian corals and sea pens, where the different species that could comprise the taxa have similar weights, if not morphologies. More precise identification of the sponges in each region would allow for separate analyses based on size/biomass as was done for the gorgonian corals.

The polygons identified through the KDE analyses identify significant biomass aggregations from research vessel trawl catch data. Trawl catches of corals and sponges are the result of a stochastic sampling process from a latent (unobserved) mean density on the ocean floor. Catches sampled from the same latent density can vary considerably from one set to another due to the distributional properties of marine biota (e.g., fine scale patchiness in distribution) and an often low and variable catchability to survey trawl gear. This is generally termed observation error. KDE does not explicitly account for observation error. Catches are assumed to be 'perfect' observations and neighboring catches of different magnitude are effectively viewed as reflecting a small scale gradient in density when these catches may be the result of sampling from the same latent density. Some caution is therefore required in interpreting the boundaries of purported areas of a certain density as these boundaries may be more dispersed than otherwise implied by the KDE surface.

The boundaries of the polygons can and should be refined using more detailed site-specific data from both environmental and fishery sources. The analysis is not intended to produce hard boundaries for management decisions, but rather to focus attention on the key areas for identifying significant concentrations of corals and sponges. Figure 161 shows that within the polygon delimiting the catches above the threshold, there are smaller catches, null catches and unsurveyed areas. It also shows that there are sea pens outside of the polygon. The patchy distribution within the polygons (and elsewhere) may be ecologically relevant and should not be considered as an indication of poor habitat quality. As mentioned previously, smaller catches may reflect recruitment, thinning from fishing (science and commercial) and even observation and/or data entry errors. NAFO considers the polygons to represent significant concentrations of vulnerable marine ecosystem indicators under the Precautionary Approach (NAFO, 2014). The limitations of the spatial resolution of the models, particularly at the borders, are acknowledged (NAFO, 2014).

We also point out that the KDE polygons are subject to change and are influenced by the search radius used. By optimizing the radius in the way we described earlier, we reduced the subjectivity of this element but in some cases we chose to use smaller or larger values; more often larger values were used in order to perform the aerial analysis on a continuous surface. Over-smoothing will create larger polygons around the data, however if used in combination with SDMs this should not be an issue. Additional data that changes the spatial data extent and/or changes the density structure of the points over the surface will also change the kernel surface even if the search radius is unchanged. This was seen in the figures that compared the results from the 2010 analyses (Kenchington et al., 2010) with the current analyses. This can produce changes to the number and/or shape of the polygons which in some cases may be informative in and of themselves (e.g., Kenchington et al., 2012). A simple sensitivity analysis could be conducted by applying KDE at each given year separately to create an averaged KDE output. While an optimal search radius would need to be identified each year, a comparison of average versus aggregated KDE outputs could be used to identify potential shifts in species hotspots. This should be considered in future analyses.

The KDE method only uses the geo-referenced biomass data from the trawl surveys to construct the polygons. In some cases it may be important to closely refine the boundaries of the polygons, particularly if they lie over a depth gradient, or to consider whether a species group occurs in an area not sampled by the survey. Species distribution models (SDMs; e.g., Beazley et al., 2016a,b; Guijarro et al., 2016; Murillo et al., 2016) can be used to refine the boundaries of the polygons and to identify potential areas of occurrence and/or high biomass in unsampled areas. Figure 162 shows the same polygon identified in Figure 161 overlain on a modeled distribution of sea pen presence/absence probability (Murillo et al., 2016). The random forest (RF) model (Figure 162) in this example shows a very high presence probability of the sea pens throughout most of the polygon, with lower probability outside. The SDM predicts that the polygon has potential for sea pen habitat even in areas where no data were available.

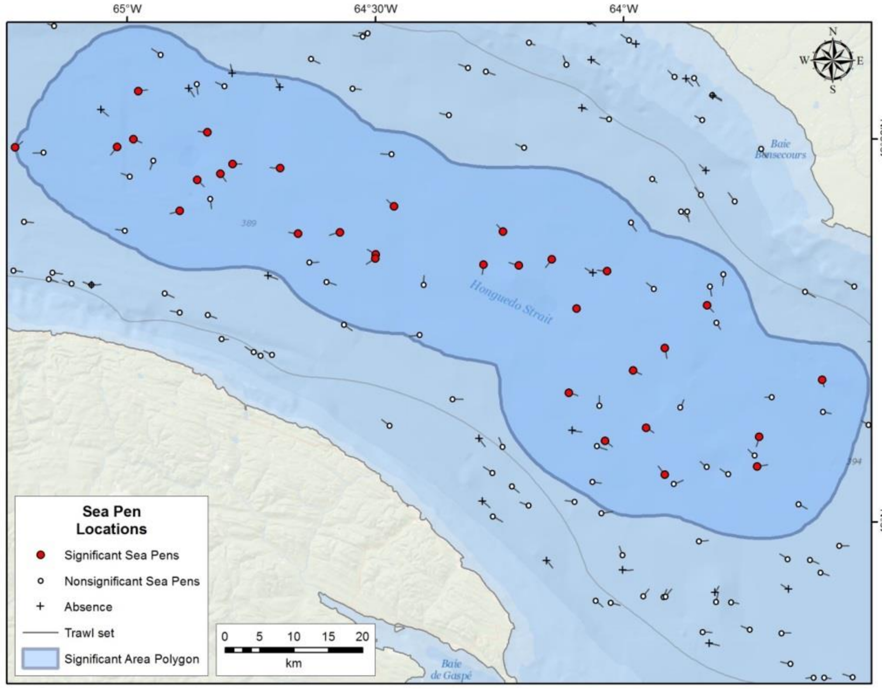

Figure 161. Close up of all catches within a single polygon identifying significant concentrations of sea pens in the Gulf of St. Lawrence. The start and end of each tow is plotted.

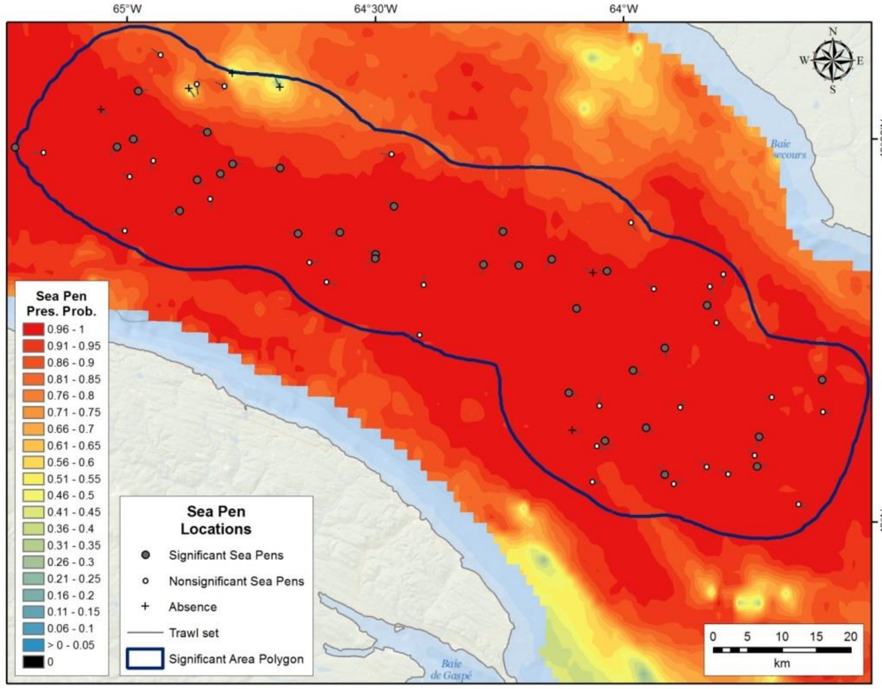

Figure 162. Close up of all catches within a single polygon identifying significant concentrations of sea pens in the Gulf of St. Lawrence overlain on a random forest model of sea pen presence probability (Murillo et al., 2016).

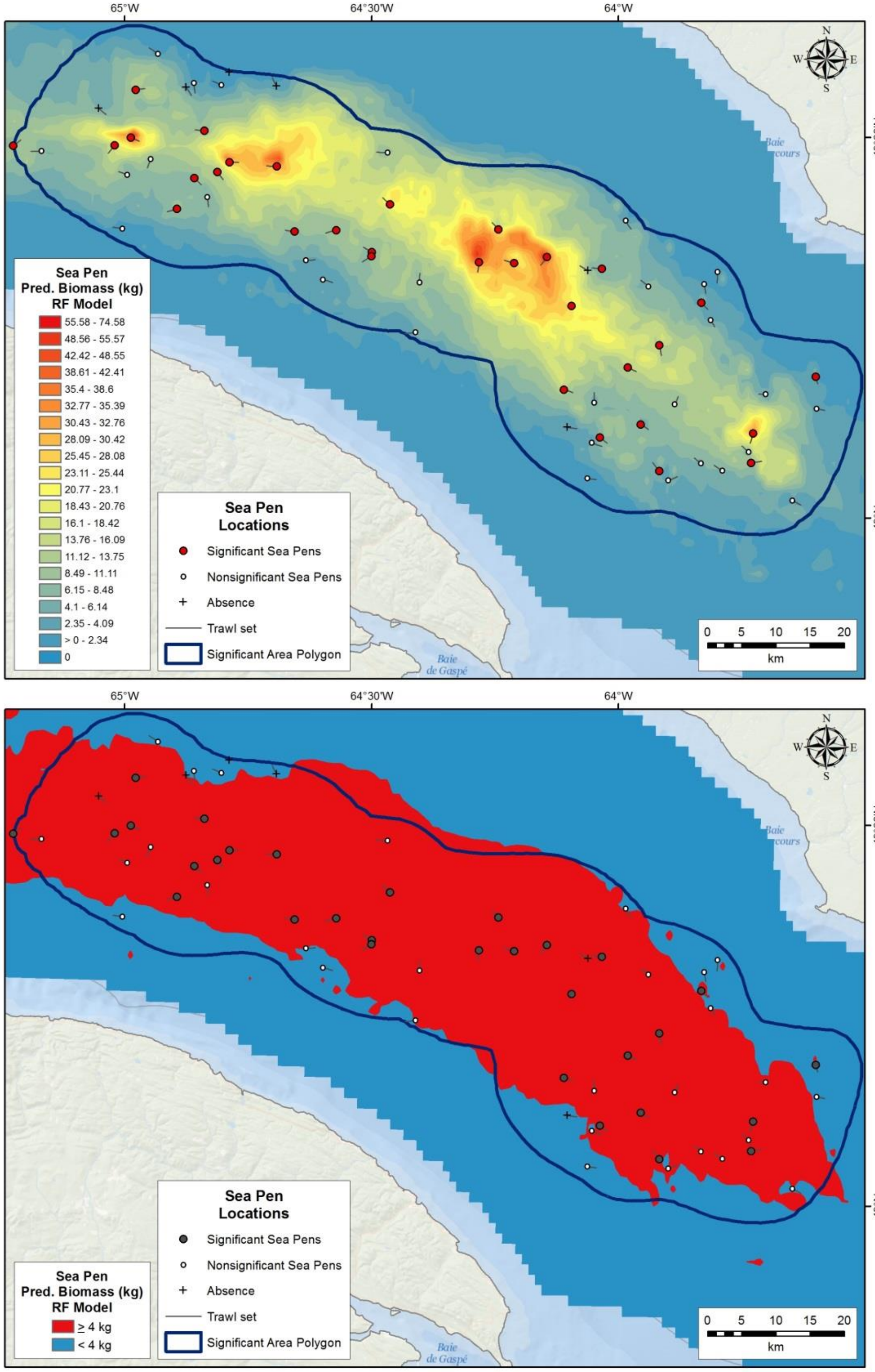

Figure 163. Close up of all catches within a single polygon identifying significant concentrations of sea pens in the Gulf of St. Lawrence overlain on a random forest biomass model of sea pen predicted biomass (Murillo et al., 2016). Upper panel: Full biomass prediction; Lower panel: predicted area for sea pen biomass ≥ 4 kg, the threshold used to define the KDE polygon.

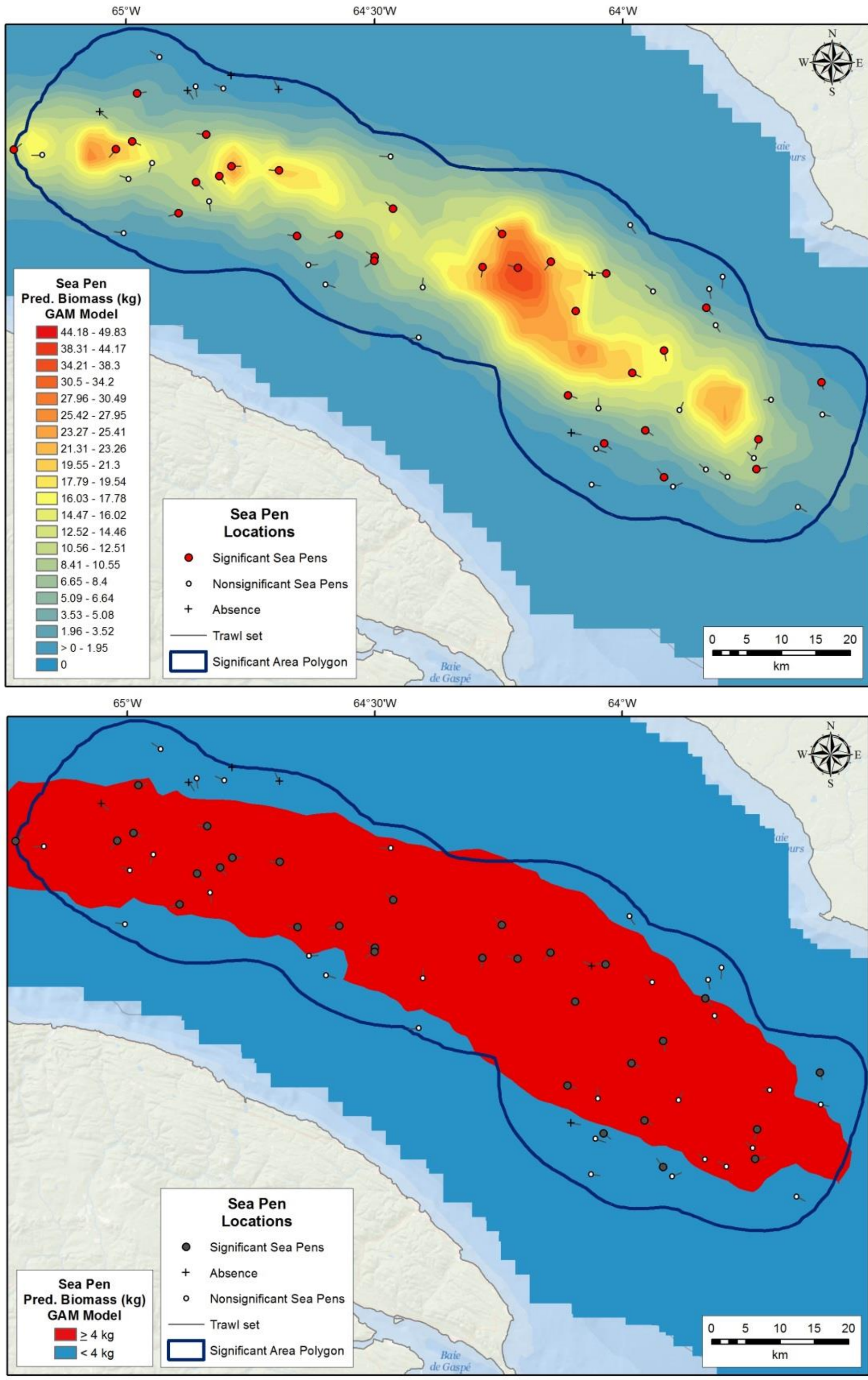

Figure 164. Close up of all catches within a single polygon identifying significant concentrations of sea pens in the Gulf of St. Lawrence overlain on a GAM biomass model of sea pen predicted biomass (Murillo et al., 2016). Upper panel: Full biomass prediction; Lower panel: predicted area for sea pen biomass ≥ 4 kg, the threshold used to define the KDE polygon.

A SDM run on biomass using the RF method shows that the area predicted to have high biomass is smaller than the KDE polygon (Figure 163). In the upper panel of the figure all biomass is shown while in the lower panel the biomass used to define the KDE threshold has been selected and mapped, showing that the RF model could be used to trim the polygon while maintaining the biomass identified in the KDE analysis. Machine learning techniques such as RF can also be compared with regression models such as generalized additive models (GAMs). This comparison is elaborated on in Murillo et al. (2016) but here we show the comparative results to Figure 163 produced from GAMs (Figure 164). In this instance the RF model seems a better fit to the data, and offers less scope for trimming the KDE polygon than the GAM output. NAFO has provided managers with KDE polygons, species distribution maps and fishing locations to assist in the development of management measures to protect vulnerable marine ecosystems (NAFO, 2014).

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APPENDIX 1

Geospatial Analytical Tools Used to Determine Significant Concentrations of Benthic Structure-forming Species or Species Groups

An automated model was developed using geoprocessing tools in order to reduce subjectivity in determining the area surrounding catches above different biomass levels on a kernel density surface. Here we present an improved version which more fully automates the process through to exporting model outputs to MICROSOFT EXCEL.
MODEL BUILDER, a visual programming language used within ARCGIS 10.2, was used to create customize geoprocessing tools to improve project workflows. Three of these customized tools have been developed to create significant concentration area polygons of coral and sponge taxa. The first tool, DENSITY POLYGON GENERATOR, creates a kernel density surface from the weight (biomass) values of coral and sponge taxa and from this surface density polygons are generated; the second tool, INTERVAL DATASET GENERATOR, creates a series of catch weight threshold datasets from the coral and sponge taxa; the third tool, DENSITY POLYGON DISSOLVER, selects and creates the lowest area polygon which completely contains the dataset that is equal or greater than a given by-catch weight threshold. It then merges the output polygons into a common feature class in which the attribute table can be exported to an excel format where statistical and graphical operations can take place. It should be noted that the first two tools described create outputs that are used as inputs for the third tool.

Descriptions of each of the three tools are provided along with an accompanying figure. In the figures, red ovals represent input data, orange boxes represent individual geoprocessing tools, blue ovals represent adjustable variables for the tools they are pointing to and green ovals represent the output derived from each tool.

Tool 1: Density Polygon Generator

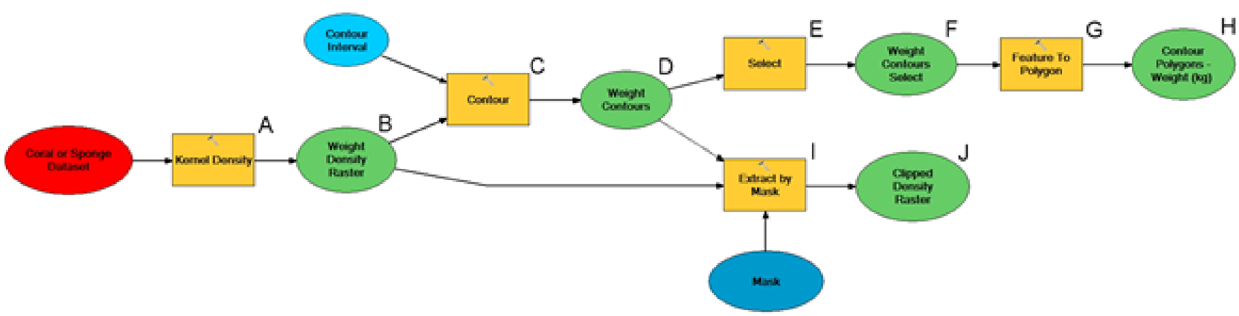

Figure A1. Model used to generate density "donut" polygons from coral or sponge biomass distributions from the catch of research trawls.

In Figure A1, the Kernel Density tool (A) creates a density raster surface (B) by defining a circular neighbourhood (search radius) around each cell. The search radius and cell size were used to create the density surface (see "Details of KDE" above). The tool then sums the total weight found within the search radius of the cell and then divides that number by the resulting search area around each cell. The final result is a running average of features per unit area (Mitchell, 2005). The Contour tool (C) creates output contour lines (D) of the density data in increments that adequately represents the entire extent of the coral or sponge distribution. A high contour interval value of 5.0 x 10^{-4} kg/km^2 and a low contour value of 1.0 x 10^{-7} kg/km^2 was used in the analyses. The Select tool (E) selects only contour line values greater than 0 (F). The Feature to Polygon tool (G) converts the selected lines to polygons. The generated density contour polygons were used as input data for the third tool used in the analysis, the DENSITY POLYGON DISSOLVER. For map display purposes the Extract by Mask tool (I) is used to mask the density surface to exclude land and areas beyond the biogeographic zones.

Tool 2: Interval Dataset Generator

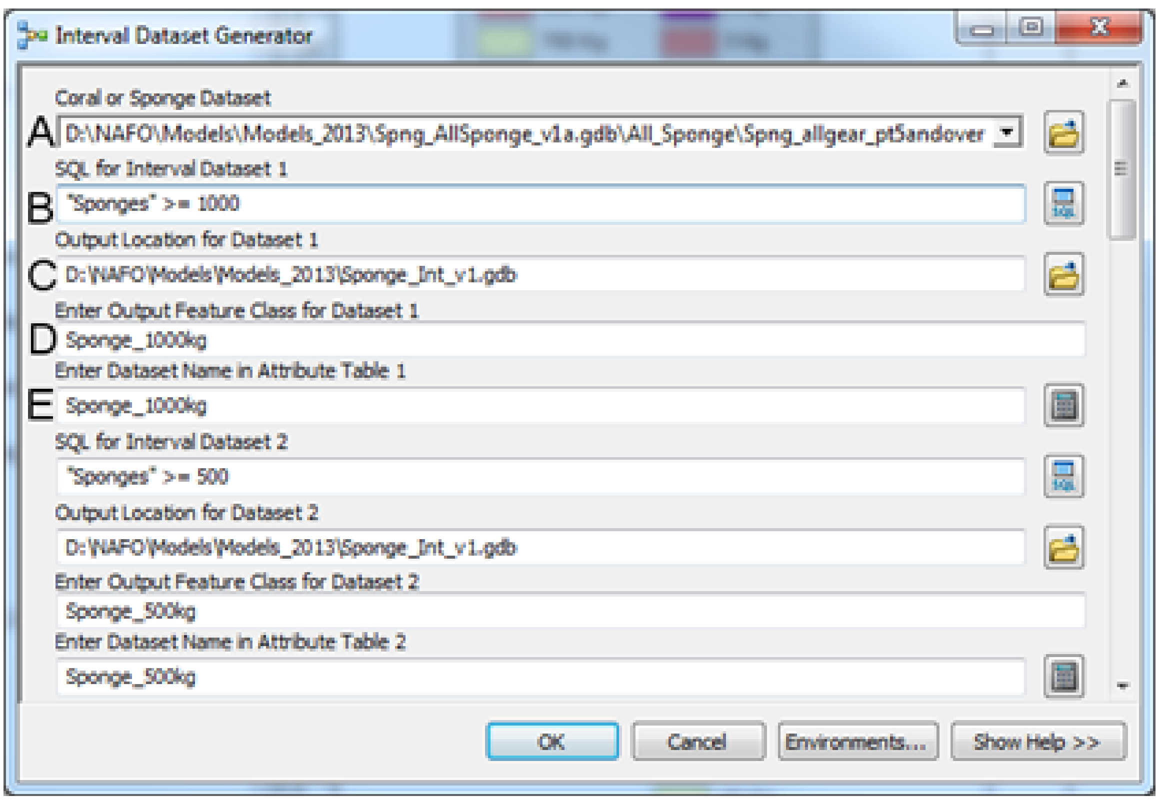

Figure A2. Model Tool Dialogue Box displaying coral or sponge dataset input (A) and two of the nine weight threshold interval input boxes (B-E are labelled for dataset 1).

Figure A3. Model used to create weight threshold interval datasets. In this figure two of the nine links to the input dataset are displayed.

The INTERVAL DATASET GENERATOR tool produces up to nine interval weight threshold datasets of coral or sponge taxon biomass each time the model is run (Figure A2). The INTERVAL DATASET GENERATOR tool (Figure A3) simply links a coral or sponge biomass dataset (A) to nine Feature Class to Feature Class geoprocessing tools (F). The Feature Class to Feature Class tool creates weight threshold interval data by entering an SQL expression (B) which subsets all data above the target weight threshold. To efficiently add the variable data (B-E) into the tool, parameters were created so the model inputs can be added from a model tool dialog box (Figure A2). To run the tool the user enters the coral or sponge taxa biomass dataset (point feature) (A). An interval weight threshold is created by entering an SQL expression (B) and the output location (C) and output feature class name (D) are entered. For this analysis the output location was a geodatabase but the shapefiles could be generated as well. With the use of the Calculate Field tool (G) the final entry, Interval Dataset Name in Attribute Table (E) adds the name of the output feature class to a Name field in the attribute table. Adding the output feature class name in a field inside the attribute table is important in creating the final table created using the third tool, DENSITY POLYGON DISSOLVER. When the tool has completed its run, nine weight threshold interval datasets are created inside a geodatabase.

Tool 3: Density Polygon Dissolver

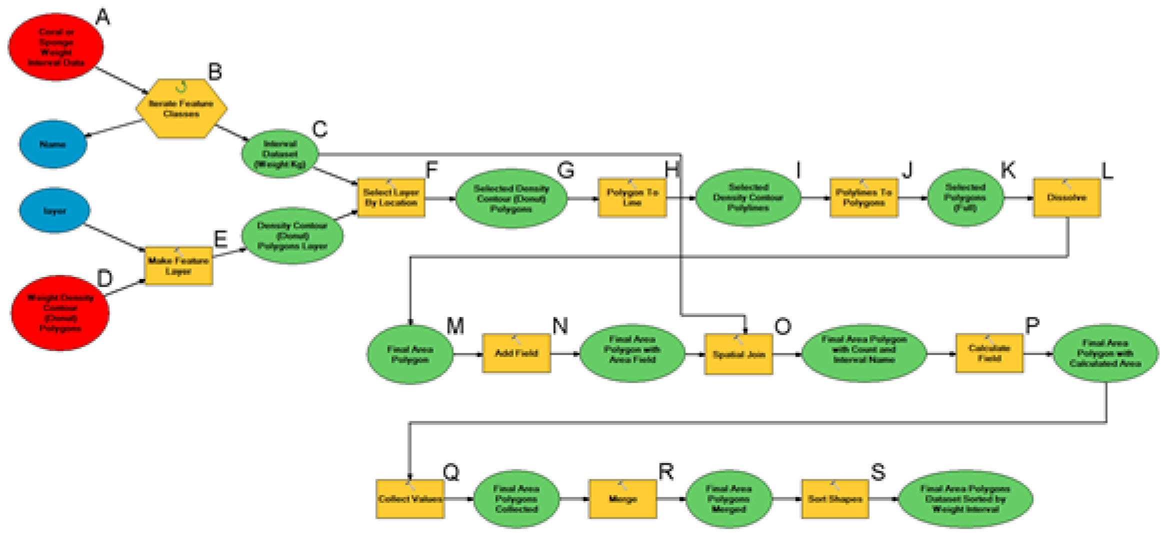

Figure A4. Model used to select the polygon that most tightly encompasses the point data of a particular weight threshold dataset. These polygons are collected and merged into a final feature class. The attribute table of the final feature class is then exported to an EXCEL file format for further analysis.

The weight density polygons, produced with the POLYGON DENSITY GENERATOR (Tool 1), and the weight threshold interval data, produced with the INTERVAL DATASET GENERATOR (Tool 2), are fed into the DENSITY POLYGON DISSOLVER (Tool three). The purpose of this tool is to select the contour polygon which most tightly encompass the subset of points within a given weight threshold and create the corresponding weight threshold polygon. Once the polygon is created, it is collected and merged into a shapefile which contain all the weight threshold polygons created by the model.

The DENSITY POLYGON DISSOLVER is an iterative tool. For each model run, a weight threshold polygon is created for all weight interval datasets (Figure A4). The Iterate Feature Class tool (B) is able to iterate over the group of weight threshold datasets (A), which is the output of the Interval Dataset Generator (Tool 2).

The model begins with the Select Layer by Location tool (F) which is used to select contour polygons (D) that Completely Contain the data points for the first weight interval dataset feeding the model with the iterator. In order for the Select Layer by Location tool (F) to function properly, the density contour polygons (output from Tool 1) must first be converted to a layer (E). This tool selects all "donut" polygons containing at least one data point from the chosen weight threshold. Using the Polygon to Line tool (H), the output donut polygons (G) are converted to density contour polylines (I). Using the Polylines to Polygons tool (J), the polylines are converted back to full polygons (K) with the donut holes filled in. The resulting overlapping polygons are then amalgamated using the Dissolve tool (L) to produce the weight threshold polygon called here, Final Area Polygon (M). The model then adds three fields to the Final Area Polygon. The first field is an area field which calculates the area of the polygon in square kilometres. The Add Field tool (N) creates the field and the Calculate Field tool (P) performs the calculation by dividing values found in a default area field which are measured in metres squared by 1,000,000. The Spatial Join tool (O) adds the next two fields by spatially joining the attributes from the weight threshold interval dataset (C) to the Final Area Polygon (K). A Join Count field produced with this tool indicates the number of points which are contained in the Final Area Polygon. A Name field from the weight interval dataset joins to the Final Area Polygon. This field contains the name of the weight interval dataset. The polygon is now fully processed and is collected with the Collect Values tool (Q) and merged. As the model iterates through the weight threshold interval datasets, the Merge tool (R) combines a newly process polygon with other weight threshold polygons produced by the model into one final feature class. The Sort tool (S) orders the feature class in ascending order by the Join Count field so that the area polygons are ordered from small areas (high weight threshold) to large areas (low weight threshold). The attribute table is then exported in an excel file format to determine significant concentration areas and to produce graphical displays.