Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

National Capital Region
Canadian Science Advisory Secretariat
Science Advisory Report 2017/007

DELINEATION OF SIGNIFICANT AREAS OF COLDWATER CORALS AND SPONGE-DOMINATED COMMUNITIES IN CANADA'S ATLANTIC AND EASTERN ARCTIC MARINE WATERS AND THEIR OVERLAP WITH FISHING ACTIVITY

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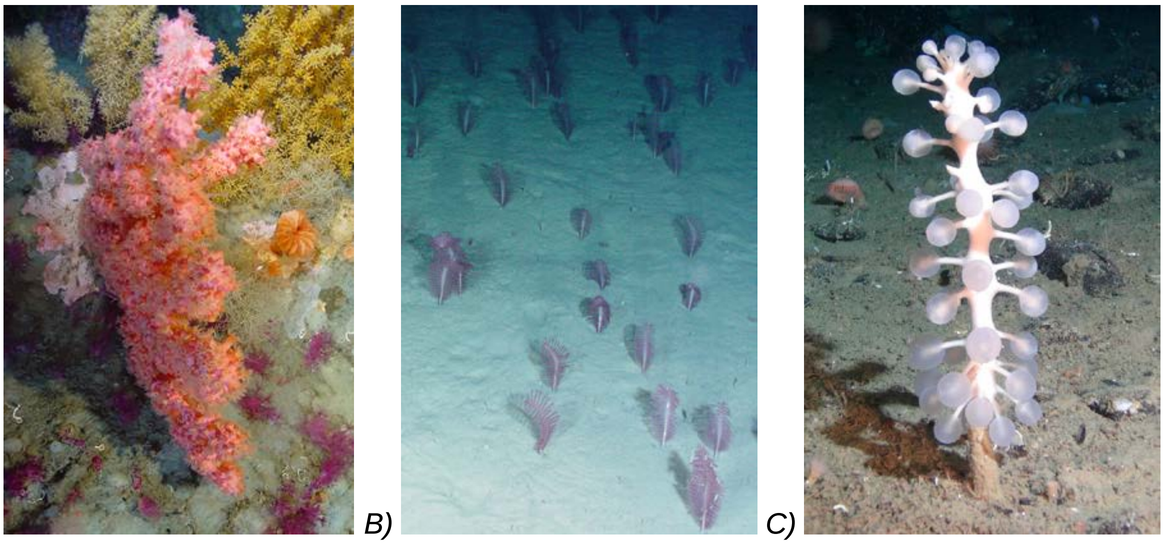


C)

*Figure 1. A) Coral garden (*includes gorgonian *and scleractinian corals) (Photo credit: DFO 2007), B) Pennatula spp. sea pen field on the Southwest Grand Banks (Photo credit: DFO 2007) C) Carnivorous sponge (Chondrocladia spp.) from Baffin Bay (Photo credit: ArcticNet 2015).*

Context:

In 2009, Fisheries and Oceans Canada (DFO) published the Policy on Managing the Impacts of Fishing on Sensitive Benthic Areas (the Policy) to provide a more systematic, transparent, and consistent approach to mitigate fishery impacts on benthic habitats, species, and communities. In order to further advance the implementation of the Policy and the associated Ecological Risk Assessment Framework (ERAF) for coldwater corals and sponge dominated communities, Ecosystems and Fisheries Management sought science advice to refine the delineation of significant areas of corals and sponges and information on the fishing activity in relation to those significant areas.

This Science Advisory Report is based on the March 8-10 2016 national peer review meeting on "Delineation of Significant Areas of Coldwater Corals and Sponge-Dominated Communities in Canada's Atlantic and Eastern Arctic Marine Waters and their Overlap with Fishing Activity". Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- For the purpose of this analysis, a Significant Benthic Area is a regional habitat that contains sponges (Porifera), large and small gorgonian corals (Alcyonacea, formerly classed as Gorgonacea) and/or sea pens (Pennatulacea) as a dominant and defining feature.

- A Sensitive Benthic Area is a Significant Benthic Area that is vulnerable to a proposed or ongoing fishing activity. For the purpose of this analysis, candidate Sensitive Benthic Areas were identified based on the co-occurrence of fishing effort with a Significant Benthic Area. Vulnerability is determined based on the level of harm that the fishing activity may have on the benthic area by degrading ecosystem functions or impairing productivity and is not addressed herein.
- The study area for this analysis is the entirety of Atlantic Canada and Eastern Arctic marine waters, which corresponds to five major Canadian biogeographic units: the Scotian Shelf, the Gulf of St. Lawrence, Newfoundland and Labrador Shelves, Eastern Arctic, and Hudson Strait and Ungava Bay in the Hudson Bay Complex.
- Kernel Density Estimation (KDE), Species Distribution Modelling (SDM) and observations of the taxa were used to delineate Significant Benthic Areas for each of these taxa. Within each biogeographic unit, spatial overlap between Significant Benthic Areas and fishing effort from 2005 to 2014 was quantified.
- Between 1.3% and 15.5% (median = 5.5%) of areas with fishing activity occurred within a Significant Benthic Area depending on the region and the coral or sponge taxa.
- Among the biogeographic units, the percent area of Significant Benthic Areas overlapping with total fishing activity ranged from 6.6 to 77.5% (median = 41.4%). When pelagic fisheries were excluded, the values ranged from 6.6% to 72.2% (median = 37.9%).

INTRODUCTION

The Fisheries and Oceans Canada (DFO) Sustainable Fisheries Framework (SFF) provides the basis for ensuring Canadian fisheries are conducted in a manner which supports conservation and sustainable use. As part of the SFF, DFO published the Policy on Managing the Impacts of Fishing on Sensitive Benthic Areas (the Policy) in 2009 to provide a more systematic, transparent, and consistent approach to mitigate fishery impacts on benthic habitats, species, and communities.

Subsequently, DFO produced two guidance documents to assist with the application of the Policy: DFO's Ecological Risk Assessment Framework (ERAF) for coldwater corals and sponge dominated communities (DFO 2013) and Guidance for Implementation of the Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas (DFO 2014).

A Science Advisory Report (DFO 2010) previously provided the foundation for the delineation of concentrations of coldwater corals and sponges in Canadian waters by providing maps of known locations. Further refinement of the delineation of aggregations of coldwater coral and sponge as Significant Benthic Areas, and information on the fishing activity in relation to these significant areas is required to further advance the implementation of the Policy, including the ERAF. With respect to coldwater corals and/or sponges, a Significant Benthic Area is a regional habitat that contains sponges (Porifera), large and small gorgonians (Alcyonacea, formerly classed as Gorgonacea) and/or sea pens (Pennatulacea) as a dominant and defining feature. These habitats are structurally complex, characterized by higher diversities and/or different benthic communities, and provide a platform for ecosystem functions/processes closely linked to these characteristics.

As per the Policy (DFO 2009), a Sensitive Benthic Area is defined as an area that is vulnerable to a proposed or ongoing fishing activity. For the purposes of this analysis, a Sensitive Benthic Area is a Significant Benthic Area that is vulnerable to a proposed or ongoing fishing activity

(Figure 2). Vulnerability is determined based on the level of harm that the fishing activity may have on the benthic area by degrading ecosystem functions or impairing productivity and is not addressed herein.

This report delineates the Significant Benthic Areas, and overlays fishing activity data from 2005 and 2014 on the Significant Benthic Areas, which provides Ecosystems and Fisheries Management with information to support the identification of Sensitive Benthic Areas. This analysis does not identify Sensitive Benthic Areas.

The study area for this analysis is the entirety of Atlantic Canada and portions of the Eastern Arctic, which corresponds to five major Canadian biogeographic units: the Scotian Shelf, the Gulf of St Lawrence, Newfoundland and Labrador Shelves, and portions of the Eastern Arctic and Hudson Bay Complex (DFO 2009). The kernel density (KDE) analyses were performed using the biogeographic units mentioned above (DFO 2009), consistent with previous analyses (DFO 2010). The species distribution models (SDMs) were performed using DFO Marine Protected Area (MPA) planning regions which are similar but not identical to the DFO Regions.

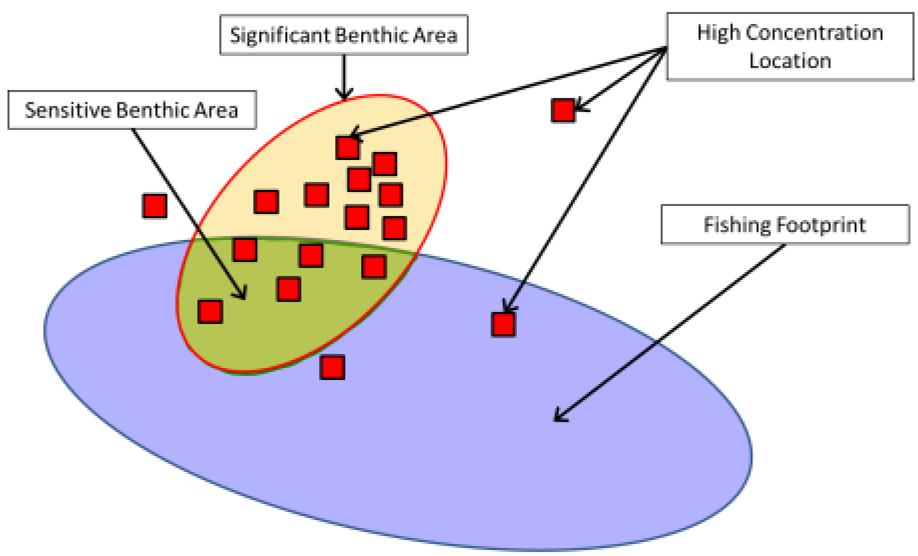


Figure 2. Conceptual model showing the relationship of high research vessel trawl catch locations of corals or sponges (high concentration location) to Significant Benthic Areas, and where the overlap of a fishing activity leads to possible Sensitive Benthic Areas.

For the purpose of summarizing fishing activity for this study, biogeographical units were defined on the basis of the corresponding Northwest Atlantic Fisheries Organization (NAFO) Divisions up to the 200-mile jurisdictional zone. In this study, the Scotian Shelf was defined by NAFO subareas 4VnVsWX and 5YZe, the Gulf of St. Lawrence was defined by NAFO subareas 4RST, Newfoundland and Labrador Shelves was defined by NAFO subareas 2GHJ and 3KLNOPnPs, and Eastern Arctic was defined by NAFO subareas 0AB.Fishing activity was not assessed in the Hudson Strait (part of the Hudson Bay Complex biogeographic unit).

ANALYSIS

Full details of the analyses employed are provided in Kenchington *et al.* (2016) and references therein. A summary of the approaches used are presented below.

Kernel Density Estimation (KDE) of Significant Benthic Areas of Coldwater Coral and Sponge Species

The primary tool used for the identification of Significant Benthic Areas of coldwater corals and sponges was kernel density estimation (KDE) applied to research vessel trawl survey data in each of the biogeographic units (or portions thereof) mentioned above. An updated analysis of Kenchington *et al.* (2010) was performed that added new survey data collected from 2009 to 2015 for the four benthic taxa examined.

KDE 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, (i.e. areas of relatively high biomass/abundance often referred to as 'heat maps'). The KDE modelled biomass surface for each of the four benthic taxa was used to fit finely spaced biomass contours (10^{-4}-10^{-7} kg) over which the original catch locations were positioned (Figure 3). The area occupied by the contours which encompassed all catches above a given weight threshold was then calculated and a comparison was made between the areas occupied by successively smaller weight thresholds. Thresholds defining significant areas (polygons) coincided with the greatest change in area, which signified an expansion of the area outside of the habitat produced by the dense aggregations. These KDE-derived polygons were considered to be the Significant Benthic Areas and as areas of high biomass are linked to benthic habitat formation with associated ecological functions such as increased biodiversity (DFO 2010).

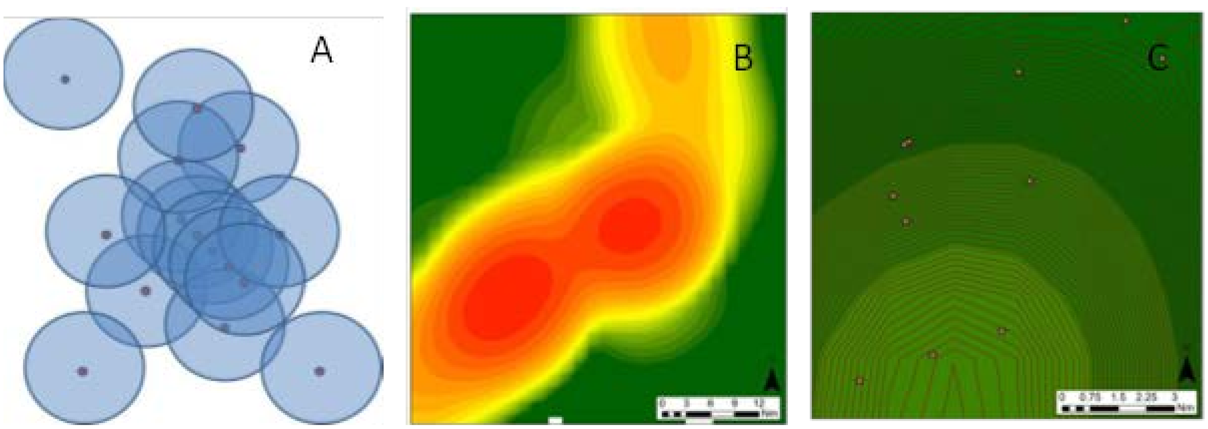


Figure 3. Conceptual model showing the application of the KDE analysis used to identify Significant Benthic Areas of corals and sponges. A) circles are drawn around each data point (start position of trawl survey tow) using an optimized search radius, and a three dimensional 'normal' curve is fit over the circle with its peak at the data point and reaching zero at the periphery; B) KDE is used to create a biomass surface; C) finely spaced biomass contours are drawn over the surface and the original data points (light coloured stars) are overlain. These contours are used to select polygons encompassing catches above iterative weight thresholds and the area enclosed for each is calculated.

Species Distribution Models (SDMs) for Identification of Significant Benthic Areas of Coldwater Coral and Sponge Species

In order to complement the KDE analyses, species distribution models (SDMs) were performed using Random Forest (RF), a non-parametric machine learning technique (Figure 4). These models were applied to the full spatial extent of the MPA planning regions and covered areas not sampled by the trawl surveys (notably deep water and rough bottoms). RF is a robust statistical method requiring no distributional assumptions of the data and can use both presence and absence information in the model. RF can be used to predict the probability occurrence (classification model) or biomass (regression model) of a species in unsampled areas based on its relationship with the environment in sampled areas.

A suite of 54 to 76 environmental variables were used as predictors in RF SDMs for each MPA planning region and included a buffer around the land. Three measures of accuracy were used to assess model performance in the presence-absence RF: 1) sensitivity, 2) specificity, and 3) Area Under the Curve (AUC). The AUC is calculated from the combination of true positive rate, that is, the correct prediction of known presences (sensitivity) and false positive rate and the incorrect prediction of known presences (specificity). Its value ranges from 0 to 1, with values larger than 0.5 indicating performance better than random.

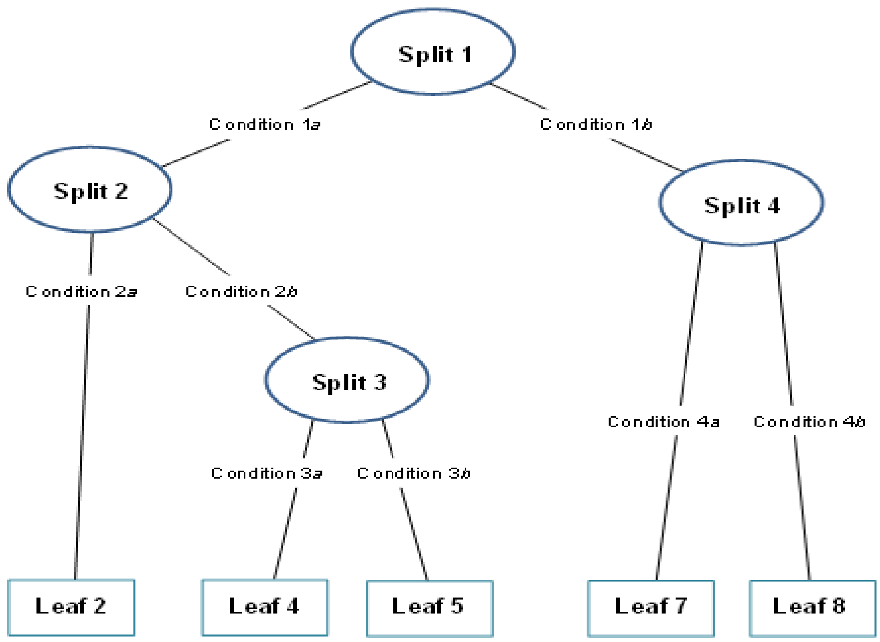


Figure 4. An example of the initial steps in a Random Forest (RF) classification or regression tree. The data is split using the best predictor variable at each step, and each tree is 'built' using random subsets of the data (approximately 2/3rds of the total available data). Consensus is built from multiple tree construction (usually ≥ 500).

Integration of KDE and SDM Results

The information from the two analytical approaches described above was integrated (Figures 5 and 6). Only SDMs that were considered to perform well were included.

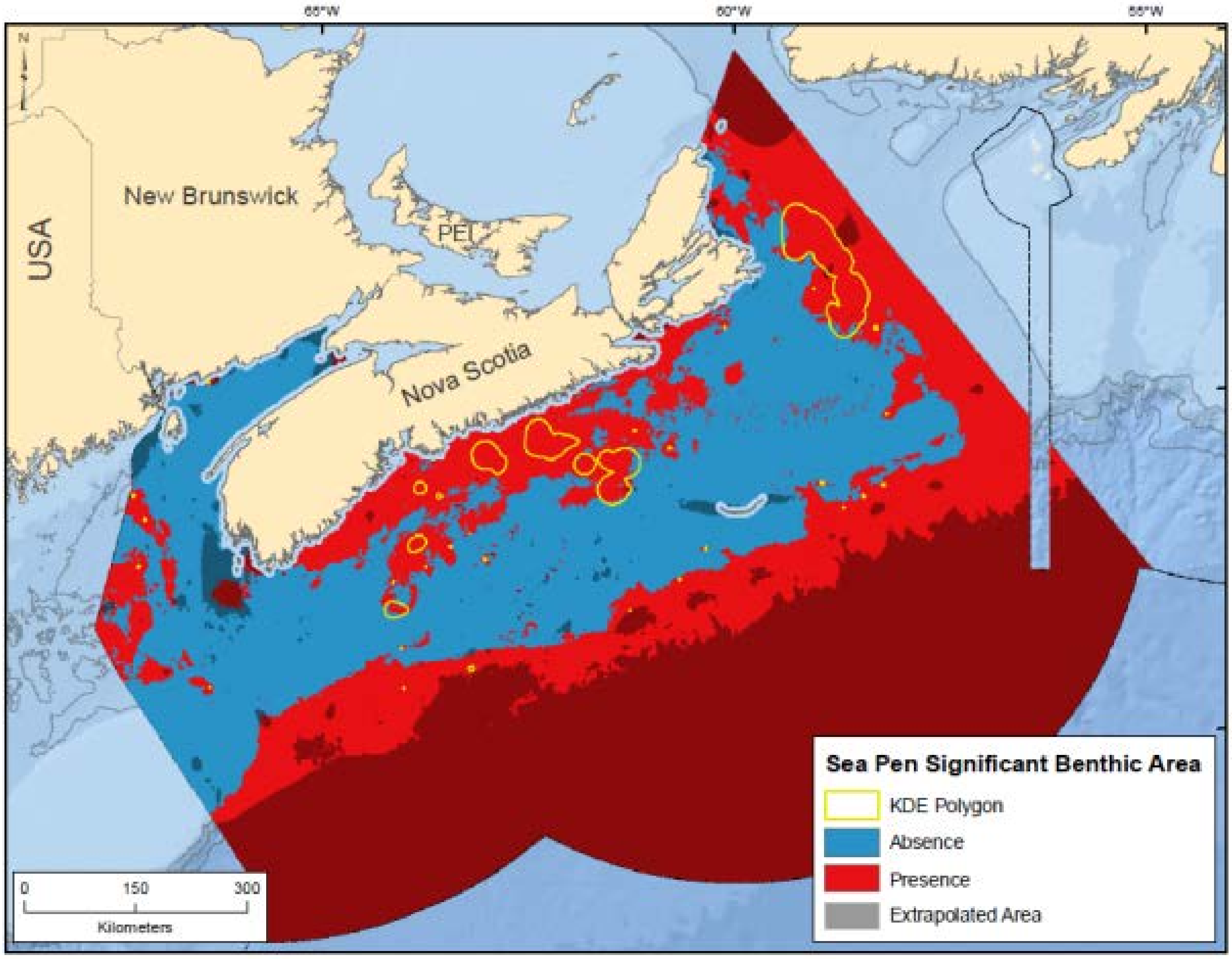


Figure 5. Overlay of sea pen KDE-derived polygons (yellow outline) on the RF presence-absence prediction for the Scotian Shelf. Note that areas of extrapolation appear dark red when overlain on the presence surface and dark blue on the absence surface.

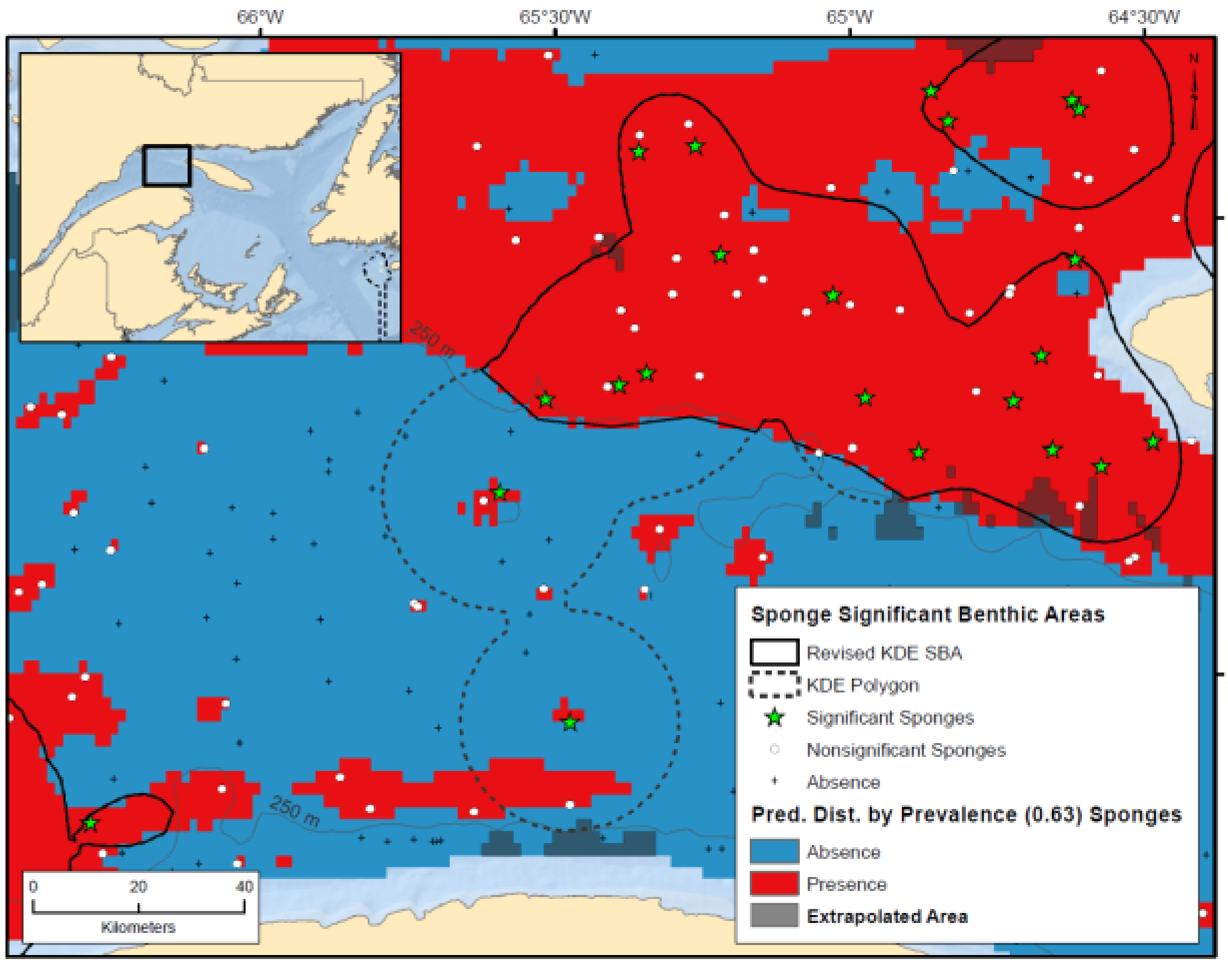


Figure 6. Close up of all catches within a single KDE-derived polygon identifying significant concentrations of sponges in the Gulf of St. Lawrence overlain on a RF model of sponge presence probability.

Refinement of boundaries

Scotian Shelf

There was a high degree of consistency between the KDE-derived polygons and the SDMs for all coral and sponge taxa on the Scotian Shelf (for example, see Figure 5). Consequently, none of the KDE-derived polygons were trimmed. The lower slope and deep water areas off the Scotian Shelf were not fully included in the spatial extent of the research vessel trawl surveys and consequently the KDE approach was not able to delineate significant concentrations of benthic taxa in those areas. It was recognized that those areas coincide with the distribution of the large and small gorgonian corals and sea pens and so new Significant Benthic Areas were drawn using the predicted presence area for the appropriate RF SDM for each taxon. These presence-absence models were considered to be more reliable than the KDE-derived polygons in slope areas due to the inclusion of benthic imagery data in the former analyses.

For small gorgonian corals, the most influential environmental variables in the RF presence-absence model were depth and slope, and predicted presence prevalence followed the 200 m depth contour along the shelf slope. As the 200 m isobath extended well into the Gulf of Maine and onto the shelf where small gorgonians were not predicted to occur by the RF model, the Significant Benthic Area polygon was clipped to the presence prevalence boundary in the Northeast Channel, The Gully, and along the western Laurentian Channel.

For large gorgonian corals, the presence prediction area from the RF presence-absence model was considered a Significant Benthic Area in the slope areas as it showed good congruence with the ecology of the taxa. For sea pens, a similar slope area determined from the RF predicted presence prevalence was recommended as a Significant Benthic Area.

Some of the Significant Benthic Areas may represent linked areas. In Figure 7 the probability scale applied to the RF presence-absence SDM shows that the two sea pen polygons delineated with the KDE may be connected through the area of high probability highlighted in red. This figure illustrates how the probability surface can be used to assess linkage of closely adjacent polygons. At a larger scale, connectivity among the Significant Benthic Area polygons was suggested for the sponges (Figure 8) where three groups of polygons appear to represent ecologically coherent networks that merit further investigation. This figure shows the sponge Significant Benthic Areas derived from the KDE analysis appear to represent ecologically coherent networks consistent with the oceanography of the region. This was evident when the prevalence surfaces were cross-compared to the KDE polygons.

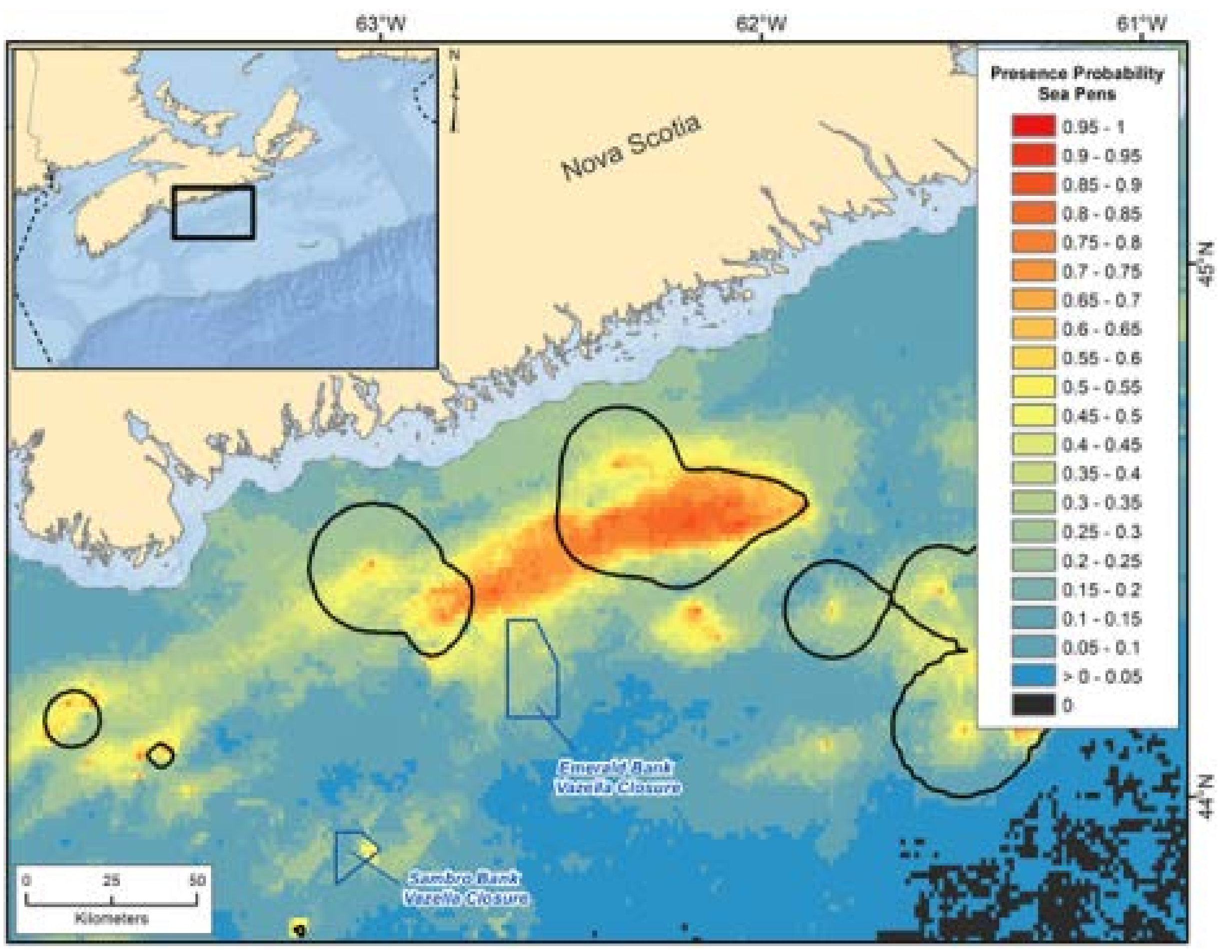


Figure 7. Sea pen significant benthic areas (black outline) identified off the coast of Nova Scotia overlain on the presence probability surface from the RF SDM.

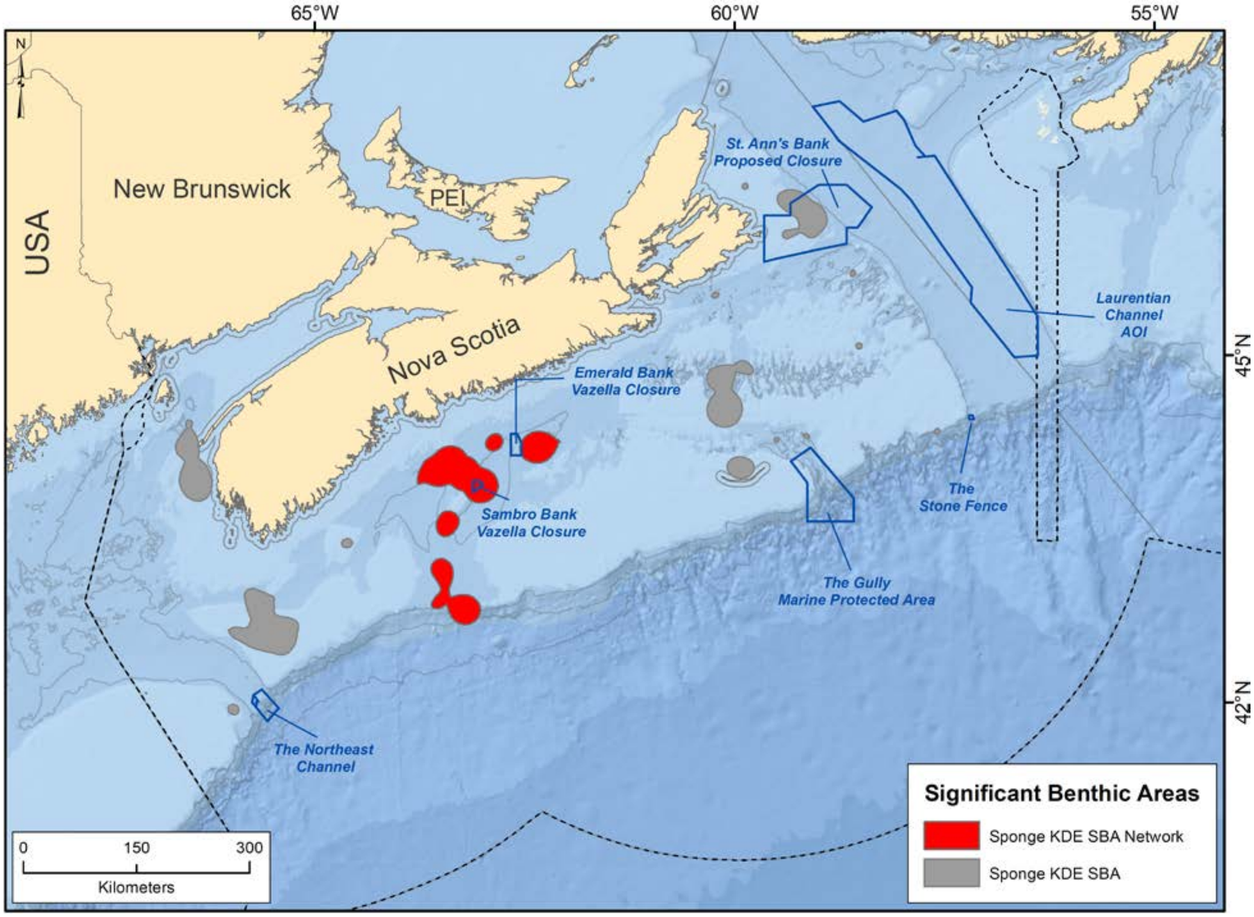


Figure 8. Sponge connectivity among significant benthic area polygons.

Gulf of St. Lawrence

The KDE analysis identified many sponge Significant Benthic Area polygons in the north of the Gulf of St. Lawrence (nGSL) and few and smaller ones in the southern Gulf of St. Lawrence (sGSL). Where the polygons crossed different habitats they were clipped to depth or underlying RF model probability. Two KDE polygons for sponges located south of east Anticosti Island were combined together using the RF species presence-absence model and one KDE-derived polygon to the north of east Anticosti Island was deleted (Figure 9), one to the north was deleted, and one polygon crossing to the land was clipped. In the sGSL, one sponge area south of the Magdalen Islands corresponded roughly with a scallop/sea cucumber fishing area; other smaller polygons surrounding single catches may be formed into meaningful clusters using a nearest-neighbour type of analyses (Figure 10). For these areas, the prevalence prediction surface combined with a nearest-neighbour calculation may help to group smaller areas for protection.

Large, elongated sea pen areas in the Laurentian Channel were probably connected through strong bidirectional (tidal) current. There was good overlap between concentrations in the southern and northern Gulf from the different surveys, overlapping at the shelf break between the two zones. One KDE polygon from the Gulf Region surveys may have extended over the shelf due to contamination in the trawl catches and this polygon was clipped to the 200 m isobath using Canadian Hydrographic Service (CHS) Atlantic Bathymetry Compilation. No substantial overlap between sponge and sea pen Significant Benthic Areas was observed.

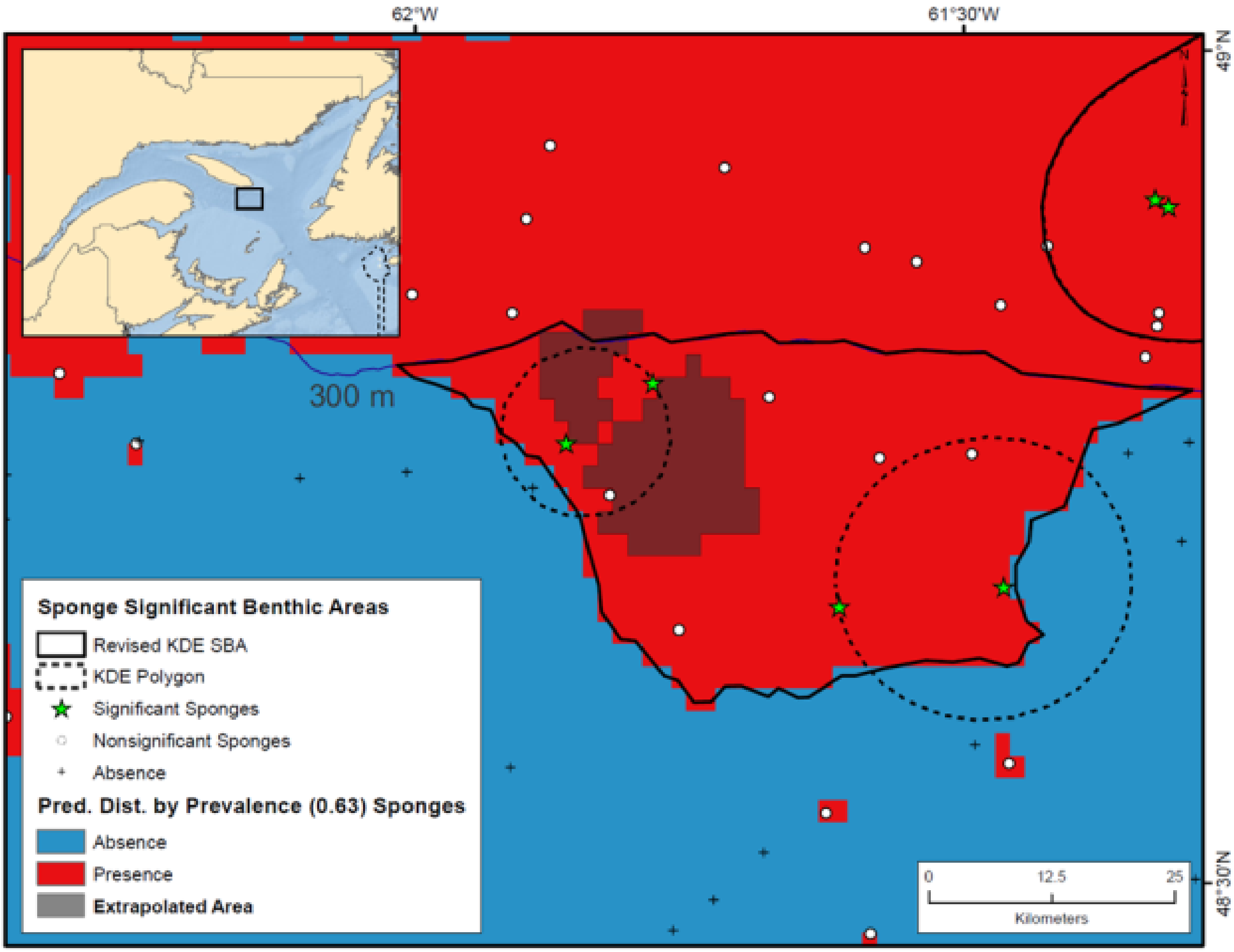


Figure 9. Two small KDE-derived polygons for sponges south and east of Anticosti Island (dashed lines) were combined using the 300 m depth contour to the north and clipping to the presence probability based on the prevalence map from the RF presence-absence SDM for the southern boundary (black outline).

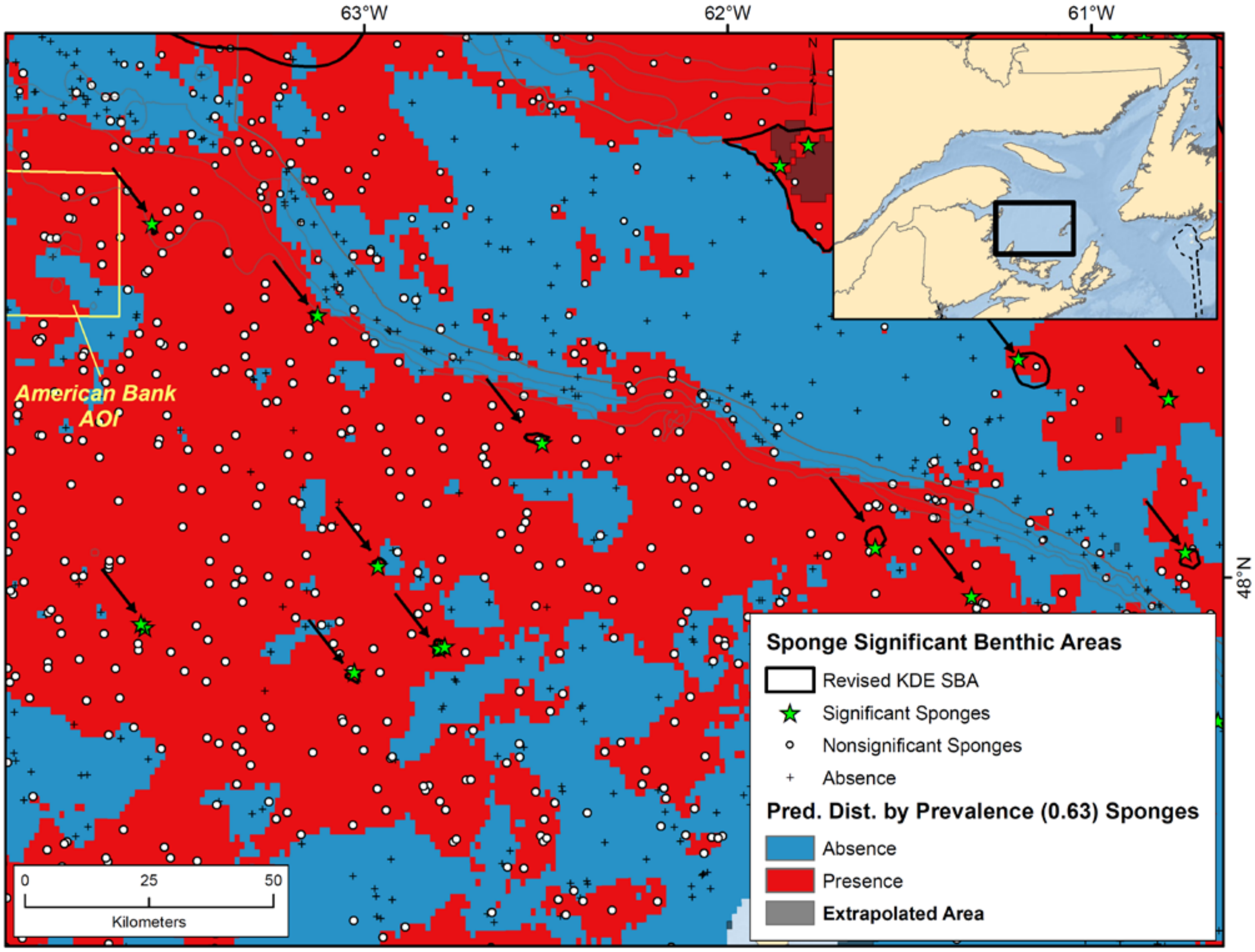


Figure 10. The sponge Significant Benthic Areas derived from the KDE analysis in the southern Gulf of St. Lawrence were often small in area (black lines surrounding green stars), and separated by smaller catches (white circles).

Newfoundland and Labrador Shelves

One sponge KDE polygon located on the edge of Saglek Bank off northern Labrador was modified. The southwestern portion of the polygon was clipped based on the 250 m CHS depth contour to exclude absence areas predicted by the model (Kenchington *et al.* 2016).

One sea pen KDE-derived polygon was modified, and a new Significant Benthic Area for sea pens was added. The modified KDE-derived polygon was located on the northwest boundary of the NAFO 3O Coral Protection Zone. The northern portion of the polygon was clipped along the presence-absence boundary excluding the model absence areas. The new sea pen Significant Benthic Area was located on the continental slope northeast of Newfoundland (Figure 11). This Significant Benthic Area coincided with an area of sea pen presence predicted by the RF model. This area also had a high probability of sea pens based on the probability scale, and had good congruence with sea pen records from the Fisheries Observer Program (FOP) that were used to validate the model. It was clipped to create a single, continuous polygon.

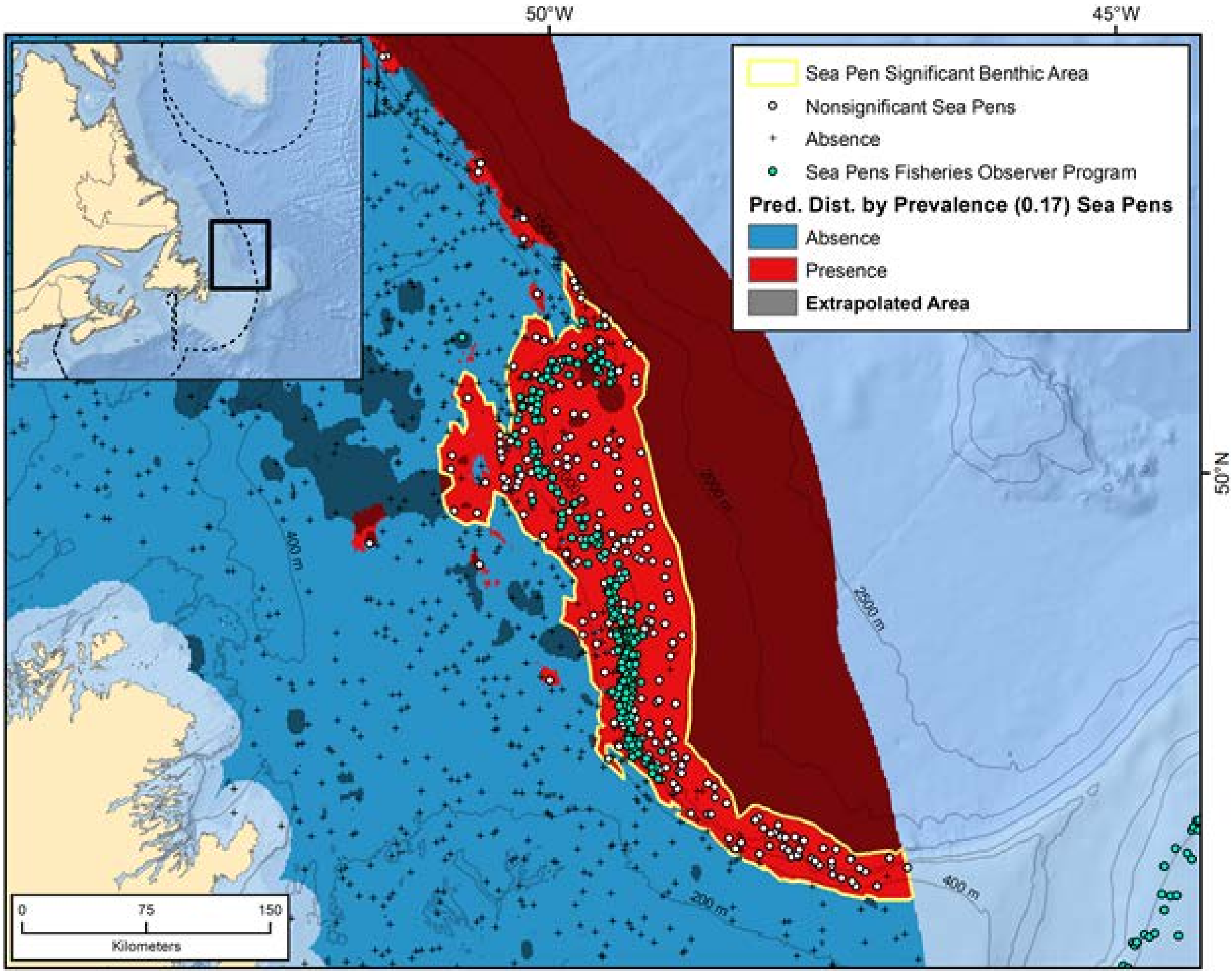


Figure 11. Significant Benthic Area (red area with yellow outline) for sea pens delineated from the RF presence-absence SDM. The area is overlain with all of the catch data (presence of sea pens and absence) as well as with data from the FOP that was not used in the analysis but used to independently validate the presence-absence model.

Three large gorgonian coral KDE-derived polygons were modified from their original extent. All three polygons were clipped to the presence/absence boundary from model prevalence. The first polygon was located along the northwest boundary of the NAFO 3O Coral Protection Zone. The two other modified large gorgonian coral KDE-derived polygons were located along the slope northeast of Newfoundland. These were clipped based on the presence-absence boundary from model prevalence.

Three KDE-derived polygons for small gorgonian corals were modified from their original extent. All three were located along the northern boundary of the NAFO 3O Coral Protection Zone. The westerly-most polygon was clipped based on the 400 m CHS depth contour. This contour closely followed the undulating presence-absence boundary. Most small gorgonian KDE-derived polygons in the Newfoundland and Labrador Region were located below 400 m depth. The other two polygons were clipped based on the presence-absence boundary from model prevalence.

Eastern Arctic and Hudson Strait

There was a high degree of consistency between the KDE-derived polygons and the SDMs for the Eastern Arctic. It was noted that combining the presence-absence maps with the KDE can provide guidance for linking polygons that were proximate to one another. FOP data that was not used in the analysis overlaid the modelled species presence very well. For one location in the Narwhal Overwintering and Deep-Sea Coral Conservation area the presence-absence map was used to expand the KDE polygon, creating a new Significant Benthic Area for large gorgonian corals (Figure 12). This was based on the overlay of a high catch of the large gorgonian coral *Keratoisis* sp. from the FOP data which gave confidence that the KDE polygon was too small to define the habitat.

For Hudson Strait, only the sponges were modeled. The SDM gave only marginal performance (AUC = 0.64) and this area was highlighted as one that could be improved through further survey effort. No changes were made to the KDE-derived polygons.

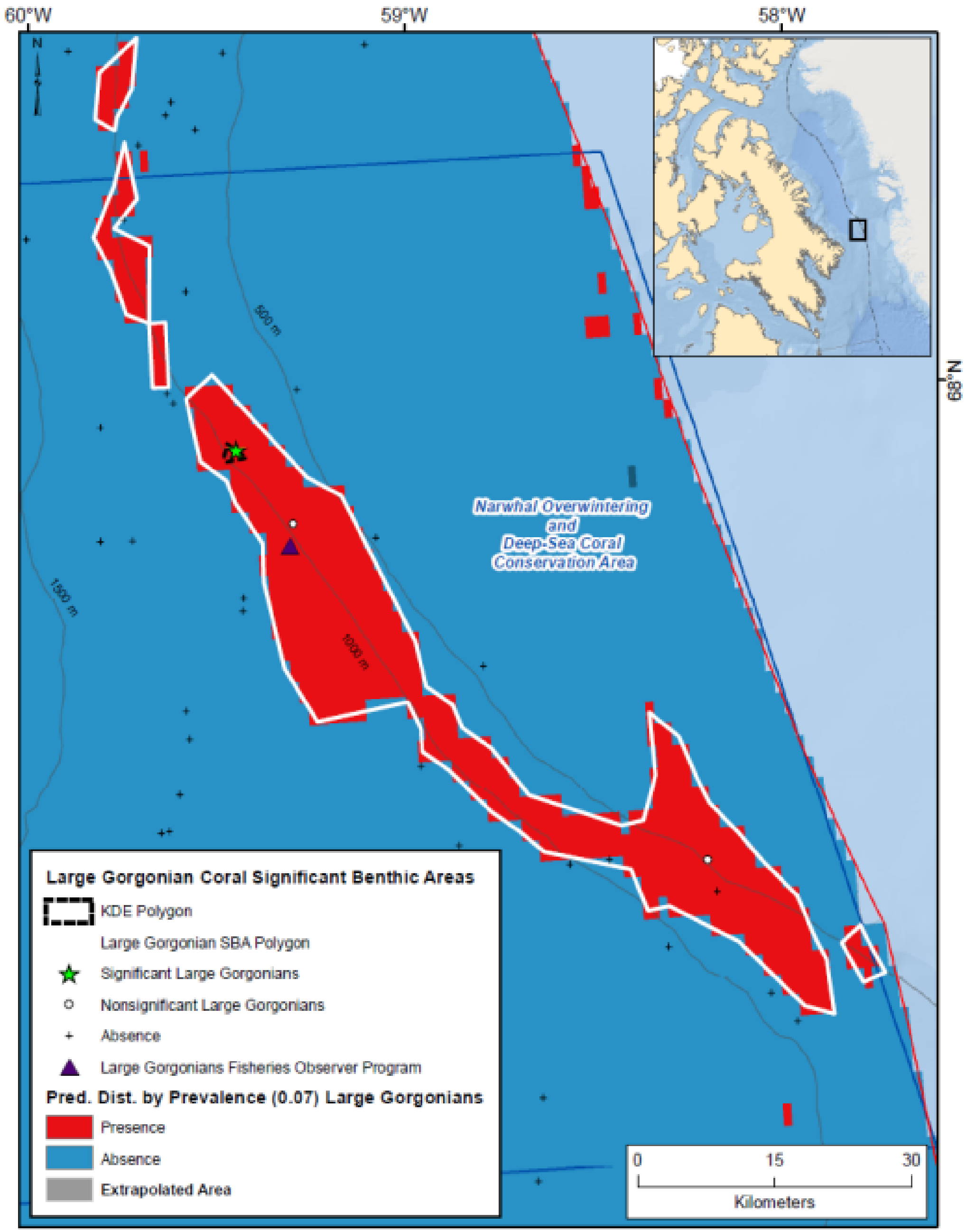


Figure 12. Significant Benthic Area (red area with white outline) for large gorgonian corals delineated from the RF presence-absence SDM. A very large catch of large gorgonian corals from the FOP (triangle) was positioned in this area and provided independent confirmation of the Significant Benthic Area.

Characterization of fishing effort

Fishing activity layers were created to examine the overlap with the Significant Benthic Areas defined by the analyses detailed above. The layers represented the extent (i.e. ”footprint”) and intensity of fishing vessel activities based on fishing locations which were derived from two data sources: logbook and Vessel Monitoring System (VMS) data. Logbooks are records kept by fishers with details on the vessel, effort and catch characteristics, whereas VMS data is positional information collected automatically by satellites. Data from VMS provides high resolution positions recorded at higher frequencies compared to logbooks; however, VMS may not be available for some fisheries depending on the region, gear type, directed species, and vessel size.

Because gear bottom impacts vary greatly across fisheries, fishing activity was grouped into categories with similar gears, target species, and general areas of operation. A total of 13 fisheries classes (Table 1) were defined, which encompass 98% of all the fishing effort recorded in fisheries logbooks across Atlantic Canada and the Eastern Arctic. The remaining 2% was grouped in a single fisheries class labelled “Other”, which included records that did not match the criteria to the other 13 classes defined.

*Table 1. Fisheries classes defined for the analysis of overlap between fishing activity and Significant Benthic Areas. *“Other” includes combinations of traps directing for pelagic species, and gear and species that are likely erroneous – e.g. bottom trawl directing for a pelagic species, etc.*

Fishery class	Location	Gear category	Gears	Taxa
Groundfish Mobile	Offshore	Mobile	Trawls, bottom seines	Groundfish
Shrimp	Offshore	Mobile	Trawls	Shrimp
Scallop	Inshore	Mobile	Dredge	Scallop
Clam	Inshore	Mobile	Dredge, hydraulic device	Clams, oyster, whelks, cockles
Echinoderm	Inshore	Mobile	Dredge, drag	Urchins, sea cucumber
Groundfish Fixed	Offshore	Fixed	Gillnet, longline, handline, pots	Groundfish
Crab Offshore	Offshore	Fixed	Traps, pots	Snow crab, stone/king crab
Miscellaneous Offshore	Offshore	Fixed	Hagfish barrel, pots, traps	Hagfish, shrimp
Lobster	Inshore	Fixed	Pots	Lobster
Crab Inshore	Inshore	Fixed	Traps, pots	Crabs excluding snow crab and stone/king crab
Whelk	Inshore	Fixed	Traps, pots	Whelks
Miscellaneous Inshore	Inshore	Fixed	Eelpot, drag rake, rakes and tongs, fyke net, weir, diving, hand dredge, hand tools, miscellaneous gears	Groundfish, eel, clam, seaweeds, macroalgae, urchins, sea cucumber, oyster, mussel, lobster
Pelagic	Pelagic	Fixed or mobile	Midwater trawls, seines, gillnets, longline, jiggers, trolling, rod and reel, handline, harpoon, seal hunting	Pelagics, squid, seals
Other*	Inshore, offshore or pelagic	Fixed or mobile	Unspecified gears, traps directing a pelagic species	Unspecified species, pelagics

Given the diversity of gears and modes of operation, the unit of effort considered for logbook data in this study was vessel-day (VD) where one fishing location was displayed for a given vessel-day of fishing, which allows for general comparisons across fisheries classes. Where data were available, the footprint of fisheries classes was estimated by plotting fishing locations on a 1 km x 1 km grid, and the intensity of the fishing activity was calculated by the cumulated number of fishing observations within each cell of the grid. This allowed defining the areal extent of the fishing operations, the footprint, and the intensity of use.

The unit of effort for VMS data was hours fished per 1 km x 1 km cell. The number of hours was calculated as the sum of the time intervals between VMS points that were considered to be moving at fishing speeds. Fishing speeds were determined for each fishery class within a region by examining histograms of speeds and selecting thresholds that captured peaks of low speed activity.

Percentile calculations

For comparative purposes, fishing activity was standardized by converting fishing intensities to percentiles using vessel-days for logbooks, and hours fished per unit area for VMS. Percentiles were calculated by summing the total effort a given fishery exerted in each cell, ranking cells by descending effort, and calculating the cumulative percentage of the total effort of the entire fishery (Figure 13). The cells were then categorized into 20 percentile bins of fishing activity. The 20th percentile bin represents the area where the most intense fishing activity occurred and the 100th percentile bin represents the area where the least amount of fishing activity occurred. This procedure identified concentrations of fishing activities and provided standardization across data sources (logbooks and VMS), thereby allowing their integration.

1. *Tabulate effort per cell*

Cell	Effort (hours)
1	5.4
2	1.1
3	9.8
4	7.8
5	8.3
6	0.7
7	12.9
8	8.5
9	3.8
10	4.9
11	6.5
12	4.6
13	22.6
14	14.5
15	0.6
16	1.5
17	13.8
18	13.2
19	5.3
20	9.4
Total	155.2

2. *Sort by descending effort*

3. *Calculate effort as % of total, and calculate cumulative %*

4. *Group cumulated percentages into bins of 20*

Cell	Effort (hours)	Effort (%)	Cumulated effort (%)	Percentile bin
13	22.6	14.6	14.6	Top 20
14	14.5	9.4	23.9	20.1 - 40
17	13.8	8.9	32.8	20.1 - 40
18	13.2	8.5	41.3	40.1 - 60
7	12.9	8.3	49.7	40.1 - 60
3	9.8	6.3	56.0	40.1 - 60
20	9.4	6.1	62.1	60.1 - 80
8	8.5	5.5	67.6	60.1 - 80
5	8.3	5.3	72.9	60.1 - 80
4	7.8	5.0	77.9	60.1 - 80
11	6.5	4.2	82.1	80.1 - 100
1	5.4	3.5	85.6	80.1 - 100
19	5.3	3.4	89.0	80.1 - 100
10	4.9	3.1	92.1	80.1 - 100
12	4.6	3.0	95.1	80.1 - 100
9	3.8	2.4	97.5	80.1 - 100
16	1.5	0.9	98.4	80.1 - 100
2	1.1	0.7	99.1	80.1 - 100
6	0.7	0.5	99.6	80.1 - 100
15	0.6	0.4	100.0	80.1 - 100

Decreasing effort intensity

Figure 13. Schematic steps used to classify cells into bins of fishing activity intensity. The top 20th percentile represents the cells with the most intense fishing activities and the 80th percentile bin (labelled "80.1 – 100") represents the cells with the least intense fishing activities.

Overlap between Significant Benthic Areas and Fishing Activities

Within each biogeographic region, overlapping areas between Significant Benthic Areas and fishing activities were evaluated in two ways: the percentage of the fishing activity that overlapped Significant Benthic Areas and the percentage of Significant Benthic Area that is overlapped by the fishing activity.

These analyses were performed for logbook and VMS data independently as well as using combined logbook/VMS data. The combined logbook/VMS layer was made by joining together percentile-effort raster layers from the two data sources to fill gaps in each other's coverage. In cases where both VMS and logbooks had a percentile value for a given cell, VMS data superseded the logbook. All summary tables and maps presented in this document are based on combined logbook/VMS effort layers.

The size of overlapping areas was calculated for each individual fisheries class, as well as for aggregates of fisheries classes. These aggregates included all fisheries classes, all fixed gear fisheries classes, all mobile gear fisheries classes, and all fisheries classes excluding pelagic gears. Pelagic gears should not, in principle, contact the bottom, and should have no impact on Significant Benthic Areas. However, some pelagic gears may on occasion contact the bottom, so they were included in the results.

These overlap values provided a basic measure on spatial co-occurrence. Evaluation of impacts of fishing on Significant Benthic Areas should also consider, in addition to the spatial overlap, factors like gear type, intensity of fishing, and type of taxa affected.

Sources of Uncertainty

Significant Benthic Area Polygon Delineation

The KDE analysis was constrained to areas covered by the trawl surveys. Many of the Significant Benthic Area indicator species occur in areas that are not surveyed, especially along the slopes. Use of SDMs alongside the KDE analysis should complement the latter work.

The SDMs were performed using buffers around land and therefore coastal areas were not considered in this analysis. This also applies to the KDE analysis as the trawl surveys that generated the data do not cover coastal areas unless the interpolated polygons encroached into those areas. KDE polygons that extended into coastal areas were not clipped in order to highlight potential habitats for further investigation.

RF SDMs can only reliably interpolate to areas with similar environmental characteristics found in the data set. Areas outside of that environmental envelope are termed areas of extrapolation and are considered to be less certain. Areas of extrapolation have been noted on all SDM maps. The large Significant Benthic Areas identified only through SDMs should be further refined with targeted sampling and reanalyses.

Trawl catches of corals and sponges are the result of a stochastic sampling process and catches 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. Some caution is therefore required in interpreting the boundaries of the Significant Benthic Area derived from KDE as these boundaries may be more dispersed than otherwise implied by their delineation. This will also apply to biomass models using data generated from the surveys.

In the SDM context, RF make distinct spatial predictions that can result in very “patchy” predicted distribution maps at smaller spatial scales and the resolution of the models at 1 km^2 precludes habitat delineation at smaller scales that could be explored using benthic cameras and other tools (multibeam bathymetry, surficial geology). Caution should be made to not overanalyze predicted SDM maps at smaller spatial scales. This fine scale patchiness in the RF presence-absence maps occurred in some regions but notably in the Eastern Arctic.

In most regions the sponges were only identified to phylum (Porifera). This level of data collection should be improved with species identified at least to morphotype if not fully identified. This will improve future models and enable predictions of recovery and vulnerability. For example at a minimum sponge data could be grouped into large and small taxa as was done for the gorgonian corals. Full identification to species may not be necessary as previous analyses have shown that rarer taxa are often better modelled together with species having similar habitat preferences.

Fishing Activity Overlaps

Although all fishing activity records reported area of operation (i.e. statistical unit areas) not all logbook records had coordinate positional data. This coverage is highly variable across fisheries classes and biogeographic units, but most of the effort without positional data is associated with the lobster fisheries class, and is exerted in inshore waters and the Gulf of St. Lawrence, and typically in shallow waters (<50 m depth).

Since Significant Benthic Areas were not evaluated in shallow and/or coastal waters, the limitations in positional information are not expected to have a major impact in the estimated overlaps between Significant Benthic Areas and fishing activities; still, the estimated values should be considered a minimum estimate for these overlaps.

Conversely, the analysis of fishing activity using a 1 km x 1 km grid obscures fishing patterns that can be derived from VMS data (e.g. trawl tracks in the case of mobile gears), and potentially inflates overlap values at small spatial scales. This allows integrating and comparing data from multiple, very different fisheries classes, into synoptic analyses targeting large spatial scales. Exploring overlaps at smaller spatial scales would benefit from finer resolution analyses.

CONCLUSIONS AND ADVICE

Significant Benthic Areas

The locations of the catches used to delineate the Significant Benthic Area polygon areas are detailed in Kenchington *et al.* (2016).

Scotian Shelf

Significant Benthic Areas Drawn from KDE Modelling

KDE-derived polygons were created for sponges, sea pens and large gorgonian corals (Figure 14). There were insufficient data to perform the analyses on small gorgonian corals.

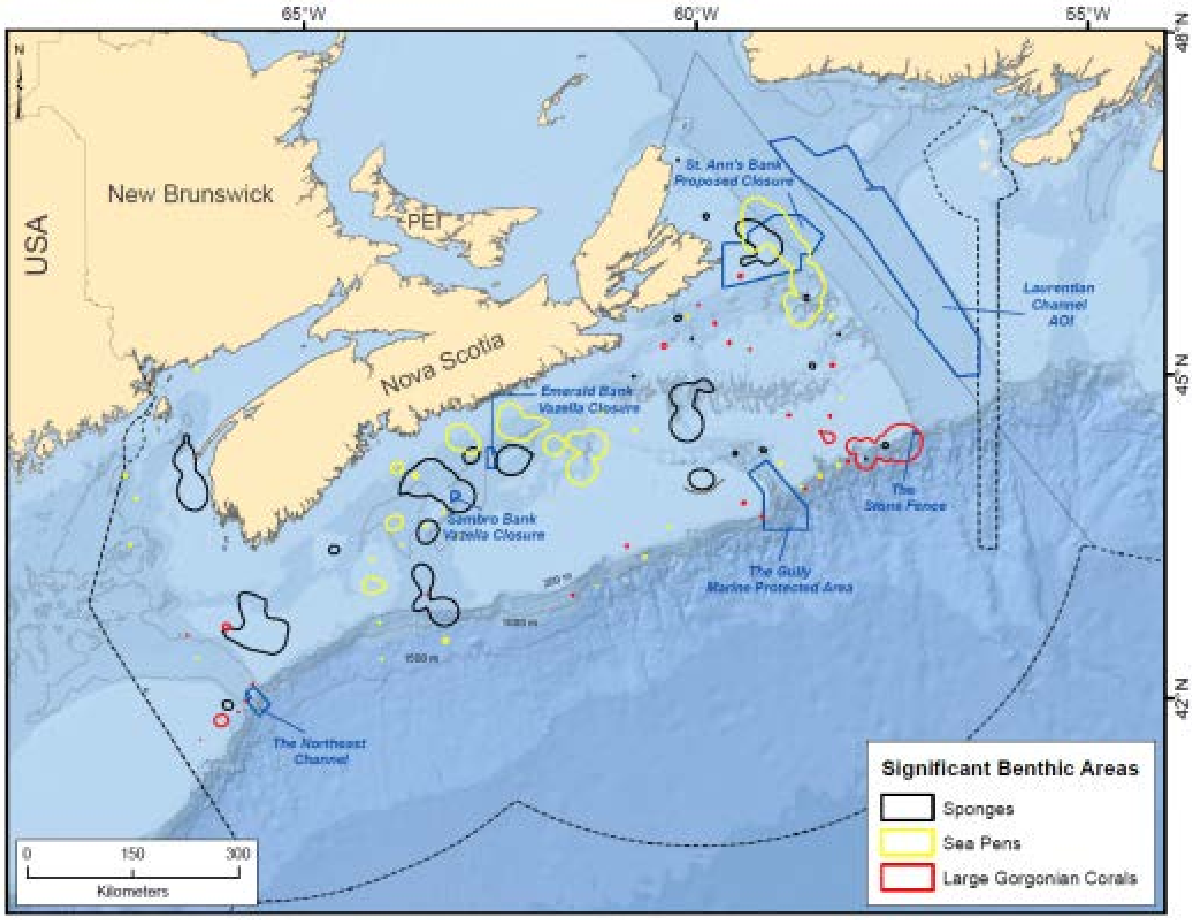


Figure 14. Location of sponge (black outline), sea pen (yellow outline) and large gorgonian (red outline) Significant Benthic Areas as determined from KDE analyses. Note that there are many small polygons for each taxon that are not readily seen at this scale. Details of those can be found in Kenchington et al. 2016.

Significant Benthic Areas Drawn from Species Distribution Modelling

The RF SDMs based on species presence-absence were used to identify Significant Benthic Areas on the continental slopes for sea pens (Figure 15), large (Figure 16) and small gorgonian corals (Figure 17). Due to their similar distributions each is presented separately below.

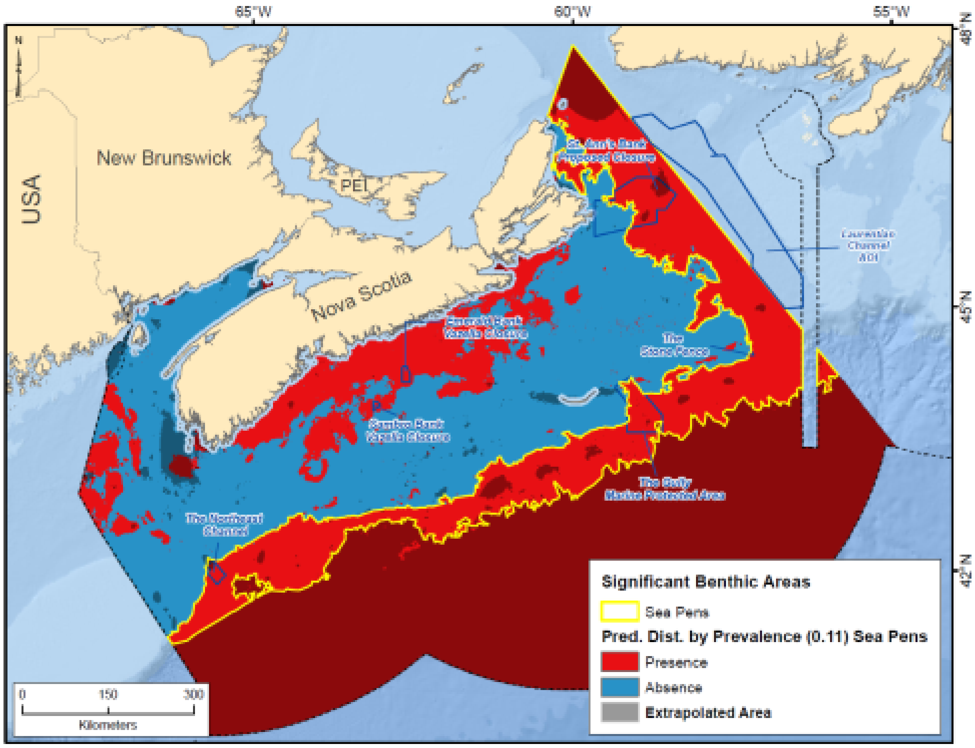


Figure 15. Significant Benthic Areas (yellow outline) for sea pens delineated from the RF presence-absence SDM.

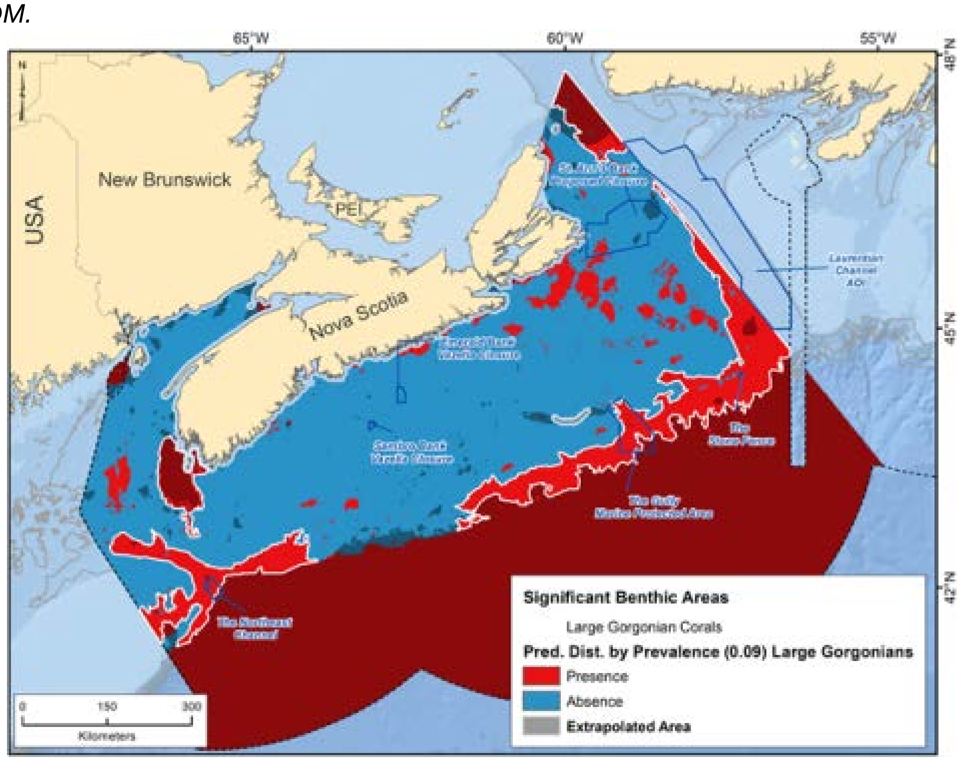


Figure 16. Significant Benthic Areas (white outline) for large gorgonian corals delineated from the RF presence-absence SDM.

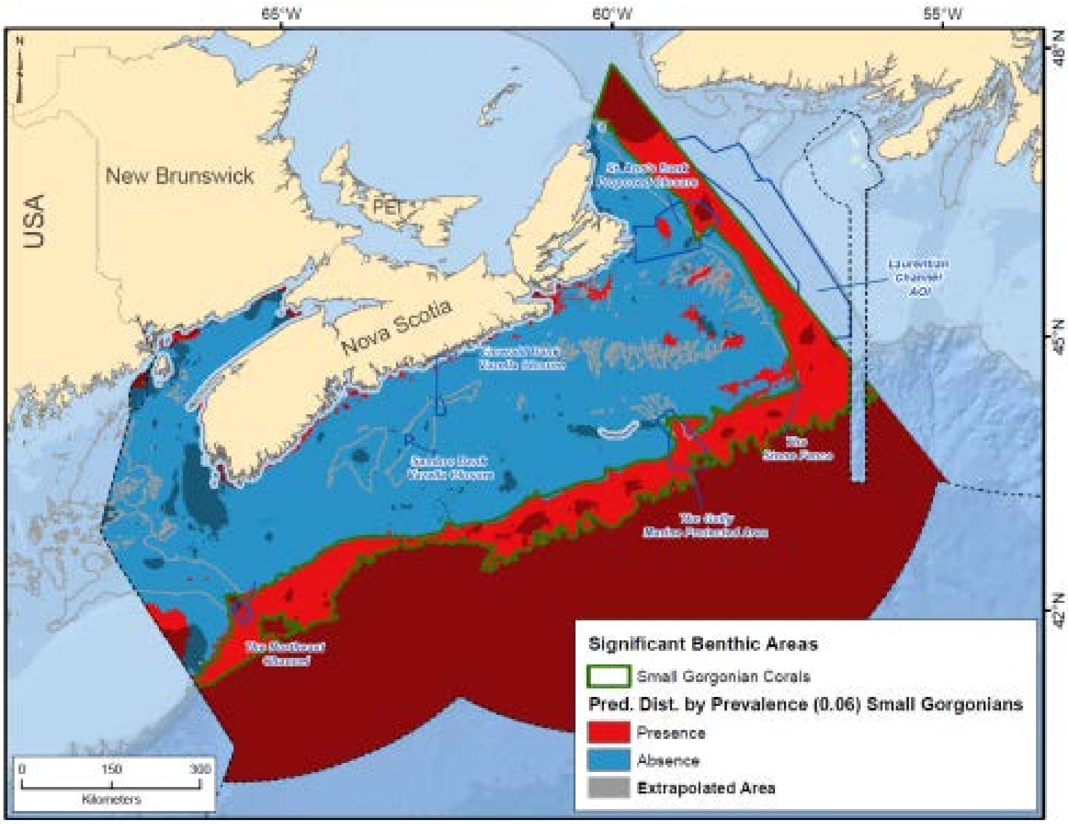


Figure 17. Significant Benthic Areas (green outline) for small gorgonian corals delineated from the RF presence-absence SDM.

Gulf of St. Lawrence

KDE polygons were created for sponges and sea pens. Large and small gorgonian corals were not present in the databases analyzed (Figure 18).

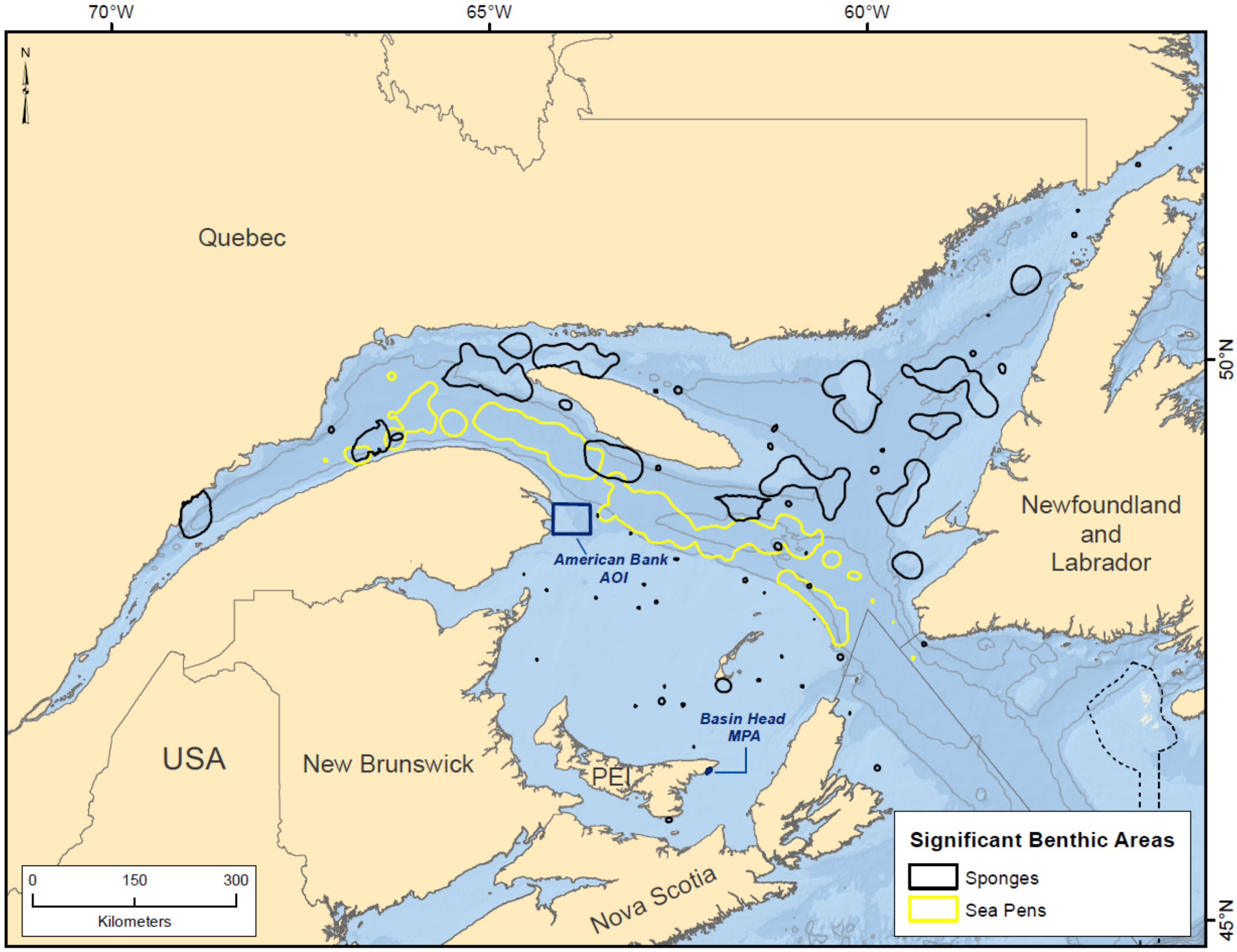


Figure 18. Significant Benthic Areas for sponges (black polygons) and sea pens (yellow polygons) for the Gulf of St. Lawrence derived from the KDE analyses. A number were clipped or modified using the RF presence-absence maps. Note that there are many small polygons that are not readily visible at this scale. Details of those can be found in Kenchington et al., 2016.

Newfoundland and Labrador

KDE polygons were created for sponges, sea pens, large and small gorgonian corals and modified using the RF presence-absence SDMs. The final combined Significant Benthic Areas are presented in Figure 19. This figure includes the new polygon created for the sea pens from the SDM model, east of Newfoundland.

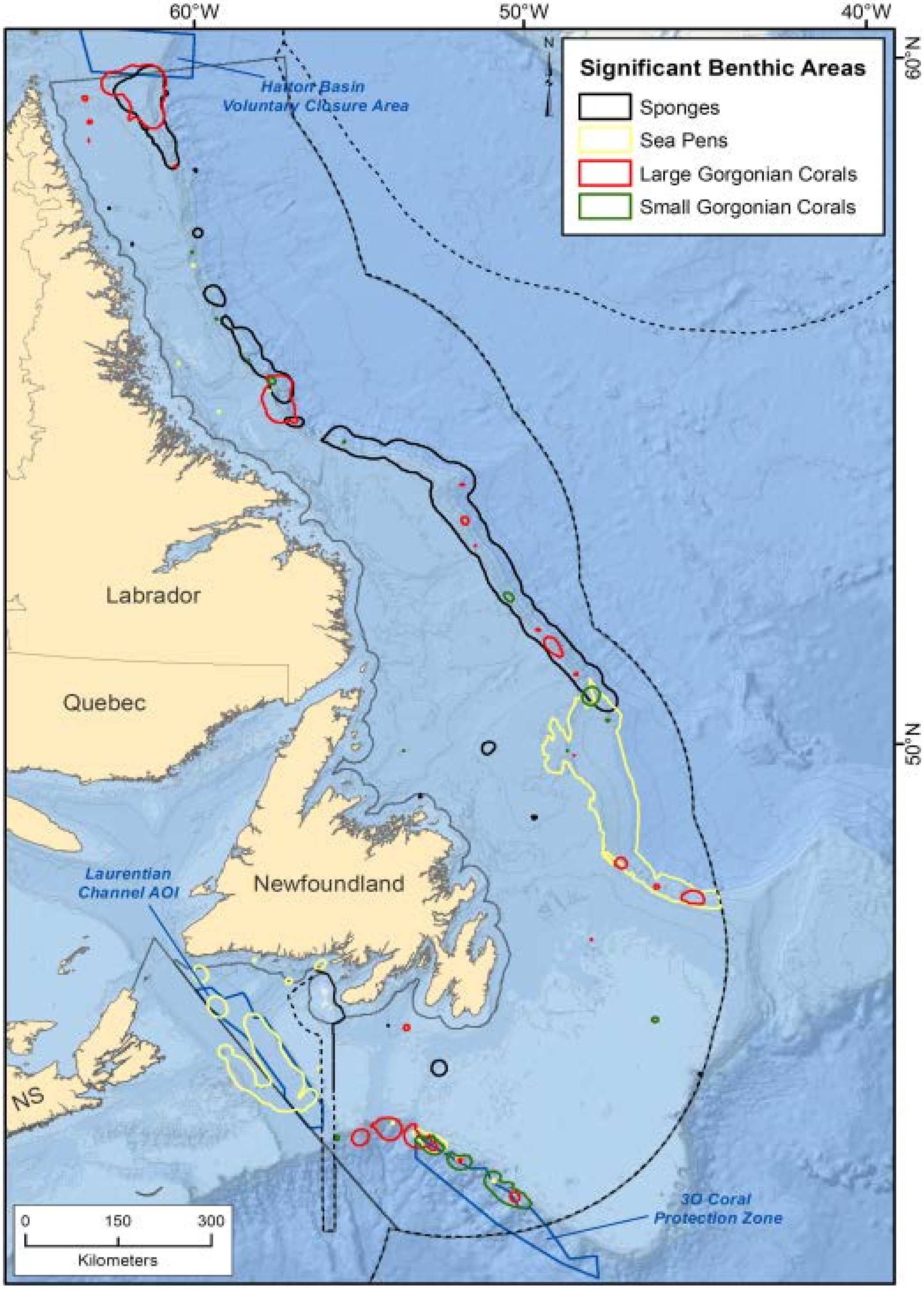


Figure 19. Significant Benthic Areas for sponges, sea pens, large and small gorgonian corals for the Newfoundland and Labrador region. All but one of the polygons were derived from the KDE analyses but a number were clipped using the RF presence-absence prevalence maps. One sea pen polygon was created from the latter along the slope east of Newfoundland. Note that there are a number of small Significant Benthic Areas that are not readily seen on this projection. Details of those can be found in Kenchington et al. 2016.

Eastern Arctic

Significant Benthic Areas Drawn from KDE Modelling

KDE-derived polygons were created for sponges, sea pens, large and small gorgonian corals and one Significant Benthic Area in the Narwhal Overwintering and Deep-Sea Coral Conservation Area was adopted for large gorgonian corals based on presence-absence random forest SDM prevalence (Figure 20). Analyses were performed separately for different gear types within each taxon (Kenchington *et al.* 2016).

Hudson Strait Portion of Hudson Bay Complex

KDE polygons were created for sponges (Figure 21). Sea pens and large and small gorgonian corals were either not present or present with insufficient data to perform the analyses.

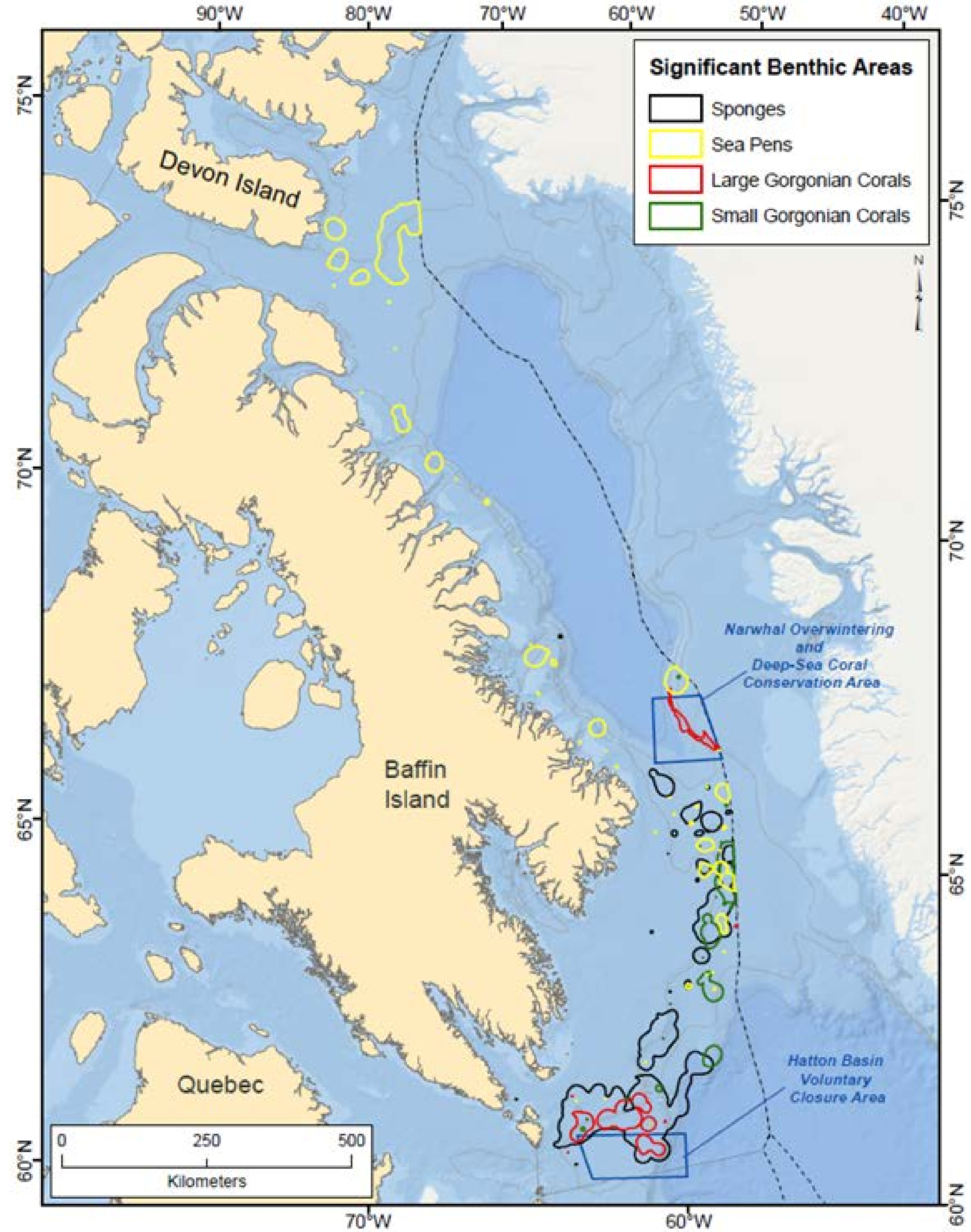


Figure 20. Location of sponge (black outline), sea pen (yellow outline), large gorgonian (red outline) and small gorgonian coral (green outline) Significant Benthic Areas as determined from KDE analyses and RF SDM based on presence-absence (large gorgonian coral Significant Benthic Area in the Narwhal Overwintering and Deep-Sea Coral Conservation Area). Note that there are many small polygons for each taxon that are not readily seen at this scale. Details of those can be found in Kenchington et al., 2016.

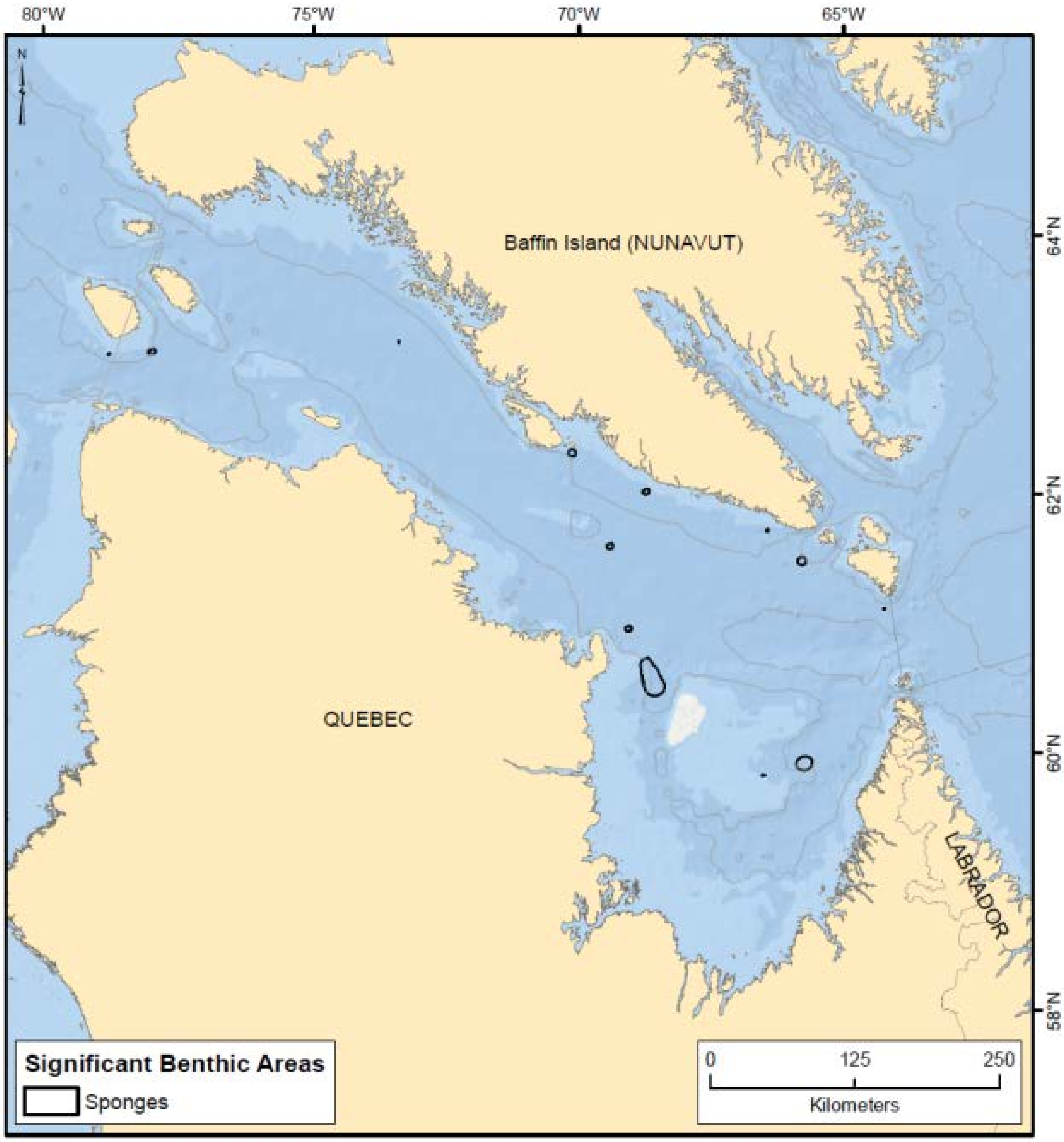


Figure 21. Location of sponge (black outline) Significant Benthic Areas in Hudson Strait, as determined from KDE analyses. Note that there are many small polygons for each taxon that are not readily seen at this scale. Details of those can be found in Kenchington et al., 2016.

Final Delineation of Significant Benthic Areas in Atlantic Canada and Eastern Arctic

The integration of the analyses detailed above allowed the most updated delineation of Significant Benthic Areas in Atlantic Canada and Eastern Arctic. These delineations supersede and improve prior exercises on this subject (Figure 22).

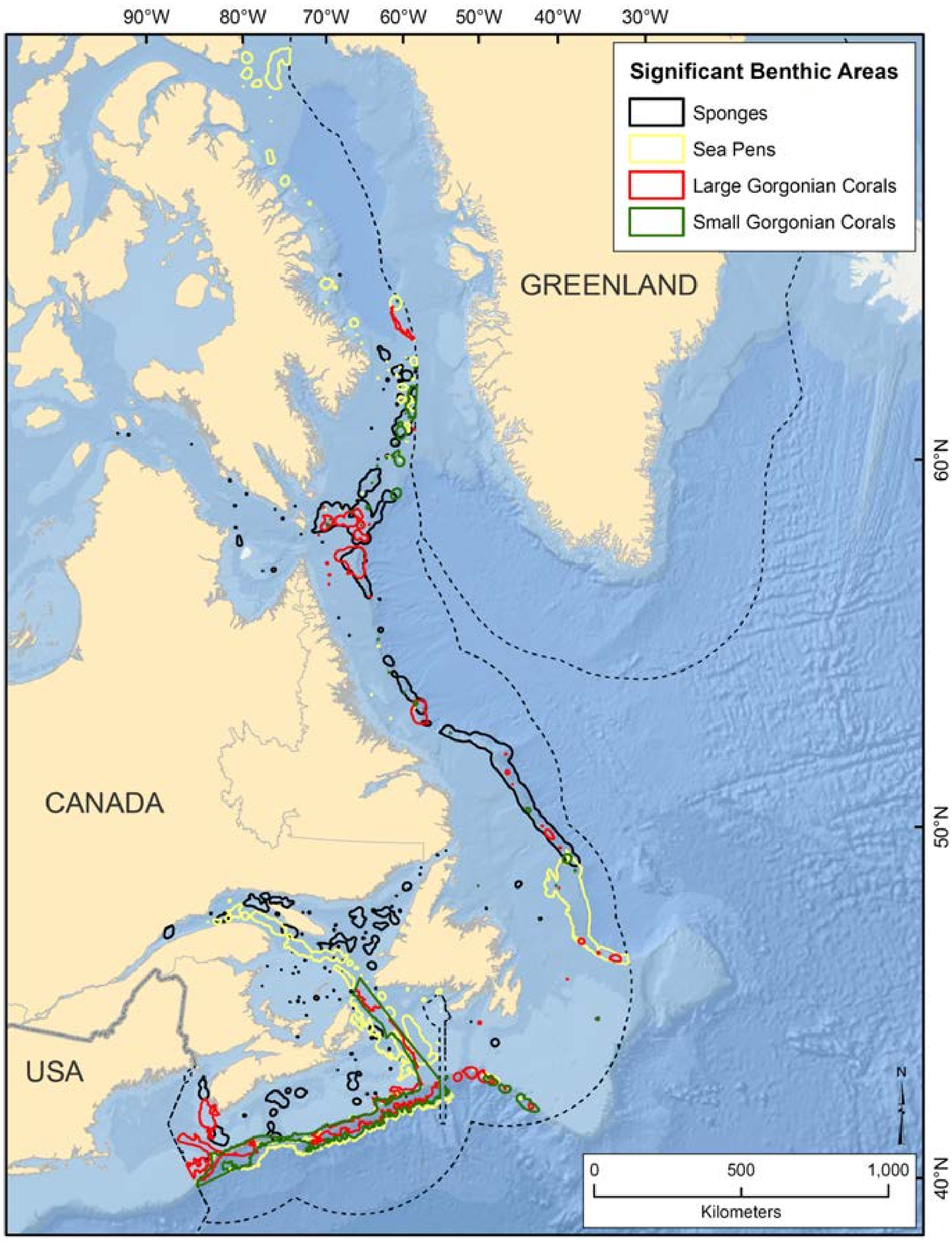


Figure 22. Summary view of all Significant Benthic Areas currently delineated in Atlantic Canada and Eastern Arctic. Note that there are many small polygons for each taxon that are not readily seen at this scale. Details of those can be found in Kenchington et al., 2016.

Advice: Significant Benthic Areas

The analyses presented above highlight Significant Benthic Areas for coldwater corals and sponges in Atlantic Canada and the Eastern Arctic. The fine scale boundaries of the polygons can, and should be, refined using more detailed site-specific data. Data from *in situ* benthic camera observations are recommended to provide details of these areas, along with tools to refine habitats at finer scales than the 1 km^2 grid used if warranted, such as multibeam bathymetry and surficial geology. The analysis is not intended to produce hard boundaries, but rather to focus attention on the key areas for identifying significant concentrations of corals and sponges.

Comparison of the KDE results from 2010 to 2016 showed stability in the polygons delineated (Kenchington *et al.*, 2016). Differences were attributed to the use of optimized search radii in the current analysis, to the random change in the density distribution of the data due to the additional data points causing the polygon boundaries to shift and modulate, and in some cases to the use of different threshold values. The current work is considered to be more robust than the previous analyses as it utilized environmental data to refine the KDE-derived polygons via its integration in species distribution models (SDMs).

The SDMs for sponges might be improved by identifying the catch to lower taxonomic rank than phylum or to identify morphological groupings. At present data collected at the phylum level is considered to be too coarse for addressing vulnerability and sensitivity. The Hudson Strait Area was the only area surveyed where the models did not perform well and additional survey data from that region could improve prediction of Significant Benthic Areas.

Otherwise it is recommended that future work focus on collecting more site-specific data as noted above, and to determining connectivity patterns between and amongst the Significant Benthic Areas. Research on ecosystem function is also severely lacking and the role of these species as fish habitat requires further examination in addition to their wider role as structure forming organisms which modify habitat and locally enhance biodiversity (DFO 2010).

Overlap with Fisheries

Logbook information provides a general picture of how fishing activity is distributed across fisheries classes in Atlantic Canada and Eastern Arctic (Figure 23). A major proportion of this activity does not have positional data, and is associated with the lobster fisheries class and takes place in coastal shallow waters, and the Gulf of St. Lawrence (Figure 24).

Taking into account that most Significant Benthic Areas occur in deeper offshore waters, and that most of the lobster fishing activity is exerted in waters of less than 50 m depth, the available activity with positional data provides a reasonable representation of the activity distribution relevant to assess the overlap between fishing activities and Significant Benthic Areas. Small scale, local studies may require additional analyses at finer resolutions.

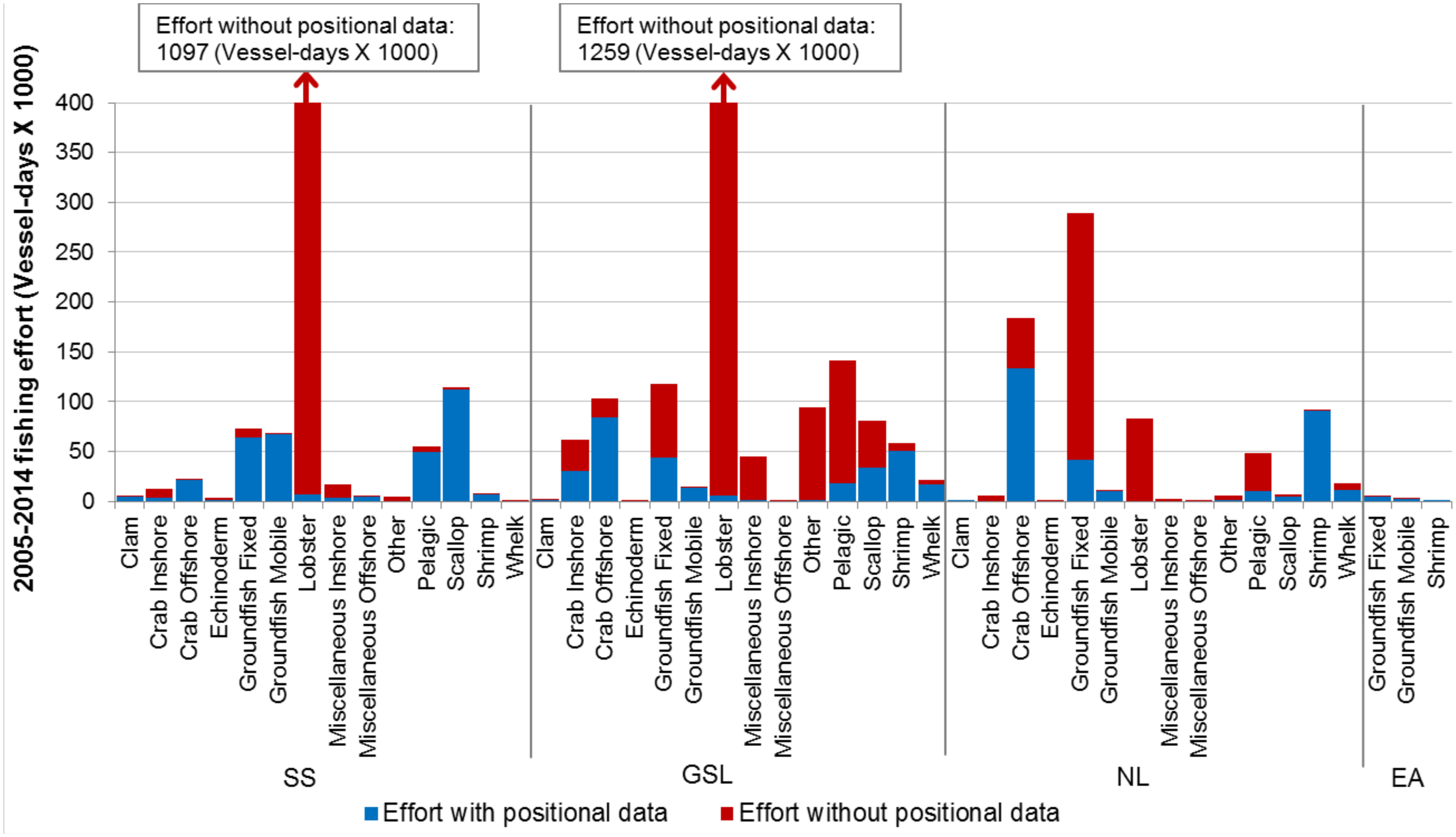


Figure 23. Distribution of logbook fishing activity from 2005 to 2014 by fisheries class and biogeographic unit, with indication of the fraction of activity with and without positional data. SS: Scotian Shelf, GSL: Gulf of St. Lawrence, NL: Newfoundland and Labrador, EA: Eastern Arctic, VD: Vessel-days.

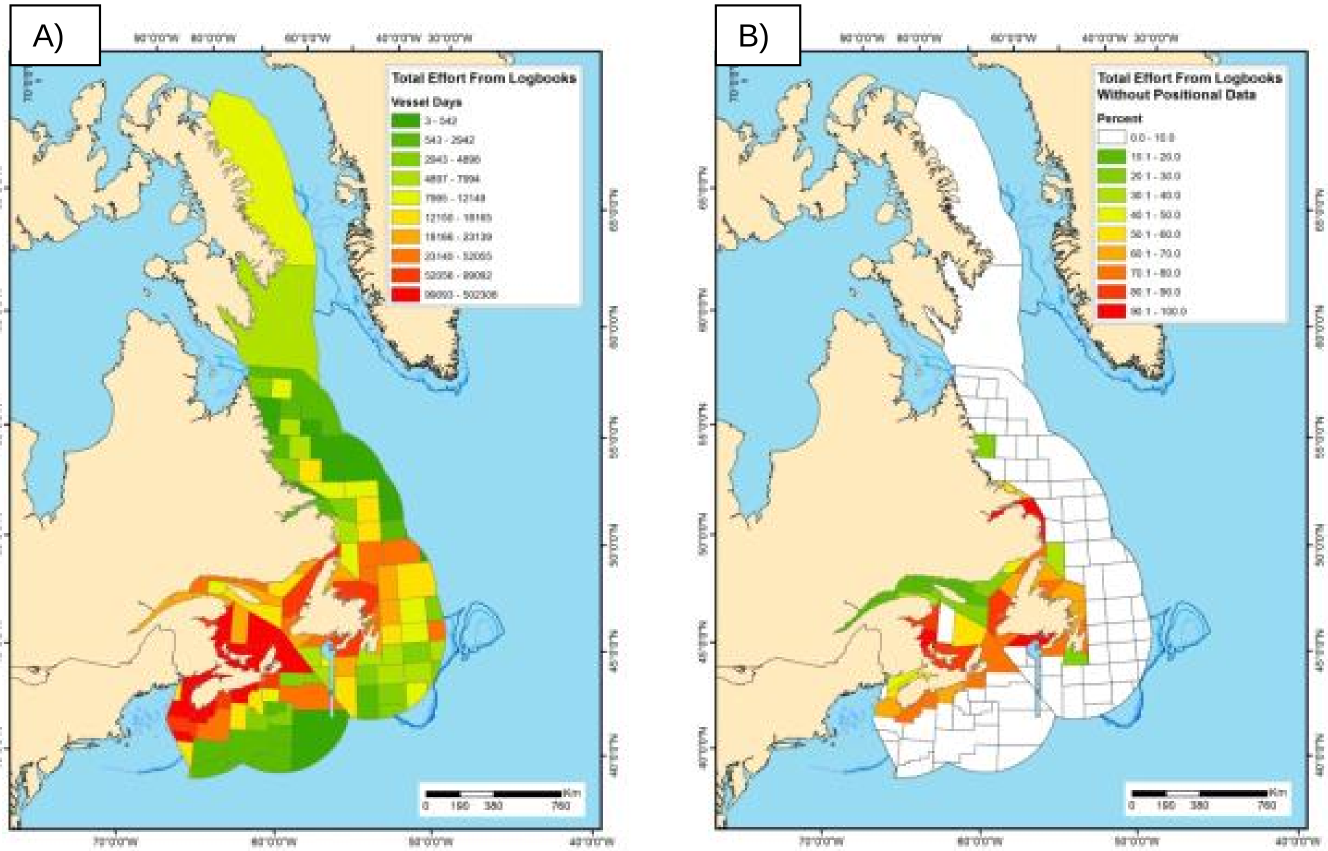
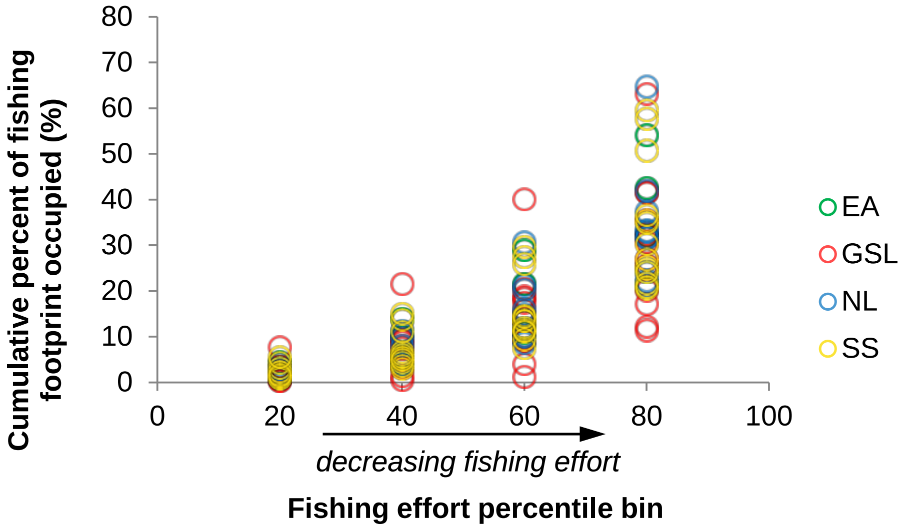


Figure 24. Distribution of fishing activity (vessel-days) by statistical unit area in Atlantic Canada and Eastern Arctic from 2005 to 2014. A) Total fishing activity, B) fraction of fishing activity without positional data in each statistical unit area.

Fishing activity shows a consistent pattern across Atlantic Canada and Eastern Arctic, with most effort concentrated in core fishing areas within the full spatial extent of the fisheries (Figure 25A). These results indicate that 80% of all fishing effort with positional data occurred in less than 40% of the full extent of the area fished by each fishery class in each biogeographic unit from 2005 to 2014 (Figure 25B).

A)



B)

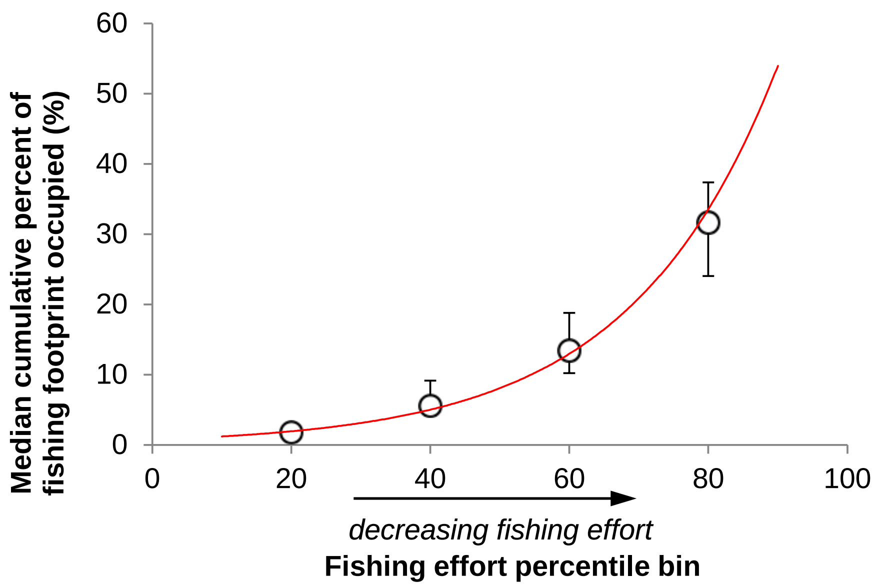


Figure 25. Concentration of fishing activity from logbook/VMS merged data (%) in Atlantic Canada and Eastern Arctic from 2005 to 2014. A) Distribution of area occupied by top activity percentiles of individual fisheries classes in each biogeographic unit; 100% on both axes correspond to the full fishing effort in the entire area occupied by a fishery class in a biogeographic unit; B) median and 25-75% range of the percentage of the total extent of the fisheries occupied by top activity percentiles depicted in A); the red line represents the fitted regression line. SS: Scotian Shelf, GSL: Gulf of St. Lawrence, NL: Newfoundland and Labrador, EA: Eastern Arctic.

There are overlaps between fishing activities and the identified Significant Benthic Areas in Atlantic Canada and Eastern Arctic. Significant Benthic Areas comprised a median of 5.5% of the overall fished area (all fisheries combined), although it ranged from 1.3 - 15.5% (Figure 26). The percent area of Significant Benthic Areas that overlapped with total fishing activity ranged from 6.6 – 77.5%, with generally low values observed in the Eastern Arctic. This range reduced to 6.6 – 72.2% when the pelagic fisheries class was excluded (Figure 27).

For most biogeographic units, a low proportion of Significant Benthic Areas was overlapped by fishing activity from the highest intensity percentile class, and increasing proportions of Significant Benthic Area are overlapped by less intense percentile classes of fishing activity (Figure 28). This appears to indicate that Significant Benthic Areas are not part of main fishing areas (i.e. areas with highly aggregated activities) in the Scotian Shelf, Gulf of St. Lawrence, and Newfoundland and Labrador biogeographic units.

In the Eastern Arctic, where the percentage of the fishing activity represented by Significant Benthic Areas is the highest for activity with the most intense percentile class. This trend is particularly pronounced with sea pens, but is also observed with sponges (Figure 28).

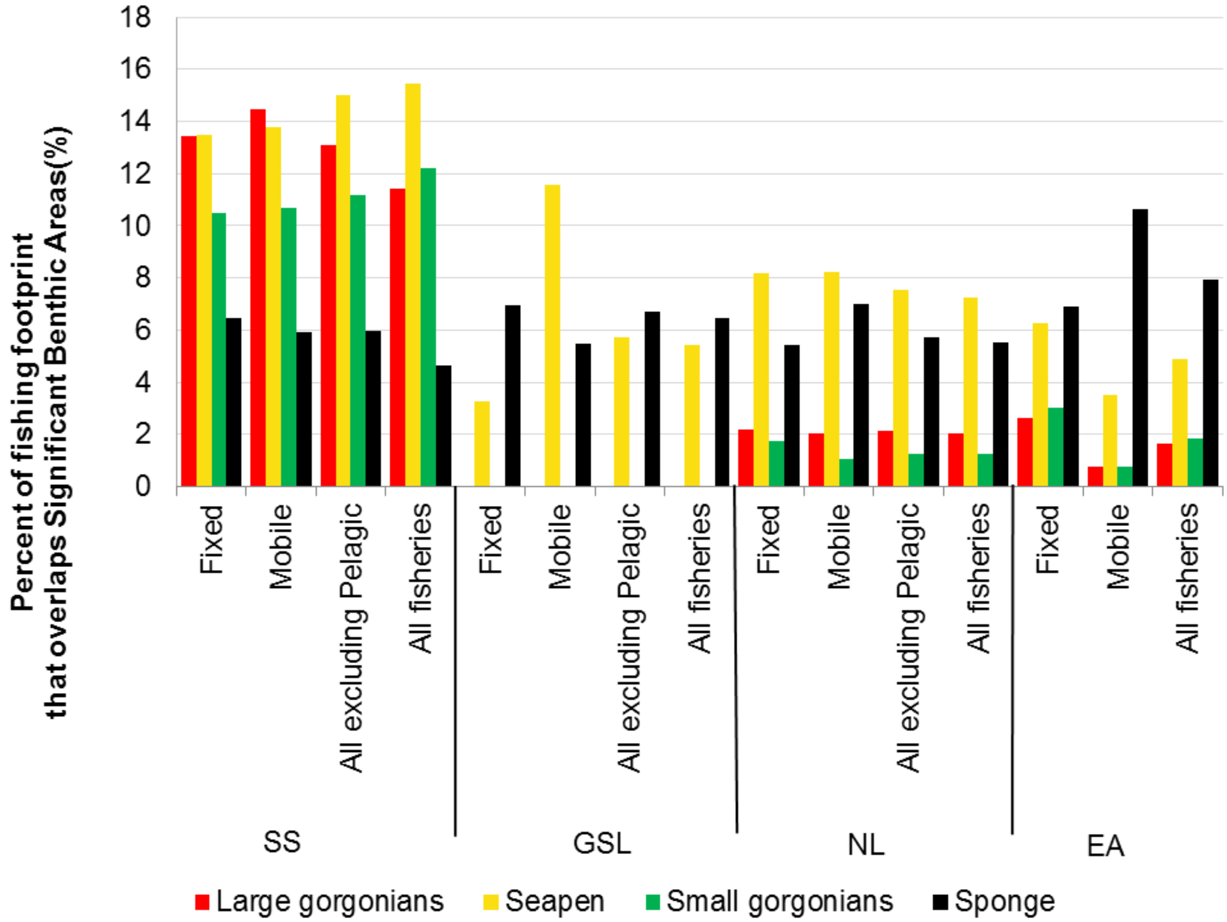


Figure 26. Percentage of the fishing footprint of different aggregates of fisheries classes (all fixed gears, all mobile gears, all gears excluding pelagic, and all fisheries) overlapping with Significant Benthic Areas in Atlantic Canada and Eastern Arctic, discriminated by Significant Benthic Area taxa. SS: Scotian Shelf, GSL: Gulf of St. Lawrence, NL: Newfoundland and Labrador, EA: Eastern Arctic. In EA there is no Pelagic fisheries class.

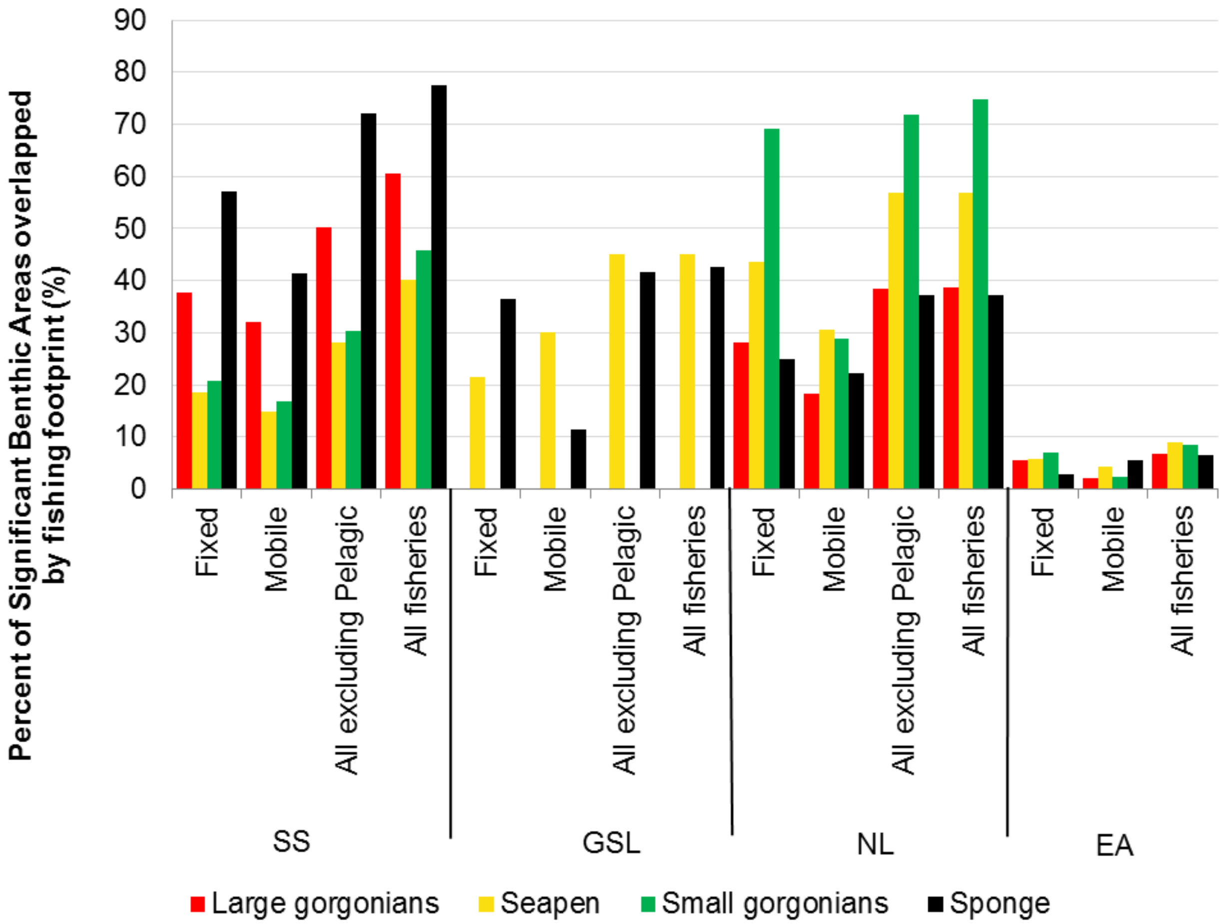


Figure 27. Percentage of the Significant Benthic Area which overlaps with the fishing footprint of different aggregates of fisheries classes (all fixed gears, all mobile gears, all gears excluding pelagic, and all fisheries) in Atlantic Canada and Eastern Arctic, discriminated by Significant Benthic Area taxa. SS: Scotian Shelf, GSL: Gulf of St. Lawrence, NL: Newfoundland and Labrador, EA: Eastern Arctic. In EA there is no Pelagic fisheries class.

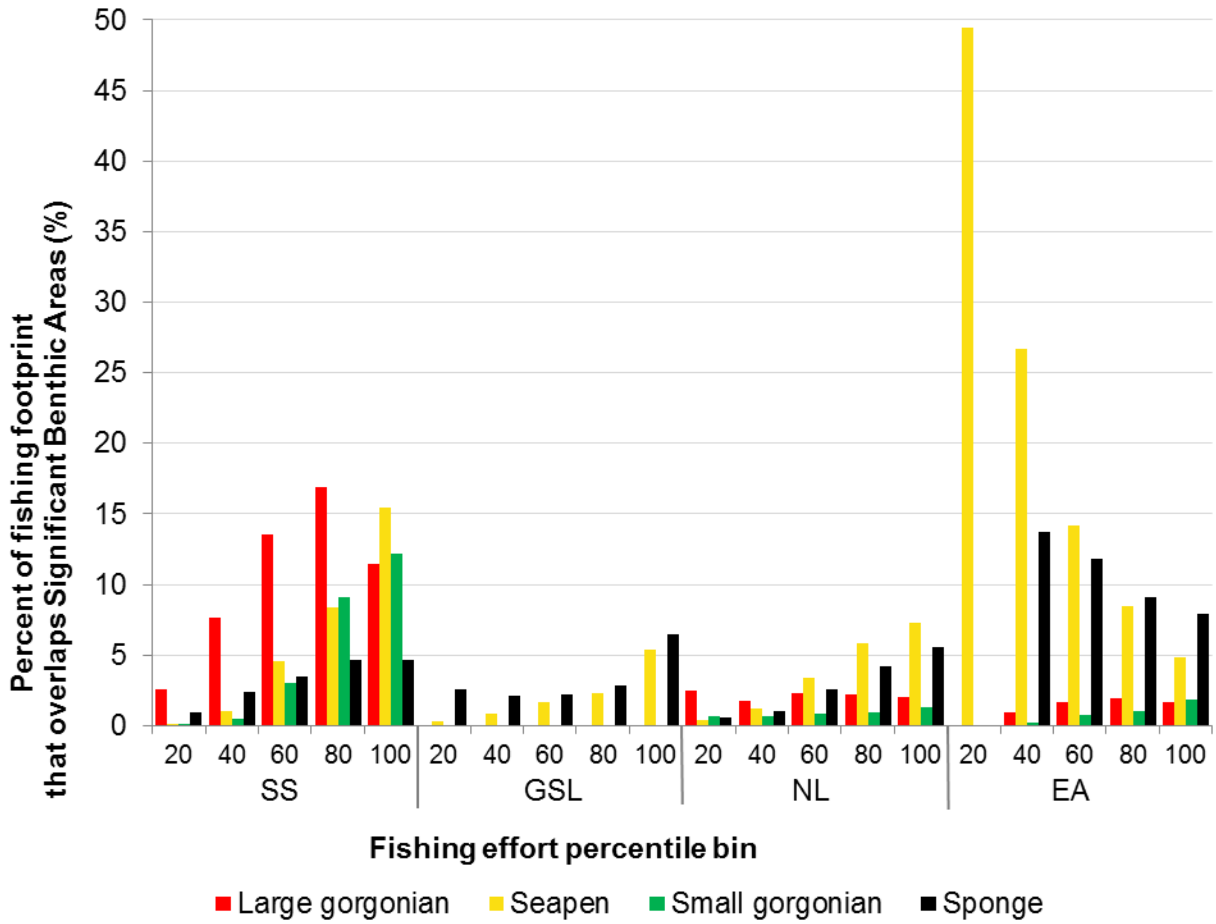


Figure 28. Changes in the percentage of total fishing footprint overlapping with Significant Benthic Areas in relation to fishing effort concentration expressed as top fishing effort percentiles (increasing numbers represent decreasing effort, i.e. the highest effort concentration is represented by the top 20% and the entire extent of the fishing footprint is represented by the 100%) in Atlantic Canada and Eastern Arctic, and discriminated by Significant Benthic Area taxa. SS: Scotian Shelf, GSL: Gulf of St. Lawrence, NL: Newfoundland and Labrador, EA: Eastern Arctic.

The percent area of Significant Benthic Areas the overlapped with specific fisheries classes ranged from 0 – 68.9% with generally low values observed in the Eastern Arctic. Individual fisheries classes show lower overlaps when compared with all fisheries classes combined (Tables 2 to 5).

Scotian Shelf

The estimated overlaps for the Scotian Shelf biogeographic unit are presented in Table 2 and the overlap between all Significant Benthic Areas with all fisheries classes is presented in Figure 29.

Table 2. Overlap between fisheries class footprints and Significant Benthic Area in the Scotian Shelf biogeographic unit based on positional data from merged logbooks and VMS. The areas of Significant Benthic Areas are: Large gorgonian (LGO) = 40749 km², seapen (SPN)= 83086 km², small gorgonian (SGO)= 57386 km², and sponge (SPG)= 12896 km².

Fisheries Class or Aggregate	Effort with positional data (%)	Fishing footprint (km²)	Area of overlap between fisheries class footprint and Significant Benthic Area (km²)				Percent of fisheries class footprint that overlaps with Significant Benthic Area (%)				Percent of Significant Benthic Area that overlaps with fisheries class footprint (%)			
			LGO	SPN	SGO	SPG	LGO	SPN	SGO	SPG	LGO	SPN	SGO	SPG
Clam	99.7	5688	674	581	185	68	11.9	10.2	3.2	1.2	1.7	0.7	0.3	0.5
Crab Inshore	26.3	2212	101	115	275	51	4.6	5.2	12.4	2.3	0.2	0.1	0.5	0.4
Crab Offshore	97.1	30249	186	1968	62	1433	0.6	6.5	0.2	4.7	0.5	2.4	0.1	11.1
Echinoderm	49	1242	57	8	45	47	4.6	0.6	3.6	3.8	0.1	0	0.1	0.4
Groundfish Fixed	87.7	76592	14028	12274	10761	6236	18.3	16	14.1	8.1	34.4	14.8	18.8	48.4
Groundfish Mobile	99.2	62562	9672	11417	9486	3788	15.5	18.2	15.2	6.1	23.7	13.7	16.5	29.4
Lobster	1.1	17976	4828	834	1172	627	26.9	4.6	6.5	3.5	11.8	1	2	4.9
Misc Inshore	18.8	779	0	10	1	10	0	1.3	0.1	1.2	0	0	0	0.1
Misc Offshore	89.1	14739	1223	2779	1959	717	8.3	18.9	13.3	4.9	3	3.3	3.4	5.6
Other	19.2	2931	249	273	108	203	8.5	9.3	3.7	6.9	0.6	0.3	0.2	1.6
Pelagic	90.2	91397	12692	17154	18293	3635	13.9	18.8	20	4	31.1	20.6	31.9	28.2
Scallop	97.8	25795	4539	36	15	1331	17.6	0.1	0.1	5.2	11.1	0	0	10.3
Shrimp	97.8	6754	9	584	8	657	0.1	8.7	0.1	9.7	0	0.7	0	5.1
Whelk	93.6	440	0	18	0	0	0	4.2	0	0	0	0	0	0
All fisheries excl. Pelagic	21.1	155948	20453	23438	17400	9311	13.1	15	11.2	6	50.2	28.2	30.3	72.2
All Fisheries	23.9	215319	24646	33325	26311	9997	11.4	15.5	12.2	4.6	60.5	40.1	45.8	77.5

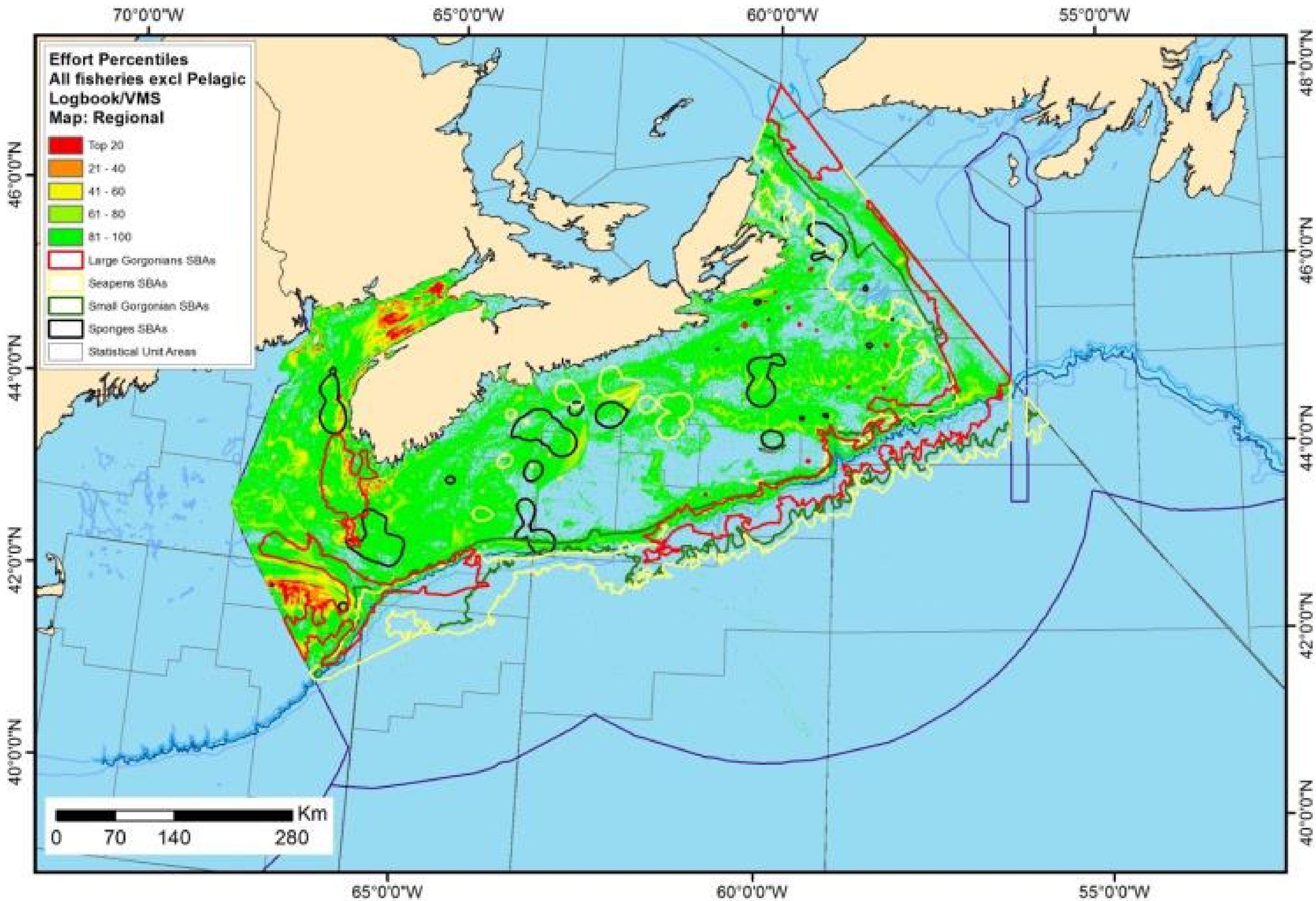


Figure 29. Regional map showing the overlap between Significant Benthic Areas and total fishing activity (excluding pelagic fisheries class) from merged logbook/VMS data in the Scotian Shelf. Activity concentration is represented with a colour scheme going from red (highest top 20% of activity concentration) to green (lowest bottom 20% of activity concentration).

Gulf of St. Lawrence

The estimated overlaps for the Gulf of St. Lawrence biogeographic unit are presented in Table 3. The overlap between all Significant Benthic Areas with all fisheries classes is presented in Figure 30.

Table 3. Overlap between fisheries class footprints and Significant Benthic Area in the Gulf biogeographic unit based on positional data from merged logbooks and VMS. The areas of Significant Benthic Areas are: seapen = 15115 km^2, and sponge = 19090 km^2.

Fisheries Class or Aggregate	Effort with positional data (%)	Fishing footprint (km^2)	Area of overlap between fisheries class footprint and Significant Benthic Area (km^2)		Percent of fisheries class footprint that overlaps with Significant Benthic Area (%)		Percent of Significant Benthic Area that overlaps with fisheries class footprint (%)	
			Seapen	Sponge	Seapen	Sponge	Seapen	Sponge
Clam	62.9	399	0	42	0	10.5	0	0.2
Crab Inshore	48.3	9046	5	102	0	1.1	0	0.5
Crab Offshore	81.3	51245	210	2022	0.4	3.9	1.4	10.6
Echinoderm	62.9	409	0	0	0	0	0	0
Groundfish Fixed	38.6	43937	3114	5019	7.1	11.4	20.6	26.3
Groundfish Mobile	88.0	10147	2741	311	27	3.1	18.1	1.6
Lobster	0.5	NA	NA	NA	NA	NA	NA	NA
Misc Inshore	2.2	410	0	2	0	0.5	0	0
Misc Offshore	19.1	65	2	0	3.5	0	0	0
Other	9.3	6924	4	20	0.1	0.3	0	0.1
Pelagic	14.4	14851	163	301	1.1	2	1.1	1.6
Scallop	42.5	4945	14	245	0.3	5	0.1	1.3
Shrimp	88.6	24538	1915	1608	7.8	6.6	12.7	8.4
Whelk	73.7	3081	30	160	1	5.2	0.2	0.8
All fisheries excluding Pelagic	15.6	118672	6803	7938	5.7	6.7	45	41.6
All Fisheries	16.1	125900	6819	8150	5.4	6.5	45.1	42.7

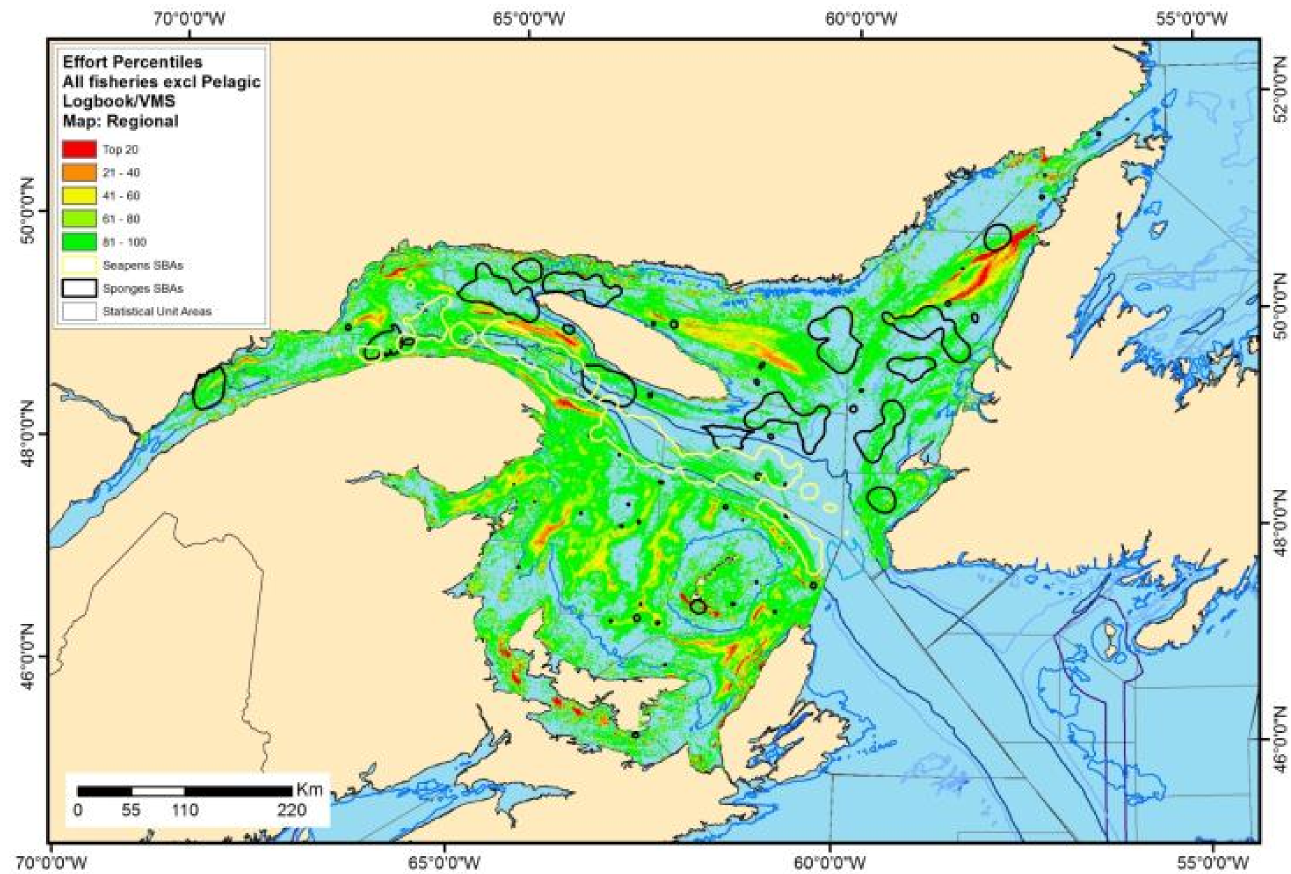


Figure 30. Regional map showing the overlap between Significant Benthic Areas and total fishing activity (excluding pelagic fisheries class) from merged logbook/VMS data in the Gulf of St. Lawrence. Activity concentration is represented with a colour scheme going from red (highest top 20% of activity concentration) to green (lowest bottom 20% of activity concentration).

Newfoundland and Labrador

The estimated overlaps for the Newfoundland and Labrador biogeographic unit are presented in Table 4. The overlap between all Significant Benthic Areas with all fisheries classes is presented in Figure 31.

Table 4. Overlap between fisheries class footprints and Significant Benthic Area in the Newfoundland and Labrador biogeographic unit based on positional data from merged logbooks and VMS. The areas of Significant Benthic Areas are: Large gorgonian (LGO) = 15542 km^2, seapen (SPN)= 37457 km^2, small gorgonian (SGO)= 4987 km^2, and sponge (SPG) = 43472 km^2.

Fisheries Class or Aggregate	Effort with positional data (%)	Fishing footprint (km^2)	Area of overlap between fisheries class footprint and Significant Benthic Area (km^2)				Percent of fisheries class footprint that overlaps with Significant Benthic Area (%)				Percent of Significant Benthic Area that overlaps with fisheries class footprint (%)			
			LGO	SPN	SGO	SPG	LGO	SPN	SGO	SPG	LGO	SPN	SGO	SPG
Clam	100	902	0	0	0	0	0	0	0	0	0	0	0	0
Crab Inshore	0.5	19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crab Offshore	72.48	136130	411	411	37	1649	0.3	0.3	0	1.2	2.6	1.1	0.7	3.8
Echinoderm	42.66	129	0	0	0	0	0	0	0	0	0	0	0	0
Groundfish Fixed	14.54	66617	3987	16107	3436	9316	6	24.2	5.2	14	25.7	43	68.9	21.4
Groundfish Mobile	98.47	30318	1308	8298	1380	3685	4.3	27.4	4.6	12.2	8.4	22.2	27.7	8.5
Lobster	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Misc Inshore	0.2	4	0	0	0	0	0	0	0	0	0	0	0	0
Misc Offshore	99.5	1872	275	347	98	0	14.7	18.5	5.2	0	1.8	0.9	2	0
Other	11.07	673	0	42	1	1	0	6.3	0.1	0.1	0	0.1	0	0
Pelagic	25.51	20527	324	302	1656	74	1.6	1.5	8.1	0.4	2.1	0.8	33.2	0.2
Scallop	73.08	3064	0	28	0	0	0	0.9	0	0	0	0.1	0	0
Shrimp	98.82	106358	1555	3519	58	6125	1.5	3.3	0.1	5.8	10	9.4	1.2	14.1
Whelk	61.94	6281	1	35	0	0	0	0.6	0	0	0	0.1	0	0
All fisheries excl. Pelagic	42.04	282832	5986	21290	3582	16205	2.1	7.5	1.3	5.7	38.5	56.8	71.8	37.3
All Fisheries	41.26	293715	6002	21306	3726	16228	2	7.3	1.3	5.5	38.6	56.9	74.7	37.3

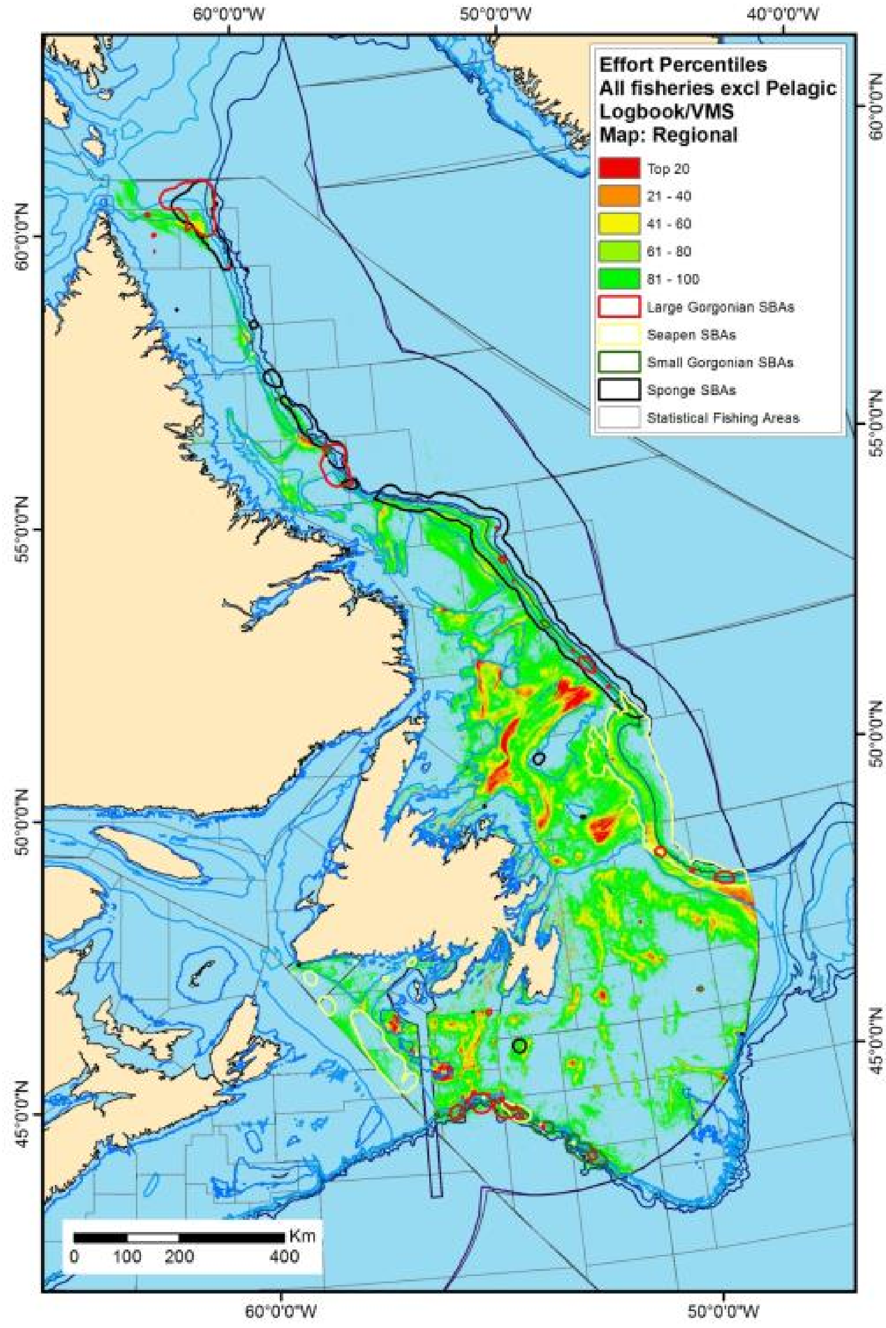


Figure 31. Regional map showing the overlap between Significant Benthic Areas and total fishing activity (excluding pelagic fisheries class) from merged logbook/VMS data in Newfoundland and Labrador. Activity concentration is represented with a colour scheme going from red (highest top 20% of activity concentration) to green (lowest bottom 20% of activity concentration).

Eastern Arctic

The estimated overlaps for the Eastern Arctic biogeographic unit are presented in Table 5. The overlap between all Significant Benthic Areas with all fisheries classes is presented in Figure 32.

Table 5. Overlap between fisheries class footprints and Significant Benthic Area in the Eastern Arctic biogeographic unit based on available positional data from merged logbooks and VMS. The areas of Significant Benthic Areas are: Large gorgonian (LGO)= 7199 km^2, seapen (SPN)= 16123 km^2, small gorgonian (SGO)= 6320 km^2, and sponge(SPG) = 36136 km^2.

Fisheries Class or Aggregate	Effort with positional data (%)	Fishing footprint (km^2)	Area of overlap between fisheries class footprint and Significant Benthic Area (km^2)				Percent of fisheries class footprint that overlaps with Significant Benthic Area (%)				Percent of Significant Benthic Area that overlaps with fisheries class footprint (%)			
			LGO	SPN	SGO	SPG	LGO	SPN	SGO	SPG	LGO	SPN	SGO	SPG
Groundfish Fixed	99.4	14939	393	938	448	1032	2.6	6.3	3.0	6.9	5.5	5.8	7.1	2.9
Groundfish Mobile	100.0	14690	67	6214	143	1752	0.5	4.2	1	11.9	0.9	3.9	2.3	4.8
Shrimp	100.0	4401	76	49	1	275	1.7	1.1	0	6.2	1.1	0.3	0	0.8
All fisheries excl. Pelagic	There is no Pelagic Fisheries Class in this biogeographic unit. Therefore, the “All Fisheries” and “All fisheries excluding pelagics” aggregates render identical results.													
All Fisheries	99.7	29841	487	1457	541	2373	1.6	4.9	1.8	8.0	6.8	9.0	8.6	6.6

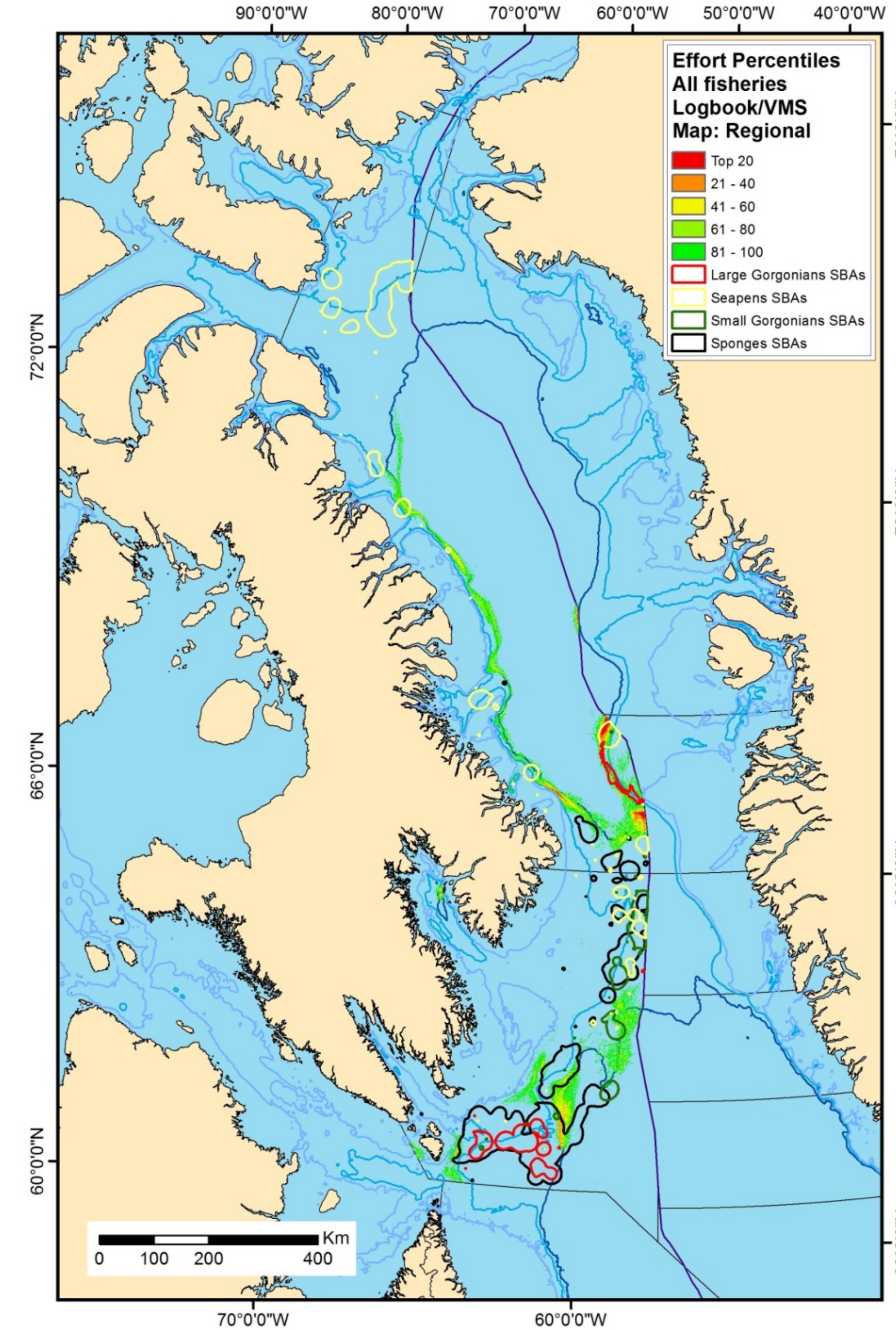


Figure 32. Regional map showing the overlap between Significant Benthic Areas and total fishing effort (there is no Pelagic fisheries class in this biogeographic unit) from merged logbook/VMS data in Eastern Arctic. Effort concentration is represented with a colour scheme going from red (highest top 20% of effort concentration) to green (lowest bottom 20% of effort concentration).

Advice: Overlap with Fisheries

The percent area of Significant Benthic Areas across regions overlapped by all fishing activities was a median of 41.4%, although can be up to 77.5% in some instances. This indicates that in some cases Significant Benthic Areas comprise a considerable portion of the fishing footprint.

The percent Significant Benthic Areas overlapping with total fishing effort was reduced from 6.6% up to 77.5% when pelagic fisheries were excluded. This comparison indicates that the additional co-occurrence with fishing activities associated with pelagic fisheries is relatively modest, but not entirely negligible.

The percent area of Significant Benthic Areas overlapping with individual fisheries classes was, in most cases, lower than the overlaps observed when all fisheries classes are considered together. This indicates that assessing the impacts of fishing on Significant Benthic Areas would require considering all fisheries in an integrated analysis. Independent analyses by individual fisheries classes would risk masking the actual magnitude of fishing impacts on Significant Benthic Areas, which would be defined by the cumulative impacts of all fisheries operating in a given area. Cumulative impacts refer to the sum of individual fisheries impacts: all fisheries have different impact rates and these impact rates need to be considered individually and then added together. This would mean considering each individual fishery class, but summing across fishery classes to get a cumulative impact.

Significant Benthic Areas across regions comprised a median of 5.5% of the overall fished area, although can be up to 15.5% in some instances. This indicates that in most cases Significant Benthic Areas are a relatively small proportion of the fishing footprint of the different fisheries classes.

The examination of the overlaps in relation to the concentration of fishing activity indicated that for the Scotian Shelf, the Gulf of St. Lawrence, and the Newfoundland and Labrador biogeographic units, Significant Benthic Areas do not appear to overlap strongly with the areas within the fisheries footprints that concentrate the highest of the fishing effort. Conversely, Significant Benthic Areas appear to be areas with the highest intensities of fishing activities in Eastern Arctic. The reasons for this difference are unknown, but it could be related to the history and developmental stage of fisheries between these areas. This issue requires further investigation.

These analyses identified areas of co-occurrence between fishing activities and Significant Benthic Areas, indicating potential Sensitive Benthic Areas. Different fishing gears would have different impacts on Significant Benthic Areas. Mobile bottom-contacting gears are typically considered more harmful than fixed gears, while pelagic gears, depending on how likely the specific gear type is to contact the bottom, may or may not impact Significant Benthic Areas.

OTHER CONSIDERATIONS

All analyses presented here have been focused on key coral and sponge taxa widely recognized as Significant Benthic Area forming taxa. Other taxa, like bryozoans and sea squirts also possess life history characteristics that make them valid Significant Benthic Area taxa from an ecological perspective. Information on these taxa is scarce, but increasing. These and other taxa with similar ecological characteristics are conceptually equivalent (i.e. habitat forming, and vulnerable to fishing impacts).

The analyses presented here provide a basis for developing a risk assessment of fishing impacts on Significant Benthic Areas. These studies would provide useful information for the identification and prioritization of Sensitive Benthic Areas. It is also important to keep in mind that the analyses presented here considering the distribution of fishing effort over a relatively recent period of time. Many of these areas have a longer history of fishing, and it is possible that historical Significant Benthic Areas and/or their original boundaries and extent have already been affected by interactions with fisheries. These analyses describe the current situation, but made no attempt to estimate historical effects. Current levels of overlap may not reflect historical levels and contemporary distributions may have been modified by past fishing effort.

The effort estimates used in these analyses integrate information across multiple, very different, fisheries classes at the biogeographic unit scale. However, management action at smaller spatial scales can benefit from refined effort better tailored to describe the effort of specific fisheries classes. For example, estimation of tow tracks for trawl fisheries. These refinements can provide a more accurate delineation of the fine scale areas of interaction between specific fisheries and Significant Benthic Areas, and can help to design more effective management tools (e.g. delineation of closures for Significant Benthic Area protection that minimize impacts on fishing grounds).

It is important to improve our ability to accurately map all fishing activities. Reasonable VMS coverage for large offshore vessels typically exists, but coverage for medium and small vessels is limited. Improved positional coverage together with an effective integration with logbook data could provide a much improved basis for integrated analyses like the ones presented here, as well as for subsequent follow-up studies to track the effectiveness of any potential management measure that may be put in place. Such highly resolved data would be of value for a multiplicity of fisheries assessments beyond Significant Benthic Areas.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 8–10, 2016 National Peer Review on the Delineation of Significant Areas of Coldwater Corals and Sponge-Dominated Communities in Canada's Atlantic and Eastern Arctic Marine Waters. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2009. Development of a Framework and Principles for the Biogeographic Classification of Canadian Marine Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/056.

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THIS REPORT IS AVAILABLE FROM THE:

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2017. Delineation of Significant Areas of Coldwater Corals and Sponge-Dominated Communities in Canada's Atlantic and Eastern Arctic Marine Waters and their Overlap with Fishing Activity. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/007.

Aussi disponible en français :

MPO. 2017. Délimitation des zones importantes de communautés dominées par les coraux et les éponges d'eau froide dans les eaux marines du Canada atlantique et de l'est de l'Arctique et chevauchement avec les activités de pêche. Secr. can. de consult. sci. du MPO, Avis sci. 2017/007.