A Hierarchical Classification of the Seabed Based on Physiographic and Oceanographic Features in the St. Lawrence

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Appendix A. List of variables in the database. This appendix provides a translation of the description for each variable and corresponding legend as it appears in the database. Metadata as well as many names of variables and values of categorical variables are in French in the database. *66*

Appendix B. Description of variables in the database with regards to their characteristics, scale of measurement, and whether they were used to classify cells into megahabitats (in French in the database). *70*

Abstract

Dutil, J.-D., Proulx, S., Chouinard, P.-M., and Borcard, D. 2011. A hierarchical classification of the seabed based on physiographic and oceanographic features in the St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2916: vii + 72 p.

A hierarchical framework has been proposed to classify marine waters surrounding North America into 24 different marine ecoregions based on large-scale oceanographic features. One of those ecoregions (Acadian-Atlantic) includes shelf waters from the Strait of Belle Isle (Canada) down to Cape Cod (U.S.A.) and encompasses the St. Lawrence estuary and Gulf. The present report aims at proposing a hierarchical classification of the seafloor at the scale of the megahabitat for the St. Lawrence estuary and Gulf as a basis for mapping and describing marine habitats for conservation and integrated management purposes. Information on salinity, temperature, dissolved oxygen, depth, slope, and variability in landscape and sediments were aggregated using a grid made up of 100 km^2 cells. Based on that information, cluster analyses were conducted grouping cells into 13 different megahabitats. Four megahabitats described the deep waters, and areas outside channels formed 9 megahabitats: four in the southern Gulf and five in the northern Gulf. These groups of cells were spatially coherent. The tool proposes a novel way of making validated and integrated data available to end users. Potential applications include the screening of areas considered for inclusion in a network of protected areas and a quantitative assessment of surface areas for each class of habitat. The method can also be applied to describe the habitats of species at risk.

Résumé

Dutil, J.-D., Proulx, S., Chouinard, P.-M., and Borcard, D. 2011. A hierarchical classification of the seabed based on physiographic and oceanographic features in the St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2916: vii + 72 p.

Il existe une classification hiérarchique qui classe les eaux marines bordant l’Amérique du Nord en 24 écorégions distinctes fondées sur les caractéristiques océanographiques à l’échelle continentale. L’une de ces écorégions (Acadie-Atlantique) inclut le plateau continental entre le détroit de Belle Isle (Canada) et Cape Cod (U.S.A.) et inclut l’estuaire et le golfe du Saint-Laurent. Le présent rapport a pour objectif de proposer une classification hiérarchique des fonds marins à l’échelle du mégahabitat pour l’estuaire et le golfe du Saint-Laurent à des fins d’identification et de description des habitats devant faire l’objet d’un plan de conservation ou de gestion intégrée. Les données disponibles sur la salinité, la température, l’oxygène dissous, la profondeur, la pente et la variabilité du relief de même que sur les sédiments ont été agrégées en utilisant une grille avec une résolution de 100 km^2. Des analyses de groupement de ces données ont identifié 13 habitats différents. Quatre de ces habitats sont associés aux chenaux profonds et neuf au haut des talus et aux plateaux avoisinants, quatre dans le sud et cinq dans le nord du golfe du Saint-Laurent. Ces regroupements de cellules étaient spatialement cohérents. L’outil proposé se veut un moyen d’intégrer des données validées pour les rendre disponibles aux gestionnaires. Il permet de délimiter des aires de conservation représentatives des habitats rares ou d’une diversité d’habitats et de quantifier la superficie de chaque type d’habitat dans un secteur donné. L’information peut aussi être utilisée pour décrire l’habitat d’espèces en péril.

Introduction

When new projects or new issues arise concerning specific areas in the coastal or offshore marine areas, jurisdictions with management responsibilities raise the question as to which species and which habitats might be impacted. This is true for activities with potentially negative impacts as well as for projects aimed at conservation, such as the creation of marine protected areas. Marine protected areas can be designated for various purposes, including the conservation of marine biodiversity and the protection of rare and vulnerable ecosystems. A particularly rich area may also be designated where pressures of human activities are expected to increase or are considered to pose significant risk for the sustainable use of marine resources. During the planning process, candidate sites must be screened and sites considered for designation must be assessed based on a suite of criteria. When a particular site has been selected and designated, managers aim to describe the state of its resources. Conservation objectives are set and are included in the management plan for the designated area. Furthermore, protected areas must be selected so as to form a cohesive network of sites. Thus the question arises as to how representative the selected area might be compared to other sites in the region or under a national or international system of classification. This whole process is very demanding in terms of data review and calls for an efficient method to integrate many sources of information on habitats and species.

A hierarchical framework has been proposed to classify terrestrial ecosystems in Canada (Ecological Stratification Working Group 1996). The Canadian landscape was divided into large ecozones (i.e., units greater than 200 000 km^2). Those large units were in turn divided into ecoprovinces, ecoprovinces into ecoregions, and ecoregions into ecodistricts sharing common and distinctive characteristics in terms of flora, fauna, climate, landscape, and human activities. Canada comprises 15 different terrestrial ecozones and over 1000 ecodistricts. While terrestrial landscapes can be classified based on a broad spectrum of information sources and databases, less information is available to develop a similar system for the marine ecosystems. Several studies proposed a classification of marine ecosystems at a broad scale (reviewed by DFO 2009). The Commission for Environmental Cooperation (U.S.A., Canada, Mexico), for instance, undertook such an effort (Wiken et al. 1996, Wilkinson et al. 2009) and classified the marine waters surrounding North America into 24 different Level I marine ecoregions, based on large-scale oceanographic features. One of those, ecoregion 7 (Acadian-Atlantic), includes shelf waters from the Strait of Belle Isle (Canada) down to Cape Cod (U.S.A.) and encompasses the St. Lawrence estuary and Gulf. Within the St. Lawrence west of Cabot Strait, this classification recognized two Level II geomorphological regions, the Acadian Shelf (ecoregion 7.2) and the Laurentian/Esquiman Channel (ecoregion 7.4), which extends out of the Gulf to slope waters. Ecoregion 7.2 was split into three different coastal regions, the St. Lawrence estuary including part of the Gulf west of Anticosti Island (7.2.1, St. Lawrence estuarine area), and the northern (7.2.2, North Gulf Neritic) and southern Gulf (7.2.3, Magdalen Shallows), excluding the channels.

Based on guiding principles for the classification of marine areas and based on existing classification systems, Canada's three oceans were classified into 12 broad areas that differ in oceanographic and bathymetric features. Three such areas are recognized for the Atlantic Ocean (DFO 2009). Those ecoregions now form the geographical basis for implementing a marine protected area network in Canada (DFO, framework document in preparation). While this classification is useful in selecting representative areas at a large scale, more detailed information is required to create a network of protected areas at a regional scale. Recent efforts in the St. Lawrence have focused on defining ecologically and biologically significant areas (EBSAs) through regional expert workshops during which physical, chemical, and biological information was considered. Maps were produced for each set of data independently resulting in a hundred different EBSAs. Their relative importance was assessed based on overlaps between layers of information and based on scores obtained for each layer on several criteria (Savenkoff et al. 2007). Chabot et al. (2007) for instance have examined the patterns of distribution and abundance of 44 species of benthic invertebrates. Based on catch in biomass during bottom trawl research surveys in the St. Lawrence estuary and Gulf, areas of maximum relative abundance for each species were identified and an index of benthic invertebrate concentration was used to map 17 potential EBSAs. This approach was considered satisfactory in terms of identifying the most significant EBSAs, but it was not designed to describe and to classify habitats. The present paper aims at proposing a classification of the seafloor at the scale of the megahabitat for the St. Lawrence estuary and Gulf as a basis for mapping, describing, and quantifying marine habitats for conservation and integrated management purposes. Potential applications include the screening of areas considered for inclusion in a network of protected areas (under the Oceans Act), and the identification of essential habitats for species at risk (under the Species at Risk Act). The classification proposed follows a hierarchical framework and is based on physiographic and oceanographic data, consistent with Wilkinson et al. (2009), though at a different scale. Classes of megahabitats are formed based on statistical analyses of the data, not taking into consideration the biota, which will be dealt with in a separate analysis.

Materials and Methods

Study area and mapping grid

The database described below was intended to be made available to other organizations and thus is described in great detail in this section. The full list of variables and a short description of each variable are given in both the database and the appendix Full_list_of_variables.

The study area considered included the Saguenay Fjord, the St. Lawrence middle and lower estuary, and the Gulf of St. Lawrence east up to Cabot Strait and the Strait of Belle Isle (Fig. 1). A grid was formed made up of 100 km^2 square cells (10 km x 10 km), and each cell was designated by column number from left to right (n=115) and row number from top to bottom (n=85). The cell at the west end of baie des Chaleurs, for instance, is designated as 36-59. To minimize distortion, the grid was projected using a Lambert conformal conic projection (NAD 1983 Quebec Lambert, false easting: 0.00000000, false northing: 0.00000000, central meridian: -68.50000000, standard parallel 1: 46.00000000, standard parallel 2: 60.00000000, latitude of origin: 44.00000000). Surface areas of cells are marginally underestimated northward by roughly 1% north of Anticosti Island and 2% at the northern tip of the study area (Belle Isle).

The latitude and longitude of each cell are those of the geometric center (centroid). The dividing line between the land and the ocean was determined from the CanVec data products (NRCan, spatial resolution of 1:50,000) rather than from nautical charts (Canadian Hydrographic Service), which use different scales depending on location within the study area. Both the mainland and islands longer than 1.5 km on their longer axis were considered. Cells located entirely over land, based on the dividing line between land and ocean, and cells located out of the study area, based on reference lines shown in Fig. 1, were removed from the database. Proximity to the shoreline was described with two variables, a quantitative (Cote_Dist) and a qualitative (Hab_Cotier) variable. The quantitative variable measures the distance between the cell centroid and the nearest shore (in metres). Cells overlapping the dividing line between land and ocean were categorized as being coastal; others were classified as offshore. The perimeter and surface area of each cell were determined and included as variables in the database. These values are constant for all cells except for inshore cells or for cells located partly inside and partly outside of the study area (Cabot Strait); in such cases, the perimeter and surface area of the portion of the cell over ocean and in the study area were used. Cells were further described by the surface area of sheltered, semi-sheltered, and exposed habitats as in ICES (2009) and based on two unpublished reports (Bédard, M. C., Proulx, S., Cairns, D., and Dutil, J.-D., 2009, A method for the classification and mapping of sheltered and semi-exposed habitats in estuarine and coastal waters, 29 pages; Kervella, A., Proulx, S., Dutil, J.-D., and Cairns, D., 2010, A method for the classification and mapping of sheltered and semi-exposed habitats in estuarine and coastal waters: breakdown by depth stratum, 62 pages). The surface area of islands longer than 1.5 km on their longer axis was considered in those calculations. Based on the position of their centroid, cells were further classified as to location in the Saguenay Fjord, middle and lower estuary, and Gulf based on reference lines shown in Fig. 1.

Each cell in the grid was then characterized by its physiographic and oceanographic features using data obtained from different sources. Landscape features were described from bathymetry data provided by the Canadian Hydrographic Service. The location of the coast line was not available at the time. Within each cell, the number of depth observations varies considerably depending on the technology used in the surveys, from a few observations in the worst cases to thousands of observations with multibeam sounding technology. Those data were submitted to spatial interpolation (natural neighbor method). Depth was estimated at 500 m intervals within the 10 km x 10 km cell and slopes were calculated from interpolated values. The 400 pixels grid produced was then used to calculate the mean, minimum, and maximum depths and slopes as well as the standard deviation of depths and slopes within each cell. Depths and slopes were in turn used to determine two landscape features (referred to as Geomorph_1 and Geomorph_2 in the database). Cells were classified as belonging to a slope (mean slope > 0.8°), a plateau (mean depth < 200 m and mean slope < 0.8°), or a channel (mean depth > 200 m and mean slope < 0.8°), based on the class representing the greater proportion of the cell surface area (Geomorph_1). The seabed was also classified using tools provided by ESRI® ArcGIS®-based Benthic Terrain Modeler; raw position index values were standardized with mean value at 0 and one standard deviation at 100 (Lundblad et al. 2006). The analysis only considered depth estimates in a 2.5 km radius. Observations below -1 standard deviation were categorized as pits and those beyond +1 standard deviation were categorized as humps. Observations in between were categorized as being uniform. Cells were assigned to the category representing a greater surface area than any other category. Thus a cell classified as being uniform has a surface area with at least 34% of the observations falling within ± 1 standard deviation of the mean (Geomorph_2). Those two classification systems were crossed and the surface area of each of the nine feature combinations (e.g., slopes with pits, plateaus with humps, channels with uniform terrain) determined. Based on this procedure, two other variables were created, one indicating the number of different feature combinations represented within each cell (variable Relief_var, range of values 1 to 9), and the dominant feature combination in each cell based on surface area (variable Relief_dom). In most cases, observations for Geomorph_2 fell within ± 1 standard deviation of the mean, indicating that the seabed is relatively uniform when a 500 m interpolation grid is used (variable Geo2_Uniforme_Count). The relative importance of pits and humps in each cell was determined as their relative proportion of the total cell surface area (variables Geo2_Bosse_Count and Geo2_Creux_Count). Geomorph_1 and Geomorph_2 are also coded as binary variables in the dataset. The dataset also contains one variable indicating the number of depth estimates obtained for each cell; depths, slopes, and landscape features are less reliable for cells with fewer depth estimates.

Bottom salinity and temperature (°C) were obtained from Petrie et al. (1996). This atlas provides monthly average values at various depths for 21 areas in the St. Lawrence. For each cell, using the mean, minimum, and maximum depth values in the database (as estimated by interpolation; see above) the nearest corresponding depth strata in the atlas were determined. From those depth strata, mean annual and minimum and maximum monthly salinity and temperature were obtained, producing 18 climatological descriptors in the database (two environmental variables and three statistical parameters at each of three depths). Seabeds at similar depths and located in a common area thus share a similar climatology. Coastal areas outside the limits of areas in Petrie et al. (1996) were assigned values from the nearest neighbor area. No data were available for the middle estuary in Petrie et al. (1996). When cells overlapped the dividing line between two areas, cells were assigned to one of the two areas based on the location of their centroid. The database contains Petrie et al.'s (1996) code for the area as well as the nearest depth stratum for the mean, minimum, and maximum depth (as estimated by interpolation; see above).

Dissolved oxygen decreases near the bottom and varies spatially (from Cabot Strait moving to the head of deep channels). Data from various surveys conducted between 1981 and 2007 on the CCGS *Calanus II*, CCGS *Teleost*, and CCGS *A. Needler*, including data from D'Amours (1993), were expressed as percent saturation and checked for outliers. The sampling stations are clustered and no data were available for some cells. Dissolved oxygen data were thus submitted to spatial interpolation by the cokriging method with depth as the covariable. A 1 km square grid of kriged estimates was produced from which an average bottom dissolved oxygen value based on 100 kriged estimates was calculated for each cell. Few data were available for shallow coastal areas and for the southern Gulf in general. Kriged estimates in parts of those areas tended to be unreliable and were replaced by values within the range observed during surveys and as follows: dissolved oxygen in shallow areas was fixed at 100%, whereas in other areas it was set as being equal to nearest neighbor values at similar depths. In the database, dissolved oxygen is expressed both as a percentage saturation (kriged estimates with modifications) and as a class from 1 (hypoxic, < 25% saturation) to 8 (normoxic, > 85% saturation), with intermediate values graded by 10% intervals (variable O2_Sat_Classe).

Surface sediment data were obtained from Loring and Nota (1973), who produced contour maps showing the distribution of fine (pelite), medium (sand), and coarse (gravel, pebbles, cobbles, and boulders) surface sediments, including glacial drift deposits as well as bedrock when near or at the surface, in the Saguenay Fjord, St. Lawrence estuary (part of the middle estuary and entire lower estuary), and entire Gulf of St. Lawrence. Cells were assigned the value for the corresponding contour map. When cells overlapped the dividing line between two areas, the location of its centroid was used to select one of the two areas. When a centroid was located outside the contour maps (coastal areas and upper portion of the middle St. Lawrence), no value was assigned. The database contains Loring and Nota's (1973) original code with corresponding French and English descriptors as well as a new numeric code ranging from 1 (very fine) to 69 (very coarse). These categories can be rearranged to suit specific analyses as they most often represent combinations of various materials (e.g., gravel with or without rock showing at the surface). The new numeric code provided in the database is based on the dominant material in Loring and Nota's (1973) classification.

Statistical analyses

A subset of the data in the database was used for the purpose of classifying the seabed into megahabitats. Twenty-six variables were selected describing depth (four variables), slope (four variables), salinity (nine variables) and temperature (nine variables) and were reduced to four factors as follows. The four sets of data (depth, slope, salinity, temperature) were each submitted to a principal component analysis (PCA, based on the covariance matrix, scaling of eigenvectors to length 1). The PCA scores for individual cells were in turn submitted to a hierarchical cluster analysis (resemblance matrix based on euclidian distance as calculated from raw scores, and clustering based on group average). Thus 26 variables describing depth, slope, salinity, and temperature were reduced to four factors, one each for depth, slope, salinity, and temperature.

Megahabitats were classified using those four factors together with the following class variables: proximity to the shoreline (Hab_Cotier, two classes), Geomorph_1 (three classes), Geomorph_2 (three classes), dissolved oxygen (eight classes), and the new numeric code for surface sediments (69 classes). The resemblance matrix was based on Gower's coefficient, and hierarchical clustering used group average. Significantly different clusters of cells were identified through a similarity profile test at $\alpha = 0.10$. There were 378 cells, out of 2810, with missing data for one of the 26 variables or with 10 depth values or less. Those cells were mainly located in the Saguenay Fjord, much of the middle estuary, the Strait of Belle Isle, and parts of the coastal areas, particularly in the southern Gulf, and were not used in the statistical analyses. A second classification was achieved using seven out of the nine variables described above, i.e., the four factors describing depth, slope, salinity, and temperature; Geomorph_1; O2_Sat_Classe; and SS_Code_N. In addition, variable Hab_Cotier was replaced by variable Cote_Dist, variable Geomorph_2 was removed, and the following variables were added: Relief_var, Geo2_Uniforme_Count, Geo2_Bosse_Count, and Geo2_Creux_Count.

Results

The study area included 2810 cells or portions of cells representing a total surface area of 236 237 km^2 (Fig. 2). The middle and lower estuary represent 2965 and 8937 km^2, respectively, compared to 224 030 km^2 for the Gulf. The portion of the Gulf of St. Lawrence north of the 200 m isobath on the southern slope of the Laurentian Channel (referred to as the northern Gulf herein), represents 140 901 km^2, or 62% of the surface area of the Gulf. A total of 865 cells were classified as being coastal (42 404 km^2) and 1945 as being offshore (193 833 km^2). When proximity to the shoreline is determined as the distance between the centroid of a cell and the nearest shore, 16% of the cells have their centroid on land and 38% have their centroid within 10 km of the shoreline. Seventy-five and 95% of the cells are within 40 and 80 km of the nearest shoreline, respectively. Only seven centroids are located beyond 100 km of the nearest shoreline. The surface area of sheltered and semi-exposed zones represented 1.0% (2289 km^2) and 3.2% (7542 km^2), respectively, of the total surface area in the study area (Fig. 3).

Mapping of individual variables

The data were mapped variable by variable for descriptive purposes. This section does not present a full account of maps and statistics that can be generated from the database looking at each variable separately. Rather, it shows several examples of how the database can be used to provide distributional data for the study area or parts thereof.

A total of 2692 cells have interpolated values for depth (Figs 4, 5, 6). Maximum cell depth ranges down to 100 m in the middle estuary, 348 m in the lower estuary, 227 m in the southern Gulf, and 520 m in the northern Gulf. The 0–50 and 50–100 m mean depth intervals represent the greatest area and proportion of the seafloor (50.3%). Cells with mean depths (Table 1) less than 200 m represent 161 339 km^2 of seafloor or 69.2% of the study area, whereas cells with mean depths greater than 300 m represent 34256 km^2 or 14.7% of the study area. These figures change slightly when minimum and maximum cell depths are considered. Cells with minimum depth greater than 300 m represent 25061 km^2 or 10.7% of the study area and cells with maximum depth greater than 300 m represent 49256 km^2 or 21.1% of the study area. Minimum slope ranges from 0 to 2° and maximum slope from 0 to 15° in the study area (Figs 7, 8, 9). Whereas near-flat cell bottoms are observed in all areas (Fig. 8), slopes are steepest in the lower estuary and along the Gaspé Peninsula and north shore of the Gulf (Fig. 9). Except for two areas east and west of the Magdalen Shallows, the seabed is on average very flat in the southern Gulf (Fig. 7), where the slope averages 0.17° (average maximum slope 1.6°), compared to 0.52° (4.0°) in the northern Gulf, 0.47° (2.1°) in the middle estuary, and 0.83° (4.3°) in the lower estuary.

The study area is dominated by plateaus (61.2% of the total surface area, 142 755 km^2) and channels (28.2% of the total surface area, 65 767 km^2). Slopes represent 10.6% of the total surface area (24 629 km^2). Most (98%) of the total surface area of the southern Gulf are plateaus whereas plateaus and channels occupy similar surface areas of the bottom in the northern Gulf (39.5% of the total surface area, 54 651 km^2 for plateaus, and 45.3% of the total surface area, 62 671 km^2 for channels). A total of 15.2% of the seafloor is classified as a slope (21 025 km^2), with slopes located along the Laurentian Channel and in the Mecatina Trough area. (Fig. 10). The middle estuary has only plateaus (2 724 km^2, 96.8%) whereas the lower estuary looks more like the northern Gulf, with a more equal distribution of cells into plateaus (3338 km^2, 37.4%), slopes (2487 km^2, 27.9%), and channels (3095 km^2, 34.7%). When considering the variable Geomorphology_2, few cells end up being classified as non-uniform seabeds (2.4% of the study area, 5783 km^2). However, this is misleading, because cells that are classified as uniform seabeds (i.e., observations of that category representing the greatest surface area in the cell) are actually made of a variety of terrains (pits and humps present, but not dominating; Figs 11, 12). This is exemplified in Fig. 13, which focuses on an area located near the southwest tip of Newfoundland. Relief diversity (variable Relief_var) is low in the southern Gulf and in the channels in the northern Gulf, and moderately high in the middle estuary and along the lower estuary and north shore of the Gulf as well as at the tip of the Gaspé Peninsula and Cape Breton Island (Figs 11, 12, 14). Very diversified reliefs occur mainly on the north shore of the lower estuary, around Anticosti, south on the west coast of Newfoundland, and along the Mecatina Trough.

Salinity and temperature on the bottom are strongly influenced by depth and thus their distribution partly reflects depth distribution in the study area. Nine different maps can be produced to show the distribution of bottom salinity in the study area (mean annual and monthly minimum and maximum salinity at each of three cell depths); three figures are shown to illustrate where mean annual salinity varies within cells when mean, minimum, or maximum depth is considered (Figs 15, 16, 17) and two other figures are shown to stress the range of salinities observed within cells by comparing the minimum monthly salinity at minimum depth and the maximum monthly salinity at maximum depth (Figs 18, 19). Eighty-six percent of the bottom waters in the study area have mean annual salinities greater than 31 (Table 2). This percentage increases to 99.8% in the northern Gulf. Low mean annual salinities (< 29) on the bottom (2% of the seabed in the study area) are observed in a greater proportion in the lower estuary (7.3%; no data for the middle estuary) and southern Gulf (4.8%) largely reflecting differences in mean depth among regions.

Nine different maps can also be produced to show the distribution of bottom temperature in the study area. Two figures are presented to compare the minimum monthly temperature at minimum depth and the maximum monthly temperature at maximum depth (Figs 20, 21). In the estuary and Gulf, but excluding the middle estuary and Saguenay Fjord (no data in Petrie *et al.* 1996), 56% of the seabed (128 008 km^2), essentially channels and parts of the coastal area in the southern Gulf, experiences maximum monthly temperatures above 4°C (Table 3; Fig. 21). In contrast, 62% of the seabed (141 550 km^2) experiences minimum monthly temperatures below 0°C. Very cold temperatures occur essentially throughout the study area except for the slopes and in the channels (Fig. 20). These same data are expressed as a range of mean monthly temperatures in Fig. 22. Fig. 22 shows that, in general, the seabed in the study area is exposed to a narrow range of temperatures, i.e., there is only a weak seasonal signal over a wide area. Sixty-three percent of the seabed (145 298 km^2) experiences a range of temperatures less than 2.5°C, 85% (117 388 km^2) in the northern Gulf and 26% (21 618 km^2) in the southern Gulf. The southern Gulf appears to be a very different environment compared to other regions in the study area in that a larger proportion of the seabed (21%; 21 391 km^2) experiences seasonal amplitudes of temperature greater than 10°C. The highest values (19°C and above) only occur in coastal southern Gulf.

Spatially interpolated dissolved oxygen data combined into discrete percent saturation classes adequately reflect the known distribution for that variable on the bottom in the St. Lawrence (Fig. 23). Oxygen saturation gradually decreases from Cabot Strait to the heads of the Anticosti and Esquiman channels, with particularly low and widespread hypoxic conditions being observed in the lower estuary and the western portion of the northern Gulf. Elsewhere, at shallower depths, normoxic conditions prevail. Twenty-two percent (49 012 km^2) of the total surface area of the seabed in the estuary and Gulf experience hypoxic or nearly hypoxic conditions (< 45% saturation), and 56% (124 380 km^2) experience normoxic or nearly normoxic conditions (> 75% saturation). Saturation levels above 75% prevail in the middle estuary (100% of the seabed) and in the southern Gulf (3% of the seabed < 45% saturation, or 2786 km^2; and 86% > 75% saturation, or 72 065 km^2). In the lower estuary as much as 49% of the seabed exhibits saturation levels below 45% (4 380 km^2), and only 31% exhibits saturation levels above 75% (2 810 km^2).

In the northern Gulf, normoxic and nearly normoxic waters (37% of the seabed, or 52 315 km^2) represent a similar surface area as hypoxic and nearly-hypoxic waters and (33% of the seabed, or 46 226 km^2).

Surface sediments are represented using 69 different classes, but these classes can be grouped in a number of ways depending on the specific objectives of a project. One example is shown describing groups of surface sediments based on granulometry (Fig. 24), from smaller particles in the deep channels (pelites and sandy pelites, 25% of the seafloor) to sandy or shell gravel patches representing less that 4% of the seafloor. Surface sediments with rock outcrops (dark shades, 24% of the seafloor) are shown as separate groups. The other example shows sandy sediments (Fig. 25), with dark shades indicating sand mixed with coarse sediments. Coarse sandy sediments (sandy gravel, gravel with sandy patches and gravelly pelitic sand) represent 18% of the seafloor compared to 54% for fine sandy sediments. Coarse sandy sediments occur over larger areas in the southern Gulf and along the west coast of Newfoundland. Seventy percent of the surface area of the seafloor falls into one of the sandy sediment groups.

Classification of megahabitats

The classification of cells or portions of cells into discrete classes of megahabitat could be achieved for 95% of the cells in the study area (2432 cells; 224 667 km^2).

The PCAs were efficient in reducing the number of variables (Table 4). The first component explained a great proportion of the variability in depth (95.2%) and slope (98.0%) data, with the second component explaining much of the rest (4.5% and 1.7% for depth and slope, respectively). In the PCA for depth, mean, minimum, and maximum depth values (depths have negative values in the geodatabase) had similar loadings and correlated negatively with the first component, whereas only minimum (negative correlation) and maximum (positive correlation) depth values had strong loadings on the second component. Thus score 1 reflects bathymetry (dark tones indicate deeper areas in Fig. 26) and score 2 areas with a greater difference between minimum and maximum cell depth (light tones indicate greater differences in Fig. 27). In the PCA for slope, maximum slope had a very strong loading on the first component (positive correlation) whereas mean slope had a very strong loading on the second component (negative correlation). Thus Fig. 28 highlights areas with steep maximum slopes whereas dark cells in Fig. 29 rather show gentle slopes. The first two components of the PCA also captured 98% of the variability in the salinity data, 91.2% and 6.8% for the first and second component, respectively. All variables were negatively correlated to the first axis, and the second axis opposed minimum salinities at minimum depth (positive correlation) and minimum salinities at maximum depth (negative correlation), i.e., dark cells indicate less saline waters in Fig. 30, and light tones indicate areas with a contrast in salinity with depth within cell in Fig. 31. The situation was more complex for temperature with three or four components required to adequately describe the variability in the data. The first component explained 57.4% of the variability, with strong loadings for the maximum temperature (at mean, minimum, and maximum depths; negative correlation), i.e., dark cells may represent areas where very cold temperatures prevail on the seabed during most of the year (Fig. 32). The second component explained 30.4% of the variability, with strong loadings for the minimum temperature (at mean, minimum, and maximum depths; negative correlation), i.e., dark cells may represent areas where very cold temperatures prevail on the seabed during part of the year, either in winter (shallows) or summer (CIL) (Fig. 33). The third component explained only 7.4% of the variability and opposed all temperatures at minimum depth (positive correlation) to maximum temperature at mean and maximum depth (negative correlation); dark cells represent areas with higher temperatures at minimum depths, excluding areas with high maximum temperatures, as is expected, for instance, in deeper coastal areas and in deep channels (Fig. 34).

The first cluster analysis identified 80 significant groups of cells ($\pi = 4.74$, $p < 0.05$). Cells formed two groups at a similarity value of 58 (Fig. 35), roughly dividing the study area into relatively shallow areas as one category (surface area, 95 213 km^2), and relatively deep areas as a second category (surface area, 129 446 km^2). The first category (relatively shallow areas) was more diversified (50 significant clusters) than the second (30 different clusters). For detailed analyses, 13 groups were formed as follows: the two large groups were split until they contained sub-groups with less than roughly 400 cells, unless a similarity value of 85 was reached. Only significant groups were retained, based on the similarity profile analysis. Thus relatively deep areas split into four significant groups of cells (megahabitats) at a similarity value of 78.6 (Fig. 35). Their spatial distribution is shown in Fig. 36 and their characteristics in Table 5. The relatively shallow areas split into ten groups of megahabitats at a similarity value of 84.3 (Fig. 35). One group was made of a single cell which separated from other groups at a similarity value of 61. That cell (coastal, with a very small surface area of marine habitat) resembled group M more closely, and thus the two groups were lumped resulting in nine groups of cells (megahabitats). Their characteristics are shown in Table 6 and their spatial distribution in Figs 37 and 38.

The Deep-A megahabitat includes the bottom of the three main channels, Anticosti, Esquiman, and Laurentian, and is characterized mainly as being the deepest and having the highest salinity and lowest level of oxygen saturation as well as more gentle slopes and less diversified landscapes (Relief_var = 1) than other megahabitats in that category (Relief_var > 5). The Deep-B megahabitat differentiates from other megahabitats in that category by having very coarse sediments, a wide range of depths (slopes), and a high oxygen saturation. Deep-C and Deep-D habitats both include areas under the cold intermediate layer, with habitat Deep-C including portions of the plateaus below the cold intermediate layer and habitat Deep-D being located deeper than habitat Deep-C on slopes bordering the channels. Thus habitat Deep-C is characterized by a slightly lower temperature and a higher oxygen saturation than habitat Deep-D. The Mecatina Trough classifies entirely as Deep-C habitat. Megahabitat Deep-A is by far the most important in terms of surface area, 61 834 km^2 compared to 18 560 and 13 572 km^2 for Deep-C and Deep-D, respectively. Megahabitat Deep-B totaled only 1247 km^2.

The northern Gulf and southern Gulf do not share similar megahabitats in relatively shallow waters. Four megahabitats mainly occur in the southern Gulf (Shal-E, Shal-G, Shal-H, and Shal-J; Fig. 37), with three megahabitats (Shal-E, Shal-H, and Shal-J) representing 96.2% of the surface area of relatively shallow areas and 82.3% of the total surface area in the southern Gulf compared to 4.5% of the total surface area in the northern Gulf. Five megahabitats mainly occur in the northern Gulf and lower estuary (Shal-F, Shal-I, Shal-K, Shal-L, and Shal-M; Fig. 38), with three megahabitats (Shal-I, Shal-K, and Shal-M) representing 75.2% of the surface area of relatively shallow areas and 53.9% of the total surface area in the northern Gulf and lower estuary, compared to 4.9% of the total surface area in the southern Gulf (Table 7).

Megahabitats in the southern Gulf have a gentle slope on average compared to megahabitats in the northern Gulf. In the southern Gulf, megahabitat Shal_E includes nearshore seabeds around the Îles-de-la-Madeleine and the Maritime Provinces, including the Northumberland Strait. These seabeds are in very shallow waters, with the highest maximum temperature and lowest minimum salinity for the group. Megahabitats Shal_H and Shal_J cover much of the remaining coastal seabeds of the southern Gulf, with megahabitat Shal_H (Miscou, Shediac Valley, baie des Chaleurs, and Magdalen Shallows) having a lower maximum temperature and higher minimum salinity than megahabitat Shal_E. Deeper waters of the southern Gulf make up megahabitat Shal_J. Very cold temperatures prevail year round as a result of the CIL in summer and cold surface layer in winter. Megahabitat Shal_G represents a smaller surface area (2900 km^2) just below the CIL; in that habitat, slopes are less gentle and sediments are coarser than for the other southern Gulf habitats, with lower oxygen, higher salinity, and slightly higher temperature than in megahabitat Shal_J.

Megahabitat Shal_I in the northern Gulf more or less corresponds to megahabitat Shal_E in the southern Gulf, i.e., a large proportion of coastal seabeds covered by the surface layer, but megahabitat Shal_I has a greater depth, steeper slopes, higher salinities, and in particular a greater diversity of reliefs as well as maximum temperatures that are colder by several degrees. Megahabitat Shal_K is located adjacent to megahabitat Shal_I in deeper water and above habitat Deep-C. It includes few coastal cells except on the southwest tip of Newfoundland, and it is also present in the southern Gulf as small clusters at the tip of the Gaspé Peninsula and Cape Breton Island. Except for depth, these seabeds are not markedly different from those of habitat Shal_I: salinity is higher, minimum and maximum temperature at minimum and maximum depth, respectively, are higher by 1°C, and sediments are finer but often associated with bedrock in habitat Shal_K.

Megahabitats Shal_L and Shal_M have very similar characteristics in terms of depth, slope, salinity, oxygen, and temperature, and mainly differ in the type of relief that represents the greatest proportion of seabed within a cell (variable Géomorph_1): plateaus (mean depth < 200 m and mean slope < 0.8°) for habitat Shal_L, and slopes (slopes defined as cells with mean slope > 0.8°) for habitat Shal-M. In fact, Shal-M is the only habitat where plateaus do not represent the greatest proportion of seabed within a cell. Both of these habitats occur mainly in coastal areas (60% of the cells) where steep, rugged terrain occurs, such as in the lower estuary. Habitat Shal_L also occurs on the tip of the Gaspé Peninsula and Cape Breton Island and Habitat Shal_M along the Mecatina Trough. Finally, habitat Shal_F only represents six coastal cells, mainly around Anticosti Island, and a very small surface area (127 km^2).

The classification described above is one of many classifications that can be achieved with the dataset, but alternate analyses may yield similar results if focusing on large groups. This is exemplified in Fig. 39 which shows a good agreement between two classifications, one based on 31 variables and the other based on 34 variables.

Discussion

The present report describes the major habitats found on the seabed of the St. Lawrence estuary and Gulf. Groups of habitats were described using the term “megahabitats” to stress the fact that variability in the data at a fine scale is unknown or not accounted for in the underlying data set. For instance in some areas, few bathymetric data are available for interpolation, even for pixels spaced by as much as 500 m. While coastal cells are expected to have a minimum depth of 0 m, it sometimes occurs that minimum depth is different from 0. This is explained by the absence of coastline data (depth 0) and by the fact that a resolution of 500 m was used for the interpolation; hence only a rough estimate of minimum depth near shore is available. Salinity and temperature data were obtained from Petrie et al. (1996). Their atlas divided the study area into several polygons broader that the cells used in our grid, so seabeds at similar depths and located in the same polygon share the same salinity and temperature data. Kridged estimates or different polygons based on more recent data (Gilbert et al. 2004) could have provided greater reliability and accuracy for our classification. Furthermore, many of the variables used in the classification may show temporal trends that are also not taken into consideration in this approach. Temperature, for instance, varies from year to year (Galbraith et al. 2009, Gilbert and Pettigrew 1997) and is known to have reached minimum values in the CIL in the mid 1990s, with an effect on the volume of that layer and its overlap on the seabed (Gilbert *et al.* 2004). Dissolved oxygen has been shown to have decreased over the second half of the 20th century in the lower estuary (Gilbert et al. 2005). Fish generally exhibit negative impacts below 75% saturation. The database presented in this report suggests that 44% of the seabed fits in that category.

The database and proposed classification can nevertheless be used for several purposes. The database may provide distributional data for the study area or parts thereof and for various purposes, such as delimiting a proposed marine protected area, describing habitats exploited more intensively by a fishery, and determining the characteristics of habitats potentially affected by planned human activities including drilling or releasing material from dredging operations. The information can be visualized variable by variable to locate outstanding features and can also be overlapped with other data (layers of information), such as species distribution in the area, to explore potential relationships between organisms and habitat features, species-by-species or community-wide (factors that explain the presence of a given fish or benthic assemblage in a given location / habitat). The proposed classification might also be used as a framework to select representative sites for various types of studies, including those looking at the effect of habitats on growth and production of benthic organisms. One of the potential uses of this classification is exemplified in Fig. 40, which shows for each cell the number of megahabitats located within a 15 km radius of its centroid. Thus diversity can be assessed in several ways: (1) looking within a cell at specific variables, such as variable Relief_var, which counts relief categories represented within a cell; (2) looking at characteristics of the megahabitat to which a cell belongs—some are intrinsically diversified and others not; and (3) examining the diversity of megahabitats in the area surrounding the cell, as shown in Fig. 40. Thus areas such as the lower estuary along the north shore, several areas around Anticosti, the head of Esquiman Channel, the tip of the Gaspé Peninsula, and two areas on the south side of the Laurentian Channel in the Gulf would appear as areas of great diversity based on the latter criterion. These results correspond also to the conclusion of Lévesque et al. (2010) for the biodiversity of the benthic community.

One limitation of our approach is that it focuses on the seabed, not the water column. Nevertheless, the proposed classification fits rather nicely with the smaller scale classification recently proposed for the same region by Wilkinson et al. (2009). Within the St. Lawrence west of Cabot Strait, this classification recognized two Level II geomorphological regions, the Acadian Shelf (ecoregion 7.2), and the Laurentian/Esquiman Channel (ecoregion 7.4), which extends out of the Gulf to slope waters (Figs 41, 42, 43). Ecoregions 7.2 and 7.4 correspond to megahabitats E to M and A to D, respectively, of the classification described above. Ecoregion 7.2 was further split into three different coastal regions, the St. Lawrence estuary including part of the Gulf west of Anticosti Island (7.2.1, St. Lawrence estuarine area), and the northern (7.2.2, North Gulf Neritic) and southern (7.2.3, Magdalen Shallows) Gulf, excluding the channels. Whereas ecoregions 7.2.2 and 7.2.3 in Wilkinson et al. (2009) fit well with our Shallow water 2 and Shallow water 1 megahabitats, respectively, there is no support in our data for the boundary between ecoregion 7.2.1 (Level III) and ecoregion 7.4 (Level II). Stronger differences between the lower estuary and the Anticosti Gyre may occur in the surface layer characteristics, and this is not accounted for in the present study.

Overall, the dataset and proposed classification can be used to describe the landscape and prevailing climatic conditions that species and life stages living in the St. Lawrence estuary and Gulf may experience in a specific location and on the seafloor. Research scientists and biologists may use it to explore species-environment relationships. Managers may find it useful as an inventory of data and habitats for planning purposes. The present report is also a demonstration of how published and unpublished data can be organized and made available to users and decision makers looking for a pratical tool to answer practical questions.

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Table 1. Surface area (km^2) of seafloor by mean, minimum, and maximum depth interval in the estuary and Gulf of St. Lawrence. The study area includes observations for part of the Saguenay Fjord.

	Surface area for mean depth				Surface area for minimum depth	Surface area for maximum depth
Depth interval (m)	Middle estuary	Lower estuary	Gulf	Study area	Study area	Study area
Emerging	16	27	31	75	7 743	26
0 – 50	2 576	2 432	48 987	53 994	83 128	36 852
50 – 100	190	667	62 480	63 369	57 595	53 401
100 – 200	37	1 951	41 915	43 903	31 647	49 688
200 – 300		2 650	34 927	37 577	28 000	43 950
300 – 400		1 196	22 022	23 218	18 178	33 095
> 400			11 039	11 039	6 883	16 161

Table 2. Surface area (km^2) of the seafloor overlaid by waters of different salinities at mean, minimum, or maximum cell depth in the estuary and Gulf of St. Lawrence. Surfaces under the column “Study area” do not include the Saguenay Fjord and middle estuary. Minimum and maximum monthly salinities and mean annual salinity were obtained from Petrie et al. (1996).

	Surface area for mean annual salinity at mean cell depth				Surface area for minimum monthly salinity at minimum depth	Surface area for maximum monthly salinity at maximum depth
Salinity interval	Middle estuary	Lower estuary	Gulf	Study area	Study area	Study area
≤ 27	No data	0	0	0	4 868	0
27 – 29	No data	622	3 996	4 619	29 179	0
29 – 31	No data	967	25 943	26 911	45 709	15 550
31 – 33	No data	1 709	94 683	96 392	80 615	71 384
33 – 35	No data	5 162	96 777	101 940	69 490	136 312
> 35	No data	0	0	0	0	6 616

Table 3. Surface area (km^2) of the seafloor overlaid by waters of different temperatures at mean, minimum, or maximum cell depth in the estuary and Gulf of St. Lawrence. Surfaces under the column “Study area” do not include the Saguenay Fjord and middle estuary. Minimum and maximum monthly temperatures and mean annual temperature were obtained from Petrie et al. (1996).

	Surface area for mean annual temperature at mean cell depth				Surface area for minimum monthly temperature at minimum depth	Surface area for maximum monthly temperature at maximum depth
Temperature (°C)	Middle estuary	Lower estuary	Gulf	Study area	Study area	Study area
< 0	No data	0	479	479	141 550	100
0 – 1	No data	683	71 760	72 443	17 222	7 464
1 – 2	No data	1 685	26 391	28 077	9 596	36 389
2 – 4	No data	2 546	25 743	28 290	15 815	48 139
4 – 6	No data	3 545	86 213	89 759	45 678	113 323
6 – 10	No data	0	10 813	10 813	0	11 864
10 – 14	No data	0	0	0	0	9 761
> 14	No data	0	0	0	0	2 820

Table 4. Results of principal component analyses (PCAs) conducted on depth, slope, salinity, and temperature data for the estuary and Gulf of St. Lawrence. Percent variability explained by each component and variables with the three highest loadings on each of the most significant components are shown. Min, minimum; Max, maximum; SD, standard deviation.

	Percent variability			
Component	Depth	Slope	Salinity	Temperature
1	95.2	98.0	91.2	57.4
2	4.5	1.7	6.8	30.4
3	0.2	0.3	0.8	7.4
4	0.0	0.1	0.7	3.1
5	-	-	0.3	1.1

Loadings on components 1 and 2 – PCAs on depth, slope, and salinity

Variable	Loading on PCA 1	Loading on PCA 2
Mean depth[1]	-0.587	
Min depth	-0.544	-0.698
Max depth	-0.600	0.633
SD of depth		-0.335
Mean slope	0.219	-0.944
Min slope		-0.224
Max slope	0.958	0.231
SD of slope	0.186	
Mean salinity at min depth		0.391
Min salinity at mean depth	-0.391	
Min salinity at min depth	-0.425	0.593
Min salinity at max depth	-0.351	-0.406

Loadings on components 1, 2, and 3 – PCA on temperature

Variable	Loading on PCA 1	Loading on PCA 2	Loading on PCA 3
Min temperature at mean depth		-0.476	
Min temperature at min depth		-0.424	
Min temperature at max depth		-0.451	
Max temperature at mean depth	-0.505		-0.413
Max temperature at min depth	-0.677		0.497
Max temperature at max depth	-0.328		-0.482

[1] The PCA was run on depths expressed as negative values

Table 5. Characteristics of four groups of megahabitats in relatively deep waters of the St. Lawrence estuary and Gulf. For a description of variables, refer to Materials and Methods. Values are means for all cells within that class of megahabitat.

Characteristic	Megahabitat class			
	Deep - A	Deep - B	Deep - C	Deep - D
Bathy_Mean	-323.55	-222.80	-155.50	-212.85
Bathy_STD	13.86	46.03	20.55	44.96
Bathy_Max	-347.89	-313.43	-204.67	-288.86
Bathy_Min	-288.11	-122.22	-111.62	-109.68
Pente_Mean	0.31	1.04	0.53	0.96
Pente_STD	0.17	0.40	0.33	0.55
Pente_Min	0.04	0.19	0.04	0.13
Pente_Max	0.92	2.45	1.80	2.91
Relief_dom_N	7.00	3.21	1.02	4.92
Relief_var	2.73	5.29	5.57	6.59
O2_Sat_Classe	3.00	5.36	4.98	3.71
SalMoyMoy	34.57	33.97	33.47	34.04
SalMinMoy	34.46	33.77	33.18	33.78
SalMaxMoy	34.69	34.14	33.77	34.27
SalMoyMin	34.42	33.02	32.84	32.78
SalMinMin	34.26	32.78	32.56	32.47
SalMaxMin	34.57	33.23	33.09	33.04
SalMoyMax	34.63	34.45	34.07	34.49
SalMinMax	34.53	34.32	33.80	34.34
SalMaxMax	34.73	34.59	34.29	34.64
TempMoyMoy	4.91	3.86	2.59	3.96
TempMinMoy	4.45	3.49	1.82	3.41
TempMaxMoy	5.40	4.31	3.29	4.49
TempMoyMin	4.63	2.15	1.16	1.24
TempMinMin	4.16	1.40	0.38	0.39
TempMaxMin	5.13	3.04	1.96	2.08
TempMoyMax	4.95	4.53	4.20	4.83
TempMinMax	4.48	4.10	3.70	4.32
TempMaxMax	5.44	4.94	4.70	5.33
SS_Code_N	3.33	39.79	13.67	9.81
Géomorph_1	3.00	2.00	1.00	2.28
Géomorph_2	1.00	1.07	1.00	1.01
Géomorph_3	0.00	0.07	0.04	0.03

Table 6. Characteristics of nine groups of megahabitats in relatively shallow waters of the St. Lawrence estuary and Gulf. For a description of variables, refer to Materials & Methods. Values are means for all cells within that class of megahabitat.

Characteristic	Megahabitat class								
	Shal - E	Shal - F	Shal - G	Shal - H	Shal - I	Shal - J	Shal - K	Shal - L	Shal - M
Bathy_Mean	-15.80	-14.25	-103.03	-35.42	-55.62	-65.09	-115.08	-80.82	-93.81
Bathy_STD	4.99	11.55	9.23	5.22	15.52	4.82	15.04	37.33	40.54
Bathy_Max	-25.84	-43.58	-127.50	-47.09	-94.26	-76.56	-151.36	-170.70	-177.78
Bathy_Min	-4.87	-0.56	-83.69	-24.52	-23.47	-54.62	-81.88	-11.12	-17.58
Pente_Mean	0.17	0.66	0.24	0.14	0.50	0.14	0.42	0.91	1.33
Pente_STD	0.10	0.45	0.15	0.10	0.35	0.08	0.28	0.89	0.82
Pente_Min	0.01	0.07	0.01	0.01	0.02	0.01	0.02	0.07	0.12
Pente_Max	0.52	1.70	0.88	0.49	1.96	0.45	1.57	4.41	4.09
Relief_dom_N	1.01	2.00	1.00	1.01	1.03	1.00	1.00	1.15	4.26
Relief_var	1.80	4.33	2.55	1.65	5.21	1.52	4.45	5.70	5.81
O2_Sat_Classe	7.91	5.83	3.66	7.71	7.56	6.79	6.49	4.82	5.60
SalMoyMoy	29.71	30.95	32.77	30.57	31.99	31.82	32.86	32.32	32.55
SalMinMoy	28.79	30.08	32.36	29.74	31.60	31.33	32.57	31.90	32.24
SalMaxMoy	30.82	31.75	33.05	31.37	32.34	32.19	33.16	32.69	32.83
SalMoyMin	29.48	30.34	32.33	30.12	31.24	31.59	32.44	29.82	30.73
SalMinMin	28.40	28.85	31.98	29.11	30.46	31.08	32.14	28.31	29.58
SalMaxMin	30.79	31.66	32.57	31.17	31.97	31.91	32.71	31.14	31.70
SalMoyMax	30.09	31.82	33.01	31.06	32.60	32.03	33.31	33.55	33.58
SalMinMax	29.35	31.55	32.63	30.35	32.30	31.55	33.00	33.26	33.35
SalMaxMax	31.05	32.15	33.32	31.67	32.86	32.48	33.63	33.78	33.81
TempMoyMoy	5.79	3.07	1.31	2.48	1.04	0.49	1.05	1.13	1.22
TempMinMoy	-1.33	-1.10	0.55	-1.16	-0.82	-0.74	0.33	0.04	0.13
TempMaxMoy	13.02	8.10	2.08	6.25	3.18	2.13	1.74	2.42	2.39
TempMoyMin	7.11	4.60	0.85	3.69	3.11	0.74	0.61	3.60	3.10
TempMinMin	-1.29	-1.07	-0.15	-1.16	-1.06	-1.07	-0.42	-1.11	-1.15

Characteristic	Megahabitat class								
	Shal - E	Shal - F	Shal - G	Shal - H	Shal - I	Shal - J	Shal - K	Shal - L	Shal - M
TempMaxMin	15.98	12.46	1.97	8.74	8.55	2.85	1.72	9.50	8.69
TempMoyMax	4.43	1.52	1.65	1.61	0.82	0.53	2.16	2.87	2.85
TempMinMax	-1.26	-0.89	0.96	-1.06	-0.13	-0.42	1.37	2.32	2.21
TempMaxMax	10.07	4.12	2.27	4.48	1.77	1.88	2.93	3.48	3.52
SS_Code_N	40.06	34.50	47.24	32.60	42.60	33.07	27.43	34.52	28.52
Géomorph_1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.99
Géomorph_2	1.01	2.00	1.00	1.01	1.00	1.00	1.00	1.12	1.57
Géomorph_3	0.67	1.00	0.00	0.23	0.47	0.04	0.14	0.58	0.60

Table 7. Surface areas of megahabitats in the lower estuary, and the northern and southern Gulf of St. Lawrence.

Megahabitat		Surface area			
		Total	Lower estuary	Northern Gulf	Southern Gulf
Deep water	Deep - A	61834	2595	59239	0
	Deep - B	1247	0	1247	0
	Deep - C	18560	200	15664	2696
	Deep - D	13572	1000	11877	695
Shallow water	Shal - E	20161	0	568	19593
	Shal - F	128	39	77	12
	Shal - G	2900	0	300	2600
	Shal - H	16654	704	538	15412
	Shal - I	20997	873	16390	3734
	Shal - J	36209	0	4809	31400
	Shal - K	16002	0	12902	3100
	Shal - L	2813	1043	670	1100
	Shal - M	13583	1987	11297	299

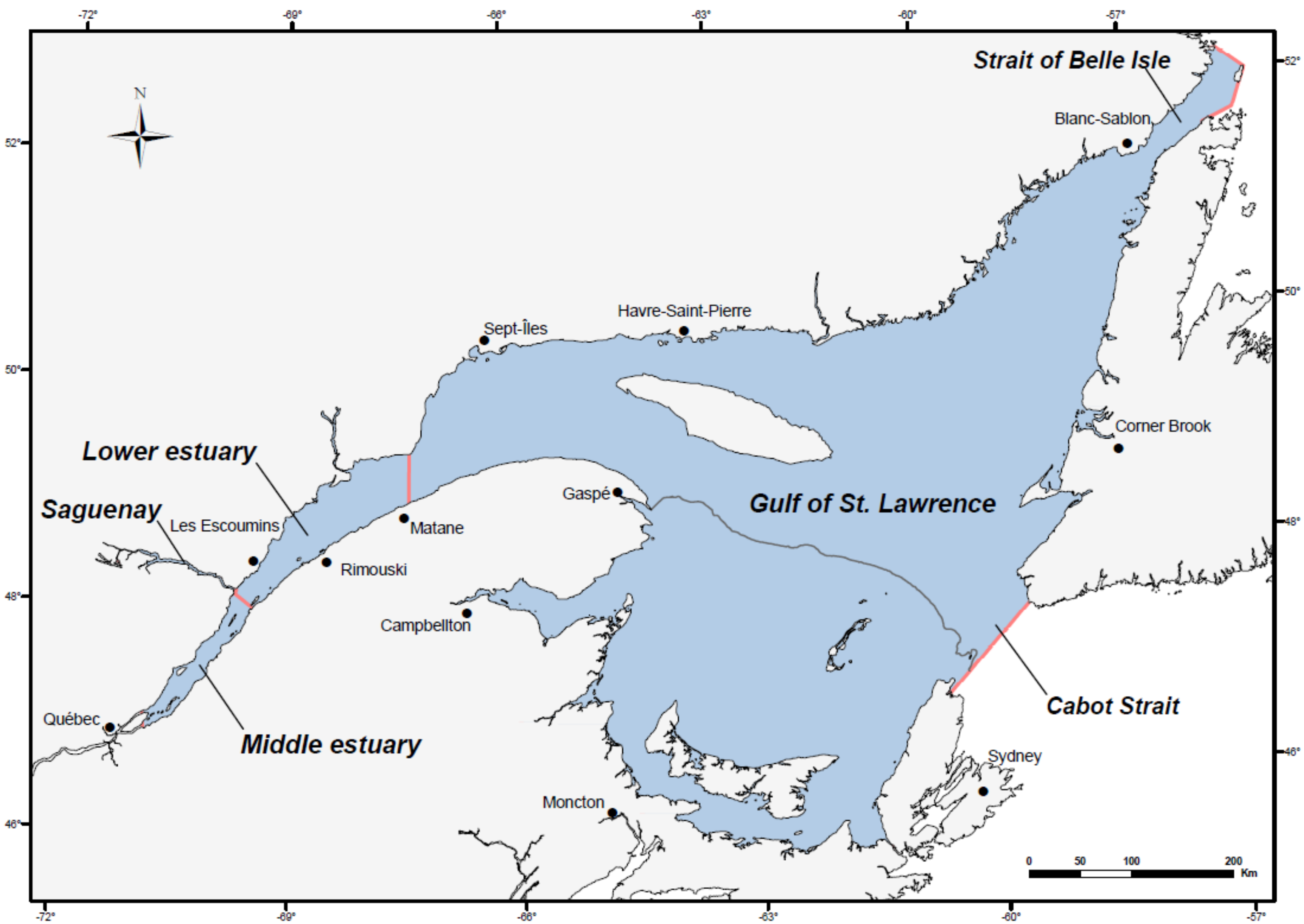


Fig. 1. The area considered in the present study included the Saguenay Fjord, the St. Lawrence middle and lower estuary, and the Gulf of St. Lawrence east to Cabot Strait and the Strait of Belle Isle. Solid red lines indicate the limits of the study area and subareas.

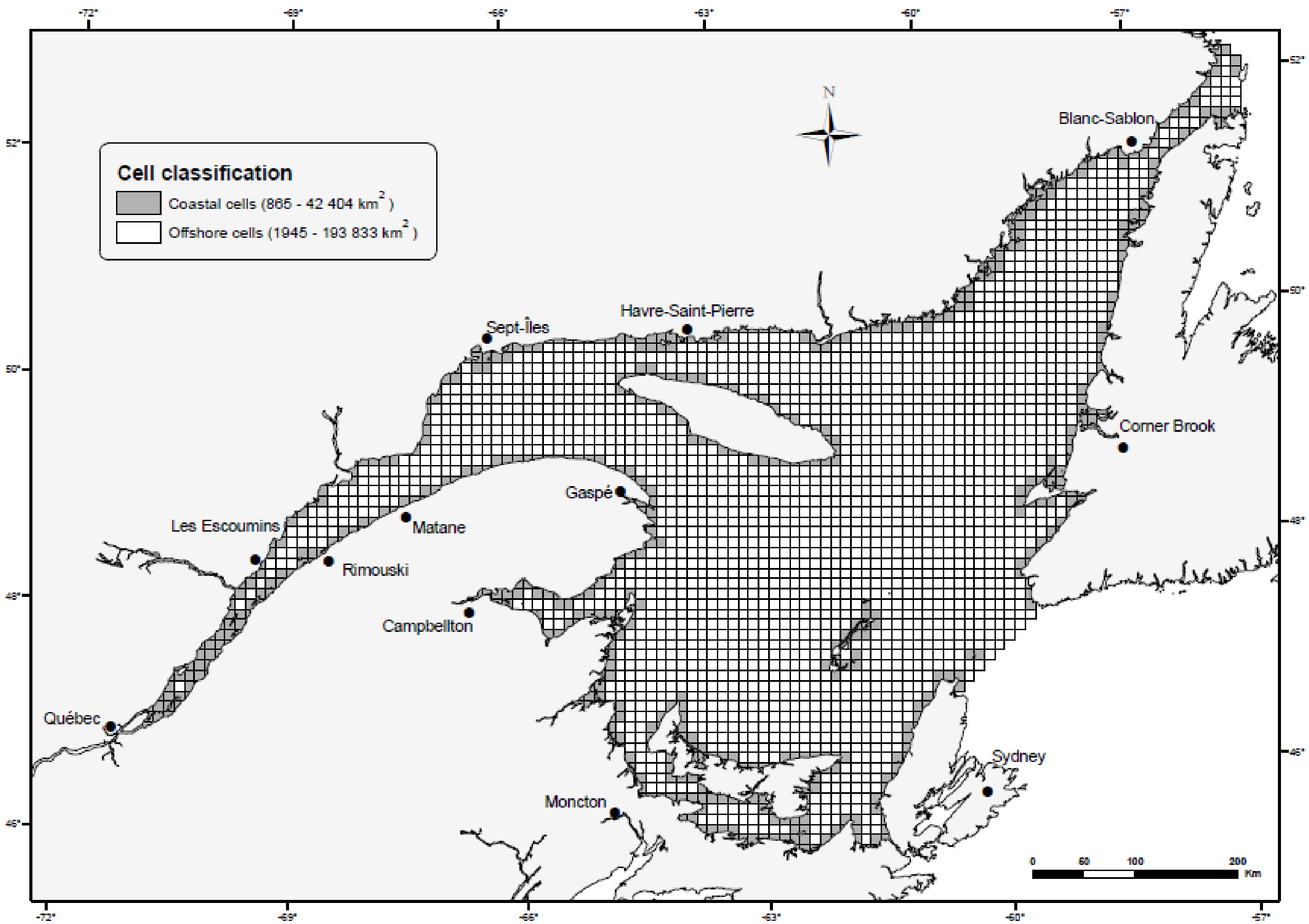


Fig. 2. Grid showing the actual mapping domain for this project (236 237 km^2). Square cells represent 100 km^2, irregular cells are those overlapping the terrestrial domain and the limits of the study area. Coastal cells are shaded in gray.

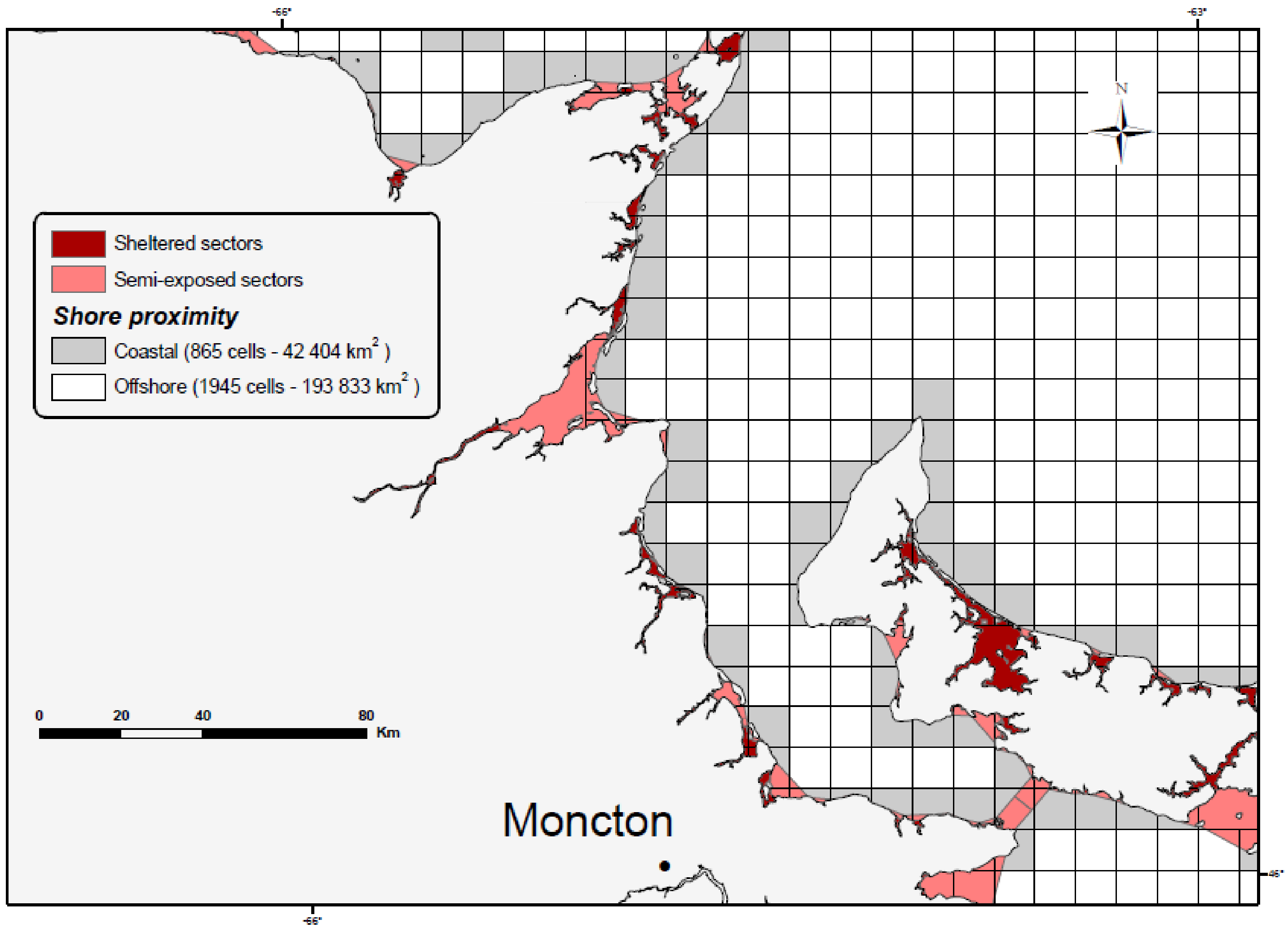


Fig. 3. Cells were divided into sheltered, semi-exposed, and exposed zones, based on the degree of exposure to open ocean waves and currents, following Bédard et al. (2009, unpublished report) and Kervalla et al. (2010, unpublished report). The surface area of each category within each cell was calculated from intersections between input layers. This figure shows an example for Prince Edward Island and New Brunswick.

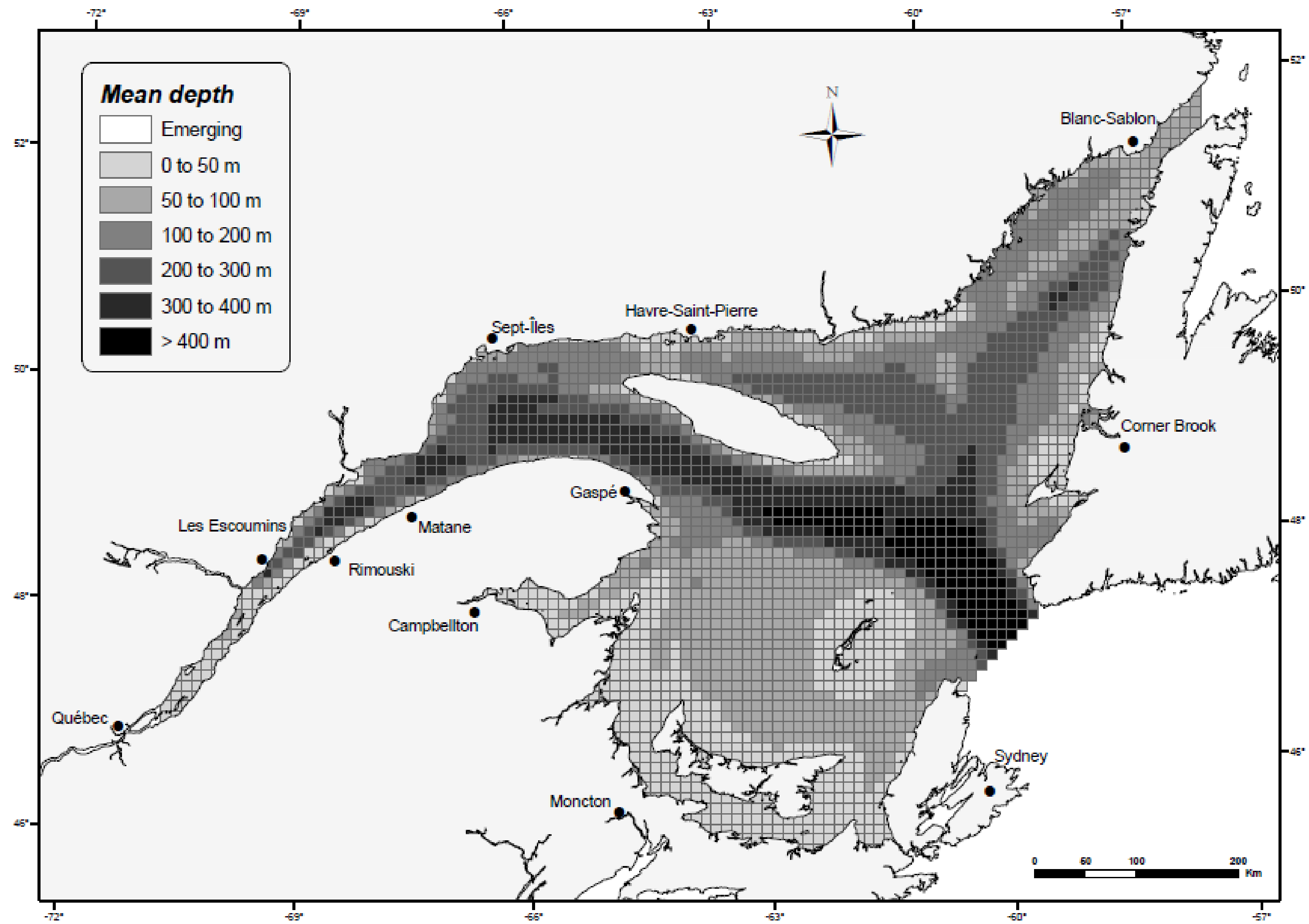


Fig. 4. Mean depth (m) of 10 km x 10 km cells from a 500 m interpolation in the estuary and Gulf of St. Lawrence.

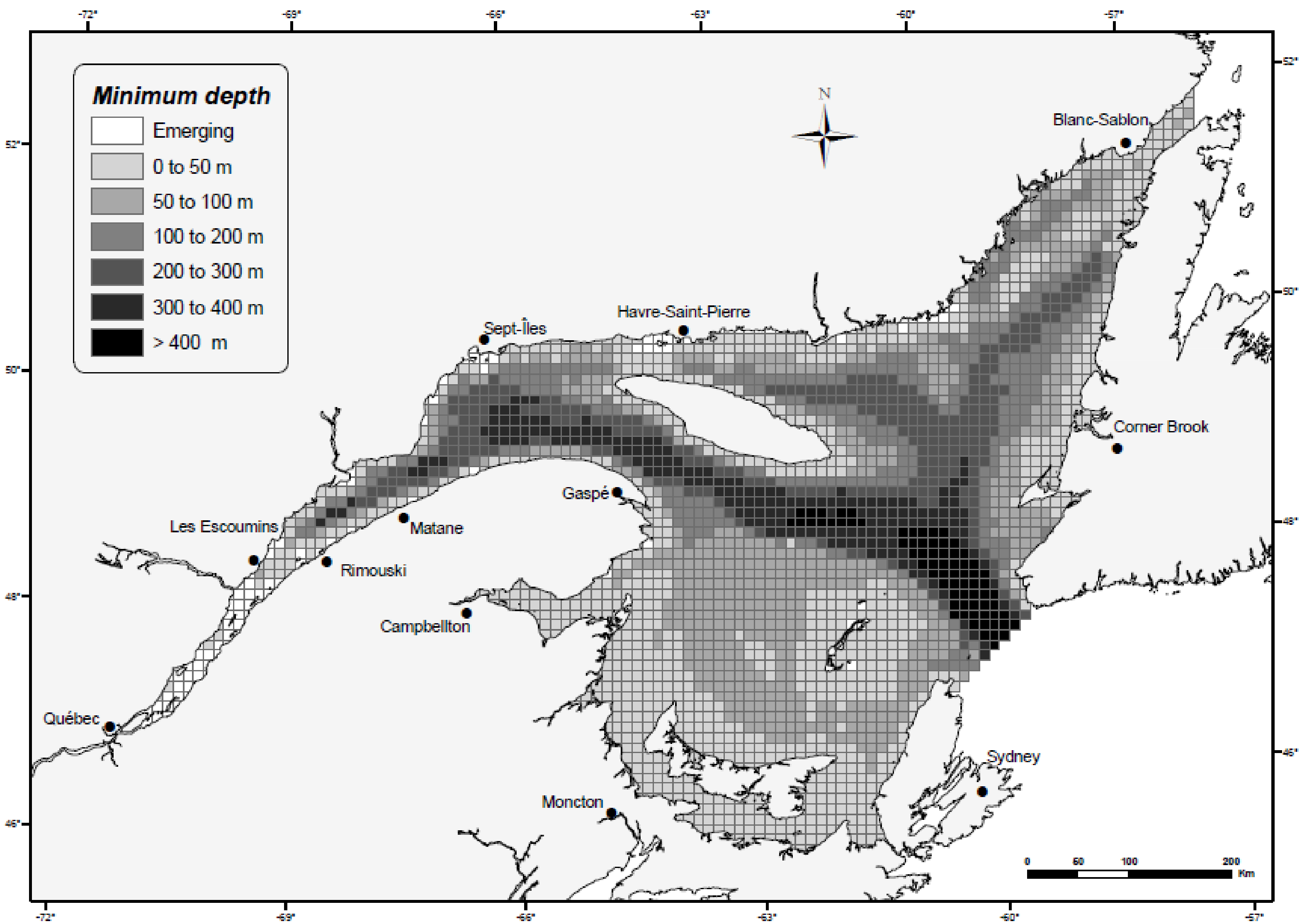


Fig. 5. Minimum depth (m) of 10 km x 10 km cells from a 500 m interpolation in the estuary and Gulf of St. Lawrence.

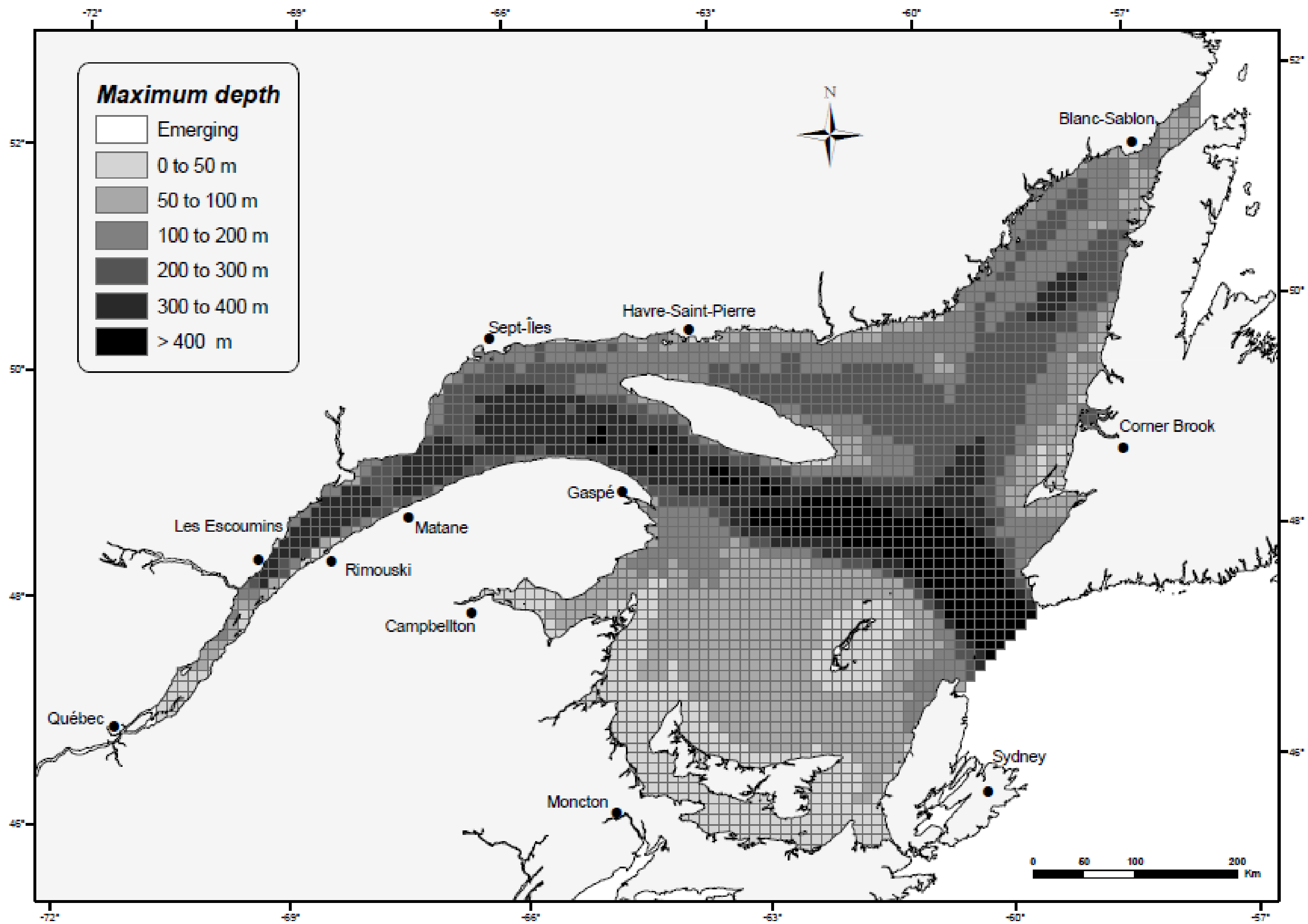


Fig. 6. Maximum depth (m) of 10 km x 10 km cells from a 500 m interpolation in the estuary and Gulf of St. Lawrence.

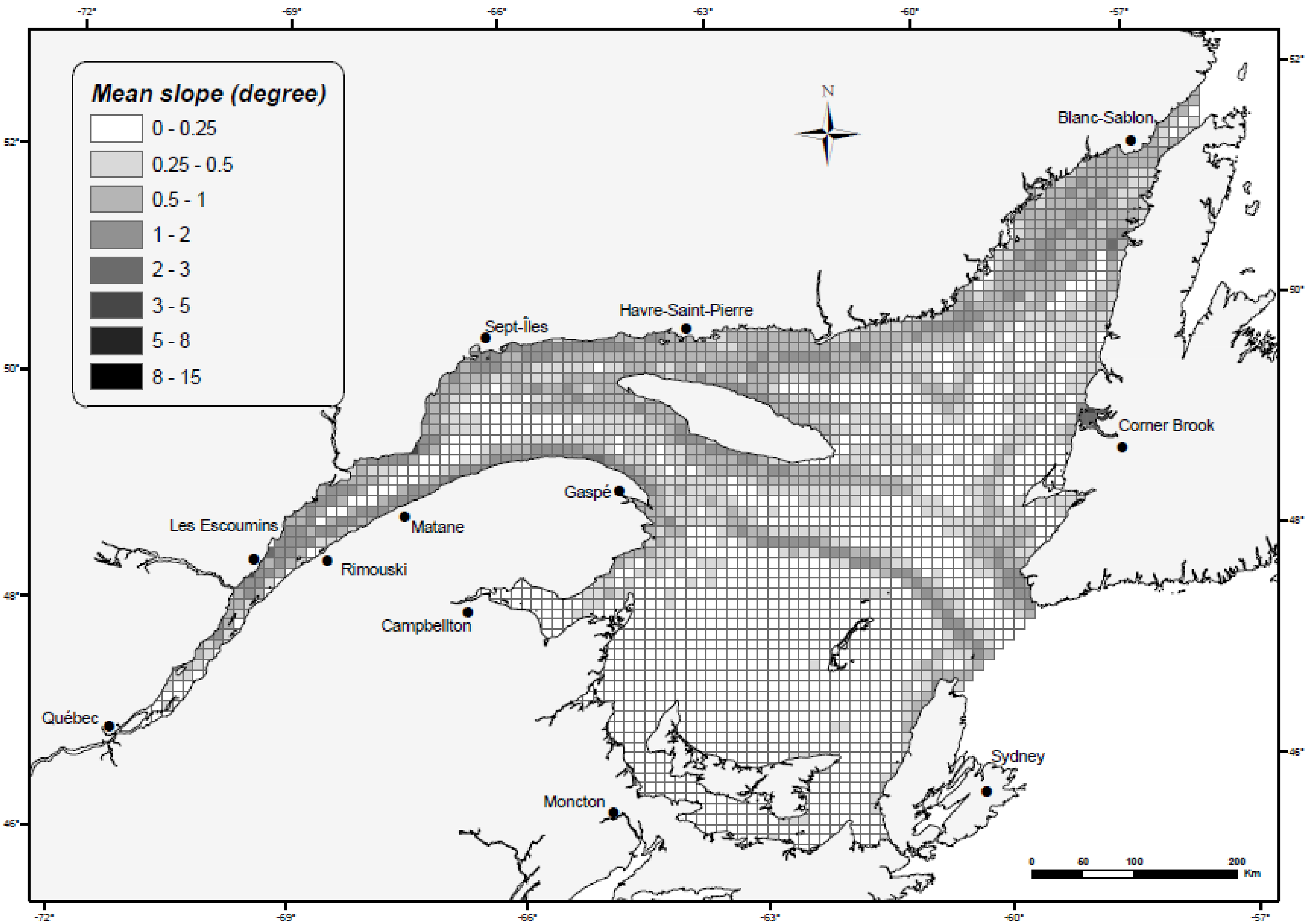


Fig. 7. Mean slope (degree) of 10 km x 10 km cells calculated from a 500 m interpolation of depths in the estuary and Gulf of St. Lawrence.

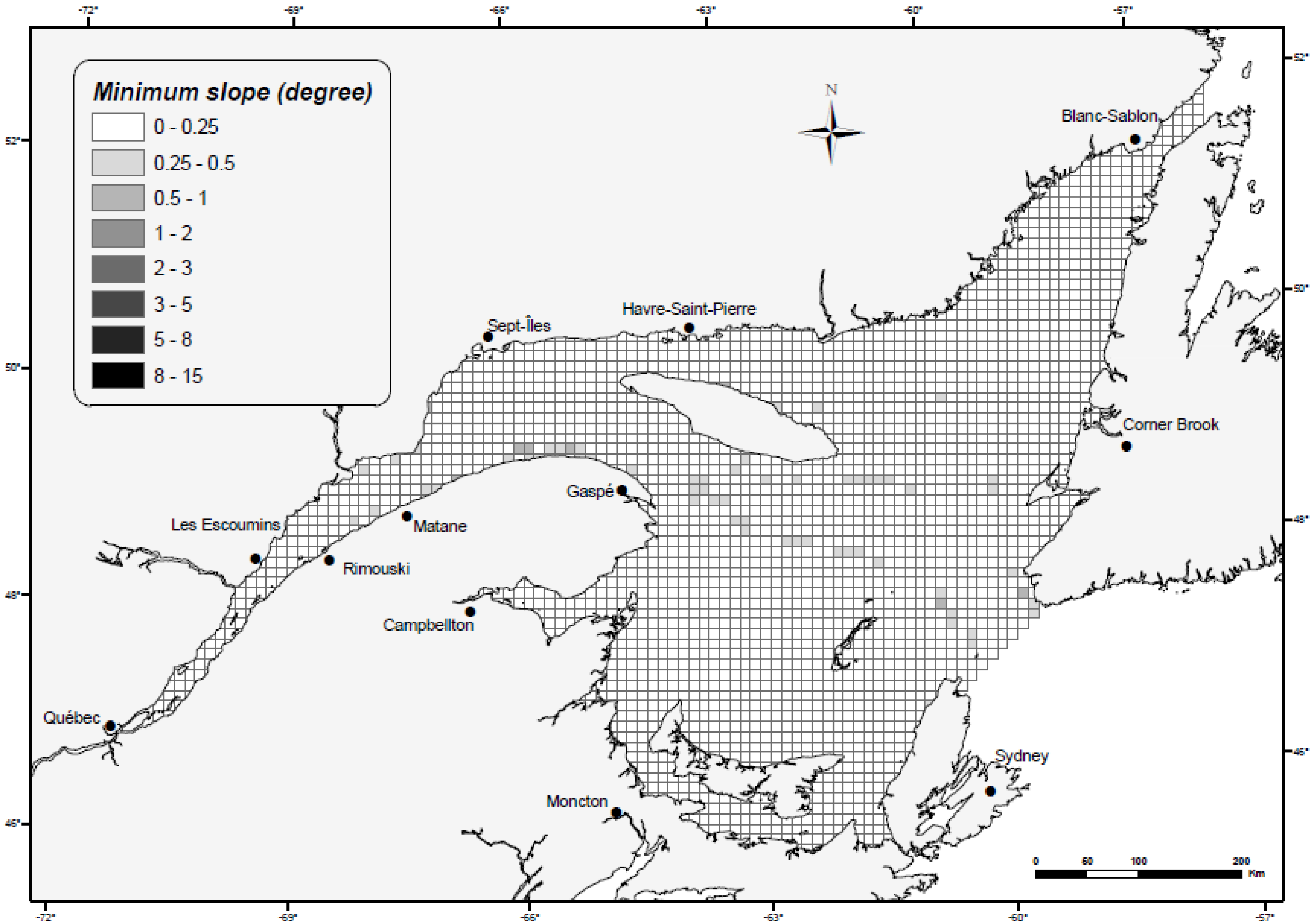


Fig. 8. Minimum slope (degree) of 10 km x 10 km cells calculated from a 500 m interpolation of depths in the estuary and Gulf of St. Lawrence.

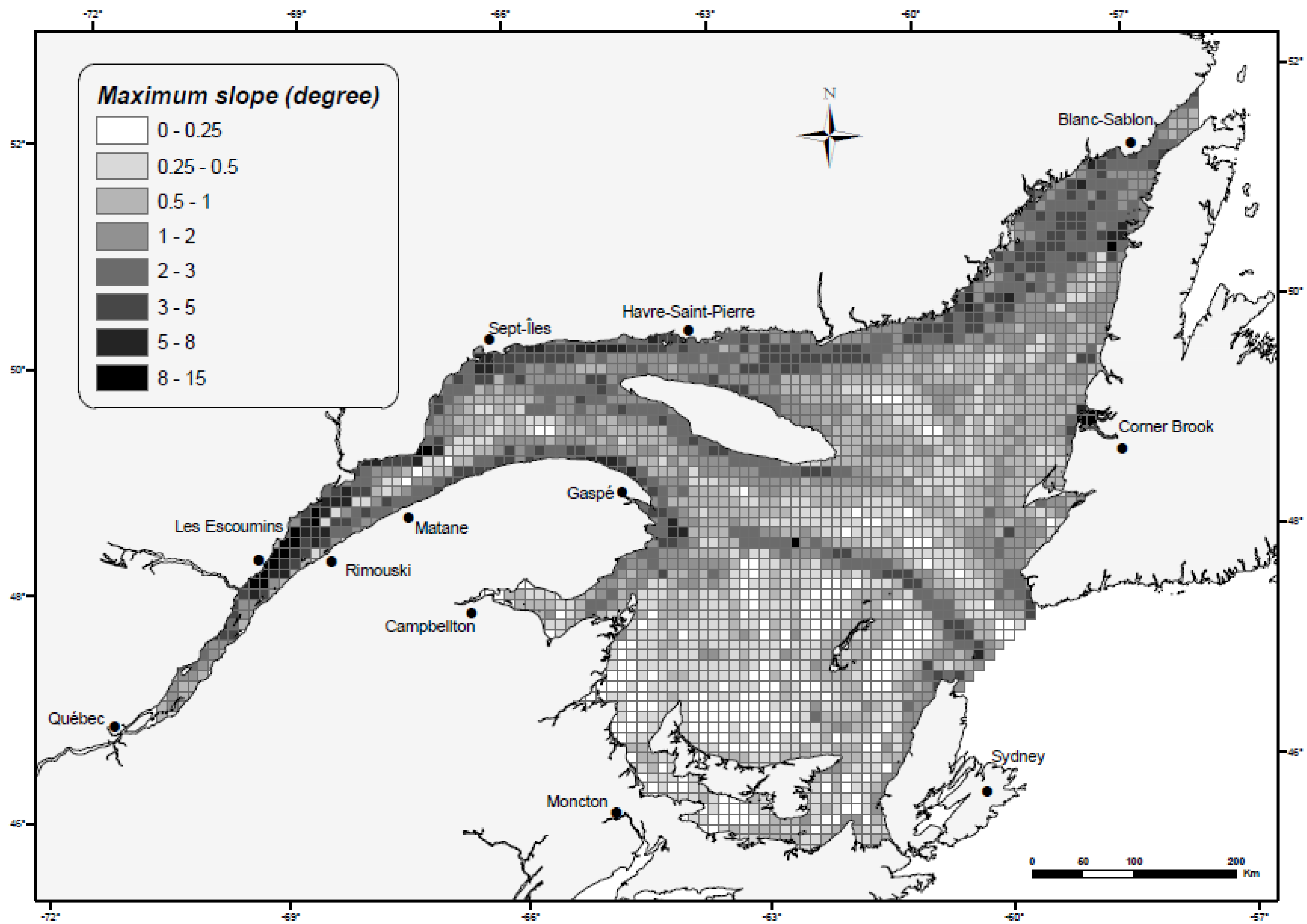


Fig. 9. Maximum slope (degree) of 10 km x 10 km cells calculated from a 500 m interpolation of depths in the estuary and Gulf of St. Lawrence.

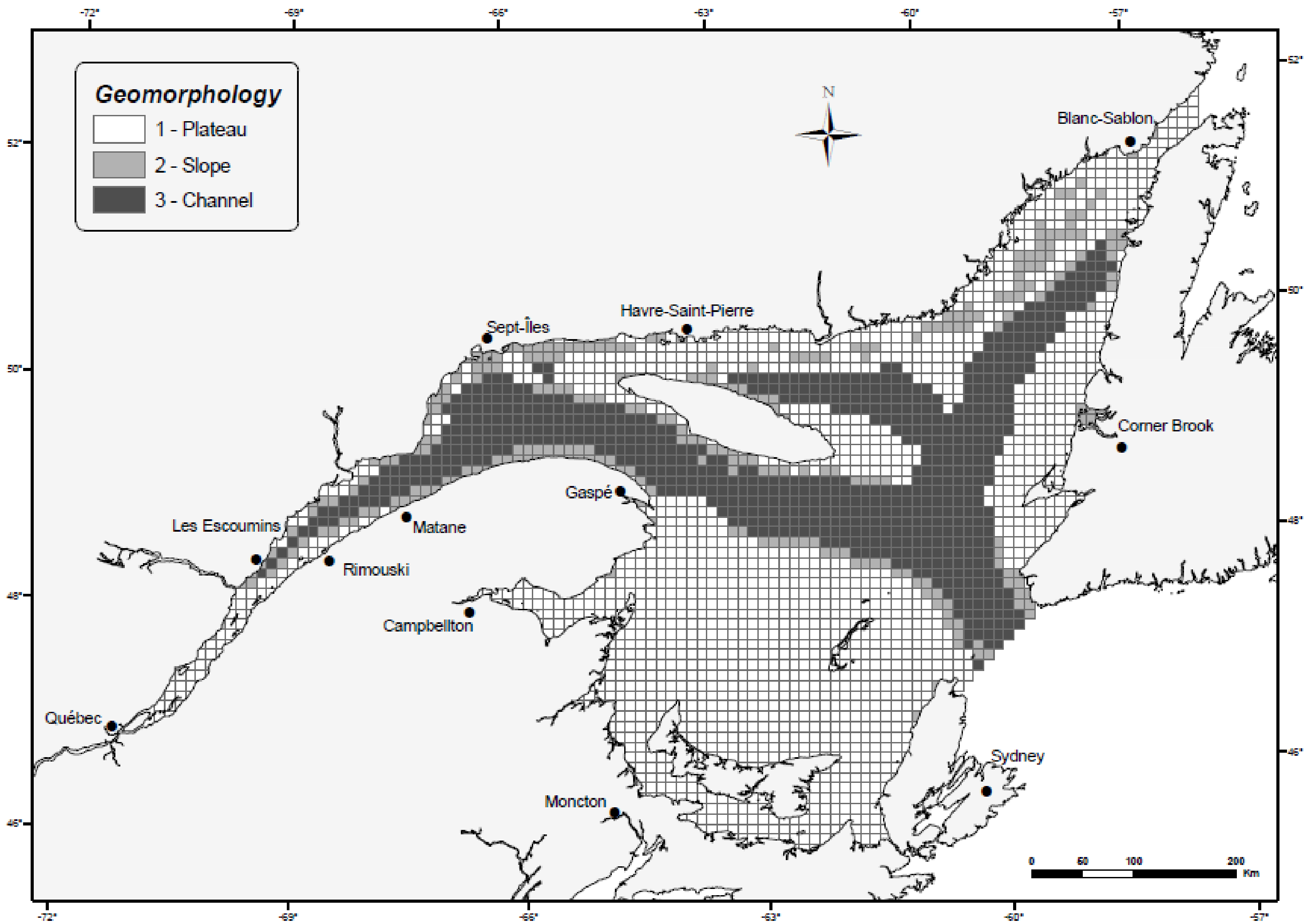


Fig. 10. Cells were classified as belonging to a slope (mean slope > 0.8°), a plateau (mean depth < 200 m and mean slope < 0.8°), or a channel (mean depth > 200 m and mean slope < 0.8°) based on the class representing the greater proportion of the cell surface area (variable Geomorph_1).

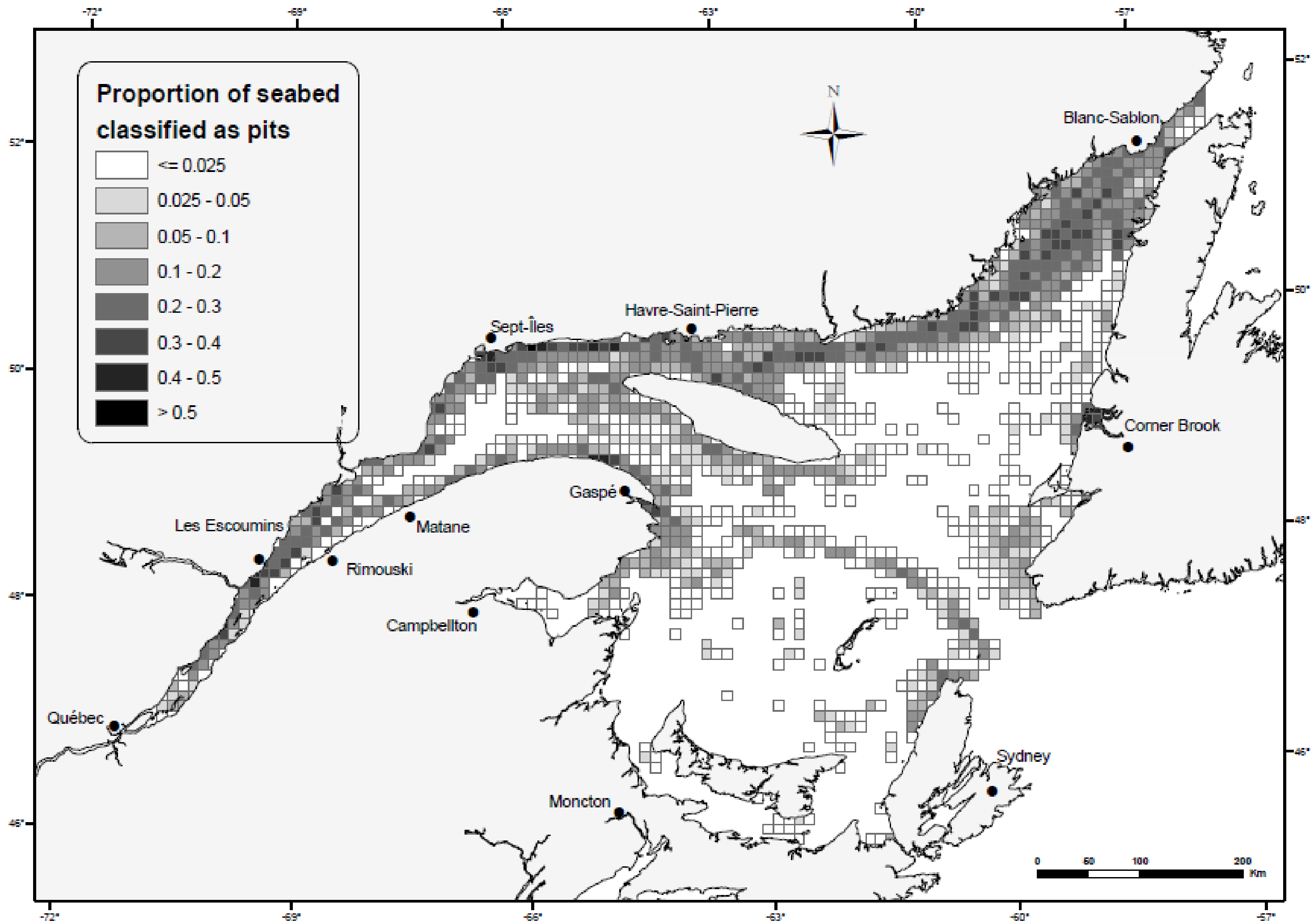


Fig. 11. Location in the study area and relative importance of pits within cells; relative importance is expressed as a proportion of the total cell surface area. Missing cells are those where no observation was classified as belonging to a pit.

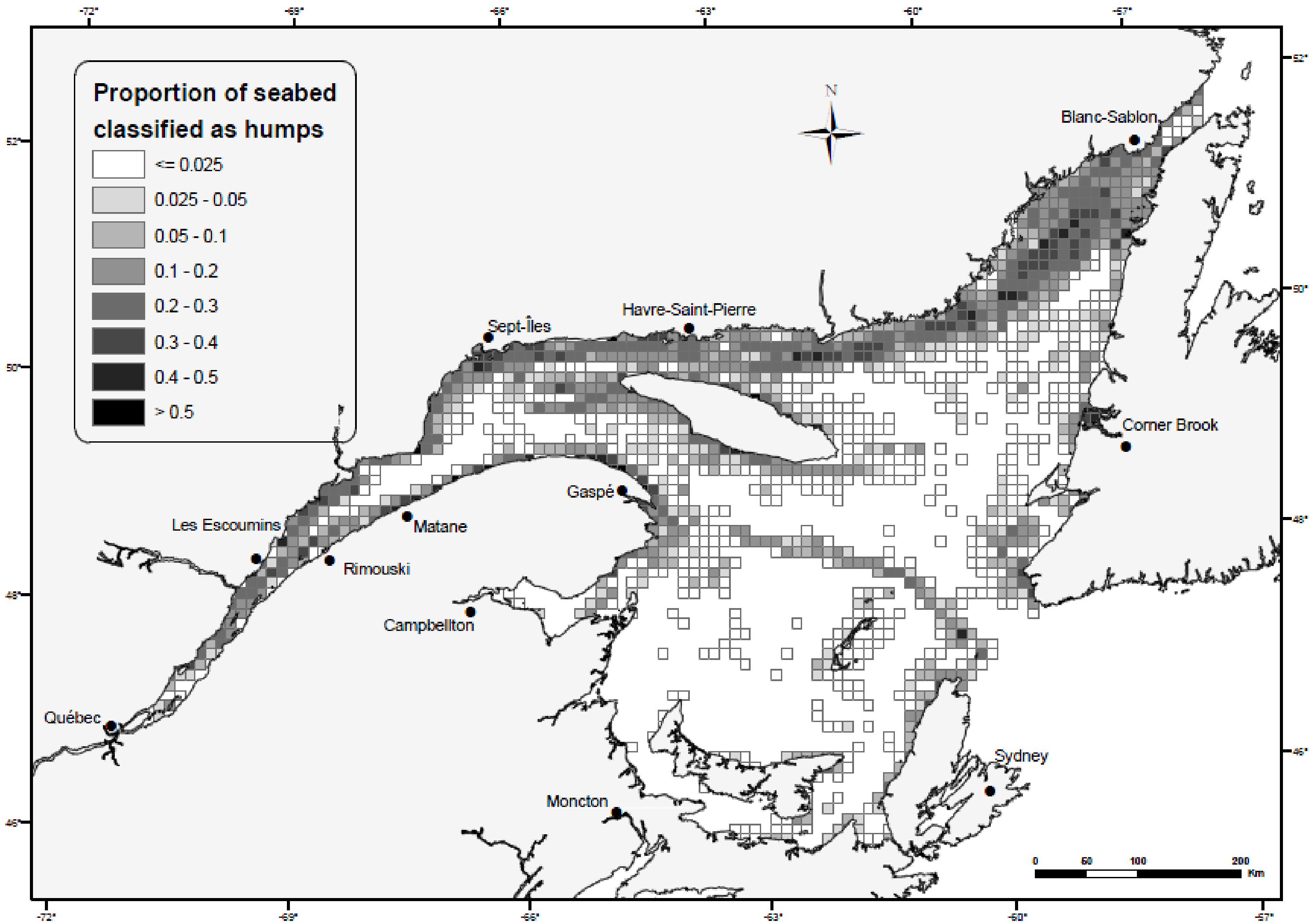


Fig. 12. Location in the study area and relative importance of humps within cells; relative importance is expressed as a proportion of the total cell surface area. Missing cells are those where no observation was classified as belonging to a hump.

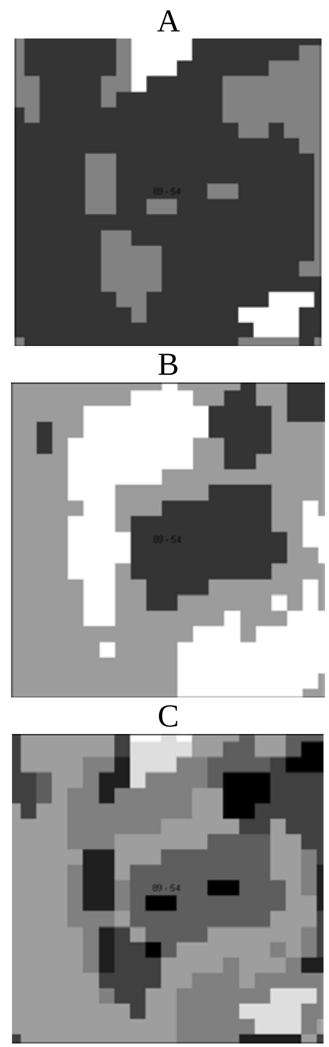


Fig. 13. A cell classified as a slope and dominated by uniform terrain can actually be made of a mosaic of reliefs. A – Plot of Geomorph_1, classification of pixels as belonging to a slope, a plateau, or a channel; B– Plot of Geomorph_2, classification of pixels as part of a uniform terrain, pits, or humps; C– Plot of Relief_var showing the diversity of reliefs when variables Geomorph_1 and Geomorph_2 are crossed.

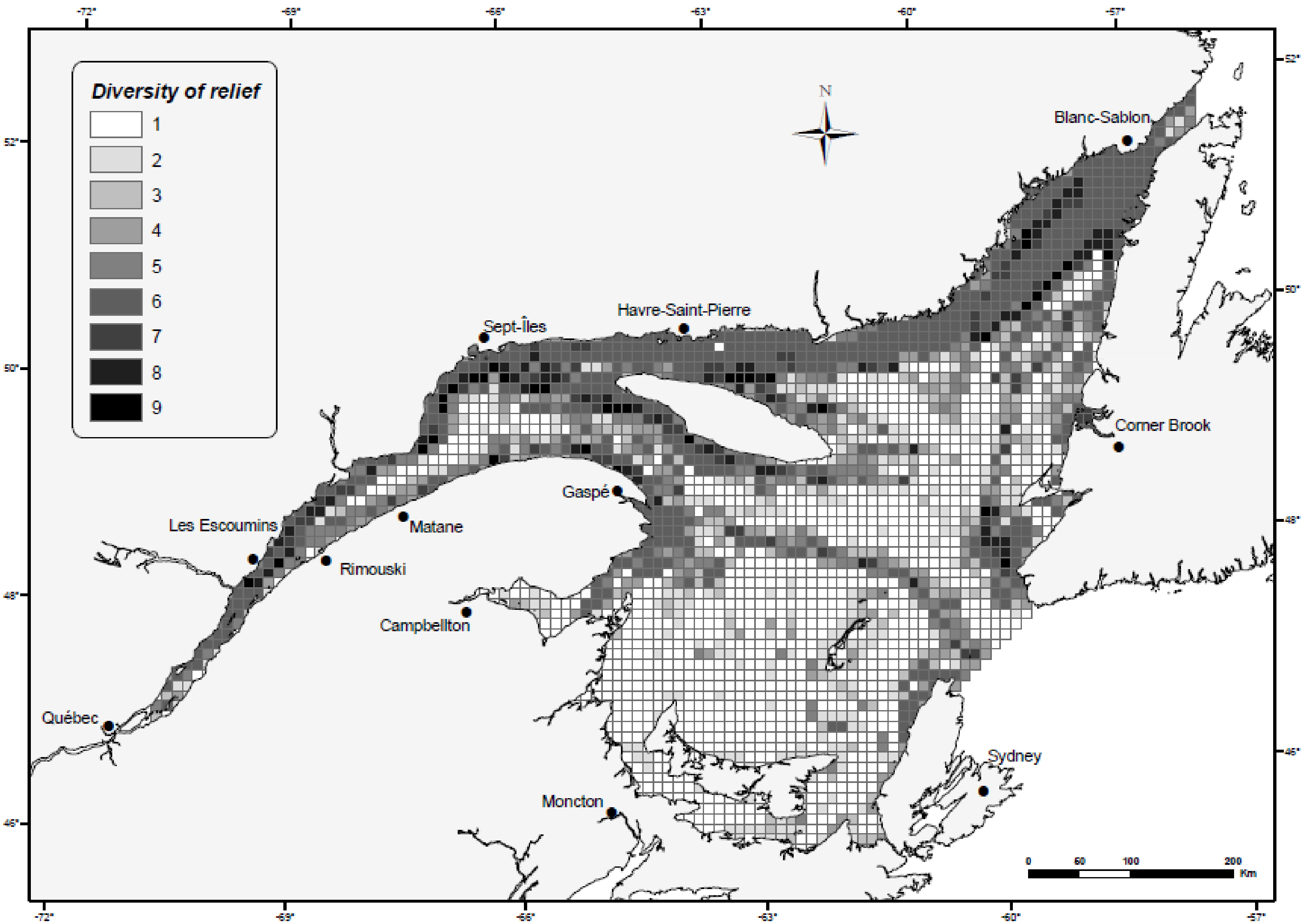


Fig. 14. Number of combinations (maximum nine) of two variables describing the geomorphology of the seabed represented within each cell. Higher numbers represent more diversified reliefs.

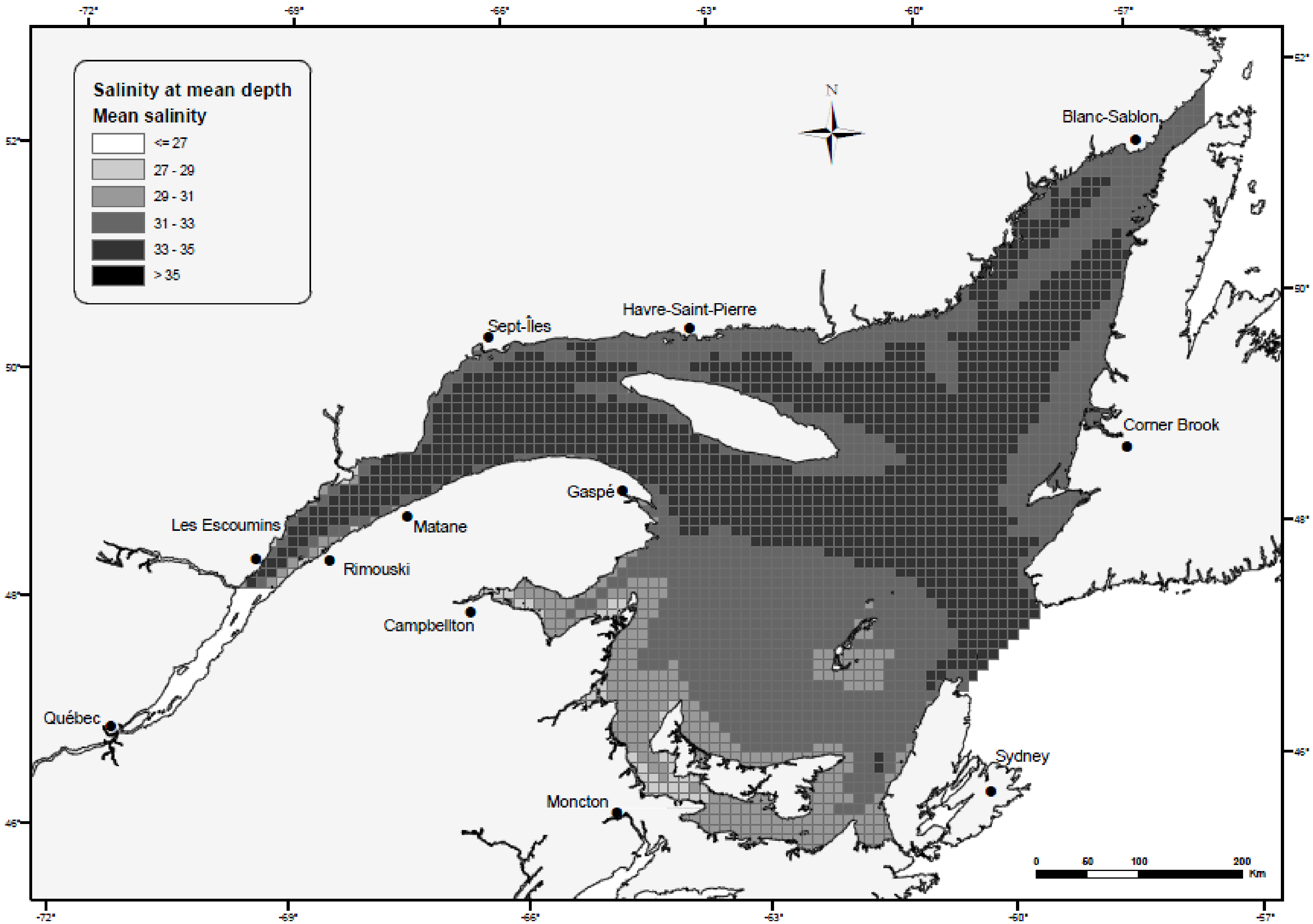


Fig. 15. Mean annual salinity on the seabed at mean cell depth.

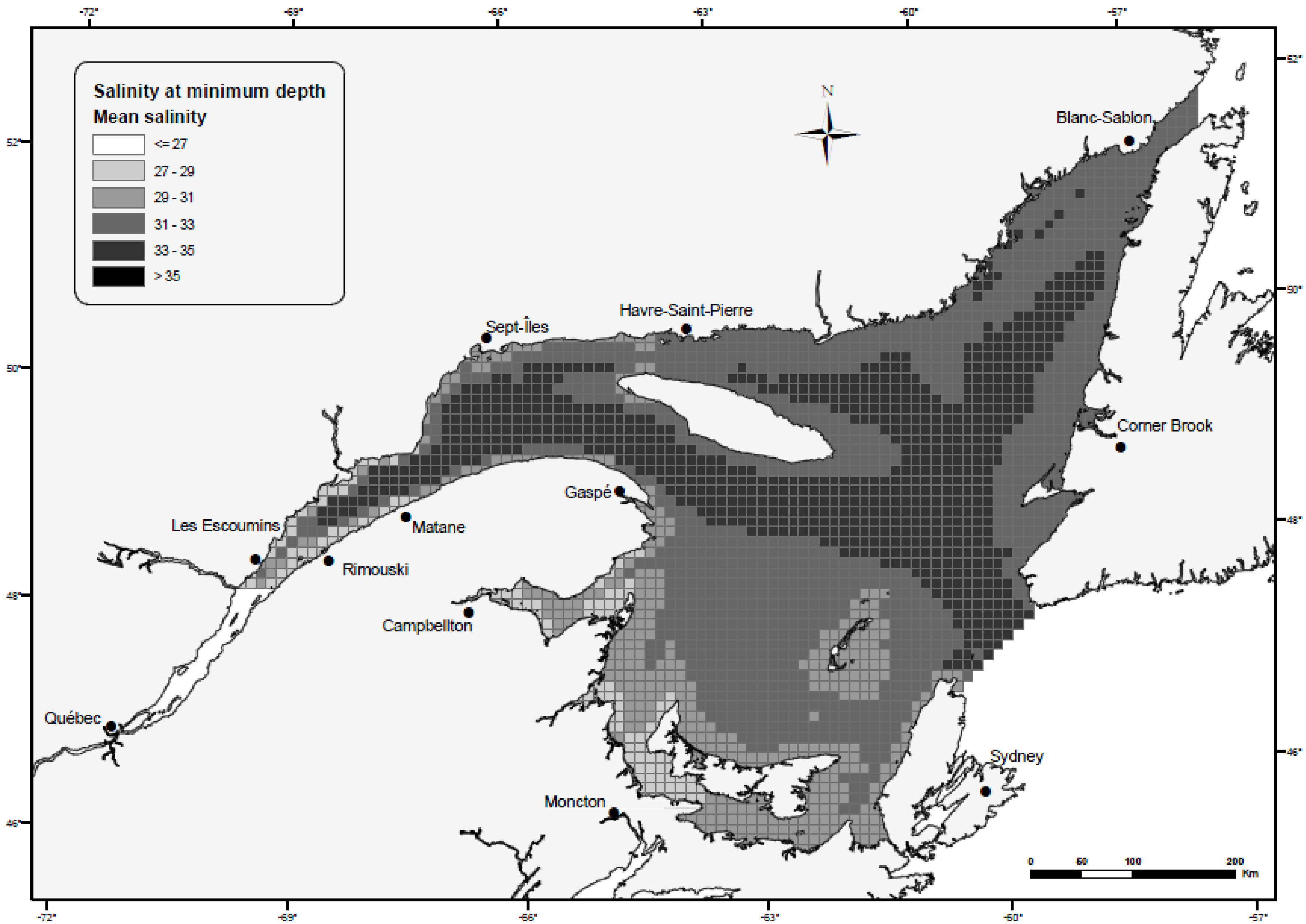


Fig. 16. Mean annual salinity on the seabed at minimum cell depth.

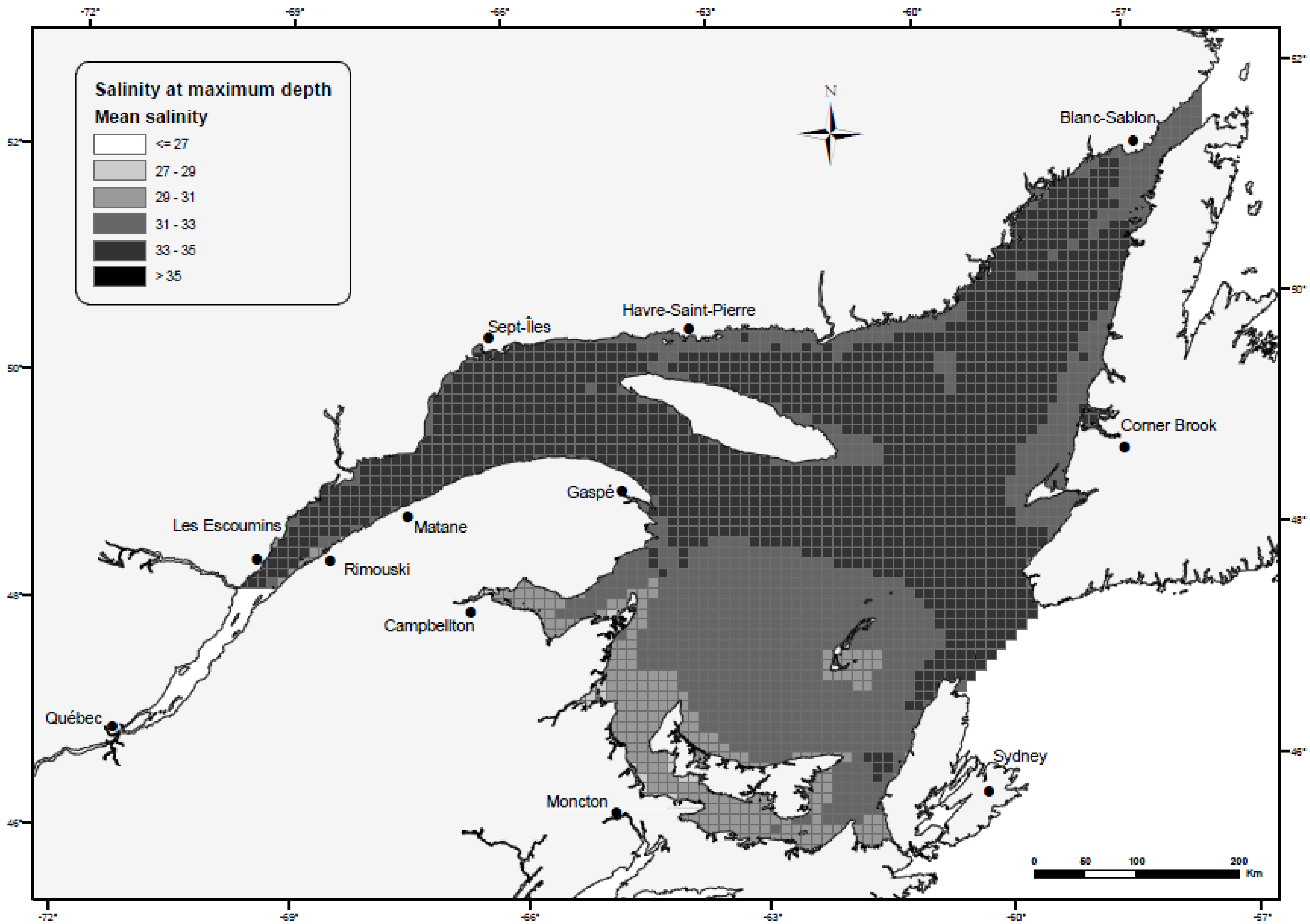


Fig. 17. Mean annual salinity on the seabed at maximum cell depth.

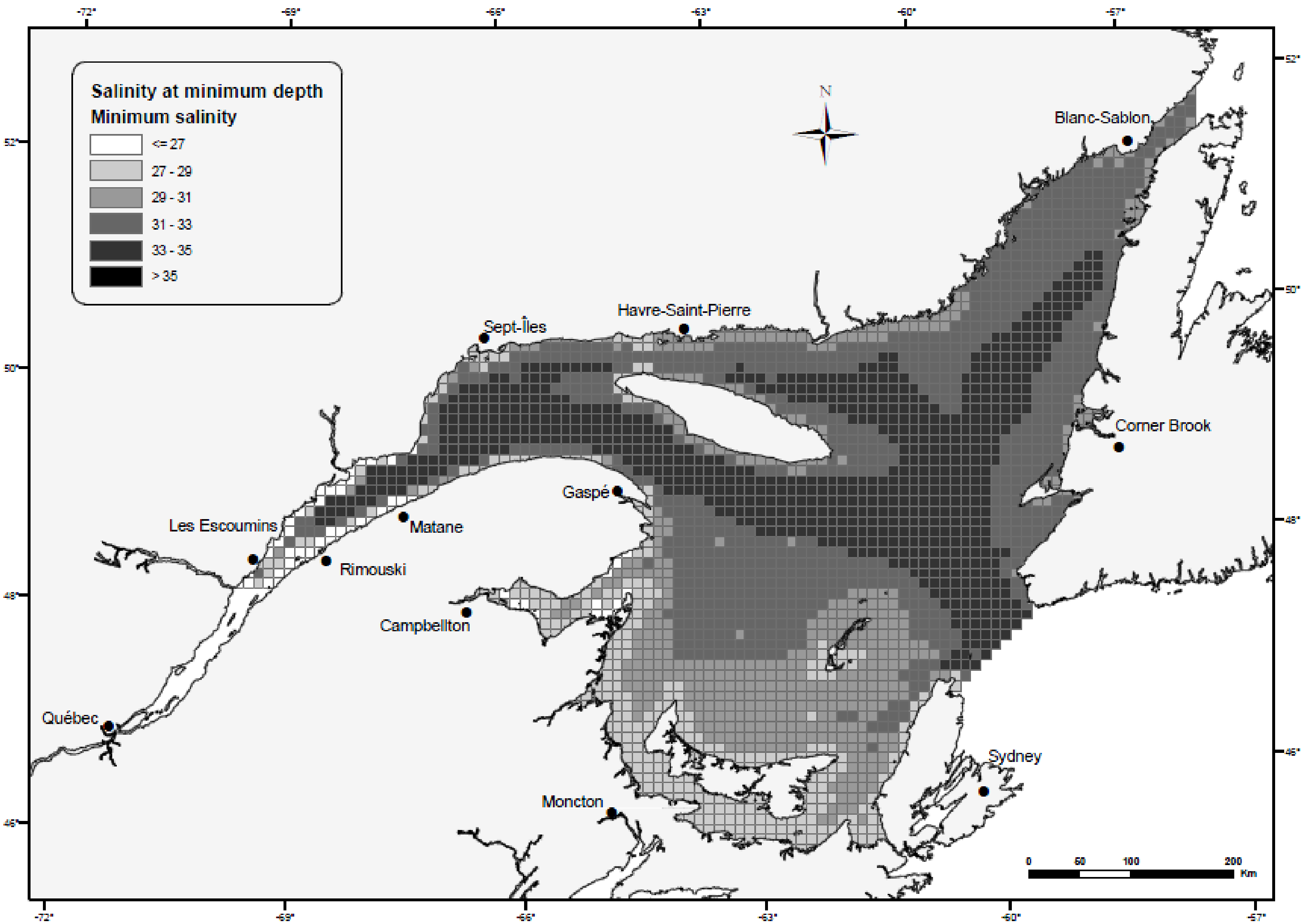


Fig. 18. Minimum monthly salinity on the seabed at minimum cell depth.

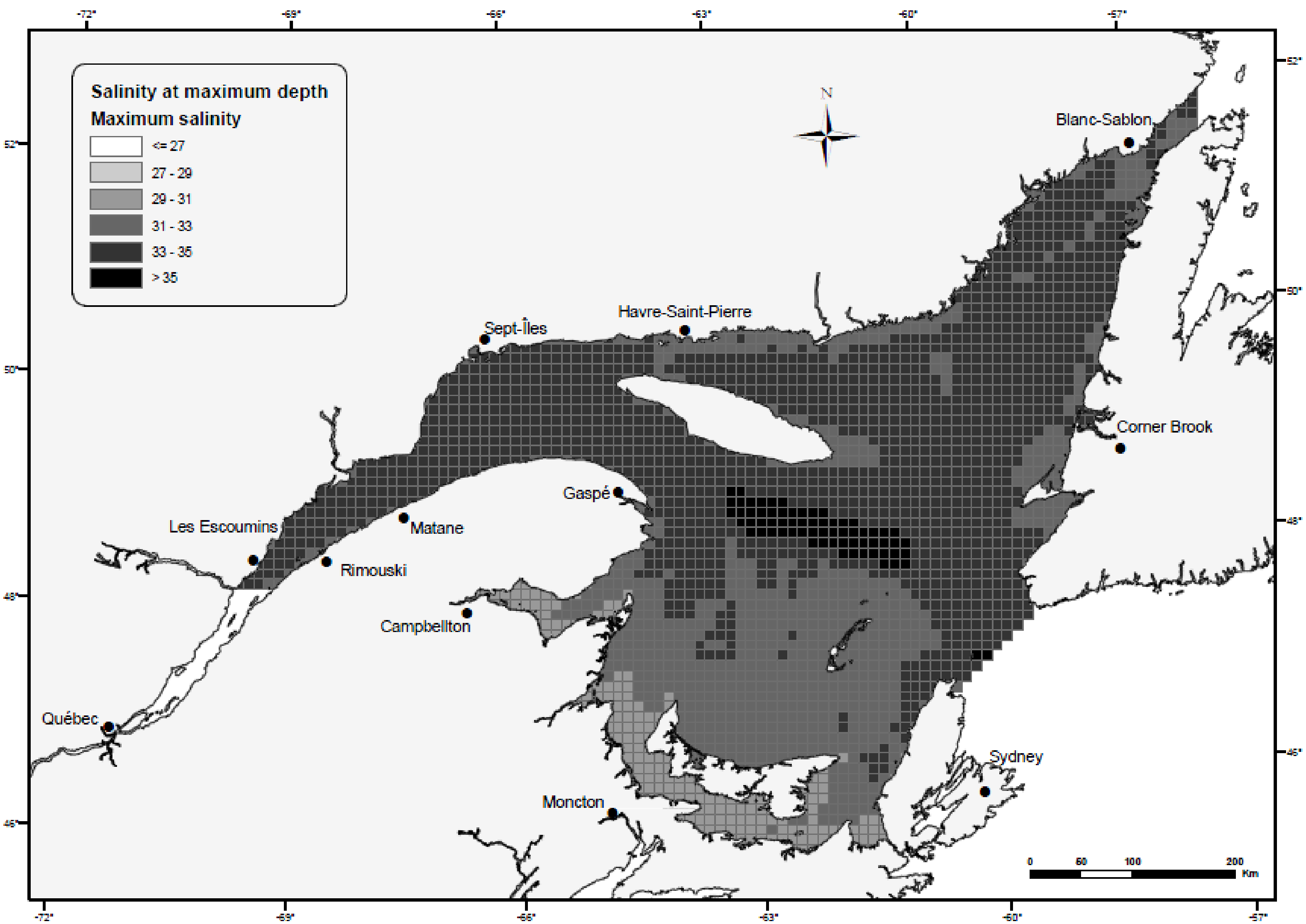


Fig. 19. Maximum monthly salinity on the seabed at maximum cell depth.

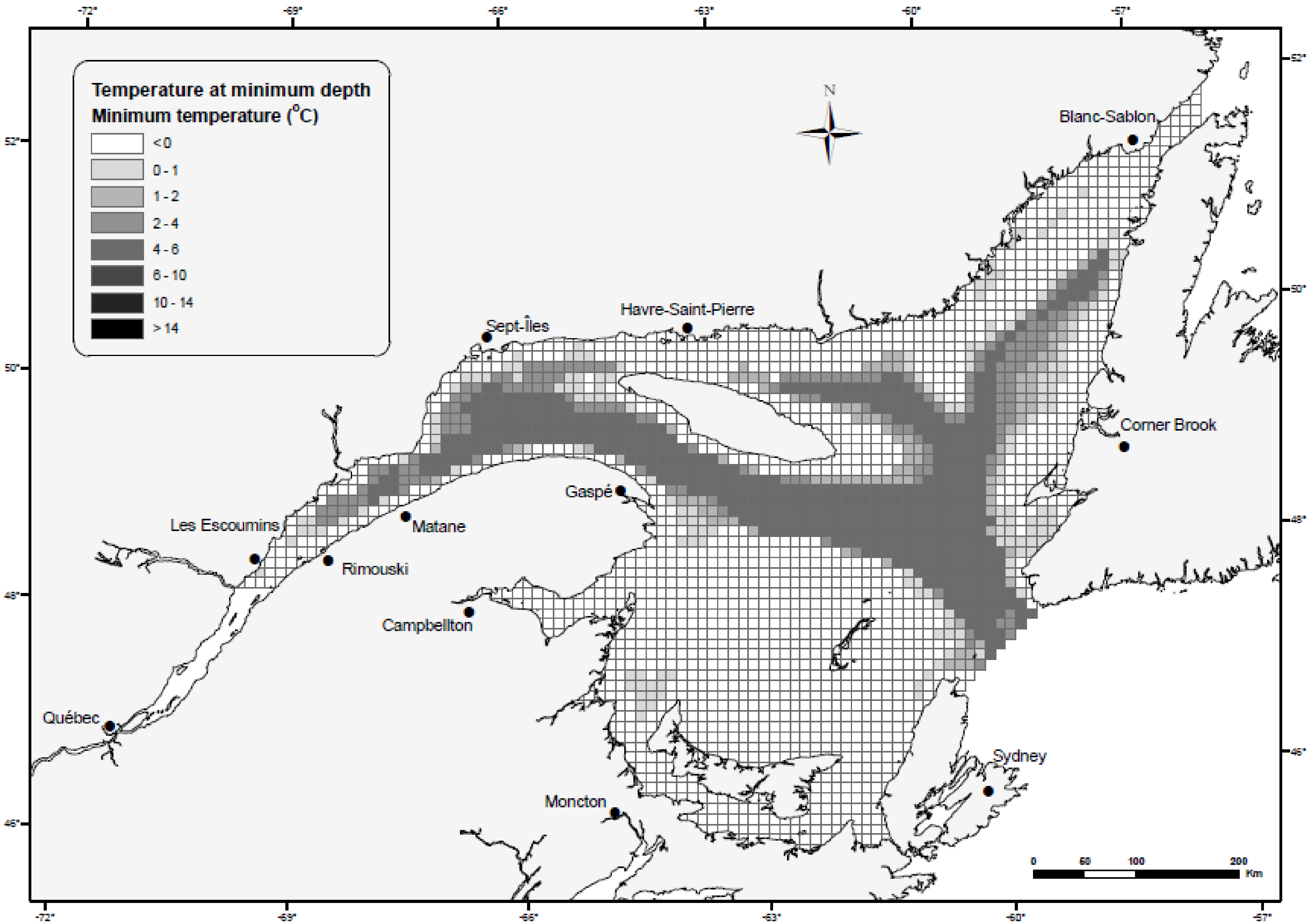


Fig. 20. Minimum monthly temperature (°C) on the seabed at minimum cell depth.

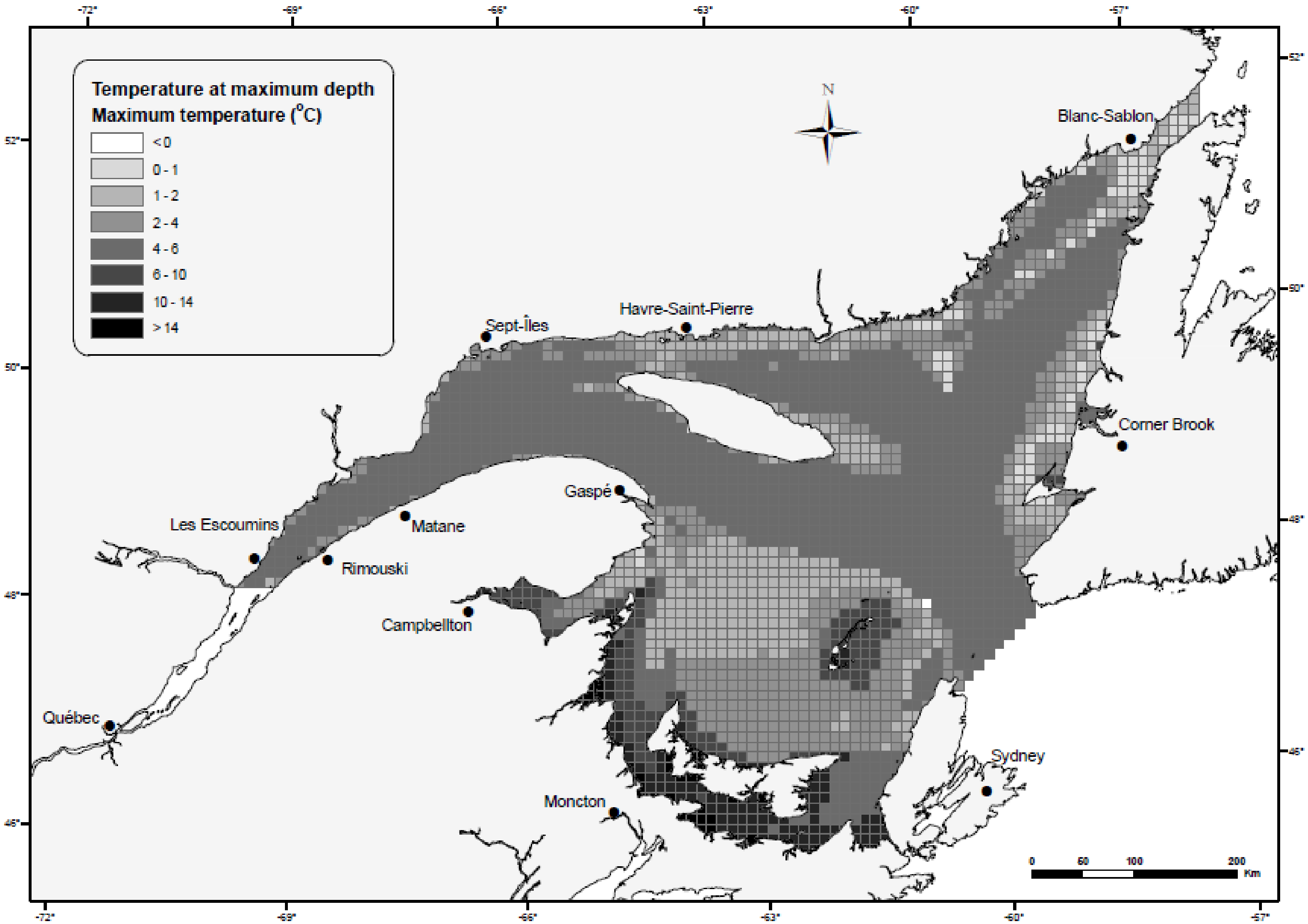


Fig. 21. Maximum monthly temperature (°C) on the seabed at maximum cell depth.

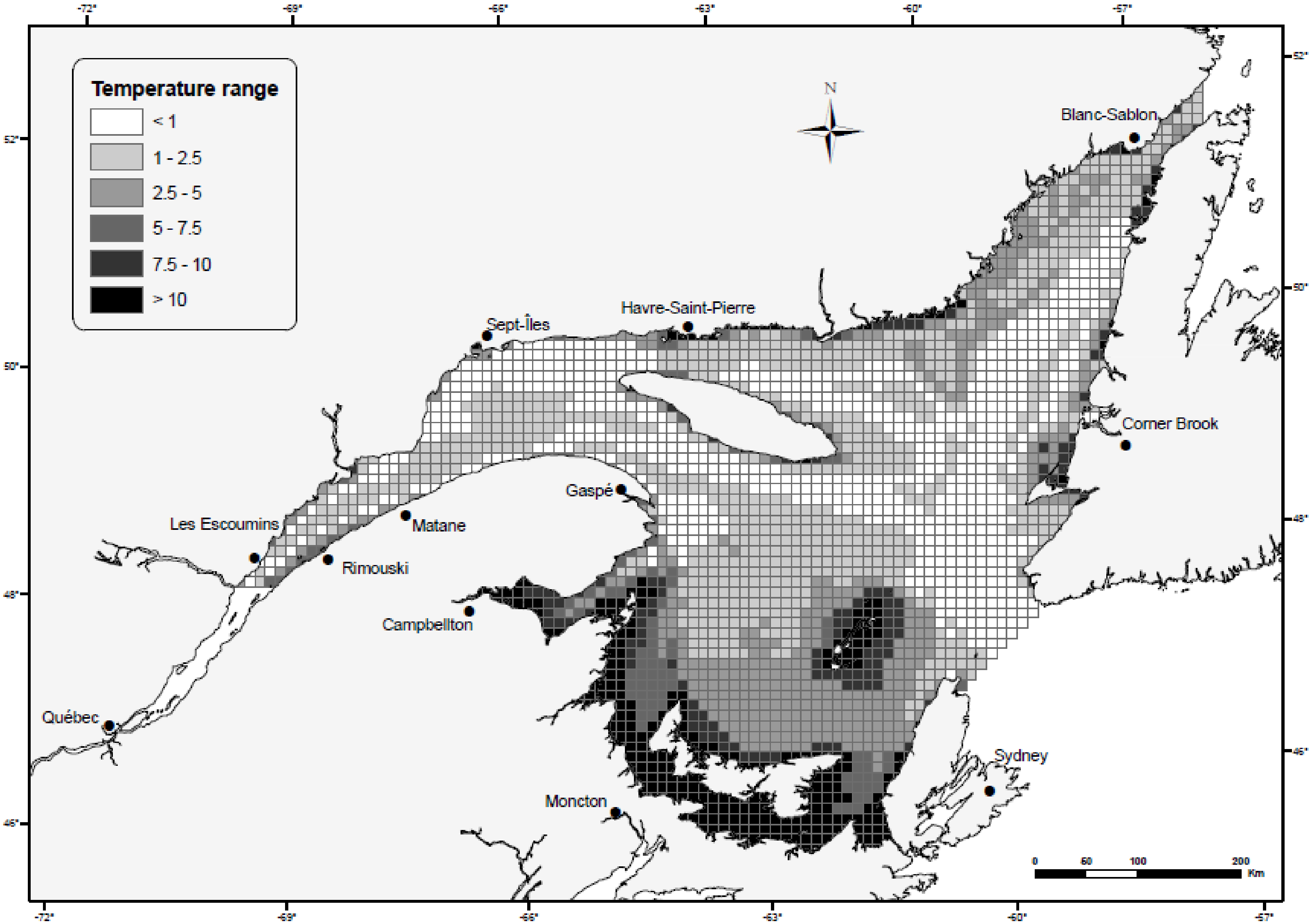


Fig. 22. Range in mean monthly temperature (°C) on the seabed at mean cell depth.

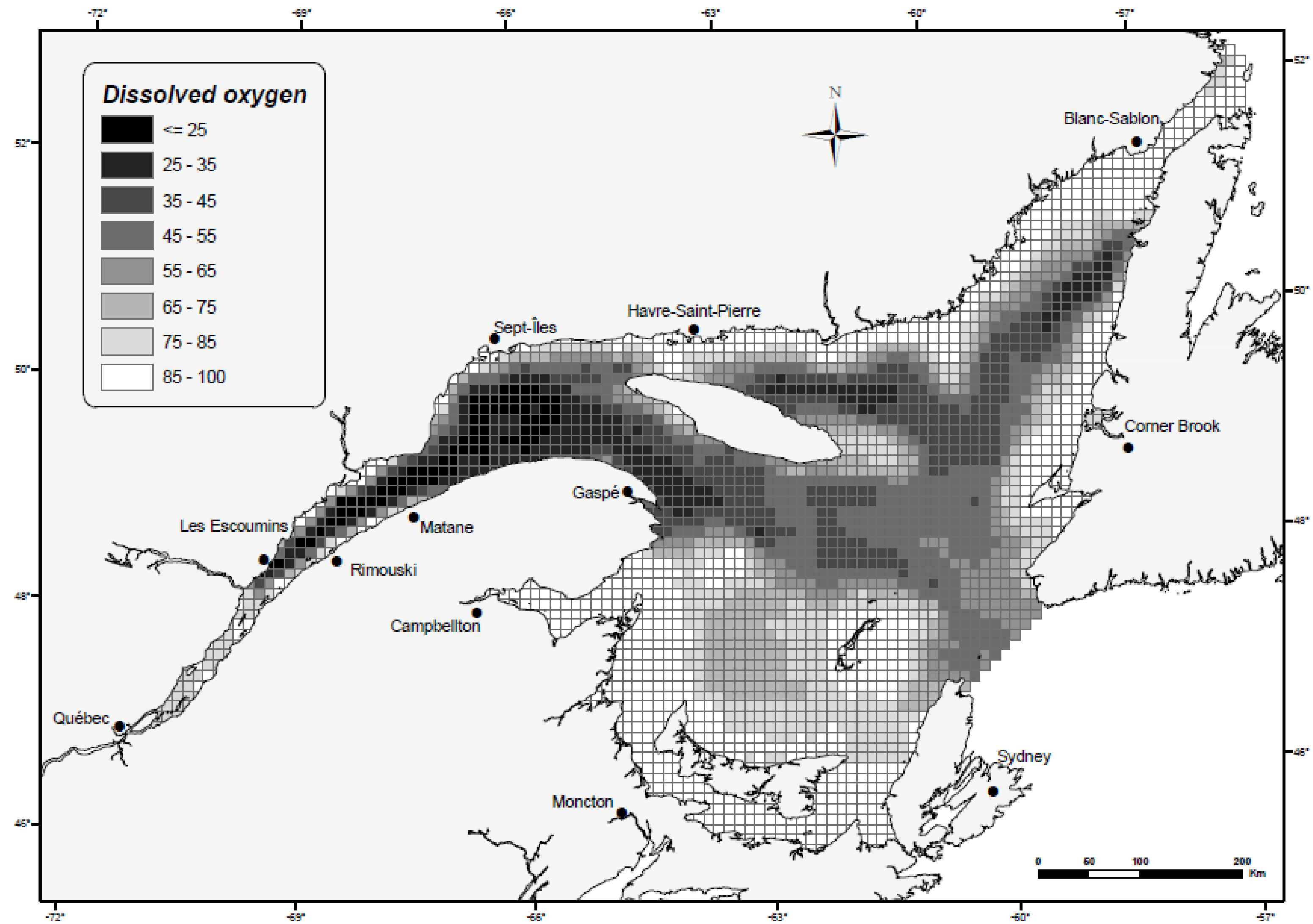


Fig. 23. Dissolved oxygen on the bottom in the study area (% saturation). Data obtained from different sources were submitted to spatial interpolation. Kriged estimates were expressed as a class from 1 (hypoxic, < 25% saturation) to 8 (normoxic, > 85% saturation), with intermediate values graded by 10% intervals (variable O2_Sat_Classe).

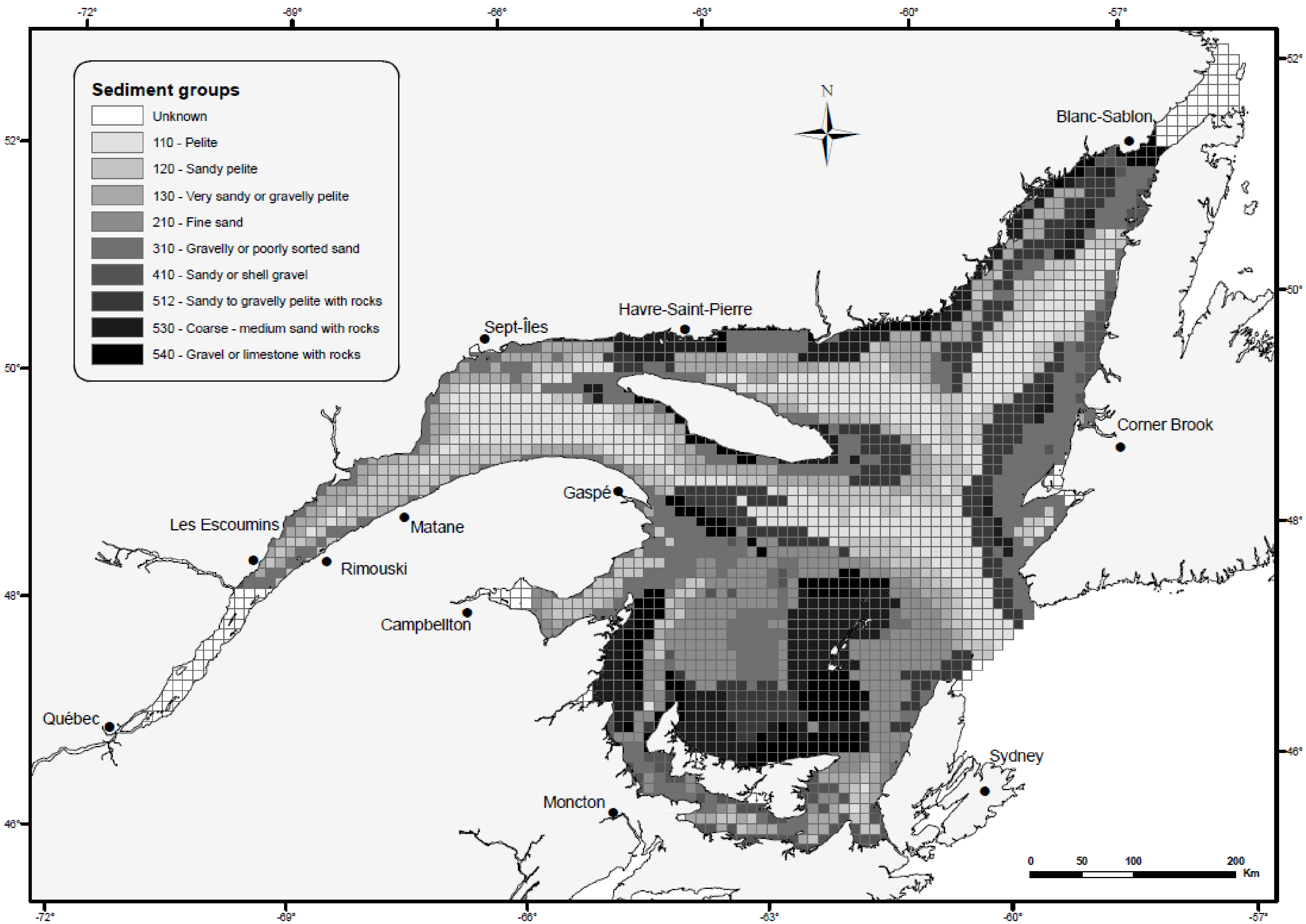


Fig. 24. Surface sediment groups based on granulometry, with emphasis on rock outcrops. Surface sediment data were obtained from Loring and Nota (1973). Cells were assigned the value for the corresponding contour map.

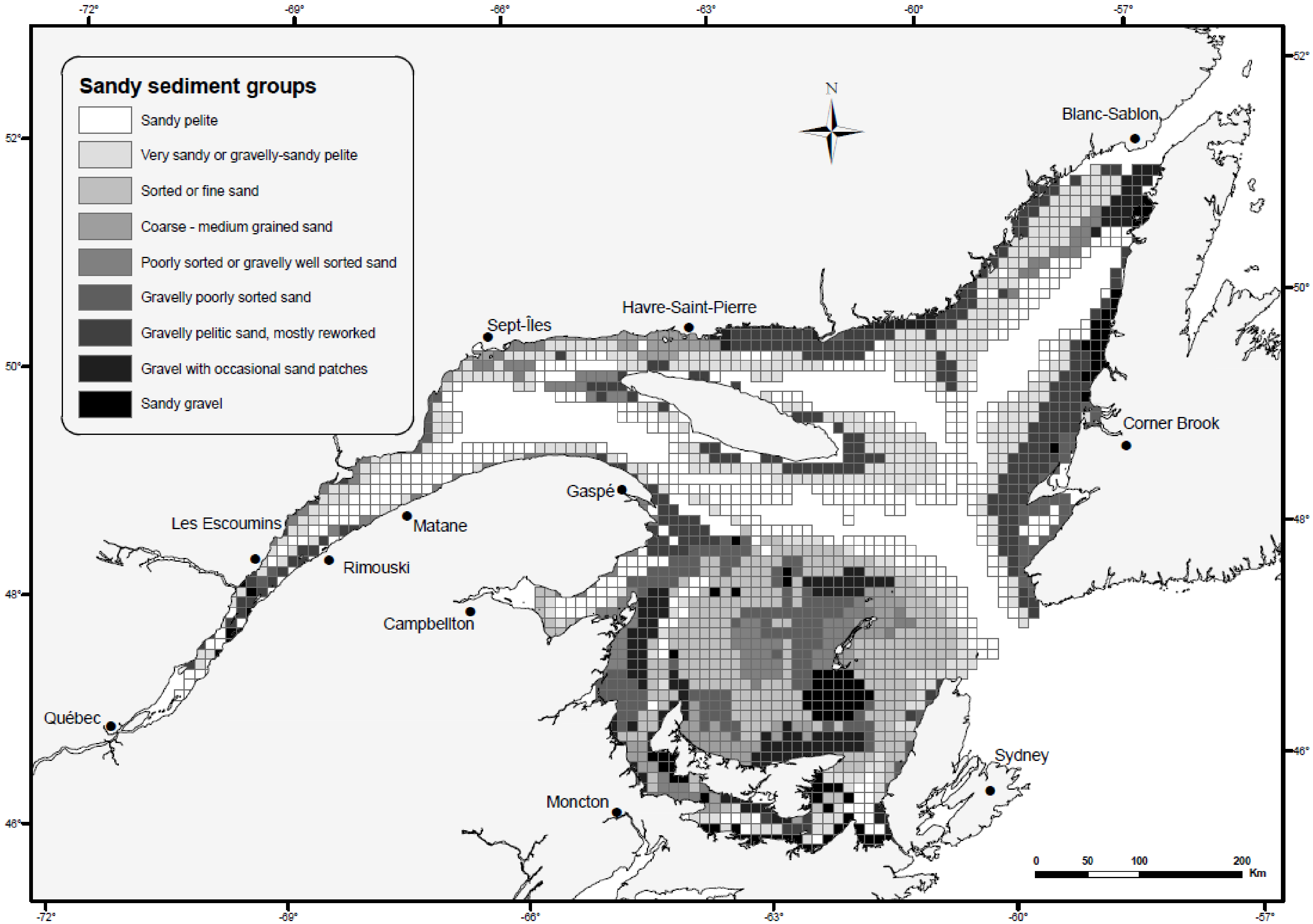


Fig. 25. Sandy surface sediment groups based on granulometry. Surface sediment data were obtained from Loring and Nota (1973). Cells were assigned the value for the corresponding contour map.

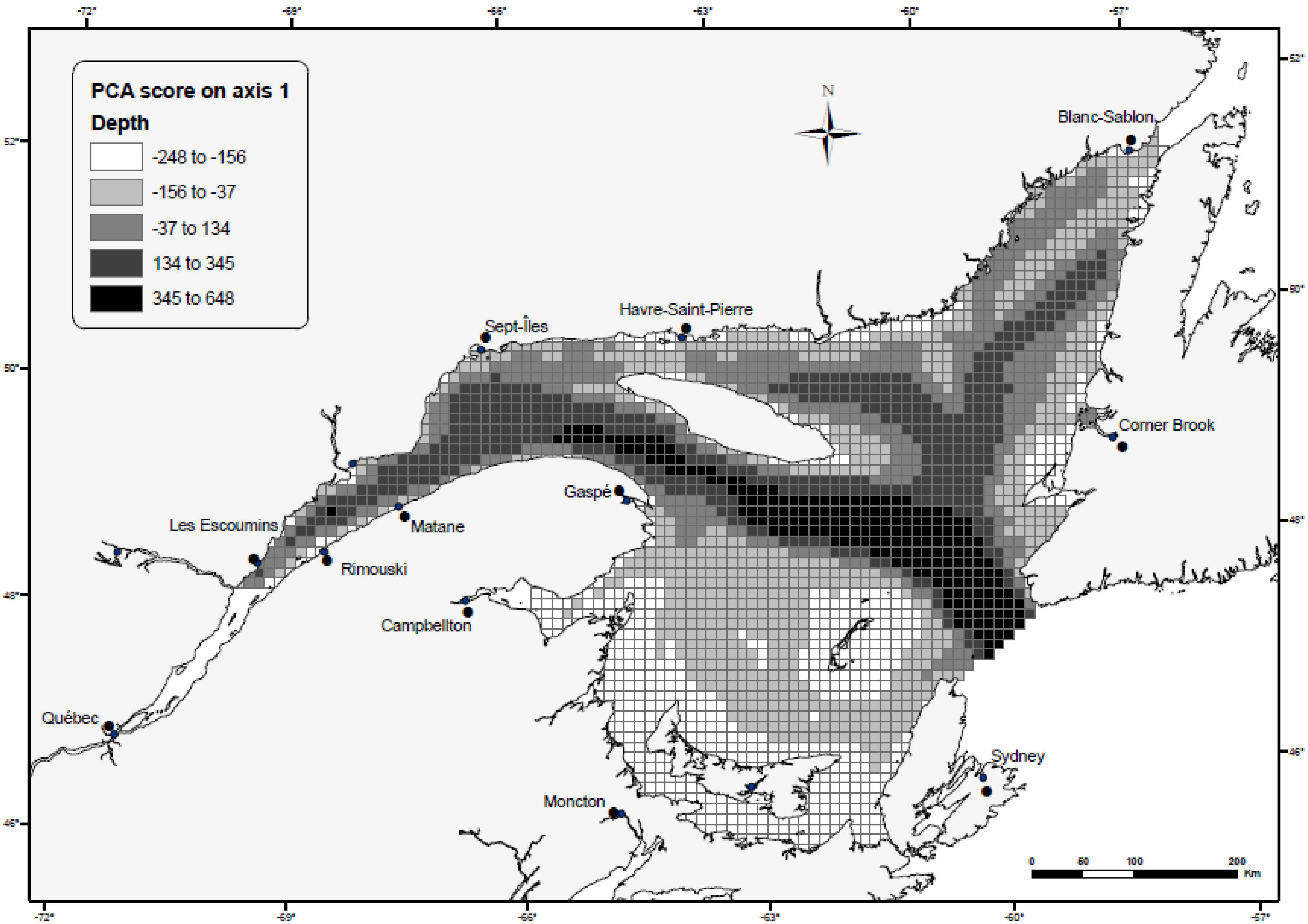


Fig. 26. Map of PCA scores (first axis) based on four variables describing cell depth (mean, minimum, maximum, and standard deviation).

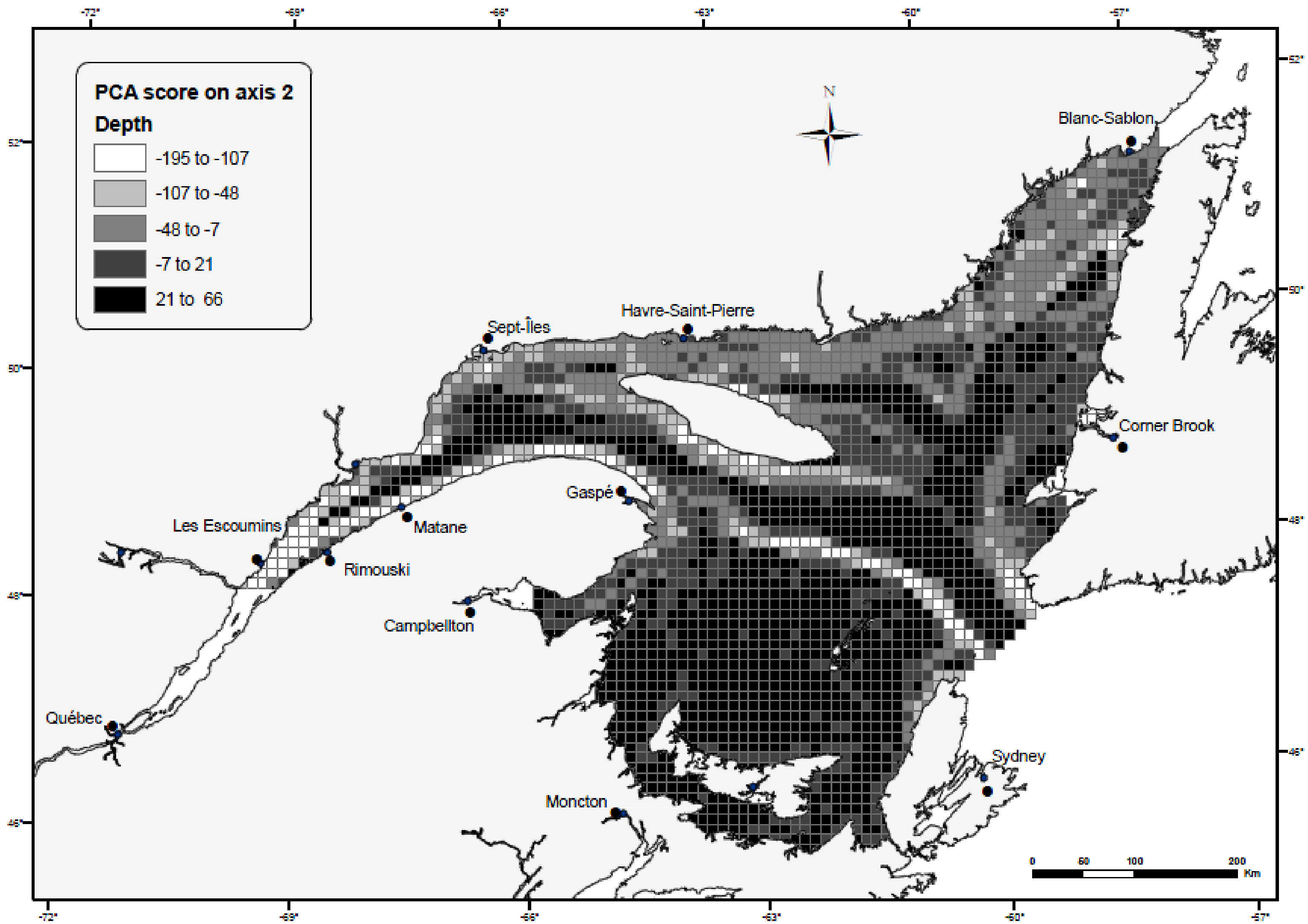


Fig. 27. Map of PCA scores (second axis) based on four variables describing cell depth (mean, minimum, maximum, and standard deviation).

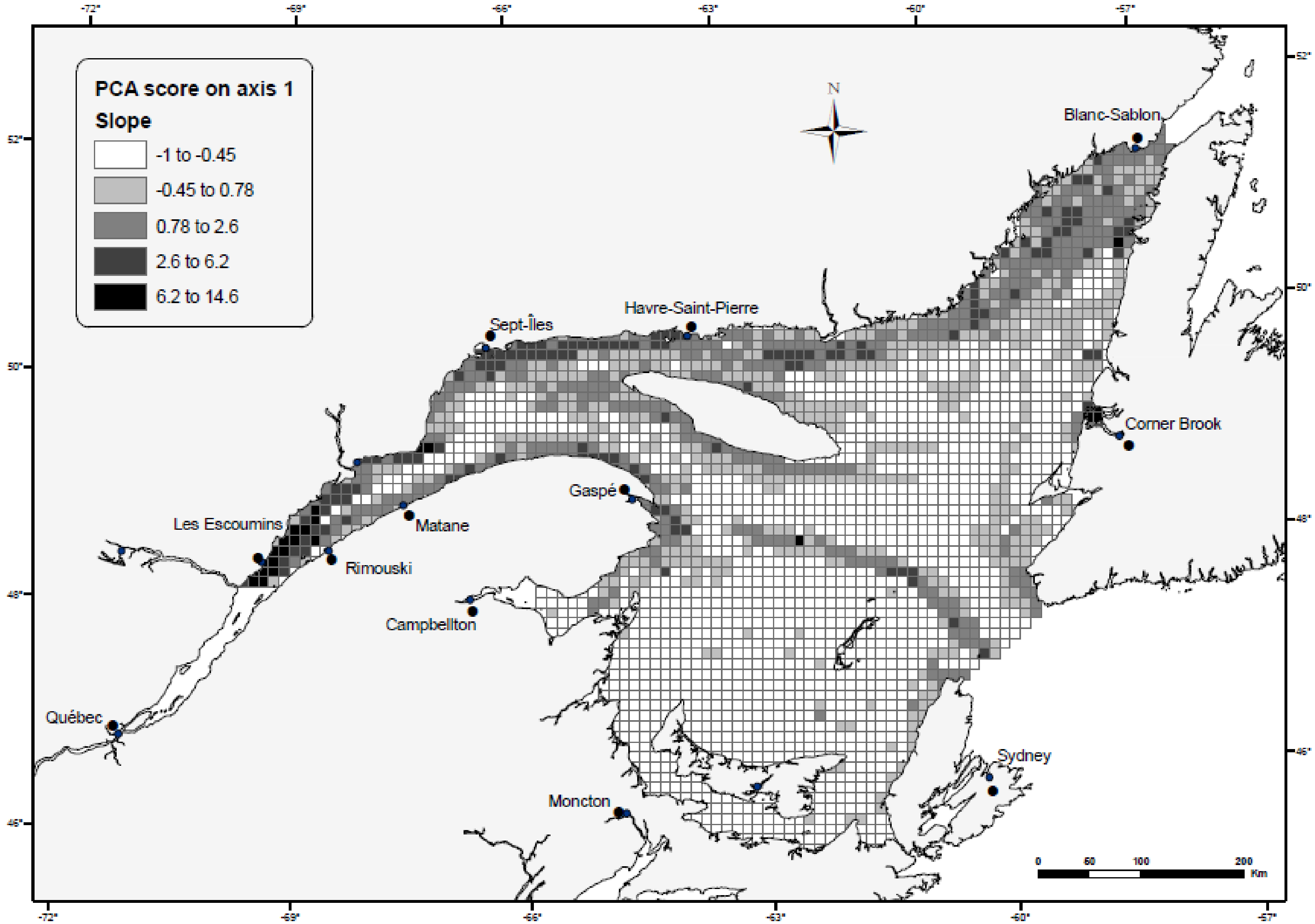


Fig. 28. Map of PCA scores (first axis) based on four variables describing cell slope (mean, minimum, maximum, and standard deviation).

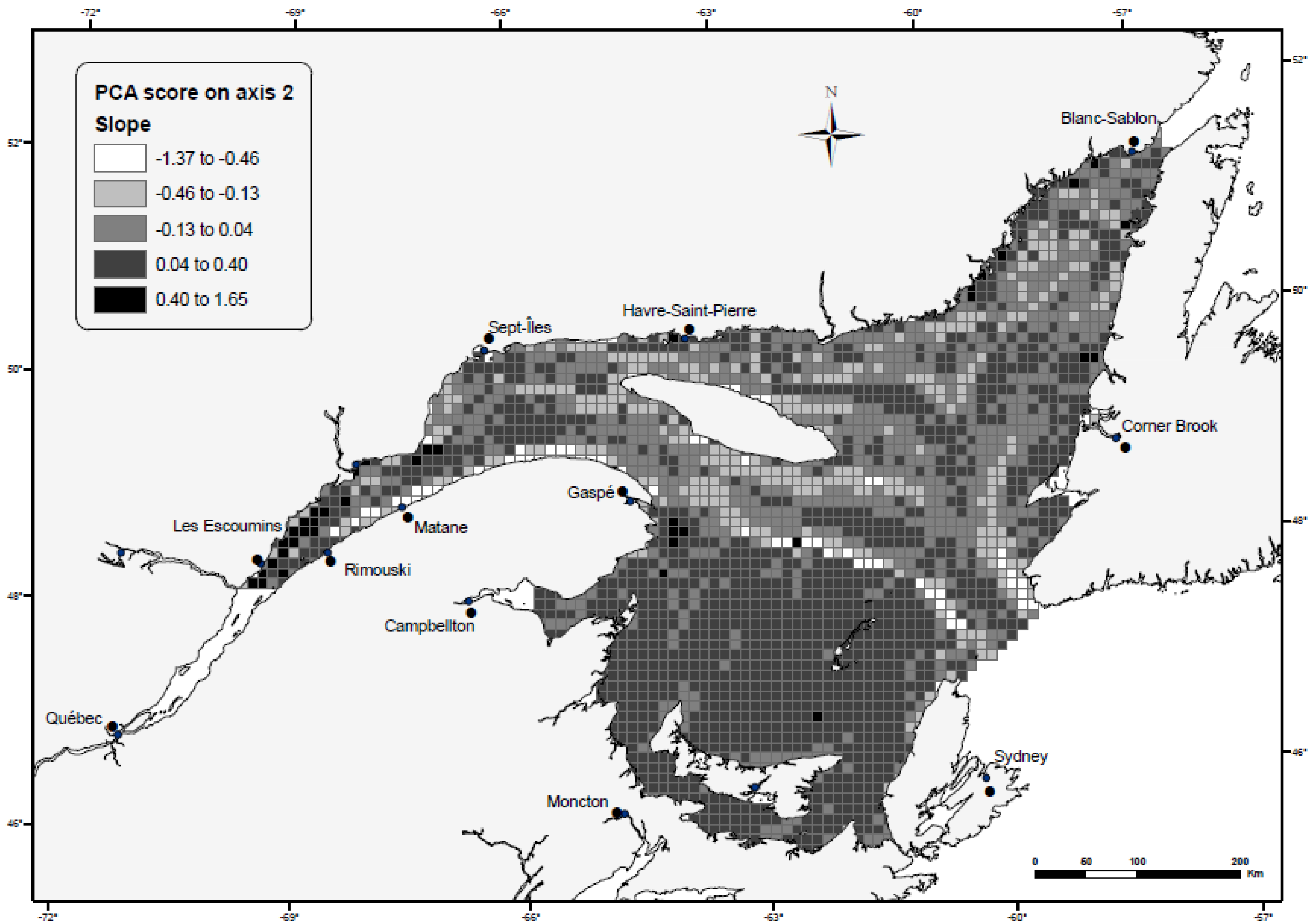


Fig. 29. Map of PCA scores (second axis) based on four variables describing cell slope (mean, minimum, maximum, and standard deviation).

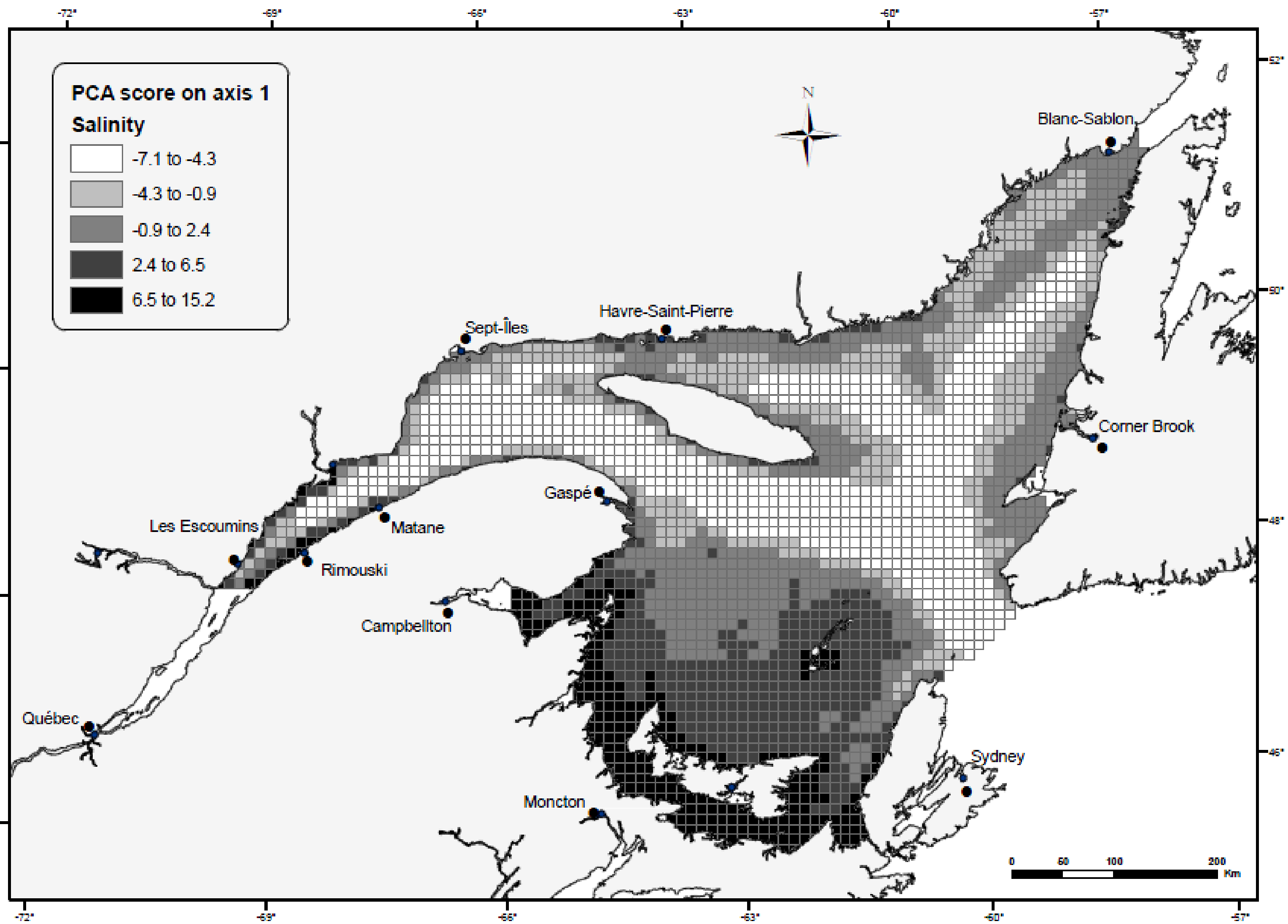


Fig. 30. Map of PCA scores (first axis) based on nine variables describing cell salinity (mean, minimum, and maximum salinity at mean, minimum, and maximum depth).

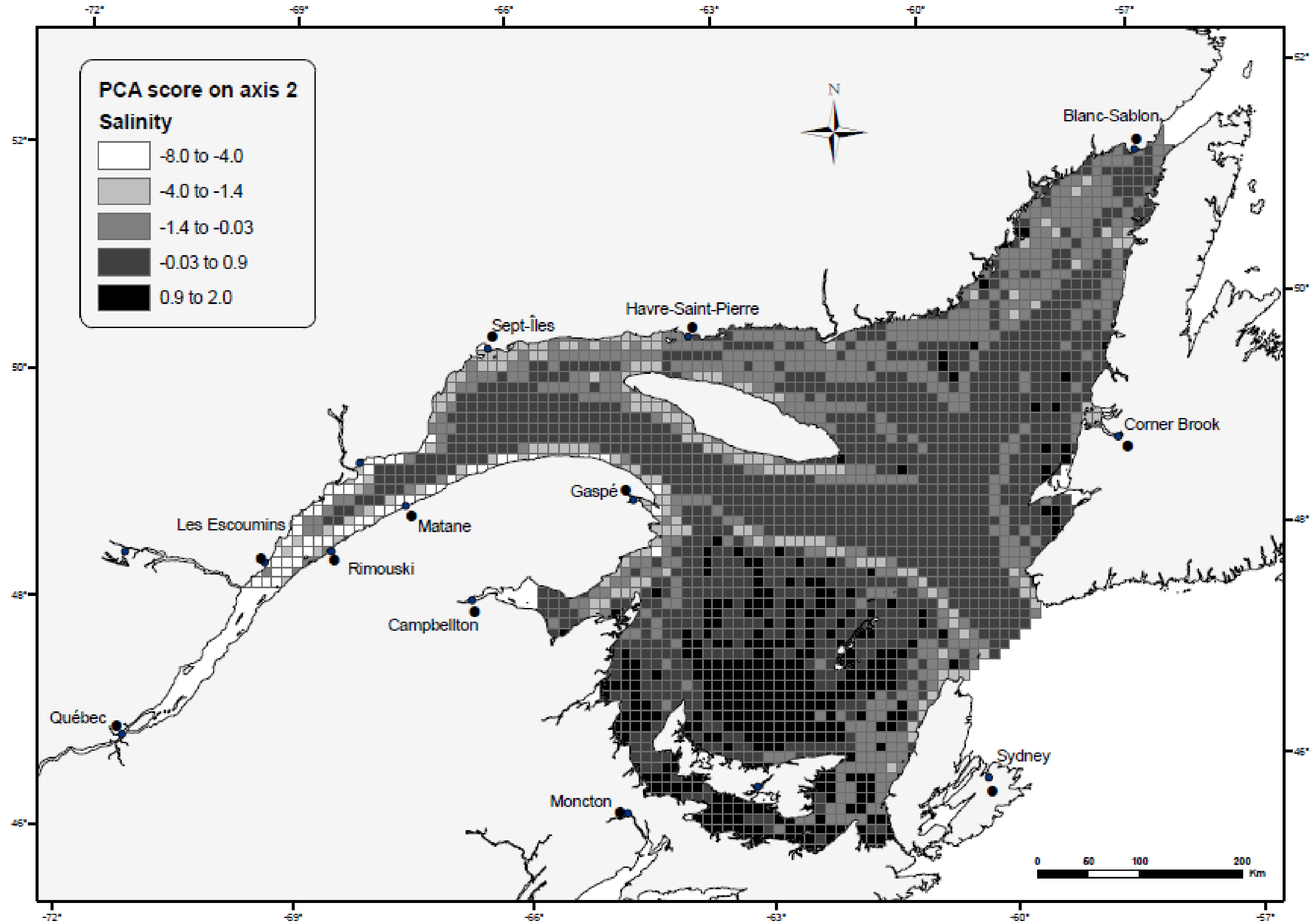


Fig. 31. Map of PCA scores (second axis) based on nine variables describing cell salinity (mean, minimum, and maximum salinity at mean, minimum, and maximum depth).

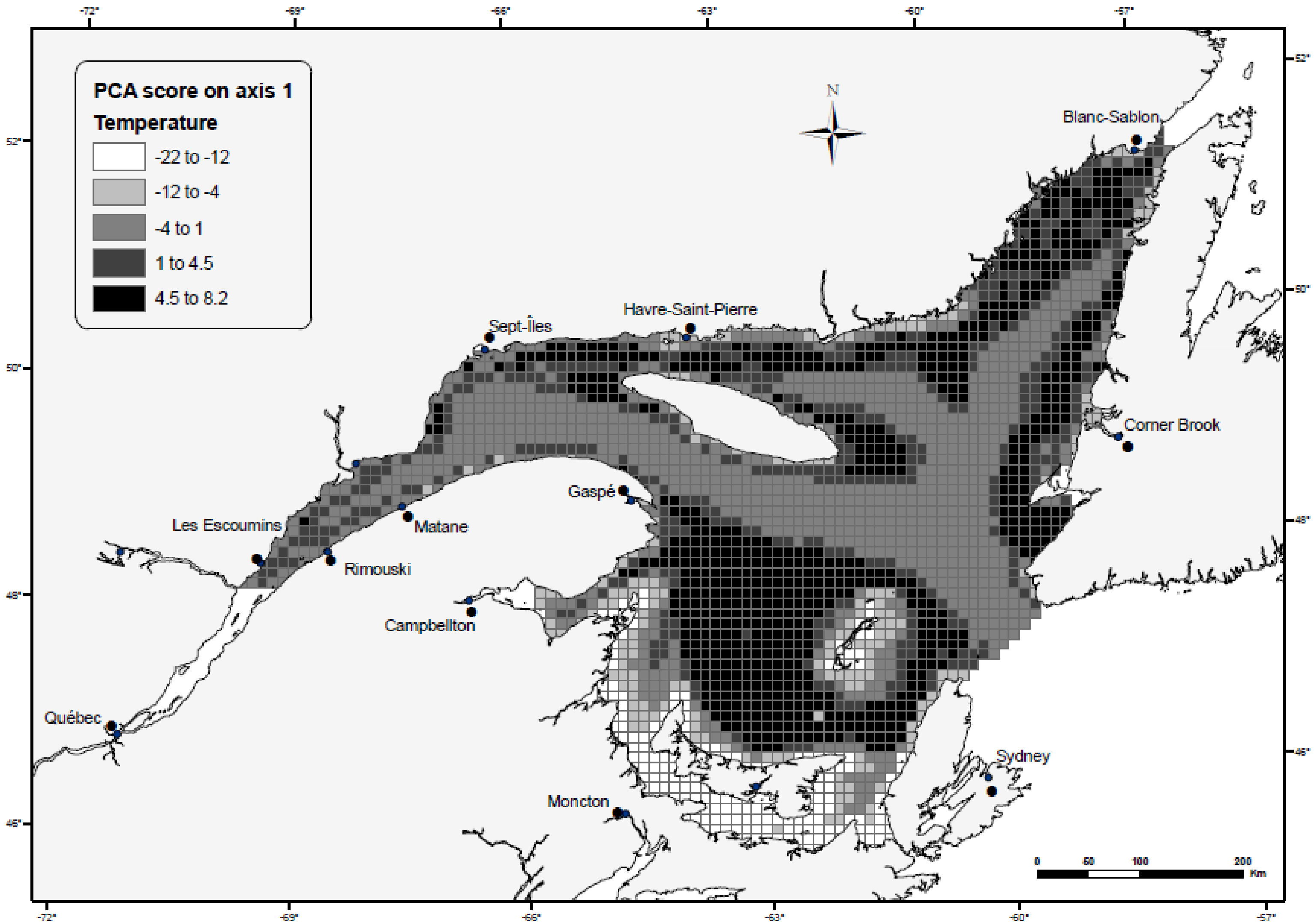


Fig. 32. Map of PCA scores (first axis) based on nine variables describing cell temperature (mean, minimum, and maximum temperature at mean, minimum, and maximum depth).

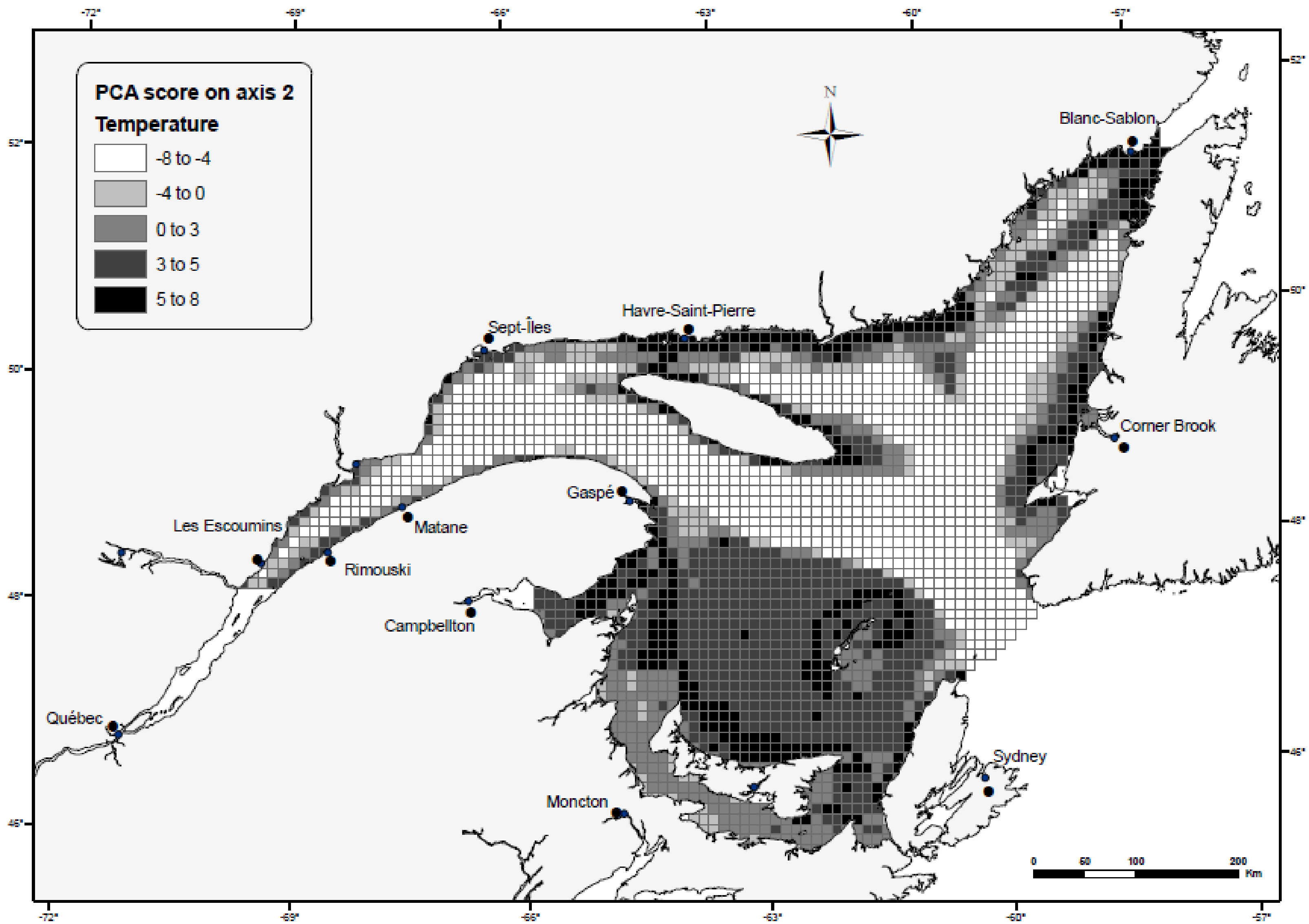


Fig. 33. Map of PCA scores (second axis) based on nine variables describing cell temperature (mean, minimum, and maximum temperature at mean, minimum, and maximum depth).

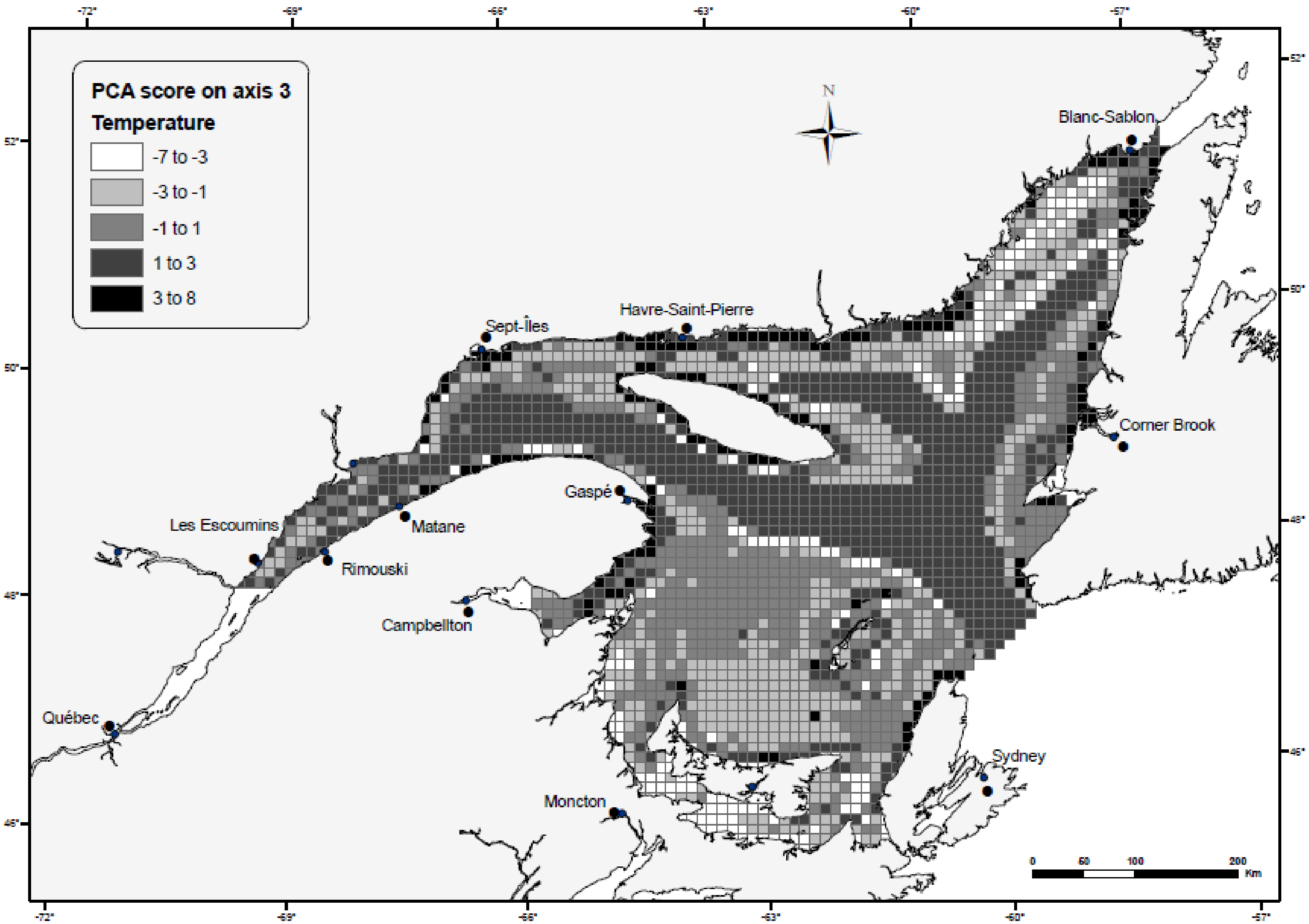


Fig. 34. Map of PCA scores (third axis) based on nine variables describing cell temperature (mean, minimum, and maximum temperature at mean, minimum, and maximum depth).

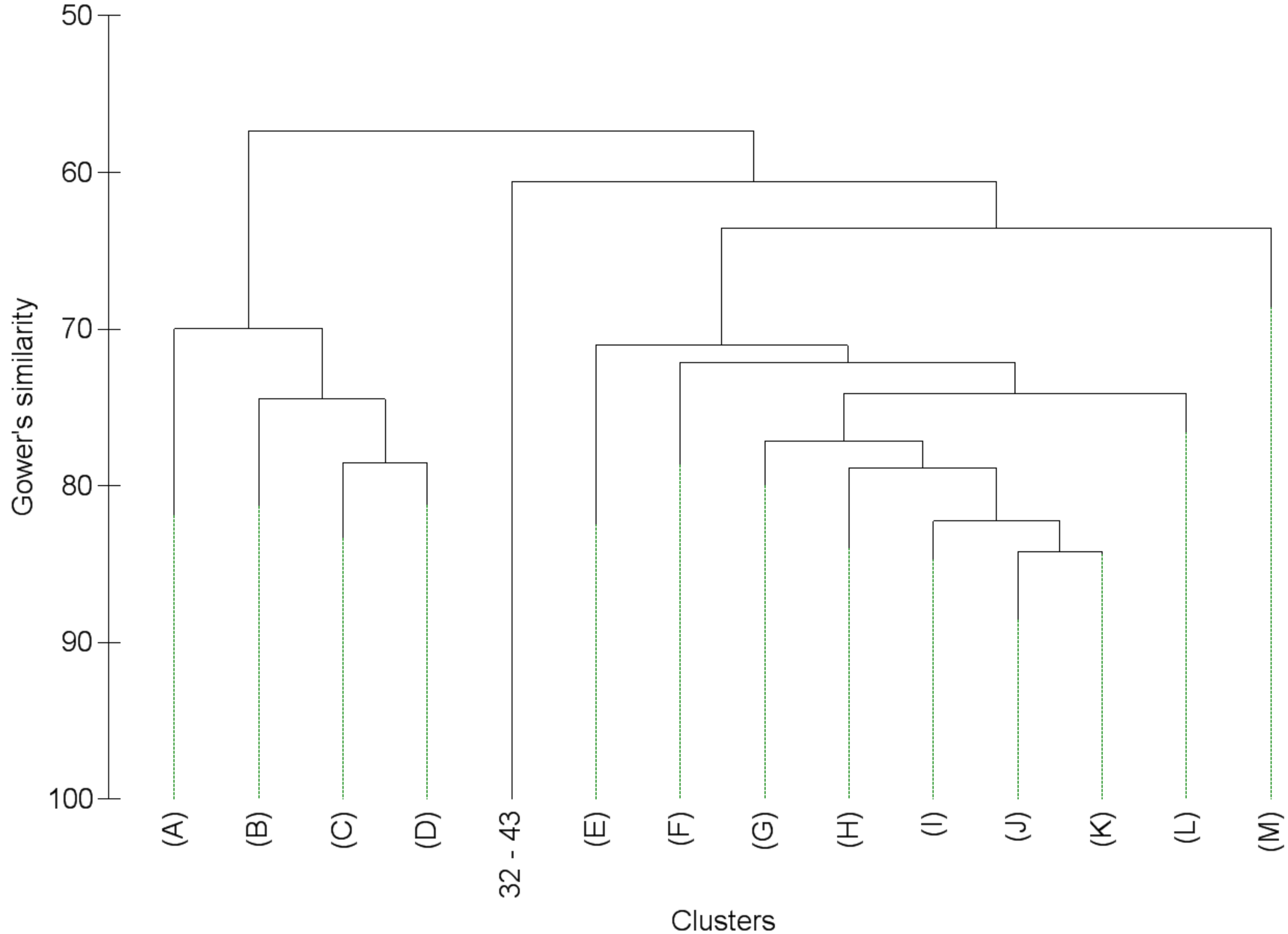


Fig. 35. Hierarchical clustering of cells using the group average method and a resemblance matrix based on Gower's coefficient. Eighty different clusters were considered significant in the analysis, 14 of which are shown. Relatively shallow areas cluster as one category and relatively deep areas as a second category (clusters A, B, C, and D) at a similarity value of 60.

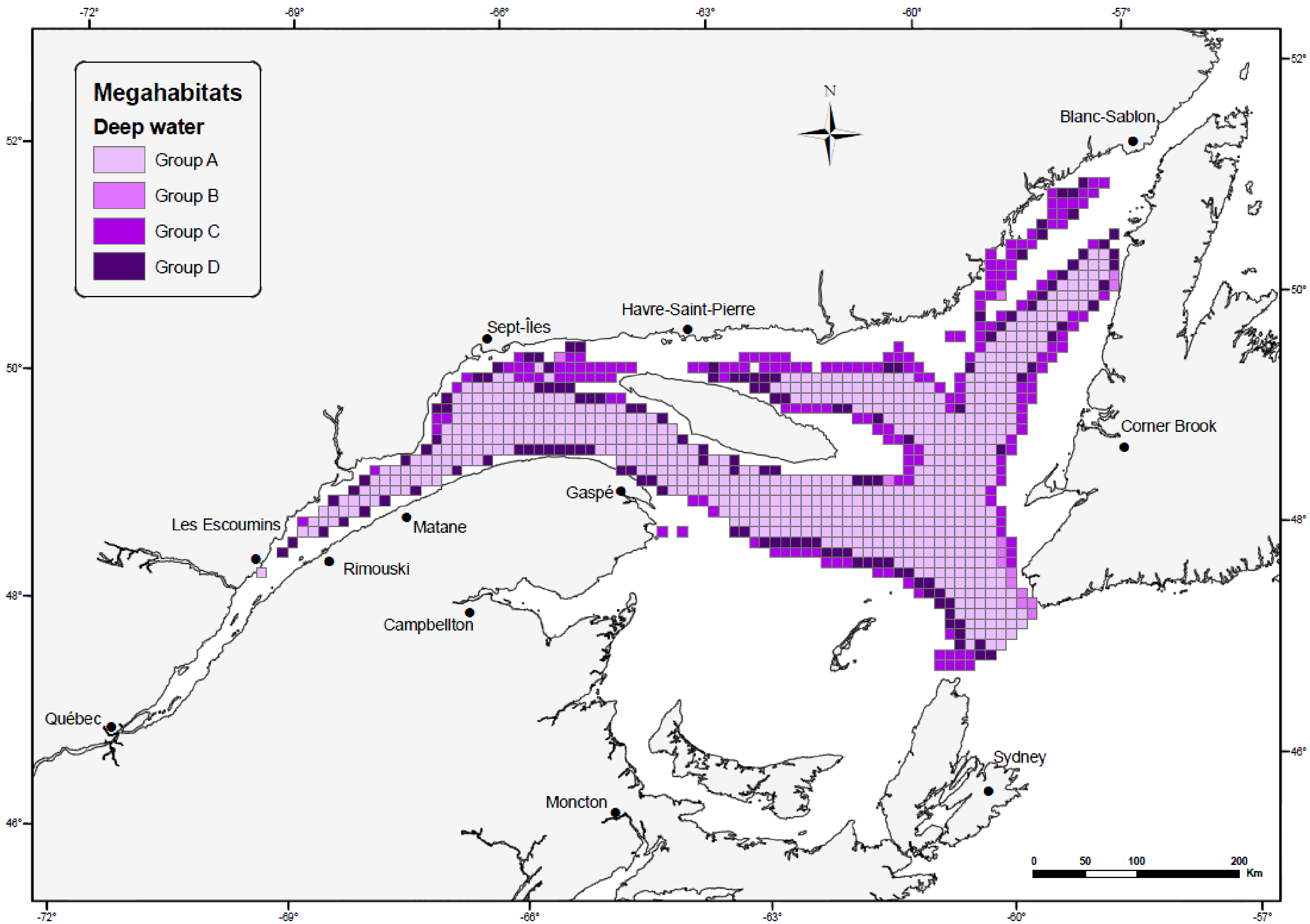


Fig. 36. Spatial distribution of four megahabitats in deep waters of the St. Lawrence estuary and Gulf.

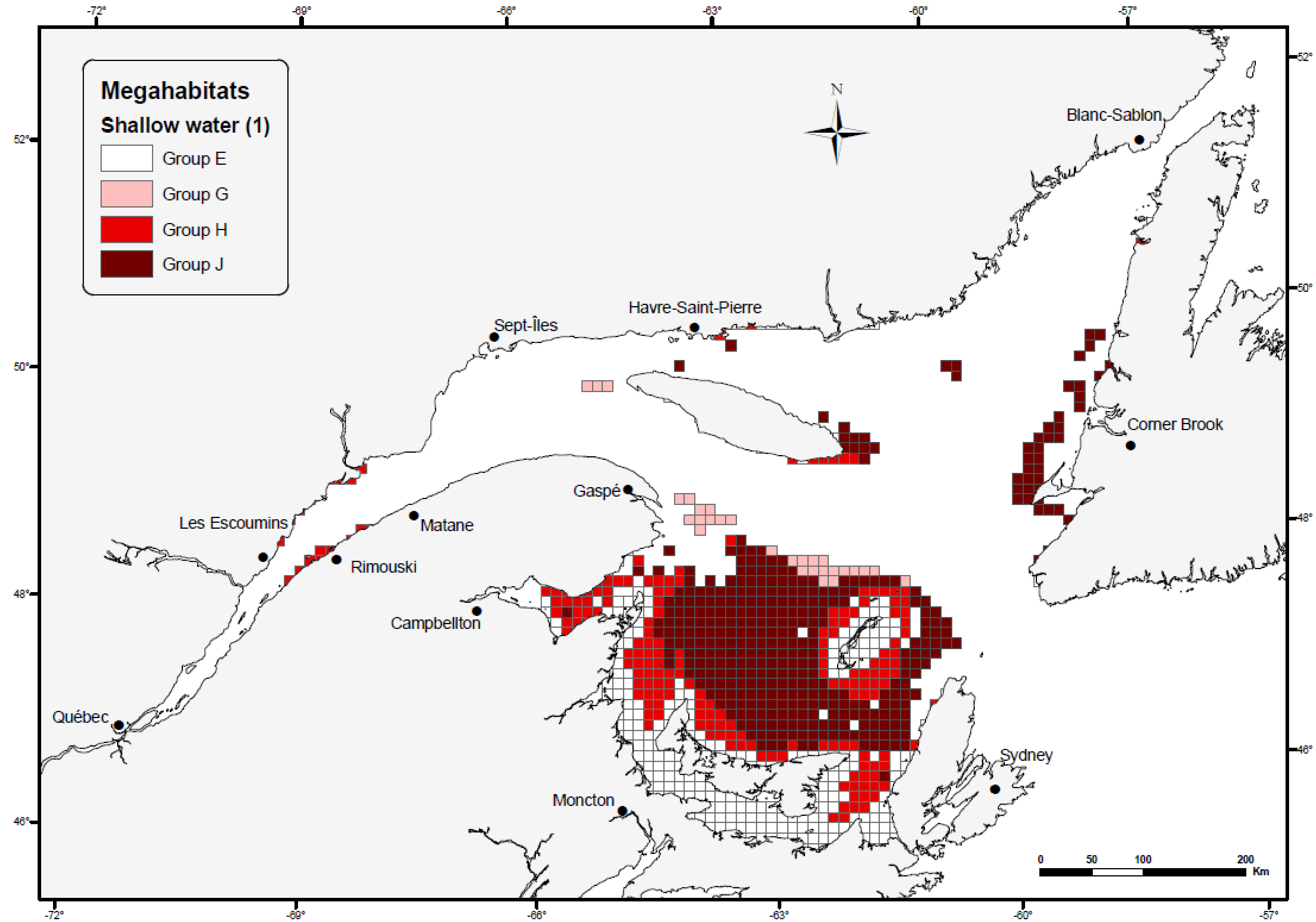


Fig. 37. Spatial distribution of megahabitats in shallow waters of the southern Gulf of St. Lawrence.

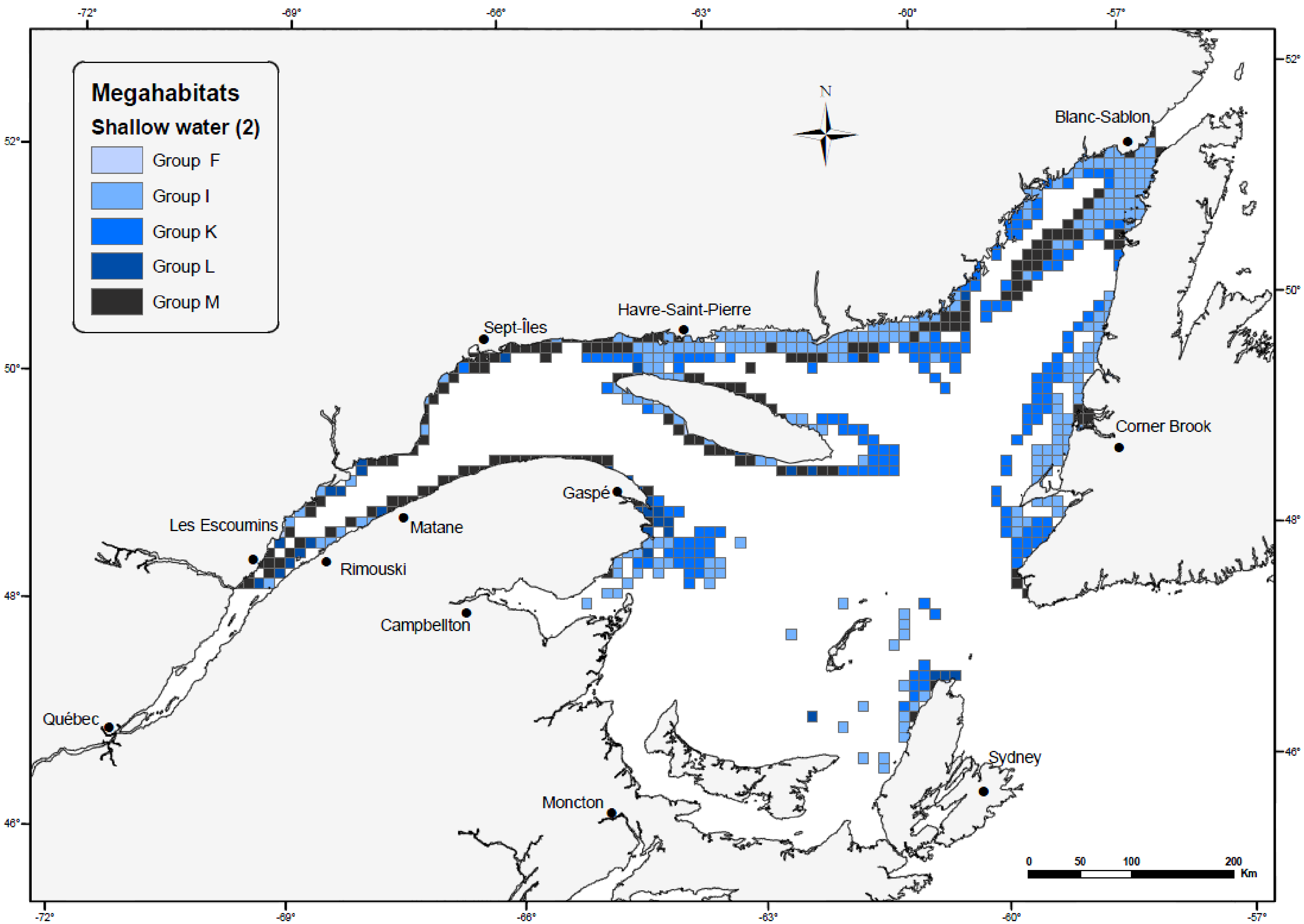


Fig. 38. Spatial distribution of megahabitats in shallow waters of the St. Lawrence lower estuary and Gulf.

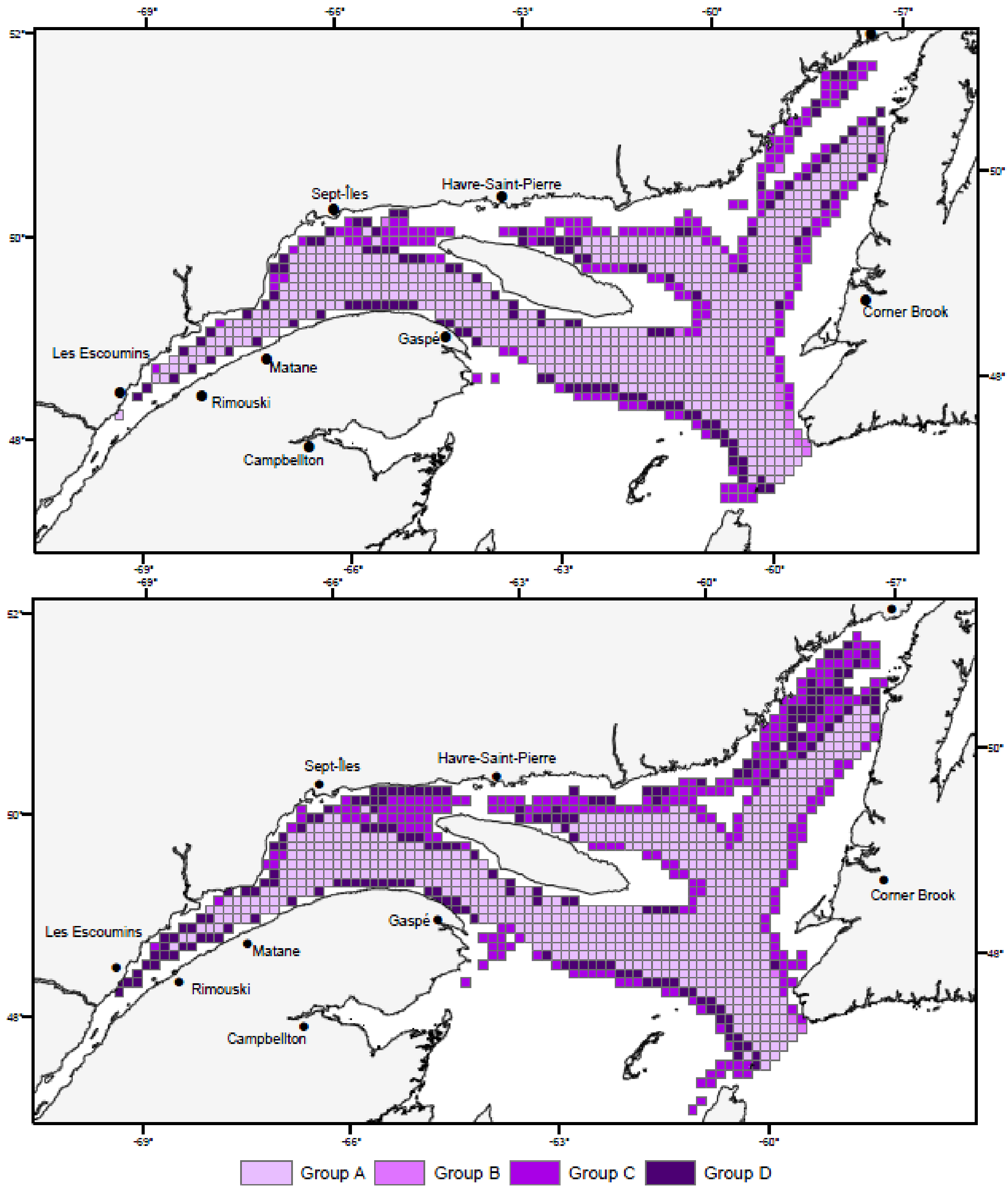


Fig. 39. Spatial distribution of four megahabitats in deep waters of the St. Lawrence estuary and Gulf based on two classifications. The upper panel shows the classification achieved based on 31 variables and the lower panel the classification achieved based on 34 variables. The two classifications share 29 variables. Refer to subsection “Statistical analyses” in Materials and Methods for a more detailed description.

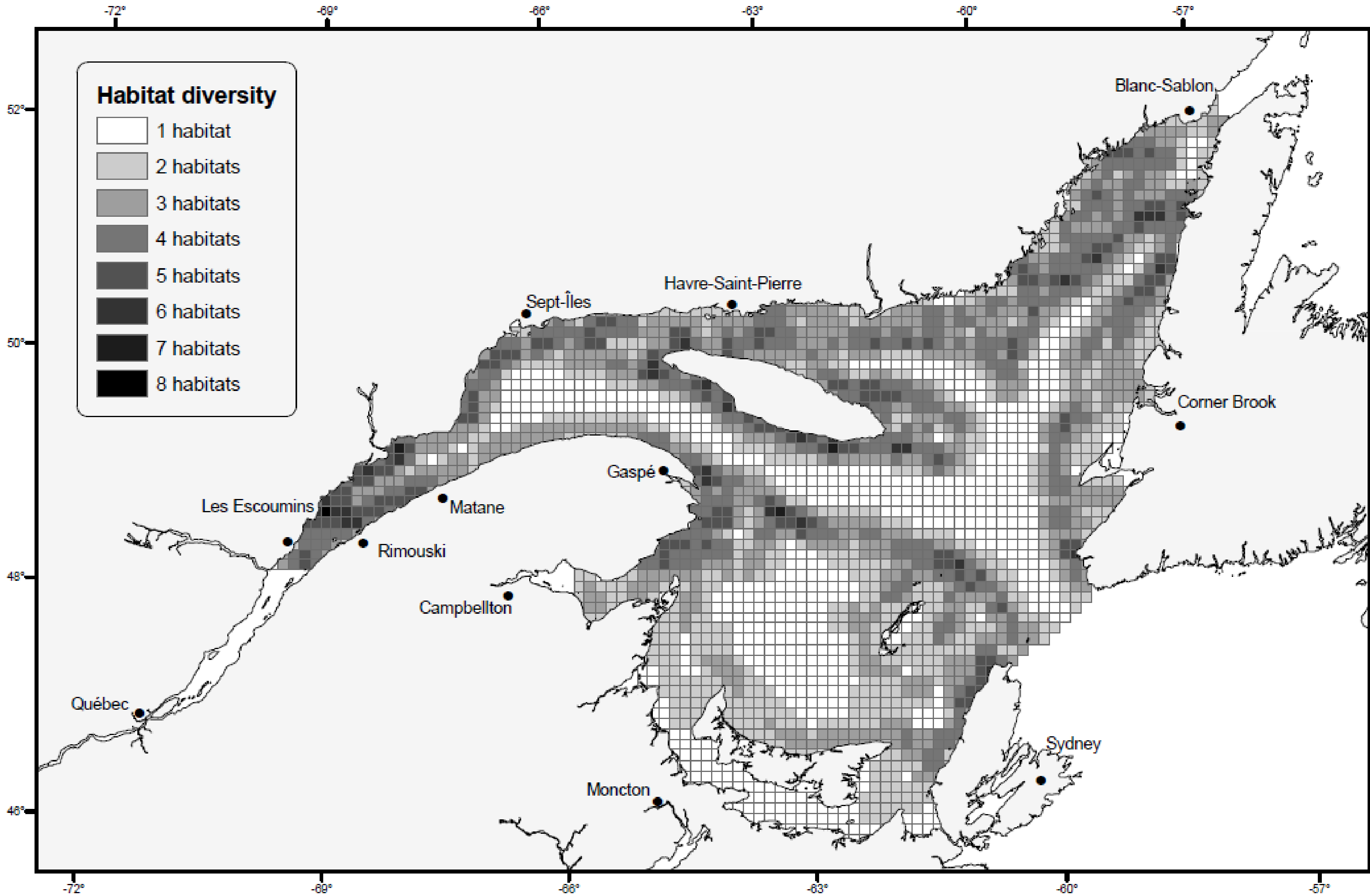


Fig. 40. Number of megahabitats within a 15 km radius from each cell centroid.

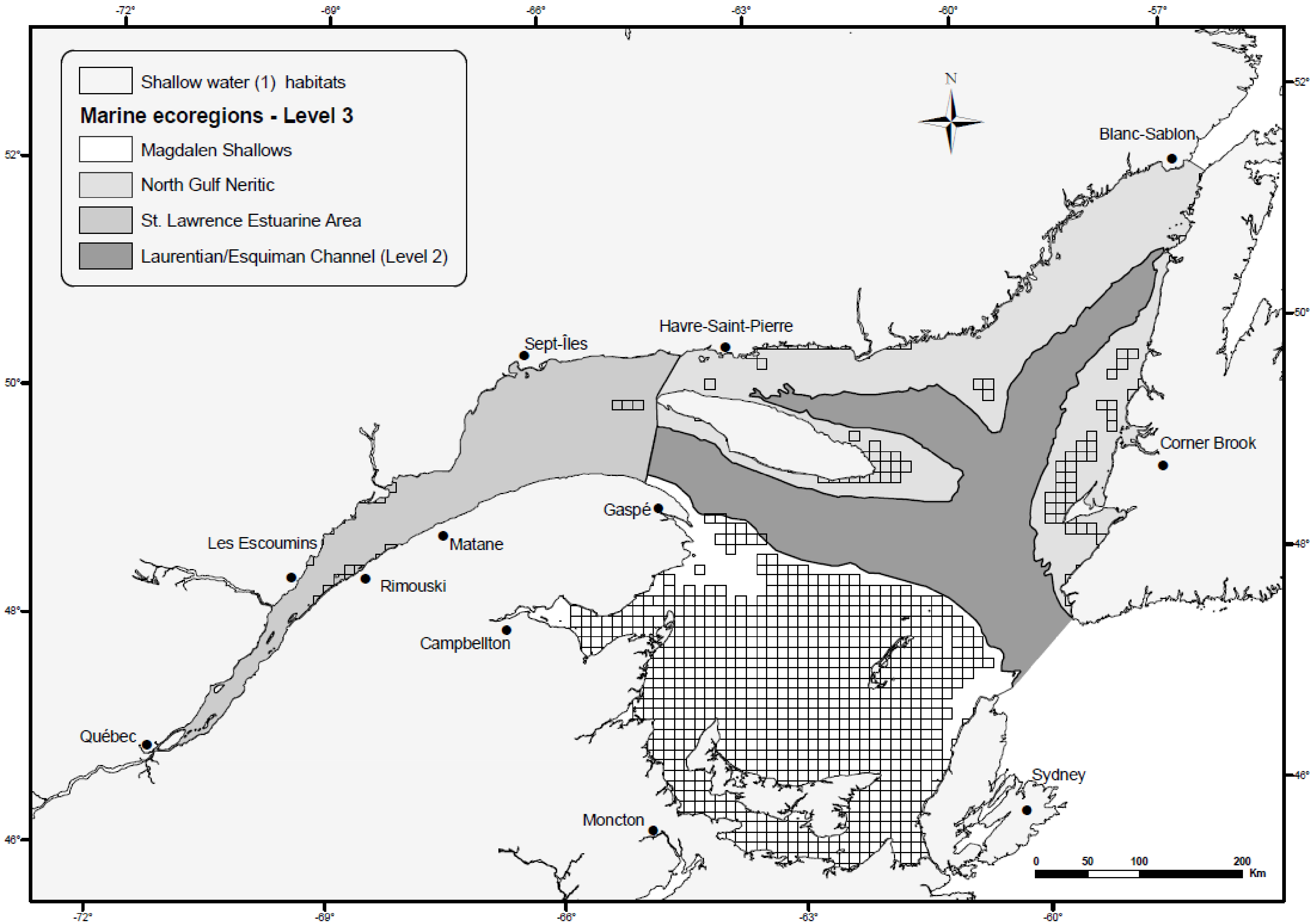


Fig. 41. Overlap between megahabitats E, G, H, and J of the present study and ecoregions as defined by Wilkinson et al. (2009).

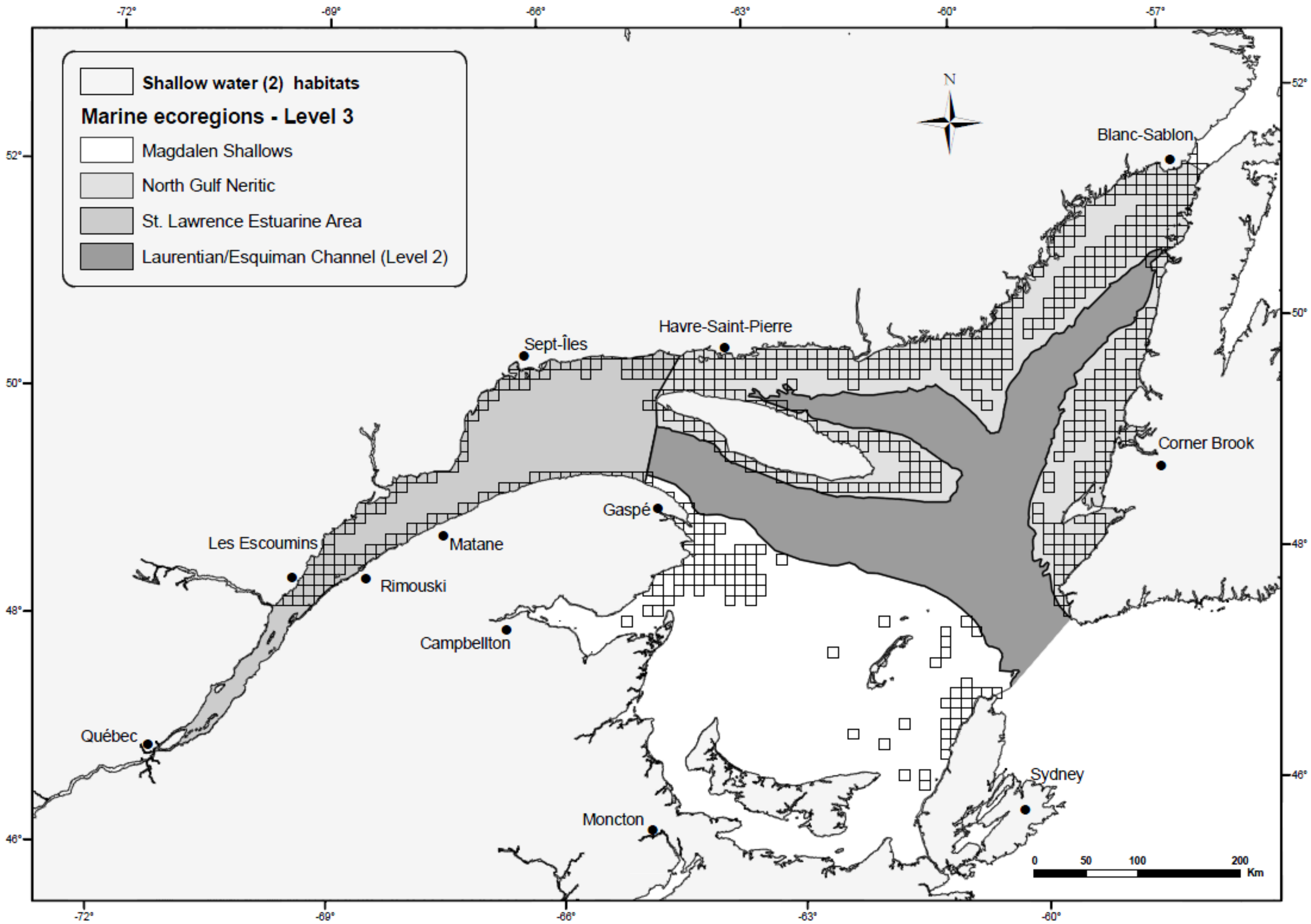


Fig. 42. Overlap between megahabitats F, I, K, L, and M of the present study and ecoregions as defined by Wilkinson et al. (2009).

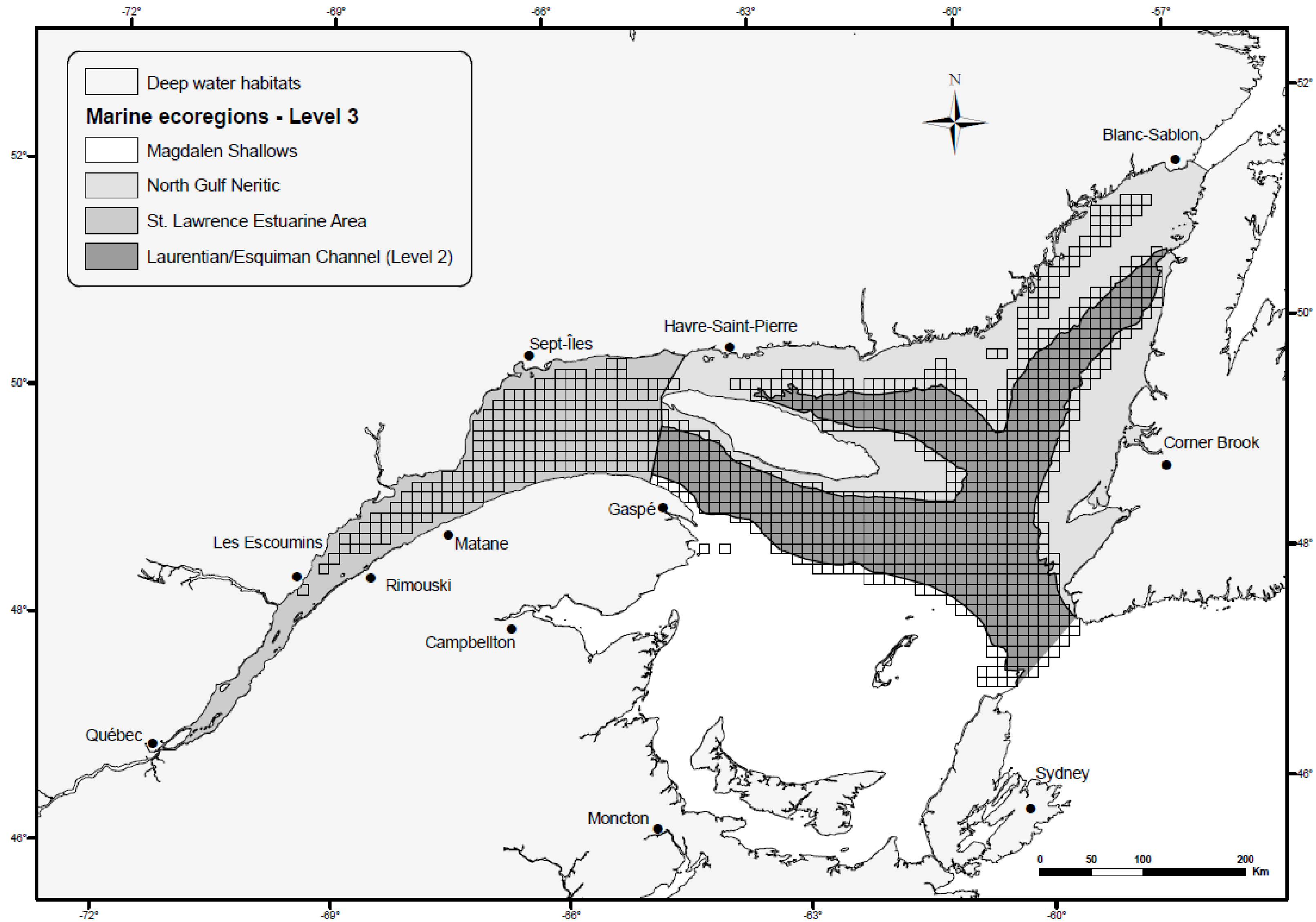


Fig. 43. Overlap between megahabitats A, B, C, and D of the present study and ecoregions as defined by Wilkinson et al. (2009).

Appendix A. List of variables in the database. This appendix provides a translation of the description for each variable and corresponding legend as it appears in the database. Metadata as well as many names of variables and values of categorical variables are in French in the database.

Variable	Legend	Description
OBJECTID		Sequential number attributed automatically by the program (ESRI® ArcGIS® software)
Shape		Vector data type (Information generated by ESRI® ArcGIS® in the geodatabase
Shape_Length		Cell perimeter in meters (Information generated by ESRI® ArcGIS® in the geodatabase)
Shape_Area		Cell surface area in square meters (Information generated by ESRI® ArcGIS® in the geodatabase)
Col_Row	Cell ID	Cell (10 km X 10 km) designation using column number (1 to 115) and row number (1 to 85) from left to right and from top to bottom (9775 cells matrix)
Longitude		Position in decimal degrees – WGS84 (World Geodetic System, 1984 revision)
Latitude		Position in decimal degrees – WGS84 (World Geodetic System, 1984 revision)
Perim_m	Périmètre	Perimeter of the portion of the cell in the marine environment (m)
Sup_km2	Superficie	Surface area of the portion of the cell in the marine environment (km^2)
Sup_hect	Superficie (hectares)	Surface area of the portion of the cell in the marine environment (hectares)
Sup_Protege	Superficie - Secteur protégé	Surface area of sheltered marine environment (km^2)
Sup_SemiExp	Superficie - Secteur semi-exposé	Surface area of semi-exposed marine environment (km^2)
Sup_Expose	Superficie - Secteur exposé	Surface area of exposed marine environment (km^2)
Hab_Marin	Appartenance au milieu marin	Cells overlapping the marine environment (cells with value “Oui” are selected)
Hab_Cotier	Appartenance au milieu côtier	Classification into coastal (cells with value “Oui”) and offshore (cells with value “Non”) cells. Coastal cells are those that overlap the shoreline on the mainland and along islands longer than 1.5 km (longest axis)
Cote_Dist	Distance à la côte	Distance between the cell centroid and the nearest shore (m) at low tide on the mainland and on islands longer than 1.5 km on their longer axis (based on the CanVec data product -NRCan, spatial resolution of 1:50,000)
Sect_geo	Secteurs géographiques	Cell localisation (based on centroid coordinates) in one of the following geographic entities: Saguenay Fjord, middle estuary, lower estuary, northern and southern Gulf of St. Lawrence
ZE_Loup	Zone d'étude sur le loup	Cells used in a study on wolffish (cells with value “Oui”). That study included 3 geographic sectors: lower estuary, northern and southern Gulf of St. Lawrence

Variable	Legend	Description
Bathy_Count		Number of pixels (500 m X 500 m) with depth data available (maximum 400)
Bathy_Mean	Profondeur moyenne	Mean depth for the cell
Bathy_STD	Profondeur moyenne (écart-type)	Standard deviation of depths for the cell
Bathy_Max	Profondeur maximale	Maximum depth
Bathy_Min	Profondeur minimale	Minimum depth
Pente_Count		Number of pixels (500 m X 500 m) with slope data available (maximum 400)
Pente_Mean	Pente moyenne	Mean slope for the cell
Pente_STD	Pente (écart-type)	Standard deviation of slopes for the cell
Pente_Min	Pente minimale	Minimum slope
Pente_Max	Pente maximale	Maximum slope
Geomorph_1	Géomorphologie	Class with greatest area within the cell; 3 classes are defined according to depth and slope of each pixel (Plateau = < 200 m and slope < 0.8 dgr, Slope (pente) => 0.8 dgr, Channel (chenal) = > 200 m and slope < 0.8 dgr)
Geomorph_2	Géomorphologie-rugosité	Class with greatest area within the cell, i.e., representing more than 34% of the cell surface area; 3 classes are defined (1=Uniform, 2=Hump, 3=Pit) using a normalised bathymetric index (Weiss 2001) analysing depth and slope in a 2.5 km radius (see BTM - Benthic Terrain modeler)
Geo2_Uniforme	Proportion - Uniforme	Proportion of the cell surface area classified as being a uniform terrain, based on Geomorph_2
Geo2_Bosse	Proportion - Bosse	Proportion of the cell surface area classified as being humps, based on Geomorph_2
Geo2_Creux	Proportion - Creux	Proportion of the cell surface area classified as being pits, based on Geomorph_2
Relief_dom	Relief dominant	Relief (Geomorph_1 X Geomorph_2) with greatest area of the cell (1=Uniform plateau, 2=Humps on plateau, 3=Pits on plateau, 4=Uniform slope, 5=Humps on slope, 6=Pits on slope, 7=Uniform channel, 8=Humps on channel, 9=Pits on channel)
Relief_dom_N	Relief dominant	Numeric code for variable Relief_dom
Relief_var	Variabilité du relief	Number of reliefs (maximum of 9) represented in the cell
Aire_Protegee	Aire protégée	Field "Code _Marin" of protected areas (see table AIRES_PROTÉGÉES): RMB-x=Biosphere Reserve or RAMSAR site, ZPM-x=Marine Protected Area, FED-x=other protected areas under federal jurisdiction,AP-x= other protected areas listed in the Atlas for Canada
O2_Sat_Mean	Oxygène au fond,% sat	Mean oxygen saturation (%) based on cokriging interpolation (depth as covariable)
O2_Sat_Classe	Oxygène au fond, classe	Classes of mean dissolved oxygen saturation: class 1 - 0 to 25%, 2 - 25 to 35%, 3 - 35 to 45%, 4 - 45 to 55%, 5 - 55 to 65%, 6 - 65 to 75%, 7 - 75 to 85%, 8 - 85 to 100%

Variable	Legend	Description
Polygone_Petrie	Polygone de Petrie	Delineation of climatologic sectors, adapted from Petrie et al. (1996): Temperature, salinity and sigma-t atlas for the Gulf of St. Lawrence. Can. Data Rep. Hydrogr. Ocean Sci./Rapp. Stat. Can. Hydrogr. Sci. Ocean. 178: v+256 pages
BathyMoy_ajustée	Classe de profondeur moyenne	Depth class in Petrie et al. (1996) corresponding to mean depth (field Bathy_Mean)
BathyMin_ajustée	Classe de profondeur minimale	Depth class in Petrie et al. (1996) corresponding to minimum depth (field Bathy_Min)
BathyMax_ajustée	Classe de profondeur maximale	Depth class in Petrie et al. (1996) corresponding to maximum depth (field Bathy_Max)
SalMoyMoy	Salinité MoPrMo	Bottom mean annual salinity according to "BathyMoy_ajustée" field
SalMinMoy	Salinité MiPrMo	Bottom montly minimal salinity according to "BathyMoy_ajustée" field
SalMaxMoy	Salinité MaPrMo	Bottom montly maximal salinity according to "BathyMoy_ajustée" field
SalMoyMin	Salinité MoPrMi	Bottom mean annual salinity according to "BathyMin_ajustée" field
SalMinMin	Salinité MiPrMi	Bottom montly minimal salinity according to "BathyMin_ajustée" field
SalMaxMin	Salinité MaPrMi	Bottom montly maximal salinity according to "BathyMin_ajustée" field
SalMoyMax	Salinité MoPrMa	Bottom mean annual salinity according to "BathyMax_ajustée" field
SalMinMax	Salinité MiPrMa	Bottom monthly minimal salinity according to "BathyMax_ajustée" field
SalMaxMax	Salinité MaPrMa	Bottom monthly maximal salinity according to "BathyMax_ajustée" field
TempMoyMoy	Température MoPrMo	Bottom mean annual temperature (°C) according to "BathyMoy_ajustée" field
TempMinMoy	Température MiPrMo	Bottom montly minimal temperature (°C) according to "BathyMoy_ajustée" field
TempMaxMoy	Température MaPrMo	Bottom montly maximal temperature (°C) according to "BathyMoy_ajustée" field
TempMoyMin	Température MoPrMi	Bottom mean annual temperature (°C) according to "BathyMin_ajustée" field
TempMinMin	Température MiPrMi	Bottom montly minimal temperature (°C) according to "BathyMin_ajustée" field
TempMaxMin	Température MaPrMi	Bottom montly maximal temperature (°C) according to "BathyMin_ajustée" field
TempMoyMax	Température MoPrMa	Bottom mean annual temperature (°C) according to "BathyMax_ajustée" field
TempMinMax	Température MiPrMa	Bottom montly minimal temperature (°C) according to "BathyMax_ajustée" field
TempMaxMax	Température MaPrMa	Bottom montly maximal temperature (°C) according to "BathyMax_ajustée" field
SS_Code	Sédiment-code	Surface sediments code as described in Loring and Nota (1973): Morphology and sediments of the Gulf of St. Lawrence. Bulletin of the Fisheries Research Board of Canada 182: xiv + 147 p.

Variable	Legend	Description
SS_Code_N	Sédiment-code	Numeric code for variable SS_Code
SS_Desc_Fr	Sédiment-descr F	French description of the surface sediments code
SS_Desc_An	Sédiment-descr A	English description of the surface sediments code
Ecoregion_L1	Écorégion niveau 1	Ecoregion code according to Wilkinson et al. (2009). Marine Ecoregions of North America. Commission for Environmental Cooperation. Montreal, Canada. 200 pp. Ecoregions L1 - 6= Baffin/Labradoran Arctic, 7= Acadian Atlantic
Ecoregion_L2	Écorégion niveau 2	Ecoregion code according to Wilkinson et al. (2009). Marine Ecoregions of North America. Commission for Environmental Cooperation. Montreal, Canada. 200 pp. Ecoregions L2 - 6.2= Ungava/Labradoran Shelf, 7.2= Acadian Shelf, 7.4= Laurentian/Esquiman Channel
Ecoregion_L3	Écorégion niveau 3	Ecoregion code according to Wilkinson et al. (2009). Marine Ecoregions of North America. Commission for Environmental Cooperation. Montreal, Canada. 200 pp. Ecoregions L3 - 6.2.2= Ungava/Outer Banks/Labradoran Neritic, 7.2.1=St. Lawrence Estuarine Area, 7.2.2= North Gulf Neritic, 7.2.3= Magdalen Shallows, 7.2.4= Scotian Neritic, 7.2.5= Gulf of Maine/Bay of Fundy
Megahabitat	Mégahabitat	Classification of cells into 13 megahabitats according to the present report
MHVar_3x3	Diversité des habitats	Number of megahabitats (variable “Megahabitat”) in a 15 km radius around the cell

Appendix B. Description of variables in the database with regards to their characteristics, scale of measurement, and whether they were used to classify cells into megahabitats (in French in the database).

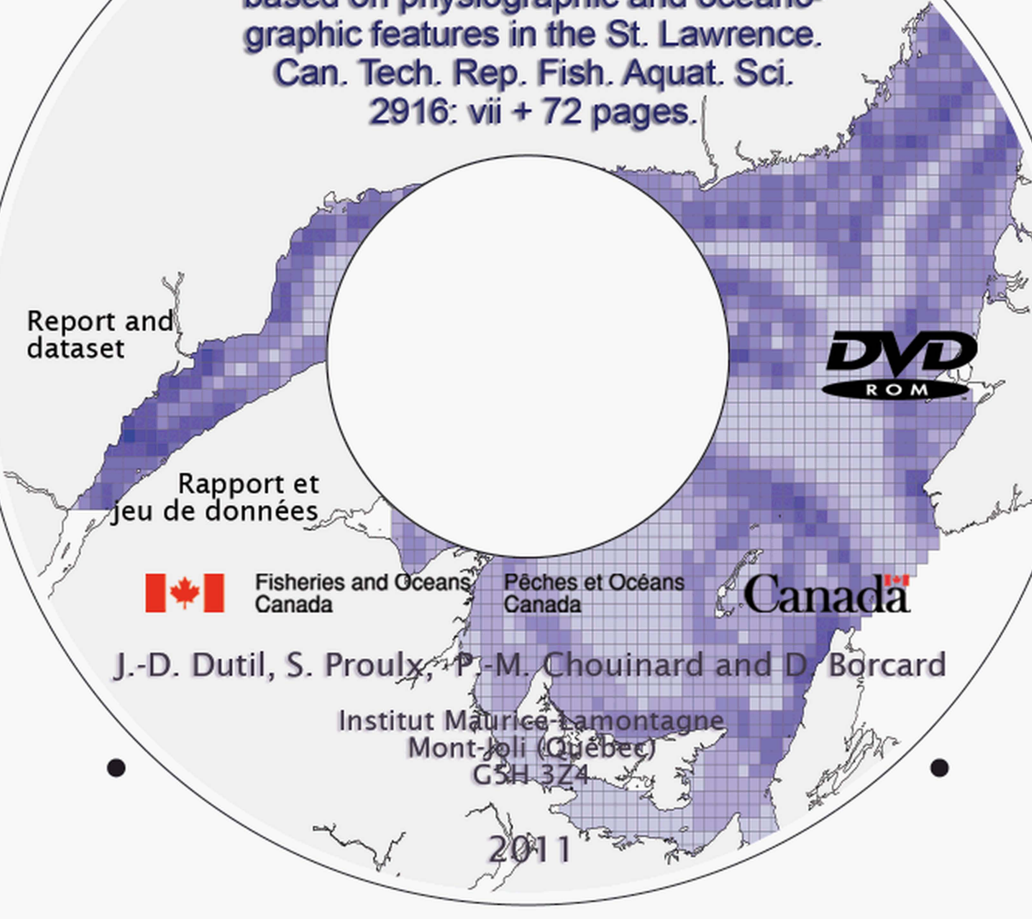
Variable	Type of variable (1) - qualitative or quantitative	Type of quantitative variable – rank, discrete or continuous	Scale of measurement - local or regional *	Type of variable (2) - geologic, geographic, topographic, or physico-chemical	Cluster on cells-habitats	Example of value
OBJECTID	N/A	N/A	N/A	N/A	N/A	122
Shape	N/A	N/A	N/A	N/A	N/A	Donnée binaire
Shape_Length	Quantitative	Continuous	Local	Geographic	N/A	40000
Shape_Area	Quantitative	Continuous	Local	Geographic	N/A	100000000
Col_Row	Qualitative	N/A	Local	Geographic	Yes	23 - 52
Longitude	Quantitative	Continuous	Local	Geographic	No	-68.5681
Latitude	Quantitative	Continuous	Local	Geographic	No	48.6348
Perim_m	Quantitative	Continuous	Local	Geographic	No	40000
Sup_km2	Quantitative	Continuous	Local	Geographic	No	100
Sup_hect	Quantitative	Continuous	Local	Geographic	No	10000
Sup_Protege	Quantitative	Continuous	Local	Geographic	Yes	0
Sup_SemiExp	Quantitative	Continuous	Local	Geographic	Yes	0
Sup_Expose	Quantitative	Continuous	Local	Geographic	Yes	100
Hab_Marin	Qualitative	N/A	Local	Geographic	N/A	Oui
Hab_Cotier	Qualitative	N/A	Local	Geographic	Yes	Non
Cote_Dist	Quantitative	Continuous	Local	Geographic	No	14426
Sect_geo	Qualitative	N/A	Regional	Geographic	No	Estuaire maritime du Saint-Laurent
ZE_Loup	Qualitative	N/A	Regional	Geographic	Yes	Oui
Bathy_Count	Quantitative	Discrete	Local	N/A	No	400
Bathy_Mean	Quantitative	Continuous	Local	Topographic	Yes	-244.4
Bathy_STD	Quantitative	Continuous	Local	Topographic	Yes	77.4
Bathy_Max	Quantitative	Continuous	Local	Topographic	Yes	-331.6
Bathy_Min	Quantitative	Continuous	Local	Topographic	Yes	-68.1

Variable	Type of variable (1) - qualitative or quantitative	Type of quantitative variable – rank, discrete or continuous	Scale of measurement - local or regional *	Type of variable (2) - geologic, geographic, topographic, or physico-chemical	Cluster on cells-habitats	Example of value
Pente_Count	Quantitative	Discrete	Local	N/A	No	400
Pente_Mean	Quantitative	Continuous	Local	Topographic	Yes	1.48
Pente_STD	Quantitative	Continuous	Local	Topographic	Yes	1.01
Pente_Min	Quantitative	Continuous	Local	Topographic	Yes	0.07
Pente_Max	Quantitative	Continuous	Local	Topographic	Yes	5.84
Geomorph_1	Qualitative	N/A	Local	Topographic	Yes	Pente
Geomorph_2	Qualitative	N/A	Local	Topographic	Yes	Uniforme
Geo2_Uniforme	Quantitative	Continuous	Local	Topographic	No	0.7468355
Geo2_Bosse	Quantitative	Continuous	Local	Topographic	No	0.2531646
Geo2_Creux	Quantitative	Continuous	Local	Topographic	No	0
Relief_dom	Qualitative	N/A	Local	Topographic	Yes	Pente uniforme
Relief_var	Quantitative	Rank	Local	Topographic	Yes	5
Aire_Protegee	Qualitative	N/A	Regional	Geographic	No	ZPM-1
O2_Sat_Mean	Quantitative	Continuous	Local	Physico-chemical	Yes	30.12439919
O2_Sat_Classe	Quantitative	Rank	Local	Physico-chemical	Yes	2
Polygone_Petrie	Qualitative	N/A	Regional	Geographic	No	7
BathyMoy_ajustée	Quantitative	Discrete	Local	Topographic	No	250
BathyMin_ajustée	Quantitative	Discrete	Local	Topographic	No	75
BathyMax_ajustée	Quantitative	Discrete	Local	Topographic	No	300
SalMoyMoy	Quantitative	Continuous	Regional	Physico-chemical	Yes	34.28
SalMinMoy	Quantitative	Continuous	Regional	Physico-chemical	Yes	34.15
SalMaxMoy	Quantitative	Continuous	Regional	Physico-chemical	Yes	34.45
SalMoyMin	Quantitative	Continuous	Regional	Physico-chemical	Yes	32.45
SalMinMin	Quantitative	Continuous	Regional	Physico-chemical	Yes	32.25
SalMaxMin	Quantitative	Continuous	Regional	Physico-chemical	Yes	32.72
SalMoyMax	Quantitative	Continuous	Regional	Physico-chemical	Yes	34.38
SalMinMax	Quantitative	Continuous	Regional	Physico-chemical	Yes	34.25

Variable	Type of variable (1) - qualitative or quantitative	Type of quantitative variable – rank, discrete or continuous	Scale of measurement - local or regional *	Type of variable (2) - geologic, geographic, topographic, or physico-chemical	Cluster on cells-habitats	Example of value
SalMaxMax	Quantitative	Continuous	Regional	Physico-chemical	Yes	34.47
TempMoyMoy	Quantitative	Continuous	Regional	Physico-chemical	Yes	4.35
TempMinMoy	Quantitative	Continuous	Regional	Physico-chemical	Yes	4.03
TempMaxMoy	Quantitative	Continuous	Regional	Physico-chemical	Yes	4.82
TempMoyMin	Quantitative	Continuous	Regional	Physico-chemical	Yes	0.80
TempMinMin	Quantitative	Continuous	Regional	Physico-chemical	Yes	0.04
TempMaxMin	Quantitative	Continuous	Regional	Physico-chemical	Yes	1.67
TempMoyMax	Quantitative	Continuous	Regional	Physico-chemical	Yes	4.47
TempMinMax	Quantitative	Continuous	Regional	Physico-chemical	Yes	3.85
TempMaxMax	Quantitative	Continuous	Regional	Physico-chemical	Yes	5.13
SS_Code	Qualitative	N/A	Regional	Geologic	Yes	1c
SS_Desc_Fr	Qualitative	N/A	Regional	Geologic	No	Pélite sableuse
SS_Desc_An	Qualitative	N/A	Regional	Geologic	No	1c - Sandy Pelite
Ecoregion_L1	Qualitative	N/A	Regional	Geographic	No	6
Ecoregion_L2	Qualitative	N/A	Regional	Geographic	No	6.2
Ecoregion_L3	Qualitative	N/A	Regional	Geographic	No	6.2.2
Megahabitat	Qualitative	N/A	Local	Habitat	N/A	A
MHVar_3x3	Quantitative	Discrete	Local	Habitat	N/A	8

* When the data for a given variable were obtained from observations made within the limits of a cell, they are referred to as local measurements, whereas properties attributed to a cell on the basis of its localization in a broader area in which all cells share a common value for that variable are referred to as regional measurements.

A hierarchical classification of the seabed based on physiographic and oceanographic features in the St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2916: vii + 72 pages.



Report and dataset

Rapport et jeu de données

DVD ROM

Fisheries and Oceans Canada
Pêches et Océans Canada
Canada

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