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Recent findings on the life history and catches of wolffish (*Anarhichas* sp.) in research surveys and in the Sentinel Fisheries and Observer Program for the Estuary and Gulf of St-Lawrence

Nouvelles données sur la biologie et les captures de loups (*Anarhichas* sp.) dans les relevés de recherche, et dans les Pêches sentinelles et le Programme des observateurs pour l'estuaire et le golfe du Saint-Laurent

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ABSTRACT

The three species of wolffish that inhabit the eastern Canadian Coast are considered as being at risk. Two species are listed as threatened (*Anarhichas denticulatus*, *Anarhichas minor*) whereas the third species (*Anarhichas lupus*) is listed as being of special concern. Since 2000 and 2001 when the status of those species was first assessed, the Department of Fisheries and Oceans has taken steps to facilitate their recovery. From a research and monitoring perspective, concrete actions included collecting more data and better data on which to base conservation measures in the future, as well as supporting research on life history, distribution and habitat associations of all three species. The present report reviews recent projects and publications on wolffish based on material collected in the Estuary and Gulf of St. Lawrence and addressing the following topics: fish species assemblages to which wolffish are associated, use of shelters by juvenile spotted wolffish, diving and towed camera surveys, metabolism, growth and reproductive biology, including new tools for fish identification and critical reviews of fish identifications on research surveys. Catch and effort data were aggregated using a grid made up of 100 km^2 square cells. The probability of catching wolffish of a given species in a set and within a cell (relative occurrence) was calculated as the ratio of the number of sets in which a species was recorded and the total number of sets made. This method allows the mapping of catch and effort for numerous time series based on data from different programs in both the whole study area (research surveys and Sentinel Fisheries using bottom trawls and a random stratified design) or in specific areas within the Gulf. The method also allows an estimate of surface areas occupied by each species and lends itself to matching area of occupancy and characteristics of the habitat. The data suggest no temporal trend in abundance. Wolffish represent a small biomass compared to other demersal species, with northern wolffish being very rare. The west coast of Newfoundland appears to be a hot spot for the distribution of spotted and striped wolffish in the Gulf.

RÉSUMÉ

Les trois espèces de loups présentes sur la côte est du Canada sont considées en péril. Deux espèces ont le statut d'espèces menacées (*Anarhichas denticulatus*, *Anarhichas minor*) alors que la troisième (*Anarhichas lupus*) a un statut préoccupant. Depuis 2000 et 2001 lorsque leur statut a été évalué pour la première fois, le ministère des Pêches et des Océans a pris des mesures pour favoriser leur rétablissement. Du côté recherche et monitorage, cela s'est traduit par un effort pour obtenir plus de données et des données de meilleure qualité, de même qu'un appui accru à la recherche sur la biologie, la distribution et les habitats propices aux trois espèces. Ce rapport passe en revue les résultats de recherches récentes ayant porté sur les loups dans l'estuaire et le golfe du Saint-Laurent et ayant porté sur ces sujets: les assemblages d'espèces de poissons auxquels les loups sont associés, l'utilisation d'abris par les loups tachetés au stade juvénile, des relevés par plongée et par caméra remorquée, le métabolisme, la croissance et la reproduction, de même que la production de guides d'identification et une évaluation de la fiabilité des identifications lors des relevés de recherche. Les données de capture et d'effort ont été agrégées par cellule de 100 km^2. La probabilité de capture d'un loup d'une espèce donnée dans un trait et dans une cellule (son occurrence relative) a été évaluée comme étant le rapport entre le nombre de traits où une espèce est présente et le nombre total de traits. Cette approche a permis de cartographier la capture et l'effort de plusieurs séries temporelles à partir des données de divers programmes et ce pour l'ensemble du Golfe (relevés de recherche et Pêches Sentinelles par chalut selon un patron aléatoire stratifié) ou dans des secteurs spécifiques du Golfe. La méthode permet le calcul des aires de fréquentation tout en se prêtant bien à associer ces aires aux caractéristiques de l'habitat. Les données ne montrent aucune tendance temporelle significative. Les loups représentent une faible biomasse dans le Golfe comparé à d'autres espèces démersales, le loup à tête large étant considéré comme très rare. La côte ouest de Terre-Neuve est un haut lieu de la distribution du loup tacheté et du loup atlantique dans le Golfe.

INTRODUCTION

The status of wolffish (*Anarhichas* sp.) in Canadian waters has raised concerns given the dramatic declines observed in their relative abundance through the 1980s and 1990s, a decline that occurred concurrently with that of other species in the same area, particularly Atlantic cod (*Gadus morhua*). Two of the three species of wolffish that inhabit eastern Canada, the northern wolffish (*Anarhichas denticulatus*) and spotted wolffish (*Anarhichas minor*), have been listed as being threatened, whereas the third species, the Atlantic wolffish (*Anarhichas lupus*), is of special concern. As a result, the Department of Fisheries and Oceans has prepared a Recovery Strategy for northern wolffish and spotted wolffish, and a Management Plan for Atlantic wolffish in Canada. That report was issued in 2008 (Kulka et al. 2007, referred to as the Strategy Document herein), but the assessment, status report and associated research documents for the three species date back to 2000 and 2001 (McRuer et al. 2000, Simpson and Kulka 2002). Kulka et al. (2004) have analyzed population trends and distribution and habitat associations for wolffish in the «center of distribution» of the species, referring to the Labrador Shelf and Grand Banks, and did not consider the Gulf of St. Lawrence and areas south of Newfoundland in their analysis. The research document prepared by McRuer et al. (2000) has examined those areas, but focused on the Atlantic wolffish.

The major goal put forth by the Strategy Document is to increase the abundance and distribution of all three species of wolffish in eastern Canada to levels above those observed in the 1980s and more particularly the 1990s. Several actions were recommended to reach that goal, many of which dealing with monitoring and mitigation of human activities and potential impacts. Fisheries and Oceans Canada has addressed that challenge over the past several years and raised awareness with staff, observers, dockside monitors, fishers and the industry. For instance in the Gulf of St. Lawrence, projects were supported that aimed at increasing the rate of reports (more data and better data on wolffish in logbooks) and the coverage of the Observer Program in fleets with a greater potential impact on wolffish. Three local offices participated and annual reports are available (Sylvio Coulombe, DFO Québec Region, personal communication). Starting in 2004, under SARCEP funding, the Fisheries and Aquaculture Management team has monitored fishing activities concerning species at risk and made that information available in the management of fishing activities dataset. The mandatory immediate release of northern and spotted wolffish caught incidentally in fishing gears has on the other hand lowered our capacity to acquire new data, a basic requirement to meet two other objectives listed in the Strategy Document, i.e., to study the biology and life history of wolffish and to identify and protect their habitat. The reassessment of the status of the three species under SARA requires more data and better data on which to base our management and protection actions, particularly in the St. Lawrence where few data were available for the previous assessment. The present report reviews recent projects and publications on wolffish based on material collected in the St. Lawrence, and inventories and describes the data series observed from research surveys and in the Sentinel Fisheries and Observer Program up to and including 2009. Landings data as compiled in ZIFF files and for the same area are presented in a separate report (Ouellet et al. 2011).

MATERIALS AND METHODS

This research document is split into two main sections, one which reviews the recent literature (Recent projects and publications) and one which inventories the data series available (Data available) that are relevant to wolffish in the study area. The study area includes the Saguenay

Fjord, the St. Lawrence middle and lower Estuary, and the Gulf of St. Lawrence east up to Cabot Strait and Belle Isle Strait (Figure 1).

RECENT PROJECTS AND PUBLICATIONS

Papers published between 2000 and 2010 and based partly or entirely on data, samples or specimens collected in the study area were reviewed and are included in the list of references. The section is divided into different themes: species identification and associations, direct observations and behavior, population structure, metabolism and growth, and reproductive biology. The emphasis has been put on studies most relevant to natural populations and conservation and management issues. Projects funded through DFO «SARCEP» funds are addressed in separate sub-sections. Papers by the authors of this report and yet unpublished were also included in the present review.

DATA AVAILABLE

Datasets were inventoried looking for data on the 3 species of wolffish in the study area. The data had to meet several criteria: 1- precision and reliability of identifications; 2- availability of information on latitude and longitude of catches; 3-clear information on gear and some information on the level of effort. Observations were categorized as belonging to the middle or lower Estuary, and northern and southern Gulf based on the dividing lines shown in Figure 1. Catch and effort data were aggregated using a grid made up of 100 km^2 square cells (10 km x 10 km) (Dutil et al. 2011). The number of sets in which a species was recorded and the number of sets made were determined for each cell. The probability of catching wolffish of a given species in a set and within a cell was calculated as the ratio of the number of sets in which a species was recorded and the total number of sets made (e.g., 2 occurrences of spotted wolffish in trawl sets per 10 trawl sets in a given cell). Catch and effort data outside the limit of the study area in Cabot Strait and Belle Isle Strait, but located within the limit of our grid, were included. In the present document the number of sets in which a species was recorded is considered as its frequency of occurrence and is coined «occurrence», the number of sets made is considered as the level of effort and is coined «fishing effort». The term «relative occurrence» designates the ratio of these two frequencies.

Annual groundfish bottom trawl research surveys (Québec and Gulf regions)

Research surveys to assess the distribution and abundance of groundfish were conducted annually from 1978 in the northern Gulf (Québec Region of DFO) and from 1971 in the southern Gulf (Gulf Region of DFO). Vessel and gear changed over time and surveys took place in summer in some years and in winter in other years. These surveys follow a stratified random sampling strategy based on predetermined depth strata. The data from both regions and up to 2008 are considered in the present document. Wolffish were identified to species by science staff and identification to species is considered reliable. However, whether all catches were recorded in all years in the northern Gulf is unclear (Dutil et al. 2006). Survey catches are reported by weight; numbers of wolffish in the catch and individual lengths are available only for some sets in some years.

Sentinel Fisheries – fixed gears

The Program started in the early 1990s and data are available starting in 1994. Data for the fixed gear section of the Program are available in databases managed by the Québec Region. Data for the period from 1994 to 1998 were retrieved from ASCII files (Québec Region) or

Access files (Gulf Region); data from 1999 to 2009 were obtained from two Oracle databases, one devoted to the Sentinel Fisheries Program (Québec Region) and the other to the Observer Program (Gulf Region). In the Sentinel Fisheries Program database, data for the fixed gear fishery are available for vessels based in Québec (La Tabatière, 4S) and Newfoundland (Corner Brook, 3Pn and 4R). Both Québec and southern Gulf vessels participate in the fixed gear fishery of the Observer Program. Sources of data are coded 1, 2 or 14: 1= Sentinel Fisheries for cod, fixed gears, Québec – La Tabatière, activities in 4S; 2= Sentinel Fisheries for cod, fixed gears, Newfoundland – Corner Brook, activities in 3Pn and 4R; 14= comparative survey of fixed and mobile gears, Newfoundland – Corner Brook (fixed gears were selected). In the Observer Program database, data from the Sentinel Fisheries were selected as «TYP_ACTI in ('SG')» and «CAT_ENG in ('F')»; relevant observations can be identified from variable NO_VOY which is coded starting with a «G», standing for Gulf region, and a «4» following the two digits for year (for example for 2003 «G03401») although activities based in the Québec Region (NO_VOY is coded starting with a « L» or a «Q») also contribute.

The fixed gear fishery targeted Atlantic cod in areas where the cod fishery took place traditionally. Fishing took place at the same sites and during the same period year after year. Thus a grid of fixed stations was sampled repeatedly in contrast to the annual research surveys' stratified random sampling strategy. Catches of wolffish have been recorded to species level starting in 1996 in the Observer Program, with identification to species made by the observers, whereas records to species level are only available starting in 2002 in the Sentinel Fisheries Program database with identifications made by the fishermen themselves. Catches are reported as weights and split into landed and not landed. Numbers of fish caught and individual lengths are not available generally and if available are only available for recent years and are not entered in the databases. The data for the period from 1996 to 2008 are examined in the present document.

Over the period from 1996 to 2008, 15272 fishing activities using fixed gears took place under the Program. Several gears were used, but gillnets (6793 activities) and longlines (8437 activities) account for a great proportion of the fishing activities (99%). Only the data from the gillnets and the longlines are considered in the present document. Fishing effort, occurrences, and relative occurrences were calculated as described above, i.e. based on presence/absence in the catch and number of activities, and aggregated using a grid made up of 100 km^2 square cells.

Sentinel Fisheries – mobile gears

The Program started in the early 1990s and data are available starting in 1994. Over the period from 1994 to 2008, 16,492 fishing activities using mobile gears took place under the Program and in the study area, 6,840 for the Québec region and 9,652 for the Gulf region. Catches of wolffish have been recorded to species level from the start of the Program and identifications were made by observers in both the northern Gulf and southern Gulf surveys. Data for the Québec Region were compiled using a program called PACES (Programme d'analyse des campagnes d'échantillonnage stratifiées) and analyzed using SAS software. Those for the Gulf Region were obtained from the Access (1994-1998) and Oracle (1999-2008) databases using SAS software. Numbers of fish and individual lengths are available, though from other databases (Gulf region data are incomplete in the Observer Program database).

There are major differences in the way the Program was conducted in the northern and southern Gulf. In the northern Gulf, five different sets of surveys were conducted. The main set aimed at assessing cod and other groundfish abundance and followed a stratified random

sampling strategy based on predetermined depth strata (as per the research surveys) with the number of stations proportional to the surface area of the stratum. The survey area included NAFO subdivisions 3Pn, 4R, 4S, and deeper waters of 4T. The series involved nine vessels, four from Québec (Rivière-au-Renard, described as Type de projet = 3 or 4) and five from Newfoundland (Corner Brook, described as Type de projet = 5). Excluding 1994 and early 1995 when partial surveys were conducted at other times of the year (surveys no 1 and no 2), two surveys were conducted each year between 1995 and 2009, one in July (up to 2009) and one in October (series ended in 2002). This sums up to 23 surveys, 8 in October (1995-2002, surveys no 4, 6, 8, 10, 12, 14, 16 and 21) and 15 in July (1995-2009, surveys no 3, 5, 7, 9, 11, 13, 15, 20, 22, 25, 28, 32, 34, 36 and 38). The four other sets did not follow a stratified random sampling strategy and pursued different goals, 1- to study the mixing of the two cod stocks in winter (fixed stations, 4 surveys in January, surveys no 17, 23, 26 and 29, and one survey in March, survey no 18, 2002-2006); 2- to assess northern Gulf cod reproductive capacity (fixed stations, 7 surveys in May, survey no 19, 24, 27, 31, 33, 35 and 37, 2002-2009); 3- to compare catch rates for cod for fixed and mobile gears (survey no 23 in July 2003); 4- to assess cod recruitment (survey no 30 in March 2006). Note that two surveys are coded as no 23; they can be distinguished using variable SOURCE (or month).

In the southern Gulf, the mobile gear fishery targeted Atlantic cod and other groundfish. From 1994 to 2002, fixed stations were visited year after year in areas where the cod fishery used to take place, using trawls (3 types) and seines (2 types). Starting in 2003, a stratified random sampling strategy was implemented using a single type of trawl (same as in the northern Gulf) and four vessels sampling 200-250 stations per year (Poirier and Currie 2007, Savoie and Surette 2010). In the Observer Program database, data from the Sentinel Fisheries were selected as «TYP_ACTI in ('SG')» and «CAT_ENG in ('M')»; relevant observations can be identified from variable NO_VOY which is coded starting with a «G», standing for Gulf region, and a «4» following the two digits for year (for example for 2003 «G03401»). Activities based in the Québec Region (NO_VOY is coded starting with a « L» or a «Q») also contribute to the Program in the Gulf Region. For 1994 and 1995, variable «TYP_ACTI» was not coded as «SG» or «SQ»; observations for those years can be selected based on variable TYP_EXPED (value PF, «Poisson de fond») and variable ESP_VISEE (value=10, Atlantic cod).

The following is an account of sets and series considered in our analyses.

The first analysis examined stratified random surveys conducted with trawlers in the northern Gulf (1995-2008) and the southern Gulf (2003-2008). Only data obtained in the study area and from trawlers geared with a rock hopper 300 (OTB2) were used: for the northern Gulf, random stratified surveys conducted in July (14 surveys up to 2008, 4,105 fishing activities in the study area) and October (8 surveys, 2,212 fishing activities in the study area); for the southern Gulf, random stratified surveys conducted in August (6 surveys, 2003-2008, 1,483 fishing activities).

The second analysis examined fixed stations surveys conducted with trawlers mainly in the period from July to October in the southern Gulf (9 surveys, 1995-2002, 4,063 fishing activities). Only data obtained in the study area and from trawlers geared with a rock hopper 300 (OTB2) were used.

The third analysis examined fixed stations surveys conducted in winter in the northern Gulf (5 surveys to study the mixing of stocks in winter – see above, only 56 activities as most activities occurred outside of the study area), to which we added two stratified random surveys conducted in winter (surveys no 1 and no 2 – see above, 153 fishing activities in the study area).

Data obtained to compare catch rates for cod for fixed and mobile gears (July 2003, 22 activities in the study area) and to assess cod recruitment (March 2006, 25 activities in the study area) were not considered in our analyses as they were not repeated. The trawl used in the March 2006 survey was also not the same as used in all other surveys. Surveys to assess northern Gulf cod reproductive capacity were also left out as they represented a limited effort over a limited area where much information was available from other surveys (less than 50 fixed stations each year, 267 activities in the study area up to 2008). Data obtained using seines were also discarded. Those data were obtained between 1994 and 2002 in the southern Gulf, but two fleets used different types of seines in different areas. A few records with erroneous latitude and longitude (5) were also excluded from the analyses.

Occurrences, relative occurrences and fishing effort were calculated as described in the previous section, i.e., based on presence/absence in the catch and number of activities, and aggregated using a grid made up of 100 km^2 square cells.

Observer Program excluding Sentinel Fisheries

The Observer Program started in the late 1980s, but few data are available before 1990. There are no records of wolffish catches for 1987 and 1988, and catches were not identified by observers in 1989. In 1990 and 1991, wolffish catches were not consistently identified to species. For the period from 1987 to 1998, data stored in Access files (see above) were used whereas data for the period from 1999 to 2008 were extracted from an Oracle database. These data represent a mix of Sentinel Fisheries activities (as observers participate in the Sentinel Fisheries) and other commercial activities. Activities outside the Sentinel Fisheries Program were selected as «TYP_ACTI NOT in ('SG') and TYP_ACTI NOT in ('SL') and TYP_ACTI NOT in ('SQ'). For 1994 and 1995, variable «TYP_ACTI» was not coded as «SG» or «SQ»; observations for those years were removed based on variable TYP_EXPED (value PF, «Poisson de fond») and variable ESP_VISEE (value=10, Atlantic cod). Records with missing or erroneous latitude and longitude, records outside the study area, and records with gear undetermined were not included in the analyses. Thus we focused our analyses on the period from 1992 to 2008, during which wolffish were identified to species level and identifications made by observers, excluding the Sentinel Fisheries observations and excluding observations made outside of the study area. Catch weights are available, but not individual lengths or numbers caught. Fixed and mobile gears are analyzed separately.

Occurrences, relative occurrences and fishing effort were calculated as described in the previous section, i.e., based on presence/absence in the catch and number of activities, and aggregated using a grid made up of 100 km^2 square cells.

RESULTS AND DISCUSSION

RECENT PROJECTS AND PUBLICATIONS

Species identification and associations

Conservation and management decisions must rest on valid data. Correct identification at the species level is a very basic aspect of data validity. In some cases, particularly in the commercial fisheries in the 1980s and 1990s, landed and discarded wolffish were not identified to species. This is often the case for accidental catches. In research surveys, sampling is directed at commercial species and in some regions not all fish species were identified or were

identified correctly in the past. This has largely been addressed and more data and more reliable data on fish species, commercial or not, have been gathered in more recent years. In the northern Gulf of St. Lawrence, the validity of data gathered during research surveys from 1978 to 2003 (Dutil et al. 2006) has been assessed, new approaches have been developed from 2001 and surveys from 2004 fully account for species diversity in the catch. This process has been greatly facilitated by having teams dedicated to non-commercial species and the advent of digital cameras.

Two guides for the identification of fish species have been published, one for the southern Gulf of St. Lawrence (Daigle et al. 2006a) and one for the northern Gulf of St. Lawrence (Nozères et al. 2010a). Both provide excellent visual aids to fish species identification, including a poster comparing the three wolffish species, and should be used by scientific teams on the surveys as well as by observers, dockside monitors, fishers and the industry. They are also available in French (Daigle et al. 2006b, Nozères et al. 2010b).

Contributions based on regional SARCEP funding (Québec)

Chouinard and Dutil (manuscript submitted for publication) described demersal fish assemblages in the St. Lawrence Estuary and Gulf based on the stratified random bottom trawl surveys conducted annually by DFO between 2004 and 2008. During these surveys, no northern wolffish were caught, but 82 taxa were inventoried including spotted and Atlantic wolffish. The composition of the catch at each sampling station was described and sampling stations grouped based on catch composition. Two methods were used to determine the relative importance of a species in structuring the assemblages, the indicator value index (Dufrene and Legendre 1997) and the Bray-Curtis similarity index (SIMPER procedure; Clarke and Gorley 2006). Species whose indicator value was over 15% were considered as major contributors to shaping a given assemblage.

Hierarchical cluster analysis defined 9 groups of stations, each cluster consisting of similar stations in terms of the presence and abundance of species caught. Among those, six clusters represented 99% of all stations (clusters B, C, E, G, H, I). Thirty-five taxa were classified as key species, with each assemblage being characterized by 2 to 12 key species (Table 1). Group B stations were mainly located on slopes along deep channels near Cabot Strait and up to the entrance of Esquiman and Antiscoti channels at an average depth of 244 m. Redfish (*Sebastes fasciatus* and *S. mentella*) contributed most to similarity between stations; 52 species occur in those stations with white hake (*Urophycis tenuis)*, silver hake (*Merluccius bilinaris)*, and Atlantic argentine (*Argentina silus*) representing key species for this assemblage. Group G stations are mainly located on slopes and on plateaus above the slopes further up along Esquiman and Antiscoti channels, particularly on the west coast of Newfoundland, at an average depth of 160 m. Species richness is 58, with American plaice (*Hippoglossoides platessoides*) contributing most to similarity between stations. Vahl's eelpout (*Lycodes vahlii*), Atlantic wolffish (*A. lupus*), and Atlantic hookear sculpin (*Artediellus atlanticus*) represented key species. Group H stations are closer to shore, with an average depth of 83 metres. They are aggregated at the two tips of Anticosti and along the west coast of Newfoundland including Belle Isle Strait. Species richness of this assemblage is 55 species. Atlantic cod (*Gadus morhua*) contributed most to similarity between stations; mailed sculpin (*Triglops murrayi*) and shorthorn sculpin (*Myoxocephalus scorpius*) were key species of this assemblage.

Looking more specifically at stations where wolffish were caught, the same dataset can also be used to identify fish species that are most often encountered by wolffish in their habitat. Species contributing most to grouping stations with Atlantic or spotted wolffish, are listed in Table 2.

There was a significant difference in species composition between stations with Atlantic wolffish and stations without Atlantic wolffish (ANOSIM, P<0.10, R= 0.326, percent dissimilarity 74.6%) and between stations with spotted wolffish and stations without spotted wolffish (ANOSIM, P<0.10, R= 0.119, percent dissimilarity 71.2%)(Figure 2). Atlantic wolffish contributed 6.4% to grouping stations with Atlantic wolffish (Simper), and spotted wolffish contributed 4.5% to grouping stations with spotted wolffish. Atlantic wolffish and spotted wolffish were encountered most frequently in clusters B, C, G, H and I (Table 1), with Atlantic wolffish always present in a greater number of stations than spotted wolffish.

Direct observations and behavior

There is one element of habitat features that is often alluded to when referring to wolffish, i.e., visual observations made by scuba divers: Keats et al. (1985) in the Avalon Peninsula, eastern Newfoundland, Pavlov and Novikov (1993) on the Kandalaksha coast of the White Sea (Russia), Kulka et al. (2004) in the Avalon Peninsula (eastern Newfoundland) and in Bonne Bay (west coast of Newfoundland, in the Gulf of St. Lawrence), and Larocque et al. (2008) along the north coast of the Gaspé Peninsula, Québec. In all cases, divers investigated rocky coastal areas and observed *A. lupus* under rocks and boulders. The use of shelters by *A. minor* has been shown for juvenile fish, based on studies conducted in the laboratory (Lachance et al. 2010).

Atlantic wolffish use shelters when feeding, mating and during egg guarding. Keats et al. (1985) diving observations took place in the daytime all year round at depths from 5 to 15 m. They observed Atlantic wolffish seasonally, most often in holes under large boulders, but sometimes in the open swimming or stationary on the bottom. Both paired and solitary individuals were observed. Pairs were common in late summer and were most likely associated to spawning. From September, solitary individuals were observed guarding egg masses, each guardian overlooking a single clutch. Keats et al. (1985) sampled eight guardians; they were all males. Feeding activity, as determined from the relative mass of food remains in the gastrointestinal tract, declined during pair formation and for males during egg guarding, but otherwise wolffish fed during the period when they where associated to shelters. Kulka et al. (2004) made observations along transects from the shoreline down to 30 m. Wolffish were counted and their habitat association described. Only *A. lupus* were observed at those depths, never on soft (fine-particle) bottoms. Kulka et al. (2004) concluded that rocks and caves in the nearshore area are important features of the mating and spawning habitats for that species.

Based on diving observations at depths down to 30m, Pavlov and Novikov (1993) reported that Atlantic wolffish preferred a «complex bottom relief formed of rocks or large stones», that they rarely occurred in other habitats. Slopes of 15-30 ° were deemed favorable. A majority of the fish were observed in shelters, several others being observed near shelters. Pairs of fish were also observed, but no egg clutches. Shelters were described as a cavity between or under a stone with shell (food) remains at the entrance and several alternate entrances. Pavlov and Novikov (1993) also gave a qualitative account of shelter use and reported no apparent territorial behavior, no fidelity to a particular shelter and sometimes a close proximity between occupied shelters (< 2 m).

Contributions based on regional SARCEP funding (Québec)

The situation in the Gulf of St. Lawrence is not different from what has been observed in the Avalon Peninsula and Kandalaksha coast of the White Sea. Larocque et al. (2008) made 24 dives in the period from June to August around rocky outcrops in the Les Méchins area along

the north coast of the Gaspé Peninsula, Québec. Their study reported depth distribution and provided a detailed description of shelter location, shelter dimensions and size of Atlantic wolffish associated with these shelters. Atlantic wolffish were most abundant in shelters located near the base of the reef, below the thermocline and influence of strong tidal and coastal currents. Shelters were in close proximity with shelters occupied by other species, were sometimes occupied by other fish species when wolffish left, and were even occasionally shared with other fish species. One pair was observed that produced a clutch. These observations suggest that Atlantic wolffish are not territorial towards other fish species using shelters on the reef. Video records showing Atlantic wolffish in shelters in their natural habitat can be viewed on a DVD attached to the paper copy of a recently published report (Larocque et al. 2010, see below). Shelters may be required for successful reproduction (Pavlov and Novikov 1993, Kulka et al. 2007), such as for mating and egg guarding (Keats et al. 1985, Larocque et al. 2008). Whether eggs are laid in a shelter in non-rocky and offshore areas is unknown (Kulka et al. 2004).

There is no account of similar observations on spotted or northern wolffish. This is a reflection of the fact that spotted and northern wolffish are distributed at greater depths beyond the reach of divers. Shelter use and territoriality were therefore investigated in the laboratory on F1 offsprings (20–42 cm) from wild animals obtained from the Gulf of St. Lawrence (Lachance et al. 2010). Lachance et al.'s (2010) laboratory experiments assessed shelter use and behavior of juvenile spotted wolffish, using time-lapse video cameras (Figure 3). The location and movements of fish in the tanks and interactions between individuals were monitored day and night. Four experiments were conducted using one or two fish per tank, with and without a shelter. The fish did not show fidelity to a particular site in experiments without shelter. They seemed to prefer to be in close proximity and exhibited few signs of aggressiveness to each other. When a shelter was available, spotted wolffish spent most of their time in the shelter or in close association with the shelter (> 95% of the time in a 24 h period). They spent very little time exploring the water column. The presence of a shelter did not enhance aggressive behaviors. When day and night observations were compared, no clear diel pattern emerged. This is the first study demonstrating the association of spotted wolffish with shelters. Overall juvenile spotted wolffish do not exhibit aggressive territoriality and appear to restrict their routine activities to the seafloor.

Larocque et al. (2010) examined how multibeam acoustic data and optical imagery can be used to describe the potential habitat of wolffish (*Anarhichas* sp.) in the Gulf of St. Lawrence. As of mid-June 2010, this report is in its final review stage. Two sites located along the Gaspé Peninsula were selected based on historical catch data and their habitat features were examined at different spatial scales using towed video and multibeam acoustic surveys. High-resolution bathymetry and backscatter coupled with information extracted from video allowed for a detailed description of environments known to be used by wolffish. Features believed to be favorable were identified on the two survey sites, including shelters and deep glacial scours. The survey methods that were used revealed many different bottom types and a level of physical complexity that were not suspected for this area. Information on the presence of potential preys was also acquired and mapped. Overall, the report is a demonstration of how data from different sources can be integrated to gain insight into what is the habitat of a low-density species that can’t be studied in situ. In addition to the technical report, the resulting information is also presented within a multimedia DVD-ROM published as an appendix to the report. Video, fixed imagery and interactive maps derived from the multibeam data provide an overview of the environment that is used by wolffish in a format that is accessible to non-specialists.

Population structure

The recovery strategy for northern and spotted wolffish and management plan for Atlantic wolffish are currently based on the assumption that fish from different locations across each species range form a single population. There is little evidence to suggest that each species has several stocks in Canadian waters, but many points could be made to challenge such an assumption including for instance a very short pelagic stage, presumably low mobility at all life stages, and very wide distribution within and beyond Canadian territorial waters. In a situation where more than one population exists, the status of each population should be determined and conservation and management measures should target the most vulnerable. The Strategy Document (Kulka et al. 2007) recommended to study population structure within eastern Canadian waters. Few studies have been published that address this issue in the Northwest Atlantic.

Microsatellite markers are a useful tool to identify species, either for forensic purposes or in field studies when examining larval stages. Based on samples obtained from the Grand Banks, Labrador Shelf and several locations in the North Atlantic, and using microsatellite markers (14 loci), McCusker et al. (2008) showed strong differentiation among species (Figure 4). Discrimination was highly reliable, even when using eight or five loci.

Based on allozyme polymorphism and variation in mitochondrial DNA among spotted wolffish samples obtained from five locations, including two sites within the Gulf of St. Lawrence, Imsland et al. (2008) concluded that a high level of geographic population structure exists for that species across the North Atlantic, suggesting the existence of different populations of spotted wolffish. Consistent with the assumed low mobility of the species, gene flow between neighboring spotted wolffish populations was considered low. While the Gulf of St. Lawrence samples were distinct from the other samples, marked differences were also observed between the two samples from the Gulf of St. Lawrence (Imsland et al. 2008). The limited field sampling, differences in fish size and age structure between samples, aquaculture origin of some of the samples, and low polymorphism of the selected genetic markers, preclude any firm conclusion regarding stock structure, particularly within Canadian waters.

Two other papers examining the structure of wolffish populations are in preparation, one on the Atlantic wolffish, and one on spotted and northern wolffish (Paul Bentzen, Dalhousie University, personal communication). The latter one will not address population structure within Canada, but the one on Atlantic wolffish will include samples from southern and northern Gulf and other locations across the range of the species.

Contributions based on regional SARCEP funding (Québec)

Nil

Metabolism and growth

Whereas the status of wolffish has raised concerns in eastern Canada, the spotted wolffish is generally considered as having a high potential for mass production in land-based aquaculture facilities. Controlled experiments have been conducted aiming to assess the metabolism and growth capacity of wolffish under different sets of environmental conditions. Though derived from laboratory observations, results from these experiments may nevertheless shed some light on physiological limitations and adaptations and may prove useful for the interpretation of field observations. Studies have mainly focused on the effects of salinity, temperature and dissolved

oxygen on the survival and growth of wolffish. Like many other marine species, wolffish can withstand low salinities. Spotted wolffish were not adversely affected by salinities down to 12 psu (Foss et al. 2001). Gulf of St. Lawrence Atlantic wolffish survived and grew well at salinities down to 7 psu (Le François et al. 2001, 2004). These results would suggest that salinity is not in itself a driving factor explaining the relative distribution of both species in estuarine and coastal habitats. While Atlantic and spotted wolffish occupy a range of temperatures in the northeast Atlantic, they perform better at intermediate temperatures. Though the rate of protein synthesis in white muscle was lower at 4 °C than at higher temperatures, consistent with a faster growth in length and mass at 8 and 12 °C than at 4 °C (Lamarre et al. 2009), Gulf of St. Lawrence juvenile spotted wolffish grew well at temperatures down to 4 – 5 °C (Savoie et al. 2008, Lamarre et al. 2009), i.e., at temperatures encountered year round on the slopes bordering the deep channels and at the bottom of the deep channels in the Gulf of St. Lawrence. Temperatures down to 4 – 5 °C however may depress cardiac mitochondrial respiration in Atlantic wolffish (Lemieux et al. 2010) and the low dissolved oxygen tensions that prevail near the bottom in the channels may jeopardize survival and more particularly growth in both Atlantic (Le François et al. 2001) and spotted wolffish (Jetté et al. 2010, Larouche et al. 2010). Two other studies on plasma antifreeze proteins revealed a very important piece of information. Freezing point depression was marginal in adult spotted wolffish, but was very significant in both juvenile and adult Atlantic wolffish seasonally exposed to near freezing temperatures (Desjardins et al. 2006, 2007), suggesting that Atlantic wolffish, which tend to occur at shallower depths, had the capacity to survive when exposed to ice laden waters, whereas spotted wolffish who are found at greater depths in the St. Lawrence do not.

Contributions based on regional SARCEP funding (Québec)

Nil

Reproductive biology

Contributions based on regional SARCEP funding (Québec)

The development of an aquaculture industry will require catching more wild individuals and controlling their reproductive cycle in order to building a large and productive broodstock. Wolffish in culture must be artificially fertilized; yet it is difficult to differentiate males and females using secondary sex characteristics until a few months before spawning when ovaries become apparent in sonograms and later on macroscopically as gravid females have developed a large abdomen. Roy et al. (Robert Roy, DFO Québec Region, personal communication) have determined the profiles of sex steroids in spotted wolffish during an annual cycle. They measured estradiol (E2), testosterone (T) and 11-ketotestosterone (11-KT) in plasma from mature male and female spotted wolffish by ELISA and compared the profiles with levels in fish of indeterminate sex and immature fish. Mature males produced milt during several months, with mean levels of T ranging from 7.2 to 13.3 ng/ml and those of 11-KT ranging from 19.2 to 56.6 ng/ml from February to May. Mature females released eggs in different months and peak levels of T and E2 attained maximum levels in different months for individuals. The authors were able to identify indeterminate fish and an immature fish as males based on levels of plasma T and 11-KT. Monitoring of steroid levels was a useful predictor for the timing of egg release by individual females wolffish. Though intended for broodstock management purposes, immunoassay methods developed by Roy et al. provide a useful, safe and non-invasive method to identify the sex and maturity of spotted wolffish in the wild.

DATA AVAILABLE

Annual groundfish bottom trawl research surveys (Québec and Gulf regions)

Spatial distribution of effort

Fishing effort during the annual groundfish bottom trawl research surveys was widespread over the study area except in the coastal area (< 50 m), in the deep water at Cabot Strait and along much of the lower north shore of the Gulf where the seabed is rough for trawling (Figure 5). Furthermore, more effort was devoted near Chaleurs Bay and along the southern portion of the West Coast of Newfoundland, as well as in slope waters south of the Laurentian Channel, as a result of combining the overlapping southern and northern Gulf surveys. Total fishing effort was 13,209 sets, 305 in the Estuary, 7431 in the northern Gulf and 5,473 in the southern Gulf, i.e. north and south of the dividing line shown in Figure 1.

Relative occurrence of the three species

No wolffish have ever been reported from annual groundfish bottom trawl research surveys in the Estuary of the St. Lawrence. In the Gulf, the occurrence of wolffish appears to be low, with 102 occurrences for northern wolffish (93 and 9 in the northern and southern Gulf, respectively), 248 occurrences for spotted wolffish (244 and 4 in the northern and southern Gulf, respectively) and 1,306 occurrences for Atlantic wolffish (1,081 and 225 in the northern and southern Gulf, respectively). Thus the relative occurrence in the whole study area varied between species (Chi-square=1,632.4, 2 df; $p<0.001$), 0.8% for northern, 1.9% for spotted and 9.9% for Atlantic wolffish. Assuming a similar catchability for the three species, northern wolffish would appear to occur 2.4 and 12.8 times less frequently in the trawled areas than spotted and Atlantic wolffish, respectively. Spotted wolffish would occur 5.3 times less frequently than Atlantic wolffish.

Spatial and temporal distribution of relative occurrences

Northern wolffish were caught mainly near Cabot Strait on the west coast of Newfoundland, in the Esquiman and Laurentian channels and to a lesser extent on the slopes south of the Laurentian Channel up to the tip of the Gaspé Peninsula (Figure 6). Values of relative occurrence by cell range only up to 0.33, suggesting a low probability of capture anywhere in the study area. Spotted wolffish in contrast occupy the northwest portion of the study area, particularly the Esquiman Channel and bordering areas (Figure 7) with generally higher values of relative occurrence suggesting the species might be more common where it occurs than northern wolffish is. Atlantic wolffish are more widespread than the other two species, but clearly avoid the bottom of deep channels (Figure 8). Though in general their relative occurrence is low in the southern Gulf, they are present along the 200 m isobath on the slopes south of the Laurentian Channel. Relative occurrences are broken down by year and are shown for the northern (Estuary excluded) and southern Gulf in Table 3.

Sentinel Fisheries – fixed gears

Spatial distribution of effort – longlines

Figure 9 shows that fishing effort with longlines mainly occurred in the coastal zone in Belle Isle Strait, along the west coast of Newfoundland and Nova Scotia, in Chaleurs Bay, north of Prince Edward Island and around the Îles-de-la-Madeleine. Thus in contrast to research surveys, longlines may only provide information on some of the habitats within the study area. Total

fishing effort was 8437 activities, none in the Estuary, 1403 in the northern Gulf and 7034 in the southern Gulf, i.e. north and south, respectively, of the dividing line shown in Figure 1.

Relative occurrence of the three species – longlines

Longliners reported 1097 occurrences of wolffish in the period from 1996 to 2008, 21 for northern (10 and 11 in the northern and southern Gulf, respectively), 146 for spotted (105 and 41 in the northern and southern Gulf, respectively) and 930 for Atlantic wolffish (543 and 387 in the northern and southern Gulf, respectively). Only a small proportion of those occurrences were associated to a catch greater than 50 kg and those occurred mainly for Atlantic wolffish and essentially along the west coast of Newfoundland, the only exception being one catch of Atlantic wolffish reported for the Miscou area:

	Species		
	Northern wolffish	Spotted wolffish	Atlantic wolffish
Northern Gulf	0	9	98
Southern Gulf	0	0	1

Relative occurrence varied between species and between the northern and southern Gulf. The relative occurrence of northern wolffish was 0.25%: 0.71% in the northern Gulf and 0.16% in the southern Gulf. That of spotted wolffish was slightly greater, 1.7% overall, and this resulted from more frequent occurrences in the northern Gulf (7.5%) than in the southern Gulf (0.6%). The relative occurrence of Atlantic wolffish was greatest, 11%, with much more frequent occurrences in the northern Gulf (46.8%) than in the southern Gulf (6.2%). Assuming a similar catchability for the three species, northern wolffish would appear to occur 7.0 (146/21) and 44.3 (930/21) times less frequently in the fished areas than spotted and Atlantic wolffish, respectively, and spotted wolffish would occur 6.4 (930/146) times less frequently than Atlantic wolffish. Only the latter figure compares to that obtained from the research surveys.

Spatial and temporal distribution of relative occurrences – longlines

Northern wolffish were caught very infrequently throughout, except for a few cells in the Belle Isle Strait area where relative occurrences remain low but are above those for other areas (Figure 10). Relative occurrences of spotted wolffish are higher in some areas of the west coast of Newfoundland (Figure 11) and those of Atlantic wolffish are consistently high all along the west coast of Newfoundland (Figure 12). In the southern Gulf, though the relative occurrence of the three species is low, the Miscou Bank and northwest tip of Cape Breton Island stand out. Relative occurrences are broken down by year and are shown for the northern (Estuary excluded) and southern Gulf in Table 4.

Gillnets and longlines compared

Both gillnets and longlines were mainly used in the coastal zone. The fishing activities overlapped in Belle Isle Strait, on the west coast of Newfoundland and south of the Gaspé Peninsula, but elsewhere gillnets and longlines were not used in exactly the same areas suggesting that the two gears might provide complementary information. Relative occurrence was determined for cells in which fishing effort totaled 20 activities or more each for both gears

(Table 5 and Figure 13). Longlines yielded consistently more observations of wolffish than gillnets in areas where both gears were used suggesting that gillnets may not provide useful information on relative occurrence in cells where longlines suggest a species might be abundant (Table 5).

Wolffish were reported in the gillnet and longline catches 1179 times. In some cases, more than one species of wolffish was reported resulting in a total of 1267 records under the Program, 1097 of which were caught with longlines (86.7%) and 165 with gillnets (13.0%). Figure 14 shows cells where gillnets were used in the fixed gear Sentinel Fisheries Program, but not longlines. Black boxes indicate cells where gillnets caught any of the three species of wolffish. The low proportion of shaded cells, for instance in the Mecatina Trough, may reflect the absence of those species or their low vulnerability to the gear. Nevertheless, gillnets revealed the presence of wolffish east of Northumberland Strait.

Sentinel Fisheries – mobile gears

Spatial distribution of effort – stratified random surveys

Fishing effort was limited to the northern Gulf of St. Lawrence before 2003 with roughly 500 sets each year throughout the area excluding the rough seabeds along the lower north shore (Mecatina Trough) (Figure 15). From 2003, fishing effort was extended to the southern Gulf of St. Lawrence, but the total number of sets was not increased (Figure 16). Total fishing effort was 7,800 activities, none in the Estuary, 6,372 in the northern Gulf (4,516 before 2003 and 1,856 from 2003 to 2008) and 1,428 in the southern Gulf (58 before 2003 and 1,370 from 2003 to 2008), i.e. north and south, respectively, of the dividing line shown in Figure 1. Because fishing effort was not distributed similarly between the two periods, temporal trends in relative occurrences must be examined for the two periods separately.

Relative occurrence of the three species – stratified random surveys

Between 1995 and 2008, stratified random surveys reported wolffish in 840 sets corresponding to 900 occurrences of the 3 species, 26 occurrences for northern (22 and 4 in the northern and southern Gulf, respectively), 191 occurrences for spotted (185 and 6 in the northern and southern Gulf, respectively) and 683 occurrences for Atlantic wolffish (644 and 39 in the northern and southern Gulf, respectively). Only one catch greater than 50 kg (56 kg, July 2004, Atlantic wolffish, west coast of Newfoundland). Stratified random surveys accounted for 64.2% of all sets by trawlers in the study area (7,800/12,149) and 64.2% of all wolffish occurrences in trawler catches in the study area (900/956).

Relative occurrence varied between species and between the northern and southern Gulf. The relative occurrence of northern wolffish was 0.33%, 0.35% in the northern Gulf and 0.28% in the southern Gulf. That of spotted wolffish was 10 times greater, 2.45% overall, and this resulted from more frequent occurrences in the northern Gulf (2.90%) than in the southern Gulf (0.42%). The relative occurrence of Atlantic wolffish was greatest, 8.76%, with more frequent occurrences in the northern Gulf (10.11%) than in the southern Gulf (2.73%). In the northern Gulf of St. Lawrence, where more effort was devoted to stratified random surveys than in the southern Gulf of St. Lawrence, northern wolffish would appear to occur 8.4 (185/22) and 29.2 (644/22) times less frequently in the fished areas than spotted and Atlantic wolffish, respectively, and spotted wolffish would occur 3.5 (644/185) times less frequently than Atlantic wolffish.

Spatial and temporal distribution of relative occurrences – stratified random surveys

Relative occurrences of northern wolffish were very low throughout the study area. In contrast with research surveys which suggested higher relative occurrences near Cabot Strait on the west coast of Newfoundland, in the Esquiman and Laurentian channels and to a lesser extent on the slopes south of the Laurentian Channel up to the tip of the Gaspé Peninsula (Figure 6), stratified random surveys of the Sentinel Fisheries Program show no clear spatial pattern although higher occurrences also occured in the northwest portion of the study area (Figure 17). Relative occurrences of spotted and Atlantic wolffish were greatest on the west coast of Newfoundland (Figure 18 andFigure 19). The two species show a large degree of overlap in spatial distribution with Atlantic wolffish being more present near the coast and avoiding deep channels. These observations are consistent with research surveys observations (Figure 7 and Figure 8), except for the fact that other areas with high relative occurrences of spotted and Atlantic wolffish in research surveys do not show up clearly in the Sentinel Fisheries surveys. This may have to do with an uneven spatial distribution of effort in the Sentinel Fisheries surveys. Sampling effort was greatest in the northern Gulf of St. Lawrence and particularly on the west coast of Newfoundland, and sampling effort in the northern Gulf of St. Lawrence decreased by 50% starting in 2003. Relative occurrences are broken down by year and are shown for the northern (Estuary excluded) and southern Gulf in Table 6.

Spatial distribution of effort – fixed stations

Fishing effort was restricted to cod fishing grounds in the southern Gulf, i.e., the Shediac trough and Cape Breton trough (Figure 20). Thus in contrast to stratified random surveys, fixed stations data for the southern Gulf may only provide information on some of the habitats within the study area. Total fishing effort was 4,063 activities with great fishing efforts per cell (up to 100).

Relative occurrence of the three species – fixed stations

During those surveys, wolffish occurred in the catch in 47 sets (48 occurrences), only 2 occurrences for northern, 21 occurrences for spotted and 25 occurrences for Atlantic wolffish. Catch never exceeded 50 kg in any set. The relative occurrence of northern wolffish was <0.1% and was similar for spotted (0.51%) as for Atlantic wolffish (0.62%) in the sampled area. Those low figures are consistent with observations from stratified random surveys in the same area. Seines yielded a similar number of occurrences of wolffish as trawlers (4,029 fishing activities yielded 40 occurrences of wolffish, 0 northern, 14 spotted and 26 Atlantic).

Spatial and temporal distribution of relative occurrences – fixed stations

While the fishing effort of trawlers at fixed stations was divided between two areas, the Shediac trough (2,422 activities) and Cape Breton trough (1,641 activities), wolffish catches occurred in the Shediac trough only, in the Miscou Bank area and at the tip of the Gaspé Peninsula (Figure 21, Figure 22, Figure 23). Relative occurrences are broken down by year and are shown for the the Shediac trough and Cape Breton trough in Table 7.

Seasonal distribution

Fishing effort in winter along the west coast of Newfoundland was limited to 209 sets and produced very few wolffish of any species, no northern, 2 spotted and 4 Atlantic wolffish, resulting in relative occurrences of 0, 0.010 and 0.019 for northern, spotted and Atlantic wolffish,

respectively. Relative occurrences were compared for winter surveys and summer surveys. Summer surveys (Annual groundfish bottom trawl research surveys and Sentinel Fisheries stratified random surveys using trawlers) summed up to 2,457 activities resulting in 146 occurrences of spotted and 577 occurrences of Atlantic wolffish in cells where sampling occurred in both winter and summer (137 cells). Differences in occurrence between winter and summer surveys were mapped (Figure 24 and Figure 25). The low occurrences in the winter surveys precludes any firm conclusions based on those data, but the figures suggest that catchability or distribution changed markedly between the two periods.

Observer Program excluding Sentinel Fisheries

Diversity of gears and target species

The records collected by observers show a great diversity in the gears used by commercial fleets. The fixed gear fishery uses 8 different types of gears and the mobile gear fishery 13 different types of gears. Some gears account however for a large proportion of the total fishing effort monitored by observers.

Longlines (6,295 activities) and gillnets (11,210 activities) represented 97% of the fishing effort monitored in the fixed gear fishery (17,505/18,115 activities). Wolffish were not target species in the monitored activities. Longlines mainly targeted cod (52%, 3,317/6,293) and Atlantic halibut (41%, 2,609/6,293) whereas gillnets mainly targeted Greenland halibut (59%, 6,602/11,202) and cod (30%, 3,411/11,202).

Trawls and seines represented 94% of the fishing effort monitored in the mobile gear fishery (37,456/39,785 activities). Again, wolffish were not target species in the monitored activities. Trawls with a grid are used for fishing shrimp (14,841/14,857) and the grid is designed so as to minimize the bycatch of fish. Trawls without a grid target cod (56%, 8,597/15,367), redfish (11%, 1,700/15,367), winter flounder (8%, 1,161/15,367) and other flatfish. Seines are used for fishing plaice (35%, 2,496/7,225), cod (30%, 2,167/7,225) and witch flounder (25%, 1,809/7,225).

Spatial distribution of effort

The fishing effort of commercial fleets is not distributed randomly in the study area. The spatial distribution of effort is strongly aggregated, reflecting the known patterns of distribution of target species, with fixed gears and mobile gears often used in different areas. Thus data for fixed gears (Figure 26) and mobile gears (Figure 27) in the Observer Program exhibit a strong aggregated pattern of spatial distribution. Observers monitored gillnet fisheries in the Estuary and western section of the Gulf, whereas longline fisheries were monitored in several specific areas of the Gulf east of areas where gillnets were used. Shrimp trawlers were monitored in the Anticosti and Esquiman channels, and south and west of Anticosti Island. Other trawlers were monitored in the same areas as well as along the Laurentian channel to Cabot Strait and in the southern Gulf, mainly at the tip of Gaspe down to Miscou and in the Cape Breton area. Seines were monitored mainly around the Îles-de-la-Madeleine and in the Cape Breton area.

Temporal patterns in wolffish abundance in specific areas

The strong spatial aggregation of fishing effort of both fixed gear and mobile gear fisheries precludes any analysis of the temporal patterns in wolffish abundance over the whole study area. Thus we have selected 7 different areas where a significant monitoring effort occurred either in the fixed or mobile gears fisheries in order to describe temporal patterns in abundance

in specific areas within the Estuary and Gulf of St. Lawrence (Figure 28). Monitoring effort by observers for the main gears used in the fixed and mobile gears fisheries in the Estuary and Gulf of St. Lawrence is broken down by year in Table 8.

West coast of Cape Breton

Only seines were monitored consistently in the Cape Breton area through the period from 1992 to 2008 (Table 9). Catches of wolffish have been marginal in seines, particularly for northern and spotted wolffish, with some indication of higher relative occurrences in the 1990s.

Southwest Anticosti

Starting in 1993, only trawls equipped with a grid (shrimp trawlers) were monitored regularly by the Observer Program in southwest Anticosti (Table 10). The Nordmore grid used by shrimp trawlers is designed so as to reduce the bycatch of commercial-sized fish. Wolffish catches in shrimp trawlers may thus be indicative of the distribution of small-sized wolffish, i.e. habitats potentially favorable to juveniles. Northern wolffish were reported from southwest Anticosti only in one year whereas both spotted and Atlantic were observed regularly, though at low relative occurrences, with no trends in relative occurrence over time. Both Atlantic and to a lesser extent spotted wolffish were reported from that area in stratified bottom trawl surveys (Figure 7, Figure 8, Figure 18 and Figure 19.

Northeast Anticosti

Both shrimp trawlers and more recently and to a lesser extent longlines were monitored in the northeast Anticosti area. Few occurrences of wolffish were reported from shrimp trawlers (Table 11): relative occurrences were low and there was no trend in relative occurrence over time. In contrast, relative occurrences in the catch of longliners were very high for two species, spotted and Atlantic wolffish (Table 12). This may be explained by two factors, catchability and relative distribution of the fishing effort. Catchability tends to be greater in longlines than in trawls (Ouellet et al. 2011) and the bycatch of large fish is low in trawls equipped with a Nordmor grid. Longlines were set on the flanks of the channel (average depth 206 m, range 74-284), whereas shrimp trawls were used in deeper areas of the channel (average depth 258 m, range 11-259). Differences in terrain and oceanographic conditions (dissolved oxygen and bottom temperature) may have contributed to these differences. There was no trend in relative occurrence of wolffish in the catch of longliners over time, but the level of fishing effort of longliners monitored by observers was low in the 1990s.

Baie des Chaleurs

Baie des Chaleurs is one area where more types of gears were monitored by observers more consistently over time. More fishing effort was monitored in the mobile gear fisheries up to year 2000 and in the fixed gear fisheries from year 2000 (Table 13). In the fixed gear fisheries, very few occurrences were reported for northern and spotted wolffish; few were also reported for Atlantic wolffish with great variability in relative occurrences from year to year and no marked trend over time (Table 14). Similar observations can be made on records for the mobile gear fisheries. The 70 occurrences of northern wolffish reported by the Observer Program in 1993 (seiners) is at odds with observations for other gears (Table 15).

North Gaspé

In the North Gaspé sector, observers have monitored the gillnet fishery regularly over the period from 1994 to 2008 (Table 16). Trawlers activities have also been monitored but the focus changed from trawlers without a grid before year 2000 to trawlers with a grid after year 2000. There were very few occurrences of northern wolffish in the area in any fishery. There were also very few occurrences of spotted and Atlantic wolffish reported in the catch of gillneters and shrimp trawlers (Table 17 and Table 18), but both species occurred in the catch of trawlers without a grid. Relative occurrences were low in the 1990s but declined to 0 in recent years.

Though monitoring effort for longliners was minimal (Table 16), relative occurrences of both spotted and Atlantic wolffish were high with no apparent decline in recent years (Table 17). Larocque et al. (2008) described the use of rocky habitats in the coastal zone by Atlantic wolffish in Les Méchins in the North Gaspé area. Atlantic wolffish used shelters under large boulders in steep areas from which trawlers are excluded.

Magdalen Shallows

Two types of gears were mainly monitored in the Magdalen Shallows area, seiners and longliners. Monitoring effort was continuous for seiners over the period from 1992 to 2008, but was more important after year 2000 than before year 2000 for longliners (Table 19). There were no observations of northern or spotted wolffish in the area under the Observer Program. Few occurrences of Atlantic wolffish were reported by longliners resulting in low relative occurrences of that species in the area.

Lower Estuary of the St. Lawrence

Monitoring effort by the Observer Program has been low in the lower Estuary of the St. Lawrence (Table 20). There are few occurrences of wolffish catches in the records. These occurrences were mainly associated with shrimp trawlers (18 in 2007) and other trawlers in the early 1990s, indicating the three species were present in the area in the early 1990s, though relative occurrences were low.

Temporal trends

Relative occurrences for the various series compiled do not suggest any significant trend over time. For northern wolffish relative occurrences are consistently low with the highest values observed before 1990 (Figure 29). Those of spotted wolffish are more variable, with higher values observed also after 1990 (Figure 30). Relative occurrences of striped wolffish are higher than those of the other two species (notice the scale on the y axis differs) with no evidence of a decline or increase over time (Figure 31).

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Table 1. Fish species contributing most to clustering stations of groups B, C, G, H and I, in which wolffish were caught in a greater proportion of the stations.

Species	Assemblage					Stations with		
	B	C	G	H	I	Atlantic wolffish	Spotted wolffish	Both species
Moustache sculpin				●		●		●
Greenland halibut		●					●	
Marlin-spike		●					●	
Atlantic hookear sculpin			●			●	●	●
Daubed shanny					●	●		●
Snakeblenny					●	●		●
Atlantic wolffish			●			●		●
Spotted wolffish	●						●	●
Atlantic cod			●			●	●	●
Fourbeard rockling		●					●	
Atlantic hagfish		●					●	
American plaice			●			●	●	●
Witch flounder			●			●	●	●
Alligatorfish					●	●		●
Smooth skate		●					●	
Thorny skate		●				●	●	●
Rockfishes	●					●	●	●

Table 2. The contribution and cumulative contribution of twelve species to similarity in species composition among stations with Atlantic or with spotted wolffish. Contribution is expressed as a percentage and is based on the Simper procedure. Atlantic wolffish contributed 6.4% to similarity among stations where that species was caught, whereas spotted wolffish contributed 4.5% to similarity among stations with spotted wolffish.

Atlantic wolffish			Spotted wolffish		
Species	%	Cumulative %	Species	%	Cumulative %
Atlantic cod	21.7	21.7	American plaice	19.3	19.3
American plaice	21.1	42.8	Atlantic cod	17.4	36.7
Rockfishes	14.2	57.0	Rockfishes	16.3	53.0
Moustache sculpin	9.8	66.8	Moustache sculpin	8.5	61.5
Atlantic wolffish	6.4	73.2	Atlantic wolffish	4.8	66.3
Thorny skate	3.4	76.6	Spotted wolffish	4.5	70.8
Daubed shanny	2.8	79.4	Witch flounder	3.6	74.4
Witch flounder	2.7	82.1	Atlantic hookear sculpin	3.5	77.9
Atlantic hookear sculpin	2.6	84.7	Thorny skate	3.3	81.2
Fourline snakeblenny	1.8	86.5	Daubed shanny	2.3	83.5
Alligatorfish	1.7	88.2	Fourline snakeblenny	1.7	85.2
Snakeblenny	1.6	89.8	Snakeblenny	1.6	86.8
Atlantic herring	1.2	91.0	Greenland halibut	1.6	88.4

Table 3. Relative occurrence for the three wolffish species by year for two areas, the northern Gulf, excluding the Estuary (NG) and the southern Gulf (SG), based on the annual DFO groundfish research surveys conducted by the Québec (1978-2008) and Gulf (1971-2008) regions. Relative occurrence was calculated as the ratio of occurrence (number of sets in which a species was recorded) and fishing effort (total number of sets made). No wolffish have been reported from the St. Lawrence Estuary. Figures for the northern Gulf in the period 1971 – 1977 are not shown as they are based on few sets located in a specific area north of the 200 m isobath along the south side of the Laurentian Channel.

	Northern wolffish			Spotted wolffish			Atlantic wolffish		
Year	**NG**	**SG**	**Both areas**	**NG**	**SG**	**Both areas**	**NG**	**SG**	**Both areas**
1971		0			0			0.016	
1972		0			0			0.046	
1973		0			0			0.046	
1974		0.017			0			0.017	
1975		0.016			0			0.049	
1976		0			0			0	
1977		0			0			0.034	
1978	0.053	0	0.035	0.062	0	0.041	0.186	0.000	0.123
1979	0.075	0	0.041	0.038	0	0.020	0.200	0.030	0.122
1980	0.024	0	0.016	0.071	0	0.047	0.150	0.047	0.115
1981	0.036	0	0.025	0.051	0	0.035	0.080	0.031	0.065
1982	0	0	0	0	0	0.000	0.167	0.034	0.046
1983	0.085	0.016	0.068	0.116	0	0.088	0.164	0.032	0.131
1984	0.039	0	0.028	0.060	0	0.044	0.141	0.038	0.113
1985	0.017	0	0.011	0.054	0	0.034	0.203	0.038	0.142
1986	0.023	0.005	0.017	0.058	0	0.037	0.193	0.026	0.132
1987	0.012	0	0.007	0.040	0.004	0.024	0.178	0.066	0.127
1988	0.019	0.014	0.017	0.019	0	0.013	0.155	0.093	0.135
1989	0.010	0	0.006	0.027	0	0.017	0.144	0.040	0.105
1990	0.007	0	0.004	0.023	0	0.014	0.114	0.067	0.095
1991	0.011	0	0.006	0.003	0	0.002	0.079	0.048	0.066
1992	0.006	0.004	0.005	0.003	0	0.002	0.093	0.032	0.064
1993	0	0.006	0.002	0	0	0	0.080	0.017	0.057
1994	0.004	0	0.002	0.007	0	0.005	0.096	0.046	0.077
1995	0.014	0	0.007	0.009	0	0.005	0.101	0.034	0.068

Table 3 (continued):

	Northern wolffish			Spotted wolffish			Atlantic wolffish		
Year	**NG**	**SG**	**Both areas**	**NG**	**SG**	**Both areas**	**NG**	**SG**	**Both areas**
1996	0.008	0	0.004	0.013	0	0.007	0.138	0.064	0.100
1997	0	0	0	0.027	0	0.014	0.142	0.067	0.102
1998	0	0	0	0.024	0	0.012	0.104	0.047	0.074
1999	0.004	0	0.002	0.040	0	0.021	0.146	0.028	0.089
2000	0.005	0	0.002	0.032	0	0.017	0.198	0.033	0.118
2001	0	0	0	0	0	0	0.110	0.022	0.073
2002	0.005	0	0.003	0.011	0	0.005	0.063	0.047	0.054
2003	0	0	0	0.030	0.012	0.023	0.134	0.025	0.094
2004	0	0	0	0.069	0	0.027	0.222	0.033	0.107
2005	0	0	0	0.053	0.004	0.033	0.189	0.031	0.124
2006	0	0	0	0.045	0	0.024	0.223	0.049	0.141
2007	0	0.006	0.003	0.026	0	0.014	0.236	0.038	0.140
2008	0	0	0	0.075	0.006	0.042	0.225	0.023	0.127

Table 4. Relative occurrence for the three wolffish species by year for two areas, the northern Gulf (NG) and the southern Gulf (SG) based on the DFO Sentinel Fisheries Program (fixed gears, longlines only) for the northern (2002-2008) and southern Gulf (1996-2008). Relative occurrence was calculated as the ratio of occurrence (number of activities in which a species was recorded) and fishing effort (total number of activities reported). Figures for the northern Gulf in the period before 2002 are not shown because they are not available by species.

	Northern wolffish			Spotted wolffish			Atlantic wolffish		
Year	NG	SG	Both areas	NG	SG	Both areas	NG	SG	Both areas
1996		0			0.007			0.026	
1997		0			0.011			0.054	
1998		0.008			0.003			0.059	
1999		0			0.002			0.041	
2000		0			0			0.036	
2001		0			0.002			0.015	
2002	0	0.004	0.002	0	0.002	0.001	0.379	0.063	0.193
2003	0	0	0	0.019	0.002	0.007	0.413	0.077	0.186
2004	0	0.002	0.001	0.123	0.007	0.042	0.521	0.068	0.205
2005	0	0	0	0.142	0.011	0.036	0.460	0.055	0.134
2006	0.007	0.002	0.003	0.109	0.021	0.041	0.314	0.086	0.138
2007	0.039	0.004	0.012	0.142	0.004	0.035	0.276	0.124	0.158
2008	0.023	0	0.007	0.128	0.007	0.041	0.273	0.030	0.099

Table 5. Combined relative occurrence of three species of wolffish and fishing effort (number of activities reported) of gillnets and longlines based on data in the Sentinel Fisheries Program during the period from 1996 to 2008. Data are sorted by decreasing longline fishing effort and are shown for each 100 km^2 cell in which fishing effort totaled 20 activities or more each for both gears.

Fishing effort		Northern wolffish		Spotted wolffish		Atlantic wolffish	
Longlines	Gillnets	Longlines	Gillnets	Longlines	Gillnets	Longlines	Gillnets
296	31	0	0	0	0	0.003	0
153	109	0.020	0.009	0.007	0	0.026	0.018
110	64	0	0	0.064	0	0.327	0.109
106	23	0.019	0	0	0	0.123	0.044
77	109	0.026	0	0	0	0.039	0
67	28	0	0	0	0	0	0
66	28	0	0	0	0	0	0
57	99	0	0	0.018	0	0.421	0.051
57	63	0	0	0	0	0.123	0
54	143	0	0	0	0	0	0
53	125	0	0	0.321	0.040	0.755	0.048
48	85	0	0	0.021	0	0.854	0.153
40	90	0	0	0	0	0	0.011
39	40	0	0	0	0	0.282	0
35	250	0.057	0.004	0	0	0.029	0.004
32	69	0	0	0	0	0.406	0.087
30	151	0	0.007	0	0	0.733	0.119
23	112	0	0	0.609	0.027	0.609	0.036
23	26	0	0	0	0	0	0

Table 6. Relative occurrence of three wolffish species by year for two areas, the northern Gulf (NG) and the southern Gulf (SG) based on the DFO Sentinel Fisheries Program (mobile gears, stratified random surveys using trawlers) for the northern (1994-2008) and southern Gulf (2003-2008). Relative occurrence was calculated as the ratio of occurrence (number of activities in which a species was recorded) and fishing effort (total number of activities reported). Figures for the northern and southern Gulf combined for the period before 2003 are not shown because stratified random survey effort was very limited and was unevenly distributed before 2003 in the southern Gulf of St. Lawrence.

	Northern wolffish			Spotted wolffish			Atlantic wolffish		
Year	NG	SG	Both areas	NG	SG	Both areas	NG	SG	Both areas
1995	0.003	0		0.020	0		0.122	0.333	
1996	0.009	0		0.032	0.083		0.111	0.333	
1997	0	0		0.036	0		0.121	0.167	
1998	0.002	0		0.030	0		0.114	0	
1999	0.003	0		0.037	0		0.087	0.400	
2000	0	0		0.033	0		0.111	0.231	
2001	0.002	0		0.036	0		0.095	0	
2002	0.002	0		0.022	0		0.087	0.167	
2003	0.006	0.009	0.007	0.019	0.004	0.013	0.084	0.017	0.056
2004	0.003	0.004	0.004	0.035	0.008	0.024	0.093	0.004	0.055
2005	0.003	0	0.002	0.033	0.004	0.020	0.114	0.013	0.070
2006	0	0.004	0.002	0.025	0.004	0.016	0.082	0.042	0.065
2007	0.010	0	0.006	0.010	0	0.006	0.082	0.014	0.054
2008	0.010	0	0.006	0.027	0	0.016	0.075	0.023	0.053

Table 7. Relative occurrence of three wolffish species by year for two areas in the southern Gulf, Shediac trough and Cape Breton trough, based on the DFO Sentinel Fisheries Program (mobile gears, fixed stations surveys using trawlers 1995-2002). Relative occurrence was calculated as the ratio of occurrence (number of activities in which a species was recorded) and fishing effort (total number of activities reported). Relative occurrence for wolffish observations in the Shediac trough area are calculated based on effort in the Shediac trough area and based on effort in both Shediac trough and Cape Breton trough.

Year	Northern wolffish			Spotted wolffish			Atlantic wolffish		
	Shediac	Cape Breton	Both areas	Shediac	Cape Breton	Both areas	Shediac	Cape Breton	Both areas
1995	0	0	0	0	0	0	0	0	0
1996	0	0	0	0.016	0	0.010	0.004	0	0.007
1997	0	0	0	0	0	0	0.009	0	0.014
1998	0	0	0	0.025	0	0.016	0.011	0	0.018
1999	0.003	0	0.002	0.007	0	0.004	0.006	0	0.010
2000	0	0	0	0	0	0	0.005	0	0.009
2001	0	0	0	0.003	0	0.002	0.004	0	0.007
2002	0.003	0	0.002	0	0	0	0.002	0	0.003

Table 8. Number of activities monitored by observers in the fixed and mobile gear fisheries in the St. Lawrence Estuary and Gulf, 1992-2008. Codes for gears are shown in parentheses.

Year	Fixed gears		Mobile gears		
	Longlines (LLS)	Gillnets (GNS)	Trawls with grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN & SSC)
1992	0	357	0	6510	652
1993	59	251	755	2749	997
1994	154	875	231	1027	370
1995	99	708	409	359	582
1996	38	645	214	390	493
1997	121	487	1008	359	461
1998	233	541	1166	591	327
1999	240	682	1215	484	378
2000	305	800	1281	687	314
2001	343	660	1070	521	419
2002	209	774	1150	298	372
2003	277	644	1075	225	258
2004	1204	931	1233	314	296
2005	1125	830	942	301	648
2006	349	760	1052	257	321
2007	667	665	1057	186	199
2008	872	600	1001	111	141

Table 9. Number of activities monitored by observers in the fixed and mobile gear fisheries in the Cape Breton area, 1992-2008, and occurrence and relative occurrence of three species of wolffish in the catch of seiners.

Year	Number of activities monitored					Occurrence and relative occurrence of wolffish - seiners					
	Fixed gears		Mobile gears			Northern		Spotted		Atlantic	
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)	Occurrence	Rel. occ.	Occurrence	Rel. occ.	Occurrence	Rel. occ.
1992	0	0	0	991	418	0	0	0	0	16	0.038
1993	0	0	0	55	241	0	0	0	0	3	0.012
1994	4	5	0	0	177	0	0	1	0.006	12	0.068
1995	0	0	0	0	316	1	0.003	3	0.009	6	0.019
1996	0	0	0	43	263	0	0	0	0	9	0.034
1997	3	0	0	25	223	0	0	1	0.004	1	0.004
1998	25	17	0	9	144	1	0.007	4	0.028	3	0.021
1999	54	2	0	21	175	0	0	0	0	3	0.017
2000	36	20	0	28	180	1	0.006	3	0.017	2	0.011
2001	43	4	0	18	179	0	0	0	0	1	0.006
2002	10	0	0	77	137	0	0	0	0	0	0
2003	10	0	0	28	126	0	0	1	0.008	0	0
2004	35	0	0	15	142	0	0	0	0	0	0
2005	33	0	0	24	155	0	0	1	0.006	0	0
2006	37	0	0	17	150	0	0	1	0.007	1	0.007
2007	26	0	0	10	75	0	0	0	0	0	0
2008	21	0	0	3	50	0	0	0	0	0	0

Table 10. Number of activities monitored by observers in the fixed and mobile gear fisheries in the southwest Anticosti area, 1992-2008, and occurrence and relative occurrence of three species of wolffish in the catch of shrimp trawlers.

Year	Number of activities monitored					Occurrence and relative occurrence of wolffish - shrimp trawlers					
	Fixed gears		Mobile gears			Northern		Spotted		Atlantic	
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)	Occurrence	Rel. occ.	Occurrence	Rel. occ.	Occurrence	Rel. occ.
1992	0	0	0	348	0	0	N/A	0	N/A	0	N/A
1993	0	19	239	68	0	0	0	0	0	0	0
1994	7	8	65	181	0	0	0	0	0	0	0
1995	31	0	186	0	0	0	0	0	0	0	0
1996	0	2	136	0	0	0	0	3	0.022	0	0
1997	0	0	546	161	0	0	0	2	0.004	1	0.002
1998	1	5	423	27	0	0	0	1	0.002	11	0.026
1999	4	16	585	42	0	0	0	2	0.003	1	0.002
2000	16	21	573	54	0	0	0	1	0.002	12	0.021
2001	4	13	363	5	0	0	0	3	0.008	0	0
2002	0	0	396	0	0	0	0	2	0.005	0	0
2003	9	30	500	0	0	0	0	2	0.004	8	0.016
2004	24	22	629	0	0	0	0	0	0	11	0.017
2005	38	11	418	2	0	0	0	1	0.002	1	0.002
2006	0	24	393	1	0	0	0	0	0	0	0
2007	20	53	196	0	0	4	0.020	3	0.015	13	0.066
2008	57	53	239	0	0	0	0	0	0	3	0.013

Table 11. Number of activities monitored by observers in the fixed and mobile gear fisheries in the northeast Anticosti area, 1992-2008, and occurrence and relative occurrence of three species of wolffish in the catch of shrimp trawlers.

Year	Number of activities monitored					Occurrence and relative occurrence of wolffish - shrimp trawlers					
	Fixed gears		Mobile gears			Northern		Spotted		Atlantic	
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)	Occurrence	Rel. occ.	Occurrence	Rel. occ.	Occurrence	Rel. occ.
1992	0	0	0	469	0	N/A	N/A	N/A	N/A	N/A	N/A
1993	0	0	87	3	0	0	0	0	0	0	0
1994	0	0	38	96	0	0	0	0	0	0	0
1995	0	0	25	0	0	0	0	0	0	0	0
1996	13	1	0	12	0	N/A	N/A	N/A	N/A	N/A	N/A
1997	1	0	173	2	0	0	0	0	0	0	0
1998	25	0	309	0	0	0	0	0	0	1	0.003
1999	8	0	238	0	0	0	0	0	0	0	0
2000	18	0	99	0	0	0	0	1	0.010	0	0
2001	4	5	155	0	0	0	0	0	0	2	0.013
2002	0	0	142	0	0	0	0	0	0	2	0.014
2003	27	0	85	0	0	0	0	1	0.012	0	0
2004	71	4	163	0	0	0	0	2	0.012	0	0
2005	29	0	87	0	0	0	0	0	0	0	0
2006	21	34	90	0	0	0	0	0	0	0	0
2007	51	0	289	0	0	0	0	1	0.003	0	0
2008	89	87	290	0	0	0	0	0	0	1	0.003

Table 12. Number of activities monitored by observers in the fixed and mobile gear fisheries in the northeast Anticosti area, 1992-2008, and occurrence and relative occurrence of three species of wolffish in the catch of longliners.

Year	Number of activities monitored					Occurrence and relative occurrence of wolffish - longliners					
	Fixed gears		Mobile gears			Northern		Spotted		Atlantic	
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)	Occurrence	Rel. occ.	Occurrence	Rel. occ.	Occurrence	Rel. occ.
1992	0	0	0	469	0	N/A	N/A	N/A	N/A	N/A	N/A
1993	0	0	87	3	0	N/A	N/A	N/A	N/A	N/A	N/A
1994	0	0	38	96	0	N/A	N/A	N/A	N/A	N/A	N/A
1995	0	0	25	0	0	N/A	N/A	N/A	N/A	N/A	N/A
1996	13	1	0	12	0	0	0	7	0.538	0	0
1997	1	0	173	2	0	0	0	0	0	0	0
1998	25	0	309	0	0	0	0	6	0.240	0	0
1999	8	0	238	0	0	0	0	5	0.625	4	0.500
2000	18	0	99	0	0	0	0	4	0.222	0	0
2001	4	5	155	0	0	0	0	2	0.5	3	0.750
2002	0	0	142	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2003	27	0	85	0	0	0	0	2	0.074	4	0.148
2004	71	4	163	0	0	0	0	35	0.493	30	0.423
2005	29	0	87	0	0	0	0	3	0.103	6	0.207
2006	21	34	90	0	0	1	0.048	0	0	0	0
2007	51	0	289	0	0	0	0	14	0.275	8	0.157
2008	89	87	290	0	0	2	0.022	44	0.494	57	0.640

Table 13. Number of activities monitored by observers in the fixed and mobile gear fisheries in the Baie des Chaleurs area, 1992-2008.

Year	Number of activities monitored				
	Fixed gears		Mobile gears		
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)
1992	0	180	0	1487	30
1993	17	36	0	813	271
1994	10	70	0	124	17
1995	26	83	0	109	0
1996	0	59	0	178	82
1997	16	61	0	70	65
1998	16	44	1	266	48
1999	13	121	1	203	53
2000	52	141	0	384	29
2001	30	362	0	318	36
2002	38	229	0	136	113
2003	130	0	0	13	0
2004	209	316	0	139	50
2005	108	316	0	76	38
2006	21	310	0	51	75
2007	50	200	0	36	39
2008	97	129	0	23	21

Table 14. Occurrence and relative occurrence of three species of wolffish in the catch of fixed gear fisheries (longlines and gillnets) monitored by observers in the Baie des Chaleurs area, 1992-2008.

	Longlines						Gillnets					
	Northern		Spotted		Atlantic		Northern		Spotted		Atlantic	
Year	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.
1992	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	18	0.100
1993	0	0	0	0	0	0	0	0	1	0.028	2	0.056
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
1997	0	0	0	0	4	0.250	0	0	0	0	1	0.016
1998	2	0.125	0	0	4	0.250	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	1	0.008	1	0.008
2000	1	0.019	1	0.019	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	1	0.003	1	0.003
2002	0	0	0	0	0	0	0	0	0	0	3	0.013
2003	0	0	0	0	2	0.015	N/A	N/A	N/A	N/A	N/A	N/A
2004	0	0	0	0	4	0.019	0	0	0	0	0	0
2005	0	0	0	0	2	0.019	0	0	0	0	3	0.009
2006	0	0	0	0	6	0.286	0	0	0	0	3	0.010
2007	0	0	0	0	35	0.700	0	0	0	0	4	0.020
2008	0	0	0	0	11	0.113	0	0	0	0	2	0.016

Table 15. Occurrence and relative occurrence of three species of wolffish in the catch of mobile gear fisheries (seiners and trawlers) monitored by observers in the Baie des Chaleurs area, 1992-2008.

	Seines						Trawls without a grid					
	Northern		Spotted		Atlantic		Northern		Spotted		Atlantic	
Year	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.
1992	0	N/A	0	N/A	0	N/A	7	0.005	16	0.011	80	0.054
1993	0	0	70	0.258	1	0.004	0	0	0	0	23	0.028
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
1996	0	N/A	0	N/A	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	4	0.057
1998	0	0	0	0	0	0	19	0.071	0	0	1	0.004
1999	0	0	0	0	0	0	0	0	0	0	1	0.005
2000	0	0	0	0.000	10	0.345	0	0	0	0	2	0.005
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	2	0.015	0	0	0	0
2003	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	1	0.007	0	0
2005	0	0	0	0	0	0	0	0	0	0	1	0.013
2006	0	0	0	0	0	0	0	0	1	0.020	1	0.020
2007	0	0	0	0	4	0.103	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0

Table 16. Number of activities monitored by observers in the fixed and mobile gear fisheries in the North Gaspé area, 1992-2008.

Year	Number of activities monitored				
	Fixed gears		Mobile gears		
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)
1992	0	0	0	183	0
1993	0	14	1	265	31
1994	1	152	15	51	42
1995	5	135	17	33	0
1996	2	100	10	44	4
1997	0	92	3	4	0
1998	29	159	97	127	0
1999		151	38	109	0
2000	14	168	262	49	0
2001	8	55	161	27	0
2002	4	155	74	8	0
2003	7	266	112	10	0
2004	13	204	103	0	0
2005	24	167	70	8	0
2006	2	130	191	0	0
2007	50	200	0	36	39
2008	97	129	0	23	21

Table 17. Occurrence and relative occurrence of three species of wolffish in the catch of fixed gear fisheries (longlines and gillnets) monitored by observers in the North Gaspé area, 1992-2008.

	Longlines						Gillnets					
	Northern		Spotted		Atlantic		Northern		Spotted		Atlantic	
Year	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1993	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	1	0.007	0	0
1995	0	0	2	0.400	3	0.600	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	1	0.011
1998	0	0	13	0.448	5	0.172	0	0	0	0	0	0
1999	N/A	N/A	N/A	N/A	N/A	N/A	1	0.007	1	0.007	0	0
2000	0	0	5	0.357	0	0	0	0	2	0.012	0	0
2001	0	0	0	0	3	0.375	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	1	0.143	0	0	0	0	0	0	2	0.008
2004	1	0.077	1	0.077	0	0	0	0	0	0	1	0.005
2005	0	0	7	0.292	3	0.125	0	0	0	0	0	0
2006	0	0	2	1.000	2	1.000	0	0	0	0	0	0
2007	0	0	3	0.500	3	0.500	0	0	0	0	0	0
2008	2	0.133	5	0.333	0	0	0	0	0	0	0	0

Table 18. Occurrence and relative occurrence of three species of wolffish in the catch of mobile gear fisheries (seiners and trawlers) monitored by observers in the North Gaspé area, 1992-2008.

	Trawls with a grid						Trawls without a grid					
	Northern		Spotted		Atlantic		Northern		Spotted		Atlantic	
Year	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.	Occurrence	Rel. Occ.
1992	N/A	N/A	N/A	N/A	N/A	N/A	1	0.005	6	0.033	5	0.027
1993	0	0	0	0	0	0	0	0	17	0.064	15	0.057
1994	0	0	0	0	0	0	0	0	2	0.039	1	0.020
1995	0	0	0	0	0	0	0	0	4	0.121	0	0
1996	0	0	0	0	0	0	0	0	2	0.045	2	0.045
1997	0	0	0	0	0	0	0	0	0	0	1	0.250
1998	0	0	0	0	1	0.010	0	0	1	0.008	1	0.008
1999	0	0	0	0	0	0	0	0	4	0.037	1	0.009
2000	0	0	1	0.004	21	0.080	0	0	0	0	2	0.041
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	2	0.010	5	0.026	N/A	N/A	N/A	N/A	N/A	N/A
2007	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A

Table 19. Number of activities monitored by observers in the fixed and mobile gear fisheries in the Magdalen Shallows area, 1992-2008, and occurrence and relative occurrence of three species of wolffish in the catch of longliners.

Year	Number of activities monitored					Occurrence and relative occurrence of wolffish - longliners					
	Fixed gears		Mobile gears			Northern		Spotted		Atlantic	
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)	Occurrence	Rel. occ.	Occurrence	Rel. occ.	Occurrence	Rel. occ.
1992	0	0	0	58	120	N/A	N/A	N/A	N/A	N/A	N/A
1993	19	0	0	0	39	0	0	0	0	1	0.053
1994	24	0	0	0	67	0	0	0	0	0	0
1995	11	0	0	17	30	0	0	0	0	0	0
1996	0	0	0	2	22	N/A	N/A	N/A	N/A	N/A	N/A
1997	0	0	0	0	24	N/A	N/A	N/A	N/A	N/A	N/A
1998	47	0	0	7	59	0	0	0	0	0	0
1999	27	0	0	12	48	0	0	0	0	0	0
2000	75	0	0	20	67	0	0	0	0	0	0
2001	108	5	0	0	115	0	0	0	0	0	0
2002	109	0	0	3	87	0	0	0	0	2	0.018
2003	45	0	0	8	76	0	0	0	0	0	0
2004	519	0	0	0	65	0	0	0	0	5	0.010
2005	548	0	0	9	38	0	0	0	0	17	0.031
2006	85	0	0	26	76	0	0	0	0	7	0.082
2007	180	0	0	76	52	0	0	0	0	11	0.061
2008	142	0	0	52	17	0	0	0	0	3	0.021

Table 20. Number of activities monitored by observers in the fixed and mobile gear fisheries in the lower Estuary of the St. Lawrence, 1992-2008, and occurrence and relative occurrence of three species of wolffish in the catch of trawlers.

Year	Number of activities monitored					Occurrence and relative occurrence of wolffish – trawlers without a grid					
	Fixed gears		Mobile gears								
	Longlines (LLS)	Gillnets (GNS)	Trawls with a grid (GRL1&2)	Trawls without a grid (OTB1&2)	Seines (SDN&SSC)	Northern		Spotted		Atlantic	
						Occurrence	Rel. occ.	Occurrence	Rel. occ.	Occurrence	Rel. occ.
1992	0	0	0	56	0	0	0	0	0	3	0.054
1993	0	37	43	97	0	1	0.010	3	0.031	3	0.031
1994	17	268	33	75	0	0	0	0	0	0	0
1995	10	197	46	22	0	0	0	1	0.045	0	0
1996	0	39	0	12	0	0	0	1	0.083	0	0
1997	0	98	71	0	0	N/A	N/A	N/A	N/A	N/A	N/A
1998	14	66	14	1	0	0	0	0	0	0	0
1999	0	46	29	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2000	3	132	38	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2001	0	71	47	5	0	0	0	0	0	0	0
2002	0	172	73	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2003	9	136	12	10	0	0	0	0	0	0	0
2004		145	45	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2005	7	81	60	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2006	4	86	44	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2007	0	19	110	0	0	N/A	N/A	N/A	N/A	N/A	N/A
2008	0	36	68	0	0	N/A	N/A	N/A	N/A	N/A	N/A

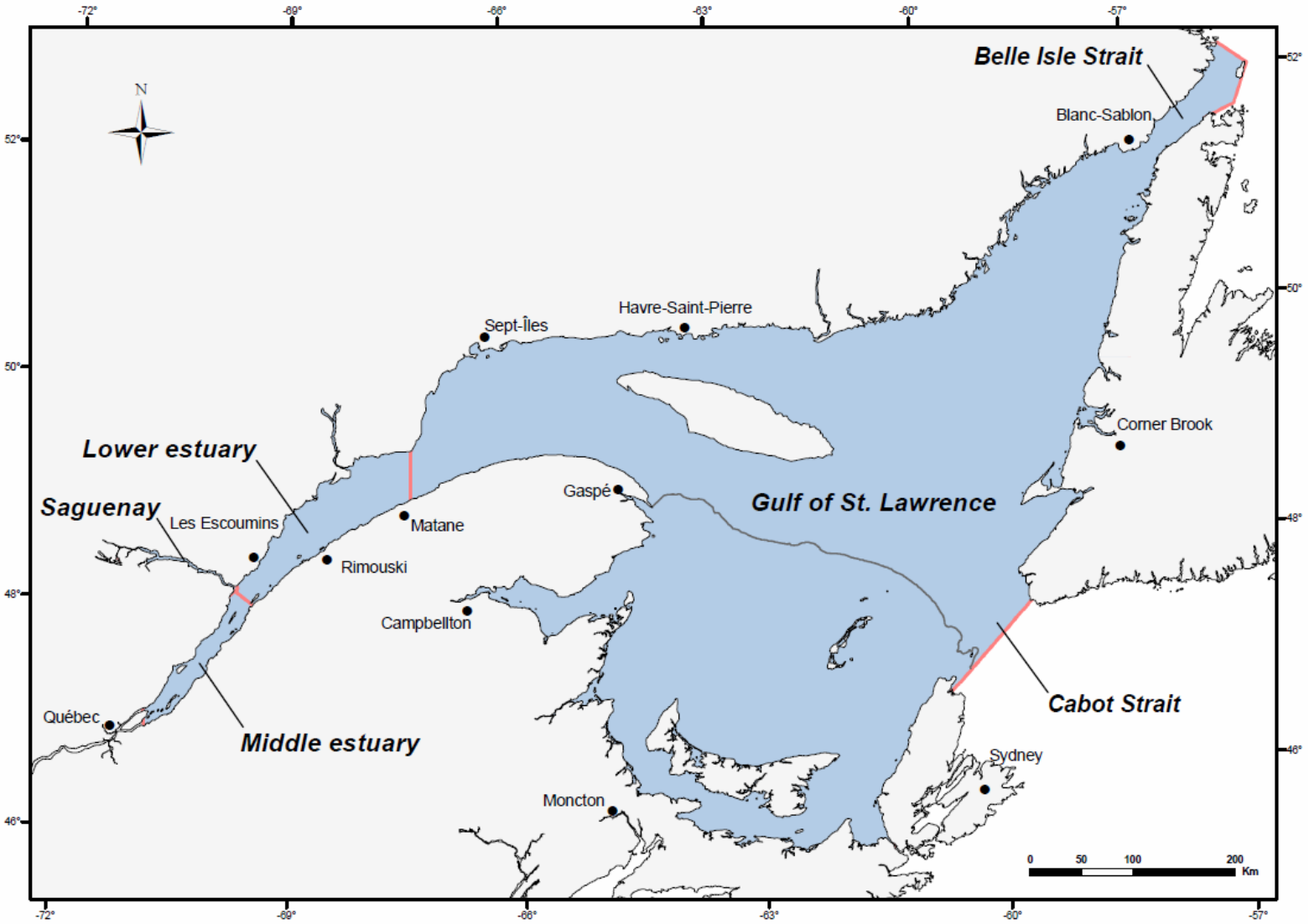

Figure 1. The study area included the St. Lawrence middle and lower Estuary as well as the northern and southern Gulf of St. Lawrence east to Cabot Strait and Belle Isle Strait. The 200 m isobath (gray line) indicates an arbitrary separation between the northern and southern Gulf of St. Lawrence.

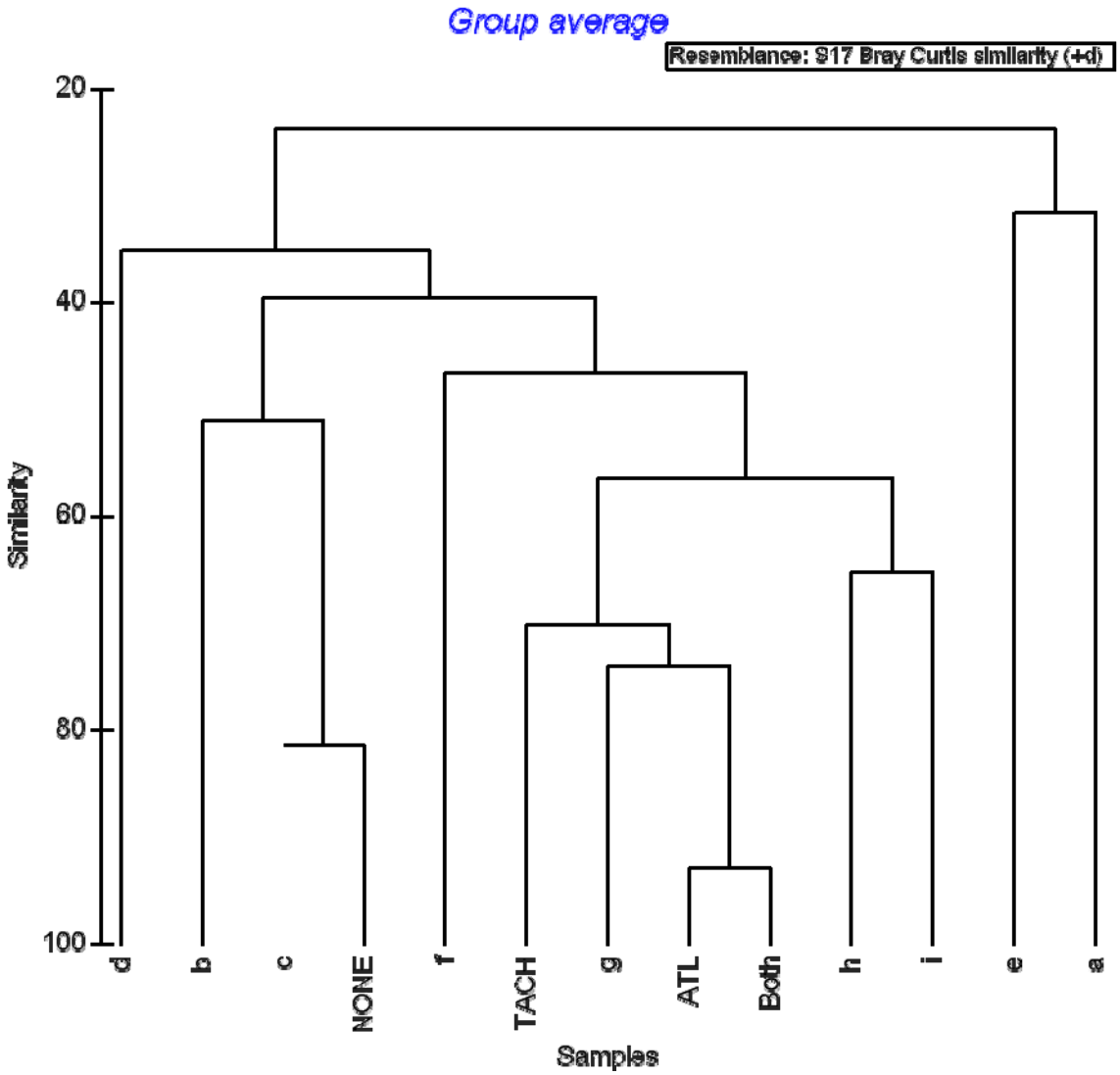

Figure 2. Hierarchical cluster showing linkages between groups of stations based on species composition and described by Chouinard and Dutil (manuscript submitted for publication), and groups of stations with either Atlantic wolffish or spotted wolffish, and groups of stations with both species or none of those two species.

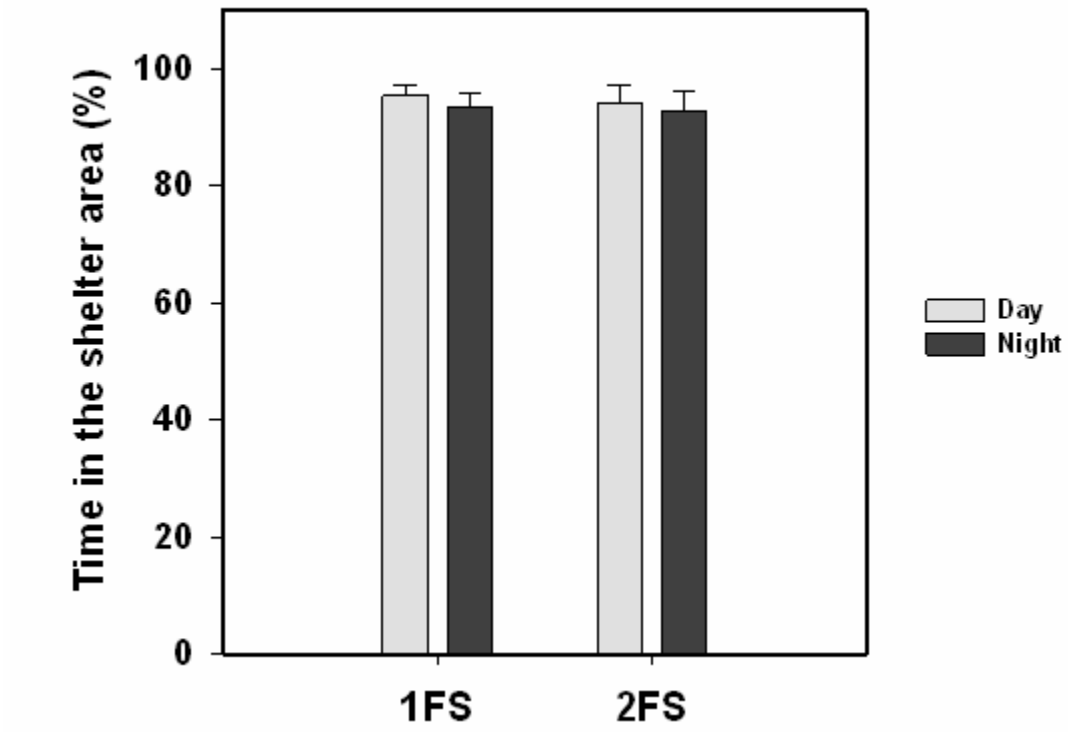

Figure 3. Territoriality and shelter use in spotted wolffish were assessed in laboratory experiments. Four experiments were conducted using one or two fish per tank, with and without a shelter. In pairs, spotted wolffish exhibited no aggressivity. When a shelter was present spotted wolffish spent most of their time in or near the shelter (from Lachance et al. 2010). 1FS-1 fish per tank, with a shelter; 2FS-2 fish per tank, with a shelter.

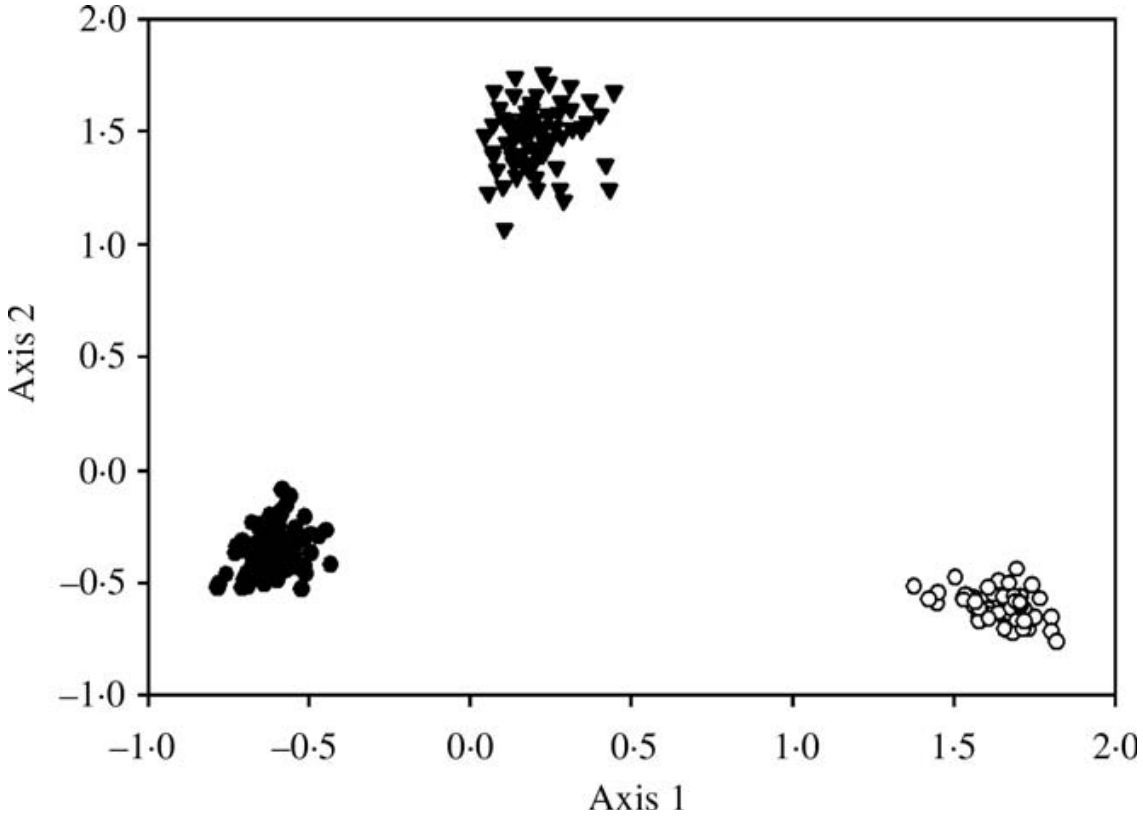

Figure 4. Two-dimensional factorial correspondence analysis of Atlantic (full circle), spotted (open circle) and northern (full triangle) wolffish based on 14 loci (from McCusker et al. 2008).

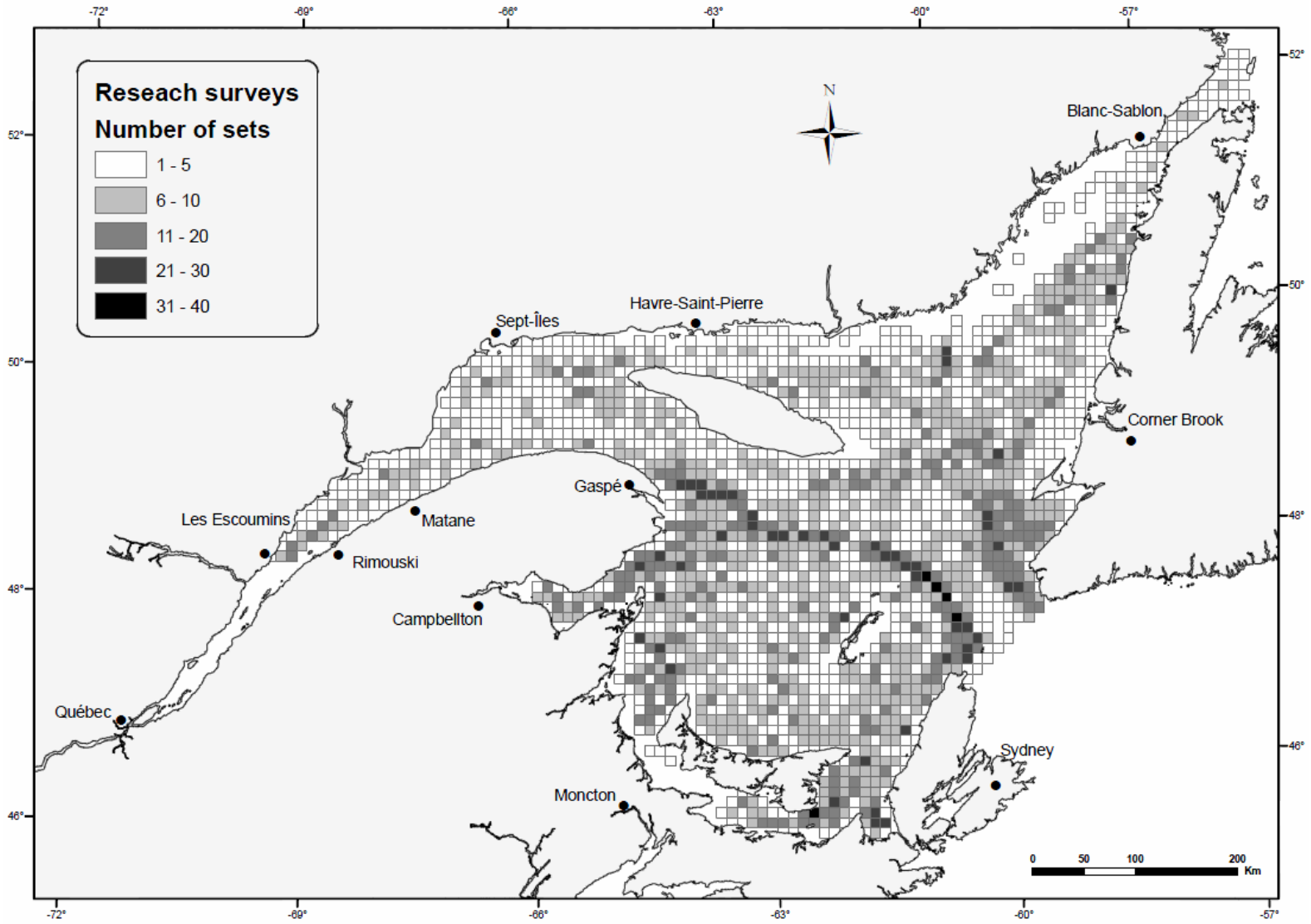

Figure 5. Spatial distribution of fishing effort (number of trawl sets) in the annual DFO groundfish research surveys conducted by the Québec (1978-2008) and Gulf (1971-2008) regions. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

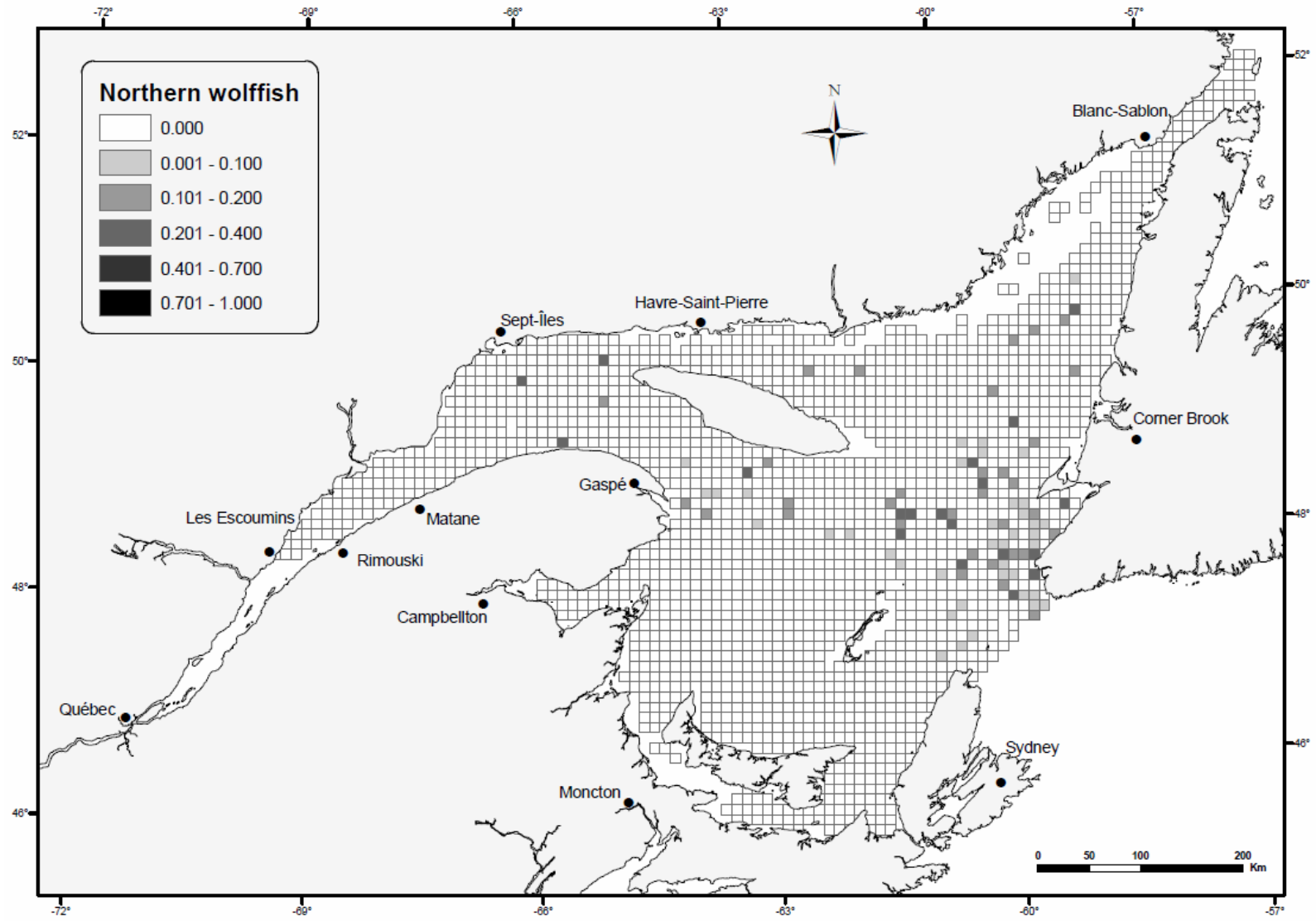

Figure 6. Spatial distribution of the relative occurrence of northern wolffish (number of sets in which species is present divided by fishing effort) in the annual DFO groundfish research surveys conducted by the Québec (1978-2008) and Gulf (1971-2008) regions. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

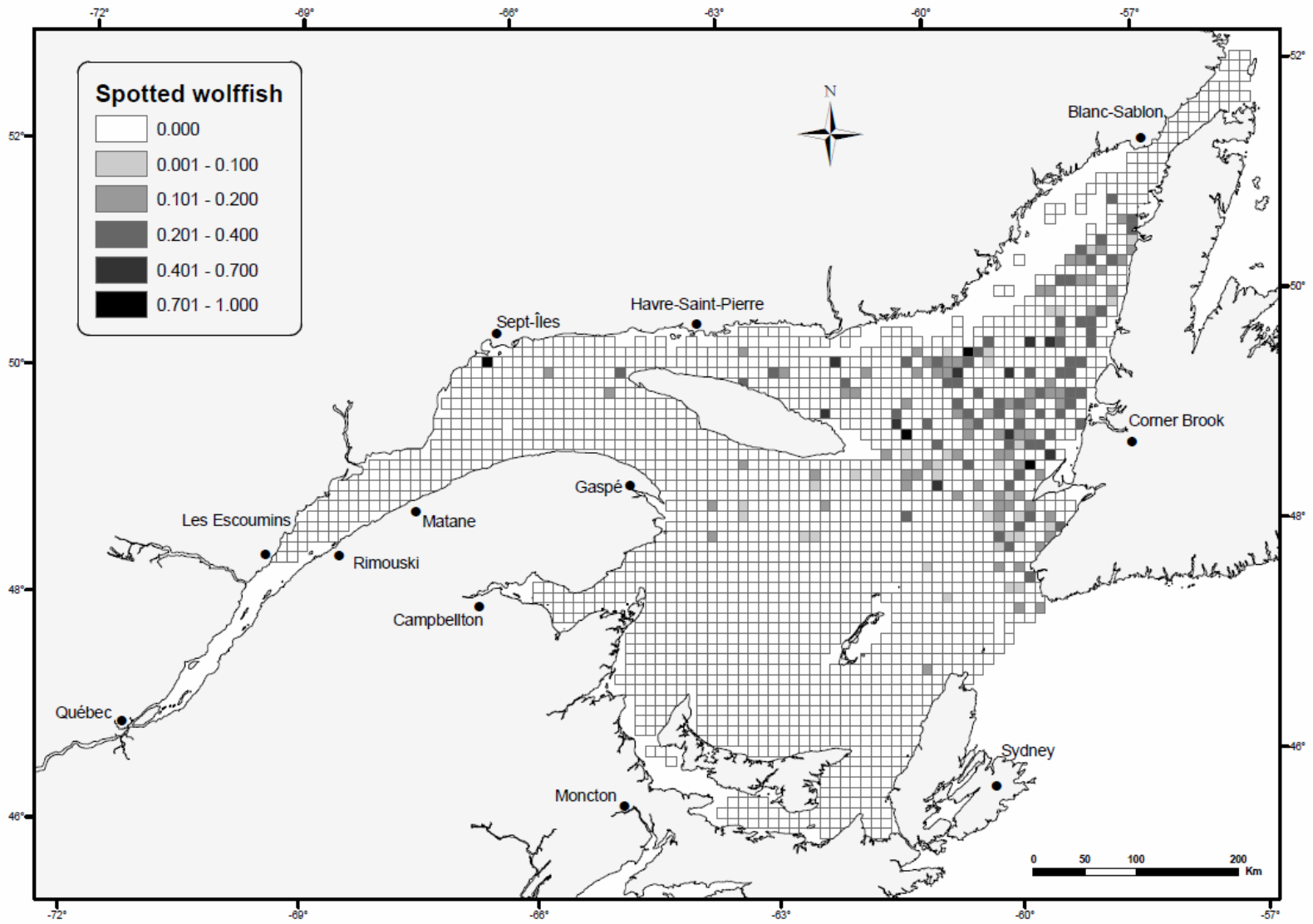

Figure 7. Spatial distribution of the relative occurrence of spotted wolffish (number of sets in which species is present divided by fishing effort) in the annual DFO groundfish research surveys conducted by the Québec (1978-2008) and Gulf (1971-2008) regions. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

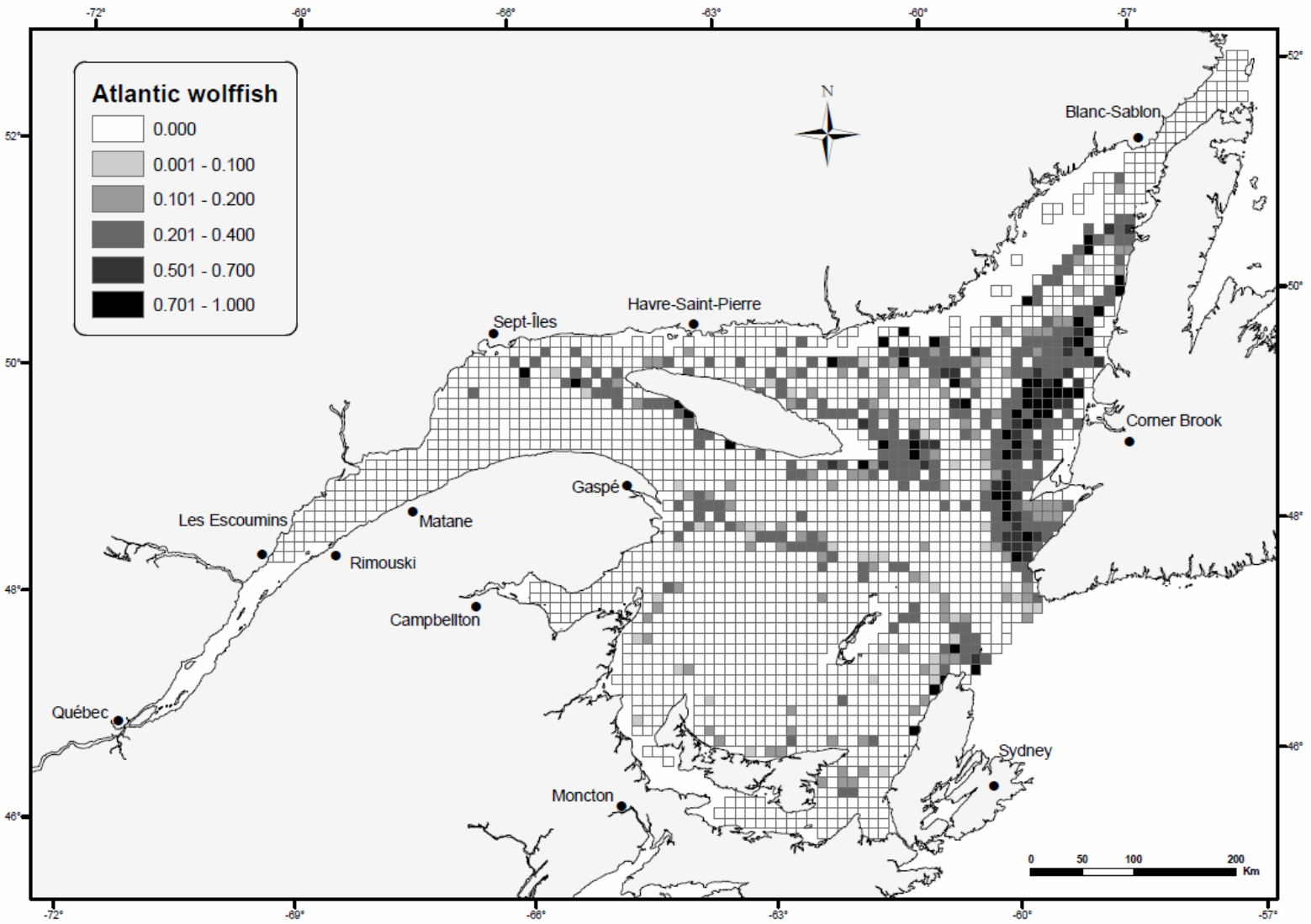

Figure 8. Spatial distribution of the relative occurrence of Atlantic wolffish (number of sets in which species is present divided by fishing effort) in the annual DFO groundfish research surveys conducted by the Québec (1978-2008) and Gulf (1971-2008) regions. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

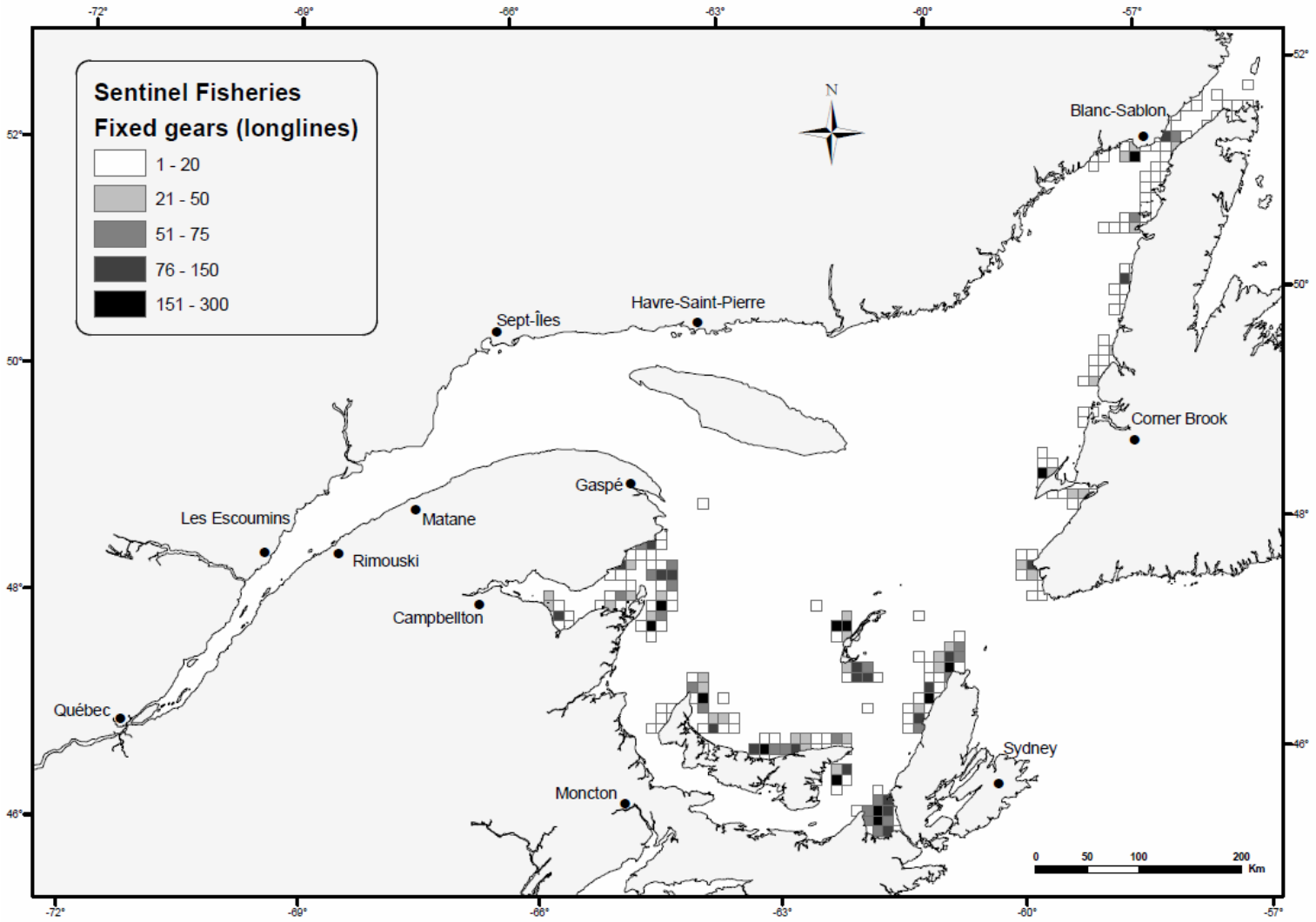

Figure 9. Spatial distribution of fishing effort (number of activities) in the Sentinel Fisheries Program (longlines) for the period from 1996 to 2008. The data are aggregated by 100 km^2 cells. No sets took place in areas where the grid is not shown.

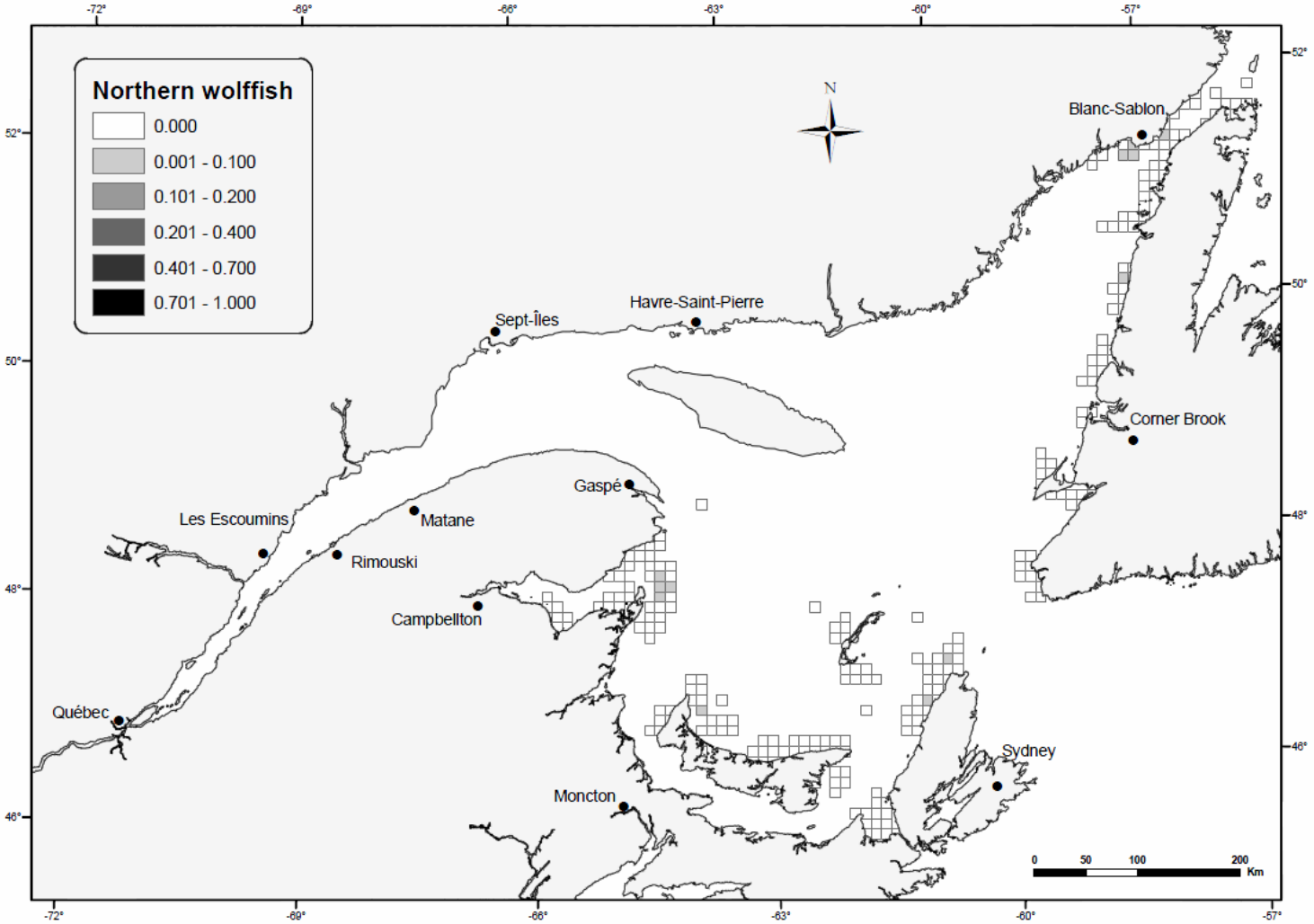

Figure 10. Spatial distribution of the relative occurrence of northern wolffish (number of activities in which species is present divided by total number of activities) in the DFO Sentinel Fisheries Program (fixed gears, longlines only) for the northern(2002-2008) and southern Gulf (1996-2008). The data are aggregated by 100 km^2 cells. No activities took place in areas where the grid is not shown. .

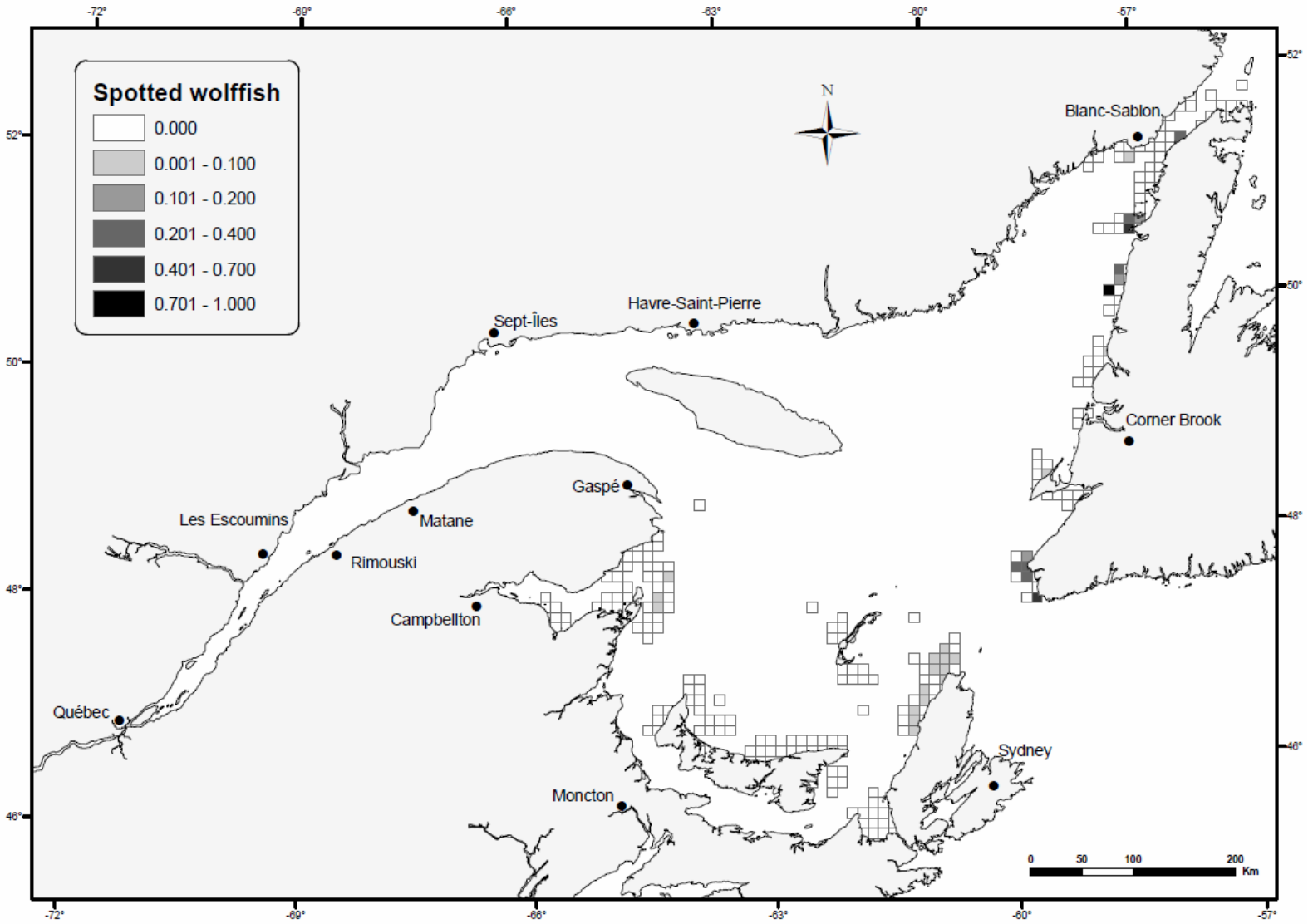

Figure 11. Spatial distribution of the relative occurrence of spotted wolffish (number of activities in which species is present divided by total number of activities) in the DFO Sentinel Fisheries Program (fixed gears, longlines only) for the northern(2002-2008) and southern Gulf (1996-2008). The data are aggregated by 100 km^2 cells. No activities took place in areas where the grid is not shown.

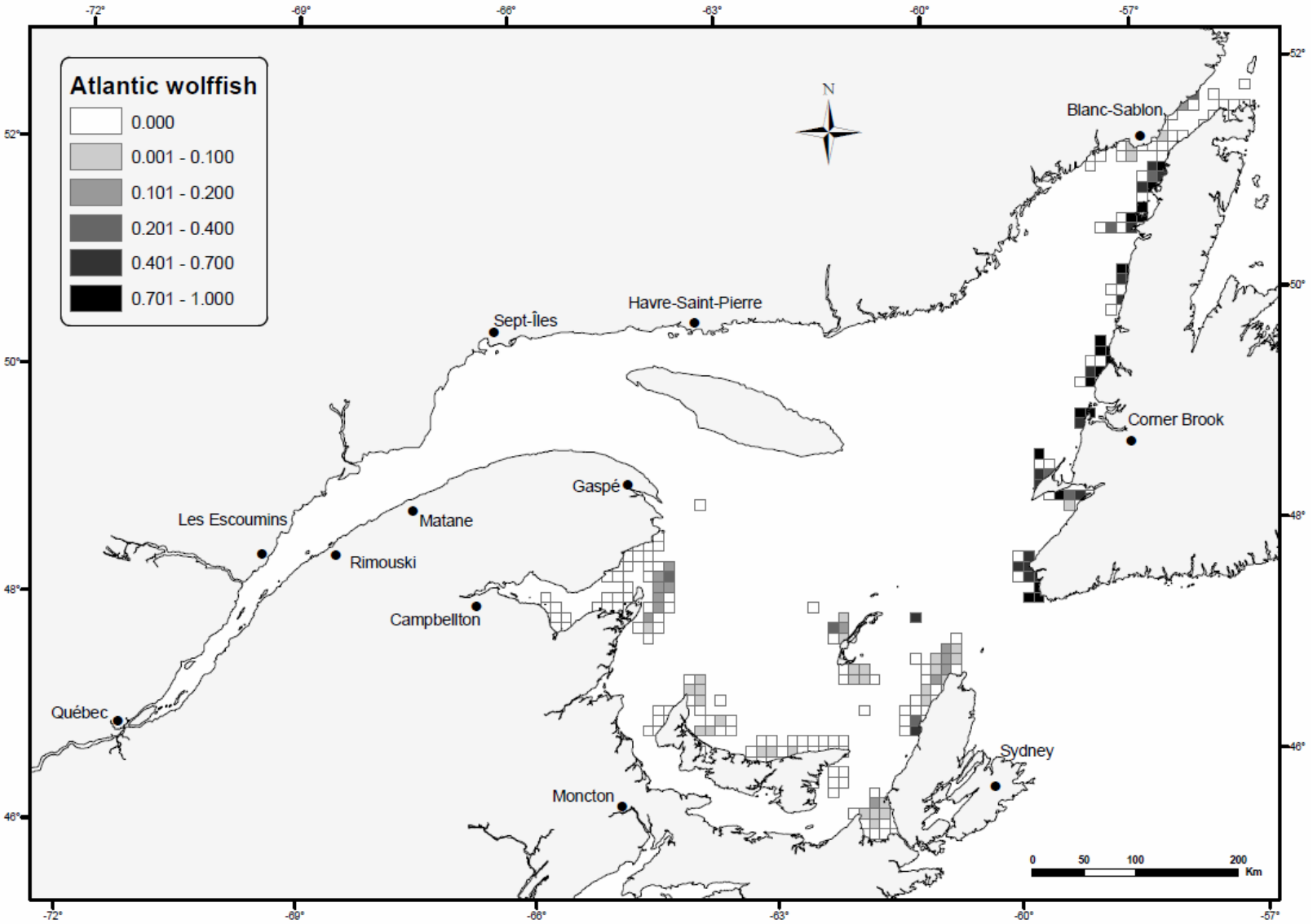

Figure 12. Spatial distribution of the relative occurrence of Atlantic wolffish (number of activities in which species is present divided by total number of activities) in the DFO Sentinel Fisheries Program (fixed gears, longlines only) for the northern(2002-2008) and southern Gulf (1996-2008). The data are aggregated by 100 km^2 cells. No activities took place in areas where the grid is not shown.

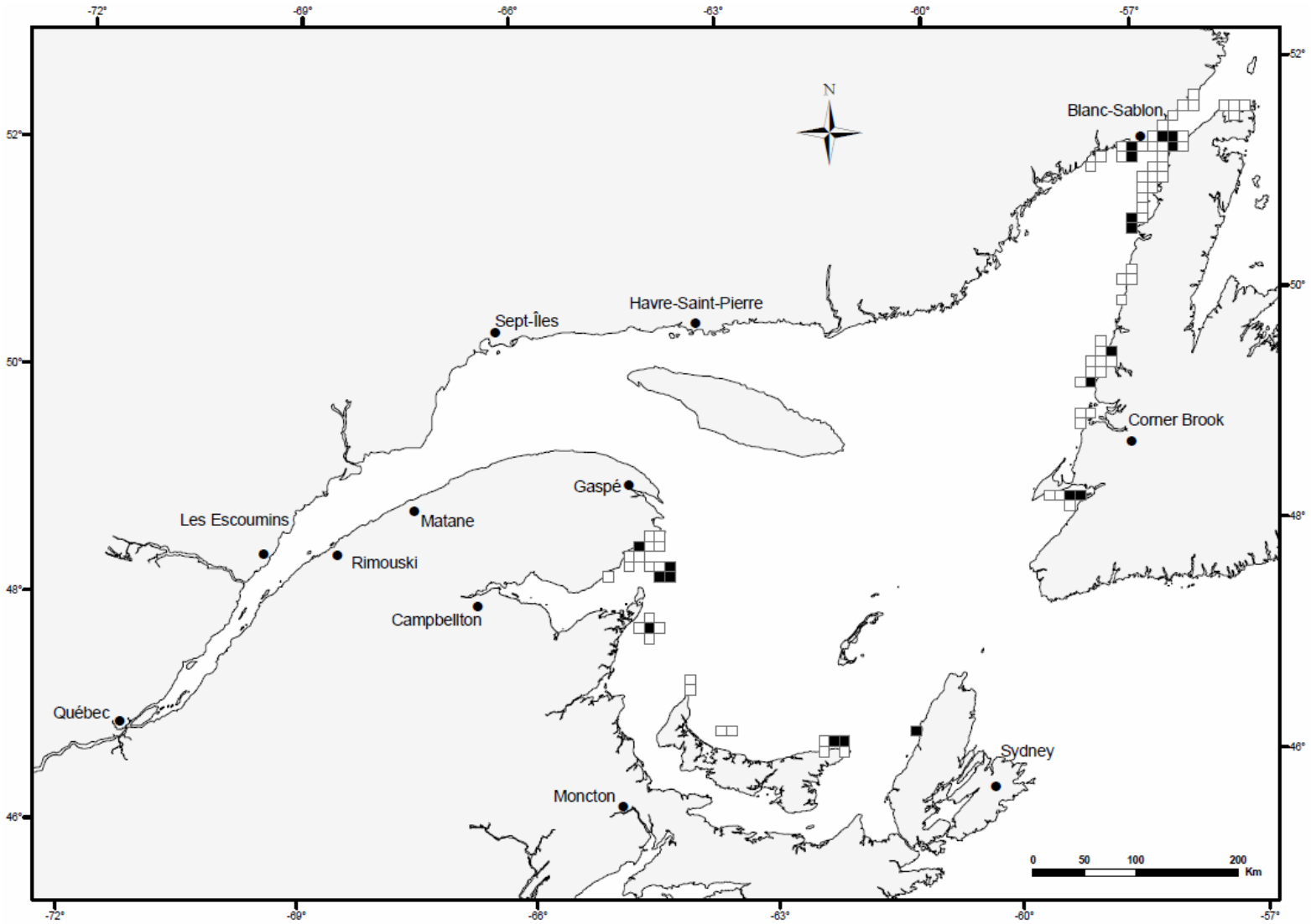

Figure 13. Overlap in the fishing effort of gillnets and longlines in the Sentinel Fisheries Program during the period from 1996 to 2008. Boxes indicate 100 km^2 cells in which both gillnets and longlines were used, and black boxes indicate cells where twenty activities or more took place per gear for both types of gears.

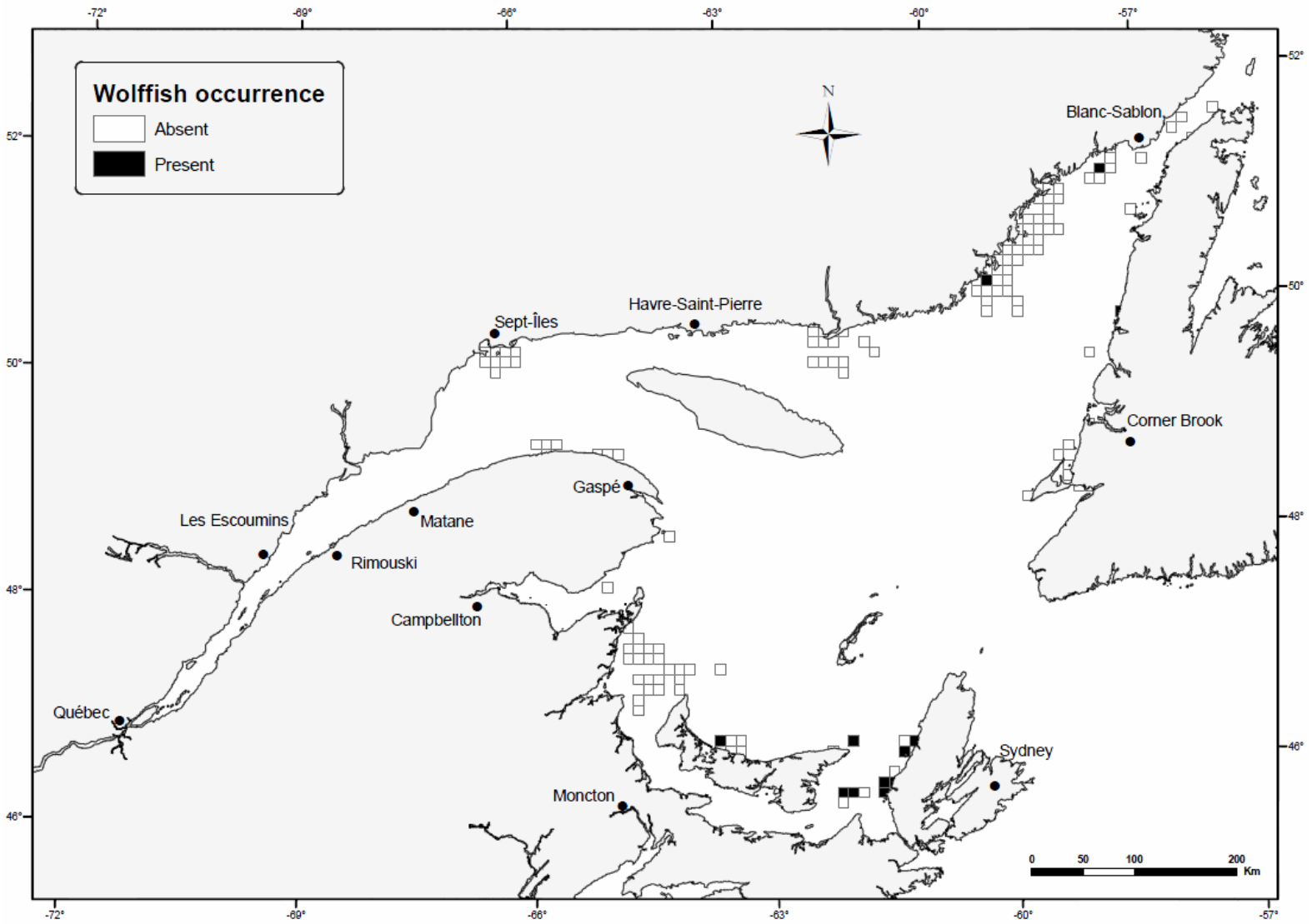

Figure 14. Boxes indicate 100 km^2 cells where gillnets were used, but not longlines, in the Sentinel Fisheries Program during the period from 1996 to 2008. Black boxes indicate occurrences of wolffish in the catch.

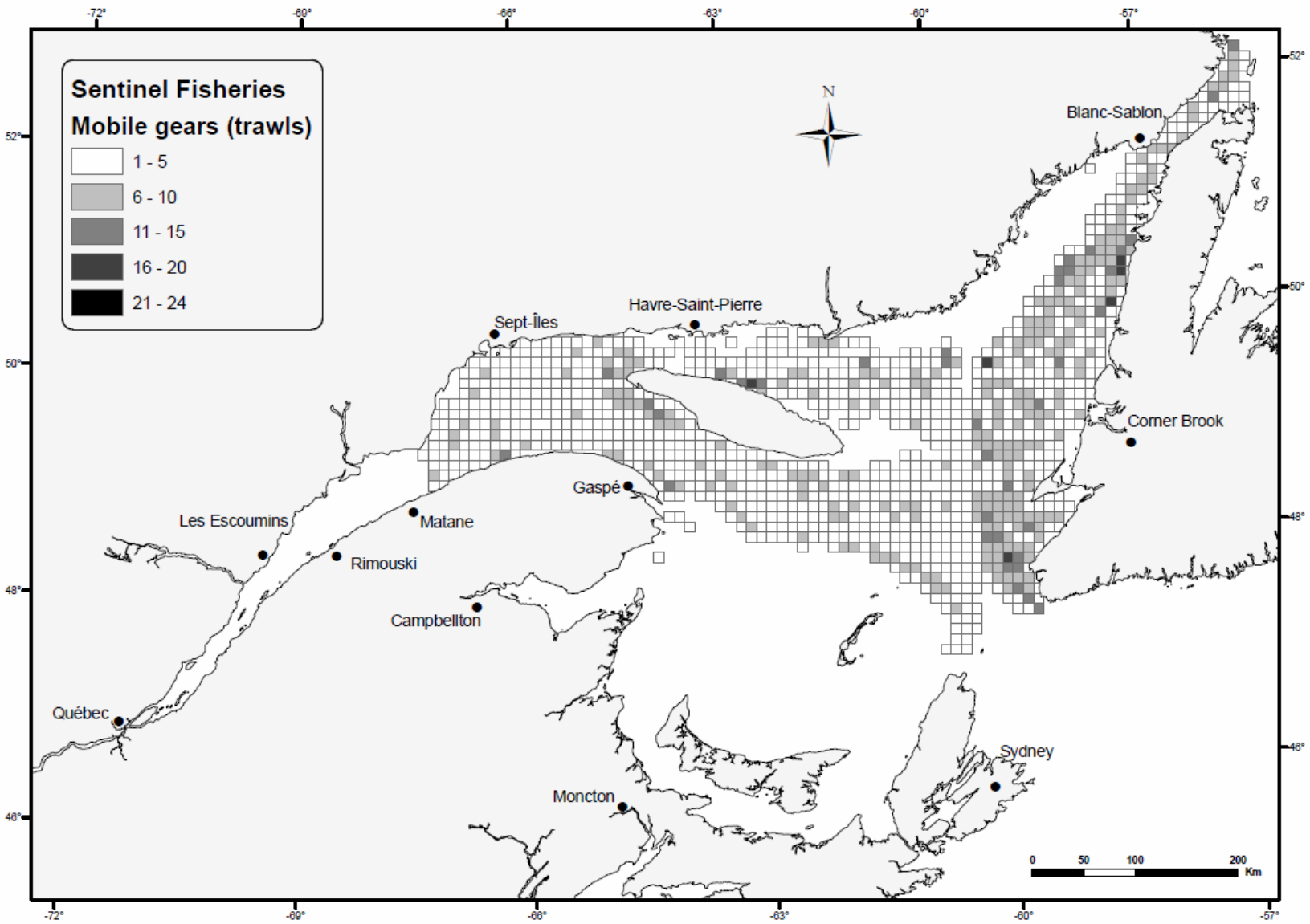

Figure 15. Spatial distribution of fishing effort (number of activities) in the Sentinel Fisheries Program (stratified random surveys using trawlers) for the period from 1995 to 2002. The data are aggregated by 100 km^2 cells. No sets took place in areas where the grid is not shown.

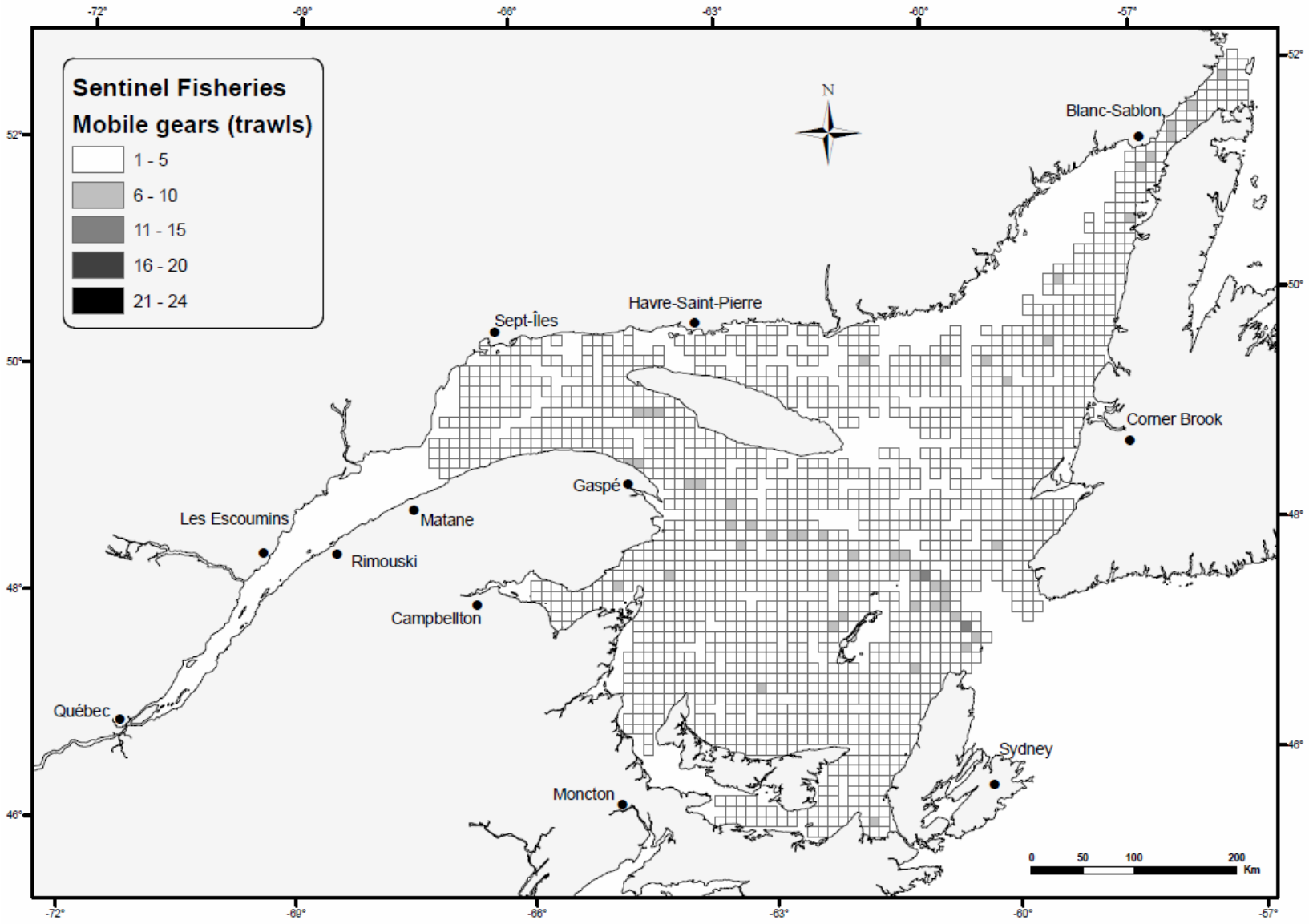

Figure 16. Spatial distribution of fishing effort (number of activities) in the Sentinel Fisheries Program (stratified random surveys using trawlers) for the period from 2003 to 2008. The data are aggregated by 100 km^2 cells. No sets took place in areas where the grid is not shown.

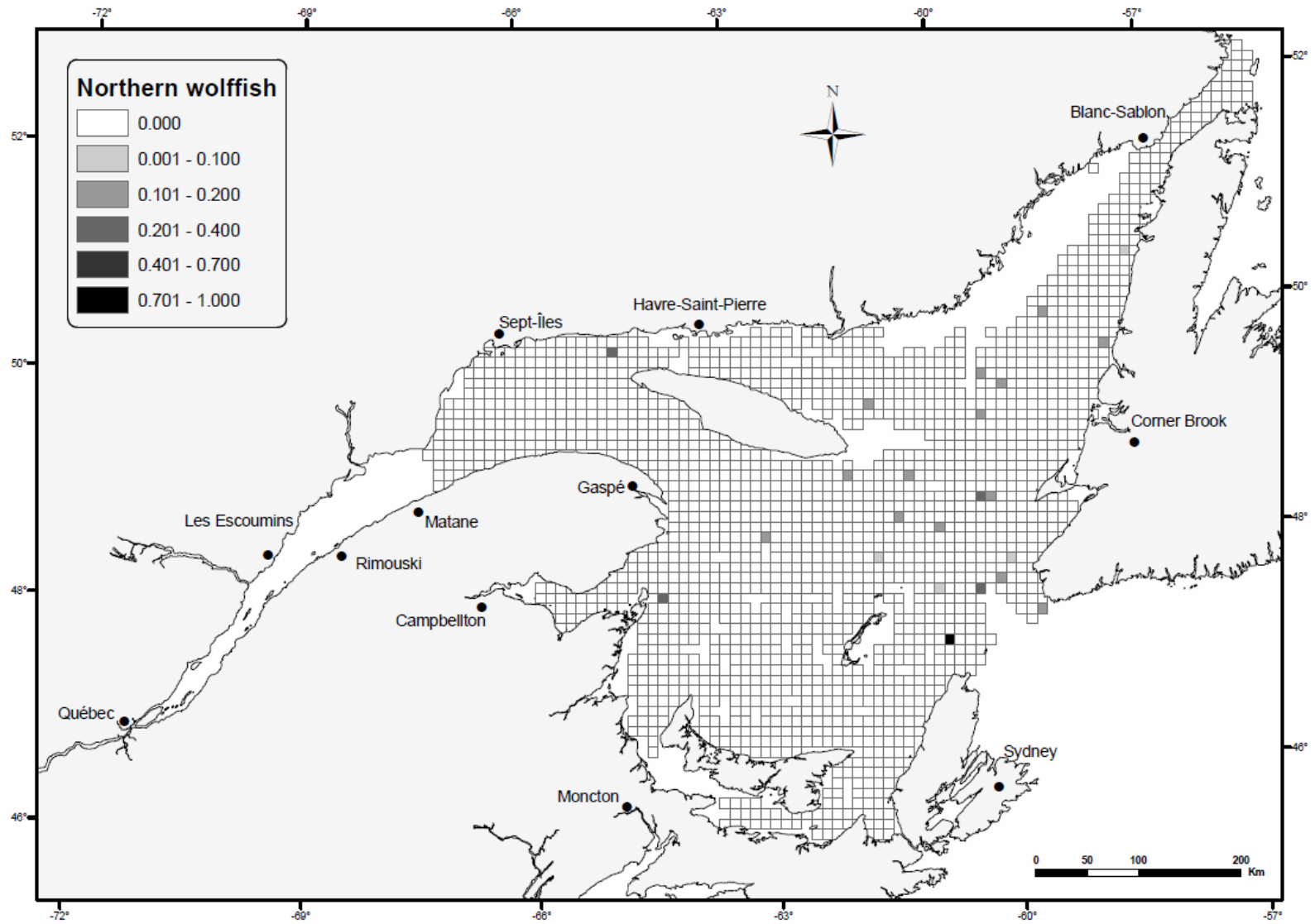

Figure 17. Spatial distribution of the relative occurrence of northern wolffish (number of sets in which species is present divided by fishing effort) in the Sentinel Fisheries Program (stratified random surveys using trawlers) for the period from 1995 to 2008. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

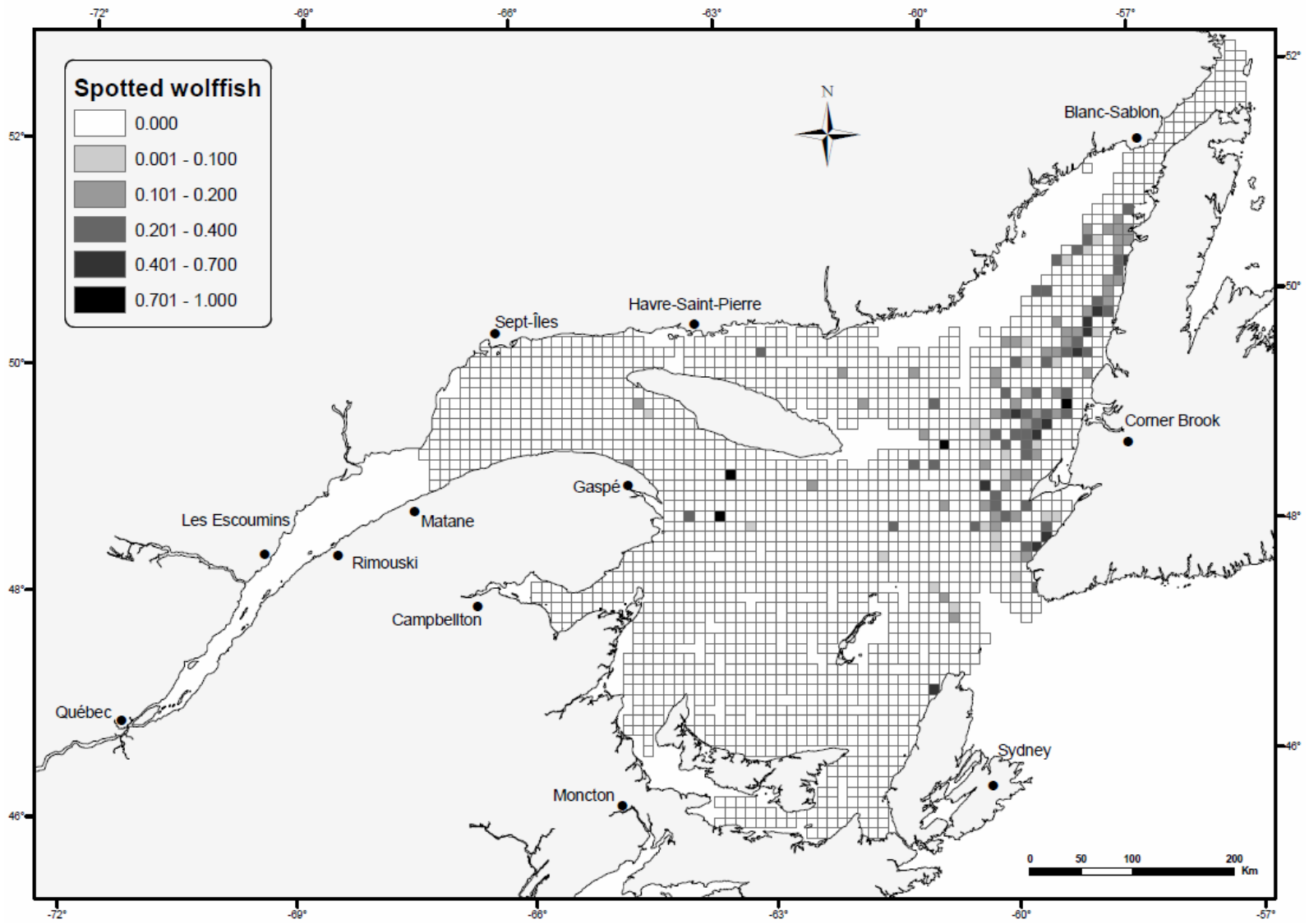

Figure 18. Spatial distribution of the relative occurrence of spotted wolffish (number of sets in which species is present divided by fishing effort) in the Sentinel Fisheries Program (stratified random surveys using trawlers) for the period from 1995 to 2008. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

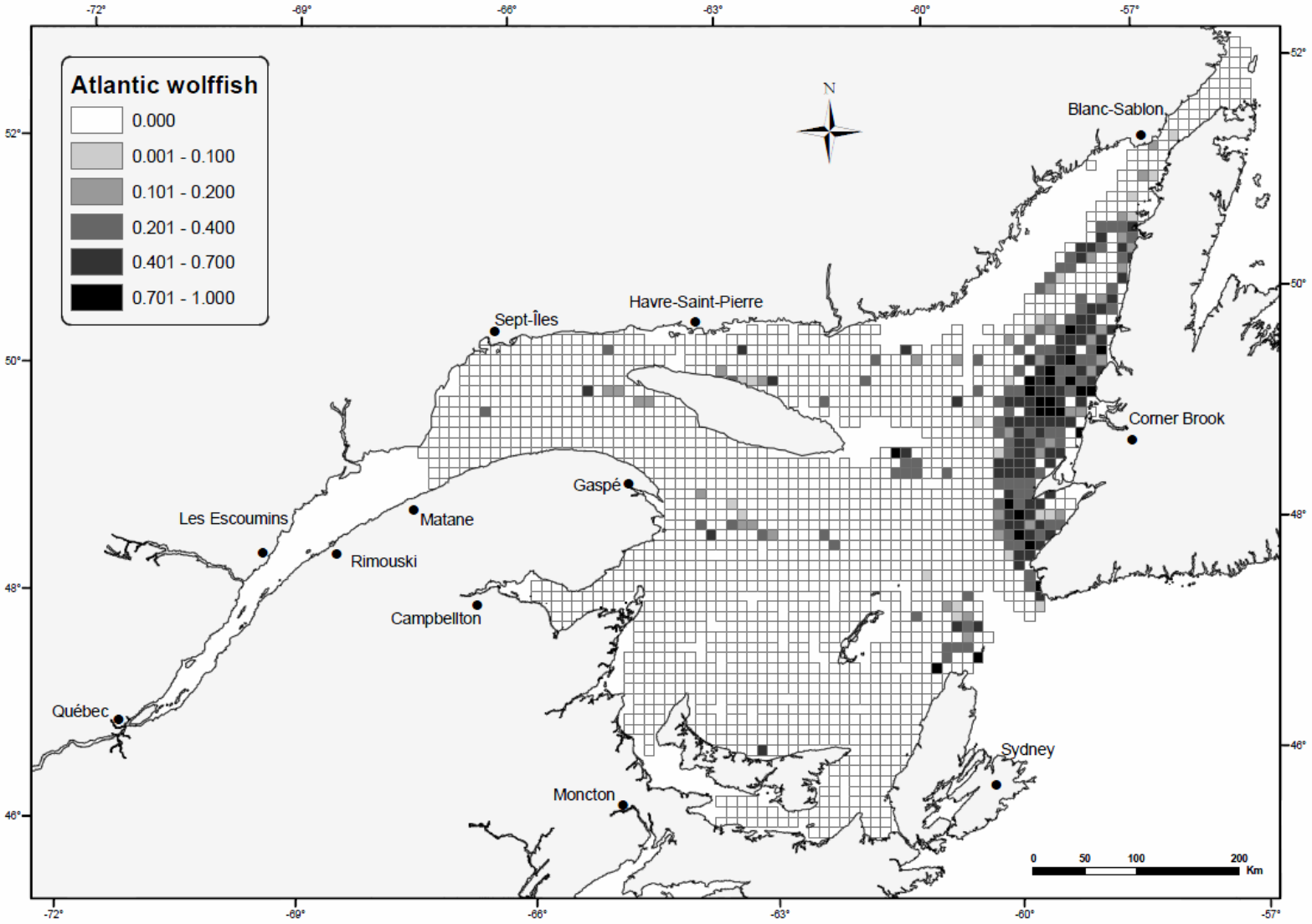

Figure 19. Spatial distribution of the relative occurrence of Atlantic wolffish (number of sets in which species is present divided by fishing effort) in the Sentinel Fisheries Program (stratified random surveys using trawlers) for the period from 1995 to 2008. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

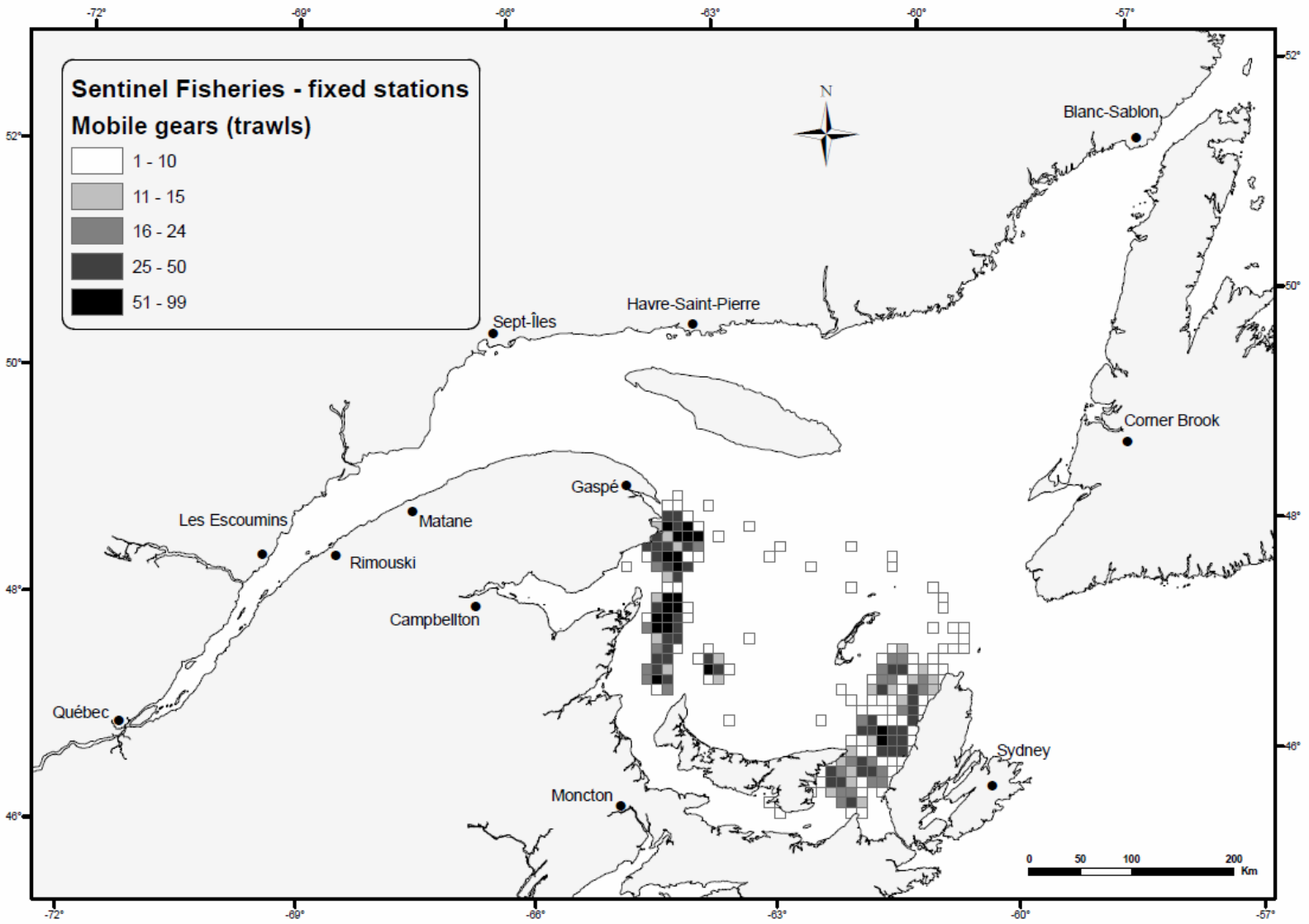

Figure 20. Spatial distribution of fishing effort (number of activities) in the Sentinel Fisheries Program (fixed stations surveys using trawlers) for the period from 1995 to 2002. The data are aggregated by 100 km^2 cells. No sets took place in areas where the grid is not shown.

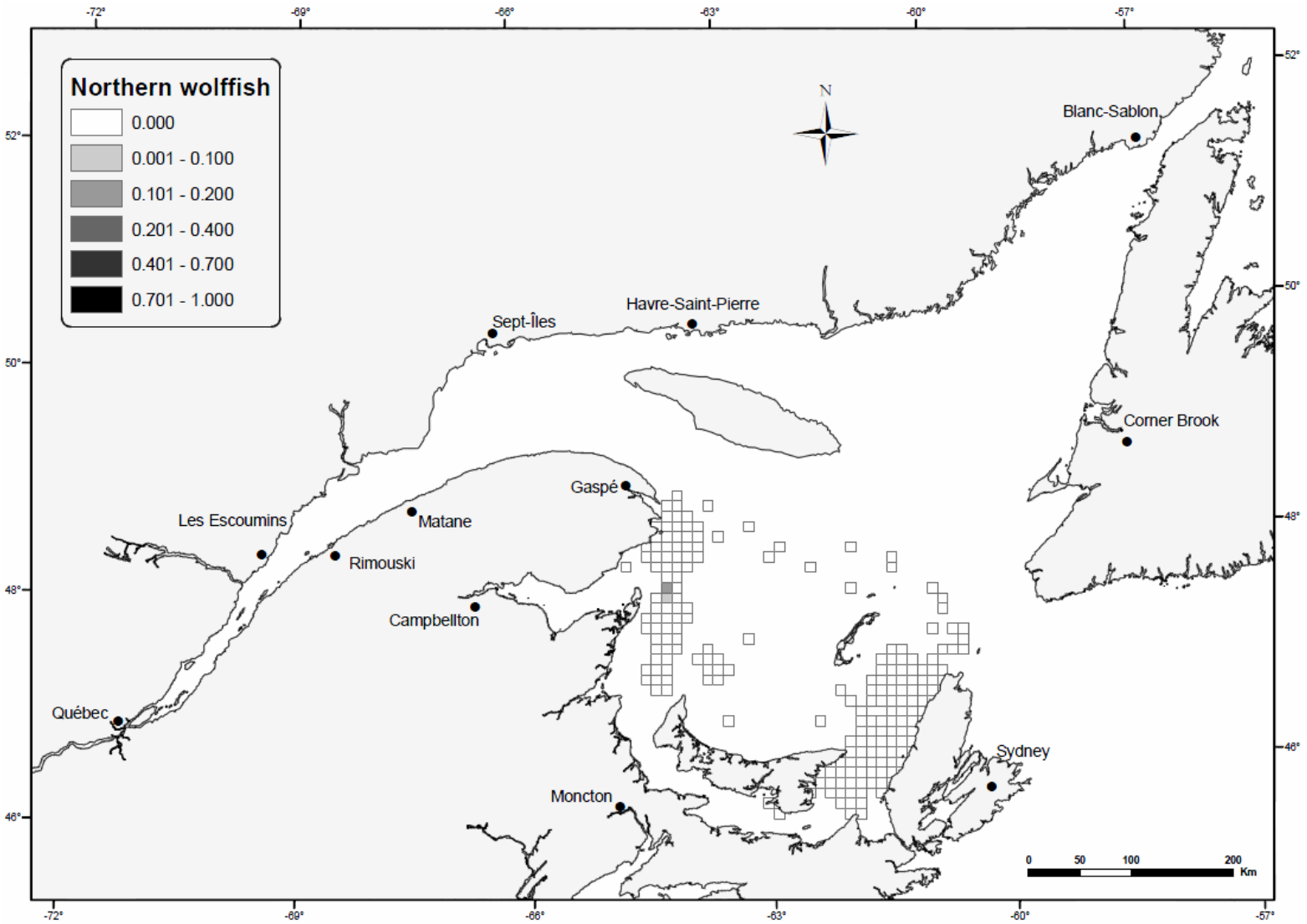

Figure 21. Spatial distribution of the relative occurrence of northern wolffish (number of sets in which species is present divided by fishing effort) in the Sentinel Fisheries Program (fixed stations surveys using trawlers) for the period from 1995 to 2002. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

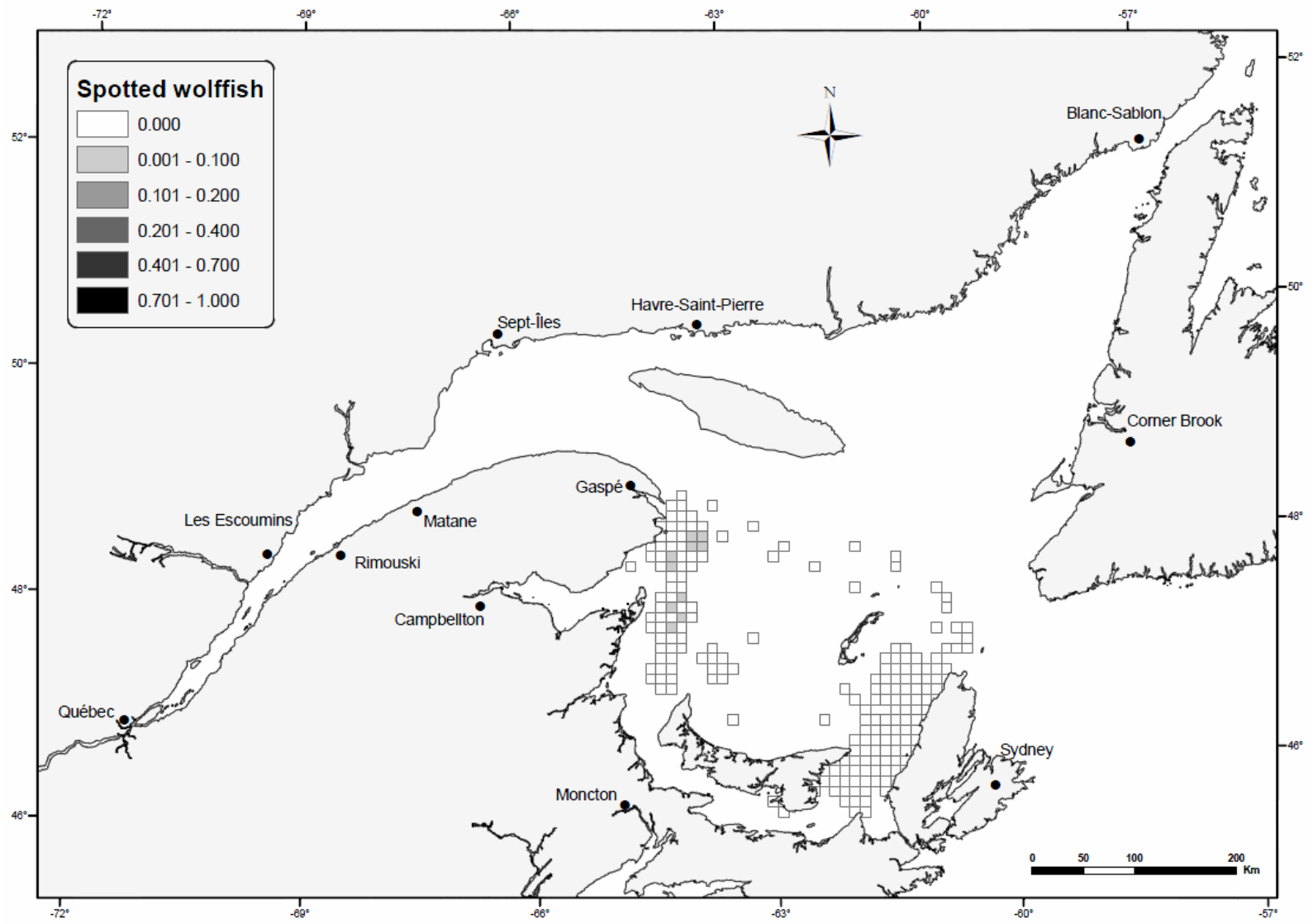

Figure 22. Spatial distribution of the relative occurrence of spotted wolffish (number of sets in which species is present divided by fishing effort) in the Sentinel Fisheries Program (fixed stations surveys using trawlers) for the period from 1995 to 2002. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

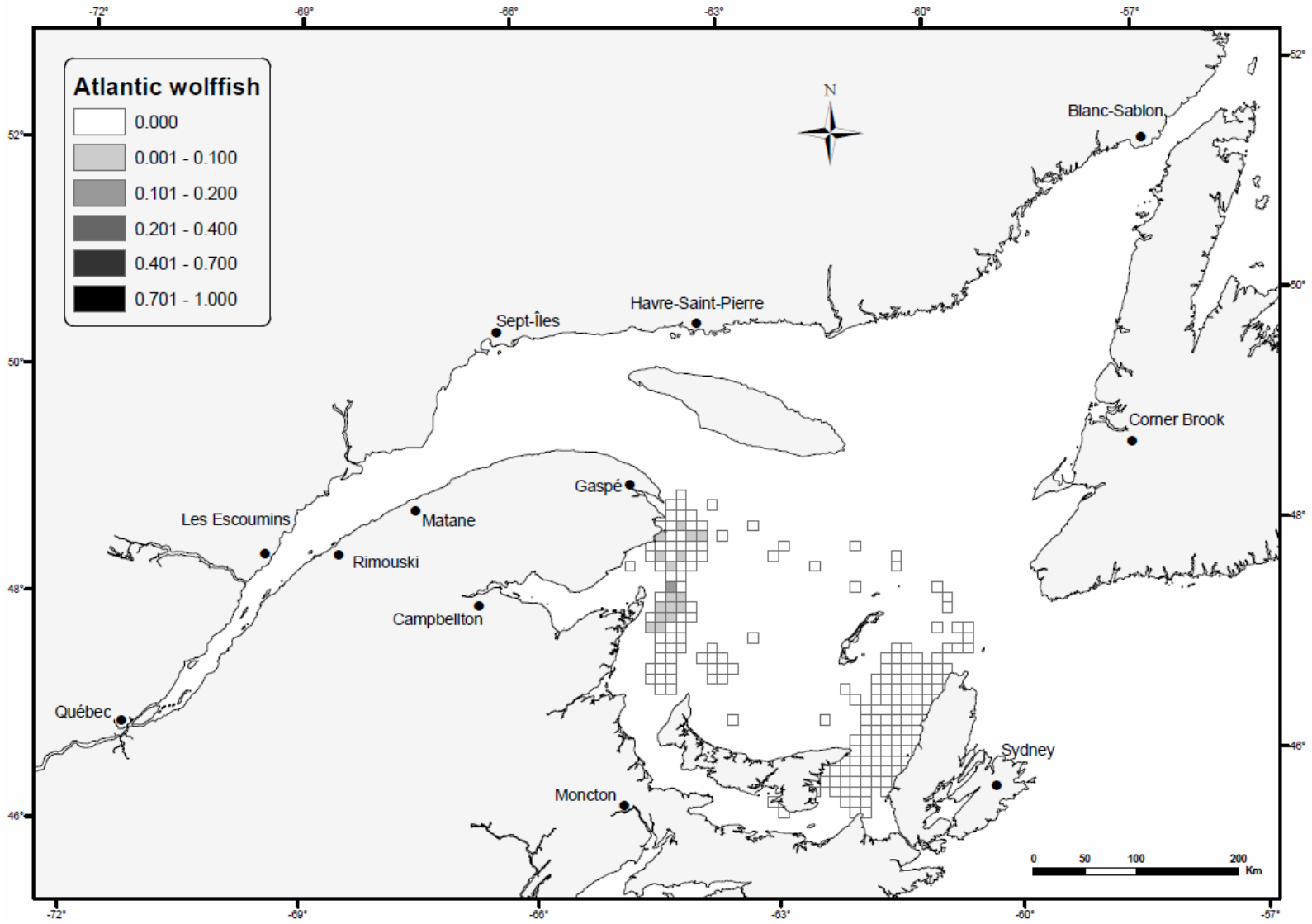

Figure 23. Spatial distribution of the relative occurrence of Atlantic wolffish (number of sets in which species is present divided by fishing effort) in the Sentinel Fisheries Program (fixed stations surveys using trawlers) for the period from 1995 to 2002. The data are aggregated by 100 km^2 cells. No trawling took place in areas where the grid is not shown.

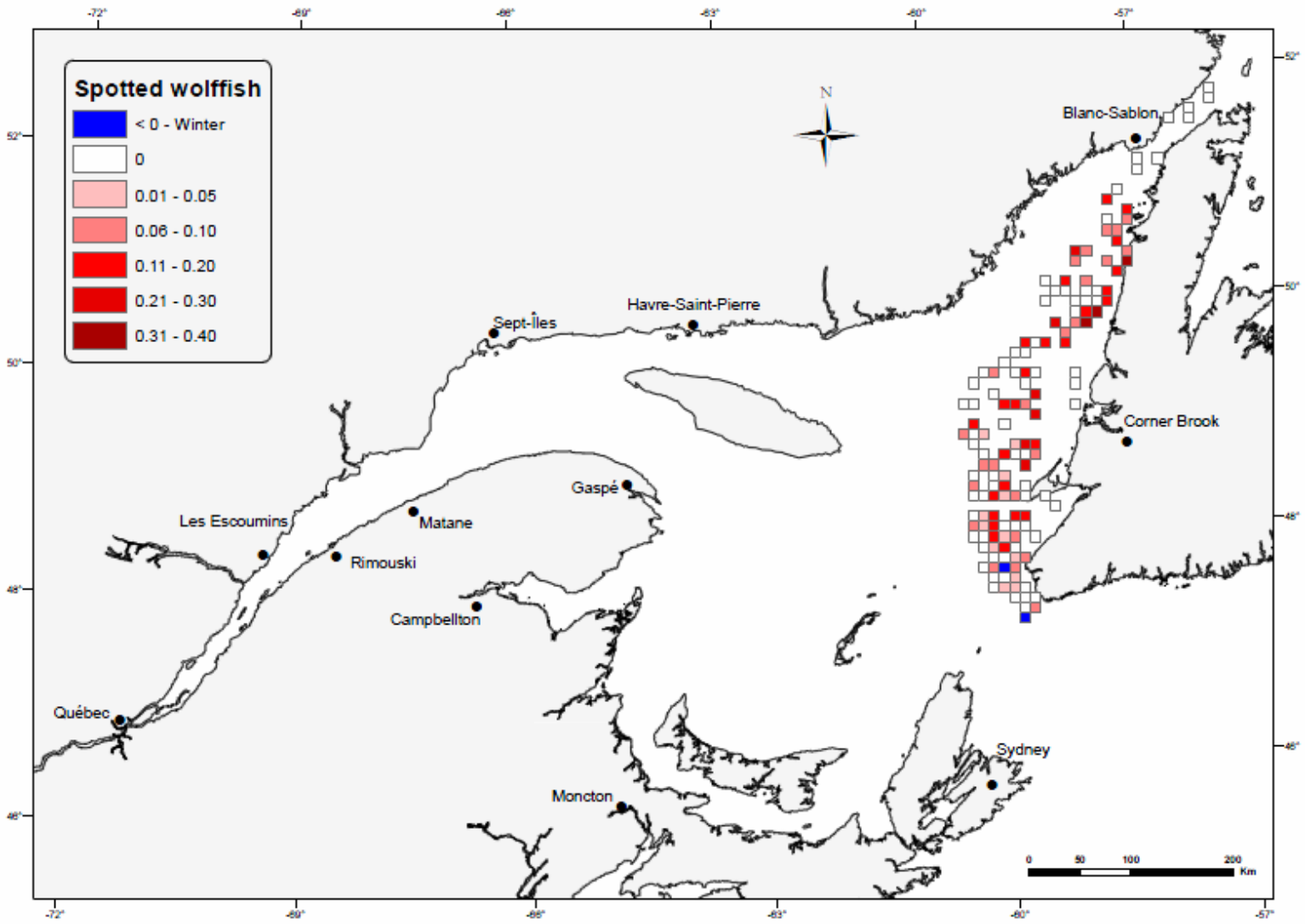

Figure 24. Compared relative occurrence of spotted wolffish in summer and winter surveys. The data are aggregated by 100 km^2 cells and differences in occurrence between winter and summer surveys are shown for cells where sampling occurred in both winter and summer. White cells indicate no catch in both seasons; blue cells indicate areas where wolffish occurrence was greater in winter; shades of red indicate summer occurrences.

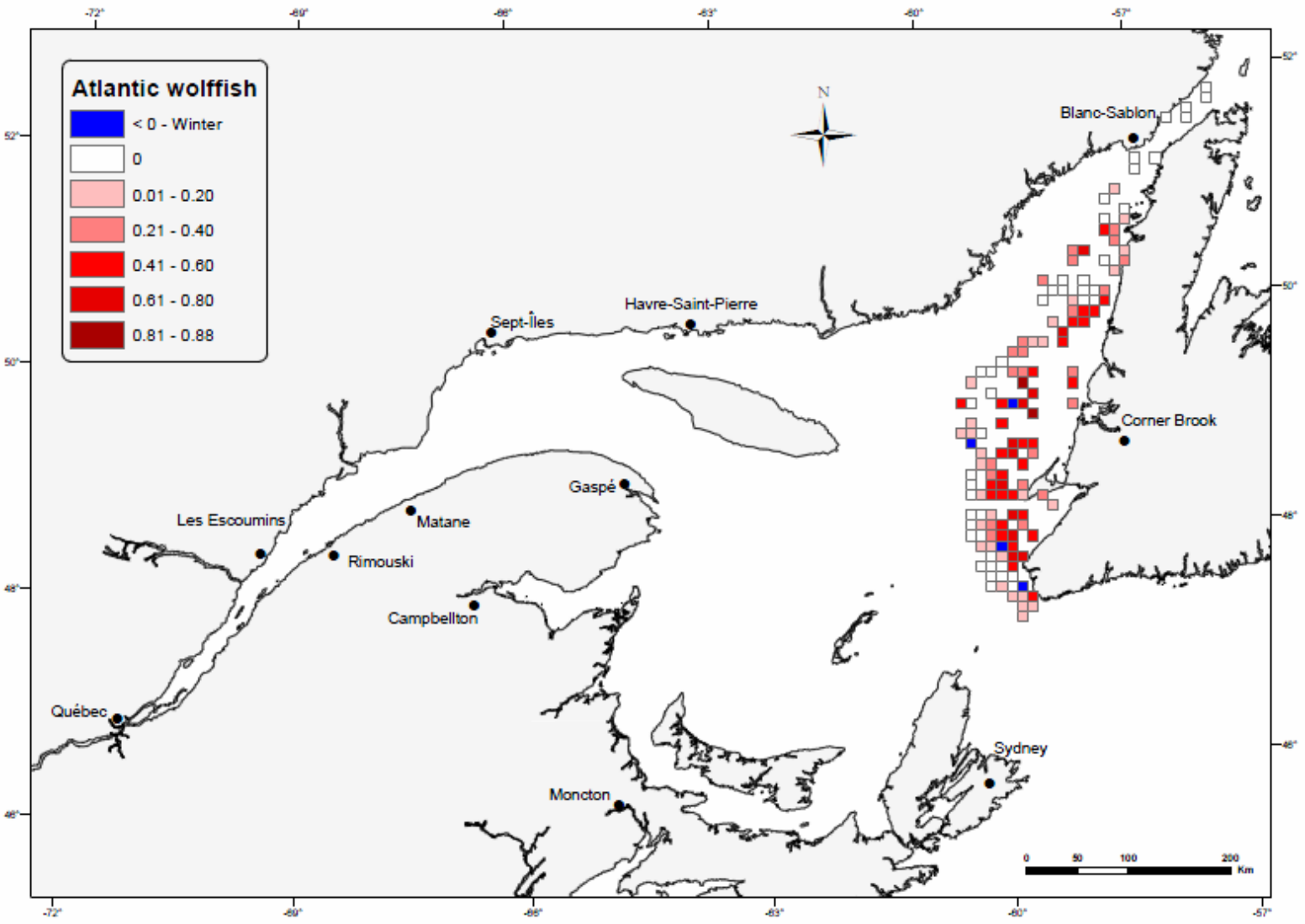

Figure 25. Compared relative occurrence of Atlantic wolffish in summer and winter surveys. The data are aggregated by 100 km^2 cells and differences in occurrence between winter and summer surveys are shown for cells where sampling occurred in both winter and summer. White cells indicate no catch in both seasons; blue cells indicate areas where wolffish occurrence was greater in winter; shades of red indicate summer occurrences.

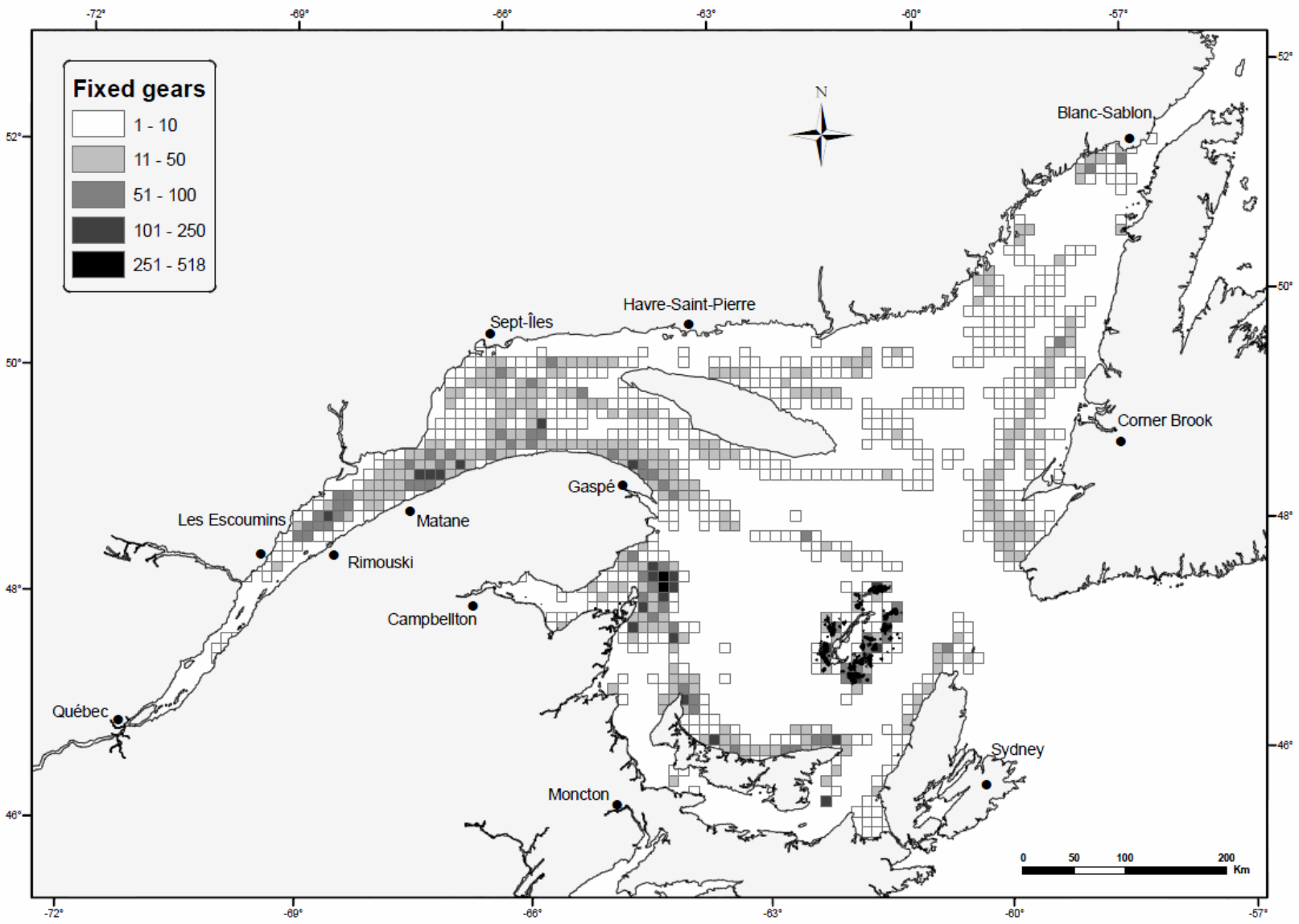

Figure 26. Spatial distribution of fishing activities for fixed gears monitored by the Observer Program, excluding Sentinel Fisheries, for the period 1992-2008.

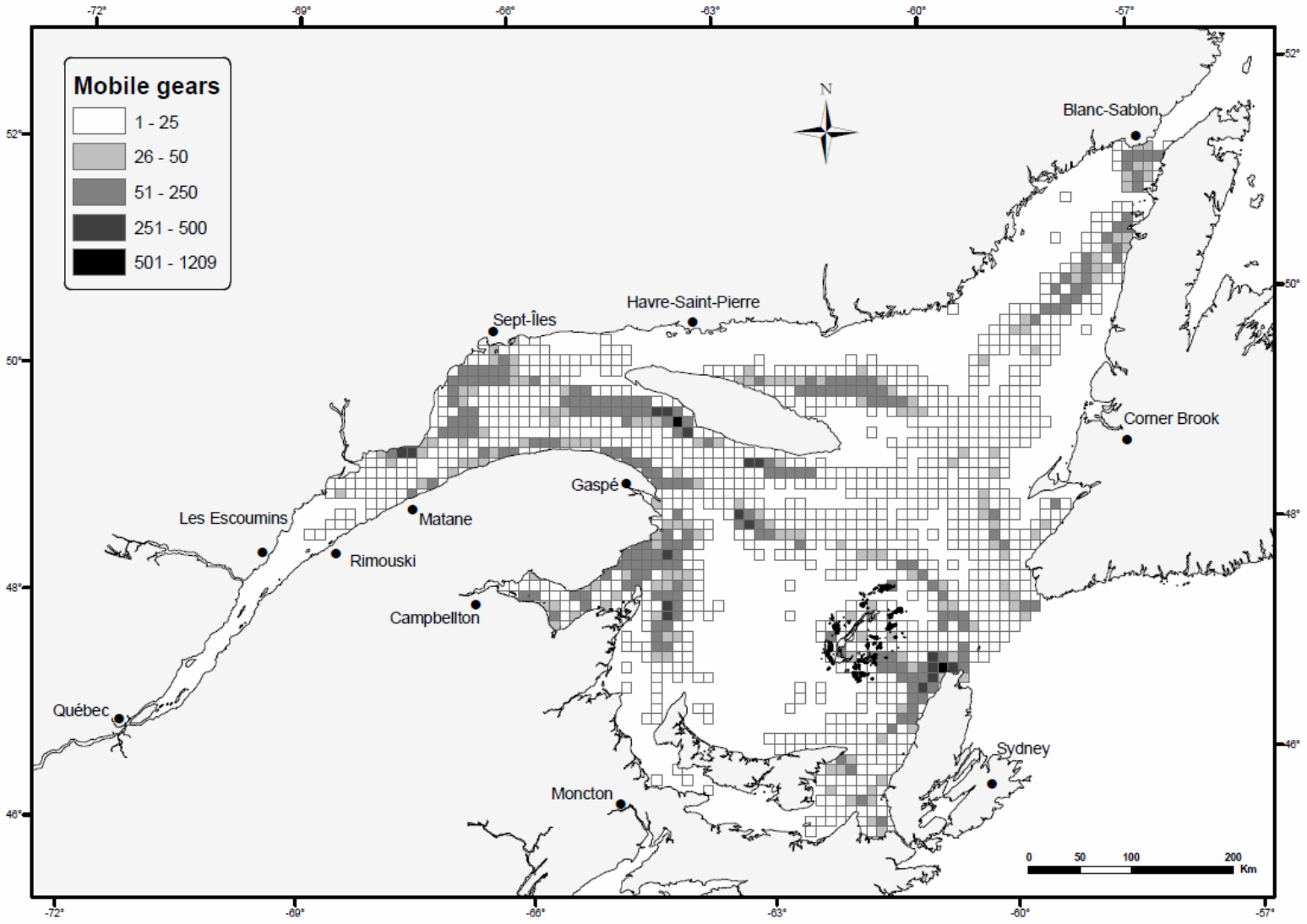

Figure 27. Spatial distribution of fishing activities for mobile gears monitored by the Observer Program, excluding Sentinel Fisheries, for the period 1992-2008.

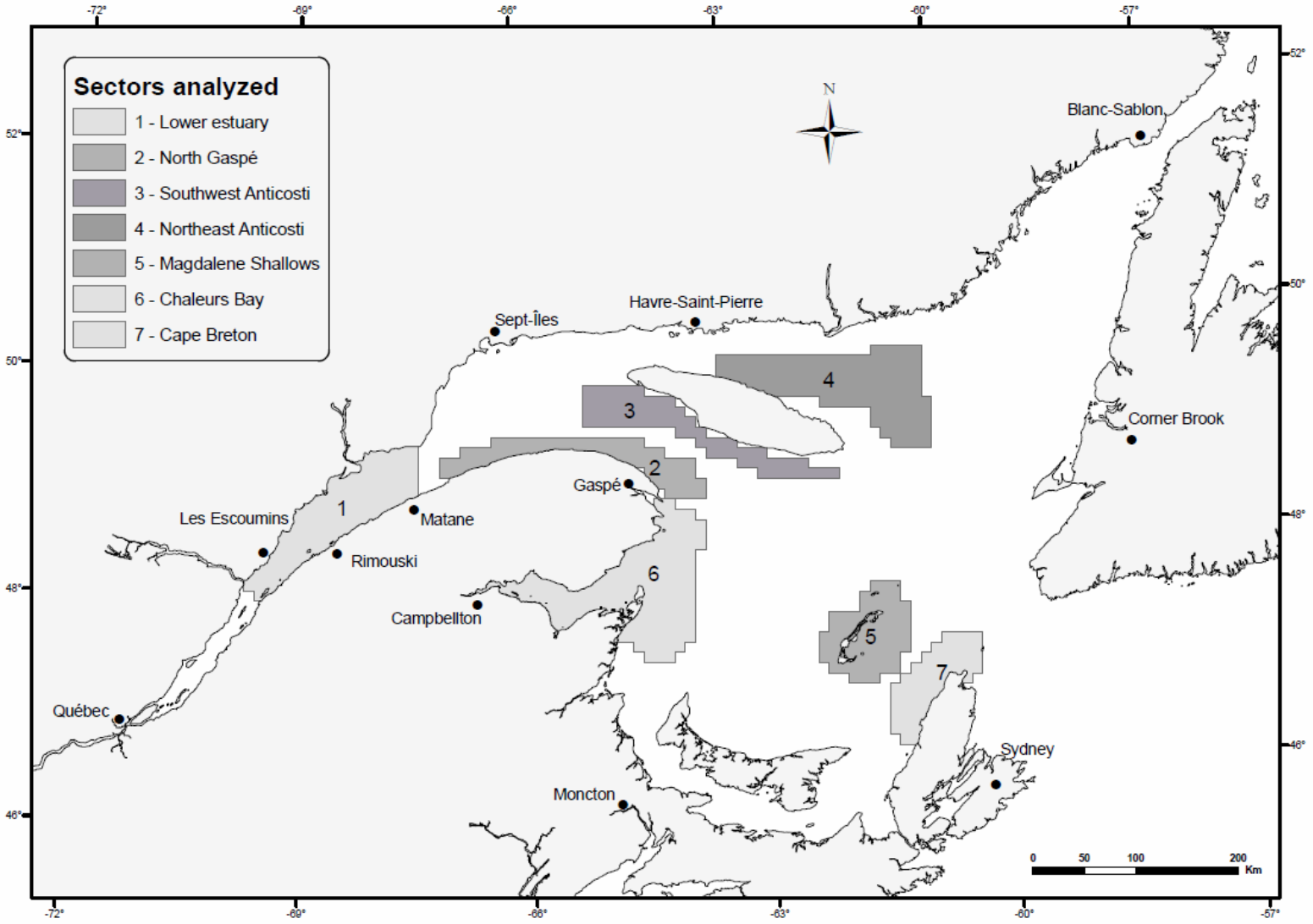

Figure 28. Seven different areas where a significant monitoring effort occurred under the Observer Program either in the fixed or mobile gears fisheries within the Estuary and Gulf of St. Lawrence.

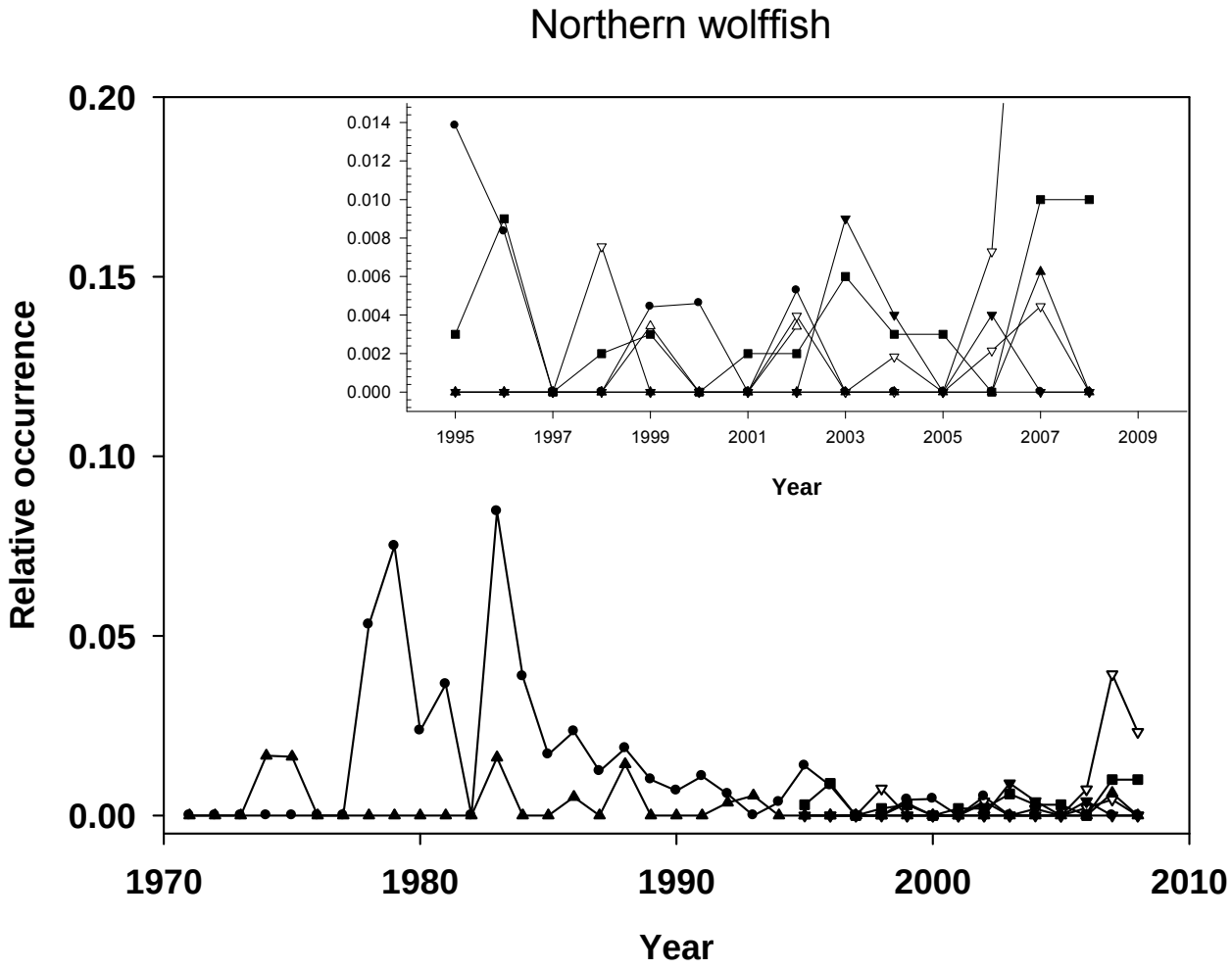

Figure 29. Compared time series of relative occurrences of northern wolffish in random stratified (full symbols) and other (open symbols) surveys: full circle, research survey in the northern Gulf; full triangle up, research survey in the southern Gulf; full square, Sentinel Fisheries random stratified survey in the northern Gulf; full triangle down, Sentinel Fisheries random stratified survey in the southern Gulf; open triangle up, Sentinel Fisheries mobile gears at fixed stations; open triangle down, Sentinel Fisheries longlines in the southern Gulf; open square, Sentinel Fisheries longlines in the northern Gulf. Northern and southern Gulf refer to sectors north and south of the dividing line shown in Figure 1.Data for the period 1995 to 2008 are shown in a different scale in the right hand corner graph.

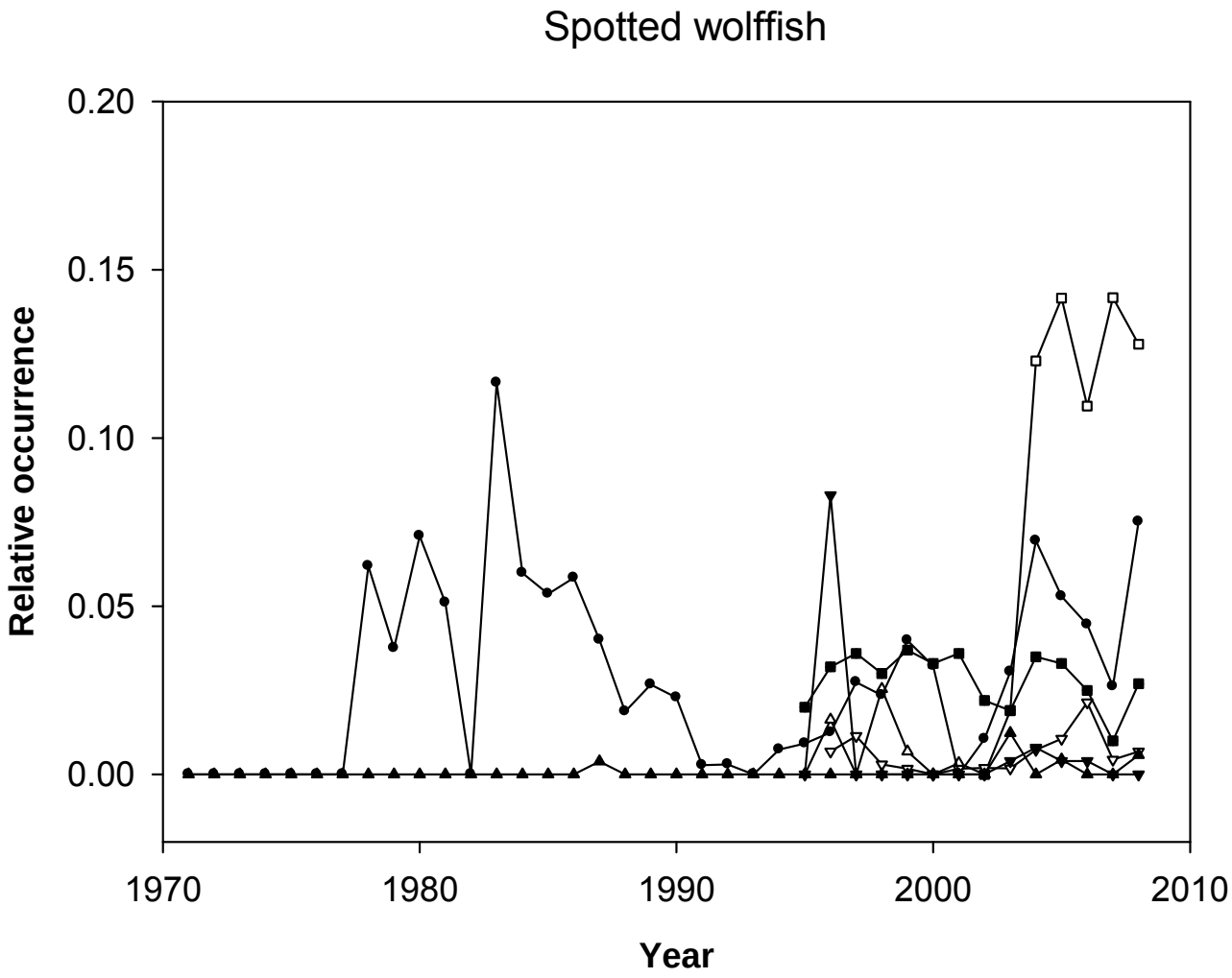

Figure 30. Compared time series of relative occurrences of spotted wolffish in random stratified (full symbols) and other (open symbols) surveys: full circle, research survey in the northern Gulf; full triangle up, research survey in the southern Gulf; full square, Sentinel Fisheries random stratified survey in the northern Gulf; full triangle down, Sentinel Fisheries random stratified survey in the southern Gulf; open triangle up, Sentinel Fisheries mobile gears at fixed stations; open triangle down, Sentinel Fisheries longlines in the southern Gulf; open square, Sentinel Fisheries longlines in the northern Gulf. Northern and southern Gulf refer to sectors north and south of the dividing line shown in Figure 1.

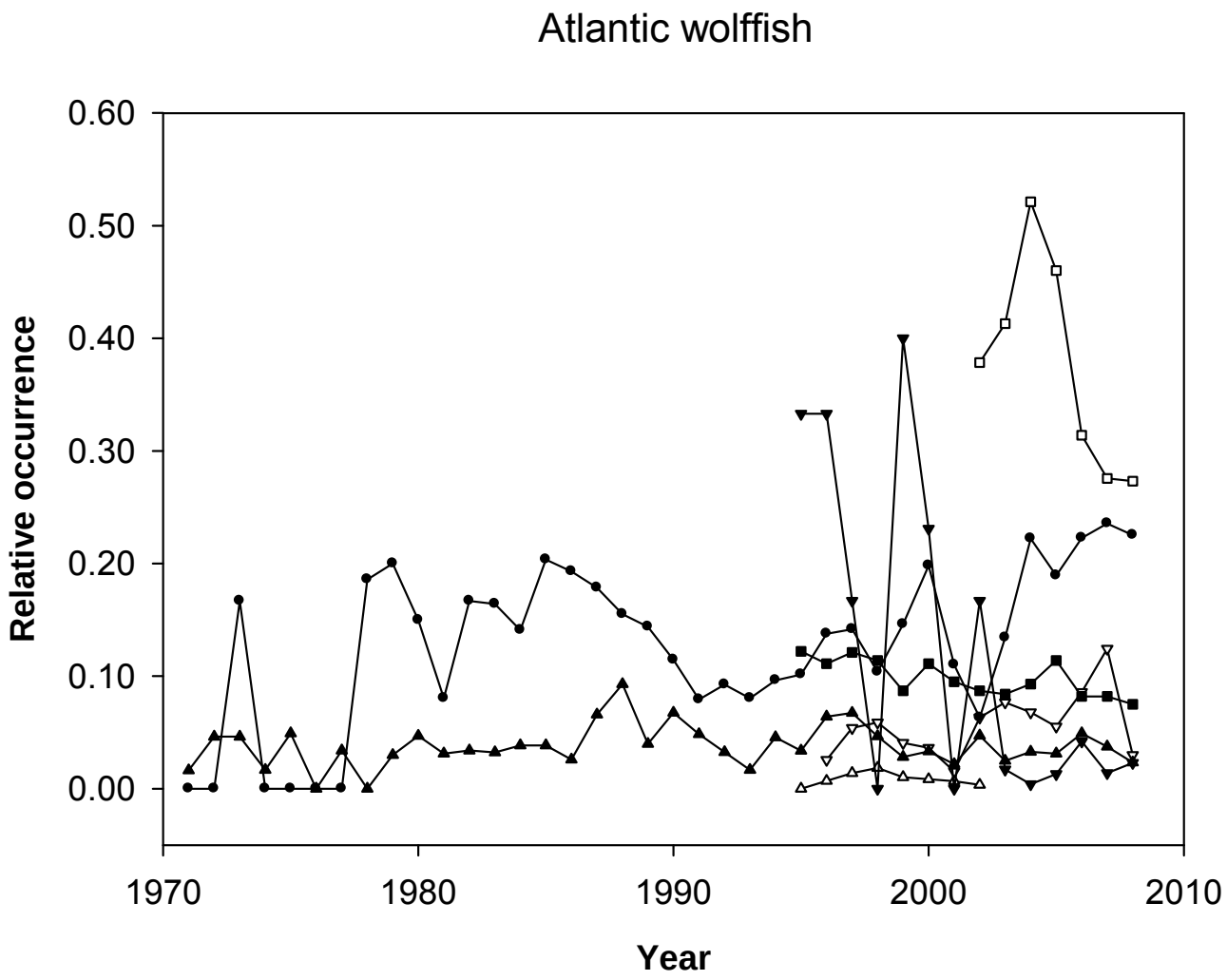

Figure 31. Compared time series of relative occurrences of striped wolffish in random stratified (full symbols) and other (open symbols) surveys: full circle, research survey in the northern Gulf; full triangle up, research survey in the southern Gulf; full square, Sentinel Fisheries random stratified survey in the northern Gulf; full triangle down, Sentinel Fisheries random stratified survey in the southern Gulf; open triangle up, Sentinel Fisheries mobile gears at fixed stations; open triangle down, Sentinel Fisheries longlines in the southern Gulf; open square, Sentinel Fisheries longlines in the northern Gulf. Northern and southern Gulf refer to sectors north and south of the dividing line shown in Figure 1.