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Mapping Spawning Times and Locations for 10 Commercially Important Fish Species Found on the Grands Banks of Newfoundland

by

L.M.N. Ollerhead, M.J. Morgan, D.A. Scruton, and B. Marrie

Science, Oceans and Environment Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, NL   A1C 5X1

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Abstract

Ollerhead L.M.N., Morgan, M.J., Scruton, D.A., and Marrie, B. 2004. Mapping spawning times and locations for 10 commercially important fish species found on the Grand Banks of Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 2522: iv + 45 p.

Using data collected on Department of Fisheries and Oceans (DFO) research vessel surveys, a Geographic Information System (GIS) was used to create maps that illustrated locations and timing of higher intensity spawning for ten commercially important fish species found on the Grand Banks. The maps showed that within the coverage of the Grand Banks surveys, peak spawning occurred for many species in spring and early summer with the location of the spawning peak often varying from month to month. Marked areas of higher intensity spawning were found for most species, with other, lesser amounts occurring simultaneously in other regions of the survey. During peak season in the spring and early summer, considerable spawning activity was observed on much of the Grand Banks. Historical versus recent spawning trends were also mapped to illustrate how the locations of the higher intensity spawning areas behaved over a longer time frame. These maps showed, for some species, that the spawning areas were static while others were dynamic.

Résumé

Ollerhead L.M.N., Morgan, M.J., Scruton, D.A., and Marrie, B. 2004. Mapping spawning times and locations for 10 commercially important fish species found on the Grand Banks of Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 2522: iv + 45 p.

On a utilisé un système d’information géographique (SIG) et des données recueillies par le ministère des Pêches et des Océans (MPO) dans le cadre de relevés par navire scientifique pour créer des cartes qui illustraient les lieux et périodes de fraye intense de dix espèces de poisson de grande importance commerciale sur les Grands Bancs. Ces cartes révèlent que, dans la zone visée par les relevés sur les Grands Bancs, le pic de fraye survient au printemps et au début de l’été chez de nombreuses espèces, en des lieux qui varient souvent d’un mois à l’autre. On a observé de nets secteurs de fraye intense chez la plupart des espèces et l’existence simultanée de secteurs de fraye moins importante dans d’autres régions des zones de relevé. En saison de pointe, soit au printemps et au début de l’été, on a observé une activité de fraye considérable sur une bonne partie des Grands Bancs. Les cartes présentent aussi les tendances historiques et récentes de la fraye afin d’illustrer l’évolution des lieux de fraye intense à long terme. Il en ressort que les frayères sont statiques chez certaines espèces et dynamiques chez d’autres.

INTRODUCTION

Traditionally, Newfoundland and Labrador has been known for its fishing industry, but in recent years oil and gas has become an increasingly important natural resource. Identifying potential conflicts between oil and gas exploration surveys and spawning areas is critical to effective management of these natural resources. Currently, the greatest concentration of offshore oil and gas activity in Newfoundland is found on the Grand Banks, consequently it is the logical place on which to center the study. Data used for this project was limited to areas of the Grand Banks that fall within NAFO divisions 3LMNOP, as shown in Fig. 1. These areas include, but are not limited to, the Grand Bank, the Flemish Cap, the Flemish Pass, the Southeast Shoal and the St. Pierre Bank. The study area lies between 41.75° to 49.5° North and 43° and 58° West.

This study modeled DFO research vessel data to produce maps illustrating areas of higher intensity spawning for ten selected commercial species found on the Grand Banks. These maps should prove invaluable to the oil and gas industry, including operators and industry regulators alike (e.g. C-NOPB, DFO) when planning seismic exploration activities. In addition, other stakeholders could use these maps as an information base from which to discuss concerns respecting seismic survey operations. This project evolved from a report prepared for Marine Environment and Habitat Management Division (MEHMD), Newfoundland and Labrador Region, DFO where a literature review was conducted that examined the spawning times and locations of 23 fish species on the Grand Banks.

Of those species included in the MEHMD report there was only sufficient data to model six finfish and four shellfish species. Within the excluded species, 11 were ruled out due to insufficient data and two, Atlantic herring and capelin, had data but were considered primarily near-shore spawners (Reid *et al.* 1999). As near-shore spawners they were excluded from the study, as their spawning activity was not considered to coincide with seismic survey activities.

This project studied American plaice (*Hippoglossoides platessoides*), Atlantic cod (*Gadus morhua*), Haddock (*Melanogrammus aeglefinus*), Redfish (*Sebastes spp*.), Witch flounder (*Glyptocephalus cynoglossus*), Yellowtail flounder (*Limanda ferruginea*), Northern shrimp (*Pandalus borealus*), Iceland scallop (*Chlamys islandica*), Sea scallop (*Placopectin magellanicus*) and Surf clam (*Spisula solidissima*).

METHODS

DFO, Newfoundland and Labrador Region, began conducting stratified random research surveys in 1971 (McCallum and Walsh 1996). Initially, these studies were performed exclusively in the spring when, in 1978, the surveys were expanded to include an additional fall survey. In the fall survey of 1995, the gear type changed from the Engel 145 survey trawl to the Campelen 1800 shrimp trawl. Several sets of maps were developed to evaluate the potential effect of the gear change on the spawning intensity models. Maps were created using each of the Engel and Campelen data separately and a third was developed using the combination of the two. Comparison of the composite maps to the individual maps showed that analyzing data collected with different gears had minimal effect on the spawning intensity models.

Whenever there were sufficient data available, the data was divided into two time periods to show both an historical perspective on spawning activity as well as the most recent spawning trends. The recent spawning trends were modeled using the five most recent years of data while the historical overview used the remainder of each dataset. Five years was chosen to represent the recent spawning trends as it contained sufficient data to illustrate the spawning trends. It is important to distinguish past versus the current state of the stocks to account for historical variability in stock location, spawning timing and abundance.

Spawning intensity maps were generated for each month where the data and literature indicated a species was actively spawning. The active spawning 'seasons' were determined by reviewing the literature and analyzing the research vessel data to see when the greatest numbers of spawning fish were being caught. As the DFO surveys are not performed year-round, sufficient mapable data were not available for all months for all species. In addition, within any survey not all sets caught fish. These "zero-catch" sets are shown in grey on the maps and indicate the survey extent and provide a measure of fishing effort.

The required data were extracted from the DFO archives, reformatted and imported into an Oracle database. Oracle (Oracle RDBMS, v8.1.7, Oracle Corporation) is a powerful data management tool and was used to analyze the data and organize it into a GIS compatible format. Oracle was also used to create weekly frequency distributions to learn when the greatest numbers of spawning fish were being caught. This analysis, in conjunction with the published literature, determined the spawning season for each species. Once the spawning seasons had been established, the necessary data were extracted from the Oracle database. Files were created for every month within the determined spawning season and then imported into the SPANS GIS (TYDAC Research Inc.) for modeling.

FINFISH

The finfish species were modeled using Length-Sex-Maturity (LSM) data. LSM data contains information that identifies the level of maturity of individual fish as determined from visual inspection of the gonads. Maturity level was then coded into one of nine maturity categories as shown in Table 1 (Templeman *et al.* 1978), with the exception of redfish (*Sebastes spp.*). Only female fish were considered for this study and of those, only fish that contained hydrated eggs were said to be in spawning condition (Mat B-P, Mat C-P and Partly Spent) as hydrated eggs are released within a few days (Kjesbu *et al.* 1990).

Redfish, unlike the other species in this study, are ovoviviparous. This is to say that eggs are internally fertilized and develop inside the female and until larvae are ready to be released (Scott and Scott 1988). This unique reproductive method required a different maturity coding be used to extract the redfish data, as shown in Table 2.

As the RV surveys do not collect LSM data on every trip, the amount of available data varies by species. Some species have data records from as far back as 1971 while others do not begin until 1995 and there was limited data available for some of the shellfish species. Table 3 lists the species included in the study and the years for which data was available for analysis and modeling.

SHELLFISH

DFO shellfish surveys have been conducted off the Newfoundland shores, for some species, since the mid-sixties. Many of these surveys, unlike the finfish surveys, are directed surveys that use fishing gear to target a particular species. Clam dredges (8 and 12 ft – 2.4 and 3.6m) were used to survey for Iceland scallop, sea scallop and surf clam. A scaling factor was applied to data collected with the smaller dredges to account for the larger area fished by the twelve-foot dredge. Northern shrimp is the only shellfish species in this study that was collected with the finfish surveys, using either the Engel or the Campelen trawl.

Unlike the finfish LSM data the shellfish research vessel (RV) surveys do not contain data on spawning condition but rather focus on abundance. In lieu of spawning data for the sedentary species, like scallops and clams, determining higher intensity spawning areas was evaluated by looking at abundance represented by the average number organisms caught. Like scallop and clams, the shrimp data does not contain spawning information and thus, these maps also depict abundance. In addition, the timing of spawning for the shellfish species is determined solely from the literature.

POTENTIAL MAPPING

The models presented in this report were generated using SPANS Potential Mapping. Potential Mapping is an appropriate analytical technique for ratio or interval point data representing a non-continuous phenomenon. This type of data is characterized by high degree of variability along with an uneven spatial distribution (Burke 1997), typical of the data collected on the RV surveys. Many of the techniques and selection of model parameters used to apply Potential Mapping to the RV survey data were adapted from Kulka (1998) and Kulka *et al.* (2003).

Potential Mapping is a spatial analysis technique that creates continuous trend surface maps from discrete point data. This is to say that spatially referenced point information can be used to calculate a continuous, or near-continuous, surface representative of an attribute of the data. The trend surface calculations were performed using a selected attribute of the data points, referred to as the Z-value. In this study, the point data represented DFO research vessel fishing sets and the Z-value being modeled, depending upon the species, was the number of female fish in spawning condition or the number of individuals caught. Calculating the average of these Z-values created the trend surface. In addition to selecting a Z-value, there were several user-defined parameters that influenced the behaviour of the model. These parameters are described below and are illustrated in Fig. 2.

Potential Mapping created a grid over the entire study area, then used this grid on which to build the modeled surface. The size of each grid cell is determined by a parameter that governs the resolution of the modeled surface and is chosen to create grid cells small enough to represent the data. In these models the grid cells were approximately 530 m^2.

Once the grid size had been set, a sampling radius was chosen for the data points. The sampling radius is a parameter that determines the 'area of influence' around each data point. Figure 3 illustrates the effect of the sampling radius parameter and how it works within the model calculations. This radius is chosen as the smallest value that creates a continuous surface with the minimal number of gaps while still expressing the variability in the data (Kulka *et al.* 2003). Too small a sampling radius would result in the areas of influence not overlapping and fail to create a continuous surface. A huge sampling radius would have an averaging effect and could potentially obscure any trends in the data. Figure 3 illustrates the effect of varying the sampling radius on a potential mapping model where the three panels demonstrate sampling radii of 5, 18 and 35 kilometers respectively. Through a series of trials it was determined that the optimum sampling radius for the volume and distribution of these data was 18 km, creating an area of influence of approximately 1000 km^2 for each point. The sampling radius was kept constant for all species in the study.

Once all parameters have been set, the model computes the values for each grid cell that will make up the interpolated surface. This calculation is done by averaging the values for each data point whose sampling radius overlaps the center of the grid cell as shown in Fig. 2. The point data Z-values are weighted by the behavior dictated by the decay rate. The modeled grid cells were then classified into one of eight predetermined legend categories. The GIS calculated the legend categories to create maps that reflected approximately equal distributions of each category in order to create an easy to read map product. A single representative dataset was chosen to prepare the legend for each species. Legend categories and colors were kept consistent within each species in order to illustrate spatial and temporal changes.

MAP PRODUCTION

A basemap was developed to create a frame of reference for the spawning/abundance models. This map is comprised of both physical features and political and regulatory boundaries of the oil and fishing industries. The predominant physical features that describe the study area are the bathymetric contours, shown in Fig. 1 in varying shades of blue. The political and regulatory boundaries, shown also in Fig. 1, depict functional boundaries and spatial references for both the oil and fishing industries, including the Northwest Atlantic Fisheries Organization (NAFO) Divisions, the 200-mile limit and the 2004 oil and gas lease parcels. The oil and gas lease parcels identify where the greatest amount of oil and gas activities are taking place. The relative location of current and future developments to the areas of higher intensity spawning was critical in evaluating the potential impacts on any aquatic resources in the area.

Combining key physical features and political boundaries into a single figure created the project basemap. This basemap was common to all spawning maps and it is therefore necessary to document these features only once and understand that it will be consistent throughout the entire report. The final basemap, shown in Fig. 4, contains both major physical and political features that create a frame of reference for the spawning maps. To simplify the map composition, some of the text labels have been removed and all the oil and gas leases have been combined into a single region.

The resulting maps from the spatial analysis were exported to another GIS application, MapInfo (MapInfo Corporation). MapInfo is more a powerful GIS with respect to cartographic layout and map production. In MapInfo, basemap layers were created, titles and annotations were added, and output files were created. These output files were then imported to CorelDraw version 10 (Corel Corporation), where the final annotations were added to the maps.

RESULTS AND DISCUSSION

AMERICAN PLAICE (*HIPPOGLOSSOIDES PLATESSOIDES*)

American plaice are said to spawn between February and September on the Grand Banks, with peak spawning occurring from April through to June (Morgan 2001; Nevinsky and Serebriakov 1975). The analysis of the RV data agreed with the published literature as it found that the peak spawning occurred in May. The pre-1998 data showed that the spawning stock is found primarily in 3L, whereas the most recent data shows the greatest concentrations occurring in 3N, on the tail of the Grand Bank. This change illustrated the dynamic nature of the spawning areas. Refer to Fig. 5a-f and Fig. 6a-c.

ATLANTIC COD (*GADUS MORUHA*)

The spawning times of Atlantic cod on the Grand Banks typically occurs from February to June, peaking in May (Myers *et al.* 1993). The DFO research data supported this time frame with the greatest number of spawning females being caught in May and June. Historically, the greatest numbers of spawning females were found in 3L. Spawning occurs primarily in the spring, however Atlantic Cod have been known to have a limited spawning throughout the entire year (Pepin and Helbig 1996). Refer to Fig. 7a-e and Fig. 8a-c.

HADDOCK (*MELANOGRAMMUS AEGLEFINUS*)

Generally, haddock spawning on the Grand Banks begins in March and continues through to August or September. For southern 3NO, Templeman *et al*. (1978) concluded that the peak spawning occurred in June and July while the RV data suggests an earlier, May spawning peak. Minimal spawning females were found in 3L and the 3P spawning peak appears to occur in March. The early 3P spawning peak was also reported by Templeman and Bishop (1979). Refer to Fig. 9a-d and Fig. 10a-b.

REDFISH (*SEBASTES* SPP.)

Spawning Redfish were found from March through to July in different places on the Grand Banks. The spawning maps showed that much of the early April spawning occurred off the south coast of Newfoundland in 3P, which was consistent with the findings of Ni and Templeman (1985). Spawning in 3NO occurred primarily in May along the edge of the Grand Bank, while in June most spawning females were found on the eastern edge of the Grand Bank in 3L and the northern portion of 3N. The maps showed that the location of the spawning areas has remained relatively constant. Refer to Fig. 11a-c and Fig. 12a-d.

WITCH FLOUNDER (*GLYPTOCEPHALUS CYNOGLOSSUS*)

Witch flounder on the Grand Banks spawn primarily between March and June (Bowering 1990). This was supported by the survey data where the largest numbers of spawning females were found in April through to July. In the peak spawning season, the largest concentrations of spawning females were found on the southern part of the Grand Bank in NAFO Div. 3O. Later in the summer, the highest concentrations were found on the northern part of the 3L and in 3N. Refer to Fig. 13a-f and Fig. 14a-c.

YELLOWTAIL FLOUNDER (*LIMANDA FERRUGINEA)*

Analysis of the research vessel data showed the greatest concentration of yellowtail flounder spawning was in the central and southern part of the Grand Bank. This analysis agreed with Pitt (1970) who suggested that spawning is concentrated on southern portion of the Grand Banks with some variation for time of year. The greatest numbers of spawning females was found between April and June, which again agrees with Pitt (1970) who concluded that spawning occurred between May and July. Refer to Fig. 15a-c and Fig. 16a-c.

NORTHERN SHRIMP (*PANDALUS BOREALIS)*

Parsons (1993) stated that Northern Shrimp spawn in the inshore shallow Newfoundland waters. Eggs were laid in the late summer and remain attached until the following spring when the females moved to the shallow coastal waters for spawning (Nicolajsen 1994). The survey data shows the greatest abundances of Northern shrimp around the Flemish Cap, along the eastern and northern edges of the Grand Banks in 3LN, and near the south coast in 3P. The limited amount of data available prevented the development of historical versus recent models. Refer to Fig. 17.

ICELAND SCALLOP (*CHLAMYS ISLANDICA)*

Iceland scallop are known to spawn in the late summer (DFO 1999). The most recent research vessel data showed the greatest concentration of Iceland scallop along the edge of the Grand Bank near the boundary between 3L and 3N as well as in 3P. Data prior to 1994 showed a different trend with a larger amount of Iceland scallop in 3Ps and less in 3N. Refer to Fig. 18a-b.

SEA SCALLOP (*PLACOPECTIN MAGELLANICUS)*

Analysis of the research vessel surveys showed that the greatest concentrations of Sea scallop were found exclusively in 3P. Squires (1962) determined that spawning occurred on the west and south coasts of Newfoundland from late August through to September. Packer *et al*. (1999) stated that spawning takes place in September and October. In addition, Squires

(1962) noted that spawning was temperature dependant and may not occur every year. Refer to Fig. 19a-b.

SURF CLAM (*SPISULA SOLIDISSIMA)*

Cargnelli *et al.* (1999) suggested that there are two Surf clam spawning peaks, one in the summer / early fall and another smaller one in October. There was limited survey data for surf clams however the data that does exist showed the greatest abundance occurred along the eastern edge of the Grand Banks in NAFO Division 3N. The limited amount of data made it impossible to divide the dataset and present the both recent and historical trend maps. Refer to Fig. 20.

DISCUSSION

This project has, within the scope of the DFO research vessel surveys, identified the location and timing of higher intensity spawning areas for ten Grand Banks finfish and shellfish species. When interpreting the results of this study it is important to understand that those regions identified as higher intensity spawning areas are where more spawning was shown to occur 'within the scope of the RV surveys'. The distribution of higher intensity spawning areas by month is, in part, a result of survey coverage. It is very possible a species may be spawning at the same time on other parts of the Grand Banks, away from the survey location in any given month. For example, the edge of the Grand Banks in 3NO was identified as a May spawning area for redfish when, because of an absence of data, it is unknown if spawning occurred in other places.

The spawning intensity maps not only identify the locations of the spawning areas but also illustrate the temporal and spatial variability of these spawning areas. The spatial variability is apparent in two temporal scales, historically and seasonally. Historical changes in spawning areas illustrate where the stocks have been found in the past and perhaps may be found in the future. Seasonal variation in the location of higher intensity spawning areas is more important when planning seismic surveys so as to avoid the most active spawning areas. There were considerable changes in the spawning areas for some species over both the short and long terms. Mapping the spawning areas using two temporal periods provided a more thorough picture of the species spawning patterns.

CONCLUSIONS

The Grand Banks are a biologically diverse ecosystem supporting many species of plants and animals as well as a rapidly expanding oil and gas industry. Expansion in the offshore oil industry relies heavily on seismic exploration surveys and it is important that these surveys do not disrupt the normal life history of the Grand Banks fish species. With the expanding scope of exploration it is important that these surveys are planned such that they avoid the areas of highest intensity spawning. This study used a Geographic Information System to map the timing and location of the spawning peaks of ten Grand Banks fish species. Industry and regulatory bodies can use these maps when planning future seismic studies to minimize any potential overlap between seismic surveys and spawning activities.

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Table 1. Female maturity stages from Templeman *et al.* 1978.

Maturity Code	Description
Immature	Ovary small, grey to pink in color: membrane thin and translucent; eggs not visible to the naked eye.
Spent L	Ovary thick-walled with no new eggs visible to the naked eye; spent in the previous year.
Mat A-P	Eggs visible to naked eye in ovary itself; all eggs opaque; maturing to spawn in present year.
Mat B-P	Opaque and clear eggs present with less than 50% of the volume being clear eggs; spawning in the present year.
Mat C-P	50% or more of the volume are clear eggs; this stage also include the ripe condition where the ovarian content is almost liquid with clear eggs; spawning in the present year.
Partly Spent P	Ovary not full as in Mat C-P; some eggs extruded but many clear eggs remaining.
Spent P	Spawning completed in present year by possibly a few clear eggs remaining; no new opaque eggs visible to the naked eye.
Spent P Mat N	Spawning completed in present year; and new opaque eggs for spawning in the next year visible to the naked eye; this stage becomes Mat A-P in January of the next year.
Mat A-N	No evidence of previous spawning; but new opaque eggs for spawning in the next year visible to the naked eye; this stage becomes Mat A-P in January of the next year.

Table 2. Redfish female maturity codes used in study.

Maturity Code	Description
Mat CP Plus	Evidence of larvae forming
Partly Spent	Larvae hatched and ready for extrusion or is in running condition

Table 3. Sampling surveys.

	Species	Years Surveyed
Finfish	American plaice	1987 – 2002
	Atlantic cod	1971 – 1972, 1974 – 2002
	Haddock	1975, 1978 – 2002
	Redfish	1995 – 2002
	Witch flounder	1980 – 2002
	Yellowtail flounder	1987 – 2003
Shellfish	Iceland scallop	1979, 1983 – 1998
	Northern shrimp	1974, 1978, 1994 – 2001
	Sea scallop	1965, 1979, 1983 – 1994, 1996 –1998
	Surf clam	1996 – 1998

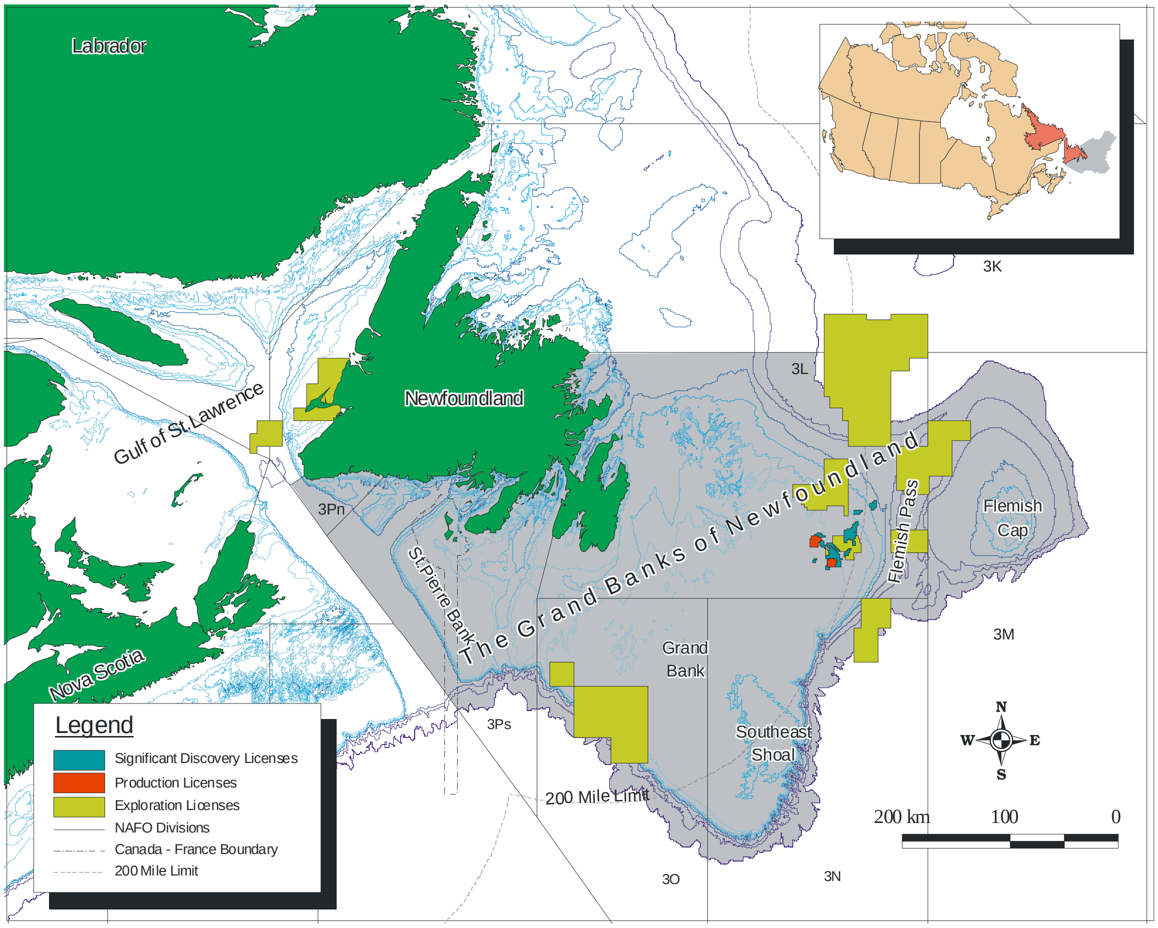

Figure 1. Study area.

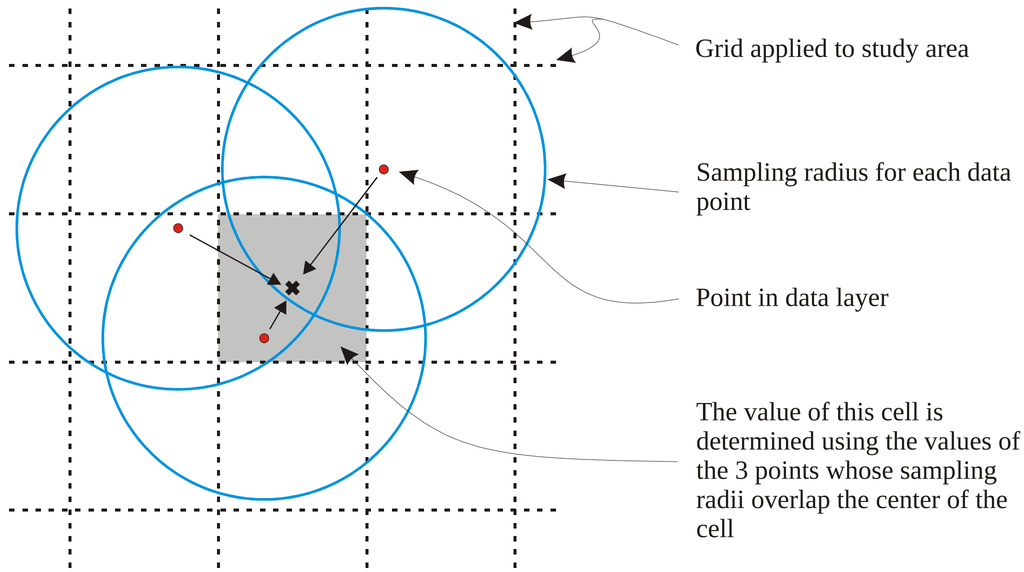

Figure 2: Potential Mapping Parameters after Burke (1997).

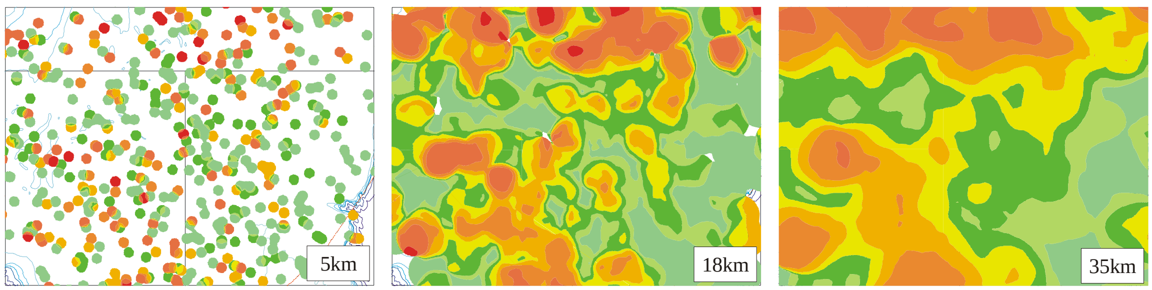

Figure 3: Effect of varying sampling radius on trend surfaces.

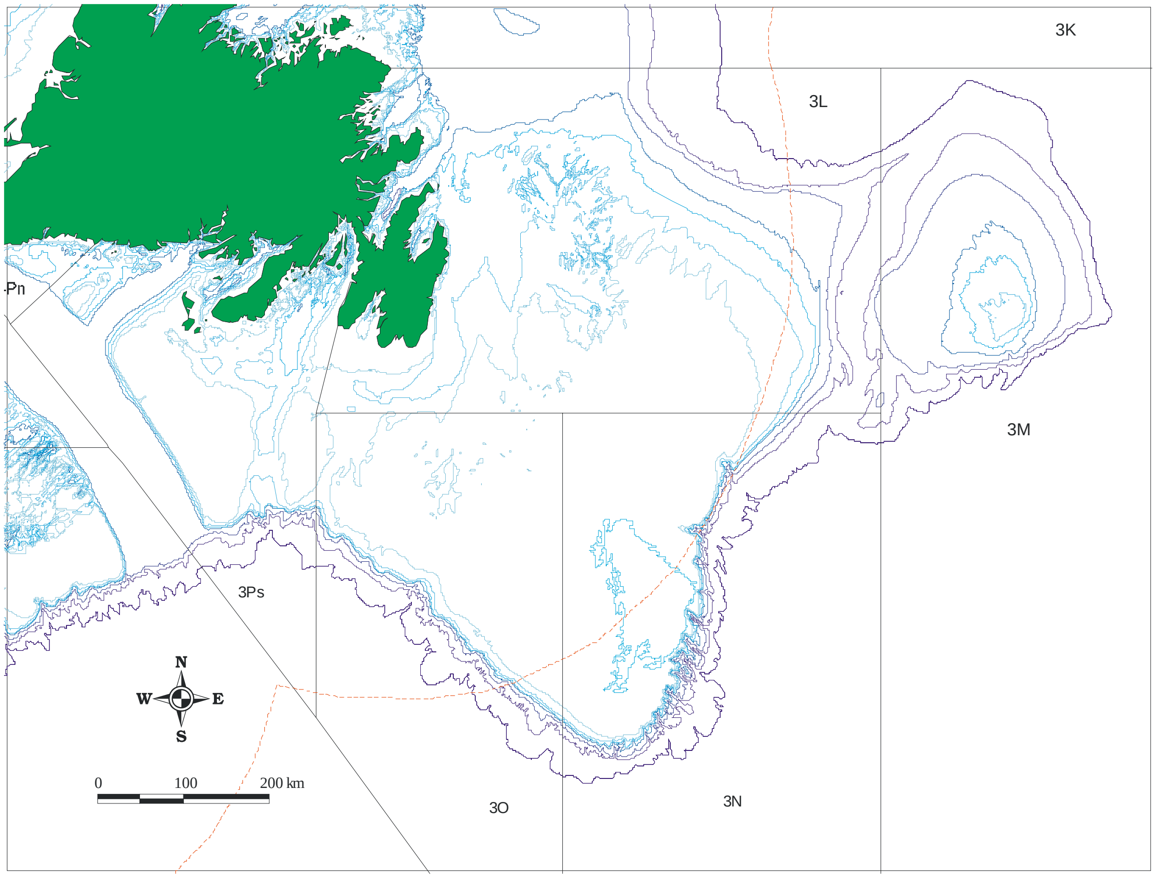

Figure 4: Project Basemap.

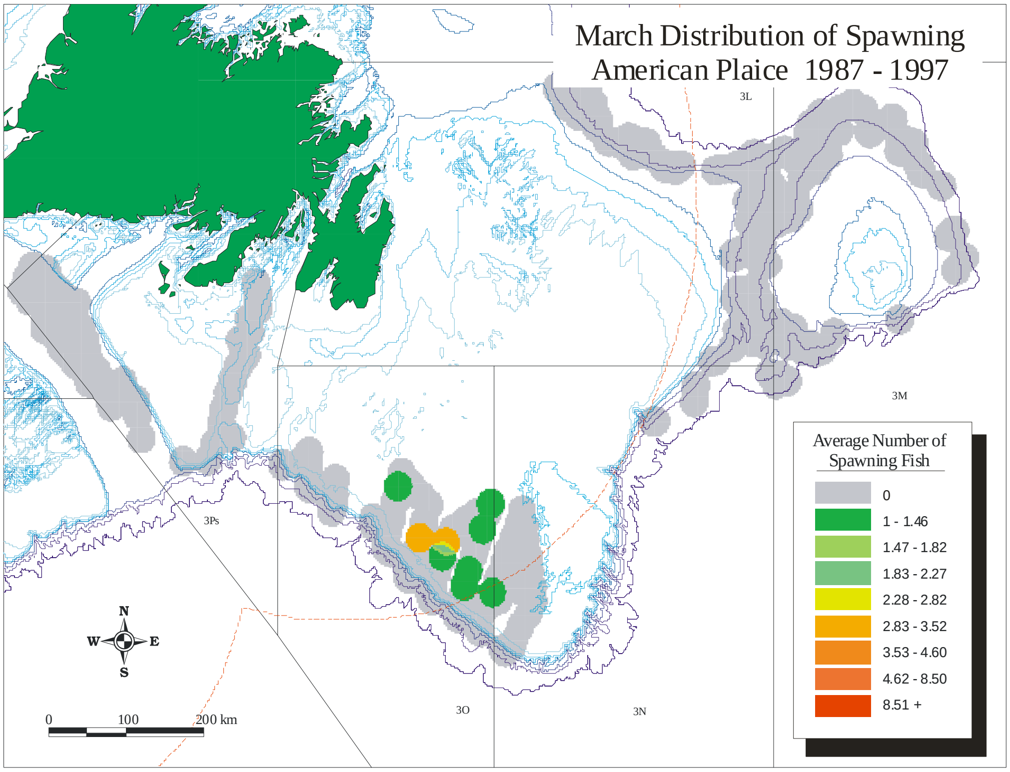

Figure 5a: March distribution of spawning American plaice, 1987-97. The 0 class represents survey sets where no fish were caught.

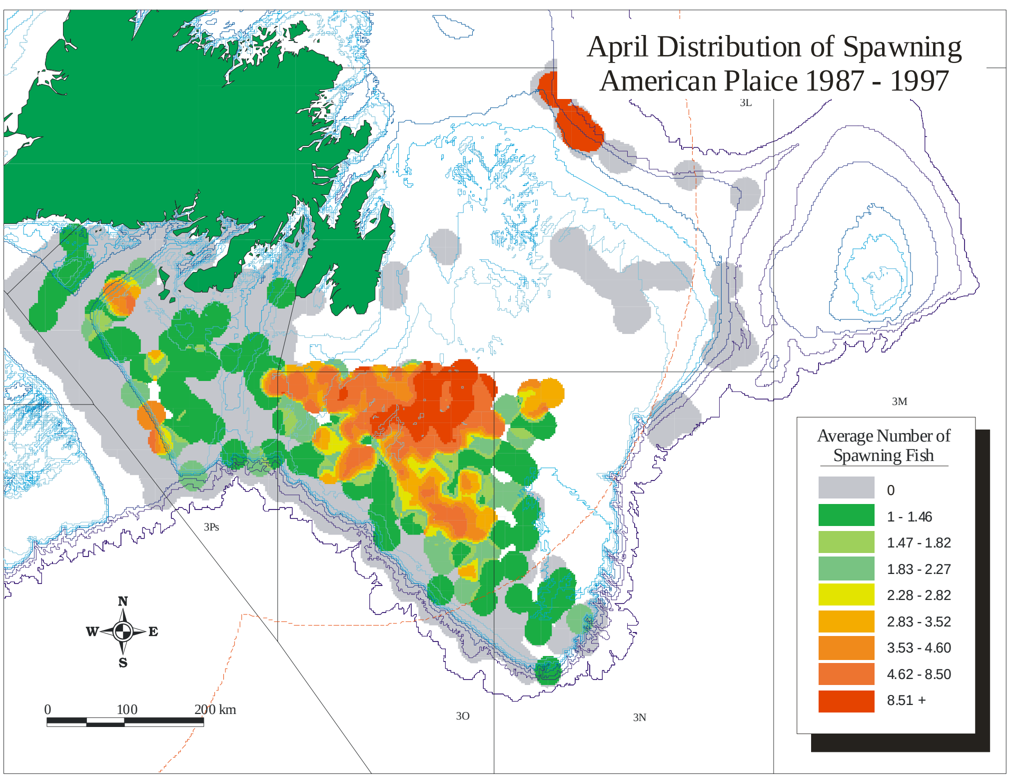

Figure 5b: April distribution of spawning American plaice, 1987-97. The 0 class represents survey sets where no fish were caught.

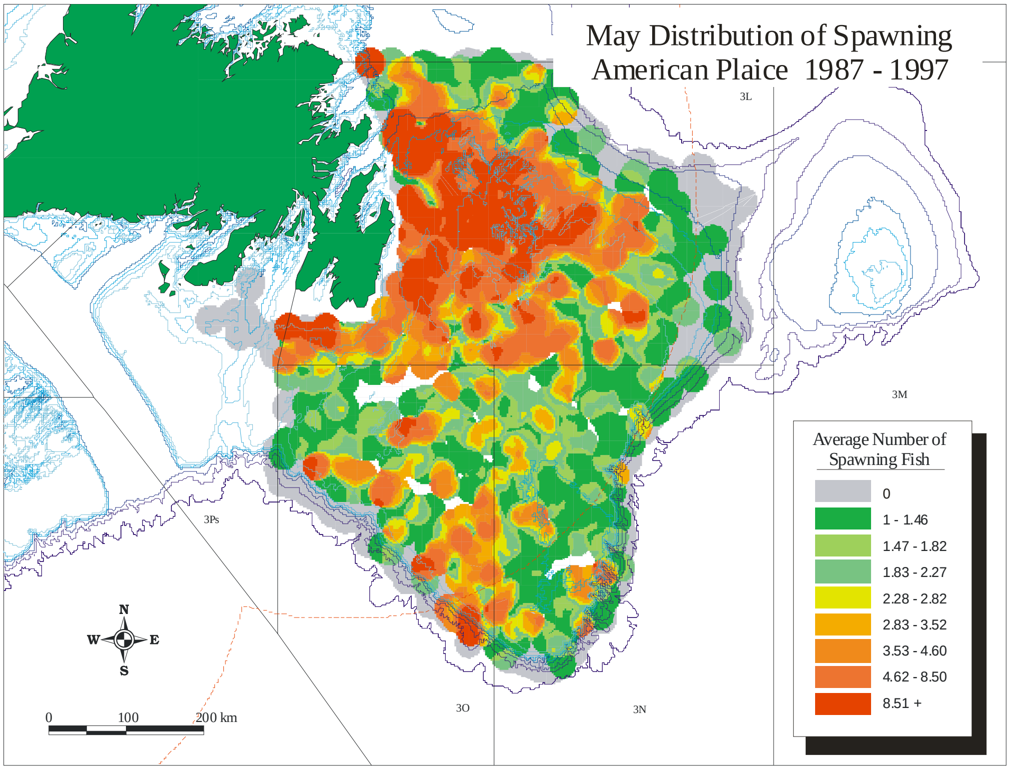

Figure 5c: May distribution of spawning American plaice, 1987-97. The 0 class represents survey sets where no fish were caught.

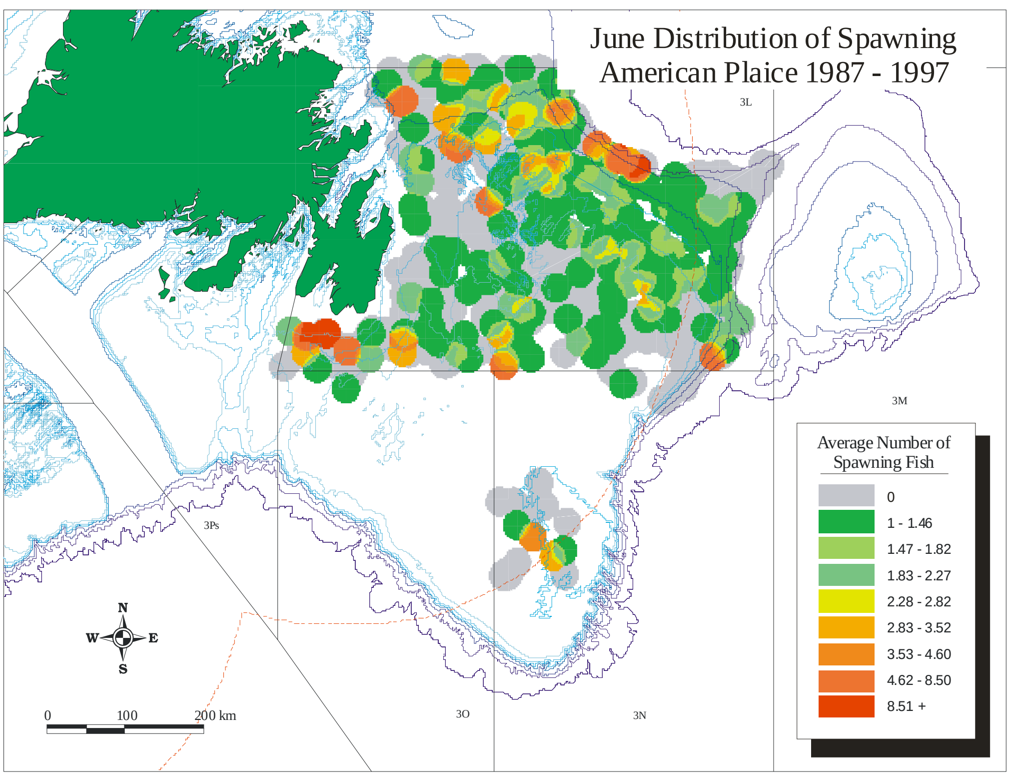

Figure 5d: June distribution of spawning American plaice, 1987-97. The 0 class represents survey sets where no fish were caught.

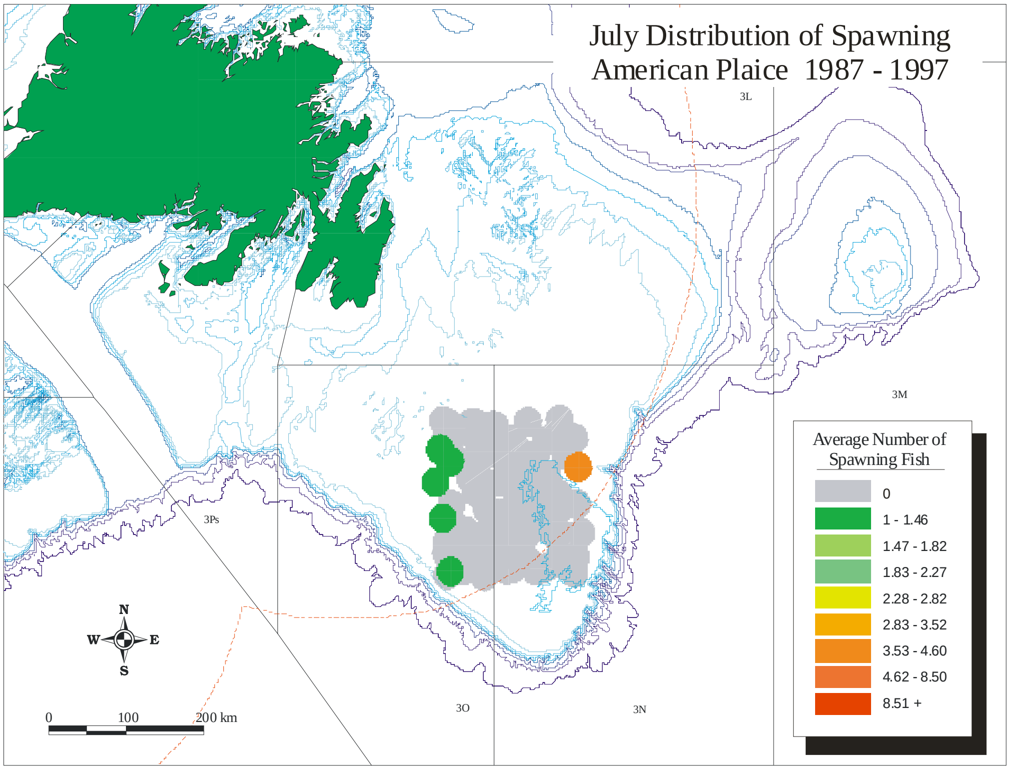

Figure 5e: July distribution of spawning American plaice, 1987-97. The 0 class represents survey sets where no fish were caught.

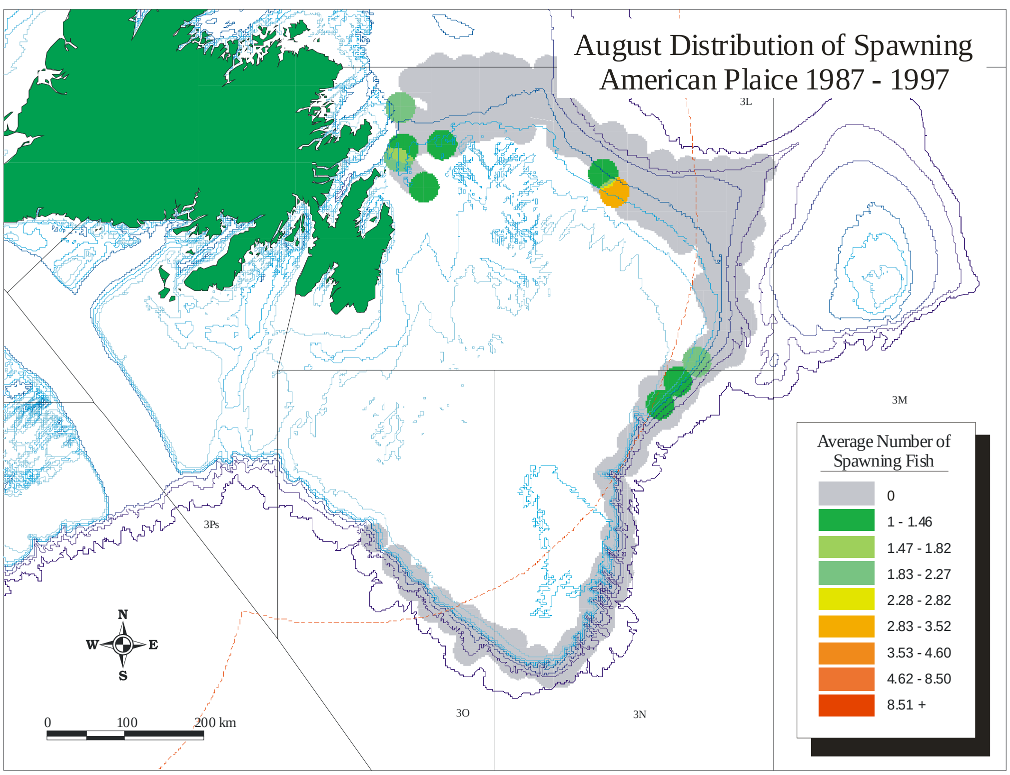

Figure 5f: August distribution of spawning American plaice, 1987-97. The 0 class represents survey sets where no fish were caught.

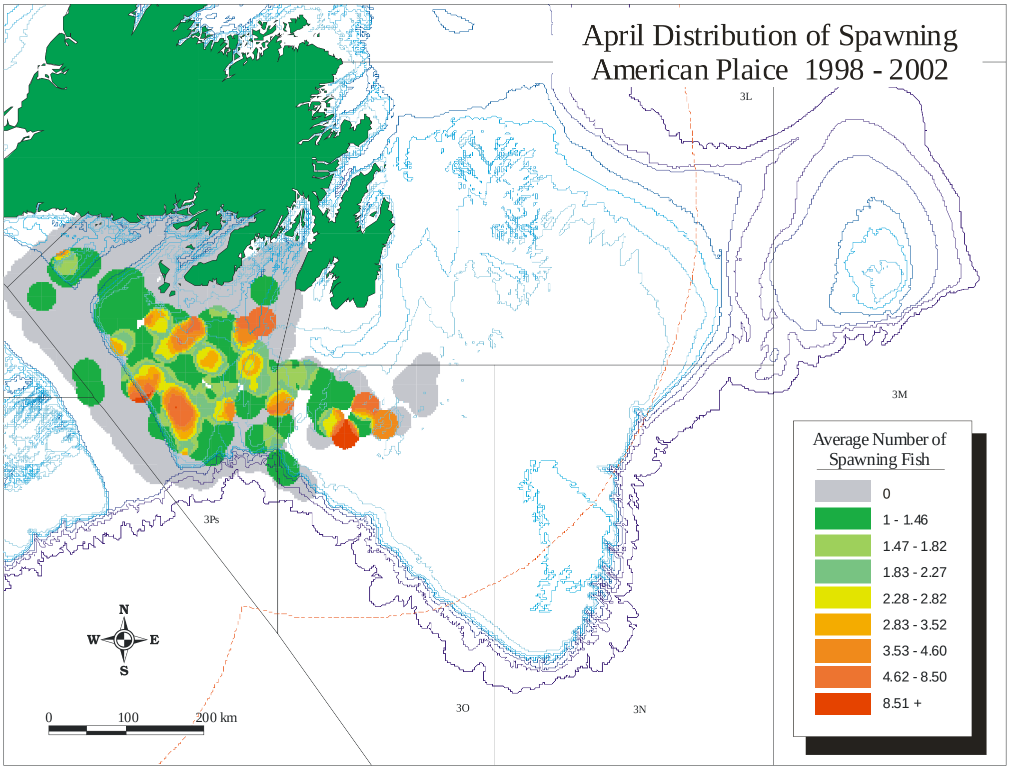

Figure 6a: April distribution of spawning American plaice, 1998-2002. The 0 class represents survey sets where no fish were caught.

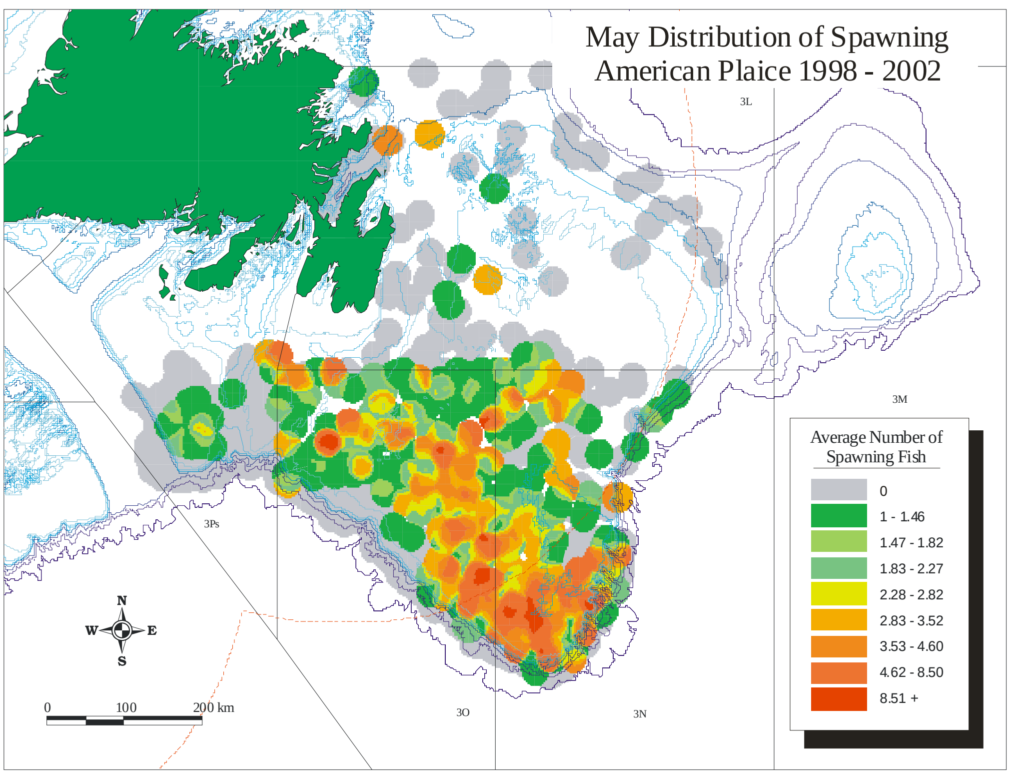

Figure 6b: May distribution of spawning American plaice, 1998-2002. The 0 class represents survey sets where no fish were caught.

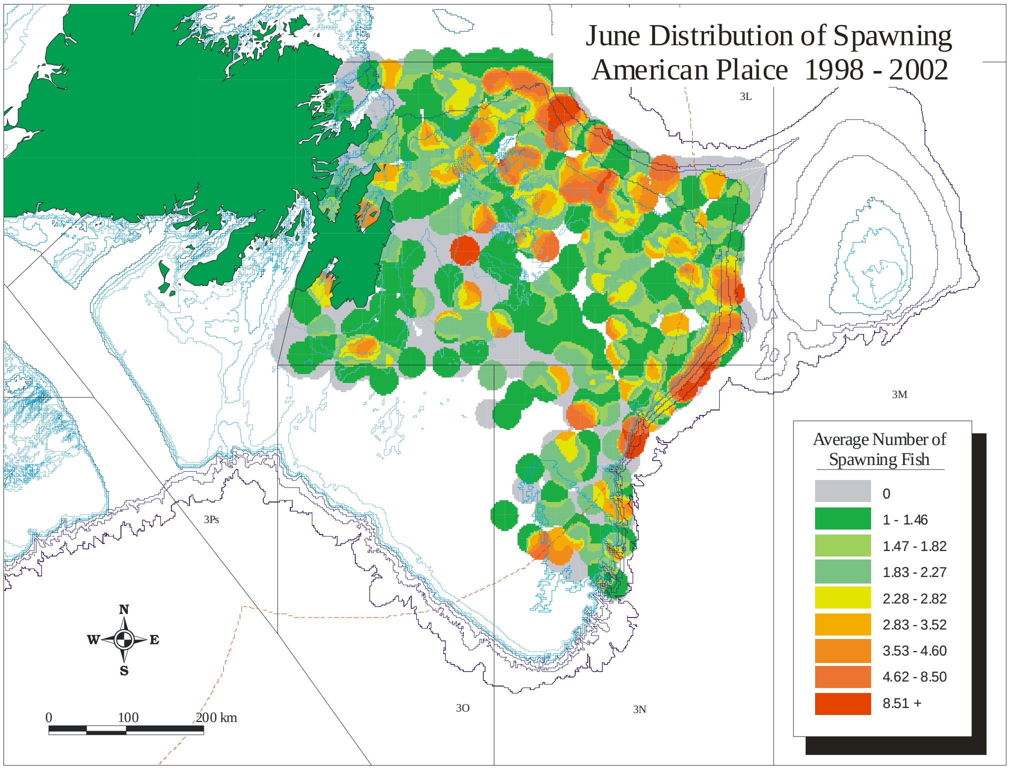

Figure 6c: June distribution of spawning American plaice, 1998-2002. The 0 class represents survey sets where no fish were caught.

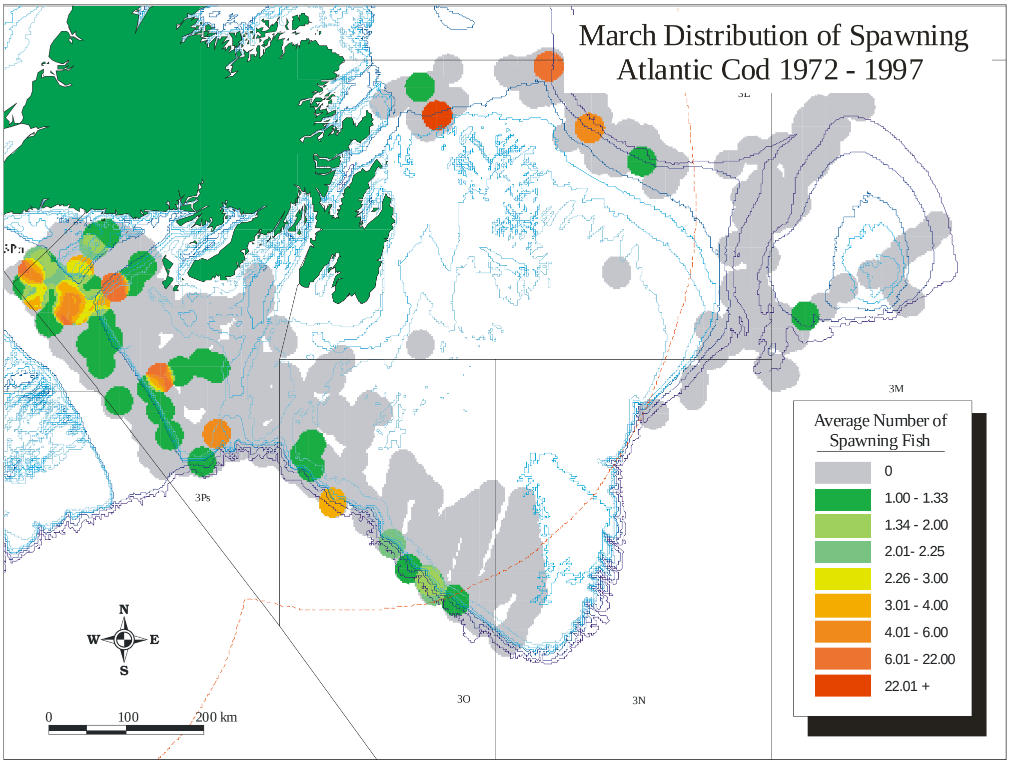

Figure 7a: March distribution of spawning Atlantic cod, 1972-97. The 0 class represents survey sets where no fish were caught.

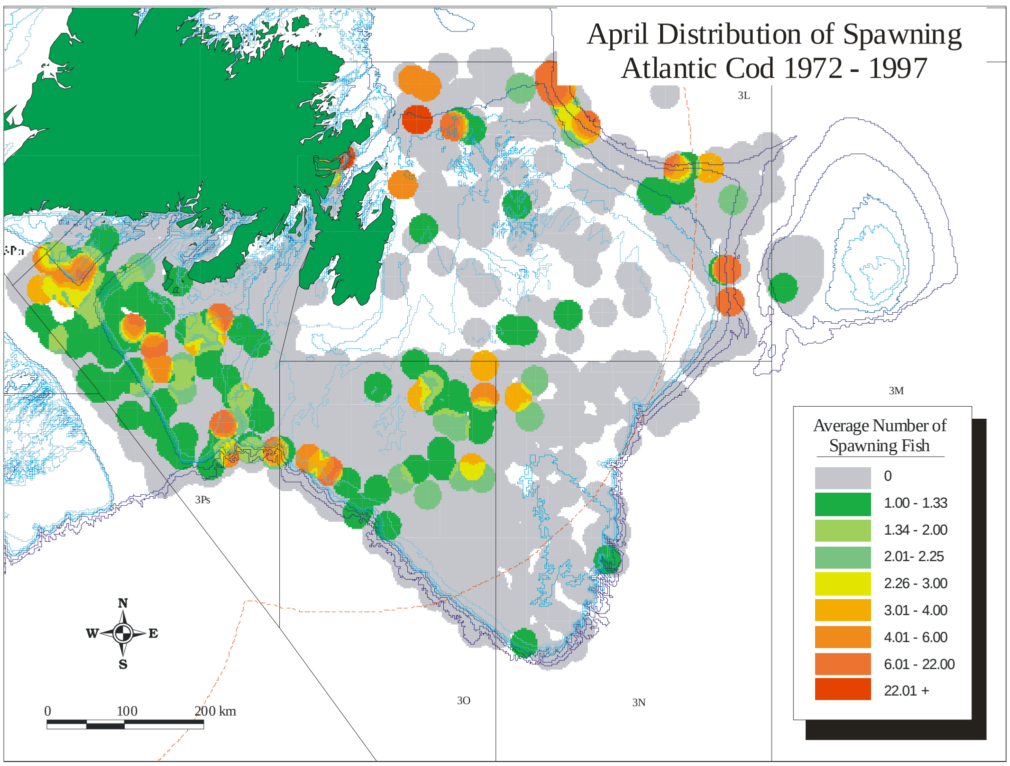

Figure 7b: April distribution of spawning Atlantic cod, 1972-97. The 0 class represents survey sets where no fish were caught.

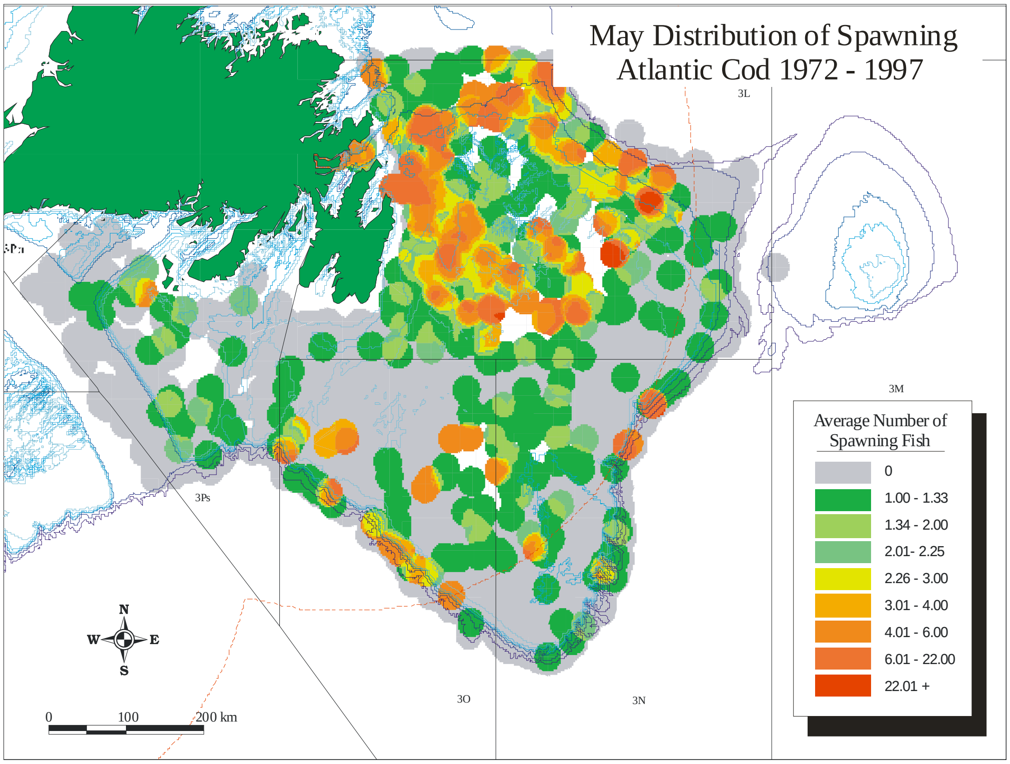

Figure 7c: May distribution of spawning Atlantic cod, 1972-97. The 0 class represents survey sets where no fish were caught.

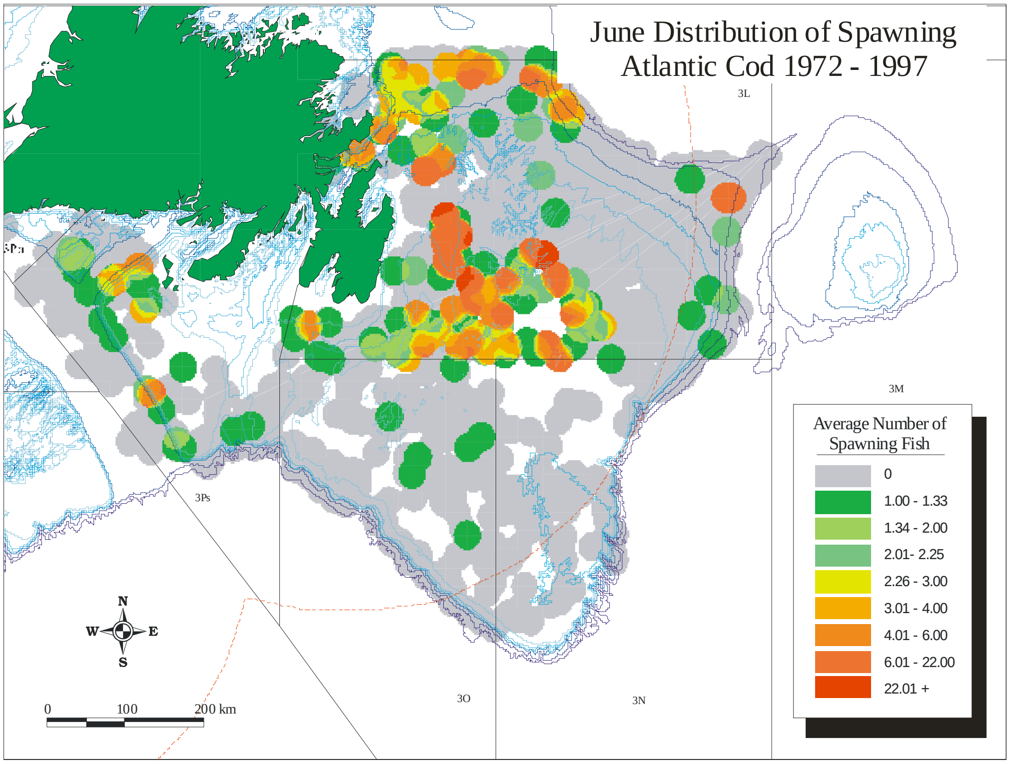

Figure 7d: June distribution of spawning Atlantic cod, 1972-97. The 0 class represents survey sets where no fish were caught.

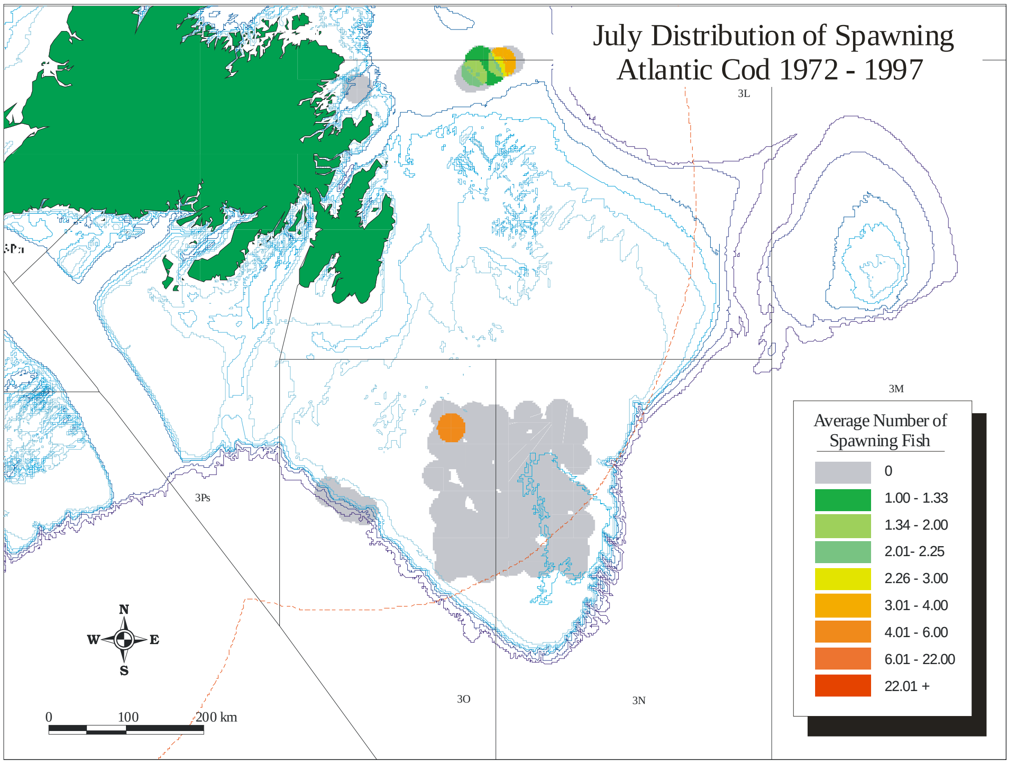

Figure 7e: July distribution of spawning Atlantic cod, 1972-97. The 0 class represents survey sets where no fish were caught.

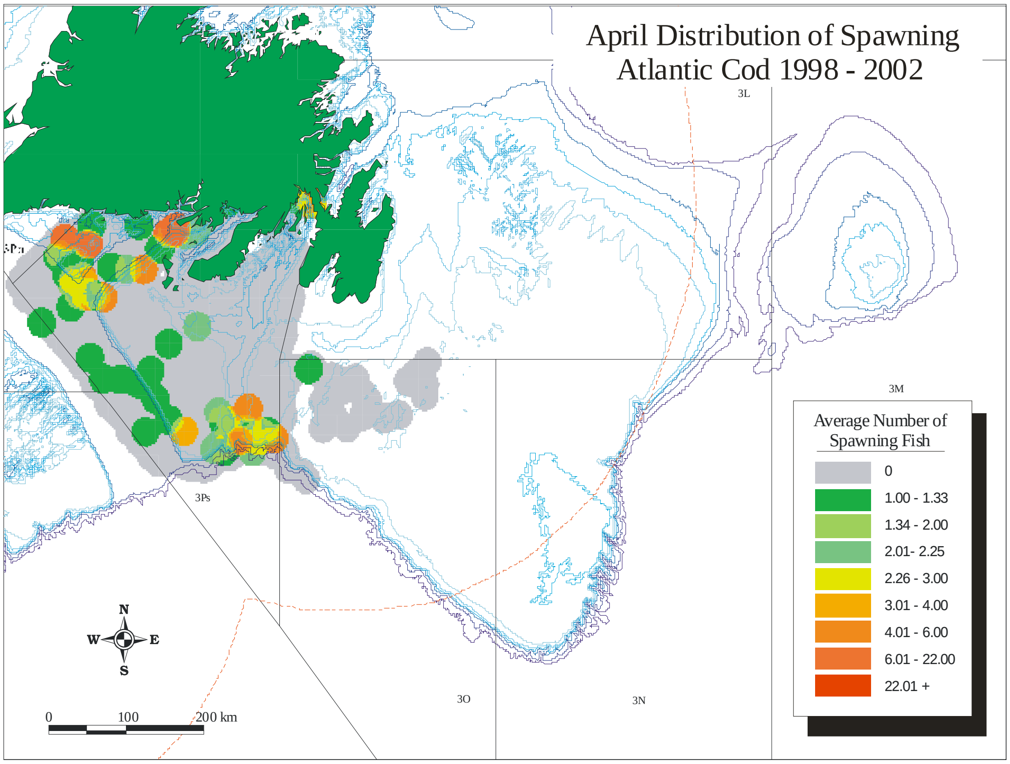

Figure 8a: April distribution of spawning Atlantic cod, 1998-2002. The 0 class represents survey sets where no fish were caught.

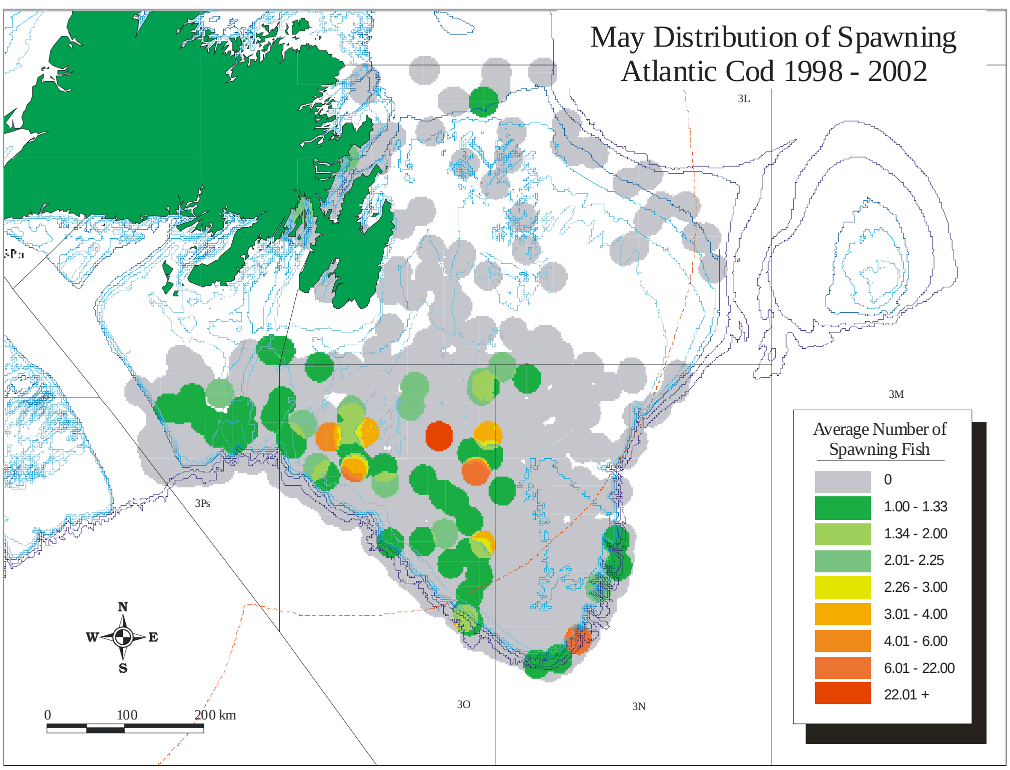

Figure 8b: May distribution of spawning Atlantic cod, 1998-2002. The 0 class represents survey sets where no fish were caught.

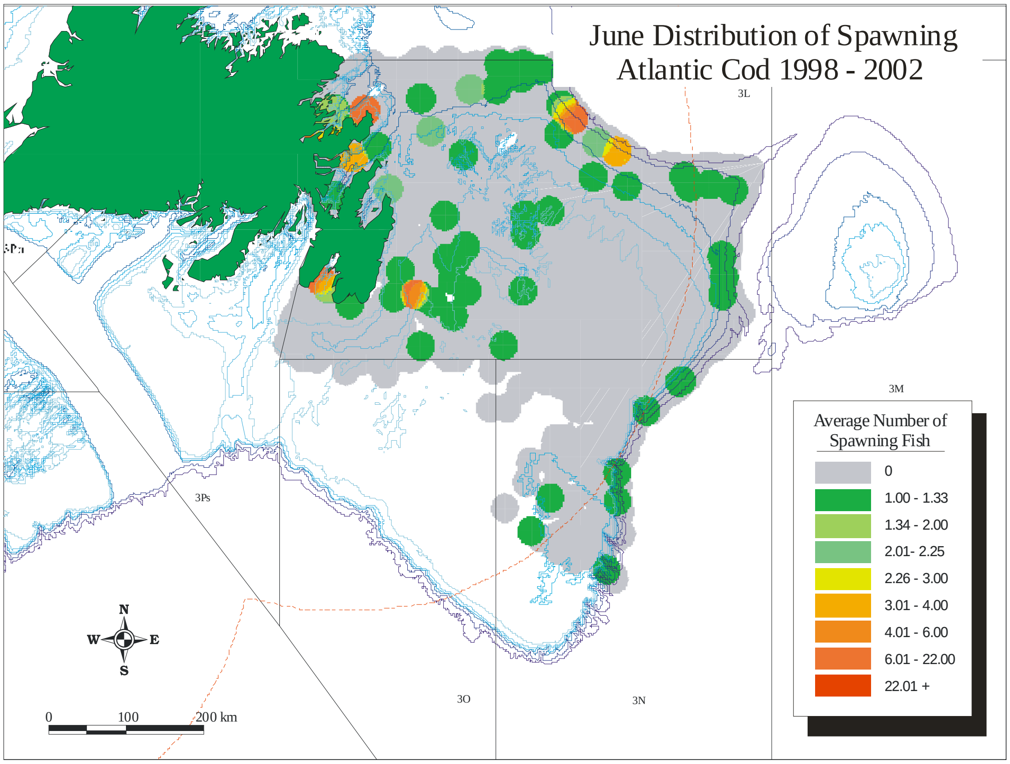

Figure 8c: June distribution of spawning Atlantic cod, 1998-2002. The 0 class represents survey sets where no fish were caught.

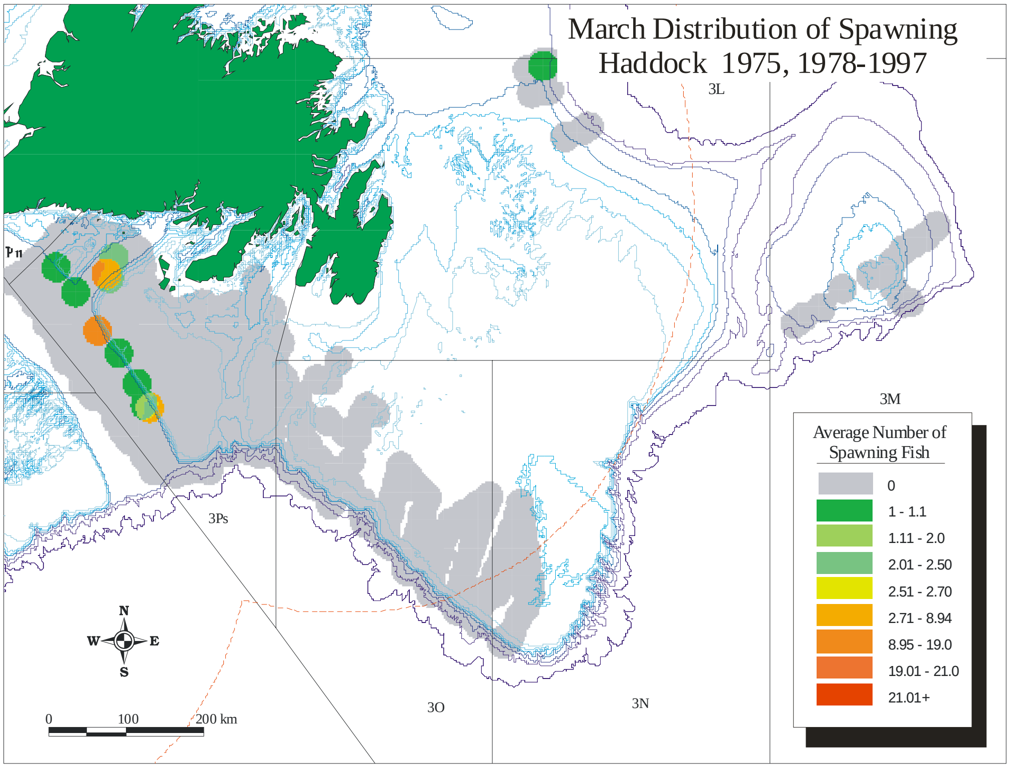

Figure 9a: March distribution of spawning Haddock, 1975, 1978-97. The 0 class represents survey sets where no fish were caught.

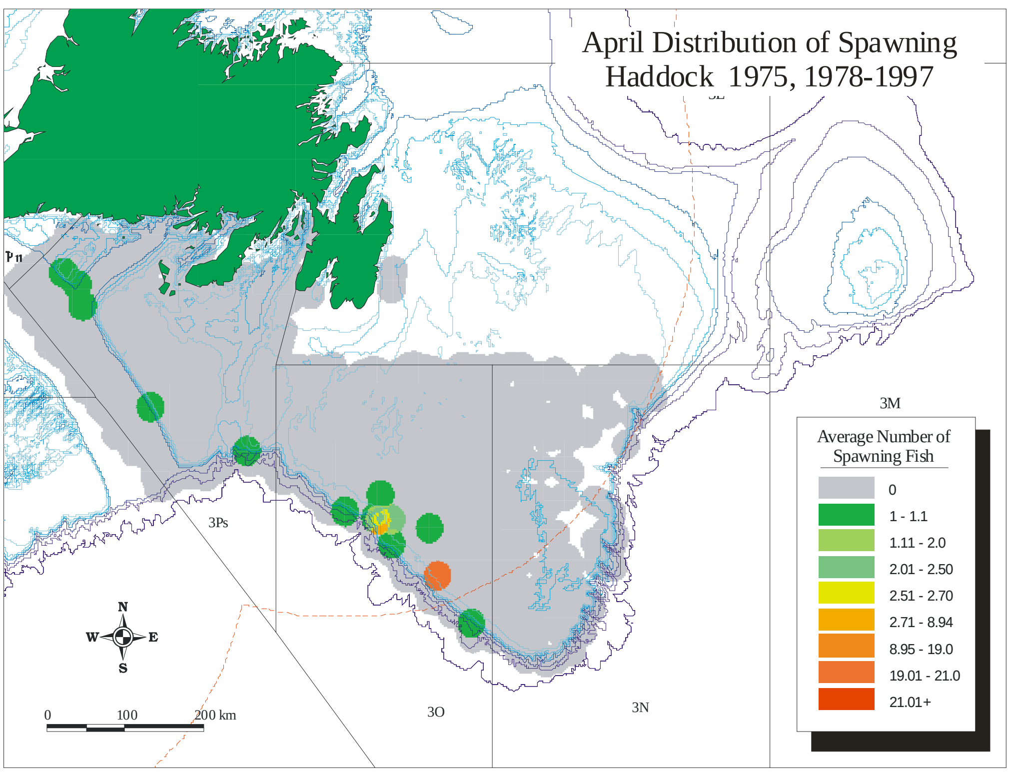

Figure 9b: April distribution of spawning Haddock, 1975, 1978-97. The 0 class represents survey sets where no fish were caught.

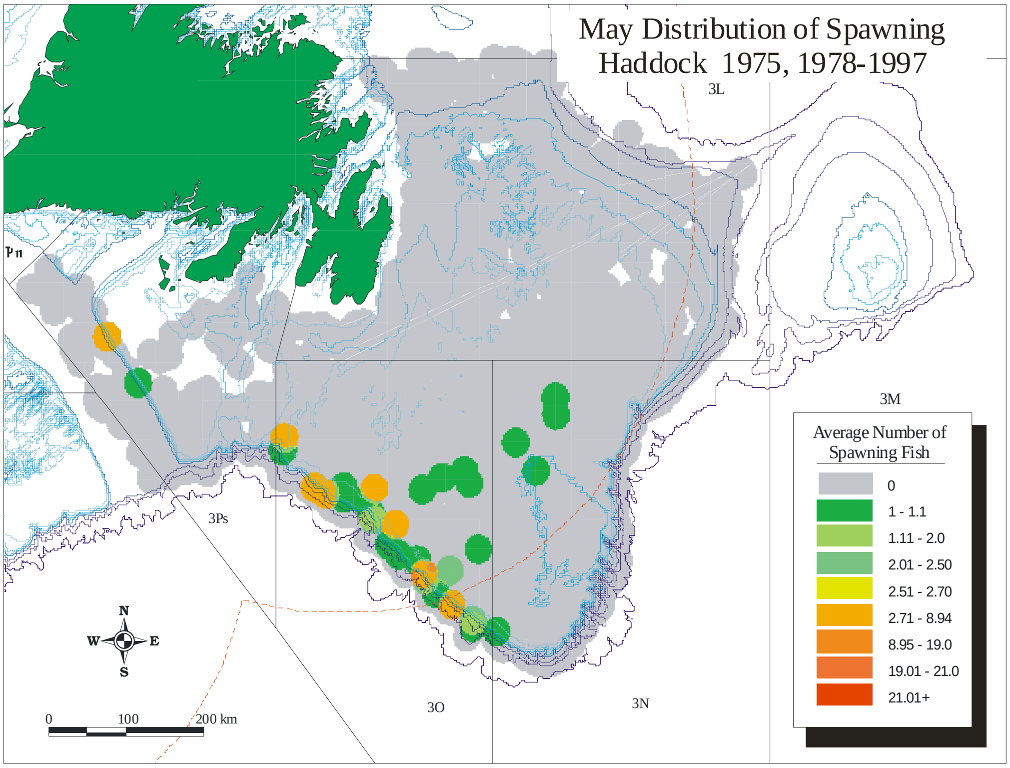

Figure 9c: May distribution of spawning Haddock, 1975, 1978-97. The 0 class represents survey sets where no fish were caught.

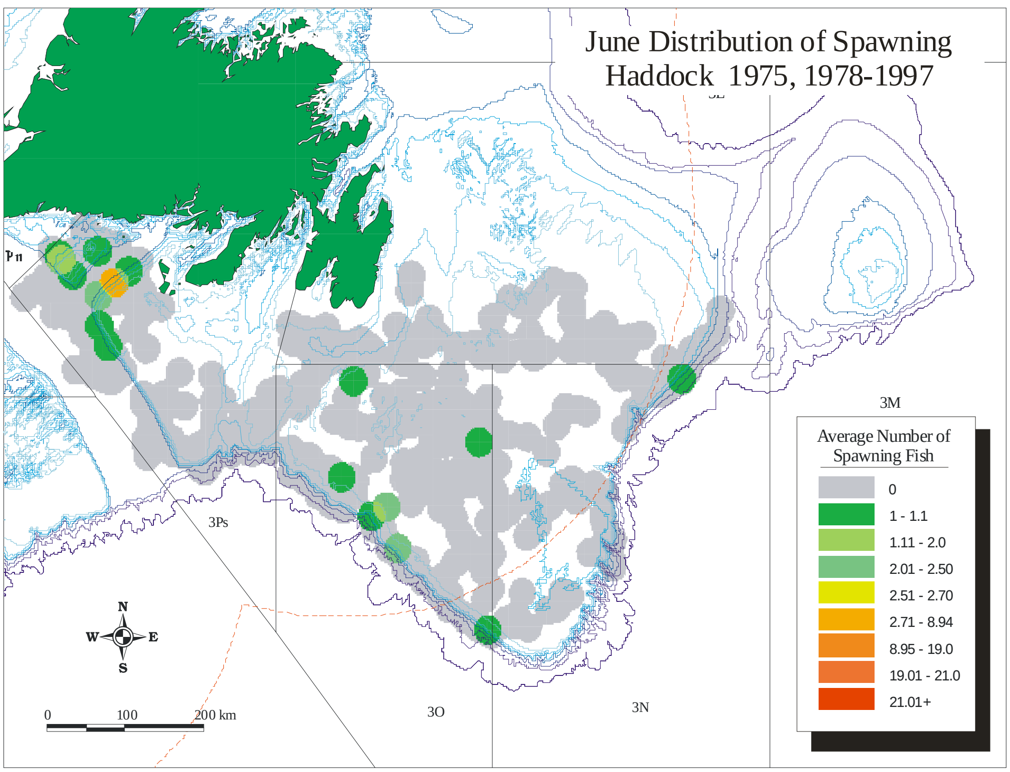

Figure 9d: June distribution of spawning Haddock, 1975, 1978-97. The 0 class represents survey sets where no fish were caught.

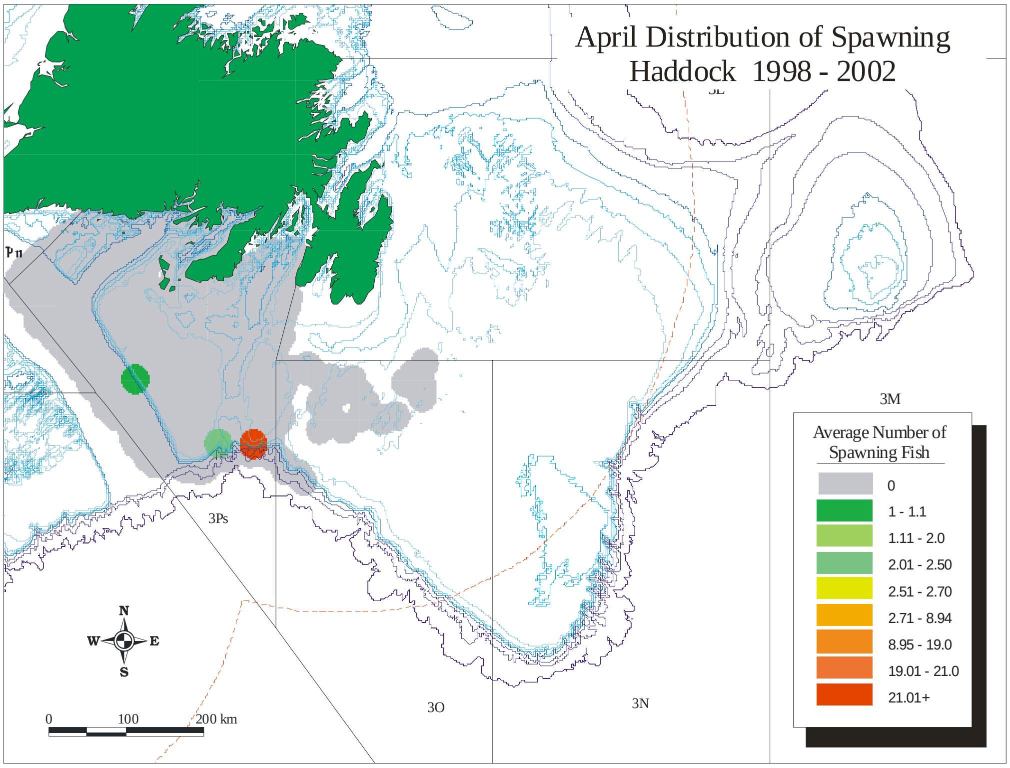

Figure 10a: April distribution of spawning Haddock, 1998-2002. The 0 class represents survey sets where no fish were caught.

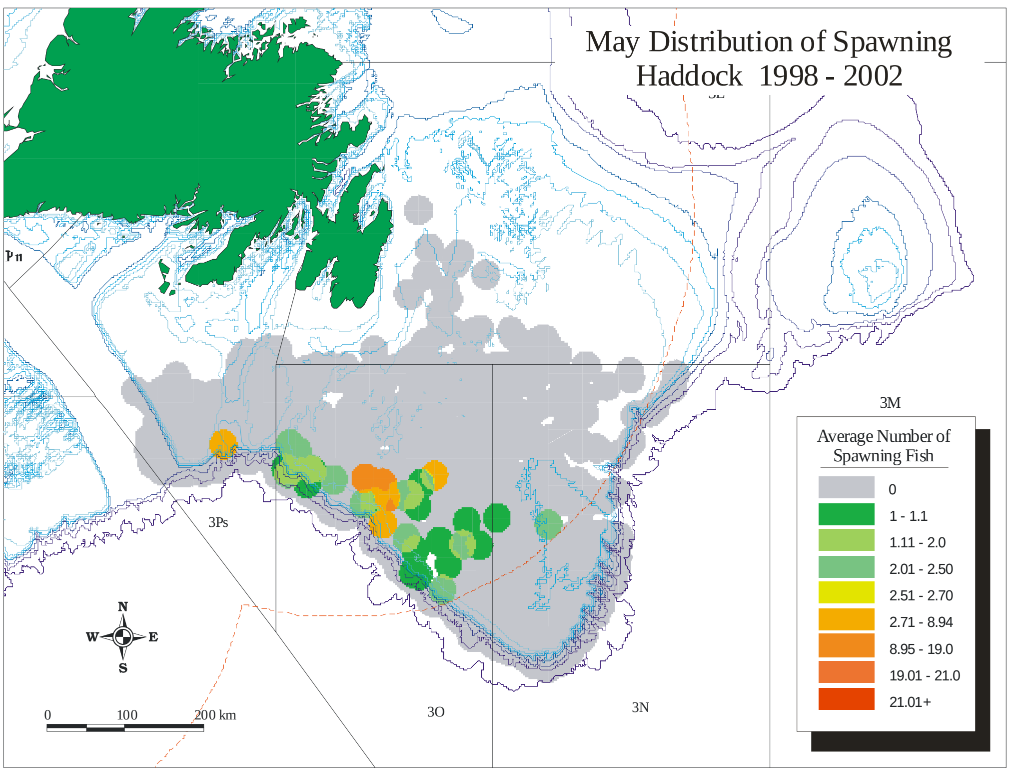

Figure 10b: May distribution of spawning Haddock, 1998-2002. The 0 class represents survey sets where no fish were caught.

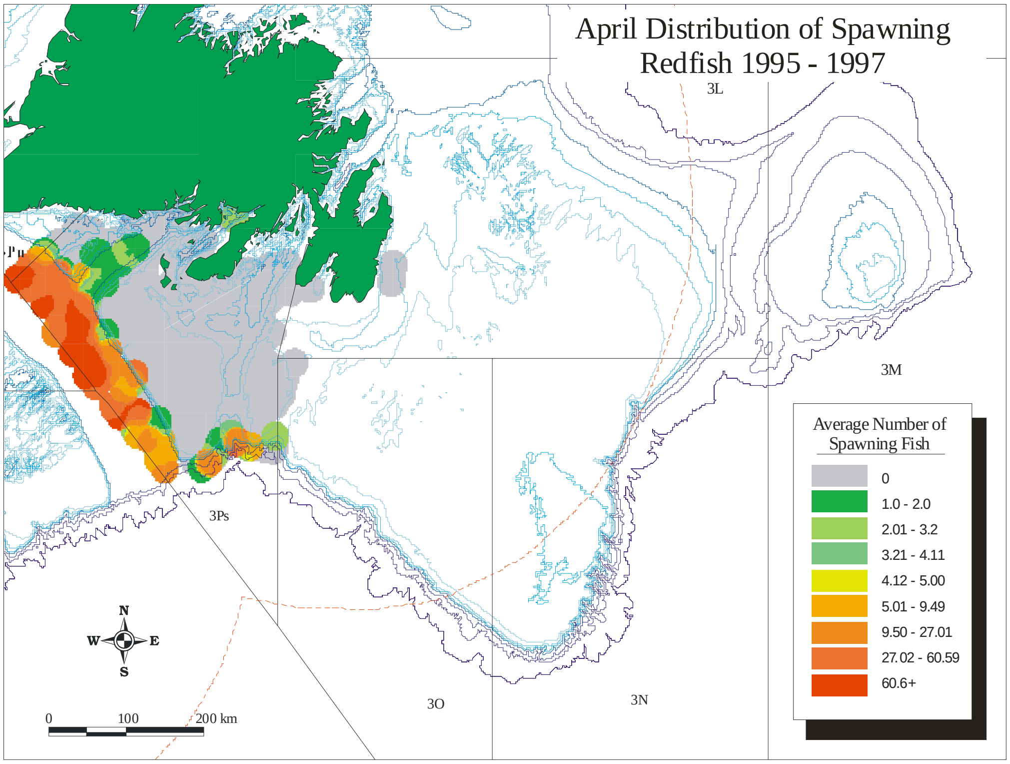

Figure 11a: April distribution of spawning Redfish, 1995-97. The 0 class represents survey sets where no fish were caught.

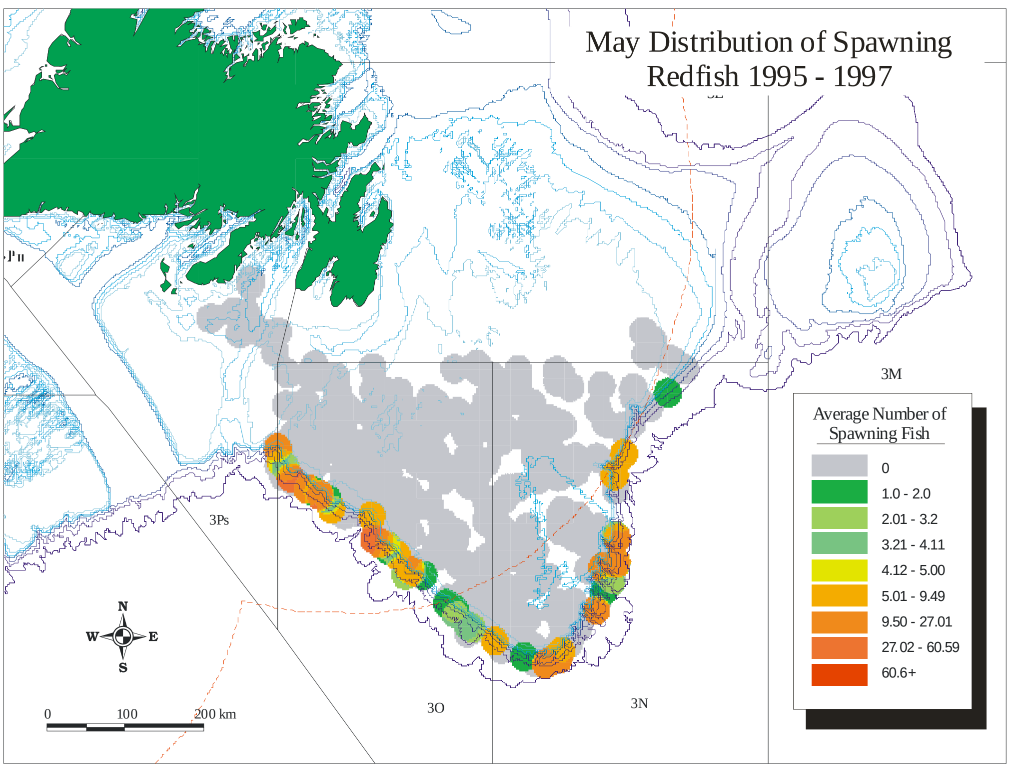

Figure 11b: May distribution of spawning Redfish, 1995-97. The 0 class represents survey sets where no fish were caught.

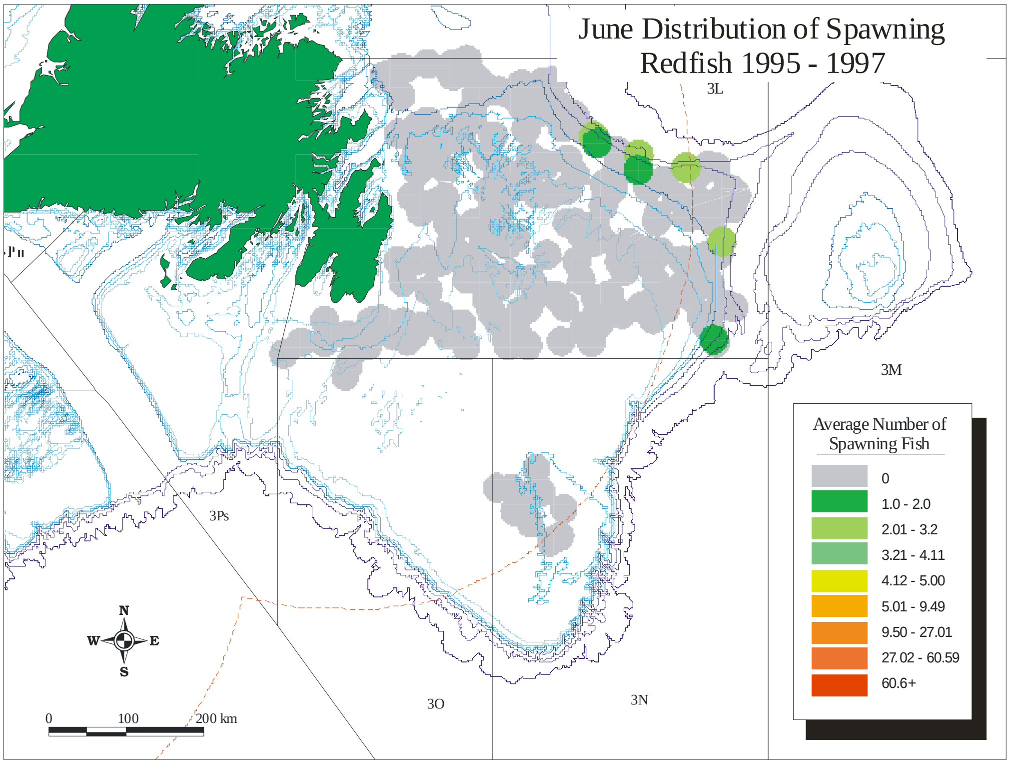

Figure 11c: June distribution of spawning Redfish, 1995-97. The 0 class represents survey sets where no fish were caught.

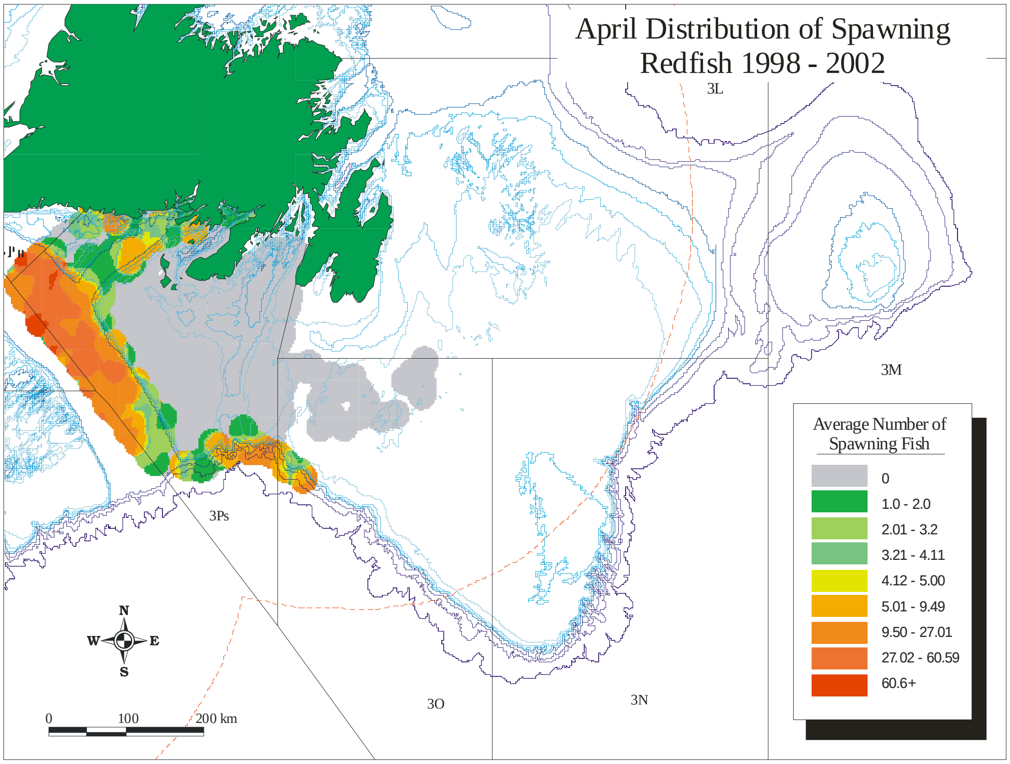

Figure 12a: April distribution of spawning Redfish, 1998-2002. The 0 class represents survey sets where no fish were caught.

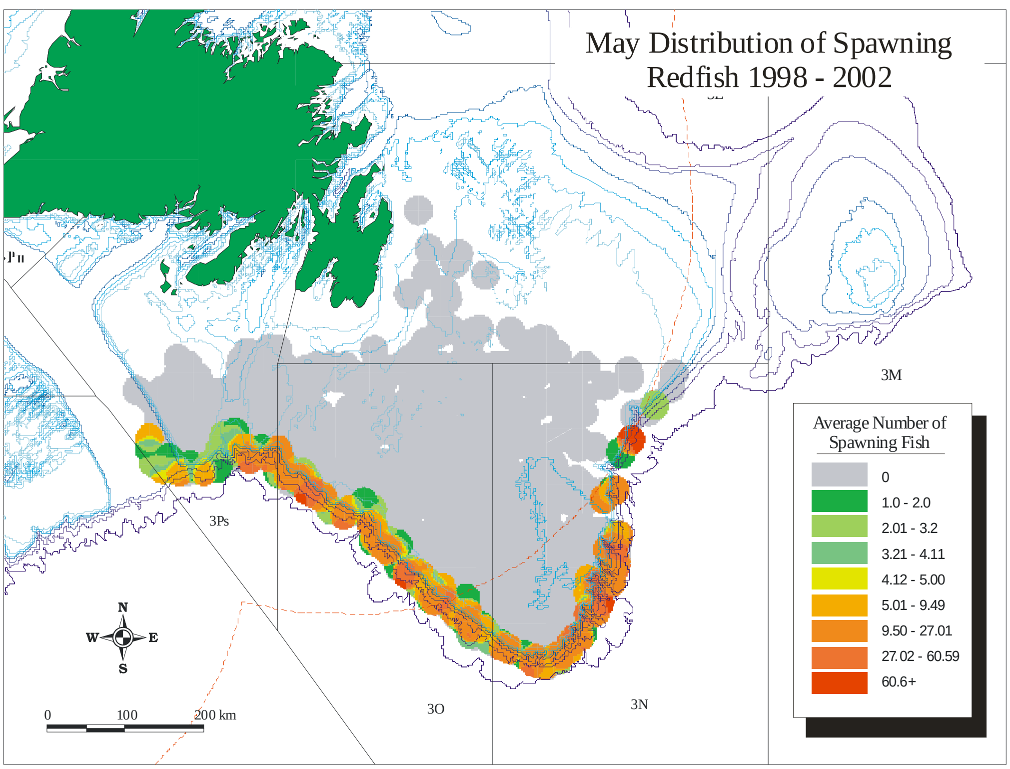

Figure 12b: May distribution of spawning Redfish, 1998-2002. The 0 class represents survey sets where no fish were caught.

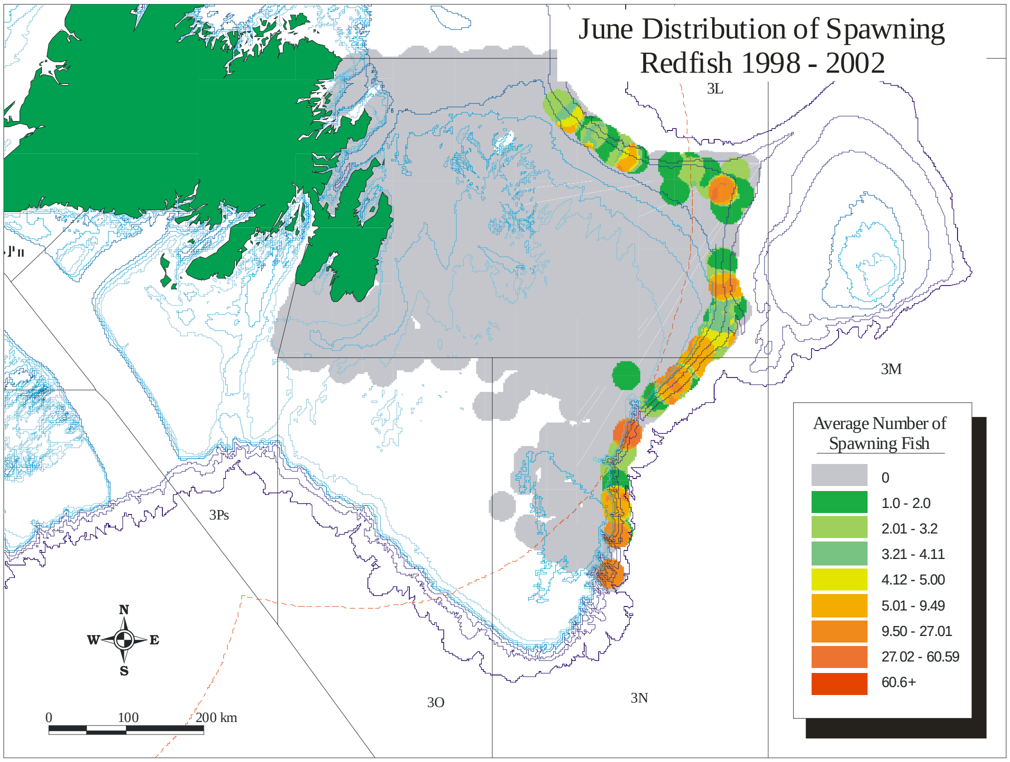

Figure 12c: June distribution of spawning Redfish, 1998-2002. The 0 class represents survey sets where no fish were caught.

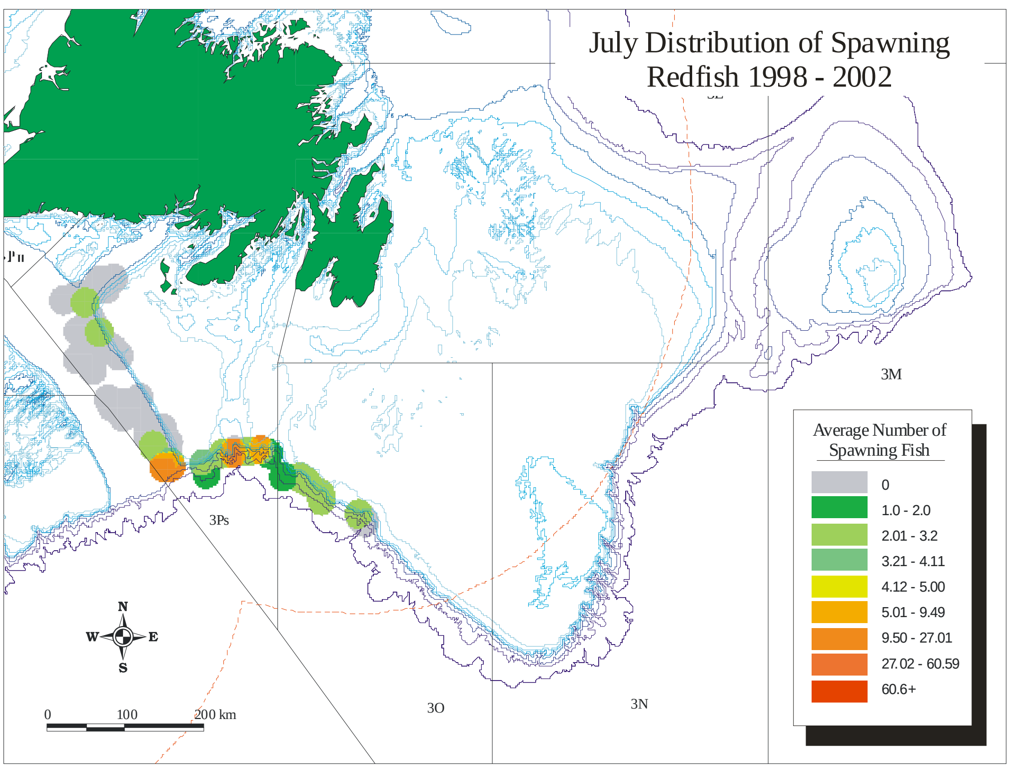

Figure 12d: July distribution of spawning Redfish, 1998-2002. The 0 class represents survey sets where no fish were caught.

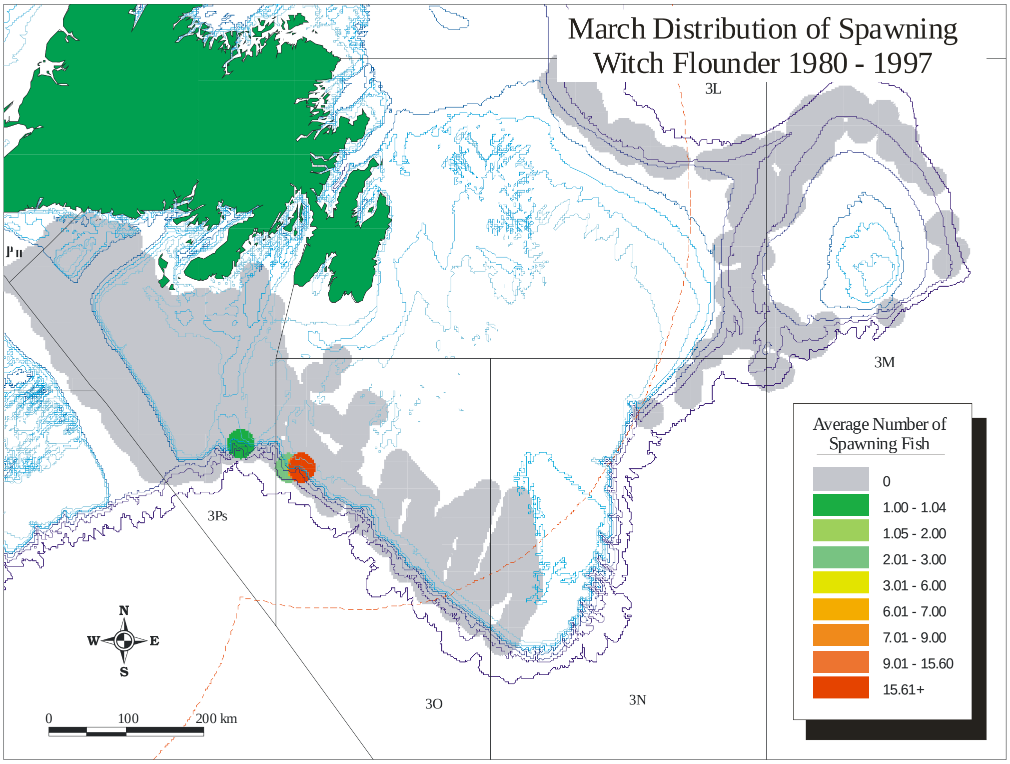

Figure 13a: March distribution of spawning Witch Flounder, 1980-97. The 0 class represents survey sets where no fish were caught.

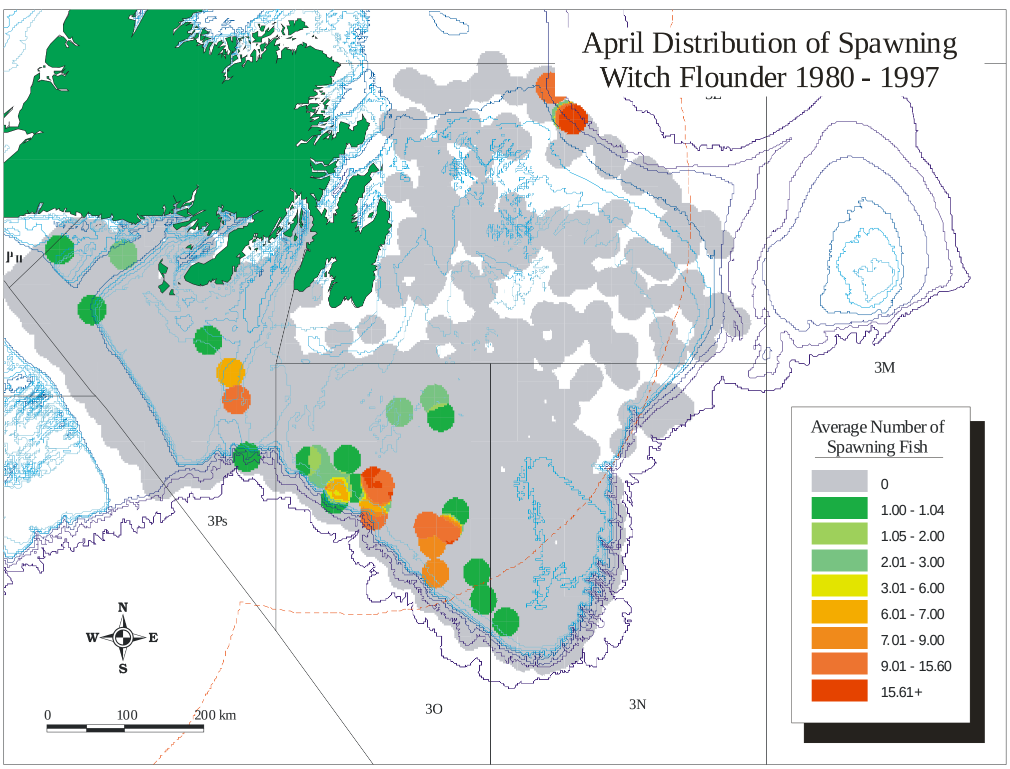

Figure 13b: April distribution of spawning Witch Flounder, 1980-97. The 0 class represents survey sets where no fish were caught.

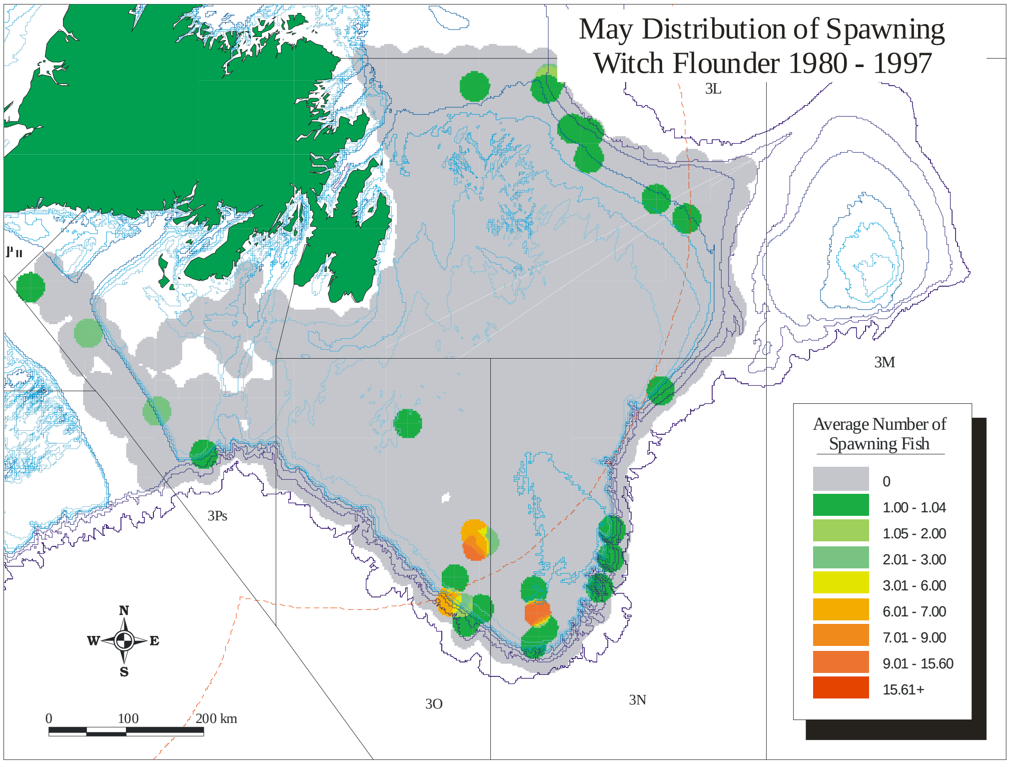

Figure 13c: May distribution of spawning Witch Flounder, 1980-97. The 0 class represents survey sets where no fish were caught.

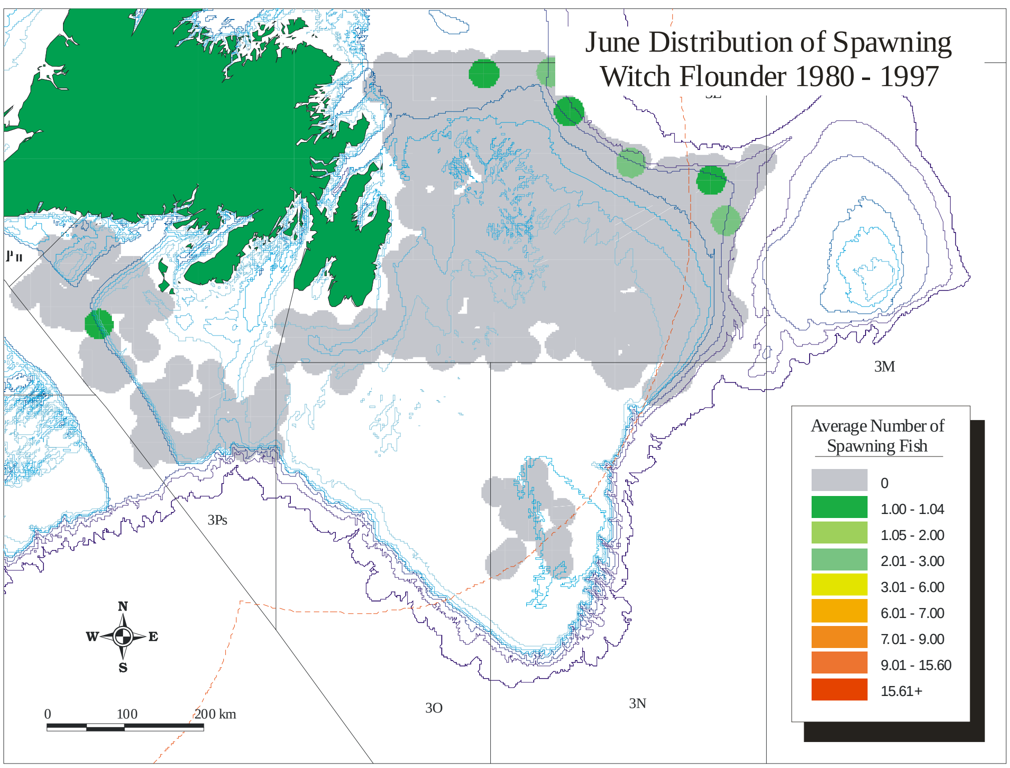

Figure 13d: June distribution of spawning Witch Flounder, 1980-97. The 0 class represents survey sets where no fish were caught.

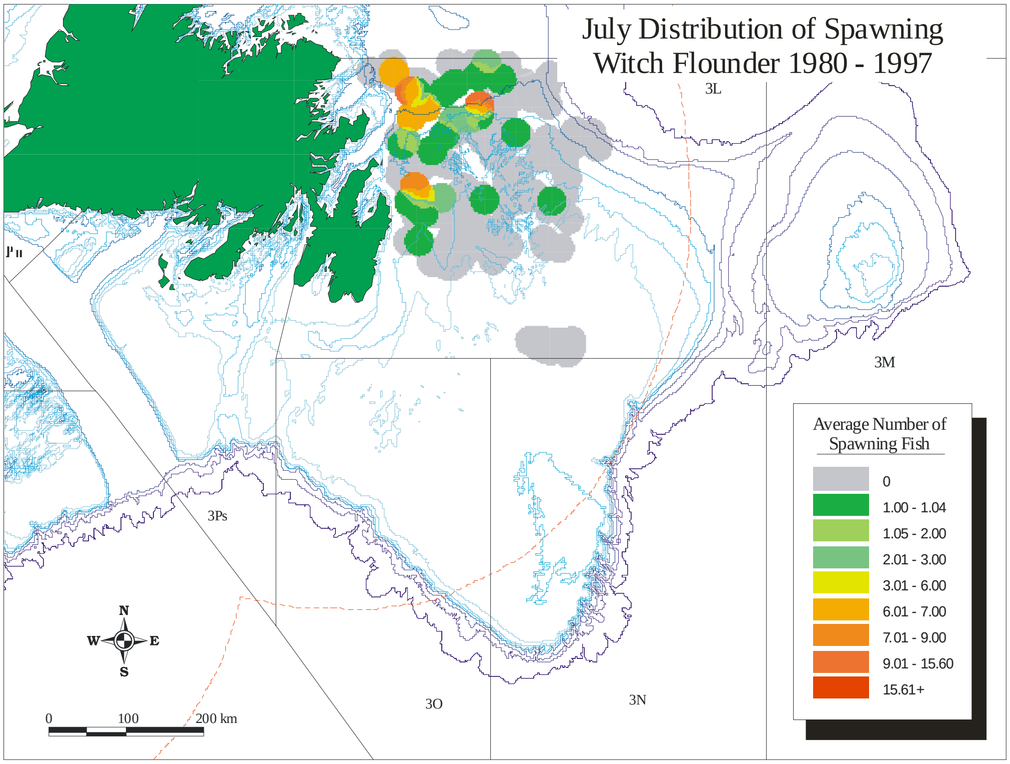

Figure 13e: July distribution of spawning Witch Flounder, 1980-97. The 0 class represents survey sets where no fish were caught.

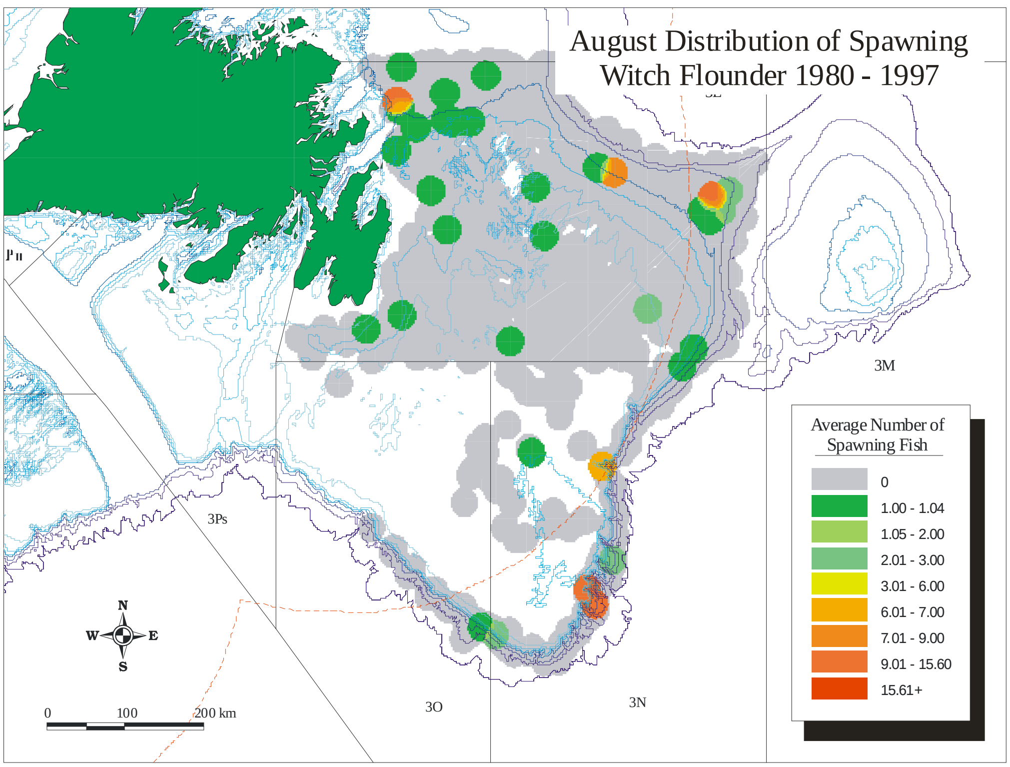

Figure 13f: August distribution of spawning Witch Flounder, 1980-97. The 0 class represents survey sets where no fish were caught.

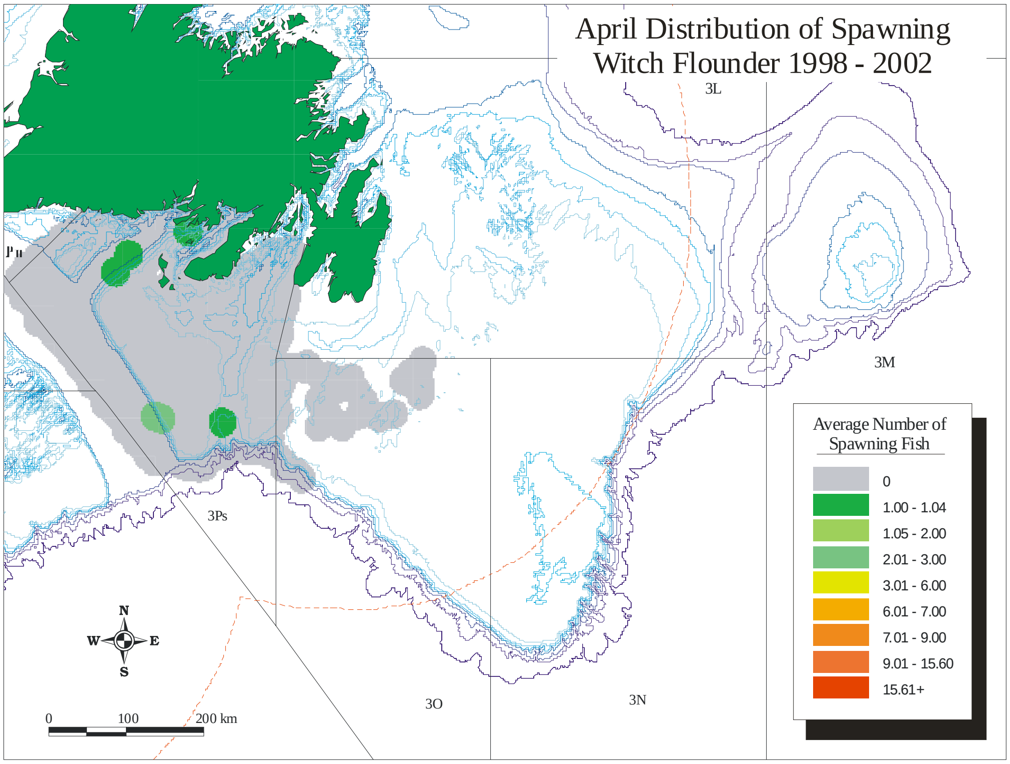

Figure 14a: April distribution of spawning Witch Flounder, 1998-2002. The 0 class represents survey sets where no fish were caught.

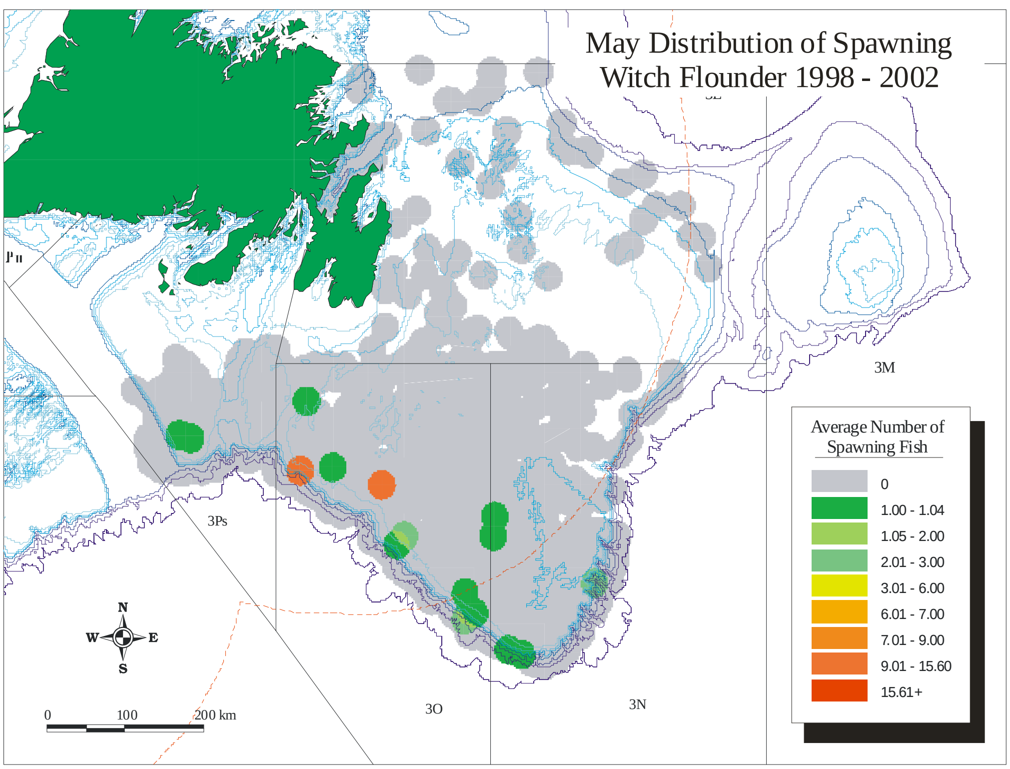

Figure 14b: May distribution of spawning Witch Flounder, 1998-2002. The 0 class represents survey sets where no fish were caught.

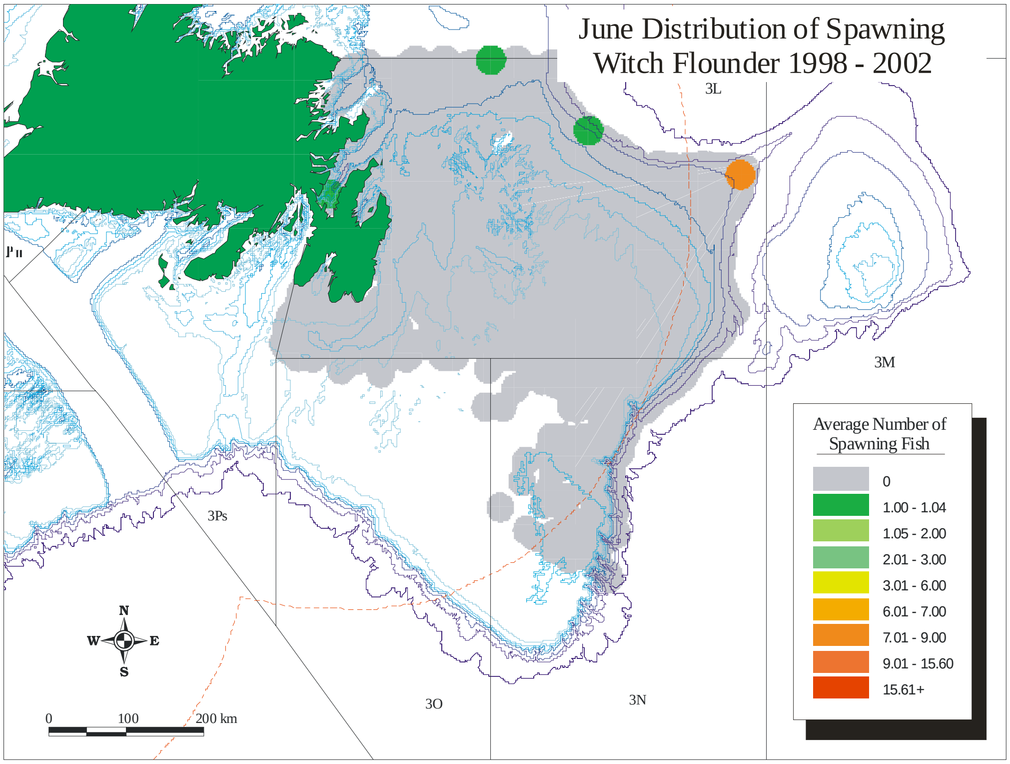

Figure 14c: June distribution of spawning Witch Flounder, 1998-2002. The 0 class represents survey sets where no fish were caught.

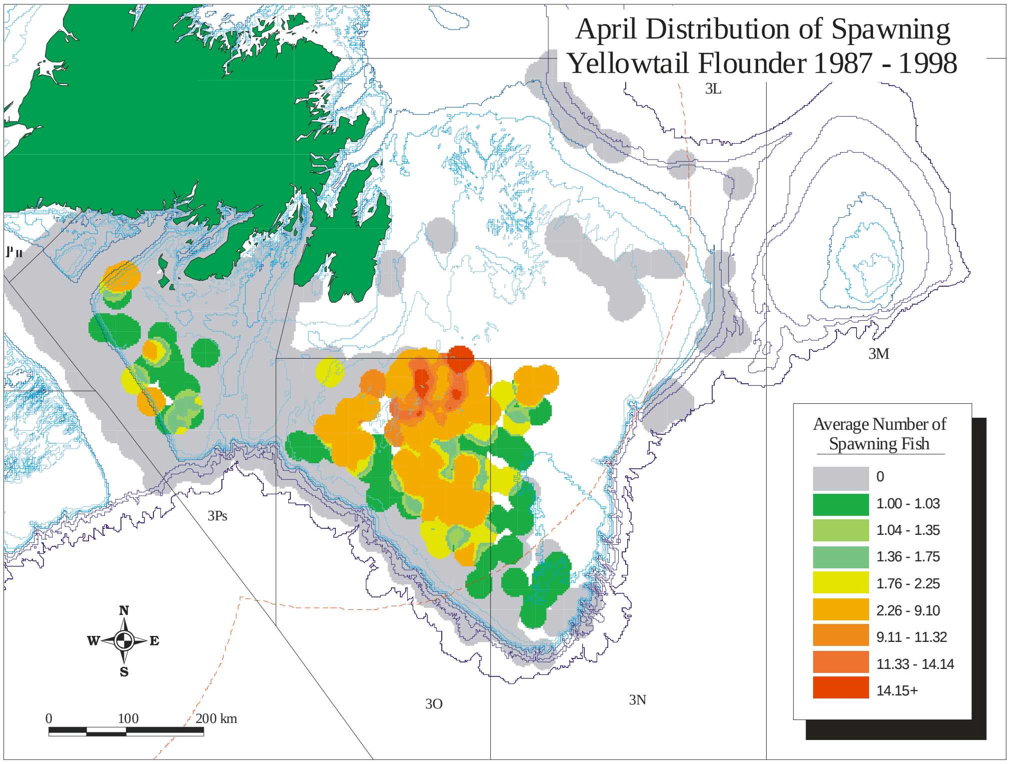

Figure 15a: April distribution of spawning Yellowtail Flounder, 1987-98. The 0 class represents survey sets where no fish were caught.

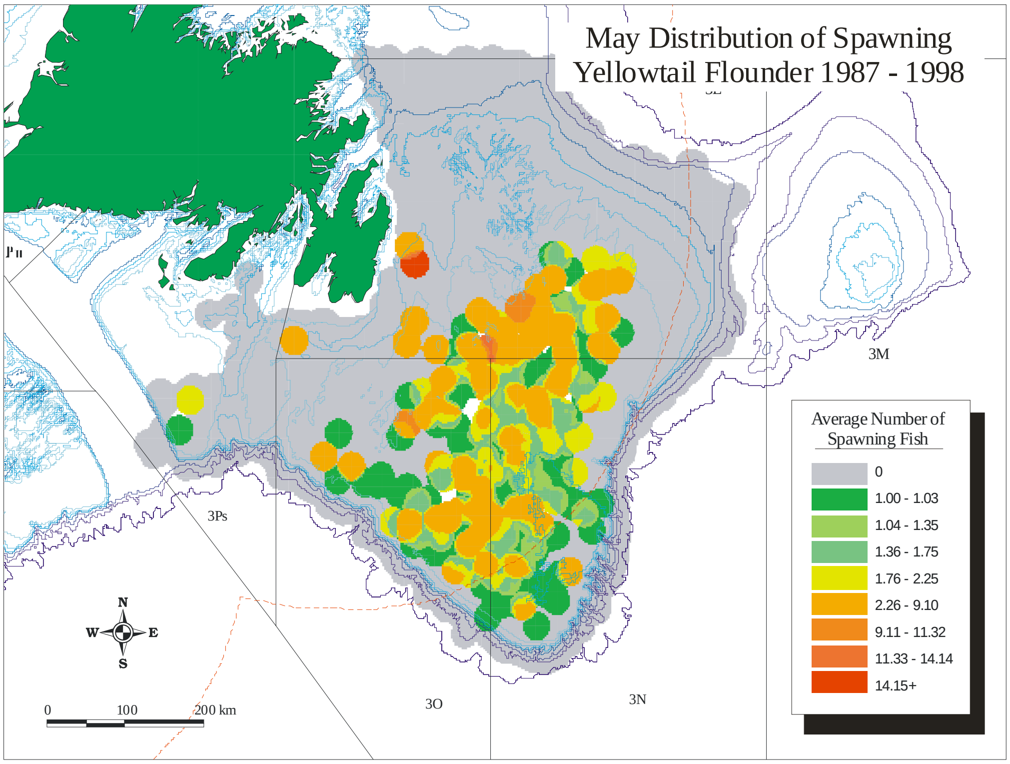

Figure 15b: May distribution of spawning Yellowtail Flounder, 1987-98. The 0 class represents survey sets where no fish were caught.

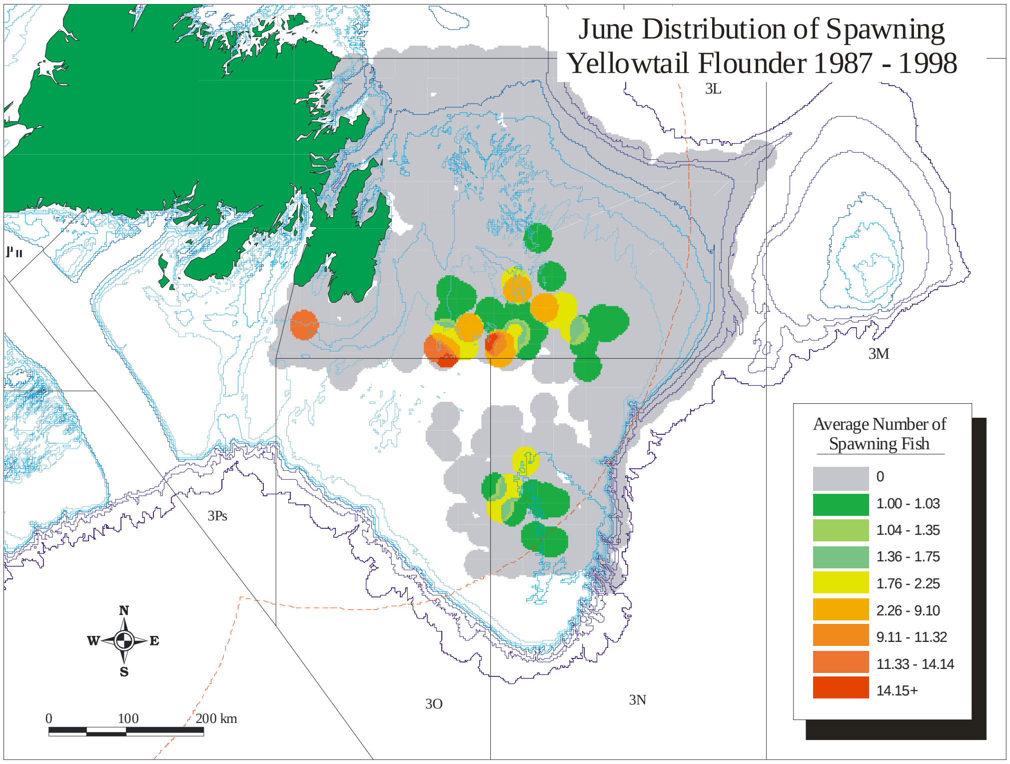

Figure 15c: June distribution of spawning Yellowtail Flounder, 1987-98. The 0 class represents survey sets where no fish were caught.

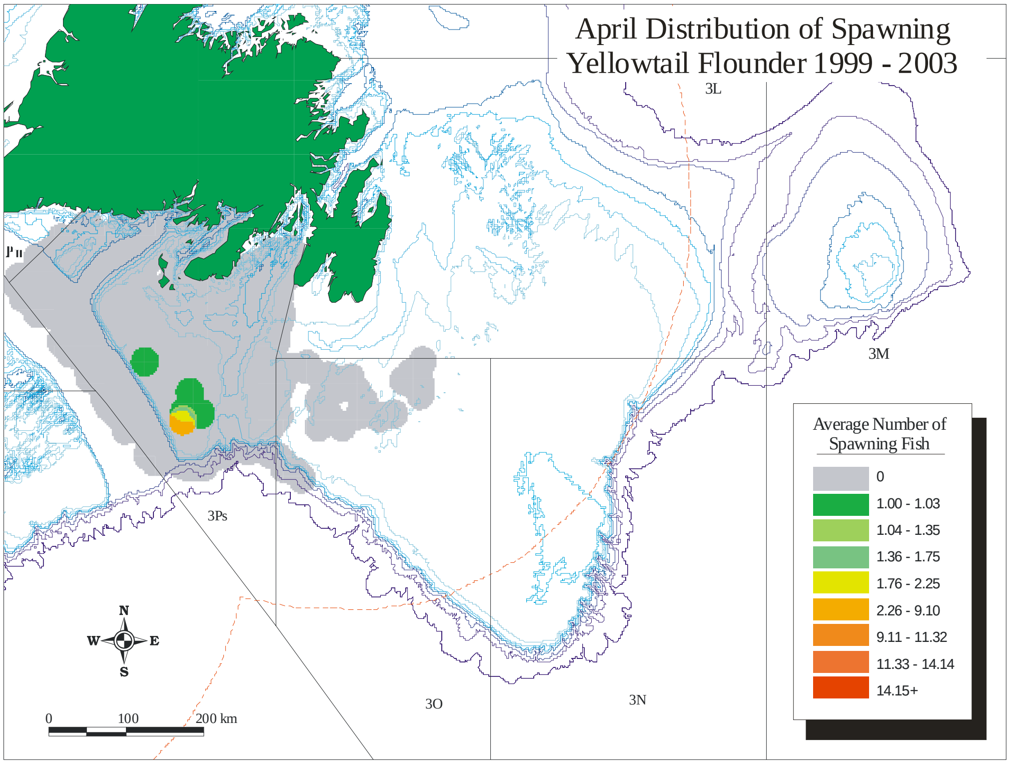

Figure 16a: April distribution of spawning Yellowtail Flounder, 1999-2003. The 0 class represents survey sets where no fish were caught.

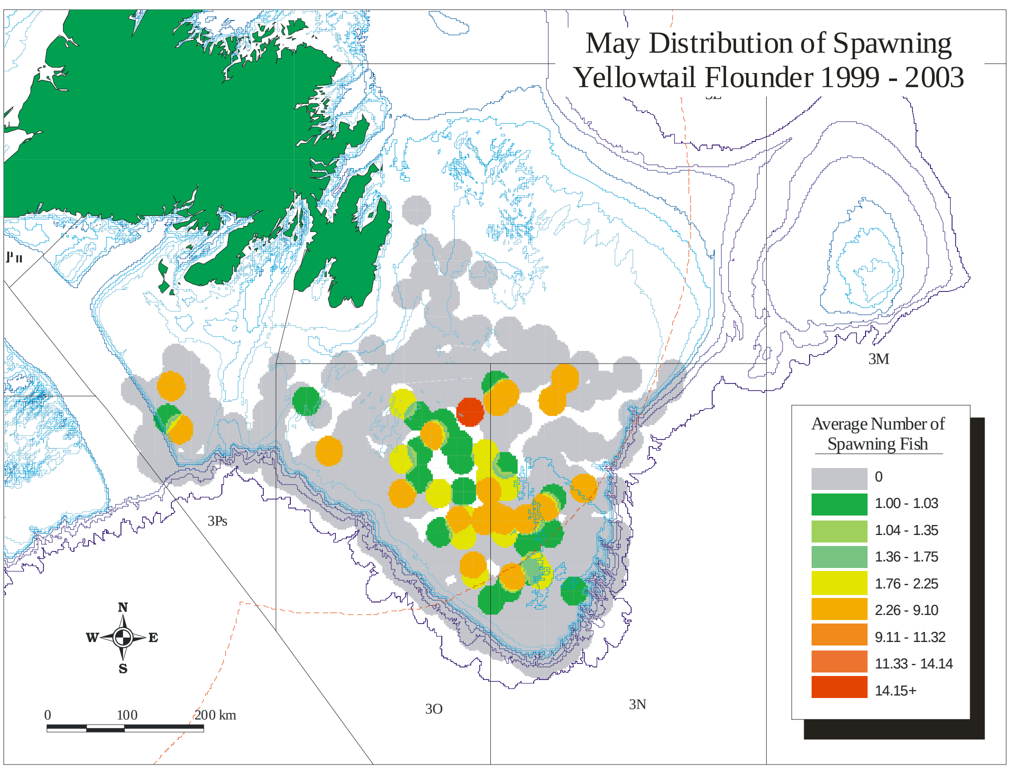

Figure 16b: May distribution of spawning Yellowtail Flounder, 1999-2003. The 0 class represents survey sets where no fish were caught.

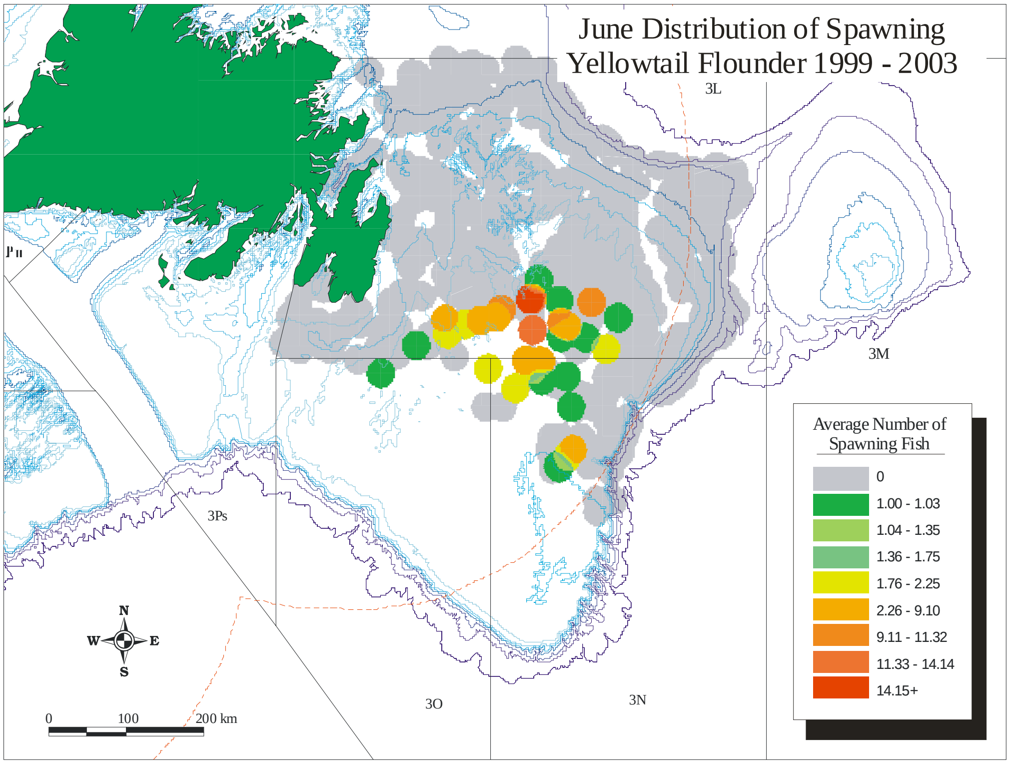

Figure 16c: June distribution of spawning Yellowtail Flounder, 1999-2003. The 0 class represents survey sets where no fish were caught.

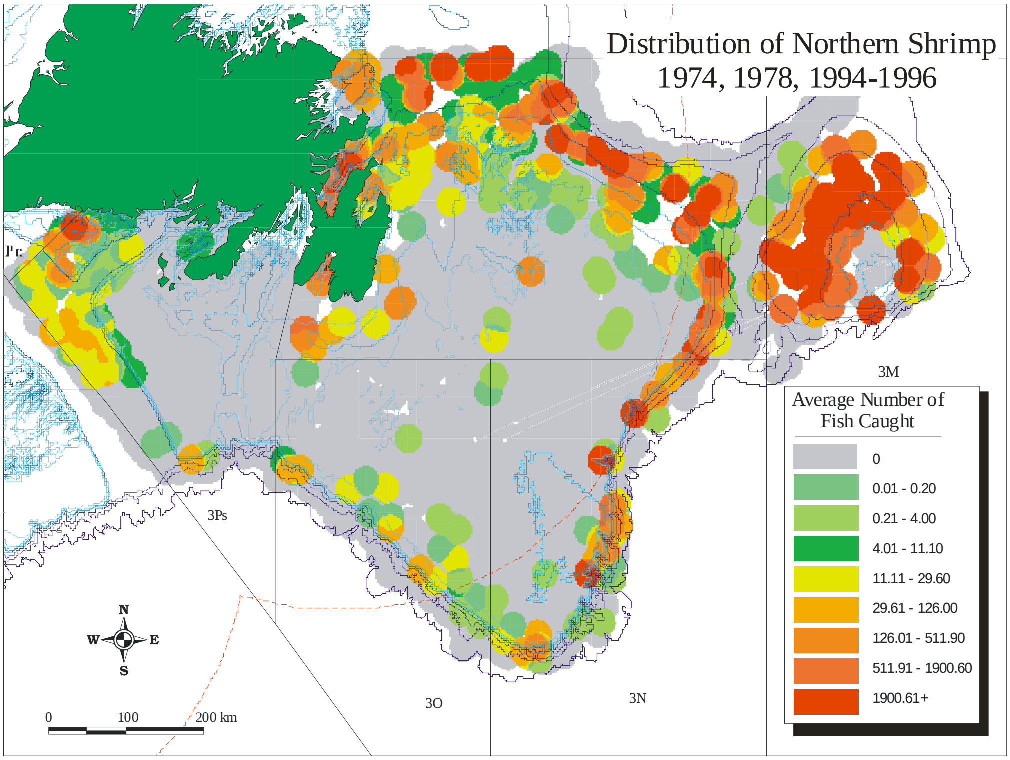

Figure 17: Distribution of Northern Shrimp, 1974, 1978, 1994-96. The 0 class represents survey sets where no individuals were caught.

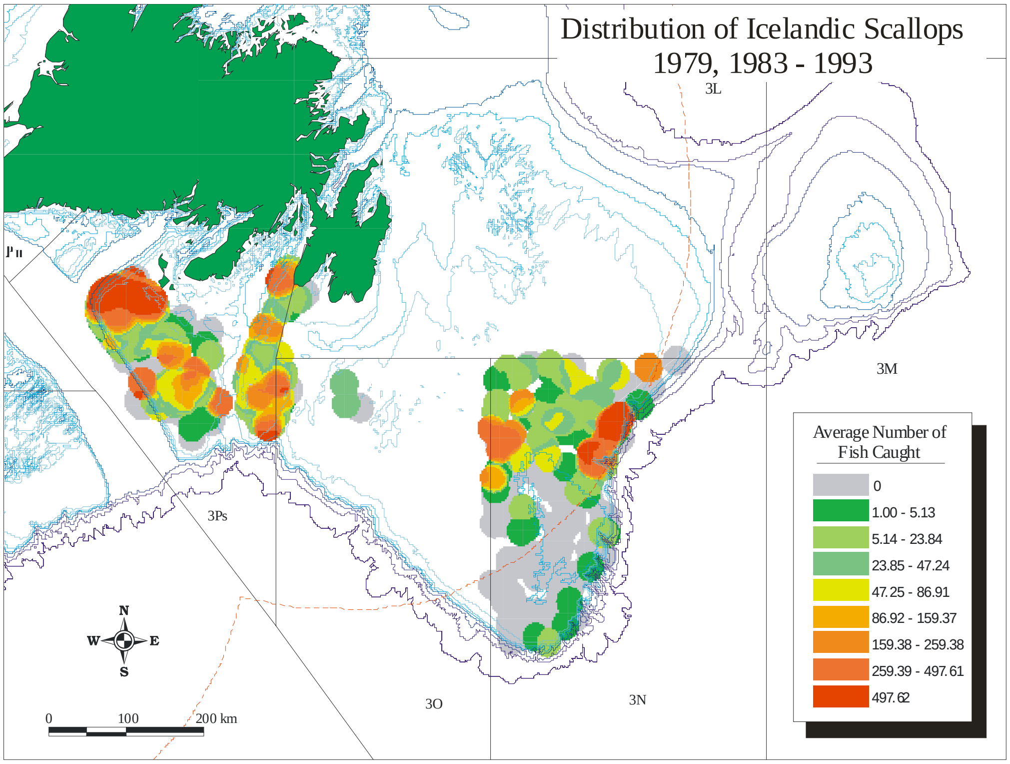

Figure 18a: Distribution of Icelandic scallops, 1979, 1983-93. The 0 class represents survey sets where no individuals were caught.

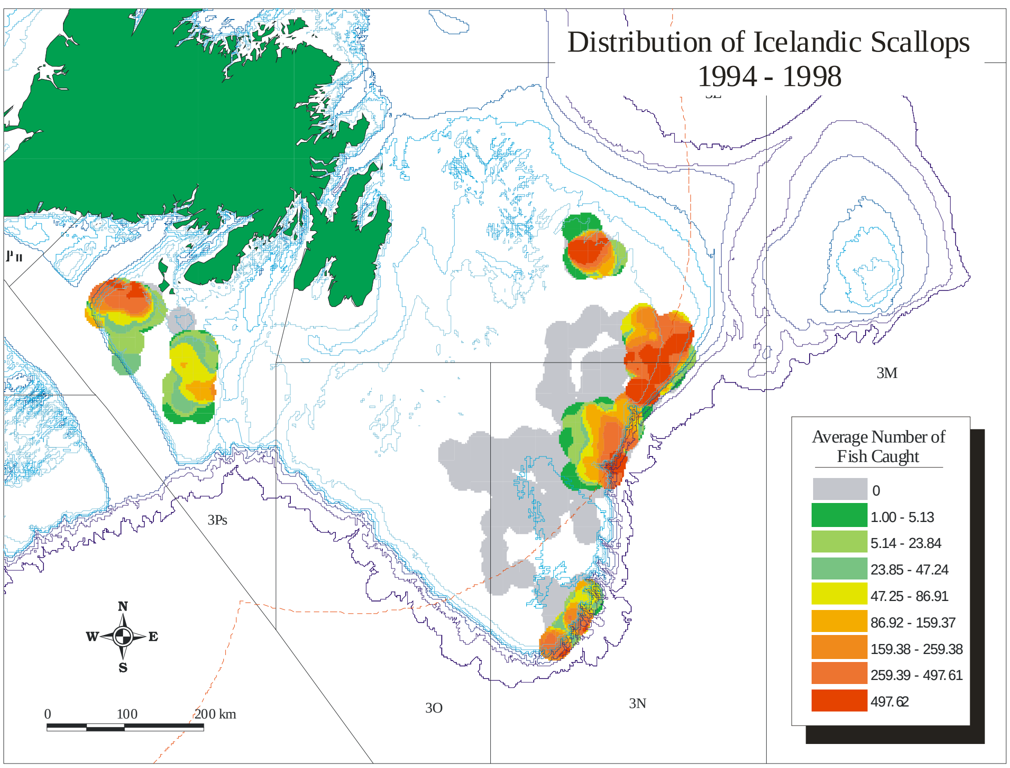

Figure 18b: Distribution of Icelandic scallops, 1994-98. The 0 class represents survey sets where no individuals were caught.

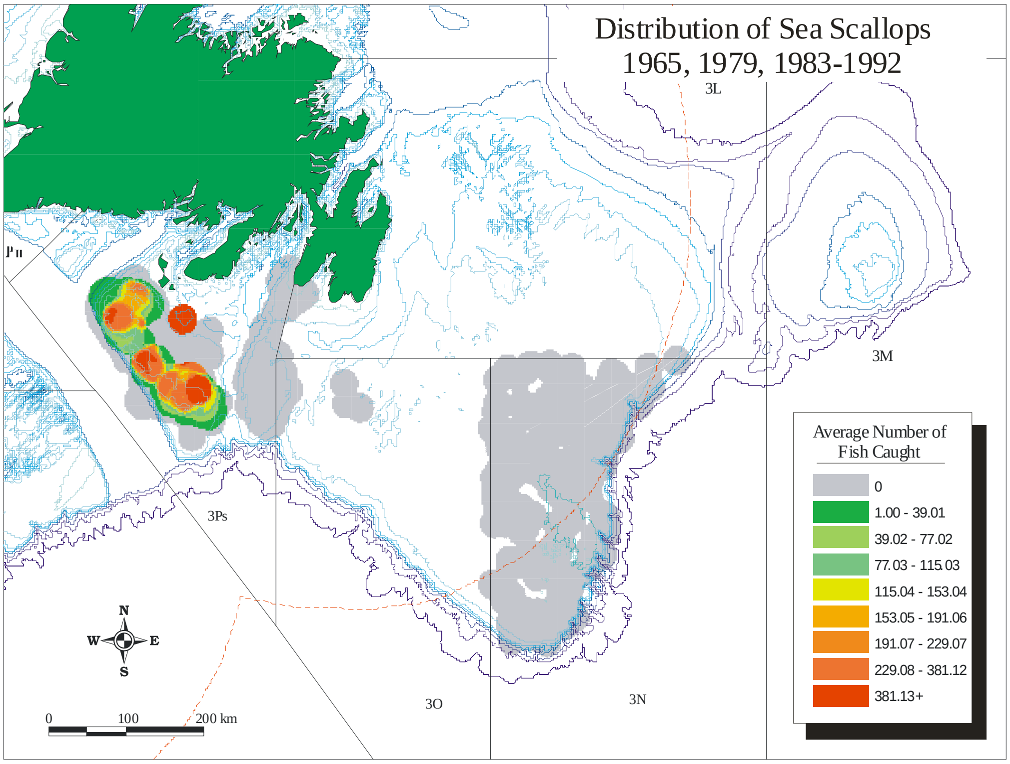

Figure 19a: Distribution of sea scallops, 1965, 1979, 1983-92. The 0 class represents survey sets where no individuals were caught.

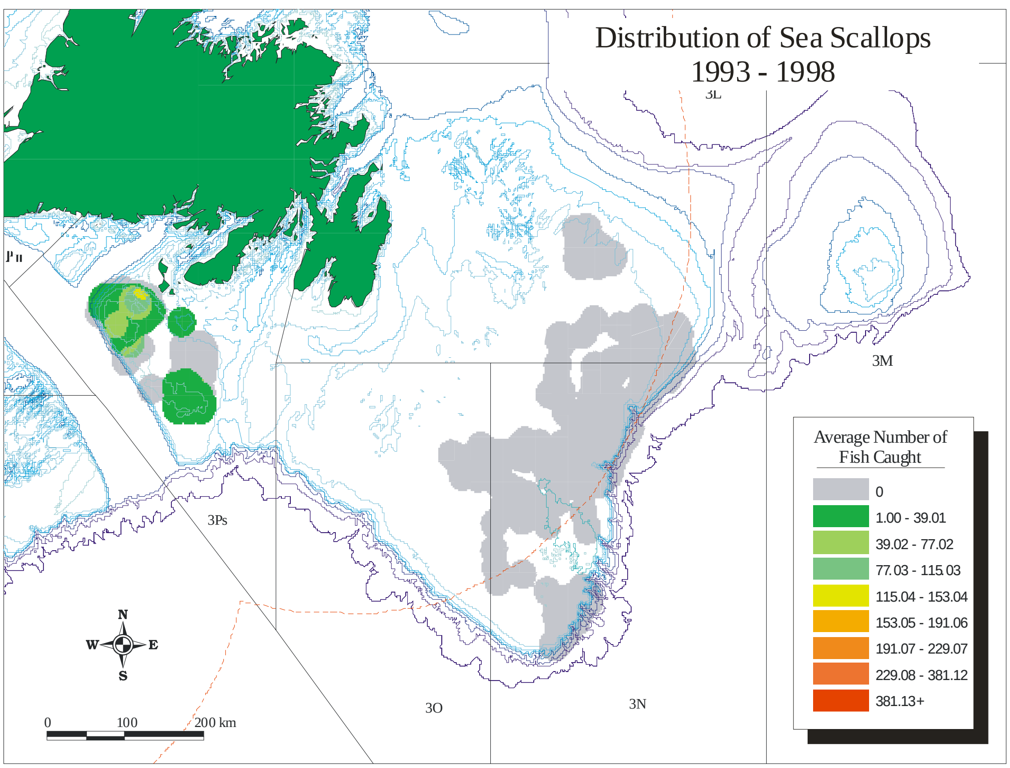

Figure 19b: Distribution of sea scallops, 1993-98. The 0 class represents survey sets where no individuals were caught.

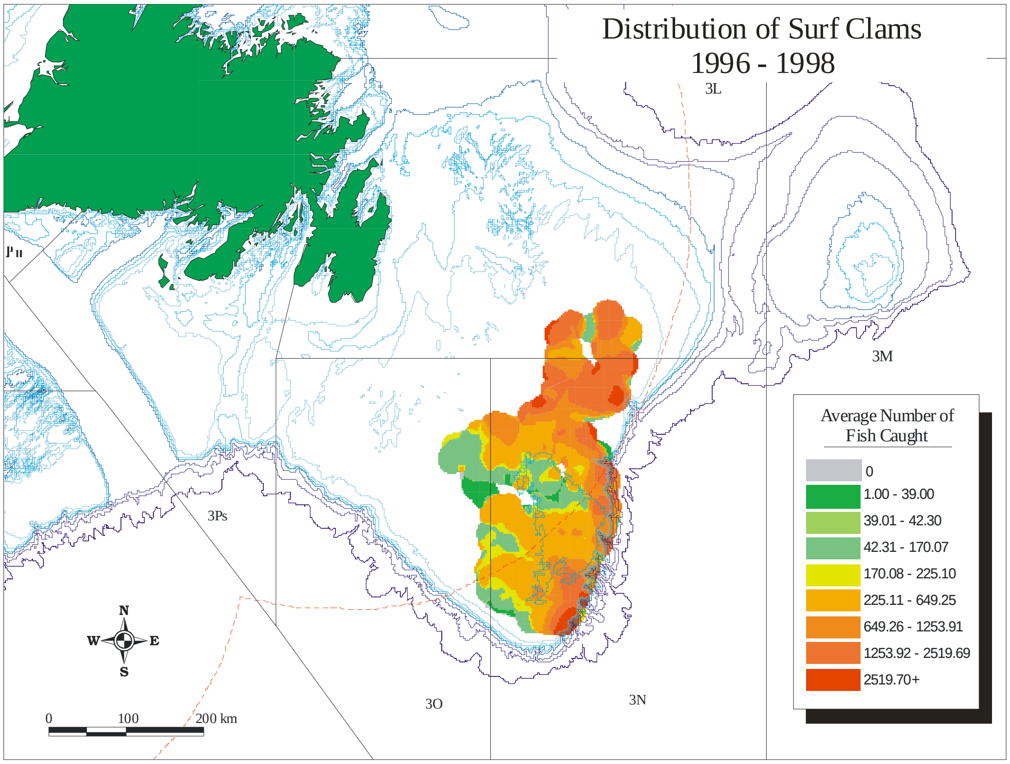

Figure 20: Distribution of surf clams, 1996-98. The 0 class represents survey sets where no individuals were caught.