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Offshore Seabird Monitoring Program

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Offshore Seabird Monitoring Program

Final Report

Canadian Wildlife Service
Environment Canada – Atlantic Region
St. John’s, Newfoundland

December 2009

Environment Canada
Atlantic Region

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Région de l’Atlantique

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Executive Summary

The waters off the coast of eastern Canada are highly productive, supporting a rich and diverse assemblage of seabirds year-round. In recent decades, this area has seen increasing hydrocarbon exploration and production. Seabirds are extremely vulnerable to oiling from accidental hydrocarbon releases in the marine environment. In November 2004, approximately 1,000 barrels of crude oil were spilled at the Terra Nova Floating Production, Storage and Offloading (FPSO) vessel on the northeastern Grand Banks. Little seabird abundance information was available at that time to assess potential spill impact highlighting the need for seabird density data in areas close to oil exploration, production and associated marine traffic. Subsequently, the ESRF funded a 3.5-year project to assess seabird abundance and distribution on the northern Grand Banks and other areas of oil industry activity in eastern Canada.

A modern survey protocol was developed in conjunction with the Canadian Wildlife Service's (CWS) Eastern Canadian Seabirds at Sea (ECSAS) program, which includes distance sampling methods to account for varying seabird detectability. An observer training program was developed and a pool of more than 20 highly qualified observers was created. Monthly surveys were conducted to the northeast Grand Banks production area from 2006 to 2009. Other regular ECSAS and ESRF supported surveys were conducted from the Gulf of Maine to the Labrador Sea. A voice-activated database system was developed to manage data collection, storage and analysis. In addition, data from the industry-sponsored rig observer program were reviewed for quality assurance.

Overall, 76 surveys trips involving 2,563 hours of observation were conducted, covering 51,392 km of ocean transect during which 123,909 birds were counted. Survey effort was greatest during the summer (May–Aug) and most restricted during the fall (Sept–Oct). Without the use of distance sampling to account for imperfect seabird detectability, density would have been underestimated by up to three times. Seasonal true density maps (in birds/km^2) and descriptions for the nine most common seabird species/groups (plus all birds combined) are included. The effect of analysis scale on variation in seabird density is presented.

Persistent seasonal and year-round hotspots of high seabird concentration in areas of current and future hydrocarbon production and exploration were identified. A standardized accredited training program is recommended to maintain the availability of qualified observers for future survey programs. The resolution of data interoperability issues among agencies conducting offshore seabird surveys in eastern Canada through the use of a common database is recommended. The importance of the rig observer program is identified and suggestions are provided for further improvements. The relationship between survey intensity and density estimate precision is highlighted and recommendations are made to improve the precision of density estimates through modest continued survey effort to existing production areas on the northeast Grand Banks and Scotian Shelf. Remaining spatiotemporal gaps in areas of current and future exploration

and development are identified. A rotating schedule of survey programs is recommended in areas of interest to the oil industry to maintain data currency into the future.

Sommaire

Les eaux de la zone extracôtière de l'est du Canada offrent un milieu fertile où vit un amalgame riche et diversifié d'oiseaux marins pendant toute l'année. Au cours des récentes décennies, l'exploration et la production d'hydrocarbures n'ont cessé de croître. Les oiseaux marins sont extrêmement sensibles au mazoutage provoqué par les déversements d'hydrocarbures dans l'environnement marin. En novembre 2004, environ 1000 barils de pétrole brut ont été déversés du navire de production, de stockage et de déchargement (FPSO) Terra Nova, au nord-est des Grands Bancs de Terre-Neuve. Peu d'information était alors disponible sur l'abondance des oiseaux marins; il a alors été difficile d'évaluer l'impact du déversement, ce qui a fait ressortir la nécessité d'obtenir des données sur la densité de la population d'oiseaux marins dans les zones à proximité des sites d'exploration et de production d'hydrocarbure et des zones de circulation maritime associées. Le FÉE a donc financé un projet de 3,5 ans axé sur l'évaluation de l'abondance et de la distribution des oiseaux marins dans le nord-est des Grands Bancs de Terre-Neuve et dans d'autres zones d'activités de l'industrie pétrolière dans l'est du Canada.

Un protocole de recherche moderne a été élaboré en collaboration avec le programme portant sur les oiseaux marins de l'est du Canada (ECSAS) du Service canadien de la faune (SCF), qui comprend des méthodes d'échantillonnage de la distance pour étudier la détectabilité variable des oiseaux marins. Un programme de formation d'observateur a été élaboré et un groupe de plus de 20 observateurs hautement qualifié a été créé. Des évaluations mensuelles ont été menées dans la région du nord-est des Grands Bancs de Terre-Neuve de 2006 à 2009. D'autres évaluations régulières, appuyées par l'ECSAS et l'ESRF, ont été menées du golfe du Maine à la mer du Labrador. Un système de base de données activé par la voix a été élaboré pour gérer la collecte, le stockage et l'analyse de données. De plus, les données provenant du programme d'observateur commandité par l'industrie d'exploitation ont été étudiées à des fins d'assurance de la qualité.

Au total, 76 déplacements d'étude totalisant 2 563 heures d'observation ont été menés, sur une superficie couvrant un transect de 51 392 km dans l'océan; 123 909 oiseaux ont été dénombrés. Les efforts d'évaluation ont été plus importants pendant l'été (mai à août) et plus restreints pendant l'automne (septembre à octobre). Sans le recours à l'échantillonnage de distance pour tenir compte de la détectabilité imparfaite des oiseaux marins, la densité de population aurait été sous-estimée de quelque 3 fois. Les cartes de densité saisonnière réelle (en oiseaux/km2) et la description des neufs espèces/groupes d'oiseaux les plus courants (plus tous les oiseaux combinés) sont incluses. L'effet de l'échelle d'analyse sur la variation de la densité des oiseaux marins est présenté.

Les zones sensibles persistantes, saisonnières et permanentes, de haute concentration d'oiseaux marins dans les zones de production et d'exploration d'hydrocarbure, actuelles et futures, ont été identifiées. Un programme de formation accrédité et normalisé est recommandé pour assurer la disponibilité d'observateurs qualifiés pour les futurs programmes d'évaluation. Il est recommandé d'utiliser une base de données commune pour résoudre les problèmes d'interopérabilité des données entre agences menant des évaluations sur les oiseaux marins extracôtiers dans l'est du Canada. L’importance du programme d’observateur sur les installations de forage est reconnue et des suggestions sont présentées pour apporter des améliorations. La relation entre l’intensité d’évaluation et la précision de l’estimation de la densité est particulièrement soulignée et des recommandations sont faites pour améliorer la précision des estimations de densité par le biais d’un modeste effort d’évaluation continue dans les zones de production existantes du nord-est des Grands Bancs de Terre-Neuve et du Plateau néo-écossais. Les écarts spatiotemporels restants dans les zones d’exploitation, actuelle et future, et le développement sont établis. Un échéancier tournant de programmes d’évaluation est recommandé dans les zones d’intérêt de l’industrie pétrolière afin de préserver l’actualisation des données pour l’avenir.

1 Introduction

1.1 Seabirds

The waters of the Grand Banks and Scotian Shelf are nutrient-rich because of an interaction of a variety of physical drivers that include major current systems (e.g., Labrador Current, Gulf Stream), bathymetry (featuring shallow banks with steeply sloping margins) and temperature and salinity patterns. These nutrients support highly productive marine ecosystems including a diverse seabird assemblage (Montevecchi and Tuck 1987). Twenty-two pelagic seabird colonies in Newfoundland and Labrador and seven in Nova Scotia have been designated as Important Bird Areas by Bird Studies Canada, including some that are recognized for their global significance to seabird populations (http://www.bsc-eoc.org/iba/IBAsites.html). At least 30 million seabirds utilize Eastern Canadian waters each year. Seabird diversity peaks in the spring and summer months because of a combination of northern hemisphere breeding birds and southern hemisphere migrants, including Greater (*Puffinus gravis*) and Sooty (*P. griseus*) Shearwaters (Huettmann and Diamond 2000), while significant numbers of over-wintering alcids, gulls, and Northern Fulmars (*Fulmarus glacialis*) use these waters during fall and winter (Brown 1986).

Seabirds play an integral role in marine food webs and have been designated as Valued Ecosystem Components in Environmental Impact Statements. The study of changes in seabird distribution, abundance and diet can be correlated with the health and current state of marine populations (Montevecchi and Myers 1996). Given that seabirds are conspicuous, relatively easy to survey at sea, and populations at breeding colonies can be easily obtained, they are often used as monitors of the marine environment (Furness and Camphuysen 1997; Furness and Greenwood 1993).

Seabirds are extremely vulnerable to oiling; seabird mortality due to bilge dumping is thought to cause substantial mortality off the coast of Newfoundland each year (Wiese and Robertson 2004). A dime-size oil spot can kill a bird by compromising feather waterproofing, thereby causing hypothermia, exhaustion, and starvation (Leighton 1993). Oil can also be ingested while preening or consuming prey. The susceptibility of seabirds to oil spills does not necessarily depend only upon the size of the spill, but more importantly upon its timing and location in relation to seabird distributions (Burger 1993).

On November 21, 2004, approximately 1,000 barrels of crude oil were spilled at the Terra Nova Floating Production, Storage and Offloading (FSPO) vessel on the northeast Grand Banks off the shore of Newfoundland. At the time of the spill, very limited data were available to assess the potential impacts on seabirds. Wilhelm et al. (2007) estimated that 9,858 birds, specifically murres (*Uria spp.*) and Dovekies (*Alle alle*) were at risk of oiling based on a small amount of data collected post-spill in the affected area. This estimate of birds at risk was restricted to these two species as they are the most abundant in the area in the winter (Wilhelm et al., 2007), and have the highest risk of oiling (Wiese and Ryan 2003). This estimate varied, depending upon the proportion of flying birds that were assumed to be at risk, and a number of other assumptions were required to obtain these estimates. An independent mortality-based model based on spill volume in the same study predicted that 4,688 birds died as a result of this spill. The lack of existing seabird data in the spill area highlighted the need for better estimates of seabird densities in offshore areas.

1.2 Oil and Gas Exploration and Production Context

Offshore petroleum exploration and production activities have been ongoing on the Grand Banks and Scotian Shelf since the 1970s. Subsequently, the number of production and exploration licences as well as significant discoveries within these regions has increased. In Newfoundland and Labrador, there are current production and/or exploration licences for portions of the northern Grand Banks, Orphan Basin, Flemish Pass, Laurentian Sub-Basin, Sydney Basin, west coast of Newfoundland and the Labrador Shelf (http://www.cnlopb.nl.ca/exp_maps.html; Figure 1). In Nova Scotia, there are licences for the Scotian Shelf near Sable Island, the Scotian Slope and on much of the Canadian section of Georges Bank (Figure 2). The activities related to oil exploration, development and associated marine traffic in areas frequented by seabirds increase the potential for seabird mortality due to accidental release of hydrocarbons. Consequently, there is a critical need to monitor seabirds at sea to ensure associated impacts are properly quantified and potentially mitigated.

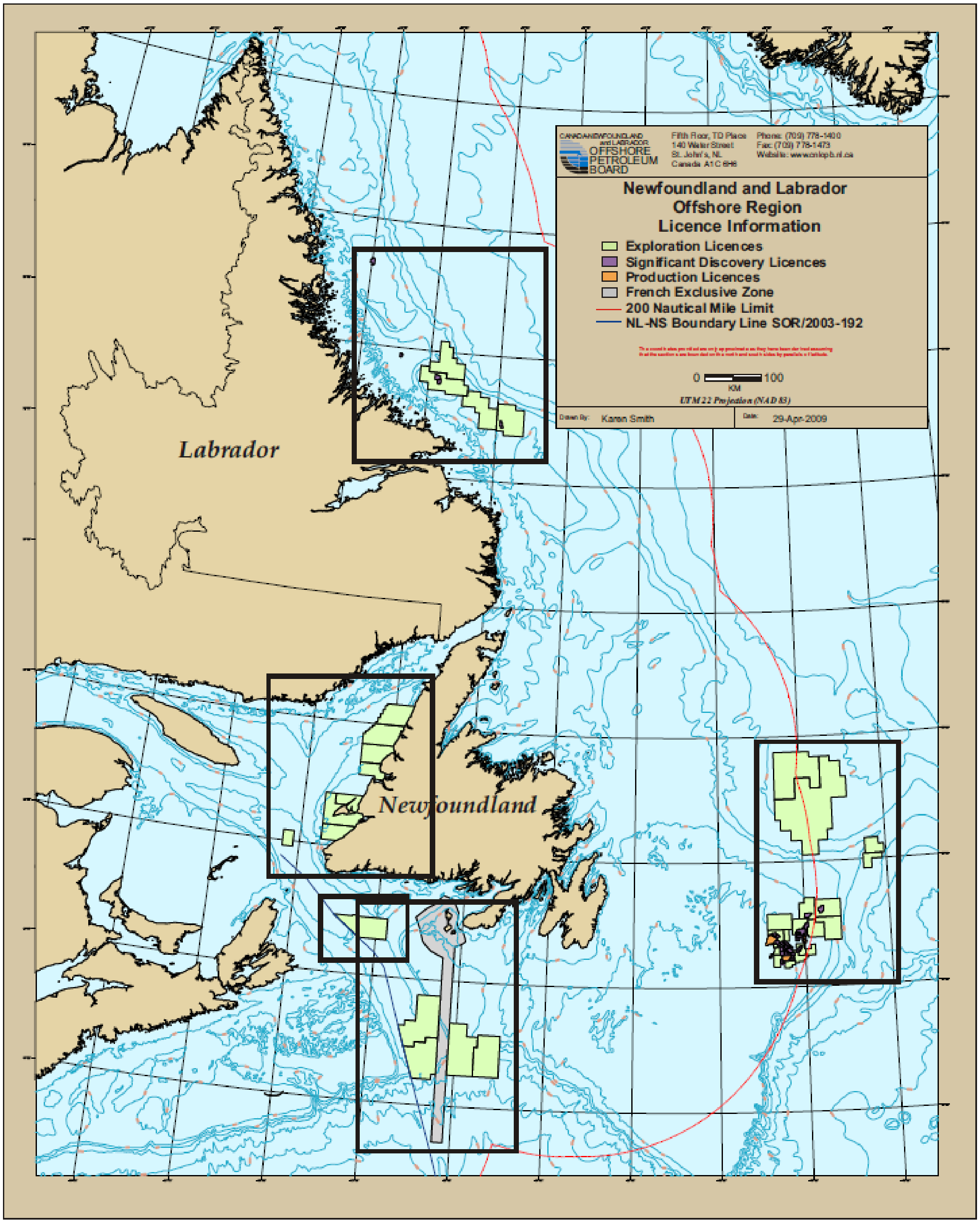

Figure 1: Offshore Newfoundland and Labrador Petroleum Licences, 2009 (*http://www.cnlopb.nl.ca/maps/onl_2009.pdf*).

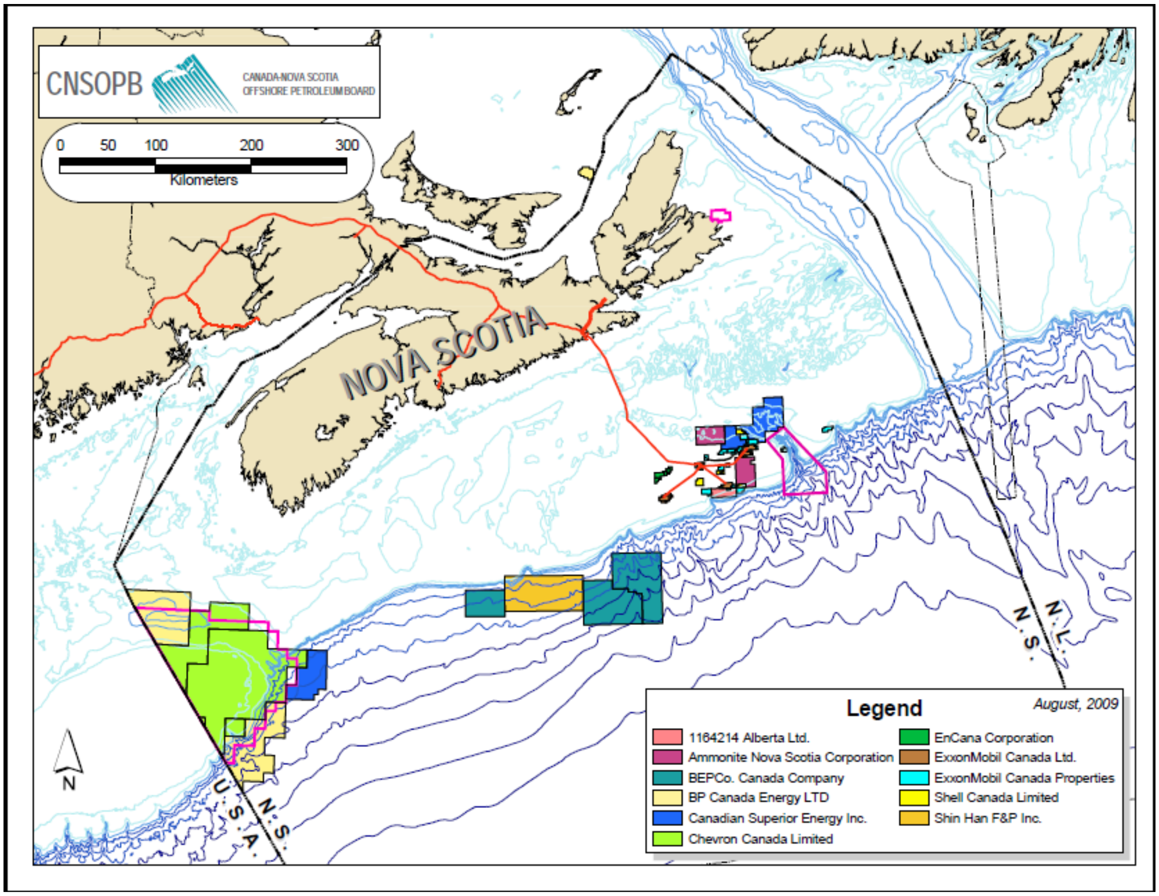

Figure 2: Offshore Nova Scotian Petroleum Exploration Licences, 2009 (*http://www.cnsopb.ns.ca/pdfs/web_map_full_size.pdf*)

An effective seabird monitoring program must capture variation in the patterns of seabird distributions, which are heavily influenced by changes in biotic, abiotic and anthropogenic factors at various spatial and temporal scales (Oedekoven et al. 2001). On short time scales (e.g., daily), fluctuations in seabird distributions can occur because of factors such as weather conditions, tides and location of food resources, and according to the specific diurnal patterns of each species (Mehlum et al. 1998). On a seasonal basis, the assemblages of species change with ice conditions, prey availability and the arrival and departure of migrants. At longer time scales (decadal), large-scale oceanographic changes, or regime shifts, can have profound effects on seabird populations (Montevecchi and Myers 1997). For example, low sea surface temperatures and salinity levels in the early 1990s altered the trophic structure of the Grand Banks (Drinkwater 1996). Migration of warm-water fish was impeded, which caused Northern Gannets (*Morus bassanus*) to shift to foraging on predominantly cold-water fish species (Montevecchi and Myers 1997). Therefore, to properly quantify seabird density, there is a need to monitor seabird diversity year round, over many years and in a variety of areas using the most modern and rigorous sampling methodologies available.

1.3 ESRF Offshore Seabird Monitoring Project

Following the 2004 Terra Nova FPSO oil spill, a proposal was presented to ESRF by the Canadian Wildlife Service (CWS) of Environment Canada and oil industry representatives to monitor seabird abundance and distribution in offshore areas potentially affected by oil exploration and production. This resulted in the ESRF Offshore Seabird Monitoring Program, the subject of this report. A Memorandum of Understanding was signed in July 2006 and the project began in late August with the following objectives:

- Collect and interpret scientifically credible observation data from periodic surveys aboard offshore vessels transiting from Newfoundland shore bases to NE Grand Banks, access to which to be provided by offshore Newfoundland Operators;
- To the extent possible, ensure consistency with other relevant observation programs, particularly for offshore Nova Scotia with respect to survey protocols, data recording, electronic database storage and analysis of seabird data collected under the Memorandum of Understanding (MOU) between Environment Canada and ESRF;
- Undertake directed surveys on offshore support vessels to address major data gaps as may be permitted by individual Newfoundland operator(s);
- Collect and/or arrange for the collection of seabird data (and marine mammal data) aboard vessels of opportunity in other areas of the Grand Banks or other regions such as offshore Nova Scotia to the extent possible and as may be permitted by operators;
- Develop databases for the storage, retrieval and analyses of seabird data collected from fixed and moving platforms;
- Act as focal point for receipt, electronic database storage and analysis of seabird data collected;
- Provide training on seabird identification, survey protocols and data recording to personnel working for, or contracted to, the offshore petroleum industry;
- Fulfill a scientific QA/QC role for existing industry observer programs, such as producing fields, onboard drilling units and seismic vessels; and
- Refine predictions related to impacts on seabirds and spills from offshore platforms, leading to a revised/improved model regarding seabird mortalities.

2 Methods

2.1 Seabird Monitoring in Eastern Canada

The first intensive inventory of seabirds within Atlantic Canada occurred under the PIROP (Programme Intégré de Recherches sur les Oiseaux Pélagiques) program. PIROP, originally a partnership between the CWS and the University of Moncton, was active from 1965 to 1992, but the bulk of the data was collected during the 1970s and early 1980s (Lock et al. 1994; Brown 1986). The PIROP program was designed to be implemented by both professional biologists and interested volunteers, and therefore employed a simple survey protocol. Observers counted all birds encountered as far as the eye could see without measuring the amount of ocean covered. Using this methodology, only relative abundance estimates could be produced in the form of number of birds per linear kilometre of survey track rather than true density estimates in birds/km^2 required to assess mortality risk due to oiling. Additionally, birds in flight were counted continuously, which is known to overestimate abundance (Spear et al. 1992), instead of using “snapshots” (see Tasker et al. 1984). Lastly, no attempt was made to account for the differential detectability of various species at increasing distances from the observer under varying weather conditions, although Diamond et al. (1986) describe post hoc estimated correction factors.

In the 1970s, protocols became more rigorous and researchers in western North America began using fixed-width transects (e.g., 300 m wide) allowing for calculation of *relative* seabird density, but that still did not take detectability into account. In a review of pelagic seabird surveys, Tasker (1984) identified various factors that could bias density estimates and attempted to minimize these factors through improvements in study design. They recommended that birds on the water be counted during 10-minute periods, while flying birds be counted instantaneously using “snapshots”. Secondly, they recommended that correction factors (i.e., coefficients of detection) be applied to account for varying detectability due to bird size, colour, behaviour, weather and observer experience. However, they provided few suggestions as to how these correction factors should be determined.

Many of the suggestions in Tasker et al. (1984) were incorporated into more recent offshore seabird surveys conducted on the Grand Banks by Memorial University researchers (Burke et al. 2005; Montevecchi and Burke 2004; Montevecchi and Burke 2002; Wiese and Montevecchi 2000). These surveys used fixed-width transects, but methods to account for overestimation of flying birds (Spear et al. 1992; Tasker et al. 1984) and for underestimation due to decreasing bird detectability with distance from the vessel were not employed (Buckland et al. 2001). Thus, the estimates produced are considered indices of “relative” abundance and not measures of “absolute” abundance or *density*.

In 2005, the CWS re-initiated its pelagic seabird monitoring program in eastern Canada (ECSAS) and developed a survey protocol based on those used elsewhere in the Atlantic. This protocol retains the recommendations of Tasker et al. (1984) and incorporates modern distance sampling techniques (Buckland et al. 2001) to account for varying seabird detectability. The program relies on ships of opportunity and participates in the Department of Fisheries and Oceans (DFO) Atlantic Zone Monitoring Program (AZMP) surveys. The AZMP program conducts physical, chemical and biological oceanographic surveys on a set series of lines several times per year and these survey lines form the core of the ECSAS monitoring program.

2.2 Study Area

Seabird surveys in this ESRF project were conducted primarily on the Grand Banks and the Scotian Shelf, but also on the Flemish Cap, Laurentian Channel, Gulf of Maine, Orphan Basin/Knoll and the Labrador Sea (Figure 3).

The Grand Banks covers an area of roughly 280,000 km^2 southeast of Newfoundland (Tankard and Welsink 1987) and are comprised of shallow-water plateaus and deep-water basins with depths ranging from 36 m to 185 m (Welsink et al. 1989). The Grand Banks are bounded by the cold Labrador Current from the north and the warm Gulf Stream to the south. The Flemish Pass separates the Grand Banks from the Flemish Cap, a smaller shallow water bank that is the easternmost extension of the North American Continental Shelf (Shaw 2006).

The Scotian Shelf is a 700 km long section of the continental shelf off the coast of Nova Scotia that varies in width from 120 km to 240 km (*www.thecanadianencyclopedia.com*) and covers an area of approximately 120,000 km^2. Its waters are shallow with an average depth of 116 m and a maximum depth of 270 m. Similar to the Grand Banks, the Scotian Shelf is influenced by the Labrador Current and the Gulf Stream and is the southernmost extent for sea ice off eastern North America.

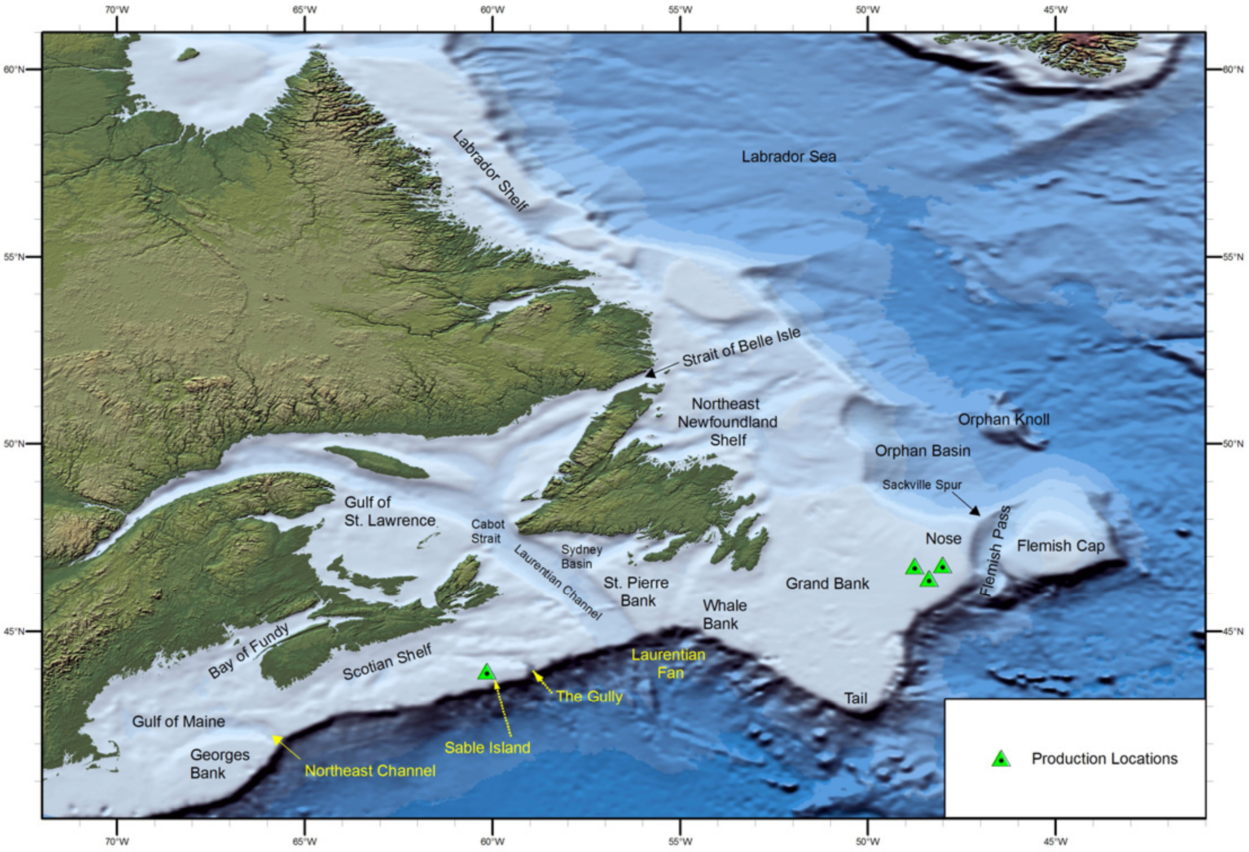

Figure 3: Map Showing the Study Area, Names of Major Bathymetric Features and Hydrocarbon Production Areas

2.3 Survey Protocol

The survey protocol used in this study (Gjerdrum et al. 2010) was developed in collaboration with the CWS's ECSAS program (see the Introduction for a history of seabird monitoring programs and protocols). The protocol employs distance-sampling methodology, which requires that the observer record the distance to each flock of birds detected. Distance sampling explicitly recognizes that more distant birds are less likely to be detected than those closer to the observer, and that species, observer and observation conditions may also influence detectability. Distance sampling analyses are conducted using the Distance program (Thomas et al. 2010). The software essentially estimates and applies a correction factor to account for birds that were present in the transect but missed during the survey. It does this by comparing the number of birds observed in various distance classes with the number expected in those classes if all birds were detected equally.

For this study, observations were conducted from a high point indoors near the front of the vessel (normally the bridge) during 5-minute periods called watches when vessel speed was between 4 kts and 19 kts. Early surveys under this program employed 10-minute watches. For each watch, the date, time, start and end positions, course, speed, weather, visibility and sea and ice conditions were recorded. Observation effort was concentrated primarily on a 90° arc forward and to one side of the vessel.

Different sampling methods were used for birds on water and those flying (Gjerdrum et al. 2010). Birds on the water were counted continuously and perpendicular distance from the vessel was recorded as the vessel passed each flock (Figure 4); if birds dove or flew off, distance to the place where they had been was recorded. Counting flying birds continuously results in an over-estimate of abundance, the magnitude of which is dependent upon the relative speeds and directions of the vessel and birds (Spear et al. 1992; Tasker et al. 1984). To address this issue, flying birds were sampled using a series of instantaneous samples called "snapshots" (Tasker et al. 1984). The number of snapshots per 5-minute watch varied depending on vessel speed and timed so that they occurred roughly every 300 m (Table 1). At each snapshot, all flocks present within the 90° arc 300 m to the side and 300 m ahead of the vessel were counted (Figure 4). After the vessel traveled another 300 m, the next snapshot was conducted, and so on until the end of the five-minute watch. Thus a series of instantaneous "point counts" were conducted for flying birds. Distance to flying birds was measured "radially" (i.e., directly to the bird) at the instant of the snapshot since flying birds do not stay in position long enough to measure distance perpendicularly as the vessel passes. Additionally, all other flying birds encountered (outside of snapshot times) were recorded, but were not used to calculate density estimates. Distances were estimated using a hand-held ruler calibrated to height of the observer's eye above the water and observer arm length (Gjerdrum et al. 2010; Heinemann 1981).

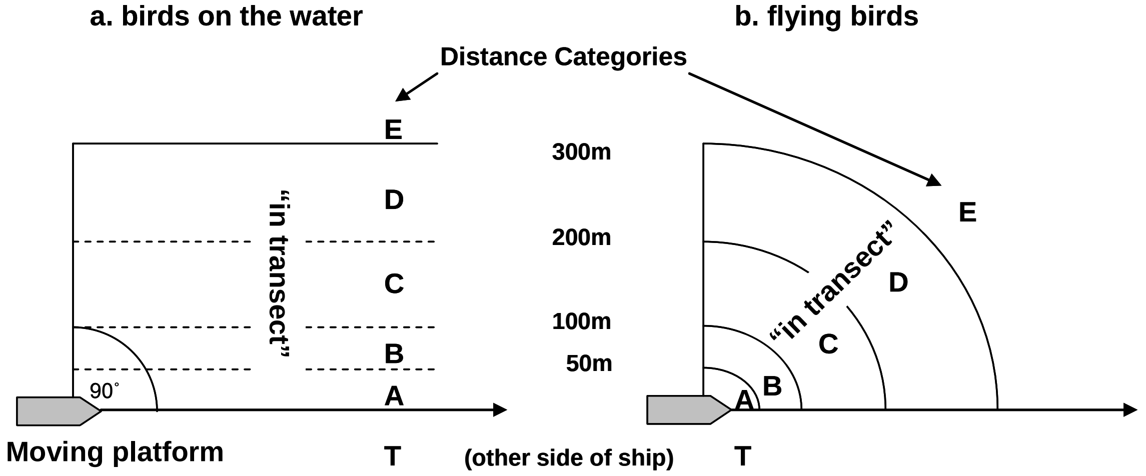

Figure 4: Illustration of Surveys Covering a 300-m Transect from a Moving Vessel. For flocks on (a) water the perpendicular distance from the vessel was recorded as the ship passed by, whereas for (b) flying birds radial distance was recorded during snapshots.

Table 1: Intervals at Which Instantaneous Snapshot Counts of Flying Birds Are Conducted. These intervals result in roughly 300 m between snapshot counts.

Platform Speed (knots)	Interval between counts (min)
< 4.5	2.5
4.5 - 5.5	2
5.5 - 8.5	1.5
8.5 - 12.5	1
12.5 – 19.0	0.5

The method of distance measurement to flying birds changed during the study period as survey protocol and analysis best practices evolved. From the beginning of the study to July 2008, distances to birds on water and flying birds were measured perpendicularly. This method (known as line-transect sampling) is best suited for continuous counting of birds on the water that do not move fast in relation to the speed of the vessel (Buckland et al. 2001). In an attempt to better model flying bird detectability, distances to flying birds were measured radially after July 2008 corresponding to point-count transect sampling (Figure 4) (Buckland et al. 2001; S. Buckland pers. comm). There was a short period from October to December 2007 when distances were not measured for flying birds as the protocol developed. This resulted in three distinct survey types (Table 2): 1) distance to both flying birds and birds on water were measured perpendicularly; 2) distance to birds on water was measured perpendicularly; distance to flying birds was measured radially; and 3) distance to birds on water was measured perpendicularly; no distance measured for flying birds. Separate analyses were performed in the Distance program to account for these differences (see below).

Table 2: Methods Used for Distance Sampling Measurement During the Study

Method	Water Bird Distance	Flying Bird Distance
1	Perpendicular	Perpendicular
2	Perpendicular	Radial
3	Perpendicular	None

Birds (and marine mammals) were identified to the lowest possible taxonomic group (species, genus, family, etc.) and assigned to the appropriate distance category. For each flock, the number of individuals was recorded as well as supplementary information on species associations, behaviour, age, sex and flight direction.

2.4 Data Storage and Management

All observations were stored in an electronic database using Microsoft Access (see section 3.3 for more details). During observation, data were either entered directly into the database using voice recognition technology or recorded on datasheets and entered into the database at a later time. Vessel position, speed and wind speed and direction were either streamed directly into the database through a connection to the ship's navigation system (or a standalone GPS) or entered manually.

2.5 Statistical Methods and Analyses

Distance 6 Release 2 (Thomas et al. 2010) was used to estimate density in each 1^{o} x 1^{o} block in the area bounded by 40º N - 61º N and 41º W - 72º W. Separate density estimates were produced for each block in each of four seasons for each species/species group (see Table 3 and Results). Since counts on consecutive 5-minute watches are likely spatially auto-correlated (Dormann et al. 2007) and non-independent, they were not used as the sample lines. Instead, series of consecutive 5-minute watches conducted on a single day in a given block were combined to create longer survey lines that served as the sampling unit for distance sampling (Buckland et al. 2001; L. Thomas, pers. comm.). Doing so also addresses the issue of unequal survey efforts because longer transects through the block will contribute more flocks, and hence more to the seabird density estimate.

To compute densities, we followed the methods outlined in Buckland et al. (2001); see also Ronconi and Burger (2009). For organisms such as seabirds that occur in flocks, an estimate of the density, $\hat{D}$, of n flocks counted on a survey transect line of length L and width w is equal to the number of flocks per unit area, called the flock encounter rate, n/wL, multiplied by the expected flock size, $E(S)$, adjusted by a correction factor, $\hat{P}$, called the detection probability[1] (Equation 1; Buckland et al. 2001). The detection probability, $\hat{P}$, accounts for the fact that not all birds in the transect are detected. It is estimated based on fitting a "detection function" to the observed distances to flocks, which assumes that all birds are detected in the transect immediately adjacent to the vessel, and declines in the transects farther from the vessel (Buckland et al. 2001). Expected flock size and detection probability were estimated across all 1° blocks. In order to produce separate density estimates for each 1° block, flock encounter rate was estimated from the survey lines in each block separately. Encounter rate, flock size and detection

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[1] In the standard formulation, animals are surveyed on both sides of the survey line; so the encounter rate is $n/2wL$.

probability each have an associated variance component that contributes to the overall variance of the density estimate. The contributions of flock size and detection probability to the combined variance are normally relatively small, compared to that for encounter rate (Buckland et al. 2001).

$$\hat{D} = \frac{n * E(S)}{wL\hat{P}} \qquad \text{Equation 1}$$

As a starting point, detection functions were fitted using a basic key function (half-normal) with optional series expansion terms chosen from one of three families (cosine, hermite or polynomial). Visual inspection and the χ^2 goodness-of-fit test were used to assess detection function model fit by examining differences between observed and expected values in each distance category (Buckland et al. 2001). We then attempted to improve detection function fit by either choosing a different key function (hazard rate or uniform with optional series expansion terms) or by including explanatory covariates such as wind speed, sea state, wave height and/or observer (using the multi-covariate distance sampling engine (Marques et al. 2007). Exploratory analyses indicated that many variables were correlated (e.g., wind speed, sea state and wave height). However, the inclusion of wind speed often produced the best model. Including observer as a covariate sometimes improved model fit, but there were often not enough observations by all observers to include observer in all analyses. For comparison, we also fit a uniform detection function with no series expansion terms (equivalent to not using distance sampling). This allowed us to compare our results with those that we would have obtained had we not used distance sampling and instead assumed that all birds within 300 m were detected.

Table 3: Species Groupings for Analysis and Mapping

Group	***Common Name***	***Scientific Name***
Northern Fulmar	Northern Fulmar	*Fulmarus glacialis*
Shearwaters	Greater Shearwater	*Puffinus gravis*
	Manx Shearwater	*Puffinus puffinus*
	Sooty Shearwater	*Puffinus griseus*
	Cory’s Shearwater	*Calonectris diomedea*
	Audubon’s Shearwater	*Puffinus lherminieri*
	Unidentified Shearwater	
Storm-Petrels	Wilson’s Storm-Petrel	*Oceanites oceanicus*
	Leach‘s Storm-Petrel	*Oceanodroma leucorhoa*
	Unidentified Storm-Petrel	
Gannet	Northern Gannet	*Morus bassanus*
Gulls	Herring Gull	*Larus argentatus*
	Iceland Gull	*Larus glaucoides*
	Glaucous Gull	*Larus hyperboreus*
	Great Black-backed Gull	*Larus marinus*
	Lesser Black-backed Gull	*Larus fuscus*
Black-legged Kittiwake	Black-legged Kittiwake	*Rissa tridactyla*

Group	Common Name	Scientific Name
Murres	Common Murre Thick-billed Murre Unidentified Murre	*Uria aalge* *Uria lomvia* *Uria sp.*
Dovekie	Dovekie	*Alle alle*
Other Alcids	Atlantic Puffin Black Guillemot Razorbill Unidentified Alcid	*Fratercula arctica* *Cepphus grylle* *Alca torda*

When sample size was small for a particular species in a specific season (n < ~ 70 flocks detected), the detection function model fit was often poor. For these analyses, we used a detection function for the same species and survey method during another season or pooled data across seasons for the same survey method (Thomas et al. 2010). It was not possible to directly estimate detectability for flying birds for the small number of surveys that did not record distance (Method 3, Oct–Dec 2007, 7 survey trips). In these cases, a detection function for flying birds in the same season (or pooled across seasons, if necessary) was chosen from another survey method (i.e., 1 or 2). Among models with good visual and χ^2 fits, final detection function models were selected using Akaike Information Criterion (AIC) with correction for small sample sizes (Burnham and Anderson 2002). AIC is a statistical method of ranking models that provide the best compromise between increasing model fit and reducing the number of parameters in the model.

2.6 Combining Density Estimates

Distance sampling analyses for flying versus water birds and for each survey method were necessarily conducted separately and the results subsequently combined for two reasons. First, the detection process for flying birds versus swimming birds is likely to be different, even if the same measurement technique (e.g., perpendicular, as in Method 1, see Table 2) is employed for each. Second, distances to flying and swimming birds were measured differently in methods 2 and 3 (see Table 2) requiring different distance sampling analysis frameworks (line-transect versus point-transect) that cannot be carried out in the same analysis. Thus, for each species (or species group), separate density estimates were computed for flying and water birds and were subsequently summed to give the density estimate for that species for each survey method and season in each 1° block. The rule of decomposition of variance (Weiss 2005) was used to compute the combined variance from the individual variances of the water and flying birds. This resulted in a maximum of three separate (species-specific) density estimates in each block during each season - one for each survey method. The weighted average of these three was computed (based on kilometers surveyed using each survey method) to yield the final species-specific density and variance estimates for each block during each season. Seasonal 1° block density maps were plotted for each species/group using ArcGIS 9.3.

3 Results

3.1 Training

Observer training was identified as a priority area in the project terms of reference and a key element in the success of this project was the availability of highly skilled observers.

A standardized observer training program was developed that included two components: safety and observation training. Safety training requirements were dictated by both industry and government regulations, depending upon the type of vessel/platform on which the observer was stationed. Training courses taken by observers included Basic Safety Training (BST), Marine Emergency Duties A-1 (MED-A1) and/or H_2S Alive. Observers either received safety training in advance of conducting surveys at sea or in readiness for emergency spill response. Courses were provided by private and institutional facilities located in Newfoundland and Nova Scotia.

The observation training component consisted of three modules: 1) seabird identification, 2) protocol implementation and 3) database usage. For each module, PowerPoint presentations were developed and printed copies of these along with other reference material were made available to the observers. These modules were designed to be delivered in a classroom setting during a 1-2 day course including a practical seabird identification field trip. The classroom training provided a sound foundation upon which observers could develop their skills with further practical training. New observers were accompanied on their first at-sea voyage by an experienced observer to provide first-hand guidance. Subsequently, these observers were able to conduct surveys on their own. Since 2006, 27 people have received safety or observation training as part of this project (or as part of the CWS's ECSAS program): Susan Abbott, Karel Allard, Robert Decker, Garry Donaldson, Dave Fifield, Rosalind Ford, Carina Gjerdrum, Paul Harris, Tony Lock, Peter Mallam, Greg McClelland, Eric Mills, Travis Pearce, Greg Robertson, Rob Ronconi, Pierre Ryan, Jon Stone, Peter Thomas, Erica Titford, Brian Veitch, Brad Way, John Wells, Regina Wells, Sabina Wilhelm and Sarah Wong. Experience showed that the availability of qualified observers was often limited and that this pool of observers is an extremely valuable resource.

3.2 Survey Effort

During the period from March 1, 2006 to October 31, 2009, 44 ESRF-supported survey trips were conducted from vessels of opportunity.[2] A further 32 trips were conducted by the CWS as part of the ECSAS program (Table 4, Figure 5). ESRF surveys were conducted year round on a roughly monthly basis, while other CWS survey effort varied seasonally with the greatest effort occurring during summer. During these 76 surveys, a total of 51,392 km of ocean transect was covered during 2,563 hours of observation time during which 123,909 birds were counted. The vast majority of surveys were conducted from either oil industry supply ships or DFO research/fishery patrol vessels. A small number of other surveys were conducted from ferries, cargo vessels, seismic ships or sailboats. The majority of DFO research vessel trips were conducted under the AZMP program (Figure 6).

In keeping with study objectives, ESRF-funded survey effort was largely concentrated on the Grand Banks with a particular emphasis on the northern Grand Banks production area and transit route to St. John's (Figure 5). Secondary areas of emphasis included the Orphan Basin, Flemish

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[2] One of these was jointly sponsored by the ESRF and Memorial University.

Cap/Flemish Pass, Scotian Shelf, northeast Newfoundland Shelf and Labrador Shelf. Additional CWS surveys focused on the Scotian Shelf, Grand Banks, Flemish Cap/Flemish Pass, southern Labrador Shelf and Labrador Sea.

Figure 7 shows survey effort by 1° block in each of four seasons: spring (Mar–Apr), summer (May–Aug), fall (Sep–Oct), and winter (Nov–Feb). For seabirds that breed in the North Atlantic, these correspond to the migratory (spring and fall), breeding (summer) and non-breeding (winter) periods, while for southern hemisphere breeders, the breeding and non-breeding seasons are reversed. Note that, as defined, summer and winter are each four months long, while spring and fall are two months long.

The route between St. John's and the Grand Banks production area was covered monthly on a year-round basis. During the spring, good spatial coverage of the Grand Banks, Flemish Cap and Scotian Shelf was obtained through a combination of ESRF trips and the Grand Banks and Scotian Shelf AZMP surveys. The best overall coverage was obtained during the summer when good coverage was extended to the southern Labrador Sea, the Orphan Basin and much of the Northeast Newfoundland Shelf. With the exception of parts of the Grand Banks and Scotian Shelf, geographical coverage during the fall was the poorest of the four seasons, although, importantly, this season provided the only coverage of the Labrador Shelf north of Groswater Bay. The northern Grand Banks were well covered during the winter, while sections of the Northeast Newfoundland Shelf, Flemish Cap, southern Grand Banks and Scotian Shelf received relatively less effort.

Table 4: Survey Effort and Birds Counted During 76 Seabird Monitoring Trips Between March 1, 2006 and October 31, 2009. Survey trips in bold were completed under the ESRF program; the remainder were completed under the Canadian Wildlife Service Eastern Canadian Seabirds At Sea (ECSAS) program. Survey methods are presented in Table 2.

Start Date	End Date	Observer(s)	Vessel	Survey Time (min)	Survey Length (km)	Survey Method	Birds Counted
01-Mar-2006	02-Mar-2006	Carina Gjerdrum Fulton Lavender	*Princess of Acadia*	250	110.0	1	10
11-Mar-2006	14-Mar-2006	Fulton Lavender Susan Abbott	*Skogafoss*	1,030	398.4	1	389
21-Apr-2006	06-May-2006	David Fifield	CCGS *Hudson*	3,274	1,139.9	1	701
22-Apr-2006	03-May-2006	Pierre Ryan Carina Gjerdrum	CCGS *Teleost*	3,561	1,287.3	1	7,300
24-May-2006	08-Jun-2006	Carina Gjerdrum	CCGS *Hudson*	3,315	1,296.3	1	4,849
21-Aug-2006	24-Aug-2006	Tony Lock Jon Stone	M.V. *Joseph and Clara Smallwood*	280	173.9	1	190
24-Aug-2006	24-Sep-2006	Greg McClelland	*Kommandor Jack*	5,196	1,493.2	1	2,304
16-Sep-2006	18-Sep-2006	Carina Gjerdrum	*Hebron Sea*	592	169.1	1	92
05-Oct-2006	20-Oct-2006	Carina Gjerdrum	CCGS *Hudson*	3,093	1,191.9	1	1,295
31-Oct-2006	05-Nov-2006	Rob Ronconi Sarah Wong	*Balaena*	1,400	234.9	1	55
04-Nov-2006	**05-Nov-2006**	**Greg McClelland**	***Maersk Dispatcher***	**233**	58.5	**1**	**129**
04-Nov-2006	**10-Nov-2006**	**David Fifield**	***Maersk Chancellor***	**395**	148.2	**1**	**313**

Start Date	End Date	Observer(s)	Vessel	Survey Time (min)	Survey Length (km)	Survey Method	Birds Counted
19-Nov-2006	**04-Dec-2006**	**David Fifield** **Garry Donaldson**	**CCGS *Hudson***	**3,216**	1,088.4	**1**	**2,817**
23-Jan-2007	**25-Jan-2007**	**David Fifield**	***Maersk Placentia***	**623**	214.0	**1**	**118**
28-Feb-2007	**02-Mar-2007**	**Pierre Ryan**	***Atlantic Eagle***	**750**	272.1	**1**	**293**
06-Mar-2007	**07-Mar-2007**	**David Fifield**	***Maersk Chancellor***	**450**	167.3	**1**	**45**
04-Apr-2007	22-Apr-2007	Carina Gjerdrum	CCGS *Hudson*	4,066	1,549.2	1	3,150
05-Apr-2007	**19-Apr-2007**	**David Fifield**	**CCGS *Leonard J. Cowley***	**3,467**	1,001.3	**1**	**1,095**
12-Apr-2007	27-Apr-2007	Pierre Ryan	CCGS *Teleost*	3,545	1,379.7	1	2,783
28-Apr-2007	**08-May-2007**	**David Fifield**	**CCGS *Hudson***	**2,925**	1,090.8	**1**	**2,564**
03-May-2007	26-May-2007	Sarah Wong	*Balaena*	616	115.0	1	159
10-May-2007	27-May-2007	Carina Gjerdrum	CCGS *Hudson*	4,758	1,851.9	1	3,006
06-Jun-2007	26-Jun-2007	Rob Ronconi Sarah Wong	*Balaena*	1,620	259.8	1	198
07-Jun-2007	19-Jun-2007	Greg McClelland	CCGS *Hudson*	2,628	408.9	1	1,791
20-Jun-2007	**08-Jul-2007**	**David Fifield**	***Anticosti***	**4,350**	890.7	**1**	**2,110**
04-Jul-2007	20-Jul-2007	John Wells	CCGS *Louis S. St. Laurent*	4,677	1,826.8	1	1,132
08-Jul-2007	31-Jul-2007	Greg McClelland	CCGS *Teleost*	4,326	1,500.2	1	1,365
02-Aug-2007	09-Aug-2007	Susan Abbott	CCGS *Hudson*	1,316	436.1	1	851
10-Aug-2007	**22-Aug-2007**	**Rosalind Ford**	**CCGS *Leonard J. Cowley***	**2,768**	735.6	**1**	**2,260**
18-Sep-2007	**21-Sep-2007**	**David Fifield** **Brian Veitch**	***Atlantic Hawk***	**562**	186.1	**3**	**524**
25-Sep-2007	**01-Oct-2007**	**Rob Ronconi**	***Ryan Leet***	**730**	216.2	**1**	**155**
28-Sep-2007	19-Oct-2007	Carina Gjerdrum	CCGS *Hudson*	3,947	1,295.5	3	1,792
10-Oct-2007	**11-Oct-2007**	**Brian Veitch**	***Atlantic Hawk***	**179**	65.4	**3**	**201**
22-Oct-2007	**29-Oct-2007**	**Karel Allard**	***Panuke Sea***	**516**	163.5	**3**	**1,988**
07-Nov-2007	**08-Nov-2007**	**Brian Veitch**	***Atlantic Eagle***	**149**	55.0	**3**	**74**
16-Nov-2007	**21-Nov-2007**	**Carina Gjerdrum**	**CCGS *Hudson***	**803**	236.4	**3**	**788**
22-Nov-2007	**06-Dec-2007**	**David Fifield**	**CCGS *Hudson***	**2,315**	668.3	**3**	**830**
07-Dec-2007	**08-Dec-2007**	**Sarah Wong**	**CCGS *Edward Cornwallis***	**638**	237.3	**3**	**1,600**
13-Dec-2007	**26-Dec-2007**	**Rosalind Ford**	**CCGS *Leonard J. Cowley***	**1,033**	261.7	**3**	**430**
18-Jan-2008	**19-Jan-2008**	**Sarah Wong**	**CCGS *Hudson***	**820**	275.3	**3**	**300**
18-Jan-2008	**24-Jan-2008**	**Pierre Ryan**	***Atlantic Hawk***	**688**	186.5	**3**	**295**
06-Feb-2008	**12-Feb-2008**	**Karel Allard**	***Hebron Sea***	**775**	249.9	**3**	**369**
27-Feb-2008	**05-Mar-2008**	**Pierre Ryan** **Peter Mallam**	**CCGS *Leonard J. Cowley***	**2,259**	502.2	**3**	**2,980**
28-Mar-2008	**31-Mar-2008**	**David Fifield**	***Atlantic Eagle***	**505**	188.4	**1**	**49**
15-Apr-2008	29-Apr-2008	Carina Gjerdrum	CCGS *Hudson*	2,875	1,179.7	1	3,228
20-Apr-2008	04-May-2008	Pierre Ryan	CCGS *Teleost*	4,448	1,515.1	1	2,177
08-May-2008	**19-May-2008**	**David Fifield**	**CCGS *Hudson***	**2,561**	930.3	**1**	**1,074**
20-May-2008	03-Jun-2008	Rob Ronconi	CCGS *Hudson*	3,996	1,509.5	1	1,493
06-Jun-2008	**11-Jun-2008**	**Peter Mallam**	***Maersk Norseman***	**475**	180.0	**1**	**354**
04-Jul-2008	**18-Jul-2008**	**David Fifield**	**CCGS *Louis S. St. Laurent***	**4,633**	1,802.6	**2**	**1,055**

Start Date	End Date	Observer(s)	Vessel	Survey Time (min)	Survey Length (km)	Survey Method	Birds Counted
07-Jul-2008	**20-Jul-2008**	**Peter Mallam**	**CCGS *Teleost***	**3,444**	1,198.7	**2**	**2,026**
17-Jul-2008	25-Jul-2008	Eric Mills	CCGS *Hudson*	852	272.6	2	83
05-Aug-2008	15-Aug-2008	Garry Donaldson	*Orlova*	2,147	736.7	1	1,728
16-Aug-2008	**20-Aug-2008**	**David Fifield**	***Atlantic Hawk***	**1,182**	324.9	**2**	**341**
03-Sep-2008	**10-Sep-2008**	**Karel Allard**	***Sable Sea***	**526**	151.5	**2**	**425**
22-Sep-2008	**24-Sep-2008**	**Pierre Ryan**	***Atlantic Osprey***	**526**	205.4	**2**	**138**
28-Sep-2008	21-Oct-2008	Karel Allard	CCGS *Hudson*	4,822	1,807.4	2	2,431
04-Oct-2008	07-Oct-2008	Sarah Wong	*Sable Sea*	733	223.9	2	214
10-Oct-2008	**20-Oct-2008**	**David Fifield**	**CCGS *Teleost***	**1,644**	508.8	**2**	**2,392**
03-Nov-2008	**06-Nov-2008**	**David Fifield** **Erica Titford**	***Maersk Gabarus***	**394**	109.0	**2**	**1,025**
21-Nov-2008	**23-Nov-2008**	**Rob Ronconi** **Erica Titford**	**CCGS *Hudson***	**636**	231.7	**2**	**180**
11-Dec-2008	**13-Dec-2008**	**David Fifield** **Regina Wells**	***Burin Sea***	**92**	28.0	**2**	**86**
11-Dec-2008	**14-Dec-2008**	**Rob Ronconi**	**CCGS *Hudson***	**625**	218.3	**2**	**217**
26-Jan-2009	**07-Feb-2009**	**Regina Wells**	***Atlantic Kingfisher***	**554**	154.3	**2**	**612**
19-Feb-2009	**27-Feb-2009**	**Regina Wells**	***Atlantic Kingfisher***	**795**	244.7	**2**	**245**
20-Feb-2009	**04-Mar-2009**	**Susan Abbott**	**CCGS *Leonard J. Cowley***	**2,723**	698.3	**2**	**2,776**
09-Apr-2009	29-Apr-2009	Karel Allard	CCGS *Hudson*	3,903	1,471.9	2	1,831
25-Apr-2009	03-May-2009	Pierre Ryan	CCGS *Teleost*	2,651	933.4	2	802
02-May-2009	**17-May-2009**	**Sarah Wong**	**CCGS *Hudson***	**2,049**	719.0	**2**	**1,339**
17-May-2009	01-Jun-2009	Rosalind Ford	CCGS *Hudson*	4,102	1,602.4	2	2,408
24-Jul-2009	**26-Jul-2009**	**Pierre Ryan**	***Maersk Chancellor***	**545**	243.5	**2**	**729**
28-Jul-2009	12-Aug-2009	Karel Allard Emily Wilson	CCGS *Hudson*	3589	1,062.2	2	34,618
25-Aug-2009	**26-Aug-2009**	**David Fifield**	***Atlantic Kingfisher***	**673**	283.1	**2**	**383**
07-Sep-2009	**22-Sep-2009**	**Rosalind Ford**	**CCGS *Hudson***	**1,461**	468.6	**2**	**217**
26-Sep-2009	**19-Oct-2009**	**David Fifield**	**CCGS *Hudson***	**6,093**	2,100.9	**2**	**643**
09-Oct-2009	03-Nov-2009	Rosalind Ford	CCGS *Teleost*	3,366	999.3	2	900
			Totals	**153,754**	51,392.3		**123,909**

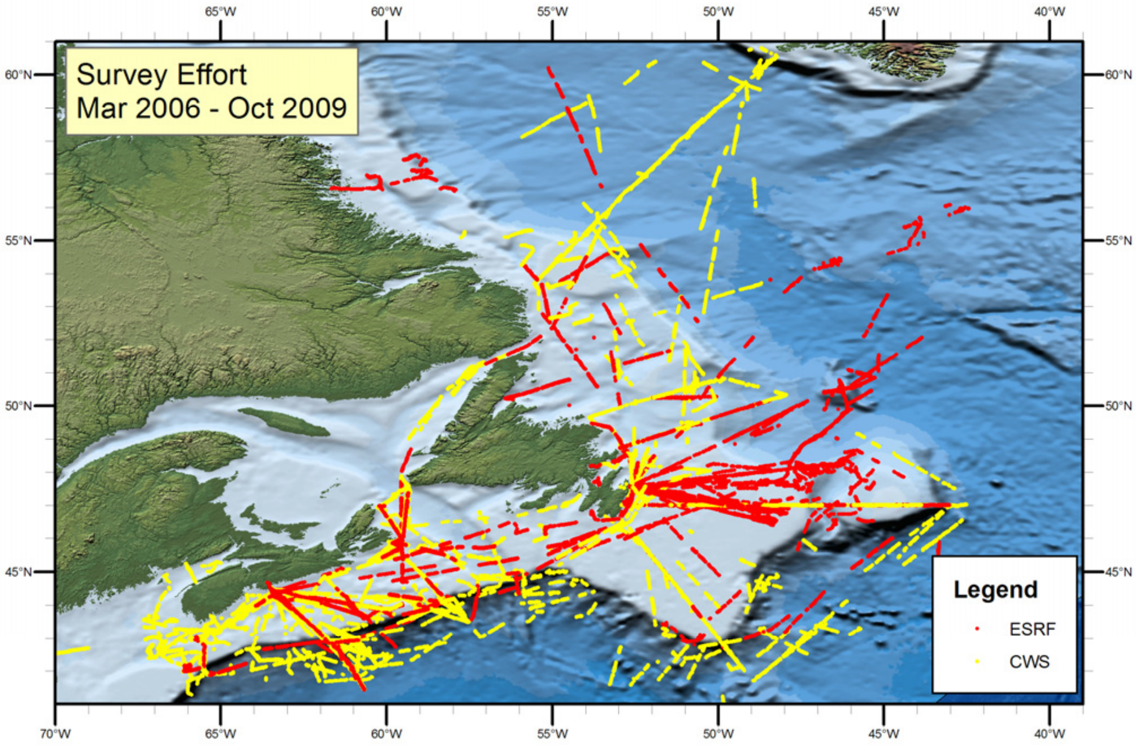


Figure 5: Survey Effort During the Period from March 1, 2006 to August 31, 2009. Each dot shows the position of a (normally 5-minute) survey watch.

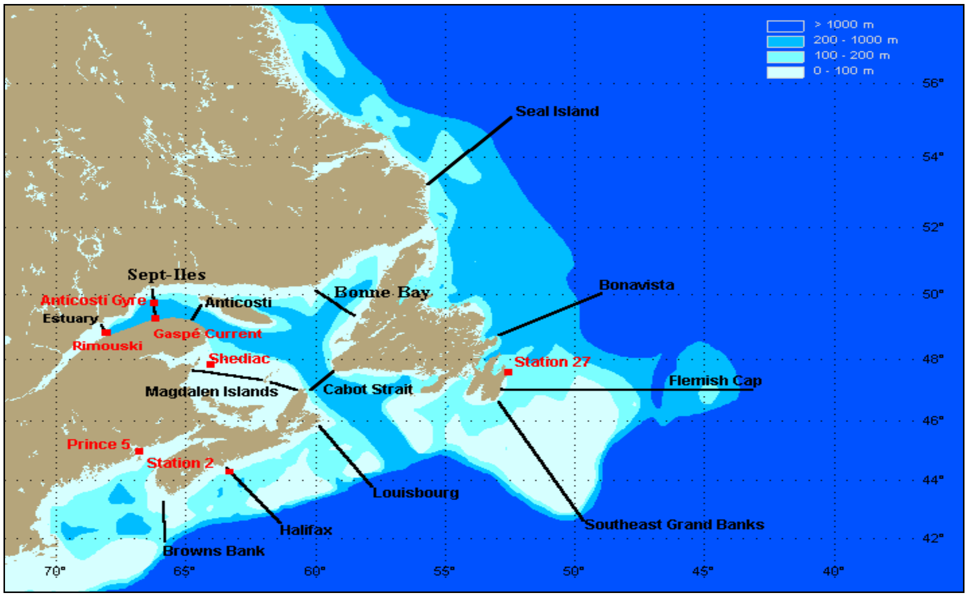


Figure 6: Locations of Repeatedly Surveyed Lines on DFOs Atlantic Zone Monitoring Program (AZMP). *Source: http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/map-carte-eng.html*

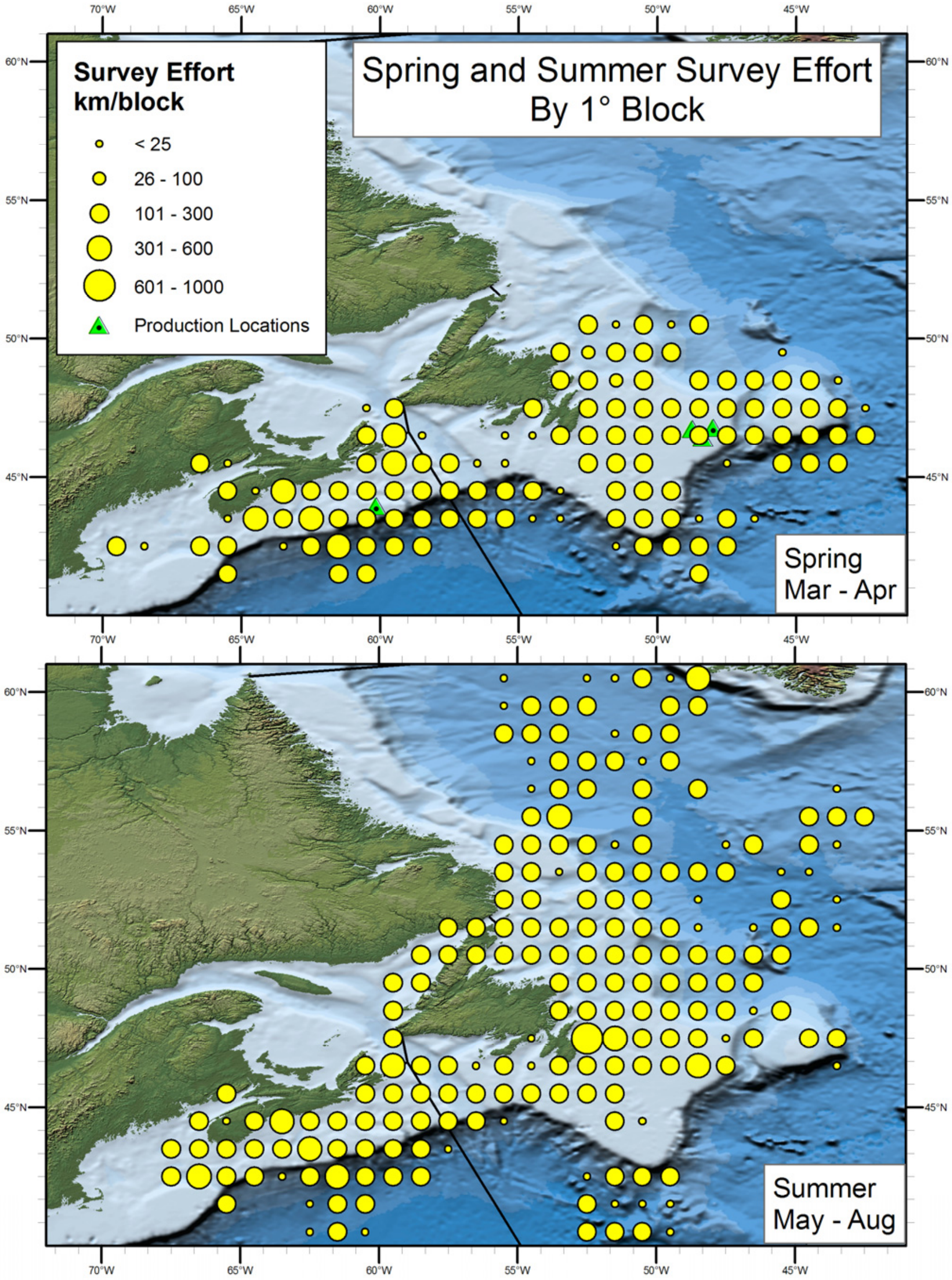


Figure 7: Combined ESRF and Other CWS Survey Effort During Spring (March–April) and Summer (May–Aug) by 1° Block

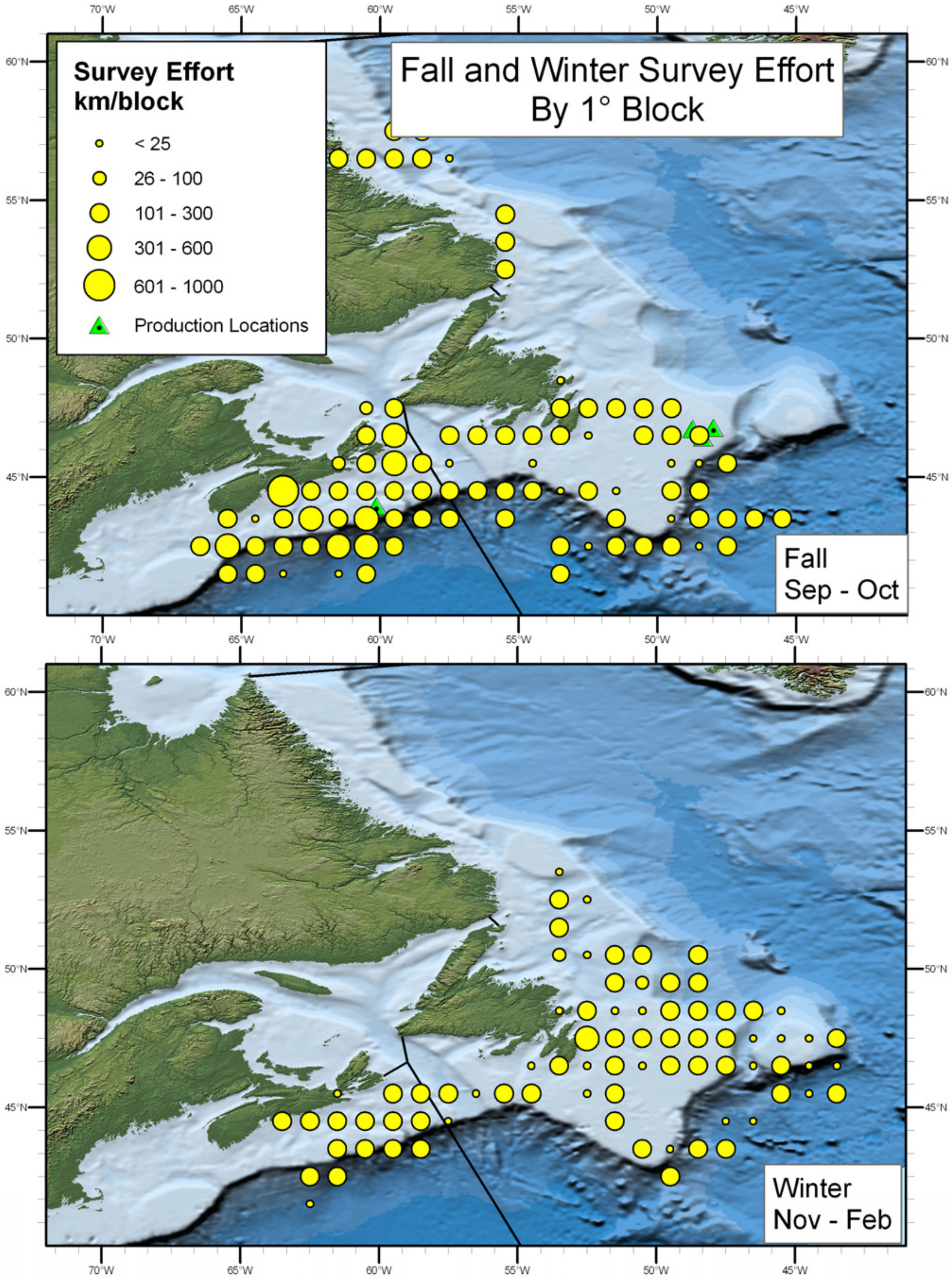


Figure 7 (cont'd): Combined ESRF and Other CWS Survey Effort During Fall (Sept–Oct) and Winter (Nov–Feb) by 1° Block

3.3 Database

The strength of any project depends heavily upon the extent to which its data are efficiently managed. One of the goals of this project was to develop an integrated database framework to host the data being generated and provide flexible and efficient access to that data. This database needed to

- be robust and fault tolerant;
- be easy to use;
- be based on a readily available relational database management system;
- be able to include legacy data from the PIROP program as well as data collected under the new protocol used in this project (and by the CWS's ECSAS program);
- be able to manage both moving (e.g., vessels) and stationary (e.g., rigs) survey types;
- be usable for direct data entry during surveys;
- be easy to integrate surveys from multiple simultaneous surveys trips; and
- include a powerful query interface to extract information.

To achieve these goals, a database was constructed using Microsoft Access. Microsoft Access was chosen because (1) it is based on a robust commercially proven relational database engine, (2) it has a powerful facility for building easy-to-use forms, (3) it has a powerful query facility, (4) it is readily available with Microsoft Office, (5) it is familiar to many users, and (6) it has a broad base of vendor and user support. The first version of the database was constructed by the CWS for the PIROP and ECSAS programs in April 2006 and it received continuous upgrades and enhancements during the lifetime of this project.

3.3.1 Database Structure

The database consists of two Microsoft Access MDB files, a relatively small *frontend* that contains all the forms, queries and custom Visual Basic code, and which is linked to the *backend* which contains the actual tables that hold the data. This frontend/backend split is a common database design paradigm that has the advantage of allowing for updates to the small frontend to be distributed to users without requiring the backend to be updated as well.

The database was designed around a core of three tables (Figure 8): (1) the **cruise** table, each entry of which contains information about a single survey trip including dates, observers, ship name and other details, (2) the **watch** table, each entry of which contains information about a single five-minute survey period conducted during a cruise, including date, time, observer, weather, ship speed and course, position, and other details, and (3) the **sightings** table, each entry of which contains information about a single flock detected during a watch, including species, flock size, behaviour, distance, flight direction and other details. In addition, the database contains a suite of auxiliary tables containing codes for bird names, bird behaviour, weather, ice, sea state, distance classes and flight directions as well as GPS communication settings, observer names and ship names (Figure 9).

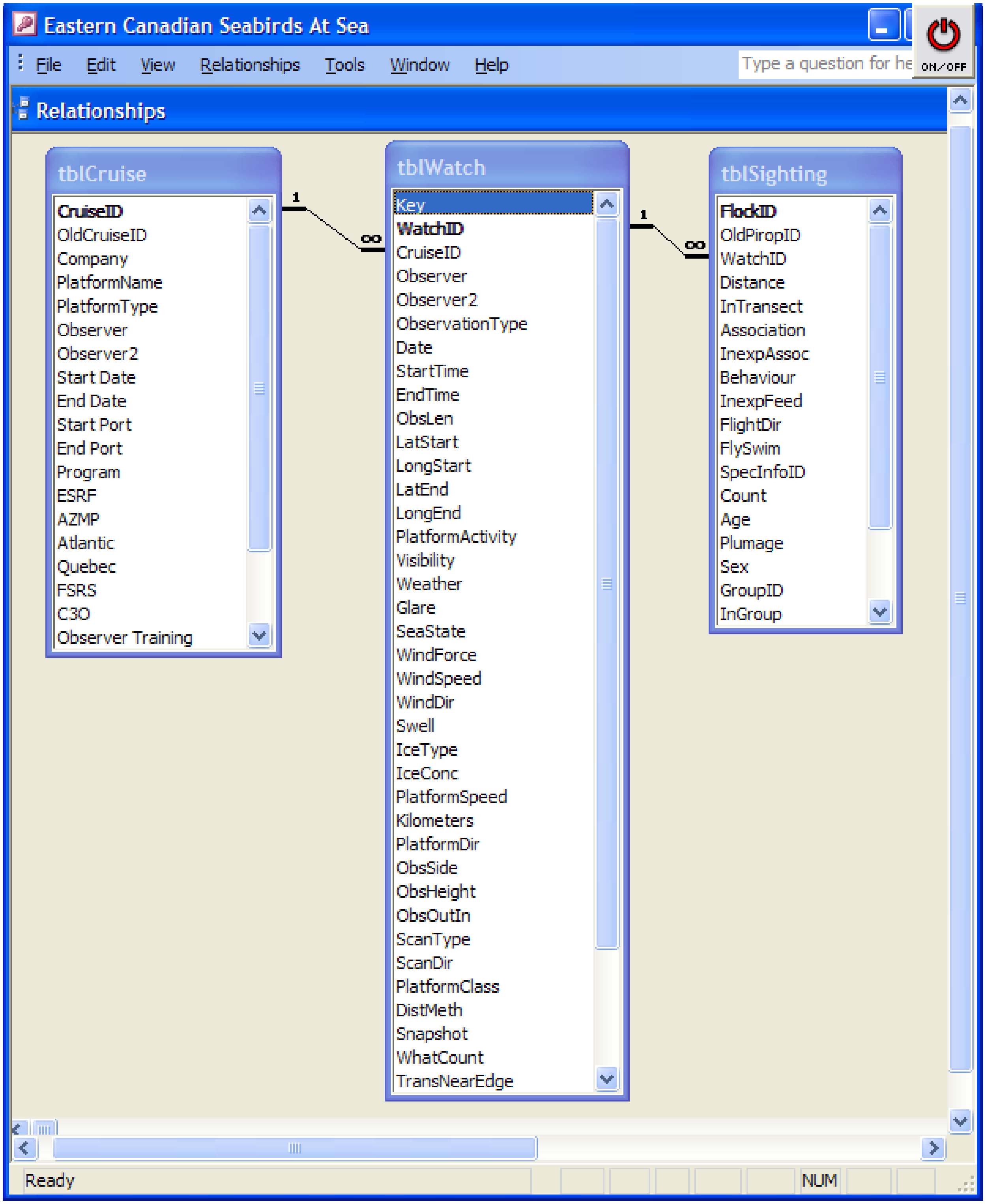
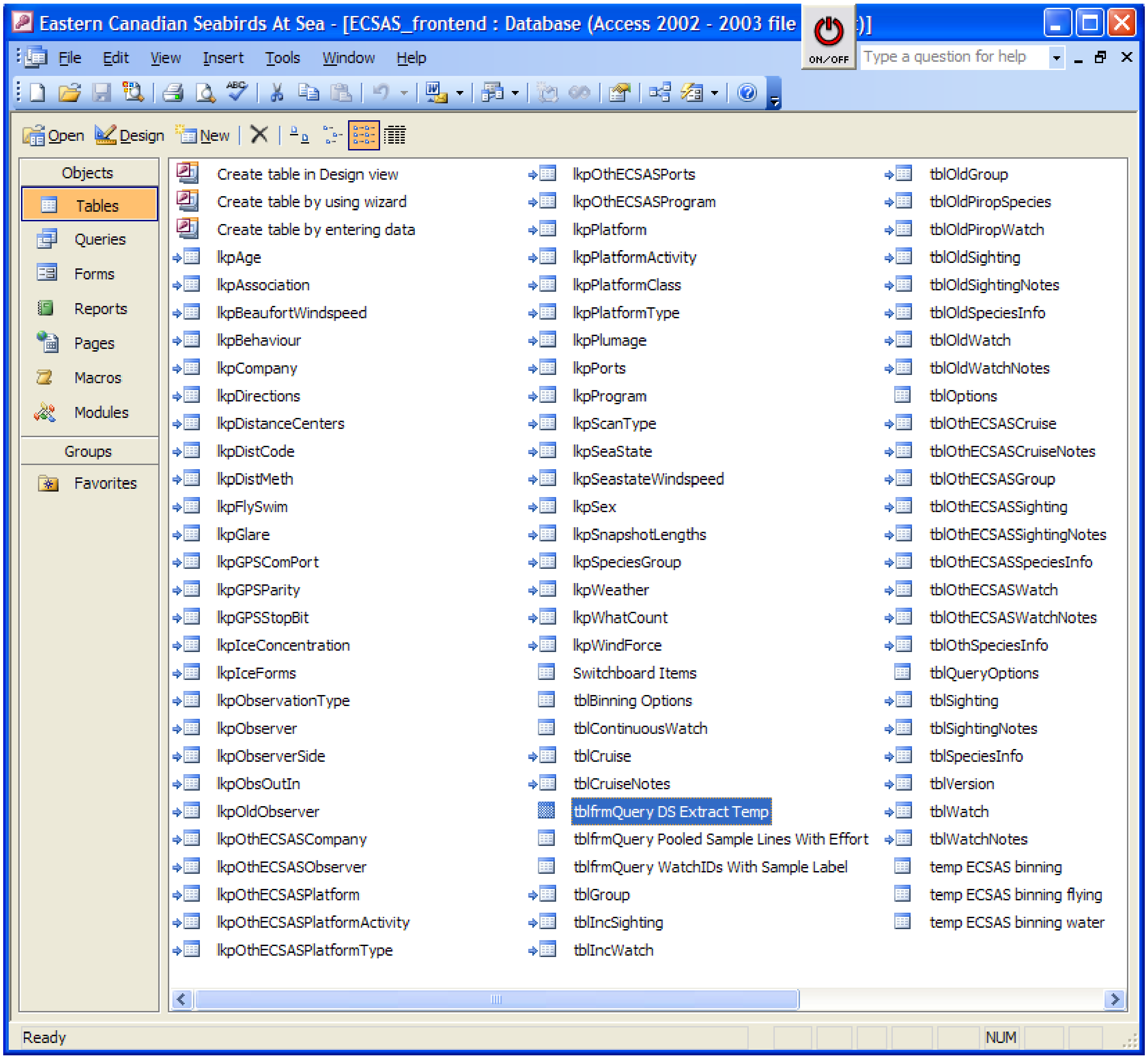


Figure 8: Diagram Showing Relationships Between the Three Core Database Tables: tblCruise, tblWatch and tblSighting



Create table in Design view
Create table by using wizard
Create table by entering data
lkpAge
lkpAssociation
lkpBeaufortWindspeed
lkpBehaviour
lkpCompany
lkpDirections
lkpDistanceCenters
lkpDistCode
lkpDistMeth
lkpFlySwim
lkpGlare
lkpGPSComPort
lkpGPSParity
lkpGPSStopBit
lkpIceConcentration
lkpIceForms
lkpObservationType
lkpObserver
lkpObserverSide
lkpObsOutIn
lkpOldObserver
lkpOthECSASCompany
lkpOthECSASObserver
lkpOthECSASPlatform
lkpOthECSASPlatformActivity
lkpOthECSASPlatformType
lkpOthECSASPorts
lkpOthECSASProgram
lkpPlatform
lkpPlatformActivity
lkpPlatformClass
lkpPlatformType
lkpPlumage
lkpPorts
lkpProgram
lkpScanType
lkpSeaState
lkpSeastateWindspeed
lkpSex
lkpSnapshotLengths
lkpSpeciesGroup
lkpWeather
lkpWhatCount
lkpWindForce
Switchboard Items
tblBinning Options
tblContinuousWatch
tblCruise
tblCruiseNotes
tblfrmQuery DS Extract Temp
tblfrmQuery Pooled Sample Lines With Effort
tblfrmQuery WatchIDs With Sample Label
tblGroup
tblIncSighting
tblIncWatch
tblOldGroup
tblOldPiropSpecies
tblOldPiropWatch
tblOldSighting
tblOldSightingNotes
tblOldSpeciesInfo
tblOldWatch
tblOldWatchNotes
tblOptions
tblOthECSASCruise
tblOthECSASCruiseNotes
tblOthECSASGroup
tblOthECSASSighting
tblOthECSASSightingNotes
tblOthECSASSpeciesInfo
tblOthECSASWatch
tblOthECSASWatchNotes
tblOthSpeciesInfo
tblQueryOptions
tblSighting
tblSightingNotes
tblSpeciesInfo
tblVersion
tblWatch
tblWatchNotes
temp ECSAS binning
temp ECSAS binning flying
temp ECSAS binning water

Figure 9: Complete List of Tables in the ECSAS Database

3.3.2 Database Usage

The database contains an easy-to-use, forms-driven interface (Figure 10) that contains commands for adding and editing cruises, watches and sightings, viewing existing data, setting program options, constructing queries and performing administrative tasks. Two main forms are used to enter data: the cruise form and the watch form. A single cruise form is filled out for each survey trip offshore (Figure 11) and includes information such as the ship name, dates of the trip, start and end ports, the survey program under which the trip was completed, etc. During the trip, a series of watch forms (Figure 12) are filled in, one for each 5-minute observation period. The watch form contains (1) a summary of the cruise information in the Cruise Data section at the top, (2) the Watch Data section and (3) the Sighting Data section.

3.4 Watch Data

The Watch Data section contains the date, observer name(s), starting and ending times, start and end positions, weather and ice information, ship speed and course, plus several fields detailing observation methodology such as distance sampling type (see Table 2), angle of view and transect width. The Watch Data section also includes timers for the snapshot interval and watch. These are used to automatically notify the user when to conduct each snapshot and when to finish the watch. Under normal usage, watch and sightings data are entered directly into the computer on the bridge of the ship during the survey. If it is not possible to use a computer during the survey, all information can be recorded on data sheets and entered manually later. The computer is connected either to a standalone GPS or to a feed from the ship's navigational system. There is a continuously updating status row near the bottom of the screen that provides the observer with the current date and time, position, ship speed and direction, and wind speed and direction. In the event that a communication problem is encountered with the data connection, these status boxes turn red to alert the observer. At the start of a watch, the start and end positions, ship speed and direction, wind speed and direction (if available), and the appropriate snapshot interval (based on ship speed, see Table 1) are filled in automatically. This avoids errors that often occur if observers have to transcribe such information from the ship's bridge displays (or data sheets). The observer fills out the weather and ice fields manually and then simply presses the "Start" button to begin the watch. The computer then automatically counts down the watch and snapshot timers, beeping at the moment of each snapshot, and beeping and stopping at the end of the watch. As the watch proceeds, the observer enters bird sightings into the Sighting Data section, optionally dictating them using voice recognition technology—see below. At the end of the watch, the observer can then proceed to the next watch by choosing the "New with Copy" button (Figure 12). This will start a new watch record that copies all pertinent user-supplied fields (such as weather and ice conditions) forward, thus avoiding having the observer retype the same information every five minutes.

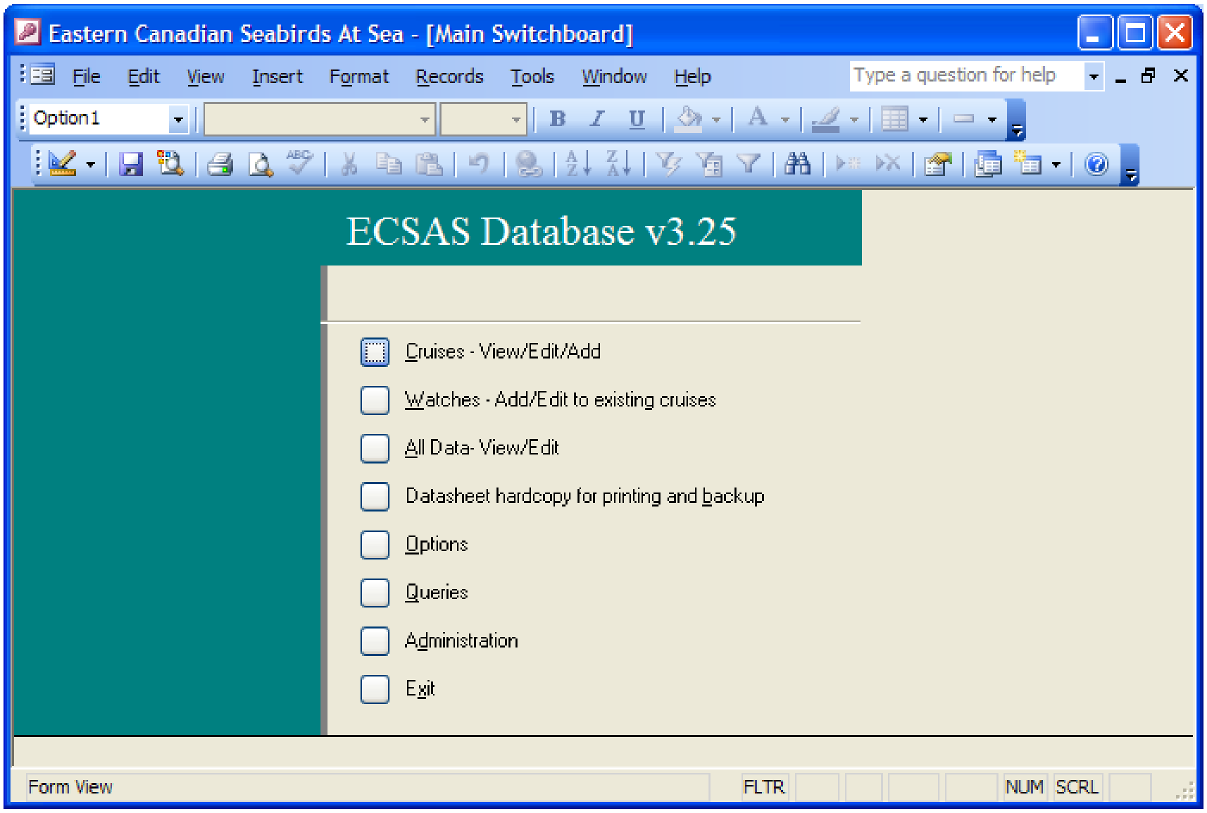
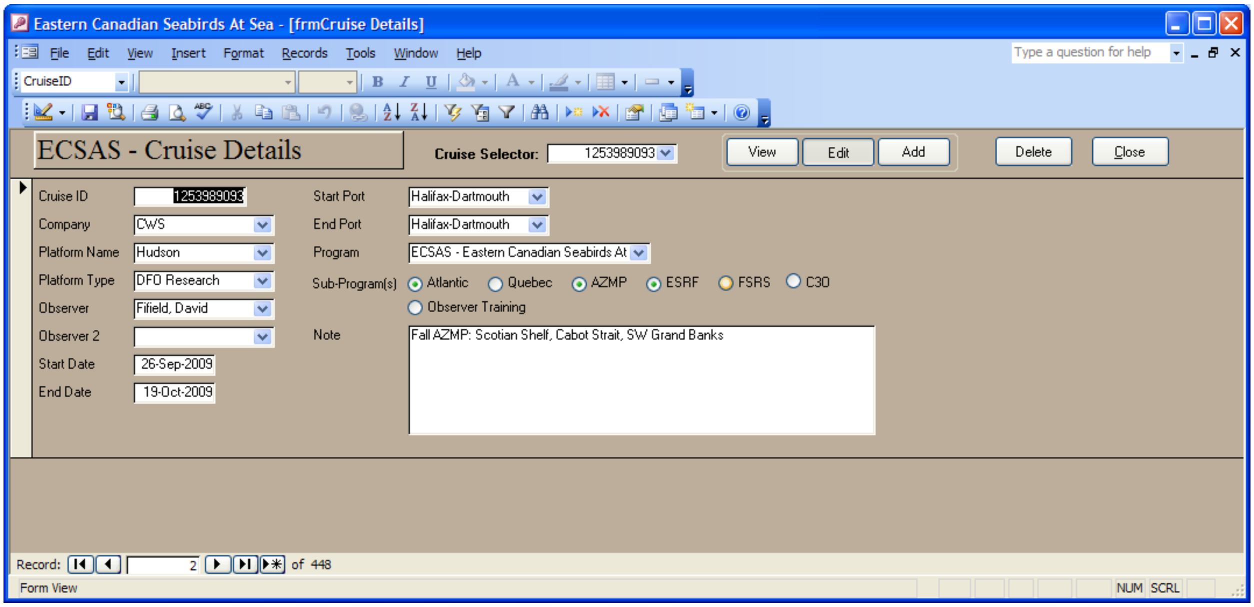


Figure 10: Main ECSAS Database Menu Screen



ECSAS - Cruise Details

Cruise Selector: 1253989093

Cruise ID	1253989093	Start Port	Halifax-Dartmouth
Company	CWS	End Port	Halifax-Dartmouth
Platform Name	Hudson	Program	ECSAS - Eastern Canadian Seabirds At
Platform Type	DFO Research	Sub-Program(s)	● Atlantic ○ Quebec ● AZMP ● ESRF ○ FSRS ○ C30 ○ Observer Training
Observer	Fifield, David		
Observer 2		Note	Fall AZMP: Scotian Shelf, Cabot Strait, SW Grand Banks
Start Date	26-Sep-2009		
End Date	19-Oct-2009		

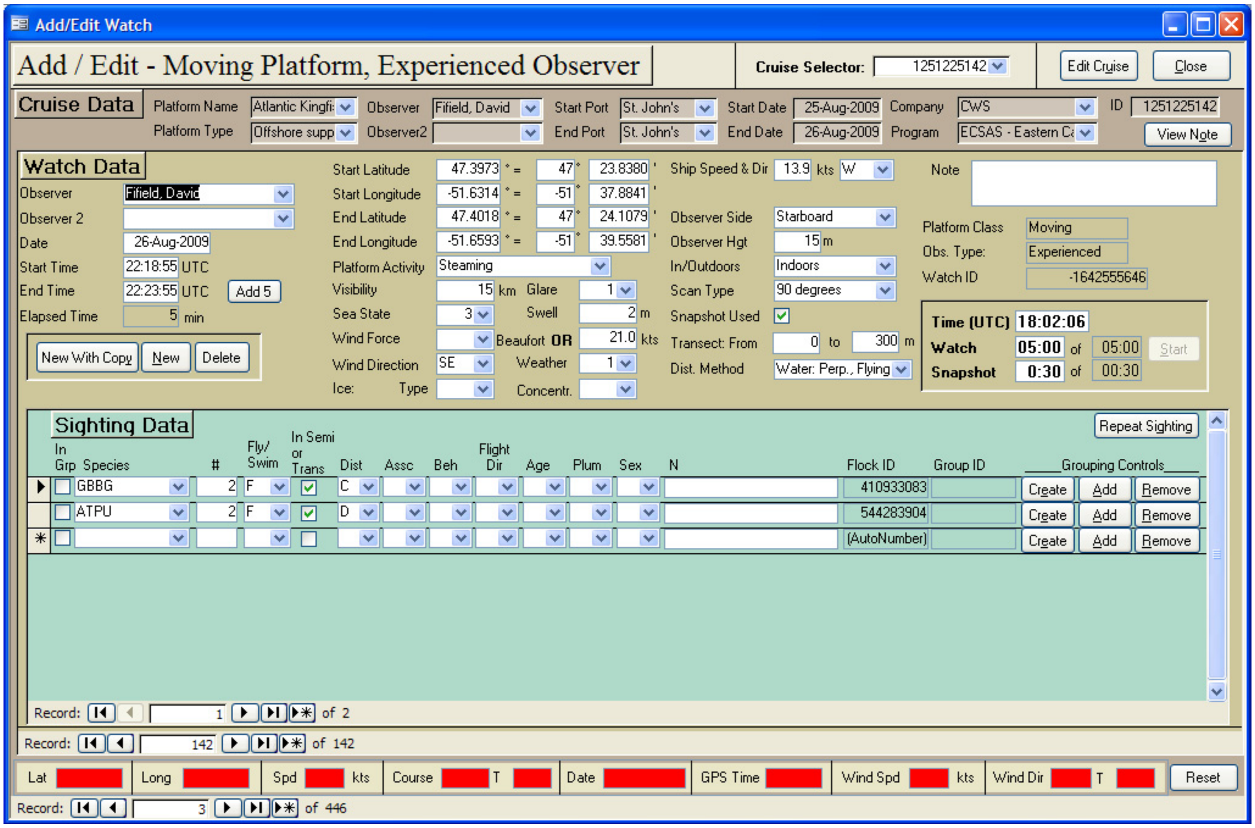
Figure 11: Cruise Details Form Showing a Single Entry from the Cruise Table. One cruise entry is filled out for each offshore survey trip.

3.4.1 Bird Sighting Data

Bird sighting information is recorded in the Sighting Data section (Figure 12). One row of sighting data is recorded for each flock of birds detected. This information includes the species name, flock size, flight or swim designation, in or out of transect designation, distance class, association (with vessels, debris, etc.), behaviour, flight direction, age, plumage, sex and any auxiliary notes. Only the first five pieces of information are mandatory for each flock, while the others are filled in as appropriate. There is a set of grouping buttons used to indicate when several rows of birds are behaving as a single group (e.g., a mixed species flock). See the survey protocol (Gjerdrum et al. 2010) or detailed descriptions of each field.

3.4.2 Voice Recognition

A voice recognition facility is included, allowing observers to dictate their sightings instead of having to type them in (or record them on data sheets and transcribe them later, as was done previously). Observers are thus able to focus their attention on the birds and not on the computer screen or datasheet. The observer, equipped with a headset microphone, utters a phrase such as “puffin two flying inside delta” to indicate a flock of two puffins flying inside the survey transect at distance D. The voice recognition software interprets this phrase and types the appropriate information into the appropriate boxes (Figure 12). The voice facility is based on the commercially available Dragon NaturallySpeaking voice recognition engine. Custom programming was created within the Dragon environment to allow the voice recognition engine to recognize the bird sighting syntax and enter the appropriate information into the appropriate database fields.



Add / Edit - Moving Platform, Experienced Observer

Cruise Selector: 1251225142

Cruise Data

Platform Name: Atlantic Kingfi
Platform Type: Offshore supp
Observer: Fifield, David
Observer2:
Start Port: St. John's
End Port: St. John's
Start Date: 25-Aug-2009
End Date: 26-Aug-2009
Company: CWS
Program: ECSAS - Eastern Ca
ID: 1251225142

Watch Data

Observer: Fifield, David
Observer 2:
Date: 26-Aug-2009
Start Time: 22:18:55 UTC
End Time: 22:23:55 UTC
Elapsed Time: 5 min
Start Latitude: 47.3973 ° = 47° 23.8380 '
Start Longitude: -51.6314 ° = -51° 37.8841 '
End Latitude: 47.4018 ° = 47° 24.1079 '
End Longitude: -51.6593 ° = -51° 39.5581 '
Platform Activity: Steaming
Visibility: 15 km
Glare: 1
Sea State: 3
Swell: 2 m
Wind Force: Beaufort OR 21.0 kts
Wind Direction: SE
Weather: 1
Ice: Type
Concentr.
Ship Speed & Dir: 13.9 kts W
Observer Side: Starboard
Observer Hgt: 15 m
In/Outdoors: Indoors
Scan Type: 90 degrees
Snapshot Used: ☑
Transect: From 0 to 300 m
Dist. Method: Water: Perp., Flying
Note:
Platform Class: Moving
Obs. Type: Experienced
Watch ID: -1642555646
Time (UTC): 18:02:06
Watch: 05:00 of 05:00
Snapshot: 0:30 of 00:30

Sighting Data

In Grp	Species	#	Fly/ Swim	In Semi or Trans	Dist	Assc	Beh	Flight Dir	Age	Plum	Sex	N	Flock ID	Group ID
☐	GBBG	2	F	☑	C								410933083	
☐	ATPU	2	F	☑	D								544283904	
☐				☐									(AutoNumber)	

Grouping Controls

Record: 1 of 2

Record: 142 of 142

Lat ▬ Long ▬ Spd ▬ kts Course ▬ T ▬ Date ▬ GPS Time ▬ Wind Spd ▬ kts Wind Dir ▬ T ▬

Record: 3 of 446

Figure 12: Watch and Sightings Data Entry/Editing Form Containing (1) a Summary of the Cruise Information in the Cruise Data Section at the Top (Brown), (2) the Watch Data Section (Beige) and (3) the Sighting Data Section (Light Blue)

3.4.3 Queries

The database contains an extensive suite of queries for extracting information (Figure 13). Specialized queries are included that provide effort and species summaries of single or multiple cruises, and abundance information by individual watch or aggregated into spatial bins. A more flexible general query form (Figure 14) has options to include or exclude data based on spatial extent, cruise date (or other attributes), survey methodology, species (or species group) and behaviour. Series of 5-minute watches can be pooled to construct longer sample lines (see section 2.5) and can be grouped into spatial blocks.[3] Buttons are provided to set other cruise, watch or sighting criteria using any of the fields in these tables. Once filtering and grouping options have been selected, a variety of queries can be performed on the selected data by selecting one of the tabs at the bottom of the form. For example, Figure 14 shows the distance sampling export tab that is used to extract individual flock sightings for input into the distance sampling software.

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[3] For example, the maps in this report were constructed by grouping survey data into 1° blocks.

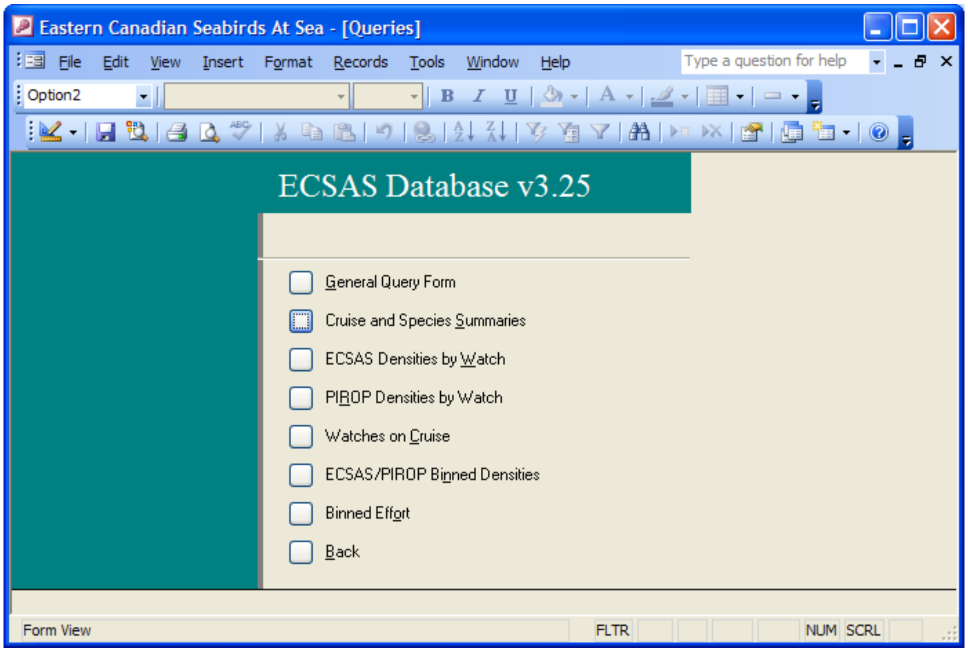
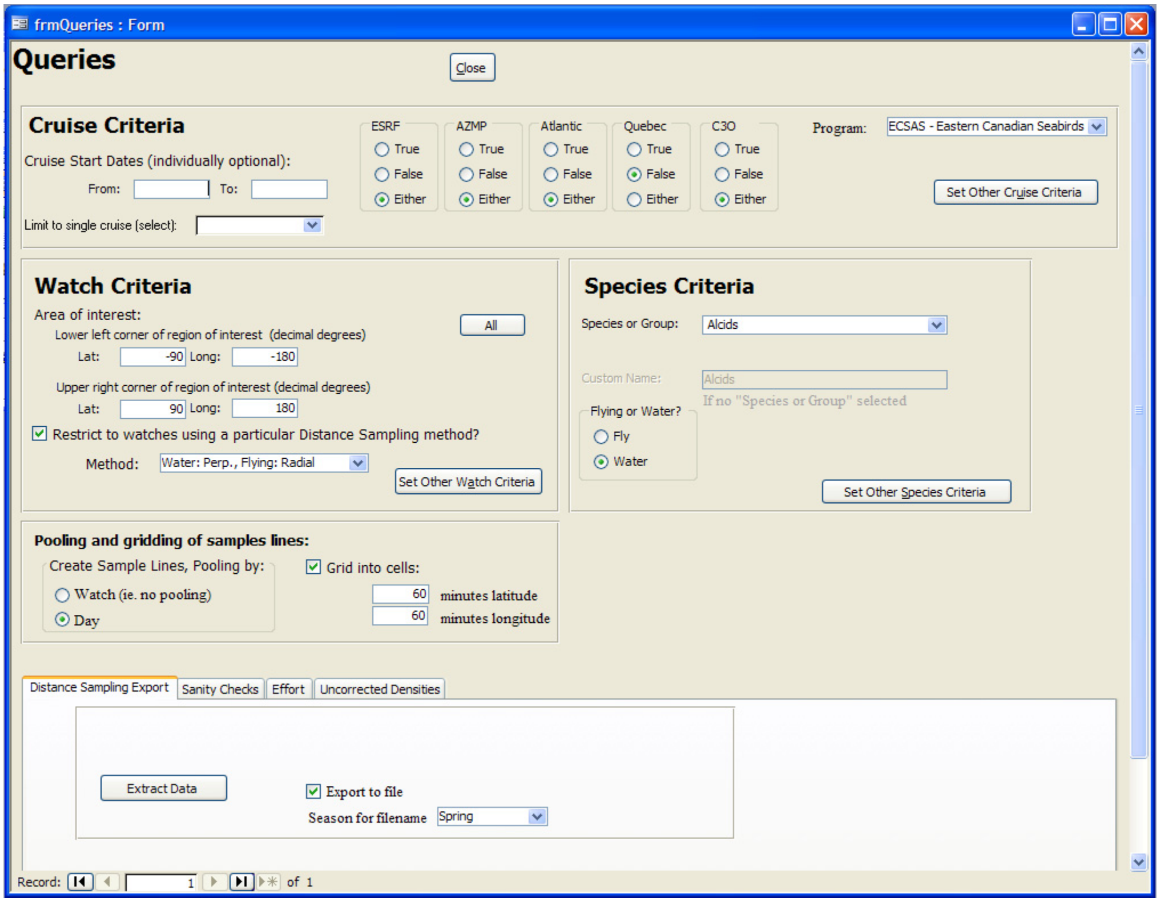


Figure 13: Eastern Canadian Seabirds at Sea (ECSAS) Database Query Menu



Cruise Criteria

Cruise Start Dates (individually optional):

From: To:

Limit to single cruise (select):

ESRF: ○ True ○ False ● Either

AZMP: ○ True ○ False ● Either

Atlantic: ○ True ○ False ● Either

Quebec: ○ True ● False ○ Either

C30: ○ True ○ False ● Either

Program: ECSAS - Eastern Canadian Seabirds

Watch Criteria

Area of interest:

Lower left corner of region of interest (decimal degrees)

Lat: -90 Long: -180

Upper right corner of region of interest (decimal degrees)

Lat: 90 Long: 180

☑ Restrict to watches using a particular Distance Sampling method?

Method: Water: Perp., Flying: Radial

Species Criteria

Species or Group: Alcids

Custom Name: Alcids

If no "Species or Group" selected

Flying or Water? ○ Fly ● Water

Pooling and gridding of samples lines:

Create Sample Lines, Pooling by:

○ Watch (ie. no pooling)

● Day

☑ Grid into cells:

60 minutes latitude

60 minutes longitude

☑ Export to file

Season for filename: Spring

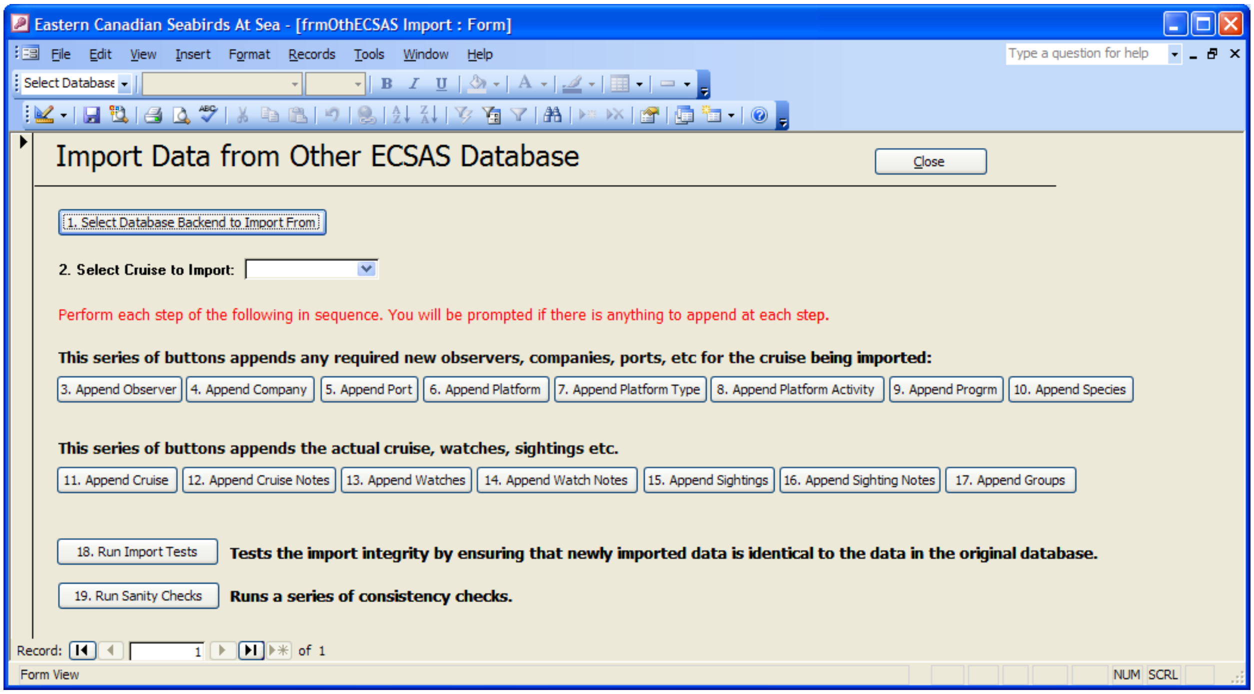
Figure 14: Eastern Canadian Seabirds At Sea (ECSAS) Database General Query Form Showing Data Filtering and Grouping Options (Upper Section) and Types of Queries That Can Be Performed on These Selected Data (Tabs in Lower Section)

3.4.4 *Data Importing*

The database allows many observers to collect data on a large number of vessels simultaneously. A separate copy of the database is installed in each observer's computer. The database administrator maintains a single master copy of the database containing all data from all surveys. At the end of a survey trip, the observer provides the database administrator with a copy of the backend MDB file from his/her computer. The administrator uses the Data Import Form (Figure 15) to add the survey data to the master database and to run a series of checks to ensure that the data were imported properly.

3.4.5 *Current Status*

The database was designed to hold both the modern survey data (ECSAS), which is the subject of this report, as well as historical pelagic survey datasets managed by the CWS. Besides the ECSAS data, the database contains pelagic seabird survey data collected under the PIROP program as well as surveys conducted by the Manomet Bird Observatory in the Gulf of Maine during the early 1980s. The database currently contains a total of 448 survey trips during which more than 3,000,000 birds were recorded.



Import Data from Other ECSAS Database

2. Select Cruise to Import:

Perform each step of the following in sequence. You will be prompted if there is anything to append at each step.

This series of buttons appends any required new observers, companies, ports, etc for the cruise being imported:

This series of buttons appends the actual cruise, watches, sightings etc.

18. Run Import Tests — Tests the import integrity by ensuring that newly imported data is identical to the data in the original database.

19. Run Sanity Checks — Runs a series of consistency checks.

Figure 15: ECSAS Database Import Screen

3.5 *Industry Observer Program*

The rig-based industry seabird observer program has been running at the northeast Grand Banks production area since 1997 (Baillie et al. 2005). Under this program, observers (either oil company employees or contractors) conduct multiple brief seabird surveys per day throughout the year using the protocol for stationary surveys found in (Gjerdrum et al. 2010). Although limited in spatial extent, the program offers the opportunity to collect seabird data at the production site on an extremely fine temporal scale that is not possible with other surveys. The CWS was engaged to provide quality assurance/quality control (QA/QC) for this observer program as part of the terms of reference for this project.

In addition to data checking, several attempts were made to visit with observers on the rigs to provide feedback. On three occasions, trips were either cancelled or delayed until no longer practicable because of weather, unavailability of industry representatives, scheduling conflicts, or lack of bunk space. In February 2009, Pierre Ryan was successful in making a trip to the Terra Nova FPSO, where he provided instruction on protocol compliance and seabird identification.

Data covering the Jan 2006–Aug 2009 period from the Terra Nova and White Rose fields were received from Provincial Aerospace Limited (PAL). During the study period, more than a dozen observers conducted surveys. Data were checked for protocol compliance, inconsistent or erroneous species identification, data integrity and observer variability.

During this review, several issues were identified.

1. In order to estimate density, it is necessary that each individual survey be an "instantaneous" (or as close as possible) count of birds (Gjerdrum et al. 2010). The review dataset contained fields for survey start and end times indicating that survey durations of between 0 and 50 minutes (mostly 15-20 minutes) were in use.

2. The protocol includes five distance categories (Gjerdrum et al. 2010) to account for differing detectability of various species under varying conditions. Only two categories (within 300 m and beyond 300 m) are being used.

3. Inconsistent/incorrect spelling of species names or non-existent species indicated (e.g., Black Crested Gull occurs several times).

4. Inconsistent entries when no birds are seen—both "No Birds" and "No Sightings" used.

5. There was considerable variability between observers in the numbers of birds detected.

6. The format for observer names is not consistent, sometimes spelled out in full, sometimes only initials.

7. Data from this program were not easily importable into the ECSAS database for use in environmental assessments, conservation planning and emergency response.

Implications of these issues and suggested improvements are discussed in section 4.5.

3.6 Distance Sampling and Detectability

Perfect detection of all birds within the 300-m transect was not assumed. Instead, distance sampling methodology was used to estimate detection probability and account for missed birds. Figure 16 shows an example of a detection function computed for murres on water for all seasons combined. The blue vertical bars indicate the probability of detection of a murre on water in the four distance classes (A–D, respectively) calculated from the observation data. The red line is the best model curve fit to this data. Murres are a small dark seabird that is hard to see, especially in rough conditions. The figure shows near-perfect detection of murres within the first distance class (A, 0 m–50 m), but detection probability drops to 0.5 in distance class B (50 m–100 m) and is below 0.1 for distance class D (200 m–300 m). The overall probability of detecting a murre within the 300-m transect was 0.32 (95 % CI: 0.30–0.36). This number is computed as the ratio of the area under the red curve to the area of the entire plot rectangle. Using this detection function, the computed overall density of murres was 0.83 birds/km^2 (95% CI: 0.69–1.00 birds/km^2). In comparison, if distance sampling had not been used (i.e., perfect detection was assumed), the computed density would have been only 0.290 birds/km^2 (95% CI: 0.283–0.344 birds/km^2). Without distance sampling, murre densities would have been underestimated at a third of the value that includes declining detection probabilities.

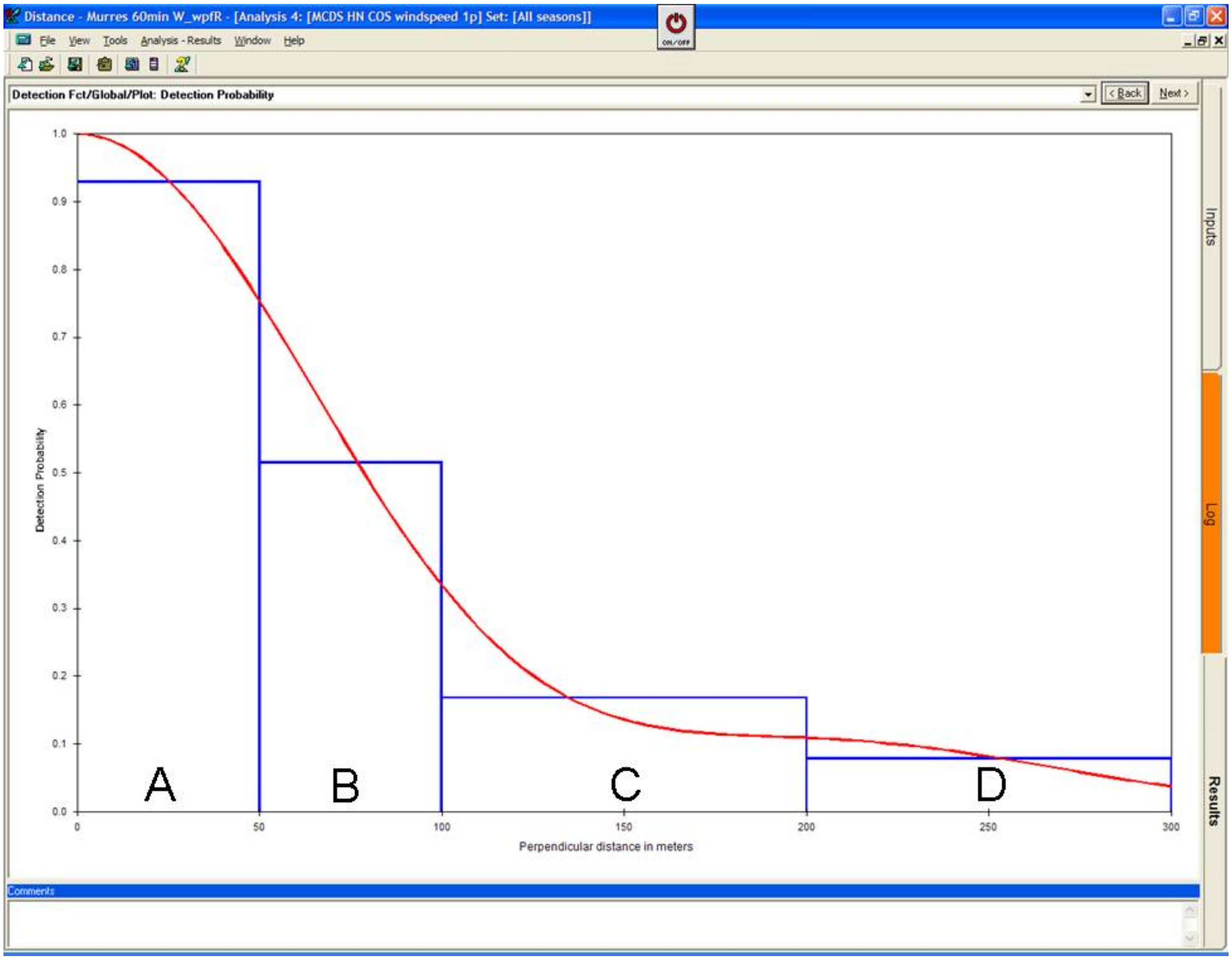


Figure 16: Detection Function for Murres on Water During Winter (Screen Capture from DISTANCE Program)

In contrast, Figure 17 shows the detection function for Northern Gannet, a large bright white seabird. The figure shows perfect detection within the first 100 m and then a drop to about 0.60% for the rest of the transect (100 m–300 m). The overall detection probability for gannets was 0.76 (95% CI: 0.61–0.96%). This corresponded to a density estimate of 0.04 birds/km^2 (95% CI: 0.02–0.10 birds/km^2). Without distance sampling the density estimate was 0.03 birds/km^2 (95% CI: 0.01–0.07 birds/km^2). Although not as great as for the murres, this still corresponds to a density underestimate of 1.3 times.

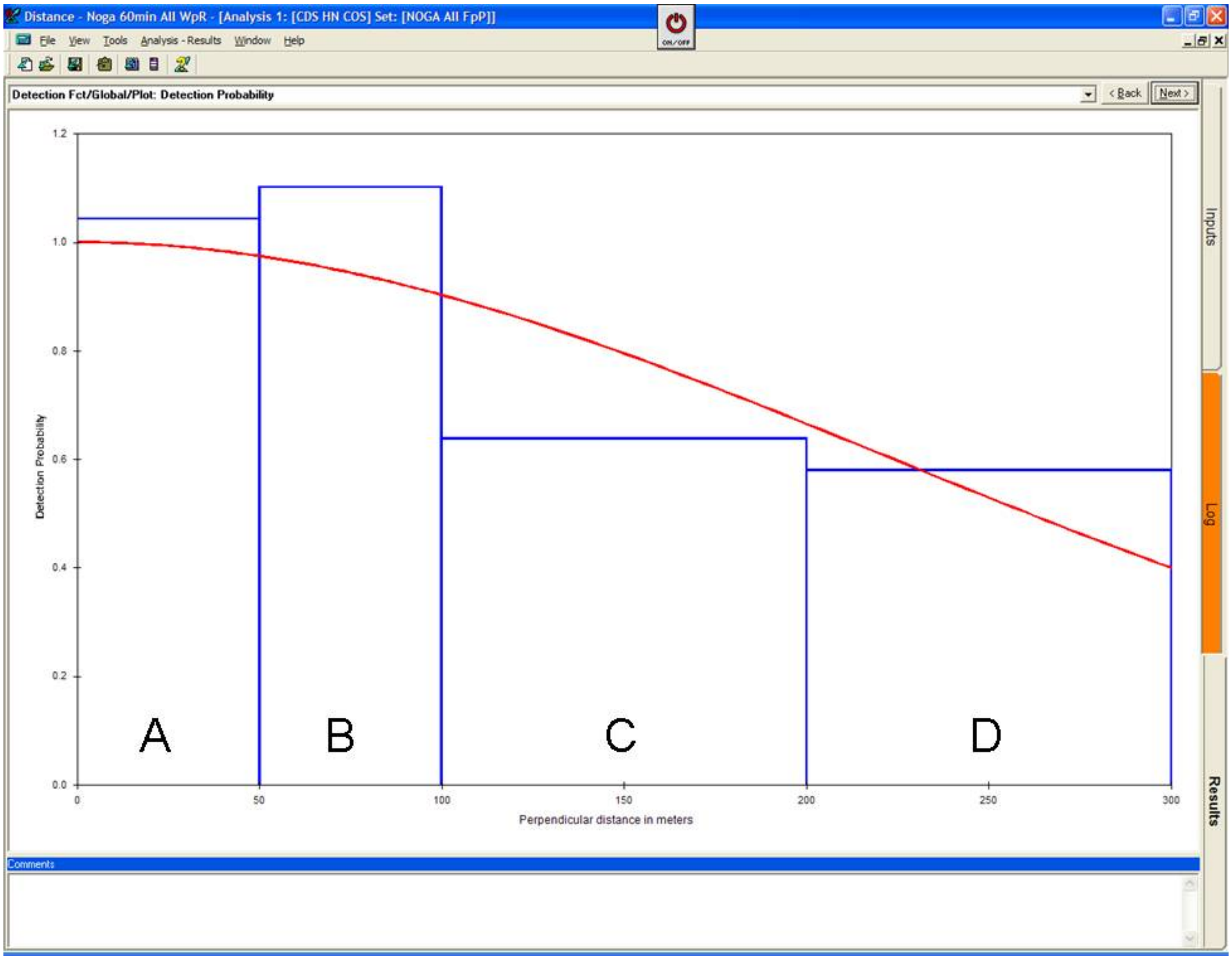


Figure 17: Detection Function for Northern Gannets (Screen Capture from DISTANCE Program).

Detection probability varied for other species, but in general, not including distance sampling methodology would have resulted in an underestimation of two to three times in most cases.

3.7 Seabird Distribution and Abundance

This section provides seasonal descriptions and maps (in Appendix 1) of the most abundant nine groups of seabirds found in the study area (Table 3) plus a tenth group consisting of all waterbirds combined. Each descriptive account begins with a brief natural history and population overview of the included species, followed by a seasonal description of density and distribution patterns. Discussion is restricted to those survey blocks containing **at least 25 km** of survey track. In order to provide a physical and biological oceanographic context for the discussion that follows, the study area was divided into biogeographic units (Figure 18). These were based on regions delineated by DFO according to differing fish, plankton and benthic communities present in the core of each area. The original DFO regions were limited to the area within the 200-nm Exclusive Economic Zone (EEZ); so they were extended to encompass all of the surveyed area. A summary of seasonal abundances in each region is presented in Table 5.

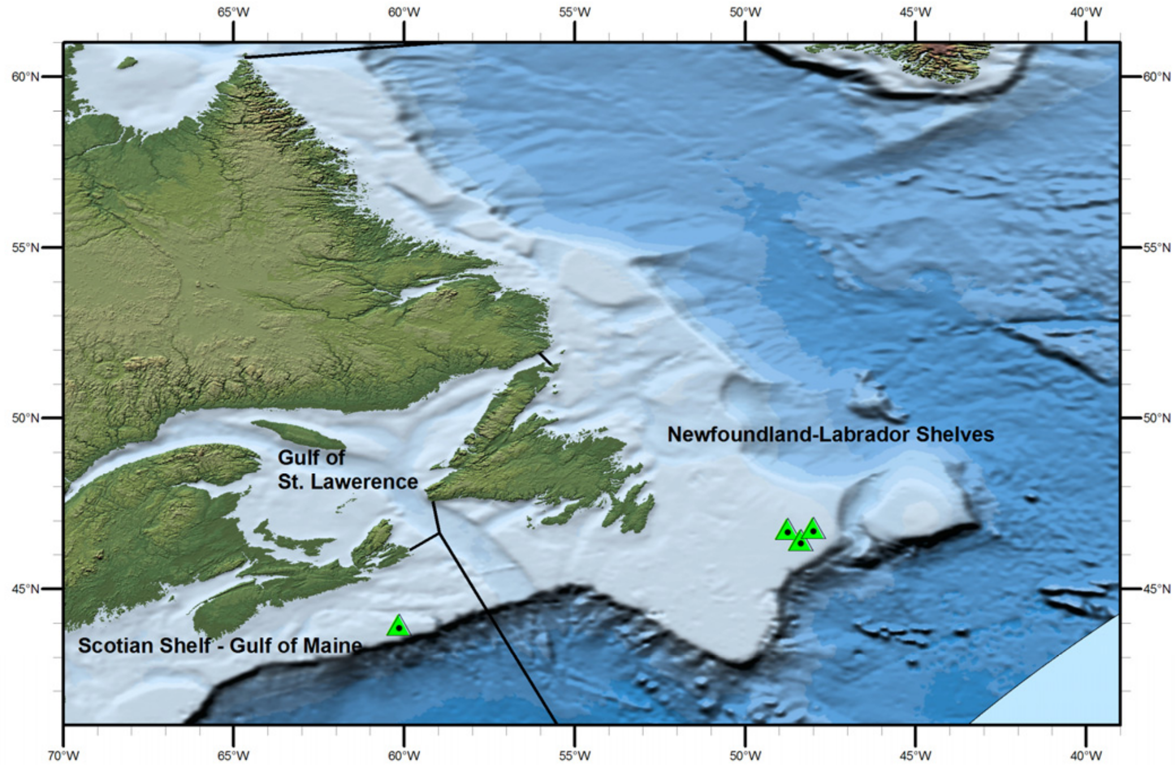


Figure 18: Map Showing Boundaries of the Three Marine Eco-Regions in the Study Area: Scotian Shelf-Gulf of Maine, Gulf of St. Lawrence and Newfoundland-Labrador Shelves

Table 5: Seasonal Weighted Median (Range in Parentheses) of 1° Blocks Surveyed of Absolute Densities (Birds/km^2) by Species Group in Each of the Three Ocean Regions in the Study Area. Individual 1º block density estimates were weighted by block survey effort to compute the overall regional weighted median. Only blocks having at least 25 km of survey effort were included.

Species	Season	Scotian Shelf – Gulf of Maine	Gulf of St. Lawrence	Newfoundland and Labrador Shelves
All Waterbirds	Spring	7.92 (0.68 - 25.37)	3.10 (0.37 - 4.52)	14.30 (1.89 - 31.77)
	Summer	8.30 (1.73 - 148.56	5.27 (2.21 - 14.31)	11.51 (0.34 - 48.78)
	Fall	4.23 (0.97 - 21.18)	11.57 (7.41 - 12.11)	9.24 (0 - 46.73)
	Winter	7.67 (4.39 - 29.44)	-	9.53 (2.31 - 45.12)
Northern Fulmars	Spring	0.75 (0 - 4.24)	1.19 (0 - 1.61)	1.00 (0 - 22.44)
	Summer	0.15 (0 - 1.64)	0.64 (0 - 4.19)	0.48 (0 - 24.17)
	Fall	0.30 (0 - 3.31)	0.27 (0.17 - 0.39)	0.65 (0 - 7.59)
	Winter	1.08 (0 -12.37)	-	1.91 (0 -36.77)
Shearwaters	Spring	0 (0 - 0.46)	0 (0 - 0)	0 (0 - 6.30)
	Summer	1.78 (0.29 - 84.02)	0.24 (0 - 0.87)	0.12 (0 -16.39)
	Fall	2.20 (0 - 18.40)	5.06 (0.20 - 8.27)	0.80 (0 - 31.57)
	Winter	0 (0 - 3.74)	-	0 (0 - 7.20)
Storm-Petrels	Spring	0 (0 - 1.36)	0.12 (0 - 0.12)	0.08 (0 - 6.66)
	Summer	0.78 (0 - 12.74)	0 (0 - 0.21)	0.17 (0 - 8.46)
	Fall	0.02 (0 - 1.47)	0 (0 - 0)	0.26 (0 - 4.41)
	Winter	0 (0 - 0)	-	0 (0 - 0.04)
Northern Gannets	Spring	0.40 (0 - 1.03)	0.94 (0 - 0.94)	0 (0 - 2.75)
	Summer	0 (0 - 1.69)	0.42 (0 - 1.37)	0 (0 - 3.31)
	Fall	0.19 (0 - 2.83)	2.42 (0.88 - 2.42)	0 (0 - 0.83)
	Winter	0.04 (0 - 0.22)	-	0 (0 - 0)
Large Gulls	Spring	1.22 (0 - 21.33)	0.34 (0 - 0.64)	0.74 (0 - 23.43)
	Summer	0.08 (0 - 8.39)	0.40 (0.16 - 1.70)	0.16 (0 - 9.38)
	Fall	0.58 (0 - 2.86)	0.93 (0.28 - 0.93)	0.13 (0 - 4.51)
	Winter	0.62 (0 - 2.31)	-	0.95 (0 - 20.83)
Black-legged Kittiwakes	Spring	0.06 (0 - 3.74)	0.50 (0 - 0.50)	0.72 (0 - 7.06)
	Summer	0 (0 - 0.76)	0.14 (0 - 2.34)	0.38 (0 - 7.87)
	Fall	0.11 (0 - 1.39)	0.79 (0.15 - 5.81)	0.05 (0 - 14.81)
	Winter	1.96 (0 - 21.31)	-	2.45 (0 - 19.93)
Dovekies	Spring	0.71 (0 - 36.98)	0 (0 - 0)	0.59 (0 - 32.10)
	Summer	0 (0 - 2.68)	0 (0 - 0.25)	0.18 (0 - 47.62)
	Fall	0 (0 - 0.25)	0.10 (0.10 - 4.37)	0.20 (0 - 35.76)
	Winter	2.13 (0 - 10.93)	-	0.93 (0 - 11.20)
Murres	Spring	0.88 (0 -4.37)	0.74 (0 - 2.33)	3.73 (0 - 12.49)
	Summer	0.06 (0 - 2.60)	0.65 (0 - 4.62)	1.79 (0 - 46.57)
	Fall	0 (0 - 0.14)	0 (0 - 0.11)	0.07 (0 - 11.59)
	Winter	0.61 (0 - 7.71)	-	3.05 (0 - 15.21)
Other Alcids	Spring	0.14 (0 - 1.53)	0.20 (0 - 0.20)	0.25 (0 - 9.36)
	Summer	0.04 (0 - 0.91)	0.11 (0 - 4.03)	0.13 (0 - 13.06)
	Fall	0.05 (0 - 0.65)	0.04 (0.04 - 1.12)	0 (0 - 3.16)
	Winter	0.37 (0 - 4.69)	-	0.36 (0 - 3.45)

NOTE TO TABLE: Sample sizes are Scotian Shelf−Gulf of Maine: spring 30, summer 35, fall 29, winter 14; Gulf of St. Lawrence: spring 3, summer 10, fall 4; Newfoundland and Labrador shelves: spring 65, summer 121, fall 42, winter 39.

3.7.1 All Waterbirds

This first account describes the combined distribution and abundance of all birds normally associated with water. This group is dominated by the seabirds (alcids, shearwaters, storm-petrels, fulmars, cormorants, gulls and terns, gannets, phalaropes, jaegers and skuas) but also includes the waterfowl, loons, grebes, herons and egrets.

Spring

During the spring (March–April), waterbird densities in 1º blocks in the Scotian Shelf region ranged from 0.68 to 25.37 birds/km^2 with a weighted median of 7.92 birds/km^2. Densities were generally < 10 birds/km^2 over the continental shelf and between 10 and 25 birds/km^2 along the continental shelf margin and in the Northeast channel. There was also a trend towards higher densities in the eastern portion of the region, with the highest density found off the edge of the continental shelf in the extreme east near the Laurentian Fan. Densities around the Sable energy production area ranged between roughly 5 to 10 birds/km^2, but increased to the high teens to the east of The Gully. In the four blocks in the Cabot Strait (Gulf of St. Lawrence region), density ranged from 0.37 to 4.52 birds/km^2 with a weighted median of 3.10 birds/km^2. Densities were higher in the Newfoundland and Labrador Shelves region, ranging from 1.89 to 31.77 birds/km^2 with a weighted median of 14.30 birds/km^2. Like the Scotian Shelf region, lower densities tended to be found over the continental shelf and closer to shore. Areas of relatively high density (15 to 25 birds/km^2) were found near the Laurentian Fan, on the Nose and Tail of the Grand Banks, around the Flemish Cap, in the western Orphan Basin and around the eastern Avalon Peninsula. Density at the northeast Grand Banks production area was around 7.5 birds/km^2, although adjacent blocks contained roughly 11 to 18 birds/km^2.

Summer

The highest density in the entire study area at any time of year, 148.56 birds/km^2, was recorded during the summer (May–August) in the Gulf of Maine. This was attributable to large aggregations of Greater Shearwaters that were present in this and surrounding blocks in the western Scotian Shelf region. In the central Scotian Shelf, densities were generally < 8 birds/km^2, while in the eastern portion, several blocks surrounding the Sable Island production area, The Gully and adjacent to the Laurentian Channel exceeded 10 birds/km^2. The overall weighted median for the region was 8.30 birds/km^2. In the eastern Gulf of St. Lawrence, density ranged from 2.21 to 14.31 birds/km^2 with a weighted median of 5.27 birds/km^2. In the Newfoundland and Labrador Shelves region, the majority of blocks south of the central Labrador Sea contained densities > 10 birds/km^2. Densities in several areas exceeded 20 birds/km^2, including the St. Pierre Bank, the eastern Avalon Peninsula (near the Witless Bay and Baccalieu Island Ecological Reserves), the Northeast Newfoundland Shelf (near the Funk Island Ecological Reserve), the western Orphan Basin, the Orphan Knoll and the Flemish Cap. Densities near the northeast Grand Banks production area were around 12 birds/km^2. The overall range for the region was 0.34 to 48.78 birds/km^2 with a weighted median of 11.51 birds/km^2.

Fall

During the fall (September–October), densities of birds in the Scotian Shelf region ranged from 0.97 to 21.18 birds/km^2 with a weighted mean all of 4.23 birds/km^2. Densities were generally lower in the central portion of the region (< 8.5 birds/km^2) with higher densities in the Northeast Channel in the west (21.18 birds/km^2) and in the vicinity of the Sable Island production area in the east (12 to 14 birds/km^2). In the Cabot Strait portion of the Gulf of St. Lawrence region, densities ranged from around 7.5 to 12 birds/km^2. In the Newfoundland and Labrador Shelves region, densities ranged from 0 to 46.73 birds/km^2 with a weighted median of 9.24 birds/km^2. In the southern half of the region, densities were generally in the range of 2.5 to 10 birds/km^2 with a trend towards lower numbers near the coast and higher numbers near the shelf break. The Laurentian Fan and eastern edge of the Grand Banks stood out as areas of higher density, ranging from 12 to 22 birds/km^2. Densities in the northeast Grand Banks production area were around 10 birds/km^2. The highest concentration of birds during the fall was recorded on the central Labrador Shelf where densities exceeded 40 birds/km^2 in several blocks owing to high numbers of dovekies, murres and fulmars.

Winter

On the Scotian Shelf during the winter (November–February), there was a general increasing trend in density from west (mostly < 10 birds/km^2) to east (> 10 birds/km^2) with an overall weighted median for the region of 7.67 birds/km^2. As in other seasons, densities were generally higher near the shelf break with the highest occurring in the block to the southeast of the Sable Island production area (29.44 ± 6.49 birds/km^2). In the Newfoundland and Labrador Shelves region, density ranged from 2.31 to 45.12 birds/km^2 with a weighted median of 9.53 birds/km^2. All blocks in the Laurentian Channel and adjacent St. Pierre Bank contained densities of between 17 and 21 birds/km^2, increasing to around 25 birds/km^2 on the central Grand Banks and Tail of the bank. Densities ranging from 10 to 20 birds/km^2 were common on the northeast Grand Banks, increasing to 40 birds/km^2 near the Sackville Spur. The extreme northeastern corner of the Orphan Basin was another area of high abundance (~26 birds/km^2), as was the central Northeast Newfoundland Shelf where densities reached a high of 45.12 ± 18.01 birds/km^2. Density in the northeast Grand Banks production area was around 16 birds/km^2.

3.7.2 Northern Fulmar

The Northern Fulmar (*Fulmarus glacialis*) is a member of the shearwater and petrel family whose most striking feature is a dual-ported nostril on top of the bill earning this family the name "tubenoses". The bulk of the world population (10–12 million birds) breed in the Palearctic, but there has been a dramatic expansion into the Nearactic during the last two centuries. The majority of the eastern Canadian breeding population (2.1 million birds) occurs in the Arctic, with only a few small colonies in the south in Newfoundland and Labrador (Hatch and Nettleship 1998). Fulmars occur south to Cape Hatteras during the winter with major concentrations on the Grand Banks (Hatch and Nettleship 1998).

Spring

In the spring (March–April), fulmars were found in most survey blocks in the study area. In the Scotian Shelf region, the overall weighted median density was 0.75 birds/km^2, with a range of 0 to 4.24 birds/km^2. Fulmars were more plentiful in the east (where densities between 1 and 4 birds/km^2 were common) than in the west where densities never exceeded 1 bird/km^2, except for three blocks in the Northeast Channel. In the block containing the Sable Island production area, a density of 0.30 birds/km^2 was recorded. In the Cabot Strait (Gulf of St. Lawrence region), density ranged from normal 0 to 1.61 birds/km^2. In the Newfoundland and Labrador Shelves region, densities ranged from 0 to 22.44 birds/km^2 with a weighted median of 1.0 birds/km^2. Numbers were highest in the southwest, on the Tail of the bank, on the Nose of the bank/Flemish Cap and in the western Orphan Basin. The highest density in the region (22.44 ± 14.17 birds/km^2) occurred on the continental slope in the southern Orphan Basin. A density of 0.50 ± 0.32 birds/km^2 was recorded around the northeast Grand Banks production area. Relatively few birds were found close to shore or on the Northeast Newfoundland Shelf.

Summer

In the summer (May–August), fulmars showed a shift in distribution towards the north, compared with the spring. In the Scotian Shelf region, most blocks contained < 0.5 birds/km^2 with only a few blocks exceeding this number (weighted median: 0.15 birds/km^2, range: 0 to 1.64 birds/km^2). A relatively low density of 0.04 ± 0.06 birds/km^2 was recorded for the block containing the Sable Island production area. Along the west coast of Newfoundland, in the eastern Gulf of St. Lawrence region, densities were variable with a weighted median of 0.64 birds/km^2 and a maximum of 4.19 ± 2.46 birds/km^2. In the Newfoundland and Labrador Shelves region, density ranged from 0 to 24.17 birds/km^2, with a weighted median of 0.48 birds/km^2. The greatest number of fulmars was found in the Labrador Sea, where most blocks contained between 1 and 5 birds/km^2. In comparison, relatively few birds were found south of Newfoundland, on the Grand Banks or on the Northeast Newfoundland Shelf where densities were generally < 0.5 birds/km^2. Around the northeast Grand Banks production area, density was 0.39 ± 0.14 birds/km^2.

Fall

Broad scale distribution during the fall (September–October) was similar to that during the summer, with fewer fulmars in the south of the study area, in comparison to the north. Most blocks in the Scotian Shelf region contained fulmars and densities ranged from 0 to 3.31 ± 1.71 birds/km^2, with a weighted median of 0.30 birds/km^2. A density of 0.27 ± 0.16 birds/km^2 was recorded for the block containing the Sable Island production area. In the four blocks surveyed in the Cabot Strait (Gulf of St. Lawrence region), density ranged from 0.17 to 0.39 birds/km^2. The weighted median density in the Newfoundland and Labrador Shelves region was 0.65 birds/km^2 (range: 0 to 7.59 birds/km^2). In the southwestern portion of the region, fulmars were most common in the Laurentian Channel, with densities of up to 3.12 birds/km^2. On the Grand Banks, numbers were greatest near the eastern shelf break, with densities of up to 4.75 ± 2.54 birds/km^2 and generally < 1 birds/km^2 elsewhere. Density around the northeast Grand Banks production area was 0.77 birds/km^2. Fulmars were more abundant on the Labrador Shelf during the fall and many blocks had densities of more than 1.5 birds/km^2, with a maximum of 7.59 ± 3.10 birds/km^2.

Winter

In the winter, higher numbers of fulmars returned to the southern portion of the study area. In the Scotian Shelf region, the weighted median density was 1.08 birds/km^2. There were generally fewer birds close to the coast, with the highest density (12.37 ± 3.66 birds/km^2) occurring near the edge of the Laurentian Channel. In the block containing the Sable Island production area, 0.93 ± 0.51 birds/km^2 were recorded, although the next neighbouring block to the east contained 5.61 ± 3.32 birds/km^2. In the Newfoundland and Labrador Shelves region, the weighted median density was 1.91 birds/km^2. High densities were found across the Laurentian Channel, reaching a maximum of 17.24 ± 7.12 birds/km^2. On the northeastern Grand Banks, Orphan Basin and Northeast Newfoundland Shelf, densities were generally between 2 and 5 birds/km^2, with a few blocks near the shelf break exceeding 10 birds/km^2 (max: 36.77 ± 11.84 birds/km^2 on the Sackville Spur). Around the northeast Grand Banks production area, a density of 2.99 ± 1.20 birds/km^2 was recorded. Few fulmars were found on the southeastern Grand Banks during the winter, although survey effort was geographically sparse.

3.7.3 Shearwaters

The shearwaters are so named because of their habit of flying close to the ocean's surface on stiff wings that nearly "shear" the water. The shearwaters occurring in the study area (in decreasing order of abundance) are Greater Shearwater (*Pufinus gravis*), Sooty Shearwater (*Puffinus griseus*), Cory's Shearwater (*Calonectris diomedea*), Manx Shearwater (*Puffinus puffinus*) and Audubon's Shearwater (*Puffinus lherminieri)*.

Greater Shearwaters breed on a few remote islands in the central south Atlantic and during migration proceed north along the east coasts of South and North America. Virtually all of the world's population spends the non-breeding season in the northwest Atlantic (Brown 1986). The Sooty Shearwater is far less numerous in the Atlantic. It breeds in the southwest Atlantic in the Falkland Islands and Tierra del Fuego, but the bulk of the world's breeding population occurs in the Pacific. The south Atlantic population follows the same northward migratory route as Greater Shearwater spending the non-breeding season in the northwest Atlantic.

Cory's Shearwater breeds in the Azores, Canaries and Cape Verde Islands as well as in the Mediterranean (Harrison 1983). It occurs regularly but in small numbers in the warm Gulf Stream waters from the edge of the Scotian Shelf to the Laurentian Channel and off the southern Grand Banks (Brown 1986) and was recorded around 200 times in this study.

Manx Shearwater is the northernmost breeding species of any shearwater having the centre of its distribution in northwestern Europe (Lee and Haney 2009). It is the only species in this group to breed within the study area, although in very small numbers. Its world population is estimated to be 400,000 to 500,000 pairs with a few pairs breeding at its only known regular North American breeding colony on Middle Lawn Island near the Burin Peninsula of Newfoundland (Lee and Haney 2009; Robertson 2002). It has also bred sporadically on other islands in the northeast US (Lee and Haney 2009). Its abundance at sea during the summer and fall (although less common than the previously mentioned shearwaters) cannot be explained by the small numbers breeding in the northwest Atlantic, which indicates that some birds at sea in the study area must come from other populations. Audubon's Shearwater breeds in the tropical Atlantic and is regularly seen in the warm waters off of the east coast of North America (Brown 1986). It was recorded twice off the southeast Scotian Shelf during this study.

Spring

During the spring (March–April), shearwaters were most abundant in the southern half of the study area, particularly on the Grand Banks. Less than half of the blocks in the Scotian Shelf region contained shearwaters and maximum density was only 0.46 ± 0.35 birds/km^2. Numbers averaged higher at the mouth of the Laurentian Channel in the Newfoundland and Labrador Shelves region with density ranging from 0.25 to 1.74 birds/km^2. The southeastern Grand Banks held the highest concentration of shearwaters during the spring with densities of up to 6.30 ± 3.99 birds/km^2. Numbers were considerably smaller in the deeper water off the Tail of the bank and around the Flemish Cap where most blocks containing shearwaters had densities of less than 0.30 birds/km^2 (max: 0.51 ± 0.28 birds/km^2). The central Flemish Cap, most of the northern Grand Banks and the Northeast Newfoundland Shelf contained no shearwaters.

Summer

In the summer (May–August), numbers of shearwaters increased dramatically, particularly in the southern half of the study area. In the Scotian Shelf region, most blocks contained at least 1 bird/km^2 (weighted median: 1.78 birds/km^2) with areas of extreme high concentration in the mouth of the Bay of Fundy (max: 84.02 ± 16.52 birds/km^2) and the eastern Scotian Shelf adjacent to the Laurentian Channel (max: 11.38 ± 5.84 birds/km^2). In the block containing the Sable Island production areas, density was 1.45 ± 0.74 birds/km^2. Density of shearwaters was considerably lower in the Gulf of St. Lawrence region with less than 0.35 birds/km^2 occurring in the Cabot Strait and a maximum of 0.82 ± 0.44 birds/km^2 in the Strait of Belle Isle (weighted median: 0.24 birds/km^2). The highest densities in the Newfoundland and Labrador Shelves region were found on the St. Pierre Bank and nearby Laurentian Channel, where the average was around 5 birds/km^2 and the maximum exceeded 16 birds/km^2. The overall weighted median density for the region was 0.12 birds/km^2. On the northern half of the Grand Banks, densities of up to 4.25 birds/km^2 were common, but higher numbers of up to 15 birds/km^2 were found on the Nose of the bank. Density in the block containing the northeast Grand Banks production area was 9.34 ± 3.34 birds/km^2. The slope waters of the eastern/southern Orphan Basin and the Flemish Cap were also areas of high concentration with densities consistently between 3 to 7.5 birds/km^2 and exceeding 12 birds/km^2 in one block. Shearwaters were generally scarce on the Northeast Newfoundland Shelf, except for a tendency towards increased numbers near the shelf break and an area of concentration inshore to the south and east of Funk Island. The area of the Labrador Sea south of Greenland received sparse coverage, but nonetheless revealed densities of shearwaters between 0.50 and 5.17 birds/km^2, while the central Labrador Sea contained few shearwaters.

Fall

As in the summer, shearwaters were abundant in the southern half of the study area in fall (September–October). Almost every block in the Scotian Shelf region contained between 1 to 10 birds/km^2 (weighted median: 2.20 birds/km^2). Areas of particularly high concentration included the slope waters southeast of the Northeast Channel with density of 17.52 ± 5.53 birds/km^2 and the area around (and to the east of) the Sable Island production area with maximum density of 18.40 ± 4.65 birds/km^2. Density in the four blocks of the Cabot Strait ranged from 0.20 to 8.27 birds/km^2. The weighted median density in the Newfoundland and Labrador Shelves region (0.80 birds/km^2) was lower than that for the other regions, although the region contained the highest density estimate. Densities on and to the east of the Grand Banks were mostly in the range of 1 to < 5 birds/km^2 with a maximum of 31.57 birds/km^2 in one block on the southeast Grand Banks. In the block containing the northeast Grand Banks production area, density was 1.95 ± 1.18 birds/km^2. An area of lesser concentration was found at the mouth of the Laurentian Channel where several blocks contained > 3 birds/km^2 (max: 8.39 birds/km^2).

Winter

During the winter (November–December), most blocks in the study area contained no shearwaters. In the Scotian Shelf region, density ranged from 0 to 3.74 birds/km^2. All blocks that contained shearwaters in the region were either near the shelf break or in the Laurentian Channel. No shearwaters were counted in the block containing the Sable Island production area, although the next block to the east contained 1.33 birds/km^2. In the Newfoundland and Labrador Shelves region, density ranged from 0 to 7.20 birds/km^2 with the highest density found on the southern Grand Banks. In the block containing the northeast Grand Banks production area, shearwater density of 1.20 ± 0.96 birds/km^2 was recorded.

3.7.4 Storm-Petrels

The storm-petrels includes two species of diminutive "tubenoses", Leach's Storm-Petrel (*Oceanodroma leucorhoa*), which breeds in the north Atlantic and winters mainly in the tropical Atlantic, and Wilson's Storm-Petrel (*Oceanites oceanicus*), which breeds in Antarctica and nearby southern ocean islands and spends the austral winter (boreal summer) in the north Atlantic (Huntington et al. 1996). More than a third of the world's population of Leach's Storm-Petrels occurs at the world's largest colony on Baccalieu Island in eastern Newfoundland (about 3.4 million pairs) (Sklepkovych and Montevecchi 1989). To avoid predation, both species are nocturnal in their breeding colonies and are thus rarely seen from land. They are commonly seen offshore during the northern summer, where they can forage beyond 200 km from their colony, but are essentially absent from the study area during winter (Huntington et al. 1996).

Spring

Storm-petrels were found in relatively low numbers in the Scotian Shelf region during the spring (March–April). As with other species, abundance on the western half of the Scotian Shelf was noticeably lower (no storm-petrels found) than in the east, where roughly half the survey blocks contained storm-petrels, with densities of up to 1.36 birds/km^2. Density in the block containing the Sable Island production area was 0.07 ± 0.06 birds/km^2. Only a single block in the Cabot Strait (Gulf of St. Lawrence region) contained storm-petrels with a density of 0.12 ± 0.11 birds/km^2. In the Newfoundland and Labrador Shelves region, the weighted median density was a relatively low 0.08 birds/km^2. A little more than 50% of the blocks on the Grand Banks contained storm-petrels. The highest densities in the study area occurred to the south and east of the Grand Banks where storm-petrels were found in approximate densities of between 1 to 7 birds/km^2. Most blocks on the northeast Grand Banks and Flemish Cap/Pass contained < 0.5 birds/km^2 with the exception of the area to the south of the Flemish Cap where density reached a high of 3.45 ± 1.18 birds/km^2. In the block containing the northeast Grand Banks production area, density was 0.19 ± 0.14 birds/km^2. Fewer storm-petrels were found on the Northeast Newfoundland Shelf, with areas near the coast having no birds and the highest densities occurring near the shelf break (max: 1.2 birds/km^2).

Summer

In the summer (May–August), storm-petrel numbers increased in the study area, particularly on the Scotian Shelf and in the Orphan Basin. Storm-petrels were found in almost every survey block in the Scotian Shelf region, where a weighted median density of 0.78 birds/km^2 was recorded. In this region, most blocks contained > 0.25 birds/km^2 with densities reaching 12.74 birds/km^2 in the mouth of the Bay of Fundy. Density around the Sable Island production area was of 0.45 ± 0.29 birds/km^2. Very few petrels were found in the western part of the Gulf of St. Lawrence, where the maximum density was only 0.21 birds/km^2. In the Newfoundland and Labrador Shelves region, the overall weighted median density of storm-petrels was 0.17 birds/km^2. Densities in the Laurentian Channel were similar to those of the adjoining Scotian Shelf with a maximum of 2.38 ± 1.20 birds/km^2. Distribution was patchy on the northern Grand Banks and off the Tail of the bank with densities generally < 1 bird/km^2 and with many blocks containing no storm-petrels. The greatest concentration of storm-petrels during the summer was found in the Orphan Basin and along the northern edge of the Flemish Cap, where almost every block contained between 1.00 and 8.46 birds/km^2. Around the northeast Grand Banks production area, storm-petrel density was 0.30 ± 0.33 birds/km^2. Storm-petrel density on the Northeast Newfoundland Shelf was quite variable with a weak tendency towards more birds near the shelf break. The greatest density of storm-petrels in the Newfoundland and Labrador Shelves region was 3.25 ± 1.86 birds/km^2 in an area to the east of the world's largest colony at Baccalieu Island. Storm-petrels were almost absent from the southern Labrador Shelf and central Labrador Sea during the summer.

Fall

In the fall (September–October), storm-petrels were detected in about half the blocks in the study area. In the Scotian Shelf region, the overall weighted median density was 0.02 birds/km^2. The highest densities in the region were found mostly in the central Scotian Shelf centered on Sable

Island, where densities ranged from < 0.25 to a maximum of 1.47 birds/km^2 in the block to the north of the production area. Similar numbers were found at the edge of the St. Pierre bank in the Newfoundland and Labrador Shelves region. The overall weighted median density for the region was 0.26 birds/km^2. The highest density in the region, 4.41 birds/km^2, was found on the continental shelf break to the south of the Tail of the bank. A similar density of 4.24 birds/km^2 was found in the block to the east of the northeast Grand Banks production area. No storm-petrels were found on the Labrador Shelf during the fall.

Winter

In the winter (November–February), storm-petrels were almost completely absent from the study area, except three blocks on the Grand Banks with densities of < 0.04 ± 9.0 birds/km^2.

3.7.5 Northern Gannet

Northern Gannets (*Morus bassanus*) breed in only six colonies in the Northwest Atlantic: three in eastern Newfoundland and three in the Gulf of St. Lawrence. The North American population is in excess of 75,000 pairs and is growing steadily at most colonies (Mowbray 2002). During the winter, their range extends from the Gulf of Maine south to Florida and west into the Gulf of Mexico as far as Texas and Mexico (Mowbray 2002). They are found almost exclusively in continental shelf waters at all times of the year, although small numbers of North American birds have been found to cross the Atlantic to winter off western Africa with birds from European colonies (Fifield et al., unpubl. data).

Spring

In the spring (March–April), most survey blocks in the Scotian Shelf region contained observations of gannets. Density was generally < 1 bird/km^2 with an overall range of 0 to 1.03 ± 0.30 birds/km^2 with a weighted median of 0.40 ± 1.56 birds/km^2. Density in the block containing the Sable Island production area was very low at 0.06 ± 0.07 birds/km^2, although surrounding blocks were considerably higher. In the Newfoundland and Labrador Shelves region, densities were similar, except for three blocks (two with < 25 km effort) in the Laurentian Channel/St. Pierre Bank area containing 2.75 ± 0.41 to 6.93 ± 2.38 birds/km^2. This region is in relatively close proximity to the large colony at Cape St. Mary's on the southwestern Avalon Peninsula of Newfoundland. In the remainder of the region, densities were < 0.67 ± 0.26 birds/km^2. On the northern Grand Banks and Northeast Newfoundland Shelf, gannets were generally found close to shore in relatively small numbers (0.06 ± 0.05 to 0.07 ± 0.26 birds/km^2). No gannets were found on the northeast Grand Banks or in the Flemish Cap/Pass and Orphan Basin areas.

Summer

During the summer (May–August), gannets were generally found close to shore in the study area, with the highest densities observed in the vicinity of their breeding colonies in southern and eastern Newfoundland. In the Scotian Shelf region, about half of the blocks contained gannets, but densities were generally quite low with a range of 0 to 1.69 birds/km^2 and a weighted median of 0 birds/km^2. The maximum density occurred off the western tip of Nova Scotia. The pattern was similar in the Cabot Strait portion of the Gulf of St. Lawrence region, where density ranged from 0 to 1.37 birds/km^2 with a weighted median of 0.42 birds/km^2. In the Newfoundland and Labrador Shelves region, most blocks (especially those further offshore) contained no gannets. In the southern part of the region, the highest density (1.89 birds/km^2) was found close to the breeding colony at Cape St. Mary's. On the Northeast Newfoundland Shelf, gannets were generally found at densities of < 1 bird/km^2 with the notable exception of a single block (3.31 ±

2.05 birds/km^2) to the east of the colony at Funk Island. Density around the northeast Grand Banks production area was 0.07 ± 0.10 birds/km^2.

Fall

In the fall (September–October), gannets were more common in the southern portion of the study area than in the north (although more northerly regions had less survey coverage). Most survey blocks in the Scotian Shelf region contained gannets with a density of generally < 0.5 birds/km^2, with the exception of a single block southwest of Cape Breton Island (2.83 ± 1.45 birds/km^2) and another near the Sable Island production area (2.83 ± 1.90 birds/km^2). The overall weighted median density for the region was 0.19 birds/km^2. Numbers were higher in the four blocks of the Gulf of St. Lawrence region near the Cabot Strait (range: 0.88 to 2.42 birds/km^2). Densities in the Newfoundland and Labrador Shelves region were generally lower, where the weighted median was 0 birds/km^2 (range: 0 to 0.83 birds/km^2). At the northeast Grand Banks production area, density was very low at 0.01 ± 0.03 birds/km^2. No gannets were found off the coast of Labrador during the fall, although survey coverage was limited.

Winter

Very few gannets were found in the study area during the winter (November–February) when most birds have migrated further south. Low densities (0 to 0.22 birds/km^2) were found in the Scotian Shelf region. All other regions contained no gannets during the winter, except for a single block (0.64 ± 0.35 birds/km^2) with < 25 km effort on the Flemish Cap, which contained birds in two successive years.

3.7.6 Large Gulls

This group is composed of those gulls that regularly occur offshore in the study area and includes Herring Gull (*Larus argentatus*), Great Black-backed Gull (*Larus marinus*), Iceland Gull (*Larus glaucoides*) and Glaucous Gull (*Larus hyperboreus*) as well as the less common European visitors, Lesser Black-backed Gull (*Larus fuscus*) and Yellow-legged Gull (*Larus cachinnans*). Herring and Great Black-backed Gulls breed throughout the study area and into the Canadian low Arctic as scattered single pairs or in colonies, with total numbers in the study area in the tens of thousands (Good 1998; Pierotti and Good 1994). Both species are present offshore year-round, although herring gulls tend to be found closer to land (Brown 1986). Glaucous Gulls have a circumpolar distribution and in the eastern Nearctic, they breed coastally from central Labrador north to Baffin Island, Greenland and across the Canadian Arctic in numbers exceeding 70,000 birds, although exact numbers are poorly known (Gilchrist 2001). They winter from Labrador south to the New England coast, with the majority occurring in the Atlantic provinces, particularly offshore Newfoundland (Gilchrist 2001). Iceland Gulls breed on southern Baffin Island and in Greenland in numbers exceeding 45,000 pairs, with the vast majority of these (40,000 pairs) occurring in Greenland (Snell 2002). Many Iceland Gulls remain in the north at polynyas during the winter, but they also occur regularly in Atlantic Canada, particularly in shelf waters surrounding Newfoundland (Snell 2002).

Spring

In the spring (March–April), large gulls were present in almost every survey block with the notable exception of the Flemish Cap and the area east of the Tail of the Grand Banks. In the Scotian Shelf region, density ranged from 0 to 21.33 birds/km^2 with a weighted median of 1.22 birds/km^2. Densities were generally higher over the shelf in the eastern half of the region, where most blocks contained > 1 birds/km^2. Densities were more variable in the western part of the region, ranging from 0 to a high of 21.33 birds/km^2 in the central Gulf of Maine. Density in the block containing the Sable Island production area was quite low at 0.08 ± 0.07 birds/km^2, although surrounding blocks contained significantly higher densities (1.71 to 6.68 birds/km^2). Densities in the Cabot Strait (Gulf of St. Lawrence region) were generally lower than on the adjoining Scotian Shelf, reaching a maximum of only 0.64 ± 1.74 birds/km^2. In the Newfoundland and Labrador Shelves region, densities ranged from 0 to 23.43 birds/km^2 with a weighted median of 0.74 birds/km^2. The highest concentrations on the Grand Banks occurred in the vicinities of the Nose and Tail of the bank, areas that are frequented by fishing trawlers that attract gull species. Most blocks in these areas contained > 2 birds/km^2 with highs of 23.43 birds/km^2 (Nose) and 15.58 (Tail). Density in the block containing the northeast Grand Banks production area was 0.22 ± 0.17 birds/km^2.

Summer

By the summer (May–August), gulls were rare offshore in the study area, reflecting their movement to coastal breeding sites. Roughly half of the blocks in the Scotian Shelf region contained no gulls and most of the remainder contained only small numbers, with a weighted median of only 0.08 birds/km^2. The area at the mouth of the Bay of Fundy was an exception, where the maximum density of 8.39 ± 2.42 birds/km^2 was recorded. No gulls were recorded in the block containing the Sable Island production area, although surrounding blocks contained up to 0.12 birds/km^2. In the Gulf of St. Lawrence region, the weighted median was 0.40 birds/km^2 with a high of 1.70 ± 0.79 birds/km^2 in the northeast near the Strait of Belle Isle. In the Newfoundland and Labrador Shelves region, the overall weighted median was 0.16 birds/km^2, but very few gulls were found south of Newfoundland or on the southern Grand Banks. Density in the block containing the Grand Banks production area was 0.02 ± 0.02 birds/km^2. Density was generally < 0.50 birds/km^2 on the Northeast Newfoundland Shelf, except in proximity to the coast. The highest density in the region (9.38 birds/km^2) was observed to the north of the Wadham Islands and northwest of Funk Island. More than half of the blocks in the Labrador Sea contained no gulls and those that did generally had densities of < 0.5 birds/km^2 (max: 1.45 birds/km^2). No gulls were found near the Flemish Cap and only one block south of the Tail of the Grand Banks contained gulls during the summer.

Fall

By the fall (September–October), higher numbers of gulls had returned to the waters of the Scotian Shelf region, although they were still generally more abundant near the coast. Densities ranged from 0 to 2.86 birds/km^2 with a weighted median of 0.58 birds/km^2. In the block containing the Sable Island production area, density was 1.35 ± 0.54 birds/km^2. In the Cabot Strait (Gulf of St. Lawrence region) density ranged from 0.28 to 0.93 birds/km^2. In the Newfoundland and Labrador Shelves region, density ranged from 0 to 4.51 birds/km^2 with a weighted median of 0.13 birds/km^2. Several localized areas of higher-than-average concentration were recorded in the region, including the Laurentian Channel/St. Pierre Bank, Tail of the Grand Banks and off the northern Avalon Peninsula. Density at the Grand Banks production area was low at 0.11 ± 0.10 birds/km^2. Numbers on the Labrador Shelf were higher in general with densities of up to 4.5 birds/km^2.

Winter

In the winter (November–February) on the Scotian Shelf, the distribution of gulls was similar to that of the spring, with higher densities in the eastern portion of the region than in the west. The overall weighted median for the region was 0.62 birds/km^2 with the maximum, 2.31 ± 1.20 birds/km^2, occurring in the block to the east of the Sable Island production area. In the Newfoundland and Labrador Shelves region, the weighted median density was 0.95 birds/km^2, but there was great variability across the region. Numbers were low in the south and west portions, while the highest numbers were found on the Nose of the bank, where density ranged up to 20.8 birds/km^2 on the Sackville Spur. Density was 1.09 ± 1.20 birds/km^2 in the block containing the northeast Grand Banks production area.

3.7.7 Black-legged Kittiwake

Black-legged Kittiwakes (*Rissa tridactyla*) are one of the smallest and the most pelagic of the gull species that occur in the study area. They are rarely seen on land outside of the breeding season, preferring instead to spend their time at sea where they capture prey from the surface and during brief shallow dives. Their eastern Canadian breeding population is estimated to be 525,000 birds (with another 40,000 in Greenland) distributed in an area that includes Cape Breton Island, the Gulf of St. Lawrence, Newfoundland and Labrador, Baffin Island, Jones Sounds and Barrow Strait (Baird 1994). During the winter, their range extends from Newfoundland south to Florida and birds from Greenland and Europe join local breeders in large numbers on the Grand Banks (Baird 1994).

Spring

Black-legged Kittiwakes were very rare in the western half of the Scotian Shelf region during the spring (March–April), while on the eastern Scotian Shelf, density ranged from 0 to 3.74 birds/km^2. The overall weighted median for the region was 0.06 birds/km^2. Only two of the four blocks in the Cabot Strait portion of the Gulf of St. Lawrence region contained kittiwakes, and the densities were 0.28 and 0.50 birds/km^2. Kittiwakes were found in almost every survey block in the Newfoundland and Labrador Shelves region, except for part of the Flemish Cap and the area east of the southern Grand Banks. Densities in the region were generally higher close to land (near their breeding colonies) but also near the edge of the continental shelf. Roughly half of the blocks in this region had densities < 1 bird/km^2 with an overall weighted median of 0.72 birds/km^2 (range: 0 to 7.06 birds/km^2); the highest density occurred in the deep water to the south of St. Pierre Bank. Density in the area of the northeast Grand Banks production area was 0.72 ± 0.30 birds/km^2.

Summer

During the summer (May–August), kittiwakes were virtually absent from the Scotian Shelf region, reflecting their more northerly breeding range. In the Gulf of St. Lawrence region, density along the west coast of Newfoundland ranged from 0 to 2.34 birds/km^2 with a weighted median of 0.14 birds/km^2. Kittiwakes were broadly distributed across the Newfoundland and Labrador Shelves region, where density ranged from 0 to 7.87 birds/km^2. There was a trend towards higher numbers in coastal areas, but with comparable densities in a few offshore areas, particularly near the shelf edge east of southern Labrador (maximum: 7.22 birds/km^2) and in the Orphan Basin (maximum: 6.96 birds/km^2). Densities further offshore in the central Labrador Sea were lower with most survey blocks containing < 1 bird/km^2, but with occasional higher concentrations of up to 3.43 birds/km^2. In the vicinity of the northeastern Grand Banks production area, density was only 0.01 birds/km^2.

Fall

By the fall (September–October), numbers of kittiwakes had increased in the Scotian Shelf region, although most survey blocks contained fewer than 1 bird/km^2 (range: 0 to 1.39 birds/km^2, weighted median: 0.11 birds/km^2) with the highest abundance occurring near the Sable Island production area. Density in the four Gulf of St. Lawrence region blocks near the Cabot Strait varied widely, ranging from 0.15 to 5.81 birds/km^2. In the Newfoundland and Labrador Shelves region, densities varied widely with a range of 0 to 14.81 birds/km^2, but with a weighted median of only 0.05 birds/km^2. On the Grand Banks, densities were generally quite low with a maximum of 0.54 birds/km^2 in the vicinity of the oil production area. Densities along the Labrador Shelf ranged from 0.76 birds/km^2 in the south to a high of 14.81 birds/km^2 near the shelf break east of Nain.

Winter

Kittiwakes were widespread and relatively abundant in most regions during the winter (November–February) with almost every block containing birds. In the Scotian Shelf region, densities ranged from 0 to 21.31 ± 18.21 birds/km^2 with an overall weighted median of 1.96 birds/km^2. Around the Sable Island production area, density was 1.64 ± 0.89 birds/km^2, although the next block to the east contained 15.90 birds/km^2. In the Newfoundland and Labrador Shelves region, most survey blocks contained densities in the 1-to-10 birds/km^2 range, although several blocks (on the Newfoundland Shelf, western Orphan Basin, northern Grand Banks and Laurentian Channel) exceeded 10 birds/km^2 (range: 0 to 19.93 birds/km^2, weighted median: 2.45 birds/km^2). Density at the northeast Grand Banks production area was 10.27 ± 7.43 birds/km^2.

3.7.8 Dovekie

Weighing only 160 g, Dovekies (*Alle alle*) are the smallest member of the Alcid family that occurs in the study area. The majority of the world population (over 40 million pairs) breed in Greenland, Svalbard and the Russian arctic (Stenhouse and Montevecchi 1996). They winter from the most northern ice-free waters of the Labrador Sea south to Cape Hatteras, with particularly large concentrations wintering on the Grand Banks (Brown 1986). Like other alcids, they are considered poor fliers and spend much time on the water, especially during the winter, making them susceptible to oiling.

Spring

In the spring (March–April), Dovekies showed a patchy distribution across the study area. Densities tended to be lowest near shore and highest near the continental slope. Dovekies were found in almost every survey block in the Scotian Shelf region (particularly the eastern half). Density was generally high (range: 0 to 36.98; weighted median: 0.71 birds/km^2) with many blocks having >10 birds/km^2. Around the Scotian Shelf production area, density was 1.09 ± 1.01 birds/km^2. No Dovekies were found in the Cabot Strait portion of the Gulf of St. Lawrence region. In the Newfoundland and Labrador Shelves region, densities ranged from 0 to 32.10 birds/km^2 (weighted median: 0.59 birds/km^2). Densities were highest over the shelf break in the Laurentian Channel and western Grand Banks area. Elsewhere in the region, Dovekies congregated in high numbers around the Flemish Cap/Pass, where most blocks had densities of > 5 birds/km^2 (max: 26.36 ± 4.30 birds/km^2), and in the western Orphan Basin (max: 21.05 ± 2.57 birds/km^2). Around the northeast Grand Banks production areas, density was lower at 0.18 ± 0.14 birds/km^2.

Summer

By the summer (May–August), most Dovekies had moved north towards their Arctic breeding grounds. In the Scotian Shelf region, few blocks contained Dovekies and only two had densities of > 1 birds/km^2. No Dovekies were detected in the block immediately surrounding the Sable Island production area, although the highest density for the region (max: 2.68 ± 2.06 birds/km^2) occurred in the next block to the west. Only a single block in the Gulf of St. Lawrence region (in the Strait of Belle Isle) contained any Dovekies (0.25 ± 0.24 birds/km^2). In the Newfoundland and Labrador Shelves region, a similar pattern of abundance was observed on the St. Pierre Bank and southern/southwestern Grand Banks, where roughly half of the survey blocks contained Dovekies, but abundance varied widely from 0 to 4.79 birds/km^2. In the shallow waters of the Northeast Newfoundland Shelf, most blocks contained no Dovekies. In the Orphan Basin and Labrador Sea more than half of the blocks contained > 1 bird/km^2 and several contained > 10 birds/km^2 (max: 47.62 ± 23.57 birds/km^2). Very few Dovekies were found around the northeast Grand Banks production area during the summer and the density was only 0.04 ± 0.05 birds/km^2.

Fall

During the fall (September–October), Dovekies begin their southward migration reaching the northern portion of the study area. Almost no birds were observed in the Scotian Shelf region, except for small numbers in the eastern portion (range 0 to 0.25 birds/km^2). Density was higher (although quite variable) in the four Cabot Strait (Gulf of St. Lawrence region) blocks, ranging from 0 to 4.37 birds/km^2. This area has been shown to contain consistently high concentrations of the copepods that Dovekies feed on during the fall (Gjerdrum et al. 2009). In the Newfoundland and Labrador Shelves region, densities varied widely, ranging from 0 to 35.76 birds/km^2 (weighted median: 0.20 birds/km^2). Few birds were found on the Grand Banks, although three blocks near the Avalon Peninsula and along the edge of the southern Grand Banks contained densities of > 1 bird/km^2. Density near the northeast Grand Banks offshore production area was 0.21 ± 0.23 birds/km^2. Abundance off southern Labrador was higher, ranging from around 1.99 to 5.78 birds/km^2. In the central Labrador Shelf, numbers were considerably higher with most blocks containing > 10 (max: 35.76) birds/km^2.

Winter

By the winter (November–February), Dovekies had moved south to occupy most survey blocks in the study area, but the strong association with the continental shelf that was apparent during the spring and summer was less obvious. In the Scotian Shelf region, most blocks contained > 1 bird/km^2 (range: 0 to 10.93 birds/km^2, weighted median: 2.13 birds/km^2) with the highest density occurring to the east of the Sable Island production area. In the Newfoundland and Labrador Shelves region, roughly half of the survey blocks contained > 1 bird/km^2, with an overall range of 0 to 11.20 birds/km^2 and a weighted median of 0.93 birds/km^2. Local highs occurred on the St. Pierre Bank (6.84 ± 2.63 birds/km^2), central Grand Banks (7.89 ± 2.10 birds/km^2), Flemish Pass to the east of the Grand Banks production area (7.44 ± 1.46 birds/km^2) and the northeast Newfoundland shelf (11.20 ± 5.58 birds/km^2). Patchy distribution and generally lower density (0 to 0.91 birds/km^2) were observed on the Flemish Cap, although few survey blocks contained > 25 km of effort.

3.7.9 Murres

The murres, including Common Murre (*Uria aalge*) and Thick-billed Murre (*Uria lomvia*), are pursuit diving seabirds in the Alcid family. They are grouped here because they share similar behaviour and oiling risk and are not always distinguishable from each other at sea. In eastern Canada, they breed in densely packed colonies from 46º to 82º N (Common Murres breed only to 56º N). The total Atlantic population for both species combined has been estimated to be 16–25 million breeding birds (Gaston and Jones 1998). Murres arrive at their breeding colonies in the spring to raise a single chick, after which the male parent leads the partially grown flightless chick to sea. Adults moult their flight feathers nearly simultaneously, rendering them flightless for a number of weeks. Large numbers of murres winter on the Grand Banks, in the Labrador Sea, off the coast of western Greenland, on the Scotian Shelf and in the Gulf of Maine (Ainley et al. 2002; Gaston and Hipfner 2000). During this period, they spend a large portion of their time on the water which makes them particularly susceptible to oil pollution.

Spring

During the March–April period, murres were present in almost every block surveyed in eastern Canada. Densities in the Scotian Shelf region ranged from 0 to 4.37 bird/km^2 with a weighted median of 0.88 bird/km^2. Roughly half of the survey blocks had densities of < 1 bird/km^2 and most of the remainder had < 5 birds/km^2. The highest density in the region (4.37 ± 1.76 birds/km^2) was found to the northeast of The Gully. Around the Sable Island production area, density was around 2.69 ± 1.77 birds/km^2. In the Cabot Strait (Gulf of St. Lawrence region), densities ranged from 0 to 2.33 birds/km^2. Densities were generally higher in Newfoundland waters, where most survey blocks contained between 1 and 10 birds/km^2 (range: 0 to 12.49 birds/km^2, weighted median 3.73 birds/km^2) with the maximum occurring near the Tail of the Grand Banks. In the northeast Grand Banks production area, density was 4.19 ± 1.46 birds/km^2.

Summer

During the May–August period, densities on the Scotian Shelf and in the southern half of the Gulf of St. Lawrence were very low and coincided with the birds having moved to their more northerly breeding grounds. In these areas, roughly half of the survey blocks contained no murres and the vast majority of the remainder had densities of < 1 bird/km^2. Densities were higher in the Newfoundland and Labrador Shelves region, with a weighted median of 1.79 ± 0.94 birds/km^2 (range: 0 to 46.57 birds/km^2). The highest densities in the region occurred on the Grand Banks and the northeast Newfoundland Shelf, where most survey blocks contained > 3 birds/km^2. Three blocks in the vicinity of Funk Island, the largest Common Murre breeding colony in the North Atlantic, had the highest densities: 15.08 to 46.57 birds/km^2. In the deeper waters of the Labrador Sea and Orphan Basin, birds were generally less abundant with densities in most blocks of < 3 birds/km^2.

Fall

During the September–October period, murre densities were very low in the Scotian Shelf region, with only four blocks containing any murres and a maximum density of only 0.14 birds/km^2. In the Cabot Strait (Gulf of St. Lawrence region), only one block of four contained any murres (0.11 ± 0.09 birds/km^2). Densities in the southwestern portion of the Newfoundland and Labrador Shelves region were similar, with almost every survey block containing no murres. On the Grand Banks, most birds occurred in shallow shelf waters. The majority of survey effort was concentrated on a line between St. John's and the oil production area, where density was in the range of 0.94 to 6.50 birds/km^2. The limited data on the central Labrador Shelf indicates that this area is important to murres during their fall migration, with densities ranging from 2.76 to 11.59 birds/km^2.

Winter

Murres were found in almost every block surveyed during the winter months, November–February, with density generally lower in blocks adjacent to the coast and higher on the continental shelf and slope regions. Density in the Scotian Shelf region was relatively low, with many blocks containing < 1 bird/km^2. The block to the southeast of the Sable Island production area was an obvious exception with a density of 7.71 ± 4.86 birds/km^2. The overall weighted median density in the Scotian Shelf region was 0.61 (range: 0 to 7.71 birds/km^2). Density in the Newfoundland and Labrador Shelves region was higher with a weighted median of 3.05 birds/km^2 (range: 0 to 15.21 birds/km^2). On the Grand Banks, most blocks on the shelf had densities of > 3 birds/km^2 with a density of 6.65 ± 2.83 birds/km^2 at the production area. The highest densities were found over the southern half of the shelf, where several blocks had densities of > 10 birds/km^2, (max: 15.21 birds/km^2). In the deeper waters (> 500 m) of the Orphan Basin adjacent to the continental shelf, density was generally lower with all survey blocks having densities of < 2.40 birds/km^2. No murres were found in deeper water blocks beyond 1,000-m depth.

3.7.10 Other Alcids

This group contains all other members of the Alcid family (excluding murres and dovekies) that occur in the study area, including Atlantic Puffin, Razorbill, Black Guillemot and any Alcid not identified to species. None of these species occurred in sufficient numbers to warrant a map of their own.

Alcids are generally poor flyers that are thought to spend a large portion of their at-sea time on the water, particularly during the winter (Gaston and Hipfner 2000; Gaston and Jones 1998). During the winter moult, all flight feathers are lost more or less simultaneously, rendering them flightless for several weeks (Hipfner and Chapdelaine 2002; Butler and Buckley 2002; Harris 1984).

Most of the North American population of Atlantic Puffins (~400,000 pairs) breed in a few coastal island colonies in eastern Newfoundland and Labrador (75 %) and in smaller colonies in Labrador, the Gulf of St. Lawrence, the Bay of Fundy, and the eastern Arctic (Lowther et al. 2002). Nesting in an underground burrow, they raise a single chick that proceeds to sea on its own at the end of the breeding season. Their winter distribution is poorly known since they are seldom seen at sea in appreciable numbers during this period.

Razorbills are considered the closest living relatives to the extinct Great Auk (*Pinguinus impennis*). They raise a single chick in a rock crevice in colonies often closely associated with murres. The largest North American colony on the Gannet Islands, Labrador accounts for roughly 25% of the continental population of 38,000 breeding pairs. The remainder breed in over 100 smaller colonies in eastern Newfoundland, Labrador, Nunavut, the Gulf of St. Lawrence and the Bay of Fundy/Gulf of Maine (Hipfner and Chapdelaine 2002). The largest winter concentrations of Razorbills are found in the Bay of Fundy/Gulf of Maine, although smaller numbers are also found around the coast of Newfoundland (Hipfner and Chapdelaine 2002).

Black Guillemots typically lay two eggs in a pebble nest secreted in a rock crevice (Gaston and Jones 1998). They breed either singly or in loose colonies from 43º to 78º N in eastern Canada. Birds in the northern part of the range may winter in deep water in association with ice edges or mobile pack ice (Butler and Buckley 2002). In the ice free waters of Atlantic Canada, they are seldom seen far from shore during the winter.

Spring

Spring (March–April) abundance of other alcids in the Scotian Shelf region was < 1 bird/km^2 in all survey blocks, except four, and had a range of 0 to 1.53 birds/km^2 (weighted median: 0.14 birds/km^2) with the highest density occurring to the east of The Gully. Density around the Sable Island production area was about 0.73 ± 0.41 birds/km^2. Only one block in the Cabot Strait (Gulf of St. Lawrence region) contained any other alcids (0.20 ± 0.20 birds/km^2). In the Newfoundland and Labrador Shelves region, most blocks contained < 0.50 bird/km^2 (range: 0 to 9.36 birds/km^2, weighted median: 0.25 birds/km^2). Two areas were exceptions to this rule: three coastal blocks in eastern Newfoundland and three on the Southeast Shoal. The Southeast Shoal blocks had densities from 1.07 to 1.49 birds/km^2, while the coastal blocks ranged from 1.17

birds/km^2 in Bonavista Bay to 9.36 birds/km^2 in the block containing the Witless Bay Ecological Reserve. This high concentration of birds was attributable to the large numbers of puffins that congregate in the reserve to breed. No other alcids were detected in the block containing the northeast Grand Banks production area, but surrounding blocks contained up to 0.43 birds/km^2.

Summer

Density of other alcids during the summer (May–August) was relatively low in the Scotian Shelf region, and roughly half of the blocks had no birds from this group. The weighted median for the region was 0.04 birds/km^2 (range: 0 to 0.91 birds/km^2). The highest density occurred in the Bay of Fundy (0.91 ± 0.39 birds/km^2), which contains a number of small puffin and Razorbill colonies. In the vicinity of the Sable Island production area, density was 0.13 ± 0.19 birds/km^2. In the Gulf of St. Lawrence, density ranged from 0 to 4.03 birds/km^2 (weighted median: 0.11 birds/km^2). Around Newfoundland, the highest densities were observed closest to land where these birds congregate to breed, particularly around the eastern half of the island. Lower densities were observed further offshore, particularly in deeper waters beyond the edge of the continental shelf. As in the spring, the highest density (13.06 ± 2.72 birds/km^2) during this period was in the vicinity of the Witless Bay Islands Ecological Reserve. More than 50% of the blocks in the deep waters of the Labrador Sea, Orphan Basin and off the Tail of the Grand Banks contained no birds from this group; the remainder had densities of less than ~ 0.50 birds/km^2. The overall weighted median for the region was 0.13 birds/km^2 (range: 0 to 13.06 birds/km^2). Density in the area of the northeast Grand Banks production area was 0.08 ± 0.09 birds/km^2.

Fall

In the fall (September–October) on the Scotian Shelf, most birds from this group were found either relatively close to shore or near the shelf edge in the vicinity of The Gully/Sable Island. Densities were relatively low with a range of 0 to 0.65 birds/km^2 and a weighted median of 0.05 birds/km^2. Density in the block containing the Sable Island production area was 0.14 ± 0.19 birds/km^2. In the four Cabot Strait blocks (Gulf of St. Lawrence region), density ranged from 0.04 to 1.12 birds/km^2. In the Newfoundland and Labrador Shelves region, density ranged from 0 to 3.16 birds/km^2 with a weighted median of 0 birds/km^2. The highest densities were found close to shore east of Newfoundland, with smaller numbers on the northeast Grand Banks near the production area (0.65 ± 0.51 birds/km^2). Very few birds from this group were found off the edge of the Grand Banks or on the Labrador shelf.

Winter

During the winter (November–February), densities in most parts of the Scotian Shelf region were < 1 bird/km^2 (range: 0 to 4.69 birds/km^2; weighted median: 0.37 birds/km^2), with the notable exception of the area east of Cape Breton and a single block immediately to the south of Sable Island that contained 4.69 ± 2.85 birds/km^2. In the Newfoundland and Labrador Shelves region, density was higher, ranging from 0 to 3.45 birds/km^2 with a weighted median of 0.36 birds/km^2. Density was generally greater on the Grand Banks and Northeast Newfoundland Shelf and lower in the deeper waters beyond the shelf edge and around the Flemish Cap. Density in the area of the northeast Grand Banks production area was 0.60 ± 0.42 birds/km^2.

3.8 Density Maps

The maps in Appendix 1 give the reader an overview of the species distribution information available in the dataset. They are not to be used as an off-the-shelf tool to obtain precise seabird density estimates during an emergency response. The ability of these maps to provide such detailed information is limited by the fact that each map is often a composite of data for several species and spans either two (spring, fall) or four (summer, winter) months of the year. During an emergency response, customized maps should be produced to take into account the appropriate spatial and temporal scale of the circumstances at hand.

3.9 Effect of Spatial Scale on Density

Figure 19 shows a map of murre densities during the winter (November–February) in the region surrounding the Grand Banks production area. For this analysis, available data from the winters from 2006−2007 to 2008−2009 were aggregated into 1/6° (i.e., 10 minute) blocks. The map highlights the variability of seabird densities when viewed with fine-scale resolution. Densities in the area ranged from 0 to 17.67 ± 10.78 birds/km^2 and most blocks contained > 2 birds/km^2, while per-block survey effort ranged from 1 to 42.8 km. Density tended to increase with effort and densities of 0 birds/km^2 only occurred in blocks with less than 5 km of effort, although the highest density was found in a block with only 4.4 km of effort.

The map shows a patchy distribution pattern that is typical of many seabirds and it may be tempting to conclude that the area east of Hibernia is a murre hotspot, while the area to the west is not. Caution must be exercised when interpreting seabird densities at this scale. The north-south distance between the centers of adjacent blocks at this scale is only 18.5 km. This distance can be covered by a murre in flight averaging 65 km h^{-1} (Benvenuti et al. 1998) in approximately 17 minutes. Median and mean winter flight durations for murres are 2.1 and 4.0 minutes respectively with a maximum of 298 min (Fifield et al. 2010), indicating that flocks of murres likely move from block to block over fairly short time frames. Given this fact, murre densities at this scale can be expected to fluctuate considerably at a small temporal scale. This effect will decrease as the scale of aggregation and sample size increases.

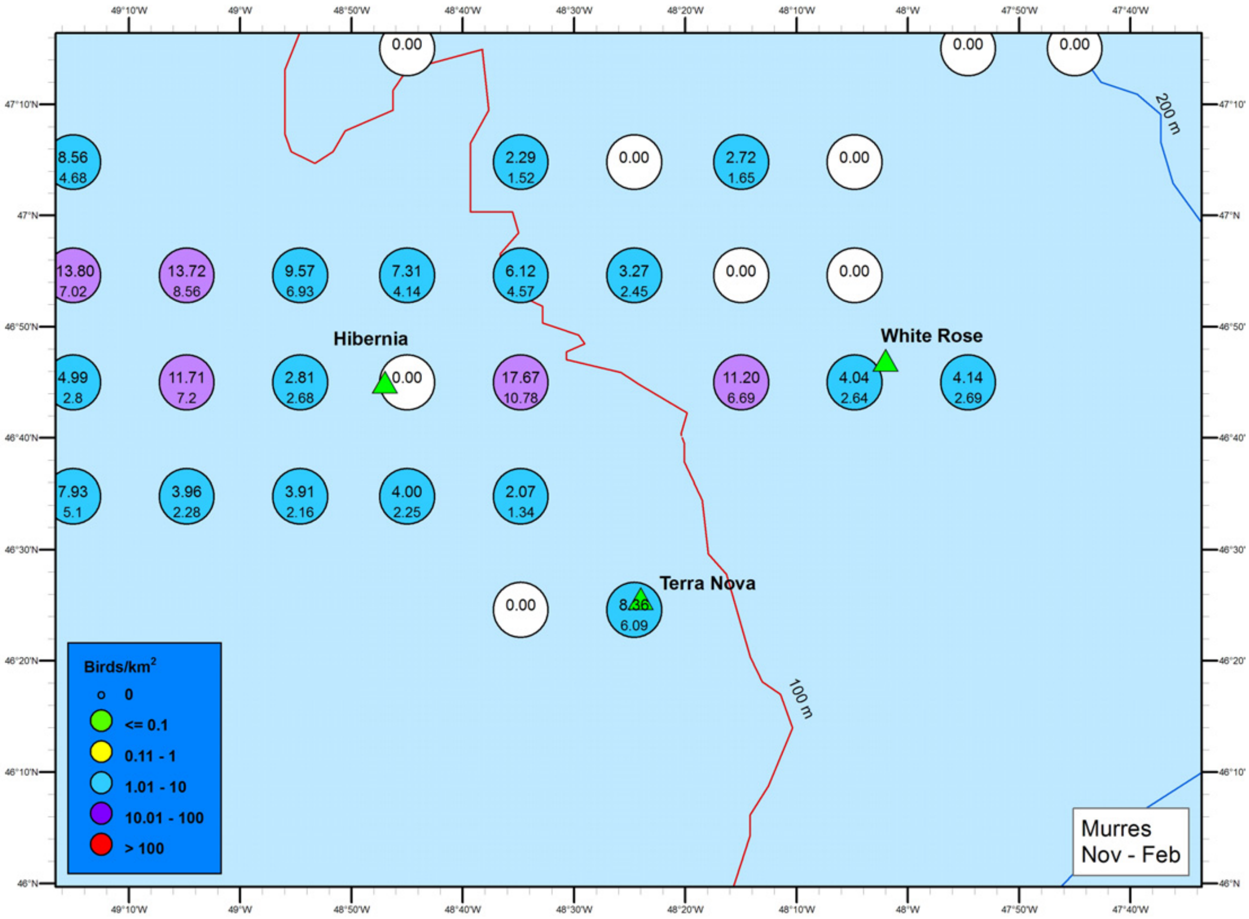


Figure 19: Winter (November–February) Murre Densities in 10-Minute Survey Blocks Around the Northeast Grand Banks Production Area

4 Discussion and Recommendations

4.1 Survey and Analysis Protocols

Protocols for monitoring seabirds at sea have undergone considerable improvement over the last three decades (Tasker et al. 1984). They have evolved from being capable of producing qualitative indices of abundance to furnishing quantitative estimates of density that take detection uncertainty into account. During protocol design, the desire to use the best available survey methodology and analysis techniques must be balanced with the ability to maintain compatibility with legacy datasets and survey programs in other jurisdictions. The protocol used for this project employs modern line-transect sampling techniques and distance sampling analysis to produce estimates of actual seabird density, while at the same time retaining broad compatibility and comparability with the PIROP dataset. It was conceived in conjunction with the European Seabirds at Sea program to ensure comparability across the North Atlantic. This is particularly important as oil exploration interest grows in multi-jurisdictional areas, such as Baffin Bay and Davis Strait where seabird surveys are being conducted by both Canadian and Danish agencies on opposite sides of the international border. The ability to collaborate and share information about seabirds that regularly cross invisible international boundaries is extremely important and is facilitated by adopting common protocols.

In addition to this project (and the CWS's ECSAS program), various other agencies collect seabird distribution and abundance information in the context of oil industry operations. For example, seabird surveys have been carried out by industry consultants (along with marine mammal observations) during seismic surveys. Additionally, operators of the Terra Nova and White Rose fields are sponsoring an ongoing rig observer program using protocols developed by the CWS. As new techniques and methodologies become available and are adopted and integrated into existing standardized protocols worldwide, it is important that compatibility be maintained amongst seabird surveyors operating in the Northwest Atlantic. While this is currently broadly true, there are some differences in protocols currently in use. In particular, distance sampling (to quantify detectability) and/or snapshot methods (to address relative bird movement) have not been used consistently by all survey programs, thus limiting them to producing only indices of relative abundance. Results from such survey programs have limited applicability and are difficult to compare with results from surveys that incorporate these modern techniques. The adoption and execution of distance sampling is simple and does not place an onerous burden on observers.

> ***Recommendation 1** – The CWS ECSAS survey protocol, which includes snapshots for relative movement and distance sampling for detectability, should be adopted as the common standardized protocol used by all survey programs.*

It is equally important to be cognizant of ongoing advances and opportunities for improvement in protocol design/execution. For example, dedicated aircraft have previously been used to survey seabirds in the North Atlantic and are regularly used for pelagic seabird surveys in Europe. Although the per-hour cost of dedicated aerial platforms may at first appear prohibitive, they may be more cost-effective because of their ability to cover large survey areas in a short amount of time. This option is being assessed for use in Canadian waters by the CWS, Quebec Region (F. Bolduc, pers. comm.) and will be investigated in future seabird studies on the Labrador shelf.

4.2 Analysis Techniques

The details of how seabird monitoring data is filtered, analysed and represented graphically can have a large impact on its interpretability and usability. Such details are sometimes glossed over in scientific papers and reports, making it difficult to compare across regions or time. In making comparisons, it is also important to consider what issue is being addressed. For example, the analysis and mapping presented in this report are intended to illustrate how estimates of seabird density vary in space and time in the study area. The analysis (and graphical representation) might have been considerably different if the issue had been the identification of year-round hotspots in the study area, regardless of the exact numbers of birds involved (K. Allard, pers. comm.). Thus it is important to determine the issue being addressed when we design and compare standardized analysis approaches. As data analysis and mapping techniques become increasingly powerful, it is important to develop consistency among agencies conducting such surveys in the Northwest Atlantic and keep abreast of recent advances.

> ***Recommendation 2** − Industry, the private sector and government agencies involved in pelagic seabird monitoring should develop standardized data analysis and mapping techniques and endeavour to maintain consistency as they keep themselves apprised of new developments in the field.*

4.3 Training

The importance of maintaining consistency among observers (and for each observer over time) should not be underestimated. Although there is some ability to account for inter-observer differences at the analysis stage (Marques et al. 2007), it is preferable to ensure that surveys are carried out as consistently as possible by all observers. With this in mind, a standardized observer training program was developed in conjunction with the CWS's ECSAS program. It consists of classroom modules on seabird identification, protocol implementation and database usage, followed by an at-sea practicum. As a result of this training, a pool of more than 20 highly qualified observers has been established. This is an extremely valuable resource.

The availability of individuals with the aptitude and willingness to conduct pelagic seabird surveys at short notice under often physically and mentally challenging conditions is limited and probably the largest constraint in conducting surveys. In fact, experience has proven that it is far easier to find a survey vessel of opportunity than it is to find a qualified observer to place upon it. Surveys are often sporadic in their occurrence and unpredictable in their exact timing, and are thus not a dependable source of income for independent observers who must, of necessity, find other work that limits their availability. Therefore maintaining a sufficient pool of qualified observers is of paramount importance. Safety training and various clearances required to board vessels (medicals and insurance) further reduce the pool of potential observers. Once trained, it is equally important to maintain the quality of an observer's skills over time. To that end, seabird observers in Great Britain undergo regular skill audits and refresher training (A. Webb, pers. comm.). In addition to maintaining observer skill levels, this also affords the opportunity to introduce new skills, equipment and techniques as they become available.

> ***Recommendation 3*** *– The CWS should continue its standardized training program and provide formal accreditation when training new and existing observers. A refresher program should also be developed to maintain skills and provide updates as protocols are updated and improved.*

Data analysis skills are equally important to the successful delivery of a seabird survey program and should not be overlooked. The ability to apply appropriate analysis techniques to seabird survey data is a skill that is just as important as the ability to collect the data in the first place. Modern seabird survey programs include methods such as distance sampling to assess and account for varying seabird detectability. While application of the field protocol for collecting distance sampling data is simple, analysis is not as straightforward. The distance sampling software and analysis techniques (Thomas et al. 2010; Buckland et al. 2001) are extremely powerful and broad in their applicability, but are fraught with many nuances and pitfalls that are not obvious to the untrained analyst. Fortunately, excellent training workshops facilitated by the developers of distance sampling are regularly available in Scotland and increasingly available in North America.

> ***Recommendation 4*** *− Appropriate data analysis training such as the distance sampling workshops should be made available to all practitioners responsible for analysing pelagic seabird survey data.*

4.4 Data Storage and Interoperability

Resource managers need quick and efficient access to seabird data for a variety of tasks including environmental assessments and emergency response. Since the early 1960s, more than

3,000,000 individual birds have been recorded under various monitoring programs in the Northwest Atlantic. A robust, easy-to-use database system is therefore a key element in the management of this volume of information.

A custom-designed Microsoft Access database (hereafter called the ECSAS database) was built to manage the data for this project (and the ECSAS program in general). It features voice activation for dictating bird sightings, integration with ship navigation systems for position, speed and direction, and automatic timers to implement watch and snapshot timing. A powerful, customizable query interface was constructed to extract data for distance sampling or other analyses, and to provide a variety of summaries of survey effort and seabird sightings at a range of spatial scales. It is currently in use for all CWS at-sea surveys in Atlantic Canada and Quebec. In addition to modern data, it also includes all data from the PIROP program that ran from the 1960s to the early 1990s.

Seabird abundance and distribution data from vessel surveys conducted by oil industry consultants and from the rig-based industry observer program are regularly made available to the CWS for archiving and for use during environmental assessments, conservation planning and emergency response. These data are stored by industry consultants either in a variety of incompatible databases or as Excel spreadsheets, which lack the data integrity mechanisms enforced by relational database management systems, such as Access or SQL Server. Data are typically delivered to the CWS as Excel spreadsheets, thus losing the hierarchical table structure in the host database system and integrity assurance (if any). This makes it difficult or impossible to integrate these data into the ECSAS database and makes them unavailable to decision makers.

It is highly desirable to integrate all seabird survey data into a single database allowing managers to make decisions by leveraging the best information from the most complete datasets available. The ECSAS database is capable of housing all types of at-sea seabird survey information collected from both moving and stationary vessels/platforms. It can be used by many observers on multiple vessels at a time and has a simple mechanism for combining these data into a master database.

The ECSAS database can be made available for use by all agencies/consultants involved in collecting at-sea survey data. The CWS could continue to act as the central clearinghouse for all datasets, and there are facilities to protect proprietary data (if any) in distributed copies. Having all consultants use the same database would offer many benefits, including (1) eliminating the considerable cost of each agency/consultant developing its own comparable databases, (2) providing a consistent standardized interface for data collection and querying across survey projects, (3) automatic assurance of protocol adherence through data integrity checking (included in ECSAS), (4) simplified, fast and efficient data integration into the CWS master database, and (5) the ability so share data easily among agencies, as desired.

> ***Recommendation 5*** *− The ECSAS database should be adopted as the common data management and sharing platform for all industry-related seabird surveys.*

4.5 Industry Observer Program

The observer program has been operating since 1997 and has generated a valuable long-term dataset of observations in the Northeast Grand Banks production area. Although the dataset is limited in geographical scale, it is extremely valuable because of its fine temporal scale and long-term nature, thereby providing precise information on the timing of seabird movements.

The program has matured over time and was previously reviewed by Baillie et al. (2005), and many of problems identified in that review have been addressed. This review (see section 3.5) focused on issues of protocol compliance, seabird identification, data management inconsistencies and inter-observer variability.

Protocol Compliance

Baillie et al. (2005) recommended the use of instantaneous counts in order to allow for the calculation of density estimates from this dataset. Previously, 20-minute counts had been used which cannot be used to compute densities, and this was identified as an important factor limiting the potential usefulness of this dataset (Baillie et al. 2005). It was intended for the survey program to switch to using instantaneous counts, but this is not reflected in the data reviewed for 2006–2009. Feedback on this issue was provided in December 2009 to program administrators who are making the appropriate changes (P. Barron, pers. comm.).

During the life of this ESRF project, the protocol for stationary surveys has evolved and now includes the use of distance sampling (with five distance categories, A-E, Figure 4) to account for variable detectability across species, observation conditions and observers. Without distance sampling, seabird density will likely be severely underestimated (see section 3.6). This facet of the protocol is not yet being implemented as part of the industry observer program.

These protocol compliance issues have been partially addressed by having new rig observers take a standardized training course provided by the CWS. A refresher course for experienced observers that highlights changes in the protocol may also be advantageous. Most importantly, there is no substitute for practical guidance and auditing in the field. Regular visits with rig observers offshore would surely help to address these issues, but opportunities to do so were limited during the life of this project.

Seabird Identification

There were inconsistencies in the use of seabird names and/or potential incorrect identification problems. Seabird names were sometimes misspelled and/or referred to nonexistent species. For example, large flocks of up to 80 Cory's Shearwaters were reported on several occasions. This species was recorded regularly as consisting of small flocks in the southern part of the study area (Laurentian Channel, Scotian Shelf) in vessel-based surveys, but rarely observed this far north and never in such large numbers. The sightings were correctly flagged as "uncertain" and likely represent a misidentification of Greater Shearwater. Issues of seabird naming and misidentification can easily be addressed by a combination of classroom training and skills instruction offshore.

> ***Recommendation 6*** *– The CWS should continue to act in a QA/QC role for the rig observer program and provide feedback on seabird identification, protocol compliance and data management.*
>
> ***Recommendation*** *7 − An accredited training program should be undertaken by new and existing observers and regular CWS staff visits with rig observers offshore should be made a priority.*

Data Management

Inconsistent spelling of seabird and observer names and inconsistent use of terminology to indicate when no birds are seen can easily be addressed by appropriate database software that includes pull-down menus. In addition, such software programs should contain sanity checks for protocol compliance. The existing ECSAS database possesses these features because it was designed to store observations from offshore rigs.

Data from the rig observer program is currently provided to the CWS in Excel spreadsheet format and regular data summaries are provided to the oil companies. Ideally, these data would be consolidated into the ECSAS master database and be available for emergency response, environmental assessments and conservation planning. Importing the data from these spreadsheets (or an incompatible Access database) into the ECSAS database would be a difficult, time-consuming and error-prone process. This lack of importing capability has severely limited the usefulness of these data. The simplest solution for these problems is for the rig observer program to adopt the ECSAS database for use offshore. Importing data into the ECSAS master database would then be a simple matter, and program managers could continue to generate data summaries for the oil industry using the powerful and flexible query interface provided in ECSAS, (which can be extended as necessary). Under this scenario, the CWS would provide the necessary training for observers and data managers.

> ***Recommendation 8*** *− The ECSAS database should be adopted as the data management platform by the industry observer program.*

To summarize, the industry observer program still has some technical issues to address in order to further enhance the quality and accessibility of this dataset. The merit of this dataset is primarily the high frequency of observations. These data indicate when important seasonal movements occur each year and can be used for real-time assessments of which birds may be at risk at the time of an incident.

4.6 Distribution and Density of Seabirds at Sea

Since 2006, 76 survey trips (in conjunction with the CWS's ECSAS program) covering 51,392 km of ocean transect from the Gulf of Maine to the Labrador Sea were conducted by almost 20 observers, during which more than 123,000 birds were recorded (see section 3.2). In comparison, the PIROP program covered only twice as much ground (110,576 km) in 281 survey trips over a period of more than 20 years. The data collected under the PIROP program yielded only relative abundance of birds, whereas the ECSAS program now permits the computation of absolute densities of birds/km^2. This is a major step forward for at-sea monitoring in the Northwest Atlantic and this report contains the first analysis of this dataset.

4.6.1 Detection Probability and Distance Sampling

Previous survey programs in the Northwest Atlantic did not take seabird detectability into account, assuming instead that all birds within a (normally) 300-m transect were detected. We tested this assumption using distance sampling (Buckland et al. 2001) by computing detection probabilities for each species on a seasonal basis (see section 3.6). Our results indicate that the assumption of perfect detectability is not justified and instead is far less than 1.0 for all species. For example, detection probability ranged from approximately 0.30 for small dark birds on water, such as Dovekies, murres and storm-petrels, up to approximately 0.70 for large white birds on water, such as Northern Gannets. Failure to incorporate these detection probabilities would have resulted in an underestimation of density of up to 3 times.

A variety of sources of seabird density data (including the ECSAS dataset) are typically used by consultants when preparing environmental assessments. In many cases, seabird surveys have been conducted by consultants themselves during previous seismic or other substrate mapping programs. Prior to the publication of this report, no detection-corrected seabird density information was available for the study area and thus no previous environmental assessment has taken seabird detectability into account.[4] Therefore, seabird densities discussed in previous environment assessments are probably significantly underestimated.

The CWS plans to update its analysis of seabird densities in the Northwest Atlantic on a yearly basis as new data are accumulated.

> ***Recommendation 9*** *− Future seabird surveys should incorporate distance sampling methodology and analysis to estimate absolute seabird density. Future environmental assessments should the most recently available detection-corrected density estimates as references.*

4.6.2 Scale-appropriate Analyses

The accompanying maps and descriptions are an example of the seasonal analysis and visualization of the dataset for common species/groups aggregated into 1° blocks. An example of a finer-scale analysis for murres during the winter around the northeast Grand Bank production area is also included. This dataset is a resource that must be considered on a spatio-temporal scale appropriate to the task at hand.

For example, when assessing the seabird resource at risk because of a relatively localized hydrocarbon spill, it may be tempting to interrogate the data on a fine spatial scale. But, with a small block size and relatively low survey effort per block, the block-to-block variation in density may be an artefact of the relative magnitudes of the block size and typical flight range of the species of interest. This can be offset by applying more intensive survey effort or by aggregating the available data over a larger spatial scale.

The maps in this report should suffice to provide a quick overview of seabird density in a given area at a given time of year, but customized analysis and mapping will likely be necessary for more specialized requirements.

4.6.3 Hotspots

The descriptions in section 3.7 provide details of the abundance of each individual species or group on a seasonal basis. Each description highlights the density of the included species in the places where they were (or were not) found. As a result of this exercise, a number of areas have emerged that are important to one or more species/groups in one or more seasons. Many of these areas were recognized by Brown (1986), although he only presented relative abundance and not the absolute densities reported here. The following paragraphs summarize these areas.

Continental Shelf Edge

The edge of the continental shelf stands out in all seasons as an area of importance to many species. This should come as no surprise given what is known about highly productive upwellings that often occur on continental shelf margins. This pattern was apparent all along the

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[4] Previous ECSAS data maps included in environmental assessments contained no detectability correction.

shelf edge from the Gulf of Maine in the south to the Northeast Newfoundland Shelf in the north. Perhaps the most striking example of this pattern was for Dovekies during the spring (Gjerdrum et al. 2009). This species is almost entirely dependent upon invertebrates (mostly calanoid copepods) that are brought to the surface in large concentrations in areas of upwelling, and their distribution strongly tracks the shelf break during this period. Although this pattern was strongest for Dovekies, most other species, including the tubenoses, gulls and murres, also exhibited a preference for shelf edge habitat during one or more seasons.

Gulf of Maine, Bay of Fundy and Northeast Channel

Survey effort in the Gulf of Maine and Bay of Fundy was most widespread during the summer, although the Northeast Channel (to the east of Georges Bank) was covered in all seasons, except the winter. During the spring, this region hosted relatively high densities of murres and Northern Gannets, while high numbers of gulls were found here during the spring and summer. The highest density in the study area was recorded here because of large aggregations of Greater Shearwaters during the summer. Shearwaters, Northern Fulmars and storm-petrels were found in high numbers in this region during the summer and fall.

Scotian Shelf and Laurentian Channel

The eastern half of the Scotian Shelf and the adjoining Laurentian Channel was one of the more productive regions for seabirds in the study area. Fulmars were abundant in this region throughout the year and in the spring, high numbers of gulls, murres and gannets frequented the area. By the summer, murres and gannets were joined by large numbers of storm-petrels (particularly on the western Scotian Shelf) and shearwaters. The latter two species remained into the fall, when they were joined by gulls that had probably returned from their coastal breeding sites. During the winter, this region hosted large numbers of gulls, murres and other alcids.

Cabot Strait

The Cabot Strait (along with the Strait of Belle Isle) is one of only two marine access routes to the Gulf of St. Lawrence that hosts significant breeding colonies of alcids, gannets and kittiwakes. The Cabot Strait stood out as an area of high density in the fall for kittiwakes, Dovekies, gannets, shearwaters and other alcids. High concentrations of zooplankton prey are present in the area during the fall (Head and Pepin 2007) and strong currents through the strait may be partially responsible for making this and other prey available for species that feed on or near the surface (Gjerdrum et al. 2009).

Grand Banks

Overall, the Grand Banks was the most important region for seabirds in the study area. Within the Grand Banks, the northeast and southeast portions (including the Nose and Tail of the bank) were the most productive areas. The northeast section of the bank also includes the location of the Jeanne D'Arc Basin oil production area. High concentrations of a variety of species were found during all seasons, but especially during the non-breeding season (fall, winter and spring). Murres were found in high abundance year-round on the bank, especially in the northeast, although the southern half of the bank had higher concentrations during the winter. During the spring, Black-legged Kittiwakes, Dovekies, gulls and Northern Fulmars were found in relatively high concentrations, particularly on the northeast portion of the bank. During the summer, storm-petrels and shearwaters were the most abundant birds on the bank, particularly in the northern half (although survey effort was limited in the south). Survey effort on the bank was most limited during the fall; so generalizations are difficult to make, but murres, Dovekies and Northern Fulmars had their highest densities (outside the Labrador Shelf) on the northeast Grand

Bank during this period. Additionally, the highest density of storm-petrels and shearwaters during the fall occurred on the bank. In the winter, high concentrations of Black-legged Kittiwakes, Dovekies, gulls and Northern Fulmars were all found on the Grand Banks and the highest densities of shearwaters in the study area during the winter were found on the southern Grand Bank early in that season.

Flemish Cap and Pass

The Flemish Cap and Pass emerged as local hotspots during the spring and winter for a number of species, including Black-legged Kittiwake, Dovekie, gulls (spring only), murres and Northern Fulmar, and for shearwaters during the summer. Although there was no survey effort in this area during the fall, it is likely that these same species that occurred in high concentrations during the rest of the non-breeding season are also present during the fall (Brown, 1986).

Orphan Basin and Sackville Spur

The deep water of the Orphan Basin is located to the north and east of the Grand Banks, with the Northeast Newfoundland Shelf forming its western boundary. The Sackville Spur protrudes at the extreme northeast of the Grand Banks, separating the Orphan Basin from the Flemish Pass. While the central and eastern basin and area around the Orphan Knoll had high local densities of Black-legged Kittiwake during the summer, the areas along the Basin’s western and southern boundaries were the most productive. During the spring, gulls and fulmars were found in their highest concentrations in the Newfoundland and Labrador Shelves region along the Sackville Spur. During the summer, the maximum density for Dovekies in the study area was found in the northeast Orphan Basin, and Northern Fulmars, storm-petrels and shearwaters were common along the southern edge. In the winter, fulmars and gulls were especially prevalent on the Sackville Spur.

Northeast Newfoundland Shelf

The coastline along the Northeast Newfoundland Shelf is home to some of the largest seabird colonies in the world (e.g., Funk Island and Baccalieu Island). These colonies are likely responsible for the large numbers of Black-legged Kittiwake, gulls, Northern Gannets, murres and other alcids present on the shelf during the spring and summer. During the winter, this area emerged as a hotspot for Black-legged Kittiwakes, Dovekies, gulls and murres. The shelf received no survey effort during the fall.

Labrador Shelf/Labrador Sea

The Labrador Shelf received limited survey coverage during the summer and fall, while parts of the Labrador Sea were only surveyed during the summer. The Labrador Sea and the shelf edge along the adjoining Hamilton Bank, Hawke Saddle and Belle Isle Bank contained locally high concentrations of Black-legged Kittiwakes, Dovekies and Northern Fulmars during the summer. In the fall, the highest concentrations of Black-legged Kittiwakes, Dovekies, murres, gulls and fulmars in the study area were found on the central Labrador Shelf, an area that was also identified by Brown (1986).

4.7 Remaining Gaps

The study area has been the subject of intense survey effort since 2006, yet many spatial and temporal gaps remain in areas of current or future interest to the oil industry. Seabirds are inherently highly variable in their abundance because they exhibit a patchy distribution in response to an environment that is inherently highly variable. Quantifying this variability with any degree of precision requires many repeated surveys over time. Many 1° survey blocks in the study area have only been crossed by a single survey transect in any given season. The precision of the density estimates (in particular, the encounter rate variance—see section 2.5) increases with the number of survey lines in each 1° block. For survey blocks containing only a single line, no encounter rate variance component can be estimated and thus quality of the standard error will be low. This highlights the inherent trade-off between obtaining density estimates at a spatial scale of interest and the precision of those estimates. The precision of the density estimates contained herein will improve over time with modest continued survey effort.

> ***Recommendation 10** – At least seasonal "maintenance" surveys to increase estimate precision and maintain data timeliness should continue to be conducted to the production areas on the northeastern Grand Banks and Scotian Shelf.*

4.7.1 Seasonal Gaps

During the spring, the northern limit of survey effort was the 51st parallel, leaving half the Northeast Newfoundland Shelf and all of the Labrador Shelf/Labrador Sea unsurveyed. Although part of these shelf areas are ice-covered during this period, Brown (1986) identified the ice-free portions as areas of high concentration of oil-vulnerable birds (i.e., alcids) during the winter and spring. Likewise, the eastern Gulf of St. Lawrence south to Cabot Strait received no coverage during the spring. Other gaps in the spring in the Newfoundland Labrador Shelf region include the Newfoundland south coast, portions of the Laurentian Channel, St. Pierre Bank and the southwestern Grand Banks. In the Scotian Shelf region, the extreme western portion of the shelf, parts of the Gulf of Maine and the Bay of Fundy lack adequate coverage.

The summer season has enjoyed the best survey coverage since 2006; nonetheless, almost the entire Labrador Shelf remains unsurveyed during the summer. The southeastern Grand Banks and to a lesser extent the Flemish Cap and the Sydney Basin are also lacking adequate summer coverage.

Fall survey coverage in the Newfoundland and Labrador Shelves region was the most geographically limited, although it was the only season to include surveys of the central Labrador Shelf. While survey effort was concentrated on the northeast Grand Banks production area (and the route to St. John's), the entire Northeast Newfoundland Shelf, Orphan Basin, Flemish Cap, eastern Gulf of St. Lawrence, Sydney Basin and much of the Laurentian Channel, St. Pierre Bank and the southeast Grand Banks were not surveyed during the fall. In the Scotian Shelf region, the Bay of Fundy and much of the Gulf of Maine require survey coverage.

In comparison to the fall, the Newfoundland and Labrador Shelves region received more geographical coverage during the winter, whereas the Scotian Shelf and Gulf of St. Lawrence regions received less. The Labrador Shelf, Labrador Sea, the eastern Gulf of St. Lawrence, the Sydney Basin, the western Scotian Shelf and the Bay of Fundy were entirely unsurveyed, as were portions of the Northeast Newfoundland Shelf, southern Grand Banks, Flemish Cap, the Laurentian Channel and St. Pierre Bank.

It is important to ensure that the effort invested in this project is not wasted by allowing the collected data to become stale, as happened with the PIROP program after the 1980s. The amassed data must retain its currency if it is to remain an effective tool. It is unlikely that it will ever be logistically or financially practical to maintain the intensive effort required over all areas of industry interest simultaneously. Thus, it will be necessary to rotate future periods of intensive effort on a scheduled basis over different geographical regions. Through this approach, a viable and useful dataset can be maintained in order to address seabird issues in areas of industry interest in perpetuity.

> ***Recommendation 11*** *− Data currency should be maintained through a rotating schedule of intensive effort focusing on major areas of interest including the Grand Banks, Scotian Shelf, Labrador Shelf, and south Newfoundland coast/Laurentian Channel/Sydney Basin. Exact timing and order should be determined in accordance with data gaps and the geographical focus of potential or realized oil industry activity.*

From this analysis, it is evident that the largest remaining gap in terms of both space and time is the Labrador Shelf on a year-round basis and this area should be a priority for future work.

> ***Recommendation 12*** *− Intensive survey effort should be directed towards remaining gap areas beginning with the Labrador Shelf.*

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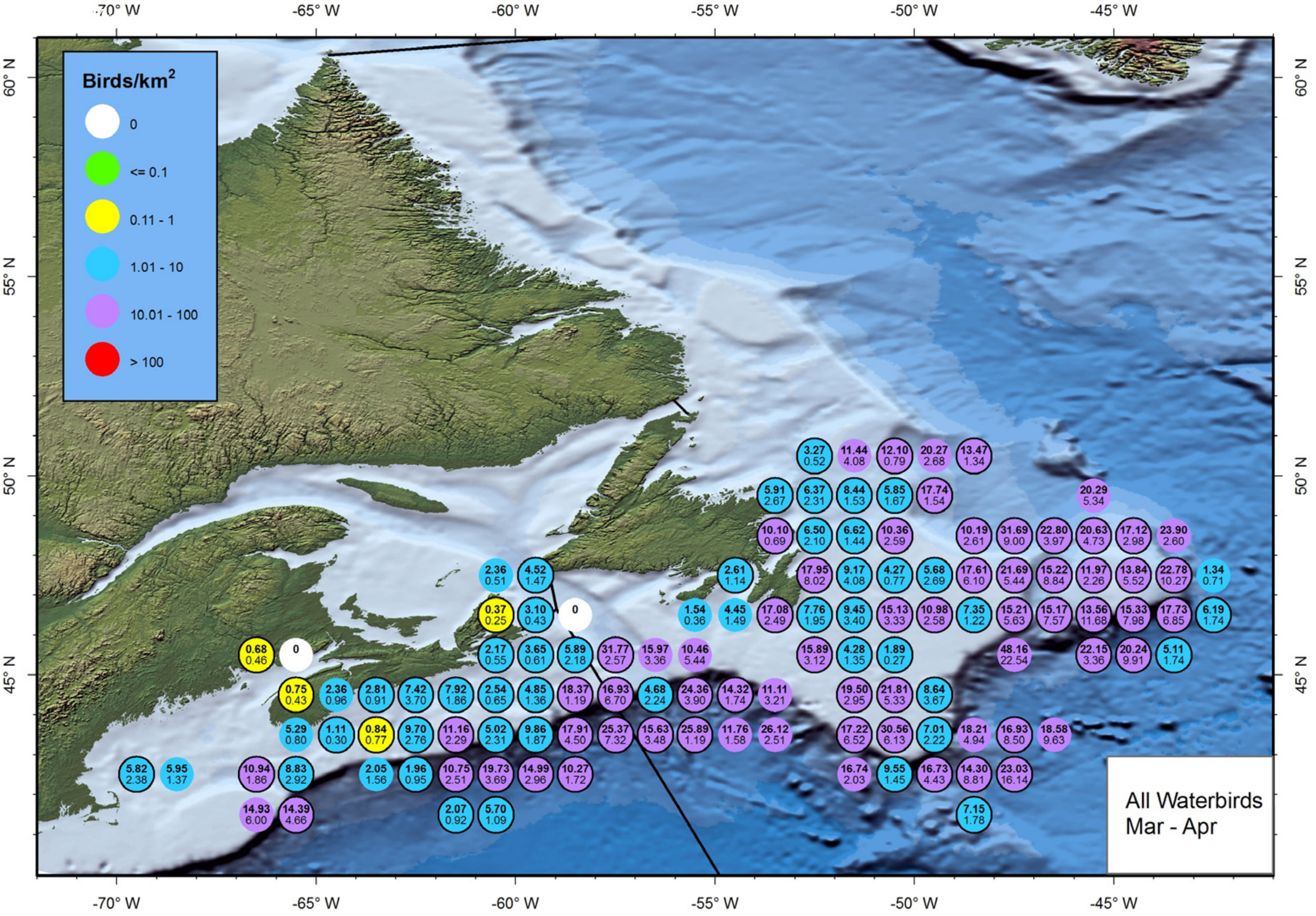
5.1 Personal Communications

Karel Allard, Canadian Wildlife Service, Dartmouth, NS, September 2009
Pat Barron, Provincial Aerospace Ltd., St. John's, NL, December 2009
François Bolduc, Canadian Wildlife Service, Ste. Foy, QC, December 2009
Steve Buckland, University of St. Andrews, Scotland, April 2008
Len Thomas, University of St. Andrews, Scotland, May 2009
Andy Webb, Joint Nature Conservation Committee, UK, September 2006

6 Appendices

6.1 Appendix 1: Maps of Seasonal Densities of Seabirds

Maps of seasonal densities of seabirds at 1º survey block intervals. Numbers in circles are densities in birds/km^2 (top) ± SE (bottom). Survey blocks outlined in solid black have > 25 km of effort. Note that the maps are drawn in unprojected geographic co-ordinates (latitude, longitude) and thus the area represented by a 1° block at the northern extreme is less than that in the southern extreme.


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
All Waterbirds
Mar - Apr
3.27 0.52
11.44 4.08
12.10 0.79
20.27 2.68
13.47 1.34
5.91 2.67
6.37 2.31
8.44 1.53
5.85 1.67
17.74 1.54
20.29 5.34
10.10 0.69
6.50 2.10
6.62 1.44
10.36 2.59
10.19 2.61
31.69 9.00
22.80 3.97
20.63 4.73
17.12 2.98
23.90 2.60
2.36 0.51
4.52 1.47
2.61 1.14
17.95 8.02
9.17 4.08
4.27 0.77
5.68 2.69
17.61 6.10
21.69 5.44
15.22 8.84
11.97 2.26
13.84 5.52
22.78 10.27
1.34 0.71
0.37 0.25
3.10 0.43
0
1.54 0.36
4.45 1.49
17.08 2.49
7.76 1.95
9.45 3.40
15.13 3.33
10.98 2.58
7.35 1.22
15.21 5.63
15.17 7.57
13.56 11.68
15.33 7.98
17.73 6.85
6.19 1.74
0.68 0.46
0
2.17 0.55
3.65 0.61
5.89 2.18
31.77 2.57
15.97 3.36
10.46 5.44
15.89 3.12
4.28 1.35
1.89 0.27
48.16 22.54
22.15 3.36
20.24 9.91
5.11 1.74
0.75 0.43
2.36 0.96
2.81 0.91
7.42 3.70
7.92 1.86
2.54 0.65
4.85 1.36
18.37 1.19
16.93 6.70
4.68 2.24
24.36 3.90
14.32 1.74
11.11 3.21
19.50 2.95
21.81 5.33
8.64 3.67
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1.11 0.30
0.84 0.77
9.70 2.76
11.16 2.29
5.02 2.31
9.86 1.87
17.91 4.50
25.37 7.32
15.63 3.48
25.89 1.19
11.76 1.58
26.12 2.51
17.22 6.52
30.56 6.13
7.01 2.22
18.21 4.94
16.93 8.50
18.58 9.63
5.82 2.38
5.95 1.37
10.94 1.86
8.83 2.92
2.05 1.56
1.96 0.95
10.75 2.51
19.73 3.69
14.99 2.96
10.27 1.72
16.74 2.03
9.55 1.45
16.73 4.43
14.30 8.81
23.03 16.14
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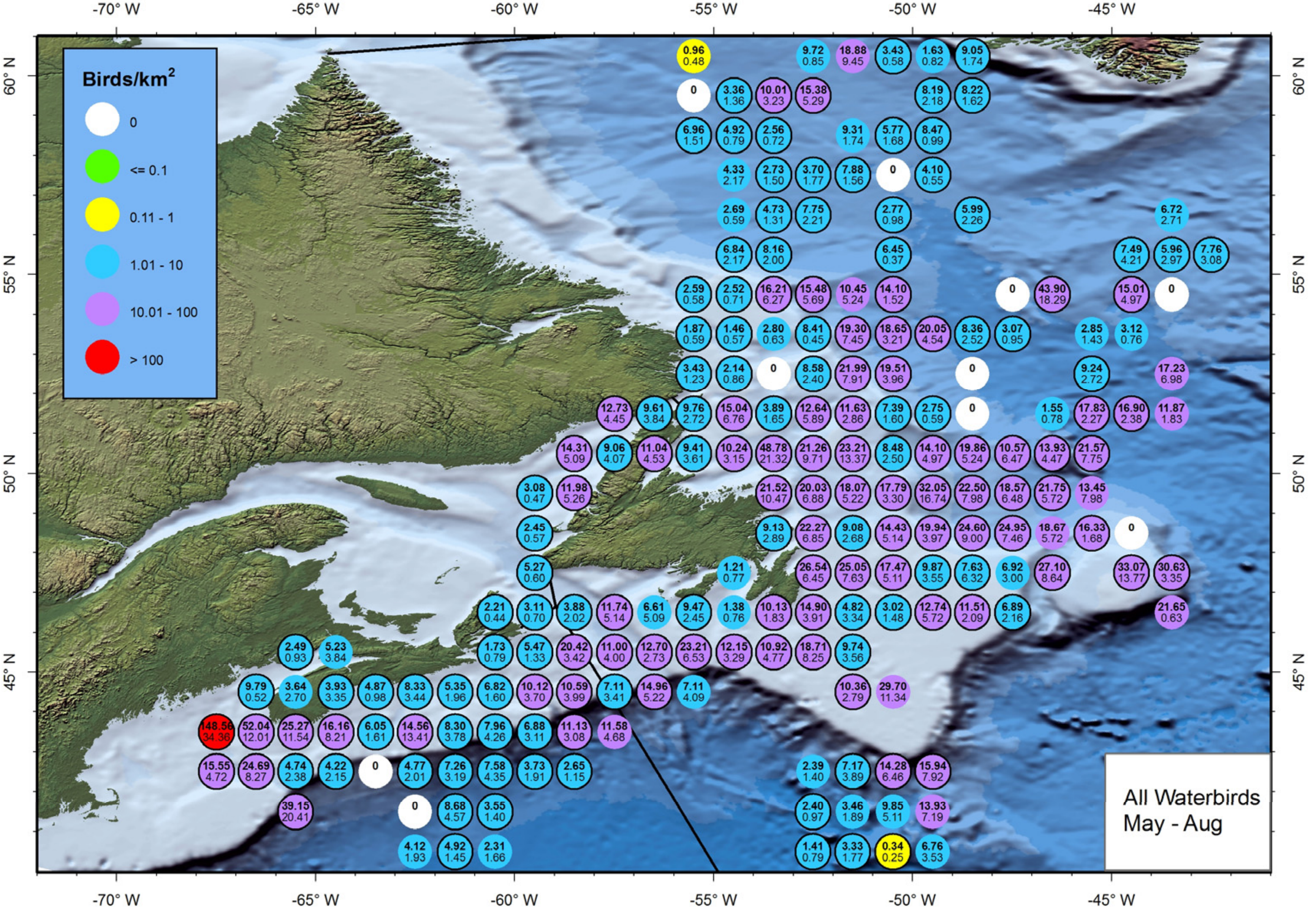
2.07 0.92
5.70 1.09
7.15 1.78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-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
All Waterbirds
May - Aug
0.96 0.48
9.72 0.85
18.88 9.45
3.43 0.58
1.63 0.82
9.05 1.74
0
3.36 1.36
10.01 3.23
15.38 5.29
8.19 2.18
8.22 1.62
6.96 1.51
4.92 0.79
2.56 0.72
9.31 1.74
5.77 1.68
8.47 0.99
4.33 2.17
2.73 1.50
3.70 1.77
7.88 1.56
0
4.10 0.55
2.69 0.59
4.73 1.31
7.75 2.21
2.77 0.98
5.99 2.26
6.72 2.71
6.84 2.17
8.16 2.00
6.45 0.37
7.49 4.21
5.96 2.97
7.76 3.08
2.59 0.58
2.52 0.71
16.21 6.27
15.48 5.69
10.45 5.24
14.10 1.52
0
43.90 18.29
15.01 4.97
0
1.87 0.59
1.46 0.57
2.80 0.63
8.41 0.45
19.30 7.45
18.65 3.21
20.05 4.54
8.36 2.52
3.07 0.95
2.85 1.43
3.12 0.76
3.43 1.23
2.14 0.86
0
8.58 2.40
21.99 7.91
19.51 3.96
0
9.24 2.72
17.23 6.98
12.73 4.45
9.61 3.84
9.76 2.72
15.04 6.76
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11.63 2.86
7.39 1.60
2.75 0.59
0
1.55 0.78
17.83 2.27
16.90 2.38
11.87 1.83
14.31 5.09
9.06 4.07
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9.41 3.61
10.24 3.15
48.78 21.32
21.26 9.71
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8.48 2.50
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13.93 4.47
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18.07 5.22
17.79 3.30
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22.50 7.98
18.57 6.48
21.75 5.72
13.45 7.98
2.45 0.57
9.13 2.89
22.27 6.85
9.08 2.68
14.43 5.14
19.94 3.97
24.60 9.00
24.95 7.46
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0
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1.21 0.77
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25.05 7.63
17.47 5.11
9.87 3.55
7.63 6.32
6.92 3.00
27.10 8.64
33.07 13.77
30.63 3.35
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11.74 5.14
6.61 5.09
9.47 2.45
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14.90 3.91
4.82 3.34
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5.47 1.33
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10.92 4.77
18.71 8.25
9.74 3.56
9.79 0.52
3.64 2.70
3.93 3.35
4.87 0.98
8.33 3.44
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15.55 4.72
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4.77 2.01
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2.65 1.15
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14.28 6.46
15.94 7.92
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0
8.68 4.57
3.55 1.40
2.40 0.97
3.46 1.89
9.85 5.11
13.93 7.19
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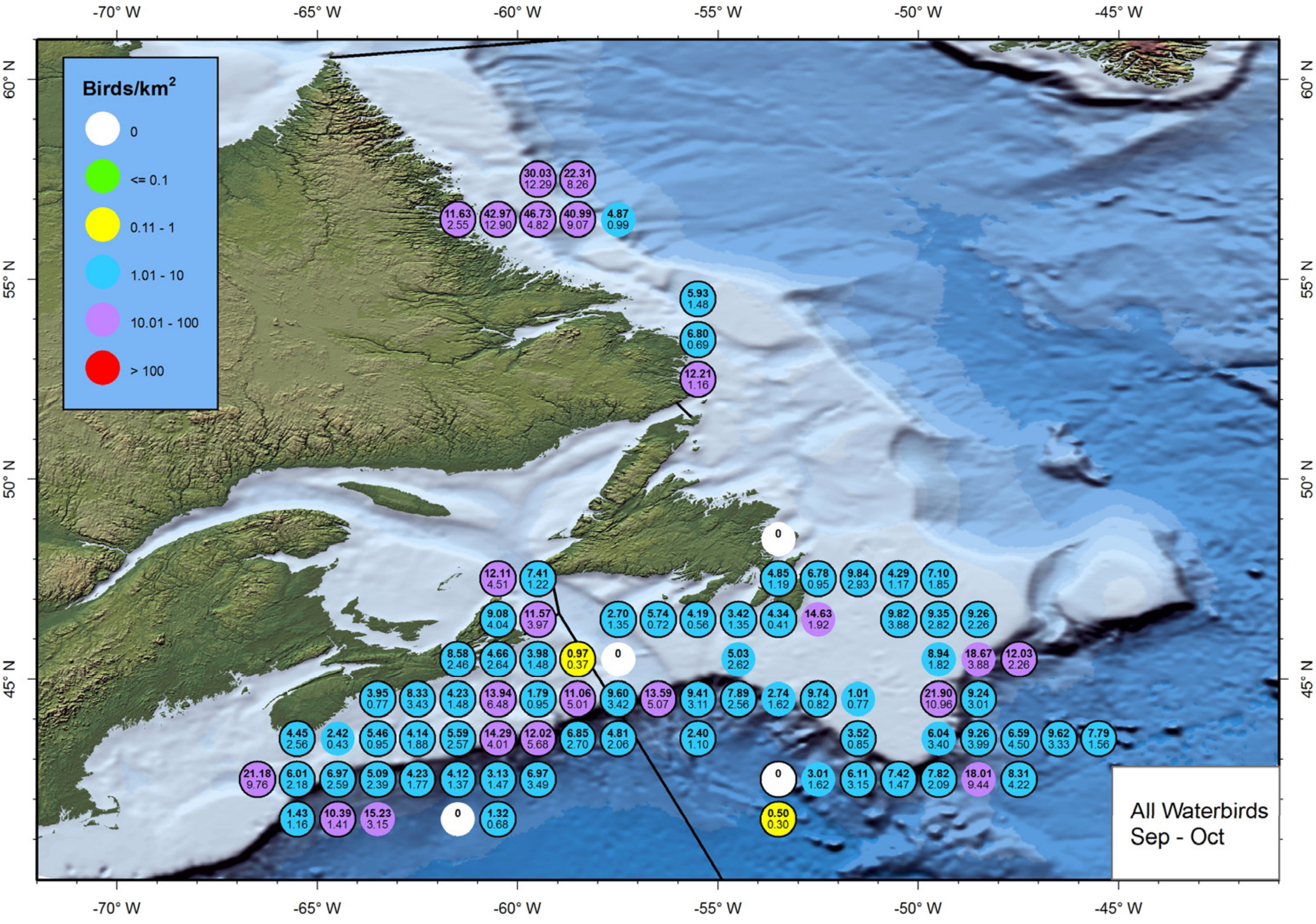
6.76 3.53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-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
30.03 12.29
22.31 8.26
11.63 2.55
42.97 12.90
46.73 4.82
40.99 9.07
4.87 0.99
5.93 1.48
6.80 0.69
12.21 1.16
0
12.11 4.51
7.41 1.22
4.85 1.19
6.78 0.95
9.84 2.93
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7.10 1.85
9.08 4.04
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21.90 10.96
9.24 3.01
4.45 2.56
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5.46 0.95
4.14 1.88
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12.02 5.68
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6.97 3.49
0
3.01 1.62
6.11 3.15
7.42 1.47
7.82 2.09
18.01 9.44
8.31 4.22
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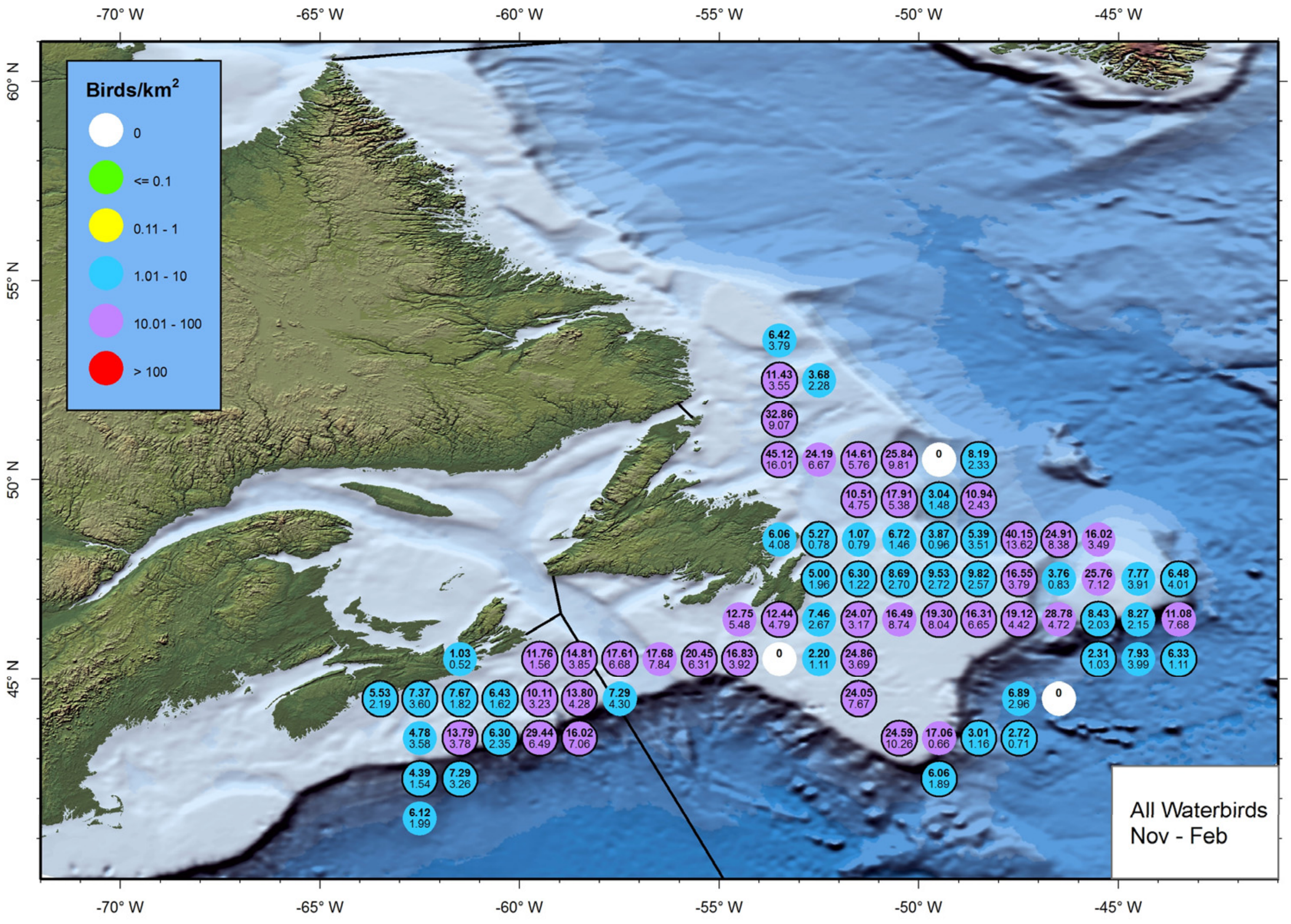
All Waterbirds
Sep - Oct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55° N
50° N
45° N
Birds/km²
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1.01 - 10
10.01 - 100
> 100
6.42 3.79
11.43 3.55
3.68 2.28
32.86 9.07
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24.19 6.67
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25.84 9.81
0
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24.07 3.17
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19.30 8.04
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8.27 2.15
11.08 7.68
1.03 0.52
11.76 1.56
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17.68 7.84
20.45 6.31
16.83 3.92
0
2.20 1.11
24.86 3.69
2.31 1.03
7.93 3.99
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7.67 1.82
6.43 1.62
10.11 3.23
13.80 4.28
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24.05 7.67
6.89 2.96
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29.44 6.49
16.02 7.06
24.59 10.26
17.06 0.66
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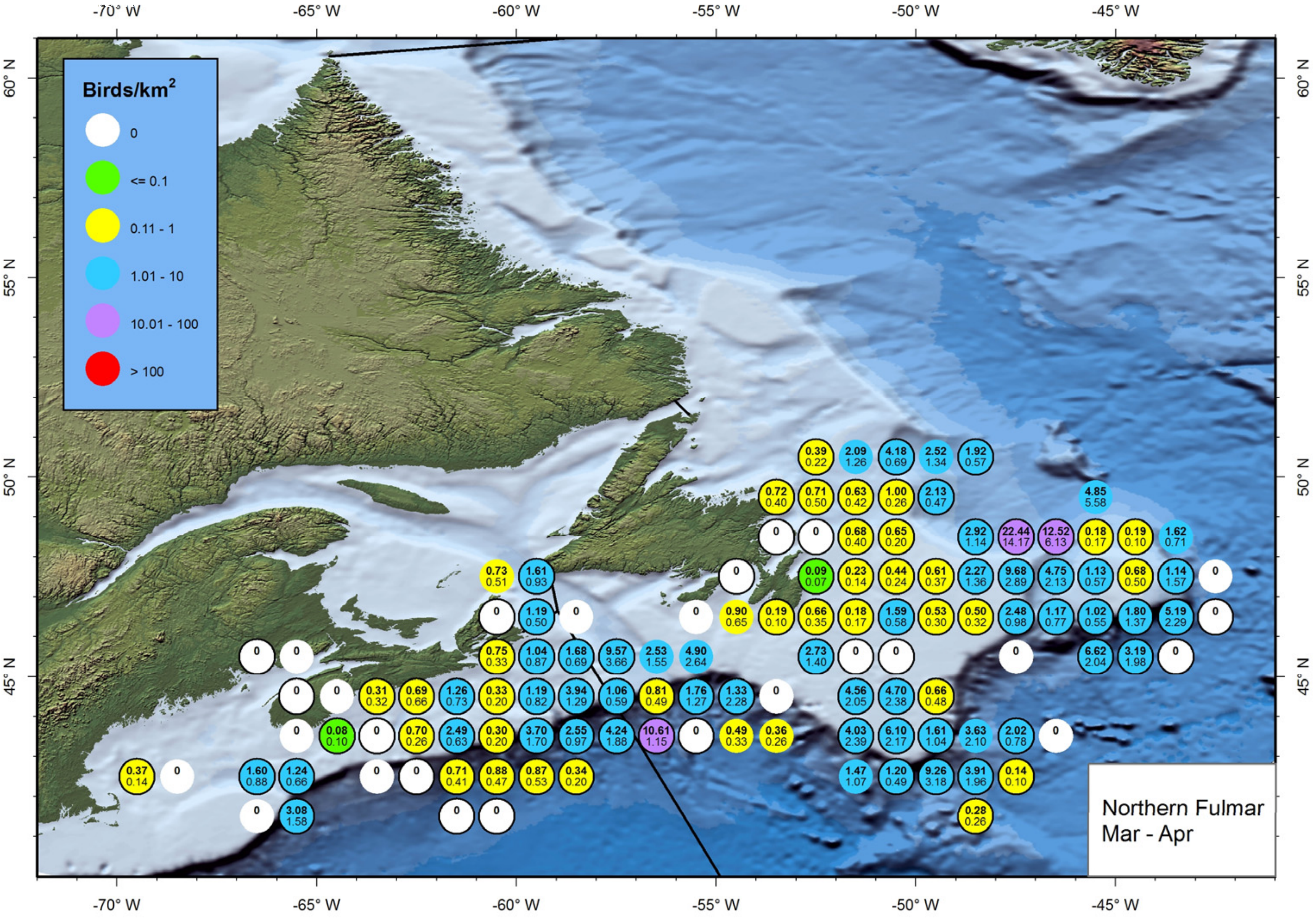
6.06 1.89
6.12 1.99
All Waterbirds
Nov - Feb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-65° W
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-55° W
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-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0.39 0.22
2.09 1.26
4.18 0.69
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0.19 0.10
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1.02 0.55
1.80 1.37
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1.20 0.49
9.26 3.18
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0
3.08 1.58
0
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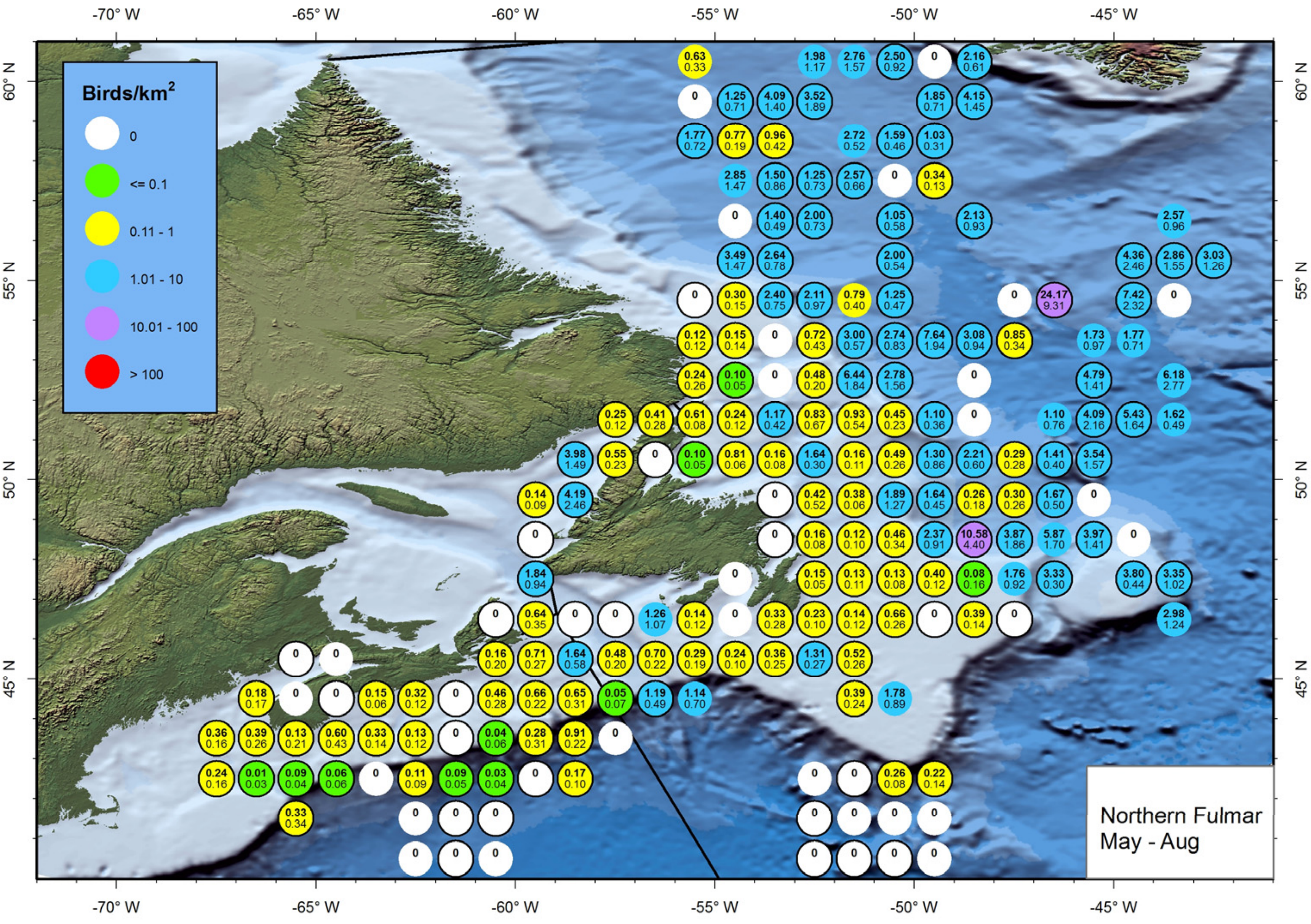
0.28 0.26
Northern Fulmar
Mar - Apr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60° N
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50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Northern Fulmar
May - Aug
0.63 0.33
1.98 1.17
2.76 1.57
2.50 0.92
0
2.16 0.61
0
1.25 0.71
4.09 1.40
3.52 1.89
1.85 0.71
4.15 1.45
1.77 0.72
0.77 0.19
0.96 0.42
2.72 0.52
1.59 0.46
1.03 0.31
2.85 1.47
1.50 0.86
1.25 0.73
2.57 0.66
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1.05 0.58
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2.57 0.96
3.49 1.47
2.64 0.78
2.00 0.54
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1.10 0.76
4.09 2.16
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10.58 4.40
3.87 1.86
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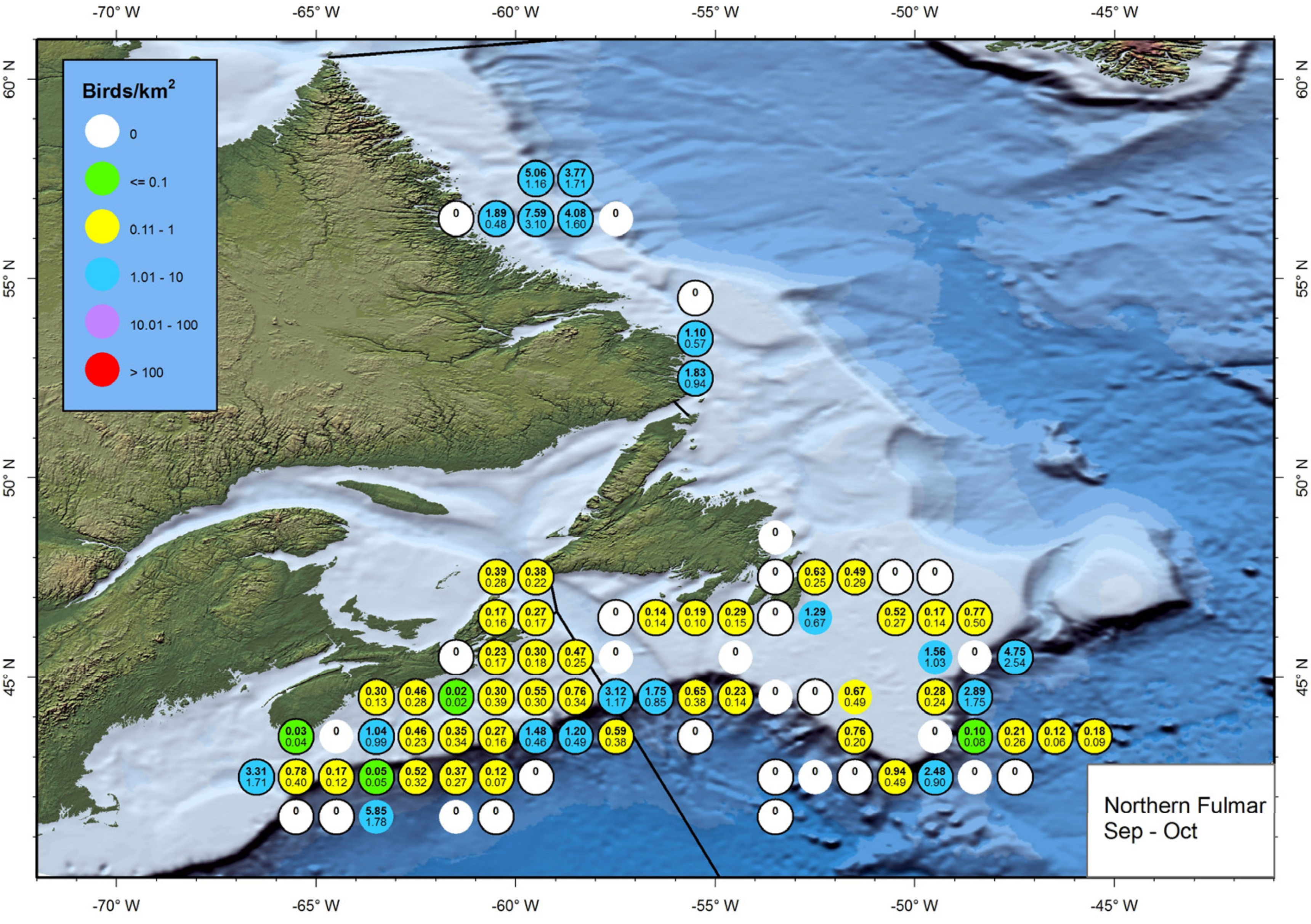
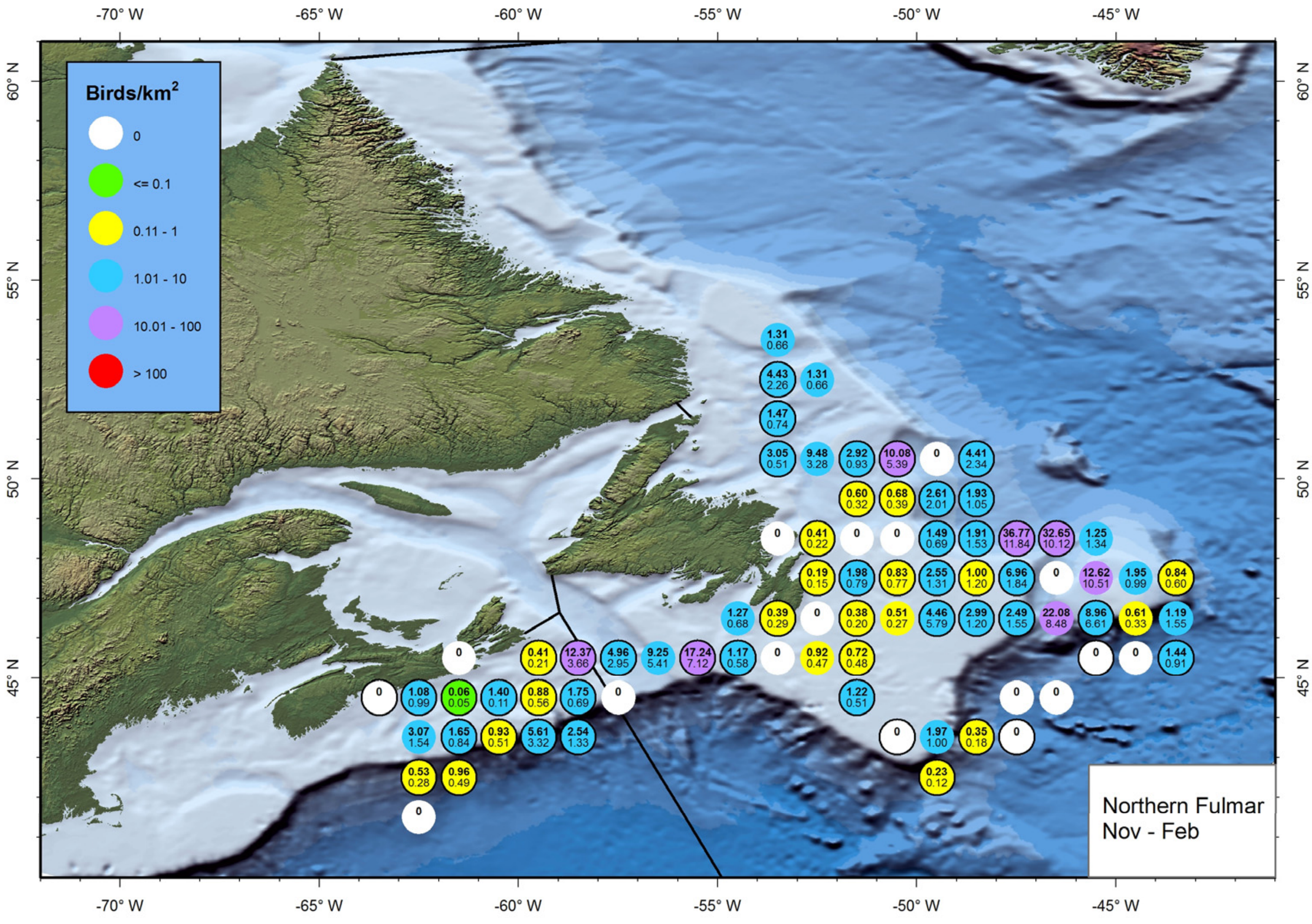
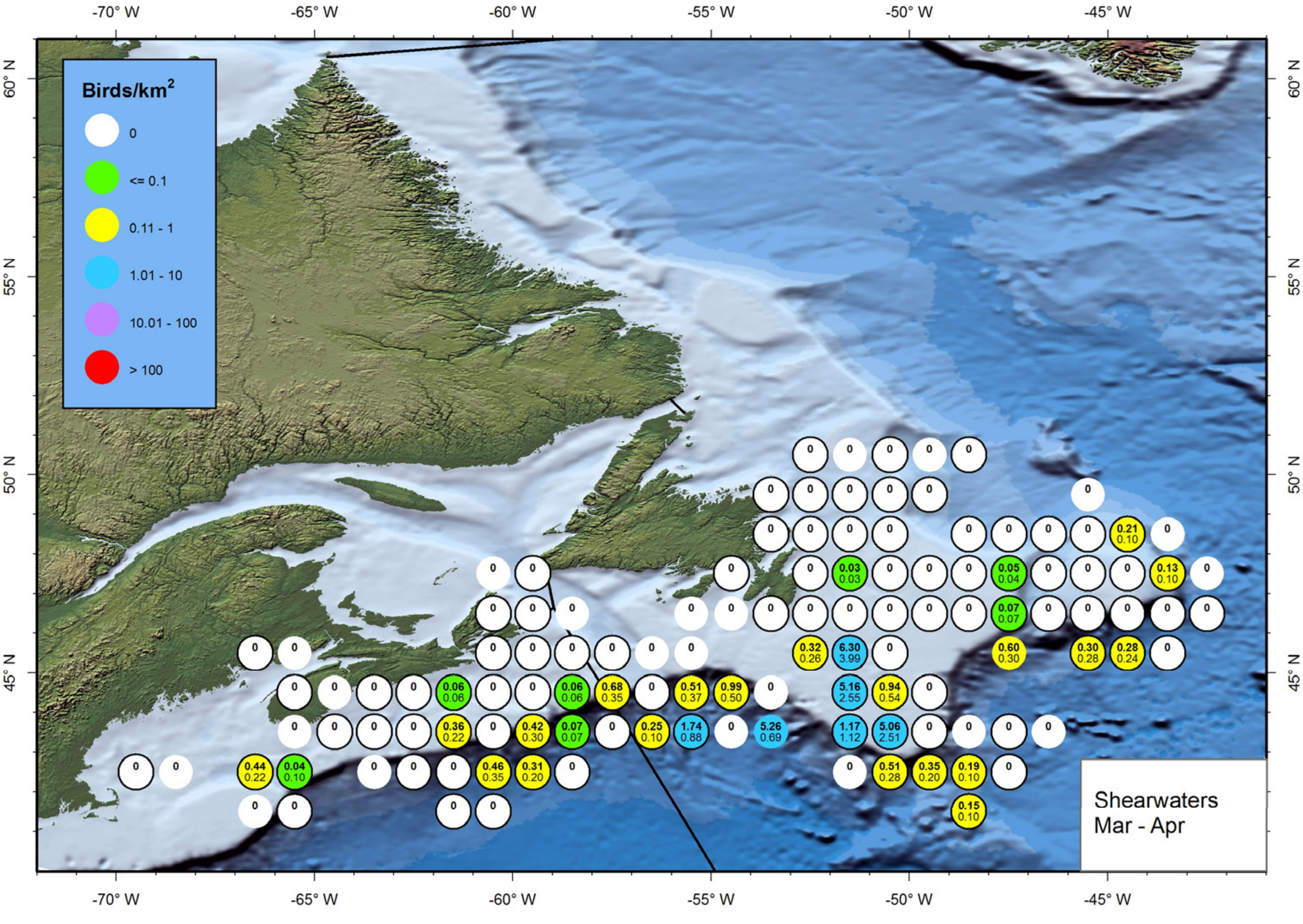
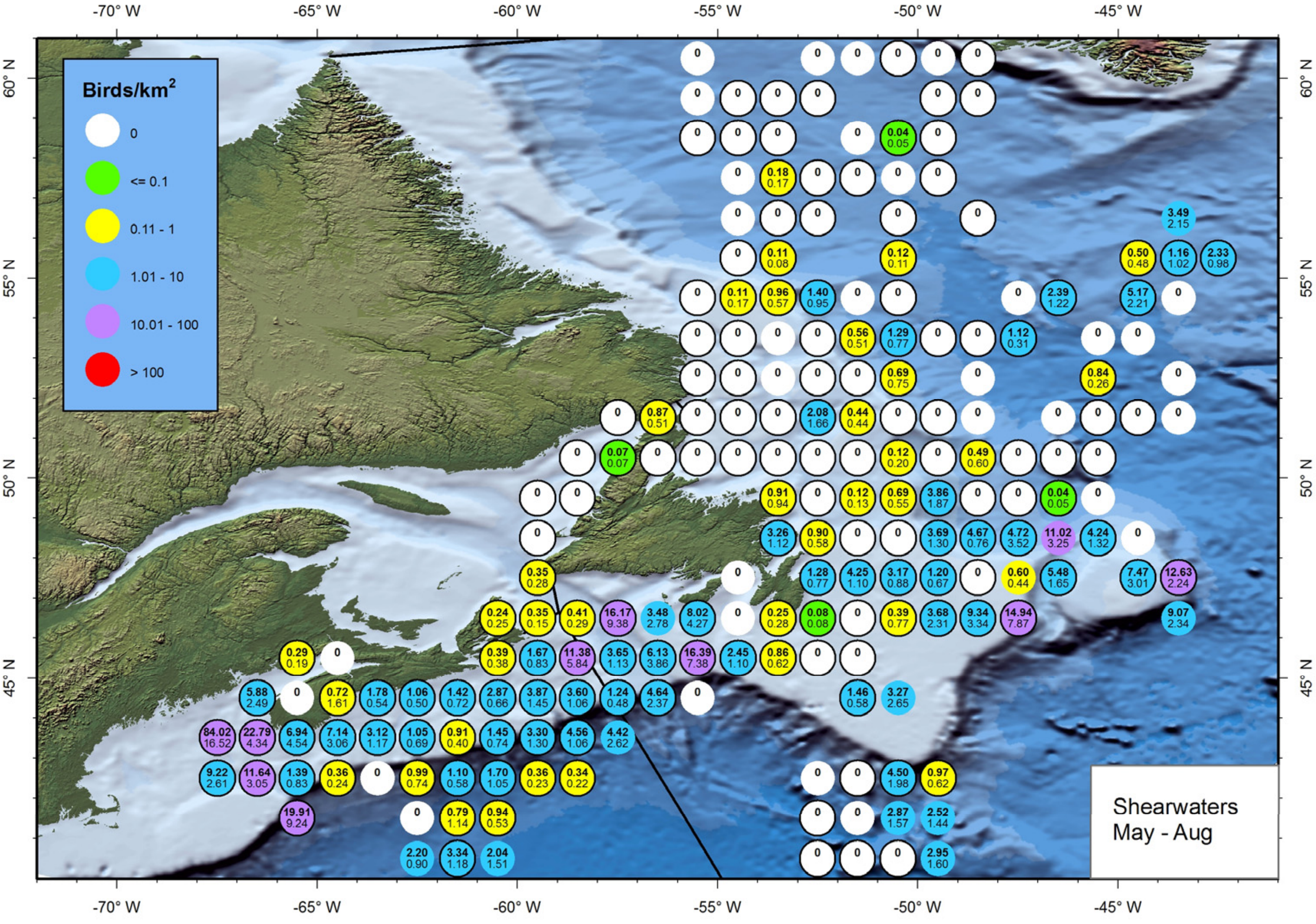
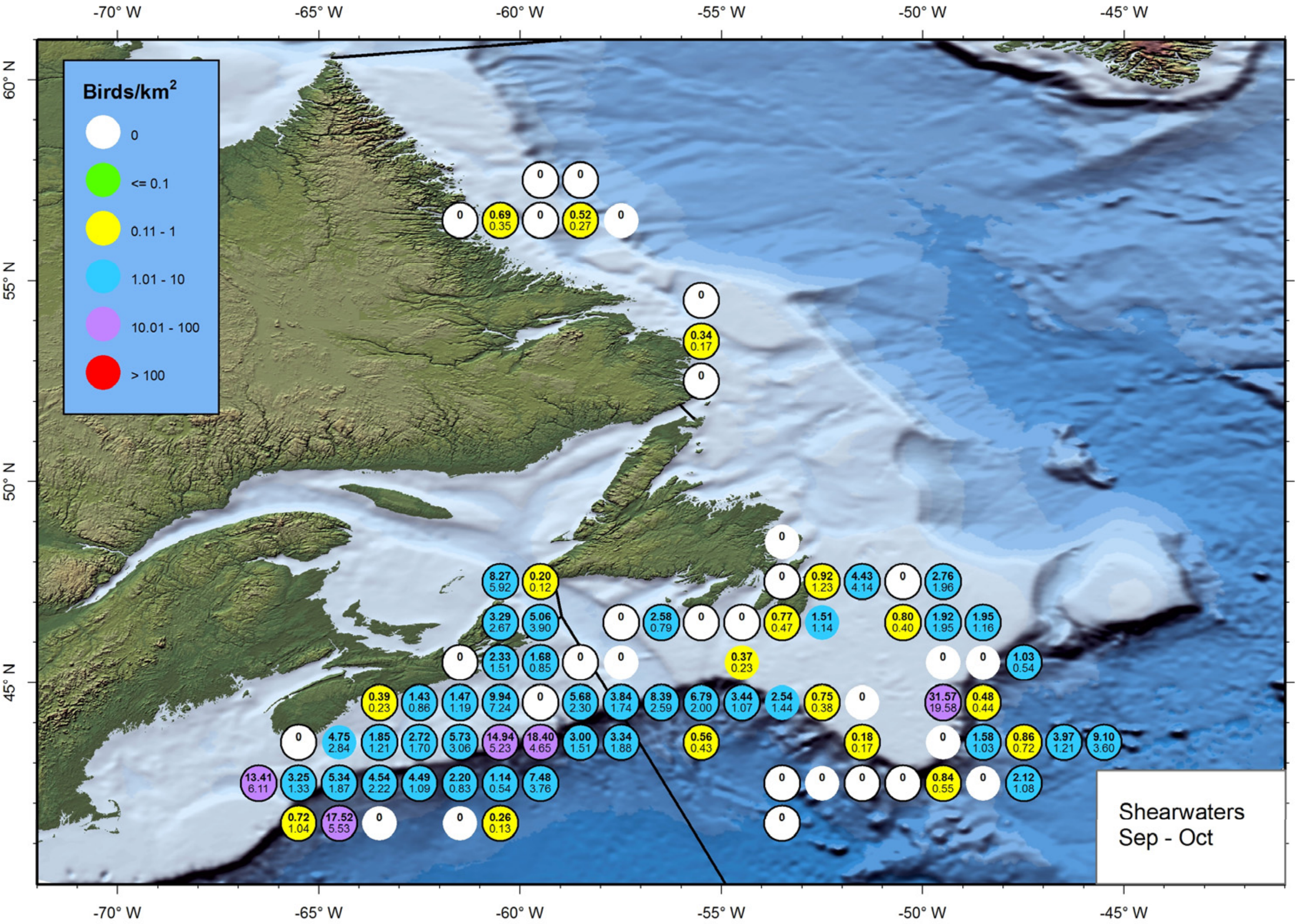
0.48 0.20
0.70 0.22
0.29 0.19
0.24 0.10
0.36 0.25
1.31 0.27
0.52 0.26
0.18 0.17
0
0
0.15 0.06
0.32 0.12
0
0.46 0.28
0.66 0.22
0.65 0.31
0.05 0.07
1.19 0.49
1.14 0.70
0.39 0.24
1.78 0.89
0.36 0.16
0.39 0.26
0.13 0.21
0.60 0.43
0.33 0.14
0.13 0.12
0
0.04 0.06
0.28 0.31
0.91 0.22
0
0.24 0.16
0.01 0.03
0.09 0.04
0.06 0.06
0
0.11 0.09
0.09 0.05
0.03 0.04
0
0.17 0.10
0
0
0.26 0.08
0.22 0.14
0.33 0.34
0
0
0
0
0
0
0
0
0
0
0
0
0
0

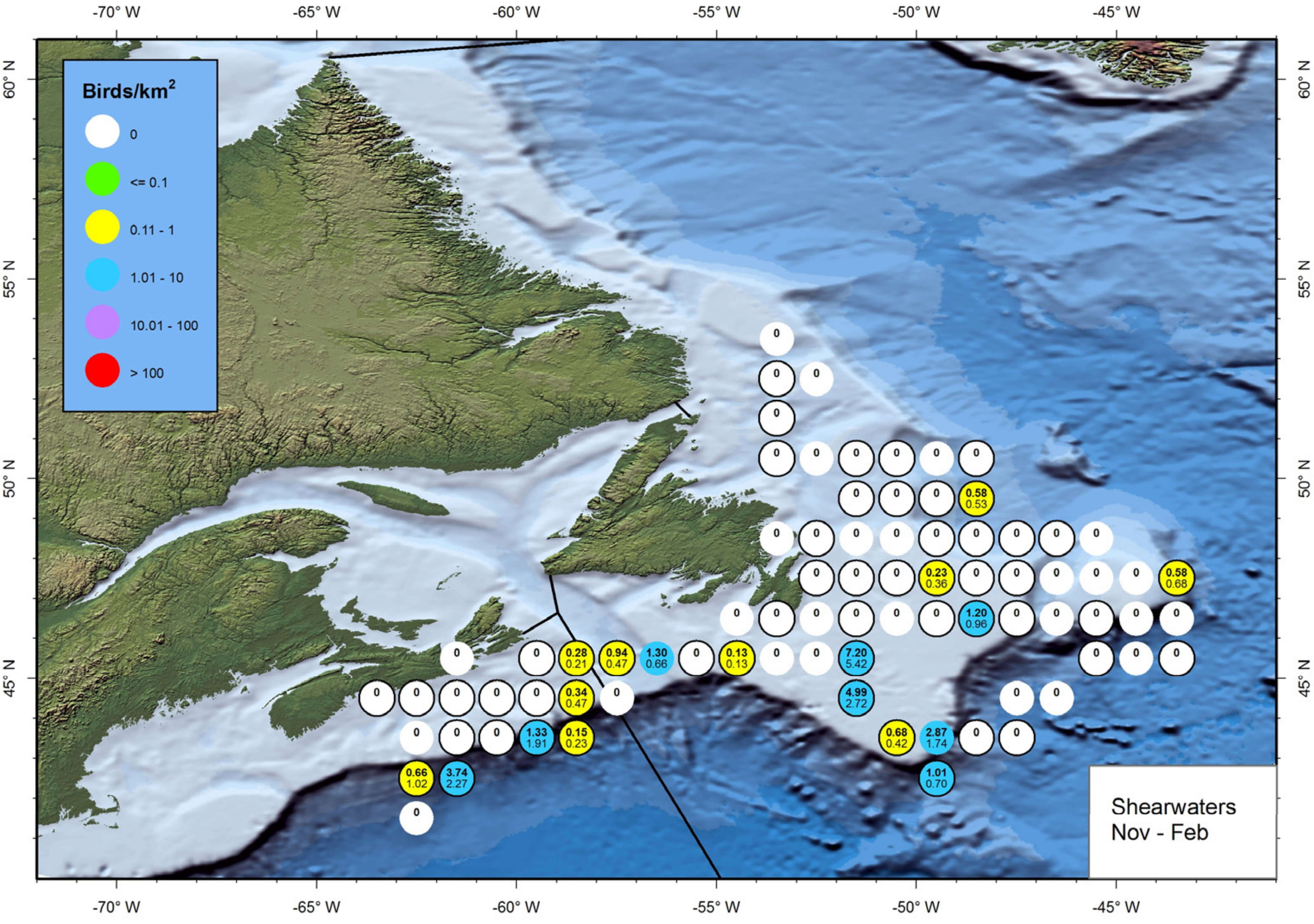

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
5.06 1.16
3.77 1.71
0
1.89 0.48
7.59 3.10
4.08 1.60
0
0
1.10 0.57
1.83 0.94
0
0.39 0.28
0.38 0.22
0
0.63 0.25
0.49 0.29
0
0
0.17 0.16
0.27 0.17
0
0.14 0.14
0.19 0.10
0.29 0.15
0
1.29 0.67
0.52 0.27
0.17 0.14
0.77 0.50
0
0.23 0.17
0.30 0.18
0.47 0.25
0
0
1.56 1.03
0
4.75 2.54
0.30 0.13
0.46 0.28
0.02 0.02
0.30 0.39
0.55 0.30
0.76 0.34
3.12 1.17
1.75 0.85
0.65 0.38
0.23 0.14
0
0
0.67 0.49
0.28 0.24
2.89 1.75
0.03 0.04
0
1.04 0.99
0.46 0.23
0.35 0.34
0.27 0.16
1.48 0.46
1.20 0.49
0.59 0.38
0
0.76 0.20
0
0.10 0.08
0.21 0.26
0.12 0.06
0.18 0.09
3.31 1.71
0.78 0.40
0.17 0.12
0.05 0.05
0.52 0.32
0.37 0.27
0.12 0.07
0
0
0
0
0.94 0.49
2.48 0.90
0
0
0
0
5.85 1.78
0
0
0
Northern Fulmar
Sep - Oct

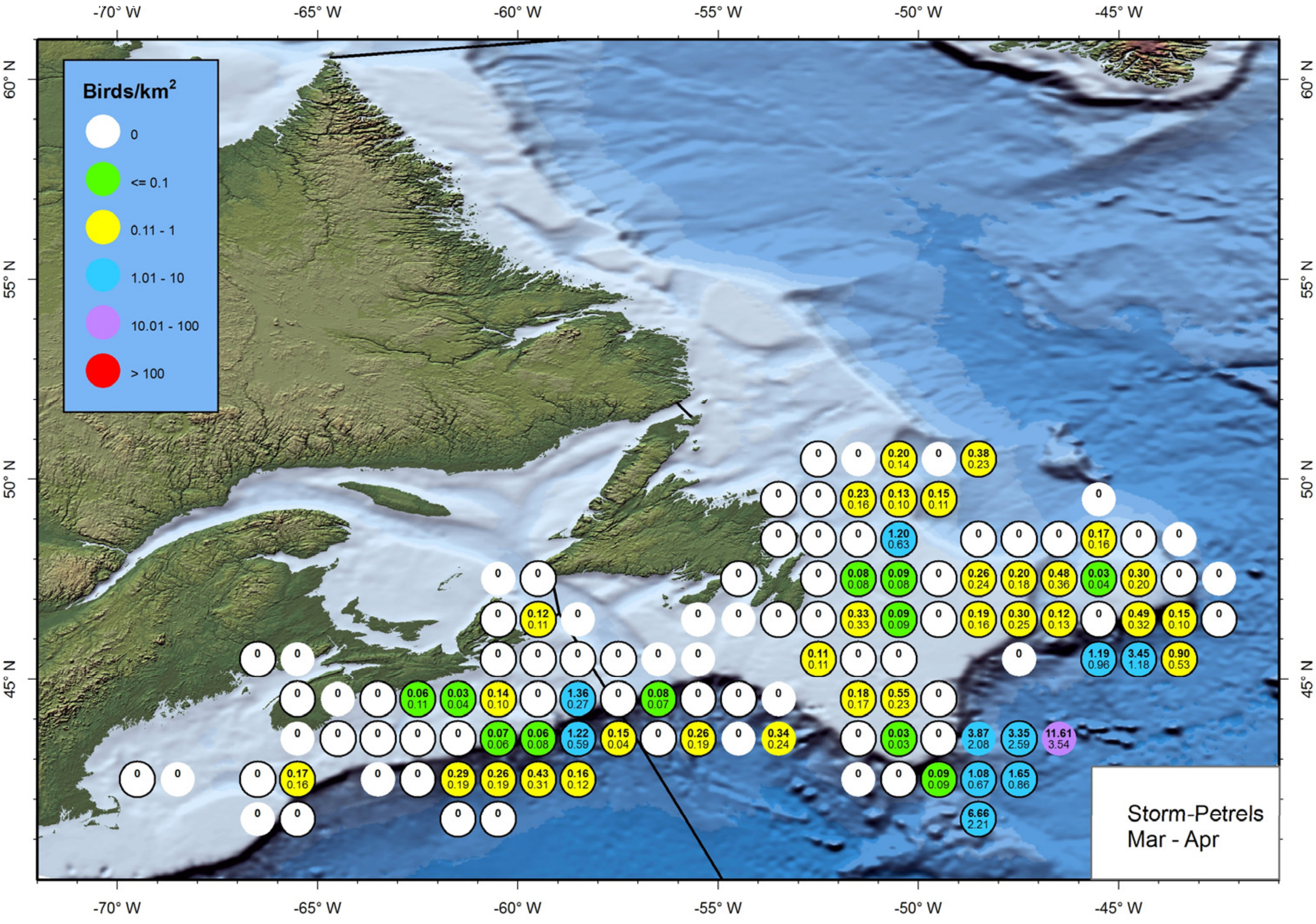

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
1.31
0.66
4.43
2.26
1.31
0.66
1.47
0.74
3.05
0.51
9.48
3.28
2.92
0.93
10.08
5.39
0
4.41
2.34
0.60
0.32
0.68
0.39
2.61
2.01
1.93
1.05
0
0.41
0.22
0
0
1.49
0.69
1.91
1.53
36.77
11.84
32.65
10.12
1.25
1.34
0.19
0.15
1.98
0.79
0.83
0.77
2.55
1.31
1.00
1.20
6.96
1.84
0
12.62
10.51
1.95
0.99
0.84
0.60
1.27
0.68
0.39
0.29
0
0.38
0.20
0.51
0.27
4.46
5.79
2.99
1.20
2.49
1.55
22.08
8.48
8.96
6.61
0.61
0.33
1.19
1.55
0
0.41
0.21
12.37
3.66
4.96
2.95
9.25
5.41
17.24
7.12
1.17
0.58
0
0.92
0.47
0.72
0.48
0
0
1.44
0.91
0
1.08
0.99
0.06
0.05
1.40
0.11
0.88
0.56
1.75
0.69
0
1.22
0.51
0
0
3.07
1.54
1.65
0.84
0.93
0.51
5.61
3.32
2.54
1.33
0
1.97
1.00
0.35
0.18
0
0.53
0.28
0.96
0.49
0.23
0.12
0
Northern Fulmar
Nov - Feb

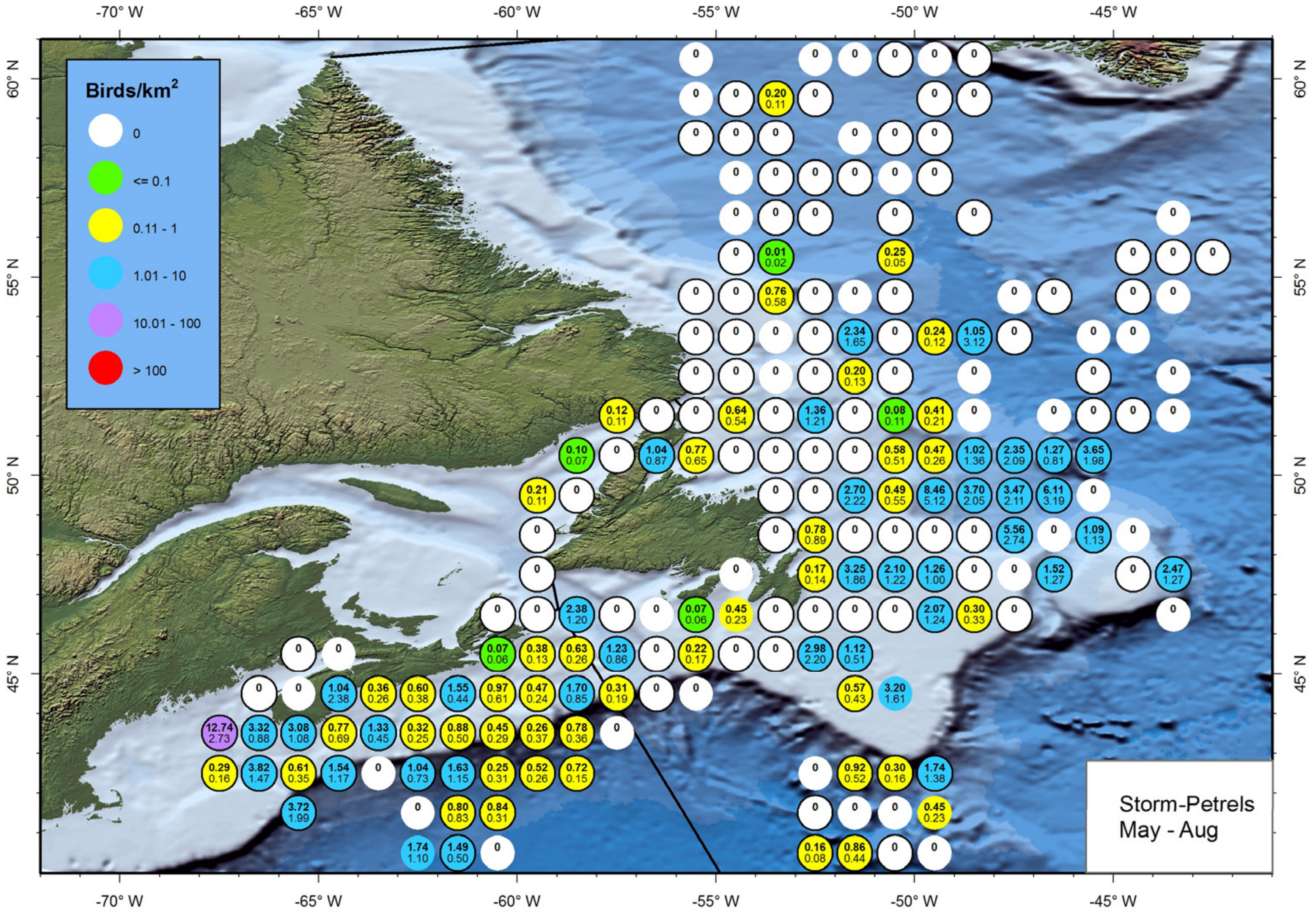

Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Shearwaters
Mar - Apr
-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N

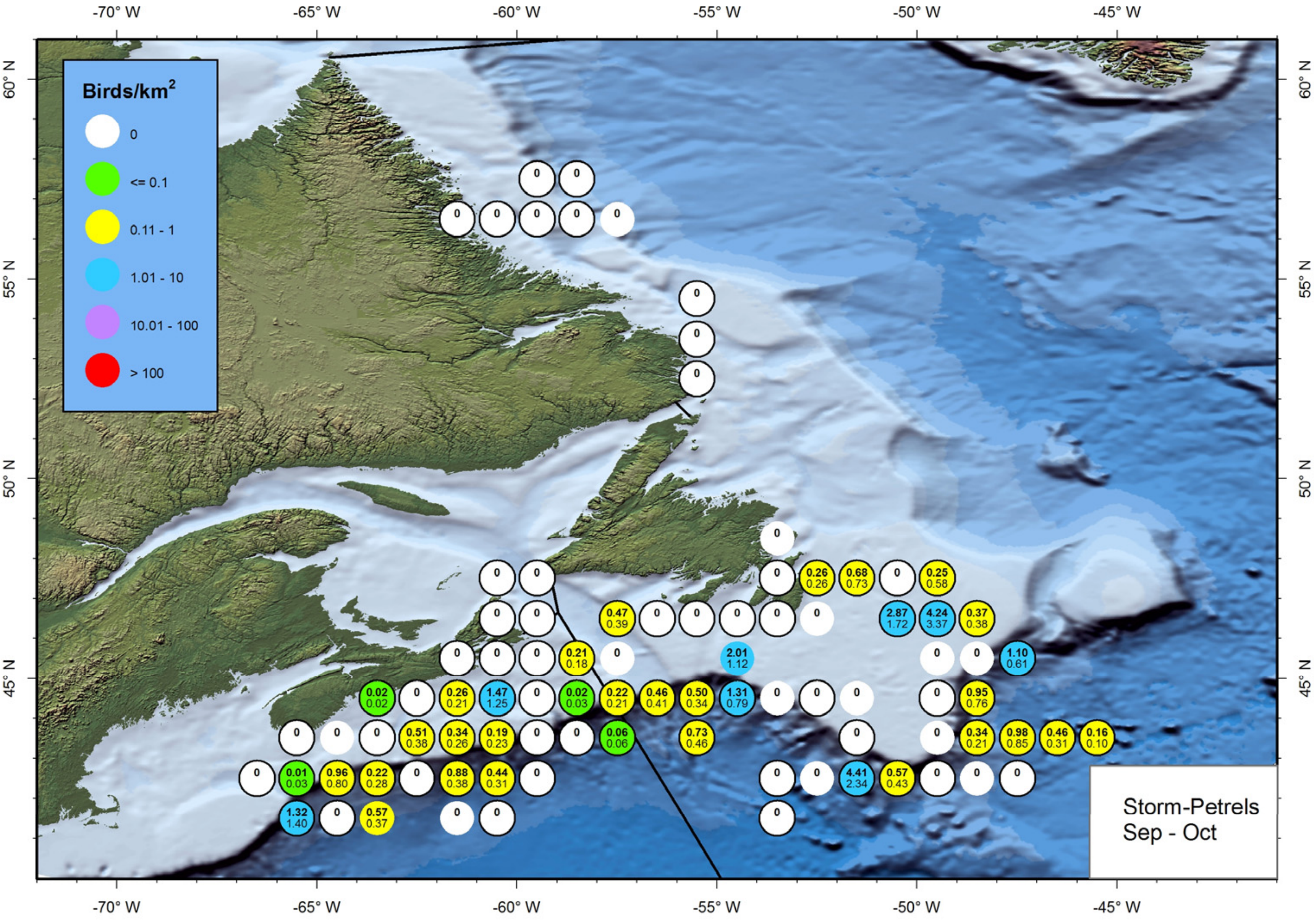

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Shearwaters
May - Aug
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0.04 0.05
0
0
0.18 0.17
0
0
0
0
0
0
0
0
0
3.49 2.15
0
0.11 0.08
0.12 0.11
0.50 0.48
1.16 1.02
2.33 0.98
0
0.11 0.17
0.96 0.57
1.40 0.95
0
0
0
2.39 1.22
5.17 2.21
0
0
0
0
0
0.56 0.51
1.29 0.77
0
0
1.12 0.31
0
0
0
0
0
0
0
0.69 0.75
0
0.84 0.26
0
0
0.87 0.51
0
0
0
2.08 1.66
0.44 0.44
0
0
0
0
0
0
0
0
0.07 0.07
0
0
0
0
0
0
0.12 0.20
0
0.49 0.60
0
0
0
0
0
0.91 0.94
0
0.12 0.13
0.69 0.55
3.86 1.87
0
0
0.04 0.05
0
0
3.26 1.12
0.90 0.58
0
0
3.69 1.30
4.67 0.76
4.72 3.52
11.02 3.25
4.24 1.32
0
0.35 0.28
0
1.28 0.77
4.25 1.10
3.17 0.88
1.20 0.67
0
0.60 0.44
5.48 1.65
7.47 3.01
12.63 2.24
0.24 0.25
0.35 0.15
0.41 0.29
16.17 9.38
3.48 2.78
8.02 4.27
0
0.25 0.28
0.08 0.08
0
0.39 0.77
3.68 2.31
9.34 3.34
14.94 7.87
9.07 2.34
0.29 0.19
0
0.39 0.38
1.67 0.83
11.38 5.84
3.65 1.13
6.13 3.86
16.39 7.38
2.45 1.10
0.86 0.62
0
0
5.88 2.49
0
0.72 1.61
1.78 0.54
1.06 0.50
1.42 0.72
2.87 0.66
3.87 1.45
3.60 1.06
1.24 0.48
4.64 2.37
0
1.46 0.58
3.27 2.65
84.02 16.52
22.79 4.34
6.94 4.54
7.14 3.06
3.12 1.17
1.05 0.69
0.91 0.40
1.45 0.74
3.30 1.30
4.56 1.06
4.42 2.62
9.22 2.61
11.64 3.05
1.39 0.83
0.36 0.24
0
0.99 0.74
1.10 0.58
1.70 1.05
0.36 0.23
0.34 0.22
0
0
4.50 1.98
0.97 0.62
19.91 9.24
0
0.79 1.14
0.94 0.53
0
0
2.87 1.57
2.52 1.44
2.20 0.90
3.34 1.18
2.04 1.51
0
0
0
2.95 1.60

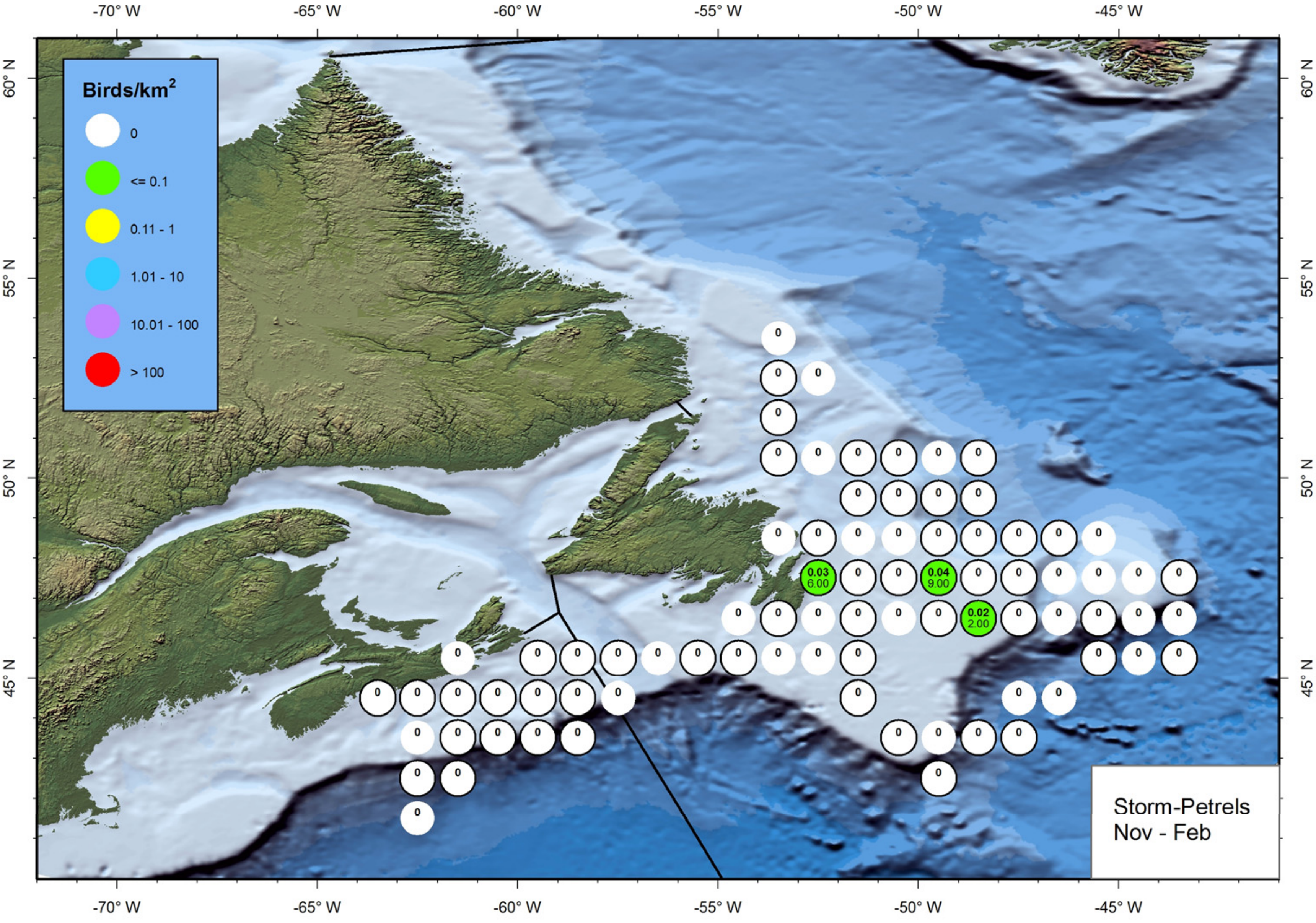

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
0
0.69 0.35
0
0.52 0.27
0
0
0.34 0.17
0
0
8.27 5.92
0.20 0.12
0
0.92 1.23
4.43 4.14
0
2.76 1.96
3.29 2.67
5.06 3.90
0
2.58 0.79
0
0
0.77 0.47
1.51 1.14
0.80 0.40
1.92 1.95
1.95 1.16
0
2.33 1.51
1.68 0.85
0
0
0.37 0.23
0
0
1.03 0.54
0.39 0.23
1.43 0.86
1.47 1.19
9.94 7.24
0
5.68 2.30
3.84 1.74
8.39 2.59
6.79 2.00
3.44 1.07
2.54 1.44
0.75 0.38
0
31.57 19.58
0.48 0.44
0
4.75 2.84
1.85 1.21
2.72 1.70
5.73 3.06
14.94 5.23
18.40 4.65
3.00 1.51
3.34 1.88
0.56 0.43
0.18 0.17
0
1.58 1.03
0.86 0.72
3.97 1.21
9.10 3.60
13.41 6.11
3.25 1.33
5.34 1.87
4.54 2.22
4.49 1.09
2.20 0.83
1.14 0.54
7.48 3.76
0
0
0
0
0.84 0.55
0
2.12 1.08
0.72 1.04
17.52 5.53
0
0
0.26 0.13
0
Shearwaters
Sep - Oct

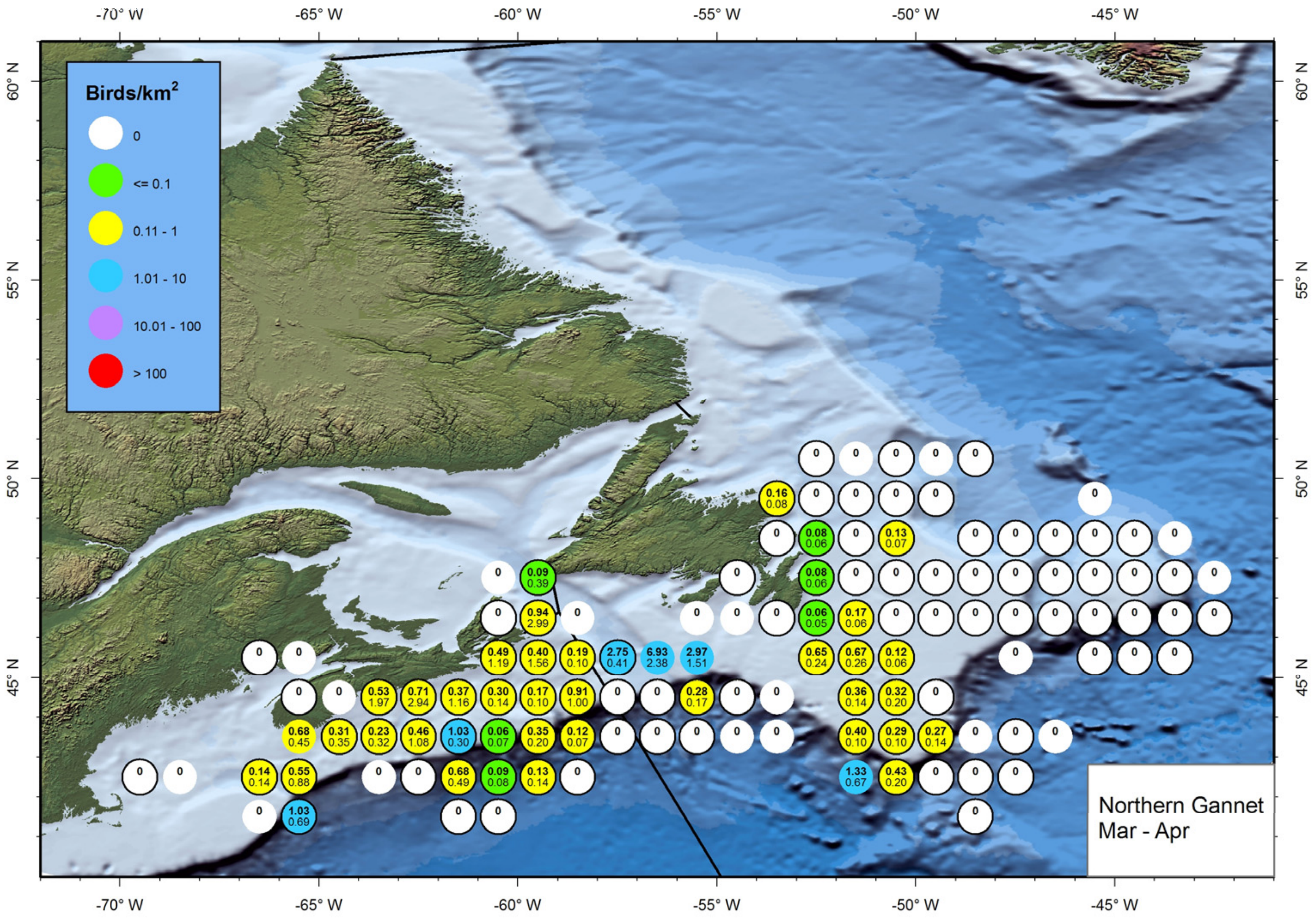

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0.58
0.53
0.23
0.36
0.58
0.68
1.20
0.96
0.28
0.21
0.94
0.47
1.30
0.66
0.13
0.13
7.20
5.42
0.34
0.47
4.99
2.72
1.33
1.91
0.15
0.23
0.68
0.42
2.87
1.74
0.66
1.02
3.74
2.27
1.01
0.70
Shearwaters
Nov - Feb

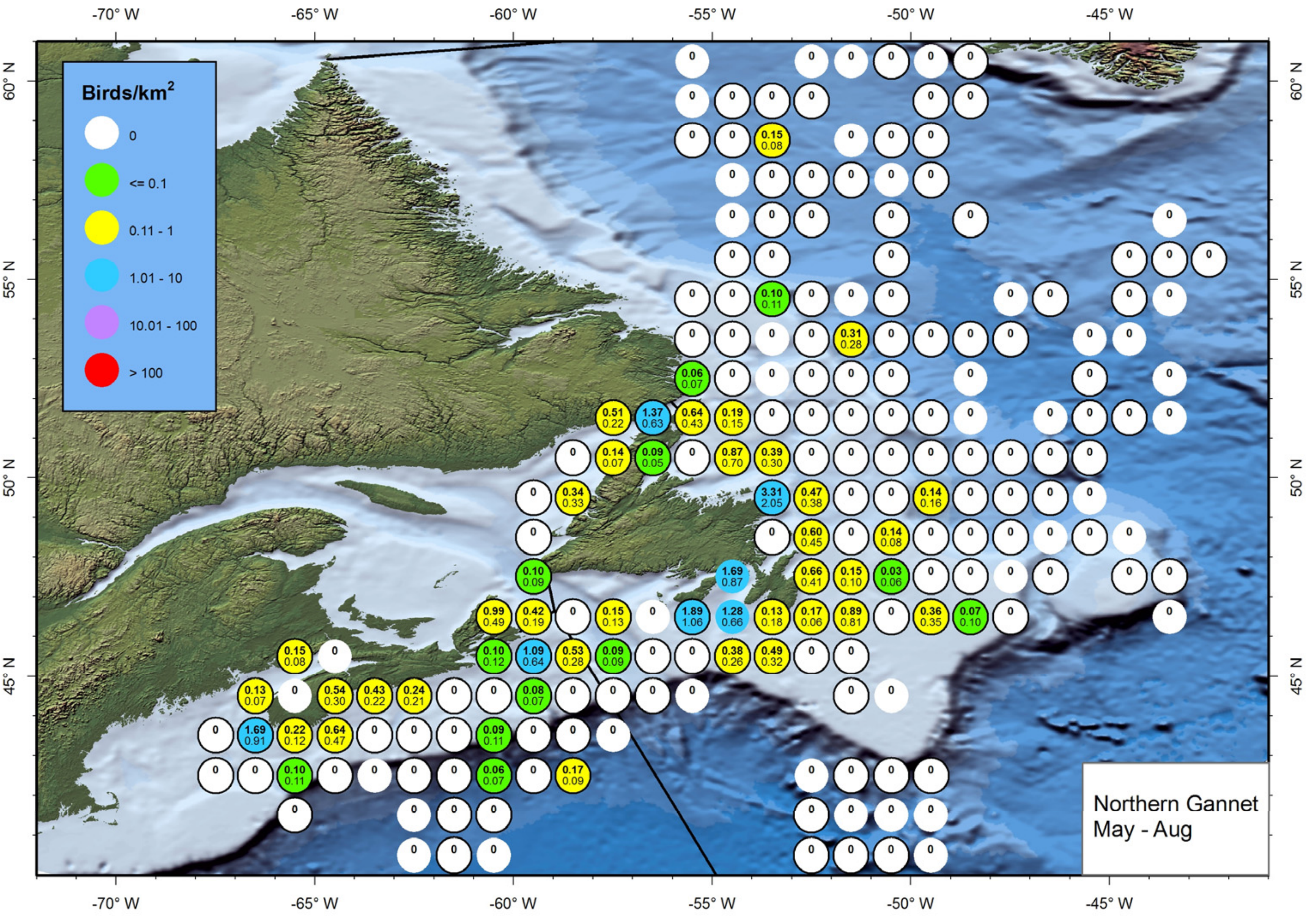

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
0.20 0.14
0
0.38 0.23
0
0
0.23 0.16
0.13 0.10
0.15 0.11
0
0
0
0
1.20 0.63
0
0
0
0.17 0.16
0
0
0
0
0
0
0.08 0.08
0.09 0.08
0
0.26 0.24
0.20 0.18
0.48 0.36
0.03 0.04
0.30 0.20
0
0
0
0.12 0.11
0
0
0
0
0
0.33 0.33
0.09 0.09
0
0.19 0.16
0.30 0.25
0.12 0.13
0
0.49 0.32
0.15 0.10
0
0
0
0
0
0
0
0
0
0.11 0.11
0
0
0
1.19 0.96
3.45 1.18
0.90 0.53
0
0
0
0.06 0.11
0.03 0.04
0.14 0.10
0
1.36 0.27
0
0.08 0.07
0
0
0
0.18 0.17
0.55 0.23
0
0
0
0
0
0
0.07 0.06
0.06 0.08
1.22 0.59
0.15 0.04
0
0.26 0.19
0
0.34 0.24
0
0.03 0.03
0
3.87 2.08
3.35 2.59
11.61 3.54
0
0
0
0.17 0.16
0
0
0.29 0.19
0.26 0.19
0.43 0.31
0.16 0.12
0
0
0.09 0.09
1.08 0.67
1.65 0.86
0
0
0
0
6.66 2.21
Storm-Petrels
Mar - Apr

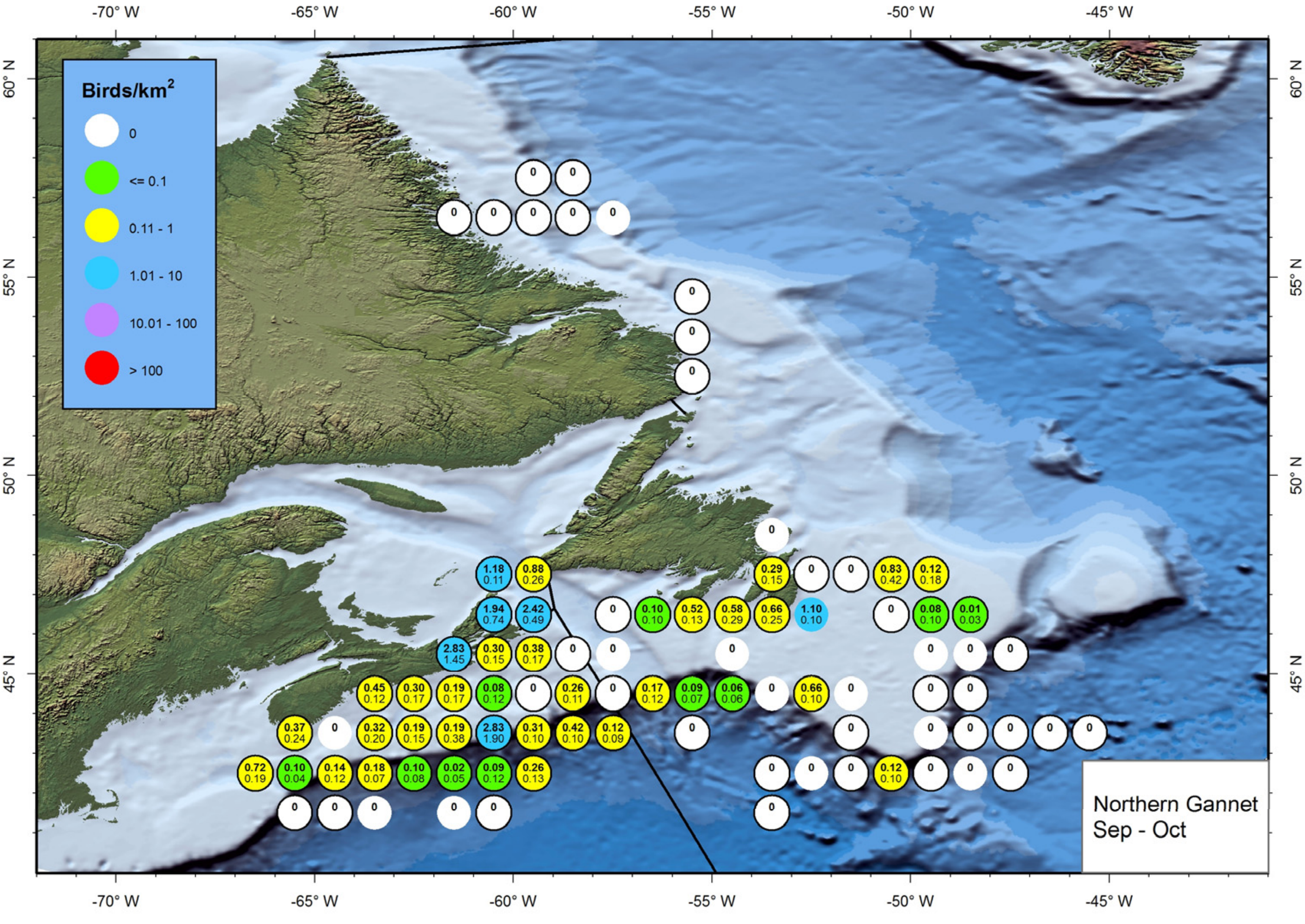

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Storm-Petrels
May - Aug
0
0
0
0
0
0
0
0
0.20 0.11
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0.01 0.02
0.25 0.05
0
0
0
0
0
0.76 0.58
0
0
0
0
0
0
0
0
0
0
0
0
2.34 1.65
0
0.24 0.12
1.05 3.12
0
0
0
0
0
0
0
0.20 0.13
0
0
0
0
0.12 0.11
0
0
0.64 0.54
0
1.36 1.21
0
0.08 0.11
0.41 0.21
0
0
0
0
0
0.10 0.07
0
1.04 0.87
0.77 0.65
0
0
0
0
0.58 0.51
0.47 0.26
1.02 1.36
2.35 2.09
1.27 0.81
3.65 1.98
0.21 0.11
0
0
0
2.70 2.22
0.49 0.55
8.46 5.12
3.70 2.05
3.47 2.11
6.11 3.19
0
0
0
0.78 0.89
0
0
0
0
5.56 2.74
0
1.09 1.13
0
0
0
0.17 0.14
3.25 1.86
2.10 1.22
1.26 1.00
0
0
1.52 1.27
0
2.47 1.27
0
0
2.38 1.20
0
0
0.07 0.06
0.45 0.23
0
0
0
0
2.07 1.24
0.30 0.33
0
0
0
0
0.07 0.06
0.38 0.13
0.63 0.26
1.23 0.86
0
0.22 0.17
0
0
2.98 2.20
1.12 0.51
0
0
1.04 2.38
0.36 0.26
0.60 0.38
1.55 0.44
0.97 0.61
0.47 0.24
1.70 0.85
0.31 0.19
0
0
0.57 0.43
3.20 1.61
12.74 2.73
3.32 0.88
3.08 1.08
0.77 0.69
1.33 0.45
0.32 0.25
0.88 0.50
0.45 0.29
0.26 0.37
0.78 0.36
0
0.29 0.16
3.82 1.47
0.61 0.35
1.54 1.17
0
1.04 0.73
1.63 1.15
0.25 0.31
0.52 0.26
0.72 0.15
0
0.92 0.52
0.30 0.16
1.74 1.38
3.72 1.99
0
0.80 0.83
0.84 0.31
0
0
0
0.45 0.23
1.74 1.10
1.49 0.50
0
0.16 0.08
0.86 0.44
0
0

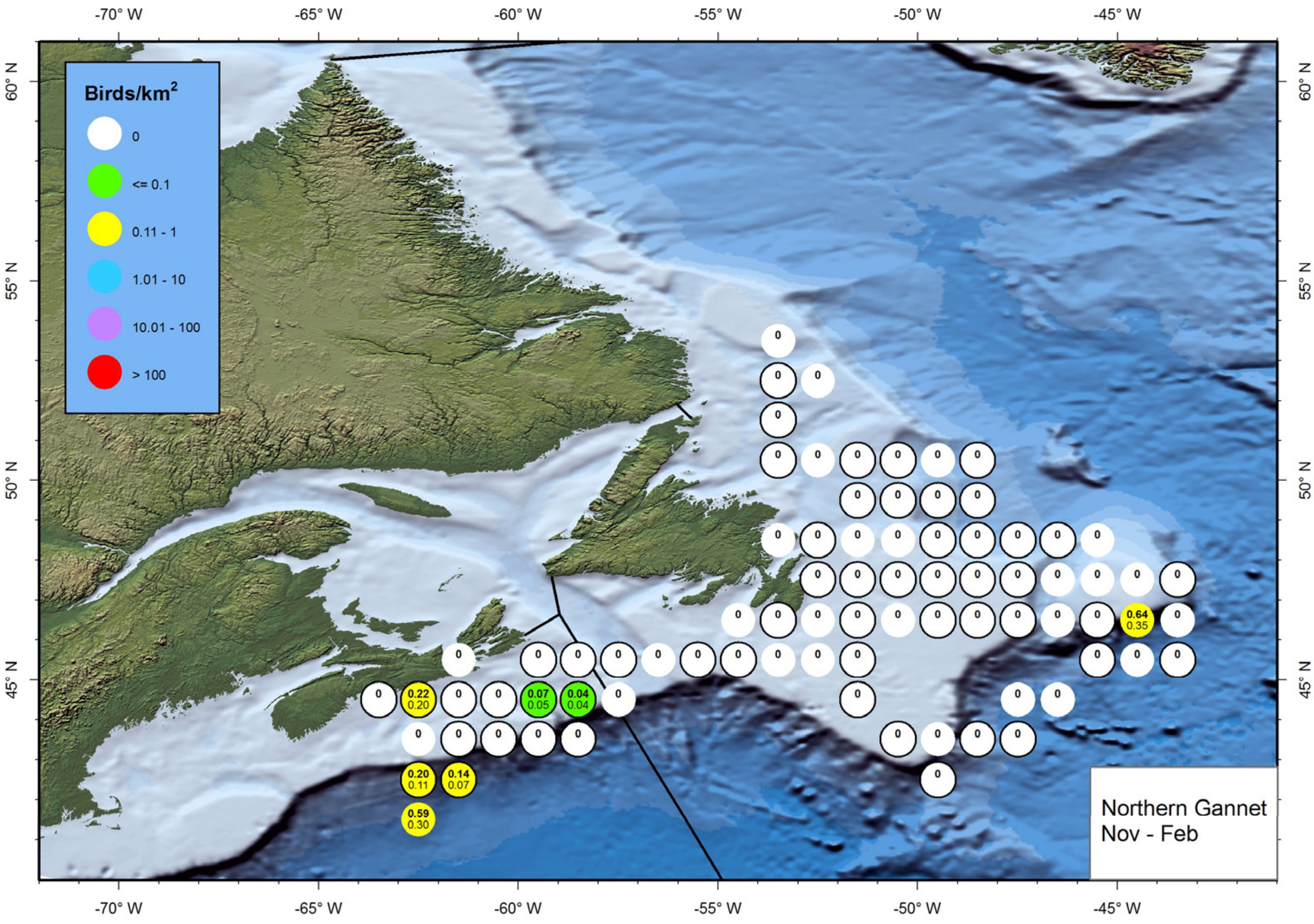

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
0
0
0
0
0
0
0
0
0
0
0
0.26 0.26
0.68 0.73
0
0.25 0.58
0
0
0.47 0.39
0
0
0
0
0
2.87 1.72
4.24 3.37
0.37 0.38
0
0
0
0.21 0.18
0
2.01 1.12
0
0
1.10 0.61
0.02 0.02
0
0.26 0.21
1.47 1.25
0
0.02 0.03
0.22 0.21
0.46 0.41
0.50 0.34
1.31 0.79
0
0
0
0
0.95 0.76
0
0
0
0.51 0.38
0.34 0.26
0.19 0.23
0
0
0.06 0.06
0.73 0.46
0
0
0.34 0.21
0.98 0.85
0.46 0.31
0.16 0.10
0
0.01 0.03
0.96 0.80
0.22 0.28
0
0.88 0.38
0.44 0.31
0
0
0
4.41 2.34
0.57 0.43
0
0
0
1.32 1.40
0
0.57 0.37
0
0
0
Storm-Petrels
Sep - Oct

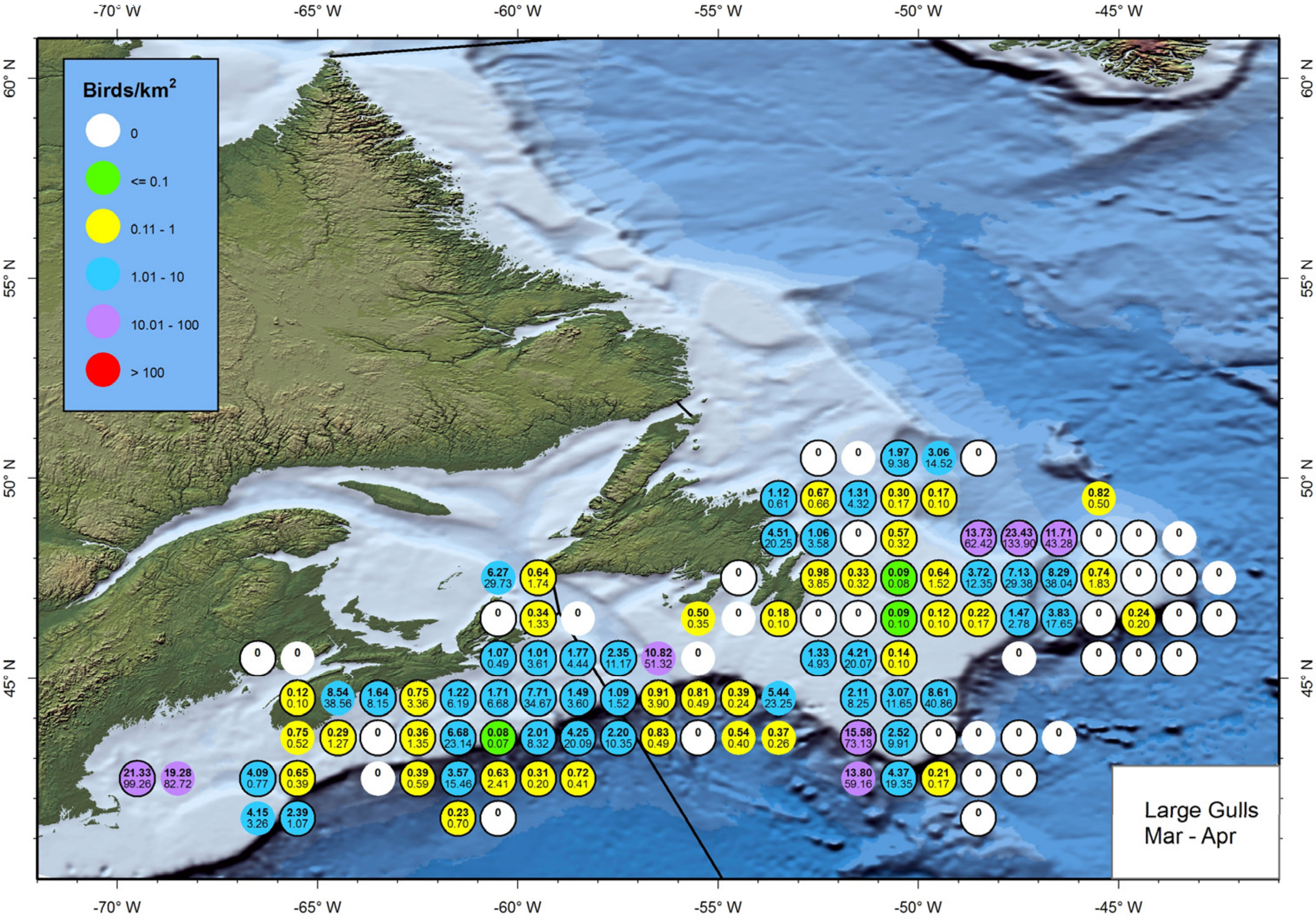

Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
0.03
6.00
0.04
9.00
0.02
2.00
Storm-Petrels
Nov - Feb

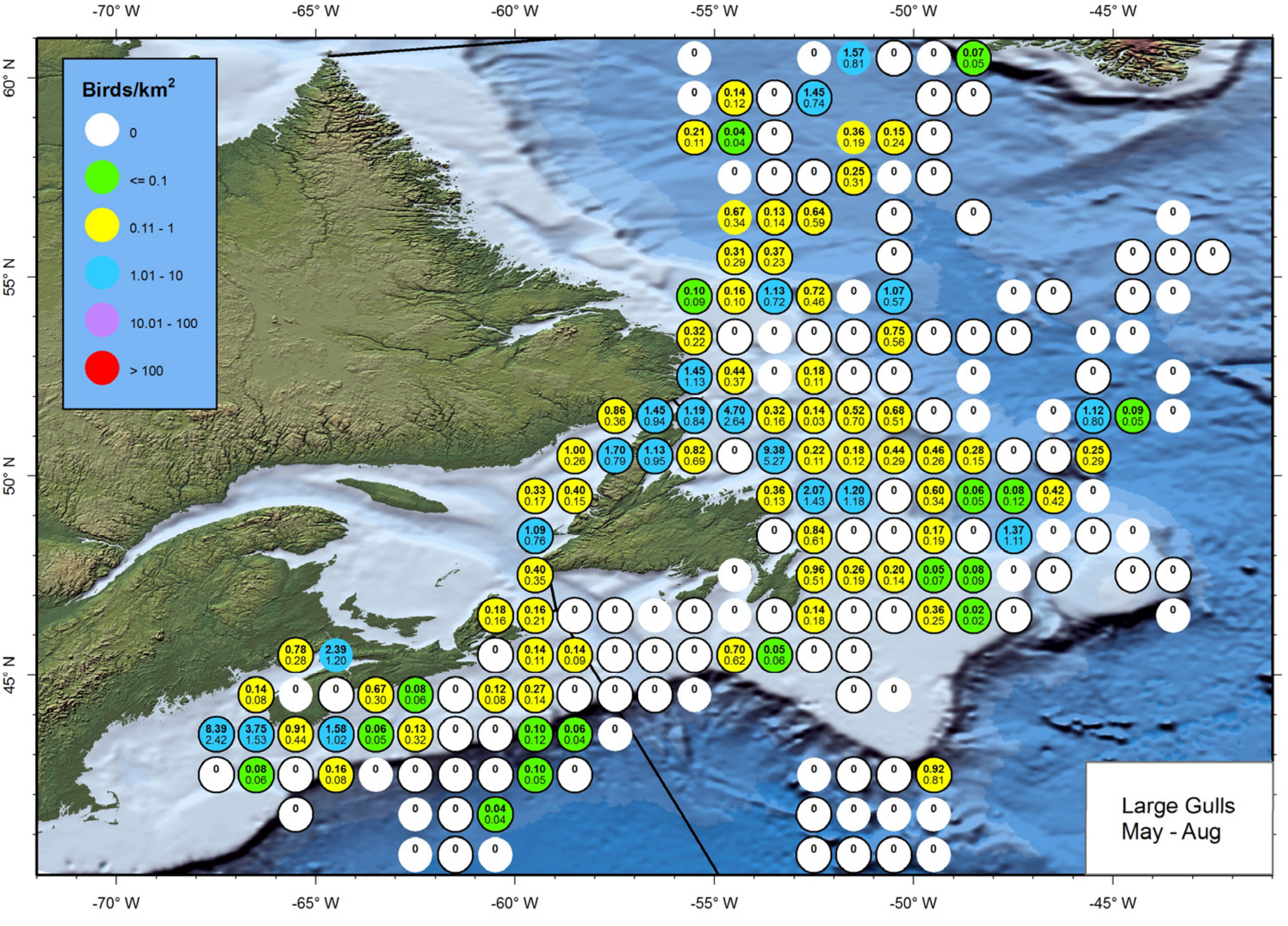

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Northern Gannet
Mar - Apr
0 0 0 0 0
0.16 0.08
0 0 0 0 0
0
0 0.08 0.06 0 0.13 0.07 0 0 0 0 0 0
0 0.09 0.39 0 0.08 0.06 0 0 0 0 0 0 0 0 0 0
0 0.94 2.99 0 0 0 0 0.06 0.05 0.17 0.06 0 0 0 0 0 0 0 0 0
0 0 0.49 1.19 0.40 1.56 0.19 0.10 2.75 0.41 6.93 2.38 2.97 1.51 0.65 0.24 0.67 0.26 0.12 0.06 0 0 0 0
0 0 0.53 1.97 0.71 2.94 0.37 1.16 0.30 0.14 0.17 0.10 0.91 1.00 0 0 0.28 0.17 0 0 0.36 0.14 0.32 0.20 0
0.68 0.45 0.31 0.35 0.23 0.32 0.46 1.08 1.03 0.30 0.06 0.07 0.35 0.20 0.12 0.07 0 0 0 0 0 0.40 0.10 0.29 0.10 0.27 0.14 0 0 0
0 0 0.14 0.14 0.55 0.88 0 0 0.68 0.49 0.09 0.08 0.13 0.14 0 1.33 0.67 0.43 0.20 0 0 0
0 1.03 0.69 0 0 0

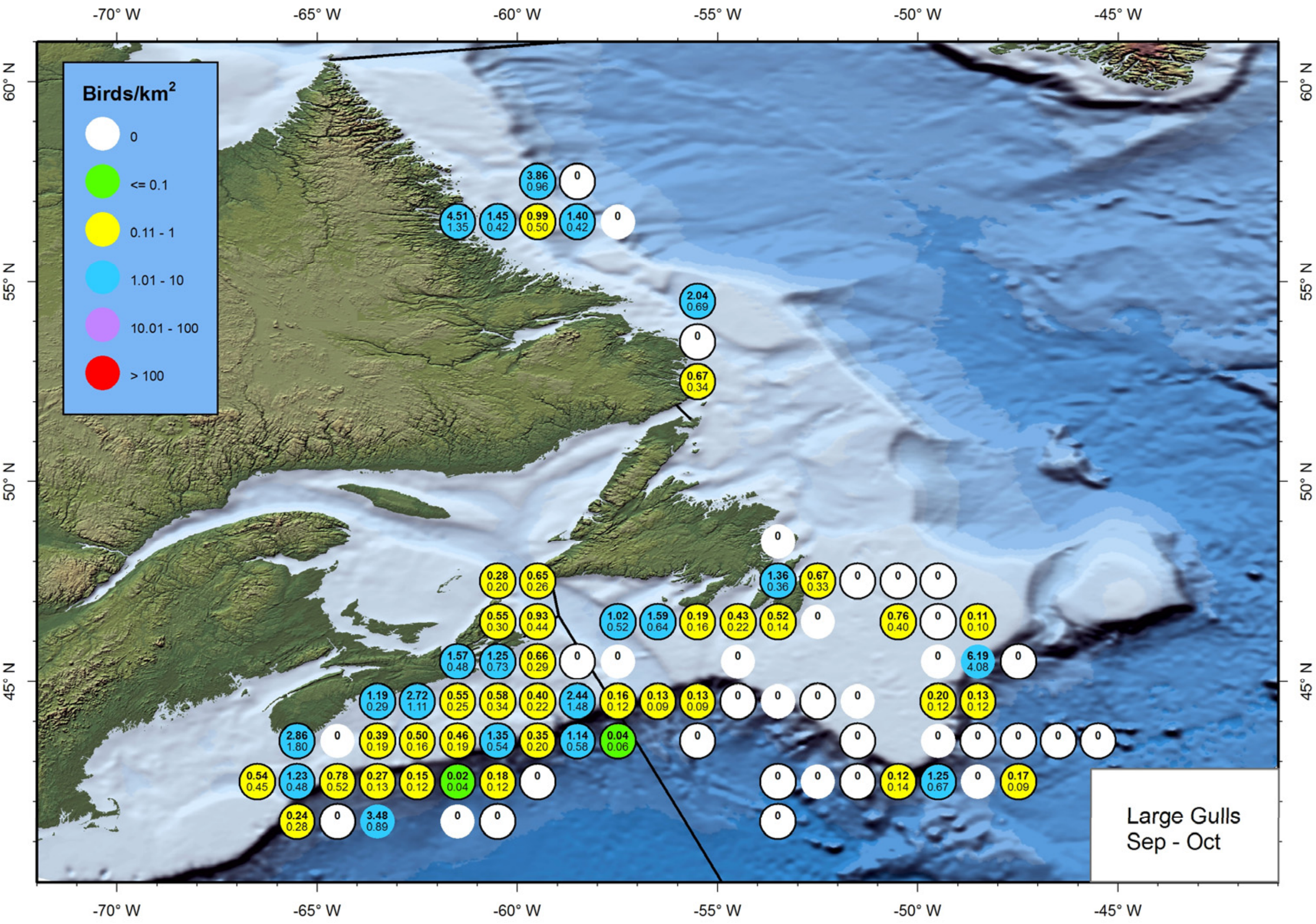

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
○ 0
● <= 0.1
● 0.11 - 1
● 1.01 - 10
● 10.01 - 100
● > 100
Northern Gannet
May - Aug

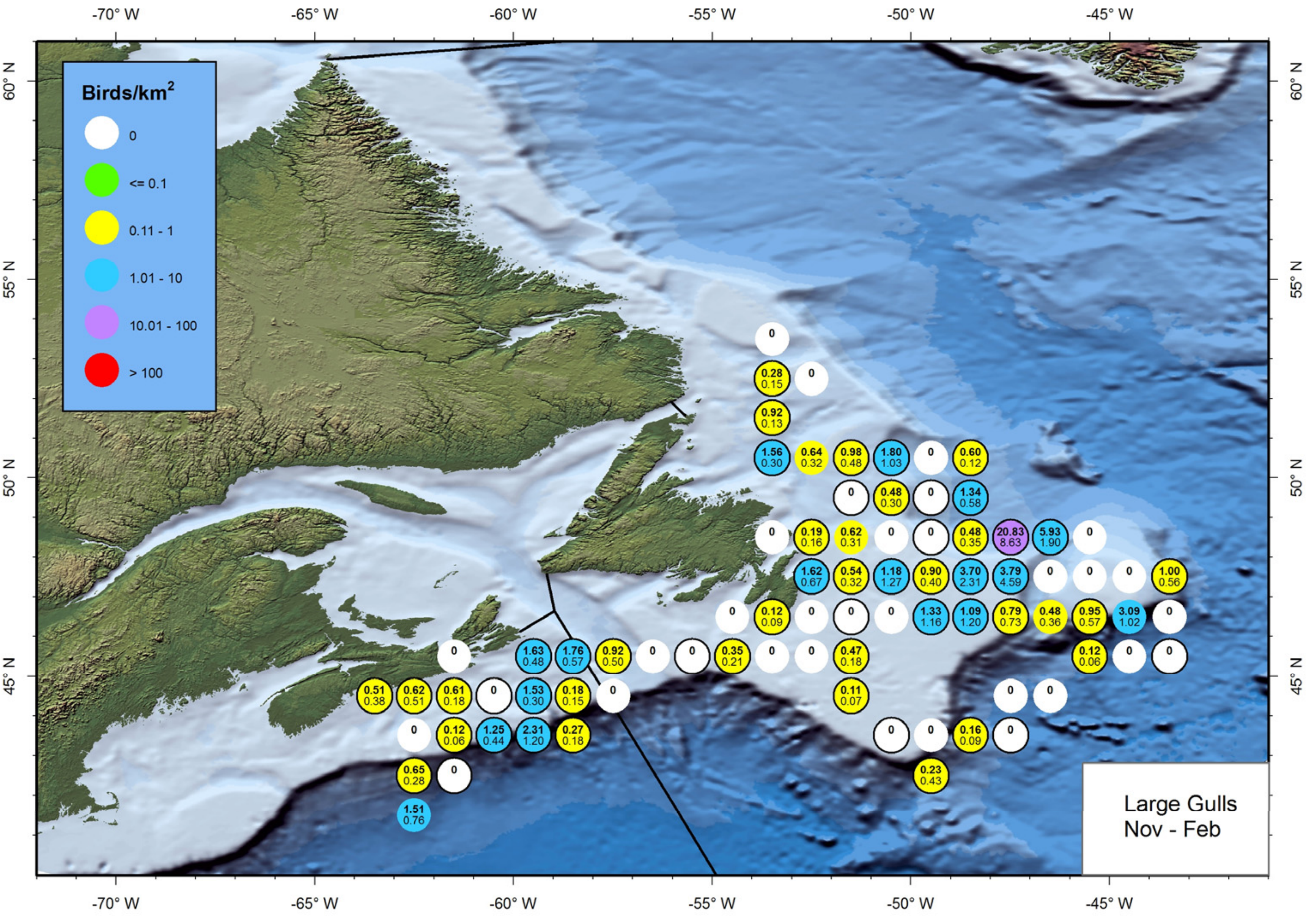

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
0
0
0
0
0
0
0
0
0
1.18 0.11
0.88 0.26
0.29 0.15
0
0
0.83 0.42
0.12 0.18
1.94 0.74
2.42 0.49
0
0.10 0.10
0.52 0.13
0.58 0.29
0.66 0.25
1.10 0.10
0
0.08 0.10
0.01 0.03
2.83 1.45
0.30 0.15
0.38 0.17
0
0
0
0
0
0
0.45 0.12
0.30 0.17
0.19 0.17
0.08 0.12
0
0.26 0.11
0
0.17 0.12
0.09 0.07
0.06 0.06
0
0.66 0.10
0
0
0
0.37 0.24
0
0.32 0.20
0.19 0.15
0.19 0.38
2.83 1.90
0.31 0.10
0.42 0.10
0.12 0.09
0
0
0
0
0
0
0
0.72 0.19
0.10 0.04
0.14 0.12
0.18 0.07
0.10 0.08
0.02 0.05
0.09 0.12
0.26 0.13
0
0
0
0.12 0.10
0
0
0
0
0
0
0
0
0
Northern Gannet
Sep - Oct

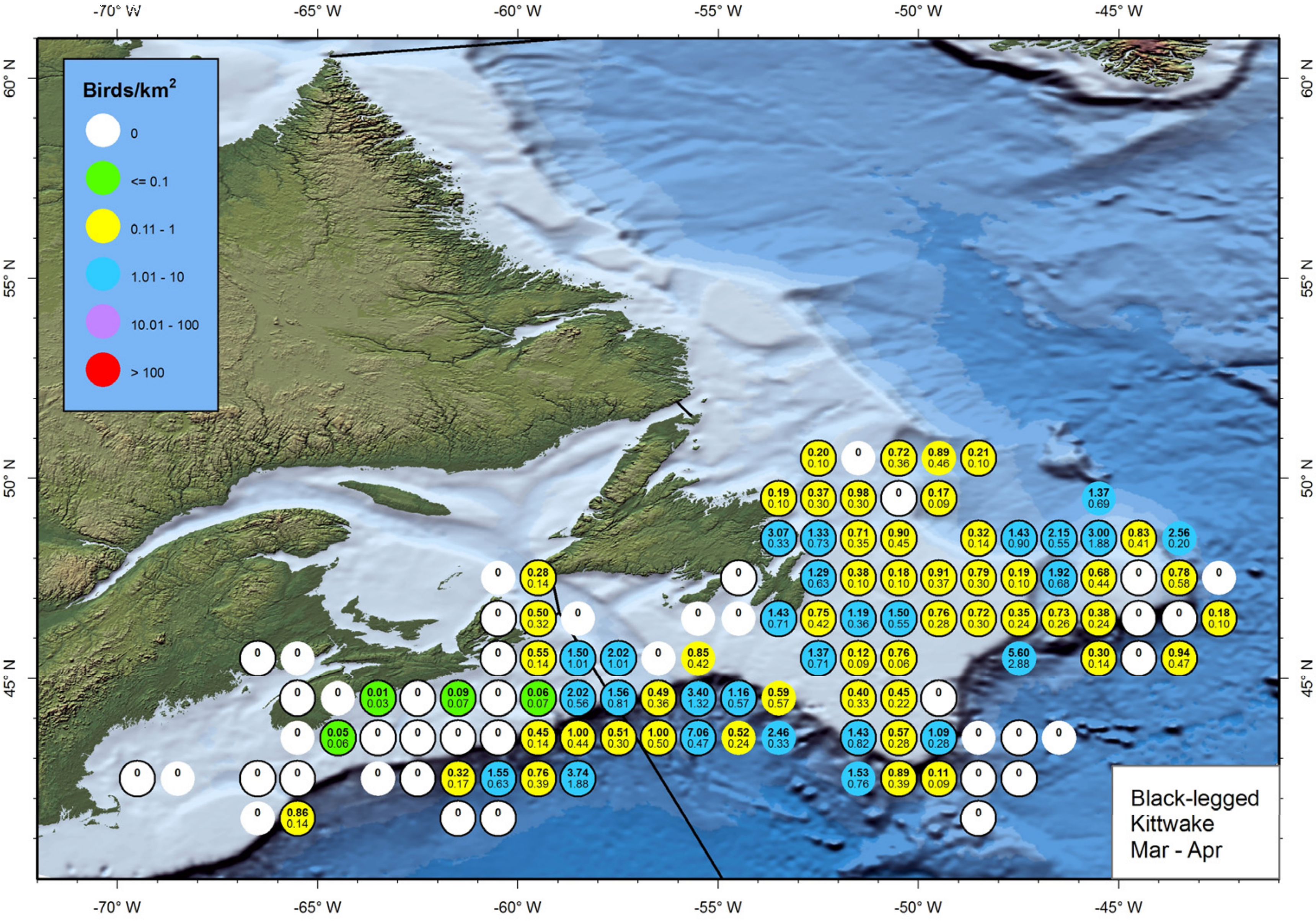

Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Northern Gannet
Nov - Feb
-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
0.22
0.20
0.07
0.05
0.04
0.04
0.20
0.11
0.14
0.07
0.59
0.30
0.64
0.35
0

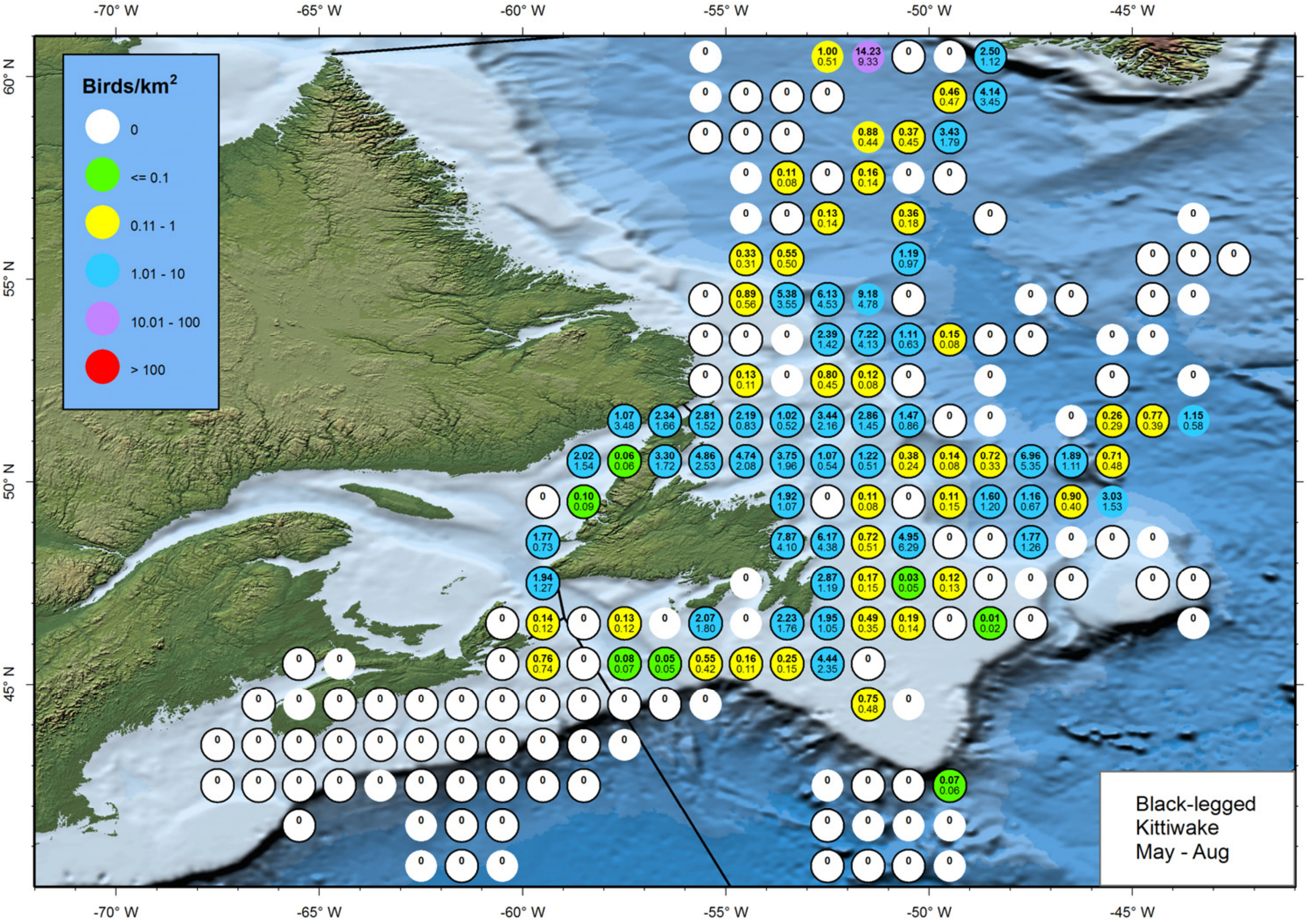

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
1.97 9.38
3.06 14.52
0
1.12 0.61
0.67 0.66
1.31 4.32
0.30 0.17
0.17 0.10
0.82 0.50
4.51 20.25
1.06 3.58
0
0.57 0.32
13.73 62.42
23.43 133.90
11.71 43.28
0
0
0
6.27 29.73
0.64 1.74
0
0.98 3.85
0.33 0.32
0.09 0.08
0.64 1.52
3.72 12.35
7.13 29.38
8.29 38.04
0.74 1.83
0
0
0
0
0.34 1.33
0
0.50 0.35
0
0.18 0.10
0
0
0.09 0.10
0.12 0.10
0.22 0.17
1.47 2.78
3.83 17.65
0
0.24 0.20
0
0
0
0
1.07 0.49
1.01 3.61
1.77 4.44
2.35 11.17
10.82 51.32
0
1.33 4.93
4.21 20.07
0.14 0.10
0
0
0
0
0.12 0.10
8.54 38.56
1.64 8.15
0.75 3.36
1.22 6.19
1.71 6.68
7.71 34.67
1.49 3.60
1.09 1.52
0.91 3.90
0.81 0.49
0.39 0.24
5.44 23.25
2.11 8.25
3.07 11.65
8.61 40.86
0.75 0.52
0.29 1.27
0
0.36 1.35
6.68 23.14
0.08 0.07
2.01 8.32
4.25 20.09
2.20 10.35
0.83 0.49
0
0.54 0.40
0.37 0.26
15.58 73.13
2.52 9.91
0
0
0
0
21.33 99.26
19.28 82.72
4.09 0.77
0.65 0.39
0
0.39 0.59
3.57 15.46
0.63 2.41
0.31 0.20
0.72 0.41
13.80 59.16
4.37 19.35
0.21 0.17
0
0
4.15 3.26
2.39 1.07
0.23 0.70
0
0
Large Gulls
Mar - Apr

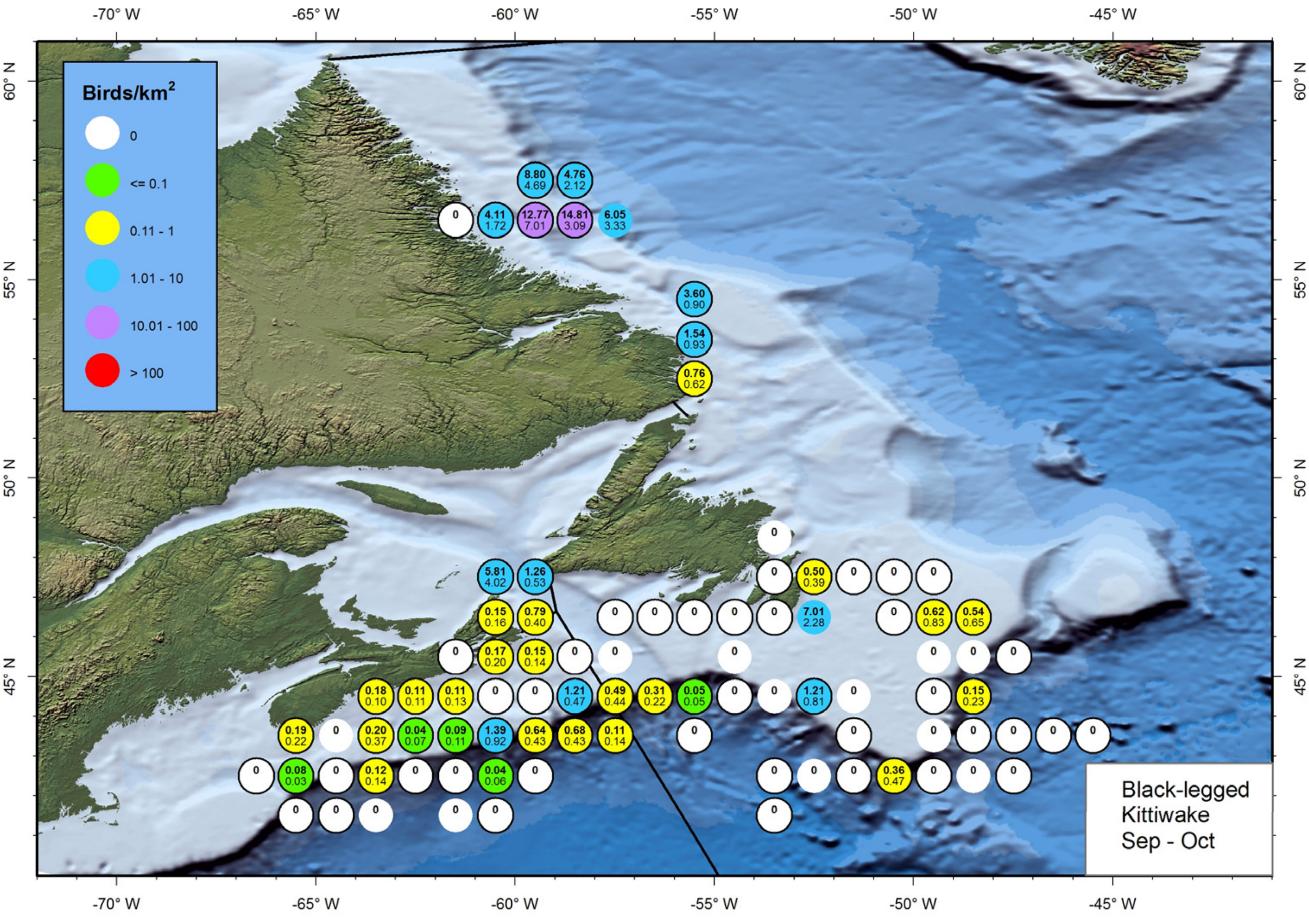

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Large Gulls
May - Aug
0 0 1.57 0.81 0 0 0.07 0.05
0 0.14 0.12 0 1.45 0.74 0 0
0.21 0.11 0.04 0.04 0 0.36 0.19 0.15 0.24 0
0 0 0 0.25 0.31 0 0
0.67 0.34 0.13 0.14 0.64 0.59 0 0 0
0.31 0.29 0.37 0.23 0 0 0 0
0.10 0.09 0.16 0.10 1.13 0.72 0.72 0.46 0 1.07 0.57 0 0 0 0
0.32 0.22 0 0 0 0 0.75 0.56 0 0 0 0 0
1.45 1.13 0.44 0.37 0 0.18 0.11 0 0 0 0 0
0.86 0.36 1.45 0.94 1.19 0.84 4.70 2.64 0.32 0.16 0.14 0.03 0.52 0.70 0.68 0.51 0 0 0 1.12 0.80 0.09 0.05 0
1.00 0.26 1.70 0.79 1.13 0.95 0.82 0.69 0 9.38 5.27 0.22 0.11 0.18 0.12 0.44 0.29 0.46 0.26 0.28 0.15 0 0 0.25 0.29
0.33 0.17 0.40 0.15 0.36 0.13 2.07 1.43 1.20 1.18 0 0.60 0.34 0.06 0.05 0.08 0.12 0.42 0.42 0
1.09 0.76 0 0.84 0.61 0 0 0.17 0.19 0 1.37 1.11 0 0 0
0.40 0.35 0 0.96 0.51 0.26 0.19 0.20 0.14 0.05 0.07 0.08 0.09 0 0 0 0
0.18 0.16 0.16 0.21 0 0 0 0 0 0 0.14 0.18 0 0 0.36 0.25 0.02 0.02 0 0
0.78 0.28 2.39 1.20 0 0.14 0.11 0.14 0.09 0 0 0 0.70 0.62 0.05 0.06 0 0
0.14 0.08 0 0 0.67 0.30 0.08 0.06 0 0.12 0.08 0.27 0.14 0 0 0 0 0 0
8.39 2.42 3.75 1.53 0.91 0.44 1.58 1.02 0.06 0.05 0.13 0.32 0 0 0.10 0.12 0.06 0.04 0
0 0.08 0.06 0 0.16 0.08 0 0 0 0 0.10 0.05 0 0 0 0 0.92 0.81
0 0 0 0.04 0.04 0 0 0 0
0 0 0 0 0 0 0

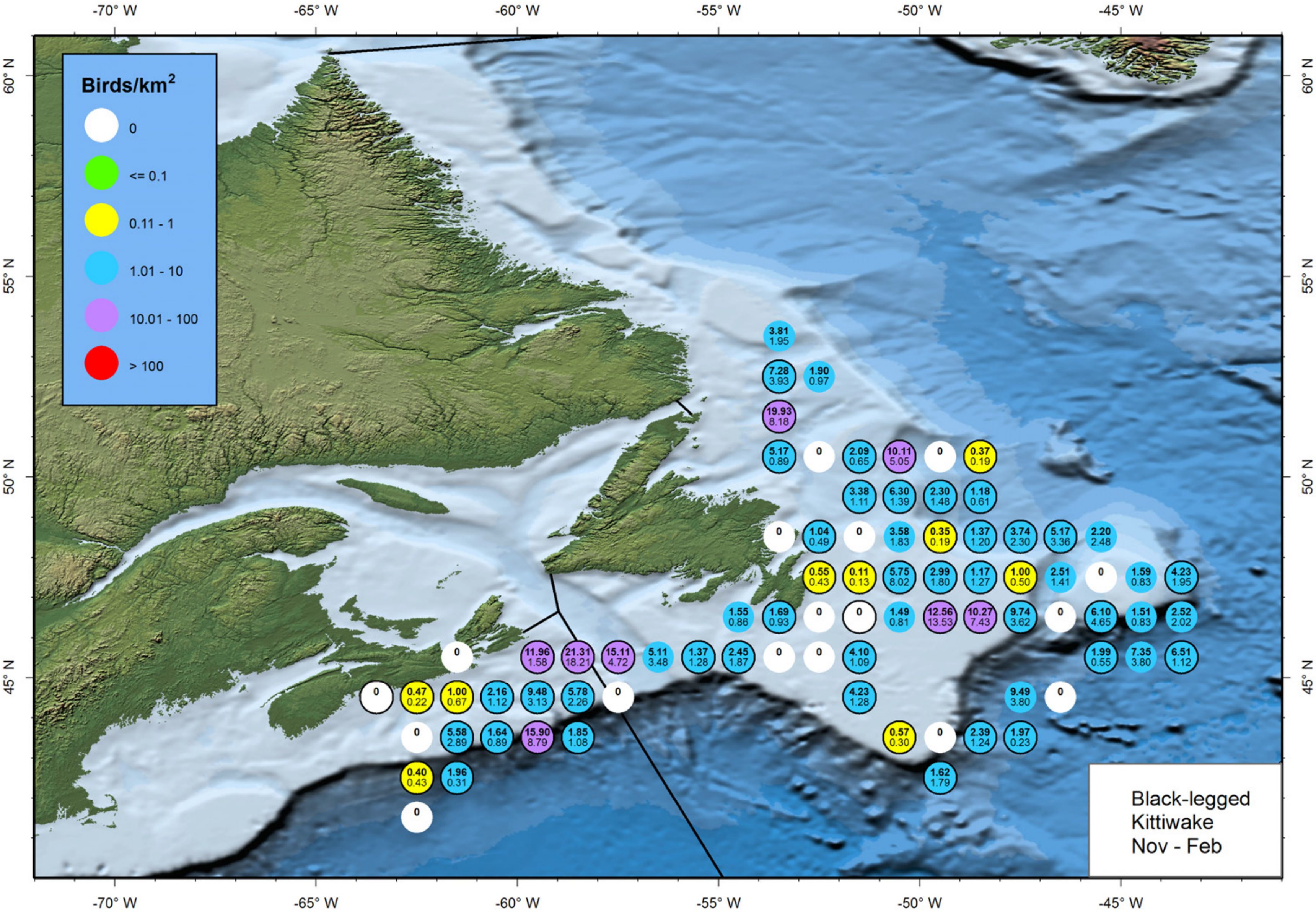

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
3.86 0.96
0
4.51 1.35
1.45 0.42
0.99 0.50
1.40 0.42
0
2.04 0.69
0
0.67 0.34
0
0.28 0.20
0.65 0.26
1.36 0.36
0.67 0.33
0
0
0
0.55 0.30
0.93 0.44
1.02 0.52
1.59 0.64
0.19 0.16
0.43 0.22
0.52 0.14
0
0.76 0.40
0
0.11 0.10
1.57 0.48
1.25 0.73
0.66 0.29
0
0
0
0
6.19 4.08
0
1.19 0.29
2.72 1.11
0.55 0.25
0.58 0.34
0.40 0.22
2.44 1.48
0.16 0.12
0.13 0.09
0.13 0.09
0
0
0
0
0.20 0.12
0.13 0.12
2.86 1.80
0
0.39 0.19
0.50 0.16
0.46 0.19
1.35 0.54
0.35 0.20
1.14 0.58
0.04 0.06
0
0
0
0
0
0
0
0.54 0.45
1.23 0.48
0.78 0.52
0.27 0.13
0.15 0.12
0.02 0.04
0.18 0.12
0
0
0
0
0.12 0.14
1.25 0.67
0
0.17 0.09
0.24 0.28
0
3.48 0.89
0
0
0
Large Gulls
Sep - Oct

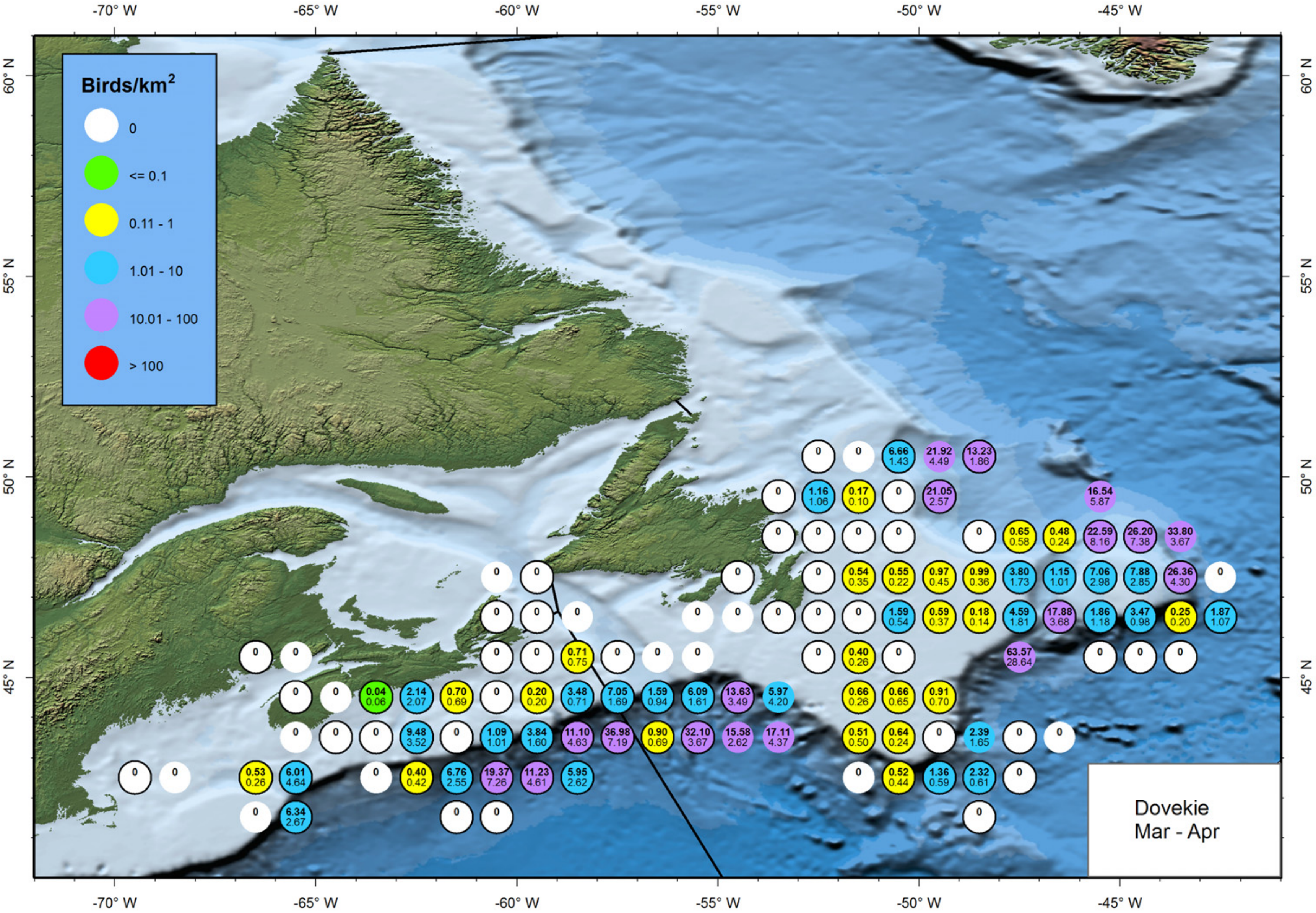

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0.28 0.15
0
0.92 0.13
1.56 0.30
0.64 0.32
0.98 0.48
1.80 1.03
0
0.60 0.12
0
0.48 0.30
0
1.34 0.58
0
0.19 0.16
0.62 0.31
0
0
0.48 0.35
20.83 8.63
5.93 1.90
0
1.62 0.67
0.54 0.32
1.18 1.27
0.90 0.40
3.70 2.31
3.79 4.59
0
0
0
1.00 0.56
0
0.12 0.09
0
0
0
1.33 1.16
1.09 1.20
0.79 0.73
0.48 0.36
0.95 0.57
3.09 1.02
0
0
1.63 0.48
1.76 0.57
0.92 0.50
0
0
0.35 0.21
0
0
0.47 0.18
0.12 0.06
0
0
0.51 0.38
0.62 0.51
0.61 0.18
0
1.53 0.30
0.18 0.15
0
0.11 0.07
0
0
0
0.12 0.06
1.25 0.44
2.31 1.20
0.27 0.18
0
0
0.16 0.09
0
0.65 0.28
0
0.23 0.43
1.51 0.76
Large Gulls
Nov - Feb

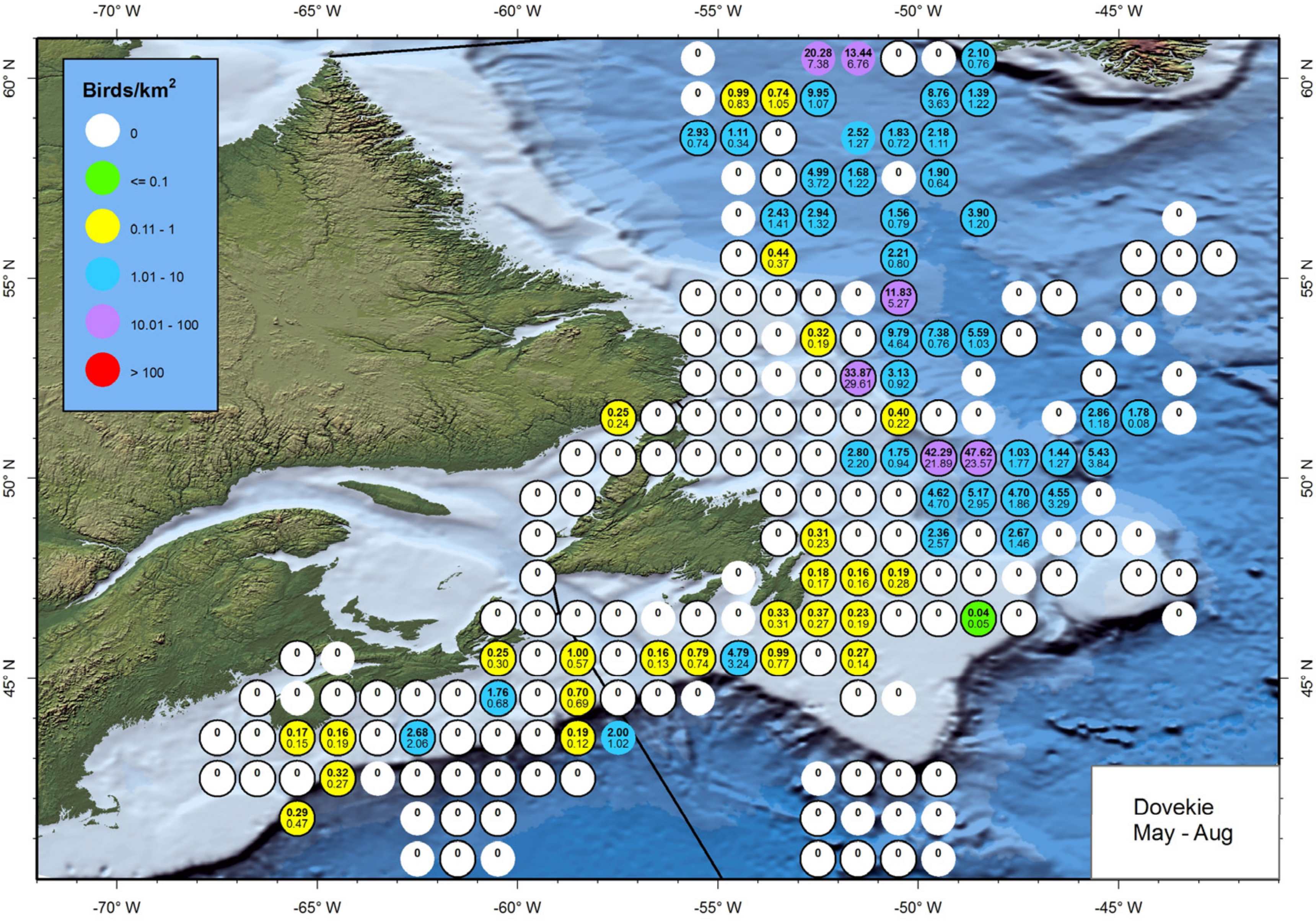

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0.20 0.10
0
0.72 0.36
0.89 0.46
0.21 0.10
0.19 0.10
0.37 0.30
0.98 0.30
0
0.17 0.09
1.37 0.69
3.07 0.33
1.33 0.73
0.71 0.35
0.90 0.45
0.32 0.14
1.43 0.90
2.15 0.55
3.00 1.88
0.83 0.41
2.56 0.20
0
0.28 0.14
0
1.29 0.63
0.38 0.10
0.18 0.10
0.91 0.37
0.79 0.30
0.19 0.10
1.92 0.68
0.68 0.44
0
0.78 0.58
0
0
0.50 0.32
0
0
0
1.43 0.71
0.75 0.42
1.19 0.36
1.50 0.55
0.76 0.28
0.72 0.30
0.35 0.24
0.73 0.26
0.38 0.24
0
0
0.18 0.10
0
0
0
0.55 0.14
1.50 1.01
2.02 1.01
0
0.85 0.42
1.37 0.71
0.12 0.09
0.76 0.06
5.60 2.88
0.30 0.14
0
0.94 0.47
0
0
0.01 0.03
0
0.09 0.07
0
0.06 0.07
2.02 0.56
1.56 0.81
0.49 0.36
3.40 1.32
1.16 0.57
0.59 0.57
0.40 0.33
0.45 0.22
0
0
0.05 0.06
0
0
0
0
0.45 0.14
1.00 0.44
0.51 0.30
1.00 0.50
7.06 0.47
0.52 0.24
2.46 0.33
1.43 0.82
0.57 0.28
1.09 0.28
0
0
0
0
0
0
0
0
0
0.32 0.17
1.55 0.63
0.76 0.39
3.74 1.88
1.53 0.76
0.89 0.39
0.11 0.09
0
0
0
0.86 0.14
0
0
0
Black-legged Kittwake Mar - Apr

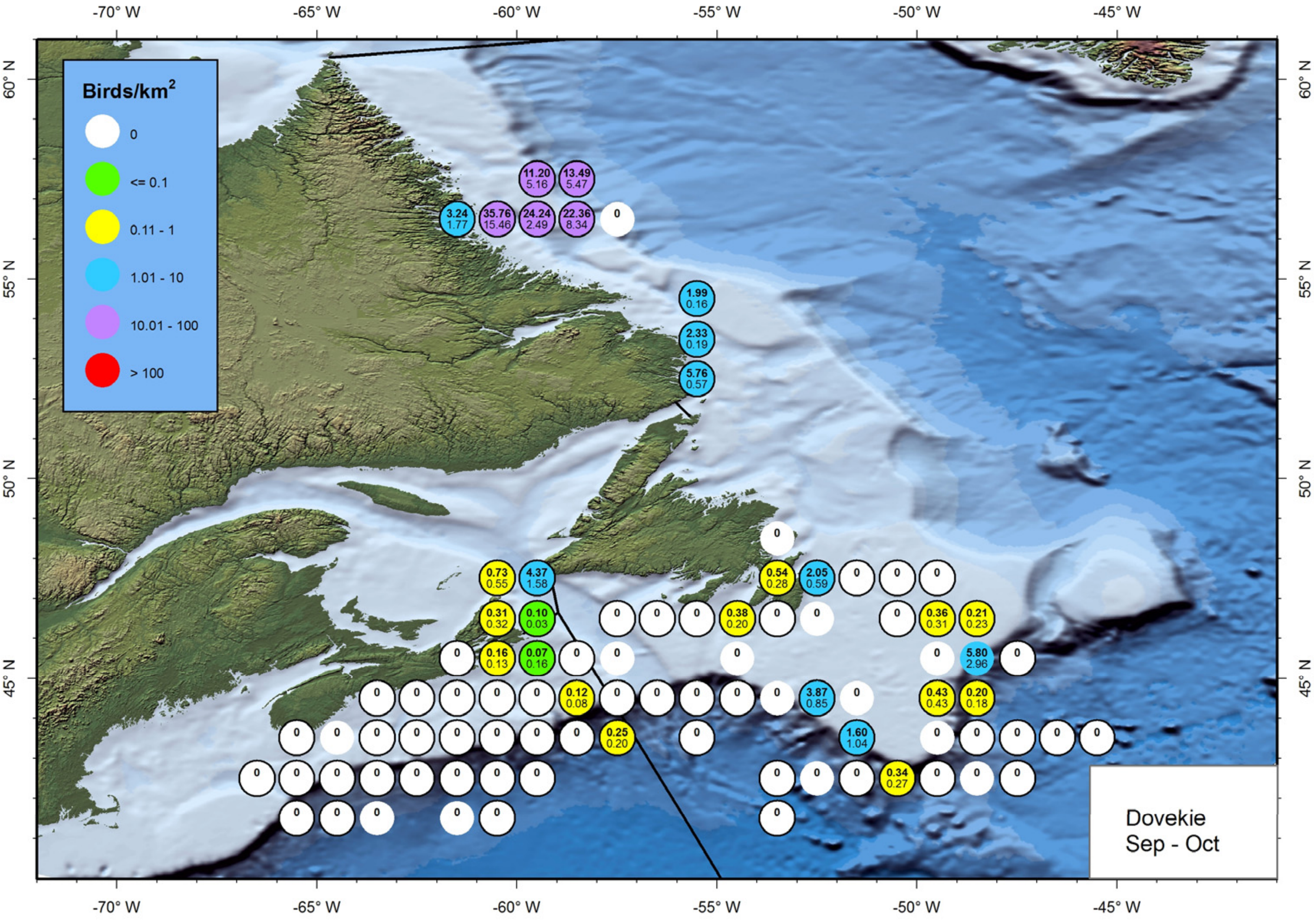

Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Black-legged
Kittiwake
May - Aug
-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
0 1.00 0.51 14.23 9.33 0 0 2.50 1.12
0 0 0 0 0.46 0.47 4.14 3.45
0 0 0 0.88 0.44 0.37 0.45 3.43 1.79
0 0.11 0.08 0 0.16 0.14 0 0
0 0 0.13 0.14 0.36 0.18 0 0
0.33 0.31 0.55 0.50 1.19 0.97 0 0 0
0 0.89 0.56 5.38 3.55 6.13 4.53 9.18 4.78 0 0 0 0 0
0 0 0 2.39 1.42 7.22 4.13 1.11 0.63 0.15 0.08 0 0 0 0
0 0.13 0.11 0 0.80 0.45 0.12 0.08 0 0 0 0
1.07 3.48 2.34 1.66 2.81 1.52 2.19 0.83 1.02 0.52 3.44 2.16 2.86 1.45 1.47 0.86 0 0 0 0.26 0.29 0.77 0.39 1.15 0.58
2.02 1.54 0.06 0.06 3.30 1.72 4.86 2.53 4.74 2.08 3.75 1.96 1.07 0.54 1.22 0.51 0.38 0.24 0.14 0.08 0.72 0.33 6.96 5.35 1.89 1.11 0.71 0.48
0 0.10 0.09 1.92 1.07 0 0.11 0.08 0 0.11 0.15 1.60 1.20 1.16 0.67 0.90 0.40 3.03 1.53
1.77 0.73 7.87 4.10 6.17 4.38 0.72 0.51 4.95 6.29 0 0 1.77 1.26 0 0 0
1.94 1.27 0 2.87 1.19 0.17 0.15 0.03 0.05 0.12 0.13 0 0 0 0 0
0 0.14 0.12 0 0.13 0.12 0 2.07 1.80 0 2.23 1.76 1.95 1.05 0.49 0.35 0.19 0.14 0 0.01 0.02 0 0
0 0 0 0.76 0.74 0 0.08 0.07 0.05 0.05 0.55 0.42 0.16 0.11 0.25 0.15 4.44 2.35 0
0 0 0 0 0 0 0 0 0 0 0 0 0.75 0.48 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0.07 0.06
0 0 0 0 0 0 0 0
0 0 0 0 0 0 0

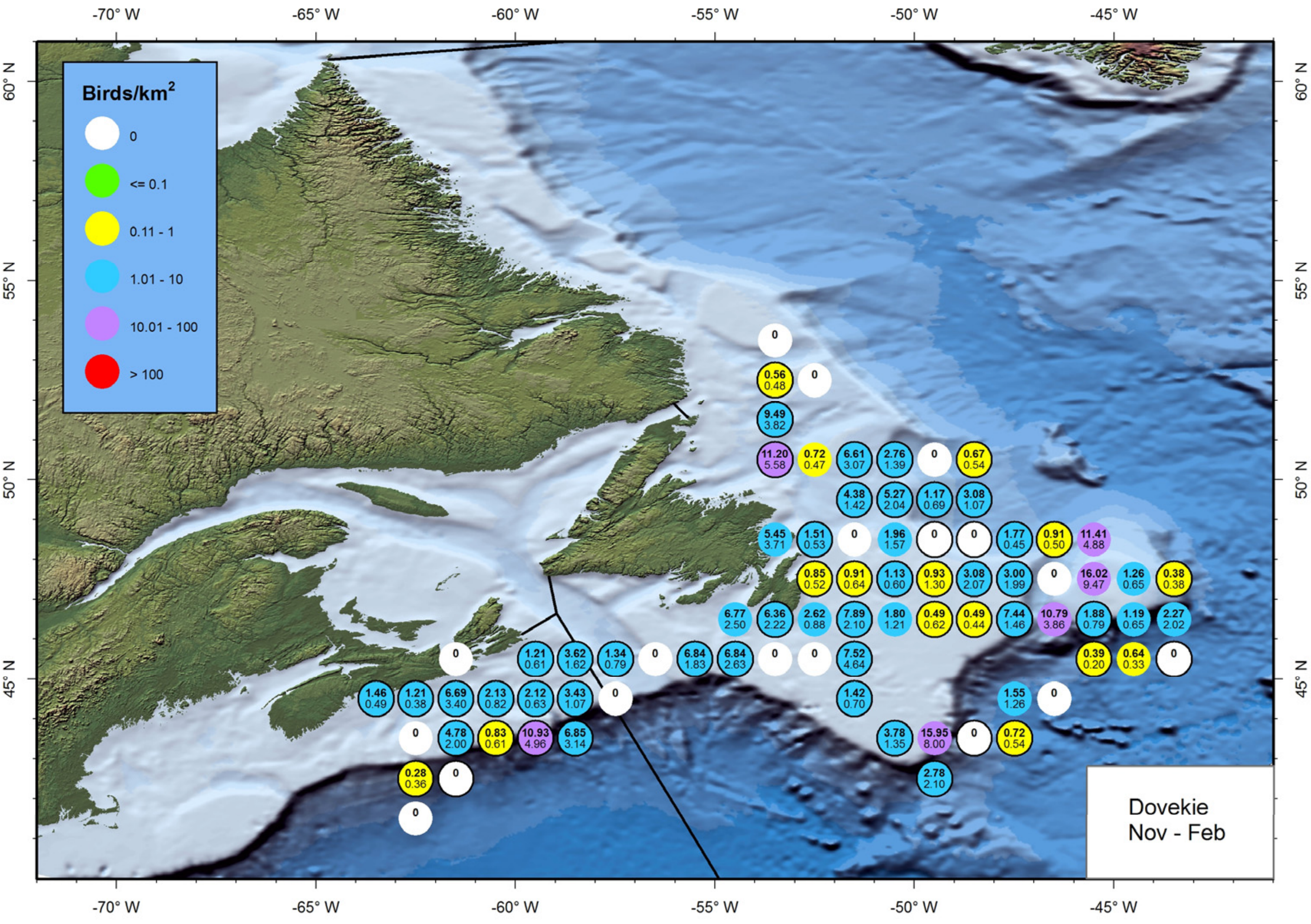

Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Black-legged
Kittiwake
Sep - Oct
-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
8.80 4.69
4.76 2.12
0
4.11 1.72
12.77 7.01
14.81 3.09
6.05 3.33
3.60 0.90
1.54 0.93
0.76 0.62
0
5.81 4.02
1.26 0.53
0
0.50 0.39
0
0
0
0.15 0.16
0.79 0.40
0
0
0
0
0
7.01 2.28
0
0.62 0.83
0.54 0.65
0
0.17 0.20
0.15 0.14
0
0
0
0
0
0
0.18 0.10
0.11 0.11
0.11 0.13
0
0
1.21 0.47
0.49 0.44
0.31 0.22
0.05 0.05
0
0
1.21 0.81
0
0
0.15 0.23
0.19 0.22
0
0.20 0.37
0.04 0.07
0.09 0.11
1.39 0.92
0.64 0.43
0.68 0.43
0.11 0.14
0
0
0
0
0
0
0
0
0.08 0.03
0
0.12 0.14
0
0
0.04 0.06
0
0
0
0
0.36 0.47
0
0
0
0
0
0
0
0
0

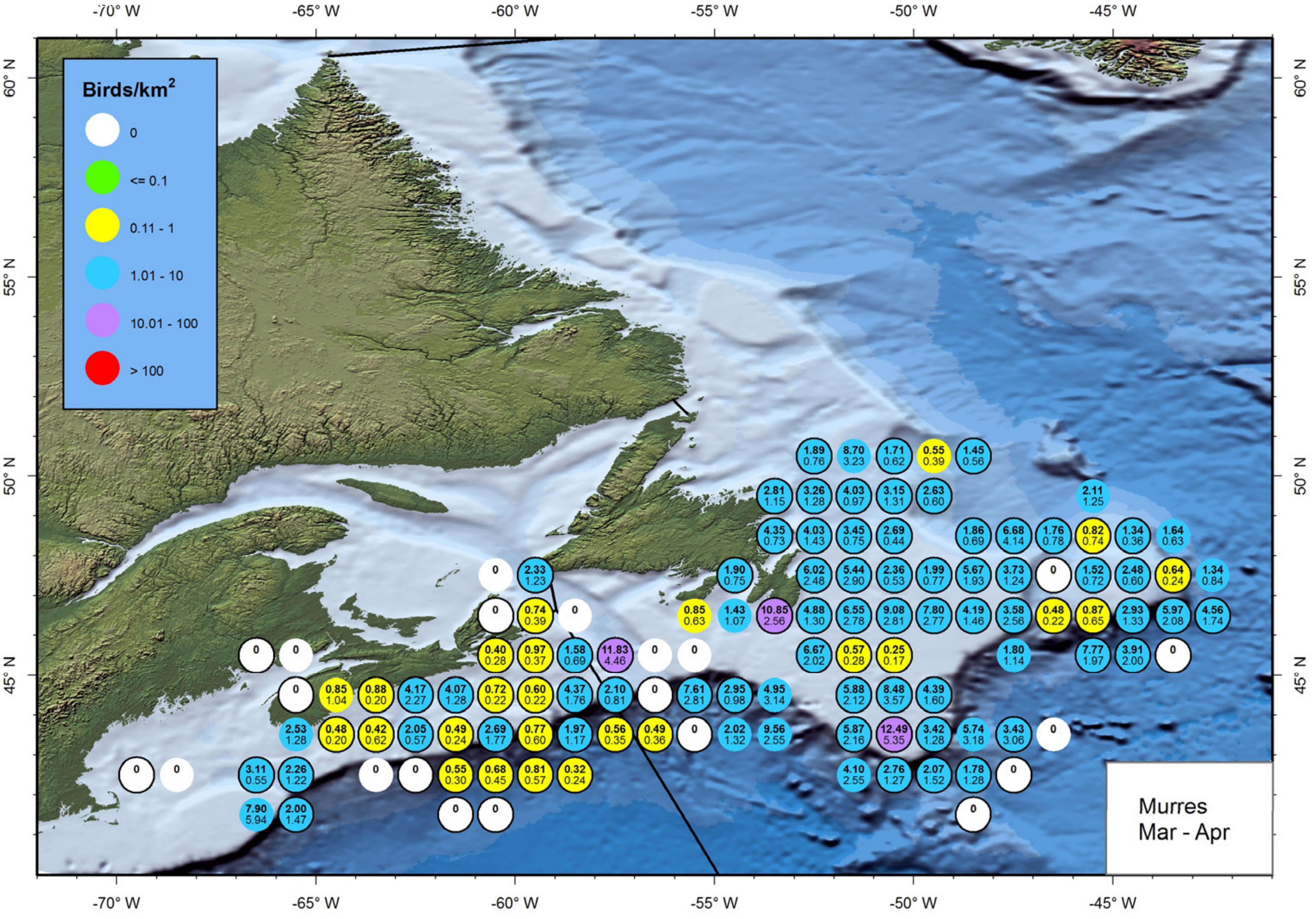

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
3.81 1.95
7.28 3.93
1.90 0.97
19.93 8.18
5.17 0.89
0
2.09 0.65
10.11 5.05
0
0.37 0.19
3.38 1.11
6.30 1.39
2.30 1.48
1.18 0.61
0
1.04 0.49
0
3.58 1.83
0.35 0.19
1.37 1.20
3.74 2.30
5.17 3.36
2.20 2.48
0.55 0.43
0.11 0.13
5.75 8.02
2.99 1.80
1.17 1.27
1.00 0.50
2.51 1.41
0
1.59 0.83
4.23 1.95
1.55 0.86
1.69 0.93
0
0
1.49 0.81
12.56 13.53
10.27 7.43
9.74 3.62
0
6.10 4.65
1.51 0.83
2.52 2.02
0
11.96 1.58
21.31 18.21
15.11 4.72
5.11 3.48
1.37 1.28
2.45 1.87
0
0
4.10 1.09
1.99 0.55
7.35 3.80
6.51 1.12
0
0.47 0.22
1.00 0.67
2.16 1.12
9.48 3.13
5.78 2.26
0
4.23 1.28
9.49 3.80
0
0
5.58 2.89
1.64 0.89
15.90 8.79
1.85 1.08
0.57 0.30
0
2.39 1.24
1.97 0.23
0.40 0.43
1.96 0.31
1.62 1.79
0
Black-legged
Kittiwake
Nov - Feb

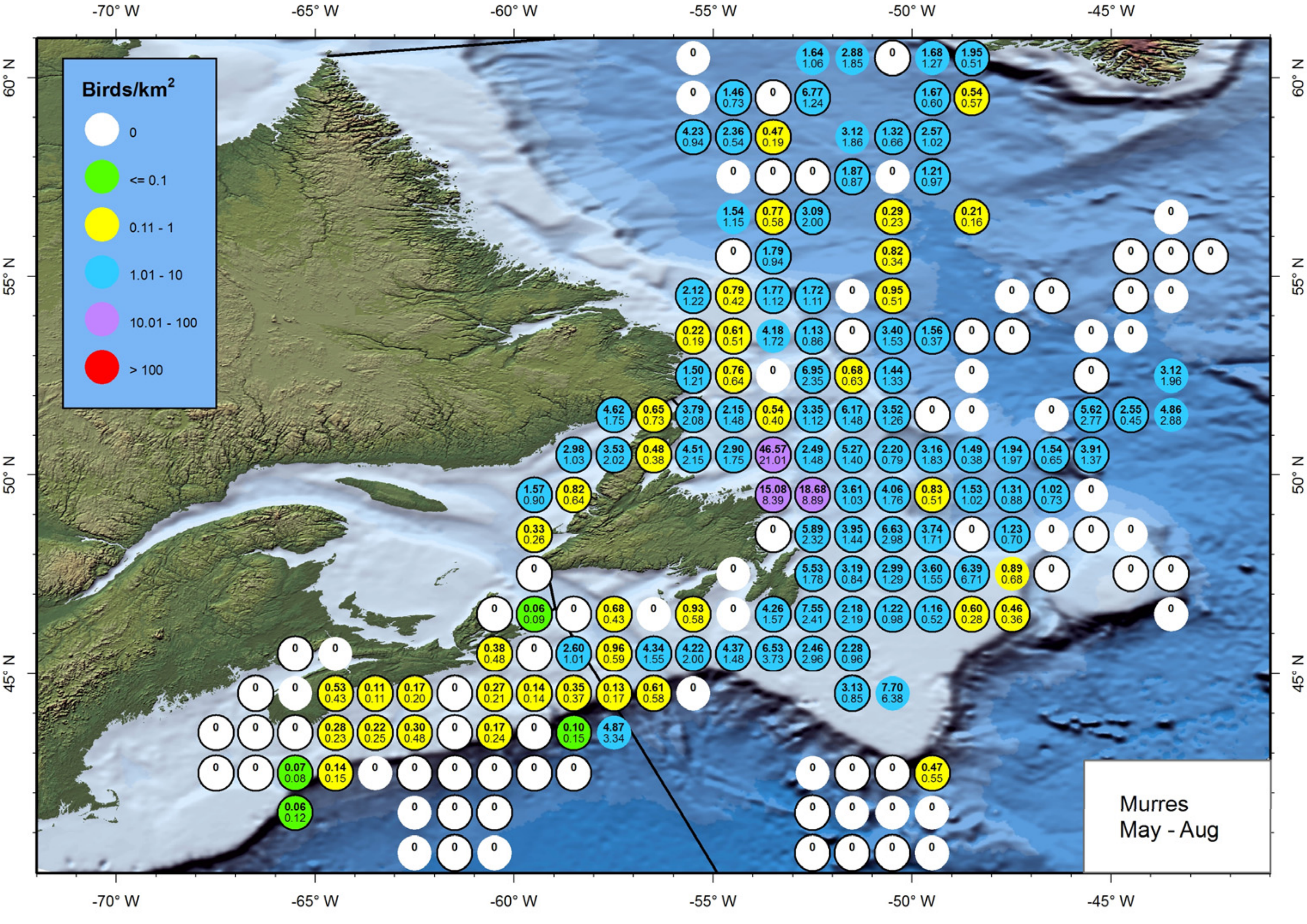

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
6.66 1.43
21.92 4.49
13.23 1.86
0
1.16 1.06
0.17 0.10
0
21.05 2.57
16.54 5.87
0
0
0
0
0
0.65 0.58
0.48 0.24
22.59 8.16
26.20 7.38
33.80 3.67
0
0
0
0
0.54 0.35
0.55 0.22
0.97 0.45
0.99 0.36
3.80 1.73
1.15 1.01
7.06 2.98
7.88 2.85
26.36 4.30
0
0
0
0
0
0
0
0
0
1.59 0.54
0.59 0.37
0.18 0.14
4.59 1.81
17.88 3.68
1.86 1.18
3.47 0.98
0.25 0.20
1.87 1.07
0
0
0
0
0.71 0.75
0
0
0
0
0.40 0.26
0
63.57 28.64
0
0
0
0
0
0.04 0.06
2.14 2.07
0.70 0.69
0
0.20 0.20
3.48 0.71
7.05 1.69
1.59 0.94
6.09 1.61
13.63 3.49
5.97 4.20
0.66 0.26
0.66 0.65
0.91 0.70
0
0
0
9.48 3.52
0
1.09 1.01
3.84 1.60
11.10 4.63
36.98 7.19
0.90 0.69
32.10 3.67
15.58 2.62
17.11 4.37
0.51 0.50
0.64 0.24
0
2.39 1.65
0
0
0
0
0.53 0.26
6.01 4.64
0
0.40 0.42
6.76 2.55
19.37 7.26
11.23 4.61
5.95 2.62
0
0.52 0.44
1.36 0.59
2.32 0.61
0
0
6.34 2.67
0
0
0
Dovekie
Mar - Apr


Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Dovekie
May - Aug
-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
11.20 5.16
13.49 5.47
3.24 1.77
35.76 15.46
24.24 2.49
22.36 8.34
0
1.99 0.16
2.33 0.19
5.76 0.57
0
0.73 0.55
4.37 1.58
0.54 0.28
2.05 0.59
0
0
0
0.31 0.32
0.10 0.03
0
0
0
0.38 0.20
0
0
0
0.36 0.31
0.21 0.23
0
0.16 0.13
0.07 0.16
0
0
0
0
5.80 2.96
0
0
0
0
0
0
0.12 0.08
0
0
0
0
0
3.87 0.85
0
0.43 0.43
0.20 0.18
0
0
0
0
0
0
0
0
0.25 0.20
0
1.60 1.04
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0.34 0.27
0
0
0
0
0
0
0
0
0
Dovekie
Sep - Oct


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0.56 0.48
0
9.49 3.82
11.20 5.58
0.72 0.47
6.61 3.07
2.76 1.39
0
0.67 0.54
4.38 1.42
5.27 2.04
1.17 0.69
3.08 1.07
5.45 3.71
1.51 0.53
0
1.96 1.57
0
0
1.77 0.45
0.91 0.50
11.41 4.88
0.85 0.52
0.91 0.64
1.13 0.60
0.93 1.30
3.08 2.07
3.00 1.99
0
16.02 9.47
1.26 0.65
0.38 0.38
6.77 2.50
6.36 2.22
2.62 0.88
7.89 2.10
1.80 1.21
0.49 0.62
0.49 0.44
7.44 1.46
10.79 3.86
1.88 0.79
1.19 0.65
2.27 2.02
0
1.21 0.61
3.62 1.62
1.34 0.79
0
6.84 1.83
6.84 2.63
0
0
7.52 4.64
0.39 0.20
0.64 0.33
0
1.46 0.49
1.21 0.38
6.69 3.40
2.13 0.82
2.12 0.63
3.43 1.07
0
1.42 0.70
1.55 1.26
0
0
4.78 2.00
0.83 0.61
10.93 4.96
6.85 3.14
3.78 1.35
15.95 8.00
0
0.72 0.54
0.28 0.36
0
2.78 2.10
0
Dovekie
Nov - Feb


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
1.89 0.76
8.70 3.23
1.71 0.62
0.55 0.39
1.45 0.56
2.81 1.15
3.26 1.28
4.03 0.97
3.15 1.31
2.63 0.60
2.11 1.25
4.35 0.73
4.03 1.43
3.45 0.75
2.69 0.44
1.86 0.69
6.68 4.14
1.76 0.78
0.82 0.74
1.34 0.36
1.64 0.63
0
2.33 1.23
1.90 0.75
6.02 2.48
5.44 2.90
2.36 0.53
1.99 0.77
5.67 1.93
3.73 1.24
0
1.52 0.72
2.48 0.60
0.64 0.24
1.34 0.84
0
0.74 0.39
0
0.85 0.63
1.43 1.07
10.85 2.56
4.88 1.30
6.55 2.78
9.08 2.81
7.80 2.77
4.19 1.46
3.58 2.56
0.48 0.22
0.87 0.65
2.93 1.33
5.97 2.08
4.56 1.74
0
0
0.40 0.28
0.97 0.37
1.58 0.69
11.83 4.46
0
0
6.67 2.02
0.57 0.28
0.25 0.17
1.80 1.14
7.77 1.97
3.91 2.00
0
0
0.85 1.04
0.88 0.20
4.17 2.27
4.07 1.28
0.72 0.22
0.60 0.22
4.37 1.76
2.10 0.81
0
7.61 2.81
2.95 0.98
4.95 3.14
5.88 2.12
8.48 3.57
4.39 1.60
2.53 1.28
0.48 0.20
0.42 0.62
2.05 0.57
0.49 0.24
2.69 1.77
0.77 0.60
1.97 1.17
0.56 0.35
0.49 0.36
0
2.02 1.32
9.56 2.55
5.87 2.16
12.49 5.35
3.42 1.28
5.74 3.18
3.43 3.06
0
0
0
3.11 0.55
2.26 1.22
0
0
0.55 0.30
0.68 0.45
0.81 0.57
0.32 0.24
4.10 2.55
2.76 1.27
2.07 1.52
1.78 1.28
0
7.90 5.94
2.00 1.47
0
0
0
Murres
Mar - Apr


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Murres
May - Aug
0
1.64 1.06
2.88 1.85
0
1.68 1.27
1.95 0.51
0
1.46 0.73
0
6.77 1.24
1.67 0.60
0.54 0.57
4.23 0.94
2.36 0.54
0.47 0.19
3.12 1.86
1.32 0.66
2.57 1.02
0
0
0
1.87 0.87
0
1.21 0.97
1.54 1.15
0.77 0.58
3.09 2.00
0.29 0.23
0.21 0.16
0
0
1.79 0.94
0.82 0.34
0
0
0
2.12 1.22
0.79 0.42
1.77 1.12
1.72 1.11
0
0.95 0.51
0
0
0
0
0.22 0.19
0.61 0.51
4.18 1.72
1.13 0.86
0
3.40 1.53
1.56 0.37
0
0
0
0
1.50 1.21
0.76 0.64
0
6.95 2.35
0.68 0.63
1.44 1.33
0
0
3.12 1.96
4.62 1.75
0.65 0.73
3.79 2.08
2.15 1.48
0.54 0.40
3.35 1.12
6.17 1.48
3.52 1.26
0
0
0
5.62 2.77
2.55 0.45
4.86 2.88
2.98 1.03
3.53 2.02
0.48 0.38
4.51 2.15
2.90 1.75
46.57 21.01
2.49 1.48
5.27 1.40
2.20 0.79
3.16 1.83
1.49 0.38
1.94 1.97
1.54 0.65
3.91 1.37
1.57 0.90
0.82 0.64
15.08 8.39
18.68 8.89
3.61 1.03
4.06 1.76
0.83 0.51
1.53 1.02
1.31 0.88
1.02 0.73
0
0.33 0.26
0
5.89 2.32
3.95 1.44
6.63 2.98
3.74 1.71
0
1.23 0.70
0
0
0
0
0
5.53 1.78
3.19 0.84
2.99 1.29
3.60 1.55
6.39 6.71
0.89 0.68
0
0
0
0
0.06 0.09
0
0.68 0.43
0
0.93 0.58
0
4.26 1.57
7.55 2.41
2.18 2.19
1.22 0.98
1.16 0.52
0.60 0.28
0.46 0.36
0
0
0
0.38 0.48
0
2.60 1.01
0.96 0.59
4.34 1.55
4.22 2.00
4.37 1.48
6.53 3.73
2.46 2.96
2.28 0.96
0
0
0.53 0.43
0.11 0.11
0.17 0.20
0
0.27 0.21
0.14 0.14
0.35 0.37
0.13 0.17
0.61 0.58
0
3.13 0.85
7.70 6.38
0
0
0
0.28 0.23
0.22 0.25
0.30 0.48
0
0.17 0.24
0
0.10 0.15
4.87 3.34
0
0
0.07 0.08
0.14 0.15
0
0
0
0
0
0
0
0
0
0.47 0.55
0.06 0.12
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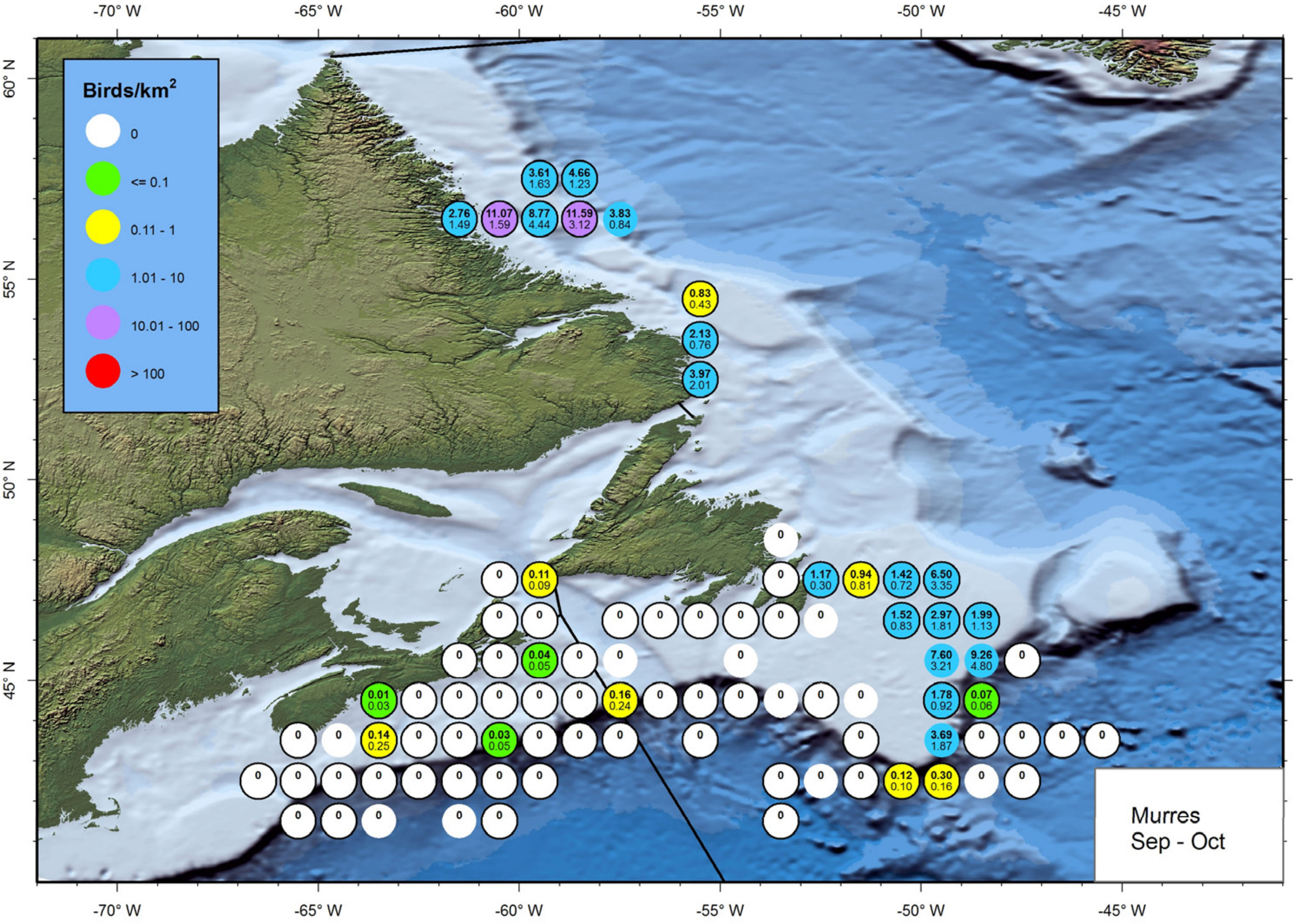
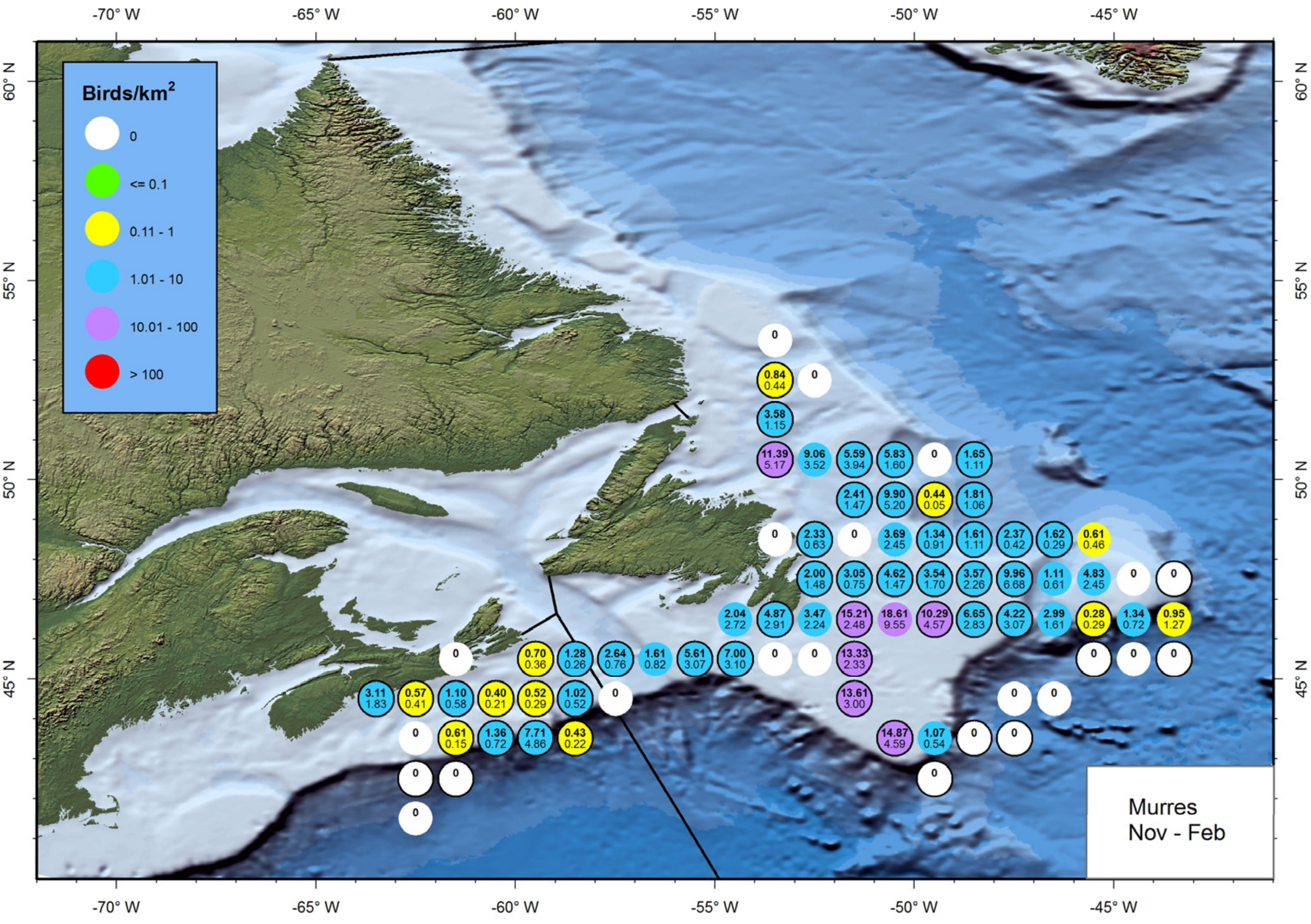
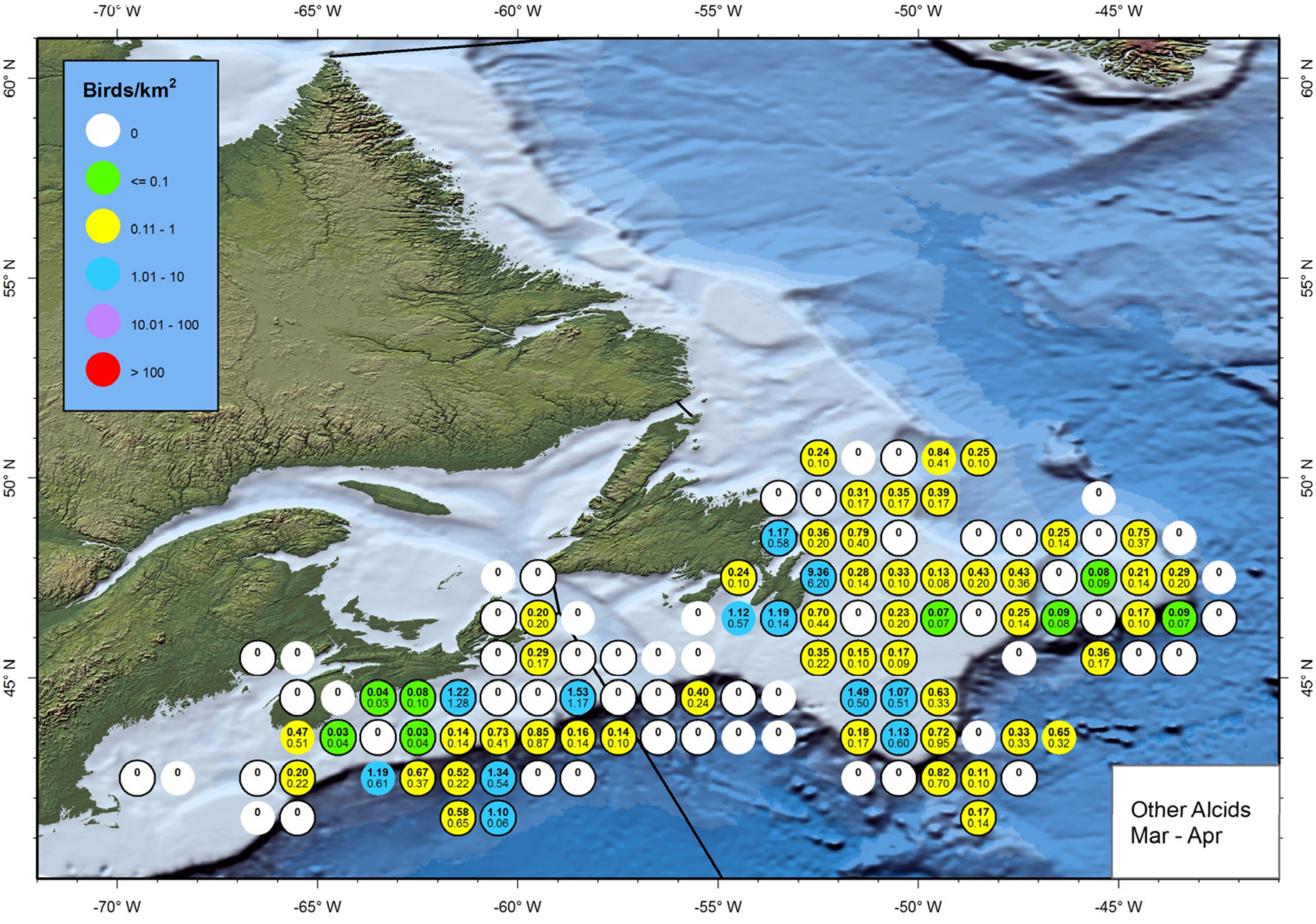
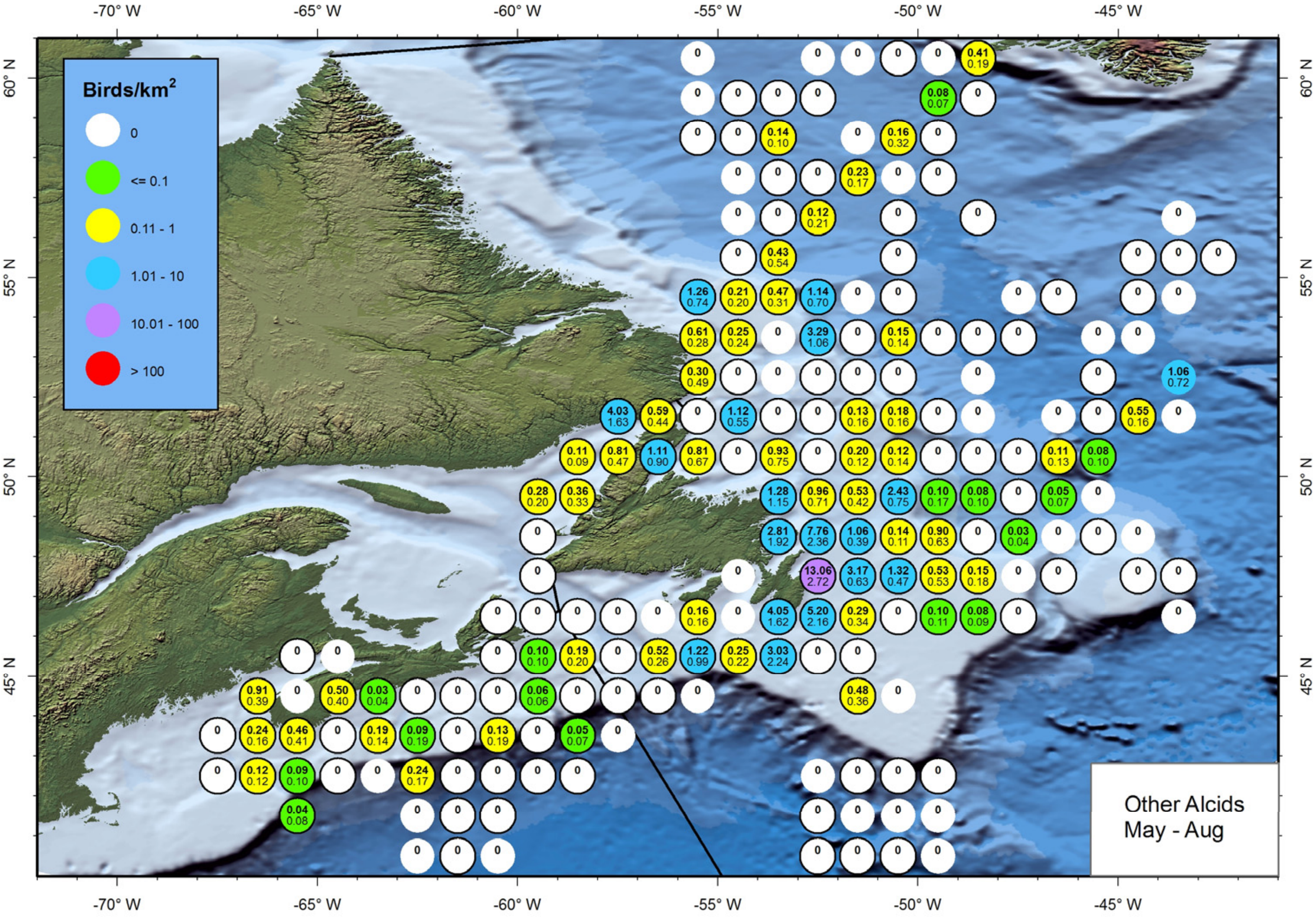

-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
3.61 1.63
4.66 1.23
2.76 1.49
11.07 1.59
8.77 4.44
11.59 3.12
3.83 0.84
0.83 0.43
2.13 0.76
3.97 2.01
0
0
0.11 0.09
0
1.17 0.30
0.94 0.81
1.42 0.72
6.50 3.35
0
0
0
0
0
0
0
0
1.52 0.83
2.97 1.81
1.99 1.13
0
0
0.04 0.05
0
0
0
7.60 3.21
9.26 4.80
0
0.01 0.03
0
0
0
0
0
0.16 0.24
0
0
0
0
0
0
1.78 0.92
0.07 0.06
0
0
0.14 0.25
0
0
0.03 0.05
0
0
0
0
0
3.69 1.87
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0.12 0.10
0.30 0.16
0
0
0
0
0
0
0
0
Murres
Sep - Oct


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0.84 0.44
0
3.58 1.15
11.39 5.17
9.06 3.52
5.59 3.94
5.83 1.60
0
1.65 1.11
2.41 1.47
9.90 5.20
0.44 0.05
1.81 1.06
0
2.33 0.63
0
3.69 2.45
1.34 0.91
1.61 1.11
2.37 0.42
1.62 0.29
0.61 0.46
2.00 1.48
3.05 0.75
4.62 1.47
3.54 1.70
3.57 2.26
9.96 6.68
1.11 0.61
4.83 2.45
0
0
2.04 2.72
4.87 2.91
3.47 2.24
15.21 2.48
18.61 9.55
10.29 4.57
6.65 2.83
4.22 3.07
2.99 1.61
0.28 0.29
1.34 0.72
0.95 1.27
0
0.70 0.36
1.28 0.26
2.64 0.76
1.61 0.82
5.61 3.07
7.00 3.10
0
0
13.33 2.33
0
0
0
3.11 1.83
0.57 0.41
1.10 0.58
0.40 0.21
0.52 0.29
1.02 0.52
0
13.61 3.00
0
0
0
0.61 0.15
1.36 0.72
7.71 4.86
0.43 0.22
14.87 4.59
1.07 0.54
0
0
0
0
0
0
Murres
Nov - Feb


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0.24 0.10
0
0
0.84 0.41
0.25 0.10
0
0
0.31 0.17
0.35 0.17
0.39 0.17
0
1.17 0.58
0.36 0.20
0.79 0.40
0
0
0
0.25 0.14
0
0.75 0.37
0
0
0
0.24 0.10
9.36 6.20
0.28 0.14
0.33 0.10
0.13 0.08
0.43 0.20
0.43 0.36
0
0.08 0.09
0.21 0.14
0.29 0.20
0
0
0.20 0.20
0
0
1.12 0.57
1.19 0.14
0.70 0.44
0
0.23 0.20
0.07 0.07
0
0.25 0.14
0.09 0.08
0
0.17 0.10
0.09 0.07
0
0
0
0
0.29 0.17
0
0
0
0
0.35 0.22
0.15 0.10
0.17 0.09
0
0.36 0.17
0
0
0
0
0.04 0.03
0.08 0.10
1.22 1.28
0
0
1.53 1.17
0
0
0.40 0.24
0
0
1.49 0.50
1.07 0.51
0.63 0.33
0.47 0.51
0.03 0.04
0
0.03 0.04
0.14 0.14
0.73 0.41
0.85 0.87
0.16 0.14
0.14 0.10
0
0
0
0
0.18 0.17
1.13 0.60
0.72 0.95
0
0.33 0.33
0.65 0.32
0
0
0
0.20 0.22
1.19 0.61
0.67 0.37
0.52 0.22
1.34 0.54
0
0
0
0
0.82 0.70
0.11 0.10
0
0
0
0.58 0.65
1.10 0.06
0.17 0.14
Other Alcids
Mar - Apr


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
Other Alcids
May - Aug
0
0
0
0
0
0.41 0.19
0
0
0
0
0.08 0.07
0
0
0
0.14 0.10
0
0.16 0.32
0
0
0
0
0.23 0.17
0
0
0
0
0.12 0.21
0
0
0
0
0.43 0.54
0
0
0
0
1.26 0.74
0.21 0.20
0.47 0.31
1.14 0.70
0
0
0
0
0
0
0.61 0.28
0.25 0.24
0
3.29 1.06
0
0.15 0.14
0
0
0
0
0
0.30 0.49
0
0
0
0
0
0
0
1.06 0.72
4.03 1.63
0.59 0.44
0
1.12 0.55
0
0
0.13 0.16
0.18 0.16
0
0
0
0
0.55 0.16
0
0.11 0.09
0.81 0.47
1.11 0.90
0.81 0.67
0
0.93 0.75
0
0.20 0.12
0.12 0.14
0
0
0
0.11 0.13
0.08 0.10
0.28 0.20
0.36 0.33
1.28 1.15
0.96 0.71
0.53 0.42
2.43 0.75
0.10 0.17
0.08 0.10
0
0.05 0.07
0
0
2.81 1.92
7.76 2.36
1.06 0.39
0.14 0.11
0.90 0.63
0
0.03 0.04
0
0
0
0
0
13.06 2.72
3.17 0.63
1.32 0.47
0.53 0.53
0.15 0.18
0
0
0
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0
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0
0
0.16 0.16
0
4.05 1.62
5.20 2.16
0.29 0.34
0
0.10 0.11
0.08 0.09
0
0
0
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0
0.10 0.10
0.19 0.20
0
0.52 0.26
1.22 0.99
0.25 0.22
3.03 2.24
0
0
0.91 0.39
0
0.50 0.40
0.03 0.04
0
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0.06 0.06
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0
0
0.48 0.36
0
0
0.24 0.16
0.46 0.41
0
0.19 0.14
0.09 0.19
0
0.13 0.19
0
0.05 0.07
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0.12 0.12
0.09 0.10
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0.24 0.17
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0.04 0.08
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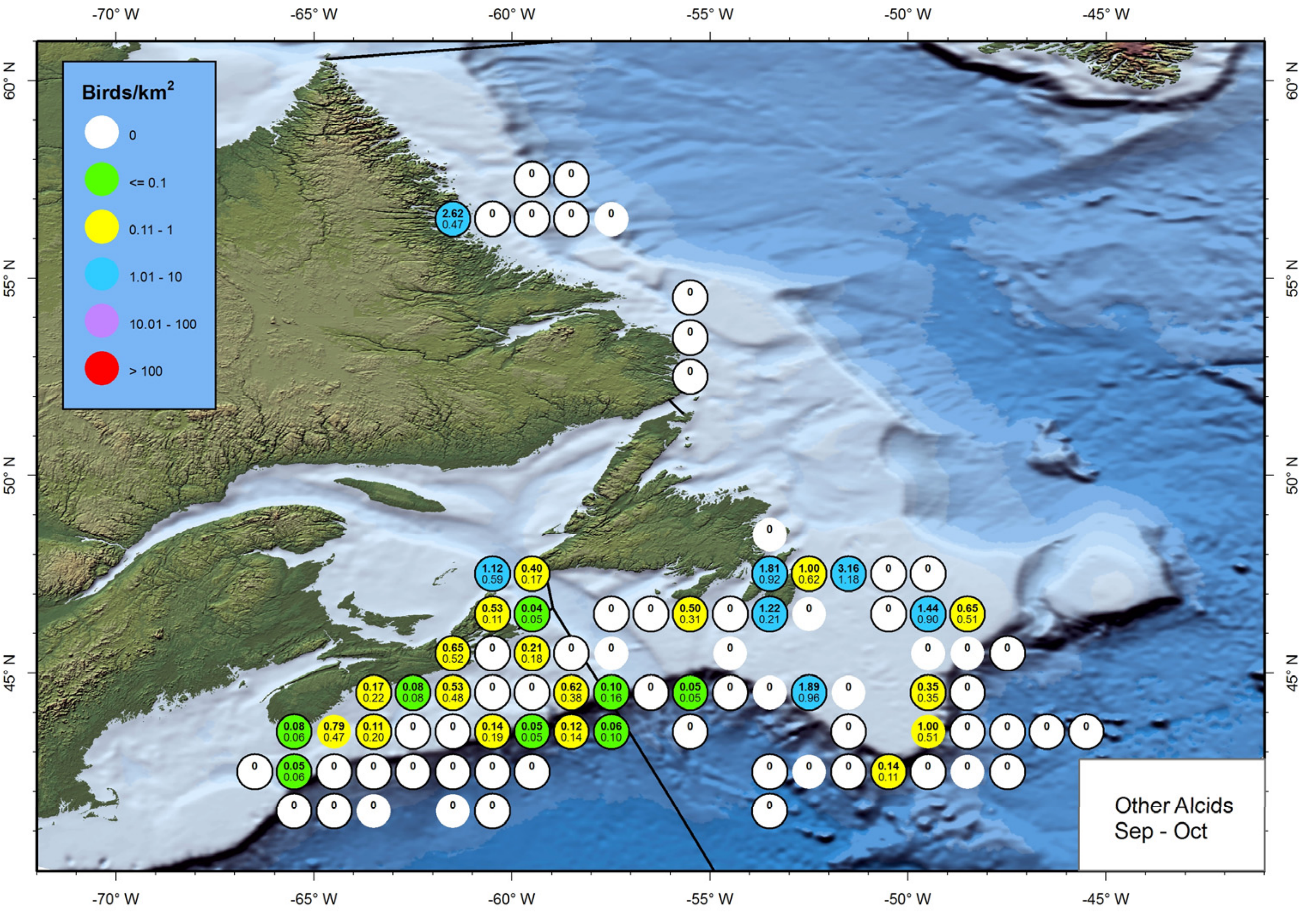
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-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km²
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
2.62
0.47
0
0
0
0
0
0
0
0
1.12
0.59
0.40
0.17
1.81
0.92
1.00
0.62
3.16
1.18
0
0
0.53
0.11
0.04
0.05
0
0
0.50
0.31
0
1.22
0.21
0
0
1.44
0.90
0.65
0.51
0.65
0.52
0
0.21
0.18
0
0
0
0
0
0
0.17
0.22
0.08
0.08
0.53
0.48
0
0
0.62
0.38
0.10
0.16
0
0.05
0.05
0
0
1.89
0.96
0
0.35
0.35
0
0.08
0.06
0.79
0.47
0.11
0.20
0
0
0.14
0.19
0.05
0.05
0.12
0.14
0.06
0.10
0
0
1.00
0.51
0
0
0
0
0
0.05
0.06
0
0
0
0
0
0
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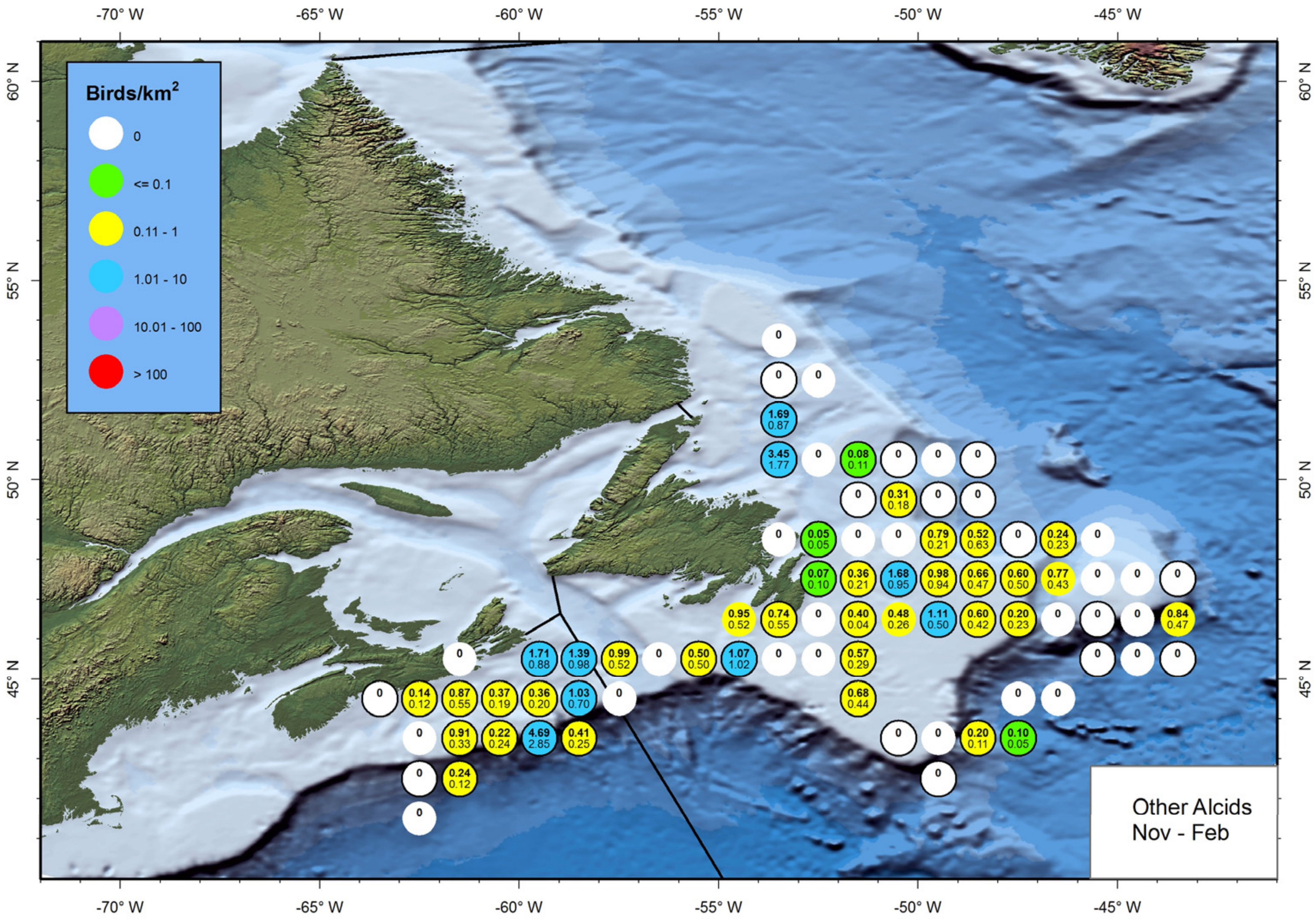
0
0
0.14
0.11
0
0
0
0
0
0
0
0
0
Other Alcids
Sep - Oct


-70° W
-65° W
-60° W
-55° W
-50° W
-45° W
60° N
55° N
50° N
45° N
Birds/km^2
0
<= 0.1
0.11 - 1
1.01 - 10
10.01 - 100
> 100
0
0
0
1.69 0.87
3.45 1.77
0
0.08 0.11
0
0
0
0
0.31 0.18
0
0
0
0.05 0.05
0
0
0.79 0.21
0.52 0.63
0
0.24 0.23
0
0.07 0.10
0.36 0.21
1.68 0.95
0.98 0.94
0.66 0.47
0.60 0.50
0.77 0.43
0
0
0
0.95 0.52
0.74 0.55
0
0.40 0.04
0.48 0.26
1.11 0.50
0.60 0.42
0.20 0.23
0
0
0
0.84 0.47
0
1.71 0.88
1.39 0.98
0.99 0.52
0
0.50 0.50
1.07 1.02
0
0
0.57 0.29
0
0
0
0
0.14 0.12
0.87 0.55
0.37 0.19
0.36 0.20
1.03 0.70
0
0.68 0.44
0
0
0
0.91 0.33
0.22 0.24
4.69 2.85
0.41 0.25
0
0
0.20 0.11
0.10 0.05
0
0.24 0.12
0
0
Other Alcids
Nov - Feb

6.2 Appendix 2: Summary of Recommendations Stemming from This Report

Recommendation 1 *– The CWS ECSAS survey protocol, which includes snapshots for relative movement and distance sampling for detectability, should be adopted as the common standardized protocol used by all survey programs.*

Recommendation 2 *− Industry, private sector and government agencies involved in pelagic seabird monitoring should develop standardized data analysis and mapping techniques and endeavour to maintain consistency as they keep themselves apprised of new developments in the field.*

Recommendation 3 *– The CWS should continue its standardized training program and provide formal accreditation when training new and existing observers. A refresher program should also be developed to maintain skills and provide updates as protocols are updated and improved.*

Recommendation 4 *− Appropriate data analysis training, such as the distance sampling workshops, should be made available to all practitioners responsible for analysing pelagic seabird survey data.*

Recommendation 5 *− The ECSAS database should be adopted as the common data management and sharing platform for all industry-related seabird surveys.*

Recommendation 6 *– The CWS should continue to act in a QA/QC role for the rig observer program by providing feedback on seabird identification, protocol compliance and data management.*

Recommendation 7 *− An accredited training program should be undertaken by new and existing observers and regular CWS staff visits with rig observers offshore should be made a priority.*

Recommendation 8 − *The ECSAS database should be adopted as the data management platform by the industry observer program.*

Recommendation 9 *− Future seabird surveys should incorporate distance sampling methodology and analysis to estimate absolute seabird density. Future environmental assessments should use the most recently available detection-corrected density estimates as references.*

Recommendation 10 *− At least seasonal "maintenance" surveys to increase estimate precision and maintain data timeliness should continue to be conducted to the production areas on the northeastern Grand Banks and Scotian Shelf.*

Recommendation 11 *− Data currency should be maintained through a rotating schedule of intensive effort focusing on major areas of interest including the Grand Banks, Scotian Shelf, Labrador Shelf, and south Newfoundland coast/Laurentian Channel/Sydney Basin. Exact timing and order should be determined in accordance with data gaps and the geographical focus of potential or realized oil industry activity.*

Recommendation 12 − Intensive survey effort should be directed towards remaining gap areas beginning with the Labrador Shelf.