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Baseline Surveys for Seabirds on the Labrador Sea (2010-08S):

Interim Report

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1. Background

As part of the Memorandum of Understanding *"Baseline surveys for Seabirds on the Labrador Sea (2010_08S)*, Environment Canada is to compile data and provide a report on at-sea survey progress made in 2013. This report summarizes ship-based and aerial surveys during the field season of 2013; these concerted efforts have substantially increased survey coverage since previous work done in 2006-2009 (Fifield et al. 2009).

2. Summary

Offshore seabird monitoring is required to accurately assess the potential spill impact on marine seabirds. Fifield et al. (2009) recommended that baseline pelagic at-sea survey coverage in the Labrador Sea be improved, particularly given the recent exploration interest in the Labrador Sea Strategic Environmental Assessment (SEA) area. Subsequently, ESRF funded a project to address this data gap. Following survey protocols developed by Fifield et al. (2009) and Gjerdrum et al. (2012), this report summarizes survey effort and ship-based density of marine birds in 2013. It also reports on abundance data and effectiveness of pelagic aerial surveys for monitoring seabirds.

In conjunction with the Canadian Wildlife Service's Eastern Canada Seabirds At Sea (ECSAS) program, 19 survey trips were conducted in 2013 in Atlantic Canada, 5 of which were specifically on the Labrador Shelf. In addition, 2 aerial surveys were conducted on the Labrador Shelf. Putting ship-based and aerial together, the Labrador Shelf surveys covered a total of 4,760 km^2 of ocean and counted 36,513 birds overall. Survey effort occurred from August – November 2013. Distance sampling was used for both ship-based and aerial surveys, which is essential for more precise abundance estimates. Drawing on the strength of the long-term ECSAS database, detection functions were used to calculate seabird density (cf. Fifield et al. 2009) for ship-based surveys. Ship-based density estimates generally had wide confidence limits, a function of only having one year of data and will be greatly improved by increased survey effort in future years. Further effort is required to establish detection functions and density estimates for aerial surveys. We report here uncorrected abundance and distribution information for aerial surveys.

Results from 2013 indicate seabirds were abundant across the Labrador Shelf SEA, particularly over Nain Bank and the Labrador Trough, and including the areas of exploration and significant discovery. Ship-based surveys indicate northern fulmar and dovekie to be the most abundant species seen on Labrador Shelf, followed by Black-legged kittiwake, shearwaters, gulls, and murres. Similarly, aerial surveys found fulmar, gulls, alcids, and eiders to be highest in abundance.

3. Introduction

The Labrador Sea is important to marine birds year-round, by supporting breeding seabird colonies during summer, and providing important staging, migration, and wintering habitat for seabirds from widespread colonies internationally, including Canada, Greenland, Iceland, Svalbard, and the UK (Brown 1986, Huettmann and Diamond 2000, Bakken and Mehlum 2005, Frederiksen et al. 2011, Mosbech et al. 2012, Jessopp et al. 2013, Linnebjerg et al. 2013, Fort et al. 2013, McFarlane Tranquilla et al. 2013). However, explicit local-scale spatial information on marine bird distribution has been limited by patchy marine survey coverage in the Labrador Sea (Fifield et al. 2009), mostly due to logistical difficulties.

The Labrador Sea contains significant oil and gas reserves and has been a focus for resource exploration for decades (AMAP 2010). Yet, only recently has an increase in interest for offshore exploration in the Labrador Sea prompted a demand for better baseline biological data, which is currently sparse in this region (Fifield et al. 2009), but which is needed to support regional scale environmental assessments (C-NLOPB 2008). Seabirds are extremely vulnerable to the effects of oil at sea (Wiese and Robertson 2004, O'Hara and Morandin 2010), but determining the effect of an accidental hydrocarbon release in the marine environment is difficult when seabird densities in a particular area, and a particular season, are not known.

Understanding the spatial and temporal extent of overlap of marine bird populations with offshore resource activities will be critical to the environmental assessment process (Camphuysen et al. 2004, Fifield et al. 2009), and to understanding potential risks to marine birds. This report, supported by ESRF, details the collection of baseline data on marine seabird distributions in the Labrador Sea that could be affected by offshore activities.

4. Objectives

As stated in the MOU, this project supports baseline surveys of seabirds in the Labrador Sea, in order to provide information that will support regulatory decision-making regarding mitigation of the effects of oil and gas production activities along the Labrador Sea (Figure 1).

The specific objectives of this study are to

1. Conduct baseline surveys of seabirds in the Labrador Sea in support of ongoing oil and gas exploration and future oil and gas development;
2. To identify, collate, and integrate any existing data relevant to pelagic seabird distributions in the Labrador Sea;
3. To provide fundamental information on the distribution and species population densities of the seabirds in the study area;
4. To involve, train, and transfer expertise to local and in particular, aboriginal individuals, the technical skills involved in conducting such surveys whenever possible;
5. To maintain positive control of the scientific methodology and quality of the data gathered during the surveys;
6. To ensure safety of any in-field study operations

5. Methods

5.1. Ship-based surveys

The study area is aligned with the Labrador Shelf Strategic Environment Assessment (SEA) Area (C-NLOPB 2008), defined using NAFO regions (2G, 2H, 2J) within the Canadian EEZ (Figure 1). Surveys were conducted within the purview of Canadian Wildlife Service's ongoing East Coast Seabirds At Sea (ECSAS) program (Gjerdrum et al. 2012), benefitting from access to a pool of experienced observers, established logistical support, and the strength of an ongoing database archive. Ship-based surveys were conducted following a standardized protocol that incorporates distance sampling methods (Gjerdrum et al. 2012).

Observers were placed on ships of opportunity, except for one survey on the Labrador Shelf (aboard the F/V *What's Happening* from Nain, Labrador, captained by Mr. Joey Agnatok). The latter deploy hydroacoustic recorders at two points on the Labrador Shelf to detect marine mammals (in collaboration with Dr. Jack Lawson, DFO; see MOU *"Mid-Labrador Marine Megafauna and Acoustic Surveys on the Labrador Coast (2010-07S)" and associated report*).

Ship-based seabird surveys consisted of 5-minute watches along a continuous transect line. Transect coordinates at the beginning and end of each watch were recorded using ship-based navigation systems or, if not available, with hand held Garmin GPS units. Environmental data variables were also collected and updated at the beginning of each watch (Table 1; see also Gjerdrum et al. 2012). Birds were recorded along the transect, incorporating distance sampling for birds on water and in flight; birds on the water were recorded continuously throughout the transect, but we used a shapshot approach for flying birds (Tasker et al. 1984, Gjerdrum et al. 2012). All birds (flying and on water) that had a distance were used to determine detectability. As outlined in Gjerdrum et al. (2012), birds were assigned distance categories with the help of a ruler pre-marked with the distance bands. Distance bands were lettered A, B, C, D, and E, and corresponded to distance ranges 0-50, 50-100, 100-200, 200-300, and > 300 metres respectively (see Table 2). Data were collected with the observer estimating perpendicular distance as defined above to each individual bird or the centroid of a group of birds. Ship-based survey area was calculated as the product of transect length and transect width.

5.2. Aerial surveys

Aerial seabird surveys on the Labrador shelf (Figure 2) were done in collaboration with marine mammal surveys conducted by Dr. Jack Lawson (DFO; see above). Aerial surveys were designed to cross the shelf, to capture variation in seabird distribution across a variety of depths and to ensure survey coverage beyond the shelf edge. Aerial surveys were conducted along six transect lines, and transect length and direction were defined by Dr. Jack Lawson prior to the study. The first survey occurred on 16 October 2013, but due to weather it was only a partial survey; the first full replicate (a complete survey of all 6 lines) was on 17 October 2013. A second full replicate was completed in on 2 November 2013. Flight paths were chosen to ensure proximity to airstrips and fuel throughout the duration of the survey.

Aerial transect definition - Aerial surveys were conducted using distance sampling, aided by the use of a clinometer to establish transect widths and distance bands (Camphuysen et al. 2004). Similar to ship-based surveys, this method estimates the perpendicular distances from the survey line to the animals detected (Buckland 2001). In contrast to the 5-minute watches of ship-based surveys, aerial surveys were continuous except when the plane was turning from the pre-established survey line. In the case of ship-based seabird surveys, birds are assigned to distance categories which are parallel bands of known width (Gjerdrum et al. 2012; Camphusen et al. 2004), however, in the case of aerial surveys, the increased elevation means that transect width has the potential to be considerably greater for aerial than for ship-based surveys, and the closest transect (distance band from 0-50 m from the transect line) can be in a blind spot (directly underneath the plane). Therefore, two different transect widths and two window types (bubble and flat) were tested for the aerial survey based on observer field and depth of view (see Table 2).

Aerial Survey Distance Categories - Birds were assigned to a distance category based on a pre-determined distance band that was marked on the observer window using a dry erase marker. For replicate 1, bands were lettered A, B, C, D, and E and corresponded to the same distance ranges used in the ship-based survey (Gjerdrum et al. 2012; see Table 2). During replicate 1, there was a large blind spot on the starboard side due to the flat window. Also, due to the flight altitude, the distance bands appeared very narrow to the observer. To remedy this, during replicate 2, the distance bands were widened and the blind spot was accounted for. The new bands were lettered Z , A, B, C, D, and E, and corresponded to distance ranges 0-100, 100-200, 200-300, 300-500, 500-700, and > 700 metres respectively (see Table 2). Distance band Z only existed on the port side of the aircraft and allowed for the assignment of extra observations that did not exist on the starboard side of the aircraft due to the presence of the bubble window. Clinometer angles (Table 2) corresponding to desired distances (e.g. angle from horizon corresponding to 100 meters) were measured using an arc distance formula, which takes into account the curvature of the earth (Lerczak and Hobbs 1998). Methods for establishing distance bands and associated detection functions for seabirds (cf. Fifield et al. 2009) from aerial survey data require further testing.

Future Challenges #1:

For aerial surveys, further research is necessary to determine optimal distance categories based on field of view and detectability. Much of the literature proposing distance categories deals with much lower altitudes, which allow for a more parallel observation angle, and for distance band limits as far as 1000 meters from the platform. At an altitude of 600 feet this distance limit is not feasible. Even the limit used in the present study (700 meters) was less than desirable, with very few observations falling near this limit. Further trials would allow for the development of a standardized survey protocol for pelagic seabird surveys at 600 feet (also see Bolduc and Desbiens 2011).

Aerial Survey Platform and Equipment - Transects were flown using a twin engine Twin Otter aircraft operated by Air Labrador based out of Goose Bay, Newfoundland and Labrador. The port (left) side of the aircraft was equipped with a bubble window provided by Dr. Jack Lawson (DFO) while the starboard (right) side had a Twin Otter standard flat window. For replicate 1, observers recorded data by dictating observations into a Sony ICD-BX132 voice recorder and recorded flight track information using a Garmin GPSmap 62s handheld GPS. For replicate 2, the port side observer used a Panasonic Toughbook laptop linked to a Garmin GPSmap 78s handheld GPS and a Plantronics Digital DSP 400 headset with microphone connected to the computer. Recordings were captured using USFWS VoiceGPS software. The starboard side observer continued with replicate 1 method of voice dictation into a SONY ICD-BX132 voice recorder. A SUUNTO clinometer was used to measure angle from the horizontal.

Aerial Survey Data Collection - Surveys were flown at an optimum flight speed of 100 knots and altitude of 600 feet. Data were collected by two observers from both the port and starboard side simultaneously, with observers switching positions at regular intervals during replicate 1 and remaining on the same side during the entirety of replicate 2. For replicate 1, data were recorded to the nearest minute, with time read from the voice recorder display. For replicate 2, data were recorded to the nearest second, with time automatically recorded with the computerized system and manually recorded from a stopwatch with the voice recorder system (observations from replicate 2 were subsequently binned into one-minute segments during data analyses to ensure similar count units across both replicates). Birds were assigned a distance category as outlined above. Numbers of Individuals were counted and distance categories were assigned based on the distance to an individual bird or distance to the centroid of a group of birds. All birds observed were considered in transect unless they were in distance category E. Environmental data as described in Table 1 were also collected for the aerial surveys. Aerial survey area was calculated as the product of transect length and 300-m transect widths for replicate 1, and 700-m transect widths for replicate 2.

Future Challenges #2:

The absence of a bubble window on the starboard side created issues both in pooling port and starboard side data, as well as in overall detectability. Significantly more birds were recorded from the port (bubble window) side, as would be expected. The flat window on the starboard side had distortion near the edges, further restricting visibility. Bubble windows should be used for all observers for further trials.

Future Challenges #3:

At a survey altitude of 600 feet, detectability is limited. Species identifications are typically limited to the genus or family level, except in the case of obvious species (e.g. Northern Fulmar, Great Black-backed Gull). On further trials *double observer* methods as outlined in Buckland et al. (2010) should be employed due to the uncertainty in detection. Ideally, aerial surveys for seabirds should be conducted at an altitude of 60 m (200 feet) or less.

5.3. Data Transcription

Ship-based surveys – Data was either entered directly into the ECSAS Access database using voice recognition software and linking to the ship's navigation system, or recorded on datasheets and entered into the database later (see full details in Fifield et al. 2009).

Aerial Surveys - Recordings from voice recorders and the USFWS VoiceGPS system were saved to a .wav file for data backup and transcribed to a Microsoft Excel file (.xls). Coordinate information for each observation was interpolated by matching the time dictated into the voice recording or captured by the software with the time in the track file recorded from the handheld GPS. Tracks, observations, and raw counts were then mapped using ESRI's ArcGIS 10.1 software. Observation data was binned into one minute intervals.

5.4. Seabird Counts and Density Estimation

Total seabird counts over all surveys are presented. However, raw counts significantly underestimate seabird distribution due to decreasing bird detectability with increasing distance from the observation platform (Buckland et al. 2001, Fifield et al. 2009). Therefore density corrected for detectability was calculated whenever possible; for this report, we calculated density for ship-based surveys only. At the survey flight altitude of 600 ft, gull species were indistinguishable from one another; gull species were thus defined by as white winged or black winged gulls.

For aerial surveys, counts were pooled into one-minute observation segments; for replicate 1, this is how the data were collected. For replicate 2, which recorded data at one-second intervals, this required pooling data into one-minute segments. Subsequently, all observations and watches are reported in one-minute segments.

For ship-based surveys, seabird densities were calculated in R (version 2.15) using a newly-developed GeoAviR package (Roy et al. 2013) that links to DISTANCE (Thomas et al. 2010). Given that the 2013 Labrador Shelf surveys alone did not provide enough detections to obtain reliable estimates of species-specific detection functions, all data from ECSAS database (2006-2013) were used to calculate the detection functions for particular species (Fifield et al. 2009). Survey transects were overlaid with a 100km x 100km grid bounded by (52 – 61 °N) and (49 - 64 °W) over the study area. Only the grid cells that overlapped with survey effort were retained in the analyses. GeoAviR was used to compute detection functions (see Appendix 1) and density for each seabird species (or family group) in each grid cell (c.f. Fifield et al. 2009, Buckland et al. 2001), along with variance (coefficient of variation, upper and lower 95% confidence intervals). Shapefile outputs from R were mapped in ArcMap 10.1. To compute overall seabird density, the shapefiles of species densities from the R output were converted to rasters, overlaid on each other, and averaged using cell statistics (Spatial Analyst tools), to produce a map illustrating grid cells in the study area where average density of all seabirds was highest.

6. Results

6.1. Objective 1. Conduct baseline surveys of seabirds in the Labrador Sea in support of ongoing oil and gas exploration and future oil and gas development

6.1.1. Ship-based Surveys

From February to November 2013, ECSAS observers were placed on 19 ships of opportunity, 6 of which were supported by ESRF (during August-November). ECSAS ship-based surveys covered 24182 linear km (7255 km^2) overall, including 4662 linear km (1398 km^2) on the Labrador Shelf alone (Table 3), and counted 66,548 marine birds, including 30,212 on the Labrador Shelf. Among the most frequent observations on the Labrador Shelf were of northern fulmar, kittiwake, dovekie, and thick-billed murre (Table 4).

Ship-based survey effort was distributed unevenly across the study area, as depicted in Figures 5 and 6, with transect length (range 9-340 km) and survey frequency (range 1-9 days) varying substantially per grid cell. This effort has implications for accuracy of density estimates (see Table 7 and Appendix II).

6.1.2. Aerial Surveys

In November 2013, two aerial surveys covering 3,384 km^2 (survey length x transect width) were conducted on the Labrador Shelf, and counted 6,263 marine birds (Table 3). By far the most frequent observations were of northern fulmar, followed by unidentified white-winged gull (potentially including kittiwakes, Iceland gull and glaucous gull), and large alcids (likely thick-billed murre, common murre and razorbill; Table 5).

6.2. Objective 2. To identify, collate, and integrate any existing data relevant to pelagic seabird distributions in the Labrador Sea

This segment of the project began in November 2013 and is ongoing. A list of candidates that may have completed baseline seabird surveys in the Labrador Sea is being compiled through investigations into EA applications and collaboration with C-NLOPB project records. To date, 6 discreet datasets associated with seismic projects have been identified, and we expect more datasets to trickle in over time. Once identified, proponents will be contacted to release raw data directly. Given the relatively limited ship traffic and expense of operating on Labrador Sea, any industry collected data could have great value to augment the data set.

Other existing data include incidental seabird sightings from DFO marine mammal surveys (Dr. Jack Lawson) and from the Irish whale and dolphin group.

Data entry (of raw data and metadata into a database) is also ongoing. One valuable outcome of this is the recognition of the type and quality of data collected by proponents (through their consultants). Proponents are provided a standardized protocol with datasheets, including a list of specific data fields, in an attempt to ensure the highest standard of data collection. Once the all the data holdings are made available and examined, specific recommendations on improving or maintaining data quality from industry will be provided.

6.3. Objective 3. To provide fundamental information on the distribution and population densities of the seabirds in the study area

6.3.1. Ship-based Surveys

Survey frequency was not yet sufficient to determine seasonal abundances (cf. Fifield et al. 2009), therefore all data were pooled to represent overall seabird patterns. Detection probabilities were calculated to inform densities of the following groups: large alcids, fulmars, shearwaters, dovekies, storm petrels, and gulls. Interestingly, detection probabilities for all groups declined to less than 40% past the 100m distance band, seemingly without relation to body size. By way of comparison, Barbraud and Thiebot (2009) reported a much higher detectability among *flying* seabirds of multiple body sizes in the South Atlantic: in their study, detectability was 0.98 within the first 100m and did not decline to below 40% until past 800m transect width. This may partly be due to bird behaviour (flying), and partly because they were generally counting larger seabirds (ranging from <500 g to 11000 g) compared to those observed in this study. Full details on ship-based species detection probabilities (on-water seabird detections) from this study are presented in Appendix 1. We recommend further investigation to clarify and confirm conditions under which detectability varies in this study area.

Northern fulmar and dovekie were the most abundant species in survey cells on Labrador Shelf (see below). Figures 7-13 detail the densities (birds/km^2) of birds per grid cell (100 km x 100 km) on the Labrador Shelf, from ship-based surveys. In addition, Table 6 summarizes density and associated variance estimates for each species, and Appendix 2 details density and variance in each survey grid cell for each species.

Large Alcids – Distribution of large alcids (thick-billed murre *Uria lomvia*, common murre *Uria aalge*, razorbill *Alca torda*) was widespread in the study area, with occurrences in almost every surveyed grid cell (Figure 5). Higher densities of large alcids (13-66 birds/km^2) occurred in survey cells closer to shore and on the shelf, particularly near Nain Bank and the Labrador Trough; densities were lower past the shelf (Figure 7). Average density of alcids overall was 7.81 $\pm$ 11.4 (SD) birds/km^2 (Table 6).

Dovekie – Distribution of dovekies *Alle alle* was more limited than that of other alcids, possibly reflecting a seasonal element of their distribution on the Labrador Shelf; this species breeds at higher latitudes and is present in Labrador Shelf waters only in winter and spring (Fort et al. 2013). Densities were highest (20-124 birds/km^2) in coastal and shelf grid cells, especially over Nain Bank and the Labrador Trough, but a few higher densities were also seen past the shelf in the Labrador Basin (Figure 8). Despite more limited distribution, dovekies were the second-most abundant species in the study area, averaging 14.6 $\pm$ 29.3 (SD) birds/km^2 (Table 6).

Northern fulmar – Distribution of Northern fulmar *Fulmarus glacialis* was extensive, with detections in every surveyed grid cell. Highest densities (25-109 birds/km^2) seemed to coincide with the shelf and shelf edge (Figure 9), particularly Nain Bank. Average density of fulmars overall was 17.5 $\pm$ 19.4 (SD) birds/km^2 (Table 6), making them the most abundant species in this study area.

Gulls – Distribution of gulls (includes Great Black-backed Gull, Herring Gull, Glaucous Gull, Iceland Gull, Black-legged Kittiwakes) was widespread, with detections in almost every surveyed grid cell (Figure 10). Highest densities (18-33 birds/km2) did show any particular distribution pattern. Average density of gulls overall was 8.6 $\pm$ 7.4 (SD) birds/km^2 (Table 6).

Shearwaters – Distribution of shearwaters (includes great shearwater *Puffinus gravis*, sooty shearwater *Puffinus griseus*), Cory's shearwater *Calonectris diomedea*, and Manx shearwater *Puffinus puffinus*) was not as widespread, occurring mostly on the shelf and shelf edge, and less abundant nearshore and in the north of the study area (Figure 11). One exception to this is the nearshore segment at the Strait of Belle Isle where a high density was observed. Average shearwater density overall was 2.5 $\pm$ 4.9 (SD) birds/km^2 (Table 6).

Storm-Petrels – Distribution of Leach's Storm-Petrels *Oceanodroma leucorhoa* was very sparse, occurring in only 6 grid cells in the south of the study area (Figure 12) over Hamilton Bank, and almost always over or beyond the Labrador shelf. Likewise, densities were very low, ranging from 0 – 0.62 birds/km^2, and averaging 0.05 $\pm$ 0.14 (SD) birds/km^2 (Table 6).

All Seabirds – All species were combined to calculate average seabird density per grid cell in the study area. Seabirds were seen in every grid cell, with the highest densities in the central portion of the study area, over Nain Bank and the Labrador Trough, and overlapping three significant discovery licences (Figure 13). Overall seabird density ranged from 0.8 – 36 birds/km^2.

6.3.2. Aerial Surveys

Uncorrected species level and group level abundance estimates are displayed in Figures 14-17. These are displayed as absolute counts, uncorrected for detectability, despite distance sampling methods employed. This was due to lack of statistical power, i.e. more observations/detections for each species/group would be needed before a detection function could be computed.

All Waterbirds - The waterbird group in the Labrador Shelf region is dominated by seabirds, particularly fulmars, alcids, gulls, terns, and kittiwakes. Also found in the region are several species of waterfowl, including scoters and eiders.

Raw counts of all waterbirds yielded a total of 6,301 birds (Table 5) recorded over 790 one-minute segments (average 7.98 $\pm$ 31.81 (SD) per segment; Table 7). Highest abundance was found on the most southerly transect (Transect 6; see also Figure 2c), and near the coast on northerly transects (Transects 1 and 2; Figure 14).

Alcids - Alcids were identifiable at the group level based on colouration and flight and dive behaviour. Included in this group were the common murre (*Uria aalge*), thick-billed murre (*Uria lomvia*) and Razorbill (*Alca torda*). Raw counts of alcids yielded a total of 856 birds over a total of 146 one minute segments (average 5.86 $\pm$ 7.76 (SD); Table 7). The densest aggregations were found around the most northerly transects, Transects 1 and 2 (Figure 15).

Northern Fulmars – By far the most predominant species observed was Northern fulmar (Table 5, Figure 16). These were one of few species that could be positively identified at this altitude, largely due to their unique aggregation and flight behaviour. Raw counts of Northern Fulmars yielded a total of 3,664 birds (Table 5) over 340 one-minute segments (average 10.78 $\pm$ 31.41 (SD) per segment; Table 7). Densest aggregations were along Transect 6 and 5 (Figure 16; see also Figure 2), the two most southerly lines on the survey. Although not corrected for density, the distribution of these observations likely provide a more accurate index than values determined through ship based surveys. Northern Fulmars are notorious ship followers, making ship-based estimates difficult to interpret. With an aerial survey at an altitude of 600 feet there is no association between fulmars and vessels, and subsequent distribution is likely to be more representative.

Gulls -Black winged gulls likely to be those that regularly occur offshore in the Labrador Shelf, mainly Great Black-backed Gull (*Larus marinus*) and possibly the occasional Lesser Black-backed Gull (*Larus fuscus*). Black winged gulls in the aerial survey were not abundant; four sightings (totalling 4 birds; Table 5) were recorded in the database but are not further presented in the results.

White winged gulls (Figure 17) likely included Herring Gull (*Larus argentatus*), Glaucous Gull (*Larus hyperboreus*), Black-legged Kittiwake (*Rissa tridactyla*), and possibly some Ring-billed Gull (*Larus delawarensis*), Iceland Gull (*Larus glaucoides*), and tern species. Raw counts of gulls yielded a total of 833 birds (Table 5) over a total of 278 one minute segments (average 2.96 $\pm$ 5.02 (SD); Table 7). Dense aggregations were found around Transects 1, 2, and 6, though white winged gulls were found consistently throughout the survey extent. This widespread distribution was also seen in ship-based surveys.

6.4. Objective 4. To involve, train, and transfer expertise to local and in particular, aboriginal individuals, the technical skills involved in conducting such surveys whenever possible

As identified in Fifield et al. (2009), training a pool of skilled observers is critical to conducting effective at-sea seabird surveys over a broad geographic area. Six observers were trained in 2013 for the ECSAS program. As well, two at-sea survey training workshops were conducted (January 2013 (NS) and October 2013 (NL)) to review seabird identification and provide instruction for data recording and management. These workshops were followed by ship-board training with an experienced observer in 5 cases.

One of the ships we surveyed from was the the F/V *What's Happening*, a 65ft Inuit-owned crab fishing boat belonging to Jack Angnatok from Nain, Labrador. The vessel was comfortable, with a port indoor observation station and starboard outdoor observation station, and the captain and crew were proficient, knowledgeable, interested in the research, and expressed an interest in future work. It is recommended that this local connection be continued, and may present an excellent platform for training local and aboriginal individuals in the future.

6.5. Objective 5. To maintain positive control of the scientific methodology and quality of the data gathered during the surveys

All data collected in 2013 were under the purview of the ECSAS program, therefore all QA/QC measures of that program were in place. As a result, all observers were trained in seabird identification, the CWS protocol, distance sampling techniques and how to use the database to record their data. All data were examined by Carina Gjerdrum before final importation into the ECSAS database. The ECSAS program uses the latest methods for ship-board seabird surveys, with detailed instruction on how to record each possible type of bird detection (Gjerdrum et al. 2012).

To increase the utility of data collected by industries operating on the Labrador Sea, a seabird observation protocol was developed that could be incorporated by marine mammal observers operating on seismic vessels. This consultation was undertaken with Danish authorities, as wildlife observers on seismic vessels in Greenlandic waters are required to collect both marine mammal and seabird data (in Canada they are only required to site marine mammals, although EC, through CNLOPB, requests that all seismic vessels collect seabird data). These protocols were provided to GX Technology (GXT) for use this summer and the success of these modified protocols will be assessed when the data from GXT are made available.

6.6. Objective 6. To ensure safety of any in-field study operations

EC staff were required to read and sign off on relevant Task Hazard Analysis and Safe Working Practices. In the field, all observers were equipped with first aid, communications, navigation, and safety gear as appropriate for the survey platform (more equipment was provided to aerial observers in a Twin Otter, compared to observers on CCG vessels). Safe in-field operations were additionally supported through Small Vessel Operator’s Proficiency (SVOP), Marine Emergencies Duties - A1, Basic Safety Training, and Wilderness and Remote First Aid training for observers and field personnel. Contractors were required to meet the minimum training requirement of vessels they were on, and all contractors had comprehensive liability insurance. Offshore aerial surveys also required life vests with attached oxygen reserve.

7. Discussion

Significant progress was made in extending year-round coverage (May-Nov) on the Labrador Shelf, which was previously limited (Fifield et al. 2009). However, continued effort is required to address seasonal-specific abundance and distribution patterns of seabirds in the Labrador Shelf, rather than pooled estimates for year-round coverage. Although logistically challenging, any future opportunity for survey effort in the winter and spring will be helpful.

In general, May through August is a period where locally breeding seabirds will be abundant near their coastal breeding colonies, with influxes of austral breeding species (shearwaters) later in the summer and into the fall. The fall (Sep-Oct) and early winter (Nov) will be a time of significant migrations (McFarlane Tranquilla et al. 2013, Fort et al. 2013), as Arctic breeding species migrate south from Baffin Bay/Davis Strait and Hudson Strait; influxes of European breeding birds is also expected this time of year (Fredericksen et al. 2011). This differs from the Grand Bank, which is a terminal wintering area for many species.

Ship-based coverage for the Labrador Shelf was uneven both in space and time (Figures 5,6). Therefore, seabird densities presented in this report should be treated as preliminary because densities may be artificially inflated or depressed (i.e. see Appendix II for confidence intervals). Inflated densities could arise if ship transects happen to be focused in high density areas or are timed when seasonal peaks in migration may occur. Depressed densities may occur when seasonal peaks are missed, or when most of the survey effort occurs in areas not commonly used by particular species. More survey effort will resolve these issues; as more data are collected, the densities can be stratified into finer units of time (i.e. to produce seasonal estimates) and seabird spatial distributions can be more closely defined (i.e. if species assemblages and densities differ across shelf zones of the Labrador Sea).

In spite of some constraints, ship-based surveys clearly show that northern fulmar, dovekie, kittiwake, and thick-billed murre are abundant species on the Labrador Shelf. None of these species are abundant breeders in Labrador, indicating the importance of the Labrador Shelf as non-breeding habitat for seabirds. This is corroborated by aerial surveys, which made the same findings but at a lower species resolution: northern fulmar, white-winged gulls (including kittiwakes) and large alcids were abundant. Interestingly, aerial surveys detected very large groups of fulmar independent of the ship-following behavioural bias that is often noted by ship-based observers for this species. Dovekie were not observed in abundance on aerial surveys, possibly due to low detectability from the air.

High densities of seabirds were seen over Nain Bank, Labrador Trough, and Makkovik/Hopedale banks where significant discovery and exploration licences also occur.

The overall assemblage of seabirds on the Labrador Sea had both similarities and differences to the Grand Bank (Fifield et al. 2009). Shearwaters were seen in abundance in later summer and early fall in both regions. Dovekies were present in larger numbers in the fall, similar to the Grand Bank. Northern Fulmar densities were higher in Labrador, compared to regions to the south (also noted by Fifield et al. 2009). Not surprisingly, when identified to species, Thick-billed Murres were more commonly seen on the Labrador Sea than Common Murres; although this likely has a strong seasonal component, with Thick-billed Murres more likely to be present during winter (McFarlane Tranquilla et al. 2013). A mix of both murre species are more likely to be seen in areas to the south (Tuck 1961, McFarlane Tranquilla et al. 2013). Leach's Storm-petrel were noticeably absent on the Labrador Sea, which has implications for stranded seabird programs that would be put in place on industry platforms. Northern Gannets were also noticeably absent in the Labrador Sea.

The data collected in 2013 on the Labrador Sea has begun to fill information gaps for this region. Future work is needed to address the spatial and season gaps, allowing the data to be appropriately stratified. Given the costs and efforts of operating in Labrador, other tools and data to improve seabird densities should be considered. Techniques to combine results from the aerial and ship-based surveys are one such approach, such as density surface models (Hedley et al. 2004). Information from tracking studies can also be used inform or test these models (Robertson et al. 2012), which will further the ability to accurately predict seabird densities in Labrador waters.

8. Conclusions and Recommendations for 2014

Conclusions

- In general survey efforts were very successful and have already greatly increased the amount of information available for the Labrador Shelf
- The aerial approach worked better than expected; it provided greater spatial coverage per unit time, potentially fits well with oil and gas emergency response using fixed-wing aircraft, and has the advantage of removing the over-detection bias for ship-following birds such as fulmars. However, there are methodological and technical details that need more attention, and these surveys do not allow the differentiation of most species.
- Running survey data through a large long-term database like ECSAS is necessary to inform detection functions, particularly when small numbers of individual surveys would not otherwise have the statistical power to do so. Even data collected outside of the Labrador Shelf is useful to this project.
- The development of the R package GeoAviR by François Bolduc proved to be invaluable to analyse the data collected for Labrador Shelf. Traditionally the analysis to produce

the detection-corrected densities presented in this report would take weeks to conduct. GeoAviR automates many of the analyses, and the analysis was conducted in a few days.

Recommendations

- Further develop techniques for aerial surveys and formalize the methodology to compute detection functions and densities.
- Continue to fill data gaps for Labrador Sea, especially to address seasonal patterns. In particular, spring surveys (when there are fewer surveys) will continue to be important (cf. Fifield et al. 2009). Capturing seasonal variation in seabird densities will be very important to appropriately estimate risk to seabirds in the case of an accidental hydrocarbon release (Fifield et al. 2009).
- Explore modeling tools and techniques to combine data sets (ship-based, aerial-based and tracking) allowing for more precise estimates of seabird densities. Continue to collect data in areas adjacent to the Labrador Shelf when opportunities arise, especially areas in the north and immediate south, which have similar species assemblages (and therefore can be used to inform detection functions).
- Continue to work with industry to ensure than any data collected in Labrador (and elsewhere) follows the ECSAS protocol and are made available. Continue with efforts to identify and enter previously collected data.
- Nurture the relationship Mr. Joey Agnatok captain of the F/V *What's Happening* from Nain, Labrador. This vessel and crew proved to be an excellent survey platform, and has the added advantage of engaging the local and aboriginal community.
- Given the exceptional usefulness of the GeoAviR package, support future development of the package to increase its user-friendliness.

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10. Tables & Maps

Table 1: Environmental Data Variables

Variable Name
Visibility
Weather code
Glare conditions code
Sea state code
Wave height (m)
True wind speed (knots) OR BF scale
True wind direction (deg)
Ice type code
Ice concentration code

Table 2: Distance categories for aerial and ship-based surveys, and clinometer angles used for aerial surveys

Aerial Replicate 1 and Ship Based Survey		
Distance category	**Distance band (m)**	**Clinometer angle of top of band (aerial)**
A	0-50	74.8
B	50-100	61.5
C	100-200	42.7
D	200-300	31.6
E	> 300	N/A
Aerial Replicate 2		
Distance category	**Distance band (m)**	**Clinometer angle of top of band (aerial)**
Z	0-100	61.5
A	100-200	42.7
B	200-300	31.6
C	300-500	20.2
D	500-700	14.8
E	> 700	N/A

Table 3. Summary of seabird at-sea survey effort and data collected in Atlantic Canada and the Eastern Arctic in 2013, with particular reference to the Labrador Shelf (ESRF program, in grey; see also Figure 2). *Note number of watches for ship-based transects are tallies of 5-minute watches per trip, whereas aerial surveys are continuous watches and will equal number of trips.

Program	Platform	Trips	Number of watches*	Date range (2013)	Area surveyed (km^2)	Birds counted	Species counted
All ECSAS	Ship	19	14,912	26 Feb – 18 Nov	7,255	66,549	44
Subset ESRF	*Ship*	*5*	*3, 281*	*10 May – 16 Nov*	*1,398*	*30,212*	*27*
ESRF	Plane	3	3	16-17 Oct, 7 Nov	3,384	6,301	5 (3 unk)
Sum Labrador Shelf		8	3,284	Feb - Nov	4,760	36,513	28

Table 4. Summary of species sighted during surveys in 2013 throughout Atlantic Canada (including the eastern Arctic) compared to those sighted on the Labrador Shelf only.

			Atlantic Canada			Labrador Shelf		
Family	**Species sighted**	**Latin**	**No. of detections**	**No. of days detected**	**Total count**	**No. of detections**	**No. of days detected**	**Total count**
Gaviidae	Common Loon	*Gavia immer*	17	7	35	0	0	0
	Red-throated Loon	*Gavia stellata*	1	1	1	1	1	1
Procellariidae	Northern Fulmar	*Fulmarus glacialis*	4380	153	25680	1620	51	16704
	Manx Shearwater	*Puffinus puffinus*	22	15	29	1	1	1
	Great Shearwater	*Puffinus gravis*	1335	90	6116	433	34	2268
	Sooty Shearwater	*Puffinus griseus*	323	57	1404	33	12	44
	Cory's Shearwater	*Calonectris diomedea*	16	9	17	0	0	0
	Unidentified Shearwater	*Puffinus* or *Calonectris*	12	10	17	1	1	1
Hydrobatidae	Leach's Storm-Petrel	*Oceanodroma leucorhoa*	438	55	1612	14	5	16
	Wilson's Storm-Petrel	*Oceanites oceanicus*	160	29	232	0	0	0
	Unidentified Storm-Petrel	*Oceanodroma* or *Oceanites*	324	45	655	0	0	0
Pelicaniformes	Double-crested Cormorant	*Phalacrocorax auritus*	1	1	1	0	0	0
	Great Cormorant	*Phalacrocorax carbo*	1	1	1	0	0	0
	Unidentified Cormorant	*Phalacrocorax*	2	2	3	1	1	2
Sulidae	Northern Gannet	*Morus bassanus*	225	42	445	1	1	1
Anatidae	Greater White-fronted Goose	*Anser albifrons*	1	1	14	0	0	0
	Common Eider	*Somateria mollissima*	6	6	166	2	2	158
	King Eider	*Somateria spectabilis*	1	1	2	0	0	0
	Long-tailed Duck	*Clangula hymenalis*	13	9	252	0	0	0
	White-winged Scoter	*Melanitta fusca*	7	4	24	0	0	0
	Red-breasted Merganser	*Mergus serrator*	1	1	1	1	1	1
	Unidentified Waterfowl	Anatidae	2	2	2	1	1	1
Scolopacidae	Red Phalarope	*Phalaropus fulicaria*	26	13	154	13	6	53
	Red-necked Phalarope	*Phalaropus lobatus*	16	9	63	5	2	46
	Unidentified Phalarope	*Phalaropus*	12	9	69	1	1	1

Table 4 continued.

			Atlantic Canada			Labrador Shelf		
Family	**Species sighted**	**Latin**	**No. of detections**	**No. of days detected**	**Total count**	**No. of detections**	**No. of days detected**	**Total count**
Laridae	Great Skua	*Stercorarius skua*	20	9	24	3	2	3
	South Polar Skua	*Stercorarius maccormicki*	4	4	4	0	0	0
	Pomarine Jaeger	*Stercorarius pomarinus*	112	47	172	35	14	44
	Parasitic Jaeger	*Stercorarius parasiticus*	17	15	20	6	5	7
	Long-tailed Jaeger	*Stercorarius longicaudus*	25	15	32	8	4	8
	Unidentified Jaegers and Skuas	*Stercorarius*	40	17	53	6	4	7
	Black-legged Kittiwake	*Rissa tridactyla*	1688	132	6471	638	50	2791
	Ivory Gull	*Pagophila eburnea*	11	5	15	0	0	0
	Sabine's Gull	*Xema sabini*	11	5	103	0	0	0
	Black-headed Gull	*Larus ridibundus*	2	2	3	0	0	0
	Ring-billed Gull	*Larus delawarensis*	2	2	58	0	0	0
	Herring Gull	*Larus argentatus*	431	84	842	134	33	306
	Iceland Gull	*Larus glaucoides*	47	20	83	24	10	39
	Glaucous Gull	*Larus hyperboreus*	883	89	2628	387	37	1770
	Thayers Gull	*Larus thayeri*	25	8	28	0	0	0
	Lesser Black-backed Gull	*Larus fuscus*	1	1	6	0	0	0
	Great Black-backed Gull	*Larus marinus*	214	63	361	49	18	71
	Unidentified Gull	*Larus*	35	20	98	19	8	57
	Common Tern	*Sterna hirundo*	10	4	17	0	0	0
	Arctic Tern	*Sterna paradisaea*	14	10	43	3	3	9
	Unidentified Tern	*Sternidae*	9	8	18	2	2	4
Alcidae	Dovekie	*Alle alle*	1854	104	11515	577	35	3404
	Thick-billed Murre	*Uria lomvia*	1332	120	4105	592	48	1816
	Common Murre	*Uria aalge*	223	53	602	42	15	84
	Unidentified Murre	*Uria*	243	55	1076	58	18	171
	Atlantic Puffin	*Fratercula arctica*	345	57	592	76	14	144
	Black Guillemot	*Cepphus grylle*	85	23	183	17	5	31
	Razorbill	*Alca torda*	47	20	79	9	4	17
	Unidentified Murre or Razorbill	*Uria* or *Alca*	40	16	91	0	0	0
	Unidentified Alcid	Alcidae	116	37	232	63	16	131
Totals	**Total**				**66549**			**30212**

Table 5. Summary of species sighted from Labrador Shelf aerial surveys, from 16-17 October and 7 November, 2013.

Family	Species sighted	Latin	No. of detections	No. of days	Total count
Procellariidae	Northern fulmar	*Fulmaris glacialis*	1121	3	3,664
Alcidae	Unidentified alcid	*Alcidae*	227	3	856
	Dovekie*	*Alle alle*	1	1	1
Laridae	Great black-backed gull	*Larus marinus*	4	2	4
	Unidentified white-winged gull	*Laridae*	513	3	825
	Unidentified gull	*Laridae*	3	1	7
	Glaucous gull	*Larus hyperboreus*	1	1	1
Anatidae	Common eider	*Somateria mollissima*	4	1	905
	Unknown birds		15	3	38
				Total	***6,301***

*plus possibly 5 dovekie grouped with Unidentified alcid

Table 6. Summary of species (or group) density (birds/km^2) from ship-based surveys on the Labrador Shelf in 2013.

Species/group	Average density ± SD	Minimum density	Maximum density	Coefficient of Variation ± SD
Large Alcid	7.82 ± 11.4	0.00	65.96	41.5 ± 33.1
Dovekie	14.60 ± 29.3	0.00	124.15	68.0 ± 43.7
Gulls	8.56 ± 7.45	0.00	33.35	43.8 ± 31.0
Northern fulmar	17.46 ± 19.36	0.83	109.15	64.7 ± 43.8
Leach's Storm Petrel	0.05 ± 0.14	0.00	0.61	35.5 ± 31.1
Shearwater	2.53 ± 4.88	0.00	21.39	55.0 ± 39.9

Table 7. Summary of species (or group) abundance (birds/one-minute observation segment) from aerial surveys on the Labrador Shelf in 2013.

Group	Total count	Number of segments detected	Avg number seen per segment ± SD	Min - Max
All Waterbirds	6301	790	7.98 ± 31.1	1 – 601
Northern fulmar	3664	340	10.78 ± 31.41	1 – 235
unidentified white winged gulls	825	278	2.97 ± 5.02	1 – 60
large alcids	856	146	5.86 ± 7.76	1 – 57
other	956	26	36.77 ± 129.1	1 - 601

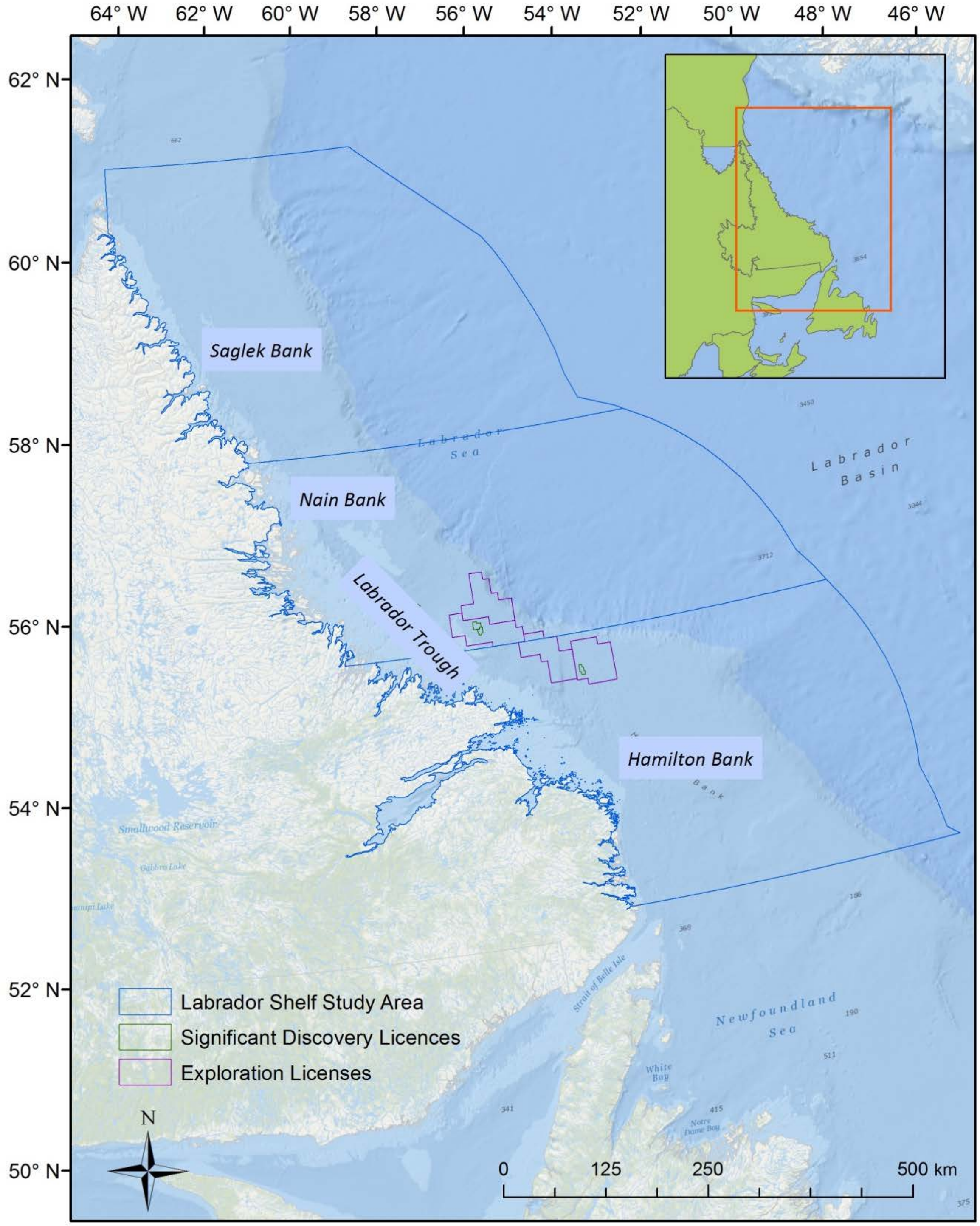


Figure 1. Labrador Sea study area, which encompasses the area of the Labrador Shelf delineated by NAFO regions 2G, 2H, 2J, out to the Canadian EEZ (Exclusive Economic Zone). C-NLOPB exploration and discovery licences on the Labrador Shelf are also indicated.

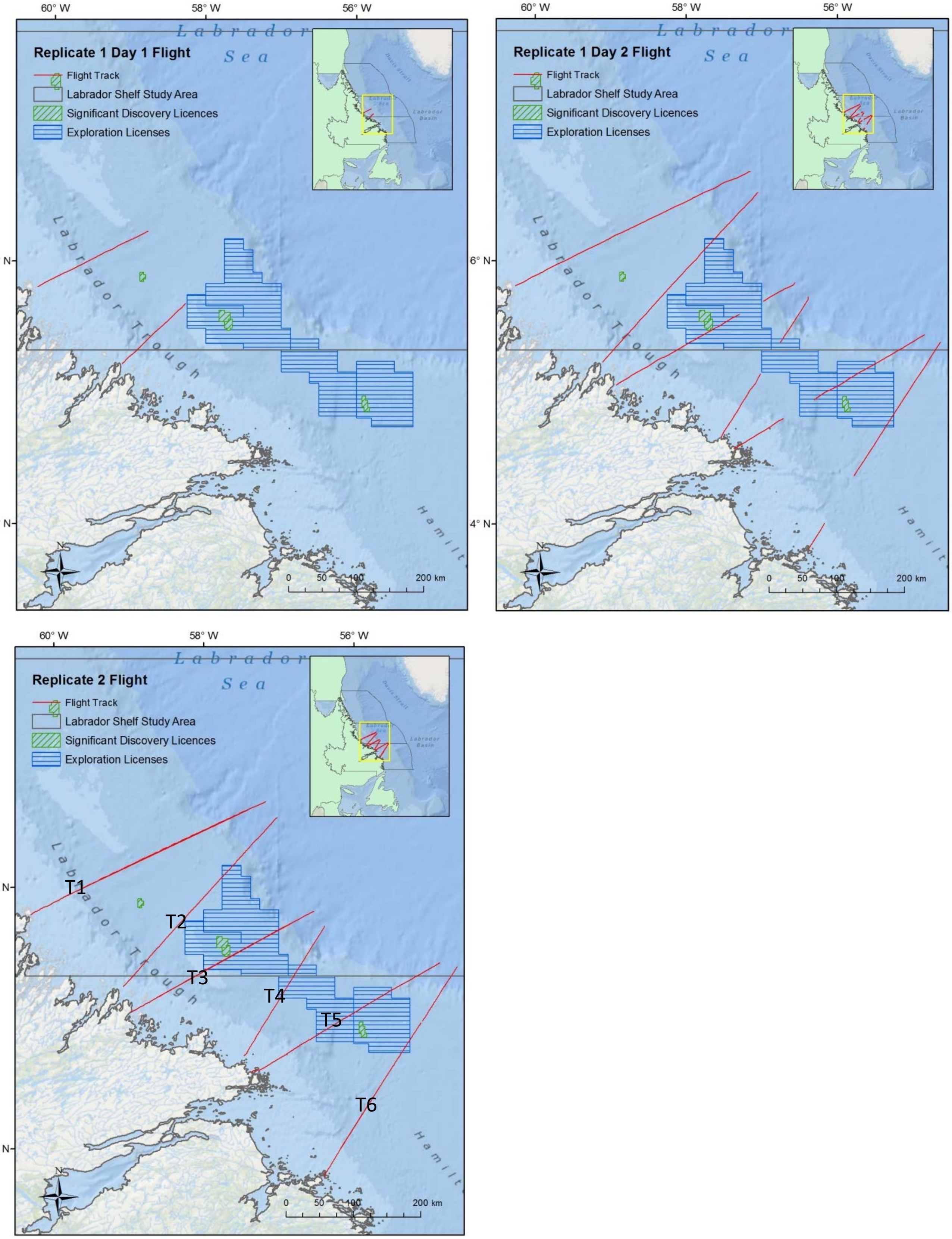


Figure 2a-c. Aerial survey transects (1-6) with replicates in the Labrador Shelf Study Area: (a) first partial replicate (flight 1), (b) one full replicate (flight 1), and (c) the second full replicate (flight 2) with individual transect lines indicated (T1-T6).

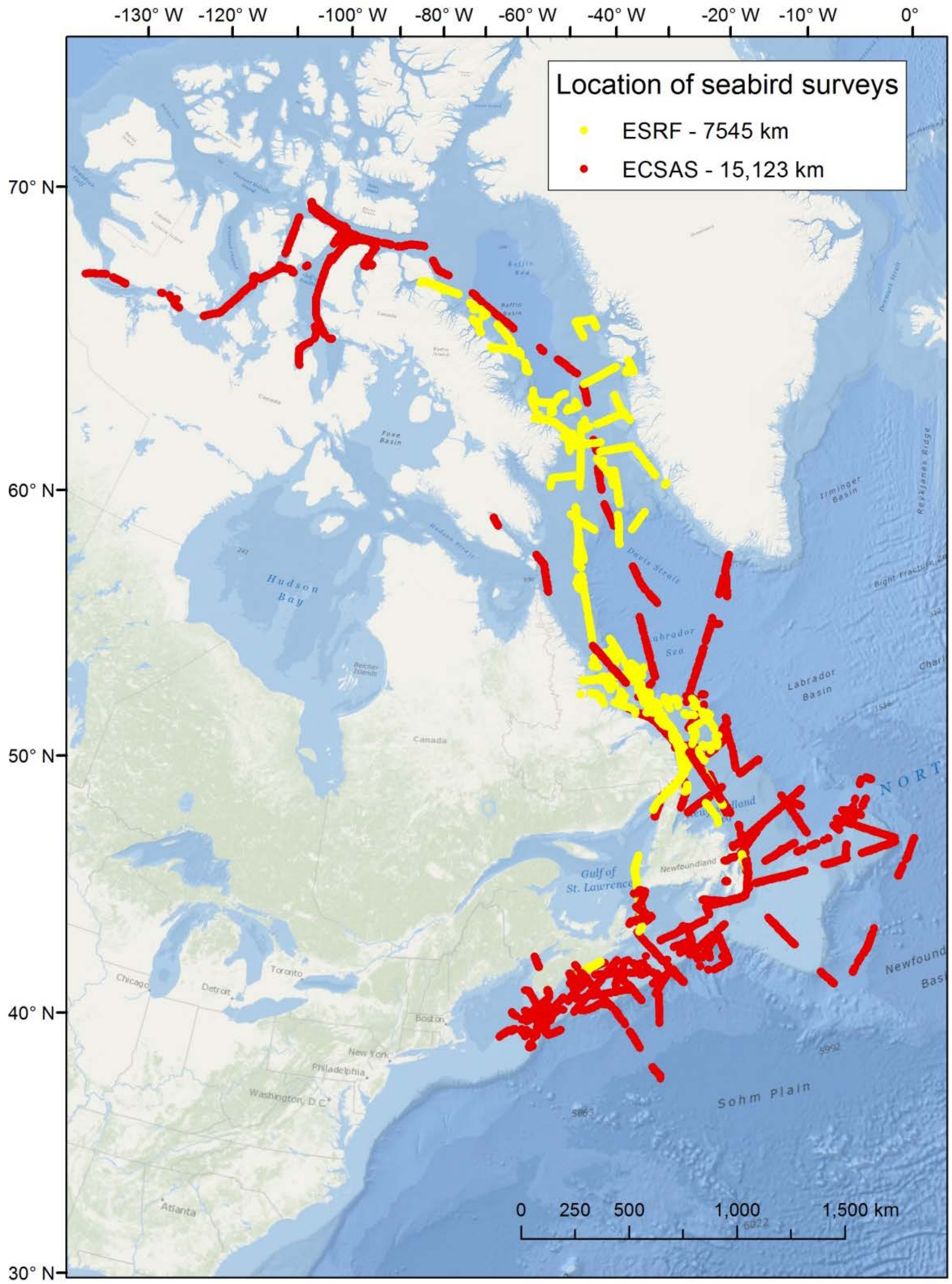


Figure 3. Ship-based survey effort in 2013, including all ECSAS surveys (red), and those supported by ESRF (yellow) that were completed specifically to address the data gap in the Labrador Sea and eastern Canadian Arctic.

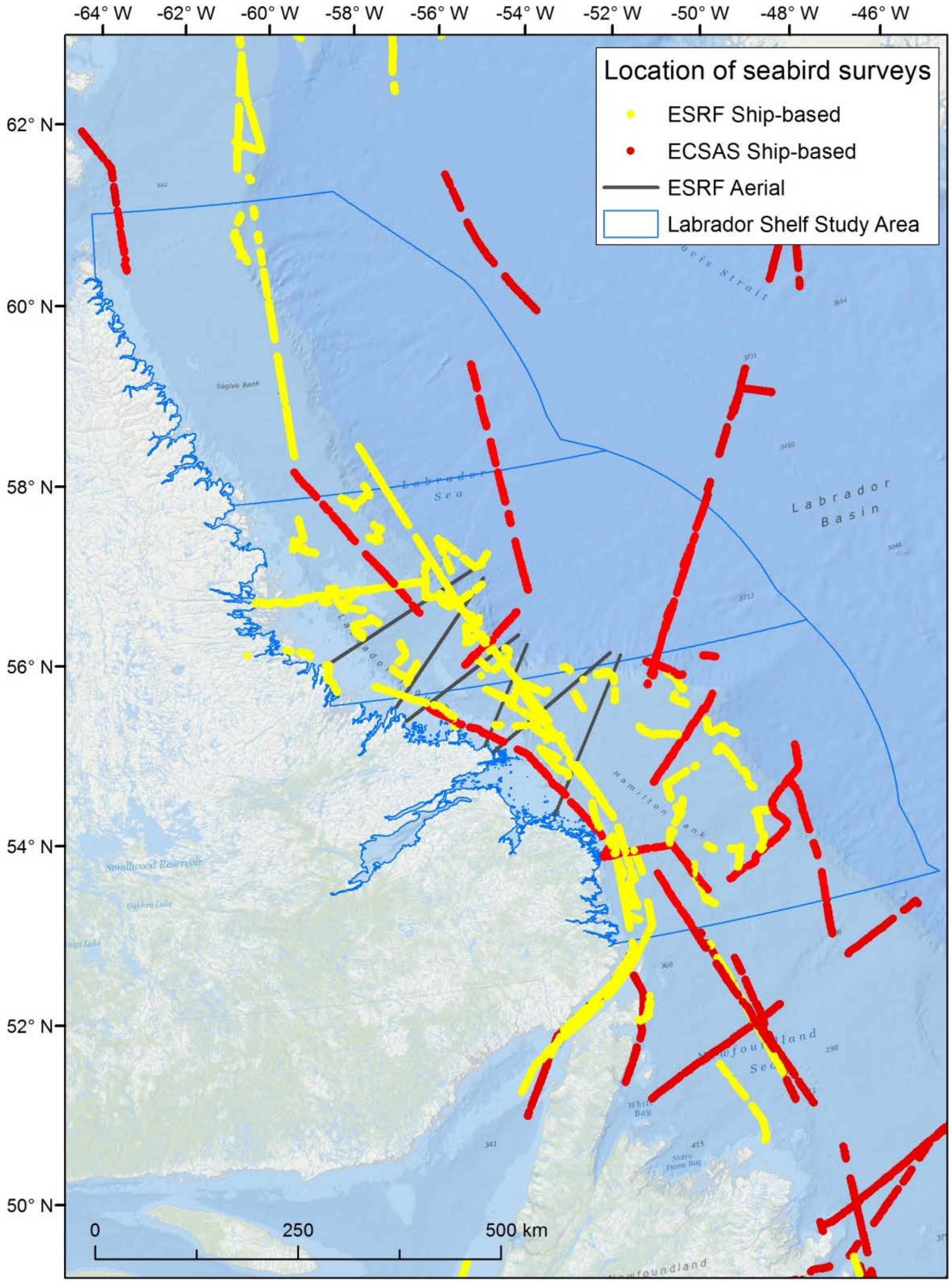


Figure 4. Ship-based survey effort and aerial transect on the Labrador Shelf Study Area.

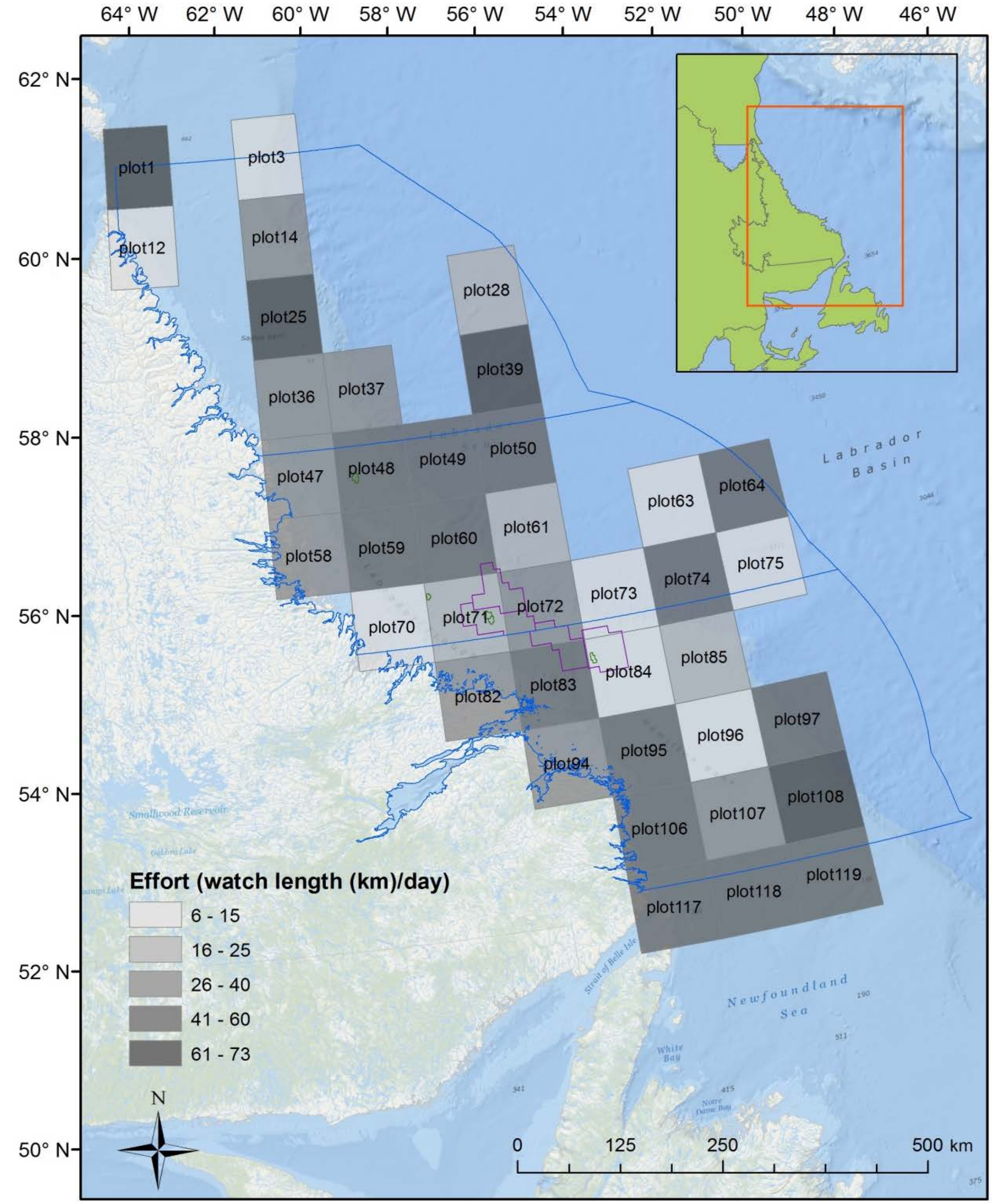


Figure 5. Watch length (km) per grid cell from ship-based surveys. Grid cell IDs (see Appendix II) are also indicated.

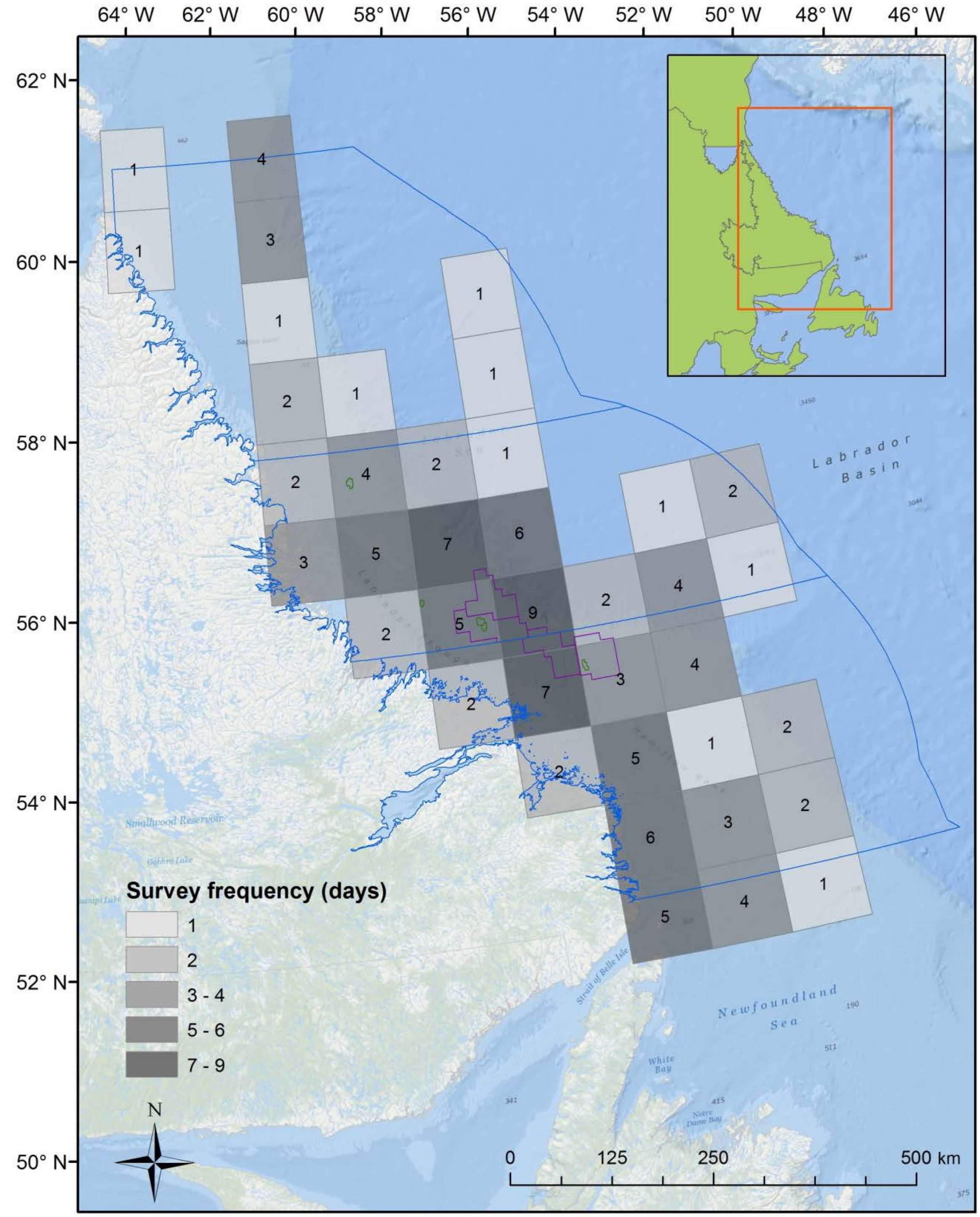


Figure 6. Frequency of ship-based surveys (days) occurring in each grid cell over the study area.

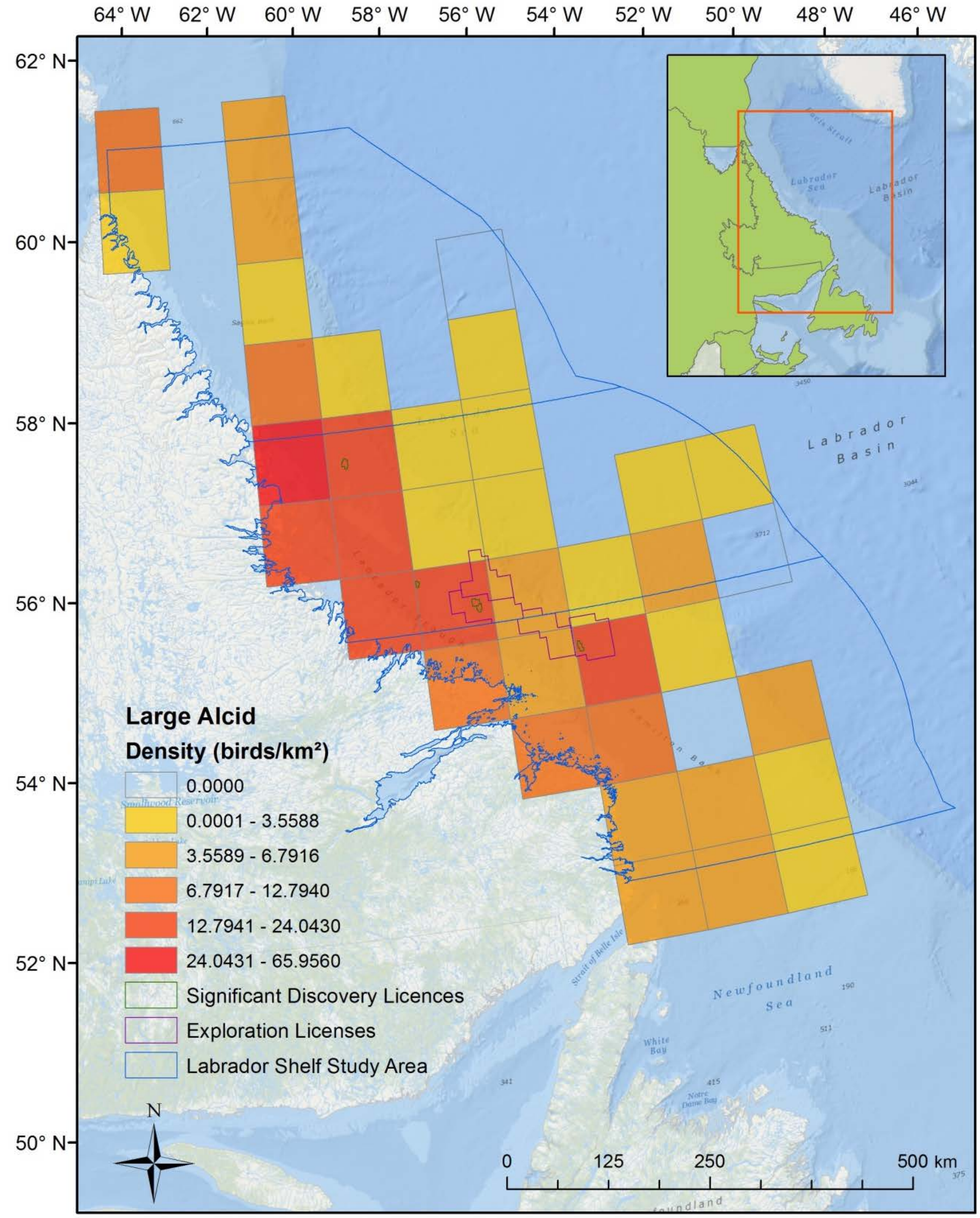


Figure 7. Density (birds / km^2) per grid (100 km x 100 km) of large alcids (*Uria aalge, Uria lomvia, Alca torda*) from ship-based transects.

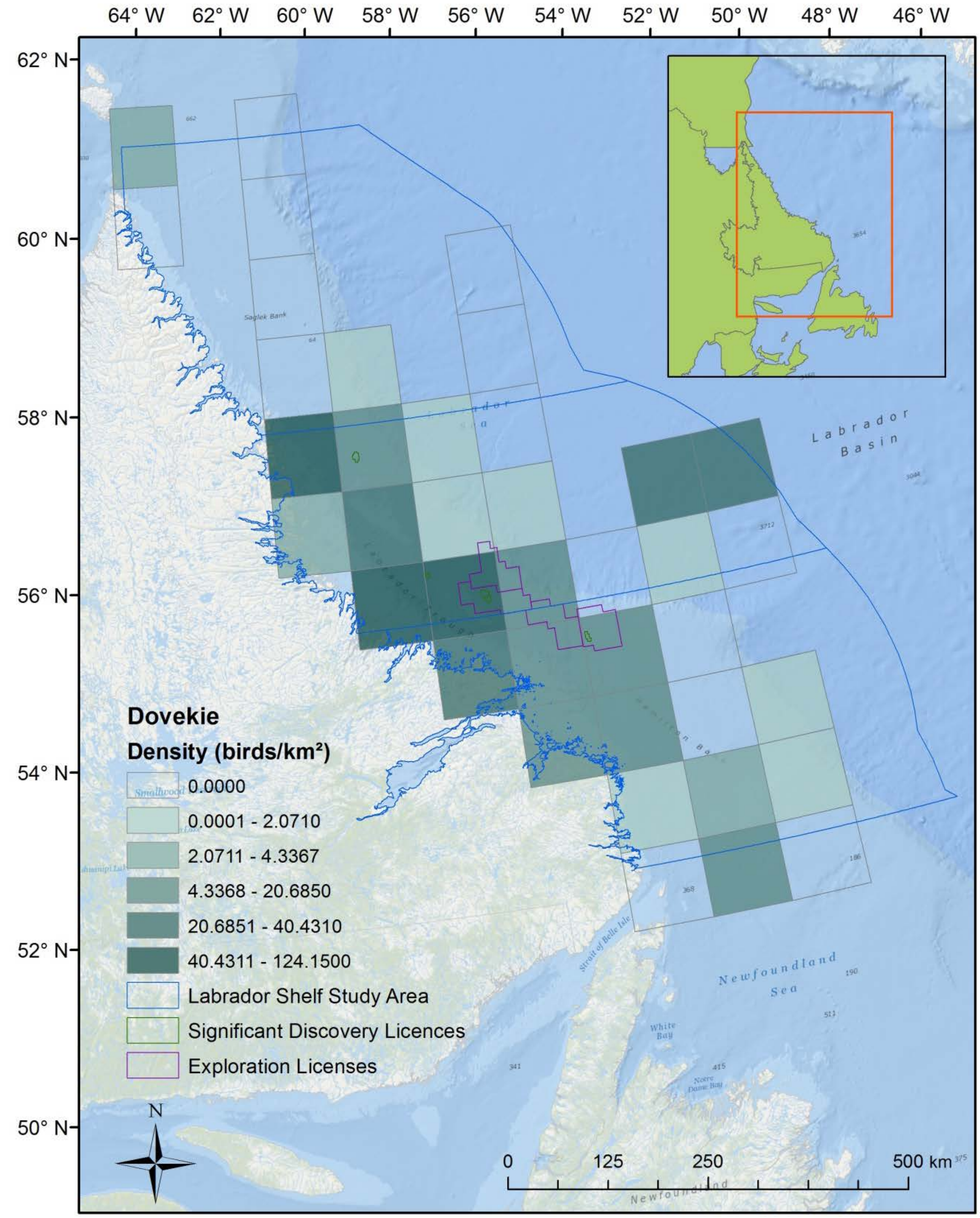


Figure 8. Density (birds / km^2) per grid (100 km x 100 km) of dovekie (A*lle alle*) from ship-based transects.

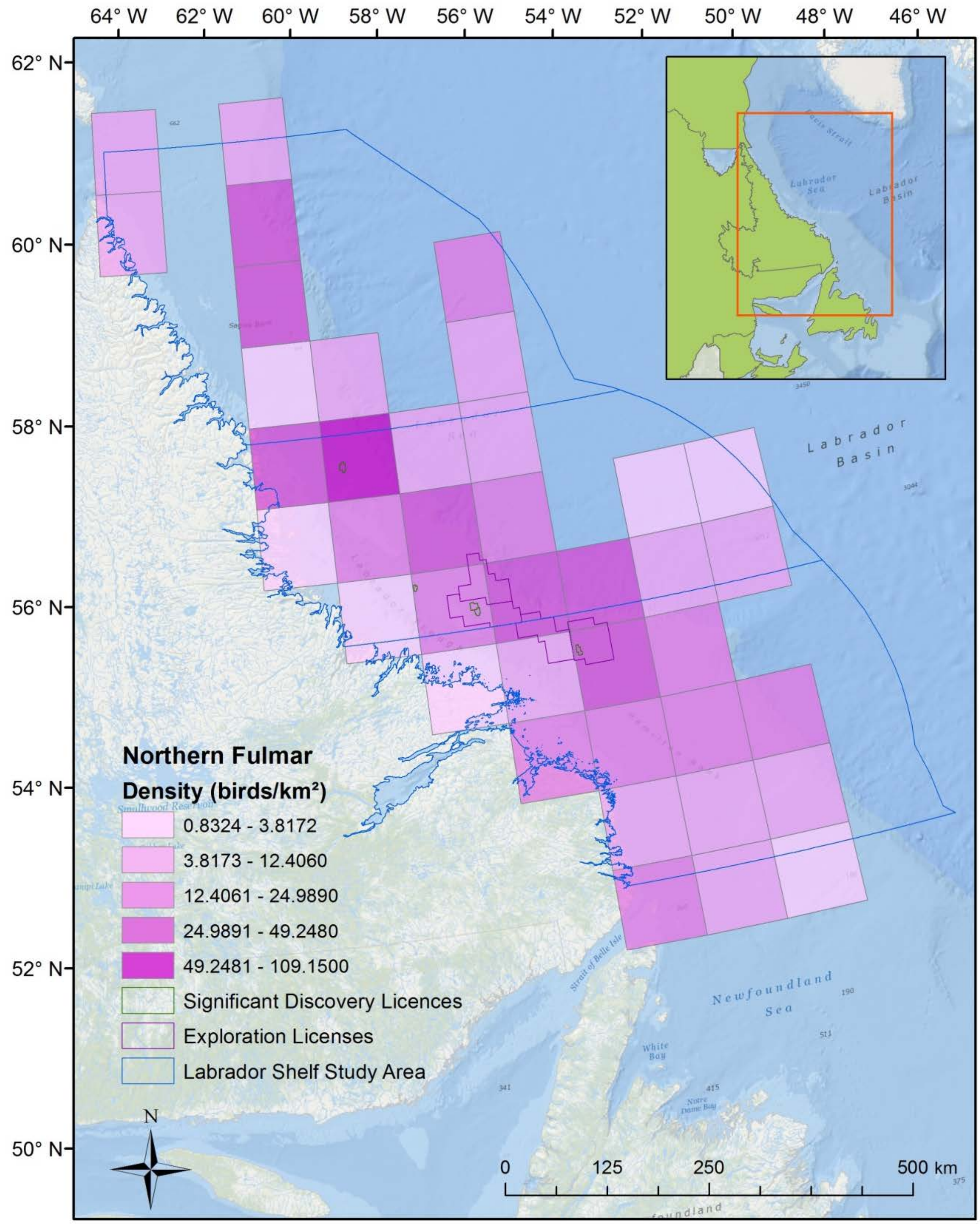


Figure 9. Density (birds / km^2) per grid (100 km x 100 km) of northern fulmars (*Fulmaris glacialis*) from ship-based transects.

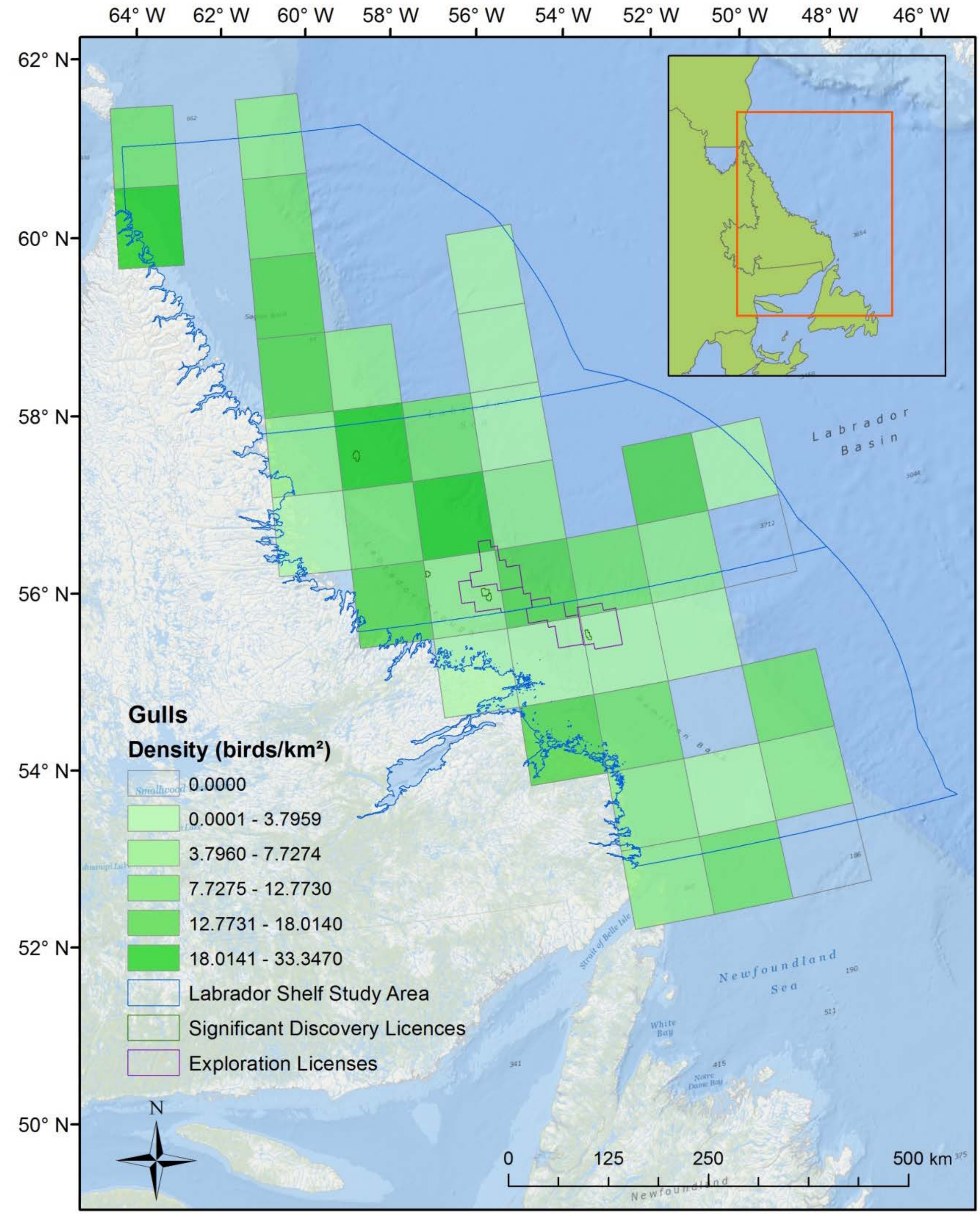


Figure 10. Density (birds / km^2) per grid (100 km x 100 km) of gulls (*Laridae*) from ship-based transects.

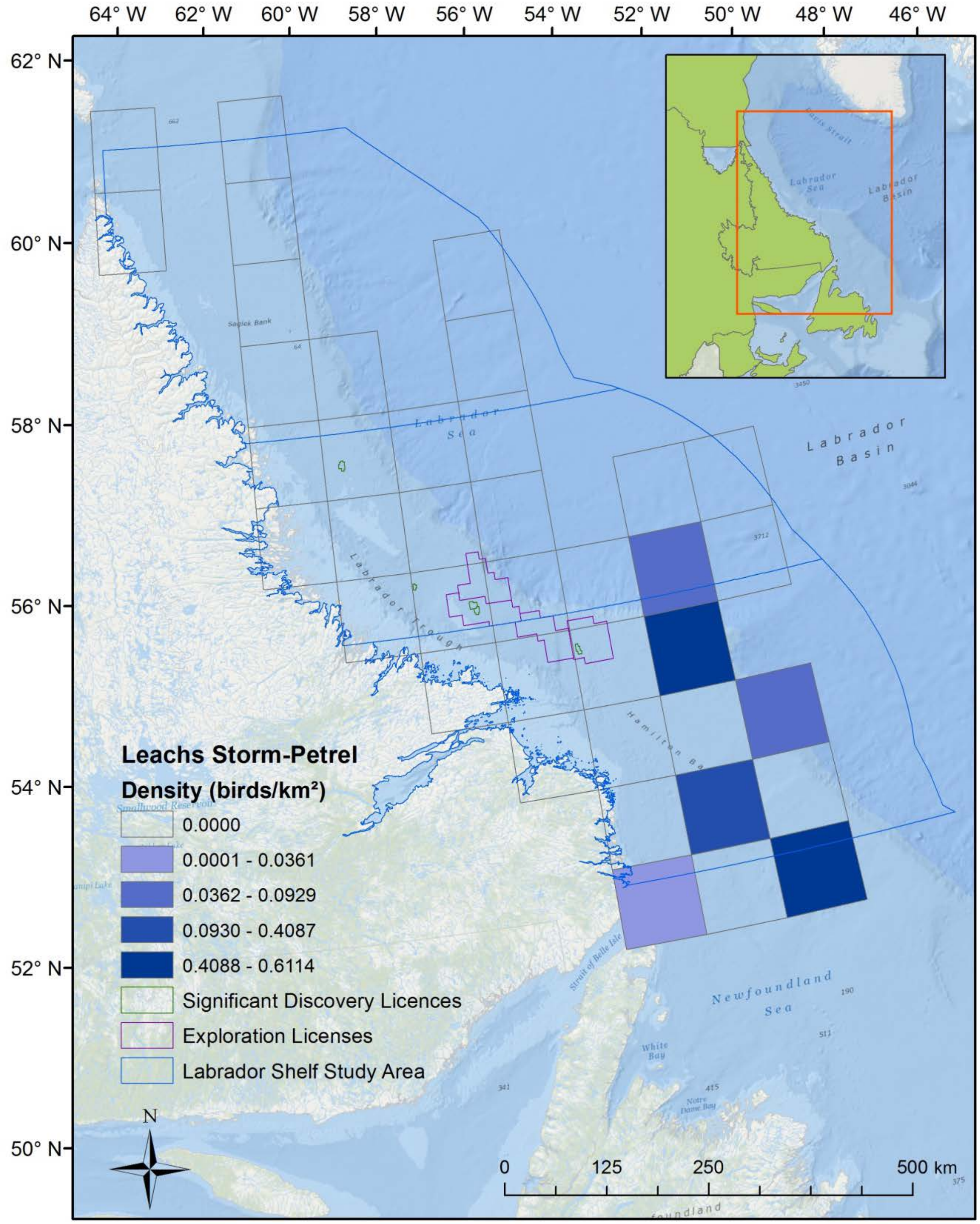


Figure 11. Density (birds / km^2) per grid (100 km x 100 km) of storm petrels (*Hydrobatidae*) from ship-based transects.

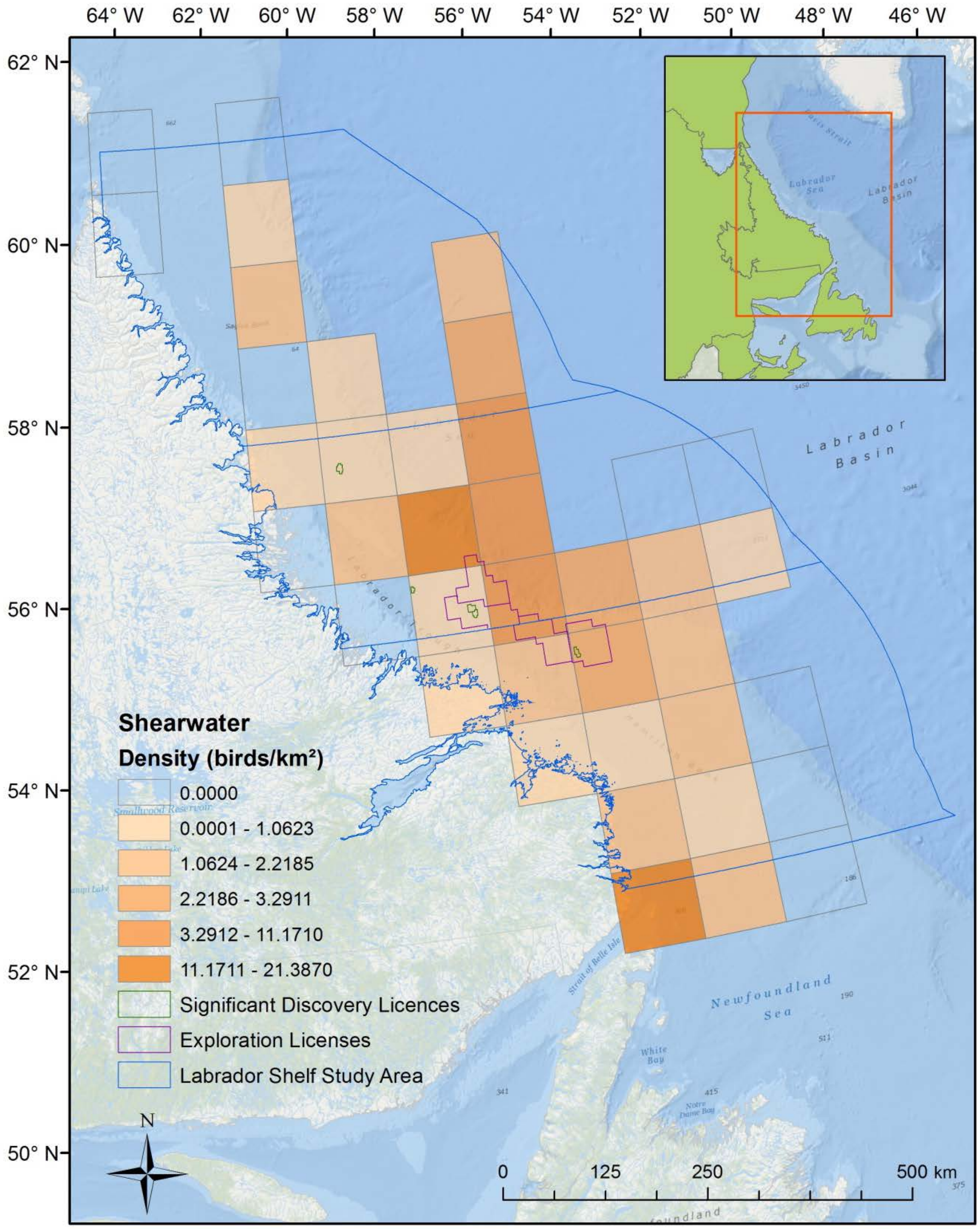


Figure 12. Density (birds / km^2) per grid (100 km x 100 km) of shearwaters (*Procellariidae*) from ship-based transects.

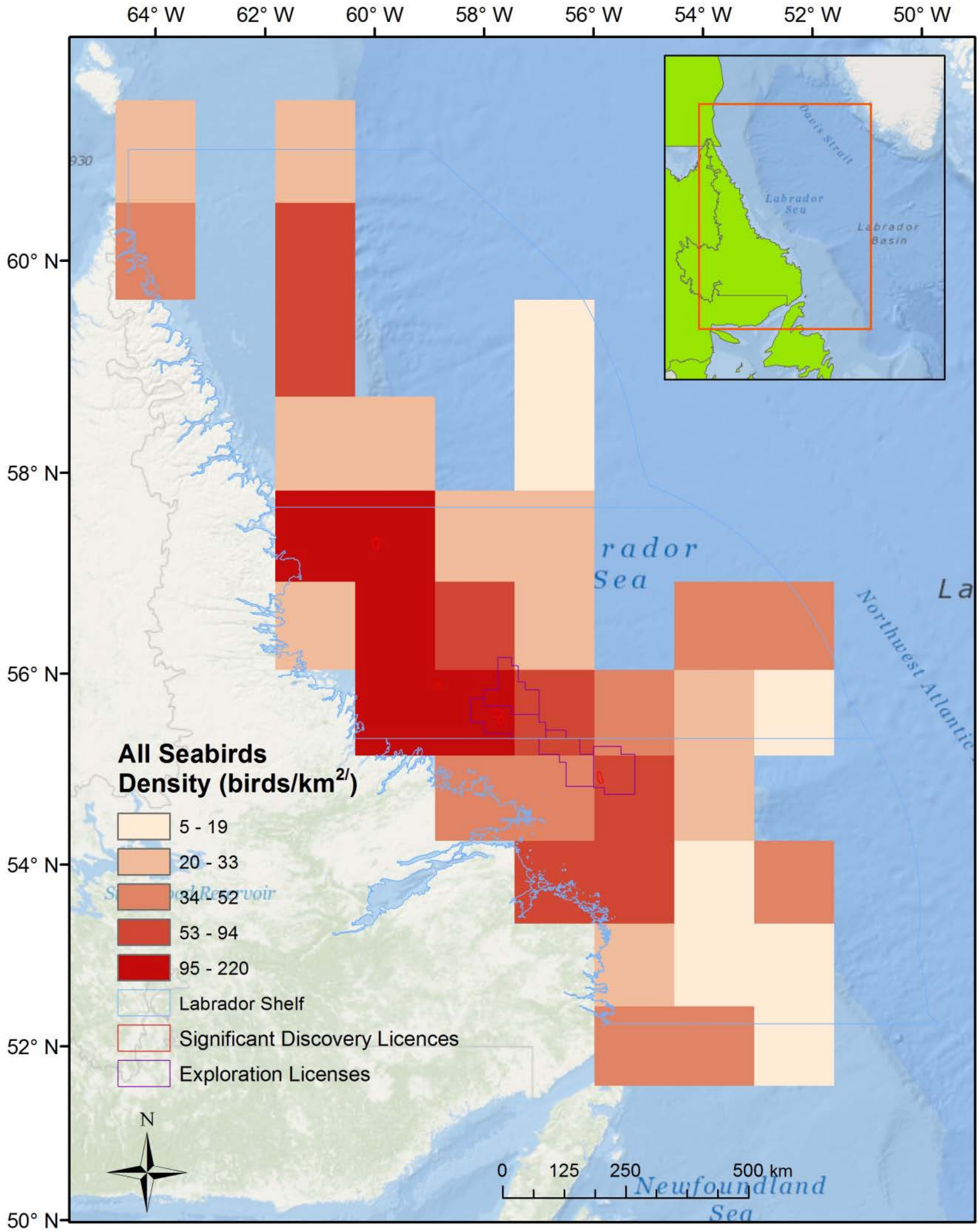


Figure 13. Average density (birds / km^2) per grid (100 km x 100 km) summed for all species observed from ship-based transects.

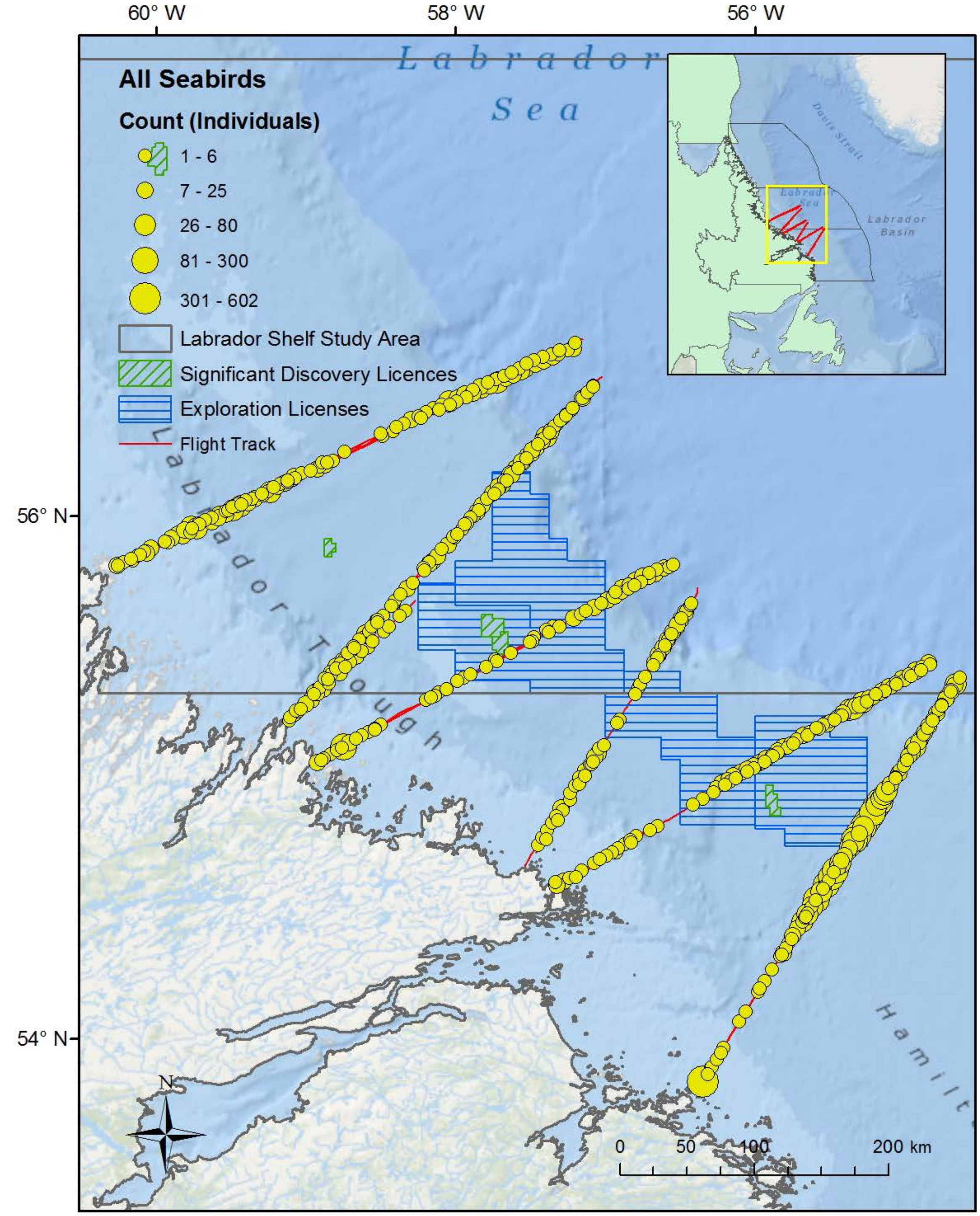


Figure 14. Distribution and uncorrected abundance of all seabirds along aerial transects over the Labrador Shelf.

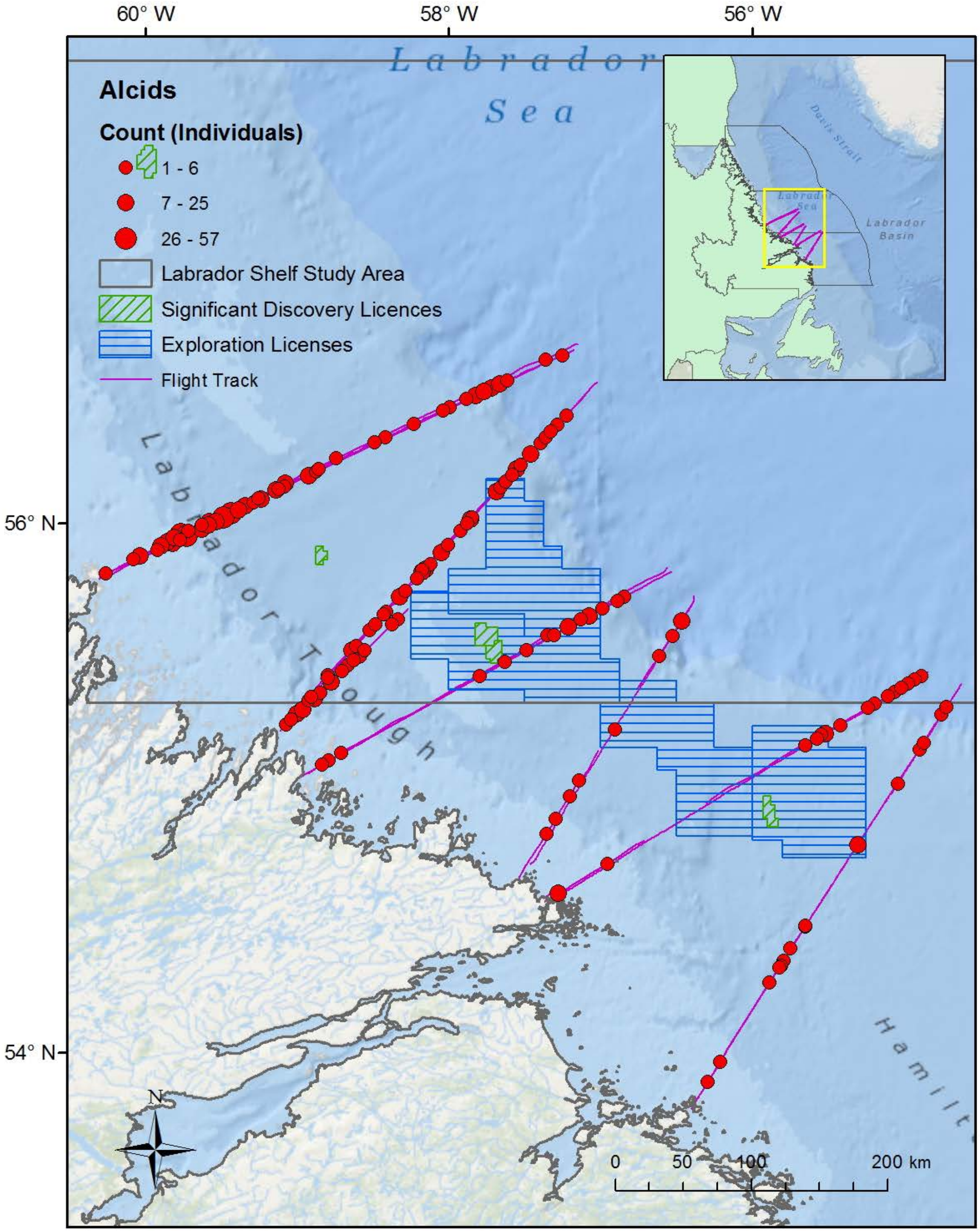


Figure 15. Distribution and uncorrected abundance of large alcids (*Alcidae*; likely thick-billed murre, common murre, razorbill) along aerial transects over the Labrador Shelf.

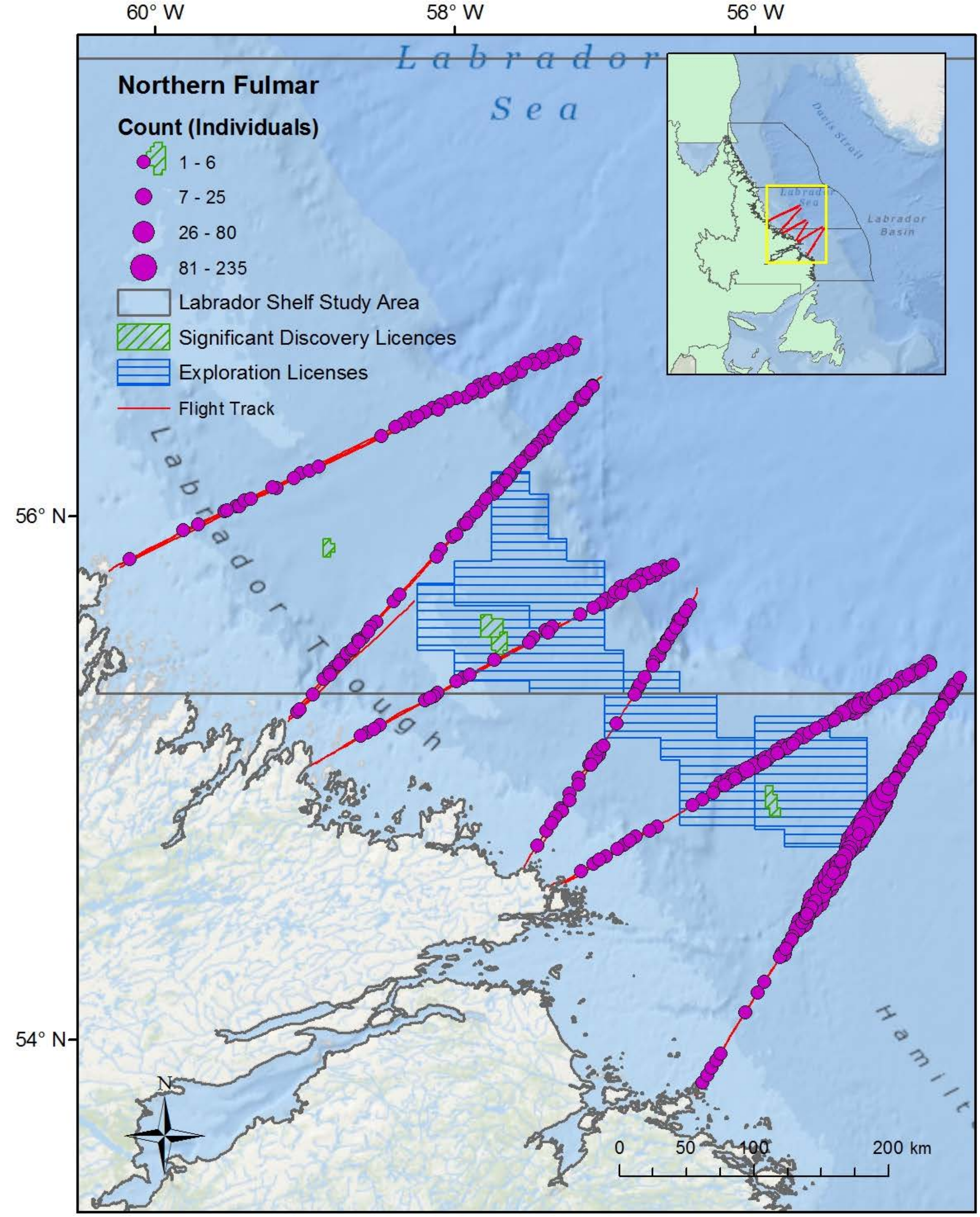


Figure 16. Distribution and uncorrected abundance of Northern Fulmar (*Fulmaris glacialis*) along aerial transects over the Labrador Shelf.

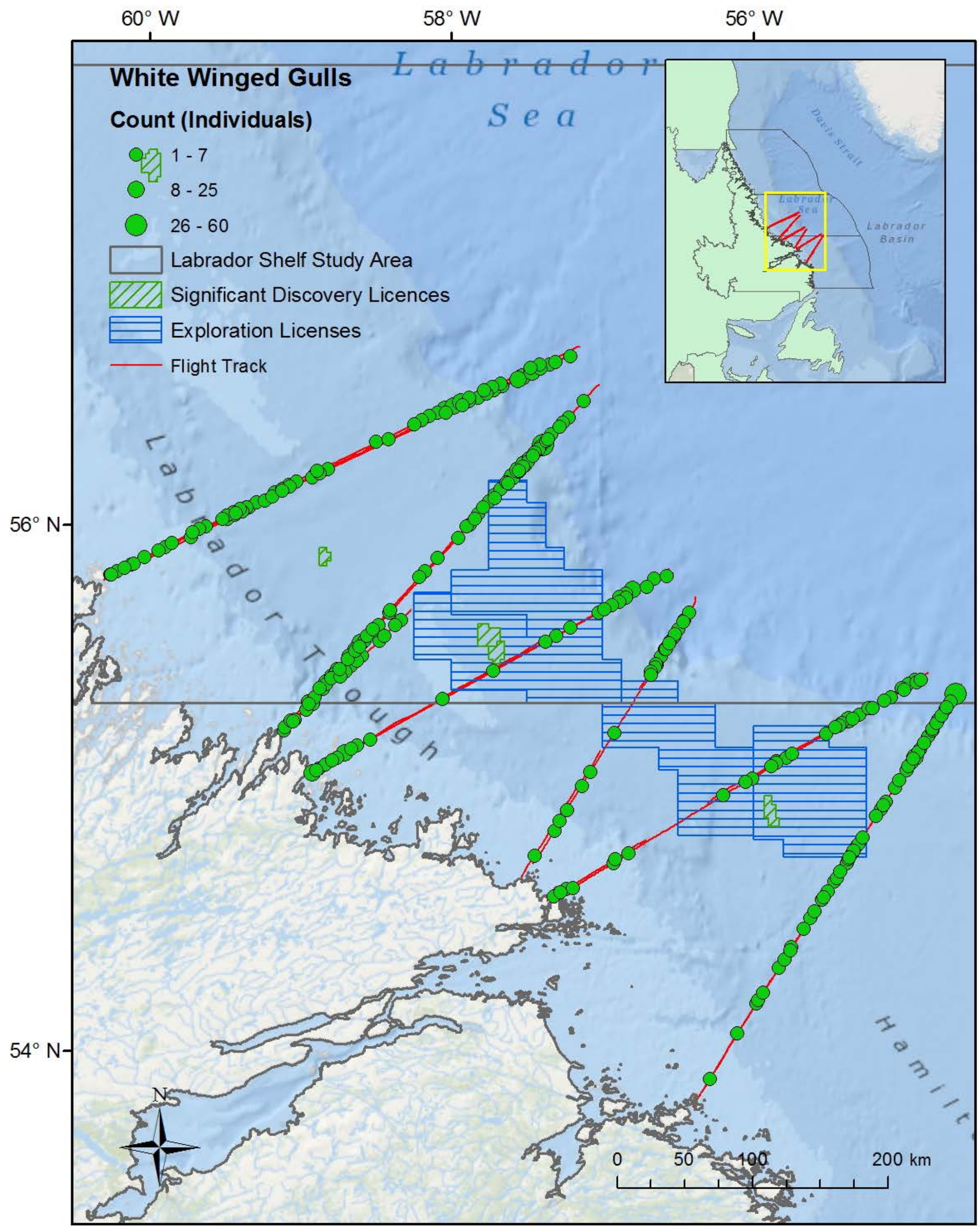


Figure 17. Distribution and uncorrected abundance of white-winged gulls (*Laridae*) along aerial transects over the Labrador Shelf.

11. Appendix I.

Specific detection probabilities from the DISTANCE and GeoAviR programs, used to estimate density of seabirds in the Labrador Sea.

Overall detection probability

Large Alcid

Parameters Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
Global	A(1)	141.2	1.476			
Global	A(2)	0.4140	0.1831E−01			
Global	A(3)	−0.9180E−01	0.2797E−01			
Global	f(0)	0.77468E−02	0.14220E−03	1.84	0.74731E−02	0.80306E−02
Global	p	0.43028	0.78982E−02	1.84	0.41508	0.44605
Global	ESW	129.08	2.3805	1.84	124.52	133.81

SE backcalculated from CI for more precision use parbootq()

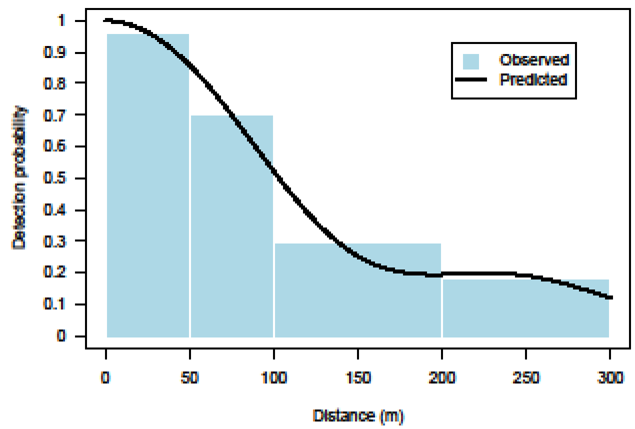
Model Fitting

Descriptives
effort : 70242.24
samples : 634
width : 300
left : 0
observations : 9913
: Half−normal key, k(y) = Exp(−y**2/(2*A(1)**2))
: Cosine adjustments of order(s) : 2, 3

Chi−square test on model fit

Stratum	Cell	CutsLo	CutsUp	Observed	Predicted	Chi.values
Global	1	0.000	50.0	3654	3654.00	0.000
Global	2	50.0	100.	2672	2672.00	0.000
Global	3	100.	200.	2222	2222.00	0.000
Global	4	200.	300.	1365	1365.00	0.000

Detection probability vs. distance



Density Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
area	DS	1.0933	0.70137E−01	6.42	0.96403	1.2399
area	E(S)	1.8836	0.14267E−01	0.76	1.8558	1.9117
area	D	2.0593	0.13303	6.46	1.8143	2.3374
area	N	2.0000	0.12920	6.46	2.0000	2.0000

p: probability of observing an object in the defined area
f(0): probability density function at distance 0
ESW: effective strip width
D: bird density (nb birds / km2)
DS: group density (nb groups / km2)
E(S): expected group size
N: nb of birds in the area

Detailed results in:
Q:/GW/EC1130MigBirds_OiseauxMig/Seabirds/GeoAviR/Analysis/GeoAviR_projects/NLDec

Overall detection probability

Dovekie

Parameters Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
Global	A(1)	129.1	1.598			
Global	A(2)	0.3742	0.2453E−01			
Global	A(3)	−0.7618E−01	0.3459E−01			
Global	f(0)	0.81459E−02	0.17982E−03	2.21	0.78010E−02	0.85061E−02
Global	p	0.40920	0.90331E−02	2.21	0.39187	0.42730
Global	ESW	122.78	2.7000	2.21	117.56	128.19

SE backcalculated from CI for more precision use parboot()

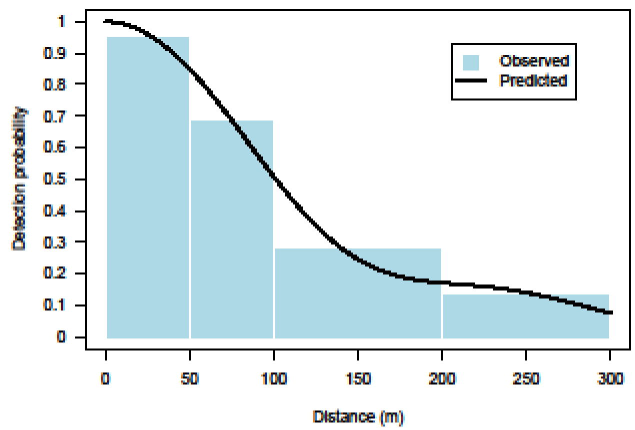
Model Fitting

Descriptives
effort : 70242.24
samples : 634
width : 300
left : 0
observations : 6491
: Half−normal key, k(y) = Exp(−y**2/(2*A(1)**2))
: Cosine adjustments of order(s) : 2, 3

Chi−square test on model fit

Stratum	Cell	CutsLo	CutsUp	Observed	Predicted	Chi.values
Global	1	0.000	50.0	2507	2507.00	0.000
Global	2	50.0	100.	1806	1806.00	0.000
Global	3	100.	200.	1472	1472.00	0.000
Global	4	200.	300.	706	706.00	0.000

Detection probability vs. distance



Density Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
area	DS	0.75275	0.68603E−01	9.11	0.62966	0.89991
area	E(S)	2.7291	0.32366E−01	1.19	2.6664	2.7933
area	D	2.0543	0.18880	9.19	1.7159	2.4596
area	N	2.0000	0.18381	9.19	2.0000	2.0000

p: probability of observing an object in the defined area
f(0): probability density function at distance 0
ESW: effective strip width
D: bird density (nb birds / km2)
DS: group density (nb groups / km2)
E(S): expected group size
N: nb of birds in the area

Detailed results in:
Q:/GW/EC1130MigBirds_OiseauxMig/Seabirds/GeoAviR/Analysis/GeoAviR_projects/NLDec

Overall detection probability

Northern Fulmar

Parameters Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
Global	A(1)	148.1	1.507			
Global	A(2)	0.3185	0.1709E−01			
Global	A(3)	−0.1641	0.2585E−01			
Global	f(0)	0.65281E−02	0.12466E−03	1.91	0.62883E−02	0.67771E−02
Global	p	0.51061	0.97502E−02	1.91	0.49185	0.53008
Global	ESW	153.18	2.9250	1.91	147.56	159.02

SE backcalculated from CI for more precision use parboot()

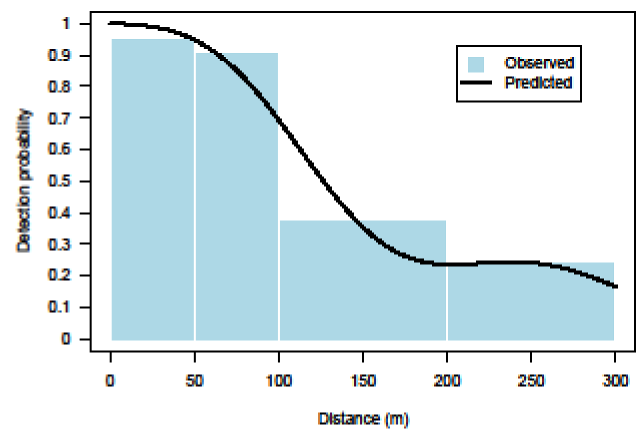
Model Fitting

Descriptives
effort : 70242.24
samples : 634
width : 300
left : 0
observations : 11905
: Half−normal key, k(y) = Exp(−y**2/(2*A(1)**2))
: Cosine adjustments of order(s) : 2, 3

Chi−square test on model fit

Stratum	Cell	CutsLo	CutsUp	Observed	Predicted	Chi.values
Global	1	0.000	50.0	3673	3828.11	6.285
Global	2	50.0	100.	3517	3265.08	19.438
Global	3	100.	200.	2881	3058.38	10.288
Global	4	200.	300.	1834	1753.43	3.702

Detection probability vs. distance



Density Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
area	DS	1.1064	0.70719E−01	6.39	0.97608	1.2542
area	E(S)	1.7374	0.10956E−01	0.63	1.7160	1.7590
area	D	1.9223	0.12346	6.42	1.6948	2.1803
area	N	2.0000	0.12846	6.42	2.0000	2.0000

p: probability of observing an object in the defined area
f(0): probability density function at distance 0
ESW: effective strip width
D: bird density (nb birds / km2)
DS: group density (nb groups / km2)
E(S): expected group size
N: nb of birds in the area

Detailed results in:
Q:/GW/EC1130MigBirds_OiseauxMig/Seabirds/GeoAviR/Analysis/GeoAviR_projects/NLDec

Overall detection probability

Gulls

Parameters Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
Global	A(1)	136.2	1.531			
Global	A(2)	0.3445	0.2125E−01			
Global	A(3)	−0.2098	0.3100E−01			
Global	f(0)	0.68377E−02	0.15258E−03	2.23	0.65451E−02	0.71434E−02
Global	p	0.48749	0.10878E−01	2.23	0.46663	0.50929
Global	ESW	146.25	3.2635	2.23	139.99	152.79

SE backcalculated from CI for more precision use parboot()

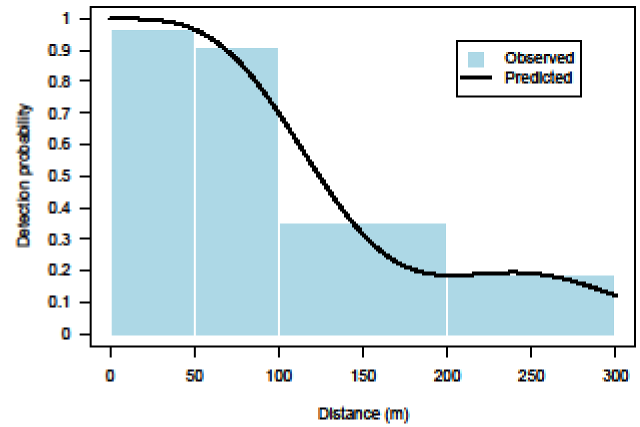
Model Fitting

Descriptives
effort : 70242.24
samples : 634
width : 300
left : 0
observations : 8411
: Half−normal key, k(y) = Exp(−y**2/(2*A(1)**2))
: Cosine adjustments of order(s) : 2, 3

Chi−square test on model fit

Stratum	Cell	CutsLo	CutsUp	Observed	Predicted	Chi.values
Global	1	0.000	50.0	2770	2852.92	2.410
Global	2	50.0	100.	2599	2463.84	7.415
Global	3	100.	200.	1987	2077.96	3.982
Global	4	200.	300.	1055	1016.28	1.475

Detection probability vs. distance



Density Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
area	DS	0.81877	0.41654E−01	5.09	0.74102	0.90467
area	E(S)	1.6785	0.12621E−01	0.75	1.6539	1.7034
area	D	1.3743	0.70674E−01	5.14	1.2424	1.5201
area	N	1.0000	0.51426E−01	5.14	1.0000	2.0000

p: probability of observing an object in the defined area
f(0): probability density function at distance 0
ESW: effective strip width
D: bird density (nb birds / km2)
DS: group density (nb groups / km2)
E(S): expected group size
N: nb of birds in the area

Detailed results in:
Q:/GW/EC1130MigBirds_OiseauxMig/Seabirds/GeoAviR/Analysis/GeoAviR_projects/NLDec

Overall detection probability

Leachs Storm−Petrel

Parameters Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
Global	A(1)	130.8	2.479			
Global	A(2)	0.3594	0.2941E−01			
Global	f(0)	0.84403E−02	0.18210E−03	2.16	0.80907E−02	0.88050E−02
Global	p	0.39493	0.85208E−02	2.16	0.37857	0.41199
Global	ESW	118.48	2.5562	2.16	113.57	123.60

*SE backcalculated from CI for more precision use parboot()

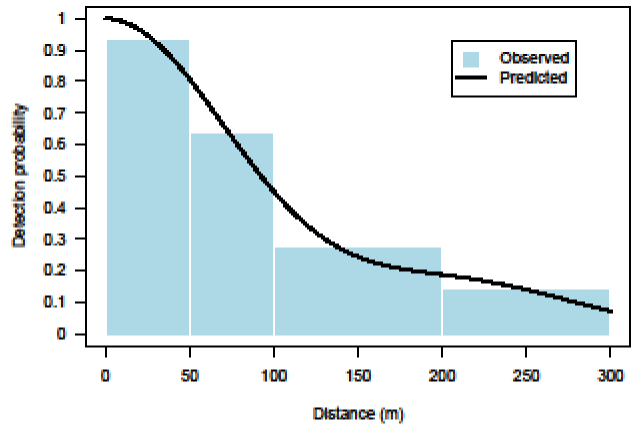
Model Fitting

Descriptives
effort : 70242.24
samples : 634
width : 300
left : 0
observations : 2698
: Half−normal key, k(y) = Exp(−y**2/(2*A(1)**2))
: Cosine adjustments of order(s) : 2

Chi−square test on model fit

Stratum	Cell	CutsLo	CutsUp	Observed	Predicted	Chi.values
Global	1	0.000	50.0	1055	1061.63	0.041
Global	2	50.0	100.	722	712.39	0.130
Global	3	100.	200.	611	614.38	0.019
Global	4	200.	300.	310	309.60	0.001

Detection probability vs. distance



Density Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
area	DS	0.32419	0.34936E−01	10.78	0.26253	0.40034
area	E(S)	1.6294	0.20504E−01	1.26	1.5897	1.6701
area	D	0.52825	0.57312E−01	10.85	0.42717	0.65324
area	N	1.0000	0.10850	10.85	0.00000	1.0000

p: probability of observing an object in the defined area
f(0): probability density function at distance 0
ESW: effective strip width
D: bird density (nb birds / km2)
DS: group density (nb groups / km2)
E(S): expected group size
N: nb of birds in the area

Detailed results in:
Q:/GW/EC1130MigBirds_OiseauxMig/Seabirds/GeoAviR/Analysis/GeoAviR_projects/NLDec

Overall detection probability

Shearwater

Parameters Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
Global	A(1)	152.4	2.560			
Global	A(2)	0.3385	0.2684E−01			
Global	A(3)	−0.1327	0.4147E−01			
Global	f(0)	0.66757E−02	0.20052E−03	3.00	0.62940E−02	0.70806E−02
Global	p	0.49932	0.14998E−01	3.00	0.47077	0.52960
Global	ESW	149.90	4.4995	3.00	141.23	158.88

SE backcalculated from CI for more precision use parboot()

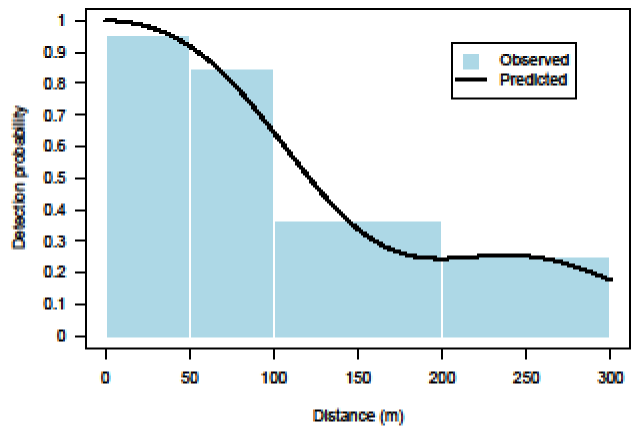
Model Fitting

Descriptives
effort : 70242.24
samples : 634
width : 300
left : 0
observations : 4586
: Half−normal key, k(y) = Exp(−y**2/(2*A(1)**2))
: Cosine adjustments of order(s) : 2, 3

Chi−square test on model fit

Stratum	Cell	CutsLo	CutsUp	Observed	Predicted	Chi.values
Global	1	0.000	50.0	1451	1491.08	1.077
Global	2	50.0	100.	1282	1218.83	3.274
Global	3	100.	200.	1108	1151.90	1.673
Global	4	200.	300.	745	724.19	0.598

Detection probability vs. distance



Density Estimates

Stratum	Parameters	Estimates	SE*	% of var.	95% Lower	95% Upper
area	DS	0.43585	0.47179E−01	10.82	0.35262	0.53871
area	E(S)	2.0681	0.27644E−01	1.34	2.0147	2.1231
area	D	0.90140	0.98315E−01	10.91	0.72812	1.1159
area	N	1.0000	0.10907	10.91	1.0000	1.0000

p: probability of observing an object in the defined area
f(0): probability density function at distance 0
ESW: effective strip width
D: bird density (nb birds / km2)
DS: group density (nb groups / km2)
E(S): expected group size
N: nb of birds in the area

Detailed results in:
Q:/GW/EC1130MigBirds_OiseauxMig/Seabirds/GeoAvIR/Analysis/GeoAvIR_projects/NLDec

12. Appendix II.

Densities (birds/km^2) and coefficients of variation for density estimates in each surveyed grid cell (see Figure 5 for location of grid cells), per species.

		Density Estimates and Variation			
Species Group	Grid Cell ID	Density (birds/km^2)	Coeffecient of Variation	95% LowerCI	95% UpperCI
Alcid	1	8.04	21.51	5.07	12.75
Alcid	3	4.66	64.7	0.85	25.54
Alcid	12	1.83	5.45	1.64	2.03
Alcid	14	4.71	30.88	2.23	9.96
Alcid	25	1.87	18.78	1.15	3.04
Alcid	28	0.00	na	na	na
Alcid	36	12.79	52.88	0.57	288.62
Alcid	37	2.37	8.88	1.95	2.89
Alcid	39	1.00	5.45	0.90	1.12
Alcid	47	65.96	19.31	18.95	229.60
Alcid	48	18.59	13.65	13.52	25.55
Alcid	49	1.63	35.04	0.07	36.59
Alcid	50	0.58	5.45	0.53	0.65
Alcid	58	16.00	98.3	0.56	453.14
Alcid	59	15.78	30.57	7.13	34.96
Alcid	60	3.56	38.7	1.46	8.65
Alcid	61	1.39	89.26	0.21	9.19
Alcid	63	2.73	5.45	2.45	3.03
Alcid	64	2.40	149.87	0.03	16879.00
Alcid	70	24.04	25.74	10.90	53.03
Alcid	71	20.42	23.45	12.36	33.73

Alcid	72	4.60	28.13	2.49	8.50
Alcid	73	2.79	65.38	0.00	4277.70
Alcid	74	5.00	51.53	1.70	14.68
Alcid	75	0.00	na	na	na
Alcid	82	8.21	114.45	0.00	0.00
Alcid	83	3.89	26.86	2.10	7.21
Alcid	84	15.48	64.48	1.52	157.41
Alcid	85	0.97	52.04	0.19	4.97
Alcid	94	11.26	33.1	1.13	111.79
Alcid	95	11.43	14.2	8.46	15.45
Alcid	96	0.00	na	na	na
Alcid	97	4.94	54.25	0.83	29.56
Alcid	106	6.79	39.19	2.62	17.62
Alcid	107	4.17	84.05	0.22	79.28
Alcid	108	0.76	34.33	0.28	2.05
Alcid	117	6.75	39.6	3.03	15.04
Alcid	118	6.24	43.2	1.91	20.45
Alcid	119	1.25	5.45	1.12	1.39
Dovekie	1	4.21	30.32	1.67	10.58
Dovekie	3	0.00	na	na	na
Dovekie	12	0.00	na	na	na
Dovekie	14	0.00	na	na	na
Dovekie	25	0.00	na	na	na
Dovekie	28	0.00	na	na	na
Dovekie	36	0.00	na	na	na
Dovekie	37	0.66	4.38	0.60	0.72
Dovekie	39	0.00	na	na	na
Dovekie	47	109.43	20.75	26.76	447.49
Dovekie	48	9.81	61.6	1.73	55.71
Dovekie	49	0.47	34	0.01	22.80
Dovekie	50	0.00	na	na	na

Dovekie	58	2.83	127.07	0.06	132.50
Dovekie	59	39.24	45.43	12.15	126.77
Dovekie	60	1.92	65.49	0.49	7.53
Dovekie	61	1.43	106.75	0.18	11.57
Dovekie	63	31.17	30.25	1.03	943.62
Dovekie	64	25.88	42.77	1.86	359.95
Dovekie	70	94.36	37.55	5.69	1564.30
Dovekie	71	120.50	39.04	43.76	331.80
Dovekie	72	8.57	62.01	2.32	31.66
Dovekie	73	0.00	na	na	na
Dovekie	74	0.76	36.38	0.29	2.00
Dovekie	75	0.00	na	na	na
Dovekie	82	26.92	156.33	0.00	0.00
Dovekie	83	20.08	30.91	9.70	41.53
Dovekie	84	9.44	112.72	0.32	281.53
Dovekie	85	0.00	na	na	na
Dovekie	94	13.24	163.5	0.00	5788700.00
Dovekie	95	11.19	74.17	1.84	67.96
Dovekie	96	0.00	na	na	na
Dovekie	97	1.92	62.68	0.17	22.01
Dovekie	106	2.01	56.27	0.53	7.65
Dovekie	107	3.60	128.97	0.05	236.28
Dovekie	108	1.41	115.42	0.00	17116.00
Dovekie	117	0.00	na	na	na
Dovekie	118	11.54	55.86	2.62	50.80
Dovekie	119	0.00	na	na	na
Gull	1	8.98	19.18	6.00	13.44
Gull	3	7.30	90.35	0.95	56.09
Gull	12	33.35	22.95	19.69	56.49
Gull	14	12.35	22.87	7.32	20.82
Gull	25	15.73	25.07	9.46	26.14

Gull	28	1.18	4.63	1.07	1.29
Gull	36	15.07	42.43	0.15	1494.30
Gull	37	7.73	4.63	7.06	8.46
Gull	39	0.54	4.63	0.49	0.59
Gull	47	4.58	23.84	1.89	11.10
Gull	48	23.26	52.32	5.05	107.04
Gull	49	12.26	29.96	2.11	71.18
Gull	50	0.62	4.63	0.57	0.68
Gull	58	1.94	112.01	0.04	89.45
Gull	59	11.38	23.56	6.97	18.59
Gull	60	22.09	35.05	9.88	49.36
Gull	61	5.03	90.5	0.71	35.78
Gull	63	15.56	30.59	4.54	53.36
Gull	64	1.88	119.78	0.00	201650.00
Gull	70	18.01	54.05	0.12	2739.20
Gull	71	7.60	36.75	3.02	19.16
Gull	72	13.78	24.33	8.17	23.23
Gull	73	11.29	35.37	0.25	513.37
Gull	74	6.12	31.41	2.42	15.45
Gull	75	0.00	na	na	na
Gull	82	0.94	55.04	0.00	522.80
Gull	83	2.27	32.68	1.06	4.87
Gull	84	3.56	32.28	1.18	10.80
Gull	85	3.80	81.61	0.43	33.61
Gull	94	14.51	108.83	0.04	5301.00
Gull	95	8.73	38.95	3.28	23.28
Gull	96	0.00	na	na	na
Gull	97	10.58	26.62	1.64	68.49
Gull	106	6.28	31.2	2.92	13.51
Gull	107	3.04	90.42	0.17	55.91
Gull	108	4.56	50.3	1.39	14.99

Gull	117	5.33	41.45	1.87	15.14
Gull	118	12.77	46.16	3.69	44.26
Gull	119	0.00	na	na	na
Leach's Storm Petrel	1	0.00	na	na	na
Leach's Storm Petrel	3	0.00	na	na	na
Leach's Storm Petrel	12	0.00	na	na	na
Leach's Storm Petrel	14	0.00	na	na	na
Leach's Storm Petrel	25	0.00	na	na	na
Leach's Storm Petrel	28	0.00	na	na	na
Leach's Storm Petrel	36	0.00	na	na	na
Leach's Storm Petrel	37	0.00	na	na	na
Leach's Storm Petrel	39	0.00	na	na	na
Leach's Storm Petrel	47	0.00	na	na	na
Leach's Storm Petrel	48	0.00	na	na	na
Leach's Storm Petrel	49	0.00	na	na	na
Leach's Storm Petrel	50	0.00	na	na	na
Leach's Storm Petrel	58	0.00	na	na	na
Leach's Storm Petrel	59	0.00	na	na	na
Leach's Storm Petrel	60	0.00	na	na	na
Leach's Storm Petrel	61	0.00	na	na	na
Leach's Storm Petrel	63	0.00	na	na	na
Leach's Storm Petrel	64	0.00	na	na	na
Leach's Storm Petrel	70	0.00	na	na	na
Leach's Storm Petrel	71	0.00	na	na	na
Leach's Storm Petrel	72	0.00	na	na	na
Leach's Storm Petrel	73	0.00	na	na	na
Leach's Storm Petrel	74	0.09	110.86	0.01	1.61
Leach's Storm Petrel	75	0.00	na	na	na
Leach's Storm Petrel	82	0.00	na	na	na
Leach's Storm Petrel	83	0.00	na	na	na
Leach's Storm Petrel	84	0.00	na	na	na

Leach's Storm Petrel	85	0.55	44.44	0.17	1.79
Leach's Storm Petrel	94	0.00	na	na	na
Leach's Storm Petrel	95	0.00	na	na	na
Leach's Storm Petrel	96	0.00	na	na	na
Leach's Storm Petrel	97	0.09	48.43	0.00	29.28
Leach's Storm Petrel	106	0.00	na	na	na
Leach's Storm Petrel	107	0.41	68.84	0.00	3.58
Leach's Storm Petrel	108	0.00	na	na	na
Leach's Storm Petrel	117	0.04	115.52	0.00	0.46
Leach's Storm Petrel	118	0.00	na	na	na
Leach's Storm Petrel	119	0.61	0	0.61	0.61
Northern fulmar	1	9.55	7.78	8.17	11.16
Northern fulmar	3	12.20	24.23	5.95	25.02
Northern fulmar	12	6.73	3.39	6.30	7.19
Northern fulmar	14	46.85	15.16	30.69	71.54
Northern fulmar	25	49.25	8.21	41.89	57.89
Northern fulmar	28	14.70	38.22	5.30	40.71
Northern fulmar	36	3.82	43.17	0.67	216.30
Northern fulmar	37	8.63	5.45	7.73	9.63
Northern fulmar	39	7.09	6.32	6.25	8.05
Northern fulmar	47	31.96	19.68	16.91	60.43
Northern fulmar	48	109.15	58.98	20.54	580.12
Northern fulmar	49	10.32	19.22	1.49	71.60
Northern fulmar	50	12.41	8.59	10.44	14.74
Northern fulmar	58	0.83	68.47	0.10	6.90
Northern fulmar	59	24.99	21.72	14.97	41.71
Northern fulmar	60	35.51	25.95	19.25	65.51
Northern fulmar	61	16.92	21.14	10.09	28.37
Northern fulmar	63	1.25	3.39	1.17	1.34
Northern fulmar	64	2.13	142.55	0.00	603560.00
Northern fulmar	70	1.37	130.82	0.00	427900.00

Northern fulmar	71	13.86	42.31	4.96	38.76
Northern fulmar	72	31.03	17.03	21.29	45.24
Northern fulmar	73	33.31	39.66	4.49	247.19
Northern fulmar	74	8.67	52.26	1.92	39.19
Northern fulmar	75	10.81	8.97	8.88	13.17
Northern fulmar	82	1.23	89.29	0.00	7197.50
Northern fulmar	83	10.30	25.81	5.78	18.37
Northern fulmar	84	27.95	42.22	5.60	139.60
Northern fulmar	85	17.04	15.9	10.90	26.62
Northern fulmar	94	19.34	59.52	0.08	4497.80
Northern fulmar	95	20.44	39.56	7.21	57.91
Northern fulmar	96	13.89	16.73	8.88	21.71
Northern fulmar	97	20.69	33.44	2.99	143.26
Northern fulmar	106	8.23	29.19	4.01	16.89
Northern fulmar	107	5.73	46.84	0.88	37.31
Northern fulmar	108	8.80	53.96	2.61	29.71
Northern fulmar	117	14.83	51.92	3.87	56.82
Northern fulmar	118	5.84	29.06	2.43	14.03
Northern fulmar	119	3.12	19.46	1.92	5.07
Shearwater	1	0.00	na	na	na
Shearwater	3	0.00	na	na	na
Shearwater	12	0.00	na	na	na
Shearwater	14	0.63	54.42	0.07	5.50
Shearwater	25	1.57	16.07	1.06	2.32
Shearwater	28	1.69	4.79	1.54	1.85
Shearwater	36	0.00	na	na	na
Shearwater	37	0.37	4.79	0.34	0.41
Shearwater	39	3.29	26.44	1.79	6.04
Shearwater	47	0.19	19.76	0.03	1.25
Shearwater	48	1.06	71.26	0.15	7.56
Shearwater	49	0.39	34.05	0.01	18.27

Shearwater	50	8.19	17.7	5.69	11.78
Shearwater	58	0.00	na	na	na
Shearwater	59	1.59	89.22	0.20	12.86
Shearwater	60	21.39	62.93	5.28	86.60
Shearwater	61	6.60	41.78	2.42	18.00
Shearwater	63	0.00	na	na	na
Shearwater	64	0.00	na	na	na
Shearwater	70	0.00	na	na	na
Shearwater	71	0.11	109.43	0.01	1.29
Shearwater	72	11.17	35.72	5.15	24.23
Shearwater	73	3.21	48.46	0.46	22.41
Shearwater	74	1.99	126.09	0.12	33.03
Shearwater	75	0.91	4.79	0.83	1.00
Shearwater	82	0.34	154.92	0.00	402630.00
Shearwater	83	2.10	46.54	0.77	5.74
Shearwater	84	2.92	63.6	0.29	29.27
Shearwater	85	2.22	105.86	0.19	25.60
Shearwater	94	0.79	38.74	0.01	65.61
Shearwater	95	0.40	39.27	0.14	1.12
Shearwater	96	1.41	4.79	1.28	1.55
Shearwater	97	0.00	na	na	na
Shearwater	106	2.01	97.35	0.31	13.06
Shearwater	107	0.32	64.32	0.03	3.93
Shearwater	108	0.00	na	na	na
Shearwater	117	19.90	53.73	5.13	77.24
Shearwater	118	1.97	103.28	0.14	26.83
Shearwater	119	0.00	na	na	na