Sea Duck Joint Venture
Annual Project Summary
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SDJV Project #154: Integrating Fixed-Wing and Helicopter Survey Platforms to Improve Detection and Species Identification of North American Breeding Scoters

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Project Description
Populations of North American breeding scoters appear to be declining although a large degree of uncertainty remains around estimates of population size and overall trends (Bordage and Savard 1995, Savard et al. 1998, Caithamer et al. 2000) due to observation challenges particular to this group of sea ducks. We propose to conduct experimental fixed-wing and helicopter integrated breeding surveys over portions of the core breeding range, in Labrador and the Barrenlands of the Northwest Territories, of all three North American scoter species. A secondary objective of the proposed work is to produce habitat selection models which will provide more detailed information on the distribution of breeding scoters across core areas of the breeding range and provide the information required to develop a cost-efficient stratified sampling approach.

We proposed a three-year project to evaluate geographic and annual variation and extent in the following parameters from both fixed-wing and helicopter survey platforms: 1- detection probabilities; 2- species identification /composition; 3- differences in availability bias between the two platforms (i.e. correction factor to apply to the platform with lower detection probability). More specifically, year 1 would focus on an assessment of optimal survey timing from published and unpublished information, the development of preliminary habitat models, and determining species composition and helicopter detection probabilities in the core breeding area of the Barrenlands in the Northwest Territories. We will introduce fixed-wing transects in year 2, which will allow testing of the dual-platform integrated survey approach. Helicopter and fixed-wing integrated surveys will occur at two sites: Labrador and Barrenlands. Year 3 activities are limited to post-survey obligations (e.g. removing fuel containers) and report writing. If additional work is required, a new proposal would be presented to SDJV.

The proposed work will be highly relevant to the WBPHS review by addressing issues of coverage, reallocation of survey effort and survey timing for sea ducks. Priority information needs outlined in the SDJV sea duck harvest assessment report will also be partially addressed, by providing estimates of abundance for the experimental survey areas and ultimately proposing an approach for continental population estimation. The principal outcome of the proposed study will be the production of a recommendation document describing the appropriate methodology, potential costs and feasibility of implementing operational continental breeding ground scoter surveys to SDJV and Federal Wildlife Agencies.

Objectives

The overarching goal of the proposed study is to develop aerial breeding ground survey methodology for scoters that would be applicable at population or continental scales. We are proposing a survey across the Boreal Region of Canada that would integrate fixed-wing transects and helicopter plots to allow for species identification, assessment of species composition and the estimation of detection probabilities.

There are 6 main objectives for the proposed study:

1. Identify the optimal timing for breeding scoter surveys, based on data from previous nesting and productivity studies
2. Develop and evaluate methodology to accurately assess species identification and composition from an integrated fixed-wing and helicopter survey
3. Develop and evaluate methodology for estimating detection probabilities from an integrated fixed-wing and helicopter survey. This will address the perception bias component in both fixed-wing and helicopter components as well as availability bias from the fixed-wing component, allowing the estimation of visibility correction factors
4. Evaluate annual and geographic variation in species composition and detection probabilities to determine whether these components would need to be measured annually and/or across the range in an operational survey
5. Derive baseline abundance estimates for the experimental survey areas for all three populations of eastern scoters
6. Develop habitat selection models and test hypotheses about factors influencing scoter distribution across the survey area

The development of aerial survey techniques and protocols to improve estimates of detection probability, population trends and numbers and to better classify scoters to species have been identified as Priority Science Needs by the Sea Duck Joint Venture for FY2017. Populations of North American breeding scoters appear to be declining although a large degree of uncertainty remains around estimates of population size and overall trends

(Bordage and Savard 1995, Savard et al. 1998, Caithamer et al. 2000) due to observation challenges particular to this group of sea ducks. This lack of population information severely limits our ability to manage scoter habitat and harvest (Koneff et al. 2016).

Several aspects of their distribution and biology make these species somewhat challenging to survey. As such, they have been identified amongst the highest priority species for research and monitoring (2016-18 SDJV Implementation Plan). Recent studies using PTT devices have shown that the breeding range of all three scoter species falls largely outside of the survey area of the Waterfowl Breeding Population and Habitat Survey (WBPHS - Traditional and Eastern Waterfowl Survey areas; SDJV 2015). Relatively little information on waterfowl and other migratory birds distribution and trends exists in this area encompassing the northern Boreal forest, the continuous tree line and sub-Arctic tundra of North America, where the influence of global climate change are expected to be important. Finally, there are also issues related to timing of the survey as the WBPHS is timed for early nesting dabbling ducks, primarily mallards (*Anas platyrhynchos*) and American Black ducks (*Anas rubripes*), whereas scoters are considered to be a later-nesting species.

Despite these difficulties, progress has been achieved as experimental scoter surveys in the Canadian Barrenlands, Labrador, the Hudson Bay Lowlands and Northern Québec have confirmed the feasibility of conducting aerial surveys in remote Boreal and sub-Arctic regions of North America, as well as having identified key methodological gaps or biases requiring additional research. We propose to conduct experimental fixed-wing and helicopter integrated breeding surveys over portions of the ranges of all three scoter species in North America. This work, which will draw heavily on previous experimental work supported by the SDJV and partners, is expected to enable us to make recommendations on the appropriate methodology, potential costs and feasibility of implementing operational continental breeding ground scoter surveys. A secondary objective of the proposed work is to produce habitat selection models from the data collected in the course of the experimental surveys. This product will provide more detailed information on the distribution of breeding scoters across the landscape and should provide the information required to develop a cost-efficient stratified sampling approach. It will also be useful in Land Use Planning and Environmental Assessment in the proposed survey areas where little information on waterfowl distribution is currently available.
This project will address two SDJV priority science needs:

Specifically, this project will contribute to priority need #1 by focusing on evaluating geographic and annual variation and extent in the following parameters, from both fixed-wing and helicopter survey platforms:

- Detection probabilities
- Species identification /composition
- Differences in availability bias between the two platforms (i.e. correction factor to apply to platform with lower detection probability)

This work is expected to enable us to develop survey methods that allow for survey and observer specific corrections.

The proposed work will also contribute to the ongoing WBPHS review by addressing issues of current coverage relative to new information on the distribution and abundance of waterfowl outside the survey area, and in the consideration of reallocation of survey effort and timing to expand the usefulness of the survey for monitoring northern nesting species. We expect this work to result in a recommendation document for the establishment of a continental scoter breeding ground survey which would allow Canadian and U.S Federal agencies to determine the feasibility and appropriateness of expanding the WBPHS to cover core scoter areas.
The habitat modelling component of the proposed work will also contribute to the review by providing more detailed distribution information within the experimental survey areas and a framework for expanding this approach to eventually cover a larger proportion of the range. Specifically, this will address priority #2 of the SDJV strategic plan: inform habitat conservation actions.

Finally, priority information needs for population estimates for eastern Surf Scoters and eastern Black Scoters outlined in the SDJV sea duck harvest assessment report will be partially addressed, as we will be able to provide estimates of abundance for the experimental survey areas and, ultimately, propose an approach for continental population estimation. Results from the proposed study are expected to be broadly applicable for the development of breeding ground survey methodology for all scoter populations.

Methods

Survey Timing - Breeding chronology

We used results of brood surveys and satellite tracking to evaluate the timing of breeding for scoters. Brood surveys that included brood ages were used to estimate nest initiation dates by back-dating from brood age. The satellite telemetry data was used to determine arrival and departure times from breeding sites.

Brood surveys

We identified three sources of brood surveys. These included brood surveys conducted as part of an environmental assessment of the Great Whale Hydroelectric Project, Québec conducted in 1991 (Bordage et. al 1992), a brood survey of 25km^2 plot near Goose Bay, Labrador conducted in 2007 (SGG unpublished data), and notes to file made by W. Barrow (CWS retired) when scouting sites for pre-season banding operations, 1990 to 1992.

All broods were aged by plumage development (Gollop and Marshall 1954). Broods were aged using mid-points for plumage age classes for Surf Scoters described by Lesage et. al 1996. Nest initiation dates were calculated by back-dating the brood's age from the date of the observation minus 7 days, one day for the female to lay each egg in an average Surf Scoter clutch (mean = 7 eggs; Morrier et. al 1996).

Satellite Telemetry Data

We accessed the SDJV's satellite telemetry database in August 2017 and downloaded the unfiltered telemetry data for the period that included spring migration, breeding and arrival at molt (1 April to 1 September) for all Surf, Black and White-winged Scoters from eastern North America that were in the database. We also accessed telemetry data from scoters collected in western North America that were provided by Jason Schamber. We are seeking access to other datasets. Sources of the tags used in the analyses are identified in Appendix 1.

The migration tracks for each bird was mapped and labeled by year. Tracks for each year/bird combination were visually classified as whether the bird went or not to a breeding area. They were classed as: 1) Yes - if they went to a breeding area and settled (Breeding), 2) Maybe - went to a breeding area but could not tell if they settled, and 3) No – did not go to the breeding area. All bird/year combinations that did not go to a breeding location were filtered from the dataset. For the remainder, we created a Google Earth KMZ file with the track and individual locations labeled with dates. Each track was examined in detail and we recorded if the bird appeared to settle on a breeding site, and if it did, the date of its arrival and departure from the site (See Fig. 1 for an example of the process). Again all bird/year combinations that did not settle on a breeding site were filtered from the database. The arrival and departure dates were merged with the telemetry data, and locations outside this period were filtered from the data. For each bird/year combination that remained in the dataset we calculated the mean breeding location using the function geomean (Package Geosphere; Hijmans 2016) and determined the province of each breeding attempt.

We examined data tagging effects for female Black Scoters that attempted to breed in the year they were tagged and that also attempted to breed in subsequent years. Arrival dates averaged about 2 weeks earlier (9 June ± 10d, n=32) in the year subsequent to tagging than in the year of tagging (23 June ±13d, n=28); there was no effect of tagging on departure dates. Hence, we excluded all observations made in the year of tagging from the analysis, and for individuals that had observations for multiple breeding seasons we used only one season per bird. We summarized arrival and departure dates, and length-of-stay by species, sex and province that the breeding attempt occurred.

Figure 1. Spring migration track for female Black Scoter 39082 in 2011 (left panel) and that it settled where it arrived on 6 June and departed on 6 July (right panel).

Site Selection

To select survey areas, we used telemetry data from the SDJV’s satellite telemetry database to delineate the breeding habitat of female scoters. The database was filtered to identify females that went to a breeding area. For each of the females that settled during the nesting period, we assigned a spatial data point that was associated with the area where the females spent most of her time. These spatial points were subsequently used to identify the habitat that the female selected for breeding. Given that we had presence only data (i.e. points where we knew the females were breeding) we used a Maxlike approach to estimate the probability of occurrence of breeding females (Lele and Kleim 2006; Royle et al 2012). We used the Land Cover Map of Canada and multi-spectral remote-sensed data at a 1km resolution to make spatial predictions.

Based on these habitat models, we made predictions of scoter occupancy for the entire Canadian Barrenlands region and we selected 4 possible survey areas. Those survey areas were located along the transition line between the northern boreal forest and the Barrenlands in the Northwest Territories. We subsequently selected 2 out of the 4 possible survey areas based on logistical constraint for helicopter surveys (i.e. access to lodging and fuel caches). A third survey area was included in the Northwest Territories given that it is under consideration for receiving legal designation as a protected area. These surveys will help to identify specific areas of importance for waterfowl as well as update existing information to assist with the management of a potential protected area.

The surveys were conducted at the northern edge of the boreal forest. The landscape in this region is highly diverse, being covered with wetlands, coniferous forest, and open tundra. Given the level of heterogeneity present on the landscape, obtaining a representative sample in the survey area can be challenging. This is particularly true for surveys where sampling intensity is low (~ 2.5%) to keep cost at a reasonable level. Analysis of previous waterfowl surveys conducted in the northern boreal forest demonstrated that using a simple random and systematic designs, resulted in poor coverage of the some potentially important but rare habitats (Roy et al. *unpublished data*) so we opted for a stratified-random sampling design. We first divided our sampling areas into cells of 5 x 5 km (size of the plots to be surveyed). We then developed three weighting indices to select the sample. The first index was based on landscape composition within each cell. We average the Z-score values for the habitat variables that were identified as important for waterfowl habitat in the boreal forest (number of lakes, lake area, shoreline index, river density and proportion of coniferous forest). This index gave us an idea of how representative each possible sampling site (i.e. grid cell) was for the survey area. Cells with an average Z-score near zero were representative of the survey area, while cells with a high or low averaged Z-score were identified as unique. The second weighting variable was composed of the predicted total indicated pairs of Black Scoter and Surf Scoter within each cell. The predictions were based on a habitat model that was developed from previous surveys in Labrador and Northern Quebec (Roy et al. *unpublished data*). These predictions were based on the same habitat models that were included in the Z-score index.

Given that our objective was to obtain a sample as representative as was possible, we divided the posterior distribution of each of the weighting variables into 5 categories (very low, low, average, high, very high) and calculated the proportion of each cell in each of these categories. Each cell was subsequently assigned a score value equal to the proportion to which they belong. We then averaged the scores across all three weighting variables (Z-score, predicted Black Scoters IP, and predicted Surf Scoters IP). The combined scores were then divided into 5 categories and applied a sampling procedure that insured that all categories were represented in the sample. We proceeded to draw a sample of 30 sites for each sampling area and scored the data set for its spatial coverage of the survey area. Maintaining adequate spatial coverage ensured that we would be able to detect any spatial pattern present in our habitat model that would not be explained by explanatory variables. If the sample of selected sites was too clumped it was rejected and another sample was drawn. Any set that contained an immediate neighbor was also discarded. We repeated the sampling procedure in each area until we found a data set that respected these conditions.

Figure 2. Overview of the three survey areas in northern Canada. The area of each site was: Lynx Lake = 21,750km^2, Little Duck = 18,225km^2, Ramparts = 4,692 km^2.

Figure 3. The Little Duck Lake survey area in northern Manitoba, Canada. Basal 20 plots, and extra plots labelled 21-30. Plots 1 to 24 and 26 were surveyed in June 2017. Fuel was available at the lodge and at one cache (orange triangle).

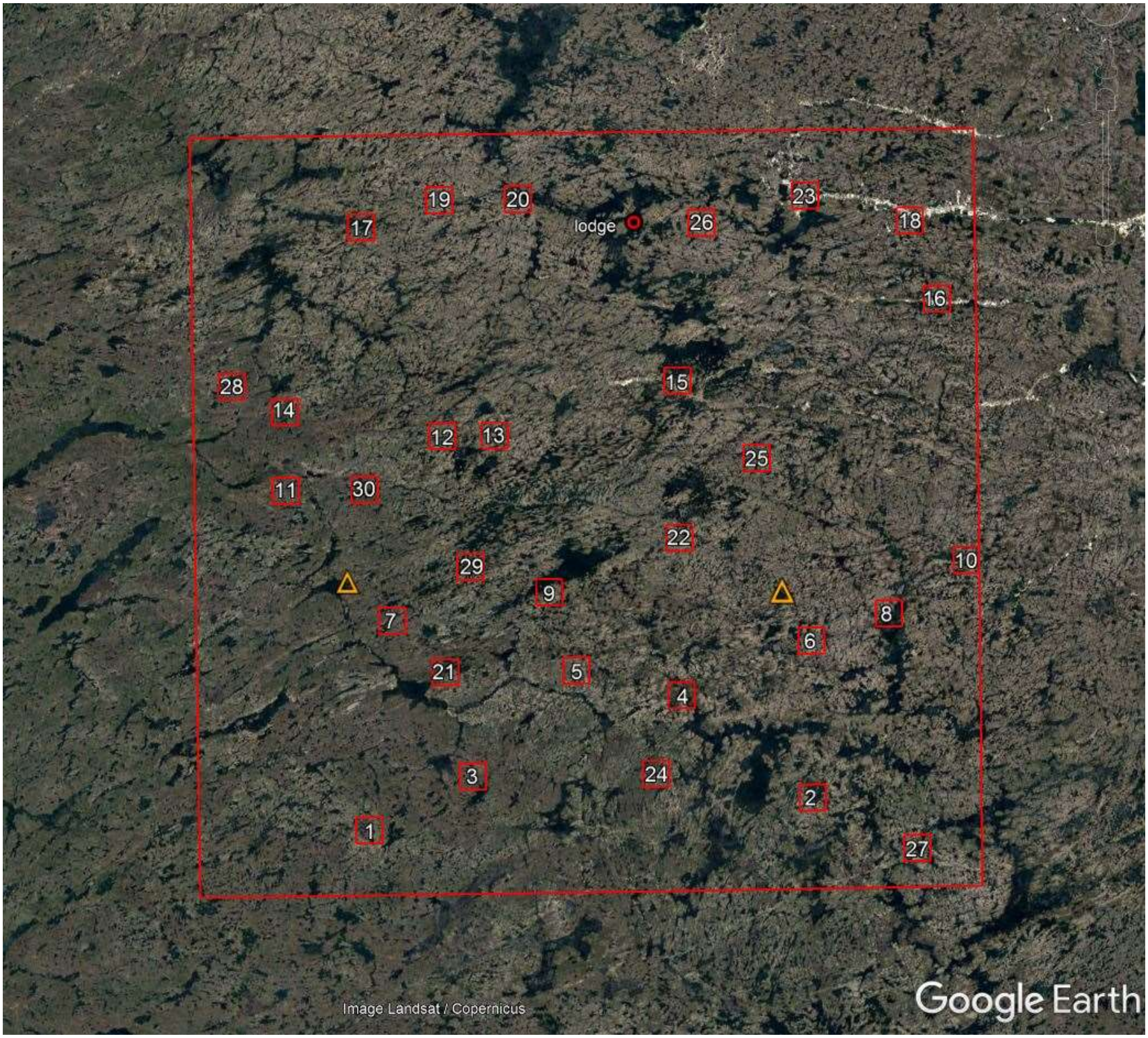


Figure 4. The Lynx Lake survey area in southeastern Northwest Territories, Canada. Basal 20 plots, and extra plots labelled 21-30. Plots 1 to 26 were surveyed in June 2017. Fuel was available at the lodge and at two caches (orange triangles).

Figure 5. The Ramparts survey area in northwestern Northwest Territories, Canada. All 20 plots were surveyed in June 2017. Fuel was available at Fort Good Hope.

Helicopter Survey

Survey Protocol

In two of the three regions (i.e. Lynx Lake and Little Duck Lake), surveys were carried out in a Bell 206L helicopter equipped with skids and bubble windows to enhance observer visibility. In Ramparts, the helicopter available was a Bell 407 also equipped with skids but it did not have bubble windows. Surveys took place in favourable weather; flights were delayed if wind speed exceeded 40 km/h, during heavy precipitations, or if visibility was reduced. Surveys were conducted throughout the day but began no earlier than one hour after sunrise and ended no later than one hour before sunset to avoid conducting surveys in difficult light conditions. The survey crew consisted of the pilot and three biologists or technicians, one sitting in the front with the pilot and two sitting in the back. During the survey, the helicopter flew over each water body, watercourse, and wetland within the plots; moving maps software allowed for the complete coverage of water on all plots. Upon arriving at a plot, the pilot reduced flight speed and descended to less than 50 m above ground level. Depending on the habitat and topography, surveys were flown at 15–50 m above ground level and at speeds ranging from a hover to 100 km/h. For all waterfowl observations the count, species and location of the observations were recorded by either the front observer or a rear observer, depending on crew, via a GPS-Voice recording software. In most cases observers were able to identify scoter to species; for birds consistently diving, the protocol followed by each crew was to try and circle it until it was identified to species. Stabilising binoculars and/or photos were taken in many cases to help identification. However, despite all efforts devoted to identify birds to species, it was on occasions not possible without spending a large amount of time, and bird identification was then left at the genus level (scoters sp., scaup sp., etc.), at the tribe level (dabblers sp., divers sp., etc.) or rarely, at "ducks" only.

Double Observer Protocol
To assess detectability, we used a double dependent observer sampling scheme. In this sampling scheme, one observer is designed as the "primary" observer and the other as the "secondary" observer. The primary observer reports all his observations to the secondary observer. The secondary observer reports all observations that are missed by the primary observer. We alternated the roles between primary and secondary observers at each plot. The original double-counting procedure was modified to accommodate the constraint imposed by making observations from a helicopter (see Gilliland et. al 2010). Observations from the two front observers and two rear observers were combined and treated as a single observer. An imaginary line was drawn through the helicopter, perpendicular the direction of travel and between the front and rear observers. The primary observer was only allowed to record his observations when he detected forward of this line. Observers were allowed to redirect the helicopter path to ensure that the age and sex of the birds were classified accurately. However, any additional observations that were made while the helicopter was being redirected by one of the observers (i.e. observations that were missed by both observers on the first pass) were recorded as not detected. One observer in each crew was inexperienced with the helicopter survey protocols. Therefore, to avoid confounding the observer's position with observers experience in our modeling exercise, the front seat observer was occupied by one of the two other experienced observers, switching position and role amongst themselves. At the end, the two experienced observers spent approximately equal time in each detection roles, and approximately equal time in the front or rear position.

Phenology Index
To determine survey timing relative to nest initiation, we calculated a phenology index (PI) afterward (see Bordage et al. 2017). This index is the ratio of the number of pairs (birds initiating nest) to that of unattended males (lone [paired birds with females incubating and having close to zero detection probability] and flocked drakes). For a specific survey, if the calculated PI nears 1.00, then the survey timing is considered adequate and is indicative of a survey conducted when half the pairs involved have initiated nesting while the other half have started incubation. A PI value much greater than 1.00 indicates a survey conducted too early in the breeding season (possibility of overestimating the breeding population), and a very small PI indicates a late survey relative to the nesting phenology (leads to underestimation of the indicated pair numbers).

Density Estimation
We have developed a three-step model to estimate detection. Given that most of the birds are observed in pairs or in groups we used the cluster as the unit of observation (Sollmann et al., 2016). Our modelling approach is divided into three steps. The first step is to estimate the detection rate of the cluster of birds that are observed during the survey, we then estimate the "true" numbers of clusters that are present in a given site, and finally we estimate the size of the missing clusters based on the size of the clusters we observed in the survey area. Each component of the detection model is explained in detail below.

Cluster Detection Model
Let $y_{1_{i,j}}$ and $y_{2_{i,j}}$ be the numbers of clusters of birds detected by the primary observer and secondary observer respectively and $y_{T_{i,j}}$ be the total number of birds detected by both observers in plot *i* for a given species *j*. The dependence between counts of primary and secondary observers may be specified using a multinomial model such as:

$$y_{1:2_{i,j}} \sim Multinomial\left(p_{1_{i,j}}, \left(1 - p_{1_{i,j}}\right) p_{2_{i,j}}\right) \qquad \text{Eq. 1}$$

where $p_{1_{i,j}}$ and $p_{2_{i,j}}$ denote the detection rate of primary and secondary observers for a given species *j* while surveying the plot *i*. Given the observers detection rate, the total detection rate for a given species in a plot can be calculated as $p_{T_{i,j}} = 1 - \left(1 - p_{1_{i,j}}\right)\left(1 - p_{2_{i,j}}\right)$ and the true number of clusters in the the survey plot ($C_{i,j}$) can estimated via a binomial distribution such as:

$$C_i = \text{Binomial}\left(y_{T_{i,j}}, p_{T_{i,j}}\right) \qquad \text{Eq. 2}$$

The sources of variation in detection rates during the survey for the pairs of observers *k* can be assessed via a logistic link:

$$\text{logit}\left(p_{k_{i,1:j}}\right) = \alpha + \beta \mathbf{X} + \gamma_1 \text{Seat}_i + \gamma_2 \text{Observer}_i \qquad \text{Eq. 3}$$

$$\beta_j \sim \text{normal}\left(0, \sigma_\beta^2\right) \qquad \text{Eq. 4}$$

where α in the intercept, β is a species specific effect, **X** is a matrix that contain the species identity, γ_i is the effect of the position of the observer in the helicopter, and γ_2 is the effect of the secondary observer. We modeled the species specific effect as a random effect where the variance parameters σ_β^2 specify the levels of variation in detection rate among species.

Cluster Abundance

We estimated the variation in cluster abundance via a compound Poisson-gamma distribution.

$$C_{i,j} \sim \text{Poisson}\left(\lambda_{i,j}\, \rho_{i,j}\right) \qquad \text{Eq. 5}$$

$$\log\left(\lambda_{i,j}\right) = \mu_j + \log(\text{Area}_i) \qquad \text{Eq. 6}$$

$$u_j \sim \text{Normal}\left(0, \sigma_\mu^2\right) \qquad \text{Eq. 7}$$

$$\rho_{i,j} \sim \text{Gamma}(r, r) \qquad \text{Eq. 8}$$

where $\lambda_{i,j}$ is the expected numbers of clusters in plot *i* for species *j*, μ_j the mean abundance of clusters in the survey area on the log scale for species *j*, and $\rho_{i,j}$ is the overdispersion term for each observation in each plot. The species specific mean abundance was modeled as random effects and the overdispersion parameter *r* was shared across species.

Cluster Size Model

The last step of the model was to estimate the size of the missing clusters. To that end, we have used a data augmentation scheme. For each species we created a vector containing the size with the observed clusters and padded the vector with missing entries. Those missing entries act as surrogates for the missed observations. We then use a Gamma-Poisson compound model to estimate the size of the cluster for a given species.

$$\text{Birds}_{j,k} \sim \text{Poisson}\left(\lambda_j^*\, \rho_{j,k}^*\right) \qquad \text{Eq. 5}$$

$$\log\left(\lambda_j^*\right) = \mu_j^* \qquad \text{Eq. 6}$$

$$\mu_j^* \sim \text{Normal}\left(0, \sigma_\mu^2\right) \qquad \text{Eq. 7}$$

$$\rho_{j,k}^* \sim \text{Gamma}(r, r) \qquad \text{Eq. 8}$$

Where Birds in the size of cluster *k* of species *j*, λ_j^* is the expected size of the clusters for species *j* in the survey area, μ_j the mean size of the clusters in the survey area on the log scale for species *j*, and $\rho_{i,j}$ is the overdispersion term for the cluster *k* of species *j*. The species specific mean cluster size was modeled as random effects and the over-dispersion parameter *r** was shared across species.

We derive the total abundance for a species (T_j) in the survey area by summing over the size of all clusters across the sites. To avoid including too many clusters in the sum we use the total number of cluster predicted in the area as the upper bound of the summation.

$$T_j = \sum_{k=1}^{C_j} Birds_k \qquad \text{Eq. 7}$$

We estimated the parameters using a Bayesian framework that was implemented in JAGS (Plummer 2003) from R using the jagsUI package (Kellner 2016; R Core Team 2013). We used non-informative priors for all parameters and we ran five chains with randomized initial values for 25,000 iterations, with the first 5,000 iterations used as a burn-in and saved every 20th iteration. Chain convergence was visually evaluated and verified using the Gelman-Rubin statistic ($\hat{R}$) with both measures indicating a reasonable assumption of convergence. We used the sums of the squared Pearson residuals to assess the model fit via posterior predictive checks (Kéry 2010) and did not find any evidence of lack of fit for the model. We report results as posterior means and 2.5 and 97.5 percentiles of the posterior distribution for credible intervals (95% BCI). For the discussion, we consider covariate effects as strong/significant if their 95% BCI do not overlap 0.

Habitat Selection Model

We used two major data sources for extracting explanatory variables. The CanVec database (v 6.18), a digital cartographical reference at the 1:50000 scale which is distributed by the Centre for Topographic Information, Natural Resources Canada (http://geogratis.ca/) and Ducks Unlimited Canada's Hybrid Wetland Layer, a raster layer that classifies the Canadian land base into three general categories: Water, Wetland, and Upland (Jones 2011).

Based on the previously published literature we extracted the following variables from the geographic data source: the numbers of lakes in a given cell, the average lake size, the variance in lake size, total shore length, total river length, the proportion of the cell covered by open water, wetlands and coniferous forest. We derived a shoreline index from the total shore length, the average lake size and the total number of lakes in a cell. A value of 1 indicates that the amount of shoreline in the cell equal to the amount of shoreline there would be if all lakes in the cell would be perfect circles, a value above 1 indicate more complex shoreline, and a value below 1 indicates that there is less shoreline than expected in the cell. The latter situation could arise, for example, if the cell is covered in part by a large lake.

Multicollinearity among predictor variables is often a problem with landscape metrics. We therefore used a variance inflation factor approach (VIF) to select a subset of explanatory variables to use for our model. We used a threshold of 2.5 for the VIF. Based on the output of the different permutations possible we ended up keeping 6 explanatory variables: The number of lakes on the log scale, the total lakes area on the log scale, the shoreline index, the proportion of wetlands, and the proportion of coniferous forest in the landscape. We felt that the combination of 6 variables would be the best combination to capture the variability in both survey area, maintain collinearity between variables to an acceptable threshold, while also have sufficient explanatory power to explain the distribution of species of ducks that could have different habitat requirement.

During the preliminary screening of the data, some species showed a quadratic correlation to some of the selected variables. We therefore built a candidate set of models that contains the 64 possible combinations of quadratic terms in the model. We fitted all the models to each species and we used bridge sampling to estimate the likelihood ratio between the models (Meng and Wong 1996, Gelman and Meng 1998).

For each species we estimated the Indicated breeding pairs (IBP) associated with each sampling sites. We estimated the variation in waterfowl IBP in the sampling sites via a negative binomial model (ZINB).We used the Negative binomial distribution with a quadratic mean–variance relationship as the probability distribution explaining the abundance of IBP at survey sites (i.e. NB2; Hilbe 2014). This distribution is parametrized in function of the mean and an over-dispersion parameter such as:

$$\mathrm{IBP}_i \sim \mathrm{NB}(\eta_i, \kappa) \quad \text{Eq. 1}$$

$$\log(\eta) = \mathbf{X}\beta + \log(\mathrm{area}) \quad \text{Eq. 2}$$

where IBP_i is the number of ducks pairs at site *I*, η is the expected mean of IBP at location *I*, κ is the over-dispersion parameter, **X** is matrix holding the explanatory variables, and β is a vector holding the estimate of the effect of the explanatory variables. We included the log of the sites area as an offset in our analysis. The explanatory variables were standardized to zero mean and unit variance to ease interpretation and convergence of the model (Kéry 2010).

We ran the series of models for each species independently in a Bayesian framework that was implemented in Stan from R using the rstan package. We used a non-informative prior for all parameters and we ran four chains with randomized initial values for 1500 iterations, with the 500 first iterations used as a burn-in. Chain convergence was visually evaluated and verified using the Gelman-Rubin statistic ($\hat{R}$). We used the package bridgesampling (Gronau and Singmann 2017) to estimate the model posterior probability and kept the model with the highest probability for each species. In the results section we present the posterior means and 2.5 and 97.5 percentiles of the posterior distribution for credible intervals (95% BCI). For the discussion, we consider explanatory variables effects as “significant” if their 95% BCI do not overlap 0 and “weak” in their 90% BCI do not overlap 0.

Preliminary Results

Survey Timing - Breeding Chronology

Brood Surveys

We obtained data for 36 scoter broods from Labrador and Québec. Nest initiation dates average between 26 May and 1 June depending on species and location (Table 1).

Satellite Telemetry Data

To date we have processed all the telemetry data from birds tagged in eastern North America for Black Scoter (Table 2 and 5), Surf Scoter (Table 3 and 5), and the eastern White-winged Scoters (Table 4 and 5). Telemetry data from birds tagged in western North America have not been processed yet.

Phenology Index

Analyses have not been completed so results are pending.

Table 1. Nest initiation dates estimated for scoters in Québec and Labrador from back-dating age of broods observed.

Area	Species[1]	Nest Initiation ± sd (n)
Labrador	SUSC	1 June ±14 (12)
Québec	Scoter	28 May ±7 (10)
Québec	SUSC	27 May ±6 (7)
Québec	BLSC	26 May ±9 (7)

[*] BLSC, Black Scoter; SUSC, Surf Scoter

Table 2. Arrival and departure dates for Black Scoters tagged in eastern North America estimated from satellite telemetry.

Area	Sex	Arrival	Departure	n
Manitoba	F	5 Jun ±3	26 Jul ±3	5
Manitoba	M	5 Jun ±6	21 Jun ±12	8
Labrador	F	8 Jun	NA	1
Northwest Territories	F	11 Jun ±6	14 Aug ±18	9
Northwest Territories	M	30 May	26 Jun	1
Nunavut	F	16 Jun ±12	4 Aug ±10	5
Nunavut	M	7 Jun ±5	3 Jul	2
Ontario	F	27 May ±8	NA	2
Quebec	F	9 Jun ±14	30 Jul ±11	10
Quebec	M	1 Jun ±8	23 Jun ±2	3
Overall	F	11 Jun ±10	4 Aug ±15	27
Overall	M	3 Jun ±7	24 Jun ±11	9

Table 3. Arrival and departure dates for Surf Scoters tagged in eastern North America estimated from satellite telemetry.

Area	Sex	Arrival	Departure	n
Manitoba	F	1 Jun ± 7	24 Jul ± 3	3
Manitoba	M	26 May ±12	14 Jun	2
Labrador	F	30 May ±6	26 Jul ± 13	8
Northwest Territories	F	10 Jun	20 Jul	1
Nunavut	F	1 Jun	20 Jul	1
Ontario	F	30 May	6 Jul	1
Quebec	F	29 May ± 5	18 Jul ± 16	16
Quebec	M	22 May ± 4	15 Jun ±9	3
Overall	F	30 May ± 5	21 Jul ± 11	30
Overall	M	24 May ± 7	15 Jun ± 7	5

Table 4. Arrival and departure dates for White-wing Scoters tagged in eastern North America estimated from satellite telemetry.

Area	Sex	Arrival	Departure	n
Manitoba	F	14 Jun ±11	2 Aug ±21	6
Manitoba	M	1 Jun ±0	20 Jun ±2	2
Northwest Territories	F	11 Jun ±9	22 Jul ±33	12
Northwest Territories	M	2 Jun	16 Jun	1
Nunavut	F	13 Jun ±3	28 Jul ±26	2
Ontario	M	11 Jun	03 Jul	1
Quebec	F	10 Jun ±10	24 Jul ±19	3
Quebec	M	7 Jun	NA	1
Saskatchewan	F	19 Jun ±0	2 Jul	2
Saskatchewan	M	4 Jun	29 Jun	1
Overall	F	12 Jun ±9	24 Jul ±27	25
Overall	M	4 Jun ±4	23 Jun ±6	6

Table 5. Average length-of-stay on the breeding site by species and sex of scoters estimated from satellite telemetry for scoters tagged in eastern North America.

	Species[1]		
Sex	BLSC	SUSC	WWSC
Female	47 days ±18 (60)	49 days ±14 (48)	43 days ±27 (34)
Male	18 days ±9 (22)	25 days ±15 (10)	24 days ±10 (8)

[1] BLSC = Black Scoter; SUSC = Surf Scoter; WWSC = White-wing Scoter; ±sd (n).

Helicopter Survey

Weather Conditions

All surveys were conducted under favorable conditions for surveys (see Methods; Table 6). Strong winds were more frequent on the Little Duck Lake site.

Table 6. Timing and conditions of 2017 scoter surveys

Site	First survey day	Last survey day	No. survey days	No. days on site	Mean temp (°C)	Mean wind speed (kt)
Little Duck Lake	12 Jun	21 Jun	8	10	14	11
Lynx Lake	10 Jun	21 Jun	10	12	11	6
Ramparts	10 Jun	16 Jun	7	7	11	5

Plot Surveys

All crews managed to fly their basal 20 plots of 5 × 5 km. Extra plots were also surveyed by the Lynx Lake and the Little Duck Lake crews (total of 26 and 25 plots respectively; Table 7).

Table 7. No of 25 km^2 plots surveyed by site in 2017 and time on plot

Site	No. of plots surveyed	Plot mean duration (min)	Plot minimum duration (min)	Plot maximum duration (min)
Little Duck Lake	25	78	44	119
Lynx Lake	26	66	35	94
Rampart	20	55	5	109

Detection Probabilities

Detection probability estimates were high for most species, but varied across sites and among observers (Fig. 6 and 7). Detection probabilities for rear observers were consistently greater than for observers seated in the front of the helicopter. Despite greater visibility from the front seat, lower detection was likely due to the added challenge of navigation, in addition to variable effort by the pilot as he maneuvered the aircraft. Worth mentioning are the different recording methods adopted by each survey crew. The Ramparts and Little Duck crews chose to have the two rear observers record data on their respective sides of the helicopter and the front observer be tasked only with navigating and observing, while the Lynx Lake crew opted to have the front observer navigate, record data and observe birds, leaving those in the rear seats to observe birds only. The double-dependent approach used allowed us to assess and correct for the bias introduced by varying detection probabilities across sites.

Density Estimates

Density estimates for breeding scaup and scoter species were very high (Table 8). Our results support our expected distribution of scoter species across Canada, with the most White-winged Scoters having been observed in the Ramparts study area (0.57 per km^2, 95% BCI: 0.57 - 0.59) and greater numbers of Black Scoters at the Lynx Lake (1.35 per km^2, 95% BCI: 1.33 - 1.38) and Little Duck sites (0.75 per km^2, 95% BCI: 0.74 - 0.76). Surf Scoter densities were similar across study sites (Table 8). Greater Scaup were most abundant at the Lynx Lake site, with none recorded at the Ramparts site among those birds that were able to be identified to species. However, when all scaup species were combined (i.e. including unidentified scaup), the Ramparts density estimate was almost double that of the two other surveyed sites. Long-tailed Ducks were most abundant at the Lynx Lake site, whereas Common Goldeneye was not observed. This likely relates to habitat differences among sites: Long-tailed Ducks were most often observed on open tundra plots, the habitat type most common at the Lynx Lake site and less common at Little Duck and Ramparts. Likewise, goldeneye require at least some forested cover for nesting, possibly explaining their absence at Lynx Lake and low densities at the two other sites. Mergansers were seen in very low densities at the Ramparts site but moderate densities at Little Duck and Lynx Lake relative to diving ducks, with the exception of Hooded Mergansers at the Little Duck site which were abundant (Table 8).

Contrast to Previous Studies

In comparison with previous studies in other regions of Canada that focused on estimating the abundance of scoter species, the sites surveyed in 2017 appear to be used to a greater extent by breeding scoters. Based on uncorrected indicated pair calculations, the three study sites held a larger number of breeding scoters per 25 square kilometers when compared against data collected in Labrador in 2009 and in the Hudson Bay Lowlands of Ontario in 2009 (Brook et al. 2012; Table 9). Population estimates for the Lynx Lake, Little Duck Lake, Ramparts River, and Labrador study sites, are shown in Figure 8. The Lynx Lake site was the largest in area (21,750km^2) and we projected density estimates from the Little Duck Lake, Ramparts and Labrador sites to this surface area to allow for a direct comparison among the 4.

Table 8. Mean number of indicated breeding pairs (standard deviation; uncorrected estimate) per surveyed plot (25km^2), predicted probability of detection (lower and upper 95% Bayesian credible interval) and estimated density of ducks per square kilometer (lower and upper 95% Bayesian credible interval) by species for each of the three study sites surveyed in 2017.

Species[†]	Little Duck Lake			Lynx Lake			Ramparts		
	IP / Plot	Detection	Density	IP / Plot	Detection	Density	IP / Plot	Detection	Density
Scoters									
BLSC	8.52 (10.39)	0.937 (0.899 - 0.967)	0.745 (0.742 - 0.757)	14.73 (12.05)	0.810 (0.748 - 0.862)	1.352 (1.33 - 1.381)	0.05 (0.22)	0.685 (0.234 - 0.925)	0.005 (0.004 - 0.012)
SUSC	6.52 (5.21)	0.909 (0.841 - 0.956)	0.444 (0.440 - 0.456)	5.15 (5.69)	0.870 (0.801 - 0.925)	0.366 (0.363 - 0.375)	3.4 (6.39)	0.702 (0.512 - 0.834)	0.340 (0.326 - 0.374)
WWSC	2.84 (6.35)	0.944 (0.869 - 0.987)	0.214 (0.213 - 0.219)	1.38 (3.65)	0.838 (0.709 - 0.934)	0.101 (0.100 - 0.109)	6.4 (11.84)	0.824 (0.717 - 0.916)	0.573 (0.566 - 0.594)
ALL	-	-	1.402 (1.395 - 1.419)	-	-	1.819 (1.798 - 1.849)	-	-	0.917 (0.896 - 0.956)
Scaup									
GRSC	3.00 (3.45)	0.948 (0.877 - 0.987)	0.183 (0.182 - 0.188)	5.54 (5.05)	0.900 (0.830 - 0.953)	0.385 (0.383 - 0.394)	-	-	-
LESC	7.6 (7.77)	0.979 (0.947 - 0.996)	0.592 (0.592 - 0.597)	7.77 (9.59)	0.874 (0.808 - 0.927)	0.507 (0.503 - 0.518)	2.45 (4.38)	0.848 (0.717 - 0.956)	0.269 (0.266 - 0.282)
SCAU	3.64 (3.74)	0.962 (0.913 - 0.991)	0.317 (0.317 - 0.323)	5.88 (5.36)	0.806 (0.715 - 0.880)	0.467 (0.458 - 0.486)	27.05 (29.46)	0.850 (0.802 - 0.890)	2.262 (2.244 - 2.292)
ALL	-	-	1.093 (1.091 - 1.101)	-	-	1.358 (1.345 - 1.382)	-	-	2.531 (0.010 - 0.026)
Mergansers									
COME	0.88 (2.07)	0.937 (0.806 - 0.993)	0.069 (0.069 - 0.074)	2.92 (4.82)	0.792 (0.647 - 0.895)	0.187 (0.183 - 0.202)	-	-	-
HOME	4.16 (4.07)	0.917 (0.855 - 0.960)	0.477 (0.474 - 0.490)	1.46 (1.88)	0.823 (0.720 - 0.907)	0.200 (0.197 - 0.211)	0.15 (0.49)	0.636 (0.207 - 0.868)	0.010 (0.008 - 0.020)
RBME	1.80 (3.49)	0.927 (0.841 - 0.979)	0.146 (0.146 - 0.152)	3.38 (3.29)	0.823 (0.716 - 0.908)	0.245 (0.242 - 0.257)	0.05 (0.22)	0.686 (0.236 - 0.922)	0.003 (0.002 - 0.008)
Other Seaducks									
COGO	0.80 (1.76)	0.941 (0.825 - 0.994)	0.061 (0.061 - 0.066)	-	-	-	0.25 (0.72)	0.733 (0.383 - 0.941)	0.017 (0.016 - 0.024)
LTDU	2.00 (3.35)	0.770 (0.601 - 0.891)	0.165 (0.157 - 0.187)	10.42 (9.00)	0.799 (0.728 - 0.858)	0.665 (0.654 - 0.683)	0.05 (0.22)	0.689 (0.277 - 0.918)	0.003 (0.002 - 0.008)

[†] BLSC = Black Scoter; SUSC = Surf Scoter; WWSC = White-winged Scoter; GRSC = Greater Scaup; LESC = Lesser Scaup; SCAU = unidentified Scaup; COME = Common Merganser; HOME = Hooded Merganser; RBME = Red-breasted Merganser; COGO = Common Goldeneye; LTDU = Long-tailed Duck

Figure 6. Predicted detection probability by species for each of the Little Duck Lake, Lynx Lake and Ramparts sites surveyed in 2017. Error bars represent upper and lower 95% Bayesian credible intervals.

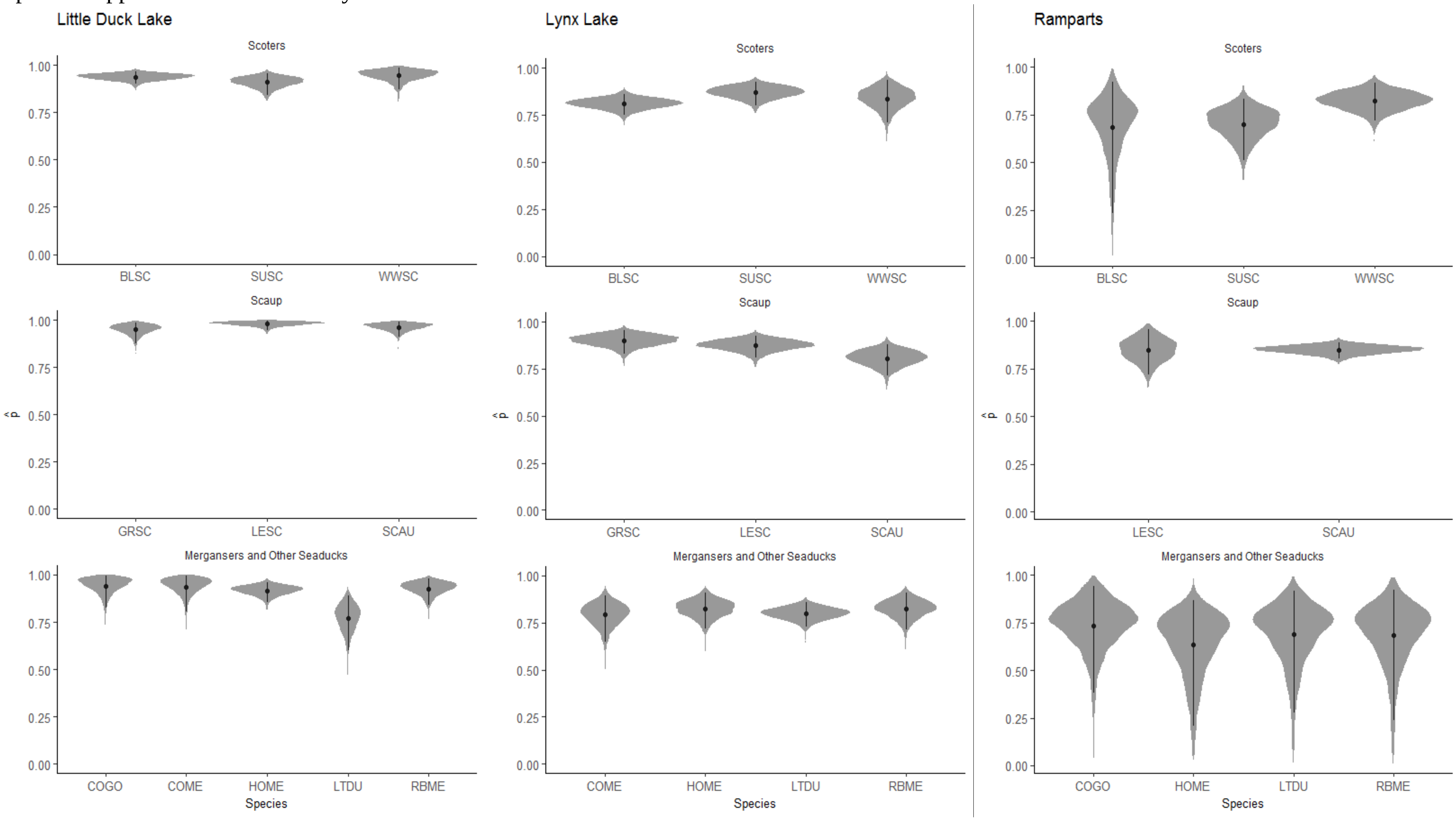


Figure 7. Predicted detection probability by observer and seat position in the helicopter for each of the three sites surveyed in 2017. Error bars represent upper and lower 95% Bayesian credible intervals.

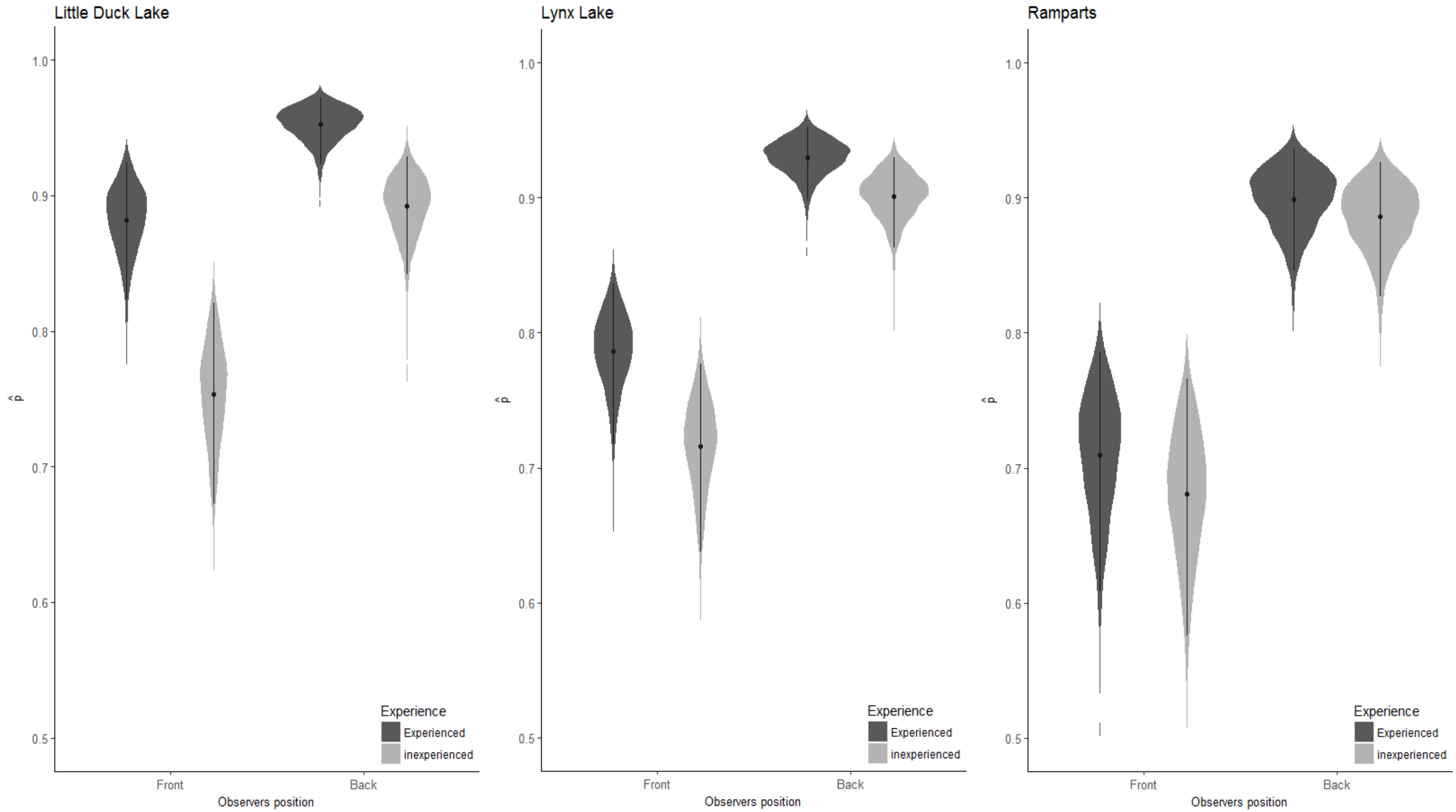
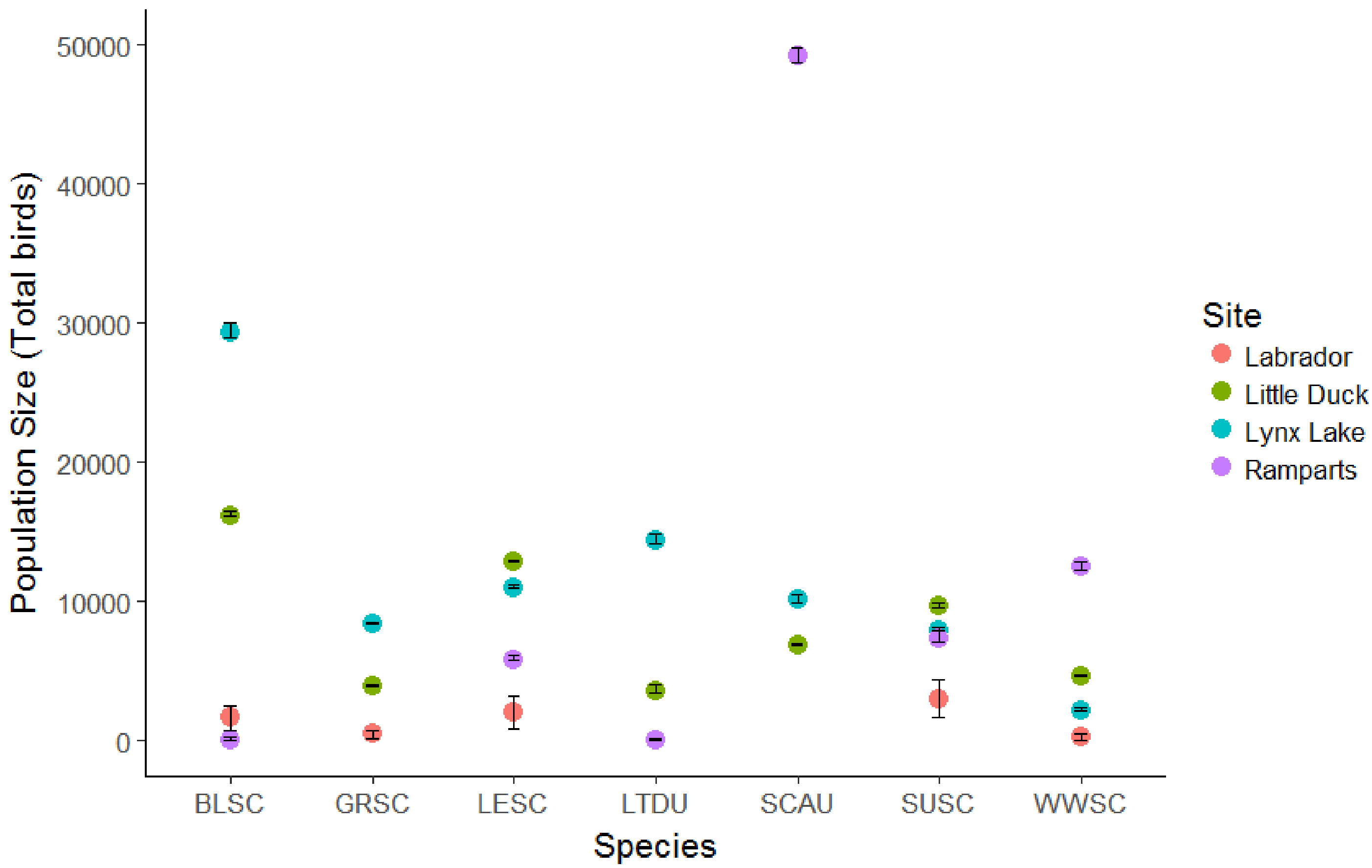


Table 9. Mean number of indicated pairs per 25 km^2 (uncorrected for detection probability) for Black, Surf and White-winged Scoters across the three sites surveyed in 2017 (Little Duck Lake, *n* = 25 plots; Lynx Lake, *n* = 26 plots; Ramparts, *n* = 20 plots). Indicated pair density per 25 km^2 for Labrador (surveyed 2009) were taken from Gilliland et al., report on SDJV Project No. 115 and indicated pairs for the Hudson Bay Lowlands, Ontario (surveyed 2009) were derived from Brook et al. (2012).

Species	Little Duck Lake	Lynx Lake	Ramparts	Labrador	Hudson Bay Lowlands
BLSC	8.52	14.73	0.05	1.9	4.0
SUSC	6.52	5.15	3.4	3.5	2.75
WWSC	2.84	1.38	6.4	0.32	1.5

Figure 8. Population size estimates (corrected for detection) for scoters and scaup at Lynx Lake (21,750km^2), Little Duck Lake (projected to a surface area of 21,750km^2), and Ramparts River (projected to a surface area of 21,750km^2 to allow for direct comparison to other sites). Population size estimates for Labrador data (projected to a surface area of 21,750km^2 to allow for direct comparison to other sites) were calculated from the Gilliland et al. report on SDJV Project No. 115.



Project Status

The project was a success in 2017. All objectives were met or surpassed. Sampling intensity objectives were surpassed at both sites identified in the proposal (Lynx Lake NT, and Little Duck Lake MB) and a third site (Ramparts River NT) was added to the project. Lynx Lake and Little Duck sites both encompassed a variety of habitats ranging from tundra to treeline to boreal which resulted in a diverse assemblage of sea ducks observed across the study sites: both Lynx Lake and Little Duck had all 3 species of scoters, Long-tailed ducks, 3 species of Mergansers, as well as Lesser and Greater Scaup. The Ramparts River site was predominantly boreal and had a much higher proportion of scaup than the other sites. The variety of habitats across the 3 sites should result in a more robust analysis of habitat selection for all three species of scoters, Long-tailed duck, mergansers and scaup and therefore allow for better planning of future survey efforts in the region. Survey timing in relation to breeding phenology also appeared to be very good. Survey data will allow us to refine our understanding of breeding phenology for scoters from the trend in relative proportion of grouped versus paired birds across the survey period. Surf and Black Scoter densities from this survey are significantly higher than observed in previous surveys conducted in eastern Canada. These results, coupled with information from the Canadian Barrenlands experimental Breeding Survey (SDJV # 141) and from satellite telemetry studies confirm that the Barrenlands region of Canada is indeed a core breeding area for those species. Information gathered during the 2017 survey will be useful in developing future sea duck surveys in the sub-arctic and boreal regions of North America.

Data analyses and planning for summer 2018 will be the main activities during fall and winter 2017-18. We currently have someone on contract doing the density and detection analyses as well as the habitat use modelling for all three sites surveyed in 2017. Results from these analyses are expected in November 2017. Planning for 2018, including selection of survey sites, development of detection estimation protocol for the fixed-wing component, integration of survey platforms, will be based on results from previous surveys (e.g. Labrador survey SDJV # 115, Barrenlands experimental breeding sea duck survey SDJV #141) as well as from the work completed in summer 2017.

In spring 2018, we will implement the second year of the proposal introducing fixed-wing aircraft to the surveys' design. This will allow testing of dual-platform surveys and will be used to develop better methodologies to integrate data from the two platforms. We propose to conduct helicopter and fixed-wing surveys at two sites where the breeding ranges of two or more species of scoters overlap: Labrador and Barrenlands. The Labrador survey will use the same area as the SDJV No. 115 Developmental Surveys for Breeding Scoters in Eastern North America, allowing for the evaluation of temporal variation in platform-specific detection probabilities and visibility correction factors. The Barrenlands survey area will be determined based on the work conducted in 2017. It will occur in an area where previous fixed-wing and helicopter surveys have been conducted. One helicopter and one fixed-wing crew will be deployed at each site. This will allow estimation of the relative differences in availability bias, species composition and detection-corrected density estimates between helicopter and fixed-wing platforms for the two sites. Revisiting the same survey area will also allow us to re-evaluate the habitat model and to estimate the temporal variation in those estimates.

Funding has not yet been secured for the 2018 survey.

Project Funding Sources (US$).

SDJV (USFWS) Contribution	Other U.S. federal contributions	U.S. non-federal contributions	Canadian federal contributions	Canadian non-federal contributions	Source of funding (name of agency or organization)
$113,800					SDJV (USFWS)
			$634,000 (includes $119,000 in-kind contribution)		CWS
	$5,000 (in-kind)				USFWS

Total Expenditures by Category (SDJV plus all partner contributions; US$).

Activity	**BREEDING**	**MOLTING**	**MIGRATION**	**WINTERING**	**TOTAL**
Banding (include only if this was a major element of study)					
Surveys (include only if this was a major element of study)	**$752,800**				**$752,800**
Research					

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Appendix 1. Sources of satellite transmitted data used in determining the arrival and departure dates of scoters tagged in eastern North America.

	Species		
Principal Investigators	BLSC	SUSC	WWSC
S. Gilliland & C. Lepage	40	26	17
P. Loring	3	0	0
M. Perry	12	9	0
P. Wilson	x	0	1
L. Savoy	x	2[1]	16
A. Wells-Berlin	x	12[2]	1
Unidentified	x	4	0

[1]Data from 2 transmitters provided by BOEM project.
[2]Data from 8 transmitters provided by BOEM project.