Boreal Avian Modelling (BAM) Project

Predictive tools for the monitoring and assessment of boreal birds in Canada

2013–2014 Annual Report to Environment Canada

2013–2014 Annual Report

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Boreal
Avian
Modelling
Project

Projet de
modélisation
de l'avifaune
boréale

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Highlights of Accomplishments 2013–2014

- **Species at Risk**
  - Generated range-wide bird-habitat models that incorporated vegetation, climate, disturbance and temporal covariates for Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk across Canada, provided updated distribution and population estimates, and provided scientific recommendations to support critical habitat identification for these Threatened species;
  - Updated results from a regional-scale study of Canada Warbler to identify offset opportunities that now take into account the economic values of land in Alberta;
  - Partnership initiated with Parks Canada and Dalhousie University to develop model regional-scale models of population distribution and habitat availability for Canada Warbler, Olive-sided Flycatcher and Rusty Blackbird in Maritime Canada.
- **Joint Oil Sands Monitoring**
  - Created specialized bird-habitat models using extensive new point count data sets and new geospatial covariates designed for to test how 80+ species of birds respond to the local scale impacts of linear features (pipelines and seismic lines) and industrial development (well-pads, processing facilities) northeastern Alberta;
  - Created maps of species distribution across Joint Oil Sands Monitoring study area based on current conditions and for estimates of habitat supply if disturbance footprint was removed (de-footprinted landscape);
  - Documented the importance of errors in measurement of covariates on habitat model predictions;
  - Reviewed two case studies of landscape analysis tools currently used in the Oil Sands Area of Alberta to assess cumulative effects of land use on landbirds;
  - Completed analyses exploring the importance of spatial scale when quantifying the effects of the energy sector on avian populations and used this to inform design of additional sampling for 2014.
- **Climate Change Impacts and Management**
  - Manuscript of an evaluation of sources of variation in projected shifts in species distribution under climate change submitted for publication (reported in 2012-13);
  - Finalized analyses to identify most probable avian climate change refugia considering variability in future projections.
  - Analyzed boreal-wide avian habitat-age associations to modify future bird projections based on most likely vegetation lag-time scenarios.
  - Identified avian conservation priorities under climate change and gaps in the existed protected areas network.

- **Conservation planning**
    - Collaborated with the BEACONs Project to identify gaps in protected areas representation of habitat for five species of forest songbirds identified as priorities by the Canadian Boreal Forest Agreement, and evaluated the ability of candidate benchmark areas to address habitat needs of these boreal bird species;
    - Provided maps of predicted density and relative abundance of selected songbird and waterfowl species to end-users involved with conservation planning across Canada.
- **Avian model development, impact assessment and population drivers**
    - Developed a more comprehensive analytical approach to quantify differential habitat selection in forest songbirds, using range-wide comparisons of Canada Warbler as an example;
    - Explored how cumulative disturbance maps (Environment Canada, 2011), in combination with BAM's spatial-temporal data spanning more than 20 years, might be used to test for and quantify the effects of land use change on regional populations of forest birds;
    - Began evaluation of temporal patterns in songbird communities in response to wildfire and spruce budworm outbreak, in collaboration with Canadian Forest Service;
    - Initiated full life cycle analysis including demonstrating a positive association between years of high mean Canada Warbler abundance on the breeding ground in northern AB and climatic variables from the wintering ground prior to spring migration, as well as meetings with emerging Partners In Flight partnership on full-life cycle analysis for this species;
    - Integrated missing information about forest management of the hemiboreal region of Quebec into the Tardis national-scale future simulation model of harvesting impacts on boreal birds;
    - Partnership with Oregan State University established to determine avian abundance thresholds in plantation forestry.
- **Detectability correction and bias in bird monitoring**
    - Established a collaboration with the Minnesota Breeding Bird Atlas to further quantify roadside bias in bird density estimates using paired data from on and off road surveys in a variety of habitat types;
    - Developed R functions to include offsets to correct for survey protocol and detectability when estimating bird density from point count data in Canada;
    - Provided statistical packages to use offsets to correct for avian point count survey protocol and detectability.

- **Database enhancements**
    - Added over 7,000 avian point counts conducted across Canada and the United States to the database, which now contains over 260,000 point counts from more than 126 projects in forested and non-forested ecosystems;
    - Generated maps of topographic wetness index and slope covering the extent of the BAM database in Canada to improve Canada-wide density models for boreal species-at-risk;
    - Addressed gaps in Common Attribute Scheme for Forest Resource Inventory (cross-walked coverage of individual inventories across Canada) coverage in northeast Alberta, initiated major updates for parts of Manitoba and Québec, and produced an elaborated document describing the dataset and the processes for producing and updating it.
- **Communications**
    - Established a prototype interactive web-mapping site to improve usability of BAM's spatial products;
    - Hosted 2 webinars for over 50 participants including EC staff, and gave 20 presentations at other meetings or conferences;
    - Produced 5 published manuscripts, 5 manuscripts accepted or under revision, and 6 manuscripts nearing submission.

1.0 Project Description and Objectives

The Boreal Avian Modelling (BAM) Project (www.borealbirds.ca) was established to address critical knowledge gaps challenging the management and conservation of boreal birds in Canada (Cumming et al. 2010). BAM develops and disseminates rigorous, predictive models and modelling products of avian populations and the impacts of human activity, such as industrial development and climate change, on boreal bird species. BAM's work draws upon a powerful database created by collating and standardizing individual research and monitoring efforts conducted in the Canadian and US boreal & hemi-boreal forest (all Canadian provinces and territories, Alaska, Great Lake States; >1.5 million records), as well as a significant library of regional and national biophysical data. The project team, based at University of Alberta and Université Laval, is supported by a Technical Committee of avian scientists across Canada and the US (including EC staff), and collaborates with federal and provincial governments, industry, and non-governmental organizations with interest in development and application of science for bird conservation and management. Results are applicable to multiple elements of boreal bird management and conservation, including migratory bird monitoring, population estimation, habitat determinations, assessment and recovery planning for species at risk, environmental assessment, and protected/priority areas and land-use planning, consistent with our over-arching project objectives.

Major project activities for 2013-14:

A. Maintaining an authoritative database of landbird and biophysical data across boreal forests of North America, including continued expansion to incorporate data from the United States and hemi-boreal regions.

B. Applying leading edge analytical techniques to estimate populations, understand distributions, model habitat relationships, and project future scenarios to predict avian response to land-use and climate change.

C. Informing monitoring needs and strategies for landbirds in the boreal regions of Canada, and providing key information for assessment and recovery planning for avian species at risk, including national-scale models to inform identification of critical habitat.

D. Contributing to conservation planning at national and regional scales through the enhancement of partnerships with government and non-government organisations, and the development of custom products for focal initiatives.

E. Communicating project results to a broad audience, and providing tools for practitioners, through maintenance and enhancement of an accessible and interactive website.

BAM continues to build its extensive array of conservation partnerships across North America's boreal forest. The continued success of the Project depends on maintaining strong partnerships with individuals and organizations contributing avian data and environmental covariates, as well as related expertise, and the critical support of funding partners.

This report summarizes work undertaken between April 1st, 2013 and March 31st, 2014, supported by the 2013-14 Environment Canada Contribution Agreement to BAM.

2.0 Accomplishments

2.1 Maintenance of avian and geospatial data

Avian Database **-** BAM continued to update the avian database with new point count data from partners for existing sampling sites for years where data was not yet available (e.g. the Calling Lake Fragmentation Study; 2008 and 2013). Partners in the Yukon provided data from nine projects, as well as updated years for four projects, adding over 1,000 new sampling locations for this under sampled region. Results from the Joint Oil Stand Monitoring (JOSM) project added 3,615 data points in habitats that were previously under sampled. The Ecological Monitoring Committee for the Lower Athabasca (EMCLA) project has contributed an additional 550 sampling locations to the dataset, that now include nocturnal surveys. As well, BAM received the U.S. National Forest Database from Technical Committee member Gerald Niemi for his study region in Minnesota, to help with roadside bias work. This has over 1,800 sampling locations. In total, over 7,000 avian point count surveys have been added to BAM's database this year.

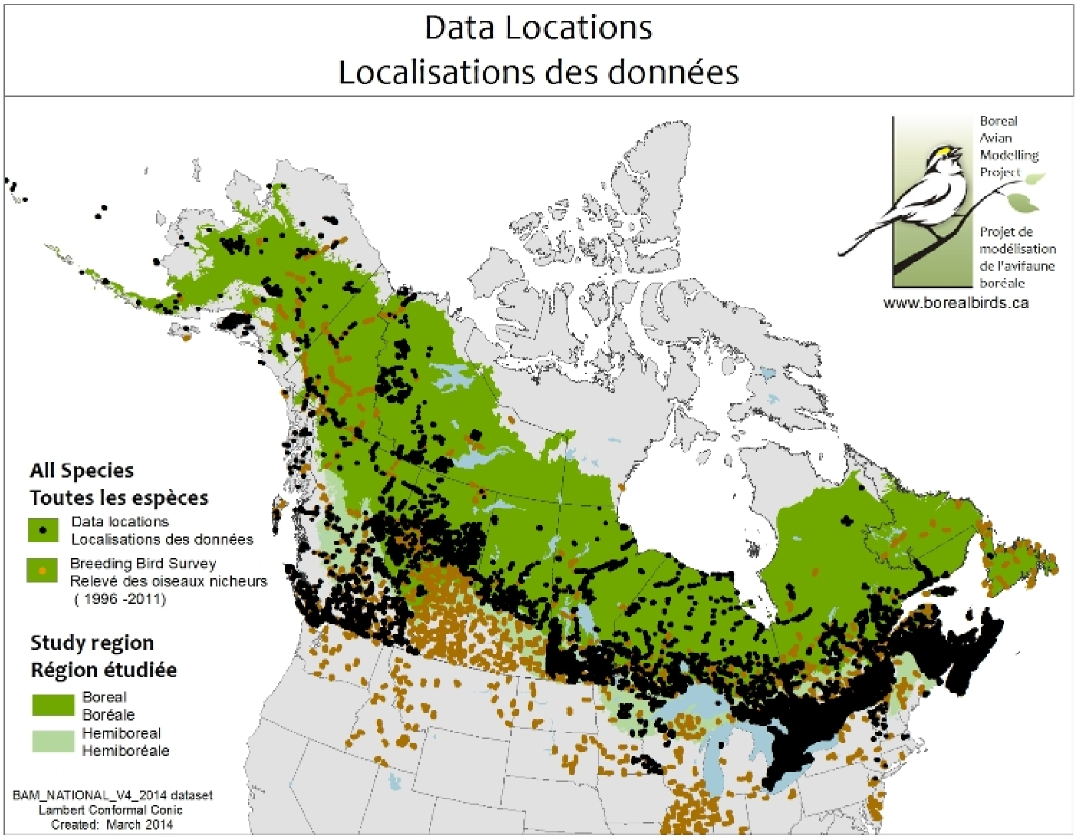


Figure 1. Locations of point count data, the black dots represent BAM Database Version 4.0, orange dots are Breeding Bird Survey locations.

Geospatial Data - To improve boreal-wide density models for species-at-risk, we generated a set of topographic wetness index (TWI) tiles (1 degree x 1 degree) based on a composite 3 arc second (90-m) Global Land Survey Digital Elevation Model (GLSDEM) provided by the Global Land Cover Facility (2014). The portion of the GLSDEM product that we used is comprised of data from the Canadian Digital Elevation Dataset (CDED) above 60 degrees north latitude and the Shuttle Radar Topography Mission (SRTM) below 60 degrees. The TWI was calculated as the log of the catchment area (km) divided by the tangent of the slope (radians) of a cell (Moore et al. 1993).

Forest Resource Inventory Data - The Common Attribute Schema for Forest Resource Inventories (CASFRI) integrates almost the complete area covered by Canadian forest resource inventories. It contains more than 25,000,000 polygons covering nearly 4,000,000 km^2, almost the entirety of managed forests in Canada, in a custom data format that is consistent across jurisdictional boundaries, but loses none of the original information contained in source data sets. As we reported in 2012-13, this allows us to develop detailed models of avian habitat relations to attributes such as forest tree species and stand age or height that are consistent across jurisdictional boundaries. In 2013-2104 we commenced or completed the following activities to maintain this database and increase the return on this investment.

1) Filled gaps in CASFRI coverage. We have received some new data from northeast Alberta filling in some holes in the JOSM area. We have a commitment from CANFOR to provide data from their tenure area in the Peace region of BC. We have made formal requests to a number of forest-tenure holders in the foothills of Alberta, and to Cenovus Energy for their FRI on the Cold Lake Air Weapons Range in Alberta. The status of these requests in uncertain at this time.
2) Incorporated major updates that were obtained from Manitoba and Quebec and that will substantially improve the thematic precision of the database in terms of canopy tree species (Québec) and canopy height or age (large parts of Manitoba). The raw data have been exported into an intermediate form. The Manitoba data have been processed into the CASFRI standard, barring some minor inconsistencies still to be resolved. The remaining processing steps will be completed for the planned release of the next CASFRI versions, planned for the summer of 2014.
3) An external funding opportunity from the Canadian Forest Service enabled Cumming's lab to complete documentation of the CASFRI data set and to complete some of the CASFRI standard's metadata. This result is documented in a report to the NRCAN Integrated Systems Approach Secretariat (Houle, Cumming and Racine 2013).
4) In February, we submitted a manuscript to the Canadian Journal of Forest Research, in which CASFRI was used to assess the tree-species representation of protected areas in boreal Canada (Cumming et al. in review). We expect this paper to dramatically raise the profile of the dataset and lead to increased opportunities for its development.
5) We provided summaries of the CASFRI data set to support ongoing BAM modelling activities, and various collaborations with other research groups, such as with Matthew Betts, Oregon State University (Section 2.4.3.1)

2.2 Species at Risk

2.2.1 Incorporating population dynamics to identify offset opportunities for species at risk: conservation decision-making for Canada Warblers in Alberta (Habitat Stewardship Program; Environment Canada)

Identifying critical habitat and threats to species at risk are required to inform national recovery strategies. The main objectives of this project are to understand breeding habitat requirements and impacts of habitat alteration on the threatened Canada Warbler. BAM in collaboration with Dr. Bayne's lab, Lesser Slave Lake Bird Observatory, and Alberta Pacific Forest Industries have been doing additional surveys and monitoring since 2012 to better quantify habitat use and productivity of Canada Warblers in riparian and interior old-growth deciduous forest in the protected area of Lesser Slave Lake Provincial Park (LSLPP) as well as in actively managed landscapes in ALPAC's FMA. For example, detailed territory mapping has shown that core territory areas of CAWA have higher shrub cover than peripheral areas. Used areas also had higher shrub cover than unused areas. However, there were no significant differences in shrub cover, or any habitat attributes, between territories of successful and unsuccessful breeders. Interactions of prey/predator abundance with territory size and breeding success are currently being analyzed. Additionally, using avian point count data collected across Alberta over the past three years, we created habitat models allowing mapping predicted Canada Warbler density throughout the province.

In this project, we built upon our provincial scale models to begin using the data to aid in conservation planning. In 2013-2014, we updated site-selection models to suggest networks of protected areas that would be required to maintain 30% of the Canada Warblers breeding in Alberta. In the past, we did this while ignoring the economic value of the land. Since then we have updated the predictions with and without considerations for economic constraints (energy and forestry sector value). Suggested protected area networks differed substantially in size and location when economic constraints are included. Smaller areas with higher bird density were selected when there was no consideration for economic constraints compared to when economic constraints were included in the model (i.e. trade-off between meeting the conservation target and minimizing economic costs). In 2014, abundance surveys and productivity monitoring on Canada Warblers in harvested forest stands and riparian buffer stands will provide demographic data that will be used to improve models of suggested protected area networks. Overall, these results will contribute to identify critical habitat of Canada Warbler and understand the effects of human activities on population dynamics. Recommendations will be provided to assist in the elaboration of the recovery strategy for this threatened species. Full report available from…

2.2.2 Scientific contribution to support critical habitat identification for Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk across Canada (collaborator: Environment Canada)

Defining critical habitat is required to inform recovery strategies for species at risk. High density areas tend to have the highest per unit area reproductive output. Hence, these areas are assumed to be the most important to protect if populations are to recover. In this study, BAM provided analyses to support critical habitat identification for three Neotropical migratory songbirds (Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk). Specifically, BAM used the best information available (i.e. avian point count and biophysical data) to: 1) generate habitat models identifying the biophysical attributes characterizing areas of low and high densities; 2) estimate population size at multiple spatial scales under various assumptions; 3) map predicted density estimates and uncertainty across Canada; and 4) provide a Schedule of Studies identifying important gaps in data availability and the limitations of current models.

Information from over 1.5 million avian point count surveys were used with land cover, disturbance, topography, climate, and spatio-temporal variables to generate 9 model subsets that explained the variation in abundance of the three focal species across Canada. We used different model subsets to account for different spatial extents and co-linearity among variables. Poisson log-linear models were produced using a branching hierarchy model building process and bootstrap procedures to account for model uncertainty.

Canada Warbler densities were higher in mixedwood and deciduous stands, eastern Canada, and stands with tall trees. There was a 50-60% decline in relative abundance from 1997 to 2013. There was a negative effect of the proportion of agricultural and human developments within a 16 km^2 area of survey points. Landscapes with a higher proportion of mixedwood and deciduous stands were more suitable. Estimated Canadian population size was 17 million birds with the highest proportion being in Ontario and Quebec (Figure 23A).

Density of Olive-sided Flycatcher was higher in conifer stands, recent burns, shrubby areas, and in western Canada. Density tended to be higher in stands with taller trees. Relative abundance did not show significant evidence of temporal trends from 1997 to 2013. Highly suitable landscapes included areas with more conifer and mixedwood and shrubby and wet areas. Estimated Canadian population size was 12.8 million birds with the highest proportions of the Canadian population being in Quebec and British Columbia (Figure 23B).

There was some evidence that shrubby areas and human development supported higher densities of Common Nighthawks. Density was consistently higher in western Canada. There was a 70-80% decline in relative abundance from 1997 to 2013. Highly suitable landscapes were comprised of conifer and mixedwood stands and shrubby and wet areas. The number of individuals in Canada was estimated at 400,000 with the highest proportions predicted to occur in the Northwest Territories and British Columbia (Figure 23C).

We also compared our population estimates to those derived from data and methods used by Partners in Flight and provide a detailed list of future studies required to address remaining gaps in the breeding ecology and habitat modelling of these species. Full report is available from…

2.2.3 Testing for differential habitat selection in Canada Warbler

Breeding habitat for Canada Warbler (CAWA) has been suggested to vary across the species' range (reviewed by Reitsma et al. 2010). In the southern part of its range, CAWA seems to prefer montane areas with a thick understory comprised of *Rododendron sp*. In the central portion of its range, it seems to prefer forested wetlands and swamps. In the northern areas of the boreal forest, trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*) stands on more rugged terrain seem to be preferred. To test the differential selection hypothesis across the range of CAWA, we estimated the interaction effect between land cover, forest cover, geographic region (east or west of west of -98° longitude) and Bird Conservation Regions (BCRs). We found consistent signal for spatial differences in expected density with respect to east-west or BCRs, but found no evidence of interaction between these spatial terms and habitat characteristics, as measured by remote-sensed landcover maps.

Observed abundance depends on both habitat selection and habitat availability; abundance per unit area is proportional to selection. Therefore differences in availability of habitats across the species range can shape differential use even if there is no difference in habitat selection. To characterize differential use we define an index of relative selection (RS) which compares selection in a given habitat category based on the density models with random selection. Selection was estimated based on abundance estimates in a given geographic area: $s_j = N_j / N$, where $j = 1 \ldots m$, that is the number of habitat types, N is the sum of predicted abundances across all habitat types within the region. This represents the frequency a given resource (habitat) unit is expected to be selected (i.e. number of males in the population that is expected to breed in that habitat). When selection is random, habitat classes are expected to be selected in proportion of their availability which can be described based on availability of habitat classes: $a_j=A_j/A$, where A_j is the area of a habitat stratum, A is the total area of the region. By using the predictions across an entire region one can eliminate the need to account for other variables (e.g. climate) because the predictions already reflect that variation. Relative selection compares actual selection $RS_j = s_j/a_j$.

We used detection-nondetection type count data in combination with offsets to adjust for uneven detection probabilities. We predicted abundance across Canada at a 1 km resolution. We determined relative selection to test differential habitat use for CAWA. We used BCR 6 in AB representing north-eastern part of the breeding range, BCR 8 in ON representing the central part of the breeding range, and BCR 12 in ON representing the southern part of the breeding range. Relative selection (RS) is >1 when a given habitat class is more often selected than based on random selection (habitats are selected in proportion to their availability in the region). RS is <1 when habitats are avoided relative to the random selection based on availability. We combined habitat type (Coniferous, Mixed, Deciduous, Wet [open and treed wetlands], Developed, Agriculture, Barren, Grassland and Shrub), tree cover (Op=open [0-25%], Sp=sparse [25-60%], Dn=dense [60-100%]), and canopy height (LoC=low canopy [0-15 m], HiC=high canopy [>15 m]).

RS was consistently higher than one in high canopy mixed and deciduous forests in BCR 6 and 8 (Figure 2). In BCR 12 (southern hemiboreal part of the range) we found higher selection for high canopy mixedwoods and RS was lower (close to 1 and slightly lower) in high canopy deciduous forests, in contrast to boreal part of the range (central and east). Most interestingly, we found that RS in wetland type habitats (open and high canopy coniferous stands and wetlands) across the three regions was highest in the central part of the range (Ontario BCR 8) consistent with our expectations based on the literature. RS was consistently lower in low canopy forest habitats, grass and shrub lands and in developed areas.

The lack of interactions in the density models, and the relative selection values exhibiting consistent trend with known habitat requirements of CAWA, implies that differential habitat selection across the species' range is most likely determined by different availability of habitats and does not necessarily reflect that CAWA populations are locally adapted to their breeding locations.

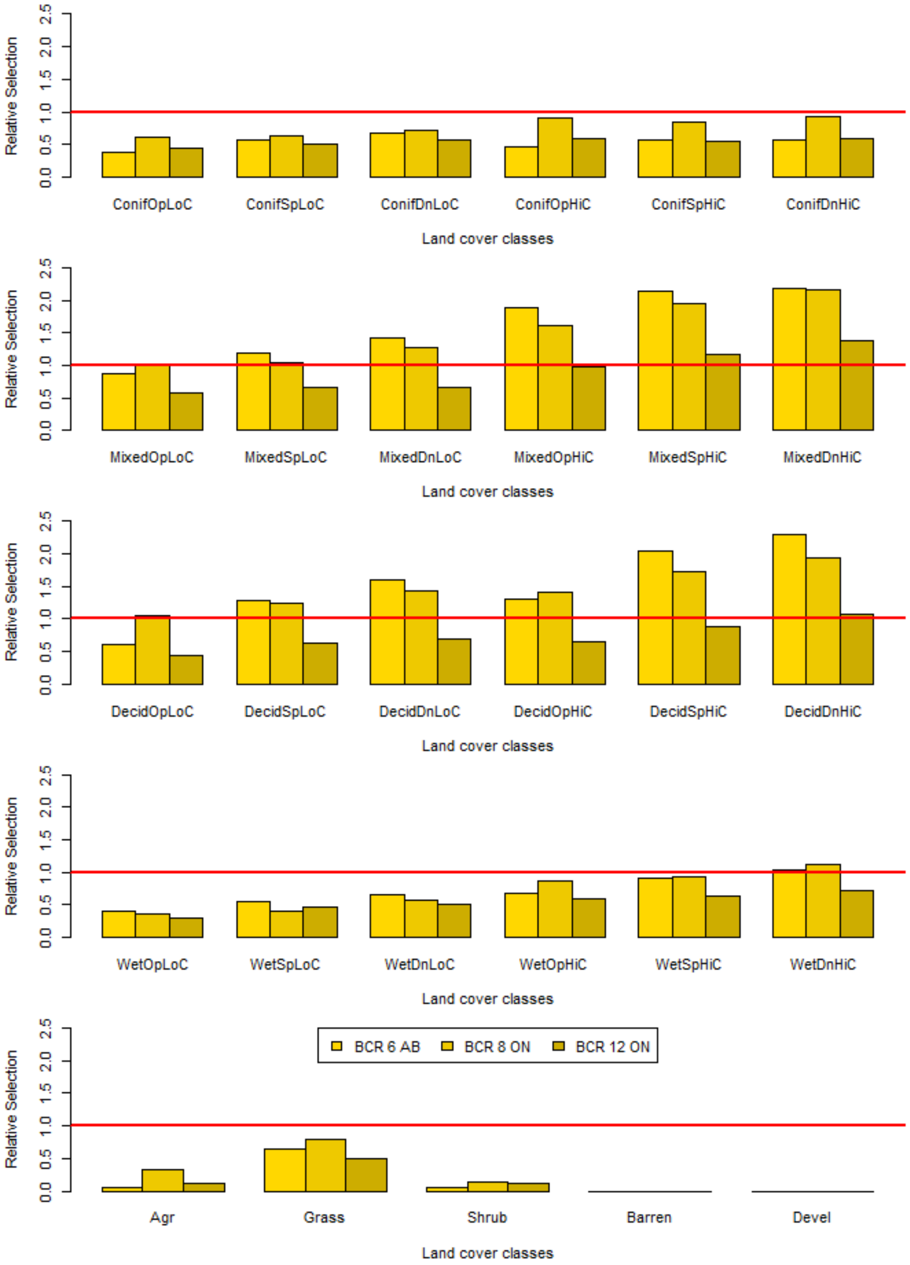


Figure 2. Relative selection for Canada Warbler in three spatial regions (BCR 6 Alberta – western part of the breeding range, BCR 8 Ontario – north-eastern part of the breeding range, BCR 12 Ontario – south-eastern part of the breeding range; see legend). Relative selection equals 1 when proportion of predicted population in a habitat class equals the proportion of that habitat class (population distributed evenly across habitat classes). The selection can be positive (a habitat class selected more often than expected based on even distribution, value > 1) or negative (a habitat class selected less often than expected based on even distribution, value < 1). Values of relative selection are based on predicted values from the climate and landscape models along a 1 km spacing prediction grid used to create distribution map. NALCMS derived habitat classes were combined with tree caver classes (Op=Open, Sp=Sparse, Dn=Dense) and canopy height information (HiC=high canopy, LoC=low canopy, threshold was 15 m).

2.3 Joint Oil Sands Monitoring

2.3.1 Bird-habitat models for delivery of Joint Oil Sands Monitoring goals relative to migratory bird monitoring in the oil sands areas of Canada

We used the most extensive standardized point count data collected and compiled by the Boreal Avian Modelling Project (BAM), including Environment Canada (EC), the Alberta Biodiversity Monitoring Institute (ABMI), and the North American Breeding Bird Survey (BBS) data and combined with these with geospatial information to build predictive models for bird species. We described the habitat associations and responses to human footprint at different spatial scales (local and quarter-section) for 77 Passerine breeding birds. We created predictive maps, assessed model performance and prediction uncertainty. We determined changes in suitable habitats for bird populations in the Boreal region of Alberta in general, and specifically in the oil sands region based on current habitat data, as well as an estimate of habitat supply with no industrial footprint. We found that species showing largest expected changes in their suitable habitats are either associated with habitats created more frequently by anthropogenic disturbances in the landscape, or species whose habitats are most often affected by disturbances related to various forms of resource extraction in the oil sands region. We compared estimated population sizes for birds within Boreal Alberta and compare these to existing estimates by Partners in Flight. We found that our estimates were on average 6 times higher than the estimates provided by Partners in Flight for the same area. We compared the different assumptions inherent in the estimators and found that the bias related to the use of roadside surveys (from BBS) affected species specific population size estimates in different ways, while the effect of the assumption regarding the effective area sampled during surveys accounted for most of the bias consistently across the 77 species.

2.3.1.1 Bird-habitat models

Species data – We compiled the most comprehensive bird point count data set in the Boreal region of Alberta collected between 1993 and 2013 to characterize the cumulative effects of human footprint on songbird abundance and distribution. The data were contributed by ABMI (5833 surveys from 5130 location), BAM (16491 surveys from 9259 locations), BBS (25084 surveys from 3039 locations), and EC (3615 surveys from 3615 locations). We used counts of 77 species that had at least 25 detections and had available estimates for singing rates and effective detection radii.

Geospatial information – We used a composite wall-to-wall land cover map of Alberta developed by ABMI to characterize vegetation at sampling location and within spatial units (quarter-sections) used for prediction. The wall-to-wall vegetation map (Alberta Biodiversity Monitoring Institute, 2013b) was used with footprint classes removed to create the backfilled vegetation layer (Alberta Biodiversity Monitoring Institute, 2014), i.e. an estimation of habitat supply with footprint removed from the landscape. The wall-to-wall human footprint map (Alberta Biodiversity Monitoring Institute, 2013a) was merged with the backfilled map in the end. The backfilled layer was also combined with other sources of information to better describe habitat conditions, i.e. percent pine and forest age from

Alberta AVI, wetness information from various sources (for full description see Alberta Biodiversity Monitoring Institute, 2014). We refer to these products as reference and current maps, respectively. The reference vegetation map describes the vegetation that would have been present in the study area if there was no human footprint (updated to the year 2010). This backfilled reference vegetation map incorporated information about fires, describes the ages of natural vegetation for 2010 conditions, and projects ages of the backfilled polygons (areas where human footprint currently exists) for 2010 conditions. This current vegetation map describes the vegetation and human footprint that currently exists (updated to the year 2010).

Modelling – We used a multi-stage variable selection procedure that included predictor variables describing point level (based on 150 m radius buffer) habitat and age relationships; point level responses to linear features; quarter section (QS; 64 ha) level response to the amount of high suitability habitats, wetlands and different types of human footprint; spatial and climate variables were used for spatially smooth the results. We also estimated year effect after accounting for local habitat, QS level and spatial/climatic effects. We estimated model parameters for 200 bootstrap runs. Based on the bootstrap estimates we predicted QS level expected abundances. We created distribution maps and estimated population size within the JOSM study area for 77 species.

Results for Canada Warbler – We present results for an example species, the Canada Warbler (*Cardellina canadensis*; AOU code: CAWA; Table 1; Figures 3--8). Local expected density for Canada Warbler was highest in old-growth deciduous and mixedwood stands. Density was low in young forests, old coniferous stands, and in open and disturbed areas (Figure 3). Canada Warbler showed a negative response to road, but the density of cutlines did not significantly affect expected density relative to non-disturbed habitats (Figure 4).

Habitat suitability was estimated independent of the variable selection process to allow for the determination of the amount of high suitability patches in the 451 m radius buffer (64 ha = area of a quarter-section). High suitability habitat classes were determined based on an optimal cut-off value after ranking habitats based on their estimated Poisson means. High suitability habitat rankings in Figure 5 are consistent with local scale habitat associations (Figure 3). Young deciduous stands (DecidA) are selected because expected density in young deciduous forests was higher than density in older coniferous stands. The inclusion of Grass habitat class is an artefact of not controlling for road effect in the Lorenz-tangent approach (roads tend to co-occur with habitats classified as Grass, i.e. road verges). The bias due to Grass being “highly suitable” is minimal due to the small percent availability of this land cover type in the Boreal.

Canada Warbler did not show response to amount of high suitability patches in the quarter-section scale buffer defined on the basis of the optimal threshold. Expected abundance showed a decline with increasing amount of treed and non-treed wetlands and various kinds of footprint in the quarter-section scale buffers around the points (Figure 6).

Current and reference abundance maps follow the distribution of deciduous forests (Figure 7). The purple pixels indicate spatial units where 50% of the potential population is expected to be found. The pixels outside of the pale yellow areas represent 95% of the potential population (Figure 7). The map shows that the Canada Warbler population is highly concentrated, this concentration is driven by a selection towards old deciduous habitats (Figure 3). Estimated current population size of Canada Warbler in the JOSM study area was 0.32 million male birds. This is 40,000 less than would be expected under reference vegetation conditions (0.36 million males; Table 1).

Results for all species – We compiled bootstrap based selection frequencies for habitat classes (similar to the information presented in Figure 5) and performed a canonical correspondence analysis. The biplot (Figure 8) shows the separation of disturbed and open habitats and closed canopy undisturbed habitats along the first axis (CA1) with species that are associated to these habitat classes. The second canonical axis (CA2) showed a gradient from old-growth mixed and deciduous forests to old coniferous stands with early-seral (young forests, shrubs) and wetlands in between. We summarized proportional change (the amount of suitable habitat lost or gained due to the presence of footprint in the landscape) for species and found that the largest proportional losses of suitable habitats were found for old-growth forest species, while largest proportional gains of suitable habitats were found for human associated species.

Our estimates (N_{QPAD}) of current Boreal population sizes were based on an exhaustive model based prediction approach using province wide vegetation and footprint maps. Existing population size estimates provided by Partners in Flight (PIF) based on BBS data are another set of population size estimates (N_{PIF}) that we can compare our estimates to. The mean observed bias (N_{QPAD} / N_{PIF}) was 15.7 and ranged between 0.12 and 143.15. The magnitude of the distance related bias was on average 4 and ranged between 1.6 and 10.8, consistent with the expected distance related biases reported by Matsuoka et al. (2012). These results reflect that the difference between the two estimates cannot be explained by the difference between maximum detection distance as used by PIF and effective detection distances used in our study. Other assumptions, such as roadside bias, habitat sampling bias, and time adjustment, might be responsible for the remaining portion of the observed bias.

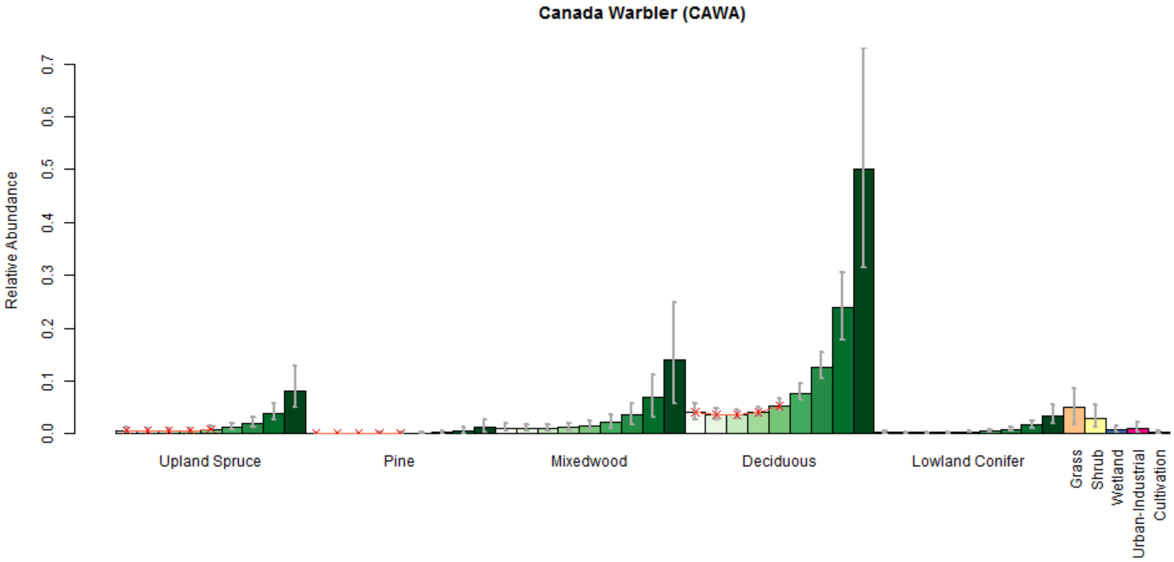


Figure 3. Local (point count, 150 m radius buffer) scale density estimates showed that Canada Warbler has highest density in old-growth deciduous and mixed forests (in green, plotted by 20-year age classes). Density was lowest in lowland spruce, pine and non-forested habitat classes including urban-industrial and cultivation footprint types. Grey error bars represent 90% confidence intervals.

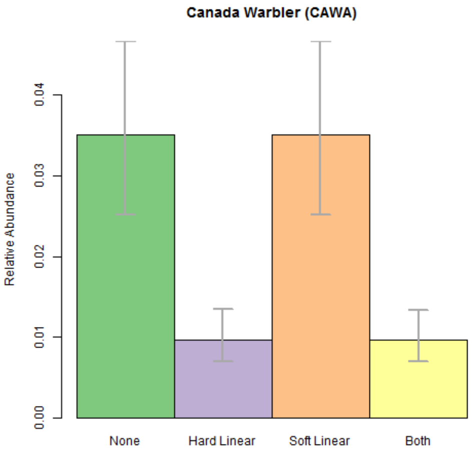


Figure 4. The effect of linear features for Canada Warbler is presented relative to habitats without hard or soft linear features. Hard linear feature (roads, rails) was represented by the presence of a paved/gravel road, soft linear feature (pipelines, seismic lines) was represented by the average proportion (8%) across the observations.

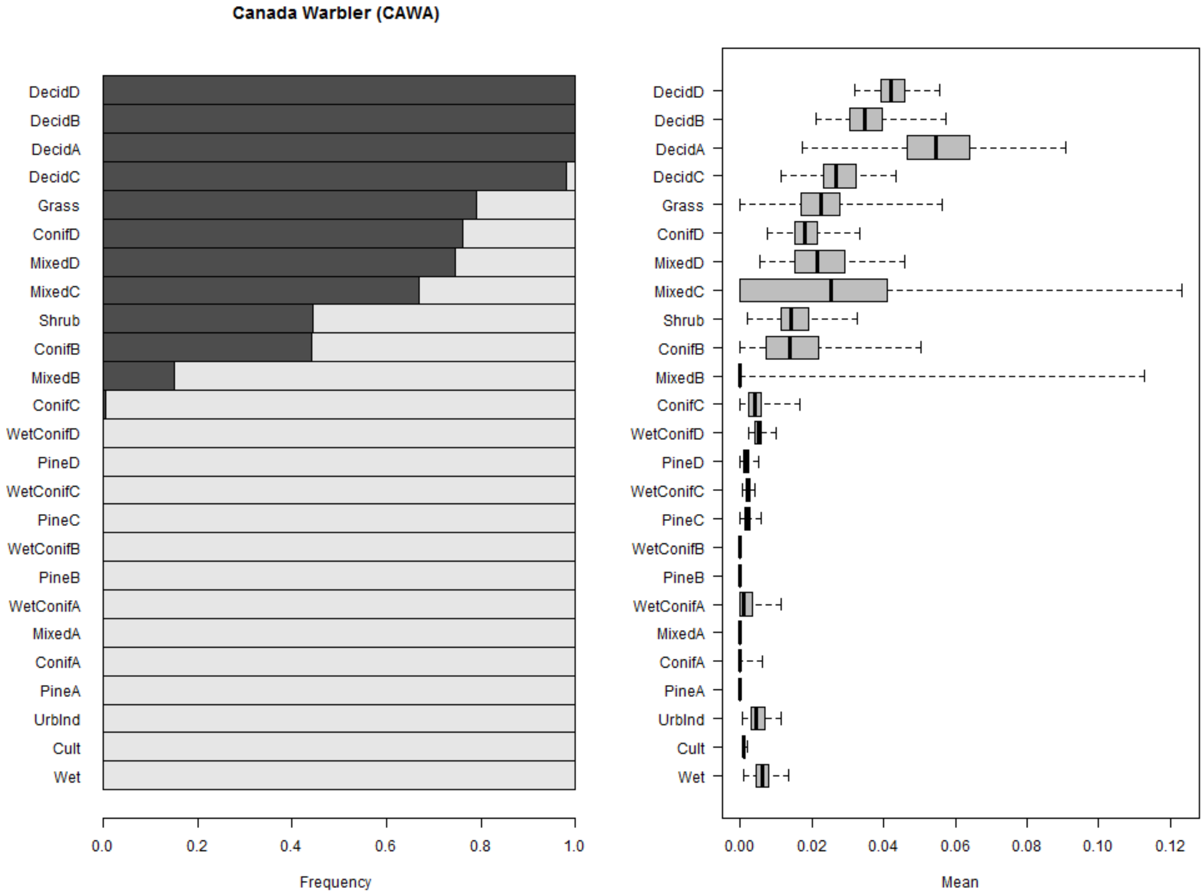


Figure 5. Habitat suitability was estimated in different combinations of habitat types and forest age classes to allow for the determination of the amount of high suitability patches at the QS scale. High suitability habitat classes were determined based on an optimal cut-off value after ranking habitats based on their estimated Poisson means. Selection frequencies based on 200 bootstrap iterations (left) and boxes for Poisson means (right) are based on bootstrap. Age categories (A-D) correspond to a modified version of the avian habitat classification system developed by Environment Canada: A = herb/shrub stage; B = pole/sapling stage, C = young forest; D = mature and old forest.

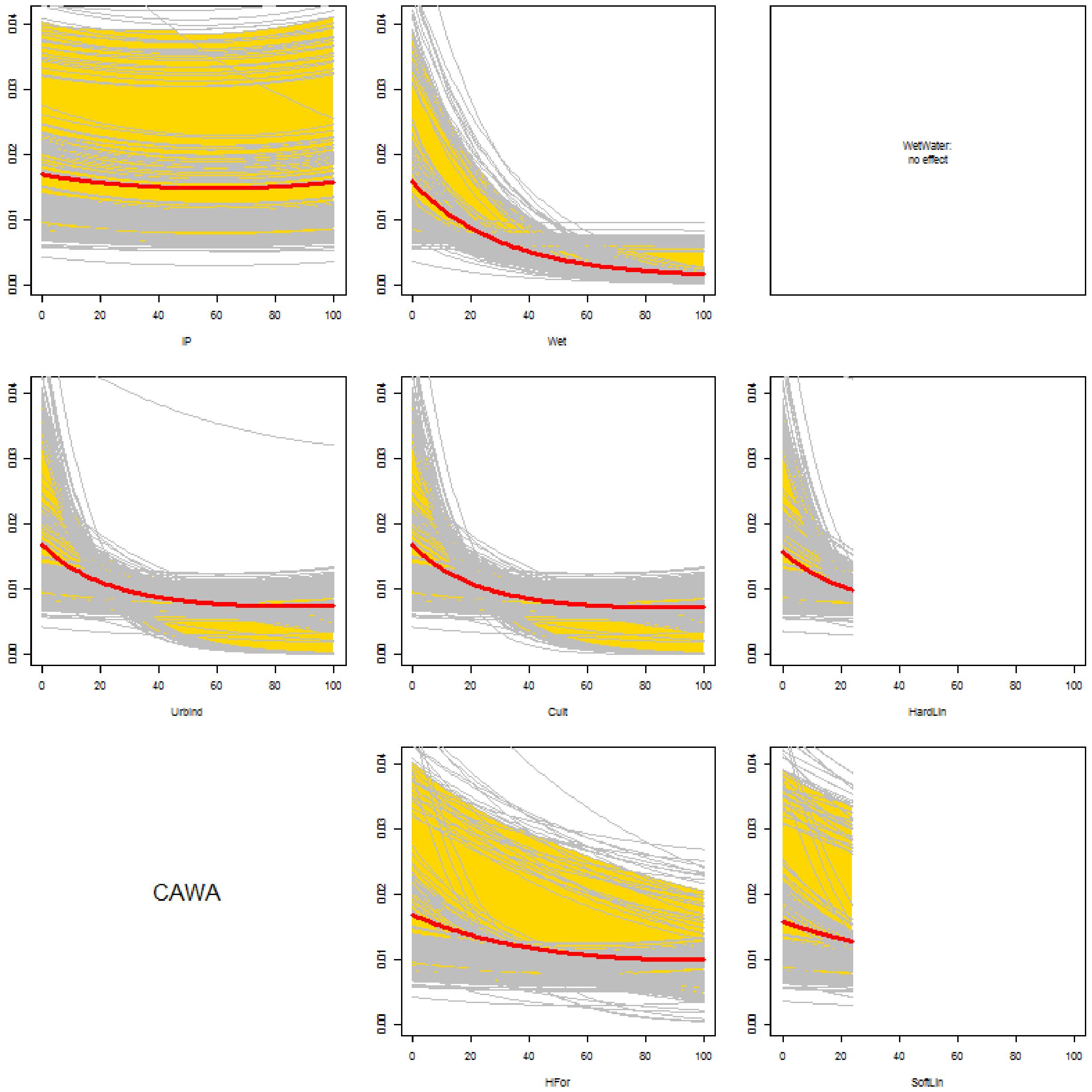


Figure 6. Quarter-section level responses were estimated based on the “QSHF'' stage that considered local and quarter-section level terms in the model selection without spatial and year effects. Grey lines represent responses based on individual bootstrap iterations; red line is the mean, yellow region is 90% confidence region. The variation in the graph represent point count level variability (it was not statistically removed). Vertical axes represent relative abundance. Horizontal axes represents percentages in 451 m radius buffers (64 ha = area of a quarter section) around points. “IP'' is amount of high suitability patches based on Lorenz-tangent based definition; ”Wet'' is amount of treed and non-treed wetlands; “WetWater'' is amount of non-treed wetlands and open water; other graphs are for different types of human footprint. Empty boxes represent the lack of an effect.

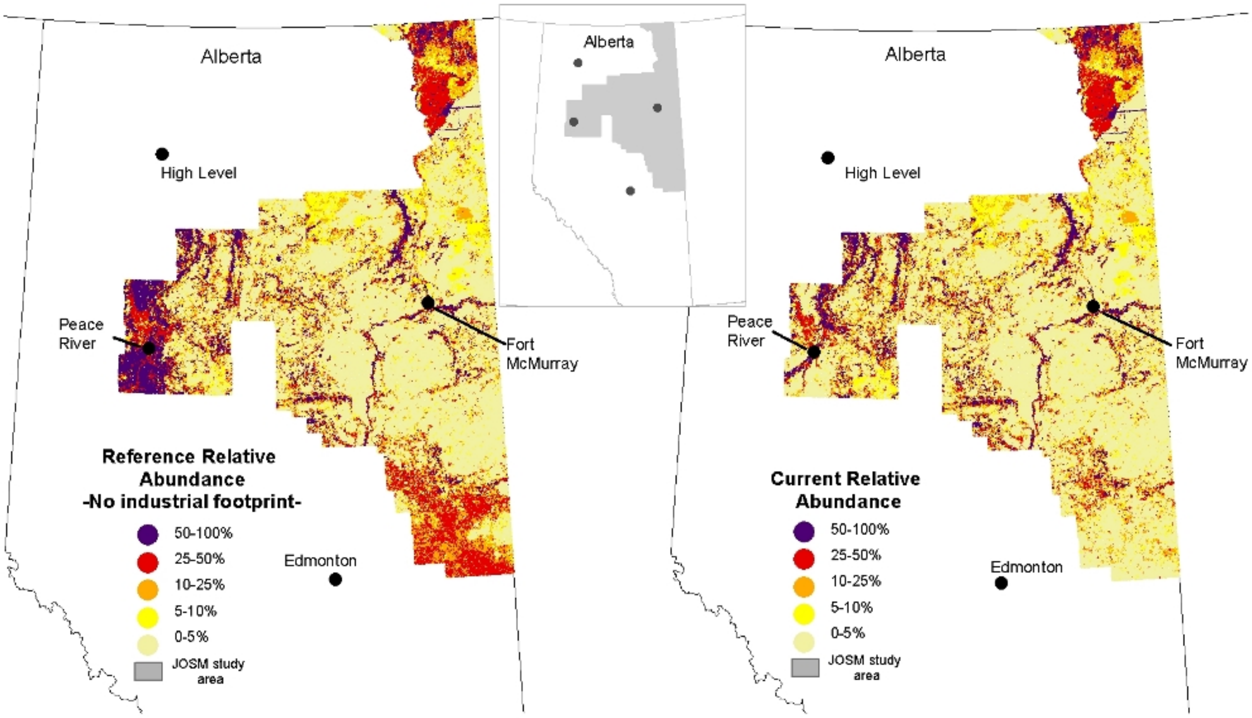
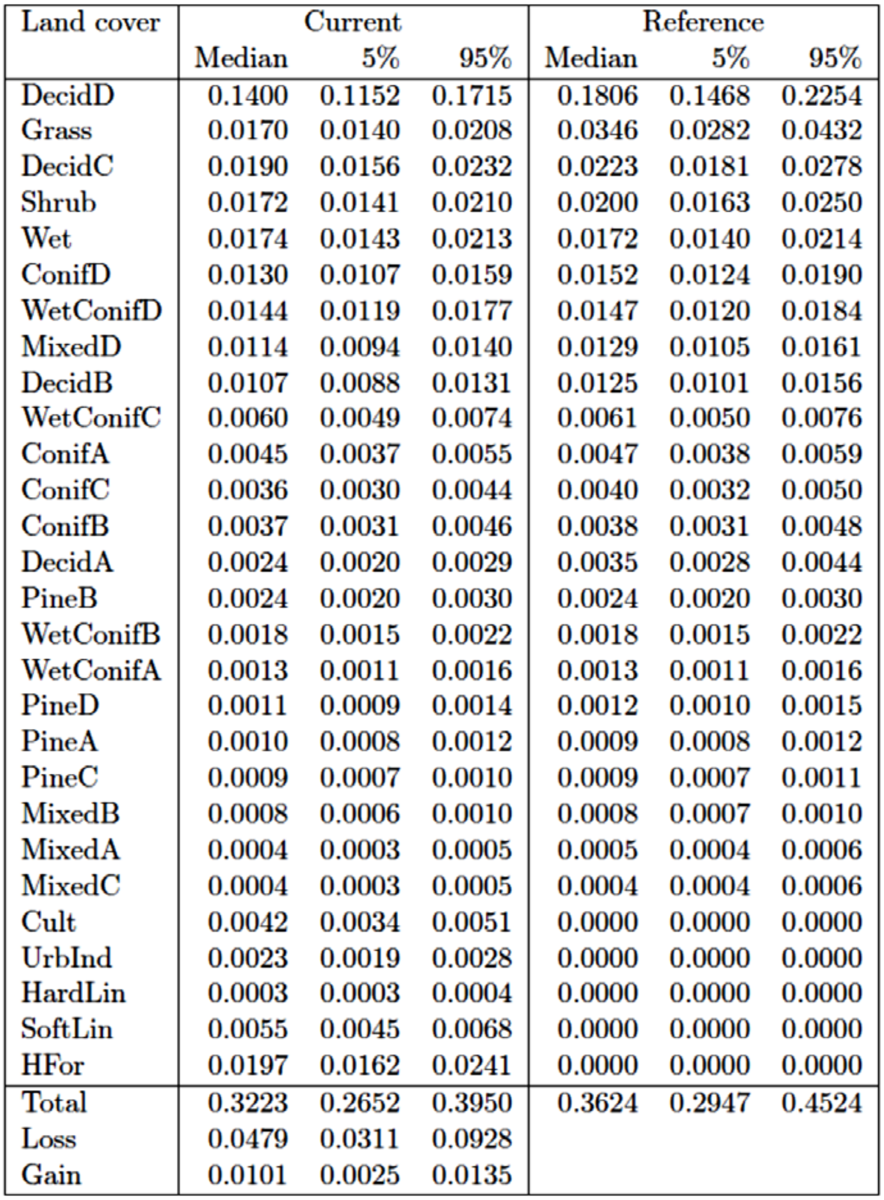


Figure 7. Current and reference (no industrial footprint) predicted distribution of Canada Warbler in the JOSM study area. Pixels represent quarter-sections. Relative abundance cut-off levels were based on cumulative distribution of pixel level mean densities, different colors represent strata containing an increasing cumulative percentage of the expected population in the JOSM study area, e.g. 50% of the potential population is predicted to be distributed in the areas coloured purple and 95% of the potential population is predicted in areas outside of the pale yellow areas.

Table 1. Estimated potential population size of CAWA in the JOSM study area in millions of male birds. Mean and 90% prediction limits are provided for current (natural vegetation and human footprint) and reference (human footprint backfilled) landscape conditions based on 200 bootstrap runs. Estimates are based on a 10% random sample of quarter-sections in the JOSM study area.



Land cover	Current			Reference		
	Median	5%	95%	Median	5%	95%
DecidD	0.1400	0.1152	0.1715	0.1806	0.1468	0.2254
Grass	0.0170	0.0140	0.0208	0.0346	0.0282	0.0432
DecidC	0.0190	0.0156	0.0232	0.0223	0.0181	0.0278
Shrub	0.0172	0.0141	0.0210	0.0200	0.0163	0.0250
Wet	0.0174	0.0143	0.0213	0.0172	0.0140	0.0214
ConifD	0.0130	0.0107	0.0159	0.0152	0.0124	0.0190
WetConifD	0.0144	0.0119	0.0177	0.0147	0.0120	0.0184
MixedD	0.0114	0.0094	0.0140	0.0129	0.0105	0.0161
DecidB	0.0107	0.0088	0.0131	0.0125	0.0101	0.0156
WetConifC	0.0060	0.0049	0.0074	0.0061	0.0050	0.0076
ConifA	0.0045	0.0037	0.0055	0.0047	0.0038	0.0059
ConifC	0.0036	0.0030	0.0044	0.0040	0.0032	0.0050
ConifB	0.0037	0.0031	0.0046	0.0038	0.0031	0.0048
DecidA	0.0024	0.0020	0.0029	0.0035	0.0028	0.0044
PineB	0.0024	0.0020	0.0030	0.0024	0.0020	0.0030
WetConifB	0.0018	0.0015	0.0022	0.0018	0.0015	0.0022
WetConifA	0.0013	0.0011	0.0016	0.0013	0.0011	0.0016
PineD	0.0011	0.0009	0.0014	0.0012	0.0010	0.0015
PineA	0.0010	0.0008	0.0012	0.0009	0.0008	0.0012
PineC	0.0009	0.0007	0.0010	0.0009	0.0007	0.0011
MixedB	0.0008	0.0006	0.0010	0.0008	0.0007	0.0010
MixedA	0.0004	0.0003	0.0005	0.0005	0.0004	0.0006
MixedC	0.0004	0.0003	0.0005	0.0004	0.0004	0.0006
Cult	0.0042	0.0034	0.0051	0.0000	0.0000	0.0000
UrbInd	0.0023	0.0019	0.0028	0.0000	0.0000	0.0000
HardLin	0.0003	0.0003	0.0004	0.0000	0.0000	0.0000
SoftLin	0.0055	0.0045	0.0068	0.0000	0.0000	0.0000
HFor	0.0197	0.0162	0.0241	0.0000	0.0000	0.0000
Total	0.3223	0.2652	0.3950	0.3624	0.2947	0.4524
Loss	0.0479	0.0311	0.0928			
Gain	0.0101	0.0025	0.0135			

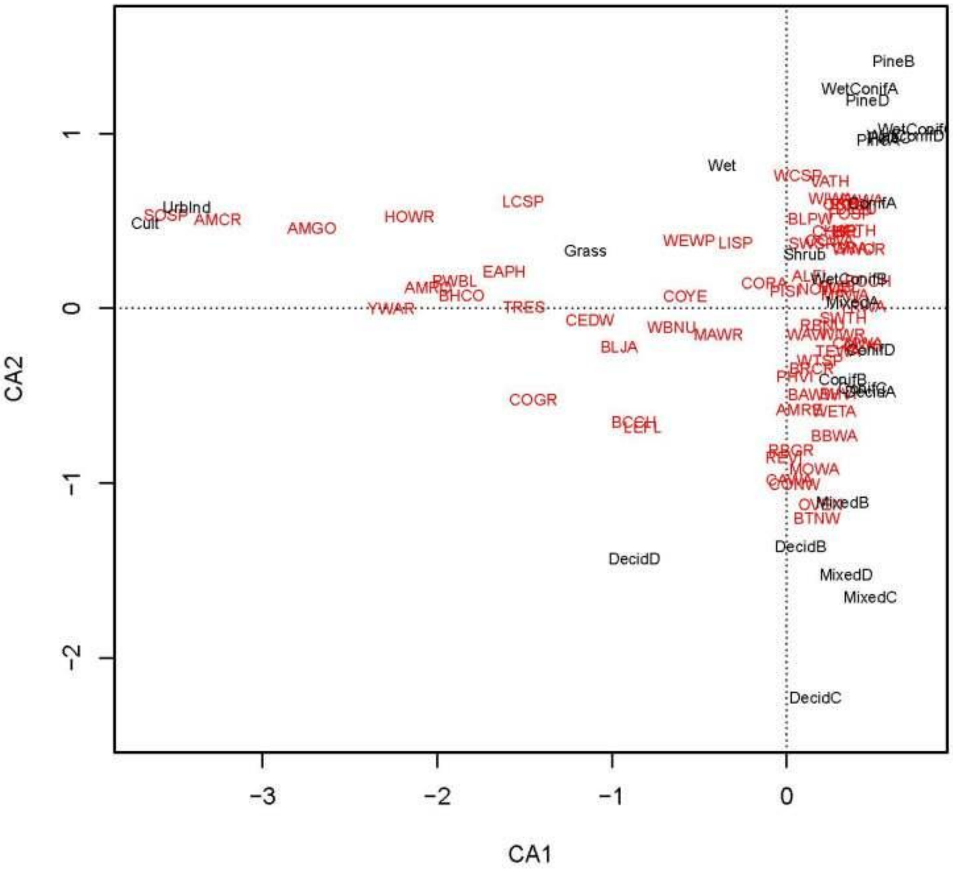


Figure 8. Canonical correspondence analysis of habitat suitabilities for species based on Lorenz-tangent approach. Input data was selection frequency of habitat patches from 200 bootstrap runs. AOU codes represent the 77 species (red), names of habitat classes are in black. The biplot shows species and habitat classes in the same ordination space. The separation of human-associated species and forest species can be seen along the 1st axis from left to right with open habitats (wetlands) in the middle. The 2nd axis represents a gradient from coniferous through early-seral to mixed-deciduous forest types.

2.3.1.2 Evaluation of Landscape Analysis Tools for Assessing Risks to Migratory Landbirds in the Oil Sands Areas of Alberta

Cumulative Effects Assessment (CEA) is a process to assess the cumulative effects or changes to the environment resulting from both natural and anthropogenic disturbances. These processes typically assess effects (1) over large, regional study areas, (2) in multiple time periods (current, past, future), (3) for a variety of indicators or species of interest, and (4) for multiple land and resource scenarios. We review two case studies of landscape analysis tools currently in use within the Oil Sands Area of Alberta to assess the cumulative effects of land and resource development on boreal landbirds. A Landscape Cumulative Effects Simulator (ALCES III) was used to simulate changes in habitat supply and landbird population size for three land use scenarios over a 100 year time period within a 6.86 million hectare rapidly changing, multi-use landscape in northeast Alberta, Canada. For a suite of four priority landbird species, habitat-specific estimates of avian density were applied to simulated ALCES III output for three future land use simulations: business as usual, protected area, and climate change. NetLogo was used to simulate spatially explicit changes in vegetation composition for a business as usual/current development scenario within a regional (approximately 2,800,000 hectares) and subregional (approximately 500,000 hectares) landscape in northeast Alberta, Canada. For a suite of 90 boreal landbird species which included 28 old forest landbird species, habitat-specific estimates of avian abundance were applied to the present landscape condition, the pre-disturbance condition (backfilled disturbance map), and the future condition (25 years and 50 years into the future) using the business as usual/current development scenario. We also provide an assessment of five landscape tools currently available for conducting cumulative effects assessments: A Landscape Cumulative Effects Simulator (ALCES), Cumulative Regional Effects Analysis Tool (CREATe), Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), Marxan, and NetLogo. The comprehensive assessment of each landscape analysis tool includes: cost, technical requirements, values and disturbance types supported, and data requirements. Full report (Mahon et al. 2014) is available upon request.

2.3.2 Predicting the impact of energy sector activity on avian populations: Does scale matter?

This year we used parts of the BAM dataset to evaluate how energy sector development in western Canada’s oilsand’s region influences boreal birds. Extraction of conventional and in-situ oil and gas reserves has resulted in development that, while extensive in extent, has a low percentage loss compared to other industrial sectors like forestry. What has occurred from energy sector development however is a dramatic increase in the perceived amount of fragmentation and degradation of the forest via edge effects. While there are some generalities about which species show a negative, neutral, or positive response to edge, there is larger variation in edge effects caused by landscape context, within and between species variation, and the nature of the disturbance creating the edge. In addition, much uncertainty in the relative importance of habitat loss and edge effects, especially that caused by the energy sector is the spatial scale at which impact assessments are done The majority of energy impact studies have compared the relative abundance of birds at edge versus interior using point counts. With little rationale for the method chosen, researchers have employed various combinations of unlimited and limited distance sampling to assess these impacts. How point counts are conducted and the statistics employed to determine the effect size of energy impacts may have strong influence on how important habitat loss and edge effects are perceived to be. With unlimited distance counts, the proportion of the sampling area that is near an edge versus far is an unknown proportion of the total area. This proportion presumably declines the further an observer can hear. Thus, the larger the area sampled, the less influence that edge and that disturbance will have on the count of birds because the proportion of the area sampled that is influenced by the disturbed habitat decreases. Thus, documenting how point count radius influences bird abundance is important for measuring impacts. In addition, to determine whether local edge effects have population-level impacts, changes in bird density or abundance from multiple point counts conducted at the stand or landscape level also need to be evaluated as a function of area disturbed or edge density. Thus, we used a series of edge–interior point count studies conducted in the western boreal forest to determine:

A) the magnitude of local-scale edge effects for individual bird species for different types of energy sector developments (pipe lines, seismic lines, and well pads);

B) how interpretation of effect size from energy impacts varies as a function of the sampling area of individual point counts;

C) whether or not local-scale models accurately predicted numerical responses at larger scales in independent datasets.

Local-scale impact models were created using point counts from the BAM database where the exact location of the point count relative to energy sector impacts was known (n=2193). Of these, 1008 had been conducted with an observer standing directly on the energy sector footprint and 1185 in the forest interior. The number of point counts conducted on pipe lines versus the forest interior adjacent to the same pipelines was 156 and 308, respectively. The number of point counts conducted on seismic lines versus the forest interior adjacent to the same seismic lines was 747 and 772, respectively. Finally, 105 point counts had been conducted on well pads and 105 in the forest interior adjacent to the same well pads. A total of 1471 unique point count locations were visited, with 100% of the pipeline, 24% of the seismic line, and 15% of the well pad point count locations visited twice per year. The pipeline point count locations were visited in two sequential years. Results are reported as incidence rate ratios with the forest interior as the reference condition (hereafter impact ratio). The forest interior has a value of 1 with the reported value showing how many times more or less likely a species was observed on average at an energy sector footprint relative to the interior sites that were matched to that disturbance. We did this separately for the 0-50m, 0-100m, and 0-unlimited distance data. Models were created for 15 species of passerines that were found at least once within each energy sector footprint type and matched interior, each of the vegetation classes, as well as being present in all of the different point count radii. We clearly show that some species are locally more or less abundant near energy sector footprint than in the forest interior. Generally, the species we observed with negative impact Ratios are those that other studies have found to be less tolerant of human disturbance and more likely to be less abundant near edge (i.e. Ovenbird, Western Tanager). Those with positive impact Ratios are also those that tend to prefer early successional habitat and/or are found near forest edges (i.e. Chipping Sparrow, Tennessee Warbler, and White-throated Sparrow) in other areas.

Table 2 – Impact ratios and their standard errors for three types of energy sector footprint in western Canada using three types of point counts (50m radius, 100m radius, and unlimited distance radius). An impact ratio > 1 indicates a species is more likely to be detected at an energy sector footprint than the forest interior. An impact ratio < 1 indicates *a species is less likely to be found at an energy sector footprint than forest interior.* ^{NS} indicates $P > 0.05$, * $P \leq 0.05$ & $P > 0.01$, ** $P \leq 0.01$ & $P > 0.001$, ** $P \leq 0.001$

	PIPE LINE IMPACT RATIO			SEISMIC LINE IMPACT RATIO			WELL PAD IMPACT RATIO		
SPECIES	50m	100m	UNLIMITED	50m	100m	UNLIMITED	50m	100m	UNLIMITED
AMRE	0.92 ± 1.16 ^{NS}	0.45 ± 0.3 ^{NS}	0.38 ± 0.24 ^{NS}	1.19 ± 0.55 ^{NS}	1.14 ± 0.3 ^{NS}	1.17 ± 0.3 ^{NS}	0.51 ± 0.44 ^{NS}	1.06 ± 0.42 ^{NS}	1.03 ± 0.38 ^{NS}
BAWW	1.94 ± 1.36 ^{NS}	2.10 ± 1.04 ^{NS}	1.90 ± 0.88 ^{NS}	1.14 ± 0.4 ^{NS}	0.95 ± 0.25 ^{NS}	0.94 ± 0.25 ^{NS}	0.29 ± 0.26 ^{NS}	0.48 ± 0.31 ^{NS}	0.48 ± 0.3 ^{NS}
CHSP	2.96 ± 0.73 ***	2.22 ± 0.4 ***	2.24 ± 0.39 ***	1.20 ± 0.18 ^{NS}	1.07 ± 0.1 ^{NS}	0.99 ± 0.08 ^{NS}	1.81 ± 0.62 ^{NS}	2.25 ± 0.59 **	2.29 ± 0.58 **
DEJU	1.86 ± 0.67 ^{NS}	1.09 ± 0.29 ^{NS}	1.03 ± 0.27 ^{NS}	1.53 ± 0.28 *	1.22 ± 0.16 ^{NS}	1.05 ± 0.12 ^{NS}	1.61 ± 1.25 ^{NS}	1.72 ± 1.12 ^{NS}	1.35 ± 0.83 ^{NS}
LEFL	1.17 ± 1.01 ^{NS}	0.88 ± 0.44 ^{NS}	0.87 ± 0.42 ^{NS}	0.90 ± 0.44 ^{NS}	0.99 ± 0.27 ^{NS}	0.91 ± 0.24 ^{NS}	1.77 ± 1.21 ^{NS}	2.89 ± 1.15 **	2.79 ± 1.05 **
MAWA	0.59 ± 0.29 ^{NS}	0.56 ± 0.18 ^{NS}	0.59 ± 0.17 ^{NS}	0.68 ± 0.16 ^{NS}	0.73 ± 0.11 *	0.76 ± 0.12 ^{NS}	0.91 ± 0.58 ^{NS}	1.61 ± 0.74 ^{NS}	1.59 ± 0.72 ^{NS}
OVEN	0.58 ± 0.15 *	0.62 ± 0.09 **	0.64 ± 0.08 **	0.72 ± 0.13 ^{NS}	0.79 ± 0.09 *	0.87 ± 0.09 ^{NS}	0.15 ± 0.05 ***	0.70 ± 0.11 *	0.70 ± 0.1 *
RBGR	3.82 ± 4.59 ^{NS}	2.39 ± 1.03 *	1.65 ± 0.51 ^{NS}	0.76 ± 0.52 ^{NS}	0.71 ± 0.18 ^{NS}	1.01 ± 0.21 ^{NS}	0.36 ± 0.47 ^{NS}	1.26 ± 0.5 ^{NS}	1.12 ± 0.35 ^{NS}
REVI	0.96 ± 0.37 ^{NS}	0.82 ± 0.19 ^{NS}	0.81 ± 0.16 ^{NS}	0.62 ± 0.16 ^{NS}	0.62 ± 0.11 **	0.78 ± 0.11 ^{NS}	0.43 ± 0.18 *	0.89 ± 0.2 ^{NS}	0.86 ± 0.18 ^{NS}
SWTH	1.22 ± 0.24 ^{NS}	1.14 ± 0.14 ^{NS}	1.05 ± 0.11 ^{NS}	1.04 ± 0.17 ^{NS}	0.98 ± 0.11 ^{NS}	0.91 ± 0.09 ^{NS}	0.5 ± 0.16 *	1.23 ± 0.22 ^{NS}	1.23 ± 0.21 ^{NS}
TEWA	1.69 ± 0.24 ***	1.38 ± 0.16 **	1.30 ± 0.14 *	1.49 ± 0.18 **	1.23 ± 0.11 *	1.20 ± 0.1 *	1.38 ± 0.26 ^{NS}	1.32 ± 0.19 ^{NS}	1.32 ± 0.19 ^{NS}
WAVI	2.83 ± 2.91 ^{NS}	3.79 ± 2.62 ^{NS}	3.14 ± 1.91 ^{NS}	0.66 ± 0.52 ^{NS}	0.66 ± 0.29 ^{NS}	0.70 ± 0.27 ^{NS}	0.53 ± 0.58 ^{NS}	1.00 ± 0.56 ^{NS}	0.98 ± 0.5 ^{NS}
WETA	0.55 ± 0.88 ^{NS}	0.69 ± 0.26 ^{NS}	0.74 ± 0.22 ^{NS}	0.44 ± 0.39 ^{NS}	0.38 ± 0.15 *	0.65 ± 0.21 ^{NS}	0.10 ± 0.23 ^{NS}	0.51 ± 0.24 ^{NS}	0.53 ± 0.23 ^{NS}
WTSP	9.01 ± 5.17 ***	4.12 ± 1.22 ***	4.14 ± 1.03 ***	0.98 ± 0.22 ^{NS}	0.93 ± 0.13 ^{NS}	1.00 ± 0.1 ^{NS}	1.00 ± 0.28 ^{NS}	1.25 ± 0.19 ^{NS}	1.20 ± 0.16 ^{NS}
YRWA	0.89 ± 0.17 ^{NS}	0.9 ± 0.13 ^{NS}	0.88 ± 0.13 ^{NS}	1.05 ± 0.11 ^{NS}	1.02 ± 0.09 ^{NS}	1.02 ± 0.08 ^{NS}	0.48 ± 0.13 **	0.97 ± 0.19 ^{NS}	1.00 ± 0.2 ^{NS}

We then used the predictions from our local scale impact models to assess how effectively we could predict a numerical response of birds at a larger spatial scale. We used an independent dataset from the Alberta Biodiversity Monitoring Institute (hereafter ABMI) to predict the change in bird population size. The ABMI dataset provided a numerical estimate of bird abundance by pooling data from 9 points counts conducted in an area of approximately 60 hectares to get a quantitative estimate of the number of birds present along an energy sector footprint gradient. We then correlated the predicted abundance from our local scale BAM models with ABMI's site level population estimates.

Our expectation was that for species with negative impact ratios, particularly those with strong patterns like the Ovenbird, we would see a population response to increasing amounts of energy sector footprint in the ABMI data. Conversely, we expected that the strong positive impact ratio of White-throated Sparrows would result in more White-throated Sparrows in areas with more energy sector footprint. However, local scale impact models were not good predictors of bird abundance at ABMI sites. In our detailed report in Appendix 1, we provide some potential reasons to explain this discrepancy. As a result of this work, the current sampling plan for JOSM-related field work in 2014 will include data collection to fill in holes in our local-scale impact models and to create additional estimates of avian abundance at larger spatial scales along a human impact gradient. These new data will be used to complete a paper on this topic in the fall of 2014.

2.3.3 Dealing with the uncertainty of habitat classification in species-habitat modelling through covariate measurement error models

BAM Project activities rely extensively on data from remote sensing to create predictive statistical models to map the abundance of birds. Significant effort has been made to improve these models by collecting more species data at ever increasing spatial extents. Similarly, much research has been done to correct for errors in the estimation of species abundance abundance through our QPAD approach (Solymos et al. 2013). While such efforts have improved our ability to predict species abundance, there remains uncertainty in model predictions.

A source of uncertainty that has been ignored by BAM and almost all other modelling efforts is the reality that predictor variables (i.e. the habitat types in GIS layers) are also measured with error. All GIS products come with a standard caveat that the layer has a certain level of classification error. Yet when modelling the distribution of species, ecologists ignore these caveats and use statistical models that assume the GIS products they are using are accurate. Simply comparing two different GIS layers purporting to measure the same phenomena reveals this is rarely true. Thus, we invested considerable time this year evaluating the effect this has on predictions made by BAM bird models.

Rather than trying to address such uncertainty by continually improving the GIS layer in the hope of reaching some unattainable truth, an alternative approach is to incorporate the differences between GIS layers for the same location and use that variation when estimating species – habitat relationships. An approach we are developing to do this is known as covariate measurement models. Covariate measurement models (hereafter CME) accept that the predictor variables are measured with error and deals with this problem by using multiple estimates of the same variable from different GIS sources when creating bird-habitat models. Details of the approach are available in Appendix 2. As an example, we selected 10,050 point count locations from the BAM database to test for an effect of the area of trees on the probability of observing an Ovenbird as the amount of treed area increased. Treed area was estimated using a variety of different GIS layers. These two layers result in different estimates of the area treed for exactly the same location. Below is an example of how much of a difference this type of error can have when predicting bird abundance and what happens when CME approaches are used. Similar analyses were conducted to estimate the response of Ovenbird to: 1) forest composition while controlling for treed area; 2) variation in grain size of data layers (ABMI, EOSD, and Land Cover Classification of Canada 2005, LCC); 3) data from remote sensing vs. aerial photography; and 4) species location error. BAM is currently developing new statistical techniques and code to integrate this type of modelling structure into bird-habitat models. These approaches are at the leading edge of statistical modelling and have not been used before to the best of our knowledge in any bird modelling efforts. This approach is very computationally demanding, so BAM is working to better develop the efficiency of these tools. A paper outlining the approach and why ecologists should be using such tools is in preparation.

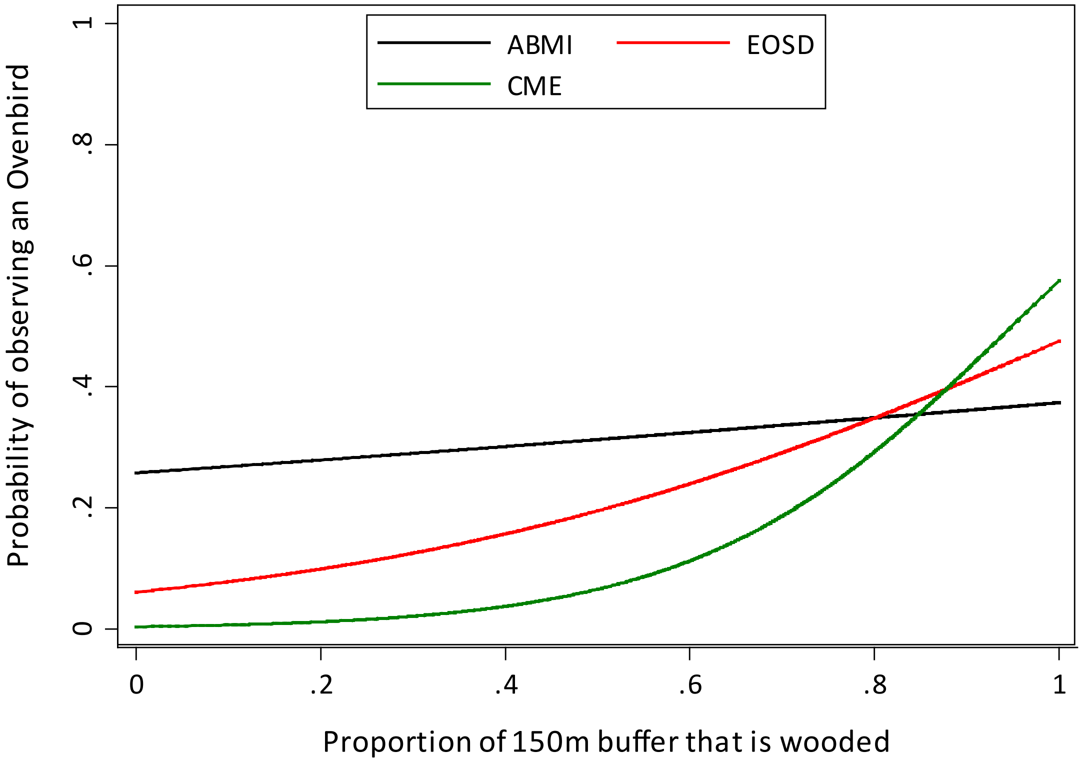


Figure 9. Probability of observing an Ovenbird as a function of the proportion of a 150m buffer being treed. Probability curves are shown for individual logistic regressions using the ABMI (Alberta Boreal Monitoring Institute) and EOSD (Earth Observation for Sustainable Development of Forests) geospatial data layers as the predictor of the area that is treed (wooded). The CME curve shows the estimated probability when the true estimate of treed is applied using the CME approach.

2.4 Climate change Impacts and Management

2.4.1 Sources of variation in projected shifts in species distribution under climate change

Climate-change distributional projections for 80 boreal bird species were evaluated and synthesized in a manuscript quantifying and analyzing various sources of prediction uncertainty. The manuscript was submitted to the journal Ecological Applications and has been provisionally accepted (pending suitable revisions). An abstract of the paper follows:

For climate-change projections to be useful, the magnitude of change needs to be understood relative to the magnitude of uncertainty in model predictions. We sought to quantify the signal-to-noise ratio in projected distributional responses of boreal birds to climate change, and to compare different sources of uncertainty. Boosted regression tree models of abundance were generated for 80 boreal-breeding bird species using a comprehensive dataset of standardized avian point counts (349,629 surveys at 122,202 unique locations) and 4-km climate, land-use, and topographic data. For projected changes in bird abundance, we calculated signal-to-noise ratios, and examined variance components related to choice of global climate model (GCM) and two sources of species distribution model (SDM) uncertainty: sampling error and variable selection. We also evaluated spatial, temporal, and inter-specific variation in these same sources of uncertainty. We found that the mean signal-to-noise ratio across species increased over time to 2.87 by the end of the century, with signal > noise for 88% of species. Across species, the climate-change effect represented the largest component (0.44) of variance in projected abundance change. Among the sources of uncertainty evaluated, the choice of GCM (mean variance component = 0.17) was most important for 66% of species, sampling error (mean = 0.12) for 29% of species, and variable selection (mean = 0.05) for 5% of species. Increasing the number of GCMs from four to 19 had minor effects on these results. Sampling uncertainty, concentrated in under-sampled northern areas, was most important for near-term projections, but GCM uncertainty, highest in arid western regions, was projected to become twice as important by the end of the century. We conclude that SDM-based projections of avian responses to climate change can and should be used to inform broad-scale conservation and management decisions for a majority of species. However, different conservation approaches may be warranted for different species depending on the strength of the climate change signal relative to the noise. Figure 8 illustrates the variability in the magnitude and primary source of uncertainty across the species studied. A follow-up analysis is planned to evaluate patterns across species and potential mechanisms for this variability.

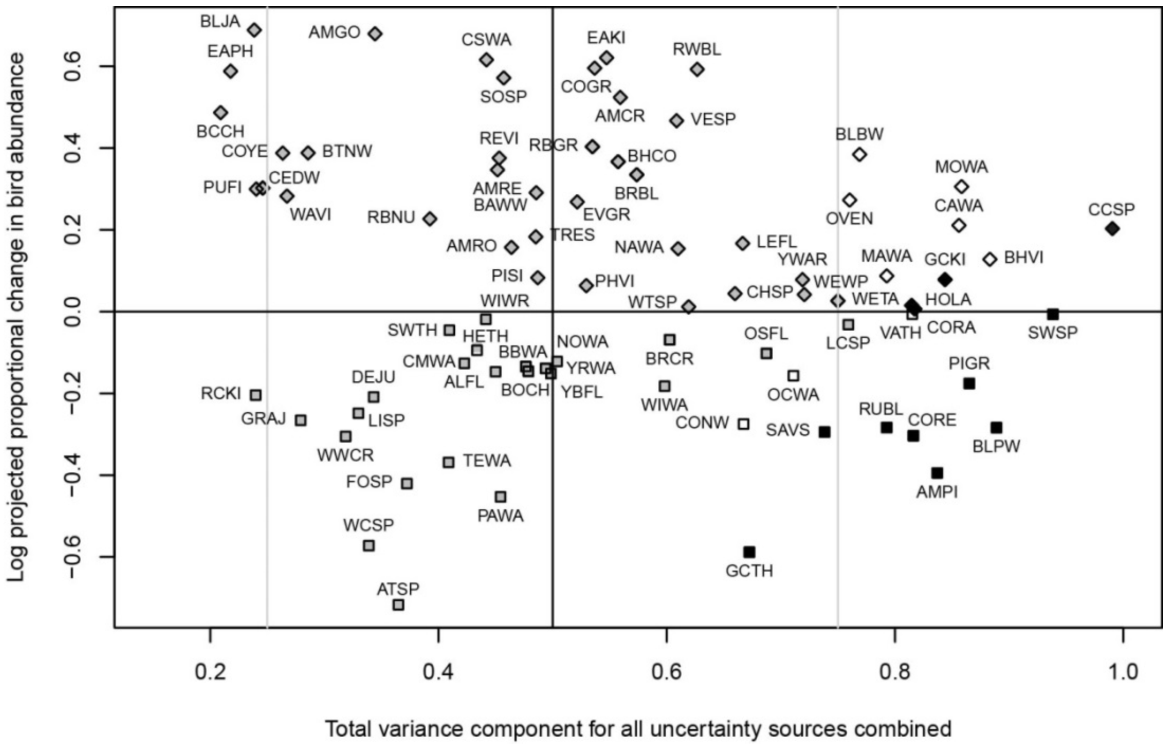


Figure 10. The magnitude of uncertainty (x-axis) plotted against the magnitude of projected proportional change (y-axis) by the end of the century (2071-2100) for 80 boreal species based on four complementary GCMs. Diamonds = mean projected increase; squares = mean projected decrease. Gray = climate change effect is greatest source of variability; white = GCM is greatest source of variability; black = sampling or variable selection (CCSP only) is greatest source of variability. The x-axis represents the sum of all variance components except the climate-change effect. The y-axis represents the log-transformed projected proportional change + 1 (y = 0 indicates no change).

2.4.2 Climate change refugia, conservation priorities, and evaluation of current and potential future protected areas

In the long term (over multiple centuries), ecological communities may be expected to track climate and shift northward and upslope as projected by global climate models (GCM). However, in the short term, which is of considerably greater importance to managers and conservationists, a time lag is likely to exist in ecosystem responses to climate change. A well-recognized component of this time lag is dispersal limitation, which may prevent organisms from relocating to suitable habitat quickly enough to keep pace with climate change. However, a largely overlooked component—arguably more important in boreal systems—is the delay in forest growth and succession.

Considering the potential for time lags in vegetation responses to climate change, as well as the inherent variability in species' vulnerability to climate change, our objective was to develop a systematic conservation planning approach that considers these factors explicitly. For each of 53 boreal forest passerine species, we identified "strict" refugia based on overlap between current and future core habitat areas, and also calculated alternative future core habitat scenarios based on different combinations of climatic and successional suitability for three future thirty-year periods (2011-2040, 2041-2070, 2071-2100)

We used Canada-wide forest inventory data with a common attribute schema (CASFRI; Cumming et al. in review) to estimate species-specific differences in habitat age preferences and identify the most likely trajectories for distributional changes over the next century. Given the wide range of forest types and ages utilized by many species, we used the 25th percentile of all CAS-FRI overlapping observations within our database to denote the minimum age class required to support core populations of a given species (Figure 9). We found that over 2/3 of the 53 species evaluated preferred mid- to late-successional forest, and are likely to exhibit lags of at least 30 years in their responses to climate change.

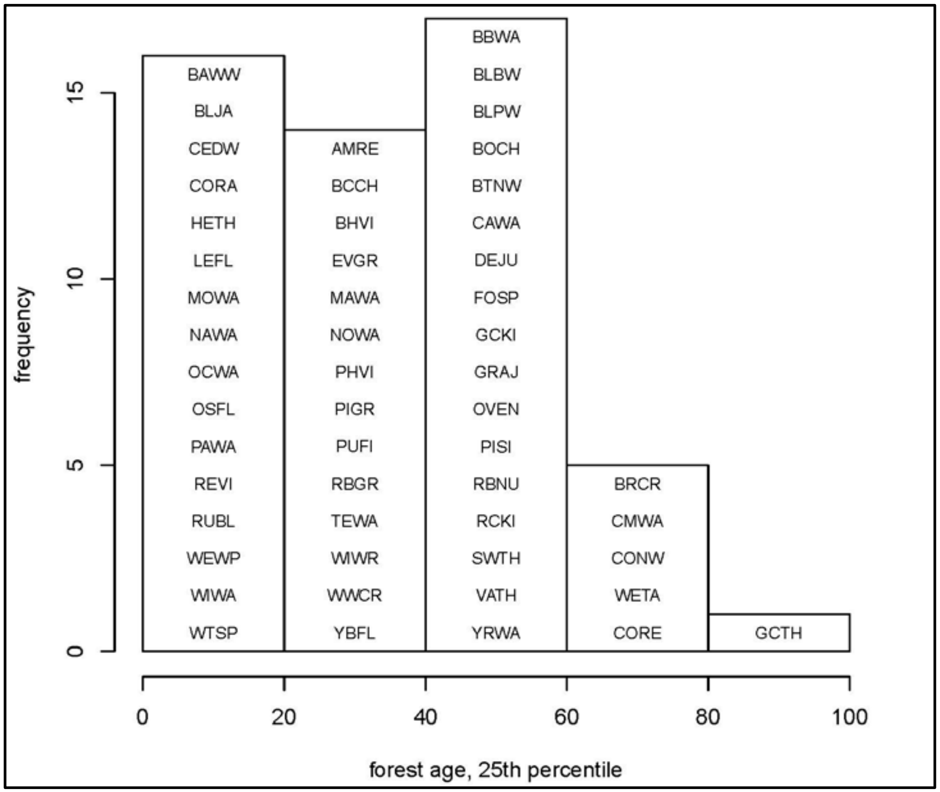


Figure 11. 25th percentiles of habitat age associations for 53 boreal forest species. 25% of detections for a given species occurred in habitat that was as young as or younger than the specified age (based on 20-year age categories).

These species-specific minimum habitat age classes were used to identify the most likely scenarios of projected future change for each species (Table 3). For example, a bird species requiring 100-year-old forest would not be expected to gain new habitat within any of the three future 30-year periods evaluated; it would be restricted to refugia. An early-seral species would be assumed to gain new habitat as soon as it became climatically suitable (following disturbance). A species requiring 50-year-old forest would be able to disperse into new areas 50 years after they became climatically suitable, i.e., within the second thirty-year period (e.g., Bay-breasted Warbler Figure 12).

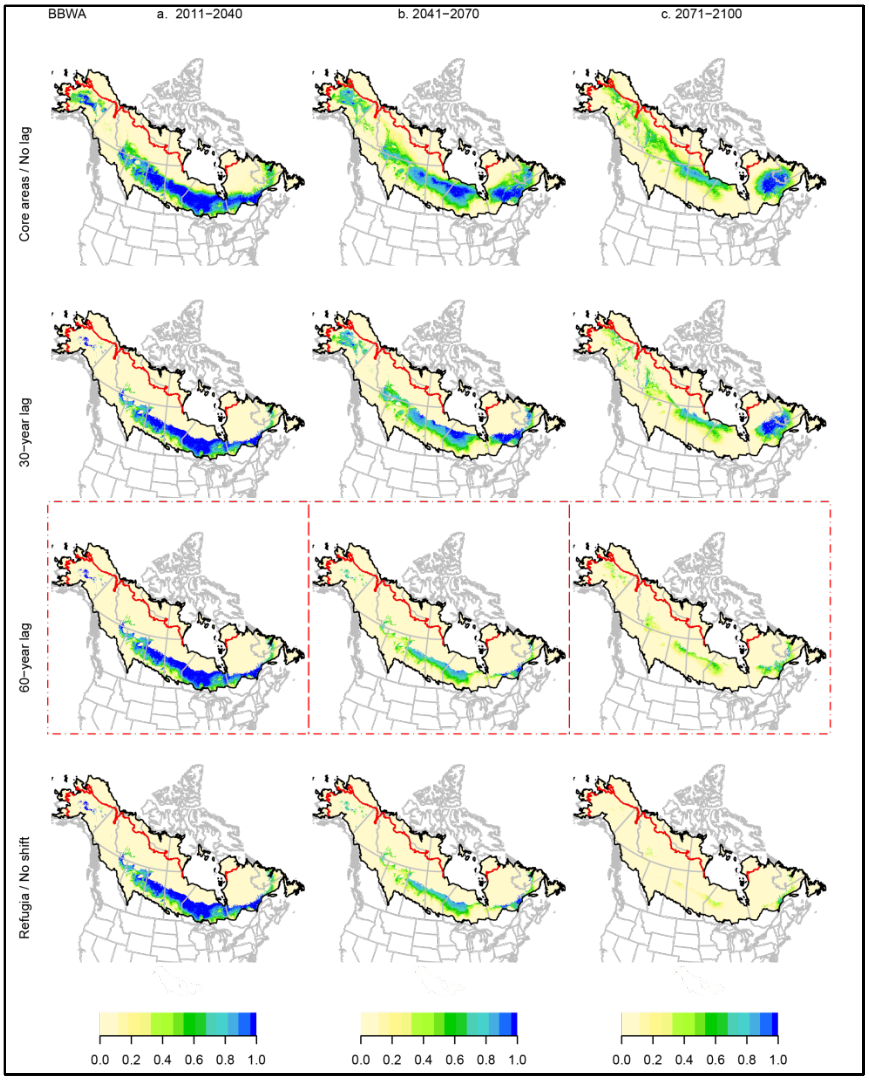


Figure 12. Alternative scenarios for an example species, Bay-breasted Warbler, with most likely scenario (based on Figure 11) outlined with red dotted lines. Map values represent the proportion of scenarios (11 bootstrap replicates x 4 GCMs x 2 variable sets) for which a given pixel meets the core area criteria: projected density ≥ mean density within model-building study area (including hemiboreal). No lag = core areas; 30-year lag = overlap between future time period of interest and previous 30-year period; 60-year lag = overlap between future time period of interest and that two time periods earlier (e.g., 2041-2070 and current period); 90 year lag = refugia (overlap between future and current period only).

Table 3. Proportional change in core habitat area for 53 species under different lag-time assumptions. Most likely scenario (based on Figure 11) outlined.

Species	Lag time	Climatic change	30-year lag	60-year lag	Refugia only	Combination
AMRE	30	1.22	0.44	-0.15	-0.60	0.44
BAWW	0	0.63	0.01	-0.34	-0.60	0.63
BBWA	60	0.02	-0.37	-0.77	-0.93	-0.77
BCCH	30	1.05	0.18	-0.27	-0.73	0.18
BHVI	30	0.17	-0.27	-0.58	-0.79	-0.27
BLBW	60	1.56	0.56	-0.13	-0.65	-0.13
BLJA	0	1.31	0.34	-0.27	-0.82	1.31
BLPW	60	-0.47	-0.75	-0.78	-0.81	-0.78
BOCH	60	-0.28	-0.53	-0.59	-0.69	-0.59
BRCR	60	0.03	-0.48	-0.56	-0.64	-0.56
BTNW	60	0.90	0.31	-0.16	-0.55	-0.16
CAWA	60	1.38	0.53	0.02	-0.40	0.02
CEDW	0	0.84	0.13	-0.29	-0.63	0.84
CMWA	60	-0.13	-0.46	-0.71	-0.86	-0.71
CONW	60	-0.13	-0.44	-0.68	-0.86	-0.68
CORA	0	0.45	0.05	-0.09	-0.21	0.45
CORE	100	-0.64	-0.65	-0.72	-0.91	-0.91
DEJU	60	-0.27	-0.46	-0.55	-0.62	-0.55
EVGR	30	1.21	0.45	-0.06	-0.49	0.45
FOSP	60	-0.59	-0.75	-0.79	-0.82	-0.79
GCKI	60	0.53	0.19	-0.25	-0.58	-0.25
GCTH	100	-0.81	-0.85	-0.88	-0.92	-0.92
GRAJ	60	-0.45	-0.63	-0.73	-0.85	-0.73
HETH	0	-0.31	-0.50	-0.56	-0.65	-0.31
LEFL	0	0.63	0.23	-0.10	-0.36	0.63

Species	Lag time	Climatic change	30-year lag	60-year lag	Refugia only	Combination
MAWA	30	0.00	-0.31	-0.55	-0.75	-0.31
MOWA	0	0.87	0.22	-0.19	-0.56	0.87
NAWA	0	0.80	0.27	-0.18	-0.53	0.80
NOWA	30	-0.23	-0.44	-0.54	-0.64	-0.44
OCWA	0	-0.28	-0.42	-0.60	-0.64	-0.28
OSFL	0	0.06	-0.01	-0.23	-0.37	0.06
OVEN	60	0.72	0.16	-0.18	-0.52	-0.18
PAWA	0	-0.77	-0.86	-0.88	-0.91	-0.77
PHVI	30	-0.01	-0.39	-0.77	-0.94	-0.39
PIGR	30	-0.53	-0.60	-0.67	-0.73	-0.60
PISI	60	0.02	-0.44	-0.64	-0.76	-0.64
PUFI	30	1.01	0.09	-0.27	-0.53	0.09
RBGR	30	1.26	0.50	-0.04	-0.53	0.50
RBNU	60	0.87	0.46	0.00	-0.39	0.00
RCKI	60	-0.19	-0.44	-0.60	-0.75	-0.60
REVI	0	0.87	0.23	-0.14	-0.48	0.87
RUBL	0	-0.64	-0.67	-0.74	-0.90	-0.64
SWTH	60	0.04	-0.15	-0.35	-0.59	-0.35
TEWA	30	-0.41	-0.60	-0.78	-0.92	-0.60
VATH	60	0.21	-0.28	-0.58	-0.69	-0.58
WETA	60	0.19	-0.32	-0.45	-0.78	-0.45
WEWP	0	-0.05	-0.30	-0.38	-0.50	-0.05
WIWA	0	-0.33	-0.52	-0.58	-0.62	-0.33
WIWR	30	0.06	-0.12	-0.32	-0.57	-0.12
WTSP	0	-0.12	-0.30	-0.41	-0.55	-0.12
WWCR	30	-0.50	-0.68	-0.73	-0.77	-0.68
YBFL	30	-0.11	-0.32	-0.45	-0.60	-0.32

Species	Lag time	Climatic change	30-year lag	60-year lag	Refugia only	Combination
YRWA	60	-0.07	-0.30	-0.43	-0.65	-0.43

Using these modified projections of changes in species' core habitat distributions, with species weighted equally, we used the Zonation algorithm and software (Moilanen 2007) to develop multi-species conservation priorities for three future 30-year periods (Figure 13). We found that when only climatic responses were considered, conservation priorities generally shifted northward over time. When focusing on strict refugia, priority areas remained relatively constant over time. With a species-specific seral-stage adjusted approach, results were intermediate and less spatially compact (i.e., more dispersed clusters).

Zonation priority areas based on current distributions and future refugia were found to be more optimal (and thus more efficiently protected) than the highest-ranking areas within climate-shifted distributions (Figure 14). This can be attributed to the relatively compact and highly overlapping concentration of species' current distributions compared to future distributions.

Comparing resulting conservation priorities to the existing protected areas network, we found that current protected areas were closer to optimal for climatically-based core area shifts that assumed no time lag ("core"). They fell far short for strict refugia, and had intermediate optimality for seral-stage adjusted lag-time scenarios ("combo"). Optimality increased over time for "core" and "combo" scenarios.

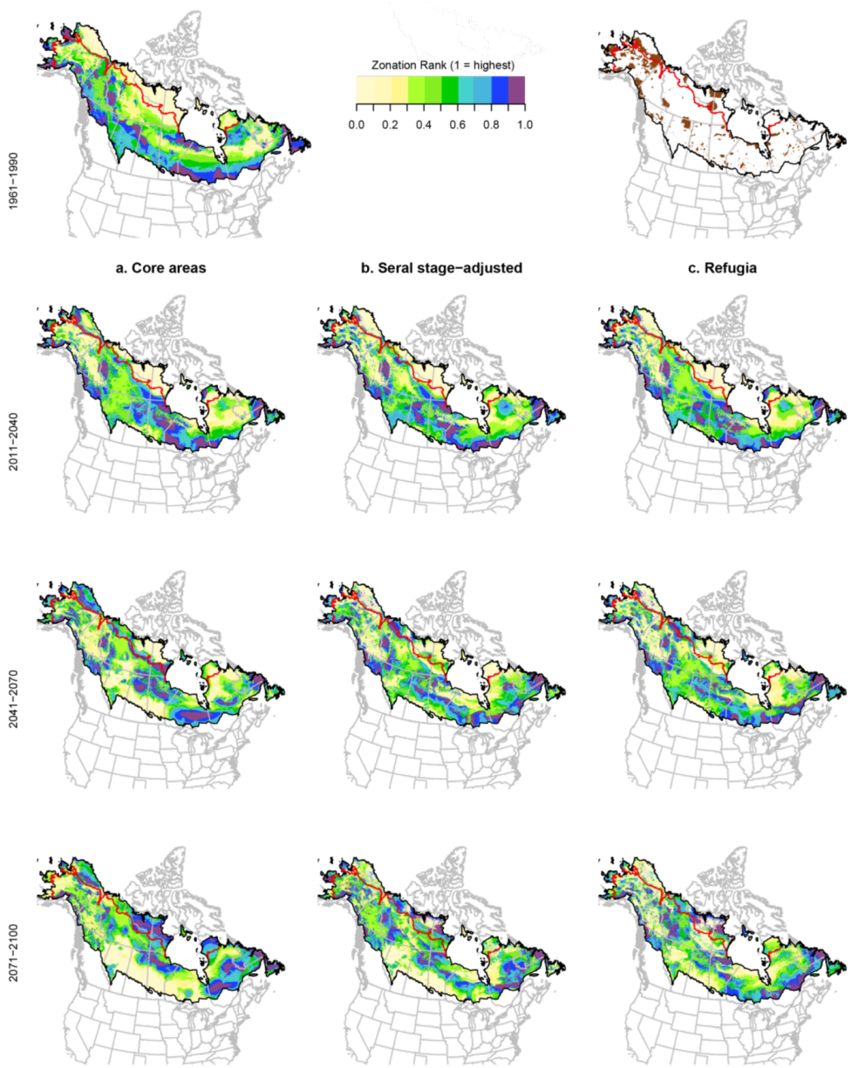


Figure 13. Zonation results for three scenarios, all 53 species weighted equally.

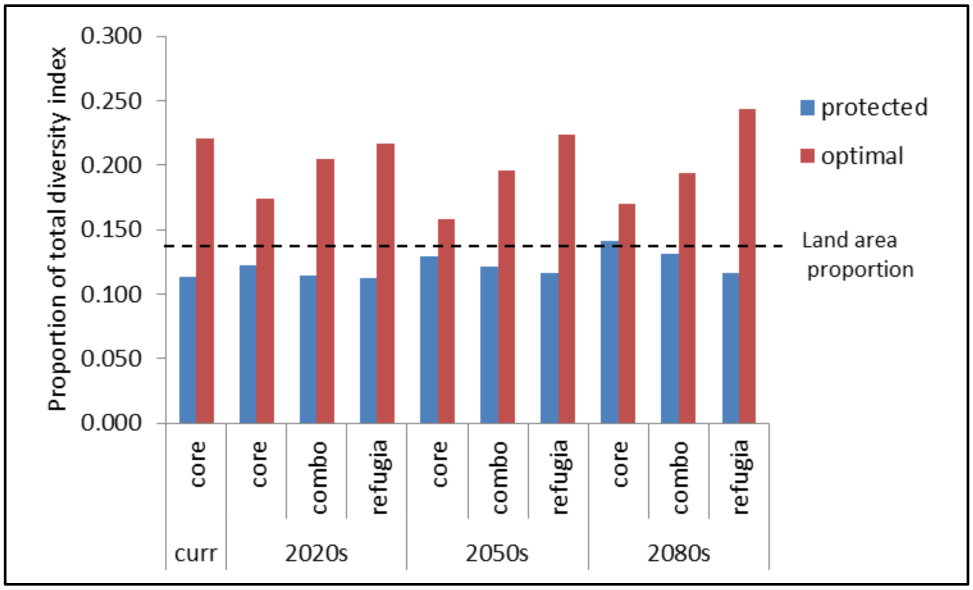


Figure 14. Proportion of overall boreal bird diversity conserved by the current protected areas network (13.9% of total land base) vs. an optimal network based on Zonation's "core area" algorithm for the same area. Core = projected core areas without constraints; refugia = overlap between current and future core areas; combo = seral-stage modified projections for core areas.

2.5 Conservation planning: National and Regional Scales

2.5.1 Canadian Boreal Forest Agreement and BEACONs project

The Canadian Boreal Forest Agreement (CBFA) is an unprecedented collaboration between the largest Canadian forest products companies and key environmental non-governmental organizations operating in the boreal region of Canada. Across their planning area of approximately 72 million hectares (720,000 km^2), among other goals, the CBFA seeks to accelerate the development and implementation of:

1. A network of protected areas that, taken as a whole, represent the diversity of boreal ecosystems and ecological processes.

2. World-leading forest practices that are based on principles of ecosystem-based management.

3. Plans to protect boreal Species-at-Risk, such as Olive-sided Flycatcher and Canada Warbler.

The BEACONs Project is a long-term collaborative study to advance the scientific foundations for systematic conservation planning in the Canadian boreal region, and is tasked with providing scientific advice to the CBFA. BAM has provided critical assistance to this work in the form of new national species distribution models which are being used to:

1. Validate the ecological surrogates used by BEACONs in conservation planning (reported in 2012-13);

2. Conduct a gap analysis of the existing protected areas network in the boreal region and,

3. Design a network of ecological benchmarks across the boreal region.

Activities 2 and 3 are collectively referred to as the Pan-boreal Assessment, and BAM's support for this work is highlighted here.

Pan-Boreal Assessment:

The Pan-boreal Assessment, conducted by BEACONs with support from BAM, is a comprehensive spatial analysis of the existing protected areas network in boreal regions of Canada with respect to representation of ecosystem diversity and provision of ecological benchmarks. Its purpose was to identify gaps in representation related to a suite of broad-scale biophysical indicators, and opportunities for establishment of ecological benchmarks based on standardized ecological criteria. A detailed 7-tiered assessment framework was developed of which the 3rd, a Gap Analysis of Existing Protected Areas, and 5th, Identification of Candidate Benchmark Areas, are addressed here relative to boreal songbirds. The primary objectives of the pan-boreal gap analysis were to: 1) evaluate the degree to which existing protected areas represent ecosystem diversity; 2) evaluate the suitability of these areas to serve as ecological benchmarks, and 3) evaluate the potential of the broader ecological strata to address these conservation needs. The protected areas dataset included in this evaluation was drawn from diverse sources, and is a complete and up-to-date coverage of existing or interim protected areas in Canada. A report on this work, including web-based posting of the results is anticipated in May 2014.

2.5.1.1 Gap analysis of existing protected areas

Representation of biological features at all organizational levels, and the range of environmental conditions under which they occur, is a well-established objective of conservation planning. However, there is inadequate data on which to address this comprehensively, thus a subset of indicators of environmental variability are typically identified as coarse-filter surrogates of biodiversity. Representation alone does not address the question of how much of each feature should be conserved to ensure a high likelihood that it will persist over time; specifically, identification of how many or how much of a species, community or ecosystem is needed within a planning region, and how these occurrences should be distributed. Some consideration of targets was undertaken within the broader pan-boreal assessment. However, there is a need for flexibility in planning and implementation in order to evaluate how different levels of representation contribute to the persistence of conservation features over space and time.

The pan-boreal analysis relied on the use of biodiversity indicators (species, communities, ecosystems, and ecological processes) whose distributions could be mapped consistently across the extent of the boreal zone of Canada. In all, 25 map-based indicators were selected as representing both coarse- and fine-filter elements of boreal biodiversity, encompassing the following:

- Representation of large-scale environmental variation in ecological patterns and processes that are assumed to influence biodiversity at coarse spatial scales;

- A fire regionalization map to represent the large-scale natural disturbances in the boreal zone;

- Freshwater ecosystems including bogs, fens, and other wetland features not captured by broad aquatic regions;

- Species-level representation of richness and distribution for select taxa.

The contribution of BAM to this work was to provide spatial predictions of the occurrence probabilities for five species of forest songbirds identified as of importance by National Working Groups within the CBFA, in consultation with BAM. These species were chosen for their differential habitat affinities and current conservation status as species of actual or potential concern. The five species were: Blackburnian Warbler, Black-throated Green Warbler, Canada Warbler, Cape May Warbler, and Olive-sided Flycatcher. BAM's MAXENT models of these species distributions were used in three components of this analysis: 1) assessing the representativeness of the existing protected areas system, 2) identifying gaps in the system and 3) evaluating the effectiveness of alternate networks, designed by BEACONs, in increasing representation. With the exception of woodland caribou, these were the only individual species considered in the pan-boreal assessment. BAM's work made possible the development of the high resolution species models used by BEACONs and the CBFA. This represents major progress towards quantitative conservation planning in the boreal, considering that prior to the work of BAM, only products such as the Natureserve range maps were available for such purposes.

All pan-boreal analyses were undertaken at multiple spatial scales, delineated by strata reflecting ecological and hydrological classification systems. Figures 15 and 16 illustrate a sample result of the gap analysis of existing protected areas for the Olive-sided Flycatcher (OSFL) in Ecoregion 88, an area of 195,485 km^2 straddling Saskatchewan/Manitoba border, north of The Pas.

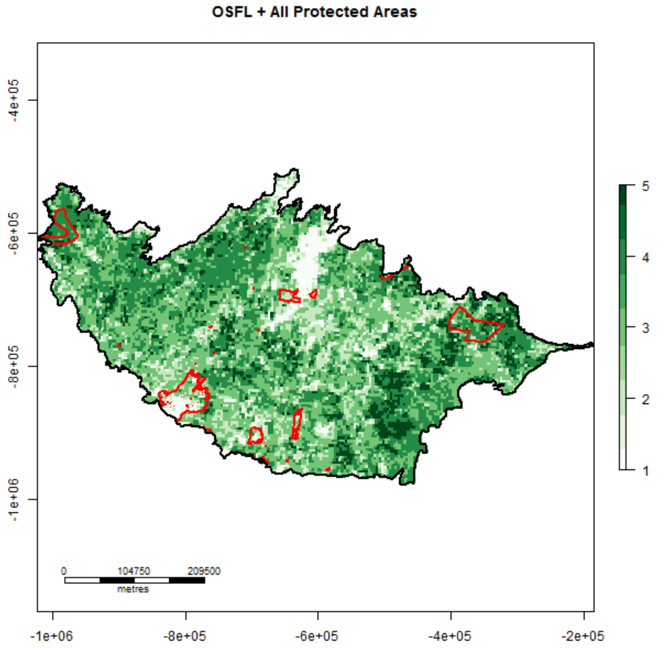


Figure 15. Predicted density distribution of the Olive-sided Flycatcher (OSFL) in Ecoregion 88, with existing protected areas shown as red outlines.

2.5.1.2 Identification of candidate benchmark areas

An important value of protected areas is to serve as ecological benchmarks; however, the existing protected areas network across Canada was not designed to meet this objective. A full elaboration of the conceptual and analytical frameworks for addressing requirements for ecological benchmarks in boreal regions of Canada, and a detailed description of relevant datasets, will be available in the final report of the pan-boreal assessment. Highlights of the approach are provided here. Ecological benchmarks were designed based on three principal criteria: 1) intactness, a measure of the absence of human industrial activity and a proxy for the maintenance of biological and physical processes; 2) hydrological connectivity, a measure of the integrity of aquatic systems; and 3) size, a measure of the resilience of the system to disturbance. This approach focuses on processes that shape ecological systems at broad spatial extents and over relatively long time frames, with associated flows guiding the size, condition, and configuration of potential benchmark sites. Unlike conventional approaches to reserve design, the design of ecological benchmarks is not driven by representation. Rather, representation becomes an additional criterion for the evaluation and selection of benchmark areas for a broader suite of conservation and resource management objectives. As with the representation analyses described previously, BAM provided predictive models and collaborated with BEACONs to evaluate the ability of candidate benchmark areas to address habitat needs for select boreal bird species.

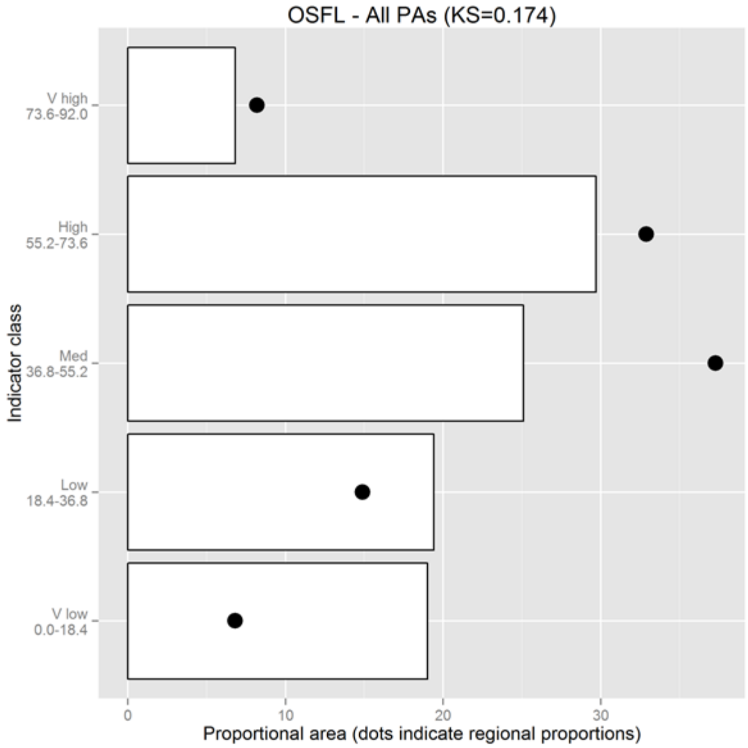


Figure 16. Bar plot for Ecoregion 88 illustrating the proportion of each predicted density class for the Olive-sided Flycatcher (OSFL) within protected areas (open bars), and within the broader strata (black dots). Medium, high, and very high predicted density areas for the Olive-sided Flycatcher are under-represented in existing protected areas.

As a first step, benchmark criteria were applied both to existing protected areas, and to the design of benchmarks de novo, across a hierarchy of ecological strata. Protected areas that met specified intactness and size criteria, as well as benchmark areas constructed de novo along hydrological networks within each ecological stratum, were considered to contribute to the benchmark potential of that stratum (Figure 17).

Benchmark networks were then drawn from the benchmark potential of each stratum, and ranked based on the four biophysical indicators described previously for the surrogacy analysis. When multiple solutions for benchmark networks were identified, which is often the case when benchmark potential is high, additional criteria were considered to further rank options. Complementarity to existing protected areas with respect to a broader suite of biodiversity values; in this case, boreal birds, was one criteria applied (Figure 18).

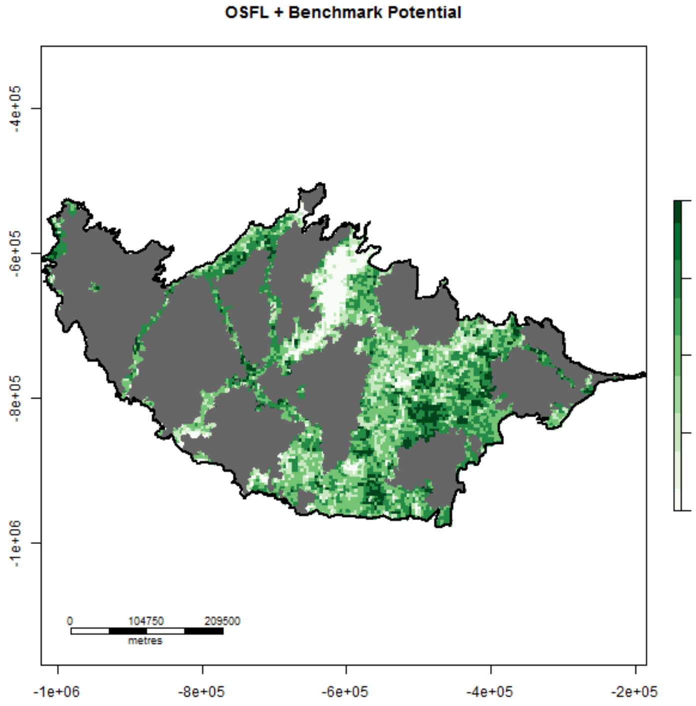


Figure 17. The benchmark potential of Ecoregion 88 (grey area) superimposed on the predicted density distribution of the Olive-sided Flycatcher (OSFL). The benchmark potential of this stratum is high.

2.5.1.3 Ongoing work to support the CBFA

We are presently collaborating with BEACONs to undertake an evaluation of the resilience of candidate benchmark networks using a dynamic landscape simulation model that assesses whether representation of selected indicators (i.e. maintenance of high value habitat for boreal bird species) is maintained through time under an active disturbance regime. Using the climate projections described in section 2.3.1, we will extend this evaluation to address the potential effects of climate change on the persistence of indicators within candidate protected areas networks, and also incorporate predicted climate refugia into relevant analyses.

The results of BAMs collaboration with BEACONs and the CBFA are being incorporated into conservation planning exercises across boreal regions in Canada, and will influence the identification of ecological benchmarks, site-specific protected areas, and management prescriptions for the broader matrix, including forestry operations. In addition to the national evaluations, active regional planning exercises are currently underway in Newfoundland, Manitoba, Saskatchewan, Alberta and British Columbia.

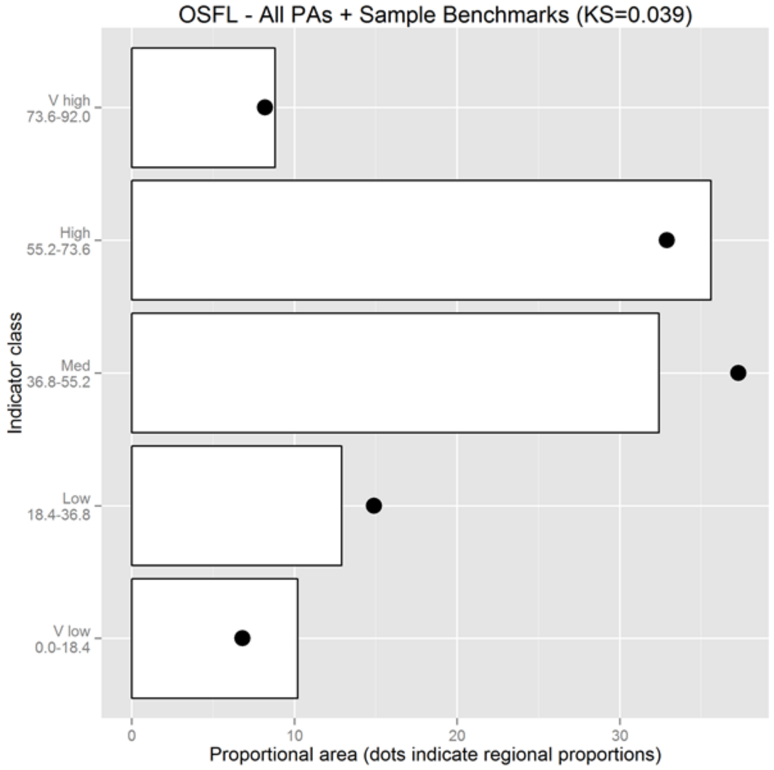


Figure 18. A sample benchmark network for Ecoregion 88 improves representation of high and very high predicted density areas for the Olive-sided Flycatcher (OSFL) relative to the existing protected areas in the region. Open bars indicate proportional distribution in existing areas; black dots represent the distribution in the sample benchmark network.

2.6 Modelling and Projection

The reasons for documented declines in forest songbirds are not well understood (Sauer et al. 2011, North American Bird Conservation Initiative Canada, 2012), but boreal ecosystems, the core of the range for many of these species, are experiencing marked, cumulative impacts from large-scale industrial timber harvest, agricultural expansion, oil and gas exploration (Hobson et al. 2002, Hauer et al. 2010), and climate change (ACIA 2004). However, it has not been established to what extent these activities have contributed to the observed declines. The majority (94%) of boreal birds are migratory (Blancher and Wells 2005). Thus observed declines may be the result of environmental changes outside the breeding grounds. Furthermore, reported trends are mainly based on BBS routes located in the south or transitional areas, so it is possible that they reflect local changes on the forest periphery and thus overestimate impacts at the population level. To address more fully the detection and attribution of population trends in boreal birds, BAM will initiate full life-cycle population modeling of boreal birds, building on our past models to include effects of wintering grounds and migratory pathways.

BAM is developing a multiyear program to assimilate available data on species distributions on the wintering ground, and on climate, annual weather, habitat and landuse change on the wintering grounds, flyways and staging areas. At the same time, we are systematically exploring the potential ability of the BAM database to detect and attribute trends in species abundances. This is challenging because of the highly unbalanced sample design. To make the most of BAMs existing data, and to identify locations where new data would be most valuable, or where monitoring efforts should be concentrated, it's necessary to control for possibly confounding historical factors such as: annual weather conditions on the breeding grounds, forest dynamics including natural disturbances such as fire and insect outbreak, landuse change and forest dynamics. Much of our work this year comprised initial attempts to address some of these factors. Beyond applications to migratory bird and land management, this work provides a novel approach to address historical shortcomings in status and trend monitoring (NABCI Canada, 2012). The boreal forest is a vast landscape with extensive roadless and unsettled areas, unconducive to volunteer- and road-based monitoring surveys like the BBS. Although a long-term landbird monitoring program for the boreal forest is a priority for Environment Canada (Avian Monitoring Review Steering Committee 2012), there exist many logistic and financial barriers to establishing such an effort. Developing methods of trend detection from heterogeneous and spatially /temporally sparse data is a pragmatic approach to improve the effectiveness of monitoring efforts.

We outline progress made this year to address these issues.

2.6.1 Separating the effects of climate and vegetation, and confounding factors of inter-annual variation in weather and disturbances both on the breeding and wintering grounds

The long term objectives of full life cycle analysis, and the subtask of trend detection, require that we separate the effects of climate and vegetation, and account for confounding factors of inter-annual variation in weather and accumulated disturbances both on the breeding and wintering grounds, whether natural or human caused.

2.6.1.1 Relationships between regional species abundances and monthly global climate indices

To inform future full life-cycle analyses for Canada Warbler (*Cardellina canadensis*) and other species, we have conducted a preliminary analysis of abundance data from 1993 to 2011 from the Calling Lake, Alberta study site (Schmiegelow et al. 1997) with respect to three global climate indices. Only reference and fragment (i.e., uncut) plots were used for this analysis, with abundance averaged across point count stations by plot and year for 13 resident species, 34 short-distance migrant species, and 36 long-distance migrant species. Mean breeding season bird abundance was regressed against January, February, and March indices from the same year. The indices evaluated were the southern oscillation index (SOI), Pacific decadal oscillation (PDO), and North Atlantic Oscillation (NAO).

Research conducted through an initiative from Partners in Flight identified a positive association between wintering Canada Warbler body condition and monthly values of SOI (G. Colorado, unpubl. data). We found a similar positive association between mean Canada Warbler abundance at Calling Lake and Jan-March SOI (Figure 19). A positive SOI index reflects La Niña conditions, which translates into higher winter precipitation in northern South America, where the Canada Warbler overwinters.

Further analysis and synthesis of remaining species will be conducted in upcoming months.

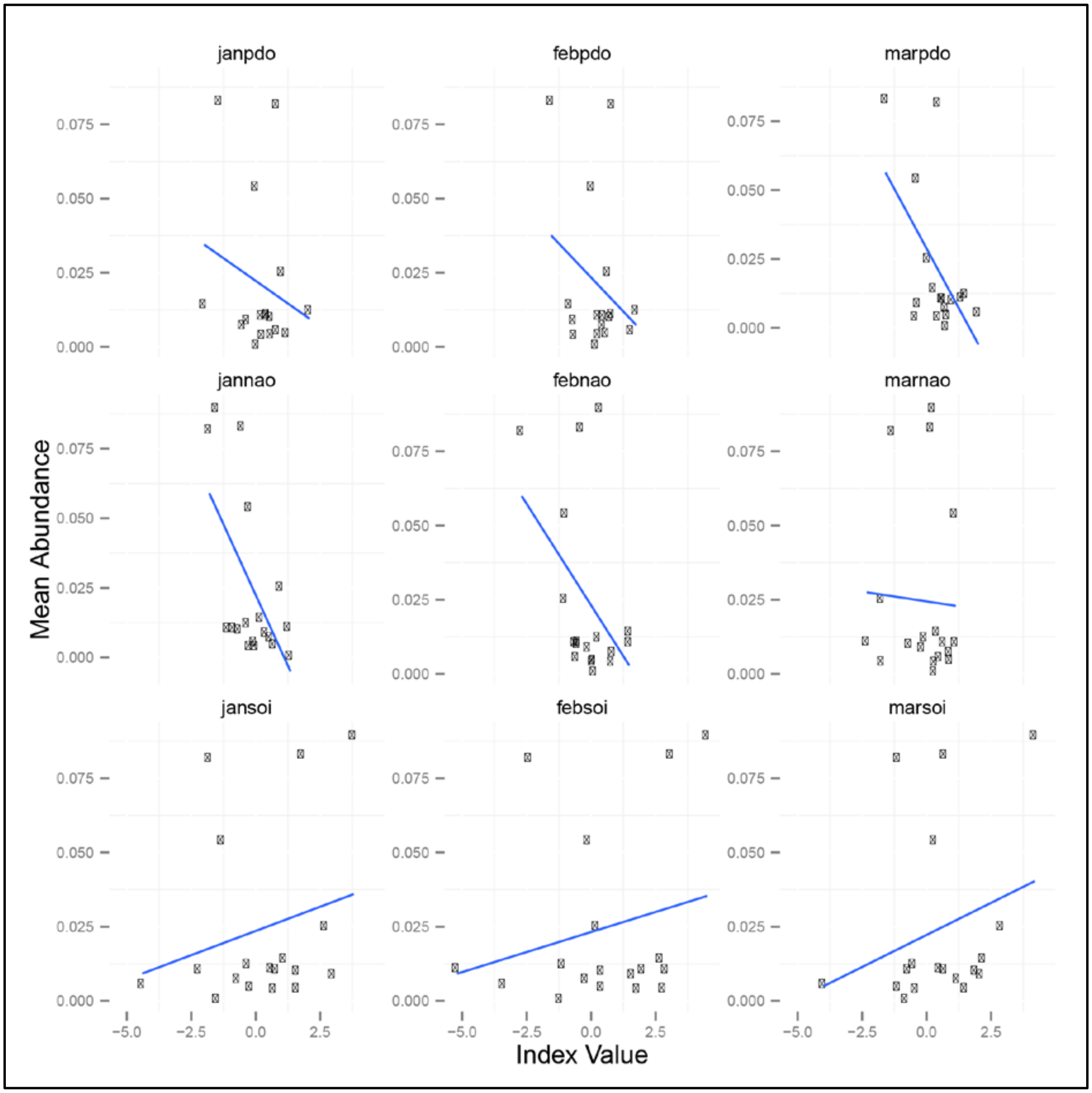


Figure 19. Annual mean abundance at Calling Lake vs. climate index values for January, February and March, 1993-2011. Each graph represents a combination of month (January, February or March) and Index type (Southern Oscillation Index, Pacific Decadal Oscillation, or North Atlantic Oscillation).

2.6.1.2 Relationships between disturbances by wildfire and spruce budworm on forest songbird communities

Other processes on the breeding grounds that may effects estimates of population density are natural disturbances, especially fire and insect defoliation. The most important defoliator is spruce budworm. Failing to account for these spatially extensive and protracted events is likely to complicate trend detection and lead to biased estimates of habitat relations. To account for the effects of natural disturbances in our modelling efforts, BAM has entered into collaboration with Lisa Venier and Stephen Holmes of the Canadian Forest Service, Sault Ste. Marie, two experts on the relationships between insect defoliators and forest bird communities. They have led an initiative to assemble a 50+ year time-series of annual defoliation maps created by extensive aerial surveys conducted by provincial and territorial governments (see Figure 20). Fires history is described by mapped fire data for the same period assembled by other groups within NRCAN (Figure 21). To support the project, BAM financed the GIS work necessary to link the spatial temporal datasets to be used in the analysis; preliminary GIS work is completed. Venier and Holmes will conduct exploratory analysis of the final data set using community analysis techniques including ordination and canonical ordination to examine community response to disturbance variables. The results will then be reviewed determine future analyses and assess the potential for a publication.

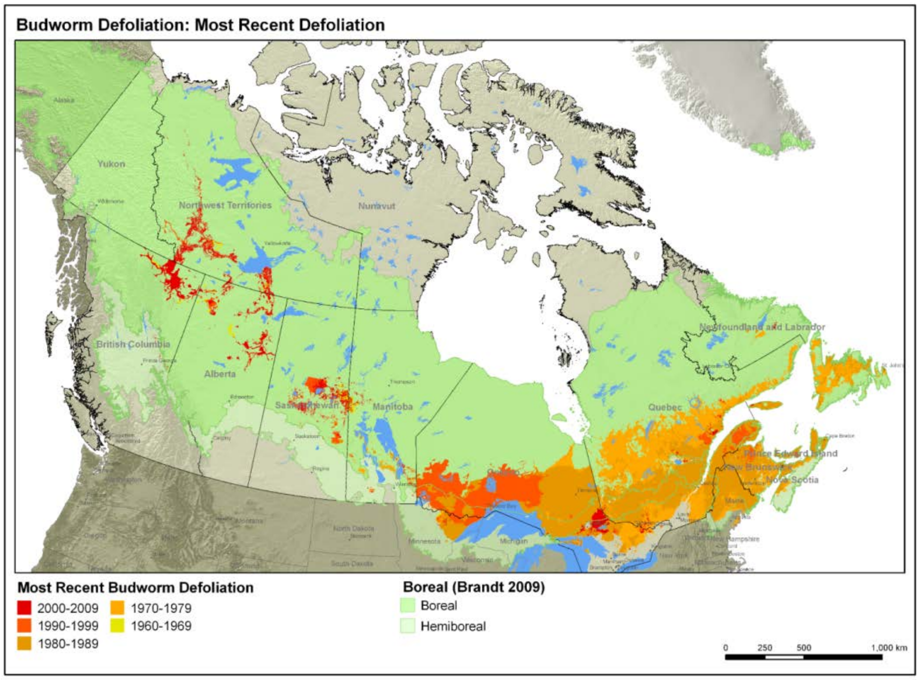


Figure 20. Spruce budworm defoliation in Canada.

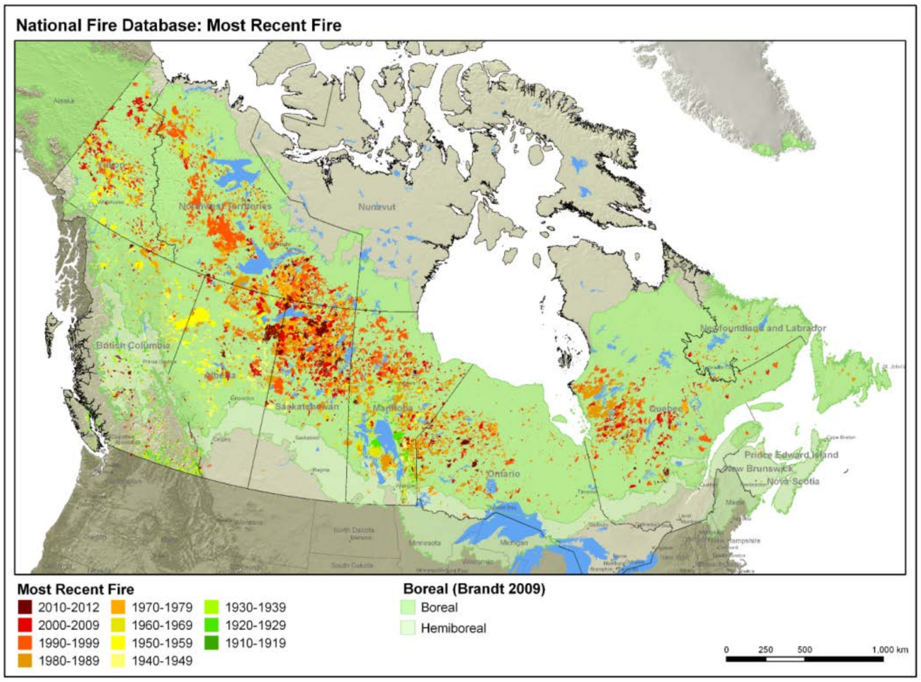


Figure 21. Forest fire boundaries in Canada.

2.6.1.3 Before-After, Control-Impact (BACI) study of anthropogenic effects on forest birds

One part of full life cycle analysis is developing ways to detect changes in mean species abundance and to attribute these changes to specific causes. One suspected cause is landcover change on the breeding grounds, due either to vegetation dynamics, natural disturbances, or industrial activity. Here, we focus on industrial activity. No detailed history of landcover change exists for the boreal region. However, several geospatial products have mapped estimates of industrial impact by comparing remote-sensed imagery between two time periods. Examples include recent products by Environment Canada, and the Global Forest Watch Canada intact forest maps. We use the latter to illustrate our developing approach. The maps show estimated areas affected by industrial activities that are detectable in Landsat imagery captured c. 2000 CE. Areas with no detectable activity were considered intact. Many intact areas are surrounded by non-intact forest, and these intact areas are called “intact fragments”. Much of the BAM data was collected between 1990 and 2010. A standard BACI design to test for an effect of the anthropic disturbances would be to compare post-2000 and pre-2000 samples in the non-intact forests with pre- and post-2000 samples in the intact fragments, considered as controls. The difficulty is that the “treatment” was not imposed all at once in 2000. In any particular non-intact area, treatment began at some unknown time before 2000, and may well have continued and even intensified after 2000. Equally, areas identified as intact in 2000 have not necessarily remained so. Thus, some areas identified as intact fragments in 2000 maps have surely degraded and are no longer intact, while non-intact areas have likely seen increased development in many areas, or have experiences lagged effects of habitat change in the years since 2000. The only reasonable certainty is that areas that were intact in 2000 were also intact prior to 2000. On these considerations, we have proposed a modified BACI design of stratified repeated measures that would test for differential rates of change in mean abundance by time and state (intact or not) in 2000, while controlling for landcover class. The model was presented to the BAM Team Meeting of February 27th 2014 under the title "Net impact of land-use on birds: what can intactness and change maps tell us?" Various refinements are being considered, the most important being 1) the careful design or subsetting of the BAM stations and visits used in any analysis so as to minimize confounding and balance the design with respect to land cover classes; and 2) introducing spatial structure by way of climate covariates or stratification by BCR. Once some initial results have been obtained, we will extend the analysis to incorporate other periodic change maps from various sources.

2.6.1.4 Incorporating climatic controls in bird habitat models to estimate abundance and explore potential range limits

As part of collaboration with Environment Canada, we provided habitat models and estimated population sizes across Canada and by Bird Conservation Regions (BCR) and jurisdictions to assist critical habitat identification for Canada Warbler, Olive-sided Flycatcher *(Contopus cooperi)*, and Common Nighthawk (*Chordeiles minor*)(see section 2.3.6 for details). We used the best avian point count and biophysical data available to generate the habitat models. Specifically, we used information on land cover (four layers varying in spatial extent), stand cover (dense, sparse, open), canopy height, natural (fire) and anthropogenic (clearcuts, road, and other linear/polygonal disturbances) disturbances, topographic wetness index, slope, and information about landscape composition within 4 km cell around each point count station. Also considered in our models were 10 climatic variables representing variation in moisture, temperature, extreme weather, and precipitation (Table 4; see also section 2.4.1).

Poisson log-linear models were generated for each species using an elaborate, structured, forward stepwise selection process. All variables were divided in different stages (or steps) along the model building process (e.g. land cover, Road, topography, spatial variation, etc.; see Figure 22 for the total number of stages for three models). At each stage, we considered the variable or combination of variables the most often selected as the best predictor(s) explaining variation in density of a focal species based on 200 bootstrap iterations. For each bootstrap iteration, the best variable or combination of variables was selected using consistent AIC (CAIC = 0.5 AIC + 0.5 BIC). Models were built by adding predictor(s) at each stage while controlling for the effects of predictors already selected at the previous stages (Figure 22).

Information for each predictor selected in the habitat models was extracted from points spaced 1 km apart across the boreal and hemiboreal regions of Canada. Using information from the habitat models, we predicted bird abundance across these two regions for each species (Figure 23). We did not constrain population size estimates at the northern end of the species breeding range because this region is poorly sampled and uncertainty is high. Our preliminary results suggest that, based on the current biophysical information currently available, high abundance for all three species are predicted to occur beyond the

Table 4. List of climate variables considered in habitat models for Canada Warbler, Olive-sided flycatcher, and Common Nighthawk.

Variables	Description
MAP	Mean annual precipitation (mm)
MSP	Mean summer (May-Sep) precipitation (mm)
DD0	Degree days below 0 °C
DD5	Degree days above 5 °C
EMT	Extreme minimum temperature (°C)
PET	Potential evapotranspiration (cm)[1]
MAT	Mean annual temperature (mm)
TD	Temperature difference (mean temperature of the warmest month - mean temperature of the coldest month; °C)
CMIJJA	Climate moisture index for June/July/August (mm)[1]
CMI	Climate moisture index (precipitation – potential evapotranspiration; mm)[1]

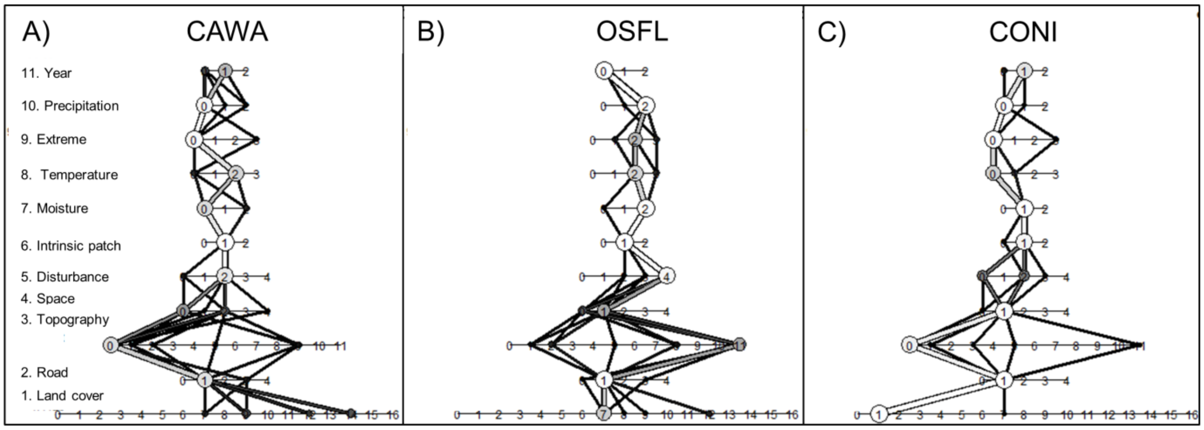


Figure 22. Selection paths of variables best explaining variation in abundance of the three focal species across Canada based on the branching hierarchy model building process. Results represent selection frequencies from 200 bootstrap iterations at each stage leading to the resulting model. Horizontal lines are the stages of the branching hierarchy model building process (numbers are the different variables for a given stage). Size of fill and shades for each circle are proportional to selection frequencies (idem for thicker and lighter lines). Full explanation in Haché et al. 2014.

northern breeding limit as currently defined by Nature Serve (http://www.natureserve.org). Refinement of these habitat models would require additional studies including validation of model predictions by conducting avian point count surveys in these northern locations. The current population size estimates are dependent on the accepted size of the species breeding range; thus an improved understanding of the northern breeding range limits of boreal birds is required to confidently define population size. .

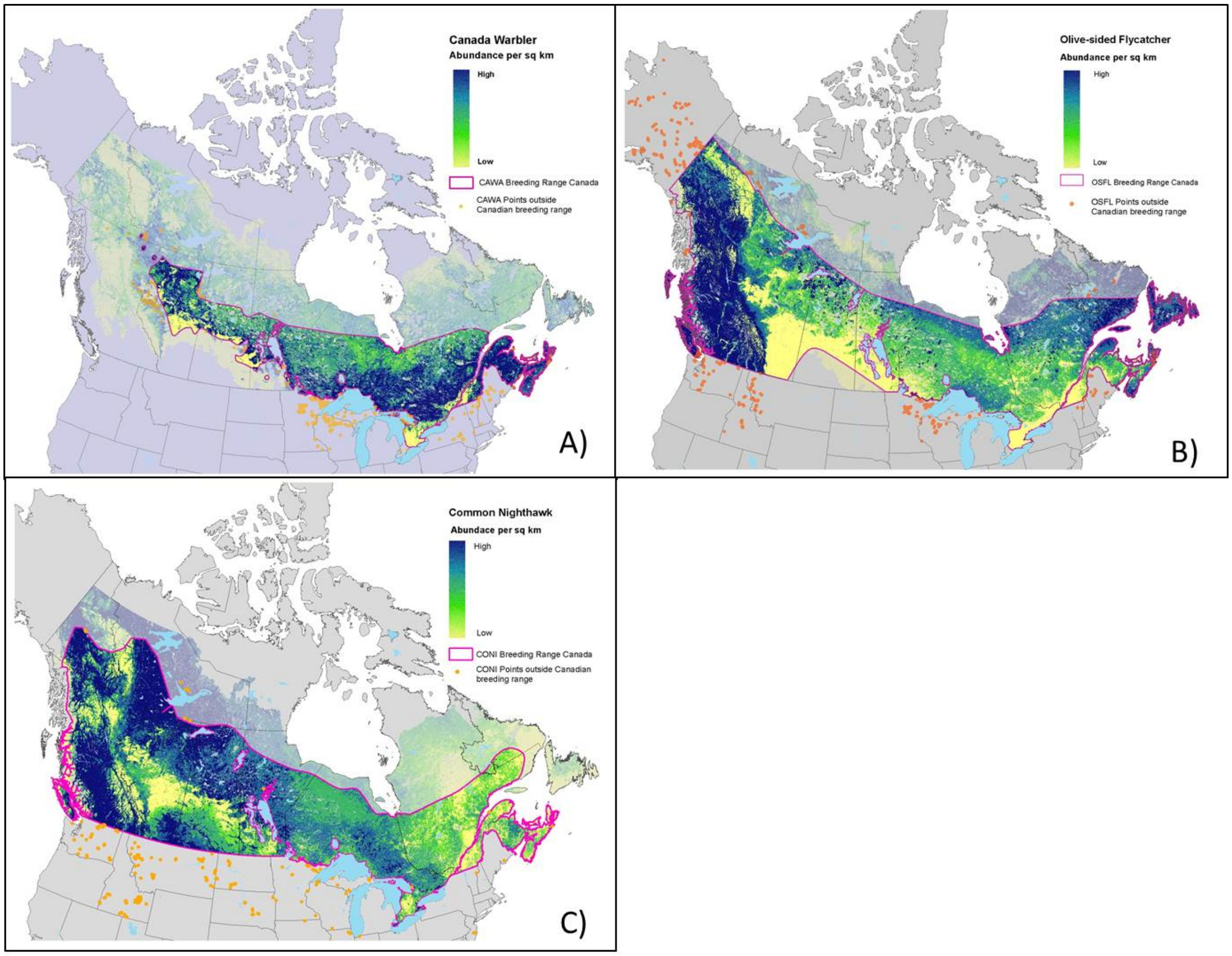


Figure 23. Predicted abundance for Canada Warbler (A), Olive-sided Flycatcher (B), and Common Nighthawk (C) across Canada. Pink lines delimit breeding ranges according to Nature Serve (http://www.natureserve.org/)(Ridgely, 2005). Shaded areas are those parts of the boreal and hemiboreal forests beyond the Nature Serve ranges in Canada.

2.6.2 Development and application of the Tardis national-scale simulation model

Tardis is a suite of methods and software for low spatial resolution simulation over very large areas, targeted at forest management and natural disturbances in the boreal forest. Most of the work proposed related to the Tardis model could not be completed by fiscal year end because of funding delays. We were, however, able to obtain the missing forest management information for hemiboreal Quebec. The remaining tasks (expansion to New Brunswick, incorporation of more complex avian models that include climate and CASFRI-based habitat attributes, and the design of a simulation experiment incorporating the effects of fire, harvesting, climate change and protected areas on some species of interest) are being pursued by Cumming's lab at Laval, as resources permit.

2.7 Partnerships and Collaborations

The BAM project is developing into a science hub providing data, models and expertise to a growing number of partners in government, industry and the conservation community. The BAM team welcomes opportunities for collaboration and actively engages other experts in avian ecology and conservation. Core funding for the project manager and data coordinator, the project ecologist, and additional spatial analysis capacity enable us to provide support for data requests, and to participate in collaboration opportunities as they arise. We describe here collaborations undertaken in the current reporting period that are not highlighted elsewhere in this report.

2.7.1 Maps of predictive abundances of selected songbird and waterfowl species for to the Ecosystem Potential Index of Canada (EPIC) project (Collaborator: Marlene Doyle, Science & Technology Branch, Environment Canada)

In collaboration with NRCan and in support of the Statistics Canada-led Measuring Ecosystem Goods & Services (MEGS) project, Environment Canada's Landscape Science & Technology Division, Wildlife & Landscape Science Directorate (WLSD), S&T Branch is developing approaches to quantify and map changes in ecosystem functions at a broad scale (pan-boreal) for the purposes of reporting and, potentially, to support scenario analysis (The Ecosystem Potential Index for Canada (EPIC) project). Models to assess ten ecosystem services were developed based on biophysical characteristics known to affect each ecosystem service. The results were assessed by watershed and mapped showing relative potential to provide each service.

Project Goals:

a. Develop a tailored framework for linking biophysical impacts as typically delivered through an Environmental Assessment process to quantifiable changes in ecosystem services that can be valued in an economic analysis.

b. Identify transferable or new approaches, tools and datasets by which the biophysical basis to support the economic valuation of a key set of ecosystem services and impacts for Environment Canada program requirements could be enhanced.

c. Test the application of the approaches and tools for a pilot case study, using a small set of quantifiable ecosystem goods and services, as identified through application of the ES toolkit guidance.

d. Develop a pragmatic process flow and decision tree that support efficient economic valuation with rigorous biophysical underpinnings, including useful tools, approaches, guidelines, and data sources and capturing the multi-disciplinary knowledge and information currently available at Environment Canada and beyond.

BAM provided maps of predicted density and relative abundance of waterfowl and select songbirds in Canada to Environment Canada's EPIC initiative. The waterfowl maps represent the results of predictive models built using Boosted Regression Tree analysis from the Waterfowl Breeding Population and Habitat Survey and several environmental datasets. Maps of predicted abundance of 20 songbird species (Alder Flycatcher, American Robin, Baltimore Oriole, Bay-breasted Warbler, Black-and-white Warbler, Blackburnian Warbler, Brown Creeper, Canada Warbler, Cape May Warbler, Chestnut-sided Warbler, Common Yellowthroat, Gray Catbird, Least Flycatcher, Ovenbird, Palm Warbler, Red-eyed Vireo, Tennessee Warbler, Winter Wren, White-breasted Nuthatch, and White-throated Sparrow) were also provided.

2.7.2 Quantifying components of roadside bias using data from the Minnesota Breeding Bird Atlas (Collaborator: Dr. Gerald Niemi, University of Minnesota)

Clearings created by roads in the boreal forest can influence observed counts. The magnitude and sign of difference between a roadside and an off-road count might depend on species' habitat affinities. We can expect a positive bias for species that use early succession habitats and forest edges. A negative bias is expected for species associated to forest interiors. The bias is minimized on narrow roads thus it is important to also consider surrounding habitat and types of roads when evaluating roadside bias. Roadside bias is result of multiple components. Identifying the components and evaluating their relative importance is imperative for effectively reducing the roadside bias in analyses aimed to estimate songbird densities using roadside count data. Following the notation in Solymos et al. (2013a), the expected value of the count is $E[Y] = N\ p\ q$ (abundance within the sampling area, p is probability of singing within the time interval of the survey given presence; q is probability of detection within the area of sampling given singing). The expected value of a roadside count is: $E[Y'] = N'\ p'\ q' = a_1 N\ a_2 p\ a_3 q = (a_1 a_2 a_3)\ N\ p\ q = a\ N\ p\ q$, where a is a coefficient corresponding to the roadside bias. Its components $(a_1 a_2 a_3)$ are unknown presently largely unknown. The goal of the collaboration is to partition a into the 3 components across a variety of species, so that we can get a better idea about general patterns across species with respect to life histories and habitat affinities.

The first component (a_1) is the numerical/density effect. Density is assumed to be constant within the sampling area. Road surface and verges represent different density strata, the position of the road relative to the position of the observer has consequences on the size of these strata within the point radius. The second component (a_2) is the behavioural bias affecting singing behaviour. Large roads might provide posts for singing, especially in non-forest matrix surrounding the road. Singing behaviour might also be affected in forest matrix. The second component (a_3) is the detectability effect. Anisotropy in sound attenuation is expected, i.e. parallel to or perpendicular to the road, position of observer also affects the anisotropy (e.g. forest edge, road edge few metres from forest edge) is expected to affect sound attenuation patterns. This might be similar to a tree cover effect (see Solymos et al. 2013a), but can be magnified by reflectance. This bias is likely to be maximized by certain road types (e.g. dirt/gravel road without early seral vegetation), where distance effect on road is statistically indistinguishable from off-road distance effect.

We will use partially matched design (on and off road) from Minnesota bird data sets to estimate singing behaviour (using multiple time interval data) and detectability related component of the bias. The density related component is the residual from the total bias that is estimated by comparing corrected and uncorrected counts. The Minnesota data sets provide a unique opportunity for separating the components of roadside bias, because it contains roadside surveys that were collected by registering individuals within different time and distance intervals. The BAM database has such survey design only for off-road surveys. The expected outcomes of the collaboration: (1) recommendations for survey protocols on minimizing roadside bias by design (for single species and for multiple species); (2) developing model based corrections for fully incorporating Breeding Bird Survey (BBS) style surveys (3 minutes unlimited distance roadside surveys) from the Boreal into continental scale abundance estimation and mapping.

2.7.3 Effects of forest harvesting and silviculture on bird communities

Dr. Matthew Betts and Dr. Heather Root (Oregon State University) will conduct an analysis of BAM avian and Forest Resource Inventory data to test for effects of forest harvesting and silvicultural practices on forest bird communities. Specifically, they will be looking for thresholds of plantations forestry on songbird abundance. The requested avian data required intersections with the Alberta Vegetation Inventory (AVI) layer at several buffer distances.

2.7.4 NSERC CRD application to assemble multispectral Landsat images for the western boreal region with Foothills Research Institute.

Dr. Steve Cumming is involved in a new collaboration with Nicholas Coops of UBC and David Andison who represents the Foothills Research Institute (FRI). Of relevance to BAM, Coops, Andison and Cumming recently applied for an NSERC Collaborative Research and Development grant, with FRI as industrial partner, acting as representative for a consortium of forest products companies acting in the western boreal region. Applications to this funding pool have a success rate of more than 80%. The essence of the proposal is to assemble multispectral Landsat images for the western boreal region for 1900, 2000 and 2010, using best available pixel techniques developed at the Pacific Forestry Centre. The CASFRI database will be used to develop predictive statistical model linking the imagery to CASFI attributes such as height, species composition, and density. These will enable prediction over large areas of Alberta, Saskatchewan and the Northwest Territories where no FRI data exist. The time series land-cover data will also provide a refined higher resolution history of landcover change and disturbance, which can be used to extend and refine the BACI analysis described in Section 2.6.1.3.

2.7.5 Species distribution models of the Rusty Blackbird (Euphagus carolinus), Olive-Sided Flycatcher and Canada Warbler at the national and regional (Maritime) level, and an assessment of habitat availability in Maritime National Parks

PhD. Candidate Alana Westwood from Dalhousie University is collaborating with BAM and Parks Canada to complement existing work (see Section 2.2.2) by creating Maritime-specific models for CAWA, RUBL, and OSFL. Alana will use the resulting mapped products to determine the contribution of existing national parks to available high-quality habitat across the Canadian range of these three species.

2.7.6 General assistance with requests

Requests for the BAM version of the BBS database, which includes estimated locations for missing 50 stop coordinates, were filled for Graduate students at the University of Toronto (Jennifer Weaver) and Simon Fraser University (Janie Dubman), these requests were forward to BAM from the CWS BBS office. General request for information from the website form that were handled include request for information on banding, boreal forests, submitting data to BAM and accessing BAM data.

2.8 Web-based dissemination of BAM products and other Communications

2.8.1 Interactive web mapping site

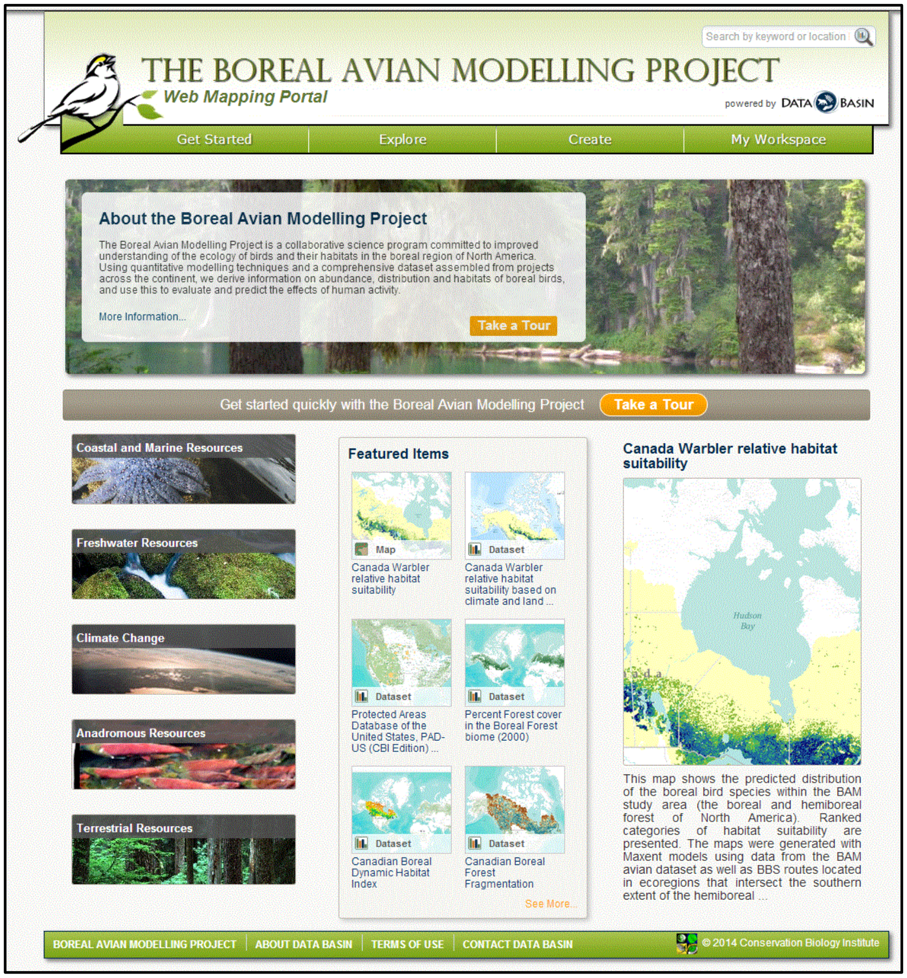
BAM maintains a web site to provide a web presence for the project and to disseminate results. Until recently, analytic results were provided as tabular summaries (e.g. of mean species density by habitat class within BCR), and as static maps (e.g. of predicted density or occurrence probability). The maps were provided as graphic images, in standard formats. These are valuable for visualisation, but are not directly usable for many other purposes. In particular, they cannot support many kinds of simple geographic or cartographic analysis that many users will wish to perform. The target user communities for the BAM website increasingly are accustomed to dynamic mapping capacities which allow users to customise data representation, to create their own maps, and to access and extract the underlying spatial data for their own later use. BAM recognises that in order to meet user expectations, it too must provide such facilities on the project website. Accordingly, we have committed to enhance our online presence in order to support these user needs. The technical requirements to design and support dynamic mapping are beyond the capacity of our current web hosting service.

After an extensive evaluation of specialist commercial and non-profit agencies, we decided to work with the Conservation Biology Institute (CBI) and their Data Basin web-mapping site. CBI developed the Data Basin to support needs such as ours, with an emphasis on the requirements of conservation planning organisations. Currently Data Basin provides web mapping and related services to an international clientele of 8,700 members, including academic research groups, private firms, ENGOs and all levels of government. BAM users gain access to all the public data provided by these members, adding value to BAM products.

BAM staff has worked with the CBI design team to develop the specifications for the service, and a work plan for design and implementation. A custom built web-mapping portal is being built in parallel to the BAM website. In later versions, the portal and BAM website will be fully integrated with seamless movement between them. The portal interface will showcase spatial information from BAM. It will be possible to share spatial data layers such as predictive maps of species abundance, and metadata to understand the meaning and purpose of the layers. Within the portal, data products are organised into “galleries” grouping the products in various ways, such as by project (e.g. climate change) or bird species. Access to data can be controlled by defining working groups with specific membership and access privileges to non-public data, allowing for flexible collaborations between team members and others. Products will be made available to download as allowable per data sharing agreements. Predictive species abundance maps, for example, may be publically available without restriction, while access to raw observational data can be restricted as required by the data owners. One of the benefits to the Data Basin structure is that it is extremely easy to create new galleries, and to add maps, datasets and layers as they are produced by ongoing work. Unfortunately, the Data Basins portal is English only; therefore we will also maintain accessibility to results on our current bilingual site.

The structure for the portal home page is currently as shown in Figure 24. Results of our climate change analysis, including spatial projections of species distributional changes over time, will be made available first. These map layers are quite large and the output format requires conversion so they can be rendered online. The Data Basin team have converted the map files for one prototype species to NetCDF and created a time series map tool to show the data. Currently they are fine-tuning the layers to show only the study area, and optimizing for visualization. Once they have finalized the process for the prototype species we will be able to quickly replicate the work for 75 species. Meanwhile, the BAM team is converting more than 150 the static density and distribution maps from the website (Figure 25) for accessibility on the portal.

The layer creation for the distribution and density mapping work are scheduled for completion by the middle of June 2014. The climate prediction layers work should be available by the end of June. The metadata and documentation that accompanies all layers on the gateway are being assembled and will be posted as they become available.

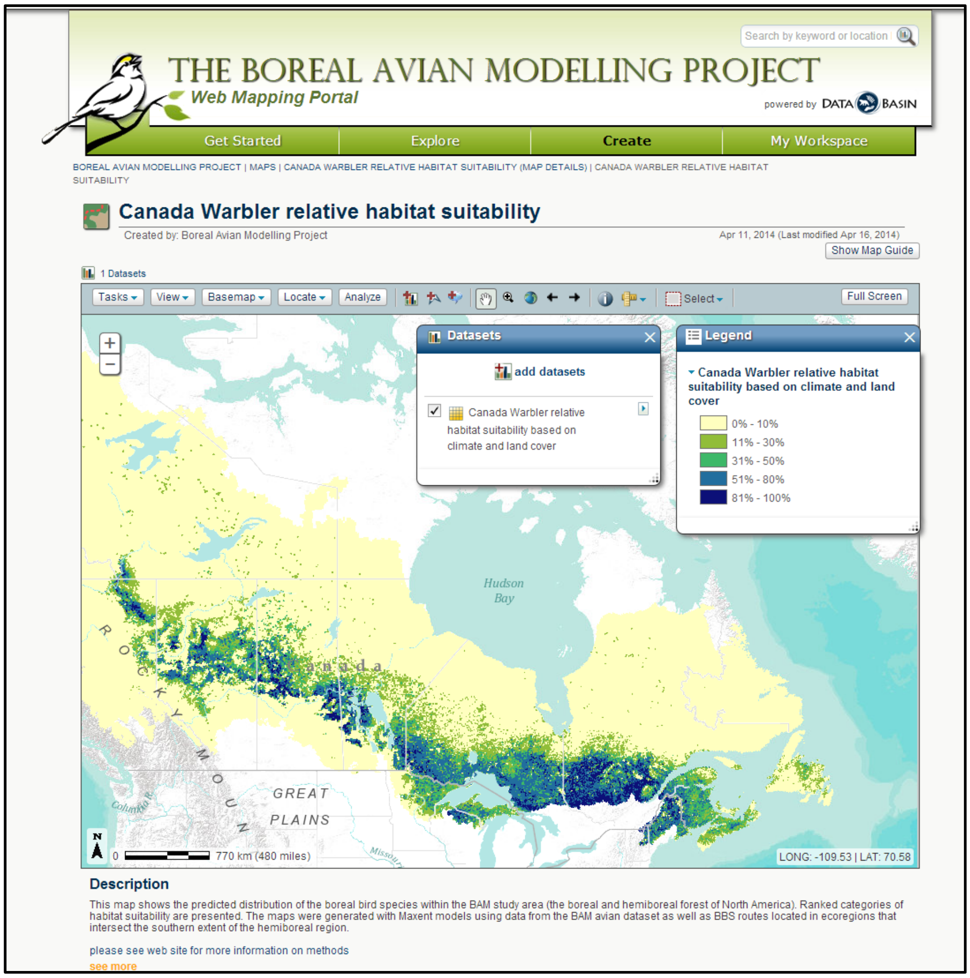


About the Boreal Avian Modelling Project

The Boreal Avian Modelling Project is a collaborative science program committed to improved understanding of the ecology of birds and their habitats in the boreal region of North America. Using quantitative modelling techniques and a comprehensive dataset assembled from projects across the continent, we derive information on abundance, distribution and habitats of boreal birds, and use this to evaluate and predict the effects of human activity.

This map shows the predicted distribution of the boreal bird species within the BAM study area (the boreal and hemiboreal forest of North America). Ranked categories of habitat suitability are presented. The maps were generated with Maxent models using data from the BAM avian dataset as well as BBS routes located in ecoregions that intersect the southern extent of the hemiboreal ...

Figure 24. BAM web mapping portal home page, hosted on the Data Basin site.



This map shows the predicted distribution of the boreal bird species within the BAM study area (the boreal and hemiboreal forest of North America). Ranked categories of habitat suitability are presented. The maps were generated with Maxent models using data from the BAM avian dataset as well as BBS routes located in ecoregions that intersect the southern extent of the hemiboreal region.

please see web site for more information on methods

see more

Figure 25. Example of a BAM species distribution map hosted on the Data Basin BAM web mapping portal

2.8.2 Offsets to correct for survey protocols: supporting information

The analysis of large heterogeneous data sets of avian point-count surveys compiled across studies is hindered by a lack of analytical approaches that can deal with detectability and variation in survey protocols. In Solymos et al. (2013a) we reformulated removal models of avian singing rates and distance sampling models of the effective detection radius (EDR) to control for the effects of survey protocol and temporal and environmental covariates on detection probabilities. We estimated singing rates and EDR for 75 boreal forest songbird species and found that survey protocol, especially point-count radius, explained most of the variation in detectability. However, environmental and temporal covariates (date, time, vegetation) affected singing rates and EDR for 73% and 59% of species, respectively. Unadjusted survey counts increased by an average of 201% from a 5-min, 50-m radius survey to a 10-min, 100-m radius survey (n = 75 species). This variability was decreased to 8.5% using detection probabilities estimated from a combination of removal and distance sampling models. Our modelling approach reduced computation when fitting complex models to large data sets and can be used with a wide range of statistical techniques for inference and prediction of avian densities.

We produced on-line supporting information for the publication describing the so called "QPAD" approach of using offsets to correct for survey protocol and detectability in log-linear models by Solymos et al. (2013a) where we described (1) how to estimate QPAD model parameters in the programming language R; (2) how to retrieve the QPAD model parameter estimates reported in the paper; (3) and how to use these estimates in statistical inference and prediction. We developed R functions that are part of the 'detect' R package (Solymos et al. 2013b). The most recent version of the supporting can be retrieved from: http://dcr.r-forge.r-project.org/qpad/QPAD_SupportingInfo.pdf. Point level offsets were developed for species in the national BAM database to be used in analyses e.g. climate change forecasting, national predictive mapping and population size estimation, JOSM related modeling activities in Alberta.

2.8.3 Presentations 2013–2014

Bayne E. M. Applying remote sensing-based land cover to biodiversity assessments: The elusive pursuit of "truth". Remote Sensing of Alberta's Dynamic Landscapes Workshop. Edmonton, Alberta. January 23, 2014.

Bayne, E.M. What surprises might climate change have in store for Alberta's biodiversity? College of Alberta Professional Forest Technologists. April 3, 2014.

Cumming S.G., E.M. Bayne , F.K.A Schmiegelow and S. Song . The TARDIS macroscope: a low spatial resolution dynamic model designed for boreal forests. 16th International Boreal Forest Research Association Conference. Edmonton, Alberta. October 7-10, 2013.

Matsuoka, S.M., D. Stralberg, & R. Greenberg. 2013. Understanding declines in Rusty Blackbirds. Presentation at the Greenberg Innovation Sessions. Chestertown, Maryland. September 23, 2013.

Schmiegelow, F.K.A. The Pan-Boreal Assessment: Support for National-scale Conservation Planning. Canadian Boreal Forest Agreement, Protected Areas Working Group. Vancouver, British Columbia, April 15, 2013.

Schmiegelow, F.K.A. Northern Land-use Planning: Advancing the Science of Sustainability Minister of Energy, Mines and Resources & Staff, Yukon Government. Whitehorse, Yukon. June 5, 2013.

Schmiegelow, F.K.A. Science-based Support for Broad-scale Conservation of Boreal Systems Institute for Wetland and Waterfowl Research. Ducks Unlimited Canada – Webinar. July 23, 2013.

Schmiegelow, F.K.A. Perspective on Scientific Advances and Needs to Conserve Nearctic Boreal Systems. NASA ABoVE and Yukon Scientists. Whitehorse, Yukon. September 6, 2013.

Schmiegelow, F.K.A. CBFA Pan-Boreal Assessment: Science-based Support for the Design of Conservation Networks. Canadian Boreal Forest Agreement, Steering Committee – Webinar. October 16, 2013.

Schmiegelow, F.K.A. CBFA Pan-Boreal Assessment: Science-based Support for the Design of Conservation Networks. Canadian Boreal Forest Agreement, Internal Webinar Series. October 31, 2013.

Schmiegelow, F.K.A. Integrated Planning for Forest Practices, Protected Areas, Species at Risk & Climate Change. Canadian Boreal Forest Agreement Secretariat Retreat. Quebec City, Quebec. November 12, 2013.

Schmiegelow, F.K.A. Conservation by Design: Advancing the Science of Sustainability in Canada's North. Yukon College Public Lecture Series. Whitehorse, Yukon. November 14, 2013.

Schmiegelow, F.K.A. Challenging Conventional Conservation Paradigms. Northwest Boreal Landscape Conservation Cooperative. Fairbanks, Alaska. November 19, 2013.

Schmiegelow, F.K.A. Scientific Approaches to Land-use Planning in Northern Canada Land-use Planning Directorate. Yukon Energy, Mines and Resources. December 16, 2013.

Schmiegelow, F.K.A. The Canadian Boreal Forest Agreement: Seizing the potential. Keynote presentation to 16th International Boreal Forest Research Association Conference. Edmonton, Alberta. October 7-10, 2013.

Sólymos, P., S.G. Cumming, E.M. Bayne, P. Fontaine, S.M. Matsuoka, D. Stralberg, L. Mahon, F.K.A. Schmiegelow, and S. Song: Modeling and forecasting habitat suitability for boreal forest birds in Canada: an integrative approach. 16th International Boreal Forest Research Association (IBFRA) Conference, Edmonton, Alberta. October 7 to 10, 2013 [poster presentation]

Sólymos, P. Calibrating Indices of Avian Density from Non-Standardized Survey Data. Environment Canada landbird biologists and Boreal Avian Modelling Project technical committee. Webinar. Edmonton, Alberta. February 12, 2014.

Song, S. Boreal Avian Modelling Project: Update to Environment Canada's Landbird Technical Committee by conference call. Edmonton, Alberta. April 7, 2013

Song, S. Boreal Avian Modelling Project: Update to Environment Canada's Migratory Bird Managers by conference call. Edmonton, Alberta. July 24, 2013.

Stralberg, D., E.M. Bayne, S.M. Matsuoka, P. Sólymos, F.K.A. Schmiegelow, S.G. Cumming, and C. Handel. Shifting patterns of fragmentation and connectivity: Effects of projected climate change on boreal passerine breeding distributions. Canadian Society for Ecology and Evolution annual meeting. Kelowna, BC, May 14, 2013.

Stralberg, D. 2013. Assessing responses of boreal songbird distribution and abundance to climate change. Environment Canada landbird biologists and Boreal Avian Modelling Project technical committee. Webinar. Edmonton, Alberta. September 25, 2013.

Stralberg, D. Assessing responses of boreal songbird distribution and abundance to climate change. Boreal Partners in Flight meeting. Webinar. Fairbanks, AK. November 15, 2013 .

2.8.4 Publications 2013–2014

Cumming, S. G., D. Stralberg, K. Lefevre, E.M. Bayne, S. Fang, P. Fontaine, D. Mazerolle, F.K.A. Schmiegelow, P. Sólymos, and S. Song. 2013. Climate and vegetation hierarchically structure patterns of songbird distribution in the Canadian boreal region. Ecography 37: 137-151. doi: 10.1111/j.1600-0587.2013.00299.x

Mahon, C. Lisa, E.M. Bayne, P. Sólymos, S.M. Matsuoka, M. Carlson, E. Dzus, F.K.A. Schmiegelow, S. Song. 2014. Does expected future landscape condition support proposed population objectives for boreal birds? Forest Ecology and Management 312: 28-39.

Sólymos, P., S.M. Matsuoka, E.M. Bayne, S.R. Lele. P. Fontaine, S.G. Cumming, D. Stralberg, F.K.A. Schmiegelow, S. Song. 2013. Calibrating indices of avian density from non-standardized survey data: making the most of a messy situation. Methods in Ecology and Evolution 4:1047-1058.

2.8.5 Publications (submitted, in review, or in revision 2013–2014)

Barker, N.K.S., S.M. Slattery, M. Darveau, S.G. Cumming. In review. Modeling distribution and abundance of multiple species: Different pooling strategies produce similar results. Submitted to Ecosphere September 2013.

Cumming S.G, .C.R. Drever , M. Houle M, J. Cosco , P. Racine , E.M. Bayne and F.K.A Schmiegelow A gap analysis of tree-species representation in the protected areas of the Canadian boreal forest: an application of a new assemblage of digital Forest Resource Inventory data. Submitted to *Canadian Journal of Forest Research* February 16 2014).

Stralberg, D., S.M. Matsuoka, A. Hamann, E.M. Bayne, P. Sólymos, F. K. A. Schmiegelow, X. Wang, S. G. Cumming, and S. J. Song. in revision. Projecting boreal bird responses to climate change: the signal exceeds the noise. Ecological Applications.

2.8.6 Publications (in preparation 2013-2014)

Ball, J.R., P. Sólymos, and E.M. Bayne. In preparation. Habitat associations of Canada Warbler *Cardellina canadensis* in Alberta. Journal TBD.

Barker, N.K.S., E.T. Reed, S.G. Cumming. In preparation. Expanded application of the Waterfowl Breeding Population and Habitat Survey: A guide for secondary users. Journal of Fish and Wildlife Research.

Barker N.K.S, S.G Cumming and M. Darveau. Models to predict the distribution and abundance of breeding ducks in Canada. *Avian Ecology and Conservation.* Expected submission: May 2014

Barker, N.K.S., M. Bidwell, C.Roy, S.G. Cumming. In preparation. Affinities and adaptations of waterfowl for biomes in Canada. Journal TBD.

Matsuoka, S.M., E.M. Bayne, P. Sólymos, D. Stralberg, S. Song, F.K.A. Schmiegelow, and S.G. Cumming. In preparation. Estimating population sizes of landbirds breeding across the Nearctic boreal forest zone. Ecological Applications.

Mahon, C.L., T. Habib, D. Farr, T. Mahon, E.M. Bayne, and T. Fontaine. 2013. Priority area assessment for landbirds in Bird Conservation Region 6-Boreal Taiga Plains using two measures of area occupied. The Condor: Ornithological Applications.

Sólymos, P., S.M. Matsuoka, , D. Stralberg, and E.M. Bayne, (in preparation). Testing for phylogenetic signal in detectability and related traits among boreal songbirds. Target journal: Biology Letters

2.8.7 Technical Reports (2013-2014)

Barker, N.K.S. 2013. Relative abundance of pairs of cavity, ground, and over-water nesting ducks in Canada. Unpublished report, Université Laval, Ducks Unlimited Canada-QC, and Boreal Avian Modelling Project, Québec, QC.

Bayne, E. 2014. Dealing with uncertainty of habitat classification in species-habitat modelling through covariate measurement error models. Boreal Avian Modelling Project, Edmonton, AB.

Bayne, E., T. Flockhart, S. Haché, R. Krikun, A. Hunt. 2014. Incorporating population dynamics to identify offset opportunities for species at risk: conservation decision-making for Canada Warblers in Alberta. Technical report to Habitat Stewardship Program, Environment Canada, Edmonton, AB.

Bayne, E., C.L. Mahon, P. Solymos, C. Machtans, H. Lankau, J. Ball, S. Van Wilgenburg, S. Cumming, T. Fontaine, J. Schieck, F. Schmiegelow, S. Song. 2014. Impact of energy sector footprint on avian populations in the western boreal forest: Do local scale impacts predict larger scale population responses? Boreal Avian Modelling Project, Edmonton, AB.

Cumming, S.G., M. Houle, and J.-L. DesGranges. 2013. Évaluation des modèles servant à prédire les assemblages aviaires dans Canada de l'Est. Université Laval et Environnement Canada, Région du Québec, Québec.

Haché, S., P. Solymos, T. Fontaine , E.M. Bayne , S.G.Cumming, F.K.A Schmiegelow, and D. Stralberg . 2014. Critical habitat of Olive-sided Flycatcher, Canada Warbler, and Common Nighthawk in Canada (Project K4B20-13-0367). Technical report for Environment Canada. 130p.

Houle M, S.G. Cumming and P. Racine. 2013. Common Attribute Schema for Forest Resource Inventory (CASFRI): Technical Assessment for Integration within CFS to

Support an “Integrated Systems Approach”. Prepared for the ISA Secretariat, Canadian Forest Service, Natural Resources Canada. October 2013.

Huggard, D. and C. Machtans. 2013. Precision Analysis of Bird Trend Monitoring in NWT Proposed National Wildlife Areas. Report by Apophenia Consulting and Canadian Wildlife Service. http://www.borealbirds.ca/library/index.php/technical_reports

Labbé, J-P and S.G. Cumming. 2013. TARDIS: Forest Management Data Assembly. 11 March 2013. 64pp, and many digital appendices.

Mahon, C.L., J. Smith, E.M. Bayne, and P. Solymos. 2014. Evaluation of landscape analysis tools for assessing risks to migratory landbirds in the oil sands areas of Alberta. Technical report, Joint Oil Sands Monitoring: Cause-Effects Assessment of Oil Sands Activity on Migratory Landbirds, Edmonton, AB

Matsuoka S.M., BPIF. 2013. Update on the Boreal Avian Modelling Project. 2013 Summary of Landbird Projects For Boreal Partners in Flight.

Sólymos, P., L.C. Mahon, and E.M. Bayne. 2014. Development of predictive models for migratory landbirds and estimation of cumulative effects of human development in the oil sands areas of Alberta. Technical report, Joint Oil Sands Monitoring: Cause-Effects Assessment of Oil Sands Activity on Migratory Landbirds, Edmonton, AB. pp. 829.

3.0 Project Management

3.1 Steering Committee, Project Staff and Affiliates

The project Steering Committee consists of Drs. Fiona Schmiegelow, Erin Bayne, Steve Cumming, and Samantha Song. Collectively, they hold responsibility for project coordination, including staff management, liaison with project partners and the Technical Committee, and overall project direction.

Team members this year included:
- Database Manager (Trish Fontaine)
- Statistical Ecologist (Dr. Péter Sólymos 0.5 FTE)
- Project Ecologist (Dr. Samuel Haché)
- Project Affiliate (Dr. C. Lisa Mahon, Environment Canada)
- Project Affiliate (Steve Matsuoka U. S. Fish and Wildlife Service, Alaska Office)
- Postdoctoral Fellow (Alberto Suarez, University of Alberta)
- PhD Candidate with Drs. Bayne and Schmiegelow (Diana Stralberg)
- PhD Candidate with Dr. Cumming (Nicole Barker) in association with Ducks Unlimited Canada

3.2 Technical Committee

Our Technical Committee (TC) continues to provide independent scientific advice on project direction and results. We would like to thank Peter Blancher, Environment Canada, who retired from Environment Canada this year, for his past involvement with the TC. Our Technical Committee members are:

Dr. Marcel Darveau, Ducks Unlimited/Université Laval
Dr. André Desrochers, Université Laval
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