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Boreal Avian Modelling (BAM) Project

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

Annual Report – April 2014-March 2015

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HIGHLIGHTS OF ACCOMPLISHMENTS IN 2014 – 2015

Monitoring Guidance and Survey Design

- Evaluated potential bias in roadside surveys of boreal landbirds:
 - Quantified differences in detectability of birds along roadsides versus within forests using a sound transmission study;
 - Compared bird densities from roadside and forest interior point counts to better understand the sources of roadside bias;
 - Conducted a simulation study to explore how roadside bias is expected to vary with road width, bird density, and other factors;
- Quantified the temporal coverage of data within the BAM Avian Database and the BBS Database;
- Investigated the application of standard time-series models to the BAM Avian Database to evaluate its power to detect population trends;
- Used automated recording unit (ARU) data to determine the optimal sampling duration for point counts and for processing of ARU recordings;

Quantifying and Projecting Threats to Boreal Birds

- Quantified the impact of forest edge created by gas wells, pipelines, and seismic lines on boreal bird density;
- Assessed the effect of point count radius on the power to detect edge effects on boreal bird density;
- Used independent data to validate stand-level population responses predicted from edge effects detected using point count-level analyses;
- Updated regional models of cumulative impacts of anthropogenic disturbance assessing indirect and direct effects of different sectors (e.g., agriculture, forestry, mines/wells) on 81 species' abundances in the Alberta oil sands region;
- Derived a national geodatabase of annual, anthropogenic disturbance across the North American boreal forest from existing databases;
- Developed a project design for evaluating impacts of annual, anthropogenic disturbance on forest birds at a national scale;
- Completed background work advancing the integration of avian density models with the Tardis forest management simulation tool;

Broad-scale Conservation Planning

- Proposed a new conservation planning approach that incorporates refugia for boreal songbirds based on lags in vegetation response to climate change;
- Advanced use of three BAM products (maps of bird density, climate refugia, and future core habitat) in protected areas design via partnerships held by the Boreal Ecosystems Analysis for Conservation Networks (BEACONS) project with the Northwest Boreal Landscape Conservation Cooperative and the Canadian Boreal Forest Agreement;
- Contrasted candidate protected areas networks designed using a species-based approach versus the BEACONS ecosystem-based approach;

Species at Risk and Critical Habitat

- Prepared for revised national habitat modelling by considering comments received on previous work;
- Assembled environmental predictor data to support regional modelling of species at risk for Maritime and north-western boreal study areas;

Annual Life Cycle Analysis

- Began identifying and assembling information on migratory connectivity for the Ovenbird, which will be used as a test case of BAM's contribution to annual life cycle analyses;
- Conducted preliminary analyses assessing the capacity of the BAM Avian Dataset to understand inter-annual variation in Ovenbird abundance;
- Initiated conversations with staff from Environment Canada to pursue collaborative work on annual life cycle analysis using the BAM Avian Database;
- Initiated collaboration with the Smithsonian Institution to support a project identifying migratory connectivity between wintering and breeding grounds for several species including Canada Warbler, Common Nighthawk, and Olive-sided Flycatcher;

Avian Ecology and Habitat Selection

- Explored methods to delineate breeding ranges of boreal songbirds and waterfowl from maps of predicted densities;

Database Management and Outreach

- Updated the BAM Avian Database – now includes data from over 146,000 point count locations from 135 projects;
- Updated BAM's BBS Database – now includes over 65,000 point count locations covering all Canadian BBS routes, some from Alaska, and some from northern US routes;
- Continued adding ARU data to the BAM Avian Database;
- Expanded the Common Attribute Schema for Forest Resource Inventories (CASFRI) database with data from Manitoba, Quebec, and British Columbia;
- Populated the BAM Data Basin portal (<http://borealbirds.databasin.org/>) with 170 layers representing current and future bird density and species richness estimates;
- Responded to regular requests from individuals, researchers, or organizations regarding data, data products, project information, and potential collaboration;
- Described the BAM data management system within a manuscript for a Wildlife Society Bulletin special topics issue;

Collaboration

- Continued collaboration with a diversity of groups, including the Alberta Biodiversity Monitoring Institute (ABMI), the Boreal Ecosystems Analysis for Conservation Networks (BEACONS) project, Ducks Unlimited Canada (DUC), the Canada-Alberta Joint Oil Sands Monitoring (JOSM) Project, and individuals from Dalhousie University, Environment Canada, National Resources Canada (NRCan), Oregon State University,

Parks Canada, the Smithsonian Migratory Bird Centre, the United States Geological Service (USGS), the University of Minnesota Duluth, Weber State University, and Yukon College.

- Initiated collaboration to support Environment Canada’s project to identify Migratory Birds Zone of Interest within the boreal region;

CONTENTS

HIGHLIGHTS OF ACCOMPLISHMENTS IN 2014 – 2015	2
CONTENTS	4
PROJECT OVERVIEW AND OBJECTIVES	5
<i>Project Objectives</i>	<i>6</i>
<i>Proposed Major Activities, 2014–2017</i>	<i>6</i>
MONITORING GUIDANCE AND SURVEY DESIGN	7
Integrating On-road and Off-road Point Count Surveys	7
Monitoring Guidance	13
Automated Recording Units (ARUs)	17
QUANTIFYING AND PROJECTING THREATS TO BOREAL BIRDS	19
Joint Oil Sands Monitoring	19
Avian Response to Disturbance at the National Scale	26
Future Land-use Risk Simulation Studies	28
BROAD-SCALE CONSERVATION PLANNING	31
Protected Areas Design	31
SPECIES AT RISK AND CRITICAL HABITAT	35
Methods to Support Critical Habitat Identification for Species at Risk	35
Regional Models for Species at Risk	37
ANNUAL LIFE CYCLE ANALYSIS	39
Initiating Annual Life Cycle Research	39
AVIAN ECOLOGY AND HABITAT SELECTION	41
Range Delineation	41
Improved Habitat Models	45
DATABASE MANAGEMENT AND OUTREACH	46
Maintenance of Avian and Geospatial Databases	46
Provision of Findings	50
Distribution and Access to the BAM Database	51

COLLABORATIONS	53
Continue Current Collaborations.....	54
APPLICATIONS OF BAM RESULTS IN 2014-15	54
PROJECT COMMUNICATIONS IN 2014-15.....	55
<i>Webinars</i>	55
<i>Presentations, Reports, and Publications</i>	56
PROJECT MANAGEMENT.....	59
<i>Project Team</i>	59
<i>Affiliated Members</i>	60
<i>Support Team</i>	61
PARTNERSHIPS	61
<i>Funding Partners</i>	61
<i>Data Partners</i>	62
REFERENCES.....	64

PROJECT OVERVIEW 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 harmonizing 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 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.

PROJECT OBJECTIVES

- Maintain a comprehensive, integrated database of spatially-referenced avian point count data from boreal North America, linked to a geodatabase of environmental and habitat descriptors.
- Provide a data repository that ensures historical point count data are appropriately archived and accessible.
- Develop, apply and refine state-of-the art ecological and analytical methods to:
 - Provide reliable information on boreal bird habitat associations;
 - Describe species distributions;
 - Refine and forecast population status and trends;
 - Test hypotheses about key mechanisms driving patterns, such as climate, land use, and latitude.
- Contribute to conservation, management and monitoring of boreal avifauna and their habitats, including range delineation, identification of priority areas for monitoring and conservation within those ranges, and development of model-based solutions to address population targets.
- Build support from academia, industry, governments, non-governmental organizations and other interested parties for further development and testing of boreal bird population models, and their proactive application to the management of boreal forests and biodiversity conservation.
- Encourage public awareness and support education by providing broad access to current information on the status of boreal bird populations and the threats they face.

BAM has developed many partnerships within the research and conservation community operating in the North American boreal region. Our partners have made important contributions to the success of the BAM project by providing avian data, access to environmental covariates, scientific expertise, and financial support. This has allowed us to develop a number collaborative and partnered projects beyond what could be supported by our Contribution Agreement with Environment Canada. The results of these additional projects are included in this report, and the contributions of collaborators and partners are explicitly acknowledged throughout.

PROPOSED MAJOR ACTIVITIES, 2014–2017

Major project activities during the 2014-17 period include work within the following themes:

1. Monitoring Guidance and Survey Design
2. Quantifying and Projecting Threats to Boreal Birds
3. Broad-scale Conservation Planning
4. Species at Risk and Critical Habitat
5. Annual Life Cycle Analysis
6. Avian Ecology and Habitat Selection
7. Database Management and Outreach
8. Collaborations

This report describes progress for each activity from April 1, 2014 to March 31, 2015.

MONITORING GUIDANCE AND SURVEY DESIGN

Roadside surveys of birds are widely used to examine spatial and temporal patterns in the abundance of bird populations. They have been central in both evaluating the status of bird populations and directing conservation for species in need of management. Analyses of roadside survey data often assume that roadside counts of birds are similar to survey counts in off-roads areas, and therefore representative of bird populations.

Recent work regarding roadside counts, especially from the North American Breeding Bird Surveys (BBS), indicates that there might be several issues with this commonly held assumption:

- (1) roads create edges in forested landscapes, the numerical and behavioural consequences of which are largely unknown;
- (2) detectability could be different along roads than in the forest interior;
- (3) roadside surveys might provide a biased sample of available habitats, especially in the northern i.e. boreal, regions, because roadside surveys are concentrated along the southern edge of the boreal forest, and road might not be randomly distributed in the landscape; and
- (4) roadside surveys might represent a biased sample of disturbances in the landscape, leading to potential bias in trend estimates.

Points (1) and (2) are addressed in a BAM project on *Identifying and accounting for roadside bias in Breeding Bird Survey data*, on page 8. Points (3) and (4) are addressed in work conducted by Steve Van Wilgenburg (EC – CWS) and in some anticipated BAM work (see *Monitoring Guidance*, page 13).

Integrating On-road and Off-road Point Count Surveys

Effects of differential sound transmission on apparent relative abundance

In association with Daniel Yip (MSc student with Erin Bayne), the Alberta Biodiversity Monitoring Institute (ABMI), and funding from a Natural Resources and Engineering Research Council (NSERC) Collaborative Research and Development (CRD) grant.

Roadside point counts such as those of the BBS typically assume that all birds observed have the same probability of detection given song pitch and distance from the observer. Observations are treated as relative abundance, assuming that they reflect actual abundance. However, this assumption may be violated since sound transmission varies with habitat type. Thus, effects of song pitch and distance from observer on detectability vary between roadside point counts and those from the forest interior.

The purpose of this study was to evaluate if differences in bird counts between forest interior and roadside locations reflect actual differences in bird abundance. The results of this study have implications for combining BBS and BAM data in statistical analyses. A sound transmission experiment was used to evaluate if sound propagation differed within the forest interior, along the forest-road edge, and along the road. We played a recording of 36 known sounds - a series of tones, white noise, and known bird songs - and re-recorded the playback

to simulate a point count observer. Recordings were processed by human observers to determine detection of each sound at multiple playback distances.

We found that distance influenced the probability of detection for all species (Figure 1). Across all species, detection was higher along roads than along forest edges and within the forest interior. An interaction between distance and habitat suggested that detection probability decline is more abrupt in the interior forest than the edge or road.

Our results demonstrate that differential transmission along open road corridors may significantly alter BBS counts compared to forest interior counts. This information has implications for accounting for roadside bias (see *Identifying and accounting for roadside bias in Breeding Bird Survey data*, page 8) and for incorporating roadside surveys within the BAM Avian Database.

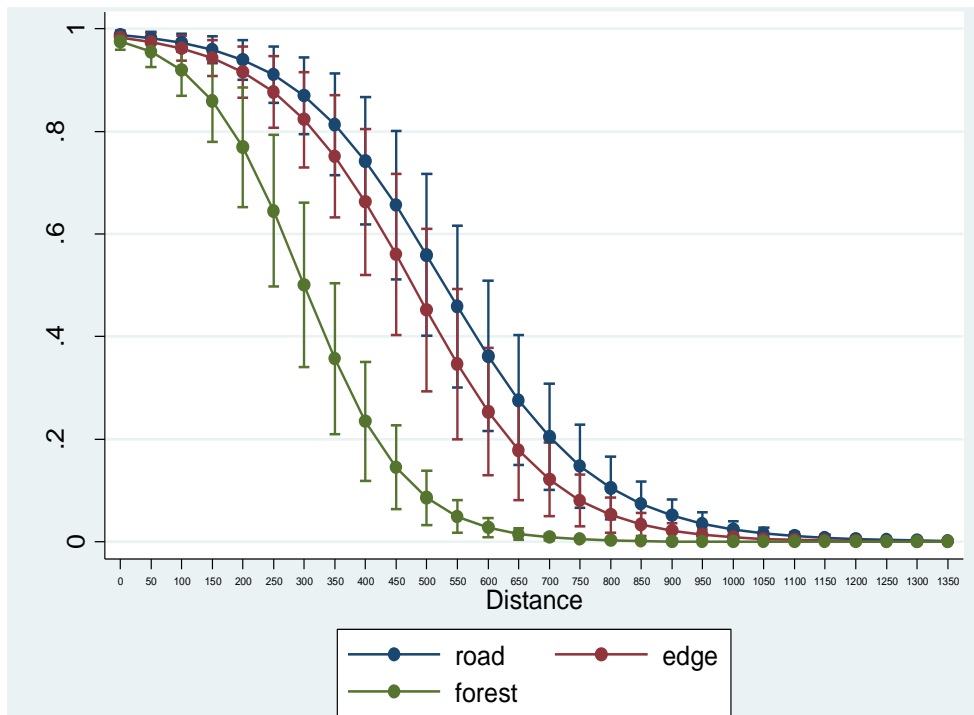


Figure 1. Detection probability in each habitat type (road, edge, forest) by distance. Error bars are 95% confidence intervals.

A first draft describing this work has been completed and is currently being revised by co-authors. We anticipate submission to an as yet undecided journal by the end of summer 2015.

Identifying and accounting for roadside bias in Breeding Bird Survey data

In association with Gerald Niemi and Edmund Zlonis (University of Minnesota Duluth).

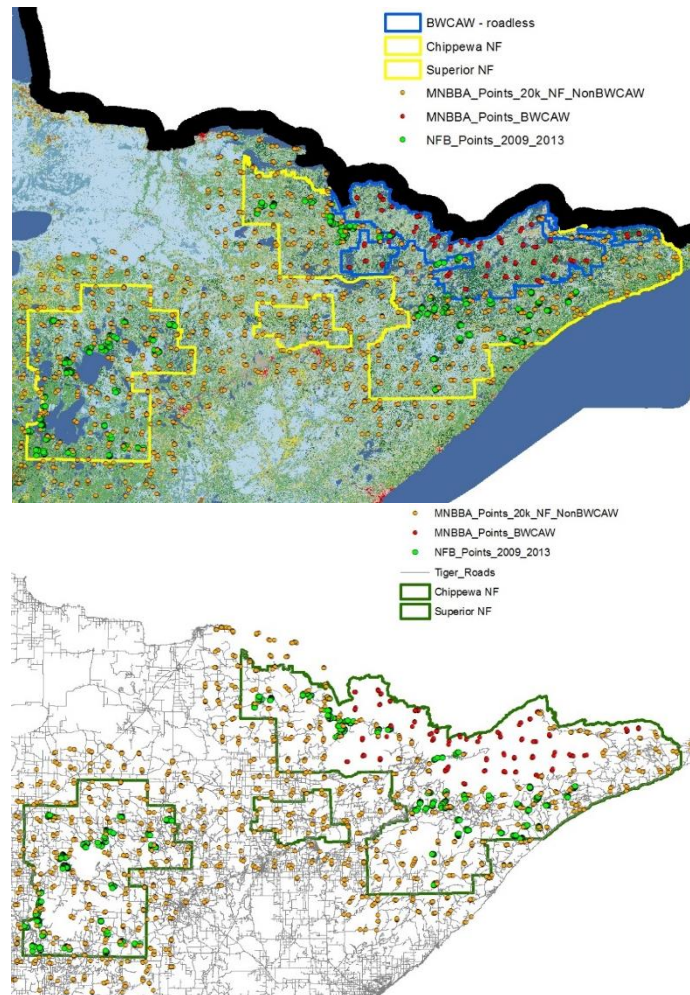
The goal of this project is to better understand the complexity of roadside-related biases, namely: (1) effects of road edge; and (2) differential detectability along roads versus forest interior. Based on this understanding, we could improve data analysis and future sampling by (A) providing recommendations on sampling design features that minimize the roadside bias; and (B) developing model-based analytical techniques to account for the bias.

This work uses the Minnesota Breeding Bird Atlas for roadside surveys, and the Minnesota National Forest Birds dataset for forest interior point counts. The point count methodologies

employed in the recent surveys from these projects (2009-2013; n = 14096) allowed us to disentangle the temporal and spatial dimensions of the roadside bias. These point counts included at least three time intervals within a 10 minute count, and at least two distance intervals with finite truncation distance (50 and 100 m) in addition to the unlimited distance band.

We restricted the dataset to point counts where the surrounding habitat contained within a 150 m radius buffer was forested. Part of the study area is shown in Figure 2.

Figure 2. Distribution of the Minnesota data set near two national forests in northeast MN showing land cover classes (top) and the road network (bottom). Maps produced by Edmund Zlonis.



Quantifying contributions of factors to roadside bias – The counts from the combination of three point count durations (0-3 min, 0-5 min, and 0-10 min) and two point count areas stemming from different distance intervals (0-50 m and 0-100 m) were regressed against habitat (deciduous, mixedwood, coniferous), presence of road, road width, and the interactions between habitat & road width, duration & road width, and point count area & road width. A Poisson generalized linear model (GLM) was used for each species. Backward stepwise model selection was used to simplify the models based on AIC. Final models were used to make predictions in a full factorial design using species, duration, point count area, habitat, road width, and their interactions as predictors. Under each covariate combination,

we predicted the expected count for on-road vs. off-road surveys. The log of the expected value of roadside bias, $\log(\text{on-road}/\text{off-road})$, was used as the response variable in an ANOVA to quantify the effect of each of the factors.

The magnitude and direction of the expected bias were species-specific (Table 1). The main effect of species (65%) and species*habitat and species*road width interactions (18% and 10%, respectively) topped the variance partitioning results. The second most important main effect was point count area (4%) and its interaction with species (3%). Main effects of habitat, duration, and the duration*species interaction were less important (<1%). Figure 3 shows example results for a single species, the Ovenbird.

Table 1. Percent of variance in expected roadside bias explained by each effect in the full factorial design.

Effect	Variance Explained (%)	p-value
Species	65.21	< 0.001
Species * Habitat	17.64	< 0.001
Species * Road width	10.22	< 0.001
Point count area	3.94	< 0.001
Species * Point count area	2.91	< 0.001
Habitat	0.06	< 0.001
Species * Duration	0.02	< 0.001
Duration	< 0.01	< 0.001
Road width	< 0.01	< 0.001
Duration * Point count area	< 0.01	< 0.001
Duration * Road width	< 0.01	< 0.001
Point count area * Habitat	< 0.01	0.01
Duration * Habitat	< 0.01	0.23
Habitat * Road width	< 0.01	0.48
Area * Road width	< 0.01	0.23

We conclude that roadside bias (magnitude, direction, interactions) is very species-specific, creating a challenge to develop general solutions. The following recommendations can be summarized based on the variance partitioning results:

- Point count duration is not as significant as point count area, thus the 3-minute nature of BBS counts is not an important contributing factor to the roadside bias.
- Roadside bias showed strong interactions with point count area, habitat, and road width. Such interactions need to be included when modeling road effects to account for the bias in GLM type models. That is, models should incorporate roads in addition to interactions with surrounding habitat type, road characteristics, and point count area if it varies across studies.

This work is currently being written up as a manuscript, with anticipated submission to an as yet undetermined journal by December 2015.

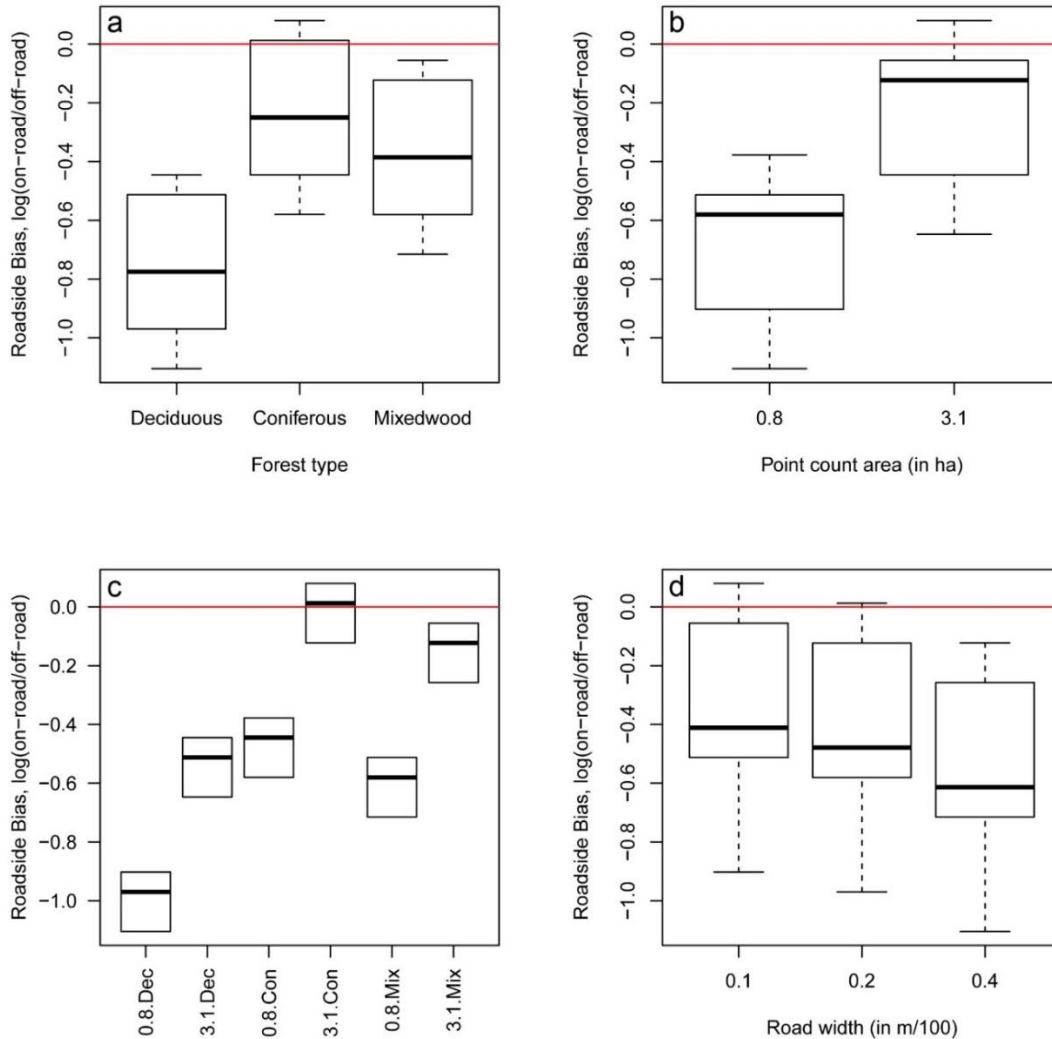


Figure 3. Expected roadside bias for Ovenbird as a function of: (a) forest type; (b) point count area; (c) interaction between forest type and area; and (d) road width (in metres / 100).

Simulation of roadside bias – We conducted a simulation study to further explore the mechanisms contributing to roadside bias. Our simulated roadside survey was characterized by three habitat strata: forest interior (Habitat; green in Figure 4), forest-road edge (E; yellow in Figure 4), and road (R; grey in Figure 4). Thus the model is called HER. The following assumptions were made when simulating the data:

- The shape of the distance function describing the probability of detection as the function of distance from observer (half-Normal decay) was not affected by the road – road is narrow enough for this to be true.
- The road surface was considered non-habitat; density in this stratum was set to 0.

The parameters in the HER model included: effective detection radius; singing rate in forest interior; a scaling constant (g) that describes singing rate in the edge habitat relative to the interior; a scaling constant (δ) that describes density in the edge relative to the interior; road width (w_r); and edge width (w_e).

The simulation results indicate that roadside bias is increasingly negative with increasing road width. That is, increasingly fewer birds will be observed in a roadside count as road width increases. The presence of an edge and positive density and/or behavioural contrast counterbalanced the negative bias due to the presence of the road (Figure 4).

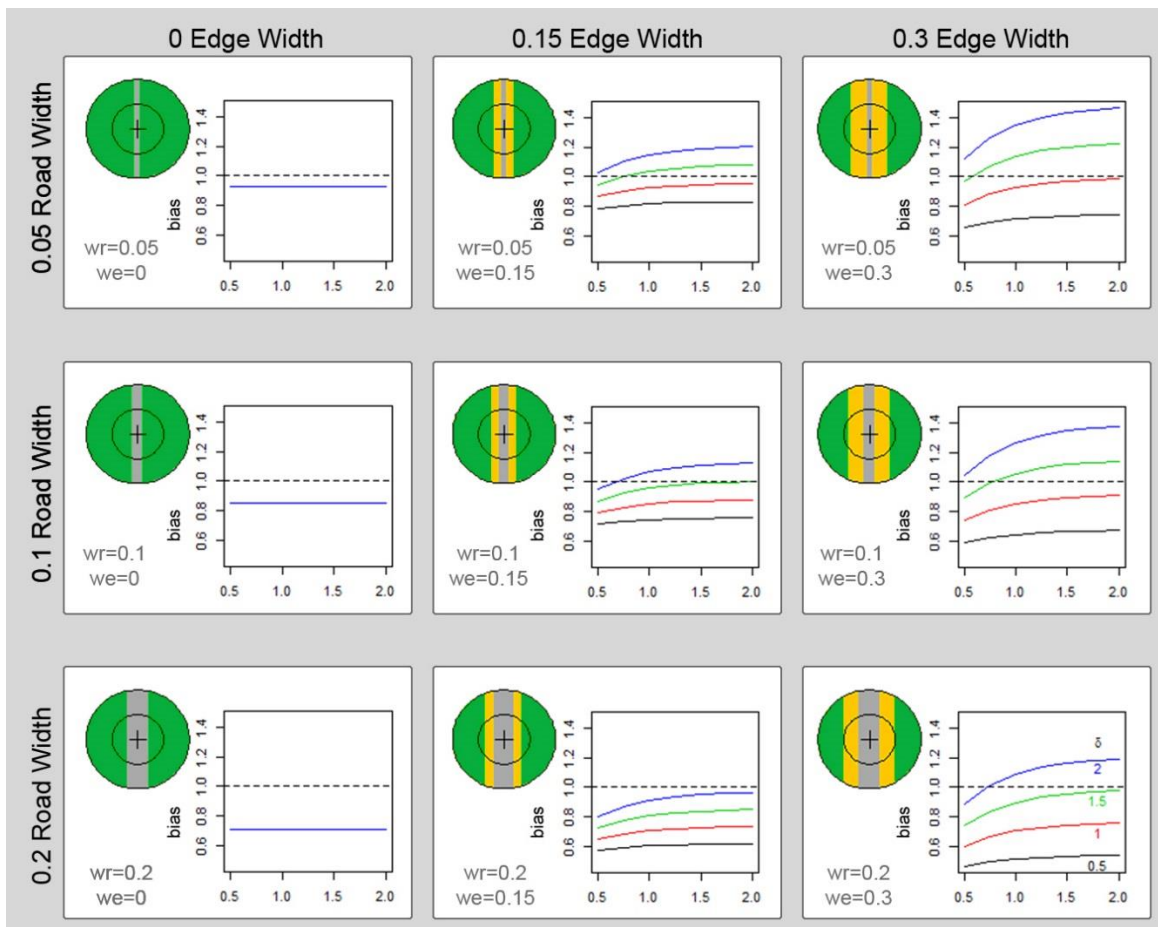


Figure 4. Expected roadside bias based on a simulation of three edge widths (columns; w_e) and three road width (rows; w_r). Colours within the point count diagram represent habitat (green), edge (yellow), and road (grey). The y axis shows the roadside bias (on / off road), and the x axis shows the scaling constant (g) for singing rate in edge versus forest. Line colours indicate the value of the scaling constant (δ) that describes species density in edge versus forest.

The complexity of the mechanism and the many possible combinations of the parameters (g , δ , w_r , w_e) hinders our ability to make general recommendations. Roadside bias likely varies by species depending on behavioural and numerical responses to the presence of edge habitat. The effective width of the edge habitat is also likely to change by species, possibly scaling with territory size.

More work is necessary to explore the HER model. Fortunately, the spatio-temporal resolution of the surveys in the Minnesota data sets provides us the opportunity to estimate some of the parameters in this model. This work may be incorporated in the aforementioned manuscript describing the variance partitioning component, or it may yield a separate manuscript with anticipated submission by March 2016.

Monitoring Guidance

Avian point count surveys do not adequately sample all locations or habitat types. The BBS offers the vast majority of the long-term historical record on boreal birds in Canada; however, roadside bias may compromise the suitability of BBS data for some purposes (see *Integrating On-road and Off-road Point Count Surveys*, page 7). Off-road point count surveys available may compensate for these biases, but extensive and repeated surveys are more expensive, meaning that few long-term datasets from this kind of project exist. Furthermore, the results will likely be spatially biased, and may not be directly compatible with international monitoring efforts for population-wide reporting. With the combination of the BAM Avian Dataset and the BBS Dataset, BAM is uniquely positioned to synthesize and examine the comprehensiveness of sampling of boreal songbirds by point count surveys, and to identify where further sampling is needed.

The over-arching objective of these projects is to quantify the coverage of both on-road and off-road point count data, in terms of:

- (a) geographic space;
- (b) time;
- (c) habitat types;
- (d) disturbance types (e.g., fire, forest harvest, defoliation);
- (e) time since disturbance; and
- (f) species distribution for a subset of species of interest.

(a) and (b) are covered within *Developing methods to model spatio-temporally sparse point count data*, page 13. (a) through (e) are covered within *Comprehensiveness of avian point count sampling in the boreal region: A gap analysis*, page 17. (f) is covered within *Prioritizing avian point count sampling to understand distributions of species at risk*, page 17.

Along-side this objective is the development of methodological approaches to: (1) quantify population trend from spatio-temporally sparse data; and (2) identify future sampling priorities based on the above analyses. A culminating product will include recommendations for future monitoring sampling as gleaned from application of these methods.

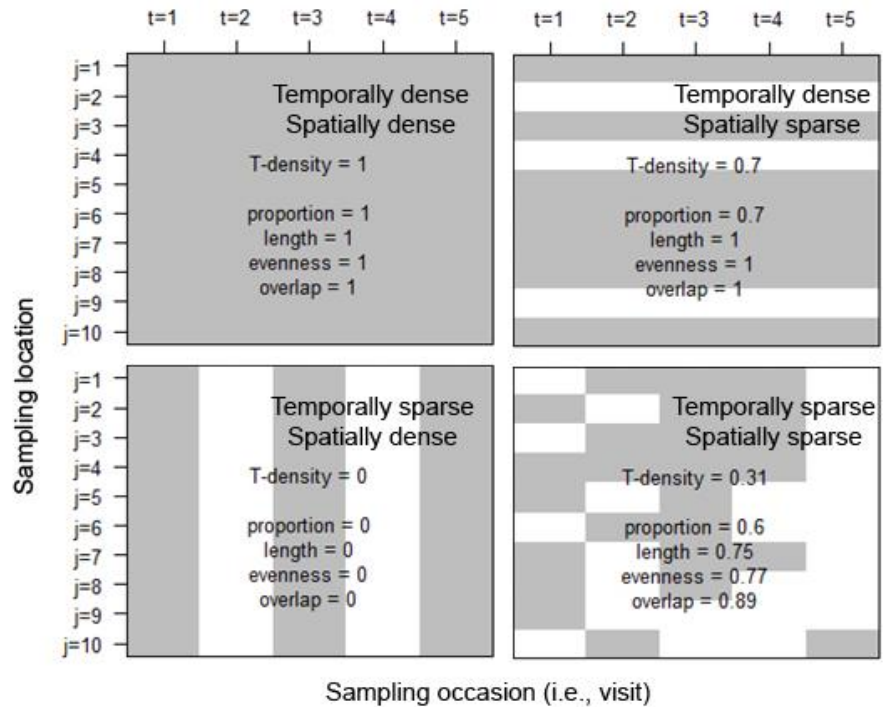
Developing methods to model spatio-temporally sparse point count data

Point count sampling of boreal songbirds is not balanced in space and time. Missing data for surveyed locations or times can yield spatially and/or temporally sparse data. Data sparsity introduces heterogeneity in habitat sampling, in that projects conducted in different years tend to cluster spatially and might target different types of habitats. The collated BAM Avian Database combines many individual temporally and spatially sparse datasets to improve data density. However, even the BAM Avian Dataset is temporally sparse, and in particular lacks “anchor” points: locations revisited over long time series. Instead, intervals between visits are highly variable, and temporal patterns of revisits are spatially inconsistent. The BBS sampling design provides the most temporally dense dataset. Being based on yearly revisits of same locations, it yields temporally dense data, i.e. very few missing data for each location. The spatial coverage of the BBS, however, is sparser than would be desired for estimating population trends of songbirds across the boreal forest. Estimating population trends from

spatio-temporally sparse data is difficult since missing data cause problems for typical autoregressive time-series models.

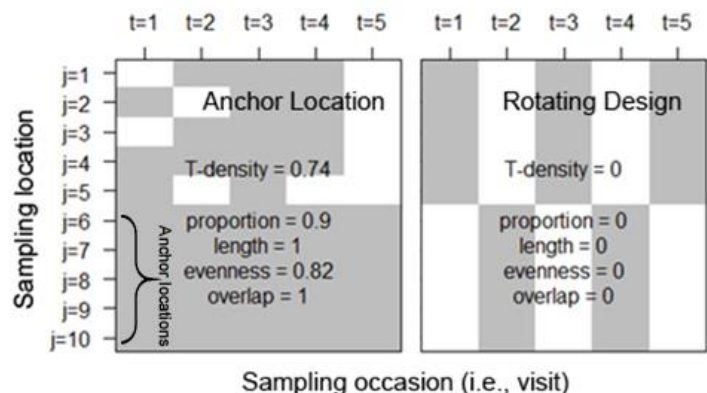
Our goal is to develop a method to apply standard time-series modelling techniques to spatio-temporally sparse data. To better understand the limitations of the available data sets we needed to: (1) quantify the spatio-temporal distribution of point count observations in the BAM and BBS data sets; (2) develop methodologies that are robust to spatial pooling of the temporally sparse BAM data set; and (3) validate results against a temporally dense data set (BBS) for species and regions where the difference between BAM and BBS is known to be minimal.

Figure 5. Different levels of spatial (columns) and temporal (rows) density of sampling. Grey indicates sampling while white indicates missing data. The BAM dataset is an example of temporally sparse, spatially sparse data, while BBS is an example of temporally dense, spatially sparse data. Temporal (T-) density is calculated as the product of the other four quantities.



Quantifying spatio-temporal distribution of sampling – The ideal sampling design is both temporally and spatially dense, as in the first panel of Figure 5. The spatial density of the sampling has implications for statistical power to detect change and may introduce biases by non-representative sampling of the area of interest. The temporal density of the sampling creates non-continuous time series, hindering the ability to estimate trend. Some specific sampling designs might be seen as a compromise between sparse and dense data, for example a temporally sparse design with ‘anchor’ locations, or a rotating panel design (Figure 6).

Figure 6. Specific sampling designs to help better estimate trend by maximizing sampling density in a cost-effective way. See text for definitions of T-density, proportion, length, evenness, and overlap.



Temporal density of a sampling design can be expressed as the product of four quantities. For each location, we count the number of consecutive observations where the observation in the previous year ($t-1$) was not missing:

- proportion: the proportion of locations possessing a time series of at least 2 consecutive visits;
- length: the maximum time series length in the data standardized by the maximum possible time series length (year max – year min);
- evenness: a measure of similarity in length of time series in different locations. The value is 1 when the time series lengths are equal, and less than 1 when the distribution is uneven;
- overlap: a measure of the capacity for the sampling design to produce a continuous time series by joining overlapping partial time series;
- Temporal-density: the product of the above four metrics.

Table 2. Temporal density metrics for BBS and BAM datasets. Metrics were calculated for unique sampling locations (point-level) and years. BAM data were also pooled by BCR/Jurisdictions, which is the reporting unit used most often at national scale.

Criteria	BBS, point-level	BAM, point-level	BAM, BCR/Jurisdiction level
Proportion	0.89	0.04	0.75
Length	1	0.667	1
Evenness	0.63	0.622	0.58
Overlap	N/A	N/A	N/A
T-density	0.56	0.018	0.44

The overall temporal density is highest for BBS, not surprisingly (Table 2). The proportion of revisited locations (proportion) seems to be driving the differences between BBS and BAM sampling patterns. Pooling BAM data to the BCR/Jurisdiction level increases the proportion metric quite considerably, which increases the temporal density much closer to that of the BBS. This indicates that pooling BAM data to the BCR/Jurisdiction level produces uninterrupted time series that can be analyzed using autoregressive models.

Sparse-to-dense approximation – Pooling data over spatial units improves temporal density, as shown in Table 2, so that trends can be estimated. BAM statistical offsets to correct for heterogeneous sampling effort and detectability (Sólymos et al. 2013) are calculated for points, not pooled aggregates. We are currently exploring models to estimate trend using spatially pooled corrected densities from the BAM dataset.

An example time series of Canada Warbler abundance based on pooled data is shown in Figure 7. In comparing the apparent trends from temporally-sparse BAM data to those from temporally-dense BBS data, we can validate trends calculated from the spatially-pooled BAM data. At the BCR/Jurisdiction level, the apparent trends seem to differ substantially between BBS (dense) and BAM (sparse) data sets. However, at the national level, the overall shape of the curves is more similar.

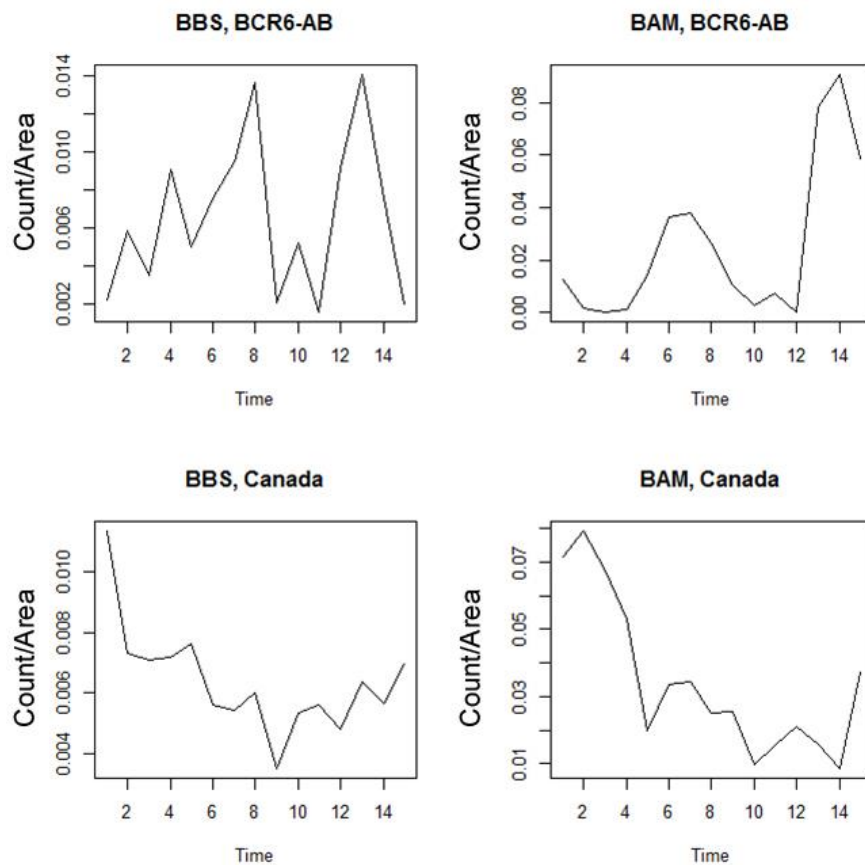


Figure 7. Standardized and pooled Canada Warbler observations as time series for BCR 6 in Alberta and for Canada. Count/Area is density-based pooled counts divided by pooled area sampled (without correcting for differences in habitat suitability / carrying capacity).

The pooled data from the sparse-to-dense approximation can be used in two types of trend modeling approaches. The first is an autoregressive (growth model, population viability analysis) type model where an observation in year t depends on abundance in year $t-1$. An alternative approach is the log-linear trend modelling approach, similar to how BBS data are analyzed. The model involves spatial and temporal random effects, and a linear term describing yearly changes in population abundance. Detectability and predicted densities are used as offsets in the trend model.

Our next steps are to explore the application of these two modelling approaches to the BAM data. We will conduct a power analysis using simulated data to assess the capacity of each of these two approaches for detecting trend from the BAM dataset. Our simulated data will include different combinations of decadal trend, spatial sampling density, the number of “anchor sites”, and the existence of a habitat sampling bias over time.

The final step will be to use different combinations of the BAM, BBS, and BAM+BBS databases in trend modelling. The results based on the different datasets will be compared, and the optimal spatial resolution for pooling of BAM data will be determined. The final outcome for this work will be a rigorous assessment of the capacity for BAM data to estimate trend in boreal songbirds. An additional outcome will be recommendations for cost-effective sampling design in the boreal forest to reduce biases in trend estimation. The target date for completion of this work is March 2016.

Comprehensiveness of avian point count sampling in the boreal region: A gap analysis

In association with Environment Canada (EC) staff.

Due to the nature of the BAM database, sampling is not balanced across the boreal region. The objective of this project is to identify poorly-represented portions of parameter space as defined by geographic space, time, vegetation, current and projected climate conditions, and disturbance history. We expect that an initial quantification of parameter space covered by the BAM database will accompany a data paper describing the BAM database (see Increasing awareness of the BAM database, page 53), and anticipate significant progress in 2015-16. This work represents an extension of an existing gap analysis, with more specific parameter spaces.

As a follow-up to this initial analysis, power analyses will determine where additional sampling is necessary, depending on the research objective, such as detecting habitat associations, identifying trends, delineating ranges, and detecting responses to projected climate and land-use change. Our intent is to map the spatial patterns of likely prediction uncertainty based on sampled conditions.

The outcome of this project will inform new monitoring programs by identifying conditions (e.g., habitat, climate, disturbance) and locations where more sampling is needed for a variety of research questions. Steve Van Wilgenburg (EC – CWS) has completed related work by examining the potential bias of roadside surveys (i.e., BBS) in sampling habitat and disturbance conditions. We therefore anticipate collaboration with him and other EC landbird staff who have expressed interest.

Prioritizing avian point count sampling to understand distributions of species at risk

In association with Environment Canada (EC) staff.

Implementing new monitoring programs is expensive, so developing cost-effective recommendations is imperative to their implementation. As part of the above work assessing current sampling of the boreal region, we will use a very similar analytical framework to identify areas where additional sampling would provide key information for federally listed species at risk. An extension for species at risk involves species-specific information such as distribution. We also intend to factor in sampling costs. That is, recommendations for additional sampling will be based on feasibility and expense of sampling, in addition to filling sampling gaps. This project will be led by Samuel Haché, Wildlife Biologist with EC and Contributing Scientist with BAM, in collaboration with monitoring agencies such as EC to ensure utility in the results. We anticipate significant progress in 2015-16.

Automated Recording Units (ARUs)

Automated recording units (ARUs) are increasingly being used to supplement human observers in point count surveys, yielding a mixture of data collected by humans and ARUs. ARUs yield data similar to point counts of long duration (e.g., on the scale of days) and unlimited distance. ARU data represent a potential means of greatly expanding the BAM Dataset, but first we must determine how best to integrate ARU data with conventional point

count data. The challenges are multi-fold. Raw audio files must be processed, preferably in a time-efficient manner. The methods used to process ARU data vary from project to project in terms of duration sampled, the process used to identify species (e.g., visual scanning versus listening to recordings), and the format in which data are archived. To integrate ARU data into the BAM Dataset, we must identify a standard format for receiving processed ARU data. We then must develop statistical methods to standardize ARU data with conventional point counts, to remove heterogeneity and permit inclusion of both types of data in the same analysis.

Assessing the capacity of boreal ARU projects to broaden BAM's coverage

In association with ABMI, the Canada-Alberta Joint Oil Sands Monitoring (JOSM) Project, and NSERC CRD.

We have not yet begun identifying projects with ARUs within the boreal region. We anticipate starting this work in 2015-16 with an early focus on integrating data from nocturnal species. We will begin soliciting ARU data within 2015-16, and invite interested organizations and/or individuals to contact us if they would like to contribute data for this effort.

Identifying standards for processing ARU data

In association with ABMI, JOSM, and NSERC CRD.

Early uses of ARUs typically echoed short-duration, human point count methods. With advances in recorder battery and memory cards, these approaches are currently being re-evaluated. ARUs can be left in place for extended periods of time so that data processing, rather than data collection, is the challenge.

The purpose of this project is to identify the most time-effective ways to sub-sample recordings of long durations in relation to identifying all species at a location. ARUs were deployed within a variety of habitats in Alberta, and collected recordings over a 24-hour period. Human observers listened to recordings and tracked species identified within 1-minute intervals. This level of sub-sampling permitted comparison of short-duration to long-duration sampling.

Preliminary results indicated that vocalization rate varied substantially by species. Controlling for species, we found that a short duration (e.g., 2-minute) point count can yield an unbiased estimate of calling rate compared to a longer duration (e.g., 10-minute) point count.

This work is currently in progress, and we anticipate the analysis and writing to be completed by July 2015. We expect that results will inform the most efficient strategy to use when processing ARU data. Furthermore, results can also inform point count design, in terms of optimal survey duration and sub-sampling.

ARUs statistical methods and integration with conventional point counts

In association with ABMI, JOSM, and NSERC CRD.

The Alberta Biodiversity Monitoring Institute (ABMI) surveys birds by means of ARUs. As discussed above, work is on-going to develop methods for processing these data. Future work involves developing methods to extract data from ARU surveys that are compatible with the

present BAM database, or statistical methodologies to make estimated densities comparable. No progress was made on this element within 2014-15 though we have begun incorporating ARU data within the BAM database (see *Data from automated recording units (ARUs)*, page 48).

QUANTIFYING AND PROJECTING THREATS TO BOREAL BIRDS

Joint Oil Sands Monitoring

Throughout this fiscal year, BAM continued analysis of individual and cumulative effects of oil sands activity on boreal birds. BAM's contribution to the Canada-Alberta Joint Oil Sands Monitoring (JOSM) Project was conducted along-side contributions from Lisa Mahon of EC, one of BAM's contributing scientists. As a whole, this work has covered topics including:

- (a) assessment of data/knowledge gaps in current study design;
- (b) an understanding of ecological niches of songbirds;
- (c) assessment of additive and interactive cumulative effects of forestry and energy sectors;
- (d) quantification of local impacts of oil sands activity on songbird density;
- (e) assessment of effects of point count radius on detection of local scale impacts;
- (f) prediction of numerical (cf. behavioural) response of songbirds to energy sector land-use change;
- (g) creation of predictive models to assess population change likely caused by energy sector disturbance.

(a), (b), and (c) were covered as part of Lisa Mahon's work, which is reported separately by EC. (d) and (e) are described below in *Local scale impacts of energy development on songbird density*, page 19. (f) is covered in *Predicting boreal bird abundance based on habitat and cumulative effects of energy infrastructure*, page 22. A pilot version of (g) was completed during the previous fiscal year, but significant updates were made during this fiscal year, as described in *Cumulative impacts of anthropogenic disturbance in the Alberta oil sands region*, page 23.

During 2015-16, we plan to synthesize results from various lines of evidence to generate overall conclusions regarding bird response to oil sands activity.

Local scale impacts of energy development on songbird density

In association with JOSM.

Anthropogenic edge is rapidly increasing in the western boreal forests of North America, especially with expanding energy development. Edge effects are not well-documented, but are hypothesized to be stronger for bird species associated with late-successional forest, and may vary with the type of edge habitat (i.e., well pads, pipelines, or seismic lines).

The main objective of this project was to determine the effect of energy sector developments on boreal songbirds in Alberta. Specifically, we quantified bird density along forest edge relative to forest interior.

Identification of edge effects is complicated by variability in point count radius. Increasing radius increases the likelihood that interior forest point counts will include edge habitat (Figure 8A relative to 8B) and that edge point counts will include more forest interior habitat (Figure 8C relative to 8D). Thus, larger point count radii might have less power to detect existing edge effects. We therefore accounted for point count radius (50-m, 100-m, and unlimited-distance [~ 150 -m]) in our analyses, with the objective of assessing how spatial extent and intensity of sampling influence our quantification of energy sector impacts.

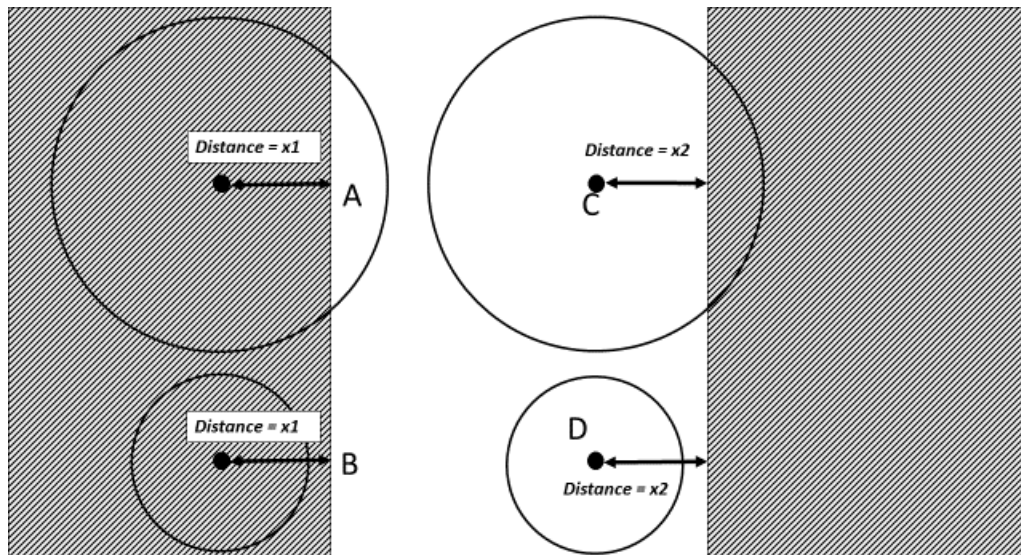


Figure 8. Point counts of different size in forest habitat (A, B) and edge habitat (C, D) between forest patches. Forest point counts A and B have their centres at the same distance (x_1) from the forest edge, but as point count A expands, it is increasingly likely to contact edge habitat, making it less different from edge point count C. Edge point counts C and D also have their centres at the same distance from forest edge (x_2), but as point count C expands, it is increasing likely to contact forest habitat, making it less different from forest point count A. The smaller point counts B and D are more likely to be different from each other than the larger point counts A and C.

Our data represent a subset of the BAM Avian Dataset comprised of edge and forest interior point counts from the western boreal forest. We modelled the number of individuals observed per species per point count using generalized linear mixed models. The infrastructure type was the independent variable of primary interest, modelled as a fixed effect with four levels (pipeline, seismic line, well pad, or none i.e. forest interior). Other variables were included to control for variability in vegetation composition, tree height, latitude, longitude, time of day, time of year, observer, and replicate count. Models were repeated for each of the three point count radii. Effect sizes of the three infrastructure types were calculated relative to the forest interior using AIC model-weighted unconditional estimates. These represent the impact ratio of average relative density between a particular type of edge point count and its forest interior equivalent for each species.

We found that most species showed neutral or positive responses to energy infrastructure, in the sense that their densities at edge points were not less than within forest interior points, on average (Figure 9).

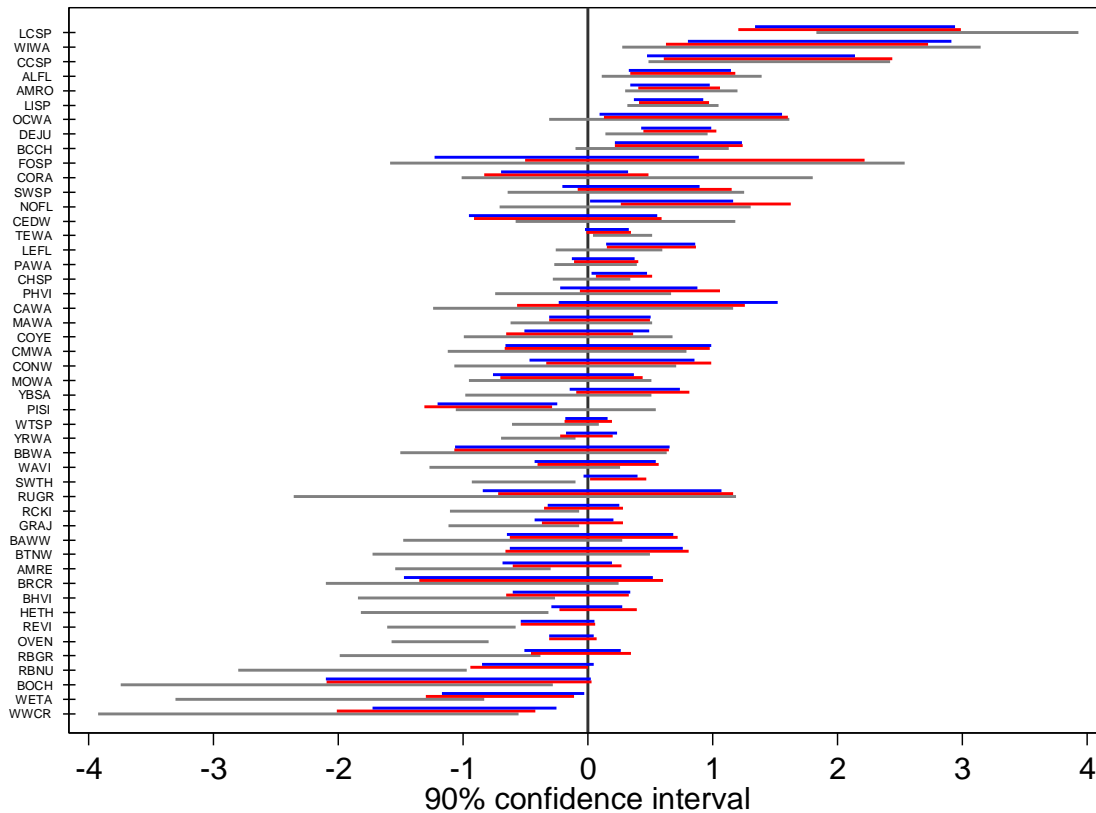


Figure 9. 90 % confidence intervals of difference in densities of birds associated with well pads relative to forest interior habitats. Positive values indicate a preference for edge habitats. Negative values indicate a preference for interior habitats. Blue = unlimited distance point counts. Red = 100-m point counts. Gray = 50-m point counts.

We found increased density on edge point counts for many species associated with grasslands, early-successional shrublands, or multiple forest stages (e.g. Alder Flycatcher, American Robin, Lincoln’s Sparrow). Birds that decreased within one or more types of infrastructure edge were usually birds associated with late-successional forest stages (e.g., Ovenbird, Red-eyed Vireo, Western Tanager).

Averaged across species, we found larger differences in songbird density between edge and forest interior for well pad and pipeline edges than for seismic lines. We also found larger differences in density between edge and forest interior, but greater uncertainty in effect size estimates, for 50-m point counts relative to larger point counts. Therefore, point count radius did not influence whether differences were detected between edge and interior points, because it also affected the precision of the measured difference.

This work represents an extension and refinement of work reported previously (2.3.2 *Predicting the impact of energy sector activity on avian populations: Does scale matter?* in the 2013-14 Annual Report to EC). A manuscript has been prepared based on the work described above. It is currently being reviewed by co-authors and will tentatively be submitted to *Avian Conservation and Ecology* in June 2015.

Predicting boreal bird abundance based on habitat and cumulative effects of energy infrastructure

In association with JOSM.

Relative to spot-mapping, radiotracking, or nest-monitoring, point counts are a faster means of obtaining large datasets to test for edge effects on forest birds. However, ornithologists should be cautious about analyzing edge effects at the scale of individual point counts, and then using those edge effects to predict bird abundance in independent locations, especially at larger scales. In general, variation among methods used in individual studies may make it unlikely that edge effects from one study will accurately predict birds in another study. It is also possible that the numerical response of birds to edge detected using point counts may be confounded with behavioural responses that do not reflect the species' population response to edge. For example, birds may sing along edges during early-morning point counts but avoid edges for foraging later in the day (Figure 10). This would yield detection of a positive edge effect at the local scale but not at the landscape scale.

The purpose of this study was to investigate if edge effects quantified at the individual point count scale could predict boreal bird abundance at the landscape scale. The analysis took place in three stages.

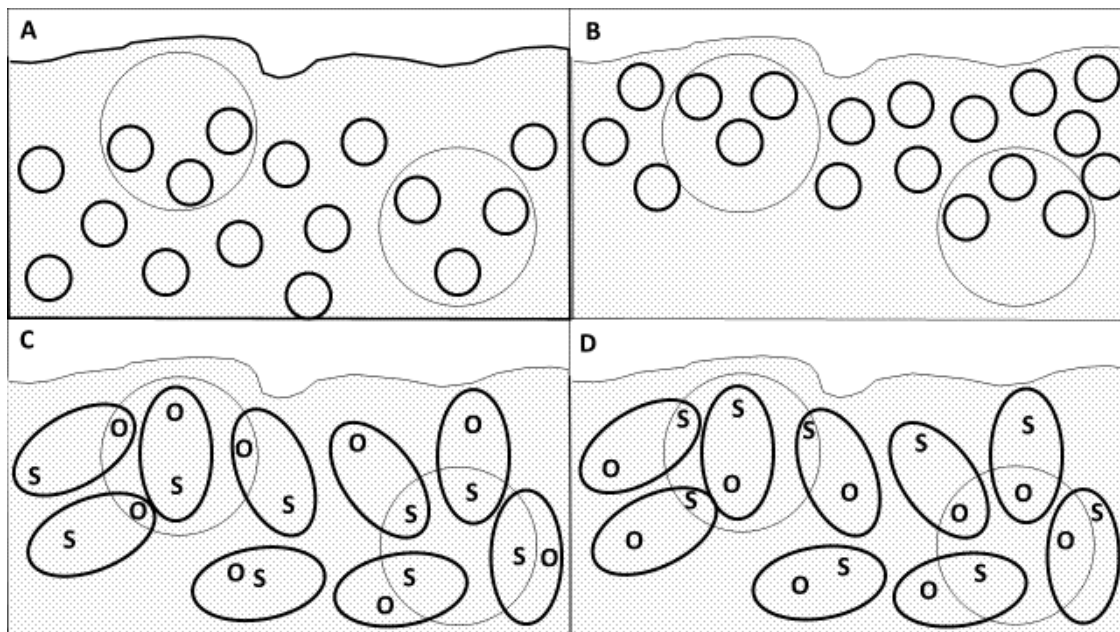


Figure 10. Four landscapes (A-D) each containing one edge point counts (left large circle in each panel) and one forest interior point counts (right large circle in each panel). Bird behaviors that go undetected within individual point counts may result in a different edge effect detected (or not detected) at local scales within point counts than at landscape scales. A = negative edge effect (due to territory avoidance of edge) not detected in point count, but detected at landscape scale. B = positive edge effect (due to territory concentration at edge) not detected in point count, but detected at landscape scale. C = negative edge effect (due to singing activity [S] away from edge) detected in point count, but not at landscape scale, because other activities (O) such as foraging still occur at edge. D = positive edge effect (due to singing activity [S] close to edge) detected in point count, but not at landscape scale.

First, we modelled densities of boreal forest birds using local-scale (~150 m radius) metrics, without accounting for habitat loss or edge effects related to energy infrastructure. From these models, we generated habitat suitability ratios for each habitat and species.

Second, we calculated mean impact ratios of each species within different types of edge relative to forest interior (see *Local scale impacts of energy development on songbird density*, page 19). We used results from this analysis to select a subset of nine species: three that consistently increased with edge (Alder Flycatcher, American Robin, Lincoln's Sparrow), three that consistently decreased with edge (Ovenbird, Red-eyed Vireo, Western Tanager), and three that responded neutrally or inconsistently to edge (Swainson's Thrush, White-throated Sparrow, Yellow-rumped Warbler).

Third, we combined the previous two models to predict landscape-level abundances of the nine species of songbirds based on habitat and infrastructure edge effects, and then evaluated the predictions using independent data from ABMI. The initial habitat suitability models from stage 1 were used to estimate density in the dominant habitat-age class. Edge effects at various scales were added as correction factors to generate landscape-level predictions of species' abundance assuming no edge effect, a 50 m footprint, a 100 m footprint, and a 300 m footprint. Predictions were compared to actual landscape-level abundances observed within ABMI grids of nine point counts.

We found that observed abundance of each species was positively related to predicted abundance with or without a zone of impact associated with the energy sector. However, the linear relationship between observed and predicted abundance was weak and accounted for very little variation in observed abundance of each species. Thus, local-scale edge effects from point counts have little predictive power for independent data at other spatial scales.

This work is currently in progress and we anticipate having a manuscript ready for review by co-authors in June 2015.

Cumulative impacts of anthropogenic disturbance in the Alberta oil sands region

In association with JOSM and ABMI.

Impacts of energy sector development may be proportionate or disproportionate to the area of land impacted. The purpose of this project was to quantify population changes in response to anthropogenic activity within the oil sands region. We did this by creating models of songbird-habitat associations and then comparing observed populations to those predicted under assumed conditions of no human activity (Alberta Biodiversity Monitoring Institute 2014, Sólymos et al. 2014). We also attributed the overall impact to particular disturbances in terms of direct and indirect effects.

We built habitat association models for 81 species within Alberta using point counts from the BAM database in combination with landcover and bioclimatic variables. Individual species results are reported elsewhere (Sólymos et al. 2015); example results for Canada Warbler are presented in this report.

Canada Warblers were predicted in highest density in upland forest stands, especially in old-growth deciduous and mixedwood stands (Figure 11).

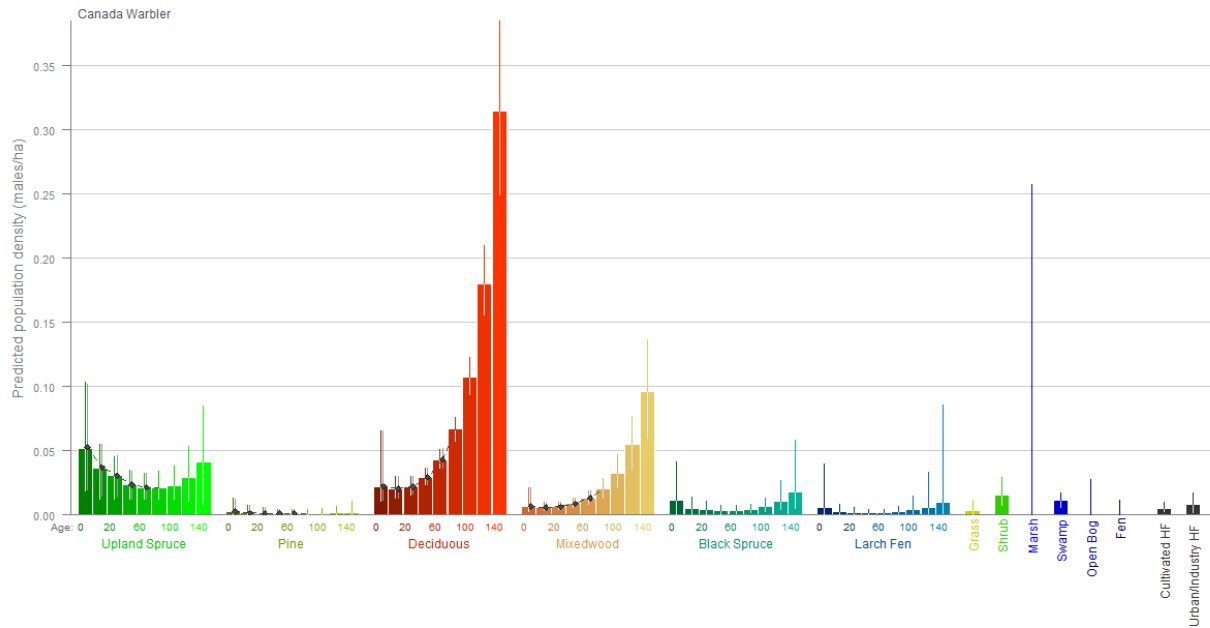


Figure 11. Canada Warbler density (males/hectare) based on habitat, estimated from habitat-association models. Forest age is shown on the x-axis in 20-year increments for each forest type. Vertical lines indicate 90% confidence intervals. Dots within the forested habitat types show predicted species density in cutblocks of various ages.

To compare effects of anthropogenic disturbance on songbird abundance, we used a predicted landscape by “filling in” disturbed habitat based on the likely historical habitat (Alberta Biodiversity Monitoring Institute 2014). This simulated landscape allowed us to compare current songbird abundance and distribution with hypothesized abundance and distribution without the current human footprint. We found that human disturbance resulted in negative effects on Canada Warbler abundance (Figure 12).

To attribute the differences in songbird abundance between disturbed and hypothesized undisturbed landscapes, we grouped human disturbances according to “sectors”: agricultural, urban/industrial, mines/wells, energy-related soft linear features (transmission lines, pipelines, seismic lines), forestry, and transportation-related linear features (roads, rails). We further partitioned the effects of land cover conversion into direct (i.e. habitat loss) and indirect effects (i.e. proximity effects), to understand whether effects stemmed from direct habitat loss or from proximity effects.

Across all 81 species, the overall impact of a given sector on bird populations was proportional to the area of the landscape disturbed by that sector. Since agriculture and forestry covered the largest area within the oil sands region, these sectors contributed the most to the predicted population differences. After standardizing population differences by the area disturbed, the unit area effects of vegetated and non-vegetated linear features had the highest overall impact on species’ populations.

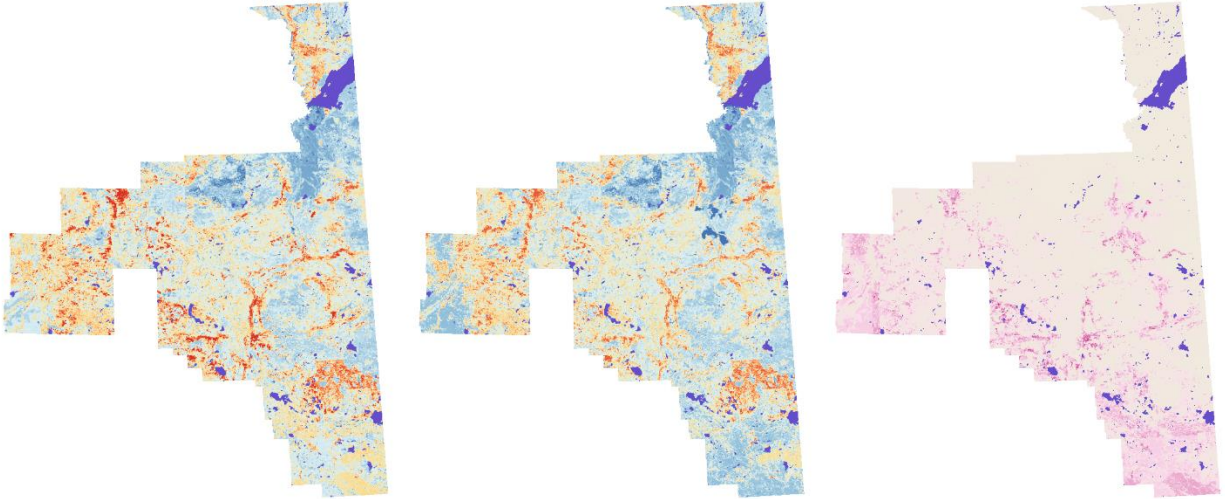


Figure 12. Predicted Canada Warbler density (males/hectare) under reference conditions (far left) and under disturbed conditions (middle), with red indicating higher densities and blue indicating lower densities. The far right graph represents the difference between the two density maps, with the intensity of red indicating lower densities under disturbance conditions.

For Canada Warbler, forestry and mines/wells had the largest per unit effect on the species' population (Figure 13). Agriculture had a larger cumulative effect due to the large extent of cultivated land.

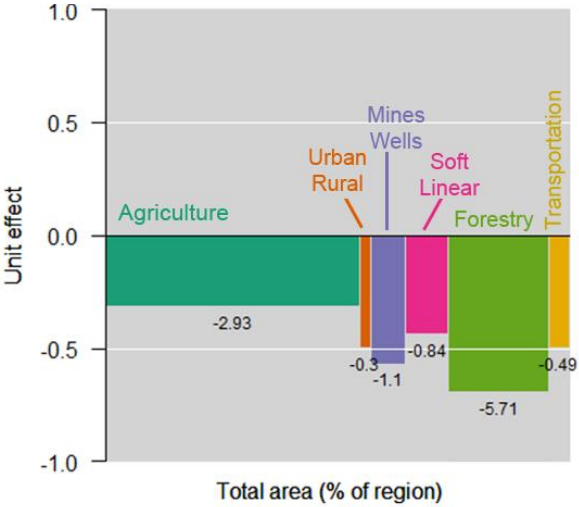


Figure 13. Effects of different sectors on expected abundance (numbers under each bar). Areal extent and unit effect of each sector are indicated by the width and height of bars, respectively. Bar area represents each sector's cumulative impact (unit effect x area of footprint).

When incorporating direct and indirect effects, we found that the indirect negative effect of soft linear features was highest, followed by the direct effect of forestry and agriculture, and the indirect effect of transportation (Figure 14).

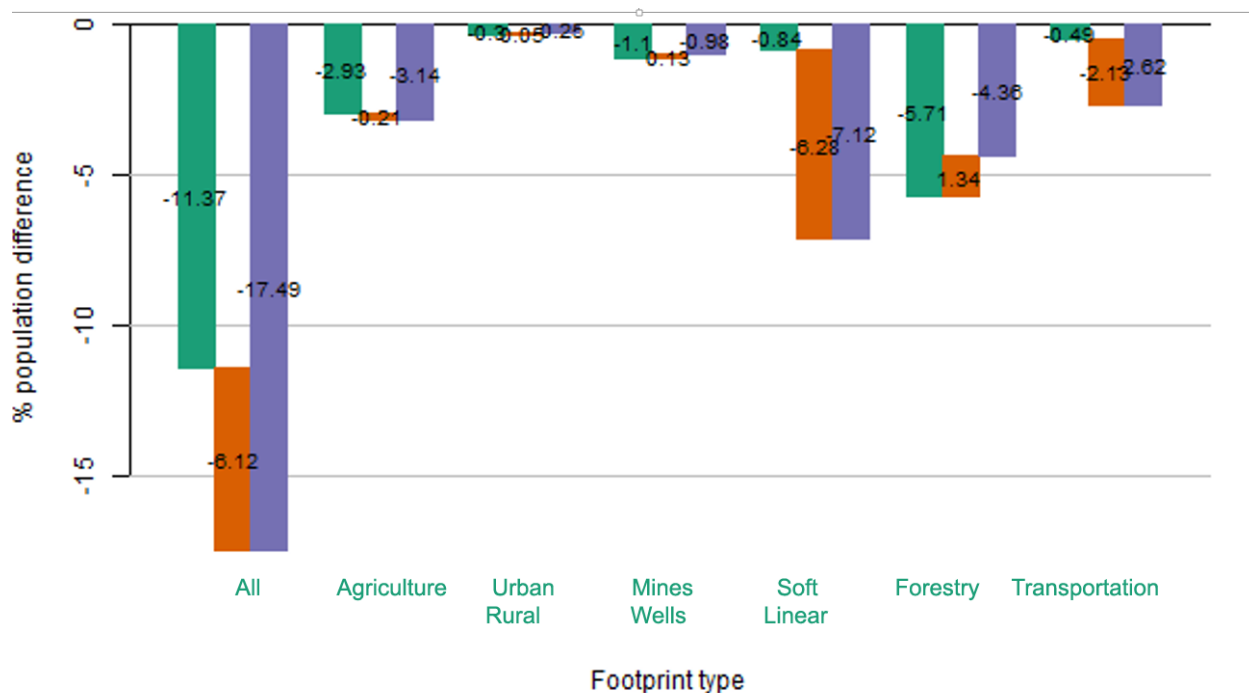


Figure 14. Direct (green) and indirect (orange) effects of different sector types. Combined effects represent the total (blue) effect of a single sector. Numbers represent the percent population difference within the region relative to the total population size predicted using the simulated undisturbed landscape.

This work has been described in detail in a report (Sólymos et al. 2015). Preparation of a manuscript detailing some of this work is underway, with expected completion of an initial draft by January of 2016.

Avian Response to Disturbance at the National Scale

Response of boreal birds to land-use change

In association with Boreal Ecosystems Analysis for Conservation Networks (BEACONS).

Land-use change, including agricultural land conversion, forest management, energy and mining sector activities, and transportation infrastructure, is a major threat to boreal birds. The main goal of this project is to evaluate the effect of anthropogenic disturbances on the abundance of boreal bird species, particularly species associated with late seral forest. Here we describe the project design.

Our first step was to isolate anthropogenic disturbances from recently available data on global forest extent and change from 2000 through 2013 (Hansen et al. 2013). These data allow temporal matching of bird count data with forest condition, but they do not distinguish between natural and anthropogenic disturbances. We therefore derived a new product by removing forest patches affected by fire (the predominant natural disturbance agent in the boreal region) from the disturbance data. Fire records were taken from the Canadian National Forest Database and the Alaska Fire History Database. The result is a database containing

annual records of anthropogenic disturbances occurring between 2000 and 2013 in North American boreal regions.

By combining the anthropogenic disturbance database with the BAM database, we identified bird point-count stations (hereafter “points”) that were within 100 m of a disturbed patch (i.e. “disturbed points”), as well as points that fell within undisturbed forest patches (i.e. “intact points”). From the set of disturbed points, we selected those that were sampled for birds after the forest disturbance occurred. These are our “treatment” points (Figure 15). Points that were either sampled before the forest disturbance occurred or that fell within intact forest patches represent our “control” points (Figure 15).

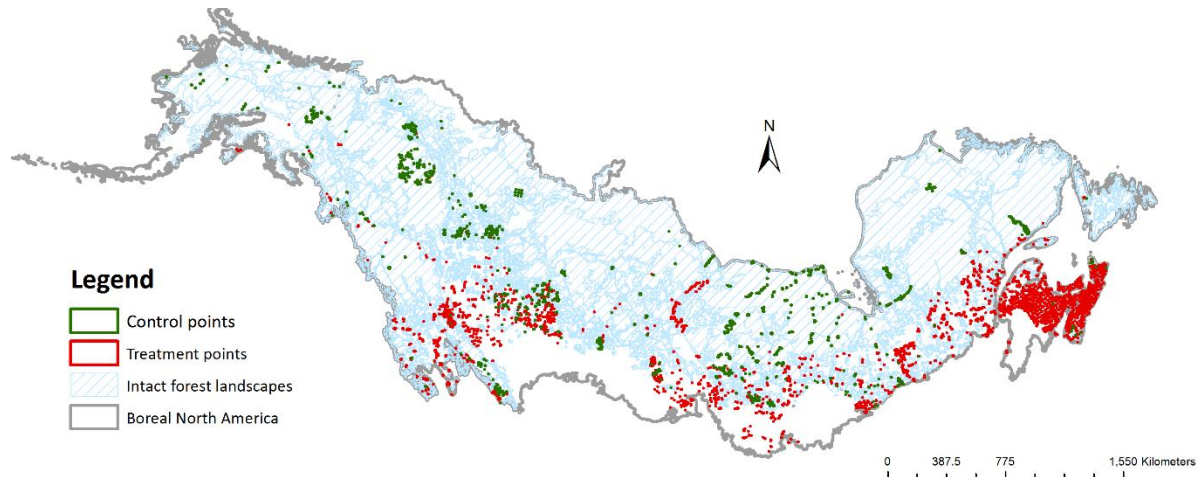


Figure 15. Map showing the distribution of treatment (disturbed) and control (intact) points across boreal North America.

To evaluate the effect of anthropogenic disturbances on boreal birds, we are building statistical models to compare bird densities in treatment vs. control points. These models will include covariates to control for both spatial and temporal heterogeneity, including but not limited to land-cover class, bird conservation region (BCR), year of sampling, and time between sampling and disturbance.

If we find differences between treatment and control points, we will calculate the effect size so we can estimate the loss of bird population over the period 2000-2013, and the anticipated loss if projected industrial development in the North American boreal forest is realized. Future analyses may evaluate the relative effect of different types of anthropogenic disturbance on bird abundance, but this extension requires derivation or development of additional products from existing disturbance mapping efforts.

With these models, we will assess whether previous bird density estimations from BAM (<http://www.borealbirds.ca/index.php/density>) adequately account for the effects of anthropogenic disturbances. If not, our new models will provide the basis to calculate new, more accurate density estimates.

This work is currently in progress, having been delayed by the need to derive our own database of annual, anthropogenic disturbance, as described above. We plan to run models in June, and to have a draft manuscript documenting results by fall 2015.

Avian response to projected changes in climate and landscapes across Alaska and northwestern Canada

In association with the United States Geological Survey (USGS).

The Integrated Ecosystem Model for Alaska and Northwest Canada (IEM) is a dynamically linked landscape modeling framework being developed by the University of Alaska to explore potential impacts of climate change on ecosystems across landscapes in northwestern North America. One of the intended but as yet untested applications of the IEM is to use the model's simulations of future landscapes as inputs into models that evaluate potential impacts of climate change on wildlife populations.

The purpose of this project is to test the IEM for applications to birds by simulating responses of boreal birds to future projections of climate and associated landscape changes. We will use outputs from the IEM in combination with a unique dataset of avian surveys to identify habitats, geographic areas, and bird species that will likely be most vulnerable to projected climate change across the landscape. Results can be used by managers to determine how and where to best allocate scarce resources to preserve the ecosystem services that migratory birds provide. This modeling effort will be conducted by an international research team from Alaska and Canada that has expertise in migratory birds, boreal, subarctic, and arctic ecosystems, and climate modeling. This project is being conducted by Steve Matsuoka, Research Wildlife Biologist with the USGS and PhD candidate with Fiona Schmiegelow and Erin Bayne.

Projecting Alberta boreal bird population responses to climate- and disturbance-driven changes in vegetation composition and age structure

In association with the Biodiversity Management & Climate Change Adaptation project, the Climate Change & Emissions Management Corporation, François Robinne, and Marc-André Parisien.

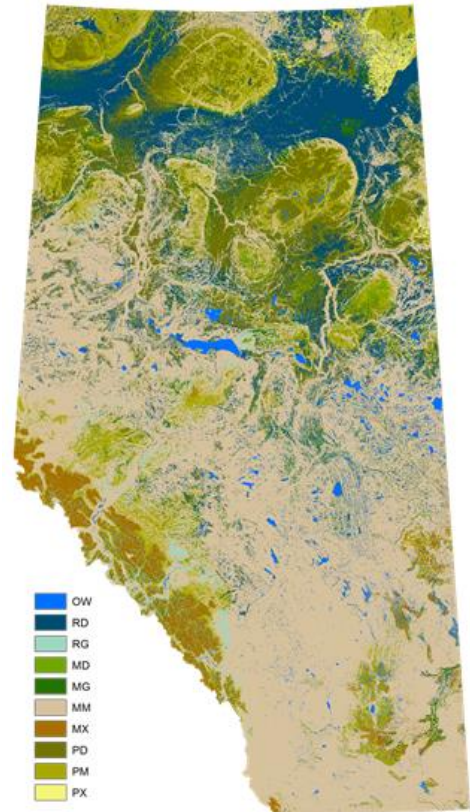
Climate factors are strong predictors of avian distributions at broad spatial scales. However, they may be proximate rather than ultimate drivers, given the importance of local and landscape-level vegetation differences for avian community composition in the boreal forest. There may be a lag in bird responses to climate change if vegetation change is delayed due to successional lags, hydrologic feedbacks, or lack of disturbance catalysts. Alternatively, increased frequency of drought and natural disturbance events may facilitate rapid vegetation change, creating a much younger forest. Climate-induced changes in disturbance regimes may alter vegetation composition and age structure enough to limit suitable habitat availability for some bird species, especially when combined with anthropogenic disturbance. Thus, it is critical to understand decadal-scale dynamics of vegetation succession in response to climate and land-use change.

The purpose of this project is to predict how avian populations may respond to climate change when incorporating vegetation response and anthropogenic disturbance (i.e., harvest). Although such dynamics are complex, first-order approximations based on data-rich regions

such as Alberta may yield insights regarding limiting factors and conservation priorities in upcoming decades.

For the purposes of this project, we assume that avian response to climate change is completely mediated by vegetation. This assumption facilitates comparison with projections based on climate only, and removes the difficulty of disentangling the different effects of climate and vegetation. We will project vegetation change as a function of climate and terrain at a 500-m grid cell resolution, and use the projected vegetation as inputs in existing bird models. This will involve the development of two sets of climate- and terrain-based models: one for vegetation type (overstory + understory) and one for fire return interval.

Figure 16. Terrain- and climate-based predicted moisture/nutrient categories for Alberta. OW = open water, RD = rich/hydric, RG = rich/hyric, MD = medium/hydric, MG = medium/hygric, MM = medium/mesic, MX = medium/xeric, PD = poor/hydric, PM = poor/mesic, PX = poor/xeric.



We will combine predictions from these models for future time periods to develop a simple simulation of vegetation changes in Alberta over the next century, assuming no dispersal limitations and no natural tree mortality (i.e., disturbance-mediated succession only). We will then use these models to address how combined near-term changes in climate, natural disturbance (fire), and anthropogenic disturbance may affect regional avian populations over time, via changes in vegetation.

This work is currently in progress. Models of vegetation (ecosite type) constrained by moisture/nutrient class have been developed based on data from ABMI, Alberta ESRD, Erin Bayne, and Lisa Mahon (Figure 16). Climatic models of fire extent (potential area burned) developed by University of Alberta collaborators François Robinne and Marc-André Parisien are being refined for future projection purposes. We are currently working on linking bird and vegetation models using bird data from the BAM database and ABMI. When models are finalized, vegetation change will be simulated based on projected climate and disturbance (area burned + planned harvest as available) in 30-year increments.

The results will be described in a scientific manuscript, with a first draft expected by March 2016.

Simulating the medium-term impacts of fire, forest management, and climate change on boreal songbird populations

The purpose of this project is to project bird species' distributions and abundances under various scenarios of climate change and protected areas design. This study will use Tardis, a spatial simulation model designed to simulate forest management and fire regime over very large areas (Cumming and Vernier 2002, Krawchuk and Cumming 2011). In past years, it was adapted to read tables of forest resource inventory data extracted from the national CASFRI product that was developed in Steve Cumming's lab with support from BAM (see *Forest Resource Inventory Data*, page 49).

This project is a more elaborate and sophisticated modelling study based on the prototype presented in the 2012-13 annual report (*2.2.2.4 Methods to implement national habitat models in Tardis*). It will involve coupling Tardis with climate change projections, alternate protected areas designs, and specialized bird distribution models optimized for use in Tardis. In effect, this work depends on custom avian models that include climate covariates, forest habitat variables maintained by the Tardis model, and sensitivity to range limits. These are the models described under *Integrated high-resolution models of the effects of climate and forest habitats on the distribution and abundance of boreal songbirds*, page 45, which have not yet been built. However, during 2014-15, considerable background progress has been made:

1. A more detailed outline of the paper and constituent simulation experiments and criteria for selection of bird species to be modelled was written and circulated for comment;
2. Forest management data were acquired and assimilated for New Brunswick and hemi-boreal areas of Québec, which had been excluded in early definitions of the BAM study area;
3. Substantial improvements were made to the underlying forest resource inventory dataset, including numerous bug fixes, the inclusion of updated and markedly improved inventories for Québec and much of Manitoba, and filling in some large data gaps in Alberta, including the Cold Lake Air Weapons Range;
4. The Tardis spatial grid has also been changed to be more consistent with standard downscaled climate grids.

We hope to complete simulation experiments by March 2016, with submission of a manuscript to follow in summer 2016.

Protected Areas Design

Integrating climate change refugia into protected areas planning

In association with the Biodiversity Management & Climate Change Adaptation project and the Climate Change & Emissions Management Corporation.

It is challenging but essential to consider climate change-induced range shifts in protected areas design if species are to be protected in the long-term. The purpose of this project was to evaluate how lags in vegetation response may influence distributional shifts of boreal birds in response to climate change. We also assessed the efficacy of current protected areas to protect boreal birds in the face of this reality.

Specifically, we used forest inventory and avian survey data to generate alternative projections of changes in 53 species' core habitat distributions based on different vegetation lag-time assumptions, rather than just assuming birds would shift to match their appropriate climate niche. We used a seral-stage-modified refugia approach and the Zonation algorithm to identify multi-species boreal conservation priorities over the 21st century. The sensitivity of land rankings to seral-stage affinity and species' weights was assessed to determine the conservation value of the existing protected areas network compared to the Zonation-derived solution for the best protected areas network in the face of climate change.

End-of-century projected changes in songbird distribution were reduced by up to 169% when vegetation lags were considered. Zonation land rankings based on unconstrained climate projections were concentrated at high latitudes, whereas those based on strict and modified refugia scenarios were concentrated in coastal and high elevation areas, as well as biome transition zones, which were fairly consistent over time and species weights. The existing protected areas network covering 14% of the study area was estimated to conserve 12-14% of baseline avian biodiversity across time periods and scenarios, compared to 16-25% for top-ranked Zonation areas. Results suggest there are gaps in the ability of the current protected area network of Canada to protect birds in the face of climate change.

Our primary conclusion was that limits to forest growth and succession may result in dramatic reductions in suitable habitat for some boreal songbirds over the next century. Our seral-stage-adjusted approach provides conservative and efficient boreal conservation priorities anchored around climatic macrorefugia that are robust to century-long climate change and complement the current protected areas network.

Optimization of protected areas will vary under different assumptions about how birds will respond to climate change (Figure 17). The *unconstrained* scenario shows the areas possessing the greatest value to the most species of birds if they track climate change directly and move to their required climate space. The *strict refugia* scenario shows that protected areas options become very limited if birds can't move in response to climate shifts and only persist where the climate remains within the acceptable range of a species. The *modified refugia* scenario accounts for limitations on distributional shifts caused by the availability of suitable habitat between climatically suitable versus unsuitable areas. We feel this intermediate scenario is more likely to represent what might unfold in the face of climate change.

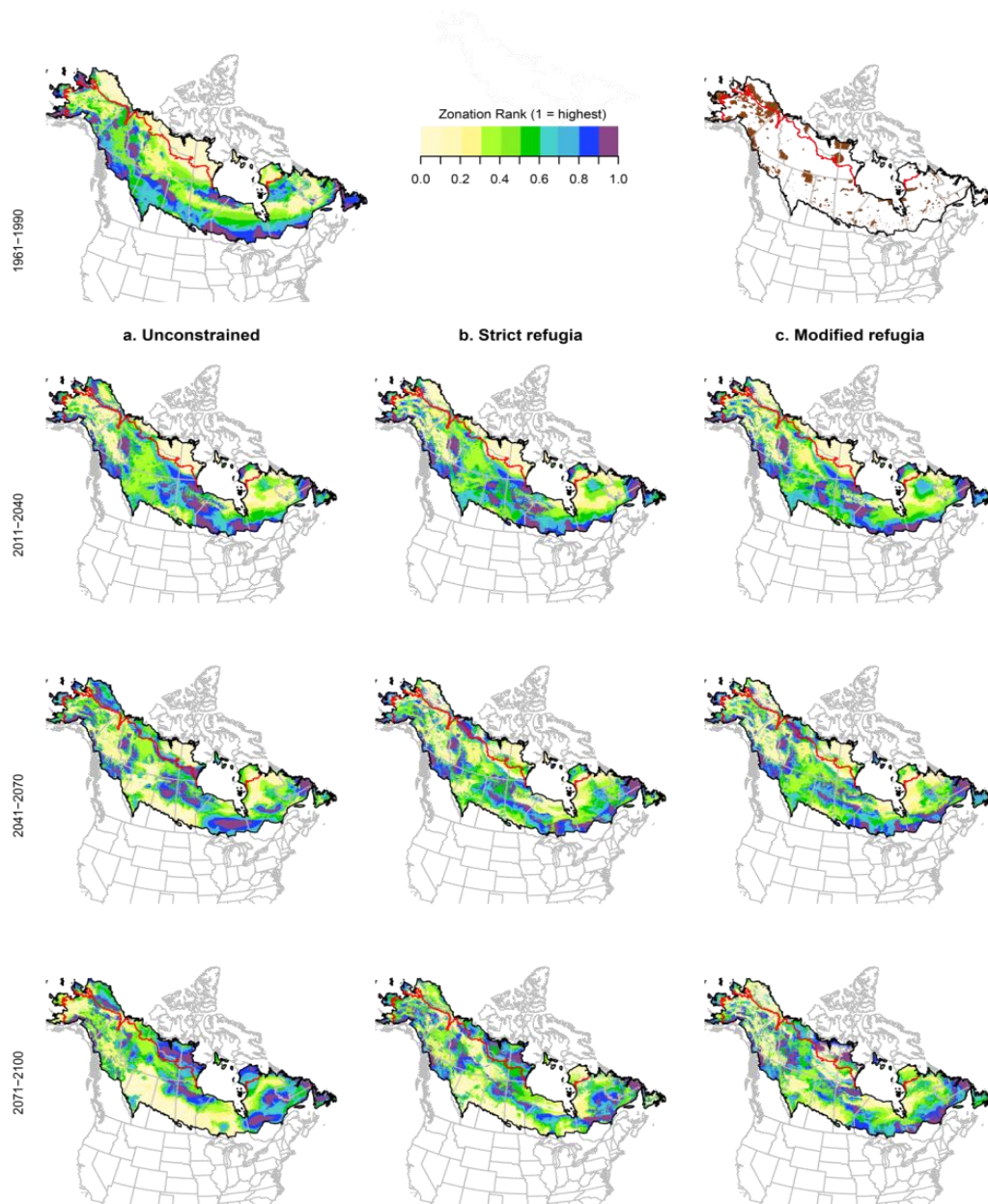


Figure 17. Zonation results (land ranking maps) for 53 species for the current period and three future time periods (2011-2040, 2041-2070, 2071-2100) for three scenarios: (a) *unconstrained* = projected core areas without time lags; (b) *strict refugia* = overlap between future and current core areas; and (c) *modified refugia* = species-specific time lags based on seral-stage habitat associations. Higher Zonation ranks indicate greater value to the most species, suggesting priority areas for protection.

A paper detailing this work was accepted by the journal *Diversity and Distributions*.

Advancing bird conservation in collaboration with the Boreal Ecosystems Analysis for Conservation Networks (BEACONS) Project

In association with the Northwest Boreal Landscape Conservation Cooperative and the Canadian Boreal Forest Agreement.

The objective of this work is to advance boreal bird conservation through application of BAM products to on-the-ground conservation planning efforts in collaboration with the BEACONS Project. As a central element of the Conservation Matrix Model, the BEACONS approach uses biodiversity surrogates in identifying candidate protected areas networks that provide ecological benchmarks and are representative of boreal ecosystems.

In 2014-15, BEACONS advanced the use of BAM products in protected areas design via partnerships with the Northwest Boreal Landscape Conservation Cooperative (NWB LCC; <http://nwblcc.org/>), which includes trans-border planning for Alaska, Yukon and Northwest Territories, and the Canadian Boreal Forest Agreement (CBFA; <http://www.canadianborealforestagreement.com/>), which includes a pan-boreal assessment of existing protected areas and regional conservation planning in BC, Alberta, Saskatchewan, and Manitoba (Figure 18).

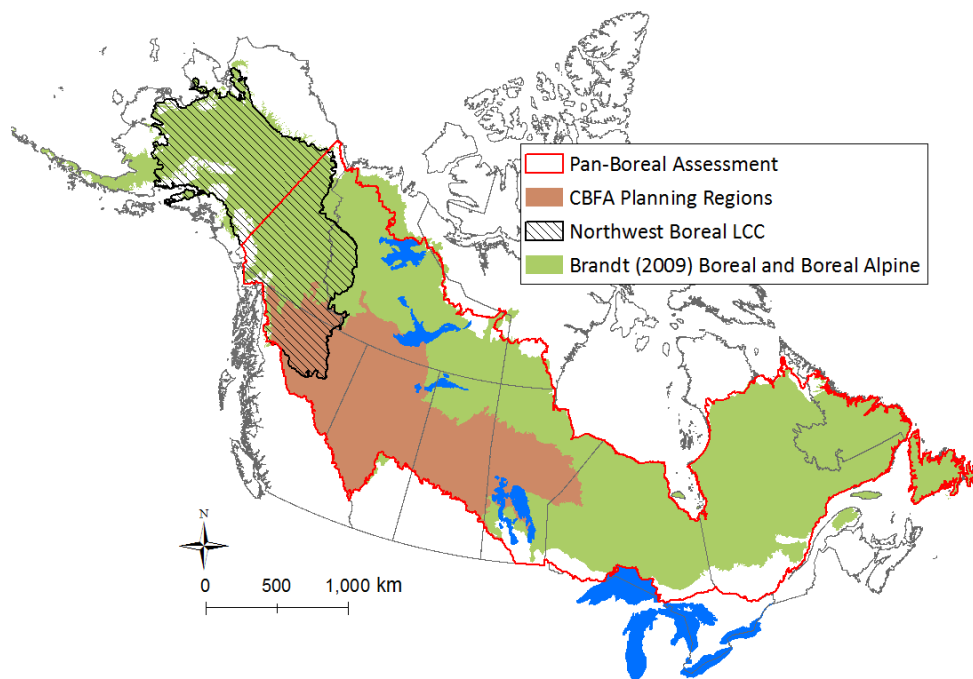


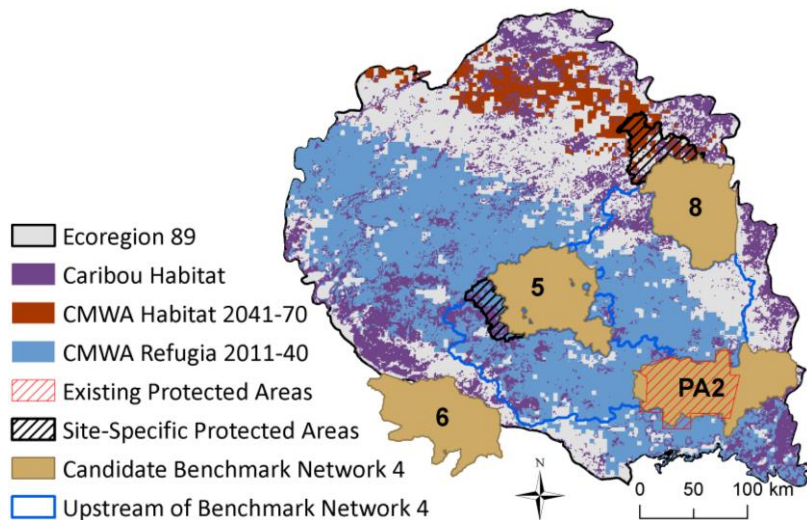
Figure 18. Spatial extent of the Northwest Boreal Landscape Conservation Cooperative (Northwest Boreal LCC) and the Canadian Boreal Forest Agreement (CBFA).

The three products were: (1) Maxent models of predicted bird density (Boreal Avian Modelling Project 2012), (2) climate refugia (Stralberg et al. 2015a), and (3) future core habitat (Stralberg et al. 2015b).

The BAM products have been used to support the conservation goals and protected area objectives for boreal songbird species selected as conservation features of interest, included in selection of benchmark networks, and included in the identification of site-specific protected areas (Figure 19). The results to date have been presented to key partners in government, industry and non-government organizations in Canada and the U.S.

Anticipated next steps include completion and refinement of protected areas work to reflect partner input, expansion of analyses to consideration of lands outside protected area networks, and evaluation of monitoring needs for identified species of interest, in conjunction with implementation of active adaptive management.

Figure 19. A case study completed for ecoregion 89 in Saskatchewan and Manitoba that illustrates the identification of candidate protected area networks that provide for (1) ecological benchmarks and (2) site-specific protected areas to complete the representation of conservation features of interest, including Cape May Warbler (CMWA) climate refugia and future core habitat.



Identifying priority areas in EC Zones of Interest

In association with Tony Turner (EC – CWS, Habitat Section) and the Migratory Birds Zones of Interest project.

EC has initiated a project to identify zones of interest for habitat conservation planning and implementation in Canada. One component is the Migratory Bird Zones of Interest project, which aims to identify the 50% of the boreal region where the Canadian Wildlife Service should focus its conservation attention for priority landbirds. The project will use the Marxan site-selection tool in combination with BAM data products to identify areas of highest species diversity and density, while prioritizing other targets such as habitat connectivity and intactness. BAM is primarily contributing to the project in an advisory capacity, and by providing data products for use in the models and scenario analysis. Initial analyses are slated for completion in summer 2015, with results presented to CWS Migratory Bird and Habitat managers in fall 2015.

Species- vs. ecosystem-based conservation planning

In association with Ducks Unlimited Canada.

Recommendations for protected areas designs will vary with the conservation objective. In a partnered project, PhD candidate Nicole Barker compared species-based methods to ecosystem-based methods of designing protected areas networks. The purpose was to compare networks created using traditional waterfowl habitat-based methods versus those created using the BEACONS ecosystem-based approach.

In this preliminary work, candidate networks of four area targets were created within the eastern and western boreal regions of Canada. Waterfowl-based networks were built to solely prioritize areas of highest waterfowl abundance. Ecosystem-based networks were built using standard BEACONS parameters, so that individual networks were benchmarks and networks were ranked based on representation of biodiversity surrogates. Performance of all networks was assessed in terms of waterfowl protection and ecological representation.

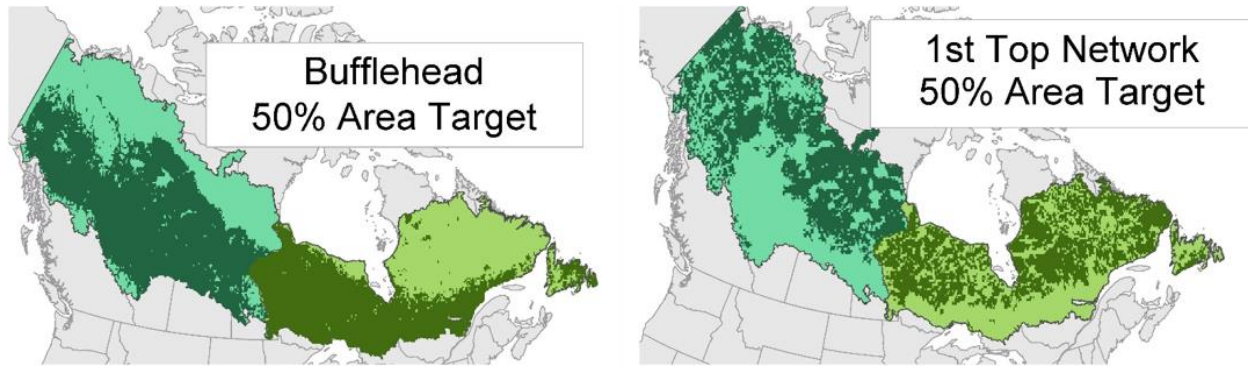


Figure 20. Potential protected areas networks built to contain 50% of the eastern and western Canadian boreal regions. Left: Networks were built to preserve the 50% of the land containing the most Bufflehead pairs. Right: Networks were built using BEACONS methodology to achieve benchmarks of minimum area, intactness, and connectivity that represent the biodiversity of the overall study area.

Preliminary results indicate that the waterfowl habitat approach often prioritized land in the southern boreal region, while the BEACONS approach prioritized the northern boreal region, likely due to the intactness criterion (Figure 20). The waterfowl approach protected a larger proportion of the waterfowl population than did the BEACONS approach; however, the BEACONS approach protected waterfowl proportionately to network area, and achieved vastly superior ecological representation.

Extensions to this work will assess more realistic, intermediate scenarios, and will inform how species models are incorporated into application of the BEACONS approach.

SPECIES AT RISK AND CRITICAL HABITAT

Methods to Support Critical Habitat Identification for Species at Risk

Recovery planning for Threatened Species at Risk that are widespread and relatively abundant but declining represents a challenge for the identification of critical habitat. This fiscal year, BAM continued to support recovery efforts for species at risk through predictive models and through exploration of methods to support EC's efforts in identifying critical habitat, as defined in the Species at Risk Act.

Analytical framework to inform critical habitat identification

In association with Environment Canada.

The federal Species at Risk Act defines critical habitat as the habitat necessary for the survival or recovery of a wildlife species listed nationally. Identifying critical habitat for species at risk is an important regulatory responsibility, but our knowledge of species-habitat relationships is generally limited to broad habitat types and based on occupancy data. This is especially true for forest birds with relatively large Canadian breeding ranges (e.g., boreal and hemi-boreal regions). Other issues for most of these species across their breeding range are: (1) potential differential habitat selection among populations; (2) lack of consistent understanding of effects of human land-use; and (3) uncertainty regarding their northern range limits. This non-exhaustive list of issues constrains our ability to identify critical habitat, produce effective recovery documents, and implement reliable spatially-explicit action plans.

In 2013-14, under contract, BAM produced a technical report to EC summarizing habitat models and maps of predicted density and related prediction uncertainty for three species at risk in Canada (Canada Warbler, Common Nighthawk, and Olive-sided Flycatcher; Haché et al. 2014). Results informed Recovery Strategies for these species released in 2014-15 (Environment Canada 2015a, 2015b, 2015c).

The purpose of the next stage of this project is to further the models described in the previous report by addressing feedback provided on the Haché et al (2014) report.

This work is currently in progress. A recent update of the Avian Database has been executed (see *Avian Database and Breeding Bird Survey (BBS) Database*, page 46), and new statistical offsets are being calculated. Biophysical data have been extracted for each avian point count location. We anticipate significant progress in 2015-16.

Identifying preferred habitat via variation in species' density over time

As migratory birds reach the breeding grounds at the beginning of the breeding season, they are assumed to preferentially select the best available unoccupied habitats. Once optimal habitats are filled to their carrying capacity, individuals may settle in suboptimal habitats. Suboptimal habitats will therefore have relatively low density when the overall population size is low and higher density when populations are high. Meanwhile, densities in high quality habitats are expected to remain near carrying capacity in all years, and densities in very low quality habitats or hostile environments are expected to remain low to 0 in all years. Therefore, we expect to see a unimodal pattern of inter-annual variation in relation to habitat quality, with low variation in the highest and lowest quality habitats.

The purpose of this project is to assess the feasibility of using inter-annual variability in mean density as an indicator of preferred habitat. Here we present an example using data collected in the Liard Valley (S. Cumming, unpublished data; Machtans et al. 2014) to demonstrate the potential of this approach. The temporal variability, as indicated by the difference between minimum and maximum density among six years of sampling within three habitat types was smallest in the habitats with highest relative abundances (Figure 21), as expected.

We will conduct a comprehensive analysis of this kind, using a more complete sample of repeated measurements currently in the BAM database. We expect to complete analyses by December 2015.

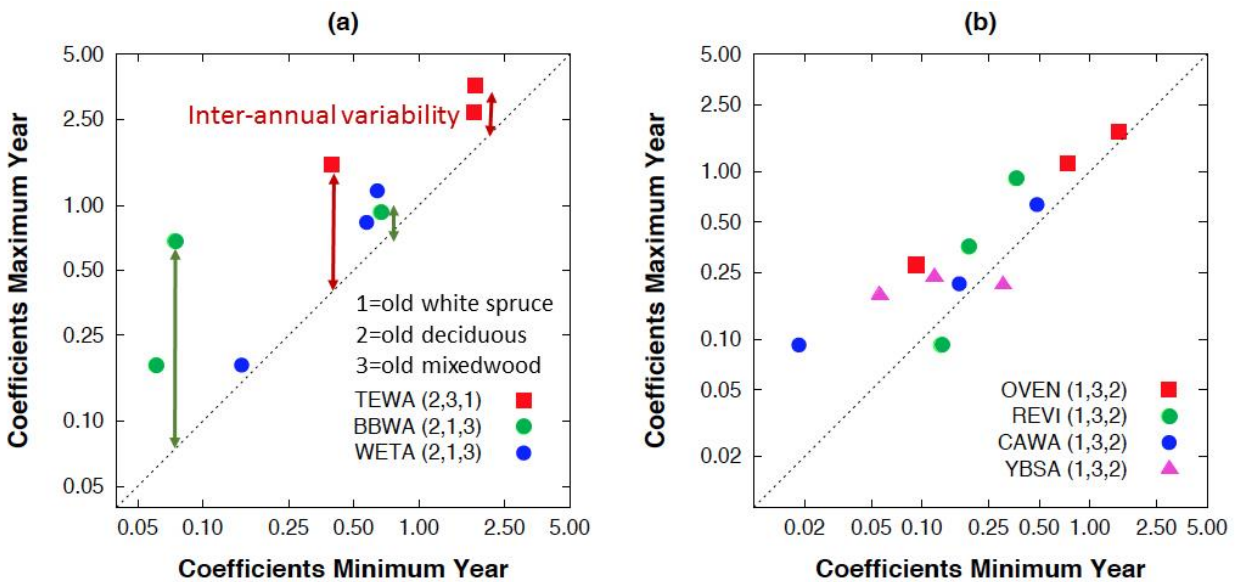


Figure 21. Similarity between estimated minimum (x-axis) and maximum (y-axis) annual density over a time series from the Liard Valley for seven species. Colours indicate different species: Tennessee Warbler (TEWA), Bay-breasted Warbler (BBWA), Western Tanager (WETA), Ovenbird (OVEN), Red-eyed Vireo (REVI), Canada Warbler (CAWA), and Yellow-bellied Sapsucker (YBSA). Densities were measured in three different habitats (1=old white spruce, 2=old deciduous, 3=old mixedwood); ranking of habitats in terms of relative abundance (from left to right on the x-axis) are indicated in parentheses for each species).

Regional Models for Species at Risk

Maritime models for species at risk and comparison with national models

In association with Dalhousie University and Parks Canada.

At the national scale, BAM has used point count data to generate habitat models for Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk (Haché et al. 2014). While national analyses provide predictions of species' densities over the entirety of a species' range, finer-scale regional analysis is important to determine ecological relationships and validate ecological assumptions made for national scale models. This project uses point count data, biophysical data, and the same methods as national models to build habitat models for Canada Warbler (CAWA), Olive-sided Flycatcher (OSFL), and Rusty Blackbird (RUBL) within the Canadian Maritimes.

The objectives of this project are to: (1) Identify the biophysical attributes characterizing areas of low and high densities of each species; (2) estimate population size; (3) map predicted density estimates (and their uncertainty); and (4) compare these estimates and mapped products to those developed by at the national level for CAWA and OSFL (Haché et al. 2014).

Regional models are being constructed using the same methods as the national models, to permit comparison of estimated population size and spatial distribution of the species. This work is being conducted by PhD candidate Alana Westwood (Dalhousie University), and is currently on-going. The regional scale of the work permits finer-scaled biophysical predictors such as forest connectivity and canopy structure; available datasets have been identified and are currently being extracted for model-building.

Contribution of protected areas to habitat for three species at risk

In association with Dalhousie University and Parks Canada.

For national parks to meet their mandate of preserving ecological integrity, it is important to assess their contribution to habitat for species at risk. The objective of this project is to determine the contribution of existing protected areas in Canada to available high-quality habitat for CAWA, OSFL, and RUBL.

Maps of predicted densities generated from regional models (see *Maritime models for species at risk and comparison with national models*, page 37) will be used to determine if protection status of a site is a significant contribution to population size, and to determine if predicted densities within National Parks and other protected areas are higher than unprotected areas. Comparison between protected and unprotected will be completed by assessing densities within protected areas and comparing them to randomly selected unprotected areas of the same size using correlation and Kappa statistics. This work is being conducted by PhD candidate Alana Westwood, and is awaiting completion of regional models.

Understanding declines of Olive-sided Flycatchers and Western Woodpeewees in the northwestern boreal region

In association with Yukon College and the Yukon Research Centre.

Both Western Wood-Pewee and Olive-sided Flycatcher have experienced widespread declines over the past 40 years. The purpose of this project is to investigate climate and habitat factors affecting the abundance and distribution of these species in the northern and western boreal regions, with special reference to naturally-disturbed habitat (mostly fire), small water bodies, and linear anthropogenic disturbances. This work is informed by previous modelling exercises in identification of critical habitat for Olive-sided Flycatcher, and designed to determine ecological relationships and validate ecological assumptions made for the national scale model. The BAM Dataset will be augmented with targeted regional sampling in the Yukon.

This work is currently in progress; covariate datasets have been identified and data are currently being acquired and manipulated to prepare for model-building.

A second component of this work examines breeding phenology of these species in relation to seasonal variation in insect abundance, as a test of potential mismatch in timing of breeding relative to climate-induced changes in food availability. Preliminary results suggest that peak energetic demands during breeding coincide temporally with peak abundance in large insects (Figure 22), indicating that the mis-match hypothesis may not be a factor in population declines.

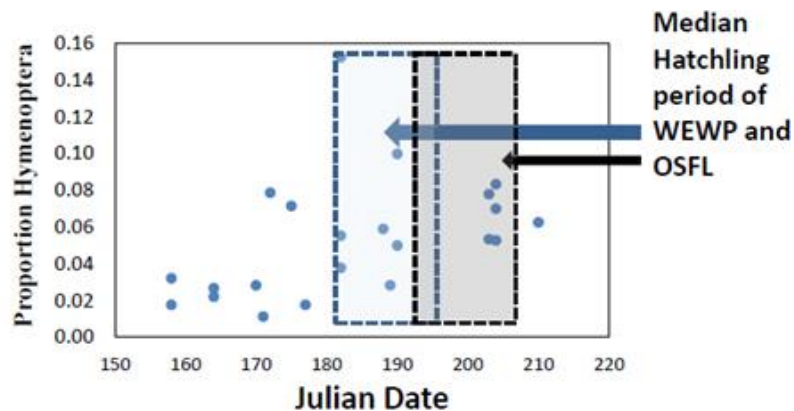


Figure 22. Insect abundance in relation to median hatchling periods of Western Wood-pewee (WEWP) and Olive-sided Flycatcher (OSFL).

Both components of this project are part of Tara Stehelin's (Yukon College) PhD thesis.

ANNUAL LIFE CYCLE ANALYSIS

Initiating Annual Life Cycle Research

To understand the causes of avian population declines, we must consider the threats faced on the wintering grounds in addition to those on the breeding grounds. We recently began exploring the potential of the BAM dataset to identify factors other than those on the breeding grounds that might be driving boreal bird declines.

Review of wintering and breeding ground connections

In association with Keith Hobson (EC – S&T Branch) and Steve Van Wilgenberg (EC - CWS) and Pete Marra (Smithsonian Migratory Bird Center).

In order to better understand the relative influence of wintering and breeding ground conditions on the annual life cycle of boreal-breeding songbirds, we need better information on linkages between breeding and wintering ground areas for individual species, i.e., migratory connectivity.

The purpose of this work is to synthesize and summarize current knowledge on linkages between wintering and breeding grounds. These linkages will be used to improve model specification for models of inter-annual variability, as described in the next section. We have initiated this work in three components.

First, have begun assembling and synthesizing migratory connectivity data for the Ovenbird as a model species. BAM team members have on-going work using stable isotopes, geolocators, and genetics to link breeding and wintering ground areas. This work is in progress and we have compiled these data and assigned linkages between wintering and breeding ground regions based on a global ecoregional classification.

Second, we are collaborating with Keith Hobson and Steve Van Wilgenburg of EC to synthesize information on links between breeding and wintering areas on evidence from geolocators, band recoveries, and stable isotope analyses. Our plan is to select a subset of 5-10 boreal forest-breeding, long-distance migrant species to be selected according to three criteria:

1. adequate space/time replication within the BAM database;
2. several geographically separate "subpopulations" with distinct and known breeding and wintering grounds;
3. documented connectivity between breeding and wintering grounds.

This work is currently in progress. We aim to select species in summer 2015, and then initiate further communication among the working group and collaborators in the following months.

Third, we are supporting the Smithsonian's migratory connectivity project in collaboration with Peter Marra. This project includes an extensive geolocator and GPS transmitter program on a wide variety of bird species including but not limited to the Canada Warbler, Common Nighthawk, and Olive-sided Flycatcher. BAM data are being used to identify potential capture locations in 2015-16.

Disentangling the roles of breeding and wintering ground climates on annual boreal bird abundance

In association with the Biodiversity Management & Climate Change Adaptation project and the Climate Change & Emissions Management Corporation.

The purpose of this project is to explore the capacity of the BAM dataset in understanding annual variation in bird populations from a full life cycle perspective. Thus far, we have conducted preliminary analyses using the Ovenbird as a model species.

Due to the ad hoc nature of the BAM avian dataset, we first obtained annual mean density estimates for each 0.5-degree cell surveyed within a given year, corresponding with Climatic Research Unit (CRU) gridded climate data. To derive these estimates, we restricted our data to point count locations within landcover classes representing preferred Ovenbird habitats, i.e., mixedwood and deciduous forest. Using this filtered dataset, annual density estimates were obtained by fitting separate Poisson GLMs for each year from 1993 to 2009, with grid-cell ID as a fixed effect, using point-specific density offsets to account for discrepancies in site and survey conditions, as well as count radius and duration. These annual models were used to predict mean density for each grid cell and year surveyed, within suitable habitats.

We developed generalized linear mixed models of annual density based on local climate variables (monthly precipitation and monthly minimum temperature) and global climate indices obtained from NOAA (seasonal PDO, NAO, and AMO) calculated for a 12 month period extending from July of the previous year to June of the survey year. We evaluated monthly local variables, as well as seasonally aggregated global indices, ensuring that highly correlated variables were not simultaneously considered as candidate variables. We evaluated the influence of each climate variable in eastern (Ontario and east) and western regions (Manitoba and west), and compared local and global models in terms of AIC and percent deviance explained.

With this preliminary analysis, we found that very little variation in mean annual Ovenbird density was explained by local or global climate metrics (~1%). Given the large sample size, we did detect some signal of climate response, which differed by region. In the East, we found local climatic variables to be more explanatory of annual variation in Ovenbird density than other variables tested. In the west, global climate indices were more predictive.

The relatively weak results thus far lead us to two primary conclusions, which influence our next steps:

First, variables representing natural and anthropogenic disturbance events may be more explanatory than climate variables. Furthermore, other local climate variables such as cumulative, multi-year moisture indices or extreme weather events may be more predictive of local density. Therefore, we will explore other cumulative metrics such as the Palmer drought severity index or soil moisture index. We will research storm events, but to our knowledge the types of products available for the U.S. through NOAA (e.g., severe weather inventory, <http://www.ncdc.noaa.gov/swdi/#Intro>) are not available for Canada.

Second, more specific wintering ground climate metrics are needed. Given the large differences in responses to global climate indices among eastern and western boreal regions, we suspect that density fluctuations vary greatly among populations, and would be more easily identifiable with more refined climate inputs that account for known migratory connectivity patterns. Therefore, we have begun compiling available information on migratory connectivity, starting with Ovenbird, to partition breeding and wintering grounds appropriately for analysis (see *Review of wintering and breeding ground connections*, page 39). We will calculate temperature and climate anomalies separately for each wintering region, and models will incorporate any known genetic or migratory structure of breeding populations. New models will also be based on the most updated version of the BAM dataset, and will include more recent bird and climate data (through 2012).

We plan to conduct further exploratory analyses within summer 2015. We anticipate completion of preliminary results by December 2015.

Threats to Olive-sided Flycatchers and Western Wood-pewees on wintering grounds

In association with Yukon College and the Yukon Research Centre.

The purpose of this project is to identify potential threats to Olive-sided Flycatchers and Western Wood-pewees on both the breeding and wintering grounds. The first step is to identify wintering grounds and migratory patterns for these species. This work is part of the PhD thesis of Tara Stehelin, and is being conducted in collaboration with researchers in Alaska and possibly the Northwest Territories. The next steps are to deploy geolocators on Olive-sided Flycatchers breeding in the Yukon, to identify migratory patterns. Isotopic analysis will be used to help identify wintering grounds. The final product of this work will be a manuscript, with anticipated completion of March 2017.

AVIAN ECOLOGY AND HABITAT SELECTION

Range Delineation

Conservation of species requires knowledge of the extent of their breeding ranges. Range maps of North American bird species are housed by Bird Life International (BirdLife International and NatureServe 2012). In some cases, these maps do not agree with all species' observations within the BAM Avian Database. BAM is well-positioned to assist in

updating current range maps using standardized methods and survey data from across Canada.

One major goal is to develop a systematic, model-based method to delineate species' ranges based on model predictions of species' densities. Exploratory work has been conducted on both waterfowl and songbirds, as described in *Delineating breeding ranges of waterfowl*, page 42 and *Delineating breeding ranges of boreal songbirds*, page 44. The second goal is the outcome of the application of this model-based method: the delineated ranges themselves, which will incorporate the most comprehensive and up-to-date information on species distributions available. Delineated range limits of boreal-breeding birds will inform conservation planning and recovery strategies for species at risk. A third goal is to incorporate species ranges into species distribution and abundance models, to calibrate the models and correct for spurious correlations with non-causal environmental variables. This last component is described in *Integrated high-resolution models of the effects of climate and forest habitats on the distribution and abundance of boreal songbirds*, page 45.

Delineating breeding ranges of waterfowl

In association with Ducks Unlimited Canada.

In a partnered project, Nicole Barker (PhD candidate with Steve Cumming) tested several methods to delineate species' breeding ranges from maps from species abundance models (Barker et al. 2014). The purpose of this project was to identify a standardized method for delineating species ranges from continuous maps of predicted density. While her thesis focused on waterfowl, the methods explored should be applicable to songbirds as well.

Delineating a species' range from a continuous map of species density requires the selection of a density threshold to separate presence (inside the range) from absence (outside the range). Barker evaluated 13 *a priori* thresholds, such as the mean species' density, the area containing 75% of the population, and others. She evaluated the performance of metrics by calculating the agreement between observed presences and absences from the Waterfowl Breeding Population and Habitat Survey and the hypothetical range map created from each threshold. No single *a priori* threshold performed well across all 17 maps considered (Figure 23).

Range maps were therefore created using the optimum density threshold for each species. Agreement with between actual species' observations and theoretical range maps was systematically calculated for many (~10-50, depending on the species) potential density thresholds. The density value producing the best agreement was used as the threshold. The species' range was created from this threshold such that all densities above that value were considered within the range; all densities below that value were considered outside the breeding range (Figure 24). Range maps for all 17 species were created for use in her thesis research.

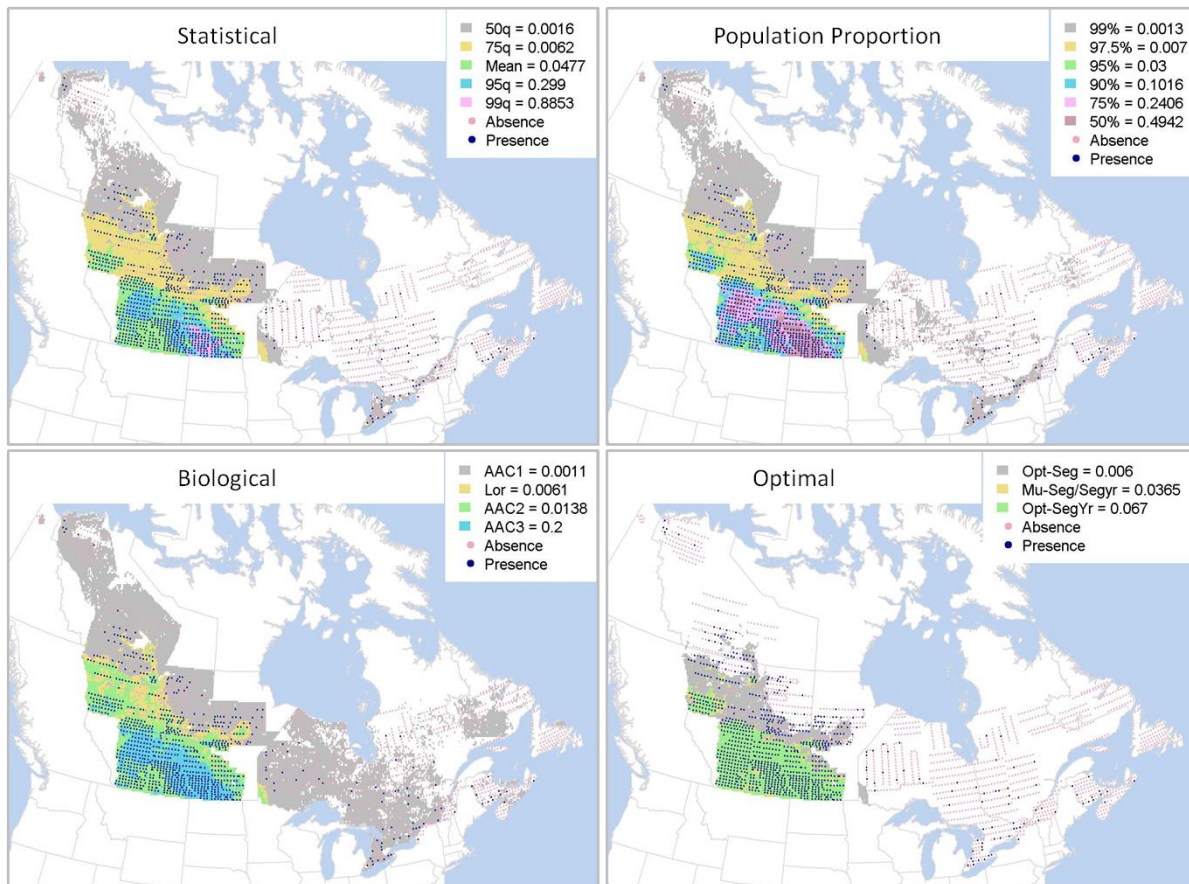


Figure 23. Potential Blue-Winged Teal ranges delineated from predicted density surfaces using various thresholds. Coloured areas indicate the ranges delineated by a particular threshold. Smaller ranges are nested within larger ones, so for example, the 90% population range (in blue) includes the 75% population range (in pink). Points indicate the centroids of survey segments, and are coloured to represent observed presences and absences. The ideal range should contain all blue points and no pink points.

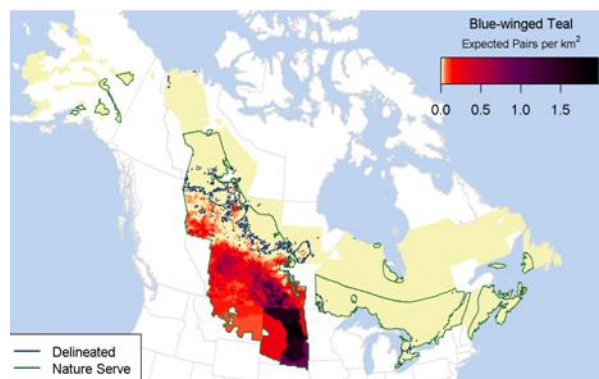


Figure 24. Breeding ranges of the Blue-Winged Teal. The NatureServe range is shown in green while the delineated range is shown in blue.

Next steps involve collaboration to develop standardized methods for both waterfowl and songbirds. A manuscript describing the synthesized results is anticipated for fall of 2016.

Delineating breeding ranges of boreal songbirds

Several methods for creating binary maps from continuous maps of predicted density have also been explored for songbirds. Methods explored include using the overall mean across the map, using the tangent to the Lorenz Curve of species densities, and converting densities to probabilities of occurrences. The advantage of this last approach is that standard methods already developed for delineating species' ranges from probability of occurrence maps can then be applied.

The conversion from density to probability is achieved by calculating the "probability that at least one individual occurs" within a given grid cell, based on species' densities. One challenge associated with this method is the scale at which the conversion takes place, since the same underlying density can produce different probabilities depending on the scale used. Different spatial scales for which probabilities are estimated will yield different range maps for the same probability threshold (Figure 25).

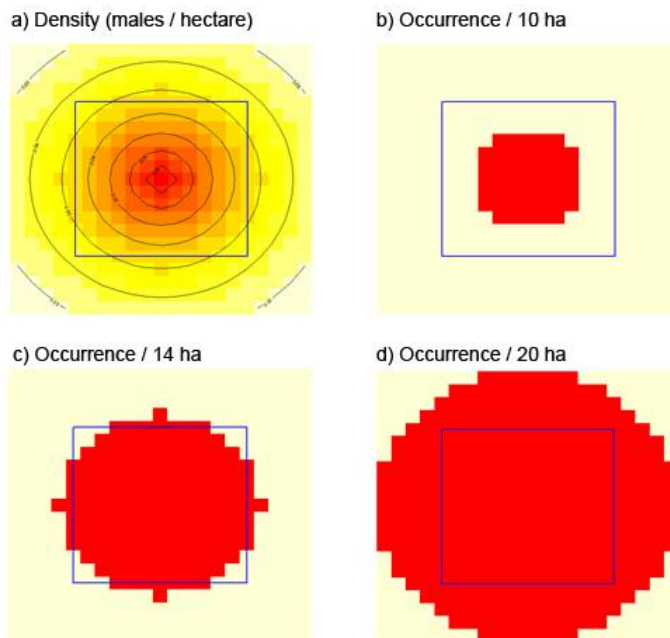


Figure 25. Potential ranges (red circle in b, c, and d) delineated from predicted density (a), in comparison with the actual range (blue square). The scale used affects the size of range, based on a given probability threshold (e.g., 0.5) because the probability of at least one male occurring within 10 ha is smaller than the probability of at least one male occurring within 20 ha.

This work is currently in progress and we expect anticipate significant progress in 2015-16.

Evaluating BAM models against independent data

The large recent growth in use of eBird (and to a limited extent, other citizen-science projects) to digitally archive species occurrence locations provides an important new resource to be mined for modelling and prediction purposes. Given the limitations of these data for density estimation, we will focus on using them to evaluate current distribution predictions used to develop climate-change projections, as well as those emerging from new range delineation efforts. We will use standard approaches to evaluate the sensitivity and specificity of predictions by bird conservation region, restricting our validation data to surveys that were intended to record all species present. Results may lead to the incorporation of eBird data into range delineation methods described above, using the absence information in particular

to help identify northern range margins. This work depends on the completion of range delineation work described above, and thus significant progress has not been made during this fiscal year.

Improved Habitat Models

National models to predict Canadian population sizes for boreal songbirds

In 2013-14, BAM developed an approach to model habitat associations and population sizes for species at risk (see *Analytical framework to inform critical habitat identification* page 36). In 2014-15, we advanced the approach, and it was used to build models for species within the Alberta oil sands region (see *Cumulative impacts of anthropogenic disturbance in the Alberta oil sands region* page 23).

The purpose of this project is to integrate the approach with other BAM projects, with the eventual goal of estimating the Canadian population size for all species modelled by BAM (80 songbird species). The first step is to refine and finalize the approach for the Canada Warbler (see *Analytical framework to inform critical habitat identification* 36). The second step is to apply the method to all species at national scale.

This work is currently in progress. A recent update of the Avian Database has been executed (see *Avian Database and Breeding Bird Survey (BBS) Database*, page 46), and new statistical offsets are being calculated. Biophysical data have been extracted for each avian point count location. We anticipate significant progress in 2015-2016.

Mapping wet areas to improve regional models of boreal landbirds

In association with Roberta Newbury (post-doctoral fellow with Erin Bayne) and NSERC CRD.

The purpose of this work is to determine improvements in predictive avian-habitat models by including information from wet areas mapping. The specific objective is to determine if wet areas mapping improves predictive capacity for modelling boreal bird abundance as well as determining the mechanism for this pattern (i.e., increased shrub density in wetter areas).

A draft manuscript is currently in preparation with anticipated completion of summer 2015.

Integrated high-resolution models of the effects of climate and forest habitats on the distribution and abundance of boreal songbirds

One challenge associated with purely correlative models of species abundance is extrapolation. Predictions outside the study area and temporal forecasts may be erroneous if the environmental factors identified as important in species distribution models are not in fact the determinants of abundance.

The purpose of this project is to build improved models of avian abundance which may be informative about causal factors in abundance, especially with respect to range limits. Zero-inflated (ZI) count models (Poisson and Negative Binomial) are currently being explored for this purpose.

In ZI models, the occurrence process is modelled using the zero-inflation part of the model, which yields delineations of species' ranges. The abundance process is modelled using the count part of the model, and can be used to describe habitat associations within the range. Different environmental predictors can be used in the different parts of the model; regional or climatic covariates can be used for the distribution process, while land cover variables can be used for the abundance process. These models can be computationally demanding, which explains why correlative models are more common. However, a computationally efficient conditional likelihood framework described by Péter Sólymos (Sólymos et al. 2012) is expected to yield reliable parameter estimates.

This work is currently in progress. Next steps include building trial models for species of interest, including species at risk such as Canada Warbler, but also those with distinct longitudinal range limits that may not be accurately characterized by existing correlative models. Variants of these new models will be used within the Tardis landscape simulator to forecast the effect of changes in habitat supply and climate change on species distribution and abundance (see

Simulating the medium-term impacts of fire, forest management, and climate change on boreal songbird populations, page 30). We expect initial models to be completed in fall 2015. Assuming that the procedure appears to be reliable, models for a more complete set of species will be developed by March of 2016.

DATABASE MANAGEMENT AND OUTREACH

Maintenance of Avian and Geospatial Databases

Avian Database and Breeding Bird Survey (BBS) Database

BAM Avian Database – We updated the BAM Avian Database to Version 4. This update included new data and fixes to known errors or missing values from previous versions. Several projects were added, increasing the number of sampling locations, events, total bird observations, and spatial coverage (Table 3 and Figure 26).

Table 3. Contents of Version 4 of the BAM Avian Database and Version 3 of the BBS Database, in comparison with the previous versions.

	BAM		BBS	
	V4 (2015)	V3	V3 (2015)*	V2
Projects	135	115	All of the Canadian BBS routes plus Alaska and some of the northern US routes.	
Sampling Locations	146,433	129,361	65,609	59,564
Sampling Events	251,977	223,540	605,689	513,468
Total Bird Observations	2,419,207	2,107,048	4,429,705	3,465,075

*Note that the versions for BAM's Avian Database and BBS database are different because we began maintaining the BBS database later than the original BAM Avian Database.

BAM's BBS Database – We updated the BAM version of the BBS Database to Version 3. This update included location data from the BBS office, which allows us to correct location data missing from Version 2. This update also increased the number of routes sampled and include data from more recent surveys 2012 and 2013 (Table 3 and Figure 26).

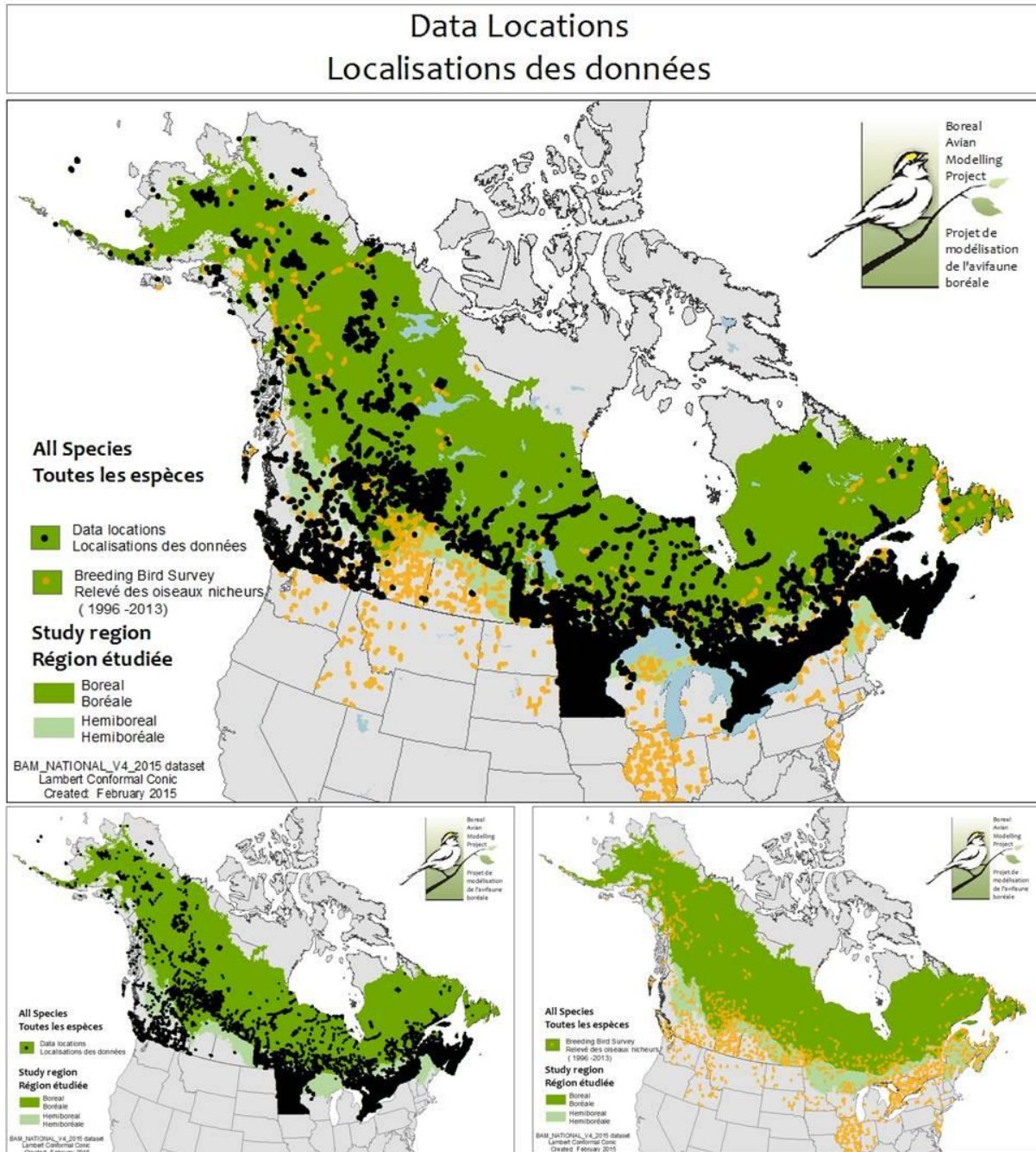


Figure 26. Locations of point count data. The black dots represent the BAM Avian Database (Version 4); orange dots are Breeding Bird Survey locations (Version 3). The two surveys are shown independently in the smaller maps to aid visualization in point-dense regions.

Estimation and integration of new offsets – The analysis of large datasets of avian point count surveys compiled from different projects is hindered by a lack of standardization across various methods used. To accommodate the resulting heterogeneity, BAM created models to account for different point count methods and detectability of birds (Sólymos et al. 2013). The result is project-, station-, visit-, and species-specific statistical offsets which are appended to the Avian Database and used in subsequent analyses. To update Version 4, statistical offsets must be recalculated to account for the new data. We expect this work to be completed by the end of June 2015.

Data from automated recording units (ARUs)

In association with ABMI, JOSM, and NSERC CRD.

Data from automated recording units (ARUs) are in some ways similar to point count data, but there are some key differences. For instance, ARUs conduct more sampling throughout the day, can be longer duration than most point counts, and the bird observations are not associated with particular distances. Further, sometimes the data processed by visual inspection or automated recognition instead of listening, depending on the study (see *Automated Recording Units (ARUs)*, page 17).

In 2013-14, we started including data from ARUs into the BAM Avian Database. The data from the Ecological Monitoring Committee for the Lower Athabasca (EMCLA) project is acting as the test case. We have built in quality-control flags to indicate these data as being ARU methods. We will continue to work on the difference in the sampling and data collection methods for this data versus traditional point count methods (see *ARUs statistical methods and integration with conventional point counts*, page 18). In the meantime, we expect to begin soliciting ARU data from data partners within this coming fiscal year.

Geospatial Database

Two additions to the BAM Geospatial Database were executed in the 2014-15 fiscal year.

To improve boreal-wide avian models, 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).

We also included the Global Forest Watch Forest Loss layers. This layer is used for both national models explicitly testing for effects of disturbance (see *Response of boreal birds to land-use change*, page 26) and within national density models to account for disturbance (see *Analytical framework to inform critical habitat identification*, page 36).

Forest Resource Inventory Data

In association with John Cosco (Timberline Forest Inventory Consultants), Graham Stinson (Pacific Forestry Centre, NRCan), BEACONs, Canadian Foundation for Innovation, Geomatics for Informed Decisions Networks of Centres of Excellence, NSERC, NRCan, EC, and the Foothills Research Institute.

Considerable progress was made on CASFRI v4 (Figure 27). There were numerous important bug fixes related to the classification of non-productive forest and of non-forested vegetated areas. Major updates were obtained from Manitoba and Quebec with improved canopy species attributes. This should markedly improve the discriminatory power with respect to avian species habitat selection in these areas. Notably, the new Quebec inventory standards are much more commensurate with those common in western Canada than was the case; this should increase our ability to detect differences in habitat selection as between eastern and western Canada.

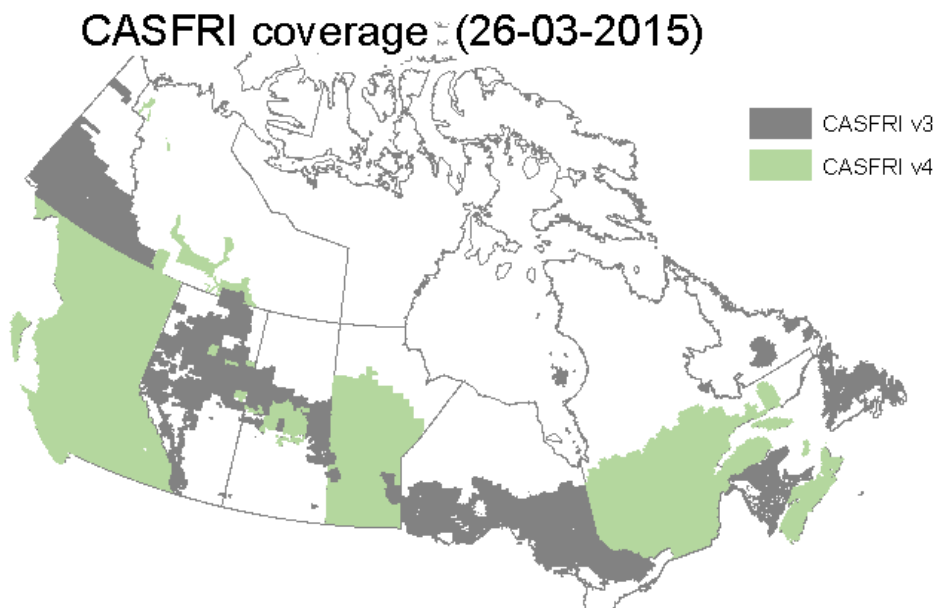


Figure 27. Status of CASFRI v4. Shaded green areas indicate significant updates, including a complete re-inventory in Quebec, reinterpretation of old inventory to modern standards (Manitoba), and the filling in of a number of data gaps (Alberta).

We also acquired new data to fill in some important gaps in Alberta. Notably, this involved our first data partnership with a major energy sector company, Cenovus Energy Ltd., who provided newly created inventory for the Alberta side of the Cold Lake Air Weapons Range. Completion of CASFRI v4 is some months behind schedule, in part because the main programmer found a full time position elsewhere. However, we expect completion by end of May 2015.

We published a paper in 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. 2014). We expect this paper to dramatically raise the profile of the dataset and lead to increased opportunities for its development.

Regional models of species at risk (see *Maritime models for species at risk and comparison with national models*, page 37) will be using CASFRI data. This work will act as a pilot study.

Interactive web-mapping

In association with the Conservation Biology Institute.

In 2013-14 we initiated the use of interactive mapping of BAM products on the web. BAM has partnered with the Data Basin group within the Conservation Biology Institute (CBI). This partnership allows BAM spatial products to be hosted with a known spatial database repository and gives access to the public to products we have created (Figure 28). The architecture of the Data Basin site requires strict metadata to accompany the data layers and provides linkages back to information on the BAM website. By using the Data Basin portal users are linked into a wide network of projects and data layers created to support learning, research, and environmental stewardship. Our aim is to archive and make available spatial files for as many projects and results as possible.



Figure 28. Screen capture of the BAM Data Basin home page at <http://borealbirds.databasin.org/>. The Climate Change gallery is populated, while other themes are place-holders for future map and data products.

This work is currently in progress, as we make the switch from providing static image maps on the BAM website to this dynamic spatial data approach. In 2014-15, we populated the Climate Change theme with work done by Diana Stralberg, with over 170 layers representing current and future species density and species richness for 80 species. The next phase of the work will be using the new version of the database to populate the Data Locations theme and to update layers that were previously created for the website with older versions of the data.

Evaluation of needs for the BAM website

With the move to use Data Basin for distribution of spatial products, we recognize the need for a reassessment of our current website, www.borealbirds.ca. A detailed review of this website is being undertaken by our Coordinating Scientist. This review will involve a user needs assessment to identify the users of our website, the desired content and products, and the effectiveness of our web design. The result of this evaluation will be a detailed report summarizing required updates to existing products, required new products, and a plan of activities including timeline for completion. This report is expected to be completed in fall 2015.

Distribution and Access to the BAM Database

Accommodating regular data/information requests

BAM regularly receives contact from individuals, researchers, or organizations through the website feedback form or direct contact. The nature of these requests varies greatly, from permission to use website figures, to requests for data subsets, to questions regarding data-handling and analysis, to suggestions of collaborative work. BAM encourages such contact and requests, since we are well-positioned to make connections and initiate collaborations, provide information or data, and assist with technical needs.

Many of these requests are simple to fill, such as providing a high resolution or modified map figure from our website. As the website is updated and the Data Basin platform is populated, many of the discrete requests for products will be fulfilled without direct attention from BAM staff. This will make access to our products easier and more efficient.

Data requests require more individual attention. The Database Manager must evaluate the specifics of the data request (locations, time periods, projects included, etc) and determine if data provision fits within data sharing agreements of those involved. In some cases, data are not publicly available and therefore cannot be supplied. However, BAM can still assist with these requests when data products are requested, rather than raw data themselves.

BAM staff have met with other organizations to share methodologies on data management and data analysis. On occasion, initial correspondence develops into a formal collaboration with BAM. In these situations, work is typically on-going before BAM is contacted, and the project needs are advice, technical support, or data. Therefore, BAM often acts in an advisory capacity for these collaborations. One example is the *Maritime models for species at risk and comparison with national models* project described on page 37.

As requests have increased and diversified since the projects initiation, we find the need to standardize our work-flow for handling requests. This task is on our Coordinating Scientist's workplan for summer 2015.

Providing guidance for data management in long-term ecological monitoring projects

In association with Dave Rugg (USDA Forest Service).

BAM was invited to contribute to a Wildlife Society Bulletin special topics issue on data management. We prepared a manuscript describing the BAM data accumulation, maintenance, and standardization process as a case study of creating a long-term monitoring database from disparate projects. In this manuscript, we describe the history and structure of the BAM database, the processes for standardizing heterogeneous data, and the processes for on-going data management and accumulation (Figure 29).

This paper has been accepted for publication.

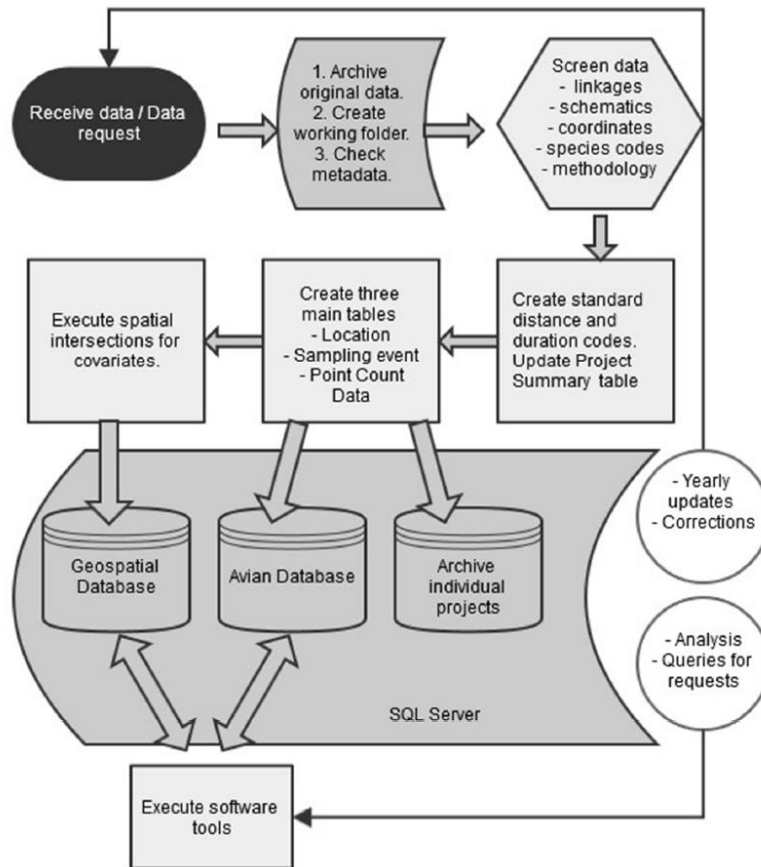


Figure 29. Workflow of adding a new dataset to the Avian Database, or servicing a request for a subset of the BAM database.

Increasing awareness of the BAM database

To increase exposure of the BAM project and database, we will submit an aggregated dataset and accompanying extended metadata to the journal *Ecology*; the intent is that the dataset will be housed in Ecological Archives and described in an associated journal publication.

The dataset to be submitted for publication will consist of annual presence/absence information from the last ~25 years at a 4-km grid-cell level (corresponding with climate data), constituting a historical atlas of avian sampling in boreal and hemi-boreal regions of North America. We will further summarize representation of some key datasets by the dataset, including bird conservation regions, climatically-defined subregions, and general vegetation classes. This work will be conducted alongside the gap analysis described on page 17, in *Comprehensiveness of avian point count sampling in the boreal region: A gap analysis*.

This work is at the conception stage. We hope to have initial metadata and aggregated data prepared by January 2016.

COLLABORATIONS

BAM welcomes collaborations with projects that align with our mandate for conservation of boreal birds. Our major active collaboration is with the BEACONS Project (discussed above, *Advancing bird conservation in collaboration with the Boreal Ecosystems Analysis for Conservation Networks (BEACONS) Project*; page 33), augmenting ecological surrogates used for boreal-wide conservation planning with predictive bird species distribution and abundance maps. Some active collaborations involve data sharing, analysis or targeted science to assist groups within EC achieve their objectives, such as delivery of Joint Oil Sands Monitoring in Alberta (see *Joint Oil Sands Monitoring*, page 19), and contributions to recovery planning for Species at Risk (see *Species at Risk and Critical Habitat*, page 35). Collaborations with other universities and organizations occur via PhD students such as Nicole Barker (Université Laval and Ducks Unlimited Canada, see *Species- vs. ecosystem-based conservation planning* on page 34 and *Delineating breeding ranges of waterfowl* on page 42), Steve Matsuoka (USGS, see *Avian response to projected changes in climate and landscapes across Alaska and northwestern Canada* on page 28), and Alana Westwood (Dalhousie and Parks Canada; see *Maritime models for species at risk and comparison with national models* on 37 and *Contribution of protected areas to habitat for three species at risk* on page 38) The primary venue for collaboration with EC is the Landbird Technical Committee and its Boreal sub-committee (general and special-topics webinars, direct solicitation for input and dialogue, distribution of reports, etc.).

In 2013-14 we adopted an additional model for collaboration, whereby we provided limited resources, financial and/or in kind, to promote and support the involvement of outside researchers (from the Technical Committee or the broader community) on selected topics. Progress within 2014-15 on these projects is discussed below.

Effects of plantation forestry on bird communities in western Canada

Heather Root (Weber State University) and Matthew Betts (Oregon State University) have been running occupancy models using BAM data from Alberta and British Columbia to examine the effects of plantation forestry at local and landscape scales. Linear models are complete for both datasets for each species and in aggregation for estimates of total species richness and cavity-dwelling species richness. Next steps for the project involve running models allowing for threshold responses and combining results with those from other study areas. Anticipated completion for this work is June 2016.

Effects of spruce budworm outbreaks on avian communities

BAM financial contribution in 2013-14 to this collaboration with Lisa Venier (NRCan) supported GIS analysis to link BAM point count data to historical fire and insect outbreak maps available to NRCan. Analyses have continued in 2014-15. Preliminary ordination studies showed definite relationships between “old forest species” and recent (<10 years) defoliation events. Somewhat counter-intuitively, there was also an indication of a relationship between open-forest species and areas 21-30 years post outbreak; this may reflect a delayed or protracted response of canopy structure and understory development to budworm mortality. This preliminary analysis was to have led to a more thorough community level analysis using Non-metric Multidimensional Scaling. Unfortunately, our sample sizes are too large to successfully apply this specific technique. We are now planning to adopt a species-level analysis, possibly modelling on the treatment-control study led by Alberto Suarez-Esteban (see *Response of boreal birds to land-use change*, page 26) for testing for the effects of anthropogenic disturbance. The work continues, and we expect to develop a publishable study by summer of 2016.

APPLICATIONS OF BAM RESULTS IN 2014-15

Here we present a summary from 2014-15 of application of BAM results to conservation and management efforts, as well as describe other known applications of BAM data, data products and analyses that occurred in the past fiscal year. Applications are additive to those documented in previous BAM reports.

- *Monitoring sampling guidance*: Bird Studies Canada and a regional office of EC requested information from BAM regarding sampling coverage in specific regions;
- *Oil Sands Monitoring*: EC used data from BAM to inform the sampling plan for Status and Trend Monitoring of Listed, Rare, and Difficult-to-Monitor Landbirds, part of its contribution to the Canada-Alberta Joint Oil Sands Monitoring (JOSM) Project. These data were one of the sources used to identify historic detection locations of priority bird species in the JOSM area for resampling in 2014 and future years;
- *Informing Recovery Strategies for species at risk*: BAM's national habitat models and maps of predicted species density informed Recovery Strategies for Canada Warbler, Common Nighthawk, and Olive-sided Flycatcher released in 2014-15 (Environment Canada 2015a, 2015b, 2015c).

- *Incorporating boreal birds in conservation planning*: BAM's refugia, distribution, and density models were incorporated within the BEACONS toolset;
- *Zones of Interest*: BAM provided substantial input to EC's Migratory Bird Zones of Interest project via the following activities: (a) Led a webinar on 17 September 2014 highlighting BAM's work and potential contributions; (b) provided MaxEnt model predictions as GIS layers for requested species; and (c) provided feedback on Zones of Interest proposal;
- *Calculation of continental population sizes*: Partners in Flight revised their maximum detection distances for calculating population sizes based on a BAM paper;
- *Alberta climate change vulnerability*: Contributed to collaborative research project led by the Alberta Biodiversity Monitoring project assessing vulnerability of and potential climate-change impacts on forest and grassland birds in Alberta. Diana Stralberg's bioclimatic models were clipped to Alberta for analysis and assessment of priority conservation areas.

PROJECT COMMUNICATIONS IN 2014-15

The BAM project makes use of a variety of communication methods to solicit collaboration and input, and to extend our knowledge beyond the group, including: webinars; publications in peer-reviewed journals; unpublished reports (to EC); annual reporting to funders; our website; and presentations at a variety of venues.

WEBINARS

On April 23rd, 2014 BAM hosted a webinar led by Samuel Haché titled "**Analyses to support critical habitat identification for Canada Warbler, Olive-sided Flycatcher and Common Nighthawk**". Invited participants included the BAM Technical Committee and EC's Landbird Technical Committee, as well as EC staff involved in recovery planning for these species. This webinar discussed the results of initial results of work started in January 2014 to assist with identification of critical habitat for 3 boreal species: Canada Warbler; Olive-sided Flycatcher; and Common Nighthawk.

On September 17th, 2014 BAM hosted a webinar led by Tony Turner of EC and PhD candidate Diana Stralberg from BAM, titled "**Migratory Bird Zones of Interest Project: Exploring potential tools to identify important areas for non-congregatory priority migratory birds in Canada's boreal ecosystem**". Invited participants included the Ad hoc Migratory Bird Zones of Interests Advisory Group, EC Staff and the BAM Team. Turner provided a background, project overview, and update of the work being done within EC. Stralberg presented information on work that BAM is doing with MaxEnt, Marxan, and with the BEACONS group on this area of research. Time was allotted for a discussion session with all participants.

On February 26th, 2015 BAM hosted a webinar led by PhD candidate Alana Westwood (Dalhousie University), titled "**National and Maritime-scale species models of Olive-sided Flycatcher, Canada Warbler, and Rusty Blackbird**". Invited participants included members of Parks Canada (Atlantic Region), EC, Nova Scotia Department of Natural Resources, New Brunswick Department of Nature Resources, Nova Scotia Protected Areas Program, Bird Studies Canada, and the BAM Team. Westwood provided a rational,

background, and planned methods for work being done by BAM developing species distribution models for species at risk both at the national level and in New Brunswick and Nova Scotia. This was followed by a discussion session including all participants.

PRESENTATIONS, REPORTS, AND PUBLICATIONS

Presentations

- Bayne, E. 2014. What surprises might climate change have in store for Alberta's biodiversity? College of Alberta Professional Forest Technologists. Edmonton, AB. 3 April 2014.
- Bayne, E. 2015. Wiretapping the wilderness: New approaches to wildlife monitoring using automated acoustic recorders. Invited lecture at 2015 Land EPA Workshop. Calgary, AB. 30 Jan 2015.
- Bayne, E. 2015. What have we learned about oil sands wildlife by using automated recording units. Invited lecture at Oil Sands Monitoring Symposium. Edmonton, AB. February 24-25, 2015.
- Cumming S. G, Marchal J, McIntire E, Woolford D, and Kulperger R. 2014. Simulating fire regimes in spatial dynamic models. The 24th Annual Conference of the International Environmetrics Society. Guangzhou, China. Dec 15-18, 2014.
- Haché, S. 2014. Analyses to support critical habitat identification for Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk (Project K4B20-13-0367). Webinar for Environment Canada landbird biologists and Boreal Avian Modelling Project technical committee. Edmonton, AB. April 23, 2014.
- Haché, S. and A. Westwood. 2015. Boreal Avian Modelling Project: Advances and Applications from National to Local Initiatives. Canada Warbler International Conservation Initiative Breeding Grounds Summit. Ottawa, ON. March 10 -12, 2015.
- Scarl, J. C., Lambert, J. D., Hart, J., Dettmers, R., Sólymos, P. 2014. Ten years of mountain birdwatch: abundance and trends of Bicknell's Thrush and other high-elevation birds. Northeast/Southeast Partners in Flight Bird Conservation Conference. Wyndham Virginia Beach, VA. 6-9 October 2014.
- Solyomos, P, EM Bayne, CL Mahon, S Hache, P Fontaine, SG Cumming, D Stralberg, FKA Schmiegelow, SJ Song. 2014. Understanding the sources of biases in population size estimates based on roadside surveys in Canada. AOU/COS/SCO Joint Meeting, Estes Park, CO. Sept 2014
- Sólymos, P. & MC Roy, 2014. ABMI: Enhancing our Vision of Alberta's Biodiversity", invited talk, 2014Workshop of the Canadian Society of Environmental Biologists (CSEB), Edmonton AB, Oct 3, 2014.
- Sólymos, P. 2014. Data cloning: bridging the Bayesian and frequentist statistical paradigms, guest lecture, Budapest R User Group meetup, Budapest, Hungary, July 16, 2014
- Sólymos, P. 2014. What to do with messy data: using standardized abundance indices in species distribution modeling, invited talk, Biometry Conference (Hungarian Society for Clinical Biostatistics), Budapest, Hungary, May 16-17, 2014

- Sólymos, P. 2014. Species-habitat associations: Some things never go out of fashion. Adjunct seminar, Department of Biological Sciences. University of Alberta, Edmonton, AB. Dec 5, 2014.
- Solyomos, P. 2015. Human footprint change during the past decade. ABMI forum, Better Environmental Management Through Monitoring- February 17, 2015
- Song, S., P Solyomos, C.L. Mahon, E.M. Bayne. 2014. Using models to estimate the impacts of oil sands on migratory birds. JOSM multi-stakeholder workshop. June 2014.
- Song, S. 2015. Trend monitoring of priority migratory birds in oil sands areas: Lessons learned 2012-2015. Oil Sands Monitoring Symposium. Edmonton, AB. February 24-25, 2015.
- Stehelin, T. E. and F. K. A. Schmiegelow. 2014. Local (s. Yukon) and distribution-wide investigation into declines of two aerial insectivores; Olive-sided Flycatcher (*Contopus cooperi*) and Western Wood-Pewee (*C. sordidulus*) utilizing both habitat and climate covariates. Alaska Bird Conference. Juneau, AK, Dec. 10, 2014.
- Stralberg, D., S. Matsuoka, A. Hamann, E.M. Bayne, P. Solyomos, F.K.A. Schmiegelow, X. Wang, S. Cumming, and S. Song, 2014. Projecting boreal bird responses to climate change: the signal exceeds the noise. Second North America Congress for Conservation Biology (NACCB) meeting. Missoula, MT. July 16, 2014.
- Stralberg, D. and S. Song. 2014. Boreal Avian Modelling Project: Applications to Zones of Interest Analyses. Sept 17, 2014. Webinar for Environment Canada biologists.
- Stralberg, S., S. Matsuoka, A. Hamann, E. Bayne, P. Sólymos, F. Schmiegelow, X. Wang, S. Cumming, and S. Song. 2014. Projecting boreal bird responses to climate change: incorporating uncertainty, refugia, and time lags. Climate, Conservation, and Community in Alaska and Northwest Canada (Landscape Conservation Cooperative meeting). Anchorage, AK. Nov 3, 2014.
- Stralberg, D., Bayne, E.M., Cumming, S.G., Sólymos, P., Song, S.J. & Schmiegelow, F.K.A. 2014. Conserving boreal forest birds in a rapidly changing climate: a modified refugia approach. Presentation to Steering Committee of Alberta Biodiversity Management and Climate Change Adaptation Project. Dec 8, 2014.
- Westwood, A. 2014. An introduction to the Boreal Avian Modeling Project. Eastern Habitat Joint Venture Meeting, Fredericton, NB. Oct 8-9, 2014.

Reports

- Haché S., P. Solyomos, P. Fontaine, E.M. Bayne, S.G. Cumming, F.K.A. Schmiegelow, and D. Stralberg. 2014. Analysis to support critical habitat identification for Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk (Project K4B20-13-0367). Technical Report 1. Environment Canada.154 p.
- Haché S., P. Solyomos, P. Fontaine, E.M. Bayne, S.G. Cumming, F.K.A. Schmiegelow, and D. Stralberg. 2014. Analysis to support critical habitat identification for Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk (Project K4B20-13-0367). Technical Report 2. Environment Canada.8 p.

Sólymos, P., Mahon, C. L., and Bayne, E. M. 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.

Publications

Published

- Barker, N. K. S., S. G. Cumming, and M. Darveau. 2014a. Models to predict the distribution and abundance of breeding ducks in Canada. *Avian Conservation and Ecology* 9:7. doi: <http://dx.doi.org/10.5751/ACE-00699-090207>.
- Barker, N. K. S., S. M. Slattery, M. Darveau, and S. G. Cumming. 2014b. Modeling distribution and abundance of multiple species: Different pooling strategies produce similar results. *Ecosphere* 5:art158. doi: <http://dx.doi.org/10.1890/ES14-00256.1>.
- Cumming, S. G., C. R. Drever, M. Houle, J. Cosco, P. Racine, E. Bayne, and F. K. A. Schmiegelow. 2015. A gap analysis of tree species representation in the protected areas of the Canadian boreal forest: applying a new assemblage of digital Forest Resource Inventory data. *Canadian Journal of Forest Research* 45:163–173. doi: <http://dx.doi.org/10.1139/cjfr-2014-0102>.
- Cumming, S. G., D. Stralberg, K. L. Lefevre, P. Sólymos, E. M. Bayne, S. Fang, T. Fontaine, D. Mazerolle, F. K. A. Schmiegelow, and S. J. Song. 2014. Climate and vegetation hierarchically structure patterns of songbird distribution in the Canadian boreal region. *Ecography* 37:137–151. doi: <http://dx.doi.org/10.1111/j.1600-0587.2013.00299.x>.
- Mahon, C. L., E. M. Bayne, P. Sólymos, S. M. Matsuoka, M. Carlson, E. Dzus, F. K. A. Schmiegelow, and S. J. Song. 2014. Does expected future landscape condition support proposed population objectives for boreal birds? *Forest Ecology and Management* 312:28–39. doi: <http://dx.doi.org/10.1016/j.foreco.2013.10.025>.
- Matsuoka, S. M., C. L. Mahon, C. M. Handel, P. Sólymos, E. M. Bayne, P. C. Fontaine, and C. J. Ralph. 2014. Reviving common standards in point-count surveys for broad inference across studies. *The Condor* 116:599–608. doi: <http://dx.doi.org/10.1650/CONDOR-14-108.1>.
- Stralberg, D., S. M. Matsuoka, A. Hamann, E. M. Bayne, P. Sólymos, F. Schmiegelow, X. Wang, S. G. Cumming, and S. J. Song. 2015. Projecting boreal bird responses to climate change: The signal exceeds the noise. *Ecological Applications* 25:52–69. doi: <http://dx.doi.org/10.1890/13-2289.1>.

In press

- Barker, N. K. S., P. Fontaine, S.G. Cumming, E.M Bayne, P. Sólymos, , F.K.A Schmiegelow, and S.J. Song. (in press). Ecoinformatics and database management for ecological monitoring: lessons from a retrospective study of boreal songbirds. *Wildlife Society Bulletin*.
- Sólymos, P., Morrison, S. F., Kariyeva, J., Schieck, J., Haughland, D. L., Azeria, E., Cobb, T., Hinchliffe, R., Kittson, J., McIntosh, A., Narwani, T., Pierossi, P., Roy, M.-C., Sandybayev, T., Boutin, S., and Bayne, E. (in press). Data and information management for the monitoring of biodiversity in Alberta. *Wildlife Society Bulletin*

Sólymos, P., S.R. Lele, and E. Bayne. (in press). Revisiting the single-visit method for occupancy and abundance studies: A rebuttal of criticisms and some extensions. *Methods in Ecology and Evolution*.

Stralberg, D., E.M. Bayne, S.G. Cumming, P. Sólymos, S.J. Song, and F.K.A Schmiegelow. (in press) Conserving boreal forest birds in a rapidly changing climate: a modified refugia approach. *Diversity and Distributions*.

PROJECT MANAGEMENT

PROJECT TEAM

The BAM Project is supported by a core team of researchers, staff and students, as well as extensive contributions of time, expertise, data and financial support from many additional people and organizations.

The BAM team expanded this fiscal year with the addition of a new staff position and a post-doctoral fellow.

Steering Committee

The project Steering Committee consists of:

- Dr. Erin Bayne, University of Alberta
- Dr. Steve Cumming, Université Laval
- Dr. Fiona Schmiegelow, University of Alberta
- Dr. Samantha Song, Environment Canada

This group is collectively responsible for project coordination, including staff management, liaison with project partners and the Technical Committee, and overall project direction.

Project Staff

BAM was pleased to welcome Nicole Barker as the Coordinating Scientist. This new position within the team holds responsibilities for project management and governance, as well as scientific research. BAM also welcomed Lionel Leston, a post-doctoral fellow with Erin Bayne. Leston is investigating impacts of the energy sector on boreal birds as part of the Canada-Alberta Joint Oil Sands Monitoring (JOSM) Project.

Core staff positions this year included:

- Coordinating Scientist: Dr. Nicole Barker, , 0.5 FTE (joined mid-February 2015)
- Database Manager: Trish Fontaine
- Statistical Ecologist: Dr. Péter Sólymos, 0.5 FTE
- Post-doctoral Fellow: Dr. Alberto Suarez Esteban
- Post-doctoral Fellow: Dr. Lionel Leston

Students

As of March 30, 2015, doctoral students included:

- PhD candidate with Drs. Bayne and Schmiegelow: Diana Stralberg
- PhD candidate with Steve Cumming in association with Ducks Unlimited Canada: Nicole Barker (defended April 2015)
- PhD candidate with Fiona Schmiegelow and Erin Bayne: Steve Matsuoka, Research Wildlife Biologist, United States Geological Survey
- PhD candidate with Fiona Schmiegelow: Tara Stehelin
- PhD candidate at Dalhousie University with Erin Bayne as a committee member: Alana Westwood

Contributing Scientists

Dr. Samuel Haché, previously a Project Ecologist with BAM, is welcomed into a new role as a contributing scientist. Now a Wildlife Biologist with Environment Canada, he will continue to contribute to BAM's work on Species at Risk.

Scientists from other organizations who contribute to the BAM team include:

- Dr. Samuel Haché, Wildlife Biologist, Environment Canada
- Dr. C. Lisa Mahon, Wildlife Biologist, Environment Canada

AFFILIATED MEMBERS

Technical Committee

Our Technical Committee (TC) continues to provide independent scientific advice on project direction and results.

- Dr. Marcel Darveau, Ducks Unlimited Canada / Université Laval
- Dr. André Desrochers, Université Laval
- Dr. Pierre Drapeau, Université du Québec à Montréal
- Dr. Charles Francis, Environment Canada
- Dr. Colleen Handel, United States Geological Survey
- Dr. Keith Hobson, Environment Canada
- Craig Machtans, Environment Canada
- Dr. Julienne Morissette, Ducks Unlimited Canada
- Dr. Gerald Niemi, University of Minnesota – Duluth
- Dr. Rob Rempel, Ontario Ministry of Natural Resources / Lakehead University
- Dr. Stuart Slattery, Ducks Unlimited Canada
- Dr. Phil Taylor, Acadia University
- Steve Van Wilgenburg, Environment Canada
- Dr. Lisa Venier, Canadian Forest Service
- Pierre Vernier, University of British Columbia
- Dr. Marc-André Villard, Université de Moncton

Associated Avian Ecologists

We extend opportunities for collaboration to avian science and management staff based in universities and other research institutions, Aboriginal, non-governmental, and government agencies concerned with conservation of boreal birds in North America.

SUPPORT TEAM

Many additional people provide time and expertise to BAM project activities. In particular, we would like to recognize the contributions of the following individuals:

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