Boreal Avian Modelling Project

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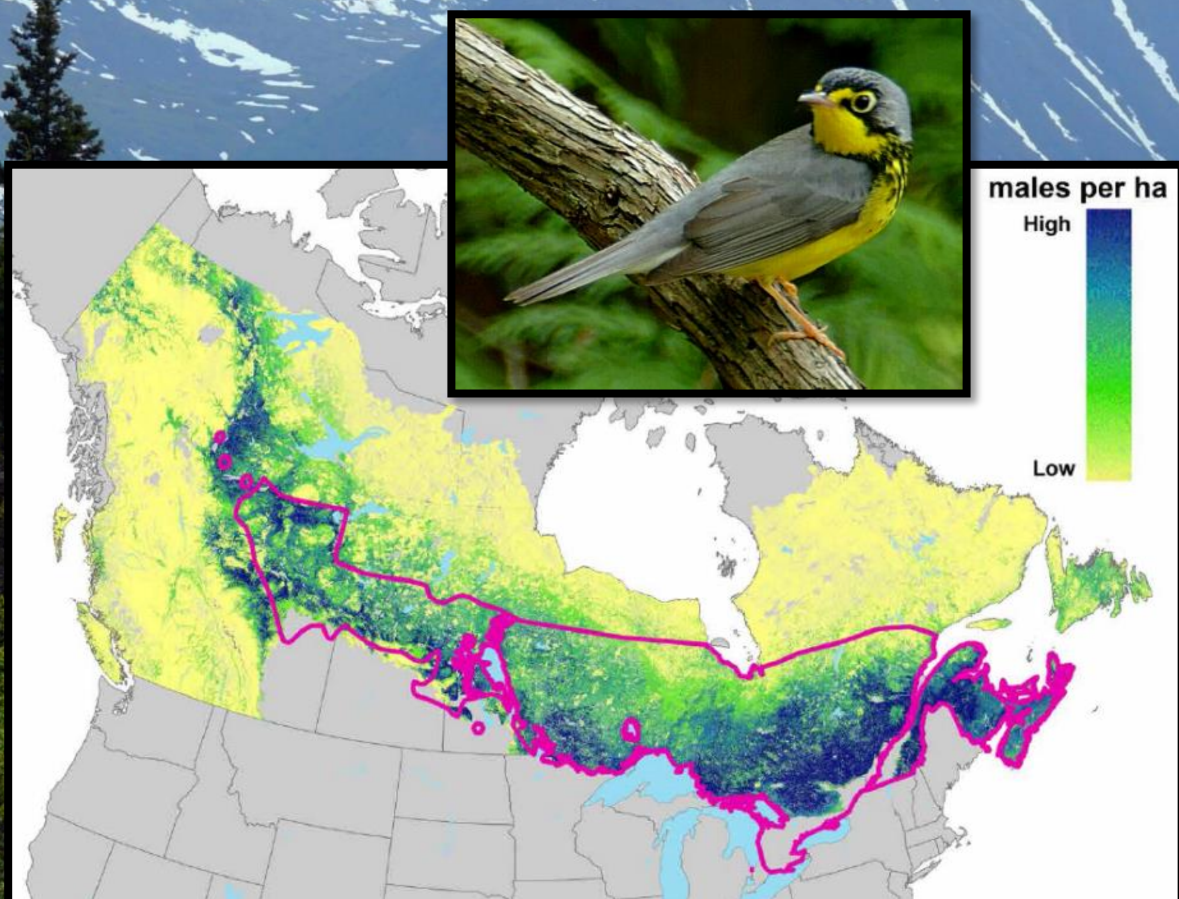
Projet de modélisation aviaire boréal



Annual Report
April 2015 - March 2016

What is...
The Boreal Avian Modelling Project

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. BAM develops and distributes statistical models of **avian populations** and the **impacts of human activity** on boreal bird species. BAM's work draws upon a powerful database created by collating and **harmonizing** data from **individual research and monitoring efforts** conducted in the Canadian and US boreal & hemi-boreal forest, plus a significant library of regional and national biophysical data.

The BAM Project Team is made up of academic researchers and government scientists, paid project staff, and graduate students. BAM collaborates with federal and provincial governments, academics, industry, and non-governmental organizations with interests in the development and application of science for bird conservation and management. Our research products are applied to many aspects of boreal bird management and conservation, including migratory bird monitoring, population estimation, habitat determinations, assessment and recovery planning for species at risk, environmental assessment, identification of priority wildlife areas, protected areas design, and land-use planning.

Our Objectives

1. **ASSEMBLE**, harmonize, and archive avian point-count survey **data**.
2. **DEVELOP** or refine **statistical methods** to analyze these data, so as to:
    3. **PROVIDE reliable information** on boreal bird distributions, abundances, trends, and habitat associations;
    4. **FORECAST** population consequences of **human land uses** and **climate change;**
    5. **CONTRIBUTE** to **conservation**, **management**, and **monitoring** of boreal avifauna and their habitats.
6. **BUILD SUPPORT** for avian conservation in academia, industry, governments, non-governmental organizations, and the public.
7. **ENCOURAGE** public **awareness** and support **education**.

Contents

Photo: White-throated Sparrow, Sean Lupo

Project Team & Technical Committee

Erin Bayne, U.Alberta ....Steering Committee
Steve Cumming, U.Laval ....Steering Committee
Fiona Schmiegelow, U.Alberta...........Steering Committee
Samantha Song, ECCC ....Steering Committee

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Photo: Jeff Ball

Highlights from 2015-16

How does BAM operate? We pursue work within three parallel but inter-connected domains: research & monitoring, data development, and application & collaboration. We conduct research, create, apply, & share new statistical approaches; develop & distribute data products; and communicate our findings in papers, reports, presentations, & webinars. This table summarizes our main achievements from April 2015 to March 2016.

Research & Monitoring	Understanding Bird Ecology	Using Canada Warblers as a test case, we have nearly finished developing our latest national density models. Updated density maps and national population estimates will be available in the coming year. Our study of the potential impact of recent wildfire on avian populations found that observed population trends can't be explained by recent fire history. Regional models of species density were generated for Canada Warbler and Olive-sided Flycatcher for Maritime national parks.
	Human Impacts	Our pan-Canadian investigation of human-induced forest loss on birds confirmed that most old forest bird species are negatively affected by both local and landscape-scale disturbance. Our local scale models of energy sector impacts on bird populations in the Alberta oil sands showed a reasonable ability to predict population-level impacts. We initiated an effort to synthesize our work to date exploring human impacts on bird populations in the Alberta oil sands.
	Climate Change	We demonstrated that range expansion to Alaska is likely with climate change, given how climate change is likely to alter the conditions of the perceived barrier of the northwestern cordillera. By combining climate projections with simulated wildfires and anticipated human activity, we evaluated scenarios of future forest change in Alberta; results predict a disproportionate loss of old forest habitat.

	Advancing Methods	Sound transmission studies confirmed that detectability of species is higher along roads than it is within the forest interior – this has implications for combining on- and off-road data. Statistical offsets to correct for bias in on-road surveys remain elusive – instead, we can reduce bias by subsetting datasets (e.g., exclude wide roads) and controlling for habitat characteristics in models. Auto-regressive trend estimation isn't easy with the BAM dataset, so we explored other methods for calculating population trends – we will systematically compare our results to BBS trends in the near future. We have a reasonable understanding of how data from human-based and automated recording unit point counts differ, based on opportunistic and experimental field datasets; we're actively working on methods to integrate these different data sources for analyses.
	Informing Surveys and Monitoring	Quantifications of how species' singing rates differ with time of day and time of year may inform survey and monitoring methods – we are currently describing results in a manuscript.
Data Development	Data Products for Distribution	Products available, publicly through Data Basin or by request, include: national density maps for 103 songbird species and 17 waterfowl species or species groups, climate-change projections for 103 species, maps of climate refugia, maps of species' probabilities of occurrence, and a number of tabular datasets.
Data Development	BAM Databases	Our avian database contains observations from 251,977 point counts from 135 projects covering 146,433 locations. Version 3 of the statistical offsets we use to harmonize our dataset will be completed in early May 2016. We're actively working on the logistics of a public version of the BAM database.
Data Development	Deriving Products for BAM Analyses	To support our analyses, we derived or summarized: annual land cover changes induced by wildfire and human-made land-use changes; known migratory connectivity; and maps of human land use in the Alberta oil sands region.
Application & Collaboration	Informing Conservation Activities	We contributed to the status report on Western Wood-Pewee in Alberta. We used BAM density maps and future projected densities to explore priority areas within the boreal region under a contract with Canadian Wildlife Service.
Application & Collaboration	Conservation Through Collaboration	We supported recovery strategies for species at risk including Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk by contributing scientific expertise and data products.

		Our songbird and waterfowl density maps supported conservation planning efforts of the Canadian Boreal Forest Agreement and the Northwest Boreal Landscape Conservation Cooperative. Our songbird density maps are being used in HABISask, a biodiversity mapping tool created by the Government of Saskatchewan. The Nature Conservancy of Canada is using our density maps of songbirds and waterfowl to identify areas of importance within the Boreal Plains ecozone. We're co-leading a workshop with the goal of conserving boreal birds through integrating science, policy, and action. Our maps of climate change refugia and songbird and waterfowl abundance supported land-use planning by the Northern Alberta Conservation Areas Working Group. Our climate change refugia layers supported a landscape management plan in the Lower Athabasca Region. Our regional density maps are being used by Parks Canada to target and plan management for species at risk in the Maritimes. Our waterfowl density maps supported the Prairie Habitat Joint Venture's identification of priority landscapes within the western boreal region, and are being used for Ducks Unlimited Canada's internal conservation planning process. We're actively discussing potential collaborations with other groups including National Audubon Society, American Bird Conservancy, and Sustainable Forest Initiative.
	Communications	BAM team members hosted 2 webinars, published 5 articles in peer-reviewed journals, finished 2 PhD theses, and gave 13 in-person talks or poster presentations from January 2015 through March 2016.
Project Management	Team Structure	Diana Stralberg completed her PhD with Erin Bayne and Fiona Schmiegelow (University of Alberta) and joined the BAM team as a Project Ecologist working primarily on inter-annual variability in species abundances, impacts of climate change, and conservation prioritization. Alana Westwood completed her PhD with Cindy Stacier (Dalhousie University) and joined the BAM team as a Contributing Scientist working on applied conservation projects for landbird species at risk. Judith Toms (Wildlife Biologist with ECCC) joined the BAM team as a Contributing Scientist working on the oil sands monitoring projects. Steve Van Wilgenburg (Wildlife Biologist with ECCC) joined the BAM team as a Contributing Scientist working on projects related to monitoring and inter-annual variability in species abundances.

Research & Monitoring

Research & Monitoring

Understanding Bird Ecology

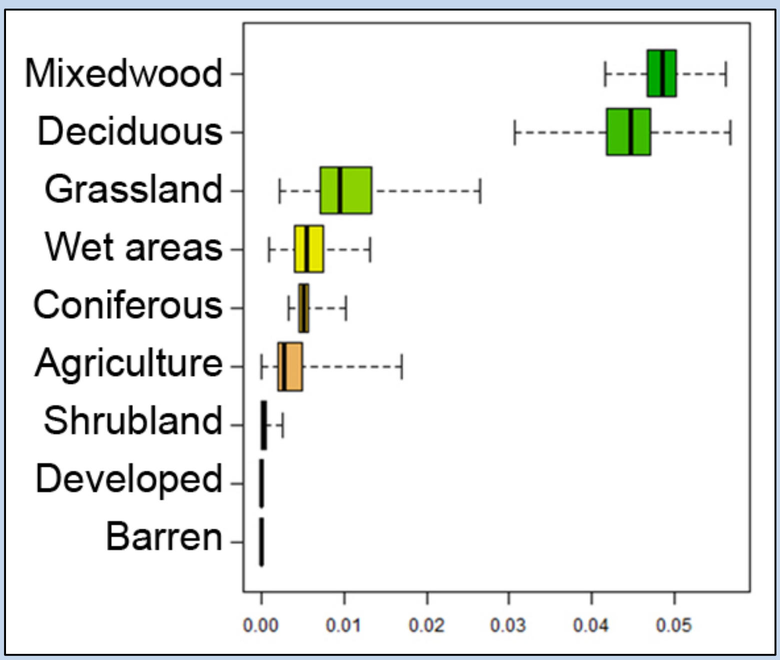
In the past year we settled on a method for our updated national models of boreal songbird density. We also finished our models within Maritimes national parks and are working on improved Alberta models. We evaluated the potential population-level effects of wildfire, and we are continuing our exploration of the drivers of inter-annual variability in breeding populations.

National distribution, abundance, and habitat associations of Canada Warblers

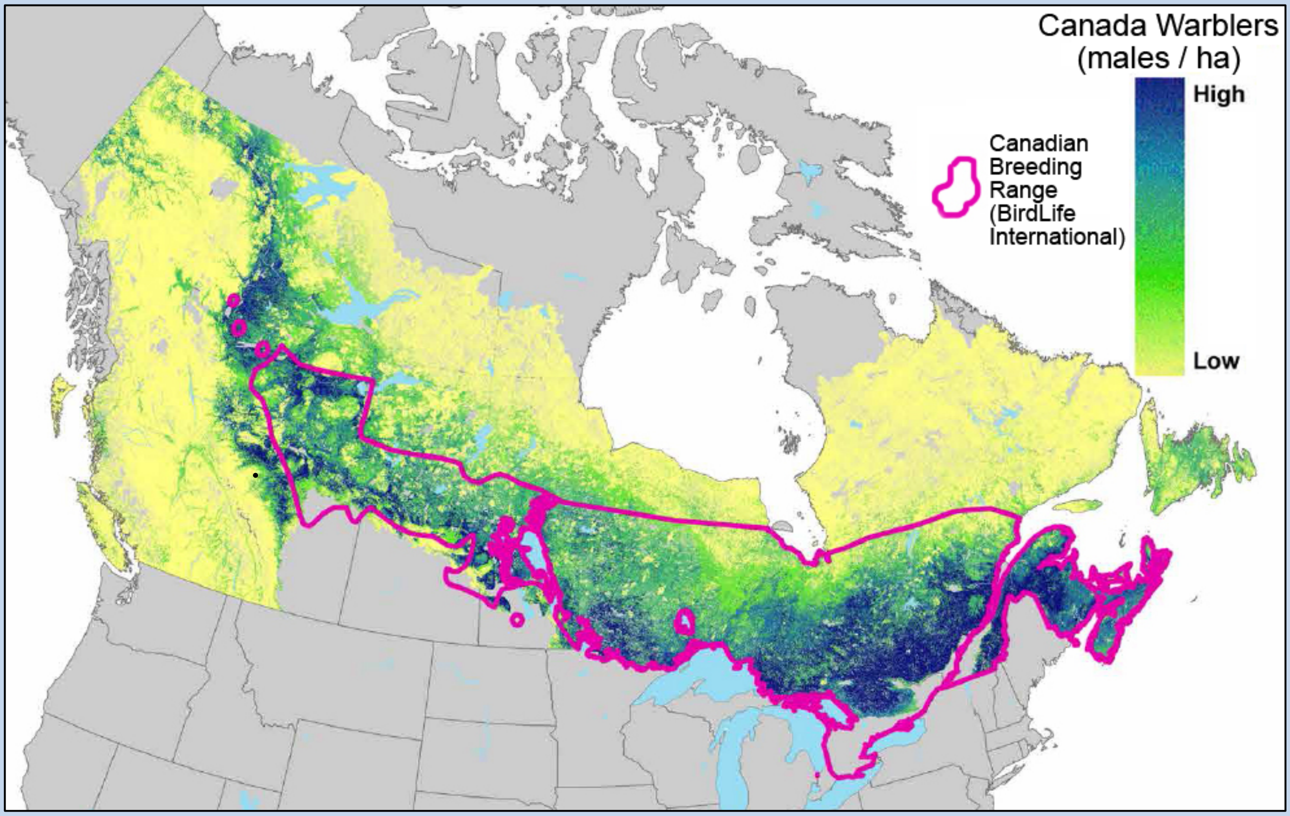
For the past two years, we've been updating our national avian density models. These models are intended to map species' densities and distributions, understand species' habitat associations, and estimate population sizes. We first developed and tested models for Canada Warblers, Olive-sided Flycatchers, and Common Nighthawks, which we described in a report to Environment Canada in March of 2014[1]. Since then, we've been refining the models using Canada Warbler as a test species. By the end of 2015-16, we had settled on a method (page 14) and written a first draft of a manuscript. We anticipate submitting the manuscript to a scientific journal in 2016-17.

Canada warbler density. We used data from over 250,000 point-count surveys along with land cover, disturbance, topography, climate, and spatio-temporal variables to generate national models explaining the variation in abundance of Canada Warblers across Canada. Poisson log-linear regression models were produced using a branching hierarchy model building process (page 14).

Density of male Canada Warblers was highest in mixedwood and deciduous stands with tall trees. We found



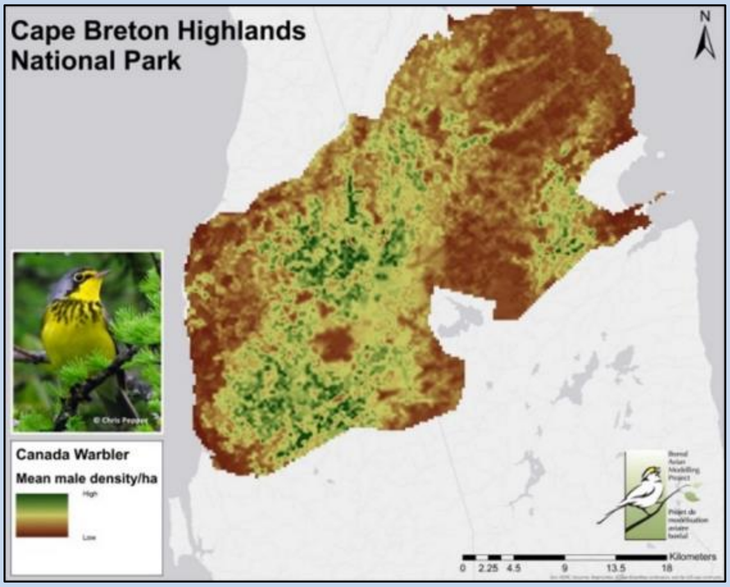
significant differences in density estimates between on- *vs* off-road surveys and human- *vs* ARU-based surveys, emphasizing the importance of our work to statistically integrate these different datasets (pages 18 and 20).



We mapped density (males/km^2) across the Canadian boreal region for 2002 and 2012 (2002 pictured). The estimated Canadian population size in 2012 was between 6.9 to 7.2 million and 7.6 to 7.8 million males depending on the model subset (total population size between 13.8 and 15.6 million individuals). The population in eastern Canada is estimated to have declined by approximately 5% annually between 2002 and 2012, whereas the western population has remained relatively constant.

Distribution, abundance, and habitat associations of Canada Warblers, Olive-sided Flycatchers, and Rusty Blackbirds in the Maritimes

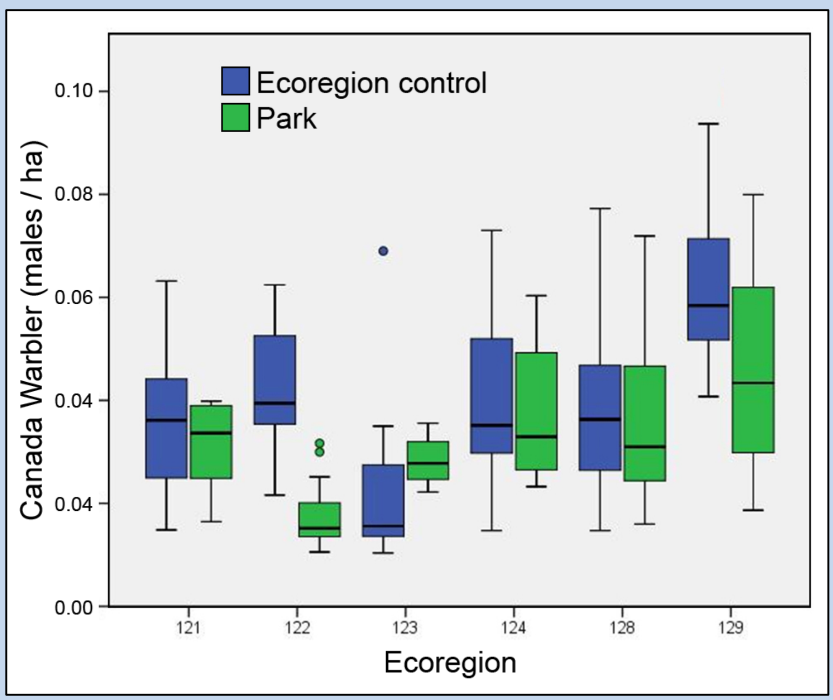
We applied BAM methods to data from the Maritimes to map species' densities and distributions, to understand their habitat associations, and to estimate their population sizes within national parks. We estimate that national parks in Nova Scotia and New Brunswick, covering approximately 2% of our study area, capture 1-2% of the regional Canada Warbler population and 2-4% of the regional Olive-sided Flycatcher population. These results, described in detail in a report completed in 2015-16[2], provide management tools for Parks Canada.

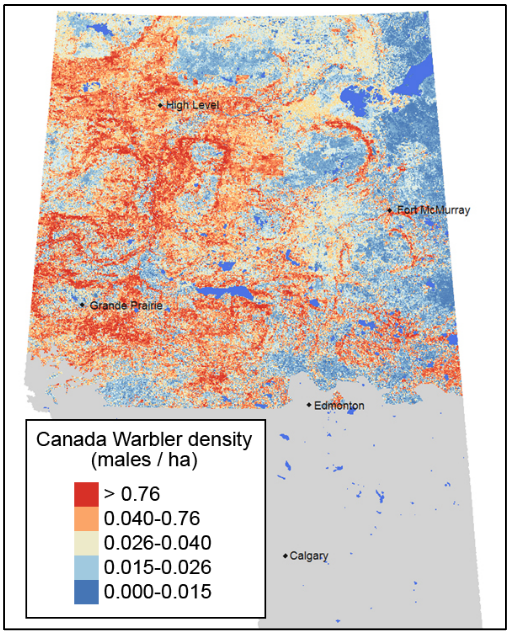


Canada Warbler and Olive-sided Flycatcher abundance. Using BAM data from Nova Scotia and New Brunswick (15,021 locations) we developed Poisson log-linear models using a branching hierarchy model building process (page 14). Wet forest habitats are notoriously difficult to model from commonly available GIS data, so we explored different methods for doing so. A suite of environmental covariates were partitioned into three model subsets based on the methods which they used to model wet forest landscapes (wetlands, depth to water table, or depth to water table x forest cover).

Overall, models using depth to water table or an interaction between depth to water table and forest cover performed best. Models with variables based on wetland layers performed poorly. Canada Warblers were densest in mixedwood forests, and there was a strong effect of wetness as measured by depth to water table. We think these results demonstrate the promise of depth to water table layers for modelling of wet forest habitat. Olive-sided Flycatchers were densest in spruce and fir forests, also with a strong positive effect of wetness. Human footprint and the presence of roads negatively affected both species' densities. Results for Rusty Blackbird were unreliable due to low sample sizes.

We predicted population density for Olive-sided Flycatchers and Canada Warblers in national parks as well as control regions within paired locations in the same ecoregions as the parks. Population density within national parks differed significantly in some ecoregions for some species, but was similar overall. Approximately 1-2% of the regional Canada Warbler population and 2-4% of the regional Olive-sided Flycatcher population are likely to occur within national parks.





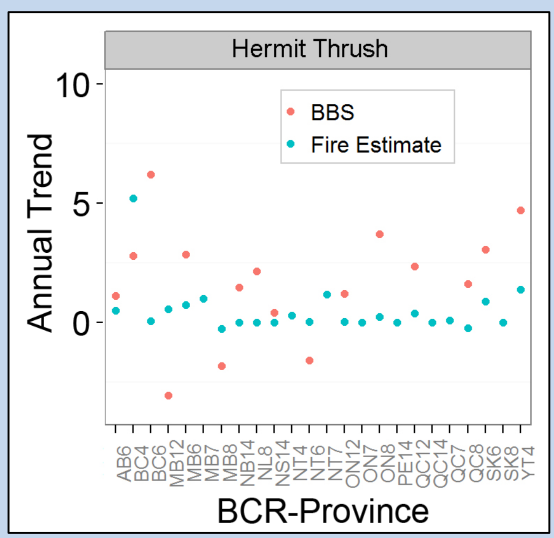
Regional models describe habitat associations of Canada Warblers

In previous years, we built regional models of local and stand-level habitat associations of Canada Warblers. Canada Warblers were associated with old deciduous forest, particularly near small streams. In 2015-16, we submitted a manuscript describing this work to the journal Avian Conservation & Ecology[3].

Breeding Bird Survey data imply decline rates higher than can be explained by wildfire alone

Boreal wildfires change forests into burned landscapes. Some bird species inhabit recent burns, but this conversion removes some habitat for many species. We can therefore assume that forest fires will affect local bird abundances in some way. We estimated the potential worst-case-scenario population-level impacts that fire could have on bird populations if we assume that fire permanently converts forest habitat to burned landscape. We found that in most cases, population trends detected from the BBS are greater in magnitude and more variable than comparable trends calculated based solely on changes in land cover resulting from fire. A manuscript describing these results will be drafted in 2016-17.

Impact of fire on populations. We created an annual land cover product based that summarized fire-induced land cover changes each year (page 37). For each year of this layer, we calculated the area of each land cover class (including burns). Multiplied by land cover-specific density estimates from previous work[4], we calculated annual population sizes. We did this at the scale of Bird Conservation Region (BCR) x Province. The result is a time series of population estimates for each BCR-Province where the only driver is fire, changing forest to burns. We also calculated trend as a mean annual percent change and contrasted it with BBS trends. BBS trends were more variable among BCR-Provinces than our trends, and tended to be larger in magnitude.



Updated models for Alberta are in progress

As part of the Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring (JOSM), BAM created Alberta-wide density models for over 80 bird species. We described these results in last year's annual report[5] and in two JOSM reports[6,7]. In 2015-16, we started updating and improving these by adding ARU data and three different wetland classification schemes. One of our goals is to identify which of the wetland layers most improves our model predictions of wetland birds, because the GIS habitat layer we currently use to model habitat for Alberta bird models may represent upland, merchantable forest habitats better than lowland forests or wetland habitats. We will continue to develop these models in 2016-17 to ultimately improve our wetland bird models, and will summarize results in a manuscript.

Comparing wetland classification schemes. We summarized habitat conditions within 150 m of 5052 upland and lowland point counts (both traditional and ARU point counts). Summaries used one of three different GIS classifiers: the Alberta Vegetation Inventory (AVI), Ducks Unlimited Canada's Enhanced Wetland Classification (EWC) layer, and a hybrid layer created by Fiera Consulting, which combined soil moisture data from Environment and Climate Change Canada with custom habitat classes derived from AVI (FIERA).

We assessed the optimal thematic resolution for different wetland classification systems based on model selection. This partitioned the original habitat classes in each GIS classifier into a smaller number of composite habitat classes. We predicted densities of each species in these composite classes and compared the predicted and observed abundance of each species in each point count. Model accuracy was measured using the amount of explained model deviance and standard classification accuracy tests derived from ROC plots. Prediction accuracy was generally high, with more than 60% of the deviance explained for most species. For the 50 species with model predictions from all three classifiers, the AVI classifier was the best performing for 42 of 50 species. However, our models could not converge on a solution for the AVI layer for eight species. Of the remaining eight species studied, EWC performed better for half, and FIERA performed better for the other half.

Identifying drivers of inter-annual variability in breeding bird abundance

To conserve species, we need to understand the factors affecting their population sizes, both on the breeding grounds and the wintering grounds. In 2014-15[5], we ran some preliminary analyses to determine whether the BAM database can provide information on understanding population drivers. In 2015-16, we used a set of five criteria to prioritize species for further analyses. We also began developing an exploratory approach to evaluate how our understanding of migratory connectivity might be informed by common, hierarchical multi-species population drivers across breeding and wintering grounds. In 2016-17, we will continue these analyses by including land use change data[8] and developing species-specific models based on *a priori* hypotheses for priority species.

Prioritizing species. We used the BAM dataset, in conjunction with published BBS trends, to prioritize species based on several *a priori* criteria. These species will be prioritized for further analysis and any new data collection. Our five criteria, selected to identify species with sufficient data and probable patterns of interest, were: 1) space/time replication within BAM survey locations; 2) regional differences (east/west) in temporal variability; 3) regional differences in trend; 4) number of distinct generalized wintering areas; and 5) availability of migratory connectivity information (page 38). We ranked species for each of the first four criteria and summed ranks. Our top ranked species were: Tree Swallow, Black-throated Green Warbler, American Redstart, Chestnut-sided Warbler, Red-eyed Vireo, Yellow Warbler, Yellow-bellied Flycatcher, Swainson's Thrush, Tennessee Warbler, and Black-and-white Warbler. These and other high ranking species will be prioritized in future species-specific analyses of sources of inter-annual variability.

Determining drivers and connectivity. For our exploratory analysis, using data-generated climate zones for boreal (breeding) and tropical/subtropical (wintering) regions, we ran regression tree models to examine the hierarchical structure of climatic drivers of inter-annual variation in species abundance, for individual species, and for all species combined. Preliminary results indicate that drivers vary considerably by species, with July breeding ground precipitation (+) and December wintering ground minimum temperature (+) explaining the most combined variation in abundance anomalies among species. Individual species' models varied widely, but were driven primarily by breeding ground climate conditions and geographic region. We suspect that the strength of wintering ground variables will increase with improved delineation of zones to include land use and geography.

Advancing Methods

We continued our efforts to combine BAM data with BBS data to obtain trend estimates, we refined our national density models, and we worked on integrating data from roadside and ARU surveys into the BAM database.

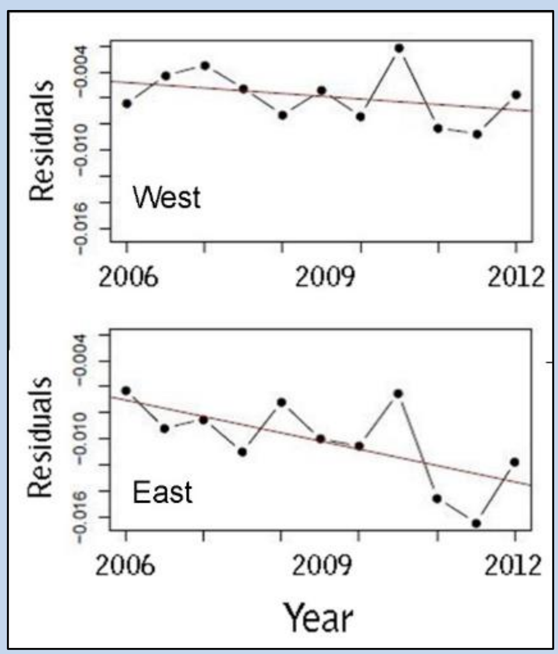
Improving boreal bird trend estimates by combining BAM and BBS data

When conserving a species, it's important to know whether its population is steady or declining, and if declining, at what rate. It's difficult to estimate population trends for boreal birds because existing datasets have inadequate or non-representative spatial and temporal sampling. The North American Breeding Bird Survey (BBS) dataset has the longest time series of data, but it samples a non-representative subset of the boreal forest[9], and its roadside surveys may introduce additional biases[9] (page 18). The BAM database (page 34) includes more off-road surveys and covers more of the boreal forest, but it doesn't have many repeated surveys in the same location, leading to low temporal coverage.

We hoped that combining the BAM and BBS datasets would produce the best of both; improved temporal *and* spatial coverage to estimate trends. We explored three statistical methods to see if it was possible. We found that some of these methods show promise for estimating trend using the BAM/BBS combined dataset, and we will continue to examine these and other methods for trend estimation using BAM's data. We welcome discussion and recommendations.

Estimating trend. In 2014-15, we developed a method to estimate trend using auto-regressive models[5]. In 2015-16, we revised it and then tested it using simulated data similar to our actual data. Results were unfortunately unreliable, so we tried two simpler statistical methods using our national Canada Warbler density models (page 7).

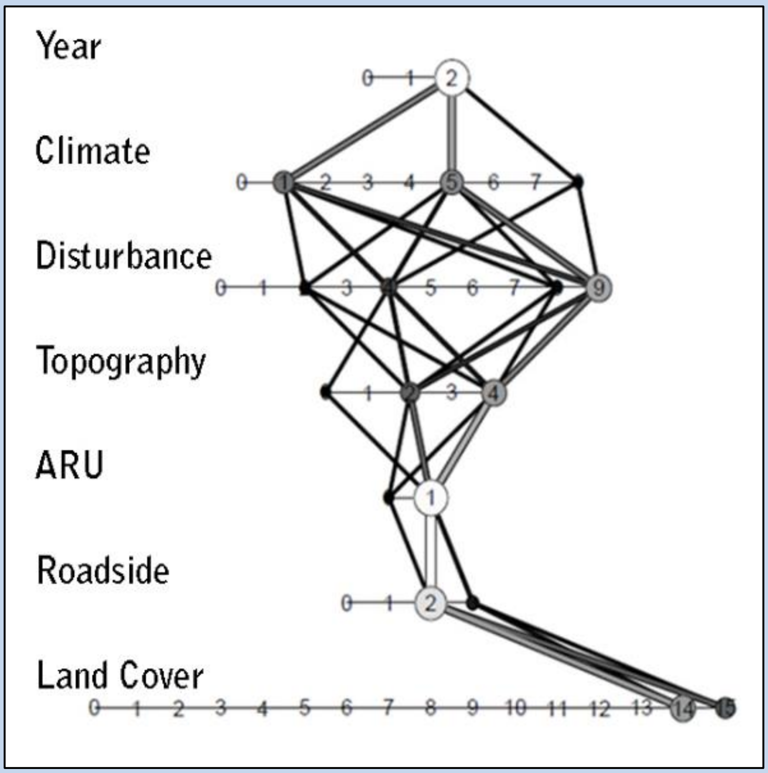
The first method calculated trend based on changes in habitat supply between 2002 and 2012. The second used a "year effect" - the coefficient associated with year in a model that allows density to vary over time. The year effect was either estimated jointly with other model parameters or was calculated using standardized model residuals. The trend estimates from the different methods were similar in magnitude and direction.



Finalizing a method to map density and estimate population size at national extent

Over the years, BAM has explored a few methods for creating maps of species' densities and for estimating population sizes. As part of our efforts to support the identification of critical habitat for species at risk in 2014-15, we explored a statistical method that could be flexible enough to use for all species[1]. In 2015-16, we revised this method based on earlier feedback and extended it to estimate short-term trends and evaluate human impact. We're currently writing a manuscript to describe this method. Later this fiscal year, we will apply it to all species with sufficient data in the BAM database, generating our best density maps and population estimates to date (page 7).

Branching forward variable selection. Our method, referred to as a branching hierarchy forward variable selection process, combines Poisson log-linear regression, stepwise staged variable selection, and bootstrapping.



Models are fit using generalized linear regression with Poisson error and a log link. Sets of variables are evaluated at discrete stages in a pre-defined order: 1) land cover; 2) on- or off-road survey; point count or automated recording unit; 4) topography; 5) disturbance; 6) climate; 7) temporal variation.

Within a stage, variables are ranked using AIC. The top ranked variables within a given stage are treated as fixed at the beginning of each subsequent stage. The process is repeated with 240 iterative bootstrap replicates. Results of this model selection process can be visualized as selection paths. Horizontal rows correspond to different stages of variables, with the numbers representing the individual variables to select from. Lines connecting stages show the paths taken by each of the 240 different bootstrap replicates. The size and shading of the paths and the circles around variable numbers indicate the selection frequency; thicker lines and larger circles of lighter shading indicate that those variables and paths were selected more often.

Developing and refining other methods

As part of our ecological and applied research, we continue to explore, develop, test, and refine existing and novel methods to achieve our research goals. Some of these are described elsewhere, including:

- Integrating Automated Recording Unit (ARU) data into the BAM point-count survey database (page 20)
- Integrating roadside surveys into the BAM point-count survey database (page 18)
- Testing the use of ARU data in N-mixture and occupancy models (page 20)

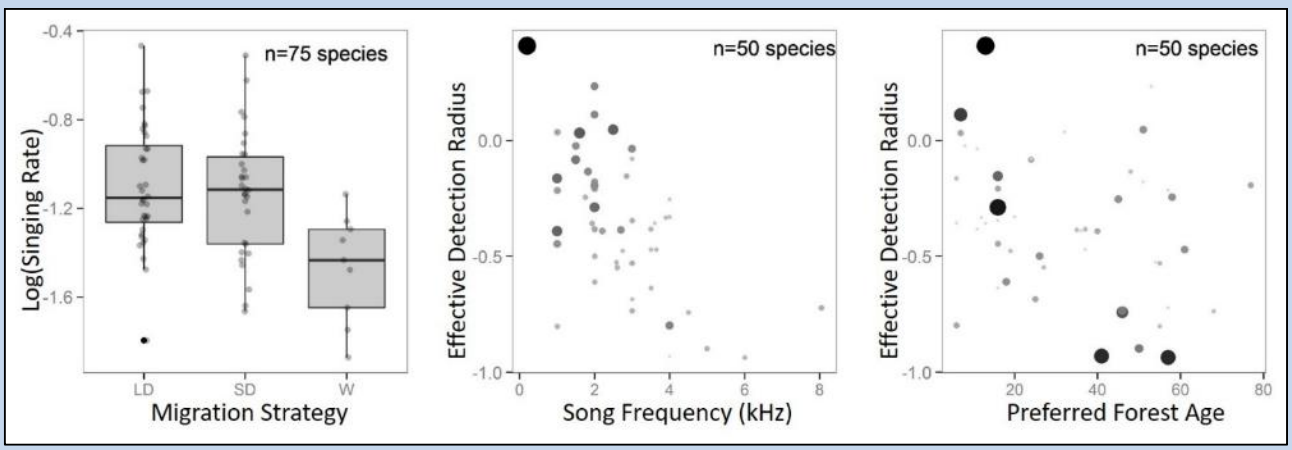
Informing Surveys and Monitoring

In the past year, we continued our efforts to quantify factors affecting species' detectability, such as time and date of the survey, and survey protocol (on- *vs.* off-road, and human- *vs.* ARU-based).

Understanding detectability to improve and validate our models and methods

In past years, we developed a method to correct for variability introduced into the BAM dataset through differences in point-count method[10]. This method also accounts for the fact that the some species are easier to hear than others; i.e., they are more detectable. We have continued to refine this method, and to explore various components of detectability so that we can validate and improve our methods (page 34). During 2015-16, we revisited a body of work we started in 2012-13, looking at how detectability might be affected or constrained by other selection pressures. This manuscript will be submitted within 2016-17.

Detectability, life history traits, and phylogeny. Species are more detectable when they have higher singing rates and/or when their songs are louder or lower frequency so as travel further through forest vegetation. This latter component is summarized as effective detection radius (EDR). We related singing rate and EDR to species relatedness using phylogenetic regression. We also evaluated relationships with species' body size, typical nest height, song frequency, migration strategy, and the minimum age of the forest inhabited.

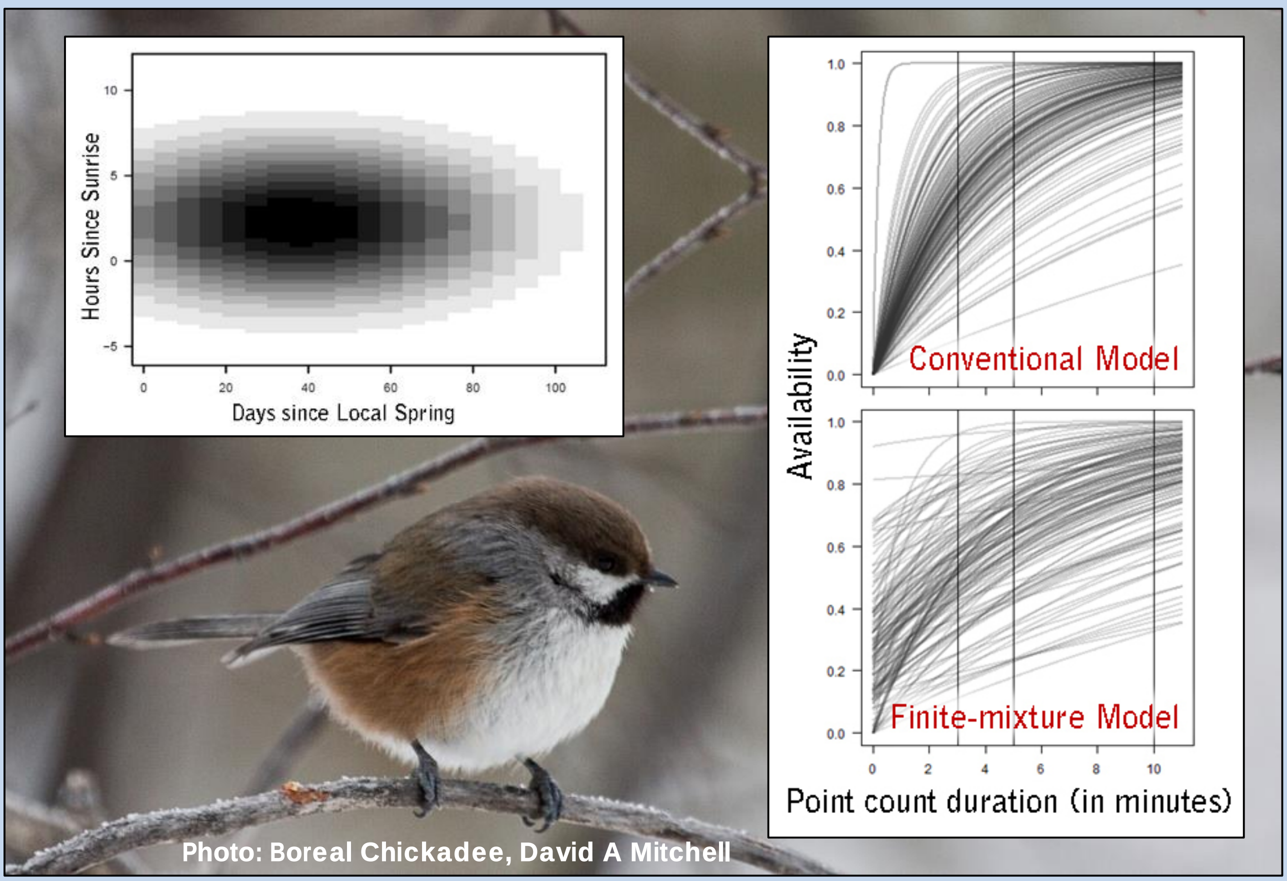


Singing rate did not have a phylogenetic signal, but EDR did. Singing rate varied with nest height and migration strategy. EDR was related to body size, song frequency, forest age association, and nest height. Since detectability has a phylogenetic signal, we suggest that it is especially important to account for imperfect detection in community analyses or else risk introducing phylogenetically non-random biases.

We also looked at how to best correct for detectability given that survey methods differ among studies and that species' singing rates vary over the course of the year and within a single day. We found that estimated time adjustments from removal models could be applied to BBS data to improve continental estimates of landbird population sizes. The resulting manuscript is in preparation and will be submitted within 2016-17.

Removal models and time of day corrections. Point count data can be analyzed with removal models to estimate and correct for the probability that a bird is available for detection by the survey observers. This availability is determined by the bird's singing rate and the duration of the point count survey. Survey duration varies among studies, and singing rate is higher at the beginning of the breeding season and in the morning for many species.

Some removal model formulations incorporate covariate effects like time of day and day of year. We explored four kinds of continuous-time removal model, including conventional and finite-mixture versions with and without covariates. Our goal was to understand relationships among model complexity, bias, variance, and sample size requirements. Preliminary results showed high variability in availability, estimated with both conventional and finite-mixture models. By applying covariates for time of day and time of year to our removal models, we estimated availability profiles for each species, indicating the probability that a species is available for detection.

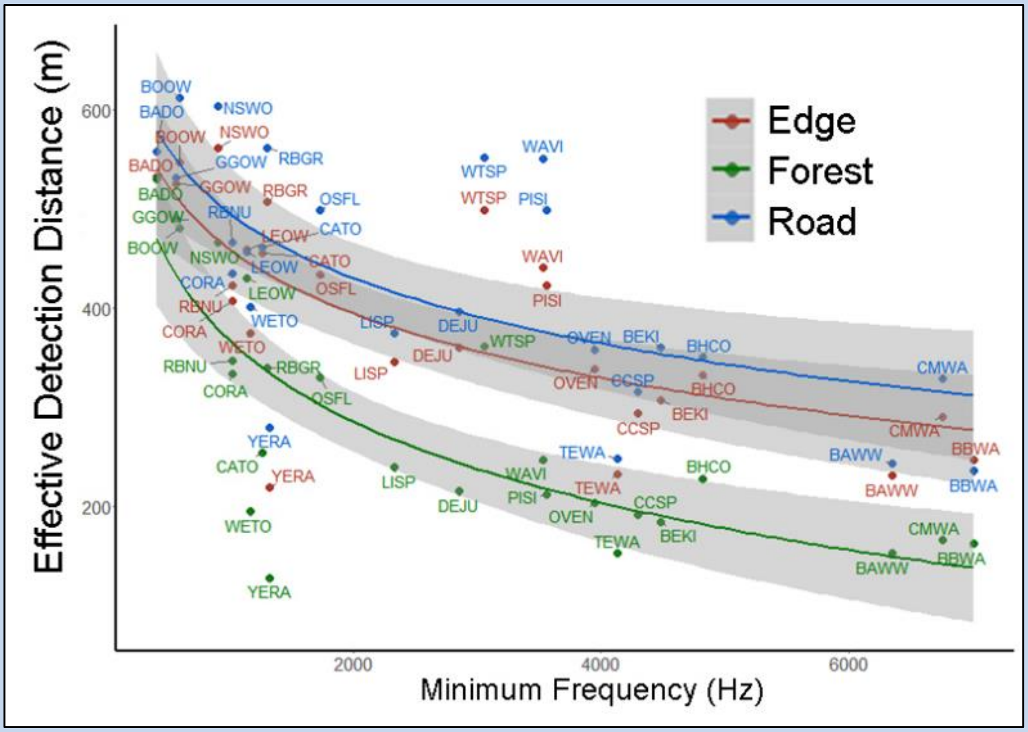


Integrating roadside and off-road point count data to model boreal bird populations

The BBS database is exclusively made up of data that were collected along roads. The BAM database includes data collected both on and off roads. Combining on- and off-road surveys would improve the sample size, the spatial and temporal coverage, and the number of species that models can be built for. However, we know that roadside surveys are biased compared to off-road surveys. Biases may come from differential sound attenuation, actual population differences along the road, increased singing rates, or other factors. We have explored a few of these with the hopes of correcting for roadside bias in our models, and so that we can provide advice on sampling approaches to reduce bias.

In our 2014-15 annual report[5], we described a sound transmission experiment evaluating the implications of sound attenuation during on- and off-road surveys. Species were easier to detect along the road and in the edge than they were in the forest interior. This work was refined in 2015-16, and a manuscript describing the work was submitted to the Journal of Applied Ecology in March 2016. This manuscript presents correction factors for 25 species that are meant to adjust roadside counts so that they're comparable to forest surveys.

Sound transmission experiments. Members of Erin Bayne's lab, in collaboration with BAM, conducted 600 playback trials along transects of varying distances in multiple locations. Broadcasted sounds included songs from 23 bird species, plus 7 different pure tones. Recorders were placed on the forest edge (1) or on the road (2) and audio was broadcasted to both simultaneously along a transect following the forest edge. For forest transects, recorders were placed within the interior forest (3) and playbacks transects ran perpendicular to the road.



Detectability decreased with distance more rapidly in the forest than on or along roads. Effective detection radii were smaller in the forest, especially for species with higher frequency songs. Correction factors indicating the magnitude of roadside bias were highest between the forest and road, and for species with high frequency songs.

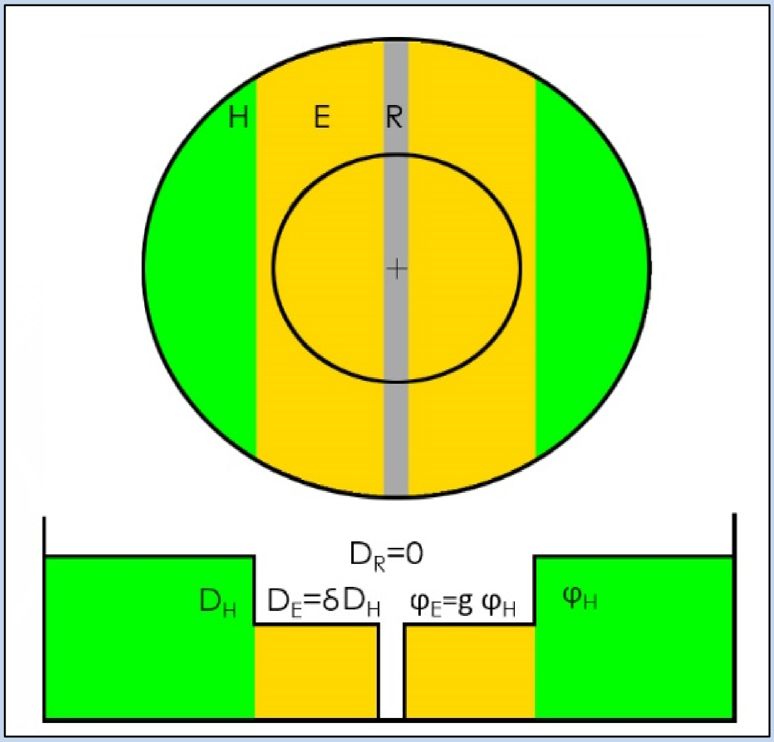
In last year's report, we described a model that quantifies differences in detectability between interior forest, edge, and road[5]. In 2015-16, in collaboration with G.Niemi, University of Minnesota, we tested this model against an extensive dataset designed for this purpose. We found that roadside bias results primarily from birds being less numerous in the forest edge compared to the interior forest, even though they sing more often in the forest edge.

Based on these results and other results from the Minnesota dataset, we make the following recommendations to minimize roadside bias:

- Use larger (i.e., unlimited) sampling radii during point count surveys;
- Preferentially sample on narrow roads *vs.* wide roads, when possible;
- Filter datasets to exclude surveys conducted on wide roads;
- Include the presence of road and a habitat x road interaction in species' models to adjust for the presence of roadside surveys. We did this in our own national density models (page 14).

We're currently summarizing these results in a manuscript that will be submitted in 2016-17.

Roadside bias model and simulations. Our HER (**H**abitat-**E**dge-**R**oad) model describes species' numerical and behavioural responses to forest edge, relative to interior forest habitat. δ is a multiplier describing the relationship between a species' density in the edge and its density in the forest interior (D). g is a similar multiplier for singing rate (φ). We assumed that density, and therefore singing rate, was 0 on the road.



When applying data to the model, we found that many species showed a negative numerical response to forest edge, and some showed a positive singing response. Since most species show an overall negative roadside bias, we can conclude that even if birds sing more in edge habitat, the positive behavioural response doesn't completely offset their decreased density along the road edge.

These preliminary results are meant to demonstrate one application of the HER model. We are currently discussing how to extend this model to include other assumptions or scenarios. We are also considering other potential applications of the HER model, such as executing simulation experiments to explore the sensitivity of roadside bias to various factors. This could be made available for other researchers to explore their own sampling methodology, if there was interest.

Integrating data from ARU and traditional point-count surveys

Automated/autonomous recording units (ARUs) have many advantages over traditional, human-based point counts. ARUs can be set up and programmed to sample once or multiple times on dates and times when regular point counts normally cannot be conducted due to accessibility, safety, or financial and temporal constraints on sending human observers. We are investigating how best to combine ARU data and traditional point-count survey data in the same models. So far, BAM models have included ARU data as unlimited distance point-count surveys with three time intervals. Any differences between the two types of data are accounted for by coding data as ARU or not. However, we'd like to seamlessly integrate the two data sources, more precisely accounting for differences. We've explored a few methods over the last year and are now working towards a synthesis that will let us calibrate data to a common standard. Work is still in progress, and will be described in manuscripts that we intend to complete in 2016-17.

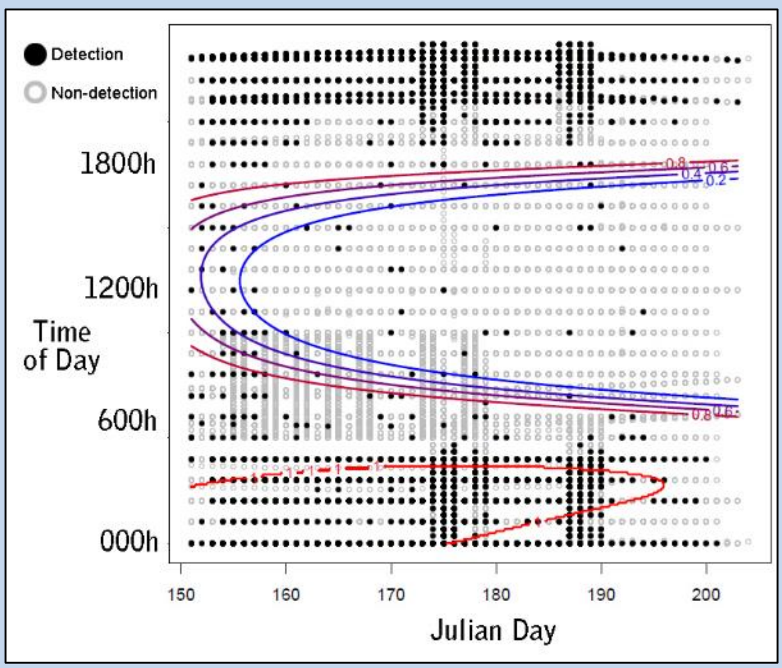
Experiments comparing ARUs to humans. Meaningful comparison between ARU data and traditional, human-based point-count data requires standardization. BAM is collaborating on two experiments to identify how best to standardize the two data types.

The first experiment, conducted by Steve Van Wilgenburg (BAM Contributing Scientist with ECCC), used paired human and ARU point counts in natural settings. The second experiment, conducted by Daniel Yip (PhD student with Erin Bayne), broadcasted tones and bird songs at various known distances, which were recorded by ARUs or a human observer. By comparing the detections in each of the two survey types, we were able to determine effective detection radii for the two survey types, and associated correction factors that adjust ARU data to point-count data.

Also in 2015-16, we looked at the potential benefits of including ARU data in the BAM database. First, we demonstrated the importance of ARUs for better understanding Common Nighthawk habitat associations. Models built in 2016-17 will account for higher singing rates at night and early in the breeding season.

Detecting Common Nighthawk. Elly Knight (a PhD student with Erin Bayne) identified over 135,000 detections of Common Nighthawks from ~1400 hours of ARU recordings using one of 25 automated recognizers built by the Bayne lab for detecting species of concern from ARU recordings.

From these detections, BAM built models of bird availability that accounted for diurnal and seasonal variation in singing rate. We can represent this information visually as a probability profile; the probability of a bird vocalizing during a given 10 minute period.



Second, we demonstrated how ARU data can be used as multiple "visits" to a survey location, giving us the ability to correct for imperfect detection at a given visit and build more accurate models of species' habitat associations. This work was presented at a meeting of the Alberta Chapter of the Wildlife Society.

N-mixture and occupancy models. Using multiple "visits" from ARU data, we demonstrated the use of single-season N-mixture and occupancy models to calculate abundance and probability of occurrence of Le Conte's Sparrow. These models account for the <1.0 probability of detecting an individual given its presence. In our case study, probability of occurrence of Le Conte's Sparrow was highest within graminoid-rich fens. Probability of detection was higher between dusk and dawn, higher later in the season, and lower under conditions of high ambient noise from wind, rain, and anthropogenic noise.


Photo: Le Conte's Sparrow, Lionel Leston

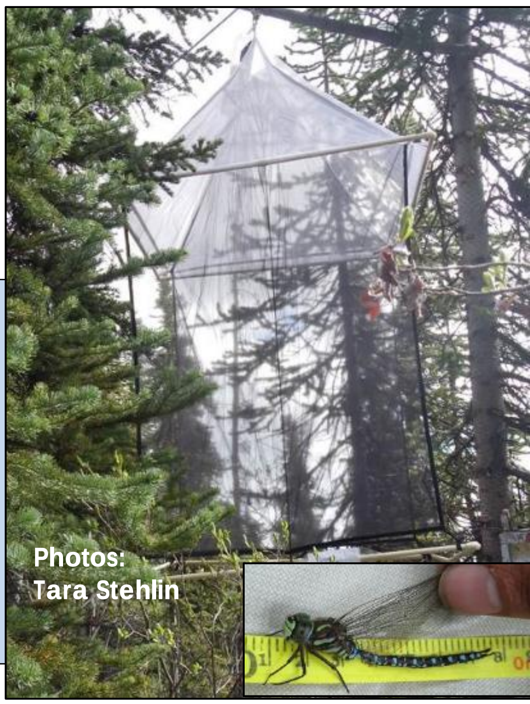

Photo: Greg Miller

Climate Change

We continued our work to understand implications of climate change on bird populations, including range expansion or shifts, and possible mismatches in timing between songbird breeding and insect food sources. We also pursued two regional modelling studies, simulating future landscapes to understand bird response to climate change.

Assessing timing mismatch between insect abundance and the breeding season

One predicted negative impact of climate change on birds is the mismatch in timing between insect abundance and the breeding season. In this project, we're looking at the peak abundance of preferred insects in relation to the peak energetic demands of Olive-sided Flycatchers and Western Wood-pewees feeding insects to young. In 2015-16, data from a third field season was added. In 2016-17, a fourth season will be added.



Photos: Tara Stehlin

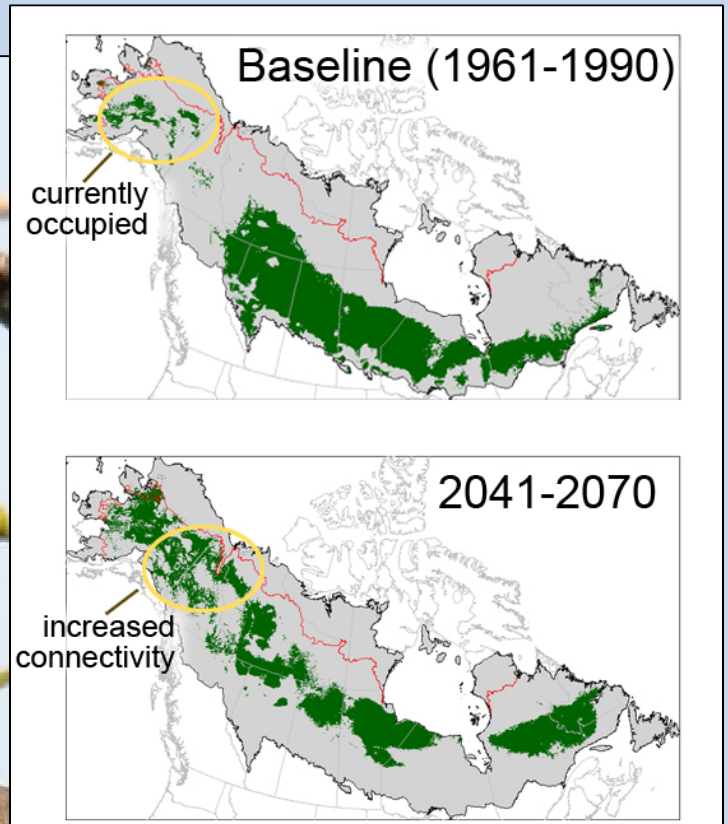
Modelling timing mismatch. Tara Stehelin (PhD student with BAM) collected data on insect abundance and breeding and nesting phenology during the field season. A climate-modified Lotka-Volterra model is being used to quantify daily abundance of insects in relation to peak energetic needs of birds feeding chicks. Data from the first three seasons have been incorporated into the model, and at least one more field season is anticipated.

Barriers to range expansion in western North America

Although Alaska's climate is theoretically suitable for many species that breed in the Canadian boreal, only a few species actually breed there. We looked at past and future climates and biological factors to understand what is stopping species from crossing the northwestern cordillera mountains into Alaska from the Canadian boreal. We found that climatic suitability was a major factor, and that species will likely be able to cross into Alaska as climate change alters the climatic suitability of the barrier. This work was finished in 2015-16 and included as part of Diana Stralberg's PhD thesis; a manuscript was submitted to Ecography in January of 2016.

Paleo-hindcasting and phylogenetic logistic regression. Paleo-hindcasting uses bioclimatic niche models and past historical or simulated climate data to project or "hindcast" species' likely distributions in previous time periods. Using bioclimatic models of density for 80 boreal passerine species[11], we developed distribution predictions for two paleo-climate periods. We used climate data from the last glacial maximum, approximately 20,000 years ago, and from the mid-Holocene warm period, approximately 6,000 years ago. We wanted to know if species with western glacial refugia were more likely to breed in Alaska currently, and whether species with increased prior connectivity across the cordillera were more likely to have crossed over.

Photo: Tennesee Warbler, USFWS



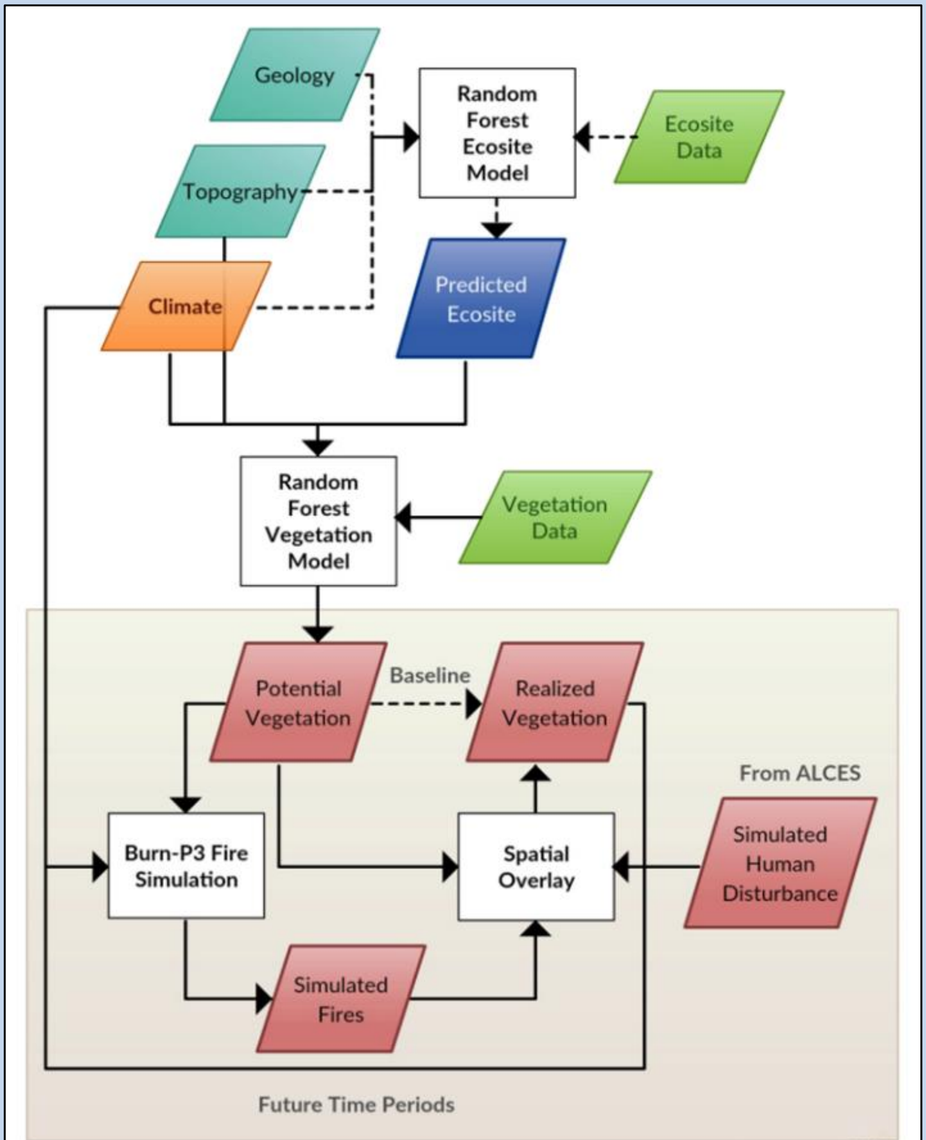
We then used phylogenetic logistic regression analysis to evaluate the relative importance of physical, migration, and competition factors *vs.* the suitability of current and past climates. Controlling for current climatic suitability within boreal Alaska, we found that species with the greatest climatic suitability across the northwestern cordillera, presently and also during the relatively warm mid-Holocene period, were most likely to be regular breeders in the Alaskan boreal region. This analysis suggests that the perceived barrier of the northwestern cordillera may be easily weakened as climate change improves conditions there for many forest species. Indeed, several of the species that our analysis considered most likely to shift into Alaska in the future already have some evidence of breeding activity there, including Tennessee Warbler and Yellow-bellied Flycatcher[12,13].

We suggest that conservationists and land managers prepare to reevaluate conservation policies and strategies in light of evolving ecological communities.

Changes in Alberta vegetation and age-structure from climate change and human disturbance

In the western boreal region, climate change is expected to produce weather conditions that are more conducive to fires, resulting in more frequent and larger wildfires. When combined with increased human activity, there is great potential for major changes to forest structure and species composition. We developed a hybrid modelling approach to better understand factors influencing decadal-scale upland vegetation change, and to evaluate realistic scenarios of future forest change in Alberta. In 2015-16, this work was included in Diana Stralberg's PhD thesis. In 2016-17, models will be updated with recent climate projections and used to determine possible future changes in bird habitat suitability. A manuscript is currently in progress.

Hybrid modelling approach. Our modelling approach combined: 1) topographically and geologically constrained projections of climate-driven vegetation change potential; 2) weather- and fuel-based simulations of future wildfires using Burn-P3[14]; and 3) projections of large-scale industrial development activities using the ALCES model[15]. We simulated scenarios of change in forest composition and structure over the next century, concluding that at least one-third of Alberta's upland mixedwood and conifer forest is likely to be replaced by deciduous woodland and grassland by 2090, with a disproportionate loss of old forest. During this timeframe, the rate of increase in fire probability diminished, suggesting a negative feedback process by which a warmer climate and more extensive near-term fires leads to an increase in deciduous forest that in turn, due to its relatively low flammability, leads to a long-term reduction in area burned.



Understanding bird response to climate change by simulating future forest landscapes

In 2015-16, BAM was recruited for a collaboration with Yan Boulanger (Natural Resources Canada) and Junior Tremblay (ECCC) to estimate the impacts of climate change on boreal forest landscapes while considering forest harvest and natural disturbance (wildfire and spruce budworm outbreaks). The goal is to simulate future forest landscapes and translate them into bird habitat to understand how many birds can be supported by the theoretical future landscapes. In 2015-16, plans were laid for regional work in Alberta and in Quebec.

Photo: University of Alberta

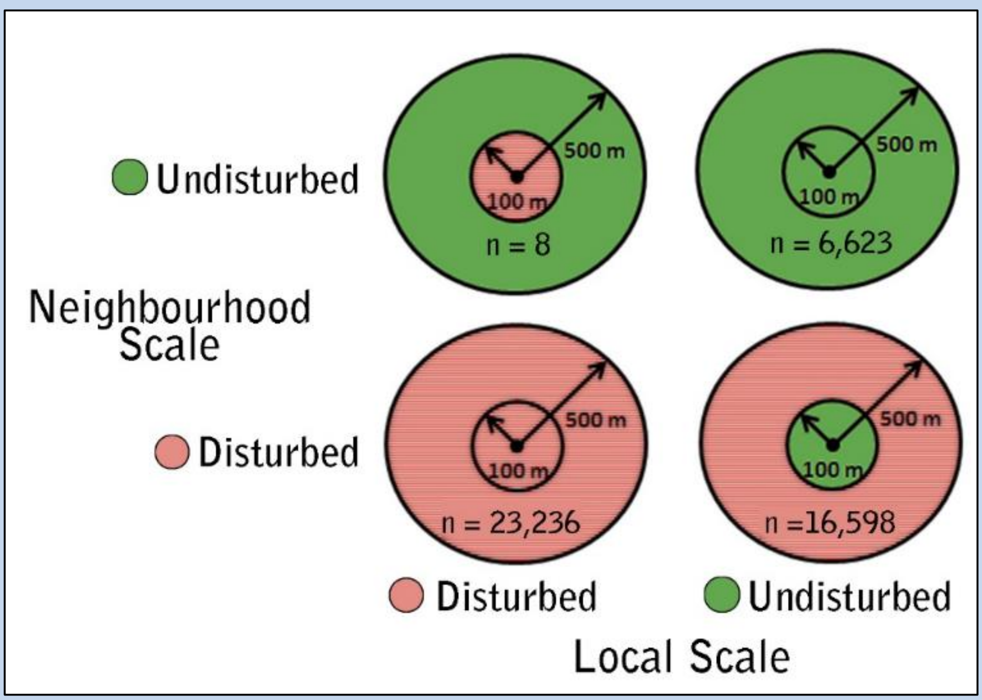
Human Impact

One of BAM's primary goals is to understand how human activities impact bird populations. In the past year, we continued this work both nationally and regionally. Nationally, we tested for effects of past disturbance on bird populations. The regional work includes a focus on monitoring of impacts of oil sands activity on boreal birds as part of a regional partnership among government, industry, and academics.

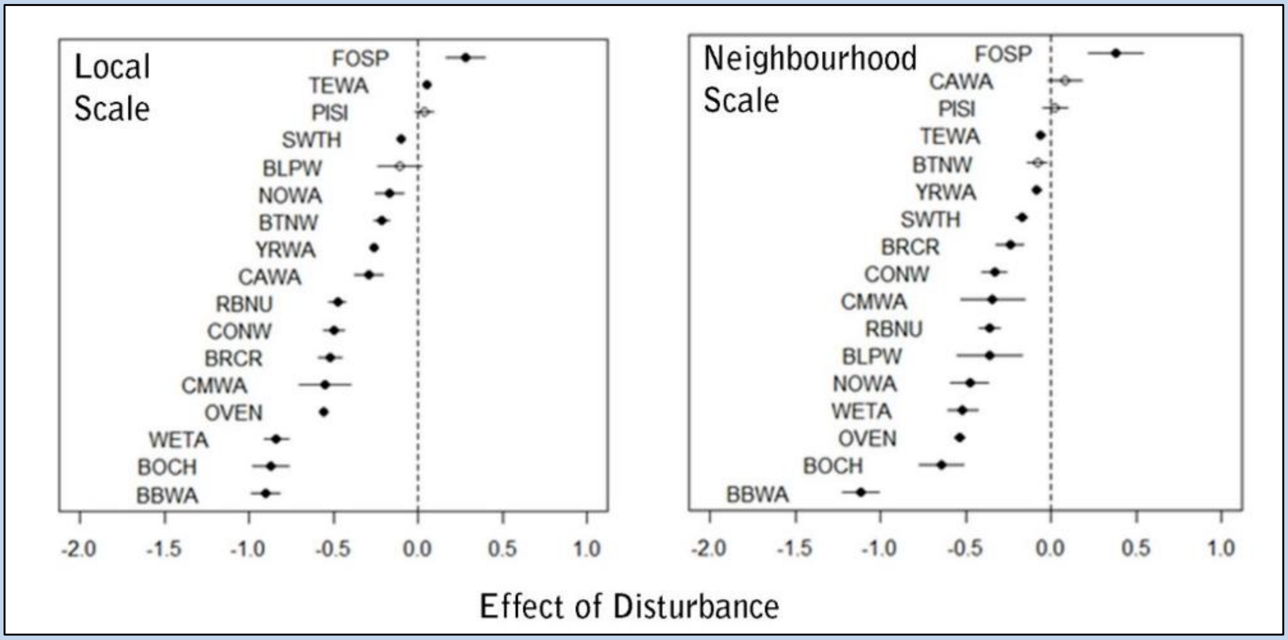
Effects of anthropogenic disturbance on boreal birds at national extent

The BAM avian database provides an opportunity to quantify impacts of human disturbance on bird populations at large spatial extent. In 2015-16, we refined previous methods[5] and ran new analyses evaluating these impacts at local and neighbourhood scales. Our results suggest that past industrial activities in the boreal forest have had negative impacts on forest-dependent bird species extending beyond the immediately surrounding areas. A manuscript is in preparation.

Potential scenarios. We calculated the proportion of disturbed area surrounding point count locations within the BAM off-road dataset using the Global Forest Change[8] and Boreal Ecosystem Anthropogenic Disturbance[16] datasets. Since bird response to disturbances may vary with scale, we calculated the proportion of disturbed area at two scales: local (0-100 m) & neighbourhood (100-500 m). This resulted in four situations based on disturbance at local or neighbourhood scales.



GLMMs. We modelled density of 17 older-forest-dependent bird species using Generalized Linear Mixed Models. The proportion of area disturbed at the local or neighborhood scale were continuous covariates or binary factors. We included BAM offsets to account for sampling differences among data sources and also accounted for inter-regional variation in climate and for regional differences in density among land-cover classes. Our preliminary results suggest that the density of most bird species decreased as the proportion of disturbed area increased at both local (100 m) and neighborhood (500 m) scales.

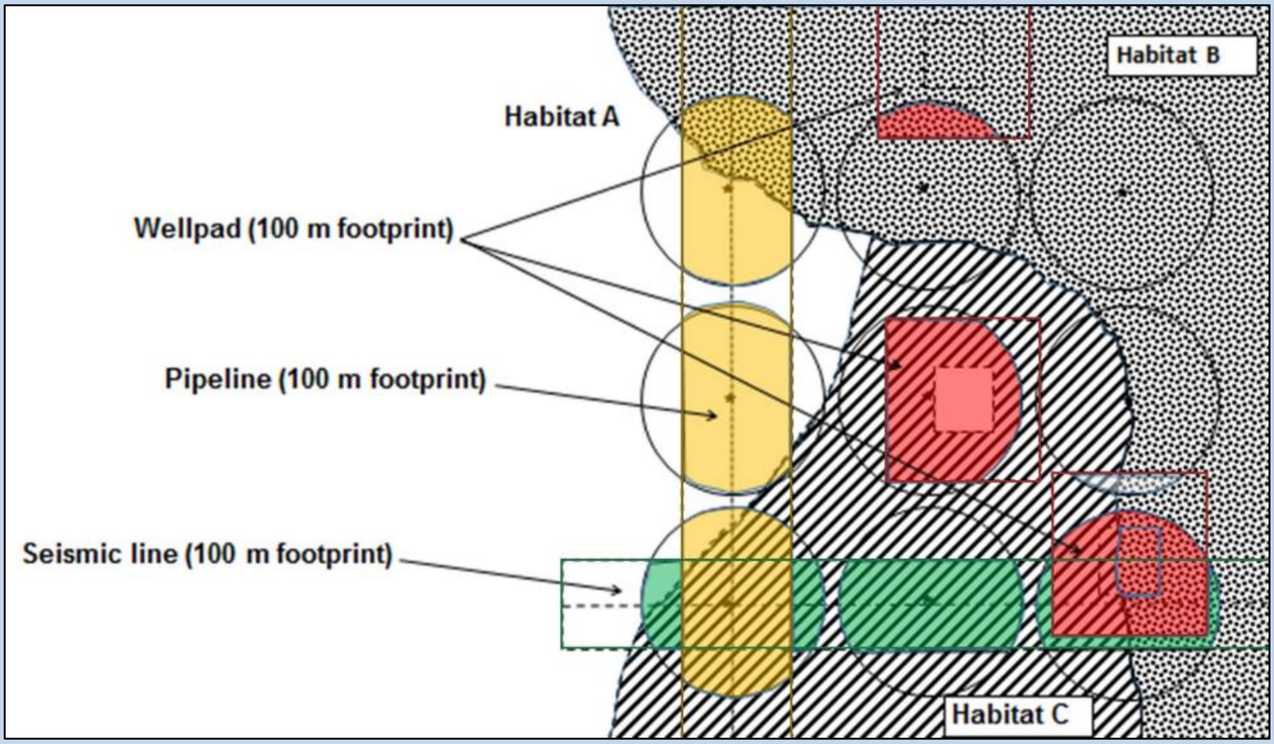


Predicting population-level effects from local scale models of energy sector impacts

In 2014-15, we created local-scale models of impacts of energy sector activities on bird populations; this work was accepted for publication in Condor in 2015-16[17]. In 2015-16, we assessed the ability of these models to accurately predict landscape abundance of species by comparing estimated abundance from each model to observed abundance per landscape. In our 2014-15 report[5], we described early results: predicted abundance was usually overestimated and not very close to the observed abundances of species in our sampled landscapes. Since then, we explored how prediction accuracy of local-scale models was affected by a number of different factors, including survey protocol and species' regional abundances. We will be submitting a manuscript summarizing these results in May of 2016.

Validating landscape population sizes. We predicted species' abundances per landscape based on previous models. Model predictions of density per habitat type were multiplied by the area of each habitat type and then summed to estimate the population size for the landscape.

Actual abundances per landscape were from two datasets: ARUs deployed by the Alberta Biodiversity Monitoring Institute (ABMI), and traditional point-count survey data from ECCC. In both datasets, surveys were conducted within "landscapes" of 9 clustered point counts.



For each dataset, we compared predicted to observed abundances of 64 species in each landscape using several validation statistics. For both datasets, we found that local models poorly predicted and ranked actual numbers per species per landscape, although local models accurately classified landscapes as suitable/unsuitable for a larger proportion of species.

However, when both datasets were combined and the predicted and observed abundances were compared within ranked groups of landscapes, the average observed numbers per landscape were highly correlated with model predicted values. This suggests that while local models have low probability of accurately predicting a species' abundance in any individual landscape, local models may be sufficient for calculating average abundance of a species in a series of landscapes. Thus, a conservation planning region can be divided into landscape planning units with ranks or numbers of a species predicted for each unit; then, units can be ranked and grouped according to estimated abundances and the average estimated number of a species in the top 10% of units will on average have higher numbers of that species than the next top 10% of units, etc.

In all three datasets (ABMI, ECCC, combined), there was some evidence that predictive accuracy of local models was higher for species that were regionally abundant or had narrower habitat requirements (i.e., specialists).

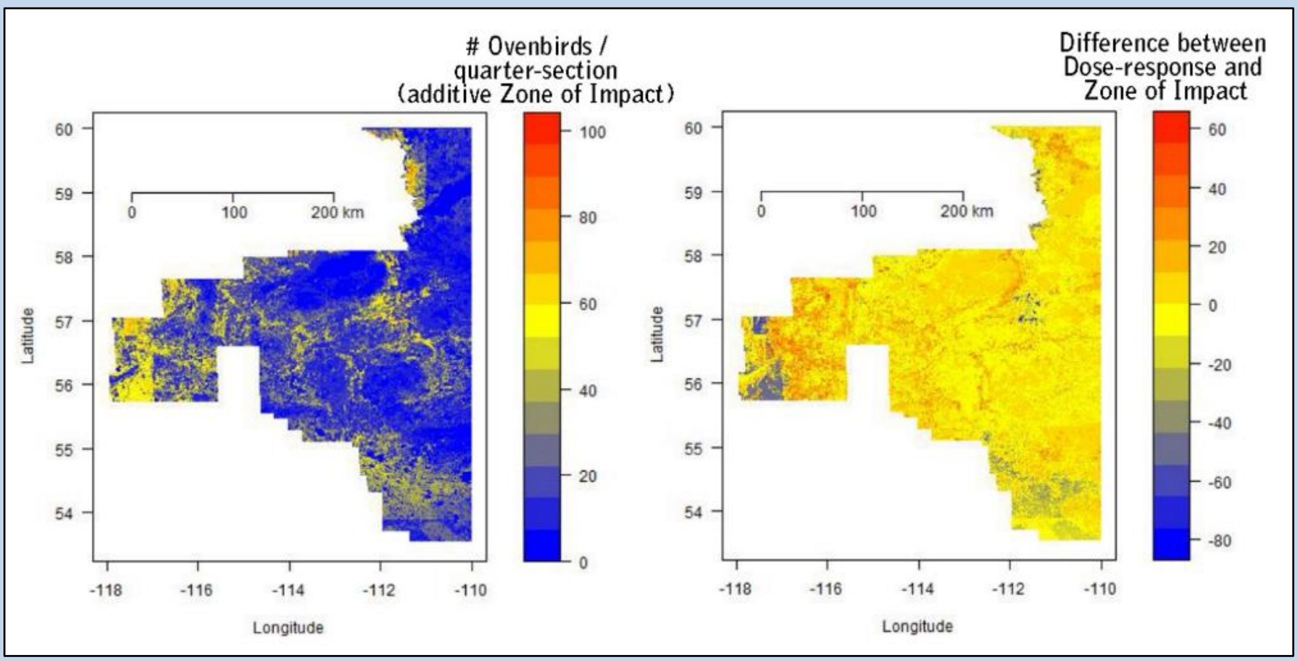
Evaluating cumulative effects of human activities on birds in the Alberta Oil Sands

BAM and collaborators have used several different models to examine the effects of human activity on bird populations in the oil sands region[6,7,17,18]. We're now trying to get an overall view of effects of energy sector activities on bird populations by synthesizing results from the different methods. In

2016-17, we hope to use these models in simulation models to project potential population implications of future development.

Estimating and comparing population sizes. Models previously built by BAM include: 1) *Dose-response:* local models of habitat, forestry extent, and human footprint extent based on collated point counts from many studies, reported in previous years[6,7]; and 2) *Control-Impact:* local control-impact studies that predicted the relative abundance of species within or beyond a given distance from different types of energy sector disturbances, accepted for publication in Condor[17]. A third approach, explored by BAM Contributing Scientist Lisa Mahon and Gillian Holloway (Fiera Consulting), looked at additive and interactive effects of different sectors on bird populations at landscape scale[18].

To date we have estimated population sizes for each modelled species within the JOSM region in northeastern Alberta using the first two methods. Dose-response models predicted abundance for 81 species based on background vegetation alone ("reference population") and based on human footprint accounting for forestry and energy sector disturbances. We made similar predictions for 46 boreal songbird species based on four local-scale, control-impact models: background vegetation alone, a model with additional forestry effects, a model with additional energy effects, and a model with additive forestry and energy effects. In comparing population predictions from each of these footprint models to the reference population predictions, we identified which species were positively or negatively affected by different land uses. Predictions from the third approach are forthcoming.



Data Development

Data Products for Distribution

We continue to make finalized data products publically available. We also made significant progress in streamlining and standardizing our process for reviewing and approving requests for unpublished data products or other information.

Products available for distribution

BAM has created many data products that are available for various applications. Many of these are online, either on the BAM website or our Data Basin portal. More will be uploaded in future, as they become available and as resources permit. The following table is an inventory of what is currently available. Interested parties can contact the BAM Coordinating Scientist, Nicole Barker, at nbarker@ualberta.ca for more information or to request a product.

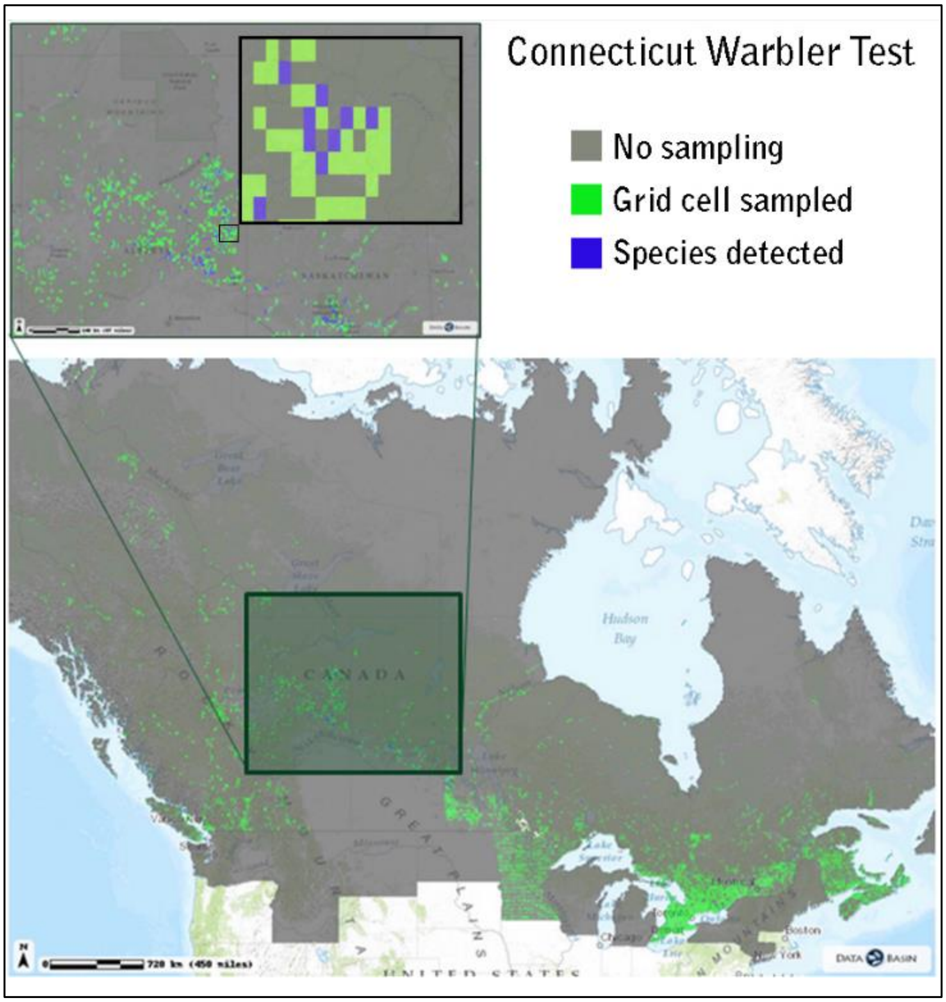
Layer	Details	Location	Reference
Density version 1. Estimated breeding density by BCR, jurisdiction, and land cover class	Males / hectare of each species estimated from hierarchical models of species' density. • Timeframe: 2005 • # species: 70 • Extent: varies by species	Table available by request to Coordinating Scientist.	BAM website[4]
Density version 2. Spatially-explicit current species density	Males / hectare of each species, predicted from Boosted Regression Tree models. • Timeframe: current • # species: 103 • Extent: northern North America, excluding high Arctic	**Interactive** maps on Data Basin **Download** ASCII grids from Data Basin	Stralberg et al. 2015. Ecological Applications[11].
Species Density under Climate Change	Males / hectare of each species, predicted from Boosted Regression Tree	**Interactive** maps on Data Basin	Stralberg et al. 2015. Ecological Applications[11].

	models and climate models. • Timeframe: 2011-2040; 2041-2070; & 2071-2100 • # species: 103 • Extent: northern North America, excluding high Arctic	**Download** ASCII grids from Data Basin	
Climate Change Refugia	Area of overlap between current and future suitable habitat for each species. • Timeframe: 2011-2040; 2041-2070; & 2071-2100 • # species: 103 • Extent: northern North America, excluding high Arctic	Temporary FTP (by request to Coordinating Scientist)	Stralberg et al. 2015. Diversity & Distributions[19].
Species Distribution & Relative Habitat Suitability	Predictions of habitat suitability from MaxEnt models of species' presence. • Timeframe: current • # species: 88 • Extent: North American boreal and hemiboreal	Static images on BAM website. Rasters available via temporary FTP (by request to Coordinating Scientist)	Described on the BAM website
Forest Age Associations	The minimum forest age inhabited by each species. • # species: 59	Table available by request to Coordinating Scientist	Appendix of Stralberg et al. 2015. Diversity & Distributions[19].
Waterfowl Relative Densities	Pairs / km^2 of each species/group, predicted from Boosted Regression Tree models. • Timeframe: current • # species: 17 species & 3 nesting guilds. • Extent: Canada	Rasters available by request from Ducks Unlimited Canada (contact Al Richard)	Barker et al 2014. ACE-ECO[20] And Barker et al 2014. Ecosphere[21].

Distributing data products

In 2015-16, we streamlined our procedures for handling requests for data products. We also developed standard collaboration agreements and metadata files for each of our major data products. We are gearing up to populate our Data Basin portal with new datasets, starting with the

"Data Locations" gallery. The goal is to have raster layers for each species, showing sampling occurrences, species' presence, and species' absence on a 4-km grid. In late 2015, we met with Data Basin to discuss possibilities, and we produced a prototype to determine how storage space, download time, and display times are affected by data formats.



One challenge associated with this gallery is restrictions included within our data-sharing agreements with data partners. Before we can launch these layers publicly, we must work with all data partners to find an acceptable format and suitable resolution for display and distribution of their data (page 13). The 4-km grid is our first prototype; additional species and resolutions will not be made public until approval has been obtained for this format or a suitable alternative.

BAM Databases

In 2015-16, we focused on quality checking the existing avian database rather than adding new data. We also started the process of updating calculations of statistical offsets that correct for differences in detectability and survey methods among datasets.

Building a public version of the BAM database

We're currently exploring the possibility of creating a version of the BAM database that would be widely available for use by anyone. Respecting our original data-sharing agreements with our data partners is however our first priority. Therefore, over the coming months, we will approach each of our data partners and re-establish terms of the data sharing agreement with this possible new direction in mind.

Estimating new statistical offsets to harmonize the BAM database

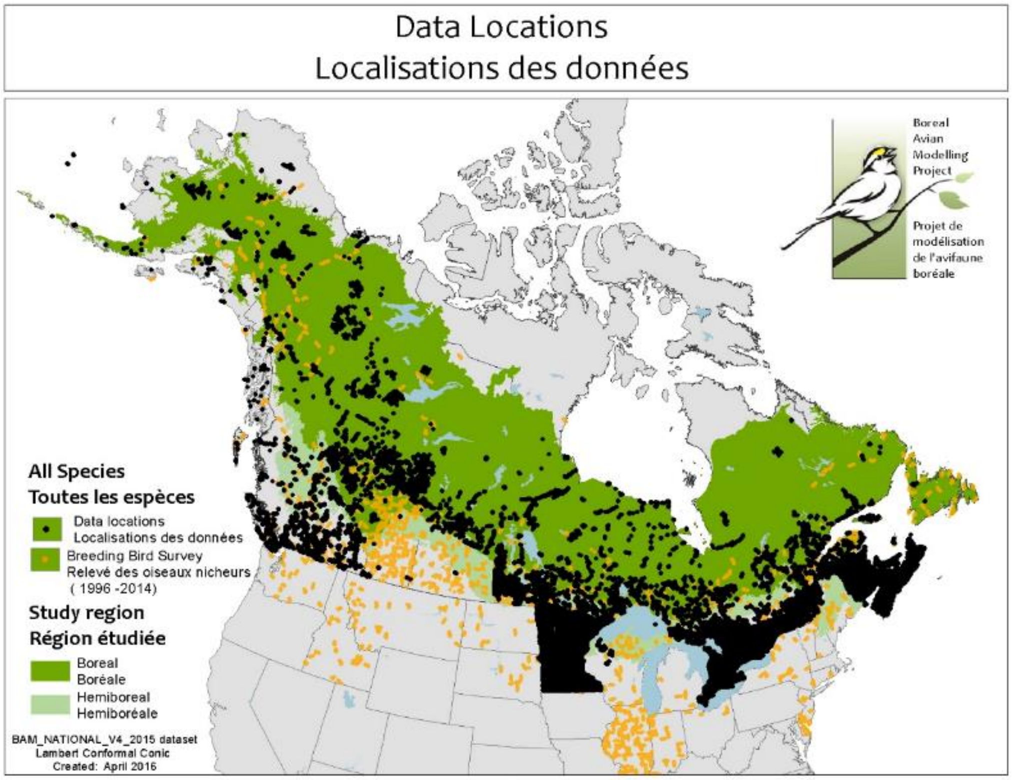
When modelling avian abundance, distribution, and trends, BAM uses statistical offsets to account for differences in sampling method and detectability in the database. The BAM database is continually growing, so we update our statistical offsets periodically to make use of the increased information. Data permitting, we occasionally re-estimate the models used to define the offsets.

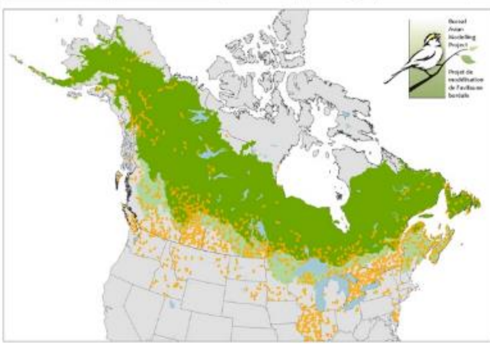
In 2015-16, we started the re-estimation procedure, for behaviour- and detectability-related parameters. When applying this improved method on the latest version of the BAM database, we'll have more accurate offsets for more species. In 2016-17, we'll finish our update, calculating new offsets to be used in future count regression models.

Offsets that account for roadside bias or effects of ARUs have proved difficult to obtain. Instead, our solution at present to use factor covariates (e.g., on/off road, and ARU/point-count) to account for potential effects of these different data sources.

New and improved method. Two changes have been made to the method of calculating offsets. First, we now separate wetlands from other habitat classes to account for the fact that estimated detection radii are larger in wetlands. Second, we use the continentally available North American land cover layer instead of a Canada-only product. This allows us to incorporate data sets from United States, and extend predictions into the full extent of the Boreal region. Using the North American layer also allows us to separate forested wetlands from forests, which weren't distinguished in the land cover layer we used previously.

The BAM Avian Database





We're in the midst of updating the database with data received in 2014 and 2015. We received datasets from Newfoundland and Labrador courtesy of ECCC, and are now processing them for integration into the BAM database. We have included BBS data from 2014. The current contents of our database are summarized below.

	BAM Avian Database	BAM's BBS Database
Version (Year Updated)	V4 (2015)	V3 (2015)
# Projects	135	All Canadian and Alaskan BBS routes; some routes from northern USA.
# Sampling Locations	146,433	65,609
# Sampling Events	251,977	605,689
# Bird Observations	2,419,207	4,429,705

The BAM Biophysical Database and prediction grids

We added Global Forest Change layers[8] to our database and intersected them with our sampled locations to prepare for model-building. We also intersected our sampled locations with standardized forest resource inventory data[22] and the most recent years of data for annual products including the Canadian National Fire Database and bioclimatic layers from Natural Resources Canada.

To make our national predictions of species' density, we need spatial data for all of our covariates across our study area. We solve this GIS problem by intersecting a grid of points at 1-km intervals with all of our model covariates, which is similar to having a raster of similar spatial resolution for all covariates. As part of acquiring new data layers for the geospatial database, we intersected each with the prediction grid points to generate our prediction grids.

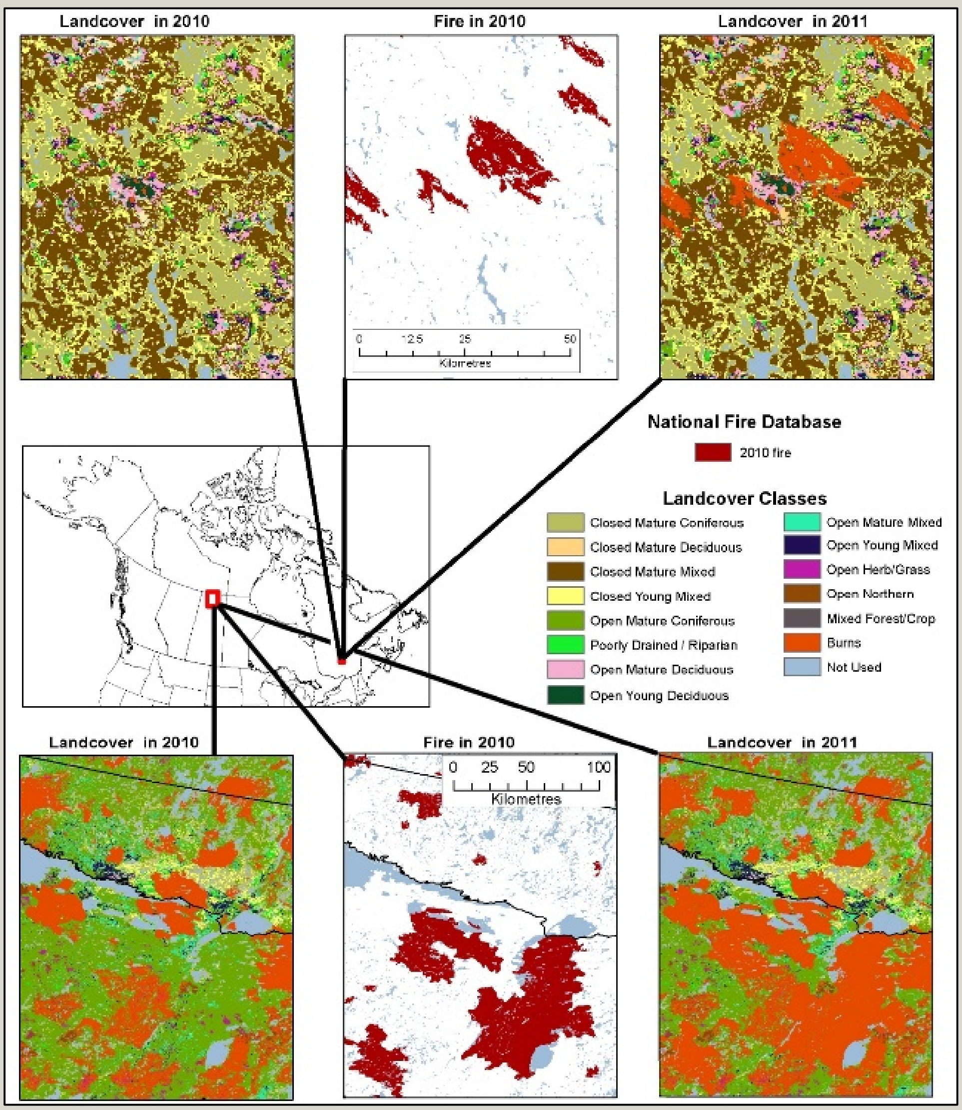
Deriving Products for BAM Analyses

Our work often requires extensive preliminary spatial data analysis to create custom data layers for modelling. In 2015-16, we derived two such products and made progress on two others.

Land cover changes resulting from forest fires and human activities

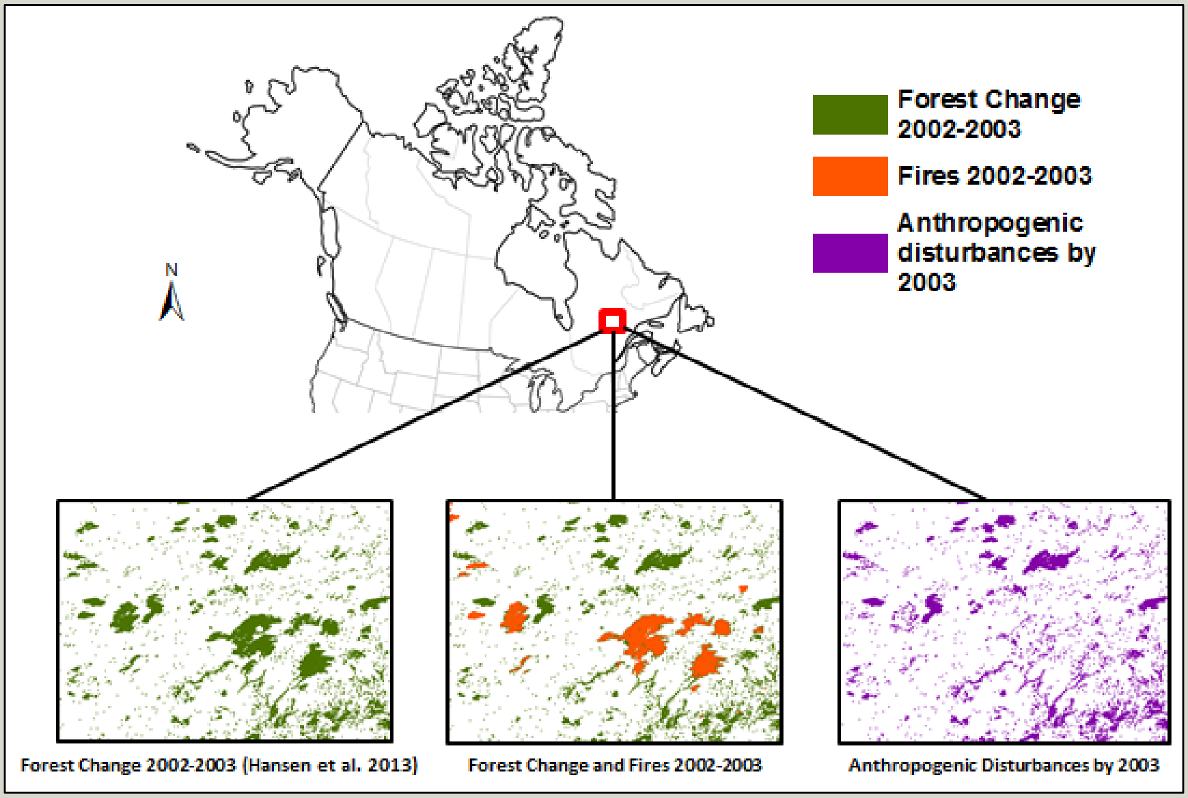
In 2015-16, we combined a static land cover layer with annual forest fires to create a layer depicting land cover in every year from 2005-2014 assuming fire was the only changing factor. We used this to estimate potential population-level effects of wildfire (page 10). In 2016-17, we'll create a similar series of rasters depicting annual changes from anthropogenic activity from the Forest Cover Change[8] layer.

Modifying 2005's land cover. Starting with the Land Cover of Canada 2005[23] layer, we iteratively modified these initial conditions using annual fire data from the Canadian National Fire Database[24]. A new annual land cover layer was produced for each year from 2005 through 2014 (n=10 years). At each annual iteration, all cells overlapped by a fire polygon were relabelled as "Burns" in the subsequent year's land cover layer. Throughout this iterative process, areas of vegetated landcover classes decrease, while the amount of recently burned areas, "Burns", increases.



We also created annual maps of anthropogenic disturbance, to be used in our national models of land-use impact (page 27).

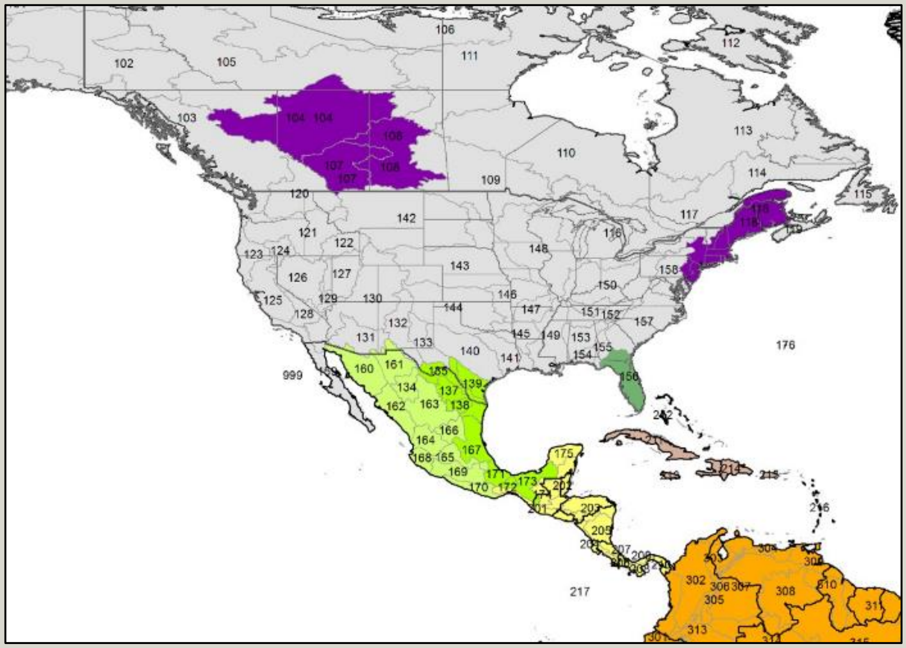
Quantifying human land-use changes. We combined the Global Forest Change dataset[8] and the National Fire Database[24] to produce a time series of annual, anthropogenic disturbance maps. Starting with the annual maps of forest change, which summarize forest loss from both human and natural disturbances, we removed annual fires through intersections with the National Fire Database.

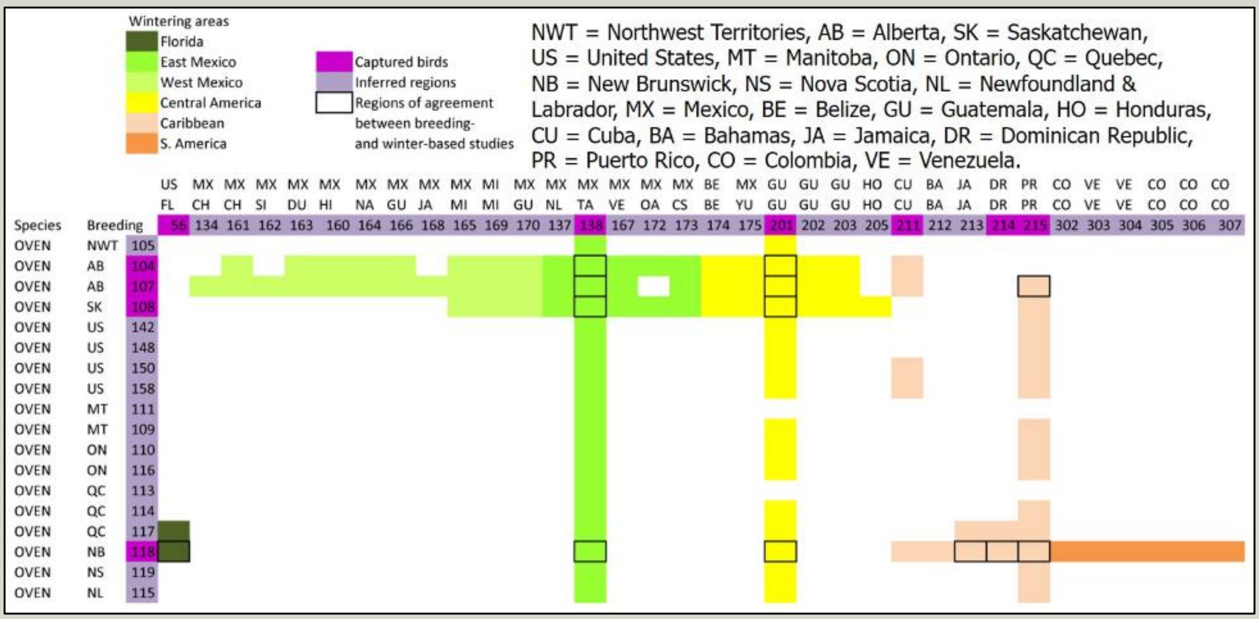


Documenting migratory connections

Many species breeding in the boreal spend the winter in Central or South America. These species are affected by things happening on the breeding ground as well as the wintering ground. To understand which factors in each location are controlling driving species' population sizes, we can try to model changes in breeding populations in relation to factors on both the breeding and wintering grounds (page 13). To do this, we need to know where there wintering grounds are. In 2015-16, we started building a database summarizing all known information about migratory connections for species breeding in the boreal forest. In 2016-17, we will compile this information into a spatial database that we can use to create migratory connectivity hypotheses.

Documenting migratory connectivity. We conducted a literature search for papers that documented migration routes, origins, and/or destinations, based on any available information. We found and reviewed over published papers covering 40 boreal- or hemiboreal-breeding migratory species. The species with the most data are Swainson's Thrush and Wilson's Warbler, followed by Ovenbird, American Redstart, Yellow Warbler, and Bicknell's Thrush. We created a pilot migratory connectivity matrix for the Ovenbird, as an example of how to combine and visualize data from multiple studies of varying spatial resolution.





Ecoregion pairs color-coded by wintering region are those with evidence of connectivity between the ecoregions indicated at left and top. Outlined boxes are regions of agreement between winter-specific and breeding-specific sources.

Through one of our graduate student projects, BAM is collaborating with Julie Hagelin of the Alaska Department of Fish and Game on a pilot project to investigate migratory patterns of Olive-sided Flycatchers. This work will continue in 2016-17.

Field work to understand migratory patterns. Tara Stehelin, BAM PhD Student, conducted field work including banding, feather collection for isotopic analyses, and geolocator deployment to track species migrations. So far geolocator data have been retrieved from ten birds returning to Alaska. Results from geolocator retrieval are expected from an additional two birds in Yukon and four birds from Northwest Territories in 2016. A similar deployment will be executed on a trial number of Western Wood-Pewees during the field season of 2016 or 2017.

BAM is contributing to the Smithsonian Migratory Bird Center's Migratory Connectivity Project through work with the Bayne lab. As of March 2016, geolocators had been placed on Broad-winged Hawks, Rusty Blackbirds, Olive-sided Flycatchers, Palm Warblers, and Common Nighthawks.

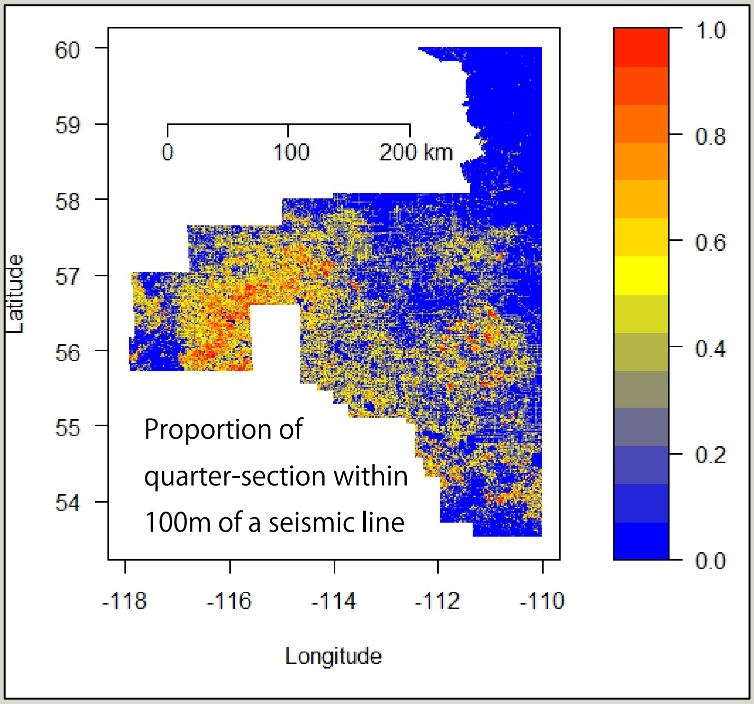
Using spot-mapping data to quality-check our models

Spot-mapping is a very labour-intensive method to identify and map the territories of individual bird over small areas. A byproduct of these surveys is a detailed account of how many individuals were present in the survey area. We're currently compiling two databases from spot-mapping data. The first is collecting all Canadian databases with a spot-mapping density; these densities will be used as "truth" for model predictions from our models built with point count data. The second database is a detailed GIS layer with spatial points of bird locations that will be used to build resource utilization functions examining edge use by birds in relation to forest and energy development. In 2015-16, we focused on building these databases.

Data Development

Detailed maps of human land use in the Alberta oil sands region

In 2015-16, we derived maps summarizing changes in land use from different human activities, including forestry and various types of energy sector infrastructure. We used these data in our analyses of cumulative effects in the oil sands region (page 29).



Land use maps. Using data products from the Alberta Biodiversity Monitoring Institute (ABMI), we calculated the proportion of each quarter-section that was comprised of different habitat and forest-age classes, either assuming no human footprint or after accounting for forest harvest (in which case we adjusted forest age based on cutblock age). We also calculated the proportional area of each quarter-section within 100 m of a seismic line, pipeline, or well-pad.

Application & Collaboration

Informing Conservation Activities

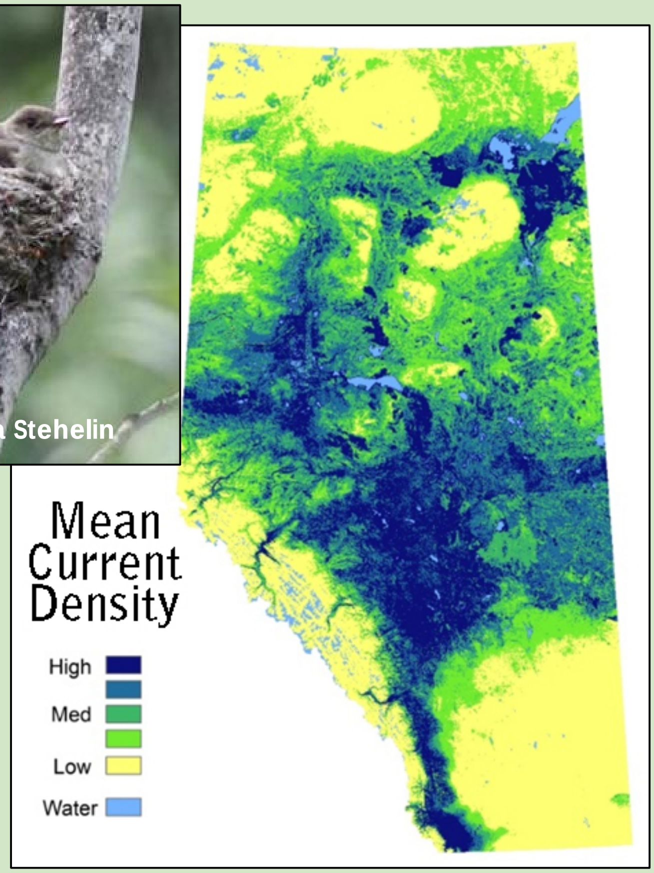
In 2015-16, we contributed to the status report for Western Wood-pewee in Alberta and conducted research to identify priority areas for boreal birds.

Status report on Western Wood-Pewee in Alberta

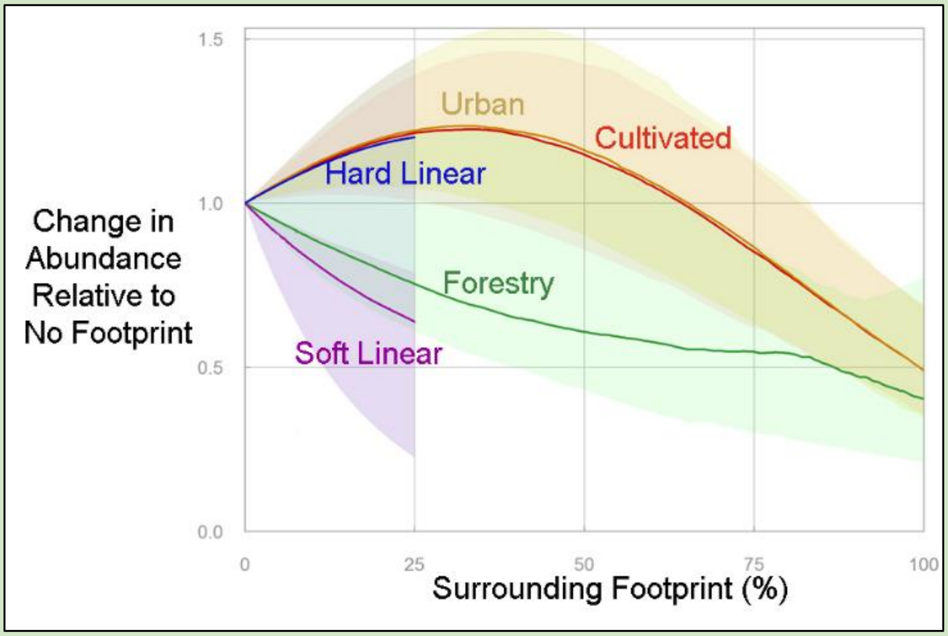
As part of a contract with the Government of Alberta and the Alberta Conservation Association, Tara Stehelin (BAM PhD Student), in collaboration with others from BAM, drafted a status report for the Western Wood-Pewee in Alberta, compiling all relevant data and information that potentially informs the status assessment of this species. The first draft of this report was submitted in early March of 2016[25], and revisions will be submitted in in 2016-17.

Reviewing Western Wood-Pewee status. We compiled data from the Fisheries and Wildlife Management Information System, BAM (including BBS), ABMI, eBIRD, and from individual contributors to map observations and generate habitat models. Regional habitat models indicated that although Western Wood-Pewees are widespread across Alberta, a steep decline is occurring (of approximately –5%/yr between 1970 and 2014), steeper than in any other jurisdiction across the continent. These declines were mostly attributed to land use change from agriculture, forestry, and energy-sector or mine development.


Photo: Tara Stehelin



Western Wood-Pewees were found in all habitat categories examined, but they were most abundant in forested habitats. They were present at some level in all seral stages, and most abundant in the youngest seral stage (0-20 yrs) for all forested habitat categories. Stands regenerating after forestry differed from stands regenerating from natural disturbance in the youngest seral stages (0 – 40 yrs). Species' density was affected by increasing human footprint in the surrounding area, the particular response depending on the proportion of the surrounding area impacted and the type of footprint (forestry, urban, cultivated land, and linear disturbance). Of particular interest, this species was almost three times more abundant with increasing presence of wet areas in the surrounding areas. The declining trend of this species is expected to continue as land rate conversion rates continue to be high in Alberta. A cumulative loss of 41% of this species is expected in Alberta over the next 10 years.

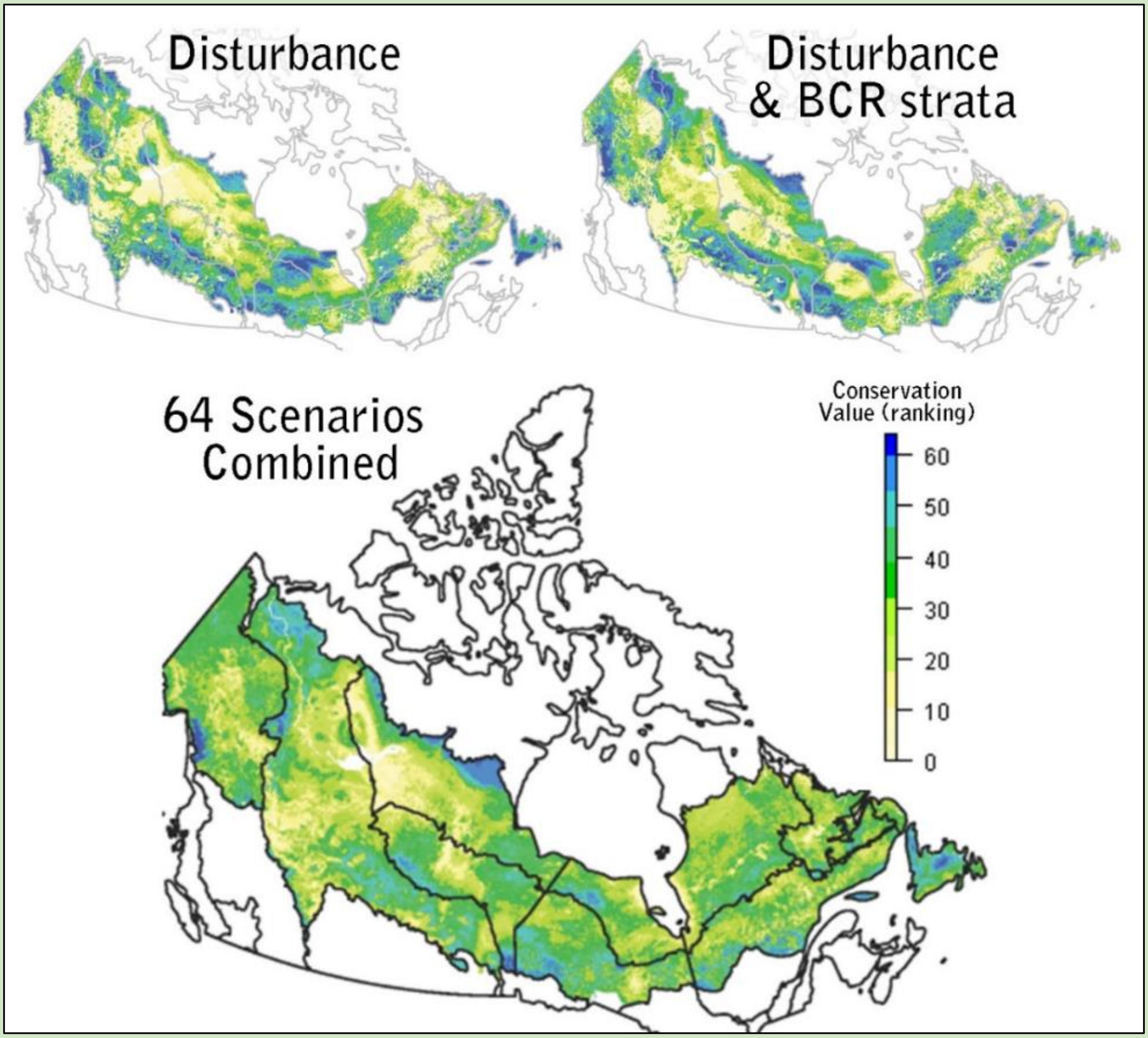


Identifying Zones of Interest for priority forest landbirds in boreal Canada

In recent years, Environment and Climate Change Canada (ECCC) started mapping national conservation priorities, including areas that are important for migratory birds. Because the boreal region is so large and difficult to access, there isn't enough readily available information to identify conservation priorities in this region. Instead, we rely on predictive maps from density models to identify areas of highly suitable habitat for migratory landbirds. In 2015-16, Matt Carlson (ALCES), with input from BAM, developed conservation prioritization scenarios using BAM's previously developed density models[26]. Subsequently, BAM refined this work to address some questions arising from the first analyses, using a single unified study area to compare results across scenarios. Major differences in priority regions were driven by external factors such as disturbance, the presence or absence of BCR and subregion stratification, and climate change. We submitted our results to ECCC in March 2016[27], and we aim to refine and summarize these results in a manuscript in 2016-17.

Conservation prioritization. We used Zonation software to identify variation in conservation value across the study area based on densities of 63 species. We used Zonation's "core area" algorithm, which identifies solutions that include the most core (high-quality) habitat for each species simultaneously, irrespective of overlap among species. We evaluated 64 scenarios looking at five different factors: 1) including climate change and uncertainty; 2) prioritizing species; 3) including non-boreal specialists; 4) regional analysis by BCR; 5) accounting for human disturbance. Climate change, stratification into regional sub-units, and discounting disturbed areas had the largest impact on prioritization results.

Given the dispersed distributional characteristics of largely territorial boreal passerines, we did not expect to identify distinct and universal hotspots. However, after constraining our study site and species to be more strictly boreal, we did find that solutions were quite similar across species weightings and uncertainty assumptions.



Conservation Through Collaboration

Since its inception in 2004, BAM's goal has been to provide information to support conservation and management of boreal birds. We do this primarily through the many partnerships we've developed within the research and conservation community. In the sections above, we described research led primarily by BAM team members. In this section, we describe how BAM data products have been used in conservation initiatives led primarily by external groups.

Informing critical habitat identification to aid recovery strategies

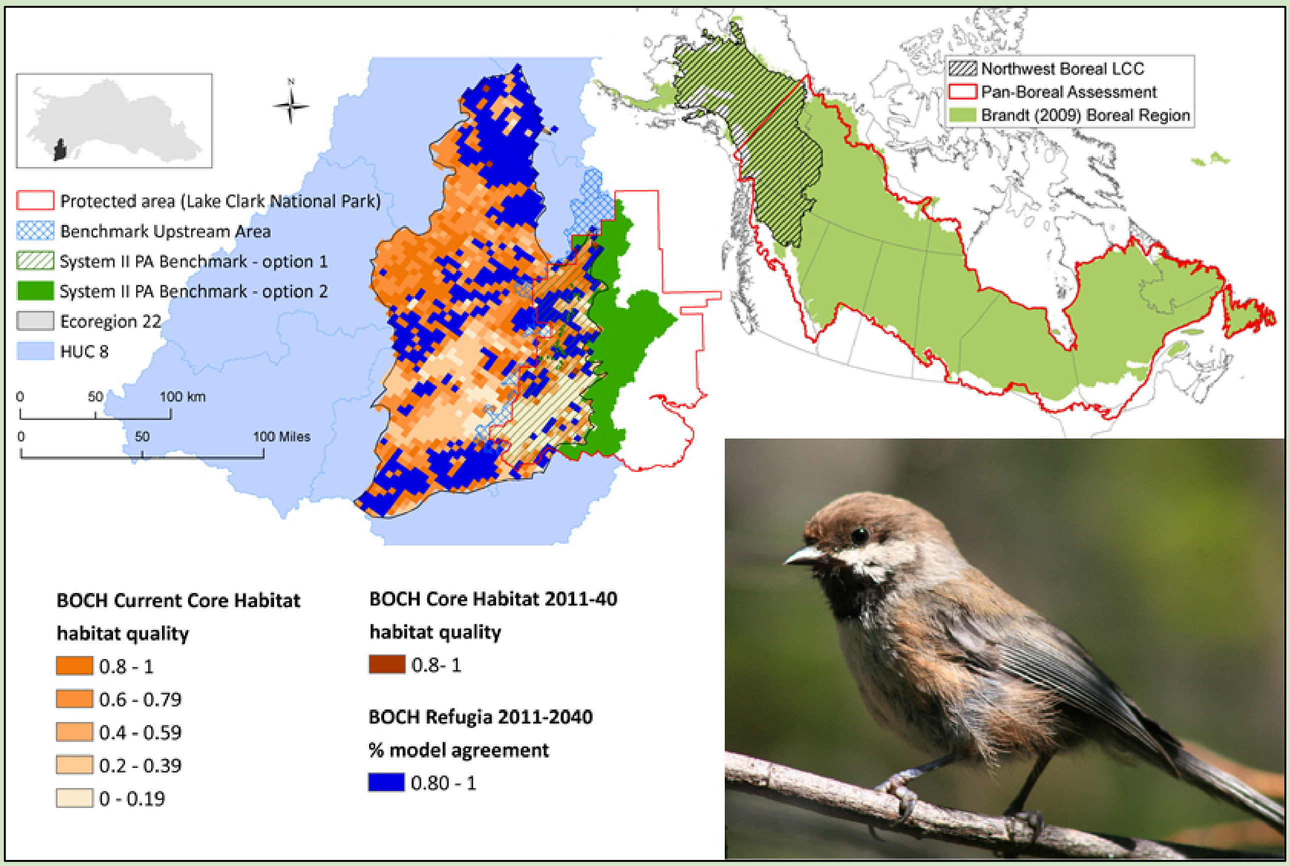

Photo: Canada Warbler, budgora

Defining critical habitat is required to inform recovery strategies for species at risk. BAM has been involved in ECCC's process to establish recovery strategies for Canada Warbler, Olive-sided Flycatcher, and Common Nighthawk in a few ways. First, we built density models to map species' distributions and abundances across Canada, as a first approximation of where important habitat might be. Second, we have two representatives on the Science Advisory Committee for species recovery strategies, Erin Bayne and Samuel Haché. Through this formal relationship, we're staying informed on what science is needed, and keeping the committee updated on what might be possible. Moving forward, we've identified a number of analyses that could be done using the BAM dataset which would provide information to ECCC that might be useful in informing critical habitat.

Facilitating conservation through collaboration with the Canadian Boreal Forest Agreement and Northwest Boreal Landscape Conservation Cooperative

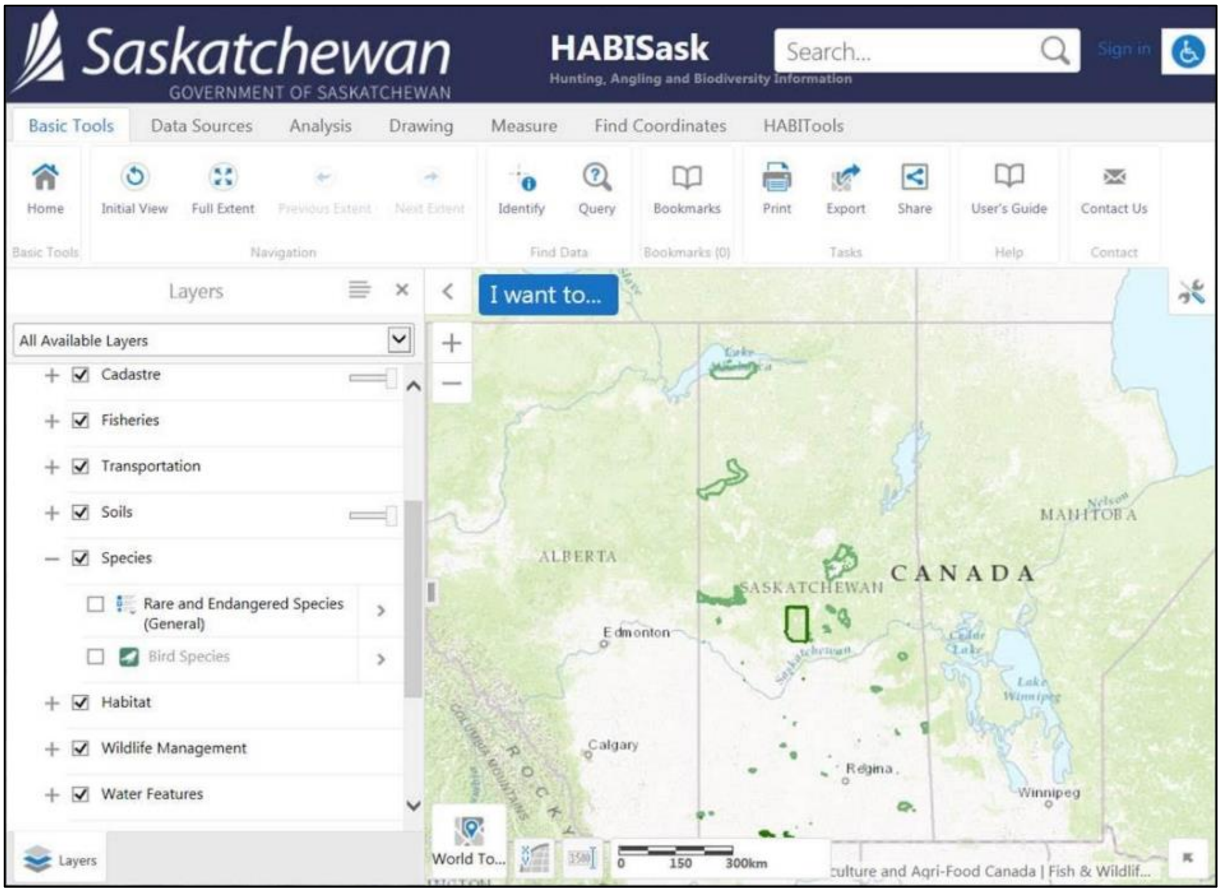
BAM's collaboration with the Boreal Ecosystems Analysis for Conservation Networks (BEACONs) project advances boreal bird conservation through application of our products to on-the-ground conservation planning efforts in association with the Canadian Boreal Forest Agreement (CBFA) and the Northwest Boreal Landscape Conservation Cooperative (NWB LCC). BAM has provided models of current and projected future species density and climate refugia for use in design and evaluation of protected areas networks. In 2015-16, BEACONs continued to apply these models in the Pan-Boreal Assessment, a boreal-wide evaluation of existing and proposed protected areas in partnership with the CBFA. As part of the NWB LCC, BAM supported BEACONs work to identify a group of 6 songbird species to use as focal species. Later, BAM models were used to identify current and future high-quality habitat for these focal species, as well as areas with the potential to act as climate refugia across Alaska and Western Canada. Reports describing the above work are not yet publicly available.

Ecoregion 22 case study. In this example, BAM data products were used to assess existing protected areas and benchmark options in Alaska's ecoregion 22. Current habitat, projected habitat, and climate change refugia for the Boreal Chickadee were used as evaluation criteria.



Supporting a tool to map biodiversity in Saskatchewan

The Hunting, Angling and Biodiversity Information of Saskatchewan (HABISask) application is a soon-to-be-launched GIS tool of the Government of Saskatchewan. The goal is to provide information for: hunters and anglers planning recreational outings; industry and consultants in early planning stages of development projects; conservation opportunities and environmental review; and for those who wish to enjoy wildlife viewing opportunities. BAM provided maps of species density to aid in the identification (and avoidance) of areas of high songbird abundance when planning development.

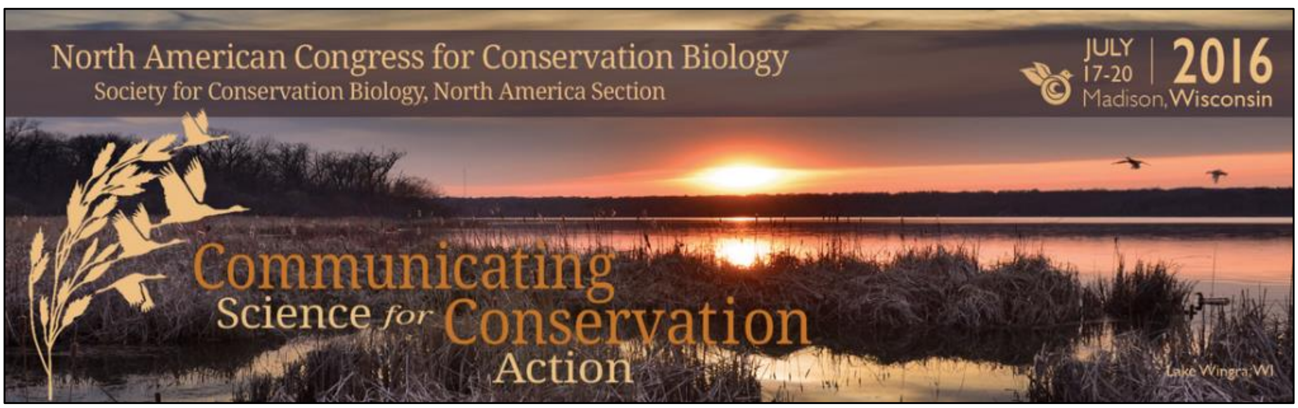


Boreal Plains Atlas

In 2015-16, BAM was approached by the Nature Conservancy of Canada for expert knowledge and data products to aid in their Nature Atlas for the Boreal Plains. The project goal is to identify areas of conservation priority within the Boreal Plains ecozone. We have met with representatives from NCC on several occasions to provide guidance on methods and our data products. We also provided density maps, distribution maps, and climate change refugia maps to support this conservation effort. BAM will continue involvement through 2016-17 by providing input on relevant materials.

Facilitating conservation of boreal birds by integrating science, policy, and action

In the fall of 2015, BAM noticed several independent research and conservation initiatives aiming to identify priority areas for birds in the boreal. We wanted to improve communication and collaboration among the various groups interested in the topic, so began a collaboration with Marcel Darveau (Ducks Unlimited Canada) to host a workshop at the North American Congress for Conservation Biology, to be held in Madison, WI in July 2016. We plan to synthesize the knowledge generated or discussed at this workshop in a special feature of the journal Avian Conservation & Ecology. In 2015-16, we initiated organization of the workshop and recruited leaders for each of our topics, who in turn recruited their own collaborators. Our workshop participant and author lists now include representatives from the American Bird Conservancy, Bird Studies Canada, the Boreal Songbird Initiative, the Canadian Forest Service, DUC, ECCC (CWS and Science & Technology), the Nature Conservancy of Canada, the National Audubon Society, the National Council for Air and Stream Improvement, Parks Canada, the Smithsonian Conservation Biology Institute, the USFWS, the USGS, the Wildlife Conservation Society, and several academic institutions. We've received great interest for this project and we're very excited about working together with everyone in 2016-17.



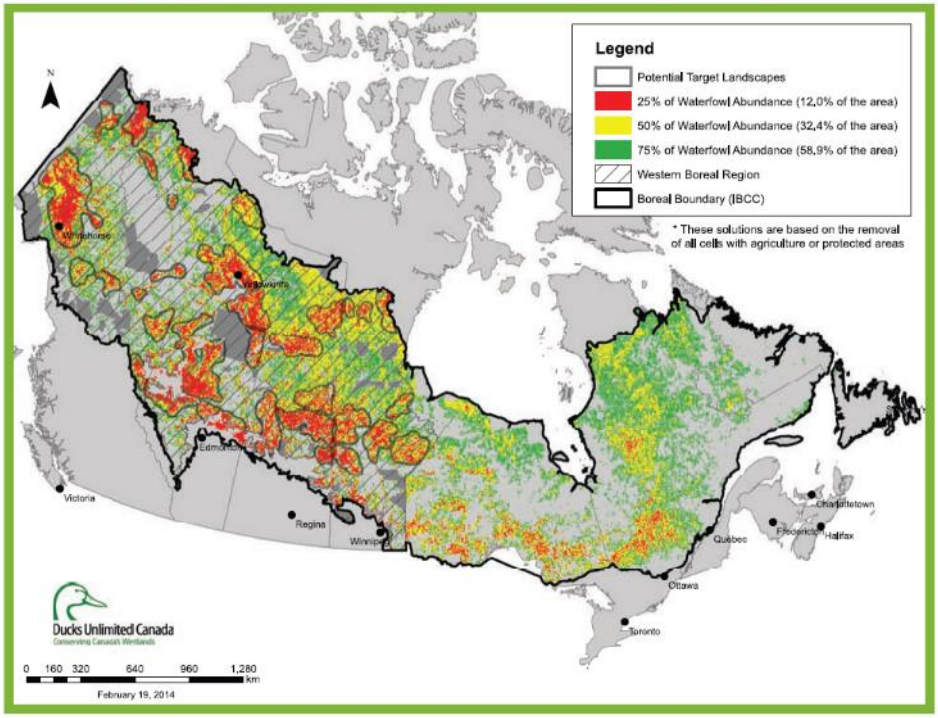
BAM contributions to other conservation and landscape management efforts

In 2015-16, we also contributed to the following efforts directly or by supplying data products:

- **Northern Alberta Conservation Areas Working Group**: We provided expert information and data products to support their efforts in identifying conservation priorities for the Alberta land-use framework, including BAM climate change refugia layers and BAM/DUC waterfowl abundance maps.
- **Alberta Environment and Parks, Planning Branch:** We provided rasters of climate change refugia to support a Marxan analysis for a landscape management plan in the Lower Athabasca region.
- **Parks Canada**: Our regional maps of species' density in Maritimes national parks are being used for planning management.

- **Prairie Habitat Joint Venture**: Maps of predicted duck abundance (a joint BAM/DUC effort) were used to develop Target Landscapes for the Western Boreal Forest Implementation Plan (2013-2020).
- **Ducks Unlimited Canada**: BAM/DUC waterfowl abundance maps are supporting DUC's internal conservation planning process.

Waterfowl distribution across the Canadian boreal forest and potential Target Landscapes in the PHJV Region outside of long-term protected and agricultural lands. The underlying duck distribution map was developed by deriving minimum area aggregations of predicted duck pairs. Colors represent quartiles of the population. Red areas have the highest density duck habitat (25% of the duck population on 12% of the land base). The next two quartiles occupy 20% (yellow) and 27% (green) of the land base, respectively. Collectively, 75% of the waterfowl population is estimated to occur on 59% of the entire Canadian boreal forest.



In progress or anticipated collaborations

In 2015-16, a number of other collaborations were explored or initiated:

- **American Bird Conservancy**: We met with the ABC to discuss areas of potential synergy in our anticipated research and future directions.
- **National Audubon Society**: We met with Audubon to describe our climate change work. Diana Stralberg will be participating in a climate change symposium organized by Audubon at the North American Ornithological Conference in August 2016.
- **Canada Warbler prioritization:** We started contributing to a project to locate priority areas for Canada Warbler conservation in BCR 14, as well as develop a series of national guidelines for Canada Warbler management.
- **Olive-sided Flycatcher status assessment:** We began assessing this species for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to inform its national at-risk designation.
- **Value of Information**: BAM was approached by Ilona Naujokaitis-Lewis (ECCC) for a collaborative project exploring the added value of using species density (instead of probability of occurrence) for conservation planning.

Communications

We communicate BAM research via webinars, publications in peer-reviewed journals, presentations, and reports.

Webinars

On February 2nd, 2016, Péter Sólymos gave a webinar to the Science Team of the National Audubon Society entitled "**Boreal Avian Modelling Project and Lessons from the BAM Database**". The presentation summarized what BAM is, and highlighted some lessons learned through compiling the BAM Avian Database. It was part of an effort to build an Audubon project database as part of Audubon's next 5-year plan.

On March 9th, 2016, BAM hosted a webinar by Péter Sólymos entitled "**Integrating roadside and off-road point count data for modelling boreal bird populations**". Invited participants included the BAM Technical Committee. The webinar discussed progress that BAM has made towards integrating on-road (i.e., BBS) and off-road surveys. Time was allotted for a discussion with all participants, and many useful suggestions were made that will inform how we move forward with this work.

Publications

Barker, N. K. S., P. C. Fontaine, S. G. Cumming, D. Stralberg, A. Westwood, E. M. Bayne, P. Sólymos, F. K. A. Schmiegelow, S. J. Song, and D. J. Rugg. 2015. Ecological monitoring through harmonizing existing data: Lessons from the Boreal Avian Modelling Project. Wildlife Society Bulletin 39:480–487.

Bayne, E. M., L. Leston, C. L. Mahon, P. Sólymos, C. S. Machtans, H. Lankau, J. R. Ball, S. L. Van Wilgenburg, S. G. Cumming, T. Fontaine, F. K. A. Schmiegelow, and S. J. Song. 2016. Boreal bird abundance estimates within different energy sector disturbances vary with point count radius. Condor *in press*. doi: 10.1650/CONDOR-15-126.1.

Mahon, C. L., G. Holloway, P. Sólymos, S. G. Cumming, E. M. Bayne, F. K. A. Schmiegelow, and S. J. Song. 2016. Community structure and niche characteristics of upland and lowland western boreal birds at multiple spatial scales. Forest Ecology and Management 361:99–116.

Stralberg, D., E. M. Bayne, S. G. Cumming, P. Sólymos, S. J. Song, and F. K. A. Schmiegelow. 2015. Conservation of future boreal forest bird communities considering lags in vegetation response to climate change: a modified refugia approach. Diversity and Distributions 21:1112–1128.

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.

Theses

Stralberg, D. 2015, December. Assessing responses of boreal songbird distribution and abundance to climate change at multiple spatial and temporal scales. Ph.D. thesis, University of Alberta, Edmonton, AB, Canada.

Westwood, A. 2015. Conservation of three forest landbird species at risk: Characterizing and modelling habitat at multiple scales to guide management planning. Ph.D. thesis, Dalhousie University, Halifax, NS, Canada.

Presentations

Bayne EM, Leston L, Mahon CL, Sólymos P, Machtans CS, Lankau H, et al. Boreal bird abundance estimates within different energy sector disturbances vary with point count radius. Poster presented at: Alberta Biodiversity Council Meeting; 2016 Feb; Calgary, AB, Canada.

Leston L and Bayne EM. Mixture and occupancy models of birds recorded by autonomous recording units in boreal wetland landscapes. Oral presentation presented at: Meeting of the Alberta Chapter of the Wildlife Society; 2016 Mar 4; Drumheller, AB, Canada.

McBlane L, Slattery SM, Morissette JL, Barker NKS, Smith K. Conserving Canada's boreal duck populations using systematic conservation planning. Poster presented at: 7th North American Ducks Symposium; 2016 Feb; Anapolis, MD, USA.

Sólymos P, Lele SR. What can we do with a single survey? Occupancy and abundance estimation in the presence of detection error. Poster presented at: ICCB-ECCB; 2015 Aug 2; Montpellier, France.

Stralberg D. Conservation of future boreal forest bird communities considering lags in vegetation response to climate change. Talk presented at: Understanding and Responding to the Impacts of Climate Change on Alberta's Biodiversity. Symposium hosted by the Alberta Biodiversity Monitoring Institute's Biodiversity Management and Climate Change Adaptation Project; 2015 Jun 16; Edmonton, AB, Canada.

Stralberg D. Projecting boreal bird responses to climate change: considering uncertainty, refugia, time lags, and barriers. PhD thesis defence presented at; 2015 Nov 2; Edmonton, AB, Canada.

Stralberg D. Incorporating boreal refugia into conservation planning. Talk presented at: Climate change and land use planning workshop: Practical approaches to incorporating climate change into land use planning. Hosted by AdaptWest; 2016 Mar 3; Edmonton, AB, Canada.

Suárez-Esteban A. Approaches to biodiversity conservation in the North. Invited talk, Doñana Biological Station (EBD-CSIC); 2015 May; Sevilla, Spain.

Suárez-Esteban A, Schmiegelow FKA, Cumming SG. Assessing the effects of anthropogenic forest disturbances on boreal birds. Invited talk, Carleton University; 2015 Dec; Ottawa, ON, Canada.

Suárez-Esteban A, Schmiegelow FKA, Cumming SG. Wings of Change: how do boreal birds respond to forest alterations? Talk presented at: Yukon Biodiversity Forum; 2015 Nov; Whitehorse, YT, Canada.

Westwood, Alana. Conversation of three forest landbird species at risk: Charaterizing and modelling habitat at multiple scales to guide management planning. PhD thesis defence presented at; 2016 Mar 3; Halifax, NS, Canada.

Westwood A, Sólymos P, Fontaine T, Bayne, Erin M. Species distribution modeling for three landbird species at risk: The contribution of protected areas to habitat and the effects of scale on population estimates. Poster presented at: WOS/AFO/SCO-SOC 2015 Joint Meeting; 2015 Jul 16; Wolfville, NS, Canada.

Van Wilgenburg SL, Sólymos P, Frey MD, Kardynal KJ. Using double sampling methods to facilitate comparability of human-observer versus automated-recording data from avian surveys. Talk presented at: Wildlife Society's 22nd Annual Conference; 2015 Oct 17; Winnipeg, MB, Canada.

Project Management

The Nature of the BAM Project

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 partners and organizations.

Project Team

Steering Committee

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

Project Staff: BAM welcomes Diana Stralberg as our newest staff member.

- Coordinating Scientist: Nicole Barker
- Database Manager: Trish Fontaine
- Statistical Ecologist: Péter Sólymos, 0.5 FTE
- Project Ecologist: Diana Stralberg, 0.4 FTE
- Post-doctoral Fellow: Alberto Suarez Esteban
- Post-doctoral Fellow: Lionel Leston

Students: Congratulations to Dr. Diana Stralberg and Dr. Alana Westwood!

- PhD candidate with Fiona Schmiegelow: Tara Stehelin

Contributing Scientists: BAM welcomes three new contributing scientists this year: Judith Toms, Alana Westwood, and Steve Van Wilgenburg.

- Samuel Haché, Wildlife Biologist, Environment and Climate Change Canada
- C. Lisa Mahon, Wildlife Biologist, Environment and Climate Change Canada
- Steve Matsuoka, Research Biologist, United States Geological Survey
- Judith Toms, Wildlife Biologist, Environment and Climate Change Canada
- Steve Van Wilgenburg, Wildlife Biologist, Environment and Climate Change Canada

- Alana Westwood, independent

Technical Committee

Our Technical Committee continues to provide independent scientific advice on project direction and results. In 2015-16, we initiated a review of our Technical Committee to ensure that the current structure and level of engagement supports effective functioning. As we continue this process over the coming year, we may contact additional scientists whose expertise complements BAM's current and anticipate research program.

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

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:

- *Connie Downes* (Environment Canada): BBS data
- *Jaqueline Dennett* (University of Alberta): Database assistance
- *Nash Goonewardena* and *Michael Abley* (University of Alberta): Technical support
- *Marie-Anne Hudson* (Environment Canada): BBS data
- *Denis Lepage* (Bird Studies Canada): Atlas Data
- *Brendan Ward, Mike Lundin, Tosha Comendant* (Conservation Biology Institute): Web mapping gateway
- *Paul Morrill* (Web Services): website design & programming
- *Marty Mossop* (Environment Canada): Yukon data
- *James Strittholt* (Conservation Biology Institute): Web mapping gateway

- *Edmund Zlonis* (University of Minnesota): Minnesota data and analysis

Partnerships

Our partners have made important contributions to the success of the BAM project by providing avian data, access to environmental covariates, and financial support. The BAM project would not exist without the generous contributions of its funding and data partners.

Funding Partners

We are grateful to the following organizations that have provided funding to the BAM Project since its initiation:

Founding organizations and funders

- Environment & Climate Change Canada
- University of Alberta
- BEACONs

Financial support received in 2015-16

- Alberta Environmental Monitoring, Evaluation and Reporting Agency / Joint Canada-Alberta Implementation Plan for Oil Sands Monitoring
- Alberta Pacific Forest Industries Inc.
- Canada Research Chairs program
- Environment and Climate Change Canada
- Forest Products Association of Canada
- Government of Alberta and the Alberta Conservation Association
- Natural Sciences and Engineering Research Council of Canada (NSERC)
- United States Fish and Wildlife Service,
    - Neotropical Migratory Bird Conservation Act Grants Program
    - Northwest Boreal Landscape Conservation Cooperatives
- Université Laval

Past financial supporters

- Alberta Biodiversity Monitoring Institute
- Alberta Conservation Association
- Alberta Climate Change Emissions Management Corporation (CCEMC)
- Alberta Innovates Technology Futures
- Alberta Land-use Framework (Government of Alberta)
- Amazon Web Services Education Research Grant Award
- Canadian Boreal Initiative
- Canada Foundation for Innovation
- Ducks Unlimited Canada
- Environmental Studies Research Fund
- Environmental Monitoring Committee of the Lower Athabasca (EMCLA)
- Fonds québécois de la recherche sur la nature et les technologies
- Forest Products Association of Canada
- Geomatics for Informed Decisions (GEOIDE)
- Government of Canada (Vanier Scholarship)

- Killam Trusts (Memorial scholarship to Stralberg)
- Ministère des Ressources naturelles et de la Faune, MRNF, Québec
- Northern Centre for Conservation Science
- Parks Canada
- Sustainable Forest Management Network
- United States National Fish and Wildlife Foundation (NFWF)
- United States Fish and Wildlife Service,
    - Landscape Conservation Cooperatives

Data Partners

The following institutions and individuals have provided or facilitated provision of bird and environmental data to the Boreal Avian Modelling Project.

Avian Data

Institutions: Acadia University; Alaska Bird Observatory; Alaska Natural Heritage Program; Alberta Biodiversity Monitoring Institute; Alberta Pacific Forest Industries Inc.; AMEC Earth & Environmental; AREVA Resources Canada Inc.; Avian Knowledge Network; AXYS Environmental Consulting Ltd.; Bighorn Wildlife Technologies Ltd.; Bird Studies Canada; Breeding Bird Survey (coordinated in Canada by Environment Canada); BC Breeding Bird Atlas; Canadian Natural Resources Ltd.; Canfor Corporation; Daishowa Marubeni International Ltd; Canada Centre for Remote Sensing and Canadian Forest Service, Natural Resources Canada; Canadian Wildlife Service and Science & Technology Branch, Environment Canada; Global Land Cover Facility; Golder Associates Ltd.; Government of British Columbia; Government of Yukon; Hinton Wood Products; Hydro-Québec Équipement; Kluane Ecosystem Monitoring Project; Komex International Ltd.; Louisiana Pacific Canada Ltd.; Manitoba Breeding Bird Atlas; Manitoba Hydro; Manitoba Model Forest Inc.; Manning Diversified Forest Products Ltd.; Maritimes Breeding Bird Atlas; Matrix Solutions Inc. Environment & Engineering; MEG Energy Corp.; Mirkwood Ecological Consultants Ltd.; NatureCounts; Nature Serve; Numerical Terradynamic Simulation Group; Ontario Breeding Bird Atlas; Ontario Ministry of Natural Resources; OPTI Canada Inc.; PanCanadian Petroleum Limited; Parks Canada (Mountain National Parks Avian Monitoring Database); Petro Canada; Principal Wildlife Resource Consulting; Quebec Breeding Bird Atlas; Regroupement Québec Oiseaux; Rio Alto Resources International Inc.; Saskatchewan Environment; Shell Canada Ltd.; Suncor Energy Inc.; Tembec Industries Inc.; Tolko Industries Ltd.; U.S. Army; U.S. Fish and Wildlife Service; U.S. Geological Survey, Alaska Science Center; U.S. National Park Service; Université de Moncton; Université du Québec à Montréal; Université du Québec en Abitibi-Témiscamingue; Université Laval; University of Alaska, Fairbanks; University of Alberta; University of British Columbia; University of Guelph; University of New Brunswick; University of Northern British Columbia; URSUS Ecosystem Management Ltd.; West Fraser Timber Co. Ltd.; Weyerhaeuser Company Ltd.; Wildlife Resource Consulting Services MB Inc.

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Common Attribute Schema for Forest Resource Inventory (CASFRI): Alberta Pacific Forest Industries Inc.; Canfor Corporation; Louisiana Pacific Canada Ltd.; Tolko Industries Ltd.; West Fraser Timber Co. Ltd.; Weyerhaeuser Company Ltd.; Blue Ridge Lumber; Buchanan Forest Products; Cenovus Energy Inc.; Daishowa Marubeni International Ltd.; Millar Western Forest Products Ltd.; Mistik Management Ltd.; Tembec Industries Inc.

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COVER PHOTOS:

Landscape: Alberto Suárez-Esteban

Canada Warbler: Ken Mattison

Map: Canada Warbler density (see page 7)

Boreal Avian Modelling Project

Projet de modélisation aviaire boréal