ANNUAL REPORT

April 2019 - MARCH 2020

Jeff Ball

BOREAL AVIAN MODELLING PROJECT

PROJET DE MODÉLISATION AVIAIRE BORÉAL

Highlights from 2019-2020

BAM conducts collaborative research in avian ecology and conservation and develops data products to support research and management of boreal birds. We collaborate with federal and provincial governments, academics, industry, and non-governmental organizations (NGOs) with interests in the development and application of science to support bird conservation and management. Our research and data products are distributed and communicated through a variety of mechanisms to support and facilitate conservation planning and management of boreal birds by our partners.

Here are our main achievements from April 2019 to March 2020.

Research & Monitoring

Boreal Bird Density, Population Status and Trends

- A comparison of the BAM spatially explicit population estimates and the Partners In Flight (PIF) population estimates demonstrated that differences align with roadside count and habitat representation differences across 81 bird species. ▶ page 9
- New Canada-wide landbird density estimates were produced for 143 species with associated model uncertainty. ▶ page 10
- Preliminary results from revised trend estimates based on spatio-temporal abundance models suggest that BAM data improve trend estimates in areas not well-sampled by the BBS. ▶ page 12
- New national models were produced for 18 species of waterfowl that explicitly account for spatio-temporal variations in abundance. ▶ page 12

Species at Risk Status, Recovery Planning, and Multi-species Management

- Regional Canada Warbler density models were produced for Alberta and Nova Scotia to support critical habitat identification. ▶ page 13
- In collaboration with Canadian Wildlife Service (CWS), BAM developed a Standard Operating Procedure (SOP) to identify Critical Habitat. The SOP was included in the CWS Statement of Work for Wood Thrush Critical Habitat identification that will help in the development of a recovery strategy for this species. ▶ page 14

Habitat Selection, Availability, and Needs

- A new publication demonstrated that differential habitat selection in boreal songbirds influences estimates of population size and distribution. ▶ page 14
- Models to quantify habitat selection showed promise for improving density prediction outside the spatial and temporal bounds of the data to which they were fit. This will help to improve predictions of future distributions and population sizes in response to landscape change. ▶ page 15

Detecting and Attributing Land-use and Climate Change Impacts on Boreal Birds

Climate change impacts

- Forest harvesting and climate-related drivers were projected to have large impacts on bird communities in Alberta due to changes in forest composition and age structure. ▶ page 16
- Forecasted distribution and abundance responses of birds (94 species) and caribou to landscape and climate change in the Northwest Territories were developed using integrated models of forest dynamics and fire. ▶ page 17

- Forest landscape simulations demonstrated that increasing anthropogenic climate change will greatly alter forest landscapes in Québec and impact biodiversity to the benefit of generalist bird species and to the detriment of caribou. ▶ page 17
- Regional comparisons (Alberta and Québec) showed that climate change and forest harvesting may impact avian species differently across their range. ▶ page 18
- Simulations of avian responses to changes in climate and forest type and age across Bird Conservation Region (BCR) 4 from 1990 to 2100 indicated that population trends of several species are already tracking changes in climate and habitat suitability. ▶ page 18
- A modelling approach was developed to evaluate historical changes in boreal bird abundance and distribution over a 25-year period to better understand individual species' climate change vulnerabilities and evaluate climate-related projections of population change. ▶ page 18
- Models of climate, land cover and disturbance were developed to predict the abundance and distribution of Olive-Sided Flycatcher and Western Wood-Pewee in northwestern North America. ▶ page 19

Energy sector impacts and cumulative effects

- Models developed to evaluate the cumulative impacts of Oil Sands Region (OSR) stressors on the Ovenbird population showed that cumulative impacts are affecting habitat availability in the region. ▶ page 21
- BAM partnered with Alberta Biodiversity Monitoring Institute (ABMI) and Environment & Climate Change Canada (ECCC) to develop models that evaluate the cumulative impacts of multiple sectors on boreal birds and attribute these impacts to specific sectors. ▶ page 21

Forestry Impacts

- Projections of how boreal birds will respond to the cumulative effects of caribou conservation, harvest, fire, and energy-sector development demonstrated that caribou-centric forestry plans have minor co-benefits for avian species in Alberta. ▶ page 22
- Data-driven risk matrices were built and evaluated to support harvest planning decisions regarding incidental take of migratory birds in Alberta. ▶ page 24
- Preliminary results showed that lands certified by Sustainable Forestry Initiative (SFI) have high conservation value for avian diversity in BCR 12 and 14 compared to non-certified lands. ▶ page 25

Projecting impacts of landscape change

- A manuscript was revised that assessed the impacts of human disturbance on the abundance of 15 migratory songbird species at a national extent (page 26). An expansion of this project was developed to hindcast the net effect of disturbance on boreal songbirds from 1985-2015. ▶ page 26

Conservation Planning for Boreal Birds

- Conservation planning scenarios to prioritize candidate areas for Canada Warbler conservation demonstrated that using low natal dispersal distance scenarios in decision-making offers a more conservative approach to maintaining Canada Warbler populations. ▶ page 27

Monitoring and Sampling

- In collaboration with forest companies in Alberta, a gap analysis identified combinations of forest attributes that are not currently sampled by the BAM avian database and that could be targeted by future industry-led surveys. ▶ page 30
- The bSims R package created by Péter Sólymos is a bird point count simulator that facilitates the design of better monitoring programs. ▶ page 31

Communications, Collaborations and Implementation

Application of Results through Collaborations

BAM contributed to more than 30 collaborative efforts to facilitate boreal bird conservation and management, involving non-governmental organizations, provincial and federal government agencies, Indigenous Peoples, industry, and academic institutions, a comprehensive list of collaborative projects starts on page 37.

BAM results have been applied by partners to facilitate and support conservation and management efforts related to monitoring design, threats assessment and management planning, priority areas assessment, and species at risk planning. A list of applications of BAM results are listed on page 5.

Communications

- BAM has a new updated website ▶ page 36.
- BAM produced 2 core papers, 5 co-produced papers, and 4 BAM informed publications since April 2019 ▶ page 399.
- BAM research and conservation efforts were highlighted in more than 35 talks at international or regional conferences, targeted workshops, webinars, and collaborative meetings since April 2019 ▶ page 40.

Data and Data Product Development

- Products currently available include:
    - *NEW* Canada-wide density maps for 143 landbird species;
    - *NEW* population size estimates for 143 landbird species;
    - *NEW* habitat associations (densities per habitat type) for 143 landbird species per BCR;
    - *NEW* Canada-wide density models for 18 waterfowl species;
    - *NEW* regional density maps for several species of conservation concern;
    - *NEW* priority areas for Canada Warbler conservation
    - Email BorealAvianModellingProject@ualberta.ca to make a request ▶ see page 32 for more details on available products.
- BAM's updated Avian Database now contains point count data from over 170 projects at more than 250,000 locations across North America ▶ page 34.
- BAM is working towards improved access to avian data in Canada in partnership with the Alberta ABMI, Bird Studies Canada (BSC), and CWS ▶ page 34.

Project Management

- BAM wishes the best of luck to Nicole Barker and Francisco Dénes as they move on to new opportunities.
- Congratulations to Tara Stehelin for successfully defending her PhD.

Applications of BAM Results

In 2019-20, BAM continued to provide research findings, methods, data products and data to support and inform conservation and management initiatives through collaborations and partnerships.

Boreal Bird Density, Population Status & Trends

- Our National Models have been used and integrated into various initiatives, including the Boreal Monitoring Strategy (page 28), trend estimation for boreal species (ECCC), estimates of biotic intactness for the Key Biodiversity Areas Criterion C initiative (WCS Canada/McGill University), and the WildTrax species tag checker tool (ABMI).

Species at risk and conservation planning

- Collaborations and discussions with ECCC are paving the way for broader adoption of BAM and ECCC's co-developed conceptual model for critical habitat identification (page 13).
- The Standard Operating Procedure (SOP) to inform the identification of Critical Habitat under the Species at Risk Act was included as an appendix in the Statement of Work for the CWS Wood Thrush Critical Habitat Identification contract (page 14).

Detecting & Attributing Land-use and Climate Change Impacts

- BAM partnered with ABMI and ECCC to develop models that separate the cumulative impacts of multiple sectors on boreal birds and attribute these impacts to specific sectors. Results for over 100 species are hosted on the ABMI's Biodiversity Browser (https://abmi.ca/home/data-analytics/biobrowser-home).
- Alberta-Pacific Forest Industries' (Al-Pac) forest management planning will be influenced by our evaluation of the cumulative effects of caribou conservation, harvest and other forms of disturbance on boreal birds in the Al-Pac forest management unit (page 22).
- A risk matrix tool developed for forest companies in Alberta will enable companies to evaluate their risk of incidental take when planning and conducting activities (page 24).

Landbird monitoring and sampling design

- ECCC's Boreal Monitoring Strategy is using BAM data, data products, and scientific expertise to inform sampling across Canada (page 28).
- A gap filling analysis—as part of incidental take risk matrix (page 24)—evaluating forest types that are under sampled in BAM's avian database will influence data collection by forest management companies in Alberta (page 30).
- The bSims R package—a bird point count simulator to help researchers design better monitoring programs—was used as a teaching tool at a workshop at the American Ornithological Society and has since been downloaded thousands of times (page 31).

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About Us

Our Vision

Conservation of North American boreal-breeding birds and their habitats is guided by rigorous, credible, and collaborative science. BAM believes that North American bird populations can be recovered and sustained through thoughtful actions based on data-driven science.

Our Mission

BAM develops high quality scientific information, products, and guidance addressing pressing management needs. We pursue our vision of conserving North American boreal-breeding birds by providing data-driven science that fills information gaps to guide conservation action. We seek to understand species' large-scale habitat needs and the impacts of human activities, informing both regional and continental conservation.

Our Objectives

1. **ASSEMBLE**, harmonize, and archive standardized boreal bird survey **data**.
2. **DEVELOP** or refine **statistical methods** to analyze these data, to:
    3. **PROVIDE reliable information** on boreal bird distributions, abundances, trends, and habitat associations;
    4. **FORECAST** population consequences of human activity and climate change;
    5. **CONTRIBUTE** to **conservation**, **management**, and **monitoring** of boreal birds and their habitats.
6. **BUILD SUPPORT** for boreal bird conservation via collaborations and outreach.
7. **FACILITATE** further research efforts by generating testable hypotheses about key mechanisms driving boreal bird populations.
8. **ENCOURAGE** public awareness and support education.

Our History

The Boreal Avian Modelling Project (BAM) was initiated in 2004 to address knowledge gaps associated with the management and conservation of boreal birds in North America.

BAM is built on the foundation of boreal bird data. The BAM database was created by collating and harmonizing avian data from the Breeding Bird Survey, Breeding Bird Atlases, and individual research, monitoring, and inventory efforts conducted across the Canadian and US boreal and hemi-boreal region.

BAM is working to develop rigorous analytical model-based approaches to support the conservation of the boreal forest region and the bird populations and communities that depend upon it. We have developed specialized statistical approaches to harmonize these datasets by correcting for survey methodology and species detectability to estimate density.

BAM models have a myriad of applications: they allow us to draw relationships between birds and their environment (e.g. vegetation, climate, disturbance) from regional to national scales, to predict their response to changes through time and across geographic areas, to explain population trends, to determine which habitats are important and why, to design monitoring efficiently and effectively, to assess how management decisions made now may affect birds in the future...just to name a few.

Our Structure

The BAM Project Team is comprised of academic researchers, government scientists, project staff, postdoctoral fellows, and graduate students

BAM is jointly coordinated by a Steering Committee, which advises on BAM's scientific direction, merit, and relevance. Day-to-day management is overseen by our Coordinating Scientist.

Project execution is facilitated by a dedicated team of staff, post-doctoral fellows, and graduate students. Contributing Scientists provide expert advice and are involved in co-production of relevant science.

A National Technical Committee of boreal bird researchers from across the North American boreal and hemiboreal facilitates data sharing and project collaboration.

The collaborative nature of the project is further highlighted by the other individuals who have provided project assistance and support over the years.

Recognizing Collaborations

Given BAM's highly collaborative structure, we wish to appropriately acknowledge intellectual and financial contributions to projects described in this report. This year, we introduce a three-way classification of projects to indicate the alignment with BAM's core goals and the degree of collaboration involved.

CORE project: A project addressing BAM's core mandate, led from inception to completion by BAM Team Members

CO-PRODUCED project: A project jointly produced between BAM and external collaborator(s). These are often conceptualized outside of BAM before BAM involvement is solicited. BAM involvement could include intellectual contribution to project goals, data provision, analysis, and interpretation of results.

INFORMED project: A project addressing BAM's mandate with relatively little contribution from BAM (e.g., data or limited expert knowledge). Alternatively, a project using BAM data or intellectual contribution but not addressing BAM's core mandate.

Learn more at borealbirds.ca

Research & Monitoring

BAM's research contributes to conservation and management of boreal birds in two ways: 1) by providing the best available information; and 2) by advancing the theoretical foundations underpinning conservation and management within the boreal region.

Here we describe progress on our research projects from April 2019 - March 2020.

Boreal Bird Density, Population Status, and Trends

Methods and products to support status assessment

Overview: Reliable and accurate estimation of species' population size, trend and distribution is important for informing status assessment, conservation planning and Species at Risk recovery actions. BAM is committed to developing approaches to estimate the density, distribution, and trends of boreal birds using heterogeneous datasets. In recent years, we have made significant progress developing a new national modelling approach and in March 2020, we released a new set of national-scale data products including density maps and population estimates for 143 landbird and 18 waterfowl species.

In 2019-2020, we published a description and test of our approach of using spatially explicit models to estimate population size (PIX) in Alberta compared to the traditional Partner's in Flight (PIF) approach. We also submitted manuscripts reviewing environmental variables influencing waterfowl distributions and predicting spatiotemporal abundance of breeding waterfowl across Canada. We will continue to collaborate with partners to further refine our methods and expand the scope of our products.

Comparing spatially explicit models (PIX) and the Partners in Flight (PIF) approach to estimate population sizes of boreal birds in Alberta, Canada

For nearly two decades, BAM has worked to develop robust methods for estimating population sizes of North American boreal birds. In 2019-20, we continued to work on a project comparing population estimates of boreal birds in Alberta, derived from spatially explicit models and the Partners in Flight approach, which applies adjustments to North American Breeding Bird Survey (BBS) counts to get population estimates. We also quantified the effects of detectability, roadside bias, and other factors on these population estimates (see Box 1 for more details). In 2019-20, a manuscript was submitted to and accepted by The Condor. [**CORE project**. Contact: Péter Sólymos]

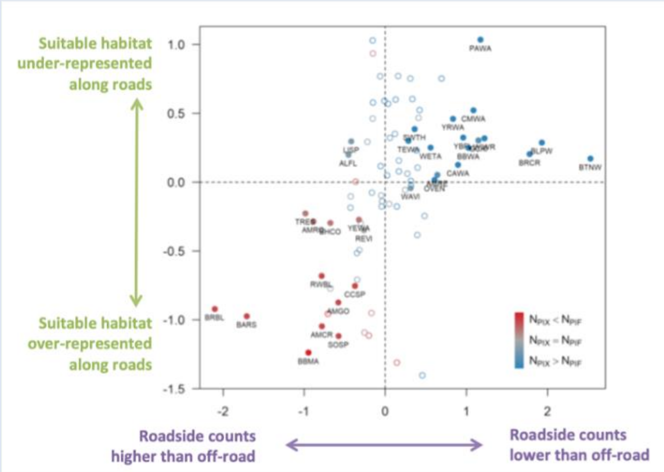


Figure. Differences between Partners in Flight roadside sample-based population estimates and spatial model "pixel"-based population estimates align with roadside count and habitat representation differences across 81 species in Northern Alberta, Canada. Red dots indicate species that are well-represented along roads; blue dots indicate species that are under-represented along roads. Filled dots indicate statistically significant differences between population estimates, $P < 0.05$. (Species codes and values for species represented by unfilled dots can be found in the paper.)

Box 1. Comparing spatially explicit models (PIX) and the Partners in Flight (PIF) approach to estimate population sizes of boreal birds in Alberta, Canada

Avian conservationists have relied on population estimates from Partners in Flight (PIF) that primarily use roadside data from the BBS. However, roadside data has two unaccounted-for assumptions that can influence population estimates. First, the density, behaviour, and detectability of species may be different along roads than away from roads. Second, the locations of roads themselves aren't random, resulting in an unrepresentative sampling of habitats.

We compared the PIF approach with spatially explicit models (PIX) for 81 landbird species incorporating roadside and off-road point-count surveys, and looked at patterns across species.

We found that time and especially detection distance adjustments explained average differences between the PIF and PIX estimates. In contrast, the variation in population estimates among species was explained mostly by differences in the roadside count and habitat representation assumptions. This variation was large enough to change the ranking of which species were estimated to be most abundant. More focused research is needed to better understand and tease apart the complexity surrounding roadside point counts.

DOI: 10.1093/condor/duaa007, Contact: Péter Sólymos; solymos@ualberta.ca

BAM National Density Models Version 4.0

Reliable information on species' population sizes, trends, habitat associations, and distributions is important for status assessment, BCR planning, broader conservation planning, and recovery planning and action for Species at Risk. BAM has developed a generalized analytical approach to model species densities in relation to environmental covariates. We used the BAM database (surveys up to 2018) and built models for 143 species. We modelled density independently in each region (portions of BCRs separated by provincial boundaries) using tree species biomass, stand age, topography, land use, and climate as predictors (see Box 2 for more details). We used machine learning to allow complex interactions and non-linear responses while avoiding time-consuming species-by-species parameterization. We used cross-validation to avoid overfitting and bootstrap resampling to provide uncertainty for our density estimates.

We provide our density results as 1 km^2 resolution raster layers, which are used to calculate population sizes and regional habitat associations (mean densities by land cover type). Results are available at https://borealbirds.github.io. In 2020, we plan to consult with the BAM Technical Committee and the broader ornithology community (particularly PIF and CWS) on the presentation of results and related strategies to support uptake of our data products into various applications, e.g., the CWS Boreal Monitoring Strategy (page 28). We also plan to host one or more webinars for applied researchers, conservation and forestry practitioners, and regional land-use planners to demonstrate possible applications of the BAM models to conservation initiatives, including landscape- and climate-change scenario evaluations. [**CORE project**. Contact: Diana Stralberg and Péter Sólymos]

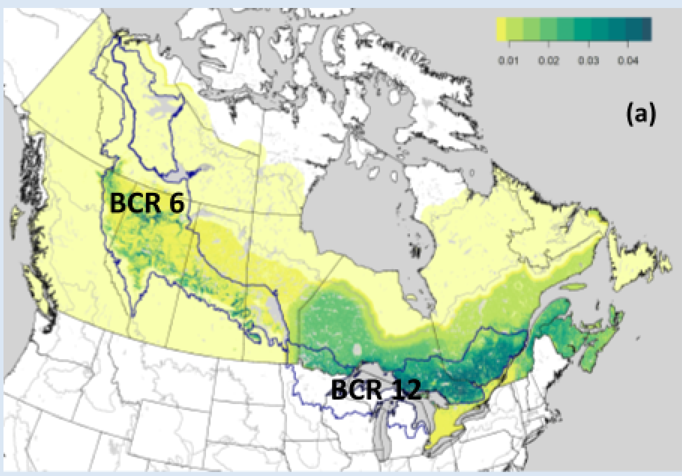
Box 2. BAM National Density Models v4.0

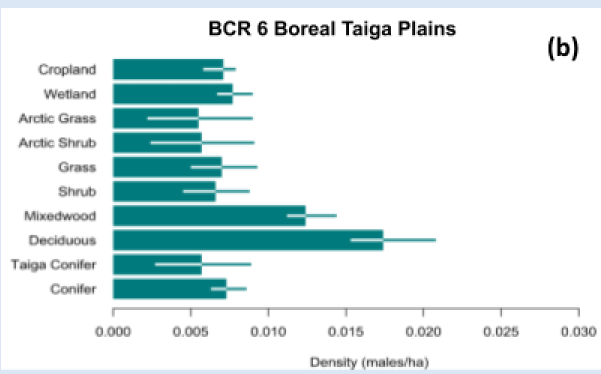
The development of comprehensive national-scale products is challenged by sparse data in remote regions, complex species' responses to environmental factors, regional variation in habitat selection, and time differences between environmental and avian data. In response to these challenges, we have developed a generalized but modular analytical method for modelling and predicting species' densities and population numbers.

We use machine-learning methods to develop bird density models that allow complex interactions and non-linear responses to environmental covariates. This way, we avoid the time-consuming chore of parameterizing models for ~150 individual species one at a time. We use a diverse set of over 100 environmental variables—including biomass of individual tree species at the stand and landscape level, forest age, topography, land use, and climate—to capture much of the existing variation in environmental conditions. When we predict these models spatially, we get a huge improvement in accuracy compared to simple regional averages.

Because species' habitat relationships can vary significantly across the vast boreal region, we develop separate models for multiple, overlapping BCR subunits (BCRs split by provincial boundaries and then buffered by 100 km) and then average them spatially (and across several subsamples of the data). This also avoids predicting outside of the BCR subunits in which a species is known to occur.

Finally, to address temporal changes in bird numbers, we incorporate survey year into the models explicitly, and match bird data with vegetation data from the corresponding time period. The resulting predictions are year-specific and can eventually be used to evaluate species' trends and inter-annual variability.





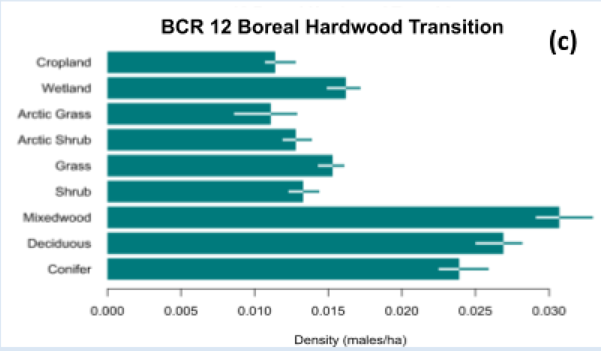


Figure. Density and habitat associations of Canada Warbler based on v4.0 BAM national models (borealbirds.github.io/species/CAWA). For each Bird Conservation Region (BCR), we have summarized mean densities by general land cover type (b&c). Predictions can also be summarized using other more detailed overlays (e.g., forest type and age categories). By "rolling up" these density predictions across larger areas, we have estimated population sizes with error bounds across Canada and by individual BCR. Our current Canada-wide estimate for Canada Warbler is 4.81 (4.59 — 5.21) million pairs (males).

Full suite of national density models found at https://borealbirds.github.io / Contact: Péter Sólymos; solymos@ualberta.ca

Revising our trend estimation procedure

Given poor coverage of BBS data in the boreal region, we have looked to other sources of data to augment the BBS for the purposes of trend estimation. Although the BAM dataset is ad-hoc and temporally sparse, it has grown substantially in extent and duration, allowing us to explore several hybrid methods for using it — in conjunction with BBS data — to estimate population trends. In the last year, with input from ECCC statisticians and biologists, we have identified several options for further exploration, one of which is a direct extension of our generalized national models. In regions not well represented by BBS, this relatively robust approach can provide an alternative to estimates based solely on repeated BBS counts. It is based on the development of spatio-temporal abundance models that combine data from multiple years to quantify habitat relationships, while considering inter-annual variation in abundance. These new generalized national models (see previous section, page 10) were separately constructed for each BCR subregion within Canada (south of the Arctic) and hemiboreal portions of the United States, thus ensuring that annual density estimates are regionally relevant.

To balance spatio-temporal coverage of input data and thereby limit the influence of sampling bias, we spatially and temporally stratified and subsampled the data for modeling purposes. We also controlled for the effects of spatial and temporal variation on abundance by including sources of temporal (sampling year) and spatial (climate, terrain, and vegetation) variation as direct covariates in our models. The boosted regression tree modelling approach that we used captures non-linear and interactive habitat relationships, thus resulting in relatively fine-scale (1-km resolution), spatially heterogeneous, annual predictions. These annual, pixel-level estimates can then be "rolled up" to estimate trends for a variety of different geographies and time periods. Trends are based on a combination of direct predicted changes as a function of changes in "habitat supply" (vegetation) over time, and unexplained ("residual") variation in abundance that may be attributed to a variety of potential (unmapped) predictors, including wintering ground and migration conditions.

Further testing is still required, but preliminary results suggest that BAM data provide the best available trend estimates in areas not well-sampled by the BBS. We are working to identify the specific areas for which BAM trend estimates constitute an improvement over BBS-based trends. [**CORE project**. Contact: Diana Stralberg and Péter Sólymos]

Predicting spatiotemporal abundance of breeding waterfowl across Canada

Antoine Adde (BAM PhD student with Marcel Darveau and Steve Cumming, Université Laval) is mapping the abundance and distribution of waterfowl in Canada. In 2019, a review of the literature was completed that summarized environmental variables known to affect breeding duck distribution and abundance in northern North America. In February 2020, this review was submitted as a manuscript to Écoscience. Following this review, models were built for mapping the spatio-temporal abundance of 18 waterfowl species at a pan-Canadian level (see Box 3 for more details on methods and results). This work was submitted as a manuscript to *Diversity & Distributions* in February 2020. This project benefits from an NSERC Strategic Partnership Grant (Cumming, Bayne, Darveau and McIntire). This research continues the 11-year collaboration between Steve Cumming and Marcel Darveau of Ducks Unlimited Canada to extend BAM's taxonomic scope to waterfowl. This has involved two former BAM graduate students, Nicole Barker (later BAM Coordinating Scientist) and Christian Roy, now both with ECCC. Steve Cumming, Nicole Barker, and Diana Stralberg are co-authors on various manuscripts proceeding from Antoine Adde's PhD thesis [**CO-PRODUCED project**. Contact: Antoine Adde]

Box 3. Predicting spatiotemporal abundance of breeding waterfowl across Canada

Our aim was to develop predictive statistical models for mapping the abundance of waterfowl species at a pan-Canadian level. We refined the previous generation of national waterfowl models to (i) explicitly account for spatiotemporal variations in abundance of 18 waterfowl species, (ii) while testing for associations with a revised suite of habitat covariates by (iii) developing new, more interpretable statistical models.

Our response variables were annual species counts on 2227 aerial-survey segments over 25 years (1990–2015). Combining machine learning and hierarchical regression modelling, we devised an innovative covariate selection strategy to select for each species the best subset of a panel of 232 candidate habitat covariates. Using the selected covariates, we implemented hierarchical generalized linear models in a Bayesian framework.

On average, the model variance explained was 47% for spatiotemporal predictions and 74% for temporally averaged spatial predictions. The 18 models included 94 significant waterfowl-habitat associations involving 42 distinct habitat covariates. Covariates for forest attributes were the most represented in our models. The proportional biomass of *Populus tremuloides* was the most frequently selected covariate.

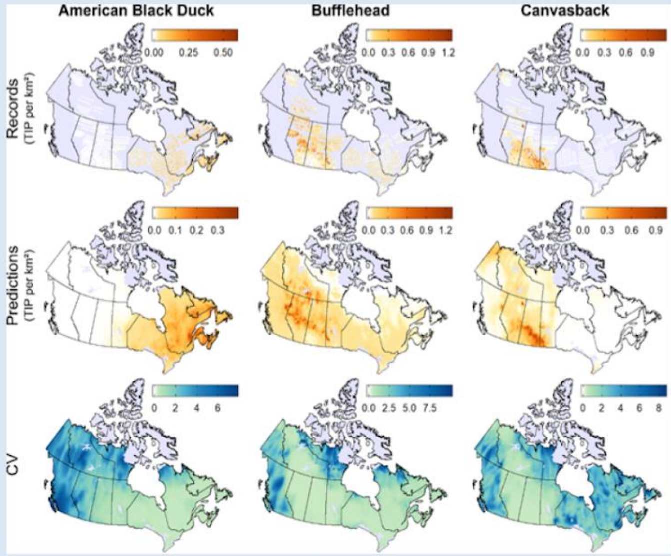


Figure. Maps of temporally averaged (1990–2015) spatial records and predictions for American black duck, bufflehead, and canvasback. Records: response variables (Total Indicated Pairs; TIP). Predictions: median of the posterior distribution (TIP). CV: coefficient of variation of the posterior distribution.

Our modelling approach explicitly accounted for spatiotemporal variation in waterfowl abundance while providing interpretable model structures and parameter estimates. Model predictions generated annual and temporally averaged spatial maps of species abundances over almost all of Canada. Possible applications include the development of biodiversity indicators, the evaluation and execution of conservation planning strategies and ecosystem services monitoring.

Work in review. Contact: Antoine Adde; antoine.adde.1@ulaval.ca

Species at Risk Status, Recovery Planning, and Multi-species Management

Testing a Critical Habitat Identification Framework

Overview: Defining and identifying critical habitat is an important step in planning recovery actions for species at risk. BAM has partnered with ECCC to inform critical habitat identification. In 2019-2020, we focused our efforts on Canada Warbler (Threatened, SARA Schedule 1) to test a critical habitat identification framework we developed in previous years.

BAM began developing predictions of Canada Warbler densities under future scenarios to identify high-priority areas of critical habitat for this species. We also supported the documentation of the conceptual framework for identification of critical habitat as a Standard Operating Procedure (SOP), to facilitate the application of this approach to different species and regions.

Regional models in Alberta and Nova Scotia to support Canada Warbler Critical Habitat identification

Step 3 in our conceptual model for guiding identification of critical habitat for wide-ranging species is the development of density models for all management units. In 2018-19, we built density models for Alberta and northern Nova Scotia. In 2019-20, we finalized these models and moved on to Step 4 of the conceptual model: population risk assessment. Forestry and climate change are two factors that will shape the future forest landscape. We are developing forest landscape simulations in both regions for current conditions to the year 2100. These simulations consider multiple forestry and climate change scenarios. We will use our regional density models and the simulated landscapes to generate predictions of Canada Warbler density under multiple scenarios. These predictions, and their variation among the different scenarios, will be used to identify high-priority areas (e.g., areas that retain high density of the species through time) using conservation planning site selection techniques (i.e., Zonation). This project is a collaboration with ECCC. [**CORE project**. Contact: Francisco Dénes]

A Standard Operating Procedure to Inform the Identification of Critical Habitat Under the Species at Risk Act

In 2019-20, we worked with CWS to develop a SOP to inform the identification of Critical Habitat under the Species at Risk Act, based on the Critical Habitat Identification Framework. This SOP is intended to describe a systematic data-driven approach that can be applied to wide-ranging boreal bird species to support their recovery. The SOP was included as an appendix in the Statement of Work for the CWS Wood Thrush Critical Habitat Identification contract [**INFORMED project**. Contact: Francisco Dénes]

Habitat Selection, Availability, and Needs

Differential Habitat Selection

Overview: Understanding habitat selection is an important step in predicting species distribution and can enhance ecological forecasting and conservation planning. Recently, BAM has begun to explore large-scale spatial variation in habitat selection across breeding ranges, as well as finer-scale habitat modelling via advanced remote sensing products.

In 2019-20, we published a manuscript quantifying differential habitat selection in birds across different regions of the Canadian boreal forest. We also incorporated LiDAR-derived habitat metrics into preliminary species distribution models for Canada Warbler within Alberta.

Differential habitat selection in boreal songbirds influences estimates of population size and distribution

Understanding habitat selection across a species range is an important step in estimating population size and distribution. BAM has undertaken efforts to test for and quantify differential habitat selection (DHS) in birds among regions of the Canadian boreal forest. In 2018-19, we developed models to test for differential selection of forest compositional and structural attributes among three boreal forest regions for six landbird species. We found strong evidence for DHS among regions for all six species. Species distribution models that did not account for DHS overestimated density (see Box 4 for more details on methods and results). This work was published in October 2019 as a manuscript in *Diversity & Distributions* (Crosby et al., 2019). This project benefits from an NSERC Strategic Partnership Grant. [**CORE project**. Contact: Andy Crosby]

Box 4. Differential habitat selection in boreal songbirds influences estimates of population size and distribution

Effective species conservation relies on accurately understanding how species use the landscape to ensure we conserve the habitat necessary for their survival and reproduction. There is a much anecdotal evidence that many bird species select habitat differently in different parts of their geographic breeding range. If true, large-scale species distribution models would not accurately estimate population size and distribution, or correctly predict to unsampled locations, if these regional difference were unaccounted for.

Our objectives were to test for and quantify differential habitat selection (DHS) in boreal birds. We developed models that allowed habitat selection to vary among 3 distinct regions of the boreal forest for 6 landbird species. We tested for differences in parameter estimates among regions, niche overlap from one region to another, and overall predictive ability of the models.

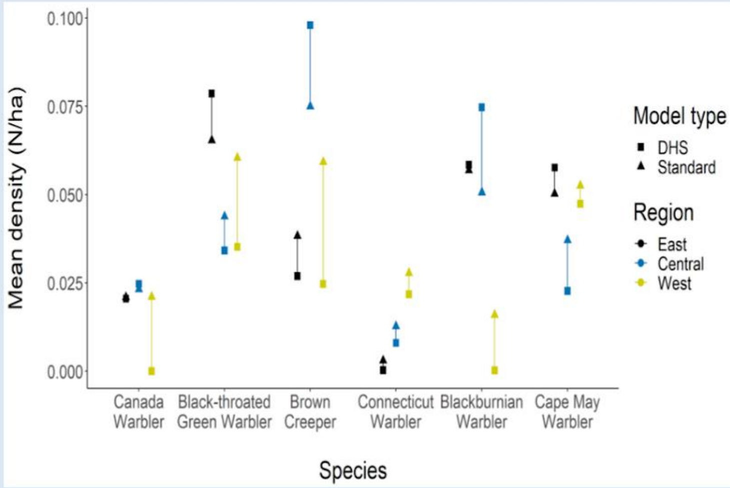


Figure. Comparison of mean density estimates (number/ha) for six songbird species in three geographically distinct regions of the Canadian boreal forest zone. Comparison is between models accounting for differential habitat selection (DHS) and models that assume spatially constant habitat selection (Standard).

Results showed substantial differences in parameter estimates among regions, generally low niche overlap between regions, and much better predictive accuracy density by DHS models relative to models of constant habitat selection across regions. Constant habitat models tended to overestimate mean density relative to DHS models.

By accounting for DHS, researchers and managers can obtain more accurate estimates of population size and distribution, and gain a better understanding of how species are using the landscape, and thus create more efficient and effective conservation plans for boreal birds.

https://doi.org/10.1111/ddi.12991. Contact: Andy Crosby; crosby@ualberta.ca

Functional response models to quantify habitat selection while accounting for habitat availability in the surrounding region

BAM is developing explanatory models of differential habitat selection (DHS) to better predict changes to bird populations in changing landscapes. These models account for the way differences in habitat availability and species density interact to affect population size and distribution, known as a functional response. In 2019-2020, we summarized habitat distribution at the landscape scale using the Common Attribute Schema for Forest Resource Inventories (CASFRI) database. CASFRI is a standardized compilation of spatially explicit forest resource inventory data from across Canada. We then developed preliminary functional response models that explain a portion of DHS in Black-throated Green Warbler. To accurately predict future distributions and population sizes in response to changing landscapes, it is essential for models to account for the effect of habitat availability on the habitat selection process. These models show promise for making better density predictions outside the spatial and temporal bounds of the data to which they were fit. In 2020, we will fully develop these models for integration with TARDIS, a forest landscape simulation model, to estimate the effects of different forest harvest strategies on bird populations at a national extent. This project benefits from an NSERC Strategic Partnership Grant. [**CORE project**. Contact: Andy Crosby]

Can new remote sensing tools improve species distribution models for birds in Alberta?

Brendan Casey (PhD Student with Erin Bayne, University of Alberta) is evaluating the benefits of using finer-scale LiDAR-derived vegetation metrics in species distribution models, compared to the more common remotely sensed forest attributes included in Forest Resource Inventories. In 2019-20, LiDAR metrics related to canopy closure, vegetation height, and vertical vegetation density, were combined with data from the Common Attribute Schema for Forest Resource Inventories (CASFRI) and wet areas mapping products to build preliminary species distribution models for Canada Warbler. In 2020, models will be finalized, and a manuscript will be submitted to the *Journal of Wildlife Management*. This project benefits from an NSERC Strategic Partnership Grant and is a collaboration with the Alberta Department of Agriculture and Forestry. [**CO-PRODUCED project**. Contact: Brendan Casey]

Threats Assessment: Impacts of Climate Change and Landscape Change on Boreal Birds

Climate Change Impacts

Overview: BAM has conducted considerable work to date to improve our understanding of the effects of climate change on boreal bird populations and their forest habitats, to document broad-scale climate-related changes in distribution and abundance, and to inform climate-smart conservation planning. This work is focused primarily on developing spatial models for the purposes of forecasting and vulnerability assessment, but also for evaluating historical climate-related changes.

In 2019-2020, we contributed to several collaborative efforts to apply bird density models to outputs of forest landscape simulation models resulting from climate change, forest harvest and wildfire in Alberta, Quebec, and the Northwest Territories. Results from these simulations have been compared with results from previous bioclimatic projections (Stralberg et al., 2015) to better understand the various factors influencing species' responses to climate change, e.g., changes in availability of mature forest habitat. We have also begun to analyze correspondence with regional trends derived from BAM data to better understand the magnitude and nature of climate-change influences on bird abundance and distribution.

Projected effects of climate change on boreal bird community accentuated by anthropogenic disturbances in western boreal forest

We have continued efforts to forecast the impacts of climate change on boreal bird communities while considering forest harvest and wildfire. In collaboration with Canadian Forest Service (CFS) researchers, we executed LANDIS-II Landscape Change Model simulations (see box 5 for more details on methods and results). In 2019-20, this work was published as a manuscript in *Diversity and Distributions*. This project is a collaboration with the CFS and ECCC. [**CO-PRODUCED project**. Contact: Junior A. Tremblay or Diana Stralberg]

Box 5. Simulating effects of climate and landscape change in Alberta

Climate change is expected to significantly influence boreal bird communities, notably through changes in forest habitat (composition and age structure).

We used the LANDIS-II forest landscape model to project changes in forest habitats and associated bird populations (72 passerine species) according to three climatic scenarios (baseline, RCP 4.5 and RCP 8.5) and three forest harvesting scenarios of differing intensity.

As a result of climate-induced increases in fire activity and decreased conifer productivity, our simulations projected that a significant proportion of Alberta's boreal forest would transition to treeless habitat (i.e., grass- or shrub-dominated vegetation) and that many conifer- dominated stands would be replaced by broadleaf tree cover. Consequently, the abundance of bird species associated with open and deciduous habitats were projected to increase.

Our study stresses the importance of considering key habitat characteristics like forest age structure and composition through forest landscape modelling, and identifies 18 bird species particularly sensitive to climate change.

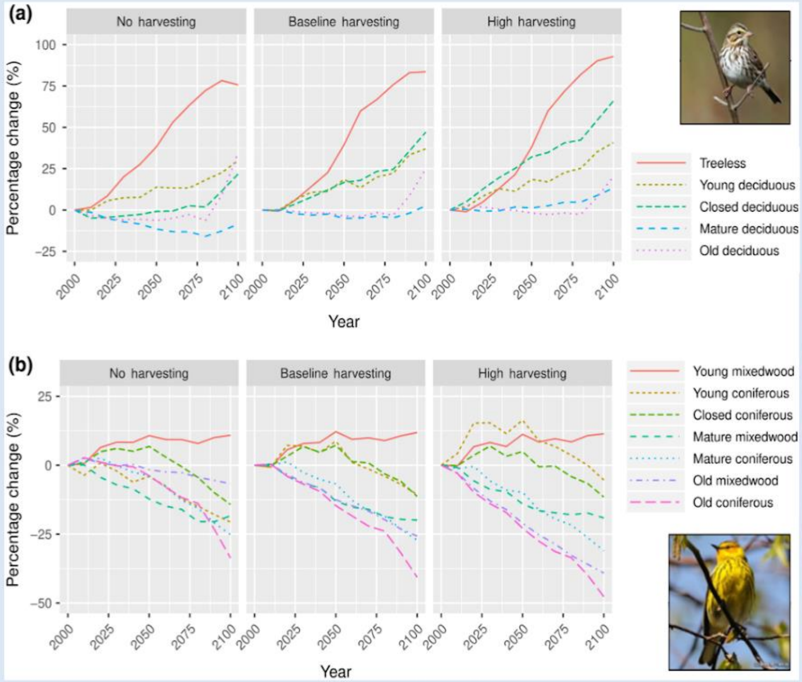


Figure. Percentage change in average bird abundance under a high-emissions climate-change scenario and three harvest scenarios. Bird species are grouped by their habitat associations where (a) Bird species associated with treeless and deciduous forest habitats and (b) Bird species associated with mixedwood and coniferous forest habitats.

doi.org/10.1111/ddi.13057. Contact: Junior A. Tremblay; junior.tremblay@canada.ca

Dynamic bird & caribou habitat with fire and climate change in BCR 6

In 2019-20, we continued to contribute to collaborative work to project changes in avian and caribou distribution and abundance in response to landscape and climate change within the Taiga Plains ecozone of the Northwest Territories. These projections were based on integrated models of forest stand dynamics and fire, all implemented in the SpaDES modelling package (Chubaty & McIntire, 2018). We made significant advances in integrating climate sensitivity into the forest biomass succession and wildfire models, as well as increasing the number of bird species modeled from 84 to 94. Currently, we are working on a final iteration that will have 100% climate sensitivity in the wildfire component, allow for incorporation of Indigenous ecological knowledge regarding caribou habitat suitability, and allow forecasting of important areas for conservation in the future using explicit spatial optimization. This project is a collaboration with Université Laval, CFS, ECCC, and the NWT Department of Environment and Natural Resources. This project benefited from additional funding from CWS Northern Region. [**CO-PRODUCED project**. Contact: Tati Micheletti].

Assessing the impact of climate change and forest management on forest landscapes, carbon stocks, caribou and bird biodiversity

The potential contributions of the forest sector to carbon sequestration and to net GHG emissions is uncertain. Indeed, it is unclear whether intensifying forest management to maximize carbon transfers from the ecosystem to long-lived harvested wood products or extending the total cutting revolution to increase ecosystem-level carbon stocks is more effective at reducing net GHG emissions. Furthermore, these emission mitigation scenarios take little account of the effects of climate change on forest dynamics, nor of the maintenance of other forest values and services, particularly biodiversity. For instance, climate-induced changes in forest productivity and natural disturbances (e.g., fire, insect outbreaks) will modify forest composition, structure and spatial patterns. Climate-induced changes to composition, structure and patterns of forest will have cumulative effects on forest values and services, and these effects will depend on (or be further modified by) the chosen carbon sequestration strategy. We used a forest landscape model to simulate the impacts of three climate change (historical, RCP 4.5, RCP 8.5) and seven harvesting scenarios (from very extensive to very intensive) on forest landscapes, carbon stocks and biodiversity (birds and woodland caribou) in a 1M ha boreal landscape north of Quebec City, Canada. Our results show that increasing anthropogenic climate forcing will greatly alter forest landscapes, regardless of the forest management scenarios, notably by reducing coniferous content. This in turn greatly affects biodiversity by favoring generalist bird species while being detrimental to caribou. Carbon stocks were generally less impacted by forest management practices. In light of these results, we are currently analysing which strategy is best in order to balance conservation values, timber production, and reduction of GHG net emissions in the context of climate change. [**CO-PRODUCED project**. Contact: Junior A. Tremblay]

A regional comparison of the impacts of climate change and forest harvesting on boreal bird communities of Canada

In this study, we use the LANDIS-II forest landscape model to project the impacts of climate change and forest harvesting on boreal bird communities in two provinces of Canada (Alberta and Québec). We found that both forest harvesting and climate-related drivers are projected to have significant impacts on bird communities in both regions, with changes projected to occur earlier and more drastically in western regions than in eastern regions of the Canadian boreal forest. With climate change, declines are projected for old forest-associated bird species in both regions, especially in conifer-dominated habitats, and a greater increase of bird species associated with early stages of forest succession and treeless habitats in western regions. Our results also show that climate change and forest harvesting may impact species differently across their range, and regional-specific measures should be implemented to ensure adequate conservation of climate-sensitive species. [**CO-PRODUCED project**. Contact: Junior A. Tremblay or Diana Stralberg]

Avian responses to climate-mediated landscape changes in Bird Conservation Region 4

In 2019-20, we continued our contributions to a project that aims to simulate bird response to landscape changes caused by increased fire severity and extent across the northwest boreal forest in Yukon and Alaska. This past year we completed our simulations of avian responses by 30 species to future changes in climate suitability and forest type and age across BCR 4 from 1990 to 2100. Changes in vegetation were from landscape simulations of climate-mediated fire activity by the University of Alaska Fairbanks Scenarios Network for Alaska and Arctic Planning (https://www.snap.uaf.edu/projects/alfresco-and-habitat-research). Our future projections of bird population trends across species were of similar magnitude and direction to observed population trends from the BBS in BCR 4 from 1993–2015. This supports the plausibility of our projections and indicates that populations of many species, including several declining species of concern, may already be closely tracking changes in climate and habitat suitability across the region. We anticipate completing analyses and a manuscript for this project in 2020-21. [**CO-PRODUCED project**. Contact: Steve Matsuoka]

Historical changes in boreal bird abundance and distribution

In 2019-2020, we improved our generalized national modelling approach to accommodate a spatially explicit analysis of historical changes in boreal bird abundance and distribution over a 25-year period beginning in approximately 1995. Results from these analyses will be used to evaluate climate-change projections, and to better understand individual species' vulnerability to climate change, as laid out in our framework for conservation of boreal birds under climate change, published in *Avian Conservation and Ecology* in 2019 (page 36). [**CORE project**. Contact: Diana Stralberg]

Conservation and management of boreal birds in a changing climate: What do we expect, what have we observed, and what do we do about it?

BAM continues to collaborate to further our understanding of climate-change impacts across the boreal region. In June 2019, we convened a special session on climate change and boreal birds at the annual meeting of the American Ornithological Society in Anchorage, Alaska. This special session was co-chaired by Diana Stralberg (BAM), Steve Matsuoka (USGS) and Junior A. Tremblay (ECCC). In this session entitled "Conservation and management of boreal birds in a changing climate: What do we expect, what have we observed, and what do we do about it?", speakers from across the boreal region, from Alaska to New England, presented research on historical trends and future projections associated with climate change, as well as climate-change vulnerability and adaptation frameworks. The workshop provided an opportunity for coordination across boreal geographies spanning from Alaska to New England. In addition to highlighting the BAM-led vulnerability framework for climate-informed bird conservation published in *Avian Conservation and Ecology* (see page 36), the symposium prompted a plan among participants to collaborate on a boreal-wide synthesis comparing historical trends with future projections [**CO-PRODUCED project**. Contact: Diana Stralberg]

Symposium participants and colleagues at the start of a working evening hike in the Chugach Mountains near Anchorage, AK.

Western Wood-Pewee and Olive-sided Flycatcher in northwestern North America

Tara Stehelin (former PhD student with Fiona Schmiegelow, University of Alberta) produced models based on climate, land cover and disturbance to describe and predict the abundance and distribution of Olive-Sided Flycatcher and Western Wood-Pewee in northwestern North America. These models used baseline climate conditions as well as climate conditions of two future time periods under two scenarios of greenhouse gas concentrations. The results from this research will augment identification of areas of conservation priority (e.g., refugia) through a comparison of mapped products such as predicted distributions, areas with new suitable habitat, and bioclimatic velocity (i.e., the speed at which a species is exposed to climate change over space and time). In 2019-20, models were completed, and uncertainty was assessed. The corresponding thesis chapters were completed, and two manuscripts are being prepared. Tara successfully defended her PhD in March 2020. Congratulations Tara! [**CO-PRODUCED project**. Contact: Tara Stehelin]

Phenological investigation between insect prey and two species of aerial insectivorous bird

Tara Stehelin (former PhD student with Fiona Schmiegelow, University of Alberta) examined relationships between insect availability and phenology (including breeding success) of breeding Olive-Sided Flycatchers and Western Wood-Pewees in southern Yukon between 2013 and 2017. In 2019-20, data analyses were completed, and results were summarized into a thesis chapter. For 2020-21, a manuscript describing this work is being prepared. [**CO-PRODUCED project**. Contact: Tara Stehelin]


Tara Stehelin

Energy Impacts and Cumulative Effects

Overview: Effective management strategies and conservation planning require an understanding of the individual and cumulative impacts of multiple stressors on boreal bird populations. BAM is striving to assess the effects of development by the energy sector on boreal birds within a cumulative impacts framework and to attribute impacts of energy and other sectors at local and landscape scales.

In 2019-2020, BAM focused on synthesizing results from previous studies to better understand the overall impacts of oil sands development on boreal bird populations. Two reports, on Ovenbird and Yellow Rail, developed new models and synthesized existing knowledge to provide a holistic overview of known individual and cumulative impacts for these species in the Oil Sands Region (OSR). We also made progress on two new projects: developing a community-level summary of the individual and cumulative impacts of multiple sectors on 80 species of boreal landbirds within the OSR and determining whether boreal landbird communities become more homogeneous as the amount of anthropogenic disturbance in the landscape increases (i.e., undergo a process of biotic homogenization).

Partitioning impacts of various Oil Sands Region stressors on the Ovenbird

In 2019-20, BAM collaborated on a report that estimated the impacts of various stressors within the Oil Sands Region (OSR) on Ovenbirds. This work developed Ovenbird models to estimate the individual and additive cumulative impacts of industrial sectors within the OSR on Ovenbird population size, with a particular emphasis on understanding the impacts of specific oil sands stressors. This report demonstrates that habitat loss, and to a lesser degree habitat fragmentation, have negative effects on the Ovenbird, and that the cumulative impacts of OSR stressors are affecting habitat availability for the Ovenbird population in the region. The report was produced in March 2020 and is a collaboration with ABMI. [**CO-PRODUCED project**. Contact: Péter Sólymos & Erin Bayne]

Yellow Rail in Alberta's Oil Sands Region

In 2019-20, a report was produced that describes results from Yellow Rail monitoring efforts in the Oil Sands Region (OSR) of Alberta. This work identified key breeding sites, created a habitat suitability map, and produced regional population estimates for Yellow Rail in the OSR. In addition, this report synthesized available information into management tools and identified priorities for future research. This report is a collaboration with ABMI and is available at https://bit.ly/38JljvT. [**INFORMED project**. Contact: Erin Bayne]

Attribution of impacts to different sectors at local and landscape scales

BAM partnered with ABMI and ECCC to develop models that separate the cumulative local- and landscape-level impacts of multiple sectors on boreal birds and attribute these impacts to specific sectors. Results of single-species models for northern Alberta are available for over 100 species on the ABMI's Biodiversity Browser (https://abmi.ca/home/data-analytics/biobrowser-home). In 2019-20, we initiated work to summarize the results of over 80 species into a single report, including describing cross-species patterns in the estimated impacts. Results will inform cumulative impacts work within this region, particularly work within the Oil Sands Region. In 2020-21, modelling will be completed, and a draft manuscript will be submitted. [**CO-PRODUCED project**. Contact: Judith Toms & Péter Sólymos]

Biotic Homogenization

Previous work in the Oil Sands Region (OSR) has described losses in forest-dependent species and increases in species that are tolerant of anthropogenic disturbances, which suggests this may result in an overall shift in the composition of the landbird community. In particular, it has been hypothesized that the landbird community is undergoing a process of biotic homogenization, whereby historically distinct bird communities become more similar to each other as the amount of disturbance on the landscape increases. This BAM-informed ECCC project is directly testing this hypothesis. Preliminary results suggest that higher levels of disturbance are associated with novel bird communities not naturally present in the boreal landscape. In 2020-21, modelling will be completed, and a draft manuscript will be submitted. [**INFORMED project**. Contact: Judith Toms]

Forestry Impacts

Overview: To understand how forest management policies and practices impact bird populations at local, regional, and national scales we have begun to quantify the impacts of different forest management strategies on bird densities. BAM is currently undertaking a multi-year project to integrate avian abundance models into simulations of landscape dynamics and simulations of strategic- and operational-level forest management planning. We continue to investigate the effects of the forestry sector on birds in a cumulative impact setting.

In 2019-20, we assessed the potential impacts of various forest management scenarios in Alberta on boreal birds and further developed a risk matrix to support harvest planning. We also developed collaborative and cross-border initiatives for bird conservation in certified and managed forests.

Caribou-centric forestry harvest plans have minor anticipated co-benefits for avian species of conservation concern

As interest in caribou conservation continues to increase, there is growing interest in understanding potential trade-offs or co-benefits with other species. In 2019-20, we continued our efforts to estimate possible impacts on boreal bird populations resulting from various harvest management options in the Al-Pac forest management unit. Using the cure4insect decision support tool (Sólymos, 2018), we applied avian habitat models to the landscapes forecasted under different timber supply scenarios, including a caribou conservation scenario, to anticipate bird population response (see box 6 for more details on methods and results). We extended this work further using a custom-built ALCES Online simulator to explore impacts of fire and energy – in addition to forest harvest – for the caribou conservation scenario. We projected how population sizes of several species including Black-throated Green Warbler, Canada Warbler (CAWA), Olive-sided Flycatcher, Cape May Warbler (CMWA) and Palm Warbler (PAWA) would respond to differences in harvest locations, energy sector development, and either increases or cessation of forest fires. A manuscript describing these results was submitted to a *Frontiers in Ecology and Evolution* special issue in March 2020. This work benefited from additional support from Al-Pac and an Accelerate grant from Mitacs. This project is a collaboration with Al-Pac and ABMI. [**CO-PRODUCED project**. Contact: Lionel Leston]

Box 6. Linking models of bird species abundance with harvest and cumulative effects simulators

We linked outputs from land use simulators and bird species abundance models to project how boreal birds will respond to cumulative effects of caribou conservation, harvest, fire, and energy-sector development in the Al-Pac Forest Management Area (FMA) in Alberta.

We used vegetation and non-forestry footprint data from two harvest scenarios in Patchworks and five cumulative effects (harvest, fire, energy sector) scenarios in ALCES Online as inputs to model density of 20 species.

In Patchworks, scenarios either included (Preferred Forest Management (PFM) Scenario) or excluded (Ecosystem Based Management (EBM) Scenario) a 20-year harvest deferral within caribou conservation zones. Birds associated with older forests (e.g., CAWA) generally increased in both these scenarios, while species associated with younger forests (e.g., PAWA) decreased over 50 years, because average projected forest age increased over 50 years. Differences between harvest scenarios were minor.

While Patchworks scenarios only simulated harvest-based disturbance, other forms of disturbance (e.g., fire, energy sector) are predicted to reduce habitat for some bird species. The ALCES Online scenarios included a baseline scenario with current burn rates, moderate energy sector development, and harvest from the Patchworks PFM scenario with a 20-year harvest deferral. Other scenarios included a doubling of the burn rate, the absence of future fire, the absence of future energy sector development and the additional presence of seismic line reclamation. CMWA responded negatively to fire and energy sector development under four cumulative effects scenarios (see Figure). However, species associated with younger habitats generally responded positively or less negatively to fire and energy sector development (e.g., PAWA).

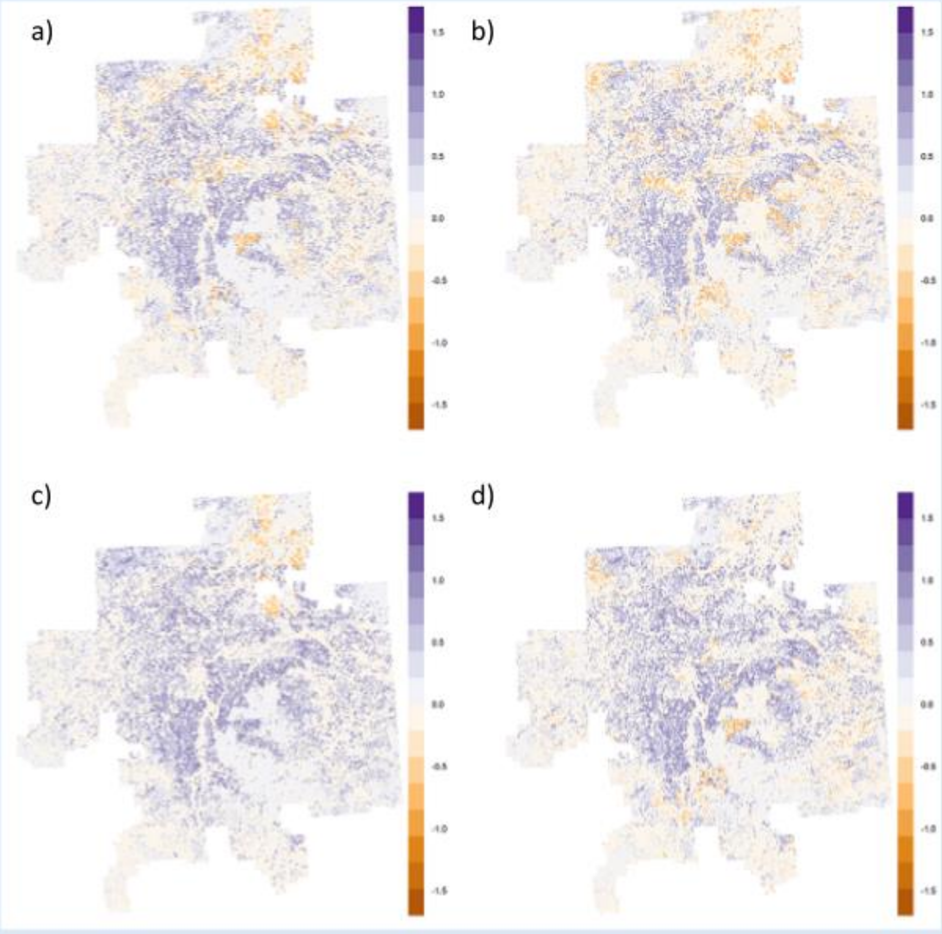


Figure. Mean change in the density (birds/ha) and distribution of Cape May Warbler over 50 years in the Al-Pac Forest Management Area under four cumulative effects scenarios in ALCES Online: a) harvest from the Preferred Forest Management (PFM) scenario + current burn rate + moderate energy sector development over 50 years ("Al-Pac BAU" scenario); b) harvest from the PFM scenario + 2*current burn rate + moderate energy sector development over 50 years ("Increased Fire" scenario); c) harvest from the PFM scenario + no fire + moderate energy sector development over 50 years ("No Fire" scenario); d) harvest from the PFM scenario + current burn rate + no energy sector development over 50 years ("No Energy" scenario). Not shown is a fifth scenario ("Seismic Reclamation") identical to the Al-Pac BAU scenario in which seismic lines were allowed to actively regenerate to forest over time.

Work in review. Contact: Lionel Leston; leston@ualberta.ca

Supporting harvest planning decisions regarding risk of incidental take

Forest companies are expected to avoid the incidental take of migratory birds (i.e., killing or harming individuals, or disturbing or destroying nests) while carrying out work on their tenure. BAM previously evaluated a tool being used by forest companies in British Columbia to assess their risk of incidental take. More recently, BAM began the process of evaluating a GIS-based risk matrix tool (created by Forsite Consultants Ltd.) developed for companies in Alberta. In 2018-19, we quality-checked data, completed initial analyses, performed an analysis of sampling gaps, and presented preliminary results to partners. In 2019-20, we finished building and evaluating data-driven risk matrices based on boosted regression trees and regional density models. We used these results to modify the existing GIS-based risk matrix tool by joining ranks based on predicted total bird densities from our risk matrices to the FORSITE application. In 2020-21, models and tools will be completed, and a report will be written and submitted. This revised tool will better enable Alberta-based forest companies to evaluate their risk of incidental take when planning and conducting activities on their tenures. This project benefits from a Mitacs Accelerate grant and is a collaboration with Forest Resource Improvement Association of Alberta (FRIAA) and ABMI (see Box for more details). [**CO-PRODUCED project**. Contact: Lionel Leston]

Box 7. Designing and validating data-driven risk matrices of incidental take by forest companies

Forestry companies require predictive tools (risk matrices) that can be used during operational planning to reduce the risk of incidental take of birds and nests during harvest operations.

A risk matrix ranks forest stands according to predicted relative abundance of nesting birds in those stands. Normally based on expert opinions, risk matrices can be based on predictions from models made from point count data. We used the cure4insect package to estimate densities of individual species in forest stands, then calculate ranks (1 to 6) based on total density across species. We then compared our ranks to expert-derived ranks developed by FORSITE.

We found strong positive correlations between the data driven ranks from the cure4insect models and ranks based on expert opinion.

Predicted individual and total species densities and data-driven ranks have been made into a GIS layer and spatially joined to the original FORSITE matrix for operational planners to compare different ranks of incidental take risk within a forest polygon. Total density and data-driven ranks will also be weighted to emphasize individual species of interest (e.g., federal Species At Risk like Canada Warbler).

Work in progress. Contact: Lionel Leston; leston@ualberta.ca

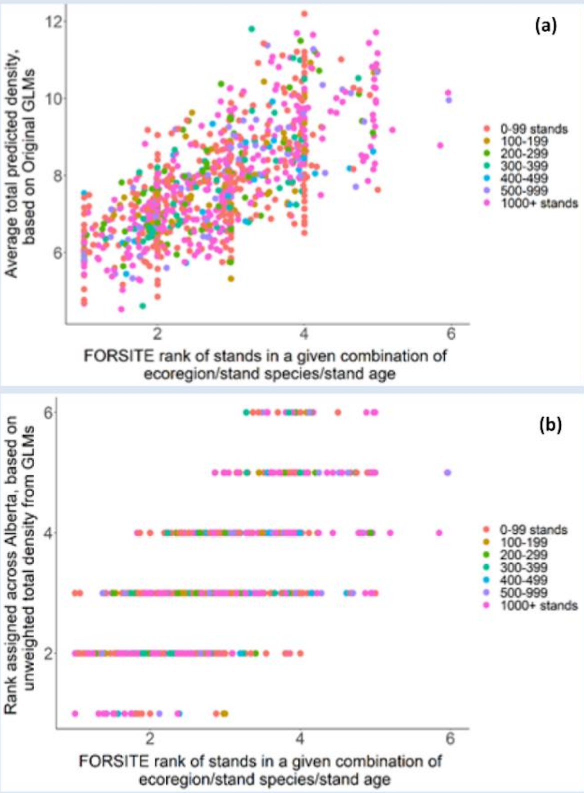


Figure. Correlations between expert-derived FORSITE ranks and (a) bird densities and (b) data-driven ranks averaged across ecoregion, dominant species, and age class. Data-driven ranks will be used to revise the FORSITE ranks and improve the risk matrix.

Impacts of residual tree retention on birds

Brendan Casey (PhD student with Erin Bayne, University of Alberta) is studying the influence of post-harvest residual tree retention on Alberta bird communities. Retention forestry is used to balance economic and environmental objectives and limit the impact of timber production on biodiversity. As more than half of Alberta's harvested forests use some form of retention, understanding its impact on migratory birds is important for informing smarter forest management practices. Towards this, automated recording units (ARUs) were placed in 250 cutblocks in 2018 and 2019 that represent a gradient of harvest intensities (clear-cut, 95%, 75%, 50%, and 25%) across a chronosequence of 5-30 years post-harvest. In 2019, acoustic data from the recordings was extracted and supplemented with acoustic data from ABMI and point count data from BAM's avian database. In

2020, we will evaluate how species richness, diversity, and community composition change in response to different retention regimes over time. A manuscript detailing the project's results will be submitted to *the Journal of Applied Ecology* by July 2020. This project benefits from an NSERC Strategic Partnership Grant and is a collaboration with the Bioacoustic Unit at the University of Alberta and the ABMI. [**CO-PRODUCED project**. Contact: Brendan Casey]

Conservation Value of Forest Certification Differs Among Bird Conservation Regions

In collaboration with SFI and forest industry partners, BAM is evaluating the conservation value of forest certification based on the contribution of certified forest lands to regional avian species richness relative to the non-certified lands. In 2019-2020, we developed community occupancy/abundance models of boreal forest birds and calculated the contribution of the bird community at each BAM sampling point to species richness of the BCR in which the point occurred. The contribution to regional species richness was based on species richness and the rarity of species at each point and served as an index of conservation value. We then aggregated points to SFI certified lands and non-certified lands. Preliminary results showed that in the Atlantic Northern Forest (BCR 14) and Boreal Hardwood Transition (BCR 12), SFI certified lands had higher conservation value for avian species richness than remaining lands, while in the Boreal Softwood Shield (BCR 8) there was very little difference. In 2020-2021, we will run updated models in all BCRs, develop a web-based tool to display results, and submit a manuscript based on project results. [**CO-PRODUCED project**. Contact: Andy Crosby]

Cross-border collaboration between BAM, American Bird Conservancy, and Sustainable Forestry Initiative for bird conservation on managed forest lands

In 2019-2020, BAM worked with SFI and American Bird Conservancy (ABC) to develop a cross-border initiative for bird conservation on managed forest lands. The project area is the Upper Great Lakes region of BCR 12 (Boreal Hardwood Transition). The cross-border project will focus on the co-production of actionable science with local forest industry, government, and community partners to identify opportunities and challenges for forest management to benefit bird populations. We held an initial in-person workshop at the SFI annual meeting in October 2019 and are in the process of planning a webinar in June 2020, to present the project proposal and begin to engage potential partners. We have also been soliciting additional data for the United States portion of the BCR 12 study region. In fall 2020, BAM and ABC will submit a joint proposal to the SFI Conservation Grants program to fund the project. [**CO-PRODUCED project**. Contact: Andy Crosby]

Forest Resource Improvement Association of Alberta (FRIAA) - Managing Alberta's forest birds through multi-scale forestry planning.

In 2019-20, BAM established a research program with FRIAA to integrate the best available information on boreal birds into forest management planning in Alberta. In 2020-21, we will collate existing bird and forestry data, create standardized models, fill data gaps through fieldwork, and use resulting information to develop simulation tools that can be used for forest planning and certification. These efforts will improve our ability to manage Alberta's forests and biodiversity by providing information that informs how forestry companies can effectively plan for timber supply while still providing suitable habitat for boreal birds.

Projects encompass three themes:

1. Improving our understanding of bird-habitat relationships across space and time.
2. Evaluating how within-block attributes & spatial configuration of harvest influence birds over time.
3. Develop tools for short and long-term population assessment of birds.

[**CO-PRODUCED project**. Contact: Erin Bayne]

Projecting Impacts of Landscape Change

Overview: BAM applies predictive species abundance models to simulated landscapes that are likely to result from climate change, disturbance regimes, and management actions in order to estimate and manage for future risks to avian populations through projected change in abundances and distributions. BAM has several landscape simulation projects, planned and ongoing, including graduate student projects that are collaborations among BAM, Canadian Forest Service, and Ducks Unlimited Canada.

In 2019-2020, we expanded on work to assess the effects of anthropogenic disturbance on boreal birds using integrated hierarchical Bayesian models and hindcasting efforts. We also continued efforts to identify and optimize forest management practices in the context of climate change to conserve avian populations.

Effects of anthropogenic disturbances on boreal birds at national extent

One of BAM's long-time goals has been to quantify the consequences of anthropogenic disturbances for populations of birds within the boreal region of Canada. In 2019-2020, we revised a manuscript assessing the impacts of human disturbance on the abundances of 15 migratory songbird species at a national extent, which was accepted for the special issue "Conservation of Boreal Birds" in *Avian Conservation & Ecology* (Suarez et al., *in review*; page 36). In this study, we found that the density of most of the songbird species decreased with anthropogenic disturbances at multiple scales across Canada's boreal forest, despite disturbances generally having a small footprint relative to the total area considered. The expansion of this project is described below. [**CORE project**. Contact: Tati Micheletti]

Hindcasting the net effect of forest harvesting on the abundance of boreal songbirds: 1985-2011

Following from the previous project, we have started to develop a spatially integrated version of the models described by Suarez et al. (*in review*). Here we integrate disturbance information at both the local and neighborhood scales into one model using a hierarchical Bayesian model structure. This approach was chosen to address spatial autocorrelation issues that occur when integrating multiple scales of disturbance into the generalized linear mixed models (GLMMs) used by Suarez et al. (*in review*). While GLMMs are not able to correct for this spatial autocorrelation, the Bayesian framework is. We believe this approach will increase our understanding of how disturbance caused by the forestry sector affects boreal landbird abundance estimates, as it allows for disturbance at both scales to be included in the modelling framework. While the previous project used data from 2000 to 2012, we have expanded to predict the effects of forestry on landbirds from 1985 to 2015 using SpaDES — a new environment for ecological modelling and spatial simulation (Chubaty and McIntire 2018). Preliminary analyses produced some unexpected results. In 2019-2020, we had several meetings among co-authors and decided to review the models and data used. We are currently expanding the models from 15 to 39 species using more up-to-date input data. Once we have the results from this updated analysis, we will review these with the co-authors and a manuscript will be written and submitted. This project benefits from an NSERC Strategic Partnership Grant and is a collaboration with the CFS. [**CORE project**. Contact: Tati Micheletti]

Historical range of variation as a strategy to identify forest management practices to conserve avian populations

Ana Raymundo (PhD student with Steve Cumming and Eliot McIntire) is forecasting the effects of alternative forest management strategies on avian abundance in three regions of the Canadian Boreal Forest: Québec, Ontario, and northeastern British Columbia. In 2019-2020, the Historical Range of Variation (HRV) in the landscape is being quantified throughout simulation experiments of vegetation dynamics and wildfire in SpaDES. Avian HRV will be derived by converting the simulated forest maps into maps of abundance of selected bird species. Harvesting scenarios will be added to the landscape dynamic to forecast the consequences of alternative forest management strategies to HRV. In 2021, simulations — and the corresponding thesis chapters and manuscripts — will be completed. This project benefits from an NSERC Strategic Partnership Grant. [**CO-PRODUCED project**. Contact: Ana Raymundo]

Optimising for sustainable harvests and bird populations in forest management planning

Isolde Lane Shaw (PhD student with Steve Cumming, Université Laval) is evaluating different approaches to incorporating bird conservation in optimisation problems for strategic and operational forest management planning. This research is focused on study regions in Québec and British Columbia, however the models built will be readily reproducible across the entire Canadian boreal forest. Using the BAM national models of bird density (Stralberg *et al.,* 2015) and spatial simulation models built in SpaDES, we will experiment with different harvesting constraints designed to benefit bird conservation while optimising sustainable harvest volumes. In 2020, a first thesis chapter and manuscript will be completed, with further simulations, chapters and manuscripts to be completed in 2021. This project benefits from an NSERC Strategic Partnership Grant. [**CO-PRODUCED project**. Contact: Isolde Lane Shaw]

Conservation Planning for Boreal Birds

Identifying, designing, and evaluating priority wildlife areas and protected areas

Overview: One of BAM's primary goals is to inform large-scale, conservation planning efforts through the creation of spatially explicit avian density and distribution information. We have collaborated with research partners and NGOs to inform multi-species conservation planning, to quantify the conservation value of certified lands, and enable cross-border conservation planning.

In 2019-2020, we published work identifying priority regions for Canada Warbler conservation in BCR 14. We continue to work with numerous partners to inform multi-species conservation planning.

Prioritizing Areas for Land Conservation and Forest Management Planning for the Threatened Canada Warbler in the Atlantic Northern Forest

In February 2020, we published our work identifying priority regions for Canada Warbler conservation and forest management in BCR 14 (see Box 8 for more details). We developed seven conservation planning scenarios to prioritize candidate areas for permanent land conservation or responsible forest management. We found that using low natal dispersal distance scenarios in decision-making offers a more conservative approach to maintaining Canada Warbler populations. This prioritization approach provides a toolkit for managers to immediately locate areas for implementing conservation and management actions. In 2019-2020, this work was published in *Diversity*. This project was a collaborative effort with ECCC, and High Branch Conservation Services, with support from Nature Canada and the Canada Warbler International Conservation Initiative. [**CO-PRODUCED project**. Contact: Diana Stralberg or Alana Westwood]

Box 8. Prioritizing Areas for Land Conservation and Forest Management Planning for the Canada Warbler

Populations of Canada Warbler (*Cardellina canadensis*) are declining in Canada's Atlantic Northern Forest. Land conservancies and government agencies are interested in identifying areas to protect populations, while some timber companies wish to manage forests to minimize impacts on Canada Warbler and potentially create future habitat.

We developed seven conservation planning scenarios using the Zonation software to prioritize candidate areas for permanent land conservation or responsible forest management. Factors used to prioritize areas included Canada Warbler population density, connectivity to protected areas, future climate suitability, anthropogenic disturbance, and recent Canada Warbler observations. We analyzed each scenario for three estimates of natal dispersal distance (5, 10, and 50 km).

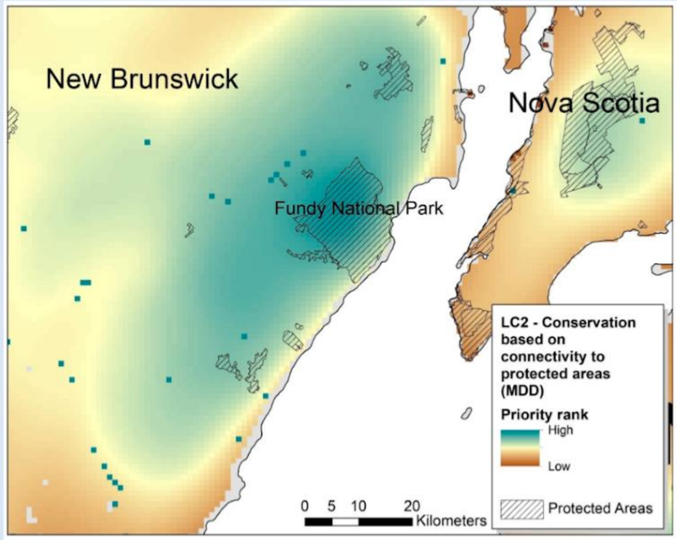


Figure. Conservation priorities for Canada Warbler based on population density and connectivity with current protected areas. Blue squares were highly prioritized because they included observations of Canada Warbler made during point count surveys between 2005 and 2015.

We found that scenarios assuming large dispersal distances prioritized a few large hotspots, while low dispersal distance scenarios prioritized smaller, broadly distributed areas, offering a more conservative approach to maintaining this species at risk.

Given the differences among the scenarios, we encourage conservation planners to evaluate the reliability of dispersal estimates, the influence of habitat connectivity, and future climate suitability when prioritizing areas for conservation.

https://doi.org/10.3390/d12020061 Contact: Alana Westwood; alana.westwood@hotmail.com

Monitoring and Sampling

Overview: BAM continues to support the design of monitoring and survey programs for boreal birds, including the development of a Boreal Avian Monitoring Strategy, an effort to monitor the status, trends and distribution of boreal forest birds at a national scale. This strategy is being led by ECCC, and involves several BAM Contributing Scientists.

In 2019-20, BAM supported ECCC in the development of a sampling scheme known as the Boreal Optimal Sampling Strategy and analyses were initiated to validate the use of proxy variables for sampling stratification. We conducted an analysis to identify gaps in the temporal or spatial coverage of the BAM database in Alberta and to help companies select future survey locations. We continue to develop tools and methods to help researchers design better monitoring programs such as the bSims R package.

Boreal Optimal Sampling Strategy

BAM continues to support ECCC's Boreal Monitoring Strategy by providing data, data products, advice and expertise as needed. In 2019-20, ECCC designed and tested a sampling scheme known as the Boreal Optimal Sampling Strategy (hereafter BOSS; Van Wilgenburg et al., 2020). The BOSS design is a randomized hierarchical sampling design stratified by political jurisdictions, ecoregions, and habitat. The BOSS design also incorporates access costs into sample unit selection such that all else being equal, study areas are more likely to be selected if they are less expensive to access. These traits make the BOSS design more efficient than similar alternative spatially balanced sample designs (Van Wilgenburg et al., 2020). The immediate goals for a Boreal Avian Monitoring Strategy are to improve representation of sampling in relation to existing gaps in space and covariates to improve estimates of species' population sizes, distributions and habitat relationships. In the long-term, the goal is to establish a spatially balanced sample across the boreal for estimating trends in species population sizes. A preliminary target is to sample ~5000 primary sampling units across Canada, representing ~90,000 new point-count sampling locations (See Figure 1). Sample sizes were allocated to spatial strata (based on the intersection of political jurisdiction and ecoregions) based on an analysis of proxy variables thought to contribute to spatial and temporal variation in avian community composition, with greater sampling allocated to strata that are predicted to be more variable. [**INFORMED project**. Contact: Steve Van Wilgenburg]

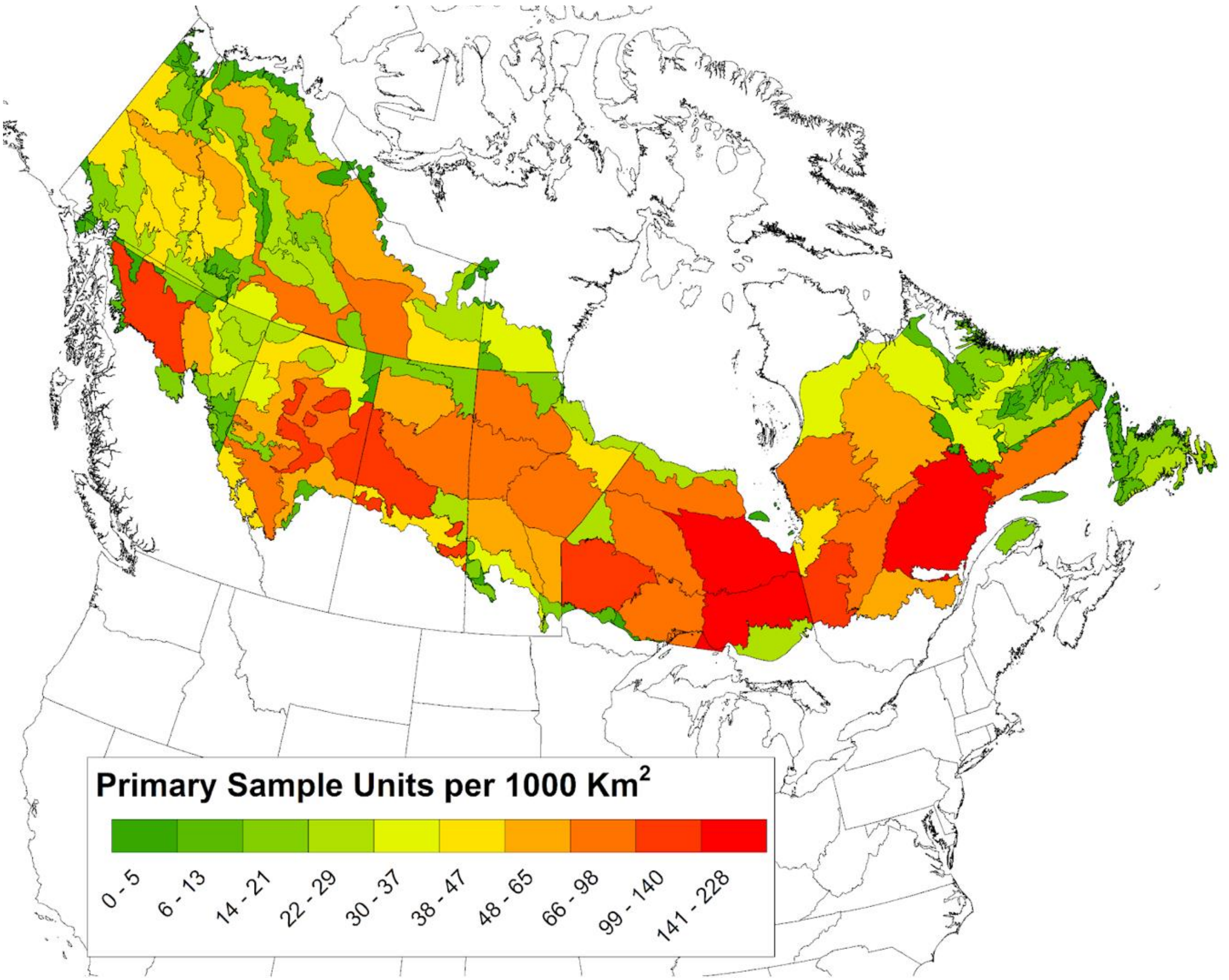


Figure 1. Spatial allocation of 4980 primary sampling units (~90,000 point counts) to spatial strata (intersection of jurisdictions and ecoregions) under the Boreal Optimal Sampling Strategy (Van Wilgenburg et al. 2020)

Validating use of proxy variables for sampling stratification

In 2019-20, an analytical design was developed to use the BAM avian data to evaluate a survey stratification using environmental proxies for variance in bird communities. Analyses were initiated late in the 2019-20 fiscal year and will continue into summer 2020. This project is led by CWS. [**INFORMED project**. Contact: Steve Van Wilgenburg]

Gap filling analysis

As part of our incidental take risk matrix project with forest companies in Alberta (page 24), we have identified combinations of forest attributes that are not currently sampled by the BAM avian database. In 2018-19, we created maps depicting the spatial distribution of these gaps and summarized the number of point counts within each combination of forest attributes to help companies select future survey locations. In 2019-20, we ranked individual forest polygons based on average predicted total densities of nesting birds based on ecoregion, dominant tree species, and age class, and compared these data-driven ranks to ranks based on expert opinion using the same ecoregion/stand/age combinations. This allowed us to determine if there was better agreement between expert opinion and data-derived ranks in better sampled combinations (see Box 9 for more details). A report based on these results will be submitted to FRIAA and ABMI in 2020-2021 to encourage the collection of new data in under sampled regions. This project benefits from a Mitacs Accelerate grant and is a collaboration with FRIAA and ABMI. [**CO-PRODUCED project**. Contact: Lionel Leston]

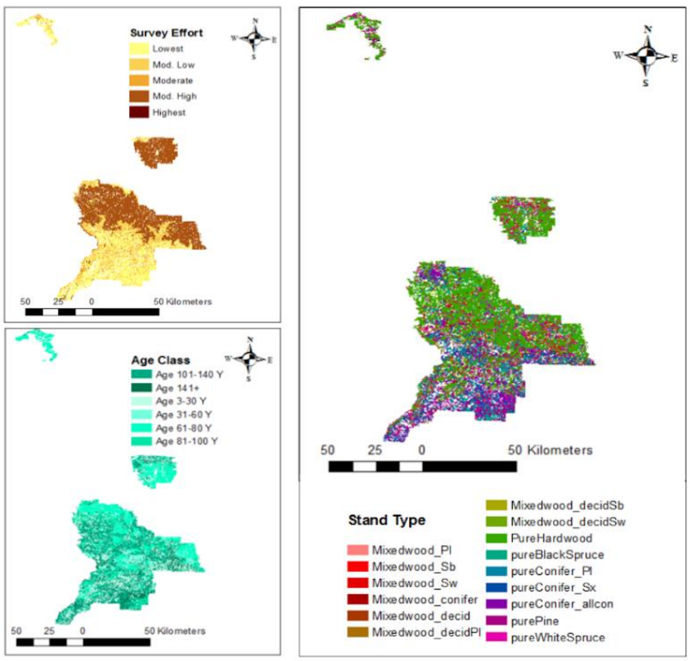


Figure. Example of maps from a one-pager sent out to individual forestry companies showing the location of stands >60 years old that have less bird survey representation in the BAM database. BAM is interested in obtaining new bird survey data within these stands. In this one-pager, poorly sampled stands of a given species, age and ecoregion are located in the southwest of the management area.

Box 9. Gap filling analysis associated with producing risk matrices for predicting incidental take of birds during timber harvest

In 2018-2019, we took a risk matrix based on expert opinion and determined the number of point counts sampled within a given type of forest polygon (unique combination of ecoregion, stand species, stand age, timber productivity). After this gap analysis, we generated maps in which undersampled forest combinations were highlighted and distributed these maps to forest companies to facilitate collection of new point count data in undersampled areas. Poorly sampled stands were usually located in mixed coniferous forest types.

In 2019-2020, we created a risk matrix based on point count data and compared uncertainty in the mean predicted total bird density in polygons by ecoregion, stand species, and age to the number of points sampled in those ranks, i.e. was there greater uncertainty in assigned ranks from ecoregions or stand types with fewer point counts. We did not find a significant relationship between uncertainty (standard deviation) in predicted total bird densities per polygon type with the number of point counts in that polygon type. We also did not find a relationship between the difference in FORSITE and data-driven ranks assigned to a polygon type with the number of point counts in that polygon type.

Work in progress. Contact: Lionel Leston; leston@ualberta.ca

Methods and products to support survey design

Péter Sólymos created the bSims R package to help researchers design better monitoring programs. The bSims package is a bird point count simulator. First presented as a teaching tool at a workshop at the American Ornithological Society 2019 Meeting in Anchorage, AK, the package has since evolved into a standalone tool that (1) allows for easy testing of statistical assumptions and exploring the effects of violating these assumptions, and (2) aids survey design by comparing different options. The package presents a spatially explicit mechanistic simulation framework that is based on statistical models widely used in the analyses of bird point count data (i.e., removal models, distance sampling; see Figure 2). The workflow involves (1) interactive exploration of multiple setups, e.g., comparing roadside vs. off-road sampling; (2) the settings can be copied from the web application and used in the command line tool to conduct more extensive simulations. [**CORE project**. Contact: Péter Sólymos]

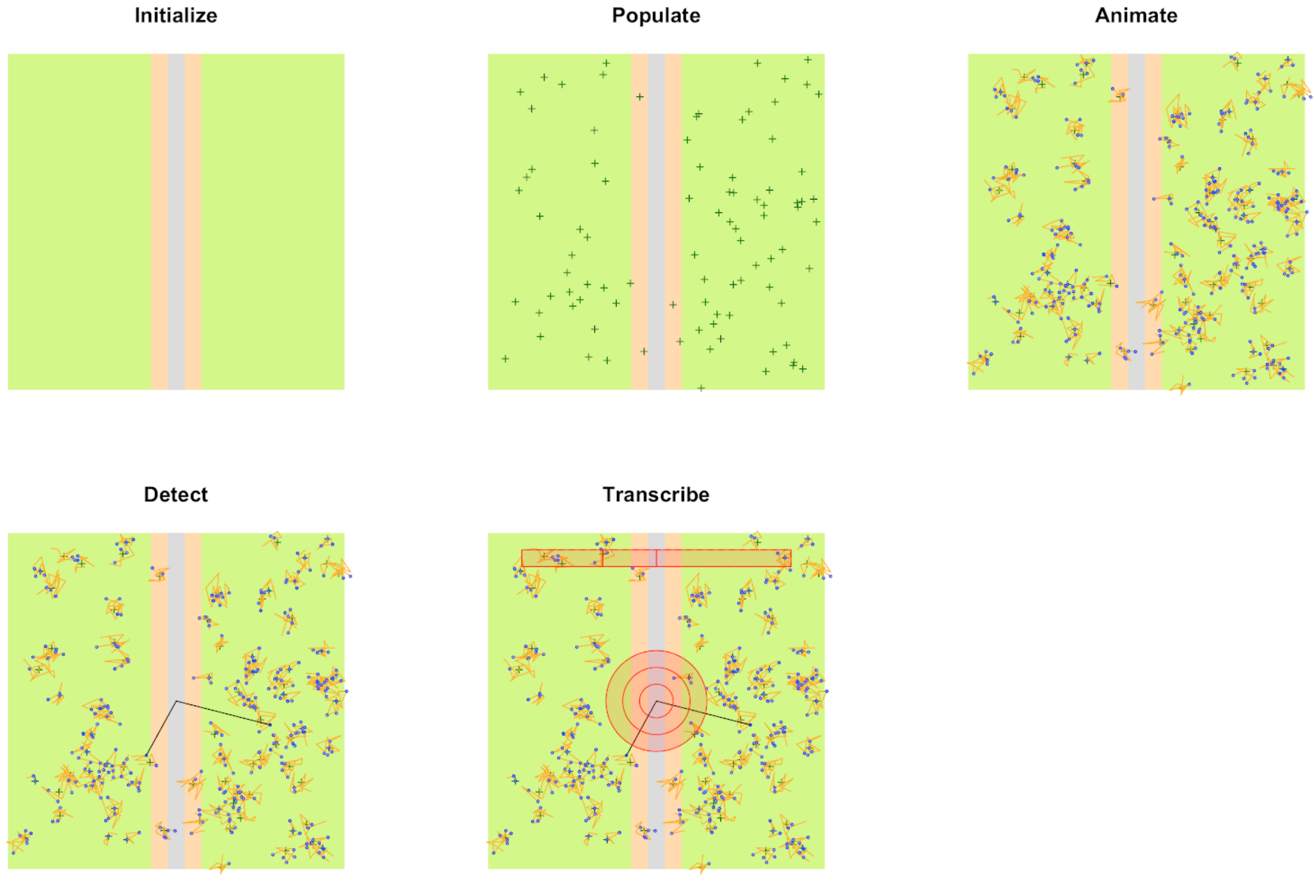


Figure 2. The bSims package implements the following main functions for simulation: (1) initialize and (2) populate the landscape, (3) animate (individual behaviours described by movement and vocalization events), (4) detect (the physical aspect of the signal transmission), and (5) transcribe (the counts by distance and time intervals).

Data and Data Products

Data Products

Overview: The results and outputs of many of our research projects are summarized into data products such as maps and data tables. BAM makes these data products publicly available to support and facilitate conservation and management of boreal birds.

In 2019-20, we released version 4.0 of our National songbird density estimates for review and continued to develop our data product distribution platform on GeoNetwork. The v4.0 National Models and the BAM Geonetwork catalogue will be available to the public in 2020.

Summary and inventory of BAM's data products

The data products that are currently available from BAM are summarized in Figure 3 (page 33). Note that several products are derived from the same underlying models (i.e., Stralberg et al., 2015). Interested parties can contact BAM at BorealAvianModellingProject@ualberta.ca for more information or to request a product. [**CORE project**. Contact: Diana Stralberg].

Canada-wide songbird densities v4.0

In March 2020, BAM did a limited release of a draft of version 4.0 of our National landbird density estimates for peer review. This product is based on National density models (see page 10 for details on methods). National-scale maps of predicted densities for 143 species with associated model uncertainty — available as images and rasters (1 km^2 resolution) — are now available for consultation. We plan to finalize these information products based on closely evaluating the results and incorporating feedback from the avian research community. Maps will be available at borealbirds.ca [**CORE project**. Contact: Diana Stralberg & Péter Sólymos].

Update on data product distribution platform

BAM is in the process of migrating our data products to GeoNetwork, which is an application to manage spatially referenced resources. In 2018-19, we uploaded several BAM data products and began developing a library of keyword tags to facilitate filtering products. In 2019-20, we continued to develop GeoNetwork as an online catalogue to search and find BAM's data products. We plan to launch our data products on GeoNetwork to the public in 2020. [**CORE project**. Contact: Mélina Houle]

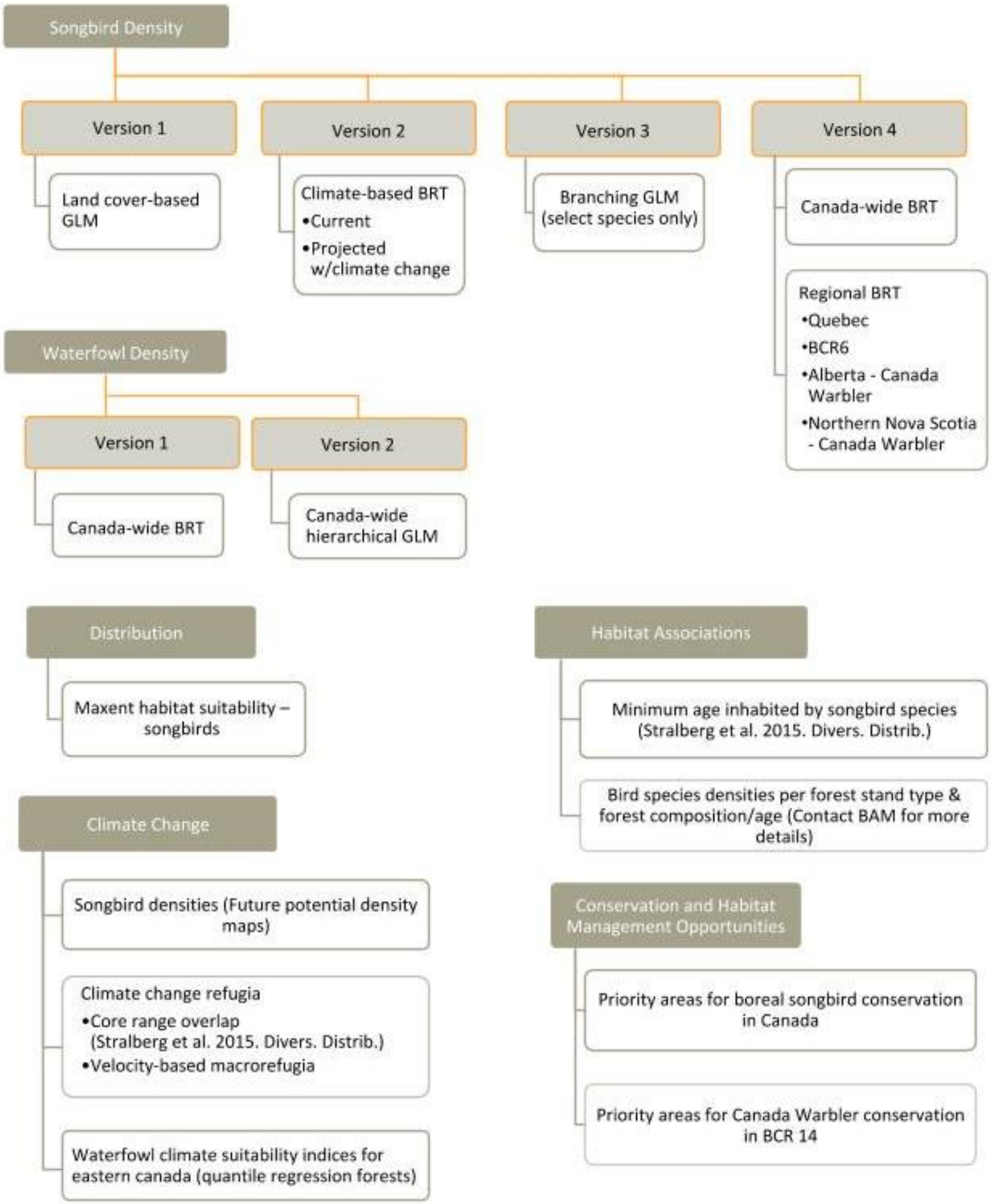


Figure 3. BAM Data Products that are accessible by visiting the data products page on our website (bit.ly/3giopMP) or by contacting BAM.

Databases

Overview: Our avian database, which contains data from over 170 different projects across Canada, is a fundamental component of BAM's work. Enhanced accessibility and sharing of this database with our partners and external parties is one of BAM's key priorities and represents an important opportunity to facilitate avian conservation.

In 2019-20, we continued to update our database, created new data partnerships, identified gaps in the spatial distribution of the database, and initiated a process to enhance the accessibility and openness of the BAM database.

BAM Avian Database update

In 2019-20, we focused on cleaning and integrating new data from various projects and data partners. We added data from multiple projects in the northeastern USA, updated one long-term project, integrated several Breeding Bird Atlases, and added Breeding Bird Survey Data.

This table summarizes the contents of the BAM Avian Database as of March 19, 2020.

	BAM Avian Database	BAM BBS Database
Version (Year Updated)	V5 (2020)	V5 (2020)
# Projects	173	Data inclusive from 1966-2018, all Canadian and Alaskan BBS routes and some routes from the northern USA.
# Sampling Locations	252,667	119,035
#Sampling Events	364,681	1,539,849
#Bird Observations	3,481,846	11,103,084

In 2020-21, we will continue to solicit point count data from new and existing partners including forest products companies. [**CORE project**. Contact: Teegan Docherty or Hedwig Lankau].

Automating the translation of Breeding Bird Survey data

BBS point count data span more than 50 years and provide important information on bird population trends, relative abundance, and species richness at the regional and continental scale. Prior to being incorporated into the BAM database, BBS data needs to be standardized with the BAM data structure. In 2019-2020, we developed an R package to automate this process from download. This package will be accessible in 2020 upon completion of a validation process. [**CORE project**. Contact: Mélina Houle]

Improving application and use of the BAM Avian Database

We continued to update a metadata document called the BAM Avian Database Manual. The purpose of the manual is to ensure the accurate and appropriate use of the data by team members and partners requesting use of BAM data. The manual describes the structure of the BAM database and summarizes the data, such as the type of data, sampling effort across Canada, and data collection methods. In 2019-20, we revised this document based on updates to the database and feedback from team members. [**CORE project**. Contact: Mélina Houle]

Enhanced sharing of the BAM Avian Database

The increasing global trend of open science offers new opportunities for data sharing, citizen science (e.g., eBird), and standardized data repositories, with the goal of making research more innovative, transparent, and reproducible. In April 2019, BAM helped to organize a workshop with the aim of connecting avian database managers and developing a collective vision and path towards open avian data in Canada. We agreed on the need for a comprehensive avian data system in Canada to input, discover, and access high-quality, wide-ranging avian data.

BAM believes that enhanced accessibility to our harmonized point count database will facilitate avian conservation and research. However, many of BAM's data existing agreements were established many years ago and given the recent growing appreciation for the power of open data, these agreements will be revisited. In 2019-20, BAM initiated plans with Birds Canada, CWS, and ABMI to develop a process to improve accessibility to our database. In 2020-21, BAM will lead a major effort to update its avian database and sharing permissions and to revisit and re-negotiate data-sharing agreements with data contributors. We will continue to collaborate with Birds Canada, CWS, ABMI and other partners to ensure alignment with the larger vision for open data. [**CORE project**. Contact: Erin Bayne or Teegan Docherty]

Communications, Collaborations, and Implementation

Communications

To increase the application of our results, BAM strives to communicate our findings and make them accessible to a wide-ranging audience using a variety of formats and platforms, including scientific publications, technical reports, presentations, webinars and workshops and our website.

Website Update

In 2019-2020, we transitioned our website to a new format and hosting platform and began populating the main pages with new content. Updates will continue in 2020-21. Further, we have compiled our data products for both download and viewing. Given that the website was built to be modular, we will continue to add new content as it is created.

Over the next fiscal year, we aim to re-examine our website content — and structure — in an effort to create a space that promotes engagement with boreal bird conservation. This work will ensure that all of BAM's content is centralized in a space that is accessible and inclusive. The current version of our website can be viewed here: https://borealbirds.ca/ [Contact: Teegan Docherty or Hana Ambury]

Conservation of Boreal Birds Special Issue

There are many active programs across North America focused on the conservation and management of boreal birds. BAM strives to encourage collaboration and communication among these various programs. In 2016, BAM and Marcel Darveau (DUC) co-led a workshop at the 2016 North American Congress for Conservation Biology that initiated a special issue of the journal *Avian Conservation and Ecology* on the topic of "Conservation of Boreal Birds".

The special issue is guest edited by Steven Cumming (BAM), Marcel Darveau (DUC) and Ilona Naujokaitis-Lewis (ECCC) and will include an introductory editorial and up to 10 papers. The review and publication process for this issue will continue into 2020 and individual papers will be available online as they are accepted (bit.ly/COBB_SpecialIssue).

BAM has contributed to several manuscripts submitted to this special issue, including:

- Editorial – An introduction to the papers within the special issue and a summary of key conservation issues for the North American boreal forest and boreal species. Manuscript is in preparation.
- Strategies for identifying priority areas for songbird conservation in Canada's boreal forest (Stralberg et al., 2018) – A framework to facilitate the selection of high priority areas for landbird conservation and an evaluation of priorities across multiple scenarios to inform conservation planning.
- Estimating the conservation value of protected areas in Maritime Canada for two species at risk: The Olive-sided Flycatcher (*Contopus cooperi*) and Canada Warbler (*Cardellina canadensis*) (Westwood et al., 2019) – An evaluation of the effects of Canadian national parks and anthropogenic disturbances on the density of Olive-sided Flycatcher and Canada Warbler.
- Monitoring boreal avian populations: how can we estimate trends and trajectories from noisy data? (Roy et al., 2019) – A review of the challenges and tools associated with trend estimation in the boreal forest.
- Conservation planning for boreal birds in a changing climate: a framework for action (Stralberg et al., 2019) – An essay outlining a vulnerability-adaptation framework to guide bird conservation based on species' individual vulnerability and exposure to climate change.

- Pathways for avian science, conservation, and management in boreal Alaska (Matsuoka et al., 2019) – A review of the efforts that are advancing conservation and management of bird populations in the Alaskan boreal.
- Effects of anthropogenic disturbances on boreal birds at national extent (Suárez-Esteban et al., *in review*) – An evaluation of the impacts of human disturbance on migratory songbird populations across boreal Canada.
- Co-producing actionable research for conserving Canada's boreal birds by building respectful partnerships (Westwood et al., 2020) – A review paper promoting the co-production of actionable and respectful conservation science for boreal birds.

BAM Collaborative Activities at a Glance

Collaborations with conservation practitioners and decision-makers are one of the main ways in which BAM's work can inform boreal bird conservation, whether through supporting species at risk assessment and planning, decision-making during planning processes, monitoring and sampling design, or other activities. We also support partners with shared research agendas in their application of BAM methods and products.

In 2019-20, we collaborated on the following initiatives:

- **Boreal Bird Density, Population Status and Trends**
  - BAM continued contributions to discussions within **Partners In Flight (PIF)** regarding population estimation. This has led to subsequent collaborations with **Canadian Wildlife Service (CWS)** on population/trend estimation as well as a broader adoption of the BAM/QPAD approach by **PIF** for population estimation. [Contact: Diana Stralberg]
  - In 2019-20, we received input from **Environment & Climate Change Canada (ECCC)** statisticians and biologists that helped us to revise our approach to trend estimation (page 12). [Contact: Diana Stralberg]
  - Our work mapping the abundance and distribution of waterfowl in Canada was completed in association with Louis Imbeau (**Université du Québec en Abitibi-Témiscamingue**) and Marcel Darveau (**Ducks Unlimited Canada**; page 12). [Contact: Antoine Adde]

- **Species at Risk Status, Recovery Planning, and Multi-species Management**
  - BAM continues to support **CWS** efforts to develop a standardized approach to identify critical habitat for wide-ranging species at risk, using Canada warbler as a test species (page 13). [Contact: Francisco Dénes]
  - BAM worked with **CWS** to develop a SOP to inform the identification of Critical Habitat under the Species at Risk Act. The SOP was included in the Statement of Work for the CWS Wood Thrush Critical Habitat Identification contract (page 14). [Contact: Francisco Dénes]

- **Habitat selection, availability, and needs**
  - A project examining the use of LiDAR in species distribution models is in collaboration with the **Alberta Agriculture and Forestry** (page 15). [Contact: Brendan Casey]

- **Detecting and Attributing Land Use and Climate Change Impacts on Boreal Birds**
  - Efforts to forecast the impacts of climate change on boreal bird communities while considering forest harvest and wildfire in Alberta is a collaboration with the **Canadian Forest Service (CFS)** and **ECCC** (page 16) [Contact: Junior A. Tremblay]
  - We contributed to a project led by **Université Laval**, in collaboration with individuals from **CFS**, **ECCC**, and the **NWT Department of Environment and Natural Resources**, with the goal of projecting landbird and caribou response to climate change, natural disturbance, and other factors (page 17). [Contact: Tati Micheletti]
  - Our work looking at the effects of climate change and forest management on forest landscapes, carbon stocks, caribou and bird biodiversity in Québec is in collaboration with **ECCC** and **CFS** (page 17). [Contact: Junior A. Tremblay]

- We continued our work looking at climate change and vegetation impacts on bird habitat in Alberta and conducted a similar evaluation in Québec in collaboration with the **Laurentian Forestry Centre** (page 18). [Contact: Junior Tremblay & Diana Stralberg]
- We continued our work with **University of Alaska Fairbanks** and the **United States Geological Survey (USGS)** to quantify bird response to climate-mediated landscape changes in BCR4 (page 18). [Contact: Steve Matsuoka]
- A special session on climate change and boreal birds at the 2019 annual meeting of the American Ornithological Society in Anchorage, Alaska, was organized and co-chaired by BAM, **USGS** and **ECCC** (page 18). [Contact: Diana Stralberg]
- BAM collaborated with **ABMI** on two reports for the Oil Sands Region of Alberta, including one on the impacts of various stressors on Ovenbirds (page 21) and one describing the results from Yellow Rail monitoring efforts (page 21). [Contact: Péter Sólymos & Erin Bayne]
- BAM partnered with **ABMI** and **ECCC** to develop models that separate the cumulative local- and landscape-level impacts of different industrial sectors on boreal birds in Alberta (page 21). [Contact: Judith Toms & Péter Sólymos]
- A study to investigate biotic homogenization resulting from anthropogenic disturbance in the Oil Sands Regionof Alberta is a collaboration with ECCC (page 22). [Contact: Judith Toms]
- BAM continued our collaboration with **Al-Pac** and **ABMI** to understand the potential impacts of caribou-specific harvest management plans on avian populations (page 22). [Contact: Lionel Leston]
- BAM continued working with forest products companies in Alberta, the **Alberta Forest Products Association, Forest Resource Improvement Association of Alberta (FRIAA),** and the **ABMI** to evaluate and advance tools to inform incidental take risk assessment (page 24). [Contact: Lionel Leston]
- Our evaluation of the impacts of residual tree retention is a collaboration with the **ABMI** (page 24). [Contact: Brendan Casey]
- BAM continues to work collaboratively with **Sustainable Forestry Initiative (SFI)**. We also have started a new collaboration with the **American Bird Conservancy (ABC)** and **SFI** for a cross-border project regarding bird conservation in SFI-certified forests (page 25). [Contact: Andy Crosby]
- Our hindcasting effort to understand impacts of forestry on bird populations is a collaboration with the **Canadian Forest Service (CFS)** (page 26). [Contact: Tati Micheletti]
- We continued our work with **CFS**, **Université Laval,** and **Ducks Unlimited Canada (DUC)**, and with input from **ECCC**, and **SFI** as part of our NSERC Strategic Partnership Grant. [Contact: Steve Cumming]

- **Conservation Planning for Boreal Birds**
  - BAM team members continued working with **ECCC**, and **High Branch Conservation Services** to identify management and conservation opportunities to benefit Canada Warbler in BCR 14 (page 27). [Contact: Diana Stralberg]

- **Monitoring and Sampling**
  - BAM has and will continue to collaborate with **CWS** to support the Boreal Monitoring Strategy (page 28). [Contact: Steve Van Wilgenburg].
  - As part of our incidental take risk assessment, we collaborated with **FRIAA** and **ABMI** and provided a summary of sampling coverage in Alberta to partner forest companies, to guide future point count sampling site selection by companies like **Weyerhaeuser**, **Al-Pac**, and **West Fraser** (page 30). [Contact: Lionel Leston]

- **Data**
  - We continued our collaboration with the **ABMI**, **CWS**, **Birds Canada**, **WildTrax**, and the **Bioacoustic Unit** to advance the state of open avian data in Canada, (page 34). [Contact: Erin Bayne]

- **Communications and Outreach**
  - The Conservation of Boreal Bird special issue was a collaborative effort, with guest editors from **BAM/ULaval, DUC,** and **ECCC** (page 36). [Contact: Steve Cumming]

Outreach & Publications

We communicate BAM research via webinars, publications in peer-reviewed journals, presentations, and reports. From January 2019 through March 2020, BAM led or significantly contributed to eleven papers in peer-reviewed journals, gave over 30 talks, poster, or workshop presentations, and organized 2 workshops and webinars.

BAM Publications

BAM Core Publications

Publications from BAM Core projects between January 2019 and March 2020.

2019 – January - December

Crosby, A.D., Bayne, E.M., Cumming, S.G., Schmiegelow, F.K.A., Dénes, F.V., Tremblay, J.A., 2019. Differential habitat selection in boreal songbirds influences estimates of population size and distribution. Divers Distrib 25, 1941–1953. https://doi.org/10.1111/ddi.12991.

2020 – January – March

Sólymos, P., J. D. Toms, S. M. Matsuoka, S. G. Cumming, N. K. S. Barker, W. E. Thogmartin, D. Stralberg, A. D. Crosby, F. V. Dénes, S. Haché, C. L. Mahon, F. K. A. Schmiegelow, and E. M. Bayne. 2020. Lessons learned from comparing spatially explicit models and the Partners in Flight approach to estimate population sizes of boreal birds in Alberta, Canada. The Condor 122. https://doi.org/10.1093/condor/duaa007

BAM Co-produced Publications

Publications from BAM Co-produced projects between January 2019 and March 2020.

2019 – January - December

Westwood, A.R., Stacier, C., Sólymos, P., Haché, S., Fontaine, T., Bayne, E.M., Mazerolle, D., 2019. Estimating the conservation value of protected areas in Maritime Canada for two species at risk: the Olive-sided Flycatcher (*Contopus cooperi*) and Canada Warbler (*Cardellina canadensis*). Avian Conserv Ecol 14(1): 16. https://doi.org/10.5751/ACE-01359-140116

Stralberg, D., Berteaux, D., Drever, R., Drever, M.C., Naujokaitis-Lewis, I., Schmiegelow, F.K.A., Tremblay, J.A., 2019. Conservation planning for boreal birds in a changing climate: A framework for action. Avian Conserv Ecol. 14(1):13. https://doi.org/10.5751/ACE-01363-140113

2020 – January - March

Cadieux, P., Boulanger, Y., Cyr, P. D., Taylor, A. R., Price, D. T., Stralberg, D., Sólymos, P., Tremblay, J. A. 2020. Projected effects of climate change on boreal bird community accentuated by anthropogenic disturbances in western boreal forest, Canada. Divers Distrib 26, 668-682. https://doi.org/10.1111/ddi.13057

Westwood, A.R., Barker, N.K., Grant, S., Amos, A.L., Camfield, A.F., Cooper, K.L., Dénes, F.V., Jean-Gagnon, F., McBlane, L., Schmiegelow, F.K.A., Simpson, J.I., Slattery, S.M., Sleep, D.J.H., Sliwa, S., Wells, J.V., Whitaker, D.M., 2020. Toward actionable, coproduced research on boreal birds focused on building respectful partnerships. ACE 15, art26. https://doi.org/10.5751/ACE-01589-150126

Westwood, A.R., Lambert, J.D., Reitsma, L.R., Stralberg, D., 2020. Prioritizing Areas for Land Conservation and Forest Management Planning for the Threatened Canada Warbler (Cardellina canadensis) in the Atlantic Northern Forest of Canada. Diversity 12, 61. https://doi.org/10.3390/d12020061

BAM Informed Publications

Publications we're aware of that use BAM data, methods, or expert knowledge, published between January 2019 and March 2020.

2019 – January - December

Matsuoka, S., J. Hagelin, M. Smith, T. Paragi, A. Sesser, and M. Ingle. 2019. Pathways for avian science, conservation, and management in boreal Alaska. *Avian Conservation and Ecology* 14. https://doi.org/10.1371/journal.pone.0234494

Roy, C., Michel, N.L., Handel, C.M., Van Wilgenburg, S.L., Burkhalter, J.C., Gurney, K.E.B., Messmer, D.J., Princé, K., Rushing, C.S., Saracco, J.F., Schuster, R., Smith, A.C., Smith, P.A., Sólymos, P., Venier, L.A., Zuckerberg, B., 2019. Monitoring boreal avian populations: how can we estimate trends and trajectories from noisy data? Avian Conserv Ecol 14. https://doi.org/10.5751/ACE-01397-140208

Yip, D. A., Knight, E. C., Haave-Audet, E., Wilson, S. J., Charchuk, C., Scott, C. D., Sólymos, P., and Bayne, E. M., 2019. Sound level measurements from audio recordings provide objective distance estimates for distance sampling wildlife populations. *Remote Sensing in Ecology and Conservation*. https://doi.org/10.1002/rse2.118

2020 – January - March

Van Wilgenburg, S. L., Mahon, C. L.,Campbell, G., McLeod, L., Campbell, M., Evans, D., Easton, W., Francis, C. M., Haché, S., Machtans, C. S., Mader, C., Pankratz, R. F., Russell, R., Smith, A. C., Thomas, P., Toms, J. D., and Tremblay, J. A., 2020. A cost efficient spatially balanced hierarchical sampling design for monitoring boreal birds incorporating access costs and habitat stratification. PLoS ONE. https://doi.org/10.1371/journal.pone.0234494

BAM Books

Books from BAM between January 2019 and March 2020.

2019 – January - December

Sólymos, P., 2019. Point count data analysis: How to violate assumptions and get away with it. pp. 197. URL: https://peter.solymos.org/qpad-book/

BAM Technical Reports

Reports describing BAM core and co-produced projects that were not peer-reviewed, completed between January 2019 and March 2020.

2019 – January - December

Micheletti, T., Stewart, F., McIntire, E.J.B., Eddy, I., Barros, C., Marchal, J., Stralberg, D., et al. (2019), Simulation Effects of Climate Change on Fire Regime: Implications for Boreal Caribou and Landbird Communities in the Northwest Territories, Technical Report.

2020 – January - March

No BAM Technical Reports were published in January through March 2020.

Presentations

Presentations given by BAM Team Members between January 2019 and March 2020.

2019 – January - December

BAM Team. (2019), "Boreal Avian Modelling (BAM) Project Overview", Talk presented at the Open Data Workshop for Avian Data in Canada, Edmonton, AB, Canada, 24 April.

Barker, N.K.S. (2019), "Application of models to date", Talk presented at the NSERC CRD Birds and Forestry Meeting, Edmonton, AB, Canada, 23 January.

Barker, N.K.S. (2019), "BAM Highlights: Conservation value of SFI-certified lands for Boreal Birds", Talk presented at the Meeting for SFI Grant Project Launch, Washington, DC, USA, 8 April.

Barker, N.K.S. and Williams, E. (2019), “Meeting in the Middle: Potential avenues for pan-American bird conservation”, Talk presented at the SFI Conservation Impact Sounding Board, Washington, DC, USA, 9 April.

Crosby, A.D. and Bayne, E.M. (2019), “Boreal Avian Modelling Project: Addressing Critical Knowledge Gaps Challenging the Management and Conservation of Boreal Birds in Canada”, Talk presented at the SFI Annual Conference, 22 October.

Crosby, A.D. (2019), "Incorporating Regional Variation into Habitat Models with Functional Responses", Talk presented at the 37th Meeting of the Society of Canadian Ornithologists, Québec City, QC, Canada, 27 April.

Crosby, A.D. (2019), "Science for the Future of Boreal BIrds: Defining the Scientific Challenges", Talk presented at the 37th Meeting of the Society of Canadian Ornithologists, Québec City, QC, Canada, 27 April.

Denés, F.V. (2019), "Identification of critical habitat for wide-ranging migratory birds: a conceptual model towards achieving self-sustaining populations", Talk presented at the Schedule of Studies Advisory Committee Meeting, Ottawa, ON, Canada, 27 February.

Haché, S., Micheletti, T., Stralberg, D., Cumming, S.G., McIntire, E.J.B., Tremblay, J.A., Leblond, M., et al. (2019), "Simulating the Effects of Climate on Fire Regime & Vegetation: Implications for Woodland Caribou & Boreal Landbird Communities", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Knight, E.C., Harrison, A., Scarpignato, A.L., Van Wilgenburg, S.L., Bayne, E.M. and Marra, P.P. (2019), "Conservation Implications of a Migratory Network for the Common Nighthawk", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Leston, L., Bayne, E.M. and Schmiegelow, F.K.A. (2019), "Long-term monitoring of boreal bird community at Calling Lake Alberta, 1993-2018 and counting", Talk presented at the Western Canada Bird Banding Conference, Edmonton, AB, Canada, 29 March.

Leston, L., Bayne, E.M. and Schmiegelow, F.K.A. (2019), "Long-term monitoring of changes in harvest area, weather, and insect outbreaks on boreal birds", Talk presented at the Alberta Chapter of the Wildlife Society AGM, Canmore, AB, 22 March.

Leston, L., Bayne, E.M., Solymos, P. andToms, J. Predicting boreal bird abundance at landscape scales. COSIA/Alberta Innovates/Emissions Reduction Alberta Oil Sands Innovation Summit, Calgary, AB.

Mahon, C.L., Holloway, G., Bayne, E.M. and Toms, J.D. (2019), "Additive and Interactive Cumulative Effects on Boreal Landbirds: Winners and Losers in a Multi-Stressor Landscape", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Matsuoka, S.M., Sólymos, P., Breen, A.L., Handel, C.M., Rupps, T.S., Mahon, C.L. and Kurkowsi, T.A. (2019), "Forecasting Avian Responses to Climate-mediated Increases in Fire Activity Across the Northwestern Boreal Forest", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Micheletti, T., McIntire, E.J.B., Stewart, F., Haché, S., Eddy, I., Barros, C., Chubaty, A.M., et al. (2019). "Data to Decisions: a multispecies approach case study for Northwest Territories", Talk presented at the Society of Canadian Ornithologists 2019, Québec, QC.

Sólymos, P. (2019), "Analysis of Point-count Data in the Presence of Variable Survey Methodologies and Detection Error", Workshop presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 25 June.

Sólymos, P. (2019), "Data integration and current models", Talk presented at the NSERC CRD Birds and Forestry Meeting, Edmonton, AB, Canada, 23 January.

Sólymos, P., Toms, J.D. and Bayne, E.M. (2019), "Understanding Cumulative Effects for Land Management in Alberta: Models and Applications", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Sólymos, P., Matsuoka, S.M., Van Wilgenburg, S.L., Stralberg, D., Cumming, S.G. and Bayne, E.M. (2019), "What Can We Do with Survey Design Specific Biases in Point-Count Data? Integrating Roadside Surveys and New Technologies", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 28 June.

Stehelin, T.E. and Schmiegelow, F.K.A. (2019), "Present and Future Distribution and Abundance of Aerial Insectivores in the Northwest Using Climate and Landcover", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Stehelin, T.E. and Schmiegelow, F.K.A. (2019), "Predicting present and future distribution and abundance of Olive-sided Flycatcher and Western Wood-pewee in northwestern North America using climate and landcover", presented at the Biodiversity Forum, Whitehorse, YT, Canada, 2 March.

Stralberg, D., Berteaux, D., Drever, M.C., Naujokaitis-Lewis, I., Schmiegelow, F.K.A. and Tremblay, J.A. (2019), "Conservation Planning for Boreal Birds in a Changing Climate: A Framework for Action", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Stralberg, D., Barker, N.K.S., Bayne, E.M., Berteaux, D., Camfield, A.F., Carlson, M., Cumming, S.G., et al. (2019), "Conservation planning for boreal birds in a changing climate", Talk presented at the Annual Partners in Flight Science Meeting, Ottawa, ON, Canada, 9 July.

Stralberg, D., Wang, X., Parisien, M.-A., Robinne, F.-N., Mahon, C.L., Sólymos, P., Nielsen, S.E., et al. (2019), "Evaluating wildfire-mediated vegetation changes and climate-change refugia potential across Alberta boreal forests", Talk presented at the ABMI Information Forum, Edmonton, AB, Canada, 29 January.

Stralberg, D., Haché, S., Van Wilgenburg, S., Toms, J.D., Sólymos, P., Cumming, S.G., Bayne, E.M., et al. (2019), "Signals of breeding and wintering climate and forest change in boreal bird population fluctuations", Talk presented at the Annual Partners in Flight Science Meeting, Ottawa, ON, Canada, 18 July.

Stralberg, D., Sólymos, P., Matsuoka, S.M., Barker, N.K.S., Denés, F., Fontaine, T., Haché, S., et al. (2019), "Towards a new generalized national model framework for the North American boreal region", Talk presented at the Annual Partners in Flight Science Meeting, Ottawa, ON, Canada, 16 July.

Toms, J.D. and Carpenter, T.M. (2019), "Community-level Response to Cumulative Effects of Forestry and Energy Development", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Toms, J.D. and Carpenter, T.M. (2019), "Assessing the cumulative impacts of resource development on landbirds in northern Alberta", Talk presented at the Society of Canadian Ornithologists' Meeting, Quebec City, QC.

Toms, J.D., Sólymos, P., Stralberg, D., Barker, N.K.S., Micheletti, T., Leston, L., Haché, S., et al. (2019), "Conservation of Boreal Birds: Status, Trends, and Data Gaps", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Tremblay, J.A., Cadieux, P., Boulanger, Y., Cyr, D., Taylor, A.R., Price, D.T., Sólymos, P., et al. (2019), "Adverse Effects of Climate Change on Boreal Bird Communities Accentuated by Natural and Anthropogenic Disturbances", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

Tremblay, J.A., Cadieux, P., Boulanger, Y., Cyr, D., Taylor, A.R. and Price, D.T. (2019), "A Synthesis of Climate Change Impacts on Boreal Bird Communities in Managed Landscapes of Canada", Talk presented at the American Ornithological Society Annual Meeting, Anchorage, AK, USA, 26 June.

2020 – January - March

Stralberg, D. (2020), "Data and metrics for vulnerability assessment and conservation planning in a changing climate", Talk presented at the NWT Protected Areas and Climate Change, 25 March.

Toms, J.D. and Docherty, T. (2020), "Pan-Canadian Approach to Species at Risk Conservation - Forest Sector Meeting", Workshop, 9 March.

Webinars and Workshops

Webinars and workshops organized or co-organized by BAM, hosted between January 2019 and March 2020.

2019 – January - December

Barker, N.K.S. and Bayne, E.M. (2019), "Open Data Workshop for Avian Data in Canada", Workshop, Edmonton, AB, Canada, 24-25 April.

"NSERC CRD Birds and Forestry Meeting". (2019), Workshop, University of Alberta, Edmonton, AB, Canada, 25 January, Organized by Erin Bayne.

2020 – January - March

No BAM webinars & workshops were organized or co-organized in January through March 2020.

Project Management

The Structure of the BAM Project

The BAM Team

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

Project Team

Steering Committee

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

Project Staff: BAM wishes good luck to Nicole Barker!

- Hana Ambury, Research Assistant, part-time. ambury@ualberta.ca
- Teegan Docherty, Coordinating Scientist, full-time. tdochert@ualberta.ca
- Trish Fontaine, Database Manager, part-time, trish.fontaine@ualberta.ca
- Mélina Houle, Database Manager, part-time. houle.melina@gmail.com
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- Diana Stralberg, Project Ecologist, part-time. diana.stralberg@ualberta.ca

Post-doctoral Fellows: BAM wishes good luck to Francisco Dénes!

- Andy Crosby. crosby@ualberta.ca
- Lionel Leston. leston@ualberta.ca
- Tati Micheletti. tati.micheletti@triade.org.br

Students: BAM wishes good luck to Tara Stehelin!

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Contributing Scientists

- Jeff Ball, Head of Non-game Migratory Bird Programs, Prairie CWS. jeff.ball@canada.ca
- Samuel Haché, Wildlife Biologist, Northern CWS. samuel.hache@canada.ca
- C. Lisa Mahon, Wildlife Biologist, Northern CWS. lisa.mahon@canada.ca
- Steve Matsuoka, Research Biologist, United States Geological Survey. smatsuoka@usgs.gov
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- Junior Tremblay, Research Scientist, ECCC S&T-Wildlife Research Division. junior.tremblay@canada.ca
- Steve Van Wilgenburg, Wildlife Biologist, Prairie CWS. steven.vanwilgenburg@canada.ca

Technical Committee

BAM's Technical Committee, composed of established avian researchers across boreal North America, serves to provide independent scientific advice to BAM.

- Marcel Darveau, Ducks Unlimited Canada / Université Laval
- André Desrochers, Université Laval
- Pierre Drapeau, Université du Québec à Montréal
- Charles Francis, CWS
- Colleen Handel, United States Geological Survey
- Keith Hobson, University of Western Ontario
- Craig Machtans, CWS Northern
- Julienne Morissette, Northern Forestry Centre
- Gerald Niemi, University of Minnesota – Duluth
- Rob Rempel, Ontario Ministry of Natural Resources & Forestry / Lakehead University
- Stuart Slattery, Ducks Unlimited Canada
- Phil Taylor, Acadia University
- Lisa Venier, Great Lakes Forestry Centre
- Pierre Vernier, University of British Columbia
- Marc-André Villard, Université du Québec à Rimouski

Support Team

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

- Connie Downes, Marie-Anne Hudson, and Kate Campbell (CWS): BBS data support
- Nash Goonewardena, Ian Paine, Michael Abley, Christie Nohos, Andrea Gougeon, Marina Offengenden, Marilyn Johnson (University of Alberta): Technical and administrative support
- Paul Morrill, Genevieve Beaulieu, Brad Grier: website design, programming, and support
- Denis Lepage and Catherine Jardine (Bird Studies Canada): Atlas data support
- Brendan Ward (Conservation Biology Institute): Data Basin support
- Laura Garland (University of Alberta): Data management support

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. If you notice any errors, please inform the Coordinating Scientist (tdochert@ualberta.ca) as soon as possible so they can be corrected.

Funding Partners

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

Founding organizations and funders

Environment & Climate Change Canada   University of Alberta   BEACONs

Financial support to BAM in 2019-2020

- Alberta Forest Products Association (AFPA) (West Fraser Timber Co. Ltd)
- Alberta Pacific Forest Industries Inc. (Al-Pac)
- Boreal Ecosystems Analysis for Conservation Networks (BEACONs)
- Canadian Forest Products Ltd. (Canfor)
- Council of Forest Industries (COFI)
- Environment & Climate Change Canada (ECCC), Canadian Wildlife Service
- Environment & Climate Change Canada, Science and Technology Division
- Mitacs Accelerate Program
- Natural Sciences and Engineering Research Council of Canada (NSERC)
- Oil Sands Monitoring (OSM) Program
- Ouranos Consortium
- Sustainable Forestry Initiative (SFI)
- Université Laval
- University of Alberta
- Wilburforce Foundation

Financial support for CASFRI

- ECCC
- GEOIDE Network
- Canada Foundation for Innovation
- NSERC Discovery Grant
- NRCan
- Sustainable Forest Management Network
- Nature Conservancy

Data Partners

The following institutions and individuals have provided or facilitated provision of bird and environmental data to the Boreal Avian Modelling Project. If you notice a name is missing, please inform the Coordinating Scientist (tdochert@ualberta.ca) so we can correct the omission.

Avian Data

Institutions: Acadia University; Alaska Bird Observatory; Alaska Natural Heritage Program; Alaska Science Center; Alberta Biodiversity Monitoring Institute; Alberta Pacific Forest Industries Inc.; AMEC Earth & Environmental; AREVA Resources Canada Inc.; Avian Knowledge Network; AXYS Environmental Consulting Ltd.; BC Hydro; Bighorn Wildlife Technologies Ltd.; Bird Studies Canada; Canadian Natural Resources Ltd.; Canadian Forest Products Ltd.; Daishowa Marubeni International Ltd; Devon Canada; Environment and Climate Change Canada; Fish & Wildlife Compensation Program; Golder Associates Ltd.; Government of British Columbia – Ministry of Environment & Climate Change Strategy; Government of Yukon; Hinton Wood Products; Hydro-Québec Équipement; Interfor; 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; Ontario Ministry of Natural Resources; OPTI Canada Inc.; PanCanadian Petroleum Limited; Parks Canada (Mountain National Parks Avian Monitoring Database); Petro Canada; Pope & Talbot Ltd.; Principal Wildlife Resource Consulting; Regroupement Québec Oiseaux; Rio Alto Resources International Inc.; Saskatchewan Environment; Shell Canada Ltd.; STRIX Ecological Consulting; 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.

Individuals: K. Aitken, A. Ajmi, B. Andres, J. Ball, E. Bayne, P. Belagus, S. Bennett, R. Berger, M. Betts, J. Bielech, A. Bismanis, R. Brown, M. Cadman, D. Collister, M. Cranny, G. Crozier, S. Cumming, L. Darling, M. Darveau, C. De La Mare, A. Desrochers, T. Diamond, M. Donnelly, C. Downs, P. Drapeau, M. Drever, C. Duane, B. Dube, D. Dye, R. Eccles, P. Farrington, R. Fernandes, M. Flamme, D. Fortin, K. Foster, M. Gill, T. Gotthardt, A. Grinde, N. Guldager, R. Hall, C. Handel, S. Hannon, B. Harrison, C. Harwood, J. Herbers, K. Hobson, M-A. Hudson, L. Imbeau, P. Johnstone, V. Keenan, K. Koch, M. Laker, S. Lapointe, R. Latifovic, R. Lauzon, M. Leblanc, L. Ledrew, J. Lemaitre, D. Lepage, K. Lewis, B. MacCallum, P. MacDonell, C. Machtans, K. Martin, S. Mason, C. McIntyre, M. McGovern, D. McKenney, L. Morgantini, J. Morton, G. Niemi, T. Nudds, P. Papadol, M. Phinney, D. Phoenix, D. Pinaud, D. Player, D. Price, R. Rempel, A. Rosaasen, S. Running, R. Russell, C. Savignac, J. Schieck, F. Schmiegelow, D. Shaw, P. Sinclair, A. Smith, S. Song, K. Sowl, C. Spytz, D. Swanson, S. Swanson, P. Taylor, S. Van Wilgenburg, P. Vernier, M-A. Villard, D. Whitaker, T. Wild, J. Witiw, S. Wyshynski, M. Yaremko.

Breeding Bird Atlas: We thank the Breeding Bird Atlas Projects of British Columbia, Manitoba, Maritimes, Ontario, and Québec for supplying data, the thousands of volunteers involved in the data collection, the regional coordinators, as well as the various atlas project partners: BC Field Ornithologists, BC Nature, Biodiversity Centre for Wildlife Studies, Bird Studies Canada, British Columbia Ministry of Environment, Federation of Ontario Naturalists, Louisiana Pacific, Manitoba Conservation, Nature Manitoba, The Manitoba Museum, Manitoba Hydro, The Nature Conservancy of Canada, Natural History Society of Prince Edward Island, Nature NB, Nova Scotia Bird Society, Nova Scotia Department of Natural Resources, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, Pacific Wildlife Foundation, Prince Edward Island Department of Natural Resources, Regroupement Québec Oiseaux.

Breeding Bird Survey: We would like to also thank the hundreds of skilled volunteers in Canada and the US who have participated in the BBS over the years and those who have served as State, Provincial, or Territorial coordinators for the BBS.

Biophysical Data

Institutions: BirdLife International & NatureServe; Global Land Cover Facility; Natural Resources Canada - Canada Centre for Remote Sensing & Canadian Forest Service; Numerical Terradynamic Simulation Group at the University of Montana.

Common Attribute Schema for Forest Resource Inventory (CASFRI): Alberta Pacific Forest Industries Inc.; Canadian Forest Products Ltd.; Forsite Consultants, Ltd.; 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.

Government of Alberta - Environment and Parks (formerly Environment and Sustainable Resource Development); Government of British Columbia - Forests, Lands & Natural Resource Operations; Government of Canada - Department of National Defence, Parks Canada Agency, Prince Albert National Park, Park, Wood Buffalo National Park; Government of Manitoba - Conservation and Water Stewardship; Government of New Brunswick - Natural Resources; Government of Newfoundland & Labrador - Natural Resources; Government of Nova Scotia - Natural Resources; Government of Ontario - Natural Resources; Government of PEI - Communities, Land and Environment (formerly Environment, Energy and Forestry); Gouvernement du Québec, Ministère de la Faune, de la Flore et des Parcs; Government of Saskatchewan - Environment; Government of the Northwest Territories - Environment and Natural Resources; Yukon Government - Energy, Mines and Resources.

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Boreal Avian Modelling Project

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