Boreal Avian Modelling Project

Predictive tools for the monitoring and assessment of boreal birds in Canada, 2009-2012

2009-10 Annual Report

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EXECUTIVE SUMMARY

The Boreal Avian Modelling (BAM) Project works to improve understanding of the influence of environmental factors and human activities on boreal bird populations. The intended areas of application of this collaborative project include conservation planning, monitoring, assessment of population status, environmental assessment, and protected areas management.

BAM uses a model-based approach to address knowledge gaps about boreal birds, drawing on existing datasets contributed by avian researchers from across Canada. These data come from more than 40 different studies that were designed to address a range of questions and that used many subtly different protocols. A major milestone and contribution of the BAM Project has been to assemble and standardize all these data sources into a comprehensive spatially-referenced dataset describing birds and their habitats across the boreal region of Canada.

The key accomplishments from 2009-2010 include:

- Inclusion of Breeding Bird Survey data and other periodic updates into the project database, to increase the sample size and to fill geographic gaps.
- Extensive analyses to determine the best approaches to derive accurate estimates of boreal bird density, and development of new statistical approaches to density estimation to address detection error and evaluation of what life history characteristics influence detection error.
- As an addition to our library of biophysical data, compilation and standardization of digital forest resource inventory data from across the country. The dataset was synthesized from 20 corporate, provincial, and territorial and federal inventories. It provides detailed stand-level information not yet obtainable from satellites.
- Identification of key biophysical factors influencing species distributions based on the updated avian data.

- Launch of a new, bilingual project website to present the project results to partners and the public.

Areas of ongoing work for 2010-2011 include:

- Further expansion of the project databases through the addition of avian and habitat data;
- Addressing additional questions about density estimates, detectability, and range delineation;
- Providing a comprehensive database of density estimates for different spatial stratifications;
- Developing habitat-based predictive models sensitive to land use practices such as forestry and road development;
- Evaluating scenarios to assess the impact of climate change and development pressures on boreal bird ecology;
- Developing new applied research projects in collaboration with members of the Technical Committee to make use of the potential of the national database;
- Communicating knowledge about boreal bird ecology to inform bird conservation and management actions through scientific publications, increased interactions with Technical Committee members, and additions to the website.

The success of the Boreal Avian Modelling Project to date is built on strong partnerships with organizations and individuals providing funding, data and collaboration. We extend our gratitude to our data partners and members of the Technical Committee for their vital support and involvement, and we look forward to future opportunities for collaboration.

PROJECT DESCRIPTION AND OBJECTIVES

Across Canada's boreal forest, management efforts are hampered by a lack of information on birds and their habitats. The boreal region is breeding habitat for the major share of North America's migratory landbirds, but is also under increasing pressure from industrial development and climate change. We have little coherent knowledge about the density, distribution, and habitat of species and communities, and little ability to effectively predict the effect of threats to populations much less the efficacy of management actions directed at mitigating any impacts. The Boreal Avian Modelling Project (BAM) was initiated to address these knowledge gaps using a model-based approach, building on the assembly of existing datasets from avian researchers across Canada. Our overall goal is to support proactive conservation of bird populations and habitats in this immense and globally significant area.

The **project's objectives** are to:

- Assemble and maintain the most complete and current repository of spatially referenced data for boreal birds and their habitats.
- Apply and refine state-of-the art analytical methods to:
    - Provide reliable information on boreal bird habitat associations
    - Describe species distributions
    - Refine and forecast population status and trends
    - Generate testable hypotheses about key mechanisms driving these patterns (e.g., climate, landuse, latitude).
- Improve the standardization and rigour of avian data collection by providing standards for bird sampling protocols and database structure.
- Provide a broader conservation legacy for avian data collected in Canada's boreal forest.
- Build support from academia, industry, governments, non-governmental organizations, and other interested parties for further development and testing of boreal bird population models as well as their proactive application to the management of boreal forests and biodiversity conversation.
- Encourage public awareness and support education by providing ready access to the most current information on the status of boreal bird populations.

Highlights of accomplishments in 2009-10

We achieved the following **key results** during the 2009-10 fiscal year:

1) Incorporated avian data from new areas to address geographic gaps in coverage, including internal efforts to enhance Breeding Bird Survey data through spatial referencing of individual stops along surveyed routes.
2) Developed and implemented a novel automated system to document the avian and biophysical database.

3) Completed extensive analyses to determine the best approach to obtain the most accurate estimates of boreal bird density possible.

4) Developed new statistical approaches to density estimation that account for detection error.

5) Completed the assembly of a national coverage of Forest Resource Inventory (FRI) data across boreal forests of Canada through development and application of a Common Attribute Schema (CAS).

6) Completed enhancements to scenario evaluation platforms to facilitate future BAM analyses.

7) Initiated expansion of our taxonomic coverage to model waterfowl distributions at regional and national extents.

8) Launched a completed revised, bilingual project website.

Progress on proposed major activities, 2009-12

1. Data compilation (Figure 1)

(i) Updates to national avian dataset

This year we obtained new datasets comprising over 400 new data sampling points from Alberta and Québec. We also received additional, more recent data from projects already in the database (updating 292 of the sampling stations with 4 years of data).

(ii) New national datasets

We are working with Newfoundland and Labrador Hydro to include 42 sampling stations from the Lower Churchill Hydroelectric Generation Project as well as with Areva Resources to include data from projects in northern Saskatchewan. The BAM website has generated interest from other organizations that may have data to contribute in areas where we currently have gaps.

(iii) Incorporation of Bird Breeding Survey (BBS) data

In an effort to address geographic areas that remain poorly sampled (e.g., Labrador, northern Québec, Yukon), we have been working with the Breeding Bird Survey office to integrate BBS data into the database. The 50-stop data from 1968–1996 for Canada have only been updated for Alberta, Saskatchewan, and Manitoba from the original 10-stop summary totals; data after 1997 conform to the 50-stop methodology. The GIS shapefiles of the routes have been updated for Alberta, Saskatchewan, Manitoba, and Ontario by the CWS office. To standardize the BBS routes with the BAM database, we require the spatial location of each of the 50 stops along the BBS route. For a fraction of the routes, the observers have taken GPS points at each of the 50 stops; the BBS office is working to increase this.

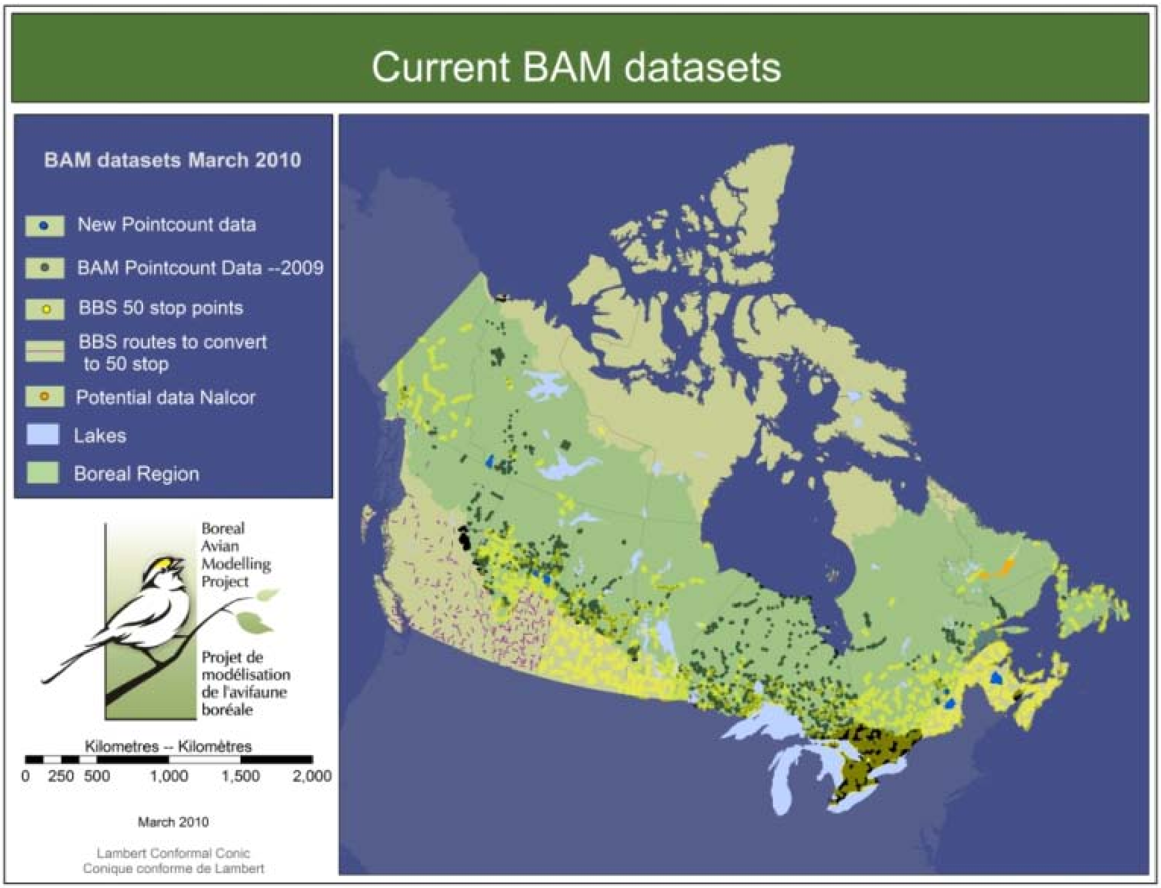

Figure 1. Scope of the BAM dataset including the existing points, new projects, potential projects, and the Breeding Bird Survey data for Canada.

To obtain the most accurate locations, BAM is first using the updated GIS route files from CWS; where those have not yet been updated, BAM is using the older route files provided by Patuxent's BBS website. Due to the age of some files and changes in technology, many of the routes do not line up well with the road layer; thus, we are checking the accuracy of the individual routes to a National Road Network layer downloaded from Geobase. Once the route has been checked and snapped to the road layer, the 50 stops are added at equidistant intervals. Routes that already have either the 10 stop points or 50 stop points from the observer's GPS those points are checked for alignment with the road layer. For provinces without updated GIS route files, the BBS office has provided us with topographic maps of the routes so we are able to either create the routes or update the older route layer. Though placing the 50-stops points ourselves is the best solution for now, we will ideally replace those stops with more accurate GPS data from the observers. To date, we have checked the routes and created the 50-stop points for the boreal of Alberta, all of Manitoba, Saskatchewan, Ontario, Quebec, Yukon, Northwest Territories, Newfoundland and Labrador, and the Maritimes. We will be able to join the spatial data points to the BBS data for each of the locations for data after 1997, and for data prior to 1997 for the provinces with the updated 50-stop data files.

(iv) Updated biophysical data layers

We have acquired a complete coverage of 1:50,000 hydrological maps from GeoGratis. These high-resolution digital maps of streams and small waterbodies are crucial for the waterfowl habitat modelling initiative discussed under Section 7 below. The datasets are very large and, accordingly, Cumming's lab has invested effort to load them into a specialized geo-database designed to support analysis of such data.

(v) Updated statistical summary describing the characteristics of both the avian and biophysical databases (e.g., variation in sampling effort among bird surveys)
We have developed a novel automated system to document the avian and biophysical database. The inputs are the Access database tables storing the bird observations, and the files storing the climate and other spatial covariates. Specialized software integrates database queries and statistical analysis and table generation using R with report generation using the LaTeX document processing system. The advantage of this programmatic approach is that updated reports can be easily generated as new data are added, provided the structure of the Access database does not change.

Three separate reports have been created. The first summarizes the contents of the avian database in various ways and produces maps representing the spatial distribution of sampling effort among years and by sampling methodology. The second report describes the correlation structure of the climatic covariates. The third report analyses compare distributions of biophysical covariates within the boreal region and the areas actually sampled by the BAM avian database. This provides insight into the adequacy of our spatial sampling and the reliability of inferences as to the effect of climatic covariates. The third report is so far limited to climate variables. The remote-sensed data layers (e.g., MODIS landcover, leaf area, NDVI) are too large to be manipulated within R on a 32 bit machine.

The three reports total more than 1 gigabyte in size, and cannot be included here. The methodology and sample results were presented to the BAM Technical Committee in a series of webinars during 2009-10. Two webinar presentations are attached here as Appendices 1 and 2. The full reports will be made available for downloading on the BAM website after review by the Technical Committee; the projected date of publication is June 30, 2010.

A shorter report (or background paper) on the project has been prepared (Appendix 3) and has now been widely circulated.

2. Species assessment and monitoring

An important goal of BAM is to provide the most accurate estimates of boreal bird density possible. To do this has required testing various statistical approaches and developing new techniques to deal with the variation in methodologies occurring in the BAM dataset. In 2009/10, these developments comprised:

(i) Evaluation of multiple visit methodology
We extensively tested the multiple visit methodology proposed by the United States Geological Survey (USGS) with respect to whether it would provide robust density estimates; we have concluded it will not. This method requires A) that the area over which birds are sampled is known accurately and B) that the birds counted are always present during multiple visits (closed population assumption). Bayne et al. recently submitted a theoretical paper (Appendix 4) that demonstrates these assumptions are rarely met when using point count methodologies and cannot be recommended for density estimation; for observed territory sizes and expected densities of birds that occur in the boreal forest, within-territory movement is sufficiently extensive that violation of the closure assumption is almost guaranteed. Estimates of density based on point counts from multiple visits using

occupancy or N-mixture models can significantly overestimate density (often 100's of percent overestimation).

(ii) Estimating density

Estimating density requires knowledge about A) the area over which birds are heard and B) the number of birds that are present but not detected during any given visit (known as detection error). Three approaches have either been tested or developed in partnership with BAM. To date, BAM has used distance-based sampling estimators to calculate the Effective Detection Radius (EDR). EDR uses information about how far birds were from the observer when detected. Based on distance sampling theory, this approach accounts for both the area sampled and detection error. Using EDR values as the denominator in density calculations (i.e., area sampled), new estimates of density have been created for boreal birds across Canada and these are the values currently reported on our website.

(iii) Addressing flaws of the EDR approach

Two potential flaws of the EDR approach have been identified. 1) EDR changes as a function of time of day, habitat, and date. In 2009, we explored the role of habitat and found relatively little change for common species in the EDR values based on habitat. However, rarer species are more variable, which we believe is a function of fewer detections (i.e., less statistical certainty) rather than a fundamental aspect of rare species biology. 2) We must assume that all point count observers have an equal and accurate ability to estimate distance to birds; there is definitely uncertainty in the validity of this assumption. We have conducted bootstrapping exercises to determine if removal of single projects (i.e., Erin Bayne's data from Alberta-Pacific Forest Industries Inc. (AlPac)) or blocks of data change EDR values substantially. In general, they do not. However, individual projects have widely differing EDR values, which could suggest two things: A) EDR values vary in different parts of the country and/or B) our assumption about equal and accurate ability to estimate distance is false. The fact that our bootstrapping approach (developed in collaboration with Steve Van Wilgenburg at Environment Canada, Saskatoon) converges on our original estimate gives us confidence that the mean value is a reasonable estimator (Figure 2). The minimum EDR estimated by bootstrap for the Ovenbird was 60 m, the average was 83 m (which is what the current estimate is), and the maximum was 145 m (which is still smaller than the maximum detection distance used by Partners in Flight (PIF). The 25th-75th percentile range is 78 to 84 m.

We do not believe that EDR should be calculated for each project or area within the BAM dataset; the high variation among projects indicates the assumption of equal and accurate ability to estimate distance may be violated. We are fairly confident that the relative ranking of species rarity vs. commonness with EDR is more robust than for naïve data. The exact accuracy of density estimates by species and resulting population estimates still require more investigation. However, our current comparisons of EDR-based density estimates to spot-mapping data for a limited number of species indicates that EDR estimates are far more accurate for boreal birds than current PIF approaches based on the maximum distance sampled. Importantly, EDR and PIF approaches are general correlated with one another in terms of maximum detection distance and EDR. This implies that ranking species commonness will be similar, but the absolute values of density will vary considerably among the approaches (Figure 3). This work was done in collaboration with Peter Blancher.

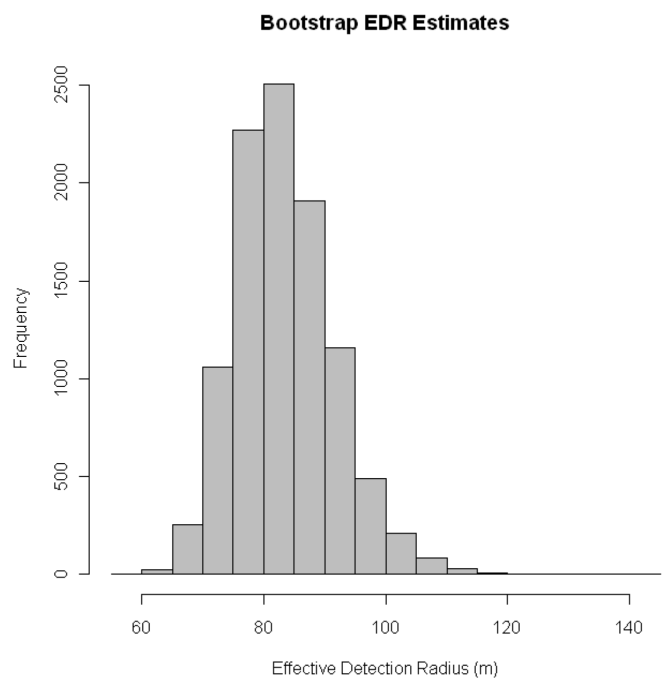

Figure 2. Bootstrap estimates of EDR based on removing subsets of the original data, using the Ovenbird as an example species.

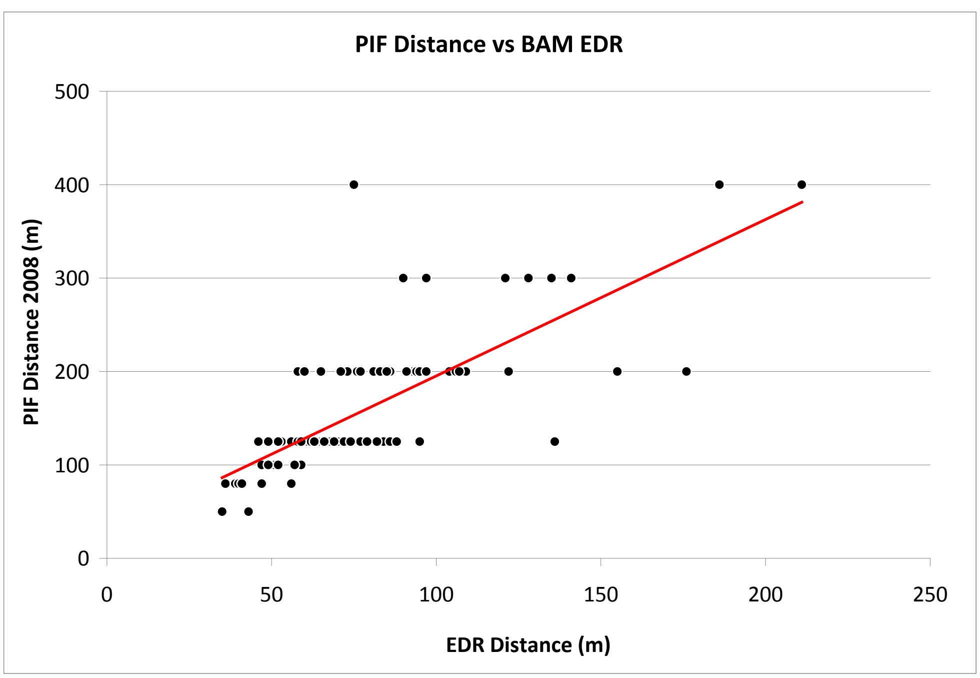

Figure 3. Correlation between EDR and maximum detection distance.

(iv) Validation and extension of new density estimates

Given this uncertainty, we are working to test our estimates against the gold-standard of spot-mapping. This work is still in its early stages. Concurrently, we have been working with a biostatistician, Dr. Subhash Lele, to develop an entirely new statistical approach to estimating density that relies on fixed distance sampling or potentially maximum distance over which a species is detected (as used by PIF) to account for detection error. Our approach uses a single-visit survey and adjusts for detection error (birds present but not heard) using occurrence data (species detected vs. not detected). A paper on this initiative is under review in Methods in Ecology and Evolution (Appendix 5).

We are currently working on a manuscript for the same journal that extends this statistical theory to count data. In our approach, we count the number of birds heard in a defined area. Some birds that are present are not counted due to individual detection error. Through our approach, we can estimate this detection error and adjust the resulting count accordingly to get a more accurate count. We recently applied this estimate to Breeding Bird Survey data that uses an unlimited radius area for sampling; this approach estimated a mean density of male Ovenbirds of 0.91 (95% CI: 0.85 – 0.97) males per hectare in mature aspen forest where the entire sampling area was forested. During Erin Bayne's Ph.D. thesis, which was done in the same area, he captured all Ovenbirds on 6-25 hectare plots, mapped the entire territory of each individual, and determined a density of 0.99 males per hectare (95% CI: 0.85-1.12). Unlike multiple visit methods, the key advance of our approach with respect to detection error is that we do not require the assumption of population closure, which is far more realistic for territorial birds. We are currently working on a simulation that uses detailed movement and singing behaviour of Ovenbirds to test the degree of bias generated by both multiple visits and our single visit approach.

(v) Correlations between detection error and EDR

We are currently determining the correlation between the concepts of multiple-visit detection error, single-visit detection error, and EDR. We have estimated detection error for the 40 most common species in the BAM dataset for which multiple visit surveys in a season have been done. For those same species we have measured EDR. Figure 4 shows the relationship between detection error as measured by occupancy estimation and n-mixture models that use multiple visits against EDR. These plots also show the relationship between detection error as estimated by n-mixtures versus occupancy models. Each data point in Figure 4 represents a species of bird. These figures demonstrate no correlation between the concept of EDR and detection error as measured by multiple-visit surveys. Future work will consider whether or not detection error as estimated by single-visits is correlated with either EDR or multiple visits. Ultimately, we are going to use this approach to determine the life-history characteristics of each species to evaluate what makes some species more or less detectable based on these different metrics. This will aid in understanding how to design point count surveys for specific types of species of concern.

(vi) Further testing of the single-visit survey method

Our current feeling is that the EDR approach is most in line with the BAM objective of estimating density and making relative rankings between species robust to differences in the distance over which birds can be heard. The single-visit survey method must be tested further as it requires fewer assumptions than distance sampling and as such would be easier to implement in the field on a broad scale. This will be tested in the next year using simulations based on movement and singing data from radio-marked Ovenbirds, as part of other ongoing BAM partnerships.

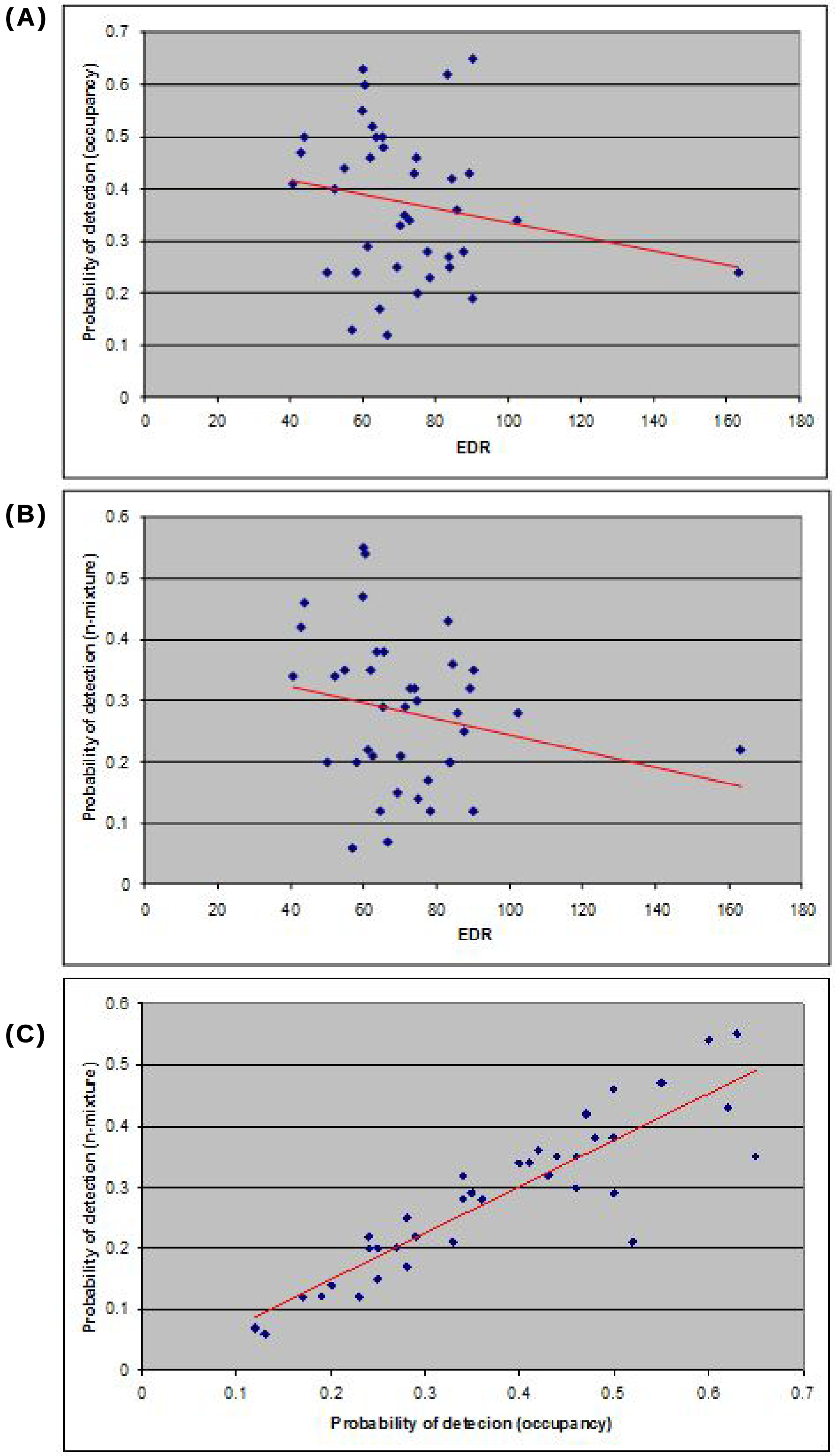

Figure 4. Scatterplots illustrating relationships between A) EDR and probability of detection based on occupancy modelling; B) EDR and probability of detection based on n-mixture modelling; and C) probability of detection based on occupancy modelling versus n-mixture modelling.

3. Selecting and developing avian habitat data layers

(i) Update on FRI/CAS assembly (Appendix 6)

The assembly of the national coverage of Forest Resource Inventory (FRI) data described in the 2008-9 report has been completed with the addition of data from several large national parks, Ontario, and some recently produced data from a new Forest Management Area in Manitoba. Year-of-photography data have also been assembled for the entire dataset from disparate sources. This is crucial ancillary information for habitat modelling as it will allow us to estimate the habitat conditions at the time of avian survey. All of the constituent datasets have been exported from their highly variable native GIS formats into standardized formats for further processing.

The Common Attribute Scheme (CAS) developed last year has been implemented as a number of specialized software tools to translate each FRI type into the CAS standard. This step has been completed in prototype for each source data set (there are roughly 18 of these). This experience with implementation has led to substantial revisions and corrections to the CAS standard, which will be reflected in the final report to be published on the BAM website.

The process of data export and CAS-translation is now being redeveloped in a single modular software system. This was necessary to incorporate design changes based on experience developed in course of the project, to unify the translation protocols developed by the four programmers who have worked on different FRI datasets, and to facilitate future additions and updates. This task was to have been completed by March 31, 2010 but is now scheduled for completion by the end of May 2010. FRI data tables for statistical modelling will be then easily generated for use by BAM.

Limitations in linking remote-sensed land cover data to important habitat attributes for birds can be substantially mitigated by the use of FRI data, hence an important impetus to develop the CAS. We are now able to represent, for available FRI data, all the disparate ecologically important attributes of the component data sets without loss of information. Nevertheless, this represents a static view of the forest at the time of inventory, which may not correspond with the time frame of avian sampling. We have initiated a cross-Canada assessment of available inventory updates, schedules of new inventories, and existence of historic digital data, and are developing update procedures to keep this database current. Documentation has also been assembled to draft a manuscript for the Forestry Chronicle outlining the CAS and describing the resultant database. This work has been undertaken in collaboration with Timberline Forest Resources.

(ii) Update on S4H collaboration

In 2008-9, we initiated a collaboration with the Canadian Forest Service (CFS) and Space for Habitat (S4H) to evaluate the alternate landcover products available for habitat modelling, including MODIS LCC05, NALC 2000, Landsat based EOSD, and FRI data. The ground truth data were vegetation relevé data used for ecosystem mapping. Ground truth data were available for a pilot region in Alberta and BC, courtesy of the Canadian Forest Service. A subset of the FRI data was prioritized for this analysis. More than six person months of specialized GIS analysis and data-cleaning were conducted by S4H staff in the summer of 2009. Preliminary results tend to confirm the superiority of MODIS LCC05 compared to the other satellite based products. Findings were presented at an international conference on remote sensing later in 2009 (Appendix 7). A manuscript is in preparation for the Canadian Journal of Remote Sensing; final analysis and writing rests with S4H. The conference presentation and other interactions have revealed interest within the remote sensing community to further explore the limitations of their existing classified products for habitat modelling applications; we have not yet been able to pursue these opportunities.

During 2010, we hope to expand the analyses using the more complete FRI coverages now available and classified relevé data for larger parts of Canada. However, our preliminary conclusion is that MODIS-based 250 m resolution landcover data is the best current choice for habitat modelling over the boreal region. In the future, we hope to identify new spatial covariates that can improve the thematic precision of both FRI and R/S land-cover data, and yield consistent predictive models of avian abundance from the two data sources.

(iii) GFWC analysis

In addition to addressing habitat composition and structure through the previous two initiatives, we are also interested in the effects of human land use on patterns of distribution and abundance of boreal birds. Understanding these relationships is key to projecting and evaluating potential future scenarios. As with forest resource inventories, there is a need to move beyond static, point-in-time representations of human land-use, and to link the available bird data to temporally consistent landscape conditions, to the extent possible. To this end, we engaged Global Forest Watch Canada to support the development of temporally-matched anthropogenic disturbance layers, and in some cases a time-series of layers (a chronosequence of maps), for key data sets and sites across the boreal forests of Canada. This project was initiated in 2009/10, and will be completed in 2010/11. A component of this work involves categorization of different types of anthropogenic disturbance that can be measured from remotely-sensed imagery (e.g., forest harvest, road, well site) rather than a simple representation of total human disturbance. This will allow us to evaluate the relative influence of different types of disturbance on forest bird species, as a basis for projecting their effects, and also provides a foundation for assessing activity-specific provisions related to incidental take.

4. Habitat associations, impact assessment, and risk characterization

(i) Update on CARTs

Last year, we updated all western models after the inclusion of additional survey data and our newly developed correction factors. In 2009–10, we have completed the National CART analysis and created 80 of the 100 species maps from the results (Figure 5); the last 20 maps are in progress, but due to the fine resolution of some of the data layers are taking longer to process at the national scale. In addition to the analysis and mapping, we have created a database of the tree structure to help in further analysis of the results. These species distribution models were based on Classification and Regression Trees (CART) that help to identify key climatic factors influencing species ranges. They describe the potential niches (“bioclimatic envelopes”) of boreal birds, delineating areas that have suitable habitat given where a species is known to occur based on existing records. CART models work by calculating how a group of explanatory variables is related to a response variable—in our case, how landscape, vegetation, and climate features influence bird abundances. For each bird species, abundance data were split into similar groups of locations (i.e., survey stations) with roughly the same bird abundance, defined by some combination of the environmental factors. The end result of the process is a “regression tree”, whose terminal nodes represent those groupings of locations (Figure 6).

Variables important for describing boreal bird distributions included type of land cover, number of growing degree days above 0°C, leaf area index, and the standard deviation of temperature measures. These results are currently being prepared for publication.

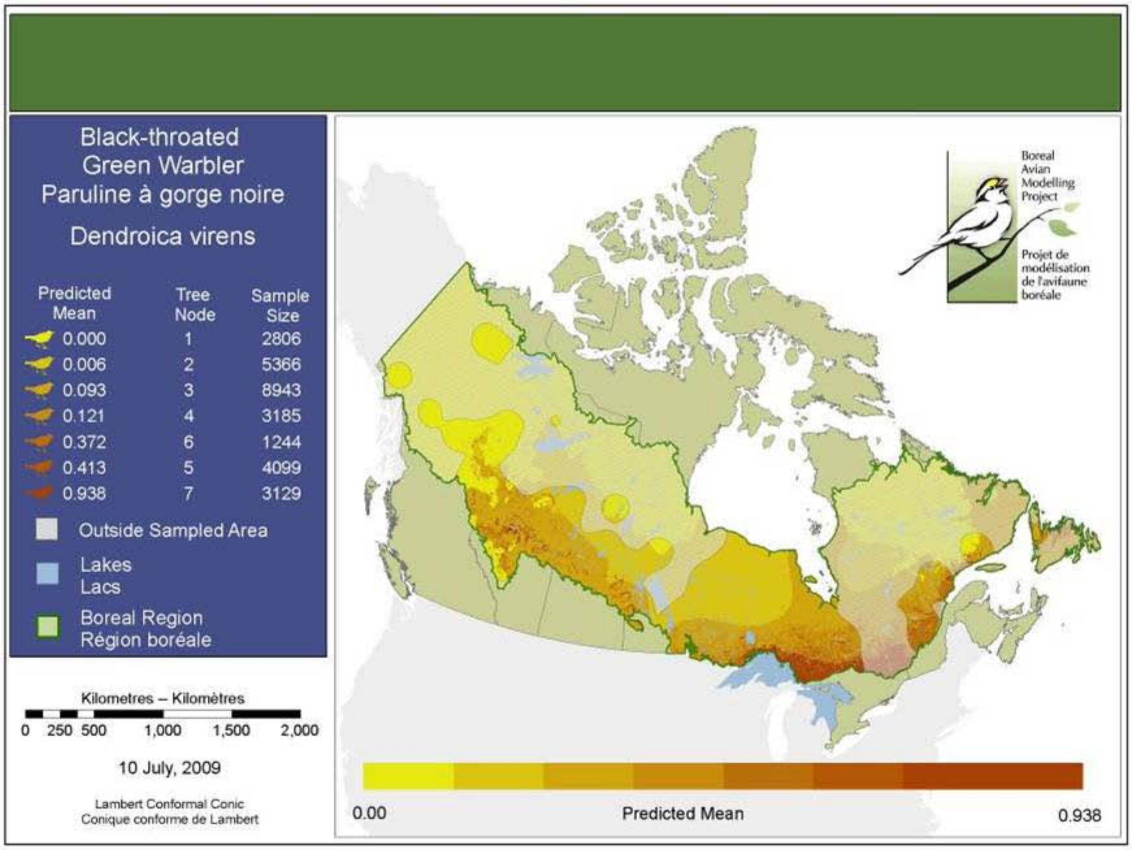

Figure 5. Example of a national CART map for Black-throated Green Warbler, showing the predicted mean number of males at each sampling station.

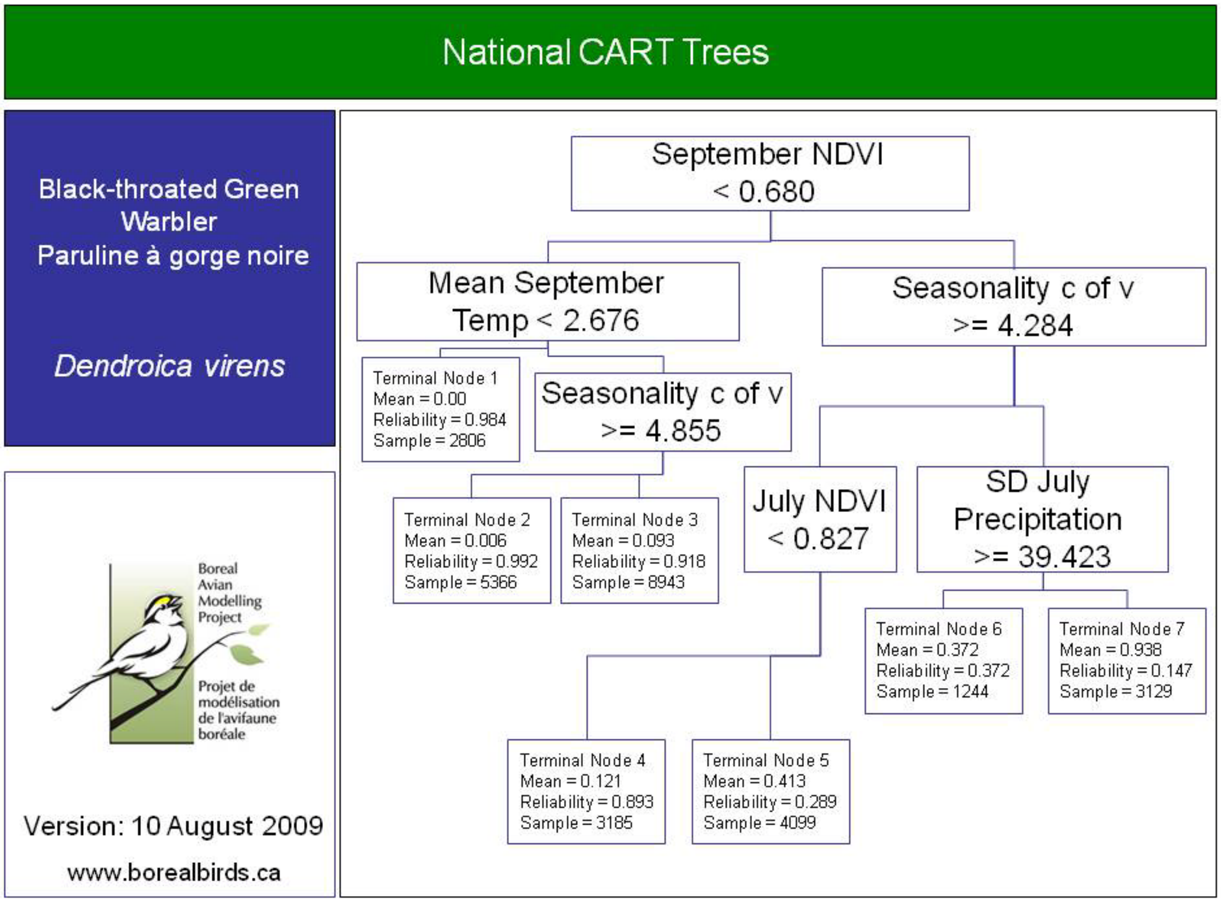

Figure 6. Example of a national CART model for the Black-throated Green Warbler. For each terminal node of the CART regression, results reported are mean abundance per count at stations within the grouping, predicted reliability of the model, and number of sampling stations surveyed.

(ii) Update on assistance to Environment Canada Marxan Analysis

The final element of EC's BCR plans is an assessment of priority areas for conservation of identified priority species. For EC-PNR's BCR 6 (Boreal and Taiga Plains) planning effort, the availability of BAM results allowed the adoption of a data-based modelling approach (Marxan) and generation of a case study that demonstrates how end users can incorporate priority species into regional landuse planning efforts. BAM provided results of habitat association for all landbird species presently on our website, 35 of which were subsequently incorporated by EC into the development of habitat suitability models for use in Marxan optimization analyses. Results will be compared with priority area analyses for all priority species (n=125) and for the subset of landbirds (n=35), but based on available species range data only. These comparisons will demonstrate any added value for priority areas assessment from the availability of the BAM data. Final results will be included in the BCR 6 Plan and serve as a model for future iterations of BCR planning across Canada.

(iii) Scenario evaluation

To conduct scenario modelling to articulate boreal bird response to changes in habitat supply caused by anthropogenic and natural disturbances, including climate change, we must develop or enhance tools with the ability to track such changes across large spatial extents at varying resolution. BAM plans to use two modeling platforms, ALCES and Tardis, for scenario evaluation, as described in the 2009-2012 proposal. In 2009-10, we significantly advanced the development of these platforms as follows.

i. ALCES

Our focus to date has been on developing trajectories for landuse issues in Alberta, but the methods we have developed can be broadly applied elsewhere in Canada and will be the focus of the next two years of work. In 2009/10, we developed the habitat supply scenarios detailed in Appendix 8 using the ALCES modelling platform in collaboration with the Integrated Landscape Management group at the University of Alberta.

ii. Tardis

Tardis is a spatial simulation tool and methodology developed in Cumming's lab and by collaborators at the University of Alberta. Tardis simulates fire regimes, forest management, conservation planning, and wildlife distributions and abundances over very large areas. The spatial units are ≈10,000 ha landscapes, and landscapes are described by lists of polygons initialized from forest resource inventory data. The common ecological data used in the management and ecological sub-models are forest composition and age structure. The landscape grid will be defined by the 300 arc-second grid of interpolated climate data that BAM uses to provide climate covariates for statistical modelling. In climate change applications, predictions of regional and global circulation models can be downscaled to these grids. This provides a direct link between the resolutions of the simulation model and the climate covariates used in the statistical fire models (to be developed by Cumming and collaborators under a separate research project) and species distribution and abundance models, such as developed by BAM. Current versions of Tardis are being used to model tradeoffs between economic development and conservation over the western boreal plains and the potential for forest management to mitigate climate change-induced increases in fire frequency, as well as to evaluate conservation strategies for woodland caribou in the Québec. Simulations over the entire Canadian boreal region as covered by FRI data will become possible over the next years. An example of a Tardis simulation run is illustrated in Figure 7 for the Canada Warbler, based on models constructed from a small subset of the BAM data set.

Our applications of Tardis will be based on Monte-Carlo simulation experiments. We will spatially project present and future fire regimes as functions of climate, landcover, fire suppression, and forest management. The ecological effects of fire and forest management will be expressed spatially in terms of forest age structure and species composition. Indirect indicators of biodiversity will then be derived from national or regional species habitat models now being developed by BAM. The main applications will be to evaluate at regional and national extents the robustness of conservation plans for forest songbirds.
Developments supported in 2009/10 included:

- The modification of Tardis to read the CAS developed by BAM and the BEACONs Project (*Boreal Ecosystems Analysis of Conservation Networks*) to encode Canada's FRI data. This is the step that will enable the simulation of the entire managed forest area in the boreal;
- The design and implementation of modules to input time series of climate surfaces;
- Improvement of the Tardis harvest schedule simulator to dynamically calculate approximate harvest rates for forest tenure areas in response to wildfire; and
- Assembly of forest tenure areas, pulp and saw mill locations and capacities, road network descriptions, and other spatial forest management information needed to initialize the model in all parts of the Canadian boreal.

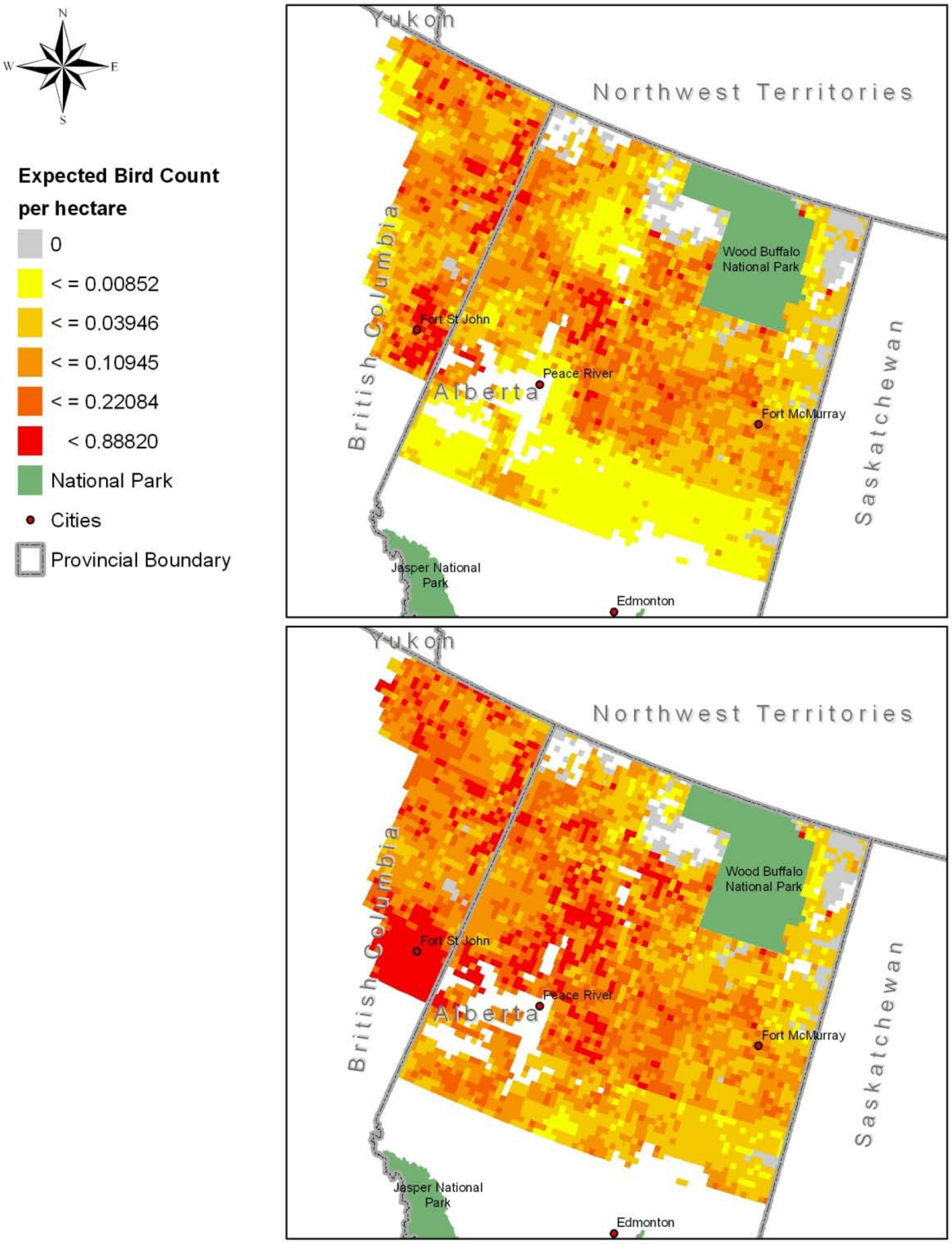

Figure 7. Expected density of Canada Warbler at t=100 yr under both a simulation of current forest management policy in the study region (top panel) and an alternate management system designed to maintain high abundances of old forest habitat (bottom panel).[1]

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[1] From: Hauer G, Cumming SG, Schmiegelow FKA, Adamowicz A, Weber M and Jagodzinski R. (in review) Tradeoffs between forestry resource and conservation values under alternate policy regimes: A spatial analysis of the western Canadian boreal plains. *Ecological Modelling* (submitted 05.02.10)

(iv) Climate change

Bayne and Schmiegelow have a new Ph.D. student starting in September 2010 (Diana Strahlberg). Diana will be linking forest bird population models to climate change model scenarios to evaluate the risks of climate change to forest birds based on changes in phenology and habitat change. Her work is supported by a 4-year Alberta Innovation Fund scholarship.

5. Expansion to other bird groups: Waterfowl

(i) Graduate student projects

Two Phd students are now engaged in research on modelling waterfowl distributions at regional and national extents. Both are working in Cumming's lab at Laval, with Technical Committee member Dr. Marcel Darveau as co-supervisor. The first student, Mr. Christian Roy, began in September 2008. The second, Ms. Nicole Barker, started in January 2010. Both students will be using the US Fish and Wildlife Service (USFWS)/CWS BPOPS dataset as the primary observational data for their modeling. Roy is focusing on cavity nesting ducks (bufflehead and two species of goldeneye) in relation to beaver abundance and forest management. Roy's studies will be regional, in boreal mixedwood regions of western Canada and the claybelt forests of Ontario and Québec. Ms. Barker will pursue national species level models of the remaining species recorded in the BPOPS database. Roy and Barker are each recipients of three year joint NSERC/FQRNT Industrial Innovation Scholarships with Ducks Unlimited Canada as the Industrial Partner.

BPOPS is a long-term dataset of repeated-measured fixed wing aerial surveys. We are collaborating on a systematic review of data quality issues in the BPOPS data set, in an effort to determine which components are subject to spatial error and the magnitude of this error. It appears that no such assessment at the level of so-called segments has been done. Ms. Barker is also conducting a literature review and critical synthesis of all published studies based on the BPOPS data set. A poster presentation of her findings has been accepted at the International Society for Conservation Biology Meeting to be held in Edmonton in July 2010.

(ii) Waterfowl distribution modelling

Cumming and two members of the Technical Committee (Darveau and Imbeau), in collaboration with Tom Nudds (University of Guelph), organized a workshop on waterfowl distribution modelling in association with the 5th North American Duck Symposium, held in August 2010 in Mississauga, Ontario. In attendance were 38 researchers representing EC, USFWS, Ducks Unlimited, and several universities. The proceedings are summarized in a workshop report (Appendix 9). Applications and limitations of the BPOPS database featured prominently in the presentations and discussion. Issues of detection error were raised by many participants. A consensus was reached that a systematic effort to estimate and correct for detection error was necessary. This could involve repeated visits within years, integration of data from more localized, higher-intensity sampling procedures (now being explored by researchers at USFWS), and application of various modern statistical modelling methodologies to model species density using the observed counts data (this would permit testing and further development of the methodologies developed or assessed by Bayne).

Methods for developing this new research effort are still under discussion. Several alternatives were considered. Some proposed a "Boreal Joint Venture", which could be developed under existing funding programs. As an alternative, considerable interest was expressed for the development of a joint proposal to NSERC, perhaps to the Strategic Project Grants program. Cumming, Darveau, Imbeau, and Nudds will be pursuing this possibility over the next year, with the view to submit a full proposal in April 2011.

PARTNERSHIPS

BAM is partnered on many levels—through our data contributors, our Technical Committee and its members, our funders, and through additional research collaborations. A number of the latter partnerships have been described in previous sections (e.g., Space for Habitat, the Breeding Bird Survey). Here we highlight our longstanding partnership with the BEACONs Project.

BEACONs conducts leading-edge research on proactive conservation planning in boreal regions of Canada, and is recognized internationally for advancing concepts and methods appropriate for large, dynamic ecosystems. An emphasis of the work to date has been the identification of ecological benchmarks, in particular, system-level benchmarks. System-level benchmarks are ecologically intact areas that are representative of natural environmental variation, including vegetation communities and productivity gradients, and are sufficiently large to maintain key ecological processes and support natural ecosystem dynamics. Protocols and tools developed by BEACONs for identification of potential ecological benchmarks across the boreal, based on various biophysical criteria, are now well-established. Through partnership with BAM and other groups, BEACONs is now extending this framework to incorporate empirical, habitat-based species models. This will facilitate further assessment of the effectiveness of existing protected areas and candidate benchmark areas, given present and projected conditions, using predicted habitat distributions and associated population condition as indicators. A critical component of achieving this is to ensure consistency in the spatial data used by the various models. Our joint support for development of the CAS and associated compilation of FRI data has been a key initiative in this regard.

The BAM project would not exist without the generous contributions of its funding and data partners.

Funding partners

We are grateful to the following organisations for funding:

Founding organisations and funders

Environment Canada
University of Alberta

Additional financial supporters

United States Fish and Wildlife Service, Neotropical Migratory Bird Conservation Act Grants Program
Alberta Research Council Inc.
Canada Foundation for Innovation
Canada Research Chairs program
Canadian Boreal Initiative
Ducks Unlimited Canada
Environmental Studies Research Fund
Fonds québécois de la recherche sur la nature et les technologies
Forest Products Association of Canada
Natural Sciences and Engineering Research Council of Canada
Sustainable Forest Management Network
Université Laval

Data partners

The following institutions and individuals generously provided or facilitated provision of bird and environmental data to the Boreal Avian Modelling Project. We gratefully acknowledge the efforts of Dr. Dan McKenney and colleagues at the Canadian Forest Service office in Sault Ste. Marie, ON, who compiled climate data tailored especially for our modelling needs.

Institutions

Acadia University, Alberta Biodiversity Monitoring Institute, Alberta Pacific Forest Industries Inc., AMEC Earth & Environmental, AREVA Resources Canada Inc., AXYS Environmental Consulting Ltd., Bighorn Wildlife Technologies Ltd., Bird Studies Canada, Canadian Natural Resources Ltd., Canfor Corporation, Daishowa Marubeni International Ltd, Canada Centre for Remote Sensing and Canadian Forest Service, Natural Resources Canada, Canadian Wildlife Service and Science & Technology Branch, Environment Canada, Global Land Cover Facility, Golder Associates Ltd., Government of British Columbia, Government of Yukon, Hinton Wood Products, Hydro-Québec Équipement, Kluane Ecosystem Monitoring Project, Komex International Ltd., Louisiana Pacific Canada Ltd., Manitoba Hydro, Manitoba Model Forest Inc., Manning Diversified Forest Products Ltd., Matrix Solutions Inc. Environment & Engineering, MEG Energy Corp., Mirkwood Ecological Consultants Ltd., Numerical Terradynamic Simulation Group, Ontario Ministry of Natural Resources, OPTI Canada Inc., PanCanadian Petroleum Limited, Parks Canada, Petro Canada, Principal Wildlife Resource Consulting, Rio Alto Resources International Inc., Saskatchewan Environment, Shell Canada Limited, Suncor Energy Inc., Tembec Industries Inc., Tolko Industries Ltd., Université de Moncton, Université du Québec à Montréal, Université du Québec en Abitibi-Témiscamingue, Université Laval, 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

J. Ball, E. Bayne, P. Belagus, S. Bennett, R. Berger, M. Betts, J. Bielech, A. Bismanis, R. Brown, M. Cadman, D. Collister, M. Cranny, S. Cumming, L. Darling, M. Darveau, C. De La Mare, A. Desrochers, T. Diamond, M. Donnelly, C. Downs, P. Drapeau, C. Duane, B. Dube, D. Dye, R. Eccles, P. Farrington, R. Fernandes, D. Fortin, K. Foster, M. Gill, R. Hall, S. Hannon, B. Harrison, J. Herbers, K. Hobson, M-A. Hudson, L. Imbeau, P. Johnstone, V. Keenan, S. Lapointe, R. Latifovic, R. Lauzon, M. Leblanc, J. Lemaitre, D. Lepage, B. MacCallum, P. MacDonell, C. Machtans, L. Morgantini, S. Mason, M. McGovern, D. McKenney, T. Nudds, P. Papadol, M. Phinney, D. Phoenix, D. Pinaud, D. Player, D. Price, R. Rempel, A. Rosaasen, S. Running, R. Russell, C. Savingnac, J. Schieck, F. Schmiegelow, P. Sinclair, A. Smith, S. Song, C. Spytz, P. Taylor, S. Van Wilgenburg, P. Vernier, M-A. Villard, D. Whitaker, J. Witiw, S. Wyshynski, M. Yaremko

PROJECT COMMUNICATIONS IN 2009- 2010

BAM continues to pursue a variety of outreach approaches tailored to different audiences.

1. Webinars

In 2009, we initiated a Webinar series to support enhanced communications with our Technical Committee. This provides an efficient and effective means of providing updates on our progress, and facilitating meaningful discussion of our methods and results. The webinars to date have been afforded excellent participation from the Technical Committee, and based on direct and indirect feedback, have been very well received. The topics covered are described below, with supporting materials provided as appendices to this report.

(i) Webinar #1

The first webinar presented an overview of the state of the project, including current staffing, the direction of BAM analyses and future goals. The structure of the avian database (the foundation of BAM's work) was discussed in detail, as well as issues associated with variation in sampling techniques, and some methods for addressing these. See Appendices 1 and 10.

(ii) Webinar #2

In the second webinar, we delved into details of some analyses, including estimation of detection radius for different species, and associated estimation of density and population size. See Appendix 11.

(iii) Webinar #3

Our third webinar focused on the assembly of biophysical variables, including climate data, remote sensed measures of productivity, and development of the CAS for the FRI. We also presented portions of the Auto-documentation system, exploring: 1) the distributions of and correlations between 30 yr means and variances of monthly temperature and precipitation and 2) the degree to which the boreal-wide distributions of the biophysical variables are effectively sampled by BAM avian sampling locations. See Appendix 2.

2. Website Update

The BAM project website was formally launched to our Technical Committee and data partners in the summer of 2009, and has since been made public. We have received very positive online feedback from users, ranging from researchers to consultants and practitioners to the general public. In the fall of 2009, high quality images of all the species represented on the site were incorporated, and the French translation was completed to create a bilingual site. The website can be viewed at www.borealbirds.ca.

3. Presentations, Reports and Manuscripts

BAM was represented in a number of venues during the 2009-10 fiscal year.

Lefevre, K et al. May 2009. Vers la conservation continentale de l'avifaune de la forêt boréale: un projet de modélisation à travers le Canada. Invited seminar, Centre d'étude de la forêt, Université Laval, Québec, QC.

Seed, et al. June 2009**.** Evaluation of alternative remote sensing land cover products for modeling and monitoring forest bird habitat in the Western Boreal Plains. The 30th Canadian Symposium onremote Sensing, Lethbridge, Alberta.

EM Bayne, August 2009. What does “occupancy rate” really mean when measuring bird abundance using point counts. Society of Canadian Ornithologists in Edmonton, Alberta

EM Bayne et al., August 2009. Large-scale evaluation of current and future risks to boreal forest bird populations. Society of Canadian Ornithologists in Edmonton, Alberta

Schmiegelow, F.K.A et al. November 2009. Boreal Avian Modelling Project*. Space for Habitat Workshop*, Vancouver, BC.

Lefevre, K. November 2009. L’étude des facteurs environnementaux qui influencent la distribution des oiseaux. Invited lecture, Département des sciences du bois et de la forêt, Université Laval, Québec, QC.

Seed et al. March 2010. Evaluation of alternative remote sensing land cover products for habitat modeling and mapping in the Western Boreal. EC_GeoSymposium 2010

Song et al. February 2010. A Large-Scale Modelling Effort To Support Management Of Incidental Take Of Migratory Birds In Canada’s Boreal Forest. Invited speaker: Symposium on Ornithological Applications, Joint Meeting of Audubon Ornithological Society, Cooper Ornithological Society and Society of Canadian Ornithologists. San Diego, USA.

Song, SJ, P. Blancher, J. Kennedy & C.S. Machtans. March 2010. Canada’s boreal forests in transition: New opportunities to achieve migratory bird conservation. Invited speaker, Special Session, 25th anniversary of Partners In Flight, 75th North American Wildlife and Natural Resource Conference, Milwaukee, USA.

A number of publications related to project results are in various stages of preparation and submission:

(Lefevre et al.) *Toward continental conservation of the boreal forest avifauna: a pan-Canadian modelling project*. Submitted to Avian Conservation and Ecology February 2 2010. Editorial decision received March 22 2010: Revise and resubmit. Resubmission expected by June 1st 2010.

Fang S, SG Cumming, FKA Schmiegelow, SJ Song and EM Bayne*. Prediction reliability measures for Classification and Regression Tree (CART) models of Poisson data*. Under revision for submission to Journal of Environmental Statistics.

(Bayne et al.) *How many Ovenbirds are in Canada’s boreal forest? A new approach to estimating population estimates*. In preparation.

Seed, Cumming, Bayne, Duffe, Baldwin. *Evaluation of alternative remote sensing land cover products for habitat modeling and mapping in the Western Boreal*. EC_GeoSymposium 2010.

BAM team. CART manuscript. Draft title "*Relative roles of climate and vegetation in explaining the distributions of boreal songbirds*". Intended for submission to Global Ecology and Biogeography or Journal of Biogeography.

BAM team. Nuisance manuscript. Draft title "*Point counts and offsets: a method to correct for nuisance variables*". Intended for submission to Condor.

PROJECT MANAGEMENT

Steering Committee and Project Staff

The project Steering Committee consists of Drs. Fiona Schmiegelow, Erin Bayne, Steve Cumming, and Samantha Song. This group is collectively responsible for project coordination, including staff management, liaison with project partners and the Technical Committee, and overall leadership of the project.

Core staff positions this year included a Database Manager (Trish Fontaine) and Project Ecologist (Dr. Kara Lefevre). We also engaged a number of technicians to assist with various components of our work, and received statistical support from Dr. Peter Sólymos.

Towards the end of the 2009/10 year, Kara Lefevre departed the project on maternity leave. In anticipation of this vacancy, we undertook a comprehensive search and interview process for a re-profiled position. We have now secured a 2-year appointment of Steve Matsuoka, who will join the project as a visiting scientist from the US Fish and Wildlife Service, Alaska office. Steve brings a wealth of research and management experience with boreal birds, and will be pivotal in expanding our work to include the boreal forests of Alaska (an obvious gap in our considerations to date). He will be based at the University of Alberta.

We also recognized a clear need for dedicated project coordination beyond that afforded by the Steering Committee. In particular, we anticipated an increased demand for collaboration, communications, and outreach activities as the project moves beyond the foundational stage of data compilation and standardization to realize the full potential of partnerships and information sharing. We advertised a position and have engaged Catherine Rostron, formerly a knowledge exchange coordinator with the Sustainable Forest Management Network, who will begin work with us on a part-time basis (50% FTE) early in 2010/11.

Technical Committee

Our Technical Committee (TC) continues to provide independent scientific advice on project direction and results. The BAM project is very grateful for the participation of the following experts:

Peter Blancher, Environment Canada
Marcel Darveau, Ducks Unlimited / Université Laval
Jean-Luc Desgranges, Environment Canada
André Desrochers, Université Laval
Andrew de Vries, Forest Products Association of Canada
Pierre Drapeau, Université du Québec à Montréal
Charles Francis, Environment Canada
Keith Hobson, Environment Canada

Craig Machtans, Environment Canada
Julienne Morissette, Ducks Unlimited Canada
Rob Rempel, Ontario Ministry of Natural Resources / Lakehead University
Stuart Slattery, Ducks Unlimited Canada
Phil Taylor, Acadia University
Steve Van Wilgenburg, Environment Canada
Lisa Venier, Natural Resources Canada
Pierre Vernier, University of British Columbia
Marc-André Villard, Université de Moncton

Contact with the TC was maintained this year through webinars and other targeted communications, small group discussions where possible (e.g., via related meetings such as the SCO meeting in Edmonton and the North American Duck Symposium), and individual communications with the project team to address technical questions, as necessary. Continuation of the webinar forum into 2010 is planned to facilitate TC involvement in the project. A physical meeting is also planned for fall 2010.

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

Gillian Binsted: technical writing and editorial support
Patrick Charlebois (Université Laval): computer programming
Paul Chytyk (YUNI Environmental Consulting): technical writing
John Cosco (Timberline Natural Resource Group): analysis and technical writing
Connie Downs (Environment Canada): BBS data
Kevin Hannah (Environment Canada): avian life history and technical support
Marie-Anne Hudson (Environment Canada): BBS data
Bénédicte Kenmei (Université Laval): computer programming
Mélanie-Louise Leblanc (Université Laval): programming of statistical summaries
Lisa Mahon (University of Alberta): statistical analysis
Paul Morrill (Web Services): website design & programming
Sheila Potter (Blue Chair Designs): graphic design and website design and development
Pierre Racine (Université Laval): GIS programming
Stephanie Topp (Environment Canada): technical writing