Boreal Avian Modelling Project

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

2011–2012 Annual Report to Environment Canada

and Final Report for the Contribution Agreement

http://www.borealbirds.ca

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

Trish Fontaine, University of Alberta
Dr. Lisa Mahon, Environment Canada
Steve Matsuoka, University of Alberta
Catherine Rostron, University of Alberta
Dr. Péter Sólymos, University of Alberta

Nicole Barker, Université Laval
Christian Roy, Université Laval
Diana Stralberg, University of Alberta

EXECUTIVE SUMMARY

The purpose of the Boreal Avian Modelling (BAM) Project is to develop and disseminate reliable, quantitative, and predictive models of the distribution and abundance of boreal birds and to facilitate their application in avian conservation and management. Specific applications include land-use planning, design and implementation of monitoring programs, current and future population status assessment, environmental impact assessment, recovery and action planning for Species At Risk, and protected areas planning and management; examples of these are presented in this report. Fundamental to our work has been the systematic assembly and integration of the most comprehensive set of observational data possible, modelled using the best available environmental covariates and advanced statistical methodologies. The observational data come from a multitude of studies conducted by scientists in government, environmental non-governmental organisations, industry and academia, working across the boreal and hemiboreal regions of North America, over the past 20 years.

This report highlights the work undertaken during 2011–2012. As this is the final year of a three-year contribution from Environment Canada (2009–2012), we also summarise the achievements of the project over the entire contribution agreement. (Full details of past years' work are presented in annual reports submitted previously and available upon request.) BAM's avian dataset contains over 1.5 million records. Our comprehensive biophysical database includes climate data and climate change projections, and a unique forest-habitat layer assembled from an almost-complete set of Canada's digital Forest Resource Inventories. These provide the foundation for BAM's analyses. Although the BAM team has conducted the majority of analytical and modelling efforts to date (with advice from our Technical Committee), increasingly we are pursuing opportunities to collaborate with other parties to merge our data and understanding to address avian conservation issues.

Notable achievements in 2011–2012 include:

- Implementing expansion of our study region to include boreal Alaska and transitional hemiboreal forests of the Atlantic Provinces, New England and the Great Lake States, by acquiring significant new avian datasets and forging international partnerships.
- Acquisition of new data layers of anthropogenic impacts and climate projections.
- Completion of methodological advances to 1) estimate avian density and population from point-count data, and, 2) assimilate complex heterogeneous data sources (e.g. BBS data and off-road points counts).
- Preparation of 11 manuscripts (either published, in review or to be submitted shortly) to document these advances. Includes completion of additional analyses and preparation of a manuscript documenting the CART process.
- Preparation of species' distribution maps for 88 boreal bird species using Maxent modelling techniques for presentation on the BAM website, and for use in assessing potential conservation networks.
- Estimation of avian densities as a function of forest type and age developed in prototype for Alberta. These were used by BAM and partners including the Government of Alberta, ALCES Group, Canadian Boreal Initiative, and Canadian Wildlife Federation to model the future state of boreal biodiversity.
- Preparation of recommendations for common standards for conducting avian point-count surveys, addressing factors including count period and radii, number of observers at a station, and number of visits to each station. Provision of assistance

for model-based survey design and recommendations for sampling to address geographic and habitat gaps in atlas surveys.
- First applications of the trans-boreal Common Attribute Schema for Forest Resource Inventory data (CASFRI) to provide tables of improved forest characteristics for each avian sampling location covered by the inventories.
- Significant progress on developing a strategic spatial simulation tool to project forestry and boreal bird interactions across the extent of Canada's managed boreal forests under present and future climate conditions.
- Collaboration with Environment Canada to develop a process to translate PIF continental avian population objectives into habitat-specific, numerical population objectives at subregional-BCR scales, making use of the BAM population density estimates. Evaluation of future scenarios to assess the ability to meet population targets.
- Inclusion of waterfowl through a companion project led by Laval and TC members from DUC.
- Extension of the knowledge developed within BAM through scientific and technical publications, presentations, interactions with Technical Committee members, website upgrades, and development of a symposium for the upcoming 2012 North American Ornithological Conference.

The continued success of the Boreal Avian Modelling Project depends on maintaining strong partnerships with individuals and organisations contributing avian data and environmental covariates, as well as related expertise, and the critical support of funding partners. We extend our gratitude to our data and funding partners and to members of BAMs Technical Committee for their vital contributions. With our technical capacity and the foundation of large datasets and strong analytical techniques now well-established, we look forward to continuing delivery and expanding opportunities for collaboration, to address detailed explorations of the questions surrounding conservation and management of boreal birds in North America.

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1.0 HIGHLIGHTS OF ACCOMPLISHMENTS 2011–2012

1. Expanded geographical study area to include boreal and hemiboreal forest regions as defined by Brandt (2009), resulting in incorporation of data from Atlantic Canada, southern Ontario and Québec, BC, and Alaska into the BAM avian dataset. BBS data for those regions incorporated into the BAM dataset. Ongoing addition of avian point count data across Canada and the United States as it becomes available. Version 3.0 of the avian database contains 1.5 million records at more than 109,000 locations.

2. Assembled data layers needed to test for and quantify effects of natural and anthropogenic disturbances on forest birds. Also received climate normals to assist with evaluation of impacts of climate change on avian populations.

3. Conducted novel analyses on structure of CART models to assess the relative importance of 131 biophysical predictor variables. Climate variables (particularly monthly means and variances of temperature and precipitation) were identified as the most important.

4. Completed Maxent modelling work to produce maps of predicted distributions of 88 boreal species (and relative habitat suitability) within boreal/hemiboreal study area. Maps will be posted to BAM website in Spring 2012.

5. Completed extensive work that advanced the methodology for estimating avian density and population, and for dealing with complex data sources, including BBS data. Extended our distance sampling methodology to account for incomplete detection rates, uneven sampling of habitats, and roadside bias effects. Conducted field experiments related to sound transmission and reception in different habitat types. Five publications are in review or were published in the past year; six more are in preparation, and 5 technical reports have been produced.

6. Estimated avian densities as a function of forest type and age using Alberta as a case study because sufficient data were available. Resultant database will be posted on the website in Spring 2012.

7. Initiated process to refine regional bird habitat models for two species (Canada Warbler and Olive-sided Flycatcher) which was only possible because of the existence of the BAM dataset.

8. Prepared recommendations for common standards for conducting avian point-count surveys to maximize the value of the collected data and to facilitate analyses conducted with multiple data sets. Addressed factors including count period and radius, number of observers at a station, and number of visits to each station.

9. Applied the completed trans-boreal Common Attribute Schema (CASFRI) to the Forest Resource Inventory data to produce tables of timber volume-age by tree species for parts of Canada. These tables will be used in simulation modelling to assist in the prediction of the structure and distribution of forests needed to understand avian habitat.

10. Assembled new FRI data for Prince Edward Island, Nova Scotia, and crown lands and woodlots in New Brunswick; translated and uploaded into PostGIS database.

11. Conducted bioclimatic modelling of North American landcover types and ecoregions and developed future climate-change projections to (1) evaluate future climate characteristics within our boreal forest study area; (2) identify non-boreal areas for inclusion in avian distribution models; and (3) inform climate inputs to avian distribution models.

12. Collaborated with Environment Canada to translate the PIF continental-scale population objectives into habitat-specific, numerical population objectives in one Forest Management Area. Expected future habitat conditions were found to be insufficient to support proposed BCR population objectives. These types of dynamic land-use models, which rely on the BAM density estimation work and on the development of forest age and composition models, proved valuable for quantifying potential impacts to bird populations.

13. Determined through Marxan modelling with Environment Canada that species' habitat suitability proved to be a better type of input data than species' range in predicting priority areas for avian conservation. Ongoing work is determining whether finer-resolution habitat suitability data will improve the predictions.

14. Provided species distribution models (Maxent maps) to Boreal Ecosystems Analysis for Conservation Networks (BEACONs, www.beaconsproject.ca) project to use in evaluating the representativeness of proposed conservation areas across boreal Canada.

15. Conducted initial work to incorporate climatic variability into density modelling efforts to allow calculation of a range of diversity indices that address abundance measures. Further analyses of diversity indices will follow.

16. Assembled data from the Waterfowl Breeding Population and Habitat Survey and began high spatial-resolution modelling of waterfowl densities. Currently applying BAM methodologies to waterfowl data. Pursuing independent funding to permit further development and exploration of this database.

17. Collaborated with a variety of government and non-government organisations to address issues of avian conservation and environmental assessment using the BAM dataset, methodology, and analyses, including:

    a. Alberta Biodiversity Monitoring Institute,
    b. Alberta Conservation Association,
    c. Alberta Landuse Framework Secretariat,
    d. Alberta Sustainable Resources Development,
    e. ALCES Group,
    f. Boreal Ecosystems Analysis for Conservation Networks (BEACONs),
    g. Canadian Wildlife Federation, and
    h. Environment Canada (BBS, National Atlas Committee, PNR, SAR, WLSD).

18. Analysed Alberta avian data and Alberta Biodiversity Monitoring Institute (ABMI) datasets to provide information to EC to assist in avian monitoring program design for the oil sands region in particular and for overall atlas sampling.

19. Completed Alberta density database using Forest Resource Inventory data to update results for Alberta Landuse Framework planning. Results from these models are being used by BAM and partners include the Government of Alberta, ALCES group, Canadian Boreal Initiative, and Canadian Wildlife Federation in their efforts to model the future state of boreal biodiversity.

20. Conducted modelling of the effects of natural and anthropogenic disturbances on forest songbird densities using subsets of the BAM data designed to document energy sector impacts like seismic lines, wellpads, and pipelines. Results from these models will determine which effects to address at a national level and how to account for natural variation.

21. Organised symposium for North American Ornithological Conference with 12 presentations to be held in Vancouver in 2012 in collaboration with staff from Cornell; the abstracts are included as Appendix 1.

22. Updating website content to reflect advances in methodologies and to post new maps, results (French translation to be completed by June 2012).

23. Extending our knowledge to the scientific and avian conservation and management community through preparing scientific papers (5 in press, 6 in preparation in 2011-2012) and technical reports (5) and making presentations (12) about BAM and its work.

2.0 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 a key breeding area for many of North America's migratory landbirds. This region is rapidly changing due to the increasing pressure caused by industrial development and climate change. Before the BAM project was initiated, we had little coherent knowledge about the density, distribution, and habitat needs of avian species and communities, and little ability to effectively predict the effects of threats to populations or the efficacy of management actions directed at mitigating negative 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. Recently we expanded our study area so that it now includes the boreal and hemiboreal regions of Canada and the United States (after Brandt 2009), resulting in data acquisition from regions in Atlantic Canada, southern Québec and Ontario, interior BC, and Alaska. Our overall goal is to generate the scientific knowledge needed to support proactive conservation of boreal forests and migratory birds in this immense and globally-significant area.

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

- Assemble and maintain a repository, as complete and current as possible, 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 and abundances,
    - Refine and forecast population status and trends, and
    - Generate testable hypotheses about key mechanisms underlying the observed spatial and temporal variation (e.g., climate, land use, latitude, vegetation).
- Improve the standardisation and rigor of avian data collection by providing standards for bird sampling protocols (from both human-observed and automated sound recordings) and database structure.
- Provide a conservation legacy for avian data collected in North America's boreal forest beyond the original study purposes.
- Build support from academia, industry, governments, non-governmental organisations, and other interested parties for further development and testing of boreal bird population models and other decision-support tools, and to foster their proactive application to the management of boreal forests and biodiversity conservation.
- Encourage public awareness and support education by providing ready access to current information on the status of boreal bird populations.

3.0 PROGRESS ON MAJOR ACTIVITIES FOR 2009–2012

This report summarises the accomplishments of the BAM team with respect to the major proposed activities laid out in the 2009-2012 Contribution Agreement (and subsequent amendments) with Environment Canada. Within each activity, we report:

- the progress made in the past fiscal year (2011–2012); and,
- a summary of our accomplishments over the duration of the agreement, as this is the final year of our 3-year contribution agreement.

3.1 Data Compilation

3.1.1 Avian Data (2011–2012)

The BAM avian point-count database has been expanded significantly over the past year, in both sample size and spatial coverage. Last year we expanded our study area to include the boreal and hemiboreal regions as defined by Brandt (2009, Fig. 1). As of February 2012, the complete database (Version 3.0) contains data from over 110 projects, representing over 1.5 million bird survey records at 109,000 point-count locations (Fig. 2).

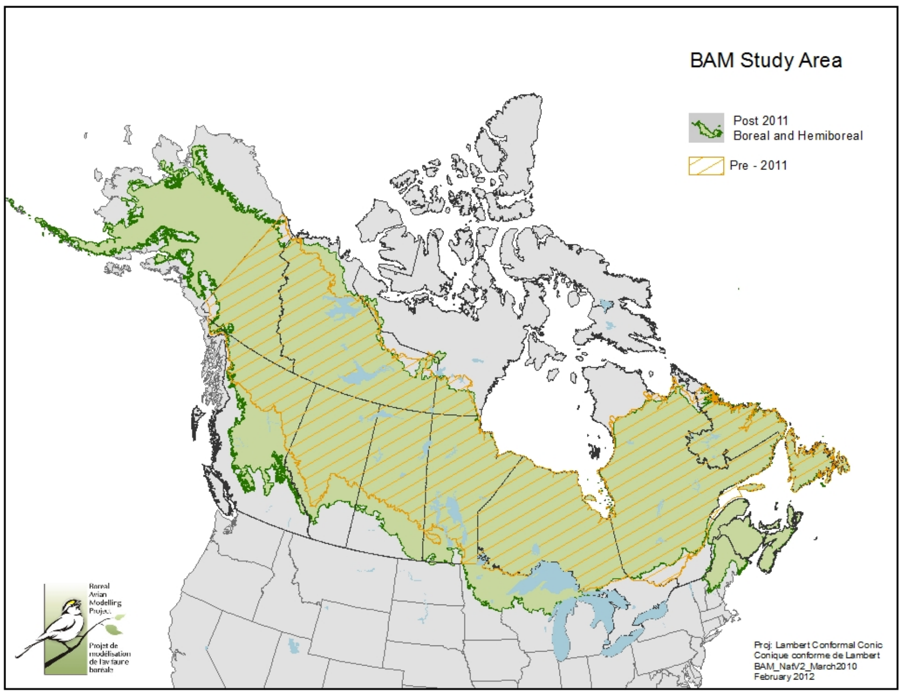


Figure 1. The boundary of BAM study area (after Brandt, 2009) compared to the pre-2011 study area.

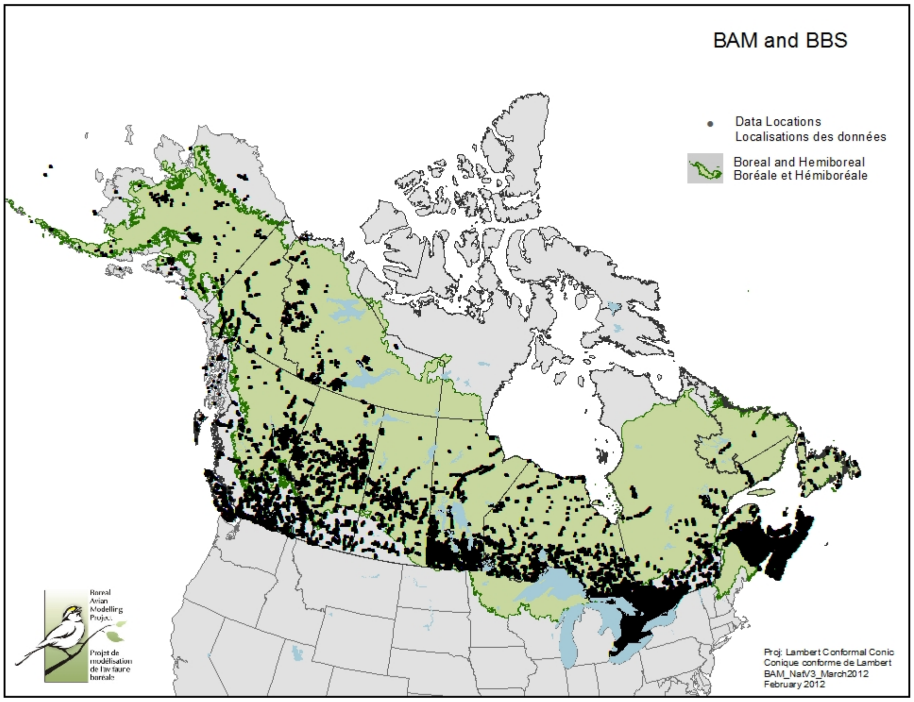


Figure 2. Location of all data points within the BAM Avian Dataset Version 3.0.

In 2011–2012, we continued to incorporate Breeding Bird Survey (BBS) data from across Canada, collected from 1996–2009. Initial efforts focused on areas such as Yukon Territory and eastern Québec where there were large gaps area covered by the BAM dataset. Efforts were later extended to all Canadian BBS points that could be spatially referenced. The task of generating or correcting geo-referenced locations for BBS stops was substantial and included corrections to bird coding. This assistance was provided directly to the Canadian Wildlife Service (CWS) BBS office. The inclusion of the BBS data has greatly increased our geographic coverage (Fig. 3). The location of data points pre-2011 (Fig. 4) demonstrates the marked increase in spatial coverage we have realized since reporting for 2010 – 2011.

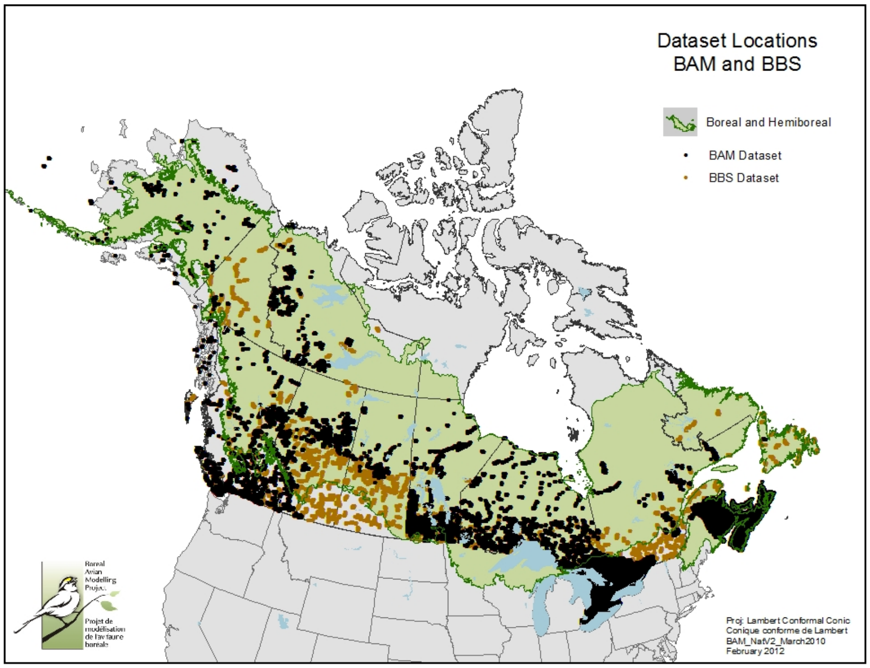


Figure 3. Location of all data points within the BAM Avian Dataset Version 3.0, displayed according to source (BAM point-count data or BBS data).

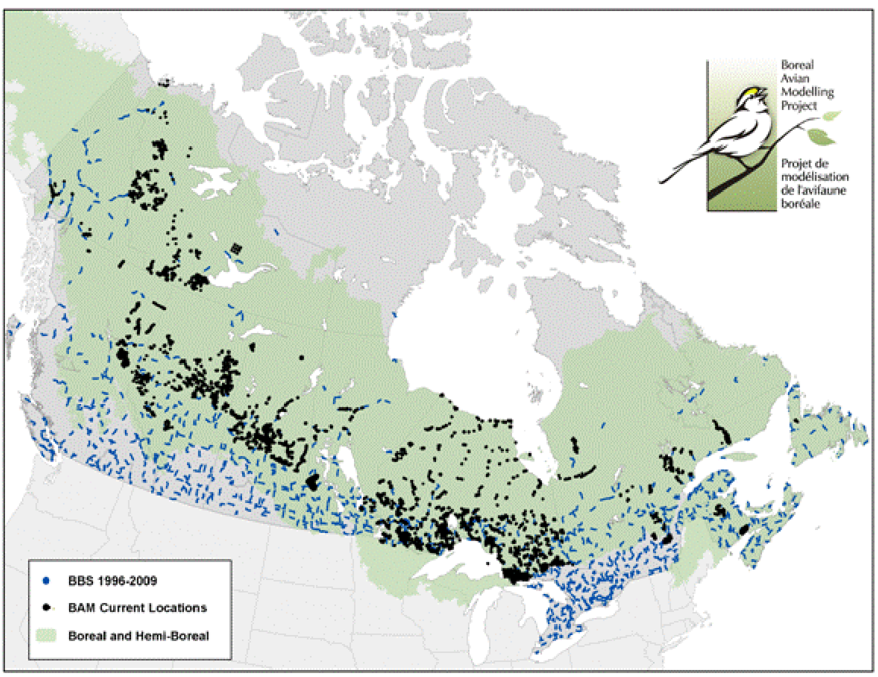


Figure 4. Location of all data points within the BAM Avian Dataset Version 2.0 (2010-11) prior to the inclusion of hemiboreal data and Alaska data.

With the assistance of our project ecologist (Steve Matsuoka, on secondment from the U.S. Fish and Wildlife Service [USFWS]) and our most recent addition to the Technical

Committee member (Colleen Handel, U.S. Geological Survey), BAM acquired the majority of the geo-referenced point-count survey data from across boreal and Arctic Alaska. This included data from the North American Breeding Bird Survey, Alaska Landbird Monitoring Survey, Alaska Off-road Breeding Bird Survey, National Park Service Inventory and Monitoring Program, and several significant avian inventories on National Wildlife Refuges and U.S. Army Training Areas. These data have been proofed and incorporated into the BAM avian database. This represents an addition of 14 new projects, 37,000 point-count locations, and over 500,000 individual bird records to the existing BAM database. We have also added Breeding Bird Atlas datasets from British Columbia, Manitoba, and the maritime provinces.

These new data have greatly improved our ability to address our program objectives. The new data from the BBS and from Alaska fill substantial gaps in our survey coverage of geographic and climate spaces, and habitat types. The BAM team continues to solicit and accept avian point-count data from existing and new regional survey programs throughout our expanded study area (Fig. 1). In particular, we are exploring new collaborations with groups conducting regional avian monitoring programs in the Upper Midwest and New England to obtain survey data from U.S portions of the hemiboreal region. These, as well as additional data from Alaska, will be added to our database as they become available.

3.1.2 Biophysical and Anthropogenic Data (2011–2012)

BAM has been working to acquire comprehensive spatial biophysical data relevant to our modelling objectives. A current priority is to identify and acquire data layers that will enable us to detect, model and predict impacts of anthropogenic disturbance and climate change on boreal bird populations. In 2011–2012, we acquired an updated version of the Geobase National Road Network data to assist in digitising BBS route locations. We also obtained permission to use portions of Global Forest Watch Canada's (GFWC) database on landscape change from human activity. This database is particularly valuable because it provides information on anthropogenic change over time within large portions of the boreal forest region. We also acquired the anthropogenic disturbance footprint data derived from 2008-10 Landsat imagery over caribou ranges in the Canadian boreal forest that was generated by EC WLSD as part of recovery strategy efforts. In contrast to other data products, this new dataset distinguishes amongst many distinct kinds of human disturbances, potentially enabling us to differentiate the effects of different industrial and development activities.

BAM continued to acquire current and projected climate data. Through a collaboration with Dr. Andreas Hamann (University of Alberta), BAM obtained 4-km climate normals (1961-1990) based on a combination of PRISM (Daly et al. 2002) and Worldclim (Hijmans et al. 2005) climate data. The western North America portion of these data are described in Wang et al. (2011). We recently used these data as inputs to our Maxent models (Section 3.2.1.2: Species distribution mapping). Diana Stralberg, in collaboration with Andreas Hamann and Xianli Wang, also used these base layers to develop 4-km gridded and downscaled future climate change projections from general circulation models included in the IPCC's 4th Assessment Report (Meehl et al. 2007). For the province of Alberta, projections have been downscaled to 1-km, 500-m, and 250-m resolution datasets.

3.1.3 Summary of BAM Accomplishments within Objective: Data Compilation 2009 – 2012

- Updated, authoritative database of landbird point count data including Canadian BBS data; Version 3.0 (February 2012), currently in use by BAM team members, contains over 1.5 million records.
- Expanded geographic extent of the avian database to include boreal and hemiboreal regions of North America, as defined by Brandt (2009). This has resulted in the addition of data from Atlantic Canada, southern Québec and Ontario, interior BC, and Alaska. Discussions underway with US Midwest regarding further data acquisition.
- BBS data for Canada geo-referenced, verified, and added to the avian database to provide additional geographic coverage and to provide additional data for statistical analyses. Minor updates pending discussion with CWS-BBS office on corrections for Quebec and Ontario.
- Updated database of biophysical layers (vegetation and climate data) from public sources for use as habitat descriptors when analysing avian data.
- Automatic documentation system developed to provide statistical summaries of the avian and biophysical databases; Version 1.0 results are posted on the web site under http://www.borealbirds.ca/library/index.php/technical_reports.
- Acquisition of 4-km climate normals for application in distribution and climate change analyses.
- Acquisition of data (or access to data) on anthropogenic disturbance (from EC WLSD and GFWC) to use in modelling impacts of human activities on boreal bird populations.

The avian and biophysical datasets will continue to be updated as new data are made available to the project or as required for specific analyses.

3.2 Species assessment, habitat associations and monitoring

3.2.1 Species' distribution mapping

3.2.1.1 Update on national-scale models of avian response to climate and land cover (CARTS)

In 2011-12 and previous reports, we described a national-scale analysis of avian response to 131 climate and land cover variables using Correlation and Regression Tree (CART) models. A full manuscript was prepared on the national CART models which used some novel analysis on the structures of the fitted models to make inferences about the relative importance of different covariates, and how these differed amongst groups of species. The paper was submitted to the journal Ecography in November 2011. The editors considered that the paper was too ambitious for the permitted length and suggested a more focussed resubmission. We declined and are now revising the manuscript for submission in Summer 2012 to the online open-access journal Ecosphere, published by the Ecological Society of America.

Findings indicated that climate variables explained the majority of deviance (77%) over all 98 species analysed. Within climate covariates, monthly means of temperature and precipitation were only slightly more important than monthly variances. "Bioclimatic" factors (e.g. evapotranspiration, seasonality) accounted for only 10% of model deviance. The two most important variables, over all species, described vegetation: these were land cover and April leaf area index. Interpretable differences existed in the variables selected for different migratory groups and for boreal specialists. Although not equal in importance to climate factors, land cover and other vegetation covariates are important determinants of spatial variation in species abundance even at continental extents. In some cases where land cover was the most important variable, this could be indicative of disequilibrium between climate and vegetation associated with land conversion on the parkland forest ecotone. These models have been crucial in helping us identify the climate covariates that have been used in our Maxent models that predict songbird distribution across the boreal region.

3.2.1.2 MAXENT models of species distribution

In 2010–2011, we began using the program Maxent (Phillips and Dudik 2008) to develop predictive models of songbird distributions across the boreal forest region. In 2011–2012, we completed our work on this front by predicting the current distributions of 88 boreal songbirds based on climate conditions (30-year averages) and land cover as classified by the North American Land Change Monitoring System (CEC, http://www.cec.org/Page.asp?PageID=924&SiteNodeID=565). These new models significantly improve upon our 2010–2011 prototypes by expanding our survey coverage to include (1) the substantial amount of new data incorporated into the BAM database (Version 3.0) and (2) additional BBS data from any ecoregion in Canada and the U.S. that overlapped the BAM study area. The larger dataset improves our predictions of bird distributions by accounting for larger portions of the breeding ranges of many species (eliminating the need to incorporate a distance-to-range-edge factor that was mentioned in the previous annual report).

For 88 boreal species, we averaged model predictions of avian distribution from 10 bootstrapped subsamples of the BAM/BBS dataset. We used the survey locations as the reference "background" for the Maxent predictions, rather than the entire boreal region, to reduce sampling bias in our predictions (Phillips et al. 2009). Although our new models were developed using data from ecoregions outside of the BAM study area, we constrained our model predictions to the BAM study area. We assessed the accuracy of each model by withholding data from model-building and then using the area under the curve (AUC) of the receiver operating characteristics plot (Fielding and Bell 1997). For each species, we produced two maps: (1) a map showing that species' predicted distribution within the Brandt-defined boreal and hemiboreal regions and (2) a map showing the data locations used in the analyses for each species (see Fig. 5 for example). Maps for these and 11 additional species will be posted to our website in Spring 2012 under Boreal Birds (http://www.borealbirds.ca/avian_db/index.php/boreal_birds).

In general our models were reasonably accurate in their prediction of species' distributions. AUC scores ranged from an average of 0.56 for American Robin to 0.97 for American Tree Sparrow. In the case of Maxent models, the AUC value can be interpreted as the likelihood that a randomly-selected presence location will have a higher suitability score than a randomly-selected background location.

Across all 88 species, AUC values averaged 0.81 ±0.09 (SD; Table 1). Models for 76 species had AUC scores > 0.70, and 17 of those can be considered to have high accuracy (>0.90) (Swets 1988).

Our Maxent-based maps are a significant improvement over the published range maps from NatureServe (http://www.natureserve.org/getData/birdMaps.jsp) for several reasons. First, our Maxent models can be interpreted as bioclimatic niche models. They thereby provide information about the relative suitability of climates and habitats within a species' range, something not provided by the NatureServe maps. In some instances these relationships point to physiographic barriers, such as the Canadian Cordillera, that may prevent colonisation of otherwise suitable habitat (Erskine 1977). For example, our models predict high suitability habitats for Cape May and Palm Warblers within the Alaskan boreal forest even though these species do not extend west of the Canadian Cordillera (Fig. 6A, B).

Second, our dataset contains occurrence records outside of NatureServe range map limits for all but 3 of the 88 species. These are reflected in the Maxent predictions. Thus both our occurrence records and model predictions might be used to refine the range limits for several species. Palm Warbler (Fig. 6B) and Connecticut Warbler (Fig. 6C) are two examples of species with predicted high suitability habitat (and occurrence data) north of mapped range limits (in eastern and western Canada). Several species, such as Canada Warbler (Fig. 5), Chestnut-sided Warbler (Fig. 6D) and Nashville Warbler (Fig. 6E) demonstrate western range extensions compared with NatureServe. All but nine species had data observations north of their published range limits. We recognise that better range maps may exist for many species (e.g., in recently revised Birds of North America volumes, http://bna.birds.cornell.edu/bna/), but in most cases, digital versions are not available for comparison. The NatureServe products are widely used in large-scale ecological analysis and conservation planning. BAM's work offers to place such efforts on a more solid empirical foundation.

Table 1. Maxent model accuracy (area under the curve, AUC) and number of occurrence records (*n*) by species. AUC = mean area under the curve across 10 bootstrapped Maxent model runs. For each bootstrap replication, 50% of species' occurrences were used to train the model, and the remaining 50% were used to test the model.

Species	AUC	*n*	Species	AUC	*n*	Species	AUC	*n*
ALFL	0.69	10,052	EAPH	0.81	3,833	RCKI	0.77	8,655
AMCR	0.67	15,176	EVGR	0.80	2,589	RECR	0.88	1,094
AMGO	0.73	11,591	FOSP	0.91	2,057	REVI	0.66	16,397
AMRE	0.72	9,371	GCFL	0.85	4,482	RUBL	0.87	544
AMRO	0.57	22,016	GCKI	0.79	5,557	RWBL	0.74	11,824
ATSP	0.97	522	GCTH	0.96	469	SAVS	0.75	10,184
BAWW	0.76	7,170	GRAJ	0.84	4,535	SCTA	0.88	1,889
BBMA	0.92	2,407	GRCA	0.80	4,764	SEWR	0.93	1,135
BBWA	0.88	2,182	HAFL	0.94	1,619	SOSP	0.69	14,573
BCCH	0.67	11,945	HETH	0.71	10,989	SWSP	0.75	4,946
BHCO	0.78	8,050	HOWR	0.83	5,570	SWTH	0.74	11,654
BHVI	0.79	5,731	LCSP	0.92	1,653	TEWA	0.85	4,701
BLBW	0.84	4,002	LISP	0.81	4,707	TOSO	0.95	567
BLJA	0.75	9,484	MAWA	0.77	9,244	TOWA	0.95	1,472
BLPW	0.92	1,278	MAWR	0.88	792	VATH	0.93	1,987
BOCH	0.85	2,225	MGWA	0.95	1,637	VEER	0.79	7,101
BRCR	0.81	2,046	MOWA	0.80	5,166	VESP	0.86	4,857
BTBW	0.89	2,994	NAWA	0.79	8,367	WAVI	0.77	7,561
BTNW	0.81	5,914	NOWA	0.72	5,101	WBNU	0.82	2,307
CAWA	0.84	2,169	OCWA	0.87	3,799	WCSP	0.93	1,784
CCSP	0.89	4,424	OSFL	0.77	2,797	WETA	0.92	2,365
CEDW	0.67	9,781	OVEN	0.74	12,047	WEWP	0.92	1,739
CHSP	0.64	15,108	PAWA	0.88	1,914	WIWA	0.84	3,166
CMWA	0.86	1,392	PHVI	0.86	1,994	WIWR	0.77	7,677
COGR	0.79	8,629	PIGR	0.89	605	WTSP	0.71	14,221
CONW	0.94	1,050	PISI	0.81	4,982	WWCR	0.84	2,691
CORA	0.68	9,801	PIWA	0.90	1,278	YRWA	0.70	12,392
COYE	0.66	12,978	PUFI	0.77	4,219	YWAR	0.67	11,661
CSWA	0.80	7,373	RBGR	0.78	6,315			
DEJU	0.76	8,801	RBNU	0.74	7,895			

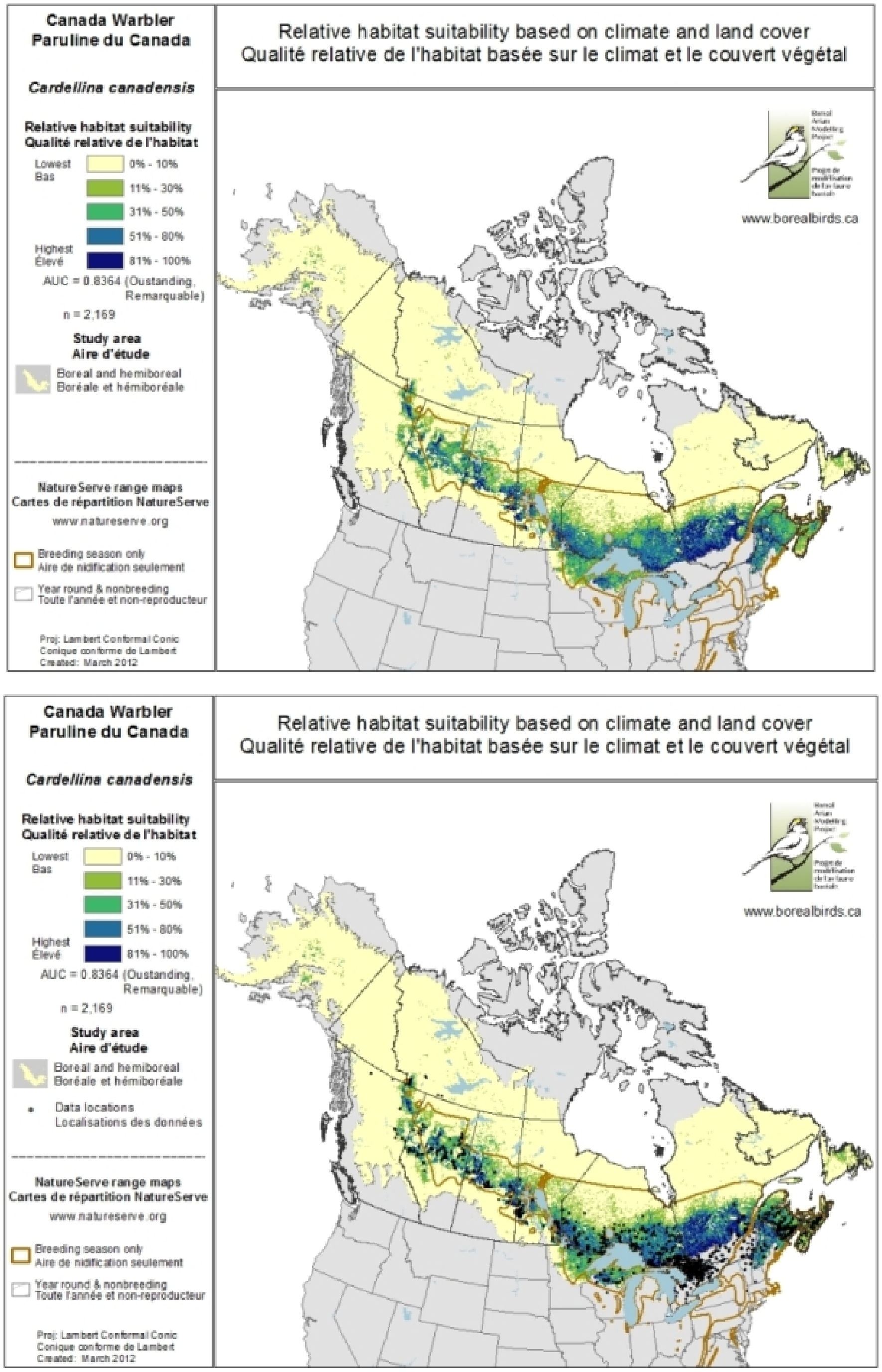


Figure 5. Maps of A) spatial predictions of Canada Warbler habitat suitability (Habitat Suitability Ranking) and B) survey locations with Canada Warblers within BAM's boreal and hemiboreal study area. Spatial predictions are based species' distribution models developed using Maxent (see main text). For comparison, we present the range limits according to NatureServe (Ridgely et al. 2003).

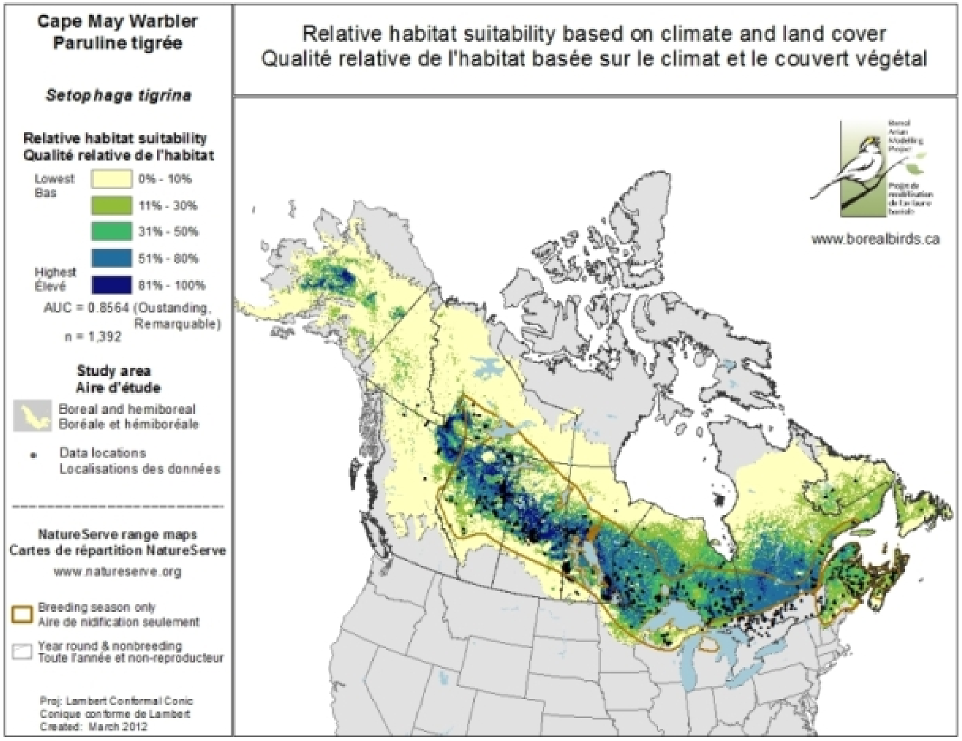


Figure 6A. Occurrence and predictions of species' distributions for A) Cape May Warbler.

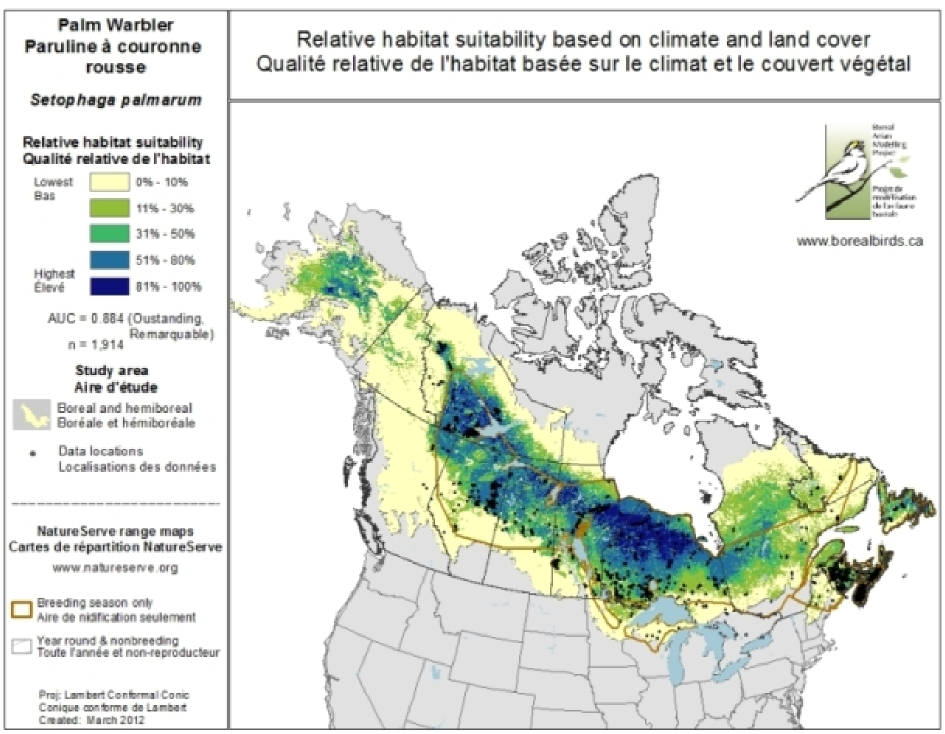


Figure 6B. Occurrence and predictions of species' distributions for Palm Warbler.

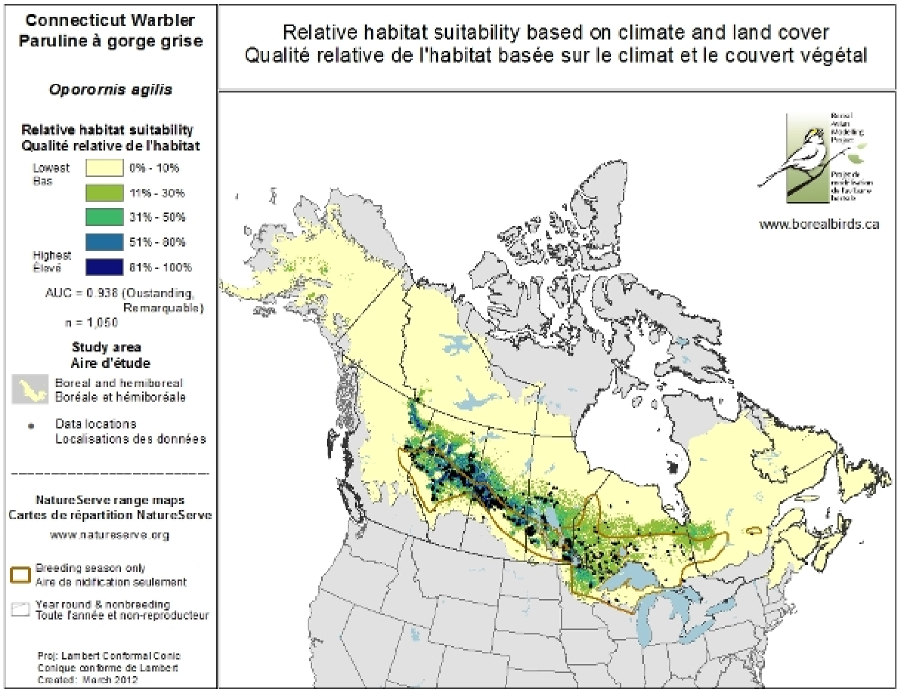


Figure 6C. Occurrence and predictions of species' distributions for Connecticut Warbler.

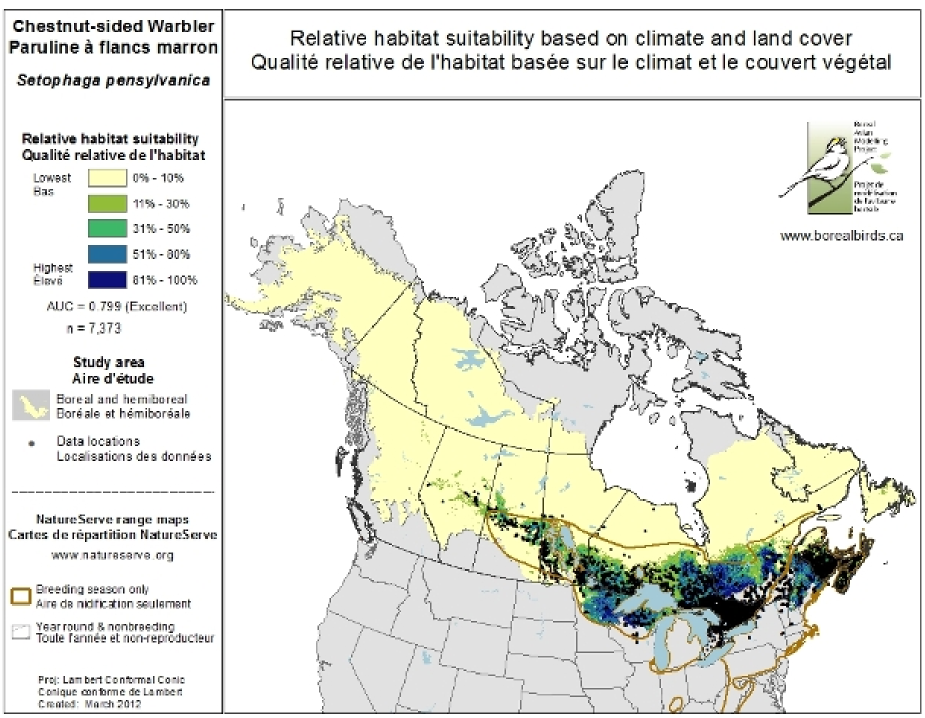


Figure 6D. Occurrence and predictions of species' distributions for Chestnut-sided Warbler.

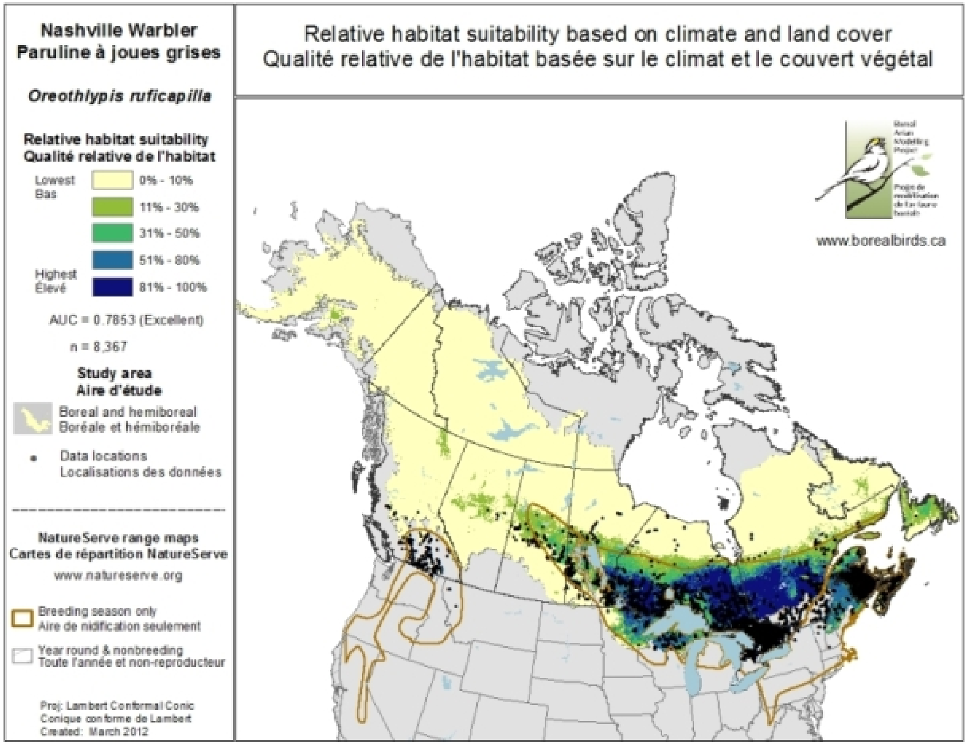


Figure 6E. Occurrence and predictions of species' distributions for Nashville Warbler.

3.2.2 Density estimation

In 2011–2012, we developed estimates of breeding densities and population sizes for 70 species of boreal forest songbirds. These estimates were based on off-road survey data only: BBS route data were not included. This work will be summarised in an avian density database, to be posted on the BAM website by May 2012. This database was made possible by our earlier methodological research that enables us to adjust density estimates for the many observational biases inherent in the BAM data set. These biases are substantial. They occur because of incomplete detection rates of birds during surveys, variability in detection rates relative to habitats and the times of day and year that surveys occur, variability in the survey protocols used by different studies, and uneven sampling of habitats and geographic strata (Cumming et al. 2010a, Matsuoka et al. 2011b, Matsuoka et al. 2012, Sólymos et al. in preparation, Bayne et al. in review).

We developed a hierarchical model that accounts for these sources of observation bias. The model estimates breeding densities and population sizes of 70 species of songbirds as functions of geographic strata and habitat classes. One major advance in this reporting year is that the model now accounts for variation in habitat use among geographic units. Here, we briefly describe this model and then present resulting estimates of population sizes and breeding densities. We compared our estimates of population size (BAM) to those estimated by Blancher (2003) using spot mapping data from the Breeding Bird Census (BBC) and BBS data analysed using the PIF approach (BBS, Rosenberg and Blancher 2005). We report whether BAM estimates are within an order of magnitude of BBC estimates, the external validation criteria used by Blancher (2003), Rosenberg and Blancher (2005), and Confer et al. (2008). We also examine the differences in population size between BAM and BBS. Finally, we discuss three critical factors based on our findings that must be accounted for when estimating avian population sizes:

(1) incomplete detection rates of birds and variability in survey protocols,
(2) uneven sampling of habitats, and
(3) roadside bias in survey counts.

3.2.2.1 The model

The hierarchical model that we used to estimate breeding density incorporated most of the recommendations for improving estimates of landbird population size (Thogmartin et al. 2006, Thogmartin 2010) and included the following specifications:

- Generalised linear model with Poisson or Negative Binomial error.
- An offset that adjusts the mean count for detection probability and how it relates to species' singing rates, species' specific effective detection radii (EDR), and variability in the length of the counting period and the count radius (Sólymos et al. in preparation).
- Geographic strata defined by the combination of Bird Conservation Region (BCR) and jurisdiction (province, territory, state).
- Habitat classes based on the Land Cover Map of Canada 2005 (Latifovic et al. 2008) collapsed into 14 categories by BAM (Cumming et al. 2010a).
- Breeding densities were estimated for each combination of BCR, jurisdiction, and habitat class.
- Population sizes were estimated by multiplying the density by (1) the area of the BCR/jurisdiction/habitat and (2) the constant 2, the pair correction (Rosenberg and Blancher 2005).

For the purposes of this report, we restricted our analyses to BCRs 4 – Northwestern Interior, 6 – Boreal Taiga Plains, 7 – Taiga Shield and Hudson Plains, and 8 – Boreal Softwood Shield (planning area) and to 23 species of birds. This is to make our results comparable to Blancher (2003: Table 3). For each of these 23 species, we estimated population sizes. We also estimated habitat-specific densities across the planning area for a subset of 8 species. We estimated population size for each combination of BCR, jurisdiction, and habitat type using the methods described above. We then summed these population sizes across BCRs 4, 6, 7, and 8 to estimate the population size for each species across the planning area. We then estimated the habitat-specific density by summing the population sizes separately for each habitat type and then dividing this by the total area of the habitat type across the planning area.

3.2.2.2 BAM compared to BBC population sizes

When we compared our estimates of breeding population sizes (BAM) to population sizes estimated by Blancher (2003), we found that BAM estimates were generally closer to BBC estimates than the BBS (Table 2). BAM estimates averaged 2.6 ± 0.8 x (0.3–18.8 times) those from the BBC, with the difference an order of magnitude for the Swainson's Thrush (18.8 x, Table 2). When we removed the Swainson's Thrush, BAM estimates exceed those from the BBC by 1.8 ± 0.2 x (range 0.3–4.1). Population sizes estimated using BBC averaged 4.1 ± 0.8 x (SE; range = 0.2–16.4) those estimated using BBS. This difference was an order of magnitude for two species, Chestnut-sided Warbler (10.5 x) and Bay-breasted Warbler (16.4 x, Table 2). We were somewhat surprised that BAM and BBC estimates were as close as they were because BBC data are limited to 138 samples across the boreal forest, most of which were sampled between 1965 and 1982 (Kennedy et al. 1999, Blancher 2003). Thus, there are clear limitations to this simple comparison.

3.2.2.3 BAM compared to BBS population sizes

BAM estimates of population size averaged 6.7 ± 1.6 x (0.9–39.6) those from the BBS, with 3 species an order of magnitude more abundant according to BAM. This was quite similar to the average difference of 8.3 x (0.9–25.3 x, n = 30 species) based on a more rigorous comparisons of abundance estimates from spot mapping and point counts in the same area, the latter using the PIF approach (Confer et al. 2008). We suggest that the large difference between BAM and BBS population sizes are due to our accounting of three contributing factors which we examine below.

3.2.2.4 Accounting for detection probabilities

The first factor contributing to the difference between BAM and BBS estimates is our more complete accounting of detection probabilities and how they are related to singing rates, detection distances, habitats, temporal sampling frames, and survey protocols. For example, differences due to our estimation of the effective detection radius (EDR) alone results in a 5.1 x (0.8–14.6 x, n = 88 species) average difference in population sizes when compared to the PIF approach (Matsuoka et al. 2012). Similarly, the combination of our adjustments for EDR, singing rate, and survey protocol results in a 6.5 x (1.1–21.1 x, n = 70 species) average difference in population size compared to the PIF approach (Sólymos et al. in preparation). Thus our accounting of detection probabilities, particularly as it relates to EDR, has a substantial effect on the estimates of population size (Thogmartin et al. 2006, Thogmartin 2010).

Table 2. Comparisons of population sizes of boreal forest birds estimated using spot mapping data from the Breeding Bird Census (BBC), Breeding Bird Survey data (BBS, Blancher 2003:Table 3), and off-road point-count data compiled by BAM (BAM). All estimates are for the Canadian portions of Bird Conservation Regions 4, 6, 7, and 8 combined. Ratios of the estimates are provided to emphasise how the population sizes change with methodology.

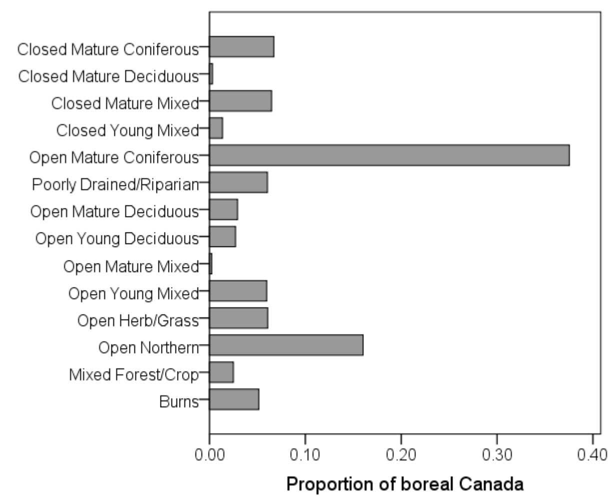
	Population sizes			Ratios of estimates		
Species	BBC	BBS	BAM	BBC : BBS	BAM : BBS	BAM : BBC
Dark-eyed Junco	210,000,000	170,000,000	288,000,000	1.2	1.7	1.4
Yellow-rumped Warbler	180,000,000	82,000,000	466,000,000	2.2	5.7	2.6
Tennessee Warbler	160,000,000	21,000,000	223,000,000	7.6	10.6*	1.4
White-throated Sparrow	110,000,000	110,000,000	239,000,000	1.0	2.2	2.2
Ovenbird	98,000,000	12,000,000	76,000,000	8.2	6.3	0.8
Chipping Sparrow	82,000,000	44,000,000	140,000,000	1.9	3.2	1.7
American Robin	73,000,000	92,000,000	91,000,000	0.8	1.0	1.2
Red-eyed Vireo	69,000,000	68,000,000	65,000,000	1.0	0.9	0.9
Ruby-crowned Kinglet	68,000,000	45,000,000	230,000,000	1.5	5.1	3.4
Magnolia Warbler	67,000,000	23,000,000	143,000,000	2.9	6.2	2.1
Blackpoll Warbler	60,000,000	13,000,000	96,000,000	4.6	7.4	1.6
Least Flycatcher	59,000,000	8,800,000	65,000,000	6.7	7.4	1.1
Chestnut-sided Warbler	45,000,000	4,300,000	12,000,000	10.5*	2.8	0.3
Yellow Warbler	45,000,000	13,000,000	91,000,000	3.5	7.0	2.0
Lincoln's Sparrow	44,000,000	30,000,000	94,000,000	1.5	3.1	2.1
White-crowned Sparrow	42,000,000	35,000,000	119,000,000	1.2	3.4	2.8
Bay-breasted Warbler	41,000,000	2,500,000	99,000,000	16.4*	39.6*	2.4
Northern Waterthrush	40,000,000	6,900,000	40,000,000	5.8	5.8	1.0
Swamp Sparrow	37,000,000	7,300,000	81,000,000	5.1	11.1*	2.2
Savannah Sparrow	36,000,000	20,000,000	148,000,000	1.8	7.4	4.1
Fox Sparrow	35,000,000	7,500,000	26,000,000	4.7	3.5	0.8
Palm Warbler	35,000,000	8,500,000	75,000,000	4.1	8.8	2.1
Swainson's Thrush	12,000,000	56,000,000	226,000,000	0.2	4.0	18.8*

* Estimates of population size differ by an order of magnitude.

3.2.2.5 Accounting for uneven sampling of habitats

A second factor contributing to the difference between BAM and BBS estimates is that we stratified the BAM surveys by habitat type to account for uneven sampling. This is different than Blancher (2003) who assumed that the BBC and BBS surveys sampled bird habitats proportional to their availability across the boreal forest. We previously found that habitat sampling was often quite biased, but the bias was similar between boreal BBS and BAM surveys. Both BAM and BBS under-sampled conifer habitats by 20%, open northern habitats by 10%, and poorly-drained and burned habitats by about 5% each (Matsuoka et al. 2011b). Thus, species with higher-than-average densities in these under-sampled habitats will likely have larger populations estimated using the BAM approach (stratification) compared to the BBS approach (no stratification). This is particularly true for species selecting conifer habitats, which collectively comprise 45% of the boreal region (Fig. 7).

Figure 7. The proportion of boreal Canada encompassed by different habitat classes from the Land Cover Map of Canada (Latifovic et al. 2008) and reclassified by BAM (Cumming et al 2010).



To emphasise this point, we examined the habitat-specific densities for the 8 species with the largest disparities between BAM and BBS population sizes (Fig. 8). This included Bay-breasted Warbler (BBWA, 39.6 x), Blackpoll Warbler (BLPW, 7.4 x), Least Flycatcher (LEFL, 7.4 x), Palm Warbler (PAWA, 8.8 x), Savannah Sparrow (SAVS, 7.4 x), Swamp Sparrow (SWSP, 11.1 x), Tennessee Warbler (TEWA, 10.6 x), and Yellow Warbler (YWAR, 7.0 x). Six of 8 of these species had higher than average densities in one of the conifer habitat types: Closed Mature Coniferous (4 species: BBWA, SWSP, TEWA, YWAR), Open Mature Coniferous (5: BBWA, BLPW, PAWA, SWSP, TEWA). Additionally, 5 of the species had particularly high densities in Poorly Drained/Riparian habitats (BLPW, PAWA, SAVS, SWSP, YWAR). Few species had higher average densities in Burns (PAWA) or Open Northern habitats (SAVS; Fig. 8). Thus, species tied to habitats that were under-sampled by surveys may show particularly large disparities between BAM's stratified population estimates and BBS unstratified estimates.

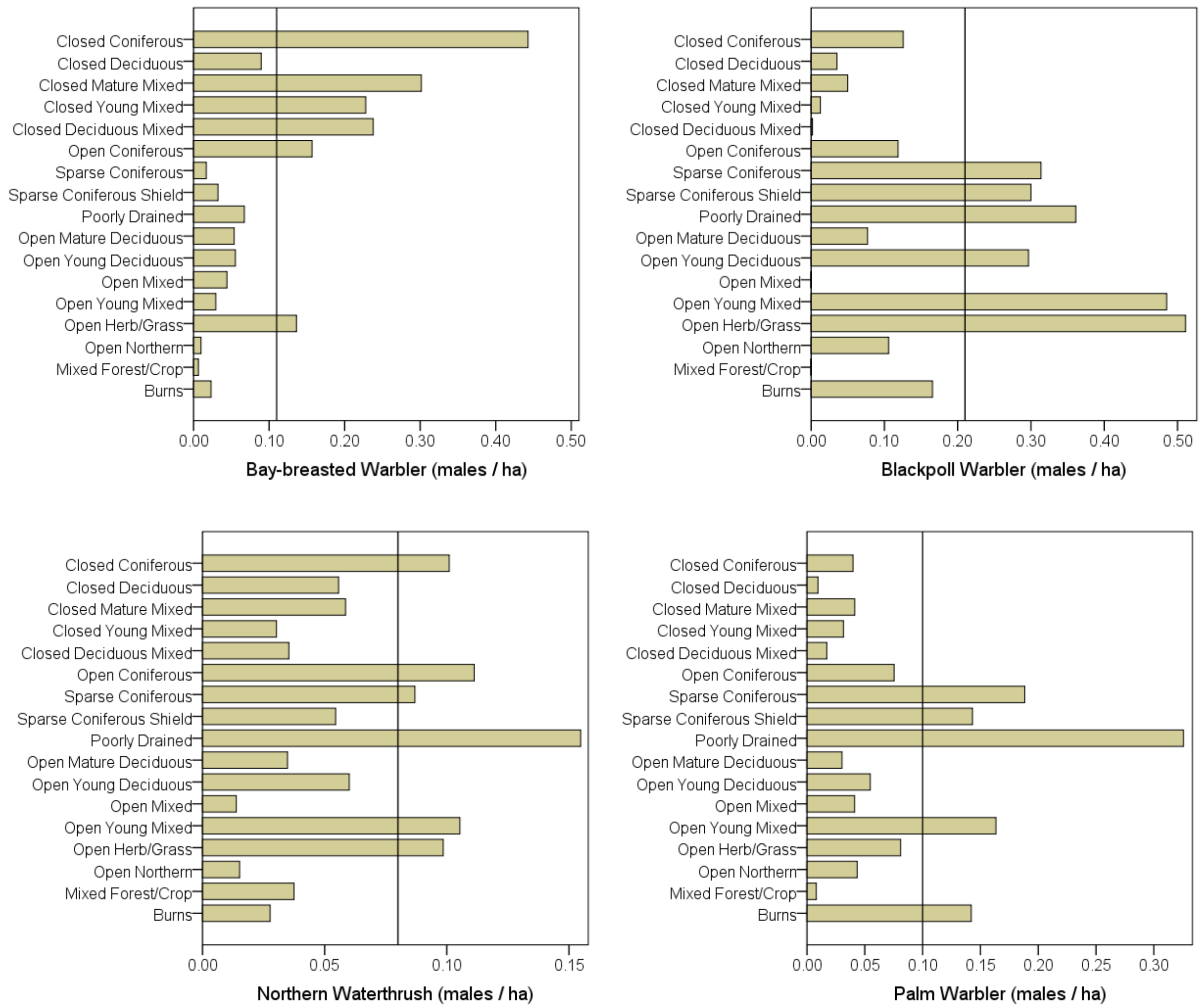


Figure 8A. Average breeding densities by habitat across boreal Canada for 8 species with large differences in population size estimated using BAM data (this report) and data from the BBS (Blancher 2003). The vertical line references that overall mean.

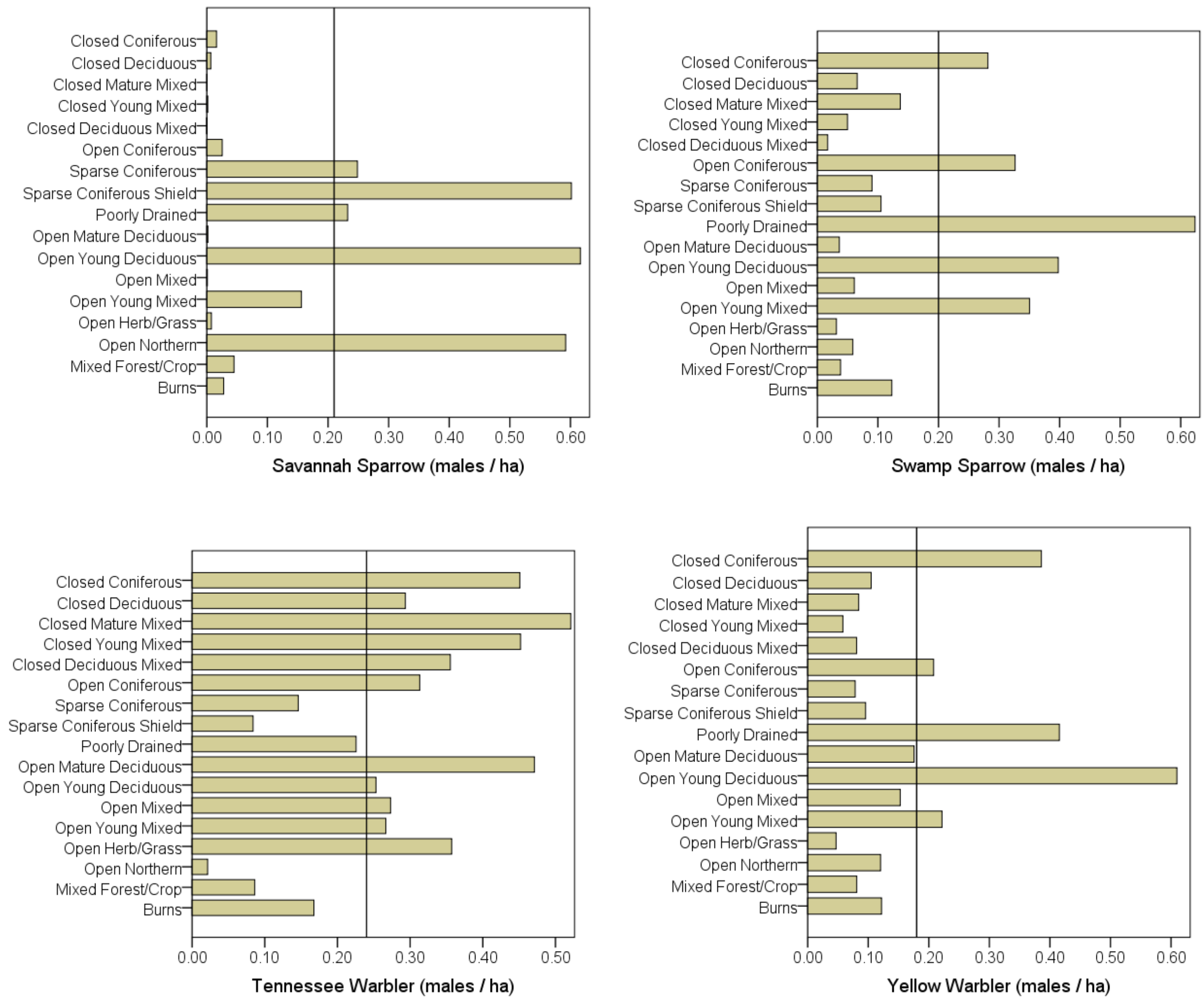


Figure 8B. Average breeding densities by habitat across boreal Canada for 8 species with large differences in population size estimated using BAM data (this report) and data from the BBS (Blancher 2003). The vertical line references that overall mean.

3.2.2.6 Accounting for roadside bias in the counts

The third factor contributing to the differences in population sizes between BAM and BBS is that roadside surveys, such as the BBS, result in a different count of birds when compared to an equivalent off-road survey (roadside bias). We have found roadside bias to be quite prevalent (79% of 85 species). Three of the four species with the largest differences in estimates between BAM and BBS (BBWA, PAWA, TEWA) had significantly lower counts during roadside surveys compared to off-road surveys (negative roadside bias). This was particularly the case for Bay-breasted Warbler, for which the magnitude of negative roadside bias was second highest among the 85 species evaluated (Matsuoka et al. 2011b). This was also the species with the largest multiplicative difference in population size between BAM and BBS (39.6 x, Table 2). Thus the combination of bias due to detection rate, uneven sampling of habitats, and roadside counts likely all contributed to the large disparity between BAM and BBS population estimates for this species.

We previously found that positive roadside bias (roadside count > off-road count) is much more prevalent and generally larger in effect size than negative roadside bias (Matsuoka et al. 2011b). In 2011–2012, we determined that this pattern occurs because many species can be consistently detected at greater distances along roadside clearings than through vegetation in off-road areas. We demonstrated this by estimating EDR from both roadside surveys and nearby off-road surveys that included at least two distance intervals (e.g., 0–50 m, and >50 m). We found that EDRs varied between off-road and roadside surveys for 29 of 72 species (40%, Table 3). Across the 29 species, EDR increased by an average of 24.5 ± 2.1 m from an off-road survey (mean = 69.8 ± 3.7 m, range = 39.8–113.7 m) to a roadside survey (mean = 94.3 ± 5.2 m, range = 56.5–176.3 m). Thus, a roadside survey on average effectively samples an area that is 1.9 ± 0.1 x (range 1.3–2.6 x) the area sampled by an equivalent off-road survey (Table 3). These differences in EDR can be incorporated into BAM's approach for estimating avian densities (Sólymos et al. in preparation). This will allow us to incorporate 60,000 roadside point counts into our analysis of avian abundance across the boreal (Matsuoka et al. in preparation-b).

Table 3. Estimates of the effective detection radius (EDR, m) for 29 species of boreal forest birds based on off-road (off) and roadside (on) point-count surveys, Canada. The multiplicative increases in the effective area sampled (increase in area) is included to emphasise the larger area sampled by a roadside survey.

	EDR		Increase		EDR		Increase
Species	Off	On	in area	Species	Off	On	in area
Alder Flycatcher	79.3	102.2	1.7	Magnolia Warbler	62.9	76.8	1.5
American Redstart	50.5	72.1	2.0	Mourning Warbler	69.6	98.8	2.0
Black-and-white Warbler	52.2	68.4	1.7	Nashville Warbler	71.3	86.9	1.5
Bay-breasted Warbler	41.0	61.5	2.3	Northern Parula	56.7	76.6	1.8
Black-capped Chickadee	55.4	77.6	2.0	Olive-sided Flycatcher	113.7	176.3	2.4
Blackburnian Warbler	48.9	65.7	1.8	Ovenbird	84.5	101.5	1.4
Blue Jay	100.2	136.6	1.9	Red-eyed Vireo	83.2	94.8	1.3
Brown Creeper	47.7	72.0	2.3	Song Sparrow	72.6	88.5	1.5
Black-throated Blue Warbler	56.9	87.0	2.3	Swainson's Thrush	86.8	113.8	1.7
Black-throated Green Warbler	64.7	83.3	1.7	Tree Swallow	61.1	98.7	2.6
Cedar Waxwing	43.8	59.5	1.9	Veery	80.1	103.7	1.7
Common Yellowthroat	77.0	91.8	1.4	White-crowned Sparrow	102.4	144.0	2.0
Golden-crowned Kinglet	39.8	56.5	2.0	Winter Wren	92.9	135.4	2.1
Least Flycatcher	53.7	81.6	2.3	White-throated Sparrow	97.5	125.7	1.7
Lincoln's Sparrow	77.6	98.6	1.6				

3.2.2.7 Playback experiment to further evaluate roadside bias

To further evaluate how roadside surveys may be biased relative to those in forest interiors, BAM conducted a playback experiment in collaboration with the Alberta Biodiversity Monitoring Institute to:

- determine how far sounds of different frequencies and birds with different song frequencies and complexities can be detected using different audio recorder types;
- evaluate how forest type influences sound transmission;
- assess how the direction that a "bird sings" influences maximum sound power levels recorded at different distances; and
- compare sound transmission along road edges relative to sound transmission through forest.

We used a high-quality car stereo to play back various types of bird songs and pure tones in different vegetation types close to versus far from the road. We then recorded these sounds with various microphone types to determine how sound transmits in different conditions. These data will be used in our upcoming corrections in density estimation to more fully address bias due to roadside surveys. The experiment was conducted in the following habitats:

Aw 1890: Aspen leading mixedwood, C-cover class, 25-metre height, 1890 origin year. Many shrubs

Aw 1940: Aspen dominated, C-cover class, 19-metre height, 1940 origin year. Few shrubs

Aw 1960: Aspen-dominated. C-cover class, 8-metre height, 1960 origin year. Few shrubs.

Aw 1990: Aspen-dominated, B-Cover class, 4-metre height, 1990 origin year. Few shrubs.

Aw2010: Aspen-dominated, Cover class N/A, 2-metre height, 2005 origin year. All shrubs

Sb 1940: Black-spruce, Cover class B, 5-metre height, origin year, 1940.

FIELD: Forest converted to grassland for grazing.

Data were collected from multiple locations along two transects (Forest and Road) for each sound recording location. The transect locations are shown in Fig. 9. An edge transect was also done but is not described here.

Results are described as mean power level at the recorder and are shown in Figure 10. This is equivalent to the background adjusted dbA rating weighted to human hearing. Based on a linear regression model predicting average power level, we found that the type of vegetation through which sound travelled had a very large effect on power levels. Dense stands of black spruce and recent clearcuts absorb sound more than most intermediate aged forests or open fields. Older stands acted more like clearcuts in sound transmission. The type of species being played back had a large effect. Low-frequency sounds and species with low singing frequency having much higher power level, meaning they can be heard

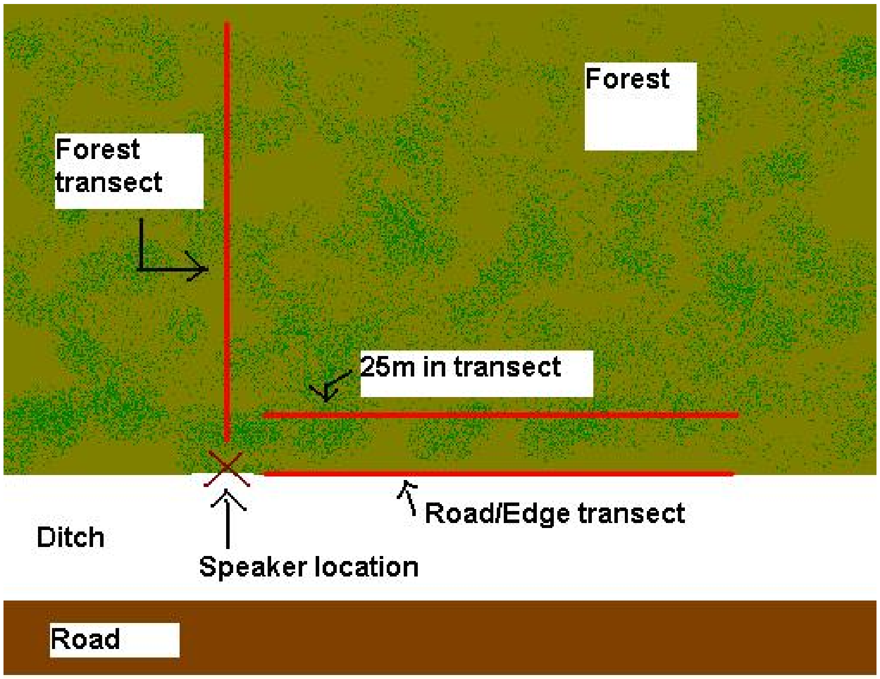


Figure 9. Layout of speaker/ recorder playback trial for determining sound power levels along roads versus through forest.

further, as expected. Differences of 20 decibels were observed during some weather conditions in different vegetation types which is a larger effect than expected. Further analysis is required to understand how vegetation type interacted with weather conditions.

The results of the playback experiment suggest that on average at the same distance in the same habitat for the same species, observers can hear 2 dbA more at the road than in the forest. This is because sound and the power level at which it arrives at the observer is being absorbed by vegetation more on the forest transect than on the road. The direction of the speaker relative to the microphone has about an equivalent effect with higher power levels when the bird faces toward the observer.

What does this mean for point count methods? As sound dissipates a typical 6 dbA per doubling of distance, observers conducting point counts near roads and in certain habitats are far more likely to hear birds at greater distances. For example, assume an observer stands at a point count station on a road and counts birds into the forest up to a maximum of 100 metres through forest. The same bird that was singing on the road edge could be detected to a maximum of 125 metres approximately. We are currently working on methods to integrate this type information into our estimates of effective detection radius which will further help correct road-based biases caused by differential ability to hear birds at long distances.

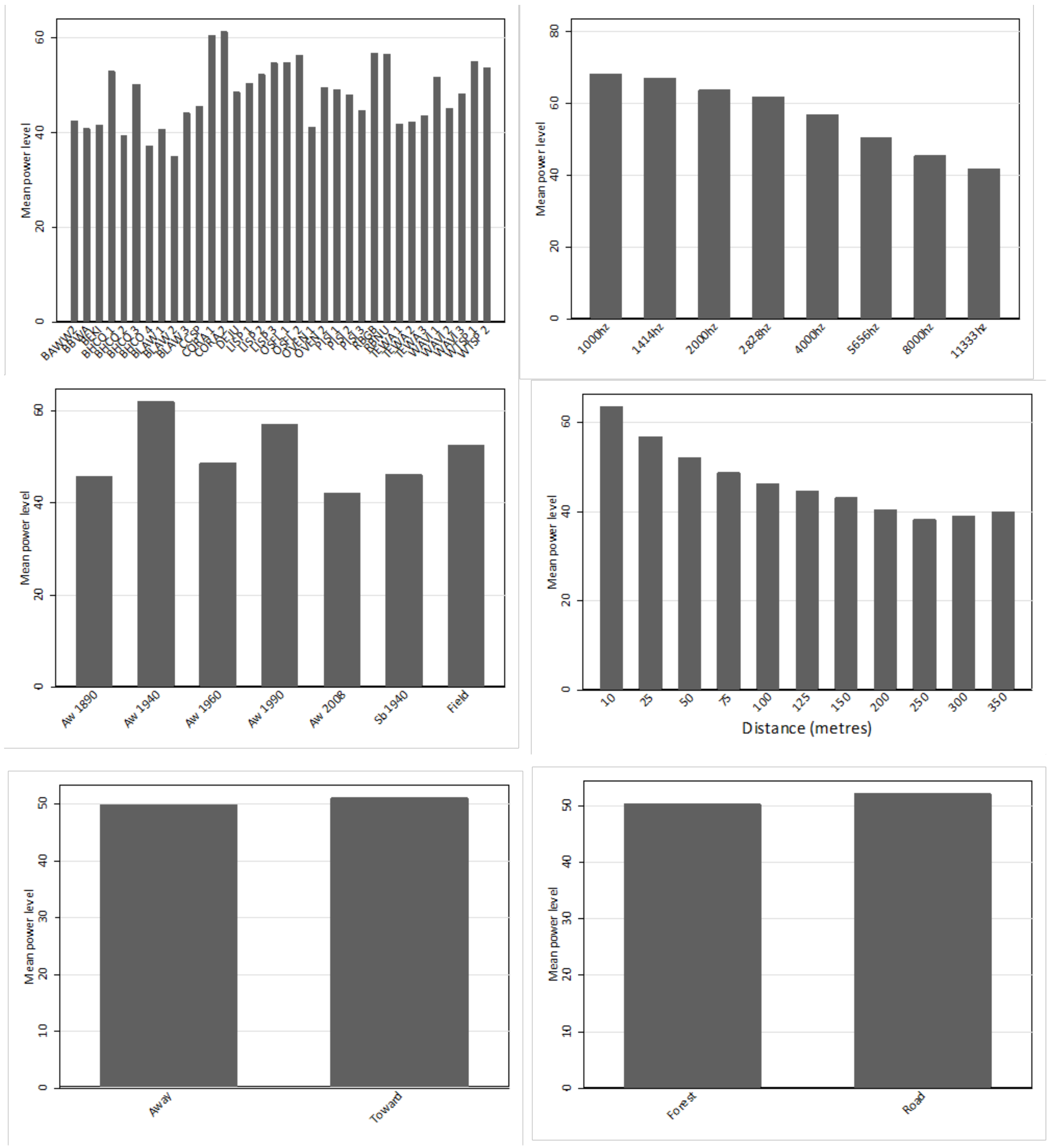


Figure 10. Average sound power levels dbA as a function of: 1) species and sub-sections of individual species songs (Top Left); 2) pure tones at different frequencies (Top Right); 3) vegetation type (Middle Left); 4) whether the “bird” was facing the recorder or oriented at 90 degrees (Middle Right); 5) Distance of “bird” from recorder (Bottom Left); and 6) whether “bird” was singing down the road versus singing through forest (Bottom Right).

3.2.3 Density estimation as a function of forest type and age

Our models of avian responses to habitat have undergone continual improvement as we have learned how to better estimate population sizes of boreal birds. In 2011–2012, we made the transition from using the survey counts as indices of avian abundance in these models to using estimates of breeding density based on adjustments of the survey counts for detection bias and variability in survey protocols (Sólymos et al. in preparation).

The habitat-specific density estimates reported in Section 3.2.2 used the Canada Landcover 2005 250m resolution data to describe broad categories of forest cover (e.g. coniferous and deciduous trees species). We have been able to develop more refined models that allow us to predict bird density as a function of tree species and forest age. To achieve this thematic precision we used covariates obtained from digital Forest Resource Inventory data. Creating these types of models is challenging because: 1) far more bird data are required to account for all the levels of forest type and age; and 2) modelling across Provincial boundaries requires that Forest Resource Inventories be standardised. BAM has made great progress in acquiring the data to achieve the former. The development of the Common Attribute Schema described in Section 3.3.1 has resolved the latter.

Here we highlight our initial models developed using only data for Alberta. For this application, we used over 50,000 point counts at more than 13,000 locations. With these data, we estimated the absolute density of singing males for 74 species of boreal forest birds relative to forest type (deciduous, mixedwood, white spruce, black spruce, and pine forest) and 20yr age classes (0–20yr to >140 years) in each of the land-use regions in Alberta. We provide an example of these models for three species in deciduous forests (Fig. 11). These data comprise part of our new web material being released in April and advanced copies are available upon request. The same approach is being applied in other areas of the country, with an initial focus on species at risk, namely CAWA and OSFL.

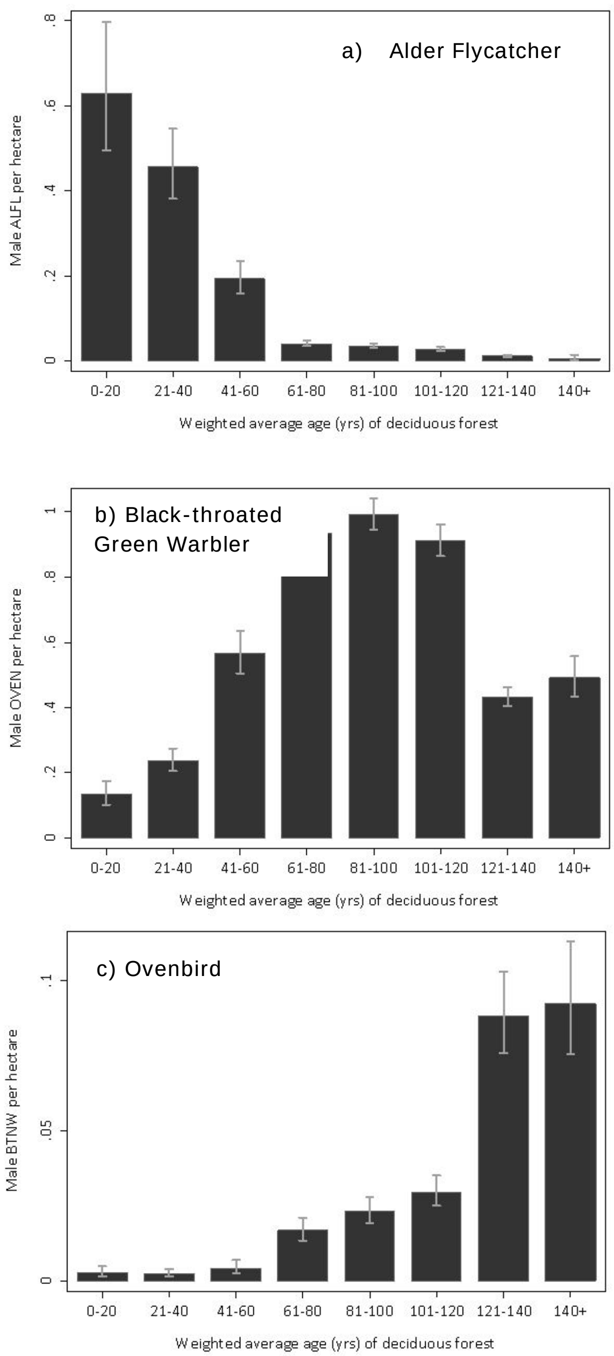


Figure 11. Mean breeding density and 95% confidence interval for a) Alder Flycatcher, b) Black-throated Green Warbler, and c) Ovenbird in relationship to forest age of deciduous forest.

3.2.4 Refining bird models for dealing with critical habitat

A major goal of BAM is to create general models that can be used for a wide variety of purposes and create a common platform for comparing results across species. However, in many cases specific models are need for specific applications. Thus, the numerous model types described in this report were built to achieve different objectives. No one model can do everything. Over the past few years we have emphasised national models that use coarse-level vegetation and climate variables, as we are interested in a broad understanding of how changes in climate and natural processes alter forest suitability for birds at very large scales. However, to predict more-localised effects such as from forest harvesting, we require the more detailed age-habitat models described in Section 3.2.3. For dealing with species at risk, even more-refined information may be needed. BAM has only recently begun to work in this area. Two species for which we are working to identify more-refined habitat models are Canada Warbler and Olive-sided Flycatcher, both Threatened species under the Species at Risk Act Schedule 1.

3.2.4.1 Regional Canada Warbler-habitat modelling in Alberta and Ontario

For Canada Warblers in Alberta strong evidence suggests that they prefer deciduous-dominated mixedwood forest that is generally older, although the birds have been found in forests as young as 50 years of age. Density peaks in the oldest age classes of forest, although our density estimate has the largest confidence interval in that age class (Fig. 12). They are generally found in stands with high timber productivity with above average soil moisture levels (Table 4). CAWA have been found rarely in forest patches in agricultural landscapes. They are entirely absent from areas of black spruce or pine and are found very rarely in white spruce.

Recently, an agreement was reached with the Alberta government to use their LiDAR-based wet-areas map to see how much this improves model predictions for CAWA given evidence of soil moisture being an important predictor. In the spring of 2012, Bayne is using the model data from BAM to target sampling for an exhaustive survey for Canada Warblers in Alberta which will refine the model more and be used to help define critical habitat. A collaboration with the University of Calgary is also being discussed to map habitat these sites this summer using high-resolution LiDAR data. Our goal is to determine the exact vegetation structure and complexity required by this species by mapping the structure of the forest. BAM's role in the ability to understand the habitat needs of threatened species needs to be emphasised. Without BAM, the number of publicly-available data points (i.e. BBS) where Canada Warbler has ever been observed is only 86 which is entirely insufficient to make any type of reliable predictive model.

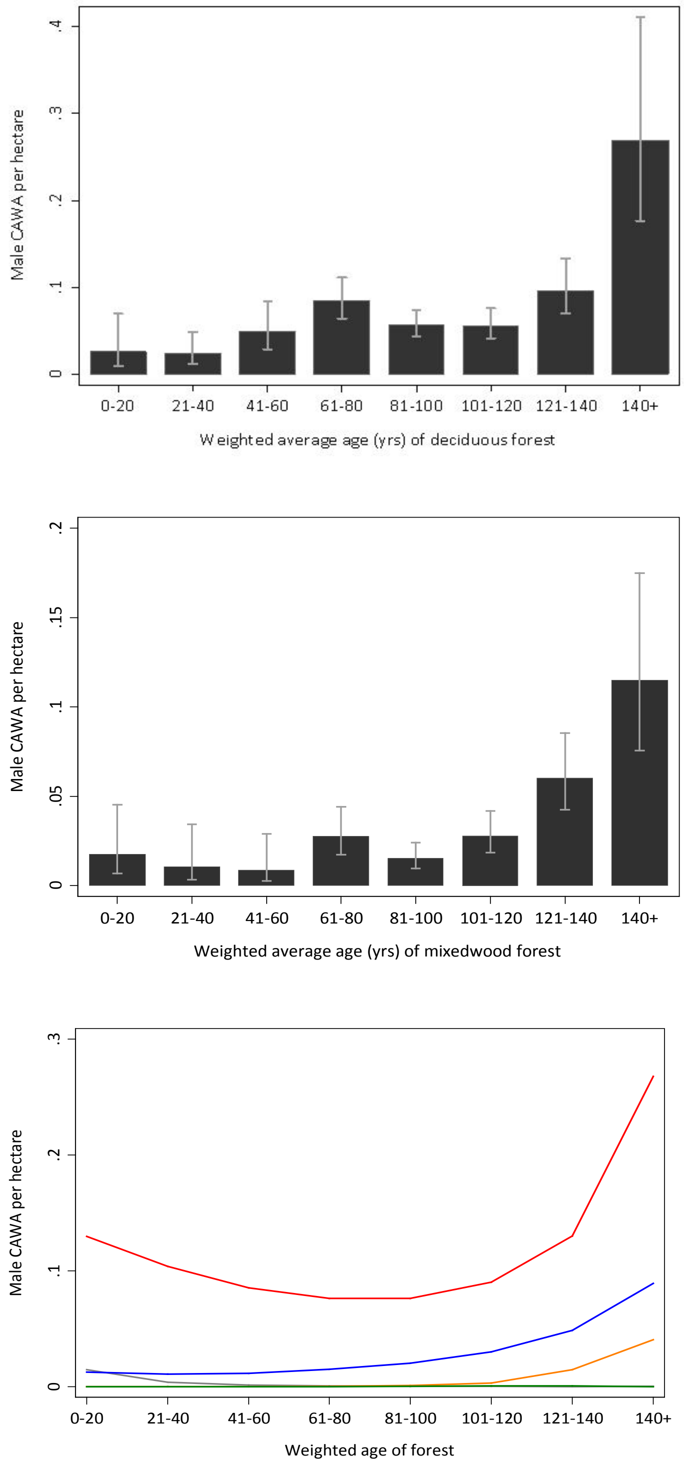


Figure 12. Top – Density and 95% confidence intervals of CAWA in different age classes of deciduous dominated forest; Middle – Density of CAWA and 95% confidence intervals in different age classes of mixedwood forest; and Bottom - Density of CAWA in 5 different forest types. Red=Aspen, Blue=Mixedwood, Orange=Upland Spruce, Green=Lowland Spruce, Gray=Pine.

Table 4. Niche breath of Canada Warblers in Alberta. Niche breadth is defined as the range of environmental conditions where Canada Warblers have been observed. Conditions are described using Alberta Vegetation Inventory data at 406 locations in the province.

Environmental Variable	Mean	25th%	Median	75th%	SD	Min	Max
Proportion Forest	0.87	0.78	0.97	1	0.19	0.1	1
Proportion Deciduous	0.72	0.58	0.79	0.94	0.26	0	1
Age (years)	86	60	84	109	32	9	162
Height (metres)	19	15	20	24	6	1	30
Density (%)	68	58	69	74	15	30	100
Moisture (Rank)	2.1	2	2	2.1	0.2	1.7	3.2
Timber Productivity (Rank)	3.5	3.1	3.7	4	0.5	1.6	4
Maximum Age (years)	115	97	115	138	30	47	191
Maximum Height (metres)	25	23	26	28	4	11	33
SD of Age	18.8	6.7	16.4	28.5	15	0	79.9
SD of Height	6.3	2.3	6.6	9.8	4	0	13.9
Proportion Shrub	0	0	0	0	0.02	0	0.43
Proportion Herb	0	0	0	0	0.02	0	0.36
Proportion Agriculture	0.02	0	0	0	0.07	0	0.68
Proportion Water	0.02	0	0	0	0.07	0	0.76
Proportion Industrial	0	0	0	0	0.02	0	0.2

A complementary effort to model Canada Warbler (CAWA) with members of BAMs Technical Committee is emerging. Initial discussions between Ontario Ministry of Natural Resources (Rob Rempel), Natural Resources Canada (Lisa Venier), EC-CWS-ON (Rich Russell) and BAM commenced in 2011-12, with anticipation of further effort to develop, test, and validate models with additional data collection. Modelling would focus on identifying patch, landscape and regional factors affecting the distribution and abundance of CAWA and associated species. The approach would be informed by regulatory and other regional management needs as articulated by provincial and federal collaborators.

3.2.4.2 Regional Olive-sided Flycatcher-Habitat Modelling in Alberta

Initial models of habitat associations for Olive-sided Flycatcher (OSFL) in Alberta were conducted using BAM dataset (including BBS) and data contributed by the Alberta Biodiversity Monitoring Institute. Results will be included in a report from ABMI anticipated in 2012-13, which will acknowledge BAMs involvement. General habitat associations corresponded well to expectations based on existing knowledge of the species' natural history: it preferred openings near riparian habitats, shrubby habitats, recent burns, and coniferous forests of various ages (Figure 13). OSFL prevalence was higher in the southern parts of the Boreal Natural Region.

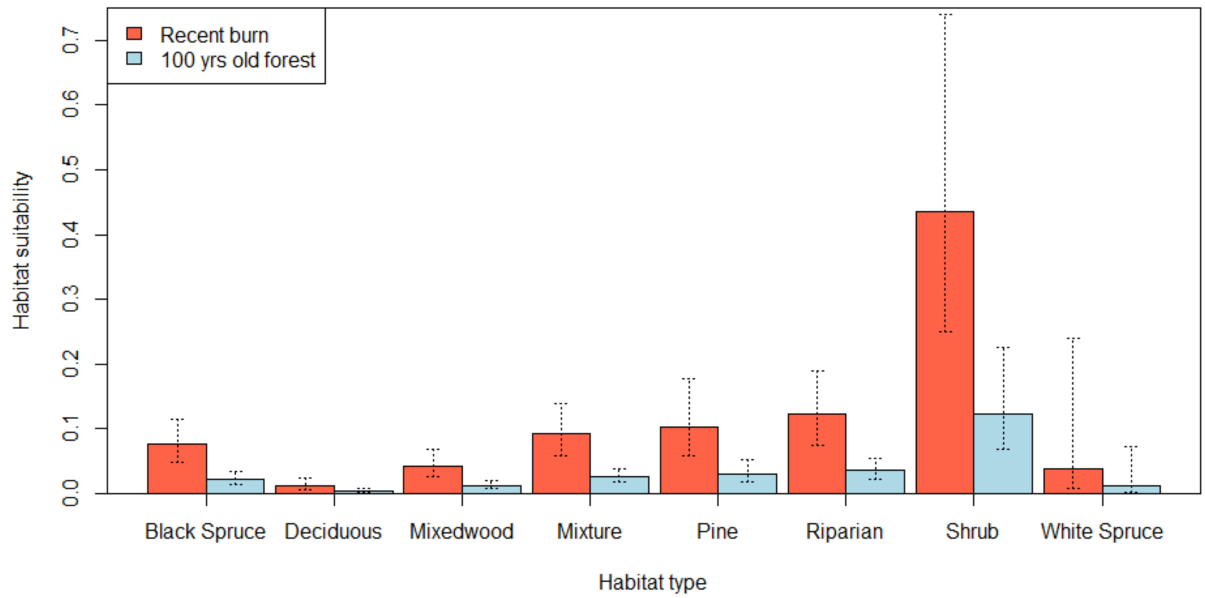


Figure 13. Habitat suitability for Olive-Sided Flycatcher in different habitats types. Dotted lines denote 90% confidence intervals.

Intermediate levels of human disturbance increased habitat suitability, but high disturbance led to low habitat suitability. The relationship with human disturbance was mostly driven by industrial and resource extraction features (Figure 14). Habitat suitability of the OSFL showed no relationship with the proportion of linear features (pipelines, transmission lines) and showed a slight decline with roads. Habitat suitability slightly increased with the proportion of clearcuts. Habitat suitability showed a significant and nonlinear relationship with industrial features (i.e. oil and gas well pads) with highest habitat suitability at intermediate disturbance levels, and this disturbance type drove the relationship with total human disturbance as well. This species preferred openings created by natural disturbance, but not openings created by forestry activities.

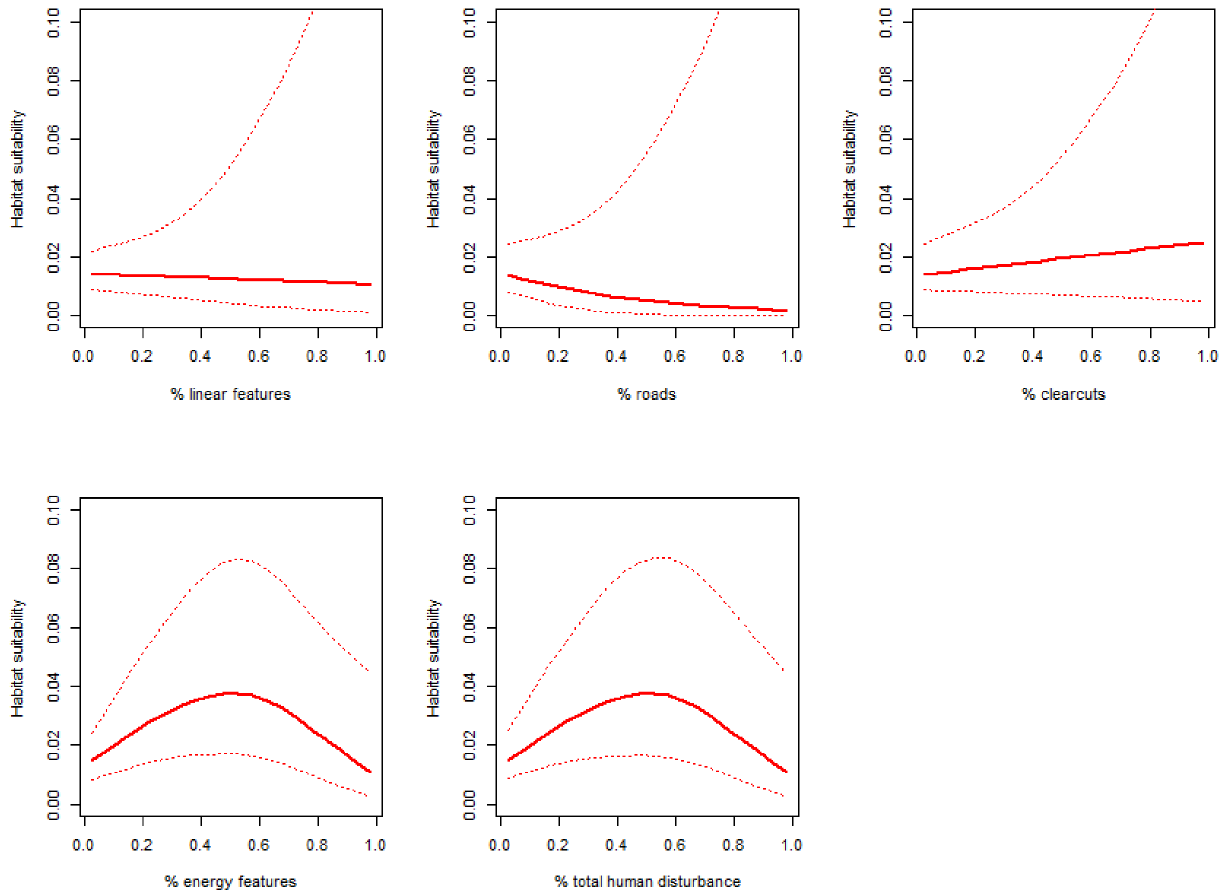


Figure 14. Habitat suitability for OSFL as a function of proportion of anthropogenic disturbance types and total human disturbance. Dotted lines represent 90% prediction intervals.

3.2.5 Recommendations for common standards for conducting avian point-count surveys

BAM has worked very hard to use efficiently the myriad types of data that are available. Many challenges BAM faced in developing new statistical techniques could have been avoided if ornithologists had used common methods to collect data. In 1991, ornithologists met and developed common standards for establishing and conducting avian point-count surveys (Ralph et al. 1993, Ralph et al. 1995). Their goal was to direct the proliferation of surveys that soon followed across North America so that the data on avian abundance could be widely compared and jointly stored and analysed by national data centers.

In 2011–2012, we reviewed how widely point-count protocols were standardised in northern North America. We identified some of the problems that occur when protocols are not standardised. We also reviewed the common standards for conducting point-count surveys to evaluate whether they are still relevant today and how they might be revised to accommodate recent changes in methodology.

We examined a dataset of 196,000 point counts compiled from disparate studies across Canada and Alaska and found that researchers used 49 different combinations of the count period, the count radius, and the subintervals therein. Only 3% of the surveys followed the protocols recommended by Ralph et al. (1993, 1995) for both the count period and radius. This greatly complicates how the data can be compared and analysed across studies. Our analyses across 88 species of birds indicated that avian counts increased by an average of 67% from a 3-min to a 10-min survey and 177% from a 50-m radius survey to an unlimited-radius survey. These are the very problems that survey standardisation was originally designed to avoid. The BAM team has developed models to adjust the surveys for variable count periods and radii (Sólymos et al. in preparation). However, these models require the surveys to be conducted relative to multiple time and distance intervals, and only 11% of the surveys across Canada and Alaska did both. Thus, standardisation of point-count protocols in the boreal region would greatly help BAM minimise these problems in our future analyses.

Since 1991, point-count protocols have been adapted in several different ways to adjust the surveys for incomplete detection rates (Nichols et al. 2009). All of these sample-based methods require the surveys to be conducted relative to multiple time intervals (removal models), count radii (distance sampling), observers (multiple-observer methods), or visits (repeated counts). Thus, these aspects of protocols have changed the most since Ralph et al. (1993, 1995). However, we feel that the common standards are still quite relevant today and recommend that they continue to form the minimum standards for data collection during point-count surveys. In our reports, we also provide recommendations for additional data that biologists might chose to collect if they require more accurate and precise estimates of abundance that are now afforded by the more complex forms of the sample-based estimators of abundance. However, we suggest that biologists carefully evaluate their objectives when considering these methods, which complicate data collection (sometimes greatly so), but often only result small to modest increases in accuracy and precision in abundance estimates (Johnson 2008).

In collaboration with EC, BAM has produced drafts of 3 reports in 2011–2012 that address protocols and standards for conducting point count surveys in the boreal forest. The first is a technical report for Environment Canada describing recommendations for conducting point count surveys of boreal birds (Mahon and Matsuoka in preparation) which should inform the design of future monitoring efforts conducted and/or supported by Environment Canada. The second will be a broader discussion of the science supporting the recommendations and will be submitted for publication in Condor (Matsuoka et al. in preparation-a). The third report (Bayne et al. 2011) outlines BAM's concerns with using multiple visits methods based on visiting sites repeatedly (available at http://www.borealbirds.ca/files/Bayne_et_al_2011_Bias_In_Estimation_Rpt.pdf).

A preliminary summary of our recommendations will be posted on our website in Spring 2012. These are based on a thorough review of the literature and insights from BAM analyses, relative to four aspects of point count survey protocols that have exhibited the greatest variation over the past 20 years. Some key points are excerpted below.

Count period

- *Minimum standard*.— The count period should be 5 or 10 min, depending on travel time between points. The initial detections of each bird should be recorded in 0–3, 3–5, and 5–10 min subintervals, the latter only for a 10-min survey (Ralph et al. 1995).
- *Additional data*.— Researchers requiring more accurate and precise estimates of abundance should consider (1) further subdividing the 5- or 10-min period into 4 or more equal time intervals and/or (2) recording the detections and redetection of each bird relative to each time interval. This information will allow more complex models of heterogeneous detection probabilities to be fit to the data using removal models (Farnsworth et al. 2002) and the more complex time-of-detection models (Alldredge et al. 2007).

Count radius

- *Minimum standard*.—All observed birds should be recorded to maximise the number of birds detected. Bird initially detected within a 50-m radius surrounding the count stations should be recorded separately from those birds initially detected beyond 50 m (Ralph et al. 1995).
- *Additional data*.— Researchers requiring more accurate and precise estimates of abundance using distance sampling (Buckland et al. 2001) should consider measuring exact horizontal distances to birds, or recording the initial detections of birds relative to four or more distance intervals bound at 10, 25, 50, 100, 200, >200 m (Rosenstock et al. 2002), with 50 m always included as one of the interval boundaries.

Number of observers at a count station

- *Minimum standard*.—A single observer should conduct the survey at a count station (Ralph et al. 1995).
- *Additional data*.—Researchers requiring more accurate and precise estimates of abundance may consider conducting a survey with 2 or more observers using one of the multiple-observer protocols (Alldredge et al. 2006, Riddle et al. 2010). The data, however, must be separated among observers when compiled and jointly analysed with surveys conducted by single observers.

Number of visits to each count station

- *Minimum standard*.—It is better to increase the number of statistically independent sampling stations than to repeatedly count a smaller number of stations (Ralph et al. 1995). Members of BAM (Bayne and Solymos) have invested considerable effort in developing statistical techniques that address the value of repeat-visit surveys for density estimation.
- *Additional data*.— Researchers should carefully examine the costs and benefits of visiting a site multiple times. We have shown through simulations that most of the existing BAM data cannot be evaluated using multiple visit methods because the underlying assumptions of this approach is violated. Revisiting sites can increase the number of species that are detected and helps with detecting birds with different timing of singing (i.e. increase coverage of optimal survey periods for resident species versus short- and long-distance migrants). However, estimation of density using repeated-count methods (Royle 2004, Chandler et al. 2011) can be very problematic unless very strict

assumptions are met; to date, repeated surveys conducted in the Canadian boreal region have not satisfied these criteria.

3.2.6 Assistance for monitoring design

The tools described above will help evaluate priorities for monitoring across the North American boreal forest and design monitoring protocols. BAM has also provided assistance for the design and implementation of new monitoring initiatives, particularly the July 2011 and February 2012 announcements of monitoring of the impacts of oil sands development on terrestrial biodiversity (Environment Canada 2011, Environment Canada and Government of Alberta 2012) and the landbird components therein.

A major emphasis of oil sands monitoring is to monitor the cause of observed changes as well as to monitor the direction and magnitude of change. For migratory birds, Environment Canada is employing a model-based approach to estimating cause-effects relationships that will draw from existing methodologies and results from BAM. This proposed work requires a variety of information including data and data products to define and quantify relationships between target species and natural habitats. Characterising habitat relationships for terrestrial landbirds in the western boreal forest has been conducted primarily by BAM and associated partners and collaborators (Alberta Biodiversity Monitoring Institute, Government of Alberta, Alberta-Pacific Forest Industries Ltd.) Ongoing delivery of oil sands monitoring will require collaboration between Environment Canada and BAM to build on existing work to quantify, evaluate, and validate comprehensive bird-habitat relationships for terrestrial landbirds in the oil sands areas.

In addition to the on-going work described above, subsections of the BAM dataset were recently used to identify gaps in existing status and trend monitoring of landbirds in the oil sands areas using precision analysis (under a contract tendered by Environment Canada). BAM data were used to demonstrate the importance of the spatial scales and types of sampling required to detect the impacts of forestry and energy sector development. The results demonstrate that point count distance and how point counts are distributed relative to human footprint strongly influence our ability to detect the impact of land use development on bird population size. Directed studies targeted at specific human disturbances provide the most efficient approach to understand how bird abundance is influenced by specific human disturbance features. Clustered point count surveys within landscapes dominated by specific disturbance types describe bird communities in and around human disturbance features and may include both positive (edge) and negative (disturbance) effects for many species. Results suggest that information obtained from both directed studies and landscape studies will be needed to understand trends in bird abundance within the oil sands region.

The habitat relationships built by BAM as part of Alberta Forest Songbird Information System (AFSIS) were also used to evaluate the potential for habitat-specific stratification for monitoring the status and trend of a sub-set of terrestrial landbirds not currently meeting target precision levels in the oil sands areas. For 14 species with enough data to analyse stratified designs and not currently meeting target precision levels in the oil sands region, results suggest that compared to the systematic design, the stratified design improved the precision of trend estimates for only seven of the 14 focal species. The stratified design targeted sampling in old spruce forest types; 10 of the 14 species were associated with old upland spruce or old lowland spruce habitat types (habitat types with limited representation within the study area). The results of this analysis demonstrate that while stratification can improve the precision of estimates for targeted species, it would result in reduced precision for other species. This is due to the difficulty of developing a common stratified sampling design for many species. This implies that tradeoffs will exist between monitoring cost and precision for uncommon, peripheral, or rare species.

3.2.7 Summary of BAM Accomplishments within Objective: Species Assessment and Monitoring 2009 – 2012

- Analyses and manuscript completed for evaluating the relative importance of 131 climate and vegetation variables for national-scale avian abundance. Importance was assessed based on frequency of selection mean and explanatory power in Classification and Regression Tree (CART) models for 97 boreal songbird species. Results were used to identify important biophysical variables for incorporation into future monitoring efforts.
- Distribution models and maps created for 88 species using Maxent modelling techniques.
- Developed and refined analytical techniques to deal with:
    - issues of detectability (availability and perception biases);
    - biases in survey coverage associated with geographic and habitat strata;
    - standardising point-count data collected over different survey periods or with different sampling protocols;
    - roadside biases in survey counts (particularly important when integrating BBS data).
- Prepared 11 scientific publications and five technical reports to support our techniques.
- Estimated avian densities in relation to forest type and age in northeastern Alberta to be used within land use planning frameworks; this regional information will be posted on the website in Spring 2012, and serves as a prototype for undertaking analyses at the national level.
- Prepared regional-scale models of Canada Warbler and Olive-sided Flycatcher in Alberta, and initiation of complementary regional modelling effort on Canada Warbler in Ontario.
- Conducted preliminary analyses and discussions with TC members about regional variations in habitat selection across Canada.
- Recommended methodology for conducting point-count surveys developed in collaboration with Environment Canada to improve the utility of point count survey data. A general summary will be provided on our website in Spring 2012.
- Gap analysis conducted and results reported to Environment Canada to address geographic and habitat gaps in current Atlas coverage of boreal bird surveys.

An ongoing objective is to refine how we estimate boreal bird populations and understand the factors that drive uncertainty. With the advancements in density estimation that we have achieved this year, we will now be able to more specifically address the question of absolute population estimates for boreal bird species. We continue to narrow the range of plausible population estimates by critically evaluating how much variation in population estimates can be explained by: 1) different approaches to measure bird abundance (i.e. point count type); 2) statistical approaches to dealing with detection error; 3) spatial scale of mapping models; 4) how time lags and natural variation affect population estimation;

and 5) variation in the underlying definitions of habitat as defined by different remote-sensing products. BAM's goal is to ensure that the most robust methods to achieving plausible population estimates are identified and to ensure that the level of uncertainty at each step is identified.

3.3 Selecting and developing avian habitat data layers

3.3.1 Update on Common Attribute Schema/Forest Resource Inventory (CASFRI)

Digital Forest Resource Inventory (FRI) data have been used to model avian habitat selection and abundance in many studies from the Canadian boreal forest region. FRI data are valuable because they provide greater thematic precision than can be obtained from any routinely-available satellite data; this includes measured canopy heights, estimated ages, and details of canopy species composition. However, details of inventories differ across Canada; each province, territory and National Park has their own standard(s), some of which change over time. To facilitate national modelling studies directed at the effects of forest management on forest songbirds, BAM has participated in a massive effort to assemble and standardise all Canadian digital Forest Resource Inventory data (Cumming et al. 2010b). To do this, we developed a standard representation of key forest inventory attributes that are common across all or most Canadian inventories. Our system represents all versions of these attributes in a standardised, documented format, without any loss of information. This standard is known as the Common Attribute Schema (for Forest Resource Inventory) or CASFRI (Cosco 2011).

As of 2010-11, Version 1 of the CASFRI project was completed for the boreal region of Canada as defined by BAM in 2006. Since then, it was decided to follow the new boreal boundaries of Brandt and to extend the spatial extent of the project into the newly defined hemiboreal region (Brandt 2009). The Canadian hemiboreal includes much of interior British Columbia west of the continental divide, the aspen parklands of Alberta, Saskatchewan and Manitoba, southern transitional forests in Ontario and Québec, and the Atlantic Provinces of Prince Edward Island, Nova Scotia and New Brunswick (PE, NS, NB). The CASFRI project already addresses the full boreal region in Canada (as contained in available FRI) and the commercially forested hemiboreal region for all regions except the Atlantic Provinces (Fig. 15).

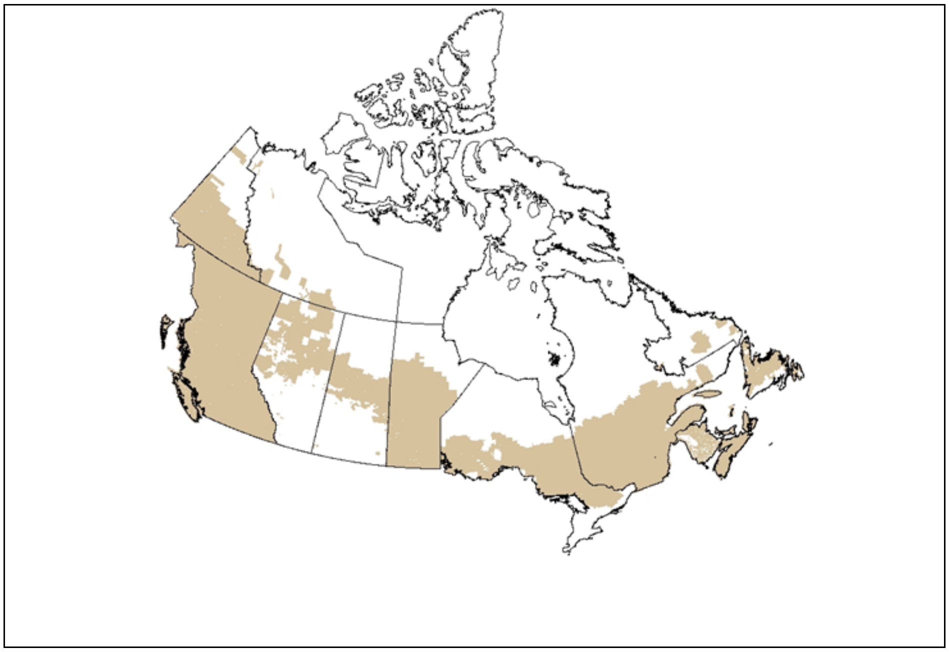


Figure 15. Current coverage of Forest Resource Inventory (FRI) data compiled under CASFRI.

3.3.2 Expansion of CASFRI to Atlantic Canada in 2011 – 2012

The 2012 amendment to BAM's EC Contribution Agreement provided for expansion of the CASFRI into the Atlantic Provinces. This is a multi-step process, as described below.

1) We begin by acquiring the digital inventory, metadata and documentation from the owners. In many cases, a data sharing agreement is required.
2) The raw data are then uploaded to a GIS where a unique CASFRI identifier is assigned to each polygon.
3) The Forest Resource Inventory data are derived from aerial photographs, and represent forest conditions at the time of photography, not the time of any particular survey. Therefore, we also acquire photo-year information and link it to each polygon. Where this is not possible, a range of photo-years is associated with a record for a larger spatial unit containing the polygon, corresponding to Forest Management Units.
4) The polygon attribute tables are exported as text files.
5) A custom Perl or Python script is written which implements the inventory-specific translation rules described in the CAS documentation (Cosco 2011).
6) The exported tables are translated into CASFRI using the appropriate translation scripts. Certain errors or oversights in the translation rules are detected and corrected at this step.
7) The translated tables and the original shape files are finally uploaded into PostGIS where they are re-projected as necessary and where the geometries are corrected using an automated methodology developed to correct inevitable errors in a dataset that presently contains more than 25 million polygons.

When a new inventory is added to the system, there is a parallel step where all the commands necessary to implement the preceding steps are encoded in a new function which is added to the main script that automates this entire process. This is essential so that the process can be replicated.

As of March 23, 2012, Steps 1-6 had been completed for PE and NS. Steps 1-5 had been completed for all provincial and federal crown forests and private woodlands in NB, and step 6 was in progress. We expect to substantially complete incorporation of the Atlantic Provinces into CASFRI by March 31, 2012, although final upload into PostGIS (step 7) may not be possible until April 2012.

We note that roughly 30% of NB forests are freehold lands where the inventory data are private property. Initial attempts to obtain permissions on these data were not successful. BAM or EC will need to explore alternate means to encourage forest companies operating in NB to provide this information. We have sought advice and assistance from EC-CWS Atlantic region in this regard.

3.3.3 Notes on future expansion and updates of CASFRI coverage

Brandt's boreal boundary encompasses large areas of interior Alaska south of the Brooks Range. No FRI data exist for these parts of Alaska, because commercial forestry in only economic in some of the non-boreal coastal temperate rainforest. This is unlikely to change in the foreseeable future. The hemiboreal region extends into the upper–tier states of the United States. It includes parts of the Upper Midwest (Michigan, Minnesota, and Wisconsin) and New England (Maine and New Hampshire). Forestry is practised in these areas. Hence, it may be possible in future to obtain FRI data from the individual states, or the USDA Forest Service. However, we have not assessed availability of such data, or the possibility of reconciling them with the CASFRI standards. Substantial updates are expected to be available for Alberta and Manitoba, early in 2012 fiscal year. These will be incorporated as they become available.

3.3.4 Applications of CASFRI to BAM core mission in 2011-12

In 2012, we initiated three main tasks using the CASFRI data. First, we produced tables of CASFRI attributes for 200-m circular buffers around all BAM avian data locations in regions covered by the FRI. These tables support the first national models of avian species abundances using FRI data, initially for Canada Warbler and Olive-sided Flycatcher. These models were to have been built in 2011–2012, but required some specialised classification by tree species groups and non-forested habitat types that was not completed by March 2012. This work is now scheduled for May 2012.

Second, we are constructing tables of the taxonomic family of the dominant canopy tree species and site habitat class at BAM avian data locations in Eastern Canada to improve performance of BAM models. This information was used to validate the species-distribution models developed by Dr. Jean-Luc DesGranges (as reported in BAM 2010–2011 progress report). The final report to EC is now awaiting translation. As noted in Section 4.10, the main findings relevant to BAM were that attributes derived from the CASFRI markedly improved the performance of BAM models that had been built using only interpolated climate data and remote-sensed landcover data. This finding provides some initial justification for the enormous effort expended on assembling the CASFRI data.

Third, we produced a complete set of input data for the Tardis simulation model, by intersecting the CASFRI coverage with the 300 arc-second landscape grid in PostGIS (see Section 3.4.1). The main implication is that the CASFRI database can be used for spatial modelling projects at national extents, and that the PostGIS system we built is capable of reliably processing these enormous datasets. The task of intersecting the CASFRI data with the Tardis grid takes about four days of processing time on the modest 32-bit machines we currently have available.

In the course of this work, numerous errors or omissions in the CASFRI standards were detected and corrected, as were many errors in the underlying FRI data provided by the data holders. The most serious error only came to light in March 2012. It pertains to spatial overlap in the contributed data, usually at jurisdictional boundaries. The problem is most severe in Alberta, where some polygons are replicated five times. A general solution to the overlap problem is being implemented in PostGIS. As a temporary measure, a uniform and unduplicated coverage was created for Alberta in mid-March 2012. It will be necessary to redo items 1 and 3 above using the corrected CASFRI data.

3.3.5 Summary of BAM Accomplishments within Objective: Selecting and Developing Avian Habitat Layers 2009 – 2012

- Assessment of MODIS LCC05 (reclassified from 39 to 17 categories) as an appropriate satellite land cover imagery for bird habitat association modelling with the BAM avian dataset.
- Recognition that the expansion of the study area to include Alaska may necessitate a shift to using a North American-wide habitat layer available from to permit boreal-wide integration.
- Creation, implementation, and testing of the Common Attribute Schema (CASFRI) used to standardise the highly-disparate Forest Resource Inventory data collected by different agencies and companies across Canada (in conjunction with BEACONs).
- Expansion of the CASFRI into the Atlantic provinces.
- Applied the completed trans-boreal Common Attribute Schema (CASFRI) to the Forest Resource Inventory data to produce tables of timber volume-age by tree species for parts of Canada. These tables will be used in simulation modelling to assist in the prediction of the structure and distribution of forests needed to understand avian habitat.

As with the avian database and other biophysical databases described in Section 3.1, ongoing efforts are required to keep the CASFRI databases current, as new Forest Resource Inventories are completed.

3.4 Risk characterisation, impact assessment and forecasting

To evaluate risks to the boreal forest, we are developing national scenario tools to document how forests have changed from the past and will change in the future as a function of land-use and climate change across boreal North America. We also have partnered with various regional collaborators to implement the bird models described in 3.2.4.

3.4.1 Tools for national scenario analyses

Over the last ten years, Cumming has developed "Tardis," a suite of methods and software for low-spatial resolution simulation over very large areas, targeted at forest management (Cumming and Armstrong 2004) and natural disturbances (Krawchuck and Cumming 2011) in the boreal forest. Tardis is a grid-based model. The current version uses the 300 arc second grid used by Natural Resources Canada to interpolate climate surfaces (McKenney et al. 2006); climate change scenarios can also be downscaled to this grid. Thus, Tardis can conveniently be linked to present and projected future climate surfaces. Model cells are approximately 100 km^2 in southern Canada, a very small size in a national context. The current version of Tardis is initialised from the CASFRI inventory. Every model cell keeps track of the areas, age structure and species compositions of forested patches, and the total area of various non-forested habitats. The use of FRI allows the model to integrate forest management and avian habitat models (Hauer et al. 2010).

At the BAM Technical Committee meeting in November 2010, it was decided to adopt Tardis as a national strategic framework to evaluate BAM's avian habitat models in the context of forest management, climate warming and protected areas design. BEACONs is also adopting this platform for broader conservation planning initiatives. Since 2010, a massive effort has been underway in Cumming's lab at Laval to develop the first national version of Tardis.

In 2009 - 2012 we focussed on assembling all the forest management-related data needed to run Tardis nationally. To do this, it was necessary to:

1) Identify the locations, capacities, and main products of each large primary forest products mill in Canada;
2) Estimate the annual volume required by tree species or species group (e.g. hardwoods vs. softwoods) and determine how this was allocated spatially; and
3) Obtain tabular growth and yield data for each jurisdiction.

Task 1 began in 2010 and has now been completed. The results for each jurisdiction will be fully documented in a forthcoming report.

For Task 2, it was necessary to depict spatially the source of fibre for each mill. For area-based tenures (usually called "Forest Management Agreements") this is well defined. However, most mills in Canada operate under volume-based tenures, where they obtain a certain proportion of their requirements from specified areas that they do not otherwise manage. Every jurisdiction in Canada is divided into regions equivalent to Forest Management Units, and it was first necessary to assemble a national map of these units from the numerous local maps (Fig. 16). A similar map defines all the Forest Management Agreement Areas, which form a separate spatial zonation. Annual species-specific volume requirements and the current distribution of supply among FMUs was determined by contacting each province's responsible department. This has been completed for every province except Ontario. Ontario provided us a large access database detailing every wood allocation from FMUs to mills or other users over the past 15years. Considerable processing is still needed to derive the information we require from this source; this work should be completed in April 2012.

The final critical components needed to run the model are stand volume-age tables, which estimate the volume of harvest by species group as a function of age. Using geographically-appropriate sets of tables is critical for model credibility in the forest management milieu. Typically such tables are produced for a relatively small number of generic forest types (e.g. cover group, strata). In most provinces, different families of tables are used in different geographic sub-regions as differences in soil development and climate greatly influence forest productivity. The tables we require are rarely available in an easily usable form. We have obtained what information is available from each province in Canada (excepting the Atlantic Provinces), and have derived the precise tables needed by Tardis for QC, AB and SK. Tables for NF, ON, MB and BC are in progress and should be concluded by end of April 2012.

A near-national rollout of Tardis, linked to FRI-based models of Canada Warbler and Olive-sided Flycatcher abundance at the cell-level, is expected by end of June 2012. Extension of Tardis to the Atlantic Provinces would require significant effort to obtain volume-age data and mill locations, as well as software development to adapt the model to simulate forest management on woodlots and private lands, which are much more important in the Atlantic Provinces than elsewhere in Canada.

This enormous effort of data assembly is applicable beyond Tardis applications. It can be used to support other widely-used modelling platforms. For example, the FRI, mill and volume-age tables could be used as inputs for regional applications of the aspatial simulation model ALCES, or for high-spatial resolution landscape models. This represents great savings in initial data assembly, often the greatest cost of applying ecological models to new areas and problems.

As noted, the Tardis national rollout is in progress, and accordingly we do not have national projections for how bird populations or distributions will change in the future. As shown in section 3.2, great care needs to be taken to understand the sources of variation that influence how we estimate avian population size. It is equally important to understand how different descriptions of the amount and type of forest currently present and likely to be present in the future must be carefully considered to understand variation in predictions about bird populations. A fundamental challenge that requires considerable data checking is dealing with differences in time between when the avian data were collected at a particular point and when the aerial photographs that were used to describe the forest conditions were taken. Many of the locations have been disturbed by harvesting or fire between the years of sampling and photography. Careful analysis is needed to develop criteria to exclude avian samples for which the FRI data may not reflect the vegetation present at the time of avian survey. The difficulty of this task is magnified by the large number of different Forest Resource Inventory products.

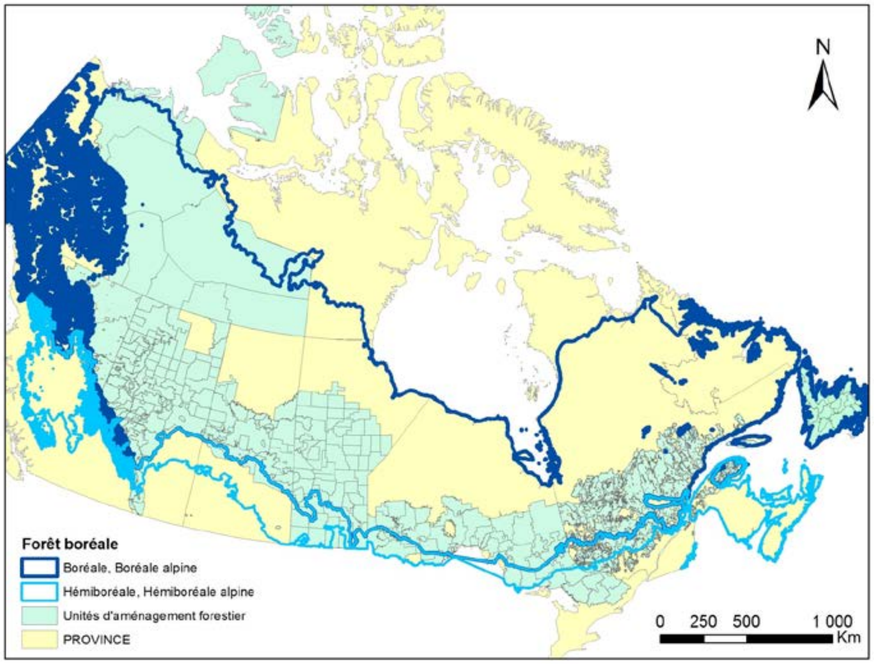


Figure 16. A national map of Forest Management Units in Canada, as used by Tardis in spatial resource allocation. Legend: Boreal Forest: dark blue line is boreal and alpine boreal region; light blue line is hemiboreal and alpine hemiboreal region; shaded blue areas are forest management units.

3.4.2 Tools for estimating impacts of climate change

Diana Stralberg, a member of the BAM team and a PhD student supervised by Erin Bayne and Fiona Schmiegelow, has begun to develop predictive bioclimatic models of avian distribution that can be used to project climate-related distribution shifts under various future scenarios. This modelling is being conducted at two different spatial scales (entire boreal region vs. Alberta) with different levels of spatial resolution and detail. Both efforts directly consider projected vegetation changes, and evaluate the constraints imposed by current vegetation and edaphic conditions. Human and natural disturbances are also being considered. Final models will utilise BAM density correction factors, and the approach of modelling density with generalised linear mixed models (Sólymos et al. in preparation). Conservation implications will be assessed for individual species and regions.

In 2010–2011 we downscaled (4-km) climate projections for a set of 24 global climate models (see 2010–2011 report). In 2011-12, we used the random forest algorithm (Breiman 2001) to predict ecoregions (North American level III ecoregion classification, CEC, http://www.cec.org/Page.asp?PageID=122&ContentID=1329) based on our derived bioclimatic variables. We then projected the locations of ecoregions in three future time periods (2011-2040, 2041-2070, 2071-2100) using the SRES A2 emission scenario, 19 climate projections using different global circulation models (GCM), and the most frequently predicted future ecoregion type among the 19 GCMs for each time period. Future ecoregions within the southern portion of the boreal forest region were projected to resemble those currently found in the Great Lakes and New England states of the U.S. We have begun to gather avian survey data in these regions to improve our projections of species distributions relative to future climate scenarios.

We also used our downscaled climate projections to develop preliminary projections of avian species distributions using an earlier iteration of Maxent models containing climate covariates only. Models suggested the potential for dramatic climate-related shifts in boreal bird distributions over the next century, with little projected overlap between current and future species distributions for many species (Fig. 17A, B, C). To evaluate the potential for constraints on vegetation change to affect avian distribution shifts, we have begun to develop and evaluate bioclimatic models for boreal/hemiboreal/tundra vegetation types, which may be used as inputs to next-generation bird models.

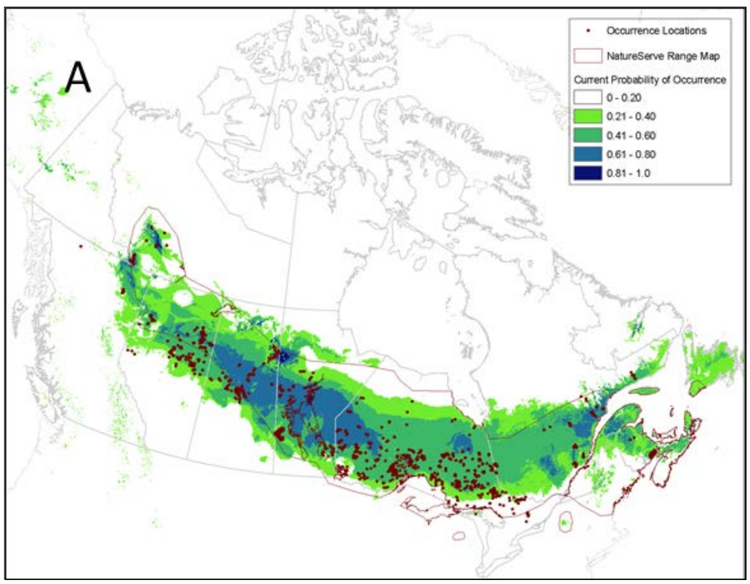
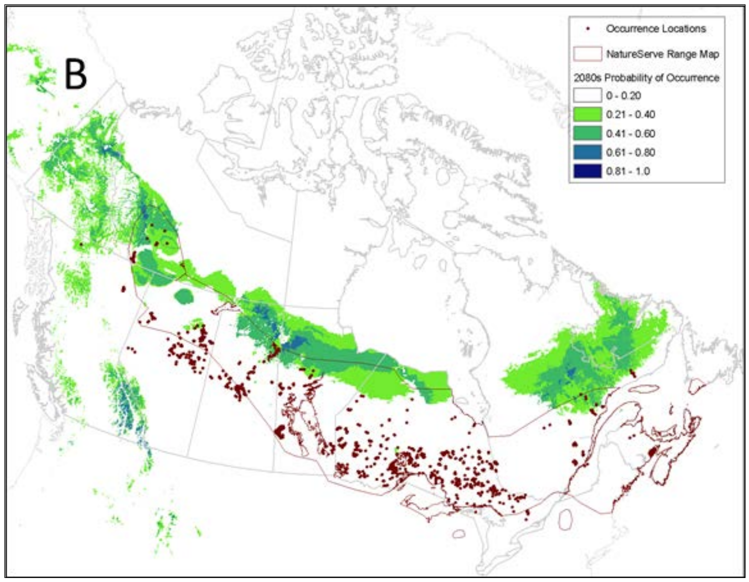


Figure 17A. Maps of A) the predicted current distribution (1961–1990) and B) the projected future distribution (2071–2100) of the Bay-breasted Warbler. Maps are based on species distribution models developed using program Maxent, bioclimatic variables downscaled to a 4-km resolution, and projected future climate conditions for the GFDL climate model under the SRES A2 emission scenario. We also show (C) the area of overlap between current and future distributions to emphasise areas that might be important refugia during climate transition.



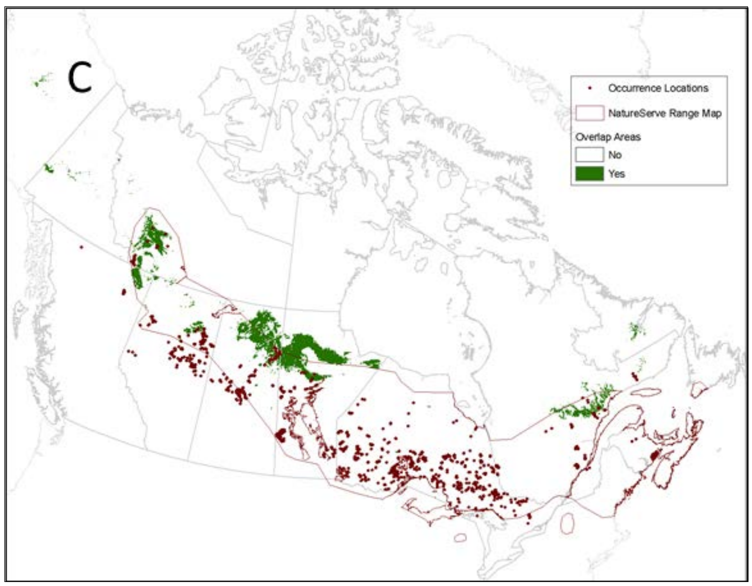


Figure 17B and 17C. Maps of A) the predicted current distribution (1961–1990) and B) the projected future distribution (2071–2100) of the Bay-breasted Warbler. Maps are based on species distribution models developed using program Maxent, bioclimatic variables downscaled to a 4-km resolution, and projected future climate conditions for the GFDL climate model under the SRES A2 emission scenario. We also show (C) the area of overlap between current and future distributions to emphasise areas that might be important refugia during climate transition.

3.4.3 Tools for regional land-use planning

BAM is participating in the process to implement the Partners in Flight (PIF) five elements process for stepping down continental population objectives to regional and local scales in the boreal forest of North America (Will et al. 2005). The five elements process represents an approach to identify biologically-based, landscape-oriented habitat objectives to support and sustain bird populations within Bird Conservation Regions (BCRs).

BAM continues to work with various partners to achieve these objectives across the country by assessing current habitat conditions, evaluating species distributions, understanding bird-habitat relationships, developing bird population projections for the future, and identifying conservation opportunities. We assert that only with a procedure to translate continental population objectives into habitat-specific, numerical population objectives at both sub-BCR (local) and BCR (regional) scales will conservation be effective. Our principle collaborators to date include the ALCES group, Canadian Boreal Initiative, Canadian Wildlife Federation, Alberta Pacific Forest Products Inc. (ALPAC), Alberta Land-use Framework, and Alberta Sustainable Resource Development. As awareness of BAM efforts increases, we anticipate expanding our regional modelling efforts.

Models in these areas are being updated continuously with new information on forest processes, fire dynamics, land management policy, and bird populations as better information is generated. These models do not specify an absolute truth, but continually improve our ability to predict change with integration of more information.

3.4.3.1 Example from the Alberta Pacific Forest Industries Inc. (ALPAC) Forest Management Agreement (FMA)

In 2011-12, BAM along with EC completed a detailed evaluation of natural (wildfire) and land use disturbances (forestry, energy, transportation, and human settlement) and the implications for boreal forest-associated birds in the 6.8 million ha ALPAC FMA (Mahon et al. in preparation-a). The goal of this project was to step down the Partners In Flight (PIF) continental population objectives into habitat-specific, numerical population objectives to determine if expected future habitat conditions could support proposed population objectives for forest-associated birds in BCR 6 (Mahon et al. in preparation-a).

This study highlights how BAM is integrating our work on density estimation, development of forest age / forest composition models, and future scenario analysis to determine risks to boreal birds caused by natural and land use disturbance. We believe this approach is a model of how BCR target-setting could incorporate current and future realities in planning processes.

In this particular application, we conducted a habitat assessment to summarise the current availability of forested habitat types within the FMA using Forest Resource Inventory data. Data from 52,552 point counts from 13,342 survey locations within the boreal regions of Alberta were used to model predicted bird densities within all forested habitat types using local-scale attributes of forest type and age. In this region, we are able to parameterise models for 20-year age increments for all major leading tree species. (In many other areas of the country insufficient data exist to obtain this resolution.) We then applied habitat-specific density estimates for boreal songbird species to current and future landscape conditions to predict changes in population size.

Our models project substantial changes to bird populations over the next 50 and 100 years in the ALPAC FMA for 74 species of boreal bird species under current land management protocols (Business As Usual) in the region (Fig. 18). Below we show examples for three bird species where we compare the proposed population objectives for BCR 6 to our estimates of population size in 30 years (2011 – 2041) under three land management scenarios applied to the ALPAC FMA: Business As Usual; Protected Areas; and Climate Change. Our results suggest that all three scenarios fall short of the proposed population objectives (Table 5) due to changes in the availability of high-suitability habitat. Thus, consideration of revised population objectives in future BCR planning and implementation efforts is merited to reflect the realities of future landscape changes in the region. We feel that these kinds of dynamic land-use models are quite useful for quantifying threats to bird populations. These models can also be used to 1) link habitat change to population change, 2) develop population-based habitat targets, and 3) focus strategic conservation actions for multiple landbird species.

3.4.4 Identifying priority areas for avian conservation using MARXAN

In 2009 – 2010 and 2010 - 2011, we reported on a collaboration with EC to use the decision support tool Marxan to examine how two types of input data, species' range and species' habitat suitability, influence the identification of priority areas for conserving priority bird species in BCR 6. In 2011 - 2012, we completed our initial analyses which indicated that the polygons most frequently selected as priority areas differed by input data type. When we used species' ranges as the input data, the model selected blocks of polygons along the northern and southern edges of the BCR. When we used species' habitat suitability as the input data, the model selected smaller, discontinuous blocks of polygons throughout the BCR. Thus, our comparative analyses revealed that using species' ranges as input data overestimated the area occupied by species and underestimated the total amount of area that needs to be conserved in priority areas. Our models based on species' general habitat suitabilities and relatively coarse-scale habitat data selected priority areas that targeted the range of suitable habitats for each target species. We are currently using a third type of input data, species' habitat suitability based on finer-resolution habitat data. This will help us determine how the type and resolution of input data influences the identification of priority areas for forest birds. This report is currently in preparation and will provide an example of how to identify priority areas within a large, multi-jurisdictional BCR using available data on land cover, species distributions, and species habitat associations (Mahon et al. in preparation-b).

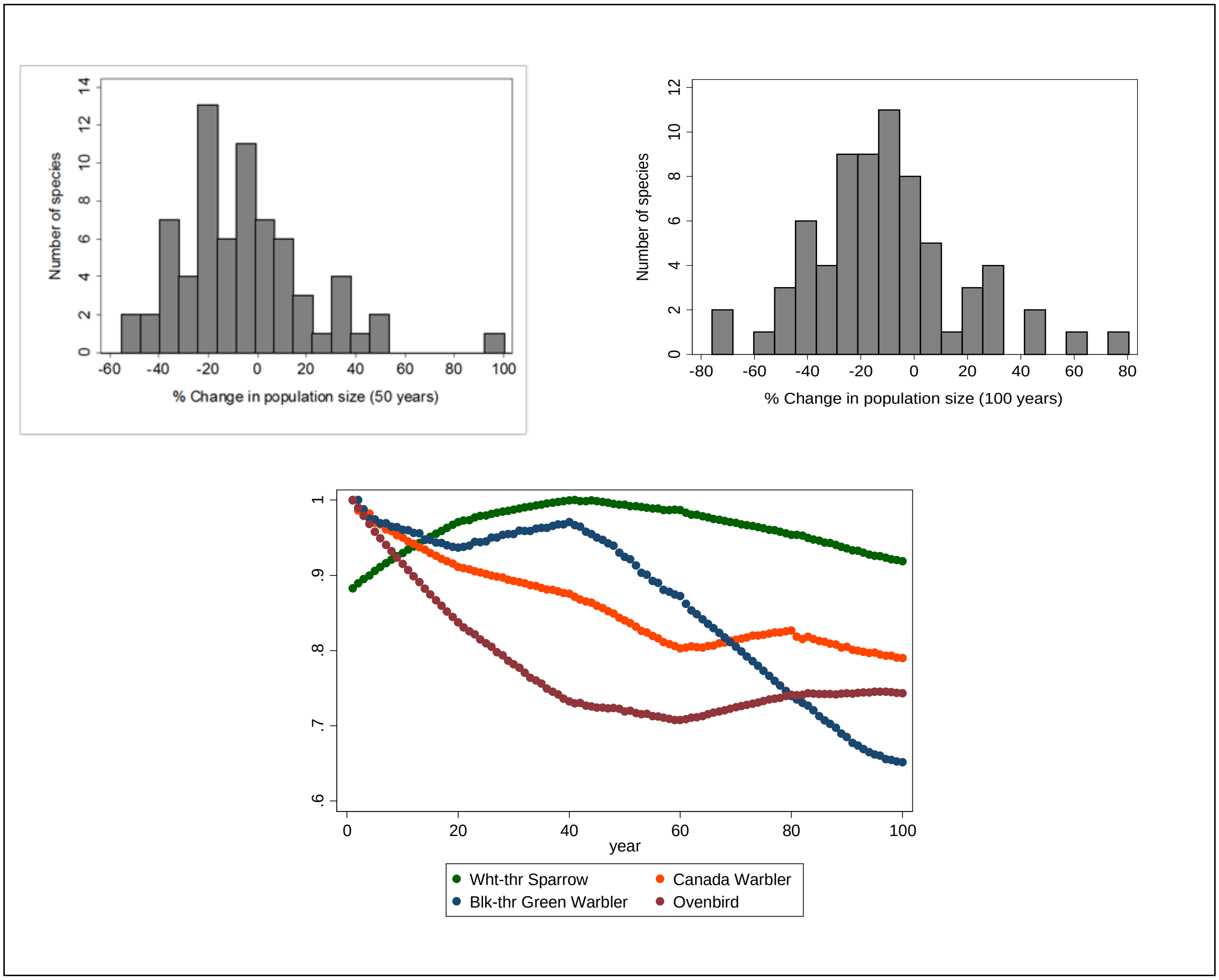


Figure 18. Percent change in relative population size for 74 species of birds over the next LEFT) 50 years and RIGHT) 100 years in the Alberta-Pacific Forest Industries Inc. Forest Management Agreement area. BOTTOM Panel shows examples of predicted trends in relative population size for selected species (deviation from maximum) if changes in forest type and age are dominant factors influencing trends in bird abundance.

Table 5. Population sizes of three species of boreal forest birds in relationship to population objectives for BCR6 (proposed objectives) and to current and future landscape conditions (30 years from now) for the Alberta-Pacific Forest Management Agreement area (FMA). Projections of future population sizes are based on three management scenarios in the FMA.

	Population size		Projected population size (30 years)		
Species	Current	Proposed Objective[1]	Business as usual	Protected Areas	Climate Change
Black-throated Green Warbler	160,455	224,638	158,715	158,902	151,578
Western Tanager	16,187	17,806	15,375	15,390	14,873
White-throated Sparrow	714,079	999,711	738,886	740,467	745,180

1. Projected from BCR 6 population objectives (Mahon et al. in preparation-a).

3.4.5 Tools for national-scale landscape design

The Canadian BEACONs Project, led by Dr. Fiona Schmiegelow and also supported, in part, by Environment Canada (Wildlife and Landscape Science Directorate), has been developing the scientific foundations and new methodologies for systematic conservation planning in the Canadian boreal region, and was a founding partner of BAM. The projects have maintained a long-standing collaboration on shared objectives. Part of BEACONs methodology is the design of optimal conservation networks. Optimality is assessed with the degree of ecological representation achieved subject to constraints (e.g. of total area meeting conditions for maintenance of dynamic system properties). The BEACONs approach is different in many ways from the MARXAN models considered above, but both are attempting to achieve ecological representation of conservation lands to facilitate biodiversity conservation. Because the full complement of biodiversity is unknown and unmapped, environmental surrogates are used in most applications. BEACONs has developed one set of surrogates, and their UBC collaborator, Nicholas Coops, has developed another suite. Both are based on first ecological principles, but neither has been evaluated against real biodiversity data. Such evaluation, or validation of surrogate sets, is of particular significance because these surrogates are being used in a gap analysis of protected areas now underway as part of the "Pan Boreal Assessment" being conducted by BEACONs under the auspices of the Canadian Boreal Forest Agreement (CBFA) http://canadianborealforestagreement.com/. BAM has worked closely with BEACONs to ensure that BAM's large suite of species distribution models can be used to evaluate the efficacy of the surrogate environmental variables proposed by BEACONs and others, and contribute to broader conservation planning initiatives, including the CBFA.

BEACONs' hypothesis is that "good" protected areas networks of a certain total size that achieves representation of a suite of environmental surrogates will hold a proportionate abundance of all species. This suggests an index of "representation quality" such that the mean proportional abundance of each species should be approximately the same, or conversely that the variance of this quantity among species should be low and inversely proportional to the expected degree of representation, as calculated from the environmental surrogates. BEACONs staff will conduct this analysis in May-June 2012, using BAM's Maxent species distribution models, and in collaboration with Diana Stralberg.

3.4.6 Summary of BAM Accomplishments within Objective: Risk characterisation, impact assessment and forecasting 2009 – 2012

- Refined the TARDIS regional spatial simulation model to incorporate FRI and climate data to predict avian responses to future landscape and climate changes.
- Tardis is now running over the entire region of Québec, Alberta and Saskatchewan simultaneously. Due to enormous efforts to increase the efficiency of the code, the model now runs fast enough to conduct Monte Carlo simulation studies.
- Climate change impacts on vegetation and boreal bird species using bioclimatic niche models being undertaken by PhD student under supervision of Bayne and Schmiegelow.
- Using spatial extent of the AlPac FMA and through collaboration with EC, demonstrated potential for applying PIF methodology for stepping down BCR 6 population objectives to derive habitat-based population objectives for forest landbirds under 3 management scenarios (business as usual, climate change, protected areas).
- Analysis of BAM dataset to identify priority habitats using Marxan modelling and a subset of boreal landbirds within BCR 6; comparison of priority network areas derived using species breeding range information versus more complex habitat suitability models.
- Developed preliminary projections of avian species distributions under climate change scenarios using an iteration of Maxent models containing climate covariates only.
- Provision of BAM data and distribution models to assist evaluation of principles for national-scale protected areas proposed by BEACONs and Canadian Boreal Forest Agreement.

Regional and national modelling efforts will continue to address the questions of habitat associations, assessment of impacts of land use and climate change on bird populations and distributions, and risk characterisation.

3.5 Community characterisation

3.5.1 Community clustering

As a preliminary exploration of the variation in avian community composition across the boreal region, we conducted an affinity propagation cluster analysis (Frey and Dueck 2007) using as inputs 10-km Maxent-based predicted distributions of 88 bird species (of an earlier iteration than as presented in Section 3.2.1). Maxent models were constructed using derived bioclimatic variables from Natural Resources Canada (McKenney et al. 2006) and land cover data from the CEC. The affinity propagation technique was chosen because, in addition to identifying meaningful clusters, it identifies "exemplars" around which clusters are based. In our case, we clustered spatial locations (10-km pixels) using a random sample (1,000) of all pixels, and identified the species predicted at each cluster's exemplar location (pixel).

We used two different approaches to evaluate levels of community clustering. First, we identified natural clusters using a 10% similarity target. This resulted in 41 distinct clusters across the boreal region of Canada (Fig. 19A), including some that appeared to be driven by land-use rather than climate/vegetation differences based on the level of spatial dispersion among them. Second, we performed a cluster analysis that specified a reduced target of 10 clusters (Fig. 18B). This resulted in a much more spatially-consistent set of clusters, reflecting major bioclimatic and vegetation gradients. We found high concordance between the resulting map and existing BCR delineations, providing support for the biological relevance of these boundaries. For each cluster's exemplar pixel, we present the 10 species with the highest predicted probabilities of occurrence (Table 6).

Future work will involve (a) updates based on most recent Maxent models, and (b) parallel analyses based on original survey data rather than predicted distributions. Although the survey data are more spatially limited, they should help us assess the validity of observed patterns, which reflect potential overlap in species distributions but not necessarily site-level species co-occurrence. With the appropriate vetting, exemplar sites and species may then be used as "reference communities" for specific regions and habitat types.

This analysis of community composition complements previous work focusing on species richness patterns, which has been delayed in anticipation of new spatially-explicit density model predictions. By incorporating climatic variability into density modelling efforts, we will be able to calculate a range of diversity indices that incorporates abundance measures (i.e., go beyond species richness). We plan to analyse patterns of alpha- and beta- diversity with respect to multiple proposed ecological theories, as described in the 2010-11 report.

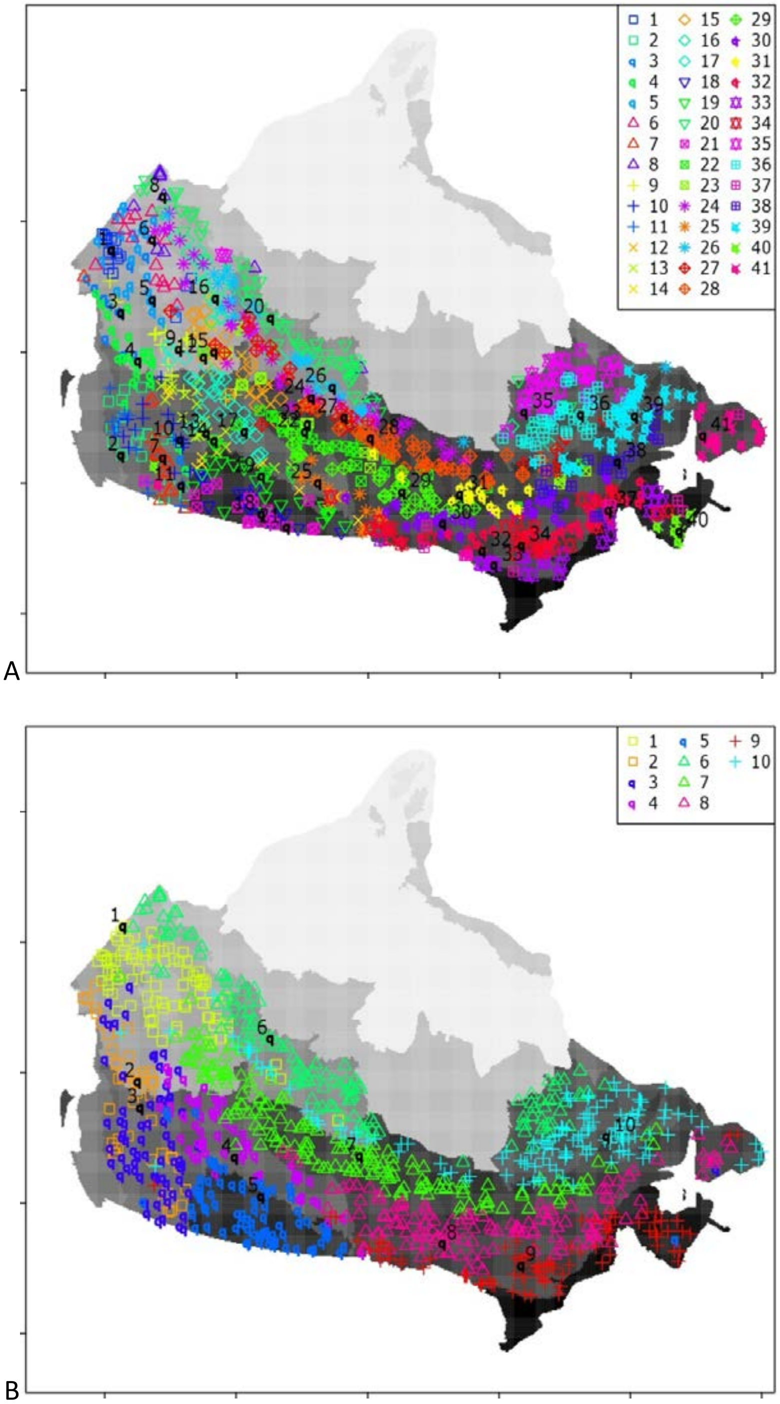


Figure 19. Affinity propagation clustering of bird species across boreal Canada based on a random sample of 1,000 pixels from 10-km Maxent model predictions and a 10% similarity target. Different color symbols represent different clusters; exemplar locations are indicated by numbers within each cluster. We conducted analyses targeting 41 (upper panel) and 10 clusters (lower panel).

Table 6. The 10 species with the highest predicted probability of occurrence (shown in parentheses) for each cluster's exemplar pixel (see Fig. 19).

Group 1	CORE (0.69)	YRWA (0.57)	Group 6	ATSP (0.82)	AMRO (0.61)
	SWTH (0.66)	CHSP (0.54)		CORE (0.76)	GCTH (0.60)
	WCSP (0.65)	DEJU (0.52)		SAVS (0.76)	BLPW (0.51)
	BOWA (0.65)	GRAJ (0.51)		WCSP (0.74)	RUHU (0.47)
	OCWA (0.62)	RUHU (0.51)		NOWA (0.67)	GRAJ (0.44)
Group 2	PIGR (0.85)	GRAJ (0.70)	Group 7	RUBL (0.78)	MAWA (0.55)
	HAFL (0.85)	VATH (0.68)		PAWA (0.70)	SWTH (0.55)
	BOWA (0.78)	LISP (0.67)		LISP (0.63)	RCKI (0.54)
	RECR (0.77)	DEJU (0.64)		YRWA (0.62)	CONI (0.53)
	DUFL (0.76)	BOCH (0.64)		NOWA (0.61)	WWCR (0.52)
Group 3	PIGR (0.67)	BOCH (0.61)	Group 8	WIWR (0.69)	AMRE (0.61)
	SWTH (0.65)	RUHU (0.60)		YBFL (0.66)	MAWA (0.60)
	GRAJ (0.64)	RECR (0.59)		NOWA (0.63)	BBWA (0.60)
	YRWA (0.62)	PISI (0.57)		SWSP (0.62)	BAWW (0.60)
	DEJU (0.61)	OSFL (0.56)		NAWA (0.62)	WTSP (0.58)
Group 4	TEWA (0.61)	OVEN (0.60)	Group 9	BAWW (0.69)	BLBW (0.61)
	PISI (0.60)	LCSP (0.58)		SWSP (0.65)	MOWA (0.61)
	CONW (0.60)	MOWA (0.57)		REVI (0.62)	CAWA (0.61)
	CORA (0.60)	CCSP (0.57)		WIWR (0.62)	AMRE (0.61)
	SWTH (0.60)	BRCR (0.56)		HETH (0.62)	BTBW (0.60)
Group 5	YHBL (0.84)	PISI (0.65)	Group 10	NOWA (0.79)	DEJU (0.61)
	BBMA (0.68)	YRWA (0.59)		WIWA (0.69)	YRWA (0.61)
	BRBL (0.68)	WTSP (0.57)		LISP (0.68)	GRAJ (0.56)
	BHCO (0.67)	RBGR (0.56)		RUBL (0.67)	RCKI (0.55)
	CONI (0.66)	AMRE (0.53)		FOSP (0.64)	AMRO (0.54)

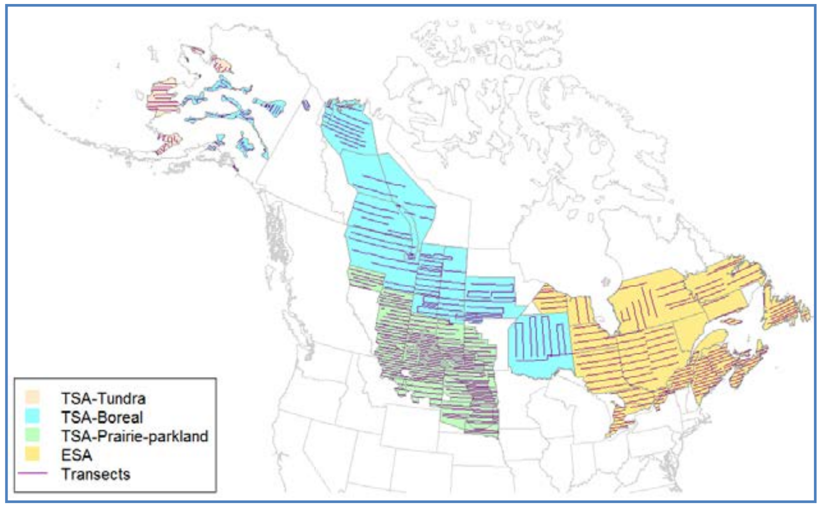
3.5.2 Summary of BAM Accomplishments within Objective: Community characterisation 2009 – 2012

- Developed code for estimating local (alpha) and landscape (beta) diversity at varying spatial scales and habitat definitions, and conducted preliminary evaluation of national patterns in alpha and beta diversity
- Undertook preliminary evaluation of community composition patterns across boreal region.

Preliminary efforts at characterising avian communities were undertaken in 2010–2011 as reported but were not pursued in 2011–2012 as BAM's resources were focused on refining methods of bird density and population estimation, and on models to assess the impacts of anthropogenic and climate change on avian populations.

3.6 Expansion to other bird groups (Waterfowl)

Figure 20. Location of aerial transects surveyed as part of the U.S Fish and Wildlife Service and Canadian Wildlife Service's Waterfowl Breeding Population and Habitat Survey.



The 2009-12 EC Contribution Agreement, proposed a "Feasibility assessment and scoping of building a parallel waterfowl component". This undertaking was fulfilled as follows. First, we organised a waterfowl modelling workshop in August 2009 as part of the 5th North American Duck Symposium, leading to a substantive workshop report, as per our annual report for 2009-10. All participants at the workshop commented on the fundamental importance of the U.S. Fish and Wildlife Service (USFWS) and Canadian Wildlife Service's (CWS) Waterfowl Breeding Population and Habitat Survey (BPOPS, Fig. 20). They also acknowledged its still-unexploited potential for other research objectives than its originally intended purpose of aiding in establishing harvest levels (Börger et al. 2010).

The BPOPS methodology involves flying individual transects (seen as straight lines in Fig. 19) and all waterfowl seen within 200 m of the flight line are recorded to species or genus. The data are spatially registered to "segments" of 28 km by 0.4 km (11.2 km^2). Transects are grouped into about 50 strata which have been traditionally the smallest spatial units of analysis. Surveys began in the 1950s in the west, and 1990 in the east (Smith 1995). A number of fundamental problems with the survey were also noted, relating to various aspects of detectability, the most crucial of which may be the lack of synchrony between surveys and breeding phenology for many species.

Two PhD students (Nicole Barker and Christian Roy) were enrolled at Laval University, supervised by Cumming and Technical Committee member Marcel Darveau, Ducks Unlimited Canada (DUC). Both were funded under a NSERC/FQRNT scholarship with DUC as the industrial partner. Their work focuses on exploiting the long-term and spatially-extensive BPOPS dataset. Christian Roy (who started in 2009) focused mostly on strata-level analysis. He is applying state-space models with climate covariates to model species' population sizes. This work will be presented at our symposium at the 2012 North American Ornithological Conference (Appendix 1). Roy has analysed the segment-level data to develop time-series models of cavity-nesting duck abundances in the western boreal region. He will test the hypothesis that a recent recovery of beaver populations has caused an increase in the abundance of Bufflehead and Goldeneye. To do this, he will use a time-series of beaver dam counts measured from air-photos at a sample of segments having significant increasing and decreasing trends in the observed counts of Buffleheads and Goldeneyes. Nichole Barker (who started in 2010) is developing segment-level models of all waterfowl species contained in the BPOPS data set. Building on the work of BAM in using CARTs to model songbird abundance data, she has developed Boosted Regression Tree models for several duck species, using some of the same variables identified by BAMs initial CART analyses.

One challenge in modelling the BPOPS data is the lack of a comprehensive, high-resolution map of aquatic habitats in Canada. DUC agreed to produce a national version of their "Hybrid wetland layer" originally developed for the western boreal region. This product, delivered in 2011, synthesises water classes in the 30-m resolution EOSD landcover product with digitised wetland and water features from the 1:50,000 NTS topographic map sheets (the CANVEC product from NRCAN). The several sources of error in the BPOPS data and some data quality issues were identified by the BAM team, and a protocol was developed to cooperate on resolving these issues with the USFWS maintain the survey data.

On the basis of these meetings, and the successful modelling efforts of our students, BAM has made the following determination. National, high spatial resolution models of waterfowl species densities will be developed based on segment-level analyses of the BPOP data. There will be no effort at this time to amass and integrate the many other potential sources of waterfowl data in Canada, whether from DUC, CWS, or academic research projects. The first versions of this work will be performed by Cummings' students with technical support from BAM core staff as needed. Their results will be incorporated on the BAM website when their theses are completed.

The potential of the BPOPS dataset extended beyond the work currently being conducted by the PhD students in Cumming's lab. Furthermore, the substantive methodological challenges posed by imperfect detection, asynchrony, and spatial error in the data are beyond the scope of these students' thesis projects. Methodological advances made by BAM in dealing with similar issues with the BAM dataset should be applied to the BPOPS data.

Therefore, in April 2012, we are submitting a proposal for an NSERC Strategic Project Grant entitled "Modelling waterfowl populations and aquatic habitats in boreal Canada under land use and climatic change." The proposal is led by Cumming with co-applicants Bayne, Darveau, and Jones (a hydrological modeller at Waterloo). The essence of the proposal is to develop spatially-dynamic models of water balance, aquatic ecosystems, and waterfowl in the Canadian boreal region that are sensitive to land use, industrial development, and climate, and that account for the various sources of observational error in the BPOPS data. If successful, project would start in April 2013 and continue for 3 years. BAM and EC are partners on this strategic grant proposal.

3.6.1 Summary of BAM Accomplishments within Objective: Expansion to other bird groups 2009 – 2012

- Recognition that parallels exist between BAM avian landbird dataset and the various waterfowl datasets, and that similar statistical methodologies will apply to both landbird and waterfowl data.

- Involvement of graduate students working on waterfowl (Roy and Barker) in the BAM team meetings to facilitate information sharing.
- The various waterfowl datasets are currently being managed separately from the BAM dataset. They will be structured in a parallel fashion to facilitate future analyses.
- The biophysical databases including the FRI data are being shared between the BAM and waterfowl researchers.
- Preliminary analyses of waterfowl distributions in relation to climate and habitat variables have been conducted using (using Boosted Regression Trees), similar to the CART models used by BAM.
- The population dynamics of seven boreal-breeding duck species were analysed, testing the hypothesis that density dependence and the effects of weather covariates on population growth varied among strata (Roy thesis, expected September 2012).

BAM's experiences with collating and working with disparate datasets resulted in the understanding that significant financial and staff resources will be required to undertake national waterfowl modelling that cannot be provided under the BAM project. As a result, Cumming is collaborating with Bayne and other researchers to develop an NSERC Strategic Project Grant application to be submitted in April 2012. The essence of this proposal is to develop spatial dynamic models of water balance, aquatic ecosystems and waterfowl in the Canadian boreal region that are sensitive to land use, industrial development and climate.

4.0 APPLICATIONS OF BAM PROJECT RESULTS IN 2009-2012

4.1 Monitoring of biodiversity in oil sands and in boreal forests

EC is using bird-habitat models developed by BAM to implement the cause-effects monitoring for forest birds in the oil sands region. These models are the foundation for cause-effects relationships, and were used to identify gaps in those relationships, to identify which species we can work with, to inform the design for filling data gaps and the resulting sampling plan for the upcoming field season. The work invested in BAM model development (its complexity, in particular) also informed EC resource and timeline estimates for implementation of the monitoring plan. BAM analyses have determined best protocols for collecting point counts that allow density estimation and these will be adopted by the oil sands monitoring program. Ongoing collaboration with BAM will assist with building and testing of models for cause-effects monitoring for forest birds.

PNR conducted monitoring in 2010 for Canada Warbler and Olive-sided Flycatcher in preparation for the Shell Jackpine and Pierre River Joint Review Panel sites. BAM provided data, base bird-habitat models, and staff time to inform the model-based sampling design. This type of sample design permits the characterisation and ranking of sites based on habitat suitability and stratify sampling accordingly) and allowing efficient, rigorous data collection.

These model-based monitoring techniques and survey protocols are highly transferable across boreal Canada and Alaska.

4.2 Environmental assessment

BAM has developed a database of density estimates stratified by regions, habitat types, and impact type that is currently available upon demand. The database will be downloadable from our website in Spring 2012. The database provides a single-source tool for consultants and government biologists to calculate regional densities of boreal landbirds which can then be applied to estimating the impact of individual projects and cumulative effects through time. These should provide better information for impact estimation for forest birds, generate more rigorous estimates, and improve efficiency by eliminating the need to collect new data, to rely on ad-hoc data collations or to derive estimates from literature. These tools will improve efficiency, which will be vital for meeting timelines recently imposed by changes to environment assessment procedures.

Preliminary discussions are underway with Rich Russell in EC Ontario region on how BAM might assist with impact assessment for chromite mining proposals in the Ring of Fire. With the foundational work invested in BAM, provision of regionally-specific density estimates and bird-habitat models, particularly for SAR migratory birds, are highly feasible. Coupled with good habitat supply data and development scenarios, these models will set the stage for rigorous, highly defensible estimates of impacts.

Data collected by private companies during environmental assessments can also be added to the BAM dataset, as per the commitment made by Total (during Total Joslyn JRP, 2010-12).

4.3 Breeding bird survey and atlassing

BAM staff assisted the CWS, BBS office by 1) digitising the geographic locations of BBS routes (50-stop locations) for the majority of boreal routes where there was no GPS data, 2) correcting errors in the database on species codes and stop locations, and 3) providing protocols to improve collection and management of geospatial information.

An analysis was conducted to identify gaps in BBS and atlas coverage in the boreal forest. BAM identified 380 areas within 30 km of existing road networks where BBS routes could be added to fill in gaps in coverage (Matsuoka et al. 2011b)

Bias associated with road-side counts (BBS) was quantified. Roadside bias may result in overestimating population size for almost 80% of species (see Section 3.2.2.6) (Matsuoka et al. 2011b).

Quantitatively-derived protocols for atlassing using point counts were delivered to National Atlas Committee. The analyses demonstrated that 2 time and 2 distance intervals provide better information for density estimation and would enhance contributions of future atlas data to national modelling objectives (Matsuoka et al. 2011a).

4.4 BCR planning and implementation

BAM provided quantitatively-derived habitat associations for Element 2 (Habitat associations) of PNR boreal BCR plans. For Element 7 of BCR 6 – Boreal Taiga Plains, data products were provided and collaboration was undertaken with Lisa Mahon to conduct priority area analyses using Marxan. Element 7 was formally removed from BCR Plans but PNR continued with this analysis as a useful example of BCR implementation. A publication (Mahon et al. in preparation-b) is anticipated shortly.

Following the recommendations of PIF, EC and BAM developed, in collaboration with Alberta Pacific Forest Industries Inc., an approach to “step forward” BCR population objectives into landscape-scale habitat objectives (Will et al. 2005). We assessed current habitat availability, developed quantitative relationships between habitat condition and bird density (habitat-specific density estimates), and evaluated whether expected future habitat conditions could support proposed BCR population objectives over the next 30 years for both current and alternative land use scenarios.

BAM has developed density and distribution estimates and acquired existing biophysical data layers (particularly the CASFRI system which standardises Forest Resource Inventory data across Canada) which provide an excellent analytical basis for quantitatively deriving all BCR elements: population estimates, habitat associations, population objectives quantitatively, threats assessment and evaluation of management actions.

4.5 Land-use and conservation planning

4.5.1 Regional land-use planning in Alberta: Land Use Framework

The models we created for Alberta have been used in a variety of land-use planning exercises. Last year we reported on models we provided to the Alberta Land-use Framework Secretariat through a database system and website known as the Alberta Forest Songbird Information System (AFSIS). This product has been updated to include our new approach to density estimation and will be presented on the BAM website in Spring 2012 (AFSIS is available upon request). AFSIS has been used by the Government of Alberta in the Land-use Framework Planning Process as a set of indicators.

4.5.2 Scenario analysis for western sedimentary basin

BAM is also running a new simulation that will predict bird response to changes in forest age and composition over the next 50 years in the southern half of BCR 6 (Western Sedimentary Basin). This project is being conducted in partnership with the ALCES group and the Canadian Wildlife Federation (CWF) and will be completed in summer 2012. The goal of this model and resulting reports is to provide CWF members and the general public with an understanding of the dynamic nature of this ecosystem while highlighting the considerable risks to birds caused by energy sector development, forestry, and mining in this region. The scenario analyses will assess the implications of a range of development rates, best management practices, and zoning options on a range of economic and ecological indicators, including songbirds. The newly-parameterised version of the ALCES model for this region is now complete and scenarios are being run by BAM.

Two fundamental advances resulted from this collaborative effort in 2011-12 that will provide a more realistic and useful risk assessment for the Western Sedimentary Basin. First, we have incorporated data on forest age-structure from remote areas of the NWT and Saskatchewan where forest resource inventory data were not previously available. These data were derived from the Canadian Forest Inventory, the large fire database, and remote sensing imagery (Chen et al. 2003). Second, CWF is now spatially mapping changes in forest conditions using the new ALCES Mapper extension. Previous versions of ALCES simply provided tabular output of forest types and human impacts. ALCES Mapper now provides a spatial and visual representation of the ALCES output based on (1) the study area divided into grid cells of user-defined size, (2) the parameterisation of the initial landscape and footprint composition within each cell, and (3) the tracking through time of changes to landscapes, commodities, and ecological indicators in each cell. ALCES Mapper also allows users to specify the general location (i.e., where specified land-use footprints can or cannot occur) and pattern (e.g., dispersed versus contiguous) of future development. This useful feature allows users to map and visualise landscape changes through time according to different zoning or resource utilisation strategies. These maps of future landscape condition can then be analysed to evaluate the spatial response of indicators such as wildlife habitat to potential future landscapes associated with land-use scenarios.

4.5.3 Identification of biodiversity offsets using Canada Warbler

In 2011-12, we started a new collaboration with Alberta Conservation Association to identify the potential for mitigating effects of oil sands development through habitat offsets and mitigation banking. This project will identify locations in Alberta that could be set aside to mitigate current and future oil sands mine development using the Canada Warbler as a model species. This project started by using the Canada Warbler models developed as part of the Alberta Forest Songbird Information System (AFSIS) created by BAM. Based on these models, preliminary sites that might support Canada Warbler have been identified. Funds from the Habitat Stewardship Program have been provided to Bayne and Alberta Sustainable Resource Development to collect additional field data to validate and improve the model in the summer of 2012. After model validation, an economic optimisation program and GIS analysis will be used to identify how different policy approaches to mitigation banking influences where offset locations could be located. With ACA we will evaluate biodiversity benefits of a single-species approach to offsets by determining the number of individuals of other species of birds that would be protected using such a strategy. The models for other species use the AFSIS system that BAM created for Alberta. We anticipate that the methods developed will be highly transferable for application in other boreal regions in Canada experiencing large-scale industrial development.

4.5.4 National-scale protected areas planning

BAM's collaboration with the BEACONs Project ensures that BAM results are considered in broader conservation initiatives throughout boreal regions of Canada. This occurs both through BEACONs development of tools that are explicitly designed to incorporate BAM models, and through active engagement and application of these tools and constituent models in land-use planning across Canada. Currently, BEACONs is leading a Pan-Boreal Assessment to support the goals of the Canadian Boreal Forest Agreement, which covers ~75 million hectares of commercial forest lands, and involves a close partnership with 23 member companies of the Forest Products Association of Canada. The primary objectives of this assessment are to identify and propose measures to address gaps in the existing protected areas network with regards to representation of ecosystem diversity, conservation of special elements such as focal species, and provision of ecological benchmarks. Extensions of this analysis will also be applied to lands managed for timber production. BAM's species distribution models will figure prominently in this effort. BEACONs is also involved with a number of regional assessments, with a variety of partners, where BAM research and products are profiled and applied.

4.6 External applications of CASFRI

BAM partnered with BEACONs to advance the development of the CASFRI to support shared objectives. As described in Section 3.4.5, BEACONs is conducting a Pan Boreal Assessment being to advance conservation goals associated with the Canadian Boreal Forest Agreement (CBFA). BEACONs will be conducting detailed spatial simulation studies of fire and forest dynamics in four regions of boreal Canada to calibrate some aspects of their methodology. The model landscapes will be initialised from CASFRI data sampled to a 6.25ha regular grid. In March 2012, Cumming's lab provided the data required for two Ontario regions. Data for the other two regions will be provided as soon as the corrections to the Alberta CASFRI data are completed.

It should be noted that CBFA has identified Canada Warbler and Olive-sided Flycatcher as priority species. This work in support of modelling initiatives will directly lead to the regional application of the national habitat models for the two species in question. More broadly, the existence of CASFRI will facilitate future spatial simulation studies anywhere in boreal

Canada, and encourage the models developed for these studies to be compatible with BAMs avian distribution models, and increase the demand for such models.

Another external application of the CASFRI dataset is now underway in collaboration with The Nature Conservancy and CBFA. In July 2011, BEACONs was asked to apply the database to a gap analysis of tree-species distributions in protected areas and forest tenure areas vis-a-vis their spatial distribution within the boreal region. The computer codes needed to run the analysis were written in January and February 2012, but the analyses themselves will not be possible until April. A paper in the Forestry Chronicle or Canadian Journal of Forest Research based on this analysis will present CASFRI to the research and management community, and highlight both BAM's contribution to development of the dataset, and planned applications. The results of these analyses will also assist BAM by informing assessment of detailed conservation needs for avian species with fine-scale habitat requirements linked to individual tree species or forest types.

4.7 Incidental take tally

BAM processed and provided population estimates to EC for forest birds that were used to estimate incidental take by terrestrial oil and gas exploration and extraction, forestry operations, roadside maintenance operations, mining operations and wind energy sector (resulting in 5 Environment Canada technical reports/peer-reviewed publications).

4.8 SAR recovery strategies and critical habitat identification

Discussions are underway with Atlantic Region (Peter Thomas, lead on OSFL, RUBL, CAWA) and SAR lead in HQ on how we can assist with development of regional and national population models of density and distribution and response to human activity, and how those can be used for assessment of critical habitat. With its data layers, methodology and models, BAM is positioned to provide population estimates by habitat type at unit scales selected by SAR planners and as required for SAR recovery strategies. These estimates can inform expected population by habitat supply and inform proposed approaches to critical habitat definition.

BAM and collaborators are undertaking regional population modelling efforts in AB and ON to predict finer-scale habitat associations and requirements using FRI data. Through HSP funds provided by EC, BAM is collaborating with ASRD to collect additional data collection on CAWA in AB to assist with analyses. In Ontario, a collaboration between OMNR (Rob Rempel), NRCan (Lisa Venier), EC-CWS (Rich Russell) is emerging to improve regional models for application in forest management planning and impact assessment of proposed mining developments.

4.9 PIF status assessments

EC (Pete Blancher) used BAM results as a source of information to guide discussion on population estimation and development of PIF population estimates, and in the review and revision of regional assessment of relative density scores for boreal BCRs.

4.10 Validation for other avian modelling efforts by EC

A model cross-validation exercise between regional neural-network IRMA models by Jean-Luc Desgranges and national Classification and Regression Tree models from BAM was conducted for a common study region in eastern ON and QC. The project was proposed by Desgranges and funded by WLSD, leveraging BAM. IRMA models validated well internally (against IRMA data) but performed poorly under cross-validation against BAM data points. BAM models performed well under internal validation and under cross-validation against independent IRMA data. Both internal and external validation improved when BAM approximations of IRMA habitat covariates were added. Of particular relevance to the BAM program was the fact that the habitat covariates derived from the Forest Resource Inventories through the CAS process substantially increased the performance of the CART models under both internal and external validation. This substantiates the utility of FRI data in national and regional modelling studies. The report is forthcoming pending translation.

5.0 PROJECT COMMUNICATIONS IN 2011–2012

The BAM project makes use of a variety of communication methods to solicit collaboration and input, and to extend our knowledge beyond the group, including: webinars; in-person Technical Committee Meetings; publications in peer-reviewed journals, the general literature, and our website; unpublished reports (to Environment Canada); annual reporting to funders; and presentations at a variety of venues. Between 2009 and 2012, we hosted one Technical Committee Meeting in Edmonton (November 2010) and six webinars. Detailed descriptions, agendas, and presentations from these events were included in previous annual reports. The webinar topics included:

- Project Overview (September 2009)
- Discussion of analytical techniques including detection radius and density estimation (November 2009)
- Biophysical variables (climate data, remote sensed measures); Development of the Common Attribute Schema (CAS) for Forest Resource Inventory (FRI) Data (February 2010)
- Beyond CARTS: Synthesis and New Directions (October 2010)
- Regional Variations in Habitat Selection (February 2011)
- BAM, BBS, and the Atlases: Effective collaboration by design (March 2011)

In 2011 – 2012, the BAM project team focused on preparing a number of scientific and technical publications, as specified below. Although we did not host any additional webinars or formal Technical Committee meetings, we did engage several members of the Technical Committee in discussions about a collaborative project to conduct regional habitat modelling for Canada Warbler in Alberta and Ontario (see Section 3.2.4.1).

5.1 Website Upgrades

A major effort is underway to update our BAM website with information about the additions to the BAM datasets, refined analytical techniques and new results about avian density and distribution. The English updates will be completed in Spring 2012. As of 2011-12, approximately 75% of the updated text has been completed (including summary descriptions of new analytical techniques and suggested protocols for survey design), the distribution maps are complete, the content of the density database has been finalised, the density maps are ready to be generated, and the initial stages of design for the on-line database are complete. Translation of these pages into French will follow as soon as translation of text is complete and formatted (anticipated 2 months maximum). The changes will address the following areas:

1. Update the description of avian database to reflect additional data, inclusion of the BBS data, expansion to include Alaska and the hemi-boreal region; also correcting species names to match the most recent AOU standards, and to confirm species' conservation status;

2. Provide an overview of the dataset, its extent, parameters, and capabilities;

3. Document the biophysical dataset, and describe the creation of the Common Attribute Schema Forest Resource Inventory (CASFRI) which is a national summary of forest resource inventory data;

4. Add a series of tools and products, including maps, queriable databases and database downloads for website users to access information derived by the BAM team from the BAM dataset, (e.g., habitat suitabilities, density estimates by BCR/jurisdication/habitat, maps of distribution or abundance);

5. Add a section of protocols and primers to assist with monitoring and survey design, environmental assessment and other applications of BAM data.

6. Expand the library component to include technical reports generated by the project; and,

7. Reconfigure the home page to better indicate what information is available on our web site, and how best to access it.

5.2 Presentations, Reports and Publications (2011 – 2012)

5.2.1 Presentations (April 2011 – March 2012)

a. Barker, N.K.S., M. Darveau, S.G. Cumming. 2010. Waterfowl conservation planning in the boreal forest: Use of a pre-existing, large-scale, time-series dataset. Presentation to the International Congress for Conservation Biology (ICCB). Edmonton. 3-7 July 2010 (inadvertently omitted from 2010-2011 annual report).
b. Bayne, E.M. Feb 2012. How many boreal birds does it take to drive a Hummer? Invited presentation to University of Calgary Ecology Seminar. Calgary.
c. Bayne, E.M. 2011. Are boreal forests going silent or just changing their tune? Invited presentation to Red Deer Natural History Club in Red Deer, Alberta, April 2011; and to the Edmonton Natural History Club in November 2011.
d. Bayne, E.M. 2011. Development of an adaptive management plan for boreal biodiversity in Northeastern Alberta: an example using forest birds. Presentation to the Ecological Monitoring Committee of the Lower Athabasca. Calgary, AB. 1 June 2011.
e. Bayne, E.M. and BAM Team. 2011. Evaluating current and future status of boreal forest songbirds through a national data collection, analysis, and reporting system. Presentation to the Director General, Canadian Wildlife Service, Environment Canada. 28 September 2011. Edmonton, Alberta.
f. Matsuoka, S.M. 2011. Boreal Avian Modelling Project: Program Overview. Presentation to the US Fish and Wildlife Service, Migratory Bird Management, Region 7. 29 November 2011. Anchorage, AK via phone.
g. Matsuoka, S.M. 2011. Boreal Avian Modelling Project: Program Overview. Presentation to the Boreal Partners-in-Flight (BPIF). 7 December 2001. Anchorage, AK via phone.
h. Racine P., M. Houle, S. Cumming. 2011. Automatisation de la conversion des inventaires forestiers canadiens avec ArcGIS et Python. Presentation to ESRI, (Automation of the conversion of Canadian Forest Resource Inventories with ArcGIS

and Python). Québec ESRI Regional User Conference, 27 April 2011. http://www.esricanada.com/en_events/4655.asp

i. Roy, C. S.G. Cumming, M. Darveau. 2010. Spatio-temporal dynamics in abundance of cavity-nesting bufflehead and goldeneye. Presentation to the International Congress for Conservation Biology (ICCB). Edmonton. 3-7 July 2010 (inadvertently omitted from 2010-2011 annual report).

j. Roy C. 2012. PhD Presentation, Université Laval. Modélisation de la dynamique des populations de canards arboricoles en forêt boréale (Modelling population dynamics of cavity-nesting ducks in the boreal forest). March 2012. Québec, Québec.

k. Solymos, P. Lele, S. R. Bayne, E. M. Keim, J. 2011. Effects of human development on biodiversity. ABBY-Net kick-off and 1st Workshop on "Natural Resource Management and Energy Systems under Changing Environmental Conditions", Munich, Germany, 10-12 November 2011, http://prezi.com/iajkw0qcfyfe/munchennov2011/

l. Song S.J. and BAM Team. 2011. Boreal Avian Modelling Project: Update to the Landbird Technical Committee. Environment Canada Landbird Technical Committee Meeting. 24 November 2011. Saskatoon, Saskatchewan.

5.2.2 Publications

1. Peer reviewed papers in 2011-2012 (5 in 2011–2012)
   a. Bayne, E. M., P. Solymos, S. G. Cumming, S. M. Matsuoka, D. Stralberg, S. J. Song, and F. Schmiegelow. In review. Model-based approaches for adjusting point-count surveys for variation in the duration of the counting time. The Auk
   This paper demonstrates that different-length point-counts can be corrected to a common standard using the concept of singing rate. The unique nature of the BAM dataset with multiple time intervals allowed us to estimate a novel approach to calculating singing rate and now provides a common database for other researchers to use to correct their data and ours to this standard.

   b. Matsuoka, S. M., E. M. Bayne, P. Sólymos, P. Fontaine, S. G. Cumming, F. K. A. Schmiegelow, and S. J. Song. 2012. Using binomial distance-sampling models to estimate the effective detection radius of point-count surveys across boreal Canada. The Auk.
   We demonstrate that binomial distance sampling is a simple but effective method to adjust broadly conducted point-count surveys for detection error and thereby estimate population sizes of forest birds across boreal Canada.

   c. Sólymos, P., S. Lele, and E. Bayne. 2012. Conditional likelihood approach for analysing single visit abundance survey data in the presence of zero inflation and detection error. Environmetrics 23:197-205.
   In this paper we explored what can be done with single visit count data when there is detection error; we showed that when appropriate covariates that affect both detection and abundance are available, conditional likelihood can be used to estimate the regression parameters of a binomial–zero-inflated Poisson (ZIP) mixture model and correct for detection error.

d. Lele, S. R., M. Moreno, and E. Bayne. 2012. Dealing with detection error in site occupancy surveys: what can we do with a single survey? Journal of Plant Ecology 5:22-31.
In this paper we explored what can be done with single visit occupancy data when there is detection error; we showed that regression parameters are estimable when appropriate covariates that affect both detection and abundance are available.

e. Sólymos, P. and S. R. Lele. 2012. Global pattern and local variation in species–area relationships. Global Ecology and Biogeography 21:109-120.
In this meta-analysis we examined what factors influence the variation in species-area relationships and how that local variation leads to the global species-area pattern.

2. Papers in preparation for submission in 2012 (6):
   a. Cumming, S. G., D. Stralberg, K. Lefevre, E. Bayne, P. Solymos, T. Fontaine, D. Mazerolle, F. Schmiegelow, and S. Song. In preparation. Climate and vegetation hierarchically structure continental patterns of songbird abundance in the Canadian boreal region. In preparation for Ecosphere.
   We reviewed the national CART models and used some novel analyses on the structures of the fitted models to make inferences about the relative importance of different covariates, and how these differed amongst groups of species.

   b. Matsuoka, S. M., E. M. Bayne, P. Sólymos, D. Stralberg, S. J. Song, F. Schmiegelow, and S. Cumming. In preparation-a. Estimating population sizes of landbirds breeding across the Nearctic boreal forest zone. Ecological Applications.
   We develop a spatial model of avian breeding density and population size for 80 passerine species that implements all of the recommendations for improving Partners in Flight's continental estimates of landbirds population sizes.

   c. Matsuoka, S. M., C. L. Mahon, P. Sólymos, E. M. Bayne, P. C. Fontaine, and C. M. Handel. In preparation-b. There and back again? A tale of common standards for conducting point-count surveys for terrestrial birds. In preparation for Condor.
   Standards for conducting point-count surveys in North America were developed from discussions among avian ecologists in 1991 and have thus become dated. We update these common standards to accommodate the many recent innovations in how point-count surveys can be conducted to adjust the surveys for detection bias.

   d. Matsuoka, S. M., P. Sólymos, E. M. Bayne, and P. C. Fontaine. In preparation-c. Roadside bias in survey counts of boreal forest birds: prevalence, effect sizes, and relationship to detection distances to birds. Biological Conservation.
   We show that roadside surveys sample a larger area than a comparable survey conducted away from roads. We then use distance sampling to adjust for this difference in detection rate so that data from roadside and off-road surveys can be jointly analysed in models of avian abundance.

e. Sólymos, P., S. M. Matsuoka, E. M. Bayne, S. G. Cumming, and S. R. Lele. In preparation. Calibrating indices of avian density from non-standardized survey data: making the most of a messy situation. Ecological Applications.
In this manuscript we describe a methodology that can be used to correct for availability bias and detection error present in point count surveys, also this method is useful in combining data with vastly different survey designs and account for other nuisance factors (time of year, time of day, tree cover) at the same time.

f. Mahon, C. L., E. M. Bayne, P. Sólymos, S. M. Matsuoka, M. Carlson, and E. Dzus. In preparation-a. Does expected future habitat condition support proposed population objectives for boreal landbirds in Bird Conservation Region 6-Boreal Taiga Plains? Auk.
We demonstrated our approach for "stepping forward" Bird Conservation Region (BCR) scale population objectives using the Partner's In Flight (PIF) Five Elements Process for three boreal landbirds within a 6.8 million hectare study area in northeastern Alberta, Canada.

5.2.3 Technical Reports

The following reports were prepared for various audiences in 2011 – 2012.

Technical Reports and newsletters (5)

a. Bayne, E., S. R. Lele, and P. Sólymos. 2011. Bias in estimation of bird density and relative abundance when the closure assumption of multiple survey approaches is violated: a simulation study.
A common approach to modelling birds in the current literature is the idea of making multiple visits to the same site. In Bayne et al. (2011) we showed how within-territory movement can lead to the violation of the closure assumption commonly assumed in models using multiple visit sampling design. The report highlights why BAM has not used this approach and shows that the resulting estimates hugely overestimate abundance.
http://www.borealbirds.ca/files/Bayne_et_al_2011_Bias_In_Estimation_Rpt.pdf

b. Cosco, J. A. 2011. Common Attribute Schema (CAS) for Forest Inventories Across Canada. Boreal Avian Modelling Project and Canadian BEACONs Project. Prepared by J.A. Cosco, Chief Inventory Forester, Timberline Natural Resource Group.
This report summarises the Common Attribute Schema which was developed for BAM and BEACONs to allow the habitat data contained in individual forest resource inventories (conducted to different standards and with different protocols across Canada) to be standardised into one biophysical database to be used in conjunction with avian (and other) data. (Cosco 2011) available at BAM website http://www.borealbirds.ca/library/index.php/technical_reports.

c. Matsuoka, S., P. Sólymos, E. Bayne, and S. J. Song. 2011. Suggestions for collecting additional data during point count surveys conducted by paid Breeding Bird Atlas crews in Canada. Unpublished report prepared for the Canadian Breeding Bird Atlas Committee. Boreal Avian Modelling Project, Edmonton, Alberta.
Matsuoka et al. (2011a) demonstrates how collecting point-count surveys relative to

two distance intervals (0-50m, >50 m) and two time intervals (0-3, 3–5 min) will greatly increase how the data can be used to estimate avian densities and populations sizes. We recommend that the Atlas Committee should consider conducting point-count surveys in this manner. http://www.borealbirds.ca/files/BAM_Suggestions_for_additional_data_in_Atlas_Collection.pdf

d. Matsuoka, S., P. Sólymos, T. Fontaine, and E. Bayne. 2011. Roadside surveys of boreal forest birds: how representative are they and how can we improve current sampling? Report to Environment Canada by the Boreal Avian Modelling Project, Edmonton, Alberta.
   Matsuoka et al. (2011b) demonstrates that roadside surveys of boreal forest birds are biased samples of boreal forest birds in terms of (1) geographic areas and habitats sampled across the boreal and (2) inflating counts of birds compared to surveys in off-road areas. We identify poorly sampled areas with roads that could be targeted for future roadside surveys. http://www.borealbirds.ca/files/Roadside_Survey_Representativeness_Rpt_to_EC_final.pdf

e. Cumming, S., M. Houle, et J-L DesGranges. 2012. Évaluation des modèles servant à prédire les assemblages aviaires dans Canada de l'Est. Report prepared by Département de foresterie, géographie et de science géomatique, Université Laval and Recherche sur la faune et les habitats, Sciences et Technologies, Environnement Canada, Région du Québec.
   This report (Cumming et al. 2012) describes a model cross-validation exercise between regional neural-network IRMA models national Classification and Regression Tree models that was conducted for a common study region in eastern Ontario and Québec. Of particular relevance to the BAM program was the fact that the habitat covariates derived from the Forest Resource Inventories through the CAS process substantially increased the performance of the CART models under both internal and external validation.

6.0 PROJECT MANAGEMENT

6.1 Steering Committee, Project Staff and Affiliates

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

Team members this year included:

- Database Manager (Trish Fontaine)
- Quantitative Ecologist (Steve Matsuoka, on secondment from the U. S. Fish and Wildlife Service, Alaska Office for two years from August 2010)
- Project Coordinator (Catherine Rostron 0.5 FTE for two years from May 2010)
- Statistical Ecologist (Dr. Péter Sólymos 0.5 FTE)
- Project Affiliate (Dr. C. Lisa Mahon, Environment Canada)
- PhD Candidate with Drs. Bayne and Schmiegelow (Diana Stralberg)
- PhD Candidate with Dr. Cumming (Nicole Barker)
- PhD Candidate with Dr. Cumming (Christian Roy)

6.2 Technical Committee

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

Marcel Darveau, Ducks Unlimited / Université Laval
Jean-Luc DesGranges, Environment Canada
André Desrochers, Université Laval
Pierre Drapeau, Université du Québec à Montréal
Charles Francis, Environment Canada
Colleen Handel, United States Geological Survey, Alaska Science Center
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

6.3 Additional Support

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

Connie Downes (Environment Canada): BBS data

Mélina Houle (Université Laval): spatial data analyst
Marie-Anne Hudson (Environment Canada): BBS data
Bénédicte Kenmei (Université Laval): computer programming
Justine Kummer (University of Alberta): database and website assistance
Rasim Latifovic (Canada Centre for Remote Sensing, CCRS, Natural Resources Canada): for land cover data
Mélanie-Louise Leblanc (Université Laval): programming of statistical summaries
Dan McKenney (Great Lakes Forest Centre, Natural Resources Canada): custom-interpreted climate data
Paul Morrill (Web Services): website design & programming
Pia Papadol (Great Lakes Forest Centre, Natural Resources Canada): custom-interpreted climate data
Sheila Potter (Blue Chair Designs): graphic design and website design and development
Pierre Racine (Université Laval): GIS programming
Xianli Wang (University of Alberta): climate data projections.

6.4 Partnerships

To achieve its objectives, BAM continues to rely on partnerships on many levels, including our data contributors, our Technical Committee and its members, our funders, and the various collaborative efforts described in the preceding sections. The BAM project would not exist without the generous contributions of its funding and data partners.

6.4.1 Funding partners

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

Founding organisations and funders

Environment Canada
University of Alberta
BEACONs

Additional financial supporters

United States Fish and Wildlife Service,
    Neotropical Migratory Bird Conservation Act Grants Program
    Landscape Conservation Cooperatives
Alberta Biodiversity Monitoring Institute
Alberta Pacific Forest Industries Inc.
Alberta Land-use Framework (Government of Alberta)
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
Geomatics for Informed Decisions (GEOIDE)

Government of Canada (Vanier Scholarship)
Natural Sciences and Engineering Research Council of Canada (NSERC)
Université Laval
United States National Fish and Wildlife Foundation (NFWF)

Past financial supporters

Alberta Innovates Technology Futures
Canadian Boreal Initiative
Forest Products Association of Canada
Killam Trusts (Memorial scholarship to Stralberg)
Ministère des Ressources naturelles et de la Faune, MRNF, Québec
Sustainable Forest Management Network

6.4.2 Data partners

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

Institutions

Acadia University, Alaska Bird observatory, Alaska Natural Heritage Program, Alberta Biodiversity Monitoring Institute, Alberta Pacific Forest Industries Inc., AMEC Earth & Environmental, AREVA Resources Canada Inc., 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., Natural Resources Canada, NatureCounts, Nature Serve, Numerical Terradynamic Simulation Group, Ontario Ministry of Natural Resources, OPTI Canada Inc., PanCanadian Petroleum Limited, Parks Canada, Petro Canada, Principal Wildlife Resource Consulting, Regroupement Québec, Rio Alto Resources International Inc., Saskatchewan Environment, Shell Canada Limited, Suncor Energy Inc., Tembec Industries Inc., Tolko Industries Ltd., US Fish and Wildlife Service, US National Park Service, 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, US Army, US Fish and Wildlife Service, US Geological Survey, US National Park Service, University of Alaska, 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, 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, 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, M. Flamme, D. Fortin, K. Foster, M. Gill, T. Gotthardt, 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, J. Lemaitre, D. Lepage, C. McIntyre, B. MacCallum, P. MacDonell, C. Machtans, C. McIntyre, M. McGovern, D. McKenney, S. Mason, L. Morgantini, J. Morton, 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, 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

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APPENDIX: 1: Abstracts for a symposium at the 5th North American Ornithological Conference, August 2012, Vancouver

Symposium: Assessing bird populations at regional to continental scales: results from innovative approaches to data intensive analyses of North American birds

Organised by Steven M. Matsuoka, Wesley M. Hochachka, Diana Stralberg, and Steven G. Cumming

1) Estimating population sizes of landbirds from non-standardized point-count surveys in North America's boreal forest: making the most of a potentially messy situation

Erin M. Bayne, Peter Sólymos, Steven M. Matsuoka, Diana Stralberg, Patricia C. Fontaine, Samantha J. Song, Fiona K. A. Schmiegelow, and Steven G. Cumming

Managing populations of birds across North American's boreal forest region is challenged by increasing rates of industrial resource use and climate change. However, there is a paucity of data from standardized bird surveys to inform avian conservation across this vast and often remote region. We recently compiled data from nearly all of the point-count surveys conducted across boreal Canada and Alaska since 1992 to (1) develop spatially-explicit models of avian breeding density and (2) estimate population sizes of birds breeding across the region to support avian conservation in northern North America. The compiled data were not standardized relative to survey protocol or sample frame. We therefore adjusted the surveys for observational biases due to incomplete detection probabilities, roadside versus off-road sampling, variation in survey protocols, and uneven temporal and geographic sampling. This was to (1) improve our inferences into the ecological associations between avian breeding densities and habitats, climate, and geographic location across the region and (2) implement the recommendation by Thogmartin et al. (2006, Auk 123:892–904) for improving estimates of landbird population sizes by Partners in Flight. We compare our estimates to those from the Partners in Flight to emphasize the differences in population size derived from each.

2) Integrating avian habitat models and conservation planning across North America's boreal forest

Steven G. Cumming and Fiona K. A. Schmiegelow

Spatially extensive datasets of songbirds and waterfowl are now routinely synthesised into species distribution models (SDMs) to generate maps e.g. of predicted species densities. Developments in systematic conservation planning enable the design of representative conservation networks over large areas such as the Canadian boreal region. The same spatial data types are used as SDM covariates and as ecological representation criteria, namely remote sensed products (e.g. landcover and productivity) and interpolated climate data; it is easy to see how the two domains might be bridged by reconciling covariate sets.

However, the continental scale of forest management in the Canadian boreal poses challenges in a third domain. Effective conservation must consider the economic costs of fully or partially protected areas, the contribution of “the matrix” to conservation objectives, and the dynamics of both natural and managed forests. This requires SDMs that are sensitive to forest management, and tools that integrate conservation strategies across both natural and managed forests so as to project management actions and ecosystem responses. This depends on SDM using only projectable climate *and* vegetation data. We present a national spatial simulation framework designed to integrate conservation planning, forest management and avian SDMs, based on a new national assemblage of forestry data, and illustrate its application to a SDM for Canada Warbler. We remark on the new sensitivities required of SDMs to capture spatial processes, the challenges of projecting vegetation dynamics, and the potential of this approach to support adaptive strategies.

3) Using MAPS vital rates to identify demographic causes of population trends

David F. DeSante, James F. Saracco, and Danielle R. Kaschube

We used 15 years (1992–2006) of constant-effort mist netting data from the Monitoring Avian Productivity and Survivorship (MAPS) program to model annual variation in population change, adult apparent survival, residency, and recruitment from Pradel and Cormack-Jolly-Seber capture-mark-recapture models, and productivity and post-breeding effects on recruitment from generalized linear mixed models for 140 landbird species. Recruitment was generally much more important than adult survival in driving annual variation in population change, but adult survival was relatively more important for declining Neotropical-wintering migrants and increasing permanent residents than for other species groups. Post-breeding effects, that include first-year survival and immigration of adults, were generally more important than productivity in driving annual variation in recruitment, and were most important for species with stable populations and for temperate-wintering migrants. For Wood Thrush (*Hylocichla mustelina*) for example, a declining Neotropical migrant, adult survival was nearly as important as recruitment in driving annual variation in population change, productivity was only weakly positively correlated with population change and recruitment, post-breeding effects were strongly positively correlated with adult survival, recruitment and population change, and adult survival was strongly positively correlated with recruitment, suggesting that both breeding and wintering populations were highly unsaturated and that population regulation was effected during the non-breeding season by survival of both young and adult birds. In contrast, for Ovenbird (*Seiurus aurocapilla*), a stable Neotropical migrant, productivity was weakly negatively correlated with population change and recruitment, and adult survival was strongly negatively correlated with population change, recruitment and post-breeding effects, suggesting that populations were saturated on both the breeding and wintering grounds and that population regulation was effected during both the non-breeding and breeding seasons by survival of young and limitations on recruitment, respectively. These examples illustrate the importance of long-term, large-scale demographic monitoring for informing landbird conservation.

4) The challenges of using continental-scale data to aid local decision-making

Daniel Fink, Wesley M. Hochachka, Kenneth V. Rosenberg, and Steve Kelling

Effective management of bird species across their ranges requires knowledge of where the species are living: their distributions and habitat associations. Often, detailed data documenting a species' distribution and niche will not be available for the entire region of interest, particularly for widely distributed species or for species that have not been the subjects of intensive study in the past. In these cases, we must use broad-scale survey data in order to interpolate a species' distribution and identify its habitat associations. In this presentation, we describe the novel use of broad-scale observational data for the purpose of inferring jurisdictional responsibilities for management of birds in the contiguous United States. We use this example to illustrate challenges to interpolating birds' distributions and deriving inferences from these interpolations, including challenges of: (1) accounting for and describing variation in a species' habitat associations through time and space (statistical non-stationarity), (2) handling a need to define discrete range boundaries in the face of models that will extrapolate non-zero probabilities of distribution well outside the actual range of a species, and (3) validating the accuracy and describing the precision of interpolations. To meet these challenges for specific applications requires clearly articulated inferential objectives. While the details of our study stem from our single research objective and we made use of only one data set (eBird checklist data), insights from the processes that we used have wider applicability in creating models of species' niches and distributions.

5) Migration dynamics of North American birds

Frank A. La Sorte, Daniel Fink, Wesley M. Hochachka, Marshall J. Ileff, and Steve Kelling

The study of avian migratory dynamics has had a long history in ecology. These studies typically involve the examination of a small number of birds that are intensively studied over short time intervals (telemetry) or many birds poorly sampled over longer time intervals (band returns). Extrapolating findings from these studies across populations or species has not been fully validated. We describe the use of a continental-extent citizen-science database of bird observations, eBird, to describe population-level migration dynamics for 93 North American bird species. We used daily observation recorded from 2007 to 2011 to estimate the speed and variability of spring and fall migration trajectories and the degree of overlap in seasonal migration routes. Daily patterns of occurrence for each species were summarized using weighted centroids and daily variability in occurrence using weighted SD. Each species' migration trajectory was modelled using generalized additive models applied to the weighted centroids. We contrasted observed dynamics across species with a set of independent predictors: body mass, migration distance, foraging guild, flight mode, and wing-aspect ratio. We selected the best combination of predictors using a bootstrap AIC stepwise procedure. Across species, migration speed and variability were similar in the spring and fall with more species following a clockwise migration trajectory. Smaller bodied, long distance migrants had higher migration speeds and less variable longitudinal patterns of occupancy during both migration periods. Smaller bodied, long distance migrants were also more likely to have clockwise migration trajectories. Our findings suggest migration strategies for small bodied, long distance migrants are more rigorously defined across space and time, with trajectories that appear to be more in line with seasonal climatic patterns. Narrower margins of error associated with successful migration for these species could explain these stronger associations. However, constrained migration strategies that are currently successful could be a hindrance under global change, especially when changing climatic conditions no longer favor current migration routes.

6) Integrating pattern and process across spatial scales to assess the potential effects of climate change on forest birds

Stephen N. Matthews, Louis R. Iverson, Anantha M. Prasad, Matthew P. Peters, and Nicholas L. Rodenhouse

Species distribution models aid in the evaluation of the potential ecological responses of birds to climate change, and they can assist in the development of management options. However, analysing ecological impacts by using summaries of coarse-scale models inhibits the ability to explain the structure of these models and how they influence habitat projections. In fact, such models are often treated as “black boxes”, making translation of modelled relationships into ecological associations difficult. We developed tools to better understand how potential habitat changes may affect 147 bird species in the eastern United States based at a coarse-scale (20 x 20 km) using RandomForest methods. Results highlighted the importance of including both climate and tree species variables in the species distribution models, where >60% of the models show more extreme projections of shifts in habitat when only climate variables were used as compared to model containing climate and tree species variables. Here we, also, present how fine-scale (1 x 1 km resolution, as aggregated from 30m National Land Cover Data) landscape composition complements and extends coarse-scale results. We selected 24 forest bird species from the northeastern U.S. and modelled the spatial agreement between coarse and fine-scale species patterns to elucidate cross scale differences. Finally, we linked these results to demographic parameters that suggest how species may respond differentially to climate change. By using a multi-layered approach, we were able to quantify to what extent broad-scale climatic and habitat pressures integrate with fine-scale stressors and avian demographic mechanisms, allowing a more comprehensive picture of potential change in the forest bird communities at a coarse spatial scale -- northeastern United States.

7) Using the Waterfowl Breeding Population and Habitat Survey to identify spatial population dynamics in boreal ducks

Christian Roy, Eliot J. B. McIntire, Steven G. Cumming, Marcel Darveau, and Nicole K. S. Barker

The importance of the boreal forest in the dynamics of waterfowl populations has long been underappreciated. However, the western boreal forest has recently been as the second most important waterfowl breeding area in North America, after the prairie pothole region.

Understanding how boreal populations are regulated and identifying the mechanisms that drive population dynamics are important steps for effective population management and conservation. We used data from the United State Fish and Wildlife Service (USFWS) annual Waterfowl Breeding Population and Habitat Survey (WBPHS) to assess the population dynamics of 7 boreal-breeding duck species in survey strata of the boreal forest and the boreal transition zone of Canada (n = 21 strata). We modelled population dynamics of each species independently, evaluating Gompertz and Ricker population models within a Bayesian state-space framework. We included random terms for intercepts and density dependence in strata, with seasonal (spring, summer, fall, winter) mean precipitation and temperature as annual covariates. We tested the hypothesis that density dependence and the effects of weather covariates on population growth varied among strata. In general, models with density-dependent terms on the log population size performed better than those with a Ricker formulation. Both the strength of density dependence and the estimated carrying capacity showed a geographical trend for all species but these trends were not significant due to sample and population size. Early nesters like the mallard showed a response to summer precipitation while late nesters like scaup and scoters showed response to autumn precipitations. For some stratum the response to precipitations was quadratic which could be liked to nestling survival. However, the effects of precipitation were not consistent across all strata and no simple spatial patterns were evident across species. In spite of few generalizations across these large spatial scales, the fact that the Gompertz model performed better for most species suggests that waterfowl boreal population response to perturbations could be slower than expected.

8) Accommodating geographic scale in the analysis of species groups from the North American Breeding Bird Survey

John R. Sauer, William A. Link, Keith L. Pardieck, David J. Ziolkowsk , Jr., and Jane E. Fallon

The North American Breeding Bird Survey (BBS) is the only source of population change information for most species of birds that breed in North America. Goals for use of BBS information have evolved significantly from initial interests in description of trends in bird populations; as the only data set with sufficient information to develop dynamic models of influence of climate, land use, and other global changes on bird populations, increasing emphasis is placed on using the data to discriminate between hypotheses of factors influencing bird populations. Analyses focus on integration of BBS data with a variety of other data to enhance inference and include environmental features that influence population change. Model-based, hierarchical analyses are needed to accommodate issues of scale and to control for factors that influence counting of birds. Summarizing patterns of population change for species groups is a computationally intensive and time-consuming task, but permits evaluation of bird population dynamics at multiple scales. We use cluster analysis of regional species occurrence data within Bird Conservation Regions to define regions of consistent species groups and use these regions as the basis of hierarchical structuring of species groups analysis. We apply this analysis to document regional variation on composite population change for grassland birds, forest birds, and other species groupings. Obligate grassland birds form 4 clusters with regional variation in patterns of composite population change.

9) Forest passerine distribution models and climate change projections for boreal North America: addressing challenges and uncertainties

Diana Stralberg, Erin M. Bayne, Fiona K. A. Schmiegelow, Péter Sólymos, Steven G. Cumming, Steven M. Matsuoka, Patricia C. Fontaine, and Samantha J. Song

Avian point-count survey data assembled across biomes and continents can provide an important resource for detecting and projecting the effects of global climate change on avian species' distributions and patterns of relative abundance. This is especially true within the remote boreal forest region of North America, where the magnitude of projected change is high but distributional knowledge is limited. Recent methodological advances and increases in data availability have improved prospects for accurate models of current species' distributions. However, there are many challenges associated with applying current models to future change scenarios. We address several of these with boreal bird examples. (1) The choice of climate space considered for model development may have significant impacts on change projections. To delineate the appropriate climate space for model development and prediction, we identified the locations of current analogues for a range of potential future boreal climates, as well as the potential for future climates with no modern analogue. (2) The potential for future decoupling of correlated climatic indices makes variable selection particularly important in a climate-change context. We have employed a combination of *a priori* mechanistic hypotheses and statistical variance partitioning to develop parsimonious models for projection purposes. (3) Distributional shifts in avian habitat specialists will likely depend upon the pace and extent of vegetation changes. Thus we have evaluated the extent to which boreal birds are climate- vs. vegetation-limited, and have considered a range of scenarios with respect to the extent and nature of future vegetation change.

10) Extinction risk estimated for every bird adequately surveyed by the North American Breeding Bird Survey

Wayne E. Thogmartin and Patrick A. McKann

The Breeding Bird Survey (BBS) is the most important means for assessing the status and trend of landbird species in North America. Information on status and trend is useful, nay, critical, in prioritizing research and conservation effort; Partners in Flight uses this information, for instance, to characterize risk for >400 species. Extinction risk is the integration of trend, variability in trend, and population size. The Partners in Flight measure of risk inexpertly reconciles these characteristics of risk. Thus, we employed autoregressive state-space models allowing us to calculate the probability of a species declining in abundance to the point where it is no longer adequately surveyed by the BBS (i.e., quasi-extinct). The generic model for this calculation is written as $x_t = x_{t-1} + u + w_t$, where w_t

$\sim N(0,\sigma^2)$, and $y_t = x_t + v_t$, where $v_t \sim N(0,\eta^2)$. y_t is the logarithm of the observed population size at time t (as described currently by annual indices of abundance calculated with hierarchical Bayesian over-dispersed count models), x_t is the unobserved state at time t, u is the growth rate, and σ^2 and η^2 are the process (environmental stochasticity) and observation error variances, respectively. These methods artfully combine trend, variability in trend, and population size to provide relative predictions of risk, as well as disentangling observation error from environmentally induced stochasticity. We calculated and mapped regional probabilities of quasi-extinction, with bootstrapped confidence intervals, for all species adequately surveyed by the BBS. Our ultimate aim is to incorporate regional estimates of the probability of quasi-extinction into the annual calculations reported by the BBS as a means of delivering objective measures of risk. Such objective measures of risk, described spatially and temporally, will provide a more robust basis for prioritization efforts.

11) Patterns in the survival and demography of *Tachycineta* swallows across the Western Hemisphere

David W. Winkler, Eldar Rakhimberdiev, Maria Stager, Caren Cooper, and Daniel Ardia

Over the past ten years, an increasing number of studies have been initiated across the Americas on the breeding biology of *Tachycineta* swallows as part of the Golondrinas de las Americas project. Some of these studies are long-term (>10 years) and others have only two or three year's data to date. We experimented with several methods to get estimates for adult survival from sites where the data by themselves are not sufficient for analysis with traditional mark-recapture methods. These survival data can be combined with data on breeding biology and reproductive success to yield estimates of the demographic status of populations across the Western Hemisphere. These estimates, though far from perfect, also will bear directly on the results of several recently completed comparative studies of latitudinal variation in parental investment and offspring growth and survival, and thus they may be relevant to evaluating potential costs of reproduction.

12) Examining the tradeoffs between using citizen science data and standardized observations for modelling how climate change will affect the distribution and abundance of birds at regional scales

Sam Veloz, Dennis Jongsomjit, Leo Salas, Nathan Elliott, and Grant Ballard

Commonly used methods to estimate the distribution and abundance of birds at regional spatial scales involve developing statistical models of the correlation between observations of birds and a set of environmental variables. When we use these models to estimate a response to future climate change we assume that our set of observations adequately sample the range of suitable conditions within which a species can persist both in current and future time periods. However when we apply these models at regional scales, we seldom have standardized observation data available which adequately sample species' ranges throughout the entire region resulting in biased estimates of species' responses to future conditions. Considerable efforts have been made to amass data from individual standardized sampling programs into centralized databases to facilitate the creation of better models, yet there are still gaps in the coverage from these data. Citizen science bird observations are increasingly becoming available and could be used to improve models when only biased standardized observation data are available. We use examples of our efforts to model the distribution of birds from Mexico through the Pacific Northwest to examine the tradeoffs between using standardized data and citizen science data to project responses to climate change scenarios. In the Pacifica Northwest, we were able to acquire close to one million standardized observations from many sources and used the data to create models of the abundance of birds with a sufficient sampling of the available environmental conditions with which to model future responses to climate change. In contrast, we were unable to obtain an adequate sample of standardized observations in the southwest and Mexico and thus used citizen science observations to develop occurrence models for this region. Our models illustrate how results from individual sampling efforts can be applied to much larger regions when data from different sources are made available through a centralized database. We also demonstrate how citizen science can fill in the gaps when standardized data are unavailable and that in many cases models from citizen science data may be superior to models constructed using standardized methods but with poor spatial coverage. Finally we show how the available data can be used to identify priorities for future monitoring efforts by examining where environmental space has been poorly sampled within the region.