Adaptive monitoring framework for warblers at risk in northeastern British Columbia: Using habitat models and expert opinion to refine monitoring

Pierre R. Vernier[1], Michael I. Preston[2], Fred L. Bunnell[3], and Andrew Tyrrell[4]

[1] Department of Renewable Resources, University of Alberta, Edmonton, AB T6G 2P5
[2] Stantec Consulting Ltd., Sidney, BC V8L 5X4
[3] Department of Forest Sciences, University of British Columbia, Vancouver, BC V6T 1Z4
[4] Canadian Forest Products Ltd., Fort St. John, BC V1J 4M6

Introduction

Forest and wildlife managers must often assess and manage species of concern in areas where there is little or no historical data to draw upon, or where relevant data is difficult and costly to acquire. This is the case for five of eight warbler species that are restricted to the northeastern corner of British Columbia. The five species – Bay-breasted Warbler (*Dendroica castanea*; BAYW), Black-throated Green Warbler (*Dendroica virens*; BTNW), Canada Warbler (*Wilsonia canadensis*; CAWA), Cape May Warbler (*Dendroica tigrina*; CMWA), and Connecticut Warbler (*Oporornis agilis*; COWA) – each rank highly (rank 2) within the provincial Conservation Framework (Bunnell et al. 2009a). Each has been designated under the Forest and Range Practices Act and regulations as 'At Risk' (herein referred to as "listed"). These species thus have a direct impact on forest management practices, but their status and trends are difficult to assess because they have low rates of detection using standard Breeding Bird Surveys (BBS), are regionally rare, and occur at the western end of their North American range. Moreover, it is not clear whether current monitoring efforts implemented by industry and government will be effective at detecting changes in warbler abundance over time or evaluating the effects of forest management practices.

In response to this situation, monitoring programs have been developed to provide current and relevant information that can be used to assist decision makers. For example, the BBS have been conducted annually in northeastern British Columbia since 2002 to provide information on the status and trends of forest birds and to evaluate the effectiveness of management activities. The BBS, however, does a relatively poor job of detecting most species of special concern, such as the five listed warbler species. This is partly because the BBS tends to sample many habitat types broadly over the landscape resulting in low overall detection rates for species that are rare or that specialize in certain habitat types. To address this gap it is necessary to adapt and refine monitoring programs to more effectively target species of conservation and management concern. One approach is to use baseline BBS and habitat data from previous years to develop models that can be used to target additional survey sites with a high predicted probability of occurrence for the species of concern.

Model-based or targeted sampling can thus be used to increase survey efficiency while reducing sampling costs by targeting locations with high probabilities of hosting the species of interest (Edwards et al. 2005, Guisan et al. 2006). This can be done, for example, by creating a binary map identifying all sites where predicted suitability is above a minimum threshold that includes the majority of species occurrences (*e.g.,* 75th percentile of predicted probability of occurrence; Engler et al. 2004). This map can then be used along with constraint factors such as accessibility, distance from roads, and minimum patch size to select future locations for sampling. This process, in combination with expert knowledge and incidental observations, can be repeated over several iterations to further refine the models and subsequently add additional high suitability sites to the monitoring program. Moreover, the approach can be combined with local knowledge to adapt the bird surveys in the field where necessary. For example, line work used to describe forested and non-forested polygons may prove to be out-dated (*e.g.,* a mature stand is now harvested) or imprecise (*e.g.,* line work is not spatially correct), thus requiring in-field adjustment to the location of some point count stations. In one study, spatial inaccuracies in line work often ranged from 25-100 m, whereas discrepancies in stand age or stand type ranged from 1.1% to 11.1% of locations, respectively (Preston 2009).

In this paper we illustrate the use of the framework to refine the BBS design for monitoring the five listed warbler species that occur in the Fort St. John Timber Supply Area (TSA). Specifically, we develop species-specific habitat models and combine them with expert knowledge to target additional survey sites that have a relatively high probability of detecting one or more of the five warbler species. The approach makes use of forest inventory, topographic, and bird monitoring data to develop habitat-based models that can be used with a GIS to predict habitat suitability at surveyed and non-surveyed sites.

Methods

Study Area

The Fort St. John TSA is located within the northern half of the Peace Forest District in northeastern British Columbia (Figure 1). The TSA consists of both managed and unmanaged forests that lie within the boreal white and black spruce (BWBS), spruce-willow-birch (SWB), and Englemann spruce–subalpine fir (ESSF) zones of the Biogeoclimatic Ecosystem Classification (BEC; Meidinger and Pojar 1991). Alpine Tundra (Boreal Altai Fescue Alpine; BAFA) occurs at higher elevations along the eastern slopes of the Rocky Mountains, in the western half of the study area. The major merchantable tree species in the study area are lodgepole pine *(Pinus contorta)*, subalpine fir *(Abies lasiocarpa),* white spruce *(Picea glauca),* trembling aspen *(Populus tremuloides),* Balsam poplar (*Populus balsamifera)*, and spruce hybrids *(Picea* spp). General forest types include conifer, deciduous, and mixedwood, especially in the BWBS zone. The study area is distinctly seasonal, and is generally characterized by long cold winters and short hot summers. Most bird species that occur in the area are summer visitants, and fewer than 20 species are relatively common, year-round forest-dwelling inhabitants. Of the more than 20 species of warbler that breed in the area, all are migratory, with the five listed warblers wintering primarily south of the contiguous United States, and mostly in the tropics. The five listed warblers arrive in the Fort St. John TSA (primarily in the BWBS) in late May and depart between late July and mid-August.

Bird Surveys

Breeding Bird Surveys were initiated in the Fort St. John TSA in 2005 to monitor trends in abundance, assess habitat associations, and evaluate the effectiveness of management activities (Bunnell et al. 2009b, Preston et al. 2006, Preston et al. 2007, Preston 2009). This approach has worked well for many common species, including both habitat generalists and specialists (Vernier and Bunnell 2007, Bunnell et al. 2009c, 2009d). However, and as anticipated, the number of provincially-listed species detected has been relatively low, necessitating a more targeted approach for these species. Consequently, we used bird survey data from 2006 and 2007 to develop habitat-based models that could be used to target additional predicted high quality sites for inclusion in the 2008 survey. The data consisted of warbler presences/absences obtained from point count stations that were established along roadside transects within areas managed for sustainable forestry (Table 1). A total of 480 roadside stations were located at 800-m intervals along 16 transects in both years. In 2007, forest interior surveys were conducted at 36 stations that were > 200 m from roads and other hard edges in mature deciduous (19 stations) and mixedwood (17 stations) stands in the

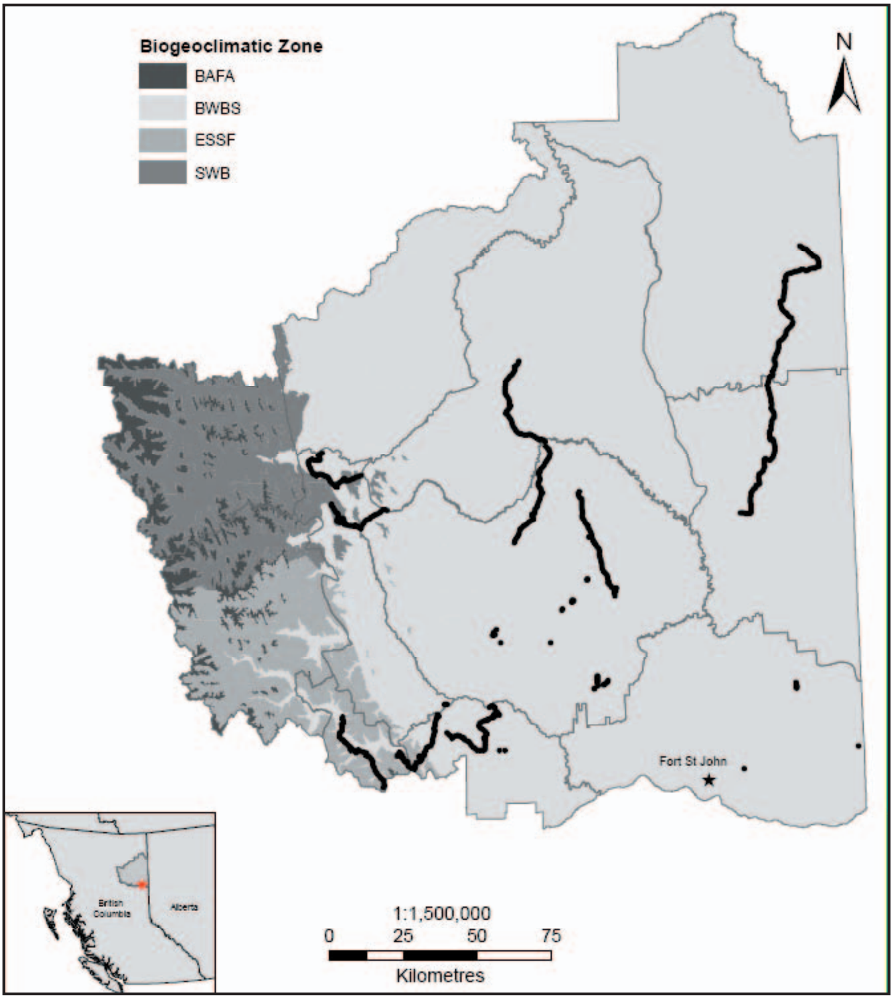

Figure 1. Locations of bird survey stations (dots) sampled between 2006-07 in the Fort St. John TSA.

Table 1. Number of warbler detections in each sampled year by survey type used for model-based habitat predictions. See *Introduction* for species codes and full names.

Year	Survey	Stations	BAYW	BTNW	CAWA	CMWA	COWA
2006	Breeding Bird Survey	480	0	2	1	7	0
2007	Breeding Bird Survey	480	2	15	2	9	2
	Forest Interior Survey	36	1	6	0	1	0
	Incidental Observations	38	0	24	5	7	2

vicinity of existing roadside transects. That same year, 38 incidental observations of listed warbler species were also recorded during the establishment of point count stations. All occurrences of listed warblers were included in the predictive model analyses. Additional information on the bird survey methodology and summary results can be found in Preston et al. (2006, 2007) and Preston (2009).

Habitat Models

We used vegetation resources inventory (VRI) and topographic data to measure habitat and terrain characteristics in and adjacent to point count stations. Only those variables that were included in the warbler models are listed (Table 2). ELEV and SLOPE measured elevation and slope at the station centre, respectively, while XCOORD and YCOORD measured the geographic location of the station to indicate if there is a spatial trend in the eastern or northern direction. Local disturbance index (LDI)

Table 2. Description and coefficients of predictor variables used to develop logistic regression models for three warbler species.

Variable	Description	BTNW	CAWA	CMWA
ELEV	Elevation at station centre		-0.007	0.004
SLOPE	Slope at station centre		0.114	-0.143
XCOORD	Standardized UTM x-coordinate [mean=0, sd=1] at station centre	1.600		
YCOORD	Standardized UTM y-coordinate [mean=0, sd=1] at station centre			
LDI	Area in cutblocks, wells, roads, cutlines, etc. within 100m buffer			-0.013
N_YDECID	Proportion of young deciduous forest (31-90 yrs and >75% deciduous species by basal area) within 100-500m annulus		0.030	
N_ODECID	Proportion of old deciduous forest (>90 yrs and >75% deciduous species by basal area) within 100-500m annulus	0.053	0.041	
N_YCONIF	Proportion of young coniferous forest (31-90 yrs and >75% conifer species by basal area) within 100-500m annulus	-0.037		
N_OCONIF	Proportion of old coniferous forest (>90 yrs and >75% conifer species by basal area) within 100-500m annulus	0.027		
N_YMIXED	Proportion of young mixedwood forest (31-90 yrs and >25% conifer and deciduous species by basal area) within 100-500m annulus		-0.049	
N_OMIXED	Proportion of old mixedwood forest (>90 yrs and >25% conifer and deciduous species by basal area) within 100-500m annulus	0.069	0.027	
Constant	Logistic regression model constant	-2.942	1.907	-2.162
AUC	Area under the ROC curve – a measure of the predictive accuracy of the model	0.881	0.889	0.723

was measured as the amount of area composed of cutblocks, roads and seismic cutlines within 100-m of the station centre. Several variables (prefixed with an N_) quantified the proportion of broad forest types and age classes as derived from VRI within a 100-500 m annulus around point count stations. All map-based variables were rasterized prior to developing and applying the models. We intersected the bird survey locations with the habitat covariate maps and used these data to develop multiple logistic regression models (Hosmer and Lemeshow 2000) to estimate the probability of occurrence of each listed warbler species as a function of the habitat covariates. We were able to develop models for three of five warbler species: Black-throated Green Warbler, Canada Warbler, and Cape May Warbler (Table 2). The number of detections for the other two species (Bay-breasted Warbler and Connecticut Warbler) were insufficient to develop reliable models.

Targeted Sampling

Our adaptive monitoring framework consisted of using species-habitat relationships and expert opinion in an iterative model-based approach to target and refine monitoring for warbler species at risk (Figure 2). Five broad steps were employed:

1) Develop predictive habitat-based models using VRI and bird monitoring data from previous years' surveys. As described in the previous section, we used logistic regression models to predict the probability that a bird would be present at each pixel in the area of interest. The predicted probability of occurrence (PPO) is usually measured as a proportion between 0 and 1. Thus, a PPO of 0.9 means that there's a very good chance of detecting that species at that location if the sampling was repeated in the same way as in the past. Conversely, a PPO of 0.1 would mean that it is very unlikely that we would detect the species.

2) Use models to identify non-surveyed high quality habitat for each listed warbler species. This was done by applying the logistic regression functions to predict and map the probability of occurrence of each listed warbler species in the Fort St. John TSA. Model predictions were restricted to the accessible portions of the Fort St. John TSA (based on availability of digitized road data). Each species' PPO map was then reclassified to a binary map using the 75th percentile as a cutoff indicating high quality habitat. Other values can be used. The maps are then combined using simple map algebra to show the best sites for the modeled species and, possibly, other species with similar habitat requirements or life history characteristics. The resultant map is used as one of the factors in the model-based sampling approach. Only species for which it is possible to develop models should be included. Other species, such as BAYW and COWA, whose sample size (number of detections) is too small for statistical analysis, require a different modeling approach such as Habitat Suitability Index (HIS) or Bayesian Belief Networks (BBN) that can be developed using expert knowledge. Those approaches are beyond the scope of this paper.

3) Combine maps of biological criteria (habitat preferences) and logistical criteria (constraints to ease sampling) to restrict the selection of candidate sampling sites (Table 3). The biological criterion of elevation range (± 100 m of known locations) of each species was used to restrict sampling to known locations for those species. Practical constraints, such as the road buffer factor, can be used when designing off-road surveys, and in this case ensured that only sites between 200-500 m from a road were considered. The road buffer is not necessary when designing or modifying roadside surveys. Proximity to stations defines the minimum distance between stations while "near existing station" favours sites that are closer to existing stations (see Table 3). These factors can each be changed and new ones can be incorporated. The habitat quality map is then combined with the survey constraints maps to arrive at a set of candidate sites for random sampling. An example Python script implementing this GIS-based procedure is available from the first author.

4) Select and survey random sites from the candidate pool of sites. The number of random sites (n = 1,000) exceeded the number that we planned on surveying, to accommodate an expected reduction in candidate sites that would be considered unsuitable (*i.e.,* they are not what they were supposed to be) or

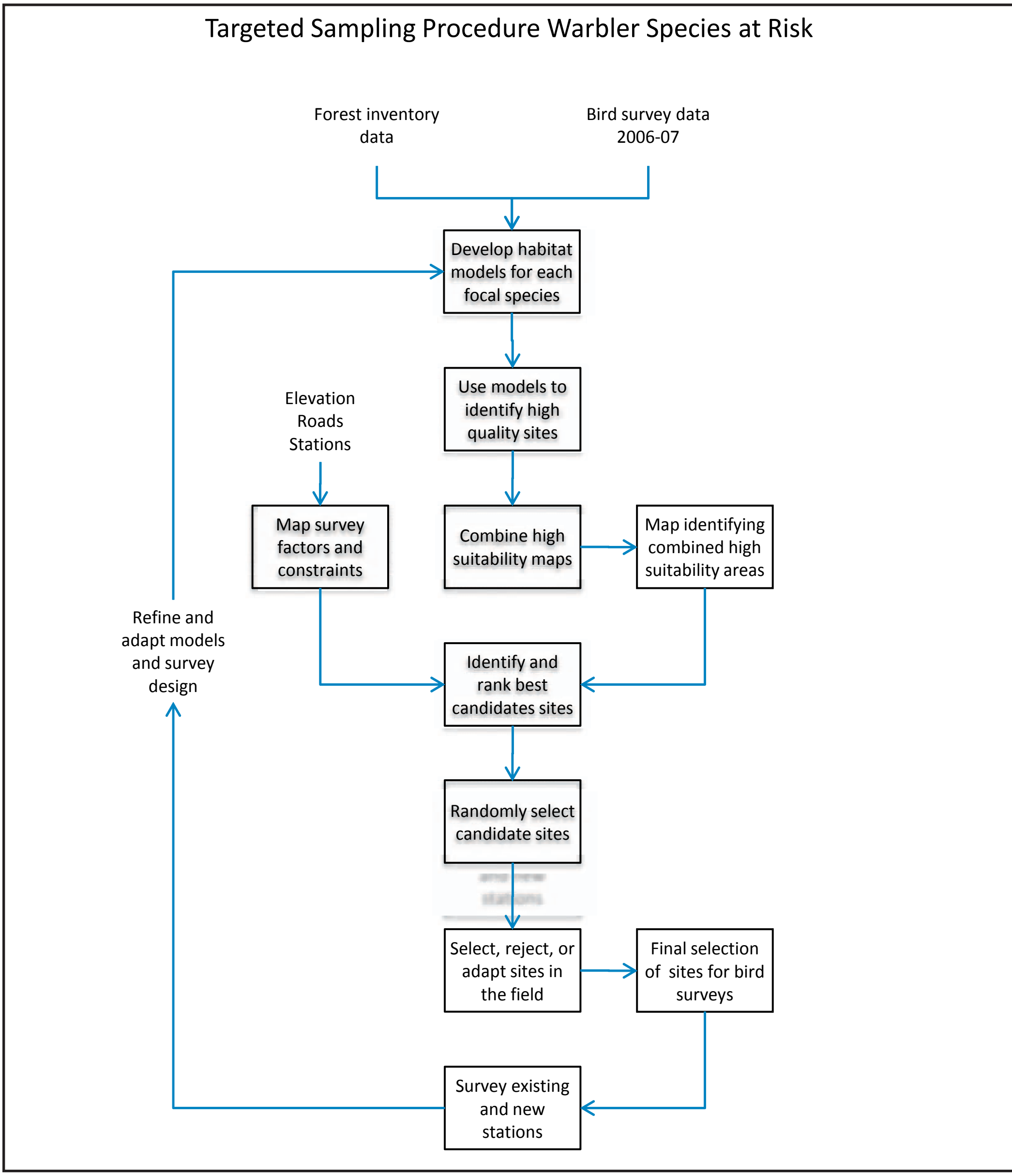

Figure 2. Flowchart outlining the steps in the adaptive monitoring framework for warbler species at risk.

Table 3. Criteria for identifying new survey locations. One or more criteria can be used and default values can be changed.

Criteria	Data	Roadside surveys	Off-road surveys
High quality habitat	PPO grid	75th percentile	75th percentile
Elevation	Elevation grid	+/- 100m of species range	+/- 100m of species range
Road buffer	Map of roads	N/A	200-500m
Proximity to stations	Map of survey stations	>400m	>200m
Near existing stations	Map of survey stations	Ranked higher	Ranked higher

that would be inaccessible in the field. No candidate sites were rejected because they were not suitable and all point count stations were located within 100 m of the randomly selected locations (while ensuring that they remained > 200 m from existing BBS stations). In some cases, additional sites were added in the field if rare but suitable habitat was in close proximity, thus increasing survey efficiency.

5) Implement surveys and repeat process the following year. Using data from 2006-2007, 86 observations representing the five warbler species of concern were used to create 1,000 new and random potential survey stations. After removing inaccessible or incorrect survey stations from the pool (while in the field), 104 point count stations were established and surveyed in 2008 (Figure 3). These were combined with the 480 existing BBS stations also located in the Fort St. John TSA. All point count stations were sampled between 1 and 30 June, using 5-minute point counts surveyed between sunrise and four hours post-sunrise, as per provincial standards (RIC 1999). Individual bird occurrences were recorded on datasheets that had an aerial photo of each point count station with 50-m concentric rings up to 200 m (see Vernier and Preston 2007). Each aerial photo also included line work and codes to delineate individual stands based on stand age and stand type (*i.e.,* leading tree species). This assisted both in evaluating error in stand age and type, and also in increasing the spatial precision of bird occurrences.

Results

We developed habitat models for three of the five warbler species for which we had sufficient data (see Table 2): Black-throated Green Warbler, Canada Warbler, and Cape May Warbler. The predictive accuracy of the three models ranged from 0.72 for Cape May Warbler to 0.88 and 0.89 for Black-throated Green Warbler and Canada Warbler, respectively. The models were thus considered to be satisfactory for the three species and were used to identify a set of new survey stations that were sampled in the spring/ summer of 2008. One of the outputs of the targeted sampling procedure was a map identifying predicted high suitability areas for detecting listed warbler species. This map was used by one of the authors (M. Preston) to locate and establish 104 model-based point count stations. Figure 4 illustrates a section of the map, reproduced in shades of grey. Further examples can be viewed at: http://biod.forestry.ubc.ca/doku.php?id=selection.

Of the 104 model-based warbler survey stations and 480 BBS stations, 68 (65.4%) and 22 stations (4.6%), respectively, included at least one of the five listed warbler species (Table 4). A total of 100 individual warblers were observed at the model-based survey stations, and 28 birds at the roadside BBS stations[1]. There were no survey stations where four or five of the warbler species co-occurred, and there was only one model-based survey station where three species co-occurred (Black-throated Green

[1] There was never more than one detection of each warbler species at each station, regardless of the survey approach.

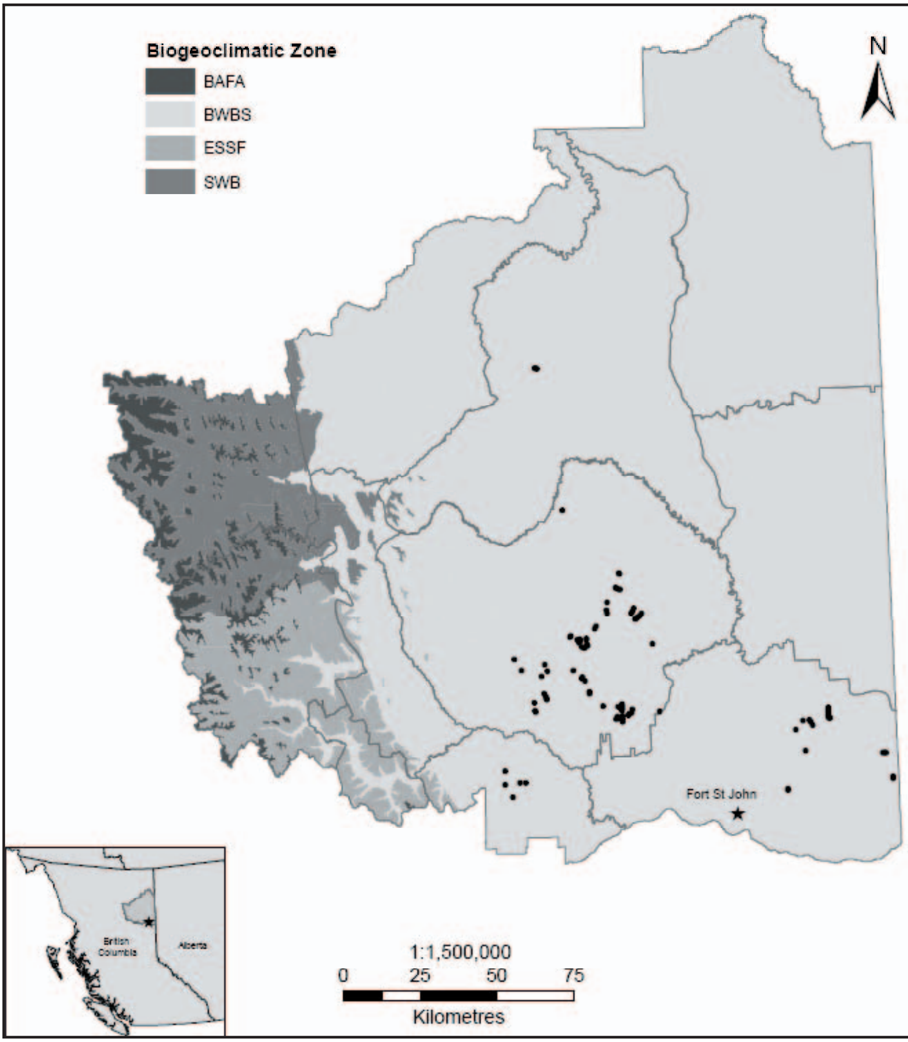

Figure 3. Locations of warbler survey stations (dots) sampled in 2008 in the Fort St. John TSA

Warbler, Canada Warbler, and Connecticut Warbler). There were 11 model-based survey stations where two of the warbler species co-occurred (10 stations were Black-throated Green Warbler and Canada Warbler co-occurrences, and one station was Canada Warbler and Connecticut Warbler co-occurrence).

The sampling efficiency (percentage of plots occupied[1]) of the model-based versus the standard BBS approach varied by species but was overall 14 times greater when all five warbler species were combined. Three species accounted for all the gains in sampling efficiency: Black-throated Green Warbler, Canada Warbler, and Connecticut Warbler. Conversely, survey efficiency for both Bay-breasted Warbler and Cape May Warbler was lower using the model-based approach, although these two species

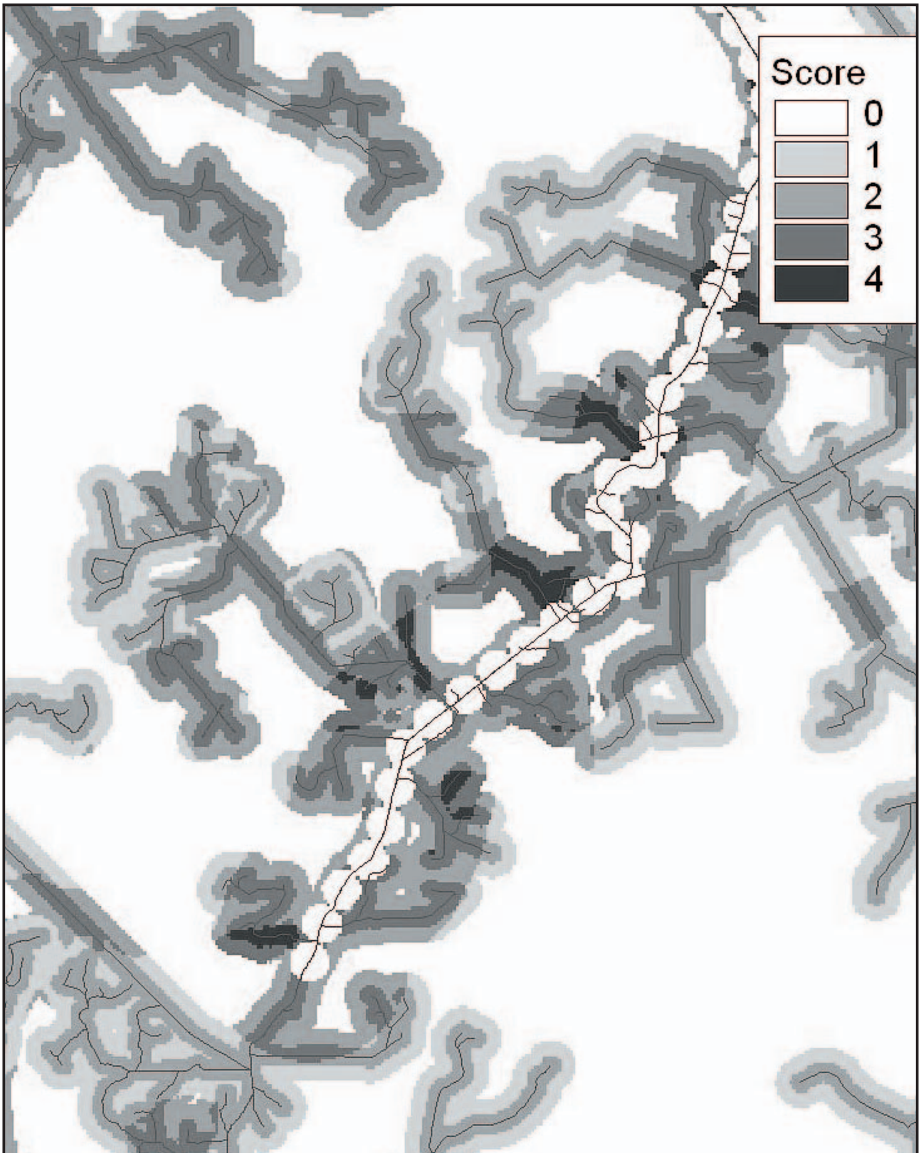

Figure 4. Example output from model-based sampling procedure. Increasing shades of grey depict increasingly more suitable areas for sampling species using roadside and forest interior surveys, respectively. Circles indicate the location of existing roadside bird point count stations. White areas are excluded based on the criteria.

Table 4. Percentage of occupied plots and total abundance of listed warblers from 104 model-based survey stations and 480 Breeding Bird Survey Stations surveyed in 2008 in the Fort St. John TSA.

	Occupied Plots (%)		
Species	**Breeding Bird Surveys**	**Model-based Surveys**	**Total Abundance**
Bay-breasted Warbler	0.2	0.0	1
Black-throated Green Warbler	3.3	42.3	76
Canada Warbler	0.2	23.1	30
Cape May Warbler	0.8	0.2	6
Connecticut Warbler	0.8	10.6	15
Total	**4.6**	**65.4**	**128**

had a very minor impact on overall efficiency due to their low prevalence in the area surveyed. By way of comparison, the total number of listed warblers detected (and by extension sampling efficiency) in 2007 and 2008 using the BBS approach was 30 and 28, respectively. The largest difference occurred for Cape May Warbler which had five fewer detections in 2008 compared to the previous year.

Discussion

In this paper, we described and illustrated a relatively simple approach for increasing the effectiveness and efficiency of surveys for species of conservation concern. The approach makes use of existing bird survey (*i.e.* BBS) and habitat data, statistical habitat models, and expert opinion to adapt and refine a sampling design. The survey and habitat data were used to develop habitat relationship models that were then used to identify and map high suitability areas for target species. In the Fort St. John TSA, the predictive map was used in the field and modified, where necessary, based on expert knowledge and field conditions, to arrive at a final selection of sampling sites. Overall, the procedure resulted in a combined 14-fold increase in survey efficiency for the five warbler species, with the best results obtained for Black-throated Green Warbler, Canada Warbler, and Connecticut Warbler. Although Connecticut Warbler was not modelled due to low sample sizes, the improvement in survey efficiency for that species was likely due to some similarities in habitat preferences with Canada Warbler. Conversely, Cape May Warbler survey efficiency decreased approximately four-fold with the use of a habitat model; the absolute detection rates however were very low using either survey approach. Bay-breasted Warbler survey efficiency also decreased using the model-based approach, but this species had the lowest detection rates among the five species using both survey types. Additional years of data will permit a more thorough evaluation of the efficiency and predictive accuracy of the models for all five listed warbler species, not just the three for which enough data was available to develop models.

While this approach demonstrates increased efficiency in sampling, the results are based on only one year of data in one region (Fort St. John TSA). We expect that model attributes will differ with more samples[1] and when applied to other areas. The models also are restricted to VRI data that does not sample understory attributes well. Such attributes may be important for some warbler species. For example, from a call play back study that assessed the prevalence of understory at sites occupied by Canada Warbler, Campbell et al. (2007) reported that all 103 sites visited had some understory, with average shrub cover being 79%, and 80% of sites having shrubs ranging in height from 2.5-3.5 m. Moreover, there are other possible methods for developing predictive habitat-based models that can be used to target

[2] Preliminary analysis of 2009 survey data indicate an increase in the number of Connecticut Warblers detected in Fort St. John (Unpublished data).

sampling (*e.g.,* Guisan et al. 2006, Schmiegelow and Cumming 2004). Our approach consisted of using logistic regression using gridded representations of forest inventory attributes, enabling the creation of a wide range of potential habitat covariates at two spatial scales (stand and neighbourhood). Such a model is then applied by aggregating combinations of habitat and identifying areas where the species has at least a 75% likelihood of occurring within a pixel. A disadvantage of the approach is the need to switch from vector to raster representations of the landscape and to generate neighbourhood covariates prior to targeting candidate sites, thereby increasing the need for GIS analysis prior to applying the models. To address this issue, we are currently exploring the use of predictive models that are linked directly to the VRI attribute table.

An alternative approach that could also be implemented directly from the original forest inventory data consists of creating broad habitat categories and evaluating each species' preference or avoidance of those classes (*i.e.,* Species Accounting System; Vernier and Bunnell 2007; Bunnell et al. 2009b). The main advantage of this latter approach is the ability to link more directly with broad habitat classes and thus potentially connect more directly to forest practices (e.g., Bunnell et al. 2009c). The challenge when relying on direct analysis of BBS results stratified by habitat is that sample size requirements increase with increasing number of habitat classes. A disadvantage to both approaches is the need to create somewhat arbitrary habitat categories, but no matter which approach is used, the effectiveness of directed sampling will depend in large part on the quality of the habitat inventory data and how current it is. Care should be taken to match year of surveys with VRI since omitted recent cutblocks would: 1) affect the accuracy of the models and 2) lead to a number of candidate sites that are not what they were predicted to be. Ensuring habitat data are current can reduce the amount of time needed to modify the sampling scheme in the field.

Forest and wildlife managers must often manage species and their habitats with incomplete and uncertain information. Monitoring programs such as the BBS help to address this problem but, in the case of rare and endangered species, additional survey efforts may be needed. The model-based survey framework described in this paper is one attempt at addressing the weaknesses of the standard BBS for species of concern. Specifically, it can be used by forest managers to refine the BBS design for monitoring the five listed warbler species that occur in the Fort St. John TSA and elsewhere in northeastern BC. Species-specific habitat models can be developed relatively easily and at little cost using existing VRI data and, when combined with expert knowledge, can be used to target additional survey sites that have a relatively high probability of detecting one or more of the species of concern. Moreover, data collected using the approach can be used to inform management practices, adapt the habitat-based models, and refine the sampling design to enhance its effectiveness – all activities that are part of the adaptive management cycle.

Acknowledgements

Thanks to Mark Phinney for his review and comments on an earlier draft of this paper which helped improve the final manuscript. Thanks to Ryan Stohmann (Stantec) for preparing Figures 1 and 3. We gratefully acknowledge support from the B.C. Forest Sciences Program, Canadian Forest Products Ltd., B.C. Ministry of Environment, and the B.C. Ministry of Forests and Range Forest Investment Account. Bird surveys were conducted by Westcam Consulting Services (M.I. Preston, J. Preston, A. Robinson, R.W. Campbell). Canadian Forest Products Ltd. provided digital forest inventory data and logistical support for the fieldwork.

Literature Cited

Bunnell, F.L., D.F. Fraser, and A.P. Harcombe. 2009a. Increasing effectiveness of conservation decisions: a system and its application. Natural Areas Journal 29:79-90.

Bunnell, F.L., L.L. Kremsater, A. Moy, and P.R. Vernier. 2009b. Summary assessment of the species accounting system and coarse-filter analyses for Canadian Forest Products tenures in northeastern British Columbia. Final Report to Canadian Forest Products and BC Forest Sciences Program. 19 pp.

Bunnell, F.L., L.L. Kremsater, A. Moy, and P.R. Vernier. 2009c. Conservation framework for

Canadian Forest Products tenures in northeastern British Columbia. Final Report to Canadian Forest Products and BC Forest Sciences Program. 41 pp.

Bunnell, F.L., L.L. Kremsater, A. Moy, and P.R Vernier. 2009d. Biodiversity sustainability analysis of the contribution of dying and dead wood to biodiversity in the Fort St. John TSA. Report to Canfor, FIA Project 2799004. 45 pp.

Campbell, R.W., M.I. Preston, M. Phinney, C. Siddle, and J. Deal. 2007. Featured Species – Canada Warbler. Wildlife Afield 4:95-160.

Edwards, T.C., R. Cutler, N.E. Zimmermann, L. Geiser, and J. Alegria. 2005. Model-based stratifications for enhancing the detection of rare ecological events: lichens as a case study. Ecology 86:1081-1090.

Engler, R., A. Guisan, and L. Rechsteiner. 2004. An improved approach for predicting the distribution of rare and endangered species from occurrence and pseudo-absence data. Journal of Applied Ecology 41:263-274.

Guisan, A., O. Broennimann, R. Engler, M. Vust, N.G. Yoccoz, A. Lehmann, and N.E. Zimmermann. 2006. Using niche-Based models to improve the sampling of rare species. Conservation Biology 20:501-511.

Hosmer, D.W., and S. Lemeshow. 2000. Applied Logistic Regression. 2nd ed. Wiley. New York, NY.

Meidinger, D. and J. Pojar (eds.). 1991. Ecosystems of British Columbia. B.C. Ministry of Forests, Victoria, B.C. Special Report No. 6.

Preston, M.I. 2009. Monitoring birds for sustainable forest management: species-habitat associations in the Fort St. John Timber Supply Area. Canadian Forest Products Ltd., Fort St. John, BC. 87 pp.

Preston, M.I., P.R. Vernier, and R.W. Campbell. 2006. A four-year summary of summer bird surveys in TFL 48 and the Fort St. John Timber Supply Area. Canadian Forest Products Ltd., Chetwynd, BC. 38 pp.

Preston, M.I., P.R. Vernier, and R.W. Campbell. 2007. Using Birds for Species Accounting and Effectiveness Monitoring in Tree Farm License 48 and the Fort St. John Timber Supply Area. Progress Report prepared for Canadian Forest Products Ltd. and Environment Canada.

Resource Inventory Committee [RIC]. 1999. Inventory methods for forest and grassland songbirds - standards for components of British Columbia's biodiversity #15, ver. 2.0, March 1999. BC Ministry of Environment, Lands and Parks, Resources Inventory Branch, Victoria, BC. 49 pp.

Schmiegelow, F.K.A., and S.G. Cumming. 2004. The Remote Areas Project: a retrospective study of avian indicators of forest change. SFM Network Project Report 2004-14.

Vernier, P.R., and M.I. Preston. 2007. Habitat representation of Breeding Bird Surveys in northeast BC with implications for monitoring listed warbler species. Wildlife Afield 4:241-255.

Vernier, P.R., and F.L. Bunnell. 2007. Using avian species monitoring and map-based data in a coarse-filter approach to sustaining biodiversity. BC Journal of Ecosystems and Management 8:29-44.

About the Authors

Pierre is a research scientist at the University of Alberta. He has been involved in conservation and forest management research in boreal and coastal ecosystems since the early 1990's. He has extensive experience in habitat modelling, biodiversity monitoring, and landscape planning using spatial and statistical analysis and tools.

Michael is a wildlife biologist with a passion for birds. Over the past 10 years he has worked primarily in the forest industry, and recently has been involved with climate change, mining, and oil & gas.

Fred is Professor Emeritus at the University of British Columbia. Currently, his primary research interests are effects of climate change on the provincial fauna and flora and developing better approaches to monitoring vertebrates.

Andrew is a registered professional forester. He has worked for Canfor in various forestry planning roles in the BC Peace for the past 13 years.