Research Report

BC Journal of Ecosystems and Management

Using avian species monitoring and map-based data in a coarse-filter approach to sustaining biodiversity

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Abstract

The coarse-filter approach to sustaining biological diversity attempts to maintain all representative ecosystems and wildlife habitats within an ecological region or a management unit. Ideally, the approach uses information that is simple to acquire or readily available. For Tree Farm Licence (TFL) 48 in northeastern British Columbia, we describe a coarse-filter approach that combines bird monitoring data with vegetation resources inventory (VRI) and Biogeoclimatic Ecosystem Classification (BEC) data to develop statistical relationships between species occurrences and broad habitat types. The resultant models can be readily added to existing geographical information system (GIS) databases to scale up habitat suitability estimates to the regional (tenure) level. We found that habitat types based on forest cover/age class were a better predictor of habitat suitability than BEC variants for most species, but together the two classification systems provided more information for predicting species occurrences. Forest cover/age class would also provide managers with specific attributes of the landscape that could be manipulated through management actions. The ability to treat space explicitly using habitat-based models is necessary because relationships developed for individual species indicate that no management strategy will accommodate all species in all planning units. For this reason, the ability to link the models to existing databases should greatly facilitate conservation planning. Implementation of this approach could consider all terrestrial vertebrates and other organism groups within a management area.

KEYWORDS: *age class, biodiversity, biogeoclimatic variant, coarse filter, forest cover, forest songbirds, habitat suitability, monitoring.*

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Vernier, P, and F. 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(3):29–44. URL: *http://www.forrex.org/publications/jem/ISS42/vol8_no3_art3.pdf*

Introduction

The conservation of native biodiversity in managed forests depends on the successful application of coarse- and fine-filter conservation strategies (Noss 1987). Coarse-filter strategies attempt to maintain all representative ecological systems or wildlife habitats within an ecological region or a management unit (Hunter *et al.* 1988; Haufler *et al.* 1996). Fine-filter strategies focus on the conservation of elements not captured by the coarse filter, such as vulnerable communities and species at risk. The strategies complement each other and are known as the "coarse-filter/fine-filter" approach to biodiversity conservation. When developing a coarse-filter approach, it is necessary to address as many species as possible using measures that are simple to acquire or that may already be available (e.g., monitoring data).

To be practical, results of biodiversity monitoring programs must be general enough for scaling up to a larger management area. One way of doing that is to exploit maps or layers within geographic information systems (GIS) that many companies use to record and analyze conditions within their management areas. Such map-based data can be combined with monitoring data to develop statistical relationships between species occurrences and habitat attributes using a variety of approaches, such as resource selection functions (Boyce and McDonald 1999; Guisan and Zimmermann 2000). Recent studies have applied similar approaches using ecosystem and forest cover maps (Scott *et al.* [editors] 2002; Wielgus and Vernier 2003; Johnson *et al.* 2004). In most cases, the resultant models can then be linked to a GIS to facilitate a coarse-filter assessment of biodiversity.

We describe a coarse-filter approach that uses available map-based inventory data to extend the results of ongoing large-scale species monitoring in northeastern British Columbia. The main objectives of the monitoring program are to (1) allow coarse-filter assessment of biodiversity over large areas, (2) detect trends in relative abundance, and (3) aid effectiveness monitoring by linking species trends to broad habitat or treatment types.

Our approach is part of the species accounting system for northeastern British Columbia being developed jointly by the University of British Columbia, Canadian Forest Products Ltd. (Canfor), and the B.C. Ministry of Environment (Bunnell and Vernier 2007). Species within the system are assigned to the least-costly form of monitoring appropriate to their natural history. The accounting system incorporates five species groups determined by their response to forest practices and their accessibility to monitoring:

> *When developing a coarse-filter approach, it is necessary to address as many species as possible using measures that are simple to acquire or that may already be available.*

Group 1: generalist species that inhabit many habitat types or respond positively to forest practices

Group 2: species that can be statistically assigned to broad forest types (e.g., older conifer stands)

Group 3: species with strong dependencies to specific elements (e.g., snags or shrubs) that may be useful in effectiveness monitoring

Group 4: species restricted to specialized and highly localized habitats

Group 5: species for which patch size and connectivity are important (patches > 2 ha)

Several species that are known or expected to occur in the area but are not dependent upon forested environments, are not included in the classification.

A major premise of our approach is to keep the accounting system as simple and as cost effective as possible, and to introduce refinements as data suggest. The intention of the accounting system is not to accommodate all species within the map-based classes, so classes were deliberately kept broad (e.g., forest cover coupled with age class). This paper explicitly addresses Groups 1 and 2.

We focus on applying the coarse filter over large areas with two objectives in mind:

1. to quantify the relationship between species occurrences and broad habitat types using BEC variants and forest cover/age class (herein referred to as FOR); and
2. to illustrate the use of the species-habitat relationships to scale up habitat suitability estimates from the local level (individual stands/polygons) to the regional level.

Although the approach considers all terrestrial vertebrates as well as other organism groups, we used birds, the richest forest vertebrate group, to illustrate its application.

Methods

Study Area

The study area is Tree Farm Licence (TFL) 48 located within the southern half of the Peace Forest District in northeastern British Columbia (Figure 1). TFL 48 consists of harvested and unharvested forests that lie within the boreal white and black spruce (BWBS), sub-boreal spruce (SBS), and Englemann spruce–subalpine fir (ESSF) Biogeoclimatic Ecosystem Classification (BEC) zones (Table 1; Meidinger and Pojar [editors] 1991). Alpine tundra (AT) occurs at higher elevations along the eastern slopes of the Rocky Mountains, in the western half of the study area. All bird survey routes were located in the BWBSmw1, BWBSwk1, ESSFmv2, ESSFwk2, and SBSwk2 variants (see Table 1 for descriptions of the variants). Variants are currently the finest resolution data available within the BEC system over large geographic areas and reflect local variation in climatic and edaphic factors within particular zones and subzones. 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)*, and spruce hybrid *(Picea* spp).

Bird Surveys

Data on avian abundance were derived from point-count surveys conducted annually in four summers from 2002–2005 (Preston *et al.* 2006). Methodology for the surveys was adapted from Bystrak (1981) and Sen (1981). Fifteen bird survey routes were located along mainline logging roads in and adjacent to TFL 48. All routes but one were 40 km long with 800 m between

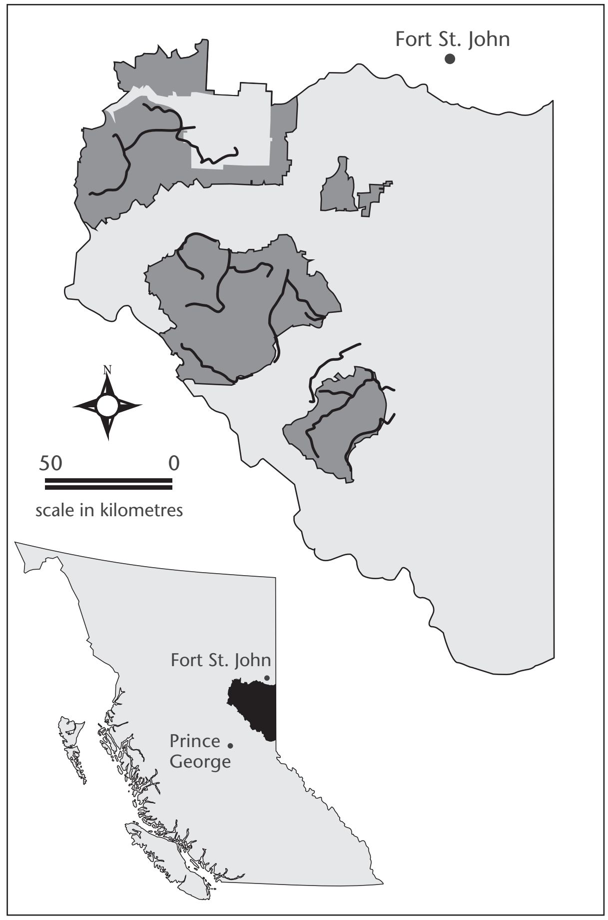

FIGURE 1. Location of bird survey stations in and around TFL 48 (shaded polygons) within the southern half of the Peace Forest District TSA in northeastern British Columbia. Only stations located inside the TFL were used in the analyses.

TABLE 1. Description, area, and number of bird survey stations in each BEC subzone/variant in TFL 48

BEC subzone/variant	Zone description (subzone/variant)	Area (ha)	Area (%)	Stations[a]
ATund	Alpine Tundra (undefined)	53 149.50	8.16	0
BWBSmw1	Boreal White and Black Spruce (moist warm/Peace)	132 505.50	20.34	220
BWBSwk1	Boreal White and Black Spruce (wet cool/Murray)	41 214.25	6.33	39
ESSFmv4	Engelmann Spruce–Subalpine Fir (moist very cold/Graham)	66.25	0.01	0
ESSFmv2	Engelmann Spruce–Subalpine Fir (moist very cold/Bullmoose)	155 247.75	23.83	56
ESSFwk2	Engelmann Spruce–Subalpine Fir (wet cool/Misinchinka)	162 382.50	24.92	75
ESSFwk2	Sub-boreal Spruce (wet cool/Finlay-Peace)	106 962.25	16.42	436

a For the analyses, each station consisted of two observations, one each on the right and left side of the road.

TABLE 2. Description, area, and number of bird survey stations in each FOR in TFL 48

Habitat class	Description	Area (ha)	Area (%)	Stations[a]
Nonfor	Non-forested, non-vegetated, and water	83 330.00	12.76	0
Recent < 30 yrs	Recently disturbed stand types (e.g., clearcuts ≤ 30 yrs)	48 282.32	7.39	224
Decid 31–90 yrs	Deciduous forest 31–90 yrs (≥ 75% decid species)	28 170.74	4.31	26
Decid > 90 yrs	Deciduous forest > 90 yrs (≥ 75% decid species)	33 481.11	5.13	64
Conif 31–90 yrs	Coniferous forest 31–90 yrs (≥ 75% conifer species)	68 419.85	10.48	64
Conif > 90 yrs	Coniferous forest > 90 yrs (≥ 75% conifer species)	348 375.70	53.34	378
Mixed 31–90 yrs	Mixedwood forest 31–90 yrs (< 75% decid or conifer species)	14 237.11	2.18	15
Mixed > 90 yrs	Mixedwood forest > 90 yrs (< 75% decid or conifer species)	28 846.47	4.42	55

a For the analyses, each station consisted of two observations, one each on the right and left side of the road.

sampling stations; one route was shortened to 25 km for logistic reasons. There were a total of 725 sampling stations. Because of limited road access, private lands, and gated roadways transect start points could not be randomly selected. For our analysis of bird and forest habitat relationships we eliminated data from stations located: (1) outside of TFL 48 (for which no vegetation resources inventory (VRI) data were available), and (2) in non-vegetated or non-forested cover types. This resulted in 413 point-count stations that were georeferenced and linked to a spatial database that included VRI and BEC data. Point counts were conducted once each summer, enabling us to survey a much larger area than would be possible with repeated sampling of the same routes.

Upon arrival at a station, observers recorded all birds seen and heard during a 3-minute sampling interval within 50 and 50–200 m distance classes. Only detections within 50 m were used for this analysis because these are likely to be more robust to false negatives (i.e., not detecting a species when it is present). All individuals detected at a station were recorded as being on the right or left side of the road, and movements during the 3-minute sampling period noted, ensuring that individuals were recorded only once. Preston and Campbell (2003) and Preston *et al.* (2006) provide additional details on the survey protocol. The appendix provides common and scientific names for the species analyzed.

Data Preparation and Habitat Types

Data preparation consisted of five broad steps. First, we assembled relevant data (VRI, BEC variants, and bird surveys) into ArcView and Microsoft Excel. Second, we used the VRI data to create a habitat field based on forest cover and age classes (Table 2). Third, for each bird survey station, we digitized an additional point to the left and right of the road (within 50 m) to enable us to link individual bird detections to a specific habitat type (BEC variant and FOR). This was only possible where the area within 50 m of the left or right side of the road comprised one habitat polygon. Detections that could not reliably be located in one habitat polygon were not used in the analysis. Fourth, we intersected the bird survey locations (right and left detections) with the VRI and BEC coverages. Finally, we exported all of the intersected data to ASCII files for subsequent statistical analysis using Stata (Stata Corporation 2005). There were 413 stations (826 left and right side detection points) located along logging roads.

Data Analysis

Species Occurrence and Habitat Type

For our first objective, we tabulated and graphed species occurrences by FOR and BEC variant. For each species, we calculated a standardized selection index (Manly *et al.* 2002) that represented the ratio of observed to expected use of each habitat type. This indicates the extent to which species are selecting habitat types in proportion to their availability. We used a Chi-square test to determine whether selection across all habitat types was non-random (Manly *et al.* 2002). We also calculated confidence intervals around the index to estimate whether each habitat type was "preferred" or "avoided." A habitat type was preferred if the lower limit of the confidence interval was greater than the proportion of stations used; conversely, a habitat type was avoided if the upper limit of the confidence interval was less than the proportion of stations used. Individual types were not tested if the observed number of used stations was less than five. We note that species can test as broadly proportional (random) across all types yet still prefer or avoid one or more type, whereas others show no selection for or against any type. We then estimated a set of five logistic regression functions for each species according to the following models:

Null Model: No selection—did not include covariates and was used to evaluate the influence of the habitat covariates in the other models

Model 1: BEC covariate

Model 2: FOR covariate

Model 3: FOR + BEC covariates

Model 4: FOR + BEC + YEAR covariates to determine if there was any remaining significant year-to-year variability

The models assume that each observation is independent and therefore contributes one degree of freedom. If this assumption is false it would have the effect of underestimating the confidence intervals around the coefficient estimates. To correct for this we used robust estimation methods that adjust for the likelihood that stations in close proximity may have similar values. The resultant models have wider confidence intervals but the same coefficient estimates and, thus, have no effect on predictions based on mean values. This approach is also robust to overly influential observations and undetected overdispersion (Vernier *et al.* 2002).

We evaluated each model using the drop-in-deviance test, the area under the receiver operator characteristic curve (ROC area; Swets 1988), and Akaike's Information Criterion (AIC; Burnham and Anderson 2002). The ROC area is a measure of the predictive performance of a model. For example, a ROC area of 0.80 means that given a pair of randomly chosen stations–one where a species was present and one where it was absent–the model would predict which is which 80% of the time. Following Swets (1988), we consider models with a ROC area < 0.70 to have poor predictive ability, between 0.70 and 0.90 to have reasonable predictive ability, and > 0.90 to have very good predictive ability. A ROC area of 0.50 indicates a model with no predictive power. Akaike's Information Criterion measures the tradeoff between model goodness of fit (measured as the log-likelihood) and model parsimony (measured by the number of parameters included in the model). Ideally, the best model would be the one with a ROC area ≥ 0.70 and the lowest AIC score.

Scaling Up Species Habitat Relations

Our second objective was to scale up species-habitat relations to evaluate tenure-wide habitat suitability for birds. The species accounting system recognizes different degrees of habitat affinity and encompasses both coarse and fine filters (Bunnell 2005). The simplest approach to assessing habitat suitability for a particular species is to determine the amount of preferred habitat. Birds are sufficiently mobile and few species require forest interior so a summary table of amount of preferred habitat is informative (habitat amount is often more important than habitat distribution; Fahrig 2003). For other less mobile species, consideration of patch size and connectivity may also be important. Still other species require specific, highly localized habitats (Bunnell 2005). We limited our analyses to the coarse filter by ranking the habitat suitability of hexagonal land units for the bird community in general. We partitioned the study area into 1000 ha hexagons (units bordering the study area were ≤ 1000 ha) and calculated, for each species, an index that measured the overall habitat suitability of each hexagon. The size and shape of the units were selected for illustration purposes. A more systematic sensitivity analysis is planned to better define the appropriate range of scales (grain and extent) for scaling up predictions to the regional level. The procedure consisted of four steps repeated for each species with a ROC area ≥ 0.70 for the FOR and FOR + BEC models as follows:

1. The logistic regression (habitat model) function was used to predict the probability of occurrence for each 1 ha pixel in the study area.
2. The probability of occurrence of all pixels in each 1000 ha hexagon was totaled.
3. A map showing the total suitability over all selected species was created by adding the values for each species.
4. The value in each hexagon from 0 to 1 was standardized (i.e., each hexagon was divided by the value of the hexagon with the highest sum probability of occurrence in the study area).

The final map identified areas of high suitability for a suite of species taken together. Similar maps can be

TABLE 3. Selection of FOR by songbird species in TFL 48 for selected species. Species were chosen to illustrate the patterns that emerged when tested statistically and sorted by the strength of overall selection[a]

	Overall selection		Selection for individual FOR						
			Recent	Decid	Decid	Conif	Conif	Mixed	Mixed
Species	χ^2	p	< 30 yrs	31–90 yrs	> 90 yrs	31–90 yrs	> 90 yrs	31–90 yrs	> 90 yrs
American Redstart	73.508	< 0.001	–	–	prefer	–	avoid	–	–
Wilson's Warbler	72.458	< 0.001	–	–	avoid	–	–	–	–
Golden-crowned Kinglet	70.213	< 0.001	avoid	–	avoid	–	prefer	–	–
Magnolia Warbler	39.930	< 0.001	avoid	–	prefer	–	avoid	–	–
Ruby-crowned Kinglet	30.862	< 0.001	avoid	–	–	–	prefer	–	–
Yellow-bellied Sapsucker	30.099	< 0.001	–	–	–	–	–	–	prefer
Swainson's Thrush	21.728	< 0.001	avoid	–	–	–	–	–	prefer
Lincoln's Sparrow	20.524	< 0.001	prefer	–	–	–	avoid	–	–
MacGillivray's Warbler	20.495	< 0.001	prefer	–	–	–	–	–	–
Red-breasted Nuthatch	19.702	0.001	avoid	–	–	–	–	–	–
Dark-eyed Junco	14.794	0.005	–	–	–	–	–	–	–
Gray Jay	12.098	0.017	avoid	–	–	–	–	–	–
Blackpoll Warbler	10.964	0.027	–	–	–	–	–	–	–
Northern Waterthrush	5.156	0.272	–	–	–	–	–	–	–
Pine Siskin	5.128	0.274	–	–	–	–	–	–	–

a Complete results are available at: *http://biod.forestry.ubc.ca/pubs/jem/table3.pdf*

created for individual species by eliminating step 3. Various weighing methods could be used to assign greater importance to certain species (e.g., species of conservation concern). In addition, the use of standardized maps facilitate the comparison and ranking of different landscapes or the same landscape over time, but are not appropriate as a measure of absolute suitability or for comparing the suitability of two species.

Results

Species Occurrence and Habitat Type

Forest Cover/Age Class

Using FOR, 46 and 27% of bird detections were located in old coniferous stands and recent cutblocks, respectively (Table 2). The five other classes each comprised less than 8% of all stations. About 80% of bird-habitat relations were non-random, meaning that at least one habitat type was statistically preferred or avoided. Selection may appear as a preference for a particular type or preference for a type coupled with avoidance of other types (Table 3). For habitat types with few stations (e.g., mixedwood forest 31–90 years old), statistically significant selection was very unlikely. Additional stations are needed to increase sample sizes for those types. In these cases the empirical use of the types is more informative. For example, 53% of the observations of the Least Flycatcher *(Empidonax minimus)* occur in deciduous stands 31–90 years old (Figure 2). About 20% of the species fit the null model indicating no habitat selection.

Biogeoclimatic Ecosystem Classification Variant

Most stations were located in two BEC variants: 53% in SBSwk2 and 27% in BWBSmw1 (Table 1). Three other variants each comprised 9% or less of all stations. No stations were located within ESSFmv4, which makes up a very small portion of TFL 48 (0.01%). Overall selection across all BEC variants was found to be non-random for about 65% of the species, indicating that at least one BEC variant was likely preferred or avoided (Table 4). Using these broad types and the current design, it is clear that relations with FOR are more strongly expressed than relations with BEC variant. Although the SBSwk2 and BWBSmw1 variants were the most commonly selected or avoided, the sampling is less proportional than it was for FOR; thus our greater interest in the latter.

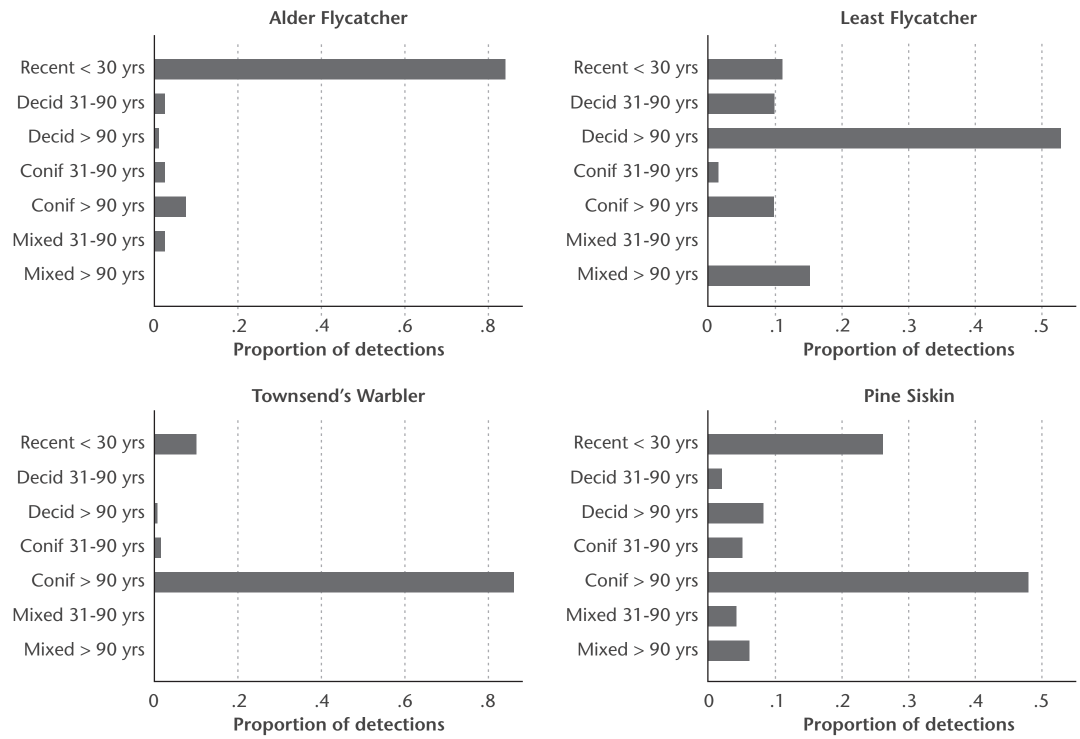

FIGURE 2. Proportion of detections by FOR for Alder Flycatcher, Least Flycatcher, Townsend's Warbler, and Pine Siskin.

TABLE 4. Selection of BEC variants by songbirds in TFL 48 for selected species. Species were chosen to illustrate the patterns that emerged when tested statistically and sorted by the strength of overall selection[a]

	Overall selection		Selection for individual BEC variants				
Species	χ^2	*p*	BWBSmw1	BWBSwk1	ESSFmv2	ESSFwk2	SBSwk2
Least Flycatcher	140.266	< 0.001	prefer	–	–	–	avoid
Wilson's Warbler	112.493	< 0.001	avoid	–	–	prefer	prefer
Townsend's Warbler	78.503	< 0.001	–	–	–	prefer	prefer
Tennessee Warbler	58.980	< 0.001	–	–	–	avoid	prefer
Orange-crowned Warbler	41.146	< 0.001	prefer	–	–	avoid	avoid
Winter Wren	36.761	< 0.001	–	–	–	prefer	–
Ovenbird	29.200	< 0.001	prefer	–	–	–	avoid
American Robin	25.417	< 0.001	prefer	–	–	–	–
Gray Jay	20.283	< 0.001	–	–	–	–	–
Swainson's Thrush	17.357	0.002	–	avoid	–	–	–
Yellow-rumped Warbler	15.593	0.004	–	avoid	–	avoid	–
Golden-crowned Kinglet	15.248	0.004	avoid	–	–	–	–
White-throated Sparrow	13.975	0.007	–	–	–	–	–
Blackpoll Warbler	13.813	0.008	avoid	–	–	–	–
Varied Thrush	13.006	0.011	–	–	–	–	–
Chipping Sparrow	8.397	0.078	avoid	–	–	–	–
Pine Siskin	3.419	0.490	–	–	–	–	–

a Complete results are available at: *http://biod.forestry.ubc.ca/pubs/jem/table4.pdf*

Resource Selection Functions

For most species, including those summarized in Table 5, the best model as indicated by the lowest AIC included FOR + BEC or FOR + BEC + YEAR (Black-capped Chickadee was an exception). Our findings illustrate three general findings. First, among the two habitat types, the major gain in predictive ability came more often from the addition of FOR to the null model. Second, the inclusion of both FOR and BEC generally resulted in a model with higher predictive ability than either of them alone. Third, although adding a year effect usually reduced the AIC and increased the ROC area, the improvement was modest, indicating that selection varies little between years.

Scaling Up Species Habitat Relations

For any species-habitat relations that we developed in this study (Tables 3 and 5), the models can be used to scale relative probability of occurrence across the entire tenure. For example, Figure 3 illustrates relative probability of occurrence of Yellow Warbler *(Dendroica petechia)* using model coefficients reported in Table 5. A more general index of habitat suitability is also possible (Figure 4) using the logistic regression functions for 14 songbird species whose ROC area was > 0.70 (YEAR was excluded). The resultant map shows overall habitat suitability aggregated to 1000 ha hexagons. For both the single- and multi-species maps, the darker the cell the higher the suitability of the habitat within that cell.

The coarse-filter approach we described is multi-purpose, intended to link monitoring and inventory data to assess biodiversity, detect trends, and relate trends to habitat.

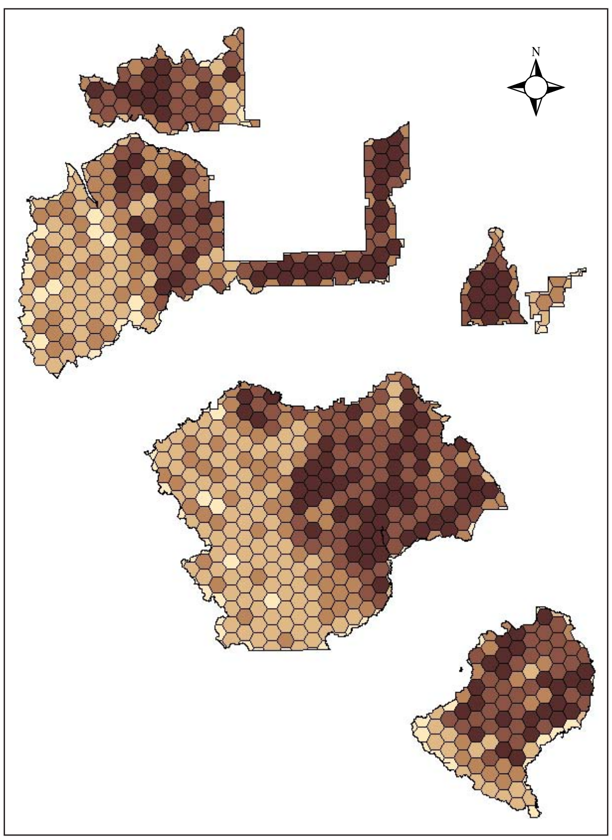

FIGURE 3. Habitat suitability for Yellow Warbler in TFL 48. The darker the hexagon, the higher the suitability.

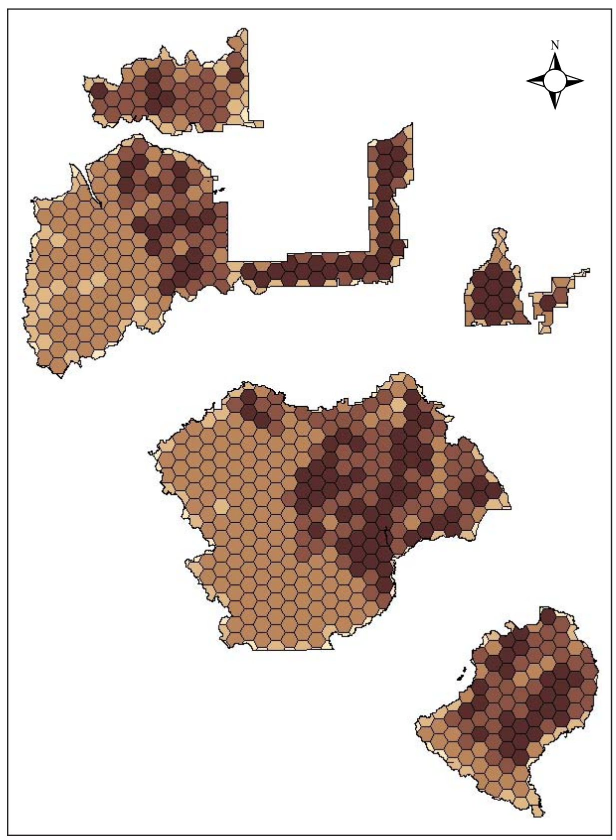

FIGURE 4. Cumulative habitat suitability for 14 songbird species that occur in TFL 48. The darker the hexagon, the higher the overall suitability for the 14 selected species.

TABLE 5. Resource selection functions for selected songbird species with a ROC area ≥ 0.700 for either the FOR or FOR + BEC model[a]

Species/Model	Deviance	DF	Drop-in-dev[b]	DF	AIC	ROC area
Ovenbird						
No selection	322.99	2810	–	–	325.0	0.500
BEC	293.46	2806	29.53	4	303.5	0.712
FOR	278.68	2804	44.32	6	292.7	0.816
FOR + BEC	269.19	2800	9.48	4	291.2	0.829
FOR + BEC + YEAR	252.25	2797	16.94	3	280.2	0.871
Alder Flycatcher						
No selection	734.23	2810	–	–	736.2	0.500
BEC	724.17	2806	10.06	4	734.2	0.591
FOR	599.60	2804	134.63	6	613.6	0.808
FOR + BEC	589.78	2800	9.82	4	611.8	0.835
FOR + BEC + YEAR	576.45	2797	13.33	3	604.4	0.845
Yellow Warbler						
No selection	720.11	2810	–	–	722.1	0.500
BEC	644.27	2806	75.85	4	654.3	0.728
FOR	632.98	2804	87.13	6	647.0	0.778
FOR + BEC	610.62	2800	22.36	4	632.6	0.793
FOR + BEC + YEAR	609.65	2797	0.96	3	637.7	0.797
Black-capped Chickadee						
No selection	332.08	2810	–	–	334.1	0.500
BEC	319.15	2806	12.93	4	329.2	0.648
FOR	298.46	2804	33.62	6	312.5	0.761
FOR + BEC	293.27	2800	5.19	4	315.3	0.775
FOR + BEC + YEAR	289.22	2797	4.05	3	317.2	0.797
Townsend's Warbler						
No selection	837.06	2810	–	–	839.1	0.500
BEC	756.07	2806	80.97	4	766.1	0.720
FOR	756.78	2804	80.28	6	770.8	0.682
FOR + BEC	694.23	2800	62.54	4	716.2	0.789
FOR + BEC + YEAR	668.74	2797	25.49	3	696.7	0.826

a Complete results are available at: *http://biod.forestry.ubc.ca/pubs/jem/table5.pdf*

b Drop-in-dev = drop-in-deviance

TABLE 6. Cost-effectiveness of bird monitoring in northeastern British Columbia

Year	Cost of monitoring[a]	Number of stations	Cost per station	Hectares surveyed[b]	Cost per hectare
2002	$11 098	350	$32	48 799	$139
2003	$19 093	648	$29	86 362	$133
2004	$22 454	723	$31	96 962	$134
2005	$25 000	1 037	$24	145 763	$141

a Cost of conducting field surveys in northeastern British Columbia as estimated for 2005

b Calculated by placing a 1 km buffer around all stations

Discussion

The coarse-filter approach we described is multi-purpose, intended to link monitoring and inventory data to assess biodiversity, detect trends, and link trends to habitat. It augments and refines most coarse-system approaches (e.g., old-growth management areas [OGMAS]) by assigning species to specific habitat classes and selecting the most efficient means of monitoring that class. Habitat classes range from specific elements[1] (e.g., snags and shrubs) through broad forest types[2], and include small localized habitats not readily assessed by coarse filters[3] and instances where the distribution of habitat is as important as the amount[4]. We have provided illustrations for monitoring Groups 1 and 2. Effectiveness monitoring is a long-term activity, but need not be expensive (Table 6). Moreover, it can be linked to readily available map-based data to project habitat suitability over large areas. We are refining the species accounting system to include other vertebrate groups, as well as plant and selected invertebrate species. For illustrative purposes we selected the largest vertebrate and monitoring group—those species which can be linked to broad habitat classes or are demonstrably generalist in habitat affinity.

To date, each annual survey has added more species to the groups as samples accumulate sufficiently to create statistical confidence. Among habitat types defined by FOR, present sampling reveals preference or avoidance of old coniferous forest, recently disturbed stands, and old deciduous forest (Table 3). Selection for BEC variants was evident for fewer species than for FOR. Of the five BEC variants, four were either statistically preferred or avoided by individual species (Table 4). Differences in selection between the two habitat classification systems may reflect a tradeoff within the design. Variants were sampled less proportionately than FOR because of our greater interest in the latter. The fact that selection was shown for four of five variants despite a lack of proportionate sampling suggests that affinities for variants can be strongly expressed. The greater selection for FOR may also reflect that birds are more closely tied to actual forest composition and structure than to potential forest cover types indicated by BEC variants.

In general, lack of habitat selection can occur for at least two reasons. First, the species is a generalist in its response to the broad habitat types. Second, there are insufficient observations to establish statistically significant preference or avoidance. The first case includes true generalists and species with discrete localized habitats that venture into the broader habitat types. For example, the Northern Waterthrush *(Seiurus noveboracensis)* is linked far more tightly to riparian areas than to these broad types, while the Pine Siskin *(Carduelis pinus)* is erratic in seeking seed crops. Another example is the White-throated Sparrow *(Zonotrichia albicollis)* which is associated with dense understorey vegetation rather than any particular BEC variant. The Gray Jay *(Perisoreus canadensis)* is likely an example of the second case; it tests as random overall with avoidance for youngest age class, which is consistent with its natural history. The fact that the two habitat types with the most stations, old coniferous forest and recent cutblocks, were the ones most commonly selected or avoided, reveals the role of sample size.

Because our approach is GIS-based, it will allow analysis of changing landscapes over time. We anticipate that with increasing samples the discrimination of habitat types can be finer, allowing better evaluation of the effectiveness of forest management activities. The predictive statistical models of habitat use indicate that adding YEAR as an effect usually improved the models, but only modestly. We expect this effect to diminish with additional data collection. Stratifying stations by FOR, and to a lesser degree BEC variant, clearly aids effectiveness monitoring by linking model predictions to specific and manageable habitat patches within larger forest management units. Moreover, stratification will have the added benefit of increasing the precision of future trend estimates and therefore reducing the number of years required to detect a trend.

As data accumulate annually, precision concerning habitat affinity and discrimination among finer habitat types will also increase. To date it appears that FOR is a better predictor of habitat suitability than BEC variant for most species (Figures 3 and 4), but together the two classification systems provide a much broader view. The

1 Group 3
2 Groups 1 and 2
3 Group 4
4 Group 5

ability to treat space explicitly is necessary because relationships developed for individual species (e.g., Table 5) indicate that there is no management strategy that will accommodate all species in all planning units. Having some means of predicting where and when habitat will be available for specific species is necessary for strategic planning, and is possible for a number of common species that occur in northeastern British Columbia.

The habitat models developed in this study are designed to aid decision-making over large spatial scales. As an illustration we used the models to scale up predictions of habitat suitability to the entire TFL. The suitability of the predictive (hexagon) maps was based on a snapshot in time therefore high or low suitability may be temporary. For example, a particular hexagon may be composed of habitat types in which species are declining even though their presence has been detected. This may be due to a source/sink process whereby individuals from good habitat disperse to poor habitat. In other words, high suitability areas, in the sense that species have a high probability of occurrence may not necessarily indicate high quality habitat over the long term. Not all species can be evaluated this way. Some cannot be accommodated by the coarse-filter approach and are treated differently within the species accounting system.

We caution, however, against using any of the models in areas other than managed forests within the BEC variants that were surveyed. This caution could be lessened by expanding the scope and spatial extent of the surveys and by carefully validating the models using spatially and temporally independent data (Boyce *et al.* 2002; Johnson and Gillingham 2004; Vernier *et al.* 2007). In fact, future data collection will help strengthen and test some of the relationships that were suggested from this exploratory analysis. In 2005, we established seven additional bird survey routes within the adjacent Fort St John Timber Supply Area. Data from these routes were withheld from initial analyses and will be used to evaluate the generality of the results from TFL 48 once another year of sampling is completed. Future sampling will also target increasing the sample size of under-surveyed habitat types (Table 1 and 2; see also Vernier and Preston 2006). Finally, we emphasize that our monitoring and modelling initiatives are ongoing and iterative, and are part of an evolving adaptive management and conservation planning process for northeastern British Columbia (e.g., Bunnell *et al.* 2003).

Management Implications

In this study, we developed models that describe the relationship between bird species occurrences and habitat characteristics derived from VRI and BEC maps. Managers need effective feedback about management planning and practices and ways of increasing monitoring cost-effectiveness by modifying the design.

Management planning should include:

- relatively rapid identification of species not accommodated by coarse-filter approaches (specific guidelines for these species are now being developed with Canfor);
- guidance on the most effective placement of OGMAS (i.e., examining their distribution across forest types compared to relative numbers of species supported within forest types);
- guidance on relative emphasis of retention by broad forest type (i.e., comparing relative type richness to type proportion within the non-timber harvesting land base, and emphasizing under-represented types in retention allocation); and
- exposure of potentially troubling practices (e.g., bird responses to vegetation management patterns within recently cut blocks revealed potential problems for shrub nesters; a more focussed study has been developed jointly with Canfor).

Our coarse filter approach is intended to be self-correcting (Bunnell and Vernier 2007), and the models help increase efficiency of monitoring. The models (1) represent hypotheses about species-habitat relationships; (2) serve as tools for managing forest bird habitat and evaluating management alternatives; and (3) can be used to refine biodiversity monitoring schemes. They are effective and cost efficient because they make use of existing GIS data collected as part of the forest management process. Our models can affect and improve monitoring design and biodiversity management in the following ways:

- Forest cover/age class provides managers with specific habitat types that are relevant to many bird species and can be manipulated in time and space through management practices.
- Biogeoclimatic Ecosystem Classification variants are correlated with fewer species, but this may change as our sampling design is modified to better represent all major variants.

- Additional analysis is needed to better understand the relationship between FOR and BEC variants. This would provide more refined guidance for stratifying management of FOR by BEC variant.
- No management strategy will work for all species in all planning units. There will be tradeoffs in terms of habitat supply, but it may be possible to combine information for several species to identify regionally important areas of good quality habitat at a scale that may be useful for strategic planning (Figures 3 and 4).
- Additional habitat characteristics (e.g., stand structure) that were not used in this study will be necessary for modelling habitat use not captured by the coarse-filter approach (e.g., rare and endangered species). This will likely require additional data collection for species at risk.
- The models can be easily applied to existing GIS databases to facilitate conservation planning and the evaluation of forest management activities. Some potential uses include: assessing the status of selected indicator species over large areas (millions of hectares); identifying priority areas based on the weighted suitability of multiple species; developing or evaluating large scale conservation plans; and ranking landscape units or management scenarios in terms of focal species.

Acknowledgements

We gratefully acknowledge support from the Forest Investment Account Forest Science Program, Canfor, and the B.C. Ministry of Environment. Fieldwork on birds was conducted by WestCam Consulting. Don Rosen of Canfor provided GIS support. Comments of three anonymous reviewers improved the manuscript.

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ARTICLE RECEIVED: December 23, 2005
ARTICLE ACCEPTED: September 28, 2007

Codes, common, and scientific names of bird species reported in this paper

Code	Species	Scientific name
AMRE	American Redstart	*Setophaga ruticilla*
AMRO	American Robin	*Turdus migratorius*
BKPW	Blackpoll Warbler	*Dendroica striata*
CHSP	Chipping Sparrow	*Spizella passerina*
DEJU	Dark-eyed Junco	*Junco hyemalis*
GCKI	Golden-crowned Kinglet	*Regulus satrapa*
GRJA	Gray Jay	*Perisoreus canadensis*
LEFL	Least Flycatcher	*Empidonax minimus*
LISP	Lincoln's Sparrow	*Melospiza lincolnii*
MACW	MacGillivray's Warbler	*Oporornis tolmiei*
MGNW	Magnolia Warbler	*Dendroica magnolia*
NOWA	Northern Waterthrush	*Seiurus noveboracensis*
OCWA	Orange-crowned Warbler	*Vermivora celata*
OVEN	Ovenbird	*Seiurus aurocapilla*
PISI	Pine Siskin	*Carduelis pinus*
RBNU	Red-breasted Nuthatch	*Sitta canadensis*
RCKI	Ruby-crowned Kinglet	*Regulus calendula*
SWTH	Swainson's Thrush	*Catharus ustulatus*
TEWA	Tennessee Warbler	*Vermivora peregrina*
TOWA	Townsend's Warbler	*Dendroica townsendi*
VATH	Varied Thrush	*Ixoreus naevius*
WTSP	White-throated Sparrow	*Zonotrichia albicollis*
WIWA	Wilson's Warbler	*Wilsonia pusilla*
WIWR	Winter Wren	*Troglodytes troglodytes*
YBFL	Yellow-bellied Flycatcher	*Empidonax flaviventris*
YBSA	Yellow-bellied Sapsucker	*Sphyrapicus varius*
YRWA	Yellow-rumped Warbler	*Dendroica coronata*
YEWA	Yellow Warbler	*Dendroica petechia*

Test Your Knowledge . . .

Using avian species monitoring and map-based data in a coarse-filter approach to sustaining biodiversity

How well can you recall some of the main messages in the preceding Research Report? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Which statement best describes the coarse-filter approach to biodiversity conservation?
   A) Conserve vulnerable communities and species at risk
   B) Ensure that the size and shape of harvest units are identical across the landscape
   C) Maintain representative ecosystems or wildlife habitats within an ecological region

2. For which group of species is the coarse-filter approach most appropriate?
   A) Species with strong dependencies to specific elements (e.g., snags)
   B) Species that are associated with broad forest types (e.g., older conifer stands)
   C) Species for which patch size and connectivity are important

3. Which classification system was a better predictor of habitat suitability for songbirds in northeastern British Columbia?
   A) Forest cover/age class
   B) Predictive ecosystem mapping types
   C) Biogeoclimatic Ecosystem Classification variants

ANSWERS

1. C 2. B 3. A