# Habitat Representation of Breeding Bird Surveys in Northeast British Columbia with Implications for Monitoring "Listed" Warbler Species

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***Introduction***

The Breeding Bird Survey (BBS) is North America's largest landbird monitoring program, and results derived from this initiative are often used to estimate the relative abundance of bird populations, describe species' trends, develop habitat models, and guide conservation planning (Rich et al. 2004, USGS 2007, Vernier and Bunnell 2007). The quality of the resultant estimates and decisions depend largely on the quality of the survey design, including the number of samples surveyed and their allocation across regional habitat types. Together, these two aspects of survey design provide information about the extent to which the surveyed area represents the larger management or conservation area of interest. This information is especially important when interpretations of survey results (*e.g.,* estimates, models, decisions) are extrapolated to a much larger region than was sampled – which is often the case in the managed forest landscapes of British Columbia. Sampling bias occurs when the amount of a specific habitat type (*e.g.,* late successional mixedwood forest) is not sampled in proportion to its availability across the larger landscape.

Both negative and positive sampling bias (under- and over-representation, respectively) can have important consequences on regional species' assessments and can result in poor conservation or management decisions. A negative sampling bias can result in under-estimating the regional abundance or trend of a species and thus falsely concluding that a species is at risk. Likewise a positive sampling bias may result in falsely concluding that a species is common across the landscape or failing to detect a declining trend when one actually exists. The consequences may be exaggerated for species that occur at low densities, are patchily distributed, or require specialized habitats (Figure 1). For example, BBS data have been used as a source of information to assess the status of rare and endangered species (*e.g.,* COSEWIC 2006, COSEWIC 2007) and to guide conservation planning (Rich et al. 2004), but potential biases affecting abundance and trend estimates are often ignored, mostly because they are unknown. Several recent studies have provided evidence that the BBS method does not proportionately represent the composition of habitat types within the larger area that they are meant to represent (Bart et al. 1995, Keller and Scallan 1999, Betts et al. 2007, Neimuth et al. 2007), thus emphasizing the need to address this issue regionally. Given that BBS data are widely used to make inferences about birds and to guide conservation decisions it is important to determine whether sampling biases exist, evaluate its consequences, and propose modifications to existing monitoring programs that address this problem.

In 2002, Canadian Forest Products Ltd. (CanFor), Chetwynd Division, initiated a bird monitoring program to assist in developing, implementing, and monitoring the effectiveness of their Sustainable Forest Management Plan (CanFor 2005). In 2005, the

**Figure 1.** Sampling bias of habitat types that are patchily distributed or generally uncommon, such as this black spruce stand at the southern limit of its range in northeast British Columbia, may mis-guide conservation planning for species using this habitat type. 120 km north of Peejay, BC. 27 May 2006 (Michael I. Preston).

Fort St. John Division adopted a similar monitoring program under the Fort St. John Pilot Project, and in 2006 the Fort Nelson Division also became involved. In this paper we evaluate the effectiveness of the BBS-type routes at proportionally representing broad habitat types in the forested landscapes of northeast British Columbia. Specific objectives are:

1. To determine how well proportions of habitat types sampled by the roadside surveys represent proportions of habitat types within each of the three larger management areas.

2. To identify gaps in the current monitoring networks and propose changes to improve representation.

3. To discuss the implications of sampling biases on habitat types often associated with "listed" warblers (*i.e.,* late successional deciduous, coniferous, and mixedwood forests).

Northeast British Columbia is host to 23 species of wood-warbler. Among these, five are restricted to this portion of the province and are listed either as "red" (extirpated, endangered, or threatened) or "blue" (special concern) by the British Columbia Conservation Data Centre (2007). The species include: Bay-breasted Warbler [red] (*Dendroica castanea*), Cape May Warbler [red] (*D. tigrina*), Black-throated Green Warbler [blue] (*D. virens*), Connecticut Warbler [red] (*Oporornis agilis*), and Canada Warbler [blue] (*Wilsonia canadensis*). Additionally, Canada Warbler (Figure 2) is currently under review by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2008). Each species is dependent on forested stands of different age and composition, and therefore respond differently to forest management practices. Understanding how well their habitats are represented, and how well the species is sampled within those habitats, is an important part of an effective monitoring program.

**Figure 2.** In British Columbia the Canada Warbler is "blue-listed", but an estimate of trend from BBS data is unknown, and sampling bias of preferred habitats may be considerable. Doig River, BC. 2 June 2007 (Michael I. Preston). BC Photo 3543.

## *Methods*

### Study Area

The study area consists of three forest management areas (FMAs) in northeast British Columbia (Figure 3): Tree Farm License (TFL) 48 (approx. 650,000 ha) is located within the southern half of the Peace Forest District, Fort St. John Timber Supply Area (TSA; approx. 4,700,000 ha) makes up the northern half of the Peace Forest District, and the Fort Nelson TSA (approx. 9,900,000 ha) occupies the entire Fort Nelson Forest District. The FMAs consist of harvested and unharvested forests that lie within the boreal white and black spruce (BWBS), sub-boreal spruce (SBS), spruce–willow–birch (SWB), and Engelmann spruce–subalpine fir (ESSF) Biogeoclimatic Ecosystem Classification (BEC) zones (Table 1; Meidinger and Pojar 1991). 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),* and spruce hybrid *(Picea* spp). We analysed each FMA individually because bird surveys and forest management within those areas are conducted independent of each other.

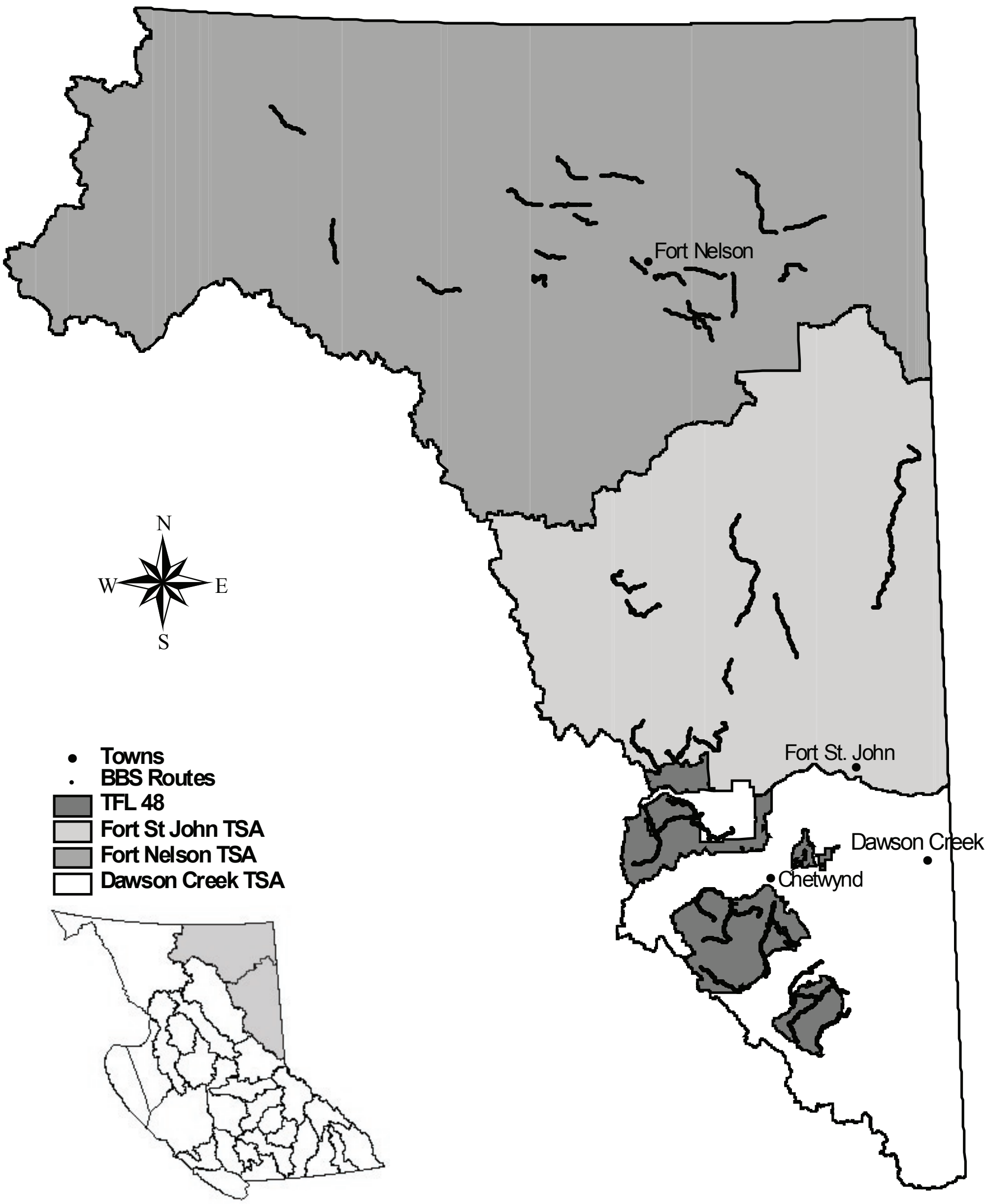


**Figure 3.** Distribution of BBS routes in TFL 48 and the Fort St. John and Fort Nelson TSAs.

**Table 1.** Description of BEC subzones in northeast British Columbia.

| BEC Subzone | Description |
|---|---|
| BAFAun | Boreal altai fescue alpine – undifferentiated |
| BAFAunp | Boreal altai fescue alpine - undifferentiated and parkland |
| BWBSdk | Boreal white and black spruce - dry cool |
| BWBSmw | Boreal white and black spruce - moist warm |
| BWBSwk | Boreal white and black spruce - wet cool |
| ESSFmv | Engelmann spruce-subalpine fir - moist very cold |
| ESSFmvp | Engelmann spruce-subalpine fir - moist very cold parkland |
| ESSFwc | Engelmann spruce-subalpine fir - wet cold |
| ESSFwcp | Engelmann spruce-subalpine fir - wet cold parkland |
| ESSFwk | Engelmann spruce-subalpine fir - wet cool |
| SBSwk | Sub-boreal spruce - wet cool |
| SWBmk | Spruce-willow-birch - moist cool |
| SWBmks | Spruce-willow-birch - moist cool scrub |

**Bird Surveys**

We adopted the North American Breeding Bird Survey (BBS) method of Sen (1981) and Bystrak (1981), but included modifications to improve upon the spatial accuracy of the data. North American BBS routes stratified by degree-block with random start points and direction determined thereafter. Each BBS route is comprised of 50 survey stations, spaced at 800-m intervals, with each station sampled for 3 minutes. In this study, minor modifications were accommodated where necessary. For all routes, stratification by degree-block and random start points were not used. Instead, route selection was largely determined by road availability and length, trying where possible to stratify by BEC subzones. In TFL 48 no additional modifications to the survey methodology were necessary; in the Fort St. John and Fort Nelson TSAs routes generally had 30 stations, 800 m apart, with each station sampled for 5 minutes. Differences in methodologies among the FMAs were reflective of:

1) route history and objectives (*i.e.,* for trend monitoring in TFL 48 methods were maintained from when the study began in 2002);

2) experience (*i.e.,* studies in Fort St. John and Fort Nelson benefitted from identified survey limitations in TFL48)

3) road availability (*i.e.,* in Fort Nelson most road lengths were too short to accommodate BBS routes with > 30 stations); and

4) a focus on managing for habitat rather than trends.

Our bird surveys began at sunrise (PDT), compared to the North American BBS that begins 30 minutes before sunrise, and lasted 3 to 4 hours depending upon the number of stations on a given route. Orthophoto data sheets were used to record bird observations at each station (Figure 4). The orthophotos provided the added benefit of being able to more accurately locate individual birds spatially, as most orthophotos had recognizable points of reference. Such spatial reference is beneficial to the analysis of bird-habitat relationships, especially where complex Vegetation Resources Inventory (VRI) and forest cover data polygons are concerned (Vernier and Bunnell 2007). To maintain consistency with the North American BBS, we indicated where

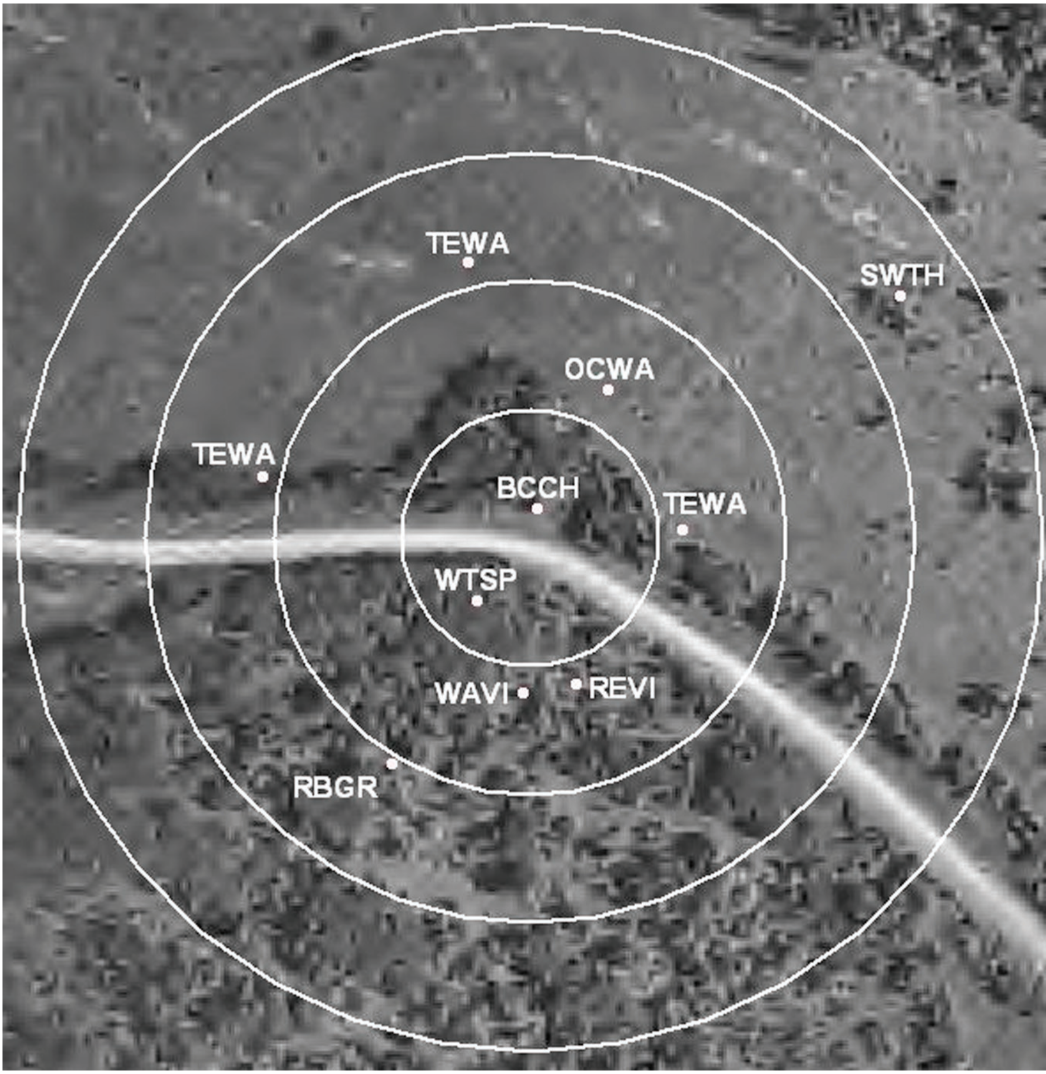


**Figure 4.** Example of a point count station overlayed on an orthophoto. Concentric rings represent 50-m increments from the station centre up to 200 m. Birds are plotted using visual, auditory, and spatial cues, and later transferred to a digital file as shown here. BCCH: Black-capped Chickadee, OCWA: Orange-crowned Warbler, SWTH: Swainson's Thrush, TEWA: Tennessee Warbler, RBGR: Rose-breasted Grosbeak, REVI: Red-eyed Vireo, WTSP: White-throated Sparrow.

necessary, those birds that occurred after the 3-minute period. Secondary information, such as age, sex, and behaviour were noted when possible. Surveys were not conducted during rain or moderate to strong winds (RIC 1999).

**Habitat Types**

We used two sources of mapped data to classify each FMA into habitat types to evaluate the effectiveness of the surveys:

1) BEC data; and

2) VRI data.

The first source of data, BEC, is a hierarchical system that combines climate, vegetation, and site classifications (Meidinger and Pojar 1991). The basic unit is the subzone which stratifies the landscape into map units according to a combination of ecological features such as climate and physiography. Subzones can be grouped into zones and divided into variants. Definitions of the subzones that occur in northeast British Columbia are listed in Table 1. The second source of data, VRI, provides information on actual forest and non-forest cover including attributes such as leading tree species, stand height, crown closure, and age class. We used leading tree species and age class attributes to classify the landscape into 10 broad habitat types (Table 2). In some areas within the FMAs, where VRI data were not yet available, we used forest cover data from the previous inventory system. The same attributes necessary to perform the analyses were available with both inventory systems; only the attribute names differed. A limitation of the forest inventory data concerns the date of reference, which varied between FMAs, and may have a minor effect on results for specific habitat types (*e.g.,* older stands converted to recently disturbed areas). However, because the rate of habitat change is relatively small compared to the size of each FMA, the seriousness of the issue is likely to be of little consequence over the short term (*e.g.,* 5 years). We do recommend repeating the analyses as new data become available.

**Representation Analysis**

We analysed the effectiveness of roadside surveys at representing regional habitat types by comparing the proportion of each habitat type within a 400 m buffer of each BBS station to the proportion of each habitat type in each FMA. This was done separately for the BEC subzones and forest cover / age class habitat classification systems. We used 400 m because:

1) it is the maximum distance at which birds are recorded at each station;

2) it is the distance we have used in the past to measure habitat covariates for use in songbird-habitat models;

**Table 2.** Description of habitat types based on forest cover and age class in northeast BC.

| Habitat Type | Description |
|---|---|
| Water | Water (rivers, lakes, and reservoirs) |
| Non-vegetated | Non-vegetated (natural or anthropogenic) |
| Non-forested | Non-forested (vegetated upland and wetland) |
| Recent disturbance | Recently disturbed stand types (*e.g.,* clearcuts ≤ 30 yrs) |
| Young deciduous | Deciduous forest 31–90 yrs (≥ 75% decid species) |
| Old deciduous | Deciduous forest > 90 yrs (≥ 75% decid species) |
| Young coniferous | Coniferous forest 31–90 yrs (≥ 75% conifer species) |
| Old coniferous | Coniferous forest > 90 yrs (≥ 75% conifer species) |
| Young mixedwood | Mixedwood forest 31–90 yrs (< 75% decid or conifer species) |
| Old mixedwood | Mixedwood forest > 90 yrs (< 75% decid or conifer species) |

3) it has been used recently in a similar study in Tennessee (Harris and Haskell 2007); and

4) it is the minimum distance between stations that ensures sampling independence for all species.

By comparing the proportion of each habitat type within each buffered area to the proportion of each habitat type within the FMA, we calculated sampling bias as:

$$Bias = 100 \times ( P_{i,buf} - P_{i,fma} ) / P_{i,fma}$$

where *Bias* is the percent bias in habitat type *i* for the buffered area; $P_{i,buf}$ is the proportion of habitat type *i* in the buffered area; and $P_{i,fma}$ is the proportion of habitat type *i* in the FMA. Positive values indicate over-representation of a habitat type in the buffered area along the survey routes; negative values indicate under-representation.

To facilitate interpretation, we consider a bias of < 20% as small, a bias of 20-50% as moderate, and a bias of > 50% as large. We also consider the absolute area sampled as an indication of how important a bias is. For example, a habitat type that represents a very large component of the landscape may be under-represented but may still contain a relatively large number of stations and thus would not be considered to be an important gap in the monitoring program. Conversely, small areas that are over-represented may or may not have a large enough number of stations to have sufficient statistical power. In the results and discussion we focus on the most important biases and gaps in the monitoring program as implemented in 2007 and provide suggestions for improving the effectiveness of the 2008 surveys.

## *Results*

### BEC Subzones

Sampling bias was evident for all BEC subzones and varied, in part, in response to the distribution of roads in northeast British Columbia (Table 3). In TFL 48, 6 of the 8 forested subzones were under-represented by up to 100%, (essentially zero representation) whereas two subzones were over-represented. Both BWBSmw and BWBSwk, which occur on the eastern side of TFL 48, were under-sampled by 28% and 89%, respectively. Likewise, 5 of the 6 ESSF subzones were under-sampled by 78-100%. The other ESSF subzone (ESSFwk) had a small positive sampling bias of 19% while SBSwk had the highest positive sampling bias (260%) amongst all subzones in northeast BC (approximately 4.5 times the proportional representation). In general, higher elevation subzones (*i.e.,* ESSF subzones) were under-represented while lower elevations (*e.g.,* SBS in the valley bottoms) were over-represented. Sampling bias was somewhat less pronounced in Fort St. John. Three of the 6 forested subzones (BWBSmw, ESSFmv, and SWBmks) had small positive or negative biases not exceeding ±5% while SWBmk and ESSFmvp were under-sampled by 46% and 87%, respectively. BWBSwk had the greatest positive sampling bias (+105%) in Fort St. John. Forested BEC subzones in Fort Nelson all had moderate to high sampling biases, reflecting the distribution of roads in that area. The largest and most actively managed subzone (BWBSwk) was over-represented by 49% while the other 4 forested subzones were under-represented by 43% (SWBmk) to 100% (BWBSwk and SWBmks).

### Forest Cover / Age Class

Sampling bias among habitat types defined by forest cover / age class also varied widely among types and regions (Table 4) but this was not as clearly related to the distribution of roads. Within TFL 48, negative sampling bias (under-sampling) was low (<20%) for young mixedwood, old coniferous, and non-forested habitat types, moderate (20-50%) for old deciduous and young coniferous forest, and high (>50%) for young deciduous forest. The other 4 habitat types all had large positive biases ranging from 54% for old mixedwood to 353% for water. In Fort St. John sampling biases were a little less extreme. Old deciduous and young mixedwood forests had small negative biases while non-forested, recent disturbance, and young deciduous were all moderately under-represented. Water had the largest negative bias (-71%). Young coniferous forest had a small positive sampling bias (17%) while non-forested habitat type was substantially over-represented in the buffers. Seven of the habitat types in Fort Nelson

**Table 3.** Percentage over- or under-representation of BEC subzones in 400 m roadside buffers compared to BEC subzones in TFL 48, Fort St. John TSA, and Fort Nelson TSA.

| | TFL 48 | | | Fort St. John TSA | | | Fort Nelson TSA | | |
|---|---|---|---|---|---|---|---|---|---|
| **BEC Subzone** | **Total area (ha)** | **Buffer area (ha)** | **Bias (%)** | **Total area (ha)** | **Buffer area (ha)** | **Bias (%)** | **Total area (ha)** | **Buffer area (ha)** | **Bias (%)** |
| BAFAun(p) | 14,124.6 | 0.2 | -99.9 | 122,269.1 | 0.2 | -100.0 | 892,107.0 | 0.4 | -100.0 |
| BWBSdk | - | - | n/a | - | - | n/a | 1,121,417.2 | 1,506.2 | -55.0 |
| BWBSmw | 138,152.3 | 2,193.5 | -27.6 | 3,612,112.0 | 17,605.9 | -2.0 | 5,610,036.5 | 24,915.4 | 48.9 |
| BWBSwk | 50,834.3 | 118.3 | -89.4 | 319,970.2 | 3,262.4 | 104.9 | 146,668.9 | 0.1 | -100.0 |
| ESSFmv | 173,316.8 | 820.0 | -78.4 | 235,788.8 | 1,171.0 | -0.2 | - | - | n/a |
| ESSFmvp | 13,751.4 | 0.2 | -99.9 | 31,630.7 | 19.8 | -87.4 | - | - | n/a |
| ESSFwc | 67,275.9 | 101.4 | -93.1 | - | - | n/a | - | - | n/a |
| ESSFwcp | 15,203.7 | 0.2 | -99.9 | - | - | n/a | - | - | n/a |
| ESSFwk | 56,690.6 | 1,483.1 | 19.3 | - | - | n/a | - | - | n/a |
| SBSwk | 120,853.6 | 9,537.2 | 260.0 | - | - | n/a | - | - | n/a |
| SWBmk | - | - | n/a | 253,695.9 | 682.4 | -45.9 | 1,773,909.2 | 3,010.4 | -43.1 |
| SWBmks | - | - | n/a | 95,039.8 | 498.3 | 5.4 | 320,938.4 | - | -100.0 |

**Table 4.** Percentage over- or under-representation of forest cover types in 400-m roadside buffers compared to forest cover types in TFL 48, Fort St. John TSA, and Fort Nelson TSA. Undefined (gray shaded) is added for completeness.

| | TFL 48 | | | Fort St. John TSA | | | Fort Nelson TSA | | |
|---|---|---|---|---|---|---|---|---|---|
| **Habitat Type** | **Total area (ha)** | **Buffer area (ha)** | **Bias (%)** | **Total area (ha)** | **Buffer area (ha)** | **Bias (%)** | **Total area (ha)** | **Buffer area (ha)** | **Bias (%)** |
| Undefined | 12.7 | - | -100.0 | 20,289.9 | 0.2 | -99.8 | 45,736.5 | 301.2 | 120.7 |
| Water | 3,389.2 | 338.2 | 353.0 | 46,610.7 | 66.1 | -71.1 | 129,243.5 | 531.1 | 37.7 |
| Non-vegetated | 6,892.1 | 560.0 | 269.0 | 171,447.5 | 220.7 | -73.7 | 32,521.3 | 78.5 | -19.0 |
| Non-forested | 70,444.7 | 1,480.0 | -4.6 | 1,203,040.5 | 4,505.4 | -23.6 | 2,484,152.2 | 1,224.2 | -83.5 |
| Recent disturbance | 51,430.9 | 2,740.4 | 141.9 | 869,552.6 | 3,241.7 | -23.9 | 381,728.9 | 2,450.7 | 115.2 |
| Young deciduous | 33,721.9 | 356.2 | -52.0 | 373,488.5 | 1,346.1 | -26.4 | 713,790.9 | 5,010.8 | 135.3 |
| Old deciduous | 28,548.4 | 412.0 | -34.5 | 198,525.4 | 970.7 | -0.2 | 411,108.3 | 3,645.7 | 197.2 |
| Young coniferous | 84,239.0 | 1,008.9 | -45.6 | 435,820.2 | 2,505.7 | 17.3 | 1,467,613.4 | 5,069.1 | 15.8 |
| Old coniferous | 329,841.4 | 6,199.1 | -14.7 | 1,046,095.6 | 7,606.7 | 48.4 | 3,229,990.5 | 6,942.8 | -28.0 |
| Young mixedwood | 17,722.2 | 376.6 | -3.5 | 187,721.5 | 794.8 | -13.6 | 499,759.3 | 1,744.4 | 17.0 |
| Old mixedwood | 26,900.8 | 912.6 | 54.0 | 192,204.5 | 1,988.5 | 111.2 | 469,709.7 | 2,433.7 | 73.7 |

were over-represented. Over-representation was relatively small for young coniferous and young mixedwood forest, moderate for water, and large for old mixedwood, recent disturbance, young deciduous, and old deciduous habitat types. Non-vegetated (-19%), old coniferous (-28%), and non-forested (-84%) habitat types had small, moderate, and large negative biases, respectively. Across all regions, only old mixedwood forest was consistently over-represented (54-111%) while non-forested habitat was consistently under-represented (5-84%).

## *Discussion*

### Roadside Habitat Sampling Bias

Our analysis confirmed the existence of positive and negative sampling biases in the current monitoring design for TFL 48, Fort St. John, and Fort Nelson. For several habitat types, based on BEC subzones or forest cover / age class, the magnitude of the biases were substantial. Similar results were also reported by Betts et al. (2007) and Harris and Haskell (2007). Among BEC subzones, sampling biases were related to road access. For example, in TFL 48 high elevation areas with few or no roads, had the largest biases. The patterns were not as clear, and often varied between FMAs, when we examined representation of forest cover / age class types. The exception was old mixedwood forest (Figure 5) which was over-sampled in all FMAs in comparison to its availability. Sampling biases are important sources of information to consider when designing, evaluating, or refining a monitoring program. Moderate or large biases can affect trend

**Figure 5.** Old mixedwood forests in northeast British Columbia are used by a variety of bird species, and despite the general over-representation of this habitat type from BBS surveys, numbers of records for the "blue-listed" Black-throated Green Warbler are small, suggesting that alternate methods may be needed to monitor this species effectively. Near Buick Creek, BC. 24 May 2007 (Michael I. Preston).

estimates and predicted habitat associations for forest songbirds (Harris and Haskell 2007) and can result in poor management and conservation decisions. For example, under-sampling late successional forest habitat important to some warbler species may result in falsely identifying small populations and can lead to expensive compensatory measures. Conversely, over-representing the same habitat type may lead to a false sense of security as to species' trend and habitat availability when extrapolated to the study region, thus leading to inaction and possible regional extirpation. Paradoxically, over-representation may still fail to adequately account for species that are dependent on smaller-scale habitat features that are not accounted for in bias assessments that use broad habitat types. Thus, information on sampling bias can be used to improve the effectiveness of the surveys and the efficiency of estimates and models, and in some instances may elucidate problems associated with habitat attributes more commonly defined at smaller spatial scales.

Several possible explanations may account for our observed sampling biases. First, which we mentioned earlier, relates to the large scale distribution of roads (confounded by elevation on the western side of the FMAs). A potential solution would be to modify the area of the available landscape used for analysis by limiting it to the accessible portion (*i.e.,* within a certain distance of all roads in the northeast), and make the assumption that areas without roads are relatively unaffected by current forest practices. Second, the local amount of non-forested habitat within the buffers often is large and variable due to road width (including additional right-of-way areas created by ditches, pipelines, and crossroads). We used a 400 m buffer because anything smaller would have exacerbated the effect (*e.g.,* Harris and Haskell 2007). A third explanation, related to the first two, involves road access. Not all roads are accessible at the time of sampling because of forestry activities, deactivations, and weather factors (*i.e.,* roads may be inaccessible or washed-out), and this may introduce biases if this is related to habitat types. Fourth, we analysed the surveys separately for each FMA in the northeast. By combining all of the data, some of the biases would be significantly reduced. For example, young coniferous forest was under-represented in TFL 48, and over-represented in the other two FMAs. This aggregated type of analysis, however, would mask potential problems identified by the FMA-level analysis.

As a quick evaluation of the combined effects of some of these factors, we repeated the analysis for forest cover / age class using a 1-km buffer around all BBS routes in the northeast as our available landscape. It would have been preferable to use all roads instead of routes to define the landscape, but at the time of analysis complete road coverages were not available. Results of this analysis revealed that sampling biases in all forested habitat types were very minor when compared to the full scale analysis (Table 5). It is clearly not possible to avoid bias due to the nature of the roadside surveys, however some gains may be possible by modifying the design. For example, some routes could be reduced in length to accomodate under-represented habitat types that occur in areas with shorter roads (*i.e.,* < 24 km), and in a few cases this has already been done (*e.g.,* Manning Cooper and Associates Ltd. 2007). Another possibility is to limit the scope of inference

**Table 5.** Percentage over- or under-representation of forest cover types in 400-m roadside buffers compared to forest cover types in a 1-km buffer around all bird survey routes in northeast British Columbia. Undefined (gray shaded) is added for completeness.

| Habitat Type | Total area (ha) | Buffer area (ha) | Bias (%) |
|---|---:|---:|---:|
| Undefined | 1,440.2 | 337.8 | -27.2 |
| Water | 4,122.7 | 1,152.3 | -13.2 |
| Non-vegetated | 2,157.5 | 1,281.1 | 84.4 |
| Non-forested | 27,734.1 | 10,086.3 | 12.9 |
| Recent disturbance | 38,576.8 | 13,191.1 | 6.2 |
| Young deciduous | 25,395.3 | 8,411.9 | 2.9 |
| Old deciduous | 22,834.6 | 7,765.1 | 5.6 |
| Young coniferous | 36,677.0 | 10,376.1 | -12.1 |
| Old coniferous | 83,668.2 | 25,354.9 | -5.9 |
| Young mixedwood | 12,071.8 | 3,568.5 | -8.2 |
| Old mixedwood | 21,899.4 | 7,531.3 | 6.8 |

of the BBS surveys to the "managed" portions of the landscapes – which should coincide with the area accessible to the surveyors. In fact, it is this component of the landscape that is most impacted by management activities and for which the surveys can provide valuable information which can help to modify forest practices.

Because it is virtually impossible to sample exactly in proportion to availability, we defined three bias categories for the purpose of interpreting the results. We considered small biases to be less than 20% and relatively unimportant except for the case when the total area being sampled is relatively small. For example, correcting for a small bias in an area that is <10,000 ha is more likely to provide results that can guide management for species of concern than would a similar correction to an area that is >1-million ha (*e.g.,* BWBSmw) or contains more generalist-type species. Attention to negative bias that exceeds 20% should be given regardless of area size. The categories, albeit arbitrary, can thus help focus attention on the most under-sampled habitat types. The actual bias percentages should also be considered since they provide information about the magnitude of the sampling biases. However, these percentages will be more prone to errors because the amount of actual forest cover at the time of the surveys may differ from the digital inventory (*i.e.,* thus marginally incompatible with the date of the bird surveys). Further to this problem, bias estimates will vary depending on whether the area within the buffers, or the larger study areas, have been affected by recent fires or harvesting activities.

**Implications for "Listed" Warbler Species**

In terms of implications for "listed" warbler species in northeast British Columbia, the most important habitat types are the ones based on forest cover and age class and in particular old deciduous, old coniferous, and old mixedwood forest types. As reported in the results, old mixedwood forest was consistently over-sampled in all three regions and should thus provide a suitable baseline for species associated with this type of forest but may over-estimate abundance if extrapolated to the greater region. Old deciduous forest was under-represented in TFL 48 and Fort St. John but substantially over-represented in Fort Nelson. This habitat type is characteristic of Canada Warbler occupancy, and over-representation may explain why the Fort Nelson area consistently has more detections relative to the number of BBS stations sampled (Campbell et al. 2007). However, as previously discussed, site-specific attributes not included in broad habitat types (*e.g.,* such as a dense layer of green alder (*Alnus viridis*) for Canada Warbler (Campbell et al. 2007) may cause estimates of prevalence to be greatly exaggerated across the landscape if all old deciduous forest is considered equally good Canada Warbler habitat.

The pattern for old coniferous was similar to old deciduous in that two of the three regions were under-represented while Fort St. John was over-represented (Figure 6). Overall, this is probably not a big concern since old coniferous forest is the most common forest type in northeast British Columbia and thus contains the largest allocation of survey stations. The main issue would be if population estimates were applied to the larger area without correcting for bias. Both Cape May Warbler and Bay-breasted Warbler are typically associated with old coniferous stands, but again, site specific attributes not included in broad habitat measures may influence site occupancy. Annual variation in site occupancy and relative abundance may also be largely determined by patterns of insect

**Figure 6.** This dense stand of healthy, mature Englemann spruce forest along the Graham River in the Fort St. John TSA is characteristic habitat for Cape May Warbler in this region. 26 June 2006 (Michael I. Preston).

abundance, especially spruce budworm outbreaks.

The Connecticut Warbler is considered a species of young and old deciduous stands (40 - 80 years old; Figure 7), but its distribution is generally more southeasterly than that of the other four “listed” warbler species occurring in northeast British Columbia (Campbell et al. 2001). In the Fort St. John and TFL 48 FMAs, under-representation of young and old deciduous habitats suggests that BBS samples may be missing this species in areas where it is expected to be more common. Conversely, over-representation of young and old deciduous habitats in Fort Nelson, and a complete absence of Connecticut Warbler records in that FMA, suggests that underlying species’ distribution patterns as well as site-specific habitat factors, must be considered when interpreting survey results and developing management plans.

**Recommendations**

If our main management concern is with “good” proportional sampling representation (<20% negative bias), then for each FMA, the following forested BEC subzones and/or habitats need more samples: TFL 48: BWBSmw, BWBSwk, ESSFmv, ESSFmvp, ESSFwc, ESSFwcp, SBSwk, young deciduous, old deciduous, young coniferous); Fort St. John TSA: ESSFmvp, SWBmk, water, non-vegetated, non-forested, recent disturbance, young deciduous); Fort Nelson TSA: BWBSdk, BWBSwk, SWBmk, SWBmks, non-forested, old coniferous). If, however, our management focus is with the five “listed” warbler species, then we need to enhance habitat sampling representation in each FMA as follows: TFL 48 (young deciduous, old deciduous); Fort St. John (young deciduous); Fort Nelson (old coniferous). Some consideration should also be given to sampling within-stand habitat attributes (*e.g.,* shrub density) when trying to monitor the five “listed” warbler species, although generally speaking, digital forest inventory information is lacking for such attributes. Another factor to reflect on, as demonstrated by our analysis of the representation of a smaller region (Table 5), is to clearly define the area that is considered available and for which inferences will be drawn since this could have important implications on abundance and trend estimates.

**Figure 7.** Throughout much of the Connecticut Warblers distribution in British Columbia, pure stands of 40 - 80 year-old deciduous forest with few shrubs appear to be preferred. 25 June 2006 (Michael I. Preston).

Recently, some effort has been made to survey forest interior habitat (Figure 8) to better sample forest interior birds and to evaluate the effectiveness of roadside surveys at detecting those species (Manning, Cooper, and Associates Ltd. 2007, Preston et al. 2007, Preston 2008). The forest interior stations are generally located at least 200 m away from roads (and other hard edges such as clearcuts) and as such have very little effect on the representation of the buffered area. However, they could provide a useful complement to roadside surveys by focusing on interior forest habitats that are seldom sampled using the road-based sampling method. Such data may enable more precise estimates of abundance, trend, and habitat relations for certain species, as well as help guide potential species-specific monitoring protocols. We intend to evaluate the effectiveness of forest interior surveys in a subsequent paper.

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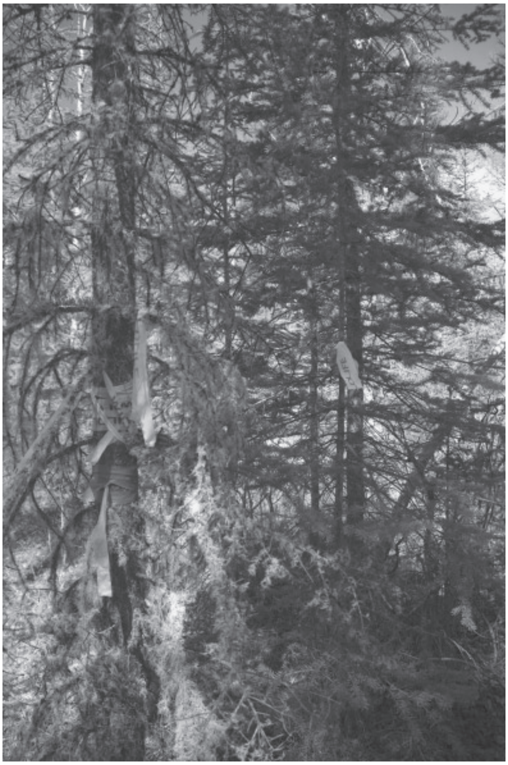

**Figure 8.** Interior forest surveys in northeast British Columbia are being used to compare the effectiveness of road-based surveys for monitoring forest-dependent species, including the five "listed" warblers in that region. Near Buick Creek, BC. 25 May 2007 (Michael I. Preston).

Paul Bitton) in the Fort Nelson TSA. We also wish to thank John Deal, Andrew Tyrrell, Don Rosen, Mark Phinney, and Darrell Regimbald for support with survey planning, field logistics, and GIS data acquisition. We are also thankful to Mark Phinney for providing helpful comments that improved the final paper.

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*"The clearest way into the universe is through a forest wilderness."*

John Muir