**Effects of spatio-temporal variation in natural succession and insect outbreaks on a remote undisturbed population of breeding North American forest birds**

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**Abstract**

**KEYWORDS**

**Introduction**

In the past 50 years, the boreal ecosystems of North America have lost an estimated 500 million birds and over 50% of species are declining (Rosenberg et al. 2019). However, long-term forest bird monitoring programs used to generate these estimates, primarily the North American Breeding Bird Survey (BBS; Downes et al. 2016, Hudson et al. 2017, Sauer et al. 2017), have limited spatial coverage and habitat representation in northern boreal regions (Machtans et al. 2014; Van Wilgenburg et al. 2015; Roy et al. 2019). As a result, range-wide trend estimates for most of these species are largely based on extrapolation from data collected from southern boreal regions (Sólymos et al. in press), where breeding birds are facing a wider range of threats originating from anthropogenic disturbances (Dunn et al. 2005; Matsuoka et al. 2011; Van Wilgenburg et al. 2015). Given the vast majority of the Canadian boreal forest remains free from anthropogenic disturbance (ca. 95%; 426/450 million ha; Pasher et al. 2013), it is important to understand population trends in both managed and unmanaged regions to provide more comprehensive status assessments.

For the landbird species breeding the Canadian boreal forest, habitat loss, alteration, and fragmentation are considered the most important factors contributing to these population declines (Taylor and Stutchbury 2016; Herse et al. 2018). For example, the effects of habitat loss and alteration due to forestry, oil and gas, agriculture, and urbanization have been well documented in intensively managed areas of the boreal forest (Mahon et al. 2014; Bayne et al. 2016; Hobson and Kardynal 2019). Recent studies have also partitioned the relative importance of these and other stressors throughout the annual life cycle of migratory species to provide spatially-explicit recommendations for conservation planning (i.e. breeding ground vs. migration vs. wintering grounds: Holmes 2007; Faaborg et al. 2010; Rushing et al. 2016). However, in unmanaged areas of the boreal forest, natural succession and natural disturbances such as forest fires, diebacks, and insect outbreaks are the primary drivers of habitat change (Brandt et al. 2013). Unfortunately, there are few long-term studies on population trends in these northern regions (e.g. Machtans et al. 2014; Desrochers and Drolet 2017; Handel and Sauer 2017), which makes it hard to quantify relative importance of these events throughout the annual life cycle of these species.

Eastern spruce budworm (*Choristoneura fumiferana* Clemens) outbreaks create resources pulses that result in positive functional and numerical responses in many “budworm specialists”, e.g. Cape May Warbler (*Setophaga tigrina*) and Bay‐breasted warbler (*Setophaga castanea*; Venier et al. 2009; Drever et al. 2018). During the years following the repeated outbreaks (4-5 years), the resulting defoliation and tree mortality alter stand structure and composition, which further influences the bird communities throughout the regeneration process (*sensu* Venier et al. 2009 and Drever et al. 2018). However, to our knowledge, very limited information is available about regional variation in the relative importance of spruce budworm outbreaks and natural succession in absence of such large-scale disturbances on trends in bird populations in northern boreal regions (REF). NEED TO ADD A BRIEF REVIEW OF MODELLING APPROACHES THAT COULD/SHOULD BE USED TO QUANTIFY THESE RELATIONSHIPS?

In 1998, Machtans and Latour (2003) initiated a landbird monitoring program in the Liard Valley, Northwest Territories, Canada (Fig. 1). The program was designed to document: 1) population trends; 2) changes in local forest stand structure and composition and the effects of these changes on population trends; and 3) differences in population trends for resident versus migratory species. Machtans et al. (2014) used generalized linear mixed-effect models to estimate 14-year trends for 50 of the 68 species monitored in this remote northern boreal region (INSERT TEXT ON WHY WE DIDN’T NEED TO OR TRY TO ACCOUNT FOR VEGETATION CHANGE AT THE TIME). Trends from this study area were generally more positive than those derived from BBS data suggesting that such breeding “refugia”, i.e. absence of anthropogenic disturbances, are critical to allow maintain and improve the status of boreal breeding birds (Machtans et al. 2014).

In this study, we generated 19 year trend estimates (1998-1997), for the same 50 forest landbird species, using the hierarchical Bayesian modelling framework being used to derive BBS trend estimates (REF). NEED A SENTENCE EXPLAINING THE BENEFITS OF THIS MODELLING FRAMEWORK. Specifically, we generated species-specific models with: 1) habitat (i.e. stand structure and composition, and budworm) and year effects (hereafter “study area trend”; year, local habitat change, and unexplained variation); and 2) year effect and accounting for and removing the variation from the habitat effects from the trend estimates (hereafter “regional trend”; year effect and unexplained variation). The difference between these two trend estimates (hereafter “local habitat trend”) provided estimates of the importance of local habitat change on population trends. Based on the hypotheses that, in absence of anthropogenic disturbances, northern boreal landscapes provide better breeding habitats than more intensively managed southern landscapes, we predicted: 1) more negative regional trends for migrants than resident species; and 2) wide-range of species-specific effects spruce budworm outbreaks on trend estimates (positive, negative, and/or neutral). Lastly, because we were not expecting significant change in local stand structure and composition, we predicted 3) NEED A PREDICTION REGARDING THE EXPECTED IMPORTANCE OF LOCAL HABITAT CHANGE ON TREND ESTIMATES

**Methods**

*Study Location*

The study was conducted in the Liard Valley, Northwest Territories (NT) within a 60km radius of the community of Fort Liard (Fig. 1). The Liard valley is in the extreme southwest corner of the NT within the Taiga Plains Mid-Boreal ecoregion (Level III ecoregion; REF). It borders the Mackenzie Mountains to the west and higher elevation boreal forest to the east. The region receives a warmer climate and Chinook-like winds in the winter, which results in more productive (i.e. increased tree biomass) forests and the highest diversity of species in the NT (REF, REF). Stands are typically comprised of deciduous (list dominant tree species) or mixedwood (main conifer species include… xx, yy, and, zz) vegetation and can reach 30 m or more in canopy height (Machtans and Latour, 2003). The study represents the northern limit of the breeding range of many species (e.g. Brown Creeper; *Certhia americana*, Canada Warbler; *Cardellina canadensis*). A detailed description of the study design can be found in Machtans and Latour 2003 and Machtans et al. 2014.

*Data Collection*

We conducted point count surveys for forest songbirds at 279 sampling stations between 1998 and 2017 (Fig. 2). Specifically, data were collected in 1998-2002, 2005, 2008, 2011, 2014, and 2017. However, fewer data were collected in 1998, as the program was expanded with additional sampling points in 1999. Daily 10-minute point count surveys started 30 minutes before sunrise and ended within 4 hours of sunrise. We recorded all individual birds observed, corresponding type of vocalization or behaviour (e.g. songs vs. calls, carrying nesting material, sex), the time of detection (0-3 min, 3-5 min, or 5-10 min) and estimated distance to individuals (< 50m, 50-100m, and > 100m) of each observation. Each survey location was surveyed twice, one round in early June and one in late June. All survey locations were sampled once before initiating the second round. Staff were qualified in the identification of birds by sight and sound or were required to carry a recording device (i.e. 2011: XX and 2014: Wildlife Acoustics SM2). In 2011, two observers (T. Kydd and XX) carried devices and in 2014 only a single observer recorded acoustic data (M. Zurawell). During the last week of May, all field staff participated in an exercise to standardize species identification, quantification of individuals, distance estimation, and data collection. Each location surveyed with a recording unit was surveyed by a skilled observer for the alternate survey. Acoustic field recordings were later transcribed by qualified individuals (C. Machtans, R. Pankratz, and E. Dastous).

In 1998/1999, 2008, and 2017, vegetation surveys were conducted to quantify changes in stand structure and composition for each sampling location Vegetation variables included: species composition, height, and diameter, standing dead tree height, size, type (i.e. coniferous versus deciduous) and rot class (after Lee et al. ), ground cover species composition and cover amount, and overall canopy height and closure (Detailed methodology is provided in Machtans and Latour 2003). In 1998/1999, multiple vegetation plots were conducted at each sampling location but this was reduced to a single plot centered on the point count location during vegetative data collection in 2008 and 2017.

Annual budworm defoliation area (ha) and distance to nearest defoliated patch (m) were quantified using the … name the layer (REF) .

Interpolating vegetation data

The vegetation surveys provided data on the local habitat at each site at the start, mid-point, and end of the study period. To match the habitat data to the more frequent bird-survey data and budworm defoliation data, we used a simple linear interpolation of each habitat variable at each site. This assumption of linear change in habitat variables across the 9-year span between subsequent habitat surveys is imperfect, but reasonable given the costs of repeated vegetation surveys.

For a handful of sites, vegetation survey data were missing from either the start or end of the survey period. In most cases, these missing data were due to safety or logistical constraints. For these sites, the habitat variables were interpolated for the available time-periods and these sites were included in the model. These sites without the full time-series of habitat data, were removed from the calculations of the final population trajectories and trends (below), so that these estimates reflected a consistent set of sites through time.

*Statistical Analysis*

We designed a hierarchical Bayesian model to estimate the change in forest-bird abundance over the study period, as well as the components of that change due to local habitat-related factors and due to other factors operating at a broader spatial scale. The trend model was based on the model used to estimate status and trends from the North American Breeding Bird survey (Smith et al. 2014). For a given species, counts at site-i in year-t, and in round-r () were modeled as overdispersed Poisson variates with mean .

The means were modeled as the exponentiated sum of fixed-effect parameters for the intercept (), and the annual-slope (), quadratic effects of a suite of local habitat predictors at site-i and year-t (), quadratic effects of two within-season temporal effects ( , time of day and day of the year,), as well as random-effects for site () and the count-level, extra-Poisson variance ().

The habitat data () entered the model as Q-element array with one element for each habitat predictor-q, with rows for each site\*year combination and two columns, one each for the linear () and the squared predictor (). The set of Q predictors for a given species were chosen based on habitat associations available from the Avian Life History Information Database (<http://www.on.ec.gc.ca/wildlife/wildspace/project.cfm>; Appendix 1).

The parameters for the effects of each habitat predictor-q were given multivariate normal prior distributions, with an inverse Wishart prior on the covariance matrix ().

For species that are known to respond strongly and directly to local outbreaks of spruce budworm (Venier et al. 2009, Table 1), we added some additional parameters to the habitat component of the model to account for the effect of local spruce budworm availability ().

We used annual maps of spruce budworm defoliation to calculate the distance between each site and the nearest patch of defoliation due to spruce budworm in a given year. We treated these budworm data as a categorical predictor because of the multimodal distribution of the data, and because of the imprecision of the budworm data on the fine spatial scale of our sampling sites. We grouped the annual distances to budworm for each site into the following four categories: 1 = <1km, to represent sites and years in which there was high local budworm availability; 2 = 1-10km, to represent sites and years in which there was some high budworm availability within the study area, but not locally; 3 = 10-50km, to represent sites and years in which there was some high budworm availability with the region, but primarily outside the study area; and 4 = >50km, to represent years in which there was little or no budworm availability with the region). For each of the first 3 distance categories (d = 1, 2, or 3), the effect of budworm was modeled as a fixed-effect intercept parameter. For the final distance category (d = 4, little or no budworm activity in the region), the effect of budworm was fixed at 0.

The data for season (day of the survey-season) and time of day (hours since sunrise) entered the model as a 2-element array with one element for each predictor, with rows for each site\*year\*survey combination and columns for the linear () and squared () predictors. The parameters for the effects of season (,) and the time of day (), were modeled the same as the habitat predictors, using a multivariate normal prior and the same prior on the covariance matrix.

The random effects for site () and for the count-level extra-Poisson variance () were both modeled as mean-0 normal distributions with estimated variances ().

*Population Trajectories and Trends*

We estimated the annual relative abundance of each species as a derived parameter, by averaging the predicted counts for each year across the set of *I*-sites that had habitat data for the entire time series (i.e., excluding the few sites with missing habitat data for part of the time series). We derived two estimates of these population trajectories (time-series of annual estimates of relative abundance) for each species. The first was an overall population trajectory that included all effects of local habitat and any changes that had occurred in habitat over the study time period. For each year-t, the overall relative abundance was calculated as:

The second trajectory represented the predicted annual relative abundance, after removing the effects of local habitat. We derived this regional trajectory as a counter-factual estimate of the temporal pattern in regional abundance that we would have expected if local habitat had remained the same over the study-period.

We refer to this as a regional trajectory, assuming that any change in abundance not due to local habitat change must be a function of processes acting at spatial scales broader than our local study area, including processes occurring outside of the species’ breeding range. Using these two trajectories, we estimated population trends (rates of average percent annual change in abundance), following Link and Sauer (2002), as the geometric mean of the annual change between the first and last years of the 20-year time-series.

The difference between the overall trend () and the regional trend (), represented the population trend due to changes in local habitat ().

Species trends were estimated for all species with >10 detections and occurring at > 3 sites.

Hierarchical Bayesian models with overdispered standard Poisson distributions were used to estimate species-specific trend estimates. All models had year as a fixed effect and site, day, and time of day as random effects. The Study Area Trend model included species-specific habitat predictors, while the Regional Trend removed the effect of these predictors from the model. The Local Habitat Trend was the difference between the two aforementioned trend estimates and provided an estimate of the effect of local vegetation change on species trend.

Precision was designated as the width of the credible interval ( i.e. difference between the upper and lower credible intervals; see Smith et al. 2014), with categories delineated as <3.5 as High, >3.5 to <6.7 as medium, and >6.7 as low. These categories identify trends that

Prediction #1. Need information on quantifying change in vegetation over study period. Need to run analysis.

Prediction #4. Need to analyze difference between migrant and resident trends

Prediction #5. Need to look at budworm and budworm-associated species.

**Results**

*Trends in stand composition and structure*

Over the 20 year study period vegetation in the study area changed XX. Vegetation characteristics – Was there change? On average the study area became more xx, shrubs XX< > etc.

Quantify distribution and abundance of budworm over the study area.

*Bird trend estimates*

We detected XX individuals of XX forest bird species and report 19-year trend estimates for 50 species.

Study Area Trends (habitat plus unaccounted for effects)

Of the twenty species with either high (10) or medium (10) precision trends, 7 showed increasing, 8 decreasing, and 5 had stable trends. The remaining 30 species had low precision. List of important species relationships.

Regional Trends (just unaccounted for effects)

Of the twenty-six species that had either high (11) or medium (15) precision trends, 6 showed increasing, 10 decreasing, and 10 had stable trends. The remaining 24 species had low precision. List of important species relationships.

After excluding local effects (i.e. regional trend), 7 species had increasing trends, 15 had decreasing trends, and 28 had stable trends. Of these 28, 18 had low precision. Of the non-stable regional trends, 18 belonged to migratory species, 72% of which were declining trends, and the remaining 4 were for resident species, 2 of which had declining trends.

I would simply report the number of increasing, decreasing, and stable trends with high and then medium precision or combined (never mind directions for those with low precision). We should also provide list of species for more important relationships.

Local Habitat Trends (just habitat effects)

Local habitat trends had the greatest precision with 28 species having trends with high or medium precision and 21 species having low precision.

I would simply report the number of increasing, decreasing, and stable trends with high and then medium precision or combined (never mind directions for those with low precision).

Interestingly, when considering local habitat trends, only 1 species White-winged Crossbill (*Loxia leucoptera*) shows a declining trend, though 4 of 8 species trends have low precision.

Of the species which had previously been identified as having an interaction with spruce budworm, XX showed a significant relationship (Table 2). There was XX significant difference in trends between migrants and resident species (XX).

Analysis for changes in vegetation over the study? (i.e. no significant change in local stand structure and composition in areas not defoliated by spruce budworm.)

Analysis in abundance of budworm-specialist species would correlate with annual availability of budworm and would be highest when budworm outbreaks occurred locally (i.e. <20km)

Differences among types of trends

**Discussion**

**References**

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**Appendix 1**. List of sp. and corresponding habitat variables.

**Appendix 2. …**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Common Name** | **Latin Name** | **Trend Type** | **Annual trend** | **Lower** | **Upper** | **Precision** | **Reliability** |
| ALFL | Alder Flycatcher | Empidonax alnorum | Local Habitat Trend | 11.49 | -5.48 | 58.87 | 64.34 | Low |
| ALFL | Alder Flycatcher | Empidonax alnorum | Regional Trend | -0.02 | -4.77 | 4.96 | 9.73 | Low |
| ALFL | Alder Flycatcher | Empidonax alnorum | Study Area Trend | 11.46 | -6.95 | 58.96 | 65.91 | Low |
| AMCR | American Crow | Corvus brachyrhynchos | Local Habitat Trend | 2.84 | -5.71 | 23.27 | 28.98 | Low |
| AMCR | American Crow | Corvus brachyrhynchos | Regional Trend | 10.68 | 3.19 | 19.24 | 16.04 | Low |
| AMCR | American Crow | Corvus brachyrhynchos | Study Area Trend | 13.51 | 2.35 | 35.39 | 33.04 | Low |
| AMRE | American Redstart | Setophaga ruticilla | Local Habitat Trend | -2.75 | -5.99 | -0.10 | 5.89 | Medium |
| AMRE | American Redstart | Setophaga ruticilla | Regional Trend | -7.11 | -9.57 | -4.59 | 4.97 | Medium |
| AMRE | American Redstart | Setophaga ruticilla | Study Area Trend | -9.86 | -14.09 | -5.94 | 8.15 | Low |
| AMRO | American Robin | Turdus migratorius | Local Habitat Trend | 2.05 | -0.54 | 12.09 | 12.63 | Low |
| AMRO | American Robin | Turdus migratorius | Regional Trend | -3.33 | -5.66 | -0.99 | 4.66 | Medium |
| AMRO | American Robin | Turdus migratorius | Study Area Trend | -1.28 | -5.31 | 9.00 | 14.31 | Low |
| BAWW | Black-and-white Warbler | Mniotilta varia | Local Habitat Trend | -1.29 | -4.12 | 1.28 | 5.39 | Medium |
| BAWW | Black-and-white Warbler | Mniotilta varia | Regional Trend | -6.62 | -10.28 | -2.67 | 7.61 | Low |
| BAWW | Black-and-white Warbler | Mniotilta varia | Study Area Trend | -7.91 | -12.81 | -2.82 | 9.99 | Low |
| BBWA | Bay-breasted Warbler | Setophaga castanea | Local Habitat Trend | 1.67 | 0.75 | 2.64 | 1.89 | High |
| BBWA | Bay-breasted Warbler | Setophaga castanea | Regional Trend | 0.84 | -0.55 | 2.21 | 2.77 | High |
| BBWA | Bay-breasted Warbler | Setophaga castanea | Study Area Trend | 2.51 | 1.10 | 3.97 | 2.86 | High |
| BCCH | Black-capped Chickadee | Poecile atricapillus | Local Habitat Trend | -4.46 | -11.03 | 0.76 | 11.78 | Low |
| BCCH | Black-capped Chickadee | Poecile atricapillus | Regional Trend | 6.15 | -0.57 | 13.42 | 14.00 | Low |
| BCCH | Black-capped Chickadee | Poecile atricapillus | Study Area Trend | 1.69 | -7.69 | 11.36 | 19.05 | Low |
| BHVI | Blue-headed Vireo | Vireo solitarius | Local Habitat Trend | 2.11 | -1.80 | 6.23 | 8.03 | Low |
| BHVI | Blue-headed Vireo | Vireo solitarius | Regional Trend | 0.75 | -4.11 | 6.02 | 10.13 | Low |
| BHVI | Blue-headed Vireo | Vireo solitarius | Study Area Trend | 2.86 | -3.13 | 9.06 | 12.19 | Low |
| BOCH | Boreal Chickadee | Poecile hudsonicus | Local Habitat Trend | -0.77 | -5.97 | 2.93 | 8.90 | Low |
| BOCH | Boreal Chickadee | Poecile hudsonicus | Regional Trend | -3.08 | -6.87 | 0.89 | 7.76 | Low |
| BOCH | Boreal Chickadee | Poecile hudsonicus | Study Area Trend | -3.86 | -10.45 | 2.05 | 12.50 | Low |
| BOWA | Bohemian Waxwing | Bombycilla garrulus | Local Habitat Trend | 0.95 | -3.14 | 10.35 | 13.48 | Low |
| BOWA | Bohemian Waxwing | Bombycilla garrulus | Regional Trend | -9.36 | -28.25 | 8.46 | 36.71 | Low |
| BOWA | Bohemian Waxwing | Bombycilla garrulus | Study Area Trend | -8.40 | -27.99 | 11.57 | 39.56 | Low |
| CAWA | Canada Warbler | Cardellina canadensis | Local Habitat Trend | -5.14 | -7.79 | -2.48 | 5.30 | Medium |
| CAWA | Canada Warbler | Cardellina canadensis | Regional Trend | -0.15 | -3.06 | 2.86 | 5.92 | Medium |
| CAWA | Canada Warbler | Cardellina canadensis | Study Area Trend | -5.29 | -8.84 | -1.63 | 7.21 | Low |
| CHSP | Chipping Sparrow | Spizella passerina | Local Habitat Trend | 1.30 | 0.53 | 2.06 | 1.54 | High |
| CHSP | Chipping Sparrow | Spizella passerina | Regional Trend | -1.02 | -2.14 | 0.13 | 2.27 | High |
| CHSP | Chipping Sparrow | Spizella passerina | Study Area Trend | 0.29 | -1.01 | 1.56 | 2.58 | High |
| CMWA | Cape May Warbler | Setophaga tigrina | Local Habitat Trend | 8.34 | 6.13 | 10.66 | 4.52 | Medium |
| CMWA | Cape May Warbler | Setophaga tigrina | Regional Trend | 2.52 | -0.16 | 5.30 | 5.46 | Medium |
| CMWA | Cape May Warbler | Setophaga tigrina | Study Area Trend | 10.86 | 7.70 | 14.24 | 6.54 | Medium |
| CORA | Common Raven | Corvus corax | Local Habitat Trend | 1.39 | -0.50 | 6.05 | 6.55 | Medium |
| CORA | Common Raven | Corvus corax | Regional Trend | 4.10 | 1.54 | 6.74 | 5.20 | Medium |
| CORA | Common Raven | Corvus corax | Study Area Trend | 5.49 | 2.15 | 10.57 | 8.42 | Low |
| COYE | Common Yellowthroat | Geothlypis trichas | Local Habitat Trend | 1.87 | -39.54 | 54.40 | 93.93 | Low |
| COYE | Common Yellowthroat | Geothlypis trichas | Regional Trend | 9.11 | -3.05 | 22.16 | 25.21 | Low |
| COYE | Common Yellowthroat | Geothlypis trichas | Study Area Trend | 10.98 | -30.11 | 64.62 | 94.73 | Low |
| DEJU | Dark-eyed Junco | Junco hyemalis | Local Habitat Trend | 7.49 | -0.37 | 27.89 | 28.26 | Low |
| DEJU | Dark-eyed Junco | Junco hyemalis | Regional Trend | 0.20 | -3.39 | 3.69 | 7.08 | Low |
| DEJU | Dark-eyed Junco | Junco hyemalis | Study Area Trend | 7.69 | -0.93 | 28.55 | 29.48 | Low |
| EVGR | Evening Grosbeak | Coccothraustes vespertinus | Local Habitat Trend | 4.87 | -2.66 | 14.08 | 16.74 | Low |
| EVGR | Evening Grosbeak | Coccothraustes vespertinus | Regional Trend | -0.79 | -11.86 | 11.12 | 22.98 | Low |
| EVGR | Evening Grosbeak | Coccothraustes vespertinus | Study Area Trend | 4.09 | -7.51 | 17.41 | 24.92 | Low |
| FOSP | Fox Sparrow | Passerella iliaca | Local Habitat Trend | 3.54 | -3.25 | 23.00 | 26.25 | Low |
| FOSP | Fox Sparrow | Passerella iliaca | Regional Trend | -14.54 | -18.47 | -10.27 | 8.21 | Low |
| FOSP | Fox Sparrow | Passerella iliaca | Study Area Trend | -11.00 | -20.13 | 9.57 | 29.69 | Low |
| GCKI | Golden-crowned Kinglet | Regulus satrapa | Local Habitat Trend | -13.12 | -24.39 | -2.45 | 21.93 | Low |
| GCKI | Golden-crowned Kinglet | Regulus satrapa | Regional Trend | 1.62 | -8.78 | 14.01 | 22.79 | Low |
| GCKI | Golden-crowned Kinglet | Regulus satrapa | Study Area Trend | -11.50 | -24.32 | 2.09 | 26.42 | Low |
| GRAJ | Canada Jay | Perisoreus canadensis | Local Habitat Trend | -0.03 | -0.37 | 0.34 | 0.71 | High |
| GRAJ | Canada Jay | Perisoreus canadensis | Regional Trend | -3.59 | -5.37 | -1.80 | 3.57 | Medium |
| GRAJ | Canada Jay | Perisoreus canadensis | Study Area Trend | -3.62 | -5.45 | -1.81 | 3.63 | Medium |
| HAFL | Hammond's Flycatcher | Empidonax hammondii | Local Habitat Trend | -1.15 | -7.61 | 6.22 | 13.83 | Low |
| HAFL | Hammond's Flycatcher | Empidonax hammondii | Regional Trend | 2.43 | -3.87 | 8.94 | 12.80 | Low |
| HAFL | Hammond's Flycatcher | Empidonax hammondii | Study Area Trend | 1.29 | -5.99 | 10.09 | 16.09 | Low |
| HETH | Hermit Thrush | Catharus guttatus | Local Habitat Trend | -0.35 | -4.87 | 1.82 | 6.69 | Medium |
| HETH | Hermit Thrush | Catharus guttatus | Regional Trend | 4.78 | 2.33 | 7.42 | 5.10 | Medium |
| HETH | Hermit Thrush | Catharus guttatus | Study Area Trend | 4.43 | -0.74 | 8.20 | 8.95 | Low |
| LEFL | Least Flycatcher | Empidonax minimus | Local Habitat Trend | -0.03 | -2.86 | 3.03 | 5.88 | Medium |
| LEFL | Least Flycatcher | Empidonax minimus | Regional Trend | -5.35 | -8.82 | -1.90 | 6.92 | Low |
| LEFL | Least Flycatcher | Empidonax minimus | Study Area Trend | -5.38 | -10.20 | -0.35 | 9.85 | Low |
| LISP | Lincoln's Sparrow | Melospiza lincolnii | Local Habitat Trend | 2.82 | -0.79 | 13.99 | 14.78 | Low |
| LISP | Lincoln's Sparrow | Melospiza lincolnii | Regional Trend | 5.10 | -0.57 | 10.58 | 11.15 | Low |
| LISP | Lincoln's Sparrow | Melospiza lincolnii | Study Area Trend | 7.92 | 0.51 | 19.48 | 18.97 | Low |
| MAWA | Magnolia Warbler | Setophaga magnolia | Local Habitat Trend | -0.14 | -1.04 | 0.71 | 1.75 | High |
| MAWA | Magnolia Warbler | Setophaga magnolia | Regional Trend | -2.28 | -3.46 | -1.08 | 2.38 | High |
| MAWA | Magnolia Warbler | Setophaga magnolia | Study Area Trend | -2.43 | -3.86 | -1.00 | 2.86 | High |
| MOWA | Morning Warbler | Geothlypis philadelphia | Local Habitat Trend | 0.16 | -5.26 | 5.44 | 10.70 | Low |
| MOWA | Morning Warbler | Geothlypis philadelphia | Regional Trend | 0.13 | -7.73 | 10.20 | 17.92 | Low |
| MOWA | Morning Warbler | Geothlypis philadelphia | Study Area Trend | 0.30 | -10.19 | 12.50 | 22.69 | Low |
| NOWA | Northern Waterthrush | Parkesia noveboracensis | Local Habitat Trend | 2.97 | -0.86 | 13.84 | 14.70 | Low |
| NOWA | Northern Waterthrush | Parkesia noveboracensis | Regional Trend | -3.54 | -8.33 | 0.88 | 9.21 | Low |
| NOWA | Northern Waterthrush | Parkesia noveboracensis | Study Area Trend | -0.56 | -7.46 | 10.99 | 18.45 | Low |
| OCWA | Orange-crowned Warbler | Oreothlypis celata | Local Habitat Trend | 24.75 | 1.85 | 72.82 | 70.97 | Low |
| OCWA | Orange-crowned Warbler | Oreothlypis celata | Regional Trend | -9.90 | -22.17 | 1.83 | 24.00 | Low |
| OCWA | Orange-crowned Warbler | Oreothlypis celata | Study Area Trend | 14.85 | -14.73 | 65.36 | 80.09 | Low |
| OVEN | Ovenbird | Seiurus aurocapilla | Local Habitat Trend | 0.94 | 0.01 | 1.88 | 1.87 | High |
| OVEN | Ovenbird | Seiurus aurocapilla | Regional Trend | -0.91 | -2.21 | 0.39 | 2.60 | High |
| OVEN | Ovenbird | Seiurus aurocapilla | Study Area Trend | 0.03 | -1.49 | 1.53 | 3.01 | High |
| PAWA | Palm Warbler | Setophaga palmarum | Local Habitat Trend | 2.33 | -0.62 | 4.79 | 5.41 | Medium |
| PAWA | Palm Warbler | Setophaga palmarum | Regional Trend | 1.82 | -0.86 | 4.50 | 5.36 | Medium |
| PAWA | Palm Warbler | Setophaga palmarum | Study Area Trend | 4.15 | 0.15 | 8.03 | 7.88 | Low |
| PHVI | Philadelphia Vireo | Vireo philadelphicus | Local Habitat Trend | 0.01 | -1.17 | 1.50 | 2.68 | High |
| PHVI | Philadelphia Vireo | Vireo philadelphicus | Regional Trend | 0.59 | -7.96 | 9.54 | 17.50 | Low |
| PHVI | Philadelphia Vireo | Vireo philadelphicus | Study Area Trend | 0.60 | -8.04 | 9.75 | 17.79 | Low |
| PISI | Pine Siskin | Spinus pinus | Local Habitat Trend | 0.45 | -0.41 | 3.66 | 4.07 | Medium |
| PISI | Pine Siskin | Spinus pinus | Regional Trend | -9.89 | -11.95 | -7.83 | 4.12 | Medium |
| PISI | Pine Siskin | Spinus pinus | Study Area Trend | -9.44 | -11.91 | -5.94 | 5.97 | Medium |
| PUFI | Purple Finch | Haemorhous purpureus | Local Habitat Trend | -0.87 | -6.32 | 5.13 | 11.44 | Low |
| PUFI | Purple Finch | Haemorhous purpureus | Regional Trend | -10.88 | -22.55 | -0.20 | 22.34 | Low |
| PUFI | Purple Finch | Haemorhous purpureus | Study Area Trend | -11.75 | -25.53 | -0.75 | 24.78 | Low |
| RBGR | Rose-breasted Grosbeak | Pheucticus ludovicianus | Local Habitat Trend | 1.92 | 0.73 | 3.17 | 2.44 | High |
| RBGR | Rose-breasted Grosbeak | Pheucticus ludovicianus | Regional Trend | 2.06 | 0.07 | 4.07 | 4.00 | Medium |
| RBGR | Rose-breasted Grosbeak | Pheucticus ludovicianus | Study Area Trend | 3.98 | 1.43 | 6.46 | 5.03 | Medium |
| RBNU | Red-breasted Nuthatch | Sitta canadensis | Local Habitat Trend | -1.13 | -3.03 | 0.68 | 3.71 | Medium |
| RBNU | Red-breasted Nuthatch | Sitta canadensis | Regional Trend | -8.10 | -10.26 | -5.93 | 4.33 | Medium |
| RBNU | Red-breasted Nuthatch | Sitta canadensis | Study Area Trend | -9.23 | -11.55 | -6.88 | 4.68 | Medium |
| RCKI | Ruby-crowned Kinglet | Regulus calendula | Local Habitat Trend | -3.29 | -4.92 | -1.74 | 3.18 | High |
| RCKI | Ruby-crowned Kinglet | Regulus calendula | Regional Trend | 2.07 | -0.65 | 4.90 | 5.55 | Medium |
| RCKI | Ruby-crowned Kinglet | Regulus calendula | Study Area Trend | -1.22 | -3.70 | 1.41 | 5.11 | Medium |
| REVI | Red-eyed Vireo | Vireo olivaceus | Local Habitat Trend | -0.84 | -1.70 | 0.03 | 1.73 | High |
| REVI | Red-eyed Vireo | Vireo olivaceus | Regional Trend | -2.15 | -3.40 | -0.90 | 2.50 | High |
| REVI | Red-eyed Vireo | Vireo olivaceus | Study Area Trend | -2.99 | -4.67 | -1.34 | 3.33 | High |
| SWTH | Swainson's Thrush | Catharus ustulatus | Local Habitat Trend | -0.59 | -1.22 | 0.06 | 1.28 | High |
| SWTH | Swainson's Thrush | Catharus ustulatus | Regional Trend | 0.26 | -0.56 | 1.09 | 1.65 | High |
| SWTH | Swainson's Thrush | Catharus ustulatus | Study Area Trend | -0.33 | -1.14 | 0.49 | 1.62 | High |
| TEWA | Tennessee Warbler | Oreothlypis peregrina | Local Habitat Trend | 5.56 | 4.90 | 6.23 | 1.32 | High |
| TEWA | Tennessee Warbler | Oreothlypis peregrina | Regional Trend | 0.20 | -0.63 | 1.05 | 1.68 | High |
| TEWA | Tennessee Warbler | Oreothlypis peregrina | Study Area Trend | 5.76 | 4.71 | 6.83 | 2.12 | High |
| VATH | Varied Thrush | lxoreus naevius | Local Habitat Trend | 4.04 | -1.21 | 9.49 | 10.70 | Low |
| VATH | Varied Thrush | lxoreus naevius | Regional Trend | 2.94 | -4.34 | 10.36 | 14.70 | Low |
| VATH | Varied Thrush | lxoreus naevius | Study Area Trend | 6.98 | -1.98 | 16.48 | 18.46 | Low |
| WAVI | Warbling Vireo | Vireo gilvus | Local Habitat Trend | 0.04 | -0.26 | 0.33 | 0.59 | High |
| WAVI | Warbling Vireo | Vireo gilvus | Regional Trend | 2.85 | 0.81 | 5.02 | 4.21 | Medium |
| WAVI | Warbling Vireo | Vireo gilvus | Study Area Trend | 2.89 | 0.87 | 5.05 | 4.18 | Medium |
| WETA | Western Tanager | Piranga ludoviciana | Local Habitat Trend | 0.19 | 0.00 | 0.39 | 0.39 | High |
| WETA | Western Tanager | Piranga ludoviciana | Regional Trend | -3.88 | -4.79 | -2.96 | 1.83 | High |
| WETA | Western Tanager | Piranga ludoviciana | Study Area Trend | -3.69 | -4.59 | -2.79 | 1.80 | High |
| WEWP | Western Wood-pewee | Contopus sordidulus | Local Habitat Trend | 5.01 | -7.34 | 38.33 | 45.67 | Low |
| WEWP | Western Wood-pewee | Contopus sordidulus | Regional Trend | -6.57 | -29.22 | 11.00 | 40.22 | Low |
| WEWP | Western Wood-pewee | Contopus sordidulus | Study Area Trend | -1.56 | -27.59 | 34.17 | 61.75 | Low |
| WIWR | Winter Wren | Troglodytes hiemalis | Local Habitat Trend | -4.51 | -6.58 | -2.31 | 4.26 | Medium |
| WIWR | Winter Wren | Troglodytes hiemalis | Regional Trend | 7.21 | 4.42 | 10.00 | 5.58 | Medium |
| WIWR | Winter Wren | Troglodytes hiemalis | Study Area Trend | 2.70 | 0.11 | 5.20 | 5.09 | Medium |
| WTSP | White-throated Sparrow | Zonotrichia albicollis | Local Habitat Trend | -0.27 | -1.33 | 0.86 | 2.19 | High |
| WTSP | White-throated Sparrow | Zonotrichia albicollis | Regional Trend | 0.47 | -0.99 | 1.95 | 2.93 | High |
| WTSP | White-throated Sparrow | Zonotrichia albicollis | Study Area Trend | 0.20 | -1.57 | 2.03 | 3.61 | Medium |
| WWCR | White-winged Crossbill | Loxia leucoptera | Local Habitat Trend | -0.32 | -0.62 | -0.01 | 0.61 | High |
| WWCR | White-winged Crossbill | Loxia leucoptera | Regional Trend | 9.59 | 7.48 | 11.74 | 4.26 | Medium |
| WWCR | White-winged Crossbill | Loxia leucoptera | Study Area Trend | 9.27 | 7.16 | 11.44 | 4.28 | Medium |
| YBFL | Yellow-bellied Flycatcher | Empidonax flaviventris | Local Habitat Trend | 6.02 | -2.96 | 35.31 | 38.27 | Low |
| YBFL | Yellow-bellied Flycatcher | Empidonax flaviventris | Regional Trend | -9.72 | -14.83 | -4.75 | 10.08 | Low |
| YBFL | Yellow-bellied Flycatcher | Empidonax flaviventris | Study Area Trend | -3.70 | -13.50 | 25.70 | 39.20 | Low |
| YBSA | Yellow-bellied Sapsucker | Sphyrapicus varius | Local Habitat Trend | 0.32 | -0.07 | 0.71 | 0.78 | High |
| YBSA | Yellow-bellied Sapsucker | Sphyrapicus varius | Regional Trend | -2.49 | -3.57 | -1.41 | 2.16 | High |
| YBSA | Yellow-bellied Sapsucker | Sphyrapicus varius | Study Area Trend | -2.16 | -3.32 | -1.05 | 2.27 | High |
| YRWA | Yellow-rumped Warbler | Setophaga coronata | Local Habitat Trend | -1.20 | -2.01 | -0.39 | 1.61 | High |
| YRWA | Yellow-rumped Warbler | Setophaga coronata | Regional Trend | -3.05 | -4.27 | -1.84 | 2.44 | High |
| YRWA | Yellow-rumped Warbler | Setophaga coronata | Study Area Trend | -4.25 | -5.43 | -3.09 | 2.34 | High |
| YWAR | Yellow Warbler | Setophaga petechia | Local Habitat Trend | 27.04 | -27.80 | 190.90 | 218.70 | Low |
| YWAR | Yellow Warbler | Setophaga petechia | Regional Trend | 14.86 | -15.12 | 60.42 | 75.54 | Low |
| YWAR | Yellow Warbler | Setophaga petechia | Study Area Trend | 41.90 | -22.76 | 220.47 | 243.23 | Low |