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Trends in abundance of common passerine species in Wrangell-St. Elias National Park and Preserve, 1997–2019

Natural Resource Report NPS/CAKN/NRR—2021/2282

ON THE COVER

A white-crowned sparrow perches on a tall willow in the early morning hours (NPS/Jared Hughey)

Trends in abundance of common passerine species in Wrangell-St. Elias National Park and Preserve, 1997–2019

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Executive Summary

The Central Alaska Inventory and Monitoring Network (CAKN) monitors passerine species with the primary objectives of documenting changes in their distribution and abundance. Towards these objectives, we conduct roadside surveys in Wrangell-St. Elias National Park and Preserve (WRST) along the Nabesna and McCarthy roads. Here, we document trends in relative abundance of common breeding species in WRST from 1997–2019 using these data combined with counts from the North American Breeding Bird Survey (BBS) made along the same road sections. Among forest-associated species, Swainson's thrush (*Catharus ustulatus*) and varied thrush (*Ixoreus naevius*) exhibited positive and negative trends in abundance, respectively. Among shrub tundra-associated species, only savannah sparrow (*Passerculus sandwichensis*) showed strong evidence of change (i.e., a negative trend). The direction of these trends was consistent with state- and regional-scale analyses of BBS data, suggesting that the observed trends in WRST are part of larger-scale population changes within the northern boreal region.

Acknowledgments

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Introduction

Warming in interior Alaska is amplified (Trenberth et al. 2007, Clegg and Hu 2010), inducing a cascade of impacts within this region including increased shrub cover and the upslope migration of treeline (Stueve et al. 2011, Brodie et al. 2019). Changes in vegetation structure in concert with lengthening of the growing season are expected to affect the distribution of subarctic-adapted vertebrates including boreal-breeding birds (Mizel et al. 2016, Stralberg et al. 2017, Winker and Gibson 2018). Many species of boreal-breeding birds are restricted to Canada, where, presumably, portions of the cordilleran mountain ranges that stretch across western North America have served as barriers to their expansion into Alaska (Stralberg et al. 2017). However, under a warming climate, the ranges of many of these species are expected to expand into Alaska at some future point in time (Stralberg et al. 2017).

Wrangell-St. Elias National Park and Preserve (WRST) is uniquely positioned for detecting range expansion in boreal birds due to is location near the southern and eastern limits of the boreal biome within Alaska. Thus, long-term monitoring of passerines in this park may be useful for indicating ecological responses to climate change in the subarctic. The Central Alaska Inventory and Monitoring Network (CAKN) monitors passerine species with the primary objectives of documenting changes in their distribution and abundance. Towards these objectives, we conduct roadside surveys in Wrangell-St. Elias National Park and Preserve (WRST) along the Nabesna and McCarthy roads. Here, we document trends in relative abundance of common breeding species in WRST from 1997–2019 using these data combined with counts from the North American Breeding Bird Survey (BBS; Bystrack 1981) conducted along the same road sections. In addition, we use the combined BBS and CAKN data along with sightings from the citizen science based site, eBird (Sullivan et al. 2009), to summarize recent observations within and immediately adjacent to WRST of boreal passerines with breeding distributions that are largely restricted to Canada or that have distributions in Alaska which are primarily coastal.

Methods

Study area

We conducted passerine surveys along the Nabesna and McCarthy roads beginning near their intersection with the park boundary and moving east into the WRST (Fig. 1). We established one survey route along the Nabesna Road comprising 50 points and two routes along the McCarthy Road comprising 50 and 59 points, respectively. Points were established at approximate 0.8 km intervals. These routes were conducted concurrently with three BBS routes which cover the same stretches of road and each have 50 points with 0.8 km spacing. However, the CAKN routes were slightly offset from the BBS routes primarily to avoid locating points near private residences.

The McCarthy Road routes traverse a region of boreal forest with shallow discontinuous permafrost. Black spruce (*Picea mariana*) forests and muskeg dominate on poorly drained, permafrost-rich sites; Balsam poplar (*Populus balsamifera*), quaking aspen (*Populus tremuloides*), and white spruce (*Picea glauca*) forests dominate on well-drained, permafrost-free sites; and willow (*Salix sp.*), shrub birch (*Betula sp.*), and alder (*Alnus sp.*) dominate dense riparian and upland shrublands. The Nabesna Road region has a climate more characteristic of interior Alaska and vegetation is dominated by black spruce and low birch shrubland. Elevations range from 778–1008 m (mean = 913 m) on the Nabesna route and 154–507 m (mean = 417 m) on the McCarthy routes.

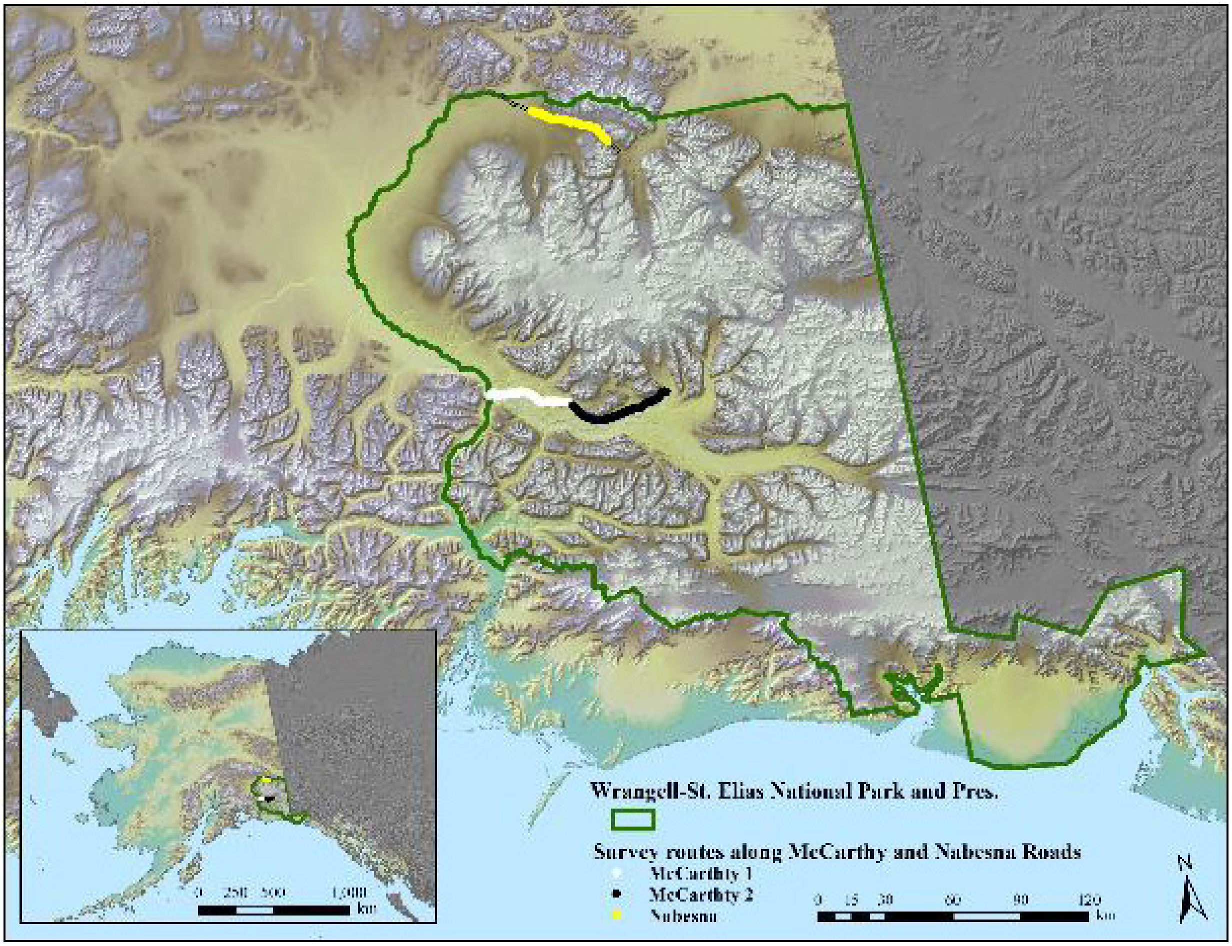

Figure 1. Location of BBS and CAKN survey routes along Nabesna and McCarthy roads in WRST.

Sampling methods

Under the CAKN monitoring program, observers conducted repeated surveys from early May to the beginning of July from 2010–2019. Points were surveyed 2–6 times each year (mean = 3.6 visits/year). Under the BBS monitoring program, routes were surveyed once per year in mid-June from 1989–2019. Not all BBS and CAKN routes were surveyed in all years. Due to potential evidence of species misclassification in a subset of early BBS surveys, we restricted our analyses of these data to the years 1997–2019. Specifically, certain observers may have misclassified orange-crowned warblers (*Oreothlypis celata*) as dark-eyed juncos (*Junco hyemalis*), as evidenced by the absence of the former species during the surveys by particular observers coupled with their relative abundance immediately after those observers were replaced. One of these observers also recorded a suspiciously high count of song sparrows (*Melospiza melodia*) while recording the comparatively common fox sparrow (*Passerella iliaca*) as absent. The two species could theoretically be mistaken for each other, and this observer was responsible for nearly all song sparrow detections in the dataset.

Under both CAKN and BBS programs, standard 3-minute point count surveys were conducted during favorable weather from 0.5 hours before sunrise to approximately 6 hours thereafter, and all birds seen or heard within ~400 m during the count period were recorded (Bystrack 1981). Most of

the 20 observers represented in the dataset conducted surveys in multiple years and at least two observers conducted both BBS and CAKN surveys.

Analysis

We used Poisson regression in a Bayesian framework to assess trends in relative abundance (hereafter, abundance) in the breeding passerines common to our routes (Barker et al. 2018). Under this framework, the model for the log-transform of the mean count includes covariates of abundance in addition to covariates of detectability which are nuisance parameters (Link and Sauer 1997). We restricted our analysis to the 11 most abundant species to ensure sufficient data to adequately model covariates of abundance and detection (see Appendix A for total detections of species). We jointly modeled the CAKN and BBS data and fit the same model to each species. To avoid spatial autocorrelation between CAKN and BBS point-level counts, we aggregated the latter to the route-level for analysis. The BBS methodology permitted using the route-level counts because routes were completed in full by a single observer, whereas the CAKN routes were occasionally only partially done and/or were conducted by multiple observers on a given survey date necessitating a point-level model. The observations from the CAKN surveys y_{jkt}^{C} corresponded to the counts made at each point $j = 1, 2, \ldots J$, during each repeat survey $k = 1, 2, \ldots K$, in each year $t = 1, 2, \ldots T$.

We specified a model for the log-transform of the mean count λ_{jkt}^{C} on the CAKN surveys:

$$\log(\lambda_{jkt}^{C}) = \beta_{0i} + \beta_1 year_t + \beta_2 date_{jkt} + \beta_3 date_{jkt}^2 + \gamma_g + \delta_t + \varepsilon_{jt}$$

where the β_{0i} are route-specific intercepts (i = 1, 2, and 3), β_1 is a trend term, β_2 and β_3 are the linear and quadratic effects of Julian date, respectively, the γ_g are normal random variables $N(0, \sigma_\gamma^2)$ for each observer, the δ_t are normal random variables $N(0, \sigma_\delta^2)$ for each year, and the ε_{jt} are normal random variables $N(0, \sigma_\varepsilon^2)$ used to accommodate repeated sampling of sites within years and extra-Poisson variation.

The model for expected mean count on the BBS surveys, λ_{it}^{B} on route i in year t, shared the parameters β_{0i}, β_1, β_2, β_3, γ_g, and δ_t with the model for the CAKN counts, but included an offset of log(50) to account for aggregating the count over 50 points.

We fit models in a Bayesian framework using Just Another Gibbs Sampler (JAGS) version 4.3.0 (Plummer 2003) via the runjags package (Denwood and Plummer 2016) in program R 3.4 (R Core Development Team 2018). We specified vague normal priors for all regression coefficients except the linear and quadratic effects of Julian date which were given informative priors based upon their posterior distributions estimated from a timeseries of counts made along the park road in Denali (J. Mizel, unpubl. data). The hierarchal standard deviation parameters were given half-Cauchy priors (Gelman 2006). We estimated the posterior distributions of the parameters from four Markov chain Monte Carlo chains run for 1,000,000 iterations. We assessed convergence visually and using the Gelman-Rubin diagnostic (Brooks and Gelman 1998). We scaled continuous covariates (mean = 0, SD = 1) to improve convergence properties. See Appendix A for total counts of passerines

(Table A1) and non-passerines (Table A2) and see appendix B for estimates of route-specific intercepts, date effects, and hierarchical standard deviations.

Results and Discussion

Observations of species primarily occurring in Canada

Tennessee warbler (*Oreothlypis peregrina*) and yellow-bellied flycatcher (*Empidonax flaviventris*) were the most frequently observed passerines with distributions that are largely restricted to the Canadian boreal belt (Table 1). Several other Canadian boreal species were observed only once in or adjacent to the park (Table 1). Pacific wren (*Troglodytes pacificus*), MacGillivray's warbler (*Geothlypis tolmiei*), eastern phoebe (*Sayornis phoebe*), and warbling vireo (*Vireo gilvus*) were among the observed species that have not been previously documented as breeding in interior Alaska (Gibson 2011, Gibson and Withrow 2015, Stralberg et al. 2017). Although breeding was not confirmed in these four cases, the warbling vireo observation was of multiple counter-singing males.

Table 1. Observations within and adjacent to WRST of bird species with distributions primarily restricted to the Canadian boreal region. Some species are coastal breeders within Alaska. Observations are limited to the boreal regions of the park and exclude areas south of the McCarthy Road. Number of observations are given in parentheses if multiple observations were recorded.

Species	Source	McCarthy Road	Nabesna Road	Other locations
Sora	CAKN, eBird	2011 (2), 2013	–	Kenny L., 2011, 2012
Yellow-bellied sapsucker	CAKN	2013, 2015, 2018 (6)	–	–
Yellow-bellied flycatcher	CAKN, BBS	–	2011, 2012 (2), 2014	–
Eastern phoebe	CAKN	–	2015	–
Warbling vireo	CAKN	2019 (3)	–	–
Pacific wren	BBS	1995	–	–
Cassin's finch	eBird	–	2012	–
Song sparrow	eBird	–	–	Chitna, 2019
Brewer's (Timberline) sparrow	Doyle 1997	–	–	Gold Hill, Mentasta Mts.
Brown-headed cowbird	eBird	–	–	Glennallen, 2016
Tennessee warbler	CAKN, BBS	1995 (2), 2013 (3), 2014, 2015 (18), 2017 (3)	–	–
MacGillivray's warbler	eBird	2017	–	–
Common yellowthroat	eBird	–	–	Richardson Hwy., 2017
Cape May warbler	M. Vail, CAKN	2013 (8)	–	–

Trends in common species

Among forest-associated species, Swainson's thrush (*Catharus ustulatus*) and varied thrush (*Ixoreus naevius*) exhibited positive and negative trends in abundance, respectively (Table 1). Among shrub tundra-associated species, only savannah sparrow (*Passerculus sandwichensis*) showed strong evidence of change (i.e., a negative trend; Table 1). The direction of these trends was consistent with state- and regional-scale analyses of BBS data (Handel and Sauer 2017, Sauer et al. 2017; Table 2), suggesting that the observed trends in WRST are part of larger-scale population changes within the northern boreal region. It is possible that estimating separate trends for Nabesna and McCarthy roads may have identified different trajectories, possibly due to different habitat change or distributional shifts, but this likely would have resulted in overfitting in the case of certain species.

Table 2. Posterior means and 95% CIs for log-linear trends in relative abundance estimated from roadside surveys conducted in WRST, 1997–2019. The direction of trends from broad-scale analyses of BBS data are shown for the sake of comparison. These comparisons include analyses conducted by Handel and Sauer (2017) for the Northwest Interior Forest Bird Conservation Region (BCR 4) in Alaska (1993–2015) and those done by Sauer et al. (2017) for this same BCR but at a continental scale over the period, 1966–2015. Only the directions of trends with 95% CIs that do not overlap 0 are shown for these comparison studies.

Species	Mean	95% CI	BCR 4 (AK); 1993–2015	BCR 4; 1966–2015
American robin	−0.02	(−0.20, 0.16)	–	Increasing
Dark-eyed junco	−0.20	(−0.45, 0.05)	–	–
Lincoln's sparrow	0.11	(−0.22, 0.46)	–	Increasing
Myrtle warbler	−0.10	(−0.36, 0.15)	–	–
Orange-crowned warbler	−0.03	(−0.33, 0.27)	–	Decreasing
Ruby-crowned kinglet	0.13	(−0.17, 0.41)	Increasing	–
Savannah sparrow	**−0.46***	**(−0.87*, −0.07*)**	Decreasing	Decreasing
Swainson's thrush	**0.27***	**(0.00*, 0.54*)**	Increasing	–
Varied thrush	**−0.48***	**(−0.82*, −0.15*)**	–	Decreasing
White-crowned sparrow	−0.06	(−0.27, 0.15)	Decreasing	Decreasing
Wilson's warbler	0.17	(−0.57, 0.08)	Decreasing	Decreasing

* 95% CI does not include 0, also shown in bold text.

We were unable to assess whether local changes in habitat structure could be involved in the observed trends or if they are driving distributional changes. The Copper River Basin and, specifically, the McCarthy road corridor has been subject to recurrent outbreaks of spruce beetles (*Dendroctonus rufipennis* (Kirby) since 1920 which, through the mortality of large-diameter spruce and the release of understory vegetation, has resulted in a mosaic of successional stages across the landscape (Matsuoka et al. 2001). Such changes in vegetation structure appear to strongly affect the abundance of some forest- and shrub-associated species. In the McCarthy road corridor, Matsuoka et

al. (2001) found that most understory-nesting passerines (including both forest- and tall shrub-adapted species) had higher abundance in stands with moderate and/or high spruce mortality compared to stands with low mortality.

Thus, our trend estimates may partially reflect successional changes over the survey period. For previous analyses of the Denali roadside data, we used elevation as a proxy for variation in vegetation (Mizel et al. 2016). However, the Nabesna and McCarthy routes are situated primarily below treeline and cover a limited elevational gradient. For the WRST roadside data to help understand broader ecological patterns such as successional changes, it may be necessary to assess abundance-habitat relationships directly via remotely sensed vegetation data. In addition, off-road sampling of above-treeline bird assemblages (to be implemented in 2021) may help compliment the below-treeline focus of the roadside surveys and should allow a greater understanding of distributional change due to changes in vegetation structure across the forest-tundra gradient. In particular, the above-treeline surveys should improve trend estimation for shrub-adapted birds. These species were not well-represented in the roadside data which resulted in imprecise trend estimation in some species and precluded fitting our model for others.

Our analysis suggests that the CAKN roadside surveys conducted in WRST primarily serve to augment the BBS effort which is limited to a single visit per season. In light of our difficulties in identifying the mechanisms underlying the observed trends in WRST roadside counts, the CAKN roadside effort is likely to be most valuable in the context of broad-scale analyses (e.g., Handel and Sauer 2017) or in complimenting off-roading sampling in above-treeline sections of WRST, as opposed to being used to estimate trends that are specific to the park roads alone.

Literature Cited

Barker, R. J., M. R. Schofield, W. A. Link, J. R. Sauer. 2018. On the reliability of N-mixture models for count data. Biometrics 74: 369–377.

Brodie, J. F., C. A. Roland, S. E. Stehn, E. Smirnova. 2019. Variability in the expansion of trees and shrubs in boreal Alaska. Ecology 100: e02660.

Brooks, S. P., A. Gelman. 1998. General methods for monitoring convergence of iterative simulations. Journal of Computational and Graphical Statistics 7: 434–455.

Bystrack, D. 1981. The North American breeding bird survey. Stud Avian Biol 19: 34–41.

Clegg, B. F., F. S. Hu. 2010. An oxygen-isotope record of Holocene climate change in south-central Brooks Range, Alaska. Quaternary Science Reviews 29: 928–39.

Denwood, M., M. Plummer. 2016. Package ‘runjags’. <http://runjags.sourceforge.net>.

Doyle, T. J. 1997. The Timberline Sparrow, *Spizella (breweri) taverneri*. in Alaska, with notes on breeding habitat and vocalizations. Western Birds 28: 1–12.

Gelman, A. 2006. Prior distributions for variance parameters in hierarchical models (comment on article by Browne and Draper). Bayesian Analysis 1: 515–534.

Gibson, D. D. 2011. Nesting shorebirds and landbirds of interior Alaska. Unpublished report, USGS Alaska Science Center, Anchorage, Alaska.

Gibson, D. D., and J. J. Withrow. 2015. Inventory of the species and subspecies of Alaska birds, second edition. Western Birds 46: 94–185.

Handel, C. M., and J. R. Sauer. 2017. Combined analysis of roadside and off-road breeding bird survey data to assess population change in Alaska. The Condor: Ornithological Applications 119(3): 557–575.

Link, W. A., and J. R. Sauer. 1997. Estimation of population trajectories from count data. Biometrics 53: 488–497.

Matsuoka, S. M., C. M. Handel, and D. R. Ruthrauff. 2001. Densities of breeding birds and changes in vegetation in an Alaskan boreal forest following a massive disturbance by spruce beetles. Canadian Journal of Zoology 79(9): 1678–1690.

Mizel, J. D., J. H. Schmidt, C. L. McIntyre, and C. A. Roland. 2016. Rapidly shifting elevational distributions of passerine species parallel vegetation change in the subarctic. Ecosphere 7: e01264.

Mizel, J. D., J. H. Schmidt, C. L. McIntyre, M. S. Lindberg. 2017. Subarctic-breeding passerines exhibit phenological resilience to extreme spring conditions. Ecosphere 8: e01680.

Plummer, M. 2003. JAGS: a program for analysis of Bayesian graphical models using Gibbs sampling. <http://www.r-project.org/conferences/DSC-2003/Drafts/Plummer.pdf>.

R Core Team. 2018. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Sauer, J. R., K. L. Pardieck, D. J. Ziolkowski Jr, A. C. Smith, M. A. R. Hudson, V. Rodriguez, H. Berlanga, D. K. Niven, and W. A. Link. 2017. The first 50 years of the North American breeding bird survey. The Condor: Ornithological Applications 119(3): 576–593.

Stralberg, D., S. M. Matsuoka, C. M. Handel, F. K. Schmiegelow, A. Hamann, and E. M. Bayne. 2017. Biogeography of boreal passerine range dynamics in western North America: past, present, and future. Ecography 40(9): 1050–1066.

Stueve, K. M., R. E. Isaacs, L. E. Tyrrell, R. V. Densmore. 2011. Spatial variability of biotic and abiotic tree establishment constraints across a treeline ecotone in the Alaska Range. Ecology 92: 496–506.

Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: A citizen-based bird observation network in the biological sciences. Biological conservation 142(10): 2282–2292.

Trenberth, K. E., P. D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J. A. Renwick, M. Rusticucci, B. Soden, and P. Zhai. 2007. Observations: Surface and atmospheric climate change. Chapter 3. Climate Change 235–336.

Appendix A. Total counts from roadside surveys in WRST, 1997–2019.

Table A1. Total counts in descending order of all passerines detected and classified to species by both CAKN and BBS surveys conducted along the Nabesna and McCarthy Roads in WRST, 1997–2019.

Species	Total Count
Swainson's thrush	7935
Yellow-rumped (myrtle) warbler	7227
Dark-eyed junco	6987
White-crowned sparrow	6418
American robin	4980
Ruby-crowned kinglet	2993
Orange-crowned warbler	2055
Canada jay	1694
Wilson's warbler	1452
Common/hoary redpoll	1003
Lincoln's sparrow	971
Varied thrush	967
Savannah sparrow	689
Alder flycatcher	650
Boreal chickadee	604
White-winged crossbill	521
Fox sparrow	448
Western wood-pewee	420
Common raven	410
Pine siskin	402
Olive-sided flycatcher	312
Gray-cheeked thrush	258
Northern waterthrush	257
Hermit thrush	218
Pine grosbeak	212
Bohemian waxwing	191
Tree swallow	180

Species	Total Count
Rusty blackbird	117
Yellow warbler	99
Black-capped chickadee	95
Blackpoll warbler	84
Chipping sparrow	73
Violet-green swallow	65
Golden-crowned kinglet	48
American tree sparrow	38
Tennessee warbler	17
Townsend's warbler	14
Bank swallow	13
Hammond's flycatcher	13
Black-billed magpie	11
Golden-crowned sparrow	5
Townsend's solitaire	5
American pipit	3
Brown creeper	3
Yellow-bellied flycatcher	2
Cape May warbler	1
Eastern phoebe	1
Horned lark	1
Red crossbill	1
Red-breasted nuthatch	1
Red-winged blackbird	1
Smith's longspur	1
Warbling vireo	1

Table A2. Total counts in descending order of all non-passerines detected and classified to species by both CAKN and BBS surveys conducted along the Nabesna and McCarthy Roads in WRST, 1997–2019.

Species	Total Count
Wilson's snipe	247
Northern (yellow-shafted) flicker	217
Herring gull	118
Trumpeter swan	116
Lesser yellowlegs	100
Lesser scaup	89
Mew gull	89
Barrow's goldeneye	71
Solitary sandpiper	62
Mallard	58
Common loon	53
Ring-necked duck	53
Bald eagle	49
American wigeon	47
American three-toed woodpecker	44
Canada goose	35
Upland sandpiper	35
Bonaparte's gull	33
Pacific loon	32
Hairy woodpecker	31
Downy woodpecker	28
Green-winged teal	27
Red-tailed hawk	27
White-winged scoter	21
Bufflehead	20
Northern shoveler	20
Willow ptarmigan	16
Arctic tern	14
Great horned owl	14
Common goldeneye	13

Species	Total Count
Greater scaup	12
Merlin	12
American kestrel	10
Belted kingfisher	10
Greater yellowlegs	10
Northern goshawk	10
Spotted sandpiper	10
Northern pintail	8
Red-necked grebe	8
Yellow-bellied sapsucker	8
Northern harrier	7
Red-throated loon	7
Northern hawk owl	6
Spruce grouse	6
Great gray owl	4
Redhead	4
American golden-plover	3
Black-backed woodpecker	3
Golden eagle	3
Horned grebe	3
Sora	3
Peregrine falcon	2
Blue-winged teal	1
Boreal owl	1
Gadwall	1
Greater white-fronted goose	1
Gyrfalcon	1
Osprey	1
Red-breasted merganser	1
Ruffed grouse	1
Sharp-shinned hawk	1

Species	Total Count
Short-eared owl	1
Snow goose	1

Appendix B. Parameter estimates from analyses of WRST roadside data, 1997–2019.

Table B1. Posterior means and 95% CIs (shown in parentheses) for the route-specific intercepts β_{0i}, the linear and quadratic date effects (β_2 and β_3, respectively), and the hierarchical standard deviations of the observer, year, and site-year effects (σ_γ, σ_ε, and σ_δ, respectively). Estimates for the trend terms are shown in Table 2. All estimates are on the log-scale and β_{01}, β_{02}, and β_{03} correspond to Nabesna, McCarthy 1, and McCarthy 2 routes, respectively.

Species	$\boldsymbol{\beta_{01}}$	$\boldsymbol{\beta_{02}}$	$\boldsymbol{\beta_{03}}$	$\boldsymbol{\beta_2}$	$\boldsymbol{\beta_3}$	$\boldsymbol{\sigma_\gamma}$	$\boldsymbol{\sigma_\varepsilon}$	$\boldsymbol{\sigma_\delta}$
American robin	−0.05 (−0.3, 0.20)	−0.21 (−0.46, 0.04)	−0.11 (−0.35, 0.14)	0.23 (0.17, 0.29)	−0.67 (−0.75, −0.59)	0.41 (0.26, 0.58)	0.33 (0.28, 0.39)	0.25 (0.11, 0.40)
Dark-eyed junco	−0.05 (−0.40, 0.30)	0.02 (−0.32, 0.37)	=0.00 (−0.36, 0.34)	0.45 (0.41, 0.49)	−0.25 (−0.29, −0.20)	0.62 (0.41, 0.88)	0.19 (0.14, 0.25)	0.36 (0.21, 0.52)
Lincoln's sparrow	−2.83 (−3.29, −2.37)	−2.64 (−3.11, −2.19)	−2.74 (−3.22, −2.28)	0.46 (0.12, 0.79)	−0.52 (−0.92, −0.11)	0.58 (0.34, 0.85)	1.36 (1.22, 1.51)	0.40 (0.16, 0.67)
Myrtle warbler	−0.29 (−0.62, 0.03)	0.28 (−0.04, 0.61)	0.46 (0.13, 0.79)	0.85 (0.79, 0.92)	−1.19 (−1.27, −1.11)	0.54 (0.35, 0.76)	0.09 (0.02, 0.16)	0.37 (0.21, 0.56)
Orange-crowned warbler	−2.28 (−2.69, −1.88)	−1.74 (−2.14, −1.33)	−1.35 (−1.76, −0.96)	2.10 (2.01, 2.20)	−1.83 (−1.91, −1.74)	0.6 (0.38, 0.86)	0.75 (0.67, 0.83)	0.43 (0.24, 0.64)
Ruby-crowned kinglet	−1.13 (−1.50, −0.76)	−0.51 (−0.89, −0.15)	−0.57 (−0.95, −0.21)	−0.49 (−0.65, −0.33)	−0.43 (−0.65, −0.21)	0.56 (0.33, 0.82)	0.53 (0.46, 0.59)	0.39 (0.19, 0.61)
Savannah sparrow	−2.89 (−3.52, −2.29)	−3.69 (−4.37, −3.07)	−4.08 (−4.79, −3.43)	1.82 (1.72, 1.93)	−1.49 (−1.58, −1.38)	1.01 (0.56, 1.41)	1.73 (1.52, 1.94)	0.33 (0.10, 0.56)
Swainson's thrush	−1.73 (−2.12, −1.33)	−0.41 (−0.80, −0.01)	−0.25 (−0.65, 0.14)	2.39 (2.20, 2.58)	−1.64 (−1.83, −1.45)	0.62 (0.38, 0.91)	0.22 (0.17, 0.27)	0.38 (0.19, 0.60)
Varied thrush	−2.14 (−2.59, −1.66)	−2.68 (−3.18, −2.20)	−1.25 (−1.70, −0.78)	0.03 (−0.04, 0.09)	−0.64 (−0.73, −0.55)	0.75 (0.45, 1.11)	1.09 (0.95, 1.22)	0.36 (0.12, 0.62)
White-crowned sparrow	−0.05 (−0.43, 0.33)	−0.31 (−0.69, 0.06)	−0.93 (−1.32, −0.56)	1.03 (1.00, 1.06)	−0.72 (−0.76, −0.69)	0.74 (0.49, 1.02)	0.6 (0.55, 0.65)	0.28 (0.17, 0.39)

Species	β_{01}	β_{02}	β_{03}	β_2	β_3	σ_γ	σ_ε	σ_δ
Wilson's warbler	−1.65 (−2.13, −1.17)	−2.98 (−3.48, −2.48)	−2.57 (−3.05, −2.07)	2.54 (2.43, 2.65)	−2.48 (−2.58, −2.38)	0.78 (0.45, 1.15)	0.86 (0.75, 0.97)	0.46 (0.26, 0.68)

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