Changes in Regional Winter Abundance of the Golden-crowned Sparrow Revealed by Christmas Bird Count Data

Edward R. Pandolfino[1] and Lily A. Douglas[2]

[1]*1328 49th Street, Sacramento, CA 95819 erpfromca@aol.com*

[2]*U.S. Fish and Wildlife Service, 2800 Cottage Way, Sacramento, CA 95825*

ABSTRACT

Assessing trends in abundance of bird species whose breeding range is poorly sampled by Breeding Bird Surveys poses significant challenges. The Golden-crowned Sparrow (*Zonotrichia atricapilla*) is one such species. Range-wide data from the Christmas Bird Count (CBC) can be used to assess trends in this species' winter abundance and, by inference, range-wide breeding population trends. We used CBC data from throughout the winter range of the Golden-crowned Sparrow over the 40 years from 1984–2023 to assess abundance trends. Our analysis suggests that the overall population is stable, but that numbers are increasing significantly at the northern edge of the winter range, and declining significantly at the southern edge, suggesting a poleward shift in relative abundance in recent decades. Increases in winter temperatures throughout this species' winter range may be a key driver of this northward shift either through changes in over-winter survival, breeding season productivity, or both.

The Golden-crowned Sparrow's (*Zonotrichia atricapilla*) breeding range lies almost entirely within remote, largely roadless areas of Alaska, British Columbia, and Yukon Territory. As a result, Sauer et al. (2020) were unable to use Breeding Bird Survey (BBS) data to estimate trends in its breeding population. This sparrow's winter range includes southern British Columbia, Washington, Oregon, California, portions of western Idaho and Nevada, and northernmost Baja California. This region, except for Baja California, includes numerous Christmas Bird Count (CBC) circles within which data have been collected for several decades.

Previous attempts to use CBC data to assess Golden-crowned Sparrow population trends have been almost exclusively regional, and nearly all used older (pre-2000) data. Unitt (2004) found no significant trend from San Diego County CBCs through 2000, and Pandolfino and Handel (2018) found no significant trend in California's Central Valley from 1979 through 2014. Data from throughout California showed non-significant increases from the early 1960s through the early 1990s (Sauer et al. 1996, Norment et al. 1998). Marshall et al. (2003) reported that CBC data from the 1970s through the 1990s showed minor change in Oregon winter populations. CBC data from Washington from this same period suggested an increasing population (Sauer et al. 1996, Wahl et al. 2005), and increasing numbers from British Columbia CBCs from the 1970s into the 1990s also suggested increases in wintering birds in that province (Campbell et al. 2001, Ryder 2015). We used CBC data from throughout the regular winter range of the Golden-crowned Sparrow for the 40-year period from 1984 to 2023 to assess any regional or range-wide population trends.

METHODS

We accessed CBC data (National Audubon Society 2020) for the Golden-crowned Sparrow from the winter of 1983–84 (Count Year 84) through winter of 2022–23 (Count Year 123). We only used data from CBC circles that:

- reported an average of >5 Golden-crowned Sparrows per year over at least one of the four decades (the first, second, third, or fourth 10-year period) covered by our dataset; and
- were surveyed during most (>10) of the years of both the first half (Count Years 84–103) and the second half (Count Years 104–123) of the 40-year period.

The first criterion ensured that we used CBC circles where the species occurred regularly during at least some the 40-year period of analysis. The second criterion ensured that every CBC circle we used was active over the entire period of analysis.

We found 133 CBC circles that met the selection criteria (Appendix A) from southern British Columbia through Washington, Oregon, east-central Nevada, and California. All data were normalized by using the number of Golden-crowned Sparrows reported per party-hour to account for differences in effort levels among the counts. We used linear regression analysis (Data Analysis package from Excel) to assess trends in abundance regionally and throughout the winter range. We used birds-per-party-hour as the response variable and year as the effect variable. Trends with a probability (p) value of <0.05 were considered statistically significant.

The regions we used for comparison (British Columbia, Washington, Oregon, northern and southern California, and west-central Nevada) were chosen arbitrarily, using political borders for the northern regions, and dividing California at 36° north latitude. This is approximately the latitude of the northern borders of Kern and San Luis Obispo counties, used by the publication North American Birds (https://www.aba.org/north-american-birds/) as the border between northern and southern California.

We also examined changes in urban land cover within these CBC circles using data from the North American Land Change Monitoring System (CEC 2020, CEC 2023) and the National Land Cover Database (Dewitz and U.S.G.S. 2021). For the U.S., we compared the percent change in urbanized land cover within U.S. count circles between the years 2001 and 2020, and for British Columbia we compared data from 2010 to 2020. This latter time frame was used due a lack on comparable land cover data for Canada prior to 2010.

RESULTS

Abundance over the full winter range of the Golden-crowned Sparrow showed no significant trend (r^2 = 0.003, p = 0.11) for 1983–2022 (Figure 1). Regional analysis, however, showed a significant increase in abundance (3.7%/yr, r^2 = 0.80, p < 0.0001) in the northern parts of the winter range (British Columbia and Washington; Figure 2a) and a significant decline (-2.6%/yr, r^2 = 0.55, p < 0.0001,) in the southern California portion of the range; Figure 2b). These trends were consistent throughout each region (Figure 3). Of the 25 southern California CBC circles, 23 (92%) showed decreasing abundance, whereas nearly all circles in the northern parts of the range (34 of 35; 97%) showed increasing abundance. Of the 73 CBC circles in the central portion of the winter range in Oregon, northern California, and Nevada, approximately half showed increasing abundance (36 of 73; 49%) and half showed decreasing abundance (37 of 73; 51%).

The amount of urban land cover in southern California circles increased by 3% (an average increase of approximately 45ha/circle), while the amount of urban land in Washington and British Columbia increased by 5 and 6%, respectively (50 and 60ha/circle).

Average winter temperatures have increased throughout the winter range of this sparrow in recent decades (Table 1).

Table 1. Increases in average winter temperatures within the winter range of the Golden-crowned Sparrow since 2001 in the U. S. and since 2010 in British Columbia.

Region	Rate of Increase (Mean C°/decade)	Source
British Columbia	0.22	BCME 2016
Washington	0.17	NOAA 2023
Oregon	0.22	NOAA 2023
California	0.28	NOAA 2023

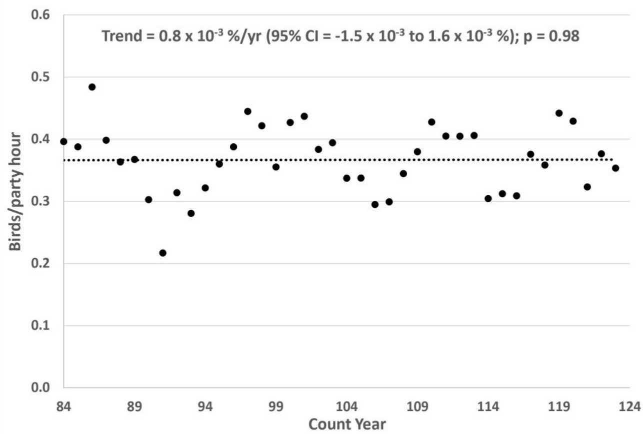

Figure 1. Golden-crowned Sparrow abundance from all CBC circles used, with linear regression trend line and statistics. CI = Confidence Interval.

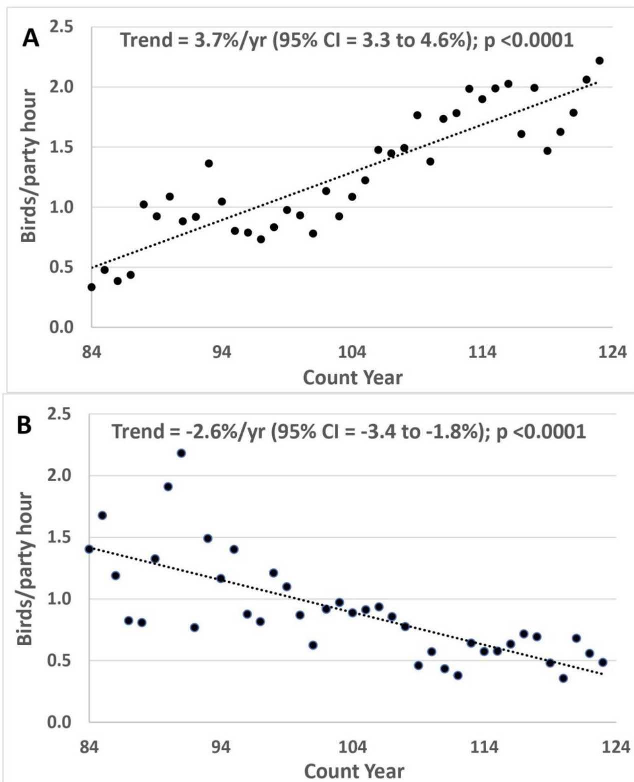

Figure 2. Golden-crowned Sparrow abundance from CBC circles with linear regression trend line and statistics from A) all British Columbia and Washington, and B) all southern California (south of 36°).

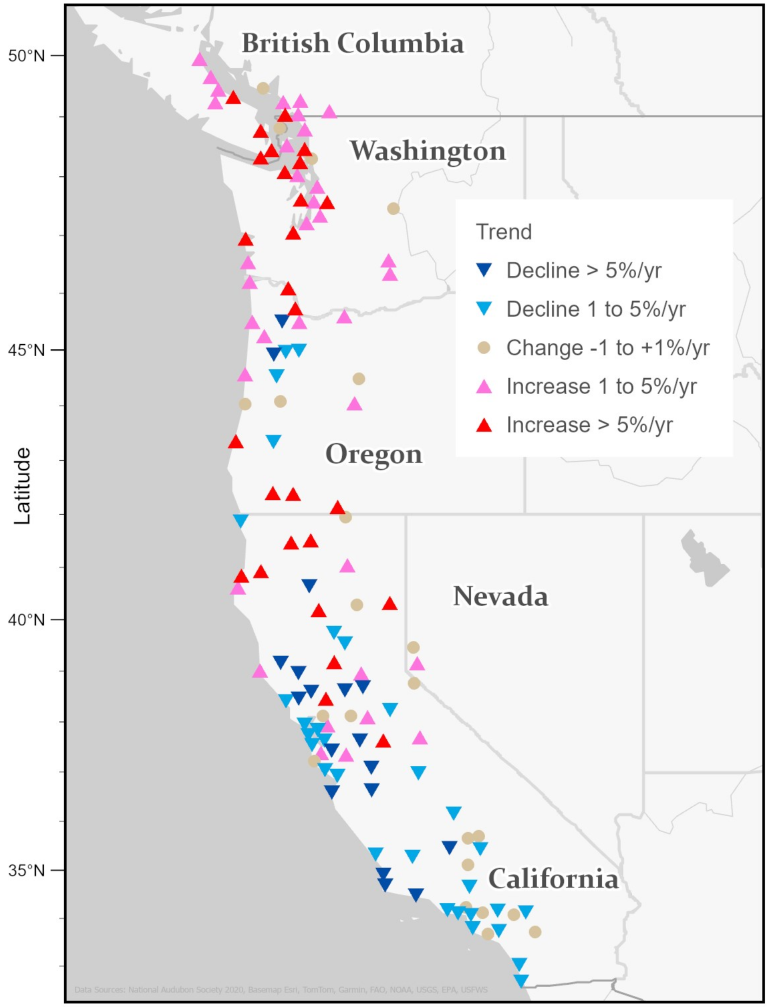

Figure 3. Locations of CBC circle used and abundance trends from linear regression analysis of each circle.

DISCUSSION

A rich and rapidly growing body of research has demonstrated that birds are shifting their breeding and/or winter ranges poleward (e.g., Hitch and Leberg 2007, La Sorte and Jetz 2010, OEHHA 2018, Meehan et al. 2019), with winter range shifts happening even faster than breeding range shif

(Lehikoinen et al. 2021). In most cases, a warming climate is the main driver of these shifts. Winter temperatures have steadily increased throughout the winter range of the Golden-crowned Sparrow, which may be a key factor driving the northward shift in winter abundance for this sparrow. However, other factors may be involved independently or in concert with climate change in wintering areas.

During this same period, breeding season temperatures have also increased in the Golden-crowned Sparrow's breeding range, with temperatures in the northern portions increasing most rapidly (Lindsey and Dahlman 2023). We previously showed that this species uses a chain migration strategy, in which the most northerly breeders winter furthest north, and vice versa (Pandolfino and Douglas 2021). Although increasing temperatures have generally been found to negatively affect breeding success in birds due to phenological mismatches between food sources and breeding dates (Visser et al. 2012, Mayor et al. 2017, Youngflesh et al. 2023), at least one northern species (Black Grouse, *Tetrao tetrix*) has been documented to have benefited from these warmer conditions (Wegge and Rolstad 2017).

If increases in breeding season temperatures have allowed the most northerly-breeding Golden-crowned Sparrows to reproduce more successfully than southern breeders, this could explain our observation of increasing winter abundance in the north. Indeed, as arctic, and northern subarctic areas warm, tundra is being replaced by shrublands (Winker and Gibson 2018), and these changes were predicted to produce an increase in Golden-crowned Sparrow breeding abundance there (Thompson et al. 2016, Mizel and Swanson 2022). Without data on breeding success, however, this hypothesis cannot be directly evaluated. Also, this would not explain our finding of decreasing abundance in the southernmost parts of the winter range unless the warmer conditions at the southern edge of the breeding range also have reduced reproductive success.

Another key factor to consider is the loss of winter habitat to urbanization, or other sorts of conversion to unsuitable habitat. If Golden-crowned Sparrow winter habitat were being lost at a greater rate in southern California than in British Columbia and Washington, this could help explain the declines observed there. Reliable land cover data for these areas are only available for the most recent few decades. When we compared increases in urban land use for the CBC circles in southern California to those in Washington (2020 vs 2001) and British Columbia (2020 vs. 2010), we found no support for the hypothesis that increased urbanization explains the difference between the observed population trends in the southern and northern regions.

Saunders et al. (2022) compared the relative importance of climate and habitat change as drivers of winter range shifts for 89 bird species that winter in the eastern U.S. They found that habitat specialists (e.g., grassland birds) were more affected by habitat change than climate, while habitat generalists were more affected by climate. Golden-crowned Sparrows are largely habitat generalists in winter, using a wide variety of shrubby habitats, including urban areas (Norment et al 1998). They also use a variety of habitats, including grasslands, during migration (Iverson 2022, Iverson et al. 2023).

We previously found that all the identifiable Golden-crowned Sparrow songs recorded in British Columbia and Washington in winter were of the song dialect associated with the most northerly breeding population (northern Alaska; 10 of 10 individuals; Pandolfino and Douglas 2021). Our recordings were all from the most recent 14 years, and all but two were from the last seven years. Because we found no song dialects of more southerly breeders in the northern winter range, it is unlikely that the increase in Golden-crowned Sparrow numbers in that area is due to southern breeders shifting their range to the north. Instead, this finding is consistent with the increase being due to higher rates of over-winter survival among these birds, and/or higher rates of fecundity of this population, perhaps due to birds returning to the breeding grounds in better condition or to more shrub habitat becoming available in these high latitude regions (Thompson et al. 2016, Mizel and Swanson 2022). It is also possible that the warmer temperatures have allowed higher reproductive success and a longer suitable breeding period. Also, birds in better condition at the end of winter may be better able to cope with stresses of migration. However, our previous findings that the northernmost breeders winter in the northernmost part of the range may only apply to singing males. If female Golden-crowned Sparrows winter in different parts of the range than males, northward shifts among females would not have been detected by our song-based method.

Thus, the most likely hypothesis to explain our observations of increasing abundance in the north of the winter range and decreasing abundance in the south is that warmer winter temperatures in the northern (historically cooler) part of the Golden-crowned Sparrow's winter range have allowed higher rates of survival and/or reproductive success in that population, with warming temperatures in the southern range having the opposite effect. The remarkable insulating qualities of feathers allow birds to survive extremes of cold better than extremes of heat (Gill 1995). Given adequate food supplies, birds can cope with very low temperatures. Given that the northern parts of the Golden-crowned Sparrow's winter range have warmed, it may be that birds now need less food to tolerate winter temperatures there, which could improve over-winter survival and post-winter fitness. In southern California, where winter temperatures are typically much warmer, a warming climate may be taxing these sparrows' limits of tolerance. Since the primary means of countering over-heating in birds is by evaporative cooling (Gill 1995), the relatively xeric southern California areas may put birds at risk of dehydration when trying to maintain ideal body temperature.

Both the northern and southern parts of the Golden-crowned Sparrow's range where we noted significant changes in abundance are at the edges of the species' winter range. It may be that Golden-crowned Sparrows there are near their extremes of both cold (in the north) and heat (in the south) tolerance. Thus, even the relatively small temperature changes shown in Table 1 may be adequate to explain the substantial changes in winter abundance. Other, secondary, effects of warmer temperatures (e.g., changes in local flora, prevalence of body parasites, timing of seed crop availability) also may have contributed to changes in over-winter condition of Golden-crowned Sparrows and thus survival. Data on vital rates (e.g., productivity, breeding season survival, over-winter survival and fitness), such as those obtained from Monitoring Avian Productivity and Survival (www.birdpop.org/pages/maps.php) station efforts, could help to illuminate the drivers of these changes in regional winter abundance.

ACKNOWLEDGMENTS

We thank Dan Airola and the peer reviewers for many suggestions which allowed us to present our findings more concisely and coherently. CBC data are provided by National Audubon Society and through the generous efforts of Bird Studies Canada and countless volunteers across the Western Hemisphere. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

LITERATURE CITED

BCME (British Columbia Ministry of Environment). 2016. Indicators of Climate Change for British Columbia: 2016 Update. Ministry of Environment, British Columbia, Canada. https://www.env.gov.bc.ca/soe/indicators/climate-change/temp

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser, A.C. Stewart, and M.C.E. McNall. 2001. The birds of British Columbia: Volume 4. University of British Columbia Press, Vancouver, BC, Canada.

CEC (Commission for Environmental Cooperation). 2020. 2010 Land Cover of North America at 30 meters. North American Land Change Monitoring System. Canada Centre for Remote Sensing (CCRS), U.S. Geological Survey (USGS), Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Comisión Nacional Forestal (CONAFOR), Instituto Nacional de Estadística y Geografía (INEGI). Ed. 2.0, Raster digital data [30-m]. Available at http://www.cec.org/north-american-environmental-atlas/land-cover-2010-landsat-30m/

CEC (Commission for Environmental Cooperation). 2023. 2020 Land Cover of North America at 30 Meters. North American Land Change Monitoring System. Canada Centre for Remote Sensing (CCRS), U.S. Geological Survey (USGS), Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Comisión Nacional Forestal (CONAFOR), Instituto Nacional de Estadística y Geografía (INEGI). Ed. 1.0, Raster digital data [30-m]. Available at http://www.cec.org/north-american-environmental-atlas/land-cover-30m-2020/

Dewitz, J., and U.S. Geological Survey. 2021. National Land Cover Database (NLCD) 2019 Products (ver. 2.0, June 2021): U.S. Geological Survey data release. https://doi.org/10.5066/P9KZCM54.

Gill, F.B. 1995. Ornithology: Second Edition. W. H. Freeman & Company, New York, NY, USA.

Hitch, A.T., and P.L. Leberg. 2007. Breeding distributions of North American bird species moving north as a result of climate change. Conservation Biology 21:534–539. DOI: 10.1111/j.1523-1739.2006.00609.x

Iverson, A.R. 2022. Wildlife Movement and Connectivity across Large Scales: Migratory Ecology of Golden-crowned Sparrows (*Zonotrichia atricapilla*) and Evaluating Landscape Connectivity Designs for Terrestrial Wildlife in California. UC Davis. ProQuest ID: Iverson_ucdavis_0029D_21618. Merritt ID: ark:/13030/m55508wm. Retrieved from https://escholarship.org/uc/item/46z838mw

Iverson, A.R., D.L. Humple, R.L. Cormier, and J. Hull. 2023. Land cover and NDVI are important predictors in habitat selection along migration for the Golden-crowned Sparrow, a temperate zone migrating songbird. Movement Ecology 11:2. https://doi.org/10.1186/s40462-022-00353-2

La Sorte, F.A., and W. Jetz. 2010. Avian distributions under climate change: Towards improved projections. Journal of Experimental Biology 213:862–889. doi:10.1242/jeb.038356

Lehikoinen A., Å. Lindström, A. Santangeli, et al. 2021. Wintering bird communities are tracking climate change faster than breeding communities. Journal of Animal Ecology 90:1085–1095. https://doi.org/10.1111/1365-2656.13433

Lindsey, R., and L. Dahlman. 2023. Climate change: Global temperature. National Oceanic and Atmospheric Administration. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Mayor, S. J., R.P. Guralnick, M.W. Tingley, J. Otegui, J.C. Withey, S.C. Elmendorf, M.E. Andrew, S. Leyk, I.S Pearse, and D.C. Schneider. 2017. Increasing phenological asynchrony between spring green-up and arrival of migratory birds. Science Report 7, Article 1902. doi:10.1038/s41598-017-02045z

Marshall, D.B., M G. Hunter, and A.L. Contreras. 2003. Birds of Oregon: A General Reference. Oregon State University Press, Corvallis, OR, USA.

Meehan, T.D., N.L. Michel, and H. Rue. 2019. Spatial modeling of Audubon Christmas Bird Counts reveals fine-scale patterns and drivers of relative abundance trends. Ecosphere 10(4):e02707. 10.1002/ecs2.2707

Mizel, J.D, and D.K. Swanson. 2022. Hindcasts of passerine density in arctic and subarctic Alaska suggest noncomplementary responses to shrub expansion by tundra- and shrub-adapted species. Arctic, Antarctic, and Alpine Research 54:25–39. https://doi.org/10.1080/

National Audubon Society. 2020. The Christmas Bird Count Historical Results. Available at http://www.christmasbirdcount.org [Accessed September 2023].

NOAA (National Oceanic and Atmospheric Administration) 2023. Climate at a Glance: Statewide Time Series. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series

Norment, C.J., P. Hendricks, and R. Santonocito. 1998. Golden-crowned Sparrow (*Zonotrichia atricapilla*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.gocspa.01

OEHHA (Office of Environmental Health Hazard Assessment, California Environmental Protection Agency). 2018. Indicators of Climate Change in California. https://oehha.ca.gov/climate-change/document/indicators-climate-change-california

Pandolfino, E.R., and C.M. Handel. 2018. Population trends of birds wintering in the Central Valley of California. P. 215–235 in: Trends and Traditions: Avifaunal Change in Western North America (W. D. Shuford, R. E. Gill Jr., and C. M. Handel, eds.). Studies of Western Birds 3. Western Field Ornithologists, Camarillo, CA, USA.

Pandolfino, E.R., and L.A. Douglas. 2021. Using song dialects to assess the migration strategy of the Golden-crowned Sparrow. Western Birds 52:311–321.

Ryder, J.M. 2015. Golden-crowned Sparrow. in: The Atlas of the Breeding Birds of British Columbia, 2008–2012 (Davidson, P.J.A., R.J. Cannings, A.R. Couturier, D. Lepage, and C.M. Di Corrado, eds.). Bird Studies Canada. Delta, B.C. http://www.birdatlas.bc.ca/accounts/speciesaccount.jsp?sp=GCSP&lang=en [Accessed September 2023].

Saunders, S.P., T.D. Meehan, N.L. Michel, B.L. Bateman, W. DeLuca, J.L. Deppe, J. Grand, G.S. LeBaron, L. Taylor, H. Westerkam, J.X. Wu, and C.B. Wilsey. 2022. Unraveling a century of global change impacts on winter bird distributions in the eastern United States. Global Change Biology 28:2221–2235. https://doi.org/10.1111/gcb.16063

Sauer, J.R., S. Schwartz, and B. Hoover. 1996. The Christmas Bird Count homepage. Version 95.1. Patuxent Wildlife Research Center, Laurel, MD, USA.

Sauer, J.R., W.A. Link, and J.E. Hines. 2020. The North American breeding bird survey, results, and analysis 1966–2019. U.S. Geological Survey Eastern Ecological Science Center at the Patuxent Research Refuge, Laurel, MD, USA.

Thompson, S.J., C.M. Handel, R.M. Richardson, and L.B. McNew. 2016. When winners become losers: predicted nonlinear responses of arctic birds to increasing woody vegetation. PLoS ONE 11:e0164755. doi:10.1371/journal.pone.016475

Visser M.E., L.T. Marvelde, and M.E. Lof. 2012 Adaptive phenological mismatches of birds and their food in a warming world. Journal of Ornithology 153:5–184. doi:10.1007/s10336-011-0770-6

Wahl, T.R., B. Tweit, and S.G. Mlodinow. 2005. Birds of Washington: Status and Distribution. Oregon State University Press, Corvallis, OR, USA.

Wegge P., and J. Rolstad. 2017. Climate change and bird reproduction: Warmer springs benefit breeding success in boreal forest grouse. Proceedings of the Royal Society B 284:20171528. http://dx.doi.org/10.1098/rspb.2017.1528

Winker, K., and Gibson, D.D. 2018. Some broad-scale effects of recent and future climate change among migratory birds in Beringia. Pp. 432–440 in: Trends and Traditions: Avifaunal Change in Western North America (W. D. Shuford, R.E. Gill Jr., and C. M. Handel, eds.). Studies of Western Birds 3. Western Field Ornithologists, Camarillo, CA; doi 10.21199/SWB3.23

Unitt, P. 2004. San Diego County Bird Atlas. Volume 39. Proceedings of the San Diego Society of Natural History. San Diego Natural History Museum/Ibis Publishing, San Diego, CA, USA.

Youngflesh, C., G.A. Montgomery, J.F. Saracco, D.A.W. Millerd, R.P. Guralnick, A.H. Hurlbert, R.B. Siegel, R. LaFrance, and M.W. Tingley. 2023. Demographic consequences of phenological asynchrony for North American songbirds. PNAS 20:e2221961120. https://doi.org/10.1073/pnas.2221961120

Appendix A. All Christmas Bird Count Circles used.

State/ Province	Christmas Bird Count Circles
British Columbia	Campbell River, Chilliwack, Comox, Deep Bay, Duncan, Ladner, Parksville-Qualicum Beach, Pender Islands, Pitt Meadows, Port Alberni, Sooke, Sunshine Coast, Vancouver, Victoria, White Rock-Surrey-Langley
California (north)	Angwin, Año Nuevo, Arcata, Auburn, Benicia, Calaveras, Caswell-Westley, Centerville Beach to King Salmon, Chico, Clear Lake, Contra Costa County, Crystal Springs, Del Norte County, Etna, Fall River Mills, Folsom, Hayward-Fremont, Honey Lake, LaGrange-Waterford, Lake Almanor, Los Baños, Lost Lake-Fresno, Manchester, Marin County (southern), Monterey Peninsula, Moss Landing, Mount Hamilton, Mount Shasta, Oakland, Oroville, Palo Alto, Panoche Valley, Peace Valley, Putah Creek, Red Bluff, Redding, Sacramento, San Francisco, San Jose, Santa Cruz County, Santa Rosa, Springville, Stockton, Tule Lake, Ukiah, Wallace-Bellota, Western Sonoma County, Willow Creek, Woodfords, Yosemite N.P.
California (south)	Bakersfield, Butterbredt Spring, Carrizo Plain, Claremont, Grass Mountain, Idyllwild, Kern River Valley, La Purisima, Los Angeles, Malibu, Morro Bay, Orange County (coastal), Orange County (northeastern), Palos Verdes Peninsula, Pasadena-San Gabriel Valley, Rancho Santa Fe, Redlands (Mill Creek), San Bernardino Valley, San Diego, San Fernando Valley, Santa Barbara, Santa Maria-Guadalupe, South Fork Valley, Tehachapi, Thousand Oaks
Nevada	Carson City, Truckee Meadows
Oregon	Bend, Columbia Estuary, Coos Bay, Corvallis, Dallas, Eugene, Florence, Forest Grove, Grants Pass, Hood River, Klamath Falls, Medford, Portland, Roseburg-Sutherlin, Salem, Sauvie Island, Sequim-Dungeness, Silverton, Tillamook Bay, Upper Nestucca, Utopia, Yaquina Bay
Washington	Bellingham, Cowlitz-Columbia, East Lake Washington, Edmonds, Grays Harbor, Kent-Auburn, Kitsap County, Leadbetter Point, Oak Harbor, Olympia, Padilla Bay, Port Townsend, San Juan Islands Archipelago, Seattle, Skagit Bay, Tacoma, Toppenish N.W.R., Wenatchee, Yakima Valley