Black-capped Chickadee at the University of Guelph's Arboretum. *Photo: B.P.M. Edwards*

# The University of Guelph's Arboretum Winter Bird Count, 1980–2022

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## Introduction

Bird census data provide important insights into the ecology and distribution of bird species across space and time. Long-running monitoring programs such as the North American Breeding Bird Survey (Hudson *et al.* 2017) provide trend estimates of North American birds through time, and provide critical information about status of birds for listing and delisting purposes (Rosenburg *et al.* 2019, NABCIC 2019). Additionally, regionally-based census programs such as Breeding Bird Atlases (Cadman *et al.* 2007) provide region-specific information about the relative abundance, distribution, and habitat use of breeding birds.

Although bird census data tend to be heavily biased toward breeding birds and the breeding season, winter surveys such as the Christmas Bird Count (CBC; Bock and Root 1981) and the Mid-winter Waterfowl Survey (Sharp *et al.* 2002) do exist to fill in the important gap of the winter season. The CBC is run, in partnership,

through Birds Canada and the National Audubon Society and is the largest and longest-running bird census in North America (Bock and Root 1981). Although the CBC lacks the rigorous structure seen in surveys such as the North American Breeding Bird Survey (Butcher *et al.* 1990), it provides insight into winter bird communities across North America (Bock and Root 1981; Link and Sauer 1999; Niven *et al.* 2004).

Large-scale, long-term surveys like the CBC can provide large-scale insights to bird demography, but lack the spatial coverage and structure to pick up high-resolution information in specific areas. This is where targeted monitoring programs that focus on smaller areas come in to play. One example of a small-scale, long-running program is the University of Guelph's Arboretum Winter Bird Count (WBC). The WBC was started by then-Arboretum naturalist Alan P. Watson in 1980, and has run every January since, providing 43 years of data tracking the winter bird communities of the University of Guelph Arboretum ("the Arboretum" herein), Guelph, Ontario. The Arboretum has been recognized as a key birding hotspot in Ontario (Burrell and Burrell 2019), and has produced numerous publications describing the biodiversity that can be found within (see https://arboretum.uoguelph.ca/).

The purpose of this paper was to analyse and summarize the results of the first 43 years of WBC data, and to compare some of the trends seen in the WBC data to Guelph's CBC that takes place the December prior to the WBC. Broadly, we provide a summary of species seen during the WBC (including numbers and notable species), and we compare overall trends in bird abundance over the WBC study period to that of the CBC. We predicted that broad-scale comparisons such as overall abundance should correlate relatively well, because the birds counted during the WBC are likely to be a subset of birds counted during the same year's CBC. We then provided some species-level analysis and comparison of abundances for Ruffed Grouse (*Bonasa umbellus*), Evening Grosbeak (*Coccothraustes vespertinus*), Red-bellied Woodpecker (*Melanerpes carolinus*), Downy Woodpecker (*Picoides pubescens*), American Tree Sparrow (*Spizelloides arborea*) and Mourning Dove (*Zenaida macroura*). We choose these species to include representatives for regular winter residents (i.e., American Tree Sparrow, Downy Woodpecker and Mourning Dove), species that show strong population changes (e.g., decline of Evening Grosbeak, range shift of Red-bellied Woodpecker), and species that show temporal population cycles (i.e., Ruffed Grouse). We predicted that for species-specific trends, the WBC should correlate well with CBC data for species that show a strong trend through time (e.g., declining species like Evening Grosbeak and American Tree Sparrow, increasing species like Red-bellied Woodpecker); for other species, we predict the two datasets may not correlate as much because WBC data are subject to a specific latent "site-level" effect, whereas the trends in the greater CBC

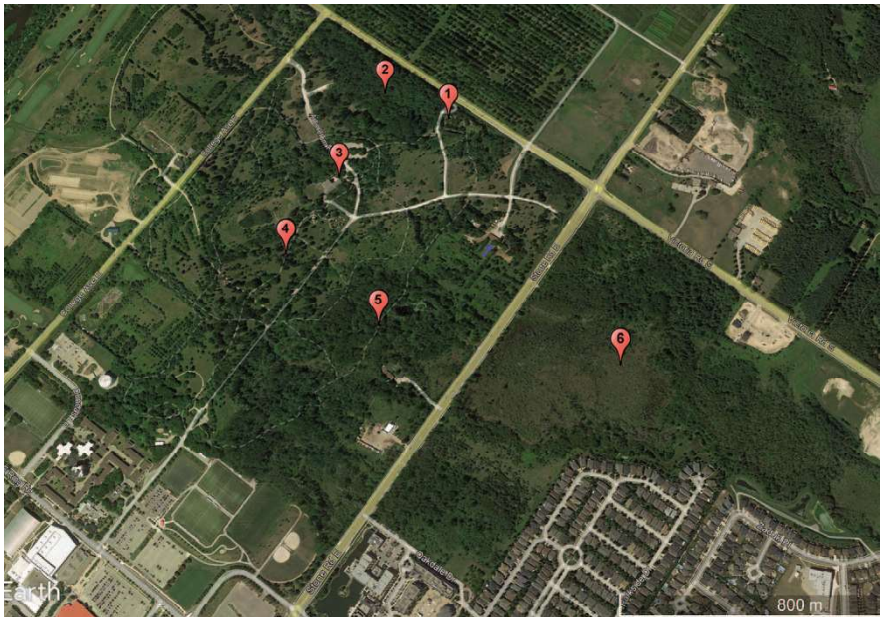


Figure 1. Map of the University of Guelph Arboretum with six key survey areas: 1) J.C. Taylor Nature Centre Feeders, 2) Victoria Woods, 3) Arboretum Centre Feeders, 4) World of Trees, 5) Wild Goose Woods, and 6) University of Guelph Arboretum Nature Reserve. *Google Earth*

area would have these latent site-level effects averaged out across all sites and therefore show less of the site-specific, species-level population dynamics. Finally, we provided a changepoint regression analysis and comparison of gull abundance over the study period to serve as an example analysis of WBC data. We predicted that both datasets should show a changepoint in abundance trends starting in 2003, the same year that the Guelph landfill was closed (LaMarre 2015).

## Methods

### *Study Site*

The Arboretum is situated in the east-end of Guelph, Ontario, adjacent to the University of Guelph campus, bordered by Stone Road East, Victoria Road and College Avenue. The Arboretum contains several areas of interest for birds, including mature deciduous forests, provincially significant wetlands and feeders at the J.C. Taylor Nature Centre and Arboretum Centre. These key locations are shown in Figure 1.

### *Survey Protocol and Track*

The WBC takes place on the first or second weekend of January each year. All volunteers go as one group through the entire survey and record all birds that can be identified by either sight or sound. If a bird cannot be identified to the species level, volunteers are asked to identify as specific as possible (e.g., family, genus,

etc.). The survey begins at 0800 EST (except for years 1980 – 1986, inclusive, when surveys began at 0900 EST), and typically lasts for three to four hours.

The survey route is an approximately 5-km track through a variety of different habitats (Figure 1). Surveyors begin with a five to 10-minute feeder watch at the J.C. Taylor Nature Centre. The feeders are filled within two days prior to the count to ensure adequate feed for the count. The survey then continues through the adjacent Victoria Woods, typically with a focus on woodpeckers using the mature deciduous forests for food sources. Then, the survey continues to the Arboretum Centre's feeders for a second feeder watch before continuing through the English, Japanese and Italian gardens and the "World of Trees" area. The survey then enters a portion of Wild Goose Woods, before finishing in the Nature Reserve.

### *Analyses*

We fit two simple linear regression models between total species and year for each dataset to test for a trend in annual total species over time. We note that since the outcomes are counts of species, it is technically incorrect to use simple linear modelling here. However, we chose this type of modelling over the more correct Poisson generalized linear modelling approach to allow us to interpret the slope coefficients as "expected additional species per year," rather than "expected rate change of species compared to previous year." We also generated a simple plot of species accumulation over the study period of the WBC survey.

To compare the WBC versus Guelph's CBC, we accessed Guelph's CBC data through the National Audubon Society's data downloader tool (National Audubon Society 2020) and processed the data using the "audubon-cbc-cli" tool (https://github.com/rgeraldporter/audubon-cbc-cli). We used only the data between the periods of 1980 and 2021 (the maximum available year for CBC data as of this study). Since CBC raw data are reported as "Birds Per Party Hour" (BPPH herein; Bock and Root 1981), we converted raw WBC counts to BPPH by dividing the total number of birds for each species by the total hours for the count.

To compare overall abundances between the CBC and WBC, we tested for a correlation between the two datasets. To do this, we summed the BPPH across species for each year, for each data set, and calculated the first differences for each year between 1986 and 2021 to account for any trend in the data (i.e., for each year, BPPH for current year minus the BPPH for the previous year). We only used this subset of years because it was the largest contiguous block of data for each dataset. We then performed a Pearson correlation test between the first differences of summed BPPH. We also performed a simple linear regression on each dataset's summed BPPH to test for any trend over time.

We also compared trends between CBC and WBC for six species that regularly winter in Guelph: Red-bellied Woodpecker, Evening Grosbeak, Ruffed Grouse, Mourning Dove, Downy Woodpecker and American Tree Sparrow.

Similar to previous analyses, we derived a trend for each species, for each dataset, using simple linear regression, and compared the trends using a Pearson's correlation test of the first differences.

Finally, to test for changes in gull abundance since the closure of the Guelph landfill in 2003, we summed the BPPH for four gull species that were consistently recorded on both surveys: Ring-billed Gull (*Larus delawarensis*), Herring Gull (*Larus argentatus*), Great Black-backed Gull (*Larus marinus*), and Glaucous Gull (*Larus hyperboreus*). We performed a changepoint regression analysis on these data using the "segmented" package in R (Muggeo 2017). This allowed us to estimate when a change in trend happens within a time series, if a change happens at all (Gillis and Edwards 2019). We also tested for a correlation in the two trends using a Pearson's correlation test of the first differences.

Data used for this study and associated scripts can be found open-source at https://github.com/BrandonEdwards/uog-arb-wbc.

## Results

Since 1980, the WBC has recorded 60 species from 26 families. The rate of species discovery has slowed since the mid-2000s (Figure 2), so it is unlikely that several new species will be added on any single upcoming survey. Still, in the last decade, seven new species have been added to the species list; the most recent addition being White-crowned Sparrow (*Zonotrichia leucophrys*) in 2022. Three

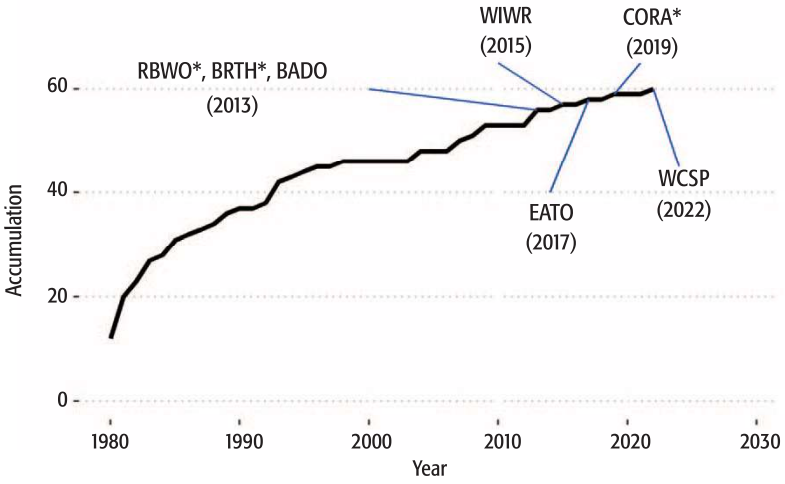


Figure 2. Species accumulation curve for the University of Guelph Arboretum's Winter Bird Count. New species added to the survey's overall species list in the last decade are highlighted along with the year they were first observed. Species with an asterisk (*) are species that have been recorded again since their initial discovery. Species codes are as follows: Red-bellied Woodpecker (RBWO), Brown Thrasher (BRTH), Barred Owl (BADO), Winter Wren (WIWR), Eastern Towhee (EATO), Common Raven (CORA), White-crowned Sparrow (WCSP).

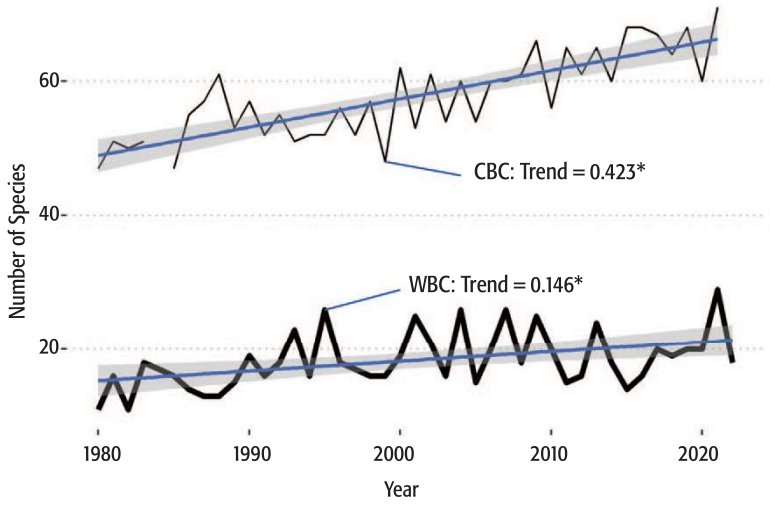


Figure 3. Total species observed during the Guelph Christmas Bird Count (CBC, light line) and Winter Bird Count (WBC, bold line) each year, with trend line and standard error bands. Both surveys have seen in increase in the number of species per year over the study period. The WBC survey saw its minimum number of observed species in 1980 and 1982, and its maximum number of observed species in 2021. (*) indicates statistical significance at the 5% level.

Table 1. Correlation coefficient between Winter Bird Count and Christmas Bird Count, Winter Bird Count trend and Christmas Bird Count trend for all birds, gulls only and the six selected species. (*) indicates statistical significance at the 5% level. Trends for gulls are overall trends, not accounting for any estimated changepoint.

| Species | Correlation coefficient | Trend (Winter Bird Count) | Trend (Christmas Bird Count) |
|---|---|---|---|
| All Birds | 0.32 | -0.04 | -0.33 |
| Gulls | 0.31 | -0.60* | -0.48* |
| Red-bellied Woodpecker | 0.64* | 0.00069* | 0.0044* |
| Evening Grosbeak | 0.89* | -0.11* | -0.03* |
| Ruffed Grouse | 0.51* | -0.02 | -0.0080* |
| Mourning Dove | 0.17 | 0.06 | 0.0060 |
| Downy Woodpecker | 0.1 | 0.04* | 0.0018 |
| American Tree Sparrow | 0.33 | -0.13* | -0.05* |

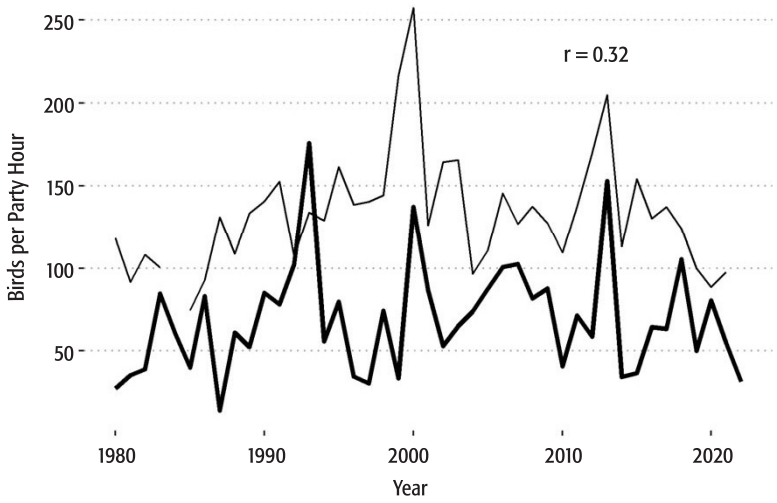


Figure 4. Total Birds Per Party Hour for each year of the Winter Bird Count (bold line) and Guelph Christmas Bird Count (light line) with Pearson correlation coefficient.

other notable additions are Common Raven (*Corvus corax*), first recorded in 2019 and again in 2021, Brown Thrasher (*Toxostoma rufum*) which was recorded for the first time in 2013 then again in 2022, and Red-bellied Woodpecker, which was documented for the first time in 2013 and has been recorded semi-regularly each year since. Other new additions over the last decade include Barred Owl (*Strix varia*), Winter Wren (*Troglodytes hiemalis*) and Eastern Towhee (*Pipilo erythrophthalmus*), all of which have only been recorded once.

The annual number of species has significantly increased over the study period for both the WBC ( trend = 0.146, $p < 0.05$) and for the CBC (trend = 0.423, $p < 0.05$). For each year of the survey, the CBC consistently records approximately 20 – 30 more species than the WBC (Figure 3).

Annual total BPPH fluctuated from year to year for both CBC and WBC, with weak evidence of a correlation between the two datasets ($r = 0.32$, $p = 0.056$; Table 1, Figure 4). The minimum BPPH observed during the WBC study period was 14.0 in 1987, compared to the CBC's minimum BPPH of 74.6 recorded in 1985. The maximum BPPH observed during the WBC study period was 175.7 in 1993, whereas the CBC's maximum BPPH of 257.2 was observed in 2000. Nonetheless, Figure 4 shows some correspondence in peaks and troughs between each of the datasets.

When comparing the WBC to the Guelph CBC on a species-specific basis, the two datasets correlated significantly for three of the six species modelled (Table 1, Figure 5). As expected, Red-bellied Woodpecker and Evening Grosbeak had strong correlations; Ruffed

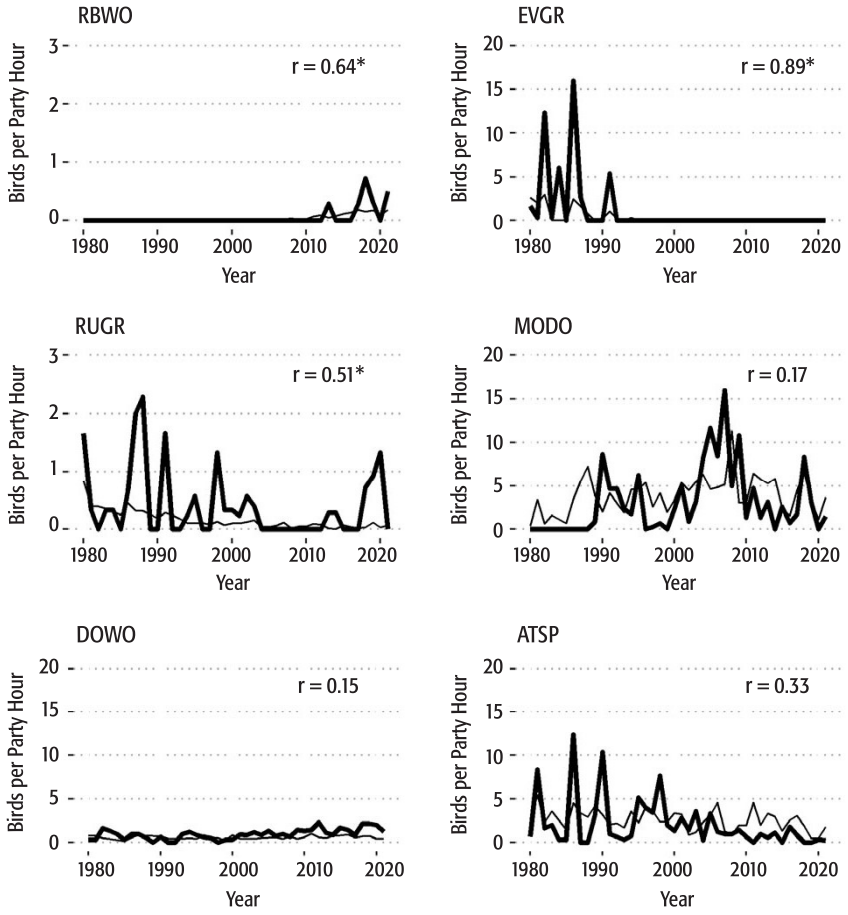


Figure 5. Yearly Birds Per Party Hour for Red-bellied Woodpecker (RBWO), Evening Grosbeak (EVGR), Ruffed Grouse (RUGR), Mourning Dove (MODO), Downy Woodpecker (DOWO) and American Tree Sparrow (ATSP), with Pearson correlation coefficient (r). Bold line is Winter Bird Count data and lighter line is Christmas Bird Count data. (*) indicates statistical significance at the 5% level.

Grouse also showed a moderate correlation. Even when considering only the period of non-zero birds for Evening Grosbeak (i.e., 1980 – 1995) and Red-bellied Woodpecker (i.e., 2010 and onward), there was still strong evidence of a strong correlation between the datasets for Evening Grosbeak ($r = 0.88$, $p < 0.05$), but weak evidence of a correlation for Red-bellied Woodpecker ($r = 0.53$, $p = 0.10$). The WBC dataset tended to find higher magnitude trends for all six species than the CBC dataset (Table 1). The statistical significance of the trends was the

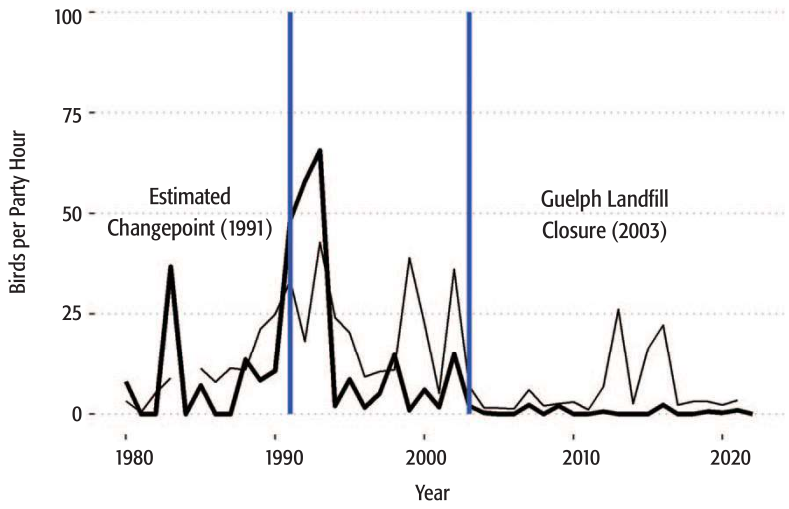


Figure 6. Birds Per Party Hour for four species of gulls (Ring-billed Gull, Herring Gull, Great Black-backed Gull, and Glaucous Gull) for Winter Bird Count data (bold line) and Christmas Bird Count data (light line). Guelph landfill closure indicated by vertical line at year 2003, and estimated changepoint from the changepoint regression shown by vertical line at year 1991.

same for Red-bellied Woodpecker, Evening Grosbeak, and American Tree Sparrow; the WBC dataset had a significant positive trend for Downy Woodpecker only, and the CBC dataset had a significant negative trend for the Ruffed Grouse only. Both datasets had a non-significant trend for Mourning Dove.

There was weak evidence of a correlation between the CBC and WBC datasets for gulls per party hour over the study period ($r = 0.31$, $p = 0.062$). Interestingly, there was no evidence that trends of gull abundance changed in 2003; on the contrary, changepoint regression analysis detected a changepoint in 1991 rather than 2003. Despite the unexpected changepoint, both surveys show a declining trend for gulls over the study period (Table 1, Figure 6).

## Discussion

The goal of this paper was to provide some analyses of the WBC that has taken place each January since 1980 at the University of Guelph Arboretum, and to compare these results to that of the Guelph CBC. We predicted that overall abundance changes and trends should roughly correlate between the two datasets, but may differ when considering species-specific trends due to a difference in site effects. We also predicted a change in trends for gull species following the closure of the Guelph landfill in 2003.

Overall, we found that the number of species being recorded during the WBC each year tended to increase over time at a rate of 0.15 species per year (roughly equivalent to an increase of one species every 6.7 years), whereas the

number of species being recorded during the CBC each year tended to increase over time at a rate of 0.42 species per year (roughly equivalent to an increase of one species every 2.4 years). These increases could be due to a variety of reasons. Species undergoing active range shifts, such as the Red-bellied Woodpecker in its northward shift, would contribute to this increase over time as more of these species find suitable habitat in new areas (Kirchman and Schneider 2014). Additionally, shifts in annual climate patterns could play a part in increased "rare" sightings at the site during the winter. The differences in the rates of increase could be due to the fact that the CBC covers a much wider area than the WBC and therefore has a higher chance of gaining new species year after year. This is also evident in examining the differences between the number of species each year, in that the CBC consistently records more species than the WBC.

Although we did not find a statistically significant correlation, we did find weak evidence of a correlation in overall abundance (indexed as BPPH) between the WBC data and the CBC data through time. This weak correlation is evident when viewing Figure 4, in that several places along the time series have matching peaks and troughs (e.g., see years 2000 and 2013 for matching peaks, and 2010 and 2014 for matching troughs). Mismatches in peaks and troughs could be due to a variety of factors. One explanation could be different number of people in each "party" for both surveys. That is, years that have peaks in CBC but troughs in WBC could have been years where the CBC has particularly more observers than average, resulting in more chances of birds being detected. The WBC has never kept track of the number of observers, and so this could not be controlled for during this study. Another explanation could be the different timing of the Guelph CBC (taking place in late December) compared to the WBC (taking place in early January). This timing could bring different weather conditions, affecting the availability and detectability of birds for each survey. For example, if the CBC had a year with relatively warm and sunny weather, and the WBC that same year had colder or snowier weather, we might expect to see a peak in BPPH for that year in the CBC data, but perhaps a trough in the WBC data. Future studies might consider adding weather as a covariate to control for those effects between the datasets.

When considering comparisons of trends at the species-specific level, many of our predicted patterns held true. We did in fact find that both surveys were highly correlated for trends of Red-bellied Woodpecker, Evening Grosbeak and American Tree Sparrow. Indeed, the former two species have undergone dramatic changes over a short period, with Evening Grosbeak declining to 0 BPPH starting in the mid 1990s, and Red-bellied Woodpecker going from 0 birds to regularly occurring starting in the early 2010s. The strong correlation for Evening Grosbeak still held true when considering only the period of time in which Evening Grosbeaks were observed, but was considerably weaker for Red-bellied Woodpecker. In looking at BBS trends for these two

species, Evening Grosbeak has seen a declining trend in Canada since 1970 whereas Red-bellied Woodpecker has seen an increasing trend in Canada since 1970 (Smith *et al.* 2020). American Tree Sparrow has seen a less dramatic but certainly pronounced decline over time, evidenced by trends seen in the BBS (Naugler *et al.* 2020, Smith *et al.* 2020). Ruffed Grouse also showed a moderate correlation, which could be due to the fact that Ruffed Grouse tend to undergo a cyclical population trend on a 10 – 20 year basis (Thompson III and Fritzell 1989).

Mourning Dove and Downy Woodpecker both had weak and non-significant correlations between the two datasets, but the WBC data showed a stronger magnitude in upward trend for these species, both of which have also experienced a slightly increased trend in BBS results since 1970 (Smith *et al.* 2020). Future studies should seek to investigate whether this lack of correlation is due to the more local surveys (such as the WBC) picking up habitat-specific dynamics, or if it is just by chance alone.

Surprisingly, we did not find evidence of a change in trend following the closure of the Guelph landfill in 2003. Instead, for both datasets, the changepoint regression found evidence of a changepoint in 1991, 12 years prior, and thus unrelated to the closure. There is potential that this could simply be a coincidental finding, as both datasets had their highest rates of gulls in 1993, shortly after the estimate changepoint. That is to say, the changepoint analysis could simply be noting the sharp increase in 1993 as a changepoint. Alternatively, there could be other factors at play that we have not considered, and future studies could investigate this change in trend.

### A Changing Landscape

The overall landscape within the Arboretum has changed noticeably over the last several decades. Within the Arboretum, the plant diversity and age has greatly increased over the 43-year period of the survey. In the 1980s, the collection known as the "World of Trees" contained only very small trees and were essentially open fields, whereas today this collection is home to English, Japanese and Italian gardens. In the same time-period, Victoria Woods and Wild Goose Woods were isolated woodlots; today, Victoria Woods is a mature deciduous forest home to tree species such as sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*) and black cherry (*Prunus serotina*) and Wild Goose Woods is now a diverse habitat that contains both mature and young trees as well as areas of ephemeral swamp land. The Arboretum Nature Reserve, a 40-hectare area separated from the main area by Stone Road East, has fields that have changed from primarily goldenrod/aster to dense Scot's Pine (*Pinus sylvestris*) and White Pine (*Pinus strobus*). The Nature Reserve also contains old-growth hemlock, beech and maple forests, grassy fields and a provincially significant wetland.

The landscape surrounding the Arboretum has also changed since the 1980s. In 1981, the population of Guelph was 71,207 and has since doubled to 143,740 in 2021 (Statistics Canada

2022), and significant development in the City of Guelph has taken place to account for this population growth. In 1998, construction started on "The Village by the Arboretum" subdivision on land that was leased by the University of Guelph and is directly adjacent to the Nature Reserve. This construction included a large retirement home, several houses, and a stormwater management pond. People started to live in the area by 2000, and the subdivision continues to be developed to this day. Additionally, during the study period, the large area on the east side of Victoria Road changed with the addition of tree plantations, which were subsequently cut down in 2020. Finally, as we have touched on in this study, Guelph's landfill was closed in 2003 and subsequently converted to a remediation site to provide greenspace for the growing Eastview neighbourhood (LaMarre 2015).

Both these changes within and beyond the Arboretum are sure to affect the species composition over time, in ways which could be measured by considering more covariates. For example, future studies could use a simple changepoint analysis to look for changes in different species pre- and post-construction of The Village by the Arboretum, similar to what we have done to test for changes in gull abundance. More advanced studies could make use of GIS analyses to investigate how species composition changes with changing landscape composition of the Arboretum over the years. Although this study is only a first pass at an analysis of these data, we feel there are several other avenues that this dataset can be taken down for interesting studies on this dynamic urban greenspace.

## Conclusion

Tracking animal communities through time within a small spatial extent can provide unique insights to species responses to microhabitat changes and to changes in landscape nearby. These data can provide meaningful local-scale information to augment data collection at larger scales, such as that from CBCs. From a conservation perspective, the ability to track impacts of small-scale efforts will be increasingly important as conservationists continue to encourage wildlife-friendly communities. We have shown that the small-scale data collected by the WBC can generally correlate with the larger-scale data collected by the CBC, but can also provide unique insights into wintering bird communities in specific habitats or areas.

Long-term surveys in small sites such as the Arboretum can be useful in informing local development plans, especially when considering habitat losses for species that use the site in both the winter and breeding season. Citizen science platforms such as eBird make it easy to access data from small scale areas by exploring data collected at "hotspots" (Sullivan *et al.* 2014). We encourage researchers to make use of these long-term citizen science datasets that exist at the local scale to make more informed decisions about protecting the valuable habitats that are continually being lost (Binley *et al.* 2021).

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