

CONCURRENT CHANGES IN BIRD DIVERSITY AND THE ENVIRONMENT:

RESULTS OF THE 2016 GRASSLANDS BREEDING BIRD CENSUS AT

BEARVERHILL LAKE, ALBERTA

Cala Jorgensen

Intern at the Beaverhill Bird Observatory

There is global demand for long-term ecological monitoring of landscapes undergoing climate change (McCollin, 2014). These effects can most easily be observed by analyzing the changes in species occurrence and abundance over time (Stephens et al., 2016). The breeding bird census (BBC) technique has proven to be an effective form of long-term breeding bird monitoring when compared to bird banding and migration counts (Svensson, 1978b). Not only do BBCs reveal population trends in half the time as other monitoring measures, but they are able to account for more variation in observations as well (Svensson, 1978b). The BBC is considered standard practice for understanding population and community ecology in the ornithological community and has been utilized in many large-scale avian monitoring programs including the Common Bird Census in Britain, The Swedish Breeding Bird Census, and the Audubon programme of North America (Bibby, Burges, & Hill, 1992; Svensson, 1978a; Svensson, 1978b; Enemar, Sjostrand, & Svensson, 1978). BBCs can provide valuable information about the community ecology of an area and may inform environmental impact assessments, infrastructure planning and development, and development of new ecological theories (Svensson, 1978a).

Beaverhill Lake, situated 8 km east of Tofield, Alberta, was designated as an Important Bird Area of Global Significance in 1997 and is a critical habitat for the long-term success of many waterfowl and shorebird populations (Krikun & Holroyd, 2001). However, natural and man-induced forces have caused the levels of the lake to fluctuate over the years, giving way to the grassland and marshes that currently serve as critical breeding habitat for wetland and grassland bird species alike (Krikun & Holroyd, 2001; Priestley, 2007). As natural succession takes place, the composition of species inhabiting the area continue to change (Vourisalo, Lehtikoinen, & Lemmetien, 2015; Krikun & Holroyd, 2001; Priestley, 2007). Understanding how these community structures transform through succession is critical in a time where wetlands throughout Alberta are becoming increasingly threatened (Krikun & Holroyd, 2001; Priestley, 2007). The following describes the findings of the 2016 Grasslands Breeding Bird Census, including analyses of species diversity using Shannon-Weiner, Simpson's, and Pielou's indices, highlights

overarching trends observed throughout the history of the census, and a brief exploration of the factors that may contribute to variation in results.

Summary of Previous Surveys

The first BBC of the Beaverhill grasslands was established along the east side of the southern shore of the Lake in the spring of 1992 (Holroyd, 1992). A grid of 50 m by 50 m quadrants totaling 18.9 ha² was established and observations were taken at each of these points (Holroyd, 1992). This census was repeated, unadulterated, in 1993 (Duxbury & Holroyd, 1993). The results of the 1993 census were fairly consistent though it saw a decline in duck nest sites and some grassland bird species (Savannah and Sharp-tailed Sparrows) and an increase in Redwinged Blackbird nests (Duxbury & Holroyd, 1993). It wasn't until 2004, when the lake was almost completely dry, that the census was repeated (Priestley, 2007; MacDonald & Roberto-Charron, 2014). A new breeding grid was established in the same area as the previous censuses using GPS devices; the new plot measured 400 m by 400 m, a combined area of 16 ha² (MacDonald & Roberto-Charron, 2014). This census saw a continuation in the decline of Savannah Sparrows and waterfowl nest sites, an increase in Clay-colored Sparrow populations, and the introduction of Yellow Warblers and Least Flycatchers as plant succession progressed (Priestley, 2007). The modernized census was repeated in 2013 and 2014, and the previous trends persisted (Forest, 2014; MacDonald & Roberto-Charron, 2014). By the end of 2014, a number of new species had been documented including the American Bittern, Gadwall, American Coot, Alder Flycatcher, American Robin, Gray Catbird, Brown-headed Cowbird, Black-capped Chickadee, and Warbling Vireo (MacDonald & Roberto-Charron, 2014). A slight resurgence of Redwinged Blackbirds was also observed by MacDonald & Roberto-Charron (2014), but was nowhere near the levels in the early 1990s.

Methods

The Study Area

The 2016 study plot was the same as the study area established in 2004. The same observation points marked on the GPS device from previous years were used to ensure consistency between censuses. These points were situated every 50 metres, labeled 00 through 07 along the east-west axis and A through H along the north-south axis. Observation points H00 and H01 were not included in the survey as they were located in water of Beaverhill Lake during the original survey. Visual aids, such as wooden stakes and flagging tape, were used for observation points that proved difficult to locate with the GPS.

The gradient of vegetation on the landscape displayed obvious shoreline succession. Dry sedge grasslands occupied the northern half of the study plot (approximately rows D through H) and extended beyond the historical shoreline. Sporadic clusters of willows and two small patches of dry, mixed deciduous forest also occupied this region. The forest edge of the nearby poplar-dominated woodlands occupied the southern boundary of the area (primarily up to row A). Between the forest edge and grasslands was a dense thicket of shrubs, primarily comprised of willows, which gradually blended into its neighbouring habitats (roughly north of row A up to D). A small, cattail-dominated, marsh existed in the far southeast corner of the plot. A simplistic representation of these dominant habitats can be seen in Figure 1.

Data collection

Censuses were conducted approximately 20-80 minutes after sunrise (between 05:20 and 06:20) on June 5, 11, 12, 19, 22, and 27 of 2016 and ranged in duration between 5 and 8 hours, ending before noon. The following exceptions to these generalities occurred: on June 5, the introductory census commenced at 08:15; the June 11 census only persisted for four hours (forced to end early due to poor

weather conditions); the June 22 census concluded at 13:45. Surveys did not take place during high levels of precipitation or wind.

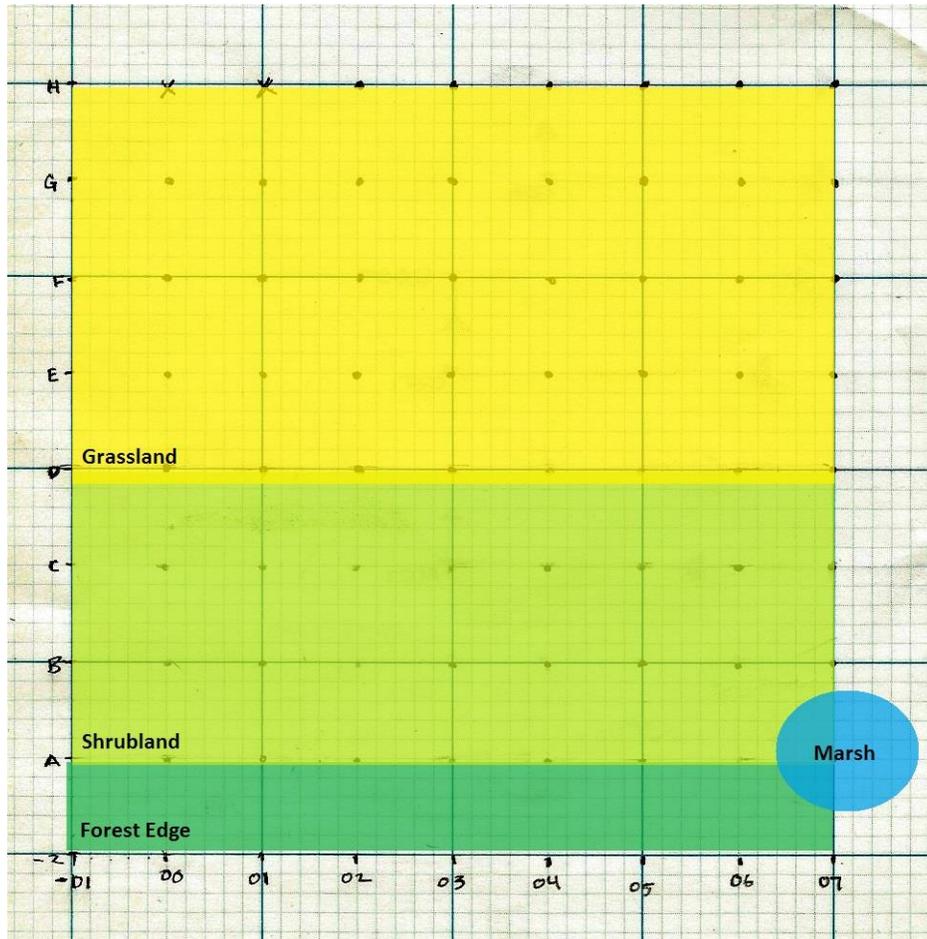


Figure 1. A rough approximation of the dominant habitat types exhibited throughout the Beaverhill grasslands study plot in 2016, where one small square represents a 10m by 10m section.

Observation points were located using a GPS-Garmin unit. Two to eight minutes were spent at each point, depending on the level of activity, and audio and visual observations were recorded in each of the cardinal directions. Routes taken between observation points were altered between visits to ensure even data collection. Observations were recorded on a map as a circled species code if the bird

was calling or a floating species code (or boxed, for clarity on some maps) if the bird was seen and not heard. Simultaneous calls were documented by a dashed line connecting the two individuals. Observed flight paths were noted by a solid line with an arrow pointing towards the final destination. If the final destination was unknown, the arrow would be placed in the middle of a solid line, noting the direction of flight. These codes are in compliance with International Bird Census Committee (IBCC) standards (Bibby et al, 1992).

Data Interpretation

Once the censuses were completed the observations were compiled onto species-specific maps. This was done after the field work had been completed in order to prevent observer bias. Occurrences were marked by a number corresponding to the survey number when they were observed. For example, an individual observed on June 5, 2016 would be recorded as a one since it was the first survey. All additional information was recorded in the same way it had been on the original map. Breeding territories of each individual species were determined using the IBCC guidelines provided in Bibby et al. (1992) and Svensson (1978a). Simultaneous calls between clusters were assumed to be territorial and dictated boundaries between breeding individuals or pairs. In some cases, it was necessary to use the observer's best judgement.

Three indices were used to calculate the species diversity and evenness for the 2016 and 2013 censuses: the Shannon-Wiener Diversity Index; Pileou's Evenness; the Simpson Index (formulas listed in Appendix I). Raw observation data provided in Forest (2014) was used to perform these calculations for the 2013 BBC. These results were compared to those of the 1992, 1993, 2004, and 2014 censuses, provided in MacDonald & Roberto-Charron (2014). A scatterplot of the number of territories observed for each of the species present in all of the census years was created to determine if any obvious population trends existed.

Results

General Results

A total of 299 breeding territories were observed in 2016 (see Table 1 for a full breakdown of these territories by species). The Clay-colored Sparrow prevailed as the dominant species throughout the study plot with a total of 83 observed breeding territories. The Yellow Warbler and Least Flycatcher also showed high densities (43 and 27 territories respectively) in the southern, more densely vegetated

Table 1. The number of breeding territories for each species observed within the grasslands study plot throughout the history of the Beaverhill Breeding Bird Census

Species	Year of Breeding Bird Census					
	1992	1993	2004	2013	2014	2016
Mallard	4	6	0	0	0	3
Gadwall	0	0	0	0	0.5	0
Northern Shoveler	1	0	0	0	0	2
Blue-winged Teal	3	0	0.5	0	0	1
Lesser Scaup	6	0	0	0	0	0
Duck spp.	6	2	0	0.2	0	0
Sora	0	0	0	0	0	2
American Coot	0	0	0	0	1	0
Wilson's Phalarope	11	5	0	0	0	0
American Bittern	0	0	0	0	0.5	1
Broad Winged Hawk	0	0	0	0	0	1
Northern Harrier	0	1	1	0	0	0
Short-eared Owl	0	0	1	0	0	0
Alder Flycatcher	0	0	0	0	1.5	13
Least Flycatcher	0	0	3	3.8	8	27
Marsh Wren	0	0	0.5	0	0	0
House Wren	0	0	0	0	0	1
American Robin	0	0	0	0	0.5	0
Gray Catbird	0	0	0	0	1	0
Yellow Warbler	2	2	4.5	7.8	6	43
Yellow-rumped Warbler	0	0	0	0	0	16.5
American Redstart	0	0	0	0	0	7
Common Yellowthroat	1.5	2.5	4	0	0	0
Savannah Sparrow	48	35	32	25.4	11	52
Clay-colored Sparrow	6	5	16	43.4	10	83
Le Conte's Sparrow	4	6	1	0	0.5	7
Lincon's Sparrow	0	0	1	0	1	0
Sharp-tailed Sparrow	9	7	4	0	0	0
Song Sparrow	0	0	1	0	0	0
Vesper Sparrow	0	0	0	0	0	16
Rose-breasted Grosbeak	0	0	0	0	0	4
Red-winged Blackbird	16.5	17	0.5	0.2	2	1
Yellow-headed Blackbird	3	0	0	0	0	0
Brewer's Blackbird	0	0	1	0	1	0
Baltimore Oriole	0	0	0	0	0	5.5
Brown-headed Cowbird	0	0	0	0	2	10
Black-capped Chickadee	0	0	0	0.8	1	3
Warbling Vireo	0	0	0	0.8	0	0
Total	121	88.5	71	82.4	47.5	299

portion of the plot. Meanwhile, a resurgence of Savannah Sparrows was observed throughout the grasslands with 52 territories. The 2016 census saw the introduction of eight new species to the area including Sora, Broad-winged Hawk, House Wren, Vesper Sparrow, Yellow-rumped Warbler, American Redstart, Baltimore Oriole, and Rose-breasted Grosbeak. The 2016 BBC also documented Mallard, Northern Shoveler, and Blue-winged Teal territories, which have not been detected since 1993, 1992, and 2004, respectively. Growth of some more recently occurring populations of Least Flycatchers, Brown-headed Cowbirds, Alder Flycatchers, and Black-capped Chickadees continued (with 27, 13, 3, and 3 territories, respectively).

Species Richness & Diversity

Species richness increased from 16 species in 2014 to 21 species in 2016 (see Table 2 for a comparison of this and other parameters across all census years). There was an apparent increase in diversity in 2016 based on the results of the Shannon-Weiner, Simpson, and Pielou indices, all of which showed the highest scores of species abundance and evenness in the history of the Beaverhill grasslands. Conversely, only eight species were observed in 2013, giving it the lowest measure of species richness to date. Yet based on the Shannon-Weiner, Simpson, and Pielou indices, this year saw the second highest levels of species abundance and evenness, after 2016.

Table 2. Comparison of species richness, diversity, and evenness throughout the history of the grasslands breeding bird census at Beaverhill Lake, Alberta.

Year of Census	Species Richness	Shannon-Wiener Index	Pielou's Evenness Index	Simpson's Index
1992	14	0.50604	0.19175	0.20105
1993	11	0.54442	0.22704	0.21708
2004	15	0.55672	0.20558	0.26741
2013	8	1.184705	0.569723	0.383719
2014	16	0.5126	0.18488	0.14947
2016	21	2.28418	0.75026	0.14256

Population trends

Only five species were consistently detected in all six censuses including the Yellow Warbler, Savannah Sparrow, Clay-colored Sparrow, Le Conte’s Sparrow, and Red-winged Blackbird. Figure 1 displays a series of scatterplots highlighting population trends for each species. The strongest trend observed was a linear decline of Red-winged Blackbird ($m = -0.6918$, $R^2 = 0.8255$). At the same time,

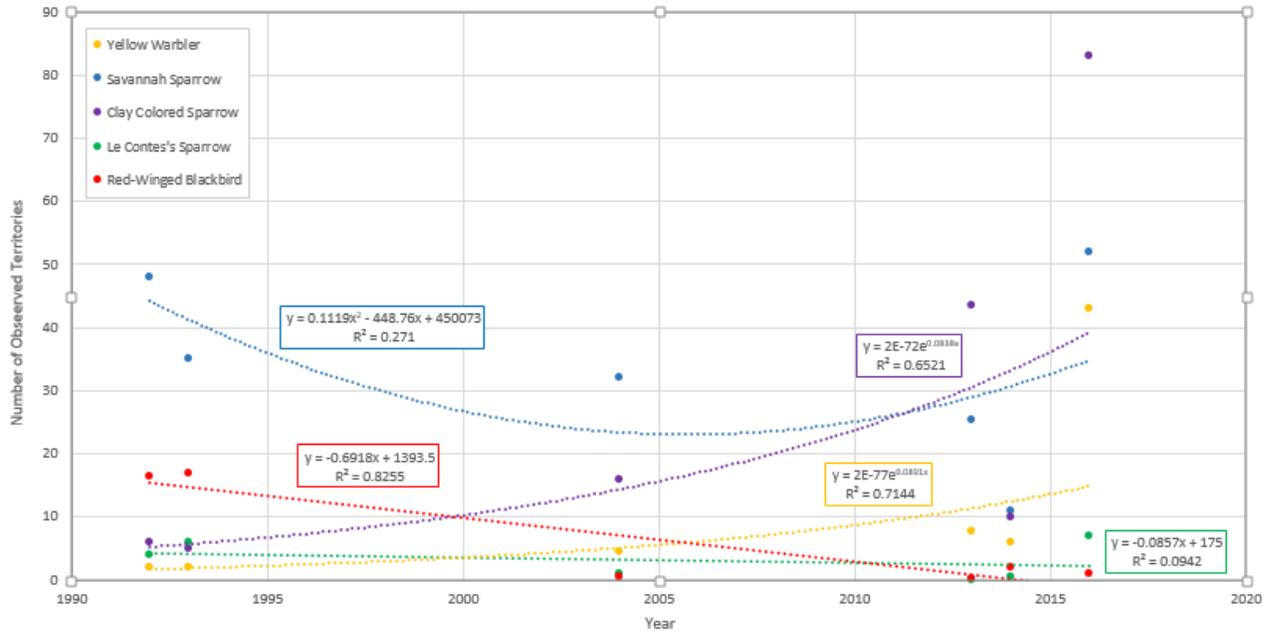


Figure 2. Population trends exhibited by the Yellow Warbler, Savannah Sparrow, Clay Colored Sparrow, Le Conte’s Sparrow, and Red-Winged Blackbird throughout the history of grasslands breeding bird censuses at Beaverhill Lake, Alberta.

Yellow Warbler ($y = 2E-77e^{0.0891x}$, $R^2 = 0.7144$) and Clay Colored Sparrow ($y = 2E-72e^{0.0838x}$, $R^2 = 0.6521$) populations exhibited positive exponential growth. Trends for Savannah and Le Conte’s Sparrow populations were of negligible significance ($R^2 = 0.271$ and $R^2 = 0.0924$ respectively).

Discussion

The 2016 grasslands BBC saw a dramatic increase in the number of territories compared to previous years, with 299 territories in total. At the same time, this study observed the highest values of species richness, diversity, and evenness to date. The observed increase in species abundance and diversity was likely a result of changing environmental conditions, i.e., climate and vegetative cover.

However, there were a number of inefficiencies in the study that may have exaggerated these counts. The following will explore these factors in more detail.

Environmental Factors

The effects of a changing climate. Climate change can have a significant impact on the structure of bird communities (Virkkala, 2016; Svensson, 1978a). In fact, temperature has larger effect on species richness than precipitation, site age, or nearby human population size or density (Gagne et al., 2016). Migration patterns specifically, are dependent on resource availability and weather (Svensson, 1978b). A warming climate has resulted in early spring arrivals across the globe (Lehikoinen & Virkkala, 2016). The Beaverhill area experienced abnormally warm conditions in the early spring of 2016; consequentially, the Beaverhill Bird Observatory saw many early arrivals of migrants when performing their 2016 spring Migration Monitoring banding program (Methuen, 2016). These favorable conditions may have facilitated an extended migration period for some species, providing one explanation for the arrival of new species and individuals to the area (Lehikoinen & Virkkala, 2016).

After a few years of consistently higher temperatures, entire distributions of species begin to shift toward the poles, leading to a gradual “global homogenization” of bird communities (Virkkala, 2016; Lehikoinen & Virkkala, 2016). The Clay-colored Sparrow, for instance, has established itself as most prevalent species of the northern Canadian prairies, implying that the changes observed in ecological structure of the Beaverhill grasslands may be universal (Cornell University, 2015). Bird populations along the southern boundary of the European boreal forest increased by 29% between 1981 and 2009 (Virkkala, 2016). Beaverhill Lake is situated just south of Alberta’s boreal forest region and may be experiencing a similar effect as birds previously occupying warmer, more southern regions move in. Stephens et al. (2016) noticed that in United States, populations of birds that benefited from climate change showed a pronounced increase while those that were negatively impacted remained relatively

stable. This helps to explain why certain populations (i.e., Clay-colored Sparrows and Yellow Warblers) saw a rapid and dramatic increase in abundance as temperatures rose at Beaverhill, while others (such as the Le Conte's Sparrow) did not. As a general statement, it is likely that climate change is the primary factor influencing the fluctuations in the Beaverhill grassland bird community, but further research is needed to confirm the mechanisms of this impact.

Changes in the vegetative landscape. While climate change is the driving force behind changes in vegetative land cover, it is thought that climate change affects bird communities on a grand scale whereas land cover impacts them on a more localized level (Virkkala, 2016). Biological topography plays a large role in a bird's migration, breeding, foraging, and nesting behaviours and therefore heavily influences their distribution (Vourisalo et al., 2015). Older and more established sites are correlated with higher levels of species richness (Gagne et al., 2016). As grasslands age, they are first colonized by shrubs, then woodlands; consequentially, an increase in woodland bird species and a decrease in open-habitat species occurs (Priestley, 2007; Sirami et al., 2007). The Beaverhill grasslands are currently in the midst of succession and pertain to a wide variety of habitats; therefore, they are able to provide for a large diversity of bird species with varying preferences.

Consistent with the results in Sirami et al. (2007), the 2016 grasslands BBC saw an introduction of four open-woodland and forest-edge bird species (American Redstart, Rose-breasted Grosbeak, Vesper Sparrow, and Baltimore Oriole) and the proliferation of Least Flycatcher and Black-capped Chickadee populations, which also occupy this niche. The open-grassland species (Le Conte's and Savannah Sparrows) however, also saw an increase, not a decrease. The majority of observed territories were occupied intermediate species that prefer shrublands (Clay-colored Sparrows and Alder Flycatchers), areas with both open and forested habitats (Yellow-rumped Warblers), or areas undergoing regrowth or some form of disturbance (Yellow Warblers). Even slight increases in abundancies can have resonating

effects on the overall ecology of an area (Stephens et al., 2016). For example, the increased abundance of Yellow Warblers, which are common targets of nest parasitism by Brown-headed Cowbirds, has likely contributed to the recent surge in populations of the latter species (Cornell University, 2015). On the other hand, the consistent decline of Red-winged Blackbird populations reflects the gradual disappearance of cattail-dominated wetlands, which is critical breeding habitat for the species (Cornell University, 2015). Holistically, these results perpetuate the notion that Beaverhill Lake is currently in a mid-successional stage and changes in the landscape are impacting breeding bird communities.

July visit. One additional visit occurred on July 21, 2016 but was not included in the census as it took place well beyond the breeding season and, accordingly, observed a tremendous decline in activity. It is included here, however, to note the dramatic change in habitat structure that occurred less than one month after the final observation date. Between June 27 and July 21, a total of 138.1 mm of precipitation fell in the area (Alberta Climate and Information Services [ACIS], 2016). This resulted in a mass flooding of the entire grassland area, with some areas up to 50 cm deep. A large portion of the sedge species had grown over 1 m in height and a considerable amount of new willow growth had appeared along the northern border of the shrubland section. This single census visit estimated three to four territories of Wilson's Snipe, a species never before recorded in the area. A variety of aquatic invertebrates were observed in what could, at this time, be considered marshlands or, in some areas, shallow open water. These qualitative observations highlight that significant fluctuations occurring in the climate, hydrology, and landscape of Beaverhill Lake and support the need for further study.

Inefficiencies of the Study

While the breeding bird census is perhaps the most effective methods in observing bird communities (as discussed in the introduction), there were a number of inefficiencies in this study, such

as a reduced number of census visits, mapping techniques, detection errors, and observer bias that may have impeded territory counts and will be discussed here.

Low frequency of visits. The summer of 2016 saw an unusual amount of precipitation for the area, presenting a major challenge for data collection. The neighbouring town of Tofield, Alberta had 16 days of 24 hour rainfall, with some bouts lasting up to three days at a time (The Weather Network, 2016). A total of 127.6 millimetres of accumulated precipitation was recorded in the area for the month of June, compared to an average of 79.9 mm (ACIS, 2016). Because a breeding bird census cannot occur during periods of heavy rain, the number of visits during the 2016 BBBC was substantially lower than previous years. Longer periods of time (5 to 8 hours) were spent in the field during, compared to previous years (2.5 to 3 hours by MacDonald & Roberto-Charron, 2014), to account for this. Increasing the duration of the visits was found to be a suitable method for recovering survey efficiency in cases such as these (Svensson, 1978a).

Another way to account for low visitation during a BBC is to reduce the number of observations needed to designate a territory. Following IBCC territory mapping standards, a series of six censuses only requires two observations to designate a territory (Bibby et al., 1992; Svensson, 1978a). Following these parameters, Svensson (1978a) found that only 45-55% observation efficiency is required per visit in order to obtain the overall observation standard of 80-90%. This is a realistic estimate as the average observation efficiency amongst observers is 50% (Enemar et al., 1978; Svensson 1978a). Hindsight shows that this model is equivalent to, if not more effective than, performing eight visits using three observations per territory, which needs an observation efficiency of 50-55% in order to achieve the same results (Svensson, 1978a). However, lowering the required number of observations per territory to account for a lower frequency of visits may result in a higher number of observed territories (Svensson, 1987a). While large and diverse data sets are ideal in any study, considering the challenges posed by

weather and precipitation, appropriate measures were taken to improve to validity to the 2016 grasslands BBC.

Detection errors. Some common detection errors may have also contributed to inflated territory counts. Individuals foraging outside of their breeding territories may have been counted twice, attributing to population over-estimates (Svensson, 1978a). This may have been especially true for the incredibly dense population of Clay-colored Sparrows, which are characteristic of foraging outside their relatively small territories (Cornell University, 2015). Additionally, this species, along with Savannah Sparrows and Yellow Warblers (which collectively contributed over half of the observed territories), produce more conspicuous songs and therefore may have been recorded more frequently. It is known that a primary weaknesses of the BBC model is its inability to detect low density and inconspicuous species (Bibby et al, 1992; Svensson, 1978a). This effect was especially evident in the results of the 2013 BBC, which saw relatively high densities of only a handful of species.

First-time observer bias. The highest amount of variation in BBC results occurs when there is a change in observer due to a slight change in methods or potential observer bias (McCollin, 2014). First-time observers are known to inflate bird counts (Gagne et al., 2016; Kendall, Peterjohn, & Sauer, 1996). However, these overestimates are usually negligible (1.8%) and while omitting this type of data would reduce observer bias, it would also reduce precision (Kendall et al., 1996). Likewise, using a calculated efficiency error has proven to be ineffective in accurately depicting natural populations (Svensson, 1978a). Instead, large-scale studies, such as the North American Breeding Bird Survey, account for first-time observer inefficiencies by observing long term trends (such as those presented in Figure 2) or use a covariate to lessen the impact of variation (Kendall et al., 1996). Currently, the Beaverhill Grasslands BBC pertains to a relatively small data set and is performed by a new observer nearly every year, so omitting first-time observer data or introducing a co-variate would not be feasible at this point. Furthermore,

population trends require more comprehensive and consistent data to be considered significant. A first-time observer effect is difficult to account for within the current parameters of the Beaverhill BBC. Continued study, preferably by an experienced observer, is recommended in order to make sound conclusions about changes occurring in the bird communities of the Beaverhill grasslands.

Conclusion

This study observed the highest levels of species richness, abundance and evenness in the Beaverhill grasslands to date. Most breeding bird populations saw an increase; the census saw the introduction of many woodland species and high densities of shrubland and intermediate species. The Red-winged Blackbird was the only species to show a substantial decline due to habitat loss. The results of this study suggest that succession is still underway and, combined with the effects of climate change, is heavily impacting the structure of bird communities in the area. Though inefficiencies in the study, such as low observer visitation (due to a high occurrence of precipitation), adjusted mapping techniques, and first-year observer bias may have exaggerated these results. More concrete data is needed to confirm the strength of these observed trends and come to accurate conclusions about the current and future state of breeding bird populations. Continued monitoring, by an experienced observer, of bird and plant diversity as well as climatic factors is recommended to gain a deeper understanding of the effects of these ecological processes on the community structure of the Beaverhill grasslands.

Acknowledgements

I thank the Beaverhill Bird Observatory for providing the opportunity to conduct this study, Geoff Holroyd for introducing me to the Breeding Bird Census technique and for editing this report, and SCiP (Serving Communities internship Program; www.scip.ca) for funding the study.

References

- Alberta Climate Information Services [ACIS]. (2016). Current and historical Alberta weather station data viewer [raw data file]. Retrieved from: <http://agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp>
- Bibby, C., Burgess, N., & Hill, D. (1992). *Bird Census Techniques*. San Diego, CA: Academic Press Limited. Retrieved from: <https://books.google.ca/books?id=5TqfwEHCVuoC&lpg=PA42&dq=territory%20mapping%20bird%20census&pg=PP1#v=onepage&q=common%20bird%20census&f=false>
- Cornell University. (2015). *All about Birds*. Retrieved from: <http://www.birds.cornell.edu>
- Duxbury, J., & Holroyd, G. (1993). *Grass-Sedge Wetland Breeding Bird Census*. In Duxbury, J. (ed.), *Beaverhill Bird Observatory 1993 annual report* (28-29). Edmonton, AB: Beaverhill Bird Observatory. Retrieved from: <http://beaverhillbirds.com/docs/annualReports/1993-AnnualReport.pdf>
- Enemar, A., Sjistrand, B., & Svensson, S. (1978). The effect of observer variability on bird census results obtained by a territory mapping technique. *Scandinavian Journal of Ornithology* 9(1), 31-39. Retrieved from <http://www.jstor.org/stable/3676136>
- Forest, A. (2014). *Breeding grid final intern report*. In Roberto-Cahrron, A. (ed.), *Beaverhill Bird Observatory annual report 2013* (79-82). Edmonton, AB: Beaverhill Bird Observatory. Retrieved from: <http://beaverhillbirds.com/docs/annualReports/2013-BBO-Annual-Report.pdf>
- Gagne, S., Sherman, P., Singh, K., & Meentemeyer, R. (2016). The effect of human population size on the breeding bird diversity of urban regions. *Biodiversity Conservation* 25(1), 653-671. doi: 10.1007/s10531-016-1080-3

- Holroyd, G. (1992). Grass-sedge wetland breeding bird census. In Rowell, P. (ed.), *Beaverhill Bird Observatory 1992 annual report* (29). Edmonton, AB: Beaverhill Bird Observatory. Retrieved from: <http://beaverhillbirds.com/docs/annualReports/1992-AnnualReport.pdf>
- Kendall, W., Peterjohn, B., & Sauer, J. (1996). First-time observer effects in the North American Breeding Bird Survey. *The Auk* 113(4); 823-829. Retrieved from: <http://www.jstor.org/stable/4088860>
- Kirkun, R., & Holroyd, G. (2001). *Beaverhill Lake: Important bird area conservation plan*. Retrieved from: <http://beaverhillbirds.com/docs/BeaverhilLakeIBAConservationPlan.pdf>
- Lehikoinen, A. & Virkkala, R. (2015). North by north-west: Climate change and directions of density shifts in birds. *Global Change Biology* 22(1), 1121-1129. doi: 10.1111/gcb.
- MacDonald, Z., & Roberto-Charron, A. (2014). Revisiting the Beaverhill Lake breeding bird census. Edmonton, AB: Beaverhill Bird Observatory.
- McCollin, D. (2014). Reconstructing long-term ecological data from annual census returns: A test for observer bias in counts of bird populations on Skokholm 1928-2002. *Ecological Indicators* 46(1); 336 – 339. doi: <http://dx.doi.org/10.1016/j.ecolind.2014.06.022>
- Methuen, K. (2016). *Beaverhill Bird Observatory spring report 2016*. Retrieved from: <http://beaverhillbirds.com/docs/annualReports/2016-SpringReport.pdf>
- Priestley, L. (2007). *Beaverhill Bird Observatory 1987 to 2006: 20 years of monitoring*. Edmonton, AB: Beaverhil Bird Observatory. Retrieved from: http://beaverhillbirds.com/docs/BBO_20_years.pdf
- Sirami, C., Brotons, L., & Martin, J. L. (2007). Vegetation and songbird response to land abandonment: From landscape to census plot. *Diversity and Distributions* 13(1), 47-52. doi: 10.1111/j.1472-4642.2006.00297.x

Stephens, P., Mason, L., Green, R., Gregory, R., Sauer, J., Alison, J., ... Willis, S. (2016). Consistent response of bird populations to climate change on two continents. *Science Magazine*, 356(6281); 84-87. doi: 10.1126/science.aac4858

Svensson, S. (1978a). Census efficiency and number of visits to a study plot when estimating bird densities by the territory mapping method. *Journal of Applied Ecology* 16(1), 61-68.

Svensson, S. (1978b). Efficiency of two methods for monitoring bird population levels: Breeding bird censuses contra counts of migrating birds. *OIKOS* 30(1), 373-386.

The Weather Network. (2016). *Tofield, Alberta June 20016* [data set]. Retrieved from: <https://www.theweathernetwork.com/ca/monthly/alberta/tofield?year=2016&month=6&dispt=calendar-container-monthly>

Virkkala, R. (2016). Long-term decline of southern boreal forest birds: Consequence of habitat alteration or climate change? *Biodivers Conserv* 25(1), 151-167. doi: 10.1007/s10531-015-1043-0

Vuorisalo, T., Lehtikoinen, E., & Lemmetyinen, R. (2015). The roots of Finnish avian ecology: From topographic studies to quantitative bird censuses. *Annales Zoologici Fennici* 52 (5-6), 313-324. doi: <http://dx.doi.org/10.5735/086.052.0506>

Appendix I**Shannon Weiner Index**

$$H = -\sum_{i=1}^s \rho_i \log_2 \rho_i$$

Where:

s = the number of species

P = the proportion of the total sample belonging to the i^{th} species

Simpson's Index

$$D = \sum (n / N)^2$$

Where:

N = the total number of organisms of all species

n = the total number of organisms of a particular species

Pielou's Evenness Index

$$J' = \frac{H'}{H'_{\max}}$$

Where H' is determined by the Shannon Weiner Index and H'_{\max} is the maximum possible valued for the Shannon Weiner is determined by:

$$H'_{\max} = -\sum_{i=1}^s \frac{1}{S} \ln \frac{1}{S} = \ln S.$$