Revisiting the Beaverhill Lake Breeding Bird Census:

How the species diversity of breeding birds has changed with the disappearance of Beaverhill Lake

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Executive Summery:

During the months of June and July 2004, Lisa Priestley and Geoff Holroyd completed a breeding bird census within the Beaverhill Lake Natural Area (Priestley and Holroyd 2005). The purpose of the study was to inquire as to how breeding bird diversity had changed since 1992-93—when the last censuses were completed—as a result of the depletion of water levels at Beaverhill Lake, Alberta. One decade later, in 2014, the study described in this paper revisits the Beaverhill Lake breeding bird census. A total of eight surveys were carried out over June and early July 2014 to determine how many breeding pairs of different species of birds were utilizing the study area for their nesting territories. Due to the disappearance of Beaverhill Lake, the habitat within the study area has changed dramatically over the course of the four breeding bird censuses. This has led to changes in both the abundance and the species diversity of breeding birds. The species diversity of breeding birds found in each census is analyzed using three separate indices to reveal how breeding bird diversity within the study area has shifted with the changes in habitat between 1992 and 2014.

Cover photos:
Top: Least flycatcher (*Empidonax minimus)* fledglings photographed within the Beaverhill Lake Natural Area (2014).
Bottom: Looking north onto the dry lakebed of Beaverhill Lake from within the breeding bird census survey grid (2014).

Acknowledgements:

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Introduction:

Designated as an Important Bird Area (IBA) in 1997, Beaverhill Lake has historically served as a nesting area for many species of migrating waterfowl and shorebirds in vast quantities (Krikun and Holroyd 2001). In recent years however, Beaverhill Lake water levels have decreased, leaving behind only two small pockets of standing water located on the east side the otherwise dry lakebed (Dekker 2004). Natural forest succession is taking place along the former riparian zone surrounding the lakebed as various shrub and tree species colonize the area. This change in habitat has led to changes in the diversity of bird species that utilize the Beaverhill Lake area as their breeding grounds. Through the Beaverhill Bird Observatory, researchers have been able to monitor the changes that are occurring among breeding birds at Beaverhill Lake as the water levels continue to change (Priestley 2006).

A breeding bird census can be used to determine the species composition of breeding birds found within an area of interest, as well as to quantify their abundances (Conway 2002). To complete a breeding bird census, the locations of all birds seen and heard during multiple surveys are mapped out on a grid established within the study area. The Beaverhill Lake breeding bird census was first completed by Jason Duxbury and Kevin Hento in 1992, and was again completed the following year by Jason Duxbury along with Josh Bilyk in 1993. Over one decade later, the project was reinvigorated in May 2004 when Geoff Holroyd, Sarah Trefry, Jill Thompson, and Crystal Rausch set up a breeding bird survey grid replicating the one used in the 1992-93 studies (Priestley and Holroyd 2005). After the

establishment of the grid, Lisa Priestley and Geoff Holroyd proceeded to complete the census over June and early July 2004. This grid was also used for the breeding bird census that was completed over June and early July 2014.

This paper describes the most recent Beaverhill Lake breeding bird census that was completed in 2014. The results of this census are compared to those of the three previous Beaverhill Lake breeding bird censuses. The diversity of breeding birds found in each of the censuses is analyzed using species richness (species abundance) along with three indices of species diversity: the Simpson's index, the Shannon-Weiner index, and the Pielou's Evenness index (see appendix). The Simpson's and Shannon-Weiner indices account for both species richness and species evenness, and as such offer more insight as to the true diversity of species found within the study area. The Pielou's Evenness index is only an indicator of species evenness. Analyzing the data using these three indices should reveal what changes the disappearance of Beaverhill Lake has had on breeding bird diversity.

The drying of Beaverhill Lake has had significant impacts on the shoreline habitat surrounding the lake, and it is expected that the changes in breeding bird diversity will be equally significant. Though the change in water levels at Beaverhill Lake are not known to be exclusively caused by human activity (Priestley 2006), establishing a relationship between retreating water levels and the resulting changes in breeding bird diversity will help shed light on the impacts humans could have on breeding bird populations when water tables are anthropogenically altered.

Methods:

The survey area for the Beaverhill Lake breeding bird census is located on the southeast edge of the historical Beaverhill Lake shoreline, in the transition zone between the woodland edge and the dry lakebed. The southwest corner of the grid coordinates are 53°22.921'N, 112°31.439'W, 671m elevation. From this southwest grid point, the survey grid extends 400 meters north and 600 meters east. The survey grid extends up to 50 meters north of the historical Beaverhill Lake shoreline on the north edge of the survey area. An overstory comprised of balsam poplar (*Populus balsamifera*) and trembling aspen (*Populus tremuloides*) dominates the forested area surrounding the lakebed on the southeast corner of the Beaverhill Lake. Small bluffs of balsam poplar and trembling aspen are also found within the transitional zone between the forest edge and the dry lakebed. Encroaching from the edge of these bluffs towards the historical shoreline are various shrubs, primarily species of willow (*Salix spp.)*. Sedge-grassland is found between the willows and extends across the dry lakebed, beyond the area that the willows have been able to colonize thus far.

To map the locations of birds heard or seen, the breeding bird grid established within the study area in May 2004 by Geoff Holroyd, Sarah Trefry, Jill Thompson, and Crystal Rausch was used. This grid is a replicate of the one used in 1992-93 (Duxbury and Holroyd 1993), which covered a total area of 18.9 ha (Priestley and Holroyd 2005). Grid points were 50 meters apart and were labeled by number on the west-east axis (00, 01, 02, through to 11), and by letter on the south-north axis (A through I). A00 marked the most southwesterly point on the grid. It

will be noted that H11, I10, and I11 were not included in the survey grid as they encroached on nearby grazing land that was fenced off. As such, grid points H10 and I09 represent the most easterly edge at the north end of the survey grid. The locations of grid points were mapped from a handheld GPS unit to reestablish the grid for the 2014 surveys. Wooden stakes labeled with a corresponding grid point code (example A00 or A01) were used in conjunction with a handheld GPS to aid in locating the grid points when conducting surveys.

Surveys were completed on multiple mornings between June 1st and July 9th in all four of the breeding bird censuses. Survey durations varied between two and half hours to three hours, depending on how many birds were observed. All surveys were completed before 10:00 am. Nine surveys were completed in the 1992 census (June 23, 24, 25, 26, 27, 30, July 1, 2, 3), eight surveys in the 1993 census (June 8, 11, 16, 17, 21, 22, 25, 28) (Duxbury and Holroyd 1993), and six surveys in 2004 census (June 12, 17, 26, July 1, 5, 6) (Priestley and Holroyd 2005). During the 2014 census, eight surveys were completed (June 8, 16, 20, 23, 24, July 1, 2, 6). Surveys were not conducted on mornings when precipitation was persistent.

To quantify the number of breeding pairs of each species present within the grid, maps with the recorded locations of the observed birds were interpreted. The following observations were recorded:

- Two males of the same species seen or heard calling simultaneously to one another. Special note given to this kind of observation as this likely denotes the location of a territorial boundary.

- Individual males persistently calling, even if unanswered by other males of the same species.
- Breeding pairs seen together. Male does not have to be calling.

Birds seen that were neither calling nor observed with their breeding partner were not recorded. Individual birds or groups of birds flying overhead without stopping to land within the breeding bird grid were also not recorded. Birds calling on edge of the grid were recorded, as it is possible that their breeding territory lay at least partly inside of the grid. It will be noted that a grid of Tree Swallow (*Tachycineta bicolor*) nest boxes were located in within the breeding bird census grid. As such, Tree Swallow observations were not recorded and the species was not included within the census.

The resulting data was analyzed using three indices of species diversity, the Simpson's index, the Shannon-Wiener index, and the Pielou's Evenness index. These indices are outlined in the appendix.

Results:

1992 and 1993: In 1992, a total of 121 nesting territories of 14 different species were observed. In 1993, the number of nesting territories declined to 88.5 and the number of species declined to 11. The most significant change in breeding bird abundance and diversity within the survey grid between 1992 and 1993 was the declination of waterfowl. Besides mallards, all breeding waterfowl found within the grid in 1992 (northern shoveler, lesser scaup, blue-winged teal, and other unidentified duck species) decreased. Other noteworthy changes include the decline

of wilson's phalarope, savannah sparrow, and sharp-tailed sparrow nesting territories. Yellow-headed blackbirds completely disappeared from the survey grid between 1992 and 1993 censuses. The abundances of other species showed relatively little change.

2004: A total of 71 nesting territories of 15 different species were observed in 2004. The number of waterfowl species decreased from 1992/93 abundances, as the only waterfowl to be observed was a breeding pair of blue-winged teal, who's nesting territory was only partly inside of the survey grid (0.5 of a nesting territory). Wilson's phalarope (a species that was observed in both the 1992 and 1993 censuses) were not recorded within the survey area. LeConte's and sharp-tailed sparrow abundances both decreased. Red-winged blackbird territories declined by 97% between 1993 and 2004, with only 0.5 of a nesting territory present within the grid in 2004. Relative to 1993 abundances, savannah sparrow nesting territories decreased, while clay-coloured sparrow numbers more than tripled. Yellow warbler nesting territories more than doubled between 1993 (2 territories) and 2004 (4.5 territories). Common yellowthroat nesting territories were found to be more numerous in 2004 than in 1993 (2.5 in 1993 and 4 in 2004). New species found in 2004 that were not present in the 1992/93 censuses include short-eared owl, least flycatcher, marsh wren, lincoln's sparrow, song sparrow, and brewer's blackbird.

2014: A total of 47.5 nesting territories of 16 different species were observed during the 2014 Beaverhill Lake breeding bird census. Savannah sparrow numbers decreased (from 32 in 2004 to 11 in 2014). Clay-coloured sparrow nesting territories also decreased (from 16 in 2004 to 10 in 2014); however the abundance

of clay-coloured sparrow territories still remained higher than what was observed in 1992 and 1993 (6 and 5, respectively). Sharp-tailed sparrows were completely absent from the survey grid (9 territories in 1992, 7 in 1993, and 4 in 2004). No common yellowthroats were observed in 2014, a species that was present in all 3 previous surveys. Least flycatcher nesting territories more than doubled since the last census (from 3 in 2004 to 8 in 2014). Yellow warbler territories increased from 4.5 in 2004 to 6 in 2014. Red-winged blackbird territories increased from 0.5 in 2004 to 2 in 2014, but remained lower than 1992 and 1993 when 16.5 and 17 territories were found, respectively. New species observed in 2014 that were not observed in any of the previous censuses include american bittern, gadwall, american coot, alder flycatcher, american robin, gray catbird, brown-headed cowbird, and black-capped chickadee.

Table 1. Total number of nesting territories observed in 1992, 1993, 2004, and 2014.

Species	Year of Breeding Bird Census			
	1992	1993	2004	2014
American Bittern	0	0	0	0.5
Mallard	4	6	0	0
Gadwall	0	0	0	0.5
Northern Shoveler	1	0	0	0
Lesser Scaup	6	0	0	0
Blue-winged Teal	3	0	0.5	0
Duck spp.	6	2	0	0
Northern Harrier	0	1	1	0
American Coot	0	0	0	1
Wilson's Phalarope	11	5	0	0
Short-eared Owl	0	0	1	0
Alder Flycatcher	0	0	0	1.5
Least Flycatcher	0	0	3	8
Marsh Wren	0	0	0.5	0
American Robin	0	0	0	0.5
Gray Catbird	0	0	0	1
Yellow Warbler	2	2	4.5	6
Common Yellowthroat	1.5	2.5	4	0
Savannah Sparrow	48	35	32	11
Clay-colored Sparrow	6	5	16	10
LeConte's Sparrow	4	6	1	0.5
Lincoln's Sparrow	0	0	1	1
Sharp-tailed Sparrow	9	7	4	0
Song Sparrow	0	0	1	0
Red-winged Blackbird	16.5	17	0.5	2
Yellow-headed Blackbird	3	0	0	0
Brewer's Blackbird	0	0	1	1
Brown-headed Cowbird	0	0	0	2
Black-capped Chickadee	0	0	0	1
TOTAL	**121**	**88.5**	**71**	**47.5**

Indices of species diversity: Three indices of species diversity were calculated based on the data found within Table 1.

Table 2. Species richness and species diversity index values calculated from the data from each of the four censuses.

	Species Richness	Simpson's Index	Shannon-Wiener Index	Pielou's Evenness Index
1992	14	0.20105	0.50604	0.19175
1993	11	0.21708	0.54442	0.22704
2004	15	0.26741	0.55672	0.20558
2014	16	0.14947	0.51260	0.18488

Discussion:

The changes in breeding bird populations observed in the 1992, 1993, 2004, and 2014 censuses were likely due to changes in the habitat surrounding Beaverhill Lake. As water levels dropped and Beaverhill Lake dried, changes in the plant community surrounding the lake were quick to follow. When the first Beaverhill Lake breeding bird census was completed, the survey area along the shoreline of Beaverhill Lake was primarily dominated by marsh-like vegetation such as cattails (*Typha latifolia*), rushes (*Scirpa sp.*), and various sedges (Priestley and Holroyd 2005). As the lakebed dried, foliage along the former shoreline and within the riparian zone changed. With the disappearance of standing water and the marsh-like vegetation along the former shoreline, a sedge-grassland community was able to colonize the area. Following the establishment of this sedge-grassland community, shrubs such as willows (*Salix spp.*) were able to expand their range towards the dry lakebed. Bluffs of balsam poplar (*Populus balsamifera*) and trembling aspen (*Populus tremuloides*) continue to spread past the forest edge into

the areas dominated by various sedges, grasses, and willows. What was once primarily shoreline and riparian habitat has undergone a transformation into sedge-grassland and forest habitat, a result of natural forest succession.

As vegetation composition and structure change, shifts in bird populations are expected to follow (Venier and Pearce 2005). Waterfowl species such as the mallard, northern shoveler, lesser scaup, blue-winged teal, and other Anatids (ducks, geese and swans) depend on shallow water habitat for foraging areas and for nesting sites (Cornell Lab of Ornithology). Shorebirds like the wilson's phalarope that forage for small invertebrate prey on moist mudflats and in shallow waters also depend on a similar type of marsh-like habitat. The disappearance of waterfowl and shorebirds within the survey area is likely a result of the disappearance of their preferred habitat. The loss of marsh-like vegetation may also explain the disappearance of sharp-tailed sparrows, as this is the habitat they are typically associated with (Cornell Lab of Ornithology).

It will be noted that during the 2014 census, a small marsh located on the southernmost edge of the grid that was reported to be dry in 2004 by Priestley and Holroyd (2005) had standing water over 0.5 meters deep. This was where the american bittern, gadwall, american coot, and red-winged blackbird nesting territories (all of which are associated with marsh-like habitat (Cornell Lab of Ornithology)) were found in the 2014 census. Besides this marsh, there was no standing water within the breeding bird grid.

The decline in savannah sparrow nesting territories between 1992 and 2014 could be explained by changes in habitat structure. Priestley and Holroyd (2005)

developed bird/habitat associations for both savannah sparrows and clay-coloured sparrows. Savannah sparrows were described as being associated with grassland habitat with less than 5% willow cover, whereas clay-coloured sparrows were predominantly associated with grassland habitat with 10% to 50% willow cover. With the retreat of Beaverhill Lake, various species of willow, among other shrubs and trees, were able to expand their range outwards towards the lakebed, altering the sedge-grassland habitat beyond the edge of the forested areas. This made much of the habitat within the survey area less suitable for savannah sparrows (which prefer open grassland), while making it a more suitable for clay-coloured sparrows (which show a preference for grasslands with higher shrub density). As Figure 1 depicts, savannah sparrows show a decrease in nesting territory abundance, while it appears that clay-coloured sparrows may be following a positive trend overall, increasing in the number of nesting territories over time.

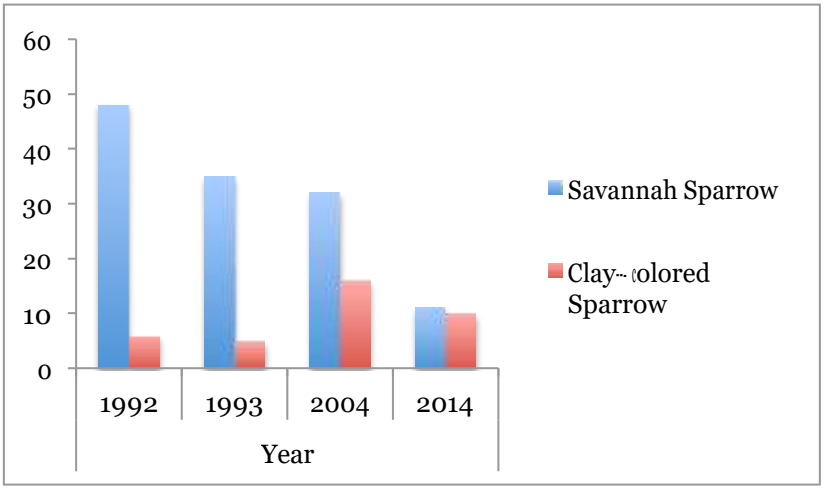

Figure 1. The number of savannah sparrow and clay-coloured sparrow nesting territories observed in 1993, 1994, 2004, and 2014.

The appearance of new species within the survey grid in 2004 and 2014 was likely a result of changes in vegetation structure and composition. Various willow species along with trembling aspen and balsam poplar continued to encroach on the sedge-grassland habitat between the forested area and dry lakebed, making the habitat more suitable for perching birds that nest in shrubs and trees. New species found to have nesting territories within the breeding bird grid in 2004 and 2014 that nest above ground in woody plants include alder flycatcher, least flycatcher, american robin, gray catbird, brewer's blackbird, and black-capped chickadee. Brown-headed cowbirds were also found to frequent the breeding bird grid. Brown-headed cowbirds do not build nests in trees and shrubs themselves- they are obligate brood parasites, laying their eggs in the nests of other nest-building songbirds, notably yellow warblers and least flycatchers (Briskie, Sealy and Hobson 1990). A least flycatcher nest was located less than 100 meters from the westerly edge of the breeding bird grid and was found to have three least flycatcher eggs along with a single brown-headed cowbird egg, leading to the conclusion that brood parasitism is occurring inside of the survey area as well.

It is clear that the species diversity of breeding birds at Beaverhill Lake has changed over the past 22 years with the disappearance of the lake. What is also clear is that the total number of breeding birds have shown a declining trend over the four censuses, from 121 in 1992, to 88.5 in 1993, to 71 in 2004, to 46.5 in 2014. Interestingly, despite these declines in breeding bird abundances, species richness has slightly increased from 1992 to 2014 (14 in 1992, 11 in 1993, 15 in 2004, 16 in 2005). Species richness can be used an indicator of species diversity, but it does not

account for the relative abundances of each species present. Analyzing species diversity using various indices can provide more information than just how many species are present.

Table 2 in the results section displays the results of the three indices that were used (Simpson's index, Shannon-Wiener index, and Pielou's Evenness index). The formulas for all three indices are outlined in the appendix. The Simpson's index measures the probability that two individuals selected at random will be of the same species, thus the lower the resulting value, the higher the species diversity. It is useful because it takes into account both species richness and evenness when measuring species diversity. Using the Simpson's index to indicate how species diversity has changed over time, it appears that even though the overall abundance of breeding birds decreased over the four censuses species diversity may have increased with the disappearance of Beaverhill Lake (Simpsons index results: 1992 census: 0.20105, 2014 census: 0.14947). When using the Shannon-Wiener index, which also takes into account species richness as well as species, it is found that species diversity has remained relatively constant, and may have even decreased (1992 census: 0.50604, 2014 census: 0.51260). The Simpson's index and Shannon-Weiner index seem to contradict one another, but neither of the two indices show any significant reduction in the species diversity between 1992 and 2014. The Pielou's Evenness index indicates that evenness in the distribution of individuals among different species has slightly declined from the 1992 census (0.19175) and the 2014 census (0.18488). It may be true that species richness in the Beaverhill

Lake area has increased over the past two decades, while species evenness has slightly declined.

Conclusion:

Because the results from the Simpson's index and Shannon-Wiener index contradict one another, it cannot be claimed that breeding bird diversity has increased with the drying of Beaverhill Lake, as the Simpson's index alone may suggest. What can be said however is that even though the overall abundance of breeding birds utilizing the area immediately surrounding Beaverhill Lake has decreased, there is no evidence to suggest that the species diversity of breeding birds is significantly lower than when Beaverhill Lake breeding bird census was first established in 1992. As demonstrated by the savannah sparrow and clay-coloured sparrow bird/habitat associations, when habitats change and become less suitable for a current occupant, other species may find the new emerging habitats more preferable and colonize the area, thus maintaining the level of species diversity. The species composition of breeding birds at Beaverhill Lake is changing as the ecosystem evolves, but it is important to remember that these shifts are all a part of natural forest succession, and that these shifts do not always lead to decreases in species diversity.

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Appendix:

The three indices used to assess species diversity:

- The Simpson's index: $\lambda = \sum_{i=1}^{R} p_i^2$ Where *Pi* is the proportion of individuals belonging to the i^{th} species. λ is the probability that two individuals selected at random will be of the same species, a measure of species diversity. Low λ values indicate high species diversity.
- The Shannon-Wiener index: $H' = -\sum_{i=1}^{R} p_i \ln p_i$ Where *Pi* is the proportion of species belonging to the i^{th} species. *H'* describes the diversity of species within a community. High *H'* indicate high species diversity.
- The Pielou's evenness index: $J' = \frac{H'}{H'_{\max}}$ Where *H'* is derived from the Shannon-Wiener index and H'_{max} is the natural log of the number of species: $H'=\ln(S)$. *J'* describes the relative abundance of species within a community. High *J'* values indicate even distribution of individuals among species.