Nesting Biology and Breeding Density of Least Flycatchers *Empidonax minimus* in the Beaverhill Natural Area

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Abstract

Least Flycatchers *Empidonax minimus*, like most aerial insectivores, have declined rapidly over the last 50 years in North America, mostly due to the extensive use of insecticides. Since the Least Flycatcher is the most common bird encountered at the Beaverhill Bird Observatory (BBO), likely due to the high insect densities, we initiated a study during the spring of 2022 analysing the nesting success and habitat preferences of this species. In addition, we estimated breeding densities according to data collected by a breeding bird census conducted yearly at BBO. We monitored 28 nests until fledging and found a high success rate, as well as a high breeding density in our research area. The Least Flycatchers seem to have a preference for nesting in Trembling Aspen trees *Populus tremuloides*, compared to Balsam Poplar trees *Populus balsamifera* in our study area. Our study shows no evidence for any clustered breeding, a well-documented breeding behaviour for Least Flycatchers elsewhere.

1 Introduction

Over the last five decades North America lost 2.9 billion birds (Rosenberg et al., 2019). This net loss in bird abundance encompasses birds of all biomes, representing a decline of 29% since the 1970s. Multiple drivers contribute to the declines in bird populations, including habitat loss and fragmentation, decreased prey abundance, direct and indirect effects of contaminants such as pesticides, window collisions, cat predation, and climate change (Calvert et al., 2013; Loss et al., 2015; Spiller & Dettmers, 2019).

For birds spending part or all of their life cycle in Canada, the largest population declines have been observed in shorebirds (-40%), grassland birds (-57%), and aerial insectivores (-59%; NABCI-Canada, 2019; Figure 1). Population changes of aerial insectivores (including swallows, swifts, nightjars, and flycatchers) are often assessed at a guild level, while the population declines seem to vary by region and species (Nebel et al., 2010; Smith et al., 2015; Spiller & Dettmers, 2019). Nebel et al. (2010) showed the probability of aerial insectivore declines to be the greatest in northeastern North America, as well as long-distance migrants to decline more than short-distance migrants. According to the Breeding Bird Survey data, swifts, swallows, and nightjars seem to experience steeper population declines than flycatchers as a group (Sauer et al., 2017). More studies are needed on species specific life history characteristics and population changes, structured by region.

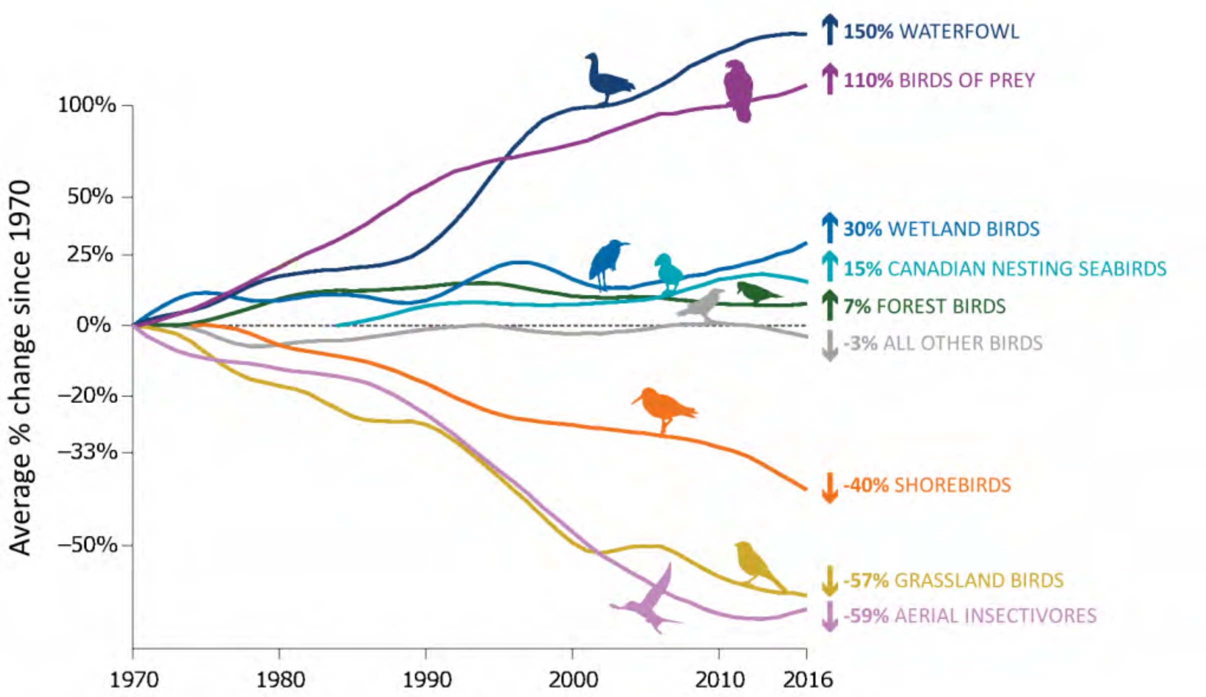

Figure 1: Average status of the Canadian bird populations. Obtained from The State of Canada's Birds (NABCI-Canada, 2019)

One flycatcher species experiencing steep population declines is the Least Flycatcher (*Empidonax minimus*, LEFL) with a negative population change of 53% since the 1970s (Spiller & Dettmers, 2019; de Zwaan et al., 2022). LEFLs are among the smallest of the aerial insectivores in North America, breeding in the deciduous and mixed forests of southern and western Canada, and northern United States (Figure 2; Tarof & Briskie, 2020). Despite its decreasing population trend, the IUCN Red List of Threatened Species assessed the LEFL as a species of Least Concern because of its large range and extremely large population size globally (IUCN, 2021). However, the species may be at risk in the future if its populations continue to decline rapidly (Spiller & Dettmers, 2019; de Zwaan et al., 2022).

The Canadian Species at Risk Act includes a provision to identify and protect critical habitat for endangered and threatened species, with critical habitat being defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species" ([SARA] Species At Risk Act, 2002). The LEFL's critical habitat will need to be identified if its populations continue to decline. More studies are needed on the LEFL's preferred habitat and how the species interacts with its environment. Understanding how breeding success is influenced by environmental factors, including weather, food supply, and predation risk as well as the location of the nest in relation to habitat, is important for conservation actions to be effective in the future (Goodenough, 2014). At present, knowledge on habitat-productivity relationships is lacking for the LEFL and would be informative for future conservation strategies.

LEFLs generally nest in the lower to mid canopy of deciduous forests and feed on insects by hawking (Robinson & Holmes, 1982; Darveau et al., 1993). Nests have been found in a variety of trees depending on the geographical region and include birches (*Betula* spp.), maples (*Acer* spp.), poplars (*Populus* spp.), and pines (*Pinus* spp.; Tarof & Briskie, 2020). A small cup nest is built in branch crotches or forks (Darveau et al., 1993) and consist mostly of grasses, plant down, and spider webs. Clutch size ranges from 2 to 5 eggs, with four-egg clutches being the most common (Briskie & Sealy, 1989a).

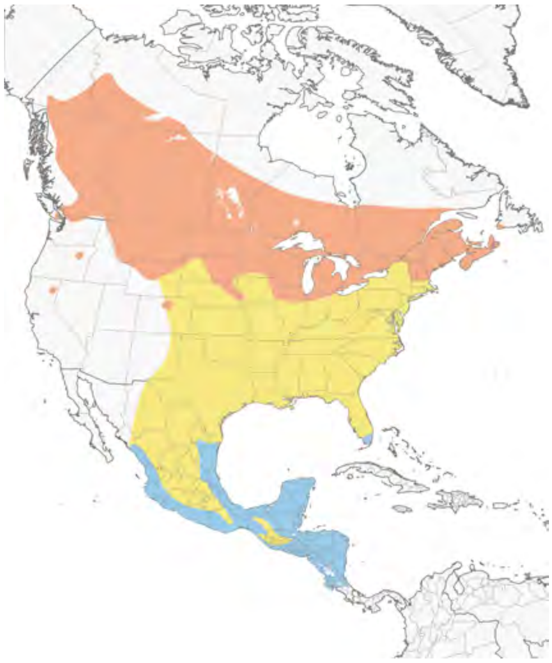

Figure 2: Range of the Least Flycatcher in North-America. Red = breeding range, yellow = migration range and blue = non-breeding range.

Earlier studies showed that habitat changes may influence reproductive success by hindering nest concealment or altering insect communities (DesGranges, 1987). Also breeding density has been negatively associated with forest decline (Darveau et al., 1992).

The LEFL is well known for its clustered breeding behavior in which males establish territories in dense clusters, leaving adjacent suitable habitat unoccupied (Tarof & Ratcliffe, 2000; Perry & Andersen, 2003; Mills et al., 2006; Geboers & Nol, 2009). The reason for this breeding behavior is subject to debate, although some studies suggest these clusters function as hidden leks (Tarof & Ratcliffe, 2004; Tarof et al., 2005). The hidden lek hypothesis implies that females persue extra pair copulations, preferring socially monogamous males that cluster their territories (Tarof & Ratcliffe, 2000;

Tarof et al., 2005; Manica et al., 2020). Other than easy access to extra-pair mates, clustering may be beneficial because of adequate food supplies or collective antipredator behavior (Perry & Andersen, 2003; Tarof et al., 2005; Perry et al., 2008).

Regardless of decreasing population trends, large numbers of breeding LEFLs are observed yearly in the Beaverhill Natural Area. In fact, LEFLs are the most common bird banded at the Beaverhill Bird Observatory since 1984 (BBO; Unpublished data). Since the LEFL is so abundant in our research area, we initiated a study analysing the productivity of LEFLs within the Beaverhill Natural Area. We aimed to understand habitat preferences in relation to breeding success and compare our breeding LEFLs to populations elsewhere in North America. In addition, we will interpret our finding within the context of identifying critical habitat for this declining species.

Figure 3: Picture of a Least Flycatcher banded at the BBO.

2 Material and Methods

2.1 Study site

Our study site was located south of Beaverhill Lake within the Beaverhill Natural Area, 60 km east of Edmonton and 10 km east of Tofield in Alberta, Canada (53.381 N -112.529 W; Figure 4). The study was near the Beaverhill Bird Observatory (BBO; research and education centre), the second oldest bird observatory in Canada, which has been operational since 1984. The boundaries of the study area (size = 50 ha or 0.5 km^2) are shown on Figure 4 (red square) and roughly overlap with some of the hiking trails out of convenience. The Beaverhill Natural Area consists of an early successional Trembling Aspen – Balsam Poplar forest in the Aspen Parkland Natural Region.

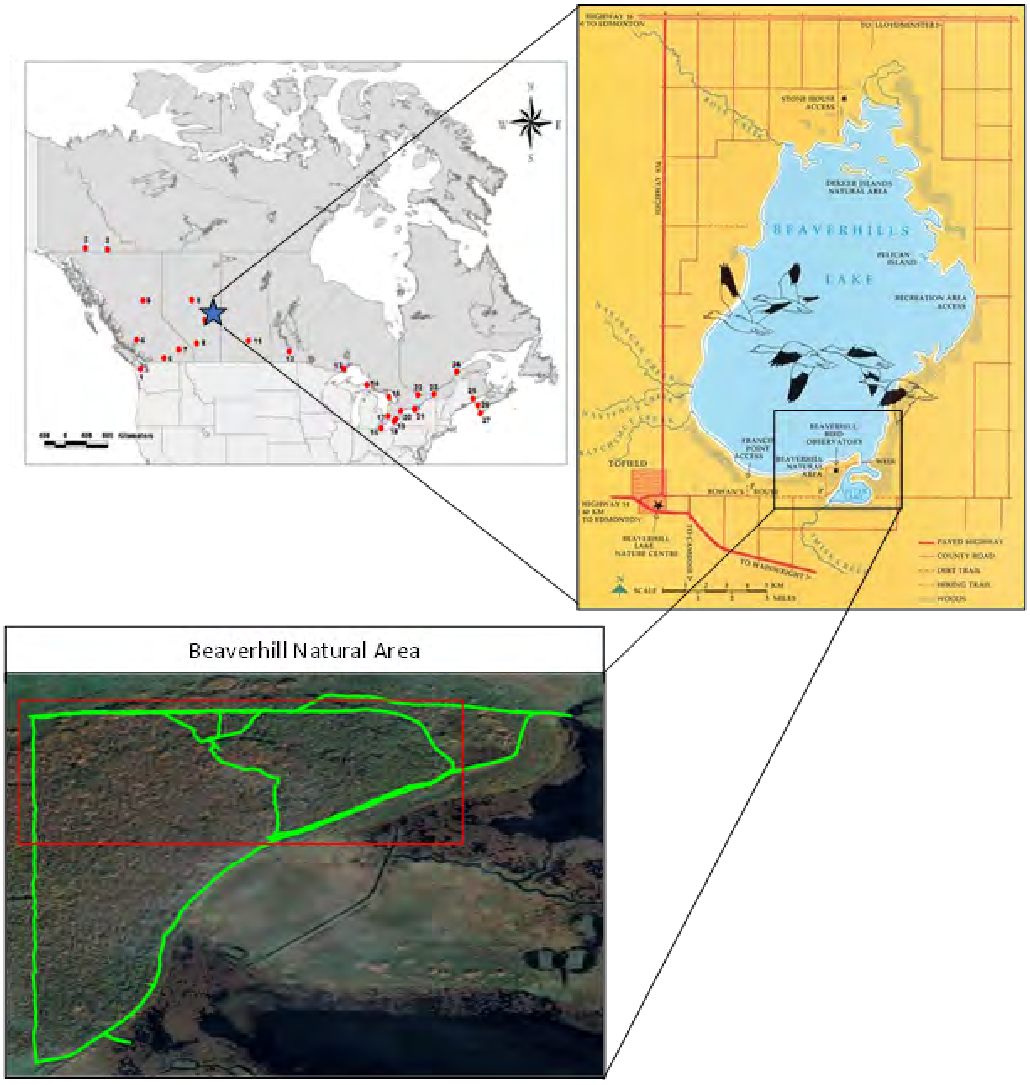

Figure 4: Map of Canada with star indicating the Beaverhill Natural area, 60 km east of Edmonton, Alberta, Canada. Red dots show all the bird observatories in Canada. Zoomed in on Beaverhill Lake and Beaverhill Natural Area with green lines indicating the hiking trails and the red square the study area.

2.2 Nest searching

We initiated nest searching on June 7 by moving randomly through the study site, looking and listening for LEFLs. When we found a LEFL, we observed its behaviour and followed the individual in order to find its nest. Behaviours such as collecting nest material, singing, looking or moving towards the same direction, mating, and chasing others away, were used as cues to find the nest. In addition, trees were scanned for nests in those locations where a nest could be expected (mid canopy in crotch of tree).

When a nest was found the location was marked in a GPS, the tree was marked with blue flagging, and a nest card was filled in. We used the Prairie Nest Records Scheme Coding System's nest cards for recording information on the nest site, habitat, and behaviour of the adults. Each nest card had a unique number that was assigned to the corresponding nest. These nest cards were also used for monitoring of the nest (see section 2.3). A more detailed description of the coding system used for the nest cards can be found in Appendix 1.

Figure 5: LEFL female on nest.

Figure 6: LEFL nests found differed in heights, ranging from 2m to 8m.

2.3 Nest monitoring

Nests were visited every 3 days (or 4 due to bad weather) to monitor egg laying, incubation, hatching, nestling period, and fledging. This was done by looking into the nest with a pole camera connected to a smartphone, using a USB camera app (Figure 7). Nests located at heights more than 8 m were too high to be monitored with the pole camera and were not used in our analysis. All observations, including adult behaviour, were recorded on the nest card of the corresponding nest. Young were aged based on pictures taken with the pole camera using the aging guide by Meghan Jacklin (Jacklin, 2017).

A nest was assumed to be successful when fledglings were observed leaving the nest, when the empty nest showed signs of fledging such as droppings or when the young were capable of leaving the nest at the previous nest visit (12 days old). All nests were empty by July 21.

2.4 Habitat and nest site characteristics

Each nest was visited again after July 21 for a quantitative analysis of nest site and habitat characteristics. First, for the nest site characteristics, the nest tree species was determined as either a Trembling Aspen *Populus tremuloides* or a Balsam Poplar *Populus balsamifera* (no other tree species were represented).

Figure 7: (A) Monitoring a nest with the pole camera connected to a smartphone. (B) Close-up of the pole camera above the nest. (C) Pole camera head.

Height of the nest tree and height of the nest were estimated with a clinometer or if possible an exact measurement was taken with a measuring tape for low nests. We measured the circumference of the nest tree at 1.3 m to calculate Diameter at Breast Height (DBH) according to the formula:

$$DBH = \frac{Circumference}{\pi}$$

We recorded the number of branches on which the nest was built (other than the trunk), the orientation of the nest in relation to the trunk, the distance between the nest and the trunk, and the leaf cover within 20 cm over the nest. Second, for the habitat characteristics, all trees within a 5 m radius plot around the nest tree were counted, identified to species, and measured for DBH. All stems with a diameter larger than 3 cm were considered trees, while smaller stems (woody) were counted as saplings. In addition we estimated ground cover, shrub cover, and shrub height, and recorded the number of dead standing snags. Canopy cover was estimated using a densiometer and canopy height was measured with a clinometer (Figure 8).

Basal area (BA) was calculated for each tree in each plot according to the formula:

$$BA = \pi \cdot (\frac{DBH}{2})^2$$

The basal area per hectare was determined by adding all of the tree's basal areas and dividing by the area of the plot (= 78.54 m^2).

2.5 Breeding density

Breeding density of LEFLs was estimated by Jon Van Arragon who conducted a breeding bird census (Van Arragon, 2022). The breeding bird census method is used at BBO yearly since 2015 to map territories and estimate breeding densities of bird species breeding in the Beaverhill Natural Area.

Figure 8: (A) Clinometer, (B) Densiometer and (C) plot of 5 m radius around nest tree with blue flagging.

Breeding territories of LEFLs were mapped based on singing individuals, observed by following a 10x10 point grid within a 25 ha (= 0.25 km^2) census area which is located within our study area. Individual points were located 50 m apart and the survey was replicated 6 times between June 8 and July 12. Locations of detected LEFLs were recorded on a map of the grid, as well as the method of detection (song, call, or sight). Territory boundaries were established based on the locations of countersinging individuals (birds singing in response to singing neighbours of the same species). Breeding density was calculated by dividing the number of territories by the census area.

2.6 Analyses

We performed statistical tests for the effect of nest site and habitat characteristics on the predicted clutch size, brood size, number of fledglings, and the nest outcome. The following statistical tests were performed in SPSS version 28.0.1.1 (14) using the 0.05 significance threshold (Table 1).

Table 1: Overview of the statistical tests performed in SPSS. We performed Independent samples t-tests, Pearson correlation tests, and Chi-square tests.

	Predicted clutch size	Brood size	# Fledglings	Outcome
Nest site				
Host tree species	t-test	t-test	t-test	Chi-square
Alive/dead	t-test	t-test	t-test	Chi-square
Dbh nest tree	Correlation	Correlation	Correlation	t-test
Height of nest	Correlation	Correlation	Correlation	t-test
Height of nest tree	Correlation	Correlation	Correlation	t-test
# Branches	Correlation	Correlation	Correlation	t-test
Nest cover	Correlation	Correlation	Correlation	t-test
Habitat				
Total Basal area	Correlation	Correlation	Correlation	t-test
Basal area for aspen	Correlation	Correlation	Correlation	t-test
Basal area for balsam	Correlation	Correlation	Correlation	t-test
Total # trees in plot	Correlation	Correlation	Correlation	t-test
Dominant species	t-test	t-test	t-test	Chi-square
Shrub cover	Correlation	Correlation	Correlation	t-test
# Dead snags	Correlation	Correlation	Correlation	t-test
Canopy height	Correlation	Correlation	Correlation	t-test
Ground cover	Correlation	Correlation	Correlation	t-test
Canopy cover	Correlation	Correlation	Correlation	t-test
Check for consistency				
Total # saplings	Correlation	Correlation	Correlation	t-test
# Aspen saplings	Correlation	Correlation	Correlation	t-test
# Balsam saplings	Correlation	Correlation	Correlation	t-test
# Aspen trees	Correlation	Correlation	Correlation	t-test
# Balsam trees	Correlation	Correlation	Correlation	t-test

3 Results

3.1 Nest searching

We found 34 nests of which 28 were monitored with the pole camera (Figure 9). Out of the 6 nests that were not monitored, 3 nests were old (i.e. from 2021), and 3 nests were too high for the pole camera to reach.

Figure 9: Location of the nests found in our study area (red dots).

3.2 Nest monitoring

Clutch size Clutch size was determined for 15 nests of which 2 nests had a clutch size of 5 eggs, 11 a clutch size of 4 eggs, and another 2 nests a clutch size of 2 eggs (Figure 10). Clutch size was not determined for 13 nests. Assuming that the number of eggs equals the number of young, we inserted the brood size for these nests (predicted clutch size) and expanded our sample size for analysis of clutch size and habitat parameters.

Out of 28 nests, 5 nests had a predicted clutch size of 5 eggs, 17 nests of 4 eggs, 4 nests of 3 eggs, and 2 nests of only 2 eggs (Figure 11). Overall, we found a mean clutch size of 3.87 (SD = 0.83) and mean predicted clutch size of 3.89 (SD = 0.79). Since these values were so similar, we continued to use predicted clutch size in our further analyses.

Brood size and number of fledglings Off all nests, 5 nests produced 5 young, 14 nests 4 young, 4 nests 3 young, and 1 nest had only 2 young (Figure 12). Out of the 28 nests, 4 nests failed at the egg stage and did not produce any young. Twelve nests produced 4 fledglings, while 5 nests produced 5 fledglings, and another 5 nests only 3 fledglings (Figure 13).

There were 2 nests that failed during the nestling stage, adding with the 4 nests that did not produce any young to 6 nests that did not produce any fledglings. Overall, we found a mean brood size of 3.39 (SD = 1.57) and a mean number of fledglings of 3.14 (SD = 1.78).

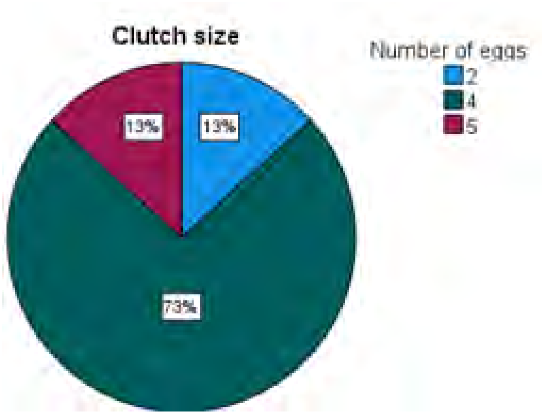

Figure 10: Pie chart for clutch size (N = 15).

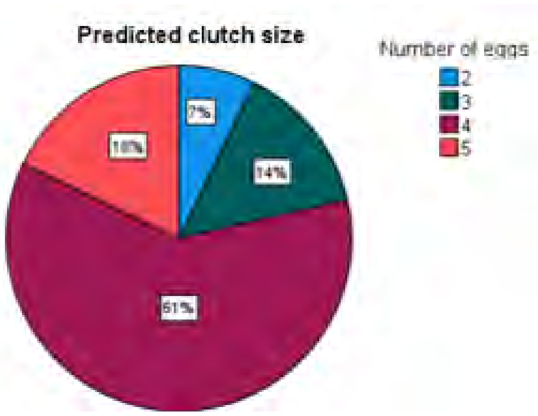

Figure 11: Pie chart for predicted clutch size (N = 28).

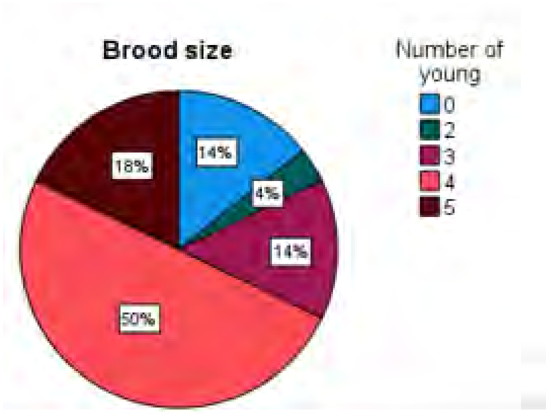

Figure 12: Pie chart for brood size (N = 28).

Figure 13: Pie chart for the number of fledglings (N = 28).

Figure 14: Nest monitoring with the pole camera, obtaining data on clutch size and brood size, and following the nest up until fledging or nest failure. From left to right, top to bottom: clutch size of 4, nest with hatchlings, nest in which the young were 2 days old, 3 days old, 4 days old, 5-7 days old, 8-10 days old, 11-12 days old, and a successful empty nest.

Nest outcome Out of the 28 monitored nests, 22 nests were successful which was a success rate of 79% (Figure 15). Of the nest failures (6 nests), 2 nests had cowbirds eggs, 1 nest failed due to house wren predation, and 3 nests failed from unknown causes (Figure 17). In the 22 successful nests, all young that hatched also fledged.

3.3 Habitat and nest site measures

Nest site The majority of our nests were located in Trembling Aspen trees and the others were located in Balsam Poplar trees (Figure 16). Of the nests that were in an Aspen tree, 76% were successful and 24% were failures. Of the nests in a Balsam tree, 85% were successful and 15% were failures. However, there was no significant association between nest tree species and nest outcome.

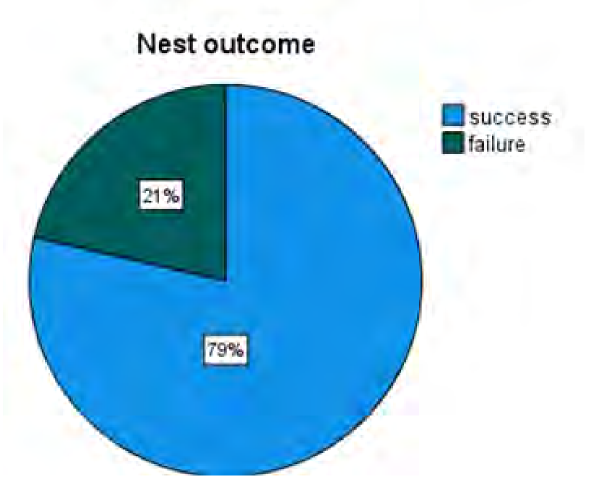

Figure 15: Pie chart for nest outcome.

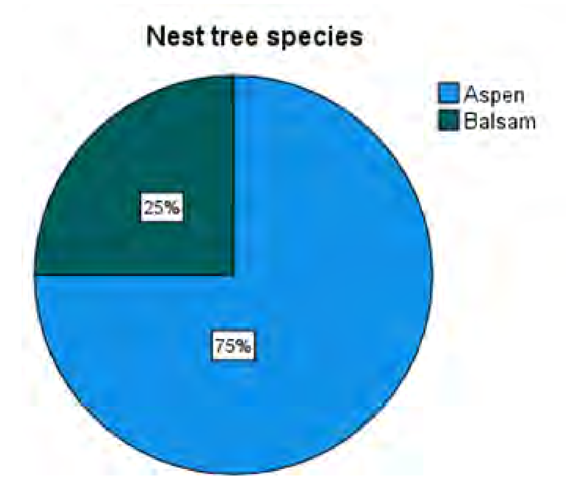

Figure 16: Pie chart for nest tree species (N = 28).

Figure 17: (A) nest with a cowbird egg, (B) nest predated by house wrens and (C) nest with dead hatchling.

Of the nests that were in living trees (93%), 79% were successful and 14% were failures. There were no successful nests in dead trees. We found a significant relationship between tree status and the brood size as well as the number of fledglings. Brood size was higher in living trees (mean = 3.58, SD = 1.45) than in dead trees (mean = 1.00, SD = 1.41; t = 2.43, p = 0.022), and the number of fledglings was higher in living trees (mean = 3.38, SD = 1.60) than in dead trees (mean = 0.00, SD = 0.00; t = 2.94, p = 0.007). In addition, there was a significant association between tree status and the nest outcome (χ^2 = 7.90, p = 0.040) with more successful nests being in live trees (79%; compared to no successful nests in dead trees). There was no significant relationship between tree status and the predicted clutch size.

We found a mean nest height of 3.63 m (SD = 1.67), a mean height of the nest tree of 10.14 m (SD = 2.41), a mean DBH of the nest tree of 9.85 cm (SD = 2.87), and a mean cover over the nest of 7% (SD = 14.15; Table 2). We did not find a significant difference in these variables between nests found in Aspen or Balsam trees. There was a significant association between the height of the nest tree and the nest outcome (p = 0.021, t = 2.46), with more successful nests in higher trees (mean = 10.67, SD = 2.13) compared to failures (mean = 8.17, SD = 2.55). There was no significant relationship between height of the nest tree and the predicted clutch size, the brood size, and the number of fledglings. We did not find a significant association between the other nest site variables (host tree species, height of the nest, DBH of the nest tree, number of branches, and nest cover) and the predicted clutch size, brood size, number of fledglings, or nest outcome.

Habitat We found a mean canopy height of 12.47 m (SD = 1.53), a mean canopy cover of 98% (SD = 2.72), a mean shrub cover of 8% (SD = 8.10), and a mean ground cover of 95% (SD = 13.74). The mean total basal area of trees was 29.22 m² per hectare (SD = 11.05). The mean number of trees in the plots was 22 (SD = 7.53), the mean number of saplings in the plots was 15 (SD = 11.34), and the mean number of snags in the plots was 10 (SD = 5.61; Table 3).

We did not find a significant relationship between any of the habitat variables (canopy height, canopy cover, shrub cover, ground cover, total basal area, total number of trees, total number of saplings, and number of dead snags) and the predicted clutch size, brood size, number of fledglings, and the nest outcome.

When the nest was in an aspen tree, the mean number of aspen trees within the 5 m radius plot was higher than the mean number of balsam trees (19:4; Table 4). When the nest was in a balsam tree, the reverse was true: the mean number of balsam trees in the plot was higher than the mean number of aspen trees (14:3).

Table 2: Mean and std. deviation of the nest height, height of the nest tree, DBH of the nest tree, and cover over the nest.

Tree species		Nest height (m)	Height nest tree (m)	DBH nest tree (cm)	Cover nest (%)
Aspen	Mean	3.50	9.88	8.88	4.29
	Std. Deviation	1.81	2.65	2.46	11.94
Balsam	Mean	3.99	10.89	12.75	13.21
	Std. Deviation	1.22	1.34	1.99	18.86
Total	Mean	3.63	10.14	9.85	6.52
	Std. Deviation	1.67	2.41	2.87	14.15

Table 3: Mean and std. deviation of canopy height, canopy cover, shrub cover, ground cover, total basal area, total number of trees, total number of saplings, and the number of dead snags in the 5 m radius plot.

Tree species		Canopy height (m)	Canopy cover (%)	Shrub cover (%)	Ground cover (%)
Aspen	Mean	12.68	98.59	6.07	99.52
	Std. Deviation	1.69	1.80	6.96	2.18
Balsam	Mean	11.82	95.69	13.21	80.00
	Std. Deviation	0.62	3.88	9.43	22.36
Total	Mean	12.47	97.86	7.86	94.64
	Std. Deviation	1.53	2.72	8.10	13.74
		Total BA (m^2 per hectare)	# Trees	# Saplings	# Dead snags
Aspen	Mean	29.54	23.52	13.48	10.90
	Std. Deviation	11.55	7.26	12.20	4.66
Balsam	Mean	28.23	16.71	19.29	5.29
	Std. Deviation	10.18	6.21	7.32	6.45
Total	Mean	29.22	21.82	14.93	9.50
	Std. Deviation	11.05	7.53	11.34	5.61

The mean total number of aspen trees in the 5 m radius plot was 15.11, while the mean total number of balsam trees was 6.71. The mean number of aspen saplings was 12.82 which is higher than the mean number of balsam saplings (2.11).

We found a significant negative association between the total number of saplings and the brood size (p=0.016, r = -0.451), but not for the predicted clutch size, the number of fledglings, and the nest outcome. When separating the number of saplings by tree species, we only found a significant association between the number of aspen saplings and the brood size (p=0.044). We did not find any significant relationship between the number of aspen or balsam trees within the 5 m radius plot and the productivity variables.

3.4 Breeding density

We found 99 LEFL territories in the census area (Appendix 2). This is equal to a breeding density of 396 territories per km^2 or 4.0 territories per hectare.

Table 4: Mean and std. deviation of the number of aspen trees and saplings; and the number of balsam trees and saplings in the 5 m radius plot.

Tree species		# Aspen trees	# Balsam trees	# Aspen saplings	# Balsam saplings
Aspen	Mean	19.10	4.43	10.86	2.62
	Std. Deviation	8.81	5.12	11.39	3.25
Balsam	Mean	3.14	13.57	18.71	0.57
	Std. Deviation	6.18	4.96	7.68	0.98
Total	Mean	15.11	6.71	12.82	2.11
	Std. Deviation	10.74	6.42	11.01	2.97

Table 5: Summary of the statistical outcomes of the testing variables on the predicted clutch size, brood size, number of fledglings and nest outcome.

	Predicted clutch size	Brood size	# Fledglings	Outcome
Nest site				
Host tree species	NS	NS	NS	NS
Alive/dead	NS	$p = 0.022$	$p = 0.007$	$p = 0.005$
DBH nest tree	NS	NS	NS	NS
Height of nest	NS	NS	NS	NS
Height of nest tree	NS	NS	NS	$p = 0.021$
# Branches	NS	NS	NS	NS
Nest cover	NS	NS	NS	NS
Habitat				
Total Basal area	NS	NS	NS	NS
Basal area for aspen	NS	NS	NS	NS
Basal area for balsam	NS	NS	NS	NS
Total # trees in plot	NS	NS	NS	NS
Dominant species	NS	NS	NS	NS
Shrub cover	NS	NS	NS	NS
# Dead snags	NS	NS	NS	NS
Canopy height	NS	NS	NS	NS
Ground cover	NS	NS	NS	NS
Canopy cover	NS	NS	NS	NS
Check for consistency				
Total # saplings	NS	$p = 0.016$	NS	NS
# Aspen saplings	NS	$p = 0.044$	NS	NS
# Balsam saplings	NS	NS	NS	NS
# Aspen trees	NS	NS	NS	NS
# Balsam trees	NS	NS	NS	NS

4 Discussion

We assessed productivity of LEFLs in the Beaverhill Natural Area and aimed to understand habitat preferences in relation to breeding success. We recorded a nest success rate of 79%, which is much higher than success rates recorded in other studies in North America (Michigan 52%; Quebec 53%; Delta Marsh 38%; Briskie & Sealy, 1989b; Darveau et al., 1993; Tarof & Briskie, 2020). The high success rate we observed might be a result of the high food availability in the Beaverhill Natural Area. Local insect abundances have likely increased since 2016 when Beaverhill Lake started to fill again after drying up in 2005. A continental review of clutch size in Tree Swallows *Tachycineta bicolor* showed that clutch size increased with latitude, with the Beaverhill Natural Area close to the maximum clutch size (Dunn et al., 2000). The larger clutches were correlated with high summer evapotranspiration as a measure of terrestrial primary productivity which was assumed to be correlated with resource abundance. The high insect abundances in combination with long day lengths optimized breeding conditions, resulting in high success rates and breeding densities of Tree Swallows (Hussell, 1985). Similarly, breeding conditions (day length and food abundance) in the Beaverhill Natural Area might be optimal for LEFLs and could explain the high success rate we observed.

In addition, the breeding density of 4.0 territories/ha found in our research area is double the magnitude of breeding densities recorded in other studies (Michigan 2.0; New Hempshire 1.4; Minnesota 1.5; Virginia 2.0-3.0; Ontario 1.5; Darveau et al., 1993; Tarof & Briskie, 2020) and likely reflects good breeding conditions in the Beaverhill Natural Area. Our study shows no evidence for any clustered breeding, a well-documented breeding behaviour for Least Flycatchers (Tarof & Ratcliffe, 2000; Tarof, 2001; Perry & Andersen, 2003; Perry et al., 2008). Possibly, the 33 nests found in our research area are part of one big cluster, since clusters of up to 30 territories have been observed in previous studies (Tarof et al., 2005).

We recorded an average clutch size of 3.89, which is comparable to the average clutch size found in other studies across North America (Michigan 3.95; Quebec 3.97; Delta Marsh 3.92, Winnipeg 3.89, Ontario 3.41; Briskie & Sealy, 1989a; Darveau et al., 1993; Tarof & Briskie, 2020). Hatching success is generally high for LEFLs and this is also observed in the Beaverhill Natural Area.

Overall, nest sites were characterized by dense canopy cover and low shrub cover, and this is similar to earlier studies finding LEFLs nesting in semi-open, mid-successional deciduous forests with moderate understories and well developed canopies (DellaSala & Rabe, 1987; Tarof & Ratcliffe, 2004). Earlier studies showed that habitat changes may influence reproductive success by altering nest concealment or adjusting local insect communities (DesGranges, 1987). Ongoing forest succession in the Beaverhill Natural Area increased suitable habitat for LEFLs over the past years and may contribute to the high breeding density and high productivity found in our study area.

We found a significant association between nest outcome and height of the nest tree as well as tree status, with more successful nests in higher trees compared to lower trees and in living trees versus dead trees. In addition, there was a significant relationship between tree status and the brood size as well as the number of fledglings. Brood size and the number of fledglings were larger in live trees, likely because live trees provide more cover than dead trees. No significant relationships were found between nest outcome and the other habitat variables included in our study. However, we acknowledge that our sample size of 28 monitored nests is small and future studies in our research area should do similar analyses with a larger sample size to obtain greater statistical power. To get a better understanding of habitat in relation to breeding success, future research should compare productivity and habitat variables in low density versus high density sites, and between sites of high failure and low failure rates, as well as include food availability measures.

The conservation of this declining aerial insectivore will depend on the management of its habitats throughout its annual movements. In Canada, if the Least Flycatchers continue to decline, researchers will need to identify the species' critical habitat according to the Species at Risk Act. We suggest that habitats with high density of nesting LEFLs that are highly productive should be used to define its critical habitat. The data that we have presented shows that the Beaverhill Natural Area would qualify as critical habitat for LEFLs. We suggest that this one year study be repeated and that other studies should be conducted elsewhere to identify similar productive habitat for this species as well as for other species, before they reach an endangered status which increases the difficulty of obtaining useful productivity information.

5 Conclusions

We found a high nest success rate as well as a high breeding density of LEFLs in our research area, suggesting that the Beaverhill Natural Area is a good breeding habitat for LEFLs. More research is needed on why nesting success and breeding density are so high compared to other areas. Our findings indicate that the Beaverhill Natural area is an important area for LEFL conservation and should be identified as critical habitat for this species.

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Appendices

Appendix 1: Information collected on nest cards.

Appendix 2: Map of LEFL territories.

Appendix 1: Information collected on nest cards.

We collected the following information on visitor status, nest outcome and habitat according to the Prairie Nest Records Scheme Coding System.

Visitor status	
Adult activity	**Nest building stage**
Adult/Male/Female/Pair - On/at/flushed from nest - In vicinity of nest - Building nest/ carrying nest material - Feeding young at nest	- Nest site empty - Nest $\frac{1}{4}$ built - Nest $\frac{1}{2}$ built - Nest $\frac{3}{4}$ built - Nest complete
Eggs	**Young**
- Number of eggs - Covered/uncovered - Hatching - Cowbird egg present/absent - House wren indications present /absent	- Number of young - Naked - Downy - Blind - Eyes open - Primary feathers in pin - Primary feathers short; less than 1/3 emerged from sheath - Primary feathers medium; 1/3 - 2/3 emerged from sheath - Primary feathers large; more than 2/3 emerged from sheath - Ready to fledge - Left naturally before fledging - Fledged

Nest outcome
Success
- Adult carrying food near nest
- Adult visibly agitated or giving alarm calls near nest
- Hatched shell fragments in empty nest
- Nest empty, undisturbed with well-trodden lining containing feather scale and/or droppings
- Fledged young seen near nest
- Young seen fledging
- Young capable of leaving nest on previous visit
- Some young fledged, other live young still in nest
Failure **At egg stage / young stage / unknown stage**
- Eggs not hatched
- Eggs injured/broken
- Eggs killed/thrown out by cowbird
- Eggs killed by house wren
- Eggs deserted/starved/dead
- Empty damaged nest
- Empty undamaged nest
- Predation
- Thrown/fallen out
- Wind damage
- Eggs covered with new layer

Habitat	
Class	**Sub-class**
	- Deciduous
- Woodland	- Coniferous
	- Mixed
Structure	**Modification**
- Young	
- Mature	
- Mixed age	
- Old Growth	
- Closed canopy	
- Open canopy	
- Parkland (trees scattered in grassy areas)	- No human disturbance
- Wet/ standing water present	- Human disturbance light to moderate
- Standing dead trees present	- Human disturbance heavy
- Fallen dead wood present	
- No understory	
- Grass/fern/herb layer present	
- Low shrub layer (<2m)	
- Tall shrub layer (>2m)	
- Very low shrub layer (<1m)	

Appendix 2: Map of LEFL territories.

Map of Least Flycatcher territories (big circles) found in our census area in 2022 based on counter singing individuals.