POSSIBLE INFLUENCE OF SEASONAL PRECIPITATION ON THE REPRODUCTIVE SUCCESS OF TREE SWALLOWS (*TACHYCINETA BICOLOR*) OVER THE YEARS AND THE IMPORTANCE OF STANDARDIZED DATA FORMAT OVER THE YEARS

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Abstract

Seasonal weather patterns have become increasingly more extreme and unpredictable over the years due to the worldwide effects of anthropogenic climate change. Adverse weather conditions are known to influence the behavior of migratory bird species in both breeding and non-breeding seasons. During breeding seasons, not only do these conditions affect the reproductive output of the adults, but they can also induce longer-term effects during the post-hatch parental care period. Tree swallows (*Tachycineta bicolor*) are a model migratory bird species popular among ornithology researchers, but studies regarding climatic effects on the behavior of this taxon remains relatively scant. Tree swallow surveys carried out annually by the Beaverhill Bird Observatory during the breeding season might offer useful data for this line a research. A simple linear regression analysis from data compiled from 2014 to 2019 showed a strong positive correlation but this relationship was statistically insignificant. While other studies of other swallow and migratory bird species have established some effects between precipitation and reproductive success, more in-depth studies are required to establish a proper cause-effect relationship between these two variables in this species. The inconclusive results suggest that the methodology used was not an ideal way to utilize the data at hand. An improved historical data record with more years and more clarity is essential given that some records in recent years contain conflicting or ambiguous data.

INTRODUCTION

A growing body of research in the past two decades have suggested that major climatic shift in the Canadian prairies, including Alberta, is inevitable even if carbon emissions are slashed (Li et al. 2000; Lemmen et al. 2004; Schneider et al. 2009). The rate that the climate is changing is abnormally rapid and even unprecedented in the Earth's history (Zeebe et al. 2016), threatening not only our ways of lives but also the survival of other species in the biosphere (Thomas et al. 2004). An understanding of how climatic and seasonal variables, such as temperatures, humidity, and precipitation, affect the species survival in this changing time is vital for future conservation. Long-term studies in zoology and ecology is an option to improve our understanding of this matter. The amount of data that spans across years or decades required for these studies can only be found in established wildlife observatories such as the Beaverhill Bird Observatory (BBO), which was established in 1984. This is the second oldest migration monitoring observatory in Canada. Located within the Beaverhill Natural Area, the BBO boasts extensive long-term datasets that track changes in a variety of avian species such as populations, migration, and reproductive success (McGregor 2001). The tree swallow (*Tachycineta bicolor*) (Figure 1) is one such species that has been monitored by the BBO since its establishment.

Tree swallows are a species of migratory songbird popular among researchers since it is willing to use nest boxes, tolerates considerable human disturbance, and can return to breed repeatedly in old colonies (Kuerzi 1941). This species migrates to northern prairies like Alberta during spring-summer to breed and heads down to Central America before winter comes (Kuerzi 1941). These birds come back to the Beaverhill Natural Area every year to breed and get monitored by the BBO from May to early August. Eggs are usually laid in clutches of 4-7 and hatched after 14-15 days of incubation (Kuerzi 1941). Nestlings mature and fledge after 18-22 days (Kuerzi 1941). Both parents are involved in parental care, although incubating and brooding is still a duty exclusive to the female (Kuerzi 1941).

In literature, rainfall patterns have been known to leave potential consequences on the reproductive success of passerine birds, including other swallow species (Faaborg et al. 1984; Evans et al. 2000; Öberg et al. 2015). Rainfall can cause changes in prey activity, foraging patterns, and energy demands (Öberg et al. 2015). Other swallows have been known to halt foraging completely during rain (Evans et al. 2000). Heavy or persistent rain can cause more severe consequences such as stunted juvenile growth or increase offspring mortality due to heat loss (Öberg et al. 2015). Furthermore, sometimes predator activity could also change due to rain. Some rodents are common nest predators of swallows and they have been reported to increase their activity during rain (Vickery and Bider 1981). With such exhaustive documentation in the literature on rainfall's importance, information on the relationship between rainfall and the tree swallow's reproduction is required for predicting how this species will respond in the face of on-going climate change. This relationship is especially relevant since Alberta has been swinging back and forth between different weather extremes, with 2016 and 2019 being record-breaking wet years intersected with the relatively dry 2017 and 2018. I hypothesized that high rainfall would have a negative effect on the reproductive success of the tree swallows. This relationship would translate to relatively lower reproductive success during wet summers. One of the most commonly used parameters to determine reproductive success in this tree swallow population is the clutch size (Giacobbo 2014; Schnierer 2017; Walker 2017). Yet, there are alternative parameters that could be used to evaluate success in a different perspective. Fledging success, for example, is a great parameter in assessing reproductive success since it accounts for the 18-22 days long period of post-hatch parental care (Gates 2007) and reflects more accurately on whether the parents have successfully passed on their genes. Some previous studies on the population at the BBO have looked at the relationship between precipitation and fledging success but they were limited to comparing two specific years (Priddle 2015; Schnierer 2017). This study aims to determine a reproductive pattern from 2014 to 2019 and serves as a stepping stone for larger projects.

Figure 1. A female tree swallow incubating her eggs in a nest box. Beaverhill Natural Area

MATERIALS AND METHODS

Study site

This study was conducted near the Beaverhill Natural Area. A total of 65 nest boxes belong to the road grid, which is one of BBO's three swallow grids. These boxes were installed on the fence posts along Township Road 510 and Range Road 183, east of Tofield, Alberta (Figure 2). The wooden boxes are approximately 1 m above the ground and were separated from the road by a drainage ditch. Distance between each box varied between 10 m to 20 m. Each box has a removable lid for human survey normally secured by a metal wire and a small entry hole for the birds that blocks access of most predators. However, some nest predators like mice and weasels can still access the box (Dunn 1977). The only known frequent nest predator record in 2019 data and the historical data is the deer mouse (*Peromyscus maniculatus*). Sometime within June 24th – 25th a common raven (*Corvus corax*) or raccoon figured out how to unwrap the metal wire to open the box's lid. They succeeded in opening 10+ boxes and resulted in the loss of at least 28 swallow nestlings.

Figure 2. The location of road grid (red) in relation to Tofield and Beaverhill Bird Observatory (light green tree). © Maxar Technologies 2019

Tree Swallow Data Collection

2019 dataset

The nest boxes were surveyed weekly on weather-permitting days from May 18th, 2019 to July 28th, 2019. Two last nests that fledged after July 28th was surveyed by BBO's staff.

The following data was recorded and monitored: species of nest builder, nest building stage, presence of adults at the time of the survey, number of eggs or nestlings, and egg temperature or age of nestling. Each nestling was banded when they were around 12 days old. After banding, the nestling was left undisturbed to avoid early fledging. On the 30th day since the nestling hatched, the nest was surveyed again to assess the fledging result and to have the box cleaned in preparation for the breeding season next year. Fledging success was determined by the presence of fecal waste in the nest, which were no longer cleaned by the parents close to fledging day (Weatherhead 1984).

Mountain bluebird (*Sialia currucoides*) (Figure 3) and house wren (*Troglodytes aedon*) are known to sometimes occupy boxes on the grid as well. These birds were monitored using the same procedure.

Figure 3. A mountain bluebird nest at the road grid on June 2019.

2014 – 2018 dataset

Historical data from 2014 - 2018 collected by past interns were supplied by Sara Pearce Meijerink, BBO's head biologist. Only data from 2015 was missing.

Precipitation Data

Raw data on daily rainfall was recorded by the Shonts AGCM station (Figure 4) of Agriculture Alberta. This station is situated near Range Road 182, approximately 5 km from the surveyed grid. Precipitation was measured using an all-season weighing type gauge (Precipitation Weighing) ('Alberta Climate Information Service (ACIS)' 2019). Monthly precipitation total was calculated in Microsoft Excel because the monthly value available on ACIS is computed and not actual measured data (Supplementary Data 1).

Figure 4. Shonts AGCM station where precipitation data was obtain. © ACIS

Statistical Analyses

An analysis that could tease out a relationship between fledging success and rainfall would have been an ideal way to examine the relationship posited in the hypothesis. Although retrieving fledging success from the 2019 data was a simple process, attempts to reliably gather this information from the provided historical data proved difficult. Instead, the opposite value of fledging success - reproductive failure, which includes every nest that did not make it to fledging - was easier to identify and, thus, chosen as the parameter for the analysis (Supplementary Data 2).

A linear regression analysis was performed using Microsoft Excel to determine a cause-effect relationship between precipitation and reproductive failure. Since the number of occupying tree swallows varies year over year, the reproductive failure rate was used to prevent unequal sample size bias. This value is calculated as the ratio between the number of failures over the number of occupied boxes/number of nests made (Supplementary Data 3). Data from other bird species were excluded. Known isolated incidents that resulted in the reproductive failure of many nests, such as the predator incident in June 2019, were excluded as well.

To track changes as rainfall increased over time, two separate regressions were calculated for accumulated data after June (May -> June) and after July (May -> July). There were little precipitation and almost no reproductive failure in May to warrant one more regression (Supplementary Data 2).

RESULTS

A simple linear regression on data from May to June found a strong positive (r=0.616) correlation but an insignificant regression equation ($F(1,3)=1.830$, $p > \alpha=0.05$) with an R^2 of 0.379 (Figure 5).

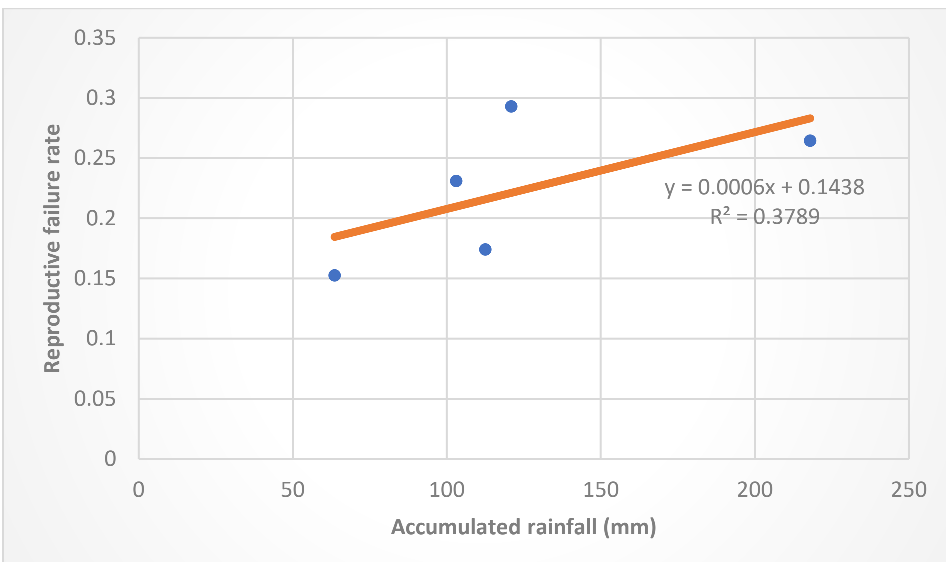

Figure 5. A scatterplot showing how reproductive failure rate from May to June correlate with accumulated rainfall (mm) over years. The trendline shows a positive linear relationship and a linear regression equation.

A simple linear regression on data from May to July found a weak negative (r=-0.307) correlation and an insignificant regression equation ($F(1,3)=0.313$, $p > \alpha=0.05$) with an R^2 of 0.265 (Figure 6). July 2018 saw 16 nest failures, which is twice the total July failures of the other 3 years combined and made the failure pattern in 2018 not follow the shape of patterns in other years (Figure 7).

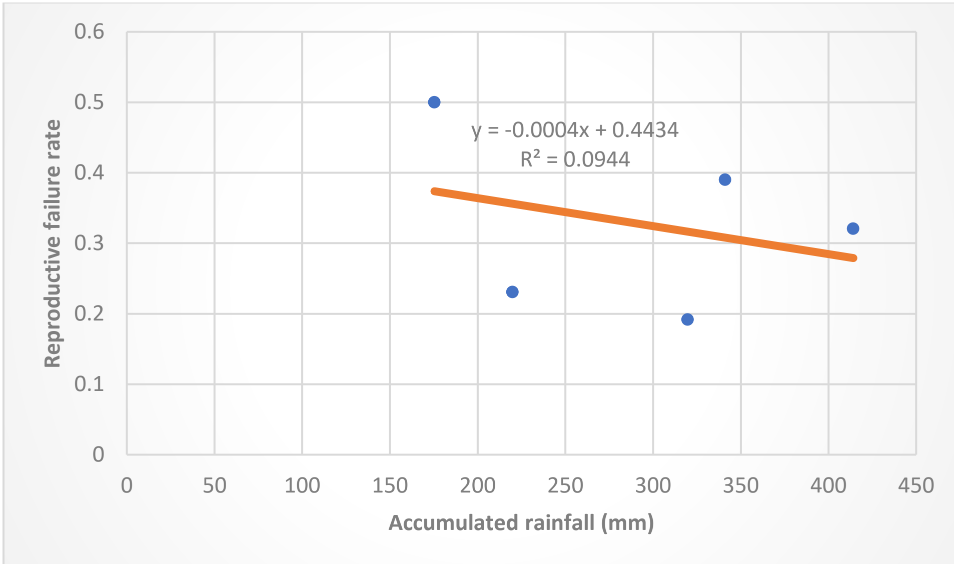

Figure 6. A scatterplot showing how reproductive failure rate from May to July correlate with accumulated rainfall (mm) over years. The trendline shows a negative linear relationship and a linear regression equation.

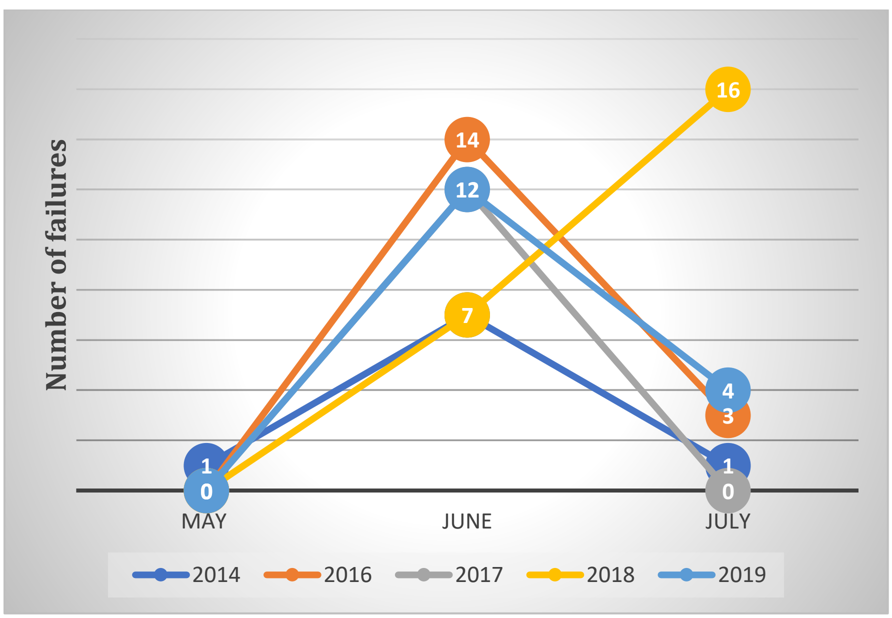

Figure 7. A line chart showing the patterns of reproductive failure throughout the tree swallow's breeding season. Most years had their mortality peaked on June except for 2018.

To exclude the July 2018 outlier, another simple linear regression was performed with the 2018 data excluded. The analysis found a moderately positive ($r=0.515$) correlation but an insignificant regression equation ($F(1,2)=0.721$, $p > \alpha=0.05$) with an $R^2=0.265$ (Figure 8).

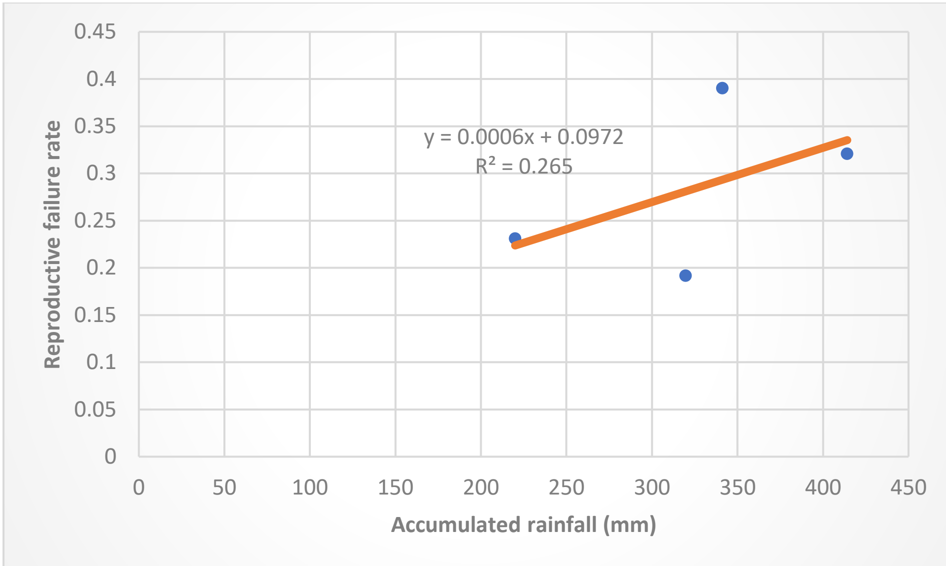

Figure 8. A scatterplot showing how reproductive failure rate from May to July correlate with accumulated rainfall (mm) over years with 2018 data excluded. The trendline shows a positive linear relationship and a linear regression equation.

DISCUSSION

Methodology Review

The results were not statistically significant. The hypothesis was not supported. It was still worthwhile to note that there was a pattern of positive regression between the two variables (Figure 5 & 8), especially once an outlier was removed (Figure 6 & 8). The low sample size used in the analyses might be to blame for the low statistical significance. There were a total of 65 boxes surveyed around 7-8 times each per season for 4 years. The total number of data entries reported from these 4 years is roughly 1,800 entries. The actual sample size was not small, but the decision to group these entries into just 4 samples representing 4 years did not seem to be the intuitive way to make use of the available data. This grouping ultimately gave the outlier from July 2018 too much pull over the entire analysis. Given that the BBO was established 1984 (McGregor 2001), this method might still provide fruitful results in future studies if data from even older years were included. More complex statistical analyses such as the generalized linear mixed models in R employed by Öberg et al. (2015) could also be more suitable than the simple linear regression model used in this report, provided that more detailed parameters can be extracted from the historical datasets.

Historical Datasets Review

It was mentioned earlier in the report that the desired parameter – fledging success – had to be replaced with the reproductive failure rate due to difficulties in retrieving this data from the datasets of previous years. Overall, these datasets differ in which conditions and data were recorded and how they were abbreviated. This difference could result in conflicting interpretation and understanding of the same data from different researchers, especially if some of these previous datasets do not have an associated legend. Future works on standardizing these datasets are required to ensure that the collected data remain useful for future research.

Besides the overall standardizing issue discussed above, each dataset provided for this report also contain some specific details that need to be noted if they were to be used for future studies:

2014 dataset – Fledging success was recorded but scattered among many pages of data. The last survey on August 4th had comments on every nest and appeared to serve as a summary for that breeding season. Further inspection showed that it contradicts with data from the second to last survey on July 10th: some nests that were previously destroyed/abandoned were then listed as "fledged" on August 4th. A few unoccupied boxes were listed as "fledged", too. The only way that could make the last survey's data accurate was to have multiple new nests built with new clutches laid, hatched, and fledged within the 25-day gap between the two surveys. In the absence of supporting evidence for such occurrence, data reported in the last survey was disregarded. Given that Giacobbo (2014) used this dataset for their report in fledging success, it is important to review the data used in the report to see whether it reflects this problematic data.

2016 dataset – No fledging success was recorded. Only 6 nest failures were reported. However, several other nests eggs and/or nestlings under fledging age either vanished (nest reported as empty in the following survey) or got cleaned out within the last two surveys. These eggs/nestlings probably did not survive and were counted as failures as well. All birds that survived past banding age were assumed to have fledged successfully.

2017 dataset – No fledging success was recorded. Two nest deaths were reported. Other detectable reproductive failures were eggs/nestlings under fledging age that vanished in subsequent surveys, similar to the case of the 2016 dataset. All birds that survived past 2-3 surveys were assumed to have fledged successfully, although with less confidence than the birds in the 2016 dataset because no age was reported at any point.

2018 dataset – Fledging success was recorded but scattered among many pages of data. Deaths of eggs/nestlings were extensively documented. The last survey was also problematic in similar ways to the last 2014 survey. Most previously inactive/destroyed/fledged nests were left blank and required scanning through past surveys to identify their statuses. To add more to the confusion, among the boxes listed as "inactive", there were 3 successfully fledged nests and 2 nests with young nestlings recorded in the second to last survey. If these nestlings had been dead by the time of the last survey, it was unknown why their deaths had not been recorded. Two other nests were described to have "blue-green eggs" but were still labelled as tree swallow' nests. This description fits better with the eggs of mountain bluebirds.

CONCLUSION

A positive but statistically insignificant relationship was found between rainfall and the reproductive failure rate of tree swallows over the years. Since a similar pattern has been found in other songbirds taxa, more data from other years could be added in future analyses before a more conclusive answer could be drawn. Gaps and conflicting, unstandardized data from previous years also made it impossible to interpret the success/failure rate without a degree of uncertainty. On the other hand, this problem helps highlight the importance of standardized data format: data should be useful not just for one report but for future research, too.

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Supplementary Data

S1. Precipitation in Beaverhill Natural Area by month and year.

	2014	2016	2017	2018	2019
May	35.3	114.9	31.7	15.9	13.6
June	77.3	103.1	71.4	47.7	107.4
July	207.1	196.204	116.9	111.8	220.2
Total	319.7	414.204	220	175.4	341.2

S2. Reproductive failure of tree swallows at the road grid by month and year.

	2014	2016	2017	2018	2019
May	1	0	0	0	0
June	7	14	12	7	12
July	1	3	0	16	4
Total	9	17	12	23	16

S3. Number of new tree swallow's nests being built per month.

	2014	2016	2017	2018	2019
May	44	51	51	44	35
June	2	2	1	2	6
July	1	0	0	0	0
Total	47	53	52	46	41