May 3rd, 12:00 AM - 12:00 AM

Summer Precipitation Occurrence Effect on Two Passerine Species in Thule, Greenland

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2017

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Introduction

Increase in atmospheric greenhouse gases, such as carbon dioxide and methane, are causing a warming climate by trapping the heat emitted from the Earth (National Research Council 2015). Anthropogenic activities, such as the burning of fossil fuels, have increased these greenhouse gas emissions causing global climate change, with a global average surface temperature increase of 0.8° C since 1890 (National Research Council 2015). Climate change is occurring at a faster rate in the Arctic than the rest of the globe, causing temperature rises at twice the rate of the global average, sea ice decline, glacial ice decline, warming oceanic temperatures, snow cover decline, thawing permafrost, and increased precipitation events in the form of rain instead of snow (Yannic et al. 2014). The region of the Arctic includes areas in Alaska, Canada, Greenland, Iceland, Finland, Norway, Russia, and Sweden, all of which are areas with differing ecosystems and species, which could be impacted differently by the effects of climate change (National Research Council 2015).

Specific occurrences of climate, flora, and fauna, do not occur uniformly throughout the Arctic, since the geographic region of the Arctic itself is vast and does not have definitive boundaries. Scientists have agreed, that a common way of distinguishing areas of the Arctic, such as High and Low Arctic (figure 1), is to do so by using the 10° C summer isotherm (Canadian Arctic 2016). The 10° C summer isotherm boundary is an area where there is an average temperature of 0° C which corresponds with the Arctic tree line boundary as well (Canadian Arctic 2016). Both the 10° C summer isotherm and the tree line boundary do not occur uniformly in regions of the Arctic due to the many different ecological and physical climatic differences throughout the Arctic (Canadian Arctic 2016). These ecological and climatic characteristics may be affected and change in different ways as a result of climate change, causing species to react differently in varying regions throughout the Arctic.

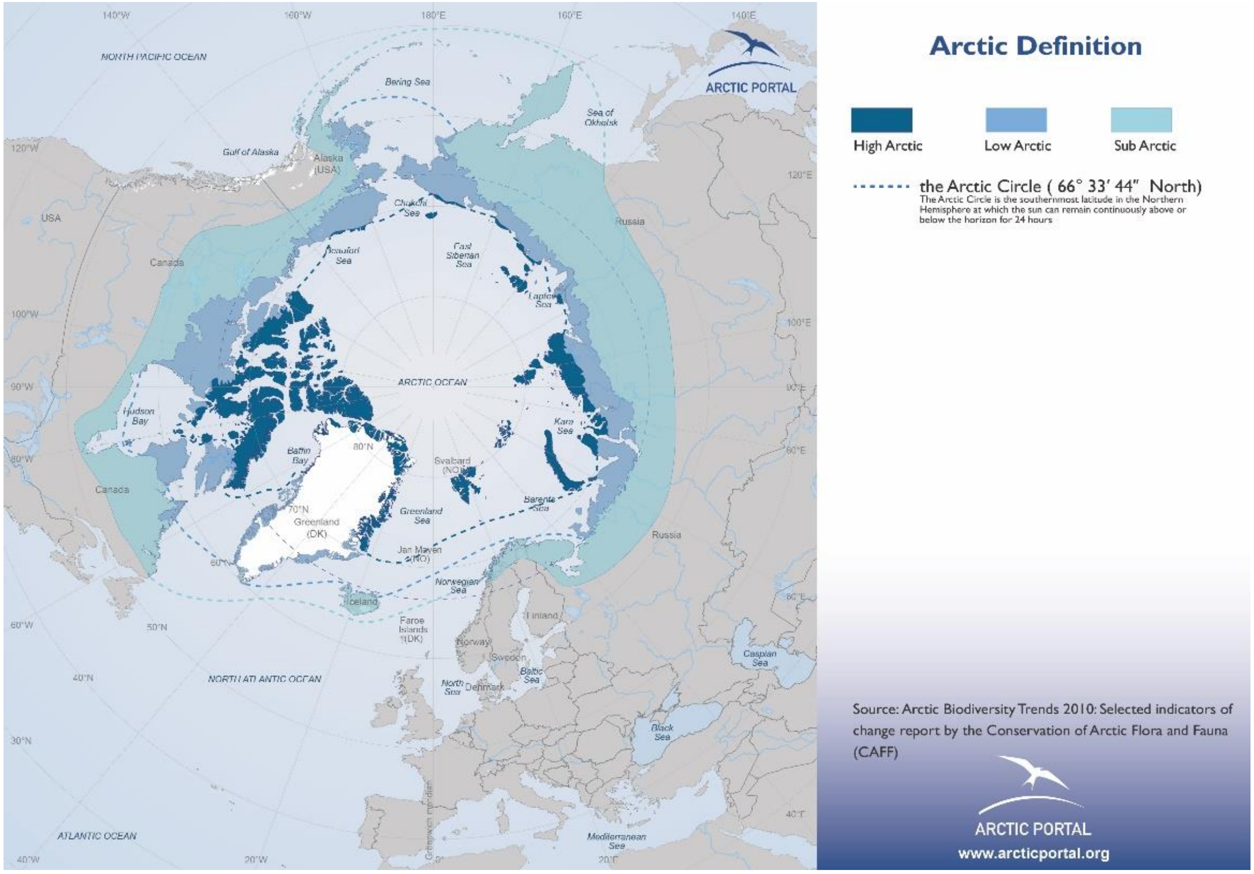

Figure 1 Boundaries of the High, Low, and Subarctic regions of the Arctic. One can observe that the boundaries do not all occur uniformly. Obtained from Arctic Portal 2016.

Increased rain events in particular are predicted to affect migratory bird species that breed throughout the Arctic (Robinson et al. 2014). Arctic bird migration and reproduction is designed to ensure that departure and arrival times are synched with the most favorable times of year which include: moderate climate, optimal food supply, and high nesting availability (Carey 2009). Birds that migrate from all around the globe come to and from the Arctic for the nesting season and rarely stay longer than three months, making the time available for breeding short and decisive for population maintenance and increase (Robinson et al. 2014). Although a warming climate may provide benefits to migratory avian species, like decreased snow cover and warmer temperatures, increased occurrence of heavy rainstorms may indirectly affect the population by impacting distribution and abundance of food supply, and directly by increasing mortality rates of juvenile bird species and overall breeding failure (Yannic et al. 2014). Juvenile birds have a downy plumage, which is poorly insulated and less waterproof than the plumage of adults; therefore, juvenile birds are extremely vulnerable to increased occurrence of summer rain events in the Arctic (Yannic et al. 2014). Juvenile bird species survival rates can have strong effects on wildlife populations, thus, understanding how migratory Arctic bird species respond to climate change requires studying the juvenile population and success rate of birds in differing regions of the Arctic (Dybala 2013).

Several recent studies (e.g. Anctil et al. 2013, Bruggeman et al. 2015, Fossoy et al. 2015, Kruase et al. 2016, Perez et al. 2016, Robinson et al. 2014, and Yannic et al. 2014), conducted in different geographic regions of the Arctic, on different migratory bird species, showed a similar trend of precipitation negatively affecting breeding. Although Arctic migratory species are adapted to harsher environmental conditions, unpredicted rain events occurring more frequently due to climate change, affect the reproductive success of many of these species (Yannic et al. 2014).

Research Questions

In conjunction with the High Arctic Institute and Augustana College, this research aims to answer the question of: Is there a correlation between increased summer precipitation events and the breeding success of Snow buntings (*Plectrophenax nivalis*) and Lapland longspurs (*Calcarius lapponicus)* in Thule, Greenland? The answer to this question would lead to the question of whether this correlation would suggest that climate change is negatively impacting migratory bird species across the Arctic when compared to prior research and literature. For this research, it was hypothesized that summers with larger precipitation events, four weeks before or two weeks after juveniles left the nest, would indicate a late breeding season or failed breeding season. Summers which were drier with fewer precipitation events were predicted to have higher breeding success and more juvenile passerine species observed.

Background

Since 1993, the High Arctic Institute has monitored many species of Arctic birds in northwest Greenland near the Thule Air Base, to see how climate change in the Arctic has affected their survival rates and breeding success. In particular, passerines such as the Snow Bunting (*Plectrophenax nivalis)* and the Lapland Longspur (*Calcarius lapponicus)* have been monitored since 2010. Because these observations have been noted at U.S. Thule Air Base in Greenland (where weather is recorded and monitored daily and is easily accessible) one could compare juvenile populations to the minimum and maximum precipitation amounts during a breeding season to try and find a correlation between increased summer rain events and breeding success. This research can and will build upon prior research conducted in many different geographic locations throughout the Arctic, such as: The west shore of Hudson Bay Canada (Anctil et al. 2013), Nunavut, Canada (Robinson et al. 2014), Northeastern Greenland (Yannic et al. 2014), and the Brooks Range in Alaska (Pérez et al. 2016). Adding to this research can help to show whether increased rain storms are occurring uniformly across the Arctic and if so how these events impact the many different migratory bird species (raptors, shorebirds, and passerines alike) that reside there during the breeding/nesting season. If climate change is impacting migratory bird species, the effect could trickle down the rest of the food chain and therefore affect all ecosystem resilience.

Literature

Arctic ecosystems often have characteristics specific to the harsh conditions of the Arctic, making the species that migrate and breed there sensitive to climate change (Fossoy et al. 2015). Birds that migrate to and reproduce in the Arctic must have well synched arrival and departure times because of the climate, nesting availability, and food supply only available during the warmer seasons (Carey 2009; WWF 2008). A typical breeding season for Arctic migratory birds is three months, making the time for nesting, breeding, and population growth vital for each species (Robinson et al. 2014; WWF 2008). Global climate change is currently causing rapid shifts in temperature while also increasing the occurrence of extreme weather events, such as heavy precipitation (Krause et al. 2016). Extreme weather events represent 5% of recorded weather patterns across the globe and with climate change, this percentage will increase and the duration of these events will also increase (Krause et al. 2016). Unpredictable weather events affect the clutch size and number of fledglings a nest may have because most migratory passerine bird nests in the Arctic are low to the ground with little coverage which may cause higher juvenile mortality rates and breeding failure (Fossoy et al. 2015; Fisher et al. 2015).

The research on the correlation between Arctic summer storms and migratory juvenile bird species mortality has shown two reoccurring trends. First, that it is not the total amount of precipitation of a breeding season that results in juvenile bird species mortality rates, but the occurrence of severe storms that result in significant precipitation in single weather events (Anctil et al. 2013; Yannic et al. 2014). Second, that in times of high stress, like severe storms, adult passerine species abandon their eggs or chicks in favor of self-preservation due to lack of food abundance (Yannic et al. 2014; Pérez et al. 2016).

Breeding Effort

During the breeding season, nestlings are reliant upon parental brooding to maintain a healthy body temperature so when increased precipitation, higher wind speeds, and lower temperatures occur, adult species are required to brood more (Yannic et al. 2014). This decreases the amount of time the adult species have to forage for food for both themselves and their chicks (Yannic et al. 2014). Therefore, poorer weather conditions result in a tradeoff where more energy from the adult species is devoted to self-preservation and foraging for food rather than parental commitment (Pérez et al. 2016).

Heavy Precipitation Events

Strong winds correlated with heavy rain events directly affect the reproductive success of migrating Arctic bird species (Yannic et al. 2014). In a nest observation of Peregrine falcons (*Falco Peregrinus*) near Nunavut, Canada, over one third of nestling mortality rates were caused by heavy rainstorms (Anctil et al. 2013). Cameras set up to record the Peregrine falcon nests showed that weather-related juvenile fatalities occurred during short periods of time, from twenty-four hours to only two hours after the storm event, depending on whether the chicks were brooded or not (Anctil et al. 2013). These observations indicated that the frequency of summer storms had a greater impact on juvenile fatalities than overall precipitation during the nesting season (Anctil et al. 2013). This trend was not only observed in northern Canada but also northeastern Greenland among Ivory gull *(Pagophila eburnean*) populations (Yannic et al. 2014). Two breeding colonies for Ivory gulls located in northeast Greenland experienced close to one hundred percent juvenile mortality rates after heavy rain and wind storms (Yannic et al. 2014). In each of the colonies, the adults abandoned their eggs or chicks during the storms allowing the nests to be vulnerable to the storms (Yannic et al. 2014).

These studies have shown that these heavy rain events are significant to the species survival when they last up to or longer than forty-eight hours (Anctil et al. 2013). However, most studies done on Arctic migratory birds have been done in Low Arctic regions like Alaska, southern Canada, and southern Greenland. The climate conditions in the High Arctic are even harsher than the lower regions of the Arctic, so understanding how High Arctic migratory birds react to extreme weather events is important for creating a broad geographic picture. Observations and juvenile re-capture rates in Thule, Greenland will add to this collection of data to show how these increasing weather events impact passerine species. Juvenile bird species survival rates can have strong effects on wildlife populations, thus, understanding how migratory Arctic bird species respond to climate change requires studying the juvenile population and success rate and will help allow people to manage them in the future (Dybala 2013; Bruggeman et al. 2015).

Methodology

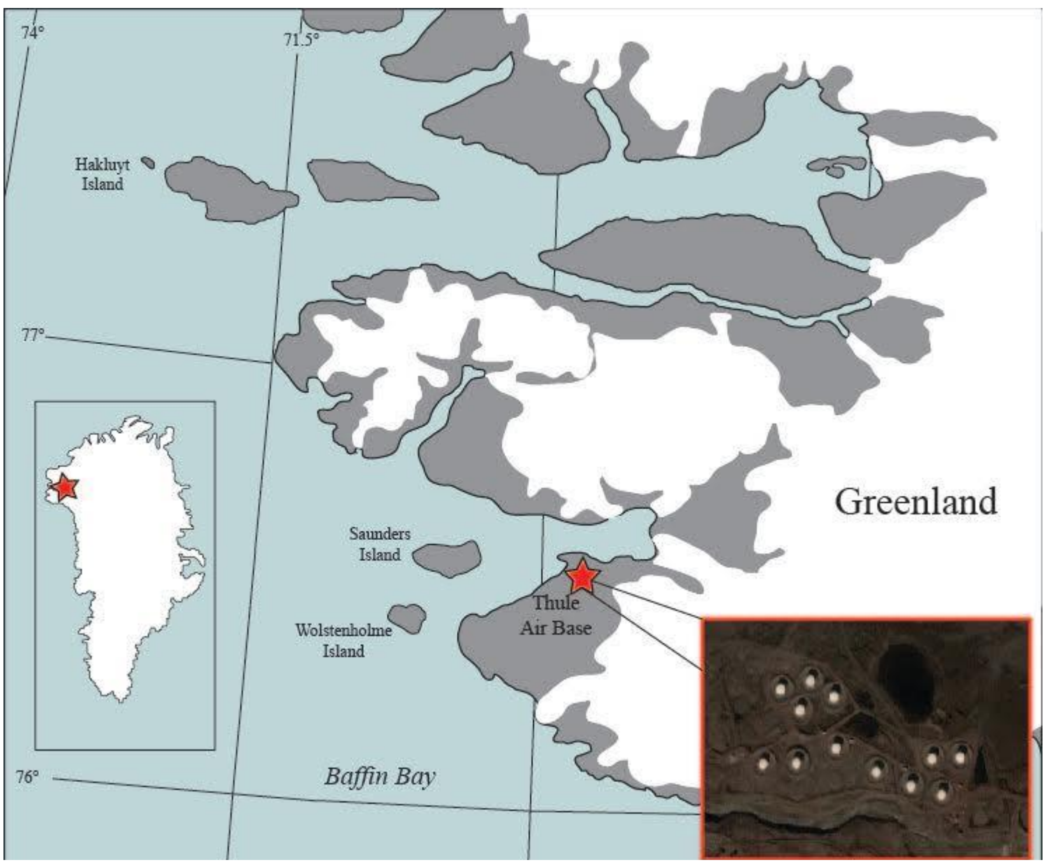

Figure 2. Study area map of Thule, Greenland. This shows where Thule is in relation to the island of Greenland, and where the "tank farm" is located within Thule.

Study Area

For this study, research was conducted at Thule Air Base located in northern Greenland (76.5333° N, 68.7000° W) (figure 2). All research for this project was conducted between the years of 2010 to 2016 during the field season for the months of June, July, and August when nesting and breeding for these two-passerine species (Snow bunting and Lapland longspur) occur. Research collection for weather and passerine trapping was done at Thule Air Base at a location given the nickname the “tank farm” because it is where above ground fuel tanks are stored for the airbase. This site was selected because of the presence of small ponds that attract a relatively high density of passerines compared to the surrounding tundra landscape. Because trapping and data collection was conducted on the airbase, weather data for this research was made accessible, as weather was recorded and monitored daily by airbase personnel.

Weather Data Collection

Thule Air Base weather data was accessed through the National Oceanic and Atmospheric Administration (NOAA) and Weather Underground (WU) daily average, maximum, and minimum temperature and precipitation was recorded for Thule, Greenland every day for the months of March through August from 2010-2016. March through May was recorded for a buffer of weather data to see how temperatures occurring in the spring could affect the summer months (June through August). NOAA weather data was recorded into an Excel file and double checked with data from Weather Underground to make sure there were no errors in the data or to fill in gaps within the NOAA data. The weather data was then used to create several graphs which was compared to the bird trapping data in order to observe correlations.

Passerine Species

The two avian species observed in this study included two common Arctic passerines: the Snow Bunting (*Plectrophenax nivalis*) and the Lapland Longspur (*Calcarius lapponicus*). These two species were chosen due to their similar size, habitats, diet, nest building habits, and because they are both common and easily found at Thule Air Base in northern Greenland.

Lapland Longspur (*Calcarius lapponicus*).

The Lapland Longspur is a medium sized bird (15-16 cm) that breeds throughout most of the Arctic (figure 3) (Hussell and Montgomerie 2002; Salomonsen and Gitz-Johansen 1950). The main arrival of Lapland Longspurs to northern Greenland typically occurs in mid-May and can last until the first part of June, with the male Lapland Longspurs arriving three to six days before females (Hussell and Montgomerie 2002; Salomonsen and Gitz-Johansen 1950). After the birds arrive, courtship and nest building takes place at the end of May/early June and can last up to 18 days with egg laying taking place immediately after (Hussell and Montgomerie 2002; Salomonsen and Gitz-Johansen 1950). Eggs are incubated for ten to thirteen days and juvenile

Figure 3. An adult Lapland Longspur. Photograph taken by Jack Stephens

birds leave the nest five to six days after hatching (Hussell and Montomerie 2002) which is why precipitation four weeks before juvenile birds were observed was considered. Because nests of Lapland Longspurs are built on flat ground in patches of moss or grass (Hussell and Montgomerie 2002; Salomonsen and Gitz-Johansen 1950) the clutch size (usually five to six eggs/chicks) is directly exposed to weather conditions like precipitation.

Snow Buntings (*Plectrophenax nivalis*)

Snow Buntings (figure 4) are one of the most common birds in Greenland and can be found throughout the High Arctic (Montgomerie and Lyon 2011; Salomonsen and Gitz-Johansen 1950) and although more common than the Lapland Longspur, the two species have very similar nesting and breeding habits. Male Snow Buntings arrive in early April to try and occupy territory and females do not arrive until three to four weeks later (Montgomerie and Lyon 2011; Salomonsen and Gitz-Johansen 1950). Courtship and nest building takes place around May 20th and can last up to ten days (Montgomerie and Lyon 2011). Snow Buntings also nest on the ground, but also prefer to make cavities in rocks or under boulders and offer more protection than Lapland Longspur nests (Montgomerie and Lyon 2011; Salomonsen and Gitz-Johansen 1950). Incubation, hatching, and the time when birds leave the nest have not been researched extensively but some observations indicate that incubation lasts twelve days and juveniles leave the nest at four days (Montgomerie and Lyon 2011).

Figure 4. An adult Snow Bunting. Photograph taken by Jack Stephens.

Data Collection

In order to measure success rates of *Plectrophenax nivalis* (Snow Bunting) and *Calcarius lapponicus* (Lapland Longspur) and increased summer precipitation were correlated in Thule, Greenland, a research technique called sampling was used. Sampling is a means of selecting parts of an interested population in order to make generalizations about the entire population. Sampling was done at set locations on Thule Air Base's tank farm, where roughly ten trapping locations have been set each year from 2010 to 2016, during the summer nesting season (June

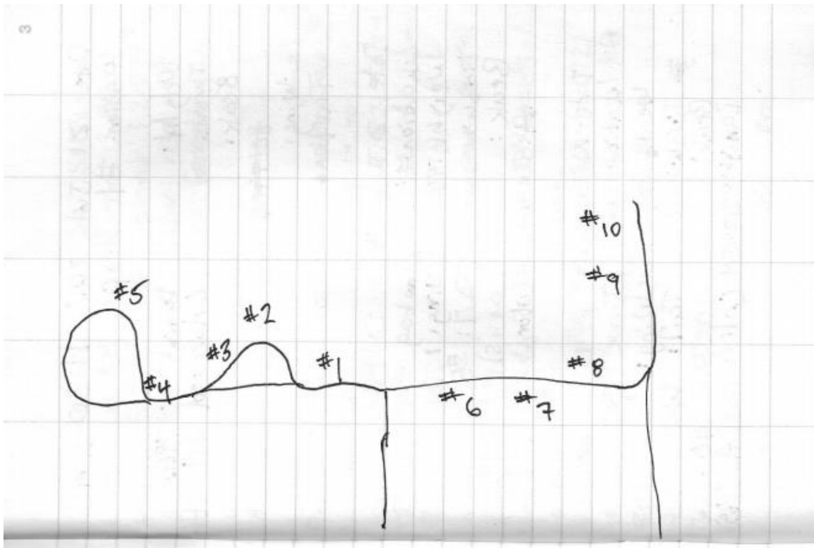

Figure 5. A hand drawn sketch of where the ten Potter traps were set in the Tank Farm. Drawn by Kurt Burnham.

through August) (figure 5). Some years more or less than ten traps were set due to traps breaking or needing maintenance. Prior to setting traps, seed plots (piles of bird seed) were established at the ten locations in the tank farm in order to attract passerine bird populations (figure 6). After the seed plots were well established with the populations, potter traps (figure 7) were set in order to trap birds. Potter traps are metal wire cages where a bird is lured into a cage for seed placed within the trap. Once in the potter trap, a door releasing mechanism is tripped from the bottom of the cage trapping the bird in a safe environment out of reach of predators (Sutherland, Newton, and Green 2004). Traps were checked and reset every hour so birds were not in danger or kept within the trap for too long. Once birds were caught, they were given a Danish government band on their right tarsus (leg) and a colored band representing the year caught on their left tarsus

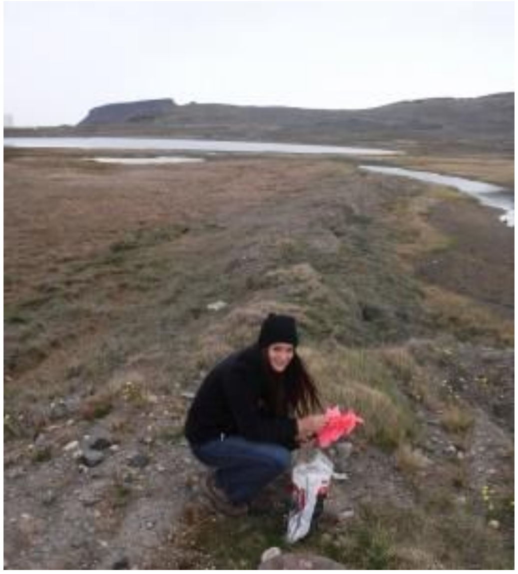

Figure 6. Photograph of author in the field establishing seed plots in the tank farm. Picture taken by Bridger Konkel.

(leg). Banding was done so that when a bird was recaptured the year it was first observed could be easily recorded. This is especially important for seeing trends within juvenile bird populations, as re-catching birds with colored bands show what years were more successful for breeding. Along with the band color and number, the time, date, weather observations, and trap number were also recorded as well as the sex, species, age, and weight, tarsus, tail, and beak length of the bird caught or re-caught.

Figure 7. Photograph of potter trap with two caught juvenile Snow Buntings and one adult. Picture obtained from the High Arctic Institute.

Data Analysis

After all bird and weather data was collected and recorded, the date of the first two consecutive juveniles of each species was recorded to indicate when in the breeding season the fledglings left the nest. This date was compared with the date of a "heavy rain event" (classified in our research as over seven millimeters in a forty-eight-hour period) four weeks before the two juveniles were caught, when the nests would have been susceptible to the rain event. Heavy rain events two weeks after the date when two fledged juveniles were caught was also recorded. Effort of trapping for each year was also recorded for any potential bias in data by recording how many days were spent trapping every year. This number was also used when comparing weather, and bird data. All of these were converted into graphs and tables which can be seen in the results.

Results

Weather in June

Over the seven-year period, precipitation differed significantly during the month of June. Figures 8, 9, and 10 show that 2012 was the driest and warmest year recorded during the study, whereas the previous year (2011) had rain events that surpassed the calculated average precipitation. In 2011 a rain event on June 7th (a date four weeks before fledglings had left the

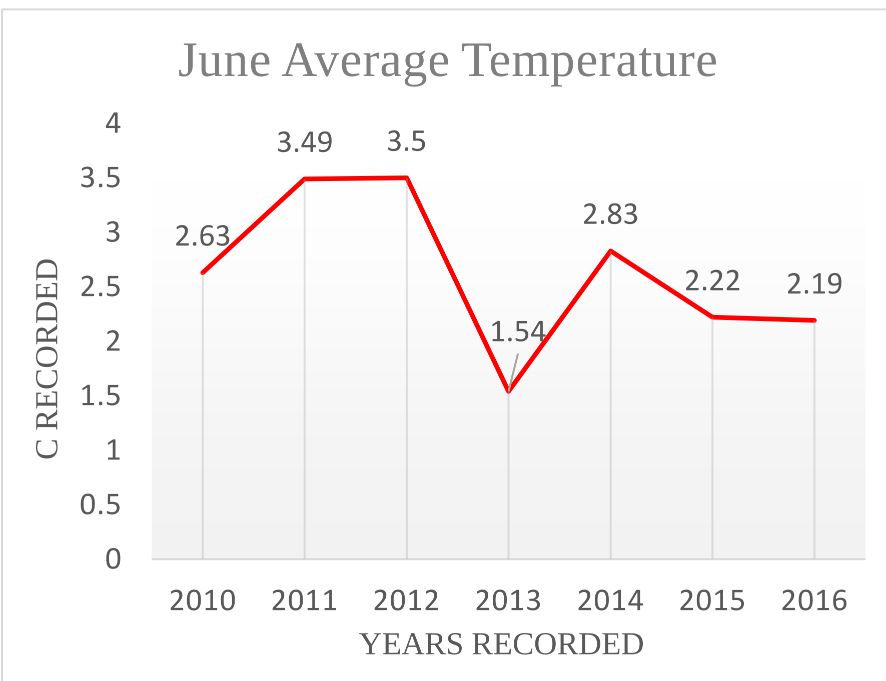

Figure 8. June average Temperatures recorded from NOAA and WU for the years of 2010-2016 in Celsius.

nest) (tables 1 and 2) was 256.28 mm in a twenty-four-hour period. The second highest amount of precipitation over the study period was in 2015 and was 12.945 mm which is much less in comparison to 2011.

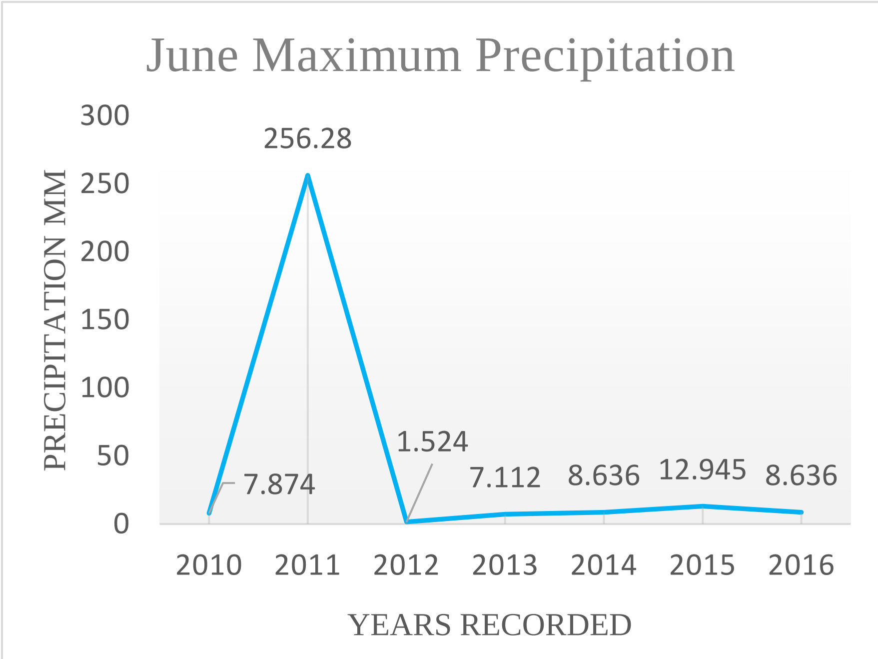

Figure 9. June maximum precipitation recorded from NOAA and WU for the years of 2010-2016 in mm.

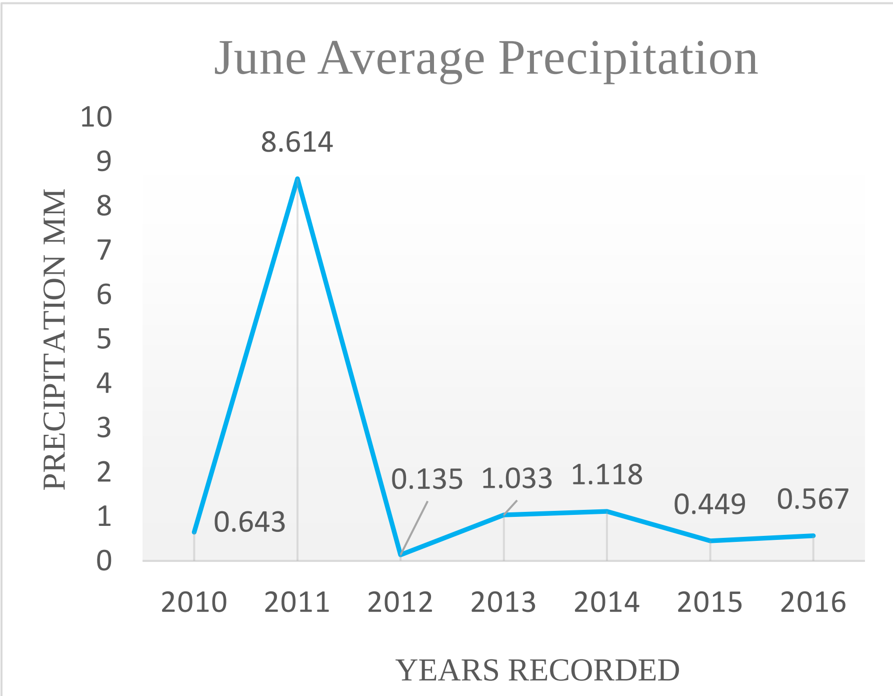

Figure 10. June average precipitation recorded from NOAA and WU for the years of 2010-2016 in mm.

Table 1. Records of when the first two juvenile Lapland Longspurs of the season were observed and precipitation events four weeks prior.

Year	Date of Two Consecutive Juvenile Lapland Longspurs Observed	Date of Precipitation Event 4 Weeks Before	Precipitation
2010	July 21st	July 12-13th	15.748 mm
2011	August 1st	June 7th	256.287
2012	July 22nd	None	None
2013	July 26th	June 25-27th	13.97 mm
2014	July 21st	June 18-21st	20.828 mm
2015	July 28th	June 23-24th	13.462 mm
2016	July 28th	June 23-25th	17.018 mm

Table 2. Records of when the first two Snow Buntings were observed and precipitation events four weeks prior

Year	Date of Two Consecutive Juvenile Snow Buntings Observed	Date of Precipitation Event 4 Weeks Before	Precipitation
2010	July 16th	July 12-13th	15.748 mm
2011	August 1st	June 7th	256.287 mm
2012	July 18th	None	None
2013	July 22nd	July 16-21st	10.16 mm
2014	July 16th	June 14-16th	16.256 mm
2015	July 16th	None	None
2016	July 17th	None	None

Weather in July

Figures 11, 12, and 13 show July's average precipitation and temperatures during the study. 2012 and 2013 were years of the highest amounts of precipitation (up to 13.716 mm in one rain event) and 2011 was the warmest recorded July with an average of 8.76 °C.

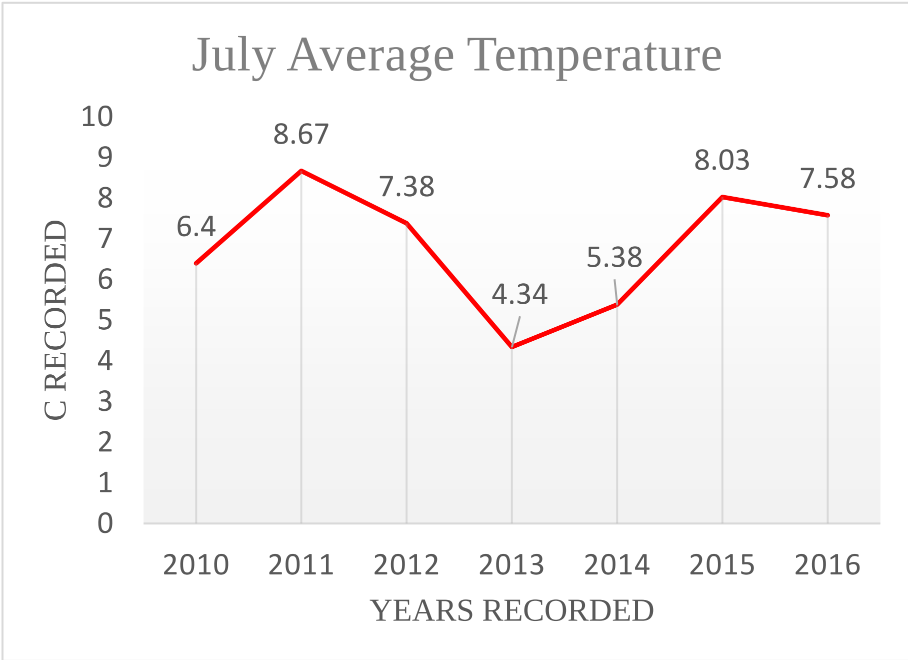

Figure 11. July average temperatures recorded from NOAA and WU from 2010-2016.

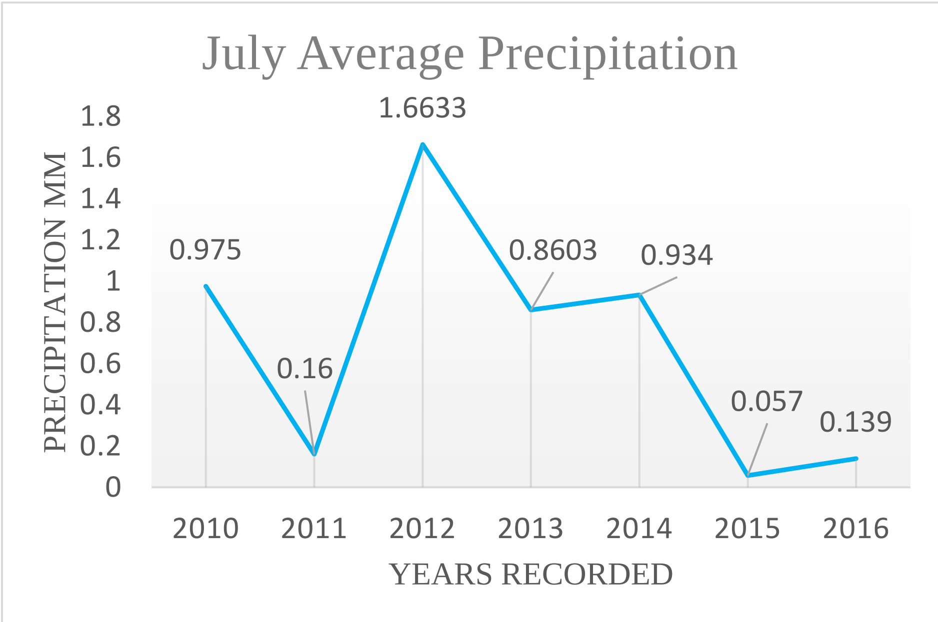

Figure 12. July average precipitation recorded from NOAA and WU from 2010-2016.

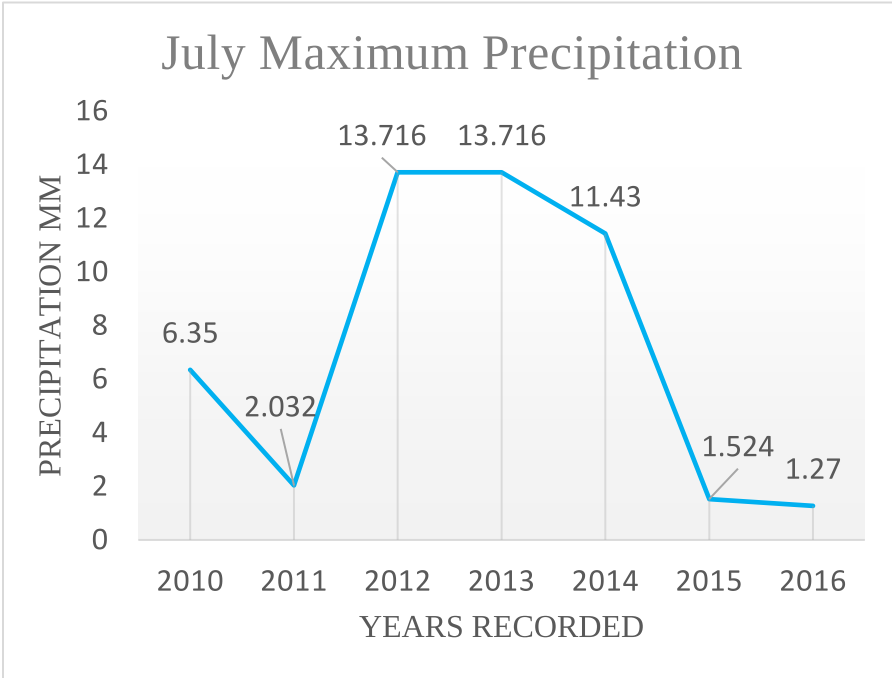

Figure 13. July maximum precipitation recorded from NOAA and WU from 2010-2016.

Snow Bunting Observations

During the 2010-2016 study period, 2014 was the year with the highest percentage of caught juvenile Snow Buntings with 98 birds total out of the total of 196 across the years (figure 14). The lowest number was observed in 2011 with only 4 juvenile Snow Buntings caught.

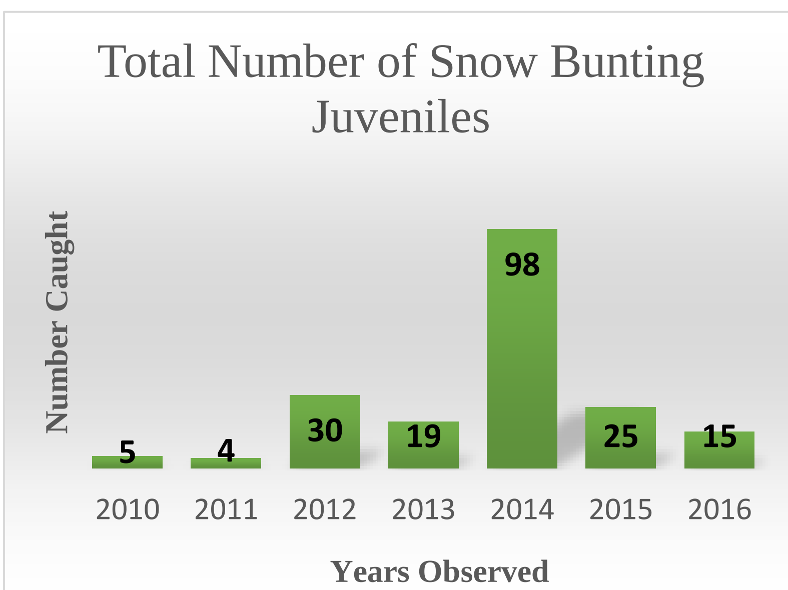

Figure 14. Total number of juvenile Snow Buntings caught between 2010-2016 using Potter traps.

Lapland Longspur Observations

Overall, fewer Lapland Longspurs were caught in relation to Snow Buntings over the 2010-2016 study period (figure 15). The year with the most caught juvenile Lapland Longspurs was also 2014 with 25 birds total, and the year with the lowest number caught was in 2016 with 2 birds total.

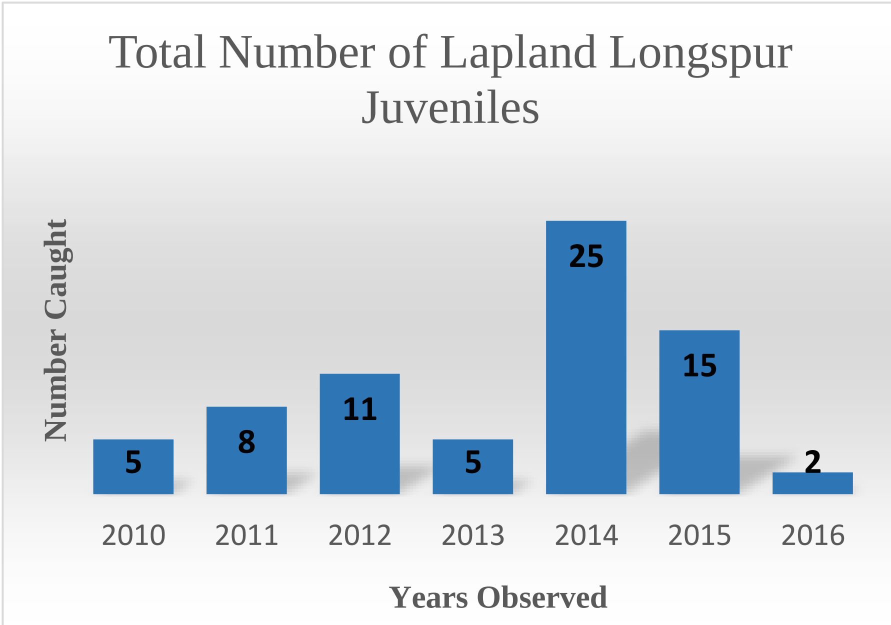

Figure 15. Total number of juvenile Lapland Longspurs caught between 2010-2016 using Potter traps.

Trapping Effort

Throughout the 2010-2016-time frame of the study, different effort was given to the number of days spent trapping (figure 16). This variation could have influenced the number of birds were caught for each species.

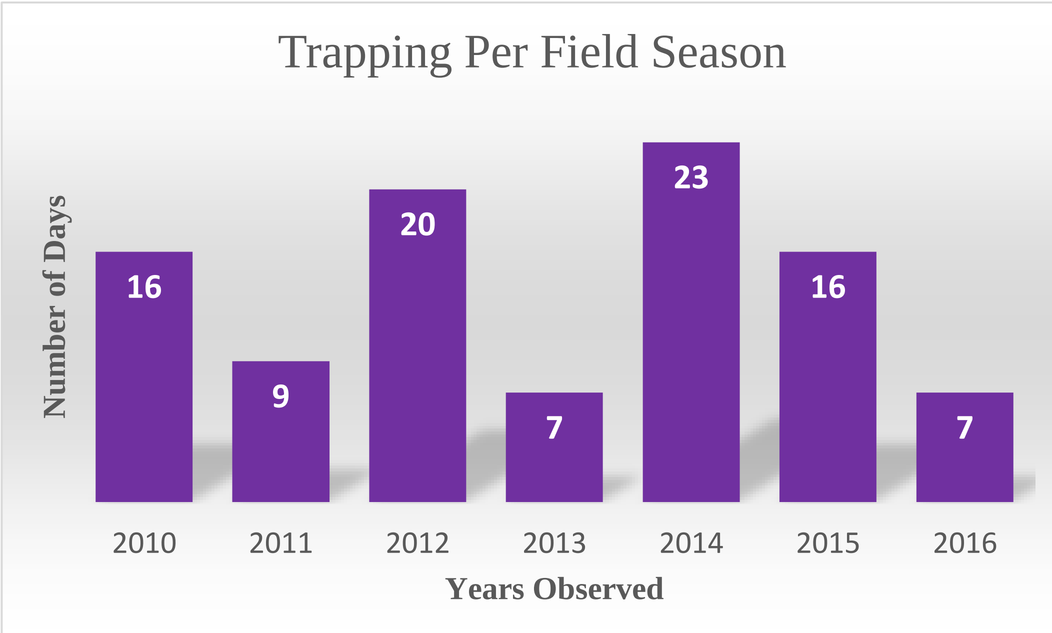

Figure 16. The number of days per year spent trapping juvenile Snow Buntings and Lapland Longspurs in the Tank Farm.

Discussion

The results obtained from this study showed trends similar to what was found in prior literature and research, however the results were not as significant or direct as those studies (Anctil et al. 2013 and Yannic et al. 2014). Prior studies used tactics such as video cameras to directly witness juvenile mortality events (Anctil et al. 2013) while this study found results more based on inference and hypothesis using capture trends. The one common trend observed from this study was that large precipitation events did have an effect on the capture amount and timing of juvenile Snow Buntings and Lapland Longspurs.

2011 showed the most significant evidence, of having a rain event during the nesting/brooding time that effected the timing of when juvenile passerine species left the nest and how many were caught. Because Lapland Longspurs and Snow Buntings tend to leave their nests during mid-July to late-July, it was interesting to observe that the first date two of each species was seen was August 1st (table 1 and 2). This late observation date could be correlated with the large precipitation event which occurred on June 7^{th,} when over 256.28 mm of precipitation occurred during a twenty-four-hour period. The timing of this rain event correlated with when researchers have observed that nest building, egg laying, brooding, and chick hatching occurs (4 weeks before fledglings leave the nest). The severe rain event which occurred on June 7th could have caused breeding failure for both species observed, and birds that bred later or tried to breed again were more successful, indicating the later observation date.

The trapping and weather data observed in 2012 and 2014 provides an anomaly in this research. 2014 had more trapping effort given, through the numbers of days spent trapping, which could indicate why more birds were caught (98 juvenile Snow Buntings and 25 juvenile Lapland Longspurs) (figures 15 and 16). 2012 had a similar trapping effort given, with 20 days of trapping recorded when compared to the 23-day trapping effort given in 2014 (figure 16). 2012 had noticeable fewer birds caught than 2014 with roughly the same amount of trapping effort given. When comparing this to the temperature and precipitation events, it was observed that 2014 had two large rain events before two juveniles of each species were observed (table 1 and 2). For Lapland Longspurs there was a rain event four weeks before the species was observed during June 18-21st where 29.828 mm of rain was recorded. For Snow Buntings, there was a rain event four weeks before the species was observed during June 14-16th when 16.25 mm of rain was recorded. Based on the prior research and literature, a large number of birds should have not been observed during 2014, however this number could be due to the number of days spent trapping. In 2012 there was no rain events recorded for either species four weeks before the two species were first observed (tables 1 and 2). However, one theory that could be made relates to the June average temperature and July precipitation trends. 2012 was the hottest year recorded during the study, having a 3.5°C average and July 2012 had the highest precipitation average and maximum precipitation recorded, being 1.66 mm and 13.72 mm (figures11, 12, and 13). A productive nesting period, with a warm June, followed by a wet July two weeks after juveniles left the nest, could have led to a failed breeding season resulting in fewer birds being caught.

Precipitation events effect many species of birds in various geographic regions of the Arctic differently due to the different biomes and ecosystem characteristics found throughout the Arctic. The results of this study matched the overall results of prior studies, such as, Anctil et al. 2013, Yannic et al. 2014, and Pérez et al. 2016, however the results did not match up thoroughly. This could be due to the differentiation between the study locations. Most studies were performed in regions of the Low Arctic whereas this study was the only one conducted in the High Arctic. The study methods were also conducted differently. Many studies utilized video cameras and observed nesting populations directly over a few breeding seasons, while this study looked at many breeding seasons indirectly. This could explain some of the differences observed, which is why it is crucial for similar studies to be done throughout the Arctic in order to catch and record the comparison in avian species vulnerability and resilience. In relation to this studies research questions, there was an observed correlation with increased summer precipitation events and the breeding success of Snow Buntings and Lapland Longspurs. This study, along with the prior research done on the topic, indicates that climate change is negatively affecting bird species in regions of the Arctic due to increased summer precipitation events in the form of rain.

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