Can the Nestling Period Affect How a House Sparrow Forages and Survives After it Leaves the Nest?

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Biographical Sketch

My name is Jordan Lam and I am a B.S. Biology major with an Art minor. As a first-generation college student, I did not know what to expect from college. I started my academic career at Lafayette the summer before starting my freshman year in the Summer to Advance Leadership Program (SPAL), and I was able to learn about the variety of disciplines that Lafayette offered in the STEM field. After starting freshman year, I was given the offer to join the Science Horizons program and learn more about the biology program that Lafayette offered. I learned a lot about the different fields of biology and was able to work closely with a cohort of other biology students on technical skills. At the end of my first semester, Science Horizons helped me get an offer to work in Professor Butler's lab for the summer as a Nalven Scholar. I, unfortunately, was unable to join the lab that summer due to COVID-19.

I maintained contact with Professor Butler and was able to join his lab in the spring semester of my sophomore year. From then until now I've been involved with many different parts of campus. I've joined the biology honors society, Tri-alpha first-generation society, and biology inclusion committee. I've served on the leadership committee and been in leadership roles for the WJRH radio club, Pi Beta Phi Sorority, and Alternative School Break club. I've worked for CITLS and for the Advising and Co-curricular programs office, as well an LEO/Pardner and first-generation peer mentor for first-year students. Lafayette has been a very big part of my life and I am excited to use the skills I've learned in my next chapter of life.

The painting below is untitled. I painted it for my introductory painting class because we had to paint something that we loved and was inspirational. It is a human mixed with a bird on top of a nest made from scraps of this thesis. I love being outside and spending time in Metzgar Field with the birds. Sometimes I lay on the grass and pretend I can be a bird with a simpler life.

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Abstract

Foraging is a necessary means of survival for animals. As the environment changes, many foraging patterns of animals develop as well to adapt to the differences. Many factors can affect how available food is, how it is able to be collected, and how deftly an animal is able to collect it. During the breeding season, birds will forage for themselves to produce enough energy to lay eggs as well as forage for their young. The young will also have to forage for themselves after they leave the nest. However, there are a lot of factors during the nestling stage that can have lasting effects on the individual. This thesis examines the traits and information about a nestling that can be gathered during the nestling stage and how that information is related to foraging habits after they've left the nest. I have gathered information over the summer of 2022 on 72 nests, and 213 nestlings. I also collected over 5,000 data points on the RFID-equipped feeder to quantify post-nestling foraging behavior. I compared variables such as nestlings' mass, tarsus length, number of siblings, brood order, Julian dates for seasonality, duration of the incubation period, and duration of the nestling period with the presence at the feeder and the duration that they were detected. The incubation period and mass of a nestling yielding interesting results. The incubation period has a negative correlation with mass (p=0.00424), and statistical difference between groups of siblings (p=1.57e-04). The mass has statistical significance when compared to multiple variables, such as genetic sex (p=0.0028). They both have a significant relationship with the persistence of nestlings at the feeder as well. Furthermore, aside from the finding that males are larger than females, genetic sex does not have a significant relationship with many of the early-life nestling traits.

Introduction

Foraging is necessary for all animals to get enough food to satisfy their nutritional needs and to function properly. The optimal foraging pattern for an individual can be affected by a plethora of variables, such as social ranking (Evans et.al, 2018), the type of food available (Perkins et.al, 2007), and the other animals or species that are in the same area that compete for the same resources or are the prey for other animals (Francis et.al, 2018). In birds, there is also a significant difference in foraging behavior between juveniles and adults that might be driven by a difference in morphology, learned behaviors, and nutritional needs (Marchetti and Price, 1988). For example, a juvenile bird is less developed skeletally and muscularly, and therefore they cannot fly as well or quickly (Marchetti and Price, 1988). An adult bird also has had more opportunities to observe and learn from others than a juvenile bird has and is thus more likely to avoid or perform certain behaviors (Marchetti and Price, 1988).

In many songbirds, young juvenile birds (i.e., fledglings) tend to associate with good foragers and will change their behaviors as needed to maximize the amount of food they are able to find and improve their individual foraging efforts (Thompson & Ridley, 2012). By foraging with an experienced mentor, the fledgling can easily find food and learn foraging skills at the same time (Thompson & Ridley, 2012). However, mentors and older birds are not the only type of social relationship that can affect foraging skills. For house sparrows (*Passer domesticus*), foraging with siblings can also be beneficial. Although many juveniles form flocks soon after fledging, only a little over half disperse from their natal colony (Fleischer 1983a, Fleischer et al. 1984). Siblings in the same brood that end up in the same flock after fledging tend to stick together and prefer exploring with one another (Tóth et al., 2009). Siblings tend to avoid aggressive behaviors when foraging with kin, allowing siblings to concentrate on eating and gathering resources (Tóth et al., 2009). Also, same-brood siblings are more likely to engage in new activities, such as exploring a novel foraging site, with a sibling than a non-sibling member of the flock (Tóth et al., 2009). The bolder that a bird is, the more likely it will come across a foraging site (Tóth et al., 2009). Therefore, having siblings in the same flock can lead to increased feeding opportunities.

In addition to social factors that impact foraging skills, there are likely to be non-social factors that affect foraging patterns. A brood is a group of birds that have hatched and lived in the same nest. Many birds have one partner for the entirety of the mating season (Nice, 1941), and because of this, nestlings can have siblings from a different brood that was made later in the breeding season. Multi-brood species are species that have multiple clutches of offspring within a breeding season. Multi-brood species may have advantages regarding survival rates (Ringsby et.al, 1998). Besides having multiple offspring to increase the odds of survival, some studies show that for multi-brood species there is a positive relationship between the time of year that the egg is laid and survival (Ringsby et.al, 1998), meaning that clutches of eggs laid later in the breeding season have a higher chance of survival. Furthermore, the survival rate of multi-brood species has been shown to be affected by clutch size (Ringsby et.al, 1998). With more nestlings, there is less food available for each individual, and therefore they have less stored energy.

Other non-social factors that can impact foraging include body mass, age, and genetic sex (Francis, et. al., 2018). Male and female house sparrows' approach unfamiliar territory in different ways. Males tend to explore more readily and, as a result, eat for longer periods of time than females (Tuliozi et al., 2018). Males that forage alongside an unfamiliar companion also explore more than their female counterparts (Tuliozi et al., 2018). However, there is no clear pattern between these sex-related differences in foraging and survival rates (Cleasby et.al, 2010).

Because of some of these behavioral differences, genetic sex may be associated with foraging patterns in familiar areas as well.

Another factor that can affect foraging is the size of a house sparrow. House sparrow nestling survival is positively associated with mass and tarsus length (Cleasby et.al, 2010). One explanation for this pattern could be that a heavier nestling is able to last longer without food by using its extra stored energy (Cleasby et.al, 2010). Another explanation for overall size helping with survival could be that larger birds tend to be more socially dominant and therefore have more access to resources (Cleasby et.al, 2010). Regardless of the mechanism, it is likely larger birds may be more likely to survive for longer periods of time.

The hatch date of nestlings can also affect their survival and therefore ability to forage. There has been evidence that hatch date and survival are positively correlated, meaning that birds that hatch later in the breeding season are more likely to survive to the next year (Cleasby et.al, 2010). This is likely due to the colder weather and less predictable weather conditions during the earlier part of the breeding season (Cleasby et.al, 2010).

Foraging for food is a big part of a house sparrow's life and is a key part of their survival. In the early stages, there are approximately 14 days between when a house sparrow egg hatches and when the nestling leaves the nest (Lowther & Cink, 2020). In those 14 days, nestlings experience a lot of changes and develop traits that will help them survive outside of the nest (Lowther & Cink, 2020). In this study, I looked at variables and traits of nestlings within these 14 days and their correlation with later-life foraging patterns. I looked at factors such as number of siblings, number of likely broods before them, genetic sex, body mass, tarsus length, the time it took for the eggs to hatch, and the time it took for nestlings to leave the nest to determine whether or not they can be correlated with an individual's foraging behavior. Furthermore, I looked at whether or not individuals remained in the same area for the duration of the study and whether or not the nestling traits correlated with each other.

Materials and Methods

Field protocols

I collected all data for this study at Metzgar Field Complex at Lafayette College from 2021 to 2022. The field site is an open complex that contains several athletic fields and open land. It is fenced in from a small farm, open corn fields, walking paths, and a small airport on its perimeter. Eighty-three woodcrete nest boxes (Kinsman Company, 1B-38) are set up along the perimeter of the complex. During the breeding season, these boxes are often occupied by house sparrows (*Passer domesticus*), eastern bluebirds (*Siala sialis*), tree swallows (*Tachycineta bicolor*), and house wrens (*Troglodytes aedon*), and I focused on house sparrows in this study. I counted house sparrow nestlings and eggs between April to July with other members of the Butler Lab. I collected data on house sparrow feeding year-round.

We regularly checked the nest boxes throughout the period of data collection. All eighty-three boxes were checked twice a week from late April to the end of July. During these nest checks, I recorded the number of eggs and/or nestlings or the size of the nest inside the box. I determined each species by egg color and recorded it. We checked boxes daily with eggs or nestlings when eggs were likely to hatch, or nestlings were likely to leave the nest. Once a box had eggs in it, we checked them daily starting 9 days after the last egg was laid until the last egg hatched. We defined the duration between the last egg laid until the median date between the first egg hatched and the last egg hatched as the incubation stage. Once the nests had nestlings in them, we checked them daily starting 10 days after the first egg hatched until all the birds had left the nest or died. We defined the nestling period as the time between the number of days between the hatching of the first egg and the median fledge date.

I banded house sparrow nestlings when they were typically: heavier than 19 grams, older than 10 days, and had a tarsus longer than 17 mm. When banding, I added a USGS aluminum band to the right leg and a radio-frequency identification (RFID) tag to the other leg. I made the RFID tags using a passive integrative transponder (PIT) tag and two plastic leg bands (Wallace et.al, 2020). I also collected blood when a sparrow was typically mostly feathered and weighed more than 18 grams. I used a needle to prick the basilic vein of the nestling and a capillary tube to collect the blood. I then transferred the blood to a 1.5 mL test tube labeled with the bird's USGS band number. I used a cotton ball to apply pressure to the prick until it stopped bleeding. The whole blood was later stored at -80°C.

RFID-equipped feeders that could read the sparrows' PIT tags were set up in two areas of the field complex approximately 480 meters away from each other and at least 10 meters away from the nearest nest box. The RFID feeder was a standard plastic bird feeder with a wire cage around it that has small holes to prevent animals larger than songbirds to enter. It had 12 sensor rings, 8 at the bottom below the feeder on a wooden platform, and 1 on each of the 4 feeder perches. The sensors were powered by a solar-charged battery that were also attached to the wooden platform (Figure 1). One was placed in the center of a circle of nest boxes and was referred to as the ‘farm’ feeder due to its close proximity to the nearby school-operated farm. The other feeder station was located between a fence and storage barn and was called the ‘barn’ feeder. Both feeders were filled every other day with ACE bird seed and data was downloaded from them every month during the summer and every few months the rest of the year. The RFID feeder stations recorded data whenever an RFID tag was within approximately an inch of one of its twelve sensors. The data collected included which of the 12 sensors it was detected at, the timestamp, the date, and the RFID tag number.

Genetic sexing

To determine the genetic sex of each nestling, I performed a DNA extraction for each of the samples using 5 μL of whole blood per sample. I pipetted the blood into 1.5 mL microcentrifuge tubes with 500 μL of 2-[Tris-(hydroxymethyl) methylamino]-1-ethane sulfonic acid (TES) buffer, vortexed the tubes, and heated this solution at 60°C for 15 minutes, and then put it on ice for 15 minutes after adding 60 μL of potassium acetate. I then centrifuged the tubes for 10 minutes at 12,000 x *g*. I then transferred the supernatant to a new tube, added 500 μL of room-temperature isopropanol, and centrifuged the solution again for 30 minutes at 12,000 x *g*. Afterward, I performed three 70% ethanol washes on the pellet and resuspended the pellet in water. I determined the approximate amount of DNA and pureness using a bio photometer (Eppendorph Bio Spectrometer basic). We decided that the minimum amount of DNA to be amplified was at least 30 microliters, and the optimal pureness to be an A260/A280 number of 1.80. I then performed a 1:10 dilution using deionized water for each sample in a new 1.5 mL microcentrifuge tube and stored them in the -20°C freezer until I performed a PCR.

I then performed a PCR on each extraction by adding 1 μL of the extraction to 0.2 mL PCR tubes. I then added 9 μL of a 'PCR cocktail' consisting of 5 μL of Gotaq Green master mix, 3 μL of nuclease-free water, and 0.5 μL of each working solution of P2 primer and P8 primer per sample to isolate the CHD-W and CHD-Z genetic sex genes (Griffiths et.al, 1998). The primers

P2 and P8 on either end of the sex chromosomes and will yield a single band of approximately 350 bp for males and two bands of approximately 350 bp and 380 bp for females. I ran each sample through the thermal cycler (Bio Rad, Model No. T100 Thermal Cycler). The thermal cycler protocol called for an initial denaturation of 95°C for 5 minutes, 40 cycles of amplification, and an elongation of 72°C for 5 minutes. The amplification cycles consisted of 94°C for 30 seconds, 48°C for 45 seconds, and 72°C for 45 seconds. In total, the thermal cycler ran for approximately 2.5 hours and ended at 12°C to allow for late retrieval. I then performed a gel electrophoresis using a 3% agar gel and 10 μL of SYBR-safe dye. The gel was created using 100 mL of 1X Tris-acetate-EDTA (TAE buffer) and 3 grams of agarose. Each of the gels was then imaged and labeled with the corresponding sample names. The images were taken using a geldoc (BioRad ChemiDoc MP Imaging System, Model No. Universal Hood III) and imaging program (Image Lab 5.2). Females were determined by displaying 2 bands compared to the control sex samples and males were determined by displaying a single band compared to the control sex samples. A sample was deemed undeterminable if there were no bands.

Data Analysis

I used R-Studio version 4.2.2 to analyze the data. I started by putting all of the data into an Excel spreadsheet and for each individual bird I recorded nest box identity (which of the 83 nest boxes the nest was in), species, an arbitrary number for the nestling out of how many were in the nest, the number of siblings, brood number, the date the nestling was banded, the USGS band number and the RFID code from their RFID tag. I defined the brood number as the first, second, or third nest that has been in the nest box during the season. I also imputed the data that we measured in the field such as body mass in grams and right tarsus in millimeters. Using the data I took from the field season, I was able to calculate the date of the first egg laid, the date of the last egg laid, and the average date between those laid by dates. I also calculated and input the date that the first egg in the nest hatched, the date that the last egg in the nest hatched, and the average date between those hatching days. I also calculated the incubation period, the date of the first nestling that fledged from a nest, the date of the last nestling to fledge, the average date between the two fledging dates, and the duration of the nestling period. The nestling period, the period of a bird's life where it lives in the nests, was calculated by finding the number of days between the date of the first egg hatching (first hatch date) and the average fledging date. Using the RFID date, I was able to calculate the duration of detections, and persistence. I defined persistence as having no detections, detections for less than a week, and detections for more than a week. I also calculated the Julian date for the average hatch date so that I could use it to determine how nest changed throughout the breeding season. For the Julian date, 1 was equal to January 1st, 2023, and so forth. After performing the genetic sexing protocol, I was able to enter the genetic sex data into the spreadsheet as well. After inputting all the data for each bird, I created pivot tables in Excel to summarize the data. The pivot table helped me calculate analyze the RFID data such as: how many times a bird was at the top of the feeder, the bottom of the feeder, total times at the feeder, first detection, last detection, and the number of detections. I then exported the Excel sheet into R-studio. There were 72 nests in total, 213 individuals across those nests, and I was able to determine the genetic sex for 162 of those individuals.

To determine what parameters were affected by the number of siblings, I used ANOVA tests with the number of siblings as the independent variable, and one of the following as a dependent variable: body mass, tarsus length, incubation period duration, nestling period duration, detection, and duration. I used the number of siblings from 0-4 as the categories. For body mass, incubation period duration, I then followed each test up with a TukeyHSD test to determine which within-group differences had significant relationships. I only followed these variables up with a TukeyHSD because they had p-values less than 0.05 for the ANOVA test. To test the relationship between the number of siblings and brood number, presence, persistence, or genetic sex, I used chi-square tests. I used the number of siblings from 0-4 as one set of categories, and one of the following for the other categorical value: the brood number (1-3), Yes/No present, “Not Present”, “Present Less than a Week”, and “Present More than a Week” or “Male” and “Female”.

Similarly, to determine what parameters were affected by the brood number, I used ANOVA tests with the brood number as the independent variable, and one of the following as a dependent variable: mass, tarsus length, incubation period duration, and nestling period duration. I also followed each test up with a TukeyHSD test to determine which within groups had significant relationships. To test the effects of the brood number and presence, persistence, or genetic sex, I used chi-square tests. I used the brood number 1-3 as one set of categories, and one of the following for the other categorical value: “Yes”/” No” present, “Not Present”, “Present Less than a Week”, and “Present More than a Week” or “Male” and “Female”.

To determine what parameters had significant relationships with the genetic sex of an individual, I also used ANOVA tests. Genetic sex was the independent variable, and one of the following as a dependent variable: mass, tarsus length, incubation period duration, and nestling period duration. With “Male” or “Female” being the categories. I then followed each test up with a TukeyHSD test to determine which within groups had significant relationships. To test the effects of genetic sex on presence and persistence, I used a chi-square test. I used “Male” and

“Female” as one set of categories, and one of the following for the other categorical value: Yes/No present or “Not Present”, “Present Less than a Week”, and “Present More than a Week”.

To determine if body size impacted other variables, I looked at mass and tarsus length. To determine what parameters were related to the mass, I used simple linear regressions with the mass as the independent variable, and one of the following as a dependent variable: tarsus length, incubation period duration, and nestling period duration. To test the relationship between mass and presence, I used a two sample T-test with “Yes” or “No” as the independent variables and the mass as the dependent variable.

Similarly, to determine what parameters were affected by the tarsus, I used simple linear regressions with the tarsus as the independent variable, and one of the following as a dependent variable: incubation period duration or nestling period duration. To test the relationship between tarsus length and presence, I used a Wilcoxon sign-rank test with “Yes” or “No” as the independent variables and the tarsus length as the dependent variable.

To determine if duration in a life stage related to other variables, I looked at the incubation period duration and the nestling period duration. To determine what parameters were related to the incubation period duration, I used simple linear regressions with the incubation period duration as the independent variable, and nestling period duration as a dependent variable. To test the relationship between incubation period duration and presence, I used a Wilcoxon sign-rank test with “Yes” or “No” as the independent variables and the tarsus length as the dependent variable.

To see if the duration of time foraging at the feeder impacted variables, I looked at the persistence. To determine what parameters were affected by the persistence, I also used ANOVA tests with the persistence as the independent variable, and one of the following as a dependent variable: mass, tarsus length, incubation period duration, and nestling period duration. I then followed each test up with a TukeyHSD test to determine which within groups had significant relationships.

Finally, to see if the time of year impacted variables, I looked at the Julian date of the average hatching date. To determine what parameters were related to time of year, I used linear regressions with Julian date as one variable, and one of the following as the other: mass, tarsus length, incubation period duration, and nestling period duration. I also used ANOVA tests with the number of siblings, genetic sex, presence or persistence as independent variables and the Julian date as the dependent variable. I then followed each test up with a TukeyHSD test to determine which within groups had significant relationships.

Results

Related Sparrows, Detection, and Duration

There was a statistical significance associated with the number of siblings on body mass and incubation period duration (Table 1). For each variable, I performed a TukeyHSD test to determine which groups within the number of siblings were statistically different from each other. The mass of nestlings with 3 siblings was statistically greater than nestlings with 4 siblings (Figure 2). There was a statistical difference in number of incubation days between nests with 1 and 4 siblings, 2 and 4 siblings, and 3 and 4 siblings as seen in figure 3. There were no significant differences between number of siblings and brood number, tarsus length, days in the nestling period duration, genetic sex, presence, and persistence.

Furthermore, there was a statistical significance associated with the brood number on tarsus length and incubation period duration (Table 6). For each variable, I performed a TukeyHSD test to determine which groups within the number of siblings were statistically different from each other. The tarsus length of nestlings in the second brood were larger than nestlings in the first brood (Figure 4). The incubation period duration was longer for nestlings in the first brood than the second or third brood (Figure 5). There was a statistically significant relationship between brood number and presence. Birds in the first brood were likely to be not present at all and birds in the second brood were likely to be present (Figure 6). There was also a statistically significant relation between brood number and persistence. Not surprisingly, birds in the first brood were likely to be not present at all and the birds in the second brood were likely to be there longer than a week (Figure 7). There were no significant differences between brood number and mass, days in the nestling period, and genetic sex.

Genetic Sex, Detection, and Duration

There was a statistical significance between the genetic sex and body mass (Table 10). The mass of a male nestling was significantly higher than a female. There were no significant differences between genetic sex and tarsus length, incubation period duration, days in the nestling period, presence, and persistence.

Size, Detection, and Duration

There was a statistically significant between body mass and tarsus length, incubation period duration, nestling period duration, and persistence (Table 13). There was also a statistical significance between the mass and presence of a nestling (Table 14). The mass of a nestling had a moderately positive correlation with the tarsus length of a nestling (Figure 8). The mass of a nestling had weak negative correlations with the incubation period (Figure 9) and nestling period (Figure 10) durations. Lighter nestlings were less likely to be present at the feeder (Figure 11). The persistence had a statistical difference between “Not Present” and “Present More than a Week” (Figure 12).

Furthermore, there was a statistical significance between tarsus length and incubation period duration, nestling period duration, and persistence (Table 15). There was also a statistical significance between the tarsus length and presence of a nestling (Table 16). The tarsus length had weak negative correlations with the incubation period duration (Figure 13) and nestling period duration (Figure 14). Nestlings with shorter tarsus’ were less likely to be present at the feeder (Figure 15). The tarsus length had a statistical difference between “Not Present” and “Present More than a Week” (Figure 16).

Incubation Period Duration, Nestling period Duration, Detection, and Duration

There was a statistical significance between the incubation period duration and presence (Table 18) and incubation period duration and persistence (Table 17). Nestlings that were incubated for longer were less likely to be present at the feeder (Figure 17). The incubation period duration had a statistical difference between “Present Less than a Week” and “Present More than a Week”, and “Not Present” and “Present More than a Week” (Figure 18). There were no significant relationships between the incubation period duration and nestling period duration. There were also no significant relationships between the nestling period duration and presence (Table 19) or persistence (Table 20).

Time of Year, Detection, and Duration

There was a statistically significant relationship between Julian date and body mass, tarsus length, incubation period duration, nestling period duration, and persistence (Table 21). There was also a statistically significant relationship between presence and Julian date (Table 22). There is a weak positive correlation between Julian date and body mass or tarsus length. There is a weak negative relationship between Julian date and incubation period duration (Figure 19) or nestling period duration. Birds that were born later in the year were more likely to be present at the feeder (Figure 20). There is a statistical difference between Julian date and birds who were "Not Present" and "Present More than a Week" (Figure 21). There was no significant relationship between Julian date and genetics sex or number of siblings.

Discussion

House sparrows can eat and survive by foraging. House sparrows are an invasive species so they encounter various types of ecosystems and within those ecosystems their foraging skills may have to adapt. It is unclear how early life variables can affect how a house sparrow forages later in life. Being able to identify how theses variables effect later life foraging will help us predict how a house sparrow will forage and what early life variables are important for survival. Information on house sparrow foraging is important to finding a way to mitigate their spread as an invasive species and preserving the native species.

In this study, I compared the early nestling variables with each other to identify significant relationships between them. Though multiple statistical tests, I have found that a nestling's size has significant relationships with many of the other factors. Studies have found that within a nest, larger siblings tend to receive more food than their smaller siblings regardless of begging (Rodriguez-Girones, 2002). This is consistent with my finding that sparrows with 4 siblings weightless on average. With a larger sibling out competing them, the more siblings there are the less food each sparrow will get. A house sparrows' mass is closely related to the probability that it can survive its first year of life, with heavier house sparrows being more likely to live (Ringsby et.al, 1998). Studies have shown that survival is lower in larger broods (Seel, 1970). These birds either died or made the choice to forage somewhere other than the bird feeder. This is interesting because we can see how the number of siblings a sparrow has can indirectly influence its survival or foraging behavior.

Research has found that as the number of nestlings increases, the incubation period duration decreases indicating a greater spread of hatching in larger clutches (Seel, 1996). This is consistent with my data analysis on the number of siblings in relation to incubation period duration. Specifically, there was a significant decrease in the number of incubation days for the largest clutch size. As the breeding season progresses, the incubation period duration decreases possibly because of rising air temperatures during the mid to late breeding season (Seel, 1996). This also matches with my findings that incubation period duration decreased as the brood order increased and incubation also decreased as the breeding season went on. The temperature would have also increased during the breeding season. This is important to note because birds were more detected around the area for longer than a week in the middle of the breeding season or by the second clutch. This median brood was incubated for a median amount of time, and statistically less than the first brood. My data also shows statistically that sparrows that were incubated for a shorter amount of time were detected in the area for longer than a week. It is important to note again that being not detected does not mean that the sparrow died, but it does mean that they would have had to find another food source and forage in a different way. The connection between lower incubation, median Julian date and brood order, and detection indicates that there may be an ideal temperature that indicates if a sparrow that will forage at the feeder. The nestling period duration does not have the same amount of significant relationships to the other variables like the incubation period duration, so it may not be the environment within the nest that affects the nestling but the environment within the egg.

A new addition to our lab was obtaining the genetic sex of the nestlings because there is no visible difference in sex until they are adults. A study has shown that extra food during the nestling period duration can result in a sex-biased variance where females are smaller than males on average (Cleansby et.al, 2022). This is consistent with my results that male house sparrows were significantly heavier than females even at the nestling stage. It is also shown that males may grow larger in body size, meaning both mass and tarsus, in severe weather (Cleasby et.al, 2010). My data also supports the fact that body mass increases with tarsus length. However, it has been seen that females are more likely to survive to adulthood (Cleasby et.al, 2010). This could be because male house sparrows are more aggressive and more likely to invest in energy-wasting plumage (Cleasby et.al, 2010). A larger body seems to help increase survival rate, but it does not guarantee survival because of other social factors.

Body mass seems to have a lot of positive effects on a house sparrow's life. Some studies show that house sparrows with a larger body mass in the nest will not disperse as far when they leave (Fleischer et.al, 1984). This correlates with my data that shows that birds that were detected for over a week weighed more than birds that were not detected at all. Larger house sparrows are more dominant and control more of the food (Fleischer et.al, 1984). This could imply that these heavier sparrows are dominating the feeders and are more likely to stay around because they have an accessible food source.

This study was limited in the data that we were able to collect. Unfortunately, our RFID system broke down for several days sporadically throughout the season and we missed data points. We were unable to obtain blood samples from some individuals, so I was unable to determine the genetic sex. I also only analyzed data from one year. In the future, it would be good to analyze multiple years. In addition to that, I would be interested to see if we can find groups of siblings at the feeder at the same time.

House sparrows are invasive and there is no current plan on how to stop them from spreading. In our own field site, they have taken over many nest boxes from native birds. House sparrows foraging techniques and adaptability are what make them able to spread quickly. If we can find more ways to hinder the way that they forage, we can stop their migration without killing them. Through this thesis, I have found that there are possible factors that we can see at a nest level that can affect how house sparrows' forage.

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I would like to acknowledge the Lafayette Biology Department for their support. I always had someone to contact if I needed help with the van or finding a resource. I would also like to thank Sigma Xi for their generous grant. Without it I would not have been able to create the RFID tags for this project. I would like to acknowledge my lab partners Brooke Weiss, Zack Cullen, Devon Hallihan, Caroline Garti, and Dory Howard. Thank you for helping me keep track of field data and for keeping me company on especially tedious days. Without your assistance, I would not have been able to gather data on as much of the field season. I would like to acknowledge and thank my thesis committee Professor Daniel Stroembom and Professor Allison Lewis for your continuous assurance throughout this process and for providing me with insight and knowledge on statistics and RStudio. I would like to acknowledge Professor Jeff Norman for assisting me with the genetic sexing process. Without your guidance, I would not have had a working protocol that can be used by the lab group for many future years. And my biggest thanks go to Dr. Michael Butler. I cannot thank you enough for believing in me when I did not believe in myself. You have helped me find a happy, safe, and inquisitive home away from home.

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Tables

Table 1. Observations of the number of siblings (from 0-4 siblings) on the mass, tarsus length, incubation period, nestling period, and duration.

Independent Variable	**Dependent Variable**	***F***	**Degrees of Freedom**	***p-value***
Number of Siblings	Body mass (g)	4.047	4, 208	0.00351
Number of Siblings	Tarsus Length (mm)	0.996	4,208	0.411
Number of Siblings	Incubation Period Duration	5.922	4,208	0.000157
Number of Siblings	Nestling Period Duration	0.818	4,208	0.515

The mass of a nestling had a statistical difference between a nest with 3 and 4 siblings (p = 0.013). The incubation period duration had a statistical difference between a nest with 1 and 4 siblings (p=0.0019), 2 and 4 siblings (p=0.022), and 3 and 4 siblings (p=0.016).

Table 2. Observations of the number of siblings (from 0-4 siblings) on brood number (1-3).

	1st brood	**2nd brood**	**3d brood**
0 siblings	1	0	0

1 sibling	5	4	0
2 siblings	8	4	1
3 siblings	12	9	3
4 siblings	16	10	0

X-squared = 5.3911, df = 8, p-value = 0.7151. There was no statistical difference between the groups.

Table 3. Observations of the number of siblings (from 0-4 siblings) on the persistence of a bird ("Not Present", "Present Less than a Week", and "Present More than a Week").

	Not Present	**Present Less than a Week**	**Present More than a Week**
0 siblings	1	0	0
1 sibling	6	2	7
2 siblings	15	5	15
3 siblings	38	8	22
4 siblings	50	4	40

X-squared = 7.9, df = 8, p-value = 0.4433. There was no statistical difference between the groups.

Table 4. Observations of the number of siblings (from 0-4 siblings) on the genetic sex.

	Male	**Female**
0 siblings	1	0
1 sibling	7	8
2 siblings	12	6
3 siblings	23	21
4 siblings	45	39

X-squared = 2.39, df = 4, p-value = 0.6637. There was no statistical difference between the groups.

Table 5. Observations of the number of siblings (from 0-4 siblings) on the presence.

	Yes	**No**
0 siblings	1	0
1 sibling	6	9
2 siblings	15	20
3 siblings	38	30
4 siblings	50	44

X-squared = 3.4121, df = 4, *p*-value = 0.4914. There was no statistical difference between the groups.

Table 6. Observations of the brood number (from 1-3) on the mass, tarsus length, incubation period duration, and nestling period duration.

Independent Variable	**Dependent Variable**	***F***	**Degrees of Freedom**	***p-value***
Number of Broods	Body mass (g)	2.23	2,210	0.11
Number of Broods	Tarsus Length (mm)	10.19	2,210	5.98e-05
Number of Broods	Incubation Period Duration	10.71	2,210	3.71e-05
Number of Broods	Nestling Period Duration	0.506	2,210	0.606

The tarsus length of a nestling had a statistical difference between broods 1 and 2 (p = 3.5e-5). The incubation period duration had a statistical difference between broods 1 and 2 (p=0.0015) and 1 and 3 (p=7.9e-4).

Table 7. Observations of the brood number (from 1-3) of an individual on the persistence of an individual ("Not Present", "Present Less than a Week", and "Present More than a Week").

	Not Present	**Present Less than a Week**	**Present More than a Week**
1st Brood	78	8	27

2nd Brood	25	10	51
3d Brood	7	1	6

X-squared = 31.86, df = 4, p-value = 2.04e-6.

Table 8. Observations of the brood number (from 1-3) on the genetic sex.

	Male	**Female**
1st Brood	42	30
2nd Brood	42	40
3d Brood	4	4

X-squared = 0.845, df = 2, p-value = 0.655. There was no statistical difference between the groups.

Table 9. Observations of the brood number (from 1-3) on presence.

	Yes	**No**
1st Brood	78	35
2nd Brood	25	61
3d Brood	7	7

X-squared = 31.236, df = 2, p-value = 1.649e-07. There is a significant relationship between bro od number and presence.

Table 10. Observations of genetic sex (Male or Female) on the mass, tarsus length, incubation period duration, and nestling period duration.

Independent Variable	**Dependent Variable**	***F***	**Degrees of Freedom**	***p-value***
Genetic Sex	Body mass (g)	9.214	1,160	0.0028
Genetic Sex	Tarsus Length (mm)	1.239	1,160	0.267
Genetic Sex	Incubation Period Duration	0.345	1,160	0.558
Genetic Sex	Nestling Period Duration	0.579	1,160	0.448

Mass was significantly different between the genetic sexes of house sparrows (p=0.0028).

Table 11. Observations genetic sex on the persistence of a bird (“Not Present”, “Present Less than a Week”, and “Present More than a Week”).

	Not Present	**Present Less than a Week**	**Present More than a Week**

Male	41	8	39
Female	32	8	34

X-squared = 0.244, df = 2, p-value = 0.8851. There was no statistical difference between the groups.

Table 12. Observations of genetic sex on presence.

	Yes	**No**
F	32	42
M	41	47

X-squared = 0.071867, df = 1, p-value = 0.7886. There was no statistical difference between the groups.

Table 13. Observations of mass on tarsus length, incubation period duration, and nestling period duration.

Independent Variable	**Dependent Variable**	***F***	**Degrees of Freedom**	***R^2 value***	***p-Value***
Body mass (g)	Tarsus Length (mm)	154.6	1,211	0.422	< 2e-16
Body mass (g)	Incubation Period Duration	8.36	1,211	0.0381	0.00424
Body mass	Nestling	26.48	1,211	0.1115	6.08e-07

(g)	Period Duration				
Persist	Body mass (g)	7.657	2,210	N/A	0.000617

The mass of a nestling had a positive correlation with the tarsus length of a nestling (*p* = < 2e-16). The incubation period duration had a negative correlation with mass (*p*=0.00424). The nestling period duration had a negative correlation with mass (*p*=6.08e-07). The persistence had a statistical difference between “Not Present” and “Present More than a Week”(*p*=3.91e-4).

Table 14. Observations of mass on presence of a nestling at the feeder.

Independent Variable	**Dependent Variable**	***t-value***	**Degrees of Freedom**	***p-Value***
Presence	Body Mass (g)	14.57	1,211	1.78e-4

There was a significant difference between whether or not the bird was present in relation to body mass (*p*=1.78e-4).

Table 15. Observations of tarsus length on incubation period duration, nestling period duration, and persistence.

Independent Variable	**Dependent Variable**	***F***	**Degrees of Freedom**	***R^2 value***	***p-Value***

Tarsus Length (mm)	Incubation Period Duration	8.36	1,211	0.3811	0.00423
Tarsus Length (mm)	Nestling Period Duration	14.14	1,211	0.0628	0.0002192
Persist	Tarsus Length (mm)	12.17	2,210	N/A	9.98e-06

The incubation period duration had a negative correlation with tarsus length (*p*=0.00423). The nestling period duration had a negative correlation with tarsus length (*p*=2.192e-4). The tarsus length had a statistical difference between "Present Less than a Week" and "Present More than a Week" (*p*=0.024) and "Not Present" and "Present More than a Week"(*p*=9.0e-6).

Table 16. Observations of tarsus length on presence of a nestling at the feeder.

Independent Variable	**Dependent Variable**	***W-value***	***p-Value***
Presence	Tarsus Length (mm)	3898.5	8.399e-5

There was a significant difference between whether or not the bird was present in relation to tarsus length (*p*=8.399e-5).

Table 17. Observations of incubation period duration on nestling period duration and persistence.

Independent Variable	**Dependent Variable**	***F***	**Degrees of Freedom**	***R^2 value***	***p-Value***
Incubation Period Duration	Nestling Period Duration	0.125	1,211	0.00059	0.724
Persist	Incubation Period Duration	5.479	2,210	N/A	0.00479

The incubation period duration had a statistical difference between “Present Less than a Week” and “Present More than a Week” (p=0.0108) and “Not Present” and “Present More than a Week”(p=0.0426).

Table 18. Observations of incubation period duration on presence of a nestling at the feeder.

Independent Variable	**Dependent Variable**	***W-value***	***p-Value***
Presence	Incubation Period Duration	6571	0.0311

There was a significant difference between whether or not the bird was present in relation to incubation period duration (p=0.0311).

Table 19. Observations of nestling period duration on presence of a nestling at the feeder.

Independent Variable	**Dependent Variable**	***W-value***	***p-Value***
Presence	Nestling Period Duration	6137.5	0.283

There was no significant difference of whether or not the bird was present in relation to nestling period duration.

Table 20. Observations of nestling period duration on persistence.

Independent Variable	***Dependent Variable***	***F***	***df***	***p-Value***
Persist	Nestling Period Duration	1.269	2,210	0.283

There is no statistical correlation between nestling period duration and persistence.

Table 21. Observations of Julian date on number of siblings, body mass, tarsus length, incubation period duration, nestling period duration, genetic sex, and persistence.

Independent Variable	**Dependent Variable**	***F***	R^2	**Degrees of Freedom**	***p-value***

Julian Date	Body mass (g)	10.38	0.046	1,211	0.0014
Julian Date	Tarsus Length (mm)	43.84	0.172	1,211	2.908e-10
Julian Date	Incubation Period Duration	83.64	0.283	1,211	<2.2e-16
Julian Date	Nestling Period Duration	7.952	0.036	1,211	0.00526
Number of Siblings	Julian Date	1.125	N/A	4	0.346
Genetic Sex	Julian Date	0.01	N/A	1	0.92
Persist	Julian Date	13.65	N/A	2	2.66e-6

The date had a statistical difference between birds that were not present at the feeder and birds that were there longer than a week (p = 1.8e-6).

Table 22. Observations of Julian date on presence of a nestling at the feeder.

Independent Variable	**Dependent Variable**	***W-value***	***p-Value***

Presence	Julian Date	3587.5	3.78e-6

There was a significant difference between whether or not the bird was present in relation to Julian date.

Figures

Figure 1. Bird feeder with RFID-detectable capabilities. There are 4 rings at the 4 perches at the top. There are 8 rings at the bottom of the feeder. It is powered by a solar panel that is attached to the wooden base. It is surrounded by mesh that is wide enough for a songbird to enter but small enough that larger animals will not be able to enter.

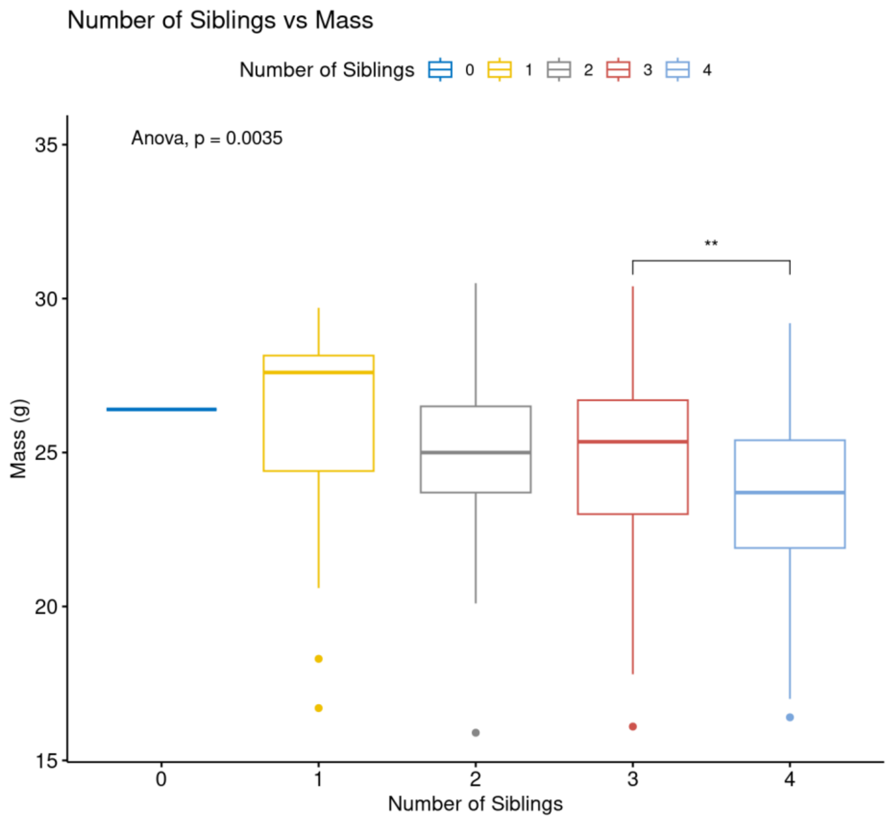

Figure 2. The mass is significantly different between the nests with 3 and 4 siblings.

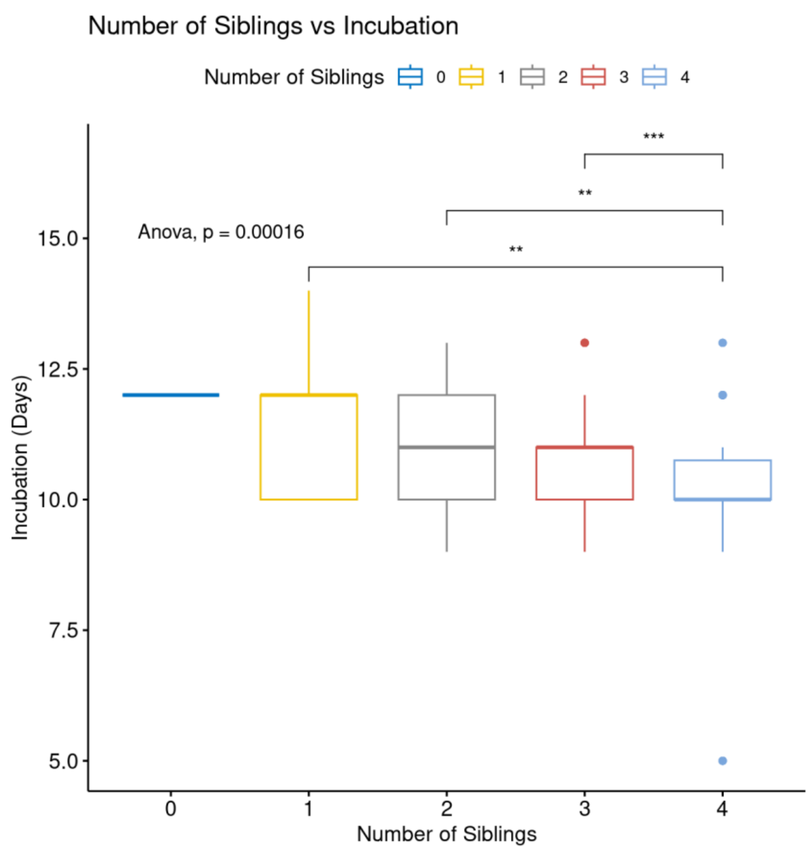

Figure 3. The incubation period duration had a statistical difference between a nest with 1 and 4 siblings, 2 and 4 siblings, and 3 and 4 siblings.

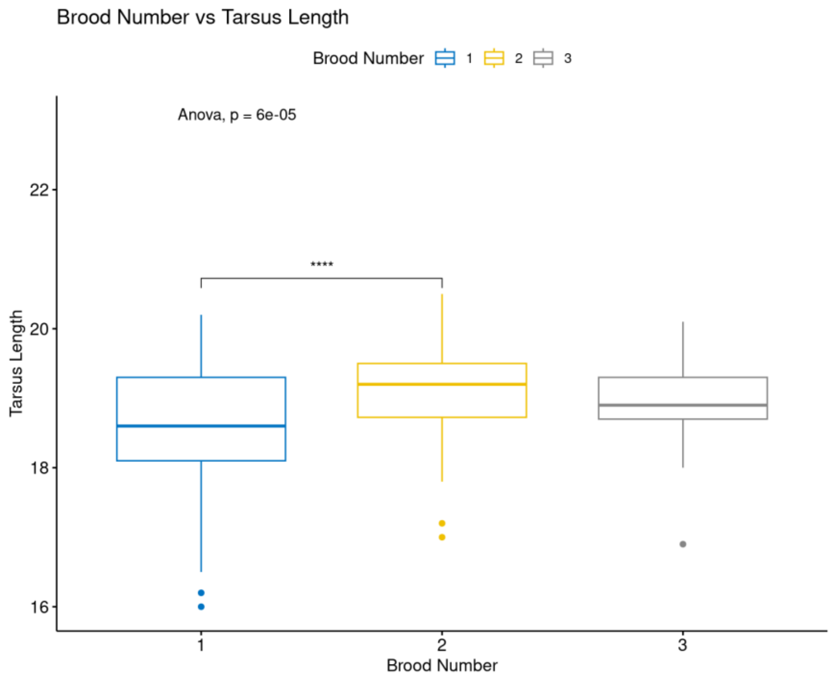

Figure 4. The tarsus size had a statistical difference between brood numbers 1 and 2

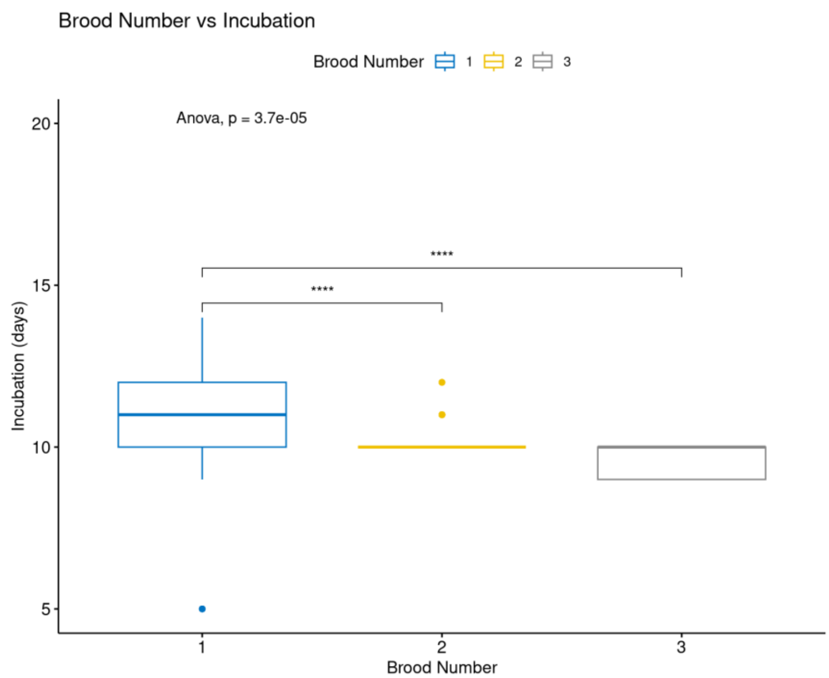

Figure 5. The incubation period duration had a statistical difference between broods 1 and 2 and 1 and 3.

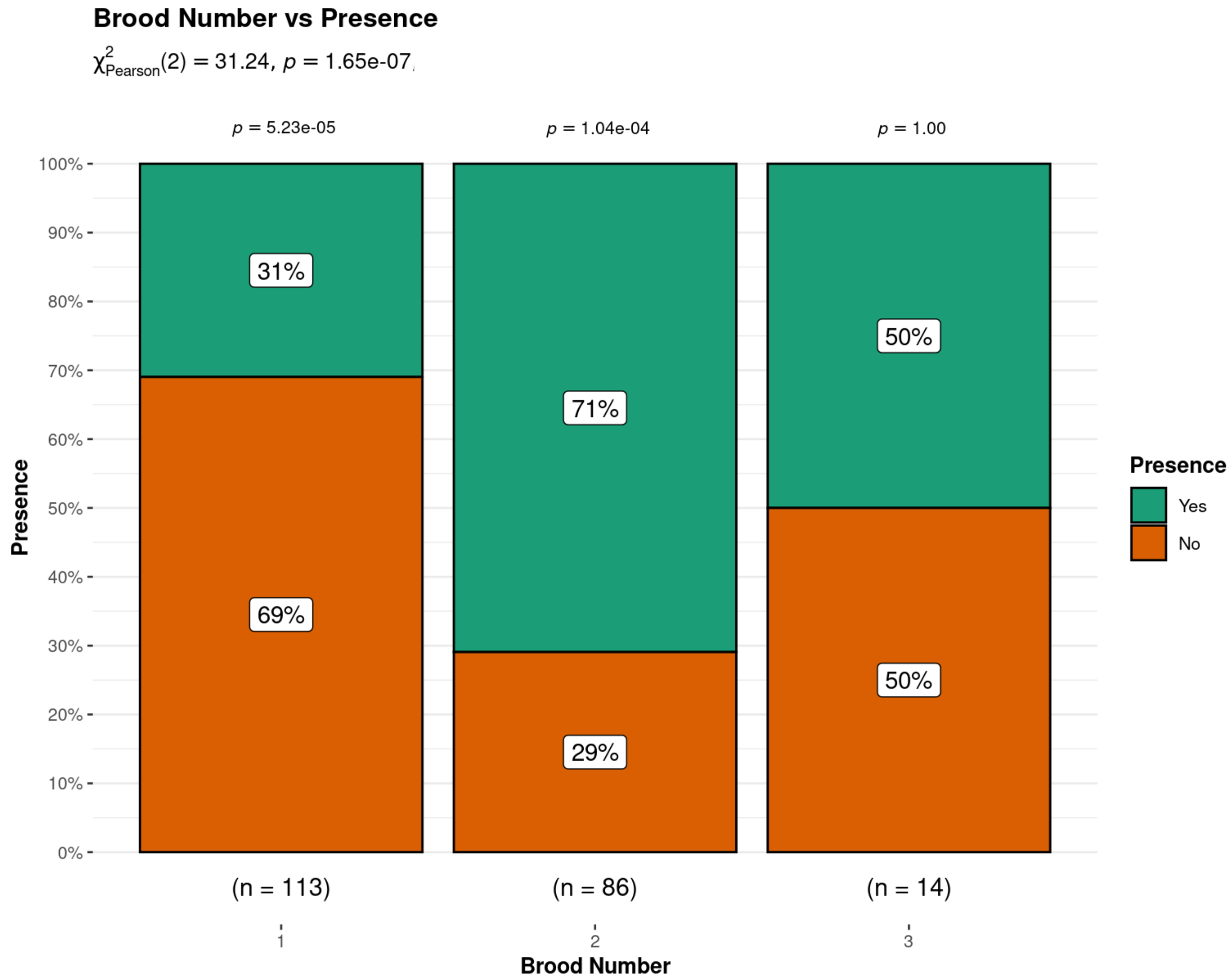

Figure 6. Brood numbers and presence. There is a significant amount of individuals from the first brood to not be detected at the feeder and a significant amount of individuals from the second brood who were detected.

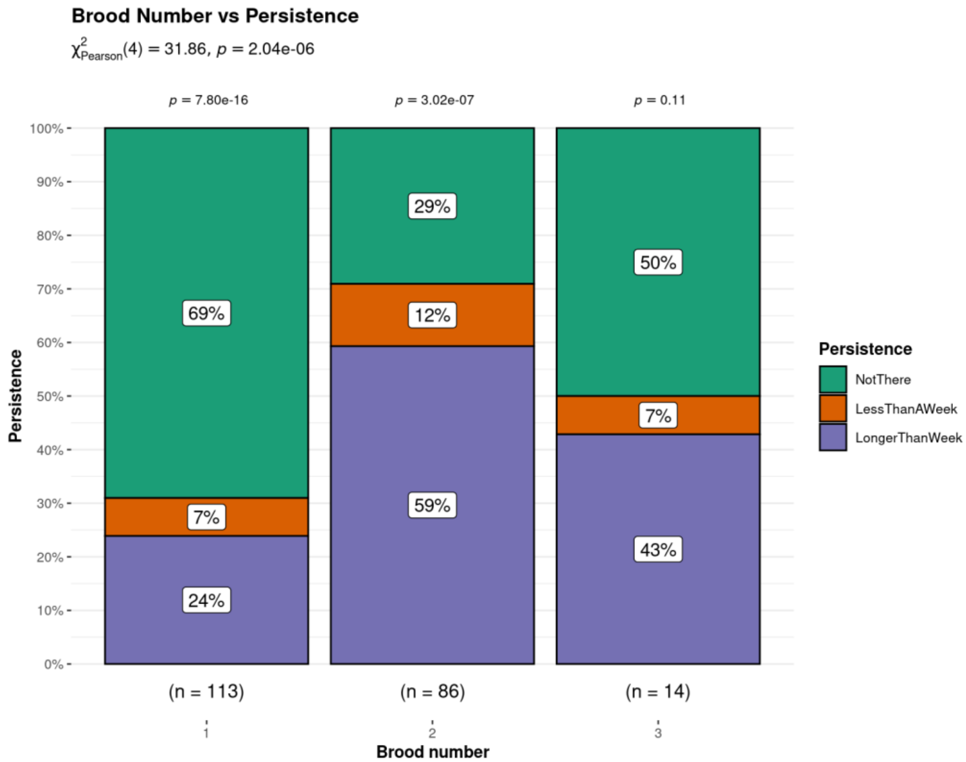

Figure 7. Broods and persistence. There is a significant amount of individuals from the first brood to not be detected at the feeder and a significant amount of individuals from the second brood who were detected for longer than a week.

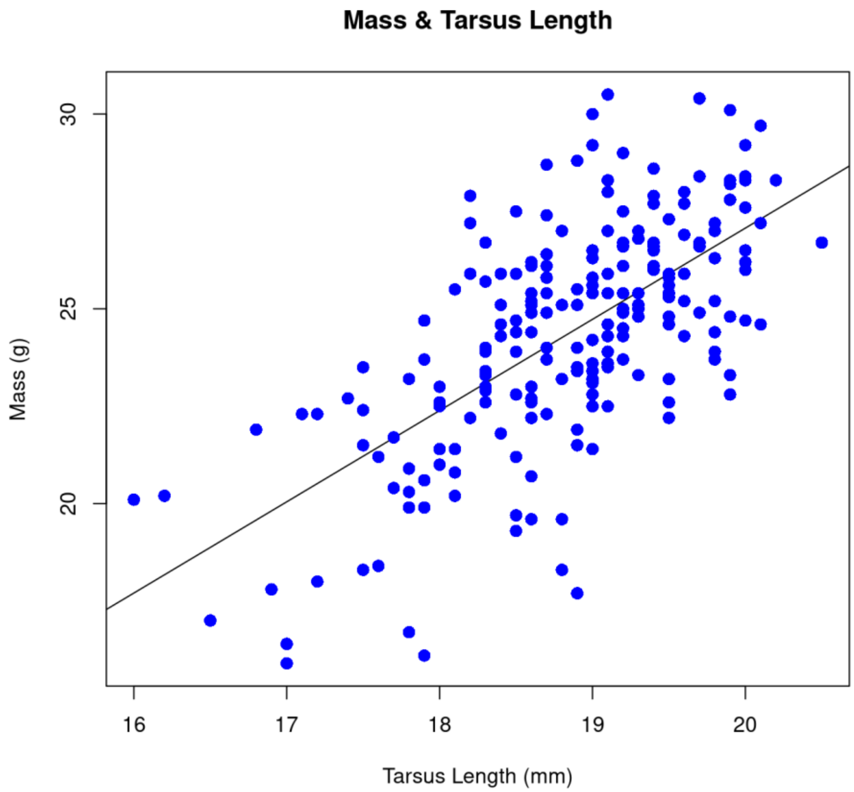

Figure 8. There was a positive correlation between mass and tarsus length.

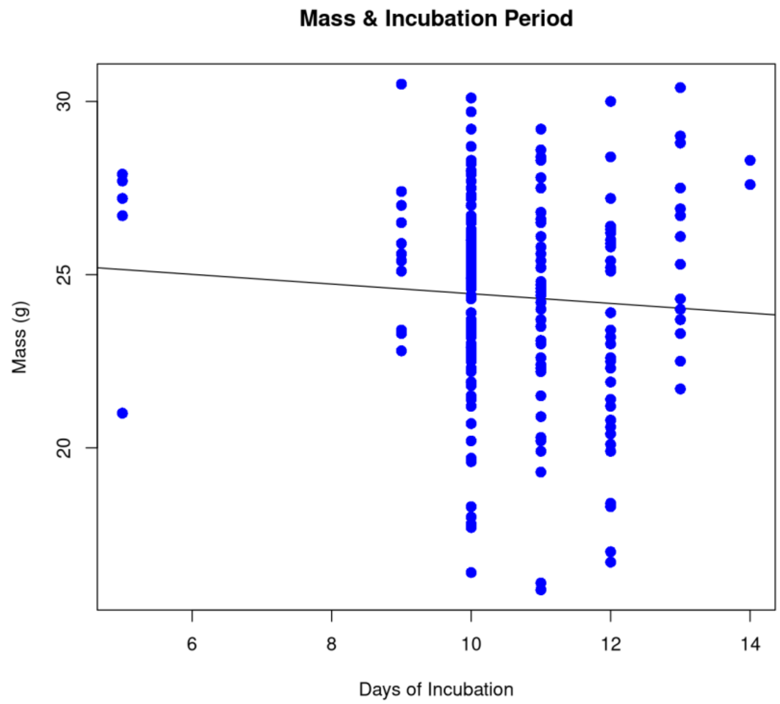

Figure 9. There is a negative correlation between body mass and incubation period duration.

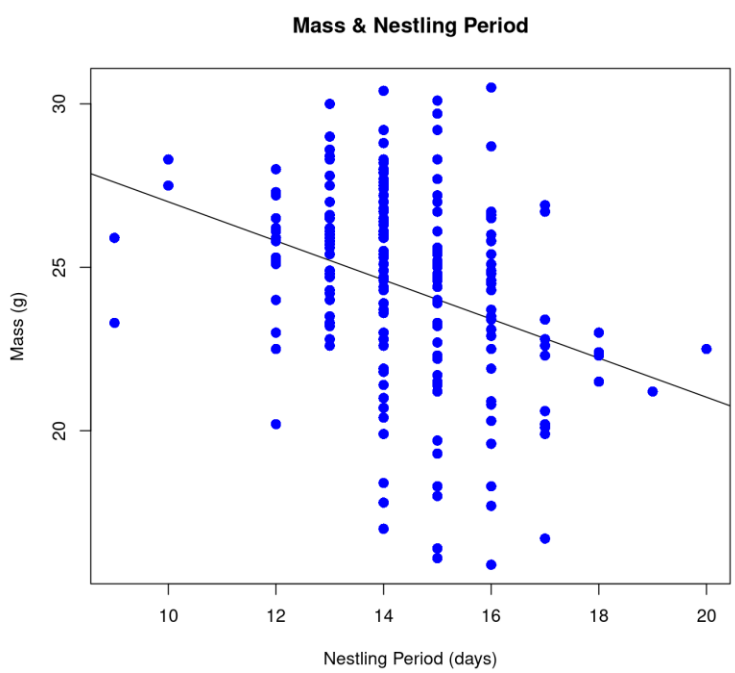

Figure 10. There is a negative correlation between body mass and nestling period duration.

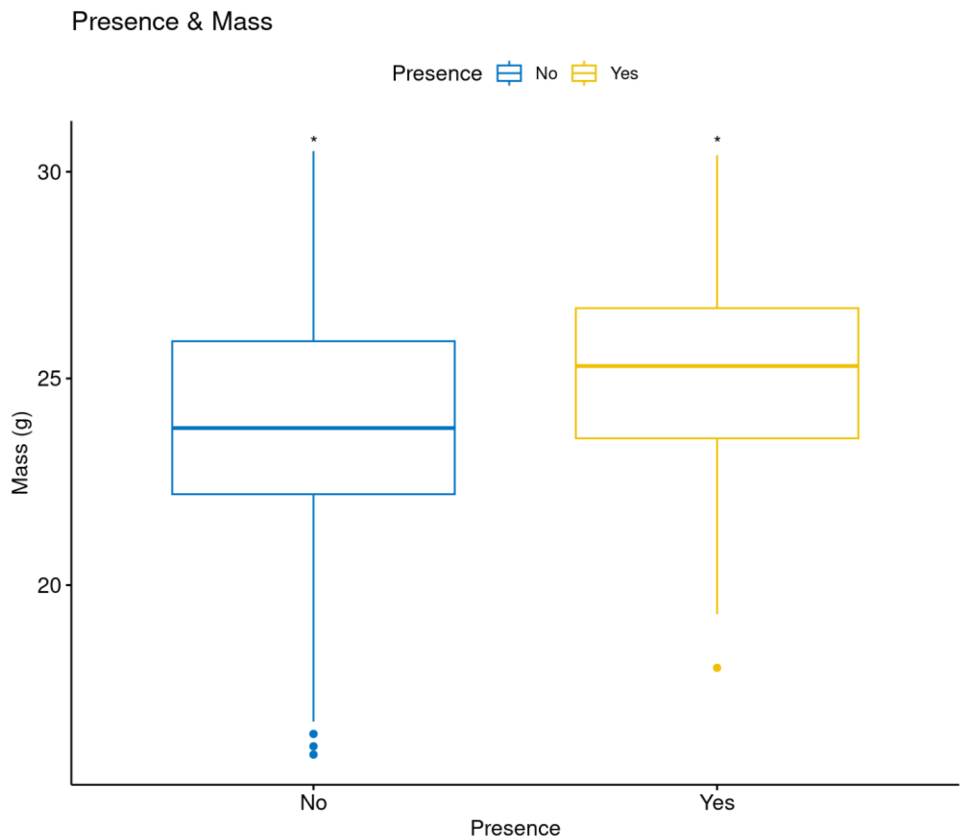

Figure 11. There is a statistical difference between whether or not a nestling is present at the feeder in correlation with mass.

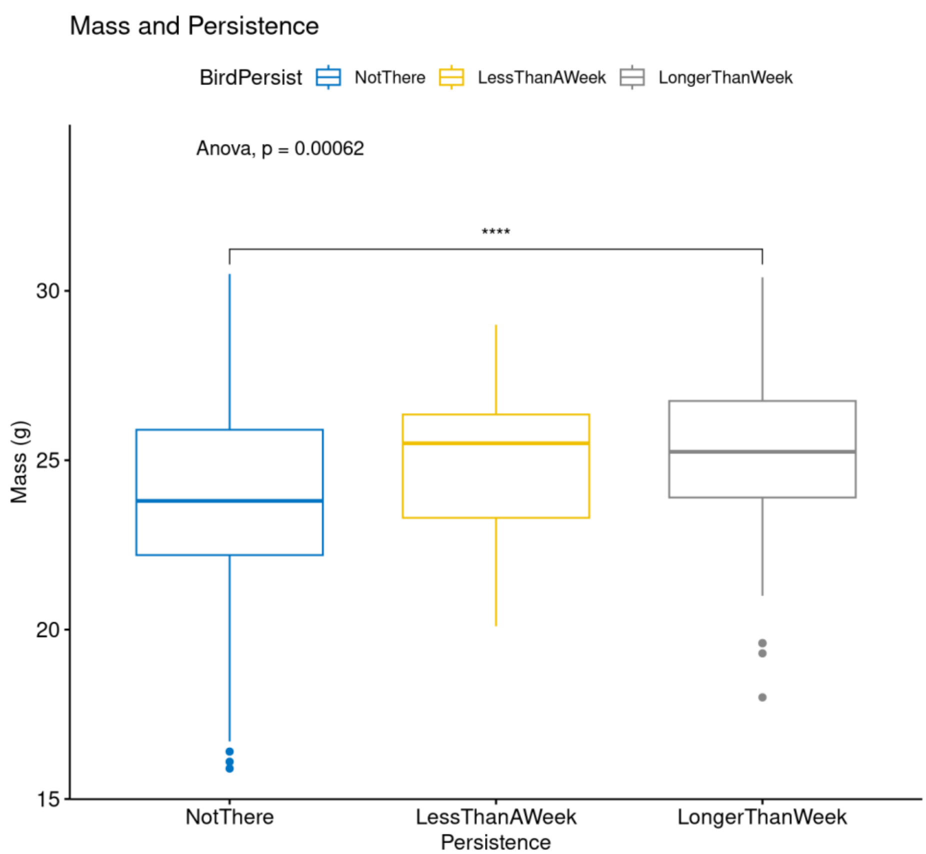

Figure 12. There was a statistical difference of mass between house sparrows who were not present at all and those who were present for more than a week.

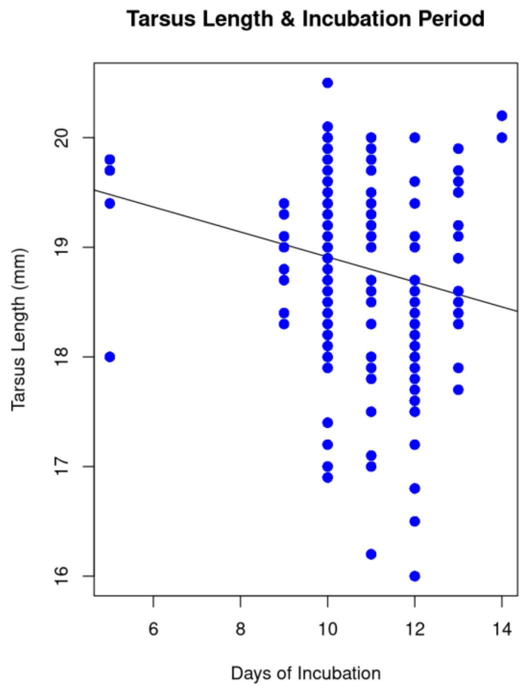

Figure 13. There is a negative correlation between incubation period duration and tarsus length.

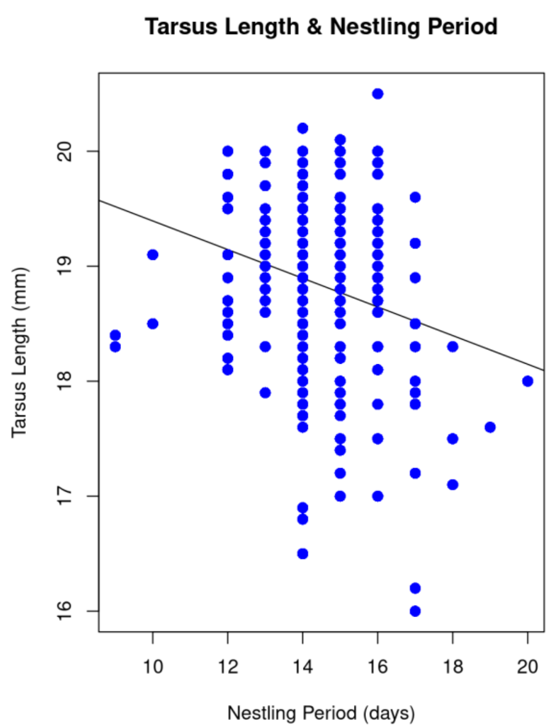

Figure 14. There is a negative correlation between incubation nestling period duration and tarsus length.

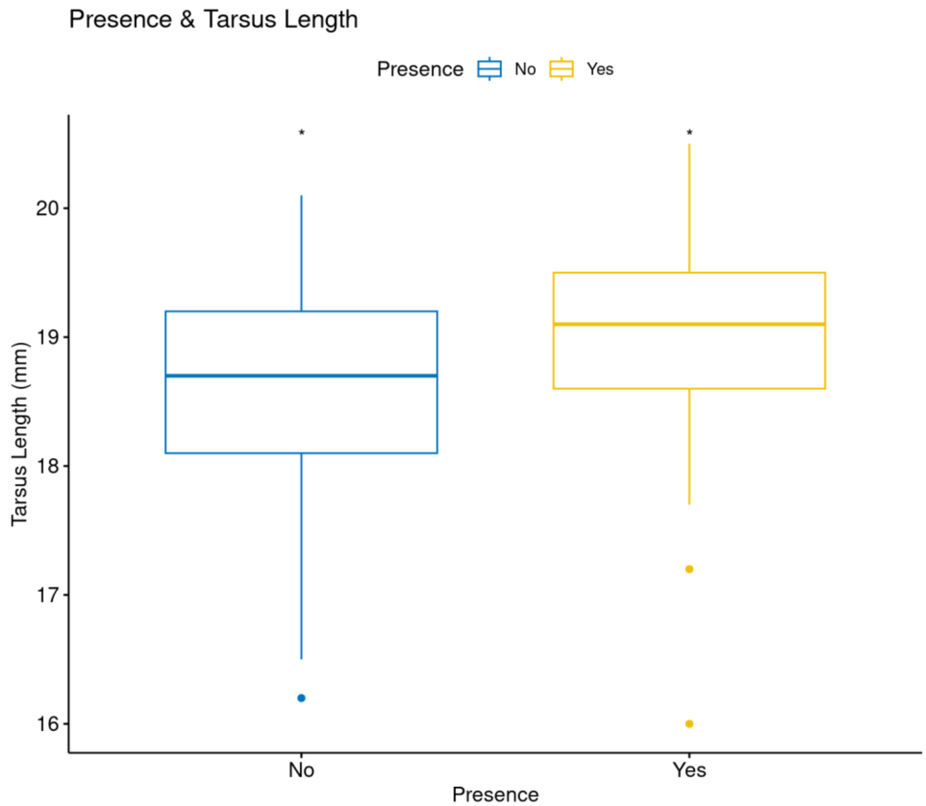

Figure 15. There is a statistical difference between whether or not a nestling is present at the feeder in correlation with tarsus length.

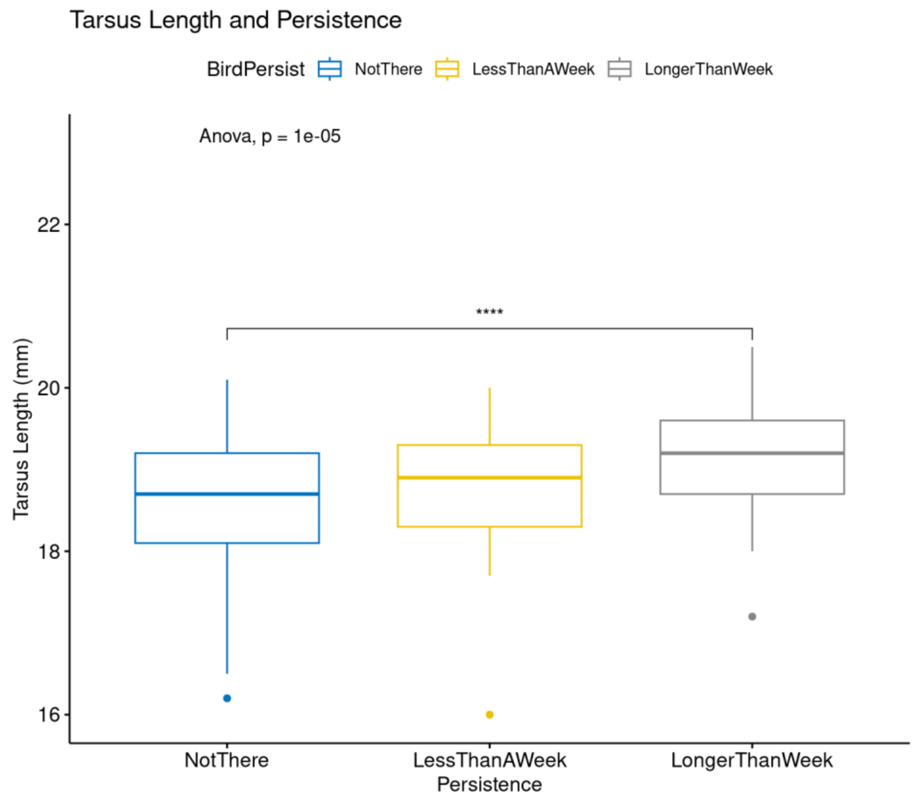

Figure 16. The tarsus length had a statistical difference between “Not Present” and “Present More than a Week”.

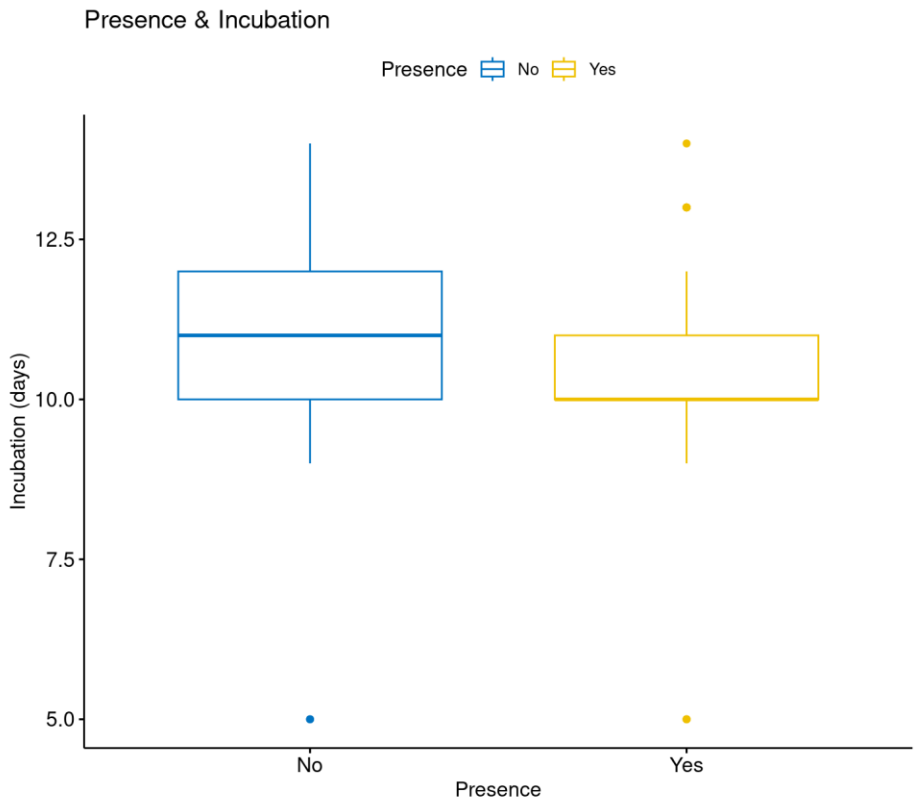

Table 17. Nestlings that were incubated for longer were less likely to be present at the feeder.

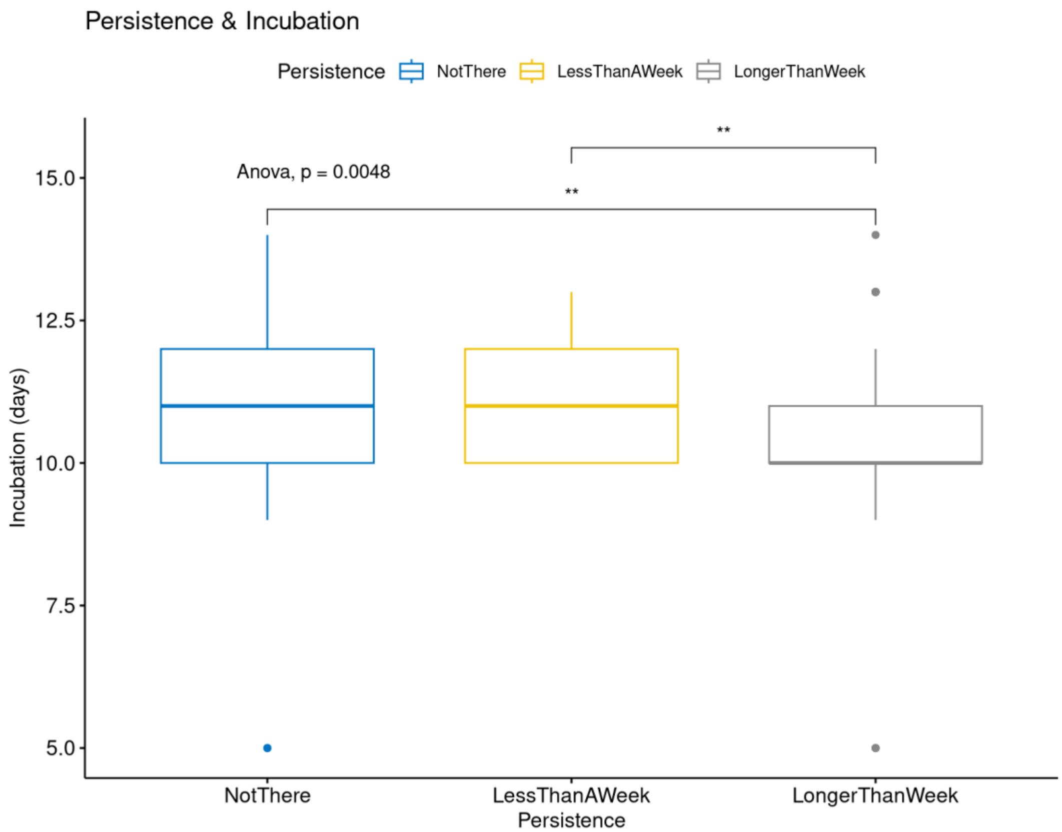

Figure 18. There is a significant difference in incubation period duration between birds who were not detected and those who were detected for longer than a week. Also, there is a significant difference in incubation period duration between birds who were detected for less than a week and those who were detected for longer than a week.

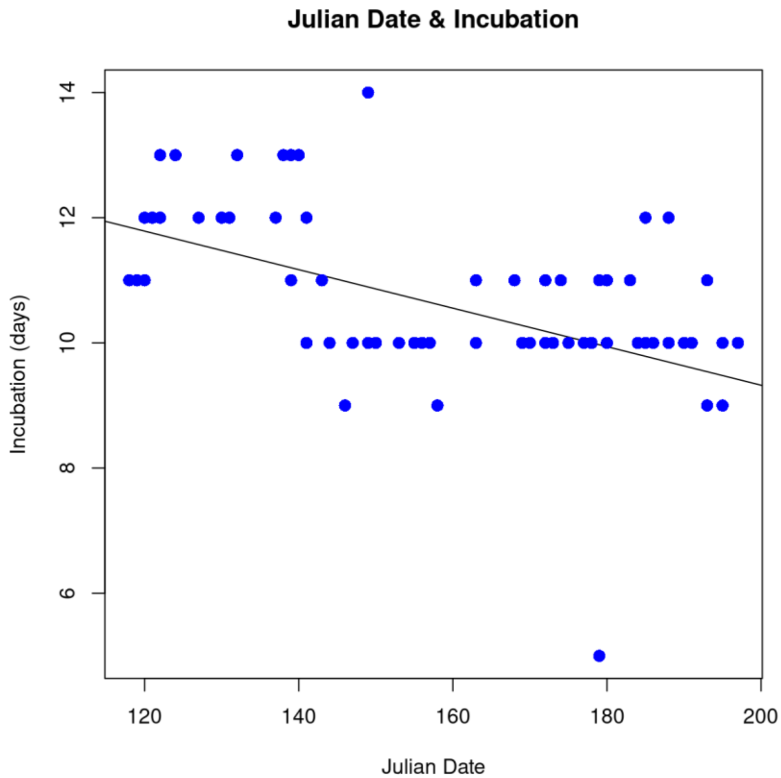

Figure 19. There is a negative correlation between Julian date and incubation period duration.

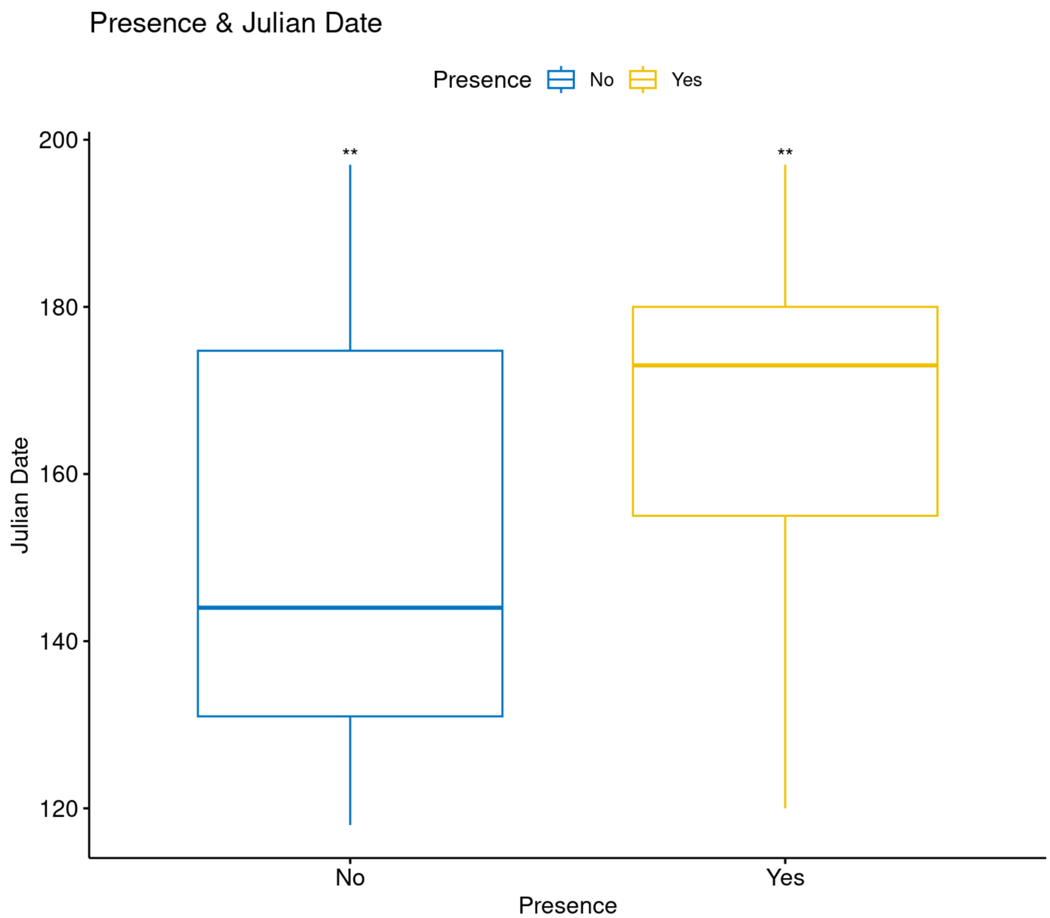

Figure 20. Birds that were born later in the year were more likely to be present at the feeder.

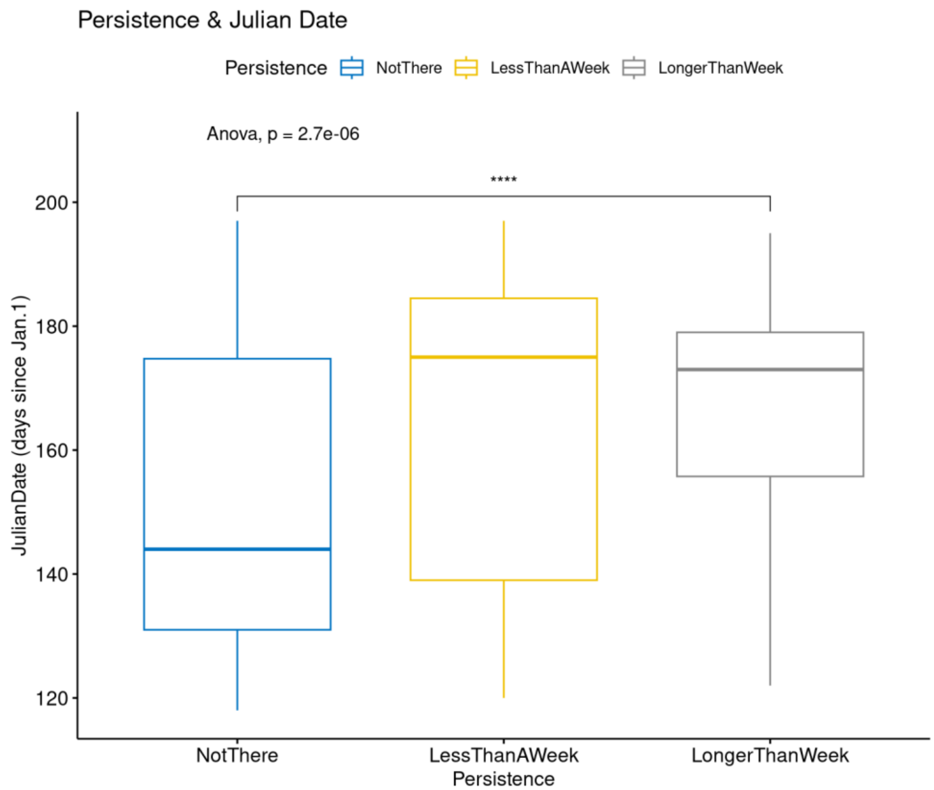

Figure 21. There is a significant difference in Julian date between birds who were not detected and those who were detected for longer than a week.