# Sparrow Nest Project

## I. Introduction

The interactions and adaptations observed among animal species and their surroundings often prompt intriguing inquiries. In the avian realm, elements like nesting behaviors wield substantial influence over the viability and reproductive prosperity of bird communities. Among these avian creatures, sparrows emerge as a prime avenue for investigating the influence of nesting patterns on their attributes and conduct. This study hones in on a pivotal query: Does the type of nest allocated to sparrows on Kent Island exert an influence on the size of the sparrow populace? In particular, the investigation scrutinizes whether sparrows that inhabit diverse nest types—ranging from unaltered control nests, to magnified nests deliberately engineered to exceed typical dimensions, and finally to reduced nests intentionally crafted to be smaller than the norm—display variances in their body weights. Unraveling the nexus between nest type and sparrow dimensions can furnish invaluable insights into avian adjustments and behaviors. Should certain nest varieties allure larger sparrows, it could imply a predilection for particular nest attributes capable of affording heightened safeguarding, comfort, or accessibility. Conversely, a lack of noticeable differences in sparrow size tied to nest types might suggest that nest dimensions hold limited sway over sparrow body weight. Such findings stand poised to enrich our broader comprehension of the factors that mold avian populations and their reactions to shifts in their surroundings.

To address this inquiry, we will initially leverage our dataset to offer contextual insight into the question of whether the mean weight of sparrows residing in control nests, enlarged nests, and reduced nests are equivalent. This analysis will enable us to determine if the various nests for sparrows on Kent Island indeed attract sparrows of different sizes. To tackle this question, we will conduct a hypothesis test focused on equal means, employing a significance level of 5%. We will utilize an F-test of equal means for the single-factor ANOVA group means to derive our test statistic. The resulting F-test statistic will provide insight into our p-value, which signifies the likelihood of obtaining our data assuming that the average weight changes of sparrows in each treatment group are identical.

Should our computed p-value fall below our 5% significance level, we can deduce that at least one treatment group's average weight change in sparrows is distinct. Conversely, if our p-value surpasses the significance level, we lack sufficient evidence to refute the assertion that each treatment group's average weight change in sparrows differs. This test will elucidate whether there exists a disparity in average weight change in sparrows among the treatment groups, thus facilitating the progression to our subsequent objective.

The subsequent phase of our project is dedicated to assessing the degree of differentiation between the average weight changes of sparrows in each treatment group. To achieve this, we will simultaneously construct confidence intervals for the disparity between the average weight changes of sparrows in each treatment group. Subsequently, we will compute the confidence interval for the treatment group that exhibited a propensity for hosting the largest sparrows among groups.

Two confidence intervals will be created, facilitating comparisons between Control and Enlarged, and Control and Reduced treatment groups. By examining these confidence intervals, we can discern which treatment group exhibits greater proficiency in attracting sparrows of either larger or smaller sizes compared to its counterpart. Since we are working with simultaneous confidence intervals, our choice of multiplier is pivotal in satisfying the equation. Two multipliers, Tukey's and Bonferroni's, are under consideration. Tukey's multiplier, specifically tailored for our analysis, stands at 2, given its specialization in simultaneous confidence intervals. In contrast, Bonferroni's multiplier is more general in nature and can be employed for constructing any confidence interval. The selection of the multiplier will be guided by their respective formulas, with preference for the smaller multiplier. This selection ensures the derivation of the narrowest possible confidence interval with a 95% confidence level, enhancing the precision of our interpretation regarding the distinctions in average weight changes of sparrows among the treatment groups.

These confidence intervals will empower us to discern which treatment group attracts sparrows of distinct sizes most effectively. Furthermore, our curiosity extends to comprehending the extent to which the average weight change of each group influences the overall weight change across the entire dataset. This measure is represented by the Greek letter $\gamma_i$, indicating the average effect of a specific treatment group's average weight change on the collective weight change encompassing all treatment groups. Armed with this data, we can compare and contrast the impact of each treatment group's average on the overall average change in sparrow weights within the entire sample. This analysis will also allow us to identify treatment groups that wield comparable influences on the overall average, as well as those that exert distinct impacts. The outcome will pinpoint the treatment group with the most substantial and the least significant effect on sparrow weights, relative to other treatment groups.

This experiment endeavors to illuminate the correlation between various nest types and the dimensions of sparrows. By doing so, we seek to enhance our understanding of avian ecology on a broader scale, with the potential to provide insights that could inform conservation initiatives and strategies for effective habitat management.

# II. Summary of the Data

## 1) Summary Data Values

| | control | enlarged | reduced | overall |
|:---|---:|---:|---:|---:|
| Means | 13.9244 | 13.5156 | 15.5692 | 14.1345 |
| Std. Dev | 2.4196 | 2.1040 | 1.4593 | 2.2426 |
| Sample Size | 45.0000 | 45.0000 | 26.0000 | 116.0000 |

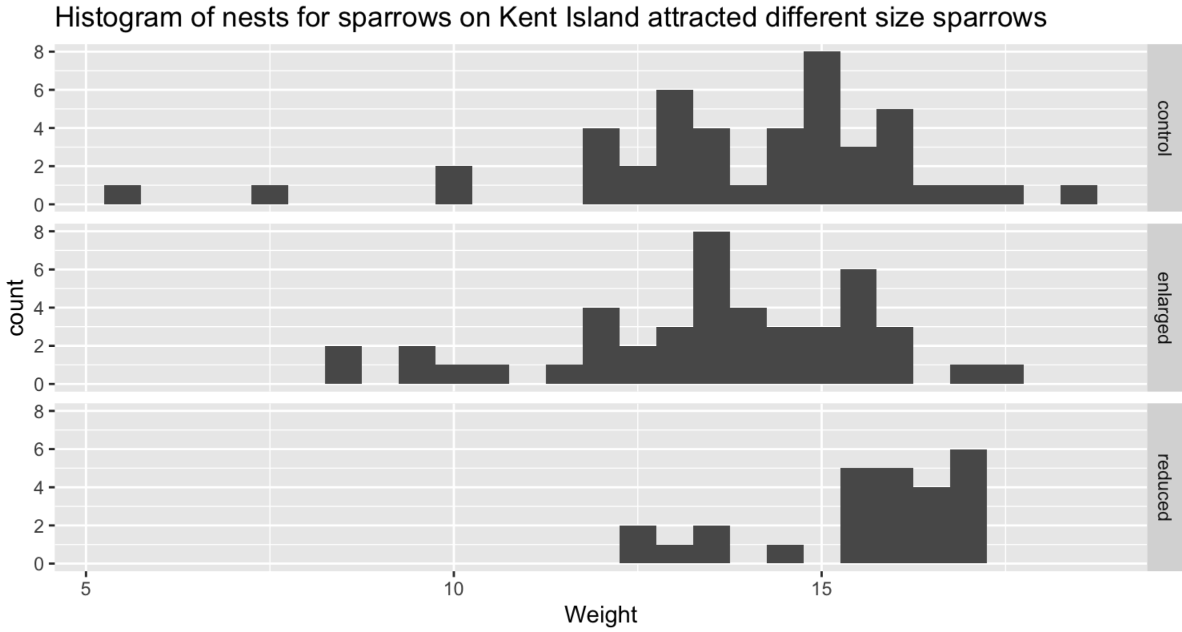
This table compiles the collected data from the three distinct treatment groups: Control group, Enlarged group, and Reduced group. It provides an overview of key statistical metrics for each group, including the mean (average) weight of attracted sparrows, the standard deviation indicating the dispersion of data within each group, and the sample size representing the number of subjects in each group.

The data reveals that the Reduced group had subjects that, on average, attracted the heaviest sparrows, with an average weight of around 15.562 grams. In contrast, the Enlarged group attracted sparrows with the lowest average weight, approximately 13.5156 grams. This table also offers insights into the variability of data within each group through the standard deviation. The Control group stands out with the widest data spread, a finding that aligns with the boxplots where it displayed elongated tails compared to the other groups. Conversely, the Reduced group exhibited the least dispersion of data, a fact that corroborates the observations from the Reduced group's boxplot.

Moreover, the table presents the sample size for each group. Notably, both the Control group and the Enlarged group share an identical sample size of 45, enabling a relatively fair comparison between them. However, the Reduced group deviates with a smaller sample size of 26, placing it as an outlier. The presence of this outlier underscores the challenge of making precise comparisons due to the lack of uniformity in sample sizes.

Finally, amalgamating the data across all treatment groups yields comprehensive insights into the entire sample. By considering all the conducted tests, the average weight of sparrows attracted to the nests across all three treatment groups is determined to be 14.1345 grams. The standard deviation of approximately 2.2426 indicates the degree to which the average sparrow weight can deviate from the mean. The table concludes by presenting the total number of attracted sparrows in the dataset, amounting to 116 across the three treatment groups.

## 2) Histogram of Weight by Treatment groups

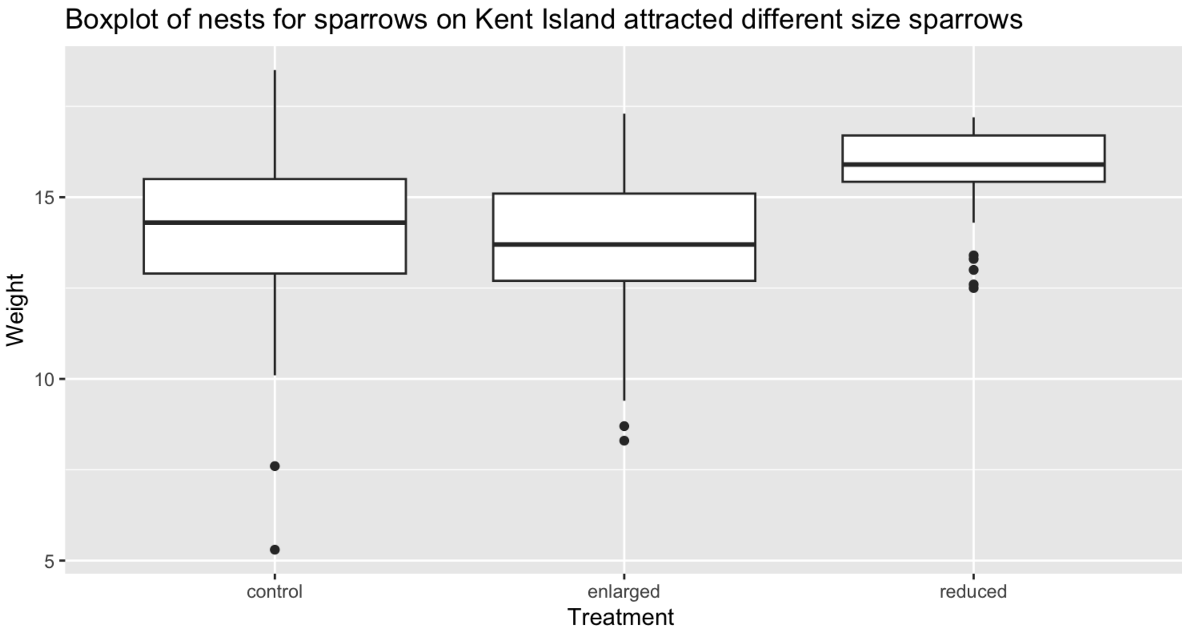



The histograms presented above depict the distribution of sparrow weights (measured in grams) grouped by their respective treatment types. A detailed examination of the Control histogram reveals a slight left skew. Notably, there exists a substantial variation in sparrow weights, ranging approximately from 5.3 to 18.5 grams. Furthermore, there are three instances where sparrow weights appear only once, suggesting the presence of outliers. This inference is supported by the histogram's depiction of values clustered below 10 grams.

The Enlarged histogram, in contrast, displays a relatively more even distribution. Sparrow weights fall within the range of approximately 8.3 to 17.3 grams. There is a sparrow value, around 8.5 grams, far to the left from the rest of the distribution that only occurs twice. This distribution pattern similarly indicates the presence of outliers within this dataset.

Lastly, the Reduced histogram portrays a tight concentration of sparrow weights between 12.5 to 17.2 grams. The closely clustered data points suggest minimal variance in sparrow weights within this group. However, it is worth noting that even within this distribution, outliers are still evident. There are two instances where sparrow weight values occur only once, along with two instances where values occur twice. The histogram for the reduced group appears to exhibit a distinct variance compared to the others, which could raise some concerns. In summary, the histograms provide insights into the distribution of sparrow weights across different treatment groups. They highlight the varying degrees of dispersion and the potential presence of outliers in each group's dataset.

## 3) Boxplot of Weight nests for sparrows on Kent Island attracted different size sparrows




The box plot graphically illustrates the dispersion of sparrow weight changes across the three distinct treatment groups, while also highlighting any potential outliers. Additionally, it provides insights into the mean and quartiles of each treatment group's distribution. Analyzing the Control group's box plot reveals a relatively higher variability in data. This is evident from the greater distance between the upper quartile (approximately 15.5 grams) and the lower quartile (around 13.0 grams) in relation to the median (14.3 grams). Furthermore, the Control group's box plot displays elongated tails reaching as far as 18.5 grams at the upper end and dropping to 10.0 grams at the lower end. These extended tails indicate a wider dispersion of higher-weight data points in the Control group compared to the other treatment groups. Additionally, two outliers are observed in the Control group's boxplot, both falling below 9.95 grams.

Moving to the Enlarged group's boxplot, a lower median of around 13.7 grams is noticeable, coupled with a narrower spread between the quartiles and the median. The upper quartile lies around 15.0 grams, and the lower quartile is approximately 12.7 grams. The boxplot's shorter upper tail reaching 7.50 grams and an elongated lower tail down to 9.90 grams signify the distribution's characteristics. This group also includes two outliers, both below 8.5 grams.

In contrast, the Reduced group's boxplot exhibits the highest median value, approximately 15.9 grams, and the smallest range between the quartiles and the median. The upper quartile is around 17.0 grams, and the lower quartile is approximately 15.5 grams. Analyzing the three boxplots, we can deduce that the Reduced group, on average, attracted the largest sparrows compared to the other groups due to it having the greatest mean value. Moreover, the Reduced group's boxplot has the shortest upper tail (17.2 grams) and lower tail (14.3 grams). Despite having the least variability among data points, this group contains the highest number of outliers, clustered around 13.0 grams.

In summary, the boxplots offer valuable insights into the distribution of sparrow weight changes within each treatment group. They also allow us to draw conclusions about the relative attraction of sparrows by the Reduced group, its consistency in sparrow weights, and the presence of notable outliers.

# III. Diagnostics

In any statistical analysis, it is important to not only perform hypothesis testing and calculate confidence intervals, but also to evaluate the assumptions underlying the chosen statistical methods. Assumptions serve as the groundwork of the analysis, and the breach of these assumptions can lead to results and conclusions that are unreliable. In the context of the sparrow nest experiment on Kent Island, where the goal is to understand the impact of different nest types on sparrow size, it is crucial to assess the assumptions associated with the statistical model used for analysis. We will delve into the assumptions of the model and conduct diagnostics to identify potential infractions, if any.

## 1) Assumptions of the Model:

Independence: A core assumption in statistics is that our observations are independent. For the sparrow experiment, this means the weights of individual sparrows shouldn't depend on each other across different nest types. If this assumption is broken, it might be due to shared factors among sparrows in a nest or more similarity in size within nests.

Normality: Many statistical methods bank on the data following a normal distribution. In our case, this implies that sparrow weights within each nest type should roughly look like a normal curve. If things don't align and our distributions are skewed or have heavy tails, our methods might falter.

Homogeneity of Variance: Another key assumption is that the weight variances are roughly the same across nest types. If these variances differ a lot, it could mess with our results.

## 2) Outliers:

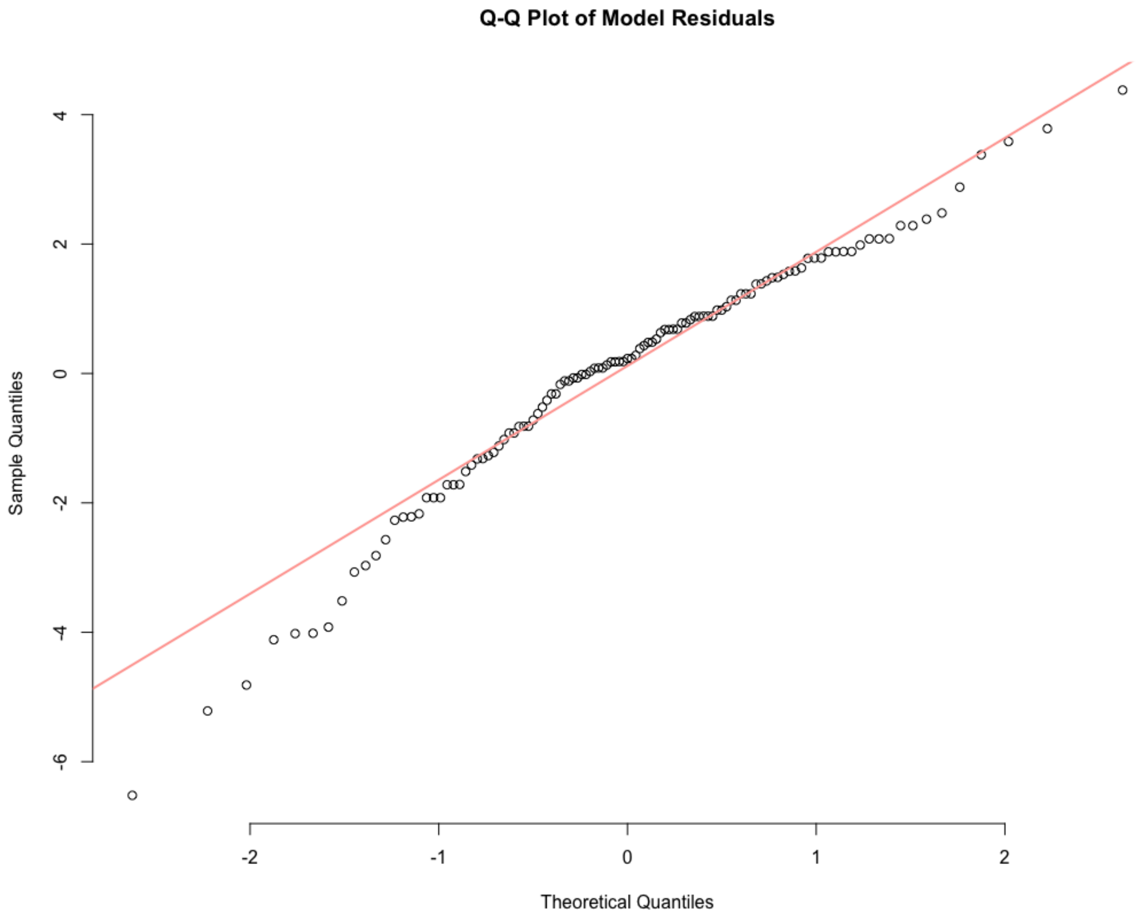
Outliers are observations that are significantly different from the rest of the data. They can have a disproportionate impact on statistical analysis, so we've decided to ditch them from our dataset to keep things clean.

## 3) Semi-Studentized Residuals:

Semi-Studentized Residuals: To pinpoint those outliers, we used semi-studentized residuals. These are like normalized residuals that help us see how much our model's predictions deviate from the actual data. Following this using the data values given we obtain the T cutoff at the alpha level of 0.01 with the model 1-$\alpha/(2\times n_T)$, only using this model when we are comparing multiple residuals, Yielding a T cut-off value of 4.0737. By crunching the numbers, we set a threshold of 4.0737 and found one outlier - one sparrow that weighed way less than the others in the control group at row 45.

## 4) Assessing Normality:

Checking Normality Assumption: One of the assumptions underlying statistical methods is that the data should follow a normal distribution.Since you're interested in comparing sparrow weights across different nest types, it's crucial to know if the weights are normally distributed within each group. This impacts the validity of hypothesis testing and the reliability of confidence intervals.




In our Q-Q plot, we observed that the points generally followed the diagonal line, suggesting that the assumption of normality is not severely violated.

## 5) Shapiro-Wilk Test:

The Shapiro Wilk Test provides a quantitative assessment of whether the sparrow weights in each nest type category (control, enlarged, reduced) can be reasonably assumed to follow a normal distribution. The results of the Shapiro-Wilk test can influence how you proceed with the subsequent statistical analysis. If the assumption of normality is met, you can proceed with standard parametric methods. If not, you might need to explore alternative methods.

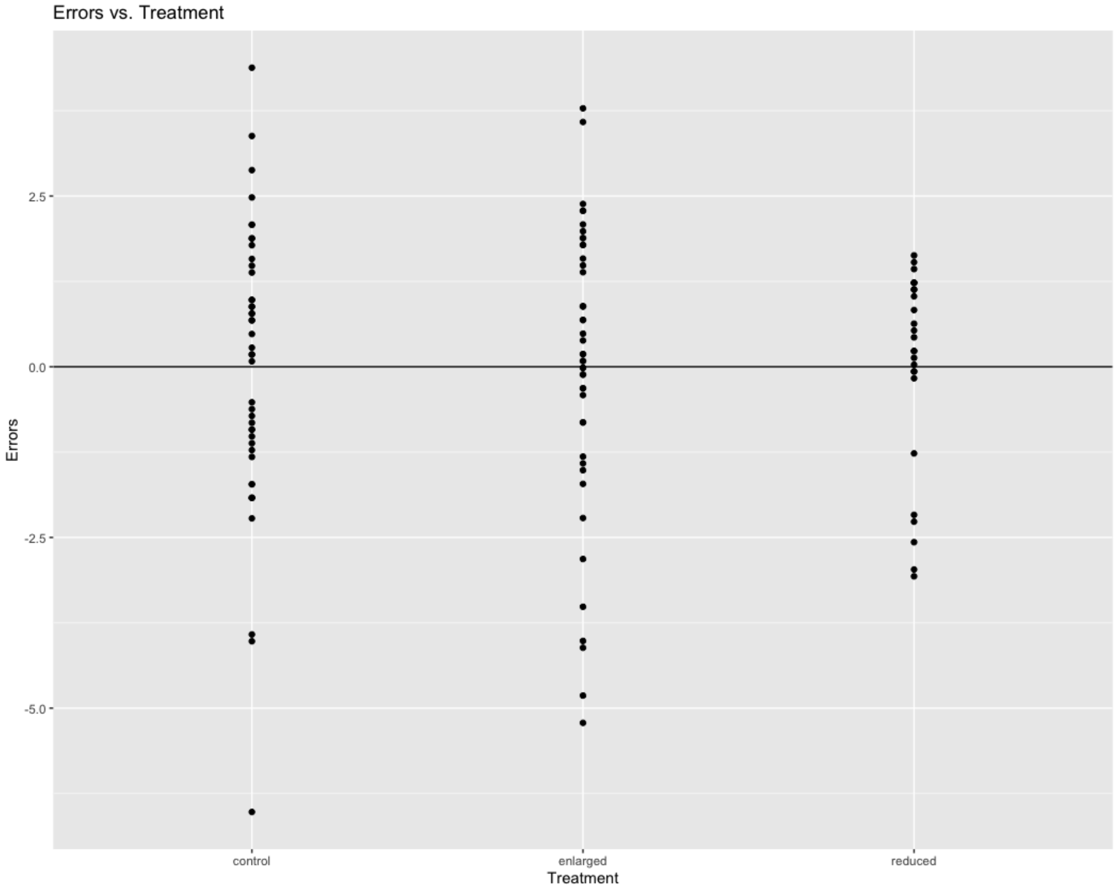
```
Shapiro-Wilk Normality Test

data:  ei
W = 0.96432,  p-value = 0.003714
```

A p-value of 0.003714 obtained from the Shapiro-Wilk test indicates that there is strong evidence to reject the null hypothesis that the data follows a normal distribution. In other words, the p-value is significantly below the commonly used significance level of 0.05. A p-value less than 0.05 (or your chosen significance level) is considered statistically significant. In this case, with a p-value of 0.003714, the result is highly significant. This means that the data's departure from normality is not likely due to random chance. Since the p-value is low, it provides evidence that the sparrow weight data within the specific nest type you tested significantly deviates from a normal distribution. The lower the p-value, the stronger the evidence against normality.

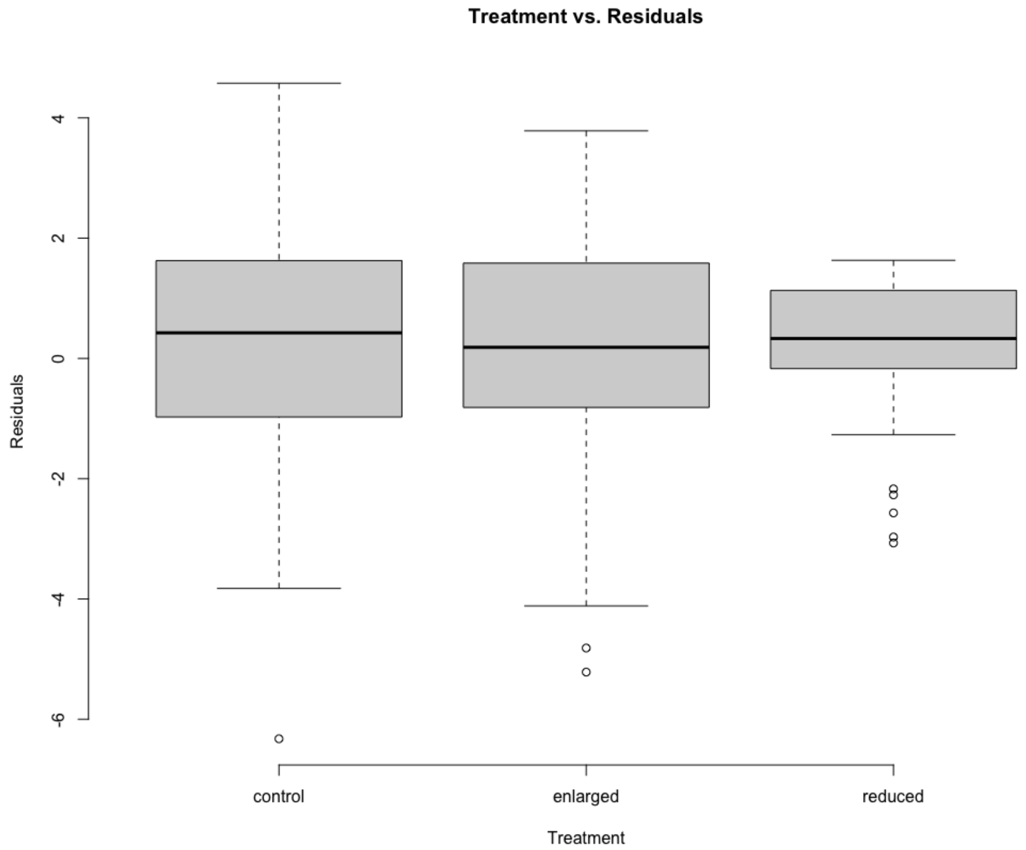
## 6) Homogeneous Variance using Error vs. Treatment Graph:

Another important assumption is that of homogenous variance across treatment groups. To assess this assumption, we examined the "Error vs. Treatment" graph.

This plot displays the residuals against the treatment groups. Ideally, the spread of residuals should be relatively consistent across treatments. Our graph showed varying spreads, which could indicate potential heteroscedasticity.




To further investigate variance homogeneity, we used boxplots for each treatment group. These boxplots visually display the distribution of residuals within each treatment. The boxplots hinted at differences in variability, causing the need for a Brown-Forsythe Test.




## 7) Brown-Forsythe Test:

We conducted the Brown-Forsythe test to quantify these differences. The test yielded a p-value of 0.1785612. Since this p-value is above the 0.05 threshold, we lack significant evidence to reject the null hypothesis of equal variances.

The error vs. treatment graph plots the residuals of the model against the nest type category. If the variances are equal, the residuals should be randomly scattered around the line y=0. The error vs. treatment graph for the sparrow weight data showed some evidence of heteroscedasticity, but the Brown-Forsythe test did not find significant evidence to reject the null hypothesis of equal variances.

# IV. Analysis

## 1) Model Fit

For the analysis, we use the group mean model to determine whether significant differences exist between the different types of nests for sparrows on Kent Island and how they relate to their sizes (weight). The model is defined as:

$Y_{ij} = \mu_i + \epsilon_{ij}$

We expect to see if there are significant differences in average weight between the "control" group, "enlarged" groups, and "reduced" group. The control group refers to the group that doesn't experience manipulation. The enlarged group is the group manipulated to be a larger nest than normal. The reduced group is the group manipulated to be a smaller nest than normal. $\mu_i$ refers to the average weight in group i, which means that i = 1 for control, 2 for enlarged, and 3 for reduced. $\epsilon_{ij}$ is the individual error for $j^{th}$ value in $i^{th}$ group.

## 2) Hypothesis Test

Based on our expectations and goal, our null hypothesis is:

$H_0$: $\mu_1 = \mu_2 = \mu_3$

$H_0$ means the average weight for the control, enlarged, and reduced groups are the same. Our alternative hypothesis is:

$H_A$: $\mu_1 \neq \mu_2$ or $\mu_1 \neq \mu_3$ or $\mu_2 \neq \mu_3$

$H_A$ means that at least one of the nest groups has a different average weight compared to other groups.

Then, we calculate the test statistic for the hypothesis test by using ANOVA.

ANOVA table:

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|:---|---:|---:|---:|---:|---:|
| Treatment | 2 | 72.74446 | 36.372231 | 8.128796 | 0.0005031 |
| Residuals | 113 | 505.61761 | 4.474492 | NA | NA |

The test statistic is the F test, which is equal to MSA/MSE. Based on the table, we have an F value of 8.1288 with a p-value of 0.0005031. It means we have a 0.05031% chance for the null hypothesis to be true.

## 3) Confidence Intervals

We will use 95% simultaneous confidence interval for the following group and group comparing:

$\mu_3$

$\mu_1$ - $\mu_2$

$\mu_1$ - $\mu_3$

Since the reduced group has the largest sparrow, we calculate the confidence interval for $\mu_3$. Before we calculate the simultaneous confidence interval, we need to decide on the multiplier. We need the smallest multiplier to maximize accuracy. Here is the multiplier table:

| multiplier | value |
|:---|---:|
| Tukey | 2.374993 |
| Scheffe | 2.480554 |
| Bonferroni | 2.430142 |

Since the smallest value is Tukey, we will use the Tukey multiplier for our simultaneous confidence interval calculation. Based on the ANOVA table, MSE is equal to 4.474492.

For $\mu_3$, the results are:

$\mu_1 = (15.56923) \pm 2.374993 \times \sqrt{4.474492 \times (1/26)} = (14.58498, 16.55448)$

Based on the result, with a 95% confidence interval, the average weight of the control group's sparrow is between 14.58498 and 16.55448.

For $\mu_1$ - $\mu_2$, the results are:

$\mu_1 - \mu_2 = (13.92444 - 13.5156) \pm 2.374993 \times \sqrt{4.474492 \times ((1/45) + (1/45))} =$ (-0.6502255, 1.4680033)

In this comparison, because it contains 0, we can conclude that with a 95% confidence interval, there is no significant difference between the true average weight of the control group and the enlarged group. We are 95% confident that the difference between the control and enlarged groups is between -0.6502255 grams and 1.4680033 grams. At most, the control group can have 1.468003 grams more weight than the enlarged group. Or, the control group can have 0.6502255 grams less weight than the enlarged group at least.

For $\mu_1$ - $\mu_3$, the results are:

$\mu_1 - \mu_2 = (13.92444 - 15.5692) \pm 2.374993 \times \sqrt{4.474492 \times ((1/45) + (1/26))} =$ (-2.8823581, -0.4072146)

In this comparison, because the confidence intervals don't contain 0 and are all negative numbers, we can conclude that with a 95% confidence interval, there is a significant difference between the true average weight of the control group and the reduced group. We are 95% confident that the difference between the control and reduced groups is between -2.8823581 grams and -0.4072146 grams. At most, the control group has 2.8823581 grams less weight than the reduced group. Or, at least the control group has 0.4072146 grams less weight than the reduced group.

## 4) Factor Effect Model

In order to determine the factor's effect in our model, we build a single-factor ANOVA factor effect model:

$Y_{ij} = \mu_. + \gamma_i + \epsilon_{ij}$

This model shows the difference between the overall mean and the factor level means. In this model, $\mu_.$ is the overall mean for three treatments. $\gamma_i$ is the "effect" of a treatment on the entire model. And $\epsilon_{ij}$ is the $j^{th}$ residual in one specific treatment. After calculating the value of gammas, here is the result of subtracting the group mean and overall mean:

| treatment.name | gamma_i |
|:---------------|-------:|
| Control | -0.4120 |
| Enlagred | -0.8208 |
| Reduced | 1.2328 |

Based on the result, $\gamma_1$ = -0.4120, $\gamma_2$ = -0.8208, $\gamma_3$ = 1.2328.

### 5) Power Calculation

Function: $\phi = (1/\sigma_\epsilon) \times \sqrt{(\Sigma n_i \times (\mu_i - \mu_.)^2/a}$

The non-central parameter, $\phi$, measures the proportion of rejecting $H_0$ over $H_0$ false, representing our model's power, which is the probability of not making a type II error. In this function, $\sigma_\epsilon$ can be replaced by $\sqrt{MSE}$.

$\phi = (1/\sqrt{4.474492}) \times \sqrt{(45 \times (-0.4120)^2 + 45 \times (-0.8208)^2 + 26 \times (1.2328)^2)/3} =$ $2.40234 \approx 2.5$

We chose $\alpha = 0.05$. The degrees of freedom are:

d.f.num = a - 1 = 3 - 1 = 2

d.f.denum = $n_T$ - a = 116 - 3 = 113 $\approx$ 120

With values $\phi$, $\alpha$, and degrees of freedom, the result is 0.98. It means that we have a probability of 98% to reject the null hypothesis when the null hypothesis is false in reality. In other words, there is a 98% probability that all the average weights of three groups in different treatments are not the same when, in the real world, at least one group's average weight differs from others.

## V. Interpretation

The results from our hypothesis test on whether the average sparrow weight for each different nest size are significantly different tell us that if the average sparrow weights were in fact the same for each nest size, we would observe our data .05013% of the time. At an alpha of 0.05, we can claim there is significant statistical evidence for at least one nest's average sparrow weight being different from the rest. That said, we must keep in mind that at an alpha of 0.05 there is still a 5% chance that we may reject our null hypothesis, that every nest's average sparrow weight is equal, even though it is in fact true. Furthermore, from our power calculation we have an overall power equal to 0.98, which corresponds to there being a 98% chance that we will correctly reject the null hypothesis, that all average sparrow weights between each nest group are equal, when it is in fact false. This makes our Type II error rate equal to .02 or there is a 2% chance that we will fail to reject the null hypothesis when it is in fact true.

Following from our results of our hypothesis test, since we concluded that at least one nest's average sparrow weight was different from the rest we constructed multiple 95% confidence intervals to analyze from which nests it differed from and by how much. Once again, as we have chosen 95% confidence intervals to analyze the data we must consider that there is a 5% chance that our confidence intervals do not capture the true values and differences between means. By comparing each nesting group's average sparrow weight we were able to find that the reduced nesting group tended to have the highest sparrow weight. Our first confidence interval estimated µ3 with a 95% confidence interval where $\mu_3$ = (14.58398, 16.55448). The results of this confidence interval tell us that we can be overall 95% confident that the true average sparrow weight for the reduced nests group is between 14.58398g and 16.55448 grams. That is we can expect that the lowest weight a sparrow from the reduced nest group would weigh would be 14.58398g and the highest a sparrow from this group would weigh would be 16.55448g. Our second confidence interval was concerned with measuring the difference between the average control nest's sparrow weight to the average enlarged nest's sparrow weight. The 95% confidence interval for $\mu_1 - \mu_2$ = (-0.6502255, 1.4680033). The results of this confidence interval show that we can be overall 95% confident that the difference in the average sparrow weight between the control nests and the enlarged nests is between -0.6502255 and 1.4680033. That is to say that we would expect a sparrow's weight from the control nest group to be between 0.6502255g lighter and 1.4680033g heavier than a sparrow from the enlarged nest group. However, since our confidence interval contains 0 we must conclude that there is no statistically significant difference between the average weight of sparrows between the control and enlarged nest groups. Our last confidence interval explored the magnitude of the difference in average sparrow weight between the control nest group and the reduced nest group. The 95% confidence interval for $\mu_1 - \mu_3$ =(-2.8823581, -0.4072146). This confidence interval tells us that we can be 95% confident to expect a sparrow from the control nest group to be between 0.4072146g and 2.8823581g smaller than the reduced nest group. Since our confidence interval does not contain 0, we can be overall 95% confident that there is a statistically significant difference between the control and reduced group such that on average the control group average sparrow weight is lighter than the reduced group average sparrow weight.

Our confidence intervals gave us some insight into the true average weight of sparrows in the control nest group as well as differences between groups; however in order to assess the effect that the nest size has on sparrow size in general, we must look at the factor effects. By analyzing our $\gamma_i$, we can measure how much the average sparrow weight from each nest size differs from the overall average sparrow weight. Our calculations show that the control nest size contributed to a 0.4120g lighter average weight than the overall average, the enlarged nest size contributed to a 0.8202g lighter average weight than the overall average, and the reduced nest size contributed to a 1.2328g heavier average weight than the overall average.

# VI. Conclusion

The results of our data analysis show that the average weights of sparrows from the three nest sizes are not all equal. From our first confidence interval of the nesting group which tended to have the largest sparrow weight, we are overall 95%

confident that the true average sparrow weight for the reduced nest group is between 14.58398g and 16.55448g. To measure the sparrow weight differences between groups we performed two more confidence intervals. The results from our confidence interval of $\mu_1 - \mu_2$ tell us that there is no statistically significant difference between the average sparrow weight of the control group and enlarged group. That is to say that there is no significant difference in the sizes of sparrows attracted by the control and enlarged nests and any difference in sample averages is due to likely random chance. Our last confidence interval of the difference of $\mu_1 - \mu_3$, showed that the average sparrow weight of the reduced group tends to be larger than that of the control group. That is to say that the reduced size nests attracted larger sparrows on average. Furthermore, by using the factor effects model we were able to quantify the effect each type of nest contributed to the deviation from the overall average sparrow weight. From our estimations of $\gamma_i$, we were able to conclude that the control nest size and the enlarged nest size resulted in lower average sparrow weights when compared to the overall mean, while the reduced nest size resulted in a higher average sparrow weight compared to the overall mean. With a power of .98, which is fairly high, we are confident in stating our null hypothesis is false, the alternative hypothesis is true and the conclusions that follow from there. The results of our data analysis provide insight into how nest size affects the size of the sparrow that is attracted to it.

# Appendix

```
# Summary:
sparrow <- read.csv("~/Desktop/sparrow.csv")
library(knitr)

group.means = by(sparrow$Weight, sparrow$Treatment, mean)
```

```
overall.means = mean(sparrow$Weight)
group.sds = by(sparrow$Weight, sparrow$Treatment,sd)
overall.sds = sd(sparrow$Weight)
group.nis = by(sparrow$Weight, sparrow$Treatment,length)
overall.nis = length(sparrow$Weight)
overall_data = c(overall.means,overall.sds,overall.nis)
the.summary = rbind(group.means,group.sds,group.nis)
the.summary = cbind(the.summary,overall_data)
the.summary = round(the.summary,digits = 4)
#names(the.summary)
colnames(the.summary) = c("control","enlarged","reduced","overall")
rownames(the.summary) = c("Means","Std. Dev","Sample Size")
the.summary
knitr::kable(the.summary)

summary(sparrow$Weight)
the.sparrow = lm(Weight ~ Treatment, data = sparrow)
anova.table = anova(the.sparrow)
anova.table
Weight = sparrow$Weight
Treatment = sparrow$Treatment
hist(Weight)

ggplot(sparrpw, aes(x = Weight)) + geom_histogram(binwidth = 0.5) +
facet_grid(Treatment~.) + ggtitle("Histogram of nests for sparrows on
Kent Island attracted different size sparrows")

ggplot(data = sparrow, aes(x = Treatment, y = Weight, color =Treatment))
```

```
  labs(x = "Treatment",
       y = "Weight",
       title = "Boxplot of nests for sparrows on Kent Island attracted
       different size sparrows")

#Diagnostics:
sparrow$ei = the.sparrow$residuals
nt = nrow(sparrow)
a = length(unique(sparrow$Treatment))
SSE = sum(sparrow$ei^2)
MSE = SSE/(nt-a)
eij.star = the.sparrow$residuals/sqrt(MSE)
eij.star
alpha = 0.01
t.cutoff = qt(1 - alpha/(2*nt), nt-a)
t.cutoff
CO.eij = which(abs(eij.star) > t.cutoff)
CO.eij
outliers = CO.eij
outliers

new.sparrow = sparrow[-outliers,]
diagnostic.model = lm(Weight ~ Treatment, data = new.sparrow)

qqnorm(diagnostic.model$residuals, frame = FALSE,
main = "Q-Q Plot of Model Residuals")
qqline(diagnostic.model$residuals, col = "#ffa7a1", lwd = 2)
```

```
ei = diagnostic.model$residuals
the.SWtest = shapiro.test(ei)
the.SWtest

plot(diagnostic.model$fitted.values, diagnostic.model$residuals,
main = "Errors vs. Group Means",xlab = "Group Means", ylab = "Errors")
        abline(h = 0,col = "purple")

qplot(Treatment, ei, data = diagnostic.model) +
ggtitle("Errors vs. Treatment") + xlab("Treatment") + ylab("Errors") +
geom_hline(yintercept = 0)

boxplot(ei ~ Treatment, data = new.sparrow,
main = "Treatment vs. Residuals",
ylab = "Residuals", frame = FALSE)

the.BFtest = leveneTest(ei ~ Treatment, data = sparrow, center = median)
p.val = the.BFtest[[3]][1]
p.val

#Analysis:
data1 = sparrow
treatment.weight.model = lm(Weight ~ Treatment, data = data1)
library(ggplot2)
library(dplyr)
library(tidyverse)
library(ggplot2)
library(knitr)
```

```
treatment.weight.anova.table = anova(treatment.weight.model)
treatment.weight.anova.table
knitr::kable(treatment.weight.anova.table)
summary(treatment.weight.model)
# Confidence intervals:
treatment.weight.MSE = treatment.weight.anova.table[2,3]
alpha = 0.05
# Function:
give.me.CI = function(ybar, ni, ci, MSE, multiplier){
  if(sum(ci) != 0 & sum(ci !=0 ) != 1){
    return("Error - you did not input a valid contrast")
  } else if(length(ci) != length(ni)){
    return("Error - not enough contrasts given")
  }
  else{
    estimate = sum(ybar*ci)
    SE = sqrt(MSE*sum(ci^2/ni))
    CI = estimate + c(-1,1)*multiplier*SE
    result = c(estimate,CI)
    names(result) = c("Estimate","Lower Bound","Upper Bound")
    return(result)
  }
}
# Turkey:
Tuk = qtukey(1-alpha, a, treatment.weight.nt-a)/sqrt(2)
# Scheffe
S = sqrt((a-1)*qf(1-alpha, a-1, treatment.weight.nt-a))
# Bonferroni
```

```r
g=3
B = qt(1-alpha/(2*g), treatment.weight.nt-a)
value = c(Tuk, S, B)
multiplier = c("Tukey", "Scheffe", "Bonferroni")
multi.df = data.frame(multiplier ,value)
knitr::kable(multi.df)
# Largest sparrow
largest.ci = c(0,0,1)
give.me.CI(treatment.weight.group.means, treatment.weight.group.nis,
largest.ci, treatment.weight.MSE, Tuk)
# Comparing the control nest to the enlarged nest
control.enlagred.ci = c(1,-1,0)
give.me.CI(treatment.weight.group.means, treatment.weight.group.nis,
control.enlagred.ci, treatment.weight.MSE, Tuk)
# Comparing the control nest to the reduced nest
control.reduced.ci = c(1,0,-1)
give.me.CI(treatment.weight.group.means, treatment.weight.group.nis,
control.reduced.ci, treatment.weight.MSE, Tuk)
# Factor Effect Model:
control.group.mean = treatment.weight.summary[1,1]
enlarged.group.mean = treatment.weight.summary[1,2]
reduced.group.mean = treatment.weight.summary[1,3]
control.diff = control.group.mean - overall.mean
enlarged.diff = enlarged.group.mean - overall.mean
reduced.diff = reduced.group.mean - overall.mean
gamma_i = c(control.diff, enlarged.diff, reduced.diff)
treatment.name = c("Control", "Enlagred", "Reduced")
factor.df = data.frame(treatment.name, gamma_i)
```

```
knitr::kable(factor.df)
# Power calculation:
treatment.weight.phi = (1/treatment.weight.MSE)*
(sqrt((45*(control.diff^2)+45*(enlarged.diff^2)+26*(reduced.diff^2))/3))
```