Variations in American Crow Densities

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Introduction

The goal of this study was to analyze and compare the densities of the American Crow (*Corvus brachyrhynchos)* in two different environments: suburban and rural. The American Crow lives throughout most of the continental United States, including down the Pacific Coast, the area of my locations of study (Verbeek). It is an omnivore, and with the expansion and growth of urban areas, crows have expanded their diet to include more "artificial" food sources, such as human waste (Gorenzel). Due to this, I hypothesize that the density of crows in a suburban area is higher than compared with a rural area. Knowing the relative densities and estimates of the total population is important for tracking the spread of disease, such as West Nile Virus, which crows are a known carrier of.

Methods

To test my hypothesis that crow population densities are higher in suburban areas versus rural areas, I chose my neighborhood in Orange County, California and a section of Lucerne Valley, California, to estimate the density of each respective area. To conduct my sample for Orange County, I mapped out an equal area of 4.25 square kilometers on Google Earth, and using latitude and longitude lines, divided the area into equal grids of 160.934 by 128.748 meters. I then numbered off the grids in the area of study, and these numbered grids made up my sampling frame (see later for a discussion of bias in this process). Using R, I generated a random list of 15 numbers and counted the number of crows in each plot using quadrat sampling (see later for a discussion of bias in how the counting was done). Quadrat sampling seemed appropriate due to the ability to easily select grids at random and survey the area within each grid. This method was repeated for Lucerne Valley. A seed was set for each generation of random numbers so that the results could be replicated while still maintaining the inherent

randomness (the 152 comes from Statistics-152, my sampling surveys class, and the 114 comes from Environmental Science, Policy, and Management-114, this class). See the appendix for attached maps.

My survey design can be interpreted as a one-stage cluster sample, with the Primary Sampling Units (PSUs) being the plots that I sampled, and the Secondary Sampling Units (SSUs) being an individual crow in each plot. A census was taken in each PSU, as every crow within the plot was counted as an observation.

The survey of crows in Lucerne Valley was conducted between 12:00 and 4:00 PM on Sunday, April 19, 2020. Weather conditions were fairly normal/mild for the region. The sampling in Rossmoor was conducted between 9:30 and 11:00 AM on Friday, April 24, 2020. The weather was quite warm, which may have affected the results (see discussion later).

To collect the data, I inputted the sampling information into a CSV file in Microsoft Excel. I used R-Studio to open the data and perform my analysis (see appendix for attached code).

Results

For my study area in Lucerne Valley, I found 12 total crows throughout the 15 grids that I surveyed. For Rossmoor, I surveyed 9 crows out of 15 total grids. Using the unbiased estimate of the total,

$$\hat{t} = \frac{N}{n} \sum_{i \in S} t_i ,$$

where N is the total number of grids, n is the sampled number of grids, and t_i is the total number of crows in each grid, I calculated an estimate of 176 total crows in Lucerne Valley and 132 in

Rossmoor. Dividing by the total area, which was 4.25 square kilometers for each, I calculated a density of 41 crows per square kilometer in Lucerne Valley and 31 crows per square kilometer in Rossmoor. To calculate the variance of my estimate, I used

$$Var(\hat{t}) = N^2 \left(1 - \frac{n}{N}\right) \frac{s_t^2}{n},$$

where

$$s_t^2 = \frac{1}{n - 1} \sum_{i \in S} \left(t_i - \frac{\hat{t}}{N}\right)^2$$

is the sample variance. The standard error of my estimate is the square root of my variance, and the standard deviation is the standard error multiplied by the square root of *n*. The variance of my estimate for the total population size in Lucerne Valley was 5240 crows, with standard deviation and standard error of 280 and 72 crows, respectively. In Rossmoor, the variance of my estimate for the total population size was 1158 crows, with standard deviation 132 crows and standard error 34 crows. Confidence intervals were calculated using the following formula:

$$95\%\ Confidence\ Interval = \hat{t} \pm z_{\alpha/2} SE(\hat{t})$$

For Lucerne Valley, a 95% Confidence Interval for the total population size of crows was (34, 317), and in Rossmoor it was (65, 199). Standard deviations, standard errors, and confidence intervals were also calculated for the densities of each location, but the formulas used are the same (instead of using $\hat{t}$ in the formulas, use the density estimates).

Discussion

The data that I collected did not prove my initial hypothesis, which was that the density of crows in a suburban area was larger than in a rural area. I conducted a two-sample t-test on the densities of each area, and found a p-value of 1, which failed to reject the null hypothesis that the density in a suburban areas is less than or equal to the density in a rural area. However, there are some sources of bias in my estimates, which may have likely skewed my results.

Firstly, selection bias arises in the way in which I selected grids, specifically for my suburban area of study. I only included grids which contained segments of streets within my neighborhood, and excluded any that only contained houses. While this is a small number that were not included, it would be inaccurate for me to say that every square meter of my neighborhood had a chance of being a part of my sample. Any crows that were residing in this area did not have a chance of being counted.

Secondly, I took the entire quadrat for each location as the area that I was sampling, which was quite reasonable in Lucerne Valley, as the geography there is quite flat with minimal buildings, allowing for easy viewing across the entire area. However, in Rossmoor, each quadrat contained houses with backyards that I could not view, so any crows that were in this area were not counted, and my estimate of the total population in Rossmoor is biased due to measurement error.

Thirdly, the time at which I conducted my sample in Rossmoor was at a time when crows are typically quite active in the area. However, this was the beginning of a warming period in the year, and crows may have been less inclined to be flying around (and thus visible) due to the warmer temperatures.

Fourthly, more trees and buildings in my suburban area of study could have led to

measurement error, as some crows may have gone undetected.

Fifthly, some level of bias was introduced as I chose the general locations to represent the suburban and rural areas. Rossmoor may not be representative of suburban areas on average, and Lucerne Valley may not be representative of rural areas on average.

Finally, a key assumption in this survey design is that crows do not move in or out of the study location. This is a huge assumption which was definitely violated, as almost every crow counted in both locations was seen flying around instead of sitting stationary. While I do not believe that I double counted any crows, it is possible that due to their movement this could have happened, and my estimates could be off.

Due to all of these factors, I believe that my estimate of the total population and density of crows in Rossmoor, California, is not accurate, and that a larger survey with more individuals during a milder temperature would reveal a higher density of crows. I believe that my estimate in Lucerne Valley is fairly reasonable, but due to the large variance, we can see that the estimate ranges widely.

To obtain better estimates of crow densities in suburban and rural areas, I believe that large survey areas should be used. My area of study in each geographic location was quite small, and this is due to the limited resources that I have at my disposal. A survey with more people covering a wider area of study would give more accurate estimates, and I believe then my hypothesis that crow densities in suburban areas are larger than in rural areas would be proven.

Works Cited

1.) Verbeek, N. A. and C. Caffrey (2002). American Crow (Corvus brachyrhynchos), version 2.0. In The Birds of North America (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bna.647.

2.) Gorenzel, W. Paul, and Terrell P. Salmon. "Characteristics of American Crow Urban Roosts in California." *The Journal of Wildlife Management* 59, no. 4 (1995): 638-45. Accessed March 6, 2020. doi:10.2307/3801939.

Appendix

1.) Raw Data

2.) Code for Analysis

3.) Map of Survey Area in Lucerne Valley, California

4.) Map of Survey Area in Rossmoor, California

Grid	Length	Width	Crows	Time
LV6	0.08	0.1	0	3:36 PM
LV16	0.08	0.1	3	2:21 PM
LV29	0.08	0.1	0	3:35 PM
LV33	0.08	0.1	0	3:16
LV45	0.08	0.1	0	1:49 PM
LV47	0.08	0.1	4	1:44 PM
LV58	0.08	0.1	2	3:15
LV75	0.08	0.1	0	3:32 PM
LV109	0.08	0.1	1	2:39 PM
LV127	0.08	0.1	0	3:28 PM
LV160	0.08	0.1	2	12:32 PM
LV178	0.08	0.1	0	3:23 PM
LV186	0.08	0.1	0	13:15
LV205	0.08	0.1	0	2:48 PM
LV215	0.08	0.1	0	13:24
R13	0.08	0.1	0	10:57 AM
R14	0.08	0.1	1	10:54 AM
R23	0.08	0.1	1	10:53 AM
R26	0.08	0.1	0	10:39 AM
R38	0.08	0.1	1	10:47 AM
R41	0.08	0.1	0	11:00 AM
R54	0.08	0.1	0	10:24 AM
R61	0.08	0.1	2	10:32 AM
R76	0.08	0.1	1	10:19 AM
R105	0.08	0.1	0	10:13 AM
R127	0.08	0.1	0	10:07 AM
R141	0.08	0.1	1	10:04 AM
R175	0.08	0.1	1	9:53 AM
R201	0.08	0.1	0	9:47 AM
R212	0.08	0.1	1	9:47 AM

Variations in American Crow Densities

```
library(stringr)
```

Selecting the PSUs for Rossmoor

```
set.seed(152)
rossmoor_samp <- sample(1:220, 15, replace = FALSE)
rossmoor_samp
```

```
##  [1] 105  54  41 141 175  14  38  76 201  26 127  23 212  61  13
```

Selecting PSUs for Lucerne Valley

```
set.seed(114)
lucerne_samp <- sample(1:216, 15, replace = FALSE)
lucerne_samp
```

```
##  [1] 178 160 215   6  33 127  75 186 205  58  29  45  16  47 109
```

Load the Data

```
crow <- read.csv("crowdata.csv")
```

```
head(crow)
```

```
##   Grid Length Width Crows    Time
## 1  LV6   0.08   0.1     0 3:36 PM
## 2 LV16   0.08   0.1     3 2:21 PM
## 3 LV29   0.08   0.1     0 3:35 PM
## 4 LV33   0.08   0.1     0    3:16
## 5 LV45   0.08   0.1     0 1:49 PM
## 6 LV47   0.08   0.1     4 1:44 PM
```

```
crow$Length <- crow$Length * 1609.34
crow$Width <- crow$Width * 1609.34
```

Analysis for Lucerne Valley

Total Estimates

```
lucerne <- crow[str_detect(crow$Grid, "LV"), ]
head(lucerne)
```

```
##   Grid   Length   Width Crows    Time
## 1  LV6 128.7472 160.934     0 3:36 PM
## 2 LV16 128.7472 160.934     3 2:21 PM
## 3 LV29 128.7472 160.934     0 3:35 PM
```

```
## 4 LV33 128.7472 160.934     0    3:16
## 5 LV45 128.7472 160.934     0 1:49 PM
## 6 LV47 128.7472 160.934     4 1:44 PM
```

```
#Estimate of the Total Crows in Lucerne Valley
NL <- 220
nL <- 15
lucerne_total <- (NL / nL) * sum(lucerne$Crows)
lucerne_total
```

```
## [1] 176
```

```
#Variance of Total Crow Estimate in Lucerne Valley
lucerne_sample_var <- (1 / (nL - 1)) * sum((lucerne$Crows - (lucerne_total / NL)) ** 2)
lucerne_var <- (NL ** 2) * (1 - (nL / NL)) * lucerne_sample_var / nL

lucerne_var
```

```
## [1] 5240.19
```

```
#Standard Error of Total Crow Estimate in Lucerne Valley
lucerne_se <- sqrt(lucerne_var)
lucerne_se
```

```
## [1] 72.38916
```

```
#Standard Deviation of Total Crow Estimate in Lucerne Valley
lucerne_sd <- lucerne_se * sqrt(nrow(lucerne))
lucerne_sd
```

```
## [1] 280.362
```

```
#95% Confidence Interval for Total Crows in Lucerne Valley
c(lucerne_total - (1.96 * lucerne_se), lucerne_total + (1.96 * lucerne_se))
```

```
## [1]  34.11725 317.88275
```

Density Estimates

```
#Estimate of Crow Density in Lucerne Valley
lucerne_density <- lucerne_total / 4.25
lucerne_density
```

```
## [1] 41.41176
```

```
#Variance of Crow Density in Lucerne Valley
lucerne_density_sample_var <- (1 / (nL - 1)) * sum((lucerne$Crows - (lucerne_total / NL)) ** 2) * (1 /
lucerne_density_var <- (NL ** 2) * (1 - (nL / NL)) * lucerne_density_sample_var / nL

lucerne_density_var
```

```
## [1] 290.1144
```

```
#Standard Error of Crow Density in Lucerne Valley
lucerne_density_se <- sqrt(lucerne_density_var)
lucerne_density_se
```

```
## [1] 17.03274
```

```r
#Standard Deviation of Crow Density in Lucerne Valley
lucerne_density_sd <- lucerne_density_se * sqrt(nrow(lucerne))
lucerne_density_sd
```

```
## [1] 65.96753
```

```r
#95% Confidence Interval for Total Crow Density in Lucerne Valley
c(lucerne_density - (1.96 * lucerne_density_se), lucerne_density + (1.96 * lucerne_density_se))
```

```
## [1]  8.027587 74.795942
```

Anaylsis for Rossmoor, California

Total Estimates

```r
rossmoor <- crow[str_detect(crow$Grid, "R"), ]
head(rossmoor)
```

```
##    Grid   Length   Width Crows     Time
## 16  R13 128.7472 160.934     0 10:57 AM
## 17  R14 128.7472 160.934     1 10:54 AM
## 18  R23 128.7472 160.934     1 10:53 AM
## 19  R26 128.7472 160.934     0 10:39 AM
## 20  R38 128.7472 160.934     1 10:47 AM
## 21  R41 128.7472 160.934     0 11:00 AM
```

```r
#Estimate of the Total Crows in Rossmoor
NR <- 216
nR <- 15
rossmoor_total <- (NL / nL) * sum(rossmoor$Crows)
rossmoor_total
```

```
## [1] 132
```

```r
#Variance of Total Crow Estimate in Rossmoor
rossmoor_sample_var <- (1 / (nR - 1)) * sum((rossmoor$Crows - (rossmoor_total / NR)) ** 2)
rossmoor_var <- (NR ** 2) * (1 - (nR / NR)) * rossmoor_sample_var / nR

rossmoor_var
```

```
## [1] 1158.143
```

```r
#Standard Error of Total Crow Estimate in Rossmoor
rossmoor_se <- sqrt(rossmoor_var)
rossmoor_se
```

```
## [1] 34.0315
```

```r
#Standard Deviation of Total Crow Estimate in Rossmoor
rossmoor_sd <- rossmoor_se * sqrt(nrow(rossmoor))
rossmoor_sd
```

```
## [1] 131.8034
```

```r
#95% Confidence Interval for Total Crows in Rossmoor
c(rossmoor_total - (1.96 * rossmoor_se), rossmoor_total + (1.96 * rossmoor_se))
```

```
## [1]  65.29826 198.70174
```

Denisty Estimates

```
#Estimate of Crow Density in Rossmoor
rossmoor_density <- rossmoor_total / 4.25
rossmoor_density
```

```
## [1] 31.05882
```

```
#Variance of Crow Density in Rossmoor
rossmoor_density_sample_var <- (1 / (nR - 1)) * sum((rossmoor$Crows - (rossmoor_total / NR)) ** 2) * (1
rossmoor_density_var <- (NR ** 2) * (1 - (nR / NR)) * rossmoor_density_sample_var / nR

rossmoor_density_var
```

```
## [1] 64.11864
```

```
#Standard Error of Crow Density in Rossmoor
rossmoor_density_se <- sqrt(rossmoor_density_var)
rossmoor_density_se
```

```
## [1] 8.007411
```

```
#Standard Deviation of Crow Density in Rossmoor
rossmoor_density_sd <- rossmoor_density_se * sqrt(nrow(rossmoor))
rossmoor_density_sd
```

```
## [1] 31.01257
```

```
#95% Confidence Interval for Total Crow Density in Rossmoor
c(rossmoor_density - (1.96 * rossmoor_density_se), rossmoor_density + (1.96 * rossmoor_density_se))
```

```
## [1] 15.36430 46.75335
```

Comparison of the Two Groups

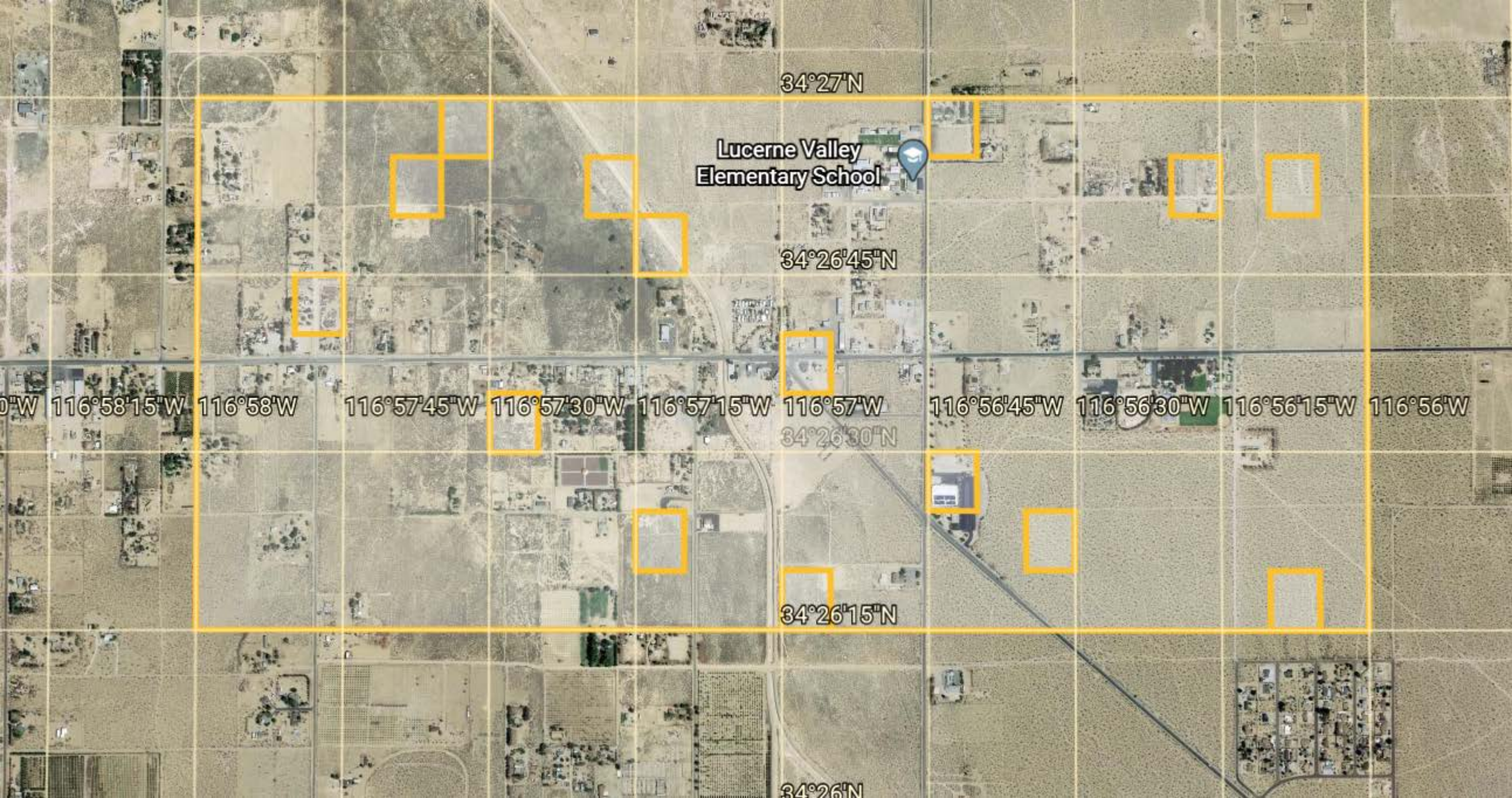
Null Hypothesis: The density of crows in Rossmoor, California, is less than or equal to the density of crows in Lucerne Valley, California.

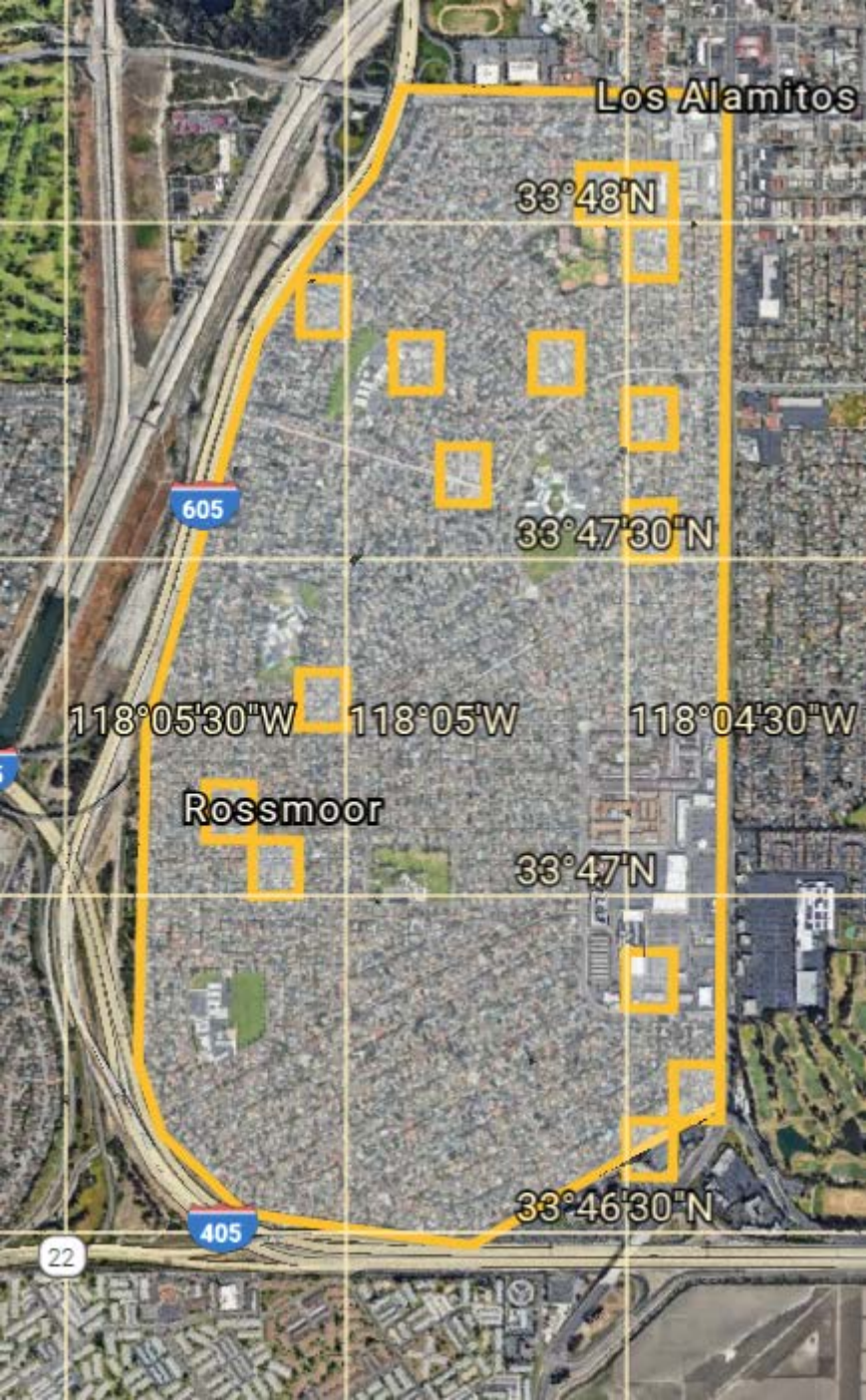
Alternative Hypothesis: The density of crows in Rossmoor, California, is larger than the density of crows in Lucerne Valley, California.

```
#Test Statistic for the Difference in Densities
difference <- rossmoor_density - lucerne_density

variance_of_difference <- (rossmoor_density_sample_var / nR) + (lucerne_density_sample_var / nL)

test_stat <- difference / sqrt(variance_of_difference)
```

```
#P-value for the Calculated Test Statistic
p_value <- pt(test_stat, df = 14, lower.tail = FALSE)
p_value
```

```
## [1] 1
```


34°27'N
Lucerne Valley
Elementary School
34°26'45"N
0"W
116°58'15"W
116°58'W
116°57'45"W
116°57'30"W
116°57'15"W
116°57'W
116°56'45"W
116°56'30"W
116°56'15"W
116°56'W
34°26'30"N
34°26'15"N
34°26'N


Los Alamitos
33°48'N
605
33°47'30"N
118°05'30"W
118°05'W
118°04'30"W
Rossmoor
33°47'N
405
33°46'30"N
22