How Luxury and Legacy Effects Shape Urban Avifauna Abundance - INSTRUCTOR VERSION

A lesson by Melanie Del Pozo and J. Herman Tomasi

This lesson will briefly introduce luxury and legacy effects hypotheses as they relate to avian urban ecology. These effects will then be evaluated statistically using simple linear regression and ANCOVA. The following focal paper will serve as the basis for this lesson:

Eric M Wood, Sevan Esaian, Christian Benitez, Philip J Ethington, Travis Long core, Lars Y Pomara, Historical racial redlining and contemporary patterns of income inequality negatively affect birds, their habitat, and people in Los Angeles, California, Ornithological Applications, 2023; https://doi.org/10.1093/ornithapp/ duad044

You will be required to read the background from the focal paper. All other relevant details to complete the lesson will be described in this document.

This lesson will take approximately 1 hour to complete. It is divided in part A and B. In part A you learn and perform linear regressions looking at luxury effects hypothesis. In part B, you get to explore the legacy effect hypothesis using ANCOVA models, and learn how to interpret its output.

Learning Objectives

After completing this lesson, you will gain familiarity with concepts such as redlining, luxury, and legacy effects hypotheses. You will also develop a critical understanding of the influence of socioeconomic factors on avifauna as a proxy for urban biodiversity in general. Additionally, you will enhance your ability to construct and interpret linear models and assess interactions between variables using ANOVA.

Prerequisites

Going into this lesson, you should have basic familiarity with:

• Ecology. Ecology knowledge is essential for this lesson, with a particular emphasis on avian ecology. Familiarity with terms such as habitat requirements, full annual cycle, and point count surveys for assessing bird abundance is necessary.

• Statistics. You should be able to conduct and interpret fundamental statistical analyses, including t-tests and linear regressions.

• R Programming. You must have the ability to execute code, load data, and import libraries. You should be adept at basic data manipulation techniques using dplyr and possess foundational graphing skills utilizing ggplot and its native functions.

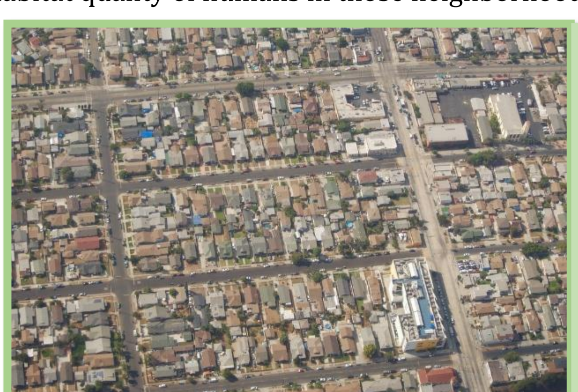
Urban Avifauna

Avifauna refers to the birds of a particular region or area. Birds are integral components, contributing to ecosystem functioning and stability in various ways. They act as pollinators, dispersers of seeds, and controllers of insect populations, thus influencing plant diversity and ecosystem structure (Whelan et al., 2008).

Birds also serve as indicators of biodiversity within ecosystems, including urban environments. Their presence, abundance, and diversity reflect the health and ecological integrity of their habitats (Whelan et al., 2008). Different bird species have distinct habitat requirements and levels of tolerance to human disturbance. Therefore, the abundance of certain bird populations in a neighborhood can inform us about the area's habitat quality, resource availability, and environmental conditions.

For instance, the presence of a Ruby-Crowned Kinglet (pictured on the right), would indicate the neighborhood has a substantial amount of diverse and less disturbed forest and woodland cover, which fulfills the its habitat needs for nesting, and foraging. In the focal paper for this lesson is based on, birds with such habitat requirements are called "forest birds". This category of birds in general need more diverse forest ecosystems for their survival and reproductive success. On the other hand, the abundance of Rock Pigeons in a neighborhood (pictured on the left) can indicate heavier human presence, and urban development. These birds are called "synanthropic" birds. They have adapted well to living alongside humans and require minimal green spaces to thrive

Throughout this lesson we are studying the abundance of these two groups of birds as a proxy to assess disparities in urban green amenities and habitat quality across different neighborhoods. After all, the presence of these birds have implications for the habitat quality of humans in those neighborhoods.



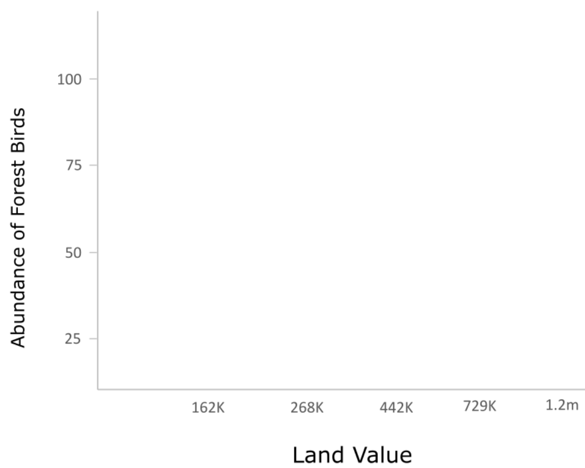
Lastly, in broader terms of avian conservation, areas that already attract forest birds during the non-breeding season (when this study is conducted) are likely to draw and accommodate a greater diversity of birds during migration seasons. Understanding what components make certain neighborhoods great habitat for birds can provide invaluable information for urban planning and avian conservation efforts.

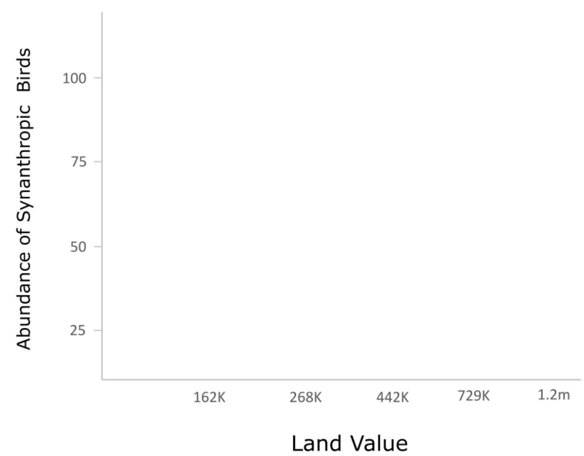
Luxury and Legacy Effects Hypotheses

Attached to this lesson you will find a copy of the focal paper. Read the background only in page 2 and 3 and answer the following questions:

1. What are the luxury and the legacy effect hypotheses, and how does it connect to HOLC grades?

2. Envision land value as the main indicator of wealth in neighborhoods. Draw a line on the following graphs of the expected relationship between land value and forest bird and synanthropic bird abundance. Do you expect the relationship to be positive, negative or neutral?

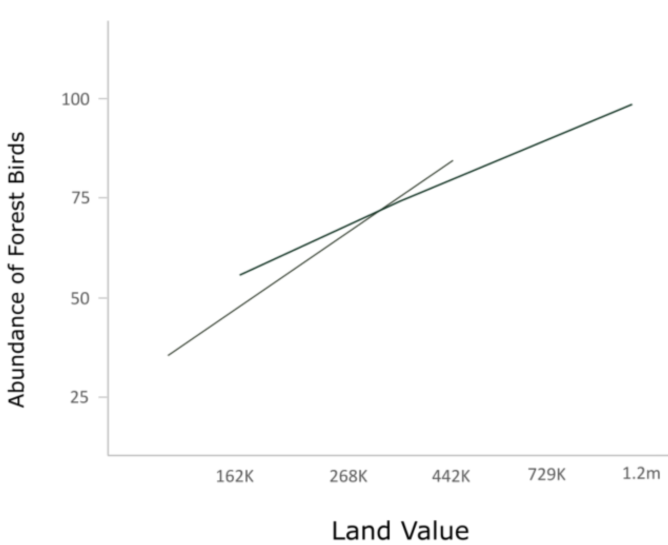




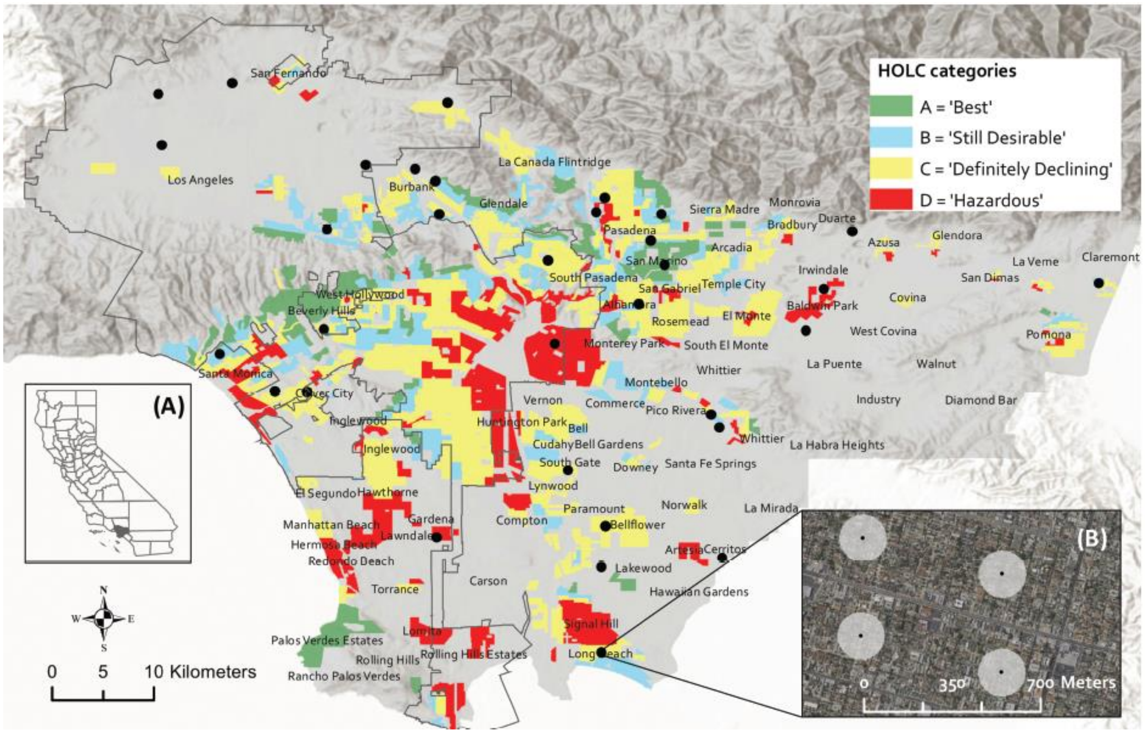
Critical Thinking Challenge

3. Do you think an increase in land value would have the same effect on forest bird abundance regardless of the HOLC grade of the neighborhood? Justify your answer.

4. The following figure has a green and a red line. Interpret this graph. Which colored line do you think would better represent neighborhoods with HOLC grade A vs HOLC grade D.



Methods



In this lesson you will be using a simplified version of the data used in the focal paper ("Wood_Data"). Here is a simplified explanation of the methods used by the author to gather the data. In the focal paper the researchers sampled bird abundance and habitat characteristics in 33 survey locations (black points in the image) across different residential communities throughout L.A. 24 of the 33 clusters were in each of the 4 categories of the HOLC security maps: A (n =3), B (n =9), C (n =8), and D (n =4). They were combined in AB zone (n= 12), CD zone (n= 12) and non-graded zone (n=12). Note that the non-graded areas were generally developed after the formal practice of redlining had ended. At each survey location, four 100-m radius bird point counts were conducted for 2 field seasons (2 visits per season) from October to March 2016-2018.

? Want to learn more about bird point count? Check this Youtube video: https://www.youtube.com/watch?v=reqjCHScWWk ¿

To each of these 100-m radios point counts, they also added parcel data that characterized residential housing patterns, including the year parcels were built, the building density, the **land value**, the last sale amount, the number of bedrooms and bath rooms, and the square footage of parcels. They also used light detection and ranging (LiDAR) to capture various parcel-level features such as building density, and vegetation and tree canopy cover within 100-meter circular buffers around the sample points.

Land value is the monetary appraisal of a piece of land. It can serve as a proxy for unmeasured amenities like manicured yards and landscaping, which likely attract specific bird communities to green environments.

For our simplified lesson, we will be using four main variables from the main data set: land value ("Land_value"), synanthropic bird abundance ("Synanthrope_abundance_sum"), forest bird abundance ("Forest_abundance_sum") and the HOLC grade each sample point belongs to ("HOLC_Code_groups").

Interactions

We may expect that a response variable is sometimes best explained by more than one predictor variable. When that is the case, the effect may be additive or may involve an interaction. In the case where it is additive, the two predictor variables explain the total variance independently of each other. Yet this is not always the case. It may be that one predictor relies on some effect of another predictor. When this occurs, we call it an interaction. One way to test for interactions is through an ANCOVA.

ANCOVA

With an analysis of covariance (ANCOVA), we are essentially trying to evaluate the effects of a continuous predictor on a continuous response, and then we determine whether there is some influence from a categorical variable. We will be doing an ANCOVA that looks at bird abundance as a function of land value and determining whether or not there is an interaction with HOLC grade. For this example, we will look at synanthropic birds to interpret an ANCOVA result.

ex.ANCOVA <- lm(s.abundance ~ log(land.value) * grade, data = data)

We have created a linear model that evaluates the effect of median (log-transformed) land value on synanthropic bird abundance, which we can call the main effect. Then, we want to know whether land value interacts with the categorical variable HOLC grade, for which the reare three values: AB, CD, and Not_redlined (hereafter ungraded). Thus, HOLC grade acts as the interaction term, which we have specified using *.

Interpreting your ANCOVA

```
Call:
lm(formula = s.abundance ~ log(land.value) * grade, data = data)

Residuals:
    Min      1Q  Median      3Q     Max 
-17.716  -8.445  -1.298   7.967  27.535 

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)    
(Intercept)                      320.174     68.207   4.694 6.93e-05 ***
log(land.value)                  -15.638      5.289  -2.956  0.00639 ** 
gradeCD                          186.827    128.562   1.453  0.15769    
gradeNot_redlined                649.416    201.587   3.222  0.00332 ** 
log(land.value):gradeCD          -13.504     10.381  -1.301  0.20431    
log(land.value):gradeNot_redlined -52.532    16.426  -3.198  0.00352 ** 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 11.92 on 27 degrees of freedom
Multiple R-squared:  0.7582,	Adjusted R-squared:  0.7134 
F-statistic: 16.93 on 5 and 27 DF,  p-value: 1.381e-07
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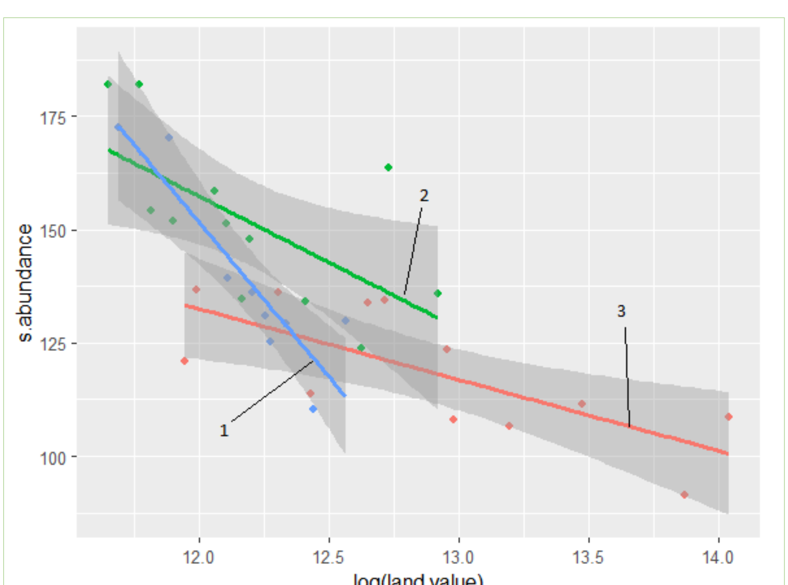
This type of readout will no doubt be familiar to you if you have ever done linear regression inR. One difference is that there are a few more lines to interpret. It may look daunting, butwe can break it down to make it clearer. When you run an ANCOVA, you are estimating slopes and intercepts of the main effect (i.e. s.abundance ~ land.value) for each categorical interaction term. The way this works in practice is that the first line "(Intercept)" estimates the y-intercept for the first categorical variable alphabetically. In this case, that is AB. The next line "log(land.value)" evaluates the main effect on AB. So, for AB-graded areas, we see that for every point increase in log-transformed land value, there is a 15.6 decrease in synanthropic bird abundance that is statistically significant ($P < 0.01$).

The next two lines represent the intercepts of the other two categorical values (CD and un-graded). A common mistake is to interpret these values as the actual intercepts. They more accurately represent the change in intercept from the first value (AB). That is, if you want to know the estimated y-intercept for Ungraded you take 320.2 + 649.4 = 1,014.6 This suggests that there is a sizeable and statistically significant difference in y-intercepts for at least two of the grade groupings. In any case, we cannot yet conclude anything about differences in effect size. For that, we need to look at the interactions.

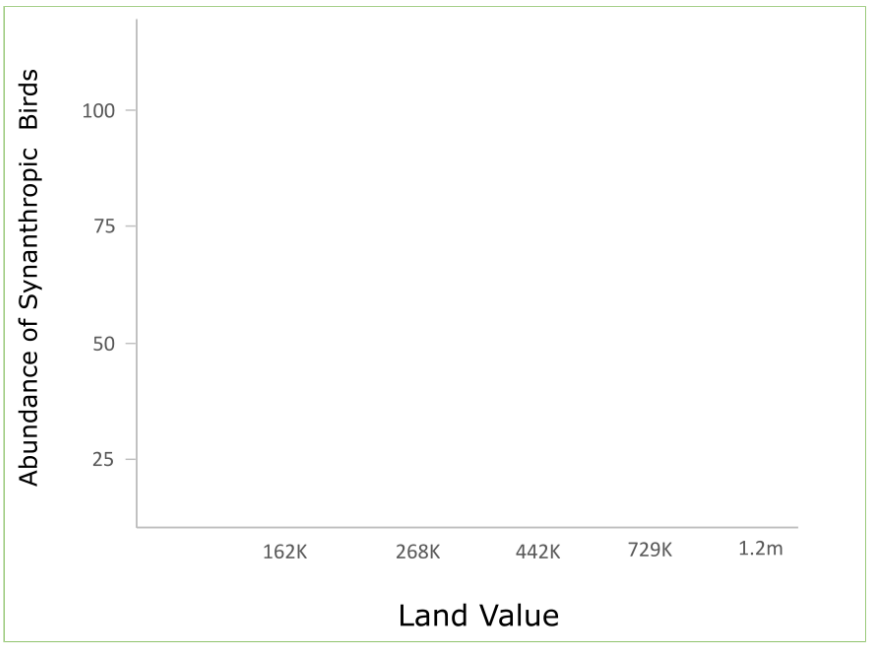
We want to look at log(land.value):gradeCD and log(land.value):gradeNot_redlined to get a sense of whether an interaction is happening. Like the intercepts, these estimates aren't the slopes themselves. We can calculate the slope by adding these values to the estimate in the second line. Let's take CD as an example. We want to add -13.5 to -15.6, and we get an estimated effect size of -29.1. Pretty different right? Well, maybe not... Take a look at that standard error. At 10.4 it is almost as large as the change in effect size. Keep going right, and we see that there is no statistically significant difference in effect size between AB and CD ($P= 0.2$). If we use the same approach for the next line, we get an effect size of -68.1 ($P < 0.01$). We can thus conclude that there is some interaction between the continuous variable land value and the categorical variable HOLC grade, at least between AB and Ungraded areas. This explanation has been fairly technical, so let's try to look at the bigger picture for a second. The results suggest that across the board, there is a negative impact of median home value on synanthropic bird abundance. In other words, as home values increase, synanthropic birds become less prevalent. This effect is largely similar between AB and CD zones but significantly more pronounced in ungraded areas. Let's look at the following graph showcasing this relationship to better make sense of it.



Here we see a graph with synanthropic bird abundance on the y-axis and log-transformed land value on the x-axis. We also see three lines (1, 2, and 3) that represent the three HOLC grade groupings. Basically, it's a visual representation of the analysis we just did.

Knowledge check

Based on our ANCOVA findings, which line do you think represents the ungraded category? Line 1 represents the ungraded category. It has a visually distinct slope that suggests that it is significantly different from the other two. In addition, the y-intercept is clearly larger. This is in line with what we see in the ANCOVA results for ungraded.



R Markdown

Please switch over to the R Markdown document titled "Code." That is where you will be able to do your own analysis using linear regression and ANCOVA to evaluate the luxury and legacy effects as they relate to avian abundance.

Citation

Eric M Wood, Sevan Esaian, Christian Benitez, Philip J Ethington, Travis Long core, Lars Y Pomara, Historical racial redlining and contemporary patterns of income inequality negatively affect birds, their habitat, and people in Los Angeles, California, Ornithological Applications, 2023; https://doi.org/10.1093/ornithapp/ duad044

Whelan, C. J., Wenny, D. G., & Marquis, R. J. (2008). Ecosystem Services Provided by Birds. The Year in Ecology and Conservation Biology 2008, 1134(1), 25-60. https://doi.org/10.1196/annals.1439.003