**The Importance of Street Trees to Urban Avifauna:**

*A lesson exploring the relationships between urban forest and foraging birds*

This QUBES lesson is based on a study conducted by Wood and Esaian called “The importance of street trees to urban avifauna.” Using this as a framework, students will explore the relationships between street trees, foraging birds, and socioeconomics in the urban setting of Los Angeles, California. A generalized linear model with negative binomial distribution will be used to analyze edited data from the focal paper in RStudio. This lesson will demonstrate why these models are used, how their interpretation can guide the management of urban forest, and how this process leads to better conservation of biodiversity in urban spaces.

**Learning Objectives**

* Explore effects of urbanization, function of urban forests, the role of socioeconomic gradients, and urban avifauna as bioindicators.
* Analyze the relationship between street tree density and feeding bird density across socioeconomic groupings using a generalized linear model with negative binomial distribution in R.
* Discuss how the results from the analysis could guide planning strategies for the assessment and management of street trees and the conservation of biodiversity.

**Prerequisites**

* Understanding of basic statistical principles for linear regressions and generalized linear models with Poisson distribution.
* General understanding of RStudio software.

**Urbanization**

Urbanization is the process of converting a natural ecosystem to one dominated by human development. Urbanization has been intensifying globally over the last half century, and it is projected that urban areas will continue to expand. Although there are associated benefits for humans, there have been negative impacts on the environment. One of the problematic aspects of human development has been the use of impervious surfaces such as concrete structures and pavement that dominate the landscape. Use of these materials has caused declines in natural areas which has led to the loss of biodiversity.

Biodiversity declines due to this type of development can be attributed to habitat loss or degradation, declines in connectivity, alters in disturbance regimes, and more (Elmqvist, Zipperer, and Guneralp, 2016). Given the historical and current uses of urban spaces, navigating the challenges associated with urbanization will be important to the conservation of biodiversity.

A city with trees and mountains in the background

Description automatically generated with medium confidence

***Figure 1.*** *Example of an urbanized landscape advancing into natural areas. Image source: Cities4Forests.*

[Click here](https://www.prb.org/resources/urbanization-an-environmental-force-to-be-reckoned-with/) for a more in-depth look at the history and environmental interactions of urbanization.

Want to learn more about biodiversity? [Click here.](https://www.youtube.com/watch?v=GK_vRtHJZu4)

**Urban Forestry**

Urban forests are the collection of trees within the boundaries of a metropolitan area. These forests come in different shapes and sizes and include parks, gardens, river corridors, and more. A key component of urban forests are street trees. Street trees are considered public resources that are planted by municipalities rights-of-way (along public roads and sidewalks).

Diagram

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Urban forests are a way to mitigate the negative impacts on biodiversity in urban areas. There are a variety of functional services associated with street trees which include improving urban aesthetic, increasing the quality of life of residents, and providing numerous environmental benefits. One of the goals of street tree plans is to provide habitat for wildlife which could contribute to biodiversity. Due to their importance, many cities have developed plans that work to promote, maintain, and provide an inventory of trees with-in a city’s boundary.

***Figure 2.*** *Benefits of a well-planned, well-managed urban forest. Image: Cities4Forests, 2019.*

**Luxury Effect Hypothesis**

While there are many services provided by street trees, it is important to note that these services are not distributed equally. The luxury effect hypothesis is defined as the positive relationship between affluence and organism diversity or activity in urban ecosystems. This trend has been found in cities around the world and affects a variety plants and wildlife. In these cases, urban forests and street trees are more prevalent in higher income communities than lower income communities. The primary reason this occurs is the costs associated with maintaining street trees as it is typically the responsibility of the property owner to cover these costs. This can cause an unequal distribution of environmental benefits for people and wildlife (Leong, Dunn, and Trautwein, 2018).

A street with cars and trees

Description automatically generated with low confidence

*Figure 4. Example images of trees in areas of differing socioeconomic status. Image derived from figure 2 of the focal paper.*

**Avifauna as Bioindicators**

A bioindicator is an organism whose status in an ecosystem is analyzed as an indication of the ecosystem's heath. Birds are often considered excellent biodiversity indicators because they are common, easy to detect, diverse, and can reach all areas of an ecosystem. Birds are also considered good representatives of their ecosystems due to their diverse use of resources such as habitat and food. When determining the quality of an ecosystem, researchers typically look at the richness (number of species) and abundance (number of individuals) of avian populations. The higher richness and abundance of birds in an area, the better quality of habitat and resources (Fraixedas, et al., 2020).

Los Angeles has a high diversity and abundance of birds that consist of hundreds of migratory and year-round species that utilize urban ecosystems throughout the annual cycle. Year-round residents are present in the ecosystem throughout the year, while migratory birds are only present for part of the year. In Los Angeles, migrants are present during the winter where they spend their time fueling up for spring migration. Migratory birds are of particular interest due to the complex factors that influence their populations and their significant declines globally (Gilroy, et al., 2016). Given that the goal of many urban forest plans is to provide habitat for wildlife, understanding the relationships between birds and street trees will be essential to their conservation.

  

***Figure 3.*** *Examples of birds surveyed from the focal paper. From left to right: Lesser Goldfinch, Orange-crowned Kinglet, and a Yellow-rumped Warbler. Source of images:* [*allaboutbirds.org.*](allaboutbirds.org)

**The Data**

The data for this lesson comes from a study published by Wood and Esaian in 2020 called “The importance of street trees to urban avifauna”. In this study, the authors wanted to understand the importance of street trees to wildlife. They did so by measuring and identifying public street trees and documenting foraging behavior of birds across two winters in residential communities situated across socioeconomic gradients throughout Greater Los Angeles (LA).

Map

Description automatically generated

***Figure 5.*** *A total of 36 sites were surveyed in LA across a socioeconomic gradient of low, medium, and high-income residential areas. These images provide a visual of the walking routes surveyed and a map of their locations. Image derived from figure 2 of the focal paper.*

There are several objectives in this study, however we will be focusing on part of objective #2:

Assess the relationship between street tree density and foraging bird density across socioeconomic gradients.

To assess this relationship, we will run a generalized linear model in R with a negative binomial distribution. This is similar to what the authors did in their study, however this process has been simplified for ease of interpretation.

**Before continuing the lesson, read the “Data Information” file to better understand the data and how it has been edited.**

**Negative Binomial Regression**

Negative binomial regression is a type of generalized linear model that has a negative binomial distribution (or family). This distribution is like Poisson in that it describes the probabilities of occurrence of positive whole numbers (aka count data). Unlike Poisson distribution, the variance does not equal the mean indicating that overdispersion is present. Overdispersion is when the variance of the **response variable** is greater than is assumed by the model.

The variance of a negative binomial distribution is a function of its mean and has an additional parameter called the dispersion parameter (k). The dispersion parameter is a measure of how much a sample fluctuates around the mean value. In other words, it tells us how many times larger the variance is than the mean. This parameter does not affect the expected counts of the data but does affect the expected variance.

Overdispersion in count data is a problem because it underestimates standard error which leads to smaller p-values. Essentially, there is a higher risk of making a type I error. Overdispersion is common in real data sets. This could be due to; predictor variables that were not included in the model, underlying heterogeneity (variation) in the sample, or there may be an excess of zero counts (requires zero inflation models).

In the R portion of this lesson, we will be assessing the influence of street tree density on total bird density. Total bird density will be the response variable and total tree density will be the predictor variable. Since there cannot be negative or partial counts of birds, this variable is considered count data.

For a GLM Refresher: [Click here.](https://www.dataquest.io/blog/tutorial-poisson-regression-in-r/#:~:text=A%20Poisson%20Regression%20model%20is,form%20by%20some%20unknown%20parameters.)

**Check your Understanding**

Before continuing to the R portion of the lesson, answer the following questions:

1. What are challenges that urbanization poses for biodiversity?
2. What are the benefits of urban forests? Are there any drawbacks?
3. Given birds are used as bioindicators, what kinds of trends would we expect to see in urban areas that display the luxury effect hypothesis? Would there be differences in birds for areas with low, medium, or high incomes?
4. When is it appropriate to use a negative binomial regression?

**Outline of R Lesson**

* Visualize the data
* Create a histogram to observe the distribution of the data.
* To test for normality, run a Shapiro-Wilkes test.
* Run a generalized linear model with Poisson distribution
* This will be used to model total bird density as a response to tree density.
* This is an incorrect model that will serve as a useful comparison for understanding negative binomial regression.
* Check for overdispersion
* Compare the mean and variance of the response variable (total bird density) and check the variance ratio.
* Using the MASS package in R, run a generalized linear model with a negative binomial distribution
* Assess the relationship between street tree density and density of birds while accounting for overdispersion.
* Build a scatterplot to visualize the negative binomial regression.
* Create boxplots to visualize the relationship between socioeconomic group, tree density, and bird density.
* Answer questions throughout the lesson to check your understanding of the material.

Need help with R? [Click here.](https://www.statmethods.net/r-tutorial/index.html)

**Questions from R lesson:**

1. What are the values for residual deviance and the associated degrees of freedom? Is overdispersion present in this data? Why might this be an issue?
2. Compare the negative binomial model to the Poisson. How is the negative binomial model accounting for the overdispersion present in the data? (Hint: consider coefficients) Is this model a better fit? Why?
3. What does the figure above indicate about the relationship between street trees and bird density? Does there appear to be a pattern associated with socioeconomic groups?
4. Interpret the boxplots depicting street tree density and total bird density. Do you think that there is support for the luxury effect hypothesis in this study?
5. How could the results from this model be used to guide management of urban forests and conservation of biodiversity? Consider the output from the model and the observations from the plots in your answer.
6. What are other ways that we can support conservation of biodiversity in (or around) urban spaces?

**Lesson Summary**

Key Takeaways

This lesson was made up of several interrelated goals.

* To promote a better understanding of the role that urban forests play in promoting biodiversity in urban areas.
* Explore how indirect factors like income can influence the distribution of trees, leading to unequal environmental benefits for wildlife and people.
* To understand the role of avifauna in determining the health of an ecosystem.
* How to use and interpret negative binomial regression in R to provide information for guiding future management of trees and to enhance conservation in urban ecosystems.

**Citations**

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