Does Urbanization Favor Exotic Species?

Gabriela Giacomangeli

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Learning Objectives

- To examine the influence of urbanization on exotic and native bees using the datasets from a focal paper
- To critically think about how urbanization affects native species vs exotic species, and how this impacts conservation efforts
- Use AIC for model selection, and interpret a generalized linear model with a Poisson distribution

Prerequisites

Students should have both R and RStudio installed on their computers and have basic knowledge of how the program works

Quick Bee Facts

Why Honeybees?

The honeybee is **responsible for nearly a third of crop pollination**. But these hardworking insects produce more than that! They have six hive products — pollen, honey, beeswax, royal jelly, propolis, and venom. These are all collected and used for nutritional and medical purposes by humans (U.S. FDA, 2018).

However, European honeybees are not native to the United States. The European honeybee may be outcompeting native species for resources such as food and habitat, and urbanization may be aiding the European honeybee in its competitiveness. Since humans first

began keeping honeybees, their principal aim has been the harvest of honey. Beekeepers select the appropriate type of honeybee based on temperament, physical characteristics, disease resistance, and productivity (USDA, 2023).

Urbanization and Exotic Species

Exotic species and how they affect/alter natural systems is already a global environmental/conservation issue as they can cause biodiversity loss, biotic homogenization, and changes to ecosystem function (Simberloff, et al. 2013). The European honeybee is an established exotic species that has been introduced worldwide for pollination and honey production.

Additionally, it is widely understood that **urbanization alters natural ecosystems in a multitude of ways**. Bee populations are an interesting focal point in a larger issue because it has multiple areas of interest and importance. **Pollinators are facing an increase in diseases, increase in the usage of pesticides and other chemicals, loss of habitat, loss of species and genetic diversity**.

There are a few reasons as to why cities allow exotics such as the European honeybee to have an established population. One reason is that cities can be a frequent introduction point for exotic bees, which usually occurs through international commerce. This is because cities are hubs for ports of entry. Another reason relates to the behavior of exotic bees. Most exotic bees are cavity nesting, and urbanization can provide suitable nest sites for these species (Fitch, et al. 2019).

Focal Paper

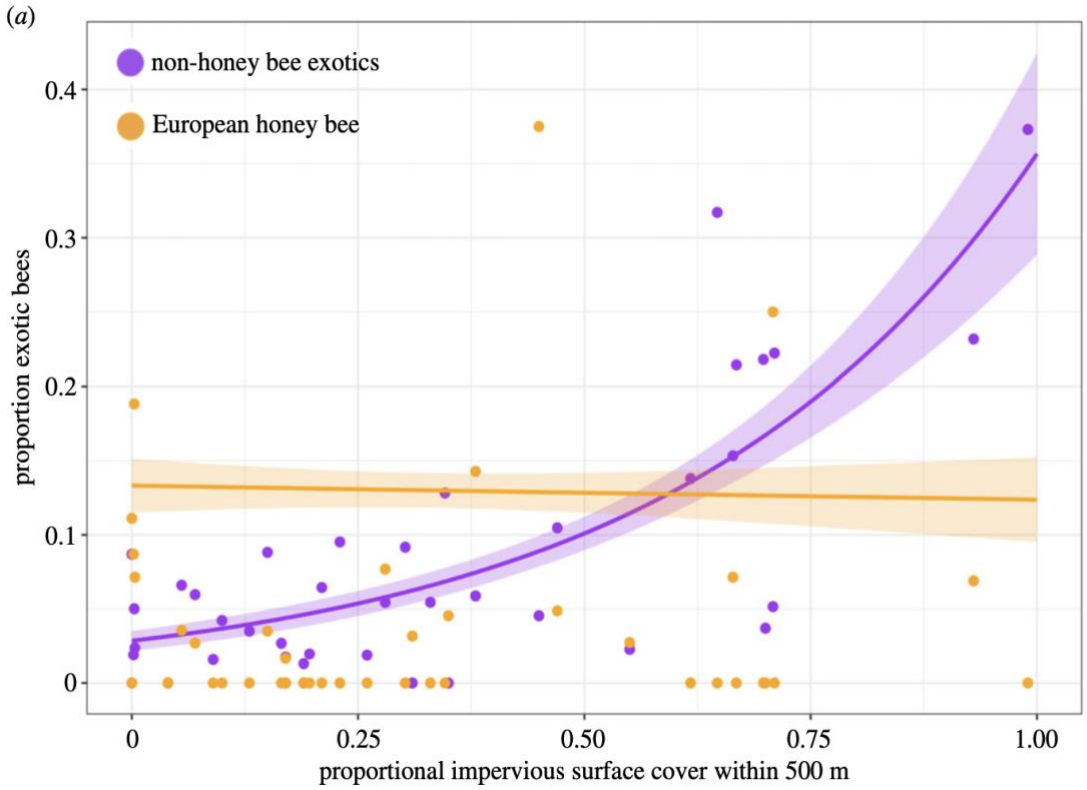
Fitch, Gordon et al. (2019), Does urbanization favour exotic bee species? Implications for the conservation of native bees in citiesBiol. Lett.152019057420190574
http://doi.org/10.1098/rsbl.2019.0574

In the focal paper, the authors hypothesize that urbanization favors exotic bee species over native bee species. They also focus on four main questions:

1) Are exotic bee abundance and richness positively associated with increased urbanization?

2) Is the relationship between exotic bees and urbanization mediated by (i) proximity to registered IPOE, (ii) prevalence of exotic plants, (iii) urban warming and/or (iv) nesting strategy?
3) Do different exotic bee species demonstrate similar responses to urbanization?
4) Is there evidence for negative effects of exotic bees on native bees?

In this lesson, **we will be focusing on whether exotic bee richness is positively associated with increased urbanization**. We will recreate a similar figure to figure 2(a) (see below), but instead we will be looking at exotic and native species richness in response to proportional impervious surface cover.



Answer these questions after reading the focal paper:

1. Why is it important to study European honeybees?

2. What are other ways that urbanization can impact the environment?

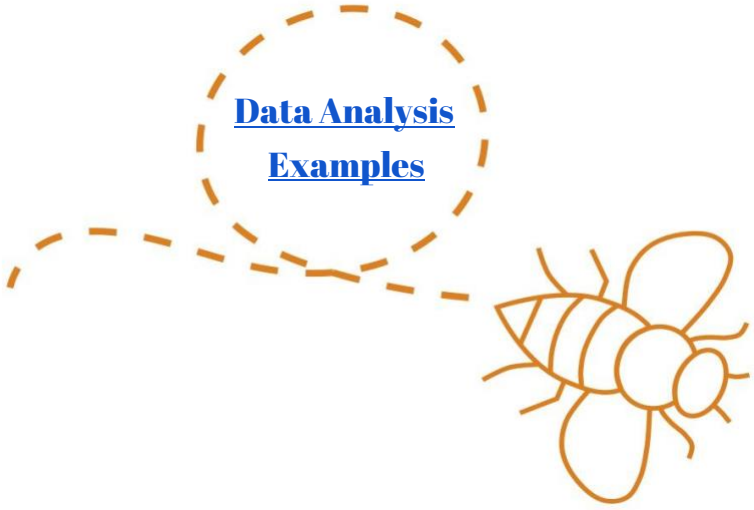
3. Do some research: What is the difference between species richness and species abundance?

4. Review the methods section of the paper: What do you think about their study design? (Consider things like site selection and survey methods. Why do you think they decided to set up their experiment like this?)

Statistical Analysis in R

In R we will be using data from the focal paper to see if urbanization influences exotic and native bee richness. In the focal paper, the researchers used 4 concentric buffers (500 m, 1 km, 1.5 km, and 2 km. We will use AIC to figure out how the authors determined which buffer is the best predictor of exotic bee richness.

We will then create a Poisson regression to see if exotic and native bee species richness increases in proportion with impervious surface cover. Check out the data analysis examples link below that will provide more information on examples of Poisson regression.



Interpreting AIC

The **Akaike information criterion (AIC)** is a method used to compare different possible models and determine which one is the best fit for the data (Bevans, R. 2022). AIC is calculated from:

- the number of independent variables used to build the model.
- the maximum likelihood estimate of the model (how well the model reproduces the data).

	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
500m	3	138.84	0.00	0.52	0.52	-66.10
1km	3	139.78	0.94	0.32	0.84	-66.57
1.5km	3	141.88	3.04	0.11	0.95	-67.62
2km	3	143.53	4.69	0.05	1.00	-68.44

From this table we can see that the best model is the 500m model – (exotic.richness~NLCD500m + Year, data = beedata, family = poisson)

However, the Akaike's rule of thumb is two models are essentially indistinguishable if the difference of their AICs is less than two. In the table above, the difference between 500m and 1km is less than 2, so while the 500m AIC is the lowest, it's really not distinguishable from the others.

Generalized Linear Models and Poisson Distribution

There are three main components to generalized linear models:

1. Family - the distribution of the response variable
2. Linear predictor - how to model the response variable for a given explanatory variable or variables
3. Link function - provides the relationship between the linear predictor and the mean of the distribution function

Generalized linear models can model data that is not normally distributed. Linear regression can only model data that has a gaussian distribution, but generalized linear models are flexible in that they can model many different distributions. One such distribution is **Poisson** for **count data.** We will be using glm() to fit a Poisson regression model. The Poisson distribution is best applied to statistical analysis when the variable is a count variable. For this instance, it is how many times a species of bee occurred at each site.

Interpreting a glm() output in R:

The **coefficient estimate** in the output indicate the average change in the log odds of the response variable associated with a one unit increase in each predictor variable

The **standard error** gives us an idea of the variability associated with the coefficient estimate

The **p-value** essentially tells us how well each predictor variable can predict the value of the response variable in the model

Here the **p-value** is less than .05, we would say that NLCD500m is a statistically significant predictor variable in the model

The **z-value** is the regression coefficient divided by standard error

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Call:
glm(formula = exotic.richness ~ NLCD500m, family = poisson(link = "log"),
    data = beedata)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.1036  -0.7685  -0.1562   0.4485   2.2440

Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)   0.3560     0.1832   1.943 0.051963 .
NLCD500m      1.2519     0.3522   3.555 0.000378 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for poisson family taken to be 1)

    Null deviance: 62.752  on 40  degrees of freedom
Residual deviance: 50.664  on 39  degrees of freedom
AIC: 150.24

Number of Fisher Scoring iterations: 5
```

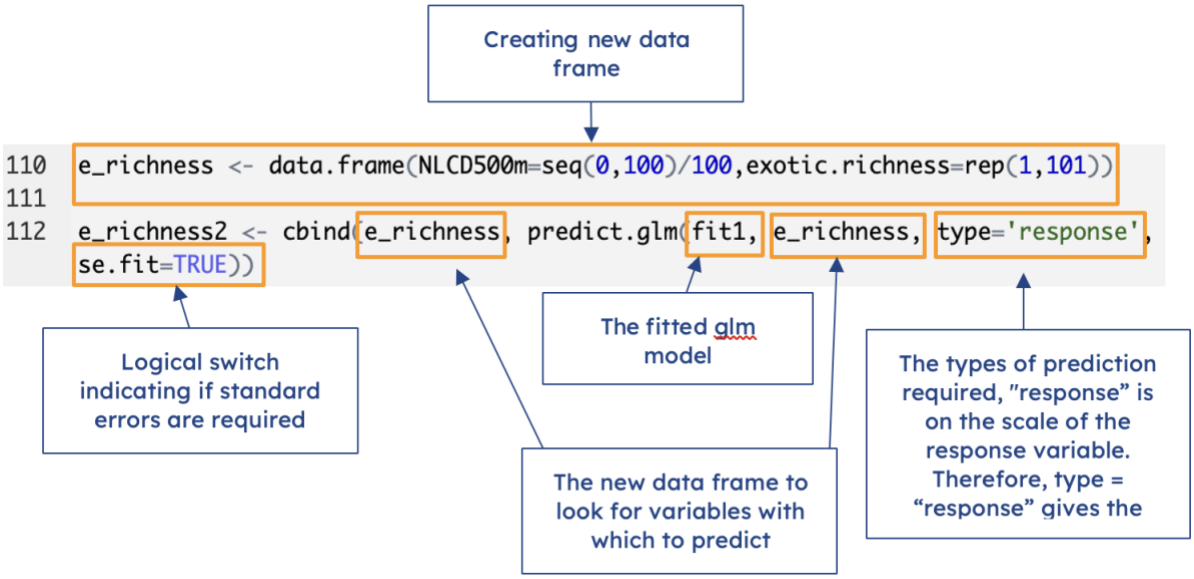
The **Akaike information criterion (AIC)** is the metric we used to compare the fit of different regression models for each buffer. This is the output for just one model, and the AIC is essentially meaningless when isolated

The **null deviance** tells us how well the response variable can be predicted by a model with only an intercept term

The **residual deviance** tells us how well the response variable can be predicted by the specific model that we fit with predictor variables. The lower the value, the better the model can predict the value of the response variable

Using predict.glm():

The predict method computes predicted values and their standard errors for a fitted generalized linear model.



After using predict.glm(), we use ggplot() to plot exotic and native species richness in response to proportional impervious surface cover (remember this is within a 500m buffer).

Takeaways for Conservation

While promoting bee- friendly management of urban land is vital to protecting pollinators, this study highlights the need to **think critically about the bee communities supported by urban environments**. While bee conservation as a whole can improve bee diversity, this may negatively affect native species. Either way, all of this is important because research like this promotes the idea that urban gardens and green space can be managed to support pollinator populations.

Due to recent findings that cities can support diverse bee communities, there has been an increase in interest that targets cities as areas for bee conservation. **But do we manage to support native species or do we manage to support pollinator populations as a whole, regardless of whether or not it is detrimental to native species?** These are real world conservation questions that often arise during decision-making processes.

Answer these questions after reading the focal paper and creating the final plot in R:

5. Compare the figure that we created to figure 2 in the focal paper. What are these figures telling us? Were the authors correct in predicting that urbanization favors exotic bees over native species?

6. Looping back to the big picture question,do you think conservation management should implement strategies to support native species or should there be a shift in supporting pollinator populations as a whole, regardless of whether or not it is detrimental to native species? Think about the data we looked at and the data in the focal paper

References

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abstract

In this lesson, students will learn about the exotic European honeybee (Apis mellifera), and why they are considered an important pollinator. They will be prompted to think about the impacts of urbanization and how to may favor one species over another. They will also use R and data from the focal paper to complete a statistical analysis.

Description

Using data from the focal paper "Does urbanization favour exotic bee species? Implications for the conservation of native bees in cities" students will test the effect of urbanization on per-site

exotic and native bee richness using generalized linear models (GLMs) fit with a Poisson distribution.