# The Influence of Urban Stressors on Avian Diversity in Manhattan, KS

**Jordan Schwabe, Jennie Tucker, Makenna Anderson, Joe Sanchez**

## Abstract

Urban environments expose birds to multiple stressors, including artificial light at night, noise pollution, traffic, and minimal green space. This study examines how these factors influence bird species richness and abundance across four different locations in Manhattan, Kansas. Field data were collected over two weeks, and artificial light and impervious surfaces were extracted using ArcGIS Pro. A multiple regression analysis showed that impervious surfaces was the strongest negative predictor of species richness and abundance, while light pollution was the strongest positive predictor. These results came after controlling the other variables. Noise and traffic did not have a significant independent effect. These results highlight the importance of habitat structure in shaping bird communities and show that artificial lighting may attract more generalist urban-tolerant species.

## Introduction

As humans expand farther into avian habitat, birds are forced to adapt to urban environments or seek out increasingly smaller and fragmented rural areas. We chose to study light pollution, noise pollution, traffic, and impervious surface percentage as proxy for urbanization specifically, all of which have been found to be stressors for avian species.

"Impervious surfaces" are areas of the environment that have been transformed into areas such as concrete, asphalt, and stone. Additionally, impervious surfaces can be referred to as other urban structure terms like urban development, built-up surfaces, urbanization, and land-use cover. These terms are a commonly used indicator of urbanization intensity in bird diversity research. In this paper, only the term "impervious surfaces" will be used for simplification purposes as well as the fact that specific impervious surfaces data were collected from USGS and analyzed in this report. Each study site represents a slightly different land use category (percent of urbanization/impervious surface), which represents an urbanization gradient. One of the goals of this project was to see if different degrees of urbanization resulted in differences in bird diversity.

Research consistently supports the conclusion that as impervious surfaces increase, bird diversity decreases. "Urban areas are growing disproportionately faster than any other form of land cover on our planet, with future predictions estimating a global increase by 200% by 2030 to accommodate the increasing urban human population" (Ibáñez-Álamo et al., 2019). This rapid rate of anthropogenic change raises concerns for avian diversity and functional traits, including diet, body size, foraging strategies, and nesting behaviors.

Birds are increasingly used as indicators of landscape and environmental quality, as well as how ecosystems are functioning, because changes in bird diversity and species richness reflect habitat loss, urbanization, and increasing impervious surfaces (Chamberlain et al., 2007; Sun et al., 2022; Zhang et al., 2023). The expansion of impervious surfaces contributes to habitat fragmentation and the loss of green space, leaving only isolated patches of suitable habitat for birds. This reduction in habitat decreases structural complexity and limits the availability of key resources such as insects, seeds, and vegetation needed for survival.

In addition, impervious surfaces drive shifts in community composition by favoring generalist, human-tolerant species, and those that nest in buildings, while sensitive species, such as specialists and forest-dependent birds, decline (Schütz & Schulze, 2015). As Ortega-Alvarez et al. (2009) state, "the replacement of natural habitats related to urbanization processes can lead to species extinctions and biotic homogenization". To mitigate these impacts, urban planning should incorporate more parks and green spaces to support and maintain bird diversity.

Research on artificial light at night (ALAN) shows a consistent pattern across many studies. ALAN disrupts basic biological rhythms, which leads to earlier dawn song, later roosting, and more nighttime activity. Degan et al. notes that *"nighttime lighting disrupts melatonin production, alters sleep patterns, and interferes with communication signals,"* which helps explain why some avian species stay active longer than they would under natural conditions (Degen et al. 2022; Dominoni 2015; Gaston et al. 2015). These shifts tend to favor generalist species that tolerate disturbance.

Movement studies show that ALAN draws nocturnal migrants toward illuminated cities. Migrants often concentrate over bright urban areas and may choose stopover sites that are lower in quality because the lighting overrides natural cues (Horton et al. 2019; La Sorte et al. 2017; McLaren et al. 2018). This attraction is strongest during fall migration when many young birds are traveling for the first time. Community level research shows that species richness declines as nighttime light increases. Sensitive and forest-dependent species become less common in brightly lit parks, while generalist species become more dominant (Wilson et al. 2021; Sanders et al. 2020). Long-term work in Shanghai shows that ALAN shapes both the spatial and temporal distribution of avian species across the city, acting as an ecological filter that favors disturbance-tolerant birds (Guo et al. 2026).

Birds are characterized by their complex vocal communication, which can be used to differentiate species (Almarza-Batuecas and Pescador 2025; Song et al. 2025; Deoniziak and Osiejuk. 2021; Jung et al. 2020). Birdsong and calls are used for defining territory, attracting mates, warning others of predators, and creating and reinforcing social bonds. Noise pollution has the potential to disrupt this communication, which can impact bird behavior, territory choice, and survival rates.

"Masking" refers to the popular theory that low frequency birdsong is covered up ("masked") by low frequency noise pollution such as traffic. This tends to cause species with low frequency calls and songs to avoid or survive poorly in loud areas with recurrent low frequency noise pollution (Almarza-Batuecas and Pescador 2025, Bergamini et al. 2024; Perillo et al. 2017;

Song et al. 2025; Wilson et al. 2021; Francis 2015). Some avian species have been found to adapt their song to prevent masking (Almarza-Batuecas and Pescador 2025; Ríos-Chelén et al. 2012). However, this is highly species specific, with many species simply avoiding noisy areas instead of changing song frequencies. High frequency birdsong is generally thought to be resistant to masking. However, consistent noise pollution could potentially have other negative impacts regardless of a species' song and calling frequencies. These results can include reduced ability to detect audible predator cues (Jung et al. 2020), and difficulty detecting prey items such as insects (Francis 2015).

On the other hand, some species seem to thrive in areas with high noise pollution (Almarza-Batuecas and Pescador 2025). Resources are left underexploited when sensitive species leave an area, allowing generalist species to fill those empty niches. Regardless of reaction, anthropogenic noise pollution further homogenizes bird communities by masking or other harmful effects, which reduces functional diversity.

Studies on traffic noise show that it has had a major impact on bird behavior and the surrounding habitat. Research like the phantom road experiment found that noise alone caused about 31% of bird species to avoid habitats that would have been suitable for them. An increase in traffic volume is also strongly linked to declines in breeding populations. This is mainly because noise interferes with their communication. Birds heavily rely on sound for mating and territorial defense, so masking these signals reduces their success for reproduction.

Overall, traffic noise acts as an invisible but powerful form of habitat degradation. (Ware et al., 2015; Reijnen et al., 1997). Research also consistently shows that higher traffic intensity leads to lower bird population density near roads. These studies have found that bird numbers can decline to as much as 25% within several hundred meters of major roads, with impact extending up to one kilometer. These findings suggest that traffic volume directly increases the size and severity of road effect zones. Overall, heavier traffic leads to a stronger and more widespread ecological impact on bird populations. (Van Dijk et al., 2025; Cooke et al., 2020; Benitez-Lopez et al., 2010).

Based on previous research, we expected that impervious surfaces, noise, and traffic would reduce both species richness and abundance because these factors are known to degrade habitat quality and interfere with communication. We also expected that light pollution would reduce richness and abundance because artificial lighting can disrupt natural behavior and attract only a small number of tolerant species. Overall, we predicted that the most urbanized sites would support fewer species and fewer individuals than the sites with more natural cover.

## Methods

### Study Sites

Bird data and environmental measurements were collected at four locations in Manhattan, Kansas. These locations were Poyntz Avenue near AJ's Pizza (39°10'46" N, 96°34'31" W°) and the mall, City Park near the playground (39°10'49" N, 96° 34'25" W), the west side of Ratone Street (39°10'46" N, 96° 33'35" W), and south Washington-Marlatt Park (39°13'19" N, 96°

37’18” W). These sites represent different varieties in urbanization from highly urbanized commercial areas to semi-natural prairie habitat.

Image (left) description: Poyntz. The location on Poyntz is highly urbanized, with 90.25% of the area being made up of impervious surfaces and very little greenspace available as potential habitat. What greenspace does exist is intensely managed turfgrass and ornamental trees and bushes, which are generally considered to be poor quality of habitat.

Image(right) description: Ratone Street. The neighborhood has a lower rate of impervious surface than Poyntz at 34%. The neighborhood has a mix of small turfgrass yards and mature trees. Litter is common.

Image (left) description: City Park. City Park has the second lowest rate of impervious surface at 31.75%. The park features mature trees and short turfgrass with buildings, benches, a playground, and concrete walkways throughout. It is a popular place for locals to spend time outside.

Image (right) description: Washington-Marlatt Memorial Park has no impervious surfaces. The park is a restored prairie maintained by Kansas State University. It features a mixture of tallgrass prairie interspersed with forested areas with mown grass paths throughout. It is a popular place for locals to spend time outside, especially dog owners.

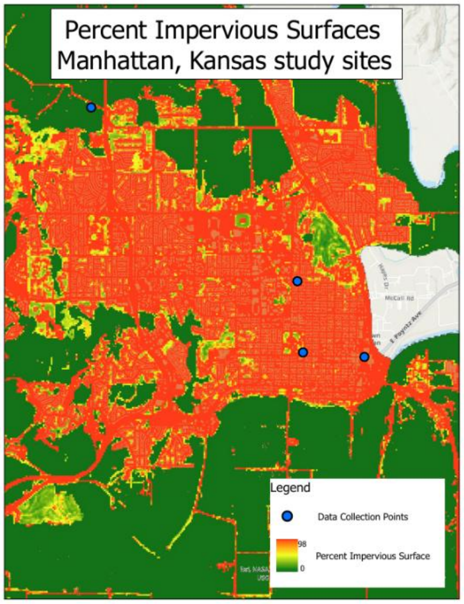
### Field Data Collection

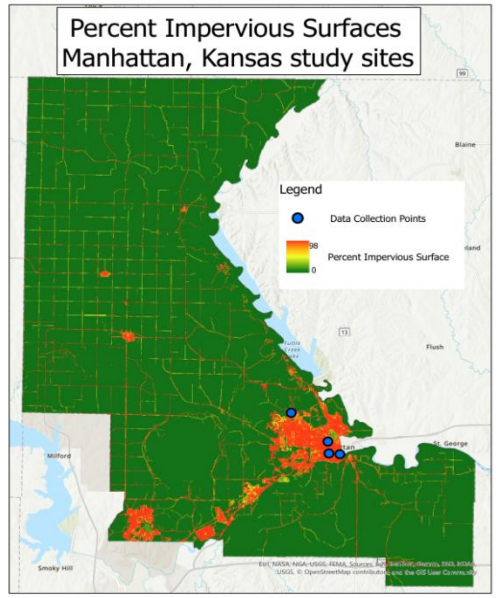
Fieldwork occurred over two weeks. At each site, bird observations, noise levels, and traffic counts were collected simultaneously during 15-minute sampling periods. Bird detection was recorded using the Merlin Bird ID iPhone app (version 3.8.3), supported by visual confirmation when possible. A point-count approach was used, assuming that repeated vocalizations in the same area came from the same individual unless multiple birds were clearly seen or heard at the same time. Merlin's automated identifications were reviewed, and incorrect suggestions were excluded from the dataset.

Noise levels were measured using the National Institute for Occupational Safety & Health (NIOSH) Sound Level Meter app (version 1.4.0). Measurements were taken with the phone's built-in microphone, and wind interference was noted when present. Traffic was recorded using a simple tally system, counting all motorized vehicles passing the nearest roadway during each 15-minute interval.

### GIS-Based Environmental Variables

Impervious surface data were obtained from publicly available USGS NLCD data from 2024 and processed in ArcGIS Pro. The shape-file was clipped to the Riley County boundary and symbolized to highlight variation in percent of impervious surfaces. A 100-ft buffer was created around each sampling point, and the percentage of impervious surface within each buffer was extracted and exported to a CSV file.



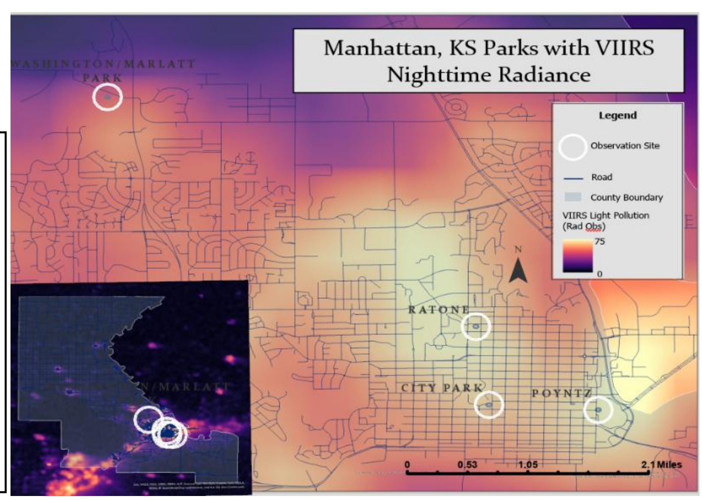




Map (above) shows the 4 study sight in Manhattan, ks hilighted as blue dots. This map also shows the percent of impervious surface, where green indicates no impervious surface and red indicates complete impervious surface.

Map(above) to the right is a zoomed out impervious surface map of the city of Manhattan, Ks.

Artificial light at night was measured using the Visible Infrared Imaging Radiometer Suite (VIIRS) Nighttime Lights Monthly Cloud-Free Composite from the ArcGIS Living Atlas. Based on previous research, Satellite-based VIIRS radiance data provide a reliable way to measure ALAN in ecological studies. The review explains that *"VIIRS offers improved sensitivity and spatial resolution,"* which supports its use for mapping light levels across urban landscapes (Kyba et al. 2015; Falchi et al. 2016). Radiance values were clipped to the Riley County boundary, and 100-ft buffers were created around each sampling point. Mean radiance values within each buffer were extracted using the Zonal Statistics as Table tool and exported for analysis.

Map showing VIIRS nighttime radiance values across Manhattan, Kansas, with observation sites located in Washington/Marlatt Park, City Park, and Poyntz. Brighter colors represent higher artificial light at night (ALAN), highlighting spatial variation in light exposure across the city's park system.



**Statistical Analysis**

All field and GIS variables were compiled into a single dataset containing species richness, total bird abundance, light pollution, impervious surface percentage, average noise level, and traffic counts. Two multiple linear regressions were conducted using the Excel Data Analysis ToolPak. The first model predicted species richness, and the second predicted total bird abundance. Both models included light pollution, impervious surface, noise, and traffic as predictors. Coefficients, p-values, and $R^2$ values were used to evaluate the strength and significance of each variable.

## Results

Bird communities varied across the four study sites. Washington Marlatt Park had the lowest light pollution at 12.22 radiance units and no impervious surface, and it consistently supported the highest species richness. Poyntz Avenue had the highest light pollution at 78.93 units and the highest impervious surface at 90.25 percent, and it supported the lowest richness. City Park and the Ratone neighborhood fell between these extremes for both environmental conditions and bird observations.

The multiple regression model predicting species richness was highly significant and explained a large portion of the variation in richness across visits. The model had an R-squared value of 0.747. Light pollution showed a strong positive effect on richness once the other variables were held constant. The coefficient for light was 0.284 and the effect was highly significant with a p-value of 0.000056. This pattern differed from the simple scatterplot, which showed a slight negative trend. The raw scatterplot was misleading because the brightest site was also the most heavily paved and had the lowest richness. The regression model and the partial regression plot revealed the true relationship. When pavement, noise, and traffic were removed from the equation, higher light levels were associated with more species.

Impervious surface was the strongest negative predictor of species richness. The coefficient was negative 0.198 and the effect was highly significant with a p-value of 0.000011. Sites with more pavement consistently supported fewer species. Average noise level also had a significant negative effect on richness after outlier removal. The coefficient for noise was negative 0.184 and the effect reached statistical significance with a p value of 0.047. Traffic showed a weak negative trend with a coefficient of negative 0.024, but it did not reach significance.

The regression model predicting total bird abundance was also significant and explained a substantial amount of variation. The model had an R- squared value of 0.634. Light pollution again showed a positive effect, with a coefficient of 0.303 and a p-value of 0.00058. Impervious surfaces showed a negative effect, with a coefficient of negative 0.190 and a p value of 0.00051. Noise had a moderate negative effect, with a coefficient of negative 0.365 and a p-value of 0.019. Traffic showed a small negative trend, with a coefficient of negative 0.044 and a p-value of 0.050.

Including outliers weakened both models. With outliers included, the explained variation dropped to 0.571 for richness and 0.538 for abundance. Standard errors increased, and noise and traffic were no longer significant predictors. Several observations had large, standardized residuals, which distorted the relationships among the variables. Removing these points improved normality, reduced variance, and revealed the independent effects of noise and traffic more clearly.

Across both models, light pollution and impervious surfaces were the most consistent predictors. Light pollution increased both richness and abundance, while impervious surfaces reduced them. Noise had a weaker but still meaningful negative effect once outliers were removed. Traffic showed a small negative trend but did not independently predict richness or abundance.

# FIGURES

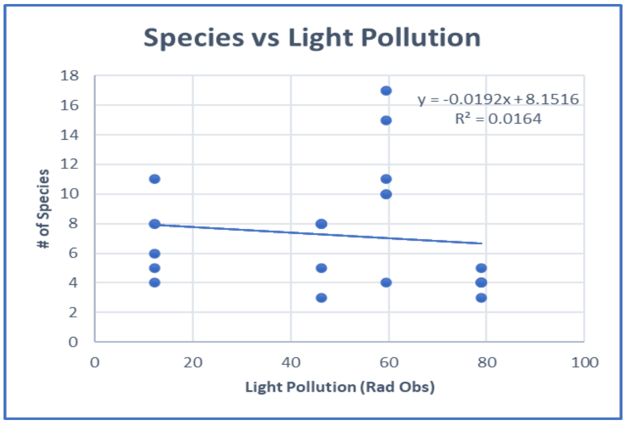



Figure 1: **Relationship between bird species richness and light pollution across study sites in Manhattan, KS.** Each point represents the number of species observed at a site, plotted against measured radiance.

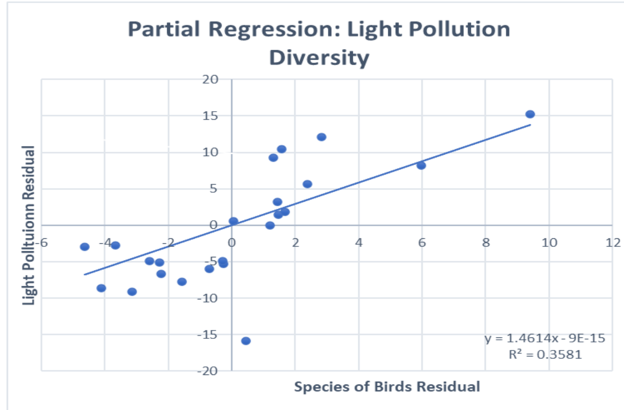



Figure 2: **Partial regression of bird diversity against light pollution residuals in Manhattan, KS.** This plot illustrates the relationship between the residuals of bird species diversity and light pollution after controlling for other environmental variables.

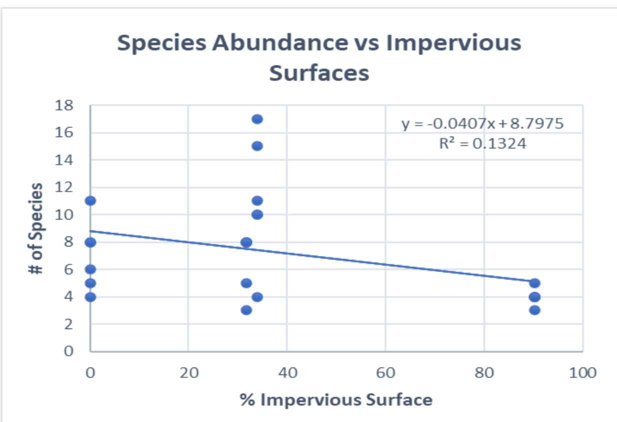



Figure 3: **Relationship between bird species abundance and impervious surface coverage in Manhattan, KS.** Each point represents the number of bird species observed at a site plotted against the percentage of impervious surface (e.g., pavement or buildings).

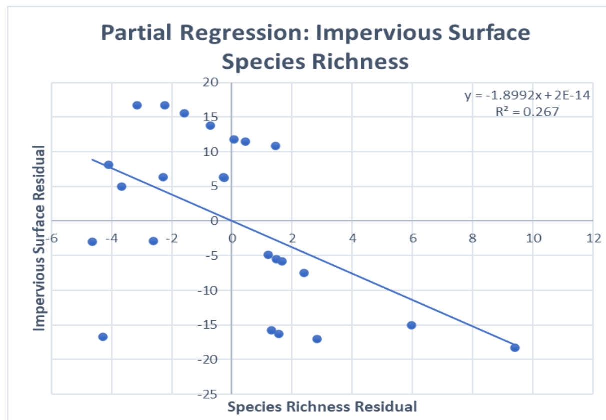



Figure 4: **Partial regression of bird species richness against impervious surface residuals in Manhattan, KS.** The negative slope indicates a moderate inverse association, suggesting that areas with higher impervious surface residuals tend to have lower species richness once other factors are controlled for.

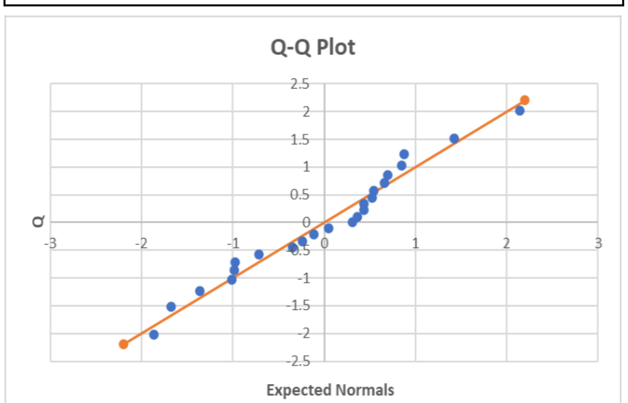



Figure 5: **Q–Q plot assessing normality of residuals in bird abundance model.** This plot compares the sample quantiles of the residuals to the expected quantiles from a normal distribution. The points closely follow the orange reference line, indicating that the residuals are approximately normally distributed.

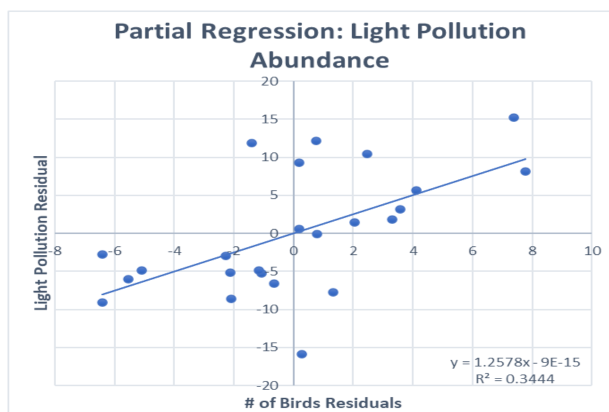



Figure 6: **Partial regression of bird abundance against light pollution residuals in Manhattan, KS.** The positive slope indicates a moderate positive association, suggesting that sites with higher light pollution residuals tend to have greater bird abundance once other factors are accounted for.

| Table 1. Multiple Regression Predicting Species Richness (No Outliers) | | | | | | |
|---|---|---|---|---|---|---|
| **Model R^2** | **0.7473** | | | | | |
| **Adjusted R^2** | **0.6799** | | | | | |
| **Standard Error Estimate** | **1.4229** | | | | | |
| **Observations** | **22** | | | | | |
| **Predictor** | **Coefficient** | **Standard Error** | **t-value** | **p-value** | **Lower 95%** | **Upper 95%** |
| **Intercept** | **11.3733** | **3.7717** | **3.0154** | **0.00869** | **3.3341** | **19.4125** |
| **Light Pollution** | **0.2844** | **0.0513** | **5.5419** | **0.000056** | **0.1750** | **0.3937** |
| **Average Noise** | **-0.1837** | **0.0851** | **-2.1582** | **0.04753** | **-0.3650** | **-0.0023** |
| **Impervious Surfaces** | **-0.1977** | **0.0309** | **-6.4044** | **0.0000119** | **-0.2636** | **-0.1319** |
| **Traffic** | **-0.0244** | **0.0133** | **-1.8413** | **0.08544** | **-0.0527** | **0.0038** |

Table 1: Multiple regression model predicting total bird abundance after removing outliers. Light pollution increased abundance once the other variables were controlled, while impervious surfaces and noise reduced abundance. Traffic showed a small negative trend that was marginally significant.

| Table 2. Multiple Regression Predicting Total Bird Abundance (No Outliers) | | | | | | |
|---|---|---|---|---|---|---|
| **Model R^2** | **0.6343** | | | | | |
| **Adjusted R^2** | **0.5428** | | | | | |
| **Standard Error Estimate** | **2.3823** | | | | | |
| **Observations** | **22** | | | | | |
| **Predictor** | **Coefficient** | **Standard Error** | **t-value** | **p-value** | **Lower 95%** | **Upper 95%** |
| **Intercept** | **25.7788** | **6.4836** | **3.9699** | **0.0011** | **12.0130** | **39.5447** |
| **Light Pollution** | **0.3028** | **0.0708** | **4.2741** | **0.00058** | **0.1526** | **0.4530** |
| **Average Noise** | **-0.3653** | **0.1405** | **-2.5994** | **0.01937** | **-0.6632** | **-0.0674** |
| **Impervious Surfaces** | **-0.1902** | **0.0438** | **-4.3391** | **0.00051** | **-0.2831** | **-0.0973** |
| **Traffic** | **-0.0437** | **0.0207** | **-2.1152** | **0.05045** | **-0.0876** | **0.00010** |

Table 2: Multiple regression model predicting species richness after removing outliers. Light pollution increased richness once the other variables were controlled, while impervious surfaces and noise reduced richness. Traffic showed a small negative trend that did not reach significance.

## Discussion

Multiple regression was essential for this study because the environmental variables were not independent of one another. Light pollution, impervious surface, noise, and traffic tended to rise and fall together across the four sites. This meant that simple scatterplots could not show the true effect of any single variable. For example, the raw plot of light pollution and species richness suggested a slight negative trend, but that pattern was created by the fact that the brightest site was also the most heavily paved and had the lowest richness. The regression model separated these overlapping influences and revealed the actual relationship. Once the effects of pavement, noise, and traffic were removed, higher light levels were associated with more species.

Using multiple regression allowed the analysis to isolate the unique contribution of each predictor. It showed that light pollution increased richness and abundance even when other variables were held constant. It also showed that impervious surface had the strongest negative effect on both metrics. Noise and traffic played smaller roles, and their effects became clearer only after outliers were removed. Without multiple regression, these patterns would have been hidden by the way the variables overlapped in the field.

The results of this study show that urban structure plays a major role in shaping bird communities in Manhattan, Kansas. Both regression models were significant, which means the environmental variables we measured were able to explain a meaningful amount of variation in species richness and abundance. The strongest patterns came from light pollution and impervious surfaces. Light pollution consistently predicted higher richness and abundance, while impervious surfaces predicted lower values for both. These patterns remained stable even after removing outliers, which suggests that they reflect real ecological relationships rather than noise in the dataset.

The positive effect of light pollution may seem surprising at first, especially because many studies describe negative impacts of artificial light at night. Our results make sense when viewed through the lens of urban ecology. Artificial light can attract insects, extend foraging time, and create conditions that benefit generalist species that already tolerate human disturbance (citation?). Birds such as robins, starlings, and finches often remain active longer in lit areas and may gather near streetlights or parking lots where food is easier to find. Light pollution can also draw migrating birds toward illuminated areas, which increases the number of individuals passing through or stopping in bright locations (citation?). These patterns help explain why light showed a positive relationship with both richness and abundance once the effects of pavement, noise, and traffic were removed.

Impervious surface percentage showed the strongest negative effect in both models. This result aligns with a large body of research showing that pavement reduces habitat quality. Areas with high impervious cover have fewer trees, shrubs, and natural ground cover. They also offer fewer nesting sites and less food. As a result, only a small number of highly urban tolerant species tend to persist in these environments. Our findings support this idea, since the most heavily paved site had the lowest richness and abundance. The negative effect of impervious surfaces remained strong even after controlling for light, noise, and traffic, which shows that habitat structure is a central driver of bird community patterns in this landscape.

Noise pollution showed a weaker but still meaningful negative effect on species richness once outliers were removed. This suggests that noise may independently reduce the number of species present at a site. Noise can interfere with communication, which affects territory defense, mate attraction, and predator detection. Species with low frequency songs are especially vulnerable because their calls overlap with the frequencies produced by traffic and other human activities. Some species adjust their songs in noisy environments, but many simply avoid these areas. The negative effect of noise in our model supports the idea that acoustic disturbance can act as a filter that removes sensitive species from the community.

Traffic volume showed a small negative trend in both models, but it did not reach statistical significance. This pattern suggests that traffic may influence birds indirectly through noise or habitat fragmentation rather than through traffic volume alone. It is also possible that our traffic counts did not capture enough variation to detect a clear effect. The sampling periods were short, and traffic patterns can shift quickly depending on time of day or day of the week. A longer sampling window or automated counters might reveal a stronger relationship.

There are several limitations to consider when interpreting these results. Noise measurements were collected using a phone app rather than professional equipment, and wind gusts occasionally increased the recorded decibel levels. This may have added extra variation to the noise data. Bird counts were also conservative to avoid double counting individuals. This approach reduces the risk of overestimating abundance but may underestimate the true number of birds present. Despite these limitations, the models showed clear and consistent patterns that match ecological expectations.

Overall, the results highlight the importance of habitat structure in urban environments. Impervious surfaces had the strongest negative effect on both richness and abundance, which reinforces the idea that vegetation and natural cover are essential for supporting diverse bird communities. Light pollution had a positive effect, which reflects the behavior of generalist species that thrive in disturbed environments. Noise and traffic played smaller roles, but noise still showed a meaningful negative effect once outliers were removed. Together, these findings show that urban stressors do not act in isolation. Instead, they interact to shape the composition and size of bird communities across the city.

## Conclusion

This study shows that the structure of the urban environment has a real influence on bird communities in Manhattan, Kansas. Light pollution and impervious surfaces stood out as the strongest predictors in both models. Light pollution increased the number of species and individuals once the other variables were accounted for, while impervious surfaces consistently reduced them. Noise had a smaller but still meaningful negative effect after outliers were removed, and traffic showed only a slight trend that never became a clear independent factor.

These patterns make sense when viewed in the context of the four sites. Areas with more pavement had fewer places for birds to feed, perch, or nest, while areas with more natural cover supported more species. Light pollution likely attracted generalist birds that are already comfortable in disturbed environments and may have extended their foraging time. Noise and traffic did not show strong effects on their own, but they may still influence birds indirectly through communication interference or changes in habitat quality.

Overall, the results suggest that the way a city is built shapes the bird communities that live in it. Impervious surfaces had the strongest negative impact, which highlights the importance of preserving vegetation and natural cover within urban areas. Light pollution had a positive effect in this study, but that pattern likely reflects the behavior of a few tolerant species rather than a benefit for birds as a whole. Understanding how these factors interact can help guide future planning decisions and improve habitat conditions for both resident and migratory birds.

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