Bird Diversity Trends Across Urban and Non-Urban Habitats: A Long-Term Analysis Controlling for Survey Methodology

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Introduction

Urbanization affects bird diversity, influencing species richness and abundance across different habitats (urban, desert, riparian, agricultural). This study uses long-term CAP LTER data to assess how urbanization and environmental factors shape bird populations. The data at hand comes from two survey strategies:

- ESCA: Broad regional sampling across diverse habitats.
- PASS: Focused surveys within specific urban neighborhoods.

Since survey strategy and habitat type are distinct, this study controls for sample size differences to ensure accurate habitat comparisons. The key research questions addressed are:

1. **How has bird species diversity changed in urban vs. non-urban habitats over time?**
2. **What environmental factors (e.g., temperature, precipitation, vegetation) influence bird diversity trends in the CAP LTER region?**

Findings will inform conservation, urban planning, and habitat management to support biodiversity.

Methods

Data Cleaning & Preprocessing

Since survey strategy (site type) and habitat type (urban, desert, riparian, agricultural) are distinct, data were cleaned to allow valid habitat-based comparisons. Incomplete records were removed, and datasets were merged using `survey_id` and `site_code`, ensuring that sample size differences between ESCA and PASS were accounted for. Species abundance and richness were standardized to control for unequal sampling effort. This set up the right foundation to get started with our analysis, and ensure a seamless journey towards addressing the research questions at hand!

Statistical Analysis

- ANOVA was used to compare species richness among habitats, and Shapiro-Wilk and Levene's tests confirmed normality and variance assumptions.
- Linear regression tested long-term bird diversity trends. Assumption checks were done through residual and QQ plots.
- Statistical controls inclusion were deployed to account for sample size differences between ESCA and PASS.

Future Analysis & Machine Learning

- Multiple regression models will be employed to determine the impact of temperature, precipitation, and vegetation on bird diversity.
- Mixed-effects models can also be employed in order to adjust for site heterogeneity.
- Machine learning algorithms Random Forest and Gradient Boosting will be employed in predictive modeling, potentially utilizing ASU's high-performance computing cluster for big-scale computation. This will help us dive deeper!

Tools & Packages

Analyses were conducted in R using `dplyr` and `tidyr` for preprocessing, `stats` for ANOVA and regression, `lme4` for mixed models, and `ggplot2` for visualization. Future machine learning models will use `randomForest`, and `xgboost`.

Acknowledgments

- Data Source: **CAP LTER Bird Monitoring Dataset**
- Tools Used: **R (ggplot2, dplyr, readr)**
- **Dr. Jeffrey Brown** for Guidance & Mentorship.

Results

Bird Species Diversity Over Time (Figure 1)

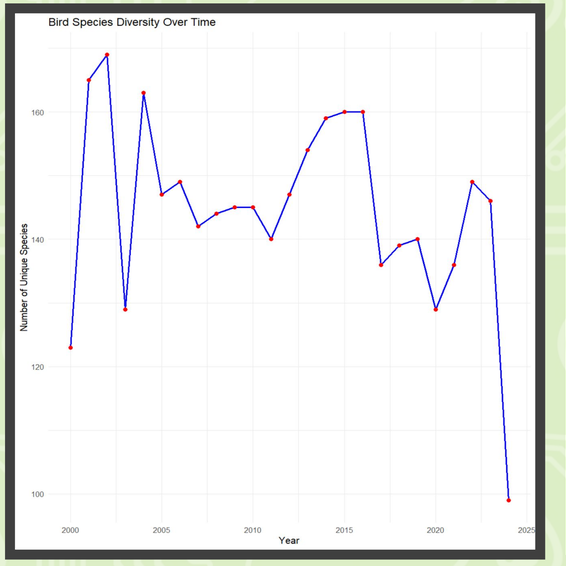
- Species diversity fluctuated over the years, with both drops and rises. There is a non-significant but weak decline in species diversity ($R^2 = 0.12$, $p = 0.07$). This suggests that time is less influential on species richness compared to factors such as urbanization, climate change, or habitat destruction.
- Abrupt declines and spikes are observed, which may reflect local disturbances or environmental changes temporarily influencing diversity.

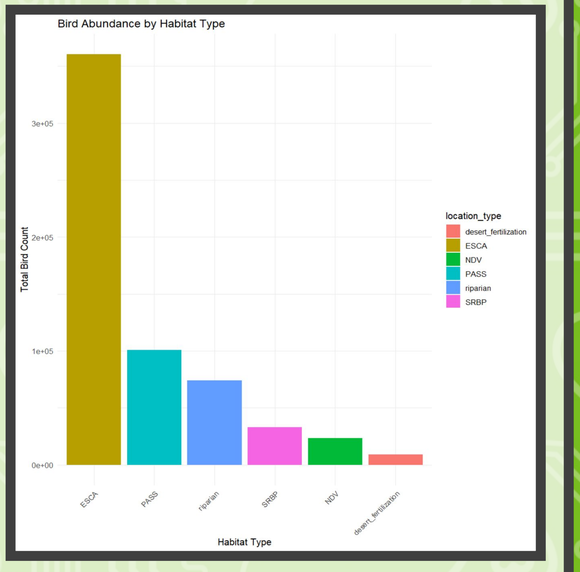
Bird Abundance by Habitat Type (Figure 2)

- ESCA sites contain a much higher quantity of birds due to the expanded sampling over numerous sites.
- PASS sites that are sampling within residential environments contain a lower total amount than ESCA but higher than single habitat categories.
- Riparian habitats contain richer bird populations compared to other singular habitats, with expected higher richness with more availability of water and cover vegetation, creating improved habitation conditions.
- Sample size differences between PASS and ESCA were balanced in order to enable comparisons based on valid habitat, rather than survey-based, and of course this is all computed.

Key Takeaways

Urban environments (PASS) have lower species richness but still have high numbers of birds, possibly due to resource concentration (e.g., bird feeders, waste food). Riparian vegetation has higher species richness, further highlighting the importance of vegetation cover and water as drivers of bird Future analysis needs to employ multiple regression models in order to test the effect of temperature, rain, and vegetation on trends while controlling for survey procedure.





Discussion & Conclusion

This study provides valuable insight into how bird diversity is influenced by habitat type, urbanization, and environmental change, with variation in survey methods (ESCA vs. PASS) accounted for. Sample size differences are overcome, and findings are more representative of habitat-specific trends than survey-related biases. The weak but discernible trend of decreasing species richness over time underlines the need for focused conservation efforts to offset biodiversity loss in urbanizing regions. Urban locations had lower species richness but high bird abundance, perhaps due to resource convergence, and held their maximum species diversity in riparian locations, emphasizing water availability and cover vegetation.

Urbanization and fragmentation of habitats significantly alter species ranges, which must be conserved to preserve biodiversity. Urbanization increases the extent of green areas, which provide nesting and foraging habitats, while habitat connectivity enhancement can reduce fragmentation effects and enable species movement. Restoration of desert and riparian habitats also improves the resilience of ecosystems and reverses the loss of biodiversity caused by climate change. Such actions are imperative to preserve the health of bird populations with rising human development.

Future research will include climate data such as temperature and precipitation to assess long-term environmental impacts while maximizing habitat-based models. Machine learning models such as Random Forest and Gradient Boosting will be used to improve predictive biodiversity modeling, with the potential to utilize ASU's high-performance computing cluster for large-scale analysis. Results of this research can be applied directly to urban planning, conservation policy, and restoration of habitats to ensure evidence-based approaches to the conservation of bird diversity in both urban and non-urban areas.