Birds of a feather: a story of urban and exurban avian population biology

Jason Walker

Arizona State University, School of Life Sciences

Jasonwalker@asu.edu

INTRODUCTION

Urbanization is a unique ecological event which is dominated by landuse transformation typically across expansive extents. This consequently leads to land cover conversion, which can be the dominant process affecting higher level trophic community structure (Hoestler 1999). Birds can utilize this changing landscape either directly through herbivory or indirectly through predation. But how does this anthropogenically altered system affect where specific types of birds will be. Typically, researchers find that urban areas tend to harbor an avian community structure in which only a few species increase in density relative to the surrounding exurban areas creating distinct differences in community diversity between these two landscapes (Degraaf and Wentworth 1981, Blair 1996). However, some have concluded that delineating heavily human-dominated ecosystems into urban and exurban is virtually meaningless from an ecological standpoint (Engels and Sexton 1994), unless a wholesale landuse transformation occurs, such as forest clearcutting (Miller et al. 2001). Spatial analysis is needed in order to quantitatively address these issues. Specifically, interpolation has been a useful approach to understanding animal population dynamics (Pfieffer and Hugh-Jones 2002, Jiguet et al. 2002, Rempel and Kushneriuk 2003).

METHODS

Data Acquisition

Bird count inventories were obtained from Central Arizona-Phoenix Long Term Ecological Research Project (CAP LTER), which occupies 6,400 km² including the Phoenix metropolitan, accompanying agricultural lands and Sonoran Desert remnants. Forty sites (fig. 1) were randomly subsampled from an already established sampling design (Hope et al. 2003), in which 204 sites were established using a dual-density tessellation-stratified procedure in order to maximize points in the urban landscape. Since Fall 2002, seasonal bird counts have been conducted at these 40 sites. For this analysis, counts were aggregated across 8 seasons, occupying 2 full calendar years in order to maximize numerical robustness for model creation.

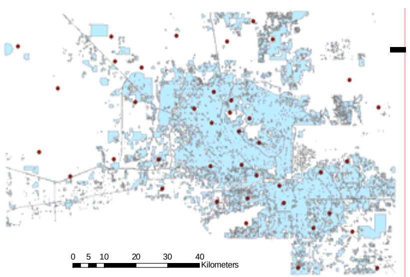

Figure 1. Urban extent of the Phoenix metropolitan (blue) and 40 sample points where seasonal bird counts were taken.

Analysis

Most geostatisical techniques supply optimal estimations only fulfill the assumption of statistical normal distribution (Cressie 1993). Highly skewed data can lead to very broad variogram variance and thus may bias the spatial autocorrelation. I evaluated these variables for normality using the standardized coefficients of skewness and kurtosis; where the resulting z values were compared against the t-value deemed appropriate for $\alpha=0.05$. The absolute values for z_1 for all species, and z_2 for Phainopepla and Rock Dove, exceeded the selected value of t; and thus, a significant deviation from normality was confirmed. A Box-Cox transformation indicated the most effective transformation would for all species would be a power law transformation of ¼. However, this transformation did not lead to results satisfying nomality.

ABSTRACT

The objective of this paper is to quantify the population distribution of 3 unique avian species using point count data within central Arizona's Sonoran Desert, which encompasses the Phoenix metropolitan area. Bird count data were collected at 40 locations throughout the study region at 8 different times corresponding with the seasons for two years. Three common and ecologically unique species were then selected out of this dataset to highlight the spatial patterns of how different species utilize the landscape as a whole. Two species were chosen to highlight the extremes of avian population segregation among urban and exurban land uses, rock dove (*Columba livia*) and Phainopepla (*Phainopepla nitens*), respectively. Experience has suggested that some native species penetrate the urban boundary and utilize its resources. Cactus wren (*Campylorhynchus brunneicapillus*) was used as an example of a native bird species that tends to encroach into the urban environment. Population probability maps were created using the geostatistical interpolation method of indicator kriging. This method shows promise for creating heuristic population maps for these species.

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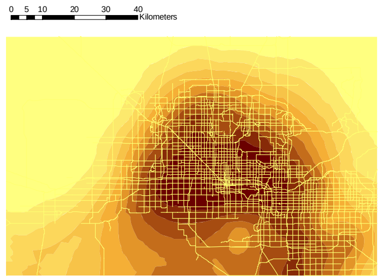
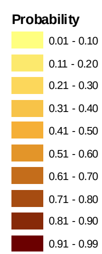


Fig. 2 (a) Rock Dove: the flagship urban species

Indicator Kriging

The strongly positive skewing characteristics of these bird count data are not appropriate for more common interpolation techniques. Indicator kriging, however, does not assume normal distribution. Rather, it builds the cumulative distribution function at each point based on the behavior and correlation structure of indicator transformed data point in the neighborhood. This is accomplished through a series of threshold values between the smallest and largest data values which are used to create an estimation of the cumulative distribution function. For each bird species, the cumulative distribution function was calculated as the median. Data were then converted to a binary system in which data above the median were recorded as 0 and those below are 1. The indicator data were then ordinary kriged using the variogram models to estimate the probability that a given point is above or below that defined threshold value.



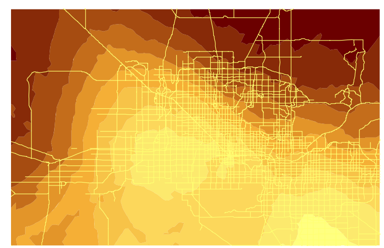


Fig. 2 (b) Cactus wren: a native species that encroaches into the city

DISCUSSION

Interpolation of bird count data across the central Arizona Sonoran desert and related Phoenix metropolitan shows striking trends in avian population distribution. The rock dove is a common species for the urban environment and that is especially clear with abundances in the boundary of the city at elevated levels and a clear and sharp decline of probability in the outlining desert regions. The opposite is true for the Phainopepla, with very strong probability values in the desert with an even sharper gradient into the city. The cactus wren is an interesting intermediary. Indicator kriging suggests that this species has a much broader gradient from exurban to urban, indicating that the wren is more able to penetrate the urban ecosystem and utilize it much more effectively than Phainopepla. However, this native species does tend to occupy the exurban areas surrounding the Phoenix metropolitan with greater abundance than the city.

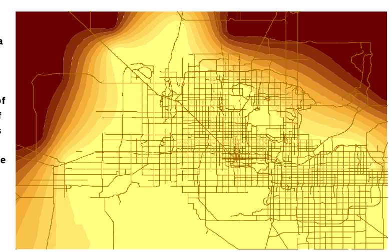


Fig. 2 (c) Phainopepla: a native species with a clear preference for relatively unaltered desert

Figure 2. Probability maps from indicator kriging suggesting the likelihood that a given location will exceed the median of the sample. Note: scale is same as Figure 1.

RESULTS

Interpolated values created with indicator kriging are presented as a probability map in Figure 2 (a-c). In order to interpret interpolation it is important to understand the deviation of the model from the measured values. Validation and cross validation is a common method to optimize model variograms to experimental variograms (Johnston et al. 2001) and was conducted on these data (summarized in Table 1). Cross validation was accomplished by removing a single data point and then predicting the associated value, and then this procedure was continued for all data points. Predicted values are compared with actual values in order to assess the strength of the model. Validation was accomplished by equally and randomly splitting the into 2 populations: one as a training set in order to develop the autocorrelation models used in the prediction, the other as a test set to validate the model.

	Validation			Cross validation		
	Phainopepla	Cactus wren	Rock Dove	Phainopepla	Cactus wren	Rock Dove
Mean probability error	-0.14	0.12	0.10	-0.04	-0.05	0.02
Root mean square probability error	0.36	0.39	0.43	0.28	0.46	0.49
Average standard error	0.22	0.48	0.51	0.21	0.50	0.50
Standardized mean probability error	-0.59	0.25	0.19	-0.38	-0.08	0.03
Standardized root mean square probability error	1.58	0.82	0.85	0.94	0.93	0.99

Table 1. Model validation and cross validation values.

The differences between estimated and measured values are described with the following statistical measures (described in Johnston et al. 2001): 1) mean prediction error (MPE), 2) root mean square prediction error (RMSPE); and 3) average standard error (ASE), standardized mean prediction error (SMPE), and 4) standardized root mean square prediction error (SRMSPE). MPE is the average value of the differences between measured and estimated values, describing the over- or underestimation tendencies of the estimation model with a perfect fit equal to 0. RMSPE is calculated by squaring all the errors, taking the average of the squared errors, and finding the square root of the average. It should be in close proximity to the average standard error, which is calculated as the square root of the sum of the prediction standard error divided by *n*. SMPE and SRMPE are equal to there respective counterparts abovementioned and standardized by *n*. For good model fit, SMPE should be near 0 and SRMSPE should near 1.

Analysis of these values indicates an strong model fit with indicator kriging. The statistical measures assessing the predictability of the experimental models created by indicator kriging indicate an overall robustness in predicting population abundance of these three common species with in CAP LTER study area. Cross validation roughly presented more favorable conditions than the validation model. Phainopepla model appears to have the worst predictability of all 3 species indicated by a larger differential between RMSPE and ASE, and relatively high SMPE and SRMSPE.

CONCLUSIONS

Urbanization has clear impacts on the population distribution of particular native and exotic species. This process creates a new dynamic ecosystem that has the opportunity to greatly affect avian community composition. There clearly appear to be bird species that are ecosystem specialists in both extremes of the urban-exurban gradient. There also appear to be native species that are able to encroach and make a living in the urban ecosystem. However, it seems that these species are more partial to their native habitat than to these constructed environments. This is another example of how directly humans can impact ecological community composition. Assessing these types of analyses has always been difficult as many population data are highly skewed with many random points having no observations and other points potentially having many observations. Indicator kriging offers an interesting alternative to more common kriging methods as there is no assumption of normality. This study has shown that this process has the potential a robust and statistically significant experimental model for interpolation of avian population counts.

LITERATURE

Blair, R. B. 1996. Land-use and avian species diversity along an urban gradient. Ecological Applications **6**:506-519.
Cressie, N. A. C. 1993. Statistics for spatial data, 1 edition. John Wiley & Sons, inc., NYC.
DeGraaf, R. M., and J. M. Wentworth. 1981. Urban bird communities and habitats in New England. Pages 396-412 *in* North American Wildlife Conference, Washington, DC.
Hostetler, M. 1997. Scale, birds, and human decisions: a potential for integrative research in urban ecosystems. Landscape and Urban Planning **45**:15-19.
Jiguet, F., R. Julliard, S. Conde, M. Weltz, D. Couvet, and D. Richard. 2002. Combining biodiversity, land cover and land use surveys: an exploratory study baed on the French Breeding Bird Survey. EUR Report 20521 EN, European Commision, Ispra, Italy.
Johnston, K., J. M. Ver Hoef, K. Krivoruchko, and N. Lucas. 2001. Using ArcGIS Geostatistical Analyst. ESRI.
Matheron, G. 1971. The Theoy of Regionalized Variables and its Applications. Paris School of Mines, Fontainebleau.
Pfieffer, D. U., and M. Hugh-Jones. 2002. Geographical information systems as a tool in epidemiological assessment and wildlife disease managment. Rev. sci. tech. Off. int. Epiz. **21**:91-102.
Rempel, R. S., and R. S. Kushneriuk. 2003. The inluence of sampling scheme and interpolation method on the power to detect spatial effects of forest birds in Ontario (Canada). Landscape Ecology **18**:741-757.
Tobler, W. 1970. A computer movie simulating urban growth in the Detroit region. Economic Geography **46**:234-240.
Webster, R., and M. A. Oliver. 2001. Geostatistics for Environmental Scientists. John Wiley & Sons, Ltd., Chichester, New York, Weinheim, Brisbane, Singapore, Toronto.

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