EFFECTS OF SOCIOECONOMICS ON EUROPEAN

STARLING (*STURNUS VULGARIS*) ABUNDANCE

IN BALTIMORE, MARYLAND

A Thesis

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the Faculty of the Graduate School

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Master of Science

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

EFFECT OF SOCIOECONOMICS ON EUROPEAN

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a candidate for the degree of master of science,

and hereby certify that, in their opinion, it is worthy of acceptance.

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EFFECTS OF SOCIOECONOMICS ON EUROPEAN STARLING (*STURNUS VULGARIS*) ABUNDANCE IN BALTIMORE, MARYLAND

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ABSTRACT

This study predicted avian species using the social area analysis approach, and census tract block group variables. By using European Starlings (*Sturnus vulgaris*) as a focal species, I wished to determine what socioeconomic variables best predicted their abundance in Baltimore City, Maryland. During May through June 2005 – 2007, birds were counted at 132 bird census points in Baltimore City. Data was gathered from the 2000 United States census tract block groups that contained these bird census points. Socioeconomic variables from the census tract block groups were used in a principal components analysis (PCA) to reduce the number of correlated variables into a smaller number of uncorrelated variables. Regression was used to predict the probability of detection for starling abundance within those census tract block groups. The regression revealed a very complicated relationship between percent of the population that is black, with a bachelor's degree or higher, families with only a female in the household and children, and median year housing unit built. These variables were the best predictors of starling abundance in residential census tract block groups. Future research can apply this principle to other species of birds as well, to create a uniform method of predicting avian species in cities that can be collated and compared among other metropolitan areas.

Introduction

Humans have become the dominant force in the world environment, changing the landscape to suit their needs (Turner *et al.* 1993). To house earths growing 6.8 billion human population, millions of acres of land have been converted into highly altered environments (Kretser *et al.* 2008). Human impact is apparent in all ecosystems, some areas represented by minimal landscape change and others with complete alterations of the natural environment such as urbanization (Dow 2000).

Urbanization is generally defined as the movement of people from rural areas to places with extensive and dramatic land use change (Walker *et al.* 2008). During the presence of urbanization, homogeneous environments are broken up into a serious of vegetation patches that exist in a matrix of human dominated landscapes (Dickman 1987). The population of urban areas is expected to increase from 49% at present to 61% in 2030, understanding this process and its effect on the environment could never be more pressing (Melles 2005; Walker *et al.* 2008).

Research in urban areas is focused among the social and biophysical environment, where the crossing of social, biological and historical causes and effects shape the urban environment (Dow 2000). Unfortunately research in urban areas has only recently attracted the attention of biologists, however present data shows that urbanization modifies areas similarly across large geographical regions (Clergeau *et al.* 1998). The ongoing and historical impact of this change, which exists in various levels of intensive and numerous forms of micromanagement, make the urban environment, especially cities, quite novel and unique (Dow 2000).

Most urban ecology research focuses on what is called the "gradient approach." Kinzig *et al*. (2005) describes this as focusing strictly on the density of the human population and the distance to the urban center, thereby ignoring and treating the characteristics of the human population as unimportant. Research focusing on this approach is abundant in the literature (Blair 1996; Peach *et al.* 2008; McCleery 2009). However, changing this approach by adding characteristics of the human population is likely to improve results in future projects (Collins *et al.* 2000; Kinzig *et al.* 2005).

As a result of this, a new standard for urban studies can be set by acknowledging the significance of human preferences, desires, and financial resources in the landscape and how this human force shapes the landscape so a variety of the populations needs and desires are achieved (Kinzig *et al.* 2005; Grove *et al.* 2006). Human influences on the environment are strong and diverse, so much that urban ecosystems are considered a built environment with environmental processes almost seeming engineered (Dow 2000).

Urban inhabitant's needs are attained by certain activities, and these activities can have an obvious or subtle human effect on the urban ecosystem (McDonnell and Pickett 1997). An obvious effect would be building a parking lot, a skyscraper, or roads (Dow 2000). These activities and actions directly affect the environment, by changing an area to reflect the needs of the surrounding inhabitants. Subtle effects are hard to measure, and can include time lags, historical effects, indirect effects and their subsequent environmental interactions, and biological legacies (McDonnell and Pickett 1997). These effects differ over an entire city, and are managed on a small scale by a household, and on a larger scale by the federal government (Dow 2000). Inconsistencies in air quality, storm water management, and state and federal spending occur and need to be considered when examining the urban landscape.

Socioeconomic status and environmental variables in cities

As more and more people migrate to urban areas and new research and interest in urban environment develops and increases, attention is being paid to why urban green space and, specifically urban tree cover, differs from neighborhood to neighborhood. Heynen *et al*. (2006) points out that the urban forest is an extension and result of "past and present structural processes inherent in the urban political economy, such as income inequality, uneven property ownership, and increased marketization of nature". Even with our indiscriminate system of government, the distribution of planted vegetation on public lands such as along streets and in parks only makes up for a fraction of the vegetation in the urban area (Heynen *et al.* 2006). Private lands that make up the vast majority of urban space are not included in this area, and thus the vegetation of these areas is left up to the individual owner (Heynen *et al.* 2006). Unfortunately this leaves poor urban residents who cannot afford to plant and maintain trees without the benefits of having a healthy urban ecosystem (Heynen *et al.* 2006). To understand vegetation dynamics and distribution in a modern day metropolis, socioeconomic status needs to incorporated into urban ecology (Grove *et al.* 2006; Heynen *et al.* 2006).

Social scientists examine urban areas with a tool called social area analysis. Developed in the 1950's, this method distinguishes and identifies different neighborhoods (census tracts block groups) analyzing characteristics of the human population (Maloney and Auffrey 2004). These characteristics are typically government data, such as the census, or other information gathered in a unbiased and uniform way. The goal of social area analysis is to "describe the uniformities and broad regularities observed in the characteristics of the urban population" (Shevky and Williams 1949). Social characteristics of the urban population follow wide patterns, and the variations that do occur in the social characteristics are ordered and calculable (Maloney and Auffrey 2004). Social area analysis allows researchers to discern patterns in cities and classify neighborhoods according to categories, which allows for the collation of studies between cities (Maloney and Auffrey 2004).

Hope *et al.* (2003) used a social areas analysis approach to determine if plant diversity reflected social, economic and cultural influences. By looking at a combination of biotic, abiotic and human related variables, they wanted to see if there were any site by site variations in the richness of perennial plants. They found the best predictor of vegetation variation in urban sites was medium family income i.e. the more money was made the higher the vegetation diversity. They termed this the "luxury effect". Building on this, Martin *et al.* (2004) included the vegetation in neighborhood parks as well as individual neighborhoods in Phoenix, AZ. They found that not only did higher medium family income predict vegetation abundance, but that native species were more represented in more affluent neighborhoods. An astounding 87% of neighborhood vegetation richness could be explained by medium family income.

Other research has shown that housing age, as well as socioeconomic status, is linked to plant density. Grove *et al*. (2006) examined a variety of factors in Baltimore City and identified age of housing as a key indicator of plants distribution and cover on public and private lands.

Urban bird studies and socioeconomic data

Birds are an excellent indicator of environmental health (Savard *et al.* 2000). Being highly visible and very sensitive to changes in the environment, they offer the researcher a very real and observable urban creature to study (Savard *et al.* 2000). Like other animals, birds respond to the distribution and diversity of vegetation, as well as changes in heterogeneity of their landscape (Donnelly and Marzluff 2004; Melles 2005). Depending on the species, landscape, and the time period, the scale at which this takes place can vary enormously.

In large cities, local habitat features (site level) such as neighborhoods are more important than landscape features (regional levels) in makeup of the urban bird community (Clergeau *et al.* 1998). The United States Census offers a perfect sample of site level socioeconomic features. The questions asked and subsequent data collected in the census gives information on the economic, social, and racial make up of the census track block group and thus neighborhood. Urban ecologists use this data with social area analysis to examine the bird community in cities and look for patterns of diversity, abundance and occurrence in urban birds.

Melles (2005) used the Canadian census to answer her question of whether socioeconomic factors influence the abundance and diversity of birds in the city of Vancouver, British Columbia. She found that native avian diversity and abundance was positively correlated with census variables high medium family income and having a university degree. Both of these variables represent a higher socioeconomic status.

Working in Chicago, Illinois, Loss *et al*. (2009) examined the correlations between socioeconomic and environmental factors, and avian species richness. By using a multiple regression they found that medium housing age was more correlated with avian species richness than any of the environmental factors. Per capita income was not related to avian species richness, but was important in determining which species of birds were seen during the bird counts. They observed that housing age seemed to summarize a mixture of environmental features in the urban landscape, and that per capita income seemed to represent unknown environmental characteristics. Further, they noted that variables clarifying the link between income level and species richness and occurrence need to be explored.

While the previous studies have explored avian richness, abundance and diversity together with socioeconomics of a population, this study furthers research with several notable differences. First, no study correlating socioeconomic variables and avian species has taken place on the east coast, where cities and towns are much older than the rest of the country. Settled first in the early 1600s, much of the east coast cities were firmly established prior to the revolutionary war. As these cities deteriorate and are revitalized, vegetation communities change from being void of any human manipulation to complete vegetation management and removal (Grove *et al.* 2006). This extensive modification greatly affects the avian community that inhabits these neighborhoods. Second, similar studies include environmental variables as well as socioeconomic variables. This study focuses strictly on socioeconomic variables. Since income level and other measures of socioeconomic variables result in vegetation differences in the landscape, by including both in an analysis the researcher adds unneeded static and error associated with each variable. If one variable is a result of another, why have both as independent variables in an analysis? The mixing of socioeconomic variables and vegetation variables produces results that lead to the diluting and making interpretation of the results more inaccurate and difficult. Third, this study is not using a direct measure for level of income. As Loss *et al.* (2009) discovered, per capita income revealed different results when examining avian richness vs. the specific species of bird seen.

The European Starling (*Sturnus vulgaris*) was introduced into the North America in 1890 and is now common and widespread throughout the United States (Cabe 1993). Originally from Europe, starlings now occur and are the most commonly seen avian species in many North American cities, including Baltimore, Maryland (Nilon *et al.* in press). Being very abundant with populations actually increasing with human disturbance of the landscape, starlings are a commonly studied species for the basic biology of birds. Considered by many localities as pests, research is also conducted to figure out the most efficient way of eradicating them (Cabe 1993).

Study goals and objectives

The goal of this study is to use a social areas analysis approach and use U.S. Census variables to model starling abundance in census tract block groups in Baltimore, Maryland. Using starlings as a focal species, this study will show that the socioeconomic characteristics of the neighborhood can accurately predict avian occurrence and abundance.

My study is part of the Baltimore Ecosystem Study (BES). One goal of BES is to understand how neighborhoods, as well as Baltimore City as a whole, change over time. To understand this process, BES scientists examine the city at different scales. Using the U.S. Census variables as a data source, this study presents a tool to predict starling abundance at the neighborhood scale.

This research is important because as the world gets rapidly more urbanized, and populations and neighborhoods come into greater and greater contact with wildlife, understanding and predicting how this might occur allows urban ecologists to "stay ahead of the curve" and fix a potential issue before it occurs. Social area analysis not only presents a method for predicting starling occurrence and abundance, but also a way of comparing and applying the results to other cities. It is important to note that education level or income level does not mean more or less of a species of bird, but that the indirect factors that come with this socioeconomic information determine avian abundance, composition and diversity. Using socioeconomic information presents a data source to measure avian species occurrence and abundance that is easily obtainable and available for both public and private use.

The objectives of this study are to:

1. Determine European Starling (*Sturnus vulgaris*) occurrence and abundance at bird census points in Baltimore City for the years 2005-2007.

2. Identify census tract block group variables that explain differences among census tract block groups that contain bird census points in Baltimore City.

3. Use selected census tract block group variables to develop models predicting European Starling (*Sturnus vulgaris*) abundance.

Based on previous research on bird abundance and neighborhood socioeconomic status I hypothesize that:

(1) Age of housing will be a key indicator of starling presence and abundance,

(2) Not having a specific income value as a predictor, I will show that education and household makeup are the driving forces behind what birds are seen and what are not

(3) Race will not be a factor in determining the occurrence and abundance of starlings

Methods

Study area

This research is part of the Baltimore Ecosystem Study (BES), a Long Term Ecological Research Project. The BES study area is Baltimore City ($238.5km^2$) located in the state of Maryland. Funded by an endowment from the National Science Foundation, BES seeks to understand how the City of Baltimore functions as an ecosystem and how this changes over time. Baltimore City was founded in 1729 and was the second largest port city along the eastern seaboard. During that last 50 years, the city moved from a manufacturing industry to a service oriented industry. The population has changed drastically dropping from its high in 1950 of 1.2 million people (Burch and Grove 1993) to its current level of 637,000 (U.S. Census Bureau 2008).

The city of Baltimore encompasses 3 ecological zones, the Piedmont plateau, the coastal plain and a freshwater estuary (Nilon *et al.* in press). Encompassing all these zones, the bird points were chosen randomly from a set of urban forest effect model (UFORE) points. The UFORE points are used to model and calculate "the structure, environmental effects, and values of urban forests" (USDA Forest Service 2009). The bird points were then dually stratified by land use, and to appear in residential census tracks. This was done to show a range of socioeconomic differences.

Bird surveys

Point counts were conducted on 132 bird points in Baltimore City. Each point was survey for 5 minutes between the hours of 5:00am and 10:00am by 2 observers. Three surveys were completed during the months of May – August for years 2005 – 2007. Thus, there are a total of 9 counts over 3 years. The direction (north, south, east or west) and the approximate distance of the bird seen or heard was recorded. Birds flying over the survey points (fly through) were also recorded. Surveys were conducted on days without any precipitation. If a survey was being completed and precipitation did start, the survey was canceled and the data was not recorded. For each species, the sum of the birds that were seen, heard, and flew over the survey point were aggregated and used as one number for that count. Each year was considered independent of the year before for statistical purposes.

Focal species

A Bray-Curtis Ordination was used to examine the pattern of the bird points in a space defined by the presence and absence of different species. This type of ordination groups entities (bird points) based on predetermined attributes along axis's to examine variation in the data (Beals 1984). In this case, attributes were defined by the species composition and abundance at each point. I identified species that were correlated with the ordination axes, and defined these species as focal species.

Census variables

In the Baltimore Ecosystem Study, social scientist use social area analysis (Grove and Burch 1997) to explain patterns in Baltimore City. Scientists use census data to gauge the economic, family, and ethnic traits of a neighborhood (Maloney and Auffrey 2004). By using the U.S. census variables, scientists can describe neighborhood characteristics, neighborhood change, and also compare cities to each other using this uniform method (Weiler and Freedman, unpublished; (Maloney and Auffrey 2004). Variables such as these, that measure social and economic factors, are easily obtainable via the U.S. Census and can be easily compared and contrasted with other research using the same variables. I am using this approach to predict and understand the pattern of individual bird species occurrence and abundance.

Census information was gathered from the U.S. Census website (U.S. Census Bureau 2009). The list of variables was chosen to represent ethnic, family and economic status and was selected from an example of socioeconomic variation in Baltimore City. (Table 1).

Because many of the census variables are likely correlated, principal components analysis (PCA) was used to transform a number of possibly correlated variables into a smaller number of uncorrelated indices (Table 2). PCA was chosen over factor analysis because I am making no assumptions about the census variables. Unlike factor analysis, which assumes that certain latent (unseen and immeasurable) factors exist and exert influence on the variables in question, in this study I was strictly interested in variable reduction procedure (O'Rourke *et al.* 2005).

I selected all variables with loadings > 0.5 or < -0.5 on principal components with Eigen value scores >1.0. I used the correlation matrix to select variables that were as uncorrelated as possible (Table 3). The raw data from these selected variables was transformed into a percentage, standardized to have a mean of 0 and a standard deviation of 1. This data was also checked for multicollinearity. These actions were done to create a uniform scale, and make interpretation of the results easier. Six bird points were excluded from the analysis because they did not have census data.

Predicting starling abundance

A multiple regression analysis using the 5 variables chosen from the PCA was used to predict starling occurrence and abundance (Table 2). A Poisson distribution was first attempted as a fit for the data. However, due to the skewness and because the data was zero inflated, a negative binomial distribution ended up fitting the data best. A full factorial regression model was completed first. By running a full factorial model using all the 5 variables in every combination possible, I was able to examine how all of the variables worked together to predict Starling occurrence and abundance. I examined all the interactions and looked for $p \leq 0.05$ significance levels. If the p-values were greater than 0.05, then they were discarded. The goal this is to discard variables that did not interact significantly with other variables, or were not significant by themselves. Once these non-significant variables were discarded, then the model was run once again without the non-significant variables. Again, by doing this I wanted to pinpoint the significant variables for further analysis and eliminated the non-significant variables from further analysis. This analysis will provide the best variable or combination of variables that predict starling occurrence and abundance.

Once the variables are either significant by themselves or in an interaction, they could not be eliminated from the regression model. At this point, the interactions were examined, focusing on the most complicated interaction even though it may not be the most significant. This was done because the most complicated interaction explained the most complicated relationship among the variables.

I then calculated the predicted probability of detection for seeing 1 to 8 starlings based on the census track block group variables in the final multiple regression model. The predicative probability is based on the negative binomial probability of detection $p_0 = 1/(1+\lambda)$, where λ is equal to mean number of starlings in a block group The predicted probability allows the researcher to determine which model is the best at predicting starling occurrence and abundance. The plots were completed to explore what types of neighborhoods starlings are occurring, and in what abundance. Plots were not created randomly; rather variable combinations representing neighborhoods likely to occur in Baltimore City were created. PAWS Statistics 18 was used to run all analysis. The final regression model resulted in a 4-way, 3-way, 2-way and single variable interactions. I created plots of the predicted probability of starlings to better understand and visualize these interactions.

Results

Starling abundance and distribution

Starlings were detected on all but 4 of the 128 points. The mean number of starlings detected across all points was 5.1 with a standard deviation of 4.1. Starlings were also the most detected species of bird during the bird counts (Table 4).

In figure1, bird points with a similar composition of species are grouped together, with larger circles representing more starling occurrences. This is one reason starlings were chosen, because they are associated with the patterns explaining differences in the species composition among the bird points. Due to this, starlings can be used as a species that explains the occurrence and abundance of other avian species that are associated with them in the Bray-Curtis Ordination.

Census variables

The PCA for the census variables resulted in three principal components that accounted for 64% of the variance (Table 2). The first principle component (PC1) explained 40% of the variance and had strong negative loadings percent of black residents (%black), percent families with only a female in the household and children (%fmkds), and percent of households on government public assistance income (%pbass), and a strong positive loading for percent of population with a bachelors degree or higher (%Bach). This can be interpreted as a measure of income level. The second principal component (PC2) explained 13% of the variance and had strong positive loadings for median year housing unit built (agehse) only, and can be interpreted as a measure of neighborhood age. The third principal component (PC3) explained 11% of the variance and had strong positive loadings for percent of Hispanic residents (%hisp) and median year householder moved into unit (mvdte), and can be interpreted as a measure of change in the neighborhood among races. Based on the correlation matrix (Table 3) and the PCA loadings (Table 2), variables %black, %fmkds, %pbass, %Bach, and agehse were retained for further analysis.

Census variables predicting starling abundance

None of the census tract block group variables alone, and one interaction term were significant ($p < 0.05$) under the full factorial model (Table 5). The 4-way interaction was significat ($p = 0.025$) that included percent of the black residents (%black), percent of population with a bachelors degree or higher (%bach), percent of families with only a female in the household and children (%fmkds), and median year housing unit built (agehse) ($p = 0.025$). This interaction encompassed all the variables except percent of households on government public assistance (%pbass). This variable, %pbass, was removed from additional models because it was not significant by itself or with others in an interaction (Table 5).

The second multiple regression model (QIC = 1295.470) resulted in two variables and five interactions that were significant ($p \leq 0.05$) (Table 6). This is the final model because every variable is either significant by itself or in an interaction, and it has a lower QIC than the first model, indicating this model is a better fit for the correlation structure (Garson 2009). Percent with a bachelors degree or higher (%Bach) ($p = 0.001$) and median year housing unit built (agehse) ($p = 0.019$) were both significant on their own. The one significant 2-way interaction was %bach and agehse ($p = 0.016$). The one significant 3-way interactions was %black, %bach, and agehse ($p = 0.030$). Lastly, the 4-way interaction was also significant and included all of the above variables ($p = 0.036$).

Predicted probability

An example of a 4-way interaction is %black, agehse, %Bach, and %fmkids. All these variables work together, and create a predicted probability for starlings. To understand how they work with each other, and because the data is continuous, each variable was broken down into a high (top 30%) or low (bottom 30%) percentage. There are 32 combinations that are needed to evaluate a 4-way interaction.

Variable combinations were chosen that represented neighborhoods in Baltimore City. These combinations were then plotted to show the number of starlings on the x-axis and predicted probability (%) of starlings on the y-axis. Each plot shows a typical neighborhood in Baltimore City and the predicted probability (%) of seeing starlings in that neighborhood..

I will explain one example of a 4-way combination. I selected a typical Baltimore City neighborhood with the 70% (top 30%) or more black residents and where the median year housing unit built (agehse) was in the bottom 30% (older houses). Within these neighborhoods, I am examining the predicted probability of starlings under 4 scenarios: (1) 70% of the resident population with a bachelors degree and higher (H%Bach), and 70% of families with only a female in the household with children (H%fmkds); (2) 30% of the resident population with a bachelors degree or higher (L%Bach), and 30% of families with only a female in the household with children (L%fmkds); (3) H%Bach and L%fmkds; (4) L%Bach and H%fmkds.

The above example reveals the complexity and confusion of trying to evaluate a 4-way interaction. Further, examining a 4-way interaction is extremely difficult and time consuming. Thus I choose to focus on the significant 3, 2 and single variable interactions. Using the top and bottom percentages, predicted probability for seeing 1 to 8 starlings was plotted to further explain and interpret the results.

When plotting the high and low percentages of the variables, I found that some of these combinations do not exist. An example would be in figure 2. Figure 2 is a significant ($p = 0.03$) 3-way interaction and was created because over 60% of Baltimore City residents consider themselves black or African-American (U.S. Census Bureau

2010). There are 4 scenarios to the right of graph, but only 3 scenarios plotted on the graph. This is because there are no neighborhoods in Baltimore City where 70% or more of black residents reside, and of those residents, 70% or more of them have a bachelors degree or higher and are living in older housing (bottom 30%). While 3 of the 4 scenarios did exist, the above scenario, neighborhoods representing H%black * H%Bach * L%agehse, simple does not exist in Baltimore City.

Further examining figure 2, scenario H%black * H%Bach * H%agehse represents neighborhoods at the extreme western part of Baltimore City. They tend to be areas of mixed housing with row homes and single family dwellings. This scenario had the highest predicted probability at 0.25 for seeing 1 starling. For seeing 2 starlings the predicted probability drops down to 0.17 and gradually drop to 0.05 for 8 starlings. This scenario is the best predictor of starling abundance in Baltimore City.

Figure 3 shows a 2-way interaction among the percent of the population with a bachelors degree or higher (%Bach) and percent median year housing unit was built (agehse). This plot explores parts of Baltimore City in terms of education and housing age only. As with figure 2, certain variable combinations did not produce a plot. Out of 4 possible scenarios, only 1 variable combination (L%Bach * L%Agehse) revealed a predicted probability for starlings. This scenario had the highest predicted probability at 0.14 for 1 starling. For seeing 2 starlings the predicted probability drops down to 0.12 and gradually drop to 0.05 for 8 starlings.

Figures 4 and 5 both show a single variable interaction. Figure 4, explores the predicted probability of starlings for education only. Out of the 2 possible scenarios, only high percent with a bachelors degree or higher (H%Bach) produced a predicted probability plot for starlings. Interestingly, this plot is exactly the same as in figure 3. Figure 5, explores the predicted probability for starlings for age of housing only. Out of the 2 possible scenarios, only L%Agehse produced a predicted probability of detection plot for starlings. This series had the highest predicted probability of detection at 0.21 for 1 starling. For seeing 2 starlings the predicted probability of detection drops down to 0.13 and then gradually drops to 0.04 for 8 starlings.

Discussion

The larger question of this project is to understand how well measures of neighborhood age, socioeconomic status, or property management decisions predict bird species abundance and distribution. Specifically I wanted to see how well census tract block group variables predict starling abundance and distribution. I hypothesized that %black would not be significant in the presence of other factors, and age of housing would be a significant predictor for starling abundance. These results indicate a much more complicated relationship than previously thought between the variables and starling distribution and abundance around Baltimore City.

Starling abundance and distribution

We detected Starlings on all but 4 of the 126 points, and starlings were the most detected species at the bird points (Table 4). These results are similar to other avian studies where starlings occurred at a majority of the bird points (Hadidian *et al.* 1997; Clergeau *et al.* 1998; Hosteler and Knowles-Yanez 2003; Melles 2005). Melles (2005) found that starlings occurred on all of the point-count stations (44) across the city of Vancouver between 1997 and 1998. Hadidan *et al*. (1997) counted birds in Washington

D.C., 48 kilometers from Baltimore. Their results showed that starlings occurred at 86% of the survey points. Nilon *et al*. (in press) also reported starlings as the most occurring species at their survey points in Baltimore City.

Census variables predicting starling abundance

This study substantiates previous research in affirming a significant correlation between avian species (in this case, starlings), abundance and distribution in urban areas, and socioeconomic data. Akin to other results, I feel that these census track block group variables are a good measure of the socioeconomic status of the neighborhood. This research, using socioeconomic data to predict starling occurrence in neighborhoods in Baltimore, can be further expand to other avian species and cities.

It is important to note that these results corroborate and differ from previous research. Education level and age of housing variables used in this study have been previously utilized in research examining avian species diversity, abundance, and occurrence (Martin *et al.* 2004; Melles 2005; Loss *et al.* 2009). My results indicate that education level and age of housing are important in predicting starling occurrence and abundance as well; however ethnicity and household makeup also play a major role in where starlings are occurring in Baltimore City. By examining figure 2, we can see the predicted probability of starlings is 0.25, which is at the most complicated relationship. I also reveal that there is a noteworthy difference in the probability of one starling occurring but not two or more. By focusing on just education and housing age, a complex relationship between ethnicity and family status is overlooked.

It's understandable why a researcher would want to pinpoint a single variable or two variables as the most important predictors for an independent variable; it makes interpretation of the data much simpler and easier. However as this study shows, using one variable may be easier and simpler, but incorporating all the variables reveals the truly complex relationship and different results. To alleviate the issues surrounding the use one variable, some researchers group variables into categories e.g. (Grove *et al.* 2006). But by doing this, it negates the initial variable and further confuses the results when they are compared and contrasted with other studies. Furthermore, by creating categories it negates the reason why census information is used in the first place.

These results indicate that 4 variables are important in predicting starling abundance. Trying to predict starling occurrence and abundance at the neighborhood level is more complicated than previously thought. While some variables alone were significant in the model, the 4 variable interaction explained the most complicated reaction, and thus reveals the intricate and multifaceted relationship between the census variables and starling abundance. . The results indicate that although starlings may not be distributed randomly around Baltimore City, they are a generalist species and occur in a variety of neighborhoods. This is in sync with the little known habitat requirements of starlings. These birds seem to occupy every habitat type except very large areas of undisturbed thick forest or woods (Feare 1984).

I found that the percentage of black residents, population with a bachelors degree or higher and families with only a female in the household and children, and median year housing unit built are the best predictors for starling occurrence in a Baltimore City neighborhood. However, determining how these variables interact with each is very difficult. Even though this 4 variable interaction was not plotted, the plots that would have been created would have likely revealed an even larger predicted probability for starling occurrence and abundance than the significant 3, 2, and single variable interactions. By plotting the significant 3, 2, and single interactions, I hoped to breakdown the variables by the highest and lowest percentage and reveal the proportion of each variable plays in predicting starling occurrence.

Although some of the interactions may be more significant than others when examining the parameter estimates (Table 6), the highest probability of starling occurrences (0.25) emerged on the most complicated graph (Figure 2). By using the predicted probability of detection I was able to figure out which model was the best for predicting starling occurrence and abundance. This is where the percentage of black residents, percentage of the population with a bachelor's degree or higher, and medium year structure built (housing age) all come into play. In figure 3, the predicted probability actually goes down when the percentage of black residents in taken out of the interaction. This variable, percentage of black residents, seems to be playing an integral role in determining the predicted probability of starling abundance.

Interestingly, when examining figure 4, I realized it is exactly the same as figure 3. This might have something to do with the level of education and its role in mitigating the relationship between education and age of housing. When age of housing is plotted alone (figure 5), the predicted probability of starlings is much higher than when it is plotted with its interaction with education level. This is likely due to the relationship between vegetation density and diversity and housing age (Grove *et al.* 2006).

Many of the plots seem to vary when it comes to the predicted probability of seeing one starling, but do not vary much in the predicted probability of seeing more 2 or more starlings. It seems that seeing one starling varies, but seeing more than one bird at a time does not vary considerably among all the interactions. This might be due to the fact that the one starling being detected at the bird point may be a fly through. A fly through is when a bird is seen flying by and recorded as such for that bird point. However, this bird might just be moving from one location to another and not occupying that block group and thus neighborhood. For the purposes of this study, a fly through, birds heard, and birds seen stationary were aggregated. However, if only one starling was seen flying threw the area, it may not have occurred in the block group, but for the purpose of our study, it was counted as one bird occurrence at that point and thus within that block group.

This is further supported by the behavior of starlings. Being a very gregarious bird (Cabe 1993), seeing one starling alone may indicate that it does not live in that block group and is just passing through. Another consideration is that starlings become very territorial during the breeding season, which happens to correspond with our field season, and will drive other starlings and birds away from a potential nest area. During this time, starlings are not as social and pairs tend to keep to themselves (Cabe 1993). This could limit the amount of starlings the observer might see during the bird counts. In actuality, there might be many more starlings in the neighborhood than detected, and thus the predicted probability of starlings may be higher than calculated. Further studies can remedy this by isolating the fly threw detection category from regular sightings and detections and only recording birds that are seen stationary and singing. Also, completing counts year round will counteract any error associated with a concentration of the field season being during the summer breeding season.

Management implications and future research

It is already known that birds and other wildlife are not distributed randomly in urban areas (Nilon *et al.* in press), instead wildlife (just like people) focus on characteristics and commonalities of the neighborhood and reside in areas of their liking. Understanding the characteristics of the human population will greatly assist urban wildlife researchers, foresters, and residents when dealing with wildlife issues. Realizing that education level and ethnicity do not directly lead to more or less species of birds, using social area analysis in this type of study allows the researcher to bring into play this indirect relationship and predict the abundance of avian species. Although this study focuses on starlings, expanding this research to other avian species and cities will likely reveal similar results. Using this uniform system and tool to predict what and where species will occur will simplify the life of any urban researcher and greatly add to our knowledge of the urban ecosystem.

Table 1. Census variables used in this study. Boldface indicates variables chosen for further analysis.

Status	*Variable*	*Block group description*
ethnic	**%black**	% Black residents
ethnic	%hisp	% Hispanic residents
family	%25yrs	% residents 25 years of age and older
family	**%Bach**	% of Population with a Bachelors degree or higher
family	**%fmkds**	% Families with only a female in the household and kids
economic	mdincm	Median household income
economic	**%pbass**	% Households on government public income assistance
economic	%owocc	% Housing units occupied by residents
economic	**agehse**	Median year housing unit built
economic	mvdte	Median year householder moved into housing unit
economic	rnt	Median gross rent of housing unit
economic	owoccvl	Median value of owner occupied housing unit

Table 2: Principal components analysis loadings and eigenvalues for census variables. Boldface indicates variables that were chosen for further analysis.

Variable	*PC1*	*PC2*	*PC3*
%black	**-0.583**	0.287	-0.480
%hisp	0.065	0.372	0.603
%25yrs	0.634	-0.148	-0.018
%Bach	**0.846**	0.068	0.138
%fmkds	**-0.751**	0.318	0.147
mdincm	0.864	-0.070	0.114
%pbass	**-0.759**	-0.002	0.170
%owocc	0.641	0.392	-0.370
agehse	0.130	**0.873**	-0.314
mvdte	-0.253	0.365	0.626
rnt	0.630	-0.097	0.038
owoccvl	0.771	0.344	0.166
eigenvalue	4.832	1.530	1.333
% of variance	40.268	12.7	11.1

Table 3. PCA correlation matrix of all the census variables

	%black	%hisp	%25yrs	%Bach	%fmkds	mdincm	%pbass	%owocc	agehse	mvdte	rnt	owoccvl
%black	1	-0.13	-0.373	-0.5	0.422	-0.455	0.401	-0.243	0.26	-0.05	-0.27	-0.355
%hisp	-0.134	1	0.066	0.089	0.062	0.078	0.046	-0.054	0.144	0.153	-0.02	0.179
%25yrs	-0.373	0.066	1	0.434	-0.567	0.415	-0.54	0.278	0.036	-0.18	0.207	0.37
%Bach	-0.5	0.089	0.434	1	-0.517	0.707	-0.573	0.489	0.104	-0.11	0.563	0.684
%fmkds	0.422	0.062	-0.567	-0.517	1	-0.632	0.582	-0.334	0.039	0.35	-0.4	-0.396
mdincm	-0.455	0.078	0.415	0.707	-0.632	1	-0.518	0.459	-0.04	-0.21	0.593	0.775
%pbass	0.401	0.046	-0.54	-0.573	0.582	-0.518	1	-0.51	-0.164	0.179	-0.37	-0.445
%owocc	-0.243	-0.05	0.278	0.489	-0.334	0.459	-0.51	1	0.445	-0.22	0.327	0.484
agehse	0.26	0.144	0.036	0.104	0.039	-0.04	-0.164	0.445	1	0.1	-0.04	0.299
mvdte	-0.054	0.153	-0.179	-0.109	0.35	-0.209	0.179	-0.224	0.1	1	-0.13	-0.015
rnt	-0.266	-0.02	0.207	0.563	-0.396	0.593	-0.367	0.327	-0.037	-0.13	1	0.422
owoccvl	-0.355	0.179	0.37	0.684	-0.396	0.775	-0.445	0.484	0.299	-0.02	0.422	1

Table 4. All species of birds detected on the counts and the number of detections for each species

Species	# of de-tections
European Starling	2266
European House Sparrow	1932
American Robin	1536
Rock Pigeon	1180
Morning Dove	785
Northern Mockingbird	675
Chimney Swift	626
Northern Cardinal	572
Common Grackle	475
Gray Catbird	336
American Crow	206
American Goldfinch	202
Herring Gull	173
Song Sparrow	154
Carolina Wren	124
House Finch	119
Eastern Kingbird	118
Downy Woodpecker	75
Carolina Chickadee	68
Yellow-shafted Flicker	66
House Wren	65
Blue Jay	44
Brown-headed Cowbird	42
Red-bellied Woodpecker	38
Cedar Waxwing	37
Wood Thrush	37
White-breasted Nuthatch	36
Barn Swallow	32
Chipping Sparrow	30
Purple Finch	28
Eastern Towhee	27
Red-eyed Vireo	27
Fish Crow	25
Eastern Wood-Pewee	24
Killdeer	21
Tufted Titmous	20
Indigo Bunting	19
Tree Swallow	14
Great Crested Flycatcher	13
Canada Goose	10
Common Yellowthroat	10
Brown Thrasher	9
Great Blue Heron	8
Ring-billed Gull	8
Eastern Bluebird	7

Acadian Flycatcher	6
Red-winged Blackbird	6
Yellow-billed Cuckoo	5
Baltimore Oriole	4
Ruby-throated Hummingbird	4
Coopers Hawk	3
Great Egret	3
Mallard Duck	3
Ovenbird	3
Rose-breasted Grosbeak	3
Ring-necked Pheasant	3
Scarlet Tanager	3
White-eyed Vireo	3
Chestnut-sided Warbler	2
Double-creasted Cormorant	2
Eastern Phoebe	2
Great Black-backed Gull	2
Red-shouldered Hawk	2
Turkey Vulture	2
American Kestral	1
Black-capped Chickadee	1
Common Nighthawk	1
Hooded Warbler	1
Laughing Gull	1
Osprey	1
Peregrine Falcon	1
Pileated Woodpecker	1
Purple Martin	1
Ruby-crowned Kinglet	1

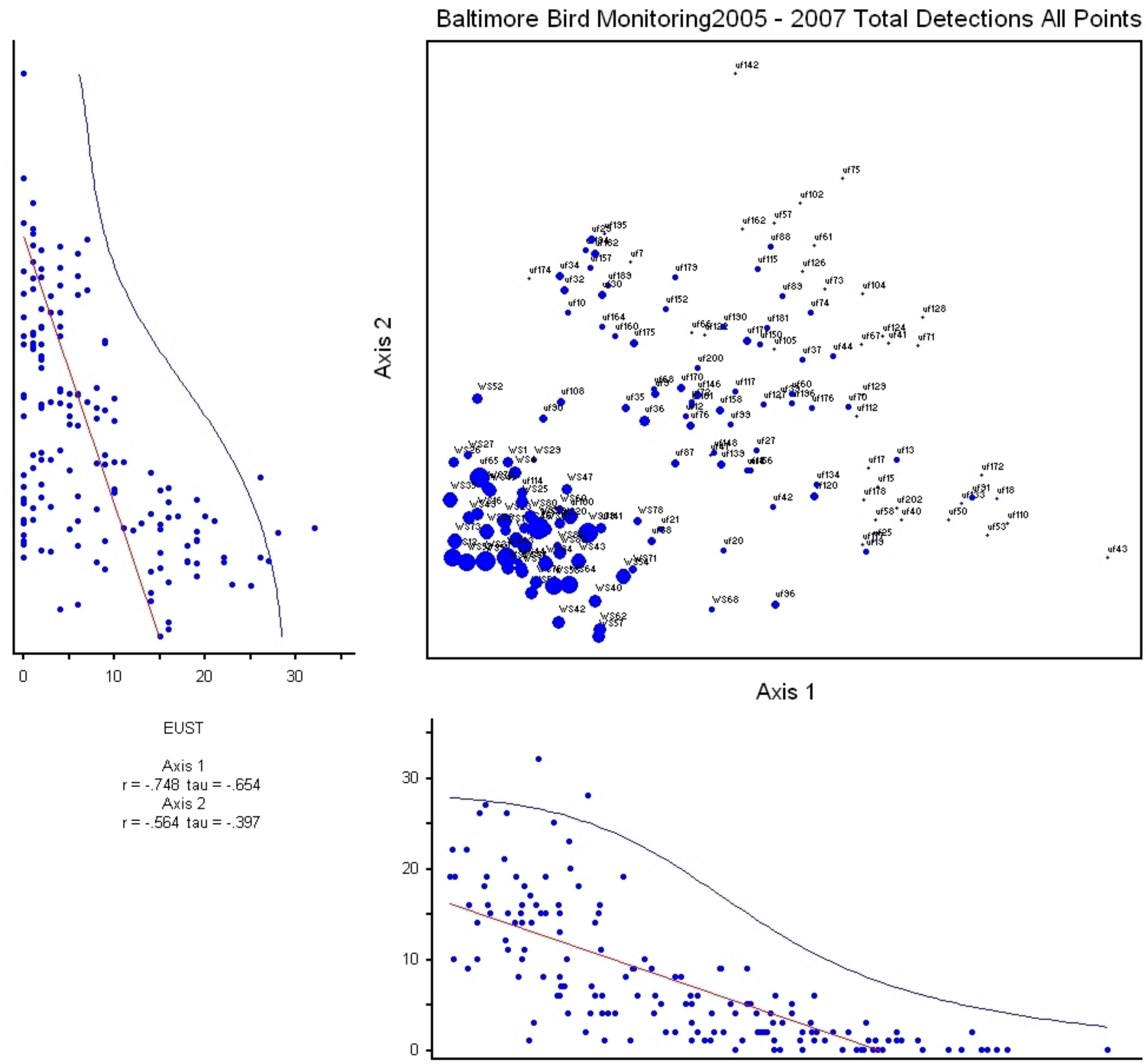

Figure 1. Bray-Curtis Ordination of Baltimore Bird Points. Size of point indicates abundance of Eurpean Starling's (*Sturnus vulgaris*). The line on the graph shows correlations between ordination axes score and European starling abundance. Abundance and ordination axes scores were correlated for the first ordination axis (-0.748) and the second axis (-0.564)

Table 5. First multiple regression model parameters for percentage of black residents, percentage of populatoin with a bachelors degree or higher, percentage of families with only a female in the household and kids, percentage of households on government public income assistance, and medium year housing unit was built. Bold face indicates significance ($p \leq 0.05$)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	1.761	.4779	.825	2.698	13.585	1	.000
%black	1.097	.6846	-.245	2.439	2.567	1	.109
%Bach	-1.191	.7558	-2.673	.290	2.484	1	.115
%fmkds	-.154	.7463	-1.617	1.309	.043	1	.836
%pbass	.125	1.2994	-2.422	2.671	.009	1	.924
Agehse	-.996	4.4303	-9.679	7.687	.051	1	.822
%black * %Bach	.904	1.1127	-1.277	3.085	.660	1	.417
%black * %fmkds	-.554	.6040	-1.738	.630	.841	1	.359
%black * %pbass	1.387	1.8959	-2.329	5.103	.536	1	.464
%black * Agehse	-10.486	6.1023	-22.447	1.474	2.953	1	.086
%Bach * %fmkds	-.496	1.2259	-2.899	1.907	.164	1	.686
%Bach * %pbass	.443	1.3172	-2.139	3.025	.113	1	.737
%Bach * Agehse	7.606	6.9614	-6.038	21.250	1.194	1	.275
%fmkds * %pbass	2.132	1.6113	-1.026	5.290	1.751	1	.186
%fmkds * Agehse	3.371	6.2665	-8.911	15.653	.289	1	.591
%pbass * Agehse	5.442	13.0257	-20.088	30.971	.175	1	.676
%black * %Bach * %fmkds	.768	.8026	-.805	2.341	.916	1	.339
%black * %Bach * %pbass	1.618	2.1006	-2.499	5.735	.593	1	.441
%black * %fmkds * %pbass	-.315	1.7231	-3.692	3.062	.033	1	.855
%black * %Bach * Agehse	-10.826	9.9147	-30.258	8.607	1.192	1	.275
%black * %fmkds * Agehse	1.780	5.1696	-8.352	11.912	.119	1	.731
%black * %pbass * Agehse	-18.654	18.0089	-53.951	16.642	1.073	1	.300
%Bach * %fmkds * %pbass	.953	1.3144	-1.624	3.529	.525	1	.469
%Bach * %fmkds * Agehse	9.810	10.7912	-11.340	30.960	.826	1	.363

%Bach * %pbass * Agehse	-2.742	11.7971	-25.864	20.379	.054	1	.816
%fmkds * %pbass * Age-hse	-8.439	14.5845	-37.024	20.146	.335	1	.563
%black * %Bach * %fmkds * %pbass	2.037	1.4533	-.812	4.885	1.964	1	.161
%black * %Bach * %fmkds * Agehse	-14.513	6.4820	-27.217	-1.808	5.013	1	**.025**
%black * %Bach * %pbass * Agehse	-12.561	18.4696	-48.761	23.639	.463	1	.496
%black * %fmkds * %pbass * Agehse	-3.229	16.2139	-35.008	28.549	.040	1	.842
%Bach * %fmkds * %pbass * Agehse	1.863	10.2661	-18.258	21.984	.033	1	.856
%black * %Bach * %fmkds * %pbass * Agehse	-22.969	12.9470	-48.345	2.406	3.147	1	.076
(Scale)	1						
(Negative binomial)	1.443						

Dependent Variable: EUST_mean

Table 6. Final multiple regression model parameter estimates for for percentage of black residents, percentage of populatoin with a bachelors degree or higher, percentage of families with only a female in the household and kids, and medium year housing unit was built. Bold face indicates significance ($p \leq 0.05$)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	2.131	.2791	1.583	2.678	58.261	1	.000
%black	.353	.3133	-.261	.967	1.267	1	.260
%Bach	-1.440	.4506	-2.323	-.557	10.212	1	**.001**
%fmkds	-.695	.3750	-1.430	.040	3.432	1	.064
Agehse	-5.314	2.2663	-9.756	-.872	5.498	1	**.019**
%black * %Bach	.659	.4044	-.133	1.452	2.657	1	.103
%black * %fmkds	-.198	.3747	-.933	.536	.280	1	.597
%black * Agehse	-2.524	2.7492	-7.912	2.864	.843	1	.359
%Bach * %fmkds	-.571	.4133	-1.381	.239	1.907	1	.167
%Bach * Agehse	8.886	3.7680	1.501	16.271	5.561	1	**.018**
%fmkds * Agehse	5.808	3.0655	-.201	11.816	3.589	1	.058
%black * %Bach * %fmkds	.728	.3722	-.002	1.457	3.821	1	.051
%black * %Bach * Agehse	-7.787	3.5809	-14.806	-.769	4.729	1	**.030**
%black * %fmkds * Agehse	.138	3.1893	-6.113	6.389	.002	1	.966
%Bach * %fmkds * Agehse	3.916	3.4945	-2.933	10.765	1.256	1	.262
%black * %Bach * %fmkds * Agehse	-6.680	3.1828	-12.918	-.442	4.404	1	**.036**
(Scale)	1						
(Negative binomial)	1.534						

Dependent Variable: EUST_mean

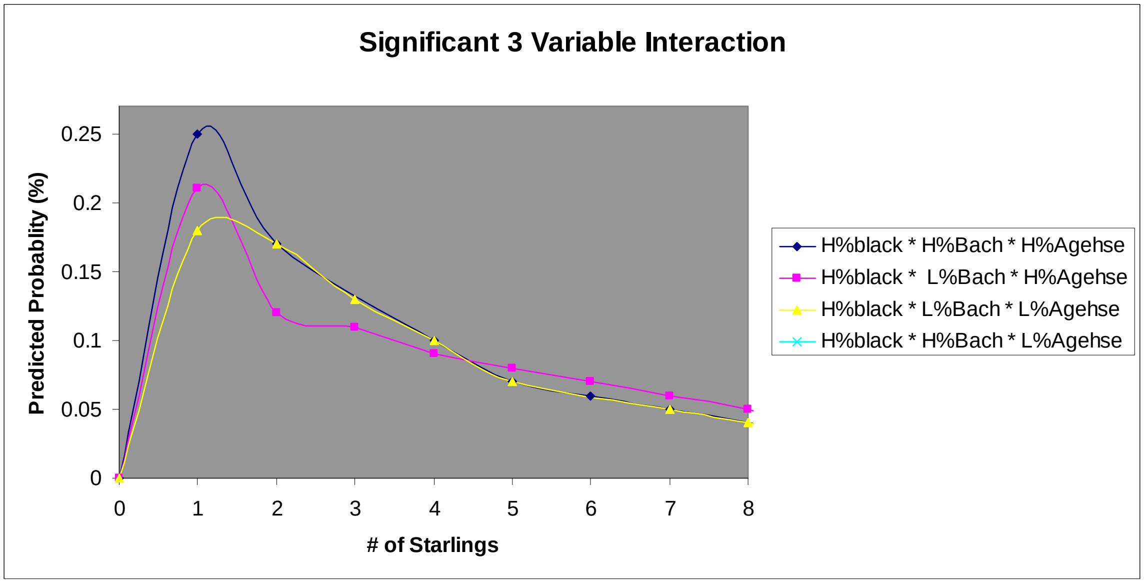

Figure 2. Predicted probability of starling occurrence within neighborhoods that are 70% or more black residents (H%black). Within these areas, the occurrence probabilities are based on a H%Bach and H%Agehse, L%Bach and H%Agehse, L%Bach and L%Agehse, and H%Bach and L%Agehse.

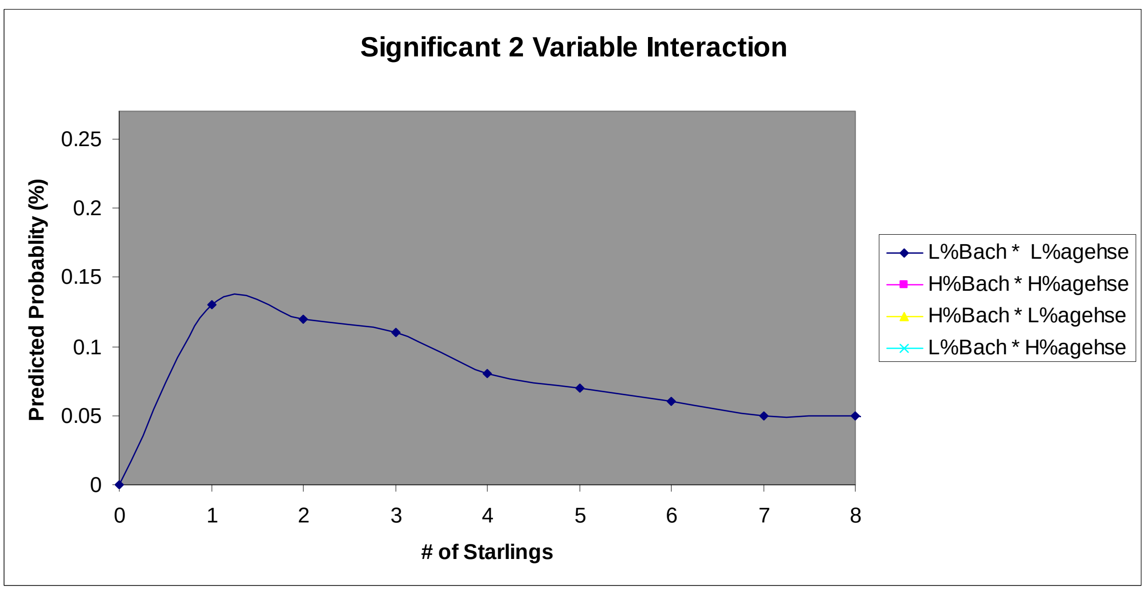

Figure 3. Predicted probability of starling occurrence only focusing on education (%Bach) and age of housing (%agehse).

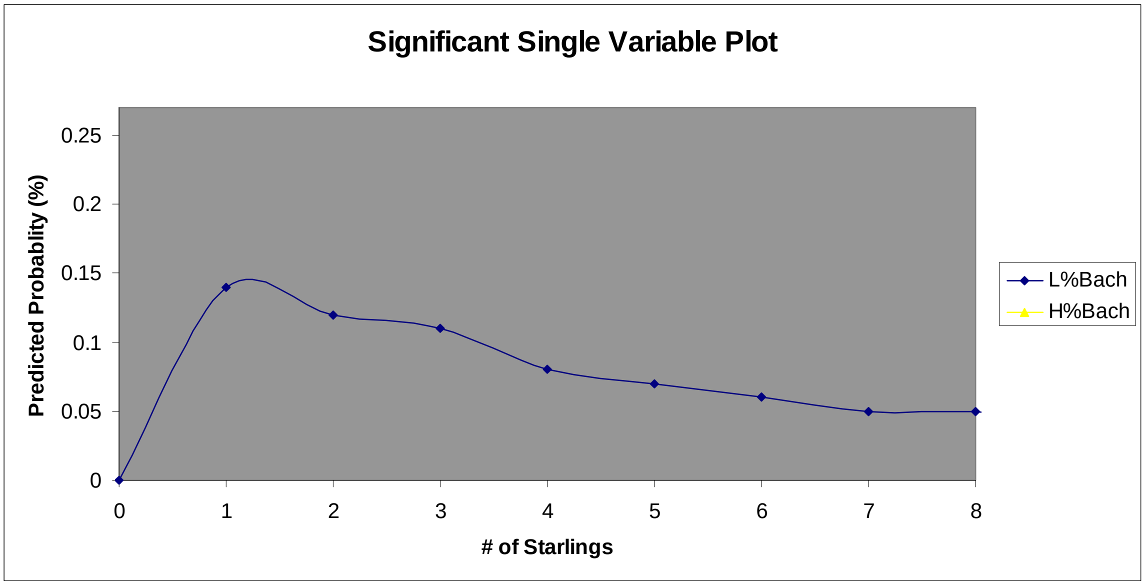

Figure 4. Predicted Probability of starling occurrence focusing only on education (%Bach).

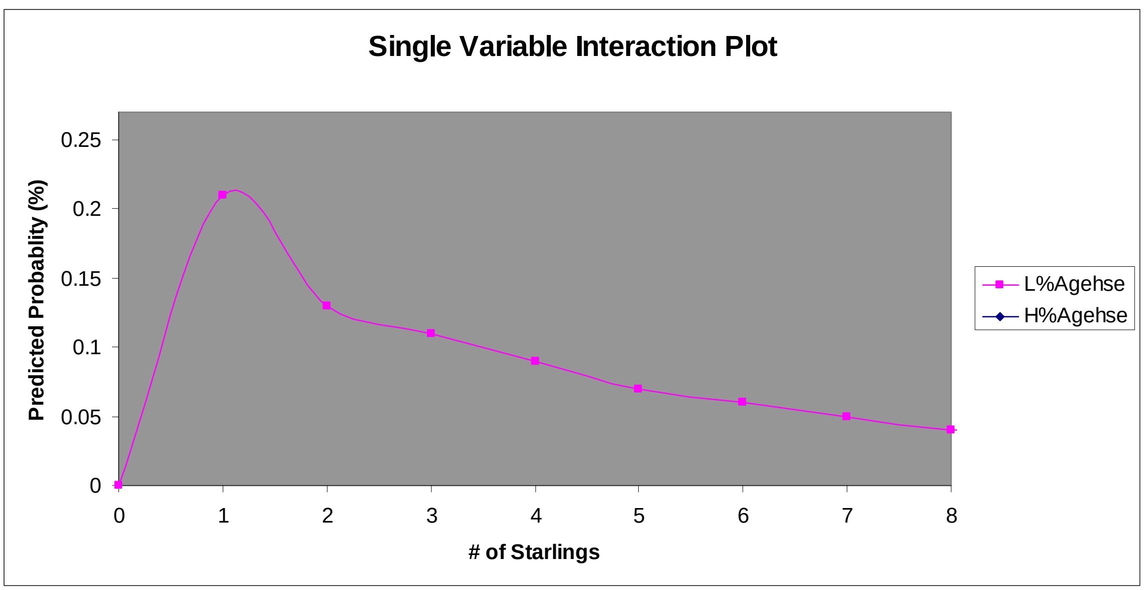

Figure 5. Predicted Probability of starling occurrence focusing only on age of housing (%agehse).

BIBLIOGRAPHY

Beals, E. W. (1984). "Bray-Curtis Ordination: An effective strategy for analysis of multivariate ecological data." Advances in Ecological Research **14**: 1-49.

Blair, R. B. (1996). "Land use and avian species diversity along an urban gradient." Ecological Applications **6**(2): 506-519.

Burch, W. R. and J. M. Grove (1993). "People, trees and participation on urban frontier." Unasylva **44**(173): 19-27.

Cabe, P. R. (1993). "European Starling (*Sturnus vulgaris*)." The Birds of North America Online Retrieved April 28, 2010, from http://bna.birds.cornell.edu/bna/species/048.

Clergeau, P., J. P. L. Savard, et al. (1998). "Bird abundance and diversity along an urban-rural gradient: A comparative study between two cities on different continents." Condor **100**(3): 413-425.

Collins, J. P., A. Kinzing, et al. (2000). "A New Urban Ecology." American Scientist **88**(5): 416.

Dickman, C. R. (1987). "Habitat fragmentation and vertebrate species richness in an urban environment." Journal of Applied Ecology **24**: 337-351.

Donnelly, R. and J. M. Marzluff (2004). "Importance of Reserve Size and Landscape Context to Urban Bird Conservation." Conservation Biology **18**(3): 733-745.

Dow, K. (2000). "Social dimensions of gradients in urban ecosystems." Urban Ecosystems **4**(4): 255-275.

Feare, C. J. (1984). The Starling. Oxford, Oxford University Press.

Garson, G. D. (2009). "Generalized Linear Models/Generalized Estimating Equations." Statnotes: Topics in Multivariate Analysis Retrieved April 28, 2010, from http://faculty.chass.ncsu.edu/garson/PA765/statnote.htm.

Grove, J. M. and W. R. Burch (1997). "A social ecology approach and applications of urban ecosystem and landscape analyses: a case study of Baltimore, Maryland." Urban Ecosystems **1**(4): 259-275.

Grove, J. M., A. R. Troy, et al. (2006). "Characterization of households and its implications for the vegetation of urban ecosystems." Ecosystems **9**: 578-597.

Hadidian, J., J. Sauer, et al. (1997). "A city wide breeding bird survey for Washington, DC." Urban Ecosystems **1**: 87-102.

Heynen, N., H. A. Perkins, et al. (2006). "The Political Ecology of Uneven Urban Green Space: The Impact of Political Economy on Race and Ethnicity in Producing Environmental Inequality in Milwaukee." Urban Affairs Review **42**(1): 3-25.

Hope, D., C. Gries, et al. (2003). "Socioeconomics drive urban plant diversity." Proceedings of the National Academy of Sciences of the United States of America **100**(15): 8788-8792.

Hosteler, M. E. and K. Knowles-Yanez (2003). "Land use, scale and bird distributions in the Phoenix metropolitan area." Landscape and Urban Planning **62**: 55-68.

Kinzig, A. P., P. Warren, et al. (2005). "The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity." Ecology and Society **10**(1).

Kretser, H. E., P. J. Sullivan, et al. (2008). "Housing density as an indicator of spatial patterns of reported human-wildlife interactions in Northern New York." Landscape and Urban Planning **84**(3-4): 282-292.
Loss, S. R., M. O. Ruiz, et al. (2009). "Relationships between avian diversity, neighborhood age, income, and environmental characteristics of an urban landscape." Biological Conservation **142**: 2578-2585.
Maloney, M. and C. Auffrey (2004). The Social Areas of Cincinnati: an analysis of social needs. Cincinnati, School of Planning, University of Cincinnati.
Martin, C. A., P. S. Warren, et al. (2004). "Neighborhood socioeconomic status is a useful predictor of perennial landscape vegetation in residential neighborhoods and embedded small parks of Phoenix, AZ." Landscape and Urban Planning **69**(4): 355-368.
McCleery, R. A. (2009). "Changes in fox squirrel anti-predator behaviors across the urban-rural gradient." Landscape Ecology **24**: 483-493.
McDonnell, M. J. and S. T. A. Pickett (1997). Introduction: Scope and need for an ecology of subtle human effects and populated areas. Humans as Components of Ecosystems. M. J. McDonnell and S. T. A. Pickett. New York, Springer**:** 1-6.
Melles, S. J. (2005). "Urban bird diversity as an indicator of social diversity and economic inequality in Vancouver, British Columbia." Urban Habitats **3**(1): 25-48.
Nilon, C. H., P. S. Warren, et al. (in press). "Baltimore Birdscape Study: Identifying habitat and land-cover variables for an urban bird-monitoring project." Urban Habitats **6**.
O'Rourke, N., L. Hatcher, et al. (2005). A Step-by-Step Approach to Using SAS for Univariate and Multivariate Statistics. Cary, NC, SAS Institute Inc.
Peach, W. J., K. E. Vincent, et al. (2008). "Reproductive success of house sparrows along an urban gradient." Animal Conservation **11**(6): 493-503.
Savard, J.-P. L., P. Clergeau, et al. (2000). "Biodiversity concepts and urban ecosystems." Landscape and Urban Planning **48**(3-4): 131-142.
Shevky, E. and M. Williams (1949). The Social Areas of Los Angeles. Berkeley, University of Califorian Press.
Turner, B. L., W. C. Clark, et al., Eds. (1993). The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years. Cambridge, UK, Cambridge University Press.
U.S. Census Bureau. (2008). "Data Finders: 2008 Population Estimates." from http://www.census.gov/.
U.S. Census Bureau. (2009). "Data Tools." from http://www.census.gov/.
U.S. Census Bureau. (2010). "State and County QuickFacts." Retrieved April 28, 2010, from http://quickfacts.census.gov/qfd/states/24/24510.html.
USDA Forest Service. (2009). "UFORE: Background." Retrieved April 28, 2010, from http://www.ufore.org/about/index.html.
Walker, J. S., R. C. Balling Jr, et al. (2008). "Birds of a feather: Interpolating distribution patterns of urban birds." Computers, Environment and Urban Systems **32**(1): 19-28.