BIRD COMMUNITY ASSOCIATIONS ACROSS LAND COVER CATEGORIES WITHIN AN URBAN MATRIX

by

Andrea E. Julian, B.S.

A thesis presented to the Graduate Council of
Texas State University in partial fulfillment
of the requirements for the degree of
Master of Science
with a Major in Wildlife Ecology
December 2013

Committee Members:

T.R. Simpson, Chair

M. Clay Green

Timothy Bonner

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ACKNOWLEDGMENTS

I would like to acknowledge those who have supported me throughout my academic career. My mom, Judy Julian, and my dad, Drew Julian, stressed the importance of education to me at a young age. Their encouragement and support inspired me to make the decision to pursue a higher education. I would also like to acknowledge my advisor and mentor, Dr. Thomas Simpson, for inspiring me to pursue a career in ecology and for introducing me to the study of birds. This pursuit has not only inspired me academically, but has brought me much joy and happiness into my personal life. Thank you to Phil Julian and Dave O'Donnell for providing GIS expertise and assistance with this project. I would also like to give thanks to Nathanial Peters, whose love and support were essential for my completion of this thesis.

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ABSTRACT

Urban areas are man-made ecosystems that have increased in size and complexity in the past century. I surveyed the avifaunal community of San Marcos, Texas over a period of one year and compared species and guild diversity to land cover within the urban matrix. San Marcos is a medium sized city (population ~50,000) that was established in 1851. Since the city's founding, land and waterways with the city have been altered by humans for residential and commercial/industrial purposes. To understand how avifaunal communities are associated within the urban matrix of San Marcos, I surveyed birds at 39 point counts during each season over a period of one year within the city's urban center and periphery. Species diversity and evenness indices were calculated. A guild analysis was also conducted to examine how land use types may influence the guild structure of the avifaunal community. Species diversity was found to be highest in sites with the least amount of impervious cover and lower at sites with the greatest amount of impervious cover and was significantly influenced by both land use type and season. Land use class and season were both found to significantly affect guild diversity. The guild analysis also indicated that functional homogenization is occurring as members of the ground foraging guild represented the majority of species and individual sightings across all seasons and sites, regardless of land cover type.

CHAPTER I

Introduction

Since the beginning of the industrial revolution over 150 years ago, cities have increased dramatically in number, size, and human population (Blair, 2004). In 1900, nine percent of the world's human population lived in urban environments. By 1980, that number had increased to over 40%, with future projections predicting 66% by 2025 (McIntyer et al., 2000; Blair, 2004). As cities grow in size and complexity, urban landscapes emerge, which are physically and functionally distinct from natural landscapes (Ortega-Alvarez and MacGregor-Fors, 2009). Urban landscapes are not static and homogenous but rather follow a process similar to succession in natural ecosystems, maturing into a complex landscape made up of discreet microhabitats often called the urban matrix (Hodgson et al., 2007; Ortega-Alvarez and MacGregor-Fors, 2009). A landscape matrix can be defined as the most widespread habitat within a landscape in which other habitat types are embedded (Ortega-Alvarez and MacGregor-Fors, 2009; Redondo-Brenes and Montagnini, 2010). The urban matrix is made up of a patchwork of discreet developments, varying in land cover, building density, age, percent impervious cover and vegetative composition (Conole and Kirkpatrick, 2011). There are no species, plant or animal, which are inherently native to an urban area. Instead, species colonize an urban area when adequate resources are available (Pidgeon et al., 2007).

The avifaunal communities which form within urban environments have a species composition and population density that is different from that of the surrounding, natural landscape. Species able to colonize and thrive in urban environments must possess a level of behavioral plasticity (Kark et al., 2007; Moller, 2009), a trait referred to by some researchers as tolerance. Tolerant species, or generalists, display behavior that is more plastic, e.g. able to utilize a variety of resources within a given environment. Bonier et al. (2007) found that bird species thriving in urban ecosystems have a broader environmental tolerance than species that avoid urban ecosystems. Birds that exist within urban ecosystems must have adaptions that allow them to acclimate to an ecosystem that is not only altered environmentally but also has a great deal of human disturbance (Kark et al., 2007). For example, urban birds must be able to utilize novel food resources and nesting structures, and become tolerant to human activity, noise and light pollution. Species that are less tolerant, such as specialist species, require a specific set of resources in order to exploit an area and may avoid urban areas depending if those environmental conditions are not present. Bonier et al. (2007) postulated that broad environmental tolerance of urban birds is due to a combination of greater behavioral, physiological and ecological flexibility.

Urban environments are broadly defined as those ecosystems which have been altered by human activity. According to this definition, McIntyre et al. (2000) argue that almost all ecosystems could be viewed as urban. Urban ecosystems, from an ecological studies perspective, are typically defined as areas altered by human activity and where humans actively live (McIntyre et al., 2000). Thus, the urban environment has both a physical and a social context. The most intensely urbanized areas of a city are where businesses are located and commerce is conducted. Most often, this is the center of the city, called the downtown or business district. These urban areas are characterized by more impervious cover in the form of high rise buildings and streets. Impervious land cover often decreases on a gradient from the urban center to the periphery of the city, where residential structures are typically located. Residential neighborhoods, though just as densely populated and disturbed by human activity, often contain more vegetative cover, in the form of yards, parks and what is called urban open space, or green space (Sandstrom et al., 2006).

Urban environments vary in terms of productivity. Urban areas that are too highly fragmented or lack sufficient vegetation or structure may become inhospitable to the majority of wildlife species, resulting in an ecosystem that becomes dominated by a few generalist species, known as "urban exploiters" (Blair, 1996; Kark et al., 2007; Conole and Kirkpatrick, 2011; Evans et al., 2011). Fragmented urban environments, covered by buildings at various densities, are subject to edge effects (Theobald et al., 1997; Moller, 2009). Urban exploiters, however, are not negatively affected by the fragmentation within urban areas. Instead, they benefit from the increased cover, nest sites and food sources available within urban areas, which allow them to increase in population density (Kark et al., 2007; Evans et al., 2011). However, the avifaunal community in general tends to suffer a decrease in species richness, diversity and evenness (Blair, 1996; Smith, 2007; Moller, 2009).

San Marcos, Texas, lies along the Interstate 35 highway corridor between Austin and San Antonio in central Texas that is currently undergoing rapid development and population growth. A recent National Public Radio (NPR) report stated that during 2012, San Marcos was the fastest growing city in the United States and that this growth has potentially damaged delicate ecosystems (NPR, http://stateimpact.npr.org/texas/2013/08/12/growing-pains-in-americas-fastest-growing-city-of-san-marcos/). The city is located within an environmentally sensitive zone since the first six kilometers of the San Marcos River, including its headwaters, are located near the central business district. The area is home to several threatened and endangered species, including the Texas Blind salamander (*Eurycea rathbuni*), the Fountain Darter (*Etheostoma fonticola*), the San Marcos salamander (*Eurycea nana*) and Texas Wild Rice (*Zizania texana*). The endangered Golden-cheeked Warbler (*Setophaga chrysoparia*) has been known to nest in green space in and around the city. In addition, its location in the Central Flyway and its rich water resources make San Marcos an important site for migrating birds and waterfowl (Polak, 2008, Johnsgard, 2012). My study was undertaken to assess the current avian community structure of San Marcos in order to understand how current land use has affected the avian community structure of this area.

There are several methods to assess avifaunal diversity. One way is to survey sites within the study area and record the number of species present and obtain diversity indices based on those surveys. Another method of assessing an avifaunal community involves grouping observed species into guilds and assessing the guild diversity. Root (1967) defined a guild as a group of species that exploit the same class of environmental resources in a similar way. Blair (1996) found that assessing species richness and diversity of urban birds could be misleading when observing community patterns in urban birds because moderate levels of development may both increase overall species diversity and decrease native bird diversity (Blair, 1996). Assessing guild diversity in addition to species diversitys may give a more robust understanding of the overall structure of urban avifaunal communities since it will show what vegetative strata is available and being exploited by avian species within the urban matrix.

Guild structure of the avifaunal community has been used by researchers to assess biotic integrity (Croonquist and Brooks, 1991; O'Connell et al., 2000). Research by O'Connell et al. (2000) placed birds in behavioral and physiological response guilds in order to determine the biotic integrity of sites with varying degrees of disturbance within central Appalachia. O'Connell et al. (2000) defined biotic integrity as the capability of a habitat to support a community of organisms comparable to that of the natural habitat of the region. Their results showed that a gradient existed in which guild structure decreased in diversity, composition and functional organization from pristine sites to more urbanized sites (O'Connell et al., 2000). Functional homogenization, the replacement of many specialist species by a few generalist species (DeVictor et al., 2007; Ortega-Alvarez and MacGregor-Fors, 2009) is a sign of degraded biotic integrity. Guild analysis can reveal whether or not functional homogenization is occurring within an avifaunal community and can thus give researchers a tool to assess the biotic integrity of urban areas.

Objectives

My objectives for this study were to determine the current structure of the avifaunal community of San Marcos, Texas by calculating species richness, diversity, and evenness in relation urban land cover. I expected to find species richness, diversity and evenness to be higher in areas where there is less impervious cover and lower in areas where impervious cover is high. Additionally, I assessed guild structure in order to understand the types of resources available and being exploited by birds observed within the urban matrix of San Marcos. My hypothesis was that guild structure would be structured highly in favor of generalist and ground foraging species and other guilds would be less abundant. Finally, I related species richness, species evenness and guild structure to the urban cover within the urban matrix of San Marcos to show how avifaunal communities are associated within the urban matrix of San Marcos. Results from my study can be used by city managers and planners in order to plan future development in order to maximize avifaunal diversity.

CHAPTER II

Study Area

San Marcos is a mid-size city (population ~50,000) located on the eastern edge of the Edwards Plateau in central Texas. Its unique location includes a variety of ecosystems: the Edwards Plateau to the west and the Blackland Prairie to the east connected by the rich riparian habitat of the spring fed San Marcos River. Located in the Central Flyway, it supports a variety of bird species, year round residents, summer residents, winter residents, and numerous migrants which pass through the area. Urban San Marcos is composed of a mixture of developments. Some neighborhoods (i.e. the "Historic District") were developed as early as the mid 1800's, and are bordered by more modern neighborhoods. The highly urbanized center is made up of the central business district and the Texas State University campus. The resulting patchwork of urban development has created unique microhabitats for wildlife.

The vegetative structure of San Marcos is highly variable. It is a patchwork of deciduous forest and open grassland that include a mixture of native, invasive, exotic and ornamental species. Common deciduous vegetation includes plateau live oak (*Quercus fusiformis*), pecan (*Carya illinoinensis*), Ashe juniper (*Juniperus ashei*), cedar elm (*Ulmus crassifolia*), Texas persimmon (*Diospyros texana*), mountain laurel (*Sophora secundiflora*), and, along the river, bald cypress (*Taxodium distichum*). Exotic and non-native species include bermuda grass (*Cynodon dactylon*), ligustrum (*Ligustrum japonicum*), nandina (*Nandina domestica*), Chinese tallow (*Triadica sebifera*), Chinese pivet (*Ligustrum sinese*) and crepe myrtle (*Lagerstroemia sp.*).

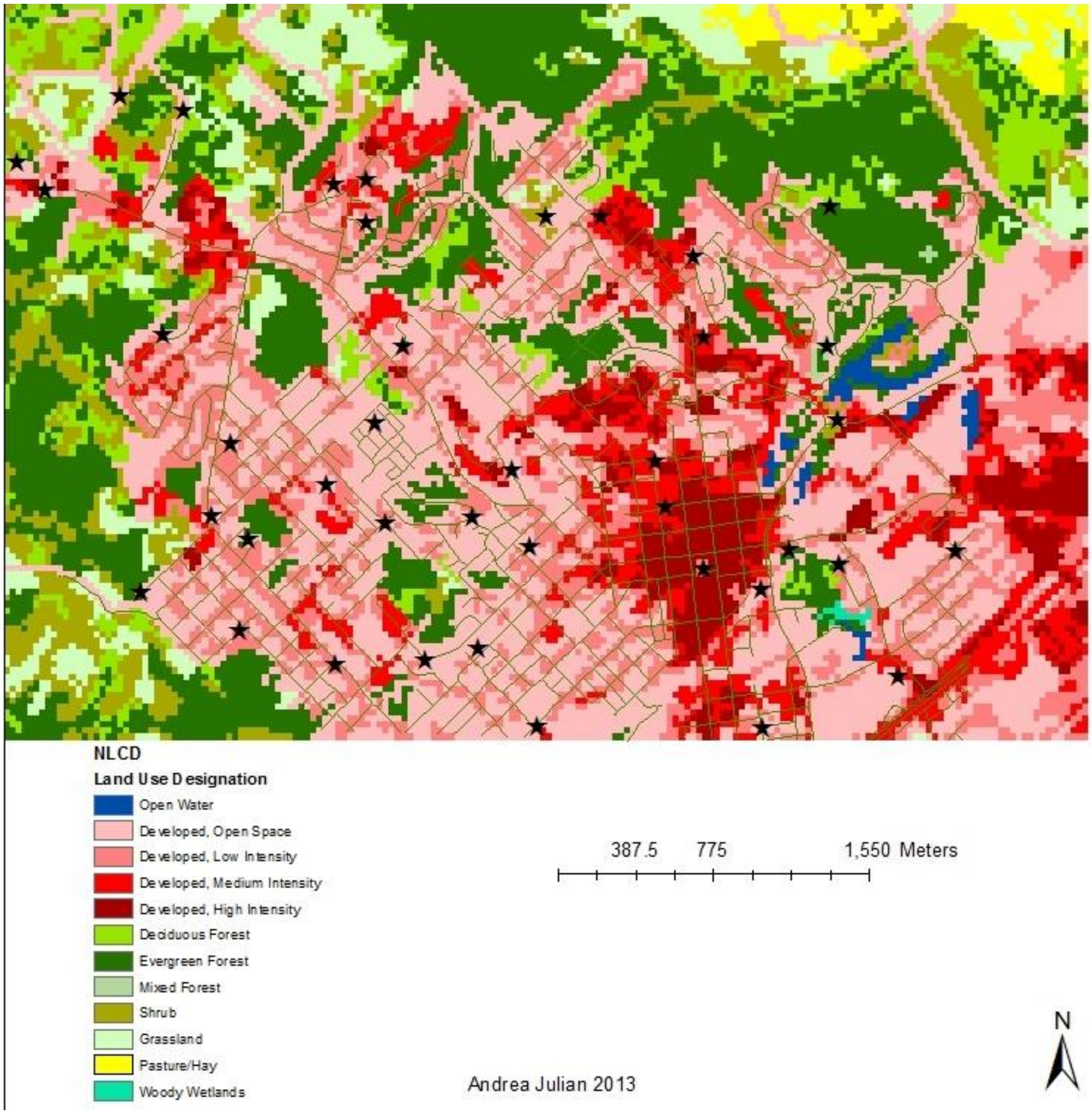

Figure 1. Map of study area showing National Land Cover Database (2006) classification for San Marcos Texas as well as the sampling sites where bird Observations were conducted from May 2012 to April 2013 (NLCD, 2006, http://www.mrlc.gov/nlcd06_data.php).

CHAPTER III

Materials and Methods

I used the National Land Cover Database (NLCD, 2006, http://www.mrlc.gov/nlcd06_data.php) as a guide to land cover types found in urban San Marcos, Texas. The NLCD is produced by the Multi-Resolution Land Characteristics (MRLC), a partnership of Federal agencies led by the U.S. Geological Survey. The NLCD divides the contiguous United States into categories based on vegetation and other attributes. If an area is covered by urban structures (i.e. roads and buildings) at a density greater than 20%, then it is designated "urban". The NLCD designates four urban classes: Developed, open space (< 20% impervious cover); Developed, low intensity (20-49% impervious cover); Developed, medium intensity (50-79% impervious cover) and Developed, high intensity (80-100% impervious cover) (Homer et al., 2012).

For purposes of this study, I selected areas of San Marcos that were significantly dominated by urban land cover classes as defined by the NLCD, including the urban center of San Marcos and the surrounding neighborhoods closest to the city center. Using the random point generator tool in Arc Toolbox (ArcGIS 10.0, ESRI, Redlands, CA), I selected 39 random sites within the designated area (Figure 1). I set a buffer of 250 m between each site to reduce the risk of double counting birds. I visually confirmed that the randomly chosen sampling sites were located in all four land cover types as designated by the NLCD. I subsequently refined site classification using the NLCD class that was most representative of the site using ArcGIS to draw a 100 meter buffer around each site. I then clipped each site by the buffer and exported it as a shape file. Using the

Model Builder tool, I split each buffered raster into 39 separate files, each with a separate attribute table.

Each buffered site contained between 31-37 pixels. Each pixel represented a 30x30 meter section of land. I counted the number of pixels at each site and calculated the percentage of each NLCD class. Sites were classified as such:

Developed, Open Space (DOS) = Sites characterized by > 50%
Vegetation/Developed, Open Space

Developed, Low Intensity (DLI) = Sites characterized by > 50%
Developed, Open Space/Developed, Low Intensity

Developed, Medium Intensity (DMI) = Sites characterized by >50%
Developed, Low Intensity/Developed, Medium Intensity

Developed, High Intensity (DHI) = Sites characterized by > 50%
Developed, Medium Intensity/Developed, High Intensity

Nine of the 39 sites fell into the Developed, Open Space (DOS) designation. These sites, dominated by vegetation, were primarily located at the outermost periphery of the sampling area. There were 16 sites in the Developed, Low Intensity (DLI) designation. These sites were developed but contained a great deal of open space. Nine sites were developed, medium level of intensity designated as Developed, Medium Intensity (DMI). Those sites which were the most highly developed and contained a majority of urban cover were designated as Developed, High Intensity (DHI). These five sites were located mostly in the downtown business district of San Marcos or the Texas State University campus.

I conducted 50 m fixed radius point counts during each chronological season, from May 2012 to April 2013. I visited each site four times each season. I timed seasonal sampling to detect spring and winter migrants, as well as residents and breeders. The duration of each point count was five minutes, chosen due to its proven efficiency in bird point count sampling (Verner, 1984). During each point count, I recorded all birds seen or heard within a 50 m radius of the designated sampling site. I did not count birds flying over unless they were within the canopy or specifically using the area for hunting or hawking purposes.

I used Vegan Package in R 2.15 (Oksanen et al., 2013) to calculate community diversity at the species and guild level. I selected Shannon-Wiener Index for species diversity and Pielou's Index was used to assess evenness. I used abundance estimates to calculate diversity indices. Following the protocol suggested for terrestrial bird count surveys by the U.S. Fish and Wildlife, I made the assumption that the community of birds I observed was a closed community (Nur et al., 1999). Since I visited each sampling site four times during each season, I assumed that the site visit in which I observed the highest number of individuals per species to be most representative of the community (Nur et al., 1999) (Appendices B – E). I used these estimates to calculate Shannon-Wiener diversity indices and Pileou's evenness for each Land Use class. I then tested whether season or land use type influenced avifaunal community diversity and evenness using a two factor Analysis of Variance (ANOVA). Further analysis and the specific influences of season and site were assessed using a Tukey's Post Hoc test.

To understand foraging opportunities present in land use types, and how urbanization was affecting functional homogenization and biotic integrity, I assessed community diversity at the guild level. I grouped observed bird species into feeding guilds based on classifications designated by De Graaf et al. (1985). De Graaf et al. (1985) proposed a comprehensive guild classification system for all North American birds based on foraging strategy. De Graaf et al. (1985) defined these guilds based on four criteria: 1) type of food taken by the species, 2) type of substrate where food is taken, 3) technique for taking the food, 4) season in which the food is taken, either breeding or non-breeding. For species that were classified into more than one feeding guild (used more than one strata to forage for food), I gave the designation of "generalist." I assessed diversity indices for guilds and tested the effects of season and land use class on diversity using a two factor ANOVA.

CHAPTER IV

Results

I visited each of the 39 sampling sites four times during each season, for a total of 624 site visits. Over the course of the study, I observed 10,675 individual birds representing 82 species (Appendix A). During this study, I observed 69 species in the Developed, Open Space sites (Appendix B), 58 species in Developed, Low Intensity sites (Appendix C), 43 species in Developed, Medium Intensity sites (Appendix D), and 28 species in Developed, High Intensity sites (Appendix E).

According to the NLCD designation, the urban area of San Marcos within my study area was dominated by Developed, Open Space and Developed, Low Intensity urban land cover (Figure 1). Using the meta data contained within the attribute table of the NLCD raster file, I calculated the total area of each urban land class type (Table 1).

Urban Land Class (NLCD)	Number of Pixels included in study area	Total Area (m^2)
Developed, Open Space	6718	6,046,200
Developed, Low Intensity	3471	3,123,900
(Developed, Medium Intensity	1856	1,670,400
Developed, High Intensity	1156	1,040,400

Table 1. Calculated area of each land cover class as defined by the NLCD that was within the defined study area of San Marcos, TX.

Species Analysis

The means of Shannon-Wiener indices of diversity for each land class type across seasons ranged from 1.57 to 2.19. The means of Pielou's evenness indices for each land class type across seasons ranged from 0.72 to 0.82. (Figures 2 and 3). The results of the ANOVA indicated that both Site and Season had a significant ($P < 0.01$) effect on bird community diversity (Table 2). Interaction between class and season was not found to be significant. A Tukey's Post Hoc analysis indicated that there were significant ($P < 0.01$) differences in community diversity between land class 4 sites and all other land class types. The post-hoc analysis also revealed that community diversity was significantly different between the fall sampling period and all other seasons (Table 3).

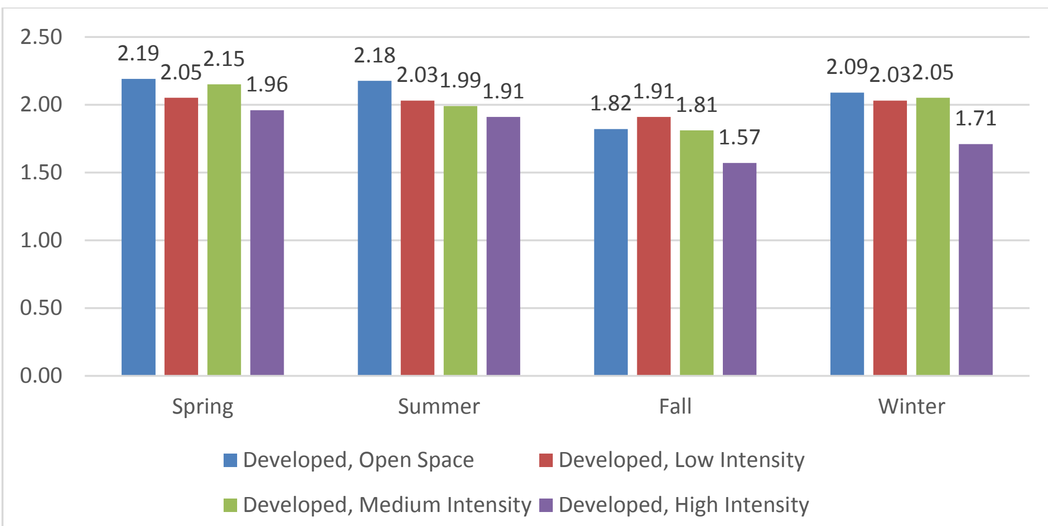

Figure 2. Mean Shannon-Wiener indices for total species diversity calculated for each land class type per season.

Table 2. Results of an analysis of variance test (two factor ANOVA) on the Shannon-Wiener indices for species diversity calculated for each land use class per season.

	Degrees of Freedom	Sum Squares	Mean Squares	F Value	Pr(>F)
Class	3	1.067	0.3558	5.396	0.00152
Season	3	1.594	0.5314	8.060	<0.0001
Class:Season	9	0.420	0.0466	0.707	0.7017
Residuals	140	9.230	0.0659		

Table 3. Results of a Tukey's Post Hoc performed on the two factor ANOVA for species diversity. Significant differences were found between Developed, High Intensity (DHI) sites and all other sites (in bold typeface). For season, significant differences were detected between fall and all other seasons (in bold typeface).

	Difference	Lower CI	Upper CI	P Adj
Class				
DLI-DOS	-0.0636	-0.2027	0.0755	0.6345
DMI-DOS	-0.0661	-0.2235	0.0913	0.6948
DHI-DOS	**-0.2817**	**-0.4679**	**-0.0955**	**0.0007**
DMI-DLI	-0.0025	-0.1416	0.1366	0.9999
DHI-DLI	**-0.2181**	**-0.3891**	**-0.0471**	**0.0063**
DHI-DMI	**-0.2156**	**-0.4018**	**-0.0294**	**0.0162**
Season				
Spring-Fall	**0.2700**	**0.1188**	**0.4212**	**0.0001**
Summer-Fall	**0.2138**	**0.0627**	**0.3650**	**0.0019**
Winter-Fall	**0.1808**	**0.0296**	**0.3320**	**0.0121**
Summer-Spring	-0.0562	-0.2073	0.0950	0.7691
Winter-Spring	-0.0892	-0.2404	0.0620	0.4197
Winter-Summer	-0.0331	-0.1843	0.1181	0.9412

I also used a two factor ANOVA to assess the influence of Land Use and season on the evenness of the avifauna community. The results of the ANOVA showed that none of the tested factors – season, class, or interaction between season and class –significantly affected the evenness of the avifaunal community.

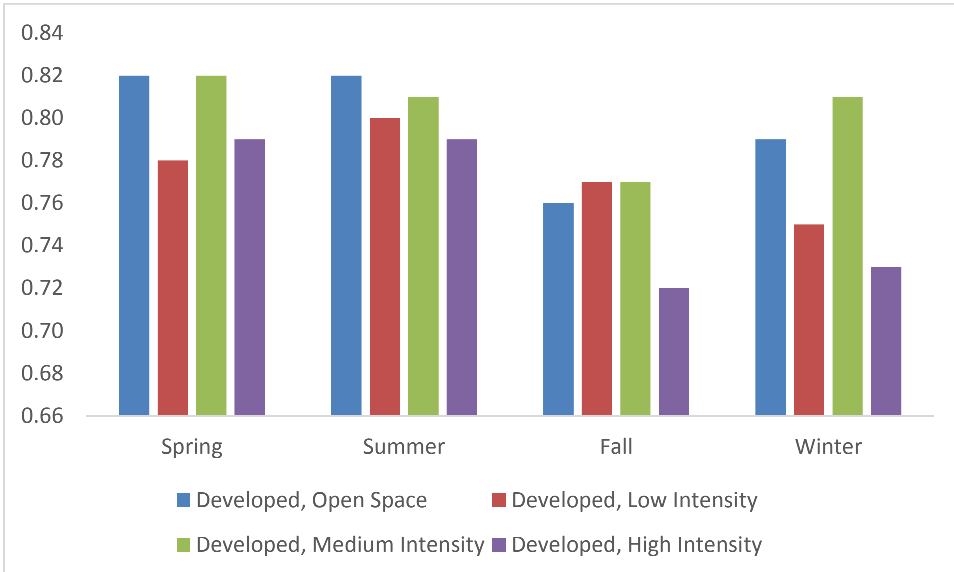

Figure 3. Mean Pielou's evenness indices for total species calculated for each land class type per season.

Table 4. Results of an analysis of variance test (two factor ANOVA) on the Pielou's evenness indices calculated for each land use class per season.

	Degrees of Freedom	**Sum Squares**	**Mean Squares**	**F Value**	**Pr(>F)**
Season	3	0.0625	0.0208	2.504	0.0617
Class	3	0.0372	0.0124	1.488	0.2204
Class:Season	9	0.0211	0.0023	0.281	0.9790
Residuals	140	1.1657	0.0083		

Guild Analysis

I analyzed community diversity at the guild level by grouping species based on their foraging strategy (De Graaf et al., 1985). The species I observed during the study fell into seven distinct guilds – canopy foragers, ground foragers, aerial foragers, generalists, water foragers, scavengers and floral specialists. Generalist species were those that utilized more than one strata when foraging for food (De Graaf et al., 1985).

I found that four of the seven guilds made up a majority of the overall observations, specifically the ground foragers, canopy foragers, aerial foragers and generalists. The other three guilds - water foragers, floral specialists and scavengers – were represented in such low numbers that they were not included in the overall guild analysis.

I analyzed guild composition by first adding the total number of abundance observations of species within each guild for each season for all sites within each land use class. Since there was an unequal number of sites located within each land use class, I then divided abundance by the number of sites within each land use class. This represented the mean number of observations for each guild within each land use class. Mean observations per land class type showed that ground foragers were the dominant guild present within the urban matrix, independent of the land use type (Figures 4, 5, 6 and 7).

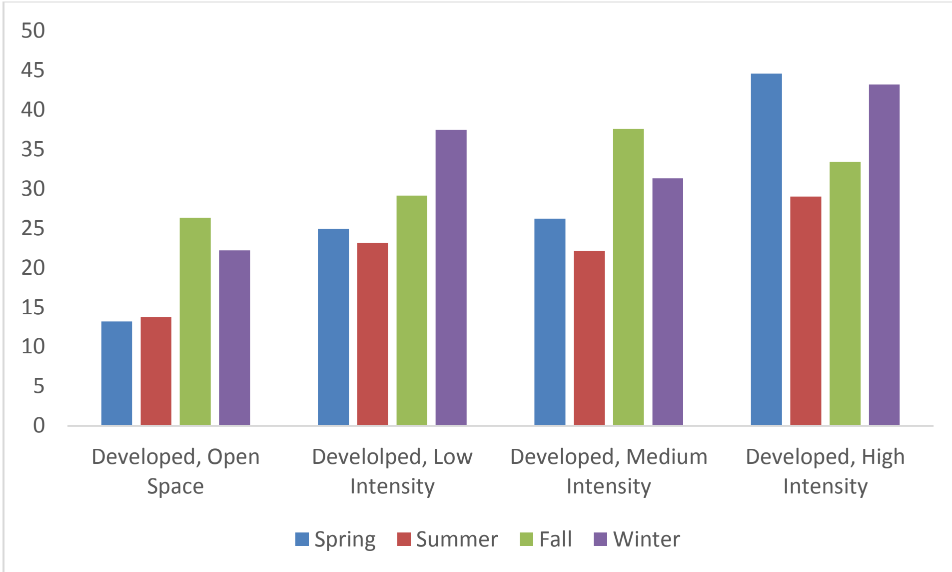

Figure 4. Mean number of individual observations of ground foragers across all land class types and seasons.

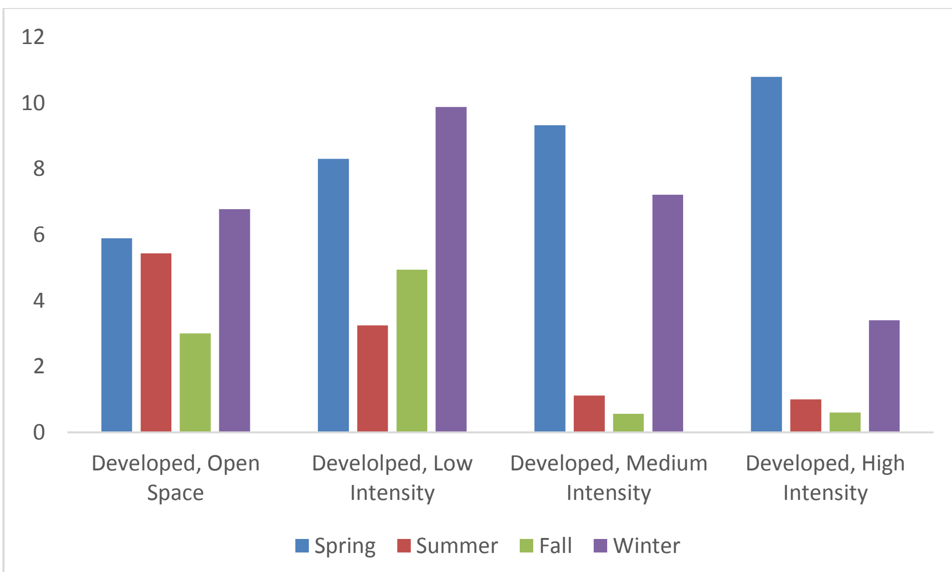

Figure 5. Mean number of individual observations of canopy foragers across all land class types and seasons.

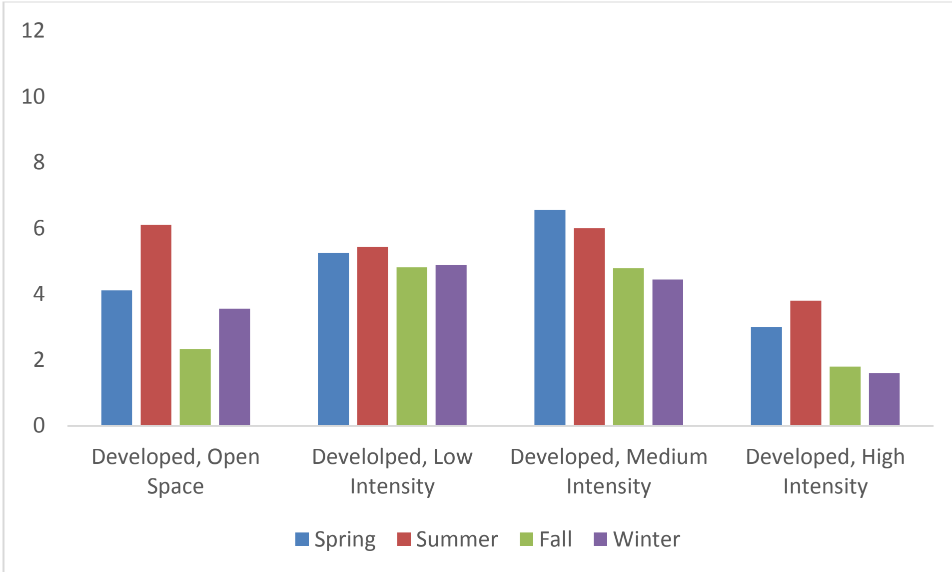

Figure 6. Mean number of individual observations of generalists across all land class types and seasons.

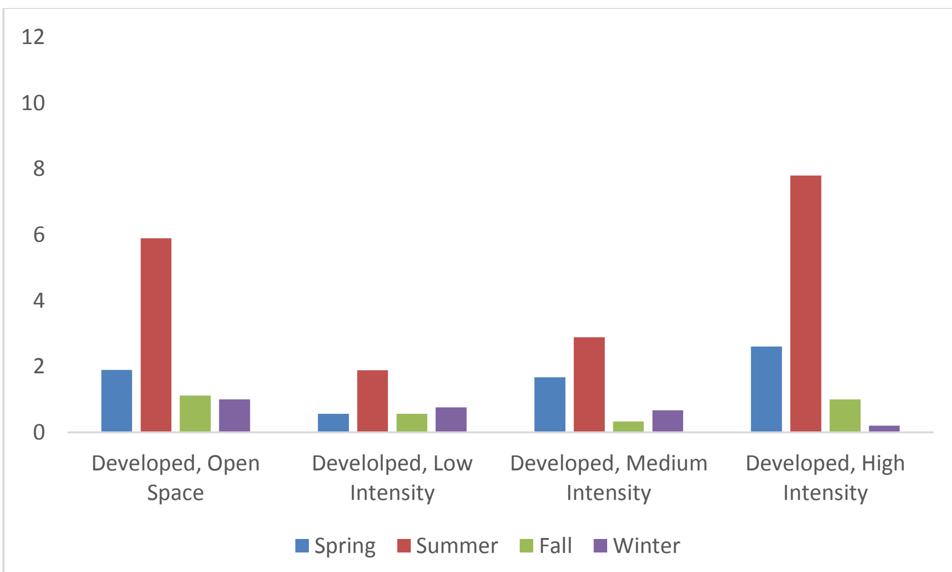

Figure 7. Mean number of individual observations of aerial foragers across all land class types and seasons.

I assessed guild diversity by calculating Shannon-Wiener diversity indices for each land class type and within each season. I used a two factor ANOVA to determine the effects of class and season on the observed community diversity. I found that both class and season were significant ($P < 0.001$) in effecting guild diversity. I did not find the interaction between class and season to be significant (Table 5). I used a Tukey's Post Hoc analysis to determine where significant differences occurred within class and season. I found that significant differences existed between Developed, Open Space sites and all other land class types. Significant differences also occurred between the Fall and the Spring and Summer seasons, and also between the Winter and the Spring and Summer seasons (Table 6).

Table 5. Results of an analysis of variance test (two factor ANOVA) on the Shannon-Wiener indices for guild diversity calculated for each land use class per season.

	Degrees of Freedom	**Sum Squares**	**Mean Squares**	**F Value**	**Pr(>F)**
Class	3	0.761	0.2536	8.801	<0.001
Season	3	0.995	0.3316	11.511	<0.001
Class:Season	9	0.242	0.0269	0.933	0.499
Residuals	140	4.033	0.0288		

Table 6. Results of a Tukey's Post Hoc performed on the two factor ANOVA for guild diversity. Significant differences between Developed, Open Space sites (DOS) and all other sites, and between Developed, Low Intensity (DLI) sites and Developed, High Intensity (DHI) sites were found. Significant differences were also found between the fall and the spring and summer seasons, and the winter and the spring and summer seasons.

	Difference	**Lower CI**	**Upper CI**	**P Adj**
Class				
DLI-DOS	**-0.0981**	**-0.1900**	**-0.0062**	**0.0316**
DMI-DOS	**-0.1364**	**-0.2404**	**-0.0324**	**0.0047**
DHS-DOS	**-0.2329**	**-0.3560**	**-0.1098**	**0.0001**
DMI-DLI	-0.0383	-0.1302	0.0537	0.7007
DHI-DLI	**-0.1348**	**-0.2478**	**-0.0217**	**0.0124**
DHI-DMI	-0.0965	-0.2196	-0.0266	0.1789
Season				
Spring-Fall	**0.1744**	**0.0744**	**0.2743**	**0.0001**
Summer-Fall	**0.1915**	**0.0916**	**0.2915**	**0.0001**
Winter-Fall	0.0582	0.0417	0.1581	0.4317
Summer-Spring	0.0172	-0.0828	0.1171	0.9701
Winter-Spring	**-0.1162**	**-0.2161**	**-0.0162**	**0.0156**
Winter-Summer	**-0.1333**	**-0.2333**	**-0.0334**	**0.0038**

Table 7. Results of an analysis of variance test (two factor ANOVA) on the Pielou's indices for guild evenness calculated for each land class per season.

	Degrees of Freedom	**Sum Squares**	**Mean Squares**	**F Value**	**Pr(>F)**
Season	3	0.2195	0.0732	7.194	0.0001
Class	3	0.0125	0.0042	0.409	0.7469
Season:Class	9	0.1095	0.0122	1.196	0.3023
Residuals	140	1.4238	0.0102		

Table 8. Results of a Tukey's Post Hoc performed on the two factor ANOVA for guild evenness. Significant differences, highlighted in bold, were found between the Fall and the Summer and Spring seasons and between the Winter and Summer seasons.

Season	**Difference**	**Lower CI**	**Upper CI**	**P Adj**
Spring-Fall	**0.0656**	**0.0063**	**0.1250**	**0.0240**
Summer-Fall	**0.0951**	**0.0357**	**0.1545**	**0.0003**
Winter-Fall	0.0192	-0.0402	0.0786	0.8343
Summer-Spring	0.0295	-0.0299	0.0889	0.5701
Winter-Spring	-0.0464	-0.1058	0.0130	0.1812
Winter-Summer	**-0.0759**	**-0.1353**	**-0.0165**	**0.0062**

CHAPTER V

Discussion

Currently, San Marcos is undergoing rapid development, and single family housing developments and mutli-family housing (e.g. apartments) are currently being constructed throughout San Marcos. Housing developments at this scale are known to maximize the disturbance to wildlife habitat (Pidgeon et al., 2007). Construction noise and disturbance often made sampling at various sites difficult throughout the duration of this study. A 2011 report by the I-35 Corridor Advisory Committee Plan (I-35 Corridor Advisory Committee, http://alt.coxnewsweb.com/statesman/pdf/2011/01/MY35AdvisoryReport.pdf) revealed that future developments are being planned. As development intensifies, the area's avifaunal community will continue to be impacted.

My analysis supported previous studies, which have found a general pattern of avifaunal community diversity to decrease with increasing impervious cover and for urban exploiter species populations to increase in areas with high amounts of impervious cover (Sandstrom et al., 2006; DeVictor et al., 2007; Kark et al., 2007; Conole and Kirkpatrick, 2011). I found that there were significant differences in species diversity at sites with the highest percentage of impervious cover, located within the urban center, compared to sites in the other land class categories (Table 2 and Table 3). The number of species recorded within Developed, High Intensity sites was significantly less than at the Developed, Open Space Sites. Developed, High Intensity sites (those with >90% impervious cover) were located in the central business district of San Marcos and on the

Texas State University Campus, which is located nearby. These sites have the greatest impervious cover and human disturbance (i.e. traffic and pedestrians) compared to sites in the other three land classes. My results suggest that there is an urban land use threshold at which avifaunal community diversity is significantly reduced.

The ground foraging guild was by far the most abundant in terms of the number of individuals and the number of species observed in all land class types and in all seasons (Tables 4, 5, 6 and 7; Appendix F and Appendix G). I defined the most successful urban exploiters as those species whose numbers comprised >3% of observations during all four seasons. These species were Blue Jays (*Cyanocitta cristata*), Eurasian Starlings (*Sturnus vulgaris*), Great-tailed Grackles (*Quisicalus mexicanus*), House Sparrows (*Passer domesticus*), Northern Cardinals (*Cardinalis cardinalis*), Northern Mockingbirds (*Mimus polyglottos*) and White-winged Doves (*Zenaida asiatica*). All of these species were members of the ground foraging guild.

My results were consistent with other studies which have found that certain functional groups tend to thrive in urban communities (Blair, 1996; Kark et al., 2007; Conole and Kirkpatrick, 2011). Kark et al. (2007) discovered through their research that urban exploiters shared certain characteristics, including diet, and found that with increasing urbanization, the proportion of granivorous species increased. Granivorous species belong to the ground foraging guild as defined by my study and these were found to be the dominant guild in both species and individual observations.

It has also been noted by researchers (Blair, 1996; Hodgson et al., 2007; Kark et al., 2007; Evans et al., 2011) that increased housing density and associated developments can negatively affect native species, leading to an increase in exotic and invasive species.

However, Blackburn et al. (2009) noted that urban environments are not always dominated by exotic species. The urban exploiters revealed by my research included a mixture of native species and exotic species. Of the seven species I found to be top urban exploiters of San Marcos, two were exotic/invasive (Eurasian Starling, House Sparrow) and two are native but invasive (Great-tailed Grackles and White-winged Doves). Three of the top urban exploiters were species native to the region and not invasive. These were Blue Jays, Northern Cardinals and Northern Mockingbirds. The number of native species out-ranked the exotics and invasives; however, the abundance of individuals of exotic and invasive species greatly outnumbered individuals of native species.

Studies have found that highly successful urban birds share certain life history traits, including residential species (as opposed to migrants), nesting above ground (i.e. cavity and canopy nesters) and having a behavioral plasticity that allows a species to have a broad environmental tolerance (Kark et al., 2007; Moller, 2009). The top urban exploiters defined by my study all shared these traits. All are residents of San Marcos and all seven species have been known to exploit novel environments. Great-tailed Grackles, for example, have expanded their range from southern Mexico (around Vera Cruz) to successfully invade northern Mexico and the southern United States (Johnson and Peer, 2001). The spread of White-wing Doves from their native range of south Texas into central and northern Texas has been well documented (Schwertner et al., 2002) as is the case study of the spread of House Sparrows from the old world to the new (Lowther and Cink, 2006).

One of the most interesting aspects of this analysis was in the diversity of the Developed, Low Intensity and Developed, Medium Intensity land classes. Developed, Open Space sites, which contain mostly vegetated open space, versus Developed, High Intensity sites, which contain mostly impervious cover, follow an expected trend – Developed, Open Space sites have the highest diversity across all four seasons and Developed, High Intensity sites have the lowest. The other two land class types – Developed, Low Intensity and Developed, Medium Intensity - vary depending on the season. Sites in these land use classes are typically single family homes on larger lots. Since San Marcos has a long history of development, many of these neighborhoods are established, having larger trees and abundant vegetation. Yards are dominated by forb species, both native and non-native, that are food for birds. In addition, I noted that many yards contained bird feeders which were regularly stocked and visited by birds. Similar results were found by Blair (1996), who found that low to medium intensity development can offer many foraging opportunities to birds, especially during the fall and winter when foraging opportunities in the surrounding landscape may be limited (Blair, 1996). The significant difference in species diversity between fall and all other seasons (Table 2) is an indication of the exploitation of urban resources by migratory species during this season. Five migrant species, the Chimney Swift (*Chaetura pelagica*), the Nashville Warbler (*Oreothlypis ruficapilla*), the Ruby-throated Hummingbird (*Archilochus colubris*), the Song Sparrow (*Melospiza melodia*) and the Tricolored Heron (*Egretta tricolor*) were observed in the study area in the fall only.

Expanding human population will lead to continued development of areas in and around cities. During my research period, San Marcos was the fastest-growing city in the United States (Heinrich, 2013). The area, which is currently home to 50,000 people, is also home to a number of rare and endangered species, including the Golden-cheeked

Warbler. Due to the rapid development of the area known as the I-35 corridor, which includes the area from Austin, Texas on the north, southward to San Antonio, Texas, it is apparent that San Marcos will continue to see development well into the future. The I-35 Corridor Advisory Committee estimates that he population of this area will increase from 9 million in 2000, to over 17 million in 2040 (I-35 Advisory Committee, 2011). Maintaining avian species diversity and ecosystem health in the face of such rapid development is an important issue in urban planning, since numerous studies have shown a decrease in avian diversity relative to increased development. (DeVictor et al., 2007; Kark et al., 2007; Moller, 2009; Conole and Kirkpatrick, 2011).

Assessing guild structure of urban communities is important because though urban areas may support a diversity of species they may all be species which are utilizing a similar life history trait, a sign of low biotic integrity. Undisturbed ecosystems in their natural state have a high level of biotic integrity because they are able to support a large diversity of species from a variety of functional groups, or guilds, because a natural landscape offers a variety of niches to be exploited by wildlife. Grouping species into functional guilds can be a better way to gauge of the biotic integrity of an ecosystem and how disturbance is affecting the wildlife community (Croonquist and Brooks, 1991; O'Connell et al., 2000). My study found the avifaunal community of San Marcos to be comprised of a majority of species that shared a similar feeding strategy. Croonquist and Brooks (1991) used avifaunal community assemblage to successfully create a model to gauge biotic integrity of ecosystems at the landscape scale in Pennsylvania. O'Connell et al. (2000) found similar success using avifaunal community guild structure to model biotic integrity of ecosystems within central Appalachia.

My study can serve as a baseline study of San Marcos, Texas, showing avifaunal community structure and guild use during this current state of rapid urban development. This study also shows that of the current amount of green space present in San Marcos is not sufficient to prevent a trend towards functional homogenization – the process of replacing many specialist species by a few generalist species. (DeVictor et al., 2007). The avifaunal community of San Marcos with a guild structure that consists of a majority of functionally similar species (i.e. ground foragers) should be considered an area of degraded biotic integrity (O'Connell et al, 2000).

Land managers and wildlife professionals in San Marcos and surrounding suburban areas will need to continue to monitor avian species and assess guild diversity into the future to ensure the biotic integrity of this environmentally sensitive area is maintained. To do this, future development should be done with an effort to maximize urban green space while reducing disturbance on wildlife habitat. I would recommend that monitoring of the San Marcos avifaunal community at the species and guild level should be continued as development continues.

APPENDICES

Appendix A. Comprehensive list of bird species observed in the entire study area, from May 2012 to April 2013. Species feeding guilds are included, and the season they were observed in are indicated.

Common Name	Scientific Name	Feeding Guild	Resident Status	Summer	Fall	Winter	Spring
American Robin	*Turdus migraforius*	Generalist	Resident	x	x		x
American Coot	*Fulica americana*	Water Forager	Resident			x	x
American Crow	*Corvus brachyrhynchos*	Ground Forager	Resident	x	x	x	x
American Goldfinch	*Spinus tristis*	Canopy Forager	Winter Resident			x	
Barn Swallow	*Hirundo rustica*	Aerial Forager	Resident	x			x
Belted Kingfisher	*Ceryle alcyon*	Water Forager	Resident	x			x
Bewick's Wren	*Thryomanes bewickii*	Ground Forager	Resident	x	x	x	x
Black-chinned Hummingbird	*Archilochus alexandri*	Floral Specialist	Summer Breeder	x			x
Black-crested Titmouse	*Baeolophus atricrisfatus*	Canopy Forager	Resident	x	x	x	x
Black-throated	*Setophaga virens*	Canopy Forager	Migrant				x

Green Warbler							
Black Vulture	*Coragyps atratus*	Scavenger	Resident	x	x	x	x
Blue-gray Gnatcatcher	*Polioptila caerulea*	Canopy Forager	Resident		x		x
Blue Jay	*Cyanocitta cristata*	Ground Forager	Resident	x	x	x	x
Bronzed Cowbird	*Molothrus aeneus*	Ground Forager	Summer Breeder	x			x
Brown-headed Cowbird	*Molothrus ater*	Ground Forager	Resident	x			x
Carolina Chickadee	*Poecile carolinensis*	Canopy Forager	Resident	x	x	x	x
Carolina Wren	*Thryomanes ludovicianus*	Canopy Forager	Resident	x	x	x	x
Cave Swallow	*Petrochelidon fulva*	Aerial Forager	Resident	x			
Cedar Waxwing	*Bombycilla cedrorum*	Canopy Forager	Winter Resident			x	x
Chimney Swift	*Chaetura pelagica*	Aerial Forager	Summer Breeder		x		
Chipping Sparrow	*Spizella passerine*	Ground Forager	Resident			x	

Cliff Swallow	*Petrochelidon pyrrhonota*	Aerial Forager	Summer Breeder	x	x		x
Common Grackle	*Quiscalus quiscula*	Ground Forager	Resident		x		
Common Nighthawk	*Chordeiles minor*	Aerial Forager	Summer Breeder	x			x
Common Raven	*Corvus corax*	Scavenger	Resident		x		
Crested Caracara	*Caracara cheriway*	Scavenger	Resident	x			
Double-crested Cormorant	*Phalacrocorax auritus*	Water Forager	Resident			x	x
Downy Woodpecker	*Picoides pubescens*	Canopy Forager	Resident		x	x	x
Eastern Bluebird	*Sialia sialis*	Generalist	Resident	x	x	x	x
Eastern Phoebe	*Sayornis phoebe*	Aerial Forager	Resident	x	x	x	x
Egyptian Goose	*Alopochen aegyptiacus*	Water Forager	Resident		x	x	
Eurasian Collared Dove	*Steptopelia decaocto*	Ground Forager	Resident			x	x
European Starling	*Sturnus vulgaris*	Ground Forager	Resident	x	x	x	x
Gadwall	*Anas strepera*	Water Forager	Resident			x	
Golden-fronted	*Melanerpes*	Generalist	Resident	x	x	x	x

Woodpecker	*aurifrons*						
Great Blue Heron	*Ardea Herodias*	Water Forager	Resident	x	x	x	x
Great-crested Flycatcher	*Myiarchus crinitus*	Aerial Forager	Summer Breeder	x			x
Great-tailed Grackle	*Quisicalus mexicanus*	Ground Forager	Resident	x	x	x	x
Green Heron	*Butorides virescens*	Water Forager	Resident	x			x
House Finch	*Haemorhous mexicanus*	Ground Forager	Resident	x	x	x	x
House Sparrow	*Passer domesticus*	Ground Forager	Resident	x	x	x	x
Hummingbird sp.		Floral Specialist	Summer Breeder	x	x		
Inca Dove	*Columbina inca*	Ground Forager	Resident	x	x	x	x
Indigo Bunting	*Passerina cyanea*	Ground Forager	Summer Breeder	x			
Killdeer	*Charadrius vociferous*	Ground Forager	Resident	x	x		
Ladder-back Woodpecker	*Picoides scalaris*	Canopy Forager	Resident	x	x	x	
Lesser Goldfinch	*Spinus psaltria*	Generalist	Resident	x	x	x	x

Loggerhead Shrike	*Lanius excubitor*	Aerial Forager	Resident			x	x
Mourning Dove	*Zenaida macroura*	Ground Forager	Resident	x	x	x	x
Nashville Warbler	*Oreothlypis ruficapilla*	Ground Forager	Migrant		x		
Northern Cardinal	*Cardinalis cardinalis*	Ground Forager	Migrant	x	x	x	x
Northern Mockingbird	*Mimus polyglottos*	Generalist	Resident	x	x	x	x
Northern Parula	*Setophaga americana*	Canopy Forager	Migrant	x			
Northern Waterthrush	*Parkesia noveboracensis*	Water Forager	Migrant				x
Orange-crowned Warbler	*Oreothlypis celata*	Canopy Forager	Winter Resident		x	x	x
Orchard Oriole	*Icterus spurius*	Canopy Forager	Migrant				x
Osprey	*Pandion haliaetus*	Water Forager	Winter Resident		x	x	
Painted Bunting	*Passerina ciris*	Canopy Forager	Summer Breeder	x			x

Pied-billed Grebe	*Podilymbus podiceps*	Water Forager	Resident		x		x
Pine Warbler	*Setophaga pinus*	Canopy Forager	Migrant			x	
Purple Martin	*Progne subis*	Aerial Forager	Summer Breeder	x			
Red-breasted Nuthatch	*Sitta Canadensis*	Canopy Forager	Migrant			x	
Red-eyed Vireo	*Vireo olivaceus*	Canopy Forager	Summer Breeder	x			
Red-shouldered Hawk	*Buteo lineatus*	Aerial Forager	Resident	x	x	x	x
Red-tailed Hawk	*Buteo jamaicensis*	Aerial Forager	Resident			x	
Red-winged Blackbird	*Agelaius phoeniceus*	Canopy Forager	Resident	x	x		x
Red-bellied Woodpecker	*Melanerpes carolinus*	Generalist	Resident	x		x	x
Rock Pigeon	*Columba livia*	Ground Forager	Resident	x	x	x	x
Ruby-crowned Kinglet	*Regulus calendula*	Canopy Forager	Winter Resident		x	x	
Ruby-throated	*Archilochus*	Floral Specialist	Sumer		x		

Hummingbird	*colubris*		Breeder				
Savannah Sparrow	*Passerculus sandwichensis*	Ground Forager	Winter Resident		x	x	x
Scissor-tailed Flycatcher	*Tyrannus forficatus*	Aerial Forager	Summer Breeder	x	x		x
Song Sparrow	*Melospiza melodia*	Ground Forager	Migrant		x		
Summer Tanager	*Piranga rubra*	Canopy Forager	Summer Breeder				x
Titmouse sp.		Canopy Forager	Resident	x	x	x	x
Tricolored Heron	*Egretta tricolor*	Water Forager	Migrant		x		
Tufted Titmouse	*Baeolophus bicolor*	Canopy Forager	Resident	x	x	x	
Turkey Vulture	*Cathartes aura*	Scavenger	Resident		x	x	x
Western Kingbird	*Tyrannus verticalis*	Aerial Forager	Summer Breeder	x	x		x
White-eyed Vireo	*Vireo griseus*	Canopy Forager	Resident	x			x
White-winged Dove	*Zenaida asiatica*	Ground Forager	Resident	x	x	x	x
Woodpecker sp.		Generalist	Resident	x		x	x
Yellow-billed	*Coccyzus*	Canopy Forager	Winter	x			

Cuckoo	*americanus*		Resident			
Yellow-crowned Night Heron	*Nyctanassa violacea*	Water Forager	Resident	x		x
Yellow-rumped Warbler	*Setophaga coronate*	Canopy Forager	Winter Resident		x	x

Appendix B. Bird species abundance within Developed, Open Space sites between May 2012 and April 2013.

Species	Summer	Fall	Winter	Spring	Overall
American Coot	0	0	7	0	7
American Crow	0	0	3	3	6
American Goldfinch	0	0	2	0	2
Barn Swallow	4	0	0	2	6
Belted Kingfisher	0	1	1	0	2
Bewick's Wren	8	2	6	14	30
Black-crested Titmouse	3	0	4	2	9
Black-chinned Hummingbird	0	0	0	3	3
Black Vulture	2	66	23	20	111
Blue-gray Gnatcatcher	0	3	0	3	6
Blue Jay	1	19	9	7	36
Bronzed Cowbird	1	0	0	1	2
Brown-headed Cowbird	3	0	0	7	10
Carolina Chickadee	14	5	15	4	38
Carolina Wren	11	12	16	11	50
Chipping Sparrow	0	0	5	0	5
Cliff Swallow	25	0	0	2	27
Common Raven	0	3	0	0	3
Common Nighthawk	0	0	0	1	1
Double-crested Cormorant	0	0	5	1	6
Downy Woodpecker	0	0	1	0	1
Eastern Bluebird	3	0	5	1	9
Eastern Phoebe	4	9	6	5	24
Egyptian Goose	0	0	4	0	4
Eurasian Starling	7	10	3	8	28
Gadwall	0	0	12	0	12
Golden-fronted Woodpecker	7	2	3	3	15

Great Blue Heron	0	2	2	1	5
Great-tailed Grackle	13	6	4	9	32
Great-crested Flycatcher	0	0	0	2	2
Green Heron	0	0	0	2	2
House Finch	9	23	15	8	55
House Sparrow	16	20	30	1	67
Inca Dove	6	7	5	2	20
Killdeer	0	11	0	0	11
Ladder-backed Woodpecker	0	1	0	0	1
Lesser Goldfinch	2	1	7	0	10
Loggerhead Shrike	0	0	2	1	3
Mourning Dove	16	3	31	8	58
Northern Cardinal	15	22	34	28	99
Nashville Warbler	0	1	0	0	1
Northern Mockingbird	42	18	13	32	105
Northern Parula	2	0	0	0	2
Orange-crowned Warbler	0	4	3	0	7
Osprey	0	1	1	0	2
Painted Bunting	4	0	0	8	12
Pie-billed Grebe	0	4	0	8	12
Purple Martin	4	0	0	0	4
Red-bellied Woodpecker	0	0	1	0	1
Ruby-crowned Kinglet	0	1	6	0	7
Red-shouldered Hawk	3	0	0	0	3
Red-tailed Hawk	0	0	1	0	1
Ruby-throated Hummingbird	0	1	0	0	1
Red-winged Blackbird	3	0	0	3	6
Savannah Sparrow	0	2	5	2	9
Song Sparrow	0	1	0	0	1
Scissor-tailed Flycatcher	7	1	0	1	9
Summer Tanager	0	0	0	1	1

Tri-colored Heron	0	1	0	0	1
Tufted Titmouse	2	0	2	0	4
Turkey Vulture	0	5	0	0	5
Unidentified Titmouse	4	0	10	3	17
Unidentified Woodpecker	1	0	6	1	8
Western Kingbird	6	0	0	3	9
White-eyed Vireo	5	0	0	3	8
White-winged Dove	29	111	50	21	211
Yellow-billed Cuckoo	1	0	0	0	1
Yellow-crowned Night Heron	1	0	0	1	2
Yellow-rumped Warbler	0	0	2	4	6

Appendix C. Bird species abundance within Developed, Low Intensity sites between May 2012 and April 2013

Species	Summer	Fall	Winter	Spring	Overall
American Crow	2	10	4	2	18
American Coot	0	0	0	1	1
American Goldfinch	0	0	10	0	10
American Robin	0	1	0	0	1
Bewick's Wren	12	2	16	20	50
Barn Swallow	0	0	0	2	2
Black-chinned Hummingbird	2	0	0	0	2
Black-crested Titmouse	0	10	7	4	21
Black Vulture	4	5	2	2	13
Blue Jay	23	49	45	21	138
Brown-headed Cowbird	12	0	0	6	18
Black-throated Green Warbler	0	0	0	3	3
Carolina Chickadee	16	34	35	8	93
Carolina Wren	17	22	21	24	84
Cave Swallow	3	0	0	0	3
Chipping Sparrow	0	0	1	0	1
Chimney Swift	0	1	0	0	1
Cliff Swallow	19	2	0	0	21
Cedar Waxwing	0	0	50	79	129
Crested Caracara	1	0	0	0	1
Downy Woodpecker	0	1	0	0	1
Eastern Bluebird	0	0	1	0	1
Eastern Phoebe	0	5	6	2	13
Eurasian Collared Dove	0	0	1	0	1
Eurasian Starling	22	54	48	44	168
Golden-fronted Woodpecker	15	11	15	17	58
Great-crested Flycatcher	1	0	0	0	1
Great-tailed Grackle	56	63	102	50	271

House Finch	21	26	22	15	84
House Sparrow	85	71	67	69	292
Inca Dove	5	8	3	17	33
Ladder-backed Woodpecker	5	1	1	0	7
Lesser Goldfinch	2	0	24	3	29
Mourning Dove	24	13	26	16	79
Northern Cardinal	46	33	40	43	162
Northern Mockingbird	68	65	31	62	226
Northern Waterthrush	0	0	0	1	1
Orange-crowned Warbler	0	2	6	2	10
Orchard Oriole	0	0	0	1	1
Pine Warbler	0	0	1	0	1
Red-breasted Nuthatch	0	0	1	0	1
Red-eyed Vireo	2	0	0	0	2
Red-shouldered Hawk	3	0	6	1	10
Ruby-crowned Kinglet	0	2	7	0	9
Red-winged Blackbird	1	1	0	0	2
Rock Pigeon	0	1	0	0	1
Red-bellied Woodpecker	1	0	0	1	2
Savannah Sparrow	0	1	0	0	1
Scissor-tailed Flycatcher	0	0	0	1	1
Tufted Titmouse	2	5	5	0	12
Turkey Vulture	0	0	1	0	1
Unidentified Hummingbird	1	0	0	0	1
Unidentified Titmouse	9	1	5	8	23
Unidentified Woodpecker	1	0	7	1	9
Western Kingbird	4	2	0	3	9
White-eyed Vireo	0	0	0	4	4
White-winged Dove	62	134	224	96	516
Yellow-rumped Warbler	0	0	9	0	9

Appendix D. Bird species abundance within Developed, Medium Intensity sites between May 2012 and April 2013.

Species	Summer	Fall	Winter	Spring	Overall
American Robin	1	0	0	1	2
American Goldfinch	0	0	3	0	3
American Crow	0	1	0	0	1
Bewick's Wren	5	2	6	12	25
Black-crested Titmouse	0	1	5	0	6
Blue Jay	11	17	26	8	62
Black Vulture	2	7	2	0	11
Brown-headed Cowbird	6	0	0	3	9
Carolina Chickadee	3	13	14	4	34
Carolina Wren	1	3	20	13	37
Cliff Swallow	13	0	0	2	15
Common Grackle	0	1	0	0	
Common Raven	0	1	0	0	1
Cedar Waxwing	0	0	15	61	76
Downy Woodpecker	0	0	0	2	2
Eastern Bluebird	1	2	3	3	9
Eastern Phoebe	2	2	3	6	13
Eurasian Starling	9	83	45	39	176
Golden-fronted Woodpecker	5	5	6	8	24
Great Blue Heron	1	0	0	0	1
Great-tailed Grackle	22	31	13	35	101
House Finch	17	14	15	16	62
House Sparrow	66	64	61	47	238
Inca Dove	3	2	4	1	10
Indigo Bunting	1	0	0	0	1
Killdeer	2	1	0	0	3
Ladder-backed Woodpecker	2	0	0	0	2

Lesser Goldfinch	0	3	12	0	15
Mourning Dove	17	0	13	9	39
Northern Cardinal	6	15	29	17	67
Northern Mockingbird	46	33	15	45	139
Ruby-crowned Kinglet	0	2	1	0	3
Red-shouldered Hawk	0	1	3	1	5
Rock Pigeon	0	0	12	0	12
Savannah Sparrow	0	0	0	1	1
Turkey Vulture	0	2	0	0	2
Tufted Titmouse	2	0	0	0	2
Unidentified Titmouse	2	1	3	4	10
Unidentified Woodpecker	1	0	4	2	7
Unidentified Hummingbird	0	1	0	0	1
Western Kingbird	11	0	0	6	17
White-winged Dove	34	107	58	48	247
Yellow-rumped Warbler	0	0	4	0	4

Appendix E. Bird species abundance within Developed, High Intensity sites between May 2012 and April 2013.

Species	Summer	Fall	Winter	Spring	Overall
Barn Swallow	3	0	0	9	12
Bewick's Wren	2	0	1	2	5
Blue Jay	2	8	7	3	20
Brown-headed Cowbird	2	0	0	0	2
Carolina Chickadee	0	1	10	1	12
Carolina Wren	1	2	2	1	6
Cliff Swallow	24	50	0	0	74
Common Nighthawk	2	0	0	0	2
Cedar Waxwing	0	0	0	52	52
Eurasian Starling	19	21	32	39	111
Eurasian Collared Dove	0	0	2	1	3
Golden-fronted Woodpecker	1	0	0	1	2
Great-tailed Grackle	34	63	54	54	205
House Finch	8	5	10	9	32
House Sparrow	23	18	50	52	143
Ladder-backed Woodpecker	1	0	0	0	1
Mourning Dove	9	7	4	9	29
Northern Cardinal	2	2	1	4	9
Northern Mockingbird	18	9	8	14	49
Rock Pigeon	11	25	33	12	81
Red-shouldered Hawk	0	0	1	0	1
Ruby-crowned Kinglet	0	0	1	0	1
Tufted Titmouse	3	0	0	0	3
Turkey Vulture	0	0	0	1	1
Western Kingbird	10	0	0	13	23

White-winged Dove	33	18	22	38	111
Unidentified Titmouse	0	0	1	0	1
Yellow-rumped Warbler	0	0	3	0	3

Appendix F. Mean number of individual observations per guild for each land use type calculated for each season.

	Total Observations					**Mean Observations per site**			
Ground Foragers	Summer	Fall	Winter	Spring	***Effort***	Summer	Fall	Winter	Spring
DOS	124	237	200	119	9	13.78	26.33	22.22	13.22
DLI	370	466	599	399	16	23.13	29.13	37.44	24.94
DMI	199	338	282	236	9	22.11	37.56	31.33	26.22
DHI	145	167	216	223	5	29.00	33.40	43.20	44.60
Canopy Foragers									
DOS	49	27	61	53	9	5.44	3.00	6.78	5.89
DLI	52	79	158	133	16	3.25	4.94	9.88	8.31
DMI	10	5	65	84	9	1.11	0.56	7.22	9.33
DHI	5	3	17	54	5	1.00	0.60	3.40	10.80
Aerial Foragers									
DOS	53	10	9	17	9	5.89	1.11	1.00	1.89
DLI	30	9	12	9	16	1.88	0.56	0.75	0.56
DMI	26	3	6	15	9	2.89	0.33	0.67	1.67
DHI	39	50	1	13	5	7.80	10.00	0.20	2.60
Generalists									
DOS	55	21	32	37	9	6.11	2.33	3.56	4.11
DLI	87	77	78	84	16	5.44	4.81	4.88	5.25
DMI	54	43	40	59	9	6.00	4.78	4.44	6.56
DHI	19	9	8	15	5	3.80	1.80	1.60	3.00

Appendix G. Mean number of species observed per guild for each land use type calculated for each season.

	Total Species Observed					**Mean Species per Site**			
Ground Foragers	**Summer**	**Fall**	**Winter**	**Spring**	***Effort***	**Summer**	**Fall**	**Winter**	**Spring**
DOS	12	13	13	14	9	1.33	1.44	1.44	1.56
DLI	12	14	13	12	16	0.75	0.88	0.81	0.75
DMI	13	12	11	12	9	1.44	1.33	1.22	1.33
DHI	11	9	11	11	5	2.20	1.80	2.20	2.20
Canopy Foragers									
DOS	10	7	10	14	9	1.11	0.78	1.11	1.56
DLI	7	10	13	9	16	0.44	0.63	0.81	0.56
DMI	3	20	8	5	9	0.33	2.22	0.89	0.56
DHI	3	2	5	3	5	0.60	0.40	1.00	0.60
Aerial Foragers									
DOS	7	2	3	8	9	0.78	0.22	0.33	0.89
DLI	5	3	2	5	16	0.31	0.19	0.13	0.31
DMI	3	2	2	4	9	0.33	0.22	0.22	.044
DHI	4	1	1	1	5	0.80	0.20	0.20	0.20
Generalists									
DOS	5	3	6	4	9	0.56	0.33	0.67	0.44
DLI	5	3	5	5	16	0.31	0.19	0.31	0.31
DMI	5	4	5	5	9	0.56	0.44	0.56	0.56
DHI	2	1	1	2	5	0.40	0.20	0.20	0.40

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