The effects of vegetation variability, demographic differences, and spatial factors on urban bird richness

By

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ABSTRACT

Urban areas are not what is usually thought of as quality habitat for wildlife, however as urbanization increases, wildlife are forced to use the urban environment. Studying the way bird richness is affected by different aspects of the city could prove useful in future management of the urban environment. First, I compared bird diversity to vegetation coverage in neighborhoods across Lubbock, Texas. The second objective was to study bird diversity and vegetation coverage differences throughout the area. My final objective was to observe the way house prices differ when considering bird diversity and vegetation coverage. I performed bird point counts during the summer of 2014, recording every bird seen and heard. I also performed vegetation surveys from May to October 2014 recording number, height, and species of trees as well as other vegetation variables within the urban area of Lubbock, Texas. Recently-sold house prices were obtained from local real estate agents. Simple and multiple linear regressions were performed to determine the effect of vegetation and house spatial placement on bird richness. T-tests were also performed to discover differences in vegetation and bird richness between two areas of Lubbock, TX that are socio-economically different. My findings supplement knowledge of bird use of urban neighborhoods in Lubbock, Texas. My study protocols identify methods and habitat variables that could be used to predict bird diversity in urban areas beyond Lubbock, Texas.

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CHAPTER I

LITERATURE REVIEW

Introduction

Urban ecology is an important field of research currently because of the rapidly growing urban habitat in the US and around the world (Adams 2005, Magle et al. 2012). The addition of urban habitat provides a unique environment to which wildlife has only recently been introduced (Sukopp 1998). Therefore, I assessed the use and value of an area for both wildlife and humans, which will benefit both groups (Adams 2005, Magle et al. 2012).

Lubbock, Texas covers 122.41 square miles with a population of 236,065 people living in 95,926 housing units, as of 2013 (U.S. Census Bureau 2013). Single-family homes make up 78.2% of the housing units, and the front- and backyard areas of these houses provide some of the habitat used by urban wildlife (U.S. Census Bureau 2013). Lubbock is in a semi-arid climate with the city landscape contains tall trees and trimmed vegetation, which is very different from the surrounding flat open habitat comprised of cotton fields and shrub land (Correll and McCoy 1979).

Farmer et al. (2013) performed a study in 2009 focusing on bird diversity compared to house prices and tree coverage, studying houses in specific neighborhoods in Lubbock, TX. The study focused on associating bird diversity and tree coverage, from an ecological standpoint, to house prices combined with house characteristics (lot size, house size, and the presence of a garage), to capture the economic view (Farmer et al. 2013). Farmer et al. (2013) found a positive association with bird diversity and house prices. As an expansion on the Farmer et al. (2013) study, I examined different neighborhoods collected more in-depth vegetation data in order to evaluate the price of a

house role on the of value urban habitat and to better understand urban birds' association with vegetation in Lubbock, TX.

Birds, and wildlife in general, rely on vegetation as an essential part of the habitat wildlife uses (MacArthur and MacArthur 1961). Vegetation provides food, cover, and nesting sites, all of which are needed in order for an animal to persist in an area (MacArthur and MacArthur 1961). Therefore vegetation can help us understand wildlife uses of a habitat (MacArthur and MacArthur 1961). The desire and need for vegetation is something humans and wildlife have in common. However, people have a perceived vision of what is desirable in the "curb appeal" of a house, which might not be ideal for urban wildlife (Nohl 1998, Wittig 1998, Goddard et al. 2009). For example, in Lubbock, TX, the visible front yard usually includes a green lawn with a few trees trimmed above the first story window and a few shrubs next to the house (personal observation). Houses are found in Lubbock, TX with more varied vegetation and taller and wider reaching trees, which might be more welcoming to urban wildlife. Knowledge of what people are willing to pay for a house with large trees could be important in encouraging the cultivation of larger trees to improve house prices. In addition to understanding the value of large trees for human use I can also connect the varied vegetation and large trees to that of wildlife use.

Birds are thought to be good indicators of environmental health and are highly associated with vegetation coverage (MacArthur and MacArthur 1961, Niemi and McDonald 2004).The first objective of my study is to identify areas with high bird diversity in Lubbock, TX. My first objective involved surveying birds at a single-house scale (versus a neighborhood scale) and identifying where within the city species of birds

are located. In my second objective, I determined vegetation coverage and bird species differences between neighborhoods in Lubbock, TX. Since Lubbock, TX is located in a semi-arid environment, more time and resources are needed in order to grow larger vegetation. Many of the areas with 'desirable' trees in Lubbock, TX are older neighborhoods and houses are priced higher partially due to the rarity of large trees (Farmer et al. 2013). Therefore, my in final objective I gathered house price data in order to quantify homeowner's value of vegetation and the environment as a whole at the house scale. By combining vegetation height and species diversity information, house prices and variables, and bird diversity, I was able to predict house price and bird diversity at other houses in Lubbock.

Literature Review

Urban Habitat

The world's population is rapidly growing with an increase of 72% in population projected by 2050 (United Nations 2012). Much of the growth is projected to occur in the urban areas of less developed regions, although urban areas of developed countries are also expected to grow (United Nations 2012). Rural populations in most countries have been declining and are projected to continue to decline (United Nations 2012). Urban areas are growing in the United States, and more than 80% of the United States population now lives in urban or suburban areas and that percentage is projected to grow to 90% by 2050 (United Nations 2012). Due to rapid population growth, more land is being taken out of natural or agricultural areas and altered for urban and suburban use, therefore the amount of impact the growth has on the environment and its inhabitants is increasing exponentially (United Nation 2012, Magle 2012).

Urban areas have very different ecological characteristics than that of undeveloped environments, where vegetation is primarily native and human impact is minimal (Sukopp 1998). The urban habitat includes more impervious surfaces, increased non-organic structures, and an average increase in air temperature of one to two degrees (heat island effect) (Sukopp 1998, McPherson et al. 1997). Increased impervious surfaces mean water is funneled out of the urban system quickly with less water infiltration and more water runoff (Sukopp 1998). An increase in non-organic structures can provide roosting sites for some bird species, e.g. Rock Doves (*Columba livia*), Mourning Doves (*Zenaida macroura*), and Barn Swallows (*Hirundo rustica*), however buildings do not provide food or hiding places for many native bird species (McPherson et al. 1997).

“Heat island” effects are found in cities due to all the dark surfaces and heat produced by buildings, however vegetation can help decrease the effect of the “heat island” by providing shape (McPherson et al. 1997). In Chicago, trees reduce home energy costs, increase individual property values, increase neighborhood air quality, and reduce water runoff (McPherson et al. 1997). The economic and ecological benefit of trees has been heavily researched, because of the human desire for trees in an urban environment (McPherson et al. 1997 Zipperer et al. 1997, Pickett et al. 2001, Breuste 2004).

People have different ideas on what is good habitat in the urban environment (Breuste 2004). In arid and semi-arid regions the idea of good habitat usually includes large trees even though the surrounding habitat is devoid of trees (Breuste 2004). Breuste (2004) claimed that "their understanding of ‘good’ nature is the green and irrigated nature, not the natural one, surrounding them." The general public perception of ‘good’ nature is likely the reason vegetation in cities looks very different from that of the surrounding environment in arid or semi-arid regions (Breuste 2004). Exotic vegetation species are common in urban landscapes, which can improve vegetative species richness in the urban habitat (Pickett et al. 2001, Zipperer et al. 1997); however, native birds tend to prefer native trees (Beissinger and Osborne 1982, Mills et al. 1989, Rottenborn 1999, Marzluff and Ewing 2001).

The introduction of nonnative vegetation species for aesthetic purposes began in the 1800’s in the U.S. (Mack and Lonsdale 2001). The new plants were chosen either because the plants were familiar, from home, or exotic, from elsewhere in the world, therefore the vegetation was not considered for wildlife value (Mack and Lonsdale 2001).However birds can make use of exotic vegetation, which can serve similar uses to

native vegetation, such as nesting, perching, and even some food (Anderson 1979, Mills et al. 1989). A more important difference between native vegetation and exotic vegetation is food availability (Mills et al. 1989). Native insects, which many native birds feed upon, are associated with native vegetation and although some exotics plants do produce food, some do not produce any food or produce food that native birds cannot consume (Mills et al. 1989).

Value of Urban Habitat

Similar to animals, people also value vegetation, which can be observed by simply driving around towns where people water lawns, trim bushes, and grow gardens (Nohl 1998, Thompson et al. 1999, personal observation). In many areas, water is abundant and watering is not needed to grow vegetation (Mennis 2006). In Detroit, MI, vegetation coverage increased as people abandoned neighborhoods, showing that a decrease in care would increase the amount of vegetation (Ryznar and Wagner 2001). However, in Chicago, IL and south-eastern Australia an association between decreased vegetation coverage and lower income neighborhoods was found, which can be attributed partly to high housing densities (Iverson and Cook 2000, Luck et al. 2009). Lubbock, TX is much drier, only averaging 19 inches of precipitation a fall each year, then both Detroit, MI and Chicago, IL, which average 32.89and 36.24 inches a year respectively (Deedler 2011, National Weather Service 2013a, National Weather Service 2013b). Therefore, extra care is required because watering is essential to grow most types of vegetation in a semi-arid environment (Hope et al. 2003), which leads me to believe that vegetation may not grow on its own if left alone unlike areas in Detroit (Ryznar and Wagner 2001). In the drier ecosystem of Phoenix, AZ, (8.03 inches average precipitation)

the age of a house and the homeowner's family income highly influenced the vegetation diversity: older homes had more vegetative diversity, and lower income homes had less vegetative diversity (Hope et al. 2003, National Weather Service 2013c). Similar to Lubbock, TX, Phoenix is located in a dry climate, and money and time must be used to grow plants (Hope et al. 2003).

The cost of water is increasing in Lubbock, TX and therefore the cost of irrigating lawns is also growing (City of Lubbock, Texas 2013a). In the summer half of the year (April-September) about 48 gallons per capita per day of extra water is used compared to the winter half of the year (October-April), the extra water is primarily used for summer activities such as irrigation (City of Lubbock, Texas 2013a). In the last 7 years, the base cost of water has tripled, the cost of water per 1000 gallons has doubled, and another increase in the water volume rate was in effect December 1, 2013 (City of Lubbock, Texas 2013a, City of Lubbock, Texas 2013c). The cost increase follows the projection of Lubbock, TX having a large shortage of water within the next 20 years, even by the most conservative water usage projection (City of Lubbock, Texas 2013a).

The discouraging water projection comes alongside a drought, which began in late 2010 (Figure 1.1) with the Lubbock, TX area being classified in D4 (exceptional drought) in the summer of 2011 (Figure 1.2), which is the highest possible drought rating (Nielsen-Gammon 2012). Some relief came late 2011 when the area was still in drought but the rating was reduced to D3, or extreme drought (Nielsen-Gammon 2012). The drought conditions persisted through 2012 (Figure 1.3) with the categorical rating never dropping below D2 (server drought) (NOAA Drought Task Force, Narrative Team 2013). Drought conditions have continued to persist (Figure 1.4 and 1.5), with no end in sight, although

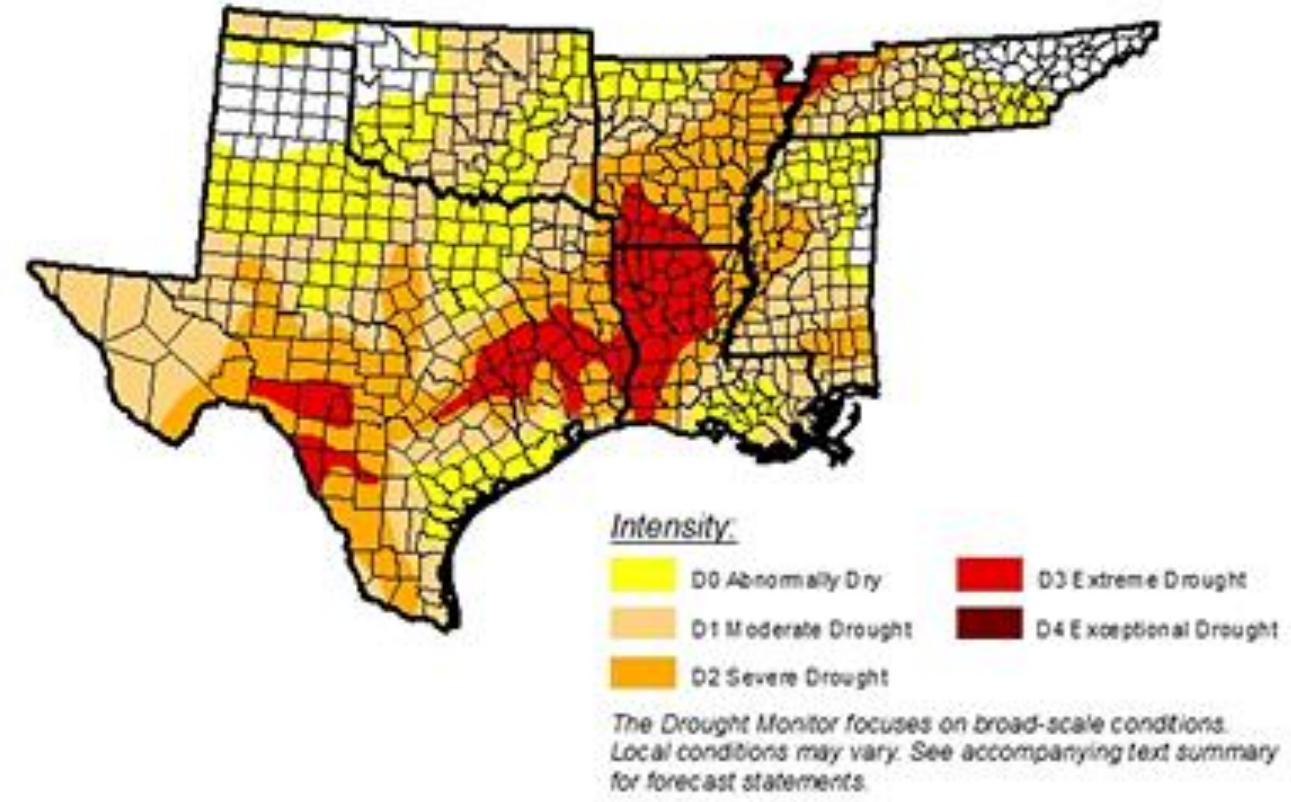
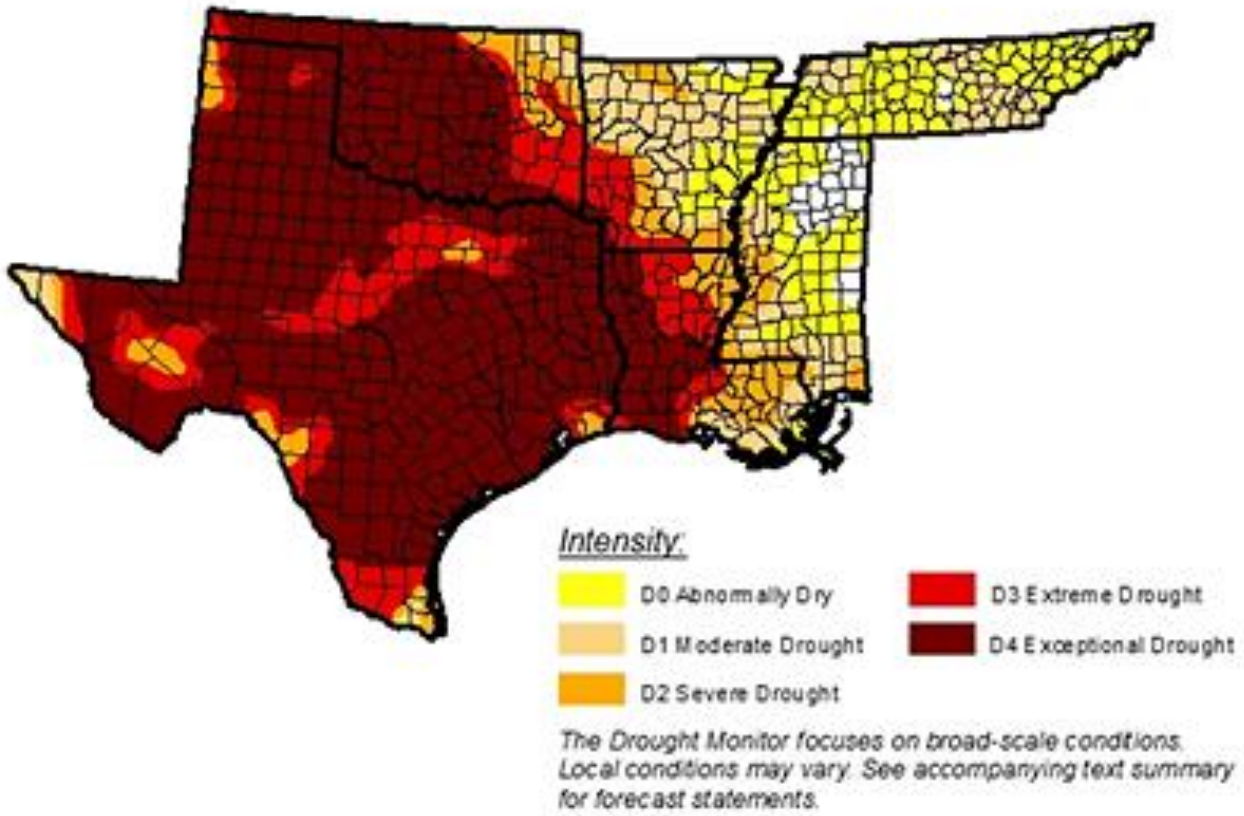


Figure 1.1: A map of the southern region of the United States including Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee representing the drought conditions in December 2010, published by NOAA's U.S. Drought Monitor (Miskus 2010). The bold black lines define state borders, while the thin black lines within the states define counties. The colors rate the drought conditions, and range from light to dark, exhibiting conditions ranging from no drought to extreme drought.



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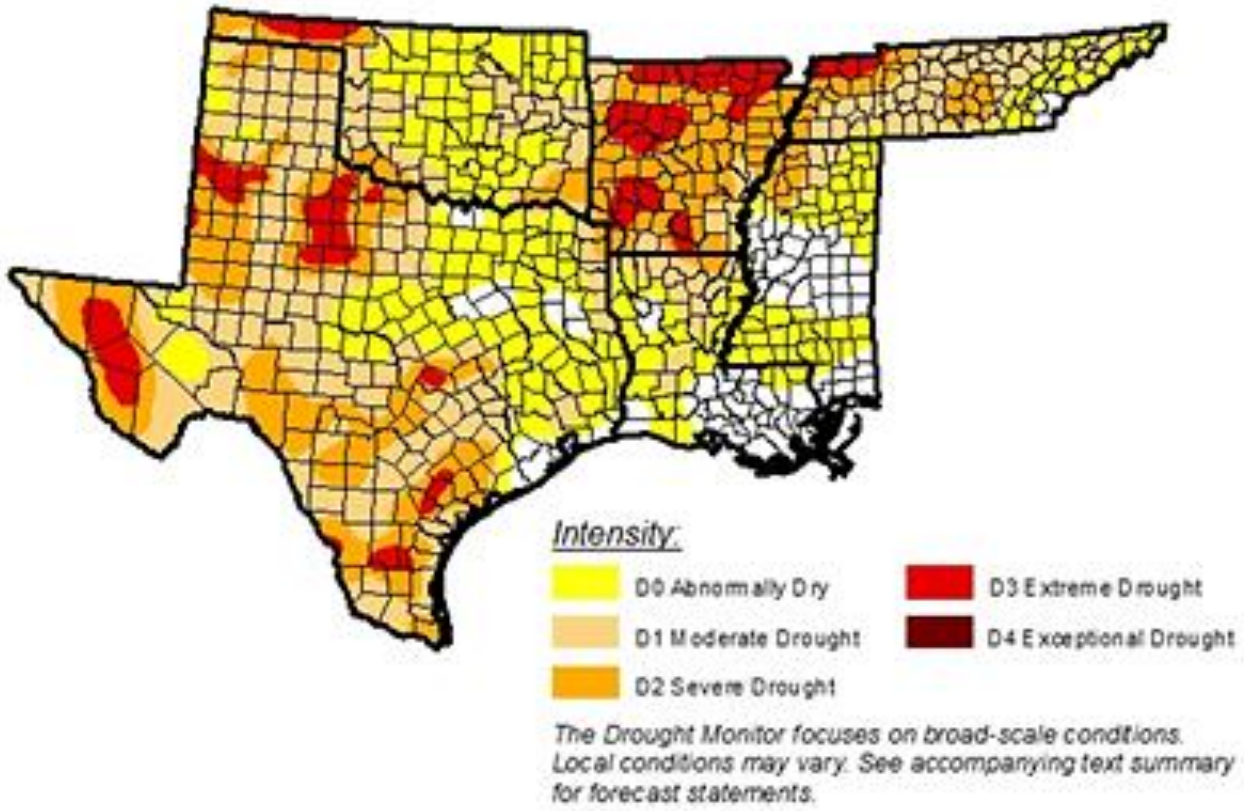

Figure 1.3: A map of the southern region of the United States including Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee representing the drought conditions in June 2012, published by NOAA's U.S. Drought Monitor (Heim 2012). The bold black lines define state borders, while the thin black lines within the states define counties. The colors rate the drought conditions, and range from light to dark, exhibiting conditions ranging from no drought to extreme drought.

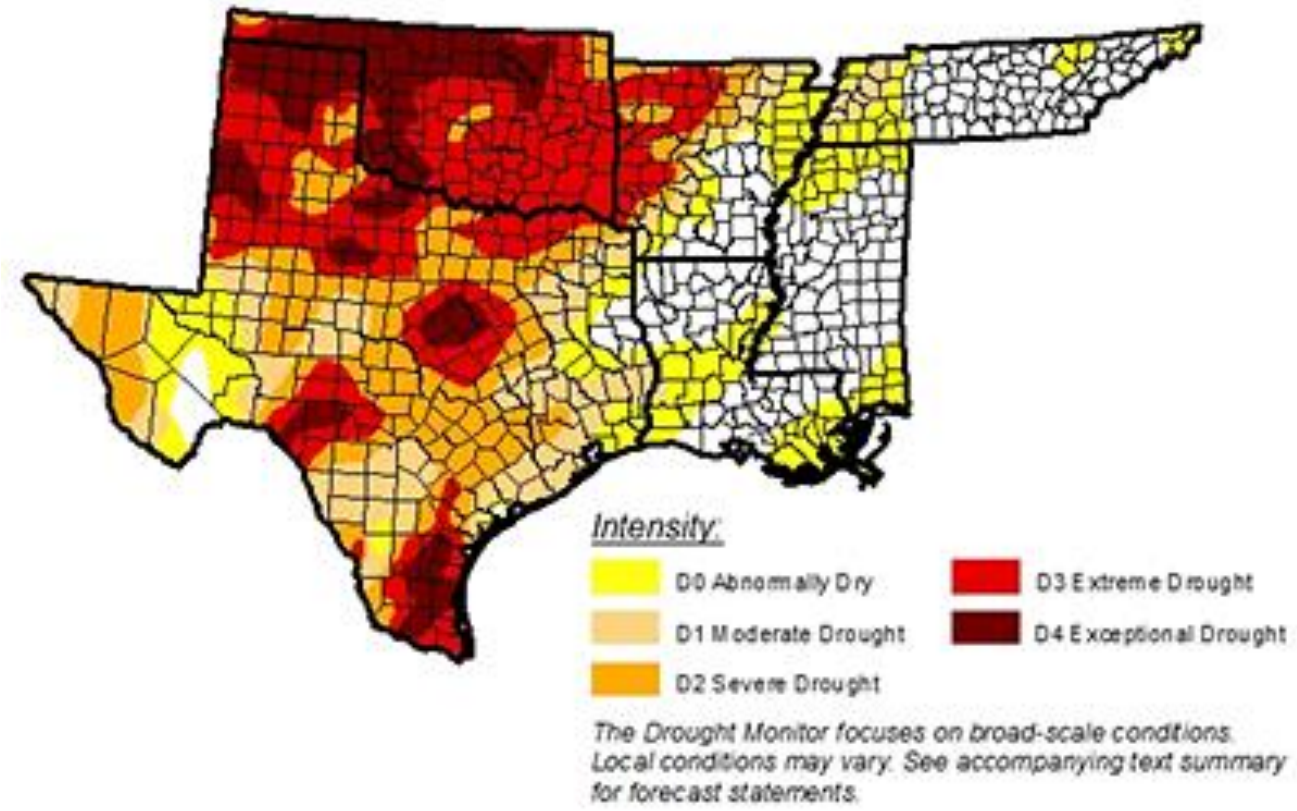

Figure 1.4: A map of the southern region of the United States including Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee representing the drought conditions in December 2013, published by NOAA's U.S. Drought Monitor (Rosencrans 2013). The bold black lines define state borders, while the thin black lines within the states define counties. The colors rate the drought conditions, and range from light to dark, exhibiting conditions ranging from no drought to extreme drought.

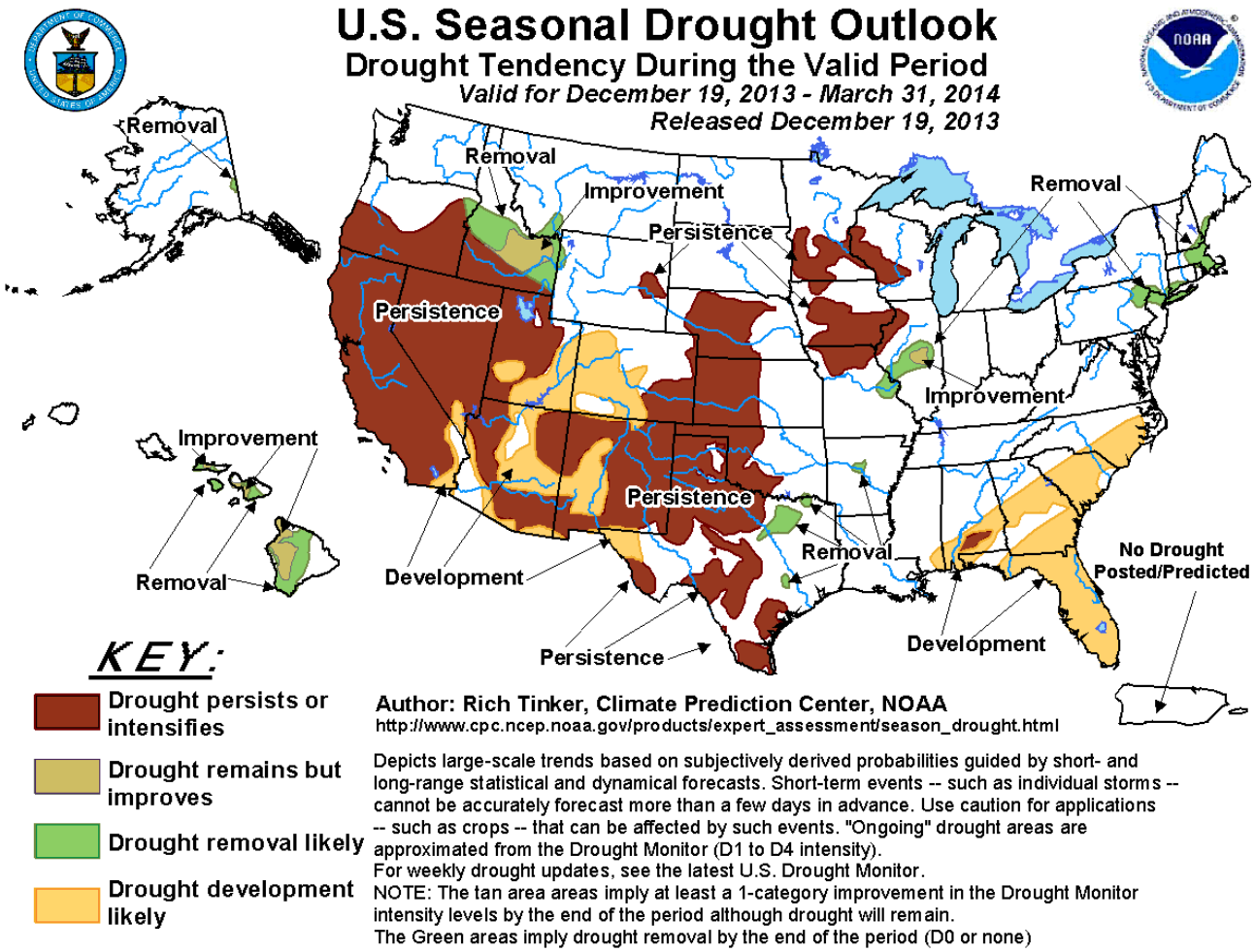

Figure 1.5: The projected progression of drought conditions in the United States from December 19, 2013 to March 31, 2014. The white represents areas where drought is neither present nor projected to occur (Tinker 2013).

the drought has not increased to the high classification that it was in the summer of 2011 (Tinker 2013). In the year of my study the drought was continuing to persist and in May 2014 the drought was increased to D4 once again (Figure 1.6). As the summer progressed the drought conditions decreased to D3 and Texas as a whole had decreased drought (Figures1.7-9).

In order to combat the shortages and drought conditions, the City of Lubbock Water Department has put in place four contingency plans ranging from "mild water shortage" to "emergency water shortage" (City of Lubbock, Texas 2013a). The Mild Water Shortage Contingency Plan has been in place since August 2012 (City of Lubbock, Texas 2013b). The plan specifies that lawns may only be watered twice a week on certain days, only during the early morning and afternoon hours, and no excess water is to pool outside of the yard (City of Lubbock, Texas 2013b). Water restrictions are meant to discourage water overuse and encourage water conservation (Shaw and Maidment 1988, Shaw et al. 1992, Kenney et al. 2004, City of Lubbock, Texas 2013a).

The City of Lubbock has attempted to encourage owners to decrease water used for irrigation by educating the public on smart ways to water, such as when and how much water is best (City of Lubbock, Texas 2013a). The City of Lubbock suggests only 1.5 inches of water to be used on a lawn per week and watering should be done in the coolest parts of the day, before or after the sun is down (City of Lubbock, Texas 2013a, City of Lubbock, Texas 2013b). Similar restrictions enforced Corpus Christi, TX, Los Angeles, CA, and Denver, CO found decreases in water use from 20 to 40% (Shaw and Maidment 1988, Shaw et al. 1992, Kenney et al. 2004) Other strategies for reducing water usage in general include a cash rebate for replacing old appliances like toilets and

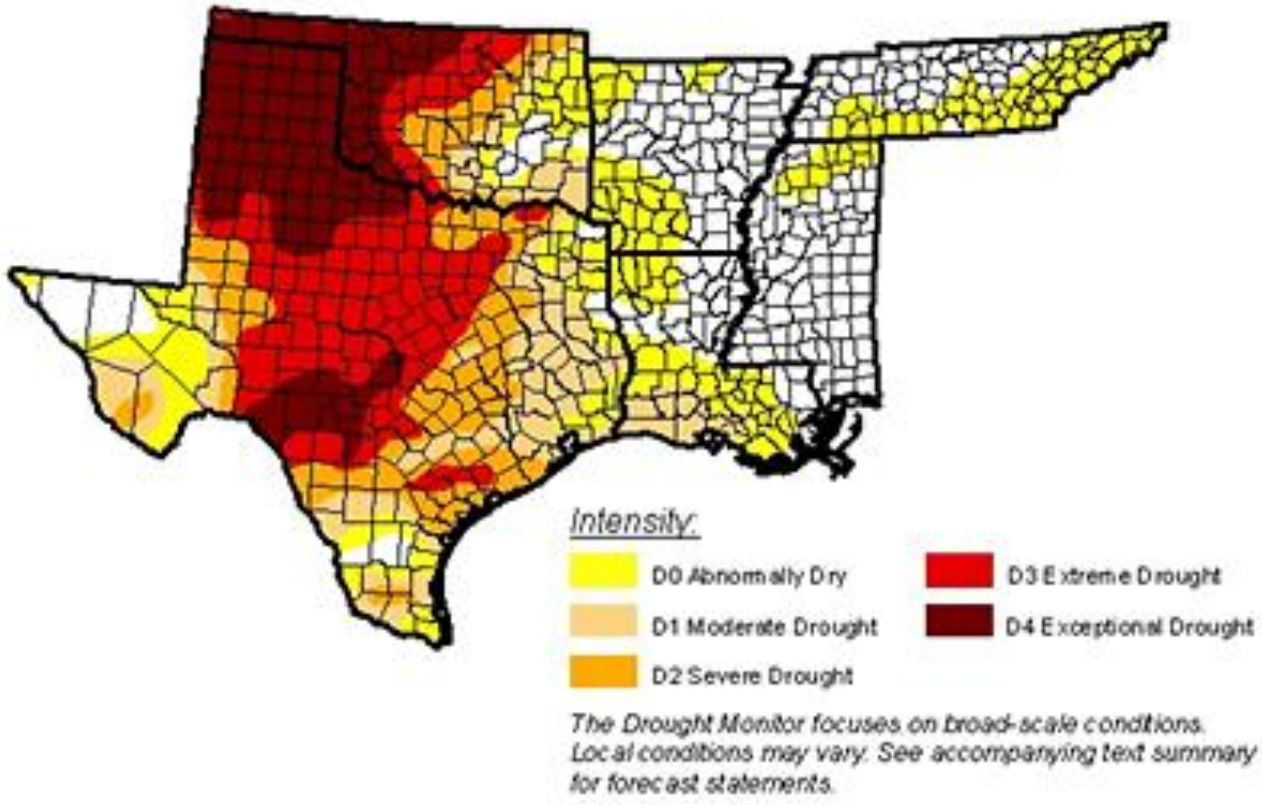

Figure 1.6: A map of the southern region of the United States including Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee representing the drought conditions in May 2014, published by NOAA's U.S. Drought Monitor (Svoboda2014). The bold black lines define state borders, while the thin black lines within the states define counties. The colors rate the drought conditions, and range from light to dark, exhibiting conditions ranging from no drought to extreme drought.

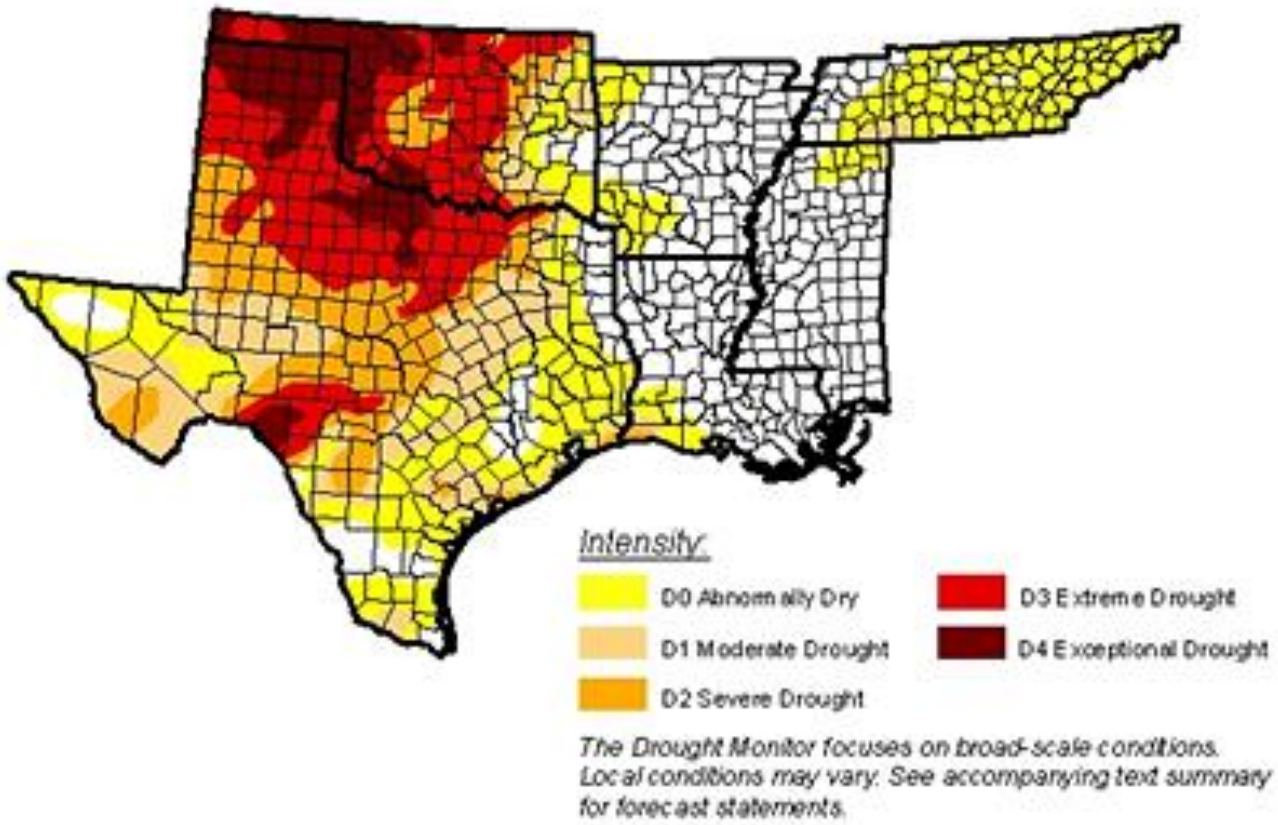

Figure 1.7: A map of the southern region of the United States including Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee representing the drought conditions in June 2014, published by NOAA's U.S. Drought Monitor (Tinker 2014). The bold black lines define state borders, while the thin black lines within the states define counties. The colors rate the drought conditions, and range from light to dark, exhibiting conditions ranging from no drought to extreme drought.

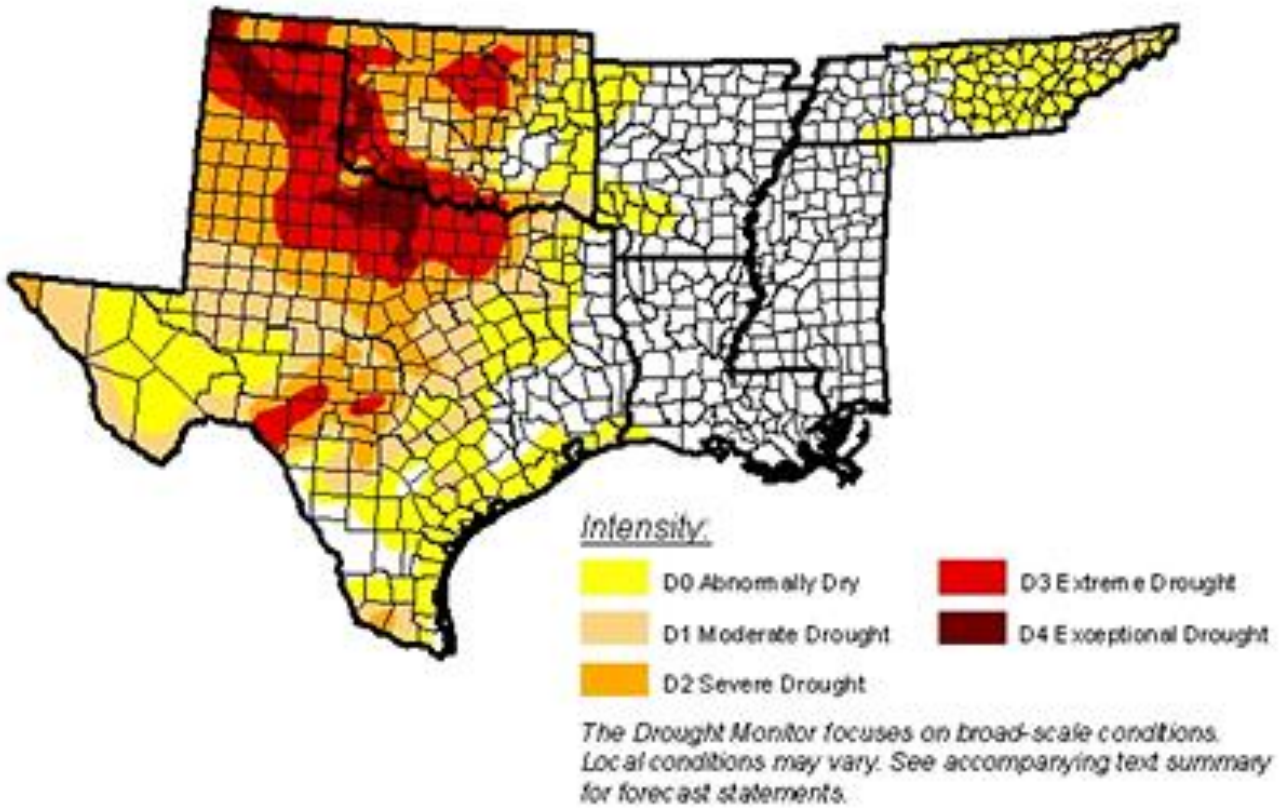

Figure 1.8: A map of the southern region of the United States including Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee representing the drought conditions in July 2014, published by NOAA's U.S. Drought Monitor (Artusa 2014). The bold black lines define state borders, while the thin black lines within the states define counties. The colors rate the drought conditions, and range from light to dark, exhibiting conditions ranging from no drought to extreme drought.

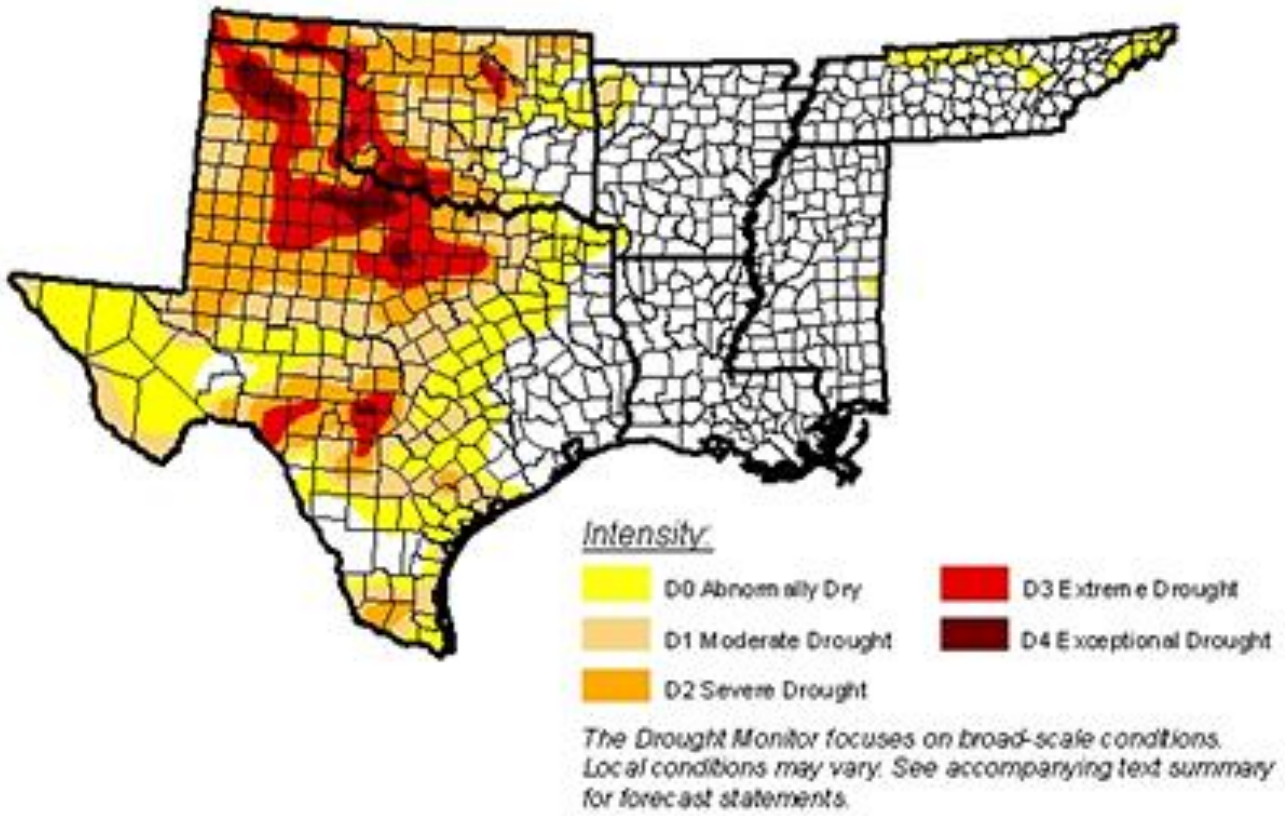

Figure 1.9: A map of the southern region of the United States including Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee representing the drought conditions in August 2014, published by NOAA's U.S. Drought Monitor (Rippey 2014). The bold black lines define state borders, while the thin black lines within the states define counties. The colors rate the drought conditions, and range from light to dark, exhibiting conditions ranging from no drought to extreme drought.

washing machines with more efficient ones and incentives for replacing grass with trees or more drought resistant grass (City of Lubbock, Texas 2013a). The City of Lubbock's Parks and Recreation Department is complying with the drought regulations (S. Gerhart, Park Operations Manager, City of Lubbock, personal communication). The Department also uses a more drought tolerant warm-season grass, Bermuda grass (*Cynodon dactylon*), compared to cool season grasses, such as fescue (*Festuca* spp.), and the parks are centrally irrigated, which has been shown to decrease the amount of water waste (Kenney et al 2004, City of Lubbock, Texas 2013b, S. Gerhart, Park Operations Manager, City of Lubbock, personal communication).

People tend to value proximity to green space and more natural locations, with less development and more native plants and animals (Thompson et al. 1999, Luttik 2000, Jim and Chen 2006, Bark et al. 2009). The closer a house is to a park the higher the selling price is of the house (Thompson et al. 1999, Luttik 2000, Jim and Chen 2006). The proximity of a park provides better and easier access to the park (Thompson et al. 1999, Luttik 2000, Jim and Chen 2006). Even views of parks and water can increase the value of houses, and the further way a house is from one of the two amenities the lower the house price is (Thompson et al. 1999, Luttik 2000). Views of parks or water give an aesthetic advantage, which is desired (Thompson et al. 1999, Luttik 2000). The use of green space may be one of the few ways people in cities can make use of outdoor space (Thompson et al. 1999, Luttik 2000, Jim and Chen 2006).

People also value green spaces that would be associated more with "normal" or "natural" habitat (Bark et al. 2009, Farmer et al. 2013). In Tucson, AZ, people were willing to pay more for houses that were close to large stretches of connected habitat,

diverse vegetation within riparian zones, and open water availability (Bark et al. 2009). The positive correlation between house prices and more natural green space shows that people are willing to pay more for a more natural and connected green space, which can produce an awareness that the natural environment may be an underutilized factor in improving the value of a home (Bark et al. 2009). Specifically, the reason that natural habitat is valued over other green areas is yet unknown, but perhaps natural habitat can be associated with areas outside of a city, containing native plants and animals in a more pristine form, instead of highly manicured and influenced by humans (Bark et al. 2009). Although the reasons people specifically value natural and connected habitat are not known, the trend is visible when looking at house prices (Bark et al. 2009).

Homeowner Types

The reasons behind people valuing environmental factors are interesting topics for both ecologists and economists (Cho et al. 2008, Bark et al. 2009, Farmer et al. 2013). I believe that most people do not live in a sterile environment, devoid of nature but instead most interact with nature every day. Therefore, people value nature differently and labeling the types of people who care about more a natural environment could prove beneficial to urban ecologists and urban planners (Farmer et al. 2013). By identifying the types of people, ecologists and planners can potentially judge citizens care of the environment and areas of the best habitat for urban wildlife (Farmer et al. 2013).

The housing market is an important method of evaluating people's value of the urban environment around them. When evaluating the market, one must consider all of the factors that contribute to the price of the house (M. Farmer, Texas Tech University, personal communication). Relators use the appraisal of a property to make the best

estimate for the price of the house, the sales comparison approach (Grissom and Diaz, 1991). The sales comparison approach is performed by studying the prices of houses that have sold in the same area and have similar house characteristics, for example square footage, lot size, the number of bedrooms, and the number of bathrooms (Grissom and Diaz, 1991). A flaw in the system is that many other factors contribute to the reason someone does or does not buy a house, for example; house "curb appeal", access to parks, school district, curb appeal, etc. (M. Farmer, Texas Tech University, personal communication). Potential homebuyers searching for houses in one neighborhood do not necessarily have the same idea of what is the ideal house to buy (M. Farmer, Texas Tech University, personal communication).

Farmer et al. (2013) introduced a new concept into the Lubbock market by trying to identify "types" of homebuyers to better understand the reason someone does or does not buy a house and if different "types" were willing to pay more for increased bird diversity and tree coverage. Two homeowner types were identified by surveying homeowners and then grouping homeowners, primarily by education level, income, and age of the homeowner (Farmer et al. 2013). Both of the identified homeowner types value the ecological factors, bird diversity and tree coverage, but one valued the factors slightly higher than the other (Farmer et al. 2013). The idea that different "types" of homebuyers will value aspects of a home differently is an important concept for realtors when selling and pricing houses (M. Farmer, Texas Tech University, personal communication). Homebuyers evaluate different properties in different ways depending on which homeowner type they identify with more (M. Farmer, Texas Tech University, personal communication).

Urban Wildlife

The amount of urban wildlife research has been increasing over the last 25 years (Magle et al. 2012). Magle et al. (2012) performed a review to track the amount urban wildlife research that was published in 16 journals dating from 1971 to 2010. Pre-1991 only 0.01% of all published articles was related to urban wildlife, in the selected journals (Magle et al. 2012). Since 1991 the percentage of urban wildlife journal articles compared to the total number of articles has increased, with 0.17% of articles focusing on urban wildlife related research between 1991 and 2000 and then increasing to 0.55% between 2000 and 2010 (Magle et al. 2012). The most urban wildlife research has focused on birds (42.73%) and mammals (38.17%) while studies on arthropods (11.38%), herptiles (9.45%), and fish (3.32%) have been studied less (Magle et al. 2012). Most likely many of urban wildlife articles focused on species "whose presence, absence or abundance reflects a specific environmental condition," or indicator species (Niemi and McDonald 2004, Jaffe and McDonough 2012).

Indicator species can help us with identifying where quality habitat is within the urban environment. Niemi and McDonald (2004) list the qualifications of a good indicator species as one that is abundant, easy to find and identify, charismatic, is affected by disturbance, inexpensive to research, and easy to measure. Although other fauna can be used, birds are some of the most commonly researched wildlife in urban environments because birds fulfill most, if not all, of the requirements for an indicator species and birds are good models to evaluate the environmental value of an area (Niemi and McDonald 2004, Magle et al. 2012).

Urban Birds

A unique aspect of researching birds in an urban environment is the fact that the number and biomass of birds usually grows with increased urbanization (Beissinger and Osborne 1982, Mills et al. 1989, Crooks et al. 2004). Although more birds may be found, the diversity and number of native species usually decreases, especially in highly urbanized areas (Beissinger and Osborne 1982, Mills et al. 1989, Crooks et al. 2004). Therefore bird diversity or specific bird species are typically researched rather than pure bird numbers (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006).

Urban bird species can be categorized in to three groups: urbanized birds (exploiters), partially urbanized birds (adaptors), and urban avoiders (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Exploiter birds are birds that thrive in urban environments and whose populations increase in more developed areas (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Exploiter birds are often exotic species, brought in from historically urban countries in Europe, but can also be very common native species (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Adaptor birds are bird species that take advantage of developed areas, and whose populations increase with slight development but then drops off again when an area is highly devolved with little vegetation (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Adaptor birds are usually native species that can be found in more natural habitats and can also take advantage of

urban areas (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Urban avoiders are birds that rarely, if ever, enter the urban habitat (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Avoider birds thrive in native habitats and either do not show up in the urban environment, or are only located on the edge where native habitat meets urban habitat (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006).

A common way of researching urban bird diversity is to examine the gradient from natural habitat to highly urbanized habitat, traditionally from the outskirts of the city to the city center, respectively (Blair 1996, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005). The habitat gradient plays an important role in understanding where and the reason birds are expected (Blair 1996, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005). Bird diversity increases in slightly developed areas, which can occur when the three classes of birds interact (Blair 1996, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005). Exploiters use the slightly developed land because urban influence still exists, adaptors take advantage of the mix between the urban and the natural and avoiders are found on the edge because native habitat still exists but just not as much as undeveloped areas (Blair 1996, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005).

A different place to examine bird diversity is within urban green spaces or parks (Blair 1996, Fernández-Juricic 2000, Fernández-Juricic 2001, White et al. 2005, Kinzig et al. 2005, Sandström et al. 2006). Generally birds make use of parks and other green

spaces, but the size and age of the park often influence bird diversity (Blair 1996, Fernández-Juricic 2000, Fernández-Juricic 2001, White et al. 2005, Kinzig et al. 2005, Sandström et al. 2006). However, in Lubbock, TX, the proximity of a park did not influence the diversity of the birds observed (Farmer et al. 2013). The findings of Farmer et al. (2013) regarding park proximity influence were likely affected by Lubbock park composition of large open grass areas with highly trimmed trees and vegetation in an urban environment plays an important role in bird habitat choice (Green and Baker 2002, White et al. 2005).

Urban Habitat for Birds

Vegetation highly influences bird diversity, especially varied vegetation height (MacArthur and MacArthur 1961). The correlation happens because different types of birds forage and breed in different heights of vegetation; therefore the more varied the vegetation the more attractive the area is for multiple types of bird species (MacArthur and MacArthur 1961, DeGraaf et al. 1985, Marzluff and Ewing 2001). The height variation concept is similar to the edge effect increasing the diversity of birds in a natural system (Blair 1996, Fernández-Juricic 2001, Hansen 2005,). Cotton fields and mesquite-shrub habitat dominate the surrounding area outside of Lubbock, TX. The low vegetation height variety means that the city provides an area where the variation in vegetation height is larger than the surrounding habitat (Correll and McCoy 1979).

Although many cites might have the option to save or cut down trees when expanding into the natural habitat, Lubbock, TX is a unique area in which very few trees are found in the native landscape and therefore Lubbock, TX introduces a new habitat full of trees (Mennis 2006, Farmer et al. 2013). Denver, CO, is similarly surrounded

mostly by shrub land, and older houses in highly residential areas had bigger and more vegetation because time is needed for vegetation to grow (Mennis 2006). The large change between the city vegetation and surrounding habitat is consistent with what is seen in Lubbock, TX when looking at tree numbers and tree sizes within the neighborhoods (Farmer et al. 2013, personal observations).

Much of the vegetation found in urban habitat is made up of patches of grass covering front yards and parks in most cities including Lubbock, TX (Breuste 2004, Farmer et al. 2013). The open grass habitat does have some value to birds (Falk 1976, Beissinger and Osborne 1982). Ground feeding and flocking species such as Great-tailed Grackles (*Quiscalus mexicanus*), and House Sparrows (*Passer domesticus*) can use sections of open grass because grass provides easily-accessible and concentrated food sources (Falk 1976, Beissinger and Osborne 1982). The openness of grass-covered lawns also allows birds to easily spot and escape predators (Falk 1976, Beissinger and Osborne 1982). However, open lawn environments are not ideal for a high diversity of birds because no vegetation variation exists with places to hide or roost (MacArthur and MacArthur 1961, Beisinger and Osborn 1982, Marzluff and Ewing 2001).

Urban Birds in Texas

Birds species found in Lubbock, TX are very different from the species found in native habitats outside of Lubbock, TX (Thompson et al. 2009, Farmer et al. 2013). Grasshopper Sparrows (*Ammodramus savannarum*), Western Meadowlarks (*Sturnella neglecta*), Cassin's Sparrows (*Peucaea cassinii*), Savannah Sparrows (*Passerculus sandwichensis*), and Horned Larks (*Eremophila alpestris*) are the most common birds in the non-urban lands enrolled in the Conservation Reserve Program grassland fields in the

Southern High Plains (Thompson et al. 2009). The Western Meadow Lark is the only species of Thompson and other's (2009) common species that was observed in the previous study and only a few were seen during the entire study (Farmer et al. 2013, raw unpublished data). In contrast, only 2 species, the Great-tailed Grackle and Mourning Dove, from the Farmer et al. (2013) study's A and B bird groups were observed by Thompson et al. (2009), which suggests little overlap between urban and non-urban species in Lubbock, TX. The lack of bird species interaction is consistent with other arid or semi-arid environments in which the landscape surrounding the cities is lacking or even devoid of trees (Guthrie 1974, Emlen 1974, DeGraaf and Wentworth 1986, Mennis 2006).

Native birds are usually associated with native vegetation, with one reason being that native insect species, an important food source, are also attracted to native vegetation (Mills et al. 1989). Many of the tree species in Lubbock, TX are non-native with only 17 native tree species of the 45 tree species I have identified in Lubbock, TX neighborhoods (Allison et al. 1997). Many of the native tree species are associated with areas with water, such as along streams or floodplains (Allison et al. 1997). No evidence shows whether Lubbock, TX birds show a partiality to native or non-native trees, but Lubbock, TX birds have shown preferences for increased vegetation coverage (Farmer et al. 2013).

Farmer et al. (2013) performed a study in 2009 focusing on bird diversity compared to house prices and tree coverage, observing houses in specific neighborhoods in Lubbock, TX. Farmer et al. (2013) identified recently sold houses, from 2008-2009, in 17 different neighborhoods in Lubbock, TX. Data were collected on the sold price of each house and other house characteristics including lot size, house size, garage existents,

and location of house within a neighborhood (Farmer et al. 2013). The neighborhoods studied consisted of primarily affluent, white home-owners (M. Farmer, Texas Tech University, personal communication). Each house was associated with a bird point count survey, performed near the house but not necessarily at the house. Tree coverage information collected using Google Earth (Google, Mountain View, CA) was also analyzed for each individual house (Farmer et al. 2013). By using different weighted variables, Farmer et al. (2013) found that bird diversity, along with other house characteristics and tree coverage, had the potential to predict house prices in an urban neighborhood.

I expanded on the research because some draw backs were found in the previous study (Farmer et al. 2013), which limited the scope of the analyses and conclusions drawn. First, the studied houses were only in primarily white, affluent neighborhoods (M. Farmer, Texas Tech University, personal communication). Second, the bird surveys were not usually performed at the exact locations of sold homes, but instead at nearby locations due to ease of access (M. Farmer, Texas Tech University, personal communication). Lastly, vegetation was analyzed by overall coverage using satellite imagery from Google Earth (Google, Mountain View, CA), rather than by height variation or species diversity, which are both valuable aspects of bird habitat choice (McArthur and McArthur 1961, Sandstrom et al. 2006, Farmer et al. 2013). My study builds upon the previous study by expanding the scope of the project to include lower income and more diverse neighborhoods, and by expanding data collection through performing bird surveys at the houses in question and collecting detailed vegetation data.

My Study

In my study, I focused on bird diversity, specifically at houses in neighborhoods in Lubbock, TX, because much of the habitat chosen by birds is located in residential areas where vegetation structure varies (Marzluff and Ewing 2001, Farmer et al. 2013). By combining ecological surveys (vegetation and birds) and economical house values, I found a way to assess an area looking both at the ecological and economic value of a house. My ultimate goal was to make suggestions to urban planners and landscape architects a suggested landscape, which will both increase the home value and provide better habitat that encourages a higher diversity of birds. I identified the value people placed on the environment in terms of their backyard and therefore will be able to suggest ways in which landscape architects and relators could potentially cater more to those specific types of people.

Goals and Objectives

The amount that people value the environment is largely unknown when considering a house scale, without including "green space" factors. My overall goal was to expand the knowledge of the urban ecosystem both by evaluating people's value of wildlife habitat at a house scale and birds' use of the urban landscape within neighborhoods. My study had three main objectives. The first was to determine the association between bird richness and vegetation in urban areas, using trees species diversity, tree density, and tree height diversity. Second, I determined bird richness and vegetation differences across and between neighborhoods in Lubbock. Last, I identified the way house characteristics, bird richness, and vegetation affect home prices.

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CHAPTER II
VEGETATION PREFERENCE OF BIRD SPECIES AND SPECIES GROUPS IN URBAN NEIGHBORHOODS

Introduction

Urban areas are increasing in the United States and across the world. About 80% of the United States' population now lives in urban areas, and the urban percentage of population is expected to increase to 90% by 2050 (United Nations 2012). With the increasing human population, the size of urban areas is also increasing and encroaching into areas that are thought to be better for wildlife, native habitat and cropland (United Nation 2012, Magle 2012). The unique urban environment may provide a different type of wildlife habitat than the areas wildlife traditionally use (Sukopp 1998). In the last 25 years, the amount of research articles being published about urban ecology has increased, focusing on wildlife use of urban areas as new habitat (Sukopp 1998, Magle et al. 2012).

Much of urban ecology research conducted has been dedicated to birds because the presence and abundance of some bird species can be used as an indicator of habitat quality, also known as indicator species (Niemi and McDonald 2004, Jaffe and McDonough 2012, Magle et al. 2012). Indicator species are typically common, easy to see and identify, affected by disturbance, easy to measure (count), inexpensive to research, and charismatic (Niemi and McDonald 2004). In urban areas, birds are especially useful as indicator species because birds are not as restricted in movement as other wildlife that might be deterred by roads, fences, or people. Although birds tend to avoid manmade objects, they can still move freely throughout the landscape, choosing preferred habitat (McClure et al. 2013). Urban birds are separated into three groups: exploiters, adaptors, and avoiders. Exploiter bird species (European starlings (*Sturnus*

vulgaris), house sparrow (*Passer domesticus*)) are birds that are very common, often non-native, and are found most in the city center. Exploiter birds usually need urbanization to survive so the less urbanized an area is the less likely exploiter birds will be seen, hence the reason why they are most common in the areas of highest urbanization. Adaptor bird species (blue jay (*Cyanocitta cristata*), American robin (*Turdus migratorius*)) are common in the urban environment and are native species. Adaptor birds have adapted to live in the urban environment but can still be readily found in the more native environment surrounding an urban area, therefore adaptor birds will are more common near the outskirts of the city where there is more native habitat then in the highly urbanized interior of the city. Avoider bid species (southern meadowlark (*Sturnella neglecta*), killdeer (*Charadrius vociferous*)) are rare and mostly found on the outskirts in an urban area. Avoider birds avoid urbanization and therefore the only areas where avoider birds are found are where urbanization meets native habitat which is in the outskirts of the city where native habitat is only a short distance away.

Vegetation is highly correlated with bird diversity on two levels, habitat stratification and vegetation species (MacArthur and MacArthur 1961, Beissinger and Osborne 1982, Mills et al. 1989, Rottenborn 1999, Marzluff and Ewing 2001). Places with native vegetation have an increased diversity of birds compared to areas with more non-native vegetation (Beissinger and Osborne 1982, Mills et al. 1989, Rottenborn 1999, Marzluff and Ewing 2001). The correlation between native birds and vegetation is partly due to native birds eating native insects, which commonly feed on native trees rather than non-native trees (Mills et al. 1989). Semi-arid landscapes, such as exist in Lubbock, TX, have few native trees and the surrounding area mostly consists of shrublands and

agricultural fields with few trees existing outside cities and towns (Mennis 2006, Farmer et al. 2013). In a preliminary study (Leuenberger 2014, unpublished data), only 17 of the 45 tree species found in Lubbock, TX were native to the region (Allison et al. 1997). The lack of native trees is not surprising because most, if not all, trees found in Lubbock, TX primarily survive on supplemental water that homeowners put on their yards. Although non-native vegetation might not be ideal, because more native birds might make use of native vegetation, birds can use non-native vegetation for nesting, perching, and food (Anderson 1979, Mills et al. 1989).

Vegetation also effects bird diversity due to variation in habitat height (MacArthur and MacArthur 1961). Vegetation stratification benefits bird diversity because different bird species require different types of vegetation to forage, hide, and build nests. Bird species richness increase with multiple layers of vegetation, because multiple species can make use of different layers (MacArthur and MacArthur 1961, DeGraaf et al. 1985, Marzluff and Ewing 2001). Both vegetation stratification and vegetation origin make Lubbock, TX ecologically unique compared to the surrounding area. Differences between urban and adjacent areas are further exhibited by the many birds found in Lubbock, TX that are rare or not found on the surrounding landscape and vice versa (Thompson et al. 2009, Farmer et al. 2013).

Vegetation in cities primarily consists of grass-covered yards and parks with trees dispersed throughout (Breuste 2004, Farmer et al. 2013). Parks can be used by residents for recreation, but birds are a common sight also (Blair 1996, Fernández-Juricic 2000, Fernández-Juricic 2001, White et al. 2005, Kinzig et al. 2005, Sandström et al. 2006), because of the bird use, parks and green space are common areas for birds to be studied

in urban environments. However, Lubbock, TX parks do not have the same effect on bird diversity as parks in other places because many of the parks in Lubbock, TX are vast areas of green grass with a few well-trimmed trees, as compared to other parks studied where green areas and parks resemble the environment outside of the city with larger forest trees and native vegetation (Blair 1996, Fernández-Juricic 2000, Fernández-Juricic 2001, White et al. 2005, Kinzig et al. 2005, Sandström et al. 2006, Farmer et al. 2011). Therefore, my focus was in the residential areas of Lubbock, TX where increased concentrations of trees exist and vegetation structure varies (Marzluff and Ewing 2001, Farmer et al. 2013). By comparing different vegetation factors to individual bird numbers, species, and diversity I found what makes up suitable bird habitat in Lubbock, TX.

Many research articles focus on certain aspects of urban ecology including the gradient from outskirts to city center, green space utilization by wildlife, and people's feelings about wildlife in the area ((Blair 1996, Thompson et al. 1999, Luttik 2000, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005, Jim and Chen 2006, Bark et al. 2009). However, not much about the way birds use different vegetation within neighborhoods and at specific houses is known. My work focused on the vegetation in people's own back and font yards affecting the birds that are found there.

Methods

I selected sites using data on recently sold houses I obtained from relators in neighborhoods throughout Lubbock, TX (Perez-Ruiz 2014). Data on recently sold houses collected in 2009-2010 on the west side and 2012-2013 on the east side of Lubbock, TX

(Farmer et al. 2013) (Figure 2.1). Each house was considered a study site (study house). I performed a bird survey and vegetation survey at each study house.

Bird surveys were conducted during the summer months (May-August 2014 and May 2015) to study breeding birds, because breeding birds sing more than winter birds and use the area more so then spring and fall birds that might be migrating through the area (Biddy et al. 1992). Bird surveys were performed in the front of each study house between 30 minutes before sunrise and 3 hours after sunrise, in order to capture birds singing. General weather data were collected at the beginning of each survey (wind speed, air temperature, and cloud cover; Appendix A). I identified the bird species and sex, and estimated the distance of every bird I heard and/or saw for five minutes, pausing for vehicles or people passing to avoid any noise disturbance in the surveys (Bibby et al 1992). I then grouped the bird species into the three urban bird types: exploiters (very common, non-native), adaptors (common, native), and avoiders (rare and found mainly on the outskirts of a city). I focused on the richness of birds (the number of species found) as opposed to abundance (the number of individual birds) because of the training purposes and the difficulty of estimating distances in an urban environment.

At each house, I surveyed vegetation in two ways at each site, one at the individual house and one at the five houses surrounding the house (Figure 2.2) when the trees were leafed out, during Spring and Summer (April-October 2014 and in April-May 2015). The two spatial levels were examined in case the study house did not resemble the rest of the neighborhood. At both levels, vegetation data were collected, including information regarding upkeep, ground cover, vegetation layers (canopy), number of trees, and tree species richness (Table 2.1). All trees were counted, and species were identified

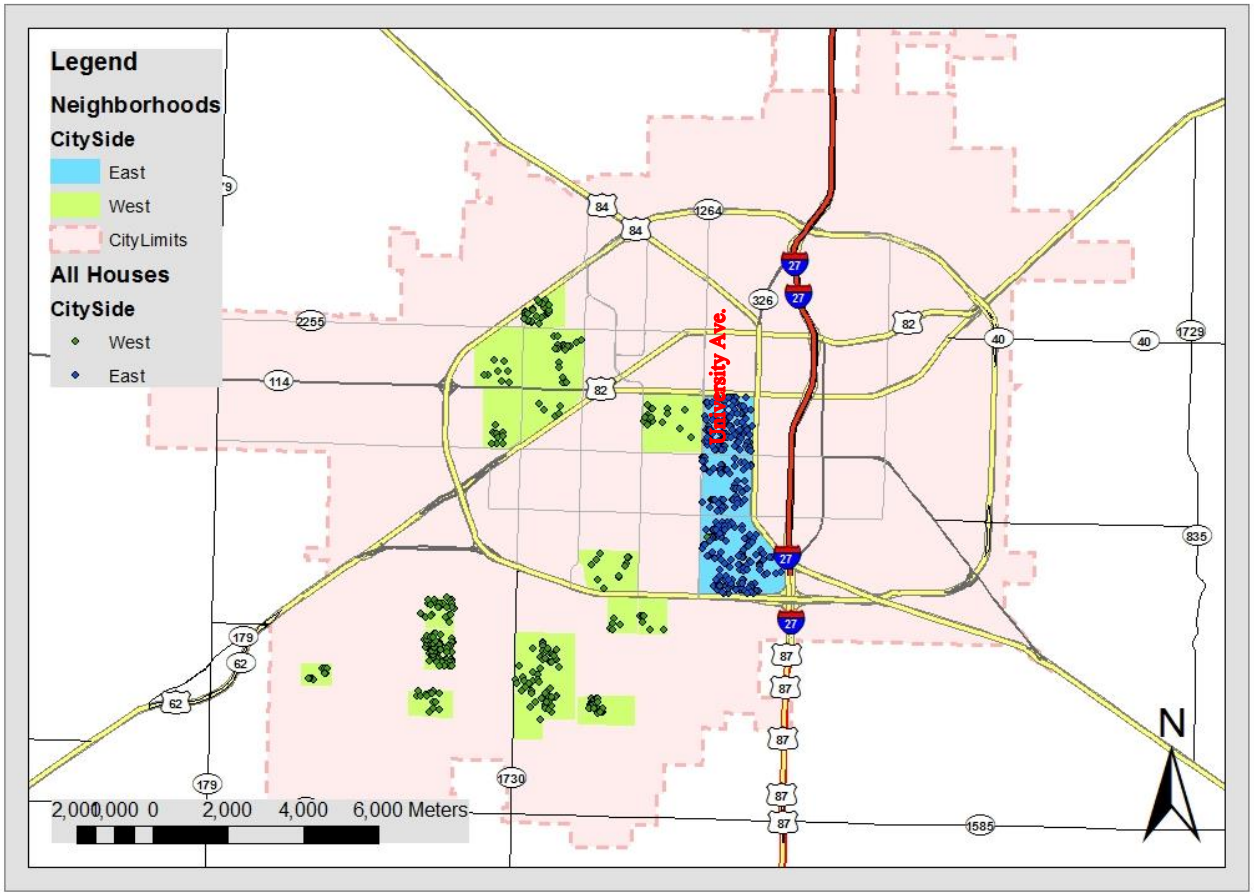

Figure 2.1. Map of Lubbock, TX, with the city limits highlighted in pink and major roads are labeled. Each site is represented by a point, green being on the west side and blue being on the east side of Lubbock. Green polygons are neighborhoods west of University Avenue (labeled in red) and blue polygons are neighborhoods east.

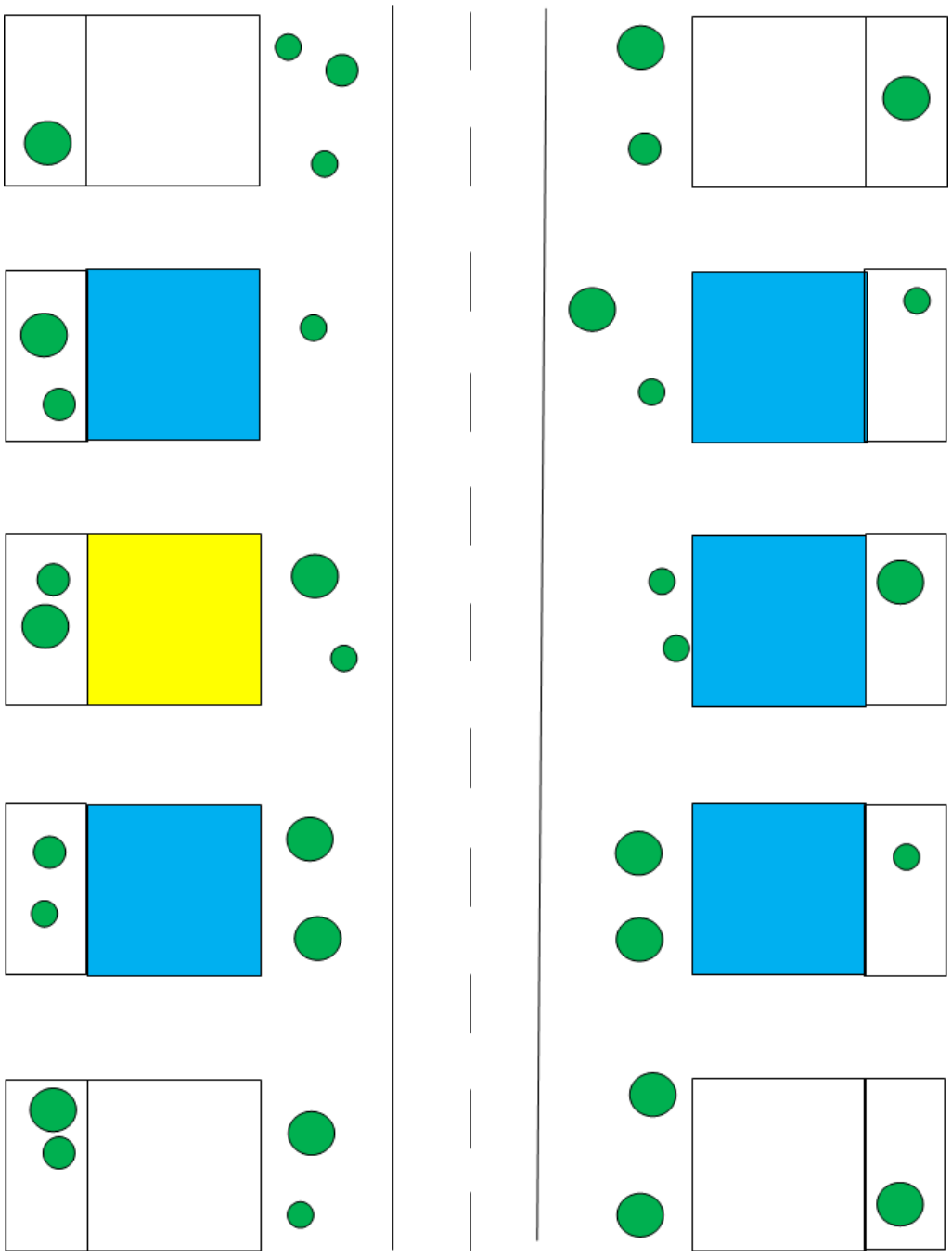

Figure 2.2: Example diagram of an aerial street view of survey points. The yellow block represents the recently sold house, where the "house" vegetation protocol was performed. The blue blocks represent the other five houses that make up the six-house block where the "neighbor" vegetation protocol was performed. The green circles represent trees, the other four white boxes on the top and bottom are other un-surveyed houses on the street, and the small rectangles on the back of each block represent fenced-in backyards.

Table 2.1: The projects vegetation variables with vegetation category, name of variable, description of variable, and the units of the variable.

Vegetation Variable Type	Variable Title	Description	Units of Measurement
Yard upkeep	Upkeep	A judged estimate on how well the front yard was manicured	Scale from 1 to 3 1 = Very manicured 2 = Medially manicured 3 = Completely wild
Ground cover	Non-vegetation	The amount of the front yard that is covered by concrete, dirt, rocks and AstroTurf.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Ground cover	Grass	The amount of the front yard that is covered by grass.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Ground cover	Other vegetation	The amount of the front yard that is covered by ivy, weeds, and other short vegetation.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Vegetation layers under 9' (Understory cover)	House 4”-2’ Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation

Table 2.1 Continued

Vegetation layers under 9' (Understory cover)	House 4"-2' Layer Coverage	The amount of the vegetation that is in the height range of ground to knee (4"-2')	"-" =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%
Vegetation layers under 9' (Understory cover)	House 2'-5' Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation
Vegetation layers under 9' (Understory cover)	House 2'-5' Layer Coverage	The amount of the vegetation that is in the height range of knee to shoulder (2'-5')	"-" =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%
Vegetation layers under 9' (Understory cover)	House 5'-9' Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation
Vegetation layers under 9' (Understory cover)	House 5'-9' Layer coverage	The amount of the vegetation that is in the height range of shoulder and roof (5' to 9')	"-" =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%

and categorized in one of three height classes (<10', 10-20', and >20') in order to determine the existence of layers of understory vegetation and the relative size and coverage of the trees (Appendix B).

Analysis

I used ArcGIS (ESRI 2015) to visually assess whether obvious trends were visible in vegetation and bird species richness. I used the spatially identified variables to develop models and statistically observed trends in species groups using R studio (RStudio 2014) to conduct simple linear regressions and multiple logistical regression models to assess the correlations between vegetation and birds in Lubbock, TX. I compared bird richness by group (exploiters, adaptors and avoiders) and presence/absence of specific adaptor species against vegetation diversity, upkeep, cover, and canopy. I chose the American robin, barn swallow (*Hirundo rustica*), blue jay, northern mockingbird (*Mimus polyglottos*), and western kingbird (*Tyrannus verticalis*) as adaptor birds to further analyze because they are common but are not found everywhere, making it possible to associate vegetation to the presence or absence of the species. I used a binomial distribution when analyzing bird species presence. For species richness regression models, I applied a Poisson distribution to account for any abnormal distribution in count data, as in most count data I had many zeros and therefore my data was not normally distributed. I performed several multiple linear regression models and chose models that were biologically relevant for each species based on the different vegetation data contributing to the model. I then performed a Chi-square goodness of fit test to assess the difference between the best regression equations and a model with no predictors, in which the regression equation was the intercept.

Results

I visually examined my data in ArcGIS (ESRI 2015) and found no instances where individual species and species groups were completely excluded from a neighborhood (Figure 2.3-2.10). I observed several spatial trends in vegetation data (Figure 2.11-2.14), and the age of study house (year the house was built) (Figure 2.15). I found that exploiter bird richness increased with house age (Table 2.2). Adaptor bird species richness increased with increased front yard maintenance, non-vegetative ground cover, and understory coverage (Table 2.2). Finally, avoider bird richness decreased with house age and houses with large trees (greater than 20 feet high) but increased with understory coverage (Table 2.2). In short, both exploiter and avoider birds were affected by the age of the house, which could be due to the location of the house within the city, while both adaptor and avoider bird richness increased with understory coverage.

After identifying definite trends in the bird group data, I observed trends in the individual species. In general, I found similar trends in the presence and absence of the five focal adaptor species, to that of the overall adaptor species group, with all the bird species being affected by level of upkeep at the house, except the northern mockingbird (Table 2.3). However, the western kingbird was negatively associated yard maintenance unlike the overall adaptor bird model. On the other hand, all of the bird species were also associated with the age of the house except blue jays, while the age of the house did not affect the overall adaptor model. Outside of the age and upkeep of the house the species were influenced by several other vegetation variables including the amount cement or dirt

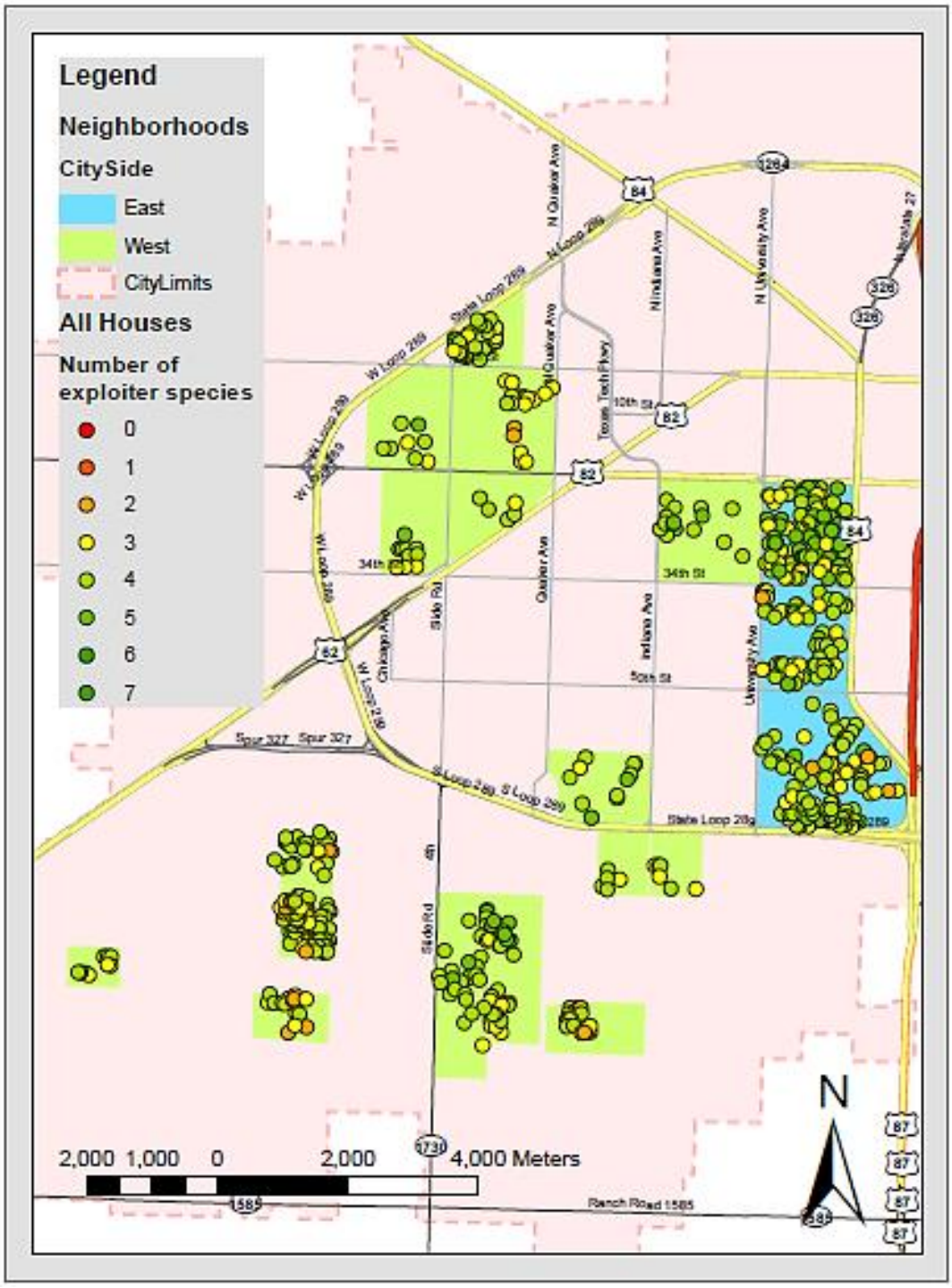

Figure 2.3: Exploiter bird species richness (very common in urban areas) with each point representing one site. Exploiter bird richness with a gradient from red (0 species seen) to green (7 species seen). Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

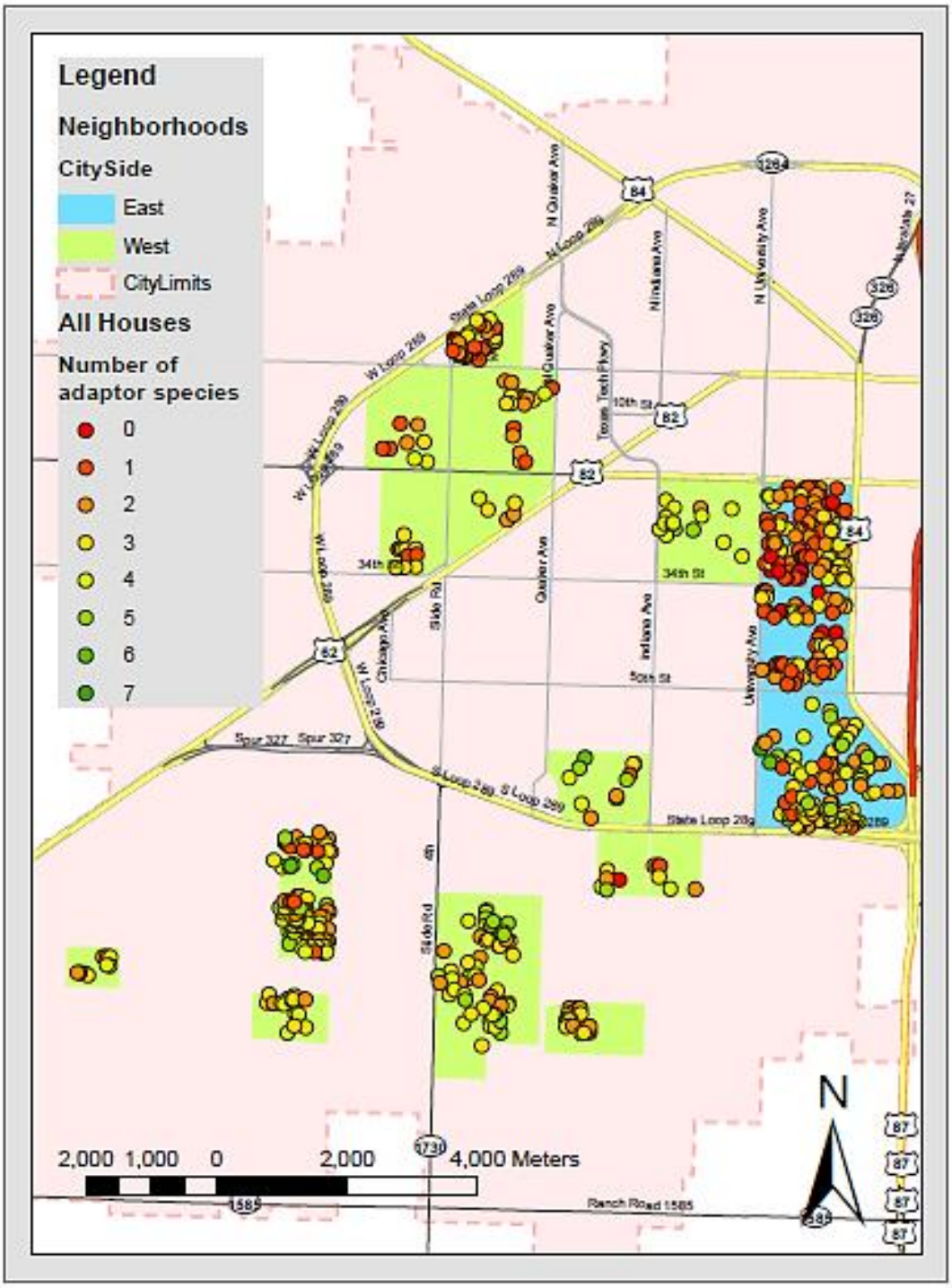

Figure 2.4: Adaptor bird species richness (common and selective) with each point representing one site. Adaptor bird richness with a gradient from red (0 species seen) to green (7 species seen). Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

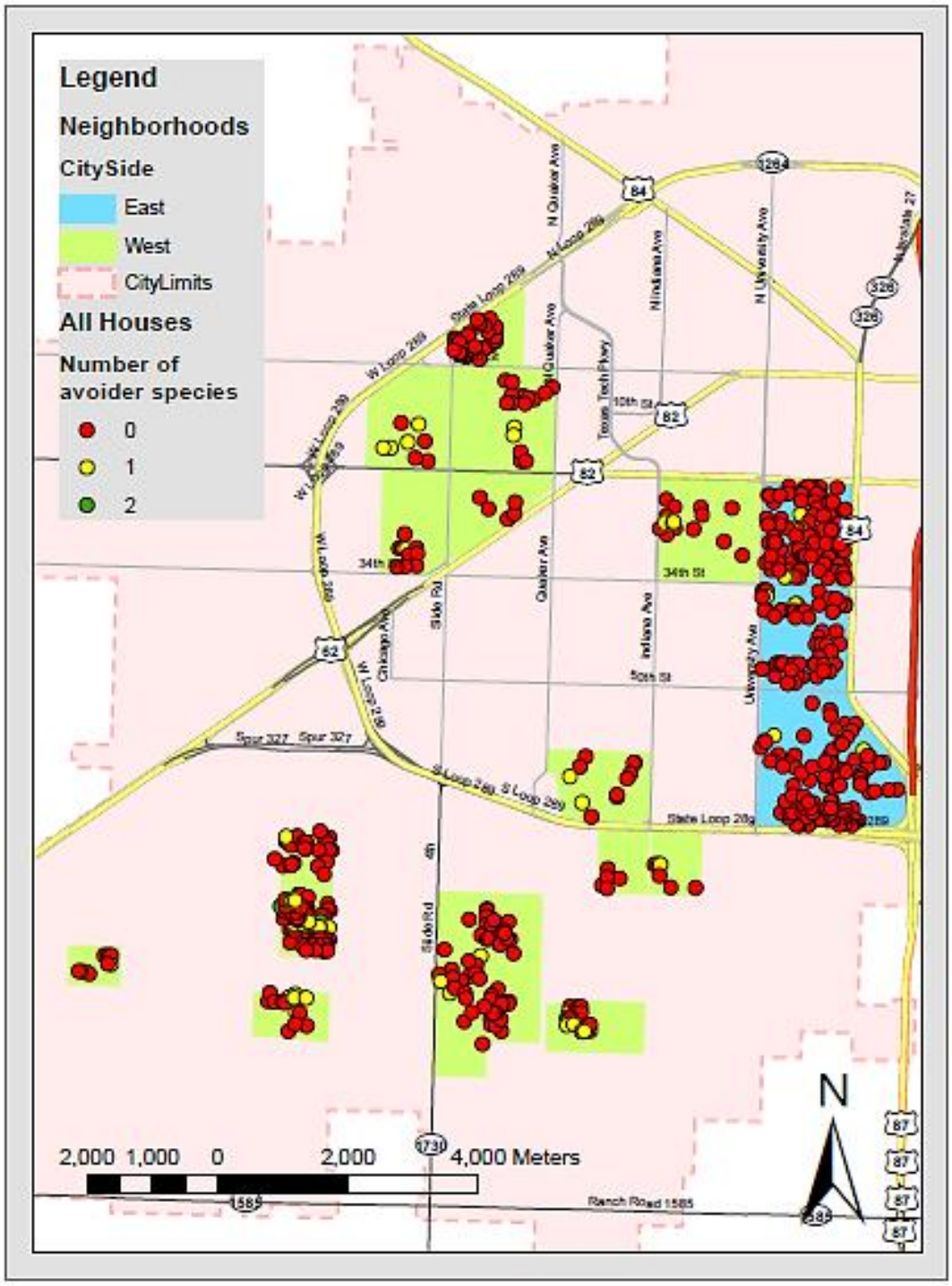

Figure 2.5: Avoider bird species richness (rare and on outskirts of urban areas) with each point representing one site. Avoider bird richness with a gradient from red (0 species seen) to green (2 species seen). Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

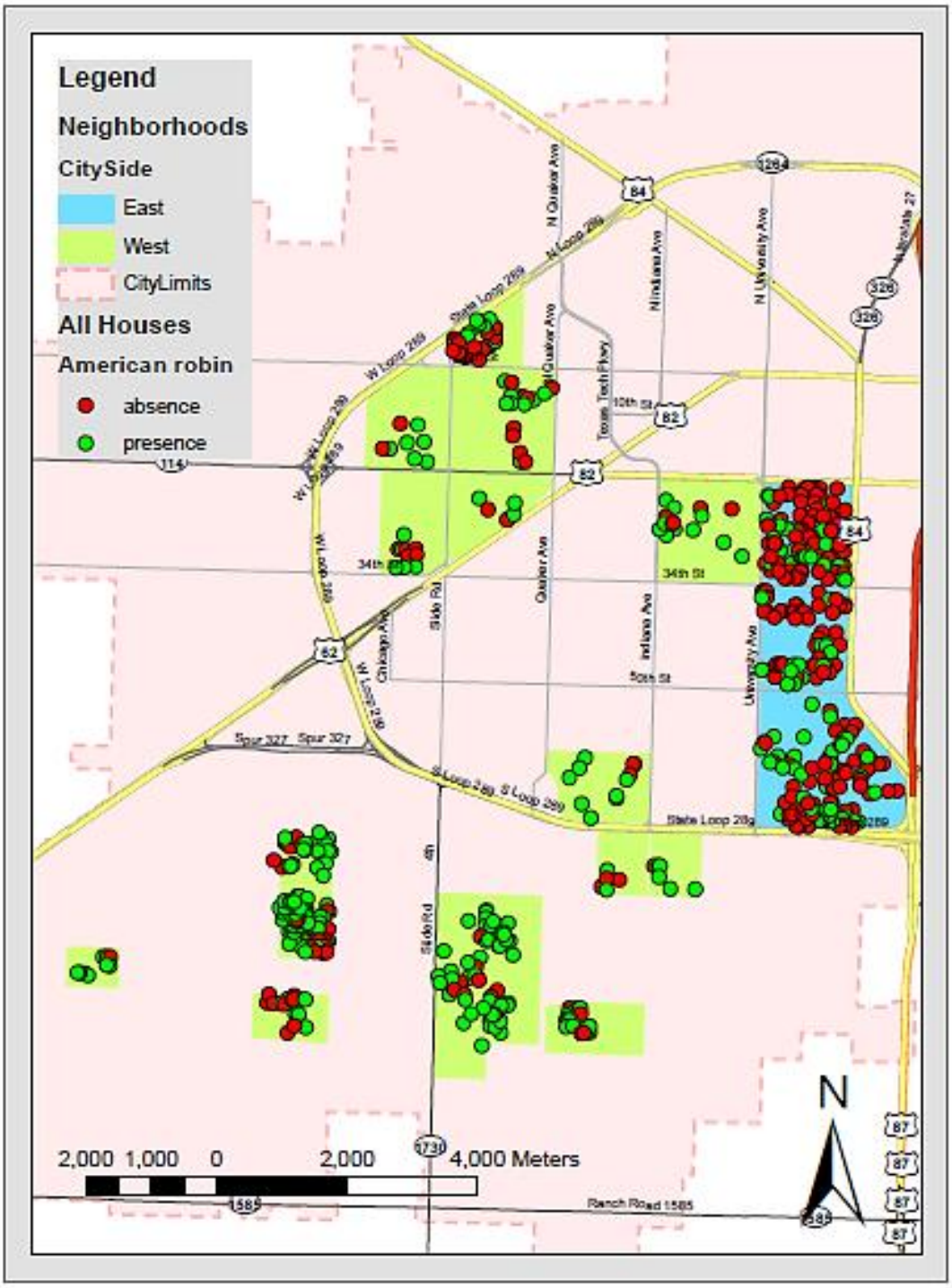

Figure 2.6: Presence (in green) and absence (in red) of American robins (*Turdus migratorius*) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

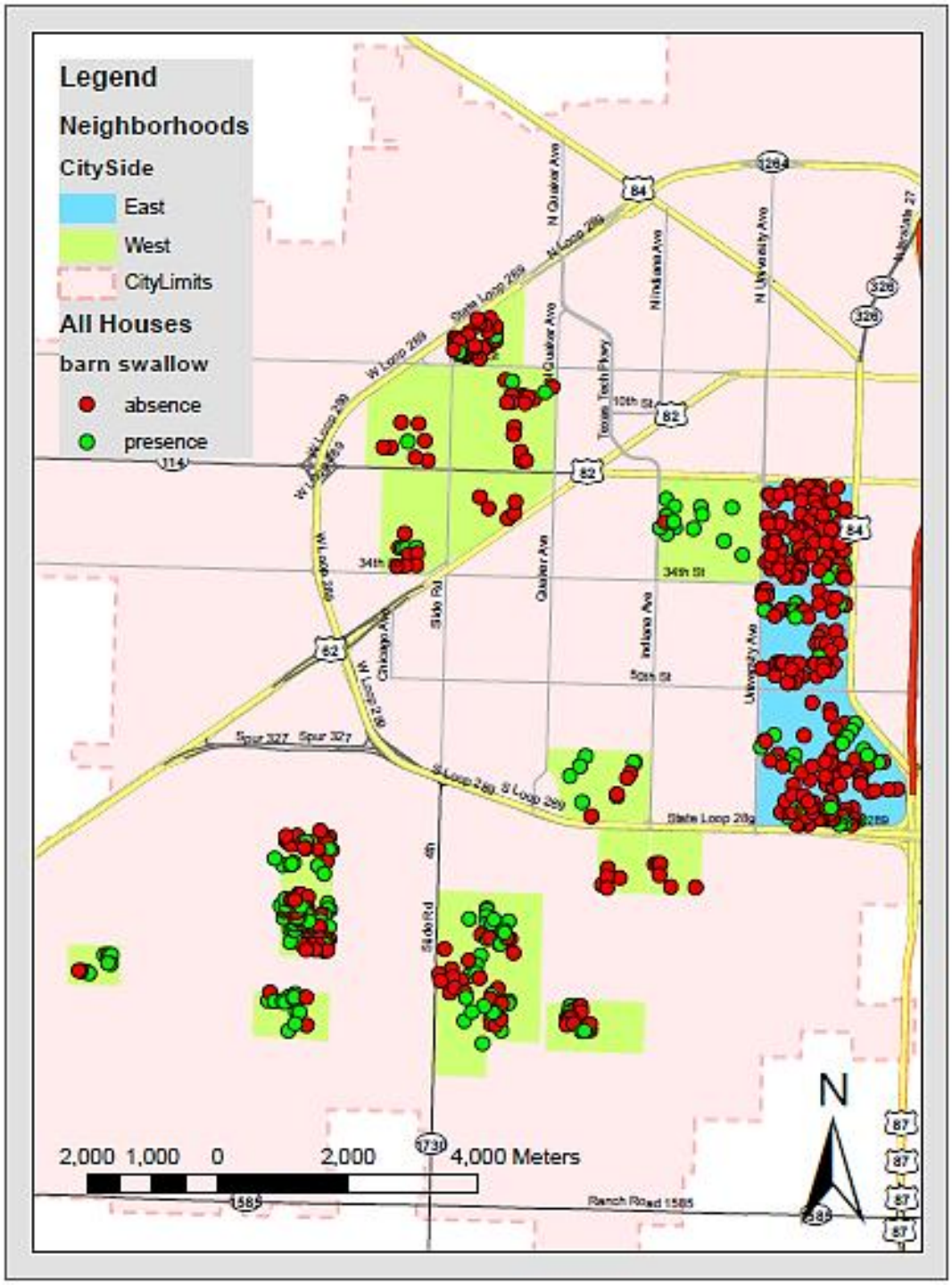

Figure 2.7: Presence (in green) and absence (in red) of barn swallows (*Hirundo rustica*) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

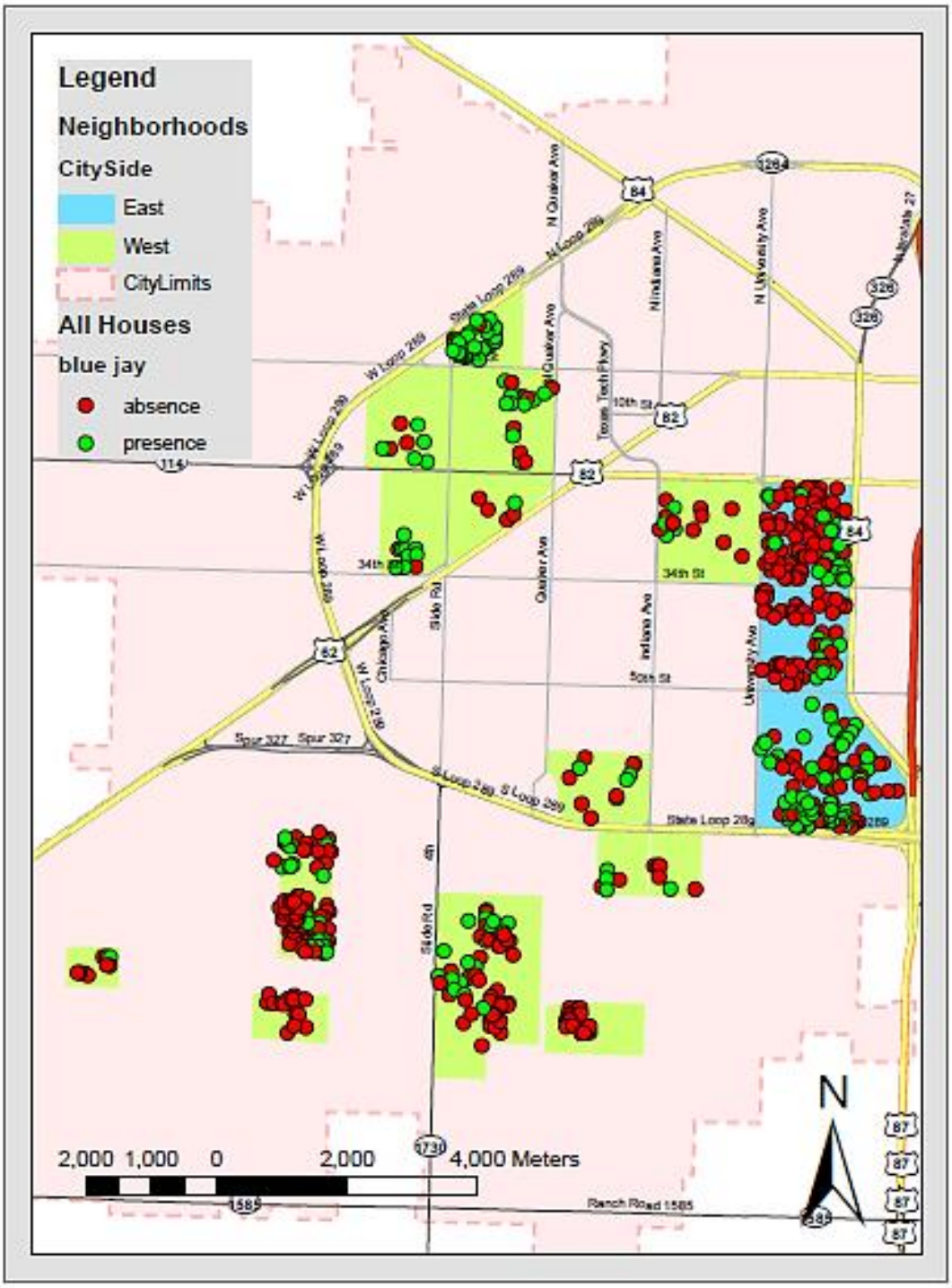

Figure 2.8: Presence (in green) and absence (in red) of blue jays (*Cyanocitta cristata*) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

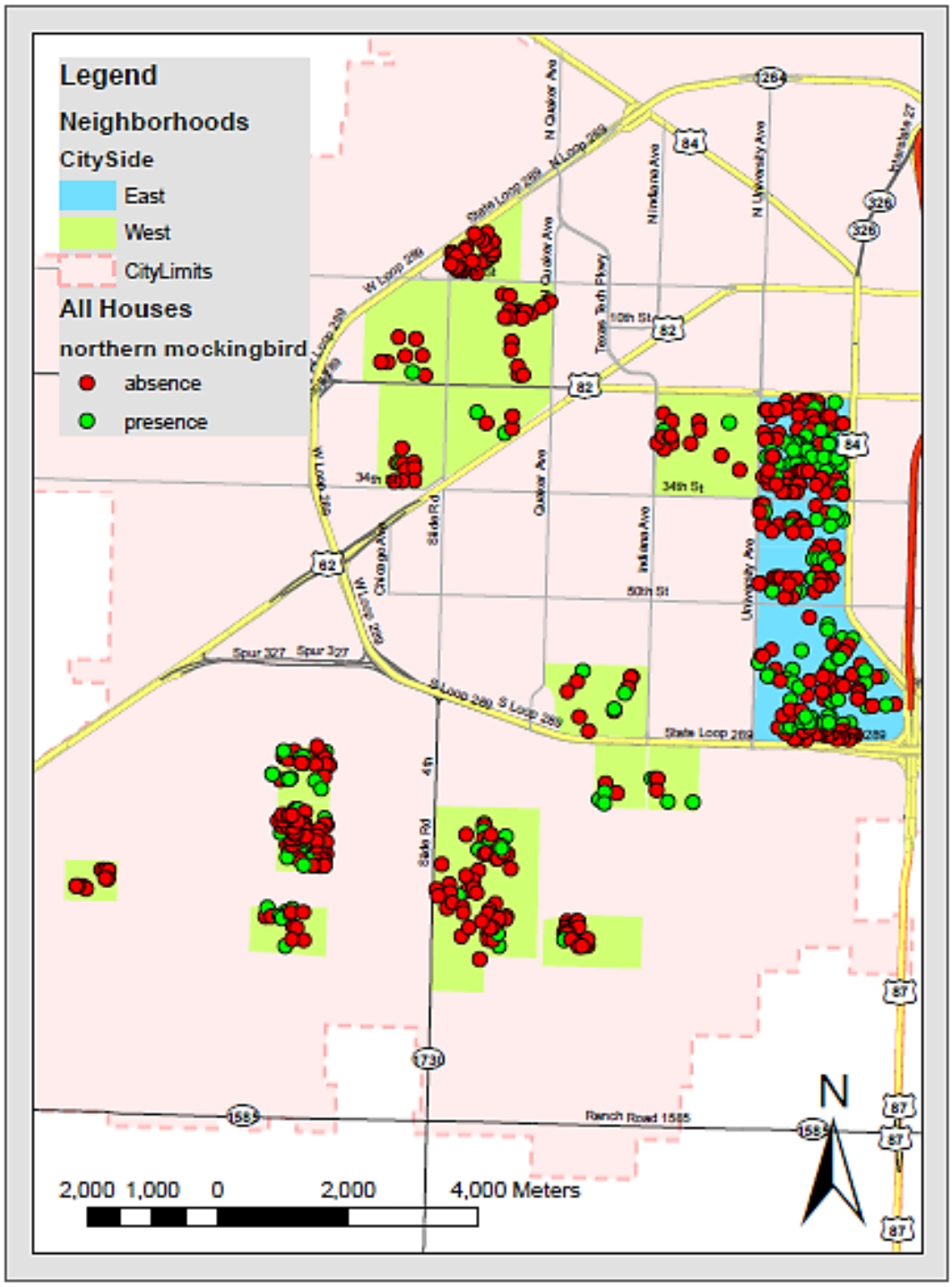

Figure 2.9: Presence (in green) and absence (in red) of northern mockingbird (*Mimus polyglottos*) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

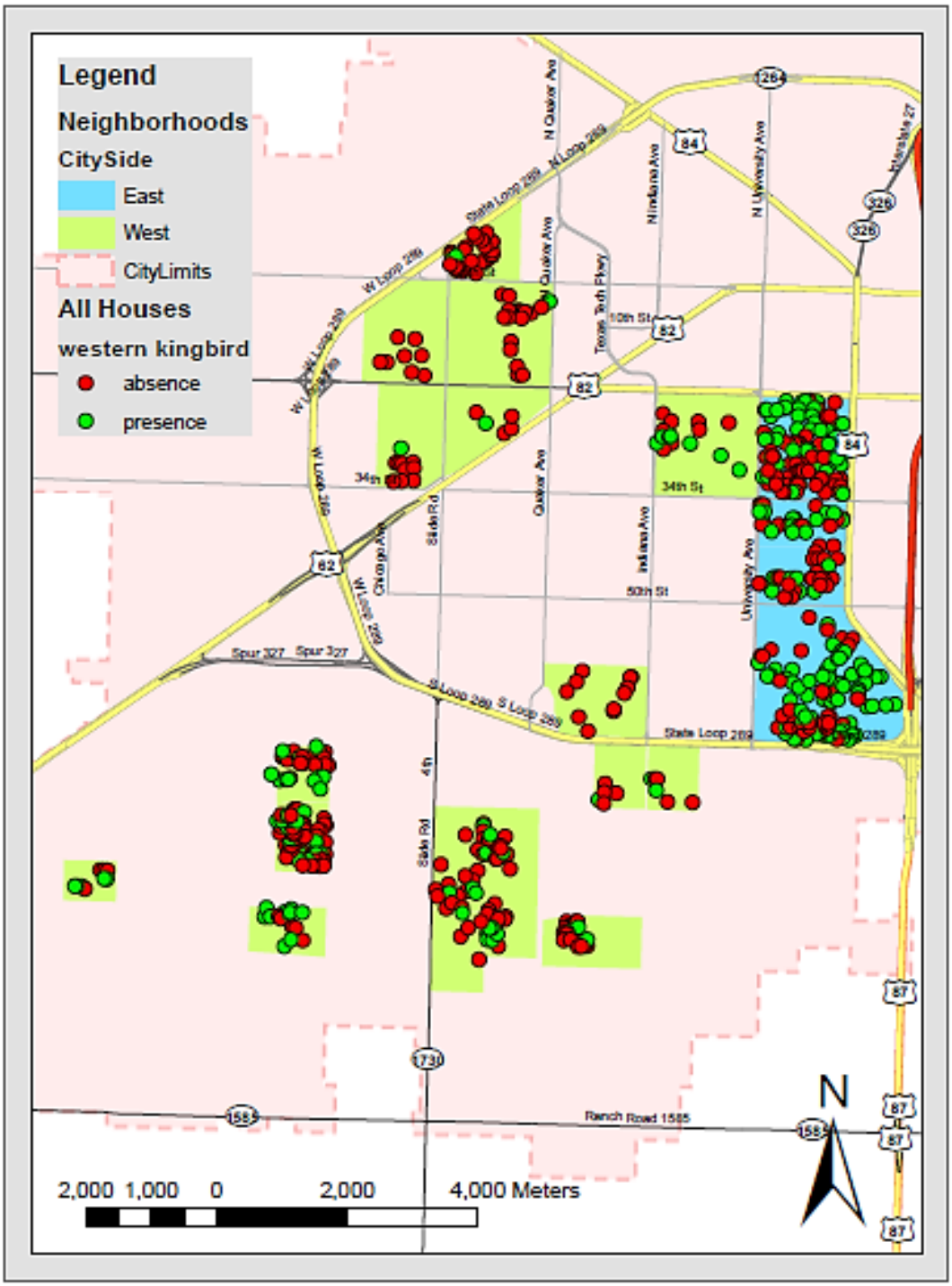

Figure 2.10: Presence (in green) and absence (in red) of western kingbird (*Tyrannus verticalis*) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

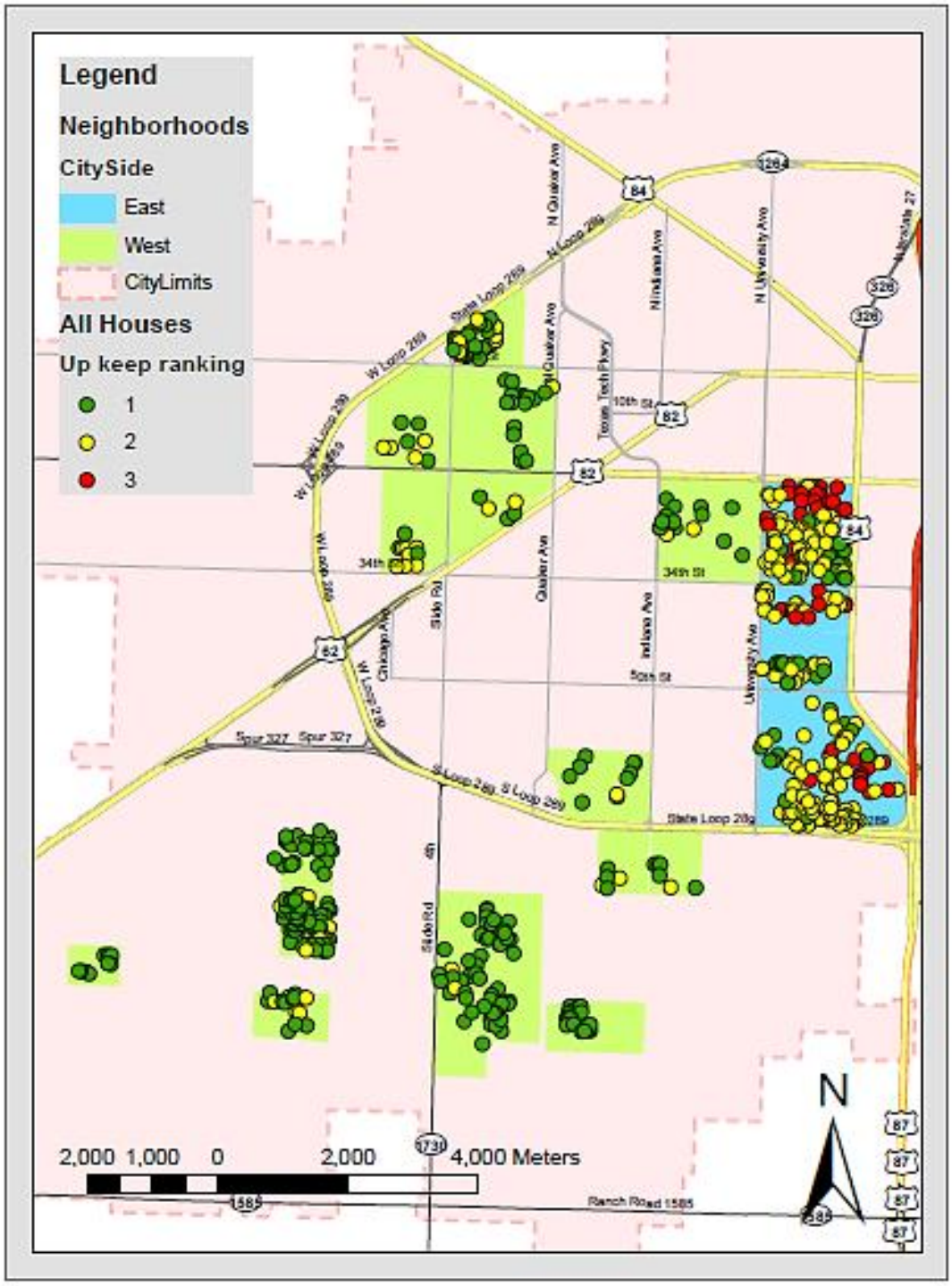

Figure 2.11: Front yard up keep ranked from 1 to 3 (1 = very manicured, green, 2 = medially manicured, yellow, 3 = completely wild, red) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

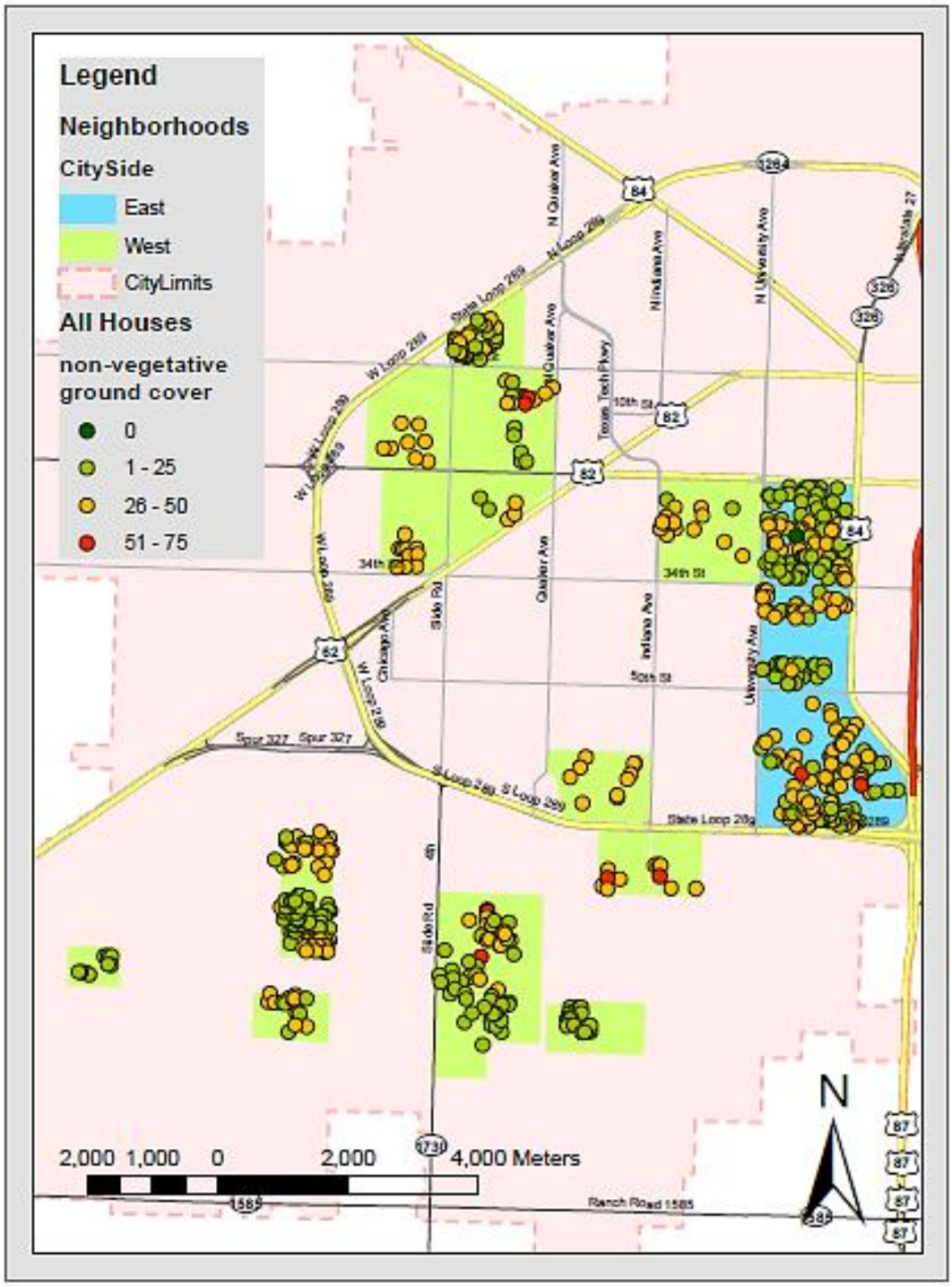

Figure 2.12: Non-vegetative ground cover with a gradient from red (the most non-vegetative surface) to green (all vegetative surface) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

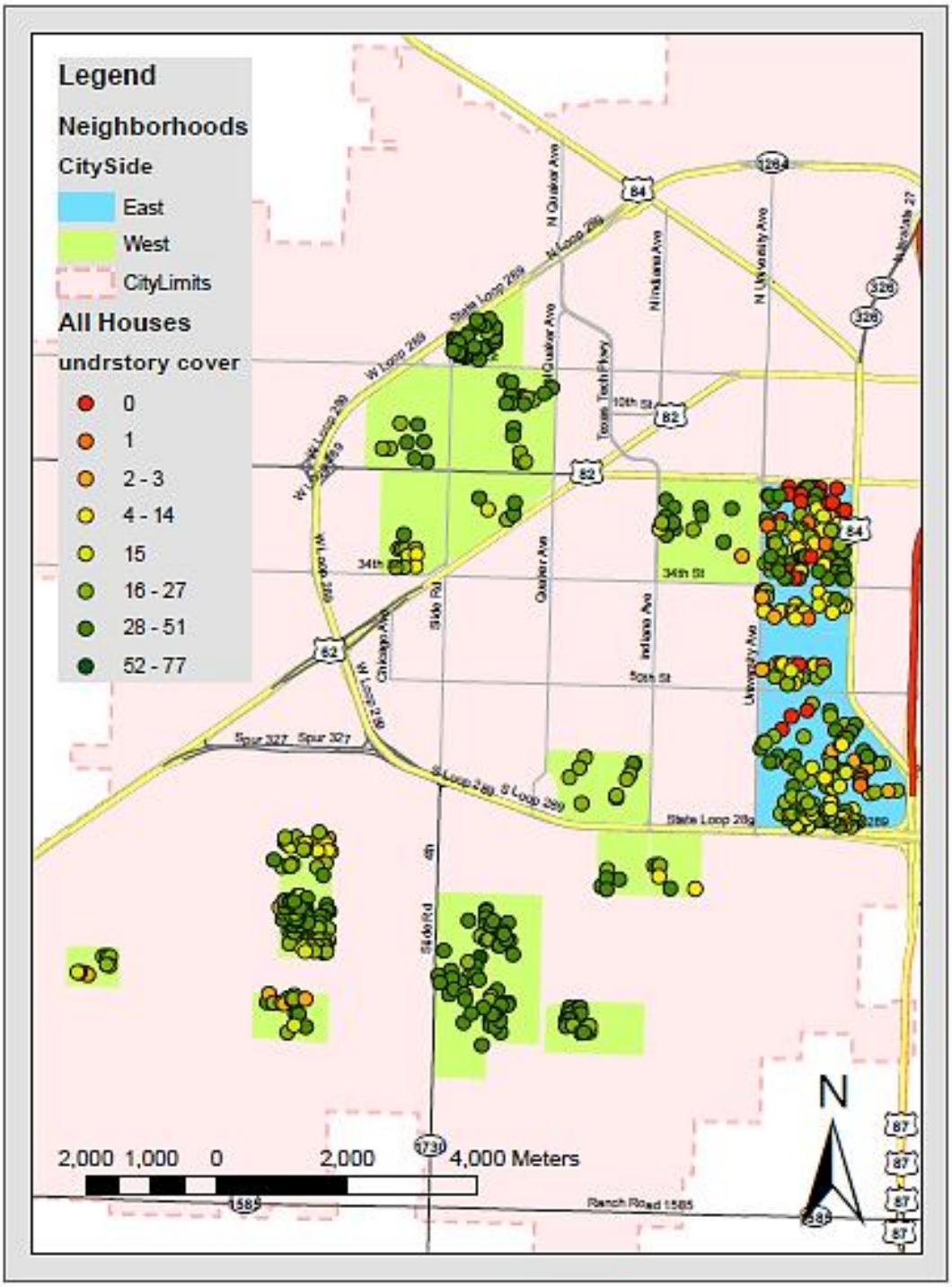

Figure 2.13: Understory coverage with a gradient from red (lowest amount of understory coverage) to green (highest amount of understory coverage) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

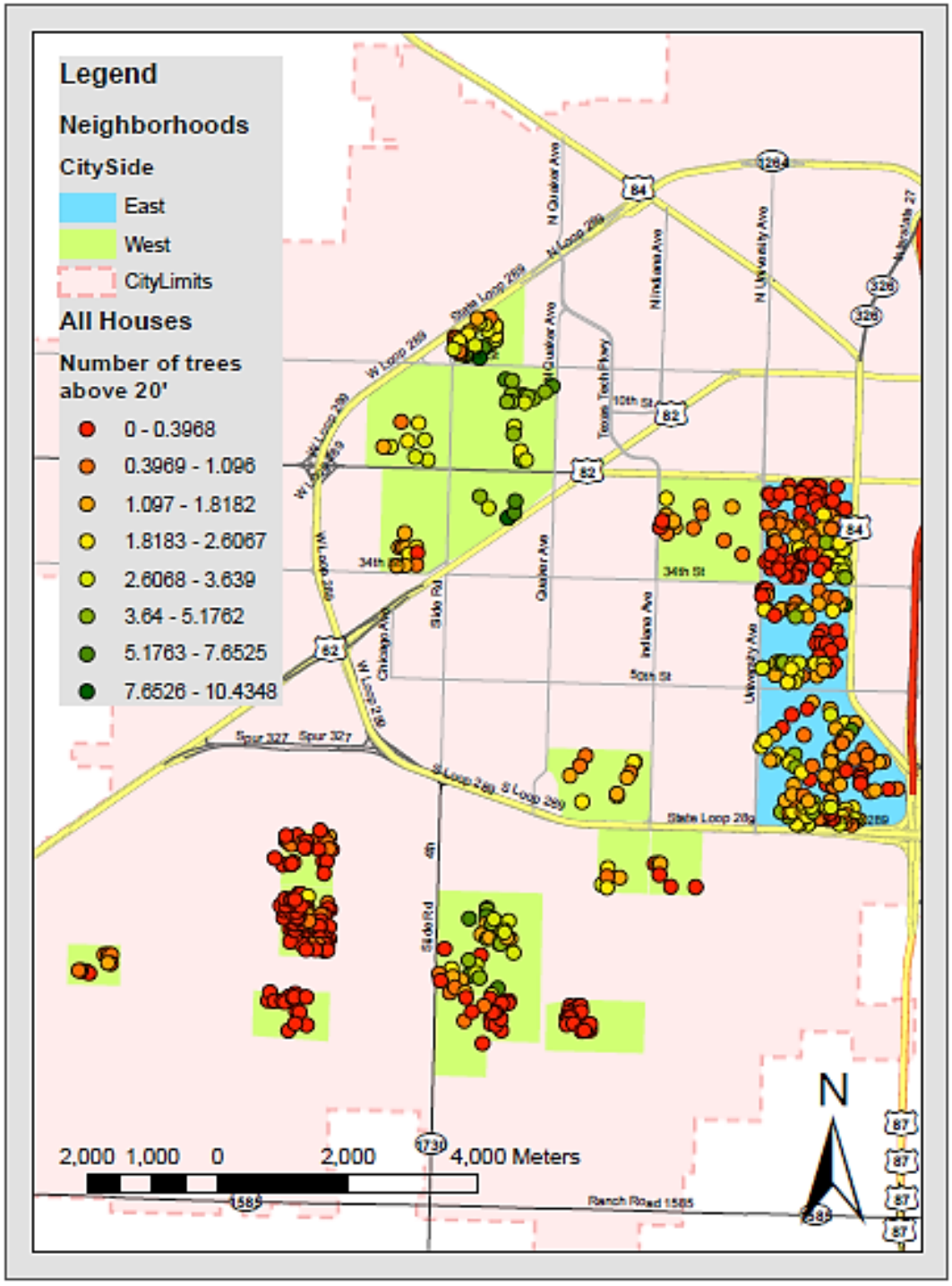

Figure 2.14: Density of trees greater than 20’ with a gradient from red (least amount of trees) to green (greatest amount of trees). Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

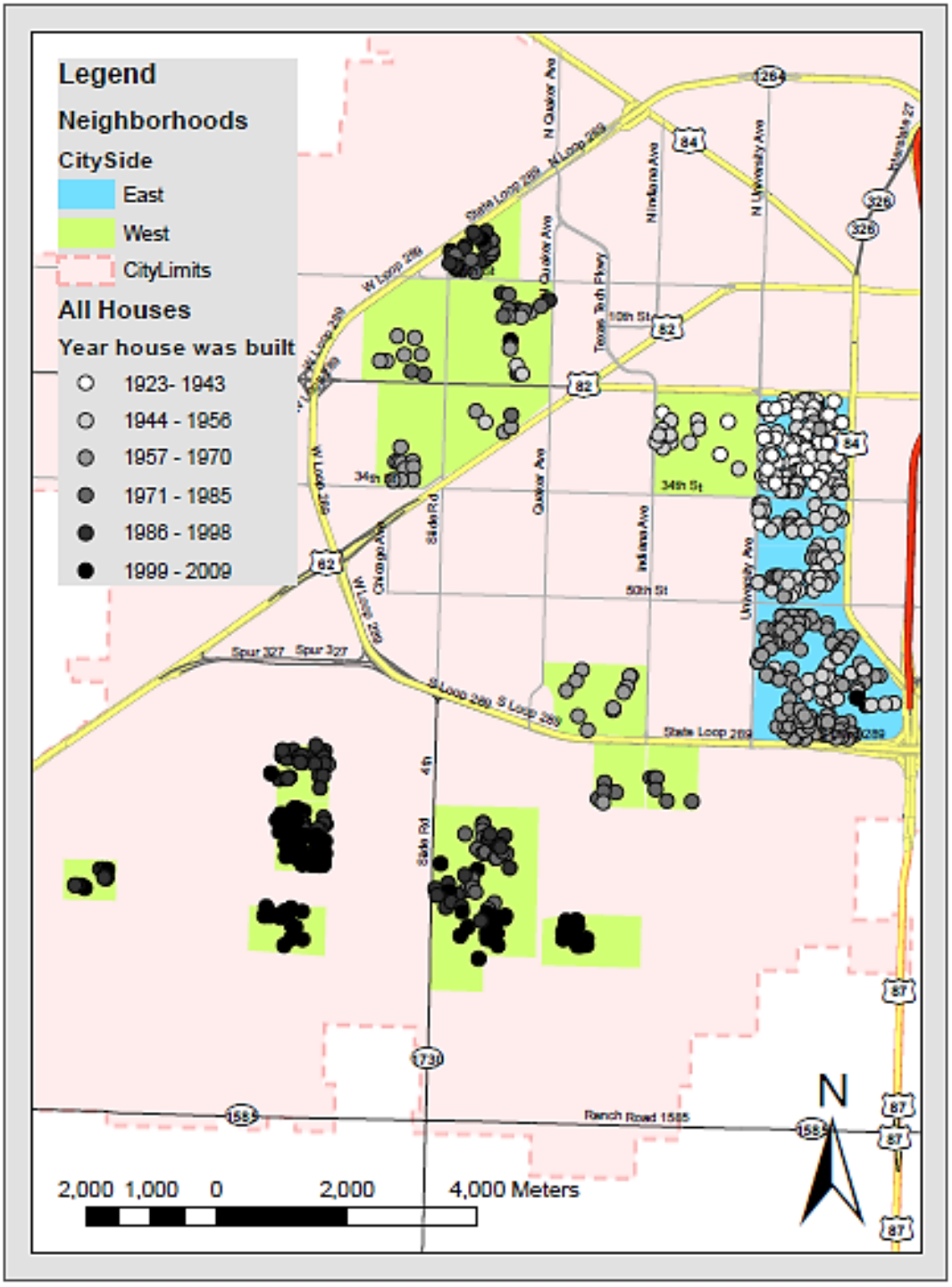

Figure 2.15: The year when the study house was built with a color gradient from black (newest houses) to white (oldest houses) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

Table 2.2: Table of the multiple regression models produced with bird species richness as the dependent variable and vegetation and house data as independent variables. Values represent the coefficient, while dashes represent variables that were not considered a good fit for the model. Data were collected at study sites in neighborhoods of Lubbock, TX. A regression analysis was performed predicting the richness of different bird groups with each vegetation and house variable, using a Poisson distribution. A Chi-square goodness of fit test was then used to assess the significance of each regression equation against a model with no predictors.

Bird Group	intercept	year house was built	very up kept yard	medium up kept yard	non vegetative ground cover	understory coverage	trees greater than 20'	χ^2	df
Exploiter bird richness	5.350*	-0.002*	-	-	-	-	-	5.030*	1
Adaptor bird richness	0.307*	-	0.371*	0.208	0.004*	0.008*	-	48.141*	4
Avoider bird richness	-30.439*	0.014*	-	-	-	0.014	-0.354*	30.620*	3

* Significant ($p < 0.05$)

Table 2.3: Table of the multiple regression models produced with bird species' presence/absence as the dependent variable and vegetation and house data as independent variables. Values represent the coefficient, while dashes represent variables that were not considered a good fit for the model. Data was collected at study sites in neighborhoods of Lubbock, TX. A regression analysis was performed predicting the presence/absence of different bird species with each vegetation and house variables using binomial distribution. A Chi-square goodness of fit test was then used to assess the significance of each regression equation against a model with no predictors.

Bird Species	intercept	year house was built	very up kept yard	Medium up kept yard	non vegetative ground cover	understory coverage	trees greater than 20'	χ^2	df
American robin	-31.390*	0.015*	1.678*	1.033*	-	-	-	98.083*	3
Barn swallow	-30.092*	0.014*	2.074*	1.435	-	0.020*	-0.105	73.238*	5
Blue jay	-3.170*	-	1.079	1.459*	-	0.029*	0.339*	68.315*	4
Northern mockingbird	28.928*	0.016*	-	-	0.021*	-	-	26.727*	2
Western kingbird	17.725*	-0.009	-0.987*	-0.382	-	-	-0.230*	43.466*	4

* Significant ($p < 0.05$)

ground cover, understory yard coverage, and the density of large trees (greater than 20 feet tall, Table 2.3)

Discussion

Although urban areas differ from native areas, my results show that vegetation coverage and variation increases wildlife species richness in an urban area similar to natural environments (MacArthur and MacArthur 1961). I found that both the adaptor and avoider species richness increased with an increase in the understory vegetation at a house. However, exploiter richness was not affected by understory coverage. The lack in influence of vegetation stratification might be due to the fact that the very common birds were found at most, if not all, of my sites (Figure 2.3) and therefore solely assessing richness would not reveal vegetation preferences, unlike the more uncommon birds, which are not found at every site (Figures 2.4 and 2.5). Vegetation stratification also does not affect some individual bird species, with only two (barn swallow and blue jay) out of the five species examined being positively associated with understory height (Table 2.3). However, the lack of correlation between understory coverage and the other three species (American robin, northern mockingbird, and western kingbird) is not surprising given that vegetation stratification increases richness not necessarily specific species because of increased niche availability over multiple layers of vegetation (MacArthur and MacArthur 1961).

Besides vegetation stratification, other vegetation, such as the amount of care in the front yard, the density of trees greater than 20 feet, and ground surface coverage, also influenced birds both in the species richness and the presence and absence of the five

adaptor species. The level of upkeep of the front yard influenced most of the individual bird species and the richness of adaptor birds. However, upkeep affected neither the very common birds, nor the very rare birds. Front yard upkeep may not affect very common bird species due to commonality, and may not affect rare bird species due to other habitat restrictions limiting rare species to certain areas. On the other hand, adaptor birds are not found everywhere but are also not as restricted to the city outskirts, and may, therefore, be choosing habitat based more on vegetation quality than the other two species groups.

Although keeping a lawn well watered and nicely manicured may increase the presence of adaptor birds, because of the recent drought and water shortages, watering the lawns is not ideal for the current environment. Xeric landscaping is a type of landscaping that utilizes native and drought tolerant plants with no grass, which can save water consumption. I identified 10 sites exhibiting xeric landscaping, but due the low sample size, I was unable to identify any trends. Phoenix, AZ is a city with large amounts of xeric landscaping where Lerman and Warren (2011) found native birds were more common at houses with xeric landscaping rather than the classic green yard. Although Lubbock is not as dry as Phoenix, AZ, with the predicted shortages in water, encouraging, xeric landscaping could provide both increased native birds and water savings.

My results exhibit a difference in vegetation preference between bird species groups but also a location gradient, with house age being a surrogate for location in the city. The very common, often non-native, birds were often sighted at older houses, while the more rare and native birds were identified at newer houses. My data are consistent with previous work where the rarest birds are found on the outskirts of the city, and the

more common birds are found at the center of the city (Blair 1996, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005).

Along with the difference in species groups, individual focal species differed from one another and from the overall adaptor species group. The difference in vegetation preference by certain species leads me to believe that grouping bird species in the categories of exploiter, adaptor, and avoider, might be too broad when considering specific vegetation preferences of indicator species. Although general richness tends to change throughout the urban landscape, identification of "good habitat" for birds in general might not be possible with my current study. However, determining the likelihood of presence of a certain species in a yard by examining what kind of vegetation exists is an interesting compromise. In future studies, I suggest a focus on the abundance of species in an area, rather than species richness. By investigating the abundance of overall birds and bird species I could understand the community and possibly better define "good" habitat in an urban setting. Although I have made interesting conclusions from the data I collected, I feel more could be done to further the understanding of birds in Lubbock, TX and other semi-arid cities. Due to time constraints and the difficulty of measuring distance in an urban environment, I was unable to produce accurate abundances of the individual species that I found.

Although I might not have an entirely clear definition of "good" habitat in Lubbock, TX, I did observe birds choosing areas based on the vegetation and location of the house within the city. However, not all bird types are affected by the same vegetation variables, even species within a bird type differ in vegetation preferences. Overall, my project revealed that vegetation had a large impact on bird richness as well as specific

bird species, but the preferences will depend on what type or species of bird is being considered not just birds in general.

Management Implications

As the field of urban ecology research grows, an important focal location for research will be in the neighborhoods of a city, not just parks and green spaces, especially in cities where the parks and green spaces are large expanses of green grass with little understory vegetation coverage and variation. Therefore, much of the habitat may not be found in green spaces but in private yards where homeowners can make decisions as to type and amount of vegetation grown in a yard. Educating homeowners who are interested in conservation on the kind of habitat to provide in order to maximize wildlife use would be beneficial to both homeowners (by improving wildlife view) and wildlife (by improving habitat). On an even larger scale, introducing the information to city managers and neighborhood associations could cause whole neighborhoods and cities to set forth a common goal of improving wildlife habitat in the city.

Homeowners who care about the wildlife in their yards can use my findings as a guide to the kind of birds expected in the yard, based on the location of the house in the city, the amount of understory coverage is in their yard, and the level that the yard is manicured. By applying my models as a key, homeowners can determine the likelihood of having any of the five focal adaptor species and the potential richness of each bird type homeowners could expect to find in their yard.

Lubbock city managers and neighborhood associations can make recommendations based on my findings. One recommendation could be for homeowners

to increase understory coverage and keep lawns nicely manicured in order to increase the richness of bird species found in the city and in the neighborhoods. Unfortunately, due to the recent drought in the southern high plains (Tinker 2013), watering lawns might not be feasible or even recommended due to Lubbock being projected to have large shortages of water within the next 20 years (City of Lubbock, Texas 2013). However, my work does show that other birds, exploiter and avoider species, are not dependent on the nicely watered yards and trees as adaptor birds. With ever-increasing water restrictions, a new type of yard that resembles the more drought tolerant shrubs and grasses found outside of the city could not only bring in more native birds, but also save money and water. Many urban homeowners are caught up in the idea of having the perfect lawn with green grass and lush trees (Nohl 1998, Wittig 1998), however, water prices continue to rise and water is runs out (City of Lubbock, Texas 2013). By letting go of the "ideal" green yard, more native birds could come into the urban areas with lawns made to look more like a native habitat rather than the artificial one that has been forced to grow.

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CHAPTER III

VARIATION IN BIRD AND VEGETATION DISTRIBUTION BOTH IN TERMS OF SOCIO-ECONOMIC CHANGES AND CITY GRADIENT

Introduction

Urban areas are increasing not only in the United States but across the world (United Nations 2012). As urban areas increase, land being urbanized is encroaching on areas considered to be "better" quality wildlife habitat (United Nation 2012, Magle 2012). However, wildlife are using urban areas to varying degrees (Magle 2012). Birds are a frequently studied group, especially in urban areas because birds are typically common, easy to identify, and can move freely across the urban landscape and therefore can be more selective when choosing habitat than wildlife with more restricted movements (Niemi and McDonald 2004).

Many studies have focused on the bird diversity and abundance gradient from city outskirts to the city center (Blair 1996, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005). When considering the gradient of a city, bird diversity is highest in slightly urbanized areas and lowest in the city center. However, bird biomass increases closer to the city center, although with only a few species (Beissinger and Osborne 1982, Mills et al. 1989, Crooks et al. 2004). The gradient of bird biomass and diversity is caused by the different bird types typically found in urban areas: exploiters, adaptors, and avoiders (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Exploiter birds are very common in urban areas and are often non-native species, such as house sparrows (*Passer domesticus*) and European starlings (*Sturnus vulgaris*) (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006).

Exploiter bird populations usually increase with increased urbanization because exploiter birds exploit the urban resources and are most commonly found in urban areas compared to the native habitat (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Adaptor birds are native species that have adapted to the urban habitat, for example blue jays (*Cyanocitta cristata*) and American robins (*Turdus migratorius*). However, adaptor birds are still located in native habitat and therefore are more common on the outskirts of the city where native habitat still exists and richness decreases toward the interior of the city (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006). Avoiders are native birds that avoid the urban environment and are rarely found in urban areas and usually only in small numbers on the city outskirts where the native habitat is closest, for example the western meadowlark (*Sturnella neglecta*) and killdeer (*Charadrius vociferous*) (Blair 1996, Odell and Knight 2001, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Sandstorm et al. 2006).

The different types of birds that exist in urban areas are probably due to the vegetation changes throughout the city area, because vegetation greatly influences bird diversity (MacArthur and MacArthur 1961, McKinney 2002). In semi-arid environments such as Lubbock, TX, vegetation is influenced by the amount people are willing to pay for water usage. In Phoenix, Arizona, an arid environment, older houses have more vegetation and lower income homeowners maintain less vegetation on their lots (Hope et al. 2003). Lubbock, TX might have a similar trend due to the semi-arid environment.

In Lubbock, TX, differences can be observed between the east and west sides of the city, separated by University Avenue. An anthropogenic change occurs across

University Avenue, essentially dividing line into two different demographic areas. The west side of the city primarily consists of affluent, white homeowners, whereas the east side of town is more diverse and with less affluent residents (M. Farmer, Texas Tech University, personal communication). The demographic distribution exhibits an ecological and socio-economic dynamic that has yet to be examined in urban ecological research. In my study, I have examined differences in vegetation and bird species in Lubbock, TX when considering not only the simple gradient of the outskirts to city center, but also changes within the city's demographic differences.

My study focused on bird species and vegetation change across Lubbock, TX. The landscape around the city consists of shrublands and agricultural fields that sharply contrast the well-watered green lawns and big trees within Lubbock, TX, but even urban vegetation varies throughout the city (Marzluff and Ewing 2001, Farmer et al. 2013). Vegetation and bird diversity can change throughout the city, both in the gradient from outskirts to center, and between the two demographically different city sides where anthropogenic changes affect vegetation and bird species. My research expands on the understanding of urban areas in semi-arid environments both in understanding bird use of urban areas and the differences in demographics causing the change habitat factors.

Methods

I obtained data on recently sold houses within Lubbock, TX from local realtors and I used each house as a study site (Perez-Ruiz 2014). My house data was collected during two different time periods; one set of data collected in 2009-2010 (on the west side of Lubbock, TX) and another set collected 2012-2013 (on the east side of Lubbock,

TX) (Figure 3.1). To determine vegetation and bird species differences throughout Lubbock, TX, I conducted a bird and vegetation survey at each study site. I kept my methods simple so my protocol could be applied to other urban areas by urban ecologist and researchers.

Bird surveys were performed during the summer months in order to focus on breeding birds, because breeding birds tend to sing more than wintering birds and use the area more so than migrating birds, which are typically just passing through (May-August 2014 and May 2015). I conducted bird surveys in front of each recently sold house between 30 minutes before sunrise to 3 hours after sunrise, in order to capture the time when birds are singing most (Bibby et al. 1992). Basic weather data were recorded (wind speed, temperature, and cloud cover) before each five-minute survey, in which all birds seen and/or heard were identified to species, judged on distance, and sex was identified when possible (Appendix A). Birds were also categorized into three groups exploiter (very common, often non-native), adaptor (common, native), and avoider (rare, more likely to be found outside of the city). For the purpose of my study, I will focus on bird richness, the number of species at each site.

Vegetation surveys were executed in two ways at each site, first at the study house and second at the five surrounding houses, which were considered one unit (Figure 3.2). All vegetation surveys were conducted when the trees were leafed out during spring and summer in order to properly identify tree species (April-October 2014 and April-May 2015). I chose to collect vegetation data (Table 3.1) that best represent the existence of layers of understory vegetation and the relative size and coverage of trees at each site. Each set of data were recorded at both scales, including: upkeep, ground cover,

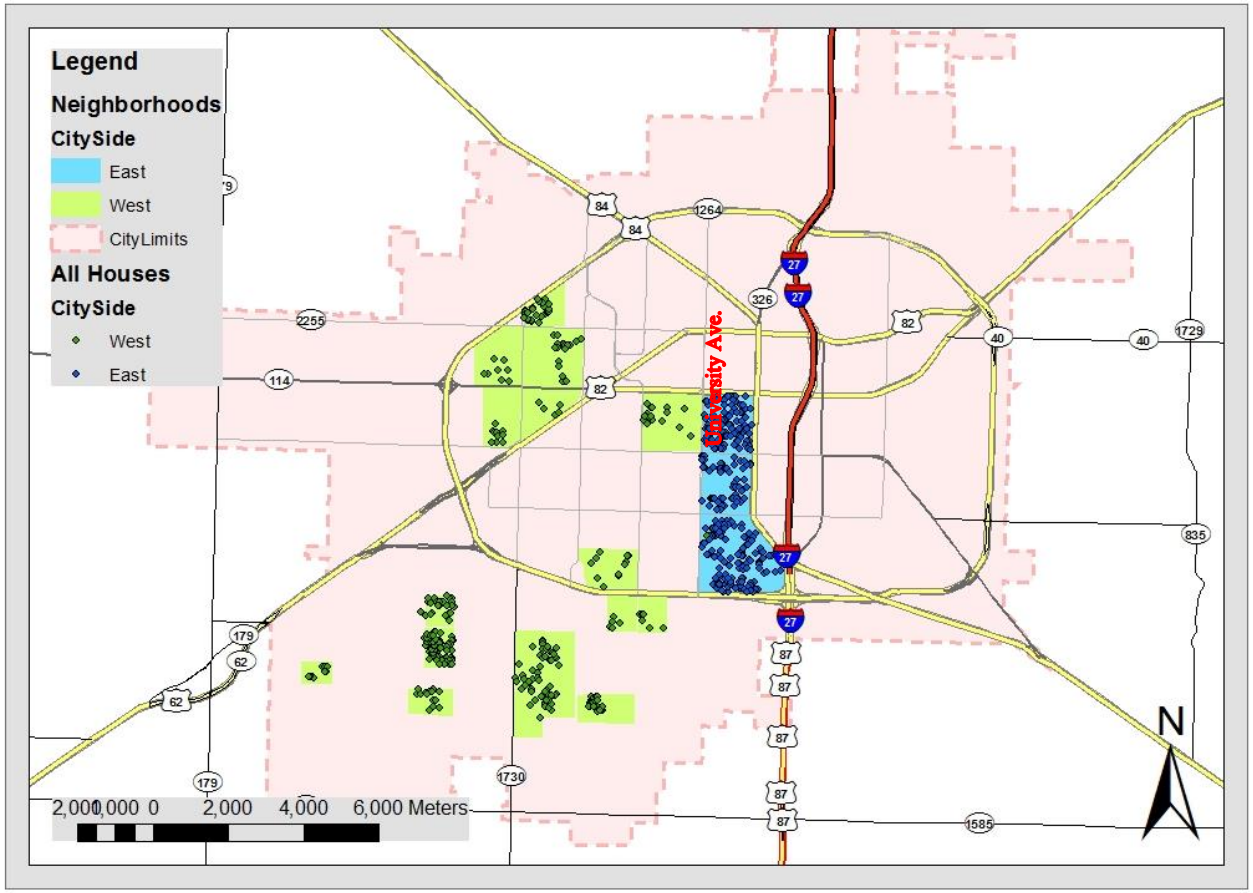

Figure 3.1. Map of Lubbock, TX, with the city limits highlighted in pink and major roads are labeled. Each site is represented by a point, green being on the west side and blue being on the east side of Lubbock. Green polygons are neighborhoods west of University Avenue (labeled in red) and blue polygons are neighborhoods east.

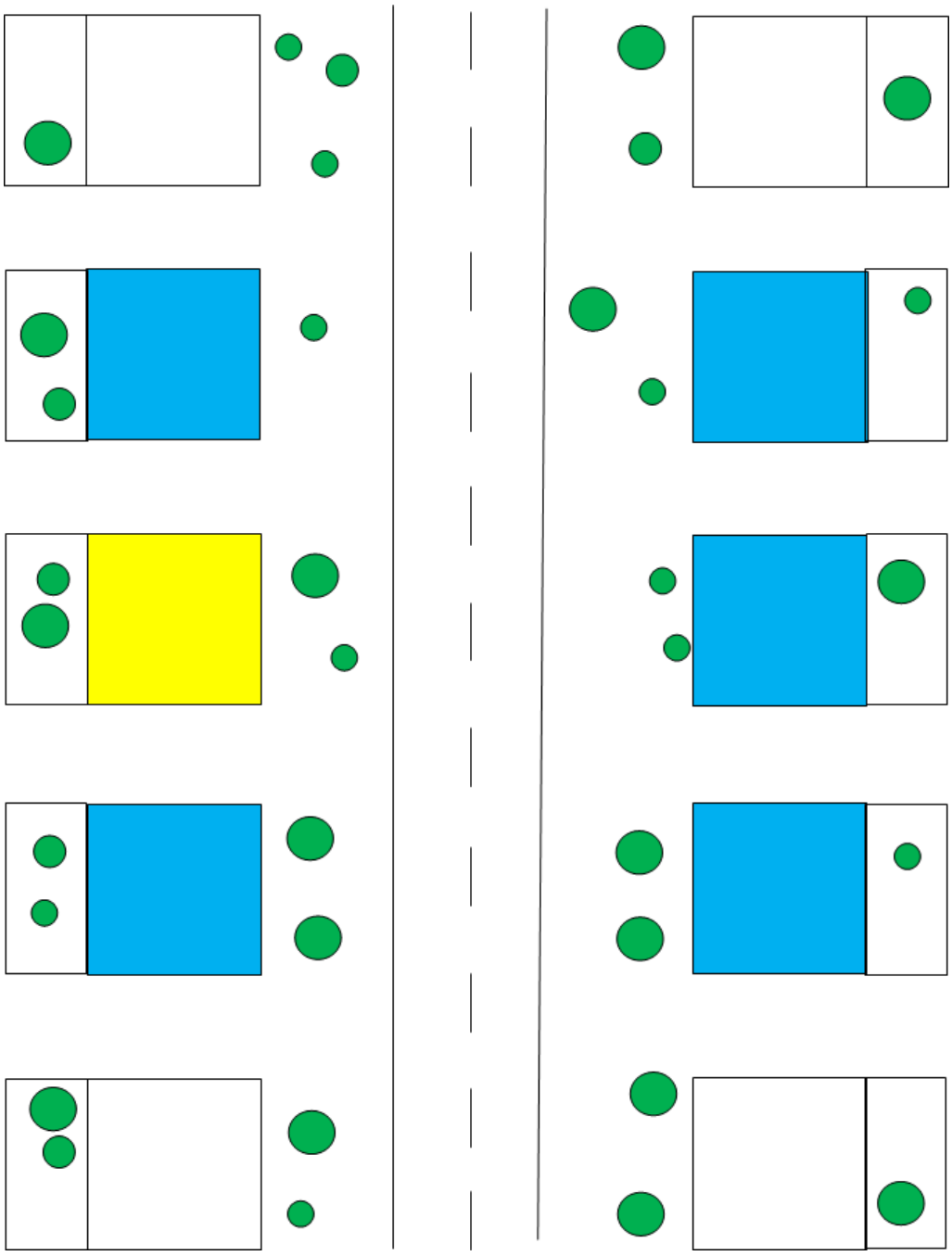

Figure 3.2: Example diagram of an aerial street view of survey points. The yellow block represents the recently sold house, where the "house" vegetation protocol was performed. The blue blocks represent the other five houses that make up the six-house block where the "neighbor" vegetation protocol was performed. The green circles represent trees, the other four white boxes on the top and bottom are other un-surveyed houses on the street, and the small rectangles on the back of each block represent fenced-in backyards.

Table 3.1: Vegetation variables examined and defined for use throughout my study. Vegetation category, the name of each variable, description of variable, and the units of the variable are defined.

Vegetation Variable Type	Variable Title	Description	Units of Measurement
Yard upkeep	Upkeep	A judged estimate on how well the front yard was manicured	Scale from 1 to 3 1 = Very manicured 2 = Medially manicured 3 = Completely wild
Ground cover	Non-vegetation	The amount of the front yard that is covered by concrete, dirt, rocks and AstroTurf.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Ground cover	Grass	The amount of the front yard that is covered by grass.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Ground cover	Other vegetation	The amount of the front yard that is covered by ivy, weeds, and other short vegetation.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Vegetation layers under 9'	House 4”-2’ Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation

Table 3.1 Continued

Vegetation layers under 9'	House 4”-2’ Layer Coverage	The amount of the vegetation that is in the height range of ground to knee (4"-2')	“-“ =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%
Vegetation layers under 9'	House 2’-5’ Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation
Vegetation layers under 9'	House 2’-5’ Layer Coverage	The amount of the vegetation that is in the height range of knee to shoulder (2'-5')	“-“ =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%
Vegetation layers under 9'	House 5’-9’ Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation
Vegetation layers under 9'	House 5’-9’ Layer coverage	The amount of the vegetation that is in the height range of shoulder and roof (5' to 9')	“-“ =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%

vegetation layers, number of trees, and tree species richness (Table 3.1). All visible trees were also counted, identified, and categorized in three height class, <10', 10'-20', >20' (Appendix B).

Analysis

To test the possible differences between the east and west side of Lubbock, TX, I performed T-tests, making comparisons using RStudio (RStudio 2014). I performed a Welch two-sample T-test to assess the differences in vegetation and bird richness between east and west Lubbock, TX. The Welch two-sample T-test adjusted the degrees of freedom in order to compensate for the lack of similar variances between the east and west sides of Lubbock, TX (Welch 1938). Therefore all of my degrees of freedom are different even though the t-tests were based on the same data set with the same sample size (N=576). I used a one-tailed T-test on house upkeep, non-vegetative surface, all layers of vegetation and overall understory coverage and all tree groupings to test whether the west side of Lubbock, TX had more vegetation than the east side.

I also tested for differences in the city gradient (from outskirts to center), in two ways. First, I conducted T-tests between the inside and outside of Texas Loop 289 in Lubbock, TX. Texas Loop 289 is a common landmark in Lubbock, TX delineating between the older sections of the city from that of newer developments. I used ArcGIS (ESRI 2015) to examine the gradient of house age as compared to location in which the house was in the city (Figure 3.3). Like many cities, Lubbock, TX has been built from the center out with new developments being placed outside of Texas Loop 289 rather than more established areas within Texas Loop 289. I applied a Poisson distribution for species count data and a binomial distribution for species presence/absence data

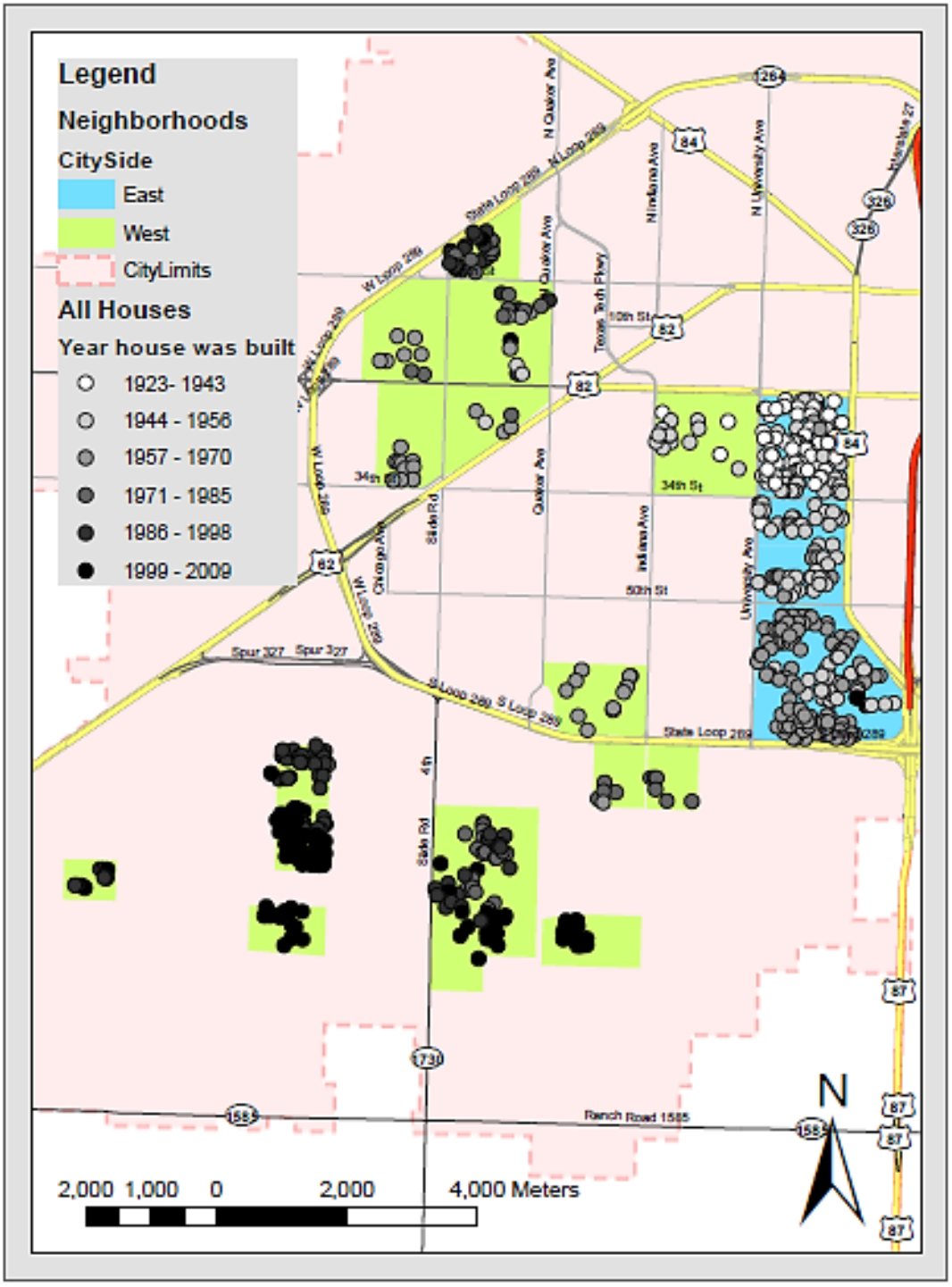

Figure 3.3: The year when the study house was built with a color gradient from black (newest houses) to white (oldest houses) with each point representing one site. Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

regressions. I then performed a Chi-square goodness of fit test to assess the differences between the regression equations and a model with no predictors where the regression equation was the intercept.

Results

I collected data from 576 houses in the Lubbock, TX area. The houses were in two areas of town, delineated by either being east (264 houses) or west (310 houses) of University Avenue in Lubbock, TX. The west side of town has significantly more manicured front yards (t-stat = 16.484, df= 471.542, $p<0.0001$) (Table 3.2).The west side of Lubbock, TX also had more vegetation layers in three levels (4"-2', 2'-5', and 5'-9') and more total understory coverage and variation. No significant difference was observed between the east and west sides of Lubbock, TX in the amount of non-vegetative ground coverage (t-stat=-1.190, df=551.852, p=0.113). A significantly higher density of trees were found in the height category 10'-20' on the west side of Lubbock, TX (t-stat=1.910, df=557.139, p=0.028), however no difference in the other tree density groups was observed. When considering the bird species and groups, I discovered differences between the east and west sides of Lubbock, TX in all three bird groups (exploiter, adaptor, and avoider species; Table 3.2).

I examined the differences between the inside of Texas Loop 289 (city center) to that of the areas outside of Texas Loop 289 (city outskirts) and found the groups of bird species did show differences. Exploiters were found significantly more in the city center (t-stat= -4.691, df= 554.640, $p<0.0001$) while both adaptor bird richness (t-stat=6.557, df= 556.405, $p<0.0001$) and avoider bird richness (t-stat= 5.263, df= 484.340, $p<0.0001$)

Table 3.2 Table of Welch's Two-sample t-tests, testing the differences of house price, vegetation variables, and bird richness between the east and west sides of Lubbock, TX. House price and vegetation variables used a one-tailed t-test while bird richness used a two-tailed t-test. Data were collected in Lubbock, TX in different areas of the city (east and west of University Avenue). T-test statistic is reported with test significance, degrees of freedom, and group means.

Variable	west greater or lesser than east	t-stat	df	West side mean	East side mean
House Price	greater	24.012*	357.695	234215.350	69047.730
House upkeep	lesser	-16.484*	471.542	1.300	2.083
House non vegetative surface	lesser	-1.190	551.852	37.419	39.205
House 4"-2' layer coverage	greater	12.326*	566.714	10.342	3.879
House 2'-5' layer coverage	greater	6.241*	562.040	8.242	4.841
House 5'-9' layer coverage	greater	6.666*	552.846	4.971	1.932
House layers coverage added	greater	12.319*	568.329	23.555	10.652
House total tree number	greater	0.290	526.316	6.710	6.605
House tree number less than 10'	greater	1.910*	557.139	1.682	1.343
House tree number between 10'-20'	greater	-0.717	484.641	3.681	3.888
House tree number more than 20'	greater	0.223	571.339	1.378	1.343
Exploiter bird species richness		-4.691*	554.640	3.571	3.856
Adaptor bird species richness		6.557*	556.405	2.945	2.239
Avoider bird species richness		5.263*	484.340	0.190	0.049

* Significant ($p < 0.05$)

were significantly greater in the outskirts (Table 3.3, Figures 3.4-3.6). In order to examine the gradient further I visually assessed and identified a spatial pattern in house age and location in Lubbock, TX, with the older houses being in the center of the city and new houses being on the edges in Lubbock, TX (Figure 3.3). Exploiter species richness increased with the age of the house whiles both adaptor and avoider species richness decreased with the age of the house (Table 3.4).

Discussion

My results show that vegetation varies when considering the socio-economics of different areas of Lubbock, TX and because of the anthropogenic changes of vegetation bird groups vary along the same economically and socially defined neighborhoods. My research supports previous research that different socio economics effect the vegetation and wildlife changes in urban areas (Iverson and Cook 2000, Ryznar and Wagner 2001, Luck et al. 2009). The semi-arid environment of Lubbock, emphasize economic differences because of the difficulty of growing vegetation and because birds are affected by vegetation, not surprisingly, therefore, the socio-economics of an area, vegetation, and bird richness are all related.

The higher priced houses, located on the west side of Lubbock, TX, had increased understory vegetation coverage and variation as compared to the lower priced houses, found east of University Avenue. However, tree density did not differ between the socio-economic different areas, showing that tree densities did not change when solely considering the economic status of a house in Lubbock, TX. The lack of difference in the density of trees between the east and west sides of Lubbock, TX might not be so

Table 3.3: Table of Welch's Two-sample t-tests, testing the differences of bird richness between the outside and inside of Texas Loop 289. Data were collected in Lubbock, TX both inside and outside of Texas Loop 289. A two-tailed t-test was used to test for any differences between the two areas of Lubbock, TX. T-test statistic is reported with test significance, degrees of freedom, and group means.

Variable	t-stat	df	inside loop mean	outside loop mean
Exploiter bird species richness	-4.831*	436.379	3.816	3.512
Adaptor bird species richness	6.964*	475.708	2.337	3.093
Avoider bird species richness	4.346*	307.415	0.072	0.214

* Significant ($p < 0.05$)

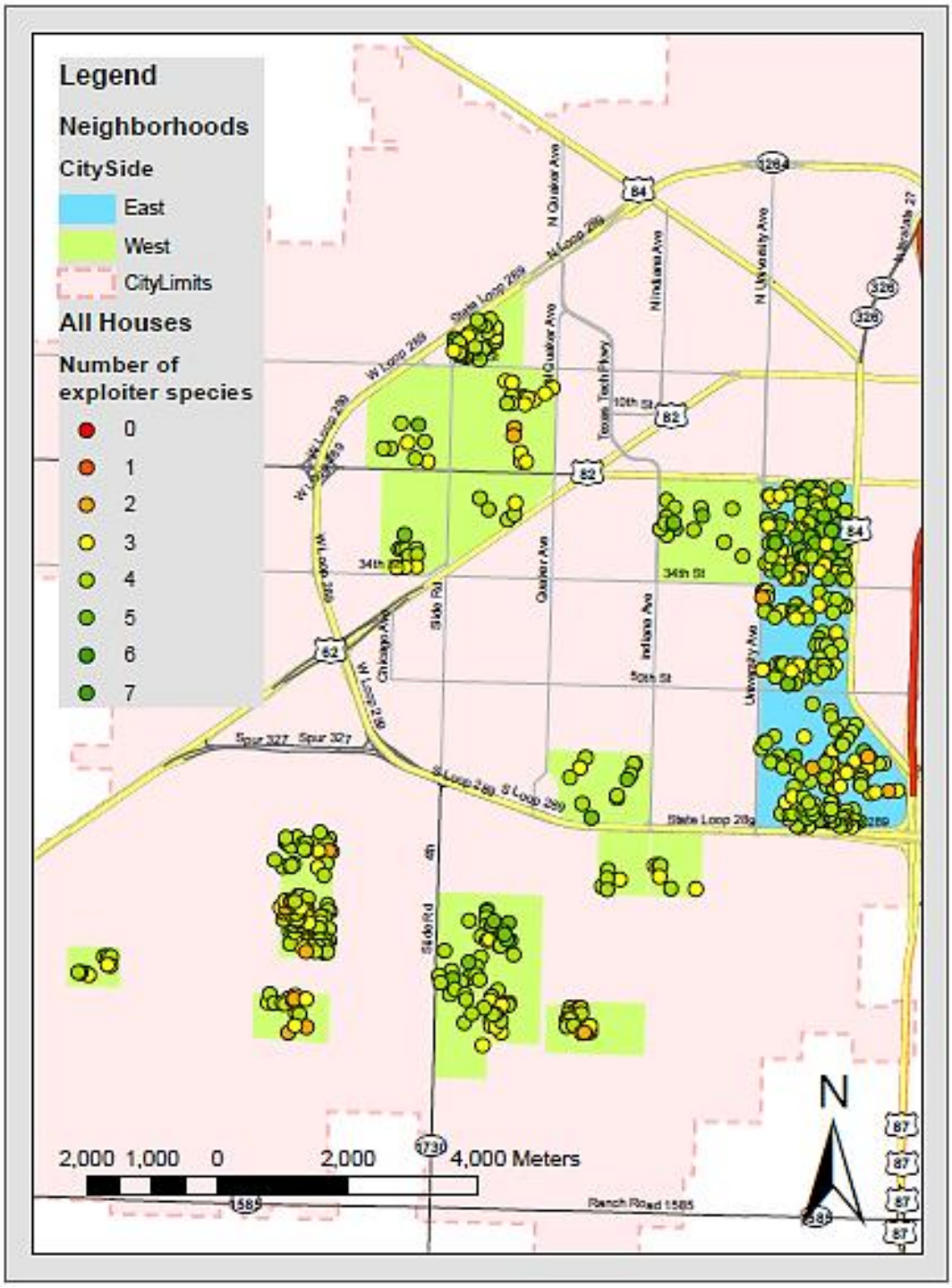

Figure 3.4: Exploiter bird species richness (very common in urban areas) with each point representing one site. Exploiter richness with a gradient from red (0 species seen) to green (7 species seen). Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX

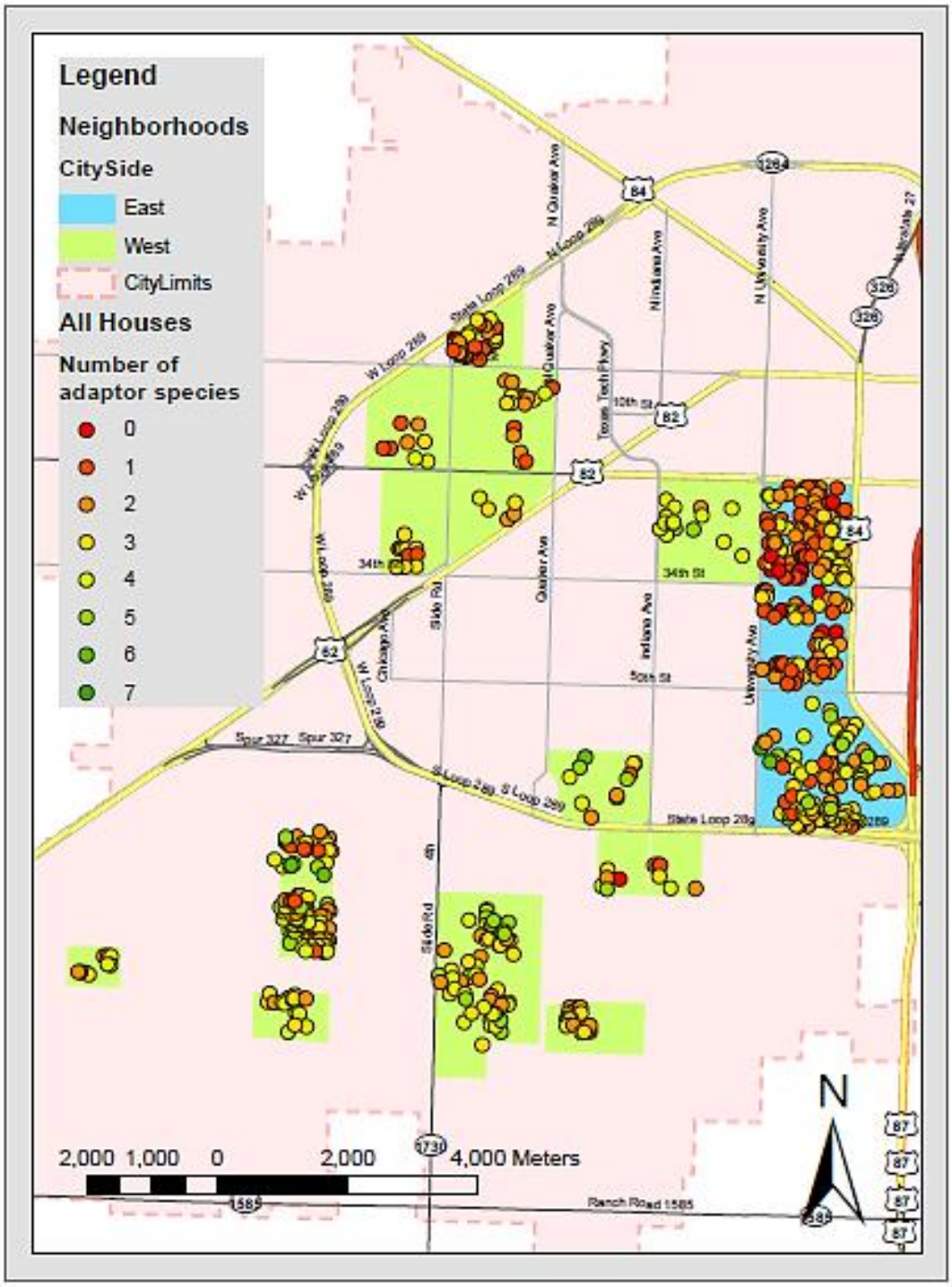

Figure 3.5: Adaptor bird species richness (common and selective) with each point representing one site. Adaptor richness with a gradient from red (0 species seen) to green (7 species seen). Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX.

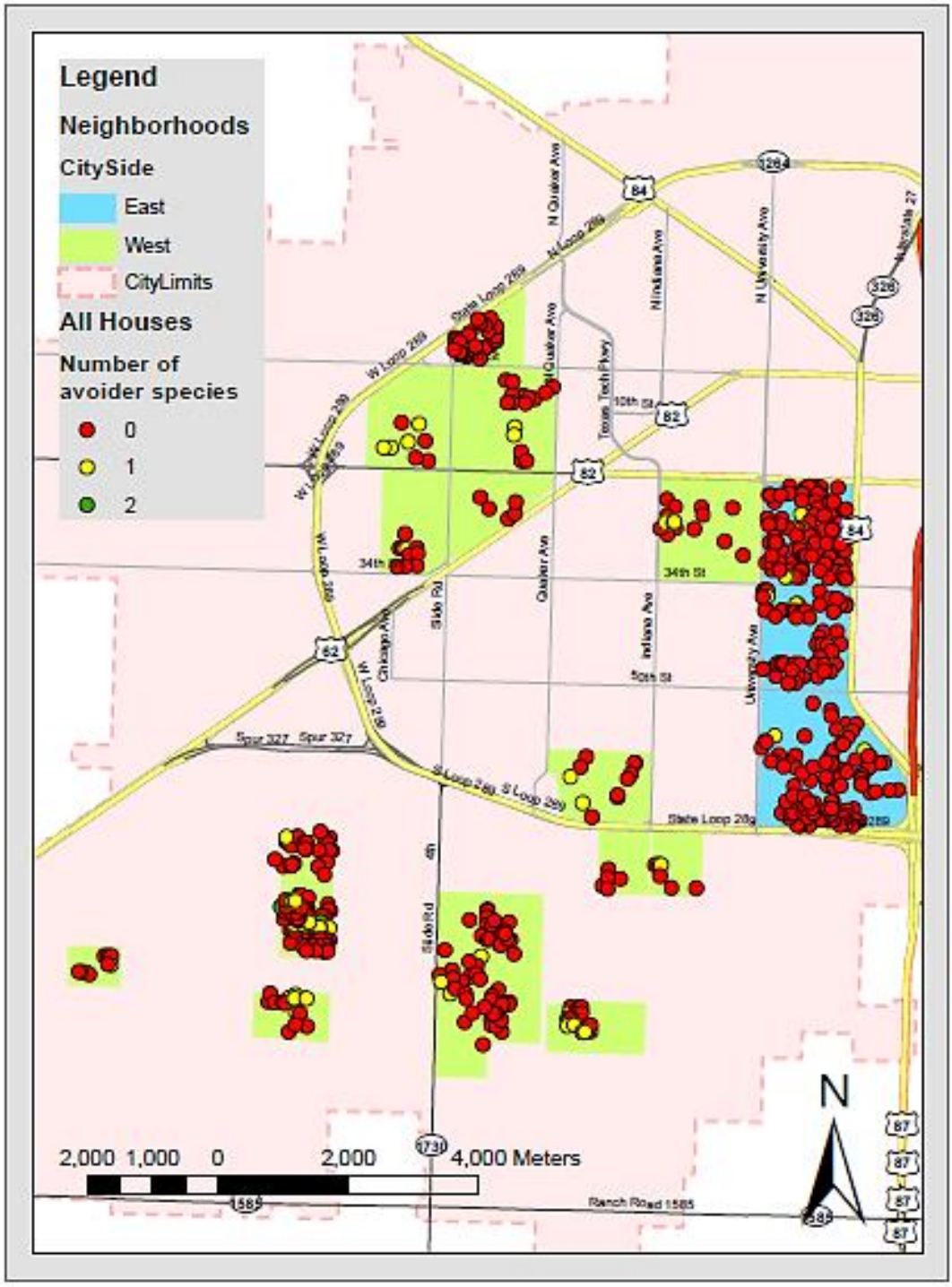

Figure 3.6: Avoider bird species richness (rare and on outskirts of urban areas) with each point representing one site. Avoider richness with a gradient from red (0 species seen) to green (2 species seen). Green polygons are west side neighborhoods while blue polygons are east side neighborhoods. Major roads are labeled and the large pink polygon designating the city limits of Lubbock, TX

Table 3.4: Table of the simple regression with bird species richness as the dependent variable and the year the study house was built as the independent variable. Data was collected at study sites in neighborhoods of Lubbock, TX. A regression analyses was performed predicting different groups of birds' richness with the year the study house was built using a Poisson distribution. The intercept and year study house was built coefficient are shown. A Chi-square goodness of fit was then used to test the significance of each regression equation against a model with no predictors.

Variable	Intercept	Year study house was built	χ^2	df
Exploiter bird species richness	5.350*	-0.002*	5.030*	1
Adaptor bird species richness	-8.131*	0.005*	18.079*	1
Avoider bird species richness	-45.367*	0.022*	18.271*	1

* Significant ($p < 0.05$)

shocking, because trees take a long time to grow, especially in semi-arid environments because of the lack of rainfall, and neighborhoods can change over time. For example, just because a house might not be as cared for at the time of the survey does not mean that the property was not cared for in the past, when the trees on the property were growing.

Bird species differing along with vegetation between the more and less affluent neighborhoods of Lubbock, TX is unsurprising, because vegetation coverage and variation highly influence bird richness (MacArthur and MacArthur 1961, McKinney 2002). All three groups of birds (exploiter, adaptor, and avoiders) differ from the ethnically diverse, less affluent areas to the primarily white, highly priced houses and neighborhoods within Lubbock, TX. Exploiter bird richness is greater in less affluent neighborhoods of the east side of the city, while adaptors and avoider bird richness is greater in the more affluent neighborhoods of the west side of the city. The difference in the bird groups' richness implies that the birds are choosing one side over the other perhaps because of anthropogenic differences in vegetation, specifically the increased amount of understory coverage and variation in the richer neighborhoods. Birds are unlikely to choose an area based on house price, however, my results show that more expensive houses have more vegetation stratification, which birds are known to prefer (MacArthur and MacArthur 1961). By association, therefore, more adaptor and avoider birds are found near more expensive houses, while exploiter bird species are more numerous at less expensive houses.

My research supports previous research on both gradient tests I performed, including the inside verses outside of Texas Loop 289, and along the house age gradient.

I examined the exploiter, adaptor, and avoider birds because each type of bird tends to occupy different areas along the outskirt to city center gradient (Blair 1996, McKinney 2002, Crooks et al. 2004, Hansen et al. 2005, Marzluff 2005, White et al. 2005), and I indeed found similar trends in my data. For example, exploiter bird richness tended to be greater in the city center, while both avoider and adaptor bird richness increased toward the city outskirts.

My research is only a snapshot of one summer. Over time the neighborhoods and the people living in the neighborhoods will change. Expanding the timeline of my project could give a long-term idea of city changes in the demographics, wealth, vegetation, and bird richness. By tracking an area through time, possible differences could be found in bird richness and used to predict when a neighborhood is on the down turn by observing changes in vegetation and bird richness.

My results show that changes do occur throughout Lubbock, TX both in vegetation and bird species, between different socio-economic areas and from city center the outskirts of the city. I found differences between the affluent and less affluent areas of town both in vegetation stratification and the level to which the yard was manicured. The wealthier areas tended to have more understory coverage and better taken care of yards while less affluent neighborhoods contains more wild looking landscapes with less vegetation stratification. Because of the semi-arid nature of the environment, and water rising in cost, the idea that the more affluent neighborhoods of the city can provide more water and lawn care than that of the less privileged neighborhoods is not surprising. Along with the vegetation difference, the kind of birds found in each designated economically different area varied as well. The rare to common birds increased in

richness in the affluent neighborhoods, possibly because the areas not only exhibit higher house prices but also have increased understory vegetation. Very common birds, however, had higher richness in neighborhoods with the lowest priced homes in my study. The vegetation and bird species differences exhibit anthropogenic differences between the demographically different areas of Lubbock, TX, which are likely attributed the economic differences in the cities' neighborhoods.

Management Implications

The differences in vegetation across socio-economic borders indicate that one barrier to a greater richness of birds could be the fact that homeowners do not have the means to properly improve their outdoor living spaces. Neighborhood associations wishing to improve bird richness and neighborhood pride can therefore encourage the planting of drought tolerant shrubs that would save owners the need to intensively care for a yard but also increase bird richness. Along with increasing bird richness, vegetation can affect the "curb appeal" of not only the house that is being sold, but also the block. The increased "cub appeal" of the block has the potential to increase house prices and salability of the neighborhood in general (Grissom and Diaz, 1991). General pride of the homeowners could be used to encourage the increase of bird diversity in some ways. For instance, the city could put on contests for the most bird species seen in the back yard or greatest richness of native birds. Contests could encourage homeowners to improve the vegetation they are providing for wildlife in the homeowners own back yard, and also to educate residents on proper vegetation for both water use and bird use.

A large project goal was to develop my protocol in order to expand the study into other cities. All cites tend to have "good" and "bad" areas that can often be distinguished because of house prices in different neighborhoods. By using recently sold houses, future studies can focus on other cities in Texas with different climates and possibly observe similar patterns in other cities as well as Lubbock. Different climates might not show the same trends that I have found in my study, therefore by using the same protocol, new study results can be compared to my results and possible difference identified. For example, in places where watering lawns is not necessary or the city looks more like the outside landscape, the socio-economic trends I have found might not apply.

Homeowners that value the environment around them can choose the area that they live in based on where they are more likely to find birds that they prefer. For example if they want more native birds they can live in the outskirts of the city while if they really enjoy a higher density of birds the city center might work best. Realtors can use my information in similar ways. By assessing if the homebuyers are concerned about the environment, or are interested in seeing more birds, realtors can recommend the outskirt areas of the city were more native birds occur. On the other hand, if realtors know that the homeowner wanted bigger mature trees and did not care about bird diversity, the center of the city might be more suitable. In the same way that people choose where they live based on school district and amenities, they can also choose based on bird richness and variety.

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CHAPTER IV

BIRD DIVERSITY EFFECTS ON HOME PRICES AND VEGETATION EFFECTS ON BIRD DIVERSITY

Introduction

My study was based on previous work by Farmer et al. (2013) where they found two types of people who had recently bought houses in Lubbock, TX. The two types of homeowners both valued the birds and the habitat in their backyard, however one valued the habitat more than the other (Farmer et al. 2013). By identifying the types of people buying houses, relators have the chance to narrow down the search for each type of homebuyer or homeowners placing houses on the market and can therefore target one type over the others and potentially alter the asking price for the house or sell the house faster (Farmer et al. 2013). The initial purpose of my research was to increase the scope and fine tune the scale of the project in order to accurately assess the value homeowners may place on the wildlife in their backyard.

The World Urbanization Prospects: The 2011 Revision has projected 90% of the United States population will be living in urban areas by 2050 (United Nations 2012). At the same time, people are caring about the surrounding wildlife in areas humans inhabit. In Pennsylvania, the amount people characterized the management and conservation of nongame wildlife as 'very important' increased from 1996 to 2014, showing that over time people care more about the wildlife in the surrounding area (Responsive Management 2014). With people increasingly caring about wildlife, homeowners may translate the concern into buying more wildlife friendly houses thus changing the dynamic of the housing market (Thompson et al. 1999, Luttik 2000, Jim and Chen 2006, Responsive Management 2014).

Although number of and height of trees and amount of area covered by other vegetation (bushes and grass) is not often taken into account in how houses are priced, curb appeal often is, therefore a poorly-landscaped yard has the potential to decrease the overall value of the house (Grissom and Diaz 1991). Curb appeal does influence house value and therefore vegetation can be an indicator of how much people value the environment in the homeowner's backyard (Nohl 1998, Thompson et al. 1999). Time, effort, and money are often expended into landscaping both the front and back yards of a house in order to be defined as "good" landscaping. Homeowners usually view "good" landscaping as areas with large trees and green lawns (Breuste 2004). In semi-arid climates, vegetation maintenance is especially expensive because in order to keep things green and healthy, vegetation has to be watered on a regular basis (Breuste 2004). Lubbock, TX gets about 19 inches of precipitation annually, and from 2010 until the present has been drought-stricken (Nielsen-Gammon 2012, National Weather Service 2013, Allgood 2015). With water prices rising along with the drought conditions, keeping yards green and healthy-looking is becoming even more expensive for homeowners (City of Lubbock 2013).

The large green trees and lawns within the city of Lubbock, TX are in sharp contrast with the landscape surrounding the city, which is mostly made up of shrublands and agricultural fields (Correll and McCoy 1979). The urban habitat can be a unique place for wildlife, and many types of animals make use of urban areas. The vegetation in urban front and back yards provides habitat for many kinds of wildlife and is aesthetically pleasing for humans. One wildlife group often studied in urban areas is birds, mostly for their charisma, commonality, and ease of identification, but also because birds can move

relatively freely through the urban landscape and are affected by disturbance (Niemi and McDonald 2004, Magle et al. 2012).The charisma, commonality, ease of identification, and reaction to disturbance of the bird group make up what is known as an "indicator species". Indicator species can be a valuable tool when deciding whether an area is "good" or "bad" habitat for wildlife (Niemi and McDonald 2004). Using birds as a proxy for other types of wildlife, I am hoping to assess relationships between quality wildlife habitat and vegetation, and compare the relationships to house prices in Lubbock, TX.

Combining human value of yard vegetation with wildlife using yard vegetation can lead to interesting links between house value and wildlife. Farmer et al. (2013) studied the relationship between bird diversity, vegetation coverage, and house prices in Lubbock, TX. The study was conducted on the west side of Lubbock, TX, which includes neighborhoods primarily white in ethnicity and relatively affluent. In the west side Lubbock, TX neighborhoods Farmer et al. (2013) found a relationship between bird diversity and vegetation coverage and house prices.

My project expanded on Farmer et al.'s (2013) research in order to include the east side of Lubbock, TX, which is more ethnically diverse with lower priced houses. I also expanded on the vegetation assessment from the Farmer et al. (2013) study. My method was a more on the ground view of vegetation, looking at layers of vegetation instead of the aerial view of the Farmer et al. (2013) study. By comparing vegetation variables, bird diversity, and house prices, I hope to gain a better understanding on how homeowners value their backyards. My study will give urban ecologists a better understanding on how homeowners value their own backyard by evaluating how much they are willing to pay by examining at house price.

Methods

I collected house characteristics (including house price, number of bedrooms and bathrooms, house square footage, lot size, and garage presence) from local realtors of recently sold houses (study house) from two areas of Lubbock, TX: the west side and the east side (Figure 4.1). I reused the data from sold houses from 2010 (sold in 2009 and 2010) for the west side of town, and assessed new houses on the east side of town (sold in 2012 and 2013) (Perez- Ruiz 2014). Although house prices may have changed slightly in the intervening years, the vegetation has not likely changed much due to the nature of growing vegetation in the semi-arid environment. Each house was GPS's with longitude and latitude in the front of the house using a Garmin Trimble.

I conducted bird surveys in front of each house during Summer 2014 (May-August) and May 2015. I conducted a survey at the front of each study house which improved upon the previous study where bird survey points were more randomly placed (Farmer et al 2013). To perform a bird survey, I collected weather data (temperature, cloud cover, and wind speed) and recorded start and stop time of the survey. Each bird survey lasted for five minutes and every bird seen and/or heard was identified to species and to sex and distance was estimated (Bibby 1992). Time was paused when a car drove by or if additional noise was heard in the area. Surveys were performed during the summer months because birds in the spring and fall might just be passing though and winter birds would not be calling therefore we focused on breeding birds. Surveys started

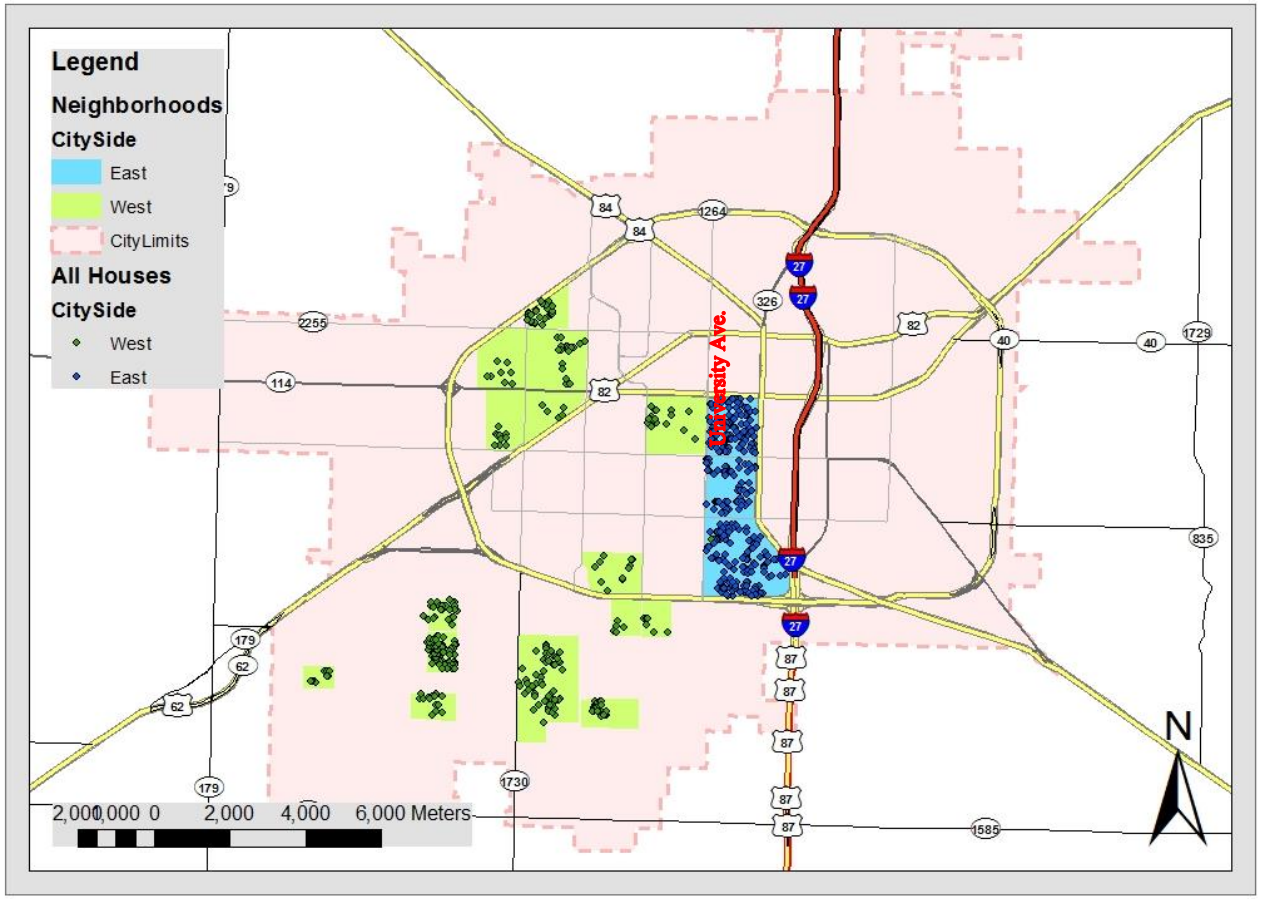

Figure 4.1. Map of Lubbock, TX, with the city limits highlighted in pink and major roads are labeled. Each site is represented by a point, green being on the west side and blue being on the east side of Lubbock. Green polygons are neighborhoods west of University Avenue (labeled in red) and blue polygons are neighborhoods east.

30 minutes prior to sunrise and ended 3 hours after sunrise, because birds call the most during the morning hours (Biddy 1992). I calculated a "bird" variable similar to the "bird" variable calculated in the study by Farmer et al. (2013). The bird variable was the total number of birds seen and/or heard at each site multiplied by the number of adaptor bird species seen and/or heard at each site.

I increased the vegetation survey from the previous study to include an on the ground approach, instead of estimating greenness from aerial views (Farmer et al. 2013). I performed a vegetation survey at each study house, and the group of houses surrounding the study house, further referred to as a 'house block' (Figure 4.2). I did the house block in order to get a more comprehensive view of the vegetation in the area, in case the study house was not representative of the rest of the neighborhood. Any house block characterized as not "normal" was evaluated on a house-by-house basis. At each house I examined different aspects of the vegetation including house upkeep, ground coverage, layers of vegetation below nine feet, and number, species and height of trees (Table 4.1).

Analysis

I used IBM SPSS Statistics (IBM Corp 2014) to run multiple linear regression analyses to determine vegetation effect on the Bird variable in Lubbock, TX. I used backward selection with the bird variable as the dependent variable and all of the vegetation variables from the six block house level of the vegetation survey. The data from Farmer et al. (2013) were assessed (Shiroya 2015, personal communication) to compare the differences between the "bird" variable from the previous study to that of the "bird" variable from my data and the resulting effects on the model.

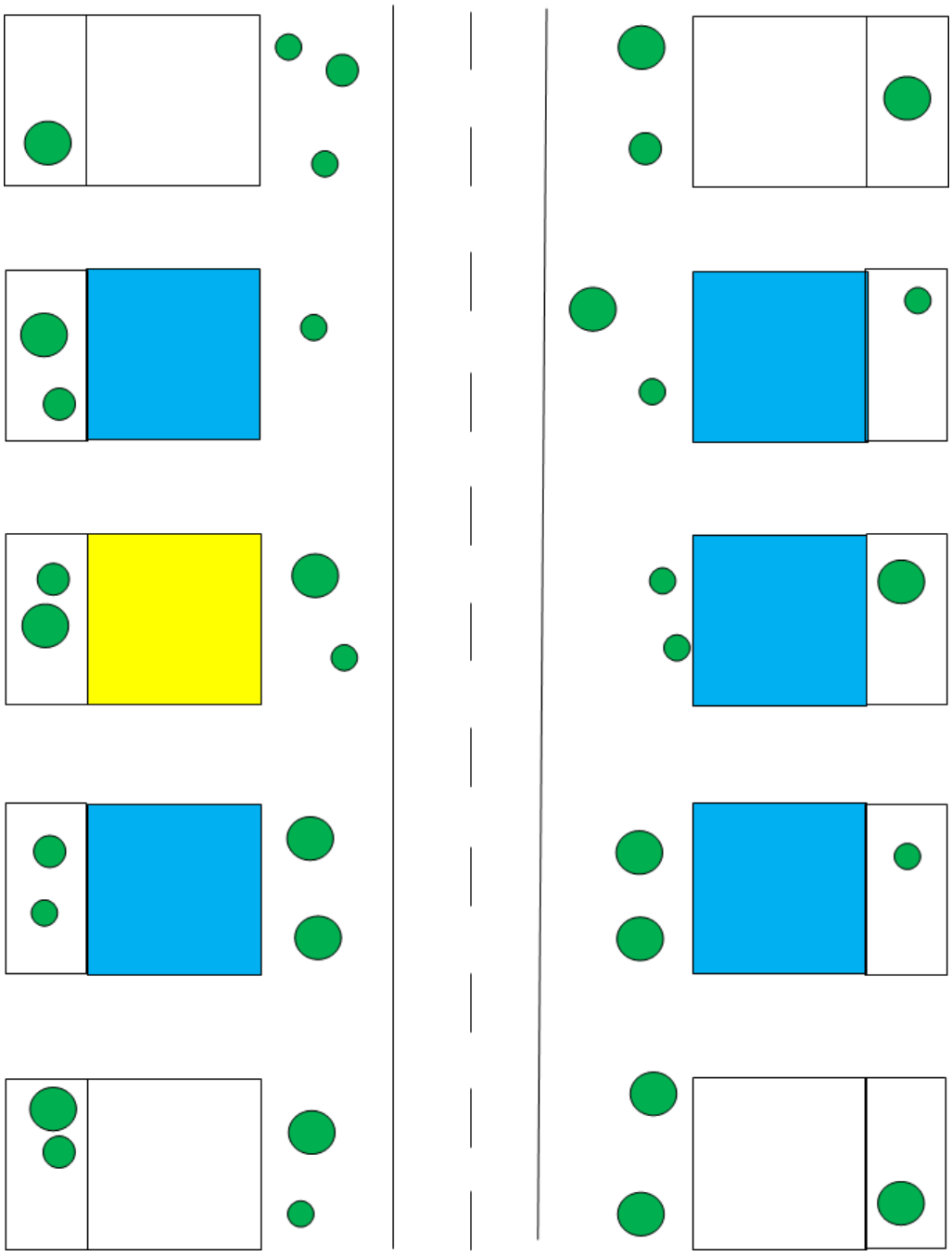

Figure 4.2: Example diagram of an aerial street view of survey points. The yellow block represents the recently sold house, where the "house" vegetation protocol was performed. The blue blocks represent the other five houses that make up the six-house block where the "neighbor" vegetation protocol was performed. The green circles represent trees, the other four white boxes on the top and bottom are other un-surveyed houses on the street, and the small rectangles on the back of each block represent fenced-in backyards.

Table 4.1: The projects vegetation variables with vegetation category, name of variable, description of variable, and the units of the variable.

Vegetation Variable Type	Variable Title	Description	Units of Measurement
Yard upkeep	Upkeep	A judged estimate on how well the front yard was manicured	Scale from 1 to 3 1 = Very manicured 2 = Medially manicured 3 = Completely wild
Ground cover	Non-vegetation	The amount of the front yard that is covered by concrete, dirt, rocks and AstroTurf.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Ground cover	Grass	The amount of the front yard that is covered by grass.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Ground cover	Other vegetation	The amount of the front yard that is covered by ivy, weeds, and other short vegetation.	All Ground Cover sum to 4 0 = 0% 1 = 25% 2 = 50% 3 = 75% 4 = 100%
Vegetation layers under 9' (Understory cover)	House 4”-2’ Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation

Table 4.1 Continued

Vegetation layers under 9' (Understory cover)	House 4”-2’ Layer Coverage	The amount of the vegetation that is in the height range of ground to knee (4"-2')	“-“ =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%
Vegetation layers under 9' (Understory cover)	House 2’-5’ Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation
Vegetation layers under 9' (Understory cover)	House 2’-5’ Layer Coverage	The amount of the vegetation that is in the height range of knee to shoulder (2'-5')	“-“ =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%
Vegetation layers under 9' (Understory cover)	House 5’-9’ Layer Presence/Absence	Whether there is vegetation in the height range of ground to knee (4"-2')	0 = No vegetation 1 = vegetation
Vegetation layers under 9' (Understory cover)	House 5’-9’ Layer coverage	The amount of the vegetation that is in the height range of shoulder and roof (5' to 9')	“-“ =no vegetation, 0= vegetation but barely any 1=1-25%, 2=26-50%, 3=51-75%, 4=76-100%

Results

Farmer et al. (2013) showed that the "bird" variable did increase the accuracy of the house prices. The improved "bird" variable produced from my study increased the accuracy of the house price because of the standardized collection method of the bird surveys (Shiroya 2015, personal communication). I found that whether the six house block was medially manicured or not, the total number of trees, the number of trees between 10 and 20 feet, and the number of trees above 20 feet best predicted the "bird" variable with an adjusted R-squared of 0.026 (Table 4.2). Not only the number of trees but also the sizes of the trees affect the "bird" variable the most, with the total number of trees (t-stat = -2.226, df=310, p=0.027), the number of trees between 10 and 20 feet (t-stat=1.935, df=310, p=0.054), and the number of trees above 20 feet (t-stat=2.910, df=310, p=0.004) significantly affecting the "bird" variable. However, similar to my previous research, the amount the front yard was manicured also significantly affected the "bird" variable according to the model selected (t-stat= -2.035, df=310, p=0.043).

Discussion

The increased detail on the assessment of birds and vegetation at each study house increased the accuracy of house prices compared to the previous study (Farmer et al. 2013). In the original study done by Farmer et al (2013) the bird surveys were done randomly in the study neighborhoods. The randomness did not look how at how well the houses were matched with the bird surveys, therefore bird surveys may have taken place either at the study house or maybe a block or two away. Although neighborhoods are very similar in vegetative structure, perhaps the bird surveys taking place so far away

Table 4:2: Backward selection process of "Bird" against all the possible six house block variables. Coefficients along with standard error reported and one variable eliminated after each models was tested where the variable eliminated had the highest significance value when considering the t-test statistic

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.092	18.486		.275	.783
	NeighborMedMan	-2.466	1.215	-.117	-2.031	.043
	NeighborNonVegSurface	.170	.183	.301	.933	.351
	NeighborGrassSurface	.167	.185	.323	.906	.365
	NeighborLowVegSurface	.128	.201	.087	.638	.524
	NeighborLayerOneNumber	.047	.120	.023	.389	.697
	NeighborLayerTwoNumber	.020	.098	.012	.203	.840
	NeighborLayerThreeNumber	-.026	.081	-.020	-.320	.749
	TotalTreeNumberNormalized	-1.259	.849	-.469	-1.483	.139
	AllTreesLessThanOneNormalized	.582	.883	.089	.658	.511
	AllTreesOneToTwoNormalized	1.356	.874	.304	1.552	.122
	AllTreesMoreThanTwoNormalized	1.735	.889	.405	1.952	.052
2	(Constant)	4.943	18.442		.268	.789
	NeighborMedMan	-2.477	1.211	-.117	-2.044	.042
	NeighborNonVegSurface	.173	.182	.306	.955	.341
	NeighborGrassSurface	.170	.184	.328	.926	.355
	NeighborLowVegSurface	.132	.200	.090	.660	.510
	NeighborLayerOneNumber	.052	.117	.026	.442	.659
	NeighborLayerThreeNumber	-.026	.081	-.020	-.318	.751
	TotalTreeNumberNormalized	-1.267	.846	-.472	-1.497	.135
	AllTreesLessThanOneNormalized	.596	.879	.091	.677	.499
	AllTreesOneToTwoNormalized	1.364	.871	.306	1.565	.119
	AllTreesMoreThanTwoNormalized	1.752	.884	.409	1.982	.048
3	(Constant)	4.851	18.412		.263	.792

Table 4:2 Continued

	NeighborMedMan	-2.466	1.209	-.117	-2.040	.042
	NeighborNonVegSurface	.175	.181	.310	.967	.334
	NeighborGrassSurface	.169	.184	.327	.923	.357
	NeighborLowVegSurface	.133	.200	.090	.664	.507
	NeighborLayerOneNumber	.046	.115	.023	.394	.694
	TotalTreeNumberNormalized	-1.282	.844	-.477	-1.520	.130
	AllTreesLessThanOneNormalized	.607	.877	.092	.692	.489
	AllTreesOneToTwoNormalized	1.366	.870	.306	1.570	.118
	AllTreesMoreThanTwoNormalized	1.749	.883	.408	1.982	.048
4	(Constant)	5.378	18.338		.293	.770
	NeighborMedMan	-2.455	1.207	-.116	-2.034	.043
	NeighborNonVegSurface	.175	.181	.309	.967	.335
	NeighborGrassSurface	.170	.183	.327	.925	.355
	NeighborLowVegSurface	.137	.199	.093	.688	.492
	TotalTreeNumberNormalized	-1.250	.838	-.465	-1.490	.137
	AllTreesLessThanOneNormalized	.587	.875	.089	.672	.502
	AllTreesOneToTwoNormalized	1.332	.865	.299	1.540	.125
	AllTreesMoreThanTwoNormalized	1.722	.879	.402	1.960	.051
5	(Constant)	5.745	18.313		.314	.754
	NeighborMedMan	-2.456	1.206	-.116	-2.036	.043
	NeighborNonVegSurface	.171	.181	.302	.946	.345
	NeighborGrassSurface	.167	.183	.322	.912	.362
	NeighborLowVegSurface	.136	.199	.092	.683	.495
	TotalTreeNumberNormalized	-.742	.364	-.276	-2.041	.042
	AllTreesOneToTwoNormalized	.842	.464	.189	1.815	.071
	AllTreesMoreThanTwoNormalized	1.208	.430	.282	2.809	.005
6	(Constant)	16.947	8.127		2.085	.038
	NeighborMedMan	-2.415	1.204	-.114	-2.006	.046
	NeighborNonVegSurface	.062	.085	.110	.732	.465

Table 4:2 Continued

	NeighborGrassSurface	.054	.079	.105	.685	.494
	TotalTreeNumberNormalized	-.768	.362	-.286	-2.124	.034
	AllTreesOneToTwoNormalized	.857	.463	.192	1.850	.065
	AllTreesMoreThanTwoNormalized	1.228	.429	.286	2.865	.004
7	(Constant)	22.401	1.631		13.731	.000
	NeighborMedMan	-2.459	1.201	-.116	-2.047	.041
	NeighborNonVegSurface	.009	.033	.015	.260	.795
	TotalTreeNumberNormalized	-.787	.360	-.293	-2.184	.030
	AllTreesOneToTwoNormalized	.874	.462	.196	1.892	.059
	AllTreesMoreThanTwoNormalized	1.194	.425	.278	2.808	.005
8	(Constant)	22.698	1.161		19.551	.000
	NeighborMedMan	-2.413	1.186	-.114	-2.035	.043
	TotalTreeNumberNormalized	-.796	.358	-.296	-2.226	.027
	AllTreesOneToTwoNormalized	.887	.458	.199	1.935	.054
	AllTreesMoreThanTwoNormalized	1.215	.417	.283	2.910	.004

a. Dependent Variable: AllBirds

from the study house might affect what birds were actually seen at that house. By comparing the accuracy of the pervious "bird" variable to that of my improved "bird" variable I was able to determine that the increased bird survey accuracy improved the model. Therefore, I recommend the more in-depth study where bird surveys are conducted at each study house as opposed to random points in a neighborhood.

The vegetation variables that affected the bird variable were interesting, with most of the variables contributing to the model being tree related. Three of the four possible tree variables were in the final model, showing that in Lubbock, TX, birds are affected significantly by the tree coverage in yards within neighborhoods. My other research does not point to trees being a large contributor to number bird species and species groups however none of my previous research questions accounted for the number of birds observed. Although I standardized my assessments wherever possible, bird number may be under or over represented due to factors out of my control such as traffic noise, time of day, time of year, and structure of the surrounding area. However, in order to be consistent with the previous study (Farmer et al. 2013), I choose to replicate the same "bird" variable.

Management Implications

Being able to identify different types of people selling and buying houses has the potential to allow realtors to exploit the resources of a house to the maximum degree. Instead of just focusing on house characteristics realtors could also pair up houses that have higher bird diversity and more vegetation to home buyers who desire higher bird diversity and more vegetation. Realtors can use the knowledge of different types of

buyers in order to find the perfect house for each type and can advertise houses in order to target the home buyers that would appreciate the house the most.

If people understand that increasing vegetation will increase the bird diversity in their backyard, and in turn their house value may increase, people might be more encouraged to improve their landscaping for wildlife. As the urban area increases, promoting the advantages of increased vegetation and bird diversity in order to increase and improve the habitat in the urban environment will be important. Birds are easy to see, very common, and are usually not too intrusive, therefore birds are a great gateway into teaching people to value the environment surrounding them.

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APPENDIX A
BIRD SURVEY DATASHEET

Lubbock Point Count Data Sheet								
Site#			Observer		Date			UTM
Start time			Assistant		Address			e
End Time			Wind	Sky	Temp			n
Individ & Position	Species Code	Sex	Heard inside of 6 house block	Heard outside of 6 house block	Non-song cues		Fly Over #	Comments
					In	Out		
1 ⊕								
2 ⊕								
3 ⊕								
4 ⊕								
5 ⊕								
6 ⊕								
7 ⊕								
8 ⊕								
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APPENDIX B
VEGETATION SURVEY DATA SHEET

Survey Number			Date						Observer				Address	
House Upkeep:			Ground cover house:			Ground cover neighbor:			Ground to knee:		Knee to shoulder:		Shoulder to roof:		House # of trees:	House # of tree Species:
									House	Neig.	House	Neig.	House	Neig.		
1	2	3	1	2	3	1	2	3	Y N	Y N	Y N	Y N	Y N	Y N		
Neigh. Upkeep:			1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	Neighbor # of trees:	Neighbor # of tree species:
1	2	3														

Tree species	Height	@ House	@ Neighbors	Notes:
	< 1 1-2 >2			
	< 1 1-2 >2			
	< 1 1-2 >2			
	< 1 1-2 >2			
	< 1 1-2 >2			
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APPENDIX C
BIRD SPECIES SEEN DURING STUDY

Species four letter code	Species common name	Species scientific name	Total number seen at sites
AMRO	American robin	Turdus migratorius	473
BASW	barn swallow	Hirundo rustica	367
BLCH	black-chinned hummingbird	Archilochus alexandri	1
BLJA	blue jay	Cyanocitta cristata	337
CAGO	Canada goose	Branta canadensis	0
CHSP	chipping sparrow	Spizella passerina	0
CHSW	chimney swift	Chaetura pelagica	1
DOGE	domestic goose	Anser cygnoides	18
ECDO	Eurasian collard dove	Streptopelia decaocto	1940
EUST	European starling	Sturnus vulgaris	348
GTGR	great-tailed grackle	Quiscalus mexicanus	2780
HOFI	house finch	Haemorhous mexicanus	292
HOSP	house sparrow	Passer domesticus	4259
INDO	Inca dove	Columbina inca	2
KILL	killdeer	Charadrius vociferus	1
MALL	mallard	Anas platyrhynchos	7
MIKI	Mississippi kite	Ictinia mississippiensis	30
MODO	mourning dove	Zenaida macroura	452
NOCA	northern cardinal	Cardinalis cardinalis	67
NOMO	northern mockingbird	Mimus polyglottos	232
SNEG	snowy egret	Egretta thula	0
BCTI	black-crested titmouse	Baeolophus atricristatus	0
RODO	rock dove	Columba livia	4
RWBL	red-winged blackbird	Agelaius phoeniceus	47
WEKI	western kingbird	Tyrannus verticalis	408
WWDO	white-wing dove	Zenaida asiatica	1398

APPENDIX D
TREE AND SHRUB SPECIES SEEN DURING STUDY

Tree common name	Tree abbreviation	Scientific name
Fraser Fir	FRFI	Abies fraseri
Box Elder	BOEL	Acer negundo
Silver maple	SIMA	Acer saccharinum
Sugar Maple	SUMA	Acer saccharum
Ailanthus	ALAN	Ailanthus altissima
Mimosa	MIMO	Albizia julibrissin
Bamboo	BAMB	Bambuseae
Trumpet Vine	TRVI	Campsis radicans
Pecan	PECA	Carya illinoinensis
Common Hackberry	HACK	Celtis occidentalis
Eastern Redbud	REDB	Cercis canadensis
Desert willow	DEWI	Chilopsis linearis
Chitalpa	CHIT	Chitalpa tashkentesis
Manhattan euonymus	MAEU	Euonymus kiautschovicus
Green Ash	GRAS	Fraxinus pennsylvanica
Honey Locust	HOLO	Gleditsia triacanthos
Kentucky Coffee Tree	KECT	Gymnocladus dioicus
rose of sharon	ROOS	Hibiscus syriacus
Possumhaw	POSS	Ilex decidua
will fleming yaupon	WIFY	Ilex vomitoria
Nellie R. Stevens Holly	NRSH	Ilex x attenuata
Rocky Mountain Juniper	ROMJ	Juniperus scopulorum
Eastern red cedar	EARC	Juniperus virginiana
Golden Rain Tree	GORT	Koelreuteria paniculata
Crapemyrtle	CRAP	Lagerstroemia sp.
Sweetgum	SWEE	Liquidambar styraciflua
japanese honeysuckle	JAHO	Lonicera japonica
Sothern Magnolia	SOMA	Magnolia grandiflora
Apple tree	APTR	Malus domestica
Common Mulberry	COMU	Morus alba
Palm tree	PATR	Phoenix canariensis
pinyon pine	PIPI	Pinus edulis
Afghan Pine	AFPI	Pinus eldarica
Chinese Pistache	CHPI	Pistacia chinensis
American Sycamore	SYCA	Platanus occidentalis

Eastern Cottonwood	EACO	Populus deltoides
Quaking Aspen	QUAS	Populus tremuloides
Honey Mesquite	HOME	Prosopis glandulosa
Plum tree	PLTR	Prunus americana
Apricot tree	ARTR	Prunus armeniaca
Purple Leaf Plum	PULP	Prunus cerasifera
Peach tree	PETR	Prunus persica
Bradford Pear	BRPE	Pyrus calleryana
Bur Oak	BUOA	Quercus macrocarpa
Chinkapin oak	CHOA	Quercus muehlenbergii
Monterrey Oak	MOOA	Quercus polymorpha
Shermard Oak	REOA	Quercus shumardii
Live Oak	LIOA	Quercus virginiana
Rose Spp.	ROSP	Rosa spp.
Globe willow	GLWI	Salix globosa
Corkscrew Willow	COWI	Salix matsudana
Bald Cypress	BACY	Taxodium distichum
Northern White cedar	NOWC	Thuja occidentalis
Cedar Elm	CEEL	Ulmus crassifolia
Lacebark Elm	LAEL	Ulmus parvifolia
Siberian Elm	SIEL	Ulmus pumila
Vanhoutte spirea	VASP	Vanhoutte spirea
Lilac Chaste Tree	LICT	Vitex agnus-castus
grape vine	GRVI	Vitis sp.
Japanese Zelkova	JAZE	Zelkova serrata