COMPARISON OF AVIAN COMMUNITIES WITHIN TRADITIONAL AND WILDSCAPED RESIDENTIAL NEIGHBORHOODS IN SAN ANTONIO, TEXAS

THESIS

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By

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF APPENDICES

Page

ABSTRACT

COMPARISON OF AVIAN COMMUNITIES WITHIN TRADITIONAL AND WILDSCAPED RESIDENTIAL NEIGHBORHOODS IN SAN ANTONIO, TEXAS

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Incorporating wildlife habitat into residential areas is becoming increasingly common for homeowners and developers, and is touted as a way to reduce some of the impacts of residential development on wildlife populations. However, few studies have tested this claim. I tested the hypothesis that a residential neighborhood in San Antonio, Texas, which was certified by the Texas Parks and Wildlife Department as a Texas Wildscape in 1996, had a more diverse bird community than an adjacent traditionally developed residential neighborhood. I also hypothesized that the bird community at a nearby natural area (Government Canyon State Natural Area) was more similar to the bird community at the wildscaped neighborhood than at the traditional neighborhood. Further, I hypothesized that differences in the density and structure of the habitat (primarily woody vegetation) influenced potential differences in the bird communities at the three sites. After two years of bird surveys, bird diversity (including independent measures of species richness and evenness) at the wildscaped neighborhood was significantly greater than at the traditional neighborhood or the natural area. The density of woody plants and the amount of vertical cover were moderately to strongly correlated with bird diversity measures at the residential sites. This study suggests that residential areas that incorporate natural landscapes into their design can attract a greater variety of birds than traditionally landscaped residential areas.

These areas may provide valuable habitat for some declining species and reduce the impacts of residential development, especially where urbanization is encroaching on natural areas.

INTRODUCTION

Neighborhood-wide, backyard wildlife management programs in residential subdivisions represent a new avenue for conservation efforts in areas where development is encroaching on wild spaces. In Texas, a number of organizations and agencies (e.g., Texas Parks and Wildlife Department and National Wildlife Federation) provide technical assistance to homeowners striving to incorporate wildlife and nature into residential developments. Some programs also recognize landowner efforts by certifying properties that meet appropriate wildlife habitat standards. While these programs are designed to improve habitat for native wildlife in urbanizing areas, the actual effectiveness of these programs, as applied to entire neighborhoods, is largely untested.

Residential development impacts natural environments in several ways, such as replacing native vegetation with buildings, pavement, and other man-made structures (e.g., direct habitat loss) (McIntyre and Hobbs 1999), decreasing the amount of continuous open-space (e.g., fragmentation), and increasing vegetational disturbance, erosion, and soil compaction (Bradley 1995). Residential development often results in the introduction of non-native vegetation through invasion or landscaping with non-native, ornamental plants (Whitney and Adams 1980, Mills et al. 1989, Bolger et al. 1997) Urbanization also can change the abundance of predators and competitors in an area (Wilcove 1985, Engels and Sexton 1994, Jokimaki and Huhta 2000) and increase disturbance from human activity (Whitcomb et al. 1981). Physical changes to the natural landscape, as well as the possible alteration in predator or competitor interactions resulting from urbanization can have a profound impact on wildlife communities (Freisen et al. 1995).

Many studies have addressed the broad effect of urbanization on bird communities (Batten 1972, Emlen 1974, Walcott 1974, Aldrich and Coffin 1980, Beissinger and Osborne 1982, Rosenberg et al. 1987). The consensus of these studies was that species composition changed as an area became developed, with species richness and diversity decreasing and overall

bird abundance increasing. However, Blair (1996) noted that many of these previous investigations were conducted at a scale too coarse to detect some important effects of urbanization.

Blair (1996) studied an urban-rural gradient in California and found that areas with a moderate level of development, such as residential neighborhoods or golf courses, had the highest species richness and abundance compared to areas with no development or areas with intense development (i.e., industrial parks). This increase in species richness was the result of the addition of urban or suburban-adaptable species to the natural avian community. However, he also noted that areas with even moderate levels of development were found to have lost species that were most sensitive to the impacts of urbanization.

The Texas Wildscapes program of the Texas Parks and Wildlife Department and the Backyard Wildlife Habitat program of the National Wildlife Federation recognize individual landowners who incorporate wildlife habitat into areas of residential and commercial use. Participation in these programs emphasizes the importance of using native plants in landscaping, conserving water, choosing natural alternatives to pesticides, and managing predators (primarily domestic cats and dogs) to help reduce the impacts of residential land use (Damude and Bender 1999). Many of the practices advocated by these programs are consistent with the recommendations for increasing the value of urban areas for native wildlife (Beissinger and Osborne 1982, Mills et al. 1989, Germaine 1998).

When backyard wildlife management programs originally designed for individual properties are expanded to include entire residential neighborhoods, the efforts of individual developers and homeowners are combined to conserve significant portions of the natural landscape and mitigate some effects of urbanization. The careful placement of roads, utilities, and homes can avoid disturbing important landscape features, such as riparian corridors or significant vegetation. Providing supplemental food, water, and shelter may also replace resources lost through the addition of impervious cover and residential landscaping. The result

can be a residential neighborhood that retains a large portion of its natural character and essential wildlife habitat resources (Damude and Bender 1999).

I studied the ability of a residential neighborhood, which was certified by the Texas Wildscapes program in 1996, to support an enhanced avian community compared to a residential neighborhood where wildlife management was not emphasized. I addressed three questions regarding wildlife and wildlife habitat in these residential neighborhoods: 1) Do residential areas with a wildlife management focus have a more diverse community of native songbirds compared to traditionally developed residential areas? 2) Does the avian community in neighborhoods with a wildlife management focus retain a higher proportion of the natural, pre-development avian community than traditional residential developments? and 3) Are potential differences in the diversity of the avian communities related to differences in vegetative structure found in each type of residential area?

I wanted to test whether the Texas Wildscapes-certified residential neighborhood would have a greater diversity and overall abundance of songbirds than a traditionally landscaped residential neighborhood. I hypothesized that the avian community of the wildscaped neighborhood would resemble more closely the avian community of the undeveloped, Government Canyon State Natural Area (GCSNA) than did the traditional residential neighborhood. Similarly, I hypothesized that the wildscaped neighborhood would have a greater diversity in vegetative structure compared to habitat in the traditionally landscaped residential neighborhood. Canopy cover, woody plant density, and the composition of the vegetation community in the wildscaped community should more closely reflect the native vegetation community, as found in GCSNA, than did the traditional residential neighborhood.

Avian and vegetational surveys were conducted in a traditional residential neighborhood and a Texas Wildscapes-certified residential neighborhood in San Antonio, Bexar County, Texas. Surveys also were conducted at GCSNA in northwest Bexar County, Texas, which contained

relatively undisturbed woodland habitat representative of the natural vegetational community in the region.

METHODS

Study Sites

This study was conducted on three sites in San Antonio and northwest Bexar County, Texas (Fig. 1). The wildscaped residential neighborhood, known as The Preserve at Santa Fe Trail, was certified by the Texas Wildscapes program in 1996. The traditionally developed site, which did not incorporate wildlife habitat at a neighborhood level, was representative of the general area and adjacent to the wildscaped neighborhood. Approximately 26.6 km west of the two residential neighborhoods, and outside of the City of San Antonio, was GCSNA. This site was not open to the public at the time of this study. GCSNA was chosen as representative of pre-development conditions in the northern San Antonio area.

Development of the Preserve at Santa Fe Trail began in 1996 and was completely built-out (homes were constructed on all available lots) by the time of this study. The neighborhood was approximately 10.1 ha and included 29 single-family, residential lots. The average lot size was approximately 0.18 ha. The developer of the neighborhood worked with Texas Wildscapes program coordinators to help achieve certification for the area. Prominent among the developer's efforts for certification was the retention of native vegetation on individual lots and in a drainage that ran through the neighborhood. The wildscaped neighborhood was located within a larger area of typical urban development, which included other residential neighborhoods, local commercial development, and an urban park.

The traditional residential neighborhood was typical of residential developments built between the 1960s and late 1990s. The area included in this study spanned approximately 24 ha, although this type of residential development was representative of the general area. Within this study area, individual lots averaged 0.11 ha in size. The same drainage crossed both neighborhoods. However, most of the woody vegetation was removed from the section passing through the traditionally landscaped neighborhood. No coordinated effort was made to

incorporate wildlife habitat or native vegetation into the development of the traditional residential neighborhood.

GCSNA was located in the northwest corner of Bexar County, Texas. This site was located in the Edwards Plateau Natural Region of Texas (Natural Heritage Policy Research Project 1978) and was representative of the oak-juniper woodland that characterizes the Texas Hill Country. The site was approximately 2,688 ha (Texas Parks and Wildlife Department 2002), although surveys for this study were confined to an area of approximately 23 ha at the eastern side of the property. This study site included a small, ephemeral drainage, similar to the drainage that ran through the residential neighborhoods. The vegetational community at this site was likely to be similar to the pre-development conditions at the residential sites.

Bird Surveys

Bird surveys were conducted with fixed-radius point counts (Hutto, et al. 1986) centered on drainages and roads, or trails within each study area. Survey points placed in drainage easements allowed visual and auditory access to the backside of lots in the residential neighborhoods, while points placed along roadways allowed visual and auditory access to the front side of residential lots. Four point count stations were located within the drainage in each of the study sites and another four point count stations were located on uplands along roads or trails.

All survey points had a fixed-radius of 50 m and each point was surveyed for 10 minutes during each visit. Points were located at least 100 m apart in the traditional neighborhood and at GCSNA, with the closest two points in the traditional neighborhood positioned 140 m apart and the closest two points at GCSNA positioned 157 m apart. Given the small size of the wildscaped neighborhood, some survey points were located closer than 100 m. The smallest distance between two adjacent survey points in the wildscaped neighborhood was 68.5 m. There was a slight overlap between the survey radiuses of four other points at this site.

Each study site was surveyed approximately two times per month between June 2000 and June 2002. For the purposes of this study, Summer was defined to include the months of June,

July, and August, Autumn included September, October, and November, Winter included December, January, and February, and Spring included March, April, and May. The number of individuals of each bird species observed by sight or sound within the survey radius during the 10-minute count was recorded for each survey point. Incidental observations of other bird species observed at each study site, either outside of a survey point radius or outside of the count duration at a point, also were recorded but not used in statistical analyses or index calculations.

Approximately 1.5 to 3 hours were spent at each site during each visit, including the time spent on site between points, and the order of site visitation was rotated with each visit to reduce bias in the time of day the surveys took place. All sites were surveyed within the same day, as weather permitted, either in the hours after sunrise or the hours before sunset (e.g., GCSNA was surveyed in the morning and the residential communities were surveyed in the evening). Morning surveys began approximately 30 to 60 minutes after sunrise and afternoon surveys were timed as to end 30 to 60 minutes before sunset, when possible.

Vegetational Surveys

Several aspects of the vegetational community at each study site were quantified by measuring the species composition, density, and the vertical cover or structure of woody plant species. A point-centered quarter method was used to quantify the density and species composition of woody trees and shrubs (Barnes 1999). Two vegetational survey points were located within the radius of each 50 m-radius bird survey point and centered along the road, trail, or drainage that passed through the bird survey point. A line that ran perpendicular to the road, trail, or drainage and a line that ran along the approximate center of the road, trail, or drainage defined the quadrants for each vegetational survey point. Species, distance from the center point, and approximate canopy cover of the nearest woody plant was recorded for each quadrant.

A vegetational profile board was used to quantify vertical woody cover, generally following the methods described in Nudds (1977). Two profile measurements were made at each

vegetational survey point, 15 m from the center of the vegetational survey point and perpendicular to the road, trail, or drainage that passed through the point.

Data Analysis

Bird observations by species at each survey point were summed for each season and the entire study. Indices and other measures of species diversity were generated from the summed data with the heterogeneity and evenness measures program in Krebs (2000). Based on a discussion in Krebs (2000), the Brillouin index (H) was used to evaluate species diversity among sites and Smith and Wilson's index of evenness (E_{var}) estimated the equitability of individual observations among species within a site. The percentage similarity program in Krebs (2000) generated measures of similarity between pairs of study sites, also using grouped observation data.

Tests for significant differences among the diversity and similarity measures for each study site were made with analysis of variance (ANOVA) tests. ANOVA tests were balanced, single-factor, fixed-effects models run with Microsoft Excel 97 data analysis macro functions (Microsoft Corporation 1985 – 1996). Statistical comparisons to evaluate potential differences among sites across the entire study were made by using the data derived from the seasonal observations, such that n = 8 survey points and a = 3 study sites. Comparisons of pairs of treatment means were made by the least significant difference (LSD) procedure, as described in Montgomery (1997) to pinpoint where significant differences existed between pairs of study sites when the ANOVA indicated significant differences at $P \leq 0.05$ among the sites. For all statistical tests, $\alpha = 0.05$.

The density, canopy cover, and Shannon-Wiener diversity index (H') of woody plants at each study site was calculated from the distance to plant and canopy cover data collected from the point-centered quarter measurements, following the procedures described in Barnes (1999). Density and canopy cover were also calculated for vegetational measurements corresponding to

each bird survey point within study sites. The average vertical cover rating for each profile board increment was calculated for each study site overall and for each bird survey point within sites. The average cover rating for all increments was also calculated for each site and for each bird survey point within sites. ANOVA and least significant difference techniques were used to detect significant differences in the density, canopy cover, and vertical cover among sites, using the parameters described above for the analysis of bird survey data.

Bird community diversity measures (species richness, abundance, diversity, and evenness) were correlated with the woody plant density, canopy cover, and vertical cover measures for the residential neighborhoods. Correlation coefficients were calculated using the Microsoft Excel 97 correlation function (CORREL) (Microsoft Corporation 1985 – 1996). A moderate correlation was defined as a correlation coefficient of greater than 0.333 or less than –0.333 for positive and negative relationships, respectively. A strong correlation was defined as a correlation coefficient of greater than 0.666 or less than –0.666 for positive and negative relationships, respectively.

RESULTS

Bird Survey Data

Each study site was visited 39 times between 1 June 2000 and 1 June 2002, with approximately 10 visits (± 1 visit) for each season. During the study, 74 bird species were observed on GCSNA, 75 species on the wildscaped neighborhood, and 55 species on the traditional neighborhood, including incidental observations made outside of the formal survey parameters (Appendix A). Fewer species were observed within the limits of the survey point radii and counting periods for each visit. Species richness, excluding incidental and out-of-point observations, at GCSNA was 54 species. Similarly, the wildscaped neighborhood had 65 species, while the traditional neighborhood had only 42 species (Appendix B through Appendix D). The number of new species observed at each site decreased as the number of seasons surveyed increased (Fig. 2), such that fewer new species were observed as the survey effort increased past five seasons.

Over the entire study, 9,169 individual bird observations were made across the three study sites. The average abundance of birds per survey point was significantly higher at the residential neighborhoods than at GCSNA in the Summer, Autumn, and Spring seasons, as well as over the entire study (Table 1, Appendix E). Further, the traditional neighborhood had a significantly higher average number of observations per point than the wildscaped neighborhood in all seasons, except for Winter. There was no significant difference in the average number of observations per point among the three sites during the Winter season (Appendix E).

The species richness of the bird community at the wildscaped neighborhood was 23 species greater than the species richness of the traditional neighborhood over the entire study. The average species richness per point over the entire study was significantly higher in the wildscaped neighborhood than at the traditional neighborhood or GCSNA (Table 1). The wildscaped neighborhood also had a significantly higher average species richness per survey

point than the other two study sites during the Winter season. In all seasons and over the entire study, GCSNA had the lowest average species richness per point (Table 1, Appendix E).

The wildscaped neighborhood showed a significantly higher average species diversity per point than the traditional neighborhood over the entire study and in all seasons, except Winter. In all seasons and over the entire study, the wildscaped neighborhood also had a significantly more diverse bird community than GCSNA. The average diversity index per point for GCSNA was similar to the diversity index for the traditional neighborhood over the entire study and for each season, except for Spring when it had the lowest diversity of the three sites (Table 1, Appendix E).

The residential neighborhoods shared 40 bird species, including common non-native species, such as the house sparrow (*Passer domesticus*) and European starling (*Sturnus vulgaris*). They also shared several common urban-adapted species (e.g., native species observed in large numbers at the residential neighborhoods that were either not observed at GCSNA or observed only rarely) and urban-tolerant species (e.g., native species observed in moderate numbers at all three sites). The urban-adapted species shared by the residential neighborhoods included the great-tailed grackle (*Quiscalus mexicanus*), purple martin (*Progne subis*), chimney swift (*Chaetura pelagia*), white-winged dove (*Zenaida asiatica*), lesser goldfinch (*Carduelis psaltria*), and blue jay (*Cyanocitta cristata*).

Twenty-eight bird species were observed at all three sites. Some species were considered urban-tolerant, such that they were relatively common at each of the study sites. Urban-tolerant species included the northern mockingbird (*Mimus polyglottos*), northern cardinal (*Cardinalis cardinalis*), mourning dove (*Zenaida macroura*), Inca dove (*Columbina inca*), house finch (*Carpodacus mexicanus*), ruby-crowned kinglet (*Regulus calendula*), Carolina wren (*Thryothorus ludovicianus*), Bewick's wren (*Thryomanes bewickii*), western scrub-jay (*Aphelocoma californica*), tufted titmouse (*Baeolophus bicolor*), and field sparrow (*Spizella pusilla*).

Eight species were observed at the both the wildscaped neighborhood and GCSNA, but not at the traditional neighborhood. These species included the white-eyed vireo (*Vireo griseus*), Acadian flycatcher (*Empidonax virescens*), eastern phoebe (*Sayornis phoebe*), golden-crowned kinglet (*Regulus satrapa*), gray catbird (*Dumetella carolinensis*), and curve-billed thrasher (*Toxostoma curvirostre*). Only the cedar waxwing (*Bombycilla cedrorum*) was observed at both the traditional neighborhood and GCSNA, but not at the wildscaped neighborhood.

Seventeen species were unique to the wildscaped neighborhood and included several warblers (e.g., black-and-white warbler, *Mniotilta varia;* black-throated green warbler, *Dendroica virens*; mourning warbler, *Oporornis philadelphia*; Nashville warbler, *Vermivora ruficapilla*; and common yellowthroat, *Geothlypis trichas*), vireos (e.g., blue-headed vireo, *Vireo solitarius*; and Bell's vireo, *Vireo bellii*), ground and brush-foraging species (e.g., white-throated sparrow, *Zonotrichia albicollis*; white-crowned sparrow, *Zonotrichia leucophrys*; Cassin's sparrow, *Aimophila cassinii*; and brown-thrasher, *Toxostoma rufum*), and flycathers (i.e., western kingbird, *Tyrannus verticalis*; and eastern wood pewee, *Contopus virens*).

Another seventeen species were only observed at GCSNA. Species unique to the natural area included many species that are typically described as "shy" or "secretive," including yellow-billed cuckoo (*Coccyzus americanus*), greater roadrunner (*Geococcyx californianus*), northern bobwhite (*Colinus virginianus*), and green-tailed towhee (*Pipilo chlorurus*).

GCSNA had the highest average index of evenness per point for all seasons and the entire study, except Winter. Conversely, the traditional neighborhood had the lowest average index of evenness per point for all time periods, except Winter. However, there was no significant difference among the evenness indices for each site during Winter (Table 1, Appendix E).

The amount of similarity between the wildscaped and traditional neighborhoods was significantly higher than the amount of similarity between either residential neighborhood and GCSNA. Further, the bird communities at GCSNA and the traditional neighborhood were the least similar (Table 1, Appendix E).

Vegetational Data

Compiling the point-centered quarter data by the corresponding bird survey point (e.g., eight point-centered quarter data points per bird survey point), revealed significant differences among the sites in the density of woody plants ($P < 0.001$). The average density of woody plants per bird survey plot at GCSNA was significantly greater than the average density of woody plants at the wildscaped neighborhood. The traditional neighborhood had the lowest average plant density of the three sites. There were no significant differences among the average amounts of woody plant canopy cover per point at each site (Table 2).

The Shannon-Wiener diversity index (H') of woody plant species diversity, calculated from data compiled by study site, was relatively low at GCSNA ($H' = 1.983$). Only 15 different species (all native to central Texas) were recorded in the point-centered quarter measurements for GCSNA.

In contrast, the species diversity at the traditional neighborhood was relatively high ($H' = 3.046$). This site included 15 native plant species and 15 non-native plants. The wildscaped neighborhood had an intermediate measure for woody plant species diversity ($H' = 2.620$), and included 17 native plants and 5 non-native plants (Appendix F).

The average cover rating for each increment of the vegetative profile board was relatively consistent within study sites (Fig. 3). Significant differences were observed in the average vertical cover rating for all increments among study sites, when compiled by bird survey point ($P = 0.002$). Vertical cover at the traditional neighborhood was significantly lower than the vertical cover at the wildscaped neighborhood or GCSNA. No significant differences were observed in the vertical cover rating between the wildscaped neighborhood and GCSNA.

The density and vertical structure of the woody plant community in the residential neighborhoods were moderately to strongly correlated with the species richness, species diversity, and evenness of the bird community at those sites (Table 3 and Table 4). Canopy cover of the

woody plants in the residential neighborhood was also moderately correlated with the evenness of the bird community in the residential neighborhoods (Table 5).

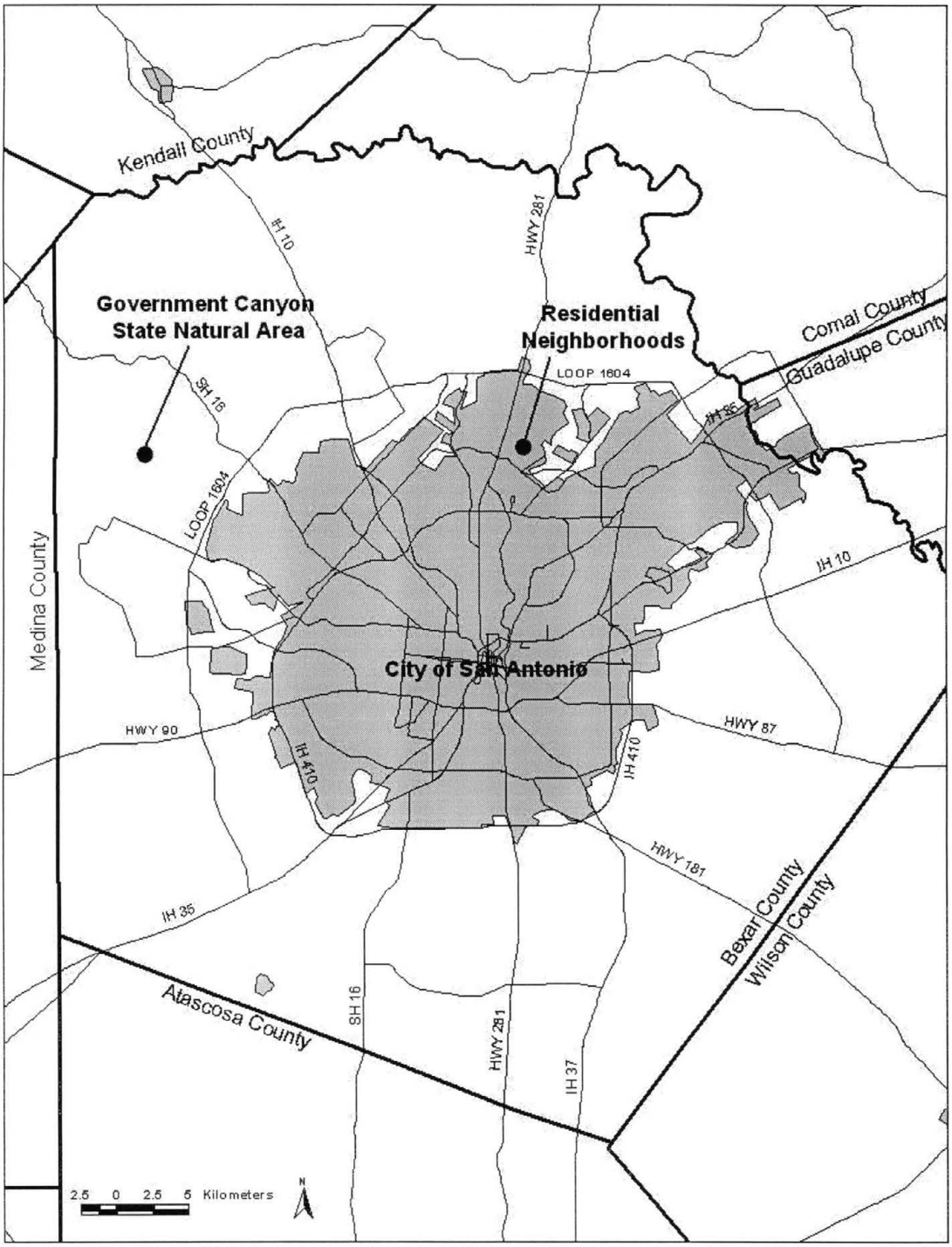

Figure 1. Location of the three study sites in Bexar County, Texas.

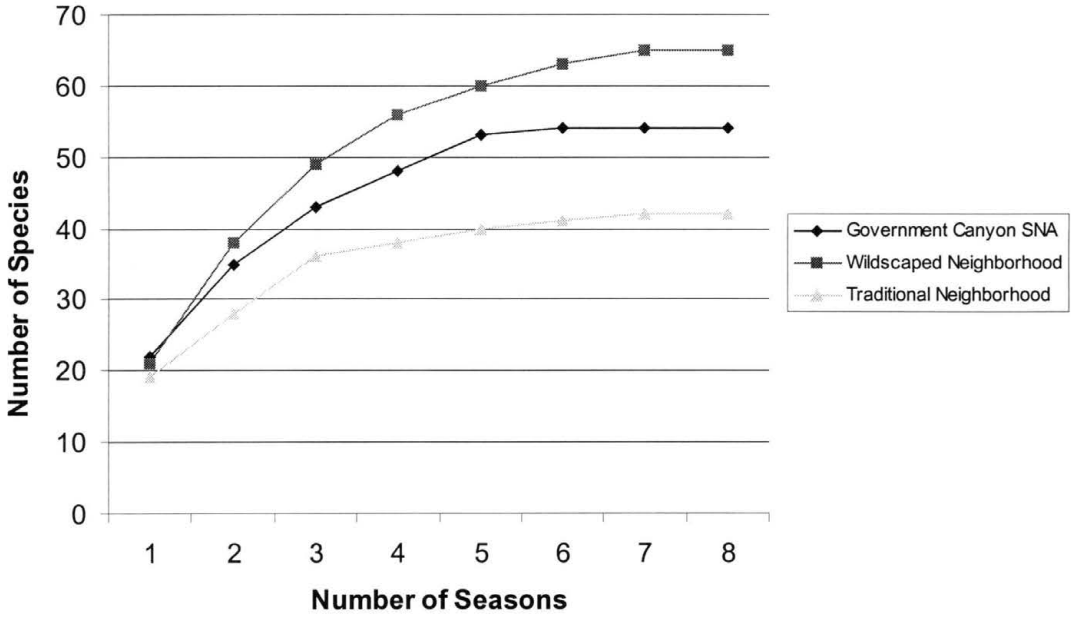

Figure 2. Number of bird species observed by season on GCSNA, the wildscaped neighborhood, and traditional neighborhood in Bexar County, Texas.

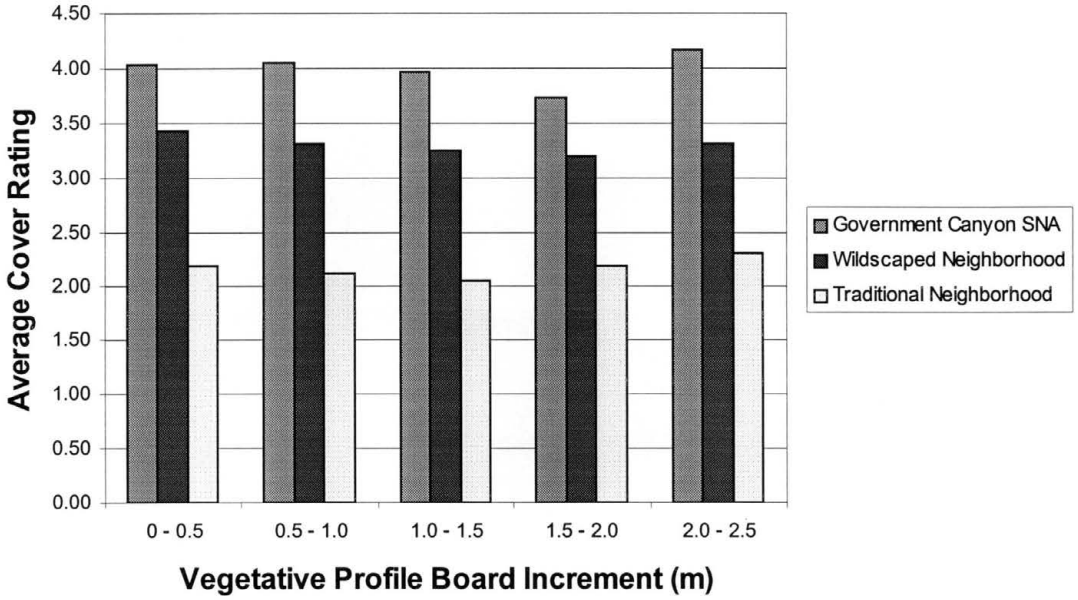

Figure 3. Comparison of the average vegetative cover rating for each vertical profile increment at GCSNA, a wildscaped neighborhood, and a traditionally landscaped neighborhood in Bexar County, Texas, Summer 2002.

Table 1. Bird species diversity and similarity measures for GCSNA, a wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, based on species observations by point and compiled over the entire study.

Diversity/Similarity Measure	Average ± SD				*P*-value
Number of Species					
Government Canyon	23.0	±	5.1	[a]	0.010
Wildscaped	31.3	±	7.1	[b]	
Traditional	24.1	±	2.6	[a]	
Number of Individuals					
Government Canyon	185.0	±	70.1	[a]	< 0.001
Wildscaped	417.3	±	174.2	[b]	
Traditional	535.1	±	178.3	[b]	
Brillouin's *H* Diversity Index (bits per individual)					
Government Canyon	3.3150	±	0.2170	[a]	0.002
Wildscaped	3.6925	±	0.3652	[b]	
Traditional	3.0175	±	0.3802	[a]	
Smith and Wilson's Index of Evenness					
Government Canyon	0.4274	±	0.0472	[a]	< 0.001
Wildscaped	0.3440	±	0.0598	[b]	
Traditional	0.2519	±	0.0533	[c]	
Percent Similarity					
Government Canyon - Wildscaped	24.761	±	5.801	[a]	< 0.001
Government Canyon - Traditional	13.005	±	6.499	[b]	
Wildscaped - Traditional	56.361	±	9.620	[c]	

[a, b, c] Common superscripts within each measure denote no significant difference between sites.

Table 2. Vegetational measurements for woody plants at GCSNA, a wildscaped neighborhood, and a traditional neighborhood in Bexar County, Texas.

Vegetation Measurement	Average ± SD		*P*-value
Density (plants per ha)			
Government Canyon	1,903.94 ± 1,379.49	[a]	< 0.001
Wildscaped	271.22 ± 280.51	[b]	
Traditional	71.65 ± 26.63	[c]	
Canopy Cover (m^2 per ha)			
Government Canyon	6,557.18 ± 3,429.43		0.144
Wildscaped	3,701.59 ± 7,978.65		
Traditional	1,360.61 ± 927.86		
Vertical Cover Rating			
Government Canyon	4.3 ± 0.8	[a]	0.002
Wildscaped	3.3 ± 1.3	[a]	
Traditional	2.2 ± 1.0	[b]	

[a, b, c] Common superscripts within each measure denote no significant difference between sites.

Table 3. Correlation coefficients for the average woody plant density per ha and bird community diversity measures at two residential communities in San Antonio, Texas.

Diversity/Similarity Measure	Summer	Autumn	Winter	Spring	Entire Study
Number of Species	0.646	0.489	0.620	0.345	0.746
Number of Individuals	0.006	0.047	-0.009	0.018	-0.139
Brillouin's *H* Diversity Index	0.549	0.499	0.557	0.358	0.648
Smith and Wilson's Index of Evenness	0.496	0.339	0.396	0.415	0.343

Table 4. Correlation coefficients for the average vertical cover rating of the vegetation and bird community diversity measures at two residential communities in San Antonio, Texas.

Diversity/Similarity Measure	Summer	Autumn	Winter	Spring	Entire Study
Number of Species	0.650	0.457	0.764	0.250	0.463
Number of Individuals	0.157	-0.014	0.251	0.270	-0.074
Brillouin's *H* Diversity Index	0.638	0.524	0.673	0.539	0.463
Smith and Wilson's Index of Evenness	0.429	0.511	0.253	0.410	0.371

Table 5. Correlation coefficients for the average vegetative canopy cover per ha and bird community diversity measures at two residential communities in San Antonio, Texas.

Diversity/Similarity Measure	Summer	Autumn	Winter	Spring	Entire Study
Number of Species	0.105	0.005	0.196	-0.156	0.279
Number of Individuals	-0.315	-0.239	-0.203	-0.378	-0.286
Brillouin's *H* Diversity Index	0.251	-0.003	0.294	-0.031	0.302
Smith and Wilson's Index of Evenness	0.556	0.231	0.477	0.559	0.427

DISCUSSION

This two-year bird survey was successful in identifying most species that occurred at each of the three sites (Fig. 2) and provided a solid data set by which to compare aspects of the bird community. The approximately 10 visits made to each site per season also allowed a detailed comparison of the bird community within seasons, in addition to comparisons made over the entire study. However, bird community diversity and similarity measures for individual seasons were generally similar to results based on bird observations compiled over the entire study.

An exception to the consistency of seasonal results and results for the entire study was observed during Winter. During this season, the bird community at GCSNA showed a marked decrease in species evenness and an increase in the number of individuals observed, because of a large number of American robins (*Turdus migratorius*) during the first Winter. American robins made up approximately 43% of the individual observations at Government Canyon during the first Winter, which was similar to the dominance of non-native house sparrows at the traditional neighborhood. Interestingly, American robins were not observed on GCSNA during the second Winter. In addition to skewing evenness and abundance measures for that season, the increased variation in these variables for this site likely reduced the differences among sites in Winter and possibly for the entire study. This may have contributed to the lack of significant differences between the bird community characteristics between GCSNA and the traditional neighborhood.

Regardless of season, I identified 106 species, many of which were easily categorized into non-native species, urban-adapted species that were abundant at the residential sites but absent or relatively rare at the natural area, or urban-tolerant species that were moderately abundant at each site. Other species were unique to a single study site. Differences and similarities in the bird communities observed at each of the three study sites during the course of this study are described below.

Wildscaped vs. Traditional Neighborhoods

The wildscaped neighborhood had a significantly higher species diversity than the traditional neighborhood. Independent evaluations of the components of species diversity (e.g., species richness and evenness) suggested that the wildscaped neighborhood had a significantly higher species richness and the distribution of individuals among species was significantly more even than that observed at the traditional neighborhood. These differences were apparent for the entire study period and within most seasons, even when considering the close proximity of the two study sites. This result may not be surprising since Mills et al. (1989) found that the presence of urban-adapted exotic species diminished greatly with distances as small as 100 m from home sites (the area directly impacted by residential construction and use). The decrease may also be apparent for other native, urban-adapted species.

Differences in the composition of the bird community at the two residential sites were evident in the 25 species that were observed in the wildscaped neighborhood, but absent from the traditional neighborhood. Most of the species missing from the traditional neighborhood were those associated with insectivorous foraging habits, such as warblers, vireos, and flycatchers. Beissinger and Osborne (1982) also found that insectivorous guilds (canopy and bark gleaners) were lacking in traditionally landscaped residential areas dominated by shade trees, lawns and ground covers, and ornamental shrubs. Others absent from the traditional neighborhood included some species typically associated with brushy ground cover and mid-story cover, such as thrashers and sparrows, that depend on protective cover while foraging on or near the ground. The traditional neighborhood only had two species (cedar waxwing and least flycatcher [*Empidonax minimus*]) that were not also observed at the wildscaped neighborhood. Cedar waxwings are typically associated with open habitats and are common in urban areas (Cornell Laboratory of Ornithology 1999). The single observation of a least flycatcher in the traditional

neighborhood was also likely a chance event, as this species (or other flycatchers) were not observed at this site during any other visit.

Despite these differences, the bird communities at the two residential sites were relatively similar. The two sites shared 10 of their 12 most common species, including the house sparrow, house finch, northern cardinal, white-winged dove, mourning dove, northern mockingbird, great-tailed grackle, Carolina wren, purple martin, and ruby-crowned kinglet. Most of these species were urban-tolerant and common at all three sites, while others were common only in urban sites.

The structure and composition of the habitat at the two residential sites had striking visual differences. These differences in general appearance were supported by measurements of the woody plant community at the two sites. The wildscaped neighborhood contained significantly more woody plants per hectare than the traditional site and had significantly more vertical cover. This is consistent with the increased complexity of the habitat at this site created by the abundance of natural vegetation in the area. Woody vegetation at the traditional neighborhood, in contrast, had a similar amount of canopy cover to the wildscaped neighborhood, but with significantly fewer plants per hectare. The vertical cover was also significantly lower than in the wildscaped neighborhood. The results for the traditional neighborhood are consistent with a traditional style of landscaping that emphasizes large overstory trees with little understory woody vegetation.

Differences in the density of woody plants were most evident in the points located within the drainage running through the two residential neighborhoods. The average density of woody plants in the portion of the drainage within the wildscaped neighborhood was nearly five times greater than in the traditional neighborhood. Whereas, the average density of woody plants at points in the front yards of the residential sites was only twice as great in the wildscaped neighborhood compared to the traditional neighborhood. The bird survey points within the drainage at the wildscaped neighborhood were also the most diverse and species rich of the site.

Other studies have also shown the importance of undisturbed drainages in urban areas to increasing native bird species richness at developed sites (Germaine et al. 1998).

The proportion of native plants recorded in the vegetational measurements was also much higher in the wildscaped neighborhood than the traditional neighborhood, because of the retention of natural, pre-development woody vegetation through most of the neighborhood and the use of native plants in subsequent landscaping. The abundance of native plants and the natural structure of the landscape in the wildscaped neighborhood likely contributed to the high species richness and diversity of the bird community at this site.

The density of woody plants and the amount of vertical cover were moderately to strongly correlated with bird species diversity, richness, and evenness at the residential sites. Mills et al. (1989) also found a strong correlation between the volume of woody plants in urban areas with the diversity of the bird community at those sites. Moreover, native bird species richness and diversity were correlated with the volume of native plants, while the abundance of exotic and non-territorial bird species correlated with the volume of non-native plants in the landscape. The results of this study support these previous findings.

Residential Neighborhoods vs. Natural Area

The wildscaped neighborhood had a significantly more diverse bird community than GCSNA. The difference resulted primarily from the high species richness observed in the wildscaped neighborhood and not the evenness of the distribution of individuals. Consistent with the results of Blair (1996), who reported that some moderately developed urban areas had higher species richness than nearby undeveloped sites, the wildscaped neighborhood included both primarily urban species and other species that were tolerant of some degree of human presence.

The species unique to the wildscaped neighborhood were attracted to the habitat resources of the site despite the human presence. There was much greater diversity in the structure of the vegetation in the wildscaped neighborhood than at GCSNA. The natural area had

a relatively homogeneous and extremely dense distribution of plants with few openings in the canopy or understory cover. The wildscaped neighborhood had pockets of dense woody, understory cover that were interspersed with more open areas. These breaks in the understory and overstory canopy may have contributed to more diversity in the herbaceous cover that could, in turn, influence food abundance (insects and seeds). In contrast, much of the understory cover in the traditional neighborhood was removed or replaced by non-native ornamental plants and ground covers, such as turfgrass and ivy. Bird species diversity was low at GCSNA and the traditional neighborhood, possibly because of the lack of diversity in the structure (horizontal and vertical) of the habitat at the natural area and the lack of structure itself at the traditional neighborhood. Roth (1976) also found that the patchiness of the distribution of woody plants was positively correlated to the diversity of bird species at a site.

Similarity indices showed that the bird community at GCSNA was significantly more similar to the wildscaped neighborhood than the traditional neighborhood. This result is consistent with one of the hypotheses of this study. However, the wildscaped neighborhood did not retain an overwhelming number of bird species found in GCSNA compared to the traditional neighborhood, as hypothesized. The wildscaped neighborhood lacked 18 of the species observed at GCSNA. The traditional neighborhood lacked 25 species found at GCSNA.

The traditional neighborhood had a similar species diversity as GCSNA, even though GCSNA had several more species than the traditional neighborhood overall, and the bird community was significantly more even at the natural area. The similarity may be primarily because of the relatively low average number of species observed at each point at GCSNA, which was similar to the traditional neighborhood. This suggests that, while GCSNA had a higher level of species richness than the traditional neighborhood, the species were not evenly distributed across the landscape. The significantly lower number of observations at GCSNA also may have contributed to the difference. The lower species richness (although not significant at a point-by-point level) and the significantly decreased level of evenness of the bird community at the

traditional neighborhood were consistent with other studies of urbanization on bird diversity (Beissinger and Osborne 1982, Mills et al. 1989).

Consistent with other studies, the bird community at the traditional neighborhood was heavily weighted towards a few common species, such as the house sparrow, white-winged dove, and great-tailed grackle (Emlen 1974, Beissinger and Osborne 1982, Germaine et al. 1998). This also was true of the wildscaped neighborhood, although at a lower abundance. These three species represented nearly 60% of the total bird observations at the traditional neighborhood, while they were virtually absent from GCSNA. The abundance of these three species at the traditional neighborhood also represented more individuals than were observed among all species at GCSNA. The extremely high abundance of these exotic and urban-adapted species may be attributed to their foraging habits and the abundance of complementary habitat in the traditional neighborhood. Doves, grackles, and house sparrows are flocking, ground-foraging species that use open, low, grassy habitats that allow them to effectively see potential predators while feeding. Urban lawns are a resource-rich variation of a grassland habitat that is able to support high numbers of these types of species (Falk 1976).

MANAGEMENT IMPLICATIONS

The results of this study suggest that residential developments can be designed in a way that is beneficial to a wide variety of bird species, not only those that are typically associated with urban areas. This also is consistent with the observation by Mills et al. (1989) that housing density is less important to predicting bird diversity than are the characteristics of the vegetation at the site. As such, the Texas Wildscapes program and similar programs have the potential to provide significant benefits to native wildlife species in residential areas. Habitat at the wildscaped neighborhood, which included large areas of natural vegetation, attracted significantly more birds than the habitat of a traditionally developed residential neighborhood. The wildscaped neighborhood also provided habitat to many more species than a comparable, undeveloped area of the Texas Hill Country. The diversity of vegetative structure and the abundance of habitat resources in the wildscaped neighborhood likely were responsible for the observed increase in species richness and diversity at the wildscaped neighborhood. Retaining native vegetation in residential areas and landscaping with native plants can be combined with other wildlife management practices, such as providing supplemental water and removing non-native species, to further reduce the impact of residential development. An educated and involved human population also may be able to improve habitat conditions for wildlife beyond conditions present without active and appropriate habitat management practices.

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APPENDICES

Appendix A. Comprehensive list of bird species, including incidental observations, observed on GCSNA, a Texas Parks and Wildlife Department-certified wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, between June 2000 and June 2002.

Scientific Name[a]	Common Name	Abbreviation	Government Canyon State Natural Area	Wildscaped Neighborhood	Traditional Neighborhood
	hummingbird sp.	HUMM	x	x	x
Accipiter cooperii	Cooper's hawk	COHA	x	x	x
Aphelocoma californica	western scrub-jay	WESJ	x	x	x
Archilochus alexandri	black-chinned hummingbird	BCHU	x	x	x
Archilochus colubris	ruby-throated hummingbird	RTHU	x	x	x
Baeolophus bicolor	tufted titmouse	TUTI	x	x	x
Bombycilla cedrorum	cedar waxwing	CEWX	x	x	x
Buteo jamaicensis	red-tailed hawk	RTHA	x	x	x
Cardinalis cardinalis	northern cardinal	NOCA	x	x	x
Carduelis psaltria	lesser goldfinch	LEGO	x	x	x
Carduelis tristis	American goldfinch	AMGO	x	x	x
Carpodacus mexicanus	house finch	HOFI	x	x	x
Cathartes aura	turkey vulture	TUVU	x	x	x
Chaetura pelagia	chimney swift	CHSW	x	x	x
Columbina inca	Inca dove	INDO	x	x	x
Coragyps atratus	black vulture	BLVU	x	x	x
Cyanocitta cristata	blue jay	BLJA	x	x	x
Dendroica coronata	yellow-rumped warbler	YRWA	x	x	x
Empidonax virescens	Acadian flycatcher	ACFL	x	x	x
Hirundo rustica	barn swallow	BASW	x	x	x
Junco hyemalis	dark-eyed junco	DEJU	x	x	x
Melanerpes aurifrons	golden-fronted woodpecker	GFWO	x	x	x
Melospiza lincolnii	Lincoln's sparrow	LISP	x	x	x

Appendix A Comprehensive list of bird species, including incidental observations, observed on GCSNA, a Texas Parks and Wildlife Department-certified wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, between June 2000 and June 2002.

Scientific Name[a]	Common Name	Abbreviation	Government Canyon State Natural Area	Wildscaped Neighborhood	Traditional Neighborhood
Mimus polyglottos	northern mockingbird	NOMO	x	x	x
Molothrus ater	brown-headed cowbird	BHCO	x	x	x
Picoides scalaris	ladder-backed woodpecker	LBWO	x	x	x
Pipilo maculatus	spotted towhee	SPTO	x	x	x
Poecile carolinensis	Carolina chickadee	CACH	x	x	x
Polioptila caerulea	blue-gray gnatcatcher	BGGN	x	x	x
Progne subis	purple martin	PUMA	x	x	x
Quiscalus mexicanus	great-tailed grackle	GTGR	x	x	x
Regulus calendula	ruby-crowned kinglet	RCKI	x	x	x
Sayornis phoebe	eastern phoebe	EAPH	x	x	x
Spizella passerina	chipping sparrow	CHSP	x	x	x
Spizella pusilla	field sparrow	FISP	x	x	x
Thryomanes bewickii	Bewick's wren	BEWR	x	x	x
Thryothorus ludovicianus	Carolina wren	CAWR	x	x	x
Troglodytes aedon	house wren	HOWR	x	x	x
Turdus migratorius	American robin	AMRO	x	x	x
Vermivora celata	orange-crowned warbler	OCWA	x	x	x
Zenaida asiatica	white-winged dove	WWDO	x	x	x
Zenaida macroura	mourning dove	MODO	x	x	x
	swallow sp.	SWAL	x	x	
Dumetella carolinensis	gray catbird	GRCA	x	x	
Piranga rubra	Summer tanager	SUTA	x	x	
Regulus satrapa	golden-crowned kinglet	GCKI	x	x	
Toxostoma curvirostre	curve-billed thrasher	CBTH	x	x	
Vermivora ruficapilla	Nashville warbler	NAWA	x	x	
Vireo griseus	white-eyed vireo	WEVI	x	x	

Appendix A. Comprehensive list of bird species, including incidental observations, observed on GCSNA, a Texas Parks and Wildlife Department-certified wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, between June 2000 and June 2002

Scientific Name[a]	Common Name	Abbreviation	Government Canyon State Natural Area	Wildscaped Neighborhood	Traditional Neighborhood
Zonotrichia leucophrys	white-crowned sparrow	WCSP	x	x	
	flycatcher sp.	EMPI	x		
	woodpecker sp.	WOOD	x		
	wren sp.	WREN	x		
Aimophila ruficeps	rufous-crowned sparrow	RCSP	x		
Amphispiza bilineata	black-throated sparrow	BTSP	x		
Ardea herodias	great blue heron	GBHE	x		
Catharus guttatus	hermit thrush	HETH	x		
Chondestes grammacus	lark sparrow	LASP	x		
Coccyzus americanus	yellow-billed cuckoo	YBCU	x		
Colaptes auratus	northern flicker	NOFL	x		
Colinus virginianus	northern bobwhite	NOBO	x		
Columbina passerina	common ground-dove	CGDO	x		
Corvus corax	common raven	CORA	x		
Dendroica chrysoparia	golden-cheeked warbler	GCWA	x		
Geococcyx californianus	greater roadrunner	GRRO	x		
Icterus galbula	Baltimore oriole	BAOR	x		
Myiarchus cinerascens	ash-throated flycatcher	ATFL	x		
Passerella iliaca	fox sparrow	FOSP	x		
Passerina ciris	painted bunting	PABU	x		
Pipilo chlorurus	green-tailed towhee	GTTO	x		
Psaltriparus minimus	bushtit	BUSH	x		
Quiscalus quisicula	common grackle	COGR	x		
Salpinctes obsoletus	rock wren	ROWR	x		
Stelgidopteryx serripennis	northern rough-winged swallow	NRSW	x		

Appendix A. Comprehensive list of bird species, including incidental observations, observed on GCSNA, a Texas Parks and Wildlife Department-certified wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, between June 2000 and June 2002.

Scientific Name[a]	Common Name	Abbreviation	Government Canyon State Natural Area	Wildscaped Neighborhood	Traditional Neighborhood
Dendrocygna autumnalis	black-bellied whistling-duck	BBWD		x	x
Dendroica petechia	yellow warbler	YEWA		x	x
Icterus spurius	orchard oriole	OROR		x	x
Lanius cristatus	loggerhead shrike	LOSH		x	x
Melospiza melodia	song sparrow	SOSP		x	x
Passer domesticus	house sparrow	HOSP		x	x
Sturnus vulgaris	European starling	EUST		x	x
	vulture sp.	VULT		x	
Aimophila cassinii	Cassin's sparrow	CASP		x	
Geothlypis trichas	common yellow-throat	COYR		x	
Chordeiles minor	common nighthawk	CONI		x	
Contopus virens	eastern wood pewee	EAWP		x	
Dendroica pensylvanica	chestnut-sided warbler	CSWA		x	
Dendroica virens	black-throated green warbler	BGWA		x	
Dolichonyx oryzivorus	bobolink	BOBO		x	
Mniotilta varia	black-and-white warbler	BWWA		x	
Myiarchus crinitus	great creasted flycather	GCFL		x	
Oporornis philadelphia	mourning warbler	MOWA		x	
Setophaga ruticilla	American redstart	AMRE		x	
Sturnella sp.	meadowlark sp.	MEAD		x	
Toxostoma rufum	brown thrasher	BRTH		x	
Tyrannus verticalis	western kingbird	WEKI		x	
Vireo bellii	Bell's vireo	BEVI		x	
Vireo solitarius	blue-headed vireo	BHVI		x	
Wilsonia pusilla	Wilson's warbler	WIWA		x	
Zonotrichia albicollis	white-throated sparrow	WTSP		x	

Appendix A. Comprehensive list of bird species, including incidental observations, observed on GCSNA, a Texas Parks and Wildlife Department-certified wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, between June 2000 and June 2002.

Scientific Name[a]	Common Name	Abbreviation	Government Canyon State Natural Area	Wildscaped Neighborhood	Traditional Neighborhood
Agelaius phoenicus	red-winged blackbird	RWBL			x
Ardea alba	great egret	GREG			x
Buteo platypterus	broad-winged hawk	BWHA			x
Columba livia	rock dove	RODO			x
Empidonax minimus	least flycatcher	LEFL			x
Tyrannus forficatus	scissor-tailed flycatcher	STFL			x

[a] Scientific and common names follow American Ornithologist's Union (2002).

Appendix B The number of observations per bird species, excluding incidental observations, made within GCSNA in Bexar County, Texas, between June 2000 and June 2002, summed by season for each year, by season with both years combined, and combined observations for the entire study.

Species	Summer			Autumn			Winter			Spring			Entire Study
	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	
AMRO	0	0	0	10	0	10	237	0	237	0	0	0	247
NOCA	54	26	80	18	28	46	49	37	86	5	26	31	243
TUTI	30	20	50	25	31	56	48	14	62	35	8	43	211
RCKI	0	0	0	13	16	29	57	27	84	26	2	28	141
WESJ	35	8	43	17	21	38	11	4	15	2	3	5	101
CEWX	0	3	3	0	0	0	70	0	70	0	0	0	73
PABU	19	21	40	0	0	0	0	0	0	15	18	33	73
BEWR	8	10	18	1	6	7	11	3	14	9	6	15	54
CAWR	12	2	14	10	2	12	1	5	6	4	6	10	42
CHSP	0	0	0	0	9	9	2	8	10	13	0	13	32
NOMO	6	0	6	3	3	6	11	2	13	1	2	3	28
BGGN	11	0	11	5	8	13	0	0	0	1	1	2	26
MODO	5	0	5	3	7	10	1	5	6	2	3	5	26
CACH	7	3	10	10	0	10	1	0	1	4	0	4	25
HOFI	5	0	5	8	0	8	7	0	7	0	0	0	20
BTSP	0	7	7	1	1	2	3	0	3	3	4	7	19
WEVI	3	9	12	0	3	3	0	0	0	2	1	3	18
DEJU	0	0	0	2	0	2	12	0	12	0	0	0	14
SPTO	0	0	0	0	1	1	10	0	10	1	1	2	13
OCWA	0	0	0	0	3	3	3	5	8	0	0	0	11
RCSP	7	0	7	3	0	3	0	0	0	0	0	0	10
YBCU	4	2	6	0	0	0	0	0	0	0	4	4	10
EAPH	0	0	0	2	2	4	2	0	2	2	1	3	9
LBWO	7	1	8	0	1	1	0	0	0	0	0	0	9
CBTH	0	0	0	2	0	2	5	0	5	0	0	0	7
INDO	1	0	1	0	2	2	0	0	0	3	1	4	7
GCKI	0	0	0	0	0	0	4	0	4	2	0	2	6
NRSW	6	0	6	0	0	0	0	0	0	0	0	0	6
GRRO	0	0	0	0	2	2	0	0	0	0	3	3	5

Appendix B. The number of observations per bird species, excluding incidental observations, made within GCSNA in Bexar County, Texas, between June 2000 and June 2002, summed by season for each year, by season with both years combined, and combined observations for the entire study.

Species	Summer			Autumn			Winter			Spring			Entire Study
	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	
LASP	0	3	3	0	0	0	0	0	0	1	1	2	5
HUMM	1	1	2	0	0	0	0	0	0	0	2	2	4
WREN	0	0	0	4	0	4	0	0	0	0	0	0	4
ATFL	1	0	1	0	0	0	0	0	0	0	2	2	3
BHCO	0	1	1	0	0	0	0	0	0	2	0	2	3
CHSW	3	0	3	0	0	0	0	0	0	0	0	0	3
FISP	0	0	0	0	1	1	2	0	2	0	0	0	3
WWDO	0	2	2	0	1	1	0	0	0	0	0	0	3
BAOR	0	0	0	2	0	2	0	0	0	0	0	0	2
BASW	0	0	0	0	2	2	0	0	0	0	0	0	2
BCHU	2	0	2	0	0	0	0	0	0	0	0	0	2
EMPI	0	0	0	1	0	1	0	0	0	1	0	1	2
FOSP	0	0	0	0	0	0	2	0	2	0	0	0	2
HOWR	0	0	0	0	0	0	1	1	2	0	0	0	2
RTHU	0	0	0	1	1	2	0	0	0	0	0	0	2
SWAL	0	0	0	2	0	2	0	0	0	0	0	0	2
ACFL	0	0	0	0	1	1	0	0	0	0	0	0	1
BLJA	0	0	0	0	1	1	0	0	0	0	0	0	1
COHA	0	0	0	0	1	1	0	0	0	0	0	0	1
GRCA	0	0	0	0	0	0	0	0	0	1	0	1	1
GTTO	0	0	0	1	0	1	0	0	0	0	0	0	1
LISP	0	0	0	0	0	0	0	0	0	1	0	1	1
NOBO	0	0	0	0	0	0	0	0	0	1	0	1	1
NOFL	0	0	0	1	0	1	0	0	0	0	0	0	1
ROWR	1	0	1	0	0	0	0	0	0	0	0	0	1

Appendix C. The number of observations per bird species, excluding incidental observations, made within a Texas Parks and Wildlife Department-certified wildscaped neighborhood in San Antonio, Texas, between June 2000 and June 2002, summed by season for each year, by season with both years combined, and combined observations for the entire study.

Species	Summer			Autumn			Winter			Spring			Entire Study
	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	
HOSP	76	119	195	56	32	88	56	29	85	63	50	113	481
HOFI	22	80	102	62	44	106	153	24	177	49	16	65	450
WWDO	93	70	163	61	54	115	82	2	84	43	33	76	438
NOMO	76	39	115	48	41	89	60	16	76	44	25	69	349
NOCA	41	31	72	24	22	46	53	20	73	38	19	57	248
MODO	41	32	73	27	12	39	53	20	73	18	18	36	221
INDO	27	4	31	36	12	48	4	10	14	4	0	4	97
GTGR	12	34	46	28	6	34	6	0	6	7	3	10	96
CAWR	22	13	35	13	15	28	13	6	19	6	6	12	94
WESJ	3	11	14	11	16	27	23	12	35	9	5	14	90
PUMA	3	30	33	0	0	0	0	0	0	26	12	38	71
RCKI	0	0	0	1	20	21	20	11	31	15	3	18	70
FISP	0	4	4	2	0	2	45	3	48	11	0	11	65
TUTI	5	21	26	3	6	9	11	2	13	7	3	10	58
CACH	4	6	10	9	4	13	26	0	26	3	2	5	54
DEJU	0	0	0	0	0	0	49	0	49	4	0	4	53
BCHU	17	9	26	5	4	9	0	0	0	1	0	1	36
SPTO	0	0	0	3	2	5	19	3	22	9	0	9	36
CHSP	0	0	0	1	7	8	14	0	14	11	0	11	33
LEGO	5	0	5	3	1	4	11	3	14	4	3	7	30
LISP	0	0	0	0	9	9	0	6	6	6	4	10	25
BEWR	7	6	13	4	2	6	0	2	2	0	2	2	23
OCWA	0	0	0	1	9	10	1	4	5	6	2	8	23
AMGO	0	0	0	0	0	0	16	0	16	2	0	2	18
BHCO	3	1	4	0	0	0	0	0	0	7	7	14	18
YRWA	0	0	0	1	0	1	3	11	14	2	0	2	17
BLJA	4	0	4	7	2	9	1	0	1	1	1	2	16
GFWO	0	2	2	1	0	1	4	1	5	5	2	7	15
BRTH	0	1	1	0	3	3	2	5	7	0	1	1	12

Appendix C. The number of observations per bird species, excluding incidental observations, made within a Texas Parks and Wildlife Department-certified wildscaped neighborhood in San Antonio, Texas, between June 2000 and June 2002, summed by season for each year, by season with both years combined, and combined observations for the entire study.

Species	Summer			Autumn			Winter			Spring			Entire Study
	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	
HUMM	0	10	10	0	2	2	0	0	0	0	0	0	12
NAWA	0	0	0	0	1	1	0	0	0	7	2	9	10
RTHA	0	0	0	0	0	0	8	0	8	0	0	0	8
BASW	1	0	1	1	0	1	0	0	0	4	1	5	7
EAPH	0	0	0	0	2	2	1	0	1	2	1	3	6
WTSP	0	0	0	0	0	0	0	1	1	5	0	5	6
BGGN	0	0	0	1	2	3	0	0	0	2	0	2	5
HOWR	0	0	0	1	2	3	0	0	0	2	0	2	5
SOSP	0	0	0	0	0	0	5	0	5	0	0	0	5
WEVI	0	0	0	0	0	0	0	1	1	1	3	4	5
EUST	0	1	1	0	0	0	1	0	1	0	2	2	4
LBWO	0	2	2	0	1	1	1	0	1	0	0	0	4
ACFL	2	0	2	0	1	1	0	0	0	0	0	0	3
GRCA	0	0	0	1	0	1	0	0	0	0	2	2	3
BOBO	0	0	0	2	0	2	0	0	0	0	0	0	2
CASP	0	0	0	0	0	0	0	0	0	0	2	2	2
CBTH	0	0	0	0	2	2	0	0	0	0	0	0	2
CHSW	0	0	0	2	0	2	0	0	0	0	0	0	2
COHA	0	0	0	0	0	0	2	0	2	0	0	0	2
RTHU	0	0	0	0	0	0	0	0	0	0	2	2	2
WEKI	0	2	2	0	0	0	0	0	0	0	0	0	2
BEVI	0	0	0	0	1	1	0	0	0	0	0	0	1
BGWA	0	0	0	0	0	0	0	0	0	0	1	1	1
BHVI	0	0	0	0	0	0	1	0	1	0	0	0	1
BWWA	0	0	0	0	0	0	0	0	0	1	0	1	1
COYT	0	0	0	0	0	0	0	0	0	1	0	1	1
EAWP	0	0	0	0	0	0	0	0	0	1	0	1	1
GCKI	0	0	0	0	0	0	1	0	1	0	0	0	1
LOSH	0	0	0	1	0	1	0	0	0	0	0	0	1

Appendix C. The number of observations per bird species, excluding incidental observations, made within a Texas Parks and Wildlife Department-certified wildscaped neighborhood in San Antonio, Texas, between June 2000 and June 2002, summed by season for each year, by season with both years combined, and combined observations for the entire study.

Species	Summer			Autumn			Winter			Spring			Entire Study
	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	
MEAD	0	0	0	0	1	1	0	0	0	0	0	0	1
MOWA	0	0	0	1	0	1	0	0	0	0	0	0	1
OROR	0	0	0	1	0	1	0	0	0	0	0	0	1
SWAL	1	0	1	0	0	0	0	0	0	0	0	0	1
TUVU	0	0	0	1	0	1	0	0	0	0	0	0	1
WCSP	0	0	0	1	0	1	0	0	0	0	0	0	1
YEWA	0	0	0	0	0	0	0	0	0	0	1	1	1

Appendix D The number of observations per bird species, excluding incidental observations, made within a traditionally developed neighborhood in San Antonio, Texas, between June 2000 and June 2002, summed by season for each year, by season with both years combined, and combined observations for the entire study.

Species	Summer			Autumn			Winter			Spring			Entire Study
	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	
HOSP	238	208	446	161	118	279	230	41	271	143	113	256	1,252
WWDO	99	113	212	57	193	250	116	45	161	64	120	184	807
GTGR	46	77	123	33	59	92	55	39	94	81	51	132	441
NOMO	48	70	118	40	44	84	61	9	70	62	38	100	372
MODO	36	16	52	26	29	55	72	26	98	53	9	62	267
HOFI	48	40	88	35	20	55	32	2	34	52	18	70	247
PUMA	0	60	60	0	0	0	3	2	5	55	47	102	167
INDO	27	9	36	30	23	53	21	3	24	18	15	33	146
NOCA	12	21	33	8	12	20	33	8	41	22	19	41	135
BLJA	5	1	6	12	16	28	14	1	15	5	9	14	63
RCKI	0	0	0	2	10	12	18	4	22	10	0	10	44
CAWR	10	5	15	4	3	7	3	1	4	4	6	10	36
EUST	2	1	3	12	5	17	2	1	3	1	5	6	29
WESJ	0	7	7	4	4	8	0	8	8	1	2	3	26
CEWX	0	0	0	0	0	0	24	0	24	1	0	1	25
BEWR	1	10	11	1	2	3	4	1	5	4	1	5	24
FISP	0	0	0	0	0	0	9	6	15	5	0	5	20
TUTI	3	2	5	0	2	2	3	1	4	4	4	8	19
BCHU	5	6	11	5	1	6	0	0	0	0	0	0	17
CHSW	5	4	9	0	2	2	0	0	0	0	6	6	17
BASW	4	8	12	1	2	3	0	0	0	1	0	1	16
LEGO	3	3	6	3	0	3	5	0	5	0	0	0	14
OCWA	0	0	0	0	5	5	3	3	6	2	0	2	13
BHCO	1	0	1	0	0	0	0	0	0	6	5	11	12
AMGO	0	0	0	0	0	0	6	0	6	4	0	4	10
GFWO	0	2	2	0	1	1	0	2	2	4	0	4	9
CHSP	0	0	0	0	0	0	5	0	5	1	0	1	6
YRWA	0	0	0	0	0	0	2	1	3	3	0	3	6

Appendix D. The number of observations per bird species, excluding incidental observations, made within a traditionally developed neighborhood in San Antonio, Texas, between June 2000 and June 2002, summed by season for each year, by season with both years combined, and combined observations for the entire study.

Species	Summer			Autumn			Winter			Spring			Entire Study
	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	Year 1	Year 2	Both Years	
BGGN	0	0	0	0	2	2	0	0	0	3	0	3	5
LISP	0	0	0	1	1	2	0	0	0	2	1	3	5
DEJU	0	0	0	0	0	0	3	0	3	1	0	1	4
HOWR	0	0	0	1	2	3	0	0	0	0	1	1	4
LBWO	0	0	0	1	2	3	1	0	1	0	0	0	4
LOSH	0	0	0	2	1	3	1	0	1	0	0	0	4
SPTO	0	0	0	0	0	0	1	0	1	3	0	3	4
HUMM	0	3	3	0	0	0	0	0	0	0	0	0	3
RTHU	0	0	0	0	2	2	0	0	0	0	1	1	3
CACH	0	0	0	0	1	1	0	0	0	0	0	0	1
LEFL	0	0	0	1	0	1	0	0	0	0	0	0	1
ORIOR	1	0	1	0	0	0	0	0	0	0	0	0	1
SOSP	0	0	0	1	0	1	0	0	0	0	0	0	1
YEWA	0	0	0	0	0	0	0	0	0	0	1	1	1

Appendix E. Species diversity and similarity measures for GCSNA, a wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, based on species observations by point and compiled by season.

Diversity/Similarity Measure	Summer		Autumn		Winter		Spring	
	Average ± SD	*P*-value	Average ± SD	*P*-value	Average ± SD	*P*-value	Average ± SD	*P*-value
Number of Species								
Government Canyon	12 4 ± 2.3 [a]	0.043	11 3 ± 2 6 [a]	0.005	9.4 ± 3.1 [a]	0.001	9.8 ± 3 7 [a]	0 003
Wildscaped	15 8 ± 2 5 [b]		16 9 ± 3.9 [b]		17.3 ± 4 3 [b]		18.3 ± 6.0 [b]	
Traditional	13.1 ± 3.0 [a,b]		14.8 ± 2.4 [b]		13 1 ± 3.6 [a]		14.6 ± 2.4 [b]	
Number of Individuals								
Government Canyon	43 4 ± 11 3 [a]	< 0 001	34.9 ± 11 33 [a]	< 0 001	78.3 ± 52.9	0 323	28.5 ± 12 5 [a]	< 0 001
Wildscaped	124 1 ± 30.0 [b]		81.4 ± 38 [b]		117.0 ± 66.1		82.4 ± 45.6 [b]	
Traditional	157.5 ± 38.7 [c]		125.4 ± 47 [c]		116.4 ± 52.3		135.9 ± 58 9 [c]	
Brillouin's H Diversity Index (bits per individual)								
Government Canyon	2.6625 ± 0.1770 [a]	0.005	2.5313 ± 0.2500 [a]	0.018	2.1589 ± 0.2273 [a]	0.005	2.3139 ± 0 3784 [a]	0 001
Wildscaped	3.0380 ± 0 2584 [b]		3.0010 ± 0.3618 [b]		3.0354 ± 0.3887 [b]		3.0564 ± 0.3790 [b]	
Traditional	2.5633 ± 0.3517 [a]		2.5968 ± 0.3546 [a]		2.6059 ± 0.4063 [a,b]		2.6823 ± 0.2722 [c]	
Smith and Wilson's E								
Government Canyon	0.6491 ± 0.0671 [a]	< 0.001	0.6930 ± 0.0493 [a]	< 0.001	0.4845 ± 0.1573	0.583	0 7200 ± 0.0663 [a]	< 0.001
Wildscaped	0.4618 ± 0.0497 [b]		0.5546 ± 0.0792 [b]		0.5306 ± 0.1206		0.6033 ± 0.1472 [b]	
Traditional	0.3571 ± 0.0373 [c]		0.3833 ± 0.0759 [c]		0.4619 ± 0.1181		0.3966 ± 0.1054 [c]	
Percent Similarity								
Government Canyon - Wildscaped	21.094 ± 7.371 [a]	< 0.001	24.513 ± 11.431 [a]	< 0.001	19.203 ± 5.855 [a]	< 0.001	15.813 ± 9.393 [a]	< 0.001

Appendix E. Species diversity and similarity measures for GCSNA, a wildscaped neighborhood, and a traditionally developed neighborhood in Bexar County, Texas, based on species observations by point and compiled by season

Diversity/Similarity Measure	Summer		Autumn		Winter		Spring	
	Average ± SD	*P*-value	Average ± SD	*P*-value	Average ± SD	*P*-value	Average ± SD	*P*-value
Government Canyon - Traditional	11.324 ± 7.500 [b]		10 183 ± 5.926 [b]		12.858 ± 7.479 [a]		7.824 ± 2.941 [a]	
Wildscaped - Traditional	62.233 ± 5.619 [c]		44 599 ± 8 849 [c]		36 863 ± 9 837 [b]		44 335 ± 10 200 [b]	

[a, b, c] Common superscripts within each measure denote no significant difference between sites

Appendix F Importance value (relative density + relative cover + relative frequency) for each plant species measured with the point-centered quarter method in GCSNA, the wildscaped neighborhood, and the traditional neighborhood in Bexar County, Texas

Scientific Name	Common Name	Government Canyon State Natural Area	Wildscaped Neighborhood	Traditional Neighborhood
Juniperus ashei	Ashe juniper	78.04	15.90	*
Aloysia gratissima	whitebrush	36.08	*	*
Sophora secundiflora	Texas mountain laurel	18.94	7.89	4.62
Opuntia engelmanii	Texas prickly pear	17.74	*	*
Diospyros texana	Texas persimmon	14 14	69.43	8.45
Ulmus crassifolia	cedar elm	9 90	68.35	8.14
Juglans microcarpa	little walnut	5 28	*	*
Colubrina texensis	hog-plum	5 24	*	*
Rhus virens	evergreen sumac	3.77	*	*
Prosopis glandulosa	honey mesquite	3.30	10.27	7.38
Acacia roemeriana	catclaw acacia	2 27	10.35	*
Bumelia lanuginosa	coma	1 86	*	*
Vitis monticola	sweet-mountain grape	1.58	*	*
Quercus fusiformis	plateau live oak	1.44	105.92	51.89
Celtis reticulata	netleaf hackberry	1.42	9.65	16.20
Acacia smallii	huisache	*	48.95	3.65
Rhus lanceolata	flameleaf sumac	*	45.81	*
Forestiera pubescens	elbowbush	*	17.65	*
Condalia hookeri	brasil	*	16.24	*
Cercis canadensis	redbud	*	10.28	*
Jasminum sp.	jasminum	*	9.83	*
Rosmarinus officinalis	rosemary	*	9.46	*
Cycas revoluta	sago palm	*	8.49	*
Zanthoxylum hirsutum	prickly ash	*	8.49	*
Lagerstroemia indica	crepe myrtle	*	8.13	39.85
Nerium oleander	oleander	*	7.88	*
Leucophyllum frutescens	cenizo	*	7.85	*
Parkinsonia aculeata	retama	*	7.84	10.79
Quercus virginiana	Spanish oak	*	7.82	14.61
Photinia sp.	red-tipped photinia	*	*	17.99
	Unidentified Ornamental 1	*	*	10.72

Appendix F. Importance value (relative density + relative cover + relative frequency) for each plant species measured with the point-centered quarter method in GCSNA, the wildscaped neighborhood, and the traditional neighborhood in Bexar County, Texas.

Scientific Name	Common Name	Government Canyon State Natural Area	Wildscaped Neighborhood	Traditional Neighborhood
	Unidentified Ornamental 3	*	*	10.67
Triadica sebifera	Chinese tallow tree	*	*	10.47
Sophora affinis	Eve's necklace	*	*	10.39
Melia azedarach	chinaberry	*	*	8.15
Taxodium distichum	bald cypress	*	*	7.49
	Palm sp.	*	*	7.48
Berberis trifoliolata	Agarito	*	*	6.03
	Unidentified Ornamental 4	*	*	5.95
Carya illinoinensis	pecan	*	*	5.33
Juniperus sp.	juniper	*	*	4.07
	Unidentified Ornamental 2	*	*	4.07
Quercus macrocarpa	burr oak	*	*	3.86
Ilex vomitoria	Yaupon	*	*	3.79
Ulmus sp	Elm	*	*	3.66
	long-needle evergreen sp.	*	*	3.63
Acer sp.	Maple	*	*	3.61
Buxus microphylla	Boxwood	*	*	3.55
Eriobotrya japonica	Loquat	*	*	3.52

VITA

Amanda Lee Hunter was born in Oshkosh, Wisconsin, on June 19, 1976. She is the oldest daughter of Glenn and Paula Hunter, who are dairy farmers in Pickett, Wisconsin. Amanda graduated from Ripon High School in 1994 and received a Bachelor of Science degree in Wildlife Ecology, with honors, from the University of Wisconsin – Madison in 1998. After graduation, she moved to Austin, Texas, and worked for the Travis County Department of Transportation and Natural Resources for three months before being hired as a staff biologist with Loomis Austin, Inc. Amanda was certified as an Associate Wildlife Biologist by The Wildlife Society in 1998. In the autumn of 1999, she entered the Graduate College of Southwest Texas State University in San Marcos, Texas, as a part-time graduate student in the Department of Biology.

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