

AVIAN SPECIES RICHNESS ALONG THE URBAN-RURAL GRADIENT  
OF THE SAN MARCOS RIVER

THESIS

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ABSTRACT

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Increasing urbanization and the resulting degradation of native vegetation cause a decrease in overall avian species richness. Riparian areas are important in urban areas because they may be the only suitable habitat available for many wildlife species. In Central Texas, ideal riparian habitat is characterized as a cottonwood-willow community. The San Marcos River, one of the most popular recreational rivers in Texas, has a narrow

riparian corridor because of recreational activities and agriculture. This study was prompted by two important factors: the loss of riparian habitat along the San Marcos River with a resultant loss of bird species, and the possible economic impact that might occur from bird watchers attracted to restored habitat of the urban section of the San Marcos River. I conducted a baseline study of resident summer birds from the headwaters at Aquarena Center in San Marcos to the confluence of the San Marcos River with the Guadalupe River in Gonzales 152 km to the southeast. My initial hypothesis was that there would be greater species richness in more secluded areas of the river than in areas more heavily impacted by human activity. It was also my hypothesis that because of a lack of a natural floodplain, cottonwood-willow habitat would be minimal. I compared bird assemblages at 12 point-count stations along the San Marcos River in urban to more rural, secluded and protected areas. I recorded qualitative data on the diversity of trees and vegetation. Observations were made in summer 2001 and 2002 between 12 June and 15 July. The observation technique was a modification of the point-count method. I assigned bird species to foraging guilds and assemblages (urban exploiters, suburban adapted and urban avoiders) related to their tolerance of human habitation. I observed 65 bird species along urban and rural portions of the San Marcos River and a portion of the Blanco River at the confluence with the San Marcos River. The urban section alone had 22 insectivores. I classified 33 bird species as urban avoiders, 30 species as suburban adapted, and two as urban exploiters. The urban sites included 19 urban avoiders. In the rural segment of the river, I recorded the most species (42) at Palmetto State Park, which also had the highest number of species for any station. My results contradicted the notion that avian richness declines in relation to an increasing

urban gradient. The most impoverished sites for species richness were the most outlying urban site at John Stokes Park and two rural sites, US 90A and CR 101. My data also indicated that specific physical characteristics of a site influenced species presence and abundance.

The urban site with the least adjacent lawn and canopy had the most insectivores. No stations along the San Marcos River had a natural floodplain that supported new growth of cottonwood and willow or sycamore saplings. I have no conclusive evidence that supports the notion that the summer residents were hindered necessarily by the lack of this type of vegetation alone.

## INTRODUCTION

Riparian areas in the Eastern United States (including Central Texas as the western boundary) are among the most productive biological systems because of the frequent flooding that supplies rich nutrients to the soil (Larue et al., 1995). That, coupled with natural disturbances caused by wind and fire, creates complex vegetative communities with varied topography. Unfortunately, waterways are also attractive sites for human habitation, thus a high proportion of urban areas have overtaken the productive bottomland that supports rich vertebrate communities (Knopf et al., 1988; Ohmart, 1994). Riparian areas are of particular importance in urban areas because as fragments of original highly diverse ecosystems, they may be the only suitable habitat available for wildlife species (Schaefer, 1994).

Generally diverse vegetation in habitats produces higher avian species richness (Shugart and James, 1973; Buffington et al., 1997; Nieto, 1999; Swanson, 1999). In Iowa, twice as many species occurred in woodlands adjacent to cornfields than in grassy/herbaceous areas (Best et al., 1990). In Charlotte, Virginia, bird communities along deforested, channelized streams increased as forest trees regenerated (Ferguson et al., 1975). Several studies in the United States and Canada (Batten, 1972; Emlen, 1974; Blair, 1996; Melles et al., 2003) showed that increasing urbanization and the resulting degradation of native vegetation caused a decrease in overall avian species richness.

Parkland, golf courses and freshwater streams and rivers can actually increase species diversity in these otherwise impoverished urban landscapes (Shaefer, 1994; Blair, 1996; Melles et al., 2003). Doyle (1990) showed that wildlife partition complex habitats precisely and only nest in certain areas within a site in the Pacific Northwest. They responded to particular vegetation as well as humidity levels, light levels, soil compactness, and canopy structure that existed along the stream bed. In Pennsylvania, Croonquist and Brooks (1991) found that a mere 2.2 m of riparian corridor significantly increased bird richness. However, area-sensitive birds needed 25.8 m on both sides of the river. In Maryland and Delaware, Keller et al., (1993) showed riparian corridors of less than 103 m were dominated by short-distance migrants, whereas, Neotropical migrants required more extensive areas. Resident birds were not affected by corridor width. Further studies (Triquet et al., 1990; Tappe et al., 1994; Darveau et al., 1995; Dickson et al., 1995; Hodges and Krementz, 1996) indicated that in decisions to restore a riparian zone, dimensions depend on the species of interest. For example, the yellow-billed cuckoo (*Coccyzus americanus*) and red-eyed vireo (*Vireo olivaceus*) require wider corridors than the indigo bunting (*Passerina cyanea*) and eastern kingbird (*Tyrannus tyrannus*) (Klapproth, 2000).

In Texas, ideal riparian habitat is characterized as a cottonwood-willow community. Cottonwood (*Populus deltoids*) seedlings, especially, require sandy areas and are dependent on seasonal flooding. Texas has lost 54% (Edwards, 1992) of wetlands and riparian zones, through destruction mostly by livestock grazing and building of dams. Livestock graze young seedlings of both willow (*Salix* sp) and cottonwood and dams

alter the annual flood pulse of rivers necessary to raise the water level to supply roots of trees.

The San Marcos River is one of the most popular recreational rivers in Texas (Texas Parks and Wildlife Department, 2003). Unfortunately, perhaps for wildlife, the river corridor has narrowed because of recreational activities and agriculture. According to the U.S. Army Corp of Engineers Ecosystem Management Program, healthy riparian buffers for birds and recreational activities are often in conflict (Fischer and Martin, 1998). Certain activities on the river, such as kayaking, canoeing, picnicking and tubing cause more disturbances. As a testament to these activities, the annual river cleanup sponsored by the San Marcos River Foundation usually results in a trash haul that fills four to five dump trucks (San Marcos River Foundation Newsletter, 2003). These recreational activities may attract urban adapted birds (Hunter, 2002; Melles et al., 2003), as well as dictate less vegetational cover in allowing human access to the water. More benign activities, such as bird watching and nature study, would benefit from a wider riparian corridor that would attract more birds.

Compared to other wetland types (i.e., coastal marshland), projects and techniques involving creation or restoration of riparian ecosystems are not well documented (Manci, 1989). Most riparian restoration has occurred in California, Arizona and New Mexico (Anderson and Layman, 1989; Anderson et al., 1989; Eichorst et al., 2001). The only study of this type in Texas involved the Rio Grande River Valley (Anderson and Layman, 1989); hence, the importance of conducting a baseline study in Central Texas.

To determine the impact recreational restrictions may have on avian diversity, I conducted a baseline study of resident summer birds because no data exist for resident bird populations along the entire San Marcos River. cursory studies by Texas State University graduate students have documented bird assemblages only at Aquarena Springs in San Marcos. How much prime riparian habitat is left along the San Marcos River, and how it affects species richness are important questions. My initial hypothesis was that there would be greater avian richness in more secluded areas of the river than in areas more heavily impacted by human activity. It also was my hypothesis that because of a lack of natural flooding events and deep channelization along the river because of dams, the occurrence of the cottonwood-willow habitat would be minimal. The mechanisms required for the propagation of these saplings no longer exists along the San Marcos River.

This study was prompted by two important factors: a) the loss of riparian habitat along the San Marcos River with the resultant loss of bird species, and b) the possible economic impact that could occur from bird watchers attracted to the restored habitat of the urban section of the San Marcos River. Bird watchers contribute about \$24 billion annually to the Texas economy as a whole (Skadberg and Kimmel, 1999). The Texas Parks and Wildlife Department is currently in the planning stages of creating a Central Texas Birding Trail, which would include the San Marcos area (Campbell, 2002). This follows on the heels of the very successful Texas Coastal Birding Trail, which many other states have used as a model to promote nature tourism (Campbell, 2002).

## MATERIALS AND METHODS

### Study Area

I conducted my study along the San Marcos River in Central Texas from the headwaters at Aquarena Center in San Marcos to the confluence of the San Marcos River with the Guadalupe River in Gonzales 152 km to the southeast (Figure 1 and Figure 2). The San Marcos River is a spring fed river with constant flow and temperature. Twelve point-count sampling station locations were determined by a combination of physical attributes (canopy height and density differences from previous sampling station, river depth, as well as the logistics of access). Access was much more limited in the rural sections and so stations were determined by roads that crossed the river. The urban San Marcos stations started at the Biology Department shed at the juncture of the main lake and the slough at Aquarena Center (Station 1) to the footbridge at Ramon Lucio Park (Station 6) at the IH 35 overpass. The intermediate observation stations were Spring Lake behind the softball field at home plate (Station 2), the second footbridge at Sewell Park (Station 3), the footbridge at City Park (Station 4), and the island at the end of the footbridge at Rio Vista Park (Station 5). The last urban station was across IH 35 at the John Stokes River Park (Station 7).

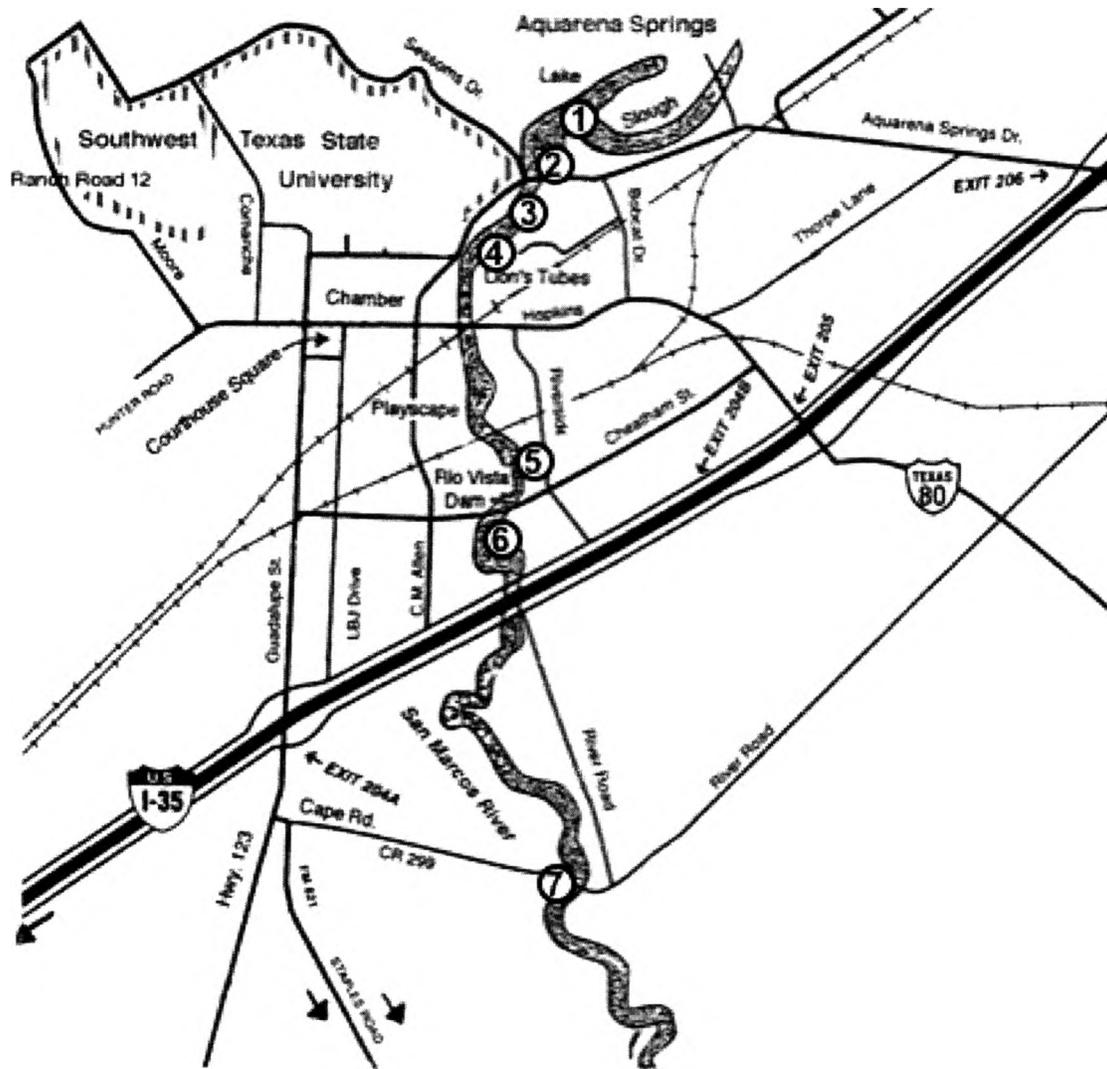


Figure 1. Map showing locations of point-count stations in the urban section of the San Marcos River.

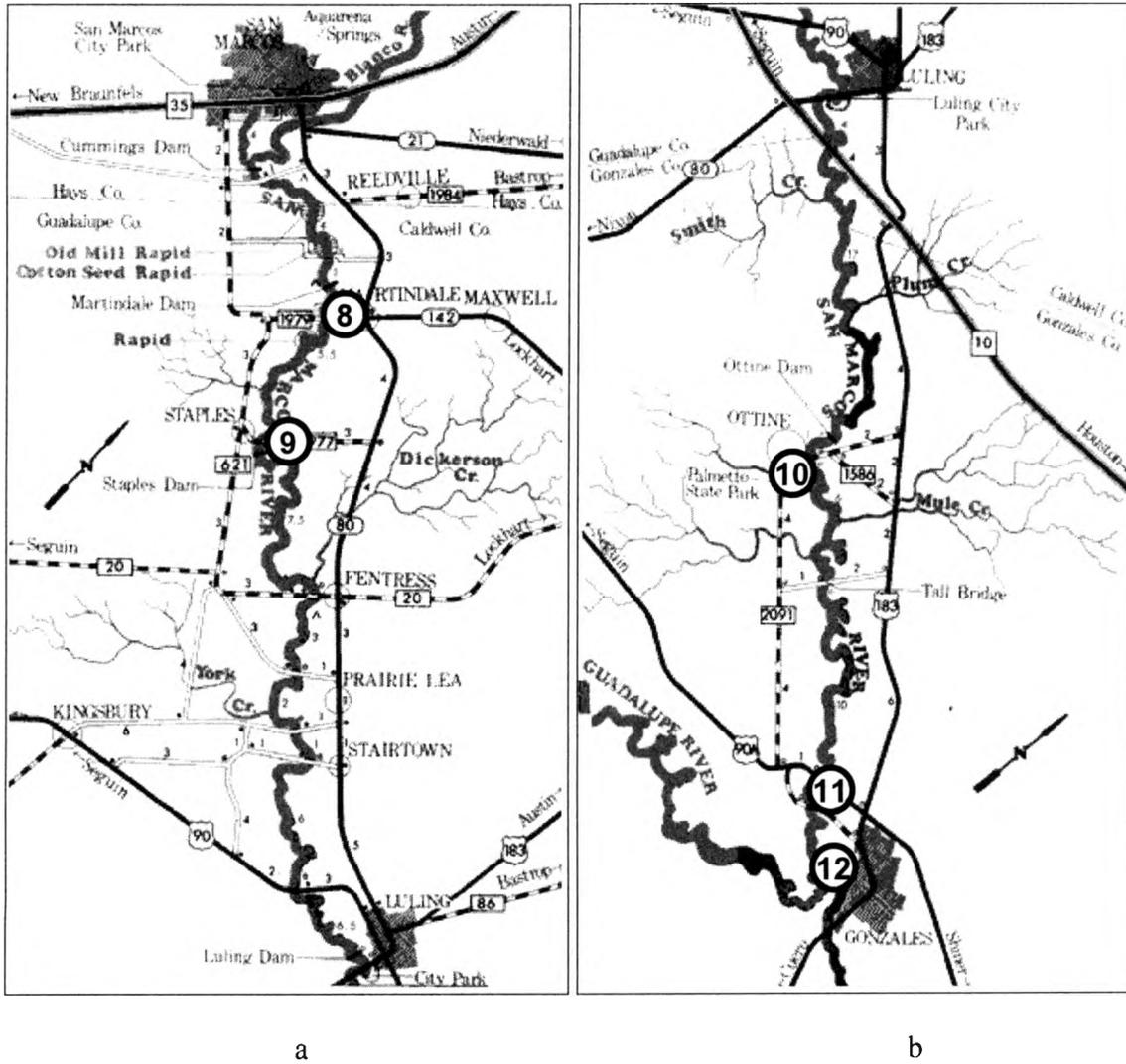


Figure 2. Maps showing a) locations of the rural point-count stations 8 and 9, and b) stations 10-12 of the San Marcos and Blanco Rivers.

For comparative purposes, a portion of the Blanco River at the Old Martindale Crossing (Station 8) close to the confluence with the San Marcos River was included in the study. The rural sections of the San Marcos River followed the river west to the crossing at County Road 101 (Station 9), Palmetto State Park (which has a Texas Parks and Wildlife Department bird list) (Station 10), the crossing at US 90A (Station 11), and Independence Park in Gonzalez which is at the confluence of the San Marcos and Guadalupe Rivers (Station 12). In addition, I recorded qualitative data on the diversity of trees and vegetation that bordered my sampling areas.

The dominant vegetation along the river was previously determined by Kainer (1992). The dominant woody species along the river include bald cypress (*Taxodium distichum*), black willow (*Salix nigra*), American and cedar elm (*Ulmus Americana*, *U. crassifolia*), pecan (*Carya illinoensis*), chinaberry (*Melia azedarach*), hackberry (*Celtis sp.*), eastern cottonwood (*Populus deltoids*), boxelder (*Acer negundo*) and sycamore (*Platanus occidentalis*). Understory consists mainly of boxelder, privet (*Ligustrum sp*) elderberry (*Sambucus canadensis*), hackberry, Chinese tallow (*Sapium sebiferum*) and black willow stands. Other woody species in the understory include Mexican buckeye, (*Ungnadia speciosa*), red buckeye (*Aesculus pavia*) burr oak (*Quercus macrocarpa*) white and red mulberry (*Morus alba and M. rubra*), Texas persimmon (*Diospyros texana*), poison ivy (*Toxicodendron radicans*), mustang grape (*Vitis mustangensis*) and Virginia creeper (*Parthenocissus quinquefolia*).

#### Qualitative Physical Descriptions by Station

Station 1. Aquarena Center: This station includes a golf course with several mature cottonwood, pecan and sycamore trees that form a canopy of 15-24 m high and an

understory of mostly box elder (average height 4.5 m). Canopy density along the water bank is 50% -80% and at 30 m from the bank. A parking lot has several mature pecan and sycamore trees planted in the median. The site is bordered by a four-lane thoroughfare, Aquarena Springs Road, parking lots, and stadium structures on the southeast side. On the northeast side is a hillside with distinct vegetative stratification. There is a shallow slough on the eastside that connects to Spring Lake. Hummingbird feeders and purple martin houses are maintained on the grounds next to a visitor's center and small hotel.

Station 2. Spring Lake: This site is bordered on the south side by a narrow (< 10 m) corridor of pecan and willow trees with a canopy of 18 m high. Young pecan saplings form an understory 3-9 m high. Canopy density at the lake bank was 90%. There is considerable leaf litter. Directly south of this corridor is a softball field, a power transformer, residential apartments and Aquarena Springs Road.

Station 3. Sewell Park: This station has two concrete walkways that border the river, a concrete basketball court, and concrete walls line the riverbank north of the footbridge as far as Aquarena Springs Road. There are sand pits for volleyball, an expanse of lawn on both sides with mature pecan, cottonwood, cypress, and sycamore trees. There is no vegetation along the river north of the footbridge, and the bank south of the footbridge is mostly elephant ear (*Colocasia esculenta*) and grape vines. There are redbud and red oak saplings along the walk. Canopy density at the riverbank varied from 7%-80% and dropped to 0%-65% 30 m from the bank.

Station 4. City Park: This station is bordered by an expanse of lawn (< 30 m wide) and a parking lot. There is almost no understory vegetation. The only riverside

vegetation is elephant ear and grape vines. There are a few young boxelder and mature pecan (50 m high) trees. Public access to the east side of the river is by a concrete wall. Erosion on the west side has created banks ~ 0.3 m in height. There is ~ 3 m wide of gradual river bank left on the southeast side of the footbridge. Canopy density was 0%-95% at the river bank and 0% 30 m from the river.

Station 5. Rio Vista Park: This site is bordered on the east by a thick forested area (> 30 m wide). On this bank, there is an upper canopy of cottonwood and pecan trees that are ~ 15-20 m high with an understory of mulberry and box elder trees and saplings. There are several mature, (18-24 m high) cypress, cottonwood and pecan trees bordering the west bank. An expanse of lawn extends to the riverbank. There is also a pavilion, pool and small parking area. Canopy density on the riverbank was 86%-90% and declined to near 0% 30 m from the riverbank. The river is deeply channelized and the west bank has a concrete retaining wall.

Station 6. Ramon Lucio Park: This station has a very homogeneous assemblage of 18 m high pecan and cedar elm trees on the north bank of the river. The river takes a sharp hairpin turn at this location before it continues underneath IH 35. The west bank of the turn has an almost impenetrable wall of grape vines, and the south bank has a lawn with 7-9 m high willow trees and a few mature cottonwood trees over 24 m high. Canopy density varied at the river bank from 30%-90%, while 30 m away from the bank it was 20%-95%.

Station 7. John Stokes Park: This station has a few dead cottonwood, box elder, hackberry, willow, and mulberry trees. The predominant understory vegetation is grape vines. A small roadway crosses the river. The river is deeply channelized and bordered

for most of its length by a concrete retaining wall. There is a small low head dam at the east end of the park.

Station 8. Blanco River at Martindale Road: This is the only site with a natural floodplain that supports the growth of cottonwood, willow and sycamore saplings. There is a steep cliff on one side with an upper canopy ~ 25 m high. A wide corridor (~ 100 m) on both sides of the river supports mature willow, sycamore, cottonwood, pecan and Chinese tallow trees. Away from the river are pastures and farmhouses.

Station 9. County Road 101: This station has agricultural ranchland on both sides. This location has the narrowest corridor of all study sites with just one tree row on each side of the river separating the river from adjacent pastureland. There are 15 m high cypress and pecan trees and an understory of 4-6 m. Although the river is shallow, it has deep cuts in the banks.

Station 10. Palmetto State Park: This site has a much greater variety of trees (black jack oak, chinquapin oak, post oak, elm, ash and pecan), a canopy height of 15-24 m, and developed understory and herbaceous layers. For most of its length, the river is highly channelized. For a short distance (< 30 m), there is a natural floodplain. I observed no new sapling growth. The corridor in several places is over 50 m wide. The canopy density at the river bank and 30 m from the bank was between 75%-95%.

Station 11. US 90A: At this site the road crosses the river at a two-lane bridge about 12 m high. One dwelling is within 100 m of the bridge. The rest of the land is pasture. The banks on one side of the river are about 10 m high. There is almost no floodplain and the river is highly channelized. A corridor about 30 m wide of pecan,

cottonwood and cypress canopy 24-26 m high with a distinct understory of younger trees that average 5-8 m in height exists on one side of the river.

Station 12. Independence Park in Gonzalez: This site has almost no access to the river from the park because of steep, 5-7 m high banks. Lawn, pavilions, park roads and buildings dominate the park. The opposite bank has a narrow corridor (< 10 m wide) adjacent to agricultural land. There are mature cottonwood, sycamore and pecan trees throughout the park with mostly boxelder and sycamore trees on the riverbank. The canopy height is 24 m high with understory of 8-10 m. The canopy density at the river bank was 0%-86% with 0%-75% canopy density 30 m from the bank.

### Sampling Methods

Since birds are most active in summer in early morning, I made observations between dawn (about 0630 h) and 0830 h, 3 times per week, in the summers of 2001 and 2002 between 12 June and 15 July. My total field observation time was about 120 h. I used a modification of the point-count observation method (Bibby et. al., 2003). After arriving on station, I delayed observations 5 min. for disturbances to subside. I recorded presence of bird species in 10 min. intervals at each station. When I identified a bird by sound alone of an unfamiliar species, I later verified my identification by sight at a later time.

I used a spherical densiometer (Model C manufactured by Forest Densiometers of Oklahoma) and a Suunto clinometer (Model PM-5/360PC, Suunto Inc., Tokyo, Japan) to estimate canopy height and cover at each station.

## Data and Analysis

For the occurrence of species at each station, I used the American Birding Association values for the probability of sighting a species on one visit. These values are as follows: A = 75%, C = 50%, U = 25%, O = 10%, and R = expected only once per season if at all.

Each station was compared to every other station using the number of common species and the number of unique species to each station by two similarity indices, Jaccard's index and Sorensen's index. Sorensen's index weights similar species more than unique species while Jaccard's index weights them equally. The formulas for each are as follows:

$$\text{Jaccard's Index of Similarity } S_j = \frac{c}{a + b + c}$$

where a = the number of species unique to site a,

b = the number of species unique to site b,

c = the number of species common to both sites.

$$\text{Sorensen's Index of similarity } S_s = \frac{c}{\frac{1}{2}A + B + c}$$

Where A = total species found at site a,

B = total species found at site b,

c = number of species common to both sites.

In both indices a value of 1.0 shows identical similarity while 0 indicates no similarity.

I assigned bird species observed to foraging guilds (Mason et al., 2003) and assemblages related to their tolerance of human habitation (Blair, 1996). These designations were urban exploiters, suburban adapted and urban avoiders. Scientific names and taxonomical designations of avian species are as per American Ornithology Union North American Birds Checklist 1998. (Appendix ).

## RESULTS

During my study, I observed 65 bird species along urban and rural portions of the San Marcos River. The species represent 15 orders and 35 families with almost half of the species (31) belonging to the order Passeriformes. A total of 46 species occurred (13 orders and 27 families) along the urban portion of the San Marcos River. Along rural portions of the San Marcos River, a total of 54 species occurred (13 orders and 30 families). Of these species, 27 were insectivores, 17 omnivores, 16 carnivores

(9 piscivores), three granivores, and two nectivores. The urban section alone had 48% (19) insectivores, 30% omnivores (14), 22% carnivores (10, of which eight were piscivores), 4% granivores (2), and 2% nectivores (1). Along the entire river, there were 24 canopy nesters, 17 cavity nesters, 14 shrub nesters, six ground nesters (none of these were songbirds), two floating raft nesters, and two ledge nesters. In the urban section, 24% (11) were cavity nesters and 17% (8) shrub nesters. I classified 33 bird species as urban avoiders, 30 species as suburban adapted, and two bird species as urban exploiters. The urban portion included 19 urban avoiders (41% of total species in this section).

Table 1 lists all bird species with their associated guilds and urban classifications.

Station 1, Aquarena Center, tied with Station 2, Spring Lake, with the most urban species at 32. Some species observed at Aquarena Center included a variety of waders: great blue heron (*Ardea herodias*), little blue heron (*Egretta caerulea*), green heron (*Butorides*

Table 1. Common and scientific names of summer bird species observed along the San Marcos and Blanco Rivers in 2001 and 2002 showing foraging and nesting guilds, habitat affinity and urban classification.

Species	<sup>a</sup> Foraging	<sup>b</sup> Nesting	<sup>c</sup> Habitat	<sup>d</sup> Classification
Pied-billed grebe ( <i>Podilymbus podiceps</i> )	C	F	W	N
Double-crested cormorant ( <i>Phalacrocorax auritus</i> )	C	G	W	N
Mute swan ( <i>Cygnus olor</i> )	O	G	W	U
Mallard ( <i>Anas platyrhynchos</i> )	O	G	W	SA
Wood duck ( <i>Aix sponsa</i> )	O	V	W	N
Black vulture ( <i>Coragyps atratus</i> )	C	V	O	N
Turkey vulture ( <i>Cathartes aura</i> )	C	V	O	N
Red-shouldered hawk ( <i>Buteo lineatus</i> )	C	C	I	N
Red-tailed hawk ( <i>Buteo jamaicensis</i> )	C	C	O	N
Crested caracara ( <i>Caracara cheriway</i> )	C	C	O	N
Great egret ( <i>Ardea alba</i> )	C	C	W	N
Snowy egret ( <i>Egretta thula</i> )	C	C	W	N
Great blue heron ( <i>Ardea herodias</i> )	C	C	W	N
Little blue heron ( <i>Egretta caerulea</i> )	C	C	W	N
Green heron ( <i>Butorides virescens</i> )	C	C	W	N
Yellow-crowned night heron ( <i>Nyctannassa violacea</i> )	C	C	W	N
Wood stork ( <i>Mycteria americana</i> )	C	C	W	N
American coot ( <i>Fulica americana</i> )	O	F	W	N
Killdeer ( <i>Charadrius vociferus</i> )	I	G	O	SA

Species	<sup>a</sup> Foraging	<sup>b</sup> Nesting	<sup>c</sup> Habitat	<sup>d</sup> Classification
Mourning dove ( <i>Zenaida macroura</i> )	G	S	E	SA
Inca dove ( <i>Columbina inca</i> )	G	S	E	SA
White-winged dove ( <i>Zenaida asiatica</i> )	G	S	IE	N
Yellow-billed cuckoo ( <i>Coccyzus americanus</i> )	O	S	IE	N
Barred owl ( <i>Strix varia</i> )	C	C	I	N
Common night hawk ( <i>Chordeiles minor</i> )	I	G	E	N
Chuck-will's widow ( <i>Caprimulgus carolinensis</i> )	I	G	I	N
Chimney swift ( <i>Chaetura pelagica</i> )	I	V	E	SA
Ruby-throated hummingbird ( <i>Archilocus colubris</i> )	N	C	E	SA
Black-chinned hummingbird ( <i>Archilochus alexandri</i> )	N	C	E	SA
Belted kingfisher ( <i>Ceryle alcyon</i> )	C	V	W	N
Golden-fronted woodpecker ( <i>Melanerpes aurifrons</i> )	I	V	E	SA
Red-bellied woodpecker ( <i>Melanerpes carolinus</i> )	I	V	E	SA
Ladder-backed woodpecker ( <i>Picoides scalaris</i> )	I	V	E	SA
Scissor-tailed flycatcher ( <i>Tyrannus forficatus</i> )	I	C	O	N
Eastern kingbird ( <i>Tyrannus tyrannus</i> )	I	C	E	SA
Western kingbird ( <i>Tyrannus verticalis</i> )	I	C	O	SA
Eastern wood-pewee ( <i>Contopus virens</i> )	I	C	I	N
Great-crested flycatcher ( <i>Myiarchus crinitus</i> )	I	V	IE	N
Barn swallow ( <i>Hirundo rustica</i> )	I	L	O	SA
Cliff swallow ( <i>Petrochelidon pyrrhonota</i> )	I	L	O	SA
Purple martin ( <i>Progne subis</i> )	I	V	E	N

Species	<sup>a</sup> Foraging	<sup>b</sup> Nesting	<sup>c</sup> Habitat	<sup>d</sup> Classification
Blue jay ( <i>Cyanocitta cristata</i> )	O	C	E	SA
American crow ( <i>Corvus brachyrhynchos</i> )	O	C	E	SA
Carolina Chickadee ( <i>Peocile carolinensis</i> )	I	V	IE	SA
Tufted Titmouse ( <i>Baeolophus bicolor</i> )	I	V	IE	SA
Black-crested titmouse ( <i>Baeolophus atricristatus</i> )	I	V	IE	SA
Carolina wren ( <i>Thryothorus ludovicianus</i> )	I	V	IE	SA
Bewick's wren ( <i>Thryomanes bewickii</i> )	I	V	IE	SA
Blue-gray gnatcatcher ( <i>Polioptila caerulea</i> )	I	C	IE	N
American robin ( <i>Turdus migratorius</i> )	I	C	E	SA
Northern mockingbird ( <i>Mimus polyglottos</i> )	I	S	E	SA
Loggerhead shrike ( <i>Lanius ludovicianus</i> )	C	S	O	N
European starling ( <i>Sturnus vulgaris</i> )	O	V	U	SA
White-eyed vireo ( <i>Vireo griseus</i> )	I	S	IE	N
Northern parula ( <i>Parula americana</i> )	I	C	IE	N
House sparrow ( <i>Passer domesticus</i> )	O	V	U	U
Great-tailed grackle ( <i>Quiscalus mexicanus</i> )	O	S	E	SA
Common grackle ( <i>Quiscalus quiscula</i> )	O	S	E	N
Brown-headed cowbird ( <i>Molothrus ater</i> )	O	P	E	SA
Summer tanager ( <i>Piranga rubra</i> )	I	C	IE	N
Northern cardinal ( <i>Cardinalis cardinalis</i> )	O	S	IE	SA
Indigo bunting ( <i>Passerina cyanea</i> )	O	S	E	N
Painted bunting ( <i>Passerina ciris</i> )	O	S	E	N

Species	<sup>a</sup> Foraging	<sup>b</sup> Nesting	<sup>c</sup> Habitat	<sup>d</sup> Classification
House finch ( <i>Carpodacus mexicanus</i> )	O	S	U	SA
American goldfinch ( <i>Carduelis trisis</i> )	O	S	E	SA

a, Foraging key: I = Insectivore, N = Nectivore, O = Ominvore, C = Carnivore,

G = Granivore.

b, Nesting key: P = Brood parasite, C = Canopy, G = Ground, S = Shrub, V = Cavity,

F = Floating raft, L = Ledge.

c, Habitat key: I = Forest interior, IE = Interior edge, O = Open, U = Urban,

W = Water.

d, Urban classification: U = Urban adapted, N = Urban avoider, SA = Suburban adapted.

*virescens*), yellow-crowned night heron (*Nyctanassa violacea*) and snowy egret (*Egretta thula*) swimmers and divers: pied-billed grebe (*Podilymbus podiceps*), mute swan (*Cygnus olor*) and mallard (*Anas platyrhynchos*). Aerialists and in-flight insect hawkers recorded at this site included the eastern and western kingbirds (*Tyrannus tyrannus*, *verticalis*), cliff swallow (*Petrochelidon pyrrhonota*), the purple martin (*Progne subis*) and chimney swift (*Chaetura pelagica*). I recorded two species of woodpecker, the golden-fronted (*Melanerpes aurifrons*), and ladder-backed (*Picoides scalaris*). One interesting find was the secretive yellow-billed cuckoo (*Coccyzus americanus*). Black-chinned hummingbirds (*Archilochus alexandri*) were attracted to feeders on the property. Other species sighted are listed in Table 2. Station 2, Spring Lake, had many of the species seen at Aquarena Center with the addition of a double-crested cormorant (*Phalacrocorax auritus*), American coot (*Fulica americana*), scissor-tailed flycatcher (*Tyrannus forficatus*), summer tanager (*Piranga rubra*) and unique to this study, a loggerhead shrike (*Lanius ludovicianus*). Station 3 (Sewell Park) had 26 species, Station 4 (City Park) 24 species, Station 5 (Rio Vista Park) 26, Station 6 (Ramon Lucio Park) 19, and Station 7 (John Stokes Park) 18 species. Unique finds at these stations included American robin (*Turdus migratorius*) at Rio Vista Park and northern parula (*Parula americana*) at John Stokes Park, which was only seen at one other site, Palmetto State Park.

I recorded the greatest number of species (42) at Palmetto State Park (Station 10), in a rural segment of the river. I observed numerous birds at Palmetto State Park that were not observed at other stations. These included the crested caracara (*Caracara cheriway*), ruby-throated hummingbird (*Archilocus colubris*), chuck-will's widow

Table 2. Common and scientific names<sup>1</sup> of bird species found along the urban section of the San Marcos River in summer 2001 and 2002.

Species	Stations						
	Aquarena	Spring Lake	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes
Pied-billed grebe ( <i>Podilymbus podiceps</i> )	O	O					
Double-crested cormorant ( <i>Phalacrocorax auritus</i> )		O					
Mute swan ( <i>Cygnus olor</i> )	C	C		C			
Mallard ( <i>Anas platyrhynchos</i> )	O	O		O	O		
Wood duck ( <i>Aix sponsa</i> )		O					
Red-shouldered hawk ( <i>Buteo lineatus</i> )	O	C	C		C	C	
Great egret ( <i>Ardea alba</i> )	O	O		O			
Snowy egret ( <i>Egretta thula</i> )	O	O					
Great blue heron ( <i>Ardea herodias</i> )	U		U				
Little blue heron ( <i>Egretta caerulea</i> )	R						
Green heron ( <i>Butorides virescens</i> )	A	A	A	A	A	A	A
Yellow-crowned night heron ( <i>Nyctanassa violacea</i> )	A		C	C	A	C	
American coot ( <i>Fulica americana</i> )		C					
Killdeer ( <i>Charadrius vociferus</i> )	A	A	A	A	A		
Mourning dove ( <i>Zenaida macroura</i> )	A	A	A	A	A	A	A

Species	Stations						
	Aquarena	Spring Lake	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes
Inca dove ( <i>Columbina inca</i> )	A	C				C	
Yellow-billed cuckoo ( <i>Coccyzus americanus</i> )	R						
Common night hawk ( <i>Chordeiles minor</i> )			O				
Chimney swift ( <i>Chaetura pelagica</i> )	A		A	A	A		A
Black-chinned hummingbird ( <i>Archilochus alexandri</i> )	A						
Golden-fronted woodpecker ( <i>Melanerpes aurifrons</i> )	A	A	A	A	A	A	A
Ladder-backed woodpecker ( <i>Picoides scalaris</i> )	A	A	A	A	A	A	A
Scissor-tailed flycatcher ( <i>Tyrannus forficatus</i> )		U	U	U	U		
Eastern kingbird ( <i>Tyrannus tyrannus</i> )	A	A	A	A	A	A	
Western kingbird ( <i>Tyrannus verticalis</i> )	C	C	C	C	C		
Great-crested flycatcher ( <i>Myiarchus crinitus</i> )	A	A	A		A	A	
Barn swallow ( <i>Hirundo rustica</i> )		C	C	C			C
Cliff swallow ( <i>Petrochelidon pyrrhonota</i> )	A	A	A	A	A	A	A
Purple martin ( <i>Progne subis</i> )	C	C					
Blue jay ( <i>Cyanocitta cristata</i> )		A	A	A	A	A	
American crow ( <i>Corvus brachyrhynchos</i> )					O		
Carolina chickadee ( <i>Poecile carolinensis</i> )	A	A	A	A	A	A	A
Tufted titmouse ( <i>Baeolophus bicolor</i> )	C		C		C	C	C
Carolina wren ( <i>Thryothorus ludovicianus</i> )	A	A	A	A	A	A	A
American robin ( <i>Turdus migratorius</i> )					R		

Species	Stations						
	Aquarena	Spring Lake	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes
Mockingbird ( <i>Mimus polyglottos</i> )	A	A	A	A	A	A	A
Loggerhead shrike ( <i>Lanius ludovicianus</i> )		O					
European starling ( <i>Sturnus vulgaris</i> )			A	A	A		A
White-eyed vireo ( <i>Vireo griseus</i> )	A	A			A	C	C
Northern parula ( <i>Parula americana</i> )							R
House sparrow ( <i>Passer domesticus</i> )	C	C		C	C	C	
Great-tailed grackle ( <i>Quiscalus mexicanus</i> )	A	A	A	A	A	A	A
Brown-headed cowbird ( <i>Molothrus ater</i> )							C
Summer tanager ( <i>Piranga rubra</i> )		R	R				
Northern cardinal ( <i>Cardinalis cardinalis</i> )	A	A	A	A	A	A	A
House finch ( <i>Carpodacus mexicanus</i> )	C			C			C

<sup>1</sup>Species occurrences at each station follow American Birding Association definitions that reflect chance of sighting per single visit: A = abundant, 75%; C = common, 50%;

O = occasional, 25%; U = uncommon, 10%; R = rare, once per season.

(*Caprimulgus carolinensis*), eastern wood-pewee (*Contopus virens*), and both black and turkey vultures (*Coragyps atratus* and *Cathartes aura*). Blanco River (Station 8) had 22 species, which included a barred owl (*Strix varia*), black-crested titmouse (*Baeolophus atricristatus*) and indigo bunting (*Passerina cyanea*). CR 101 had 18 species as did US 90A. Four unique sightings occurred at US 90A: a flock of wood stork (*Mycteria americana*), blue-gray gnatcatcher (*Poliophtila caerulea*), a belted kingfisher (*Ceryle alcyon*) and common grackle (*Quiscalus quiscula*). I recorded 24 species at Independence Park in Gonzales. Species sighted in the rural areas are listed in Table 3. Species seen in both urban and rural sites are listed in Table 4.

Both similarity indices rely on a comparison of common and unique species at each site. Table 5 shows the number of unique species in comparison with other stations as well as the total number of species observed at each station. Using Jaccard's Similarity Index, stations with the same similarity value (0.690) were Sewell Park (Station 3) and City Park (Station 4). Three sets of stations had a value of 0.677: Sewell Park with Rio Vista Park (Station 5), City Park with Rio Vista Park, and Rio Vista Park with Ramon Lucio Park (Station 6). All were urban stations east of IH 35. All values for the Jaccard's similarity index for all stations are listed in Table 6. In rural stations, the highest Jaccard's similarity value (0.519) was between Palmetto State Park (Station 10) with an urban station, albeit the most rural one, John Stokes (Station 7). The next highest rural value (0.512) was between Palmetto State Park and Aquarena Center.

Table 3. Common and scientific names of bird species found along the rural section of the San Marcos and Blanco Rivers in summer of 2001-2002<sup>2</sup>.

Species	Stations				
	Blanco	CR 101	Palmetto	US 90A	Gonzales
Pied-billed grebe ( <i>Podilymbus podiceps</i> )			R		
Great blue heron ( <i>Ardea herodias</i> )			U		
Little blue heron ( <i>Egretta caerulea</i> )	C				
Yellow-crowned night heron ( <i>Nyctanassa violacea</i> )		R	U		
Green heron ( <i>Butorides virescens</i> )	A		U		C
Wood stork ( <i>Mycteria americana</i> )				R	
Wood duck ( <i>Aix sponsa</i> )			U		
Black vulture ( <i>Coragyps atratus</i> )			C		
Turkey vulture ( <i>Cathartes aura</i> )			C		
Red-shouldered hawk ( <i>Buteo lineatus</i> )		U	U		C
Red-tailed hawk ( <i>Buteo jamaicensis</i> )		U	R		
Crested caracara ( <i>Caracara cheriway</i> )			U		
American coot ( <i>Fulica americana</i> )			U		
Killdeer ( <i>Charadrius vociferus</i> )	U		C		
White-winged dove ( <i>Zenaida asiatica</i> )	C	U			C
Mourning dove ( <i>Zenaida macroura</i> )	C		C		A
Inca dove ( <i>Columbina inca</i> )			U		

Species	Stations				
	Blanco	CR 101	Palmetto	US 90A	Gonzales
Yellow-billed cuckoo ( <i>Coccyzus americanus</i> )	C		U	U	U
Barred owl ( <i>Strix varia</i> )	R		C		
Common night hawk ( <i>Chordeiles minor</i> )			C		
Chuck-will's widow ( <i>Caprimulgus carolinensis</i> )			C		
Chimney swift ( <i>Chaetura pelagica</i> )		U	C		U
Ruby-throated hummingbird ( <i>Archilochus colubris</i> )			U		
Belted kingfisher ( <i>Ceryle alcyon</i> )				U	
Golden-fronted woodpecker ( <i>Melanerpes aurifrons</i> )	C		R	A	
Red-bellied woodpecker ( <i>Melanerpes carolinus</i> )		U	C	C	C
Ladder-backed woodpecker ( <i>Picoides scalaris</i> )		U	U		C
Scissor-tailed flycatcher ( <i>Tyrannus forficatus</i> )		U	C		U
Western kingbird ( <i>Tyrannus verticalis</i> )	U	U	R		C
Eastern wood-pewee ( <i>Contopus virens</i> )			R		
Great-crested flycatcher ( <i>Myiarchus crinitus</i> )			U	C	
Barn swallow ( <i>Hirundo rustica</i> )		C	C	C	U
Cliff swallow ( <i>Petrochelidon pyrrhonota</i> )	U	U	C		
Purple martin ( <i>Progne subis</i> )	U	U	C	A	A
American crow ( <i>Corvus brachyrhynchos</i> )	U		C		C
Carolina chickadee ( <i>Poecile carolinensis</i> )	A	C	C	C	A
Black-crested titmouse ( <i>Baeolophus atricristatus</i> )	C				
Carolina wren ( <i>Thryothorus ludovicianus</i> )	A	A	A		A

Species	Stations				
	Blanco	CR 101	Palmetto	US 90A	Gonzales
Bewick's wren ( <i>Thryomanes bewickii</i> )			C		
Blue-gray gnatcatcher ( <i>Polioptila caerulea</i> )				R	
Northern mockingbird ( <i>Mimus polyglottos</i> )	C				A
European starling ( <i>Sturnis vulgaris</i> )		U	C		C
White-eyed vireo ( <i>Vireo griseus</i> )	A	A	C		U
Northern parula ( <i>Parula americana</i> )			C		
House sparrow ( <i>Passer domesticus</i> )				C	C
Great-tailed grackle ( <i>Quiscalus mexicanus</i> )	C		U	U	C
Common grackle ( <i>Quiscalus quiscula</i> )				C	
Brown-headed cowbird ( <i>Molothrus ater</i> )			U	U	C
Summer tanager ( <i>Piranga rubra</i> )				U	U
Cardinal ( <i>Cardinalis cardinalis</i> )	A	A		A	A
Indigo bunting ( <i>Passerina cyanea</i> )	U		U		
Painted bunting ( <i>Passerina ciris</i> )			C	C	
House finch ( <i>Carpodacus mexicanus</i> )	U	U			
American goldfinch ( <i>Carduelis tristis</i> )	U				

<sup>2</sup>Species occurrences at each station follow American Birding Association definitions that reflect chance of sighting per single visit: A = abundant, 75%; C = common, 50%; O = occasional, 25%; U = uncommon 10%; R = rare, once per season.

Table 4. Common and scientific names of bird species found along urban and rural sections of the San Marcos and Blanco Rivers in summer 2001 and 2002<sup>3</sup>.

Species	Stations												
	Aquarena	Spring Lk.	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes	Blanco	CR 101	Palmetto	US 90A	Gonzales	
Pied-billed grebe ( <i>Podilymbus podiceps</i> )	O	O								R			
Double-crested cormorant ( <i>Phalacrocorax auritus</i> )		O								U			
Mute swan ( <i>Cygnus olor</i> )	C	C		C									
Mallard ( <i>Anas platyrhynchos</i> )	O	O		O	O								
Wood duck ( <i>Aix sponsa</i> )		O								U			
Black vulture ( <i>Coragyps atratus</i> )										C			
Turkey vulture ( <i>Cathartes aura</i> )										C			
Red-shouldered hawk ( <i>Buteo lineatus</i> )	O	C	C		C	C			U	U		C	
Red-tailed hawk ( <i>Buteo jamaicensis</i> )									R	R			
Crested caracara ( <i>Caracara cheriway</i> )										U			

Species	Stations											
	Aquarena	Spring Lk.	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes	Blanco	CR 101	Palmetto	US 90A	Gonzales
Great egret ( <i>Casmerodius albus</i> )	O	O		O								
Snowy egret ( <i>Egretta thula</i> )	O	O										
Great blue heron ( <i>Ardea herodias</i> )	U		U							U		
Little blue heron ( <i>Egretta caerulea</i> )	R							C				
Green heron ( <i>Butorides striatus</i> )	A	A	A	A	A	A	A	A		U		C
Yellow-crowned night heron ( <i>Nycticorax violaceus</i> )	A		C	C	A	C			R	U		
Wood stork ( <i>Mycteria americana</i> )											R	
American coot ( <i>Fulica americana</i> )		C								U		
Killdeer ( <i>Charadrius vociferus</i> )	A	A	A	A	A			U				
Mourning dove ( <i>Zenaida macroura</i> )	A	A	A	A	A	A	A	C		C		A
Inca dove ( <i>Columbina inca</i> )	A	C				C				U		
White-winged dove ( <i>Zenaida asiatica</i> )								C	U	U		C
Yellow-billed cuckoo ( <i>Coccyzus americanus</i> )	R							C		U	U	U

Species	Stations											
	Aquarena	Spring Lk.	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes	Blanco	CR 101	Palmetto	US 90A	Gonzales
Barred owl ( <i>Strix varia</i> )								R		C		
Common night hawk ( <i>Chordeis minor</i> )			O							C		
Chuck-will's widow ( <i>Caprimulgous carolinensis</i> )										C		
Chimney swift ( <i>Chaetura pelagica</i> )	A		A	A	A		A		U	C		U
Ruby-throated hummingbird ( <i>Archilocus colubris</i> )										U		
Black-chinned hummingbird ( <i>Archilochus alexandri</i> )	A											
Belted kingfisher ( <i>Megacyryle alcyon</i> )											U	
Golden-fronted woodpecker ( <i>Centurus aurifous</i> )	A	A	A	A	A	A	A	C		R	A	
Red-bellied woodpecker ( <i>Centurus carolinus</i> )									U	C	C	C
Ladder-backed woodpecker ( <i>Dendrocopas scalaris</i> )	A	A	A	A	A	A	A		U	U		C
Scissor-tailed flycatcher ( <i>Tyrannus forficatus</i> )		U	U	U	U				U	C		U

Species	Stations											
	Aquarena	Spring Lk.	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes	Blanco	CR 101	Palmetto	US 90A	Gonzales
Eastern kingbird ( <i>Tyrannus tyrannus</i> )	A	A	A	A	A	A						
Western kingbird ( <i>Tyrannus verticulatus</i> )	C	C	C	C	C			U	U	R		C
Eastern wood pewee ( <i>Contopus virens</i> )										R		
Great-crested flycatcher ( <i>Myiarchus crinatus</i> )	A	A	A		A	A				U	C	
Barn swallow ( <i>Hirundo rustica</i> )		C	C	C			C		C	C	C	U
Cliff swallow ( <i>Petrochelidon pyrrhonata</i> )	A	A	A	A	A	A	A	U	U	C		
Purple martin ( <i>Progne subis</i> )	C	C						U	U	C	A	A
Blue jay ( <i>Cyanocitta cristata</i> )		A	A	A	A	A						
American crow ( <i>Corvus brachyrhynchos</i> )					O			U		C		C
Carolina chickadee ( <i>Parus carolinensis</i> )								A	C	C	C	A
Tufted titmouse ( <i>Baeolophus bicolor</i> )												
Black-crested titmouse ( <i>Baeolophus atricristatus</i> )								C				

Species	Stations											
	Aquarena	Spring Lk.	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes	Blanco	CR 101	Palmetto	US 90A	Gonzales
Carolina wren ( <i>Thryothorus ludovicianus</i> )	A	A	A	A	A	A	A	A	A	A		A
Bewick's wren ( <i>Thryomanes bewickii</i> )										C		
Blue-gray gnatcatcher ( <i>Poliptilia caerulea</i> )											R	
American robin ( <i>Turdus migratorius</i> )					R							
Mockingbird ( <i>Mimus polyglottos</i> )	A	A	A	A	A	A	A	C				A
Loggerhead shrike ( <i>Lanius ludovicianus</i> )		O										
European starling ( <i>Sturnus vulgaris</i> )			A	A	A		A		U	C		C
White-eyed vireo ( <i>Vireo griseus</i> )	A	A			A	C	C	A	A	C		U
Northern parula ( <i>Parula americana</i> )							R			C		
House sparrow ( <i>Passer domesticus</i> )	C	C		C	C	C					C	C
Great-tailed grackle ( <i>Quiscalus mexicanus</i> )	A	A	A	A	A	A	A	C		U	U	C
Common grackle ( <i>Quiscalus quiscula</i> )											C	
Brown-headed cowbird ( <i>Molothrus oter</i> )							C			U	U	C

Species	Stations											
	Aquarena	Spring Lk.	Sewell Park	City Park	Rio Vista	R. Lucio Pk.	John Stokes	Blanco	CR 101	Palmetto	US 90A	Gonzales
Summer tanager ( <i>Piranga rubra</i> )		R	R								U	U
Northern cardinal ( <i>Cardinalis cardinalis</i> )	A	A	A	A	A	A	A	A	A		A	A
Indigo bunting ( <i>Passerina cyanea</i> )								U		U		
Painted bunting ( <i>Passerina ciris</i> )										C	C	
House finch ( <i>Carpodacus mexicanus</i> )	C			C			C	U	U			
American goldfinch ( <i>Spinus trisis</i> )								U				

<sup>3</sup>Species occurrences at each station follow American Birding Association definitions that reflect chance of sighting per single visit: A = abundant, 75%; C = common, 50%; O = occasional, 25%; U = uncommon, 10%, R = rare, once per season. Pk = park. Lk = Lake.

Table 5. Comparison of sampling stations along the San Marcos and Blanco Rivers showing number of similar avian species, unique species, and total species at each station. X = species tallied in previous section.

Stations compared (a with b)	# of similar species	# unique to a compared to b	Total species at a
1 with 2	24	8	32
1 with 3	19	9	32
1 with 4	22	12	32
1 with 5	21	11	32
1 with 6	18	12	32
1 with 7	13	18	32
1 with 8	17	16	32
1 with 9	12	17	32
1 with 10	21	11	32
1 with 11	8	20	32
1 with 12	15	18	32
2 with 1	x	8	32
2 with 3	20	12	32
2 with 4	20	11	32
2 with 5	20	12	32
2 with 6	17	15	32
2 with 7	12	20	32
2 with 8	11	20	32
2 with 9	10	22	32
2 with 10	21	12	32
2 with 11	9	25	32
2 with 12	13	18	32
3 with 1	x	6	26
3 with 2	x	6	26
3 with 4	20	6	26
3 with 5	21	5	26

Stations compared (a with b)	# of similar species	# unique to a compared to b	Total species at a
3 with 6	16	10	26
3 with 7	14	11	26
3 with 8	13	14	26
3 with 9	12	13	26
3 with 10	20	6	26
3 with 11	8	19	26
3 with 12	14	10	26
4 with 1	x	4	24
4 with 2	x	4	24
4 with 3	x	3	24
4 with 5	20	4	24
4 with 6	14	9	24
4 with 7	13	10	24
4 with 8	12	12	24
4 with 9	11	10	24
4 with 10	16	6	24
4 with 11	7	18	24
4 with 12	13	11	24
5 with 1	x	5	26
5 with 2	x	7	26
5 with 3	x	5	26
5 with 4	x	6	26
5 with 6	18	8	26
5 with 7	14	10	26
5 with 8	13	12	26
5 with 9	12	13	26
5 with 10	18	8	26
5 with 11	7	18	26
5 with 12	16	8	26
6 with 1	x	1	19
6 with 2	x	1	19

Stations compared (a with b)	# of similar species	# unique to a compared to b	Total species at a
6 with 3	x	3	19
6 with 4	x	5	19
6 with 5	x	1	19
6 with 7	12	7	19
6 with 8	10	8	19
6 with 9	8	11	19
6 with 10	14	5	19
6 with 11	7	12	19
6 with 12	12	8	19
7 with 1	x	3	18
7 with 2	x	3	18
7 with 3	x	3	18
7 with 4	x	3	18
7 with 5	x	4	18
7 with 6	x	5	18
7 with 8	11	7	18
7 with 9	9	8	18
7 with 10	14	3	18
7 with 11	7	12	18
7 with 12	14	4	18
8 with 1	x	5	22
8 with 2	x	6	22
8 with 3	x	11	22
8 with 4	x	9	22
8 with 5	x	9	22
8 with 6	x	13	22
8 with 7	x	11	22
8 with 9	9	13	22
8 with 10	14	7	22
8 with 11	5	14	22
8 with 12	13	9	22

Stations compared (a with b)	# of similar species	# unique to a compared to b	Total species at a
9 with 1	x	6	18
9 with 2	x	7	18
9 with 3	x	4	18
9 with 4	x	6	18
9 with 5	x	6	18
9 with 6	x	9	18
9 with 7	x	8	18
9 with 8	x	9	18
9 with 10	15	3	18
9 with 11	5	13	18
9 with 12	14	4	18
10 with 1	x	20	42
10 with 2	x	22	42
10 with 3	x	21	42
10 with 4	x	25	42
10 with 5	x	24	42
10 with 6	x	27	42
10 with 7	x	27	42
10 with 8	x	25	42
10 with 9	x	25	42
10 with 11	11	30	42
10 with 12	16	18	42
11 with 1	x	9	18
11 with 2	x	8	18
11 with 3	x	10	18
11 with 4	x	11	18
11 with 5	x	11	18
11 with 6	x	11	18
11 with 7	x	11	18
11 with 8	x	11	18
11 with 9	x	11	18

Stations compared (a with b)	# of similar species	# unique to a compared to b	Total species at a
11 with 10	x	6	18
11 with 12	11	7	18
12 with 1	x	8	24
12 with 2	x	8	24
12 with 3	x	8	24
12 with 4	x	8	24
12 with 5	x	8	24
12 with 6	x	11	24
12 with 7	x	10	24
12 with 8	x	10	24
12 with 9	x	9	24
12 with 11	x	13	24

The mean of Jaccard's values for all comparisons between urban stations was 0.549, while the mean of all comparisons between rural sites was 0.340. The lowest Jaccard's similarity values occurred in comparisons between rural stations. The lowest value (0.167) occurred between the Blanco River (Station 8) and the bridge at US 90A crossing (Station 11). The next most dissimilar was CR 101 (Station 9) with US 90A with a value of 0.172.

In using Sorensen's Index when comparing stations, which more heavily weights the common species found at each location, all values but one increased. Similarity value of John Stokes Park with Palmetto State Park (0.519) tied for the highest similarity of rural stations. The mean of all urban stations compared to each other using Sorensen's Index was 0.693, with the rural stations being 0.452. Sorensen's Similarity Index values are listed in Table 7. Using either index, urban stations had about 1.5 times more similarity to each other than rural stations. In ranking purely rural stations with each other, there was no difference in the two indices in the highest similarity, which was Station 9 with Station 12 (CR 101 with Gonzales).





## DISCUSSION

The highest avian species richness (42 species) along the San Marcos River, occurred at Station 10 (Palmetto State Park), a secluded and minimally developed rural area. The next highest species richness, surprisingly, occurred in urban sites, Aquarena Center and Spring Lake, each with 32 species. These results contradicted studies in Canada by Melles et al. (2003) that showed avian richness declined in relation to an increasing urban gradient. At the Aquarena site there is moderate development with a golf course. Blair (1996) found an increase in avian richness with moderately developed urban areas that may be associated with golf courses in California. In contrast to Aquarena Center and Spring Lake, Ramon Lucio Park, a moderately developed urban station with 19 species, had lower species richness than more highly developed and utilized urban park stations in this study: City Park, Sewell Park, Rio Vista Park, and a more rural park, Independence Park, in Gonzales. These findings are consistent with many studies that showed intermediate levels of urban development increased species richness (Lancaster and Rees, 1979; Blair, 1996; Clergeau et al., 1998; McKinney and Lockwood, 2001; Crooks et al., 2004). One factor that may have influenced the lower species richness at Ramon Lucio Park was the nearby presence of IH 35, a major interstate highway with heavy traffic that crosses the river. Studies in Massachusetts (Forman and Deblinger, 1999) and the Netherlands (Reijnen et al. 1995; Reijnen et al.,

1996) showed decreased species diversity and abundance of up to one-third because of the proximity of a major roadway in an urban area. These studies verified that the excessive noise generated from heavy traffic flow in urban areas influenced the composition of the bird community up to a distance of 830 m. The Ramon Lucio site was within that critical-effect distance. All other urban sites and the suburban park, Independence Park, in Gonzales had higher species richness than most rural sites. This was consistent with Blair's (1996) findings along an urban gradient in Santa Clara, California and in Ohio (Blair, 2004) as well as several other studies (Lancaster and Rees, 1979; Clergeau et al., 1998; McKinney and Lockwood, 2001; Crooks et al., 2004) that showed increased species richness with moderate development or disturbance.

The most impoverished sites for species richness were the most outlying urban site at John Stokes Park and two rural sites at US 90A and CR 101. Both sites were located in agricultural areas and had very narrow and sparsely vegetated corridors along the river. One (US 90A) has very steep banks and is on a major two-lane roadway. The other (CR 101) was bordered by < 50 m width of greenway with minimal vertical spatial structure. These physical habitat attributes are indicators of low avian species richness (Lancaster and Rees, 1979; Tilghman, 1987; Mills et al., 1989).

Besides addressing species richness, it is equally important to determine niche type for birds species composing the community. Several researchers have coined terms such as urban adapted (Hunter, 2002; Mason et al., 2003) for differentiating the ability of birds to cohabitate with humans. In my study, I used the terms urban exploiters, suburban adapted and urban avoiders (also referred to as the pre-development) species (Blair, 1996). There are many definitions of what constitutes urban adapted as

varying studies seem to categorize some birds differently than others (Blair, 1996; Mason et al., 2003; Crooks et al., 2004). I found many birds that Blair called suburban adapted, such as grackles and the European starling, could easily qualify for urban-adapted status, as they have adapted to functioning in an urban setting, especially by feeding on human litter, such as French fries. My determinations of a niche designation along with their feeding and nesting guilds are listed in Table 1.

In my study, I classified two exotic species, mute swan and house sparrow (*Passer domesticus*), as urban exploiters. Although the European starling (*Sturnus vulgaris*) is an exotic, I decided to keep Blair's designation for this species as suburban adapted. Other suburban adapted birds included the mallard, killdeer, mourning and Inca doves, chimney swift, both hummingbird species, all woodpecker species, eastern and western kingbirds, both swallow species, blue jay, crow, robin, mockingbird, titmice, chickadees, both wren species, cardinal, house and gold finches, both grackle species and the cowbird. Many might argue the status of some of these such as chickadees, cardinals, blue jays, mockingbird and grackles as urban adapted, but I think the distinction lies in the characterization of the local landscape. "Urban" implies more paved areas and concrete, while "suburban" implies house lots with yards, trees, lawns and feeders that may support these woodland edge species. The remaining species could be termed urban avoiders and their presence in urban study sites were only made possible because of one specific or a set of specific habitat requirements that the unique qualities of a riparian, urban greenway provides.

When I examined the actual composition of bird assemblages of each station along the San Marcos and Blanco Rivers, the number of suburban adapted birds ranged

from 16-18 of the total species with only two exceptions. At Aquarena Springs, suburban adapted (18 species) and urban exploiters (2 species) made up 63% of species. This finding is consistent with Blair's Santa Clara study (1996), where he found a loss of over 40% of predevelopment species at an urban golf course. This can be compared to my most natural site, Palmetto State Park, with almost the exact opposite composition. Suburban adapted species (17) made up 40% of the total species, leaving 60% predevelopment species. I believe these percentages are of interest for two reasons. First, Palmetto State Park was surrounded by agricultural land and small rural town dwellings, which may greatly influence the number of suburban adapted summer residents, and second, Aquarena Center had a similarity index most like the Palmetto State Park site. The similarities are most evident in the suburban adapted birds making up the communities (Table 1).

Suburban adapted birds were consistently found at stations 1-5 with the highest percentage found at Station 5, Rio Vista Park (20 species, 77% of the bird community). The presence of a broad and stratified green corridor opposite lawns, pavilions, pool and parking lots of the park grounds provided for predevelopment species, such as the white-eyed vireo (*Vireo griseus*), great-crested flycatcher and yellow-crowned night heron. This corridor also provided a foraging path for the resident red-shouldered hawk pair.

An interesting decline in suburban adapted species in the urban section of the river occurred at Ramon Lucio Park with only 13 suburban species. This station only had a total of 19 species, so suburban species represented 68% of the avian assemblage. This was less than the nearby Rio Vista Park that had 26 species, 100% of which were suburban adapted. I think the difference in richness between these nearby parks can be

explained by the level of development in Ramon Lucio Park compared to Rio Vista, the previously mentioned interstate highway at Ramon Lucio, and physical attributes of the river at this location. At this station, the river is less than half the width at Rio Vista, the river corridor makes a hairpin turn, and one side of the river bank has an almost impenetrable wall of ivy.

At the US 90A station, the suburban adapted and urban exploiters comprised 55% of total species richness. There is one dwelling within 100 m of the bridge and the rest of the land is pasture. The banks of the river on one side are ~ 10 m high. There is almost no floodplain and the river is highly channelized. In this setting, my findings agree with the results of other studies that moderate urbanization increases overall richness (Lancaster and Rees, 1979; Blair, 1996; Clergeau et al., 1998; McKinney and Lockwood, 2001; Blair, 2004; Crooks et al., 2004) and agricultural use decreases species richness (Taylor, 1986; Bock et al., 1993). Although species richness decreased, however at these more rural sites, the overall community had a much better representation of predevelopment species. This is an important point to consider when addressing conservation of overall biological diversity in a region. This site provided food resources, foraging sites, cover, and habitat for the wood stork, yellow-billed cuckoo, blue-gray gnatcatcher and painted bunting. My data also indicated that specific physical characteristics of a site influenced not only how many species may be present, but what species were present. These findings also were consistent with the results of other urban bird studies (Crooks et al., 2004; Mason et al., 2003, Melles et al., 2003; Miller et al., 2003). For example, the presence of thick, structured vertical strata, high canopies, and greenways wider than 100 m may explain the presence of red-shouldered hawk, yellow-

billed cuckoo and white-eyed vireo at many urban stations (Mason et al., 2003). A quiet, shallow body of water at Spring Lake, shielded from busy roadways by banks of trees as well as a high hillside, allowed ample privacy for a host of waders, such as the little blue heron, common egret, great blue heron, and swimmers, such as pied billed grebe, wood duck and American coot that would not normally be seen in an urban pond.

A greenway wider than 100 m, with dead tree snags along some stretches of the urban section of the San Marcos provided habitat for the great-crested flycatcher. The great-crested is much more territorial than its more social cousin the western kingbird (Clark, 2001). Therefore it was highly likely that the sightings of this tyrant flycatcher at Aquarena Center, Spring Lake, Sewell Park and Rio Vista represented more than one breeding pair. In a similar fashion, multiple sightings of red-shouldered hawks throughout the urban section of the river probably represented one pair that nested behind the Freeman Aquatic Building at the Texas State University campus. This may show a lack of suitable habitat in the surrounding landscape because according to Moorman and Chapman (1996), red-shouldered hawks in Georgia were not found in areas with building densities as high as are found in the urban San Marcos area. This location may represent a true “oasis” in an impoverished ecosystem. A purple martin house and hummingbird feeders at the Education Building at Aquarena attracted purple martins and hummingbirds at this site. The only other site with nectivores was at Palmetto State Park.

The physical characteristics of the San Marcos River provided habitat for water birds in certain areas of the river. Waders, such as the great-blue heron, common egret, yellow-crowned night heron, and green heron occurred in shallows. However, much of the San Marcos River is heavily channelized and unavailable for waders. This may act to

concentrate wading birds in smaller stretches of the river and may have long-term consequences on future impacts (from fecal parasites) on the ecology of the river. The green heron and yellow-crowned night heron appeared to be the least shy of the waders and were much more evident at many stations, including stations more heavily used by people.

Knopf and Samson (1994), Mason et al.(2003), and Miller et al. (2003) found that characteristics of the adjacent landscape as well as level of development may be just as important as local habitat characteristics to birds using urban habitats. In North Carolina, Mason et al. (2003) found insectivores were more abundant in urban areas that had adjacent lawns or canopy cover. In my study, the urban site with the least adjacent lawn and canopy had the most insectivores (13), which represented 50% of the total species. The urban site with the least insectivores was John Stokes Park with nine (47%). Palmetto State Park had 19 insectivores (43%), while Aquarena Springs with the same number of total species only had 12 (28%). Studies in Colorado (Miller et al., 2003) and North Carolina (Mason et al., 2003), showed that low nesting and ground nesting songbirds decreased in urban areas. In my study I found no ground nesting songbirds in urban sites.

Another objective of my study was to determine cottonwood and willow sapling existence on the San Marcos River and how the presence or absence of these trees may impact certain avian species (summer tanager and yellow-billed cuckoo) that rely on these trees as habitat “flags”. I examined the Blanco River at the Martindale crossing just before the confluence with the San Marcos River, where a natural floodplain had numerous cottonwood, willow and sycamore saplings and exotic Chinese tallow trees.

There is also a mature stand of cottonwood, sycamore, and pecan trees. One side of the bank has a very steep cliff > 20 m high. This area has > 400 m wide of continuous green space. The site had 22 bird species with 64% (14 species) classified suburban adapted. Of note, however, an indigo bunting and a barred owl were seen here and only at Palmetto State Park. A little blue heron (seen only at Aquarena Center), a yellow-billed cuckoo (seen only at a few other sites), American goldfinch (*Carduelis tristis*) and black-crested titmouse (*Baeolophus atricristatus*) were also only seen here. These unique bird species in an area with mature cottonwood stands are consistent with bird assemblages on the Middle Rio Grande River in New Mexico, where Farley et al. (1994) found more unique species in mature riparian woods in the summer season. The cottonwood/willow habitat provided two important habitat components. First, the young saplings help with soil erosion, and second, the unique physical attributes of cottonwood, tall with a very narrow canopy, provided substantial open understory. Some studies have indicated a reduction of insectivore bird richness with a completely enclosed hardwood canopy, although an enclosed canopy adjacent to the corridor increases richness (Schiller and Horn, 1997; Rottenborn, 1999; Manifold, 2001; Mason et al., 2003).

None of my stations along the San Marcos River has a natural floodplain that supports new growth of cottonwood and willow or sycamore saplings. Considering the species richness and the species observed at the Blanco River Station, I have no conclusive evidence that supports the notion that the summer residents are hindered necessarily by the lack of that type of vegetation alone. This is in sharp contrast to the extirpation of the yellow-billed cuckoo from Washington and declines in California because of eradication of habitat vegetation (Layman and Alterman, 1989). Historically,

certain species became locally extinct because of the lack of specific vegetation. I also think that the extent of agricultural use and roadways outweigh the consequences of deep river channelization and lack of natural floodplain in sustaining the avian fauna on the San Marcos River. This is in marked contrast to the U.S. Department of Agriculture Natural Resources Conservation Report on Riparian areas (Montgomery, 1996) that stated river channelization has the most adverse impacts on riparian systems. It is likely that the incongruities between my results and results of other researchers on riparian and urban avian richness may be because of the inability to document all species present due to the inability to detect certain species in differing habitats (Nichols et al., 1998; Swanson, 1999). I also think that regional differences between riparian habitats in the western United States, which historically have always been narrow and in sharp contrast to the surrounding arid landscape, and eastern riparian areas, which are often undifferentiated with the surrounding forests (Montgomery, 1996), make comparisons of riparian areas across geographical areas difficult and inconclusive.

My third objective was to determine if any type of river restoration or restriction could or should be implemented to enhance the habitat and bird diversity in generating more birdwatching tourism. Since summer tanagers, night hawks, various waders and flycatchers can be seen by an ardent bird watcher on a one hour walk along the river from Aquarena Springs to John Stokes Park, speaks well for the bird-friendly development that already has taken place along the river by the people of San Marcos. I think a management goal should be to maintain the level of green space that exists now in a manner that is conducive to use by birds and people. The birds seem to know what time tubers start down the river. They are harder to find past 1000 h. Allowing more

vegetation to grow up along a river will help enhance the overall habitat (Montgomery, 1996; Mason et al., 2003). For most of the length of the San Marcos River this is already occurring. The parks included in my study have only a small portion of the riverbank cleared to allow public access. Of note, perhaps the most heavily paved and cleared areas, Sewell Park, had the third highest species richness. The only other factor that could enhance the existing vegetation and river fauna would be a reversion back to a more natural floodplain. There is nothing at the present time or in the foreseeable future that could mitigate or correct the extent of river channelization.

Although I found several studies (Blair, 1996; Crooks et al. 2003; Hennings and Edge, 2003; Mason et al., 2003; Melles et al., 2003; Miller et al., 2003; Blair, 2004) of urban–rural or urban gradients in bird communities, I did not find any that specifically addressed a river as it ran its course through several urban parks, rural agricultural land, passed through a protected state park, and finally terminated at a moderately developed suburban level park.

As the State of Texas Parks and Wildlife Department expands their highly successful Coastal Birding Trails inland (Campbell, 2002), it's important for the citizens of San Marcos and the students and faculty of Texas State University to truly appreciate the avian oasis they have in the San Marcos River.

## APPENDIX

Taxonomy of Birds Seen on the San Marcos and Blanco Rivers in 2001 and 2002

According to the AOU Checklist of North American Birds 7th Edition.

<b>Order</b>	<b>Family</b>	<b>Subfamily</b>	<b>Species</b>
Anseriformes	Anatidae	Anserinae	mute swan
		Anatinae	mallard
			wood duck
Podicipediformes	Podicipedidae		pied-billed grebe
Pelecaniformes	Phalacrocoracidae		cormorants
Cooniiformes	Ardeidae		herons, egrets
	Ciconiidae		wood stork
	Cathartidae		vultures
Falconiformes	Accipitridae	Accipitrinae	hawks
	Falconidae	Caracarinae	caracara
Gruiformes	Charadriidae	Charadriinae	killdeer
Columbiformes	columbidae		doves
Cuculiformes	Cuculidae	Coccyzinae	y.b. cuckoo
Strigiformes	Strigidae		barred owl
Caprimulgiformes	Caprimulgidae	Chordeilinae	nighthawk
		Caprimulginae	Chuck-will's widow
Apodiformes	Apodidae	Chaeturinae	chimney swift
	Trochilidae	Trochilinae	hummingbirds
Coraciiformes	Alcedinidae	Cerylinae	belted kingfisher
Piciformes	Picidae		woodpeckers
Passeriformes	Tyrannidae	Fluvicolinae	wood pewee
Passeriformes	Tyrannidae	Tyranninae	Flycatchers
	Laniidae		shrikes

<b>Order</b>	<b>Family</b>	<b>Subfamily</b>	<b>Species</b>
	Vereonidae		vireos
	Corvidae		jays, crows
	Hirundinidae	Hirundininae	swallows, martin
	Paridae		chickadees, titmice
	Troglodytidae		wrens
	Sylviidae	Potioptilinae	gnatcatcher
	Turdidae		robin
	Mimidae		mockingbird
	Parulidae		wood warblers
	Thraupidae		tanagers
	Cardinalidae		cardinals, buntings
	Icteridae		grackles, starling
	Fringillidae	Carduelinae	house, gold finches
	Passeridae		house sparrow

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