INFLUENCES OF BORDERS ON GOLDEN-CHEEKED WARBLER HABITAT IN THE BALCONES CANYONLANDS PRESERVE, TRAVIS COUNTY, TEXAS

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ABSTRACT

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Destruction and fragmentation of breeding habitat threaten populations of many migrant songbird species, including the endangered Golden-cheeked Warbler. Fragmentation increases the proportion of habitat close to environmental borders, exposing flora and fauna in the bordering habitat to biotic and abiotic influences of the surrounding environments. I examined the influence of three types of bordering areas, a housing development, a utility easement, and woodland meadows, on several variables in Golden-cheeked Warbler habitat. I also examined the depth to which those influences penetrated into habitat. Type of bordering environment was an important factor in the

extent of influence on habitat variables. Survey points near the housing development had lower detection rates for Golden-cheeked Warblers, more avian predator species, higher detection rates for avian predators, lower solar radiation, and higher sound levels than points near the other two areas. Golden-cheeked Warblers were detected with greatest frequency in habitat bordering the utility easement, which also had the greatest oak canopy cover and shin oak canopy cover. Golden-cheeked Warbler detections tended to increase with distance from edge and were negatively correlated with avian predator detections and sound levels, both of which decreased with distance from edge. I found no evidence that microclimate variables (temperature, relative humidity, wind, solar raditation) were influenced by bordering environments beyond the immediate borders. Preserve managers should be aware that Golden-cheeked Warblers may not fully use habitat within 200 m to 300 m from bordering housing and other intense human-use developments.

CHAPTER I

INTRODUCTION

A probable cause for the decline in populations of many forest-dwelling migrant songbirds is the loss of woodland habitat to human development (Askins 1995, Boulinier et al. 2001). Bird populations are affected not only by reduced quantity of available breeding habitat, but also by reduced quality in remaining habitat resulting from fragmentation (Temple and Cary 1988, Fahrig and Merriam 1994, Friesen et al.1995).

Habitat fragmentation is the alteration of large areas of continuous habitat into smaller patches, either isolated or connected by corridors, surrounded by a matrix of different vegetation and/or land use (Saunders et al. 1991). Fragmentation can reduce the quality of remaining habitat patches in a number of ways. Populations may initially be trapped in reduced habitat areas, particularly near habitat borders with surrounding environments. The resulting crowded conditions can lead to increased competition for resources and degradation of the habitat through over-utilization. This in turn leads to reduced reproductive success and, ultimately, to population collapse (Saunders et al. 1991, Hagan et al. 1996). Small populations isolated in habitat remnants may experience reduced gene flow and colonization opportunities, increasing the population's susceptibility to inbreeding and extinction (Burkey 1989, Fahrig and Merriam 1994, Donovan et al. 1995).

Another consequence of fragmentation is an increase in the environmental influence of surrounding environments due to the geometric increase in proportion of remaining habitat edge to area (Temple and Cary 1988). The surrounding environment has the potential to alter the amount of solar radiation and re-radiation, soil temperature, moisture level, wind patterns, water regime, and nutrient cycling occurring at and penetrating into habitat edges (Saunders et al. 1991). These changes in microclimate can affect flora and fauna found at and/or near borders, altering the habitat so that it may no longer meet requirements of native birds (Saunders et al. 1991). Changes in temperature, humidity, wind and solar radiation affect energy requirements and physiological comfort of birds by influencing foraging behavior and habitat selection (Grubb 1975, Karr and Freemark 1983, Wolf and Walsberg 1996).

Further, habitat areas near environmental borders are susceptible to invasion by plant and animal species residing in surrounding environments. Greater numbers of predators and nest parasites aggregate along habitat edges (Brittingham and Temple 1983, Andren 1992, Arnold et al. 1996). Higher rates of nest predation and lower reproductive success rates occur for native birds nesting near habitat edges (Gates and Gysel 1978, Wilcove 1985, Andren and Angelstram 1988, Paton 1994, Robinson et al. 1995, Donovan et al. 1997).

Effects of environmental borders differ depending upon the relative proportion of remnant habitat existing at the landscape level (Paton 1994, Askins 1995, Donovan et al. 1997, Hartley and Hunter 1998), ratio of edge to habitat area as determined by patch size and shape (Andren and Angelstam 1988, Saunders et al. 1991), and type of environment bordering the habitat (Wilcove 1985, Blair 1996, Fenske-Crawford and Niemi 1997, Saracco and Collazo 1999, Mancke and Gavin 2000). Forest habitats bordering housing developments have a greater abundance of avian predator species, higher nest predation rates, and fewer Neotropical migrants in comparison to habitats bordering agricultural clearings (Wilcove 1985, Engels and Sexton 1994, Friesen et al. 1995). Higher predation rates occur at abrupt edges within forests and at exterior (agricultural) edges compared to rates at gradual edges surrounded by forest (Wilcove 1985, Andren and Angelstam 1988, Suarez et al. 1997, Saracco and Collazo 1999). However, habitat borders within mature forests have higher predation rates at gradual edges in comparison to abrupt edges (Fenske-Crawford and Niemi 1997) or no evidence of increased predation related to internal forest edges (Hanski et al. 1996). Avian nest predators were more abundant and forest-interior Neotropical migrants less abundant near edges in interior forest fragments separated by corridors as narrow as 16 to 23 m (Rich et al. 1994). However, no relationship existed between distance from edge and predation rates for nesting migrant birds residing in forest fragments within a larger woodland mosaic in northern Minnesota (Hanski et al. 1996). Nest predation rates were significantly higher in highly fragmented forests compared to larger, unfragmented areas, but predation rates were the same at the core (> 250 m from edge) as along the border (< 50 m from edge) in both types of habitat (Donovan et al. 1997). These varied results suggest that even habitat fragments of similar size and vegetative structure may differ ecologically due to differing amounts of edge, different edge structures, and influences of different bordering environments (Friesen et al. 1995).

Different bird species have different sensitivities to the effects of fragmentation. Most forest-interior breeding bird populations gradually abandoned small woodlots while remaining in large woodlots following fragmentation of southern Wisconsin forests (Temple and Cary 1988). Ambuel and Temple (1983) identified two groups of forest-dwelling bird species with area-dependent distributions: generalists, edge, and farmland species that are more commonly found in smaller woodlots and long-distance migrants occurring only in larger forests. They attributed exclusion of long-distance migrants from smaller woodland fragments to effects of area-dependent changes in competition, predation, brood parasitism, and food resources. Native woodland bird communities are also displaced by invasive and exotic species as former woodlands become increasingly urbanized (Sexton 1987, Blair 1996).

Habitat loss and fragmentation due to urbanization, agricultural practices, and creation of flood-control impoundments were the primary reasons given for the federal listing of the Golden-cheeked Warbler (*Dendroica chrysoparia*) as an endangered species in 1990 (U.S. Fish and Wildlife Service 1992). The Golden-cheeked Warbler is an endemic Neotropical migrant songbird that nests exclusively in the mixed oak (*Quercus* spp.)-Ashe juniper (*Juniperus ashei*) woodlands of 25 central Texas counties (Pulich 1976, Ladd 1985, Sexton 1987, Wahl et al. 1990, Ladd and Gass 1999). Urban and suburban development have greatly reduced woodland acreage and fragmented the remaining Golden-cheek Warbler habitat in Travis County, Texas (Shaw 1989, Wahl et al. 1990, Sexton 1992). The Balcones Canyonlands Preserve (BCP) was created in 1996 under the Balcones Canyonlands Conservation Plan to protect Golden-cheeked Warbler habitat in western Travis County from further fragmentation and destruction (U.S. Fish and Wildlife Service and Recon 1996). The approximately 11,000 ha of current BCP lands exist in patches ranging in size from about 12 ha to over 400 ha. These preserve “islands” are variously surrounded or intruded into by bodies of water, highways, utility easements, commercial sites, and residential housing developments.

Few studies have addressed the effects of fragmentation and habitat borders on Golden-cheeked Warbler populations. The results have frequently been inconclusive and/or contradictory. Kroll (1980) considered Golden-cheeked Warblers an “edge species” occupying territories adjacent to trails and roads. Later researchers disagreed, finding that the species might use habitat edges but did not prefer it (Fink 1996, Magness at al. 2006, Baccus et al. 2007). Size of habitat patch and extent of woodland in the surrounding landscape matrix are important predictors of Golden-cheeked Warbler occupancy of potential habitat (Arnold et al. 1996, Peterson 2001, DeBoer and Diamond 2006, Magness et al. 2006, Baccus et al. 2007). Breeding Golden-cheeked Warblers are unlikely to occupy otherwise suitable habitat patches of < 50 ha (Wahl et al. 1990). Arnold et al. (1996) suggested a minimum patch size threshold of 23 ha and Baccus et al. (2007) found territorial males only in habitat fragments > 15 ha in size. Golden-cheeked Warblers appear unaffected by natural canopy openings so long as a threshold proportion of habitat cover (40%) exists within the surrounding landscape (Magness et al. 2006). However, Golden-cheeked Warbler males would not span canopy openings > 15–20 m when establishing territories at Fort Hood, Texas (Horne 2000).

Urbanization (defined as homes, apartments, offices, retail and manufacturing buildings, manicured lawns, paved roads, campgrounds, golf courses, refuse areas, and parking lots) located within 500 m of otherwise suitable habitat has a negative effect on the presence of Golden-cheeked Warblers (Engels 1995). Engels and Sexton (1994) hypothesized that Golden-cheeked Warblers were adversely affected by urban development due in part to the introduction of Blue Jay (*Cyanocita cristata*) into their breeding habitat. They found a strong negative correlation between the presence of Golden-cheeked Warblers and Blue Jays in Golden-cheeked Warbler breeding habitat throughout western Travis County. Arnold et al. (1996) agreed that Golden-cheeked Warblers were more likely to be present in habitat bordering on agricultural fields than on commercial or residential developments. They also found that most avian predator species, including Blue Jays, occurred more frequently in Golden-cheeked Warbler habitat within 100 m of borders than at distances of 500 m and 1000 m from borders. However, they did not find that avian predator presence negatively correlated with the presence of Golden-cheeked Warblers. Higher levels of predation occurred at artificial nests of Golden-cheeked Warblers placed along habitat edges compared to those placed 100 m interior to the edge, but the differences were not significant at most study sites (Fink 1996). Blue Jays and fire ant activities were more frequently observed near nests bordering on commercial developments than more rural sites (Fink 1996).

As human populations and development continue to increase around the preserve "islands" of the BCP, the question of how habitat fragmentation and urbanization affect Golden-cheeked Warbler populations is more important than ever. Golden-cheeked Warblers may have evolved in relatively narrow wooded canyons bordered by open grassland, and thus, may be well adapted to influences of some natural borders (Kroll 1980, Ladd 1985, Wahl et al. 1990). However, man-made borders and related environmental influences may create different climatic and biotic conditions in adjacent Golden-cheeked Warbler habitat. To the extent that these influences penetrate otherwise high-quality habitat, negatively affecting territory establishment, mating, nesting success, food resources, and/or recruitment, the effective size of preserve land adjacent to borders is also reduced. Preserve managers need better information related to these influences and their effects by which to base guidelines for restrictions on development activities near habitat borders and for determining habitat quality in existing and potential preserve sites.

My objectives for this study were to increase our knowledge of how urban/suburban environments influence the ecology of adjacent Golden-cheeked Warbler habitat and how these influences may affect Golden-cheeked Warbler use of habitats. Specifically, I examined selected abiotic and biotic factors at varying distances from habitat edges and along three different types of urban/suburban environments bordering Golden-cheeked Warbler habitat within City of Austin BCP lands. I examined temperature, humidity, solar radiation, and wind velocity, all of which have the potential to alter vegetation, insect abundance, foraging behavior, and energetics of avian species (Grubb 1977, Karr and Freemark 1983, Saunders et al. 1991, Wolf and Walsberg 1996, Burke and Nol 1998, Dolby and Grubb 1999). I also measured noise levels as road noise has been correlated with reduced nest density and population density for numerous avian species (Kaseloo and Tyson 2004). I examined the presence of potential avian predators and brood parasites linked to nest failure of Golden-cheeked Warblers (Pulich 1976, Stake et al. 2004) and reported to have increased presence near habitat edges (Davis 1974, Pulich 1976, Toweill and Teer 1977, Wilcove 1985, Miller and Knight 1993, Fink 1996). I also searched for mounds of red imported fire ants (*Solenopsis invicta*) which have been documented as predators of young mammals, reptiles, and birds (Sikes and Arnold 1986; Allen et al. 1994, 1997). I examined canopy cover percentages and composition, factors known to influence Golden-cheeked Warbler foraging and nest site selection (Pulich 1976, Dearborn and Sanchez 2001, Magness et al. 2006).

My null hypothesis was that bordering environments would have no influence within habitat areas on the factors I examined. Thus, the factors would not differ based on distance from habitat border, nor among habitats bordered by different types of environments. The alternative hypothesis was that the transition between bordering environments and Golden-cheeked Warbler habitat would create a gradient from edge to interior habitat in these factors, and that these influences would correlate with the presence of Golden-cheeked Warblers. In addition, I hypothesized that environments with intense human development and on-going human activity would have more pronounced effects on factors in the bordering habitat than would natural woodland openings with little human activity.

CHAPTER II

STUDY AREA

My study was conducted in the City of Austin's 1918 ha Bull Creek Unit of the Balcones Canyonlands Preserve in western Travis County, Texas. Research was carried out on four contiguous parcels of the Unit: Ivanhoe tract (381 ha), 3M Mitigation tract (87 ha), Krueger tract (38.5 ha), and Jester-Burris tract (119 ha) (Balcones Canyonlands Preserve 1998). This area is on the eastern edge of the Edwards Plateau Ecological Region, straddling the Balcones Fault Zone. The tracts contain limestone plateaus with elevations near 300 m above mean sea level (MSL), with moderate to steep slopes down to drainages at about 200 m above MSL (Balcones Canyonlands Preserve 1998). West Bull Creek flows northwest to southeast through the Ivanhoe tract and an intermittent spring feeds a creek that flows to the southeast through Jester-Burris (Balcones Canyonlands Preserve 1998). Jester-Burris and Ivanhoe tracts surround on three sides a ridgeline almost completely covered with dense, single-family housing (Jester Point and Canyon Ridge developments). A series of electrical utility easements and improved gravel service roads cut through the northern end of these tracts. A narrower utility easement crosses from the 3M Mitigation tract on the northeast through Jester-Burris to the southwest.

All four tracts are heavily wooded with the dominant Ashe juniper mixed with oaks and other hardwoods. Common hardwood trees include Texas oak (*Quercus* *buckleyi*), plateau live oak (*Q. fusiformis*), shin oak (*Q. sinuata* var. *breviloba*), cedar elm (*Ulmus crassifolia*), sugar hackberry (*Celtis laevigata*), and escarpment black cherry (*Prunus serotina*). Common understory plants include wafer ash (*Ptelea trifoliate*), yaupon (*Ilex vomitoria*), Texas persimmon (*Diospyros texana*), and Carolina buckthorn (*Rhamnus caroliniana*). Historical records indicate that the forested areas within the tracts have remained unchanged for 30 to 50 years (Balcones Canyonlands Preserve 1998). The Ivanhoe tract contains a series of small meadows that were originally cleared for agricultural use (Balcones Canyonlands Preserve 1998). All four tracts contain small man-made and natural open-canopy clearings, as well as old dirt ranch roads and narrow foot trails, most of which have closed canopies. These tracts were selected as the study site because Golden-cheeked Warbler territories were documented in all four from 1989 through 2003 (Balcones Canyonlands Preserve 1998, City of Austin 2004). They collectively form a compact area with consistent topography and vegetative composition and structure which shares borders with three distinct and contrasting environments.

One bordering environment (hereafter, Jester) is a residential development characterized by cleared lots, lawns and other cultivated plants, houses and other structures, pavement, and substantial human activity. The border between the development and adjacent Golden-cheeked Warbler habitat is generally abrupt with little transition in understory vegetation. However, much of this border has a transitional overstory created by native and cultivated trees in the immediately-adjacent backyards of residences.

The second bordering environment (hereafter, Utility) is a utility easement, which consists of clearings maintained by periodic tree trimming and mowing. Improved dirt and gravel service roads run through the easement. Vehicular and foot traffic is infrequent throughout the year and restricted during Golden-cheeked Warbler breeding season (mid-March through mid-July). A 2 to 4 m shrubby transitional area separates the mowed clearing and the forest habitat along most of the utility easement.

The third bordering environment (hereafter, Meadow) consists of meadows within the Ivanhoe tract. This environment is characterized by irregular man-made clearings that have not been maintained for several decades. Vegetation is primarily grasses, forbs, and prickly pear (*Opuntia* sp.) with scattered young shrubby Ashe junipers. Edges of meadows consist of shrubby transitional zones similar to those along the utility easement border.

CHAPTER III

METHODS

I collected data during Golden-cheeked Warbler breeding season (mid-March through July) during 2004 and 2005 by establishing five 300-m transects perpendicular to borders with each environment. Due to limitations of preserve boundaries, problems of access from neighborhoods, and steep canyon topography in some areas, I was unable to space transects uniformly or randomly along borders. Instead, transects were placed at accessible locations with a minimum separation of 200 m where possible. GPS coordinates for starting points of transects along the Jester border were 30°23.659'N, 97°47.927'W; 30°23.365'N, 97°47.900'W; 30°23.173'N, 97°47.922'W; 30°23.103'N, 97°48.116'W; and 30°22.992'N, 97°48.035'W. Starting point coordinates for transects along the Utility border were 30°24.034'N, 97°48.674'W; 30°24.094'N, 97°48.755'W; 30°23.781'N, 97°47.592'W; 30°23.917'N, 97°47.504'W; and 30°24.033'N, 97°47.246'W. Starting point coordinates for Meadow transects were 30°23.057'N, 97°48.289'W; 30°23.425'N, 97°48.475'W; 30°23.612'N, 97°48.563'W; 30°23.636'N, 97°48.572'W; and 30°23.733'N, 97°48.690'W. Sampling points were located every 50 m along each transect for a total of 105 points, 35 per type of border (Fig. 1).

Avian Surveys

I conducted fixed-distance point counts at each sampling point four times during the 2004 and 2005 breeding season. During each survey, I recorded presence of all

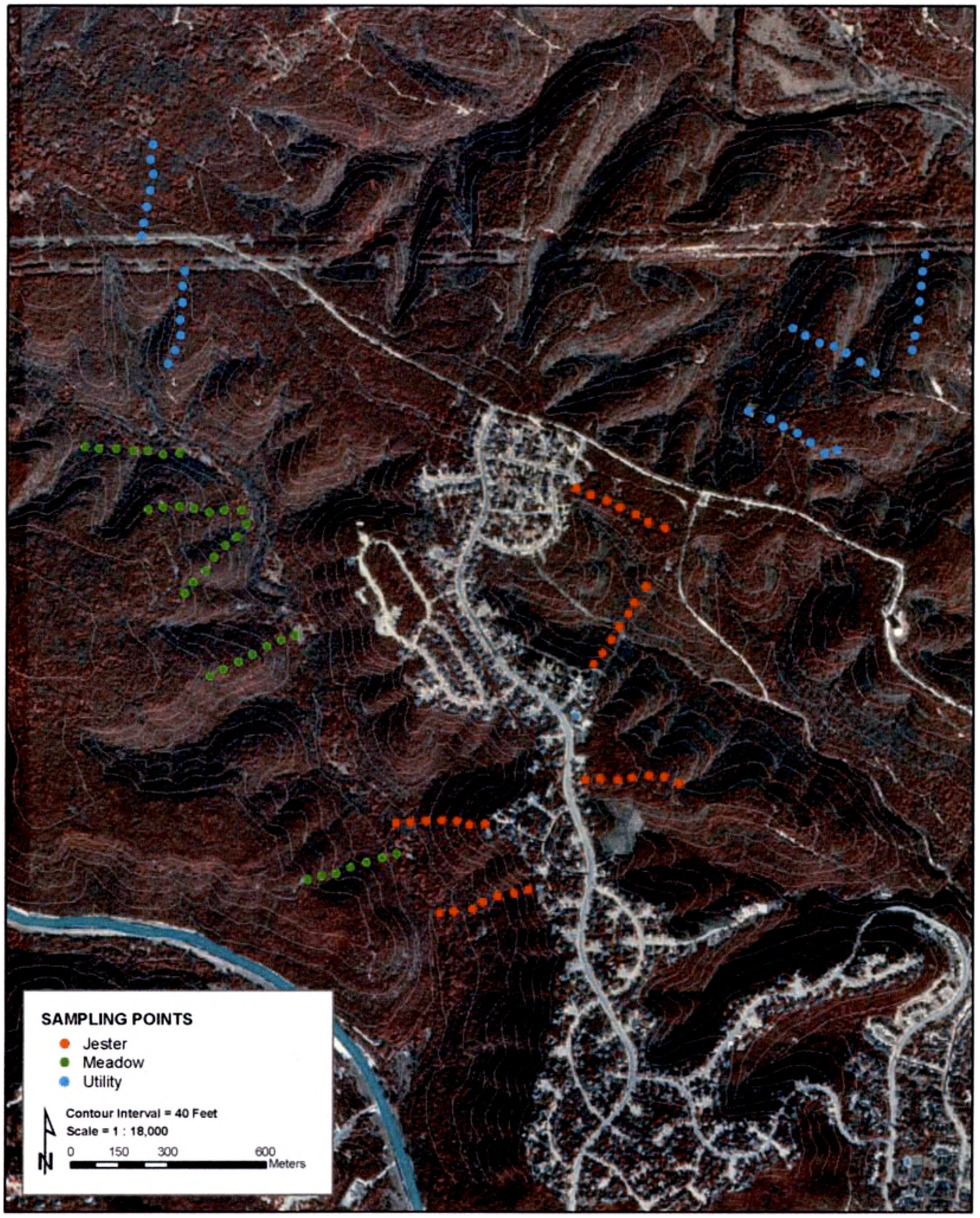


Figure 1. Map of sampling points in three border areas in the Balcones Canyonlands Preserve, City of Austin, Travis County, Texas.

species seen and heard (excluding those flying over but not landing) within a 25-m radius of each point during a 10-minute period (Hutto et al. 1986, Buskirk and McDonald 1995, Ralph at al. 1995, Boulinier et al. 1998). All surveys were conducted between 0700 h and 1200 h cst on the same morning for all points of a transect. I randomly selected the order in which transects were surveyed, completing surveys of all 15 before starting over. An alternate starting point was chosen for each survey of a transect to prevent temporal bias in sampling.

Abiotic Measurements

During surveys, I measured temperature, relative humidity (RH), wind velocity, sound, and solar radiation at each point. I measured temperature (°C) and RH (%) using a 4082 Traceable ® Humidity/Temperature Pen (Control Company, Friendswood, Texas). I measured the highest wind velocity (km/hr) over a 3-min period using a Kestrel ® 4000 Pocket Wind Meter (Nielsen-Kellerman, Boothwyn, Pennsylvania). I measured global solar radiation (Watt/m^2) in four cardinal directions at each point with a quantum radiometer/photometer (Model LI-250, LI-COR Biosciences, Lincoln, Nebraska) equipped with a pyranometer sensor (LI-200SA, LI-COR Biosciences, Lincoln, Nebraska) using 15-sec averages. I measured maximum sound level (dB with A frequency weighting) over a 30-sec period using a digital sound level meter (Model 407736, Extech Instruments, Waltham, Massachusetts). All measurements were taken at 1.5 m above ground level and repeated four times in conjunction with avian surveys during the 2004 breeding season.

Vegetative Surveys

I examined differences in canopy cover and composition of woody plant species related to border type and distance from habitat borders using the line intercept method (Bookhout 1996). I used transects extending 25 m in each cardinal direction from all points located 50 m, 150 m, and 250 m from borders. I identified all woody plants ≥ 1 m in height that intercepted transects and recorded the width of the interception. Canopy cover was estimated as the proportion of cover of all transects at a point. Vegetative surveys were not conducted at points located at environmental borders because of obvious differences in plant communities at those locations. I deemed surveys of alternate points interior to borders was sufficient to determine differences in plant species composition and canopy cover from border to woodland interior while maximizing independence in sampling points. I also calculated percent canopy cover at every point using a spherical densitometer by averaging four measurements made in each cardinal direction from the point (Bookhout 1996).

Fire Ant Surveys

I surveyed a 2-m wide strip centered on each vegetative line transect (200 m^2 per point) for mounds of red imported fire ants (*Solenopsis invicta*) to determine whether distance from border or type of bordering environment made a difference in presence of red imported fire ants in Golden-cheeked Warbler habitat.

Data Analysis

I computed the proportion of Golden-cheeked Warbler detections at each point and examined differences in Golden-cheeked Warbler presence by survey year, by distance category and by bordering environment with a 3-factor analysis of variance (ANOVA) with no replication (Quinn and Keough 2002). I removed one sample point (100 m point along the Jester boundary) with all zero values from the data set and used type III sums of squares for an unbalanced data set in analyses. I also computed the proportion of detections for each potential avian predator and brood parasite. I computed a combined proportion of detections for all predatory and parasitic species (hereafter predators) for each point. Preliminary ANOVAs indicated no difference in detections between the two survey years for Golden-cheeked Warblers and trends for predators were similar across years, so I pooled both years' data for subsequent analysis. I used Spearman's correlation tests to examine the relationship of detection of predators with border type, distance from border, and detection of Golden-cheeked Warblers for all areas combined and within each of the three border areas.

I analyzed differences in the means of abiotic variables (temperature, relative humidity, wind, sound, and solar radiation) among seven distance categories (0, 50 m, 100 m, 150 m, 200 m, 250 m and 300 m from borders) and three types of bordering environment using a series of 2-factor ANOVAs. I also used ANOVAs to examine differences among distance categories within each bordering area. Due to the abrupt change in vegetation, solar radiation levels were higher at the 0 m (border) points bordering the utility easement and meadows. I, therefore, tested differences in solar radiation excluding 0 m points. Significant results were further analyzed using the Tukey HSD test (Quinn and Keough 2002). I also used Spearman's correlations to examine the relationship of abiotic variables to the detection of Golden-cheeked Warblers.

I computed the proportion of canopy ($\geq$ 1.0 m in height) intercept of transect lines for each woody species at each point. I also computed the proportion of transects lines not covered by vegetation at each point and subtracted it from 100 to determine the proportion of total canopy cover. I used a series of ANOVAs to examine differences in percent total cover among distance categories, border types, and distance categories along each border. I used a series of ANOVAs to examine differences in proportions of cover by Ashe juniper and oak species among distance categories, border types, and distance categories along each border. I used Spearman's correlations to examine the relationship between all Golden-cheeked Warbler detections and those for each border area with percent total cover, percent Ashe juniper cover, percent oak cover, and the percent cover of the three *Quercus* species (Texas oak, plateau live oak, and shin oak) present in the study area.

Canopy cover was also estimated for each point using the means of spherical densiometer readings in each cardinal direction. I examined differences in these estimates among border types and distance categories across all and within each border area using the Kruskal Wallis test for non-parametric data. Tests were performed excluding the 0 m (border) points.

All statistical analyses were performed using S-PLUS® 7.0 (Insightful Corporation 2005). Results were considered significant at $P = 0.05$.

CHAPTER IV

RESULTS

Avian Surveys

A total of 840 point surveys were conducted at 105 points during Golden-cheeked Warbler breeding season in 2004 and 2005. Detections of Golden-cheeked Warblers did not differ between years ($F_1 = 0.283$, $P = 0.416$). Golden-cheeked Warbler detections differed significantly ($F_2 = 23.466$, $P = <0.001$) among the three border areas (Fig. 2). Mean proportions of detections were 0.079 ± 0.017, 0.182 ± 0.025, and 0.325 ± 0.027 for the neighborhood border (Jester), the meadow border (Meadow), and the utility easement border (Utility), respectively. For all areas combined, the mean proportion of Golden-cheeked Warbler detections was lowest at the 0 m distance (border) (0.117 ± 0.026) and highest at 200 m (0.25 ± 0.046) and 250 m (0.258 ± 0.050) (Fig. 3b), but there were no significant differences among distance categories ($F_6 = 1.885$, $P = 0.086$).

Six species of potential avian predators/parasites were detected during the two survey seasons: Blue Jay (*Cyanocitta cristata*), Western Scrub-Jay (*Aphelocoma californica*), Common Grackle (*Quiscalus quiscula*), Great-tailed Grackle (*Quiscalus mexicanus*), Northern Mockingbird (*Mimus polyglottos*), and Brown-headed Cowbird (*Molothrus ater*). Predator detections overall negatively correlated with detections of Golden-cheeked Warblers ($r = -0.2425$, $P = 0.0005$) (Table 1), border type ($r = -0.3229$, $P = <0.001$) (Table 1, Fig. 3a), and distance from border ($r = -0.2317$, $P = 0.0008$)

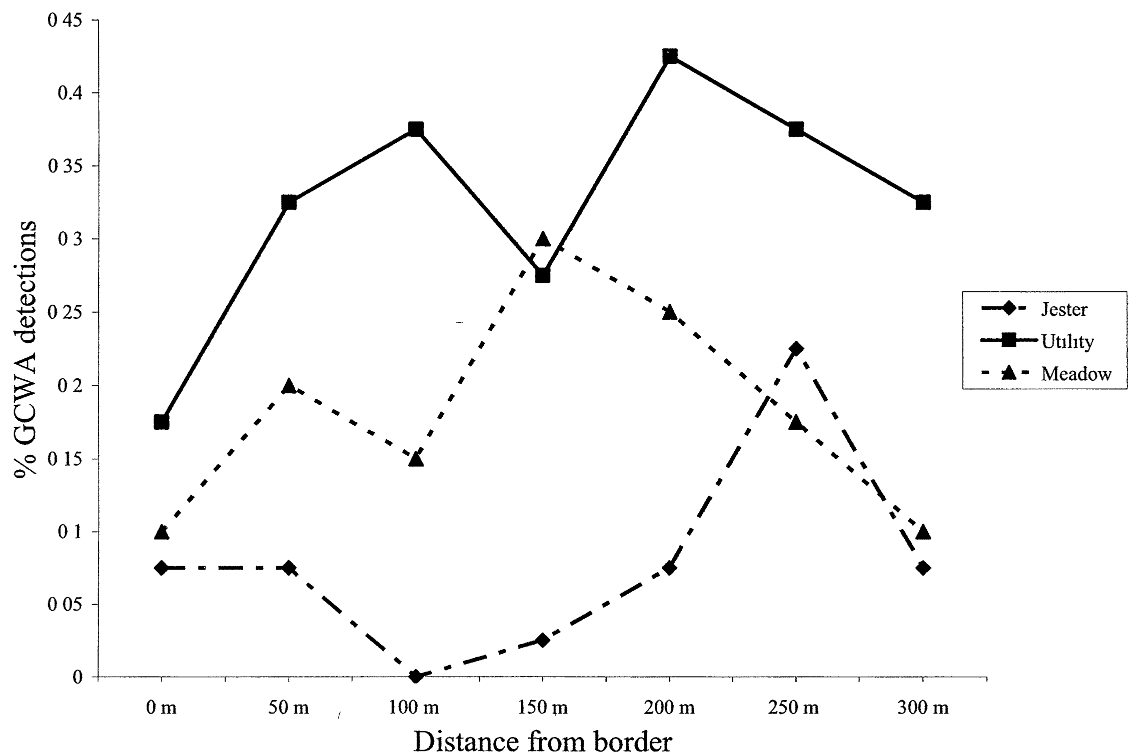
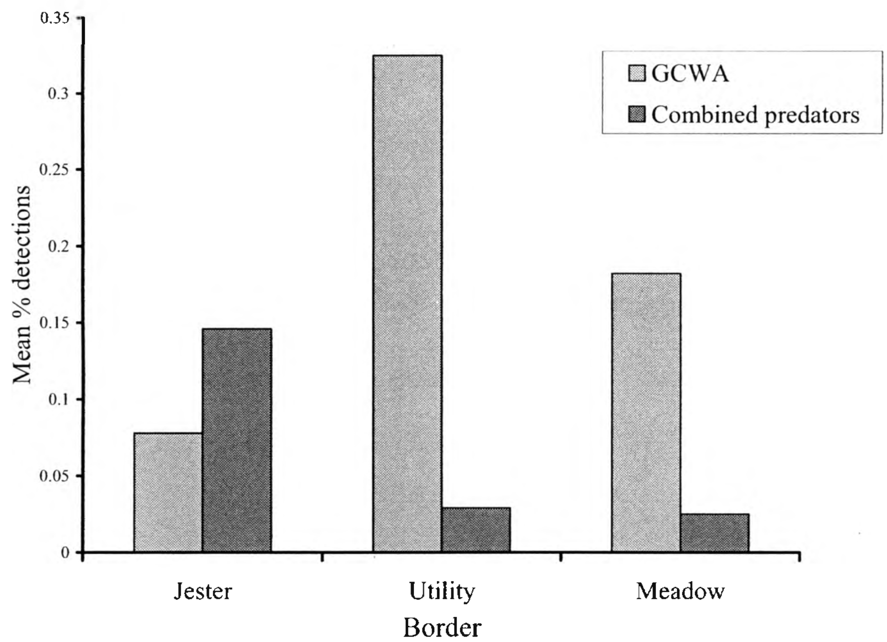
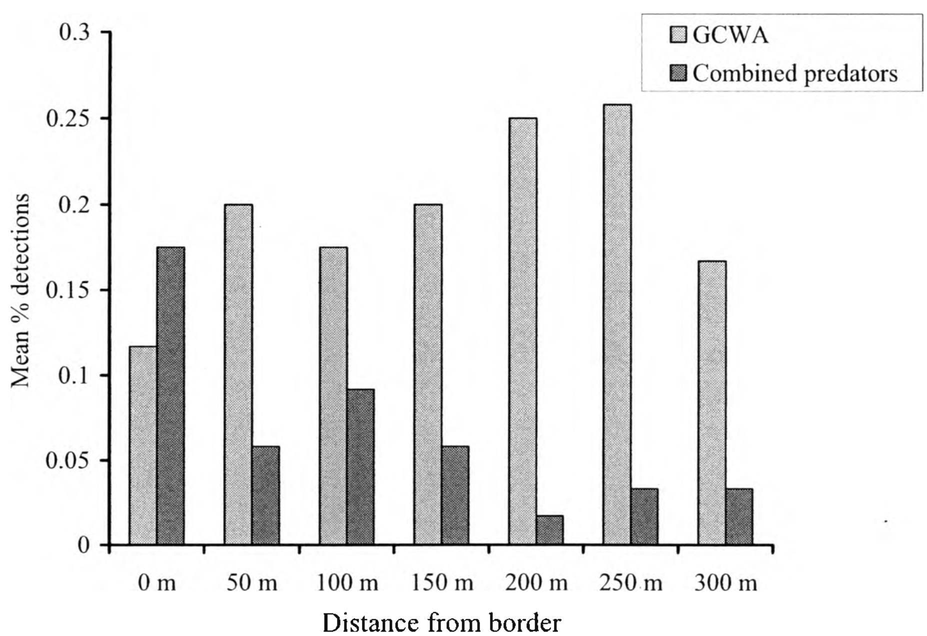


Figure 2. Mean percent detections of Golden-cheeked Warblers (GCWA) at each distance category within three border areas in the Balcones Canyonlands Preserve, City of Austin, Travis County, Texas during March - June, 2004/2005.



a)



b)

Figure 3. Mean percent detections of Golden-cheeked Warblers (GCWA) and combined avian predator/parasite species along three borders (a) and at seven distance categories (b) in the Balcones Canyonlands Preserve, City of Austin, Travis County, Texas during March-June 2004/2005.

Table 1. Results of Spearman's correlation tests for combined avian predator/parasite species. The first set gives correlation of frequency of detections of predator/parasite species in all areas with border type (Jester, Utility, and Meadow), distance from border (0, 50, 100, 150, 200, 250, and 300 m), and frequency of Golden-cheeked Warbler (GCWA) detections. The next three sets give correlation of frequency of predator/ parasite detections within each border area with distance from border and frequency of GCWA detections.

Area	Variables	*r*	*P*
All areas:			
	Border Type	-0.3228553	< 0.001*
	Distance	-0.2316804	0.0008*
	GCWA	-0.2425195	0.0005*
Jester:			
	Distance	-0.8183171	0.0405*
	GCWA	-0.4674735	0.2345
Utility:			
	Distance	-0.7748272	0.0522*
	GCWA	-0.7216878	0.0701
Meadow:			
	Distance	-0.2955414	0.4427
	GCWA	-0.7881104	0.0484*

* Significant results

(Table 1, Fig. 3b). In Jester, avian predators were detected more frequently and predator detections at the 0 m distance were more than double detections at other distances. Predator detection rates negatively correlated with distance from border at Jester ($r = -0.8183$, $P = 0.0405$) and Utility ($r = -0.7748$, $P = 0.0522$) (Table 1). Detection rates were lower overall in Utility and Meadow but Meadow did not show a distinct pattern with respect to distance from edge (Table 1). The most common predator species detected in Jester was the Common Grackle, followed by the Northern Mockingbird and Blue Jay. Western Scrub-Jays and Common Grackles were the most common species detected in Utility and Meadow. Among areas, only Meadow showed a correlation between detection of predators and detection of Golden-cheeked Warblers ($r = -0.7881$, $P = 0.0484$) (Table 1).

Abiotic Measurements

Significant differences were detected in mean temperature ($F_2 = 6.338$, $P = 0.002$), relative humidity ($F_2 = 3.259$, $P = 0.039$), wind velocity ($F_2 = 3.058$, $P = 0.048$), sound level ($F_2 = 17.174$, $P = <0.001$), and solar radiation ($F_2 = 13.254$, $P = <0.001$) among the three border areas (Table 2). Mean temperature (ºC) was lower in Jester (24.580 ± 0.245) and Utility (24.481 ± 0.260) than Meadow (25.635 ± 0.245) (Table 3). Differences in mean relative humidity (%) were detected between Jester (70.471 ± 0.801) and Meadow (66.664 ± 1.208), but not between these areas and Utility (Table 3). No differences were found in *post hoc* comparisons of mean wind velocity (km/hr) among the three areas. Mean sound levels (dB) were higher in Jester (48.889 ± 0.471) than Utility (46.066 ± 0.424) or Meadow (45.779 ± 0.379) (Table 3). Mean solar radiation (Watt/m^2) was lower in Jester (44.315 ± 2.754) than Utility (69.217 ± 5.405) or Meadow

Table 2. Results of analyses of variance for abiotic variables (temperature, relative humidity [RH], wind speed, sound, and total solar radiation). Source of variation are distance from border (0, 50, 100, 150, 200, 250, and 300 m) for all analyses, and border type (Jester; Utility, and Meadow) and interaction of distance and border type for analyses using combined data from all areas.

	Response variable														
	Temperature			RH			Wind			Sound			Radiation[a]		
Source of variation	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*
All areas:															
Distance	6	0.371	0.898	6	0.203	0.976	6	1.052	0.391	6	3.313	0.003*	5	3.235	0.006*
Border type	2	6.338	0.002*	2	3.259	0.039*	2	3.058	0.048*	2	17.174	<0.001*	2	13.254	<0.001*
DistanceX border type	12	0.207	0.998	12	0.054	0.999	12	0.845	0.603	12	1.796	0.046*	10	4.071	<0.001*
Jester:															
Distance	6	0.579	0.747	6	0.125	0.993	6	0.247	0.960	6	1.928	0.081	5	2.908	0.013*

Table 2-Continued

	Response variable														
	Temperature			RH			Wind			Sound			Radiation[a]		
Source of variation	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*
Utility:															
Distance	6	0.098	0.996	6	0.063	0.999	6	0.828	0.550	6	2.135	0.053*	5	4.151	0.001*
Meadow:															
Distance	6	0.136	0.991	6	0.131	0.992	6	1.635	0.142	6	3.125	0.007*	5	3.686	0.003*

[a] Excludes distance = 0 m

* Significant results

Table 3. Results of Tukey's multiple comparison tests for significant ANOVA results for abiotic variables.

Area	Source of variation	Response variable	Significantly different treatments (means)
All areas	Distance	Sound	0 m (49.303) – 100 m (46.442)
			0 m (49.303) – 200 m (46.125)
			0 m (49.303) – 250 m (45.857)
			0 m (49.303) – 300 m (46.440)
		Radiation	100 m (46.862) – 150 m (75.675)
			100 m (46.862) – 250 m (75.540)
	Border type	Temperature	Jester (24.580) – Meadow (25.635)
			Utility (24.481) – Meadow (25.635)
		RH	Jester (70.471) – Meadow (66.664)
		Wind	No differences detected.
		Sound	Jester (48.889) – Utility (46.066)
			Jester (48.889) – Meadow (45.779)
		Radiation	Jester (44.315) – Utility (69.217)
			Jester (44.315) – Meadow (78.020)

Table 3-Continued

Area	Source of variation	Response variable	Significantly different treatments (means)
Jester	Distance	Radiation	250 m (61.80) – 300 m (27.409)
Utility	Distance	Sound	No differences detected.
		Radiation	150 m (119.235) – 50 m (56.217)
			150 m (119.235) – 100 m (49.090)
			150 m (119.235) – 200 m (65.473)
			150 m (119.235) – 250 m (49.509)
Meadow	Distance	Sound	250 m (43.225) – 0 m (47.835)
			250 m (43.225) – 50 m (48.0)
		Radiation	100 m (45.794) – 250 m (115.31)

(78.020 ± 5.865) (Table 3).

There were no differences in mean temperature, relative humidity, or wind velocity among distance categories in the combined areas. Sound levels differed among distance categories ($F_6 = 3.313$, $P = 0.003$) as did solar radiation levels ($F_5 = 3.235$, $P = 0.006$) (Table 2). There was a significant interaction of distance category and border type for sound ($F_{12} = 1.796$, $P = 0.046$), and a highly significant interaction of distance category and border type for solar radiation ($F_{10} = 4.071$, $P = <0.001$) (Table 2). *Post hoc* multiple comparison tests indicated higher mean sound levels at 0 m (49.303 ± 0.821) than at 100 m (46.442 ± 0.595), 200 m (46.125 ± 0.624), 250 m (45.857 ± 0.643), or 300 m (46.440 ± 0.524) (Table 3, Fig. 4). Mean solar radiation was lower at 100 m (46.862 ± 2.796) than at 150 m (75.675 ± 8.298) or 250 m (75.540 ± 8.343) (Table 3).

Within the three areas, there were no differences in mean temperature, RH, or wind velocity related to distance from the border (Table 2). There were significant differences among distance categories for sound in Meadow ($F_6 = 3.124$, $P = 0.007$) and Utility ($F_6 = 2.135$, $P = 0.053$), and for solar radiation in all three areas (Table 2). Within Meadow, mean sound levels were significantly lower at 250 m (43.225 ± 0.363) than at 0 m (47.835 ± 1.187) or 50 m (48.0 ± 1.258) (Table 3). However, post hoc comparisons detected no differences in sound levels related to distance in Utility. Differences in solar radiation were detected in Jester between 250 m (61.80 ± 8.590) and 300 m (27.409 ± 2.442) and in Meadow between 100 m (45.794 ± 3.851) and 250 m (115.310 ± 22.080) (Table 3). Differences among other distances in Jester and Meadow were not significant. Within Utility, mean solar radiation was higher at 150 m (119.235 ± 21.514) than at 50 m

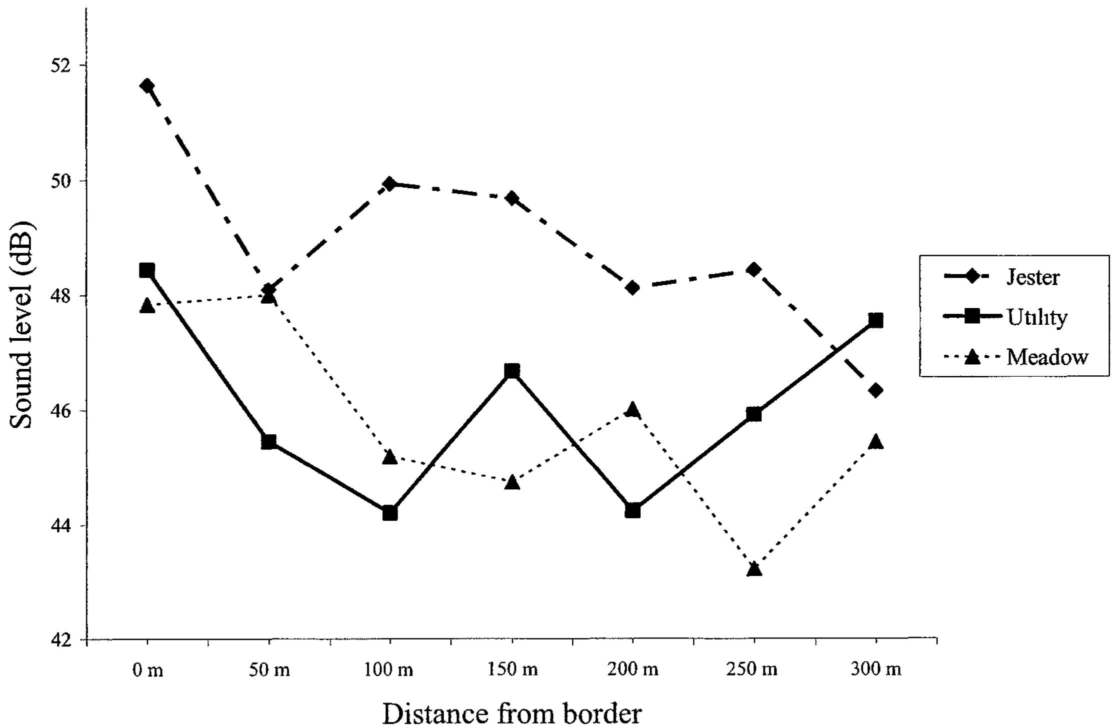


Figure 4. Mean sound levels (dB) at each distance category within three border areas in the Balcones Canyonlands Preserve, City of Austin, Travis County, Texas during March - June, 2004.

(56.217 ±5.906), 100 m (49.090 ± 4.959), 200 m (65.473 ± 9.226), or 250 m (49.509 ± 6.281) (Table 3). No other differences among distances in Utility were significant.

The presence of Golden-cheeked Warblers negatively correlated with sound level for all areas combined (r = - 0.3301532, P = 0.0008) and in Jester (r = - 0.3341945, P = 0.0512). Correlations between temperature and Golden-cheeked Warbler presence were detected in both Utility (r = - 0.4905008, P = 0.0042) and Meadow (r = 0.3460113, P = 0.0437), but in opposite directions. No other correlation was found between Golden-cheeked Warbler presence and abiotic measurements for combined areas or within the areas (Table 4).

Vegetative Surveys

Mean percent total canopy cover (92.05 ± 1.0) and mean percent Ashe juniper cover (72.27 ± 2.85) did not differ among distance categories or border type for the combined areas (Table 5). Mean percent combined oak cover was higher in Utility (46.80 ± 6.046) than in Jester (22.75 ± 3.94) but not significantly different from Meadow (31.57 ± 5.0) (Fig 5). There was no difference in percent combined oak cover detected among distance categories (Table 5). For the three oak species the only difference detected was among border types for shin oak (Table 5). Mean percent shin oak canopy cover was significantly higher in Utility (13.66 ± 3.20) than in either Jester (1.70 ±0.86) or Meadow (0.71 ± 0.46) (Fig 6). There were no differences among distance categories within the three border areas for percent total cover, percent Ashe juniper cover, percent combined oak cover, or percent cover of Texas oak, live oak, or shin oak (Table 5).

No correlations were indicated for presence of Golden-cheeked Warblers and percent canopy cover, percent juniper cover, percent combined oak cover, or for percent

Table 4. Results of Spearman's correlation tests for Golden-cheeked Warbler presence with abiotic measurements for all areas combined and within each border area.

Area	Response variable	*r*	*P*
All areas:	Temperature	- 0. 4839	0.6285
	Humidity	- 0.1843137	0.0602
	Wind velocity	0.08697347	0.3751
	Sound	- 0.3301532	0.0008 *
	Solar radiation	0.06028083	0.5696
Jester:	Temperature	0.1933688	0.2599
	Humidity	- 0.1542141	0.3681
	Wind velocity	- 0.2221454	0.1949
	Sound	- 0.3341945	0.0512 *
	Solar radiation	- 0.1647012	0.3745
Utility	Temperature	- 0.49050008	0.0042 *
	Humidity	- 0.101728	0.5525
	Wind velocity	- 0.01029454	0.9515
	Sound	- 0.1627461	0.3422
	Solar radiation [a]	- 0.2560732	0.1675

[a] Excluding 0 m distance category
* Significant results

Table 4-Continued

Area	Response variable	*r*	*P*
Meadow	Temperature	.3460113	0.0437 *
	Humidity	- 0.122689	0.4739
	Wind velocity	0.1303601	0.4477
	Sound	- 0.008540487	0.9596
	Solar radiation [a]	- 0.135306	0.467

[a] Excluding 0 m distance category
* Significant results

Table 5. Results of analyses of variance for percent total canopy cover, percent Ashe juniper cover, percent Texas oak cover, percent live oak cover, percent shin oak cover, and percent combined oak cover. Factors are distance category for all analyses, and border type and interaction of distance and border type for analyses using combined data from all areas.

	Response variable																	
	% total cover			% Ashe juniper			% shin oak			% Texas oak			% live oak			% combined oaks		
Source of variation	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*
All areas:																		
Distance	2	1.535	0.229	2	0.576	0.567	2	2.643	0.085	2	1.208	0.311	2	1.370	0.267	2	0.201	0.819
Border type	2	0.918	0.408	2	1.392	0.262	2	16.991	<0.001*	2	2.632	0.086	2	1.633	0.209	2	5.195	0.010*
DistanceX border type	4	1.506	0.221	4	0.749	0.565	4	2.490	0.060	4	0.112	0.976	4	0.649	0.631	4	0.361	0.834
Jester:																		
Distance	2	1.650	0.233	2	1.683	0.227	2	0.932	0.421	2	0.249	0.783	2	0.689	0.521	2	0.176	0.841
Utility:																		
Distance	2	2.336	0.139	2	0.211	0.812	2	2.676	0.109	2	0.504	0.616	2	1.991	0.179	2	0.229	0.799
Meadow:																		
Distance	2	1.021	0.390	2	1.339	0.299	2	3.122	0.081	2	0.531	0.601	2	1.164	0.345	2	0.515	0.610

* Significant results

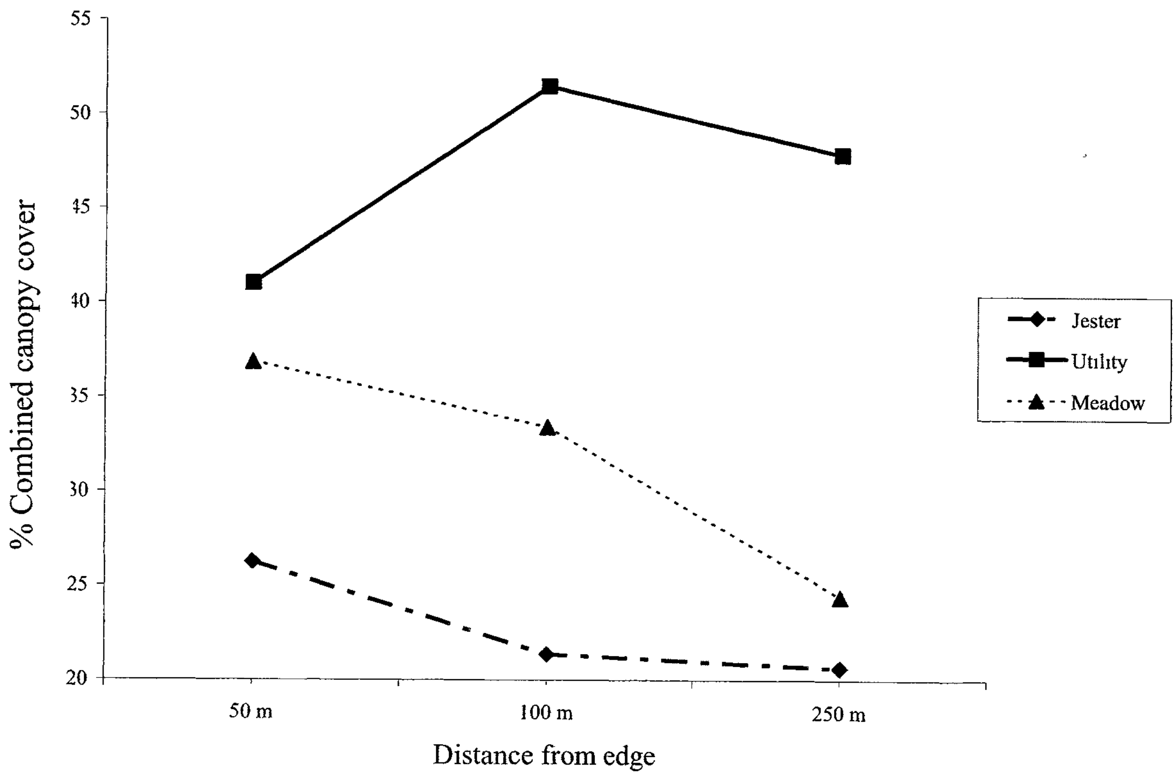


Figure 5. Mean percent combined oak canopy cover at three distances within three border areas in the Balcones Canyonlands Preserve, City of Austin, Travis County, Texas during June - July 2005.

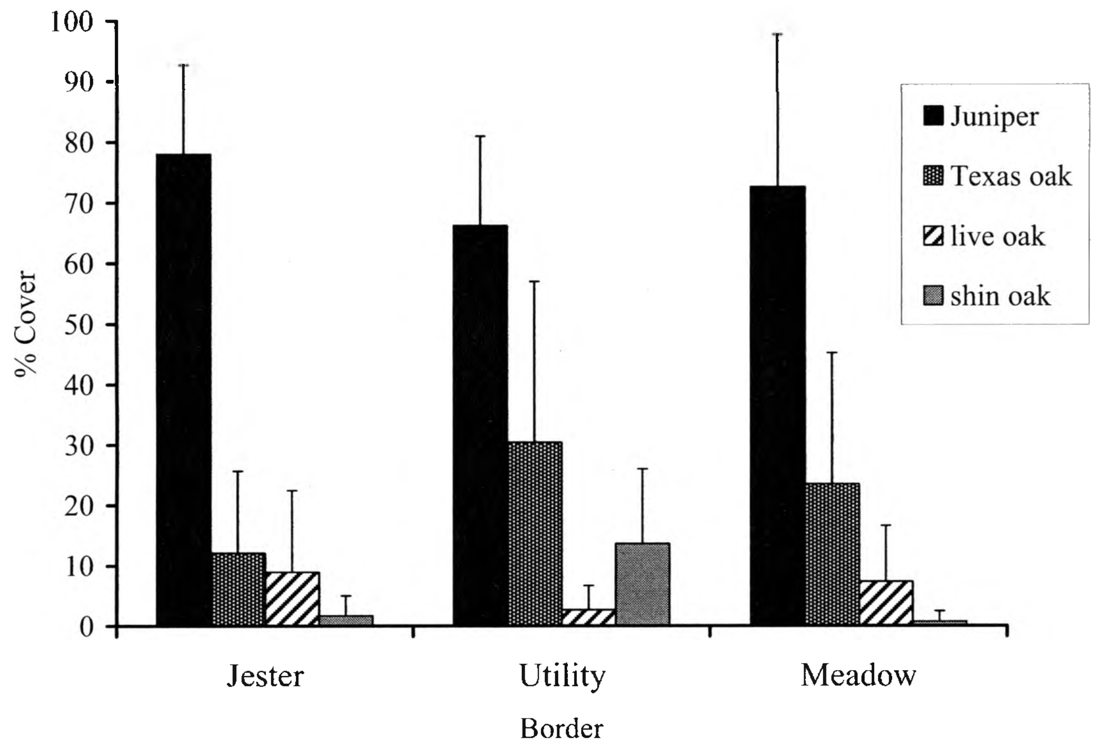


Figure 6. Mean percent canopy cover of Ashe juniper, Texas oak, live oak, and shin oak within three border areas in the Balcones Canyonlands Preserve, City of Austin, Travis County, Texas during June - July 2005. Error bars represent one standard deviation.

cover of the three oak species for the combined areas or within each area.

No differences were detected in canopy cover as measured by densitometer readings among border types or distance categories for the combined or separate areas.

Fire Ant Surveys

A total of 17 red imported fire ant mounds were detected with all but one located in Utility (Table 6). One mound was located in Meadow along with a swarm of probable red imported fire ants found in a tree along the survey line 50 m from edge. Distribution of mounds did not appear related to distance from edge.

Table 6. Red imported fire ant mounds detected within 200 m^2 quadrats placed at 50 m, 150 m, and 250 m along transects running perpendicular to three bordering environments.

Border area	Transect	Distance	No. of mounds
Meadows	2	250 m	1
	4	50 m	*
Utility	1	50 m	1
	2	50 m	2
	2	150 m	2
	3	50 m	4
	3	150 m	6
	5	250 m	1
Jester	--	--	0

* A large group of winged ants was observed on a live oak tree at this point. Identification was not conclusive but these were probably Red Imported Fire Ants.

CHAPTER V

DISCUSSION

I examined the effects of bordering environments and distance from border on several environmental variables in adjacent Golden-cheeked Warbler habitat. I also investigated how those effects influenced habitat use by Golden-cheeked Warblers.

Golden-cheeked Warbler detections differed significantly among the three treatment areas with the greatest number of detections in Utility, which borders a low-use man-made power line corridor, and the fewest in Jester, which borders a high-density housing development. Detections also tended to increase in frequency farther from all borders, although distance from border to peak detection point was greater in Jester (250 m) than Utility (200 m) or Meadow (150 m). This study provides possible explanations for the differences in warbler detections among areas and distances from borders.

Two variables stood out as correlated with distance from habitat edges with bordering communities: presence of avian predator species and sound levels. These variables also differed among areas and when all areas were considered together, they were also negatively correlated with the presence of Golden-cheeked Warblers.

Jester had greater numbers of avian predators detected overall, a greater variety of predator species detected (6 species, compared to 2 in Utility and 3 in Meadow), and the strongest correlation of predator presence with distance from border (r = -0.818). Even at the greatest distance from border (300 m), predator detection rates at Jester were greater than any distance in Utility and all distances except 100 m in Meadow. Predator detection rates were also negatively correlated with distance in Utility (r = -0.775). Rates in Meadow were lowest of the three areas with no pattern in relation to distance from border.

Predator species differed by area and distance from edge. The most common species detected in Jester were Common Grackles, Northern Mockingbirds, and Blue Jays, all common urban generalist species (Wilcove 1985, Gehlbach 2005). Blue Jays (Johnson and Johnson 1976, Yahner and DeLong 1992, Fink 1996) and Common Grackles (Davidson 1994, Saracco and Collazo 1999) have been documented attacking songbird nests and adults, although evidence of their predation on Golden-cheeked Warblers is lacking. Golden-cheeked Warblers increased movement and abandoned local habitat when exposed to recorded Blue Jay calls (Engels 1995). Engels and Sexton (1994) found a strong negative correlation for Blue Jays and Golden-cheeked Warblers, but Arnold et al. (1996) found the presence of Blue Jays and other avian predators did not exclude Golden-cheeked Warblers. Although not known for predation directly on other birds, Northern Mockingbirds are well-known for vigorously defending their breeding territory (Rosenberg 2001). A Northern Mockingbird was observed harassing a male Black-capped Vireo at one City of Austin BCP tract, possibly leading to the abandonment of a nest (City of Austin 2004). Even absent evidence of direct predation, the presence of these predators triggers defensive behaviors, such as mobbing and avoidance, which impact prey species fitness (Endler 1991). The result may be lowered prey reproductive success and/or under-use of otherwise suitable habitat (Arnold et al. 1996).

Northern Mockingbirds were only detected at the habitat border (0 m) in Jester.

They were not found in Utility or Meadow. Blue Jays were detected on at least one survey at 0 m, 50 m, 100 m, 250 m, and 300 m in Jester, but were most common at 100 m or less. The single Blue Jay detection outside of Jester occurred at a border point of a Meadow located slightly over 300 m from the Jester neighborhood. Common Grackles were also detected at every distance throughout Jester, although more frequently within 100 m of the border. They were also detected at the 0 m, 100 m, and 200 m distances in Utility, and at the 100 m distance in Meadow.

Common Grackles and Western Scrub-Jays were the primary predators detected in both Utility and Meadow. The Western Scrub-Jay has been identified as a leading predator of eggs and nestlings of small songbirds, including the Golden-cheeked Warbler (Fink 1996; Gass 1996; Stake and Cimprich 2003, Stake et al. 2004; Peterson et al. 2004). Western Scrub-Jays were common in Golden-cheeked Warbler habitat in Travis County (Pulich 1976) but no correlation was found between the presences of the two species (Engels and Sexton 1994, Arnold et al. 1996). I detected Western Scrub-Jays more frequently at or near the border (0 m to 50 m), but also at 250 m in Utility. All Western Scrub-Jay detections in Meadow were at the 100 m distance. The two detections in Jester occurred at the border.

Brown-headed Cowbirds have been documented parasitizing Golden-cheeked Warbler nests in Kendall County (Pulich 1976), Travis County (Gass 1996), and Fort Hood, Texas (Stake et al. 2004). They concentrate at habitat edges (Brittingham and Temple 1983) and are found deep in woodland habitats (Rich et al. 1994). I detected this species only at the 150 m and 250 m distances in Jester and once at the habitat border in Meadow. However, Brown-headed Cowbird presence may be underestimated as females are usually silent, have large home ranges, and commute diurnally up to 7 km between nesting and feeding grounds (Rothstein et al. 1984).

The results of my surveys for avian predators are consistent with earlier studies that found increased rates of predation and nest parasitism near woodland habitat borders (Davis 1974, Pulich 1976, Toweill and Teer 1977, Wilcove 1985, Miller and Knight 1993, Fink 1996) and greater predator abundance and predation rates at bordering environments including human settlements than at other types of borders (Wilcove 1985, Engels 1995, Arnold et al. 1996, Blair 1996, Mancke and Gavin 2000). All habitat borders provide supplemental resources that attract a variety of species (Chalfoun et al. 2002), but urban borders attract a different species mix than less developed man-made corridors and woodland meadows (Wilcove 1985, Blair 1996, Hanski et al. 1996). Arnold et al. (1996) found that Golden-cheeked Warblers may react to predators but predator presence does not exclude warblers. They speculated that negative correlations between Blue Jays and Golden-cheeked Warblers reported by earlier researchers (Engels and Sexton 1994) resulted from reduced warbler vocalization, hence reduced detection of warblers in the presence of Blue Jays. However, Arnold et al. (1996) also reported warblers occurring with greater frequency away from human developments, while Blue Jays and Common Grackles were strongly associated with habitat bordering residential areas. I detected Golden-cheeked Warblers less frequently near the Jester housing development where avian predators were most frequently detected. It is possible that detections were hampered by changes in Golden-cheeked Warbler singing and calling behavior in the presence of predator species. Reduced singing and other behavioral changes indicate increased levels of physiological stress and potentially influence nesting success and habitat selection (Karr and Freemark 1983, Gutzwiller et al. 1994). Although I cannot assume causation from correlation, my findings support the hypothesis that the presence of urban-adapted avian predators entering from bordering neighborhoods reduces habitat quality for Golden-cheeked Warblers.

The other variable strongly correlated with distance from habitat borders was sound level. Mean sound levels were higher and sound levels were more variable in Jester than the other two areas. Sound levels were also significantly higher at borders than at interior distances. Sound levels were negatively correlated with Golden-cheeked Warbler presence for all areas combined and within Jester.

Environmental noise can affect wildlife in several ways. Physiological effects can include hearing damage or loss and non-auditory effects such as changes in hormone levels in blood or urine, heart rate, and respiration rate related to stress (Kaseloo and Tyson 2004). Increased noise levels can mask environmental cues and signals from other animals, making it difficult for individuals to find mates, escape predators, locate prey, and communicate with other members of their species (Dufour 1980). Behavioral responses to noise vary based on the source of the noise, whether it is expected or not, the acoustic characteristics (loudness, duration, frequency pattern), the individual animal's experience, and the presence of related stressors (e.g., frightening objects, humans). Different species and different individual animals have shown a range of responses to noise from near indifference to flight (Dufour 1980).

Information on the effects of noise generated by urban housing developments on wildlife is lacking. Studies examining the effects of noise from military exercises, fixed-wing aircraft, helicopters, and sonic booms have shown varied behavioral and physiological effects on birds (Dufour 1980, Larkin et al. 1996). The most relevant studies may be those related to roadway noise (Kaseloo and Tyson 2004). They concluded that some but not all bird species are sensitive at least during breeding season to noise levels at distances ranging from a few meters to more than 3 km. No definitive evidence was found to explain why some species are affected but not others and at distances that seem to preclude interference with vocalizations. Road noise contributes to noise levels in urban developments, such as Jester, along with landscaping equipment (e.g., lawn mowers, trimmers, leaf blowers), construction, and home air conditioning units.

The biological and behavioral responses of Golden-cheeked Warblers to noise are not well known. More Golden-cheeked Warblers were detected in protected core habitat than in non-core habitat subject to periodic military training exercises, such as ground maneuvers, artillery firing, and aviation training activities, at Fort Hood, Texas. However, the differences were not significant and may be explained by increased fragmentation of the non-core areas (Anders and Dearborn 2004). No correlation was found between Golden-cheeked Warbler detections and noise levels ranging from 29.7 – 58.6 dB at listening posts randomly distributed in a 212-ha study area (Benson 1996). However, no prior studies have examined the long-term effects of increased noise levels generated by urban environments bordering on warbler habitat. I found mean sound levels ranging from 51.64 dB (border) to 46.33 dB (300 m) in Jester compared to a range of 48.43 dB (border) to 44.21 dB in Utility and 48 dB (50 m) to 43.23 dB (250 m) in Meadow. Consistently elevated noise levels along the habitat borders and the Jester neighborhood in particular may influence warbler habitat selection away from the noise.

A primary effect of fragmentation is the alteration of microclimate surrounding and within the habitat remnant. Alterations in fluxes of temperature, humidity, and radiation can have important effects on native vegetation and invertebrate populations (Saunders et al. 1991). Temperature, humidity, and solar radiation also affect metabolic rates and water loss in birds and change habitat use by wintering birds (Grubb 1975, 1977). Small birds are particularly sensitive to environmental changes due to high surface area-to-mass ratios (Wolf and Walsberg 1996). Differences in temperature, relative humidity, and radiation were detected between Meadow and the other two areas. However, these differences appear related to local topography and vegetation density rather than conditions at habitat borders. Although temperature correlated with Golden-cheeked Warbler detections in Utility and Meadow, it did so in opposing directions – negative in Utility and positive in Meadow. The greatest difference in mean temperature among areas and among distances within areas was 1.4 °C, which may not be biologically significant. Humidity differences mirrored temperature differences between Jester and Meadow and were not associated with distance from edge or Golden-cheeked Warbler presence.

Solar radiation levels were significantly lower in Jester than the other areas. Solar radiation levels also differed significantly based on distance from edge in all three areas. However, the differences based on distance did not follow a pattern of gradation from edge nor did radiation level correlate with presence of Golden-cheeked Warbler at any level. Variation in radiation within the study areas results from variation in the density of canopy cover and small openings in forest interiors. Small canopy openings are typical of the natural habitats in which Golden-cheeked Warblers evolved and have little effect on the species. Golden-cheeked Warblers occur more frequently in habitat patches when wooded canopy in the surrounding landscape meets a 40% threshold but does not exceed 80% (Magness et al. 2006). Solar radiation has been shown to lower metabolic rates in birds, reducing energy expenditures and water loss (Wolf and Walsberg 1996). My results suggest that small forest-interior canopy openings are neutral or perhaps favorable to Golden-cheeked Warblers.

Unfortunately, canopy openings are also likely to support red imported fire ant populations. Fire ants favor open and semi-open habitat (Allen et al. 1994) and disturbed soil (Stake et al. 2004). They are also well-documented predators of bird eggs and hatchlings, including those of Golden-cheeked Warblers (Sikes and Arnold 1986, Dickinson 1995, Stake and Cimprich 2003, Smith et al. 2004, Stake et al. 2004). I detected few fire ant mounds at survey points but one-third of those detected (6 of 17) were located along a former ranch road in Utility. None were found in Jester, the area with the lowest levels of solar radiation as well as the lowest detection rate for Golden-cheeked Warblers. My sample size was too small for statistical analysis but locations of fire ant mounds did not appear related to distance from edge. Red imported fire ants are clearly a threat to Golden-cheeked Warbler productivity, but there is no indication that warblers in the study site consider the presence of fire ant mounds in their use of otherwise suitable habitat.

The vegetation in Golden-cheeked Warbler breeding habitat has been characterized as having high percent canopy cover in middle and upper layers (Ladd 1985, Sexton 1987), high proportion of mature Ashe juniper (DeBoer and Diamond 2006), high proportion of Texas oak, hackberry, and cedar elm (Peterson 2001), and greater mean canopy coverage per plant (Peterson 2001). Ladd (1985) also found that shin oak, Lacey oak (*Quercus glaucoides*), and plateau live oak occur and sometimes replace Texas oak as the dominant hardwood in parts of Golden-cheeked Warbler breeding range. I examined percent canopy cover ≥ 1 m in height for all species and for Ashe juniper and oak species. The only vegetative differences detected were for combined oak canopy cover and shin oak canopy cover, both of which were higher in Utility than the other two areas. Vegetative variables did not differ by distance from edge nor were they correlated with presence of Golden-cheeked Warblers. However, the reduced number of sampling points for vegetation greatly lowered the statistical power of my analyses. It is possible that the higher percentage of shin oak and/or total oak coverage in Utility contributes to the quality of habitat in that area. Kroll (1980) found good Golden-cheeked Warbler habitat had Ashe juniper-oak ratios of 1.35 to 1, while ratios in poor habitat were 2.27 to 1. Ashe juniper-oak ratios in Utility were 1.40 to1, while they were 2.28 to 1 in Meadow and 3.39 to 1 in Jester. Ashe juniper-oak ratios within the study site are more likely related to the localized soils, topography, slope, and water regimes than to effects of bordering communities. Differences in the ratios may partially account for differences in rates of Golden-cheeked Warbler detections among the areas.

CHAPTER VI

MANAGEMENT IMPLICATIONS

The Golden-cheeked Warbler is a breeding-habitat specialist restricted to tracts of mature Ashe juniper-oak woodlands by dependence on shredded Ashe juniper bark for nesting materials and on various oak species for foraging (Pulich 1976). Decline in the extent of the species' woodland habitat has been a concern of biologists for over a century (Ladd and Gass 1999) and led to federal listing of the species as endangered in 1990 (U.S. Fish and Wildlife Service 1992). Of the 25 Texas counties currently known to contain Golden-cheeked Warbler breeding habitat (Ladd and Gass 1999), Travis County has the greatest amount of remaining habitat (U.S. Fish and Wildlife Service 1992). Human populations in Travis County are growing rapidly and projected to increase by over 70% between 2000 and 2040 (Texas State Data Center and Office of the State Demographer 2004). Housing and commercial development will continue to put pressure on existing and potential habitat preserves. Active habitat conservation and restoration efforts in Travis County and throughout the breeding range are necessary to ensure the continued existence of this unique songbird.

Contrary to Kroll (1980) and Ladd (1985) but in agreement with more recent studies (Engels and Sexton 1994, Arnold et al. 1996, Magness et al. 2006, Baccus et al. 2007), I found Golden-cheeked Warblers appear to be sensitive to edge effects, especially near man-made borders. As I did not replicate treatment areas, care must be taken to not assume that my findings apply beyond the study site. However, my findings provide additional evidence to support results of earlier studies on the effects of borders on breeding Golden-cheeked Warblers.

Within my study area, I found little evidence that bordering environments affect habitat microclimate (temperature, humidity, wind, solar radiation) beyond the immediate border area. I did find evidence that bordering housing developments increase the presence of avian predator species and sound levels within adjacent Golden-cheeked Warbler habitat. The presence of avian predators diminishes with distance from edge but remains at least 300 m from the border. The influence of sound also diminishes with distance up to 250 m from edge. Golden-cheeked Warblers use habitat less frequently up to 250 m from neighborhoods.

Influences of bordering communities were much more pronounced in habitat adjacent to housing developments than in habitat bordering undeveloped man-made clearings and habitat bordering natural clearings. Golden-cheeked Warbler presence in these latter areas was also reduced within 100 m of the border but beyond the immediate border, Golden-cheeked Warbler presence was significantly higher than in the area bordering the housing development.

Preserve managers should be aware that Golden-cheeked Warblers may not fully utilize habitat that is adjacent to neighborhood developments. Possible reasons for the reduced use of otherwise suitable habitat are the invasion of aggressive and predatory birds, such as Blue Jays, Northern Mockingbirds, and Common Grackles, and disturbance by increased sound levels from human activities. The effects of these disturbances extend 250 to 300 m from neighborhood borders into the habitat interior.

State of Texas management guidelines for Golden-cheeked Warblers recommend 300-foot woodland buffers between Golden-cheeked Warbler habitat and land-clearing activities (Campbell 2003). Size of habitat patch affects the extent of potential influence from borders. Pease and Gingerich (1989) recommended that less than 5% of area of any preserve should be within 100 m of preserve boundary or man-made internal opening such as roads, building, or power lines. For a square 500 ha preserve with no internal openings, 17% of the area would be within 100 m of the preserve boundary, while only 6% of a 5000 ha preserve would be that close to the boundary. I found that type of bordering environment was important regardless of habitat size and suggest that management guidelines call for deeper wooded buffer areas of 200 to 250 m between housing and other intense human-use developments and Golden-cheeked Warbler preserve boundaries.

APPENDIX A

FREQUENCY OF DETECTION OF PREDATOR SPECIES AND GOLDEN-CHEEKED WARBLERS, AUSTIN, TX, 2004

		Distance						
Area	Species*	0 m	50 m	100 m	150 m	200 m	250 m	300 m
Jester	BHCO	0	0	0	0	0	0	0
	BLJA	0.20	0	0.10	0	0	0.05	0.05
	COGR	0.20	0.15	0.10	0.15	0.10	0.10	0.10
	GTGR	0	0.05	0	0	0	0	0
	NOMO	0.40	0	0	0.05	0	0	0
	SCJA	0	0	0	0	0	0	0
	All Predators**	0.55	0.20	0.20	0.20	0.10	0.10	0.15
	GCWA	0.05	0.10	0	0	0.10	0.30	0.10
Utility	BHCO	0	0	0	0	0	0	.0
	BLJA	0	0	0	0	0	0	0
	COGR	0	0	0.05	0.10	0	0	0
	GTGR	0	0	0	0	0	0	0
	NOMO	0	0	0	0	0	0	0

APPENDIX A-Continued

		Distance						
Area	Species*	0 m	50 m	100 m	150 m	200 m	250 m	300 m
Utility cont.	SCJA	0.05	0.05	0	0	0	0	0
	All Predators**	0.05	0.05	0.05	0.10	0	0	0
	GCWA	0.15	0.30	0.35	0.30	0.45	0.30	0.30
Meadow	BHCO	0	0	0	0	0	0	0
	BLJA	0	0	0	0	0	0	0
	COGR	0	0	0.05	0	0	0	0
	GTGR	0	0	0	0	0	0	0
	NOMO	0	0	0	0	0	0	0
	SCJA	0	0	0	0	0	0	0.05
	All Predators**	0	0	0.05	0	0	0	0.05
	GCWA	0.01	0.25	0.15	0.30	0.35	0.20	0.15

*Species are: BHCO – Brown-headed Cowbird; BLJA – Blue Jay; COGR – Common Grackle; GTGR – Great-tailed Grackle; NOMO – Northern Mockingbird; SCJA – Western Scrub-Jay; GCWA – Golden-cheeked Warbler.

** All Predators is the frequency of detection of any predator/parasite species.

APPENDIX B

FREQUENCY OF DETECTION OF PREDATOR SPECIES AND GOLDEN-CHEEKED WARBLERS, AUSTIN, TX, 2005

		Distance						
Area	Species*	0 m	50 m	100 m	150 m	200 m	250 m	300 m
Jester	BHCO	0	0	0	0.05	0	0.05	0
	BLJA	0.10	0	0.05	0	0	0	0
	COGR	0.05	0.05	0.05	0	0	0	0
	GTGR	0.10	0	0	0	0	0	0
	NOMO	0.20	0	0	0	0	0	0
	SCJA	0.10	0	0	0	0	0	0
	All Predators**	0.30	0.05	0.10	0.05	0	0.05	0
	GCWA	0.10	0	0	0.05	0.05	0.15	0.05
Utility	BHCO	0	0	0	0	0	0	0
	BLJA	0	0	0	0	0	0	0
	COGR	0.05	0	0	0	0	0	0
	GTGR	0	0	0	0	0	0	0
	NOMO	0	0	0	0	0	0	0

APPENDIX B-Continued

		Distance						
Area	Species*	0 m	50 m	100 m	150 m	200 m	250 m	300 m
Utility cont.	SCJA	0	0.05	0	0	0	0.05	0
	All Predators**	0.05	0.05	0	0	0	0.05	0
	GCWA	0.20	0.35	0.40	0.25	0.40	0.45	0.35
Meadow	BHCO	0.05	0	0	0	0	0	0
	BLJA	0.05	0	0	0	0	0	0
	COGR	0	0	0	0	0	0	0
	GTGR	0	0	0	0	0	0	0
	NOMO	0	0	0	0	0	0	0
	SCJA	0	0	0.15	0	0	0	0
	All Predators**	0.10	0	0.15	0	0	0	0
	GCWA	0.05	0.15	0.15	0.30	0.15	0.15	0.05

*Species are: BHCO – Brown-headed Cowbird; BLJA – Blue Jay; COGR – Common Grackle; GTGR – Great-tailed Grackle; NOMO – Northern Mockingbird; SCJA – Western Scrub-Jay; GCWA – Golden-cheeked Warbler.

** All Predators is the frequency of detection of any predator/parasite species.

APPENDIX C

MEAN (±SE) TEMPERATURE, RELATIVE HUMIDITY (RH), AND WIND SPEED, AUSTIN, TX, 2004

Area	Distance (m)	Temperature (°C)	RH (%)	Wind (km/hr)	n[a]
Jester	0	23.995 (± 0.637)	71.0 (± 1.998)	2.305 (± 0.513)	20
	50	24.105 (± 0.604)	71.550 (± 2.275)	2.985 (± 0.569)	20
	100	24.495 (± 0.622)	70.850 (± 2.414)	2.360 (± 0.446)	20
	150	24.770 (± 0.611)	70.30 (± 2.332)	2.375 (± 0.533)	20
	200	24.980 (± 0.645)	69.950 (± 2.356)	2.380 (± 0.370)	20
	250	25.385 (± 0.637)	69.20 (± 1.819)	2.670 (± 0.504)	20
	300	24.330 (± 0.795)	70.450 (± 1.829)	2.390 (± 0.508)	20
	All	24.580 (± 0.245)	70.471 (± 0.801)	2.495 (± 0.184)	140
Utility	0	24.845 (± 1.045)	68.550 (± 2.850)	3.920 (± 0.799)	20
	50	24.230 (± 0.622)	70.50 (± 2.961)	2.590 (± 0.530)	20
	100	24.275 (± 0.594)	69.30 (± 3.115)	2.670 (± 0.365)	20
	150	24.575 (± 0.520)	70.20 (± 2.748)	3.110 (± 0.344)	20

APPENDIX C-Continued

Area	Distance (m)	Temperature (°C)	RH (%)	Wind (km/hr)	n[a]
Utility cont.	200	24.335 (± 0.593)	69.450 (± 3.153)	3.235 (± 0.396)	20
	250	24.625 (± 0.640)	68.650 (± 3.154)	2.865 (± 0.358)	20
	300	24.485 (± 0.762)	69.750 (± 3.393)	3.395 (± 0.586)	20
	All	24.481 (± 0.260)	69.343 (± 1.133)	3.112 (± 0.191)	140
Meadow	0	25.460 (± 0.927)	65.70 (± 3.213)	3.255 (± 0.663)	20
	50	25.260 (± 0.627)	67.550 (± 3.047)	1.840 (± 0.374)	20
	100	25.730 (± 0.545)	67.70 (± 3.125)	1.905 (± 0.399)	20
	150	25.515 (± 0.584)	67.80 (± 3.296)	2.370 (± 0.302)	20
	200	26.010 (± 0.581)	67.20 (± 3.154)	2.845 (± 0.409)	20
	250	25.760 (± 0.615)	65.850 (± 3.492)	3.535 (± 0.737)	20
	300	25.710 (± 0.668)	64.85 (± 3.455)	2.365 (± 0.515)	20
	All	25.635 (± 0.245)	66.664 (± 1.208)	2.588 (± 0.195)	140

[a] Number of observations

APPENDIX D

MEAN (± SE) SOUND AND SOLAR RADIATION, AUSTIN, TX, 2004

Area	Distance (m)	Sound (dB)	n^a	Solar Radiation (W/m^2)	n^b
Jester	0	23.995 (± 0.637)	20	71.0 (± 1.998)	80
	50	24.105 (± 0.604)	20	71.550 (± 2.275)	80
	100	24.495 (± 0.622)	20	70.850 (± 2.414)	80
	150	24.770 (± 0.611)	20	70.30 (± 2.332)	80
	200	24.980 (± 0.645)	20	69.950 (± 2.356)	80
	250	25.385 (± 0.637)	20	69.20 (± 1.819)	80
	300	24.330 (± 0.795)	20	70.450 (± 1.829)	80
	All	24.580 (± 0.245)	140	70.471 (± 0.801)[c]	480
Utility	0	48.435 (± 1.594)	20	199.942 (± 29.031)	80
	50	45.445 (± 1.206)	20	56.217 (± 5.906)	80
	100	44.205 (± 0.334)	20	49.090 (± 4.959)	80
	150	46.675 (± 1.329)	20	119.235 (± 21.514)	80
	200	44.240 (± 0.554)	20	65.473 (± 9.226)	80

APPENDIX D-Continued

Area	Distance (m)	Sound (dB)	n[a]	Solar Radiation (W/m^2)	n[b]
Utility cont.	250	45.915 (± 1.138)	20	49.509 (± 6.281)	80
	300	47.545 (± 0.962)	20	75.776 (± 19.265)	80
	All	46.066 (± 0.424)	140	69.217 (± 5.405)[c]	480
Meadow	0	47.835 (± 1.187)	20	283.593 (± 32.695)	80
	50	48.0 (± 1.258)	20	58.977 (± 6.665)	80
	100	45.190 (± 0.836)	20	45.794 (± 3.851)	80
	150	44.74 (± 0.829)	20	58.983 (± 9.016)	80
	200	46.015 (± 1.158)	20	94.565 (± 15.603)	80
	250	43.225 (± 0.363)	20	115.310 (± 22.080)	80
	300	45.445 (± 0.775)	20	94.494 (± 18.246)	80
	All	45.779 (± 0.379)	140	78.020 (± 5.865)[c]	480

[a] Number of observations for sound.

[b] Number of observations for radiation.

[c] Mean (± SE) for all radiation observations excluding the 0 m distance category.

APPENDIX E

PERCENT CANOPY COVER FOR VEGETATIVE SPECIES ≥ 1m IN HEIGHT, AUSTIN, TX, 2005

	Percent cover		
Species*	Jester	Utility	Meadow
Ashe Juniper (*Juniperus ashei*)	63.14	47.82	53.24
Texas Oak (*Quercus buckleyi*)	9.77	9.92	17.26
Plateau Live Oak (*Quercus fusiformis*)	7.16	1.61	5.34
Shin Oak (*Quercus sinuata* var. *breviloba)*	1.38	9.92	0.52
Yaupon (*Ilex vomitoria*)	2.55	2.61	3.09
Carolina Buckthorn (*Rhamnus caroliniana*)	1.54	0.55	5.94
Sweet Mountain Grape (*Vitis monticola*)	0.79	2.79	1.29
Walnut sp. (*Juglans* sp.)	1.21	--	2.49
Sugar Hackberry (*Celtis laevigata*)	1.52	1.04	0.46
Wafer-ash (*Ptelea trifoliate*)	0.25	2.50	.07
Escarpment Black Cherry (*Prunus serotina*)	1.04	2.50	0.07
Cedar Elm (*Ulmus crassifolia*)	0.64	0.51	0.73
Mustang Grape (*Vitis mustangensis*)	0.24	0.87	--

APPENDIX E-Continued

Species*	Percent cover		
	Jester	Utility	Meadow
Spanish Grape (*Vitis berlandieri*)	0.31	.56	0.10
Mexican Buckeye (*Ungnadia speciosa*)	--	0.81	0.05
Texas Persimmon (*Diospyros texana*)	0.06	0.76	0.02
American Beautyberry (*Callicarpa americana*)	0.48	--	0.20
Rattan-vine (*Berchemia scandens*)	0.62	0.01	--
Coma (*Bumelia lanuginosa*)	0.19	0.17	0.07
Virginia Creeper (*Parthenocissus quinquefolia*)	--	4.60	0.09
Elbow-bush (*Forestiera pubescens*)	0.08	0.16	0..06
Greenbriar (*Smilax bona-nox*)	0.02	0.03	0.23
Deciduous Holly (*Ilex deciduas*)	0.04	--	0.22
Redbud (*Cercis canadensis*)	--	0.21	0.05
Agarito (*Berberis trifoliolata*)	0.28	--	--
Downy Viburnum (*Viburnum rufidulum*)	--	0.21	--
Lindheimer Silk-tassel (*Garrya lindheimeri*)	0.15	--	0.08
Evergreen Sumac (*Rhus virens*)	0.03	0.10	0.06
Texas Ash (*Fraxinus texensis*)	--	--	0.16
Shrubby Boneset (*Eupatorium havanense*)	0.04	0.01	0.04
Catclaw Acacia (*Acacia roemeriana*)	--	0.07	0.02
Mock-orange (*Philadelphus ernestii*)	--	0.06	--

APPENDIX E-Continued

Species*	Percent cover		
	Jester	Utility	Meadow
Texas Mountain Laurel (*Sophora secundiflora*)	0.06	--	--
Bur Oak (*Quercus macrocarpa*)	--	--	0.04
Rough-leaf Dogwood (*Cornus drummondii*)	--	--	0.02
Roosevelt Weed (*Baccharis neglecta*)	0.02	--	--
Open	6.16	4.72	7.12

* Species are ranked by percent coverage for all areas combined.

LITERATURE CITED

Allen, C. R., S. Demarais, and R. S. Lutz. 1994. Red imported fire ant impact on wildlife: an overview. Texas Journal of Science 46:51-59.

Allen, C. R., S. Demarais, and R. S. Lutz. 1997. Effects of red imported fire ants on recruitment of white-tailed deer fawns. Journal of Wildlife Management 61:911-916.

Ambuel, B. and S. A. Temple 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology 64:1057-1068.

Anders, A. D. and D. C. Dearborn. 2004. Population trends of the endangered Golden-cheeked Warbler at Fort Hood, Texas, from 1992-2001. Southwestern Naturalist 49:39-47.

Andren, H. 1992. Corvid density and nest predation in relation to forest fragmentation: a landscape perspective. Ecology 73:794-804.

Andren, H. and P. Angelstam. 1988. Elevated predation rates as an edge effect in habitat islands: experimental evidence. Ecology 69:544-547.

Arnold, K. A., C. L. Coldren, and M. L. Fink. 1996. The interactions between avian predators and Golden-cheeked Warblers in Travis County, Texas. Texas Transportation Institute. Tech Rep. TX-96/1983-2F, Texas A&M University, College Station, Texas, USA.

Askins, R. A. 1995. Hostile landscapes and the decline of migratory songbirds. Science 267:1956-1957.

Baccus, J. T., M. E. Tolle, and J. D. Cornelius. 2007. Response of the Golden-cheeked Warbler (*Dendroica chrysoparia*) to wildfires at Fort Hood, Texas. Occasional Publication No. 7, Texas Ornithological Society.

Balcones Canyonland Preserve 1998. Tier III Land Management Plan: Bull Creek Unit. In Balcones Canyonlands Preserve Land Management Plan, vol. 3. Austin, Texas, USA.

Benson, R. H. 1996. The effect of roadway traffic noise on territory selection by Golden-cheeked Warblers. Journal of the Acoustical Society of America 99:2575.

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

Bookhout, T. A., Editor. 1996. Research and management techniques for wildlife and habitats. Fifth ed., rev. The Wildlife Society, Bethesda, Maryland, USA.

Boulinier, T., J. D. Nichols, J. E. Hines, J. R. Sauer, C. H. Flather, and K. H. Pollock. 2001. Forest fragmentation and bird community dynamics: inference at regional scales. Ecology 82:1159-1169.

Boulinier, T., J. D. Nichols, J. R. Sauer, J. E. Hines, and K. H. Pollock. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79:1018-1028.

Brittingham, M. C. and S. A. Temple. 1983. Have cowbirds caused forest songbirds to decline? Bio Science 33:31-35.

Burke, D. M. and E. Nol. 1998. Influence of food abundance, nest-site habitat, and forest fragmentation on breeding overbirds. Auk 115:96-104.

Burkey, T. V. 1989. Extinction in nature reserves: the effect of fragmentation and the importance of migration between reserve fragments. Oikos 55:75-81.

Buskirk, W. H. and J. L. McDonald. 1995. Comparison of point count sampling regimes for monitoring forest birds. USDA Forest Service Gen. Tech. Rep. PS-GTR-149.

Campbell, L. 2003. Endangered and threatened animals of Texas, their life history and management. Texas Parks and Wildlife. (on line) <http//www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_bk_w7000_0013.pdf>. Accessed 5 March 2007.

Chalfoun, A. D., M. J. Ratnaswamy, and F. R. Thompson III. 2002. Songbird nest predators in forest-pasture edge and forest interior in a fragmented landscape. Ecological Applications 12:858-867.

City of Austin. 2004. 2004 Golden-cheeked Warbler (*Dendroica chrysoparia*) and Black-capped Vireo (*Vireo atricapilla*) monitoring program. Balcones Canyonlands Preserve Annual Report Fiscal Year 2003-2004.

Davidson, A. H. 1994. Common Grackle predation on adult passerines. Wilson Bulletin 106:174-175.

Davis, W. B. 1974. The mammals of Texas. Texas Parks and Wildlife Department, Bulletin No. 41, Austin, Texas, USA.

Dearborn, D. C. and L. L. Sanchez. 2001. Do Golden-cheeked Warblers select nest locations on the basis of patch vegetation? Auk 118:1052-1057.

DeBoer, T. S. and D. D. Diamond 2006. Predicting presence-absence of the endangered Golden-cheeked Warbler (*Dendroica chrysoparia*). Southwestern Naturalist 51: 181-190.

Dickinson, V. 1995. Red imported fire ant predation on Crested Caracara nestlings in south Texas. Wilson Bulletin 107:761-762.

Dolby, A. S. and T. C. Grubb Jr. 1999. Effects of winter weather on horizontal and vertical use of isolated forest fragments by bark-foraging birds. Condor 101:408-412.

Donovan, T. M., P. W. Jones, E. M. Annand, and F. R. Thompson III. 1997. Variation in local-scale edge effects: mechanisms and landscape context. Ecology 78:2064-2075.

Donovan, T. M., R. H. Lamberson, A. Kimber, F. R. Thompson III, and J. Faaborg. 1995. Modeling the effects of habitat fragmentation on source and sink demography of neotropical migrant birds. Conservation Biology 9:1396-1407.

Dufour, P. A. 1980. Effects of noise on wildlife and other animals, review of research since 1971. Technical Report EPA-550/9-80-100, U. S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington D. C., USA.

Endler, J. A. 1991. Interaction between predators and prey. Pp. 169-196 in Behavioural Ecology, an Evolutionary Approach, 3rd ed. (J. R. Krebs and N. B. Davies, eds.) Blackwell Scientific Publications, Oxford, UK.

Engels, T. M. 1995. The conservation biology of the Golden-cheeked Warbler (*Dendroica chrysoparia*). Dissertation. University of Texas, Austin, USA.

Engels, T. M., and C. W. Sexton. 1994. Negative correlation of Blue Jays and Golden-cheeked Warblers near an urbanizing area. Conservation Biology 8:286-290.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. Journal of Wildlife Management 61:603-610.

Fahrig, L. and G. Merriam. 1994. Conservation of fragmented populations. Conservation Biology 8:50-59.

Fenske-Crawford, T. J. and G. J. Niemi. 1997. Predation of artificial ground nests at two types of edges in a forest-dominated landscape. Condor 99:14-24.

Fink, M. L. 1996. Factors contributing to nest predation within habitat of the Golden-cheeked Warbler, Travis County, Texas. Thesis, Texas A& M University, College Station, Texas, USA.

Friesen, L. E., P. F. J. Eagles, and R. J. Mackay. 1995. Effects of residential development on forest-dwelling neotropical migrant songbirds. Conservation Biology 9:1408-1414.

Gass, L. R. 1996. Nesting behavior of Golden-cheeked Warblers in Travis County, Texas. Thesis, Southwest Texas State University, San Marcos, Texas, USA.

Gates, J. E. and L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:871-883.

Gehlbach, F. R. 2005. Native Texas avifauna altered by suburban entrapment and method for easily assessing natural avifaunal value. Bulletin of the Texas Ornithological Society 38:35-47.

Grubb, T. C. Jr. 1975. Weather-dependent foraging behavior of some birds wintering in a deciduous woodland. Condor 77:175-182.

Grubb, T. C. Jr. 1977. Weather-dependent foraging behavior of some birds wintering in a deciduous woodland: horizontal adjustments. Condor 79:271-274.

Gutzwiller, K. J., R. T. Wiedenmann, K. L. Clements, and S. H. Anderson. 1994. Effects of human intrusion on song occurrence and singing consistency in subalpine birds. Auk 111:28-37.

Hagan, J. M., W. M. Vander Haegan, and P. S. McKinley. 1996. The early development of forest fragmentation effects on birds. Conservation Biology 10:188-202.

Hanski, I. K., T. J. Fenske, and G. J. Niemi. 1996. Lack of edge effect in nesting success of breeding birds in managed forest landscapes. Auk 113:578-585.

Hartley, M. J. and M. L. Hunter, Jr. 1998. A meta-analysis of forest cover, edge effects, and artificial nest predation rates. Conservation Biology 12:465-469.

Horne, J. S. 2000. Effects of open-canopy corridor width on definitions of forest fragmentation and habitat loss for Golden-cheeked Warblers. Endangered species monitoring and management at Fort Hood, Texas: 1999 annual report. Revised edition. Fort Hood Project, The Nature Conservancy of Texas, Fort Hood, Texas, USA.

Hutto, R. L., S. M. Pletschet, and P. Hendricks. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103:593-602.

Insightful Corporation. 2005. S-PLUS 7.0 for Windows. Insightful Corporation. Seattle, Washington, USA.

Johnson, K. W. and J. E. Johnson. 1976. An incident of Blue Jay predation on a Yellow-rumped Warbler. Wilson Bulletin 88:509.

Karr, J. R. and K. E. Freemark. 1983. Habitat selection and environmental gradients: dynamics in the "stable" tropics. Ecology 64:1481-1494.

Kaseloo, P. A. and K. O. Tyson. 2004. Synthesis of noise effects on wildlife populations. Federal Highway Administration Report, FHWA-HEP-06-016.

Kroll, J. C. 1980. Habitat requirements of the Golden-cheeked Warbler: management implications. J. Range Management. 33:60-65.

Ladd, C. G. 1985. Nesting habitat requirements of the Golden-cheeked Warbler. Thesis. Southwest Texas State University, San Marcos, Texas, USA.

Ladd, C. and L. Gass. 1999. Golden-cheeked Warbler (*Dendroica chrysoparia*). *In* The Birds of North America, No. 420 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Pennsylvania, USA.

Larkin R. P., L. L. Pater, and D. J. Tazik. 1996. Effects of military noise on wildlife: a literature review. Construction Engineering Research Lab, U. S. Army, Champaign, Illinois, USA.

Magness, D. R., R. N. Wilkins, and S. J. Hejl. 2006. Quantitative relationships among Golden-cheeked Warbler occurrence and landscape size, composition, and structure. Wildlife Society Bulletin 34:473-478.

Mancke, R. G. and T. A. Gavin. 2000. Breeding bird density in woodlots: effects of depth and buildings at the edges. Ecological Applications 10:598-611.

Miller, C. K. and R. L. Knight. 1993. Does predator assemblage affect reproductive success in songbirds? Condor 95:712-715.

Paton, P. W. C. 1994. The effect of edge on avian nest success: how strong is the evidence? Conservation Biology 8:17-26.

Pease, C. M. and L. G. Gingerich. 1989. The habitat requirements of the Black-capped Vireo and Golden-cheeked Warbler populations near Austin, Texas. University of Texas, Austin, Texas, USA.

Peterson, B. L., B. E. Kus, and D. H. Deutschman. 2004. Determining nest predators of the Least Bell's Vireo through point counts, tracking stations, and video photography. Journal of Field Ornithology 75:89-95.

Peterson, C. E. 2001. Golden-cheeked Warbler (*Dendroica chrysoparia,* Parulidae) territory and non-territory habitat choice in fragmented Ashe juniper patches on the Kerr wildlife management area. Thesis. Southwest Texas State University, San Marcos, Texas, USA.

Pulich, W. M. 1976. The Golden-cheeked Warbler: a bioecological study. Texas Parks and Wildlife Dept. Austin, Texas, USA.

Quinn, G. P., and M. J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press, Cambridge, UK.

Ralph, C. J., S. Droege, and J. R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. USDA Forest Service Gen. Tech. Rep. PSW-GTR-149.

Rich, A. C., D. S. Dobkin, and L. J. Niles. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology 8:1109-1121.

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Rosenberg, G. H. 2001. Mockingbirds and thrashers. Pages 468-474 *in* C. Elphick, J. B. Dunning, Jr., and D. A. Sibley, eds. The Sibley guide to bird life and behavior. Alfred A. Knopf, New York, USA.

Rothstein, S. I., J. Verner, and E. Stevens. 1984. Radio-tracking confirms a unique diurnal pattern of spatial occurrence in the parasitic Brown-headed Cowbird. Ecology 65:77-88.

Saracco, J. F. and J. A. Collazo. 1999. Predation on artificial nests along three edge types in a North Carolina bottomland hardwood forest. Wilson Bulletin 111:541-549.

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18-32.

Sexton, C. W. 1987. A comparative analysis of urban and native bird populations in central Texas. Dissertation., University of Texas at Austin, Austin, Texas, USA.

Sexton, C. W. 1992. Rare, local, little-known, and declining North American breeders: the Golden-cheeked Warbler. Birding 24:373-376.

Shaw, D. 1989. Applications of GIS and remote sensing for the characterization of habitat for threatened and endangered species. Dissertation, North Texas State University, Denton, Texas, USA.

Sikes, P. J. and K. A. Arnold. 1986. Red imported fire ant (*Solenopsis invicta*) predation on Cliff Swallow (*Hirundo pyrrhonota*) nestlings in east-central Texas. Southwestern Naturalist 31:105-106.

Smith, J. E., S. J. Taylor, C. J. Whelan, M. L. Denight, and M. M. Stake. 2004. Behavioral interactions between fire ants and vertebrate nest predators at two Black-capped Vireo nests. Wilson Bulletin 116:163-166.

Stake, M. M. and D. A. Cimprich. 2003. Using video to monitor predation at Black-capped Vireo nests. Condor 105:348-357.

Stake, M. M., J. Faaborg, and F. R. Thompson, III. 2004. Video identification of predators at Golden-cheeked Warbler nests. Journal of Field Ornithology 75:337-344.

Suarez, A. V., K. S. Pfennig, and S. K. Robinson. 1997. Nesting success of a disturbance-dependent songbird on different kinds of edges. Conservation Biology 11:928-935.

Temple, S. A. and J. R. Cary 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conservation Biology 2:340-347.

Texas State Data Center and Office of the State Demographer. 2004. Texas population estimates program (online). Institute for Demographic and Socioeconomic Research, University of Texas at San Antonio, San Antonio, Texas, USA.<http://txsdc.utsa.edu/ tpepp/ txpopest.php> Accessed 1 March 2007.

Toweill, D. E. and J. G. Teer. 1977. Food habits of ringtails in the Edwards Plateau region of Texas. Journal of Mammalogy 58:660-663.

U. S. Fish and Wildlife Service. 1992. Golden-cheeked Warbler (*Dendroica chrysoparia*) recovery plan. Albuquerque, New Mexico, USA.

U. S. Fish and Wildlife Service and Recon. 1996. Final environmental impact statement/habitat conservation plan for proposed issuance of a permit to allow incidental take of the Golden-cheeked Warbler, Black-capped Vireo, and six karst invertebrates in Travis County, TX. U. S. Fish and Wildlife Service, Albuquerque, New Mexico and Recon, San Diego, California, USA.

Wahl, C. R., D. D. Diamond and D. Shaw. 1990. The Golden-cheeked Warbler: a status review. Ecological Services, U. S. Fish and Wildlife Service, Fort Worth, Texas, USA.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211-1214.

Wolf, B. O. and G. E. Walsberg. 1996. Thermal effects of radiation and wind on a small bird and implications for microsite selection. Ecology 77:2228-2236.

Yahner, R. H. and C. A. DeLong. 1992. Avian predation and parasitism on artificial nests and eggs in two fragmented landscapes. Wilson Bulletin 104:162-168.

VITA

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