HABITAT USE BY THE GOLDEN-CHEEKED WARBLER IN TEXAS

A Dissertation

by

JOHN CALVIN NEWNAM

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2008

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	Keith A. Arnold
Committee Members,	William E. Grant
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ABSTRACT

Habitat Use by the Golden-cheeked Warbler in Texas.

(December 2008)

John Calvin Newnam, B.S., Texas A&M University; M.S., Texas A&M University

Chair of Advisory Committee: Dr. Keith A. Arnold

Understanding species-habitat relationships is fundamental to the conservation of a species. This is especially important when the species is considered endangered. The Golden-cheeked Warbler is a habitat specialist that breeds only in oak-juniper woodlands (considered a climax forest) of central Texas. The warbler was listed as endangered under the federal Endangered Species Act primarily because of habitat loss and fragmentation. Conservation measures include the preservation of existing habitat and attempts to manage and enhance areas that once supported the warbler to return to the climax oak-juniper woodlands. My objectives were (1) to quantify the vegetation structure and species composition by vegetation volume of occupied warbler habitat across the breeding range in Texas and (2) to quantify the habitat use by the warbler in categories of behavior, substrate, height, and tree species. Instantaneous, focal animal behavioral observations were collected for three breeding seasons at six sites across the range of the warbler. Warbler behavior and microhabitat use were compared to availability of vegetation volume by height class and tree species. I found that Golden-cheeked Warbler habitat varied by vegetation volume, canopy height and tree species among all sites. The warbler preferred twigs and foliage and the upper two height classes of the habitat structure for all behaviors. Tree species use did not match availability at any sites. The one consistent species result was the warbler used Ashe juniper significantly less than it occurred at all sites. Other major species were used disproportionately to the species occurrence at each site. Some tree species were used more often than they occur in the habitat while others species were used less than they occur in the habitat. Preferences for height class and tree species use were not significantly influenced by vegetation volume. Some other factor not measured such as prey availability may be the cause. Because warbler habitat characteristics and use vary across the range, any efforts to manipulate vegetation to become habitat must consider regional characteristics of Golden-cheeked warbler habitat.

ACKNOWLEDGEMENTS

A project of this size takes a number of people to accomplish and I would like to thank those who helped. My committee, Drs. K. A. Arnold, R. D. Slack, W. E. Grant and F. E. Smeins have been very patient and offered valuable comments and suggestions. I give a special thanks to my committee chair and friend, Dr. Arnold, who not only offered many suggestions and edited my work but also gave much moral support and encouragement. Drs. J. A. Butcher and B. Collier both gave direction and help with data management and analysis. Dr. Butcher also provided editorial comments and suggestions for the manuscript. Dr. G. Scott Mills provided many extensive and fascinating hours of discussions about the warbler and the science of ornithology.

Access to land for this study was provided by David Riskind, Mark Lockwood and many park superintendents of the Texas Parks and Wildlife Department, Carlo Abbruzzese of the city of Austin, Paul Sunby, Steve Paulson, and the Jonas Family of Austin.

Many people participated in the study from the beginning that contributed to the overall approach, sample methods, data collection and the many, many details of a study this size. First among those is Doug Booher who provided enthusiasm for all as the study took shape and was the crew boss who made things happen throughout the entire study, and a very good friend. Thanks to the many who served as field technicians and gave great effort to provide good information: Ben Archer, Marianne Bailey, John

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INTRODUCTION

Understanding species-habitat relationships, why and how animals live where they live, is fundamental to the conservation of a species (Morrison et al. 2006). Lack (1933) proposed that birds identify features of appropriate environments that trigger the bird to select a place to live. Svardson (1949) and Hilden (1965) both expressed ideas of a two-stage process in which animals first select broadly from different environments, and then select finer habitat characteristics to chose a specific place to live (Morrison et al. 2006). Morrison et al.(2006) list other influences on habitat selection identified by various researchers such as conspecifics (Butler 1980), interspecific competitors (Werner and Hall 1979), and predators (Werner et al. 1983). Morrison et al. (2006) also include any "features of the environment that are directly or indirectly related to resources needed for survival and reproduction." Cody (1985) cites Hilden's (1965) summary of the ultimate and proximate factors involved in habitat choice.

> The evolution of habitat preferences is determined by, and determines, the bird's morphological structure and behavioral functions, its ability to obtain food and shelter successfully in the habitat. The proximate stimuli for the choice of habitat might be structural features of the landscape, foraging or nesting opportunities, or the presence of other species. Such factors might operate independently, hierarchically as a system of

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This dissertation follows the style of The Condor.

sequential decisions or overrides, or synergistically in a complex fashion or 'gestalt.'

Habitat selection is recognized as a complicated process involving many interacting factors at different spatial scales and levels of discrimination (Morrison et al. 2006).

The Golden-cheeked Warbler (*Dendroica chrysoparia*) (GCW) nests only in juniper-oak woodlands of central Texas (Pulich 1976). It appears from Pulich's (1976) work that one specific habitat requirement limits the range of the species, the presence of Ashe juniper (*Juniperus ashei*), the primary component of the warbler's nest. Kroll's (1980) study in Meridian State Park determined that the warbler depends upon Ashe juniper for nesting material.

Habitat for the GCW in Texas has been described in various qualitative and quantitative approaches. H. P. Attwater (1892) describes habitat in the vicinity of Bexar county as "mountain cedar (juniper), Spanish or mountain oak, black oak, and live oak on the higher ground, and live oak and Spanish oak clumps or thickets on the lower flats among the foothills, interspersed in some localities with dwarf walnut, pecan and hackberry. All these trees grow on an average from 10 to 20 feet high, the cedar often forming almost impenetrable 'brakes'."

Pulich (1976) gives the following description of habitat: "Except for slight differences, yet demonstrable and quantifiable, particularly at the extreme southern and northern parts of the GCW range, the binding vegetation dominants throughout the warbler nesting range are similar."

Keddy-Hector (1992) summarized species composition of habitat from Attwater in Chapman (1907), Johnston et al.(1952), Pulich (1976), Kroll (1980), Ladd (1985), Riskind and Diamond (1986), and Wahl et al. (1990). He listed Ashe juniper plateau live oak (*Quercus fusiformis*), Texas oak (*Q. buckleyi*), scaly bark oak (*Q. sinuate* var. *breviloba*), Lacey oak (*Q. glaucoides*), post oak (*Q. stellata*), black-jack oak (*Q. marilandica*), American elm (*Ulmus Americana*), cedar elm (*U. crassifolia*), hackberry (*Celtis reticulata*), sugarberry (*C. laevigata*), little walnut (*Juglans microcarpa*), Arizona walnut (*J. major*), sycamore (*Platanus occidentalis*), Texas ash (*Fraxinus texensis*), Mexican persimmon (*Diospyros texana*), coma (*Bumelia lanuginose*), redbud (*Cercis canadensis*), evergreen sumac (*Rhus virens*), soapberry (*Sapindus saponaria*), deciduous holly (*Ilex deciduas*), escarpment cherry (*Prunus serotina*), Mexican bucheye (*Ugnadia speciosa*), red mulberry (*Morus rubra*) bir-tooth maple (*Acer grandidentatum*), Texas mountain laurel (*Sophora secundiflora*). poison ivy (*Rhus toxicondendron*), Virginia creeper (*Parthenocissus quinquefolia*), grape (*Vitis spp.*), black haw (*Viburnum rufidulum*), springherald (*Forestieria pubescens*), and Texas mulberry (*Morus microphylla*), Taxonomic nomenclature for plants follows Hatch et al. (1990).

Also from the above studies Keddy-Hector (1992) reported Ashe juniper to range from 10% to 83% of total trees at 27 sites throughout the breeding range of the warbler. Measurements in Travis county found Ashe juniper to account for 10% to 90% of trees present in warbler habitat, with hardwoods accounting for 10% to 85% of trees present (Travis County 1999). The studies reviewed by Keddy-Hector varied in numbers of sites and extent of coverage of the breeding range of the warbler. The studies by Pulich, Ladd, and Wahl all included multiple sites across the warbler's range, while the others had limited geographic sites. Intensive studies on habitat modeling and vegetation characteristics have been conducted on Fort Hood, Bell and Coryell counties (The Nature Conservancy 2007), again limited in geographic scope.

The habitat use and behavior of the GCW in its breeding range have not been studied as much and only on small areas of the breeding range. Gass (1996) studied nesting behavior of the GCW in Travis county. Beardmore (1994) conducted a detailed behavioral study of habitat use by the GCW on two sites in Travis County. Predator interaction has been studied in Travis County by Engles and Sexton (1994) and Arnold et al. (1996). Nest predation, species density, productivity, population trends and parasitism have been studied at Fort Hood, Bell and Coryell counties (The Nature Conservancy 2007). Habitat patch size has been investigated in Coryell and Hamilton counties by Butcher(2008). Habitat characteristics, use and experimental manipulation are being intensively studied in Coryell, Hamilton, Bosque, and Erath counties by the Leon River Restoration Project (Wilkins and Mike Morrison 2007) There have been no range-wide studies of habitat use or behavior.

The GCW was listed as an endangered species under the Endangered Species Act in December 1990 (USDI Fish and Wildlife Service 1990). The notice stated habitat loss and fragmentation coupled with the limited range of the species as the primary reasons for listing the warbler as endangered.

My objectives were (1) to measure GCW habitat at sites across the breeding range by height, vegetation volume, and tree species; and (2) to provide quantitative descriptions of GCW habitat use as determined by recording where the warbler exhibits various behaviors by height, substrate and tree species. Based on the results of Beardmore's (1994) work I predicted that the GCW has preferences for twigs and foliage substrate, uses the mid and upper height classes more than the lower, and uses tree species disproportionately compared to the species occurrence at a site. The behavioral observations and analysis in this study were conducted in the same manner as Beardmore (1994) to allow for comparison to her work in Travis County.

STUDY AREA

I conducted my study on 13 sites in 12 counties throughout the range of the GCW, from the northern extent of the range in northwest Palo Pinto County to near the western extent in north central Uvalde County. Study sites in Travis and Hays counties were studied in 1995. All study sites were used in 1996 and 1997. Ten of the sites were located on state parks operated by Texas Parks & Wildlife Department, one site on City of Austin property and two sites on private lands, one each in Travis and Hays counties, Texas (Figure 1). Availability of study sites was limited by access granted from landowners and park managers; consequently most study sites are publicly owned. Study sites were chosen because it was known that the warbler used the sites for nesting, and to sample locations across the breeding range. Ten study sites located on Texas Parks and Wildlife Department facilities included Colorado Bend State Park (CBSP) in San Saba County, Dinosaur Valley State Park (DVSP) in Somervell County, Garner State Park (GSP) in Uvalde County, Government Canyon State Natural Area (GCSNA) in Bexar County, Guadalupe River State Park/Honey Creek State Natural Area (adjoining properties) (GR/HC) in Comal and Kendall counties, Longhorn Caverns State Park (LCSP) in Burnet County, Lost Maples State Park (LMSP) in Bandera County, Meridian State Park (MSP) in Bosque County, Pedernales Falls State Park (PFSP) in Blanco County, and Possum Kingdom State Park (PKSP) in Palo Pinto County. One study site was located on the City of Austin Forest Ridge tract now a part of the Balcones Canyonlands Preserve. Two sites were located on private land; one was the

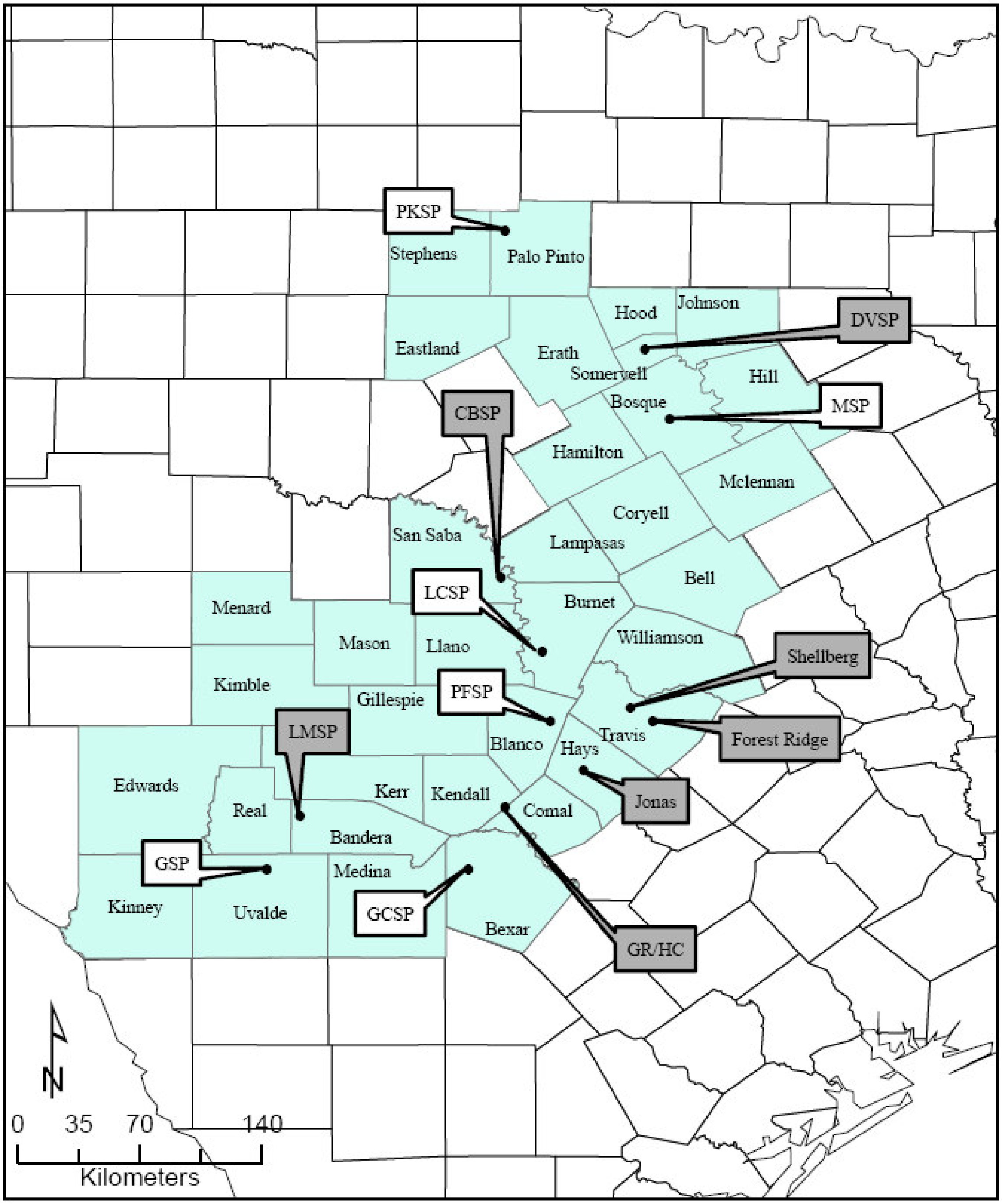

FIGURE 1. Study site locations and county level range (blue) of the Golden-cheeked Warbler in Texas. Behavior observations and vegetation measurements both were collected at sites with shaded labels. Vegetation measures only were collected at sites with white labels. State Park (SP) abbreviations are: CBSP = Colorado Bend SP; DVSP = Dinosaur Valley SP; GCSP = Government Canyon SP; GSP = Garner State Park; GR/HC = Guadalupe River SP and Honey Creek State Natural Area; LCSP = Longhorn Caverns SP; LMSP = Lost Maples SP; MSP = Meridian SP; PFSP = Pedernales SP; and PKSP = Possum Kingdom SP.

Shellberg property (also known as Vista Point in Travis County that is now a part of the Balcones Canyonlands Preserve), and the privately owned Jonas tract in western Hays County. Study sites will be referred to by county names. Data from Shellberg and Forest Ridge have been combined and treated as one site referred to as Travis County and GR/HC will be referred to as Comal County. All tables and figures list the sites in this same order by county name from north to south then east to west across the range.

METHODS

Habitat Description

Vegetation measurements were made on all 13 study sites. Vegetation was measured using a total vegetation volume (TVV) method following Mills et al. (1991). Transect start points for measuring the TVV were established during mapping of GCW locations by marking vegetation used by a warbler and recording the behavior of the bird at the time of the encounter. Transect starting points were marked in the field with survey tape and identified by date; technician's full initials and the technician's catalog number and locations were recorded on aerial photographs. Transects were established across each study site to ensure that all areas occupied by the warbler over the entire site were represented. In some cases more than one transect was measured based on the behavior of an individual bird within the same encounter. In these cases the multiple transects associated with the same bird during one encounter were averaged to give one transect value for that encounter.

One transect consisted of two 20 m lines, marked by ropes on the ground, which intersect at a right angle on their mid-points. The direction of the transect from the beginning point was determined by spinning a screwdriver on a clipboard. At every two meters along each line of a transect, points 2 m through 20 m on the first line and points 0 m through 8 m and 12 m through 20 m on the second line, a 6 m pole, 13 mm in diameter, marked in meters and decimeters, was erected vertically to count the number of vegetation intercepts within a decimeter diameter column centered around the pole for each decimeter in height. Only one hit is counted for each decimeter segment; thus, there were 10 hits maximum allowed for each meter segment. This information is summed and recorded for each meter layer and each point on the transect. All intercepts recorded per point are then summed by meter layer for the entire 20 point transect, then divided by 200 to obtain an average of the 20 points and 10 dm per each meter measured. The result is in m^3/m^2. TVV amounts for a transect may exceed 1 m^3/m^2 because hits in all meter layers to the canopy are combined. This method provides the TVV of the transect as well as vegetation volume for each meter layer and each species by meter layer (Mills, et al. 1991).

Four vegetation transects as described above were collected at each nest site. These four transects started from the point on the ground directly under the nest and extended away from that point in one of the cardinal compass directions. Vegetation volume by species and meter layer from these four transects were averaged to give one transect value for each nest.

Behavior Measurement

Behavioral observations were collected on seven of the 13 sites because limited resources prohibited behavior studies at all sites. Behavioral observations were collected during the 1995 nesting season in Travis and Hays counties. During the 1996 and 1997 seasons behavioral observations were collected in Somervell, San Saba, Travis, Hays, Comal and Bandera counties.

Behavioral observations were collected by an instantaneous, focal animal technique to record warbler behavior every 15 sec. (Altmann 1974, Martin and Bateson

1993). A team of two technicians sampled each study site one to two days each week from 1 March until the second week in June each season. Three teams were used to cover all sites each week. Observations began within 30 min. of dawn and continued for as long as warblers could be detected in the afternoon, but at least until 15:30 hours central standard time. Once a bird was detected, its sex and age, date, time of day and the name of the technician making the observations and the technician recording the observations were entered onto the data sheet. One technician called out the observations every 15 seconds (on the beep of a continuously running stop watch that automatically resets to 15 seconds without loss of time) (Weins et al. 1970) while the second technician recorded the data on a form. Data recorded for each observation included the type of behavior, (singing, hopping, perching, maintenance, eating, flying, gathering nest material, wing/tail flashing, chasing, chipping, begging, fledgling being fed, adult feeding fledgling), species of tree occupied, substrate (twigs includes leaves, branch, trunk, or ground), height above ground of bird, and the canopy height of the tree occupied. For analysis the categories of behavior above were grouped into the following categories: foraging, which includes eating, hopping, adult feeding fledgling, fledgling being feed and begging; pair bonding, which includes chasing, wing/tail flashing, gathering nesting material, and copulation; vocalizations, which include singing and chipping; locomotion was flying; resting was perching; and maintenance to align behavior category names to be consistent with Beardmore (1994). Heights of trees and birds were estimated by the technicians and recorded to the nearest meter. Technicians were trained and practiced data collection and height estimation with vegetation measuring poles before the warblers arrived each year. In addition, the same technicians collected the vegetation measurements. The team followed each individual for as long as the bird could be detected. Occasionally during the recording of behavior the individual bird could not be seen at the signal to record yet it was clear that the bird was still present so “out of sight” was recorded for the behavior and any other data, such as height, tree species, or substrate, if it could be determined. Once the bird could no longer be observed, the end time for this behavior bout was recorded and a new sheet was prepared for the next encounter. The team then moved to another area of the site to limit the possibility of encountering the same bird again on that visit. Individuals could be encountered again on the same day, particularly at sites with small numbers of warblers, however the sampling protocol separated encounters of the same individual by some time. Priority was given to collecting behavioral observations from juveniles and females, as they are the least encountered sex and age classes. Priority for recording females and juveniles was accomplished by stopping data collection for a male whenever a female or juvenile was encountered and begin recording observations of the female or juvenile on a new data sheet immediately.

Nests were marked in the field with survey tape and identified by date; technician’s full initials and the technician’s catalog number and locations recorded on aerial photograph at the time of discovery. Measurements of the nests and nest trees were taken after the breeding season. Data on nest locations included tree species and canopy height, nest height, placement and dimensions. Because data were collected after the breeding season, some nests were lost; however, the nest trees were still identifiable, consequently some data such as nest height were not available for some nest sites.

Data Analysis

Student T-test was used to determine if there was a statistical difference in total vegetation volume or canopy height between the individual behavior determined vegetation transects and the nest determined transects (Ott 1993). Levene's test (SPSS 2006) for equality of variance was used for total vegetation volume and canopy height between individual behavior transects and nest transects.

A Univariate Analysis of Variance, Tamhane's T2 (SPSS 2006), was used to compare canopy height and secondly total vegetation volume among counties by testing pairs of counties.

All observations combined and foraging observations were analyzed using Chi-square test of independence to determine if warblers used height classes and tree species preferentially. Warbler observations were compared to foliage volume by using Chi-square goodness-of-fit analysis and Bonferroni z statistic to determine whether height class or tree species were used more or less often than expected based on availability (Neu et al. 1974, Beardmore 1994). Any vegetation volume proportion that falls outside of the 95% Bonferroni confidence interval for the proportion of observations in a height class or tree species is significantly different from the warbler's use of that height class or tree species. Cramer's Phi statistic was used to determine what percent of effect found in warbler use of height class and tree species was due to vegetation volume (SPSS 2006).

RESULTS

Habitat Description

Eight hundred thirty-six vegetation transects were measured across the range of the GCW in Texas. Seven hundred fifty-three transects were established at sightings of an individual adult bird in habitat known to be occupied by territorial males and 83 transects at nest sites. Table 1 lists the number of vegetation transects and nests by county.

TABLE 1. Vegetation transects and nests by study site.

Site	Transects	Nests
Palo Pinto	31	0
Somervell	58	2
Bosque	54	1
San Saba	81	7
Burnet	24	0
Travis	155	46
Blanco	77	6
Hays	59	9
Comal	89	2
Bexar	61	3
Bandera	97	7
Uvalde	50	0
Total	836	83

Results of Levene's test indicated that I could not assume equality of variance for canopy height ($F = 8.168$, $p = 0.004$), but could assume equality of variance for total vegetation volume ($F = 2.460$, $p = 0.117$). Canopy height measured at nest sites did not differ significantly from canopy height at individual behavior transects across the range of the warbler ($T = -0.942$, $df = 118.321$, $p = 0.348$). Total vegetation volume from nest sites did not differ significantly from total vegetation volume at the individual behavior transects ($T = -1.289$, $df = 834$, $p = 0.918$). Q-Q Plots showed canopy height and total vegetation volume measures were normally distributed. Canopy height and total vegetation volume differed among counties ($F = 13.170$, $df = 11$, $p < 0.001$; $F = 8.289$, $df = 11$, $p < 0.001$, respectively). Figure 2 shows the mean canopy height for each county with 95% confidence bar. The minimum canopy height for any transect was 0.10 m. and the maximum was 16.18 m. Figure 3 shows the mean total vegetation volume for each county with 95% confidence bar. The minimum total vegetation volume for all transects was 0.08 m^3/m^2 and the maximum was 3.19 m^3/m^2. The sites are listed from top to bottom on the y-axis in the order of their location from the northern part of the range to the south and then east to west.

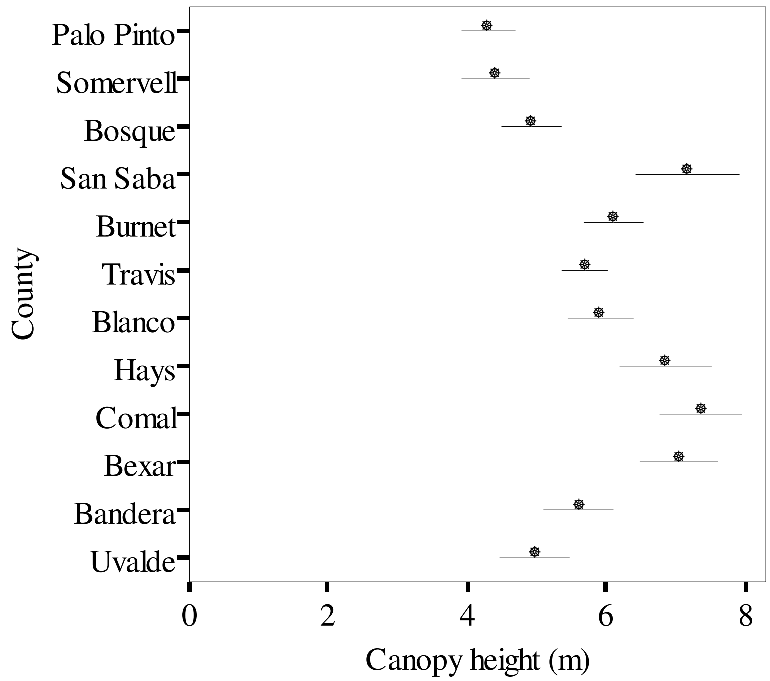

FIGURE 2. Mean canopy height of all vegetation transects by county with 95% confidence bar. Counties are listed in order from north to south and east to west across the range of the GCW in Texas.

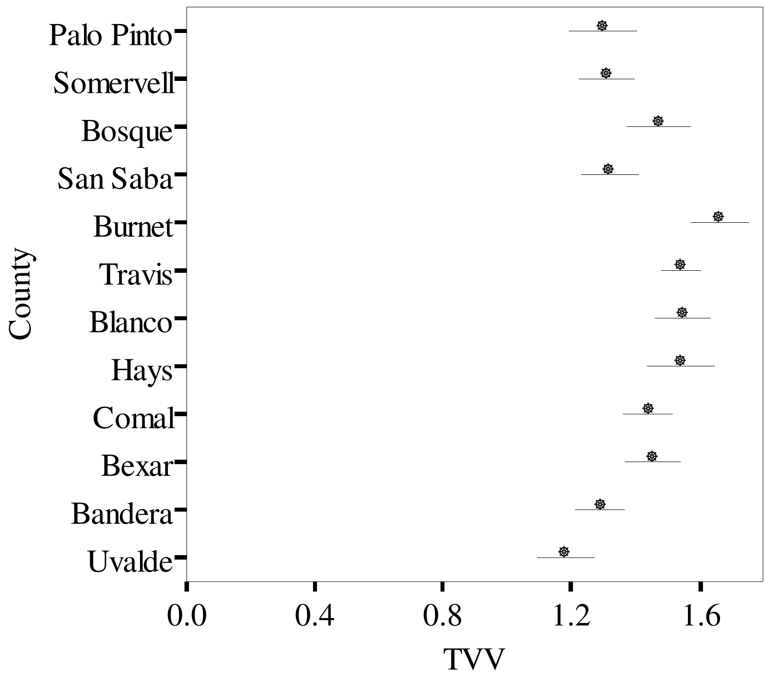

FIGURE 3. Mean total vegetation volume (TVV) (m^3/m^2) of all vegetation transects by county with 95% confidence bar. Counties listed in order from north to south then east to west across the range of the GCW in Texas.

Table 2 lists the 8 tree species with the highest percent vegetation volume by site, including values for Travis County from Beardmore (1994), with the remaining species grouped into the other category. Seventy-eight species were recorded on the vegetation transects in this study. The number of species recorded by site ranged from 8 species in Burnet County to 45 species in Travis County. A complete list of species and % vegetation volume by species and site is in Appendix A. Only 2 species, Ashe juniper and shin oak (*Quercus sinuata*), were detected at all study sites. Live oak and Lacey oak were combined as ecologically equivalent; Lacey oak replaces live oak in the western part of the GCW range. Depending on the site either live oak or Lacey oak was found at all sites. Ashe juniper occurs from 38% to 82% of the total vegetation volume across the 12 sites. Four species, Texas oak, live oak, cedar elm and green brier (*Smilax Bona-nox*), were found at 11 study sites. Four species, gum bumelia (*Bumelis lanuginosa*), hackberry (*Celtis spp.*), Texas ash, and grapevine (*Vitis sp.*), were recorded at 10 study sites. Texas pecan was recorded at only two sites, San Saba County with 8.6% of the total vegetation volume and Comal County with 0.6% of the site total vegetation volume. Big-tooth maple was recorded at one site, Bandera County with 6.3% of the total vegetation volume. Eighteen species were recorded at only one site each with 14 of those occurring at less than 1% of the vegetation volume for the site and the other four at 6.3% or less.

TABLE 2. Vegetation volume (%) by species and site.

Species	Palo Pinto	Somervell	Bosque	San Saba	Burnet	Travis	Travis*	Blanco	Hays	Comal	Bexar	Bandera	Uvalde
Juniperus asheii	80.1	64.7	66.2	38.8	82.0	63.7	35.6	66.0	59.2	53.0	37.5	45.6	67.6
Quercus fusiformis & glacoides	2.2	2.2	3.8	5.6	11.1	7.1	13.9	13.5	11.5	9.5	23.0	20.6	15.9
Quercus buckleyi	1.7	13.4	9.7	2.7	0.0	13.6	14.0	3.6	11.4	8.2	2.9	9.8	9.7
Ulmus crassifolia & americana	1.1	4.9	1.3	28.5	1.1	1.3	7.2	5.8	6.9	8.9	12.5	0.0	0.1
Quercus sinuata	11.1	9.1	8.1	0.6	0.7	4.6	1.7	2.7	0.9	3.9	0.5	0.1	0.4
Celtis species	0.3	0.1	0.6	2.8	0.0	0.7	1.7	1.9	1.2	2.1	4.3	0.2	1.0
Fraxinus texensis	1.5	4.4	3.5	0.7	0.0	1.6	NA	0.1	0.8	4.0	0.0	1.3	0.2
Juglans major	0.0	0.0	0.0	0.3	0.0	1.3	20.2	0.0	0.7	0.3	0.0	4.9	0.0
Other	2.0	1.2	6.8	18.0	5.1	6.1	5.7	6.5	7.3	10.3	19.4	17.6	5.2

* Values from Travis County by Beardmore (1994).

Behavior Measurement

A total of 31,254 instantaneous behavioral observations in 1,720 bouts was collected from the six study sites over three years. The mean number of observations per bout was 18.05 (4.5 min.) with a standard deviation of 25.09 (6.3 min.). All observations were included in the summary and analysis of behavior. Of the 1720 bouts 50% included 9 or fewer observations. Bouts including from 10 to 22 observations accounted for 25% of bouts, those including 23 to 57 observations accounted for 20%, those with 58 to 271 observations represent the remaining 5%. Some observations did not capture data for all categories of information sought, consequently when observations were sorted and tallied for different summaries the totals varied. Data collection in Somervell County during 1996 was very low because access to the warbler habitat at Dinosaur Valley State Park required crossing the Paluxy River in the riverbed that was frequently impassable because of heavy rains.

Table 3 summarizes all behavioral observations by behavior category, age and sex classes, and part of season.

TABLE 3. All behavioral observations by behavior category, sex and age, and part of season, sites and years combined.

	Sex and age						Part of season					
	Male		Female		Juvenile		March-April		May-June		Total	
Behavior	Obs.	%	Obs.	%	Obs.	%	Obs	%	Obs	%	Obs.	%
Our of sight	2726	12	523	12	247	6	2468	12	1028	9	3496	11
Vocalizations	3541	16	107	2	238	6	2434	12	1452	13	3886	12
Resting	10379	45	1693	38	2346	59	9234	47	5184	45	14418	46
Foraging	4115	18	1549	35	714	18	4028	20	2350	21	6378	20
Maintenance	1207	5	366	8	313	8	953	5	933	8	1886	6
Locomotion	774	3	199	4	65	2	650	3	388	3	1038	3
Pair Bonding	85	0	43	1	24	1	70	0	82	1	152	0
Total	22827		4480		3947		19837		11417		31254	

Table 4 lists the number of male territories mapped at each study site by other studies (Texas Department of Transportation 1994, Booher and Newnam 1996, Abbruzzese 1996). No census was conducted for females or juveniles.

TABLE 4. Male territories by site.

County	Territories
Somervell	5
San Saba	17
Travis	55
Hays	7
Comal	12
Bandera	90
Total	186

The following tables present the results of height class use preference compared to vegetation volume for all behaviors combined (Table 5) and for foraging behavior only (Table 6). Table 7 compares height class use for each site by age, sex and part of breeding season for all behaviors combined. Table 8 compares height class use for each site by age, sex and part of breeding season for foraging behavior only.

Table 5. Height classes used by Golden-cheeked Warblers, all behaviors, seasons and years combined by site. Height classess and vegetation volume proportion value used significantly different than occur are bolded.

Site	Height Class	Vegetation volume (m^3/m^2)	Proportion of total vegetation volume	Number of warbler observations	Expected number of warbler observations	Proportion of observations in each height class	Difference between actual and expected observations	Bonferroni confidence interval
Somervell	**0-3**	36.5	**0.466**	497	1159	0.200	-0.266	0.192≤p≤1.201
	4+5	26.9	**0.344**	705	855	0.284	-0.060	0.275≤p≤1.285
	>5	14.9	**0.190**	1284	472	0.516	0.326	0.506≤p≤1.517
$X^2 = 654.54$, df = 2, $p < 0.05$		Cramer's Phi = 0.363, 13.2%						
San Saba	**0-3**	26.7	**0.265**	220	1109	0.053	-0.213	0.049≤p≤1.054
	4+5	21.1	0.210	857	876	0.205	-0.004	0.199≤p≤1.206
	>5	52.9	**0.525**	3101	2194	0.742	0.217	0.735≤p≤1.743
$X^2 = 750.25$, df = 2, $p < 0.05$		Cramer's Phi = 0.300, 9.0%						
Travis	**0-3**	105.0	**0.366**	340	3769	0.033	-0.333	0.031≤p≤1.034
	4+5	82.1	**0.287**	1499	2947	0.146	-0.141	0.142≤p≤1.147
	>5	99.4	**0.347**	8445	3568	0.821	0.474	0.817≤p≤1.822
$X^2=5313.08$, df=2, $p < 0.05$		Cramer's Phi=0.508, 25.8%						
Hays	**0-3**	17.3	**0.308**	408	1595	0.079	-0.229	0.075≤p≤1.080
	4+5	15.4	**0.274**	1648	1420	0.318	0.044	0.311≤p≤1.319
	>5	23.5	**0.418**	3128	2169	0.603	0.185	0.597≤p≤1.604
$X^2 = 894.00$, df = 2, $p < 0.05$		Cramer's Phi=0.294, 8.6%						
Comal	**0-3**	21.0	**0.311**	66	772	0.027	-0.284	0.023≤p≤1.028
	4+5	12.8	0.190	459	471	0.185	-0.005	0.177≤p≤1.186
	>5	33.8	**0.499**	1958	1240	0.789	0.289	0.780≤p≤1.790
$X^2 = 756.15$, df = 2, $p < 0.05$		Cramer's Phi = 0.390, 15.2%						
Bandera	**0-3**	45.5	**0.390**	338	1524	0.086	-0.304	0.082≤p≤1.087
	4+5	27.7	**0.237**	1082	928	0.277	0.039	0.270≤p≤1.278
	>5	43.5	**0.373**	2488	1456	0.637	0.264	0.629≤p≤1.638
$X^2 = 1037.26$, df = 2, $p < 0.05$		Cramer's Phi = 0.364, 13.3%						

TABLE 6. Height classes used by Golden-cheeked Warblers for foraging only, seasons and years combined by site. Height classes and vegetation volume proportion value used significantly different that occur are bolded.

Site	Height Class	Vegetation volume (m3 /m2)	Proportion of total vegetation volume	Number of warbler observations	Expected number of warbler observations	Proportion of observations in each height class	Difference between actual and expected observations	Bonferroni confidence interval
Somervell	**0-3**	36.5	**0.466**	101	174	0.2708	-0.195	0.248≤p≤1.272
	4+5	26.9	**0.344**	155	128	0.4155	0.072	0.390≤p≤1.417
	>5	14.9	**0.190**	117	71	0.3137	0.124	0.290≤p≤1.315
$X^2 = 33.21$, df = 2, $p < 0.05$				Cramer's Phi = 0.211, 4.5%				
San Saba	**0-3**	26.7	**0.265**	81	249	0.0862	-0.179	0.077≤p≤1.087
	4+5	21.1	**0.210**	255	197	0.2713	0.062	0.257≤p≤1.272
	>5	52.9	**0.525**	604	494	0.6426	0.117	0.627≤p≤1.644
$X^2 = 103.99$, df = 2, $p < 0.05$				Cramer's Phi = 0.235, 5.5%				
Travis	**0-3**	30.9	**0.383**	234	703	0.1275	-0.255	0.120≤p≤1.129
	4+5	26.0	**0.322**	681	591	0.3711	0.049	0.360≤p≤1.372
	>5	23.8	**0.295**	920	541	0.5014	0.206	0.490≤p≤1.502
$X^2 = 339.44$, df = 2, $p < 0.05$				Cramer's Phi = 0.304, 9.2%				
Hays	**0-3**	17.3	**0.308**	119	400	0.0916	-0.216	0.084≤p≤1.093
	4+5	15.4	**0.274**	555	356	0.4273	0.153	0.414≤p≤1.428
	>5	23.5	**0.418**	625	543	0.4811	0.063	0.467≤p≤1.482
$X^2 = 201.37$, df = 2, $p < 0.05$				Cramer's Phi = 0.278, 7.7%				
Comal	**0-3**	21.0	**0.311**	29	174	0.0517	-0.259	0.042≤p≤1.053
	4+5	12.8	**0.190**	156	106	0.2781	0.088	0.259≤p≤1.279
	>5	33.8	**0.499**	376	280	0.6702	0.171	0.650≤p≤1.671
$X^2 = 27.16$, df = 2, $p < 0.05$				Cramer's Phi = 0.336, 11.3%				
Bandera	**0-3**	45.5	**0.390**	114	472	0.0941	-0.296	0.086≤p≤1.095
	4+5	27.7	**0.237**	370	288	0.3055	0.068	0.292≤p≤1.307
	>5	43.5	**0.373**	727	451	0.6003	0.228	0.586≤p≤1.601
$X^2 = 293.59$, df = 2, $p < 0.05$				Cramer's Phi = 0.348, 12.1%				

TABLE 7. Golden-cheeked Warbler observations (number Obs. and %), all behaviors combined, by site, height class, sex and age, and part of breeding season.

		Sex and age						Part of breeding season			
	Height	Male		Female		Juveniles		March-April		May-June	
Site	class	Obs.	%	Obs.	%	Obs.	%	Obs.	%	Obs.	%
Somervell	0-3m	221	12	13	25	263	42	173	17	321	22
	4-5m	360	20	24	45	321	52	223	21	482	33
	>5m	1233	68	16	30	35	6	647	62	637	44
	Total	1814	100	53	100	619	100	1043	100	1440	100
		$X^2 = 736.64$, df = 4, $p < 0.05$						$X^2 = 78.09$, df = 2, $p < 0.05$			
San Saba	0-3m	136	4	84	15	0	0	134	5	90	6
	4-5m	664	19	185	33	8	14	506	20	351	22
	>5m	2765	78	288	52	48	86	1940	75	1161	72
	Total	3565	100	557	100	56	100	2580	100	1602	100
		$X^2 = 214.55$, df = 4, $p < 0.05$						$X^2 = 3.87$, df = 2, $p > 0.05$			
Travis	0-3m	338	5	436	26	402	30	705	9	540	20
	4-5m	1639	23	771	45	350	26	1881	25	879	33
	>5m	5090	72	493	29	573	43	4919	66	1237	47
	Total	7067	100	1700	100	1325	100	7505	100	2656	100
		$X^2 = 1710.53$, df = 4, $p < 0.05$						$X^2 = 354.64$, df = 2, $p < 0.05$			
Hays	0-3m	117	4	186	17	105	11	186	8	214	8
	4-5m	816	26	397	36	435	45	546	23	1102	40
	>5m	2176	70	529	48	423	44	1675	70	1453	52
	Total	3109	100	1112	100	963	100	2407	100	2769	100
		$X^2 = 399.39$, df = 4, $p < 0.05$						$X^2 = 180.87$, df = 2, $p < 0.05$			
Comal	0-3m	46	2	20	6	0	0	56	4	12	1
	4-5m	336	17	123	36	0	0	320	21	139	15
	>5m	1654	81	200	58	104	100	1176	76	782	84
	Total	2036	100	343	100	104	100	1552	100	933	100
		$X^2 = 122.26$, df = 4, $p < 0.05$						$X^2 = 26.59$, df = 2, $p < 0.05$			
Bandera	0-3m	199	7	101	18	38	8	193	7	139	11
	4-5m	707	25	156	28	219	44	673	25	409	34
	>5m	1952	68	292	53	244	49	1824	68	664	55
	Total	2858	100	549	100	501	100	2690	100	1212	100
		$X^2 = 162.65$, df = 4, $p < 0.05$						$X^2 = 63.27$, df = 2, $p < 0.05$			

TABLE 8. Golden-cheeked Warbler foraging observations (number Obs. and %) by site, height classes, sex and age, and part of breeding season.

		Sex and age						Part of breeding season			
	Height class	Male		Female		Juveniles		March-April		May-June	
Site	(m)	Obs.	%	Obs.	%	Obs.	%	Obs.	%	Obs.	%
Somervell	0-3m	62	23	2	13	37	40	43	34	57	23
	4-5m	97	37	9	56	49	53	44	35	111	45
	>5m	105	40	5	31	7	8	38	30	79	32
	Total	264	100	16	100	93	100	125	100	247	100
		$X^2 = 35.93$, df = 4, $p < 0.05$						$X^2 = 5.91$, df = 2, $p > 0.05$			
San Saba	0-3m	46	6	36	17	0	0	42	7	39	11
	4-5m	193	27	59	29	3	23	156	26	99	29
	>5m	483	67	111	54	10	77	399	67	205	60
	Total	722	100	206	100	13	100	597	100	343	100
		$X^2 = 28.68$, df = 4, $p < 0.05$						$X^2 = 7.04$, df = 2, $p > 0.05$			
Travis	0-3m	93	7	133	25	24	12	171	12	73	14
	4-5m	427	34	222	42	76	37	511	35	214	41
	>5m	726	58	178	33	108	52	771	53	241	46
	Total	1246	100	533	100	208	100	1453	100	528	100
		$X^2 = 141.91$, df = 4, $p < 0.05$						$X^2 = 8.54$, df = 2, $p < 0.05$			
Hays	0-3m	46	7	63	14	10	5	55	9	54	8
	4-5m	250	38	167	38	138	69	198	31	357	55
	>5m	366	55	207	47	52	26	392	61	233	36
	Total	662	100	437	100	200	100	645	100	644	100
		$X^2 = 86.16$, df = 4, $p < 0.05$						$X^2 = 86.01$, df = 2, $p < 0.05$			
Comal	0-3m	20	5	9	7	0	0	27	6	2	1
	4-5m	107	27	49	37	0	0	125	30	31	21
	>5m	272	68	73	56	31	100	264	63	112	77
	Total	399	100	131	100	31	100	416	100	145	100
		$X^2 = 23.06$, df = 4, $p < 0.05$						$X^2 = 11.39$, df = 2, $p < 0.05$			
Bandera	0-3m	62	7	42	19	10	6	56	7	56	13
	4-5m	250	30	60	27	60	37	240	31	130	30
	>5m	515	62	121	54	91	57	482	62	245	57
	Total	827	100	223	100	161	100	778	100	431	100
		$X^2 = 31.64$, df = 4, $p < 0.05$						$X^2 = 11.30$, df = 2, $p < 0.05$			

Table 9 presents tree species use compared to tree species vegetation volume by site for all behaviors combined. Table 10 presents tree species use compared to tree species vegetation volume by site for foraging behavior only. Table 11 compares tree species use among males, females and juveniles, and between parts of season for all observations by site. Table 12 compares tree species use among males, females and juveniles, and between parts of season for foraging observations only by site. Nest substrate tree species compared to % vegetation volume by site is shown in Table 13. Overall, height class use is very consistent in this study with the most use in the >5m class, next most use in the 4-5m class and the least use in the 0-3m class. At all sites for all behavioral observations combined, the warbler used the >5m height class significantly more than would be expected based on the vegetation volume and the 0-3m height class significantly less than would be expected. The 4-5m height class is used significantly more than expected at two sites, Hays and Bandera, and significantly less than expected at Somervell and Travis. The amount of variability in height classes used by warblers explained by vegetation volume ranged from 8.6% to 25.8% (Table 5). All height classes at all sites were used significantly different for foraging. Height class 0-3m was used significantly less at all sites. Height classes 4-5m and >5m were used significantly more at all sites. The amount of variability in height classes used for foraging explained by vegetation volume ranged from 4.5% to 12.1% (Table 6). Even though the differences were significant, vegetation volume does not appear to be the cause of the differential height class use. There is likely another factor not measured that may explain the differential height class use, such as prey availability

TABLE 9. Tree species used by Golden-cheeked Warblers for all behaviors combined, by study site. Species names and proportion of total vegetation volume values used significantly different than they occur are bolded.

Site	Tree species	Species vegetation volume (m^3/m^2)	Proportion of total vegetation volume	Number of warbler observations	Expected number of warbler observations	Proportion of warbler observations	Difference between proportions of observations and vegetation volume	Bonferroni confidence interval
Somervell	**Juniperus ashei**	49.8	**0.647**	1315	1567	0.534	**-0.113**	0.507≤p≤0.562
	Quercus buckleyi	11.5	**0.022**	429	362	0.174	**0.153**	0.153≤p≤0.195
	Quercus fusiformis & glaucoides	1.6	**0.134**	182	50	0.074	**-0.060**	0.060≤p≤0.088
	Ulmus crassifolia & americana	3.6	**0.049**	4	113	0.002	**-0.047**	-0.001≤p≤0.004
	Quercus sinuata	7.5	**0.091**	417	237	0.169	**0.078**	0.149≤p≤0.190
	Fraxinus texensis	3.2	**0.001**	112	101	0.046	**0.044**	0.034≤p≤0.057
	Celtis species	0.1	0.044	0	3	0.000	-0.044	
	Juglans major	0.0	0.000	0	0	0.000	0.000	
$X^2 = 257.34$, df = 6, $p < 0.05$		Cramer's Phi = 0.087, 0.75%						
San Saba	**Juniperus ashei**	38.8	**0.388**	1363	1558	0.338	**-0.050**	0.312≤p≤0.363
	Quercus buckleyi	2.7	**0.056**	336	110	0.083	**0.027**	0.068≤p≤0.098
	Quercus fusiformis & glaucoides	5.5	**0.027**	806	220	0.200	**0.173**	0.178≤p≤0.221
	Ulmus crassifolia & americana	29.0	**0.285**	11	288	0.003	**-0.282**	0.000≤p≤0.006
	Quercus sinuata	0.6	0.006	44	23	0.011	0.005	0.005≤p≤0.016
	Fraxinus texensis	0.7	**0.028**	6	27	0.001	**-0.027**	-0.001≤p≤0.004
	Celtis species	2.8	0.007	20	113	0.005	-0.002	0.001≤p≤0.009
	Juglans major	0.3	**0.003**	46	12	0.011	**0.008**	0.006≤p≤0.017
$X^2 = 810.49$, df = 7, $p < 0.05$		Cramer's Phi = 0.154, 2.37%						
Travis	**Juniperus ashei**	179.3	**0.637**	2028	2582	0.492	**-0.145**	0.470≤p≤0.513
	Quercus buckleyi	41.9	**0.071**	1077	603	0.261	**0.190**	0.242≤p≤0.280
	Quercus fusiformis & glaucoides	20.5	**0.136**	635	295	0.154	**0.018**	0.139≤p≤0.169
	Ulmus crassifolia & americana	3.5	**0.013**	12	51	0.003	**-0.010**	0.001≤p≤0.005
	Quercus sinuata	12.6	**0.046**	278	181	0.067	**0.022**	0.057≤p≤0.078
	Fraxinus texensis	5.0	0.007	46	72	0.011	0.004	0.007≤p≤0.016
	Celtis species	2.0	0.016	0	29	0.000	-0.016	
	Juglans major	4.1	0.013	0	59	0.000	-0.013	
$X^2 = 458.05$, df = 7, $p < 0.05$		Cramer's Phi = 0.091, 0.82%						
Hays	**Juniperus ashei**	39.6	**0.592**	1767	3691	0.337	**-0.255**	0.319≤p≤0.355
	Quercus buckleyi	8.4	**0.115**	761	788	0.145	**0.030**	0.132≤p≤0.158
	Quercus fusiformis & glaucoides	6.2	**0.114**	2402	583	0.458	**0.344**	0.439≤p≤0.477
	Ulmus crassifolia & americana	0.3	**0.069**	247	29	0.047	**-0.022**	0.039≤p≤0.055
	Quercus sinuata	0.1	**0.009**	22	8	0.004	**-0.005**	0.002≤p≤0.007
	Fraxinus texensis	0.0	0.012	0	0	0.000	-0.012	
	Celtis species	0.1	**0.008**	1	13	0.000	**-0.008**	0.000≤p≤0.001
	Juglans major	0.1	0.007	23	5	0.004	-0.003	0.002≤p≤0.007
$X^2 = 1986.86$, df = 6, $p < 0.05$		Cramer's Phi = 0.166, 2.74%						
Comal	**Juniperus ashei**	33.8	**0.530**	608	1139	0.248	**-0.281**	0.224≤p≤0.273
	Quercus buckleyi	4.9	**0.095**	398	164	0.163	**0.068**	0.142≤p≤0.183
	Quercus fusiformis & glaucoides	8.5	**0.082**	986	286	0.403	**0.321**	0.375≤p≤0.430
	Ulmus crassifolia & americana	8.4	0.089	259	284	0.106	0.017	0.089≤p≤0.123
	Quercus sinuata	3.8	0.039	89	130	0.036	-0.002	0.026≤p≤0.047
	Fraxinus texensis	0.0	**0.021**	32	0	0.013	**-0.007**	0.007≤p≤0.019
	Celtis species	2.2	**0.040**	3	75	0.001	**-0.038**	-0.001≤p≤0.003
	Juglans major	0.6	0.003	7	21	0.003	0.000	0.000≤p≤0.006
$X^2 = 743.43$, df = 7, $p < 0.05$		Cramer's Phi = 0.154, 2.37%						
Bandera	**Juniperus ashei**	53.2	**0.456**	660	1766	0.170	**-0.285**	0.153≤p≤0.188
	Quercus buckleyi	11.4	0.206	763	380	0.197	-0.009	0.179≤p≤0.215
	Quercus fusiformis & glaucoides	24.0	**0.098**	1716	796	0.443	**0.345**	0.420≤p≤0.466
	Ulmus crassifolia & americana	0.0	0.000	0	0	0.000	0.000	
	Quercus sinuata	0.1	**0.001**	21	2	0.005	**0.005**	0.002≤p≤0.009
	Fraxinus texensis	1.5	**0.002**	52	49	0.013	**0.012**	0.008≤p≤0.019
	Celtis species	0.2	0.013	0	7	0.000	-0.013	
	Juglans major	5.7	**0.049**	392	191	0.101	**0.052**	0.087≤p≤0.115
$X^2 = 1042.36$, df = 6, $p < 0.05$		Cramer's Phi = 0.148, 2.19%						

TABLE 10. Tree species used by Golden-cheeked Warblers for foraging only, by study site. Species names and proportion values used by golden-cheeked warblers significantly different than they occur are bolded.

Site	Tree species	Species vegetation volume (m^3/m^2)	Proportion of total vegetation volume	Number of warbler observations	Expected number of warbler observations	Proportion of warbler observations	Difference between proportions of observations and vegetation volume	Bonferroni confidence interval
Somervell	**Juniperus ashei**	49.8	**0.647**	208	236	0.562	**-0.085**	0.492≤p≤0.633
	Quercus buckleyi	11.5	**0.022**	53	55	0.143	**0.121**	0.093≤p≤0.193
	Quercus fusiformis & glaucoides	1.6	**0.134**	19	8	0.051	**-0.083**	0.020≤p≤0.083
	Ulmus crassifolia & americana	3.6	0.049	0	17	0.000	-0.049	
	Quercus sinuata	7.5	**0.091**	80	36	0.216	**0.125**	0.158≤p≤0.275
	Fraxinus texensis	3.2	**0.001**	10	15	0.027	**0.026**	0.004≤p≤0.050
	Celtis species	0.1	0.044	0	0	0.000	-0.044	
	Juglans major	0.0	0.000	0	0	0.000	0.000	
$X^2 = 40.96$, df = 5, $p < 0.05$		Cramer's Phi = 0.111, 1.23%						
				370				
San Saba	**Juniperus ashei**	38.8	**0.388**	253	360	0.271	**-0.117**	0.230≤p≤0.312
	Quercus buckleyi	2.7	**0.056**	92	25	0.099	**0.043**	0.071≤p≤0.126
	Quercus fusiformis & glaucoides	5.5	**0.027**	166	51	0.178	**0.151**	0.143≤p≤0.213
	Ulmus crassifolia & americana	29.0	**0.285**	329	265	0.350	**0.065**	0.306≤p≤0.394
	Quercus sinuata	0.6	0.006	13	5	0.014	0.008	0.003≤p≤0.025
	Fraxinus texensis	0.7	**0.028**	2	6	0.002	**-0.026**	-0.002≤p≤0.006
	Celtis species	2.8	0.007	7	26	0.008	0.001	0.000≤p≤0.015
	Juglans major	0.3	**0.003**	17	3	0.018	**0.015**	0.006≤p≤0.031
$X^2 = 140.44$, df = 7, $p < 0.05$		Cramer's Phi = 0.145, 2.10%						
Travis	**Juniperus ashei**	179.3	**0.637**	846	1241	0.427	**-0.210**	0.396≤p≤0.457
	Quercus buckleyi	41.9	**0.071**	712	290	0.359	**0.288**	0.330≤p≤0.389
	Quercus fusiformis & glaucoides	20.5	0.136	258	142	0.130	-0.005	0.109≤p≤0.151
	Ulmus crassifolia & americana	3.5	**0.013**	12	24	0.006	**-0.007**	0.001≤p≤0.011
	Quercus sinuata	12.6	**0.046**	127	87	0.064	**0.018**	0.049≤p≤0.079
	Fraxinus texensis	5.0	0.007	18	35	0.009	0.002	0.003≤p≤0.015
	Celtis species	2.0	0.016	0	14	0.000	-0.016	
	Juglans major	4.1	0.013	0	29	0.000	-0.013	
$X^2 = 343.13$, df = 7, $p < 0.05$		Cramer's Phi = 0.113, 1.28%						
Hays	**Juniperus ashei**	39.6	**0.592**	417	906	0.324	**-0.268**	0.288≤p≤0.359
	Quercus buckleyi	8.4	**0.115**	187	193	0.145	**0.030**	0.118≤p≤0.172
	Quercus fusiformis & glaucoides	6.2	**0.114**	570	143	0.443	**0.328**	0.405≤p≤0.480
	Ulmus crassifolia & americana	0.3	0.069	101	7	0.078	0.009	0.058≤p≤0.099
	Quercus sinuata	0.1	0.009	8	2	0.006	-0.003	0.000≤p≤0.012
	Fraxinus texensis	0.0	0.012	0	0	0.000	-0.012	
	Celtis species	0.1	0.008	0	3	0.000	-0.008	
	Juglans major	0.1	**0.007**	3	1	0.002	**-0.005**	-0.001≤p≤0.006
$X^2 = 525.67$, df = 6, $p < 0.05$		Cramer's Phi = 0.172, 2.95%						
Comal	**Juniperus ashei**	33.8	**0.530**	160	261	0.285	**-0.244**	0.232≤p≤0.338
	Quercus buckleyi	4.9	**0.095**	84	38	0.150	**0.055**	0.108≤p≤0.191
	Quercus fusiformis & glaucoides	8.5	**0.082**	232	66	0.414	**0.331**	0.356≤p≤0.471
	Ulmus crassifolia & americana	8.4	0.089	38	65	0.068	-0.021	0.038≤p≤0.097
	Quercus sinuata	3.8	0.039	19	30	0.034	-0.005	0.013≤p≤0.055
	Fraxinus texensis	0.0	0.021	13	0	0.023	0.003	0.006≤p≤0.041
	Celtis species	2.2	**0.040**	1	17	0.002	**-0.038**	-0.003≤p≤0.007
	Juglans major	0.6	0.003	2	5	0.004	0.000	-0.003≤p≤0.011
$X^2 = 168.46$, df = 7 $p < 0.05$		Cramer's Phi = 0.153, 2.34%						
Bandera	**Juniperus ashei**	53.2	**0.456**	145	550	0.120	**-0.336**	0.094≤p≤0.147
	Quercus buckleyi	11.4	0.206	219	118	0.181	-0.025	0.150≤p≤0.213
	Quercus fusiformis & glaucoides	24.0	**0.098**	567	248	0.470	**0.372**	0.429≤p≤0.511
	Ulmus crassifolia & americana	0.0	0.000	0	0	0.000	0.000	
	Quercus sinuata	0.1	0.001	6	1	0.005	0.004	-0.001≤p≤0.011
	Fraxinus texensis	1.5	0.002	2	15	0.002	0.000	-0.002≤p≤0.005
	Celtis species	0.2	0.013	0	2	0.000	-0.013	
	Juglans major	5.7	**0.049**	185	59	0.153	**0.104**	0.124≤p≤0.183
$X^2 = 465.39$, df = 6, $p < 0.05$		Cramer's Phi = 0.177, 3.14%						

TABLE 11. Golden-cheeked Warbler observations (number Obs. and %), all behaviors combined, by tree species, sex and age, and part of breeding season.

		Sex and Age						Part of Breeding Season			
		Male		Female		Juveniles		March-April		May-June	
Site	Species	Obs.	%	Obs.	%	Obs.	%	Obs.	%	Obs.	%
Somervell	Juniperus asheii	940	52	43	90	332	54	475	46	840	59
	Quercus buckleyi	314	17	4	8	111	18	236	23	193	14
	Quercus fusiformis & glaucoides	175	10	0	0	7	1	71	7	111	8
	Ulmus crassifolia & americana	3	0	1	2	0	0	1	0	3	0
	Quercus sinuata	255	14	0	0	162	26	186	18	231	16
	Fraxinus texensis	111	6	0	0	1	0	67	6	45	3
	Celtis species	0	0	0	0	0	0	0	0	0	0
	Juglans major	0	0	0	0	0	0	0	0	0	0
		$X^2 = 151.47$, df = 8, $p < 0.05$						$X^2 = 65.30$, df = 5, $p < 0.05$			
San Saba	Juniperus asheii	1098	34	252	49	13	42	802	33	561	41
	Quercus buckleyi	319	10	17	3	0	0	262	11	74	5
	Quercus fusiformis & glaucoides	734	23	61	12	11	35	444	18	362	27
	Ulmus crassifolia & americana	949	30	186	36	7	23	847	35	295	22
	Quercus sinuata	42	1	2	0	0	0	42	2	2	0
	Fraxinus texensis	6	0	0	0	0	0	0	0	6	0
	Celtis species	20	1	0	0	0	0	0	0	20	1
	Juglans major	46	1	0	0	0	0	6	0	40	3
		$X^2 = 83.46$, df = 6, $p < 0.05$						$X^2 = 7.86$, df = 3, $p < 0.05$			
Travis	Juniperus asheii	2887	40	757	48	1004	71	2918	39	1730	64
	Quercus buckleyi	2577	36	393	25	179	13	2905	39	244	9
	Quercus fusiformis & glaucoides	1387	19	250	16	62	4	1207	16	492	18
	Ulmus crassifolia & americana	14	0	18	1	1	0	18	0	15	1
	Quercus sinuata	220	3	140	9	148	11	331	4	177	7
	Fraxinus texensis	120	2	25	2	6	0	118	2	33	1
	Celtis species	6	0	0	0	5	0	6	0	5	0
	Juglans major	3	0	0	0	0	0	3	0	0	0
		$X^2 = 886.00$, df = 12, $p < 0.05$						$X^2 = 877.32$, df = 6, $p < 0.05$			
Hays	Juniperus asheii	882	28	430	40	455	47	584	24	1183	42
	Quercus buckleyi	584	18	172	16	5	1	453	19	308	11
	Quercus fusiformis & glaucoides	1530	48	409	38	463	48	1258	52	1144	41
	Ulmus crassifolia & americana	150	5	46	4	51	5	93	4	154	6
	Quercus sinuata	4	0	18	2	0	0	14	1	8	0
	Fraxinus texensis	0	0	0	0	0	0	0	0	0	0
	Celtis species	0	0	1	0	0	0	1	0	0	0
	Juglans major	23	1	0	0	0	0	23	1	0	0
		$X^2 = 329.05$, df = 8, $p < 0.05$						$X^2 = 250.57$, df = 5, $p < 0.05$			
Comal	Juniperus asheii	466	24	74	22	68	65	232	16	376	42
	Quercus buckleyi	277	14	116	35	5	5	330	22	68	8
	Quercus fusiformis & glaucoides	844	43	113	34	29	28	679	46	307	34
	Ulmus crassifolia & americana	253	13	5	2	1	1	177	12	82	9
	Quercus sinuata	69	4	20	6	0	0	28	2	61	7
	Fraxinus texensis	32	2	0	0	0	0	32	2	0	0
	Celtis species	2	0	0	0	1	1	0	0	3	0
	Juglans major	2	0	5	2	0	0	0	0	7	1
		$X^2 = 222.24$, df = 10, $p < 0.05$						$X^2 = 311.38$, df = 6, $p < 0.05$			
Bandera	Juniperus asheii	451	17	104	23	105	22	371	15	289	26
	Quercus buckleyi	651	24	86	19	26	5	674	27	89	8
	Quercus fusiformis & glaucoides	1371	51	177	38	168	35	1323	53	393	35
	Ulmus crassifolia & americana	0	0	0	0	0	0	0	0	0	0
	Quercus sinuata	14	1	1	0	6	1	14	1	7	1
	Fraxinus texensis	44	2	8	2	0	0	45	2	7	1
	Celtis species	0	0	0	0	0	0	0	0	0	0
	Juglans major	137	5	84	18	171	36	50	2	342	30
		$X^2 = 503.73$, df = 10, $p < 0.05$						$X^2 = 819.67$, df = 5, $p < 0.05$			

TABLE 12. Golden-cheeked warbler foraging observations (number Obs. and %) by tree species, sex and age, and part of breeding season.

		Sex and Age						Part of Breeding Season			
		Male		Female		Juveniles		March-April		May-June	
Site	Species	Obs.	%	Obs.	%	Obs.	%	Obs.	%	Obs.	%
Somervell	Juniperus asheii	0	0	0	0	0	0	0	0	0	0
	Quercus buckleyi	0	0	0	0	0	0	0	0	0	0
	Quercus fusiformis & glaucoides	0	0	0	0	0	0	0	0	0	0
	Ulmus crassifolia & americana	1	1	0	0	0	0	1	2	0	0
	Quercus sinuata	0	0	0	0	0	0	0	0	0	0
	Fraxinus texensis	0	0	0	0	0	0	0	0	0	0
	Celtis species	10	6	0	0	0	0	7	11	3	2
	Juglans major	145	93	14	100	49	100	53	87	155	98
		X^2 NA						X^2 NA			
San Saba	Juniperus asheii	152	23	97	49	4	40	150	26	103	35
	Quercus buckleyi	83	12	9	5	0	0	86	15	6	2
	Quercus fusiformis & glaucoides	146	22	15	8	5	50	84	14	82	28
	Ulmus crassifolia & americana	252	38	76	38	1	10	251	43	78	26
	Quercus sinuata	11	2	2	1	0	0	11	2	2	1
	Fraxinus texensis	2	0	0	0	0	0	0	0	2	1
	Celtis species	7	1	0	0	0	0	0	0	7	2
	Juglans major	17	3	0	0	0	0	0	0	17	6
		X^2 NA						$X^2 = 105.18$, df = 5, $p < 0.05$			
Travis	Juniperus asheii	499	40	219	42	128	63	489	34	357	68
	Quercus buckleyi	555	45	123	23	34	17	654	45	58	11
	Quercus fusiformis & glaucoides	129	10	109	21	20	10	187	13	71	14
	Ulmus crassifolia & americana	6	0	3	1	3	1	6	0	6	1
	Quercus sinuata	48	4	64	12	15	7	100	7	27	5
	Fraxinus texensis	9	1	7	1	2	1	15	1	3	1
	Celtis species	0	0	0	0	0	0	0	0	0	0
	Juglans major	0	0	0	0	0	0	0	0	0	0
		$X^2 = 165.39$, df = 8, $p < 0.05$						$X^2 = 236.65$, df = 5, $p < 0.05$			
Hays	Juniperus asheii	195	28	156	41	66	33	130	20	287	45
	Quercus buckleyi	159	23	26	7	2	1	147	23	40	6
	Quercus fusiformis & glaucoides	287	41	169	44	114	57	316	49	254	40
	Ulmus crassifolia & americana	59	8	24	6	18	9	46	7	55	9
	Quercus sinuata	1	0	7	2	0	0	2	0	6	1
	Fraxinus texensis	0	0	0	0	0	0	0	0	0	0
	Celtis species	0	0	0	0	0	0	0	0	0	0
	Juglans major	3	0	0	0	0	0	3	0	0	0
		$X^2 = 96.32$, df = 6, $p < 0.05$						$X^2 = 127.87$, df = 3, $p < 0.05$			
Comal	Juniperus asheii	106	27	29	22	25	81	85	21	75	54
	Quercus buckleyi	50	13	34	26	0	0	73	18	11	8
	Quercus fusiformis & glaucoides	171	44	56	43	5	16	189	46	43	31
	Ulmus crassifolia & americana	33	9	4	3	1	3	36	9	2	1
	Quercus sinuata	11	3	8	6	0	0	13	3	6	4
	Fraxinus texensis	13	3	0	0	0	0	13	3	0	0
	Celtis species	1	0	0	0	0	0	0	0	1	1
	Juglans major	2	1	0	0	0	0	0	0	2	1
		$X^2 = 54.34$, df = 6, $p < 0.05$						$X^2 = 64.86$, df = 5, $p < 0.05$			
Bandera	Juniperus asheii	95	12	39	19	11	8	100	14	45	11
	Quercus buckleyi	171	22	40	19	8	5	178	25	41	10
	Quercus fusiformis & glaucoides	451	59	90	43	26	18	436	60	131	33
	Ulmus crassifolia & americana	0	0	0	0	0	0	0	0	0	0
	Quercus sinuata	1	0	1	0	4	3	1	0	5	1
	Fraxinus texensis	2	0	0	0	0	0	2	0	0	0
	Celtis species	0	0	0	0	0	0	0	0	0	0
	Juglans major	49	6	39	19	97	66	6	1	179	45
		$X^2 = 344.94$, df = 6, $p < 0.05$						$X^2 = 369.49$, df = 3, $p < 0.05$			

TABLE 13. Nests by tree species and site with vegetation volume (Veg.) (%).

	All sites			Somervell		Bosque		San Saba		Travis		Blanco		Hays		Comal		Bexar		Bandera	
Species	Veg.	Nests	%	Veg.	Nests	Veg.	Nests	Veg.	Nests	Veg.	Nests	Veg.	Nests	Veg.	Nests	Veg.	Nests	Veg.	Nests	Veg.	Nests
Juniperus asheii	60.3	53	(64)	64.7	2	66.2	1	38.8	2	63.7	37	66.0	5	59.2	3	53.0		37.5		45.6	3
Quercus fusiformis & glacoides	10.5	12	(14)	2.2		3.8		5.6		7.1	2	13.5	1	11.5	3	9.5	2	23.0	1	20.6	3
Quercus buckleyi	7.2	1	(1.2)	13.4		9.7		2.7		13.6	1	3.6		11.4		8.2		2.9		9.8	
Ulmus crassifolia & americana	6.0	11	(13)	4.9		1.3		28.5	5	1.3	1	5.8		6.9	3	8.9		12.5	2	0.0	
Quercus sinuata	3.6	1	(1.2)	9.1		8.1		0.6		4.6	1	2.7		0.9		3.9		0.5		0.1	
Celtis species	1.3	2	(2.4)	0.1		0.6		2.8		0.7	2	1.9		1.2		2.1		4.3		0.2	
Fraxinus texensis	1.5	1	(1.2)	4.4		3.5		0.7		1.6	1	0.1		0.8		4.0		0.0		1.3	
Juglans major	0.6	1	(1.2)	0.0		0.0		0.3		1.3	1	0.0		0.7		0.3		0.0		4.9	
Other	8.8	1	(1.2)	1.2		6.8		18.0		6.1		6.5		7.3		10.3		19.4		17.6	1
Nest totals		83			2		1		7		46		6		9		2		3		7

(Keane and Morrison 1999).

GCW use of height classes differed significantly among males, females and juveniles within each site at all sites for all behaviors and foraging only (Table 7 and Table 8). Warbler use of height class for all behaviors differed significantly between parts of season within each site at five sites, with no difference at the San Saba site. Use of height classes for foraging differed significantly between parts of season within each site at four sites, with no difference at the Somervell and San Saba sites.

Males use the >5m class most with the 4-5m class next in use and the 0-3m class the least. For foraging only the males use the >5m class less and the 4-5m and 0-3m classes more, although they are still used most to least from the highest to the lowest; this shift approaches the pattern of use by females.

Females use the >5m and 4-5m classes similarly, with use for the >5m class highest at some sights and the 4-5m class highest at others. Females use the 0-3m class more than males. Females appear to use height classes the same for all behaviors and foraging only.

Juveniles use the lower two height classes more at four sites, but all classes similar to males at San Saba and Comal for all behaviors and foraging only.

Males, females and juveniles combined use height classes most to least from the highest to the lowest classes in the first-half of the season for all behavior and similarly for foraging only with the exception of Somervell. Height class use in the second half of the season follows the same pattern as the first half with Somervell being the one exception for foraging only.

Use of each tree species for all behaviors combined and foraging only compared to vegetation volume of the tree species showed consistent use in only one of the eight species tested. Juniper was used significantly less than available at all sites for all behaviors and foraging only (Tables 9 and 10). Use of all other tree species for all behaviors and foraging only vary in significance and use more or less than the species occur. Tree species use differed significantly among males, females and juveniles, as well as between the parts of the breeding season for all behaviors combined and for foraging only, at all sites (Table 11 and Table 12). Even though the differences in use of tree species were significant, vegetation volume does not appear to be the cause of the differential species use. Again, as in the height class use, there is likely another factor not measured that may explain the differential height class use, such as prey availability.

Substrate used by GCWs was very consistent and similar for all behaviors and foraging only at all sites by age, sex and part of season. Ground and trunk substrate were used 1% or less in all categories, branches were used from 27% to 40% of the time across categories and twigs were used 60% to 73% of the time. No measurements of the amount of substrate available in each category were collected; therefore no comparisons can be made between the warblers' use and availability of the substrate category.

Substrate tree species for nests were recorded for the 83 nests found with 64% occurring in Ashe juniper (Table 13). Of the 83 nests found, 63 were found in place upon return after the season for measurement of placement height. No nests were in the 0-3 m height class, 10 (16%) were in the 4-5 m height class, and 53 (84%) were above 5 m.

DISCUSSION AND CONCLUSIONS

Holmes and Robinson (1981) point out that birds may use certain plant species preferentially and that this can be important to understanding the habitat of the species. Franzreb (1978) states that birds do not regard all trees of the same height and profile, belonging to different species, as being equally desirable for such activities as foraging and nesting. Balda (1969) points out that volume of foliage may be an important factor in limiting the density of some species of birds. One of the tasks of the GCW Recovery Plan indicates the need and importance of a definitive study of the habitat requirements and habitat selection patterns of GCWs; this study should include measurements of vegetation structure and form and warbler foraging behavior (Keddy-Hector 1992).

Only one previous study has considered the species composition and vegetation structure of GCW habitat (Beardmore 1994). Some results from this study support part of Beardmore’s (1994) findings, while others differ. Beardmore’s (1994) study included two sites in Travis County where she sampled 3 territories at each site for each year. Therefore, she sampled maximum of 12 individuals 12. Her sites were also chosen to include specific topography; canyon tops, slopes and creek bottoms.

Use of substrate is consistent in this study and matches Beardmore’s findings closely. As Beardmore discusses, the preferential use of the foliage, twigs and to a lesser extent the branches, is expected in this species and was confirmed by her study and this study.

In height classes Beardmore found warblers to use the >5 m class more than other classes except that males foraged more in the <3m class. Females used the <5 m classes for a significant amount of time. She also reported a significant amount of juvenile observations in the <3 m class, with warblers doubling the percentage use of the <3 m class when young were present. Results for Travis County from this study differ in that males did not forage more in the <3 m class, other results are similar (Table 7 and Table 8).

Part of the differences between height class use for Travis County in this study and Beardmore's may be related to the choice of sites, and the limited number of sites and individual birds she studied. Using set height classes to study the warbler may also account for part of the differences, based on the significant difference in canopy height among all sites from this study. It would be better to categorize the height classes by height proportions of the habitat to adjust for the canopy height differences. Sample size and site selection may also explain some of the difference between this study and that of Beardmore (1994) for tree species use. Beardmore (1994) studied two sites for two years selecting sites to include various topography within each site.

Beardmore (1994) found that GCWs in Travis county used plateau live oak more in March and April (61% of all observations, 88% of foraging observations), with Ashe juniper next in amount of use (12% of all observations, 6% of foraging observations), but changed to less use of plateau live oak (38% of all observations, 27% of foraging observations) and more use of Ashe juniper (31% of all observations, 49% of foraging observations) in May and June. Results from this study for Travis County differed considerably in March and April, with Ashe juniper use of 39% of all observations and

34% of foraging observations, Texas oak used in 39% of all observations and 45% of foraging observations and live oak used 16% of all observations and 13% of foraging (Table 11 and Table 12). Again, study site selection and sample size may account for much of these differences based on the differences in species composition shown for Travis County from this study and Beardmore's (1994) in Table 2.

As discussed above, prey availability is known to affect habitat use. Wharton, et al. (1996) studied the arthropod fauna available by height classes (0-3, 3-5 and >5m) in occupied GCW habitat in Travis county focusing on Ashe juniper, Texas oak, plateau live oak and cedar elm. Their study included one site for two years, with a second site added in year two. Results indicate a large number of suitable prey are available in all three height classes, but with more arthropods collected in the 0-3m class than in either the 3-5m or >5m classes. Results also show that arthropods in general occur in roughly comparable numbers on all four tree species. The study illustrated the high variability of occurrence among insect taxonomic groups within and between years.

This study supports my prediction that GCWs prefer the twigs and foliage substrate and the mid and upper height classes consistently, range-wide. In addition, the study also supports my prediction that the GCW uses tree species disproportionately compared to the tree species occurrence by vegetation volume at a site. Warblers successfully occupy sites that vary significantly in vegetation characteristics both in structure and species composition. Therefore a site-specific study may not apply across the range of the GCW. Any habitat manipulation effort must consider tree species composition and structure use by the GCW within the particular area of the GCW range under consideration.

LITERATURE CITED

Abbruzzese, C. 1996. 1996 Golden-cheeked Warbler surveys: lower bull creek macrosite. Unpublished report, City of Austin Parks Department. Austin, TX.

Altmann, J. 1974. Observational study of behavior: Sampling Methods. Behaviour 49: 227-265.

Arnold, K. A., Cade L. Coldren, and Mark L. Fink. 1996. The interactions between avian predators and Golden-cheeked Warblers in Travis County, Texas. Research Report 1983-2. DOT Report TX-96/1983-2. Texas Transportation Institute. College Station, TX.

Attwater, H. P. 1892. List of birds observed in the vicinity of San Antonio, Bexar County, Texas. Auk 9:229-238.

Balda, R. P. 1969. Foliage use by birds of the oak-juniper woodland and ponderosa pine forest in southeastern Arizona. The Condor 71:399-412.

Beardmore, C. J. 1994. Habitat use of Golden-cheeked Warblers in Travis County, Texas. M.Sc. thesis, Texas A&M University, College Station, TX.

Booher, D., and Cal Newnam. 1996. Golden-cheeked warbler surveys on state park lands. Unpublished report, Texas Department of Transportation, Austin, TX.

Butcher, J. A. 2008. Minimum patch size thresholds of reproductive success of songbirds. Ph.D. diss., Texas A & M University, College Station, TX.

Butler, R. G. 1980. Population size, social behavior, and dispersal in house mice: a quatitative investigation. Animal Behavior 28:78-85.

Chapman, F. M. 1907. The warblers of North America. D. Appleton & Co., New York, NY.

Cody, M. L. 1985. Habitat selection in birds. Academic Press, San Diego, CA.

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

Franzreb, K. E. 1978. Tree species used by birds in logged and unlogged mixed-coniferous forests. The Wilson Bulletin 90:221-238.

Gass, L.1996. Nesting behavior of Golden-cheeked Warblers in Travis County, Texas. M.A. thesis, Southwest Texas State University, San Marcos, TX.

Hatch, S. L., N. Gandhi Kancheepuram, and Larry E. Brown. 1990. Checklist of the Vascular Plants of Texas. MP-1655, Texas Agricultural Extension Service, College Station, TX.

Hilden, O. 1965. Habitat selection in birds. Annales Zoologici Fennici 2:53-75.

Holmes, R. T., and Scott K. Robinson. 1981. Tree species preferences of foraging insectivorous birds in a northern hardwood forest. Oecologia 48:31-35.

Johnston, M. C., W. L. Thompson, and E. Kincaid. 1952. 16th Breeding bird census. Audubon Field Notes 6:323-324.

Keane, J. J., and Michael L. Morrison. 1999. Temporal variation in resource use by black-throated gray warblers. The Condor 101:67-75.

Keddy-Hector, D. P. 1992. Golden-cheeked Warbler (*Dendroica chrysoparia*) Recovery Plan. U. S. Fish and Wildlife Service, Albuquerque, NM.

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

Lack, D. 1933. Habitat selection in birds with special reference to the effects of afforestation on the Breckland avifauna. Journal of Animal Ecology 2:239-262.

Ladd, C. G. 1985. Nesting habitat requirements of the Golden-cheeked Warbler. M.Sc. thesis, Southwest Texas State University, San Marcos, TX.

Martin, P. R., and Patrick Bateson. 1993. Measuring behavior: an introductory guide. 2nd ed. Cambridge Univ Press, Cambridge.

Mills, G. Scott, John B. Dunning, Jr., and John M. Bates. 1991. The relationship between breeding bird density and vegetation volume. Wilson Bulletin 103(2): 468-479. (Keane and Morrison 1999).

Morrison, M. L., Bruce G. Marcot, and R. William Mannan. 2006. Wildlife-habitat relationships: concepts and applications. 3rd ed. Island Press, Washington, DC.

Nature Conservancy, The. 2007. Endangered species monitoring and management at Fort Hood, Texas: 2007 annual report. Fort Hood, TX.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

Ott, R. L. 1993. An introduction to statistical methods and data analysis. 4th ed. Duxbury Press, Belmont, CA.

Pulich, W. M. 1976. The Golden-cheeked Warbler: A Bioecological Study. Texas Parks and Wildlife Department, Austin, TX.

Riskind, D. H., and D. D. Diamond. 1986. Plant communities of the Edward's Plateau of Texas: and overview emphasizing the Balcones Escarpment zone between San Antonio and Austin with special attention to landscape contrasts and natural diversity., p. 21-32. *In* P. L. Abbott, and C. M. Woodruff [eds.], The Balcones Escarpment, Central Texas. Geologic Society of America, Austin, TX.

SPSS. 2006. Version 15. SPSS Incorporated, Chicago, IL.

Svardson, G. 1949. Competition and habitat selection in birds. Oikos 1:157-174.

Texas Department of Transportation. 1994. 1994 Golden-cheeked Warbler survey of properties in the cypress creek macrosite, Travis County, Texas. Unpublished report, Texas Department of Transportation, Austin, TX.

Travis County.1999. Balcones Canyonlands Preserve Management Handbook VII. Golden-cheeked Warbler Management. Travis County Transportation and Natural Resources, Austin, TX.

USDI Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; final rule to list the Golden-cheeked Warbler. Federal Register 55:53153-53160.

Wahl, R., D. D. Diamond, and Denise Shaw. 1990. The Golden-cheeked Warbler: a status review. U. S. Fish and Wildlife Service, Fort Worth, TX.

Weins, J. A., Stephen G. Martin, Walter R. Holthaus, and Frank A. Iwen. 1970. Metronome timing in behavioral ecology studies. Ecology 51:350-352.

Werner, E. E., and D. J. Hall. 1979. Foraging efficiency and habitat switching in competing sunfishes. Ecology 60:256-264.

Werner, E. E., J. F. Gilliam, D. J. Hall, and G. G. Mittelbach. 1983. An experimental test of the effects of predation risk on habitat use in fish. Ecology 64:1540-1548.

Wharton, R. A., E. G. Riley, M. A. Quinn, J. B. Wooley, J. S. Schaffner, and H. R. Burke. 1996. Invertebrate species available as food for the Golden-cheeked Warbler in its nesting habitat. Research Report 1983-3F. Texas Transportation Institute, College Station, TX.

Wilkins, N., and Mike Morrison. 2007. Leon river restoration project phase II report: section 2.0 wildlife component. http://irnr.tamu.edu/lrrp/ (11 July 2008).

APPENDIX A

TABLE 14. Vegetation volume (%) of all plant species detected in vegetation transects by county.

Species	Palo Pinto	Somervell	Bosque	San Saba	Burnet	Travis	Blanco	Hays	Comal	Bexar	Bandera	Uvalde
Acacia berlandieri										< 0.1		0.4
Acacia greggi				0.1		< 0.1						
Acacia roemeriana		0.1						< 0.1		0.1	0.1	
Acacia species	< 0.1					< 0.1				< 0.1		
Acacia wrightii												0.1
Acer grandidentatum											6.3	
Aesculus pavia						< 0.1	< 0.1		0.1	1.2	0.7	0.1
Amorpha fruticosa						< 0.1						
Ampelopsis arborea								< 0.1				
Arbutus xalapensis												0.1
Berberis Swaseyi								< 0.1				
Berberis trifoliata	0.1	< 0.1		0.3		0.1	0.3	0.1		0.8	< 0.1	0.3
Buddleia racemosa								< 0.1				
Bumelia lanuginosa	0.2	0.3	0.3	1.0		0.1	< 0.1		0.3	0.3	0.2	0.1
Burkemia scandens						0.2						
Callicarpa americana						0.1		< 0.1				
Carya illinioensis				8.6					0.6			
Celtis species	0.3	0.1	0.6	2.8		0.7	1.7	0.8	2.0	4.3	0.2	
Cercis canadensis			< 0.1			0.1				< 0.1	< 0.1	0.1
Condalia species						< 0.1						1.0
Cornus drummondii			< 0.1			0.1			< 0.1			
Croton alabamensis						0.5						
Croton species										0.1		
Diospyros texana				3.7	0.0	0.5	3.2	0.6	3.3	7.7	0.4	1.2
Eupatorium havanese				< 0.1			< 0.1	0.1		< 0.1		< 0.1
Eysenhardtia texana						< 0.1	0.1	< 0.1				
Forestieria pubescens	0.1		0.4		< 0.1	0.1		< 0.1		0.8		< 0.1
Forestiera reticulata		< 0.1								0.3		0.5
Fraxinus pennsylvanicus	< 0.1						0.4	0.1				
Fraxinus texensis	1.5	4.1	3.4	0.7		1.8	0.1		4.0		1.3	0.2
Garrya ovata						0.5				0.2	< 0.1	< 0.1
Illex decidua			1.9	0.1		0.2		1.4	0.8	< 0.1		
Illex vomitoria				0.3		0.5	< 0.1	1.2	< 0.1			

TABLE 14. Continued.

Species	Palo Pinto	Somervell	Bosque	San Saba	Burnet	Travis	Blanco	Hays	Comal	Bexar	Bandera	Uvalde
Juglans species						1.4		0.9	0.5		4.9	
Juniperus ashei	80.0	63.7	66.6	38.6	82.0	62.6	64.7	56.1	52.9	37.5	45.6	67.6
Ligustrum species						< 0.1				< 0.1		
Melia azedarach		0.3							0.2	0.7		
Mimosa species								< 0.1				
Morus microphylla								< 0.1			< 0.1	
Morus rubra				0.1		< 0.1	< 0.1		0.1			
Parthenocissus quinquefolia		0.1	0.1	0.2		< 0.1		0.1		0.4	< 0.1	< 0.1
Passiflora species								< 0.1				
Philadelphus ernestii							< 0.1					
Philadelphus texensis											< 0.1	
Photinia species						< 0.1						
Platunus occidentalis				1.3		0.1			0.2		2.9	
Prosopis glandulosa	0.2						1.8	0.3				
Prunus mexicana				0.1		0.1						
Prunus serotina						0.6		0.9		0.4	3.5	0.2
Ptelea trifoliata			< 0.1	0.1		0.1		< 0.1	< 0.1	0.2	< 0.1	0.4
Quercus buckleyii	1.7	14.7	9.8	2.7		14.6	3.1	14.1	8.2	2.9	9.8	9.7
Quercus fusiformis	1.3	2.0	3.6	5.5	11.1	7.2	13.4	15.1	9.3	13.5		5.2
Quercus glaucoides	0.8								0.2	9.5	20.6	10.7
Quercus muhlenbergii								0.6			0.2	
Quercus sinuata	11.3	9.6	7.9	0.6	0.7	4.4	2.4	0.7	3.8	0.5	0.1	0.4
Quercus stellata	1.1	0.1			4.8		2.0		0.6			
Rhamnus caroliniana			0.3			0.5				0.1	< 0.1	
Rhus aromatica		< 0.1	< 0.1			< 0.1				< 0.1		
Rhus lanceolata			1.5					< 0.1				
Rhus radicans		0.1	0.6			0.1	< 0.1	< 0.1		< 0.1		
Rubus trivialis										< 0.1		
Rhus virens						0.1		< 0.1	< 0.1			0.3
Salix nigra				1.9								
Salvia ballotiflora												0.2
Sapindus saponaria				0.3					0.1			
Smilax bona-nox	0.1	< 0.1	0.1	1.1		0.2	0.2	0.1	0.4	0.7	0.1	0.2

Table 14. Continued.

Species	Palo Pinto	Somervell	Bosque	San Saba	Burnet	Travis	Blanco	Hays	Comal	Bexar	Bandera	Uvalde
Sophora affinis	0.1			0.1		< 0.1				0.1		
Sophora secundiflora				0.1		0.2				3.9	1.2	0.2
Styrax platanifolius											0.0	
Taxodium distichum									3.0			
Tilia americana									0.4		0.6	
Ungnadia speciosa		< 0.1	0.2			0.1		< 0.1	< 0.1	0.1	0.1	0.2
Ulmus americana				4.4								
Ulmus crassifolia	1.1	4.6	1.2	24.0	1.1	1.2	6.4	3.9	8.8	12.5		0.1
Viburnum rufidulum			0.6		0.2	0.2	0.1	0.1				
Vitis species		0.2	0.4	0.7		1.1	0.4	0.3	0.3	0.2	1.1	0.0
Yucca species						< 0.1						
Zanthoxylum hirsutum												0.3
Total number of species	17	19	23	27	8	45	23	35	28	36	29	30
Number of transects	31	58	54	81	24	155	77	59	89	61	97	50

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