Section 6 (Texas Traditional) Report Review

Attachment to letter dated (mm/dd/yyyy): _____

This form emailed to FWS section 6 coordinator (mm/dd/yyyy): 01/03/2010

TPWD signature date on report: N/A emailed directly from author

Project Title: Five-year Status Review: Golden-cheeked Warbler

Final or Interim Report? Final

Grant #: TX E-102

Reviewer Station: Austin ESFO

Lead station was contacted and concurs with the following comments:

☐ Yes ☐ No ☒ Not applicable (reviewer is from lead station)

Interim Report (check one):	Final Report (check one):
☐ Is acceptable as is (no comments)	☒ Is acceptable as is (no comments)
☐ Is acceptable as is, but comments below need to be addressed in the next report	☐ Is acceptable, but needs minor revision (see comments below)
☐ Needs revision (see comments below)	☐ Needs major revision (see comments below)

Comments:

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. TX E-102-R

Endangered and Threatened Species Conservation

Five-year Status Review: Golden-cheeked Warbler

Prepared by:

Julie Groce, Heather Mathewson, Micheal Morrison, Neal Wilkins

TEXAS PARKS & WILDLIFE

Carter Smith
Executive Director

Clayton Wolf
Director, Wildlife

15 April 2010

FINAL REPORT

STATE: ____Texas_______________ **GRANT NUMBER:** ___TX E-102-R___

GRANT TITLE: Five-year Status Review: Golden-cheeked Warbler

REPORTING PERIOD: ____1 Oct 08 to 31 Mar 2010_

OBJECTIVE(S):

To conduct in one year a status review of the Golden-cheeked Warbler.

Segment Objectives:

Task 1. **Updated information and current species status.**_ Summarize new information, citing detailed information and analyses and provide an updated status of the species, citing new information about the species and its breeding, wintering, and migratory range.

Task 2. **Electronic GIS layers** (shapefiles or geodatabases).

Task 3. **An annotated bibliography** using Reference Manager, ProCite or some other form of bibliographic software that can export to an RIS format, and copies (pdfs) of all literature (not already in FWS files) pertaining to the species since the time of listing.

Significant Deviations:

None.

Summary Of Progress:

Attached files contain:
Attachment A – the Five-year Status Review document (pdf)
Attachment B – zip file containing Personal Communications among Review participants.

Files to be sent separately:
Electronic files: Subgrantee is to deliver electronic GIS files to Austin ES Office.
Literature cited files: These will be mailed separately as two CDs to Austin ES Office.

Location: Texas State University, San Marcos, Texas.

Cost: ___Costs were not available at time of this report, they will be available upon completion of the Final Report and conclusion of the project.__

Prepared by: _Craig Farquhar_____________ **Date:** _15 April 2010

Approved by: ______________________ **Date:**_____15 April 2010__
C. Craig Farquhar

SCIENTIFIC EVALUATION FOR THE 5-YEAR STATUS REVIEW OF THE GOLDEN-CHEEKED WARBLER

November 2010

Prepared for
U.S. Fish and Wildlife Service

Prepared by
Julie E. Groce, Heather A. Mathewson, Michael L. Morrison, and Neal Wilkins

Institute of Renewable Natural Resources
and the
Department of Wildlife & Fisheries Sciences
Texas A&M University, College Station,Texas

Table of Contents

Figures

Tables

Executive Summary

The golden-cheeked warbler (*Dendroica chrysoparia*) was listed as federally endangered in 1990. Habitat loss and fragmentation due to juniper clearing, urban encroachment, and lack of oak recruitment, and an increasing threat of brown-headed cowbird parasitism, were given as the primary threats to the species at the time of listing. Herein we provide the scientific evaluation for the 5-year status review of the golden-cheeked warbler. We compiled, summarized, and evaluated available information on the warbler to provide a foundation for U.S. Fish and Wildlife Service's assessment of the species' status, the first such review since 1990.

In the spring and summer, golden-cheeked warblers breed in woodlands of central Texas that contain a mix of mature Ashe juniper (*Juniperus ashei*) and oak (*Quercus* spp.) and provide necessary food and nesting resources. Since 1990, potential breeding habitat for golden-cheeked warblers has been mapped using satellite imagery. Estimates for the amount of habitat have ranged from approximately 215,066 to 1.77 million ha (531,440 to 4.37 million ac). Differences in estimates are primarily due to methods used for delineating habitat (e.g., the specificity or generality of the author's definition of potential habitat). However, patterns of habitat distribution are relatively consistent across mapping projects regardless of delineation methods: smaller, isolated patches of habitat are more prominent in the northern portion of the range while larger, contiguous patches occur in the south.

The warbler winters in the highlands of Mexico and Central America and is typically found in pine-oak (*Pinus-Quercus* spp.) forests of the region. This Central American pine-oak forest ecoregion covers approximately 9.7–11.1 million ha (24.0–27.4 million ac) from southern Mexico into Nicaragua, with the majority occurring in Honduras and Guatemala. Less than 2.7 million ha (6.6 million ac) of the ecoregion are estimated to be forested. Within the ecoregion there is an estimated 1.95 million ha (4.8 million ac) of wintering habitat for the warbler.

In 1976, Pulich provided the first range-wide warbler population estimate of 14,950 individuals. This value was the product of warbler densities from 3 study sites and on-the-ground estimates of the amount of potential habitat. All range-wide population estimates made since that time have been based on the same general method (i.e., the product of warbler territory densities and amount of potential habitat), using territory density estimates derived from a limited number of study sites and the amount of potential habitat estimated from satellite imagery. In 1990, just prior to the species being listed as federally endangered, researchers estimated a population size of 9,644–32,032 individuals. Post-1990 estimates suggest 40,890–228,426 individuals could potentially occur on the breeding grounds. At the time of this review's completion, there were no published, reliable population estimates for the species beyond raw extrapolation. However, survey data from 2004 through 2009 suggests a minimum population number of 8,759 individuals. Approximately half this value is based on population estimates from long-term research at Fort Hood Military Reservation, Camp Bullis Training Site, and Balcones Canyonlands National Wildlife Refuge. The remaining number consists of individual warblers detected and counted during surveys on numerous public and private properties covering a relatively small portion of the potential habitat in the breeding range.

Across the breeding range, the variability in the known number of confirmed individuals or territories is mainly related to survey effort. Thus far, survey effort has focused on a relatively small fraction of the species' range. For example, Recovery Region 3 encompasses Fort Hood and contains about 5–10% of the species' potential habitat, yet recent population estimates suggest this region supports an estimated 4,482 breeding males, or approximately 51% of the known population. Regions 7 and 8, however, contain 35–55% of the species' potential breeding habitat, yet combined estimates from surveys within these regions account for about 5% of the known population. Given that the amount of potential habitat on and surrounding Fort Hood is approximately 5–10% of the total potential habitat across the breeding range, it is unlikely that Fort Hood harbors half the existing population of golden-cheeked warblers as suggested in our compilation of known and estimated warbler numbers. Rather, the relative lack of warbler population estimates from other areas in the breeding range reflects the fact that both the species and the habitat have not been well studied outside of Fort Hood.

Habitat loss and fragmentation continue to be the primary threat to the species. Habitat patch size appears to be an important variable influencing warbler habitat occupancy, abundance, and reproductive success. Patches of otherwise suitable habitat that are below a threshold of approximately 20 ha (50 ac) are not likely to successfully support breeding warblers in some parts of the breeding range. As landscapes throughout the breeding range continue to be fragmented by urbanization and the subdividing of large farms and ranches, it will become increasingly common for patches of breeding habitat to fall below this patch-size threshold. In addition, the loss and subsequent lack of oak recruitment into existing breeding habitat is likely to emerge as a greater threat to the species than was realized in 1990. Mortality of mature trees from oak wilt is prevalent throughout the central portion of the warbler's breeding range. Additionally, browsing pressure from increased densities of white-tailed deer and exotic ungulates is a primary factor in suppressing the recruitment of trees. The deterioration of oak canopy and shifting species composition resulting from these factors may result in reduced ability of the habitat to support breeding warblers.

While direct trend data are not available, indirect measures suggest an overall loss in breeding habitat of 5–10% since 1990. However, post-1990 estimates of woodland cover suggest a larger amount of habitat existed in 1990 than originally approximated. Most habitat loss has occurred in areas experiencing high rates of urban development. Between 1992 and 2001, land classified as woodland declined by approximately 116,421 ha (287,683 ac) throughout the species breeding range, which amounts to a 5.7% range-wide net loss of the land cover type likely to contain suitable breeding habitat for the species. The greatest proportional losses were in the central and southeastern regions of the breeding range. Although these conversions are not specific to golden-cheeked warbler habitat, the relative shifts provide an index for the portion of breeding habitat that was likely lost during this period. Adequate information did not exist at the time of this writing to directly determine habitat loss between 2001 and the base year for this review (2009), although we can assume through the conversion of private farms and ranches to other uses, the fragmentation of large ownership parcels into smaller parcels, the increasing human population and increasing building activity that continued development in these regions has resulted in further losses to the species' breeding habitat.

Habitat loss and fragmentation also threaten pine-oak forests on the wintering grounds. Although difficult to quantify, habitat loss and fragmentation are primarily due to urban development, fires, and the extraction of timber, charcoal, and firewood. Between 1990 and 2005, the United Nations Food and Agriculture Organization estimated average annual forest loss for each country was estimated at 318,667 ha/year (787,443 ac/year) in Mexico, 54,000 ha/year (133,437 ac/year) in Guatemala, 5,000 ha/year (12,355 ac/year) in El Salvador, 182,667 ha/year (451,380 ac/year) in Honduras, and 90,000 ha/year (222,395 ac/year) in Nicaragua (Table 7.7). These numbers, however, are for all forest cover types and are not specific to golden-cheeked warbler winter habitat.

Public and protected properties managed by various Federal, state, and local agencies or organizations, account for approximately 176,472 ha (436,072 ac) of land in the golden-cheeked warbler's breeding range, of which approximately 71,282 ha (176,142 ac) is woodlands and, thus, potential warbler habitat. Protected areas represent 4% of the total potential habitat in the breeding range and the majority of it occurs on Fort Hood, Balcones Canyonlands Preserve, and Balcones Canyonlands National Wildlife Refuge. There are numerous protected areas along the Sierra Madre Oriental of eastern Mexico and into Central America where the golden-cheeked warbler migrates and winters, including biosphere reserves, national parks, and nature parks. The Alliance for the Conservation of Mesoamerican Pine-Oak Forests estimates approximately 7.4% of potential habitat exists in protected areas on the wintering grounds.

Increased focus on research, management, and incentive programs since the warbler's listing in 1990 have provided some benefit to the species. Several long-term studies in the breeding range have improved our understanding of the warbler's demography and behavior while additional short-term studies have expanded our understanding of habitat use at a variety of locations throughout the range. However, a lack of dependable range-wide estimates of productivity and survival, and limited knowledge of how habitat characteristics contribute to variation in those estimates, restricts our ability to understand current and future threats to the species. Estimates of survival are further confounded by limited knowledge of dispersal dynamics. Additional research is needed on the warbler's population size and distribution, dispersal dynamics, and factors that influence productivity and survival to fully evaluate the species' status and to inform and direct the recovery of the species.

Chapter 1. Introduction

1.1 Background

The golden-cheeked warbler (*Dendroica chrysoparia*) is a neotropical migratory songbird that breeds in the mixed evergreen-deciduous woodlands of central Texas and winters primarily in pine-oak forests in the highlands of Chiapas, Mexico, and parts of Central America. The U.S. Fish and Wildlife Service (USFWS) published an emergency rule on 4 May 1990 to list the species as endangered, citing "ongoing and imminent habitat destruction" as a significant risk to the species (55 FR 18844). A proposed rule to permanently list the species as endangered was published concurrently with the emergency rule (55 FR 18846), followed by the final rule of endangered status on 27 December 1990 (55 FR 53154). Habitat loss and fragmentation due to urban encroachment and juniper clearing, along with an increasing threat of brown-headed cowbird parasitism, were cited as the primary threats to the species at the time of listing (55 FR 53154).

The Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531-1544), requires periodic reviews regarding the status of threatened or endangered species. The reviews include summaries and evaluations of the best scientific and commercial information available, either since the original listing or the last status review, to determine whether a change in the species listing status is warranted. No reviews of the golden-cheeked warbler status have been conducted since the species' listing (i.e.,Wahl et al. 1990), although a Recovery Plan was developed in 1992 (USFWS 1992). The USFWS announced the initiation of a 5-year status review for the warbler on 21 April 2006 and requested new information on the species' biology, habitat conditions, conservation measures, and threat status and trends since the time of listing (71 FR 20714).

The USFWS, in conjunction with the Texas Parks and Wildlife Department (TPWD), issued a Request for Proposal (RFP) in 2007 for assistance in accumulating, summarizing, and evaluating information for the 5-year status review of the golden-cheeked warbler. The contract was awarded in August 2008 to Texas A&M Institute of Renewable Natural Resources, a unit of Texas AgriLife Research and Texas AgriLife Extension within the Texas A&M System.

1.2 Objectives

This document serves as the scientific evaluation for the 5-year status review of the golden-cheeked warbler. The purpose of a 5-year review is to determine (1) whether the species population is increasing, decreasing, or stable; (2) whether existing threats are increasing, the same, reduced, or eliminated; (3) if there are any new threats; and (4) if new information or analysis calls into questions any of the conclusions in the original listing determination. In addition, the review provides analysis of 5 factors used by USFWS to determine a species' listing status:

(A) the present or threatened destruction, modification, or curtailment of its habitat or range
(B) overutilization for commercial, recreational, scientific, or educational purposes

(C) disease or predation
(D) the inadequacy of existing regulatory mechanisms
(E) other natural or manmade factors affecting its continued existence

While the scientific evaluation provides information on the species' biology, population, and threats to the species, it does not make recommendations as to the listing status of the species. The final review and recommendations regarding the species' status is the responsibility of the USFWS.

1.3 Authors and Review Panel

1.3.1 Status Review Team

The Status Review Team is formed by the primary drafting authors of this document. Our overall approach was to accumulate, summarize, and evaluate existing information on the golden-cheeked warbler, with a focus on research conducted and reports written since the last status review (i.e., Wahl et al. 1990). We included information that was available prior to 1990 to provide background and context where needed. We collected no new data for this review, nor conducted analyses beyond basic summary statistics. We noted information gaps in the text where existing data was not adequate to reach reliable conclusions.

Members of the Status Review Team are:

Michael L. Morrison, Principal Investigator, Professor and Caesar Kleberg Chair, Texas A&M University
Neal Wilkins, Director, Texas A&M Institute of Renewable Natural Resources
Julie E. Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources
Heather A. Mathewson, Research Associate, Texas A&M Institute of Renewable Natural Resources

1.3.2 Review Panel

The scientific evaluation required the efforts of a Status Review Team, headed by the Principal Investigator, and a Review Panel. The Review Team collected, catalogued, and summarized the existing scientific and commercial data related to the status of the species and various threats. A 14-person panel of experts was recruited by the Review Team and approved by TPWD and the USFWS to assist with enhancing the quality of the review. The panel identified additional data sources, assisted in interpretation of the data, and provided critical reviews of the evaluations and conclusions in the final report. Members of the review panel included land managers, wildlife biologists, and other scientists with expertise appropriate to one or more of the issues associated with golden-cheeked warbler populations or habitat. The Status Review Team and the Review Panel met 3 times over the course of this project and communicated outside of those meetings by phone or email.

Members of the Review Panel are:

Bill Armstrong, Texas Parks and Wildlife Department
Susan Baggett, Natural Resources Conservation Service
David Diamond, Missouri Resource Assessment Partnership
Craig Farquhar, Texas Parks and Wildlife Department
Oliver Komar, SalvaNATURA Fundacion Ecologica
Cal Newnam, Texas Department of Transportation
Lisa O'Donnell, City of Austin
Rebecca Peak, The Nature Conservancy
Chuck Sexton, US Fish and Wildlife Service
Fred Smeins, Texas A&M University
Todd Snelgrove, Texas A&M Institute of Renewable Natural Resources
Terry Turney, Texas Parks and Wildlife Department
David Wolfe, Environmental Defense Fund
Butch Weckerly, Texas State University
Christina Williams, US Fish and Wildlife Service

1.3.3 Peer review

The Review Panel reviewed the document before final submission to the USFWS. Drafts of the final report were not distributed beyond the members of the Review Panel. Peer review of the final report is the sole responsibility of TPWD and USFWS.

1.4 Scientific information and data quality

The Status Review team collected and summarized >570 documents on golden-cheeked warblers and related topics. Information presented herein consists of peer-reviewed scientific literature, agency reports, unpublished manuscripts, available archives of published and unpublished data, and a variety of public records. There is a limited amount of peer-reviewed literature specific to golden-cheeked warblers and it was necessary to use all sources of information to fully represent the current body of knowledge. Information on study design and survey methodology is explained throughout the document to qualify inferences drawn from the results.

Of the documents collected, roughly 350 documents were directly related to golden-cheeked warblers or their habitat. Approximately 23% of these documents were peer-reviewed, 40% were agency reports, 8% were theses or dissertations, 5% were book chapters, and the remaining 13% were gray literature.

1.5 Organization of the Scientific Evaluation

This document provides background and biological information regarding the golden-cheeked warbler along with discussion of threats to the species. Threats to the species are best understood within the context of the species biology and ecology. Thus, chapters 1-6 provide background information on golden-cheeked warbler distribution, biology, demographics, habitat associations, and estimates of population and habitat extent. Chapter 7 follows with an in-depth analysis and discussion of threats to the species, providing new information and supplementing information presented in previous chapters. The final chapter discusses current recovery efforts and future research needs.

1.6 Acknowledgements

We thank Tiffany McFarland and Justin Cooper for their extensive participation in the development and completion of this report. Dianne Dessecker and Chris Lituma contributed significantly to management and compilation of literature. Numerous graduate students from Texas A&M Wildlife and Fisheries Department assisted with the review and summary of many documents: Andy Campomizzi, Constanza Cocimano, Shannon Farrell, Mark Hutchinson, Jessica Klassen, and Ardath Lawson. Melissa Lackey provided information and text regarding golden-cheeked warbler vocalizations. In addition, we thank Kevin Skow and Amanda Dube, with the Institute of Renewable Natural Resources, for their GIS support.

Chapter 2. General Ecology

2.1 Physical Appearance and Molts

The golden-cheeked warbler (*Dendroica chrysoparia*) is a medium-sized wood warbler, weighing approximately 10 g and measuring 12–13 cm long (Pulich 1976, Ladd and Gass 1999). Mature male warblers have bright yellow cheeks with a thin black stripe extending horizontally from either side of the dark brown eye. The upper breast, throat, and crown are black. The back is black with fringing of olive-yellow, the tail is black above with white underneath, and the wings are black with two white wing bars. The belly is white with black streaking on the flanks. Mature females are similar overall but the back is olive-green and the yellow is paler. Juveniles are similar in coloring to the adult female (Sclater and Salvin 1902, Pulich 1976, Pyle 1997).

Mean warbler weights reported by Pulich (1976) during the breeding season were 10.19 g for males (n = 7) and 9.28 g for females (n = 11). Shortly after hatching, nestlings weighed 1.5 g (n = 2), and after 8 to 9 days weighed 9.2 g (n = 7). Weights of birds sampled in Chiapas, Mexico, mid-August to early September averaged 10.3 g for adult males (n = 3), 9.6 g for 1 adult female, and 9.4 g for 1 immature male (Pulich 1976).

Adult birds undergo one complete post-breeding molt (prebasic molt complete) on the breeding grounds between May and August before migrating south, and one partial pre-breeding molt (definitive prealternate molt partial) on wintering grounds between January and April before migrating north. Hatch-year birds undergo a partial molt (prebasic I molt partial) on the breeding grounds from May to August before migrating south (Sclater and Salvin 1902, Pulich 1976, R. Peak, personal communication). See Appendix 2.A for a detailed molt schedule.

2.2 Systematics

Scientific name: *Dendroica chrysoparia*
Common Names: Golden-cheeked warbler, Chipe caridorado, Chipe cachetidorado
Order: Passeriformes
Family: Parulidae
Subfamily: Parulinae (American Ornithologist' Union [AOU] 1983)

The golden-cheeked warbler was first described by Sclater and Salvin (1860) from a specimen collected in Guatemala in 1859. Mengel (1964) proposed that the golden-cheeked warbler evolved from an ancestral form of black-throated green warbler (*Dendroica virens*) as part of a larger superspecies complex (*virens* complex) that speciated during the Pleistocene because of habitat fragmentation by glaciation events. This complex includes the black-throated green warbler, black-throated gray warbler (*D. nigrescens*), Townsend's warbler (*D. townsendi*), hermit warbler (*D. occidentalis*) and golden-cheeked warbler. This vicariance model garnered support owing to plumage, song, and habitat similarities among the complex (Stein 1962, Mengel 1964). Evidence from plumage, song, and skeletal measures were inconclusive as to when golden-cheeked warblers diverged from the *virens* complex lineage (Stein 1962, Mengel 1964, Rising 1988). Phylogenetic analyses have not included golden-cheeked warblers because of their rarity and endangered status and it is unknown when they diverged relative to the other species in the complex (Bermingham et al. 1992, Lovette and Bermingham 1999).

Although hermit and Townsend's warblers regularly hybridize (Jewett 1944, Rohwer and Wood 1998), there have been no reports of golden-cheeked warblers hybridizing with any other species. Because the golden-cheeked warbler breeding range does not overlap with other species in the *virens* complex, hybridization is unlikely.

2.3 Geographic Distribution

2.3.1 Breeding Range

The breeding range of the golden-cheeked warbler (hereafter warbler) is restricted to central Texas primarily occurring on the eastern half of the Edwards Plateau and southern half of the Cross Timbers ecoregions (Fig. 2.1; as delineated by Griffith et al. 2004). Warbler occurrence is dependent upon the presence of woodlands comprised of Ashe juniper (*Juniperus ashei*) and oak (*Quercus* spp.; hereafter mixed woodlands) where juniper is of sufficient age to provide nesting material (see Chapter 4). Distribution of mixed woodlands within Texas counties is heterogeneous, with a larger amount of woodland occurring in the southern portion of the range (see Chapter 6).

Through accumulated records, golden-cheeked warblers have been known to breed in 27 counties in central Texas: Bandera, Bell, Bexar, Blanco, Bosque, Burnet, Comal, Coryell, Edwards, Gillespie, Hays, Johnson, Kendall, Kerr, Kimble, Kinney, Lampasas, Llano, Medina, Palo Pinto, Real, San Saba, Somervell, Travis, Uvalde, Williamson, and Young (Fig. 2.2; Pulich 1976, USFWS 1996a, Lasley et al. 1997, Ladd and Gass 1999, Klassen and Morrison 2009). Young County warrants further research as the findings of "a probable breeding population" is sparsely documented (Lasley et al. 1997, Ladd and Gass 1999).

Breeding status is uncertain and requires further study of resident warblers in Hamilton, Hood, and Stephens counties (Wilkins 2008, M. Morrison, unpublished data). Additional surveys are needed in southwestern Dallas County and southwestern Jack County where warblers were detected in 2004 (Audubon Texas 2004) and 2006 (O. Bocanegra, personal communication), respectively. Warblers have also been detected in western Hill County near its border with Bosque (Edwards and Lewis 2008, 2009), in western McLennan County near its border with Bosque (M. Morrison, unpublished data), and in eastern Erath County near its border with Somervell (Environmental Defense Fund 2009). Occupancy of golden-cheeked warblers remains uncertain in the following counties, where small amounts of potential habitat occurs, and requires further study: Comanche, Eastland, Ellis, Mason, Menard, and Mills (Ladd and Gass 1999). Warbler surveys in 2008 and 2009 noted a lack of detections in Eastland, Erath, and Mason Counties (Fig. 2.2; M. Morrison, unpublished data), although few areas were surveyed in Eastland and Mason. Urban (1959) and Howell and Webb (1995) suggested that golden-cheeked warblers breed in Coahuila, Mexico, but a search of the area during the breeding season in 1996 revealed little habitat and no birds (Ladd and Gass 1999).

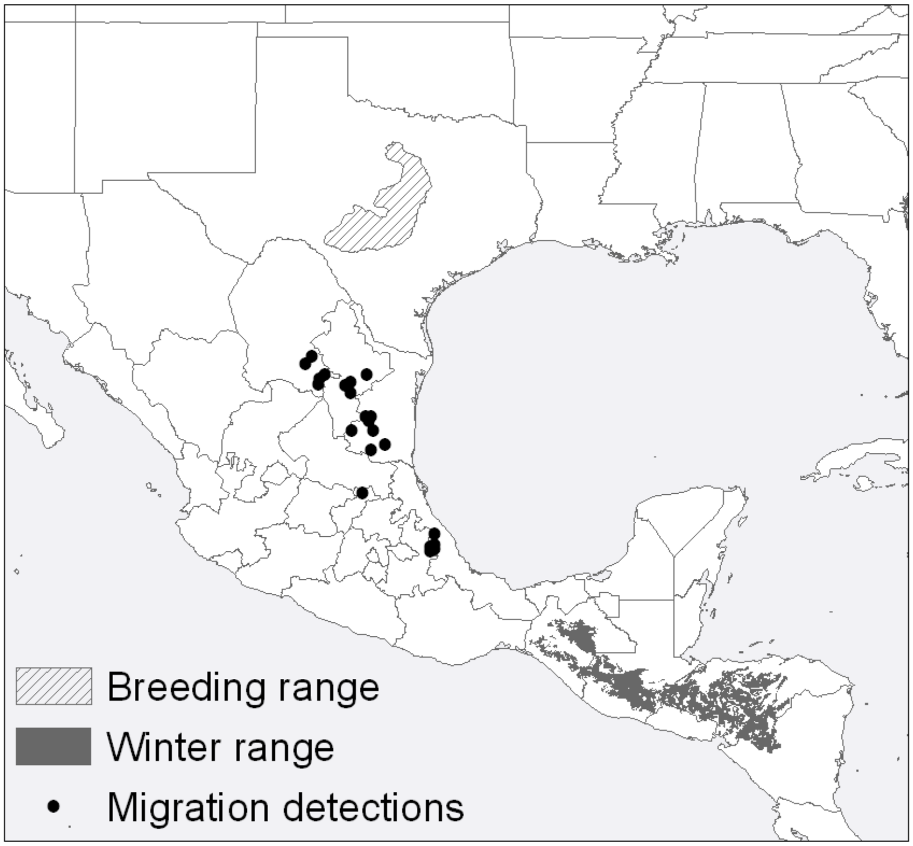

Figure 2.1. General distribution map of breeding (light color) and wintering (dark color) ranges of golden-cheeked warblers. Wintering range may extend into Costa Rica. Black dots indicate warbler detections during migration, as reported by Pulich (1976), Johnson et al. (1988), and Perrigo et al. (1990).

2.3.2 Wintering Range

The golden-cheeked warbler winters in Mexico, Guatemala, Honduras, El Salvador, and Nicaragua (Fig. 2.1). Regular occurrence of the species in northern El Salvador and north-central Nicaragua was only confirmed within the last 5 years (Morales et al. 2008, King et al. 2009, Komar 2010). With an increase in survey effort in recent years (e.g. Jones and Komar 2008a,b), several new areas with warbler occurrences have been documented (Appendix 2.B). Eight sightings from Costa Rica (highlands of the Central Valley) and 1 from Panama, all since 2000, suggest the warbler's wintering range may extend further south than Nicaragua (Garrigues 2002, May 2005, Jones 2005b, Jones and Komar 2006, 2007, 2008a). The majority of the Costa Rican sightings have been of female warblers (Jones and Komar 2008a).

Golden-cheeked warbler sightings and specimens collected during the wintering period were generally found in highland pine (*Pinus* spp.), pine-oak forests, and cloud forests above 1,000 m elevation. Warbler abundance across the wintering range appears to be highest at elevations above 1,300 m (Rappole et al. 2000, Komar 2010). Distribution across Mexico and Central

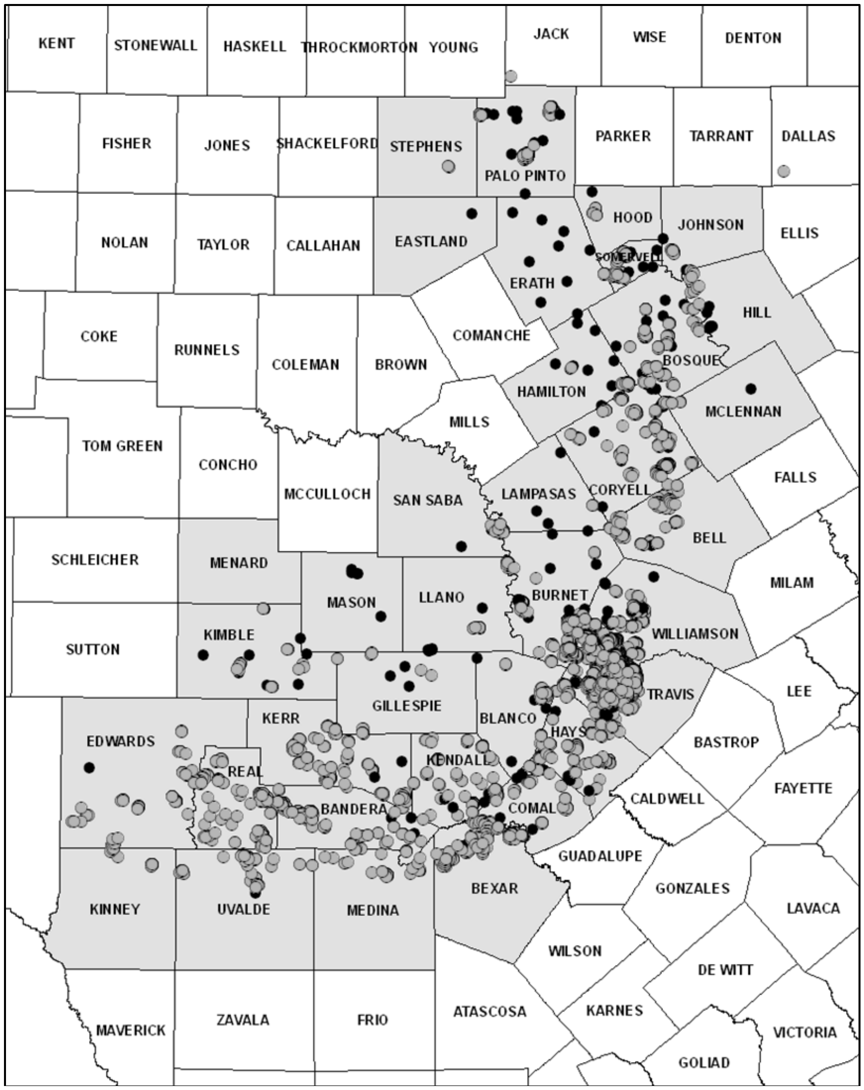

Figure 2.2. Distribution of golden-cheeked warblers detected during spring surveys, 1990–2009, based on data from the USFWS and Texas A&M University (M. Morrison, unpublished data). Gray dots indicate areas where at least 1 warbler was detected during the 20-year period. Black dots indicate areas surveyed 1–6 times in 2008 or 2009 where warblers were not detected (M. Morrison, unpublished data).

American countries appears to be heterogeneous; in a preliminary study across the wintering range, warbler abundances are higher in the northern and western portions of the range and lower to the south and east (Komar 2010).

In Mexico, the wintering range appears restricted to the southern state of Chiapas. Reports of warblers wintering in southern Mexico first emerged in the 1950's (reviewed in Pulich 1976), with continual sightings since that time. One warbler was detected in San Luis Potosi, El Lobo, in January 1974, far north of Chiapas (C. Newnam, personal communication); whether the warbler was an early migrant or resident is unclear. Braun et al. (1986) recorded 2 sightings in January 1978 and 1983, both above 1,500 m, with one sighting near San Cristóbal de las Casas and the other in Lagunas de Montebello National Park. Vidal et al. (1994) and Lyons (1994) also reported wintering warblers around San Cristóbal de las Casas at elevations between 2,100 and 2,550 m. Perrigo and Booher (1994) observed 1 warbler at 1,100 m, 16 km south of Okosingo. A single warbler was observed southwest of Presa Chicosén at approximately 1,150 m (Ladd and Gas 1999). Warblers were detected in the highlands of Chiapas during the winters of 2006 through 2009 (Komar 2010).

The occurrence of golden-cheeked warblers in Guatemala was first described from a specimen collected in Vera Paz in the 1850s (Sclater and Salvin 1860). Specimens of the warbler were collected in the Sierra de las Minas in 1958 (Land 1962), where warblers were later sighted again by Thompson (1995). More recently, warblers were sighted in southern Guatemala, between December 2007 and February 2008 by González-Callejas (2008). Fourteen individuals were detected in Guatemala (unspecified locations) during warbler surveys between December 2007 and February 2008 (Jones and Komar 2008a). New sightings from pine-oak forests of the Atitlán Reserve have been documented (Jones and Komar 2008b, Jones and Komar 2009b,c) as has one warbler occurrence in a humid broadleaf forest (Jones and Komar 2009b).

In El Salvador, 2 bird surveys occurring in December 1993 and 1994 around El Picacho reported 1 warbler each (National Audubon Society 1993, 1994). Due to the paucity of records, Komar (1998) suggested the species was only casual to El Salvador. An immature male warbler was caught and banded on 12 September 2008 in Montecristo Natural Preserve in a pine-oak forest (Komar 2008). Twelve individuals were detected during warbler surveys between December 2007 and February 2008 (Jones and Komar 2008a).

The first golden-cheeked warbler sightings and specimens from Honduras were documented in the 1930s and collected near Cerro Cantoral, Cantoral, and La Esperanza at elevations between 1,500 and 2,000 m (Monroe 1968). Several warblers were recorded in La Esperanza in 1975 by Kroll (1980). Thompson (1995) detected a male warbler at 1,815 m near La Esperanza, and another male at Cusuco National Park at 1,630 m. Rappole (1996) reported sighting many warblers in December 1995 and January1996 at elevations of 1,073 to 2,350 m. Three males were detected in hedgerows (1,100 m) in late March 2005, but may have been migrating given the time of year (Jones 2005c). Additional warblers have been sighted during warbler-specific surveys in Honduras between 2006 and 2009 (Komar 2010), with at least 17 sightings during warbler surveys, December 2007 through February 2008 (Jones and Komar 2008a). November 2007 warbler surveys documented 16 individuals occupying a feeding area of approximately 15 ha (37 ac; Jones and Komar 2008a). Two warblers were captured and banded in August 2008 at banding stations in pine-oak forest (Jones and Komar 2009a).

In Nicaragua, 2 warbler specimens were first collected from Matagalpa in 1891 (Salvin and Godman 1892). The species was not detected again in the country until 8 individuals were sighted between 2002 and 2006 in pine-oak forests (Morales et al. 2008). A minimum of 23 warblers were detected on 36 occasions from 2006 to 2008 in northwestern Nicaragua by King et al. (2009). Additional warblers were reported by Potosme and Muñoz (2007) during warbler surveys in the winter of 2006–2007. Warbler surveys during the winters of 2006 through 2009 resulted in numerous warbler detections in northern Nicaragua (Jones and Komar 2008a, Komar 2010).

2.3.3 Rare Occurrences

Golden-cheeked warblers have rarely been detected outside of Texas or the aforementioned countries. Beatty (1943) reported an adult male golden-cheeked warbler on St. Croix, Virgin Islands, in November 1939 and January 1940. Woolfenden (1967) collected an immature male warbler near St. Petersburg, Florida, in August 1964. Lewis (1974) captured a warbler in a mist-net on South Fallaron Island, California, in September 1971. This bird was a weak, immature male and died shortly after capture. In the wintering range, warblers have been detected occasionally in Caye Chapel, Belize (Jones and Komar 2009a).

2.4 Migration

2.4.1 Route

The golden-cheeked warbler is a complete (i.e., no resident populations), medium-distance, neotropical migrant. Between its wintering range in southern Mexico and Central America and its breeding range in central Texas, the warbler migrates north and south along the Sierra Madre Oriental of Mexico, through the Mexican states of Coahuila, Nuevo Leon, Tamaulipas, Queretaro, and Veracruz (Fig 2.2; Phillips 1911, Pulich 1976, Johnson et al. 1988, Lyons 1990, Perrigo et al. 1990). The route appears to follow the pine-oak and cloud forests at elevations between 1,100 and 1,500 m (Appendix 2.B). Few records exist of warblers in spring or fall migration in Texas outside of their breeding range (C. Sexton and B. Freeman, unpublished data), and migration corridors within Texas are not well known. It is possible that the lack of observations indicates a protracted migratory flight by the warbler from its stopovers in the Sierra Madre Oriental to its breeding grounds (C. Sexton and B. Freeman, unpublished data). Migration over the Gulf of Mexico has been suggested (Freeman 1993), but is not supported by evidence.

2.4.2 Spring Migration

The golden-cheeked warbler has been observed en route during spring migration in the northern state of Tamaulipas, Mexico, along the Sierra Madre Oriental, and is presumed to begin migration in February (Phillips 1911, Pulich 1976, Johnson et al. 1988, Perrigo et al. 1990). As reviewed in Pulich (1976), spring migration records in Mexico include 3 warbler specimens collected northwest of Victoria, Tamaulipas in mid-March 1909; 1 male warbler sighted northeast of Victoria in late February 1953; 2 specimens collected in Nuevo Leon at approximately 1,500 m in mid-March 1939; and 1 male sighted in pine-oak forest southwest of Monterrey, Nuevo Leon in mid-April 1963. Perrigo et al. (1990) observed at least 6 warblers near the village of Julilo, Tamaulipas in mid-March 1988 at 1,500 m in pine-oak forest of the Sierra de Guatemala (Appendix 2.B). Golden-cheeked warblers have been detected as late as 6 April in El Salvador (Jones and Komar 2007). Late spring detections for Guatemala included a female on 9 March and a male on 27 April (Jones and Komar 2008b). A late observation of a warbler in Chiapas, Mexico was on 13 April (Vidal et al. 1994).

Warblers begin arriving on their breeding grounds in early to mid-March. Some of the earliest observed arrivals of the warbler were 28 February in Coryell County (R. Peak, personal communication), 2 March in Travis County (Pulich 1976), 5 March in Kerr County (Bent 1953), and 8 March in Coryell County (Weinberg et al. 1995). Field observations suggest male warblers may arrive on the breeding grounds a few days prior to females, but this may be the result of reduced detectability of females (Pulich 1976, Weinberg et al. 1995). Older males (after second year) arrived on breeding grounds prior to second-year males at study sites on Fort Hood Military Reservation (hereafter Fort Hood) in Bell and Coryell Counties (Weinberg et al. 1995).

During migration north, golden-cheeked warblers are frequently observed as far north as Tamaulipas, Mexico moving as part of a mixed-species flock and often with other warbler species such as black-throated green warblers, Wilson's warblers (*Wilsonia pusilla*), and Townsend's warblers (Johnson et al. 1988, Perrigo et al. 1990).

2.4.3 Fall Migration

The golden-cheeked warbler begins departure from the breeding grounds by mid-June (Pulich 1976, Ladd and Gass 1999); most birds have departed by the end of July (Ladd and Gass 1999). From recent studies in progress in the breeding range, warblers were rarely detected beyond early July, although sightings have occurred into mid-August (e.g., 20 August in Travis County [City of Austin 2009]). The earliest recorded observation of a warbler in Chiapas, Mexico was 16 July (Alliance for the Conservation of Mesoamerican Pine-Oak Forests 2008). Warblers have been detected as early as 2 October in El Salvador (Jones 2005a).

Fall migration records from Pulich (1976) include collections and sightings of warblers from July through August in Mexico: Lake Tullio (at ~1,280 m) and Hipolito, Coahuila; 2 miles west of Las Vagas (at ~3,000 m); Cerro Potesti (at ~2,300 m), Nuevo Leon; Miquihuana, Tamaulipas; 1 mile west of La Joya, Veracruz. Late migration or early winter records (i.e., September and October) in Chiapas, Mexico include birds collected or sighted near Arriga, San Cristóbal de las Casas, Jitotol, and Pueblo Nuevo Solistahuacan (Pulich 1976).

2.5 Diet and Foraging Behavior

2.5.1. Breeding Grounds

Foraging substrate

Golden-cheeked warblers forage primarily in oaks, Ashe juniper, and cedar elm (*Ulmus crassifolia*; Pulich 1976, Sexton 1987, Beardmore 1994, Newnam 2008). Oak species include, but are not limited to, live oak (*Quercus virginiana*), Spanish oak (*Q. buckleyi*) and shin oak (*Q. sinuata*) (Pulich 1976, Kroll 1980, Sexton 1987, Beardmore 1994, Newnam 2008).

At a site in Bosque County, Kroll (1980) observed warblers foraging primarily in oaks, while Ashe juniper was used for singing perches. Sexton (1987) also observed warblers foraging preferentially in live oak, as opposed to Ashe juniper. At 2 sites in Travis County, Beardmore (1994) described warblers shifting their foraging preferences over the season, favoring almost entirely plateau live oak (*Q. virginiana* var. *fusiformis*) in the beginning of the breeding season, and more Ashe juniper than plateau live oak in the late breeding season. City of Austin researchers, also in Travis County, noticed similar foraging activities in which adult warblers foraged primarily in oaks and other hardwoods early in the breeding season and shifted to foraging primarily in Ashe juniper later in the breeding season (City of Austin 2009). Stratifying warbler observations by sex, Beardmore (1994) found that females foraged primarily in Ashe juniper, while males were observed foraging more in plateau live oak, with the latter possibly due to males preferentially selecting oak limbs as singing perches. Newnam (2008) showed that, across 6 counties, tree species used by warblers did not match tree species availability, and that Ashe juniper was used significantly less than it occurred on study sites; other tree species used by warblers mainly consisted of various oak species. Juveniles have been observed foraging equally in oaks and juniper (Beardmore 1994). Warblers also have been observed occasionally foraging in understory vegetation (Beardmore 1994). Appendix 2.C provides information on study locations and sample sizes for the aforementioned studies.

Diet

The warbler's diet was first described by Attwater (1892) as consisting of small, black lice (*Aphis* sp.) and other species, based on the stomach contents of young birds collected in Bexar County. Subsequently, stomach contents from 21 warblers collected from 15 counties across the breeding range were detailed in Pulich (1976) and primarily included insects, spiders, and other arthropods (Table 2.1). Field observations by Pulich (1976) included warblers preying on "spiders, brown and green caterpillars, green lacewings, small green cicadas, katydids, walkingsticks, deer flies, crane flies, adults flies, adult moths, and small butterflies". Kroll (1980) observed warblers primarily consuming Lepidoptera at a site in Bosque County (Table 2.1). A reanalysis of the gizzards of Pulich's specimens by Quinn (2000) documented the contents as primarily Lepidoptera larvae, Hymenoptera, Araneae, Coleoptera, and Homoptera (Table 2.1).

Pulich (1976) proposed that warblers forage according to prey availability. Quinn (2000) sampled the potential arthropod prey species during the warbler breeding season to determine any seasonal or spatial patterns of abundance at 2 sites in Travis County identified as golden-cheeked warbler habitat; arthropods were sampled from Ashe juniper, live oak, Texas oak, and cedar elm. Quinn (2000) found most insect taxa showed large differences in abundance between years, and oaks supported large abundances of Hemipterans, Homopterans, and Lepidopteran larvae early in the warbler's nesting season. Butcher et al. (2010) compared arthropod biomass taken from Ashe juniper and Texas oak across 12 sites in Bosque, Coryell, and Hamilton Counties during the 2006 and 2007 breeding seasons and showed biomass to be consistently higher in Texas oak than in Ashe juniper.

Foraging behavior

Pulich (1976) characterized the golden-cheeked warbler's most common method of foraging as "gleaning while hopping along a branch." Closely related *Dendroica* species (including the black-throated green warbler) have been characterized as "rapid searchers," frequently changing positions and favoring hopping over flight as means of movement, and gleaning a stationary prey item as the primary foraging method (Robinson and Holmes 1982). Primary foraging substrates are small twigs and foliage (Beardmore 1994, Newnam 2008, Appendix 2.C).

Table 2.1. Proportion of stomach and gizzard contents (Pulich, Quinn) and field observations (Kroll) of prey or other items ingested by golden-cheeked warblers.

Pulich (1976)[a]		Kroll (1980)[b]		Quinn (2000)[c]	
Coleoptera	32%	Lepidoptera larvae	53.6%	Lepidoptera larvae	22%
Homoptera	17%	Orthoptera	13.1%	Hymenoptera	16%
Lepidoptera	17%	Neuroptera	5.2%	Araneae	14.5%
Hemiptera	13%	Flies	1.3%	Coleoptera	14.5%
Arameae	11%	Lepidoptera adults	0.6%	Homoptera	14%
Diptera	3%	Mollusca	0.6%	Isoptera	9%
Hymenoptera	3%	Unidentified	25.5%	Hemiptera	6%
Insect eggs	1%			Diptera	1%
Plant material	1%			Orthoptera	0.5%
Egg shell	1%			Trichoptera	0.5%
				Other insects	2%

[a] Percents are based on 75 prey items from 21 warbler stomachs from Bosque, Burnet, Eastland, Edwards, Erath, Gillepsie, Hood, Kendall, Kerr, Kinney, Lampasas, Palo Pinto, Real, Somervell, and Williamson Counties.
[b] Percents are based on 153 prey items from an unspecified number of warblers in Bosque County.
[c] Percents are based on 200 prey items from a reanalysis of gizzards from Pulich's specimens.

The warbler has been observed to forage preferentially in the upper canopy (>3 m) (Pulich 1976, Sexton 1987, Newnam 2008). Beardmore (1994) found warblers foraged >5 m 57% of the time early in the breeding season, and <5 m 58% of the time in the late breeding season. At 2 sites in Travis County, arthropod abundance was highest at lower levels in the canopy, and decreased with increasing height, suggesting warbler foraging behavior isn't dictated by prey availability alone (Quinn 2000). Pulich (1976) observed warblers foraging mainly in mid-morning and mid- to late-afternoon, although adults were observed foraging all day when feeding young.

At 2 study sites in Travis County, warblers spent 7% of field observations engaged in foraging from March to April and this activity increased to 19% from May to June (Beardmore 1994). From 6 study sites throughout the breeding range and breeding season, male, female, and juvenile warblers spent 18%, 35%, and 18%, respectively, of observed time foraging (Newnam 2008).

2.5.2 Wintering Grounds

Foraging substrate

Golden-cheeked warblers have been observed foraging in pine, pine-oak forests and mixed habitat and in shrubby oak-dominated understory vegetation on the wintering grounds (Kroll 1980, Vidal et al. 1994, Thompson 1995, Rappole et al. 1999). In Guatemala, Thompson (1995) found that warblers showed a preference for foraging in oaks in spite of a preponderance of pines (n = 13 warblers). In observations totaling 66 minutes, warblers spent 86% of the time in oaks, 13% in pines, and <1% in sweetgum (*Liquidambar* spp.) (Thompson 1995). Rappole et al. (1999) observed warblers foraging almost exclusively in encino oaks (n = 44 warbler locations, 94% of foraging observations). Appendix 2.D provides information on study locations and sample sizes for the aforementioned studies.

Diet

Thompson (1995) observed warblers catching Lepidopteran larvae and non-Lepidopteran winged insects.

Foraging behavior

As on the breeding grounds, golden-cheeked warbler foraging behavior has been described as primarily "hopping and gleaning" with less frequent flycatching or sallies-from-a-perch behavior (Vidal et al. 1994, Thompson 1995). Sally hovering and reaching was also observed (Rappole et al. 1999, King and Rappole 2000). Most foraging maneuvers were directed towards the leaves in the outer edges of oak foliage (Rappole et al. 1999, King and Rappole 2000). King and Rappole (2000) noted foraging behavior did not differ between males and females, although males foraged higher than females. Warblers were frequently observed foraging on the upper parts of trees (Johnson et al. 1988, Perrigo et al. 1990, Vidal et al. 1994, Thompson 1995, Rappole et al. 1999). Vidal et al. (1994) found warblers (n = 26) foraging at an average height of 10 m in trees of 15 m average height. During brief encounters with the birds, Braun et al. (1986) found warblers (n = 2) foraging in a wide range of heights (1–10 m), although no mention of substrate height was given. Morales et al. (2008) reported sightings of warblers (n = 3) foraging at different heights up to 7 m. Warblers (n = 12) have also been observed foraging in scrubby understory (Kroll 1980). Appendix 2.D provides additional information on study locations and sample sizes for the aforementioned studies.

From casual observations to studies focused on its ecology, golden-cheeked warblers have consistently been observed foraging as part of mixed-species flocks on its wintering grounds. The most common species included black-throated green warblers, Townsend's warblers, and Wilson's warblers, with a variety of other species composing the remainder of the flocks (Braun et al. 1986, Perrigo et al. 1990, Rappole et al. 1999, González-Callejas 2008, Morales et al. 2008; Appendix 2.E). Typically, a single golden-cheeked warbler occupied most flocks (Vidal et al. 1994, Rappole et al. 1999, King and Rappole 2000).

On the wintering range, most researchers have detected and observed more male than female golden-cheeked warblers and expressed concern that the data were biased towards male behavior (Vidal et al. 1994, Thompson 1995, Rappole 1996, Potosme and Muñoz 2007, González-Callejas 2008). Disproportionate detection of males may reflect warbler sexual segregation (Komar 2010). In contrast, Rappole et al. (1999) found male and female warblers at a ratio of 1:1 (76 males, 70 females) in Honduras and Guatemala; they observed substantial overlap in habitat use by male and female warblers, and no evidence for sexual segregation.

2.6 Reproduction

2.6.1 Mating System and Extra-pair Relations

The majority of information from the breeding season reports that golden-cheeked warblers are seasonally monogamous; however, evidence from studies with uniquely banded individuals suggests some social polygyny may exist (R. Peak, personal communication). In 1997 at Fort

Hood, a male was observed with a banded and an unbanded female and was seen feeding fledglings of different ages (Ladd and Gass 1999). In 2009 in Edwards and Kinney Counties, a uniquely banded male was seen defending 2 nesting females (1 banded, 1 unbanded) and was later seen feeding fledgings with both females (J. Klassen, personal communication). Mate switching within breeding seasons and extra-pair relations of marked individuals have been observed for both sexes on Fort Hood during the 2003 to 2009 breeding seasons (R. Peak, personal communication). Pair bonds lasting for more than one breeding season (mate fidelity) have not been observed.

2.6.2 Territories

The average territory size based on spot-mapping and minimum convex polygon estimates ranged from 2.77–23.15 ha (6.84–57.20 ac; *n* = 622) in Travis County depending on habitat characteristics (Coldren 1998; see Chapter 5). Another study in Travis County estimated territory sizes of 0.48–7.27 ha (1.19–17.96 ac; *n* = 92), with averages of 1.19–2.47 ha (2.94–6.10 ac) depending on site characteristics (Davis and Leslie 2008; see Chapter 5). Additional research on territory mapping and estimates of territory size has occurred in recent years in Real, Kinney, and Edwards Counties, Fort Hood, and private lands around Fort Hood, but related reports and data were unavailable at the time of this writing.

Other researchers have approximated territory spacing based on estimates of territory density. Pulich (1976) estimated 1 pair per 8, 20, or 34 ha (20, 50, or 85 ac) depending on whether the habitat was "excellent, average, or marginal". Wahl et al. (1990) estimated a median density of 15 males per 100 ha (247 ac) in study sites throughout the range. At Meridian State Park, Kroll (1980) estimated 1 pair per 4.49–8.48 ha (11.10–20.95 ac). Recent territory densities at Fort Hood were estimated at 0.21–0.29 territories/ha (0.08–0.12 territories/ac) between 2003 and 2009 (Peak 2003a, 2004a, 2005a, 2006a, 2007b, Peak and Strebe 2008, Peak and Lusk 2009). Territory density estimates from 1999 through 2009 on properties within the Balcones Canyonlands Preserve ranged between 18.3 and 44.0 territories per 100 ha (247 ac) in prime plots (i.e., >75% of the area consists of >70% canopy cover) and between 7 and 18.5 territories per 100 ha (247 ac) in transitional plots (i.e., areas that may develop into prime plots over time; City of Austin 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009; Travis County 2001, 2002, 2003, 2004, 2006, 2007, 2008a,b).

2.6.3 Defense Behavior

Males defend territories from the time of territory formation through independence of fledglings from successful nests (Ladd and Gass 1999). Females defend the nest area during late incubation and the nestling stage (Ladd and Gass 1999). Warbler responses to predators include "wing-fluttering, freeze motion, attack in midair, agitated chipping, feigned wing injury, prolonged silence, perching in dense vegetation, and flying out of sight under tree canopy" (Ladd and Gass 1999). Adults rarely venture out of territories during nesting periods except to seek outside sources of water or during active defense of the territory and interactions with neighbors (Pulich 1976, Ladd and Gass 1999).

2.6.4 Nest Description

Female warblers construct open-cup nests approximately 80 mm (SD = 2, *n* = 10 nests) in outer diameter, 49 mm (SD = 4) in inner diameter, with a mean outer depth of 50 mm (SD = 5,) and inner depth of 37 mm (SD = 6; Pulich 1976). Nests are constructed predominately by materials from juniper trees, specifically strips of bark from mature trees (> 20 years; Kroll 1980) but also leaves and twigs. Other materials consist of twigs and leaves from oak trees and finer materials such as grasses, rootlets, lichen, moss, spider webs, feathers, hair, and fibers (Pulich 1976). Nests are inconspicuous but not often placed in thick concealment foliage (Pulich 1976). Males are rarely observed with nest material but may have assisted in helping to shape the nest cup (Gass 1996). Because construction is primarily by the female, it is assumed nest locations are selected by females but some behavioral observations suggest males participate in selection (Graber et al. 2006). Nests typically are located in the upright fork of branches in Ashe juniper, or sometimes various hardwood trees depending upon the local tree composition (Pulich 1976, Ladd and Gass 1999). Females often select nest locations in the top third of the nest tree, from 2 to 14.7 m (mean = 5.7 m, *n* = 333; R. Peak, personal communication) above the ground but the upper limit of the height range varies with tree canopy height (Pulich 1976, Ladd and Gass 1999).

2.6.5 Nesting Phenology

Pair formation and nest initiation begin within a week after females arrive on the breeding grounds (Pulich 1976). The number of days that females spend constructing first nest attempts range from 4 to 11 days (*n* = 23 nests, median = 6 days; R. Peak, personal communication) with lag time between end of nest construction and the egg-laying period ranging from 0 to 6 days (*n* = 23 nests, median = 3 days; R. Peak, personal communication). If the first nesting attempt fails, females spend 1–7 days (*n* = 28 nests, median = 4 days; R. Peak, personal communication) constructing second nests; lag time between end of construction of second nests and the egg-laying period range from 0 to 3 days (*n* = 28 nests, median = 2 days; R. Peak, personal communication). Warblers may make up to 5 nesting attempts throughout the breeding season if a previous attempt is unsuccessful (R. Peak, personal communication). The female lays 1 egg per day often in the early morning and initiates incubation on the last egg resulting in a 2–3 day egg-laying period (Pulich 1976). A typical clutch consists of 3–4 eggs, though 5 eggs have been observed (Pulich 1976, Ladd and Gass 1999). Egg incubation lasts approximately 12 days and the female performs all incubation duties (Pulich 1976). For a study in Travis County, incubation bouts (time female was on the nest) averaged 37 min (SE = 5, *n* = 12 females) and mean time away from nests was 13 min (SE =1, *n* = 12 females; Gass 1996). Male warblers occasionally fed females during incubation bouts (Gass 1996).

Eggs hatch within approximately 24 hours of each other and females remove or consume eggshells (Ladd and Gass 1999). Females brood young nestlings for at least the first 3 days of the nestling period after which females brood for short amounts of time or shield nestlings from direct sunlight (i.e., heat exposure) or rain (Gass 1996). In general, males and females contribute equally to feeding the young but females retain the role of primary caregiver because males are often observed passing food to the female to feed the nestlings (Gass 1996). Early in nestling period, adults regurgitate food for nestlings, a behavior also observed in other warbler species (Gass 1996). Evidence suggests that females increase feeding rates during the nestling period to compensate for the loss of a mate or reduced attentiveness by the male (Gass 1996).

Nestlings fledged from nests approximately 9–12 days after egg-hatching (Gass 1996). Within the first several days after leaving the nest, fledglings remain near the nest in dense foliage but by approximately 8 days post-fledge the young are mobile and active (Gass 1996). Adults often split broods but continue to forage together on occasion (Gass 1996). Adults have been observed bringing food to young at least 28 days post-fledge even though young are capable of foraging on their own around 14 days post-fledge (Gass 1996). Late in the nesting season, juveniles form groups with other juveniles and with heterospecifics, such as tufted titmouse (*Baeolophus bicolor*) and Carolina chickadees (*Poecile carolinensis*; Ladd and Gass 1999).

2.7 Vocalizations and Sounds

2.7.1 Types of Vocalizations

Golden-cheeked warbler songs are divided into 3 types: A-song, B-song, and C-song (Bolsinger 1997, Ladd and Gass 1999). A-song is typically 1.5 s in length, averages in frequency around 5,140 Hz, and consists of an ascending series of notes in which the highest note is sung the longest, followed by a sharp chip (Ladd and Gass 1999). Bolsinger (1997) observed 4 variants of the A-song from 13 sites across the breeding range. One of these variants was widespread, whereas the remaining 3 were represented only at a limited geographic scale or at a single site. No males were observed singing more than a single variant (Bolsinger 1997).

The B-song tends to be longer, averaging 2.0 s, lower, averaging around 4,820 Hz, and more complex, potentially containing 4 to 6 song elements (Bolsinger 1997). Chip notes are common before B-song (Bolsinger 2000). A study of regional variation in B-song showed it to vary locally between and within individual birds, shifting between seasons (Bolsinger 1997). The C-song is less standardized and more variable than the A- or B-song, and may be a subclass or variation of the B-song (Bolsinger 1997). The majority of songs observed in warbler territories are either A- or B-songs (Bolsinger 2000).

2.7.2 Daily and Seasonal Variation

Bolsinger (1997) observed warblers singing A-songs more during daylight and B-songs more commonly at or before sunrise (n = 19 males, Fort Hood). At the beginning of the breeding season, when males were still arriving on the breeding grounds, singing typically began after sunrise (Bolsinger 1997). For the remainder of the season, Bolsinger (1997) reported males singing shortly before sunrise. Pulich (1976) did not observe warbler songs until after sunrise (unspecified number of males and locations). Most singing occurred in the early morning, and singing intensity decreased throughout the day, with the exception of the early breeding season when males sang throughout the day (Pulich 1976, Bolsinger 1997). Pulich (1976) frequently heard singing near dusk, though birds ceased singing 30 minutes before sunset.

A-song was more prevalent early in the breeding season through the courtship and egg-laying period, while B-song was more common later in the season during incubation and fledgling stages (Pulich 1976, Bolsinger 1997). Vocalization rates were highest early in the season; singing rates dropped as the season progressed (Choban 1974, Bolsinger 2000, MacKenzie 2007). In contrast, Beardmore (1994) recorded relatively constant song activity across the breeding season; from March to April, birds spent 22% of observed minutes engaged in singing, and 22% engaged in singing from May to June. Similarly, Newnam (2008) found that warblers spent 12% and 13% of observed minutes engaged in singing for the same 2 seasonal intervals.

Nestling warblers began vocalizing chip notes approximately 3 days after hatching, and hatch-year males began singing short "subdued" songs after mid-June (Pulich 1976). Bolsinger (1997) suggested the A-song was learned during the hatch year.

2.7.3 Social Context

Males sang at dawn from one of a few preferred perches, usually near the territory edge or a neighbor's singing post (Bolsinger 2000). After the dawn bout, males sang nearer to the interior of territories, though usually removed from the nest location (Bolsinger 2000). Later in the season, once females began incubation, males tended to sing toward the territory edges during daytime hours (n = 19 males; Bolsinger 2000).

Males primarily sang the A-song near females and from the interior of territories (Bolsinger 1997). Pulich (1976) and Bolsinger (1997) suggested A-songs contributed to species recognition, mate attraction, and courtship. Unmated males tend to sing the A-song farther into the season than mated counterparts (Pulich 1976, Bolsinger 1997). This follows the general pattern of other wood-warbler species, including those of *Dendroica*; males among these genuses sing a stereotyped category of song abundantly in the beginning of the breeding season while unmated before switching to a second category (B-song) as the season progresses (Spector 1992). Males primarily sang the B-songs at territory edges (Bolsinger 1997). B-songs may play a role in male-male interactions, as B-songs were observed during fights and countersinging between neighboring males (Bolsinger 1997).

C-songs have been observed when a male was near young, near a female caring for young, when feeding young, and in fights (Bolsinger 1997, Bolsinger 2000). However, C-songs were rarely observed and difficult to categorize, and were presumed to be used relatively infrequently (Bolsinger 1997, Bolsinger 2000). Lockwood (1996) observed a male singing a fast-paced, twittery song during a courtship display and prior to copulation.

Chip notes may be used by males during aggressive interactions with other males, and by females while foraging, bringing food to young, and when alarmed (Pulich 1976). Young gave rapid chips when begging (Pulich 1976). In addition to song and call notes, bill-snapping was observed during aggressive interactions between males, during foraging, and during handling by field biologists (Pulich 1976).

2.8 Responses to Conspecifics and Heterospecifics

We found no information concerning competition on the breeding grounds between golden-cheeked warblers and conspecifics or heterospecifics. Black-and-white warblers (*Mniotilta varia*) are the only other warbler that breeds in the same habitat and region as golden-cheeked warblers, thus heterospecific competition is probably not a significant factor (Ladd and Gass 1999). A preliminary analysis suggested golden-cheeked warblers may prefer to settle in habitat near other golden-cheeked warblers (Campomizzi et al. 2008) and researchers are currently testing this hypothesis on private properties around Fort Hood (S. Farrell, personal communication).

On the wintering grounds, golden-cheeked warblers were often observed foraging as part of mixed-species flocks, composed mainly of other warbler species (Braun et al 1986, Perrigo et al. 1990, Rappole et al. 1999, Morales et al 2008). Documentation of aggressive intra- or interspecific interactions were infrequent on the wintering grounds. Vidal et al. (1994) recorded 2 aggressive interactions of a Townsend's warbler and a crescent-chested warbler (*Parula supercilliosa*) displacing or attacking a golden-cheeked warbler. Rappole et al. (1999) recorded only 3 episodes of interactions (2 heterospecific and 1 conspecific). One heterospecific interaction involved a hummingbird chasing a golden-cheeked warbler and the second involved a golden-cheeked warbler attacking a black-throated green warbler (Rappole et al. 1999). Kroll (1980) suggested that mixed-species flocks may partition resources because golden-cheeked warblers were observed foraging in the understory, whereas other warblers (black-throated green warbler, hermit warbler, and Townsend's warbler) foraged in the midstory and overstory. These observations were from a single-day observation of 12 individuals in the municipality of La Esperanza, Honduras (Kroll 1980).

2.9 Summary for General Ecology

- The warbler's breeding range is primarily within the mixed juniper-oak woodlands of central Texas on the eastern half of the Edwards Plateau and southerm half of the Cross Timbers and Prairies ecoregions. Since 1990, warblers have been detected in 35 counties in central Texas, although detections are limited to a few individuals in 6 of the counties.
- The warbler winters in southern Mexico (Chiapas), Guatemala, Honduras, El Salvador, and Nicaragua and are found most often in pine-oak forests above 1000 m elevation. Several warbler detections in recent years in Costa Rica suggest the winter range may extend further south than Nicaragua.
- Migration occurs along the Sierra Madre Oriental of eastern Mexico. Warblers arrive on the breeding grounds in early to mid-March and depart the breeding grounds beginning in June. Warblers migrate as part of a mixed species flock.
- Foraging on the breeding grounds occurs primarily in Ashe juniper and oaks. Prey species include a variety of insects, spiders, and other arthropods, such as Lepidoptera, Hymenoptera, Araneae, Coleoptera, and Homoptera. Foraging on the wintering grounds occurs in pine, pine-oak forests, and mixed habitat, as part of a mixed-species flock. Observed prey species include Lepidopteran larvae and non-Lepidopteran winged insects.
- The warbler is primarily seasonally monogamous, though some polygyny, mate-switching, and extra-pair relations have been observed. Mate fidelity for multiple seasons is unknown.
- Male warblers defend territories from other warblers from the time of territory formation until fledglings become independent. Females defend the immediate nest area. Responses to predators at the nest include a variety of behaviors, including distraction, antagonization, and avoidance strategies.
- Nests are typically located in Ashe juniper, but can also be found in various hardwoods, at heights averaging 5 m. Nests are composed of a variety of materials, though strips of bark from mature Ashe juniper trees are a significant component.
- A typical clutch consists of 3–4 eggs, which are incubated by the female warbler. Hatching occurs after approximately 12 days of incubation, and fledging occurs after 9–12 days. Fledglings begin to gain independence in approximately 14 days, afterwhich they may begin foraging as part of small mixed-species flocks.
- There are primarily 2 songs sung by male warblers, the A-song and B-song. The A-song is thought to play a role in species recognition, mate attraction, and courtship, while the B-song may play a role in male-male interactions and defining territorial boundaries. A third song, the C-song, is rarely documented and its function is not well understood.

Appendix 2.A. Golden-cheeked warbler molt schedule.

Nestling: hatching late March–June .

Grayish-brown natal down along coronal dorsal pterylae (Pulich 1976, R. Peak personal communication)

HY: Prejuvenal molt: occurs in April–June (on breeding grounds) to Juvenal.

Upperparts washed brownish and underparts buff, indistinctly streaked with pale gray (Pyle 1997, Ridgeway 1902, R. Peak, personal communication). Slight yellow-buff at base of lower mandible and cheeks.

HY: Prebasic I molt partial: occurs May–August (on breeding grounds) to Basic I.

Buffy-white underparts. Back feathers streaked with olive-green and indistinctly dusky at centers. Crown and eye-line olive with dusky to blackish dusky flecking. Cheeks yellow. Light black on throats. (Sclater and Salvin 1902, Pulich 1976, Pyle 1997, R. Peak, personal communication).

SY: Prealternate I molt partial: occurs January–April (on wintering grounds) to Alternate I.

MALE: Similar to adult male (DA), but pileum feathers margined with olive or yellow (Sclater and Salvin 1902).

FEMALE: Similar to adult female (DA), though duller and with less black overall (Sclater and Salvin 1902).

SY: Prebasic molt complete: occurs June–August (on breeding grounds) to Definitive Basic.

MALE: Similar to adult male (DA), though black throat feathers may be margined with pale yellow (Sclater and Salvin 1902).

FEMALE: Similar to adult female (DA), though throat feathers may be margined with pale yellow (Sclater and Salvin 1902).

ASY: Definitive Prealternate molt partial: occurs January–April (on wintering grounds) to Definitive Alternate:

MALE: Pileum, throat and upper breast black with fringes of yellow. Back and rump feathers black with fringes of olive-green. Yellow spot in center of forehead. Broad superciliary stripe and supercilium, supraloral, and malar and auricular regions bright yellow, contrasted with a black line extending from lore to eye, and eye to nape. Wings black, with greater and middle wing coverts tipped with white, creating two white wing bands. Lower breast and belly white, with streaks of black on flanks. Tail black, though inner webs of three outermost retrices mostly white (Sclater and Salvin 1902, Pulich 1976).

FEMALE: Pileum to upper tail coverts olive-green, heavily streaked with black. Upper chin and throat pale yellow, with lower throat and sides of breast heavily mottled with black. Overall similar to the male (DA), though black on tail is a duller dusky, wing bands are narrower, black streaks on flanks narrower, and yellow on face is slightly paler (Sclater and Salvin 1902, Pulich 1976).

Appendix 2.B. Non-breeding season records of golden-cheeked warblers in countries other than the United States. A dash (-) indicates no information was provided by the author.

Country	Location	Site description	Date of detection	# of individuals	Author
Belize	Caye Chapel	-	1 October 2008	1	Jones and Komar 2009a
Costa Rica	Monteverde (Cordillera de Tilaran) and El Cedral, Cerroes de Escazú	Highlands surrounding the Central Valley	9 February 2007	2	Jones and Komar 2008a
	El Cedral, Cerros de Escazú	Highlands surrounding the Central Valley	8 April 2007	1	Jones and Komar 2007
	Cerro Silencio, Tuis de Turrialba	1,850 m	22 October 2005	1	Jones and Komar 2006
	Finca Los Espinos, Oratorio de Oreamuno	*Ficus* spp., 1,700 m	25 December 2004	1	Jones 2005b, May 2005
	Cerro Pata de Gallo	Coffee plantations with relict patches of native vegetation, 1,450 m	2 September 2002	1	Garrigues 2002
El Salvador	-	-	Winter 2007	12	Jones and Komar 2008a
	Montecristo National Park	Pine-oak forest	2 October 2004, 6 April 2007, 12 September 2008	6	Jones 2005a, Jones and Komar 2007, Komar 2008
Guatemala	Los Tarrales Reserve (Atitlán volcano)	Humid broadleaf forest	19 February 2009	1	Jones and Komar 2009b
	Atitlán Reserve	Pine-oak forest	22 February 2007, 19 February 2009, 12 March 2009	3	Jones and Komar 2008a, Jones and Komar 2009b,c
	Biotopo del Quetzal	-	9 March 2008	1	Jones and Komar 2008b
	Rincón Grande	-	27 April 2008	1	Jones and Komar 2008b
	-	-	Winter 2007	14	Jones and Komar 2008a
	Cerro Alux, Chimusinique, San Jeronimo, San Lorenzo Marmol	1,534–2,232 m	December 2007–February 2008	14	González-Callejas 2008
	Sierra de las Minas and Parrachoch	Pine-oak forest, 1,400–2,040 m	8–22 January 1995	11	Thompson 1995
	Usumatlan (Sierra de las Minas)	Pine forest, deciduous woods, and second growth, 1,800–2,560 m	August and December 1958	6	Land 1962
	South of Quetzaltenango	-	winter 1975	1 probable	Simon 1975 (in Lyons 1990)
	Tactic (Alta Verapaz)	1,370 m	4 November 1859	2	Salvin 1876

Appendix 2.B continued.

Country	Location	Site description	Date of detection	# of individuals	Author
Honduras	Cusuco National Park	-	2 August 2008	2	Jones and Komar 2009a
	Monte Uyuca Biological Reserve, San Antonio de Oriente	-	7–11 November 2007	16	Jones and Komar 2008a
	Buenos Aires in the buffer zone of Cusuco National Park	Hedgerows at 1100 m (possibly migrants given where they were detected)	24 March 2005	3	Jones 2005c
	Cusuco, La Esperanza, Guayjiquiro, Lepaterique, El Cantoral, La Union, and Gualacato	Pine-oak forest, 1,000–2,350 m	December 1995–January 1996	77	Rappole 1996
	La Esperanza and Cusuco National Park	Pine-oak forest, 1,400–2,040 m	1–12 February 1995	2	Thompson 1995
	La Esperanza	Highland pine, sweetgum, and pine-encino oak forest, steep terrain, 1,500 m	1 March 1975	12	Kroll 1980
Mexico	Tehuantepec Isthmus, Oaxaca	400 m	7 April 2002	4	Rodriguez-Contreras 2006
	16 km South of Okosingo, Chiapas	Pine-oak forest, 1,100 m	6 January 1993	1	Perrigo and Booher 1994
	San Cristobal de las Casas, Chiapas	Pine, pine-oak, mixed, and oak forest, 2,200–2,550 m	August 1990-December 1992	63	Vidal et al. 1994
	Julilo, Tamaulipas	Pine-oak transition forest, 1,500 m	17 March 1988	6	Perrigo et al. 1990
	Rancho del Cielo, Tamaulipas	Dense oak-sweetgum forest, 1,100 m	18 March 1987	5–7	Johnson et al. 1988
	Lagunas de Montebello NP & San Christobal de las Casas, Chiapas	Pine-oak forest, 1,500 and 2,300 m	7 January 1978 and 15 January 1983	2	Braun et al. 1986
	Lake Tullio and Hipolito, Coahuila; Las Vagas; Cerro Potesti, Nuevo Leon; Miquihuana, Tamaulipas; La Joya, Veracruz; Galindo, Tamaulipas; Northeast of Victoria, Tamaulipas; Mesa de Chipinque, Nuevo Leon	-	various	various	Pulich 1976
	Mesa de Chipinque, Nuevo Leon	1,525 m	19 March 1939	2	Sutton and Burleigh 1941
	Galindo, Tamaulipas	-	14–22 March 1909	3	Phillips 1911

Appendix 2.B continued.

Country	Location	Site description	Date of detection	# of individuals	Author
Nicaragua	From the Reserva Natural Cordillera Dipilto Jalapa to the town of La Esperanza, Reserva Natural Tisey Estanzuela, and at Cusmapa near Somoto	Montane pine-encino oak forest between 1,136-1,690 m elevation	November 2006–January 2008	≥ 23	King et al. 2009
	Yúcul Genetic Reserve	-	16 and 18 January 2009	2	Jones and Komar 2009b
	-	-	Winter 2007	13	Jones and Komar 2008a
	El Jaguar Private Preserve (Jinotega), Dipilto and area close to Mozonte (Nueva Segovia)	Pine-encino oak forest with patches of coffee plantations, transition zones of Ficus and oak	April and November 2002, December 2004, January, March, and November 2006	8	Morales et al. 2008
	El Jaguar Private Reserve	1,350 m	4 March 2007	1	Jones and Komar 2007
	Somoto and Nueva Segovia	Oak and pine-oak cloudforest, 1,300–1,652 m	November 2006–February 2007	22	Potosme and Muñoz 2007
	Matagalpa	Approximately 1,220 m	16 and 22 September 1891	2	Salvin and Godman 1892, Pulich 1976
Panama	Los Quetzales Trail, Volcán Barú National Park above Cerro Punta, Chiriqui	-	3 January 2005	1	Jones 2005b
Mexico, Guatemala, Honduras	Central and Western highlands of Honduras, Eastern highlands of Guatemala, and San Cristobal de las Casa, Chiapas	Pine-oak forest above 1,000 m. Encino oak common.	December 1995–February 1996, January–February 1997 (Honduras); January–February 1998 (Guatemala); February–3 March 1998 (Mexico)	157	Rappole et al. 1999 and 2000
Mexico, Guatemala, Honduras, Nicaragua, El Salvador	-	Encino oak, pine-oak forests with sweetgum, 1,000–2,400 m	November–February 2006–2009	330	Komar 2010

Appendix 2.C. Locations and sample sizes for studies describing golden-cheeked warbler foraging substrate and behavior on the breeding grounds of central Texas.

Author	**Breeding seasons**	**# of study sites**	**Texas Counties**	**# of birds observed**	**Total # of observations**
Beardmore 1994	1988–1989	2	Travis	27 territories	174 foraging observations; 1252 singing observations
Kroll 1980	1973–1978	1	Bosque	Unspecified	174 foraging observations; 1,252 singing observations
Newnam 2008	1995–1996	6	Bandera, Comal, Hays, San Saba, Somervell, Travis	186 territories	6,378 foraging observations, 3,886 singing observations
Pulich 1976	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Sexton 1987	1976	1	Travis	Unspecified	Unspecified

Appendix 2.D. Locations and sample sizes for studies describing golden-cheeked warbler foraging substrate and behavior on the wintering grounds.

Author	**Wintering seasons**	**Location**	**# of study sites**	**# of birds observed**
Braun et al. 1986	1978, 1983	Tamaulipas, Mexico	2	2
Johnson et. al. 1988	1987	Chiapas, Mexico	1	5–7
King and Rappole 2000	1995–1998	Guatemala, Honduras, and Chiapas, Mexico	Unspecified	30
Kroll 1980	1975	Honduras	1	12
Morales et. al. 2008	2002	Nicaragua	1	7
Perrigo et al. 1990	1988	Tamaulipas, Mexico	1	> 6
Rappole et al. 1999	1995–1998	Guatemala, Honduras, and Chiapas, Mexico	Unspecified	157
Thompson 1995	1995	Guatemala and Honduras	6	13
Vidal et al. 1994	1990–1991, 1991–1992	Chiapas, Mexico	Unspecified	46

Appendix 2.E. Bird species commonly found in mixed-species flocks with golden-cheeked warblers on the golden-cheeked warbler's wintering grounds.

Country	Species Present in Mixed-Flock[a]	Author
Mexico	Black-throated green warbler, Towndsend's warbler, Wilson's warbler	Braun et al. 1986, Perrigo et al. 1990
Mexico	Black-throated green warbler, Blue-gray gnatcatchers, Blue-headed vireo, Wilson's warbler	Johnson et al. 1988
Mexico	Black-and-white warbler, Black-throated green warbler, Blue-headed vireo, Crescent-chested warbler, Greater pewee, Hammond's flycatcher, Hermit warbler, Hutton's vireo, Mountain trogon, Olive warbler, Painted redstart, Red-faced warbler, Slate-throated redstart, Tennessee warbler, Townsend's warbler, Tufted flycatcher, Wilson's warbler	Vidal et al. 1994
Guatemala	Baltimore oriole, Black-and-white warbler, Black-throated green warbler, Blue-headed vireo, Brown creeper, Crescent-chested warbler, Grace's warbler, Greater pewee, Hermit warbler, Hutton's vireo, Olive warbler, Painted redstart, Red-faced warbler, Summer tanager, Townsend's warbler, Tufted flycatcher, Wilson's warbler, Woodcreeper sp.	Thompson 1995
Guatemala	Hermit warbler, Towndsend's warbler, Wilson's warbler	González-Callejas 2008
Honduras	Black-throated green warbler, Hermit warbler, Townsend's warbler	Kroll 1980
Honduras, Guatemala and Mexico	Acorn woodpecker, Black-and-white warbler, Black-throated green warbler, Blue-headed vireo, Brown creeper, Crescent-chested warbler, Dusky-capped flycatcher, Grace's warbler, Greater pewee, Hammond's flycatcher, Hermit warbler, Olive warbler, Painted redstart, Slate-throated redstart, Streak-headed woodcreeper, Townsend's warbler, Tufted flycatcher, Wilson's warbler	Rappole 1996, Rappole et al. 1999
Nicaragua	Black-throated green warbler, Black-and-white warbler, Blackburnian warbler, Chestnut-sided warbler, Red-throated ant-tanager, Tennessee warbler, Wilson's warbler	Morales et al. 2008
Nicaragua	Acorn woodpecker, Baltimore oriole, Black-and-white warbler, Black-throated green warbler, Blue-headed vireo, Dusky-capped flycatcher, Greater pewee, Hermit warbler, Painted redstart, Townsend's warbler, Wilson's warbler, Yellow-throated warbler	King et al. 2009

[a] Scientific names: Acorn woodpecker (*Melanerpes formicivorus*), Baltimore oriole (*Icterus galbula*), Black-and-white warbler (*Mniotilta varia*), Black-throated green warbler (*Dendroica virens*), Blackburnian warbler (*Dendroica fusca*), Blue-gray gnatcatcher (*Polioptila caerulea*), Blue-headed vireo (*Vireo solitarius*), Brown creeper (*Certhia americana*), Chestnut-sided warbler (*Dendroica pensylvanica*), Crescent-chested warbler (*Parula superciliosa*), Dusky-capped flycatcher (*Myiarchus tuberculifer*), Grace's warbler (*Dendroica graciae*), Greater pewee (*Contopus pertinax*), Hammond's flycatcher (*Empidonax hammondii*), Hermit warbler (*Dendroica occidentalis*), Hutton's vireo (*Vireo huttoni*), Mountain trogon (*Trogon mexicanus*),Olive warbler (*Peucedramus taeniatus*), Painted redstart (*Myioborus pictus*), Red-faced warbler (*Cardellina rubrifrons*), Red-throated ant-tanager (*Habia fuscicauda*), Slate-throated redstart (*Myioborus miniatus*), Streak-headed woodcreeper (*Lepidocolaptes souleyetii*), Summer tanager (*Piranga rubra*), Tennesse warbler (*Vermivora peregrina*), Townsend's warbler (*Dendroica townsendi*), Tufted flycatcher (*Mitrephanes phaeocercus*), Wilson's warbler (*Wilsonia pusilla*), Woodcreeper sp. (subfamily Dendrocolaptinae, unknown genus), Yellow-throated warbler (*Dendroica dominica*).

Chapter 3. Demography

Survivorship, productivity, and emigration and immigration are the primary demographic parameters that provide critical information for understanding changes in populations. Since the golden-cheeked warbler was listed as an endangered species in 1990, there have been increased efforts in obtaining survival and productivity data to better understand the causes of population trends. Several life history characteristics of golden-cheeked warblers contribute to difficulties in obtaining accurate data including elusive behavior of females (Hayden and Tazik 1991, City of Austin 1999, Travis County 2000), cryptic and difficult to access nests (Hayden and Tazik 1991, Craft 1999), and high juvenile dispersal rates (Jette et al. 1998). For these reasons, much of the information available for population demographics on the breeding grounds is based on observations of the more conspicuous male, consequently underestimating measures of reproductive success and survival (Alldredge et al. 2004, Weckerly and Ott 2008). On the wintering grounds, males are readily distinguished from other *Dendroica* species, but the duller plumage of females and hatch-year birds reduces species identification also biasing estimates towards males (Vidal et al. 1994).

Two long-term research programs have provided the majority of data related to demographics, Fort Hood Military Reservation (in Coryell and Bell Counties), and the Balcones Canyonlands Preserve (BCP, in Travis County), comprised primarily of properties owned by the City of Austin and Travis County. During the course of these long-term studies, changes made to methods, study sites, and effort limit inferences across years. In this chapter, we briefly describe these long-term studies and note when changes were made to methods, effort, or study sites. We provide annual summary data for abundances and population demographics for these long-term studies. We report only estimates, statistics, and sample sizes provided in the literature and note any estimates that we calculated for ease in reporting information. We discuss factors that influence these demographics in Chapter 5.

In this chapter, we define territory success for an individual territory as having ≥ 1 nestling fledge successfully during a breeding season. For multiple territories, territory success is the percent of territories that successfully fledge ≥ 1 young, regardless of pairing status (i.e., the estimate includes males that were not paired with a female or for which pairing status was unknown). Pairing success is the proportion of males that acquire a female during the breeding season and does not account for territory or nesting success. Apparent nest survival is the proportion of total nests monitored that successfully fledged ≥ 1 young, whereas nest survival is the probability that a nest will be successful and is calculated using Mayfield estimates (Mayfield 1969) or maximum likelihood approaches (Rotella et al. 2004, Shaffer 2004).

3.1 Long-term Study Sites: Fort Hood, Balcones Canyonlands Preserve, and Camp Bullis

Beginning in 1991, the U.S. Army Construction and Engineering Research Laboratory and the Oklahoma Biological Survey collected demographic data at one study site in southwestern Fort Hood (Jette et al. 1998). Beginning in 1997, The Nature Conservancy (TNC) of Texas collected demographic data and added more study sites. From 1996 to 1997, protocols for data collection and compilation changed thus complicating abilities to compare inter-annual trends for several demographic parameters. Additionally, some approaches to data analysis were refined in 2003 (Peak 2003a). Point count surveys were conducted each year, although effort and sample sizes varied annually (see below). Estimates of territory density and productivity within monitoring sites were considered reliable among 1991-1996, 2000-2002 (except sampling effort declined in 2002), and 2003-2008 based on consistency of study sites and sampling methods within those time frames (Table 3.3; Jette et al. 1998, Anders 2000a, Peak 2003a, Peak and Strebe 2008).

The BCP system was established by the Balcones Canyonlands Conservation Plan (BCCP, finalized in 1996) to provide mitigation for incidental take in Travis County (BCP 2009; see Chapter 8). On City of Austin and Travis County properties, population trends and productivity are tracked in a series of 100-ac plots that are designated as prime or transitional plots (City of Austin 2009, Travis County 2010). Study plots classified as "prime" have ≥ 70% canopy cover, whereas "transitional" plots support few warbler territories and has the potential to become "prime" warbler habitat within the next 30 years (BCP 1998). Annual monitoring on City of Austin properties began in 1998 (City of Austin 1999). In 2008 efforts focused on nest searching and monitoring and the city initiated a banding program in 2009 (City of Austin 2008, 2009). Monitoring on Travis County properties began in 2000 and additional 100-ac plots were added as land was acquired (Travis County 2000b).

At the Camp Bullis Training Site, Bexar County, surveys for warblers began in 1991 and territory monitoring was conducted in 1998 (Weinberg 1998), in 2005 (Cooksey and Thompson 2005), and again in 2008 (Cooksey and Edwards 2008). The number of survey transects changed over the years (see below).

3.2 Trends in Relative Abundance and Density

3.2.1 Abundance on Fort Hood 1992–2008

Detection surveys were conducted annually in woodland vegetation on Fort Hood since 1992. In 1991 on Fort Hood, 123 point counts placed ≥ 300 m apart were established in woodland vegetation and a standard survey protocol was developed in 1992 (Hayden and Tazik 1991). The number of points, number of routes, time spent at each point count, and the number and timing of surveys changed during the study. Point counts established along routes ranged from 206 points on 19 routes in 1992 to 365 points on 27 routes in 1997 (Anders and Dearborn 2004, Peak 2008). From 1998 to 2008, 428 points along 31 routes were surveyed each year (Anders and Dearborn 2004, Peak 2008). Additionally, the number of visits and time spent at each point varied by survey year (Anders and Dearborn 2004, Peak 2008). From 1992 to 2001, the mean number of warblers detected from the survey points increased significantly (Anders 2001b, Anders and Dearborn 2004). Using the same data extended to 2008, Peak (2008) also detected an increasing trend in warbler abundance. However, mean number of detections from 2000 to 2008 indicated that the abundance of warblers might have been stabilizing (Peak 2008).

3.2.2 Territory Density

On Fort Hood, territory density was estimated on monitoring plots using territory-mapping methods; differences in estimates among years were likely because of differences in methods and study sites as noted above. From 1991–2008 the number of territories per hectare within monitoring plots increased (Fig. 3.1), a trend which supports the increasing trend in abundance of warblers at standard point counts across Fort Hood.

For the BCP, Weckerly and Ott (2008) recommended that trends in abundance should be reported on a per plot basis because of the amount of variability within plots among years. From 1999 to 2006, territory densities increased in 2 of 5 plots defined as prime habitat on City of Austin property (Fig. 3.2; Weckerly and Ott 2008). Territory densities in 3 transitional plots on City of Austin properties did not exceed 0.25 territories/ha (0.10 territories/ac) between 1998 and 2008. On Travis County properties, the number of territories per hectare increased on 2 of the study plots between 2002 and 2008 (Fig. 3.3; Travis County 2008b).

On Camp Bullis, Bexar County, territory densities indicated a variable trend across survey years (Fig. 3.4). Cooksey and Edwards (2008) suggested an increasing trend in density of warblers based on a linear regression of data from 1991–2008.

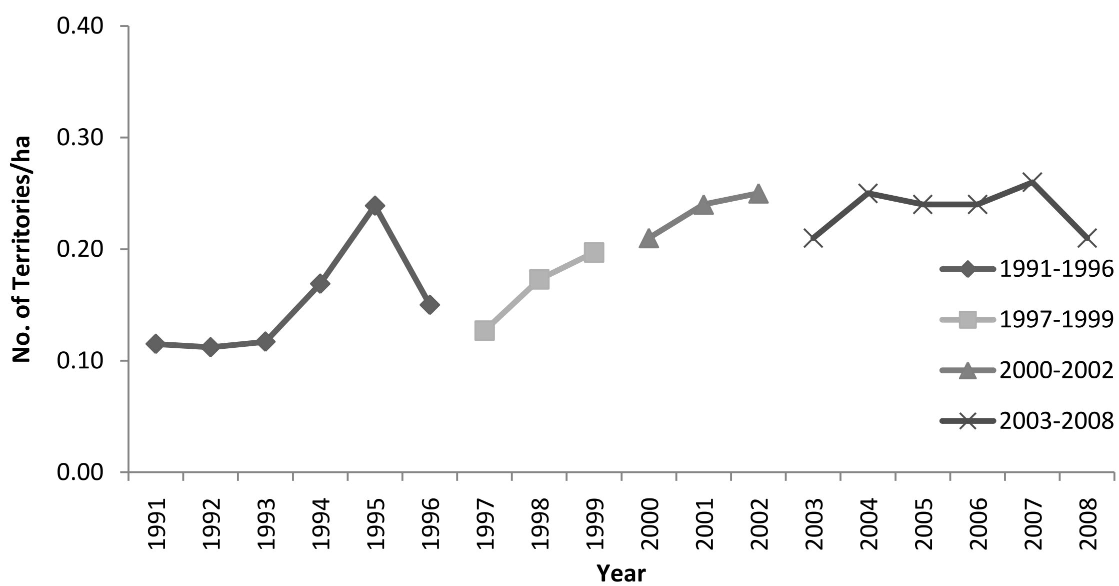

Fig. 3.1 Annual territory densities (territory/ha) of golden-cheeked warblers on monitoring sites on Fort Hood Military Reservation, Bell and Coryell Counties, Texas from 1991 to 2008. Years are grouped based on similar survey methods and number of study sites.

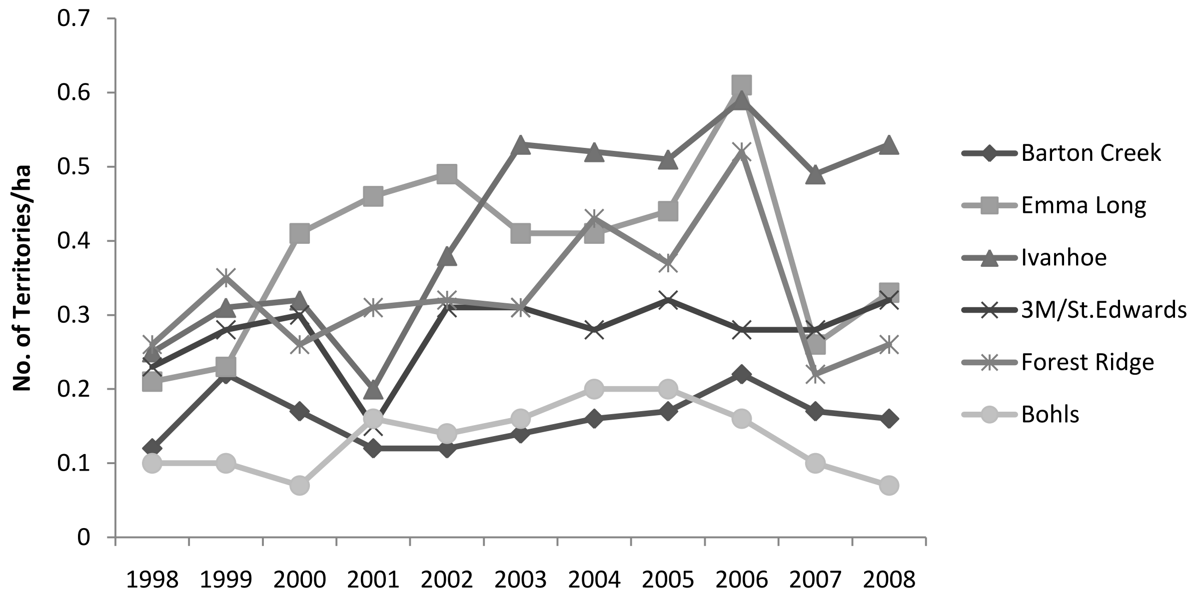

Fig. 3.2. Territory densities (number of territories/ha) of golden-cheeked warblers for prime habitat plots on City of Austin properties in Travis County from 1998 to 2008. In 2008, Bohls was reclassified as a transitional habitat plot because portions of the plot were cleared in previous years to create black-capped vireo habitat (City of Austin 2008).

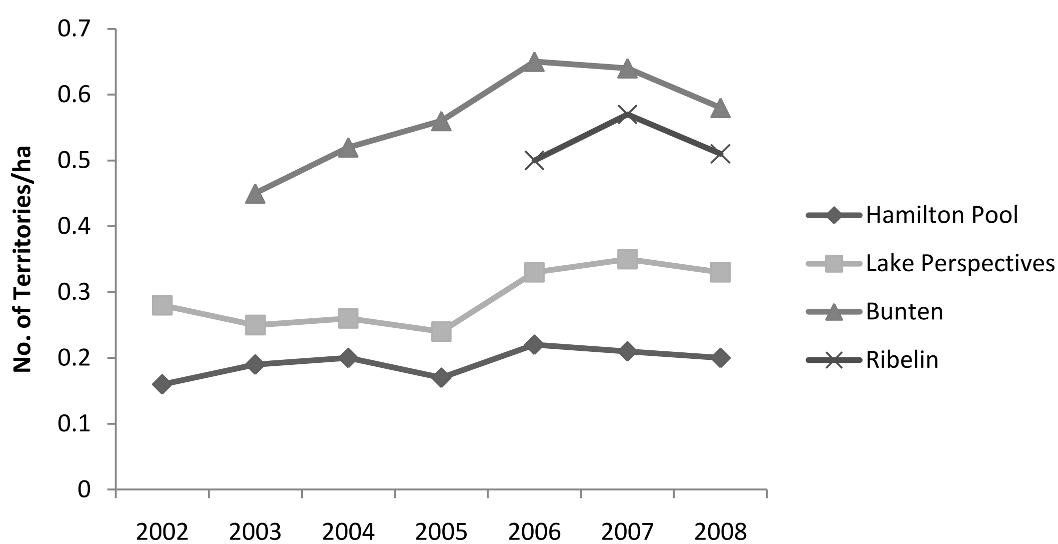

Fig. 3.3. Territory densities (number of territories/ha) of golden-cheeked warblers for 100-ac plots on Travis County properties from 2002 to 2008.

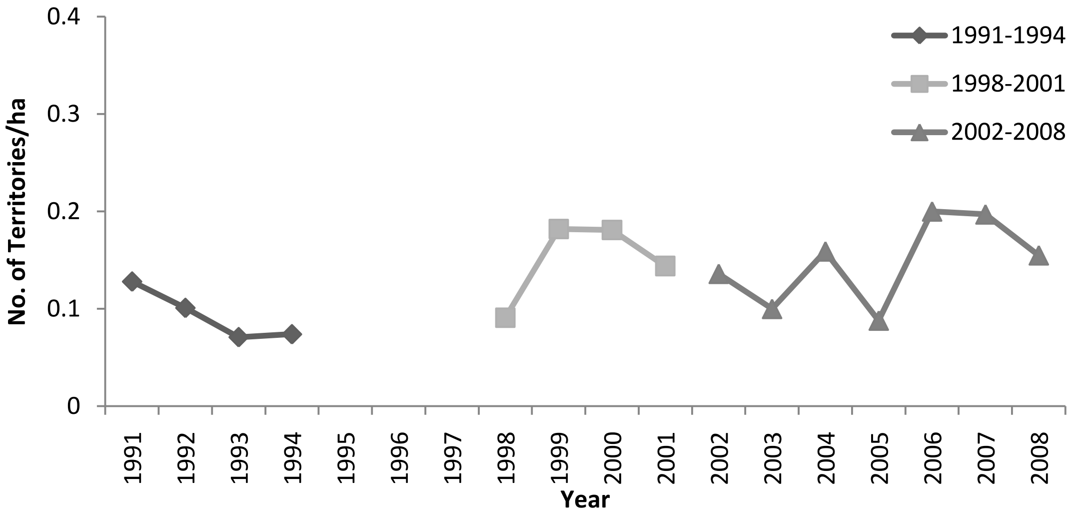

Fig. 3.4. Annual territory densities (territories/ha) of golden-cheeked warblers on Camp Bullis Training Site, Bexar County, Texas from 1991 to 2008. Years are grouped based on similar survey methods or study areas. Only partial surveys were conducted from 1995 to 1998.

3.3 Population Structure

3.3.1 Age at First Breeding

There is no obligate physiological delay in breeding capabilities in golden-cheeked warblers (Ladd and Gass 1999); however, second-year (SY) males may be less likely to acquire a mate than after-second year (ASY) males (Jette et al. 1998). From 1991 to 1996 at Fort Hood, SY males were 18.6% less likely to pair than ASY males (SY: 79%, *n* = 61; ASY: 97%, *n* = 88; Jette et al. 1998).

3.3.2 Age Ratios

On the breeding grounds, estimates for age structure were based on the detection of males because captures of females were rare (Holimon and Craft 2000, City of Austin 2009). Age ratio estimated here is the proportion of SY males to the total known-aged individuals (SY + ASY males) based on individuals that were either captured and aged using standardized aging techniques (Pyle 1997) or individuals that were uniquely banded and subsequently resighted. At Fort Hood from 1992 to 1996, the total proportion of SY males in the population was 0.417 (*n* = 70 males) and ranged from a low of 0.303 (*n* = 33 males) in 1996 to a high of 0.571 (*n* = 21 males) in 1993 (Jette et al. 1998; Table 3.1). Also on Fort Hood but in a different study location, the proportion of SY males in the population in 1995 was 0.408 (*n* = 49 known-aged males) and was 0.216 (*n* = 37) in 1996 (Maas 1998). After 1996 the study sites and effort differed annually, and the proportion of SY males in the population ranged from a low in 2007 of 0.168 (*n* = 175 males) to a high in 2005 of 0.466 (*n* = 148). Between 1993 and 1997 the proportion of SY males in a population of warblers located on Balcones Canyonlands National Wildlife Refuge (BCNWR, Travis and Williamson Counties) ranged from 0.275 (*n* = 69 males) in 1997 to 0.500

Table 3.1. Total number of after second-year males (ASY), second-year (SY) males, and the proportion of the population made up of SY males for golden-cheeked warblers at study sites in Fort Hood, Balcones Canyonlands National Wildlife Refuge (BCNWR), and Barton Creek Habitat Preserve (BCHP), Texas.

	Fort Hood			BCNWR			BCHP		
Year	ASY males	SY males	Proportion of SY	ASY males	SY males	Proportion of SY	ASY males	SY males	Proportion of SY
1992	11	6	0.353	-	-	-	-	-	-
1993	9	12	0.571	18	18	0.500	-	-	-
1994	21	17	0.447	37	21	0.362	-	-	-
1995	34	25	0.424	57	39	0.406	-	-	-
1996	23	10	0.303	59	35	0.372	28	12	0.300
1997	19	13	0.406	50	19	0.275	43	16	0.270
1998	49	39	0.443	-	-	-	-	-	-
2000	100	47	0.320	-	-	-	-	-	-
2001	111	46	0.293	-	-	-	-	-	-
2002	71	37	0.343	-	-	-	-	-	-
2003	93	56	0.376	-	-	-	-	-	-
2004	45	31	0.408	-	-	-	-	-	-
2005	79	69	0.466	-	-	-	-	-	-
2006	125	49	0.282	-	-	-	-	-	-
2007	146	29	0.168	-	-	-	-	-	-
2008	102	35	0.255	-	-	-	-	-	-

(*n* = 36 males) in 1993 (Keddy-Hector et al. 1998). In the same study, the proportions of SY male warblers at Barton Creek Habitat Preserve (BCHP; Travis County) in 1996 and 1997 were comparable to estimates at the BCNWR (Table 3.1).

3.3.3 Nestling and Hatch-year Sex Ratios

To our knowledge, no genetic analyses of nestling or hatch-year (HY) sex ratios have been documented for golden-cheeked warblers. Determining the sex of HY birds is possible after they complete their first prebasic molt (Peak and Lusk 2009). Late in the season, most HY birds can be reliably sexed (Jette et al. 1998). From mist-net efforts on Fort Hood between 1991 and 1996, the sex ratio was 1.86:1 (male:female), an estimate derived from totals of HY individuals for all years combined of 170 males, 90 females, and 54 individuals of unknown sex (Jette et al. 1998).

3.3.4 Adult Sex Ratios

Adult sex ratio is defined as the proportion of the adult (after hatch-year [AHY]) population made up of males. Estimates of adult sex ratio calculated during the breeding season require inclusion of all non-breeding adults and considerations of potential sources of bias (Donald 2007). No estimates of adult sex ratios are available for golden-cheeked warblers on the breeding grounds. Although pairing success (below) may provide an estimate of adult sex ratios (Probst and Hayes 1987), this index does not account for sources of bias caused by low detectability of females (Hayden and Tazik 1991, Jette et al. 1998).

Most researchers have found more males than females on the wintering grounds (Thompson 1995, Rappole 1996, Hernandez and Munoz 2006, Gonzalez-Callejas 2008, Komar et al. 2009). Vidal et al. (1994) found male golden-cheeked warblers to be more abundant than females (36 males, 15 females; ratio 2.4:1) in a study conducted in Chiapas, Mexico. On the other hand, Rappole et al. (1999) found golden-cheeked warbler sex ratio to approach 1:1 (76 males, 70 females) in Honduras and Guatemala. From on-going research, Komar (personal communication) has proposed the possibility of sexual segregation during winter based on elevation or latitude. Potential bias in adult sex ratio estimates on the wintering grounds may result from difficulties in distinguishing female golden-cheeked warblers from females of sibling species, (e.g., black-throated green warblers [*Dendroica virens*]), whereas male warblers are more easily distinguished among species (Vidal et al. 1994).

3.4 Reproductive Success

Indices for reproductive success often are used because of difficulties in locating and monitoring females or nests (Craft 1998) or attempts to avoid disturbance to nesting pairs (Maas 1998). The predictive accuracy of reproductive indices has not been evaluated for golden-cheeked warblers but they likely are biased because they have focused on male warblers that are more conspicuous and easier to monitor than females or nests. These male-centered surveys often mask details important for determining population dynamics, such as the frequency of unmated males, renest attempts, double-brooding, or polygyny. Furthermore, inferences among study areas and across years should be made with caution because variation in survey methods, effort, or ecological factors can bias estimates obtained by indices of reproductive activity (Rivers et al. 2003, Bonifait et al. 2006).

Indices used to infer reproductive success include estimates of territory success, pairing success, recruitment index, and nest survival estimates. The most common index for productivity estimates of golden-cheeked warblers was territory success, based on a ranking system for reproductive status, such as that developed by Vickery et al. (1992). Pairing success, or the proportion of territorial males for which females are detected, also is used as an index for breeding productivity for golden-cheeked warblers because of the difficulty in locating nests or fledgling groups. Because females are difficult to detect (Craft 1998), these estimates should be viewed as minimum estimates of paired males (Hayden and Tazik 1991). Another productivity index used on Fort Hood (1997–1999) was a recruitment index which used return rates of SY birds relative to the proportion of after-second year birds in the population, although changes to effort and methods limited inferences among years (Holimon and Craft 2000). Nest survival estimates derived from direct monitoring of nests can be calculated as apparent nest survival (number of nests that fledge young relative to the total number of nests monitored), or using Mayfield (1961) or maximum likelihood approaches (Shaffer 2004). Productivity of males is estimated by monitoring territories throughout the season and counting fledglings when detected (Hayden and Tazik 1991).

3.4.1 Pairing Success

At Fort Hood, monitoring efforts, study sites, and protocols changed annually. In 1991, pairing success estimates were probably underestimated due to low monitoring effort

(Hayden and Tazik 1991; Table 3.2). From 1992 to 1996 pairing success was 89% (*n* = 167 males) and there was no significant difference among years (Jette et al. 1998). Pairing success was significantly lower for SY males (79%, *n* = 61, range = 70–85%) than for ASY males (97%, *n* = 88, range = 82–100%; Jette et al. 1998). Similar to the previous study, pairing success estimates from 1997 to 1999 also were similar among years (Craft et al. 1999, Holimon and Craft 2000). From 2000 to 2003 pairing success ranged from 79.5% to 95% and did not differ significantly among years (Peak 2003a). Peak and Strebe (2008) reported a significant difference in pairing success among 2003–2008, when pairing success was 78.5% in 2004 compared to estimates from the other years that ranged from 82% to 94.9%.

City of Austin provided annual estimates of pairing success as the mean estimate of pairing success for 5 study sites classified as prime habitat plots and 3 transitional study plots (City of Austin 2008). We report estimates for prime plots because of low numbers of males and females detected at transitional plots (Table 3.2). Estimates for pairing success ranged 53–89% for territories at which females or fledglings were detected (City of Austin 2008). Using regression analysis, Weckerly and Ott (2008) detected an increasing trend in pairing success from 1998 to 2007 but annual variability suggested the trend was not strong.

For Travis County properties, estimates for pairing success in 2000 and 2001 were reported by Travis County as the combined total for 2 study sites that year (Travis County 2000, 2001). After 2002, Travis County reported values for each study site, thus, for ease in reporting we calculated the annual mean pairing success (Table 3.3; Travis County 2008b). Furthermore, prior to 2005, estimates included full territories (those contained entirely within the 100-ac plot) plus 0.5 of the edge territories. Although study sites and methods for calculating estimates varied annually, estimates of pairing success ranged 60–92% (Table 3.3).

Pairing success estimates at BCNWR and BCHP ranged from 50% to 66% (*n* = 62; Table 3.3; Keddy- Hector et al. 1998).

At Camp Bullis, pairing success was 63.6% (*n* = 22) in 1998 (Weinberg 1998), 6% (*n* = 31) in 2005 (Cooksey and Thompson 2005), and in 2008 a female was detected at 1 of 12 territories (8.3 %; Cooksey and Edwards 2008).

3.4.2 Recruitment index

The only study to use a recruitment index to infer productivity occurred at Fort Hood between 1994 and 1998 (Table 3.4; Holimon and Craft 2000). This index was calculated by dividing the number of SY males in a year by the total number of AHY breeding males in the previous year (Holimon and Craft 2000). This index assumed that productivity in the previous year was positively associated with the number of SY males recruited into the breeding population in subsequent years (Holimon and Craft 2000).

Table 3.2. Pairing success, territory success, and pair reproductive success for warblers on Fort Hood monitoring sites, 1991–2008. Dashes (-) indicate that no information was provided in the source. For some study years, totals and estimates may have been provided or altered in subsequent annual reports, thus, totals provided below may not directly calculate estimates of pairing, territory, or pair reproductive success.

Year	No. of Study Sites	Total No. of Territories	No. of Territories Monitored	No. of Territories with Females	Pairing Success	No. of Successful Territories	Territory Success		Pair Reproductive Success	
							proportion	95% CI	proportion	95% CI
1991	1	31	21	11	0.52	9	0.43	-	-	-
1992	1	24	24	24	0.79	16	0.67	-	0.84	-
1993	1	24	24	24	0.92	20	-	-	0.91	-
1994	1	36	33	30	-	28	-	-	0.93	-
1995	1	59	51	51	0.92	45	0.88	-	0.96	-
1996	1	32	32	30	-	25	-	-	-	-
1997	2	66	66	48[d]	0.73[d]	47	0.89, 0.52[a]	-	-	-
1998	2	89	89	65	0.73	-	-	-	-	-
1999	2	99	99	64	0.65	-	-	-	-	-
2000	3	164	156	153	0.95	137	0.88	0.816-0.923	0.93	0.871-0.962
2001	3	185	-	159	0.86	131	-	-	0.82	0.756-0.877
2002	4	161	-	128	0.80	96	-	-	0.75	-
2003	4	167	167	137	0.82	94	0.56	0.483-0.639	-	-
2004	3	158	158	124	0.79	87	0.55	0.469-0.629	-	-
2005	3	148	148	131	0.89	90	0.61	0.525-0.684	-	-
2006	3	174	174	155	0.89	97	0.56	0.481-0.630	-	-
2007	3	173	173	-	0.90	93	0.54	0.461-0.612	-	-
2008	3	137	137	130	0.95	76	0.56	0.467-0.639	-	-

[a] Estimates were provided for each of 2 study site separately (Craft 1998).

Table 3.3. Mean annual pairing success for warblers on City of Austin properties (1998–2008), Travis County properties (2000–2008), Balcones Canyonlands National Wildlife Refuge (BCNWR, 1993–1997), and Barton Creek Habitat Preserve (BCHP, 1996–1997). Dashes (-) indicate no available information.

	City of Austin[1]			Travis County[2]			BCNWR[3]			BCHP		
Year	No. of Study Sites	Total No. of Territories	Mean Pairing Success	No. of Study Sites	Total No. of Territories	Mean Pairing Success	No. of Study Sites	Total No. of Territories	Mean Pairing Success	No. of Study Sites	Total No. of Territories	Pairing Success
1993	-	-	-	-	-	-	2	86	0.61	-	-	-
1994	-	-	-	-	-	-	2	104	0.41	-	-	-
1995	-	-	-	-	-	-	2	106	0.52	-	-	-
1996	-	-	-	-	-	-	2	115	0.49	1	45	0.53
1997	-	-	-	-	-	-	2	108	0.58	1	62	0.66
1998	5	28	0.67	-	-	-	-	-	-	-	-	-
1999	5	39	0.74	-	-	-	-	-	-	-	-	-
2000	5	38	0.53	3	20	0.60	-	-	-	-	-	-
2001	5	31	0.70	4	66	0.61	-	-	-	-	-	-
2002	5	49	0.68	2	23	0.84	-	-	-	-	-	-
2003	5	46	0.71	3	45	0.92	-	-	-	-	-	-
2004	5	45	0.72	3	27	0.87	-	-	-	-	-	-
2005	5	51	0.80	3	27	0.81	-	-	-	-	-	-
2006	5	69	0.89	4	55	0.67	-	-	-	-	-	-
2007	5	37	0.84	4	50	0.90	-	-	-	-	-	-
2008	5	43	0.88	5	66	0.71	-	-	-	-	-	-

[1] Estimates for City of Austin properties include the total number of full territories detected in prime habitat plots and the mean proportion of paired territories across all study sites. Prior to 2005, estimates were calculated using full territories (those contained within the 100-ac plots) and 0.5 of the edge territories.

[2] Estimates for Travis County include one study site originally classified as transitional habitat but was surveyed similar to prime plots and was therefore included in estimates. Estimates for the proportion of paired territories in 2000 and 2001 were estimated in annual reports as totals for all plots whereas estimates for all other study years were reported by study plot. For ease in reporting, we calculated the mean proportions across all study sites for 2002–2008.

[3] Estimates for BCNWR were reported separately for 2 study sites but for ease in reporting we calculated the mean pairing success based on information provided in Keddy-Hector et al. (1998).

Table 3.4. Recruitment index at 2 study sites on Fort Hood, calculated as the number of second-year birds detected in year *t* relative to the number of breeding males in year *t*-1 for golden-cheeked warblers from 1994 to 1998 (Holimon and Craft 2000). Dashes (-) indicate no information provided in reports.

	13B		West Fort Hood	
Year	No. of Males	Recruitment Index	No. of Males	Recruitment Index
1994	36	0.56	-	-
1995	50	0.20	-	-
1996	32	0.47	-	-
1997	36	0.83	29	0.31
1998	56	0.48	33	0.21

3.4.3 Territory and Pair Reproductive Success

On Fort Hood, estimates of territory and pair reproductive success were not consistent across all years because of changes in methods, number of study sites, effort, and measures for reporting reproductive success (Jette et al. 1998, Anders 2000a, Pekins 2002b, Peak 2003, Peak and Strebe 2008). Estimates of pair reproductive success were comparable from 1993–1995, and 2000–2002, except inferences from 2002 may be limited due to reduction in study site area (Anders 2000a, Anders 2001a, Pekins 2002b). During these years, pair reproductive success was similar (0.91–0.96) but declined in 2001 and again in 2002 (Jette et al. 1998, Anders 2000a, Anders 2001b, Pekins 2002b). Territory success estimates are comparable from 2003 to 2008, when it ranged 54–61% and there was no difference among years (Table 3.2; Peak and Strebe 2008).

On the BCP, mean annual estimates for 5 study sites on City of Austin properties (1998–2008) ranged 34–82% (Table 3.5) and, using regression analysis, no trend was detected in territory success from 1998–2007 (Weckerly and Ott 2008). Territory success on Travis County properties (2000–2008) ranged 44–76% (Table 3.5). In a separate study on 63 study sites on private and public land, territory success from 1993–1995 was 39.6%, (n = 247) for all years combined and there was no significant difference in territory success among the study years (Coldren 1998). At BCNWR and BCHP, territory success estimates ranged from 27%–42% (Table 3.5; Keddy-Hector et al. 1998).

3.4.4 Nest Success

Nest searching and monitoring was conducted on Fort Hood in 1998 and from 2000–2008; nests were found opportunistically from 1991 to 1997 and 1999 (Craft et al. 1999, Holimon and Craft 2000, Anders 2000a, 2001a, Pekins 2002b, Peak and Strebe 2008). Apparent nest success ranged 50–100% at Fort Hood between 1991 and 2002 (Table 3.6) but comparisons across years is limited because of differences in methods and sample sizes. At BCNWR from 1993 to 1995, all years combined, 12 of 21 nests (57%) were successful (Gass 1996). Nest success was 49% (n = 39 nests) on City of Austin properties in 2008 (City of Austin 2008).

Whereas apparent nest survival is biased high, 2 techniques account for biases resulting from when nests are located and monitoring begins (Jehle et al. 2004). For adequate sample sizes Mayfield (1961) estimates are reliable for comparisons among years and study areas. Additionally, maximum likelihood methods allow for model-based estimates predicting nest

Table 3.5. Territory success for properties owned by City of Austin from 1998 to 2008 (COA annual reports), Travis County (Travis County annual reports), Balcones Canyonlands National Wildlife Refuge (BCNWR), and Barton Creek Habitat Preserve (BCHP; Keddy-Hector et al. 1998).

	Year	No. of Study Sites	No. of Total Territories	Territory Success
City of Austin	1998	5	28	0.54
	1999	5	39	0.67
	2000	5	38	0.34
	2001	5	31	0.50
	2002	5	49	0.40
	2003	5	46	0.67
	2004	5	45	0.50
	2005	5	51	0.63
	2006	5	69	0.70
	2007	5	37	0.82
	2008	5	43	0.69
Travis County	2000	3	20	0.60
	2001	4	66	0.44
	2002	2	23	0.55
	2003	3	45	0.76
	2004	3	27	0.58
	2005	3	27	0.79
	2006	4	55	0.51
	2007	4	50	0.76
	2008	5	66	0.49
BCNWR	1993	2	86	0.42
	1994	2	104	0.27
	1995	2	106	0.28
	1996	2	115	0.29
	1997	2	108	0.37
BCHP	1996	1	45	0.31
	1997	1	62	0.39

[1] Territory success is reported in City of Austin (2009) as the mean value across study sites; mean values for Travis County and BCNWR were calculated using data provided in Travis County (2009) and Keddy-Hector et al. (1998), respectively.

Table 3.6. Apparent nest survival (i.e., number of successful nests/total number of nests) for nests monitored on Fort Hood, 1991–2002 (Hayden and Tazik 1991, Bolsinger and Hayden 1993, Weinberg et al. 1995, 1996, Craft 1998, Craft et al. 1999, Holimon and Craft 2000, Anders 2000, 2001, Pekins 2002b). Dashes (-) indicate no information provided in reports.

Year	No. of Nests	Proportion of Successful Nests
1991	6	0.50
1992	-	-
1993	5	0.60
1994	10	1.00
1995	4	1.00
1996	-	-
1997	7	0.71
1998	16	0.50
1999	5	0.60
2000	27	0.70
2001	45	0.69
2002	34	0.62

success relative to a set of covariates (Shaffer 2004). Mayfield estimates for overall nesting success for Fort Hood from 2000 to 2002 ranged 14–50% (Table 3.7). Low overall nest survival in 2000 resulted from low survival during the incubation period and researchers at Fort Hood suggested that this estimate was underestimated during that study year (Anders 2000a). At BCNWR from 1993 to 1995, all years combined, Mayfield estimates of nest survival were 0.42 during incubation and 0.89 during the nestling period for 21 nests (Gass 1996).

Researchers used model-based estimates (logistic exposure method; Shaffer 2004) to estimate nest success at Fort Hood from 2003 to 2008 (Peak and Strebe 2008). Nest survival did not differ among years and ranged from 35% in 2005 to 46% in 2004 using a model that included temporal and edge effects (Table 3.8; Peak and Strebe 2008). For 195 nests at Fort Hood and Travis County in 2005 and 2006, overall nest survival was similar in Austin (0.399, 95% CI = 0.269–0.524) and on Fort Hood (0.396, 95% CI = 0.261–0.528).

3.4.5 Productivity

Productivity (or fecundity) is defined as the number of female young produced per female within a breeding season (Anders and Marshall 2005); however, for golden-cheeked warblers, productivity estimates are often relative to the male because of low detection rates of females (Hayden and Tazik 1991, City of Austin 1999, Travis County 2000a). In the literature on golden-cheeked warblers, estimates of productivity based on the male are reported using 4 different calculations: (1) the number of young produced per territorial male, regardless of pairing status; (2) the number of young produced per paired male, which represents a minimum estimate relative to the number of females present; or (3) the number of young produced per successful male, where male is interchangeable with territory or pair and this measure is often referred to as a measure of brood size.

The number of young fledged per territory (male) ranged 1.13–2.06 on Fort Hood between

Table 3.7. Nest survival estimates at Fort Hood for the incubation, nestling, and overall nesting periods for golden-cheeked warblers using Mayfield (1961, 1975) estimation methods. The incubation period included 3 days of egg-laying and 11 days of egg incubation, the nestling period represented 10 days, and the overall nest survival estimate was calculated by multiplying the estimates for the incubation and nestling periods (Anders 2000a).

Year	No. of Nests	Nest Survival for Incubation Period[a]	Nest Survival for Nestling Period	Overall Nest Survival
2000	27	0.19	0.78	0.14
2001	45	0.62	0.73	0.45
2002	26	0.65	0.76	0.50

Table 3.8. Nest survival estimates at Fort Hood for the incubation, nestling, and overall nesting periods for golden-cheeked warblers using logistic-exposure maximum likelihood estimates (Shaffer 2004). Overall nest survival estimates assume 3-day egg-laying period, 11-day incubation period, and 12-day nestling period (Peak and Strebe 2008). Dashes (-) indicate no information provided in reports.

Year	No. of Nests	Overall Nest Survival	95% CI	
			lower	upper
2003	53	0.38	-	-
2004	63	0.46	-	-
2005	60	0.35	-	-
2006	93	0.34	0.23	0.46
2007	76	0.37	0.29	0.45
2008	84	0.36	0.29	0.43

Table 3.9. Productivity estimates for golden-cheeked warbler males on Fort Hood, 1991–1999. Estimates are based on detections of fledglings on territories with males and should be considered a minimum estimate (Anders 2000a). Dashes (-) indicate no information provided in reports.

Year	No. of Study Sites	No. of Young Fledged	Young Fledged per Territorial Male	Young Fledged per Paired Male	Young Fledged per Successful Male
1991	1	-	-	-	1.89
1992	1	27	1.13	1.42	1.69
1993	1	45	1.80	2.05	2.25
1994	1	63	1.75	2.10	2.25
1995	1	103	2.06	2.19	2.29
1996	1	52	1.63	1.73	2.08
1997	2	50	0.76	1.04	1.03
1998	2	116	1.30	1.79	-
1999	2	76	0.77	1.12	-

1991 and 1999. The number of young produced per successful male (i.e., brood size) ranged 1.03–2.29 on Fort Hood between 1991 and 1997 (Table. 3.9). Caution is advised in inferring any trends in these data because of inconsistencies among years and because estimates are derived from the observed number of fledglings with males, which may be biased low because adult warblers split broods (Craft 1998).

The number of young fledged per territory (male) ranged from 0.99 to 1.74 on Travis County properties (2001–2008) and ranged from 0.93 to 1.68 on City of Austin properties (1998–2008; Table 3.10). For City of Austin properties, regression analysis detected no trend was detected in the number of young fledged per territory from 1998–2007 (Weckerly and Ott 2008).

The number of young fledged per successful pair (i.e., brood size) for BCP properties ranged 1.43–2.27 on Travis County properties, 1.96–2.49 on City of Austin properties, and 2.29–2.79 on BCHP (Table 3.10). For City of Austin properties, regression analysis indicated no trend in the number of young fledged from successful territories from 1998–2007 (Weckerly and Ott 2008). Estimates for the BCNWR ranged 1.86–2.87 young per pair (Table 3.10).

3.5 Dispersal and Site Fidelity

3.5.1 Juveniles

The only available information on juvenile dispersal was from research conducted on Fort Hood where HY birds were captured and banded during the post-fledging period. Between 1991 and 1996 at Fort Hood, dispersal distances for SY males from the location they were banded in the previous year as a HY was 60–10,004 m (mean = 2,461 m, *n* = 17) and 0–3,448 m for SY females (mean = 1,785 m, *n* = 6; Jette et al. 1998). In a second study at Fort Hood during this time period, no HY birds returned to the same location in the subsequent year (*n* = 26; Maas 1998). In 1997 on Fort Hood, a SY male returned 3.4 km away from the location it was banded in 1996 as a HY (Craft 1998).

3.5.2 Adults

Dispersal distances for adult warblers were reported by Fort Hood as the distance between where an individual was banded or resighted in one year and the location it was resighted in the following year. An individual was considered site faithful (i.e., maintain site fidelity) if it returned to ≤ 300 m (Jette et al. 1998) or ≤ 250 m (Maas 1998) of its location in the previous year.

At Fort Hood (1991–1996), adult males returned to locations 0–3,500 m (mean = 223 m, SD = 307, *n* = 268) from their location in the previous year and adult females returned to locations 100–1,005 m (mean = 322 m, SD = 294, *n* = 11) from locations in the previous year (Jette et al. 1998). Males banded between 1992 and 1996 as SY dispersed an average of 312 m (SE = 61.99, *n* = 6) to where they were resighted in 1997 and males banded as ASY were resighted an average of 144 m (SE = 26.99, *n* = 8) from their previous location (Craft 1998). Males banded as SY between 1993 and 1997, returned in 1998 to a mean distance of 222 m from banding locations

Table 3.10. Productivity estimates for properties owned by City of Austin and Travis County, and for the Balcones Canyonlands National Wildlife Refuge (BCNWR) and Barton Creek Habitat Preserve (BCHP). Dashes (-) indicate no information provided in reports.

	Year	No. of Study Sites	No. of Young per Territory	No. of Young per Successful Male
Travis County				
	2001	4	0.99	1.67
	2002	2	1.54	2.02
	2003	2	1.28	2.14
	2004	-	1.74	2.27
	2005	3	0.99	1.43
	2006	4	1.71	1.91
	2007	4	1.01	1.43
	2008	5	-	1.43
City of Austin				
	1998	5	0.97	2.36
	1999	5	1.30	2.34
	2000	5	0.81	2.36
	2001	5	1.56	1.96
	2002	5	0.93	2.06
	2003	5	1.30	2.08
	2004	5	1.16	2.42
	2005	5	1.40	2.20
	2006	5	1.62	2.31
	2007	5	2.03	2.49
	2008	5	1.68	2.40
BCNWR				
	1993	2	-	2.13
	1994	2	-	1.89
	1995	2	-	2.63
	1996	2	-	1.86
	1997	2	-	2.87
BCHP				
	1996	1	-	2.79
	1997	1	-	2.29

(SE = 39.87, *n* = 18) and males banded as ASY returned a mean distance of 177 m (SE = 56.14, *n* = 12; Craft et al. 1999).

Site fidelity for Fort Hood, 1992–1996, was 73% (*n* = 268) for males and 55% (*n* = 11) for females (Jette et al. 1998). In a separate location on Fort Hood, site fidelity was defined as returning ≤ 250m from the previous years' location and 12 of 40 (30%) males banded or located in 1995 returned to within ≤ 250 m in 1996 and 4 males returned within ≤ 400 m of their location in 1995 (Maas 1998). In this same study, 2 of 7 females returned in 1996 but neither were relocated ≤ 250 m of the previous location, suggesting 0% site fidelity. Dispersal distances for the 2 relocated females were 1,100 m and 316 m from their location in 1995 (Maas 1998).

From 1993 to 1997 at BCNWR and BCHP in Travis County, 55% of 138 total banded males returned to the same territory from the previous year (Keddy-Hector et al. 1998). For 79 males that returned to a different location, the average distance between years was 210 m (Keddy-Hector, unpublished data in Ladd and Gass 1999).

Little information exists concerning factors that may influence site fidelity of golden-cheeked warblers when habitat is not lost. No information is known regarding whether warblers settle at breeding locations based on information acquired on the previous year's breeding success.

3.6 Annual Survival and Longevity

3.6.1 Juvenile Survival

Return rates for SY (juvenile) birds were estimated on Fort Hood for 1992–1998 using the percent of banded HY that returned to, or adjacent to, study sites. Estimates from 1992 through 1996 did not include HY individuals that were of unknown sex (Jette et al. 1998), whereas estimates in 1997 and 1998 included all birds captured as HY (Craft 1998, Craft et al. 1999). Return rates for males ranged from 11–25% on Fort Hood and were approximately 0–11.8% for females (Table 3.11).

In a population viability analysis (U.S. Fish and Wildlife Service [USFWS] 1996a) using standard mark-recapture analysis, survival probabilities for juvenile males were estimated as 42% (1961–1964 data from Kendall County), 0% (1992–1994 data from BCNWR), and 30% (1991–1995 data from Fort Hood). Using these data and 1997–2001 data from Fort Hood, Alldredge et al. (2004) employed mark-recapture probabilistic modeling and estimated survival for HY males as 30.2% (SE = 0.110).

3.6.2 Adult Survival

Research on adult survivorship of golden-cheeked warblers is primarily reported based on return rates of banded birds. Return rates are considered poor indicators of survivorship because they do not account for emigration from study areas or variation in detection probabilities (Martin et al. 1995). In particular, estimates for adult females likely underestimate survival because of low detectability of females (Ladd and Gass 1999). Without accounting for detection probabilities, return rates will underestimate true survival rates (Martin et al. 1995).

Return rates of banded birds at Fort Hood between 1992 and 2008 ranged from 23.5% to 65.6% (Table 3.12); however, methods, effort and study sites changed among the years. From 1993 to 1996 (return years), overall return rate for males for all years was 48% (n = 127 males; Jette et al. 1998). From 2000 to 2003, return rates were significantly lower in 2002 and 2003 than the other study years (Peak 2003). Return rates for breeding males at Fort Hood from 2003 to 2008 were significantly different, probably because of low return rate estimates in 2005 (Peak and Strebe 2008).

In Travis County, males that were banded in the previous year returned in 1994 through 1997 at an overall rate of 38% (n = 244; Keddy-Hector et al. 1998; Table 3.13).

Table 3.11. Percent of birds banded as hatch-year (HY) that returned to study sites on Fort Hood as second-year (SY) birds (i.e., juvenile return rate) from 1992 to 1998 (Jette et al. 1998, Craft 1998, Craft et al. 1999). Estimates from 1992 to 1996 do not include HY birds of unknown sex (Jette et al. 1998). Dashes (-) indicate no information is provided in the reports.

	Males		Females	
Year	% Return	No. Banded as HY	% Return	No. Banded as HY
1992	100	2	0	0
1993	11.1	27	0	8
1994	18.8	16	0	6
1995	21.3	47	10	30
1996	12.5	56	11.8	34
1997	9.1	11	-	-
	Males and Females			
1998	25	12	-	-

Table 3.12. Percent of adults that returned to study sites on Fort Hood that were banded or detected in the previous year (i.e., adult return rate; TNC annual reports). Dashes (-) indicate no information provided in reports.

Year of Return	No. of Banded Males	% Return
1992	64	36.3
1993	22	50.0
1994	23	60.9
1995	32	65.6
1996	50	30.0
1997	30	43.3
1998	57	63.2
1999	-	-
2000	27	48.1
2001	164	42.1
2002	213	24.4
2003	93	36.6
2004	142	47.9
2005	149	23.5
2006	120	38.3
2007	170	44.1
2008	170	42.9

Table 3.13. Return rates of adult birds banded in the previous year that returned to study sites in Travis County (Keddy-Hector et al. 1998)

ReturnYear	No. of Males Banded	Proportion Return
1994	39	0.38
1995	43	0.33
1996	71	0.39
1997	91	0.40

In a population viability analysis (USFWS 1996) using standard mark-recapture analysis, survival probabilities for adult males were estimated as 69% (1961–1964 data from Kendall County), 61% (1992–1994 data from BCNWR), and 57% (1991–1995 data from Fort Hood). Using these data and 1997–2001 data from Fort Hood, Alldredge et al. (2004) employed mark-recapture probabilistic modeling and estimated survival for AHY males as 56.3% (SE = 0.044).

Between 1993 and 1996 on Fort Hood, 18.3% (n = 60) of banded females were resighted in the following year (Jette et al. 1998). However, little is known about female return rates because of low detection rates (Ladd and Gass 1999).

3.6.3 Longevity

The oldest golden-cheeked warbler detected breeding was a male of 8 years (Ladd and Gass 1999) and a breeding female of 6 years (R. Peak, personal communication).

3.7 Population Viability Analyses

Population viability analyses use estimates of fecundity, adult survival, and juvenile survival rates to assess the status of a population and the probability of extinction (Bessinger 2002). The USFWS (1996) conducted a population viability analysis and determined that the size of a viable population of golden-cheeked warblers should exceed 3,000 breeding pairs per population (i.e., per Recovery Region). This study used the number of fledglings per male as an estimate of fecundity from data acquired at Fort Hood between 1992 and 1994 but the authors noted that these estimates were higher than those estimates from other studies (USFWS 1996). Estimates of survival were obtained from a previous population viability analysis that used data from research conducted on Fort Hood between 1991 and 1995, from BCNWR between 1992 and 1994, and from research conducted between 1961 and 1964 (USFWS 1996). These studies were limited by the available data at the time particularly for juvenile survival rates that likely resulted in estimates biased low due to a lack of knowledge of dispersal dynamics in this species. Using a higher juvenile survival estimate, simulations suggested that populations should not fall below 3,000 pairs to maintain persistence (USFWS 1996).

Alldredge et al. (2004) improved upon the USFWS (1996) population viability analyses using data that included metapopulation dynamics. Their results supported that of the USFWS (1996) in that a minimum viable population should consist of approximately 3,000 breeding pairs per population. Their study was limited to data acquired on Fort Hood and in the Austin area and information on dispersal was limited to within Fort Hood. Alldredge et al. (2004) concurred with the USFWS (1996) warnings that estimates from Fort Hood may be “best case scenarios” because of the on-going management practices on the property. They relied upon simulations of dispersal rates to determine model parameters and emphasized the need for a better understanding of demographic parameters within these study areas but particularly across the range of the warbler (Alldredge et al. 2004).

3.8 Population Genetics

One study has addressed population genetics of golden-cheeked warblers using 109 individuals across 7 sample sites (Lindsay et al. 2008). Study areas included the Klondike Ranch in Johnson County (14 males), 3 study sites on Fort Hood (47 males), BCNWR in Travis County (17 males), Camp Bullis in Bexar County (17 males), and Kerr Wildlife Management Area in Kerr County (14 males). The authors found no evidence of genetic bottlenecks or genetic differentiation among populations, suggesting that gene flow among populations was unimpeded. The authors further suggested that there was no evidence of elevated risk of extinction resulting from genetic mechanisms examined (Lindsay et al. 2008).

3.9 Predators, Brood Parasitism, and Disease

3.9.1 Nest Predators

Fire ants

For the years 1997–2002 and 2005 on Fort Hood, fire ants depredated 3.7% (n = 27) of warbler nests (Stake et al. 2004). In Austin from 2005 to 2006, fire ants predated 5% (n = 20) of nests (Reidy et al. 2008). In a study in Austin, fire ants that predated artificial nests were located within 10 m of warbler habitat edges (Fink 1996); however, another study in Travis County found no relationship between fire ant mounds and distance from edges of warbler habitat (Sperry 2007). Also in Austin, 91% (n = 17) of fire ant mounds were found within 300 m of utility easements compared to only 1 mound located near a meadow (Sperry 2007).

Snakes

Using video surveillance at warbler nests in the Austin area in 2005, 2006, and 2008, Reidy et al. (2008) documented Texas rat snakes (*Elaphe obsoleta*) as the predator at 8 of 20 predation events compared to 6 predations by western scrub-jays (*Aphelocoma californica*) and ≤ 3 predation events by 3 additional species. All predation events occurred at night. Video cameras at nests on Fort Hood (1997–2002 and 2005) identified Texas rat snakes as responsible for 12 of 27 predation events, with 1 predation event caused by a Great Plains rat snake (*Elaphe guttata emoryi*) and the remaining events distributed among 7 other species (Stake et al. 2004, Reidy et al. 2008).

At Fort Hood, a study on rat snakes in warbler habitat found snakes predominately in trees (27%) or in tree cavities (35%), whereas 19% were on or below ground and 18% were under cover of rocks, logs, or brush piles (n = 256 snake locations; Sperry et al. 2009). Compared to random locations snakes were associated with larger trees, increased litter, understory trees, cover objects (i.e., rocks, logs, brush piles), vegetation edges, and were less associated with characteristics of open areas (i.e., grass, rock, bare ground; Sperry et al. 2009).

Avian species

Among bird species, western scrub-jays were responsible for 6 predation events and Cooper's hawks (*Accipiter cooperii*) for 2 events in Austin (Reidy et al. 2008). At Fort Hood, American crows (*Corvus brachyrhynchos*) predated 4 nests, brown-headed cowbirds (*Molothrus ater*) predated 2 nests, and a western scrub-jay and a Cooper's hawk were responsible for 1 predation event each (Stake et al. 2004, Reidy et al. 2008). Cowbirds removed young from 2 of 27 nests based on evidence from nest cameras at Fort Hood from 1997-2002 (Stake et al. 2004). For a study in progress at Kickapoo Cavern State Park (Edwards and Kinney Counties), researchers documented nest predation by western scrub-jays at 2 of 3 known warbler nests (Klassen and Morrison 2009).

Mammals

Stake et al. (2004) video-recorded 67 warbler nests from 1997 to 2002 of which fox squirrels (*Sciurus niger*) depredated 4 nests. There is no evidence that nesting close to urban areas increased predation by squirrels (Reidy et al. 2008).

3.9.2 Adult Predators

Video cameras at nests on Fort Hood (1997-2002 and 2005) and in Austin (2005-2006) documented 6 cases of predation of female warblers while on the nest (4.8%, n = 124 females; Reidy et al. 2009a). Three occurred at sites in Austin and 3 occurred at Fort Hood. Two of these females were incubating eggs and 4 were brooding nestlings less than 6 days old. Texas rat snakes predated 5 of the females and a Great Plains rat snake predated 1 female. All the adult predation events occurred at night. Daily adult female predation rate in this study was 0.008 (95% CI = 0.003-0.017; Reidy et al. 2009a).

3.9.3 Brood Parasitism

Brown-headed cowbirds are the only brood parasites in the majority of the golden-cheeked warbler breeding range (Ladd and Gass 1999). Brown-headed cowbirds parasitize broods of various host species although some individuals may preferentially parasitize some host species over others (Woolfenden et al. 2003, Strausberger and Ashley 2005, Ellison et al. 2006). Cowbirds typically lay eggs during the egg-laying stage or early incubation stage of the host species (Payne 1977) but frequently cowbirds act as predators by removing eggs and nestlings thus forcing nest failure and subsequent re-nesting (Arcese et al. 1996). Cowbird nestlings often are older (i.e., hatch earlier) than host species and cowbird nestlings may grow at a faster rate providing the cowbird nestling a competitive advantage over host nestlings (Payne 1977). Reproductive output of host species is reduced in parasitized nests because cowbirds typically remove at least one host egg (Payne 1977, Arcese et al. 1996), and because parasitism may reduce hatching success and nestling survival of host young (Hoover 2003), and juvenile and adult survival (e.g., indigo buntings [*Passerina cyanea*], Payne and Payne 1998; prothonotary warblers [*Protonotaria citrea*], Hoover and Reetz 2006). Few data exist on the effect of parasitism on golden-cheeked warbler demographics (Ladd and Gass 1999). Warblers have fledged their own young along with cowbird young (Pulich 1976, Wahl et al. 1990, USFWS 1992); however, the quality of host young may be compromised if warbler nestlings in parasitized nests are fed less often (Beardmore 1994).

For golden-cheeked warblers, Pulich (1976) documented a parasitism rate of 57.6% (n = 33 nests) in Kendall County. In Travis County, however, parasitism rates have been reported at 8.3% (n = 12; Beardmore 1994), and 14% (n = 21 territories; Gass 1996). At Fort Hood from 1991 through 1997, parasitism rates on warblers was 8.7% (n = 46; Jette et al. 1998) but cowbird trapping efforts were increased concurrently with the initiation of warbler research; no pre-trapping data exist (Eckrich et al. 1999). In Bosque County, 1 of 5 nests was observed parasitized (Kroll 1974).

Bronzed cowbirds (*Molothrus aeneus*) have expanded northward and now overlap with golden-cheeked warblers along the northern edge of the Edwards Plateau (Kostecke et al. 2004) but no documentation exists of this species' parasitizing golden-cheeked warblers. Researchers at Fort Hood trapped 24 female bronzed cowbirds in 2001 and 2002, of which 5 females exhibited gonadal development (Kostecke et al. 2004). Bronzed cowbirds may parasitize larger bodied species than species parasitized by brown-headed cowbirds (Ellison et al. 2006).

3.9.4 Disease

There is currently no published information on the prevalence of diseases in golden-cheeked warblers; however, research on other warbler species indicate susceptibility to many diseases (defined as any departure from health and includes presence of pathogens and ectoparasites; Friend et al. 2001). One exception may be the bacteria *Mycoplasmal conjunctivitis* and *Mycoplasma gallisepticum* that are commonly transmitted among birds attending feeders, such as birds in Carduelidae (Fischer et al. 1997), and are unlikely to pose a threat to warblers.

There is no known information on the prevalence of blood parasites (*Plasmodium* spp., *Haemoproteus* spp.) in golden-cheeked warblers; however, blood parasites have been detected in hooded warblers (*Wilsonia citrina*), although prevalence was low (13% of 121captured individuals; Tarof et al. 1997).

West Nile virus (WNV) was first detected in the United States in 1999 in New York and researchers documented the first case of WNV in Texas in Harris County in 2002 (Lillibridge et al. 2004). Over 198 species, including 12 species of warblers (Family Parulidae) 4 of which were *Dendroica* warblers, have been infected with WNV (Komar 2003). WNV has caused considerable declines in several passerines but the majority of these species are prevalent in human-dominated landscapes (LaDeau et al. 2008).

More than 2,500 species of mites (Subclass Acari) are known to parasitize birds (Proctor and Owens 2000). Mites have been observed on adult golden-cheeked warblers, especially on the tail (Ladd and Gass 1999). In Chiapas, Mexico, where golden-cheeked warblers overwinter, chigger mite larvae was present on 60% of warbler species (n = 10 species with > 5 captures), including black-and-white warblers (*Mniotilta varia*), the only warbler whose breeding range overlaps with that of golden-cheeked warblers (Dietsch 2005). The impact that mites may have on golden-cheeked warblers is unknown. However, mites are known to negatively affect body condition, increase physiological stress, and reduce annual return rates for palm warblers (*D. palmarum*) and prairie warblers (*D. discolor*) wintering in Mexico (Latta 2003).

3.10 Summary of Demography

- Territory density estimates at 3 study areas have experienced slight but not statistically significant increases providing some suggestion that the population in those areas has increased slightly. However, this may not reflect true population growth because of changes in study sites, monitoring efforts, and increased awareness of the birds' behaviors and habitat use across the years.
- Although primarily monogamous, evidence has emerged that golden-cheeked warblers are sometimes polygynous and that females may double-brood.
- Estimates of pairing success, territory success, nest survival, and return rates varied across years and long-term study sites. Only pairing success on City of Austin properties indicated a weak increase over time. These demographic estimates are generated from few well-studied research areas and may not reflect population estimates in other regions of the warbler's range.
- Known dispersal distances include 0–100 km for males and 0–2.24 km for females; however, information on dispersal and survival rates are limited.
- Although 2 population viability analyses have been conducted, these were limited due to lack of knowledge of dispersal dynamics, and estimates of fecundity and survival. Population viability analyses, while limited, suggested the minimum viable size of 3,000 breeding pairs per population.
- Primary nest predators are snakes and corvids. Snakes have been recently documented predating females on the nest. Primary nest predators and parasitism by brown-headed cowbird varies annually and regionally. Parasitsm rates have ranged from 8.3 to 57.6% depending on year and study site. There is no evidence that bronzed cowbirds parasitize warblers.
- There are no documented cases of disease in golden-cheeked warblers.

Chapter 4. Habitat Characteristics

Golden-cheeked warbler habitat has been described and studied for over a century. Earlier works were descriptive and naturalistic; over time research has progressed with the development of more advanced statistical techniques and broad-scale analyses (e.g., Attwater 1892, Pulich 1976, Rappole et al. 2000, Fuller 2009). Pulich (1976) provided the first in-depth, range-wide examination of habitat in Texas and the wintering grounds and his work provided baseline information for most subsequent studies. This chapter focuses on habitat characteristics of the breeding and wintering grounds as they relate to warbler occurrence, along with a discussion on the general ecology and dynamics of the woodlands in the breeding range. Influences of habitat on warbler abundance, density, and reproductive success are discussed in Chapter 5. Survey methods for research reported in sections 4.1 through 4.4 are detailed in Appendix 4.A.

4.1 Breeding Grounds

4.1.1 Vegetation Species

Within the general range of woodlands in the Edwards Plateau and Cross Timbers ecoregions (see Chapter 2), golden-cheeked warblers typically occur in mature stands of Ashe juniper (*Juniperus ashei*) mixed with a variety of oaks (*Quercus* spp.) and other deciduous tree and shrub species (Kroll 1974, Pulich 1976, Wahl et al. 1990, Reemts et al. 2008). Ashe juniper and Spanish oak (aka Texas oak, *Quercus buckleyi*) are the most commonly detected woody vegetation species throughout the breeding range relative to golden-cheeked warbler occurrence. Additional species include plateau live oak (*Q. fusiformis*), shin oak (*Q. sinuata* var. *beviloba*), Texas ash (*Fraxinus texensis*), cedar elm (*Ulmus crassifolia*), Arizona walnut (*Juglans major*), and lacey oak (*Q. laceyi*; Choban 1974, Pulich 1976, Ladd 1985, Wahl et al. 1990, Rowell et al. 2002, Cummins 2006, Newnam 2008). Shin oak has been noted more often in the northern and eastern portions of the breeding range whereas lacey oak has been noted more often in the south and west. Additional regional differences include higher occurrences of deciduous holly (*Ilex decidua*), blackjack oak (*Q. marilandica*), post oak (*Q. stellata*), Mexican buckeye (*Ungnadia speciosa*), black haw (*Viburnum rufidulum*), and gum bumelia (*Sideroxylon lanuginosum*) in the north and east, with higher occurrences of little walnut (*Juglans microcarpa*), mesquite (*Prosopis glandulosa*), and mountain laurel (*Sophora secundiflora*) in the south and west (Kroll 1980, Demoll et al. 1984, Beardmore 1994, Arnold et al. 1996, Keddy-Hector et al. 1998, Cummins 2006, Reemts et al. 2008, Heilbrun et al. 2009). Although the species composition of the trees and shrubs vary throughout the breeding range, Ashe juniper is always present and often the dominant canopy species (Shaw 1989, U.S. Fish and Wildlife Service [USFWS] 1996a, Rowell et al. 2002, Baccus et al. 2007, Reemts et al. 2008). Understory vegetation in warbler-occupied habitat is usually dominated by Ashe juniper and also includes oaks and other hardwoods (Wahl et al. 1990, Coldren 1998, Peterson 2001, Baccus et al. 2007, Reemts et al. 2008). Appendix 4.B provides a full list of associated vegetation species and scientific names.

4.1.2 Topography

Smeins and Moses (1994) analyzed aerial photographs and satellite imagery for 9 sites in Travis County and found most of the warbler habitat occurred on slopes of 4–8°. Descriptive statistics of warbler detections indicated a higher number of occurrences in habitat with 8–15° slopes (i.e., not in proportion to available habitat); additionally, east-facing slopes had fewer sightings than west-facing slopes (Smeins and Moses 1994). The researchers cautioned that the amount of search time and effort varied between and within the study sites, thus these results may not be an accurate portrayal of warbler occurrence (Smeins and Moses 1994). Cummins (2006) likewise used satellite imagery to quantify slope and aspect within 100-m and 400-m radius circles around 400 points in Coryell and Hamilton Counties. She found the average maximum slope was greater than 15° for 16.3% and 59.0% of occupied sites (n = 130) at the 100-m and 400-m scale, respectively, in contrast with 10.7% and 44.4% in unoccupied sites (n = 270). In addition, warblers tended to occur more on northern facing slopes (Cummins 2006). Deboer and Diamond (2006) found slope and aspect were significant predictors of warbler occupancy at 467 points across the breeding range, with occupied points having steeper slopes (mean = 9.3°, SD = 7.5) than unoccupied points (mean = 6.4°, SD = 6.3). Western-facing slopes were less likely to be occupied than northern-facing slopes (DeBoer and Diamond 2006). Averaging the values across all points within a patch of habitat (n = 49 patches) indicated that even at the patch-level, slope predicted warbler occupancy with occupied patches having steeper slopes (mean = 8.94°, SD = 4.5) than unoccupied patches (mean = 6.0°, SD = 2.8; DeBoer and Diamond 2006). The authors stressed, however, that warblers also were detected on relatively flat areas during their surveys and that steep slopes are not required for warbler occupancy (DeBoer and Diamond 2006). In contrast to these studies, principal component analysis of habitat characteristics at 100 sites in Travis and Williamson Counties showed slope did not influence warbler occurrence, although slope data was derived from only 1 plot per site (Arnold et al. 1996). Moses (1996) found no relationship between slope and warbler sightings at 5 of his study sites in Travis County but did find warblers were sighted more often than expected on steeper slopes (4–8°) at 1 of the study sites. Multiple logistic regression of habitat characteristics measured at 325 points on Fort Hood Military Reservation indicated no relationship between slope and warbler occurrence at the scale measured (Horne and Anders 2001).

Woodlands containing a mix of junipers and oaks are typically found in the rocky hillsides of limestone canyons and ravines (Attwater in Chapman 1907, Johnston et al. 1952, Pulich 1976) but also are found on the canyon tops or upland areas (Pulich 1976, Keddy-Hector et al. 1998). As Ladd and Gass (1999) summarized, "habitat is not restricted to or excluded from any particular landscape position, but may develop wherever suitable conditions and land-use practices exist for growth of mature juniper-oak woodlands, though varying in habitat quality." Typical occurrence of mature mixed woodlands in canyons and areas of rough topography may have more to do with surrounding land-use practices than any natural restrictions on the vegetations' ability to propagate (USFWS 1992, Ladd and Gass 1999).

4.1.3 Stand Age

Warblers are typically found in areas of mature mixed woodlands (Kroll 1974, Campbell 2003). Depending on site conditions and type of disturbance, it may require as few as 20 years to more than 50 years for an area to proceed through succession and develop into mixed woodland (Huss 1954, see review in Schmid 1969). Shredding of Ashe juniper bark (used by the warbler as nesting material) begins near the base of junipers by 20 years of age and progresses to the crown by 40 years (Kroll 1974, study site at Meridian State Park in Bosque County). Specific tree age may be less important than the characteristics typically associated with age, such as tree height and bark stripping (Campbell 2003), and studies that examined warbler occurrence relative to mature woodland usually focused on measurements of those associated characteristics (e.g., Horne and Anders 2001, DeBoer and Diamond 2006). The age at which Ashe juniper reaches adequate size and bark-stripping characteristics may depend on soil type, local climate conditions, and past land use (Kroll 1974, USFWS 1998).

For a study on Fort Hood, mature junipers were 1 of several variables included in a final regression model that related habitat characteristics to warbler occurrence at survey points (n = 325; Horne and Anders 2001). Researchers used 4 categories of juniper age class based on branch and bark characteristics and juniper height and found warbler occurrence was correlated with the more mature age categories (Horne and Anders 2001). Using similar categories for juniper maturity, DeBoer and Diamond (2006) found that, across the breeding range, warbler presence was positively correlated with patches of habitat (n = 49) containing more mature Ashe juniper trees.

4.1.4 Vegetation Structure

Golden-cheeked warblers have been found in areas where the canopy height averages 4–7.5 m, and in some areas with canopy as low as 3 m (Attwater in Chapman 1907, Pulich 1976, Kroll 1980, Shaw 1989, Beardmore 1994, Rowell et al. 2002, Newnam 2008, Reemts et al. 2008, Heilbrun et al. 2009). Average heights appear to shift depending largely on abiotic site type characteristics, with wetter sites typically supporting taller trees (Diamond 1997).

Throughout their range, warblers occur in mixed woodlands of relatively closed canopy (i.e., >50%), with most warblers found in areas averaging >70% canopy cover (Wahl et al. 1990, Beardmore 1994, Coldren 1998, Reemts et al. 2008, Heilbrun et al. 2009). However, occurrence and territories of golden-cheeked warblers have also been documented in areas of 35–40% canopy cover (USFWS 1996a, Reemts et al. 2008 at Fort Hood, Heilbrun et al. 2009 near Government Canyon State Natural Area), particularly in the western portion of the breeding range (SWCA 2003 for Edwards County; Klassen 2010 for Kickapoo Cavern State Park in Edwards and Kinney Counties). Percent tree composition varies by region and site conditions, ranging from 10 to 90% Ashe juniper and 10 to 85% hardwood trees (Shaw 1989, USFWS 1996a, Heilbrun et al. 2009). A study of vegetation characteristics within 50 m of 325 survey points at Fort Hood suggested that areas with a small proportion of hardwood vegetation were not preferred by warblers, whereas areas with a mix of junipers (1–25%) and hardwoods (75–90%) were positively related to warbler occurrence (Horne and Anders 2001). DeBoer and Diamond (2006) found warblers were more likely to occupy patches of habitat (n = 49) with a high percentage of juniper in the canopy, summarizing that "warbler presence was more directly linked to increased Ashe juniper cover than to increased overall canopy cover." Peterson (2001) found warbler territories at the Kerr Wildlife Management Area, Kerr County, in areas with plant composition of 80% juniper and 15% oaks in the canopy (i.e., >1.5 m) and 53% juniper and 33% oak composition in the understory.

In areas occupied by warblers, the density of Ashe juniper trees >3 m in height averaged 556 juniper/ha (225 juniper/ac) throughout central Texas (n = 9 sites, range = 56–1,100 juniper/ha [23–445 juniper/ac]; Shaw 1989) and 1,029 juniper/ha (416 juniper/ac) in Travis County (n = 27 territories, range = 731–1,496 juniper/ha [296–605 juniper/ac]; Beardmore 1994). Peterson (2001) estimated an average of 425 juniper/ha (172 juniper/ha) for trees >1.5 m in height at the

Kerr Wildlife Management Area (*n* = 25 territories, range values not specified). Coldren (1998), working primarily in Travis County, estimated an average density of canopy junipers (i.e., trees ≥4.5 m in height) of approximately 640 stems/ha (259 stems/ac; *n* = 100 sites). At the same sites, Coldren (1998) estimated an average basal area of about 24 m^2/ha for Ashe juniper and 8.6 m^2/ha for hardwoods >4.5 m in height. In warbler territories at Fort Hood, Reemts et al. (2008) estimated an average basal area of 14.9 m^2/ha for all woody vegetation >2 cm diameters at breast height (dbh). For woody vegetation >5 cm dbh at 1 occupied site in Travis County, Choban (1974) estimated an average basal area of 40.9 m^2/ha, about 25% of which was Ashe juniper. Density and basal area of understory vegetation may exceed that of canopy trees (e.g., Coldren 1998) or may be minimal (Kroll 1974, Pulich 1976).

Researchers also have documented warblers in hardwood savanna habitat or younger woodland, often near the more typical dense woodland habitat (Diamond and True 1998, Keddy-Hector et al. 1998, Campbell 2003, Magness et al. 2006). Research is needed to understand warbler activities in these habitat types.

4.1.5 Habitat Edge

During his research at Meridian State Park, Bosque County, Kroll (1974, 1980) found golden-cheeked warbler territories adjacent to roads, trails, and clearings, although there was limited space for territory establishment in woodland interiors given the density of roads and trails in the park. Coldren (1998) noted adults singing and foraging near habitat edges during the breeding season. At Fort Hood, Horne and Anders (2001) found distance to edge from survey points was not significantly different for occupied versus unoccupied points (*n* = 325). Other researchers found the opposite trend in Travis County, where territories were entirely within mixed woodland habitat (*n* = 27 territories; Beardmore 1994) or approximate territory centers were at least 30 m from woodland edges (*n* = 624 territories; Coldren 1998). Additionally, DeBoer and Diamond (2006) detected warblers more often at survey points (*n* = 467) located farther from a habitat edge throughout the breeding range, as did Sperry (2007) at a site in Travis County (*n* = 105 survey points). The influence of habitat edge on warbler occurrence may depend upon the type of edge habitat. At a site in Travis County, warblers were detected less often within 300 m of edges formed by residential areas compared to edges associated with grass, shrub or utility easements (Sperry 2007).

4.1.6 Habitat Patch Size

In general, a patch is a relatively homogenous area that is distinct from its surroundings (Kotliar and Wiens 1990). The term is commonly used when referring to mixed woodland breeding habitat of the golden-cheeked warbler given its distinct composition relative to adjacent land types. References to mixed woodlands as habitat patches have increased with the increase in accessibility of and ability to classify and analyze satellite imagery, which enables the entire breeding range to be classified as patches of golden-cheeked warbler habitat within a matrix of non-habitat (see Chapter 6 for further discussion). Although researchers have defined warbler habitat patches somewhat differently depending on their research objectives and methods (Appendix 4.A), what constitutes a break between patches typically ranges from 8 to 20 m (Rich et al. 1994, Coldren 1998, Horne 2000) or is further dictated by satellite imagery resolution (e.g., Wahl et al. 1990).

Golden-cheeked warblers occupy a wide range of habitat patch sizes. Of 295 patches surveyed for warblers in 11 counties throughout the range, Benson (1990) detected warblers in patches from 0.66 to 237 ha (1.63–586 ac) in size, the full range of the surveyed patch sizes. During surveys of 100 patches (6.5–731.5 ha [16.1–1807.6 ac]) in Travis and Williamson Counties, Arnold et al. (1996) detected warblers "regularly" in patches >19 ha (47 ac) and detected warblers in 5 of the 20 patches smaller than 19 ha (47 ac). The Nature Conservancy (TNC 2002) surveyed 49 patches in 17 counties; occupied patches (*n* = 34) were 7.7–23,448 ha (19.0–57,941 ac) in size while unoccupied patches (*n* = 15) ranged 6.5–410 ha (16.1–1,013 ac). TNC detected warblers in 5 of 9 patches 20–50 ha (49–124 ac) in size and in 2 of 6 patches <20 ha (49 ac); they suggested that patches 20–50 ha (49–124 ac) in size should be considered viable habitat for the species (TNC 2002). Of 12 patches (2.9–27.7 ha [7.2–68.4 ac]) surveyed in Bosque, Coryell, Hamilton Counties, Butcher et al. (2010) detected warblers in 11 patches, including the smallest.

Although warblers occur in small habitat patches (e.g., <20 ha [49 ac]), the likelihood of a warbler occupying a patch tends to increase with patch size (Coldren 1998, DeBoer and Diamond 2006, Collier et al. 2010). Chi-square analysis of 100 surveyed patches in Travis and Williamson Counties indicated that warblers selected for larger patches (mean = 232 ha) and against smaller patches (mean = 23 ha; Coldren 1998). Patch-level analysis of warbler occupancy in 49 patches throughout the breeding range indicated warblers were more likely to occupy larger patches with less edge (DeBoer and Diamond 2006). Similarly, analysis of 147 patches in Coryell and surrounding counties showed that the probability of at least 1 warbler occupying a patch increased steadily with patch size, and all patches >160 ha (>395 ac) were predicted to be occupied (Collier et al. 2010).

4.1.7 Broad Scale Metrics

Viewing golden-cheeked warbler habitat at broad spatial scales has provided additional insight into factors affecting warbler occupancy. At Fort Hood, the occurrence of warblers at a survey point was positively correlated with the percent of woodland cover within a 250-m radius and 2-km radius surrounding the point (*n* = 325; Horne and Anders 2001). Logistic regression models of 400-m radii "landscapes" (*n* = 400) in Coryell and Hamilton Counties showed warbler occurrence was more likely in landscapes with >70% juniper cover (Cummins 2006). In Bandera and neighboring counties, Magness et al. (2006) examined percent woodland cover, patch size, edge density, and patch proximity metrics at 4 spatial scales (3.1 ha, 12.6 ha, 50.2 ha, and 200.9 ha [7.7, 31.1, 124.0 and 496.4 ac]) and found that warblers were more likely to occur at points (*n* = 202) surrounded by higher percent woodland cover regardless of scale. They concluded that the amount of mature juniper-oak woodland in areas as large as 200 ha (494 ac) surrounding a point may positively influence warbler occurrence (Magness et al. 2006). In Coryell and neighboring counties, Campomizzi et al. (2008) found higher rates of warbler occupancy in areas where the percent of mixed woodland was ≥60% within 400 m of a point (*n* = 41). Studies that examine the influences of habitat beyond the boundaries of a single patch suggest patch proximity plays a role in influencing warbler occupancy; researchers have suggested smaller patches are more likely to be occupied by warblers if the patches occur in close proximity to large patches (USFWS 1996a, Peterson 2001, TNC 2002).

Land use around a patch or survey area also appears to affect occupancy. Although most of the research regarding effects of urbanization has come from the Travis County area, they all point to warblers occurring less often in patches closer to urbanized areas (Smeins and Moses 1994, Engels 1995, Coldren 1998, Fuller 2009). Comparing low, moderate, and high urbanization around survey sites (n = 295) in 11 counties, Benson (1990) determined that a higher proportion of low-urbanization sites were occupied by warblers compared to the high-urbanization sites. Similarly, when comparing road density surrounding areas of habitat (n = 8) with the number of warbler sightings within the habitat, Moses (1996) showed a general trend of decreased warbler sightings as road density increased.

4.1.8 Road Noise

Golden-cheeked warblers sang without regard to the level of roadway noise at Meridian State park in Bosque County near a highway with noise levels ranging from 29.7 to 58.6 dB (Benson 1995). Benson (1995) surveyed for warblers at 78 survey points and found no difference in warbler occurrence at high-noise locations compared to low-noise locations. The frequency of the warbler song was about 5.18 kHz, which was typically higher than that of the associated road noise (Benson 1995). Sperry (2007) found mean sound levels were higher along transects (n = 15) bordering residential areas (48.9 dB, SD = 0.47) than transects bordering utility easements (46.1 dB, SD = 0.42) or grass/shrublands (45.8 dB, SD = 0.38) in Travis County. In general, noise levels for all transects combined decreased as distance from habitat edge increased and warbler detections generally increased with distance from edge (Sperry 2007).

4.1.9 Conspecifics and Heterospecifics

Golden-cheeked warbler occurrence also may be influenced by the presence of heterospecifics or conspecifics. A patch-level analysis in Travis County showed 8 avian predators (American crow [*Corvus brachyrhynchos*], blue jay [*Cyanocitta cristata*], brown-headed cowbird [*Molothrus ater*], common grackle [*Quiscalus quiscula*], greater roadrunner [*Geococcyx californianus*], great-tailed grackle [*Quiscalus mexicanus*], red-tailed hawk [*Buteo jamaicensis*], and western scrub-jay [*Aphelocoma californica*]) were more likely to occur at sites with warblers than at sites without warblers, indicating that the predator species did not exclude warblers from patches of habitat (n = 100; Arnold et al. 1996). Engels and Sexton (1994), however, showed a negative correlation between the occurrence of blue jays and golden-cheeked warblers at survey points (n = 100) near urban areas of Travis County. They hypothesized that urban development facilitated an increase in blue jays, which negatively affected the warbler. Another study in Travis County likewise showed a negative correlation between avian predator detections and warbler detections across 105 survey points (Sperry 2007); avian predators included blue jays, brown-headed cowbirds, common grackles, great-tailed grackles, northern mockingbirds (*Mimus polyglottos*), and western scrub-jays.

As an initial step towards examining the influence of conspecifics on warbler occurrence, Campomizzi et al. (2008) reviewed warbler occupancy data to "determine if a warbler detection in a higher oak-juniper composition class would increase the probability of a detection in a neighboring, lower oak-juniper composition class." Oak-juniper composition was the percent of area categorized as mixed woodland within a 400-m radius circle (i.e., <40%, 40–60%, and >60% mixed woodland). They found warblers were detected more often at survey points in lower composition classes if the points neighbored warbler detections in higher composition classes (n = 27), whereas warblers were detected less often at points in lower composition classes if the points neighbored unoccupied points in higher composition classes (*n* = 14; Campomizzi et al. 2008). They hypothesized that golden-cheeked warblers may exhibit conspecific attraction, in which individuals of a species tend to settle near one another, and may do so regardless of the underlying habitat quality. Researchers are currently testing this hypothesis on private lands around Fort Hood. Preliminary results indicate a shift in warbler occurrence toward treatment areas where warbler songs were broadcasted; data collection and analyses, however, are ongoing as of the time of this writing (S. Farrell, personal communication).

4.2 Post-breeding Habitat

As noted by Ladd and Gass (1999), "some areas that may be used infrequently early in breeding season are more important for fledglings and family groups later in season, including (1) woodlands with less tree diversity and lower total canopy cover, (2) drier, sparser upland woodlands adjacent to more heavily used breeding habitat, (3) oak savannas, and (4) woodland edges." Coldren (1998) noted the use of edge habitat by warblers in Travis County, "particularly after the young have fledged." Results from the first of a multi-year study suggest use of woodlands with <50% canopy cover by adults and fledglings post-breeding, with some individuals detected >100 m beyond the edge of mixed woodland patches (M. Hutchinson, personal communication). Additional research is needed to understand habitat use during post-breeding activities.

4.3 Migration Route

Golden-cheeked warbler sightings during the spring and fall migration have occurred in a broad area of south Texas between the breeding range and northeast Mexico (C. Sexton and B. Freeman, unpublished data). Migration records from the Sierra Madre Oriental in Mexico occur generally within pine (*Pinus* spp.), pine-oak, and oak-sweetgum (*Liquidambar styraciflua*) woodlands, ranging from 1,100 to 2,500 m elevation (see Chapter 2). Detailed information regarding the vegetative composition at sightings of migratory warblers is not currently available.

4.4 Wintering Grounds

The winter range of the golden-cheeked warbler spans southern Mexico, Guatemala, Honduras, El Salvador, and Nicaragua, and possibly extends into Costa Rica (see Chapter 2). The range extends for approximately 800 km, but the warbler's distribution is limited within this range by certain factors such as elevation and the availability of pine-oak forest (Rappole 1996, Rappole et al. 2000).

4.4.1 Elevation and Vegetation Species

Golden-cheeked warblers are primarily found in pine and pine-oak forests on the wintering grounds (summarized in Appendix 2.B). Over 60 individual warblers were detected between 2,100 and 2,550 m elevation in pine and pine-oak forests in Chiapas, Mexico (Vidal et al. 1994), while an additional 2 warblers were observed in pine-oak forests at 1,000 m (Perrigo and Booher 1994) and 1,500 m (Braun et al. 1986). Land (1962) detected 6 individuals between 1,800 m and

2,560 m in eastern Guatemala. Gonzalez-Callejas (2008) detected the species primarily between 1,445 and 2,232 m elevation in pine-oak forests of Guatemala (*n* = 14 warblers). Over 150 warblers have been sighted in pine-oak forests above 1,000 m in Guatemala and Honduras (Thompson 1995, Rappole et al. 2000). Kroll (1980) found the species at 1,500 m elevation in highland pine and pine-oak forest of Honduras, where warblers (*n* = 12) foraged in understory oaks beneath ocote pine (*Pinus oöcarpa*), notably in encino oak (*Quercus oleoides*) and sweetgum. In northwestern Nicaragua, warblers were detected in pine-oak forests at elevations between 1,136 and 1,690 m, with 88% of the sightings >1,300 m (King et al. 2009). Current research in progress at 35 study areas in southern Mexico, Guatemala, Honduras, El Salvador, Nicaragua, and Costa Rica suggests warblers occur between 800 m and 2,600 m, with the majority of occurrences >1,400 m (Komar 2010).

During surveys in central and western Honduras, 91% of detected warblers occurred in pine-oak habitat while ≤5 warblers were detected in each of the following habitat types: pine forest, broadleaf forest, scrub habitat, or agricultural areas (*n* = 126 warbler sightings; Rappole et al. 2000). In pine-oak forests above 1,000 m in the central and western highlands of Honduras and eastern highlands of Guatemala, warblers were detected in areas dominated by ocote pine, with pinabete (*P. maximinoi*) as the predominate species in some locations (*n* = 44 sites; Rappole et al. 1999). Dominant broad-leaved tree species included encino oaks (i.e., oaks with shinny, narrow, elliptical or oblong leaves; *Q. supotifolia, Q. eliptica, Q. elongata, and Q. cortesii*) and roble oaks (i.e., oaks with large, lobed leaves; *Q. segoviensis, Q. purulhana, and Q. rugosa*). Over 60% of the trees at occupied sites were pine and encino oaks, while 7% of the trees were roble oaks (Rappole et al. 1999). Common understory species at the sites included *Cuphea* spp., *Calliandra houstoniana*, *Heterocentron subtriplineriums*, and *Stevia* species (Rappole 1996, Rappole et al. 2000). Occupied sites (*n* = 91) in Honduras had fewer pines >3 cm dbh and more oaks >3 cm dbh than random points (*n* = 184; Rappole et al. 2000). In northwestern Nicaragua, King et al. (2009) estimated fewer pines per 0.04-ha plot (0.10-ac plot; mean = 3.97 trees/plot, SE = 0.97, *n* = 36) at occupied sites than at unoccupied sites (mean = 9.54, SE = 2.16, *n* = 24), while the number of encino oaks was similar at occupied (mean = 9.39 trees/plot, SE = 1.59, *n* = 36) versus unoccupied sites (mean = 10.1, SE = 2.03; *n* = 24).

Golden-cheeked warblers have also been reported in forests near coffee plantations. In Nicaragua, Potosme and Muñoz (2007) found warblers (*n* = 22) in oak, pine-oak and cloud forests at 1,300–1,652 m elevation where native forest cover was fragmented by clearing for lumber and coffee plantations. Warblers were observed in *Lippia chiapensis* Loes, which is frequently used as a shade tree for coffee crops (Potosme and Muñoz 2007). Two warblers also were recorded in recently cleared areas of Nicaragua, where large pine and oak trees had been felled but not yet extracted from the forest (Potosme and Muñoz 2007). Warbler sightings (*n* = 3 to 5) near coffee plantations in Nicaragua were also reported by Morales et al. (2008); they observed warblers within the ecotone of coffee plantations and cloud forest, characterized by the presence of scattered oak trees and ficus (*Ficus* spp.).

4.4.2 Vegetation Structure

Oaks occupied by golden-cheeked warblers (*n* = 13) in Guatemala and Honduras were 4–20 m tall while pines were 10–30 m tall (Thompson 1995). Canopy cover in the same locations ranged from 10 to 75% (mean = 40%) while the percentage of oaks (estimated vegetation volume) range from <10 to 85% (Thompson 1995). In Honduras, Rappole (1996) found that encino oak height in areas occupied by warblers varied from site to site; in some areas the oaks formed a shrub layer of 2–5 m in height while in other areas the oaks formed part of the canopy at 15–20 m in height. At study sites (*n* = 44 occupied, 42 random) in Guatemala and Honduras, warblers occupied areas with higher basal area of encino oaks (mean = 7.5 m^2/ha, SE = 1.2), lower basal area of pines (mean = 8.8 m^2/ha, SE = 1.1), greater ground cover (mean = 40.0%, SE = 3.4), and similar canopy cover (mean = 74.0%, SE = 2.5) compared with random sites (oak: mean = 2.5 m^2/ha, SE = 0.4; pine: mean = 14.7 m^2/ha, SE = 1.3; ground cover: mean = 28.5%, SE = 2.0; canopy cover: mean = 70.6%, SE = 2.3; Rappole et al. 1999). Likewise in Nicaragua, King et al. (2009) compared sites where warblers were detected (*n* = 36) with sites where warblers were not detected (*n* = 24) and found occupied sites had higher basal area of encino oaks (mean = 5.9 m^2/ha, SE = 1.2), lower basal area of pines (mean = 2.2 m^2/ha, SE = 0.7), greater ground cover (mean = 78.6%, SE = 3.8), and similar canopy cover (mean = 63.8%, SE = 4.8) than unoccupied sites (oak: mean = 3.6 m^2/ha, SE = 1.1; pine: mean = 4.6 m^2/ha, SE = 1.2; ground cover: mean = 58.3%, SE = 6.9; canopy covery: mean = 60.6%, SE = 6.8). In Nicaragua, Potosme and Muñoz (2007) detected golden-cheeked warblers (*n* = 22) in areas with second growth vegetation mixed with coffee crops and some scattered shrubs and ranging in height from 4 to 5 m. The areas were surrounded by remnants of cloud forest with average tree heights of >25 m (Potosme and Muñoz 2007).

4.5 Detection Probability

The previous sections in this chapter provide general descriptions and insight of habitat characteristics as they related to golden-cheeked warbler occurrence. Few of the aforementioned studies, however, quantified the probability of detecting warblers relative to spatial or temporal factors or surveyor skill. Detection probability is the probability of detecting a species that occurs at a site, given the site is occupied (MacKenzie et al. 2002). Studies that do not incorporate detection probabilities in the analyses are assuming that the species is detected equally across the study area(s) or survey season. An individual may be present at a site but remain undetected during surveys, leading to potentially erroneous conclusions of habitat use or population parameters (MacKenzie et al. 2002). Non-detections may occur due to animal activity patterns (e.g., time of day or season), habitat characteristics of the survey site, weather conditions, or observer experience (MacKenzie et al. 2006). In some cases, detection probabilities are heterogeneous among individuals of a species; for example, unpaired male birds may be more vocal, and thus more easily detected, than paired males (MacKenzie et al. 2006). A survey that consistently detects the non-breeding component of a population may bias the study results towards the ecology and demographics of non-breeding birds, which may differ from the breeding population (Gu and Swihart 2003, MacKenzie et al. 2006). Presence-absence models derived from data sets that do not incorporate detection probability may overemphasize the importance of certain habitat variables or may fail to reveal habitat variables that influence occupancy (i.e., variables that appear to be related to occupancy may in fact be related to detection; Gu and Swihart 2003).

Although most studies discussed in previous sections incorporated multiple site visits in their survey methods, the inclusion of detection probabilities as a component of golden-cheeked warbler research is relatively recent. MacKenzie (2006 and 2007 unpublished reports) estimated detection probabilities of <0.40 for warblers at survey points in potential breeding habitat on private lands near Fort Hood between 2003 and 2006. For study sites in Government Canyon State Park, Balcones Canyonlands National Wildlife Reserve, and Garner State Park, Watson et al. (2008) estimated a range of detection probabilities, from approximately 0.20 to 0.80 depending on site and year of survey (2005 or 2006). Both studies focused on determining detection probability within a 100-m radius centered on a survey point. Alternatively, Collier et al. (2010) estimated warbler detection probabilities at the scale of a habitat patch, with patch sizes ranging from <1 to >1,000 ha (<2.5 to >2,470 ac). Detection probabilities decreased throughout the survey season, from approximately 0.85 in mid-March to approximately 0.30 by the end of May (Collier et al. 2010). Results from these studies indicate warblers are more likely to be detected in certain locations and at certain times of the breeding season. Low detection probabilities would necessitate increasing the number of visits to a site to limit non-detection errors (MacKenzie and Royle 2005).

4.6 General Ecology of Ashe juniper-oak Woodlands

As noted in previous sections, mixed woodlands on the southern and eastern Edwards Plateau and southern Lampasas Cut-Plain are largely composed of Ashe juniper and various hardwoods, such as Spanish oak and plateau live oak. A suite of topographic, edaphic, and climatic factors, disturbance events and land-use histories drive the vegetative community composition and dynamics in the golden-cheeked warbler's breeding range. Prior to European settlement, fire probably played a significant and widespread role in mediating vegetative community dynamics in juniper-oak communities (Smeins 1980, Fonteyn et al. 1988, Diamond et al. 1995, Fuhlendorf et al. 1996). Frequent fires would have restricted stable Ashe juniper-oak woodlands to sheltered locations (e.g., riparian corridors, canyons, steep slopes, and rocky upland outcrops). Reemts and Hansen (2008) observed that Ashe juniper recolonization of burned juniper-oak woodland areas after a crown fire was slow and protracted. However, the oak component of the burned woodland demonstrated vigorous resprouting, suggesting that multiple burns would be required to reduce oak distribution (Reemts and Hansen 2008). Fuhlendorf et al. (2008) observed that on a site formerly comprised of grassland with patches of oak, Ashe juniper gained dominance in about 60 years in the absence of fire. Fuhlendorf et al. (2008) estimated a 15-year interval between fires was required to maintain the grassland community.

Currently, the most significant factors mediating mixed woodland dynamics are anthropogenic. Large stands of Ashe juniper were harvested between the 1880's and 1950's (Huss 1954, Schmid 1969), resulting in a sudden ecological release for the existing juniper seed bank and rapid replacement of the woodland (Smeins et al. 1997). While mature Ashe juniper communities are characterized by tall juniper and open understory (Van Auken 1993, Diamond 1997), second- and third-growth juniper woodlands tend to be dense and bushy (Smeins et al. 1997). Urban expansion has resulted in direct removal of woodlands, as has the perception that Ashe juniper is economically undesirable on rangelands intended for grazing and is a source of economic income when harvested (Diamond 1997, Garriga et al. 1997). In some areas Ashe juniper has been targeted for removal in an effort to raise water tables by decreasing local evapotranspiration rates (reviewed in Jones 2006).

Increases in the extent of mixed woodlands may occur for several reasons. Current practices of fire suppression favor succession of grasslands and savannahs to woodlands (Fowler and Dunlap 1986Van Auken 2000, Diamond and True 2008). Overgrazing by domestic livestock reduces fine fuel loads in grasslands and savannahs, reducing the frequency and impact of fire on woody plants (Fuhlendorf et al. 2008). In grasslands, frequent droughts and overgrazing decrease the diversity of local herbaceous communities, and possibly resistance to colonization by Ashe juniper (Smeins and Fuhlendorf 1997, Van Auken 2000). A decrease in soil quality due to recurring patterns of soil cultivation followed by field abandonment can favor the competitive abilities of Ashe juniper and facilitate colonization (Hamilton and Ueckert 2000). Finally, an increase in atmospheric carbon dioxide may favor woody plants over some perennial grasses (Archer et al. 1995, Smeins et al. 1997, Hamilton and Ueckert 2000).

The oak component of juniper-oak woodlands may be undergoing a decline due to browsing and disease. In savannahs and mixed woodlands on the Edwards Plateau, Russell and Fowler (1999) observed high mortality of Spanish and plateau live oak seedlings and suggested browsing by deer was the cause. Unlike Ashe juniper, Spanish oak is a highly preferred browse species (Armstrong et al. 1991) and deer can significantly reduce the survival of Spanish oak saplings (Russell and Fowler 2004). Ongoing browsing pressure by deer may prevent oaks on the Edwards Plateau from replacing themselves (Russell and Fowler 2002). In addition, oak wilt, a fungal disease that reduces water transportation in oaks, has caused mortality on the Edwards Plateau and continues to infect new oaks (Appel and Maggio 1984, Wahl et al. 1990, Appel and Camilli 2006). See Chapter 7 for additional detail.

The distribution of mixed woodlands immediately prior to the time of European settlement is debated among researchers and may not be accurately resolved (Diamond and True 2008). Historic records regarding the extent of juniper-oak woodlands are conflicting; some describe the historic Edwards Plateau as a mosaic of grasslands, savannahs, and thick cedar brakes, the latter either common or restricted to canyons and slopes (Smeins 1980, Weniger 1984, Smeins and Fuhlendorf 1997), while others describe mostly savannah or mostly scrub forest with little savannah (Ford and Van Auken 1982). Several researchers suggested or documented a decrease in mixed woodlands on the Edwards Plateau since European settlement (Pulich 1976, Weniger 1984, Wahl et al. 1990, Keddy-Hector 1992). When considering the edaphic, topographic, climatic, and disturbance factors which may influence the distribution of mixed woodlands, some interpretations of aerial and satellite imagery suggest that the general range and abundance of mixed woodlands has not changed much in recent history and may have colonized former grasslands (Smeins et al. 1997, Diamond and True 2008). While some researchers assert only a slight increase in woodlands (Diamond and True 2008), others suggest a large increase has occurred (Van Auken 2000). Diamond and True (2008) modeled the historic distribution of woodlands and grasslands based on abiotic site type using remotely-sensed data (e.g., topography, land cover, hydrology) and compared the modeled historic extent to the modern extent. From their historic vegetation modeling of the Texas Hill Country (i.e., 35% of the southeastern Edwards Plateau, all within the range of the golden-cheeked warbler), they estimated that 54.5% of the Hill Country was woodland, compared to a current estimate of 57.2% woodland (Diamond and True 2008).

4.7 Summary of Habitat Characteristics

- On the breeding range, golden-cheeked warblers typically occur in woodlands comprised of mature Ashe juniper, oak species, and other hardwoods, with Spanish Oak as the most common oak species in occupied habitat.
- Although steep slopes are not required for warbler occupancy, several researchers found warblers were more likely to occur in areas with steeper slopes relative to the surroundings. This may be due, in part, to much of the habitat occurring on rocky hillsides of limestone canyons and ravines.
- Within mixed woodland, warblers are generally found in areas with canopy heights of 4–7.5 m and canopy cover of >50%, but also occur in more open areas depending on location in the breeding range or the stage of their breeding cycle.
- Although warblers have been detected in small habitat patches (e.g., <10 ha [<24.7 ac]), the likelihood of a warbler occupying a patch increases with patch size. The extent of mixed woodland surrounding a patch is also positively correlated with occupancy. Warblers have been detected both near to and far from habitat edges; their occurrence near edge could be influenced by neighboring land use.
- There is limited information regarding habitat use during post-fledgling periods on the breeding grounds and during migration. Research is currently underway to examine post-fledgling habitat use in central Texas, but research is still needed on habitat use during migration.
- In the wintering range, warblers are generally found in higher elevation (>1,000 m) pine-oak forests of southern Mexico and Central America. They have been detected less often in other vegetation types such as pine forests and broadleaf forests.
- From the few studies available on golden-cheeked warbler detection probabilities, the probability of detecting warblers during surveys range from 0.20 to >0.80 depending on time of season, site location in the breeding range, and survey methodology. Incorporating detection probability estimates when modeling habitat associations will help provide rigor in future studies regarding habitat use.
- Mixed woodlands of Ashe juniper and oak, historically influenced by fire and edaphic factors, are now largely governed by anthropogenic activities. Changes in the character and composition of mixed woodlands continue to occur due to factors such as fire suppression, browsing by domestic and feral ungulates, and oak wilt fungus.

Appendix 4.A. Survey and sampling information for studies describing golden-cheeked warbler occupancy and habitat measurements on the breeding and wintering ranges. Information presented here is relevant to the discussions in sections 4.1 through 4.4.

Breeding Range (Texas)

Author	Breeding seasons	Sample size	Counties	Bird survey methods	Vegetation survey methods	Patch or habitat definition	Patch sizes	Article type
Arnold et al. 1996	1993–1995	100 patches	Travis (*n*=99), Williamson (*n*=1)	≥3 censuses per patch, spot-mapping warbler locations	4 2x50m plot per patch extending in each cardinal direction out from single point	Not specifically defined; "all potential warbler habitat" based on aerial photos	6.5–731.5 ha	Unpublished report
Attwater (in Chapman 1907)	Unknown, pre-1905	Not specified	Bexar	Not specified	Descriptive	N/A	N/A	Book
Baccus et al. 2007	1996–1998	13 habitat units, 65 transect lines	Coryell and Bell (Fort Hood)	Point surveys to determine presence, 6 minutes per visit, territory mapping	0.04-ha circular plots, ~1 plot per 6 ha; also point-quarter method on transects	Mature Ashe juniper-oak woodlands, determined by aerial photos	3.3–172.8 ha	Published report
Beardmore 1994	1988–1989	2 public properties	Travis	Territory mapping	Point-center quarter method at 25 points over 3 territories (total of 27 territories)	N/A	>250 ha tracts of habitat	Thesis
Benson 1990	1990	295 patches	11 counties, Bell to Kerr	Modified circular plot method to determine presence, 1 visit per patch, 20 minutes per visit	N/A	Composed of mixed oak and juniper; junipers ≥5 m in height; canopy cover ≥50% at 4m; determined by aerial photos, accuracy not specified	0.66–237 ha	Unpublished report
Benson 1995	1994	78 survey points	Bosque (Meridian State Park)	Point surveys to determine presence, 1 visit per point, 20 minutes per visit	N/A	Mature juniper-oak stands	N/A	Peer reviewed
Butcher 2010	2006–2007	12 patches	Bosque, Coryell, Hamilton	Territory mapping	N/A	A stand of mature juniper-oak forest, canopy closure of 35-100%, 8-40 m from other such patches	2.9–27.7 ha	Peer reviewed
Campomizzi et al. 2008	2006	41 points	Bell, Bosque, Coryell, Hamilton	Point surveys to determine presence, 6 visits to each point	Calculated percent oak-juniper woodland composition using ArcGIS and Landsat imagery; accuracy not specified	Oak-juniper woodland	N/A	Peer reviewed

Appendix 4.A continued.

Author	Breeding seasons	Sample size	Counties	Bird survey methods	Vegetation survey methods	Patch or habitat definition	Patch sizes	Article type
Choban 1974	1974	1 site (~15 ha study area)	Travis	Census, territory mapping	For frequency: 0.03-ha circular plot with 30.5 m between each plot center point; for basal area: plotless sampling method with sighting gauge	Mature Ashe juniper-oak woodlands	N/A	Unpublished report
Coldren 1998	1993–1995	100 patches; 624 territories	Travis (*n*=99), Williamson (*n*=1)	≥3 censuses per patch, spot-mapping warbler locations	4 2x50m plot per patch extending in each cardinal direction out from single point	Not specifically defined; "all potential warbler habitat" based on aerial photos	6.5–731.5 ha	Dissertation
Collier et al. 2010	2006–2008	30 properties, 147 patches	Bell, Bosque, Coryell, Hamilton	2006-2007: point surveys with 6 visits per point; 2008: patch-level surveys, up to 6 surveys per patch	N/A	Landsat imagery classification of "oak-juniper woodland"; 78% accuracy of imagery classification	0.54–1043 ha	Peer reviewed
Cummins 2006	2003–2004	776 points for warbler surveys (376 used for model testing)	Coryell, Hamilton	Fixed-radius (100 m) point surveys to determine presence, 3 visits per point, 12 minutes per visit	In field surveys: 161 points, 4 15-m quad-rants per point; remote sensing data: quantified habitat characteristics within 100-m and 400-m radius circles around 400 points	Not pre-defined	N/A	Thesis
DeBoer and Diamond 2006	2002	49 patches, 467 points within the patches	17 counties, Palo Pinto to Uvalde	Fixed-radius (50 m) point surveys to determine presence, at most 2 visits per point, 6-9 minutes per visit	5 m fixed-radius circle at each survey point; also used remote sensing data	All forest land-cover types from the NLCD buffered 75 m in from the edge; 81% accuracy of imagery classification	6.5 to >23,000 ha	Peer reviewed
Demoll et al. 1984	1984	1 site (~15 ha study area)	Travis	Census	Visual estimate	N/A	N/A	Published report
Diamond and True 1998	1986, 1996/97	N/A	Range-wide	N/A	N/A	Thematic Mapper satellite imagery cover classes of forest and woodland; 80% accuracy of imagery classification	N/A	Unpublished report

Appendix 4.A continued.

Author	Breeding seasons	Sample size	Counties	Bird survey methods	Vegetation survey methods	Patch or habitat definition	Patch sizes	Article type
Engels and Sexton 1994	1991–1992	100 survey points on 14 tracts of land	Travis	Fixed-radius (90 m) point surveys to determine presence, 1 visit per point, 20 minutes per visit	3 10-m diameter circular plots at 90 of the survey points	Closed-canopy wood-lands (>70% canopy cover) of Ashe juniper and oaks, 5m mini-mum canopy height	N/A	Peer reviewed
Heilbrun et al. 2009	2009	608 points on 6 parcels	Bexar	Incidental detections during vegetation surveys	1-acre circular plots centered on points	Areas with ≥35% canopy closure, in which juniper comprises 10-90% of the canopy	N/A	Unpublished report
Horne 2000	1999	4 road-fire breaks, 40 territories	Coryell and Bell (Fort Hood)	Territory mapping, color banding	N/A	Oak-juniper wood-lands	N/A	Unpublished report
Horne and Anders 2001	2000–2001	325 points	Coryell and Bell (Fort Hood)	Fixed-radius (50 m) point surveys, 2 visits per point, 9 minutes per visit	0.04-ha circular plots centered on points; also used 1-m digital ortho-photo quadrangles	Closed canopy forest (>65% cover)	N/A	Unpublished report
Huss 1954	Not specified in thesis	32 burn sites (age 0–60 yrs)	Real	N/A	3-m wide belt transects	N/A	N/A	Thesis
Johnston et al. 1952	1952	1 site (~15 ha study area)	Travis	Census	Visual estimate	N/A	N/A	Published report
Keddy-Hector et al. 1998	1993–1997	3 sites	Travis	Systematic surveys, territory mapping	Visual estimate	N/A	N/A	Unpublished report
Kroll 1974	1974	4 sites	Bandera, Bosque, Travis	Territory mapping	Tenth-acre plots at 1 site, visual estimates at 3 sites	N/A	N/A	Unpublished report
Kroll 1980	1974–1978	1 public property, 400 points	Bosque (Meridian State Park)	Census, territory mapping	0.1-ha plots centered on each point, point-center quarter method	Not pre-defined	N/A	Peer reviewed
Ladd 1985	1984–1985	10 properties	8 counties, Palo Pinto to Bandera	1 property: transect surveys and territory mapping; 9 properties: not specified	1 property: point-cen-ter quarter method at 35 points along each of 27 transects; 9 proper-ties: visual estimates	Not pre-defined	N/A	Thesis
Magness et al. 2006	2002	14 properties, 202 points	mostly Bandera (some points in Uvalde, Kerr Medina, Real)	Fixed-radius (100 m) point surveys, 1 visit with 2 observers per point, 10 minutes per visit	Quantified percent woodland (areas with >30% woody cover) using satellite imagery; 85% accuracy in classifying woodland versus open habitat	Not pre-defined	N/A	Peer reviewed

Appendix 4.A continued.

Author	Breeding seasons	Sample size	Counties	Bird survey methods	Vegetation survey methods	Patch or habitat definition	Patch sizes	Article type
Moses 1996	1990–1992 (warbler location data)	8 study sites, number of warbler detections not specified but was at least 455	Travis	Used pre-existing survey data from multiple sources, data not collected with equal time effort per unit area	Classification of 1951 and 1980 aerial photos and 1991 Landsat imagery; unknown classification accuracy	Cover vegetation type consisting of Ashe juniper-deciduous spp. mixture with minimum canopy cover of 65% at 5.5 m, based on aerial photos and satellite imagery	N/A	Thesis
Newnam 2008	1995–1997	13 properties, 836 vegetation transects	12 counties, Palo Pinto to Uvalde	Behavioral observations	Total vegetation vol-ume method; each transect = 2 20-m inter-secting lines established at warbler sightings (n=753) or nests (n=83)	Not pre-defined	N/A	Dissertation
Peterson 2001	1998	1 property (Kerr WMA), 50 points (25 use, 25 non-use)	Kerr	Patch-level occupancy surveys, territory mapping; maximum of 5 visits per patch, 1-4 hrs per visit	Point-center quarter method with 100-m intersecting sampling lines extended in cardinal directions	Mature Ashe juniper with mixed oaks and various hardwoods	17.4–258.6 ha (for occupied patches)	Thesis
Pulich 1976	3–11 years (depending on site)	3 intensive study sites	intensive studies in Dallas, Bosque, Kendall; habitat descriptions for >75 counties	Census, behavioral observations	Visual estimate	Cedar brakes with some deciduous cover, average tree height of 20 feet, frequently adjacent to riparian or solid-oak types	N/A	Book
Reemts et al. 2008	2007–2008 (in progress)	28 territories	Coryell, Bell (Fort Hood)	Territory mapping	Nested, circular plots within territories (25 m^2 within 100 m^2)	Not pre-defined	N/A	Unpublished report
Rowell et al. 2002	Unknown, pre-1998	11 public properties, 549 warbler locations	12 counties, Palo Pinto to Uvalde	Not specified	Transects consisting of 2 20-m intersecting lines established at warbler locations	Not defined; “less-optimal” habitat	N/A	Unpublished report
Shaw 1989	1987–1988	14 properties	11 counties, Bosque to Uvalde	Modification of Emlen strip method to deter-mine density; 1 1.6-km transect per property, 2 visits per transect	1 1.6-km transect per property; point-quarter method (for trees) and quadrat method (for shrubs)	Woodlands containing mature Ashe juniper, determined by Land-sat satellite data; 87.7-90.7% accuracy	N/A	Dissertation

Appendix 4.A continued.

Author	Breeding seasons	Sample size	Counties	Bird survey methods	Vegetation survey methods	Patch or habitat definition	Patch sizes	Article type
Smeins and Moses 1994	1990–1994 (warbler location data)	9 sites	Travis	Not specified; authors noted inconsistent survey effort between and within sites	Classification of 1951 and 1980 aerial photos and 1991 Landsat imagery; unknown classification accuracy	Mature juniper-oak woodlands	N/A	Unpublished report
Sperry 2007	2004–2005	1 site, 15 300-m transects with 105 total points	Travis	Fixed-radius (25 m) point surveys, 4 visits per point, 10 min per visit	25-m line transects in each cardinal direction at 45 of the 105 points	N/A	N/A	Thesis
SWCA 2003	2003	25-mile road segment	Edwards	Presence/absence surveys, 20 hr per 100 acres, maximum 5 visits	Visual estimates	Not pre-defined	N/A	Unpublished report
The Nature Conservancy (TNC) 2002	2002	49 patches, number of points not specified	17 counties, Palo Pinto to Uvalde	Fixed-radius (50 m) point surveys, at most 2 visits per point, 6-9 minutes per visit	5 m fixed-radius circle at each survey point; also used remote sensing data	All NLCD forest land-cover types buffered 75 m in from the edge; 81% classification accuracy	6.5 to >23,000 ha	Unpublished report
Wahl et al. 1990	1987–1988	17 properties	12 counties, Bosque to Uvalde	Emlen strip census at 15 properties (1 1.6-km transect per property); variable circular plot method at 1 property; spot mapping at 1 property	1 1.6-km transect per property; point-quarter method at 15 prop-erties; 1974, 1979, and 1981 Landsat imagery classification, ~90% classification accuracy	Mixed evergreen-deciduous forest or woodland	<10 to >1000 ha	Unpublished report

Winter Range (southern Mexico and Central America)

Author	Winter seasons	Sample size	Country	Bird survey methods	Vegetation survey methods	Patch or habitat definition	Patch sizes	Article type
Gonzales-Callejas 2008	Dec 2007 to Feb 2008	5 study areas, 26 flocks, 14 warblers	Guatemala	Observed 5-6 mixed-species flocks per study area, each flock at least 1 km apart, 4 hours of observation per flock	Visual estimates	Coniferous and mixed forests	N/A	Unpublished report
King et al. 2009	Nov 2006 to Jan 2008	60 sites (36 use, 24 non-use), ≥23 warblers	Nicaragua	Visual searches to determine presence	0.04-ha plots at warbler locations	Pine-oak forest above 1000 m elevation	N/A	Peer reviewed
Kroll 1980	March 1975	1 site, 12 warblers	Honduras	Behavioral observations	20 0.1-ha plots within utilized areas	N/A	N/A	Peer reviewed
Braun et al. 1986	Jan 1978, Jan 1983	1 male each year	Mexico	Incidental sightings	Descriptive	N/A	N/A	Published report

Appendix 4.A continued

Author	Winter seasons	Sample size	Country	Bird survey methods	Vegetation survey methods	Patch or habitat definition	Patch sizes	Article type
Land 1962	Nov 1958 to Jan 1959	5 collecting stations, 6 warblers	Guatemala	Recorded presence	N/A	N/A	N/A	Peer reviewed
Morales et al. 2008	April 2002, Dec 2004, Jan & March 2006	1 property; 3-5 total warblers across the survey dates	Nicaragua	Recorded presence	Visual estimates	N/A	N/A	Unpublished bulletin
Perrigo and Booher 1994	Jan 1993	1 warbler	Mexico	Recorded presence	N/A	N/A	N/A	Published report
Potosme and Munoz 2007	Nov 2006 to Feb 2007	3 reserves, 22 warblers	Nicaragua	Visual searches to determine presence; unknown number of visits or length of visits	0.04-ha plots at warbler locations and at sites 100 m from warbler locations	N/A	N/A	Unpublished report
Rappole 1996	Dec 1995 to Feb 1996	7 regional localities, 77 warblers	Honduras	Non-random surveys to determine presence; also, 50 1-km stratified random transects	Tenth-acre circular plots at warbler locations, unknown number of plots	Pine-oak woodlands above 1000 m elevation	N/A	Unpublished report
Rappole et al. 1999	Dec 1995 to Feb 1996, Jan to Feb 1997, Jan to March 1998	157 warblers; 86 veg plots (44 at warbler locations)	Guatemala and Honduras	Walking transects through forested habitat	0.04-ha plots centered on warbler sightings; also measured at 5 random points along each of 42 transects	Pine-oak woodlands above 1000 m elevation	N/A	Peer reviewed
Rappole et al. 2000	Dec 1995 to Feb 1996, Jan to Feb 1997, Jan to March 1998	126 warbler locations, 275 veg plots (91 at warbler locations)	Guatemala and Honduras	Walking transects through forested habitat	0.04-ha plots centered on warbler sightings or centered on points at a random distance and direction from warbler sightings	Pine-oak woodlands above 1000 m elevation	N/A	Peer reviewed
Thompson 1995	Jan to Feb 1995	13 warblers	Guatemala and Honduras	Not specified in report	Visual estimates	N/A	N/A	Unpublished report
Vidal et al. 1994	Oct 1990 to April 1991, Oct 1991 to March 1992	1 study area, 7 transects, 335 points, ≥48 warblers	Mexico	40m x 1km transects visited weekly, also fixed-radius (25 m) 10-minute point counts	N/A	Not pre-defined	N/A	Peer reviewed

Appendix 4.B. Scientific and common names for vegetation species occurring in areas occupied by golden-cheeked warblers throughout the breeding and winter ranges. Scientific and common names have been updated from the original documents with the naming convention used in the U.S. Department of Agriculture's PLANTS Database.

Scientific name	Common name	Form
Breeding range		
Acacia berlandieri	Guajillo	Shrub
Acacia farnesiana	Sweet acacia (aka Huisache)	Shrub/tree
Acacia greggii	Catclaw acacia	Shrub
Acacia roemeriana	Roundflower catclaw (aka Roemer acacia)	Shrub/tree
Acer grandidentatum	Bigtooth maple	Tree
Aesculus pavia	Red buckeye	Shrub/tree
Arbutus xalapensis	Texas madrone	Shrub/tree
Baccharis neglecta	Roosevelt weed (aka Baccharis)	Shrub
Bernardia myricifolia	Mouse's eye (aka Southwest bernardia)	Shrub
Carya illinoinensis	Pecan	Tree
Celtis laevigata var. *laevigata*	Hackberry (aka Sugarberry)	Tree
Celtis laevigata var. *reticulata*	Netleaf hackberry	Tree
Cercis canadensis	Eastern redbud	Shrub/tree
Condalia viridis	Green condalia	Shrub
Cornus drummondii	Roughleaf dogwood	Tree
Diospyros texana	Texas persimmon	Tree
Forestiera pubescens	Elbowbush (aka Spring herald)	Shrub
Forestiera reticulata	Netleaf swampprivet (aka Net-leaf forestiera)	Shrub
Fraxinus texensis	Texas ash	Tree
Garrya ovata	Silktassel	Shrub
Ilex decidua	Deciduous holly (aka Possumhaw)	Shrub
Ilex vomitoria	Yaupon	Shrub/tree
Juglans major	Arizona walnut	Tree
Juglans microcarpa	Little walnut	Tree
Juniperus ashei	Ashe juniper	Tree
Juniperus pinchotii[a]	Redberry juniper	Tree
Juniperus virginiana[b]	Eastern red cedar	Tree
Maclura pomifera	Osage orange	Tree
Mahonia trifoliolata	Agarita (aka Algerita)	Shrub
Melia azedarach	Chinaberry	Tree
Morus microphylla	Texas mulberry	Tree
Morus rubra	Red mulberry	Tree
Pinus remota	Papershell pinyon (aka Texas pinyon pine)	Tree
Platanus occidentalis	American sycamore	Tree
Prosopis glandulosa	Honey mesquite	Shrub/tree
Prunus serotina var. *eximia*	Escarpment black cherry	Tree
Prunus virginiana	Choke cherry	Shrub/tree
Ptelea trifoliata	Common hoptree (aka Wafer ash)	Shrub/tree
Quercus buckleyi	Spanish oak (aka Texas red oak)	Tree
Quercus fusiformis	Plateau live oak (aka Texas live oak)	Tree
Quercus laceyi	Lacey Oak	Tree
Quercus marilandica	Blackjack oak	Tree
Quercus muehlenbergii	Chinkapin oak	Tree

Appendix 4.B continued.

Scientific name	Common name	Form
Quercus laceyi	Lacey Oak	Tree
Quercus marilandica	Blackjack oak	Tree
Quercus muehlenbergii	Chinkapin oak	Tree
Quercus sinuata var. *breviloba*	Shin Oak (aka Bigelow oak, Scalybark oak)	Shrub/tree
Quercus stellata	Post Oak	Tree
Quercus velutina	Black oak	Tree
Rhus virens	Evergreen sumac	Tree
Rhus spp	-	Shrub/tree
Salix nigra	Black willow	Tree
Sapindus saponaria var. *drummondii*	Western soapberry	Tree
Sideroxylon lanuginosum	Gum bumelia	Shrub/tree
Smilax spp	-	Vines
Sophora secundiflora	Mountain laurel (aka Mescal bean)	Shrub/tree
Tilia americana var. *caroliniana*[c]	Carolina basswood	Tree
Ulmus americana	American elm	Tree
Ulmus crassifolia	Cedar elm	Tree
Ungnadia speciosa	Mexican buckeye	Shrub/tree
Viburnum rufidulum	Rusty blackhaw	Shrub/tree
Vitex agnus-castus	Vitex	Shrub
Zizyphus obtusifolia	Lotebush	Shrub
Winter range		
Calliandra houstoniana	-	Shrub/tree
Cuphea spp	-	Herb/Shrub
Ficus spp	Ficus	Shrub/tree
Heterocentron subtriplineriums	-	Herb
Liquidambar styraciflua	Sweetgum	Tree
Morella cerifera	Wax myrtle	Shrub/tree
Olmediella betschleriana	Costa Rican holly	Shrub/tree
Oreopanax spp.	-	Shrub/tree
Pinus maximinoi	Pinabete [thinleaf pine]	Tree
Pinus oocarpa	Ocote pine	Tree
Quercus cortesii	“Encino oak”	Tree
Quercus eliptica	“Encino oak”	Tree
Quercus elongata	“Encino oak”	Tree
Quercus oleoides	“Encino oak”	Tree
Quercus purulhana	“Roble oak”	Tree
Quercus rugosa	“Roble oak” (aka Netleaf oak)	Shrub/tree
Quercus segoviensis	“Roble oak”	Tree
Quercus supotifolia	“Encino oak”	Tree
Stevia spp.	-	Herb/Shrub

[a] Noted by Pulich (1976) as occurring only in the western one-fourth of the warbler’s range.
[b] Noted by Pulich (1976) as occurring only in the northeastern part of the warbler’s range.
[c] Noted by Pulich (1976) as occurring in the southwestern part of the warbler’s range.

Chapter 5. Factors Influencing Demography

Loss and degradation of habitat was listed as a primary threat to the golden-cheeked warbler when it was listed as endangered (55 FR 53154). At the time of listing, few studies existed that examined the effects of variation in quantity and quality of warbler habitat relative to population demographics. This chapter addresses variation in warbler abundance, reproduction, and population demographics relative to differences in habitat characteristics. Long-term research on golden-cheeked warbler territory abundances and population demographics associated with habitat characteristics has been restricted to 2 areas within the species range: Fort Hood Military Reservation (Bell and Coryell Counties) and Travis County. At the time of this writing, limited abundance or demographic information exists for counties in 6 of the 8 Recovery Regions, although several research projects are on-going.

In this chapter, we define significant results as having *P*-values < 0.05 and we report descriptive statistics for variables when provided by authors. Territory success is defined for an individual territory as having ≥ 1 nestling fledge successfully during a breeding season. For multiple territories, territory success is the percent of territories that successfully fledge ≥ 1 young, regardless of pairing status (i.e., the estimate includes males that were not paired with a female or for which pairing status was unknown). Pairing success is the proportion of males that acquire a female during the breeding season and does not account for territory or nesting success. Apparent nest survival is the proportion of total nests monitored that successfully fledged ≥ 1 young, whereas nest survival is the probability that a nest will be successful and is calculated using Mayfield estimates (Mayfield 1961) or maximum likelihood approaches (Rotella et al. 2004, Shaffer 2004).

5.1 Nest-site Characteristics

Using information-theoretic methods, Reidy et al. (2009b) found no model support for an effect of nest height (mean = 5 m, SE = 0.6, range 2.5–9.9 m, *n* = 195 nests) or nest cover (mean = 50.4%, SE = 0.72, range = 15–95%) on nest survival relative to several candidate models (Appendix 5.A) for study sites in Travis County and Fort Hood. Effect of distance to main trunk (range = 0–4.5 m), also received no model support compared to several other variables (Reidy 2007; Appendix 5.A). Nest concealment was found to positively affect survival of artificial nests (*n* = 794) that simulated those of golden-cheeked warblers in Travis County (Fink 1996); survival was significantly lower (29% success, sample size unknown) for highly exposed artificial nests compared to survival of artificial nests that were highly concealed and difficult to detect (57% successful; Fink 1996).

Nest survival was not associated with percent canopy cover or height of canopy measured at the nest for a study at Fort Hood from 1997 to 2002 (*n* = 61 nests; Stake 2003). Using artificial nests intended to resemble warbler nests in Travis County, Fink (1996) also found no relationship between nest predation and canopy cover measured at the nest (mean cover at all nest trees = 88.9%, *n* = 397 nests) nor with diameter at breast height (dbh) of the nest tree (mean dbh of all nest trees = 102.6 cm, *n* = 794 nests). In Travis County, Gass (1996) found no correlation of apparent nest survival with relative nest height (mean = 0.81 m, SD = 0.10, range = 0.61–0.97, *n* = 17), defined as the ratio of nest height (mean = 7.1 m, SD = 3.3, range = 3.2–14 m, *n* = 17) to tree height (mean = 8.5 m, SD = 3.5, range = 4.5–17 m, *n* = 21), although no statistical analyses were provided in the report. Alternatively, a study using artificial nests found significantly increased success of artificial nests with increasing nest tree height (mean height of all nest trees = 6.7 m, range 4–13 m, *n* = 794 nests; Fink 1996). A study on Fort Hood concerning the overlap of habitat variables preferred by Texas ratsnakes (*Elaphe obsoleta*) and the effects of those variables on nest survival suggested a positive effect of nest tree dbh and a negative effect of nest height on nest survival (Sperry et al. 2009). In this study, model selection results indicated support for an additive effect of nest tree dbh and nest height on nest survival but model averaged parameter estimates indicated a nonsignificant effect on nest survival of either parameter. For tree species in which the nest was placed, nest success or failure was not correlated with tree species at 3 sites in Travis County (i.e., 6 of 15 nests failed in Ashe juniper while 3 of 5 nests failed in hardwood species), although no statistical analyses or results were given (Gass 1996).

Percent slope measured within nesting plots did not influence nest survival when evaluated against competing models (*n* = 61 nests; Appendix 5.A; Stake 2003). Additionally, nest survival analyses conducted by Reidy (2007) found no model support for the effect of slope (range 0–36°) on nest survival (*n* = 195 nests). Using artificial nests, however, Fink (1996) found slope measured at the nest tree was positively correlated with nest success (mean slope at all nest trees = 7.5, range 0–30°, *n* = 397 nests).

Stem densities and understory density were not supported as affecting nesting success by model selection results (*n* = 61 nests; Appendix 5.A; Stake 2003). However, Fink (1996) found that of 397 artificial nests placed in the lowest open understory category (i.e., >20 m visibility of vegetation <2.5 m high directly under nest), 90% of these nests were predated.

5.2 Stand characteristics

In his study on territory success, Coldren (1998) compared vegetative characteristics between patches with low territory success (<50%, *n* = 39 patches) and high territory success (>50%, *n* = 24 patches) in Travis and Williamson Counties. Vegetative characteristics were measured within a 50-m radius of each warbler detection point. Measurements included average slope, average canopy cover, species composition, along with density, basal area, and average height of junipers and hardwoods in the understory (< 4.5 m) and canopy. Depending on the patch size category, only understory juniper basal area, average understory juniper height, and average slope differed between sites with high and low reproductive success (Coldren 1998); small patches (< 32 ha [<79 ac]) with high territory success had smaller understory juniper basal area than small patches with low territory success, while in large patches (>100 ha [>247 ac]) the average height of understory juniper was lower in patches with high territory success than patches with low territory success (Coldren 1998).

Territory abundance was not associated with vegetative characteristics in a study on Fort Hood 2 years post-fire (Baccus et al. 2007). Based on vegetation measurements in randomly placed 0.04-

ha (0.10-ac) circular plots, they found no influence of percent understory of hardwoods (mean = 47.9%, SE = 6.412, n = 13 patches), percent of hardwoods in the overstory (mean = 37.7%, SE = 6.799, n = 13 patches), or percent canopy cover (mean = 81.8%, SE = 3.190, n = 13 patches) of habitat patches on the abundance of territories within patches for either year post-fire (1997 and 1998).

Density of territorial males (0.041–0.307/ha [0.017–0.124/ac]) in Travis County positively correlated (r^2 = 0.33, P = 0.02, n = 17 study plots) with the percent of woodland cover (defined as >70% canopy cover; DLS Associates 1994). However, stronger, positive correlations emerged when considering the amount of historic woodland cover (woodland cover in 1970 that still remained during the study years of 1991–1993; range = 15–95%; r^2 = 0.61, $P < 0.001$, n = 14 study plots) and percent closed-canopy forest (woodland with >70% canopy cover with no visible breaks in tree canopies; range of closed-canopy = 8–95%; r^2 = 0.6, $P < 0.01$, n = 17 study plots).

Limited research has been conducted on variation in age demographics relative to habitat characteristics. Territories for after second-year (ASY) males (n = 100 territories) on Fort Hood had significantly more oak cover at >2 m height and more juniper with dbh >15 cm at 10 cm above the ground than second-year (SY) territories (n = 47 territories; Anders et al. 2000).

5.3 Topography

Territory density was not associated with the percent of a study area classified as ravines (i.e., slope of >8% versus uplands with slope of <8%) for 17 study sites in Travis County between 1991 and 1993; the percent of study area classified as ravine ranged from 10 to 100% (DLS Associates 1994). Keddy-Hector et al. (1998) classified warbler territories in study sites in Travis County as located in hollow woodlands (slopes and creek bottoms below canyon slopes), scarp woodlands (canyon slopes), and upland woodlands (flat terrain above canyon slopes). From 1993 through1997, the annual number of territories within each topographic setting averaged 22.2 ± 9.5 males/year/site in hollow woodlands, 19.0 ± 8.3 males/year/site in scarp woodlands, and 11.0 ± 7.8 males/year/site in upland woodlands.

Keddy-Hector et al. (1998) examined differences in age structure and dispersal patterns of warblers relative to the 3 land types noted above. There was no significant difference in the proportion of SY males relative to the total known-age males (hollow woodlands: 0.52 ± 0.1, n = 197 aged males, range = 4–38 aged males/year/site; scarp woodlands: 0.33 ± 0.40, n = 170, range 2–30 males/year/site; upland woodlands: 0.57 ± 0.37, n = 84, range 1–17 aged males/year/site). There was no significant difference in male return rates for each land type: 0.45 ± 0.24 in hollow woodlands, 0.46 ± 0.32 in scarp woodlands, and 0.44 ± 0.32 in upland woodlands. There was no significant difference in territory fidelity among land types (hollow woodlands: 38%, n = 60 returning males; scarp woodlands: 45%, n = 51, upland woodlands: 59%, n = 27). Furthermore, there was no significant difference in the percent of males returning to within the same land type but not necessarily the same territory: 20 of 34 males that changed territories remained in hollow woodlands, 14 of 17 males returned to scarp woodlands, and 7 of 11 males remained within upland woodlands.

Coldren (1998), in his study in Travis and Williamson Counties from 1993 to 1995, found small patches (< 32 ha [<79 ac]) with high territory success had less topographic relief than small patches with low territory success. Alternatively, 2 studies that did not account for patch size found no relationship between slope and nest success. Gass (1996) found no correlation between nest success and canyons (8 of 14 nests failed) or uplands (1 of 6 nests failed) in Travis County but suggested that sample sizes of nests may have precluded observing an effect. Keddy-Hector et al. (1998) found no significant difference among land types in the average annual pairing success of males for 12 site-years (hollow woodlands: 50% ± 18%, scarp woodlands: 55% ± 15%; upland woodlands: 61% ± 21%) and no significant difference in average annual territory success of males for 12 site-years (hollow woodlands: 26% ± 14%, scarp woodlands: 34% ± 17%; upland woodlands: 45% ± 26%). Average annual brood sizes for 12 site-years were not significantly different among hollow woodland territories (2.25 ± 0.46 young/brood, n = 66 broods), scarp woodland territories (2.20 ± 0.52 young/brood, n = 71 broods), and upland woodland territories (2.36 ± 1.0 young/brood, n = 63 broods) and each land type produced similar numbers of fledglings (hollows = 149, scarp = 152, uplands = 150) across all years and study sites. Keddy-Hector et al. (1998) concluded that clearing of uplands would remove approximately 40% of warbler territories and 50% of the annual production of fledglings from these study areas in Travis County.

5.4 Edge Effects

5.4.1 Distance to Edge

To examine distributions of territories within patches relative to edge, Coldren (1998) categorized distances of 624 territory centers from the habitat edge into 6 50-m intervals ranging from 0 to >250 m. Using non-parametric tests, he found a significant difference between the observed and expected number of territories within the 6 distance categories based on the total area within each distance class. For all patch sizes combined, there were more territories than expected between 0–50 m from the patch edge (although no territory centers were located <30 m from the edge) and fewer than expected at distances >250 m. When examined within 3 patch size categories (small: <32 ha [<79 ac], n = 18 patches; intermediate: 32–100 ha [79–247 ac], n = 33; large: >100 ha [>247 ac], n = 12), there was no significant difference in territory distribution among distance classes in small patches (n = 49 territories) or large patches (n = 361 territories). Conversely, in patches of intermediate size, twice the number of observed territories (n = 45) than expected by chance were located between 0–50 m from patch edge while 92% fewer observed territories (n = 4) than expected were located in the >250 m distance class (Coldren 1998).

In the same study, Coldren (1998) found that observed territory success was lower than expected in each of 3 distance categories closest to the edge (<150 m) and higher than expected in each of the farthest 3 categories (>150 m); however the difference among all 6 distance categories was not significant based on a Chi-square goodness-of-fit statistic. Reidy et al. (2009b), using nest survival analysis and model selection criteria for sites in Travis County and Fort Hood, did not find a significant effect of proximity to edge when distance from nest was categorized into ≤30 m and >30 m (n = 195 nests; odds ratio = 1.114, 95% CI = 0.761–1.630); although model selection results indicated some support for edge proximity the effect size was small as indicated by the confidence intervals overlapping 1.0. In a study relating Texas ratsnake activity to warbler nest survival on Fort Hood, Sperry et al. (2009) defined edge as a >3 m break in the canopy. Using nest survival analysis and model selection criteria, model selection results indicated no effect of distance to edge on nest survival, even though ratsnakes, a known predator of warblers, appeared to prefer habitat closer to edges (Sperry et al. 2009). In a study using artificial nests at 5 sites in Travis County, Fink (1996) placed nests resembling warbler nests in size and nest location along transects <10 m from the edge and 100 m in from the edge in known warbler breeding habitat. Predation rates were not significantly different based on distance from edge in 1994, with predation rates of 58.0% (n = 116) for nests placed along the edge compared to 45.5% (n = 91) of nests along interior transects; rates were again similar in 1995 (edge: 75.9%, n = 151; interior: 75.4% n = 150).

Coldren (1998) found no significant relationship between patches classified as low or high territory success and distance from territory center to edge. However, when habitat patches were classified into 3 size classes (<32 ha, 32–100 ha, and >100 ha [<79, 79–247, >247 ac]), a significant difference emerged within large patches, in that territory success was higher than expected for all distance categories >50 m from the habitat edge. It is important to note that sample sizes were small (i.e., <20 territories) in several patch size and distance categories.

5.4.2 Edge type

Coldren (1998) classified edge types into 2 categories: hard edges were those for which the change in habitat at the edge is <3 m wide and soft edges were for width exceeding 3 m. Hard edges were associated with high levels of human disturbance and soft edges occurred along natural or low-levels of human disturbance. Coldren determined that warblers were not selecting for sites based on the proportion of edge perimeter composed of either edge type. Success of individual territories did not differ with edge type (n = 624 territories). Within all patch size classes (<32 ha, 32–100 ha, and >100 ha [<79, 79–247, >247 ac]), warblers placed territory centers significantly farther from habitat edges when the closest edge was a hard edge (mean = 254.8 m, SE = 150.62, n = 155 territories) than a soft edge (mean = 220.9 m, SE = 142.61, n = 206 territories).

5.4.3 Amount of Edge Habitat

For a study on Fort Hood, Peak (2007) defined edge density as the length of the forest edge relative to the area of the landscape. She found that increased forest edge density within 100 m of a nest (range 2.6–42.7 m/ha in the study area) predicted decreased nest survival (n = 269 nests) when considered with temporal variables (Appendix 5.A). Model-averaged parameter estimates indicated a significant influence of forest edge density (odds ratio: 0.98, 95% CI 0.95–0.99). Using the same statistical approach, Reidy et al. (2009b) also found a negative effect of forest edge density (mean = 6.1 m/ha, range = 0–46.6 m/ha) on nest survival (n = 195 nests) relative to other candidate models (Appendix 5.A). Model-averaged parameter estimates indicated a significant negative effect of open edge density within 100 m of a nest (odds ratio = 0.992, 95% CI = 0.986–0.999) relative to the other parameters. In post-hoc analysis, the amount of open area within 1 km of a nest had no effect on nest survival estimates and there was an insignificant negative effect of open area within 500 m of nests (Reidy 2007).

To assess the influence of patch edge on territory success, Maas (1998) categorized breeding patches on Fort Hood into fragmented and unfragmented habitat. She defined fragmented habitat as having unsuitable habitat (any land cover type other than mature juniper-oak vegetation) in more than one direction that created an edge >35 m in length. Unfragmented sites had edge habitat in ≤ 1 direction (i.e., a portion of a larger contiguous area of habitat). Territory success for 120 territories was significantly higher (80%, n = 60 territories) in the unfragmented patches than in the fragmented patches (53%, n = 60 territories).

Maas (1998) is the only study to date that addressed age structure or return rates based on habitat edges (or fragmentation) in warbler habitat. There was no difference in age structure of male warblers in unfragmented and fragmented study sites (1995: n = 49 males, 1996: n = 37 males). Site fidelity was defined as a warbler returning to within 250 m of the previous year's territory based on mean territory sizes estimated by Pulich (1976). There was no statistical difference between site fidelity rates in fragmented sites (38% returned, n = 24 males resighted in 1996) and unfragmented sites (44% returned, n = 16 males resighted in 1996).

Following a fire in 1996 on Fort Hood, Baccus et al. (2007) examined the influence of fire on territory abundance, density, and demographics of golden-cheeked warblers relative to patch size and proximity to intact warbler habitat within the burn area. Baccus et al. (2007) divided patches in the burn area into "semifragments" (i.e., one edge of the affected area abutted intact warbler habitat, n = 3, range = 16.7–172.8 ha [41.3–4267.0 ac]) and "fragments" (i.e., isolated patches, n = 10, range = 3.3–26.2 ha [8.2–64.7 ac]). Territory densities were higher in the semifragmented patches than in the fragmented patches for the 2 years post-fire but the difference was not significant for either year. Mean territory density in 1997 was 18.8 territories/100 ha (SE = 5.70, range = 11.4–30.0 territories/100 ha) in 3 semifragments and 12.1 territories/100 ha (SE = 2.06, range = 7.6–19.0 territories/100 ha) in 5 fragmented patches. In 1998, mean territory density was 21.0 territories/100 ha (SE = 4.7, range = 13.9–30.0 territories/100 ha) in 3 semifragments and 13.5 territories/100 ha (SE = 2.66, range = 4.5–21.4 territories/100 ha) in 5 fragmented patches. When included in a multiple regression analysis of variance with habitat size and 3 vegetation variables (see Stand Characteristics), habitat type (semifragmented or fragmented) did not emerge as a significant predictor of territory abundances in 1997 or 1998. There also was no difference between habitat types in territory size estimates in 1997 (the only year considered). For all study years combined, there was no significant difference in number of young fledged per male between semifragmented or fragmented habitat types (Baccus et al. 2007).

5.5 Patch Size

Research suggests that warbler abundance increases and territory size decreases linearly with patch size (Coldren 1998, Baccus et al. 2007). Coldren (1998) estimated territory sizes using spot mapping during 3 visits per year and found that mean territory sizes relative to patch size decreased with increasing patch size. Mean territory size was 9.75 ha (24.10 ac) in small patches (i.e., patches of size <32 ha with mean = 22.94 ha, SE = 1.36, n = 18), 7.28 ha (17.99 ac) in intermediate patches (i.e., patches of size 32–100 ha with mean = 55.52 ha, SE = 2.94, n = 33), and 3.68 ha (9.09 ac) in large patches (i.e., patches of size >100 ha with mean = 232.21 ha, SE = 31.49, n =126). Baccus et al. (2007) found that patch size on Fort Hood significantly predicted male abundance with larger patches supporting more territories. This predictability was upheld in a multiple regression analysis of variance including habitat type (semifragmented and fragmented) and 3 vegetatation variables (see Stand Characteristics).

Research also shows that pairing success and territory success increase with patch size, suggesting a minimum patch size threshold for productivity of 15–24 ha (37–59 ac; Arnold et al. 1996, Coldren 1998, Butcher et al. 2010). Coldren (1998) categorized territories as paired or unpaired and successful or failed and calculated an estimate of pairing and territory success for each patch by using the ratio of paired or successful territories to the total number of territories in each patch. Regressing these ratios against patch size, he found that warbler pairing success and territory success increased with increasing patch size (n = 63 patches). In an overlapping study in Travis and Williamson Counties, Arnold et al. (1996) reported that of 100 study patches ranging in size from 6.56 to >730 ha (16.21 to >1,804 ac), the smallest patch size within which fledglings were detected was 23.4 ha (57.8 ac). In accordance with this minimum patch size, Butcher et al. (2010) observed a minimum patch size threshold of territory success of 15–20 ha (37–49 ac) on study sites in Bosque, Coryell, and Hamilton Counties. They monitored habitat patches ranging in size from 2.9 to 27.7 ha (7.2–68.4 ac) that contained 35–100% canopy closure. Females were detected in 3 of 7 territories in patches ≤15 ha (n = 7 patches), compared to 15 of 17 paired territories in patches ≥15 ha (n = 4 patches; Butcher et al. 2010). No more than 1 territory was ever detected in patches ≤15 ha and no territories in patches ≤15 ha successfully fledged young (Butcher et al. 2010). For patches ≥15 ha, 13 of 15 paired territories fledged ≥1 young. Although the aforementioned studies found no fledglings in patches below a 15–24-ha threshold, SWCA (2007) documented fledglings in a patch as small as 4.5 ha (11.1 ac) located 183–244 m away from a 30.5-ha (75.4-ac) patch of warbler habitat within a rural landscape (county and other survey details were not provided in the report).

Maas (1998) examined the influence of patch size (i.e., small: ≤700 ha [≤1,730 ac]; large: >700 ha [>1,730 ac]) on dispersal of hatch-year (HY) or after hatch-year (AHY) males at Fort Hood. Of 26 HY males there was no significant difference in whether the male dispersed or not relative to the size of the original patch. Alternatively, AHY males exhibited greater site fidelity to larger patches; only 6.8% (n = 44) of males found in large patches in one year dispersed to different patches in the following year, whereas 28.7% (n = 115) of males found in small patches in one year dispersed to different patches in the following year. When considering AHY males that dispersed to different patches, Maas (1998) found that patch size from which an individual originated (small: 43 males, large: 9 males) was not significantly associated with the size of patch an individual dispersed to. But regardless of the size of patch from which an individual moved, dispersal to smaller patches occurred more often (73.1%, n = 52) than dispersal to large patches (26.9%, n = 52).

5.6 Patch Shape

At Fort Hood, Baccus et al. (2007) observed that patches of oval habitat supported more territories but that shape was an additive effect to the influence of patch size, in that below a threshold in patch size, patch shape may predict territory abundances. To separate patch size from differences in patch shape in Travis and Williamson Counties, Coldren (1998) found that perimeter-to-area ratio was negatively associated with territory success suggesting that pairing or territory success increased with increasing patch size (or decreasing amounts of edge habitat). Coldren (1998) used a second method to differentiate between patch size and perimeter length by examination of fractal dimensions. Results indicated that the relationship between perimeter-to-area ratio and territory success was a result of inherent changes in perimeter concurrent with changes in patch size and not from changes in perimeter alone, thus, further supporting an influence of patch size (fractal dimension = 1.13, $P < 0.0001$).

5.7 Proximity to Land Use Types

To determine selection for study sites relative to adjacent land use types, Coldren (1998) calculated (1) the proportion of the edge perimeter composed of 13 different land use types for 100 habitat patches and (2) the proportion of territories found closest to each land use category. Land use categories included agriculture, commercial development and entertainment, forested non-warbler habitat (defined as stands of young juniper with few hardwoods), grassland, industrial, open water, low-, medium-, and high-density residential, low-, medium-, and high-density transportation, and utilities. Warblers appeared to select for grassland (27 of 38 sites selected for) and agriculture (16 of 23 sites) land uses and select against commercial development and entertainment (7 of 8 sites selected against), forested non-warbler habitat (17 of 22 sites), and high-density transportation (12 of 15 sites; Coldren 1998). Coldren defined selection for a land use category as “when the territory ratio exceeded the edge ratio” and defined selection against a land use category as “when the edge ratio at a site exceeded the territory ratio”; edge ratio was the length of edge for each land use relative to the total site perimeter while territory ratio was the number of territorial centers closest to each land use category relative to the total number of territories at each site.

Coldren (1998) estimated territory sizes using spot mapping during 3 visits per season and found that, relative to 13 land use categories, mean territory sizes closest to agriculture were larger (mean = 10.33 ha [25.53 ac], $n = 64$ territories), followed by territory sizes close to high-density transportation (mean = 8.76 ha [21.65 ac], $n = 13$) and medium-density (mean = 7.65 ha [18.90 ac], $n = 93$) transportation categories, with all other territory sizes <7 ha [<17 ac]. There was no difference in pairing success relative to 13 adjacent land use categories ($n = 624$ territories) but territory success was lower for territories located adjacent to forested non-warbler habitat (5 of 34 territories observed with fledglings or adults seen carrying food; Coldren 1998).

5.8 Anthropogenic Factors

5.8.1 Urbanization

Urbanization can influence reproductive success or survival rates of species through habitat loss and fragmentation and alterations in abundances or behaviors of predators and brown-headed cowbirds (*Molothrus ater*; see review in Chace and Walsh 2006). Several studies have examined trends in predator populations in golden-cheeked warbler habitat relative to different land use practices (Arnold et al. 1996, Johnston 2006) and correlations between warbler presence and that of potential predators (Engels and Sexton 1994, Arnold et al. 1996).

Predators in warbler habitat

In Travis County in 2004 and 2005, Johnston (2006) examined trends in mammalian and avian predators along 15 transects established perpendicular to 3 edge types (5 transects/type): urban, powerline corridor, and natural edge formed by a meadow. Using track plates to detect mammals, point counts, and incidental sightings for avian and reptilian predators, Johnston (2006) found no significant difference in detections of predators at the different edge types. Although not statistically significant, Johnston (2006) found trends suggesting a decrease in detections of raccoons (*Procyon lotor*) and feral cats with increasing distance from an urban edge but no obvious trend existed for other mammals. Johnston (2006) reported no significant difference in detections of avian species, although brown-headed cowbirds were detected only at 0 m from the patch edge primarily along urban edges and, with lower detections, along powerline corridors. In addition, there was a trend towards decreasing detections of common grackles (*Quiscalus quiscula*) with distance from edge along urban transects.

Predators were more abundant than expected ≤100 m (intervals of <100 m, 100–500 m, 500–1,000 m, and 1,000–2,000 m) from warbler habitat edges, regardless of the land use type at the edge for 100 sites in Travis and Williamson Counties (Arnold et al. 1996). Red-tailed hawks (*Buteo jamaicensis*) were significantly more likely to occur in study sites adjacent to agriculture and blue jays (*Cyanocitta cristata*) were significantly associated with patches adjacent to residential areas (Arnold et al. 1996). Brown-headed cowbirds, greater roadrunners (*Geococcyx californianus*), and red-tailed hawks were significantly more likely to occur in study sites occupied by golden-cheeked warblers (Arnold et al. 1996). Also in Travis County, Engels and Sexton (1994) reported no significant association between the presence of warblers and western scrub-jays (*Aphelocoma californica*), brown-headed cowbirds, or fox squirrels (*Sciurus niger*); however, a significant negative correlation was found between presence of warblers and blue jays.

Warbler abundance and reproductive success

Warbler sightings per 100 ha (247 ac; detections and anecdotal information) decreased with increasing road densities in 9 study sites in Travis County (Moses 1996; road densities ranged 0.003–0.082 km/ha). Similarly, territory sizes were smallest for territories located closest to unpaved roads (mean = 5.33 ha [13.17 ac], *n* = 81 territories) compared to territories closest to 2-lane paved roads (mean = 7.65 ha [18.90 ac], *n* = 93) or 4-lane paved roads (mean = 8.76 ha [21.65 ac], *n* = 13; Coldren 1998).

Reidy et al. (2009) found no effect of road density (mean = 16.7 m/ha, SE = 0.37, range = 0.0–41.4 m/ha) on nest survival (*n* = 195 nests) within 500 m of nests relative to several candidate models (Appendix 5.A). The percent of area developed within 1 km of nests had no influence on nest success in Travis County or Fort Hood (Reidy et al. 2007). Additionally, there was no influence on success by building density within a 500-m radius; however, in post-hoc analysis they found that success was more influenced by building density within a 500-m radius than within a 1000-m radius, although the effect was small (Reidy 2007).

Studies comparing productivity between a rural study site (i.e., Fort Hood), and urban sites in Austin 112 km away, found similar measures of reproductive success among the sites (Reidy

2007, Reidy et al. 2008, Reidy et al. 2009). For 2005 and 2006, overall period nest survival (25 days) was similar at study sites in Fort Hood (period nest survival = 0.396, 95% CI = 0.261–0.528, *n* = 95 nests) and Austin (period nest survival = 0.399, 95% CI = 0.270–0.526, *n* = 100 nests; Reidy et al. 2009b). Reidy et al. (2008) combined studies on Fort Hood from 1997 to 2002 (Stake et al. 2004) and 2005 (Reidy 2007) and compared causes of mortality and stage-specific reproductive measures with urban sites in Austin from 2005, 2006 (Reidy 2007) and 2008. Nest predation was the primary cause of nest failure for 20 of 23 nests in Austin and 27 of 29 nests in Fort Hood, with abandonment and weather comprising loses for the remaining nests (Reidy et al. 2008). There was little difference between rural and urban landscapes for hatching success (proportion of total eggs that did not hatch in nests surviving the incubation period; Fort Hood: 94%, *n* = 126 eggs; Austin: 96%, *n* = 134), mean clutch size of successful nests (Fort Hood: 3.8, 95% CI = 3.7–4.0; Austin: 3.8, 95% CI = 3.6–4.0), nestling survival (Fort Hood: 96%, *n* = 180 nestlings; Austin: 93%, *n* = 180), or mean number of young that fledged from successful nests (Fort Hood: 3.6, 95% CI = 3.4–3.8; Austin: 3.6, 95% CI = 3.3–3.8) (Reidy 2007; J. Reidy, personal communication).

5.8.2 Recreational Activities

Recreational activities or other human intrusions may negatively impact breeding forest birds by altering behaviors, such as singing, territoriality, nest attendance, foraging or food acquisition, or can cause direct disruptions to vegetation or nests (see review in Boyle and Sampson 1985, Miller 1998).

In 1998, the U.S. Fish and Wildlife Service (USFWS) granted permission to open a mountain bike park at the Belton Lake Outdoor Recreation Area located in the southeast corner of Fort Hood in Bell County. The 175-ha (432-ac) area is designated warbler habitat and is located adjacent to one of The Nature Conservancy (TNC) long-term study areas (13B). Since the opening of the park, TNC has worked closely with the local mountain-biking association to reduce trail management activities during warbler breeding season, implement appropriate erosion control mechanisms, and to ensure compliance with USFWS regulations (Craft et al. 1999, Stake 2000, 2001a, Pekins 2002b). A 5-year study on the impact of mountain biking on golden-cheeked warbler demography indicated no differences in territory density, return rate, or male age structure at bike-use and bike-free areas. Nest survival analysis indicated no difference between bike-use and non-bike use areas; however, the lack of an effect may be an artifact of small samples size that increased the variability for each study site (Stake 2000, Peak 2003b)

Davis and Leslie (2008) compared warbler territories and nests located in biking and non-biking areas near Fort Hood and Austin, Texas (1 control and 1 biking study site in each location) for 2002 and 2003. Territory sizes were larger in biking areas, ranging from 0.48 to 7.30 ha (1.19–18.04 ac), compared to non-biking locations, which ranged from 0.24 to 4.30 ha (0.59–10.63 ac). They did not detect any significant differences in behavior of males or females between study locations. In biking areas, 21 nests (64%, *n* = 33) were successful compared to 19 nests (86.4%, *n* = 22) in non-biking areas. Using Mayfield nest survival methods (Mayfield 1961), daily nest survival rate for the incubation stage was 0.964 ± 0.018 in biking areas and 0.986 ± 0.014 in non-biking areas. Daily nest survival for the nestling stage was 0.945 ± 0.019 in the biking areas and 0.981 ± 0.013 in non-biking areas.

5.9 Wintering Grounds

On the wintering grounds of southern Mexico, Guatemala, Honduras, Nicaragua, and El Salvador, golden-cheeked warbler abundances were significantly greater in areas with encino oak cover (e.g. *Quercus sapotifolia*, *Q. eliptica*, *Q.elongata*, *Q. cortesii*; Rappole et al. 2000, Komar 2010). In Honduras (1995, 1996) and Guatemala (1998), warblers were significantly more abundant than expected in pine-oak forests, and less abundant than expected in pine, broad-leaved forests, or agricultural and scrub habitats (Rappole et al. 2000). However, the authors of this study surveyed primarily within pine-oak woodlands (935 of 1363 observer-hours [o-hs]); 174 o-hs were in broadleaf forest, 168 o-hs were in pine forests with little oak in the mid- and understory, 9 o-hs were in mixed pine and roble (broadleaved) oak (e.g., *Q. segoviensis*, *Q. purulhana*, *Q. rugosa*), and 77 o-hs were in agriculture and scrub habitats. Based on preliminary data from an in-progress research program, researchers found greater abundances of golden-cheeked warblers with increasing canopy cover of encino oaks during the winters of 2006–2008; the mean percent cover of encino oaks for mixed-species flocks with warblers was 21% (SD = 20%, n = 126 flocks) whereas the mean was 11% (SD = 15%, n = 118 flocks) for flocks without warbler detections (Komar 2010).

Golden-cheeked warblers were significantly less abundant than expected below 1,300 m elevation (mean elevation = 1,651 m, SD = 246 m, range = 1,100–2,400 m; Rappole et al. 2000). Preliminary results from Komar (2010) found that females and hatch-year warblers were more abundant than males <1,200 m, whereas adult males were more abundant >1,400 m (n = 417 flocks). Furthermore, preliminary results suggested warblers were more abundant in northern than southern latitudes (mainly observed with male warblers) across the 5 countries and somewhat more abundant in western than eastern longitudes (n = 371 flocks; Komar 2010).

5.10 Summary of Factors Influencing Demography

- Long-term research on golden-cheeked warbler territory abundances and population demographics has been restricted to 2 areas within the species range, Fort Hood (Bell and Coryell Counties) and Travis County. No current research exists for counties in 6 of the 8 Recovery Regions, although several research projects are on-going in other areas of the breeding range at the time of this writing.
- Warbler nest survival was not influenced by nest height, concealment at the nest, canopy cover, height of nest tree or canopy cover, tree species, or understory vegetation density. However, a study using artificial nests suggested that some of these characteristics may be important indicating that further research is needed on the effects of vegetation characteristics in the vicinity of nests.
- The occurrence of mature, mixed Ashe juniper-oak woodlands predicted territory settlement decisions. Older males tended to settle in areas with more mature vegetation. Furthermore, the amount of historic woodland cover strongly predicted territory abundances. Comparative analysis with several land use types suggests that warblers are less likely to settle and that territory success is lower adjacent to areas with less mature mixed woodlands or wooded areas with inappropriate species compositions.
- Slope of the land did not influence abundance or demographics regardless of the scale of measurement or whether it was a continuous or categorical designation.
- Edge effects were more apparent when measured as density within a designated area rather than strict distances to nearest edge. The effect of distance from edge appears to vary depending on location of study sites, patch sizes, and study design and analysis methods. Furthermore, earlier studies that categorized territories based on definitions of fragmentation generally found higher productivity in less fragmented territories and higher territory densities within less fragmented patches.
- Patch size was the most consistent variable affecting differences in territory abundance, success, and dispersal patterns. As patch size increases, territory abundances increase, and pairing success and territory success increase. Two studies suggested a minimum patch size of approximately 20 ha (49 ac) in which warblers are reproductively successful. Below this threshold of approximately 20 ha, most studies found reduced pairing success and productivity. Additionally, AHY males are more likely to move from smaller patches to larger patches in subsequent breeding seasons. When accounting for patch shape, patch size remained a stronger predictor of warbler abundance and productivity.
- There is some indication that warblers may select to settle territories away from land use types associated with urbanization, particularly when the land use is associated with increased road densities or 4-lane highways. However, variables representing urbanization did not influence nest survival or other reproductive parameters.
- On the wintering grounds, golden-cheeked warbler abundance is positively associated with pine-oak forests. Preliminary results of a multi-year research program indicate warbler abundance on the wintering grounds may also be influenced by elevation, latitude, and longitude.

Appendix 5.A. Variables used in studies using model selection procedures.

Citation Model	Variable	Description
Reidy 2007		
Temporal	Year	2005, 2006
	Date	Linear, quadratic, and cubic trends
	Stage	Laying, incubation, nestling
Nest-site	Nest height	m
	Nest cover	average % around nest
	Distance nest to main trunk	m
Nest-patch	Slope	percent grade in steepest direction
	Proximity to edge	≤ 30m, > 30m
Edge	Open edge density	length of edge along open habitat within 100 m
	Trail density	m/ha within 25 m
Landscape	Percent of open land	within 1 km
	Percent of developed land	within 1 km
Urban	Road density	m/ha within 500 m
	Building density	number of buildings/ha within 500 m
	Site	Fort Hood, Austin
Reidy et al. 2009b		
Temporal	Year	2005, 2006
	Date	Linear, quadratic, and cubic trends
Nest-site	Nest height	m
	Nest cover	average % around nest
Territory	Slope	percent grade in steepest direction
Edge	Proximity to edge	≤ 30m, > 30m
	Trail density	m/ha within 25 m
	Open edge density	length of edge along open habitat within 100 m
Landscape	Percent open land	within 1 km
	Percent developed land	within 1 km
Urban	Road density	m/ha within 500 m
	Building density	number of buildings/ha within 500 m
Peak 2007		
	Year	2003-2006
	Date	Linear, quadratic, and cubic trends
	Stage	Laying, incubation, nestling
	Forest edge density	length of forest edge / area of the landscape, m/ha, < 100 m
Stake 2003		
Temporal	Year	2001, 2002, or 1997-2000
	Date	
	Stage	Incubation or nestling
Nest-site	Cover	Percent of canopy cover
	Canopy height	Mean height of 4 tallest trees
	Stem count	Count of trees with dbh >7.6 cm
	Substrate	Juniper or other
Territory	Male age	
	Slope	slope > 10 degrees or no slope (< 10 degrees)

Appendix 5.A continued

Citation Model	Variable	Description
Sperry et al. 2009		
Edge	Distance to edge	Distance (m) to canopy opening > 3m
Nest tree	DBH nest tree	DBH (cm) of nest tree
	Nest height	m
Cover distance	Distance to snake cover	Distance (m) to nearest rock or log within 30 m
	Distance to understory	Distance (m) to nearest understory tree ≥ 7.5 cm and ≥ 2 m height, within 30 m
Ground cover	Litter	Mean litter depth (cm) within 1 m
	Percent grass	Percent of grass cover within 2 m
	Percent bare	Percent of bare ground wihin 2 m
	Percent rock	Percent of rock cover within 2 m

Chapter 6. Habitat and Population Estimates

Several researchers have attempted to estimate the distribution and amount of golden-cheeked warbler habitat on the breeding or wintering grounds, and only a few have offered estimates of the overall size of the warbler population. This chapter focuses on research that developed (1) range-wide habitat estimates through the creation of habitat maps or models, or (2) range-wide population estimates. Local-scale habitat models (e.g., Belviso 2000, Belaire 2007, Fuller et al. 2008) are not discussed in this chapter. While some studies provided a single value for the amount of habitat in central Texas, other studies offered the information on a county-level basis for a more complete assessment of habitat distribution. We include the county-level estimates herein and also group the counties by U.S. Fish and Wildlife Service (USFWS) Recovery Regions to facilitate comparison of habitat estimates among different projects. USFWS (1992) delineated 8 Recovery Regions in the Recovery Plan based on geology, vegetation, and watershed boundaries, thus, Recovery Region boundaries often bisected counties. Because the data was reported by county (versus sub-county), we shifted the USFWS Recovery Region boundaries to match nearby county boundaries in order to summarize the data (Figure 6.1).

6.1 Breeding Habitat Estimates

Pulich (1976) presented the first extensive description of golden-cheeked warbler breeding habitat distribution in Texas. He used estimates of virgin Ashe juniper from the Soil Conservation Service's (SCS) county-by-county surveys (Pulich 1976). Virgin Ashe juniper was defined as stands 6–12 m high with most trees >75 years old (Pulich 1965). SCS estimates for 31 counties in the breeding range totaled 299,232 ha (739,645 ac) of virgin Ashe juniper in 1974 (Pulich 1976). Based on this estimate, along with his personal knowledge of the species and habitat, Pulich concluded that 129,904 ha (321,000 ac) of "marginal", "average", and "excellent" breeding habitat existed in Texas (Table 6.1; Pulich 1976).

Since 1989, range-wide warbler habitat estimates have used various forms of remote sensing data (Table 6.2). Shaw (1989) and Wahl et al. (1990) were the first to quantify potential golden-cheeked warbler habitat using satellite imagery. They used Landsat multi-spectral scanner (MSS) images from 1974, 1976, and 1981 with 80-m pixel resolution covering most of the warbler's breeding range (43 counties). Known warbler locations were used as reference points for supervised classification of potential habitat. Because several of the image scenes were taken several years prior to the study, Wahl et al. (1990) used ground-truthing surveys to adjust for loss of habitat during that time interval. They estimated 40% loss of habitat in western Travis County and 15% loss in northern counties during the 10-year and 8-year intervals, respectively, that occurred between the date of the satellite imagery and the field surveys (Wahl et al. 1990). Their overall accuracy with in-field verification of imagery classification was 89.7% (Shaw 1989). County-by-county summation indicated 338,035 ha (835,303 ac) of potential habitat regardless of patch size (Table 6.1; Wahl et al. 1990). The overall extent of habitat was reduced to 237,163 ha (586,043 ac) after considering the aforementioned rate of loss of 40% in urban areas and 15% in rural areas (Wahl et al. 1990). In addition, they used 50 ha (124 ac) as "the lowest patch size of importance to breeding warblers", derived from Robbins et al. (1989) study on habitat

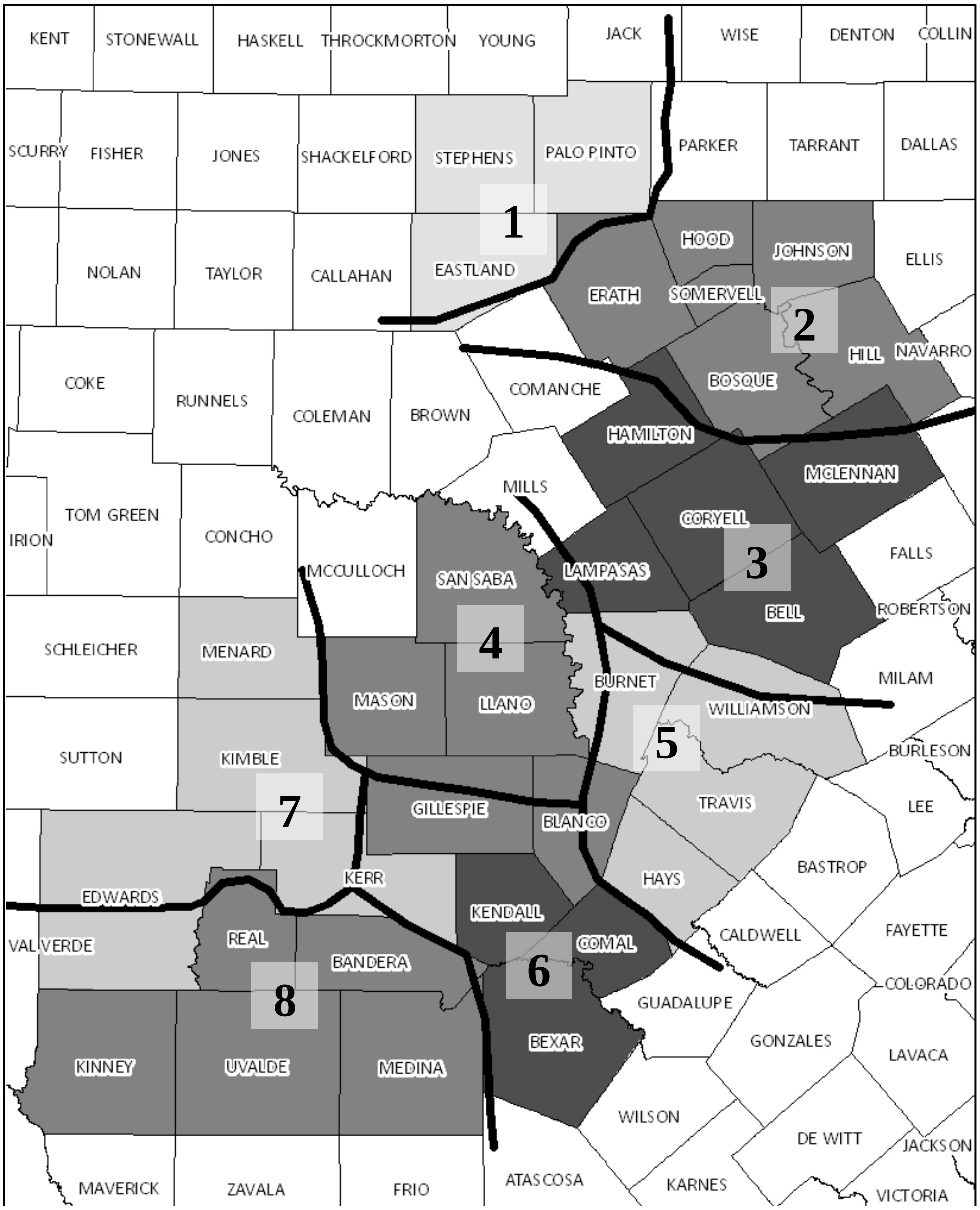

Figure 6.1. Thick outlines represent U.S. Fish and Wildlife Service Recovery Regions (USFWS 1992) for the golden-cheeked warbler. Recovery Regions discussed in this chapter are categorized as indicated by shading to facilitate summary of county-level data.

requirements of breeding forest warblers in northeastern U.S., thus they excluded habitat patches ≤50 ha, resulting in an estimated 32,149–106,776 ha (79,442–263,849 ac) of habitat throughout the warbler's breeding range (Wahl et al. 1990). The range of hectares represented the "worst" and "best" estimates of the proportion of breeding habitat in patches >50 ha (11% and 47%, respectively; Wahl et al. 1990).

Rowell et al. (1995) used golden-cheeked warbler occurrence data and Landsat Thematic Mapper (TM) images taken in 1990–1992 with 30-m pixel resolution to update Wahl's research and to estimate potential habitat in 35 counties. They applied 2 methods of supervised classification based on different spectral training-sets: (1) polygons of habitat containing juniper-deciduous woodland with >75% canopy cover, and (2) individual points (i.e., pixels) of warbler occurrence. Method 1 resulted in 1,116,665 ha (2,759,339 ac) of potential habitat while Method 2 classified 545,948 ha (1,349,067 ac) of potential habitat (Table 6.1). To facilitate comparison of their results with those of Wahl et al. (1990), they excluded all Method 2 habitat patches <50 ha (<124 ac) resulting in 215,066 ha (531,440 ac) of potential habitat (Table 6.2). Verification of the accuracy of both methods involved "visual aerial surveys and preliminary ground surveys" (Rowell et al. 1995). They did not attempt to determine if breeding populations occurred in what they classified as potential habitat and stressed that the "estimates serve only as a rough guide" of habitat extent and patch size distribution (Rowell et al. 1995).

Diamond and True (1998) examined 1986 and 1996/97 Landsat TM imagery and categorized land cover in both years into warbler nesting habitat and non-habitat. Land cover classes considered to be warbler nesting habitat included (1) Ashe juniper or mixed Ashe juniper-oak forest, (2) Ashe juniper or mixed or primarily deciduous forest, and (3) Ashe juniper or mixed Ashe juniper-oak woodland. Non-habitat classifications included (1) Ashe juniper or mixed or mainly oak savanna, (2) grassland, (3) barren or sparsely vegetated areas, (4) urban vegetated areas, and (5) water (Diamond and True 1998). Based on these land cover classifications, they estimated 1,652,035 ha (4,082,267 ac) and 1,676,140 ha (4,141,832 ac) in 1986 and 1996/97, respectively (Table 6.2; Diamond and True 1998). Although not specified in the report, the extent of the breeding range that the imagery covered was likely 29 counties in the warbler's breeding range (Rappole et al. 2003). Direct comparison of hectares between years was not reliable due to differences in image quality and land cover classification between image scenes and years (Diamond and True 1998). Rappole et al. (2003) expanded on this effort, using the 1996/97 imagery and eliminated all patches <5 ha (<12 ac) in size "as a conservative estimate for minimum patch occupancy size". Within these parameters, Rappole et al. (2003) estimated 643,454 ha (1,590,009 ac) of potential habitat (Table 6.2). This estimate, however, did not include 6 counties within the breeding range of approximately 29,000 ha (71,660 ac) of potential habitat (Rappole et al. 2003). No accuracy assessment was conducted for either habitat estimate.

In 2000, the National Land Cover Data set (i.e., 1992 NLCD) was published for the conterminous United States and included a national map of 21 land cover classes based primarily on Landsat 5 TM imagery taken in 1992 (Vogelmann 2001). The map provided the user with 30-m resolution data and approximately 81% accuracy of land cover classifications (Vogelmann 2001). Estimates of potential golden-cheeked warbler habitat by The Nature Conservancy (TNC 2002) were made by reclassifying all 1992 NLCD woodland land cover types (evergreen, mixed, and deciduous) into one category of woodland with a 75-m buffer from the edge of all woodland areas. This resulted in 756,585 ha (1,869,562 ac) of potential habitat in 35 counties (Table 6.1). DeBoer and Diamond (2006) utilized this same dataset and noted that the accuracy of the habitat map was not quantified, although all patches classified as potential habitat and surveyed in the field did contain wooded areas. USFWS (2004) utilized the TNC map for a Biological Opinion to determine the amount of potential habitat comprised of 100-ha (247-ac) patches or larger and calculated 476,740 ha (1,178,050 ac) of habitat in the breeding range (Table 6.1).

Table 6.1. Estimated extent (ha) of potential golden-cheeked warbler habitat by county and Recovery Region. The table includes only those reports for which county-level estimates are available. Researchers' definitions of warbler habitat and methods for estimating hectares are described in the text.

County	Pulich 1976	Wahl et al. 1990	Rowell et al. 1995[a]	Rowell et al. 1995[b]	TNC 2002	USFWS 2004	SWCA 2007
Region 1							
Eastland	405	64	7,499	1,073	6,490	3,345	731
Palo Pinto	4,856	15	13,116	7,399	28,035	12,599	11,436
Stephens	405	-	4,635	2,028	8,155	3,975	5,462
Young	-	-	-	-	-	-	664
Region 1 total	5,666	79	25,250	10,500	42,680	19,919	18,293
Region 2							
Bosque	4,047	6,389	25,396	19,075	11,049	1,678	13,982
Erath	405	699	4,646	4,847	5,059	403	2,698
Hill	-	734	3,171	3,557	1,573	229	2,712
Hood	405	666	4,564	4,123	3,238	209	1,648
Johnson	1,012	1,644	4,399	4,472	2,901	1,698	4,682
Somervell	2,023	1,909	7,219	6,652	4,090	1,282	5,396
Region 2 total	7,891	12,041	49,395	42,726	27,910	5,096	31,118
Region 3							
Bell	2,023	8,270	29,019	16,831	17,043	11,465	15,639
Coryell	1,214	8,294	36,177	18,073	20,186	11,543	16,398
Hamilton	405	345	8,065	4,402	2,199	100	3,497
Lampasas	2,023	540	10,447	7,097	6,173	2,041	4,539
McLennan	-	2,030	13,951	6,914	4,297	874	2,855
Region 3 total	5,666	19,479	97,659	53,317	49,898	25,923	42,928
Region 4							
Blanco	2,023	9,831	27,888	18,100	21,906	10,317	11,739
Gillespie	1,214	8,175	39,366	12,793	28,997	9,631	7,524
Llano	1,012	7,429	23,425	10,448	19,492	12,250	6,408
Mason	-	10,832	26,051	2,653	6,143	1,583	1,010
San Saba	1,619	2,277	39,212	15,722	14,812	3,558	7,500
Region 4 total	5,868	38,544	155,942	59,716	91,350	37,338	34,183
Region 5							
Burnet	4,047	18,845	42,798	23,712	40,001	22,439	22,911
Hays	10,117	20,495	46,456	26,304	28,306	14,114	16,909
Travis	10,117	43,098	51,576	38,232	24,286	17,850	32,720
Williamson	2,023	14,989	20,903	9,081	8,742	1,602	8,123
Region 5 total	26,305	97,427	161,733	97,329	101,335	56,006	80,663
Region 6							
Bexar	3,237	8,778	50,067	30,134	35,067	30,298	17,495
Comal	8,094	24,796	55,208	32,408	39,710	28,352	22,706
Kendall	12,141	13,295	30,651	22,041	19,544	8,065	20,156
Region 6 total	23,472	46,869	135,926	84,583	94,321	66,715	60,358

Table 6.1 Continued.

County	Pulich 1976	Wahl et al. 1990	Rowell et al. 1995[a]	Rowell et al. 1995[b]	TNC 2002	USFWS 2004	SWCA 2007
Region 7							
Edwards	10,117	17,189	60,478	29,994	25,658	12,552	33,126
Kerr	16,187	18,163	90,373	33,295	52,710	31,510	35,240
Kimble	2,428	12,765	44,874	10,371	21,041	5,963	6,642
Menard	-	2,030	2,387	309	705	189	178
Region 7 total	28,733	50,147	198,112	73,969	100,114	50,214	75,186
Region 8							
Bandera	8,094	21,631	95,457	43,071	58,430	43,496	58,349
Kinney	1,214	2,455	10,693	5,479	7,887	4,673	10,047
Medina	2,833	4,878	58,036	22,688	54,453	52,210	21,765
Real	10,117	26,782	74,899	33,274	61,359	54,066	78,198
Uvalde	4,047	16,541	53,563	19,296	66,848	60,581	37,212
Region 8 total	26,305	72,287	292,648	123,808	248,977	215,026	205,571
Misc. counties							
Brown	-	0	-	-	-	-	72
Comanche	-	16	-	-	-	-	1,243
Dallas	-	-	-	-	-	-	855
Ellis	-	0	-	-	-	-	149
Falls	-	0	-	-	-	-	-
Guadalupe	-	187	-	-	-	-	-
McCulloch	-	568	-	-	-	-	59
Mills	-	52	-	-	-	-	982
Parker	-	-	-	-	-	-	253
Schleicher	-	77	-	-	-	-	-
Sutton	-	262	-	-	-	-	-
Misc. counties total	0	1,162	0	0	0	0	3,613
Breeding range total (ha)	129,904	338,035	1,116,665	545,948	756,585	476,238	551,912[c]
Breeding range total (ac)	321,000	835,302	2,759,339	1,349,067	1,869,562	1,176,810	1,363,804
# Counties included	31	43	35	35	35	35	43

[a] Estimates are from Method 1.
[b] Estimates are from Method 2.
[c] Our estimate differs from SWCA Environmental Consultants' estimate of 552,195 ha due to using a slightly different factor when converting acres to hectares for each county. SWCA used a factor of 0.40489 ha per acre while we used 0.404686 ha per acre.

The 1992 NLCD was succeeded by the National Landcover Database (2001 NLCD) which was derived primarily from Landsat 5 and Landsat 7 TM imagery (Homer et al. 2007). The 2001 NLCD provided 16 cover classes and estimates of canopy cover at 30-m resolution; land cover classifications were 84% accurate while canopy cover estimates had an accuracy of ± 6–17% (Homer et al. 2007). A Steering Committee, formed by Texas Parks and Wildlife Department (TPWD) and USFWS in 2006, utilized the 2001 NLCD to estimate the extent of warbler breeding habitat (Diamond 2007). Based on the NLCD land cover types of evergreen, mixed, and deciduous forest/woodland, they defined "appropriate vegetation" as (1) evergreen forest/woodland or (2) mixed or deciduous forest/woodland within 100 m of evergreen. Within this framework they developed 13 models that incorporated local and landscape variables. Variables included distance between pixels classified as evergreen or deciduous, patch size, edge, distance to large patch, climate, topography, geology, and landscape context (Diamond 2007). Ranking rules were applied to each variable as a means of estimating low, moderate, or high quality habitat. The final 4 models incorporated landscape context, patch size, edge, and canopy closure to varying degrees. Estimates of total warbler habitat ranged from 1,580,393 to 1,999,534 ha (3,905,236 to 4,940,956 ac) depending on the model (Diamond 2007). The Steering Committee was most confident with Model C, totaling 1,771,883 ha (4,378,418 ac; Table 6.2) of warbler breeding habitat, which was "less likely to exclude GCW habitat, incorporates edge directly as a factor in habitat quality, and assumes that the largest fraction of habitat is within the highest ranked quality class" (Diamond 2007). Diamond examined the accuracy of Model C using presence-absence data from DeBoer and Diamond (2006). Although the data set had occurrence information on a range-wide scale, Diamond (2007) determined that the sample size (n = 173 survey points) was too small for any conclusions of model evaluation.

Loomis Partners (formerly Loomis Austin) likewise included classifications of habitat quality (e.g., low, medium, high) in their rangewide habitat estimates using the 2001 NLCD imagery with 30-m resolution (Loomis Austin 2008). They used a moving window analysis that averaged the percent canopy cover within a 4.4-ha (10.9-ac) area around each pixel (Loomis Austin 2008). In addition, they incorporated estimates of likelihood of occurrence, based on Magness et al. (2006), to determine what amount of potential habitat would be "likely occupied", "may be occupied", or "not likely to be occupied". Their classifications resulted in 1,679,234 ha (4,149,478 ac) of potential habitat (Table 6.2), of which approximately 28% (471,282 ha [1,164,563 ac]) was categorized as "likely to be occupied" and an additional 50% (837,023 ha [2,068,329 ac]) was categorized as "may be occupied" (Loomis Austin 2008). Loomis Partners used point data of warbler occurrences collected by the firm between 2001 and 2008 from 42 surveys across 9 counties, for a total of 5,347 point observations. Approximately 85% of the warbler detections fell within the "likely to be occupied" habitat while 13% and 0.7% of the detections fell in the "may be occupied" and "not likely to be occupied" habitat, respectively (Loomis Austin 2008). The remaining points (1.3%) fell outside the delineations of potential habitat.

Using 2004 color infrared digital imagery with 1-m resolution, SWCA Environmental Consultants (SWCA) delineated potential golden-cheeked warbler habitat in 43 counties (SWCA 2007). They defined habitat as woodlands with >50% canopy closure and composed of larger (based on crown diameter) Ashe juniper and broad-leaved hardwood trees. Areas composed of

Table 6.2. Estimated extent (ha) of potential golden-cheeked warbler habitat within the breeding range and methods used to determine estimates.

Author	# of counties	Imagery			Author's habitat definition	Habitat estimate (ha)	Estimate includes[a]:
		Data type	Resolution	Accuracy			
Pulich 1976	31	n/a	n/a	n/a	Ashe juniper stands 6-12 m high in which many trees were 75-150 years old	129,904	all habitat, reduced from SCS 1974 survey estimates
Shaw 1989, Wahl et al. 1990	43	1974–1981 Landsat MSS	80 m	89.7%	spectral signatures for sites known to be quality nesting habitat; mainly woodlands containing mature Ashe juniper	338,035	all habitat, all patch sizes, not adjusted for year of imagery
Shaw 1989	43	"	"	"	"	330,824	patches ≥1.8 ha in size, not adjusted for year of imagery
Wahl et al. 1990	43	"	"	"	"	32,149–106,776	patches ≥50 ha in size and adjusted for year of imagery
Rowell et al. 1995	35	1990–1992 Landsat TM	30 m	unknown	Ashe juniper-deciduous woodland with >75% canopy closure	1,116,665	Method 1 (polygons), all habitat
Rowell et al. 1995	35	"	"	"	"	(1) 545,948 (2) 215,066	Method 2 (pixels): (1) all habitat, or (2) patches >50 ha
Diamond & True 1998	29	1986 and 1996–1997 Landsat TM	30 m	~80%	land cover classified as Ashe juniper or mixed juniper-oak forest/woodland and Ashe juniper, mixed, or mainly deciduous forest	(1) 1,652,035 (2) 1,676,140	all habitat: (1) for 1986, or (2) for 1996-1997
Rappole et al. 2003	29	1996–1997 Landsat TM	30 m	~80%	"	643,454	all habitat patches ≥5 ha in size
TNC 2002, DeBoer and Diamond 2006	35	NLCD 1992 Landsat TM	30 m	81%	NLCD cover classes of deciduous, evergreen, and mixed woodland	756,581	all habitat buffered 75 m in from edge
USFWS 2004	35	"	"	"	"	476,740	all habitat buffered 75 m in from edge and >100 ha in size
Diamond 2007	36	mosaic of 2001–2004 Landsat TM	30 m	unknown	land cover classified as evergreen forest/ woodland, mixed forest/ woodland, or deciduous forest/woodland within 100m of evergreen	1,771,883	"Model C": all habitat pixels that contain, within a 200-m radius circle, >20% forest >50m from an edge and >40% forest <50 m from an edge
SWCA 2007	43	2004 color infrared digital imagery	1 m	unknown	>50% canopy closure and composed of combination of larger Ashe juniper and deciduous trees	552,195	all habitat patches >4 ha in size
Loomis Austin 2008	35	NLCD 2001 Landsat TM	30 m	84%	canopy cover within a 7x7-cell area around a pixel averages >30%	1,679,234	all habitat (regardless of quality)

[a] Habitat estimates refer to each authors' definition of habitat as specified in their respective studies.

smaller trees also were included as potential habitat provided canopy closure was >80% and some larger hardwoods were present. They excluded woodland patches that appeared to consist of smaller trees with more open canopy or composed almost entirely of Ashe juniper or hardwoods (SWCA 2007). In addition, they excluded all patches <4 ha (<10 ac) unless the patch occurred "close enough" (unspecified distance) to another suitable patch (SWCA 2007). The resulting map delineated 552,195 ha (1,363,804 ac) of potential habitat (Table 6.1). Eight northern counties were surveyed by road in an attempt to verify the habitat delineations; however, information on the accuracy of the estimates was not provided in the report (SWCA 2007).

Estimates of the extent of warbler habitat in Texas varied widely due to differences in year, imagery, or definitions of potential habitat (Table 6.2). Nevertheless, general patterns of habitat characteristics occur across the studies. Potential habitat is most abundant and contiguous in the southern Recovery Regions: Regions 5, 6, 7, and 8 (Figure 6.2; Wahl et al. 1990, Rowell et al. 1995, TNC 2002). This pattern of habitat roughly follows the Balcones Canyonlands ecoregion (as per Griffith et al. 2004) within the Edwards Plateau. Post-1990 estimates consistently ranked Bandera, Kerr, and Real Counties as among the top 5 counties containing the most habitat (Table 6.1). Patches of warbler habitat tend to be smaller, more fragmented, and more widely dispersed in areas north of the Colorado River (i.e., Cross Timbers ecoregion, Recovery Regions 1, 2, and 3; Wahl et al. 1990, Rowell et al. 1995, TNC 2002). While the majority of habitat patches are small, most of the habitat is contained within the relatively few, large patches throughout the range (Shaw 1989, Rowell et al. 1995, TNC 2002, DeBoer and Diamond 2006).

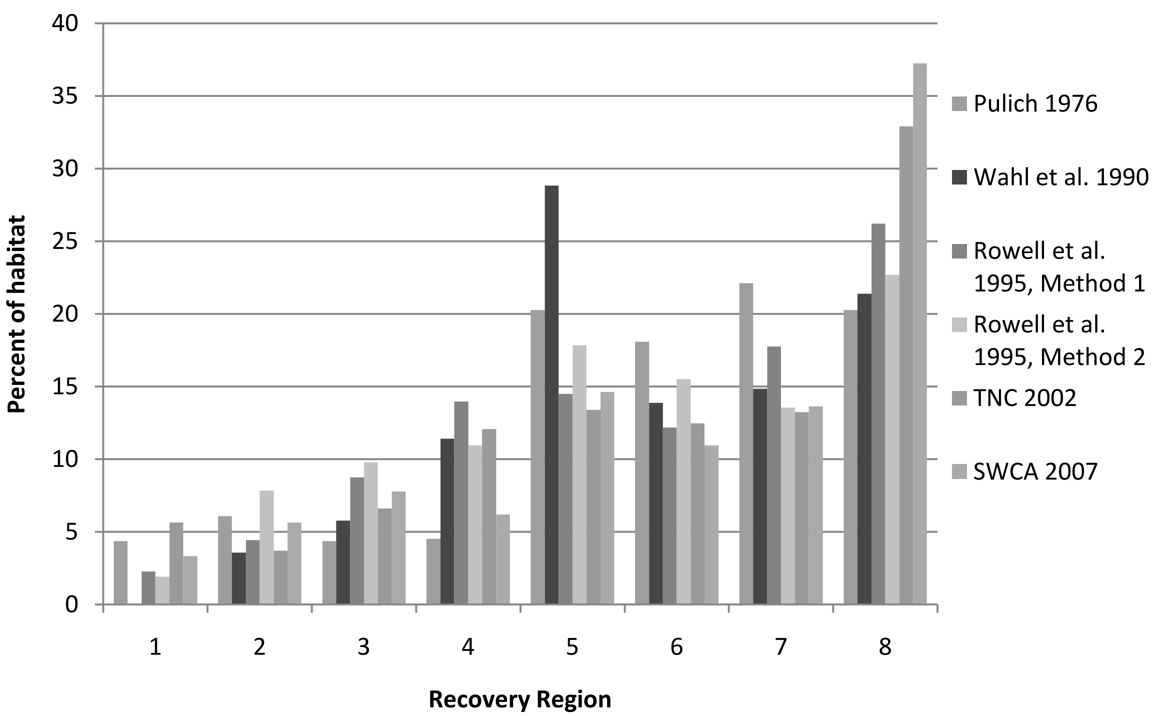

Figure 6.2. Percent of potential golden-cheeked warbler habitat by Recovery Region according to various studies. Total hectares of habitat vary by study.

6.2 Wintering Habitat Estimates

Efforts to map potential warbler habitat on the wintering grounds have not been as numerous as for the breeding grounds. The Central American pine-oak forest ecoregion generally delineates the extent of potential warbler habitat on the wintering grounds and includes both forested and non-forested areas. Estimates of the Central American pine-oak forest ecoregion, which includes southern Mexico, Guatemala, Honduras, El Salvador, and western Nicaragua, range from 10,384,271 ha (25,660,092 ac; Alliance for the Conservation of Mesoamerican Pine-Oak Forests [ACMPOF] 2008) to 11,114,600 ha (27,464,775 ac; Olson et al. 2001, World Wildlife Fund [WWF] 2004), of which an estimated 2,672,800 ha (6,604,633 ac) are still forested (ACMPOF 2008). Synthesizing numerous biogeographic maps and expert opinion, the WWF ecoregion map showed the majority of the pine-oak forest ecoregion occurring in Honduras (40%) and Guatemala (26%); Mexico contained 14% of the ecoregion while Nicaragua and El Salvador each contained 10% of the ecoregion (WWF 2004). Similarly, TNC created an ecoregion map specific to southern Mexico and Central America that estimated the Central American pine-oak forest ecoregion at 9,724,602 ha (24,030,014 ac), with a similar distribution of the ecoregion throughout the countries as WWF (V. Henríquez, personal communication). Although the ecoregion covers a substantial area, only a portion of it is considered potential warbler habitat. ACMPOF (2008) provided an estimate of 1,950,972 ha (4,820,957 ac) of potential winter habitat for the warbler within the ecoregion.

For a more precise estimate of golden-cheeked winter habitat, Rappole et al. (2000) focused their efforts on mapping potential habitat in the central and western highlands of Honduras, eastern highlands of Guatemala, and small portions of northwest El Salvador (the estimates excluded Mexico and Nicaragua). They conducted an unsupervised classification of 1994 and 1996 Landsat TM imagery (30-m resolution) and categorized land cover as forest (including broadleaf, pine-oak, pine, and early-successional forests and savanna), shrubland, and non-forest (including pasture, agriculture, developed, and bare). Because previous surveys had found warblers at higher (>1,000 m) elevations, Rappole et al. (2000) excluded all areas <914 m in elevation from estimates of potential habitat. Chi-square analysis indicated golden-cheeked warblers (n = 126) were most abundant in pine-oak forest while several warblers (<8%) were also detected in pine forest and early-successional forest (Rappole et al. 2000). Mapping of the land cover classes indicated 737,000 ha (1,821,167 ac) of pine-oak forest, 518,200 ha (1,280,500 ac) of pine forest, and 401,600 ha (992,375 ac) of early-successional forest in the study region. The accuracy of distinguishing pine-oak forest from other land cover types was approximately 84% based on data collected from 442 reference points (Rappole et al. 2000).

In a subsequent study, Rappole et al. (2003) estimated warbler winter habitat from Chiapas, Mexico, through Guatemala to southeastern Honduras and including a small portion of northern El Salvador (the estimates again excluded Nicaragua). They used 2 methods for estimating the extent of habitat: (1) 1994 and 1996 Landsat TM 5 imagery with 30-m resolution for parts of Guatemala and Honduras (39% of study area, described in Rappole et al. 2000), and (2) a U.S. Geological Survey (USGS) land cover database using Advanced Very High Resolution Radiometer data from 1992 and 1993 with 1-km resolution for the remaining 61% of the study area (Rappole et al. 2003). They defined winter habitat within this region as land cover classified as pine-oak forest above 1,219 m in elevation because the majority of warbler detections occurred above that elevation (Rappole et al. 2003). The Landsat data indicated 362,010 ha (894,546 ac) of potential habitat and the USGS data indicated 312,995 ha (773,427 ac), totaling 675,005 ha (1,667,974 ac) of pine-oak forest (Rappole et al. 2003). Including the USGS land cover class of evergreen needleleaf forest – where the largest number of warbler detections occurred outside of the pine-oak class – added 440,648 ha (1,088,865 ac) of potential habitat for a total of 1,115,653 ha (2,756,838 ac; Rappole et al. 2003).

6.3 Population Estimates

Few researchers have attempted to estimate the range-wide abundance of golden-cheeked warblers. From bioecological studies of warblers at 1 site each in Dallas, Bosque, and Kendall Counties, Pulich (1976) reported warbler densities of 34 ha/pair (85 ac/pair), 20 ha/pair (50 ac/pair), and 8 ha/pair (20 ac/pair) for "marginal", "average", and "excellent" habitat, respectively. He then multiplied the densities by the extent of habitat in each quality category (see section 6.1), resulting in an estimate of 15,630 birds in 1962 and 14,950 birds in 1974 (Pulich 1976). Multiplying Pulich's estimate of warbler density in average habitat by SCS estimates of available "Virgin juniper" habitat resulted in 36,972 birds in 1962 and 29,500 birds in 1974 (USFWS 1992). Similarly, Wahl et al. (1990) used a median warbler density of 6.7 ha/pair (16.5 ac/pair) from surveys conducted at 17 sites in the breeding range and their estimate of 32,149–106,776 ha (79,442–263,849 ac) of potential habitat (see section 6.1) to calculate a potential population size of 9,644–32,032 individuals. Wahl et al. (1990) predicted a maximum carrying capacity of 2,266–7,527 warbler pairs by the year 2000 based on estimated rates of habitat loss prior to the species' listing as endangered. To compare Wahl's estimate with Pulich's, USFWS (1992) applied several changes to Wahl's work: (1) they included in Wahl's habitat estimate all patches <50 ha (<124 ac), and (2) they used Pulich's estimates of warbler densities and proportions of "excellent", "average", and "marginal" habitat, resulting in a 1990 potential population of 27,600 individuals.

Rowell et al. (1995) initiated a project with the specific goal of updating golden-cheeked warbler breeding habitat and population size estimates for the breeding range. They began with the development of a map of potential warbler habitat derived from satellite imagery using 2 methods (see section 6.1). To estimate warbler population size, they used (1) habitat estimates from Method 2 minus all patches <50 ha (<124 ac) resulting in 215,066 ha (531,440 ac) of potential habitat, and (2) the median density of warbler pairs observed by Wahl et al. (1990; i.e., 6.7 ha/pair [16.5 ac/pair] or 0.30 individuals/ha [0.12 individuals/ac]). The choice of minimum patch size and median warbler densities were used to facilitate comparison with Wahl's findings (Rowell et al. 1995). The resulting estimate of potential carrying capacity was 64,520 individuals (Rowell et al. 1995). They qualified this value as "an indication of the maximum potential warbler population believed to be possible given our current knowledge [and] if all ecological requirements were actually met" (Rowell et al. 1995).

Using estimates of breeding and wintering habitat, Rappole et al. (2003) calculated warbler carrying capacities to assess possible habitat limitations for the species on either the breeding or wintering grounds. They included all habitat patches >5 ha (>12 ac) from 29 counties, resulting in 643,454 ha (1,590,009 ac) of potential warbler breeding habitat (see section 6.1; Rappole et al.

2003). They used density estimates of 0.355 ± 0.00101 adult birds/ha (mean ± 1 SE), derived from a population study at Fort Hood (Jetté et al. 1998); this value was used because it represented data from a long-term study "covering a significant portion of the bird's breeding range" and incorporated a large area with a wide range of habitat quality (Rappole et al. 2003). Results showed a potential carrying capacity of 228,426 individuals (95% CI: 227,142 – 229,710), suggesting the habitat could "potentially support at least this number if the population were not limited by other factors" (Rappole et al. 2003). For the wintering range (excluding Nicaragua), they estimated 675,005 ha (1,667,974 ac) of potential habitat above 1,219 m (see section 6.2). Average warbler densities for the range were estimated at 0.051 ± 0.072 individuals/ha (mean ± 1 SE) based on 47 warblers detected from 50 1-km transects (Rappole et al. 2003). They calculated a potential carrying capacity of 34,425 individuals (95% CI: 14,167–83,317). Including the land cover class of evergreen needleleaf forest, where the largest number of warbler detections occurred outside of the pine-oak class, added 440,648 ha (1,088,865 ac; see section 6.2) for an increase in winter carrying capacity to 56,674 individuals (Rappole et al. 2003). Population estimates from the breeding and wintering range suggested "the possibility of a wintering-ground habitat limitation hypothesis" for the species (Rappole et al. 2003).

SWCA estimated warbler population size based on their assessments of range-wide habitat and warbler densities (SWCA 2007). They estimated 552,195 ha (1,363,804 ac) of potential habitat (see section 6.1). They then used "high" warbler density estimates of 0.21 pair/ha (4.7 ha/pair [11.7 ac/pair]), citing research from Fort Hood, and "low" density estimates of 0.025 pair/ha (39.6 ha/pair [97.9 ac/pair]), citing research from Government Canyon State Natural Area in northern Bexar County (although the source they cited, USFWS 2004, actually noted half as many warbler territories as SWCA used in their analysis). The density estimates equated to a breeding range potential carrying capacity of 27,862–233,130 warblers (SWCA 2007). Modifications were made to the population estimates based on habitat categories of low, moderate, and high quality with 3 corresponding density estimates, a fragmentation index, a habitat isolation index, and personal opinion that ultimately resulted in a range-wide population estimate of 20,445 to 26,978 pairs of birds (40,890 to 53,965 individuals; SWCA 2007).

6.4 Estimated and Confirmed Individuals in Breeding Range

When the golden-cheeked warbler was listed as federally endangered, no known population size was provided for the species; rather, a range of possible population sizes was provided based on habitat and density estimates by Pulich (1976) and Wahl et al. (1990). It was estimated that 67% of the breeding warblers occurred in counties on the eastern Edwards Plateau, including Bexar, Comal, Hays, Travis, and Williamson (55 FR 53153).

For the present status assessment, we gathered a dataset of observations recorded from surveys conducted primarily during the 2004–2009 breeding seasons. We chose the cut-off of 2004 to focus on recently counted individuals that were potentially still alive at the time of this writing. Records were not cumulative across years; we used data from either the year of the most recent survey at a site or from the year of the most complete survey of the site. We consulted published and available unpublished records for the species, and sought additional recent data by corresponding with state wildlife biologists, consultants, and land managers throughout the breeding range. Data are expressed as counts of male or female warblers observed during the breeding season. For surveyors that reported warbler detections in terms of pairs or territories, we counted each pair or territory as a single individual if further details were unavailable.

Warbler detections depend strongly on survey effort, which was highly variable across sites and years, thus warbler counts cannot be directly compared across counties or regions. Because of inconsistent survey protocols over the years, we used direct count information where available. However, for 3 long-term study areas (Fort Hood Military Reservation, Camp Bullis Training Site, and Balcones Canyonlands National Wildlife Refuge [BCNWR]) where population estimates were available, we used the estimated population size for each property. Fort Hood estimates were derived from distance sampling surveys conducted throughout the property and calculated from a model that included covariates shown to be important in accounting for individuals present but not detected (R. Peak, personal communication). The population size for Camp Bullis was the product of warbler density estimates derived from transect surveys and 2,756 ha (6,810 ac) of estimated breeding habitat (Cooksey and Edwards 2008). The BCNWR population was estimated by extrapolating warbler densities (relative to good, moderate, and low quality habitat) across all suitable habitats within the BCNWR tracts; average warbler densities were calculated from the permanent and short-term study plots (C. Sexton, personal communication).

For surveys conducted between 2004 and 2009, the total number of individuals (male or female) was 8,759 across 33 counties (Appendix 6.A). Over half of this value was based on population estimates from Fort Hood, Camp Bullis, and BCNWR. The remaining number consists of individual warblers detected and counted during surveys on numerous public and private properties. The number of warblers detected during these surveys depended on survey effort (which was not consistent between projects or sites) and the surveys themselves occurred within a relatively small portion of the overall potential habitat in the breeding range. The habitat at Fort Hood, along with the remainder of Recovery Region 3, represents about 5–10% of the total range-wide potential habitat for the species (Table 6.1). While an estimated 4,482 males (51% of 8,759 individuals) occur on Fort Hood, it would be misleading to conclude that this is an accurate proportion of the overall population. Rather, the relative lack of warbler population estimates from other areas in the breeding range reflects the fact that both the species and the habitat have not been well studied outside of Fort Hood.

6.5 Summary of Habitat and Population Estimates

- Since 1990, potential breeding habitat for golden-cheeked warblers has been mapped and estimated using satellite imagery. Estimates range from approximately 215,066 to 1.77 million ha (531,440 to 4.37 million ac). Differences in estimates are primarily due to methods used for delineating potential habitat (e.g., the specificity or generality of the author's definition of potential habitat).
- Patterns of habitat distribution are relatively consistent across mapping projects regardless of delineation methods, with smaller, more isolated patches in the northern portion of the range and larger, more contiguous patches in the south.
- The Central American pine-oak forest ecoregion, where the majority of warblers have been detected during the winter, covers approximately 9.7–11.1 million ha (24.0–27.4 million ac) from southern Mexico into Nicaragua, with the majority occurring in Honduras and Guatemala. Less than 2.7 million ha (6.6 million ac) of the ecoregion are estimated to be forested. Within the ecoregion there is an estimated 1.95 million ha (4.8 million ac) of wintering habitat. Research that focused on a subset of wintering habitat (primarily Guatemala and Honduras) estimated 1.12–1.25 million ha (2.7–3.1 million ac) of pine-oak and pine forest (i.e., potential warbler habitat) in the study region. Additional research is needed to verify the estimated extent of available warbler habitat on the wintering grounds.
- All population estimates to date are based on the product of estimated warbler densities (often derived from a limited number of study sites) and estimated extent of potential habitat (derived from satellite imagery for all studies except Pulich [1976]). The earliest population estimate (1976) suggested 14,950 individuals, followed by an estimate of 9,644–32,032 individuals just prior to when the species was listed as federally endangered. Post-1990 estimates suggest 40,890–228,426 individuals could potentially occur on the breeding grounds. On the wintering grounds, the warbler carrying capacity was estimated at 34,425 to 56,674 individuals.
- The minimum number of warblers detected during recent surveys (2004–2009) or estimated to currently occur at long-term study sites includes 8,759 individuals. Over half of this value was based on population estimates from Fort Hood, Camp Bullis, and BCNWR. The remaining number consists of individual warblers detected and counted during surveys on numerous public and private properties covering a relatively small portion of the overall potential habitat in the breeding range.
- Given that the amount of potential habitat on and surrounding Fort Hood is approximately 5–10% of the total potential habitat across the breeding range, it is unlikely that Fort Hood harbors half the existing population of golden-cheeked warblers as suggested in our current list of known and estimated warbler numbers. Rather, the relative lack of warbler population estimates from other areas in the breeding range reflects the fact that both the species and the habitat have not been well studied outside of Fort Hood.

Appendix 6.A. Minimum number of golden-cheeked warblers detected or estimated on public and private properties, 2004–2009.

Property	**County**	**Population**	**Survey year**	**Source of information**[d,e]	**Minimum # detected**
Region 1					
Possum Kingdom SP	Palo Pinto	≥1 male	2009	Texas A&M 2009	1
Private property	Palo Pinto	5 males	2008	Texas A&M 2009	5
Private properties	Palo Pinto	≥31 makes, ≥1 female	2006, 2009	USFWS 2009	32
Region 2					
Meridian SP	Bosque	9 males	2008	Texas A&M 2009	9
Private properties	Bosque	21 males	2008, 2009	Texas A&M 2009	21
Whitney Lake	Bosque/Hill/John.	≥39 territories	2008	Edwards & Lewis 2008, 2009	39
Private property	Erath	2 males	2009	Texas A&M 2009	2
Private property	Erath/Somervell	8 males, 1 female	2009	USFWS 2009	9
Private property	Hood	1 male	2009	Texas A&M 2009	1
Cleburne SP	Johnson	2 males	2009	Texas A&M 2009	2
Dinosaur Valley SP	Somervell	6 males	2009	Texas A&M 2009	6
Private properties	Somervell	11 males, 3 females	2008, 2009	USFWS 2009	14
Private properties	Somervell	6 males	2008, 2009	Texas A&M 2009	6
Region 3					
Parrie Haynes Ranch	Bell	20 males	2009	Texas A&M 2009	20
Private property	Bell	≥2 males, 1 female	2008	USFWS 2009	3
Private properties	Bell	4 warblers	2008	Texas A&M 2009	4
Fort Hood MR	Bell/Coryell	min. estimate 4,482 males[a]	2009	R. Peak, pers. comm.	4,482
Mother Neff SP	Coryell	≥1 male	2009	Texas A&M 2009	1
Private property	Coryell	1 warbler	2009	B. Armstrong, pers. comm.	1
Private properties	Coryell/McLen.	103 territories	2006–2009	Texas A&M 2009	103
Private property	Hamilton	5 males	2009	Texas A&M 2009	5
Private property	Lampasas	1 male	2009	Texas A&M 2009	1
Region 4					
Pedernales River Nature Park	Blanco	2 males, 1 female	2009	LCRA 2009a	3
Pedernales Falls SP	Blanco	12 males	2009	Texas A&M 2009	12
Private property	Blanco	1 male	2008	Texas A&M 2009	1
Private property	Blanco	21 warblers	2009	B. Armstrong, pers. comm.	21
RM 783	Gillespie	≥2 warblers	2007	TXDOT 2007a	2
Private property	Gillespie	1 warbler	2009	B. Armstrong, pers. comm.	1

Appendix 6.A continued.

Region 4 continued					
Private property	Gillespie	1 warbler	2009	Texas A&M 2009	1
Private property	Llano	2 males	2008	Texas A&M 2009	2
Colorado Bend SP	San Saba	5 males	2008	Texas A&M 2009	5
Region 5					
Clearwater Ranch	Burnet	≥55 males, 11 females	2009	USFWS 2009	66
Canyon of the Eagles	Burnet	10 warblers	2009	LCRA 2009b	10
Double Horn	Burnet	3 males	2007	LCRA 2007a	3
Grelle RA	Burnet	2 warblers	2007	LCRA 2007b	2
Hickory Creek	Burnet	4 males, 2–3 females	2007	LCRA 2007c	6
Longhorn Cavern SP	Burnet	6 males	2009	Texas A&M 2009	6
Private property	Burnet	2 warblers	2009	B. Armstrong, pers. comm.	2
Private property	Burnet	2 males (2008)	2009	Texas A&M 2009	2
Private properties	Burnet	≥19 warblers	2007, 2008	USFWS 2009	19
Muleshoe Bend RA and TbarM	Burnet/Travis	3 warblers	2009	LCRA 2009c	3
Turkey Bend RA	Burnet/Travis	16 warblers	2008	LCRA 2008	16
Balcones Canyonlands NWR	Burn./Trav./Will.	estimated 710 territories[b]	1997–2008	C. Sexton, pers. comm.	710
Private property	Hays	31 warblers	2009	B. Armstrong, pers. comm.	31
Private property	Hays	11 warblers	2008, 2009	Texas A&M 2009	11
Private property	Hays	≥8 warblers	2008	USFWS 2009	8
Baker Sanctuary	Travis	18 males, 6 females	2009	Travis Audubon Soc. 2009	24
BCP - City of Austin properties	Travis	476 territories	2006–2009	L. O'Donnell, pers. comm.	476
BCP - Travis County properties	Travis	487 males, 58 females	2005–2009	Travis County 2006–2009	545
Barton Creek Habitat Preserve	Travis	82 males	2009	Texas A&M 2009	82
Bright Leaf	Travis	20 warblers	2009	J. Mahan, pers. comm.	20
Private property	Travis	≥11 warblers	2008	USFWS 2009	11
Gloster Bend	Travis	3 males, 1 female	2009	LCRA 2009d	4
McGregor Preserve	Travis	18 warblers	2009	LCRA 2009e	13
Westcave Preserve	Travis	6 males, 2 females	2009	LCRA 2009f	8
Wheless Preserve	Travis	93–105 territories	2006	LCRA 2006	93
Pace Bend Park	Travis	1 male	2008	USFWS 2009	1
RM 1431	Travis	2 pairs	2007	TXDOT 2007b	4
Private property	Travis	20 warblers	2009	B. Armstrong, pers. comm.	20
Private properties	Travis	4 warblers	2009	Texas A&M 2009	4
Private properties	Travis	≥27 warblers, ≥2 females	2007, 2008	USFWS 2009	29

Appendix 6.A continued.

Region 5 continued					
Cedar Breaks Park	Williamson	5 warblers	2007	USFWS 2009	5
Jim Hogg Park	Williamson	1 male	2007	USFWS 2009	1
Liberty Hill Wastewater Line	Williamson	≥2 warblers, 1 female	2006	USFWS 2009	3
Private property	Williamson	1 male	2009	Texas A&M 2009	1
Private properties	Williamson	≥33 males, ≥4 females	2006, ’07, ’09	USFWS 2009	37
Region 6					
Camp Bullis	Bexar	estimated 854 warblers[c]	2008	Cooksey & Edwards 2008	854
Crownridge Canyon NA	Bexar	4–5 males	2009	J. Neal, pers. comm.	4
Eisenhower Park	Bexar	1–3 males	2006, 2007	J. Neal, pers. comm.	1
Friederich Wilderness Park	Bexar	3 males	2005	J. Neal, pers. comm.	3
Government Canyon State Park	Bexar	≥7 males	2009	Texas A&M 2009	7
Indian Springs Cons. Area	Bexar	≥2 warblers	2007	USFWS 2009	2
Rancho Diana	Bexar	7–10 males, 1 female	2007	J. Neal, pers. comm.	8
Scenic Canyon	Bexar	3 males	2009	J. Neal, pers. comm.	3
Woodland Hills North & West	Bexar	9–11 male	2009	J. Neal, pers. comm.	9
Private property	Bexar	1 warbler	2009	B. Armstrong, pers. comm.	1
Private properties	Bexar	≥5 warblers	2007	USFWS 2009	5
Private properties	Bexar	3 warblers	2009	Texas A&M 2009	3
Bracken Bat Cave	Comal	9 territories	2008	BCI 2008	9
Honey Creek State Natural Area	Comal	≥4 males	2009	Texas A&M 2009	4
Private property	Comal	4 warblers	2009	B. Armstrong, pers. comm.	4
Private property	Comal	3 males	2008	Texas A&M 2009	3
Private properties	Comal	5 males	2007, 2008	USFWS 2009	5
Guadalupe River State Park	Kendall	≥3 males	2008	Texas A&M 2009	1
Old Tunnel WMA	Kendall	1 male	2009	Texas A&M 2009	3
Private property	Kendall	3 warblers	2009	B. Armstrong, pers. comm.	3
Private property	Kendall	1 male	2009	Texas A&M 2009	1
Private properties	Kendall	≥3 males	2008	USFWS 2009	3
Region 7					
Devils Sinkhole SNA	Edwards	1 male	2009	Texas A&M 2009	1
RM 674	Edwards	34 warblers	2009	Texas A&M 2009	34
Private properties	Edwards	19 warblers	2008, 2009	Texas A&M 2009	19
Private property	Edwards	48 males, 7 females	2009	USFWS 2009	55
Heart of the Hills FSC	Kerr	2 males	2009	Texas A&M 2009	2

Appendix 6.A continued.

Region 7 continued					
Kerr Wildlife Management Area	Kerr	92 males	2006	D. Prochaska, pers. comm.	92
Private property	Kerr	3 warblers	2009	B. Armstrong, pers. comm.	3
Private properties	Kerr	66 warblers	2008, 2009	Texas A&M 2009	66
Private property	Kerr	≥3 males, 1 female	2007	USFWS 2009	4
Walter Buck WMA	Kimble	4 warblers	2009	Texas A&M 2009	4
Private properties	Kimble	7 males	2008, 2009	Texas A&M 2009	7
Region 8					
Love Creek Preserve	Bandera	24 warblers	2008	Texas A&M 2009	24
Private property	Bandera	1 warbler	2009	B. Armstrong, pers. comm.	1
Private properties	Bandera	104 warblers	2008, 2009	Texas A&M 2009	104
Hill Country SNA	Bandera/Medina	≥2 males	2009	Texas A&M 2009	2
Lost Maples SP	Bandera/Real	18 males	2009	Texas A&M 2009	18
Private property	Edwards	48 males, 7 females	2009	USFWS 2009	55
Kickapoo Cavern SNA	Edwards/Kinney	≥25 males, ≥19 females	2009	Texas A&M 2009	44
Private property	Medina	1 male	2008	Texas A&M 2009	1
Private property	Real	4 warblers	2009	B. Armstrong, pers. comm.	4
Private properties	Real	136 warblers	2008, 2009	Texas A&M 2009	136
Private property	Real	≥4 males	2007	USFWS 2009	4
Garner SP	Uvalde	28 males	2009	Texas A&M 2009	28
Kaolin Hollow Site	Uvalde	1 male, 1 female	2005	USFWS 2009	2
Private properties	Uvalde	20 males	2008, 2009	Texas A&M 2009	20
Additional counties					
Dogwood Canyon	Dallas	1 warbler	2004	Audubon Texas 2004	1
Private property	Jack	1 warbler	2006	O. Bocanegra, pers. comm.	1
Total minimum number detected					**8,759**

[a] Estimate is based on a probability model that included covariates shown to be important in accounting for individuals present but not detected, resulting in an estimated 5,695 pairs and 95% CI: 4,482–7,236. We report the lower confidence interval estimate (i.e., minimum number of singing males) as a conservative estimate. The minimum number of individual warblers detected in 2009 was 747.

[b] Estimated is derived from extrapolating warbler densities (relative to good, moderate, and low quality habitat) across all suitable habitats within the BCNWR tracts; average warbler densities were calculated from the permanent and short-term study plots. The estimate does not take into account warbler numbers on intervening private properties within the BCNWR acquisition boundary.

[c] Estimate is based on 126 warbler observations (male and female); population estimate assumes 2,756 ha (6,810 ac) of habitat and all singing males, with a density of 0.155/ha, are paired.

[d] **Reports cited:**

Audubon Texas. 2004. Land acquisition of endangered and threatened wildlife habitat, specifically for golden-cheeked warbler near Cedar Hill State Park in Dallas County, Texas. Endangered Species Recovery Land Acquisition Grant Proposal submitted to U.S. Fish and Wildlife Service, Austin, Texas, USA.

Bat Conservation International [BCI]. 2008. 2007–2008 Annual report. <http://batcon.org/pdfs/annualreports/BCIAnnualReport08a.pdf>. Accessed 11 February 2010.

Cooksey, M. L., and S. M. Edwards. 2008. Monitoring the golden-cheeked warbler and the black-capped vireo on Camp Bullis, Texas, 2008 field season.

Edwards, S P., and J. M. Lewis. 2008. Surveys of U.S. Army Corps of Engineers lands at Whitney Lake for the endangered golden-cheeked warbler, 2008. Final Report submitted to U.S. Fish and Wildlife Serivce, Austin, Texas, USA.

Edwards, S P., and J. M. Lewis. 2009. Investigations of U.S. Army Corps of Engineers lands at Whitney Lake for the endangered golden-cheeked warbler and black-capped vireo 2009. Final Report submitted to U.S. Fish and Wildlife Serivce, Austin, Texas, USA.

Lower Colorado River Authority [LCRA]. 2006. 2006 Survey report, Wheless Preserve, Travis County.

______. 2007a. 2007 Survey report, Double Horn, Burnet County.

______. 2007b. 2007 Survey report, Grelle Recreation Area, Burnet County.

______. 2007c. 2007 Survey report, Hickory Creek (Camp Balcones Springs), Burnet County.

______. 2008. 2008 Survey report, Turkey Bend Recreational Areas, Burnet and Travis Counties.

______. 2009a. Surveys of LCRA lands at Pedernales River Nature Park for the endangered golden-cheeked warbler and black-capped vireo 2009. Final report.

______. 2009b. Surveys of LCRA lands at Canyon of the Eagles for the endangered golden-cheeked warbler and black-capped vireo 2009. Final report.

______. 2009c. Surveys of LCRA lands at Muleshoe and TbarM for the endangered golden-cheeked warbler 2009. Final report.

______. 2009d. Surveys of LCRA lands at Gloster Bend for the endangered golden-cheeked warbler 2009. Final report.

______. 2009e. Surveys of LCRA lands at McGregor Preserve for the endangered golden-cheeked warbler 2009. Final report.

______. 2009f. Surveys of LCRA lands at Westcave Preserve for the endangered golden-cheeked warbler 2009. Final report.

Texas A&M 2009: Data collected during state-wide surveys in 2008 and 2009 and on private properties surrounding Fort Hood between 2006 and 2009; data are unpublished at the time of this writing.

Texas Department of Transportation [TXDOT]. 2007a. 2007 Golden-cheeked warbler survey, RM 783, Gillespie County, Texas. Unpublished report.

______. 2007b. Survey of golden-cheeked warblers for RM 1431 at Warbler Vista BCNWR and Cedar Breaks effluent treatment facility. CSJ: 1376-01-026. Travis County, Texas.

Travis Audubon Society. 2009. Baker Sanctuary 2009 annual report. Prepared for the Balcones Canyonlands Preserve.

Travis County. 2006–2009. Monitoring of the golden-cheeked warbler (Dendroica chrysoparia) in western Travis County, Texas: 2005, 2006, 2007, 2008, and 2009 field seasons.

USFWS 2009: Data acquired from annual survey reports submitted to Austin Ecological Services Field Office, Southwest Region, U.S. Fish and Wildlife Service.

[e] **Personal communications:**

Armstrong, Beyrl, Plateau Land and Wildlife Management, Dripping Springs, Texas; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 8 February 2010.

Bocanegra, Omar, Austin Ecological Services Field Office, U.S. Fish and Wildlife Service, Austin, Texas; memo and email to Michael Morrison, Professor and Caesar Kleberg Chair, Wildlife and Fisheries Department, Texas A&M University, College Station, Texas. 3 February 2010.

Mahan, John, Director, Bright Leaf Natural Area; email to Dianne Dessecker, Research Assistant, Texas A&M Institute of Renewable Natural Resources, College Station, Texas. 6 October 2009.

Neal, Jayne, Park Naturalist, City of San Antonio Natural Areas; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 11 February 2010.

O'Donnell, Lisa, Senior Biologist, City of Austin Water Utility, Wildland Conservation Division, Balcones Canyonlands Preserve Program; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 19 February and 25 March 2010.

Peak, Rebecca, Applied Scientist, Environmental Division, Department of the Army, Fort Hood, Texas; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 28 January 2010.

Prochaska, Dale, Wildlife Biologist, Kerr Wildlife Management Area, Hunt, Texas; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 23 February 2010.

Sexton, Chuck, Wildlife Biologist, Balcones Canyonlands National Wildlife Refuge, Marble Falls, Texas; memo and email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 11 February 2010.

Chapter 7. Analysis of Threats

The U.S. Fish and Wildlife Service (USFWS) assesses threats to a species based on 5 factors: (A) present or threatened destruction, modification, or curtailment of habitat or range; (B) over-utilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) inadequacy of existing regulatory mechanisms; and (E) other natural or man-made factors affecting the species continued existence. In this chapter we discuss threats to the golden-cheeked warbler following the USFWS 5-factor analysis.

At the time of listing, threats to the golden-cheeked warbler included loss and degradation of habitat through juniper clearing, urban encroachment, reservoir development, and lack of vegetation succession on the breeding grounds and deforestation on the wintering grounds (55 FR 53154). USFWS used several metrics to illustrate increases in development and loss of habitat (55 FR 53154); we discuss each metric below and include updated data where possible. In addition, we assess several threats using indirectly related data sets due to the lack of directly measured data. We display and summarize data at the level of the county and Recovery Region (USFWS 1992, USFWS 2004) for the breeding range and at the level of the country for the wintering range. Some data, however, could only be summarized generally by ecoregion or Texas state-wide.

USFWS (1992) delineated 8 Recovery Regions in the Golden-cheeked Warbler Recovery Plan based on geology, vegetation, and watershed boundaries. However, most data pertaining to direct or indirect threats were available to us only at the level of a Texas county, and Recovery Region boundaries often bisect the same county. Thus, in order to summarize data at the level of a Recovery Region, we shifted the USFWS Recovery Region boundaries to match nearby county boundaries (Figure 7.1). We examined threats by Recovery Region to determine if the occurrence or severity of threats varies throughout the breeding range.

7.1 Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Given the complexities involved in quantifying golden-cheeked warbler habitat and the lack of field-tested maps or models of habitat on a range-wide scale (see Chapter 6), we chose to examine a suite of metrics that may indicate changes in the extent of potential warbler habitat (i.e., woodlands), fragmentation of habitat, or that illustrate changes in human population growth and development as indirect influences on warbler habitat. Metrics included remotely-sensed land cover change, trends in land use and private property size, human population growth, development of highways, buildings, and transmission corridors, reservoir construction, along with some qualitative discussion of threats on the wintering grounds.

7.1.1 Breeding Range

The best information available at the time of listing suggested 67% of the breeding warblers inhabited counties with high rates of urbanization in the eastern Edward’s Plateau, such as Bexar,

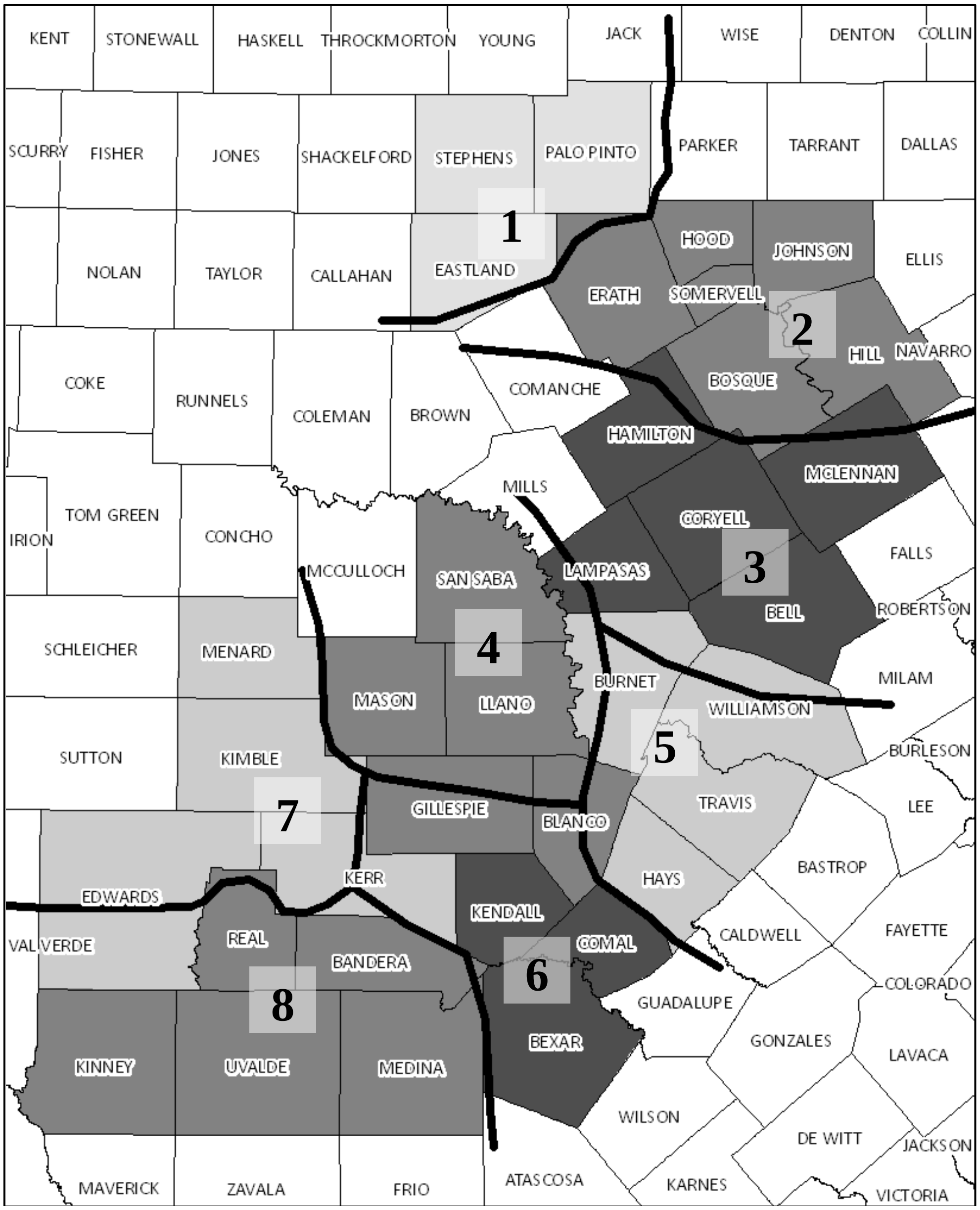

Figure 7.1. Thick outlines represent USFWS Recovery Regions (USFWS 1992) for the golden-cheeked warbler. Recovery Regions discussed in this chapter are categorized as indicated by shading to facilitate summary of county-level data.

Comal, Hays, Travis, and Williamson (55 FR 53154). Additionally, it was estimated that "Travis County has about 40 percent more golden-cheeked warbler habitat than any other county…" (55 FR 53154). Recent mapping of habitat and on-ground occupancy surveys throughout the breeding range suggest the possibility of a larger portion of warblers inhabiting areas outside the aforementioned counties than originally thought (see Chapters 2 and 6).

1992-2001 Land Cover Change

The Multi-Resolution Land Characteristics Consortium developed the National Land Cover

Dataset 1992 (NLCD 1992) and the National Land Cover Database 2001 (NLCD 2001) which classified land cover types across the United States (e.g., open water, deciduous woodland, row crops; Homer et al. 2007). The land cover datasets for both years were based on Landsat thematic mapper imagery with 30-m resolution (Homer et al. 2007). Differences in classification methods, base imagery selection, and legend definitions between the 2 products inhibit direct comparison of land cover change (Fry et al. 2009). The NLCD 1992–2001 Land Cover Change Retrofit (NLCD-LCCR) product was thus developed to allow for more accurate evaluation of real land cover changes by attempting to identify, on a pixel-by-pixel basis, areas that had actually changed rather than simply overlaying classification results from different years (Fry et al. 2009). The NLCD-LCCR data includes a from-to output that categorizes changes in cover type from the 1992 classification to the 2001 classification for each pixel at a 30-m thematic resolution (Anderson Level 1; Fry et al. 2009). We used this retrofit product to estimate changes in land cover between 1992 and 2001 by summarizing the from-to output. We combined the 3 NLCD woodland cover types (deciduous woodland, evergreen woodland, and mixed woodland) into a single Woodland category; warbler habitat is generally a subset of these NLCD woodland cover types. We then summed the values for each of the following from-to categories:

- Woodland to Urban – areas classified as woodland in 1992 and changed to urban cover type by 2001 (i.e., Woodland to Urban in the NLCD-LCCR output).
- Woodland to Other – areas classified as woodland in 1992 and changed to agriculture, grassland, or shrubland by 2001 (i.e., Woodland to Agriculture, Woodland to Barren, Woodland to Grassland/Shrub, and Woodland to Wetlands in the NLCD-LCCR output).
- Other to Woodland – areas classified as agriculture, grassland, or shrubland in 1992 that had changed to 1 of the 3 woodland cover types by 2001 (i.e., Agriculture to Woodland, Barren to Woodland, Grassland/Shrub to Woodland, and Wetlands to Woodland).

For counties on the eastern and southern edge of the warbler's breeding range, we summarized data from only those sections of counties that lie within the Edward's Plateau and the Cross Timbers and Prairies ecoregions.

An estimated 22,051 ha (54,489 ac) of land in the breeding range of the golden-cheeked warbler was reclassified as woodland between NLCD 1992 and NLCD 2001, indicating a conversion of agriculture, grassland, or shrubland to woodland during that time period (i.e., Other to Woodland; Table 7.1). This increase was offset, however, by the overall conversion of approximately 124,271 ha (307,080 ac) of woodland to agriculture, grassland, and shrubland and 14,201 ha (35,091 ac) of woodland to urban development (Table 7.1). Thus, there was a net loss of approximately 116,421 ha (287,683 ac) of woodland, averaging to a loss of 12,936 ha (31,965 ac) per year. Results indicated a net conversion from woodland to other land cover types from 1992 to 2001 for all Recovery Regions. The highest net conversion from woodland occurred in Recovery Region 4 (10.0%), followed by Recovery Regions 6 and 5 (9.4% and 9.3%, respectively). The lowest net conversion from woodland to other cover types occurred in Regions 1, 8, and 2 with 0.6%, 2.6%, and 2.8%, respectively (Table 7.1). Although these values do not indicate loss of habitat specific to the golden-cheeked warbler, it does show a general trend in land use. Also note, the apparent increase in woodland cover is over a 9-year period, suggesting relatively young woodland stands may have developed in the interim and would not be suitable breeding habitat (Baccus et al. 2007).

Table 7.1. Estimated change (hectares) in land cover type by county and Recovery Region between 1992 and 2001 based on the NLCD 1992-2001 Land Cover Change Retrofit product (NLCD-LCCR; Fry et al. 2009). USFWS Recovery Region boundaries are shifted slightly to encompass entire counties.

County	Total NLCD 1992 Woodland	1992 to 2001 Woodland to: Urban	1992 to 2001 Woodland to: Other	1992 to 2001 Other to: Woodland	Total NLCD 2001 Woodland	1992-2001 % change[a]
Recovery Region 1						
Eastland	44,657	57	1,595	1,246	44,252	-0.91
Palo Pinto	95,789	87	3,153	2,190	94,739	-1.10
Stephens	44,065	18	1,001	1,335	44,381	0.72
Region 1 total	184,512	163	5,749	4,772	183,372	-0.62
Recovery Region 2						
Bosque	74,481	23	3,170	329	71,616	-3.85
Erath	65,160	15	1,595	555	64,104	-1.62
Hill[b]	10,369	10	352	12	10,019	-3.38
Hood	24,936	100	705	69	24,200	-2.95
Johnson[b]	12,306	49	683	86	11,660	-5.25
Somervell	20,343	7	335	107	20,108	-1.15
Region 2 total	207,594	205	6,840	1,158	201,707	-2.84
Recovery Region 3						
Bell[b]	47,976	91	2,555	340	45,670	-4.81
Coryell	69,134	36	3,594	91	65,594	-5.12
Hamilton	38,750	7	1,343	147	37,546	-3.11
Lampasas	43,410	11	1,324	43	42,117	-2.98
Mclennan[b]	16,090	61	1,705	31	14,355	-10.78
Region 3 total	215,359	206	10,522	651	205,283	-4.68
Recovery Region 4						
Blanco	69,672	189	7,636	1,371	63,217	-9.26
Gillespie	75,118	74	6,745	240	68,539	-8.76
Llano	75,480	123	8,647	79	66,789	-11.51
Mason	49,796	17	3,315	34	46,498	-6.62
San Saba	80,511	70	10,252	143	70,331	-12.64
Region 4 total	350,577	474	36,595	1,867	315,374	-10.04
Recovery Region 5						
Burnet	108,330	449	9,511	4,635	103,005	-4.92
Hays[b]	82,456	613	9,538	909	73,214	-11.21
Travis[b]	77,719	4,526	4,778	1,020	69,435	-10.66
Williamson[b]	51,184	2,662	6,023	1,886	44,385	-13.28
Region 5 total	319,689	8,250	29,850	8,450	290,039	-9.27
Recovery Region 6						
Bexar[b]	53,723	3,316	4,185	843	47,065	-12.39
Comal[b]	79,839	1,217	8,286	806	71,142	-10.89
Kendall	66,576	117	4,510	1,198	63,147	-5.15
Region 6 total	200,138	4,650	16,981	2,847	181,354	-9.39
Recovery Region 7						
Edwards[b]	68,612	7	1,661	344	67,287	-1.93
Kerr	103,679	94	3,627	251	100,210	-3.35
Kimble	61,833	28	2,480	48	59,373	-3.98
Menard	6,347	7	361	32	6,011	-5.30
Region 7 total	240,471	136	8,129	675	232,880	-3.16

Table 7.1 continued.

County	Total NLCD 1992 Woodland	1992 to 2001 Woodland to: Urban	Woodland to: Other	Other to: Woodland	Total NLCD 2001 Woodland	1992-2001 % change[a]
Recovery Region 8						
Bandera	100,187	100	3,626	974	97,435	-2.75
Kinney[b]	14,986	0	1,292	7	13,701	-8.57
Medina[b]	57,601	10	1,130	358	56,819	-1.36
Real	83,515	2	568	194	83,139	-0.45
Uvalde[b]	61,085	6	2,988	98	58,189	-4.74
Region 8 total	317,374	117	9,604	1,630	309,283	-2.55
Total (ha)	2,035,714	14,201	124,271	22,051	1,919,293	-5.72
Total (ac)	5,030,359	35,091	307,080	54,489	4,742,676	-5.72

[a] Percent change measures the percentage change (positive or negative) in hectares of land from 1992 to 2001. It is calculated by subtracting the hectares of NLCD 1992 Woodland from the hectares of NLCD 2001 Woodland, dividing that value by the 1992 value, then multiplying by 100.
[b] Hectare estimates are for the portion of county within Edwards Plateau and Cross Timbers ecoregion boundaries (as delineated by Griffith et al. 2004).

1997-2007 Land Trends

Wilkins et al. (2009a) developed a tool for viewing changes in land use and ownership size between 1997 and 2007 for the state of Texas. Land use estimates were acquired from the Texas Comptroller of Public Accounts using county appraisal district data for 1997, 2002, and 2007. These data provided values for acreage designated on the tax rolls as the following land uses: Irrigated Cropland, Dry Cropland, Non-Native Pasture, Native Rangeland, Wildlife Management, and Forest. The designations are based upon what the current use of the land is and not the type of land cover found on the land. This is important when considering the forest designation which signifies a land use compatible with timber production. It should not be considered as a designation of forest land cover type and is not a direct measurement of potential warbler habitat.

For the purposes of this summary, we combined the land area values among the six land use designations to simplify the data to rural working lands (farms and ranches) versus other. For counties on the eastern and southern edge of the warbler's breeding range, we summarized data from only those portions of counties that lie within the Edward's Plateau and the Cross Timbers and Prairies ecoregions to maintain relevancy within the warbler's distribution. McLennan, Kinney, and Edwards Counties, however, include county-level data because we were unable to categorize the data by ecoregion in those counties. For the period of 1997 to 2007, the overall conversion of private farms and ranches to other uses (e.g., urban development) included approximately 103,171 ha (254,520 ac; Table 7.2). The majority of the loss occurred in Recovery Regions 5 and 6, with 9.7% and 11.5% loss, respectively, over the 10-year period. Recovery Regions 1, 7, and 8 saw small gains in these land use types of approximately 2,264–4,938 ha (5,594–12,202 ac) per Region (Table 7.2).

A decrease in land area indicates a conversion of these rural working lands to other uses between 1997 and 2007. A portion of the conversion was related to human population growth and development (Wilkins et al. 2009a). Changes in land use over the 10-year period do not necessarily represent similar changes in warbler habitat; i.e., an overall loss of these lands does not indicate a proportional loss in potential warbler habitat. Rather, it is indicative of the pressures placed upon rural working lands by human growth and provides one method of indirectly measuring the possible impact it may have on potential warbler habitat.

Another indicator of the pressures placed on potential warbler habitat is ownership size trends. Trends in ownership size between 1997 and 2007 represent consolidation or fragmentation of farming and ranching operations (Wilkins et al. 2009a). Studies have shown that as ownership density increases there is a corresponding increase in fragmentation of the landscape, i.e., there are more habitat patches per unit area (Wilkins et al. 2003, Kjelland et al. 2007). Since landscape fragmentation was listed as one of the original threats, trends indicating an increase in ownership density are indirect measures of this threat. Data for 1997, 2002, and 2007 were collected from the Census of Agriculture 2007 data (from U.S. Department of Agriculture's National Agriculture Statistics Service) and classified into 5 size categories: <40 ha (<100 ac), 40–202 ha (100–500 ac), 202–404 ha (500–1000 ac), 404–809 ha (1000–2000 ac), and ≥810 ha (≥2000 ac) (Wilkins et al. 2009a). For the purposes of this report, we summarized the total hectares within each size category to illustrate general trends in the size of farming and ranching operations within the warbler's breeding range (Appendix 7.A). Conversion from larger to smaller property units often results in an increase in the number of landowners in the same area, with corresponding shifts and variability in land management strategies and attitudes (Sanders 2005).

The land encompassed by farming and ranching operations <40 ha (<100 ac) in size increased 60,188 ha (148,728 ac; 22%) between 1997 and 2007 across the breeding range (Appendix 7.A). The greatest increase occurred in Region 7 (68.9%), followed by Region 8 (40.9%) and Region 4 (39.7%; Fig. 7.3). Across all Regions, there was a decrease in the number of hectares encompassed by all size categories >40 ha, although this did not hold true when viewed at the level of individual Recovery Regions (Figs. 7.2 and 7.3). Large ownerships (i.e., ≥810 ha [2,000 ac]) lost 231,035 ha (570,900 ac) through fragmentation into smaller ownerships (Appendix 7.A) with the greatest loss occurring in Regions 5 and 7.

Human population growth

We summarized human population estimates for each decade between 1970 and 2030 (Table 7.3) and calculated rates of increase over time (Table 7.4). Estimates are based on county-level data and are not restricted to only the sections of counties that lie within the golden-cheeked warbler breeding range. Overall number of people and density estimates (people per 100 ha [247 ac]) have been and remain the highest in Recovery Regions 5 and 6 (Figs. 7.4 and 7.5). Between 1990 and 2010, the human population throughout the golden-cheeked warbler breeding range has increased by 49.8%, higher than the overall rate of 43.6% increase for the entire state (Table 7.4). Within the breeding range, the highest rate of growth occurred in Recovery Region 5 (86.3%), followed by Recovery Regions 8 (55.9%) and 2 (50.3%). Overall population numbers and density estimates for Regions 1, 4, 7, and 8 remained relatively low (Figs. 7.4 and 7.5). Populations in all Recovery Regions are expected to increase further in the next 20 years (i.e., 2010 through 2030), although at slower rates than the past 20 years (Table 7.4). Regions 2 and 5 are predicted to maintain the highest rates of growth between 2010 and 2030 (Table 7.4).

Table 7.2. Total hectares of land by year (1997, 2002, and 2007) and Recovery Region classified as rural working lands (i.e., Irrigated Cropland, Dry Cropland, Non-Native Pasture, Native Rangeland, Wildlife Management, and Forest [Wilkins et al. 2009a]).

County	1997	2002	2007	Total change[a]	% change[b]
Region 1					
Eastland	220,069	221,193	221,781	1,713	0.78
Palo Pinto	232,270	233,000	229,774	-2,496	-1.07
Stephens	196,501	197,150	196,532	31	0.02
Young	267,705	272,880	273,395	5,690	2.13
Region 1 total	916,544	924,223	921,482	4,938	0.54
Region 2					
Bosque	259,167	257,784	261,032	1,865	0.72
Erath	238,856	238,078	236,820	-2,036	-0.85
Hill[c]	9,925	9,958	9,881	-44	-0.44
Hood	101,906	98,750	98,749	-3,158	-3.10
Johnson[c]	92,127	92,257	91,947	-180	-0.20
Somervell	38,100	35,758	37,837	-263	-0.69
Region 2 total	740,082	732,586	736,266	-3,816	-0.52
Region 3					
Bell[c]	70,090	65,967	61,621	-8,469	-12.08
Coryell	228,890	230,346	223,780	-5,110	-2.23
Hamilton	177,591	179,124	177,478	-113	-0.06
Lampasas	203,283	205,364	203,436	153	0.08
McLennan	255,225	250,518	256,577	1,352	0.53
Region 3 total	935,078	931,320	922,892	-12,185	-1.30
Region 4					
Blanco	219,182	211,328	207,528	-11,654	-5.32
Gillespie	312,285	312,549	310,693	-1,592	-0.51
Llano	220,050	217,828	217,090	-2,960	-1.35
Mason	245,161	246,799	247,016	1,855	0.76
San Saba	277,832	278,677	279,475	1,643	0.59
Region 4 total	1,274,510	1,267,180	1,261,802	-12,708	-1.00
Region 5					
Burnet	216,182	214,151	210,819	-5,364	-2.48
Hays[c]	140,808	134,829	125,476	-15,332	-10.89
Travis[c]	28,325	25,156	21,452	-6,873	-24.27
Williamson[c]	139,161	128,625	115,964	-23,197	-16.67
Region 5 total	524,476	502,760	473,711	-50,765	-9.68
Region 6					
Bexar[c]	41,636	35,439	22,272	-19,364	-46.51
Comal[c]	112,993	109,066	102,176	-10,818	-9.57
Kendall	146,864	144,990	142,383	-4,482	-3.05
Region 6 total	301,494	289,494	266,831	-34,664	-11.50
Region 7					
Edwards	614,378	616,093	616,473	2,094	0.34
Kerr	201,149	202,654	202,947	1,798	0.89
Kimble	277,336	276,756	275,592	-1,744	-0.63
Menard	218,412	217,911	218,528	115	0.05
Region 7 total	1,311,275	1,313,414	1,313,539	2,264	0.17

Table 7.2 continued

County	1997	2002	2007	Total change[a]	% change[b]
Region 8					
Bandera	128,463	132,264	131,814	3,352	2.61
Kinney	345,476	342,229	343,618	-1,858	-0.54
Medina[c]	63,254	64,835	62,623	-631	-1.00
Real	98,451	97,769	99,184	732	0.74
Uvalde[c]	83,192	84,439	85,362	2,170	2.61
Region 8 total	718,836	721,537	722,601	3,766	0.52
Total (ha)	6,722,295	6,682,514	6,619,124	-103,171	-1.53
Total (ac)	16,611,153	16,512,852	16,356,212	254,941	-1.53

[a] Total change measures the numerical change (positive or negative) in hectares of land from 1997 to 2007.

[b] Percent change measures the percentage change (positive or negative) in hectares of land from 1997 to 2007. It is calculated by subtracting the hectares of land in 1997 from the hectares of land in 2007, dividing that value by the 1997 value, then multiplying by 100.

[c] Hectare estimates are for the portion of county within Edwards Plateau and Cross Timbers ecoregion boundaries.

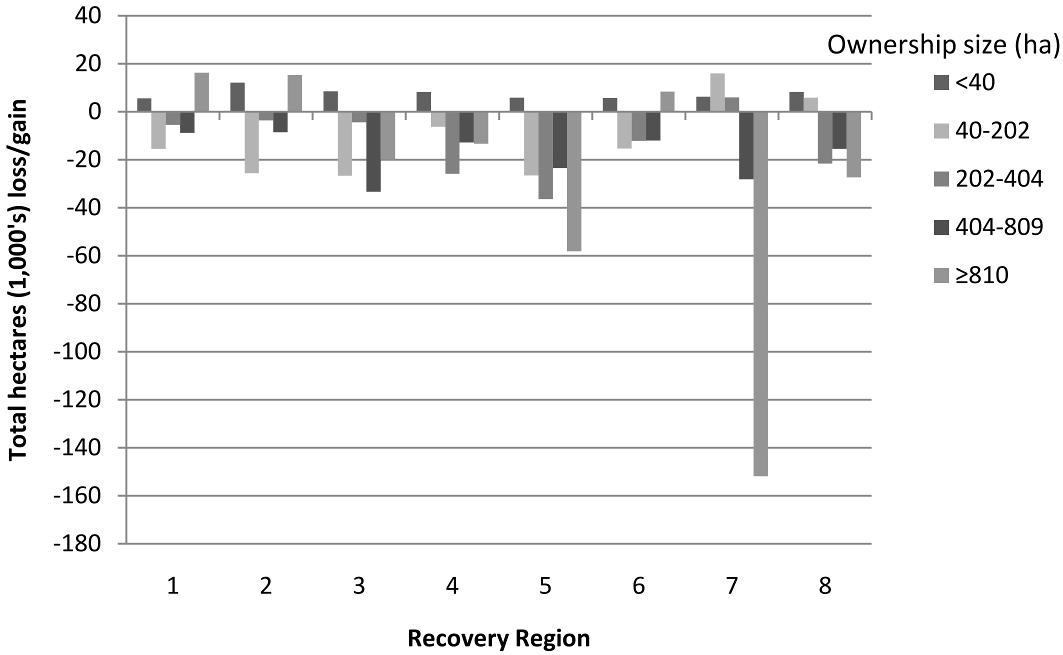

Figure 7.2. Total hectares of land removed from or added to ownership size categories between 1997 and 2007 by Recovery Region. Positive and negative values indicate an increase and decrease, respectively, in the overall hectares encompassed by the ownership size.

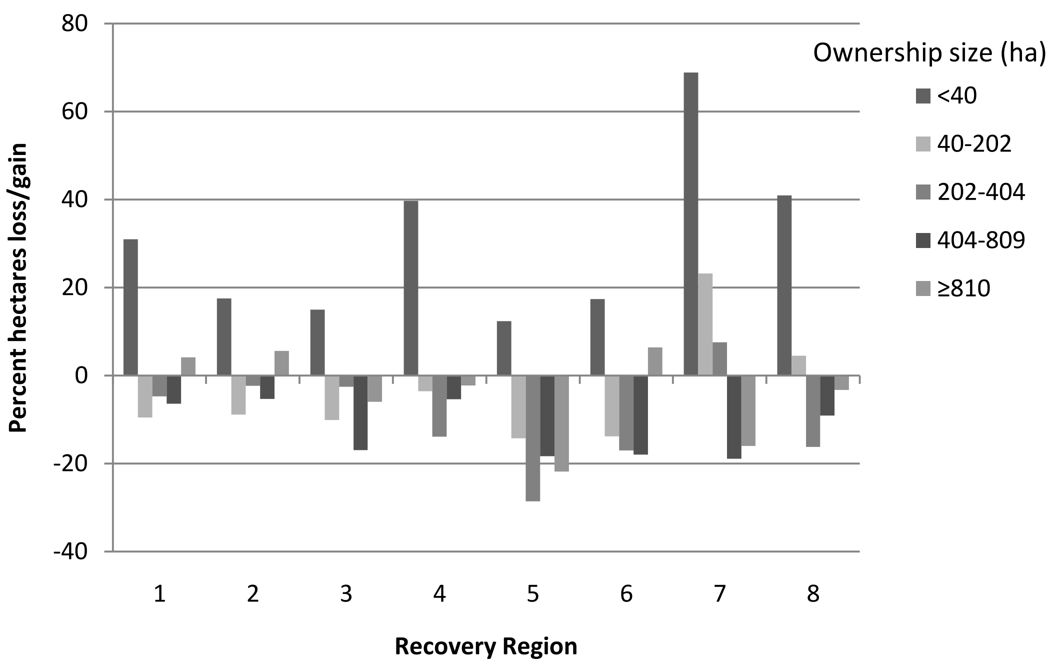

Figure 7.3. Percent of land (hectares) removed from or added to ownership size categories between 1997 and 2007 by Recovery Region. Positive and negative values indicate an increase and decrease, respectively, in the overall percent of land encompassed by the ownership size.

Table 7.3. Estimates of human population by county and Recovery Region, 1970–2030. Data are from the U.S. Census Bureau on a county-level basis.

County	1970	1980	1990	2000	2010	2020	2030
Region 1							
Eastland	18,092	19,480	18,488	18,297	18,726	19,091	19,063
Palo Pinto	28,962	24,062	25,055	27,026	29,392	32,015	33,989
Stephens	8,414	9,926	9,010	9,674	10,048	10,342	10,480
Young	15,400	19,083	18,126	17,943	18,473	19,183	19,394
Region 1 total	70,868	72,551	70,679	72,940	76,639	80,631	82,926
Region 2							
Bosque	10,966	13,401	15,125	17,204	18,624	20,435	21,720
Erath	18,141	22,560	27,991	33,001	37,315	41,591	45,261
Hill	22,596	25,024	27,146	32,321	36,441	40,633	44,250
Hood	6,368	17,714	28,981	41,100	49,468	59,034	67,846
Johnson	45,769	67,649	97,165	126,811	153,784	185,700	218,106
Somervell	2,793	4,154	5,360	6,809	7,657	8,677	9,565
Region 2 total	106,633	150,502	201,768	257,246	303,289	356,070	406,748
Region 3							
Bell	124,483	157,889	191,088	237,974	283,355	322,400	359,427
Coryell	35,311	56,767	64,213	74,978	90,921	107,938	124,057
Hamilton	7,198	8,297	7,733	8,229	8,511	9,005	9,294
Lampasas	9,323	12,005	13,521	17,762	20,447	23,357	25,478
McLennan	147,553	170,755	189,123	213,517	233,887	252,988	267,315
Region 3 total	323,868	405,713	465,678	552,460	637,121	715,688	785,571
Region 4							
Blanco	3,567	4,681	5,972	8,418	10,118	12,144	14,148
Gillespie	10,553	13,532	17,204	20,814	21,919	23,396	24,087
Llano	6,979	10,144	11,631	17,044	16,496	16,040	15,530
Mason	3,356	3,683	3,423	3,738	3,724	3,644	3,516
San Saba	5,540	6,204	5,401	6,186	6,492	6,915	7,281
Region 4 total	29,995	38,244	43,631	56,200	58,749	62,139	64,562
Region 5							
Burnet	11,420	17,803	22,677	34,147	42,716	52,645	62,721
Hays	27,642	40,594	65,614	97,589	137,341	181,905	227,610
Travis	295,516	419,573	576,407	812,280	972,165	1,111,968	1,234,774
Williamson	37,305	76,521	139,551	249,967	345,791	460,892	599,614
Region 5 total	371,883	554,491	804,249	1,193,983	1,498,013	1,807,410	2,124,719
Region 6							
Bexar	830,460	988,800	1,185,394	1,392,931	1,555,963	1,677,983	1,745,220
Comal	24,165	36,446	51,832	78,021	99,142	123,913	149,408
Kendall	6,964	10,635	14,589	23,743	29,627	36,353	42,700
Region 6 total	861,589	1,035,881	1,251,815	1,494,695	1,684,732	1,838,249	1,937,328
Region 7							
Edwards	2,107	2,033	2,266	2,162	2,358	2,452	2,347
Kerr	19,454	28,780	36,304	43,653	45,920	48,339	49,393
Kimble	3,904	4,063	4,122	4,468	4,501	4,509	4,331
Menard	2,646	2,346	2,252	2,360	2,433	2,474	2,287
Region 7 total	28,111	37,222	44,944	52,643	55,212	57,774	58,358

Table 7.3 continued

County	1970	1980	1990	2000	2010	2020	2030
Region 8							
Bandera	4,747	7,084	10,562	17,645	21,743	26,274	30,452
Kinney	2,006	2,279	3,119	3,379	3,450	3,459	3,427
Medina	20,249	23,164	27,312	39,304	47,018	55,062	62,108
Real	2,013	2,469	2,412	3,047	3,122	3,211	3,144
Uvalde	17,348	22,441	23,340	25,926	28,686	31,019	32,387
Region 8 total	46,363	57,437	66,745	89,301	104,019	119,025	131,518
Breeding range total	1,839,310	2,352,041	2,949,509	3,769,468	4,417,774	5,036,986	5,591,730

Table 7.4. Rates of human population increase by Recovery Region from 1990 to 2010, 2010 to 2030, and 1990 to 2030. Data are from the U.S. Census Bureau on a county-level basis.

Recovery Region	1990-2010 change[a]	% change[b]	2010-2030 change[a]	% change[b]	1990-2030 change[a]	% change[b]
Region 1	5,960	8.43	6,287	8.20	12,247	17.33
Region 2	101,521	50.32	103,459	34.11	204,980	101.59
Region 3	171,443	36.82	148,450	23.30	319,893	68.69
Region 4	15,118	34.65	5,813	9.89	20,931	47.97
Region 5	693,764	86.26	626,706	41.84	1,320,470	164.19
Region 6	432,917	34.58	252,596	14.99	685,513	54.76
Region 7	10,268	22.85	3,146	5.70	13,414	29.85
Region 8	37,274	55.85	27,499	26.44	64,773	97.05
Breeding range	1,468,265	49.78	1,168,552	26.45	2,636,817	89.40
State of Texas	7,408,669	43.62	6,801,835	27.88	14,210,504	83.66

[a] Year-to-year change measures the numerical change (positive or negative) in human population from the earliest to latest year.

[b] Percent change measures the percentage change (positive or negative) in human population between the 2 noted years. It is calculated by subtracting the earlier year (e.g., 1990) value from the later year (e.g., 2010) value, dividing the result by the earlier year (e.g., 1990) value, and then multiplying by 100.

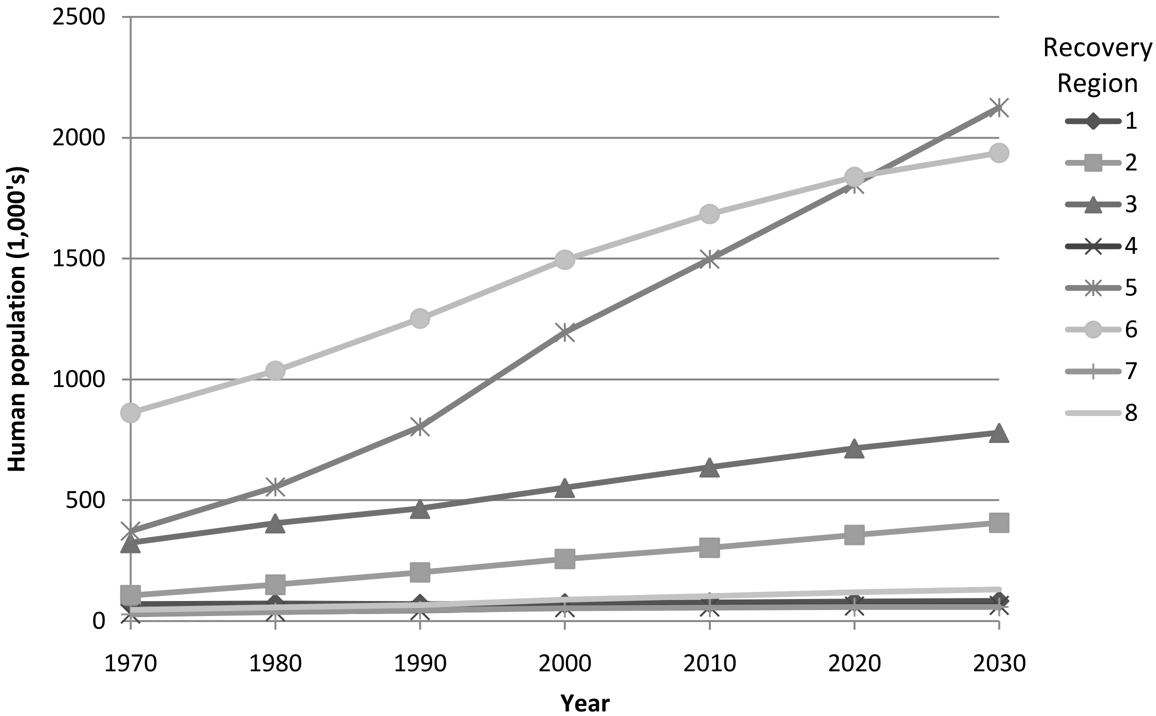

Figure 7.4. Human population estimates by Recovery Region for each decade, 1970–2030. Data are from the U.S. Census Bureau.

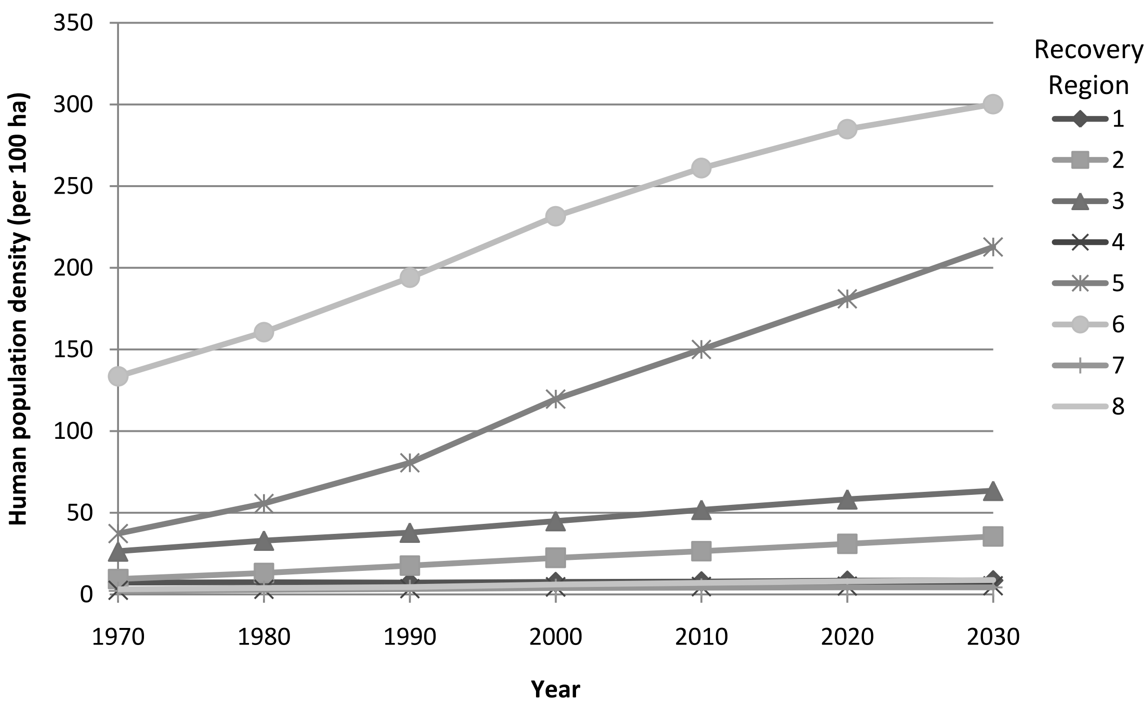

Figure 7.5. Human population density estimates by Recovery Region for each decade, 1970–2030. Data are from the U.S. Census Bureau.

Development

Highways

In the Federal listing of golden-cheeked warblers, the projected number of lane miles (i.e., the product of the centerline miles and the number of lanes) was noted as metric of human development and, thus, an indication of potential future loss or fragmentation of habitat. We collected and summarized data on miles of highway lanes from the Texas Department of Transportation to update the original estimates and determine if the threat persists in any of the Recovery Regions (Table 7.5). Our estimates include lane miles for farm-to-market roads, county roads, pass, park and recreation roads, city streets, frontage roads, and state, U.S., and Interstate Highways. Lane miles are centerline miles multiplied by the number of lanes over the same distance. We chose to summarize lane miles instead of centerline miles to better illustrate the amount of area affected by roads. Data were available at the county level and do not pertain specifically to the sections of counties that lie within the golden-cheeked warbler breeding range (i.e., Edwards Plateau or Cross Timbers ecoregions). Negative values seen in Table 7.5 do not represent loss of roads, but rather a recalculation (more accurate estimate) of road inventory over time and variances among reporting agencies (M. Chamberlain, personal communication).

Highway lane miles increased by approximately 5,500 miles (5.9%) in the 8 Recovery Regions between 1991 and 2008 (Table 7.5). The greatest rate of increase occurred in Recovery Region 5 (20.1%) followed by Region 8 (12.1%) and Region 7 (10.1%), with the highest increase in road density occurring in Region 5 (Fig. 7.6). Overall road density is highest in Region 6 followed by Region 5.

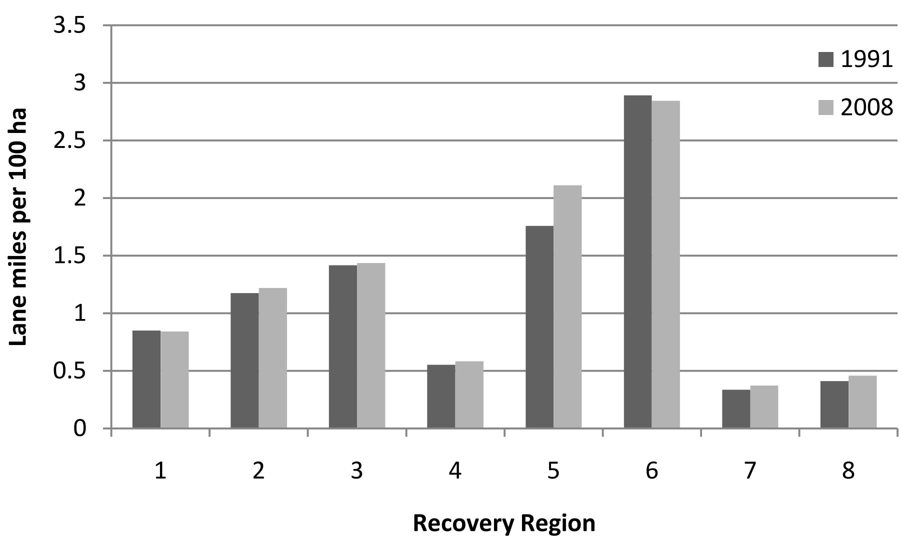

Figure 7.6. Road density by Recovery Region as estimated in 1991 and 2008. Data are from Texas Department of Transportation.

Table 7.5. Number of lane miles by county and Recovery Region in 1991 and 2008. Data are from Texas Department of Transportation and reported at the county level.

	Lane Miles		Total	%
County	1991	2008	change[a]	change[b]
Region 1				
Eastland	2,827	2,738	-90	-3.18
Palo Pinto	2,069	2,068	-1	-0.06
Stephens	1,383	1,370	-13	-0.93
Young	1,999	2,023	24	1.20
Region 1 total	8,279	8,199	-80	-0.97
Region 2				
Bosque	2,212	2,201	-11	-0.51
Erath	2,580	2,689	109	4.23
Hill	3,639	3,552	-86	-2.38
Hood	1,210	1,388	178	14.67
Johnson	3,417	3,635	218	6.39
Somervell	429	532	102	23.87
Region 2 total	13,488	13,998	510	3.78
Region 3				
Bell	5,609	5,500	-109	-1.95
Coryell	2,148	2,410	262	12.21
Hamilton	1,834	1,835	1	0.03
Lampasas	1,441	1,528	87	6.03
McLennan	6,385	6,402	17	0.26
Region 3 total	17,418	17,675	257	1.48
Region 4				
Blanco	978	931	-47	-4.77
Gillespie	1,723	1,905	183	10.61
Llano	1,598	1,738	141	8.80
Mason	1,051	1,039	-12	-1.12
San Saba	1,508	1,634	126	8.34
Region 4 total	6,857	7,248	391	5.70
Region 5				
Burnet	2,236	2,054	-183	-8.18
Hays	2,155	2,807	652	30.28
Travis	8,716	10,560	1,844	21.15
Williamson	4,448	5,655	1,206	27.12
Region 5 total	17,555	21,075	3,520	20.05
Region 6				
Bexar	15,023	14,324	-700	-4.66
Comal	2,382	2,683	301	12.65
Kendall	1,254	1,352	98	7.83
Region 6 total	18,659	18,359	-300	-1.61
Region 7				
Edwards	934	1,112	179	19.15
Kerr	1,899	2,035	136	7.18
Kimble	1,165	1,382	217	18.67
Menard	687	627	-60	-8.73
Region 7 total	4,684	5,156	473	10.09
Region 8				
Bandera	1,215	1,341	126	10.35
Kinney	605	584	-21	-3.46
Medina	2,258	2,542	284	12.58
Real	473	658	186	39.23
Uvalde	1,540	1,704	165	10.70
Region 8 total	6,090	6,830	739	12.14
Breeding range total	**93,030**	**98,539**	**5,509**	**5.92**

[a] Total change measures the numerical change (positive or negative) in number of lane miles from 1991 to 2008. Negative values indicate a shift in road classification or differences among reporting agencies.
[b] Percent change measures the percentage change (positive or negative) in number of lane miles from 1991 to 2008. It is calculated by subtracting the number of lane miles in 1991 from the number of lane miles in 2008, dividing that value by the 1991 value, then multiplying by 100. Negative values indicate a shift in road classification or differences among reporting agencies.

Buildings

When determining the endangered status of the golden-cheeked warbler, USFWS also noted that “private developments would also destroy and fragment habitat” and cited several examples of development projects and hectares of potentially affected land (55 FR 53154). We collected data from the U.S. Census Bureau on new residential single or multi-family buildings authorized by building permits for each year between 1990 and 2008. The statistics included data from any of 5 phases of residential construction: new units authorized to be built, housing units authorized to be built but not yet started, housing units started, housing units under construction, and housing units completed. The available data did not include information on hotels, motels, group residential structures (e.g., nursing homes), or publicly owned housing units (U.S. Census Bureau 2000). Furthermore, the data was available at the county level and was not restricted to the sections of counties that lie within the golden-cheeked warbler breeding range.

Annual building permit activity reached unprecedented levels since the golden-cheeked warbler was listed in 1990, most notably in Recovery Regions 5 and 6, and to a lesser extent in Regions 3 and 2 (Fig. 7.7). At the time of listing the building permit activity for Recovery Regions 5 and 6 was 1,939 and 1,700, respectively; activity peaked at 13,511 for Region 6 in 2005 and at 18,466 for Region 5 in 2006 (Fig. 7.7, Appendix 7.B). All Recovery Regions experienced at least a moderate growth in annual building permit activity from 1990 to 2005, although Regions 1, 7, and 8 exhibited the lowest overall rates of increase (Table 7.6). Although there were fewer permits issued during the 18-year period in Regions 2, 3, and 4 relative to Regions 5 and 6, the rates of increase for Regions 2, 3, and 4 were highest of all Regions (Table 7.6).

Generally, annual building permit activity in the golden-cheeked warbler's breeding range mirrored trends in both Texas and the nationwide housing market. Beginning around 2005, the nationwide housing market and Texas building permit activity entered a strong negative trend (Petersen 2008). Building permit activity in all Recovery Regions declined between 2005 and 2008, with the greatest declines of 46%, 54%, and 46% in Regions 3, 5, and 6, respectively. Persistent declines in home prices and sales, tighter credit conditions, and a general cooling of the regional economy were cited as causal factors (Petersen 2008). As the regional economy strengthens, local development may again enter a strong positive trend (Petersen 2008).

Table 7.6. Percent increase in building permit activity, 1990–2008, by Recovery Region. Data are from the U.S. Census Bureau and available at the county level. See Appendix 7.B for building permit activity for all years and counties.

Recovery Region	**1990**	**1995**	**2000**	**2005**	**2008**	**1990–2008 % change[a]**
1	5	6	6	15	11	120.00
2	149	375	733	1,375	984	560.40
3	480	2,059	2,148	4,685	2,570	435.42
4	44	126	123	404	389	784.09
5	1,939	7,955	14,061	18,001	8,193	322.54
6	1,700	6,352	8,415	13,511	5,248	208.71
7[b]	47	114	103	101	73	55.32
8	16	66	103	89	42	162.50
Breeding range	**4,380**	**17,053**	**25,692**	**38,181**	**17,510**	**299.77**

[a] Percent change measures the percentage change (positive or negative) in building permits from 1990 to 2008. It is calculated by subtracting the number of permits in 1990 from the number of permits in 2008, dividing the result by the 1990 value, then multiplying by 100.
[b] Data was unavailable for both Edwards and Menard Counties for all years.

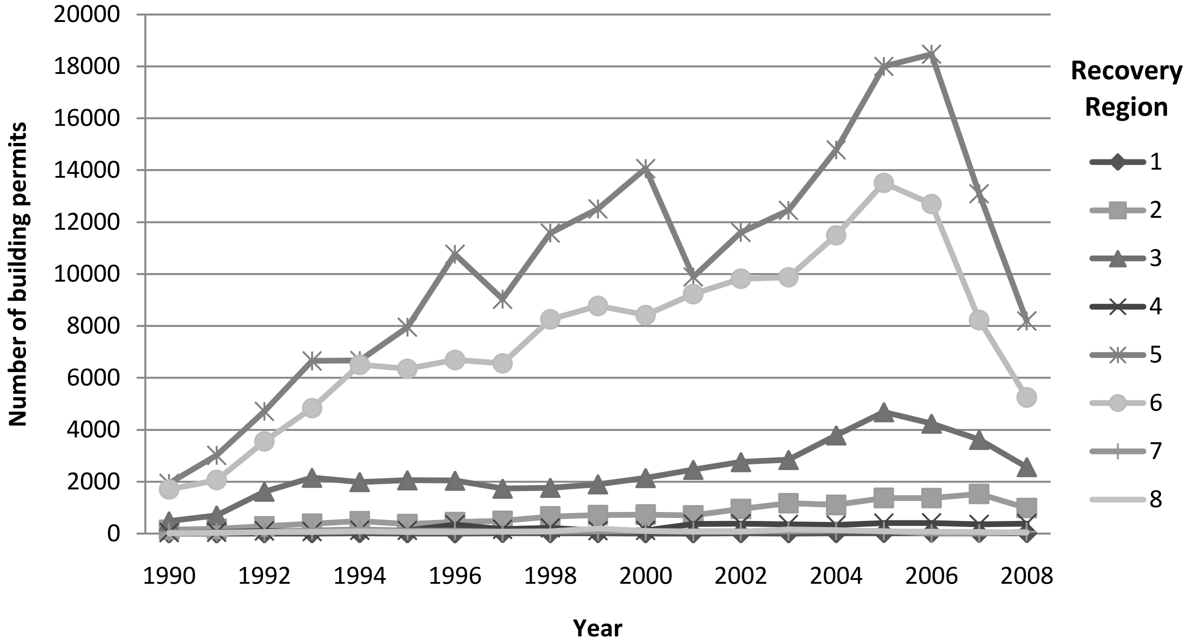

Figure 7.7. Annual building permit activity by Recovery Region from 1990 to 2008. Data are from the U.S. Census Bureau.

Reservoirs

The creation of large reservoirs and other flood control impoundments likely resulted in the loss of golden-cheeked warbler habitat prior to the species' listing (e.g., Pulich 1976, USFWS 1992). The construction of major reservoirs (an impoundment with 5,000 acre-feet of storage capacity at normal operating level) peaked in the 1960's (Fig. 7.8). Of the 196 major reservoirs in Texas, 29 occur within the breeding range of the golden-cheeked warbler, all of which were constructed prior to 1984 (Texas Water Development Board [TWDB] 2007). An estimated 179,000 ha (442,318 ac) of land within the warbler's breeding range had been inundated by large reservoirs and smaller flood control impoundments by the mid-1980's (summarized in USFWS 1992). Proposed reservoirs remained a concern at the time of listing (55 FR 53154). Forty-four reservoir projects were identified by TWDB in the 1984 State Water Plan for development between 1990 and 2030 (TWDB 1984), of which 17 could have impacted warbler habitat (Frye and Curtis 1990).

Reservoir construction has slowed considerably in recent decades (Fig. 7.8). The 1997 and 2002 State Water Plans each recommended 8 major water reservoirs to meet the needs for additional water supplies through 2050, none of which were proposed within the warbler's breeding range (TWDB 1997, TWDB 2002). Ten minor reservoirs were recommended in the 2002 State Water Plan, 3 of which occurred in the breeding range (TWDB 2002). In the 2007 State Water Plan, 14 major and 2 minor reservoirs were recommended (TWDB 2007). Of the reservoirs recommended in 2007, 1 of the proposed minor reservoirs occur in the warbler's breeding range (TWDB 2007). The area of land impacted by these reservoirs was not specified.

The slowing pace of reservoir construction is attributed to both progressive measures in water conservation as well as prohibitive limitations to development (TWDB 2002, TWDB 2007). "Emphasis on conservation, reuse, and other alternative water management strategies [have lowered] the State's reliance on new, large-scale reservoir projects" (TWDB 2002); in addition, the number of remaining prospective reservoir locations has dwindled, conflicts over environmental impacts have limited permitting, and construction costs have increased (TWDB 2002, TWDB 2007). However, future projects for flood protection and water conveyance structures may impact potential warbler habitat. Of the 41 proposed water conveyance structures proposed in the 2007 State Water Plan, 2 structures cross sections of counties in the warbler breeding range (Kerr and Bexar Counties; TWDB 2007).

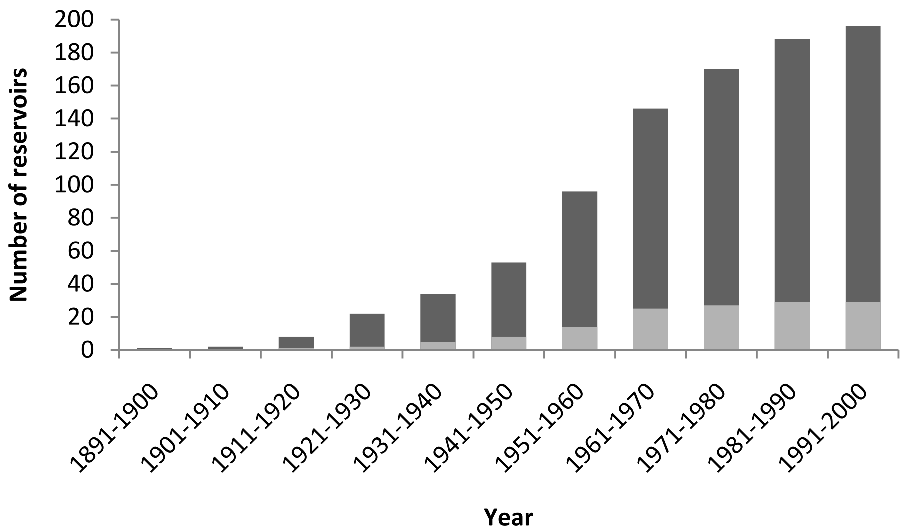

Figure 7.8. Cumulative number of major reservoirs (≥ 5,000 acre-foot storage capacity) built in Texas by decade. Yellow segments indicate number of major reservoirs built in the breeding range of the golden-cheeked warbler.

Transmission corridors

Since the time of listing, the development of transmission corridors has become an additional threat to the golden-cheeked warbler's habitat. Texas has a growing industry in wind-related energy production. The Texas State Senate passed Senate Bill 7 (1999) and Senate Bill 20 (2005), respectively, allowing for existing transmission services to provide and increase infrastructure for alternative energies. Each Senate Bill also set goals for alternative energy transmission capacity to reach 2,000 megawatt (MW) by 2009, 5,880 MW by 2015 and 10,000 MW by 2025. To achieve the latter 2 goals, the Public Utility Commission (PUC) of Texas has designated several areas in West Texas as Competitive Renewable Energy Zones (CREZ), the purpose of which is to generate and deliver wind-generated energy to other areas of the state (State Energy Conservation Office 2009). In 2009 the PUC issued a final order for the construction of 2,334 miles of transmission lines to increase transmission capability from the

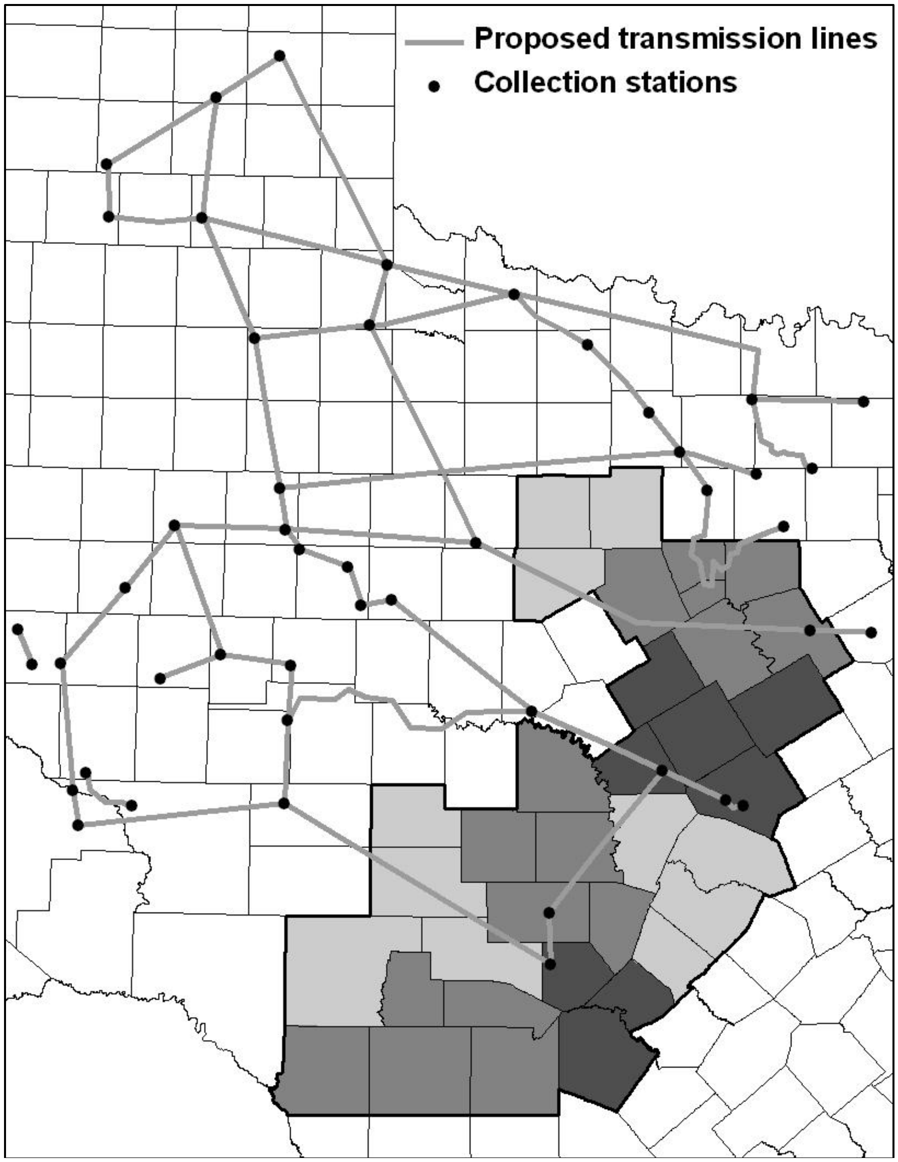

Figure 7.9. General proposed routes of transmission lines to deliver power from competitive renewable energy zones in the west to end-use consumers in the east. This includes transmission lines to be managed by LCRA and ONCOR. Counties are color-coded by Recovery Region.

CREZ to 18,456 MW, in excess of the legislative mandate (Lower Colorado River Authority [LCRA] 2009g, PUC 2009). The deadline for completion of transmission route infrastructure is 2013 (PUC 2009).

Power line construction, maintenance, and repair within the known range of golden-cheeked warblers will be handled by 2 separate utility companies: ONCOR in the northern range and the LCRA Transmission Services Corporation in the southern range (LCRA 2009g, ONCOR 2009). The proposed routing will cross at least 15 counties in the warbler's breeding range (Fig. 7.9) and, using ArcGIS, we estimated the length of the route to be approximately 700 km. The primary transmission lines will require 30–48-m wide rights-of-way (LCRA 2009g). Within the right of way, trees, shrubs, brush, and bushes are typically cleared (LCRA 2009g). Secondary transmission lines for further dissemination of wind energy will be constructed or rededicated from existing lines (LCRA 2009g). For each primary and secondary routing, potential golden-cheeked habitat is crossed repeatedly and habitat removal and fragmentation is possible.

Finalized routes are still in review (LCRA 2009g). Potential impacts to golden-cheeked warblers are unresolved as of the time of this writing, although USFWS provided notification of the intent to prepare a draft environmental impact statement to evaluate the impacts associated with construction, maintenance, operation, and repair of the LCRA (75 FR 13299) and ONCOR (74 FR 48285) proposed transmission lines.

7.2.2 Winter range

The Central American pine-oak forests that comprise the golden-cheeked warbler's winter range span 5 countries: Mexico, Guatemala, Honduras, Nicaragua, and El Salvador (see Chapter 2). In a 1995 assessment of Latin America ecoregions, the pine-oak forests were considered vulnerable (a moderate level of severity) in each country (Dinerstein et al. 1995). The United Nations Food and Agriculture Organization (FAO) estimated a decrease in overall forest cover throughout the winter range of 75,000 to >4.7 million ha (185,330 to >11.6 million ac) per country between 1990 and 2005 (Table 7.7; FAO 2009). The average annual forest loss for each country was estimated at 318,667 ha/year (787,443 ac/year) in Mexico, 54,000 ha/year (133,437 ac/year) in Guatemala, 5,000 ha/year (12,355 ac/year) in El Salvador, 182,667 ha/year (451,380 ac/year) in Honduras, and 90,000 ha/year in Nicaragua (222,395 ac/year) (Table 7.7). These numbers, however, are for all forest cover types and are not specific to golden-cheeked warbler winter habitat. It is unknown what proportion of forest loss in Mexico occurs in areas through which warblers migrate.

Additional estimates of forest loss in the winter range are limited. Using satellite images taken in 1974 and 1996, Ochoa-Gaona (2001) estimated annual deforestation rates of 2.9% and 2.3% for Huistán and Chanal, respectively. Huistán and Chanal are 2 municipalities in the highlands of Chiapas, Mexico. Throughout a slightly different time frame, 1974 to 1990, total reductions of dense forest in the central Chiapas highlands, Huistán, and Chanal were 42, 32, and 49%, respectively, with most of the deforestation in Huistán occurring specifically in pine-oak forest (Ochoa-Gaona and González-Espinosa 2000). In the mid-1980's, the estimated rate of forest loss in Guatemala was 60,000 ha/year (148,263 ac/year; Lyons 1990). More recent estimates suggest rates of loss of pine-oak forests in Guatemala and Honduras at 20,700 ha/year (51,151 ac/year) and 58,970 ha/year (145,718 ac/year), respectively (summarized in Alliance for the Conservation of Mesoamerican Pine-Oak Forests [ACMPOF] 2008).

Throughout the region, habitat loss and fragmentation result from extraction of timber, agriculture, firewood collection (favoring oak species), forest fires, cattle ranching, coffee plantations, and illegal logging (Table 7.8; Dinerstein et al. 1995, Ochoa-Gaona 2001, ACMPOF 2008, Redo et al. 2009, U.S. Agency for International Development [USAID] 2009). ACMPOF (2008) estimated that 74% of the original forest cover in the region has been lost due to agricultural expansion, resulting in a current forested area of 2,672,835 ha (6,604,719 ac).

Table 7.7. Estimates of forest cover (in thousands of ha) by country between 1990 and 2005. Numbers include overall forest cover and are not specific to golden-cheeked warbler winter habitat. Data are from the Food and Agriculture Organization of the United Nations.

Country	**1990**	**2000**	**2005**	**1990–2005 change**[a]	**% change**[b]
Mexico	69,018	65,538	64,238	-4,780	-6.93
Guatemala	4,748	4,208	3,938	-810	-17.06
El Salvador	373	323	298	-75	-20.11
Honduras	7,388	5,428	4,648	-2,740	-37.09
Nicaragua	6,539	5,539	5,189	-1,350	-20.65

[a] Year-to-year change measures the numerical change (positive or negative) in forest cover from the earliest to latest year.
[b] Percent change measures the percentage change (positive or negative) in forest cover between the 2 noted years. It is calculated by subtracting the earlier year (e.g., 1990) value from the later year (e.g., 2005) value, dividing the result by the earlier year (e.g., 1990) value, then multiplying by 100.

Table 7.8. Major threats to pine-oak forests in southern Mexico and Central American countries and qualitative level of each threat by country (ACMPOF 2008).

Threats	**Chiapas**	**Guatemala**	**El Salvador**	**Honduras**	**Nicaragua**
Unsustainable and incompatible forestry practices	High	Medium	High	Medium	High
Forest fires	High	High	Medium	High	Medium
Expansion of agriculture and livestock grazing	Medium	High	Medium	Medium	High
Extraction of firewood and timber	High	High	Medium	Medium	Medium
Illegal logging	Medium	Medium	Medium	High	Medium
Invasive insects[a]	Medium	Low	Low	Low	Medium
Housing and infrastructure construction	Medium	Medium	-	-	-
Extraction of non-wood forest products[b]	Medium	Low	-	-	-
Strip mining	Low	-	-	-	-
Overall impact by country	High	High	Medium	High	High

[a] For example, pine beetle (*Dendroctonus* sp.), long-horn beetles (*Cerambicidae* sp., locally known as oak borers), and mistletoe (*Psittacanthus* spp., *Arceuthobium aureum*)
[b] For example, bromeliads, orchids, mosses, shrubs, pine needles; overall impact of non-timber extraction on the ecosystem is unknown.

Human population

There tends to be a positive relationship between population growth and deforestation, although it is not linear and additional factors are certainly involved (e.g., governmental or institutional policies, technology, economic factors; e.g., Carr et al. 2005). We summarized country-wide population estimates from the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat as an indication of potential indirect impacts on golden-cheeked warblers (Table 7.9, Figs. 7.10 and 7.11). Depending on the country, populations increased 16–61% between 1990 and 2010 and projected population estimates are expected to increase and additional 14–51% between 2010 and 2030 (Table 7.10). Guatemala and Honduras, containing the majority of potential winter warbler habitat (Rappole et al. 2003), have had the highest rates of human population increase since the warbler was listed as endangered in 1990 and future projections of growth remain high for both countries (Table 7.10). Human population estimates specific to the warbler's winter range in Mexico are limited. However, Ochoa-Gaona (2001) estimated the populations of 2 municipalities in Chiapas, Mexico, where wintering habitat occurs: from 1974 to 1996, the population of Huistán increased from 11,039 to 19,751 (an increase of 79%) while the population of Chanal increased from 4,208 to 7,738 (an increase of 84%; Ochoa-Gaona 2001).

Table 7.9. Estimates of human population (in thousands of people) by country, 1970–2030. Data are from the United Nations Population Division.

Country	1970	1980	1990	2000	2010	2020	2030
Mexico	51,910	68,872	83,404	99,531	110,645	119,682	126,457
Guatemala	5,420	7,016	8,910	11,231	14,377	18,091	21,692
Honduras	2,691	3,634	4,901	6,230	7,616	9,136	10,492
Nicaragua	2,400	3,250	4,138	5,101	5,822	6,682	7,387
El Salvador	3,742	4,663	5,330	5,945	6,194	6,618	7,177

Table 7.10. Rate of human population increase by country from 1990 to 2010, 2010 to 2030, and 1990 to 2030. Data are from the United Nations Population Division. Population increase between years is in thousands of people.

Country	1990-2010 change[a]	% change[b]	2010-2030 change[a]	% change[b]	1990-2030 change[a]	% change[b]
Mexico	27,241	32.66	15,812	14.29	43,053	51.62
Guatemala	5,467	61.36	7,315	50.88	12,782	143.46
Honduras	2,715	55.40	2,876	37.76	5,591	114.08
Nicaragua	1,684	40.70	1,565	26.88	3,249	78.52
El Salvador	864	16.21	983	15.87	1,847	34.65

[a] Year-to-year change measures the numerical change (positive or negative) in human population from the earliest to latest year.

[b] Percent change measures the percentage change (positive or negative) in human population between the 2 noted years. It is calculated by subtracting the earlier year (e.g., 1990) value from the later year (e.g., 2010) value, dividing the result by the earlier year (e.g., 1990) value, then multiplying by 100.

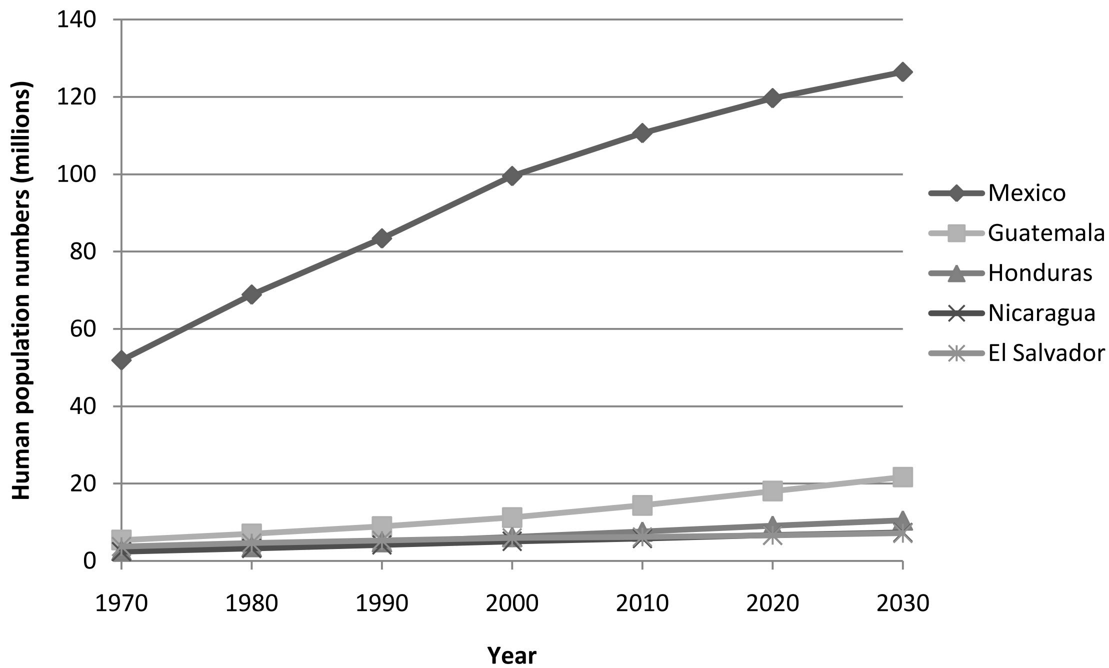

Figure 7.10. Human population estimates by country for each decade, 1970 through 2030. Data are from the United Nations Population Division.

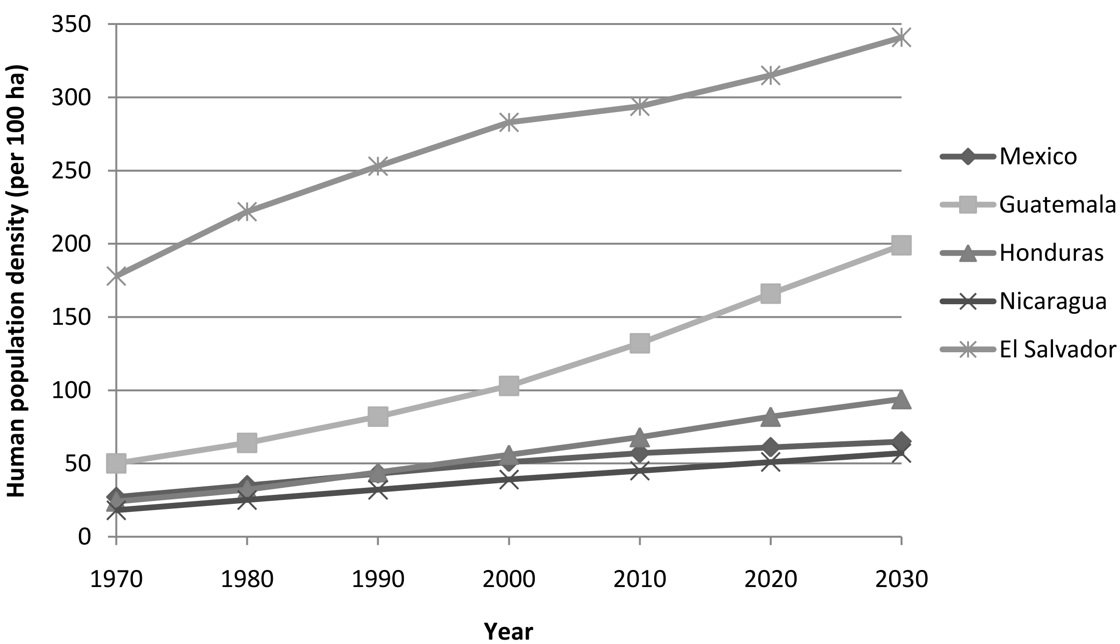

Figure 7.11. Human population density estimates by country for each decade, 1970 through 2030. Data are from the United Nations Population Division.

7.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

We found no evidence that the golden-cheeked warbler is subject to overuse by commercial, recreational, scientific, or educational purposes. Recreational birding and research do not appear to be detrimental to golden-cheeked warbler populations. One study of banded warblers on Fort Hood showed that while 7.5% of the birds (n = 161) showed minor leg injuries, 75% of the injured birds successfully reproduced and researchers observed no adverse effects on the males' foraging, defense, or other behaviors (Pekins 2002a). Leg and foot injuries have been documented for other species, for which either no obvious impact on behavior was observed or adjustments to banding protocols were required (Weiss and Cristol 1999, Pekins 2002a; but see Sedgewick and Klus 1997). A recent study in California indicated that constant mist-netting of adults in or around territories does not adversely impact reproductive performance or nestling condition (Jennings et al. 2009).

Researchers recently began using video cameras to monitor golden-cheeked warbler nests and to acquire information about nest predators (Stake et al. 2004, Reidy et al. 2008). Initial concern was that cameras would introduce a novel item into the environment and may attract attention to nests; however, a study on artificial nests using cameras in Travis County documented behavior by a snake suggesting that noise from the camera may have scared it away before it consumed quail eggs (Fink 1996). A meta-analysis of published data suggested camera surveillance may bias nest predation rates by deterring predators but the results varied considerably with geographic region, vegetation type, and study duration (Richardson et al. 2009). Using model-based maximum likelihood approaches, there was no support for an effect of nest cameras on golden-cheeked warblers at Fort Hood (Reidy 2007). Another concern is that nest cameras may provoke nest abandonment by nesting birds but for this reason the USFWS restricts when in the nesting stage researchers can set-up cameras. Nest abandonment was minimal when cameras were placed at nests after the initiation of egg incubation (Reidy et al. 2008, Stake et al. 2004).

It has been documented in the past that overexploitation of the warbler may have occurred on the wintering grounds because birds of many species were captured for the pet trade (Komar 1998) or killed for recreational hunting (Lyons 1990). The status of these activities on the warbler is unknown.

7.3 Disease and Predation

7.3.1 Disease

There is no existing information on the prevalence of pathogens, ectoparasites, or blood parasites in golden-cheeked warblers (see Chapter 3), although research on taxonomically-related species indicates the potential for susceptibility to diseases[1]. *Dendroica* warblers are among the 198 species that have suffered mortality from West Nile Virus (Komar 2003) and this virus has been

[1] Disease is defined as any departure from health and includes impairment by pathogens and ectoparasites following Fiend et al. (2001) definition.

implicated as contributing to population declines of other passerines (e.g., eastern bluebird (*Sialia sialis*), tufted titmouse (*Baeolophus bicolor*), house wren (*Troglodytes aedon*), black-capped chickadee (*Poecile atricapillus*); La Deau et al. 2007). The prevalence of blood parasites and ectoparasites in *Dendroica* warblers is variable across species and geographic locations (e.g., Tarof et al. 1997, Deviche et al. 2001, Latta 2003, Dietsch 2005). No reports exist on diseases in golden-cheeked warblers from the long-term study areas, including Ft Hood where the majority of banding and handling of individual warblers has occurred.

7.3.2 Predation

Common nest predators of golden-cheeked warblers, as identified by camera studies, include Texas rat snakes (*Elaphe obsoleta lindheimeri*), American crows (*Corvus brachyrynchos*), brown-headed cowbirds (*Molothrus ater*), western scrub-jays (*Aphelocoma californica*), Cooper's hawk (*Accipiter cooperii*), and fox squirrels (*Sciurus niger*; see Chapter 3). Using Breeding Bird Survey data from 1995–2004 (Sauer et al. 2005) and point counts on Fort Hood from 1995–2004, Kostecke (2008) determined there were no significant changes in population trends for avian predators on the Edwards Plateau (i.e., American crow, blue jay [*Cyanocitta cristata*], western scrub-jay) except for increases in brown-headed cowbirds. As detailed in Chapter 3, research in urban areas correlated warbler presence with that of several potential predator species relative to distances from different land-use types; however, this provided no indication of the direct influence that the abundance of primary predators may have on warblers (Arnold et al. 1996, Engels and Sexton 1994). Several studies showed rat snakes were a primary predator on warbler nests and adult females while on the nest (Reidy et al. 2009); however, no data exist to indicate that predation pressure by rat snakes is increasing or decreasing either because of snake populations or alterations to the environment.

Nest and territory success estimates for golden-cheeked warblers are not unusually low compared to other nesting passerines (see Chapter 3). Additionally, estimates of productivity given as the number of young fledged per pair also are not comparatively lower than other passerines (see Chapter 3). Research on predators and the potential for them to limit reproduction of warblers is restricted to few study areas within the warbler range and may be compromised by continuous removal efforts of brown-headed cowbirds (Alldredge et al. 2002), which often function as predators on songbird nests (Stake et al. 2004). The threat of predation on populations is ultimately related to how the environment influences demographics or activity of predator species; therefore, direct research on predator ecology is the most appropriate measure for evaluating predation as limiting population growth (Chalfoun et al. 2002).

7.4 Inadequacy of Existing Regulatory Mechanisms

Golden-cheeked warblers are currently protected under the Endangered Species Act of 1973, as amended (ESA), the Migratory Bird Treaty Act of 1918 (MBTA), and Texas state regulations. If in the future the warbler is considered recovered and thus removed from ESA (delisted), the species would remain protected under the MBTA, which concerns activities in which the species is directly harmed, captured, or transported. No regulatory provisions would exist, however, for protection of habitat. The U.S. Geological Survey's Bird Banding Laboratory would continue to permit and regulate capture, banding, and other research activities.

7.5 Other Natural or Manmade Factors Affecting Continued Existence

7.5.1 Parasitism

Reported estimates of brown-headed cowbird parasitism rates on golden-cheeked warblers are low (see Chapter 3) and, therefore, parasitism is considered by most to be a minor threat (Craft 1998). However, the impact of parasitism on a population depends on rates of other demographic parameters, such as survival and fecundity, before a reliable threat analysis is determinable (Powell and Knutson 2006). Furthermore, research on parasitism rates is predominately from the Fort Hood and Austin area, where trapping for cowbirds is a common management technique, and estimates from these geographic locations may not reflect rates across the breeding range. Trapping efforts on Fort Hood are sufficient to cause a significant decrease in parasitism rates in black-capped vireos (*Vireo atricapilla*), thus, researchers speculate that estimates for warblers may also be reduced although no research exists to support this conclusion (Eckrich 1999). Research suggests that the nesting period for warblers and the peak of cowbird parasitism may be discordant, such that later nest attempts by golden-cheeked warblers may be more susceptible to parasitism than earlier attempts (Weinberg 1995). No evidence exists to suggest that bronzed cowbirds are a threat to golden-cheeked warblers (see Chapter 3). Although rare, brown-headed cowbird trapping may occasionally capture non-target species; for example, Terpening (1999) documented mortality of an adult golden-cheeked warbler that was accidently captured in a brown-headed cowbird trap.

7.5.2 Vegetation succession

Along with the direct loss of warbler habitat, additional threats to the habitat may be found in long-term changes in vegetation composition. Research suggests some areas in the warbler's breeding range are experiencing limited regeneration of oaks (USFWS 1992, Russell and Fowler 2004). At the time of listing, it was suggested that high populations of white-tailed deer (*Odocoileus virginianus*), introduced feral ungulates, and oak wilt fungus (*Ceratocystis fagacearum*) were possible reasons behind the lack of deciduous tree reproduction and mortality in some areas (55 FR 53154).

Ungulate populations

As mentioned in Chapter 4, browsing by deer may influence oak regeneration within areas of the golden-cheeked warblers breeding range. Unlike Ashe juniper, Spanish oak is a highly preferred browse species (Armstrong et al. 1991), and there is some evidence Spanish oak recruitment peaked between 1900 and 1935 during a period of low deer abundance (Hahn 1945, Russell and Fowler 2002), although this was also during a period of extensive juniper clearing (Cartwright 1966, Smeins et al. 1997). Russell and Fowler (2004) showed that deer can significantly reduce the survival of Spanish oak saplings, and ongoing browsing pressure by deer may prevent oaks on the Edwards Plateau from replacing themselves (Russell and Fowler 2002).

Texas deer populations were low in the early 1900's due to intense commercial hunting (Hahn 1945). Once game laws were effectively enforced beginning in the 1930's, deer populations began to grow (Lockwood 2005). The statewide population estimate for 1950 was 500,000; by 1958 the statewide population was estimated at 1,150,000 deer (Lockwood 2005). Despite periodic die-offs attributed to overpopulation (Lockwood 2005), white-tailed deer populations have remained high. Texas Parks and Wildlife Department (TPWD) surveys conducted in 2003 and 2004 estimated statewide white-tailed deer populations at 4,007,748 and 3,915,862, respectively (Lockwood 2005).

In 2004, the Edwards Plateau contained 1,979,194 deer, or approximately 50% of the Texas deer population, despite containing only 28.6% of Texas deer habitat (Lockwood 2005); thus, in 2004 the Edwards Plateau had the state's highest deer densities and the estimate is the highest on record for this region (Lockwood 2005). For the 2004 estimate, across the Edwards Plateau there were an estimated 1 deer per 4.9 ha (12.1 ac) of deer range (Table 7.11). In the Cross Timbers and Prairies, the density estimate was 1 deer per 8.88 ha (21.9 ac) of deer range, while estimates for McLennan and Hill Counties showed 1 deer per 15.5 ha (38.3 ac) of deer range (Table 7.11; Lockwood 2005).

Table 7.11. Estimated number of deer per hectare of deer range in 2005 throughout 3 ecoregions in Texas.

Ecoregion	Counties[a]	Deer density
Edwards Plateau	Bandera, Bexar, Blanco, Burnet, Comal, Edwards, Gillespie, Hays, Kendall, Kerr, Kimble, Kinney, Lampasas, Llano, Mason, Medina, Menard, Real, San Saba, Travis, Uvalde	0.20/ha
Cross Timbers and Prairies	Bell, Bosque, Coryell, Eastland, Erath, Hamilton, Hood, Johnson, Palo Pinto, Somervell, Stephens, Williamson,	0.11/ha
Blackland Prairies	Hill, McLennan	0.06/ha

[a] County-by-ecoregion delineations are as illustrated in Lockwood 2005.

In addition to high densities of white-tailed deer, the Edwards Plateau region is also the center of Texas' exotic wildlife industry (Teer 2003). Common exotics include axis (*Axis axis*), fallow (*Dama dama*), and sika deer (*Cervus nippon*), nilgai (*Boselaphus tragocamelus*) and blackbuck antelope (*Antilope cervicapra*), and aoudad sheep (*Ammotragus lervia*; Traweek 1995). Based on statewide landowner surveys in 1988, TPWD estimated 164,257 exotic animals of 67 species in Texas; 90,400 were fenced within ranches, while 73,857 animals were free-ranging (able to move between ranches; Traweek and Welch 1992). Of all confined exotics, 68% were contained on the Edwards Plateau (Traweek and Welch 1992). A subsequent survey in 1994 estimated 195,423 exotic animals in Texas, an increase of 19% since 1988; 118,265 were fenced while 77,218 animals were free-ranging (Traweek 1995) with 62% of all confined exotics contained on the Edwards Plateau (Traweek 1995). Research projects conducted at the Kerr Wildlife Management Area concluded that these species preferred the same food items as white-tailed deer, including the leaves of woody plants (Armstrong and Harmel 1981).

The population of feral hogs (*Sus scrofa*) in Texas is estimated at 2 million throughout the state (Mapston 2004) with highest densities in eastern, central, and southern Texas (Adams et al. 2005). Feral hogs are opportunistic omnivores with food items including grasses, forbs, roots and tubers, browse, and mast (e.g., acorns) to name a few (Taylor 1999), although their foraging effects on oak regeneration is unknown.

Oak wilt fungus

Oak wilt is an infectious disease caused by the fungus *Ceratocystis fagacearum*, which disables water conduction in susceptible trees. Red oaks (e.g., *Quercus buckleyi*, *Q. marilandica*) are extremely susceptible and often die within 3–4 weeks of infection; live oaks (e.g., *Q. virginiana*, *Q. fusiformis*) are intermediate in susceptibility, and most infected trees die 1–6 months after the appearance of symptoms, while white oaks (e.g., *Q. stellata*, *Q. muehlenbergii*) are more resistant to the disease and rarely die from oak wilt (Appel and Camilli 2006, Texas Forest Service 2008). Wahl et al. (1990) suggested oak wilt as a threat to warbler populations; they offered that Kerrville State Recreation Area was a site where warblers formerly bred but the site had since suffered an outbreak of oak wilt, causing the death of many oak trees. Wahl et al. (1990) could find no current warblers at the site, though he suggested the absence of data was potentially confounded by ongoing habitat fragmentation and small patch size.

Spread of oak wilt at a regional scale in Texas was documented by Appel and Maggio (1984) who worked with aerial photography to identify oak mortality centers around Austin, between Kerrville and Bandera, and between Fredericksburg and Johnson City. They identified 425.7 ha (1,051.9 ac), 81.3 ha (200.9 ac), and 3,749.6 ha (9,265.5 ac) of oak mortality centers around Austin, Fredericksburg-Johnson City, and Kerrville-Bandera, respectively, with 37%, 0%, and 86% of the mortality suspected to be caused by oak wilt. Currently, oak wilt is known to occur in most Texas counties in the golden-cheeked warbler's breeding range, with <10 to >1000 centers of oak wilt per county (Fig. 7.12; Texas Forest Service [TFS] 2007). Highest estimated occurrences of oak wilt occur in Kerr, Bandera, Gillespie, Burnet, and Travis Counties (TFS 2007).

Appel and Camilli (2006) investigated the effects of oak wilt on Fort Hood and identified 1,164 mortality centers throughout the installation. Oak wilt was found to be the cause of mortality in 82 (69%) of sampled plots (n = 119 plots). While oak wilt was a major source of tree mortality on Fort Hood, only 12% of oak wilt centers occurred in designated warbler habitat (Appel and Camilli 2006). In comparing patterns of oak wilt across the base, Appel and Camilli (2006) noted that oak wilt occurred less frequently in areas of higher juniper-to-oak ratios, where warbler nesting sites also occurred; rather, oak wilt was more commonplace in areas of high live oak density. Oak wilt also has been identified as a cause of oak mortality on the Balcones Canyonlands Preserve (BCP), where managers attempt to control spread by red oak removal, root separation via trenching, and fungicide injections (BCP 2007b).

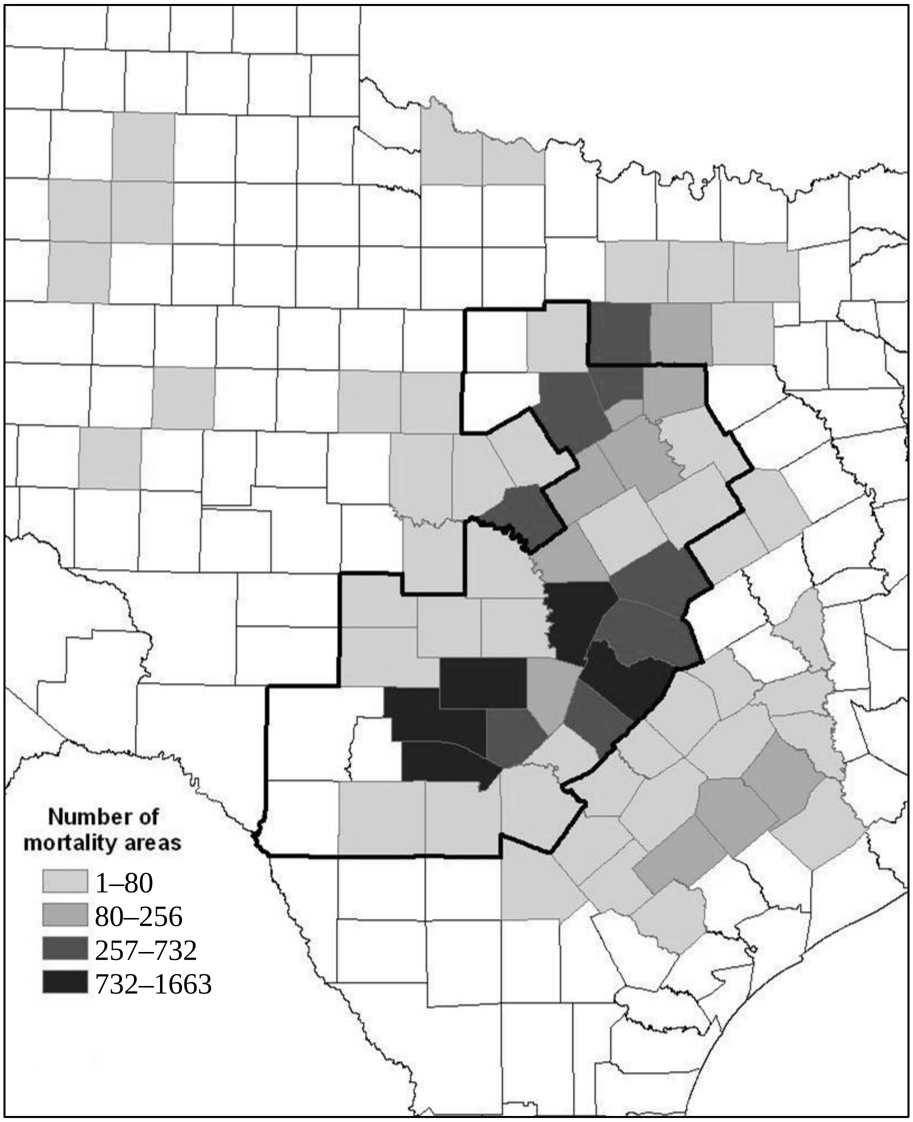

Figure 7.12. Distribution of oak wilt mortality areas throughout Texas as of 2007. Data are from the Texas Forest Service and includes both confirmed and unconfirmed tree mortality documented during ground and aerial surveys.

7.5.3 Climate change

Breeding grounds

The Environmental Protection Agency (EPA) developed an evaluation framework and assessment of the vulnerability of several species to the effects of climate change (EPA 2009). The golden-cheeked warbler was classified as "critically vulnerable" to climate change primarily because of the species' dependence upon Ashe juniper and the restrictions and sensitivity of this vegetative complex to climate change scenarios (EPA 2009). Stands of mixed Ashe juniper-oak woodlands are restricted to areas in central Texas with suitable geology, soil characteristics, precipitation, and land use practices (Diamond 1997). Increased temperatures on the southern limits of breeding birds is predicted to shift breeding ranges northward, yet warblers are limited to the north of their breeding range by distributional limits of their required breeding habitat (EPA 2009). Expansion of juniper vegetation to the north is unlikely because of geological limitations and because the Dallas/Fort Worth area is a barrier to any potential range expansion of juniper woodlands (EPA 2009). Drought conditions and increased risk of wildfires, as predicted by climate change projections, can further restrict existing breeding habitat (EPA 2009).

Wintering grounds

Climate change models focused on vegetation in Mexico indicated that with increasing temperatures and decreasing precipitation there could be a corresponding reduction in the geographic distribution of oaks and pines; furthermore, pines may be more vulnerable to fluctuations in temperature and precipitation (Gomex-Mendoza and Arriaga 2007). One of the most vulnerable pines, ocote pine (*Pinus oocarpa*; Gomex-Mendoza and Arriaga 2007), was described by Rappole et al. (1999, 2000) as the dominant canopy species in golden-cheeked warbler habitat in Honduras and Guatemala. Golden-cheeked warblers are already limited in their geographic distribution in Central America (Rappole et al. 2000) and range restrictions may increase a species' vulnerability to climate change (EPA 2009).

7.6 Summary of Threat Analysis

7.6.1 Threat Factor A: Present or threatened destruction, modification, or curtailment of habitat or range

Breeding range

The data we summarized in section 7.2 provided no indication that golden-cheeked warbler breeding habitat is increasing or stable. Most metrics indicated continued habitat loss and fragmentation of existing habitat, primarily due to human development. Remotely-sensed data suggested a steady loss of forest habitat in the breeding range. In conjunction with this loss, there has been a general shift in land use and ownership resulting in a higher number of smaller ownership parcels which may result in further fragmentation of the habitat. Human populations continue to increase in central Texas, which will create increased pressure on available habitat and changes in land use. The new threat of transmission corridors, designed to bring wind-generated power across Texas, will put additional pressure on warbler habitat throughout its breeding range.

Loss of habitat reduces available space for the warblers to forage, establish territories, and reproduce. Of the Recovery Regions containing relatively high proportions of habitat (i.e., Region 5, 6, 7, and 8; see chapter 6), threats that result primarily in habitat loss, such as changes in land cover and use, are highest in Regions 5 and 6. Factors that contribute primarily to fragmentation of habitat, such as division of land ownership into smaller parcels, are highest in Regions 7 and 8. Fragmentation of habitat has 2 main effects on warbler habitat: reduction of habitat patch size and increased amount of habitat edge. Although warblers are known to occur and breed in patches as small as 20 ha the probability of occupancy and reproductive success of golden-cheeked warblers increases with increasing patch size and reduced density of edge habitat. Research on territory success and nest survival of warblers has shown reduced success relative to various measures representing increased density of habitat edges and the type of land use adjacent to habitat. Some researcher detected certain predator species in higher numbers when proximate to habitat edges, although the pattern varied with adjacent land-use type. The subsequent effect of increased predator abundances or activity on warbler abundance or productivity was inconclusive.

Winter range and migration

Similar threats of habitat loss and fragmentation occur on the wintering grounds in southern Mexico, Guatemala, Honduras, El Salvador, and Nicaragua. Forested areas have declined in all 5 countries while human populations and pressures on the forests continue to rise. Habitat loss and fragmentation are primarily due to urban development, fires, and the extraction of timber, charcoal, and firewood. Honduras encompasses the largest extent of pine-oak forest and experiences the highest rate of forest cover loss, though the rate is not specific to pine-oak habitat. However, research is needed to better understand specific habitat use by the warbler and thus determine the effect of habitat fragmentation on the species. Eastern Mexico is the primary migratory route for warblers but neither habitat use nor threats to stopover habitat have been clearly defined.

7.6.2 Threat Factor B: Overutilization for commercial, recreational, scientific, or educational purposes

We found no evidence that the golden-cheeked warbler population is threatened by commercial, recreational, scientific, or educational purposes in Texas. No information exists to evaluate overutilization on the wintering grounds.

7.6.3 Threat Factor C: Disease and predation

We found no evidence in the scientific literature of avian diseases currently threatening the golden-cheeked warbler. Researchers at Fort Hood Military Reservation, where the majority of warbler handling and banding occurs, have not reported occurrences of disease in the species. There have been no studies to-date that specifically addressed diseases nor the probability of diseases affecting the species in the future.

Long-term research on predators and the potential for them to limit reproduction of warblers has occurred on a limited number of study areas within the breeding range. Research suggests the main predators of warblers include Texas rat snakes, corvids, and fox squirrels. We found no evidence that current predation levels are a threat to the golden-cheeked warbler population. Predation rates on the wintering grounds are unknown.

7.6.4 Threat Factor D: Inadequacy of existing regulatory mechanisms

The MBTA of 1918 along with TPWD provide protection for migratory birds and endangered species, respectively, by prohibiting the taking, killing, or possessing of the species unless appropriate permits are acquired. In addition to affording species protection, the ESA protects the habitat in which the species occur.

7.6.5 Threat Factor E: Other natural or manmade factors affecting continued existence

Golden-cheeked warblers are parasitized by brown-headed cowbirds, but the warbler population does not appear to be threatened by current parasitism rates. However, at the long-term study sites, where the majority of warbler demography research occurs, parasitism rates may be reduced due to extensive cowbird trapping in the areas; it is not known if parasitism rates would change with cessation of cowbird trapping.

The lack of oak recruitment was discussed in the original listing of the warbler and remains a threat to the habitat. Mortality of mature trees from oak wilt is prevalent throughout the warbler's breeding range. Oak wilt and browsing pressure from ungulates, particularly on the Edward's Plateau, appear to be partly responsible for the lack of seedling recruitment. Warblers forage on a variety of oak species throughout the breeding season; however, the species' tolerance for loss of oak in the breeding habitat is not known. Climate change could impact the abundance and distribution of oaks and Ashe juniper if long-term shifts in temperature and rainfall patterns occur. The magnitude and direction of change is difficult to predict at this time.

Appendix 7.A. Hectares of land encompassed by each of 5 ownership size categories. Data are from USDA Census of Agriculture.

		1-40 ha (<100 ac)				
County	**County size (ha)**	**1997**	**2002**	**2007**	**Total change**	**% change**
Region 1						
Eastland	241,173	7,209	7,020	9,082	1,872	25.97
Palo Pinto	255,068	5,942	6,522	9,356	3,414	57.46
Stephens	238,477	1,221	1,143	1,398	176	14.45
Young	240,885	3,717	3,490	3,854	137	3.69
Region 1 total	975,603	18,089	18,175	23,689	5,600	30.96
Region 2						
Bosque	259,584	7,727	8,550	9,770	2,044	26.45
Erath	282,072	13,626	14,015	16,195	2,569	18.86
Hill	255,281	14,738	17,777	19,197	4,460	30.26
Hood	113,075	7,899	8,033	9,006	1,107	14.02
Johnson	190,177	22,223	22,792	23,076	852	3.84
Somervell	49,679	2,369	3,038	3,348	979	41.33
Region 2 total	1,149,868	68,581	74,205	80,592	12,011	17.51
Region 3						
Bell	281,491	17,734	18,558	20,998	3,264	18.41
Coryell	273,566	6,698	7,300	8,184	1,486	22.18
Hamilton	216,489	5,127	4,783	5,705	578	11.27
Lampasas	184,797	4,659	5,405	6,059	1,400	30.05
McLennan	274,581	22,398	24,273	24,116	1,718	7.67
Region 3 total	1,230,924	56,617	60,320	65,063	8,446	14.92
Region 4						
Blanco	184,644	3,711	4,880	5,743	2,032	54.77
Gillespie	274,710	9,387	11,832	13,743	4,356	46.41
Llano	250,050	2,438	3,243	3,647	1,208	49.56
Mason	241,249	1,482	1,670	1,947	465	31.41
San Saba	294,579	3,584	3,148	3,703	119	3.31
Region 4 total	1,245,234	20,602	24,772	28,782	8,181	39.71

		1-40 ha (<100 ac)				
County	**County size (ha)**	**1997**	**2002**	**2007**	**Total change**	**% change**
Region 5						
Burnet	264,033	8,716	10,015	10,653	1,938	22.23
Hays	175,972	7,602	9,141	9,334	1,732	22.78
Travis	264,606	11,406	11,408	10,850	-555	-4.87
Williamson	294,234	19,456	21,279	22,173	2,717	13.96
Region 5 total	998,845	47,180	51,843	53,011	5,831	12.36
Region 6						
Bexar	325,239	21,967	21,378	22,498	531	2.42
Comal	148,720	5,699	6,734	7,914	2,215	38.87
Kendall	171,600	5,291	6,088	8,275	2,983	56.38
Region 6 total	645,559	32,958	34,199	38,687	5,729	17.38
Region 7						
Edwards	548,853	710	947	1,727	1,017	143.27
Kerr	286,670	5,491	6,238	8,264	2,773	50.50
Kimble	323,780	1,627	2,000	3,352	1,725	106.02
Menard	233,537	1,146	1,458	1,811	665	58.04
Region 7 total	1,392,840	8,973	10,643	15,153	6,180	68.87
Region 8						
Bandera	206,404	4,247	5,981	7,197	2,950	69.46
Kinney	353,501	221	111	287	67	30.28
Medina	345,375	11,714	13,177	15,838	4,124	35.21
Real	181,199	725	1,197	1,633	908	125.17
Uvalde	403,420	3,164	3,301	3,326	161	5.10
Region 8 total	1,489,899	20,071	23,768	28,281	8,210	40.90
Breeding range total	**9,128,772**	**273,071**	**297,925**	**333,259**	**60,188**	**22.04**

Appendix 7.A. Continued

County	County size (ha)	40-202 ha (100-499 ac) 1997	2002	2007	Total change	% change
Region 1						
Eastland	241,173	64,963	53,332	55,336	-9,627	-14.82
Palo Pinto	255,068	34,440	30,396	33,438	-1,001	-2.91
Stephens	238,477	26,560	21,489	23,212	-3,348	-12.61
Young	240,885	37,285	34,047	35,684	-1,601	-4.29
Region 1 total	975,603	163,247	139,264	147,669	-15,578	-9.54
Region 2						
Bosque	259,584	55,386	53,184	55,544	157	0.28
Erath	282,072	84,451	81,371	79,092	-5,358	-6.35
Hill	255,281	63,585	62,199	56,654	-6,931	-10.90
Hood	113,075	23,191	20,938	19,095	-4,096	-17.66
Johnson	190,177	53,149	47,859	42,540	-10,610	-19.96
Somervell	49,679	8,524	8,771	9,743	1,219	14.30
Region 2 total	1,149,868	288,286	274,321	262,667	-25,619	-8.89
Region 3						
Bell	281,491	57,868	52,746	48,836	-9,032	-15.61
Coryell	273,566	53,101	49,786	46,492	-6,609	-12.45
Hamilton	216,489	55,168	51,649	49,841	-5,326	-9.66
Lampasas	184,797	37,213	32,766	31,020	-6,193	-16.64
McLennan	274,581	59,748	55,377	60,176	428	0.72
Region 3 total	1,230,924	263,097	242,324	236,364	-26,733	-10.16
Region 4						
Blanco	184,644	30,638	29,457	29,143	-1,495	-4.88
Gillespie	274,710	68,314	67,038	60,380	-7,935	-11.61
Llano	250,050	24,968	25,570	25,527	559	2.24
Mason	241,249	24,989	25,618	26,114	1,125	4.50
San Saba	294,579	25,764	27,312	27,241	1,478	5.73
Region 4 total	1,245,234	174,673	174,995	168,405	-6,267	-3.59

County	County size (ha)	40-202 ha (100-499 ac) 1997	2002	2007	Total change	% change
Region 5						
Burnet	264,033	50,326	49,272	49,673	-653	-1.30
Hays	175,972	31,618	30,693	28,687	-2,932	-9.27
Travis	264,606	31,218	28,283	23,225	-7,993	-25.61
Williamson	294,234	73,117	60,976	58,114	-15,003	-20.52
Region 5 total	998,845	186,279	169,223	159,698	-26,581	-14.27
Region 6						
Bexar	325,239	51,796	53,563	37,573	-14,223	-27.46
Comal	148,720	28,122	27,273	25,868	-2,254	-8.01
Kendall	171,600	31,629	32,867	32,666	1,036	3.28
Region 6 total	645,559	111,548	113,703	96,107	-15,441	-13.84
Region 7						
Edwards	548,853	7,969	10,642	15,351	7,382	92.64
Kerr	286,670	32,725	35,633	40,741	8,016	24.50
Kimble	323,780	17,932	17,316	17,194	-737	-4.11
Menard	233,537	9,864	11,109	11,086	1,222	12.39
Region 7 total	1,392,840	68,489	74,699	84,372	15,883	23.19
Region 8						
Bandera	206,404	30,179	25,194	30,015	-164	-0.54
Kinney	353,501	2,982	3,407	7,761	4,779	160.27
Medina	345,375	68,858	72,116	68,186	-672	-0.98
Real	181,199	6,424	8,389	8,282	1,858	28.93
Uvalde	403,420	21,001	21,423	20,986	-15	-0.07
Region 8 total	1,489,899	129,444	130,529	135,231	5,787	4.47
Breeding range total	**9,128,772**	**1,385,064**	**1,319,060**	**1,290,515**	**-94,549**	**-6.83**

Appendix 7.A. Continued

County	County size (ha)	202-404 ha (500-999 ac) 1997	2002	2007	Total change	% change
Region 1						
Eastland	241,173	38,306	40,232	40,037	1,731	4.52
Palo Pinto	255,068	26,865	22,891	27,244	379	1.41
Stephens	238,477	24,990	24,615	21,931	-3,059	-12.24
Young	240,885	27,251	28,506	22,629	-4,622	-16.96
Region 1 total	975,603	117,411	116,244	111,841	-5,570	-4.74
Region 2						
Bosque	259,584	32,399	35,216	34,384	1,985	6.13
Erath	282,072	50,601	44,623	54,936	4,336	8.57
Hill	255,281	33,800	32,824	30,173	-3,626	-10.73
Hood	113,075	13,695	12,009	10,917	-2,777	-20.28
Johnson	190,177	18,605	19,419	17,028	-1,576	-8.47
Somervell	49,679	8,638	8,301	6,612	-2,026	-23.46
Region 2 total	1,149,868	157,737	152,392	154,051	-3,685	-2.34
Region 3						
Bell	281,491	31,258	27,791	31,201	-57	-0.18
Coryell	273,566	42,681	43,373	42,687	6	0.01
Hamilton	216,489	40,390	34,707	33,405	-6,985	-17.29
Lampasas	184,797	27,239	23,097	28,699	1,461	5.36
McLennan	274,581	29,438	28,511	30,602	1,164	3.95
Region 3 total	1,230,924	171,006	157,479	166,594	-4,412	-2.58
Region 4						
Blanco	184,644	25,277	28,726	30,170	4,893	19.36
Gillespie	274,710	60,638	55,576	45,230	-15,408	-25.41
Llano	250,050	30,400	29,651	28,377	-2,023	-6.65
Mason	241,249	37,673	36,792	30,091	-7,581	-20.12
San Saba	294,579	31,801	29,862	26,035	-5,766	-18.13
Region 4 total	1,245,234	185,788	180,607	159,903	-25,885	-13.93

County	County size (ha)	202-404 ha (500-999 ac) 1997	2002	2007	Total change	% change
Region 5						
Burnet	264,033	43,147	34,992	30,205	-12,941	-29.99
Hays	175,972	19,974	22,481	14,960	-5,014	-25.10
Travis	264,606	23,038	20,984	13,687	-9,351	-40.59
Williamson	294,234	41,327	41,373	32,127	-9,201	-22.26
Region 5 total	998,845	127,486	119,830	90,979	-36,507	-28.64
Region 6						
Bexar	325,239	23,515	20,838	20,139	-3,376	-14.36
Comal	148,720	21,706	14,633	14,247	-7,459	-34.36
Kendall	171,600	26,424	26,178	25,059	-1,365	-5.16
Region 6 total	645,559	71,645	61,650	59,446	-12,199	-17.03
Region 7						
Edwards	548,853	8,327	10,419	11,392	3,065	36.81
Kerr	286,670	23,366	19,102	25,498	2,133	9.13
Kimble	323,780	29,217	23,972	35,514	6,297	21.55
Menard	233,537	17,897	10,325	12,355	-5,542	-30.97
Region 7 total	1,392,840	78,806	63,818	84,759	5,953	7.55
Region 8						
Bandera	206,404	30,279	19,351	19,415	-10,865	-35.88
Kinney	353,501	7,840	5,796	7,470	-370	-4.72
Medina	345,375	55,092	52,593	50,818	-4,275	-7.76
Real	181,199	11,836	14,640	13,695	1,859	15.71
Uvalde	403,420	28,600	29,092	20,565	-8,036	-28.10
Region 8 total	1,489,899	133,648	121,471	111,962	-21,686	-16.23
Breeding Range total	**9,128,772**	**1,043,527**	**973,491**	**939,535**	**-103,992**	**-9.97**

Appendix 7.A. Continued

County	County size (ha)	404-809 ha (1000-1999 ac) 1997	2002	2007	Total change	% change
Region 1						
Eastland	241,173	33,084	35,742	39,531	6,447	19.49
Palo Pinto	255,068	31,183	26,043	27,097	-4,086	-13.10
Stephens	238,477	35,171	23,492	30,440	-4,731	-13.45
Young	240,885	39,019	34,872	32,480	-6,539	-16.76
Region 1 total	975,603	138,457	120,149	129,548	-8,909	-6.43
Region 2						
Bosque	259,584	31,225	31,703	33,839	2,614	8.37
Erath	282,072	52,250	43,972	39,770	-12,481	-23.89
Hill	255,281	37,431	35,767	39,499	2,068	5.52
Hood	113,075	13,947	13,661	12,740	-1,207	-8.65
Johnson	190,177	21,698	13,622	22,799	1,100	5.07
Somervell	49,679	4,262	5,767	3,634	-628	-14.73
Region 2 total	1,149,868	160,813	144,493	152,281	-8,532	-5.31
Region 3						
Bell	281,491	30,996	27,051	28,089	-2,907	-9.38
Coryell	273,566	44,927	40,281	32,113	-12,814	-28.52
Hamilton	216,489	41,348	36,814	34,132	-7,216	-17.45
Lampasas	184,797	36,354	34,128	40,239	3,885	10.69
McLennan	274,581	43,131	46,408	28,812	-14,319	-33.20
Region 3 total	1,230,924	196,755	184,683	163,385	-33,370	-16.96
Region 4						
Blanco	184,644	40,450	33,131	29,447	-11,003	-27.20
Gillespie	274,710	61,857	60,702	58,970	-2,887	-4.67
Llano	250,050	39,416	38,004	42,319	2,903	7.36
Mason	241,249	53,384	41,894	49,142	-4,242	-7.95
San Saba	294,579	43,541	51,020	45,860	2,319	5.33
Region 4 total	1,245,234	238,647	224,751	225,738	-12,909	-5.41

County	County size (ha)	404-809 ha (1000-1999 ac) 1997	2002	2007	Total change	% change
Region 5						
Burnet	264,033	39,991	35,216	26,392	-13,600	-34.01
Hays	175,972	20,654	11,837	13,521	-7,133	-34.54
Travis	264,606	23,267	22,122	18,579	-4,687	-20.15
Williamson	294,234	44,023	54,847	45,974	1,951	4.43
Region 5 total	998,845	127,935	124,022	104,466	-23,469	-18.34
Region 6						
Bexar	325,239	24,150	26,251	13,792	-10,358	-42.89
Comal	148,720	13,961	18,067	13,691	-270	-1.93
Kendall	171,600	28,951	26,755	27,534	-1,417	-4.89
Region 6 total	645,559	67,062	71,074	55,018	-12,045	-17.96
Region 7						
Edwards	548,853	25,755	22,647	24,983	-772	-3.00
Kerr	286,670	49,765	36,078	34,349	-15,415	-30.98
Kimble	323,780	46,324	36,321	39,614	-6,709	-14.48
Menard	233,537	27,039	31,474	21,747	-5,292	-19.57
Region 7 total	1,392,840	148,881	126,520	120,693	-28,188	-18.93
Region 8						
Bandera	206,404	26,342	27,007	27,550	1,208	4.59
Kinney	353,501	11,712	13,202	14,766	3,055	26.08
Medina	345,375	60,210	65,268	55,450	-4,760	-7.90
Real	181,199	29,460	19,117	14,080	-15,380	-52.21
Uvalde	403,420	42,209	40,749	42,603	394	0.93
Region 8 total	1,489,899	169,932	165,343	154,449	-15,483	-9.11
Breeding range total	**9,128,772**	**1,248,483**	**1,161,035**	**1,105,577**	**-142,906**	**-11.45**

Appendix 7.A. Continued

County	County size (ha)	≥810 ha (≥2000 ac) 1997	2002	2007	Total change	% change
Region 1						
Eastland	241,173	58,425	65,226	66,505	8,080	13.83
Palo Pinto	255,068	119,497	110,407	126,046	6,549	5.48
Stephens	238,477	98,214	102,410	96,743	-1,471	-1.50
Young	240,885	115,663	105,361	118,767	3,104	2.68
Region 1 total	975,603	391,798	383,403	408,060	16,261	4.15
Region 2						
Bosque	259,584	103,005	99,124	89,443	-13,563	-13.17
Erath	282,072	55,044	50,990	62,095	7,050	12.81
Hill	255,281	47,759	55,525	66,899	19,140	40.08
Hood	113,075	33,068	27,158	31,474	-1,594	-4.82
Johnson	190,177	27,091	42,806	28,649	1,558	5.75
Somervell	49,679	7,477	8,223	10,097	2,620	35.03
Region 2 total	1,149,868	273,445	283,827	288,655	15,210	5.56
Region 3						
Bell	281,491	38,908	56,336	45,678	6,770	17.40
Coryell	273,566	117,479	58,804	68,156	-49,323	-41.98
Hamilton	216,489	50,912	54,022	67,464	16,552	32.51
Lampasas	184,797	76,305	71,533	62,339	-13,966	-18.30
McLennan	274,581	50,638	63,343	70,624	19,986	39.47
Region 3 total	1,230,924	334,242	304,038	314,261	-19,982	-5.98
Region 4						
Blanco	184,644	58,515	61,343	65,617	7,102	12.14
Gillespie	274,710	85,003	66,046	85,914	910	1.07
Llano	250,050	120,629	119,324	118,212	-2,418	-2.00
Mason	241,249	129,138	118,869	109,780	-19,358	-14.99
San Saba	294,579	187,314	175,716	187,644	330	0.18
Region 4 total	1,245,234	580,599	541,296	567,166	-13,434	-2.31

County	County size (ha)	≥810 ha (≥2000 ac) 1997	2002	2007	Total change	% change
Region 5						
Burnet	264,033	85,835	99,320	78,196	-7,639	-8.90
Hays	175,972	49,563	38,493	28,829	-20,734	-41.83
Travis	264,606	81,950	37,972	39,881	-42,069	-51.33
Williamson	294,234	48,536	57,497	60,797	12,261	25.26
Region 5 total	998,845	265,883	233,282	207,703	-58,180	-21.88
Region 6						
Bexar	325,239	69,182	56,520	78,357	9,175	13.26
Comal	148,720	13,746	15,562	16,162	2,416	17.58
Kendall	171,600	48,273	40,426	45,077	-3,196	-6.62
Region 6 total	645,559	131,200	112,508	139,596	8,396	6.40
Region 7						
Edwards	548,853	432,777	349,311	349,804	-82,973	-19.17
Kerr	286,670	125,980	131,335	139,444	13,463	10.69
Kimble	323,780	234,578	169,474	155,216	-79,362	-33.83
Menard	233,537	154,919	167,742	151,822	-3,097	-2.00
Region 7 total	1,392,840	948,254	817,862	796,285	-151,969	-16.03
Region 8						
Bandera	206,404	71,784	70,917	49,134	-22,651	-31.55
Kinney	353,501	237,966	225,813	213,022	-24,944	-10.48
Medina	345,375	117,352	122,594	112,471	-4,881	-4.16
Real	181,199	112,657	118,517	113,024	367	0.33
Uvalde	403,420	288,355	297,520	313,126	24,771	8.59
Region 8 total	1,489,899	828,116	835,361	800,777	-27,339	-3.30
Breeding range total	**9,128,772**	**3,753,539**	**3,511,577**	**3,522,503**	**-231,035**	**-6.16**

Appendix 7.B. Building permit activity each year between 1990 and 2008. Data are from the U.S. Census Bureau. "N/A" indicates data was unavailable for the given year.

County	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Region 1																			
Eastland	2	1	1	1	2	2	1	2	1	3	1	0	0	1	0	0	1	0	1
Palo Pinto	3	1	4	3	1	4	0	12	6	6	4	5	8	6	7	14	15	13	9
Stephens	0	0	0	3	8	0	0	0	1	2	1	0	1	0	2	1	1	0	1
Region 1 total	5	2	5	7	11	6	1	14	8	11	6	5	9	7	9	15	17	13	11
Region 2																			
Bosque	4	3	3	6	7	13	15	6	4	6	6	8	5	4	5	5	8	7	7
Erath	12	19	31	31	53	50	43	37	20	27	23	22	50	117	52	54	36	75	61
Hill	14	9	7	12	39	18	13	14	31	33	16	22	25	20	24	15	30	21	17
Hood	12	14	10	17	31	54	61	65	92	70	30	20	93	84	95	129	121	105	101
Johnson	107	136	224	313	345	236	304	362	502	563	649	620	763	896	911	1148	1102	1268	755
Somervell	N/A	N/A	4	5	9	4	5	12	10	21	9	12	13	50	18	24	70	55	43
Region 2 total	149	181	279	384	484	375	441	496	659	720	733	704	949	1171	1105	1375	1367	1531	984
Region 3																			
Bell	197	347	1,049	1474	1318	1405	1428	1195	1242	1266	1466	1741	2086	1978	2643	3207	2887	2506	1765
Coryell	61	99	259	306	228	302	214	117	100	102	83	82	90	123	192	397	327	243	210
Hamilton	1	0	0	1	2	1	2	3	3	3	6	3	1	1	2	3	2	4	2
Lampasas	2	3	6	4	5	4	6	5	8	13	12	21	23	25	10	28	28	21	19
McLennan	219	256	305	371	439	347	393	416	417	520	581	616	561	717	944	1050	1000	846	574
Region 3 total	480	705	1619	2156	1992	2059	2043	1736	1770	1904	2148	2463	2761	2844	3791	4685	4244	3620	2570
Region 4																			
Blanco	2	2	8	2	29	25	35	16	17	12	12	20	21	21	22	26	19	18	23
Gillespie	23	34	46	51	60	62	59	44	52	76	61	86	112	82	79	92	86	73	50
Llano	15	21	51	28	39	34	243	72	144	16	24	235	246	256	218	271	294	259	307
Mason	N/A	N/A	N/A	2	1	5	3	3	4	8	3	11	0	1	14	14	12	10	4
San Saba	4	1	0	0	2	0	3	34	9	0	23	19	3	1	5	1	3	0	5
Region 4 total	44	58	105	83	131	126	343	169	226	112	123	371	382	361	338	404	414	360	389
Region 5																			
Burnet	25	24	28	127	202	225	264	259	425	423	438	445	445	417	452	452	508	491	315
Hays	18	21	22	50	84	150	218	167	418	804	842	795	1127	1148	2003	2161	2025	1554	1375
Travis	1722	2591	3894	5060	4810	4738	6486	5492	6937	7149	8049	4826	5667	6447	8100	9886	10095	7071	4079
Williamson	174	381	767	1415	1572	2842	3795	3113	3795	4132	4732	3822	4358	4442	4225	5502	5838	3973	2424
Region 5 total	1939	3017	4711	6652	6668	7955	10763	9031	11575	12508	14061	9888	11597	12454	14780	18001	18466	13089	8193

Appendix 7.B. Continued.

County	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Region 6																			
Bexar	1413	1674	2828	3999	5378	5305	5594	5391	7080	7505	7073	7730	8118	7846	9313	10767	9642	5841	3834
Comal	209	248	421	632	901	856	897	886	876	934	1064	1183	1354	1609	1637	2192	2477	1856	1221
Kendall	78	143	299	203	226	191	198	280	297	334	278	316	346	422	542	552	579	533	193
Region 6 total	1700	2065	3548	4834	6505	6352	6689	6557	8253	8773	8415	9229	9818	9877	11492	13511	12698	8230	5248
Region 7																			
Edwards	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kerr	43	49	63	119	162	107	110	76	70	90	103	82	89	88	104	88	0	0	69
Kimble	4	2	0	1	0	7	4	0	1	3	0	1	2	0	5	13	1	0	4
Menard	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Region 7 total	47	51	63	120	162	114	114	76	71	93	103	83	91	88	109	101	1	0	73
Region 8																			
Bandera	0	3	1	2	0	0	0	0	2	4	3	2	2	2	0	10	2	2	0
Kinney	2	2	2	2	0	0	2	2	1	0	3	2	2	2	2	0	1	0	0
Medina	N/A	18	52	33	58	39	39	32	38	35	35	33	21	104	111	43	31	40	16
Real	1	0	0	3	6	4	4	24	21	136	31	9	10	11	8	0	0	1	0
Uvalde	13	8	14	18	24	23	24	18	25	27	31	25	41	41	21	36	38	25	26
Region 8 total	16	31	69	58	88	66	69	76	87	202	103	71	76	160	142	89	72	68	42
Breeding range total	4380	6110	10399	14294	16041	17053	20463	18155	22649	24323	25692	22814	25683	26962	31766	38181	37279	26911	17150

Chapter 8. Recovery Efforts and Research Needs

8.1 Protection of Habitat

8.1.1 Breeding Range

A Recovery Plan for the golden-cheeked warbler was developed by the U.S. Fish and Wildlife Service (USFWS) in 1992 to direct management and recovery of the species (USFWS 1992). The criteria established for delisting the species included:

> "(1) sufficient breeding habitat has been protected to ensure the continued existence of at least one viable, self-sustaining population in each of eight regions outlined in the plan, (2) the potential for gene flow exists across regions between demographically self-sustaining populations where needed for long-term viability; (3) sufficient and sustainable non-breeding habitat exists to support the breeding populations, (4) all existing golden-cheeked warbler populations on public lands are protected and managed to ensure their continued existence, and (5) all of these criteria have been met for 10 consecutive years" (USFWS 1992).

Biologists participating in a Population and Habitat Viability Assessment Workshop in 1996 recommended maintaining a carrying capacity of 3,000 breeding pairs "to assure a probability of extinction less than 5% over 100 years" in each of the 8 Recovery Regions (USFWS 1996a). They estimated that a "target habitat area" per warbler population (i.e., per Recovery Region) would consist of approximately 13,150 ha (32,500 ac), assuming a maximum density of 4.3 ha (10.6 ac) per breeding bird and with the caveat that "the habitat is of good quality, and is sufficiently unfragmented to be usable by the warblers" (USFWS 1996a).

While the majority of land within the golden-cheeked warbler's breeding range is privately owned, several Federal, state, and local agencies or organizations also own and manage lands that contain potential habitat. The Recovery Plan (USFWS 1992) estimated a total of 126,752 ha (313,211 ac) of "some state and Federal lands" in the breeding range, with 68% of the total land managed by the Fort Hood Military Reservation. Current estimates indicate 176,472 ha (436,072 ac) of private, city, state, and Federal lands are dedicated to the management and conservation of natural and cultural resources and recreational opportunities throughout the breeding range, or dedicated to military training that allows for simultaneous protection and conservation of habitat (Table 8.1). Approximately 50% of this estimate is managed by Fort Hood (Table 8.1). For the purpose of this chapter, we call these properties "protected properties" as they are unlikely to be converted to other uses (e.g., residential development) in the near future. However, we must stress that not all these properties are dedicated solely to the protection or management of golden-cheeked warbler habitat; many properties have multiple uses (e.g., recreation, military training) and multiple species or habitats to manage. Managers of these lands include the USFWS, U.S. Army Corps of Engineers, Department of Defense (DOD), Texas Parks and Wildlife Department (TPWD), Lower Colorado River Authority (LCRA), County and City Parks and Preserves, and non-profit organizations. Properties are distributed throughout central Texas but with notable concentrations in Bexar, Travis, and Bell/Coryell Counties (Figure 8.1).

Table 8.1. Public and protected lands (private, city, state, Federal) within the breeding range of the golden-cheeked warbler. An asterisk denotes properties where warblers were detected between 2004 and 2009. The amount of woodland habitat ("Habitat" column) was estimated from the 2001 National Land Cover Database (NLCD) forested land cover classes, except where footnoted, and may overestimate the extent of suitable warbler habitat.

Property	County	Owner/ Manager[a]	Property size (ha)	Habitat (ha)	Source of information for property size
Region 1					
Possum Kingdom SP*	Palo Pinto	TPWD	619	574	www.tpwd.state.tx.us
Total			**619**	**574**	
Region 2					
Meridian SP*	Bosque	TPWD	205	151	www.tpwd.state.tx.us
Whitney Lake*	Bos./Hill/John.	USACE	8,498	2,185	B. Dempsey, pers. comm.
Lake Whitney SP	Hill	TPWD	386	119	www.tpwd.state.tx.us
Cleburne SP*	Johnson	TPWD	214	108	www.tpwd.state.tx.us
Dinosaur Valley SP*	Somervell	TPWD	617	437	www.tpwd.state.tx.us
Fossil Rim Wildlife Center*	Somervell	TPWD	1,214	321	www.fossilrim.org/
Total			**11,134**	**3,321**	
Region 3					
Parrie Haynes Ranch*	Bell	TPWD	1,780	1,378	www.tpwd.state.tx.us
Belton Lake	Bell	USACE	4,620	625	R. Adams, pers. comm.
Stillhouse Hollow Lake	Bell	USACE	3,578	1,593	R. Adams, pers. comm.
Mother Neff SP*	Coryell	TPWD	105	37	www.tpwd.state.tx.us
Fort Hood Military Res.*	Coryell/Bell	DOD	87,890	21,496[b]	Kostecke 2009
Waco Lake	McLennan	USACE	2,814	260	
Total			**100,786**	**25,389**	
Region 4					
Blanco SP	Blanco	TPWD	42	2.4	www.tpwd.state.tx.us
Pedernales Falls SP*	Blanco	TPWD	2,109	1,745	www.tpwd.state.tx.us
Pedernales River Nature Park*	Blanco	LCRA	90	49[b]	LCRA 2009
Lyndon B. Johnson SP & HS	Gillespie	TPWD	290	3	www.tpwd.state.tx.us
Enchanted Rock SP	Gillespie/Llano	TPWD	665	92	www.tpwd.state.tx.us
Colorado Bend SP*	Lamp./San Saba	TPWD	2,156	1,604	www.tpwd.state.tx.us
Mason Mountain WMA	Mason	TPWD	2,145	508	www.tpwd.state.tx.us
Total			**7,498**	**4,003**	
Region 5					
Inks Lake SP	Burnet	TPWD	486	250	www.tpwd.state.tx.us
Longhorn Cavern SP*	Burnet	TPWD	261	240	www.tpwd.state.tx.us
Canyon of the Eagles*	Burnet	LCRA	380	243[b]	LCRA 2009
Double Horn*	Burnet	LCRA	316	202[b]	LCRA 2007
Grelle RA*	Burnet	LCRA	186	111[b]	LCRA 2007
Hickory Creek*	Burnet	LCRA	61	40[b]	LCRA 2007
Muleshoe Bend RA*	Burnet/Travis	LCRA	399	202[b]	LCRA 2009
Turkey Bend RA*	Burnet/Travis	LCRA	405	304[b]	LCRA 2008
Balcones Canyon. NWR*	Burn./Trav./Will.	USFWS	7,740	5,742	C. Sexton, pers. comm.
Purgatory Greenspace	Hays	SMPR	188	148	www.smgreenbelt.org
Spring Lake Preserve	Hays	SMPR	102	90	www.smgreenbelt.org
Balcones Canyonlands Preserve*	Travis	COA/TC/LCRA TNC/TAS	11,539	13,057	BCP 2009
Bright Leaf Natural Area*	Travis	FOBL	87	86	www.brightleaf.org
Gloster Bend*	Travis	LCRA	322	162	LCRA 2009
Lake Georgetown*	Williamson	USACE	1,627	773	R. Adams, pers. comm.
Total			**24,100**	**21,650**	

Table 8.1 continued

Property	County	Owner/ Manager[a]	Property size (ha)	Habitat (ha)	Source of information for property size
Region 6					
Camp Bullis	Bexar	DOD	11,286	4,067[b]	USFWS 2009a
Government Canyon SNA*	Bexar	TPWD	3,490	3,192	www.tpwd.state.tx.us
Cibolo Canyon Cons. Area*	Bexar	LIC	308	289[b]	SWCA 2008
Crownridge Canyon Natrual Area*	Bexar	SAPR	86	76	www.sanantonio.gov
Eisenhower Park*	Bexar	SAPR	131	340	www.sanantonio.gov
Friedrich Wilderness Park/Woodland Hills*	Bexar	SAPR	237	205	www.sanantonio.gov
Gallagher*	Bexar	SAPR	274	250	www.sanantonio.gov
Indian Springs Cons. Area*	Bexar	ISCA	134	86[b]	SWCA 2008
Iron Horse Canyon*	Bexar	SAPR	238	215	www.sanantonio.gov
Mayberry/Hampton*	Bexar	SAPR	184	157	www.sanantonio.gov
Scenic Canyon*	Bexar	SAPR	183	182	www.sanantonio.gov
Sinkin Natural Area*	Bexar	SAPR	63	51	www.sanantonio.gov
Rancho Diana/Cedar Creek*	Bexar	SAPR	559	537	www.sanantonio.gov
Windgate/Schuchart*	Bexar	SAPR	460	421	www.sanantonio.gov
Bracken Bat Cave	Comal	BCI	283	202[b]	BCI 2008, SWCA 2008
Honey Creek SNA*	Comal	TPWD	928	577	www.tpwd.state.tx.us
Canyon Lake*	Comal	USACE	1,117	242	R. Adams, pers. comm.
Morton Tract	Comal	TPWD/Comal	117	100[b]	SWCA 2008
Guadalupe River SP*	Kendall	TPWD	785	521	www.tpwd.state.tx.us
Old Tunnel WMA*	Kendall	TPWD	7	4.6	www.tpwd.state.tx.us
Total			**20,868**	**11,715**	
Region 7					
Devil's Sinkhole SNA*	Edwards	TPWD	753	21	www.tpwd.state.tx.us
Heart of the Hills Fishery Science Center*	Kerr	TPWD	23	46	www.tpwd.state.tx.us
Kerr WMA*	Kerr	TPWD	2,628	1,027	www.tpwd.state.tx.us
Kerrville-Schreiner Park	Kerr	City of Kerrville	209	138[b]	www.kerrville.org
South Llano River SP	Kimble	TPWD	212	28	www.tpwd.state.tx.us
Walter Buck WMA*	Kimble	TPWD	872	424	www.tpwd.state.tx.us
Total			**4,697**	**1,684**	
Region 8					
Love Creek Preserve*	Bandera	TNC	567	400[b]	www.nature.org
Hill Country SNA*	Bandera/Medina	TPWD	2,173	1,197	www.tpwd.state.tx.us
Lost Maples SNA*	Bandera/Real	TPWD	880	780	www.tpwd.state.tx.us
Kickapoo Cavern SP*	Kinney/Edwards	TPWD	2,577	363	www.tpwd.state.tx.us
Garner SP*	Uvalde	TPWD	575	206	www.tpwd.state.tx.us
Total			**6,772**	**2,946**	
Breeding range total (ha)			**176,472**	**71,282**	
Breeding range total (ac)			**436,072**	**176,142**	

[a] Ownership acronyms: BCI = Bat Cave International; COA = City of Austin; DOD = Department of Defense; FOBL = Friends of Bright Leaf; ISCA = Indian Springs Conservation Association, Inc.; LCRA = Lower Colorado River Authority; LIC = Lumberman's Investment Corporation; SAPR = City of San Antonio Parks and Recreation; SMPR = San Marcos Parks and Recreation; TAS = Travis Audubon Society; TC = Travis County; TNC = The Nature Conservancy; TPWD = Texas Parks and Wildlife Department; USACE = U.S. Army Corps of Engineers; USFWS = U.S. Fish and Wildlife Service

[b] Amount of habitat within the property was acquired from the noted source of information rather than calculated from the 2001 NLCD forest cover classification.

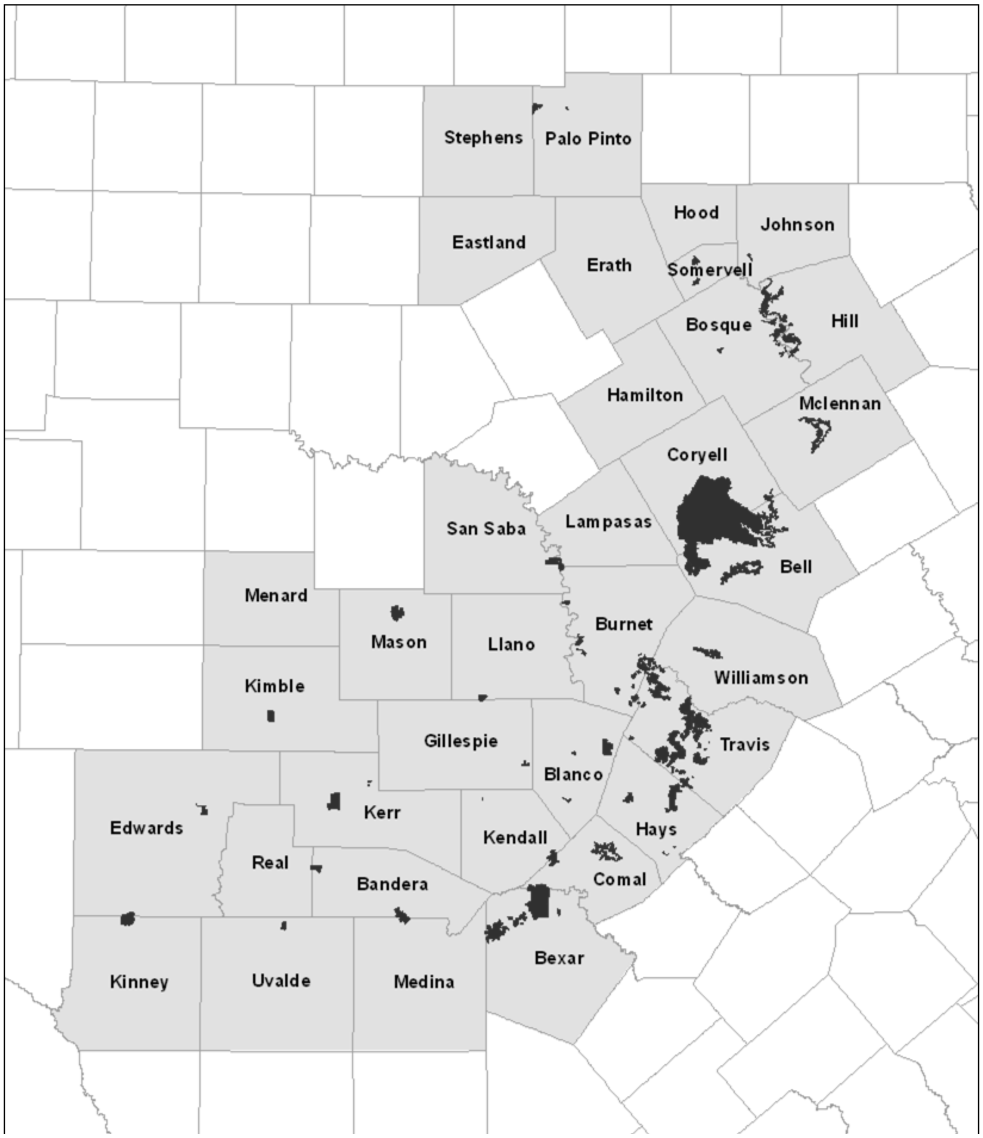

Figure 8.1. Distribution of most public and protected lands within the breeding range of the golden-cheeked warbler.

To estimate the extent of potential warbler habitat within each protected property, we used the National Landcover Database (i.e., 2001 NLCD) woodland cover classifications (Homer et al. 2007, see Chapter 6 for details) clipped to each property boundary, unless an estimate of potential habitat was available through agency reports. Golden- cheeked warbler habitat is likely a subset of the woodland cover classification (see Chapter 7). The 2001 NLCD estimates, representing circa 2001 satellite imagery, and various agency estimates indicate 71,282 ha (176,142 ac) of known and potential warbler habitat occur within these protected properties (Table 8.1).

Based on the 2001 NLCD estimates of woodland cover in the breeding range, approximately 4% of the area classified as woodland is found within protected areas, with the highest percentages of protected land occurring in Recovery Region 3 and 5 (Table 8.2). Golden-cheeked warbler habitat (i.e., mixed juniper-oak woodlands) comprises a subset of the 2001 NLCD woodland cover class; however, since we used 2001 NLCD to calculate amount of woodland for both protected areas and non- protected areas in the breeding range, the ratio of protected to total habitat specific to juniper-oak woodlands is likely to be similar.

Department of Defense

Two DOD military reservations are located within the breeding range of the golden-cheeked warbler: Fort Hood Military Reservation and Camp Bullis Training Site. Fort Hood Military Reservation encompasses 87,890 ha (217,180 ac) of land in eastern Coryell and western Bell Counties in Recovery Region 3 (see Chapter 7 for a map of Recovery Regions), of which approximately 24,340 ha (60,145 ac) is considered warbler habitat (Table 8.1; Summers 2009). The 11,286-ha (27,887-ac) Camp Bullis Training Site in northern Bexar County contains approximately 4,067 ha (10,050 ac) of warbler habitat (USFWS 2009a). Extensive year-round training of U.S. troops on both military bases includes maneuver training, live-fire training, and aviation training and may result in incidental take of the species as defined in the Endangered Species Act of 1973, as amended (ESA; USFWS 2005, Cornelius et al. 2007). Endangered Species Management Plans (ESMP) exist, unique to each base, to assist with minimizing impacts to the training missions while achieving ESA regulations for threatened and endangered species occurring on the bases. All activities that may result in permanent alteration of the habitat are subject to certain regulations; training activities are further restricted in duration and magnitude in "core" habitat areas (Thompson and Schlatter 2005, Cornelius et al. 2007). Protection, management, and research objectives include the aforementioned restrictions along with supporting minimum carrying capacities and monitoring population status and factors affecting the populations (Thompson and Schlatter 2005, Cornelius et al. 2007). Fort Hood intends to maintain an installation carrying capacity of 2,000 territorial warbler males, estimated to require a minimum of 8,520 ha (21,053 ac) of habitat (Cornelius et al. 2007). The objective at Camp Bullis is to maintain a "minimum carrying capacity equal to the historic average installation-wide density of 7 singing males per 100 ha (247 ac) of habitat" (Thompson and Sclatter 2005).

Army Corps of Engineers

The U.S. Army Corps of Engineers, administered by DOD, manage over 22,000 ha (>54,363 ac) in 6 counties within the breeding range, encompassing an estimated 4,905 ha (12,120 ac) of potential habitat (Table 8.1). Although warbler-specific management plans have not yet been developed for these properties, management is based on the 1992 Recovery Plan (USFWS 1992) and focuses primarily on avoiding or minimizing adverse impacts to the birds or habitat (R. Adams, personal communication). Activities that may affect warblers or warbler habitat are subject to habitat assessments and possible consultation with USFWS (R. Adams, personal communication).

U.S. Fish and Wildlife Service

Balcones Canyonlands National Wildlife Refuge (BCNWR) was established in 1992 as part of a larger conservation strategy in the Austin area focused on the preservation and restoration of habitat for the golden-cheeked warbler, black-capped vireo, and other endangered, threatened, and candidate species of the Edwards Plateau (USFWS 2001). USFWS intends for the BCNWR to ultimately encompass 32,375 ha (80,000 ac) of land in Burnet, Travis, and Williamson Counties; approximately 7,740 ha (19,125 ac) have been acquired thus far from willing sellers in the 3 counties (C. Sexton, personal communication). Lands within the original acquisition

Table 8.2 Percent of golden-cheeked warbler habitat contained within protected areas in each Recovery Region relative to (1) the extent of possible habitat in each Region, and (2) the overall extent of habitat in the breeding range.

Recovery Region	**Estimated protected area (ha)**	**2001 NLCD Woodland Cover (ha)**	**% protected land within each Region**[a]	**% protected land relative to total woodland**[b]
1	574	183,372	0.31	0.03
2	3,321	201,707	1.65	0.17
3	25,389	205,283	12.37	1.32
4	4,003	315,374	1.27	0.21
5	21,650	290,039	7.46	1.13
6	11,715	181,354	6.46	0.61
7	1,684	232,880	0.72	0.09
8	2,946	309,283	0.95	0.15
Breeding range (ha)	71,282	1,919,293	-	3.71
Breeding range (ac)	176,142	4,742,674	**-**	3.71

[a] Calculated by dividing the amount of protected land within a Recovery Region by the amount of 2001 NLCD woodland cover for the same Recovery Region, multiplied by 100 for percentage.
[b] Calculated by dividing the amount of protected land within a Recovery Region by the amount of 2001 NLCD woodland cover for the breeding range (i.e., 1,919,293 ha), multiplied by 100 for percentage.

boundary (18,616 ha [46,000 ac]) would protect an estimated 7,082 ha (17,500 ac) of warbler habitat (USFWS 2001). The National Wildlife Refuge System Improvement Act of 1997 (Public Law 105-57, 9 October 1997) defines their mission as administering "a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitat within the United States for the benefit of present and future generations of Americans." Warbler habitat within the BCNWR is protected, restored, and enhance where appropriate through a variety of means, including protecting juniper-oak woodlands from wildfires, reduce browsing through deer herd management, monitoring oak wilt centers, and constraints on public use (USFWS 2001). Research and educational opportunities are also provided. The Refuge also maintains contact with land managers and agencies that are focused on important areas of migration and wintering habitat with the intent of coordinating research and monitoring activities (USFWS 2001).

The Land and Water Conservation Fund (LWCF) Act of 1965 provides funds to the National Park Service, Bureau of Land Management, USFWS, and U.S. Forest Service for the purchase of lands for parks, open space, and outdoor recreation. The LWCF is the principal source of funds for BCNWR to acquire additional lands (Vincent 2006). Total LWCF appropriations to the USFWS have decreased steadily since 2001, from $121 million in FY2001 to $34.6 million in FY2008 (Vincent 2006, Vincent et al. 2008). USFWS has an additional source for land acquisition through the Migratory Bird Conservation Account (Vincent et al. 2008), which is supported with revenues from a variety of sources, such as refuge entrance fees.

Texas Parks and Wildlife Department

The mission of the TPWD is to "manage and conserve the natural and cultural resources of

Texas and to provide hunting, fishing and outdoor recreation opportunities for the use and enjoyment of present and future generations" (TPWD 2010). TPWD oversees 28 state parks, natural areas, fish hatcheries, and wildlife management areas in the breeding range, covering 27,692 ha (68,428 ac) of the protected lands in the range (Table 8.1). The 2005 Texas Wildlife Action Plan (TPWD 2005) provides guidance for research and management aimed at species of conservation need, including the golden-cheeked warbler. Guidelines include the protection and enhancement of habitat, promoting research on the breeding and wintering grounds (through partnership with Universidad Autónoma de Nuevo León), and extensive education of and coordination with private landowners to further the management of sensitive species and habitat beyond the borders of TPWD lands (TPWD 2005).

City of Austin and Travis County

The Balcones Canyonlands Preserve (BCP) system was established by the Balcones Canyonlands Conservation Plan (BCCP, finalized in 1996) to provide mitigation for incidental take in Travis County and protect the golden-cheeked warbler and 7 other locally endangered species (BCP 2009; see Habitat Conservation Plans below for details on the BCCP). The BCP currently encompasses 11,539 ha (28,513 ac) of protected land in Travis County west of I-35, with the goal of assembling a minimum of 12,314 ha (30,429 ac; BCP 2009). City of Austin owns and manages 5,497 ha (13,584 ac) within the BCP while Travis County manages 1,872 ha (4,627 ac). LCRA is a Managing Partner and manages 1,095 ha (2,707 ac) within the BCP (BCP 2009). Although not considered Managing Partners, The Nature Conservancy (TNC) of Texas and the Travis Audubon Society also manage 1,717 ha (4,244 ac) and 275 ha (680 ac) of land, respectively, within the BCP (BCP 2009). An additional 1,081 ha (2,671) of the BCP are under private management (BCP 2009).

The management goal is to purchase or otherwise protect 5,563 ha (13,746 ac) of potential warbler habitat and manage the habitat to maintain or increase the warbler population in the BCP (BCP 2007a). "Management will focus on increasing occupancy and productivity of warblers in order to maintain a source population within the preserve" (BCP 2007a). City of Austin, Travis County, and the other managing agencies and organizations annually monitor warbler populations, predators, parasites, and hardwood stand replacement (through oak wilt and white-tailed deer surveys), along with implementing outreach and educational programs (BCP 2007a). Habitat is maintained, enhanced, or created through minimizing human use and impact, encouraging hardwood regeneration by protecting against oak wilt and overbrowsing, and maintaining canopy cover of $\geq$ 50% (BCP 2007a).

San Antonio Parks and Recreation

Approximately 6,059 ha (14,972 ac) of parks and natural areas in northern Bexar County are maintained by the San Antonio Parks and Recreation Department (San Antonio Parks and Recreation [SAPR] 2005; Table 8.1). Several properties harbor golden-cheeked warblers (J. Neal, personal communication) and the natural areas are specifically geared toward protecting sensitive environments. Although no official management plan exists for SAPR specific to the golden-cheeked warbler, a number of management activities occur on properties containing warbler habitat: annual monitoring of warbler populations and habitat quality, protection and enhancement of warbler habitat (primarily through promoting hardwood recruitment and growth), and offering environmental programs (J. Neal, personal communication).

Lower Colorado River Authority
LCRA, a nonprofit public utility, manages numerous developed parks, recreation areas, and natural resource areas along the Lower Colorado River. Eight of their properties encompass warbler habitat in Blanco, Burnet, and Travis County (Table 8.1), covering 2,159 ha (5,335 ac) in the breeding range and containing approximately 1,300 ha (3,212 ac) of warbler habitat (LCRA annual reports 2007–2009). An additional 5 properties (1,095 total ha [2,707 ac]) are part of the BCP in Travis County (BCP 2009). Warbler surveys and monitoring occur annually, with a focus in areas that may be disturbed by human recreational activities. Public use is restricted on some properties. Habitat is maintained, enhanced, or restored when possible and oak wilt spread is monitored (LCRA annual reports 2007–2009).

Additional protected areas
Additional private and nonprofit organizations own and manage property with the goal of protecting and maintaining habitat for the warbler. TNC manages 2 preserves in the warbler's breeding range, including the 1,717-ha (4,244-ac) Barton Creek Habitat Preserve in Travis County and the 567-ha (1,400-ac) Love Creek Preserve in Bandera County (TNC 2008a). Management goals at Barton Creek Habitat Preserve include restoring streamside woodlands that were logged in the early 1900s in an effort to increase warbler habitat in the Preserve (TNC 2008b). The Austin Community Foundation owns Bright Leaf Nature Preserve in Travis County, a 87-ha (215-ac) property focused on conserving and enhancing warbler habitat and promoting public education and awareness of the species (J. Mahan, personal communication). Bracken Cave and Nature Reserve in Comal County is a 283-ha (700-ac) reserve owned by Bat Conservation International (BCI); part of their management strategy, besides protecting the cave and its large colony of Mexican free-tailed bats (*Tadarida brasiliensis*), is to preserve juniper thickets in their historic locations along rocky ridges and ravines while thinning dense juniper on flatland areas (BCI 2008).

8.1.2 Migration and Wintering Range

There are numerous protected areas along the Sierra Madre Oriental of eastern Mexico and into Central America, including United Nations Educational Scientific and Cultural Organization (UNESCO) biosphere reserves, national parks, and nature parks (Fig. 8.2; UNESCO 2010, World Database on Protected Areas 2010). Properties range in size from 1,100 to >383,000 ha (2,700 to 946,400 ac; Table 8.3) and are primarily managed by the governments of the respective countries (UNESCO 2010).

We found no data regarding the amount of potential golden-cheeked warbler stopover habitat in the reserves and parks along the Sierra Madre Oriental. In general, the reserves and parks along the migration route (Table 8.3) consist of terrestrial ecosystems that have not been significantly altered by human activities, although they are inhabited by native and rural communities that are allowed some form of resource extraction (Valdez et al. 2006). The National Commission of Natural Protected Areas (Comisión Nacional de Areas Naturales Protegidas [CONANP]) is responsible for the protection, restoration, and sustainable use of the resources within the reserves and parks, although their efforts are often hampered by lack of funding, lack of institutional capacity, and lack of trained personnel (Valdez et al. 2006). The stability and longevity of some of the protected areas is uncertain due to lack of meaningful compensation or benefits to private individuals that still own and manage the land (Santana 2005). Non-governmental organizations (NGOs) have played major roles in recent years with regards to purchasing and managing wildlife habitats, acquiring conservation easements, and establishing buffer zones in cooperation with Federal, state, and local governments and communities in Mexico (Valdez et al. 2006).

Specific to the warbler's wintering range of southern Mexico and Central America, the Alliance for the Conservation of Mesoamerican Pine-Oak Forests (Alianza para la Conservación de los Bosques de Pino-Encino de Mesoamérica [ACMPOF]) estimated that of the 1,950,972 ha (4,820,957 ac) of potential habitat, approximately 144,889 ha (358,029 ac), or 7.4%, are in protected areas (ACMPOF 2008). Public or otherwise protected areas within southern Mexico and Guatemala are administered by CONANP and Consejo Nacional de Áreas Protegidas, respectively, and focus on sustainable agriculture, fire prevention, and ecotourism (UNESCO 2010). The national parks in Honduras are administered by National Institute of Conservation and Forests, Protected Areas and Wildlife Development (Instituto Nacional de Desarrollo y Conservación, Forestal, de las Áreas Protegidas y la Vida Silvestre) and are ideally protected from logging, agriculture, and exploitation (U.S. Agency for International Development [USAID] 2009). The National System of Protected Areas (Sistema Nacional de Áreas Protegidas) is the administrator for the Nicaraguan national parks (Weaver et al. 2003) while the Ministry of Natural Resources and the Environment (Ministerio de Medio Ambiente y Recursos Naturales) manages the listed park in El Salvador (Table 8.3; Komar 2002). Additional areas are managed by several NGOs (Weaver et al. 2003, Valdez et al. 2006, USAID 2009).

Table 8.3. Major parks and reserves located within the migration and wintering ranges of the golden-cheeked warbler. The amount of warbler habitat in these properties is not known. An asterisk denotes properties with known warbler occurrence. Data are from United Nations Educational Scientific and Cultural Organization (UNESCO 2010) and World Database on Protected Areas (WDPA 2010).

Property name	Size (ha)	Country
Migration		
Barranca de Metztitlan Biosphere Reserve	96,043	Mexico
Cumbres de Monterrey National Park	177,395	Mexico
El Cielo Biosphere Reserve*	144,531	Mexico
Sierra Gorda Biosphere Reserve	383,567	Mexico
Wintering		
Montecristo National Park*	2,000	El Salvador
Sierra de las Minas Biosphere Reserve*	236,626	Guatemala
Celaque National Park	26,640	Honduras
Cerro El Uyuca Biological Reserve*	1,138	Honduras
Cusuco National Park*	23,440	Honduras
Pico Pijol National Park	12,210	Honduras
El Triunfo Biosphere Reserve	119,177	Mexico
La Sepultura Biosphere Reserve	167,310	Mexico
Lagunas de Montebello National Park*	6,411	Mexico
Cerro Tisey-Estanzuela Nature Reserve	6,400	Nicaragua
Cordillera Dipilto y Jalapa Nature Reserve	42,200	Nicaragua

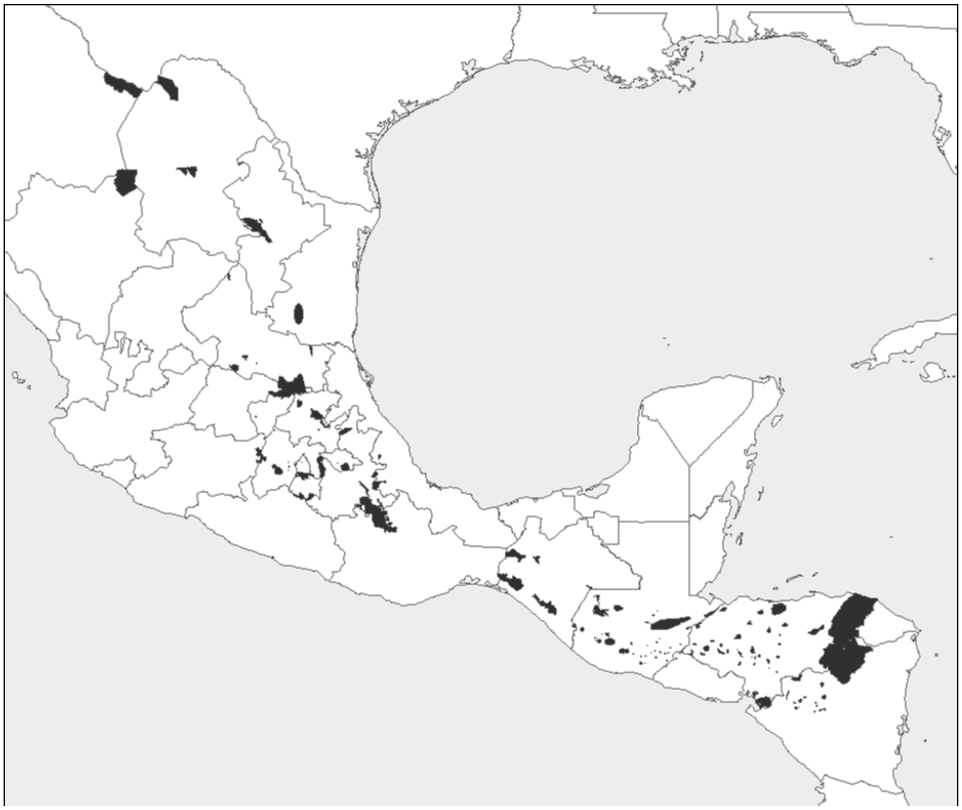

Figure 8.2. Distribution of public and protected lands occurring within or near the Sierra Madre Oriental (migration area) and the pine-oak ecoregion of southern Mexico and Central America (wintering grounds). The map focuses on the primary countries in the winter range: Mexico, Guatemala, Honduras, El Salvador, and Nicaragua. The amount of warbler habitat within the protected areas is unknown.

8.2 Conservation Tools

A variety of conservation programs and incentives exist to encourage and assist landowners with management activities that benefit endangered or threatened species. With more than 94% of the state in private ownership (TPWD 2005), conservation and management of golden-cheeked warblers on private lands in Texas is important for the recovery of the species.

8.2.1 Habitat Conservation Plans

Non-Federal landowners, who wish to conduct activities on their land that may result in the "take" of threatened or endangered wildlife or habitat must obtain an incidental take permit (i.e., section 10(a)(1)(B) permit) from the USFWS so as to comply with the Endangered Species Act (ESA). The ESA defines take as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." "Harm" includes destruction or modification of a listed species' habitat that may kill or injure the species through impairing its ability to breed, feed, or take shelter (USFWS 2009b). A habitat conservation plan (HCP) is required as part of an application for an incidental take permit, the purpose of which is to describe the effects of the incidental take and how the landowner or corporation will minimize or mitigate impacts (Hsu 1998). The ESA defines incidental take as take that is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity." Thus, the HCP process allows development to occur provided there is also a conservation benefit to the covered species (USFWS 1996b). Since 1990, over 90 incidental take permits have been requested, and corresponding HCPs produced, for residential, commercial, and utility development in warbler habitat (Table 8.4). Approximately 70 of the permits are still active. Federal Register (FR) documents that discussed the incidental take permits reported an estimated 3,660 ha (9,044 ac) of habitat would be lost or impacted by the permitted activities (Table 8.4; FR volumes 59–73). Applicants included private individuals and corporations and permit durations ranged from 1 to 30 years. Nearly half of the permits dealt with affected areas of <5 ha (<12 ac; totaling about 48 ha [119 ac]) and proposed to pay $1,500 per residence toward acquiring habitat offsite for mitigation (mostly into the Balcones Canyonlands Conservation Fund). The remaining permits allowed for multiple development projects over larger areas. In total, the HCPs proposed contributions of over $2.4 million for the acquisition and management of warbler habitat (mostly in Travis County) and proposed placement of approximately 3,583 ha (8,854 ac) of warbler habitat into permanent preservation.

Regional habitat conservation plans (RHCP) often cover a large geographic area, numerous landowners, and multiple species and rely on local or regional authorities to implement the plan (USFWS 1996b). Several RHCPs have been developed for counties along the I-35 corridor, although USFWS will continue to process applications for individual incidental take permits for those who choose not to participate in the RHCPs. RHCPs allow a broad-scale approach to ESA permitting that could result in more effective and coordinated preservation and management of larger areas of habitat.

The BCCP is a regional HCP that was created to assist Travis County landowners in complying with the requirements of the ESA and provides a voluntary, streamlined alternative to obtaining an incidental take permit from the USFWS (BCP 2009). The regional permit was issued jointly to the City of Austin and Travis County in 1996. The permit area covers Travis County, where an estimated 12,140–24,280 ha (30,000–60,000 ac) of land would be developed over the 30-year permit period, reducing warbler habitat by 71% in the county (USFWS 1996c). The BCP (described above) was established by the BCCP to provide mitigation for incidental take. Ultimately, the goal is to set aside a minimum of 12,314 ha (30,429 ac) in western Travis County as habitat for the golden-cheeked warbler and 7 additional endangered species (BCP 2009). The BCCP stipulates that at least 2 golden-cheeked warbler populations should be protected in the Travis County area – one in the BCNWR and one in the BCP – based on the idea that a catastrophe such as wildfire could completely destroy 1 population (USFWS 1996c).

Williamson County likewise developed a RHCP that was finalized in 2008. The permit intends to cover incidental take of up to 2,428 ha (6,000 ac) of warbler habitat within Williamson County over a 30-year period (SWCA 2008). The RHCP proposed to preserve and manage in perpetuity 2,428 ha (6,000 ac) of warbler habitat in large, unfragmented blocks as mitigation. However, at the time the permit was issued, the RHCP had identified mitigation for only 451 ha (1,115 ac) of impact through purchasing mitigation credits from the Hickory Pass Ranch Conservation Bank

Table 8.4. Summary of habitat conservation plans (HCPs)[a] for the golden-cheeked warbler by county and applicant type from 1993 through 2008. Data are from Federal Register volumes 59–73 and the USFWS Conservation Plans and Agreements Database.

County	Applicant type	No. of HCPs	Payment[c]	Preserved land (ha)[d]	Mitigation credits[e]
Bell/Coryell	Corporation	1	1,690,000	-	-
Bexar	Corporation	1	-	308	-
Bexar/Kendall	Corporation	1	-	29	-
Burnet	Corporation	1	300,000	8	-
Hays	Corporation	1	-	-	8
Travis	Private individual	39	111,500	39	-
	Corporation	30	373,250	3,102	-
Williamson	Private individual	4	6,000	-	332
	Corporation	3	-	97	39
TOTAL			**$2,480,750**	**3,583**	**379**

[a] Summary does not include Regional Habitat Conservation Plans.
[b] All payments, preserved land, and mitigation credits were proposed actions in the HCPs and may not be fully implemented at the time of this writing.
[c] Payment made into an established conservation fund or bank, typically the Balcones Canyonlands Conservation Fund.
[d] Preserved hectares of habitat through land acquisition or conservation easement.
[e] Number of mitigation credits the applicant proposed to purchase; typically, 1 credit = 1 acre = 0.40 ha.

(see Conservation Banks below) in Burnet County and purchasing the Whitney Tract in Williamson County. No additional take of golden-cheeked warbler habitat would be authorized under the RHCP until commensurate mitigation is provided in the form of preserves or conservation banks in the County or additional mitigation credits are available outside of the County (SWCA 2008).

Both Hays and Comal Counties have separate county-wide RHCPs (Loomis Partners 2009, SWCA 2009) and the plans are currently under review by USFWS. An estimated loss of 8,900 ha (22,000 ac) of warbler habitat could occur in Hays County over the next 30 years (Loomis Partners 2009); thus, the RHCP requests an authorized take of 3,642 ha (9,000 ac). The Hays County RHCP proposes a phased conservation banking approach to ultimately acquire 4,047–6,070 ha (10,000–15,000 ac) of preserve land over the 30-year period of the RHCP and maintain the land in perpetuity, with the understanding that not all land in the preserve would be warbler habitat (Loomis Partners 2009). Mitigation must be provided before an equivalent amount of take authorization can be issued (Loomis Partners 2009). Approximately 75% of the preserve system will be acquired through conservation easements while the remaining 25% will be purchased by the County fee simple and managed by the County (Loomis Partners 2009). Although the size, location, and configuration of the preserve system is not yet determined, the goal is to assemble large, contiguous tracts of land with any single preserve in the system a minimum size of 200 ha (500 ac; Loomis Partners 2009).

The Comal County RHCP anticipates a loss of 4,240 ha (10,477 ac) of breeding habitat to development over the life of the permit (i.e., 30 years) and requests a permitted incidental take of 2,120 ha (5,239 ac) based on an anticipated RHCP participation rate of 50% (SWCA 2009). Mitigation would involve establishing approximately 2,613 ha (6,457 ac) of preserves or conservation banks in the County, which would be managed in perpetuity by Comal County (SWCA 2009). As with the Hays County RHCP, take for the warbler will be authorized only when the County has acquired sufficient mitigation credits to cover the take (SWCA 2009). Preserves that would generate conservation credits for the RHCP would be established through fee simple purchase of habitat, public/private cooperation (e.g., conservation easements), and private conservation banks (SWCA 2009).

Bexar County and the City of San Antonio are in the early stages of developing a RHCP, titled the Southern Edwards Plateau Habitat Conservation Plan. The RHCP will cover incidental take of golden-cheeked warbler habitat and other endangered species over multiple counties, including all or parts of Bandera, Bexar, Blanco, Comal, Kendall, Kerr, and Medina Counties (Loomis Partners 2010).

8.2.2 Section 6 Grants

The Cooperative Endangered Species Conservation Fund (authorized by the ESA and administered by USFWS) "provides grants to States and Territories to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species." (USFWS 2009c). The funds may then be awarded to private individuals for conservation projects for the purpose of species and habitat conservation actions on non-Federal lands (USFWS 2009c).

Four grant programs are available through the Cooperative Endangered Species Conservation Fund; the "Traditional" Conservation Grants and the "Nontraditional" Habitat Conservation Planning Assistance Grants, HCP Land Acquisition Grants, and Recovery Land Acquisition Grants (Appendix 8.A). Conservation Grants are awarded for conservation projects focused on listed and at-risk species. "Funded activities include habitat restoration, species status surveys, public education and outreach, captive propagation and reintroduction, nesting surveys, genetic studies, and development of management plans" (USFWS 2009c). Habitat Conservation Planning Assistance Grants "provide funds to support the development of HCPs through support of baseline surveys and inventories, document preparation, outreach, and similar planning activities." HCP Land Acquisition Grants provide funding to acquire land associated with approved HCPs, supporting conservation actions by State or local governments or non-governmental organizations that complement mitigation. Recovery Land Acquisition Grants provide funds for the acquisition of habitat for endangered and threatened species in support of draft and approved recovery plans (USFWS 2009c). As of this writing, \$3,711,602, \$29,751,294, and \$2,663,812 have been awarded through the Habitat Conservation Planning Assistance Grants, HCP Land Acquisition Grants, and Recovery Land Acquisition Grants, respectively, to specifically benefit the golden-cheeked warbler (USFWS 2010; Table 8.5). An additional \$3,500,000 was awarded to projects for the protection of other species, although warbler habitat was also protected through these projects (Table 8.5).

Table 8.5. Section 6 Grants that provide protection for or otherwise benefit the golden-cheeked warbler, by year and grant program. Data are from the U.S. Fish and Wildlife Service.

Year	Habitat Conservation Planning Assistance Grants	Habitat Conservation Plan Land Acquisition Grants	Recovery Land Acquisition Grants
2003		(1) Balcones Canyonlands Conservation Plan (Travis Co.): purchase tracts within an area of 283 ha (700 ac) that provide habitat for golden-cheeked warblers. $4,993,794 (2) Bexar County Karst Invertebrate Habitat Preserve (Bexar Co.): acquire 346 ha (855 ac) around La Cantera's Canyon Ranch Karst Preserve that also harbors the warbler. $3,500,000	
2004	Williamson County Regional Habitat Conservation Plan (RHCP): used to finalize Williamson County's Habitat Conservation Planning effort. Williamson RHCP will aid in the conservation and recovery of golden-cheeked warblers and other listed species. $1,005,000	Balcones Canyonlands Preserve (Travis Co.): for the acquisition of new preserve tracts vital for the ecological viability of the BCP, including golden-cheeked warbler habitat. $3,375,000	Land acquisition in Dogwood Canyon (Dallas Co.): acquire 9.7-ha (24-ac) that will provide high quality breeding habitat for golden-cheeked warblers; part of a larger project to protect 101 ha (250 ac) of Dogwood Canyon for the benefit of the warbler and other species. $286,500
2005	Hays County RHCP: assist with development of a RHCP to permanently protect golden-cheeked warbler and black-capped vireo habitat. $753,750	Balcones Canyonlands Preserve, Lucas Tract (Travis Co.): protect 57 ha (140 ac) of habitat for the golden-cheeked warbler and black-capped vireo. $6,890,000.	Cobb Preserve, Clark Lyda Tract (Williamson Co.): protect 26 ha (65 ac) for the benefit of golden-cheeked warblers and other species. $725,000
2006	Comal County RHCP: assist with initiating a RHCP for the golden-cheeked warbler and black-capped vireo. $612,852	Cibolo Canyonlands Golden-cheeked Warbler Land Acquisition (Comal Co.): assist TNC and City of San Antonio in the purchase of golden-cheeked warbler habitat to complement the Cibolo Canyon HCP. $3,500,000	Sink Creek Watershed and Recharge, San Marcos Springs (Hays Co.): acquire 101 ha (250 ac) for the benefit of golden-cheeked warblers and other species. $1,000,000
2007		Balcones Canyonlands Preserve/Purcell Tract (Travis Co.): purchase and protect 7.1 ha (17.6 ac) of habitat adjacent to the BCP. $5,742,500	Morton Golden-cheeked Warbler Preserve (Comal Co.): preserve through fee title purchase the 116.5-ha (288-ac) Morton tract to benefit the warbler on-site. $652,312
2008		Balcones Canyonlands Preserve/Purcell Tract (Travis Co.): purchase 2 tracts (2.3 and 0.5 ha [5.6 and 1.2 ac]) within the Balcones Canyonlands to protect habitat, land is adjacent to the BCP. $5,250,000	
2009	Southern Edwards Plateau HCP: assist with developing a RHCP across several counties to protect habitat for warblers and other listed species. $1,340,000		

8.2.3 Conservation Banks

Conservation banks are permanently protected lands managed for the benefit of endangered or threatened species, candidate species, or at-risk species. In exchange for this permanent protection and management the landowner can, with USFWS approval, sell "credits" to developers who need to compensate for adverse impacts to a listed species (USFWS 2009d). Through this process landowners can generate income from their property while keeping large tracts of land intact. A long-term monitoring and management plan and funding sources to implement the plan are required of the landowner; the landowner must also grant a conservation easement to a third party (e.g., public agency, nonprofit organization) and agree to certain land use restrictions (USFWS 2009d).

As of this writing, the Hickory Pass Ranch Conservation Bank is the only conservation bank that exists for the benefit of the golden-cheeked warbler. The conservation bank was established in 2002 through an agreement between Hickory Pass, L.P., and the USFWS (Hickory Pass and USFWS 2002). Hickory Pass, L.P., owns approximately 1,215 ha (3,003 ac) of land in Burnet and Travis Counties and agreed to ultimately place the entire property under a conservation easement with the resource values being sold as mitigation credits (Hickory Pass and USFWS 2002). In 2002, SWCA estimated the property could support 80–100 golden-cheeked warbler territories (Hickory Pass and USFWS 2002). Approximately 1,058 ha (2,616 ac) have been donated thus far to the BCNWR (C. Sexton, personal communication).

Two additional conservation banks are currently under development for the benefit of golden-cheeked warblers: Clearwater Ranch Conservation Bank and Bandera Canyonlands Corridor Conservation Bank. Clearwater Ranch comprises 8,621 ha (21,303 ac) of contiguous property in Burnet County, of which 5,033 ha (12,437 ac) is considered potential warbler habitat (Loomis Partners 2009). The majority of potential habitat occurs in large (>200 ha [>494 ac]) patches (Loomis Partners 2009). As of this writing, the landowner is negotiating with USFWS about the service area for the bank (M. Taylor, personal communication). The Bandera Canyonlands Corridor Conservation Bank seeks to assemble 2,428 ha (6,000 ac) of land containing a high portion of warbler habitat in western Bandera County, with the potential of adding 1,618–2,023 ha (4,000–5,000 ac) at a later date (B. Armstrong, personal communication). The conservation bank would consist of several properties averaging 480–560 ha (1,200–1,400 ac) in size (B. Armstrong, personal communication).

8.2.4 Recovery Credit System

The Recovery Credit System (RCS) is a recent policy innovation aimed at conserving and enhancing endangered species habitat by providing incentives for private landowners to implement conservation actions on their properties (Wilkins et al. 2009b). It provides an option for Federal agencies to offset actions that impact endangered species through the creation of a partnership between the agency and private landowners. The RCS uses a reverse auction in which private landowners submit bids for the cost of habitat management and enhancement on their properties for a specified period of time (Wilkins et al. 2009b). The amount and recovery benefit of the conserved habitat on the private properties are converted to credits that can be used by the partnered Federal agency to mitigate for future incidental take on the Federal property (73 FR 44761). The RCS recently finalized a 3-year "proof of concept" project for the golden-cheeked warbler, which was implemented on private lands near Fort Hood, Texas (Robertson

Consulting Group 2010). During this project, 5,608 ha (13,858 ac) of private land was enrolled in the program, with 890 ha (2,200 ac) of occupied habitat now being conserved, enhanced, and expanded with contracts ranging from 10 to 25 years (B. Hays, personal communication). Contract duration depended on the mitigation needs on Fort Hood, whether for short-term use of an area for training purposes or long-term use to compensate for thinning or clearing of habitat on site (Wilkins et al. 2009b). Based on this RCS pilot project, USFWS published guidance for for Federal agencies to follow when developing a RCS (73 FR 44761).

8.2.5 Safe Harbor Agreements

The Safe Harbor concept was developed by Environmental Defense Fund (EDF) and the USFWS in 1995 to encourage private landowners to restore and maintain habitat for endangered species through assurances that their voluntary actions will not result in future land-use restrictions (60 FR 10400). Safe Harbor Agreements are voluntary agreements between non-Federal landowners and the USFWS, the terms of which permit incidental taking of the covered species at some point in the future on the landowner's property (62 FR 32178). For example, if the covered species increase in abundance on the property due to the landowner's voluntary management activities, the landowner would not be required to maintain this higher number of individuals or the voluntary management activities. The landowner would, however, have to maintain the baseline habitat conditions that existed on the property prior to the Safe Harbor Agreement (62 FR 32178). Landowners interested in the Safe Harbor option in the Texas Hill Country can develop an agreement directly with USFWS or develop one with EDF acting as an intermediary. In 2000, EDF received an Enhancement of Survival Permit (Safe Harbor) under section 10(a)(1)(A) of the ESA with the intent to encourage private landowners to voluntarily create, enhance, or restore golden-cheeked warbler or black-capped vireo habitat in the Texas Hill Country. Under the permit, EDF can issue Certificates of Inclusion to landowners who agree to carry out habitat improvements for warblers or vireos. The issued permit covers 37 counties in the warbler and vireo's breeding range for 30 years. These Cooperative Agreements stipulate that habitat improvements be maintained on the property for at least 4 consecutive breeding seasons, after which the landowner may, within certain parameters, "conduct otherwise lawful activities on their property that result in the partial or total elimination of the restored habitat and the incidental taking of either of these endangered species as a result of such habitat elimination" (USFWS 2000). To date, there are 2 landowners (total of 42 ha [103 ac]) with Safe Harbor Cooperative Agreements specific to the golden-cheeked warbler (D. Wolfe, personal communication).

8.2.6 Additional Incentive Programs

Several incentive programs exist that can assist private landowners with restoring or managing warbler habitat on their properties. Although these programs are not focused solely on golden-cheeked warblers, it is important to note that such programs are in place for landowners interested in managing their property for warbler habitat. Through the Landowner Incentive Program (LIP), TPWD provides technical and financial assistance to landowners who aim to create, restore, protect, and enhance habitat for rare and endangered species on their properties (TPWD 2009). The LIP is a competitive grant program in which landowners submit proposals for intended management actions. Proposals are ranked, in part, on the extent to which the proposed actions benefit the targeted species, balanced against the cost effectiveness of the proposed action (TPWD 2009).

The Wildlife Habitat Incentives Program (WHIP), administered by the Natural Resources Conservation Service (NRCS), provides financial and technical assistance landowners to develop and improve wildlife habitat on private lands, usually for the duration of 5 to 10 years (NRCS 2009). As with LIP, WHIP is a competitive grant program, with landowner proposals ranked and selected based on the benefits of the project to species of national or regional significance (NRCS 2009).

Similarly, the Partners for Fish and Wildlife Program provides expert technical assistance and cost-share incentives directly to private landowners to restore fish and wildlife habitats, including golden-cheeked warbler habitat (USFWS 2009e). To implement a project, a cooperative agreement with a minimum duration of 10 years is signed. The landowner is reimbursed after project completion, based on the cost-sharing formula in the agreement (USFWS 2009e).

The Landowner Conservation Assistance Program is a relatively new conservation tool developed by EDF in which EDF provides technical and financial assistance to landowners who agree to conduct certain management activities for the benefit of golden-cheeked warblers and black-capped vireos (EDF 2010).

8.3 Conservation Actions on Migration and Wintering Grounds

An extensive number of groups, agencies, committees, and organizations concentrate on conserving and restoring a variety of ecosystems in Mexico and Central America. While numerous NGOs and conservation strategies exist in the region, no data exist that quantify the benefits of these actions for golden-cheeked warblers.

Non-governmental organizations have become major players in habitat protection, restoration, and education (Weaver et al. 2003, Valdez et al. 2006, USAID 2009). International conservation agencies (e.g., TNC, Conservation International, Wildlife Conservation Society, World Wildlife Fund [WWF]) have aligned with local NGOs in individual countries, increasing the effectiveness of various conservation efforts (Valdez et al. 2006). Pronatura Mexico, the largest NGO in Mexico, focuses on purchasing and managing critical wildlife habitats throughout the country (Valdez et al. 2006), including the Sierra Madre Oriental and southern Mexico (Conservation International [CI] 2007, Pronatura 2009). Pronatura began implementing its Private Land Conservation Program in 2000 to promote conservation and sustainable management of private or communal lands in perpetuity (Pronatura 2009). A variety of incentives are made available to owners of lands deemed critical for conservation, including developing conservation easements, bank trusts, or private conservation reserves (Pronatura 2009). Additionally, the Mexican Fund for the Conservation of Nature (Fondo Mexicano para la Conservación de la Naturaleza [FMCN]) implements conservation projects throughout Mexico with financial support from agencies and private foundations (CI 2007, FMCN 2009). Their primary focus in pine-oak forests is to educate local communities on fire management and prevention (FMCN 2009). TNC programs in Chiapas, Mexico, include watershed conservation within El Triunfo with goals of “protecting and restoring key ecological values of the region and creating institutional and community capacity for long-term protection of the area” (TNC 2009a). TNC likewise promotes sustainable resource use, restoration, and conservation of the watersheds in La Sepultura Biosphere Reserve and is developing a fire management plan to protect the reserve’s forests (TNC 2009a). WWF recently developed an alliance with the Carlos Slim Foundation and the Mexican Federal government with the goal of advancing conservation efforts and sustainable development in 6 priority areas, including the state of Chiapas. The intent is to strengthen local organizations and communities along with supporting management strategies focused on conservation and protection (WWF 2010).

In Guatemala, TNC and the Fundación Defensores de la Naturaleza (FDN) work towards protecting the Sierra de Las Minas Biosphere Reserve, a known wintering location of golden-cheeked warblers (TNC 2009b). TNC has assisted FDN with hiring park rangers, eliminating logging operations, organizing volunteer brigades to stop forest fires in the highlands of the Reserve, developing conservation strategies, along with purchasing 1,335 ha (3,300 ac) in the Sierra de las Minas (TNC 2009b). Through a cost-share agreement with USFWS, FDN has carried out research on the warbler and its habitat in Guatemala, implemented small-scale (10 ha [25 ac]) reforestation projects in pine-oak habitat, promoted sustainable use practices to local families and communities, and encouraged landowners to participate in a government-led Forestry Incentive Program which provides financial and technical assistance in Sierra de Las Minas (FDN 2003).

BirdLife International and SalvaNATURA focus on recovery, conservation, and sustainable development in El Salvador (BirdLife International 2010). Some of their primary activities include fostering environmental and social changes in the coffee industry, long-term management and monitoring in Montecristo National Park (on the borders of Guatemala, Honduras, and El Salvador), conservation of pine-oak forest, ecological studies of the golden-cheeked warbler in Central America, and environmental education through workshops, talks, and educational materials (BirdLife International 2010).

In Nicaragua, the Wildlife Conservation Society (WCS) has partnered with indigenous associations and government agencies to inventory and monitor wintering migratory birds, provide environmental educational materials to schools, and preserve areas in Nicaragua and neighboring Honduras (WCS 2010).

One program specific to the golden-cheeked warbler and its wintering habitat was initiated in 2003 when Mexico, Guatemala, Honduras, El Salvador, and Nicaragua formed the Alliance for the Conservation of Mesoamerican Pine-Oak Forests (Alianza para la Conservación de los Bosques de Pino–Encino de Mesoamérica [ACMPOF]). ACMPOF is composed of NGO’s from Central America and Mexico, along with organizations from USA, with many additional institutions participating in the program (ACMPOF 2008). Members include Instituto de Historia Natural y Ecología (Chiapas, Mexico), Pronatura Sur (Chiapas, Mexico), Fundación Defensores de la Naturaleza (Guatemala), Fundación EDUCA (Honduras), SalvaNATURA (El Salvador), Alianza para las Áreas Silvestres (Nicaragua), TPWD, and TNC (ACMPOF 2008). Their efforts focus on gathering information on the warbler on its wintering grounds and developing a community education initiative (ACMPOF 2008).

8.4 Research

Although considerable research has been conducted on the golden-cheeked warbler since 1990, there are several critical areas of research that are lacking and are necessary to adequately assess the status of the warbler population and to evaluate results in recovery efforts. In this section we provide a brief summary of on-going research projects and, based on our accumulation and evaluation of past and current research, provide recommendations for future research that will improve our understanding of golden-cheeked warbler population dynamics and recovery.

8.4.1 Current Research

Baylor University:

- Interpretation of historic aerial photos to estimate woodland stand age and composition changes within the BCP since 1940
- Dendrochronology study to estimate and compare fire histories from pre-European and post-European settlement periods

Texas A&M University:

- Breeding range estimates of distribution, abundance, and potential habitat
- Use of social information for habitat selection
- Post-breeding habitat use
- Habitat and reproductive success in south central Texas (e.g., Edwards/Kinney)
- Effects of road construction noise
- Tree species composition and foraging effort relative to warbler productivity
- Impact of oak wilt on warbler occurrence and productivity

Texas State University:

- Occupancy and abundance estimates on Balcones Canyonlands Preserve
- Singing behavior and detection probabilities

University of Louisiana at Lafayette:

- Genetic viability

The Nature Conservancy:

- Long-term study at Fort Hood, including population trends, demography, and vegetation characterization within territories

Texas Parks and Wildlife Department:

- GIS-based identification of potential habitat in the southern Edwards Plateau

Balcones Canyonlands Preserve, City of Austin:

- Develop a habitat suitability model to assess the effects of past land use, stand age, composition, and fire history on GCWA distribution, abundance, and reproduction
- Compile historic eye-witness accounts of the Edwards Plateau with mapping of location and corresponding timelines of major historical events
- Mapping of field survey notes from original land grants in Travis County
- Long-term monitoring program to estimate population size, territory density and trends, productivity, and distribution

Balcones Canyonlands Preserve, Travis County:

- Long-term monitoring program to estimate population size, territory density and trends, productivity, and distribution

SalvaNATURA:

- Ecology and monitoring of golden-cheeked warblers throughout their winter range

8.4.2 Future Research Needs

Population Demography

For recovery of the species, research is needed that provides reliable estimates of productivity, dispersal, and survival across the warbler's breeding range, including influences of abiotic and biotic conditions on demographic rates. The capacity to conduct reliable population viability analyses (PVA) for the species is hampered by a lack of dependable estimates of productivity and survival (Chapter 3). Current estimates of demographics and habitat influences are derived from limited locations (i.e., Fort Hood and Travis County), thus, biasing estimates towards the eastern and central extent of the warbler range (see Chapters 3 and 5). Reliable estimates of productivity are acquired by focusing on breeding females and including information on nesting attempts, double-brooding, and polygyny within breeding seasons. Reliable PVAs are further limited by incomplete knowledge of dispersal dynamics of adults and juveniles, thus, confounding estimates of survival.

Habitat and Management

Several areas of research are notably absent from the existing body of knowledge on golden-cheeked warblers:

1) Post-breeding habitat use – Some researchers suggest post-breeding habitat use may vary from the breeding period, yet research on habitat use during the post-breeding season is lacking. Habitat conditions during this life history stage impact survival of both juveniles and adults.

2) Oak loss – Understanding the impact of oak loss on habitat use and population demographics is needed across the range of the warbler, particularly in areas where oak recruitment is being hampered by overbrowsing or oak wilt.

3) Climate change – Research is needed on the potential effects of rising temperatures and drought on warbler habitat, food resources, and the potential for outbreaks of pathogens on the wintering and breeding grounds.

4) Management practices – Little experimental research exists on the effects of various management techniques (e.g., understory thinning, deer exclosures, cowbird trapping) on warbler habitat and its influence on demographics. In addition, current management guidelines require maintaining 100-m buffers of woodland between core warbler habitat but limited information exists on the effectiveness of this requirement to minimize predation, parasitism, or other disturbances to the bird.

Wintering Grounds and Migration

Recovery of the species depends on understanding threats during the migratory and wintering period. No information exists on factors that limit warbler survival during the wintering period. Several studies have described habitat use during the winter but many of these may have targeted locations within known habitat; information on the range of habitat use is needed to assess potential threats to the status of the warbler. Currently, information during the migratory period is limited and research is needed on factors influencing survival of warblers during spring and fall migration.

Socioeconomic factors

There is a need for research on the effectiveness of various landowner incentive programs, motivation for landowners to participate in management activities on their property, and what incentives (e.g., economical) are most effective in decision-making at the local and governmental level. This applies to the entire range of the species (breeding, migration, and wintering). With the majority of the warbler's range under private ownership, recovery of the species is highly dependent on the participation of local landowners to preserve and manage habitat.

8.4 Summary of Recovery Efforts and Research Needs

- Public and protected properties, managed by numerous Federal, state, local agencies or organizations, encompass approximately 176,472 ha (436,072 ac) of land in the golden-cheeked warbler's breeding range, of which approximately 71,282 ha (176,142 ac) is woodlands and, thus, potential warbler habitat. This represents 4% of the total potential habitat in the breeding range, of which 1.3% is found in Recovery Region 3 (i.e., Fort Hood) and 1.1% is found in Recovery Region 5 (i.e., Balcones Canyonlands Preserve and Balcones Canyonlands National Wildlife Refuge).
- There are numerous protected areas along the Sierra Madre Oriental of eastern Mexico and into Central America where the golden-cheeked warbler migrates and winters, including biosphere reserves, national parks, and nature parks. One estimate suggests 1,951,000 ha (4,821,026 ac) of potential habitat exists on the wintering grounds, of which approximately 144,900 ha (358,056 ac), or 7.4%, occurs in protected areas.
- A variety of conservation programs and incentives exist in Texas to encourage and assist with management and conservation activities that benefit the warbler. Major results of these programs include: $2.48 million and >3,500 ha (>8,800 ac) proposed for habitat conservation and management to mitigate incidental take; over $36 million in funding for "non-traditional" grants focused on habitat conservation planning and land acquisition for habitat conservation; and the establishment of a conservation bank with the ability to provide 1,215 ha (3,003 ac) of land for mitigation or conservation.
- An extensive number of groups, agencies, committees, and organizations concentrate on conserving and restoring a variety of ecosystems in Mexico and Central America. Non-governmental organizations have become major players in habitat protection, restoration, and education in the region, with most projects focused on land acquisition and promoting sustainable land use within local communities. No data exist that quantify the benefits of these actions for golden-cheeked warblers.
- Population viability analysis is hindered because of a lack of reliable estimates of demographic parameters (survival, productivity, and emigration and immigration) for the warbler across the breeding, post-breeding, migratory, and wintering range. Future research should focus on obtaining these estimates and associating them with habitat conditions, thus providing a means to evaluate the effectiveness of various management actions in maintaining or enhancing habitat.

Appendix 8.A. Grant programs available through the Cooperative Endangered Species Conservation Fund, specifying the purpose and financial requirements for each program. Any State or Territory that has entered into cooperative agreements with the USFWS for endangered and threatened species conservation is eligible for the grants. Reprinted from U.S. Fish and Wildlife Service.

Grant Program	**Purpose**	**Species Benefiting**	**Competition**	**Financial Match Requirement**[a]
Conservation Grants	implementation of conservation projects	federally listed threatened or endangered species	formula	25% of estimated project cost; or 10% when two or more States or Territories implement a joint project
Recovery Land Acquisition	acquisition of habitat in support of approved recovery goals or objectives	federally listed threatened or endangered species	regional competition	25% of estimated project cost; or 10% when two or more States or Territories implement a joint project
Habitat Conservation Planning Assistance	support development of Habitat Conservation Plans (HCPs)	federally listed threatened or endangered species, proposed and candidate species, and unlisted species proposed to be covered by the HCP[b]	national competition	25% of estimated project cost; or 10% when two or more States or Territories implement a joint project
Habitat Conservation Plan (HCP) Land Acquisition	acquisition of land associated with approved HCPs	federally listed threatened or endangered species, unlisted (including State-listed species), proposed and candidate species covered by the HCP[b]	national competition	25% of estimated project cost; or 10% when two or more States or Territories implement a joint project

[a]As required under Section 6 of the Endangered Species Act, grants to States and Territories must include a minimum contribution by the project's non-Federal partners. These contributions can be in-kind, through staff time or use of non-Federal equipment, or financial assistance.
[b]A species covered by the HCP is any species (listed or unlisted) that is included in the section 10(a)(1)(B) permit, thus receiving incidental take authorization.

Literature Cited

Adams, C. E., B. J. Higginbotham, D. Rollins, R. B. Taylor, R. Skiles, M. Mapston, and S. Turman. 2005. Regional perspectives and opportunities for feral hog management in Texas. The Wildlife Society Bulletin 33:1312-1320.

Alldredge, M. W., J. S. Hatfield, D. D. Diamond, and C. D. True. 2002. Population viability analysis of the golden-cheeked warbler. Final report for Grant #1448-20181-00-J605, submitted to U. S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico, USA.

_____. 2004. Golden-cheeked warbler (*Dendroica chrysoparia*) in Texas: importance of dispersal toward persistence in a metapopulation. Pages 372–383 *in* H. R. Akçakaya, M. A. Burgman, O. Kindvall, C. C. Wood, P. Sjögren-Gulve, J. S. Hatfield, and M. A. McCarthy, editors. Species conservation and management: case studies. Oxford University Press, New York, New York, USA.

Alliance for the Conservation of Mesoamerican Pine-Oak Forests [ACMPOF]. 2008. Plan de Conservación de los Bosques de Pino-Encino de Centroamérica y el Ave Migratoria *Dendroica chrysoparia*. Fundación Defensores de la Naturaleza and The Nature Conservancy Guatamala.

American Ornithologists' Union. 1983. Check-list of North American Birds. American Ornithologists' Union, Washington, D.C.

Anders, A. D. 2000a. Demography of golden-cheeked warblers on Fort Hood, Texas in 2000: productivity, age structure, territory density, and adult return rates. Chapter 5 *in* Endangered species monitoring and management at Fort Hood, Texas: 2000 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

_____. 2000b. Population trends of golden-cheeked warblers on Fort Hood: 1999-2000 and an overview form 1992-2000. Chapter 4 *in* Endangered species monitoring and management at Fort Hood, Texas: 2000 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

_____. 2001a. Demography of golden-cheeked warblers on Fort Hood, Texas in 2001: productivity, age structure, territory density, and adult return rates. Chapter 4 *in* Endangered species monitoring and management at Fort Hood, Texas: 2001 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

_____. 2001b. Population trends of golden-cheeked warblers on Fort Hood from 1992-2001. Chapter 3 *in* Endangered species monitoring and management at Fort Hood, Texas: 2001 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

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

Anders, A. D., J. S. Horne, and L. L. Sanchez. 2000. Relationship between habitat characteristics and demography of golden-cheeked warblers on Fort Hood, Texas. Chapter 6 *in* Endangered species monitoring and management at Fort Hood, Texas: 2000 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

Appel, D. N., and K. Camilli. 2006. Assessment of oak wilt threat to habitat of the golden-cheeked warbler, an endangered species, in central Texas. Proceedings of advances in threat assessment and their application to forest and rangeland management conference. 18–20 July 2006, Boulder, Colorado, USA.

Appel, D. N., and R. C. Maggio. 1984. Aerial survey for oak wilt incidence at three locations in central Texas. Plant Disease 68:661–664.

Arcese, P., J. N. M. Smith, and M. I. Hatch. 1996. Nest predation by cowbirds and its consequences for passerine demography. Proceedings of the National Academy of Sciences 93:4608-4611.

Archer, S., D. S. Schimel, and E. A. Holland. 1995. Mechanisms of shrubland expansion: Land use, climate, or CO2. Climatic Change 29:91–99.

Armstrong, W. E., and D. E. Harmel. 1981. Exotic mammals competing with the natives. Texas Parks and Wildlife Department PWD LF C2000-0103 (11/81). Austin, Texas, USA.

Armstrong, W. E., D. E. Harmel, M. J. Anderegg, and M. S. Traweek. 1991. Vegetation of the Kerr Wildlife Management Area and its preference by white-tailed deer. Federal aid report series No. 30, Texas Parks and Wildlife Department, Austin, Texas, USA.
Arnold, K. A., C. L. Coldren, and M. L. Fink. 1996. The interactions between avian predators and golden-cheeked warblers in Travis County. Texas Transportation Institute. The Texas A&M Univeristy System, Texas Department of Transportation. Report 1983-2.
Attwater, H. P. 1892. List of birds observed in the vicinity of San Antonio, Bexar County, Texas. The Auk 9:229–238.
Audubon Texas. 2004. Land acquisition of endangered and threatened wildlife habitat, specifically for golden-cheeked warbler near Cedar Hill State Park in Dallas County, Texas. Endangered Species Recovery Land Acquisition Grant Proposal submitted to U.S. Fish and Wildlife Service, Austin, Texas, USA.
Baccus, J. T., M. E. Tolle, and J. D. Cornelius. 2007. Response of golden-cheeked warblers (*Dendroica chrysoparia*) to wildfires at Fort Hood, Texas. Texas Ornithological Society.
Balcones Canyonlands Preserve [BCP]. 2007a. Golden-cheeked warbler management. Chapter 7 *in* Balcones Canyonlands Preserve land management plan, Tier IIA. Austin, Texas, USA.
_____. 2007b. Oak wilt management, Chapter 3 *in* Balcones Canyonlands Preserve land management plan, Tier IIA. Austin, Texas, USA.
_____. 2009. Balcones Canyonlands Conservation Plan. Annual report FY 2009. Austin, Texas, USA.
Bat Conservation International [BCI]. 2008. Annual report 2007–2008.
Beardmore, C. J. 1994. Habitat use of the golden-cheeked warbler in Travis County, Texas. Thesis, Texas A&M University, College Station, Texas, USA.
Beatty, H. A. 1943. Records and notes from St. Croix, Virgin Islands. The Auk 60:110–111.
Belaire, J. A. 2007. Golden-cheecked warbler habitat prioritization in central Texas. Thesis, Duke University, Durham, North Carolina, USA.
Belviso, C. N. 2000. Creating a suitability map of nesting habitat for the golden-cheeked warbler (*Dendroica chrysoparia*) in Hays County, Texas. Thesis, Southwest Texas State University, San Marcos, Texas, USA.
Benson, R. H. 1990. Habitat area requirements of the golden-cheeked warbler on the Edwards Plateau. Texas Parks and Wildlife Department, Austin, Texas, USA.
Bent, A. C. 1953. Life histories of North American wood warblers, order Passeriformes. Bulletin 203. Smithsonian Institution, United States National Museum, United States Government Priting Office Washington, D.C., USA.
Bermingham, E., S. Rohwer, S. Freeman, and C. Wood. 1992. Vicariance biogeography in the Pleistocene and speciation in American wood warblers: a test of Mengel's model. Proceedings of the National Academy of Sciences of the United States of America 89:6624–6628.
Bird Life International. 2010. Bird Life International homepage. <http://www.birdlife.org/worldwide/national/el_salvador/index.html>. Accessed 8 January 2010.
Bolsinger, J. S. 1997. Patterns of use and variation in the songs of the golden-cheeked warbler (*Dendroica chrysoparia*). Thesis, University of Massachusetts, Amherst, USA.
_____. 2000. Use of two song categories by golden-cheeked warblers. Condor 102:539–552.
Bolsinger, J. S., and T. J. Hayden. 1992. Project status report: 1992 field studies of two endangered species (the black-capped vireo and the golden-cheeked warbler) and the cowbird control program on Fort Hood, Texas. U.S. Army Contstruction Engineering Research Laboratory.
_____. 1993. Project status report: 1993 field studies of two endangered species (the black-capped vireo and the golden-cheeked warbler) and the cowbird control program on Fort Hood, Texas. Natural Resource Division U.S. Army Contstruction Engineering Research Laboratory.
Bonifait, S., M.-A. Villard, and D. Paulin. 2006. An index of reproductive activity provides an accurate estimate of the reproductive success of palm warblers. Journal of Field Ornithology 77:302–309.
Boyle, S. A., and F. B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildlife Society Bulletin 13:110–116.

Bradley, C. A., S. E. J. Gibbs, and S. Altizer. 2008. Urban land use predicts west nile virus exposure in songbirds. Ecological Applications 18:1083–1092.

Braun, M. J., D. D. Braun, and S. B. Terril. 1986. Winter records of the golden-cheeked warbler (*Dendroica chrysoparia*) from Mexico. American Birds 40:564–566.

Butcher, J. A. 2008. Minimum patch size thresholds of reproductive success of songbirds. Dissertation, Texas A&M University, College Station, Texas, USA.

Butcher, J. A., M. L. Morrison, D. Ransom, Jr., R. D. Slack, and R. N. Wilkins. 2010. Evidence of a minimum patch size threshold of reproductive success in an endangered songbird. Journal of Wildlife Management 74:133–139.

Campbell, L. 2003. Endangered and threatened animals of Texas: Their life history and management. Texas Parks and Wildlife Department, Austin, Texas, USA.

Campomizzi, A. J., J. A. Butcher, S. L. Farrell, A. G. Snelgrove, B. A. Collier, K. J. Gutzwiller, M. L. Morrison, and R. N. Wilkins. 2008. Conspecific attractions is a missing component in wildlife habitat modeling. The Journal of Wildlife Management 72:331–336.

Carr, D. L., L. Suter, and A. Barbieri. 2005. Population dynamics and tropical deforestation: State of the debate and conceptual challenges. Population and Environment 27:89–113.

Cartwright, W. J. 1966. The cedar chopper. Southwestern Historical Quarterly 70: 247–255.

Chace, J. F., and J. J. Walsh. 2004. Urban effects on native avifauna: A reivew. landscape and urban planning 74:46–69.

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

Chapman, F. M. 1907. The warblers of North America. Third edition. D. Appleton & Company, New York, New York, USA.

Choban, A. M. 1974. A field study of the golden-cheeked warbler conducted during the spring and summer of 1974. Texas System of Natural Laboratories, Inc.

City of Austin [COA]. 1999. 1998 golden-cheeked warbler and black-capped vireo monitoring program. Balcones Canyonlands Preserve, The City of Austin, Natural Resources Division.

_____. 2000. 1999 golden-cheeked warbler and black-capped vireo monitoring program. Balcones Canyonlands Preserve, The City of Austin, Natural Resources Division.

_____. 2001. 2001 golden-cheeked warbler and black-capped vireo monitoring program. Balcones Canyonlands Preserve, The City of Austin, Natural Resources Division.

_____. 2002. 2002 golden-cheeked warbler and black-capped vireo monitoring program. Balcones Canyonlands Preserve, The City of Austin, Wildland Conservation Division.

_____. 2003. 2003 golden-cheeked warbler and black-capped vireo monitoring program. Balcones Canyonlands Preserve, City of Austin, Wildland Conservation Division.

_____. 2004. 2004 golden-cheeked warbler *Dendroica chrysoparia* and black-capped vireo *Vireo atricapilla* monitoring program. Balcones Canyonlands Preserve, The City of Austin, Wildland Conservation Division.

_____. 2005. 2005 golden-cheeked warbler *Dendroica chrysoparia* and black-capped vireo *Vireo atricapilla* monitoring program. Balcones Canyonlands Preserve, The City of Austin, Wildland Conservation Division.

_____. 2006. 2006 golden-cheeked warbler *Dendroica chrysoparia* and black-capped vireo *Vireo atricapilla* monitoring program. Balcones Canyonlands Preserve, The City of Austin, Wildland Conservation Division.

_____. 2007. 2007 golden-cheeked warbler and black-capped vireo monitoring program. Balcones Canyonlands Preserve Program, City of Austin Water, Wildland Conservation Division.

_____. 2008. 2008 golden-cheeked warbler (*Dendroica chrysoparia*) and black-capped vireo (*Vireo atricapilla*) monitoring program. Balcones Canyonlands Preserve, The City of Austin, Wildland Conservation Division.

_____. 2009. Golden-cheeked warbler (*Dendroica chrysoparia*) and black-capped vireo (*Vireo atricapilla*) monitoring program. Balcones Canyonlands Preserve Annual Report, Fiscal year 2008-09. City of Austin Water Utility, Wildland Conservation Division, and Balcones Canyonlands Preserve Program.

Coldren, C. L. 1998. The effects of habitat fragmentation on the golden-cheeked warbler. Dissertation, Texas A&M University, College Station, Texas, USA.

Collier, B. A., M. L. Morrison, S. L. Farrell, A. J. Campomizzi, J. A. Butcher, K. B. Hays, D. I. MacKenzie, and R. N. Wilkins. 2010. Monitoring endangered species occupying private lands: Case study using the golden-cheeked warbler. Journal of Wildlife Management 74:1–12.

Conservation International [CI]. 2007. Madrean pine-oak woodlands. <http://www.biodiversityhotspots.org/xp/hotspots/pine_oak >. Accessed 20 November 2009.

Cooksey, M. L., and S. M. Edwards. 2008. Monitoring of the golden-cheeked warbler and the black-capped vireo on Camp Bullis, Texas: 2008 field season report. Fort Sam Houston.

Cooksey, M. L., and J. E. Thompson. 2005. Monitoring the golden-cheeked warbler and black-capped vireo on Camp Bullis, Texas: 2005 field season report. Essex Corporation.

Cornelius, J. D., T. J. Hayden, and P. J. Guertin. 2007. Endangered species management plan for Fort Hood, Texas: FY06-10. U.S. Army Corps of Engineers.

Craft, R. A. 1997. 1997 field studies of golden-cheeked warblers (*Dendroica chrysoparia*) on Fort Hood, Texas. Pages 28–52 *in* Summary of 1997 Research Activities. The Nature Conservancy, Texas Conservation Data Center, Fort Hood, Texas, USA.

_____. 1998. 1997 delineation of black-capped vireo (*Vireo atricapillus*) and golden-cheeked warbler (*Dendroica chyrsoparia*) habitat on Fort Hood, Texas. Pages 53–59 *in* Summary of 1997 Research Activities. The Nature Conservancy, Texas Conservation Data Center, Fort Hood, Texas, USA.

Craft, R. A., J. R. Zelenak, and M. M. Stake. 1999. Monitoring of the golden-cheeked warbler (*Dendroica chrysoparia*) during 1998 on Fort Hood, Texas. Chapter 3 *in* Endangered species monitoring and management at Fort Hood, Texas: 1998 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

Cummins, T. 2006. The use of GIS and remotely sensed data in predicting the occurrence of two endangered avian species in central Texas. Thesis, Texas A&M University, College Station, Texas, USA.

Cureton, W. 1987. A golden-cheeked warbler (*Dendroica chrysoparia*) from Hidalgo. Mexican Birding Association Bulletin Board 1:2.

Davis, C. A., and D. M. Leslie, Jr. 2008. Effects of mountain biking activity on foraging and nesting behavior of golden-cheeked warblers, Final report. Department of Natural Resource Ecology and Management, University of Oklahoma.

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

Demoll, E. W., M. Eckhoff, and F. S. Webster. 1984. Breeding bird census: 144. Juniper-oak woods on limestone hills. American Birds 38:110.

Deviche, P., E. C. Greiner, and X. Manteca. 2001. Interspecific variability of prevalence in blood parasites of adult passerine birds during the breeding season in Alaska. Journal of Wildlife Disease 37:28–35.

Diamond, D. D. 1997. An old-growth definition for western juniper woodlands: Texas ash juniper dominated or codominated communities. U.S. Department of Agriculture, Forest Service, Southern Research Station. Report SRS-15.

_____. 2007. Range-wide modeling of golden-cheeked warbler habitat. Final Report to Texas Parks and Wildlife Department, Austin, Texas, USA.

Diamond, D. D., G. A. Rowell, and D. P. Keddy-Hector. 1995. Conservation of Ashe juniper (Juniperus ashei Buchholz) woodlands of the central Texas hill country. Natural Area Journal 15:189–197.

Diamond, D. D., and C. D. True. 1998. Golden-cheeked warbler nesting habitat area, habitat distribution, and change, and land cover within the Edwards aquifer recharge zone. Final report for Grant #1448-20181-98-G941, submitted to U. S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico, USA.

_____. 2008. Distribution of *Juniperus* woodlands in central Texas in relation to general abiotic site type. Pages 48-57 *in* O. W. V. Auken, editor. Western North American Juniperus Communities: A Dynamic Vegetation Type. Springer Science+Business Media, LLC, New York, New York, USA.

Dietsch, T. V. 2005. Seasonal variation of infestation by ectoparasitic chigger mite larvae (Acarina: Trombiculidae) on resident and migratory birds in coffee agrosystems of Chiapas, Mexico. The Journal of Parasitology 91:1294–1303.

Dinerstein, E., D. M. Olson, D. J. Graham, A. L. Webster, S. A. Primm, M. P. Bookbinder, and G. Ledec. 1995. A conservation assessment of the terrestrial ecoregions of Latin America and the Caribbean. The World Bank, Washington, D.C., USA.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

DLS Associates. 1994. Golden-cheeked warbler population study, Bull Creek Watershed, 1991–1993, Travis County, Texas. Report 93 - 394B.

Donald, P. F. 2007. Adult sex ratios in wild bird populations. Ibis 149:671–692.

Eckrich, G. H., T. E. Koloszar, and M. D. Goering. 1999. Effective landscape management of brown-headed cowbirds at Fort Hood, Texas. Studies in Avian Biology 18:267–274.

Edwards, S. P. and J. M. Lewis. 2008. Surveys of U.S. Army Corps of Engineers lands at Whitney Lake for the endangered golden-cheeked warbler. 2008 final report. Arlington Ecological Services Field Office, Arlington, Texas, USA.

_____. 2009. Investigations of U.S. Army Corps of Engineers lands at Whitney Lake for the endangered golden-cheeked warbler and black-capped vireo 2009. Arlington Ecological Services Field Office, Arlington, Texas, USA.

Ellison, K., S. G. Sealy, and H. L. Gibbs. 2006. Genetic elucidation of host use by individual sympatric bronzed cowbirds (*Molothrus aeneus*) and brown-headed cowbirds (*M. ater*). Canadian Journal of Zoology 84:1269–1280.

Engels, T. M. 1995. The conservation biology of the golden-cheeked warbler (*Dendroica chyrsoparia*). Dissertation, University of Texas, Austin, Texas, 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.

Environmental Defense Fund [EDF]. 2009. Golden-cheeked warbler survey on the Brown property, Erath and Somervell Counties, Texas. Annual report submitted to U.S. Fish and Wildlife Service.

_____. 2010. The Landowner Conservation Assistance Program. <http://www.edf.org/article.cfm?ContentID=154>. Accessed 24 January 2010

Environmental Protection Agency [EPA]. 2009. A framework for categorizing the relative vulnerability of threatened and endangered species to climate change. Global Change Research Program, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

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.

Fischer, J. R., D. E. Stallknecht, M. P. Luttrell, A. A. Dhondt, and K. A. Converse. 1997. Mycoplasmal conjunctivitis in wild songbirds: The spread of a new contagious disease in a mobile host population. Emerging Infectious Diseases 3:69–72.

Fondo Mexicano para la Conservación de la Naturaleza [FMCN]. 2009. FMCN home page. <http://www.mexicanfund.org/>. Accessed 20 November 2009.

Fonteyn, P. J., M. W. Stone, M. A. Yancy, J. T. Baccus, and N. M. Nadkarni. 1988. Determination of community structure by fire. Pages 79-90 *in* B. B. Amos, and F. R. Gehlbach, editors. Edwards Plateau vegetation: Plant ecological studies in central Texas. Baylor University Press, Waco, Texas, USA.

Food and Agriculture Organization of the United Nations [FAO]. 2009. State of the world's forests. Electronic Publishing Policy and Support Branch, Communication Division, Viale delle Terme di Caracalla, Rome, Italy.

Ford, A. L., and O. W. Van Auken. 1982. The distribution of woody species in the Guadalupe River floodplain forest on the Edwards Plateau of Texas. Southwestern Naturalist 27:383–392.

Fowler, N. L., and D. W. Dunlap. 1986. Grassland vegetation of the eastern Edwards Plateau. American Midland Naturalist 115:146–155.

Freeman, B. 1993. Golden-cheeked warblers in migration. Birding 25:150.

Fry, J. A., M. J. Coan, C. G. Homer, D. K. Meyer, and J. D. Wickham. 2009. Completion of the national land cover database (NLCD) 1992-2001 land cover change retrofit product. U. S. Geological Survey, Reston, Virginia, USA.

Frye, R. G., and D. A. Curtis. 1990. Texas water and wildlife: An assessment of direct impacts to wildlife habitat from future water development projects. <http://www.tpwd.state.tx.us/publications/pwdpubs/pwd_rp_t3200_1055/index.phtml>. Accessed 17 July 2009.

Fuhlendorf, S. D., S. A. Archer, F. E. Smeins, D. M. Engle, and C. A. Taylor, Jr. 2008. The combined influence of grazing, fire, and herbaceous productivity on tree-grass interactions. Pages 219–238 *in* O. W. V. Auken, editor. Western North American Juniperus Communities: A Dynamic Vegetation Type. Springer Science+Business Media, LLC, New York, New York, USA.

Fuller, T., T. Hollon, and S. Sarkar. 2008. Preliminary report to Smith/Robertson: Habitat suitability for the golden-cheeked warbler in Comal and Hays county, Texas. Biodiversity and Biocultural Conservation Laboratory, University of Texas,Austin, Texas, USA.

Fuller, T. L. 2009. Area prioritization for optimal conservation planning. Dissertation, University of Texas, Austin, Texas, USA.

Fundacion Defensores de la Naturaleza. 2003. Assisting ongoing efforts to conserve the endangered golden-cheeked warbler (warbler) on its wintering grounds in Guatemala, Central America.

Garriga, M., A. P. Thurow, T. Thurow, R. Conner, and D. Brandenberger. 1997. Commercial value of juniper on the Edwards Plateau, Texas. Chapter 8 *in* 1997 Juniper Symposium Proceedings. Texas Agricultural Experiment Station Technical Report, San Angelo, Texas, USA.

Gass, L. R. 1996. Nesting behavior of golden-cheeked warblers in Travis County, Texas. Thesis, Southwest Texas State University, Austin, Texas, USA.

Gomez-Mendoza, L., and L. Arriaga. 2007. Modeling the effect of climate change on the distribution of oak and pine species of Mexico. Conservation Biology 21:1545–1555.

Gonzalez-Callejas, B. R. 2008. Winter ecology, relative abundance, and population monitoring of golden-cheeked warblers throughout the known and potential winter range. Fundacion Defensores de la Naturaleza.

Graber, A. E., C. A. Davis, and D. M. Leslie, Jr. 2006. Golden-cheeked warbler males participate in nest-site selection. The Wilson Journal of Ornithology 118:247–251.

Griffith, G. E., S. A. Bryce, J. A. Comstock, A. C. Rogers, B. Harrison, S. L. Hatch, and D. B. 2004. Ecoregions of Texas (color poster with map, descriptive text, and photographs). Reston, Virginia, U.S. Geological Survey

Gu, W., and R. K. Swihart. 2004. Absent or undetected? Effects of non-detection of species occurrence on wildlife-habitat models. Biological Conservation 116:195–203.

Habib, L., E. M. Bayne, and S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. Journal of Applied Ecology 44:176–184.

Hahn, H. C. 1945. The white-tailed deer in the Edwards Plateau of Texas. Texas Game, Fish and Oyster Commission. Austin, Texas, USA.

Hamilton, W. T., and D. N. Ueckert. 2000. Rangeland brush and weed management: the next millennium: why are we here? Pages 3–13 *in* Proceedings in rangeland brush and weed management: the next millennium, symposium and workshop. Center for Grazingland and Ranch Management, Texas A&M University, College Station, Texas, USA.

Hayden, T. J., and D. J. Tazik. 1991. Project status report: 1991 field studies of two endangered species (the black-capped vireo and the golden-cheeked warbler) and the cowbird control program on Fort Hood, Texas. U.S. Army Construction Engineering Research Laboratory. Fort Hood, Texas, USA.

Heilbrun, R. D., N. Lake, A. Arnold, and D. Hisler. 2009. Habitat suitability model for evaluating City of San Antonio land donation for golden-cheeked warblers. Texas Parks & Wildlife Department PWD W7000-1685. Austin, Texas, USA.

Hickory Pass, LP., and U. S. Fish and Wildlife Service [USFWS]. 2002. Hickory Pass Ranch Conservation Bank agreement.

Holimon, W. C., and R. A. Craft. 2000. Breeding density and productivity of the golden-cheeked warbler on Fort Hood, Texas in 1999. Chapter 6 *in* Endangered species monitoring and management at Fort Hood, Texas: 1999 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

Hoover, J. P. 2003. Multiple effects of brood parasitism reduce the reproductive success of prothonotary warblers, *Protonotaria citrea*. Animal Behaviour 63:923–934.

Hoover, J. P., and M. J. Reetz. 2006. Brood parasitism increases provisioning rate, and reduces offspring recruitment and adult return rates, in a cowbird host. Oecologia 149:165–173.

Horne, J. S. 2000. Effects of open-canopy corridor width on definitions of forest fragmentation and habitat loss for golden-cheeked warblers. Chapter 8 *in* Endangered species monitoring and management at Fort Hood, Texas: 1999 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

Horne, J. S., and A. D. Anders. 2001. A model for predicting golden-cheeked warbler occurence using local and landscape-scale habitat variables. Chapter 10 *in* Endangered species monitoring and management at Fort Hood Texas: 2001 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

Howell, S. N. G., and S. Webb. 1995. A guide to the birds of Mexico and northern Central America. Oxford University Press, New York, New York, USA.

Hsu, S.-L. 1998. A model of environmental compromise between regulators and landowners under the Endangered Species Act. Dissertation, University of California, Davis, California, USA.

Huss, D. L. 1954. Factors influencing plant succession following fire in Ashe juniper woodland types in Real County, Texas. Thesis, Texas A&M University, College Station, Texas, USA.

Jehle, G., A. A. Y. Adams, J. A. Savidge, and S. K. Skagen. 2004. Nest survival estimation: A review of alternatives to the Mayfield estimator. Condor 106:472–484.

Jennings, S., T. Gardali, N. E. Seavy, and G. R. Geupel. 2009. Effects of mist netting on reproductive performance of wrentits and song sparrows in central coastal California. Condor 111:488–496.

Jette, L. A., T. J. Hayden, and J. D. Cornelius. 1998. Demographics of the golden-cheeked warbler (*Dendroica chrysoparia*) on Fort Hood, Texas. U.S. Army Corps of Engineers Technical Report 98/52.

Jewett, S. G. 1944. Hybridization of hermit and Townsend warblers. Condor 46:23–24.

Johnson, K. W., J. E. Johnson, R. O. Albert, and T. R. Albert. 1988. Sightings of golden-cheeked warblers (*Dendroica chrysoparia*) in northeastern Mexico. The Wilson Bulletin 100:130–131.

Johnston, M. C., W. L. Thompson, and E. Kincaid, Jr. 1952. Breeding bird census: 37. Juniper-oak woodlands on limestone hills. Audubon Field Notes 6:323–324.

Johnston, M. M. 2006. A survey for potential predators of the golden-cheeked warbler (*Dendroica chrysoparia*) in relation to different edges at the Balcones Canyonlands Preserve. Thesis, Texas State University, San Marcos, Texas, USA.

Jones, H. L. 2005a. Central America. North American Birds 59:162–165.
_____. 2005b. Central America. North American Birds 59:337–340.
_____. 2005c. Central America. North American Birds 59:506–510.
Jones, H. L., and O. Komar. 2006. Central America. North American Birds 60:152–156.
_____. 2007. Central America. North American Birds 61:155–159.
_____. 2008a. Central America. North American Birds 62:163–171.
_____. 2008b. Central America. North American Birds 62:314–319.
_____. 2008c. Central America. North American Birds 62:487–491.
_____. 2009a. Central America. North American Birds 63:167–173.
_____. 2009b. Central America. North American Birds 63:335–339.
_____. 2009c. Central America. North American Birds 63:513–518.
Jones, J. S. 2006. Development of a decision support geographic information system for land restoration programs in the Leon, Lampasas, and Bosque River watersheds. Thesis, Texas A&M University, College Station, Texas, USA.
Keddy-Hector, D. P., T. L. Cook, and R. C. Maggio. 1992. Remote sensing and GIS of golden-cheeked warbler breeding habitat and vegetation types in the Balcones Canyonlands. Project No. E-I-4, Job No. 39. Texas Parks and Wildlife Department, Austin, Texas, USA.
Keddy-Hector, D. P., D. D. Diamond, D. R. Hernandez, and J. S. Hatfield. 1998. Territory densities, age structure, mating success and productivity of golden-cheeked warblers in upland and canyon slope forests.
King, D. I., and J. H. Rappole. 2000. Winter flocking of insectivorous birds in montane pine-oak forests in middle America. Condor 102:664–672.
King, D. I., E. Herrera, S. Hernandez, C. A. Lively, D. W. Mehlman, J. H. Rappole, and D. Roth. 2009. The status of wintering golden-cheeked warblers in Nicaragua. Pages 45–51 *in* T. D. Rich, C. Arizmendi, D. Demarest, andC. Thompson, editors. Tundra to Tropics: Connecting Birds, Habitats and People. Proceedings of the 4th International Partners in Flight Conference. Partners in Flight. 13-16 February 2008, McAllen, Texas, USA.
Kjelland, M. E., U. P. Kreuter, G. A. Clendenin, R. N. Wilkins, X. B. Wu, E. G. Afanador, and W. E. Grant. 2007. Factors related to spatial patterns of rural land fragmentation in Texas. Environmental Management 40:231–244.
Klassen, J. A. 2010. Habitat characteristics affecting golden-cheeked warbler reproductive success in south central Texas. Presentation given at the 2010 Golden-cheeked Warbler Symposium, 15 January 2010, Austin, Texas, USA.
Klassen, J. A., and M. L. Morrison. 2009. 2009 golden-cheeked warbler monitoring at Kickapoo Cavern State Park: methods and results. Texas A&M University, College Station, Texas, USA.
Komar, N. 2003. West Nile virus: Epidemiology and ecology in North America. Advances in Virus Research 61:185–234.
Komar, O. 1998. Avian diversity in El Salvador. Wilson Bulletin 110:511–533.
_____. 2002. Priority conservation areas for birds in El Salvador. Animal Conservation 5:173–183.
_____. 2010. Ecology and monitoring of golden-cheeked warblers throughout their winter range. Presentation given at the 2010 Golden-cheeked Warbler Symposium, 15 January 2010, Austin, Texas, USA.
Kostecke, R. M. 2008. Population trends of breeding birds on the Edwards Plateau, Texas: local versus regional patterns. Southwestern Naturalist 53:466–471.
Kotliar, N. B., and J. A. Wiens. 1990. Mulitple scales of patchiness and patch structure: A hierarchical framework for the study of heterogeneity. Oikos 59:253–260.
Kroll, J. C. 1974. Nesting success of the golden-cheeked warbler (*Dendroica chrysoparia*) in relation to manipulation of ashe juniper (*Juniperus ashei*) habitat. Report RP-74-14.
_____. 1980. Habitat requirements of the golden-cheeked warbler: Management implications. Journal of Range Management 33:60–65.

Ladd, C. G. 1985. Nesting habitat requirements of the golden-cheeked warbler. Thesis, Southwest Texas State University, Austin, Texas, USA.

Ladd, C. G., and L. Gass. 1999. Golden-cheeked warbler (Dendroica chrysoparia). Account 420 *in* A. Poole, editor. The Birds of North America online. Cornell Lab of Ornithology, Ithaca, New York, USA.

LaDeau, S., P. P. Marra, A. M. Kilpatrick, and C. A. Calder. 2008. West Nile virus revisited: consequences for North American ecology. BioScience 58:937–946.

Land, H. C. 1962. A collection of birds from the Sierra de las Minas, Guatemala. Wilson Bulletin 74:267–283.

Lasley, G. W., C. Sexton, W. Sekula, M. Lockwood, and C. Shackleford. 1997. Texas region, spring migration, Mar 1-May 31, 1997. National Audubon Society Field Notes 51:892–897.

Latta, S. C. 2003. Effects of scaley-leg mite infestions on body condition and site fidelity of migratory warblers in the Dominican Republic. Auk 120:730–743.

Lewis, T. J., D. G. Ainley, D. Greenberg, and R. Greenberg. 1974. A golden-cheeked warbler on the Farallon Islands. Auk 91:411–412.

Lillibridge, K. M., R. Parsons, Y. Randle, A. P. A. Travassos da Rosa, H. Guzman, M. Siirin, T. Wuithiranyagool, C. Hailey, S. Higgs, A. A. Bala, R. Pascua, T. Meyer, D. L. Vanlandingham, and R. B. Tesh. 2004. The 2002 introduction of West Nile virus into Harris County, Texas, an area historically endemic for St. Louis encephalitis. American Journal of Tropical Medicine and Hygiene 70:676–681.

Lindsay, D. L., K. R. Barr, R. F. Lance, S. A. Tweddale, T. J. Hayden, and P. L. Leberg. 2008. Habitat fragmentation and genetic diversity of an endangered, migratory songbird, the golden-cheeked warbler (*Dendroica chrysoparia*). Molecular Ecology 17:2122–2133.

Lockwood, M. 2005. Performance report as required by Federal Aid in Wildlife Restoration Act. Big game research and suveys: White-tailed deer population trends. Federal aid project No. W-127-R-13. Texas Parks and Wildlife Department, Austin, Texas, USA.

Lockwood, M. W. 1996. Courtship behavior of golden-cheeked warblers. Wilson Bulletin 108:591–592.

Loomis Partners, Inc. 2009. Hays County Regional Habitat Conservation Plan, final draft. Prepared for Hays County Commissioners' Court, San Marcos, Texas, USA.

_____. 2010. Draft SEP-HCP plan area. <http://www.sephcp.com/docs/Maps/DRAFT_SEPHCP_Plan_Area_approved.pdf>. Accessed 25 September 2010.

Loomis-Austin, Inc. 2008. Mapping potential golden-cheeked warbler breeding habitat using remotely sensed forest canopy cover data. Report LAI Proj. No. 051001.

Lovette, I. J., and E. Bermingham. 1999. Explosive speciation in the New World *Dendroica* warblers. Proceedings of the Royal Society of London B 266:1629–1636.

Lower Colorado River Authority [LCRA]. 2006. 2006 Survey report, Wheless Preserve, Travis County.

_____. 2007a. 2007 Survey report, Double Horn, Burnet County.

_____. 2007b. 2007 Survey report, Grelle Recreation Area, Burnet County.

_____. 2007c. 2007 Survey report, Hickory Creek (Camp Balcones Springs), Burnet County.

_____. 2008. 2008 Survey report, Turkey Bend Recreational Areas, Burnet and Travis Counties.

_____. 2009a. Surveys of LCRA lands at Pedernales River Nature Park for the endangered golden-cheeked warbler and black-capped vireo 2009. Final report. LCRA Corporate Services, Austin, Texas, USA.

_____. 2009b. Surveys of LCRA lands at Canyon of the Eagles for the endangered golden-cheeked warbler and black-capped vireo 2009. Final report. LCRA Corporate Services, Austin, Texas, USA.

_____. 2009c. Surveys of LCRA lands at Muleshoe and TbarM for the endangered golden-cheeked warbler 2009. Final report. LCRA Corporate Services, Austin, Texas, USA.

_____. 2009d. Surveys of LCRA lands at Gloster Bend for the endangered golden-cheeked warbler 2009. Final report. LCRA Corporate Services, Austin, Texas, USA.

_____. 2009e. Surveys of LCRA lands at McGregor Preserve for the endangered golden-cheeked warbler 2009. Final report. LCRA Corporate Services, Austin, Texas, USA.
_____. 2009f. Surveys of LCRA lands at Westcave Preserve for the endangered golden-cheeked warbler 2009. Final report. LCRA Corporate Services, Austin, Texas, USA.
_____. 2009g. LCRA CREZ homepage. <http://www.lcra.org/energy/trans/crez/index.html> Accessed 1 Dec 2009.
Lyons, J. 1990. Winter habitat survey of the golden-cheeked warbler (*Dendroica chrysoparia*) in Guatemala. Final Section 6 Report, Job 23, Submitted to Texas Parks and Wildlife Department. Austin, Texas, USA.
_____. 1994. Recent observations of the golden-cheeked warbler (*Dendroica chrysoparia*) in Chiapas, Mexico. Texas Ornithological Society Bulletin 27:28–30.
Maas, D. S. 1998. Factors influencing demographics of golden-cheeked warbler (*Dendroica chrysoparia*) at Fort Hood Military Reservation, Texas. Thesis, University of Oklahoma, Norman, Oklahoma, USA.
MacKenzie, D. I. 2006. Analysis of 2003–2006 occupancy data for black-capped vireo and golden-cheeked warbler. Proteus Wildlife Research Consultants. Report to Texas A&M Institute of Renewable Natural Resources, College Station, Texas, USA.
_____. 2007. Analysis of 2003–2006 occupancy data for black-capped vireo and golden-chicked warbler. Proteus Wildlife Research Consultants. Report to Texas A&M Institute of Renewable Natural Resources, College Station, Texas, USA.
MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.
MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: Inferring patterns and dynamics of species occurrence. Elselvier Publishing Academic Press, Burlington, Massachusetts, USA.
Mackenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: General advice and allocating survey effort. Journal of Applied Ecology 42:1105–1114.
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 34:473–479.
Mapston, M. E. 2004. Feral hogs in Texas. Texas Cooperative Extension B-6149. Texas A&M University, College Station, Texas, USA.
Martin, T. E., J. Clobert, and D. R. Anderson. 1995. Return rates in studies of life history evolution: are biases large? Journal of Applied Statistics 22:863–876.
Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.
_____. 1975. Suggestions for calculating nest succes. Wilson Bulletin 87:456–466.
Mengel, R. M. 1964. The probable history of species formation in some northern wood warblers (Parulidae). Living Bird 3:9–43.
Miller, S. G., R. L. Knight, and C. K. Miller. 1998. Influence of recreational trails on breeding bird communities. Ecological Applications 8:162–169.
Monroe, B. L. 1968. A distributional survey of the birds of Honduras. Ornithological Monographs 7:1–458.
Morales, S., A. Martinez-Salinas, W. J. Arendt, and M. A. Tórrez. 2008. Redescubrimiento de *Dendroica chrysoparia* en Nicaragua. Zeledonia 12:30–34.
National Audubon Society. 1993. The 94th Christmas bird count. Field Notes 48:871–872.
_____. 1994. The 95th Christmas bird count. Field Notes 49:843–844.
Natural Resources Conservation Service [NRCS]. 2009. 2009 Wildlife habitat incentives program (WHIP) fact sheet. <http://www.tx.nrcs.usda.gov/programs/whip/>. Accessed 20 November 2009.

Newnam, J. C. 2008. Habitat use by the golden-cheeked warbler. Dissertation, Texas A&M University, College Station, Texas, USA.
Oberholser, H. C. 1974. The bird life of Texas. Volume 2. University of Texas Press, Austin, Texas, USA.
Ochoa-Gaona, S. 2001. Traditional land-use systems and patterns of forest fragmentation in the highlands of Chiapas, Mexico. Environmental Management 27:571–586.
Olson, D. M., E. Dinerstein, E. D. Wikramanayake, N. D. Burgess, G. V. N. Powell, E. C. Underwood, J. A. D'Amico, I. Itoua, H. E. Strand, J. C. Morrison, C. J. Loucks, T. F. Allnutt, T. H. Ricketts, Y. Kura, J. F. Lamoreux, W. W. Wettengel, P. Hedao, and K. R. Kassem. 2001. Terrestrial ecoregions of the world: A new map of life on Earth. BioScience 51:933–938.
ONCOR. 2009. Competitive renewable energy zones (CREZ). <http://www.oncor.com/electricity/transmission/crez/default.aspx> Accessed 1 Dec 2009.
Payne, R. B. 1977. The ecology of brood parasitism in birds. Annual Review of Ecology and Systematics 8:1–28.
Payne, R. B., and L. L. Payne. 1998. Brood parasitism by cowbirds: risks and effects on reproductive success and survival in indigo buntings. Behavioral Ecology 9:64–73.
Peak, R. G. 2003a. Demography of the golden-cheeked warbler on Fort Hood, Texas, 2003. Chapter 6 *in* Endangered species monitoring and management at Fort Hood, Texas: 2003 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2003b. Monitoring the golden-cheeked warbler at Belton Lake Outdoor Recreation Area mountain bike park, 1998–2003. Chapter 7 *in* Endangered species monitoring and management at Fort Hood, Texas: 2003 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2003c. Population trends of the golden-cheeked warbler on Fort Hood, Texas 1992–2003. Chapter 5 *in* Endangered species monitoring and management at Fort Hood, Texas: 2003 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2004. Demography of the golden-cheeked warbler on Fort Hood, Texas, 2004. Chapter 6 *in* Endangered species monitoring and management at Fort Hood, Texas: 2004 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2005. Demography of the golden-cheeked warbler on Fort Hood, Texas, 2005. Chapter 4 *in* Endangered species monitoring and management at Fort Hood, Texas: 2005 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2006. Demography of the golden-cheeked warbler on Fort Hood, Texas, 2006. Chapter 4 *in* Endangered species monitoring and management at Fort Hood, Texas: 2006 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2007a. Forest edges negatively affect golden-cheeked warbler nest survival. Condor 109:628–637.
_____. 2007b. Golden-cheeked warbler demography on Fort Hood, Texas, 2007. Chapter 4 *in* Endangered species monitoring and management at Fort Hood, Texas: 2007 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
Peak, R. G., and D. J. Lusk. 2009. Alula characteristics as indicators of golden-cheeked warbler age. North American Bird Bander 34:106–108.
Peak, R. G., and W. G. Strebe. 2008. Golden-cheeked warbler demography on Fort Hood, Texas, 2008. Chapter 4 *in* Endangered species monitoring and management at Fort Hood, Texas: 2008 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
Pekins, C. E. 2002a. Golden-cheeked warbler leg injuries at Fort Hood, Texas in 2002. Chapter 18 *in* Endangered species monitoring and management at Fort Hood, Texas: 2002 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2002b. Mountain biking impacts and demographic monitoring of the golden-cheeked warbler at Fort Hood, Texas in 2002. Chapter 7 *in* Endangered species monitoring and management at Fort Hood, Texas: 2002 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

Perrigo, G., and D. Booher. 1994. Slaty vireos in central Veracruz and a note on golden-cheeked warbler in Chiapas. The Euphonia 3:13–16.
Perrigo, G., R. Brundage, R. Barth, N. Damude, C. Benesh, C. Fogg, and J. Gower. 1990. Spring migration corridor of golden-cheeked warblers in Tamaulipas, Mexico. American Birds 44:28.
Petersen, D. A. 2008. Hot housing market catching cold in Texas. Southwest Economy 1:11–14.
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.
Phillips, J. C. 1911. A years' collecting in the state of Tamaulipas, Mexico. Auk 28:67–89.
Potosme, S. H., and F. Muñoz. 2007. Establecimiento de prioridades para la conservación del hábitat invernal de la reinita dorada Dendroica chrysoparia en Nicaragua. Report to The Nature Conservancy, San Antonio, Texas, USA.
Powell, L. A., and M. G. Knutson. 2006. A productivity model for parasitized, multibrooded songbirds. Condor 108:292–300.
Probst, J. R., and J. P. Hayes. 1987. Pairing success of Kirtland's warblers in marginal vs. suitable habitat. Auk 104:234–241.
Proctor, H., and I. Owens. 2000. Mites and birds: diversity, parasitism and coevolution. Trends in Ecology and Evolution 15:358–364.
Pronatura. 2009. Pronatura Asociación Civil homepage. <http://www.pronatura.org.mx/en/>. Accessed 20 November 2009.
Public Utility Commission of Texas [PUC]. 2009. Report to the 81st Texas Legislature: scope of competition in electric markets in Texas. <http://www.puc.state.tx.us/electric/reports/scope/index.cfm >. Accessed 1 December 2009.
Pulich, W. M. 1965. The golden-cheeked warbler of Texas. Audubon Field Notes 19:545–548.
_____. 1976. The golden-cheeked warbler: A bioecological study. Texas Parks and Wildlife Department. Austin, Texas, USA.
Pyle, P. 1997. Golden-cheeked warbler. Pages 478–480 *in* Identification guide to North American birds. Part 1. Slate Creek Press, Bolinas, California, USA.
Quinn, M. A. 2000. Abundance and distribution of potential arthropod prey species in a typical golden-cheeked warbler habitat. Texas A&M University, College Station, Texas, USA.
Rappole, J. H. 1996. Golden-cheeked warbler winter habitat delineation. Final report to the National Biological Service Southern Science Center. Lafayette, Louisiana, USA.
Rappole, J. H., D. I. King, and W. C. Barrow, Jr. 1999. Winter ecology of the endangered golden-cheeked warbler. Condor 101:1–9.
Rappole, J. H., D. I. King, and J. Diez. 2003. Winter- vs. breeding-habitat limitation for an endangered avian migrant. Ecological Applications 13:735–742.
Rappole, J. H., D. I. King, and P. Leimgruber. 2000. Winter habitat and distribution of the endangered golden-cheeked warbler. Animal Conservation 2:45–59.
Redo, D., J. O. J. Bass, and A. C. Millington. 2009. Forest dynamics and the importance of place in western Honduras. Applied Geography 29:91–110.
Reemts, C. M., and L. L. Hansen. 2008. Slow recolonization of burned oak-juniper woodlands by the Ashe juniper (*Juniperus ashei*): Ten years of succession after crown fire. Forest Ecology and Management 255:1057–1066.
Reemts, C. M., C. Picinich, D. Cimprich, and R. G. Peak. 2008. Vegetation studies of black-capped vireo and golden-cheeked warbler habitat. Chapter 9 *in* Endangered species monitoring and management at Fort Hood, Texas: 2008 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
Reidy, J. L. 2007. Golden-cheeked warbler nest success and nest predators in urban and rural landscapes. Thesis, University of Missouri, Columbia, Missouri, USA.
Reidy, J. L., M. M. Stake, and F. R. Thompson, III. 2008. Golden-cheeked warbler nest mortality and predators in urban and rural landscapes. Condor 110:458–466.

Reidy, J. L., M. M. Stake, and F. R. Thompson, III. 2009a. Nocturnal predation of females on nests: An important source of mortality for golden-cheeked warblers? Wilson Journal of Ornithology 121:416–421.
Reidy, J. L., F. R. Thompson, III., and R. G. Peak. 2009b. Factors affecting golden-cheeked warbler nest survival in urban and rural landscapes. Journal of Wildlife Management 73:407–413.
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.
Richardson, T. W., T. Gardali, and S. H. Jenkins. 2009. Review and meta-analysis of camera effects on avian nest success. Journal of Wildlife Management 73:287–293.
Rising, J. D. 1988. Phenetic relationships among the warblers in the *Dendroica virens* complex and a record of *D. virens* from Sonora, Mexico. Wilson Bulletin 100:312–316.
Rivers, J. W., D. P. Althoff, P. S. Gibson, and J. S. Pontius. 2003. Evaluation of a reproductive index to estimate dickcissel reproductive success. Journal of Wildlife Management 67:136–143.
Robertson Consulting Group, Inc. 2010. Third party evaluation of the Recovery Credit System proof of concept. Commissioned by the U.S. Department of Defense through the National Fish and Wildlife Foundation. <http://rcs.tamu.edu/Final_RCS_Eval_Report_March_2010.pdf> Accessed 25 March 2010.
Robinson, S. K., and R. T. Holmes. 1982. Foraging behavior of forest birds: The relationships among search tactics, diet, and habitat structure. Ecology 63:1918–1931.
Rohwer, S., and C. W. Wood. 1998. Hybrid zones between hermit and Townsend's warblers in Washington and Oregon. Auk 115:284–310.
Rotella, J. J., S. J. Dinsmore, and T. L. Shaffer. 2004. Modeling nest-survival data: A comparison of recently developed methods that can be implemented in MARK and SAS. Animal Biodiversity and Conservation 27:187–205.
Rowell, G., M. Lockwood, and L. Campbell. 2002. Assessment of golden-cheeked warbler habitat characteristics on Texas Parks and Wildlife state parks. Texas Parks and Wildlife Department Project No. 88. Austin, Texas, USA.
Rowell, G. A., D. P. Keddy-Hector, D. D. Diamond, J. Lloyd B. McKinney, R. C. Maggio, and T. L. Cook. 1995. Remote sensing and GIS of golden-cheeked warbler breeding habitat and vegetation types on the Edwards Plateau. Texas Parks and Wildlife Department Grant No.l E-1-7, Project No. 39. Austin, Texas, USA.
Russell, F. L., and N. L. Fowler. 1999. Rarity of oak saplings in savannas and woodlands of the eastern Edwards Plateau, Texas. Southwestern Naturalist 44:31–41.
_____. 2002. Failure of adult recruitment in *Quercus bucklei* populations on the eastern Edwards Plateau, Texas. American Midland Naturalist 148:201–217.
_____. 2004. Effects of white-tailed deer on the population dynamics of acorns, seedlings and small saplings of *Quercus buckleyi*. Plant Ecology 173:59–72.
Salvin, O., and F. D. Godman. 1892. On a collection of birds from central Nicaragua. Ibis 34:324–328.
San Antonio Parks and Recreation [SAPR]. 2005. San Antonio Parks and Recreation Department System Strategic Plan 2006–2016. <http://www.sanantonio.gov/sapar/systemplan0616.asp> Accessed 10 Jan 2010
Sanders, J. C. 2005. Relationships among landowner and land ownership characteristics and participation in conservation programs in central Texas. Thesis, Texas A&M University, College Station, Texas, USA.
Santana C., E. 2005. A context for bird conservation in Mexico: Challenges and opportunities. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.
Schmid, J. A. 1969. The wild landscape of the Edwards Plateau of southcentral Texas: a study of developing livlihood patterns and ecological change. Thesis, The University of Chicago, Chicago, Illinois, USA.

Sclater, P. L., and O. Salvin. 1860. Characters of eleven new species of birds discovered by Osbert Salvin in Guatemala. Pages 298–301 *in* R. Taylor, editor. Proceedings of the Zoological Society of London. The Society, London, United Kingdom.
Sedgwick, J. A., and R. J. Klus. 1997. Injury due to leg bands in willow flycatchers. Journal of Field Ornithology 68:622–629.
Sexton, C. W. 1987. A compartive analysis of urban and native bird populations in centeral Texas. Dissertation, University of Texas, Austin, Texas, USA.
Shaw, D. M. 1989. Applications of GIS and remote sensing for the characterization of habitat for threatened and endangered species. Dissertation, University of North Texas, Denton, Texas, USA.
Simon, D. 1975. Guatemala, Fuentes Georginas. Birding 7:157.
Smeins, F., S. Fuhlendorf, and Charles Taylor, Jr. 1997. Environmental and land use changes: a long-term perspective. Chapter 1 *in* 1997 Juniper Symposium Proceedings. Texas Agricultural Experiment Station Technical Report. San Angelo, Texas, USA.
Smeins, F. E. 1980. Natural role of fire on the Edwards Plateau. Pages 4–16 *in* L. D. White, editor. Prescribed burning of the Edwards Plateau of Texas. Texas Agricultural Extension Service, College Station, Texas, USA.
Smeins, F. E., and S. D. Fuhlendorf. 1997. Biology and ecology of ashe (blueberry) juniper. Chapter 3 *in* 1997 Juniper Symposium Proceedings. Texas Agricultural Experiment Station Technical Report. San Angelo, Texas, USA.
Smeins, F. E., and M. E. Moses. 1994. Effects of land use on the reproductive success of the golden-cheeked warbler: An imagery analysis of habitat alteration in Travis County from 1951–1991. Department of Rangeland Ecology and Management, Texas A&M University, College Station, Texas, USA.
Sperry, C. 2007. Influences of borders on golden-cheeked warbler habitat in the Balcones Canyonlands Perserve, Travis County, Texas. Texas State University, San Marcos, Texas, USA.
Sperry, J. H. 2008. Ecological factors associated with songbird and small mammal predation by Texas rattlesnakes. Dissertation, University of Illinois, Urbana, Illinois, USA.
Sperry, J. H., D. A. Cimprich, R. G. Peak, and P. J. Weatherhead. 2009. Is nest predation on two endangered bird species higher in habitats preferred by snakes? Ecoscience 16:111–118.
Sperry, J. H., R. G. Peak, D. A. Cimprich, and P. J. Weatherhead. 2008. Snake activity affects seasonal variation in nest predation risk for birds. Journal of Avian Biology 39:379–383.
Sperry, J. H., and P. J. Weatherhead. 2009. Does prey availability determine seasonal patterns of habitat selection in Texas ratsnakes? Journal of Herpetology 43:55–64.
Stake, M. M. 2000. Impacts of mountain biking activity on golden-cheeked warblers at Fort Hood, Texas. Chaper 7 *in* Endangered species monitoring and management at Fort Hood, Texas: 2007 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2001a. Impacts of mountain biking on golden-cheeked warbler demography at Fort Hood, Texas in 2001. Chapter 6 *in* Endangered species monitoring and management at Fort Hood, Texas: 2001 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2001b. Monitoring predation with video at golden-cheeked warbler nests on Fort Hood, Texas in 2001. Chapter 5 *in* Endangered species monitoring and management at Fort Hood, Texas: 2001 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.
_____. 2001c. Predation by a great plains rat snake on an adult female golden-cheeked warbler. The Wilson Bulletin 113:460–461.
_____. 2003. Golden-cheeked warbler nest predators and factors affecting nest predation. Thesis, University of Missouri, Columbia, Missouri, USA.
Stake, M. M., and P. M. Cavanagh. 2001. Removal of host nestlings and fecal sacs by brown-headed cowbirds. The Wilson Bulletin 113:456–459.
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.

Stake, M. M., F. R. T. III, J. Faaborg, and D. E. Burhans. 2005. Patterns of snake predation at songbird nests in Missouri and Texas. Journal of Herpetology 39:215–222.

State Energy Conservation Office. 2009. Wind Energy Transmission homepage. <http://www.seco.cpa.state.tx.us/re_wind-transmission.htm>. Accessed 1 Dec 2009.

Stein, R. C. 1962. A comparitive study of songs recorded from five closely-related warblers. Living Bird 1:61–71.

Strausberger, B. M., and M. V. Ashley. 2005. Host use strategies of individual female brown-headed cowbirds *Molothrus ater* in a diverse avian community. Journal of Avian Biology 36:313–321.

Summers, S. G. 2009. Brown-headed cowbird removal at Fort Hood, Texas. Chapter 5 *in* Endangered species monitoring and management at Fort Hood, Texas: 2009 annual report. The Nature Conservancy, Fort Hood Project, Fort Hood, Texas, USA.

Sutton, G. M., and T. D. Burleigh. 1941. Some birds recorded in Nuevo Leon, Mexico. Condor 43:158–160.

SWCA Environmental Consultants. 2003. Results of 2003 field surveys for golden-cheeked warbler and black-capped vireo along an approximately 25.25-mile segment of RR 674 in Edwards County, Texas. Texas Department of Transportation Project No. 6853. Austin, Texas, USA.

_____. 2007. Preliminary deliverable golden-cheeked warbler status review. Prepared for Texas Department of Transportation. Austin, Texas, USA.

_____. 2008. Williamson County regional habitat conservation plan environmental impact statement. Prepared for Williamson County Conservation Foundation, Cedar Park, Texas, USA.

_____. 2009. Comal County Regional Habitat Conservation Plan, final draft. Prepared for Comal County and Comal County Commissioners Court. New Braunfels, Texas, USA.

Tarof, S. A., B. J. Stutchbury, and G. F. Bennett. 1997. Low infection prevalence of blood parasites in hooded warblers. Journal of Field Ornithology 68:75–78.

Taylor, R. B. 1999. Seasonal diets and food habits of feral swine. Pages 58–66 *in* Proceedings of First National Feral Swine Conference, 2–3 June 1999, Forth Worth, Texas, USA.

Teer, J. 2003. Nonnative large mammals in North America. Pages 1180–1108 *in* G. Feldhamer, B. Thompson, and J. Chapman, editors. Wild mammals of North America, Second Editon. Johns Hopkins University Press, Baltimore, Maryland, USA.

Texas Forest Service [TFS]. 2007. Texas Oak Wilt Information Partnership homepage. <http://www.texasoakwilt.org/> Accessed 9 September 2009.

_____. 2008. How to identify and manage oak wilt in Texas. <http://www.texasoakwilt.org/Documents/Stewardship/TFS_OakWilt_v4.pdf> Accessed 1 Dec 2009.

Texas Parks and Wildlife Department [TPWD]. 2005. Texas Wildlife Action Plan. <http://www.tpwd.state.tx.us/publications/pwdpubs/pwd_pl_w7000_1187a/> Accessed 12 January 2010.

_____. 2009. Landowner Incentive Program. <http://www.tpwd.state.tx.us/landwater/land/private/lip/> Accessed 23 August 2010.

_____. 2010. Land and water resources conservation and recreation plan. Texas Parks and Wildlife Department. Austin, Texas, USA.

Texas Water Development Board [TWDB]. 1984. Water for Texas. Document No. GP-4-1. Texas Water Development Board, Austin, Texas. <http://www.twdb.state.tx.us/publications/reports/State_Water_Plan/1997/WPindex.asp>. Accessed 10 October 2009.

_____. 1997. Water for Texas: a consensus-based update to the state water plan. Document No. GP-6-2. Texas Water Development Board, Austin, Texas. <http://www.twdb.state.tx.us/publications/reports/State_Water_Plan/1997/WPindex.asp>. Accessed 10 October 2009

_____. 2002. Water for Texas 2002. Document No. GP-7-1. Texas Water Development Board, Austin, Texas. <http://www.twdb.state.tx.us/publications/reports/State_Water_Plan/2002/FinalWaterPlan2002.asp#2002SWP>. Accessed 10 October 2009.

_____. 2007. Water for Texas 2007. Document No. GP-8-1. Texas Water Development Board, Austin, Texas. . <http://www.twdb.state.tx.us/wrpi/swp/swp.htm>. Accessed 10 October 2009.

The Nature Conservancy [TNC]. 2002. A range-wide assessment of potential breeding habitat for the golden-cheeked warbler. Final report submitted to Natural Resources Management Branch, Fort Hood, Texas, USA.

_____. 2008a. The Edwards Plateau ecoregion: Fact sheet. The Nature Conservancy of Texas.

_____. 2008b. Barton Creek Habitat Preserve: fact sheet. The Nature Conservancy of Texas.

_____. 2009a. Chiapas: safeguarding Mexico's South Pacific watersheds. <http://www.nature.org/wherewework/northamerica/mexico/work/art8619.html >. Accessed 20 November 2009.

_____. 2009b. Guatemala: Motagua/Polochic System. <http://www.nature.org/wherewework/centralamerica/guatemala/work/art8613.html >. Accessed 20 November 2009.

Thompson, D. E. 1995. Observations of golden-cheeked warbler wintering in Guatemala and Honduras.

Thompson, J., and J. Schlatter. 2005. Endangered species management plan for Camp Bullis, Texas FY 05 to FY 09. Natural and Cultural Resources Division. Camp Bullis, Texas, USA.

Travis County. 1997. 1996 and 1997 endangered bird surveys. Travis County Natural Resources. Travis County, Texas, USA.

_____. 2000. Monitoring of the golden cheeked warbler: 2000 field season. Travis County Natural Resources. Travis County, Texas, USA.

_____. 2001. Monitoring of the golden-cheeked warbler: 2001 field season. Travis County Parks and Preserves. Travis County, Texas, USA.

_____. 2002. Monitoring of the golden-cheeked warbler: 2002 field season. Travis County Parks and Preserves. Travis County, Texas, USA.

_____. 2003. Monitoring of the golden-cheeked warbler: 2003 field season. Transportation and Natural Resources Department, Travis County, Texas, USA.

_____. 2004. 2004 summary of wildlife management activities on Travis County managed tracts of the Balcones Canyonlands Preserve. Travis County Parks and Natural Resources. Travis County, Texas, USA.

_____. 2006. Monitoring of the golden-cheeked warbler (*Dendroica chrysoparia*) in western Travis county, Texas: 2005 field season. Department of Transportation and Natural Resources. Travis County, Texas, USA.

_____. 2007. Monitoring of the golden-cheeked warbler (*Dendroica chrysoparia*) in western Travis county, Texas: 2006 field season. Travis County Department of Transportation and Natural Resources. Travis County, Texas, USA.

_____. 2008a. Monitoring of the golden-cheeked warbler (*Dendroica chrysoparia*) in western Travis County, Texas: 2007 field season. Travis County Department of Transportation and Natural Resources. Travis County, Texas, USA.

_____. 2008b. Monitoring of the golden-cheeked warbler (*Dendroica chrysoparia*) in western Travis County, Texas: 2008 field season. Travis County Department of Transportation and Natural Resources. Travis County, Texas, USA.

_____. 2010. Monitoring and management of the golden-cheeked warbler (*Dendroica chrysoparia)* in western Travis County, Texas: 2009 field season. Travis County Department of Transportation and Natural Resources. Travis County, Texas, USA.

Traweek, M., and R. Welch. 1992. Exotics in Texas. Texas Parks and Wildlife Department PWD-BK-W7000-206 5/92. Austin, Texas, USA.

Traweek, M. S. 1995. Statewide census of exotic big game animals. Texas Parks and Wildlife Department Federal aid project No. W-127-R-3. Austin, Texas, USA.
U.S. Census Bureau. 2000. Building permit survey documentation – state printouts. <http://www.census.gov/const/C40/Sample/stateprt.pdf>. Accessed 13 August 2009.
U. S. Fish and Wildlife Service [USFWS]. 1992. Golden-cheeked warbler (*Dendroica chrysoparia*) recovery plan. Albuquerque, New Mexico, USA.
_____. 1996a. Golden-cheeked warbler population and habitat viability assessment report. Compiled and edited by Carol Beardmore, Jeff Hatfield, and Jim Lewis in conjuction with workshop participants. Report of a August 21-24, 1995 workshop arranged by the U.S. Fish and Wildlife Service in partial fulfillment of U.S. National Biological Service Grant No. 80333-1423. Austin, Texas, USA.
_____. 1996b. Habitat conservation planning and incidental take permit processing handbook. <http://www.fws.gov/endangered/hcp/hcpbook.html>. Accessed 10 January 2010.
_____. 1996c. Habitat conservation plan and final environmental impact statement. <http://www.co.travis.tx.us/TNR/bccp/pdfs/Habitat_Conservation_Plan_Final_Environment_Impact_Statement.pdf>. Accessed 10 January 2010.
_____. 1998. Golden-cheeked warbler recovery team April 2–3, 1998 meeting minutes: responses to USFWS's questions. U.S. Fish and Wildlife Service, Austin, Texas, USA.
_____. 2000. Safe harbor agreement between Environmental Defense, Inc. and the U.S. Fish and Wildlife Service to provide Safe Harbor assurances to landowners in the Texas Hill Country who voluntarily agree to enhance habitat for the endangered golden-cheeked warbler and black-capped vireo. <http://www.environmentaldefense.net/article.cfm?contentID=142> Accessed 3 February 2010.
_____. 2001. Balcones Canyonlands National Wildlife Refuge: Comprehensive conservation plan. U.S. Fish and Wildlife Service. Albuquerque, New Mexico, USA.
_____. 2004. U.S. Fish and Wildlife Service Biological Opinion 2-12-05-F-021. Natural Resources Conservation Service. Temple, Texas, USA.
_____. 2005. U.S. Fish and Wildlife Service Biological Opinion 2-12-04-F-478. Department of the Army. Fort Hood, Texas, USA.
_____. 2009a. U.S. Fish and Wildlife Service Biological Opinion, Consultation # 21450-2009-F-0145. Department of the Army. Fort Sam Houston, Texas, USA.
_____. 2009b. Habitat conservation plans under the Endangered Species Act. <http://www.fws.gov/endangered/factsheets/hcp.pdf>. Accessed 23 August 2009.
_____. 2009c. Cooperative endangered species conservation fund grants. <http://www.fws.gov/ENDANGERED/factsheets/Sec6_Factsheet_2009.pdf>. Accessed 23 August 2009.
_____. 2009d. Conservation banking: incentives for stewardship. <http://www.fws.gov/endangered/factsheets/conservation_banking.pdf>. Accessed 23 August 2009.
_____. 2009e. Partners for fish and wildlife program. <http://www.fws.gov/partners/>. Accessed 22 July 2010.
_____. 2010. Endangered Species Act document library. <http://www.fws.gov/endangered/esa-library/index.html#grants>. Accessed 5 March 2010.
United Nations Educational Scientific and Cultural Organization [UNESCO]. 2010. Latin American and Caribbean Biosphere Reserves. <http://www.unesco.org/mabdb/br/brdir/directory/database.asp> Accessed 1 October 2009.
United States Agency for International Development [USAID]. 2009. Tropical forestry and biodiversity (FAA 118 and 119) analyses.
Urban, E. K. 1959. Birds from Coahuila, Mexico. University of Kansas Publications Museum of Natural History 11:443–516.

Valdez, R., J. C. Guzman-Aranda, F. J. Abarca, L. A. Tarango-Arambula, and F. C. Sanchez. 2006. Wildlife conservation and management in Mexico. Wildlife Society Bulletin 34:270–282.

Van Auken, O. W. 1993. Size distribution patterns and potential population change of some dominant woody species of the Edwards Plateau region of Texas. Texas Journal of Science 45:199–210.

_____. 2000. Shrub invasions of North American semiarid grasslands. Annual Review of Ecological Systems 31:197–215.

Vickery, P. D., M. L. Hunter, and J. V. Wells. 1992. Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk 109:697–705.

Vidal, R. M., C. Macias-Caballero, and C. D. Duncan. 1994. The occurrence and ecology of the golden-cheeked warbler in the highlands of northern Chiapas, Mexico. Condor 96:684–691.

Vincent, C. H. 2006. Land and water conservation fund: Overview, funding history, and current issues. Congressional Research Service Report for Congress. The Library of Congress, Washington, D.C., USA.

Vincent, C. H., R. Bamberger, D. M. Bearden, M. L. Corn, R. Esworthy, R. W. Gorte, M. Humphries, P. A. Sheikh, D. L. Whiteman, B. A. Naughton, R. Walke, and R. S. Garrett. 2008. Interior, environment, and related agencies: FY2009 appropriations. Congressional Research Service Report for Congress. The Library of Congress, Washington, D.C., USA.

Vogelmann, J. E., S. M. Howard, L. Yang, C. R. Larson, B. K. Wylie, and N. V. Driel. 2001. Completion of the 1990s national land cover data set for the counterminous United States from Landsat Thematic Mapper data and ancillary data sources. Photogrammatic Engineering & Remote Sensing 67:650–662.

Wahl, R., D. D. Diamond, and D. Shaw. 1990. The golden-cheeked warbler: a status review. Austin, Texas, USA.

Watson, C. A., F. W. Weckerly, J. S. Hatfield, C. C. Farquhar, and P. S. Williamson. 2008. Presence-nonpresence surveys of golden-cheeked warblers: detection, occupancy and survey effort. Animal Conservation 11:484–492.

Weaver, P. L., D. M. Lombardo, and J. C. M. Sanchez. 2003. Biodiversity and tropical forest conservation, protection and management in Nicaragua: assessment and recommendations. Evaluation performed for USAID/Nicaragua

Weckerly, F. W., and J. R. Ott. 2008. Statistical trends of golden-cheeked warblers on Balcones Canyonlands Preserve, City of Austin, Texas. Department of Biology, Texas State University, San Marcos, Texas, USA.

Weinberg, H. J. 1998. Results of the 1997 golden-cheeked warbler and black-capped vireo montoring program on Camp Bullis, Texas. Report USACERL 98/61.

Weinberg, H. J., J. S. Bolsinger, and T. J. Hayden. 1995. Project status report: 1994 field studies of two endangered species (the black-capped vireo and the golden-cheeked warbler) and the cowbird control program on Fort Hood, Texas. Natural Resources Division, USACERL. Champaign, Illinois, USA.

Weinberg, H. J., L. A. Jette, and J. D. Cornelius. 1996. 1995 project status report: Field studies of the endangered black-capped vireo and golden-cheeked warbler, and the cowbird control program on Fort Hood, Texas. Fort Hood, Texas, USA.

Weiss, V. A., and D. A. Cristol. 1999. Plastic color bands have no detectable short-term effects on white-breasted nuthatch behavior. Condor 101:884–886.

Weniger, D. 1984. The explorer's Texas: The lands and waters. Eakin Publications, Inc., Austin, Texas, USA.

Wildlife Conservation Society. 2010. Where we work: Nicaragua. . <http://www.wcs.org/where-we-work/latin-america/nicaragua.aspx>. Accessed 8 January 2010.

Wilkins, N., A. Hays, D. Kubenka, D. Steinbach, W. Grant, E. Gonzalez, M. Kjelland, and J. Shakleford. 2003. Texas rural lands: Trends and conservation implications for the 21st century. An overview of the Rural Land Fragmentation Project. Texas A&M University System in partnership with the American Farmland Trust.

Wilkins, R. N. 2008. Monitoring and research in support of the Fort Hood Off-Site Conservation Program and Recovery Credit System. Unpublished report to Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service, Austin, Texas, USA.

Wilkins, R. N., A. G. Snelgrove, B. C. Fitzsimons, B. M. Stevener, K. L. Skow, R. E. Anderson, and A. M. Dube. 2009a. Texas Land Trends. Texas A&M University Institute of Renewable Natural Resources. <http://www.texaslandtrends.org/>. Accessed 5 May 2009.

Wilkins, R. N., D. Wolfe, L. S. Campbell, and S. B. Baggett. 2009b. Development of Recovery Credit Systems as a Policy Innovation for Threatened and Endangered Species. Pages 233–244 *in* Transactions of the 73rd North American Wildlife and Natural Resources Conference, 23–28 March 2008, Phoenix, Arizona, USA.

Woolfenden, B. E., H. L. Gibbs, S. G. Sealy, and D. G. McMaster. 2003. Host use and fecundity of individual female brown-headed cowbirds. Animal Behaviour 66:95–106.

Woolfenden, G. E. 1967. A specimen of the golden-cheeked warbler from Florida. Auk 84:115.

World Database on Protected Areas [WDPA]. 2010. WDPA homepage. <http://www.wdpa.org/>. Accessed 3 March 2010.

World Wildlife Fund [WWF]. 2001. Central American pine-oak forests (NT0303). <http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0303_full.html> Accessed 1 September 2009.

_____. 2004. The terrestrial ecoregions database. <http://www.worldwildlife.org/science/ecoregions/item1267.html> Accessed 3 August 2009.

Personal Communications

Adams, Robert, Environmental Business Line Manager, Army Corps of Engineers, Texas; phone conversation and email to Tiffany McFarland, Research Associate, Institute of Renewable Natural Resources, College Station, Texas. August- December 2009.

Armstrong, Beryl, Plateau Land and Wildlife Management, Texas; email to Julie E. Groce, Extension Program Specialist, Institute of Renewable Natural Resources, San Antonio, Texas. 26 January 2010.

Bocanegra, Omar, Austin Ecological Services Field Office, U.S. Fish and Wildlife Service, Austin, Texas; memo and email to Michael Morrison, Professor and Caesar Kleberg Chair, Wildlife and Fisheries Department, Texas A&M University, College Station, Texas. 3 February 2010.

Chamberlain, Michael, Texas Department of Transportation, Austin, Texas; email to Julie Groce, Extension Program Specialist, Institute of Renewable Natural Resources, San Antonio, Texas. 7 December 2009.

Farrell, Shannon, graduate student, Texas A&M University, Texas; memo to the Institute of Renewable Natural Resources, College Station, Texas. 12 October 2009

Hays, Brian, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, Gatesville, Texas; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio Texas. 15 October 2009.

Henríquez, Vladlen, Biologist, Departamento de Ciencias para la Conservación, SalvaNATURA; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 9 December 2009.

Hutchinson, Mark, graduate student, Texas A&M University, Texas; memo to the Institute of Renewable Natural Resources, College Station, Texas. 3 September 2009.

Klassen, Jessica, graduate student, Texas A&M University, Texas; memos to the Institute of Renewable Natural Resources, College Station, Texas. 5 September and 13 October 2009.

Mahan, John, Director, Bright Leaf State Natural Area, Texas; phone conversation and email to Dianne Dessecker, Research Assistant, Institute of Renewable Natural Resources, College Station, Texas. 6 October 2009.

Neal, Jayne, Park Naturalist, City of San Antonio Parks and Recreation Department, Texas; phone conversation and email to Tiffany McFarland, Research Associate, Institute of Renewable Natural Resources, College Station, Texas. 5 October 2009.

Neal, Jayne, Park Naturalist, City of San Antonio Parks and Recreation Department, Texas; email to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 11 February 2010.

Newnam, Cal, District Biologist, Texas Department of Transportation, Texas; memo to Julie Groce, Extension Program Specialist, Texas A&M Institute of Renewable Natural Resources, San Antonio, Texas. 29 December 2009.

Peak, Rebecca, Applied Scientist, The Nature Conservancy; email to Heather Mathewson, Post-Doctoral Research Associate, Texas A&M Institute of Renewable Natural Resources, College Station, Texas. 20 November 2009.

Peak, Rebecca G., Applied Scientist, Natural and Cultural Resources Management Branch, Department of the Army; email to Julie Groce, Extension Program Specialist, San Antonio, Texas. 28 January 2010.

Reidy, Jennifer L. Graduate student, University of Missouri-Columbia; email to Heather Mathewson, Post-Doctoral Resesarch Associate, Texas A&M Institute of Renewable Natural Resources, College Station, Texas. 3 March 2010.

Sexton, Chuck, Refuge Biologist, Balcones Canyonlands National Wildlife Refuge, U.S. Fish and Wildlife Service; emails to Julie E. Groce, Extension Program Specialist, Institute of Renewable Natural Resources, San Antonio, Texas. 9 April 2008, 9 November 2009 and 11 February 2010.

Taylor, Melinda, University of Texas, Austin, Texas; email to Julie E. Groce, Extension Program Specialist, Institute of Renewable Natural Resources, San Antonio, Texas. 11 January 2010.

Wolfe, David, Director, Conservation Science, Environmental Defense Fund, Austin, Texas; email to Julie Groce, Extension Program Specialist, Institute of Renewable Natural Resources, San Antonio, Texas. 16 February 2010 and 30 March 2010.